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A Global Geographic Information System Data Base of Storm Occurrences and Other Climatic Phenomena Affecting Coastal Zones

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A GLOBAL GEOGRAPHIC INFORMATION SYSTEM DATA BASE OF STORM OCCURRENCES AND OTHER CLIMATIC PHENOMENA AFFECTING COASTAL ZONES

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ABSTRACT

BIRDWELL, K. R., and R. C. DANIELS. 1991. A Global Geographic Information System Data Base of Storm Occurrences and Other Climatic Phenomena Affecting Coastal Zones, ORNL/CDIAC-40, NDP-035, Oak Ridge National Laboratory, Oak Ridge, Tennessee. 329 pp.
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This document describes the contents of a digital climatological data set that may be used by raster or vector geographic information systems (GISs). The primary focus of the data set is the quantification of the occurrence of synoptic storms and other climatological factors that affect coastlines. However, recent demands for new and/or improved climatologies of storm events as well as an increase in the availability of source data have made it useful to extend the domain of most of the data variables to that of regional and/or global coverage. The expansion of the data makes the data set applicable in several areas of climatic research.

The data set contains eight data groups. Spatial coverage of data varies by data group. All data groups listed below except (3) are referenced to 1° x 1° or 5° x 5° grid cells of latitude and longitude. [Data group (3) is referenced by state.] The eight data groups are:

1. Annual probabilities of occurrence of tropical storms and hurricanes for coastal areas of the United States, Canada, and Bermuda by 1° x 1° grid cells.

2. (a) Annual probabilities of occurrence of tropical storms, hurricanes, and super typhoons (winds 67 m/s or greater) for the world by 5° x 5° grid cells.
(b) Mean forward velocities of tropical cyclones (without regard to tropical cyclone intensity) for the world by 5° x 5° grid cells.

3. The number of hurricane strikes for the U.S. Atlantic and Gulf coasts by state and Saffir-Simpson intensity class.

4. (a) Mean monthly and annual number of extratropical cyclogeneses for the Northern Hemisphere by 5° x 5° grid cells.
(b) Mean monthly and annual number of extratropical cyclone occurrences for the Northern Hemisphere by 5° x 5° grid cells.

5. Mean number of polar lows (polar air cloud vortices) per winter month for the North Pacific Ocean and Southern Hemisphere by 5° x 5° grid cells.

6. (a) Mean and relative number of cyclones (without regard to cyclone type) for January, July, and the year for the world by 5° x 5° grid cells.
(b) Mean number of hours of cyclone occurrence (without regard to cyclone type) for January, July, and the year for the Southern Hemisphere by 5° x 5° grid cells.

7. Derived index of the influence of winds on coastlines in the African, Asian, and Australian monsoon regions by 1° x 1° grid cells.

8. Mean annual sea-ice concentrations for Alaskan and U.S. Atlantic coastal areas by 1° x 1° grid cells.

These data are available as a numeric data package (NDP) from the Carbon Dioxide Information Analysis Center (CDIAC). The NDP consists of this document and a magnetic tape (or floppy diskettes) containing ARC/INFO™* export files, flat ASCII files, FORTRAN and SAS™† retrieval files, and a descriptive file. Each of the eight data groups is provided as an ARC/INFO™ export file and flat ASCII file. The flat ASCII files are provided to extend the use of the data to non-ARC/INFO™ users. This documentation provides information on file contents and formats, data sources, limitations and restrictions of the data, and the techniques used to derive the data groups in this NDP.

*ARC/INFO™ is a registered trademark of the Environmental Systems Research Institute (ESRI), Inc., Redlands, CA 92372.

†SAS™ is a registered trademark of the SAS Institute, Inc., Cary, NC 27511-8000.

PART 1
INFORMATION ABOUT THE DATA PACKAGE

1. NAME OF THE NUMERIC DATA PACKAGE

A Global Geographic Information System Data Base of Storm Occurrences and Other Climatic Phenomena Affecting Coastal Zones

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3. KEYWORDS

Climatic data sets, tropical cyclones, tropical storms, hurricanes, hurricane strikes, super typhoons, extratropical cyclones, extratropical cyclogenesis, cyclones, cyclone movement, cyclonicity, monsoons, wind, polar lows, polar air cloud vortices, sea ice, storm occurrences, storm probabilities of occurrence, coastal storms, geographic information system.

4. BACKGROUND INFORMATION

Storms can profoundly effect erosion rates in coastal areas and human and natural resources near a coast. Coastal storm effects range from accelerated shoreline erosion (Dolan et al., 1988) to loss of life and property (Case and Mayfield, 1990). Added to the concern over the effects of coastal storms associated with the current climatic regime is a fear that climatic change, especially that caused by increased "greenhouse" warming (Ramanathan, 1988), could cause an increase in the frequency and intensity of coastal storms and alter storm tracks (Emanuel, 1987). Any potential increase in coastal storm impacts could be exacerbated by a rise in sea level of a yet unknown magnitude which is expected to result from the increased melting of glaciers and ice sheets and the thermal expansion of water as the oceans warm (Polar Research Board, 1985).

Essential to an understanding of the effects of present and possible future storms is an accurate and comprehensive data base on the distribution of various types of storms, their frequency of occurrence, intensity, and velocities of movement under today's climatic regime.

The climatological data base described here offers information on tropical storms, hurricanes, super typhoons, mean forward velocities of tropical cyclones, extratropical cyclones, polar air cloud vortices (polar lows), cyclonicity, winds in monsoon regions, and sea-ice concentrations. The spatial extent of the data variables varies considerably (regional to global). Data groups describing tropical cyclones, extratropical cyclones, polar lows, and cyclonicity have the most extensive coverages.

The data set comprises data extracted from a variety of sources, including publications of the National Oceanic and Atmospheric Administration (NOAA), U.S. Navy, foreign government agencies, universities, and other miscellaneous sources. The techniques used to derive the data from these sources are discussed in Parts 1 and 2, and Appendix A.

5. APPLICATIONS OF THE DATA

The data variables in this numeric data package (NDP) were selected on the basis of the roles that they play in determining the coastal effects of climate, especially erosion and inundation from storms. The data contained in this NDP may be used in several different ways. For example, the data may be used to determine the relative risk of coastal areas to damage by storm events and the recurrence intervals calculated. When the data are combined with a digital elevation model and estimates of wave heights, they may be used to determine the maximum landward extent of flooding from tropical cyclones.

Although the NDP data represent the current climate, they provide a baseline for calculations of how storm tracks, intensities, and frequencies of occurrence may change with global warming. The wide spatial coverage of the NDP makes the data suitable for both global-scale analyses and for screening a region to identify areas needing a more detailed local or regional-scale analysis. This data set may be useful for researchers or administrators in government agencies, the private sector, or educational institutions who are trying to determine the present and future vulnerability of coastal areas to, or the general distribution of, storms and related climatic events.

6. DEFINITION OF STANDARD TERMS AND CONCEPTS USED IN THE DATA PACKAGE

The large number of data variables and groups within this NDP may cause confusion. To help alleviate this problem, the following standard definitions are used:

- Data set - refers to all eight data groups.

- Data group - refers to a set of related variables that have been placed into a single ARC/INFO™ export file and flat ASCII file.

- Data variable - refers to a single, discrete data item within a data group (e.g., wind velocity). This includes all variables that describe the variations in storm events and/or climatic factors.

- System variable - a variable that references or identifies data variables with respect to their geographic location or the physical dimensions of the grid cells (polygons) they represent.

All data variables in this data set (except for those discussed in Sect. 8) contain data values representing areas of 1° x 1° or 5° x 5° grid cells of latitude and longitude. In Sect. 8 the polygons describe the borders of states along the U.S. Atlantic and Gulf coasts (with coordinates expressed in degrees latitude and longitude). The data groups with 1° x 1° grid cells (polygons) always have borders defined by whole-numbered latitudes and longitudes (i.e., 24°W, 36°S, etc.; not 24.3°W, or 36.9°S). Likewise, data groups with 5° x 5° grid cells (polygons) always have borders defined by whole-numbered latitudes and longitudes evenly divisible by 5 (i.e., 25°N, 45°E, etc.; not 27°N, or 43°E).

7. TROPICAL CYCLONES: AN OVERVIEW

Tropical cyclones play an important role in determining coastal erosion rates and have been observed in six recognized ocean basin areas (Crutcher and Quayle, 1974). The basins in which tropical cyclones occur include the North Atlantic, Eastern North Pacific, Western North Pacific, Southwestern Pacific, North Indian, and South Indian Oceans. Tropical cyclones primarily affect oceanic and coastal areas in tropical and subtropical regions; however, their influence is not strictly limited to those areas. Although an average of only 82 of these storms occur worldwide per year (Neumann et al., 1987), their low numbers are compensated by their often violent intensity. Tropical cyclones not only threaten human lives but also influence the environment by increasing coastal erosion rates.

A tropical cyclone creates and/or accelerates coastal erosion through its effect on the ocean (as do most other types of storms). As a tropical cyclone intensifies, it creates wave heights far above normal levels. Wave heights are primarily increased in two ways: (1) As barometric pressure decreases in a given storm, the resultant force of the atmosphere against the ocean decreases. This causes the sea to expand upward, thus helping to create large swells. Another important part of the tropical cyclone's wave action, (2) the storm surge, is a large wave primarily built up by the tropical cyclone's intense winds. Storm surges vary considerably from storm to storm, but have reached heights of more than 8 m (i.e., Hurricane Camille, 1969). Both of these processes can be further enhanced in a slow-moving tropical cyclone because the slow movement gives the storm more time to attack the same coastal area.

Through erosion processes, tropical cyclones can cause significant changes in the configuration of coastal areas. In 1980, Hurricane Allen severely damaged Padre Island, Texas. Although the most intense part of Allen passed over the area within a 24-h period, the storm formed more than 60 washover channels across the island and completely destroyed the first line of sand dunes on the part of the island closest to where the storm center passed (Lawrence and Pelissier, 1981). In 1926, a beach in Miami, Florida, receded about 80 m due to the erosion caused by a single hurricane. It would have taken the normal wave action decades to accomplish the same amount of erosion (Schwartz, 1982). In 1985, a weaker but slower moving storm, Hurricane Juan, also caused erosion problems. Juan hovered for days just off the Louisiana coast. Although classified only as a Saffir-Simpson Category 1 hurricane, the storm produced swells of 11 to 15 m in the open waters of the Northern Gulf of Mexico (Case, 1986). This brought waves 1 to 2 m above normal onto the extremely low relief of the Louisiana coast.

Data on tropical cyclone tracks and intensities are available for all six major ocean basins where they occur, although the completeness and accuracy of the data vary according to region. From the available information, two data groups describing tropical cyclone probabilities of occurrence have been created and included in this NDP. One data group gives probabilities of occurrence for all 5° x 5° grid cells (of latitude and longitude) in the world. The other data group gives probabilities of occurrence for 1° x 1° grid cells in selected regions of the Eastern North Pacific and North Atlantic Oceans (includes all affected coastal areas of the United States, Canada, and Bermuda).

Due to the destructive potential of tropical cyclones, the fact that some regions typically receive more severe tropical cyclones than others, and likely data applications, tropical cyclone probabilities of occurrence for 5° x 5° grid cells have been divided into three categories: tropical storms, hurricanes, and super typhoons (for specific definitions see the data group descriptions that follow). In addition to these categories, a data variable was created that describes the average forward motion of all tropical cyclones moving through a given 5° x 5° grid cell. This allows the user the option of weighting the tropical storm, hurricane, and super typhoon variables in terms of how long it takes a given storm to traverse a given area. The 1° x 1° grid cell data group does not include the super typhoon and mean forward velocity of tropical cyclones data variables. Neither of the above data groups describes probabilities of occurrence for tropical depressions (sustained winds less than < 17.5 m/s).

7.1 TROPICAL STORM AND HURRICANE PROBABILITIES OF OCCURRENCE FOR COASTAL AREAS OF THE UNITED STATES, CANADA, AND BERMUDA (1° X 1° GRID CELLS)

For this data group, both an exported ARC/INFO™ coverage file and a flat ASCII file (intended for a raster GIS) are provided. Both files contain identical data variables and data values. Data values in this data group always describe information for 1° x 1° grid cells (polygons) of latitude and longitude.

To facilitate the use of these data with raster GIS systems, the ARC/INFO™ coverage was placed into a 180 x 360 rectangular grid (64,800 cells) before generating the flat ASCII data file. This procedure places the data group into a global grid composed of 1° x 1° grid cells of latitude and longitude. The 64,800 grid cells are numbered from left to right by row, beginning with the upper left corner grid cell (center located at 89.5°N, 179.5°W) and ending with the lower right corner grid cell (center located at 89.5°S, 179.5°E). The grid cell (polygon) ID numbers used in the flat ASCII file differ from those in the ARC/INFO™ coverage file. However, grid cell identification numbers (ID) for both types of files serve the same purpose. The IDs provide the link between each grid cell (polygon) and its corresponding data values. Figure 1 shows the grid cell (polygon) IDs for both the ARC/INFO™ coverage file and the flat ASCII file in all areas analyzed for the data group (all figures in Part 1 of this document are collected in Sect. 14, starting on page 1-43).

This data group provides two data variables, which are defined as follows:

Tropical storm probability of occurrence - the probability (expressed as a percentage) of having at least one tropical cyclone center per year in a given 1° x 1° grid cell with maximum sustained winds > 17.5 m/s but < 33 m/s.

Hurricane probability of occurrence - the probability (expressed as a percentage) of having at least one tropical cyclone center per year in a given 1° x 1° grid cell with maximum sustained winds of 33 m/s or greater.

Corrections for latitudinal differences in the areas of 1° x 1° grid cells have not been applied to this data group. Differences in grid cell sizes are not likely to cause significant problems within tropical latitudes; however, latitudinal differences in grid cell sizes may become important when making data comparisons between tropical and extratropical latitudes.

An additional category recognized by some of the data sources for this data group is that of subtropical storm. Subtropical storms are low pressure systems that possess characteristics of both tropical and extratropical cyclones. Subtropical storms have sustained wind speeds corresponding to those of tropical storms as defined herein. Whenever subtropical storms were identified in the data sources, they were included with tropical storms for the purposes of this NDP.

The data in this data group are limited in extent to selected regions of the Eastern North Pacific and North Atlantic basins. However, all significant coastal zones of the United States, Canada, and Bermuda affected by tropical cyclones are included in the analyzed data regions. These data regions are identified in Fig. 1.

The data sources and period of record for the two data variables in this data group are consistent within a given ocean basin but vary between basins. Table 1 lists the data sources and the period of record for each ocean basin.

Table 1. Data sources and period of record for tropical storm and hurricane probabilities of occurrence for coastal areas of the United States, Canada, and Bermuda (1° x 1° grid cells)

Ocean basin	Data sources[a]	Period of record
North Atlantic	(2)	1899-1989
Eastern North Pacific	(3)	1965-1986
	(4)	1987-1989

[a]Data source numbers correspond with the data source listing in Sect. 7.4.

7.2 TROPICAL STORM, HURRICANE, AND SUPER TYPHOON PROBABILITIES OF OCCURRENCE FOR THE WORLD (5° X 5° GRID CELLS) AND MEAN FORWARD VELOCITIES OF TROPICAL CYCLONES FOR THE WORLD (5° X 5° GRID CELLS)

For this data group, both an exported ARC/INFO™ coverage file and a flat ASCII file (intended for a raster GIS) are provided. Both files contain identical data variables and data values. All data values in the data group describe information for 5° x 5° grid cells (polygons) of latitude and longitude.

The data group consists of 2,592 grid cells that form a continuous global grid. Grid cell (polygon) ID numbers for each grid cell in the data group are shown in Fig. 2. The ARC/INFO™ coverage file and the flat ASCII file have identical grid cell (polygon) ID numbers. The 2,592 grid cells are numbered from left to right by row, beginning with the upper left corner grid cell (center located at 87.5°N, 177.5°W) and ending with the lower right corner grid cell (center located at 87.5°S, 177.5°E). The grid cell (polygon) ID numbers are used to provide the link between each grid cell and its corresponding data values.

To facilitate better interpretation of the data, the data groups in Sects. 7.1 and 7.2 have been categorized into a number of data variables. The (Sect. 7.2) data group has four data variables. These include tropical storm, hurricane, and super typhoon probabilities of occurrence and the mean forward velocity of tropical cyclones. The later of the four data variables allows the user to scale the influence of the former three data variables by estimating the average mobility of tropical cyclones in a given area. The four data variables are defined as follows:

Tropical storm probability of occurrence - the probability (expressed as a percentage) of having at least one tropical cyclone center per year in a given 5° x 5° grid cell with maximum sustained winds > 17.5 m/s but < 33 m/s.

Hurricane probability of occurrence - the probability (expressed as a percentage) of having at least one tropical cyclone center per year in a given 5° x 5° grid cell with maximum sustained winds of 33 m/s or greater.

Super typhoon probability of occurrence - the probability (expressed as a percentage) of having at least one tropical cyclone center per year in a given 5° x 5° grid cell with maximum sustained winds of 67 m/s or greater.

Mean forward velocity of tropical cyclones - the average forward motion of all tropical cyclone centers (of any intensity) traversing a given 5° x 5° grid cell in meters per second (m/s).

Corrections for latitudinal differences in the areas of 5° x 5° grid cells have not been applied to this data group. Differences in grid cell sizes are not likely to cause significant problems within tropical latitudes; however, latitudinal differences in grid cell sizes may become important when making data comparisons between tropical and extratropical latitudes.

The data sources for this data group were sufficient to provide global coverage of tropical cyclone probabilities of occurrence for each of the data variables defined herein. No areas of known tropical cyclone occurrence have been excluded from this data group; however, in the South Indian Ocean, there is a minor discrepancy in the definition between a tropical storm and a hurricane. Some of the data sources for the South Indian Ocean used a maximum one-minute wind speed of 28.8 m/s as the velocity at or above which a tropical cyclone was designated a hurricane. As a result, some of the tropical cyclones identified as hurricanes in that area may actually have been tropical storms, according to the more widely accepted definition of a hurricane (i.e., 33 m/s). Note that the discrepancy does not affect all the data presented for the South Indian Ocean. For those data that are affected, the difference between the two definitions of storm intensity varies by only 4.2 m/s, a discrepancy that is not likely to introduce significant error above the normal noise/error level of the data itself.

An additional category recognized by some of the data sources for this data group is that of subtropical storm. Subtropical storms are low pressure systems that possess characteristics of both tropical and extratropical cyclones. Subtropical storms have sustained wind speeds corresponding to those of tropical storms as defined herein. Whenever subtropical storms were distinguished in the data sources, they were included with tropical storms in this data group.

Construction of the data group involved the use of many data sources with varying degrees of detail and differing periods of record. As a result, the data sources, geographic coverage, and period of record for each data variable defined herein vary widely from one location to another. For each ocean basin, Tables 2, 3, and 4 list the data sources and the time period that each used, and Figs. 3, 4, and 5 show the geographic coverage and period of record for the different ocean basins for each data variable.

7.3 DATA CONSIDERATIONS

Several tropical cyclone characteristics that were not considered when these data were derived. As a result, users may need to consider the techniques used to derive these data (shown in Appendix A) for certain applications. The more important cautions are discussed below:

1. The data variables in Sects. 7.1 and 7.2 describe probabilities of occurrence of tropical storms or hurricanes passing over grid cells of 1° x 1° and 5° x 5° latitude-longitude size. Therefore, one may need to consider the influence of tropical cyclones passing through adjacent grid cells when determining the vulnerability of a point on a coast to a storm.

2. Natural regional variations in the characteristics of tropical cyclones may require that the interpretation of this data be based on the known climatic parameters of each region. For example, given that tropical cyclones of the Western North Pacific Ocean have larger diameters on average than equally intense storms in the North Atlantic Ocean, data values in the Western North Pacific may be of greater importance than those of the same value in the North Atlantic (because of the influence of a given Western North Pacific storm over a larger area).

3. During the derivation of this data group, it was noted that some tropical cyclones seem to favor a particular direction of approach to a given area. This characteristic could affect the relative destructive potential of a tropical cyclone for a given location.

4. In certain grid cells, the distribution of recorded storm centers in a given grid cell may not be uniform across the entire grid cell. In other words, a given storm type may favor occurrence in a certain portion of the grid cell (a fact that could be masked by the grid cell resolution). This phenomenon is particularly likely in the data group of Sect. 7.2 that uses 5° x 5° grid cells.

5. The average size of tropical cyclones may affect the usefulness of the data groups describing tropical cyclones. The data group of Sect. 7.2 (using 5° x 5° grid cells) is likely to be better for the analysis of general tropical cyclone influence on a given area, whereas the 1° x 1° grid cell data group of Sect. 7.1 may be better for the analysis of tropical cyclone "direct" hits.

Table 2. Data sources and period of record for the tropical storm and hurricane probabilities of occurrence for the world (5° x 5° grid cells)

Ocean basin	Data sources[a]	Period of record
North Atlantic	(1)	1899-1971
	(2)	1972-1989
Eastern North Pacific	(1)	1965-1971
	(3)	1972-1986
	(4) and (8)	1987-1989
Western North Pacific	(3)	1950-1952
	(1) and (3)	1953-1971
	(3)	1972-1987
	(5)	1988-1989
South Central Pacific (East of 150° W)	(3)	1965-1986
	(5)	1987-June 1989
	(8)	July-Dec. 1989
Southwest Pacific (West of 150° W)	(1)	1956-1970
	(3) and (6)	1971-June 1979
	(3)	July 1979-1986
	(5)	1987-June 1989
	(8)	July 1989-June 1990
North Indian	(3) and (5)	1971-1974
	(5)	1975-1989
South Indian	(1)	1939-1969
	(3)	1970-1986
	(5)	1987-June 1989
	(8)	July-Dec. 1989

[a]Data source numbers correspond with the data source listing in Sect. 7.4.

Table 3. Data sources and period of record for the super typhoon probabilities of occurrence for the world (5° x 5° grid cells)

Ocean basin	Data sources[a]	Period of record
North Atlantic	(3)	1899-1987
	(4)	1988-1989
Eastern North Pacific	(3)	1965-1986
	(4) and (8)	1987-1989
Western North Pacific	(3)	1950-1987
	(5)	1988-1989
South Pacific (East of 180°E)	(3)	July 1977-June 1982
	(7)	July 1982-June 1984
	(5)	July 1984-June 1989
	(8)	July 1989-June 1990
South Pacific (West of 180°E)	(3)	July 1979-June 1980
	(7)	July 1980-June 1984
	(5)	July 1984-June 1989
	(8)	July 1989-June 1990
North Indian	(5)	1975-1989
South Indian	(3)	July 1979-June 1980
	(7)	July 1980-June 1984
	(5)	July 1984-June 1989
	(8)	July 1989-June 1990

[a]Data source numbers correspond with the data source listing in Sect. 7.4.

Table 4. Data sources and period of record for mean forward velocities of tropical cyclones for the world (5° x 5° grid cells)

Ocean basin	Data sources[a]	Period of record
Far North Atlantic (North of 55°N)	(3) (4)	1899-1986 1987-1989
North Atlantic (South of 55°N)	(1)	1899-1971
Eastern North Pacific	(1)	1965-1971
Northern Western North Pacific (North of 50°N)	(3) (5)	1950-1986 1987-1989
Western North Pacific (South of 50°N)	(1)	1953-1971
South Central Pacific (East of 150°W)	(3) (5) (8)	1965-1986 1987-June 1989 July-Dec 1989
Southwest Pacific (West of 150°W)	(1)	1956-1970
North Indian	(1)	1877-1970
South Indian	(1)	1939-1969

[a]Data source numbers correspond with the data source listing in Sect. 7.4.

7.4 DATA SOURCES

1. Crutcher, H.L., and R.G. Quayle. 1974. *Mariner's Worldwide Climatic Guide to Tropical Storms at Sea* NAVAIR 50-1C-61. Naval Weather Service Environmental Detachment, Asheville, North Carolina.

2. Newmann, C.J., B.R. Jarvinan, A.C. Pike, and J.D. Elms. 1987. *Tropical Cyclones of the North Atlantic Ocean: 1871-1986* (document revised with National Hurricane Center charts through 1989). National Climatic Data Center and National Hurricane Center, Asheville, North Carolina.

3. Brown, G.M., and W.L. Preston Jr. 1988. *A Compilation of North Atlantic, Eastern North Pacific, Central North Pacific, and Western North Pacific Tropical Cyclone Data* (TD-9697). National Oceanic and Atmospheric Administration/National Weather Service/National Hurricane Center/National Hurricane Research Laboratory.

   Elms, J.D., and National Climatic Data Center. 1987. *Consolidated World-Wide Tropical Cyclones* (TD-9636). National Climatic Data Center, Asheville, North Carolina.

4. Case, R.A., and H.P. Garrish. 1988. Atlantic Hurricane Season of 1987. *Monthly Weather Review*. 116:939-949.

   Cross, R.L. 1988. Eastern North Pacific Tropical Cyclones of 1987. *Monthly Weather Review*. 116:2106-2117.

   Lawrence, M.B., and J.M. Gross. 1989. Atlantic Hurricane Season of 1988. *Monthly Weather Review*. 117:2248-2259.

   Garrish, H.P., and M. Mayfield. 1989. Eastern North Pacific Tropical Cyclones of 1988. *Monthly Weather Review*. 117:2266-2277.

   Case, B., and M. Mayfield. 1990. Atlantic Hurricane Season of 1989. *Monthly Weather Review*. 118:1165-1177.

   Lawrence, M.B. 1990. Eastern North Pacific Hurricane Season of 1989. *Monthly Weather Review*. 118:1186-1193.

5. U.S. Department of the Navy. *1970-1979 Annual Typhoon Reports*. U.S. Naval Oceanography Command Center, Joint Typhoon Warning Center, Guam, Mariana Islands.

   U.S. Department of the Navy. *1980-1989 Annual Tropical Cyclone Reports*. U.S. Naval Oceanography Command Center, Guam, Mariana Islands.

6. Revell, C.G. 1981. *Tropical Cyclones in the Southwest Pacific: November 1969 to April 1979,* Misc. Publication 170. New Zealand Meteorological Service, Wellington, New Zealand.

7. Diercks, J.W., R.C. Weir, and M.K. Kopper. 1982. *Forecast Verification and Reconnaissance Data for Southern Hemisphere Tropical Cyclones (July 1980 through June 1982).* U.S. Naval Oceanography Command Center, Joint Typhoon Warning Center, Guam, Mariana Islands.

   Wirfel, W.P., and S.A. Sandgathe. 1986. *Forecast Verification and Reconnaissance Data for Southern Hemisphere Tropical Cyclones (July 1982 through June 1984).* U.S. Naval Oceanography Command Center, Joint Typhoon Warning Center, Guam, Mariana Islands.

8. Wells, F.H. 1990. Unpublished tropical cyclone statistics of the July 1989 through June 1990 Southern Hemisphere tropical cyclone season (personal correspondence).

   Elms, J.D. 1990. Statistics of Central North Pacific tropical cyclones 1987-1989 (personal correspondence).

8. HURRICANE STRIKES: AN OVERVIEW

The amount of damage caused by a hurricane ranges from minimal to catastrophic, depending on such factors as storm intensity, tidal state, coastal configuration, urbanization, and industrialization of the affected area. When a hurricane crosses an unpopulated coastline, high winds and storm surges may cause rapid erosion and shore-line retreat. Although this damage may be significant, the cost of the event in human terms may be relatively minor. However, when even a relatively weak hurricane passes over the coast of a populated area, high winds may cause damage to important man-made structures. The high tides and storm surge accompanying the storm could cause temporary flooding, wash out roads and bridges, and undermine the foundations of buildings near the shoreline, causing millions or even billions of dollars in damages.

To help relate hurricane intensities to damage potential, the National Hurricane Center has adopted the Saffir-Simpson Hurricane Scale (Saffir, 1977). The scale is descriptive and has several categories ranging from 1 through 5. The hurricane categories are based primarily on sustained winds speeds produced by the storms. Each Saffir-Simpson category description contains general information on storm surge size, expected extent of flooding and damage, and what type of evacuation measure should be taken.

Data are available that provide information on the number of hurricanes that have hit the U.S. Atlantic and Gulf coasts by state and Saffir-Simpson category. The period of record covers 1899 through 1989. From these data, a data group has been created for this NDP. The data group allows the user to analyze hurricane strikes by intensity class, thereby increasing the potential versatility of hurricane information.

8.1 NUMBER OF HURRICANE STRIKES FOR THE U.S. ATLANTIC AND GULF COASTS BY STATE AND SAFFIR-SIMPSON CATEGORY

This data group consists of an exported ARC/INFO™ coverage file, a flat ASCII data file, and a vector coordinate file containing latitude and longitude coordinates for each polygon in the coverage. The latitude-longitude coordinates are provided to allow for their entry into a raster GIS. The three data files provided contain identical data values for each of the data variables.

Unlike the other data groups in this NDP, the polygons in this data group are not referenced to area-based data values. Instead, the polygons refer to coastline segments of various states or substate regions which form a part of the borders of the polygons. Since no two of the states or substates represented have coastlines of equal length, the various polygons do not describe entities that are equal to one another. As a result, the data values associated with different polygons should not be compared to one another directly without some type of adjustment to the data. For these reasons, this data group is presented separately from the other data groups describing tropical cyclones.

This data group provides data for 24 states and substates. The polygons represent coastlines of states or portions of states. Some polygons are separated from the major body of the given state or substate to which they belong (usually these polygons represent islands). In such cases, the state or substate in question consists of several polygons (all of which represent the same coastal segment). All of the polygons representing a single state or substate contain identical data values for each data variable.

Data values for each data variable are associated with the correct polygon through the use of a polygon ID. Each polygon ID provides the link between an individual polygon and its associated data values. Figure 6 shows the polygons and polygon ID numbers for this data group.

Five data variables, one for each of the five Saffir-Simpson hurricane categories, are included in this data group. Each of the data variables describes the number of hurricanes of a given Saffir-Simpson Hurricane Scale intensity class that has crossed a given state or substate coastline during the period of record. Each of the five intensity classes is defined using the maximum sustained wind speed criterion shown in Table 5. Table 5 summarizes the wind speed criteria for each of the Saffir-Simpson Hurricane Scale intensity classes.

Table 5. Definition of Saffir-Simpson Hurricane Scale intensity classes based on sustained wind speeds

Intensity class	Maximum sustained winds
1	33.0 - 42.5 m/s
2	42.5 - 49.2 m/s
3	49.2 - 58.1 m/s
4	58.1 - 69.3 m/s
5	69.3 m/s or more

The data values for each of the five data variables were obtained from Neuman et al. (1987). Neuman et al. (1987) does not summarize the hurricane strikes by category after 1986. Therefore, polygons affected by hurricanes from 1987 through 1989 have been adjusted using Atlantic Hurricane Tracking Charts obtained from the National Hurricane Center, Miami, Florida.

The data sources for this data group are of high quality throughout the period of record. The period of record for this data group encompasses the North Atlantic hurricane seasons from 1899 through 1989.

8.2 DATA CONSIDERATIONS

A few important cautions about using the data group in Sect. 8.1 are:

1. The various coastal lengths of the states and substates need to be standardized to make data values comparable from state (substate) to state (substate). This may be accomplished by scaling the various data values by the total coastal length of each represented state or substate. However, it is likely that states or substates that

have very short coastlines (and therefore very low data values) may end up being underrepresented even after the data values have been scaled. It is also important to consider the effect scaling might have on the states or substates with irregular coastlines (bays, fjords, etc., which would tend to exaggerate the relative coastline length of the these states or substates).

2. Since the data values in the data group of Sect. 8.1 provide data on tropical cyclone occurrences over lengths instead of areas, the data values for this data group are not directly comparable to other data groups in this NDP.

8.3 DATA SOURCES

1. Newmann, C.J., B.R. Jarvinan, A.C. Pike, and J.D. Elms. 1987. *Tropical Cyclones of the North Atlantic Ocean: 1871-1986*, (document revised with National Hurricane Center charts through 1989). National Climatic Data Center/National Hurricane Center, Asheville, North Carolina.

2. Case, R.A., and H.P. Garrish. 1988. Atlantic Hurricane Season of 1987. *Monthly Weather Review*. 116:939-949.

   Lawrence, M.B., and J.M. Gross. 1989. Atlantic Hurricane Season of 1988. *Monthly Weather Review*. 117:2248-2259.

   Case, B., and M. Mayfield. 1990. Atlantic Hurricane Season of 1989. *Monthly Weather Review*. 118:1165-1177.

9. EXTRATROPICAL CYCLONES: AN OVERVIEW

Generally speaking, extratropical cyclones are migratory cyclones that track through temperate and subarctic/subantarctic regions. Unlike tropical cyclones, which derive energy primarily from their vertical circulations, extratropical cyclones use the existing baroclinic nature of their environment as an energy source (Palmen and Newton, 1969). As the name implies, extratropical cyclones do not occur in most tropical regions. The factors that control the formation and life cycle of extratropical cyclones are weak or nonexistent in the tropics. Another area of infrequent extratropical cyclone occurrences is over permanent ice cap regions in the arctic and antarctic where conditions often remain too stable for the formation of such storms.

Extratropical cyclones do not ordinarily exhibit the intensity observed in many cyclones (particularly tropical cyclones); however, extratropical cyclones may still be responsible for greater overall coastal erosion than other types of synoptic scale cyclones. This results from several factors: (1) extratropical cyclones occur more often than most other types of synoptic storms; (2) the structure (i.e., size and circulation patterns) of most extratropical cyclones allows for a large oceanic wave fetch; and (3) extratropical cyclones tend to aid the development of other types of storm events, which may in turn cause coastal erosion or damage (Schwartz, 1982).

Data describing the occurrence and genesis of extratropical cyclones in this NDP are currently limited to the Northern Hemisphere. In the Southern Hemisphere, data that exclusively describe extratropical cyclone frequencies are not available. Most studies involving extratropical cyclones that have been conducted for the Southern Hemisphere encompass short periods of record, or are limited to a specific season or region. Cyclonicity data are available for the Southern Hemisphere, however. Although cyclonicity data measure the occurrence of all types of cyclones as a group, cyclonicity information may provide a viable data source from which extratropical cyclone frequencies may be estimated. The usefulness of cyclonicity data for the determining of extratropical cyclone frequencies can be seen by noting the strong correlation between the extratropical cyclone frequencies of the Northern Hemisphere (Sect. 9) and the cyclonicity frequencies of the Northern Hemisphere (Sect. 11), (see Fig. 7).

9.1 MEAN NUMBER OF EXTRATROPICAL CYCLOGENESES BY MONTH AND YEAR IN THE NORTHERN HEMISPHERE (5° X 5° GRID CELLS) AND MEAN NUMBER OF EXTRATROPICAL CYCLONE OCCURRENCES BY MONTH AND YEAR IN THE NORTHERN HEMISPHERE (5° X 5° GRID CELLS)

For this data group, both an exported ARC/INFO™ coverage file and a flat ASCII file (intended for a raster GIS) are provided. Both files contain equivalent data variables and data values. Data values in this data group always describe information for 5° x 5° grid cells (polygons) of latitude and longitude.

This data group consists of 2,592 grid cells (forming a continuous global grid). However, actual data is available only for the Northern Hemisphere. Grid cell (polygon) ID numbers for each grid cell in the data group are shown in Fig. 2. The ARC/INFO™ coverage file and the flat ASCII file have identical grid cell (polygon) ID numbers. The 2,592 grid cells are numbered from left to right by row, beginning with the upper left corner grid cell (center located at 87.5°N, 177.5°W) and ending with the lower right corner grid cell (center located at 87.5°S, 177.5°E). The polygon ID numbers are used to provide the link between each grid cell (polygon) and its corresponding data values.

The definitions of the 26 data variables within this data group are as follows:

January-December extratropical cyclogenesis - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for each month.

January-December extratropical cyclone occurrence - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for each month.

Annual extratropical cyclogenesis - the mean annual number of extratropical cyclones with centers originating in a given 5° x 5° grid cell.

Annual extratropical cyclone occurrence - the mean annual number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell.

This data group covers extratropical cyclogenesis and extratropical cyclone occurrence for the Northern Hemisphere (20°N to 85°N). This area encompasses essentially all extratropical cyclone activity in the Northern Hemisphere. No correction for the variations in 5° x 5° latitude-longitude grid cell size has been applied to the extratropical cyclone occurrence data variables. This approach corresponds to that followed by the authors of the data source (Horn and Whittaker, 1982). Some area correction, however, was applied to the grid cells for the extratropical cyclogenesis data variables. This was accomplished by grouping 5° x 5° grid cells together that were located above 65°N (see Appendix A). Such a procedure does not entirely standardize grid cell areas but it reduces the variation in the grid cell sizes without affecting the basic character of the original data.

Estimates of extratropical cyclone occurrence in the Southern Hemisphere can be determined through the use of the cyclonicity data group found in Sect. 11.1. The climate zone data variable of Sect. 11.1 is intended to aid the user in such a process. The profound influence of extratropical cyclones on the cyclonicity data group can be deduced from Fig. 7. Note that the patterns of extratropical cyclone occurrence in both hemispheres shows up rather well.

The period of record for this data group is 1958-1977 (20 years). As a result of vast improvements in the worldwide monitoring of weather conditions over the last 50 years, and the relatively recent time period of the data sources used for this climatology, it is believed that this data group is of better quality than that of earlier extratropical cyclone climatologies.

9.2 DATA CONSIDERATIONS

The extratropical cyclone data group described in Sect. 9.1 contains few problems. Two characteristics of extratropical cyclones should be brought to the attention of the user:

1. Extratropical cyclones often affect areas far removed from their centers. Therefore, areas adjacent to those areas having a high incidence of extratropical cyclone centers may be affected. This effect may need to be taken into consideration in some research and/or analysis situations.

2. Natural regional variations in extratropical cyclones may result in differences in the mean size and structure of extratropical cyclones from one region to another. This may result in research conclusions that vary according to the specific region under study.

9.3 DATA SOURCE

1. Horn, L.H., and L.M. Whittaker. 1982. *Atlas of Northern Hemisphere Extratropical Cyclone Activity: 1958-1977.* Department of Meteorology, University of Wisconsin, Madison.

10. POLAR LOWS: AN OVERVIEW

Though lesser known than other types of cyclones, polar air cloud vortices (usually called polar lows) represent another possible contributor to coastal erosion processes. Polar-low development can be both sudden and intense; therefore, like many other types of cyclones, polar lows also represent a risk to human activities (Yarnal and Henderson, 1989). The extratropical North Pacific, extratropical North Atlantic, and Southern Ocean are the primary regions affected by polar lows; however, large extratropical lakes (such as Lake Superior) seem to be affected as well (Rasmussen and Lystad, 1987).

Polar lows primarily form in winter or spring behind the leading edge of an arctic or antarctic airstream over relatively warm water (Summer, 1988). Two processes seem to contribute to their development: (1) CISK (conditional instability of the second kind) and (2) moist baroclinicity (for definitions see Appendix E). In certain polar-low cyclogenetic regions, one process generally dominates over the other and vice versa. Because of their small size (about one tenth the diameter of typical synoptic extratropical cyclone systems), polar lows went largely unobserved on the lower resolution satellite imagery of the past. Two major types of polar lows are generally recognized; these are spiral-form and comma-form (Yarnal and Henderson, 1989).

Two data sources describing polar-low occurrences have recently been compiled. One data source describes frequencies for the North Pacific region (Yarnal and Henderson, 1989); the other covers Southern Hemisphere occurrences (Carleton and Carpenter, 1990). The polar-low data group described here is derived from these two data sources (complete reprints of the articles discussing polar-low occurrences for the two data sources are in Appendix F).

This data group includes data variables describing the distribution and number of occurrences of both comma-form and spiral-form polar lows. Data from both data sources were compiled in the same way, thus making direct comparison between the data values of the Northern Pacific Ocean and Southern Hemisphere possible.

10.1 MEAN NUMBER OF POLAR LOWS PER WINTER MONTH FOR THE NORTH PACIFIC OCEAN AND SOUTHERN HEMISPHERE (5° X 5° GRID CELLS)

For this data group, both an exported ARC/INFO™ coverage file and a flat ASCII file (intended for a raster GIS) are provided. Both files contain identical data variables and data values. Data values in this data group always describe information for 5° x 5° grid cells (polygons) of latitude and longitude.

This data group consists of 2,592 grid cells forming a continuous global grid. However, grid cells outside the North Pacific region in the Northern Hemisphere do not contain actual data. Grid cell (polygon) ID numbers for each grid cell in the data group are shown in Fig. 2. The ARC/INFO™ coverage file and the flat ASCII file have identical grid cell (polygon) ID numbers. The 2,592 grid cells are numbered from left to right by row beginning with the upper left corner grid cell (center located at 87.5°N, 177.5°W) and ending with the lower right corner grid cell (center located at 87.5°S, 177.5°E). The grid cell (polygon) ID numbers are used to provide the link between each grid cell and its corresponding data values.

This data group contains three data variables. The third data variable is the direct summation of the first two. Each of the data variables is defined below:

Mean number of comma-form polar lows per winter month - the area-adjusted mean number of polar-low centers (types 6, 7, and 21) occurring per winter month in a given 5° x 5° grid cell.

Mean number of spiral-form polar lows per winter month- the area-adjusted mean number of polar-low centers (type 22) occurring per winter month in a given 5° x 5° grid cell.

Mean number of polar lows per winter month- the area-adjusted mean number of polar-low centers (types 6, 7, 21, and 22) occurring per winter month in a given 5° x 5° grid cell.

The data values obtained from both data sources were corrected for latitudinal differences in the areas of 5° x 5° grid cells. All data were standardized to the area of a 5° x 5° grid cell of latitude-longitude centered at 45°N/S latitude.

The polar-low types mentioned herein (types 6, 7, 21, and 22) refer to the polar low classification system used by the data sources. An explanation of this classification system is in the Southern Hemisphere polar low data source (Carleton and Carpenter, 1990) in Appendix F. The classification scheme used by the Northern Pacific Ocean polar low data source is simply a Northern Hemisphere equivalent (cyclonic flow is reversed from clockwise to counterclockwise) of that described by the Southern Hemisphere polar-low data source. In this data group, polar low types 6, 7, and 21 essentially refer to comma-form polar lows in the formative or mature stages (but not the decaying stages). Likewise, type 22 refers to spiral-form polar lows.

The period of record used for the North Pacific Ocean in this data group cover the winter seasons (November through March) beginning in November 1976 and ending in March 1983. The winter seasons (June through September) from 1977 through 1983 were used in the Southern Hemisphere. As a result of the differences in the number of months used for each winter season by the two data sources, all of the data variables were scaled down to a 1-month period, thus yielding a "1 winter month" frequency for both data sources. The "1 winter month" frequency does not represent any particular winter month. Instead, it describes the mean number of polar lows in an average winter month for the entire period of record.

Figure 8 shows the spatial extent of the data sources. Some satellite images used for the data sources' polar-low analyses were missing during the period of record; however, due to the low number of missing images the data are not likely to have been significantly affected.

10.2 DATA CONSIDERATIONS

A number of factors should be taken into consideration when using the polar-low data group in Sect. 10.1:

1. Polar lows tend to trail large-scale extratropical cyclones (Yarnal and Henderson, 1989). Therefore, the use of some type of correlation between extratropical cyclones and polar lows may allow for the extension of the polar-low data into the North Atlantic (where data are currently not available).

2. Since polar lows tend to result from two major causes of formation instead of one (see Sect. 10 overview), multiple terms may be more appropriate in some models that deal with formational processes of polar lows.

3. This data group addresses polar-low occurrence only in the formative and mature stages. Polar lows in the decaying stage are not included in this climatology.

10.3 DATA SOURCES

1. Yarnal, B., and K.G. Henderson. 1989. A Satellite Derived Climatology of Polar-Low Evolution in the North Pacific. *International Journal of Climatology*. 9:551-566.

2. Carleton, A.M., and D.A. Carpenter. 1990. Satellite Climatology of "Polar Lows" and Broadscale Climatic Associations for the Southern Hemisphere. *International Journal of Climatology*. 10:219-246.

11. CYCLONICITY: AN OVERVIEW

The term *cyclonicity*, as used here, does not refer to any single type of cyclone. Cyclonicity describes the extent to which a given area is dominated by centers of low pressure without regard to the particular type of cause for a given cyclone.

Although the grouping of several cyclone types together may present some difficulties in data analysis, this data group still provides a great deal of useful information since certain types of cyclones dominate particular climatic regions. As a result, cyclonicity data values often correlate well with those of the dominant cyclone type in a given region. Consequently, the frequency of the said "dominant" cyclone may be estimated on the basis of the cyclonicity data values. Extratropical cyclones, thermal lows, monsoon lows, and tropical lows represent the basic cyclone types found in the cyclonicity data.

Global cyclonicity data are provided in this data group. The data variables describe various aspects of cyclonicity for January, July, and the year. The months of January and July were chosen to provide an indication of the seasonal extremes of the data variables. Although other pairs of summer and winter months may work as well or better than January and July, these months were chosen for reasons of data availability.

Three data sources are used in developing this data group. The data sources vary somewhat in detail and analysis style. To allow data comparison between areas covered by unlike data sources, three global data variables were derived. The calculation of the global variables involved the standardization of the cyclone occurrence data from the three primary data sources. The standardized data variables allow comparison of data values on a global scale.

11.1 MEAN AND/OR RELATIVE NUMBER OF CYCLONES FOR JANUARY, JULY, AND THE YEAR FOR THE WORLD (5° x 5° GRID CELLS) AND THE MEAN NUMBER OF HOURS OF CYCLONE OCCURRENCE FOR JANUARY, JULY, AND THE YEAR FOR THE SOUTHERN HEMISPHERE (5° X 5° GRID CELLS)

For this data group, both an exported ARC/INFO™ coverage file and a flat ASCII file (intended for a raster GIS) are provided. Both files contain equivalent data variables and data values. Data values in this data group describe information for 5° x 5° grid cells (polygons) of latitude and longitude.

This data group consists of 2,592 grid cells (forming a continuous global grid). Grid cell (polygon) ID numbers for each grid cell in the data group are shown in Fig. 2. The ARC/INFO™ coverage file and the flat ASCII file have identical grid cell (polygon) ID numbers. The 2,592 grid cells are numbered from left to right by row beginning with the upper left corner grid cell (center located at 87.5°N, 177.5°W) and ending with the lower right corner grid cell (center located at 87.5°S, 177.5°E). The grid cell (polygon) ID numbers are used to provide the link between each grid cell and its corresponding data values.

This data group contains the following 19 data variables:

Climate zone - indicates the climate zone to which the given 5° x 5° grid cell is assigned. Two climate zones are possible: tropical and extratropical. This data variable is not a cyclonicity value. Rather, it is intended to assist the user of cyclonicity data in the segregation of tropical and extratropical cyclone types.

Mean number of cyclones in January (Northern Hemisphere) - the area-adjusted mean number of cyclone centers occupying a position at 1230 Greenwich Mean Time (GMT) within a given 5° x 5° grid cell over the period of record [based on observations at 5-hectopascal (hPa) isobar intervals].

Mean number of cyclones in July (Northern Hemisphere) - the area-adjusted mean number of cyclone centers occupying a position at 1230 GMT within a given 5° x 5° grid cell over the period of record (based on observations at 5-hPa isobar intervals).

Mean number of cyclones annually (Northern Hemisphere) - the area-adjusted mean number of cyclone centers occupying a position at 1230 GMT within a given 5° x 5° grid cell per year (based on observations at 5-hPa isobar intervals and data for all 12 months of the year).

Mean number of cyclones in January (Southern Hemisphere excluding the Australian Region) - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell over the period of record as interpreted from daily observations at 0000 and 1200 Universal Time (UTC) (based on observations at 10-hPa isobar intervals).

Mean number of cyclones in July (Southern Hemisphere excluding the Australian Region) - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell over the period of record as interpreted from daily observations at 0000 and 1200 UTC (based on observations at 10-hPa isobar intervals).

Mean number of cyclones annually (Southern Hemisphere excluding the Australian Region) - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell per year as interpreted from daily observations at 0000 and 1200 UTC (based on observations at 10-hPa isobar intervals and data from January and July only).

Mean number of hours of cyclonicity in January (Southern Hemisphere excluding the Australian Region) - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell as interpreted from daily observations at 0000 and 1200 UTC (based on observations at 10-hPa isobar intervals).

Mean number of hours of cyclonicity in July (Southern Hemisphere excluding the Australian Region) - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell per July as interpreted from daily observations at 0000 and 1200 UTC (based on observations at 10-hPa isobar intervals).

Mean number of hours of cyclonicity annually (Southern Hemisphere excluding the Australian Region) - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell per year as interpreted from daily observations at 0000 and 1200 UTC (based on observations at 10-hPa isobar intervals and data from January and July only).

Mean number of cyclones in January (Australian Region) - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell per January as interpreted from daily observations at 0000 and 1200 UTC (based on observations at 4-hPa isobar intervals).

Mean number of cyclones in July (Australian Region) - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell per July as interpreted from daily observations at 0000 and 1200 UTC (based on observations at 4-hPa isobar intervals).

Mean number of cyclones annually (Australian Region) - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell per year as interpretations from daily observations at 0000 and 1200 UTC [based on observations at 4-hPa isobar intervals and data from a variable number of months of the year (2 to 12)].

Mean number of hours of cyclonicity in January (Australian Region) - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell per January as interpreted from daily observations at 0000 and 1200 UTC (based on observations at 4-hPa isobar intervals).

Mean number of hours of cyclonicity in July (Australian Region) - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell per July as interpreted from daily observations at 0000 and 1200 UTC (based on observations at 4-hPa isobar intervals).

Mean number of hours of cyclonicity annually (Australian Region) - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell per year as interpreted from daily observations at 0000 and 1200 UTC [based on observations at 4-hPa isobar intervals and data for a variable number of months of the year (2 to 12)].

Relative number of cyclones in January (global) - the area-adjusted statistically standardized data value calculated by subtracting the given data source mean number of cyclone centers present per 5° x 5° grid cell per January from the mean number of cyclone centers present in a given 5° x 5° grid cell per January and then dividing by the standard deviation of the given data source mean number of cyclone centers present per 5° x 5° grid cell per January.

Relative number of cyclones in July (global) - the area-adjusted statistically standardized data value calculated by subtracting the given data source mean number of cyclone centers present per 5° x 5° grid cell per July from the mean number of cyclone centers present in a given 5° x 5° grid cell per July and then dividing by the standard deviation of the given data source mean number of cyclone centers present per 5° x 5° grid cell per July.

Relative annual number of cyclones (global) - the area-adjusted statistically standardized data value calculated by subtracting the given data source mean number of cyclone centers present per 5° x 5° grid cell per year from the mean number of cyclone centers present in a given 5° x 5° grid cell per year and then dividing by the standard deviation of the given data source mean number of cyclone centers present per 5° x 5° grid cell per year.

The border between the "Southern Hemisphere excluding the Australian Region" and the "Australian Region" is defined by a latitude-longitude box with corners of (10°S,90°E), (10°S,180°E), (55°S,90°E), and (55°S,180°E). The same box is shown in Fig. 9 where the different data source regions for this data group are illustrated.

All data values from all data sources in this data group have been corrected for latitudinal differences in the areas of 5° x 5° grid cells. Data values are standardized to that of a 5° x 5° grid cell centered at 45°N/S.

After standardizing the original data variables for area, the global data variables were calculated. The global data variables combine all available data on the number of cyclones into one compatible global set of data values based on the use of deviations from the mean for each data source (detailed information on how the global data variables were derived is in Appendix A).

Figure 7 shows the distribution of data values for the relative annual number of cyclones (global) data variable. Given some knowledge of climatological regions, it is apparent from Fig. 7 that major areas of specific types of cyclone occurrence are distinguishable.

The climate zone data variable, though not a cyclonicity data variable, is provided to assist the user in distinguishing dominant types of cyclones in various regions and is based on a modified version of the Köppen World Climate Classification. This data variable is designed to be used in the identification of areas dominated by extratropical cyclones. Although it is impossible to entirely separate the extratropical cyclone occurrences from those of other types of cyclones in the same areas, the climate zone data variable may prove useful in separating out major areas of nonextratropical cyclone occurrences.

Three data sources were used in compiling the cyclonicity data variables (see Sect. 11.3). Table 6 lists the time period and data sources used for each region. The geographic extent of these data sources is illustrated in Fig. 9.

Table 6. Data sources and period of record for cyclonicity data by region (5° x 5° grid cells)

Region	Data source[a]	Period of record
Northern Hemisphere	(1)	1899-1938
Southern Hemisphere (excluding Australia)	(2)	1973-1987
Australia-New Zealand	(3)	1965-1987

[a]Data source numbers correspond with the data source listing in Sect. 11.3.

11.2 DATA CONSIDERATIONS

With any group of real-world data, it is helpful to consider the nature of the data being presented. Two considerations concerning the cyclonicity data group are as follows:

1. Although the global data variables bring the data from the three original data sources into a compatible format, one should note that the original data sources vary from one another concerning the detail of data provided. This implies that the data's precision may remain a factor between regions having unlike data sources.

2. In addition to data that describe the number of cyclones in a given area, the Southern Hemisphere and Australian Region data sources provide information in terms of the number of hours that cyclones exist in a given area. If the user's area of interest is only in the Southern Hemisphere, the "hours" data variables are likely to be preferable to simple cyclone numbers because data on hours would better quantify the magnitude of cyclonic influence in a given area.

11.3 DATA SOURCES

1. Klein, W.H. 1957. *Principal Tracks and Mean Frequencies of Cyclones and Anticyclones in the Northern Hemisphere, Research Paper No. 40*. Extended Forecast Section, U.S. Weather Bureau, Washington, D.C.

2. Leighton, R.M. 1990. Unpublished digital-form cyclonicity data for the Southern Hemisphere for the months of January and July. Bureau of Meteorology, Melbourne, Australia (personal correspondence).

3. Leighton, R.M. 1989-1990. Unpublished digital-form cyclonicity data for the Australian region for all 12 months of the year. Bureau of Meteorology, Melbourne, Australia (personal correspondence).

The Data Source (3) data above are associated with the following research paper:

Leighton, R.M., and R. Deslandes. 1989. *Monthly Averages of Anticyclonicity and Cyclonicity in the Australian Region.* National Meteorological Centre, Bureau of Meteorology, Melbourne, Australia.

4. Espenshade, E.B., Jr. 1987. *Goode's World Atlas*, 17th Edition. Rand McNally, Chicago, Illinois.

12. COASTAL WINDS IN MONSOON REGIONS: AN OVERVIEW

The creation of this data group stemmed from a need to quantify the influence of monsoons on coastlines. Although most other data groups in this NDP describe climatological data that can be easily characterized, similar attempts to measure monsoon activity proved troublesome. Monsoon intensity does not seem to be highly correlated with any single meteorological variable; rather, a great variety of storm systems, precipitation regimes, and wind events are associated with monsoons (Oliver and Fairbridge, 1987).

In a broad sense, monsoons are seasonal winds that blow in response to the annual changes in atmospheric pressure over land and water. These pressure gradients are the result of differential heating of air masses over land surfaces and ocean surfaces and tend to occur in the region enclosed by the latitudes and longitudes of 20°W, 40°N, 160°E, and 20°S. The specific area meeting the monsoon climate criteria is illustrated in Fig. 10.

Monsoons have been identified as being capable of causing coastal erosion. Some regions of India have sustained "large scale" monsoon-induced coastal erosion, and in Hong Kong, gale force winds are occasionally observed in association with monsoon activity (Bird and Schwartz, 1985). When these "monsoon gales" occur during periods of onshore wind flow, erosion of coastline features is a likely result.

In calculating an index of mean onshore wind flow for the monsoon region, it was necessary to obtain data describing both mean wind direction and mean wind speed. Two data sources (one for wind direction and one for wind speed) were used to derive the desired data variable. From the data source describing mean wind direction, the onshore and offshore components of wind direction were calculated for each month for 1° x 1° grid cells. From the wind-speed data source, the wind intensity was calculated by month for 5° x 5° grid cells. The data computations from both data sources were then combined to create an index of the relative influence of onshore winds in monsoon environments.

12.1 INDEX OF THE INFLUENCE OF WINDS ON COASTLINES IN THE AFRICAN, ASIAN, AND AUSTRALIAN MONSOON REGIONS (1° X 1° GRID CELLS)

For this data group, both an exported ARC/INFO™ coverage file and a flat ASCII file (intended for a raster GIS) are provided. Both files contain equivalent data variables and data values. Data values in this data group describe information for 1° x 1° grid cells (polygons) of latitude and longitude.

To facilitate the use of this data with raster systems, the ARC/INFO™ coverage was placed into a 180 x 360 rectangular grid (64,800 cells) before generating the flat ASCII data file. This procedure places the data group into a global grid composed of 1° x 1° grid cells of latitude and longitude. The 64,800 grid cells are numbered from left to right by row beginning with the upper left corner grid cell (center located at 89.5°N, 179.5°W) and ending with the lower right corner grid cell (center located at 89.5°S, 179.5°E) of the grid. The grid cell (polygon) IDs used in the flat ASCII file differ from the IDs used in the ARC/INFO™ coverage file. However, grid cell (polygon) IDs for both types of files serve the same purpose. The IDs provide the link between each grid cell and its corresponding data values. Figure 11 shows the grid cell (polygon) ID numbers for both the ARC/INFO™ coverage file and the flat ASCII file for all areas containing analyzed data in this data group.

The single data variable for this data group is defined below:

Index of the influence of winds on coastlines - A numeric index of the relative influence of onshore winds on coastlines in monsoon regions for 1° x 1° grid cells. Numbers range from 0 to 154. Larger numbers indicate greater influence of onshore winds on the given coastal area.

Given the general tropical location of this data group, differences in grid cell sizes are not likely to be significant. As a result, data values in this data group are not standardized for latitudinal differences in the areas of 1° x 1° grid cells.

Two data sources were used for the wind-index data group. One contains contour charts showing mean monthly wind speeds for the globe. The other data source describes mean monthly wind directions in the form of streamlines for all regions between 35°N and 35°S. All areas defined as monsoonal in Fig. 10 fall within this area. From these data sources, a digital index number was derived for each 1° x 1° grid cell.

The wind-speed data for all 12 months of the year were calculated first. A determination was then made concerning which months of the year winds typically blow onshore (toward shore) for each 1° x 1° grid cell in the designated monsoon coastal region. Wind-speed information for the months with onshore winds was totaled to derive an index value for each of the 1° x 1° grid cells (see Appendix A).

12.2 DATA CONSIDERATIONS

Two items to consider when using the data from the wind-index data group are as follows:

1. When the use of this data group is directed at monsoonal studies, a high amount of noise is likely to exist in the data values because of the influence that nonmonsoonal meteorological phenomena exhibit on the mean wind-speed and mean wind-direction data values of the data sources.

2. Mean wind-speed data is not likely to be an entirely adequate measure of the coastal erosion caused by monsoons for some monsoon events. In many circumstances, the major portion of net monsoon-induced coastal erosion is likely to result from a few significant high-wind events rather than a long-term wind average. As a result, information quantifying monsoons that is based on means may tend to underestimate the coastal erosion risk from monsoons in some areas.

12.3 DATA SOURCES

Wind Speed:

1. Naval Oceanography Command Detachment. 1981. *U.S. Navy Marine Climatic Atlas of the World, Volume IX: World-wide Means and Standard Deviations*. Asheville, North Carolina.

Wind Direction:

2. U.S. Aeronautical Chart and Information Center. 1970. *AWSTR 215*, (Resultant Gradient-Level Wind-Charts 1-24). U.S. Air Force, St. Louis, Missouri.

13. SEA ICE: AN OVERVIEW

Sea ice affects the coastline in a number of ways. In terms of coastal erosion processes, sea ice exerts both a positive and negative influence. Which of the two influences is dominant depends on a number of climatological factors.

Most coastal erosion caused by sea ice results when the ice comes into contact with the shoreline. Pack ice may push ridges of ice onto a beach, carrying some of the beach material along in the process. Floating icebergs may run aground, gouging holes in shore areas. However, these processes tend to redistribute sediment more than they remove it. Sea-ice erosion apparently does not affect coastal areas as much as wind and wave erosion does (Schwartz, 1982).

Sea ice also offers a great deal of protection from erosion to some coastal areas. When sea-ice is present in the waters of a coastal zone, it reduces the erosion caused by wave action by reducing wave energy levels. When shorefast ice forms on a beach, the ice shelters the area from most wind erosion and essentially all wave action (Schwartz, 1982).

A significant amount of data are available for sea ice; however, the data group derived here uses only a small portion of the total amount of data available. This data group presents mean annual sea-ice concentrations for 1° x 1° grid cells containing United States coastlines affected by sea ice.

13.1 MEAN ANNUAL SEA-ICE CONCENTRATIONS FOR ALASKAN AND U.S. ATLANTIC COASTAL AREAS (1° X 1° GRID CELLS)

This data group has an exported ARC/INFO™ coverage file and a flat ASCII file (intended for a raster GIS). Both files contain equivalent data variables and data values. Data values in this data group describe information for 1° x 1° grid cells (polygons) of latitude and longitude.

To facilitate the use of this data with raster systems, the ARC/INFO™ coverage was placed into a 180 by 360 global rectangular grid (64,800 cells) before the flat ASCII data file was generated. The 64,800 grid cells are numbered from left to right by row beginning with the upper left corner grid cell (center located at 89.5°N, 179.5°W) and ending with the lower right corner grid cell (center located at 89.5°S, 179.5°E). The 64,800 grid cells have borders corresponding to whole degrees of latitude and longitude. The grid cell (polygon) IDs used in the flat ASCII file differ from the grid cell (polygon) ID numbers used in the ARC/INFO™ coverage file. However, grid cell (polygon) IDs for both types of files serve the same purpose. The IDs provide the link between each grid cell and its corresponding data values. Figure 12 shows the grid cell (polygon) ID numbers for both the ARC/INFO™ coverage file and the flat ASCII file for all areas containing real data (i.e., areas analyzed for this data group).

This data group contains one data variable defined as follows:

Mean annual sea-ice concentration - the mean concentration of sea ice for a given 1° x 1° grid cell averaged out over a year. Data values are expressed as a percentage.

The characteristics of the data sources do not require corrections for differences in the areas of 1° x 1° grid cells. The latitudinal differences in grid cell sizes result in a higher resolution of the data at more northerly latitudes, but these differences do not affect the ability to make data value comparisons of various 1° x 1° grid cells.

The derivation of the sea-ice data variable involved the use of 24 bimonthly average sea-ice concentration charts. These charts were used to derive the data values for this data group. The sea-ice concentrations were obtained from the sea-ice charts for each of the 1° x 1° grid cells in the study area and averaged to obtain the mean annual sea ice concentration for each 1° x 1° grid cell.

The primary data sources describe the data in the form of isoline charts of sea-ice concentrations. These contour maps use sea-ice concentration zones. For the purposes of converting the data into a digital format, the sea-ice zones were regarded as single midrange values. The various sea-ice zones and the single midrange values by which they were estimated are described in Table 7.

The secondary data sources were used to check for areas of occasional sea-ice presence that were not identified in the primary data sources. Typically, the areas in question do not have sea ice in coastal waters every year or experience sea ice for only short periods of each year. The secondary data sources indicate the absolute maximum extent of 10% sea-ice concentrations. This information was used to estimate sea-ice concentrations of 2% for certain 1° x 1° grid cells for the time periods in question. Mean annual sea-ice concentration data values resulting from these estimates generally have values less than 0.5% (a detailed discussion of the methods used for deriving the data values from the sea-ice data sources is in Appendix A).

Table 7. Single values used in the conversion of sea-ice concentration zones to digital format

Sea-ice concentration zone (%)	Midrange value (%)
80 to 100%	90%
50 to 80%	65%
20 to 50%	35%
0 to 20%	10%
0%	0%

13.2 DATA CONSIDERATIONS

The following comments describe certain factors that one should consider when attempting to use the sea-ice data:

1. The data values should not be seen as representative of the ice conditions for any given time during the year. Rather, the data values are intended to describe the mean sea-ice concentration in a given 1° x 1° grid cell averaged over the entire year.

2. Some areas that regularly experience near 100% sea-ice concentration are likely to be slightly under-valued in the data values as a result of the adjustments described in Table 7 (i.e., 90% is the highest possible value that could be given to a grid cell by this method).

3. This data group may be used to scale the effects of other data groups in this NDP. The effects of extratropical cyclones (see Sect. 9), for example, could be adjusted with a coefficient based on the presence of sea ice as indicated by this data group.

13.3 DATA SOURCES

Primary Sources

1. U.S. Naval Oceanography Command Detachment. 1986. *Sea-Ice Climatic Atlas: Arctic East*, Vol. 1. Asheville, North Carolina.

2. U.S. Naval Oceanography Command Detachment. 1986. *Sea-Ice Climatic Atlas: Arctic West*, Vol. 2. Asheville, North Carolina.

Secondary Sources

3. U.S. Naval Oceanography Command Detachment. 1974. *U.S. Navy Marine Climatic Atlas of the World, Volume I, The North Atlantic*. Asheville, North Carolina.

4. U.S. Naval Oceanography Command Detachment. 1977. *U.S. Navy Marine Climatic Atlas of the World, Volume II, The North Pacific*. Asheville, North Carolina.

14. FIGURES

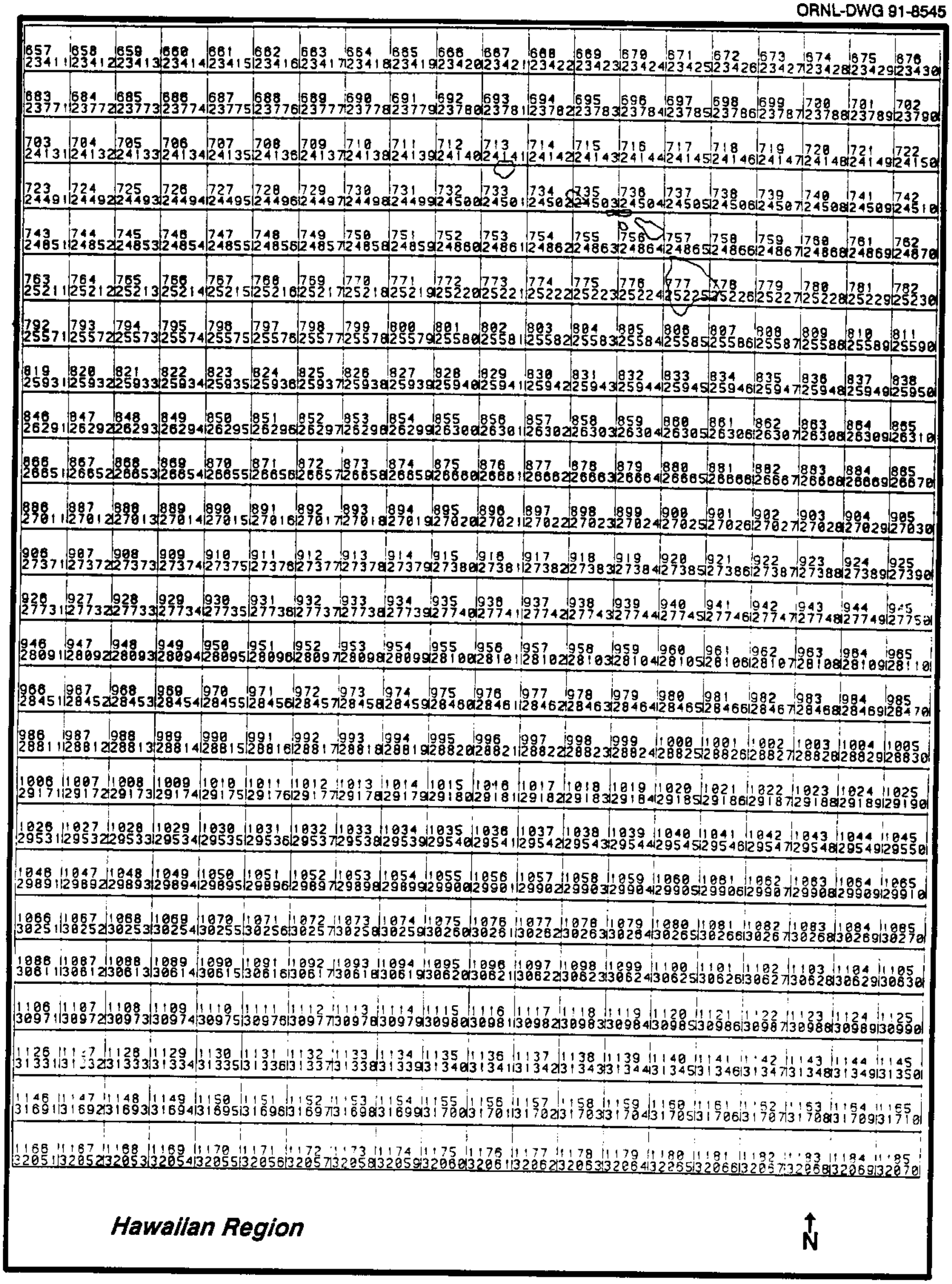
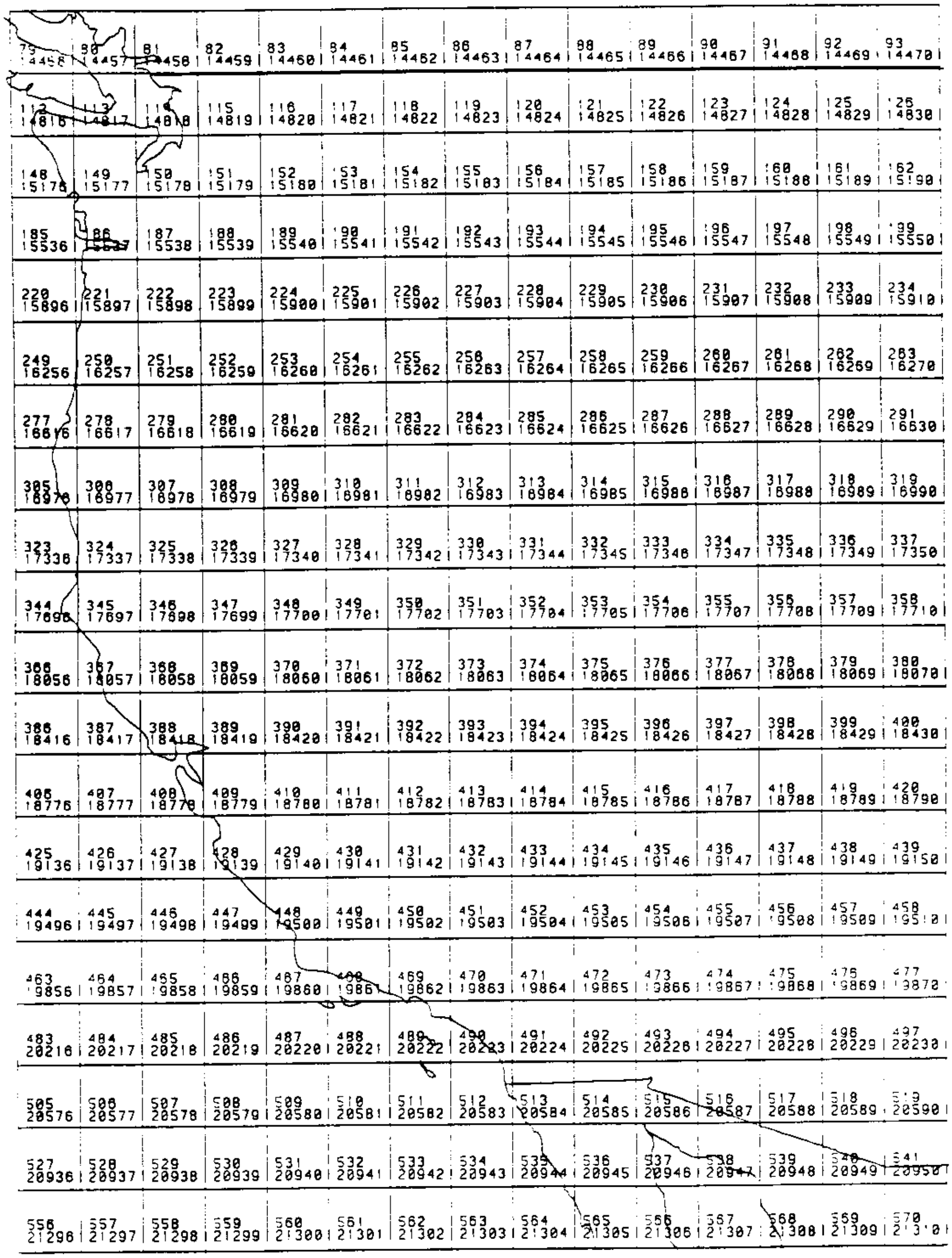


Fig. 1 (Page 1 of 6). Spatial coverage of the tropical storm and hurricane probabilities of occurrence described in Sect. 7.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).



U.S.-Canadian West Coast

Fig. 1 (Page 2 of 6). Spatial coverage of the tropical storm and hurricane probabilities of occurrence described in Sect. 7.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8547

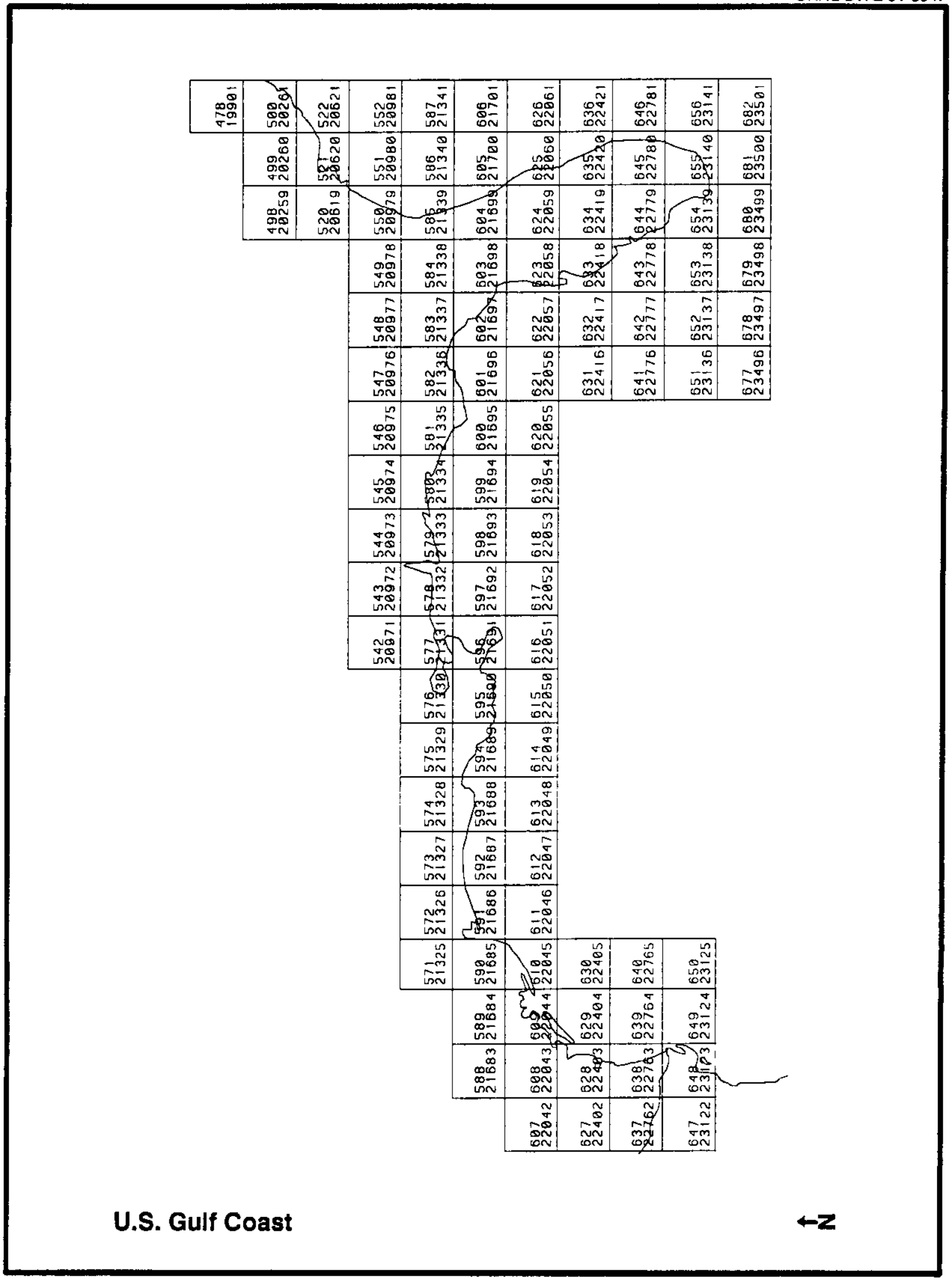


Fig. 1 (Page 3 of 6). Spatial coverage of the tropical storm and hurricane probabilities of occurrence described in Sect. 7.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8548

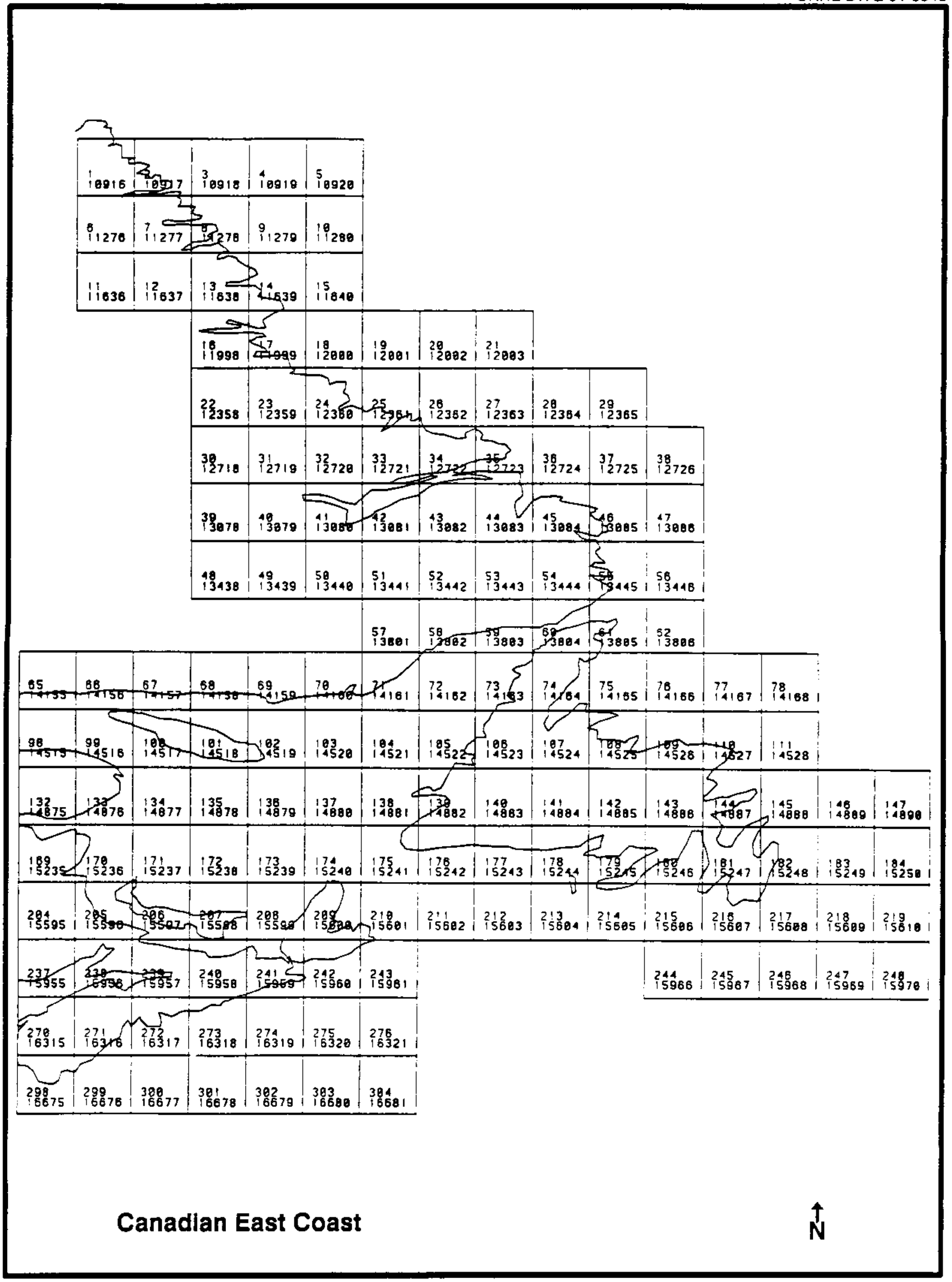


Fig. 1 (Page 4 of 6). Spatial coverage of the tropical storm and hurricane probabilities of occurrence described in Sect. 7.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8549

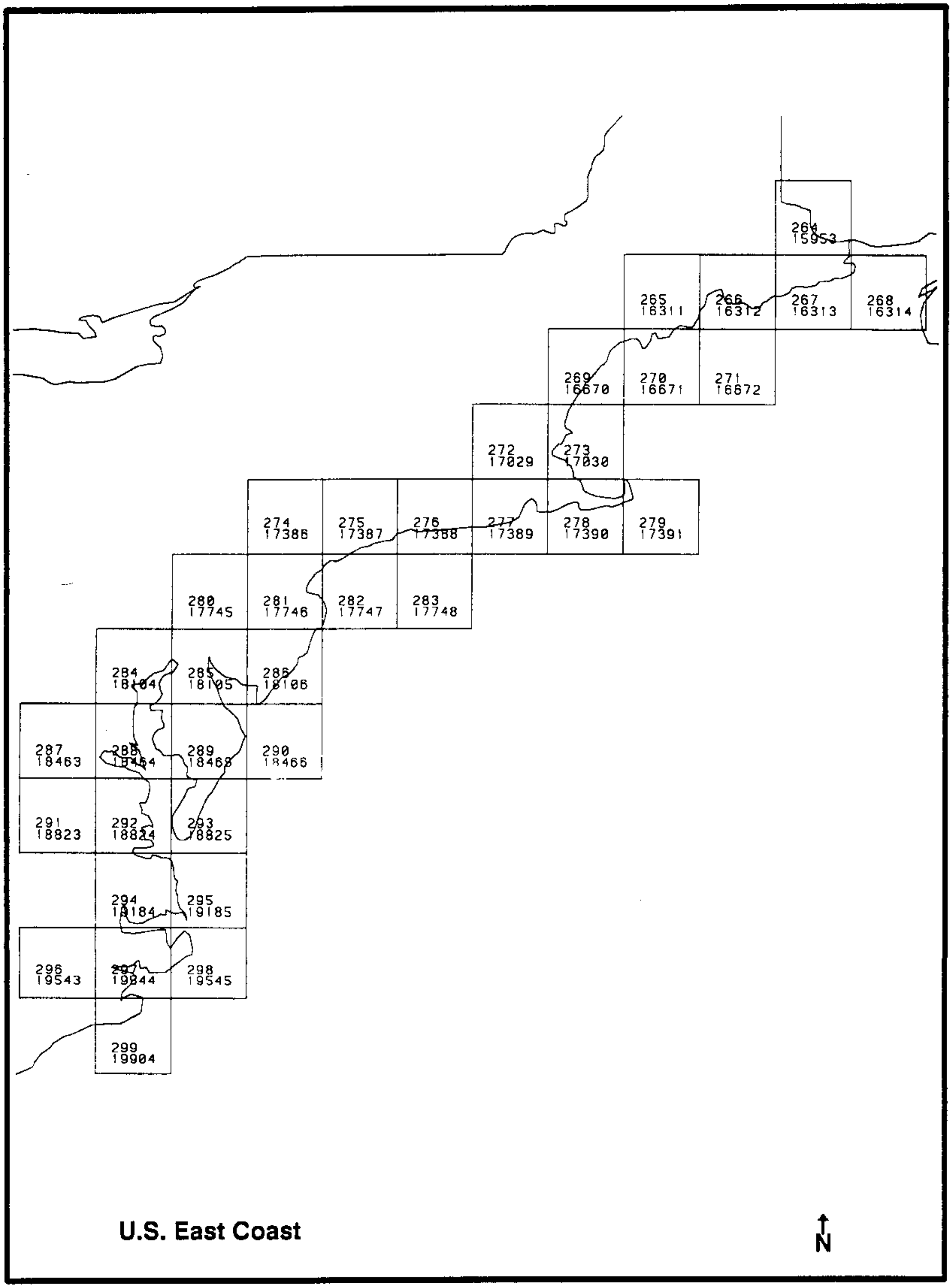


Fig. 1 (Page 5 of 6). Spatial coverage of the tropical storm and hurricane probabilities of occurrence described in Sect. 7.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8550

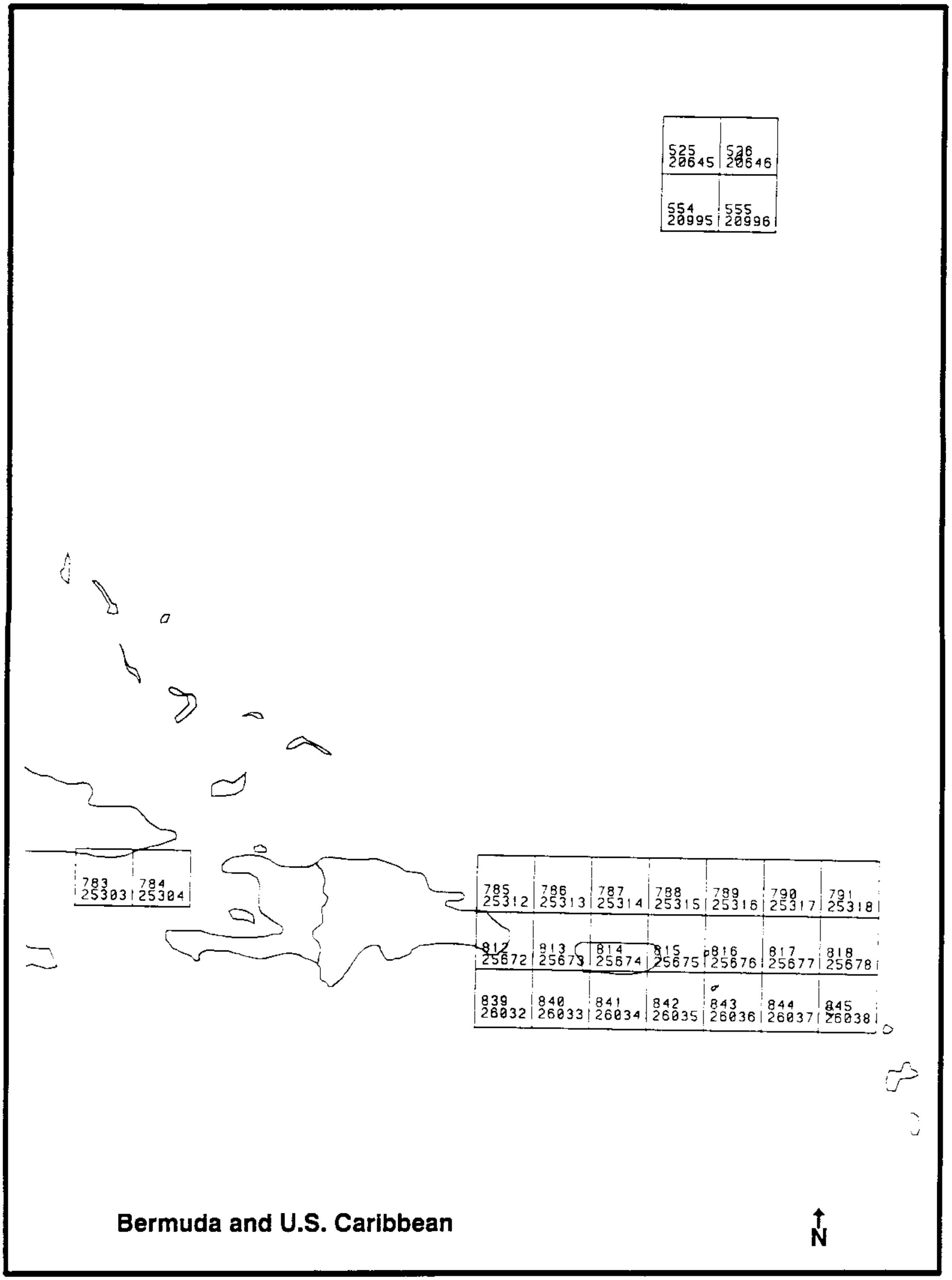


Fig. 1 (Page 6 of 6). Spatial coverage of the tropical storm and hurricane probabilities of occurrence described in Sect. 7.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8551

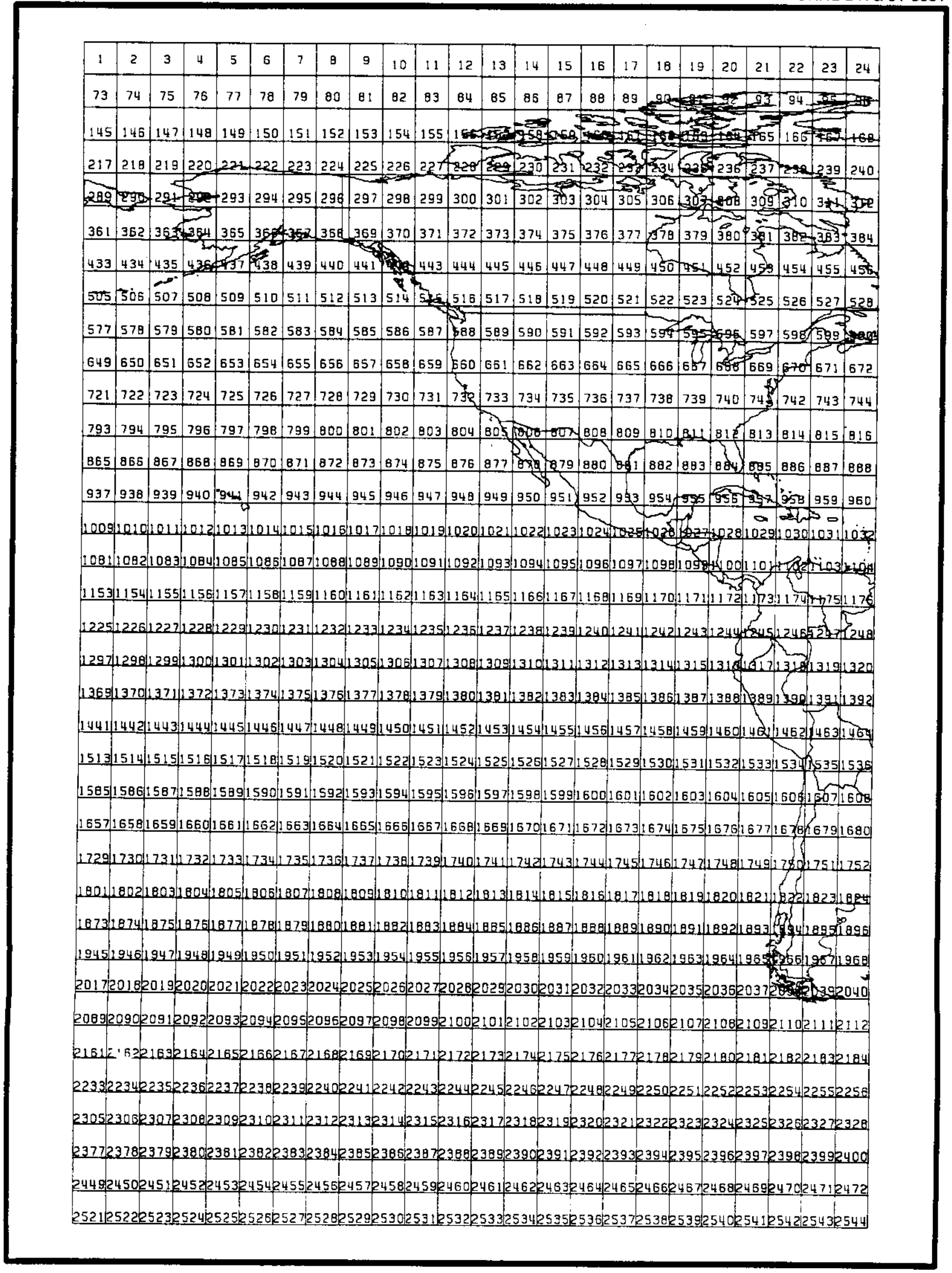


Fig. 2 (Page 1 of 3). Worldwide 5° x 5° grid cell (polygon) locations and ID numbers (ARC/INFO™ coverage and ASCII file).

ORNL-DWG 91-8552

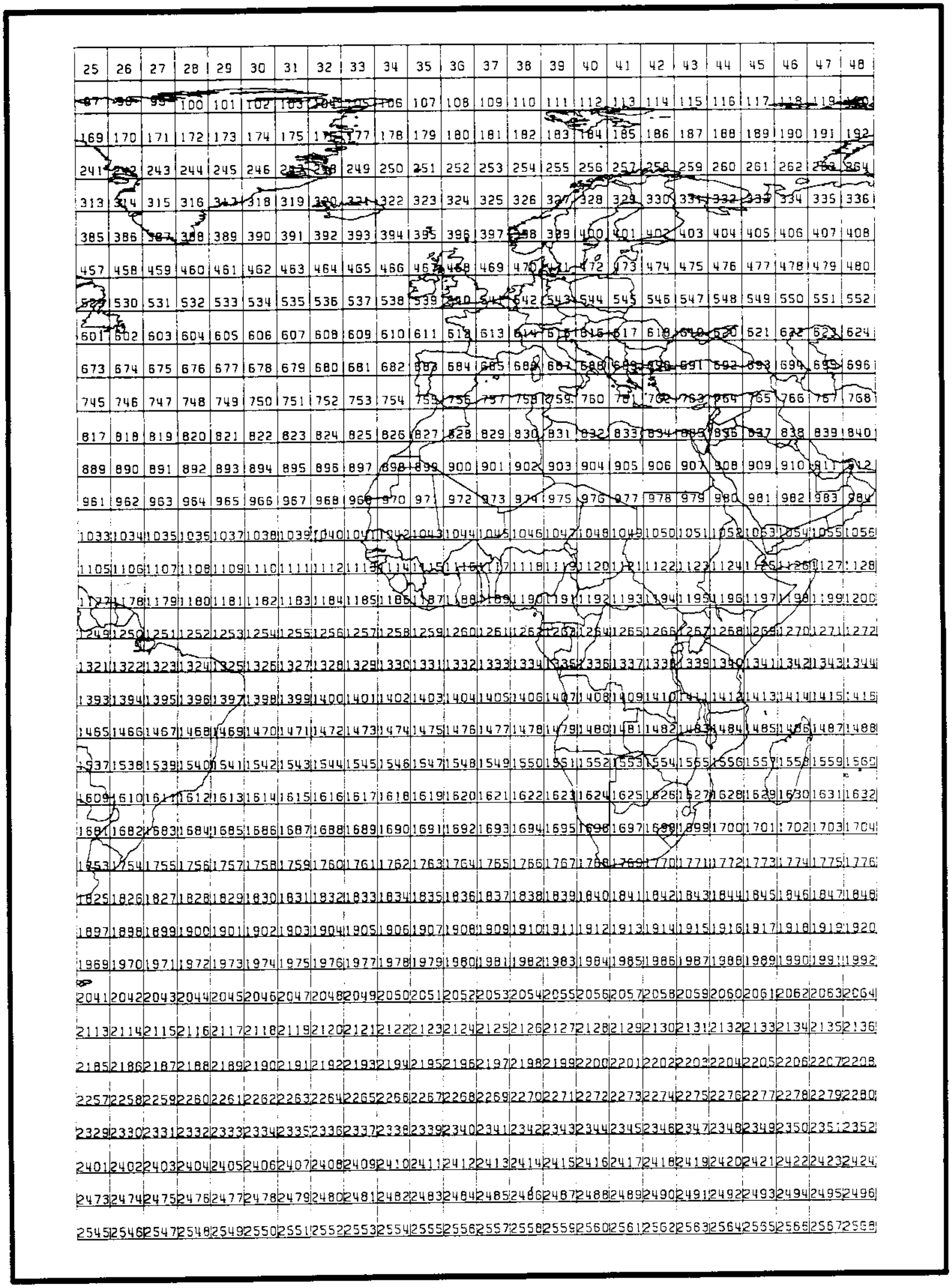


Fig. 2 (Page 2 of 3). Worldwide 5° x 5° grid cell (polygon) locations and ID numbers (ARC/INFO™ coverage and ASCII file).

ORNL-DWG 91-8553

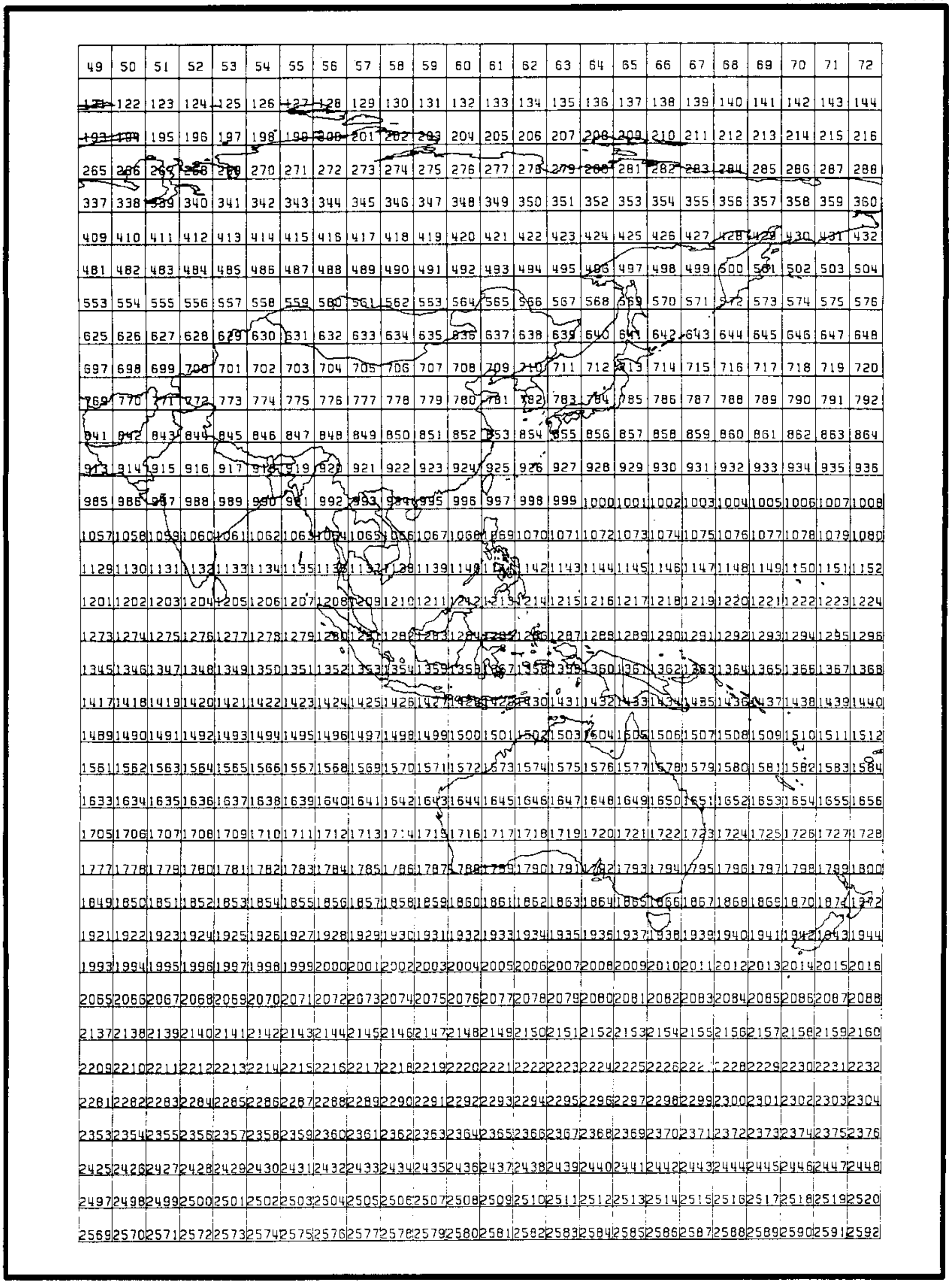


Fig. 2 (Page 3 of 3). Worldwide 5° x 5° grid cell (polygon) locations and ID numbers (ARC/INFO™ coverage and ASCII file).

ORNL-DWG 91-8554

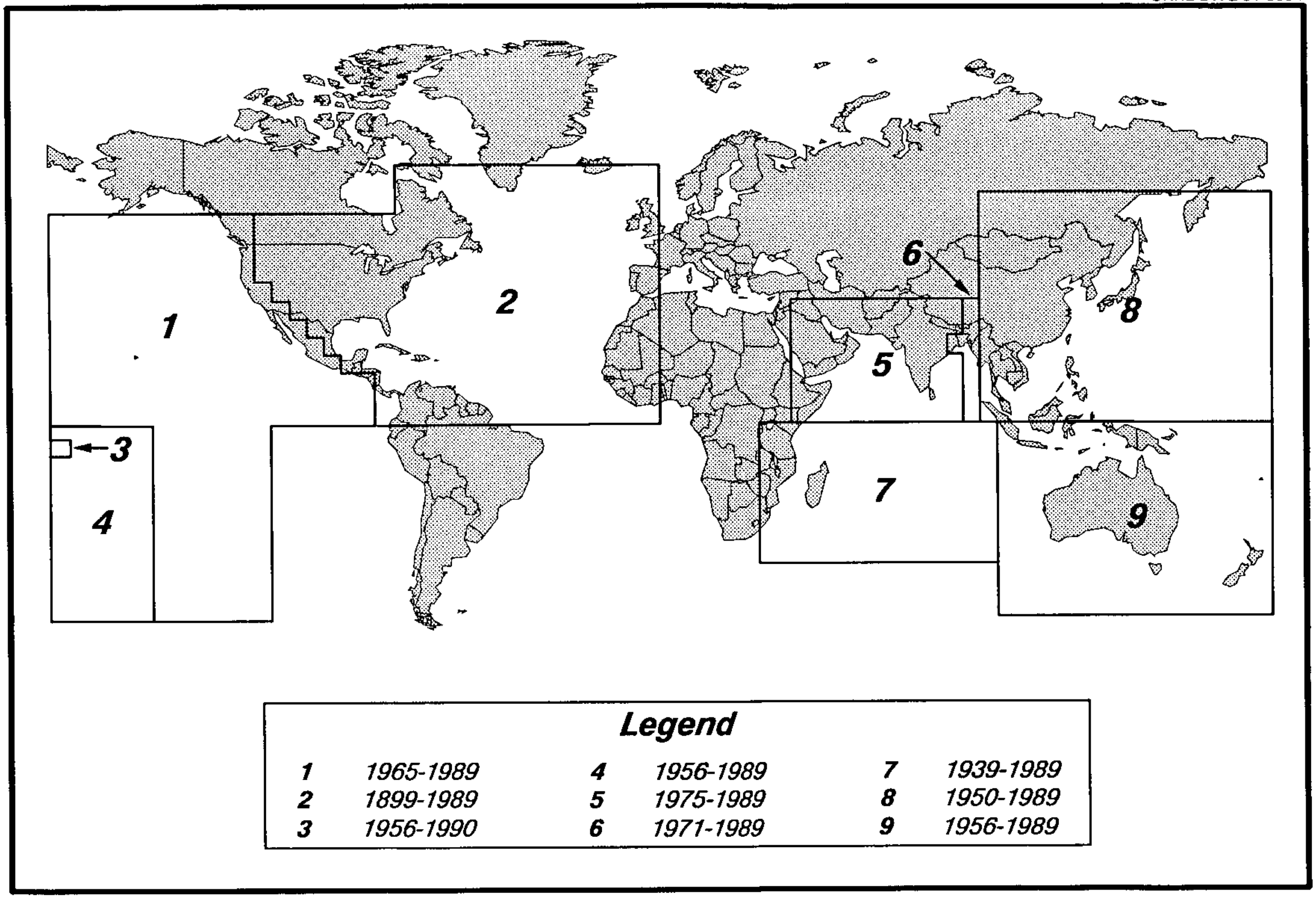


Fig. 3. Spatial coverage and period of record for the data sources used to calculate the tropical storm and hurricane probabilities of occurrence described in Sects. 7.1 and 7.2.

ORNL-DWG 91-8555

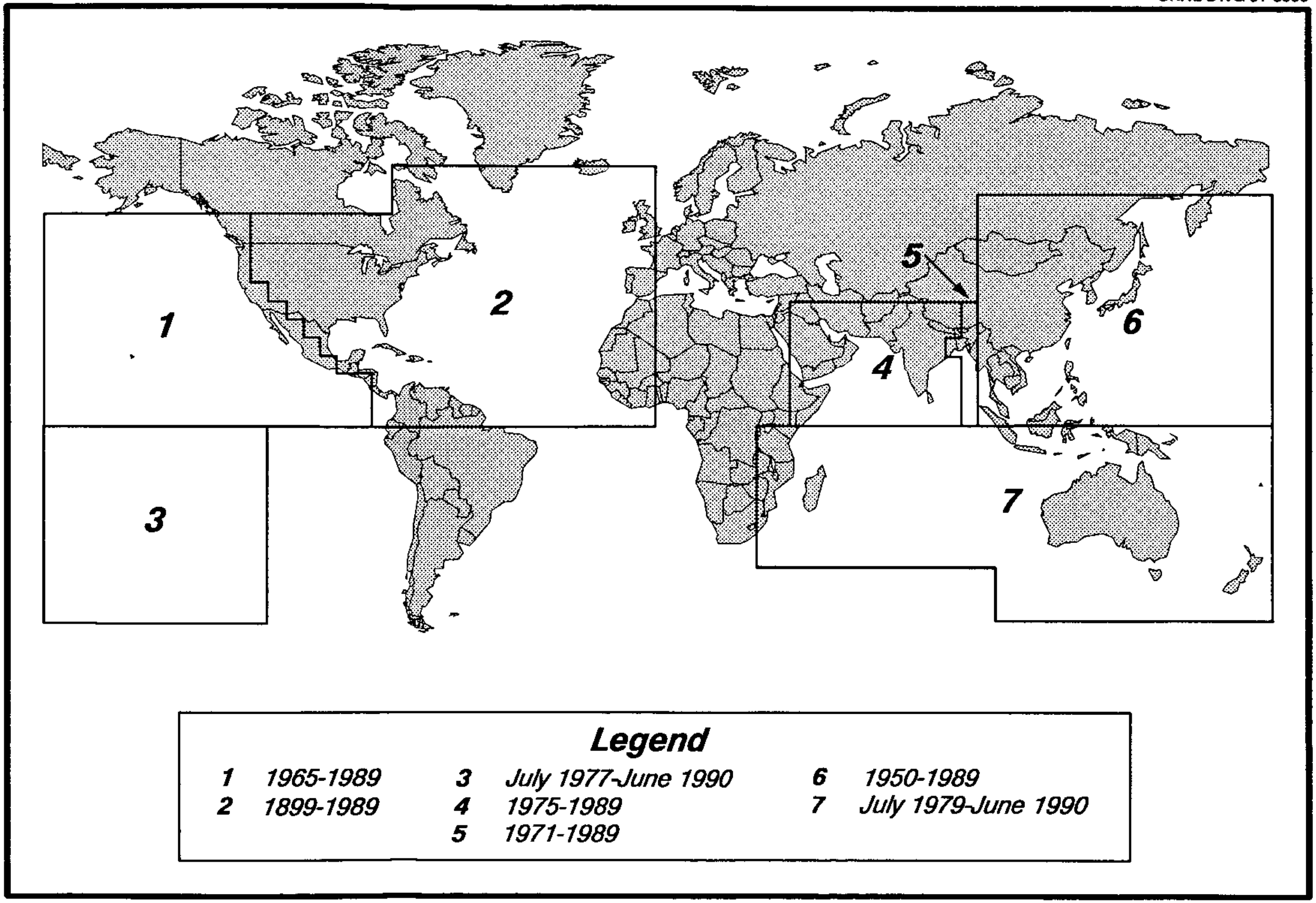


Fig. 4. Spatial coverage and period of record for the data sources used to calculate the super typhoon probabilities of occurrence described in Sect. 7.2.

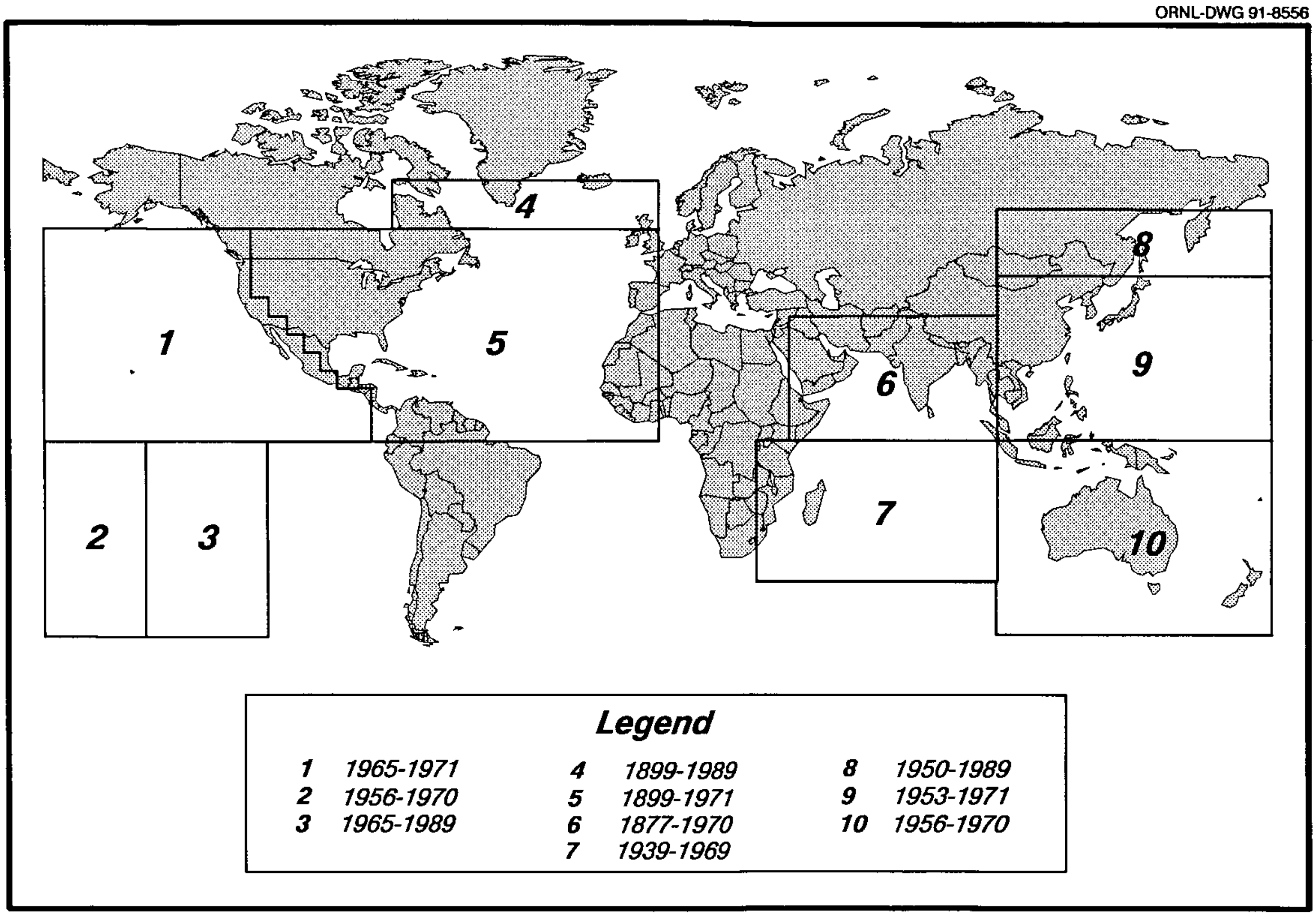


Fig. 5. Spatial coverage and period of record for the data sources used to calculate the mean forward velocities of tropical cyclones described in Sect. 7.2.

ORNL-DWG 91-8557

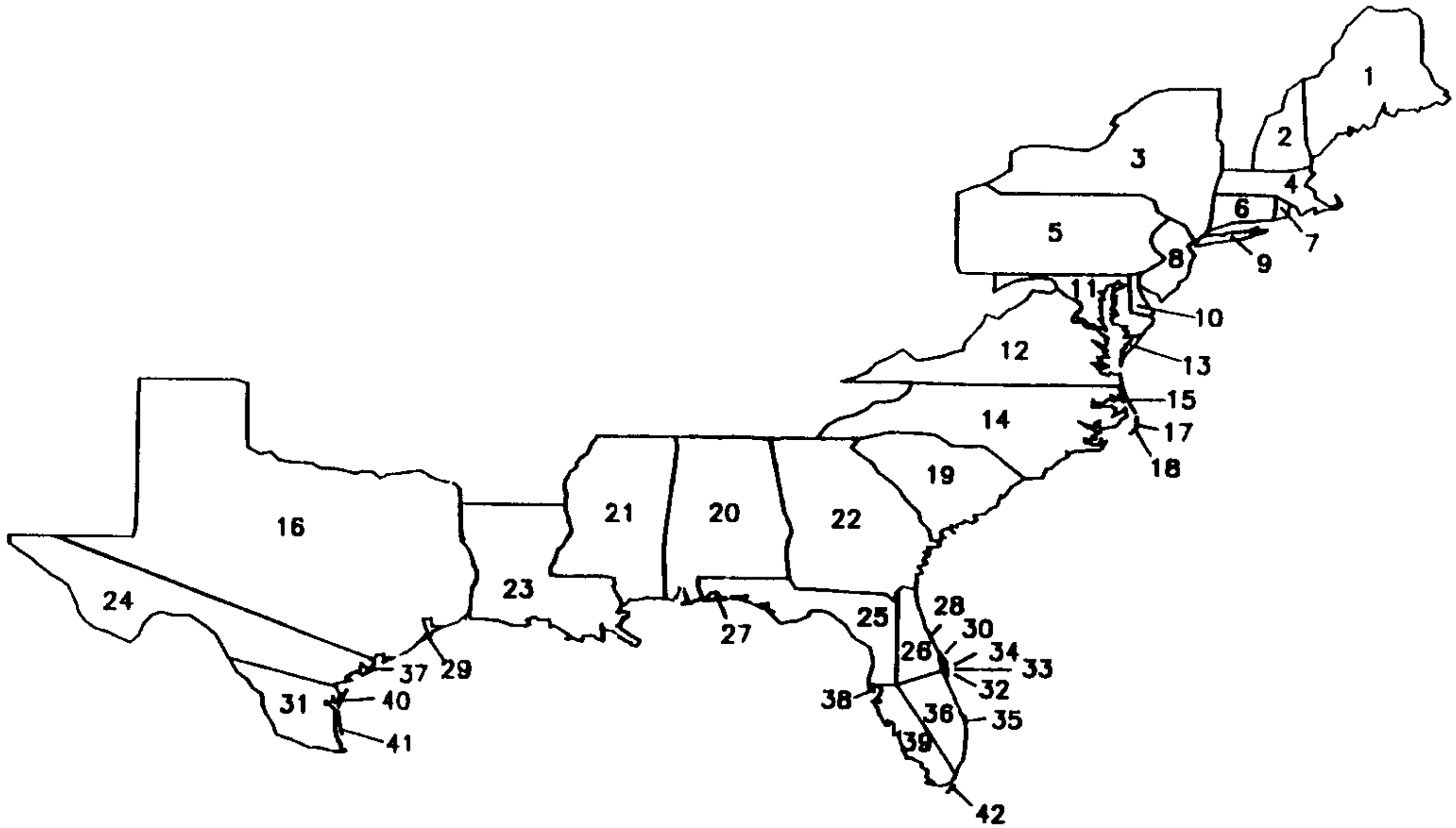


Fig. 6. U.S. state and state subdivision polygon locations and ID numbers used in the hurricane strike data described in Sect. 8.1.

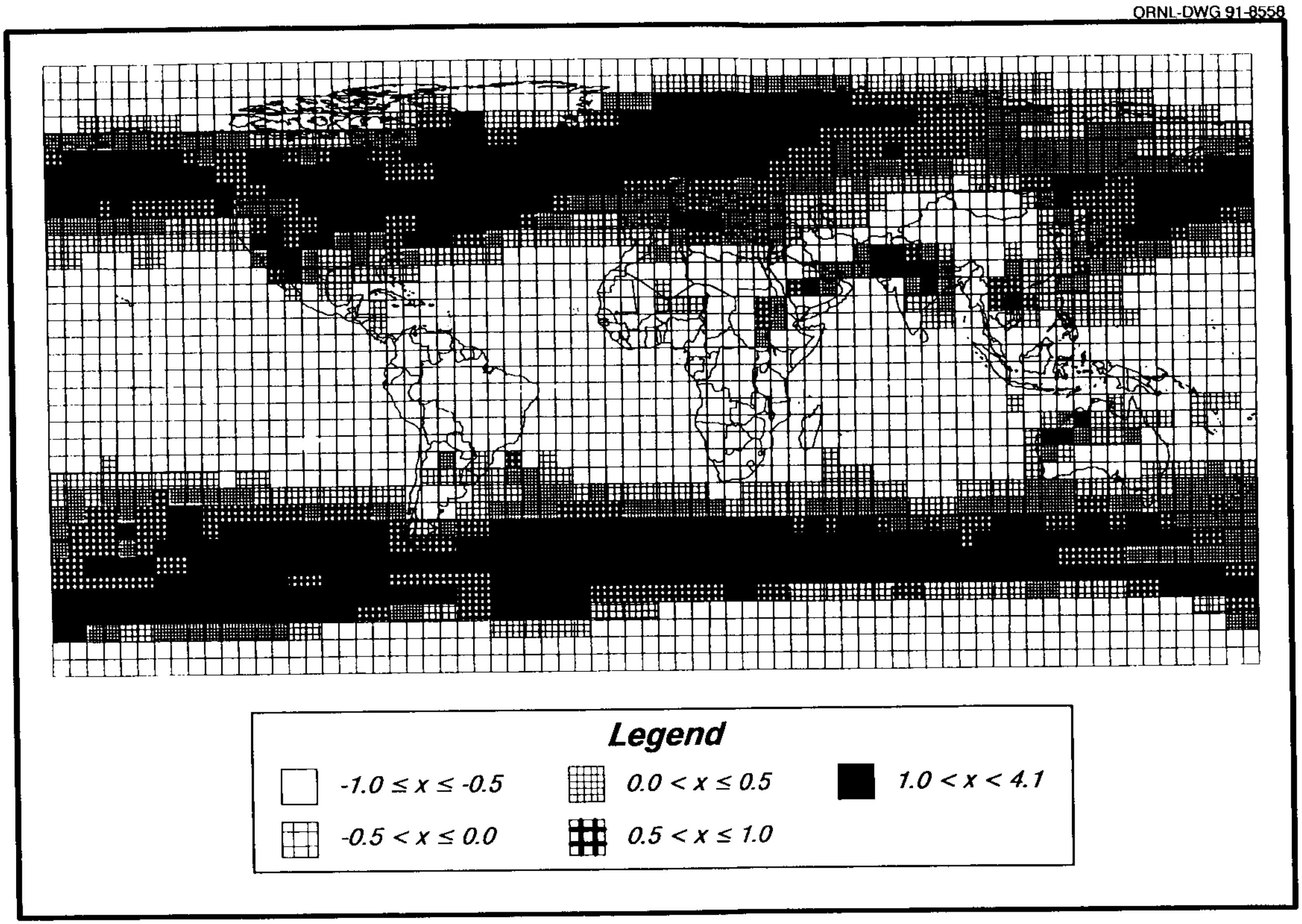


Fig. 7. Distribution of data values (x) for global annual cyclone occurrence shown in statistically standardized form [i.e., x = (original data value - given data source mean) / given data source standard deviation].

ORNL-DWG 91-8559

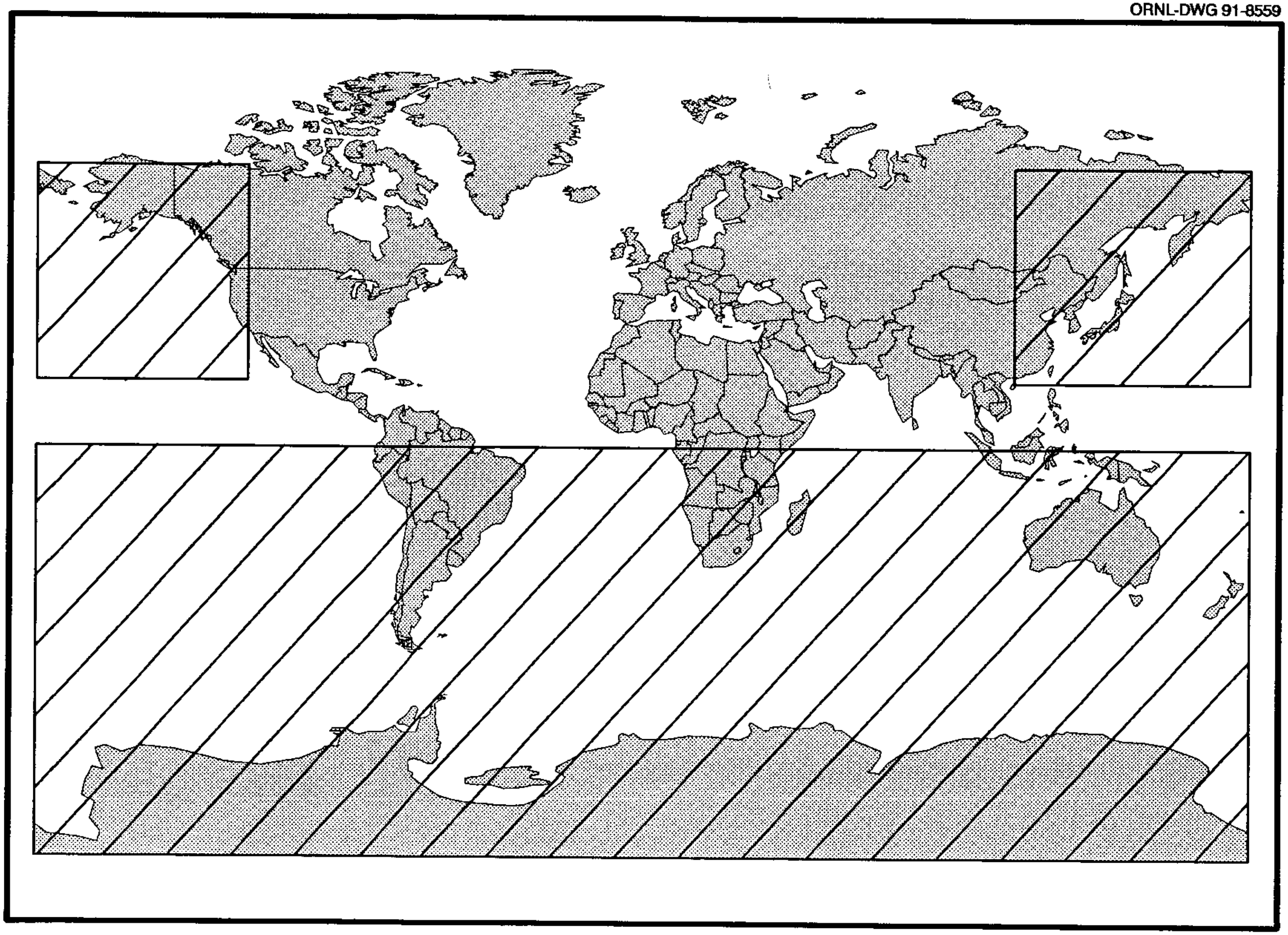


Fig. 8. Areas inside the boxes indicate the spatial coverage of the two data sources used in calculating the polar-low means described in Sect. 10.1.

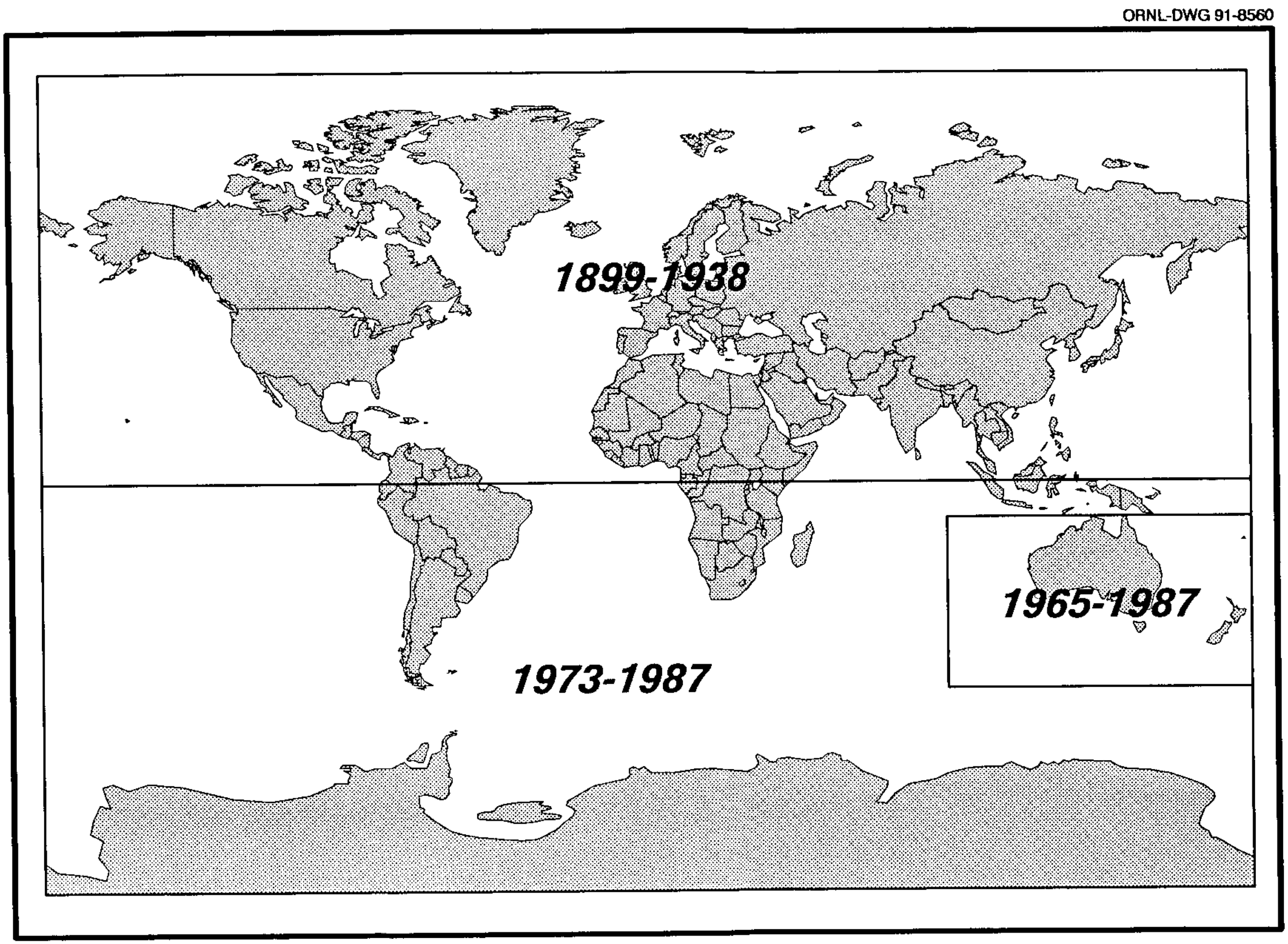


Fig. 9. Spatial coverage and period of record of data sources used in the derivation of the global annual cyclone occurrence data of Fig. 7.

ORNL-DWG 91-8561

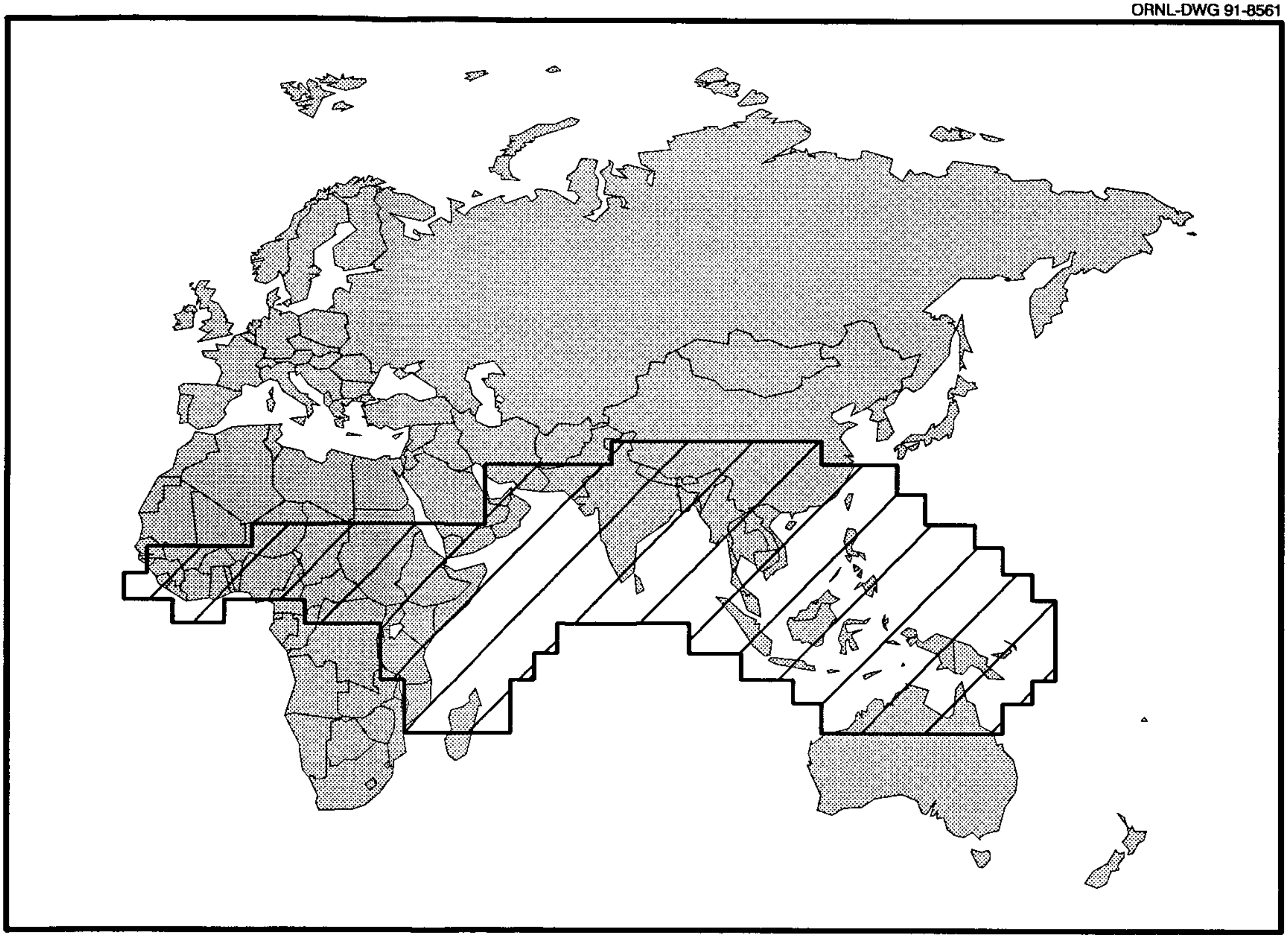


Fig. 10. Area satisfying monsoon activity criteria [from Oliver and Fairbridge (1987)].

ORNL-DWG 91-8562

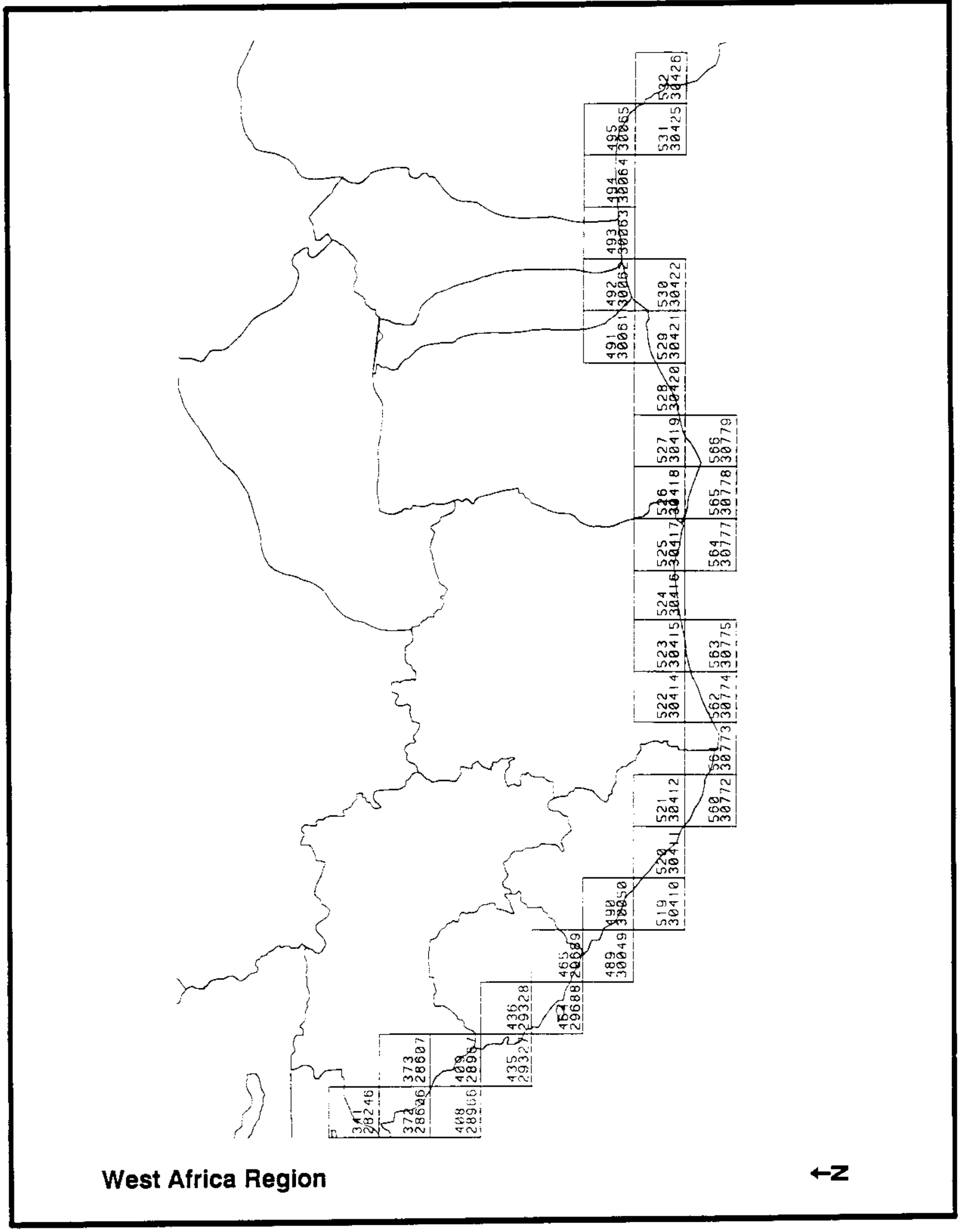


Fig. 11 (Page 1 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

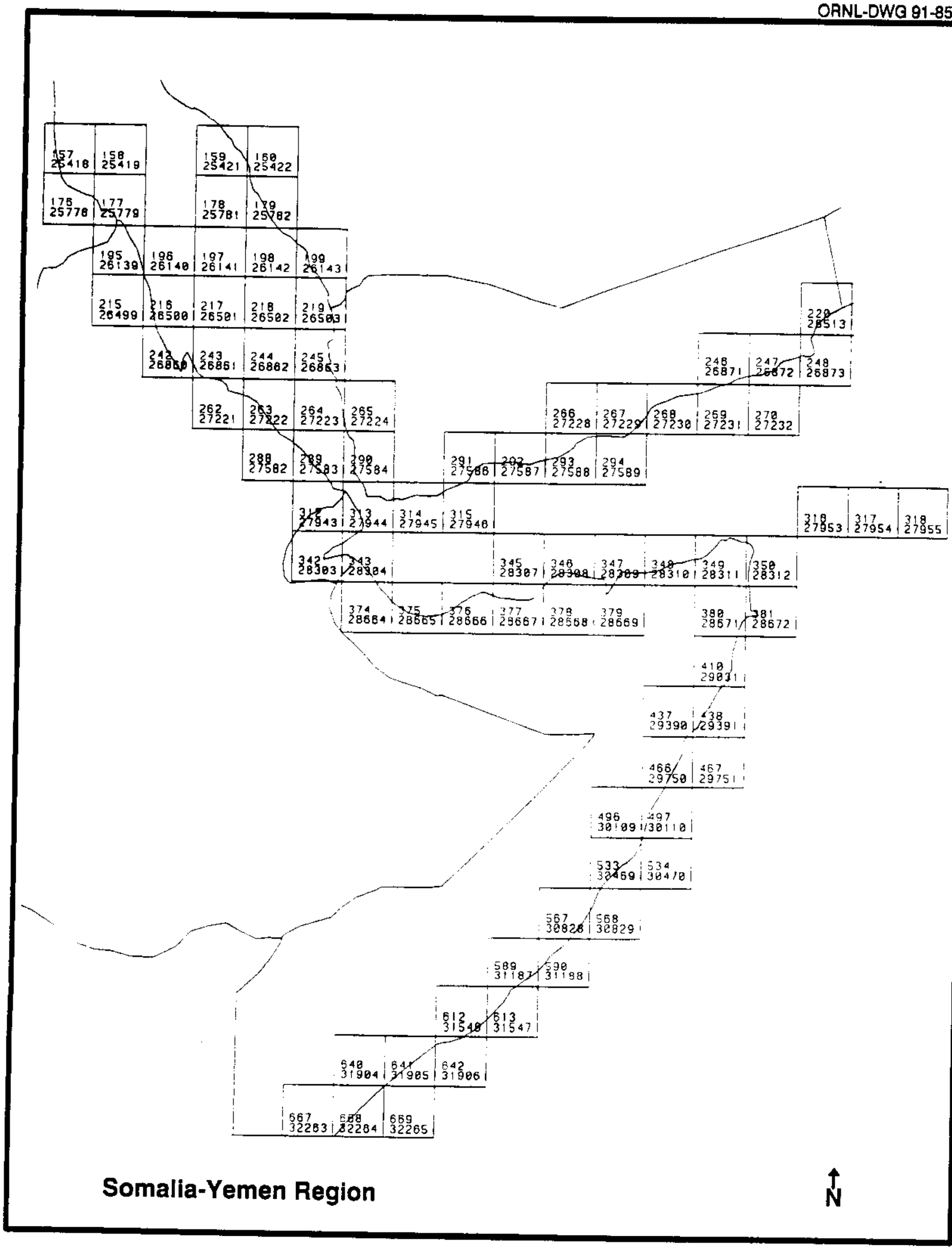


Fig. 11 (Page 2 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8564

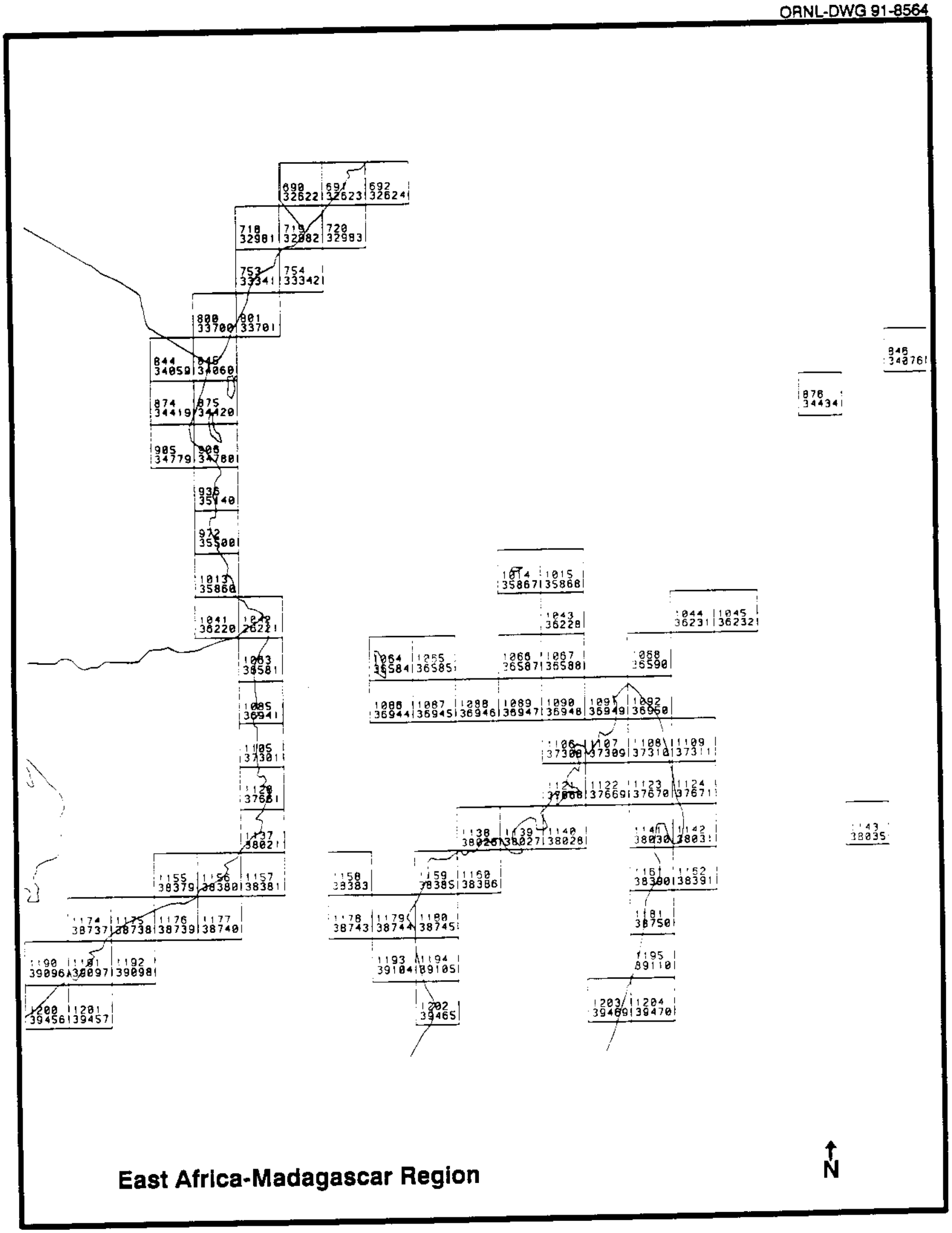


Fig. 11 (Page 3 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8565

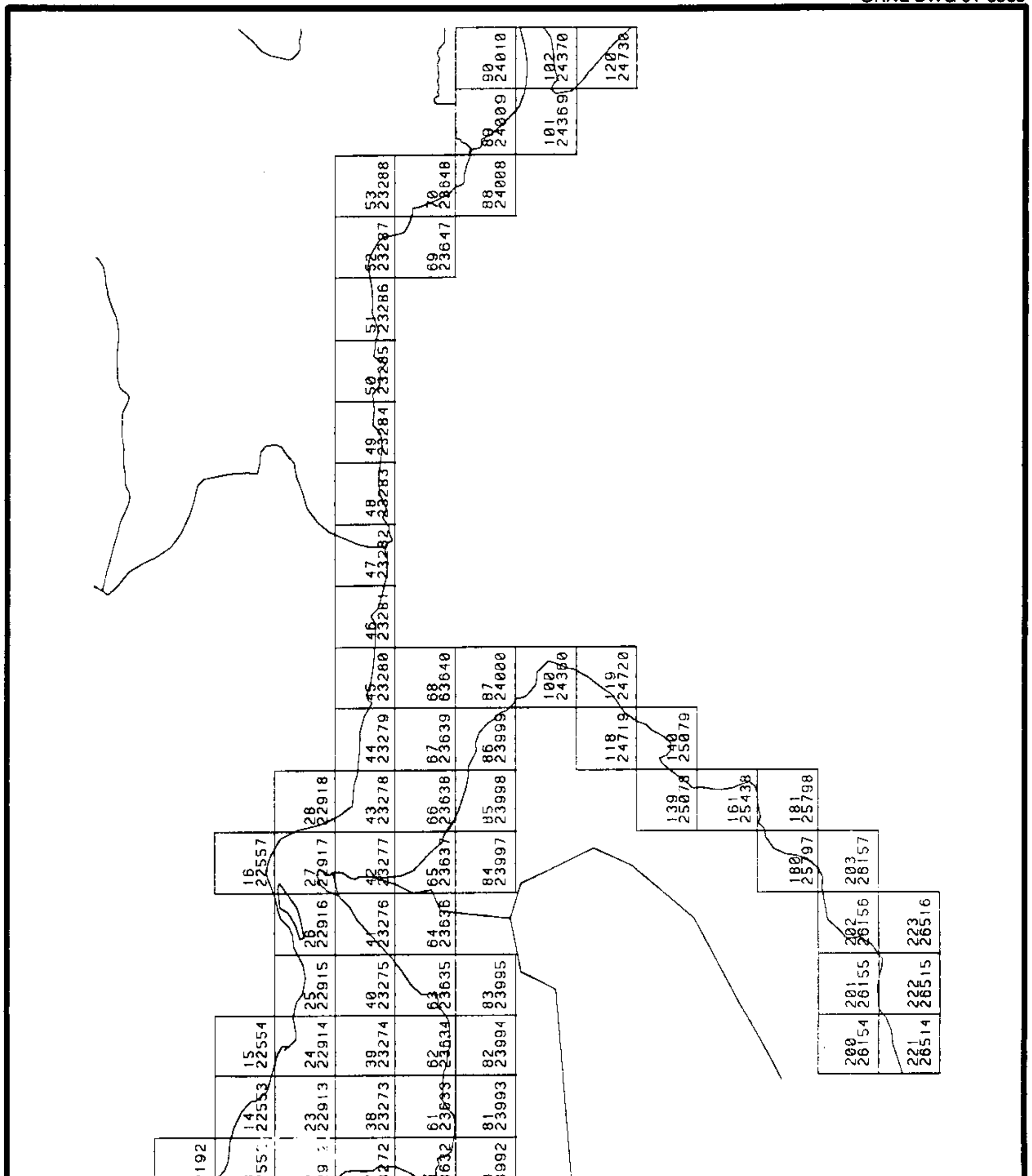


Fig. 11 (Page 4 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8566

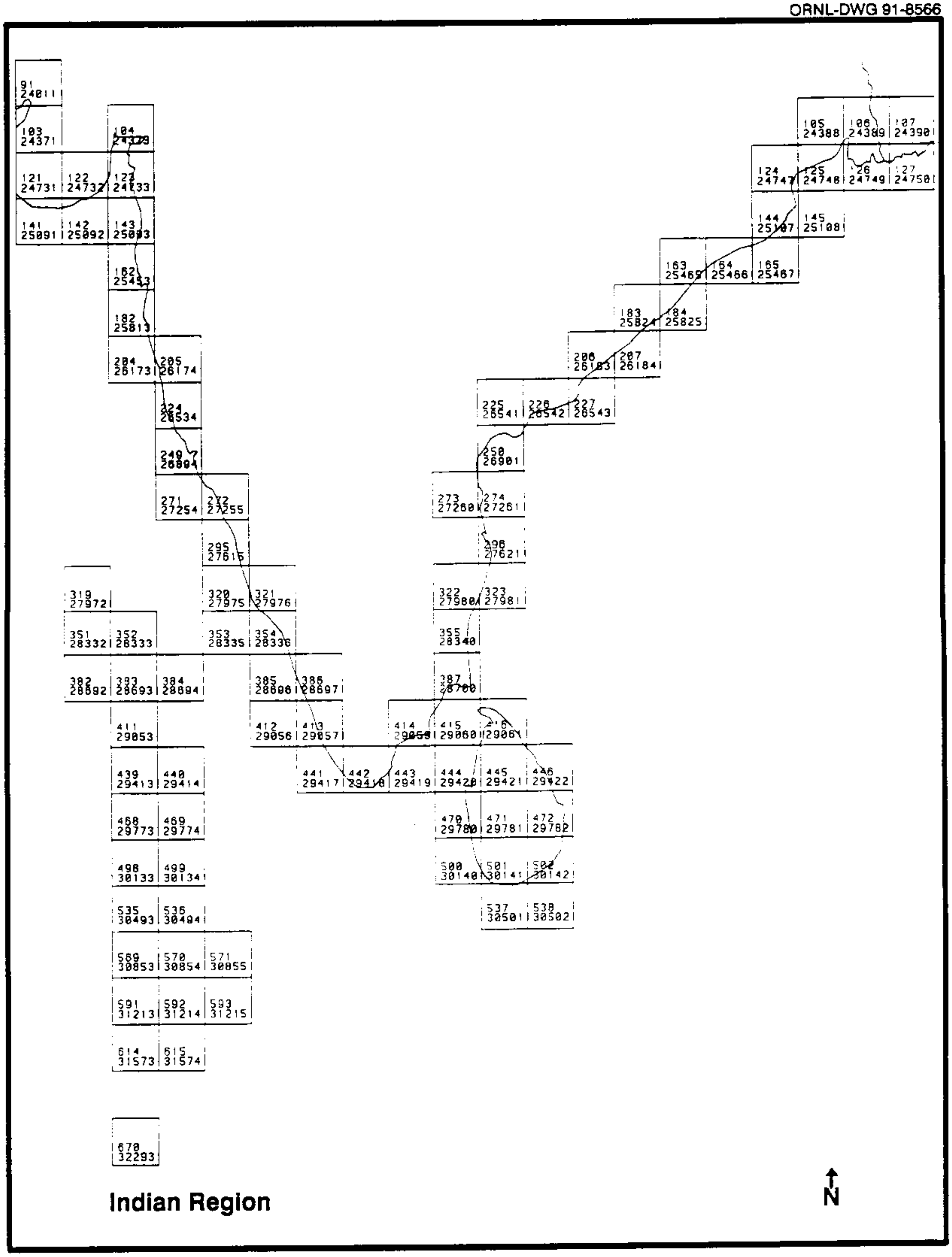


Fig. 11 (Page 5 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8567

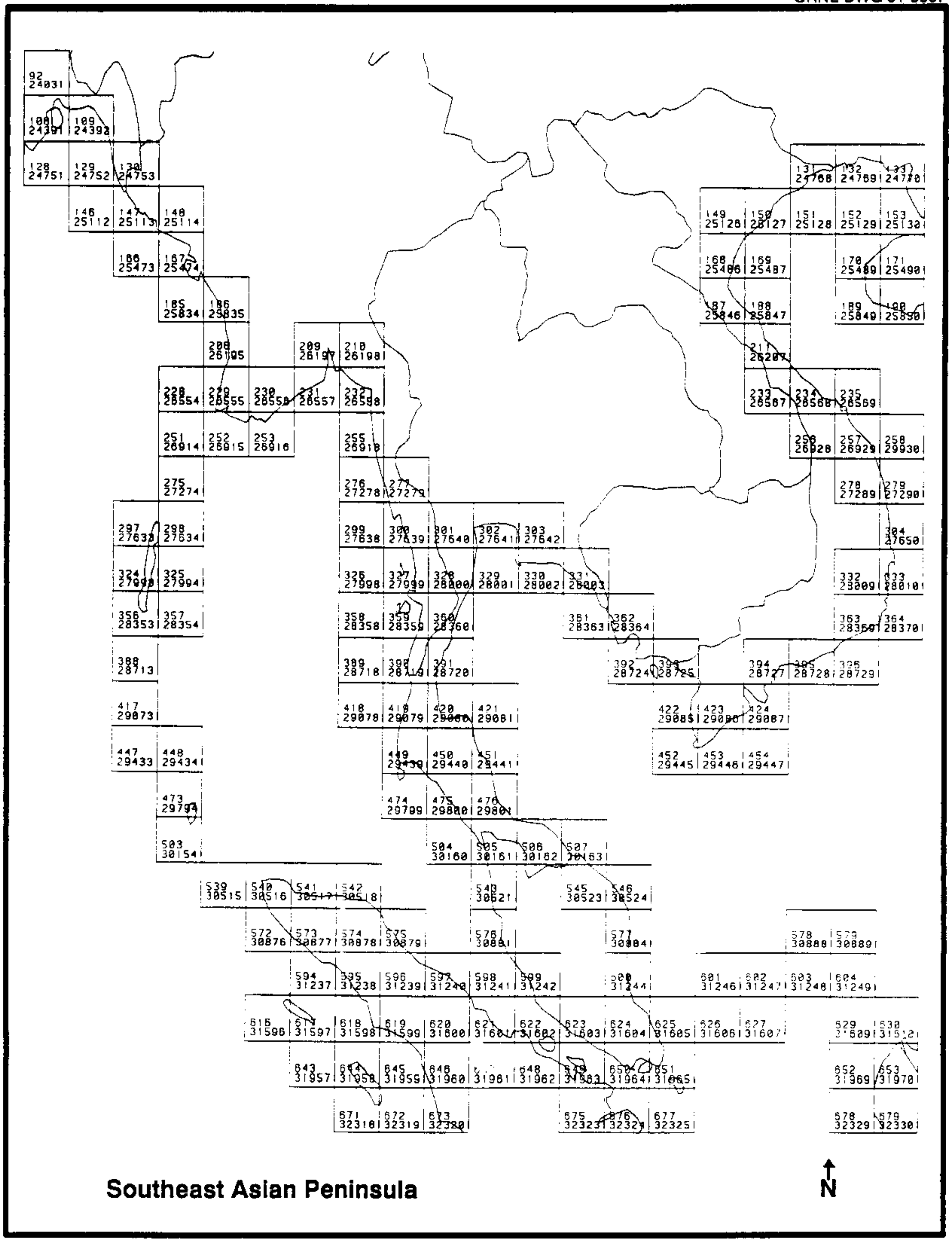


Fig. 11 (Page 6 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8568

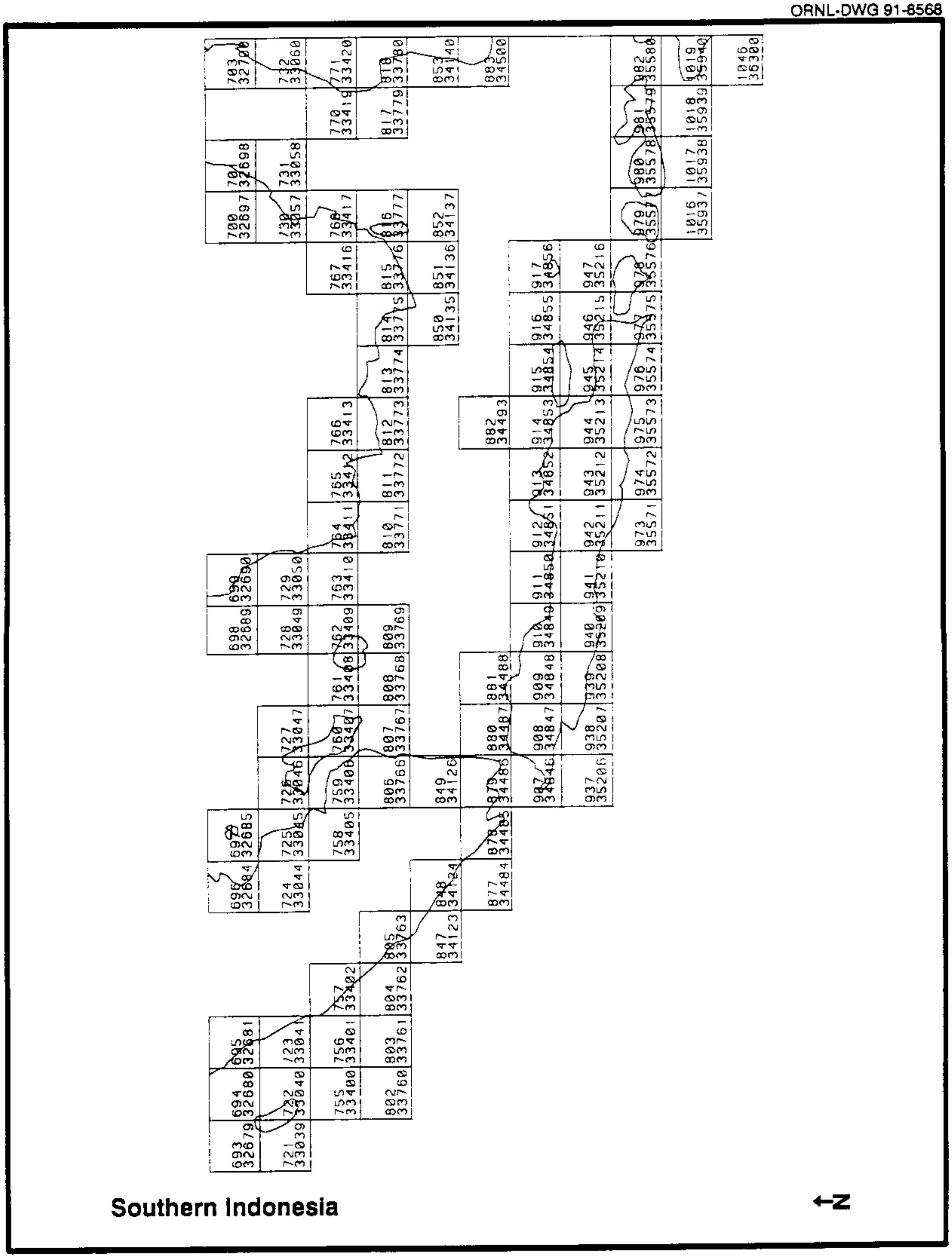


Fig. 11 (Page 7 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8569

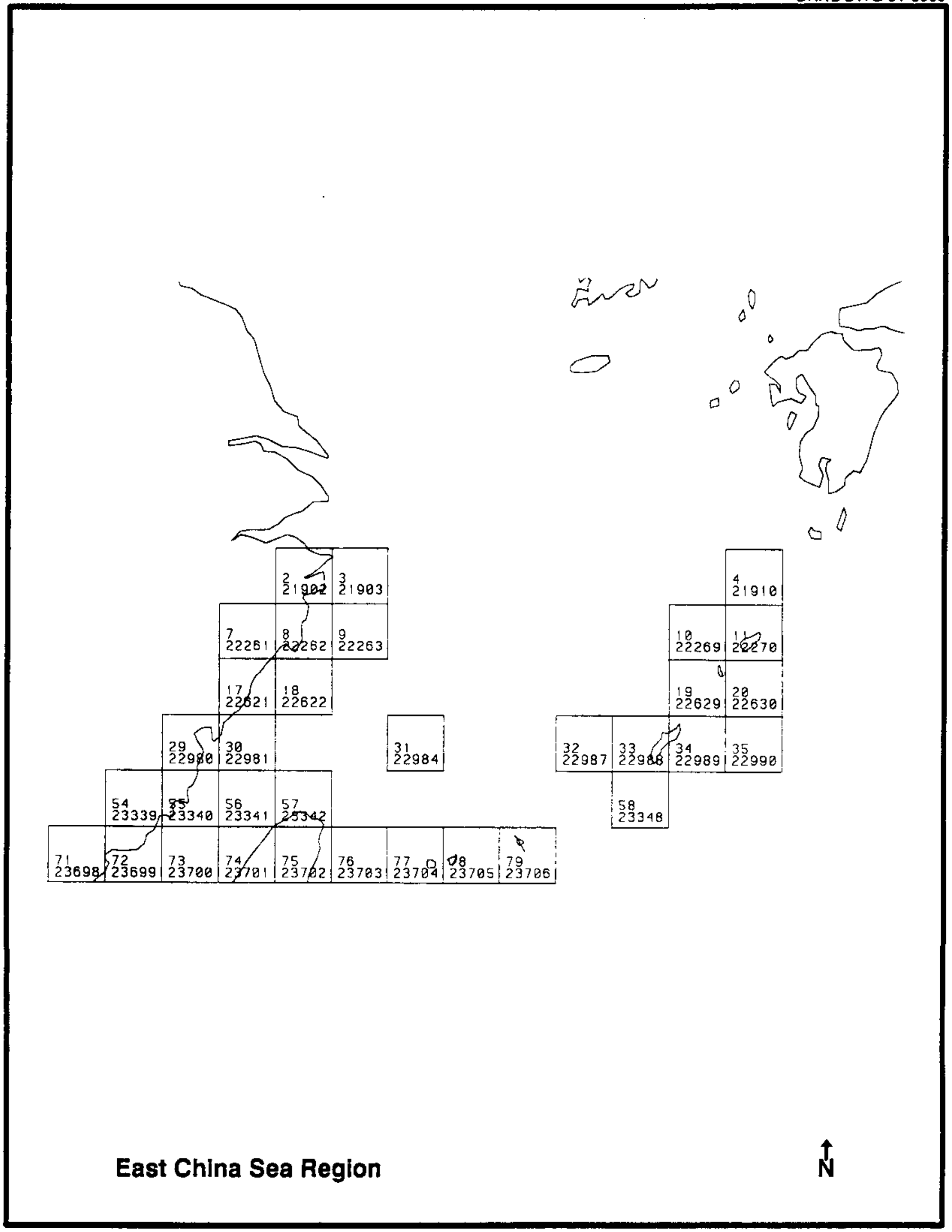


Fig. 11 (Page 8 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8570

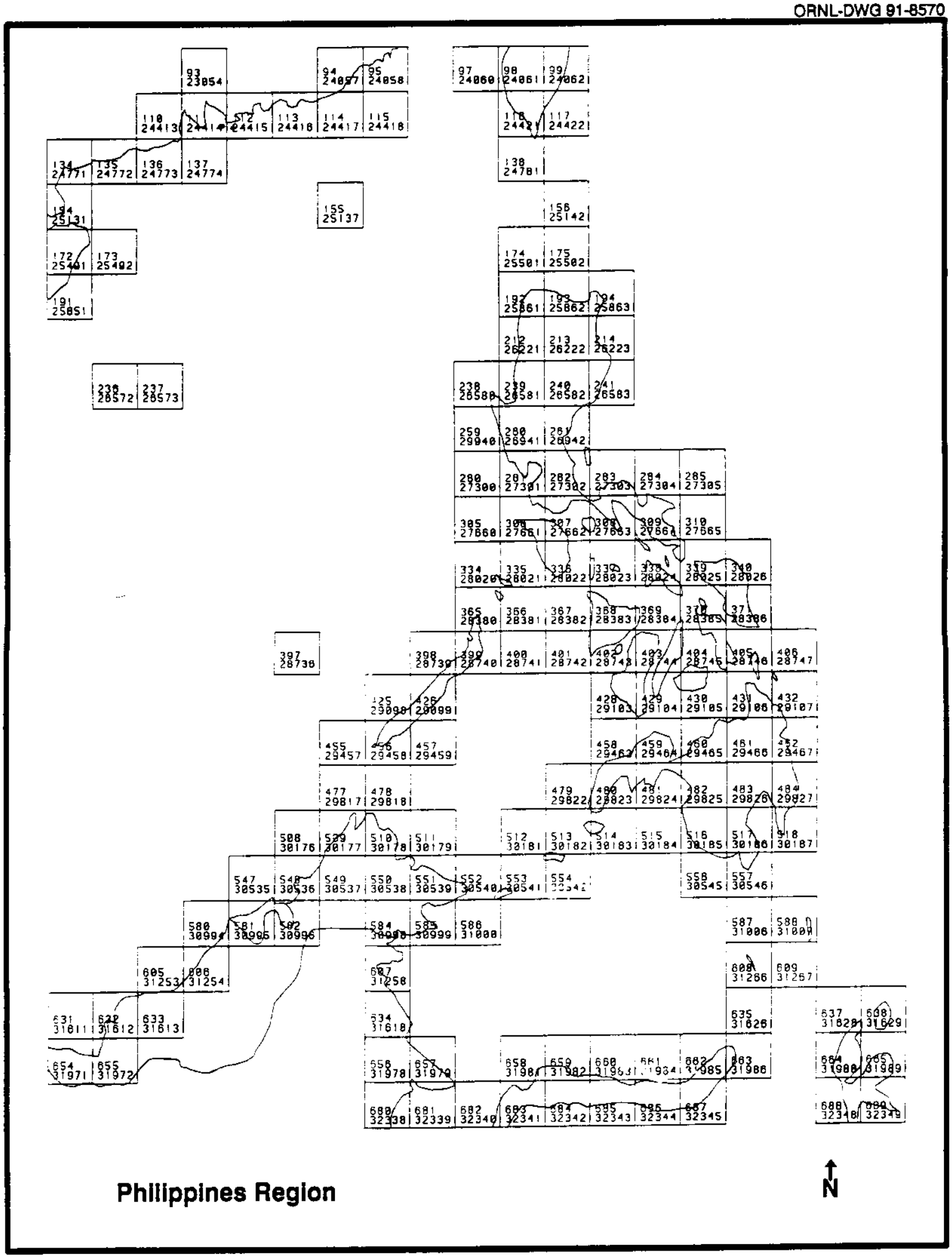


Fig. 11 (Page 9 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8571

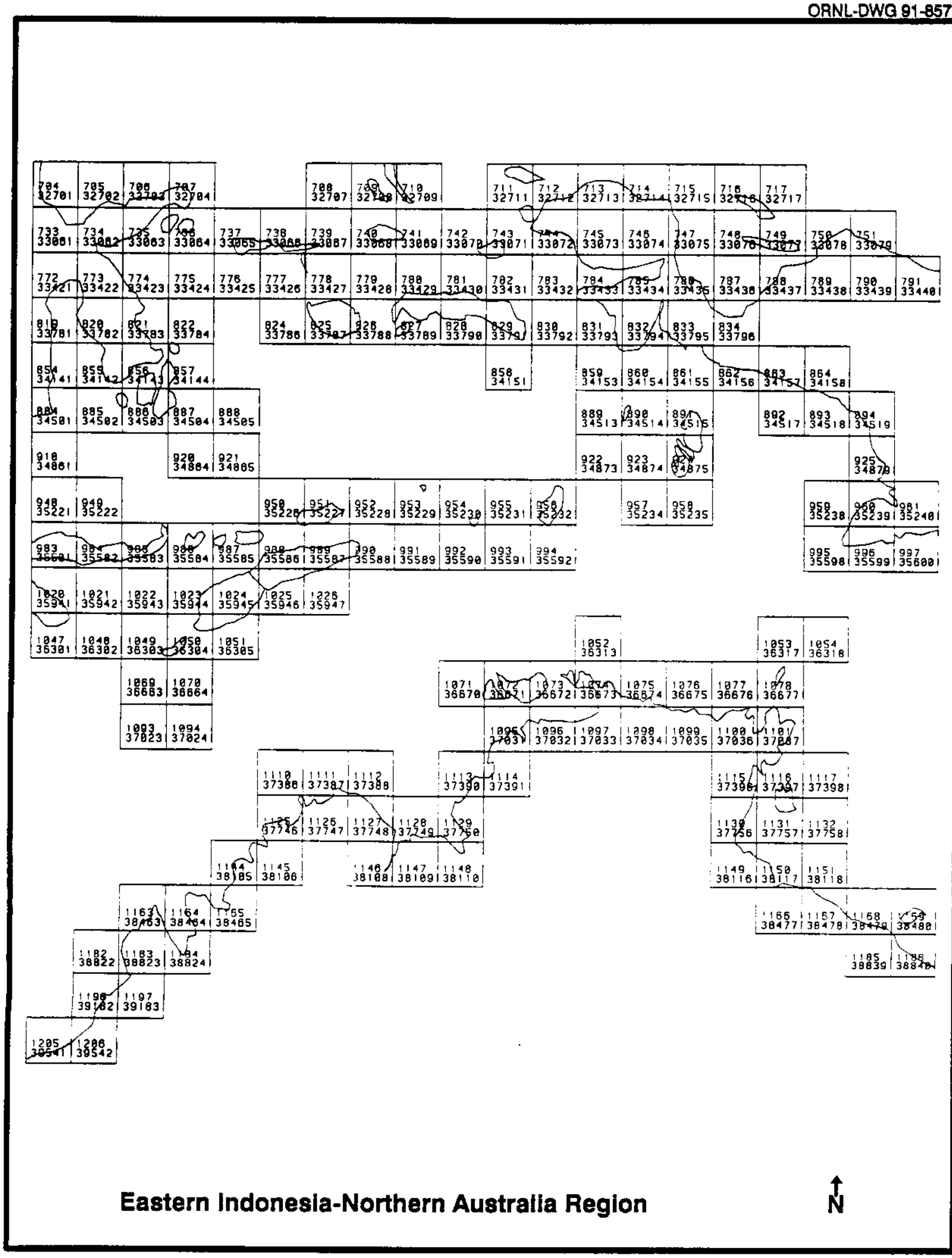


Fig. 11 (Page 10 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8572

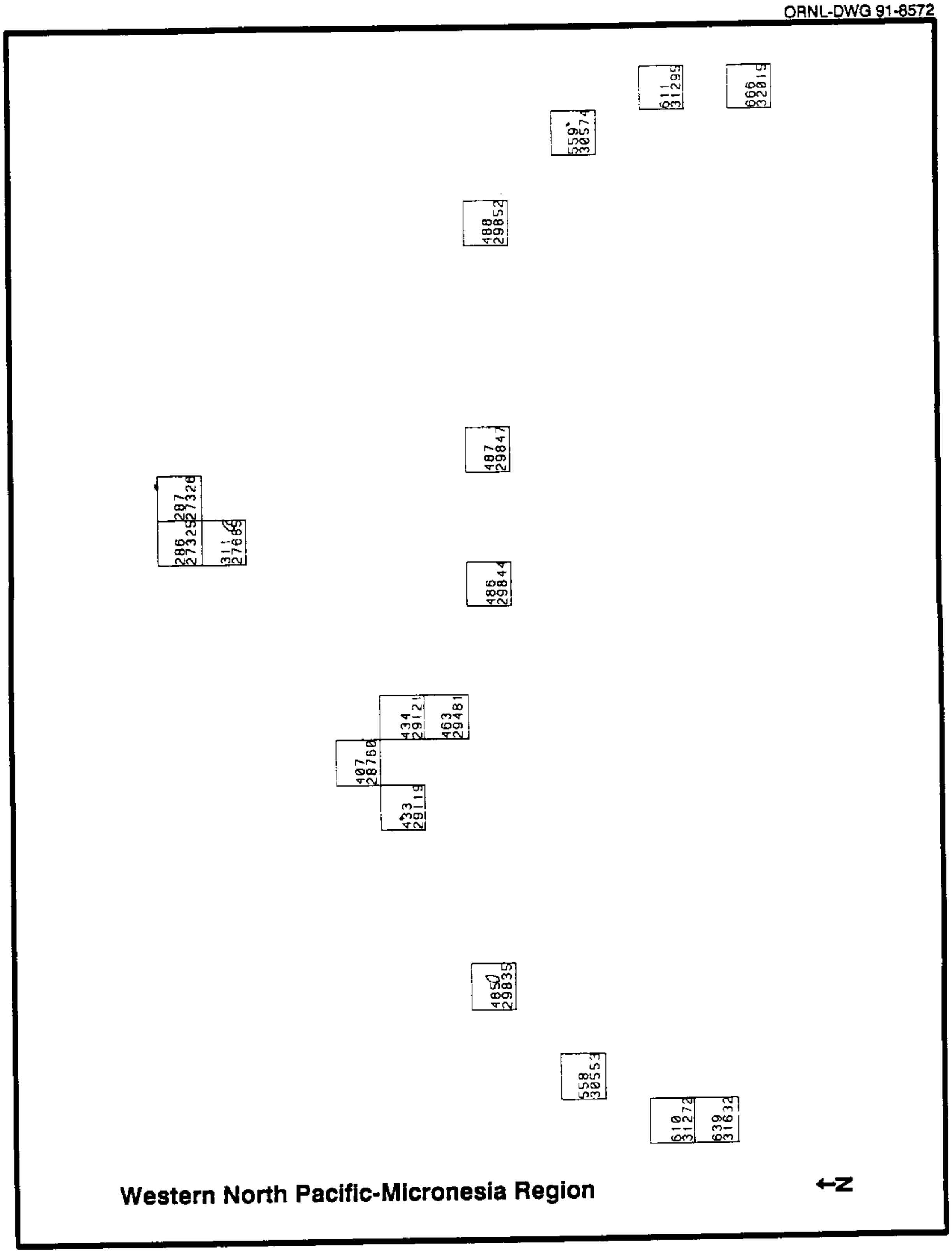


Fig. 11 (Page 11 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8573

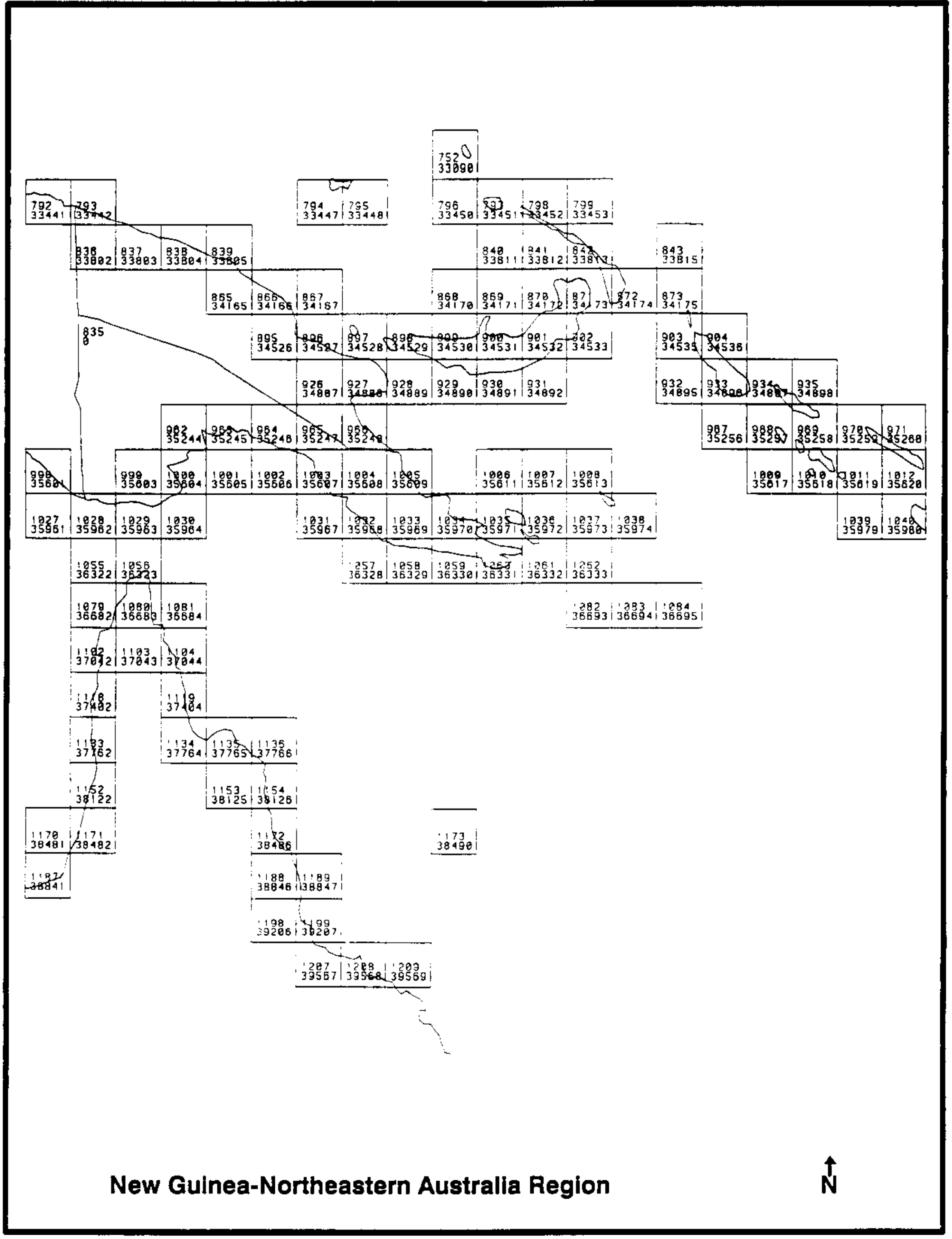


Fig. 11 (Page 12 of 12). Spatial coverage of the index of winds on coastlines in the African, Asian, and Australian monsoon regions described in Sect. 12.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8574

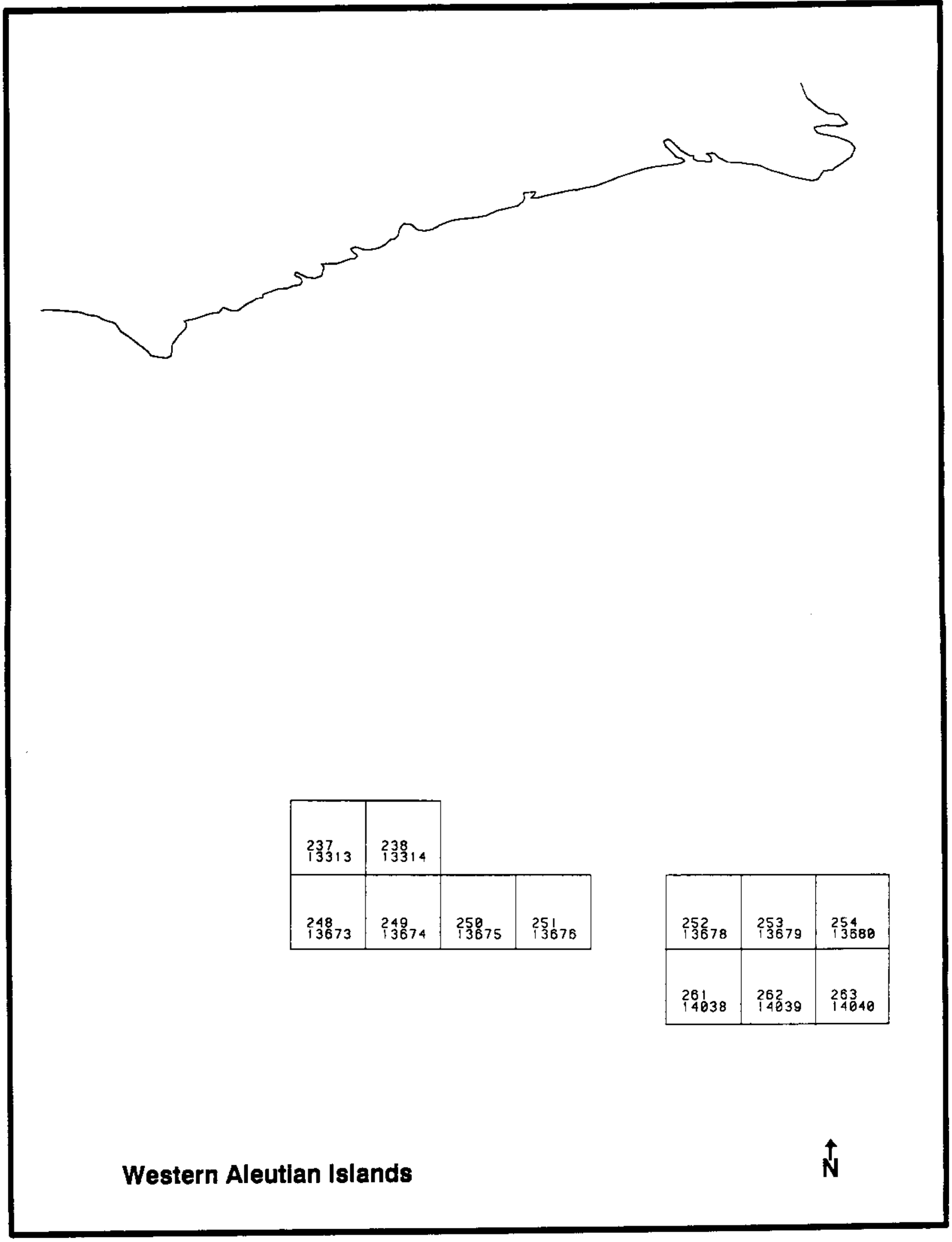


Fig. 12 (Page 1 of 5). Spatial coverage of the sea-ice concentration data values described in Sect. 13.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8575

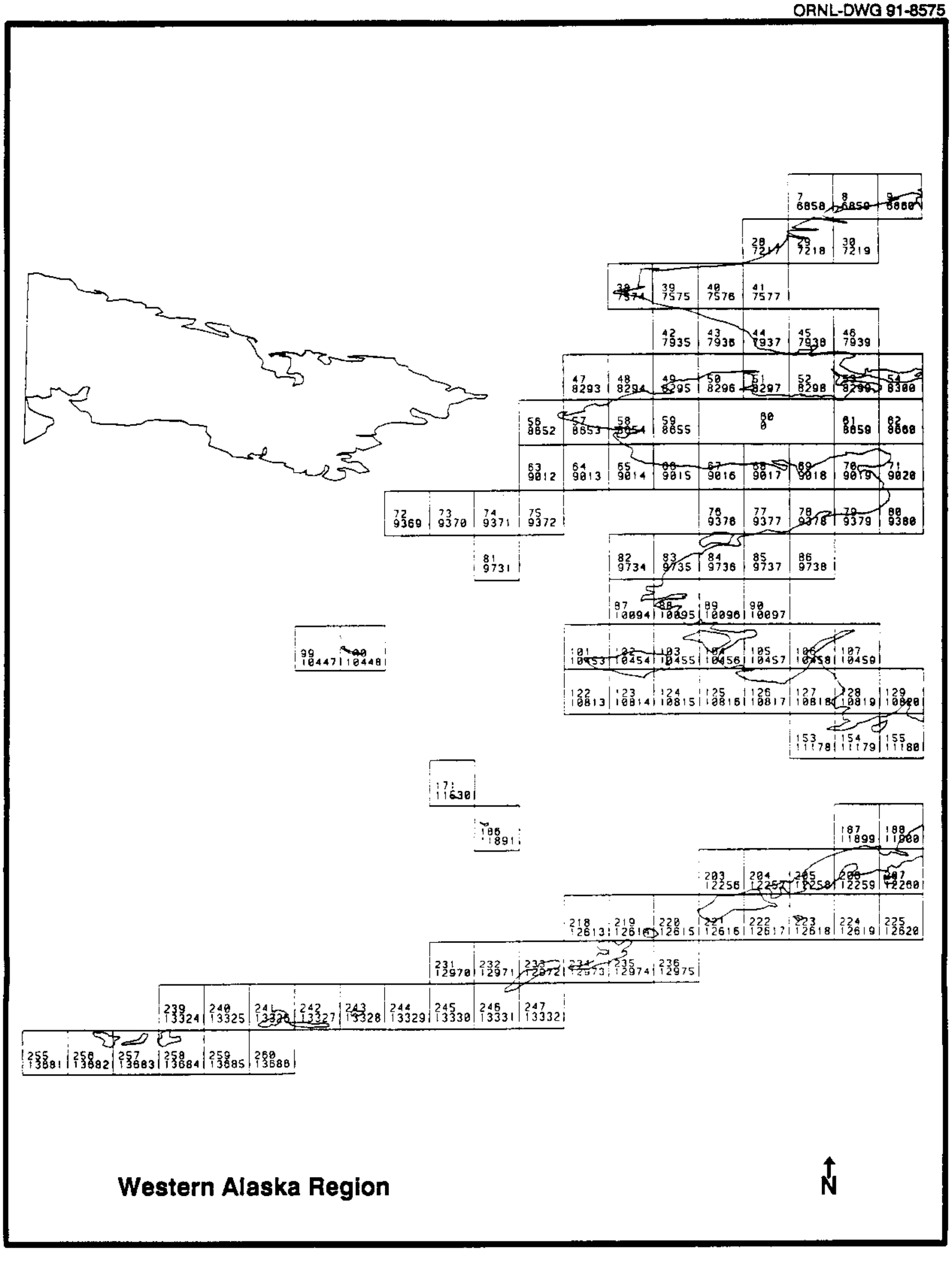


Fig. 12 (Page 2 of 5). Spatial coverage of the sea-ice concentration data values described in Sect. 13.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8576

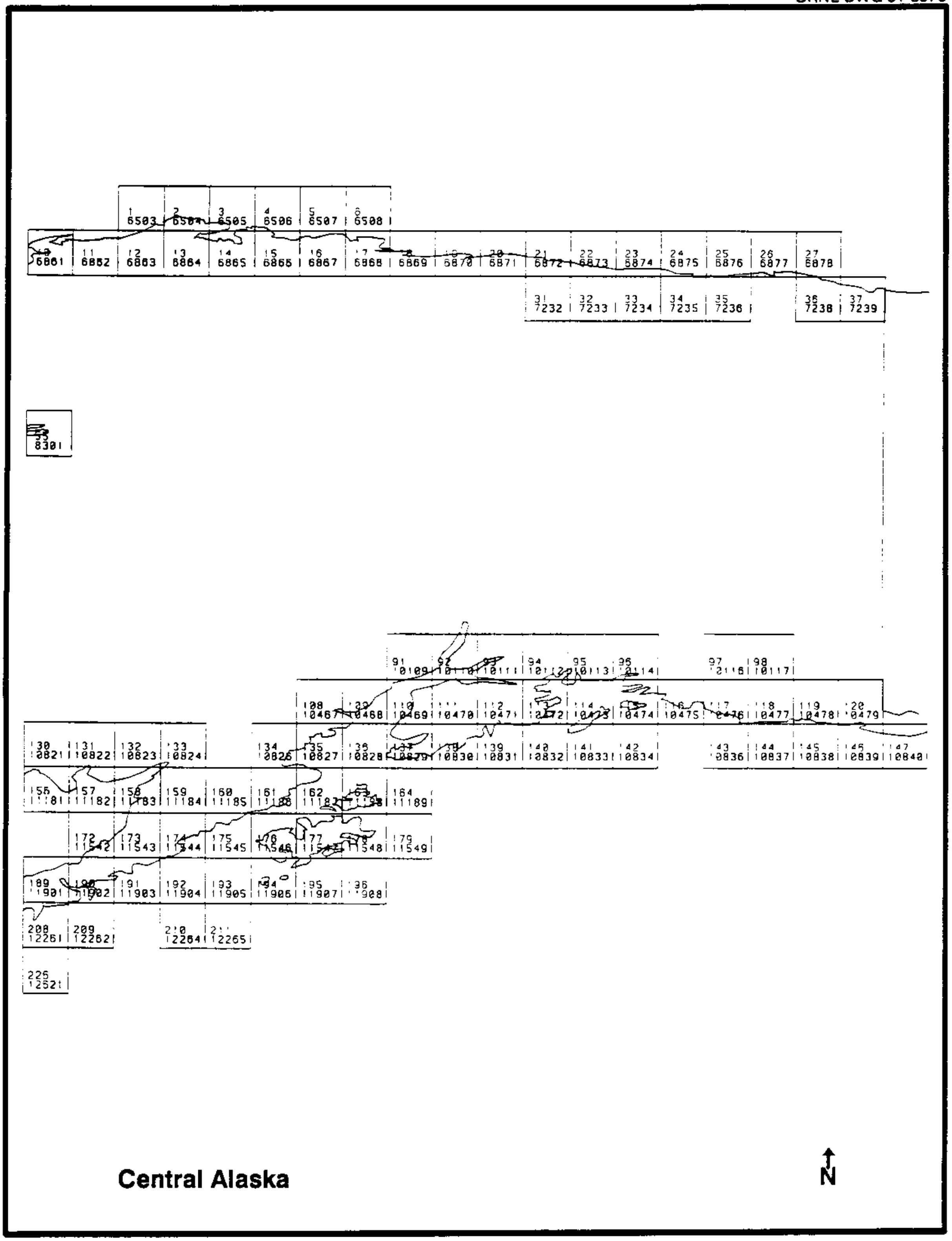


Fig. 12 (Page 3 of 5). Spatial coverage of the sea-ice concentration data values described in Sect. 13.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8577

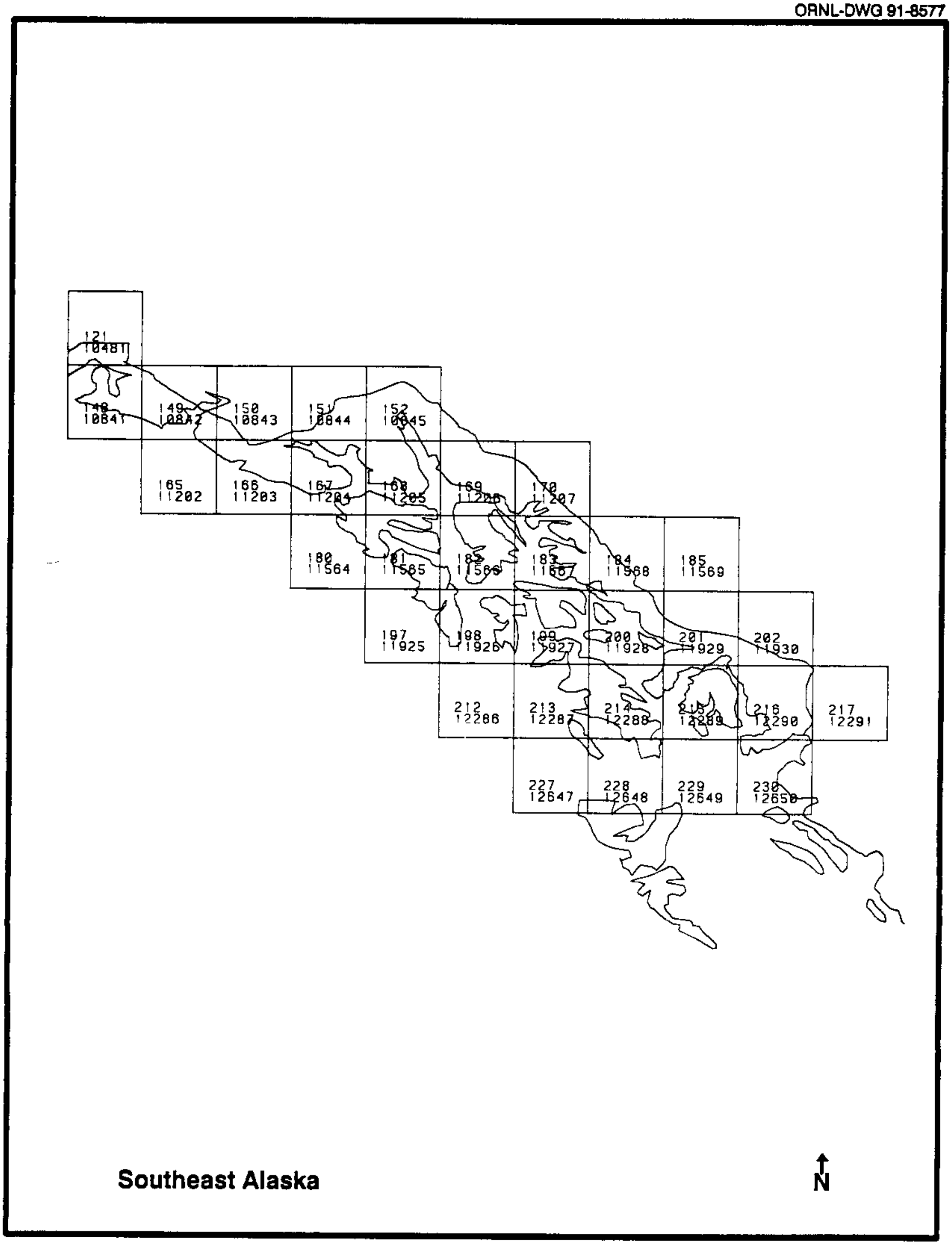


Fig. 12 (Page 4 of 5). Spatial coverage of the sea-ice concentration data values described in Sect. 13.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

ORNL-DWG 91-8578

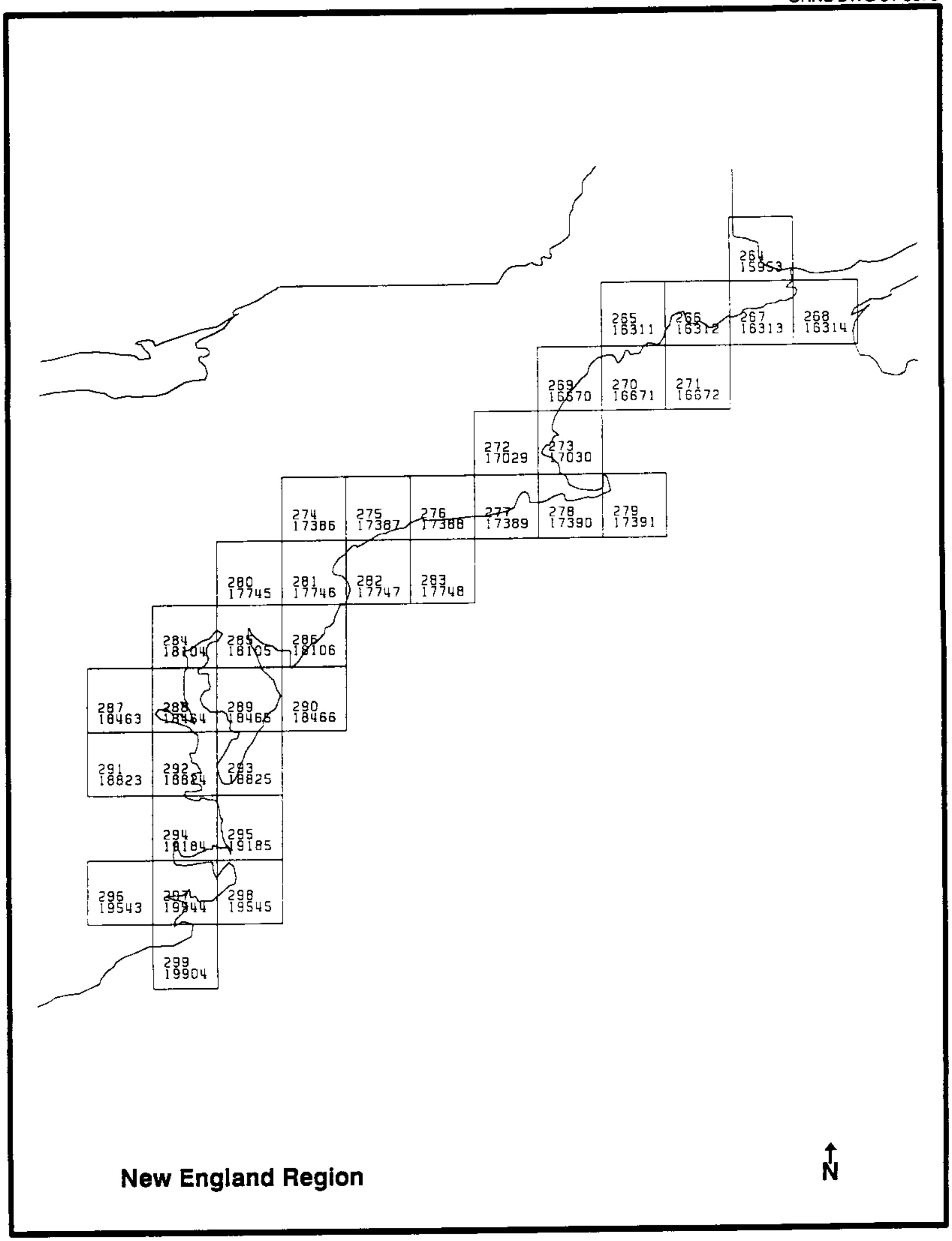


Fig. 12 (Page 5 of 5). Spatial coverage of the sea-ice concentration data values described in Sect. 13.1 showing 1° x 1° grid cell (polygon) locations and ID numbers (top numbers refer to ARC/INFO™ coverage IDs; bottom numbers refer to flat ASCII file IDs).

15. REFERENCES

Bird, E.C., and M.L. Schwartz. 1985. *The World's Coastline*. Van Nostrand Reinhold Company Inc., New York.

Carleton, A.M., and D.A. Carpenter. 1990. Satellite Climatology of 'Polar Lows' and Broadscale Climatic Associations for the Southern Hemisphere. *International Journal of Climatology* 10:219-246.

Case, R.A., and M. Mayfield. 1990. Atlantic Hurricane Season of 1989. *Monthly Weather Review* 118:1165-1177.

Case, R. A. 1986. Atlantic Hurricane Season of 1985. *Monthly Weather Review* 114:1390-1405.

Crutcher, H.L., and R.G. Quayle. 1974. *Mariner's Worldwide Climatic Guide to Tropical Storms at Sea*, NAVAIR 50-1C-61. U.S. Naval Weather Service Command, Environmental Detachment, Asheville, North Carolina.

Dolan, R., H. Lins, and B. Hayden. 1988. Mid-Atlantic Coastal Storms. *Journal of Coastal Research* 4:417-433.

Emanuel, K.A. 1987. The dependency of hurricane intensity on climate. *Nature* 326:482-485.

Horn, L.H. and L.M. Whittaker. 1982. *Atlas of Northern Hemisphere Extratropical Cyclone Activity: 1958-1988*. Department of Meteorology, University of Wisconsin, Madison.

Lawrence, M.B., and J.M. Pelissier. 1981. Atlantic Hurricane Season of 1980. *Monthly Weather Review* 109:1567-1582.

Neumann, C.J., B.R. Jarvinen, C.P. Arthur, and J.D. Elms. 1987. *Tropical Cyclones of the North Atlantic Ocean: 1871-1986*. National Climatic Data Center, Asheville, North Carolina.

Oliver, J.E., and R.W. Fairbridge, ed. 1987. *The Encyclopedia of Earth Sciences: Climatology*, Vol. 11, Van Norstrand Reinhold, New York.

Palmen, E., and C.W. Newton. 1969. *Atmospheric Circulation Systems*. University of Helsinki, Helsinki, Finland; and the National Center for Atmospheric Research, Boulder, Colorado; Academic Press, New York.

Polar Research Board. 1985. *Glaciers, Ice Sheets, and Sea Level: Effect of a CO^2-Induced Climatic Change*. Report of a workshop held in Seattle, Washington, September 13-15, 1984.

Ramanathan, V. 1988. The Greenhouse Theory of Climate Change: A Test by an Inadvertent Global Experiment. *Science* 240:293-299

Rasmussen, E., and M. Lystad. 1987. The Norwegian Polar Lows Project: A Summary of the International Conference on Polar Lows, 20-23 May 1986, Oslo, Norway. *Bulletin of the American Meteorological Society* 68:801-816.

Saffir, H.S. 1977. *Design and Construction Requirements for Hurricane Resistant Construction*. American Society of Civil Engineers, Reprint No. 2830. New York.

Schwartz, M.L. 1982. *Encyclopedia of Earth Sciences: Beaches and Coastal Environments*. Vol. 15, Hutchinson Ross Publishing Co., Stroudsburg, Pennsylvania.

Summer, G. 1988. *Precipitation, Process and Analysis*. John Wiley & Sons, Ltd., The Bath Press, Bath, Avon, United Kingdom, pp. 204-207.

Yarnal, B., and K.G. Henderson. 1989. A Satellite-Derived Climatology of Polar-Low Evolution in the North Pacific. *International Journal of Climatology* 9:551-566.

16. LIMITATIONS AND RESTRICTIONS OF THE DATA

Care has been taken to insure that the data used in this NDP was of the highest quality available. Because of the global extent of this data base, the period of record, and the sampling frequency, the accuracy of the measurements may vary within a given data variable by geographic location and data groups. Thus, the figures indicating the period of record for each geographic location within a data group should be consulted, along with the primary data sources listed for each data group. However, the use of long-term averages and standardized values should minimize the problems associated with the aggregation of multiple data sources (that may have been gathered over different time periods) into a single data variable or data group.

17. DATA CHECKS PERFORMED BY CDIAC

An important part of the NDP process at the Carbon Dioxide Information Analysis Center (CDIAC) is the quality assurance (QA) of the data before their distribution. Data received at CDIAC are rarely in perfect condition for immediate distribution, regardless of source. Reviews conducted involve the examination of the data for completeness, reasonableness, and accuracy. The QA process is an important component in the value-added concept of assuring accurate, usable climatic and CO_2 data for researchers.

The following summarizes the QA checks performed on the various data groups presented in this document.

1. Data variables obtained directly from primary data sources were interactively entered from data sheets into a VAX mainframe computer. The generated machine readable data files were then printed and compared with the original data sheets by two different individuals. All identified discrepancies were then corrected.

2. Data variables derived from multiple data sources (i.e., charts, maps, and digital tapes), such as tropical cyclone probabilities of occurrence, were checked using a random sampling approach. In this approach a minimum of 5% of the values for each data variable were recalculated, and compared with those in the machine-readable data file. The data accuracy level of the variable was obtained, and all identified discrepancies were corrected. If the accuracy level varied below 95%, data values within the given variable were given further study and the sampling process reapplied until the minimum accuracy standards were met.

3. Maximum, minimum, and mean values were generated for all data variables and checked for reasonableness.

4. The data values for each data variable were mapped to check for outliers and identify discrepancies. The data values for apparent discrepancies and outliers were recalculated and corrected if necessary.

18. HOW TO OBTAIN THE PACKAGE

This document describes the contents of a globally gridded climatological data base intended for use by vector or raster GISs. The computerized data are available on 9-track magnetic tapes or IBM DOS-compatible floppy diskettes (low or high density, 3.5- or 5.25-inch diskettes) from CDIAC. Requests for the magnetic tape should include any specific instructions for transmitting the data as required by the user and/or the user's local computer system. Requests not accompanied by specific instructions will be filled on 9-track, 6250 BPI, standard-labeled tapes with characters written in Extended Binary Codes Decimal Interchange Code (EBCDIC) and formatted as given in Part 2, Sect. 1. Requests for this data package should be addressed to:

Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory
Post Office Box 2008
Oak Ridge, Tennessee 37831-6335
U.S.A.

Telephone: (615) 574-0390
FTS 624-0390
FAX: (615) 574-2232
BITNET: CDP@ORNLSTC
INTERNET: CDP@STC.CTD.ORNL.GOV
OMNET: CDIAC

PART 2
INFORMATION ABOUT THE MAGNETIC TAPE

19. CONTENTS OF THE MAGNETIC TAPE

The following lists the files distributed on the magnetic tape by CDIAC along with this documentation. These files are also available on IBM-formatted floppy diskettes as DOS ASCII text files.

File no. and description		Logical records	Block size	Record length
1.	General descriptive information file	915	8000	80
2.	FORTRAN IV retrieval program to read and print File 5	33	8000	80
3.	SAS™ code to read and print File 5	5	8000	80
4.	Annual probabilities of occurrence of tropical storms and hurricanes for coastal areas of the United States, Canada, and Bermuda by 1° x 1° grid cells (ARC/INFO™ export file)	18426	8000	80
5.	Annual probabilities of occurrence of tropical storms and hurricanes for coastal areas of the United States, Canada, and Bermuda by 1° x 1° grid cells (flat ASCII file)	64801	8000	80
6.	FORTRAN IV retrieval program to read and print File 9	33	8000	80
7.	SAS™ code to read and print File 9	6	8000	80
8.	A. Annual probabilities of occurrence of tropical storms, hurricanes, and super typhoons for the world by 5° x 5° grid cells B. Mean forward velocities of tropical cyclones for the world by 5° x 5° grid cells (ARC/INFO™ export file)	32025	8000	80

File no. and description		Logical records	Block size	Record length
9.	A. Annual probabilities of occurrence of tropical storms, hurricanes, and super typhoons for the world by 5° x 5° grid cells B. mean forward velocities of tropical cyclones for the world by 5° x 5° grid cells (flat ASCII file)	2593	8000	80
10.	FORTRAN IV retrieval program to read and print File 13	33	8000	80
11.	SAS™ code to read and print File 13	6	8000	80
12.	Number of hurricane strikes for the U.S. Atlantic and Gulf Coasts by state and Saffir-Simpson category (ARC/INFO™ export file)	1227	8000	80
13.	Number of hurricane strikes for the U.S. Atlantic and Gulf coasts by state and Saffir-Simpson category (flat ASCII file)	43	8000	80
14.	Vector coordinate file of U.S. Atlantic and Gulf states, and state subdivisions (flat ASCII file)	1312	8000	80
15.	FORTRAN IV retrieval program to read and print File 18	49	8000	80
16.	SAS™ code to read and print File 18	11	8000	80

File no. and description		Logical records	Block size	Record length
17.	A. Mean number of extratropical cyclogeneses by month and year for the Northern Hemisphere by 5° x 5° grid cells B. Mean number of extratropical cyclone occurrences by month and year for the Northern Hemisphere by 5° x 5° grid cells (ARC/INFO™ export file)	42562	8000	80
18.	A. Mean number of extratropical cyclogeneses by month and year for the Northern Hemisphere by 5° x 5° grid cells B. Mean number of extratropical cyclone occurrences by month and year for the Northern Hemisphere by 5° x 5° grid cells (flat ASCII file)	5186	6600	132
19.	FORTRAN IV retrieval program to read and print File 22	33	8000	80
20.	SAS™ code to read and print File 22	6	8000	80
21.	Mean number of polar lows (polar air cloud vortices) per winter month for the North Pacific Ocean and Southern Hemisphere by 5° x 5° grid cells (ARC/INFO™ export file)	34077	8000	80
22.	Mean number of polar lows (polar air cloud vortices) per winter month for the North Pacific Ocean and Southern Hemisphere by 5° x 5° grid cells (flat ASCII file)	2593	8000	80
23.	FORTRAN IV retrieval program to read and print File 26	48	8000	80

File no. and description		Logical records	Block size	Record length
24.	SAS™ code to read and print File 26	10	8000	80
25.	A. Mean and/or relative number of cyclone occurrences for January, July, and the year for the world by 5° x 5° grid cells B. Mean number of hours of cyclone occurrence for January, July, and the year for the Southern Hemisphere by 5° x 5° grid cells (ARC/INFO™ export file)	47969	8000	80
26.	A. Mean and/or relative number of cyclone occurrences for January, July, and the year for the world by 5° x 5° grid cells B. Mean number of hours of cyclone occurrence for January, July, and the year for the Southern Hemisphere by 5° x 5° grid cells (flat ASCII file)	2593	6600	132
27.	FORTRAN IV retrieval program to read and print File 30	32	8000	80
28.	SAS™ code to read and print File 30	5	8000	80
29.	Index of the influence of winds on coastlines in the African, Asian, and Australian monsoon regions by 1° x 1° grid cells (ARC/INFO™ export file)	21449	8000	80
30.	Index of the influence of winds on coastlines in the African, Asian, and Australian monsoon regions by 1° x 1° grid cells (flat ASCII file)	64801	8000	80

File no. and description		Logical records	Block size	Record length
31.	FORTRAN IV retrieval program to read and print File 34	32	8000	80
32.	SAS™ code to read and print File 34	5	8000	80
33.	Mean annual sea-ice concentrations for Alaskan and U.S. Atlantic coastal areas by 1° x 1° grid cells (ARC/INFO™ export file)	5303	8000	80
34.	Mean annual sea-ice concentrations for Alaskan and U.S. Atlantic coastal areas by 1° x 1° grid cells (flat ASCII file)	64801	8000	80
Total records		413,023		

1. Tapes are 9 track 6250 BPI with all characters written in EBCDIC unless otherwise specified by the requester.

2. All records are stored in a fixed block record format.

3. ARC/INFO™ export files are coverages converted to flat ASCII, fixed block, files for data transfer purposes. You must use the IMPORT command in ARC/INFO to enter these files into your system.

4. SAS™ is a registered trademark of the SAS Institute, Inc., Cary, NC 27511-8000.

5. ARC/INFO™ is a registered trademark of the Environmental Systems Research Institute, Inc., Redlands, CA 92372.

20. DESCRIPTIVE FILE ON THE TAPE

A listing of the first file provided on the magnetic tape distributed by CDIAC follows. This file provides variable descriptions, formats, units, and other pertinent information about each file associated with this NDP.

TITLE OF THE DATA SET

A Global Geographic Information System Data Base of Storm Occurrences and Other Climatic Phenomena Affecting Coastal Zones

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SCOPE OF THE DATA

The climatological data base described here offers information on tropical storms, hurricanes, super typhoons, mean forward velocities of tropical cyclones, extratropical cyclones, polar air cloud vortices (polar lows), cyclonicity, winds in monsoon regions, and sea-ice concentrations. The spatial extent of the data variables varies considerably (regional to global). This data set may be used by raster or vector geographic information systems (GISs). The data set's primary focus is to quantify the occurrence of synoptic storms and other climatological factors that affect coastlines.

The data set contains eight different data groups, with a total of 61 data variables. The data variables were selected on the basis of their potential to affect coastal erosion rates. Most of the data variables provide information on various storm frequencies and/or probabilities of occurrence. Spatial coverage varies by data group. All data groups listed below except (3) are referenced to 1° x 1° or 5° x 5° grid cells of latitude and longitude [data group (3) is referenced by state]. The eight data groups are as follows:

1. Annual probabilities of occurrence of tropical storms and hurricanes for coastal areas of the United States, Canada, and Bermuda by 1° x 1° grid cells.

2. (a) Annual probabilities of occurrence of tropical storms, hurricanes, and super typhoons (winds 67 m/s or greater) for the world by 5° x 5° grid cells.
   (b) Mean forward velocities of tropical cyclones (without regard to tropical cyclone intensity) for the world by 5° x 5° grid cells.

3. The number of hurricane strikes for the U.S. Atlantic and Gulf coasts by state and Saffir-Simpson hurricane category.

4. (a) Mean monthly and annual number of extratropical cyclogeneses for the Northern Hemisphere by 5° x 5° grid cells.
(b) Mean monthly and annual number of extratropical cyclone occurrences for the Northern Hemisphere by 5° x 5° grid cells.

5. Mean number of polar lows (polar air cloud vortices) per winter month for the North Pacific Ocean and Southern Hemisphere by 5° x 5° grid cells.

6. (a) Mean and/or relative number of cyclones (without regard to cyclone type) for January, July, and the year for the world by 5° x 5° grid cells.
(b) Mean number of hours of cyclone occurrence (without regard to cyclone type) for January, July, and the year for the Southern Hemisphere by 5° x 5° grid cells.

7. Index of the influence of winds on coastlines in the African, Asian, and Australian monsoon regions by 1° x 1° grid cells.

8. Mean annual sea-ice concentrations for Alaskan and U.S. Atlantic coastal areas by 1° x 1° grid cells.

This data set comprises data extracted from a variety of sources, including publications of the National Oceanic and Atmospheric Administration (NOAA), U.S. Navy, foreign government agencies, universities, and other miscellaneous sources.

DATA FORMATS

Thirty-four files are provided on this magnetic tape, including this descriptive file, one vector coordinate file, eight ARC/INFO™ export files, eight flat ASCII data files, and FORTRAN IV and SAS™ retrieval codes to read and print each of the flat ASCII data files.

The ARC/INFO™ export files are exported coverages that must be read into an ARC/INFO™ GIS using the IMPORT command (this may be done after the files have been uploaded onto a computer system). These coverages are in a GEOGRAPHIC projection, which means that the coverages are projected in a spherical reference grid using latitude and longitude coordinates that are stored in decimal degrees (DD). As a result of using DD for the coordinate system, the reference grids in this NDP are not equal area or equal distance in nature.

The flat ASCII data files are provided to allow use of these data by users who do not have access to ARC/INFO™. These files contain the same information contained in the ARC/INFO™ export files. The format and contents of each of these flat ASCII files are described in the following section.

DATA GROUP TC10:
ANNUAL PROBABILITIES OF OCCURRENCE OF TROPICAL STORMS AND HURRICANES FOR COASTAL AREAS OF THE UNITED STATES, CANADA, AND BERMUDA BY 1° X 1° GRID CELLS

The names of the ARC/INFO™ coverage and flat ASCII file are **TC10.E00** (File 4) and **TC10.ASC** (File 5), respectively. A summary of the format used for File 5 follows:

```
10    READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,TC10,
   1   TC10ID,TS,TY
100   FORMAT(2F13.3,2I6,2F9.2)
```

The variables in data group TC10 are listed as they appear in TC10.ASC (File 5) in Table 8.

Table 8. Variable formats for TC10.ASC (File 5)

Variable name	Column start	Column end	Variable type	Variable description
AREA	1	13	Real	System variable - area of each grid cell in map units
PERIMETER	14	26	Real	System variable - perimeter of each grid cell in map units
TC10	27	32	Integer	System variable - internal grid cell identifier
TC10ID	33	38	Integer	System variable - external grid cell identifier
TS	39	47	Real	Data variable - annual probability of occurrence of tropical storms for each grid cell
TY	48	56	Real	Data variable - annual probability of occurrence of hurricanes for each grid cell

Flags are used in data group TC10 for data variables TS and TY under the following circumstances: (1) when the data record for a given grid cell provided what was believed to be a false-zero value, and (2) to indicate areas where tropical cyclones are not known to occur. All flags have data values greater than 100 and are defined as follows:

200.00 — Indicates that no tropical cyclone activity has been observed for the given data variable in the given grid cell during the period of record; however, the grid cell may be an area of rare or occasional tropical cyclone activity for the data variable at hand.

999.00 — Indicates that tropical cyclones of at least tropical storm intensity (sustained winds greater than 17.5 m/s) are not known to occur in the given grid cell (i.e., 999 is equivalent to zero).

DATA GROUP TC50:
ANNUAL PROBABILITIES OF OCCURRENCE OF TROPICAL STORMS, HURRICANES, AND SUPER TYPHOONS FOR THE WORLD BY 5° X 5° GRID CELLS AND MEAN FORWARD VELOCITIES OF TROPICAL CYCLONES FOR THE WORLD BY 5° X 5° GRID CELLS.

The names of the ARC/INFO™ coverage and flat ASCII file are **TC50.E00** (File 8) and **TC50.ASC** (File 9), respectively. A summary of the format used for File 9 follows:

```
10    READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,TC50,
   1   TC50ID,TS,TY,STY,TCV
100   FORMAT(2F13.3,2I6,4F9.2)
```

The variables in data group TC50 are listed as they appear in TC50.ASC (File 9) in Table 9.

Table 9. Variable formats for TC50.ASC (File 9)

Variable name	Column start	Column end	Variable type	Variable description
AREA	1	13	Real	System variable - area of each grid cell in map units
PERIMETER	14	26	Real	System variable - perimeter of each grid cell in map units
TC50	27	32	Integer	System variable - internal grid cell identifier
TC50ID	33	38	Integer	System variable - external grid cell identifier
TS	39	47	Real	Data variable - annual probability of occurrence of tropical storms for each grid cell
TY	48	56	Real	Data variable - annual probability of occurrence of hurricanes for each grid cell
STY	57	65	Real	Data variable - annual probability of occurrence of super typhoons for each grid cell
TCV	66	74	Real	Data variable - mean forward velocity of tropical cyclones (without regard to tropical cyclone intensity) for each grid cell in meters per second

Flags have been added to the data values of data group TC50 for data variables TS, TY, STY, and TCV under the following circumstances: (1) when the data record used for a given grid cell provided what was believed to be a false-zero value, and (2) to indicate areas where tropical cyclones are not known to occur. All flags have data values greater than 100. Each is explained in the following:

200.10 to 299.90 - Indicates that no tropical cyclone activity has been observed for the given data variable in the given grid cell during the period of record; however, the grid cell may represent an area of rare or occasional activity for the data variable at hand.

999.00 - Indicates that tropical cyclones of at least tropical storm intensity are not known to occur in the given grid cell (i.e., 999 is equivalent to zero).

A 200 digit in a data value for data variables TS, TY, and STY indicates that the remaining digits are an estimate of the probability of occurrence in percent for the given data variable. To obtain the estimated percent likelihood of occurrence in the given grid cell, subtract 200.

A 200 digit in a data value for data variable TCV indicates that the remaining digits are an estimate of the mean forward velocity of tropical cyclones in meters per second. To obtain the estimated mean forward velocity of tropical cyclones for data variable TCV for a given grid cell, subtract 200.

DATA GROUP HCSTATE:
NUMBER OF HURRICANE STRIKES FOR THE U.S. ATLANTIC AND GULF COASTS BY STATE AND SAFFIR-SIMPSON CATEGORY

The names of the ARC/INFO™ export file, flat ASCII data file, and ASCII vector coordinate file are **HCSTATE.E00** (File 12), **HCSTATE.ASC** (File 13), and **HCSTATE.BNA** (File 14), respectively. A summary of the format used for File 13 follows:

```
10    READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,HCSTATE,
   1   HCSTATEID,C1,C2,C3,C4,C5
100   FORMAT(F10.3,F13.3,I6,I9,F10.0,4F5.0)
```

The variables in data group HCSTATE are listed as they appear in HCSTATE.ASC (File 13) in Table 10.

Table 10. Variable formats for HCSTATE.ASC (File 13)

Variable name	Column start	Column end	Variable type	Variable description
AREA	1	10	Real	System variable - area of each grid cell in map units
PERIMETER	11	23	Real	System variable - perimeter of each grid cell in map units
HCSTATE	24	29	Integer	System variable - internal grid cell identifier
HCSTATEID	30	38	Integer	System variable - external grid cell identifier
C1	39	48	Real	Data variable - number of hurricane centers of Saffir-Simpson Class 1 that have crossed a given state or substate coastline during the period of record
C2	49	53	Real	Data variable - number of hurricane centers of Saffir-Simpson Class 2 that have crossed a given state or substate coastline during the period of record
C3	54	58	Real	Data variable - number of hurricane centers of Saffir-Simpson Class 3 that have crossed a given state or substate coastline during the period of record

Table 10 (continued)

Variable name	Column start	Column end	Variable type	Variable description
C4	59	63	Real	Data variable - number of hurricane centers of Saffir-Simpson Class 4 that have crossed a given state or substate coastline during the period of record
C5	64	68	Real	Data variable - number of hurricane centers of Saffir-Simpson Class 5 that have crossed a given state or substate coastline during the period of record

Table 11 lists the geographic name and polygon ID for each polygon in this data group. Figure 6 of Part 1 shows the geographic locations of these polygons.

Table 11. Geographic names of each polygon in data group HCSTATE (Files 12, 13, and 14)

HCSTATE-ID	Location	HCSTATE-ID	Location
1	Maine	2	N. Hampshire
3	New York	4	Massachusetts
5	Pennsylvania	6	Connecticut
7	Rhode Island	8	New Jersey
9	New York	10	Delaware
11	Maryland	12	Virginia
13	Virginia	14	N. Carolina
15	N. Carolina	16	Northern Texas
17	N. Carolina	18	N. Carolina
19	S. Carolina	20	Alabama
21	Mississippi	22	Georgia
23	Louisiana	24	Central Texas
25	NW Florida	26	NE Florida
27	NW Florida	28	NE Florida
29	Northern Texas	30	NE Florida
31	Southern Texas	32	NE Florida
33	NE Florida	34	SE Florida
35	SE Florida	36	SE Florida
37	Central Texas	38	SW Florida
39	SW Florida	40	Southern Texas
41	Southern Texas	42	SW Florida

Table 12 displays an example of the format of the data within HCSTATE.BNA (File 14), which contains the vector boundaries for the data within this data group.

Table 12. Sample listing from the vector coordinate file HCSTATE.BNA (File 14)

FORMAT: Polygon ID, number of vertices in polygon
longitude, latitude

"1",59	
-71.088,45.3014	(Point 1)
-70.6407,45.4194	
-70.5033,45.6806	
-70.2455,45.9355	
-70.279,46.1999	
-70.0352,46.4806	
-69.8728,46.8154	
-69.5779,47.1142	
-69.274,47.4105	
-69.0446,47.2721	(Point 10)
...	
-71.088,45.3014	(Point 59, closes polygon)
"2",16	
-71.088,45.3014	(Point 1)
...	

No flags are added to the data variables of data group HCSTATE. However, data values for the five data variables are not directly comparable between different polygons. This results from different coastal lengths represented by each of the state and substate polygons.

Twenty-four states and substates represent separate data entities in this data group. These 24 entities, however, are described by 42 polygons in the data group. The additional polygons are islands and/or fragments of various states or substates, which are separated from the main body of the state or substate to which they belong. Each island polygon contains the same data values as the state or substate of which it is a part.

DATA GROUP XCNORTH:
MEAN NUMBER OF EXTRATROPICAL CYCLOGENESES BY MONTH AND YEAR FOR THE NORTHERN HEMISPHERE BY 5° X 5° GRID CELLS AND THE MEAN NUMBER OF EXTRATROPICAL CYCLONE OCCURRENCES BY MONTH AND YEAR FOR THE NORTHERN HEMISPHERE BY 5° X 5° GRID CELLS

The names of the ARC/INFO™ coverage and flat ASCII file are **XCNORTH.E00** (File 17) and **XCNORTH.ASC** (File 18) respectively. A summary of the format used for File 18 follows:

```
10     READ(UNIT=5,FMT=100) AREA,PERIMETER,XCNORTH,
   1  XCNORTHID,CGJA,CFJA,CGFE,CFFE,CGMR,CFMR,CGAP,CFAP,CGMY,CFMY,
   2  CGJN
      READ(UNIT=5,FMT=101,END=999) CFJN,CGJL,CFJL,CGAG,CFAG,CGSP,
   1  CFSP,CGOB,CFOB,CGNV,CFNV,CGDC,CFDC,CGAN,CFAN
100     FORMAT(2F12.3,2I5,11F8.2)
101     FORMAT(15F8.2)
```

The variables in data group XCNORTH are listed as they appear in XCNORTH.ASC (File 18) in Table 13.

Table 13. Variable formats for XCNORTH.ASC (File 18)

Variable name	Column start	Column end	Variable type	Variable description
AREA	1	12	Real	System variable - area of each grid cell in map units
PERIMETER	13	24	Real	System variable - perimeter of each grid cell in map units
XCNORTH	25	29	Integer	System variable - internal grid cell identifier
XCNORTHID	30	34	Integer	System variable - external grid cell identifier
CGJA	35	42	Real	Data variable - mean number of extratropical cyclogeneses per January for each grid cell
CFJA	43	50	Real	Data variable - mean number of extratropical cyclone occurrences per January for each grid cell

Table 13 (continued)

Variable name	Column start	Column end	Variable type	Variable description
CGFE	51	58	Real	Data variable - mean number of extratropical cyclogeneses per February for each grid cell
CFFE	59	66	Real	Data variable - mean number of extratropical cyclone occurrences per February for each grid cell
CGMR	67	74	Real	Data variable - mean number of extratropical cyclogeneses per March for each grid cell
CFMR	75	82	Real	Data variable - mean number of extratropical cyclone occurrences per March for each grid cell
CGAP	83	90	Real	Data variable - mean number of extratropical cyclogeneses per April for each grid cell
CFAP	91	98	Real	Data variable - mean number of extratropical cyclone occurrences per April for each grid cell
CGMY	99	106	Real	Data variable - mean number of extratropical cyclogeneses per May for each grid cell
CFMY	107	114	Real	Data variable - mean number of extratropical cyclone occurrences per May for each grid cell
CGJN	115	122	Real	Data variable - mean number of extratropical cyclogeneses per June for each grid cell
The following line reads				
CFJN	1	8	Real	Data variable - mean number of extratropical cyclone occurrences per June for each grid cell
CGJL	9	16	Real	Data variable - mean number of extratropical cyclogeneses per July for each grid cell
CFJL	17	24	Real	Data variable - mean number of extratropical cyclone occurrences per July for each grid cell

Table 13 (continued)

Variable name	Column start	Column end	Variable type	Variable description
CGAG	25	32	Real	Data variable - mean number of extratropical cyclogeneses per August for each grid cell
CFAG	33	40	Real	Data variable - mean number of extratropical cyclone occurrences per August for each grid cell
CGSP	41	48	Real	Data variable - mean number of extratropical cyclogeneses per September for each grid cell
CFSP	49	56	Real	Data variable - mean number of extratropical cyclone occurrences per September for each grid cell
CGOB	57	64	Real	Data variable - mean number of extratropical cyclogeneses per October for each grid cell
CFOB	65	72	Real	Data variable - mean number of extratropical cyclone occurrences per October for each grid cell
CGNV	73	80	Real	Data variable - mean number of extratropical cyclogeneses per November for each grid cell
CFNV	81	88	Real	Data variable - mean number of extratropical cyclone occurrences per November for each grid cell
CGDC	89	96	Real	Data variable - mean number of extratropical cyclogeneses per December for each grid cell
CFDC	97	104	Real	Data variable - mean number of extratropical cyclone occurrences per December for each grid cell
CGAN	105	112	Real	Data variable - mean number of extratropical cyclogeneses per year for each cell
CFAN	113	120	Real	Data variable - mean number of extratropical cyclone occurrences per year for each grid cell

Flags are added to the data values of data group XCNORTH under the following circumstances: (1) to indicate Northern Hemisphere "tropical" zones and (2) to indicate the unavailability of data. Flagged data always have data values greater than 100. The flags are defined as follows:

> **888.00** - Indicates that the data value is referenced to a 5° x 5° grid cell that is located between 0° and 20° North latitude. Polygons within this area are generally tropical in nature. As a result, extratropical cyclone activity is either rare or nonexistent.
>
> **999.00** - This data value indicates that no data are available for the given grid cell.

This data group has not been significantly corrected for latitudinal differences in the sizes of 5° x 5° grid cells of latitude-longitude. Extratropical cyclone occurrence data variables (those beginning with CF) have received no area corrections. The extratropical cyclogenesis data variables (those beginning with CG) have been slightly corrected for latitudes above 65° North. (See Appendix A for information on how the CG variables have been corrected for latitude.)

DATA GROUP POLARLOW:
MEAN NUMBER OF POLAR LOWS PER WINTER MONTH FOR THE NORTH PACIFIC OCEAN AND SOUTHERN HEMISPHERE BY 5° X 5° GRID CELLS

The names of the ARC/INFO™ coverage and flat ASCII file are **POLARLOW.E00** (File 21) and **POLARLOW.ASC** (File 22) respectively. A summary of the format used for file 22 follows:

```
10    READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,PLOW,
   1   PLOWID,COMMA,SPIRAL,POLARLOW
100   FORMAT(2F13.3,2I6,3F9.2)
```

The variables in data group POLARLOW are listed as they appear in POLARLOW.ASC (File 22) in Table 14.

Table 14. Variable formats for POLARLOW.ASC (File 22)

Variable name	Column start	Column end	Variable type	Variable description
AREA	1	13	Real	System variable - area of each grid cell in map units
PERIMETER	14	26	Real	System variable - perimeter of each grid cell in map units
PLOW	27	32	Integer	System variable - internal grid cell identifier
PLOWID	33	38	Integer	System variable - external grid cell identifier
COMMA	39	47	Real	Data variable - mean number of comma-form polar lows per winter month for each grid cell
SPIRAL	48	56	Real	Data variable - mean number of spiral-form polar lows per winter month for each grid cell
POLARLOW	57	65	Real	Data variable - mean number of polar lows per winter month (comma- and spiral-form) for each grid cell

The following flags are added to the data values of data group POLARLOW in order to (1) indicate areas of possible rare polar-low occurrence and (2) indicate the unavailability of data. Flagged data always have values greater than 100. The two types of flags in the data values are explained below:

> **200.00** - Indicates that polar-low occurrence is a possibility in the given grid cell; however, the period of record was not sufficient to indicate polar-low activity. This flag was used only for data variable POLARLOW.
>
> **999.00** - Indicates that data on the occurrence of polar lows are not available for the given grid cell.

The polar-low climatology here describes the occurrences of polar lows in all formative and most mature stages of development (polar-low types 6, 7, 21, and 22 as used in the data sources; see Part 1, Sect. 10). Polar lows in the decaying stage of their life cycles are not included in this climatology.

DATA GROUP LOWPC:
MEAN AND/OR RELATIVE NUMBER OF CYCLONES FOR JANUARY, JULY, AND THE YEAR FOR THE WORLD BY 5° x 5° GRID CELLS AND THE MEAN NUMBER OF HOURS OF CYCLONE OCCURRENCE FOR JANUARY, JULY, AND THE YEAR FOR THE SOUTHERN HEMISPHERE BY 5° X 5° GRID CELLS

The names of the ARC/INFO™ coverage and flat ASCII file are **LOWPC.E00** (File 25) and **LOWPC.ASC** (File 26) respectively. A summary of the format for File 26 follows:

```
10    READ(UNIT=5,FMT=100) AREA,PERIMETER,LOWPC,LOWPCID,ZONE,
   1   LOWNJA,LOWNJL,LOWNAN,LOWSJA,LOWSJL,LOWSAN,LOWS2JA
      READ(UNIT=5,FMT=101,END=999) LOWS2JL,LOWS2AN,LOWAJA,
   1   LOWAJL,LOWAAN,LOWA2JA,LOWA2JL,LOWA2AN,CYCJA,CYCJL,
   2   CYCLONE
100    FORMAT(F12.3,F13.3,3I6,7F8.2)
101    FORMAT(11F8.2)
```

The variables in data group LOWPC are listed as they appear in LOWPC.ASC (File 26) in Table 15.

Table 15. Variable formats for LOWPC.ASC (File 26)

Variable name	Column start	Column end	Variable type	Variable description
AREA	1	12	Real	System variable - area of each grid cell in map units
PERIMETER	13	25	Real	System variable - perimeter of each grid cell in map units
LOWPC	26	31	Integer	System variable - internal grid cell identifier
LOWPCID	32	37	Integer	System variable - external grid cell identifier
ZONE	38	43	Integer	Data variable - the climate zone to which a given grid cell is assigned (i.e., 1 = tropical, 2 = extratropical)
LOWNJA	44	52	Real	Data variable - the mean number of cyclone occurrences per January for each grid cell (Northern Hemisphere)

Table 15 (continued)

Variable name	Column start	Column end	Variable type	Variable description
LOWNJL	53	61	Real	Data variable - the mean number of cyclone occurrences per July for each grid cell (Northern Hemisphere)
LOWNAN	62	70	Real	Data variable - the mean number of cyclone occurrences per year for each grid cell (Northern Hemisphere)
LOWSJA	71	79	Real	Data variable - the mean number of cyclone occurrences per January for each grid cell (Southern Hemisphere outside Australian Region)
LOWSJL	80	88	Real	Data variable - the mean number of cyclone occurrences per July for each grid cell (Southern Hemisphere outside Australian Region)
LOWSAN	89	97	Real	Data variable - the mean number of cyclone occurrences per year for each grid cell (Southern Hemisphere outside Australian Region)
LOWS2JA	98	106	Real	Data variable - the mean number of hours of cyclone occurrence per January for each grid cell (Southern Hemisphere outside Australian Region)
The following line reads:				
LOWS2JL	1	8	Real	Data variable - the mean number of hours of cyclone occurrence per July for each grid cell (Southern Hemisphere outside Australian Region)
LOWS2AN	9	17	Real	Data variable - the mean number of hours of cyclone occurrence per year for each grid cell (Southern Hemisphere outside Australian Region)

Table 15 (continued)

Variable name	Column start	Column end	Variable type	Variable description
LOWAJA	18	26	Real	Data variable - the mean number of cyclone occurrences per January for each grid cell (Australian Region)
LOWAJL	27	35	Real	Data variable - the mean number of cyclone occurrences per July for each grid cell (Australian Region)
LOWAAN	36	44	Real	Data variable - the mean number of cyclone occurrences per year for each grid cell (Australian Region)
LOWA2JA	45	53	Real	Data variable - the mean number of hours of cyclone occurrence per January for each grid cell (Australian Region)
LOWA2JL	54	62	Real	Data variable - the mean number of hours of cyclone occurrence per July for each grid cell (Australian Region)
LOWA2AN	63	71	Real	Data variable - the mean number of hours of cyclone occurrence per year for each grid cell (Australian Region)
CYCJA	72	80	Real	Data variable - statistically standardized data value calculated by subtracting the given data source mean number of cyclone centers present per 5° x 5° grid cell per January from the mean number of cyclone centers present in a given 5° x 5° grid cell per January and then dividing by the standard deviation of the given data source mean number of cyclone centers present per 5° x 5° grid cell per January (i.e., the global distribution of cyclones in January)

Table 15 (continued)

Variable name	Column start	Column end	Variable type	Variable description
CYCJL	81	89	Real	Data variable - statistically standardized data value calculated by subtracting the given data source mean number of cyclone centers present per 5° x 5° grid cell per July from the mean number of cyclone centers present in a given 5° x 5° grid cell per July and then dividing by the standard deviation of the given data source mean number of cyclone centers present per 5° x 5° grid cell per July (i.e., the global distribution of cyclones in July)
CYCLONE	90	98	Real	Data variable - statistically standardized data value calculated by subtracting the given data source mean number of cyclone centers present per 5° x 5° grid cell per year from the mean number of cyclone centers present in a given 5° x 5° grid cell per year and then dividing by the standard deviation of the given data source mean number of cyclone centers present per 5° x 5° grid cell per year (i.e., the annual global distribution of cyclones

The following flag is added to the data values of data group LOWPC to aid in the data interpretation.

999.00 - Indicates that data for the given data variable are not available for the given grid cell.

Data variables CYCJA, CYCJL, and CYCLONE are expressed in deviations from the mean, where the mean and standard deviation for each data source was obtained and used to convert the values in each grid cell into a standardized value. The standardized data values for each 5° x 5° grid cell in each data region were then used to form the three global data variables for January, July, and the year (see Appendix A for a full description of the methods used in obtaining the global data variables).

Comparison of the number of cyclones and/or cyclonicity data between areas using different data sources should be undertaken with caution. Although data variables CYCJA, CYCJL, and CYCLONE adequately standardize the data sources for most uses, differences in data analysis and presentation in the original data sources cannot be entirely ignored. Two particular areas of caution concerning data source differences are (1) the number of cyclone observations used in obtaining the original cyclone frequencies and (2) the resolution of the isobar analyses used (i.e., 4-hPa, 5-hPa, or 10-hPa).

DATA GROUP MONSOON:
INDEX OF THE INFLUENCE OF WINDS ON COASTLINES IN THE AFRICAN, ASIAN, AND AUSTRALIAN MONSOON REGIONS BY 1° X 1° GRID CELLS

The names of the ARC/INFO™ coverage and flat ASCII file are **MONSOON.E00** (File 29) and **MONSOON.ASC** (File 30) respectively. A summary of the format used for File 30 follows:

```
10    READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,MON,
   1   MONID,MONSOON
100   FORMAT(2F13.3,2I6,F5.0)
```

The variables in data group MONSOON are listed as they appear in MONSOON.ASC (File 30) in Table 16.

Table 16. Variable formats for MONSOON.ASC (File 30)

Variable name	Column start	Column end	Variable type	Variable description
AREA	1	13	Real	System variable - area of each grid cell in map units
PERIMETER	14	26	Real	System variable - perimeter of each grid cell in map units
MON	27	32	Integer	System variable - internal grid cell identifier
MONID	33	38	Integer	System variable - external grid cell identifier
MONSOON	39	43	Real	Data variable - a numeric index of the relative influence of onshore winds on coastlines of monsoon regions for each grid cell

The following flag is added to the data values of data group MONSOON to aid in data interpretation.

999 - Indicates that data for the given data variable are not available for the given grid cell.

DATA GROUP SEAICE:
MEAN ANNUAL SEA-ICE CONCENTRATIONS FOR ALASKAN AND U.S. ATLANTIC COASTAL AREAS BY 1° X 1° GRID CELLS

The names of the ARC/INFO™ export file and flat ASCII data file are **SEAICE.E00** (File 33), and **SEAICE.ASC** (File 34) respectively. A summary of the format used for File 34 follows:

```
10    READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,SEA,
   1   SEAID,ICE
100   FORMAT(2F13.3,2I6,F5.1)
```

The variables in data group SEAICE are listed as they appear in SEAICE.ASC (File 34) in Table 17.

Table 17. Variable formats for SEAICE.ASC (File 34)

Variable name	Column start	Column end	Variable type	Variable description
AREA	1	13	Real	System variable - area of each grid cell in map units
PERIMETER	14	26	Real	System variable - perimeter of each grid cell in map units
SEA	27	32	Integer	System variable - internal grid cell identifier
SEAID	33	38	Integer	System variable - external grid cell identifier
ICE	39	43	Real	Data variable - mean annual concentration of sea ice in percent for each grid cell

Calculations of sea-ice concentrations are limited to 1° x 1° grid cells of latitude-longitude that contain significant U.S. coastlines. Therefore, the flat ASCII file (File 34) of data group SEAICE has only 297 grid cells out of the 64,800 possible that contain real data. Grid cells not containing real data values are flagged with the following data value:

99.0 - Indicates that no data value for sea-ice concentration has been calculated for the given grid cell.

21. LISTING OF THE FORTRAN IV DATA RETRIEVAL PROGRAMS

The following is a listing of several FORTRAN IV data retrieval programs provided on the magnetic tape by CDIAC. Each program is designed to read and write the contents of one of the flat ASCII data files. The lines preceded with "//" are machine dependent job control language (JCL) statements that will vary according to the local operating environment. These JCL lines are not included in the FORTRAN files provided with this NDP and are listed here for example purposes only.

The first program (File 2 on the magnetic tape) is designed to read and print the file TC10.ASC (File 5).

```
//UIDDAT JOB (12345,TAPE,IO20),'USER ADDRESS',TIME=(1,30)
//EXEC FORTQCLG
//FORT.SYSIN DD *
C**********************************************************
C*  FORTRAN PROGAM TO READ AND PRINT TC10.ASC (FILE 5)     *
C**********************************************************
       INTEGER TC10, TC10ID, NREC
       REAL AREA, PERIMETER, TS, TY
C**********************************************************
C*  INITIALIZE A COUNTER OF THE NUMBER OF RECORDS READ     *
C**********************************************************
       NREC=0
C**********************************************************
C*  READ THE FLAT ASCII FILE INFORMATION                   *
C**********************************************************
  10   READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,TC10,
     1    TC10ID,TS,TY
 100   FORMAT(2F13.3,2I6,2F9.2)
C**********************************************************
C*  START A NEW PAGE AND WRITE A DESCRIPTIVE HEADER        *
C**********************************************************
       IF (NREC.EQ.77) NREC=0
       IF (NREC.EQ.0) WRITE(6,101)
 101   FORMAT('1','AREA',9X,'PERIMETER',4X,'#',5X,'ID',4X,
     1    'TS',7X,'TY',7X)
       NREC=NREC+1
C**********************************************************
C*  WRITE THE FLAT ASCII FILE TO THE OUTPUT DIVICE         *
C**********************************************************
       WRITE(6,102) AREA,PERIMETER,TC10,TC10ID,
     1    TS,TY
 102   FORMAT(1X,2F13.3,2I6,2F9.2)
C
       GO TO 10
 999   STOP
       END
//GO.FT05F001 DD UNIT=TAPE62,VOL=SER=TAPEVOL1,
//DISP=(,PASS),DSN=TAB.NDP035.TC10.DATA,LABLE=(5,SL)
//GO.FT06F001 DD *
```

The second FORTRAN IV program (File 6 on the magnetic tape) is designed to read and print the file TC50.ASC (File 9).

```
//UIDDAT JOB (12345,TAPE,I020),'USER ADDRESS',TIME=(1,30)
//EXEC FORTQCLG
//FORT.SYSIN DD *
C************************************************************
C*  FORTRAN PROGAM TO READ AND PRINT TC50.ASC (FILE 9)      *
C************************************************************
       INTEGER TC50, TC50ID, NREC
       REAL AREA, PERIMETER, TS, TY, STY, TCV
C************************************************************
C*  INITIALIZE A COUNTER OF THE NUMBER OF RECORDS READ      *
C************************************************************
       NREC=0
C************************************************************
C*  READ THE FLAT ASCII FILE INFORMATION                    *
C************************************************************
  10   READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,TC50,
     1    TC50ID,TS,TY,STY,TCV
 100   FORMAT(2F13.3,2I6,4F9.2)
C************************************************************
C*  START A NEW PAGE AND WRITE A DESCRIPTIVE HEADER         *
C************************************************************
       IF (NREC.EQ.77) NREC=0
       IF (NREC.EQ.0) WRITE(6,101)
 101   FORMAT('1','AREA',9X,'PERIMETER',4X,'#',5X,'ID',4X,
     1   'TS',7X,'TY',7X,'STY',6X,'TCV',6X)
       NREC=NREC+1
C************************************************************
C*  WRITE THE FLAT ASCII FILE TO THE OUTPUT DIVICE          *
C************************************************************
       WRITE(6,102) AREA,PERIMETER,TC50,TC50ID,
     1    TS,TY,STY,TCV
 102   FORMAT(1X,2F13.3,2I6,4F9.2)
C
       GO TO 10
 999   STOP
       END
//GO.FT05F001 DD UNIT=TAPE62,VOL=SER=TAPEVOL1,
//DISP=(,PASS),DSN=TAB.NDP035.TC50.DATA,LABLE=(9,SL)
//GO.FT06F001 DD *
```

The third FORTRAN IV program (File 10 on the magnetic tape) is designed to read and print the file **HCSTATE.ASC** (File 13).

```
//UIDDAT JOB (12345,TAPE,IO20),'USER ADDRESS',TIME=(1,30)
//EXEC FORTQCLG
//FORT.SYSIN DD *
C***********************************************************
C* FORTRAN PROGAM TO READ AND PRINT HCSTATE.ASC (FILE 13)   *
C***********************************************************
       INTEGER HCSTATE, HCSTATEID, NREC
       REAL AREA, PERIMETER, C1, C2, C3, C4, C5
C***********************************************************
C*  INITIALIZE A COUNTER OF THE NUMBER OF RECORDS READ      *
C***********************************************************
       NREC=0
C***********************************************************
C*  READ THE FLAT ASCII FILE INFORMATION                    *
C***********************************************************
  10   READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,HCSTATE,
     1    HCSTATEID,C1,C2,C3,C4,C5
 100   FORMAT(F10.3,F13.3,I6,I9,F10.0,4F5.0)
C***********************************************************
C*  START A NEW PAGE AND WRITE A DESCRIPTIVE HEADER         *
C***********************************************************
       IF (NREC.EQ.77) NREC=0
       IF (NREC.EQ.0) WRITE(6,101)
 101   FORMAT('1','AREA',6X,'PERIMETER',4X,'#',5X,'ID',7X,
     1   'CAT1',6X,'CAT2',1X,'CAT3',1X,'CAT4',1X,'CAT5',1X)
       NREC=NREC+1
C***********************************************************
C*  WRITE THE FLAT ASCII FILE TO THE OUTPUT DIVICE          *
C***********************************************************
       WRITE(6,102) AREA,PERIMETER,HCSTATE,HCSTATEID,
     1    C1,C2,C3,C4,C5
 102   FORMAT(1X,F10.3,F13.3,I6,I9,F10.0,4F5.0)
C
       GO TO 10
 999   STOP
       END
//GO.FT05F001 DD UNIT=TAPE62,VOL=SER=TAPEVOL1,
//DISP=(,PASS),DSN=TAB.NDP035.HCSTATE.DATA,LABLE=(13,SL)
//GO.FT06F001 DD *
```

The fourth FORTRAN IV program (File 15 on the magnetic tape) is designed to read and print the file **XCNORTH.ASC** (File 18).

```
//UIDDAT JOB (12345,TAPE,IO20),'USER ADDRESS',TIME=(1,30)
//EXEC FORTQCLG
//FORT.SYSIN DD *
C**********************************************************
C* FORTRAN PROGAM TO READ AND PRINT XCNORTH.ASC (FILE 18)  *
C**********************************************************
      INTEGER XCNORTH,XCNORTHID,NREC
      REAL AREA,PERIMETER,XCNORTH,XCNORTHID,
    1 CGJA,CFJA,CGFE,CFFE,CGMR,CFMR,CGAP,CFAP,
      2 CGMY,CFMY,CGJN,CFJN,CGJL,CFJL,CGAG,CFAG,
      3 CGSP,CFSP,CGOB,CFOB,CGNV,CFNV,CGDC,CFDC,CGAN,CFAN
C**********************************************************
C*  INITIALIZE A COUNTER OF THE NUMBER OF RECORDS READ     *
C**********************************************************
       NREC=0
C**********************************************************
C*  READ THE FLAT ASCII FILE INFORMATION                   *
C**********************************************************
 10   READ(UNIT=5,FMT=100) AREA,PERIMETER,XCNORTH,
    1 XCNORTHID,CGJA,CFJA,CGFE,CFFE,CGMR,CFMR,CGAP,CFAP,
      2 CGMY,CFMY,CGJN
     READ(UNIT=5,FMT=101,END=999) CFJN,CGJL,CFJL,CGAG,CFAG,
      1 CGSP,CFSP,CGOB,CFOB,CGNV,CFNV,CGDC,CFDC,CGAN,CFAN
 100   FORMAT(2F12.3,2I5,11F8.2)
 101   FORMAT(15F8.2)
C**********************************************************
C*  START A NEW PAGE AND WRITE A DESCRIPTIVE HEADER        *
C**********************************************************
       IF (NREC.EQ.36) NREC=0
       IF (NREC.EQ.0) WRITE(6,102)
       IF (NREC.EQ.0) WRITE(6,103)
 102   FORMAT('1','AREA',8X,'PERIMETER',3X,'#',4X,'ID',3X,
     1  'CGJA',4X,'CFJA',4X,'CGFE',4X,'CFFE',4X,'CGMR',4X,
     2  'CFMR',4X,'CGAP',4X,'CFAP',4X,'CGMY',4X,'CFMY',4X,
     3  'CGJN',4X)
 103   FORMAT(' ','CFJN',4X,'CGJL',4X,'CFJL',4X,'CGAG',4X,
     1  'CFAG',4X,'CGSP',4X,'CFSP',4X,'CGOB',4X,'CFOB',4X,
     2  'CGNV',4X,'CFNV',4X,'CGDC',4X,'CFDC',4X,'CGAM',4X,
     3  'CFAN',4X)
       NREC=NREC+2
C**********************************************************
C*  WRITE THE FLAT ASCII FILE TO THE OUTPUT DIVICE         *
C**********************************************************
       WRITE(6,104) AREA,PERIMETER,XCNORTH,
    1 XCNORTHID,CGJA,CFJA,CGFE,CFFE,CGMR,CFMR,CGAP,CFAP,
      2 CGMY,CFMY,CGJN
       WRITE(6,105) CFJN,CGJL,CFJL,CGAG,CFAG,
      1 CGSP,CFSP,CGOB,CFOB,CGNV,CFNV,CGDC,CFDC,CGAN,CFAN
```

```
 104    FORMAT(1X,2F12.3,2I5,11F8.2)
 105    FORMAT(1X,15F8.2)
C
        GO TO 10
 999    STOP
        END

//GO.FT05F001 DD UNIT=TAPE62,VOL=SER=TAPEVOL1,
//DISP=(,PASS),DSN=TAB.NDP035.XCNORTH.DATA,LABLE=(18,SL)
//GO.FT06F001 DD *
```

The fifth FORTRAN IV program (File 19 on the magnetic tape) is designed to read and print the file **POLARLOW.ASC** (File 22).

```
//UIDDAT JOB (12345,TAPE,IO20),'USER ADDRESS',TIME=(1,30)
//EXEC FORTQCLG
//FORT.SYSIN DD *
C***********************************************************
C*FORTRAN PROGAM TO READ AND PRINT POLARLOW.ASC (FILE 22)  *
C***********************************************************
      INTEGER PLOW, PLOWID, NREC
      REAL AREA, PERIMETER, COMMA,SPIRAL,POLARLOW
C***********************************************************
C*  INITIALIZE A COUNTER OF THE NUMBER OF RECORDS READ     *
C***********************************************************
      NREC=0
C***********************************************************
C*  READ THE FLAT ASCII FILE INFORMATION                   *
C***********************************************************
   10 READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,PLOW,
     1   PLOWID,COMMA,SPIRAL,POLARLOW
  100 FORMAT(2F13.3,2I6,3F9.2)
C***********************************************************
C*  START A NEW PAGE AND WRITE A DESCRIPTIVE HEADER        *
C***********************************************************
      IF (NREC.EQ.77) NREC=0
      IF (NREC.EQ.0) WRITE(6,101)
  101 FORMAT('1','AREA',9X,'PERIMETER',4X,'#',5X,'ID',4X,
     1   'COMMA',4X,'SPIRAL',3X,'POLARLOW',1X)
      NREC=NREC+1
C***********************************************************
C*  WRITE THE FLAT ASCII FILE TO THE OUTPUT DIVICE         *
C***********************************************************
      WRITE(6,102) AREA,PERIMETER,PLOW,PLOWID,
     1   COMMA,SPIRAL,POLARLOW
  102 FORMAT(1X,2F13.3,2I6,3F9.2)
C
      GO TO 10
  999 STOP
      END
//GO.FT05F001 DD UNIT=TAPE62,VOL=SER=TAPEVOL1,
//DISP=(,PASS),DSN=TAB.NDP035.POLARLOW.DATA,LABLE=(22,SL)
//GO.FT06F001 DD *
```

The sixth FORTRAN IV program (File 23 on the magnetic tape) is designed to read and print the file **LOWPC.ASC** (File 26).

```
//UIDDAT JOB (12345,TAPE,IO20),'USER ADDRESS',TIME=(1,30)
//EXEC FORTQCLG
//FORT.SYSIN DD *
C***********************************************************
C*  FORTRAN PROGAM TO READ AND PRINT LOWPC.ASC (FILE 26)    *
C***********************************************************
       INTEGER LOWPC,LOWPCID,ZONE,NREC
       REAL AREA,PERIMETER,LOWNJA,LOWNJL,LOWNAN,LOWSJA,
     1  LOWSJL,LOWSAN,LOWS2JA,LOWS2JL,LOWS2AN,LOWAJA,
     2  LOWAJL,LOWAAN,LOWA2JA,LOWA2JL,LOWA2AN,CYCJA,
     2  CYCJL,CYCLONE
C***********************************************************
C*  INITIALIZE A COUNTER OF THE NUMBER OF RECORDS READ      *
C***********************************************************
       NREC=0
C***********************************************************
C*  READ THE FLAT ASCII FILE INFORMATION                    *
C***********************************************************
  10   READ(UNIT=5,FMT=100)
AREA,PERIMETER,LOWPC,LOWPCID,ZONE,
     1  LOWNJA,LOWNJL,LOWNAN,LOWSJA,LOWSJL,LOWSAN,LOWS2JA
       READ(UNIT=5,FMT=101,END=999) LOWS2JL,LOWS2AN,LOWAJA,
     1  LOWAJL,LOWAAN,LOWA2JA,LOWA2JL,LOWA2AN,CYCJA,CYCJL,
     2  CYCLONE
 100   FORMAT(F12.3,F13.3,3I6,7F8.2)
 101   FORMAT(11F8.2)
C***********************************************************
C*  START A NEW PAGE AND WRITE A DESCRIPTIVE HEADER         *
C***********************************************************
       IF (NREC.EQ.36) NREC=0
       IF (NREC.EQ.0) WRITE(6,102)
       IF (NREC.EQ.0) WRITE(6,103)
 102   FORMAT('1','AREA',9X,'PERIMETER',3X,'#',5X,'ID',4X,
     1  'ZONE',4X,'LOWNJA',2X,'LOWNJL',2X,'LOWNAN',2X,
     2  'LOWSJA',2X,'LOWSJL',2X,'LOWSAN',2X,'LOWS2JA',1X)
 103   FORMAT(' ','LOWS2JL',1X,'LOWS2AN',1X,'LOWAJA',2X,
     1  'LOWAJL',2X,'LOWAAN',2X,'LOWA2JA',1X,'LOWA2JL',1X,
     2  'LOWA2AN',1X,'CYCJA',3X,'CYCJL',3X,'CYCLONE',1X)
        NREC=NREC+2
C***********************************************************
C*  WRITE THE FLAT ASCII FILE TO THE OUTPUT DIVICE          *
C***********************************************************
       WRITE(6,104)
AREA,PERIMETER,LOWPC,LOWPCID,ZONE,LOWNJA,
     1  LOWNJL,LOWNAN,LOWSJA,LOWSJL,LOWSAN,LOWS2JA
       WRITE(6,105) LOWS2JL,LOWS2AN,LOWAJA,LOWAJL,LOWAAN,
     1  LOWA2JA,LOWA2JL,LOWA2AN,CYCJA,CYCJL,CYCLONE
 104   FORMAT(1X,2F12.3,3I6,7F8.2)
 105   FORMAT(1X,11F8.2)
```

```
C

      GO TO 10
 999  STOP
      END
//GO.FT05F001 DD UNIT=TAPE62,VOL=SER=TAPEVOL1,
//DISP=(,PASS),DSN=TAB.NDP035.LOWPC.DATA,LABLE=(26,SL)
//GO.FT06F001 DD
```

The seventh FORTRAN IV program (File 27 on the magnetic tape) is designed to read and print the file **MONSOON.ASC** (File 30).

```
//UIDDAT JOB (12345,TAPE,I020),'USER ADDRESS',TIME=(1,30)
//EXEC FORTQCLG
//FORT.SYSIN DD *
C************************************************************
C* FORTRAN PROGAM TO READ AND PRINT MONSOON.ASC (FILE 30)   *
C************************************************************
       INTEGER MON, MONID, NREC
       REAL AREA, PERIMETER, MONSOON
C************************************************************
C*  INITIALIZE A COUNTER OF THE NUMBER OF RECORDS READ      *
C************************************************************
       NREC=0
C************************************************************
C*  READ THE FLAT ASCII FILE INFORMATION                    *
C************************************************************
  10   READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,MON,
     1    MONID,MONSOON
 100   FORMAT(2F13.3,2I6,F5.0)
C************************************************************
C*  START A NEW PAGE AND WRITE A DESCRIPTIVE HEADER         *
C************************************************************
       IF (NREC.EQ.77) NREC=0
       IF (NREC.EQ.0) WRITE(6,101)
 101   FORMAT('1','AREA',9X,'PERIMETER',4X,'#',5X,'ID',4X,
     1  'MONSOON')
       NREC=NREC+1
C************************************************************
C*  WRITE THE FLAT ASCII FILE TO THE OUTPUT DIVICE          *
C************************************************************
       WRITE(6,102) AREA,PERIMETER,MON,MONID,MONSOON
 102   FORMAT(1X,2F13.3,2I6,F5.0)
C
       GO TO 10
 999   STOP
       END
//GO.FT05F001 DD UNIT=TAPE62,VOL=SER=TAPEVOL1,
//DISP=(,PASS),DSN=TAB.NDP035.MONSOON.DATA,LABLE=(30,SL)
//GO.FT06F001 DD *
```

The last FORTRAN IV program (File 31 on the magnetic tape) is designed to read and print the file **SEAICE.ASC** (File 34).

```
//UIDDAT JOB (12345,TAPE,IO20),'USER ADDRESS',TIME=(1,30)
//EXEC FORTQCLG
//FORT.SYSIN DD *
C***********************************************************
C* FORTRAN PROGAM TO READ AND PRINT SEAICE.ASC (FILE 34)    *
C***********************************************************
       INTEGER SEA, SEAID, NREC
       REAL AREA, PERIMETER, ICE
C***********************************************************
C*  INITIALIZE A COUNTER OF THE NUMBER OF RECORDS READ      *
C***********************************************************
       NREC=0
C***********************************************************
C*  READ THE FLAT ASCII FILE INFORMATION                    *
C***********************************************************
  10   READ(UNIT=5,FMT=100,END=999) AREA,PERIMETER,SEA,
     1    SEAID,ICE
 100   FORMAT(2F13.3,2I6,F5.1)
C***********************************************************
C*  START A NEW PAGE AND WRITE A DESCRIPTIVE HEADER         *
C***********************************************************
       IF (NREC.EQ.77) NREC=0
       IF (NREC.EQ.0) WRITE(6,101)
 101   FORMAT('1','AREA',9X,'PERIMETER',4X,'#',5X,'ID',4X,
     1   'SEAICE')
       NREC=NREC+1
C***********************************************************
C*  WRITE THE FLAT ASCII FILE TO THE OUTPUT DIVICE          *
C***********************************************************
       WRITE(6,102) AREA,PERIMETER,SEA,SEAID,ICE
 102   FORMAT(1X,2F13.3,2I6,F5.1)
C
       GO TO 10
 999   STOP
       END
//GO.FT05F001 DD UNIT=TAPE62,VOL=SER=TAPEVOL1,
//DISP=(,PASS),DSN=TAB.NDP035.SEAICE.DATA,LABLE=(34,SL)
//GO.FT06F001 DD *
```

22. LISTING OF THE SAS™ DATA RETRIEVAL PROGRAMS

The following is a listing of the SAS data retrieval programs provided on the magnetic tape by CDIAC. Each program is designed to read and write the contents of one of the flat ASCII data files. The lines preceded with "//" are machine-dependent job control language (JCL) statements that will vary based on the local operating environment. These JCL lines are not included in the SAS files provided with this NDP and are included here for example purposes only.

The first SAS™ program (File 3 on the magnetic tape) is designed to read and print the file **TC10.ASC** (File 5).

```
//UIDQAS JOB (1234,TAPE,IO20),'USER ADDRESS',TIME=(1,00),
//STEP1 EXEC SAS,SASRGN= K,WORK=
//IN DD UNIT=TAPE62,VOL=SER=TAPEVOL1,DISP=(,PASS),
// DSN=TAB.NDP035.TC10.ASC,LABEL=(5,SL)
//FT06F001 DD SYSOUT=A
// SYSIN DD *
data tc10;
infile in;
input area 1-13 perim 14-26 tc1 27-32 tc2 33-38 ts 39-47
    ty 48-56;
proc print;
run;
```

The second SAS™ program (File 7 on the magnetic tape) is designed to read and print the file **TC50.ASC** (File 9).

```
//UIDQAS JOB (1234,TAPE,IO20),'USER ADDRESS',TIME=(2,00),
//STEP1 EXEC SAS,SASRGN= K,WORK=
//IN DD UNIT=TAPE62,VOL=SER=TAPEVOL1,DISP=(,PASS),
// DSN=TAB.NDP035.TC50.ASC,LABEL=(9,SL)
//FT06F001 DD SYSOUT=A
// SYSIN DD *
data tc50;
infile in;
input area 1-13 perim 14-26 tc1 27-32 tc2 33-38 ts 39-47 ty 48-56 sty 57-65 tcv 66-74;
proc print;
run;
```

The third SAS™ program (File 11 on the magnetic tape) is designed to read and print the file **HCSTATE.ASC** (File 13).

```
//UIDQAS JOB (1234,TAPE,IO20),'USER ADDRESS',TIME=(3,00),
//STEP1 EXEC SAS,SASRGN= K,WORK=
//IN DD UNIT=TAPE62,VOL=SER=TAPEVOL1,DISP=(,PASS),
// DSN=TAB.NDP035.HCSTATE.ASC,LABEL=(13,SL)
//FT06F001 DD SYSOUT=A
// SYSIN DD *
data hcstate;
infile in;
input area 1-10 perim 11-23 hc1 24-29 hc2 30-38
    c1 39-48 c2 49-53 c3 54-58 c4 59-63 c5 64-68;
proc print;
run;
```

The fourth SAS™ program (File 16 on the magnetic tape) is designed to read and print the file **XCNORTH.ASC** (File 18).

```
//UIDQAS JOB (1234,TAPE,IO20),'USER ADDRESS',TIME=(4,00),
//STEP1 EXEC SAS,SASRGN= K,WORK=
//IN DD UNIT=TAPE62,VOL=SER=TAPEVOL1,DISP=(,PASS),
// DSN=TAB.NDP035.XCNORTH.ASC,LABEL=(18,SL)
//FT06F001 DD SYSOUT=A
// SYSIN DD *
data xcnorth;
infile in;
input area 1-12 perim 13-24 XCNORTH1 25-29 XCNORTH2 30-34
    CGJA 35-42 CFJA 43-50 CGFE 51-58 CFFE 59-66 CGMR 67-74
    CFMR 75-82 CGAP 83-90 CFAP 91-98 CGMY 99-106 CFMY 107-114
    CGJN 115-122;
input CFJN 1-8 CGJL 9-16 CFJL 17-24 CGAG 25-32 CFAG 33-40
    CGSP 41-48 CFSP 49-56 CGOB 57-64 CFOB 65-72 CGNV 73-80
    CFNV 81-88 CGDC 89-96 CFDC 97-104 CGAN 105-112 CFAN 113-120;
proc print;
run;
```

The fifth SAS™ program (File 20 on the magnetic tape) is designed to read and print the file **POLARLOW.ASC** (File 22).

```
//UIDQAS JOB (1234,TAPE,IO20),'USER ADDRESS',TIME=(5,00),
//STEP1 EXEC SAS,SASRGN= K,WORK=
//IN DD UNIT=TAPE62,VOL=SER=TAPEVOL1,DISP=(,PASS),
// DSN=TAB.NDP035.POLARLOW.ASC,LABEL=(22,SL)
//FT06F001 DD SYSOUT=A
// SYSIN DD *
data polarlow;
infile in;
```

```
input area 1-13 perim 14-26 pl1 27-32 pl2 33-38 comma 39-47
     spiral 48-56 polarlow 57-65;
proc print;
run;
```

The sixth SAS™ program (File 24 on the magnetic tape) is designed to read and print the file **LOWPC.ASC** (File 26).

```
//UIDQAS JOB (1234,TAPE,IO20),'USER ADDRESS',TIME=(5,00),
//STEP1 EXEC SAS,SASRGN= K,WORK=
//IN DD UNIT=TAPE62,VOL=SER=TAPEVOL1,DISP=(,PASS),
// DSN=TAB.NDP035.LOWPC.ASC,LABEL=(26,SL)
//FT06F001 DD SYSOUT=A
// SYSIN DD *
data lowpc;
infile in;
input AREA 1-12 PERIM 13-25 LOWPC1 26-31 LOWPC2 32-37
     ZONE 38-43 LOWNJA 44-52 LOWNJL 53-61 LOWNAN 62-70
     LOWSJA 71-79 LOWSJL 80-88 LOWSAN 89-97 LOWS2JA 98-106;
input LOWS2JL 1-8 LOWS2AN 9-17 LOWAJA 18-26 LOWAJL 27-35
     LOWAAN 36-44 LOWA2JA 45-53 LOWA2JL 54-62 LOWA2AN 63-71
     CYCJA 72-81 CYCJL 82-89 CYCLONE 90-98;
proc print;
run;
```

The seventh SAS™ program (File 28 on the magnetic tape) is designed to read and print the file **MONSOON.ASC** (File 30).

```
//UIDQAS JOB (1234,TAPE,IO20),'USER ADDRESS',TIME=(6,00),
//STEP1 EXEC SAS,SASRGN= K,WORK=
//IN DD UNIT=TAPE62,VOL=SER=TAPEVOL1,DISP=(,PASS),
// DSN=TAB.NDP035.MONSOON.ASC,LABEL=(28,SL)
//FT06F001 DD SYSOUT=A
// SYSIN DD *
data monsoon;
infile in;
input area 1-13 perim 14-26 mon1 27-32 mon2 33-38 monsoon 39-43;
proc print;
run;
```

The last SAS™ program (File 32 on the magnetic tape) is designed to read and print the file **SEAICE.ASC** (File 34).

```
//UIDQAS JOB (1234,TAPE,IO20),'USER ADDRESS',TIME=(7,00),
//STEP1 EXEC SAS,SASRGN= K,WORK=
//IN DD UNIT=TAPE62,VOL=SER=TAPEVOL1,DISP=(,PASS),
// DSN=TAB.NDP035.SEAICE.ASC,LABEL=(34,SL)
//FT06F001 DD SYSOUT=A
// SYSIN DD *
data seaice;
infile in;
input area 1-13 perim 14-26 si1 27-32 si2 33-38 seaice 39-43;
proc print;
run;
```

23. PARTIAL LISTINGS OF FLAT ASCII DATA FILES

What follows is a sample listing of the first 15 lines in each of the flat ASCII data files.

Sample listing of TC10.ASC (File 5).

Area	Perimeter	#	ID	TS	TY
-64800.000	1080.000	1	0	999.00	999.00
1.000	4.000	2	1	999.00	999.00
1.000	4.000	3	2	999.00	999.00
1.000	4.000	4	3	999.00	999.00
1.000	4.000	5	4	999.00	999.00
1.000	4.000	6	5	999.00	999.00
1.000	4.000	7	6	999.00	999.00
1.000	4.000	8	7	999.00	999.00
1.000	4.000	9	8	999.00	999.00
1.000	4.000	10	9	999.00	999.00
1.000	4.000	11	10	999.00	999.00
1.000	4.000	12	11	999.00	999.00
1.000	4.000	13	12	999.00	999.00
1.000	4.000	14	13	999.00	999.00
1.000	4.000	15	14	999.00	999.00

Sample listing of TC50.ASC (File 9).

Area	Perimeter	#	ID	TS	TY	STY	TCV
-64800.000	1080.000	1	0	999.00	999.00	999.00	999.00
25.000	20.000	2	1	999.00	999.00	999.00	999.00
25.000	20.000	3	2	999.00	999.00	999.00	999.00
25.000	20.000	4	3	999.00	999.00	999.00	999.00
25.000	20.000	5	4	999.00	999.00	999.00	999.00
25.000	20.000	6	5	999.00	999.00	999.00	999.00
25.000	20.000	7	6	999.00	999.00	999.00	999.00
25.000	20.000	8	7	999.00	999.00	999.00	999.00
25.000	20.000	9	8	999.00	999.00	999.00	999.00
25.000	20.000	10	9	999.00	999.00	999.00	999.00
25.000	20.000	11	10	999.00	999.00	999.00	999.00
25.000	20.000	12	11	999.00	999.00	999.00	999.00
25.000	20.000	13	12	999.00	999.00	999.00	999.00
25.000	20.000	14	13	999.00	999.00	999.00	999.00
25.000	20.000	15	14	999.00	999.00	999.00	999.00

Sample listing of HCSTATE.ASC (File 13).

Area	Perimeter	#	ID	CAT1	CAT2	CAT3	CAT4	CAT5
-207.027	200.650	1	0	0	0	0	0	0
9.441	16.108	2	1	5	0	0	0	0
2.670	7.298	3	2	1	1	0	0	0
13.535	19.142	4	3	3	0	5	0	0
2.314	10.027	5	4	2	1	2	0	0
12.592	15.826	6	5	0	0	0	0	0
1.380	5.277	7	6	2	2	3	0	0
0.198	2.261	8	7	0	1	3	0	0
2.004	6.782	9	8	1	0	0	0	0
0.367	4.780	10	9	3	0	5	0	0
0.458	3.721	11	10	0	0	0	0	0
2.687	17.509	12	11	0	1	0	0	0
10.263	22.393	13	12	1	1	1	0	0
10.139	2.372	14	13	1	1	1	0	0
12.484	26.445	15	14	12	4	8	1	0

Sample listing of XCNORTH.ASC (File 18).

Area	Perimeter	#	ID	CGJA	CFJA	CGFE	CFFE	CGMR	CFMR	CGAP	CFAP	CGMY	CFMY	CGJN
CFJN	CGJL	CFJL	CGAG	CFAG	CGSP	CFSP	CGOB	CFOB	CGNV	CFNV	CGDC	CFDC	CGAN	CFAN
-64800.000	1080.000	1	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25.000	20.000	2	1	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
25.000	20.000	3	2	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
25.000	20.000	4	3	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
25.000	20.000	5	4	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
25.000	20.000	6	5	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
25.000	20.000	7	6	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00
25.000	20.000	8	7	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00

Sample listing of POLARLOW.ASC (File 22).

Area	Perimeter	#	ID	COMMA	SPIRAL	POLARLOW
-64800.000	1080.000	1	0	999.00	999.00	999.00
25.000	20.000	2	1	999.00	999.00	999.00
25.000	20.000	3	2	999.00	999.00	999.00
25.000	20.000	4	3	999.00	999.00	999.00
25.000	20.000	5	4	999.00	999.00	999.00
25.000	20.000	6	5	999.00	999.00	999.00
25.000	20.000	7	6	999.00	999.00	999.00
25.000	20.000	8	7	999.00	999.00	999.00
25.000	20.000	9	8	999.00	999.00	999.00
25.000	20.000	10	9	999.00	999.00	999.00
25.000	20.000	11	10	999.00	999.00	999.00
25.000	20.000	12	11	999.00	999.00	999.00
25.000	20.000	13	12	999.00	999.00	999.00
25.000	20.000	14	13	999.00	999.00	999.00
25.000	20.000	15	14	999.00	999.00	999.00

Sample listing of LOWPC.ASC (File 26).

Area	Perimeter	#	ID	ZONE	LOWNJA	LOWNJL	LOWNAN	LOWSJA	LOWSJ	LLOWSAN	LOWS2JA
LOWS2JL	LOWS2AN	LOWAJA	LOWAJL	LOWAAN	LOWA2JA	LOWA2JL	LOWA2AN	CYCJA	CYCJL	CYCLONE	
-64800.000	1080.000	1	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
25.000	20.000	2	1	2	0.00	0.03	0.15	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	-0.86	-0.76	-0.91	
25.000	20.000	3	2	2	0.00	0.03	0.15	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	-0.86	-0.76	-0.91	
25.000	20.000	4	3	2	0.00	0.03	0.15	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	-0.86	-0.76	-0.91	
25.000	20.000	5	4	2	0.00	0.03	0.15	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	-0.86	-0.76	-0.91	
25.000	20.000	6	5	2	0.00	0.03	0.15	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	-0.86	-0.76	-0.91	
25.000	20.000	7	6	2	0.00	0.03	0.15	999.00	999.00	999.00	999.00
999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	-0.86	-0.76	-0.91	
25.000	20.000	8	7	2	0.00	0.03	0.15	999.00	999.00	999.00	999.00

Sample listing of MONSOON.ASC (File 30).

Area	Perimeter	#	ID	MONSOON
-64800.000	1080.000	1	0	999
1.000	4.000	2	1	999
1.000	4.000	3	2	999
1.000	4.000	4	3	999
1.000	4.000	5	4	999
1.000	4.000	6	5	999
1.000	4.000	7	6	999
1.000	4.000	8	7	999
1.000	4.000	9	8	999
1.000	4.000	9	8	999
1.000	4.000	10	9	999
1.000	4.000	12	11	999
1.000	4.000	13	12	999
1.000	4.000	14	13	999
1.000	4.000	15	14	999

Sample listing of SEAICE.ASC (File 34).

Area	Perimeter	#	ID	SEAICE
-64800.000	1080.000	1	0	99.0
1.000	4.000	2	1	99.0
1.000	4.000	3	2	99.0
1.000	4.000	4	3	99.0
1.000	4.000	5	4	99.0
1.000	4.000	6	5	99.0
1.000	4.000	7	6	99.0
1.000	4.000	8	7	99.0
1.000	4.000	9	8	99.0
1.000	4.000	10	9	99.0
1.000	4.000	11	10	99.0
1.000	4.000	12	11	99.0
1.000	4.000	13	12	99.0
1.000	4.000	14	13	99.0
1.000	4.000	15	14	99.0

24. VERIFICATION OF DATA TRANSPORT: FLAT ASCII DATA FILES

The storm probabilities of occurrence, frequencies, and other climatic variables may be read using the FORTRAN or SAS™ input/output routines provided. Users should verify that the files have been correctly transported to their systems; to do so they should generate some or all of the statistics presented in Tables 18 through 25. These statistics were generated in SAS™ (PROC MEANS) but may be duplicated in other statistical packages or languages. If the statistics generated by the user differ from those presented here, the files may have been corrupted in transport.

These statistics are presented only as a tool to ensure proper reading of the eight flat ASCII files in this NDP. They are not to be construed as either a summary of the meteorological data or an indicator of trends in the data.

Table 18. Statistical characteristics of the variables in TC10.ASC (File 5)

Variable	Number of observations	Minimum value	Maximum value	Mean value
AREA	64801	-64800.00	1.00	0.0000000
PERIMETER	64801	4.00	1080.00	4.0166047
TC10#	64801	1.00	64801.00	32401.0000000
TC10-ID	64801	0.00	64800.00	32400.0000000
TS	64801	1.10	999.00	989.1704912
TY	64801	1.10	999.00	989.4969044

Table 19. Statistical characteristics of the variables in TC50.ASC (File 9)

Variable	Number of observations	Minimum value	Maximum value	Mean value
AREA	2593	-64800.00	25.00	0.0000000
PERIMETER	2593	20.00	1080.00	20.4087929
TC50#	2593	1.00	2593.00	1297.0000000
TC50-ID	2593	0.00	2592.00	1296.0000000
TS	2593	1.10	999.00	732.8507135
TY	2593	1.10	999.00	777.6351716
STY	2593	1.10	999.00	720.5753027
TCV	2593	1.10	999.00	959.3220594

Table 20. Statistical characteristics of the variables in HCSTATE.ASC (File 13)

Variable	Number of observations	Minimum value	Maximum value	Mean value
AREA	43	-207.0270	48.3510	0.000046512
PERIMETER	43	0.2320	200.6500	13.277604700
HCSTATE#	43	1.0000	43.0000	22.000000000
HCSTATE-ID	43	0.0000	42.0000	21.000000000
CAT1	43	0.0000	12.0000	3.976744200
CAT2	43	0.0000	10.0000	3.465116300
CAT3	43	0.0000	8.0000	3.302325600
CAT4	43	0.0000	4.0000	0.860465100
CAT5	43	0.0000	1.0000	0.139534900

Table 21. Statistical characteristics of the variables in XCNORTH.ASC (File 18)

Variable	Number of observations	Minimum value	Maximum value	Mean value
AREA	2593	-64800.00	25.00	0.0000000
PERIM	2593	20.00	1080.00	20.4087929
XCNORTH#	2593	1.00	2593.00	1297.0000000
XCNORTH-ID	2593	0.00	2592.00	1296.0000000
CGJA	2593	0.00	999.00	625.7233513
CFJA	2593	0.00	999.00	626.1306980
CGFE	2593	0.00	999.00	625.7197262
CFFE	2593	0.00	999.00	626.0971654
CGMR	2593	0.00	999.00	625.7229271
CFMR	2593	0.00	999.00	626.1579252
CGAP	2593	0.00	999.00	625.7219244
CFAP	2593	0.00	999.00	626.1297146
CGMY	2593	0.00	999.00	625.7223293
CFMY	2593	0.00	999.00	626.1070767
CGJN	2593	0.00	999.00	625.7203625
CFJN	2593	0.00	999.00	626.0856344
CGJL	2593	0.00	999.00	625.7216545
CFJL	2593	0.00	999.00	626.0462399
CGAG	2593	0.00	999.00	625.7222522
CFAG	2593	0.00	999.00	626.0735827
CGSP	2593	0.00	999.00	625.7151755

Table 21 (continued)

Variable	Number of observations	Minimum value	Maximum value	Mean value
CFSP	2593	0.00	999.00	626.0796182
CGOB	2593	0.00	999.00	625.7192056
CFOB	2593	0.00	999.00	626.1383918
CGNV	2593	0.00	999.00	625.7185692
CFNV	2593	0.00	999.00	626.1204589
CGDC	2593	0.00	999.00	625.7214038
CFDC	2593	0.00	999.00	626.1442345
CGAN	2593	0.00	999.00	626.2208060
CFAN	2593	0.00	999.00	630.8826649

Table 22. Statistical characteristics of the variables in POLARLOW.ASC (File 22)

Variable	Number of observations	Minimum value	Maximum value	Mean value
AREA	2593	-64800.00	25.00	0.0000000
PERIMETER	2593	20.00	1080.00	20.4087929
POLARLOW#	2593	1.00	2593.00	1297.0000000
POLARLOW-ID	2593	0.00	2592.00	1296.0000000
COMMA	2593	0.00	999.00	399.5958581
SPIRAL	2593	0.00	999.00	399.5279175
POLARLOW	2593	0.00	999.00	399.6008562

Table 23. Statistical characteristics of the variables in LOWPC.ASC (File 26)

Variable	Number of observations	Minimum value	Maximum value	Mean value
AREA	2593	-64800.00	25.00	0.0000000
PERIM	2593	20.00	1080.00	20.4087929
LOWPC#	2593	1.00	2593.00	1297.0000000
LOWPC-ID	2593	0.00	2592.00	1296.0000000
ZONE	2593	0.00	2.00	1.6926340
LOWNJA	2593	0.00	999.00	499.4887351
LOWNJL	2593	0.00	999.00	499.5073506
LOWNAN	2593	0.00	999.00	501.6696838
LOWSJA	2593	0.00	999.00	562.0898226
LOWSJL	2593	0.00	999.00	562.1662862
LOWSAN	2593	0.00	999.00	566.6079059
LOWS2JA	2593	0.00	999.00	565.0969225
LOWS2JL	2593	0.00	999.00	565.4419707
LOWS2AN	2593	0.00	999.00	604.3043386
LOWAJA	2593	0.00	999.00	934.7470883
LOWAJL	2593	0.00	999.00	931.2748592
LOWAAN	2593	0.00	999.00	935.1987003
LOWA2JA	2593	0.00	999.00	934.9793675
LOWA2JL	2593	0.00	999.00	933.3068222
LOWA2AN	2593	0.00	999.00	942.2219244
CYCJA	2593	-0.96	5.49	0.0013536
CYCJL	2593	-0.91	12.10	-0.0026687
CYCLONE	2593	-1.24	4.49	-0.0000771

Table 24. Statistical characteristics of the variables in MONSOON.ASC (File 30)

Variable	Number of observations	Minimum value	Maximum value	Mean value
AREA	64801	-64800.00	1.00	0.000000
PERIMETER	64801	4.00	1080.00	4.016605
MONSOON#	64801	1.00	64801.00	32401.000000
MONSOON-ID	64801	0.00	64800.00	32400.000000
MONSOON	64801	0.00	999.00	975.591426

Table 25. Statistical characteristics of the variables in SEAICE.ASC (File 34)

Variable	Number of observations	Minimum value	Maximum value	Mean value
AREA	64801	-64800.00	1.00	0.000000
PERIMETER	64801	4.00	1080.00	4.016605
SEAICE#	64801	1.00	64801.00	32401.000000
SEAICE-ID	64801	0.00	64800.00	32400.000000
ICE	64801	0.00	99.00	98.638683

25. VERIFICATION OF DATA TRANSPORT: ARC/INFO™ EXPORT FILES

The ARC/INFO™ export files were created in ARC/INFO™, version 5.0, using the EXPORT command with the COVER and the NONE options. Each export file created contains an entire coverage and its associated data files. The export files contain all coverage information and appropriate INFO file information in a fixed length, uncompressed format.

The exported coverages are in a GEOGRAPHIC projection, which is not a true projection. The GEOGRAPHIC projection in reality is a spherical reference grid using latitude and longitude coordinates that are stored in decimal degrees (DD). As a result, the reference grids in this NDP are not equal area or equal distance in nature.

After loading the ARC/INFO export files onto a system, the user should verify that the export files have been correctly transported. To verify this, the size of the export file and, after the data are imported into ARC/INFO™, the total number of INFO data records in each coverage should be compared with those presented in Table 26. If the file sizes differ from those presented here by more than 1 byte or the number of INFO data records do not match, then the coverage may have been corrupted in transport. Importation of the ARC/INFO E00 files into the user's ARC/INFO system can be accomplished using the IMPORT command with the COVER option. The IMPORT command will automatically recognize whether the export file is compressed or not.

Table 26. File size, in bytes and 512 byte blocks, and the number of INFO data records in each ARC/INFO™ export file described in this NDP

File Name	File number	Size (bytes)	Size (blocks)	Number of INFO data records
TC10.E00	4	991,498	1,937	1,186
TC50.E00	8	2,026,833	3,959	2,593
HCSTATE.E00	12	66,757	131	43
XCNORTH.E00	17	3,404,939	6,651	2,593
POLARLOW.E00	21	1,935,729	3,781	2,593
LOWPC.E00	25	2,952,623	5,767	2,593
MONSOON.E00	29	1,202,959	2,350	1,210
SEAICE.E00	33	296,961	581	300

APPENDIXES

APPENDIX A

TECHNIQUES USED TO COMPILE DATA GROUPS AND VARIABLES

APPENDIX A

TECHNIQUES USED TO COMPILE DATA GROUPS AND VARIABLES

Specific procedures used in the derivation of data variables are discussed in the pages that follow. Because of the large number of data sources used, methods employed to obtain the 61 data variables in this NDP vary widely. As a result, the eight data groups are discussed separately and by data variable or data source when necessary. Figure A-1 lists the eight data groups and the data variables associated with each. For the remainder of this appendix, the data groups are identified using the names assigned them in Fig. A-1 and Table A-1.

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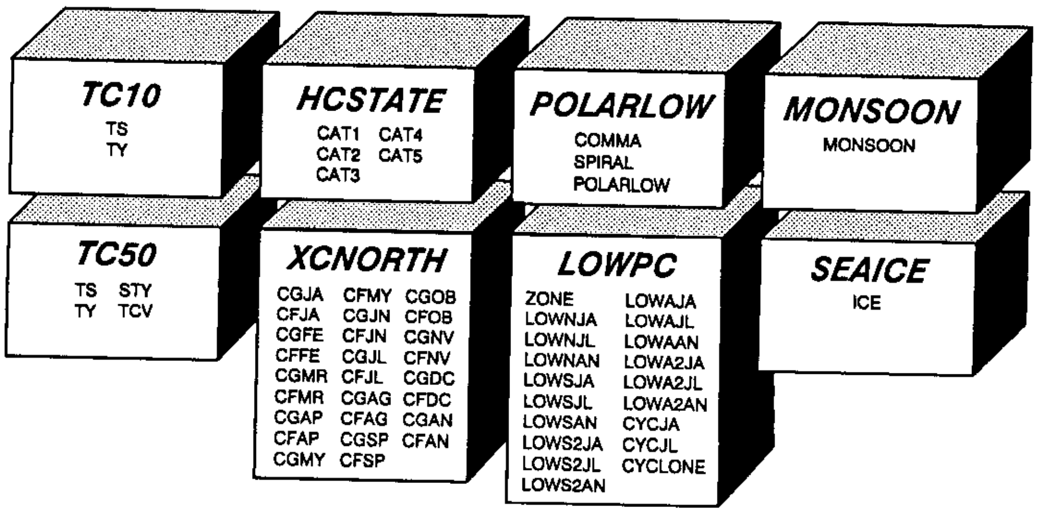

Fig. A-1. NDP-035 data group names and associated data variable names.

Table A-1. Data groups of NDP-035; each data group is described by its name and contents

Name	Description of Contents
TC10	Annual probabilities of occurrence of tropical storms and hurricanes for coastal areas of the United States, Canada, and Bermuda by 1° x 1° grid cells.
TC50	(a) Annual probabilities of occurrence of tropical storms, hurricanes, and super typhoons (winds 67 m/s or greater) for the world by 5° x 5° grid cells. (b) Mean forward velocities of tropical cyclones (without regard to tropical cyclone intensity) for the world by 5° x 5° grid cells.
HCSTATE	The number of hurricane strikes for the U.S. Atlantic and Gulf Coasts by state and Saffir-Simpson hurricane category.
XCNORTH	(a) Mean monthly and annual number of extratropical cyclogeneses for the Northern Hemisphere by 5° x 5° grid cells. (b) Mean monthly and annual number of extratropical cyclone occurrences for the Northern Hemisphere by 5° x 5° grid cells.
POLARLOW	Mean number of polar lows (polar air cloud vortices) per winter month for the North Pacific Ocean and Southern Hemisphere by 5° x 5° grid cells.
LOWPC	(a) Mean and/or relative number of cyclones (without regard to cyclone type) for January, July, and the year for the world by 5° x 5° grid cells. (b) Mean number of hours of cyclone occurrence (without regard to cyclone type) for January, July, and the year for the Southern Hemisphere by 5° x 5° grid cells.
MONSOON	Derived index of the influence of winds on coastlines in the African, Asian, and Australian monsoon regions by 1° x 1° grid cells.
SEAICE	Mean annual sea-ice concentrations for Alaskan and U.S. Atlantic coastal areas by 1° x 1° grid cells.

DATA GROUP TC10

Data group TC10 contains two data variables: TS (tropical storm probabilities of occurrence) and TY (hurricane probabilities of occurrence).

Information About the Data Sources

Specific information concerning the characteristics and use of the data sources for data group TC10 follows. Data source documents are listed by number and title. For a fuller citation of each reference, see Part 1 as noted in brackets.

1. *Tropical Cyclones of the North Atlantic Ocean, 1871-1986* [Part 1, Sect. 7.4, No. (2)]. Annual tropical cyclone tracking charts provided the information for data variables TS and TY. Tropical storm and hurricane tracks from 1899 through 1989 were used.

2. *A Compilation of North Atlantic, Eastern North Pacific, Central North Pacific, and Western North Pacific Tropical Cyclone Data (TD-9697); and Consolidated Worldwide Tropical Cyclones (TD-9636)* [Part 1, Sect. 7.4, No. (3)]. These data sources were used for the period 1965 through 1986 in the Eastern North Pacific and Central North Pacific only. The starting year of 1965 was selected because of the storm track records prior to that year are incomplete. The data sources consist of numerical information on tropical cyclones. No tracking charts were provided. The numerical information provided the storm positions and intensities necessary to create tracking charts and conduct the analysis.

3. *Monthly Weather Review*, Vols. 116-118 [Part 1, Sect. 6.4, No. (4)]. These data sources provided tracking charts that were used for data variables TS and TY. The tracking charts indicate the location and intensity of each tropical cyclone throughout all stages of its life cycle. These volumes describe all tropical cyclone occurrences in the Eastern North Pacific Ocean from 1987 through 1989 east of 140°W.

4. Unpublished statistics of Central North Pacific tropical cyclones 1987-1989, provided by J. D. Elms (1990) [Part 1, Sect. 6.4, No. (8)]. This data source provided Central North Pacific (140°W to 180°W) tropical cyclone tracking charts for the period 1987-1989. The tracking charts indicate the location and intensity of each tropical cyclone throughout all stages of development.

The data sources for data group TC10 consist primarily of two types: (1) tropical cyclone tracking charts and, (2) numerical data on the characteristics, intensities, stages, etc. of tropical cyclones. The former type of data source was preferred over the latter because it is more detailed. In the absence of the former type of data source, the latter type of data source was used. Occasionally, a data source was used to check the validity of another when analyzing questionable data.

The Data Variables

Two different methods were used to derive the data variables in data group TC10. Both data variables (TS and TY) were derived using these methods. The particular method used varied by ocean basin and the data available. Because the difference between data variables TS and TY lies only in the intensity of the tropical cyclones classified, the manner in which each data variable was derived is the same within a given data derivation method.

All analyses of data for both data derivation methods were a result of manual and/or visual inspection of the data sources. No computer processing was used in the analysis of tropical cyclone tracking charts or numerical tropical cyclone data.

None of the data values in data group TC10 were corrected for latitudinal differences in the sizes of 1° x 1° grid cells.

Data variables TS and TY contain no zero data values. After the data values were derived, data that resulted in zero values were flagged and/or given an estimated data value. For estimated data values (200-299), the hundreds digit in the data variables should be dropped. Grid cells in the ASCII data file that are located outside the area of data analysis were given data values of 999.

Each of the different derivation methods used for data variables TS and TY is discussed below. The discussion refers to both data variables TS and TY unless noted otherwise.

Data Derivation Method 1: Tracking Charts

Annual tracking charts were used to determine whether a tropical cyclone center of the required intensity tracked through a given 1° x 1° grid cell in a given year. The total number of years of tropical cyclone activity for each 1° x 1° grid cell was then tabulated. Finally, these totals were divided by the number of years in the period of record and converted to percentages. For example, a grid cell containing a TS data value of 6.6% indicates that the grid cell had tropical storm centers cross its area during 6 different years out of a possible 91 years of record (6/91 X 100 = 6.6%). Figure A-2 shows an example of an annual tropical cyclone tracking chart in which 1° x 1° grid cells are identified as having data variable TS and/or data variable TY activity for that year.

A number of guidelines governing the conversion of the tropical cyclone tracking chart data to digital data values were developed and followed during the analysis of the tropical cyclone tracking charts.

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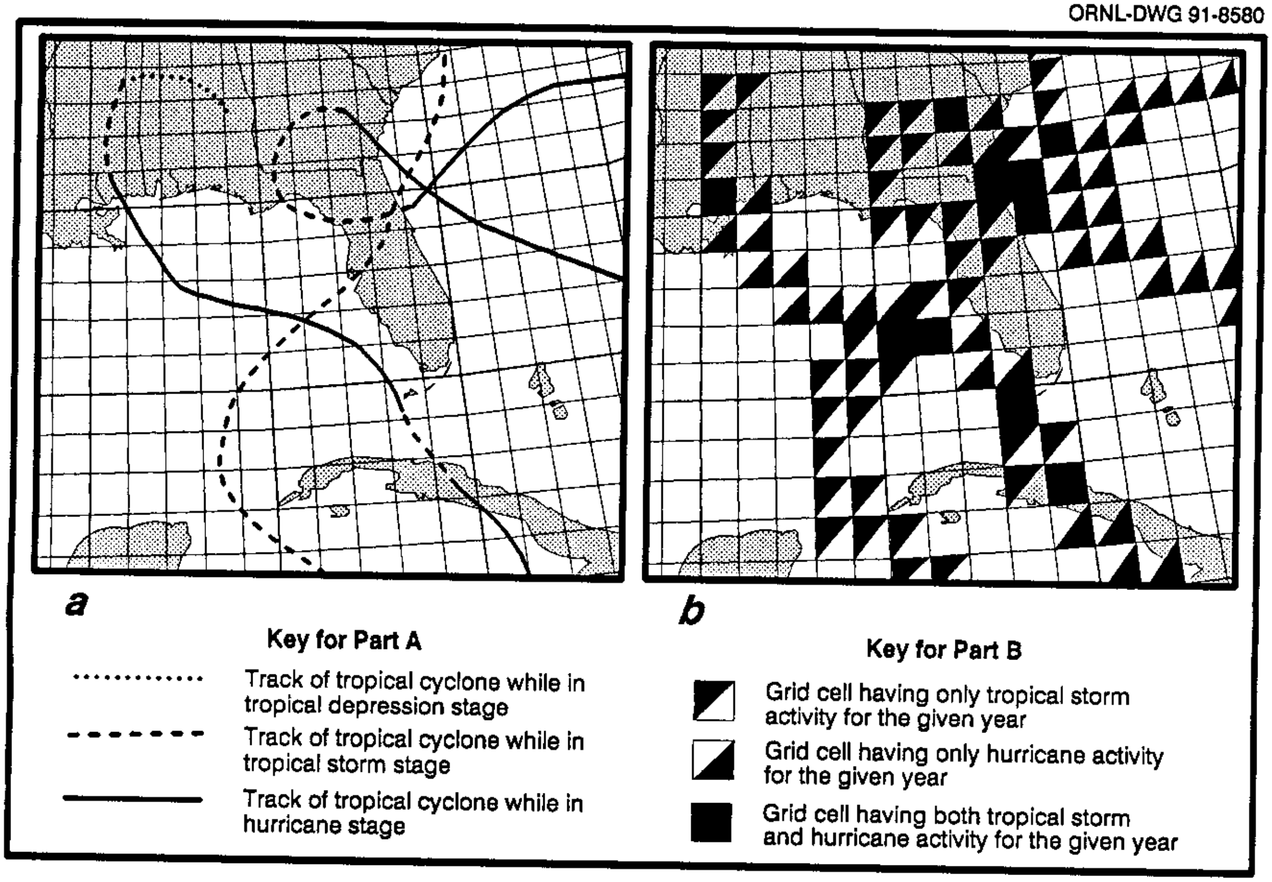

Fig. A-2. Tropical cyclone activity for a given year for 1° x 1° latitude-longitude grid cells as interpreted from an annual tropical cyclone tracking chart. (a) Theoretical annual tropical cyclone tracking chart; (b) tropical cyclone activity as interpreted from (a).

Data Guidelines

1. A grid cell was counted either as having tropical storm activity (data variable TS) or not having tropical storm activity for a given year. When the number of years having tropical storms is totaled, each year can count only once; multiple tropical storm occurrences in the same year do not increase the influence assigned to that year for the grid cell.

2. A grid cell was counted either as having hurricane activity (data variable TY) or not having hurricane activity for a given year. Where the number of years having hurricanes is totaled, each year can count only once; multiple hurricane occurrences in the same year do not increase the influence assigned to that year for the grid cell.

3. For a given year, a given grid cell was counted as having tropical storm activity (data variable TS) only if during that year at least one tropical cyclone center existed within or on the border of the given grid cell while in the tropical storm stage (i.e., having sustained winds of 17.5 m/s to 33 m/s).

4. For a given year, a given grid cell was counted as having hurricane activity (data variable TY) only if during that year at least one tropical cyclone center existed within or on the border of the given grid cell while in hurricane stage (i.e., having sustained winds of 33 m/s or greater).

5. Because of the mutual exclusiveness of data variables TS and TY, it is possible for a given grid cell in a given year to be counted as having tropical storm activity but not having hurricane activity and vice versa.

6. A tropical cyclone that changed from tropical storm to hurricane stage or vice versa while passing over a given grid cell resulted in the grid cell's being counted as having both tropical storm and hurricane activity.

7. For a given grid cell, the amount of time that a given tropical cyclone existed at a given tropical cyclone intensity (i.e., tropical storm or hurricane) did not influence the data computations (i.e., data is not time-dependent).

Data Derivation Method 2: Numerical Information

The differences between the two methods for determining the data variables TS and TY are slight. For Method 2, numerical data provided information on tropical cyclone positions (in terms of latitude and longitude) and intensities (at 6- or 12-h intervals). Therefore, it was necessary to construct and plot tropical cyclone tracks from the data. After this step was accomplished, analyses proceeded as in Method 1.

Data Guidelines

The data guidelines of Data Derivation Method 1 also apply in Data Derivation Method 2. Additional data guidelines used in Method 2 are listed in the following. These guidelines refer to the process used for reconstructing the tropical cyclone tracks.

8. In the construction of tropical cyclone tracks from numerical data, it was often necessary to estimate the location at which a given tropical cyclone changed from one intensity class to another (such as from tropical storm to hurricane). For example, if two consecutive positions of a given tropical cyclone were associated with maximum wind-speed information of differing intensity classes, then it was necessary to determine where the storm existed as one intensity class and where it existed as another intensity class between the two given positions. This was accomplished by determining the mean change in maximum wind speed per linear unit distance between the two storm positions in question. Assuming a constant change in storm intensity between the two storm positions, it was then possible to find a point between the two positions where the maximum wind speed of the given tropical cyclone was equal to a value defining a border between the two intensity classes in question. This point was then considered the location at which the given tropical cyclone changed intensity classes. This information was important for the use of the constructed tropical cyclone tracks in the same manner as in Method 1. Figure A-3

helps explain the locating of transitions between intensity classes. Note the distances in kilometers labeled between the locations of the second and third data records in Figure A-3. The tropical storm-hurricane transition is designated at a point halfway between the two data records. This results from maximum winds of 45 kt and 85 kt indicated by the data records (when using the standard tropical storm-hurricane boundary of 65 kt or 33 m/s maximum winds).

9. Between the latitude-longitude observations provided by the numerical tropical cyclone data, tropical cyclone tracks are assumed to be straight lines (as shown in Fig. A-3).

10. After analysis under this data derivation method was completed, all tropical cyclone definitions using knots were converted to m/s.

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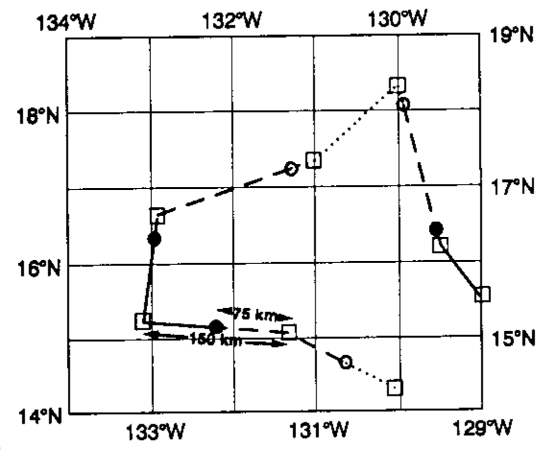
Numerical Tropical Cyclone Data Items

Date	Time	Lat.-Long.	Max. Winds
06/19/76	0600Z	14.3°N, 130.1°W	25 Kts
06/19/76	1200Z	15.1°N, 131.3°W	45 Kts
06/19/76	1800Z	15.2°N, 133.1°W	85 Kts
06/20/76	0000Z	16.7°N, 132.9°W	60 Kts
06/20/76	0600Z	17.3°N, 131.0°W	30 Kts
06/20/76	1200Z	18.3°N, 130.0°W	30 Kts
06/20/76	1800Z	16.2°N, 129.5°W	75 Kts
06/21/76	0000Z	15.6°N, 129.0°W	95 Kts

a



b

Key for Part B

- □ Location of actual latitude-longitude observations
- ● Point of tropical storm-hurricane transistion as estimated from the data
- ○ Point of tropical depression-tropical storm transistion as estimated from the data
- ············· Estimated track of tropical cyclone while in tropical depression stage
- - - - - - - - Estimated track of tropical cyclone while in tropical storm stage
- ———— Estimated track of tropical cyclone while in hurricane stage

Fig. A-3. The conversion of numerical tropical cyclone data into tropical cyclone tracks (with intensity stages). (a) Numerical tropical cyclone data; (b) tropical cyclone track resulting from the given data.

DATA GROUP TC50

Data group TC50 contains four data variables: TS (tropical storm probabilities of occurrence), TY (hurricane probabilities of occurrence), STY (super typhoon probabilities occurrence), and TCV (mean forward velocities of tropical cyclones).

Information About the Data Sources

Specific information concerning the characteristics and use of the data sources used for data group TC50 follows. Data source documents are listed by number and title. For a fuller citation of each reference, see Part 1 as noted in brackets.

1. *Mariner's Worldwide Climatic Guide to Tropical Storms at Sea* [Part 1, Sect. 7.4, No.(1)]. This data source provided tropical storm and hurricane probabilities of occurrence (in percent) for 5° x 5° grid cells of latitude-longitude for most areas of the globe. Each 5° x 5° grid cell was provided with two digital values (one for tropical storms and one for hurricanes) that were used for data variables TS and TY.

2. *Tropical Cyclones of the North Atlantic Ocean, 1871-1986* [Part 1, Sect. 7.4, No. (2)]. Annual tropical cyclone tracking charts provided information for data variables TS and TY. Tropical storm and hurricane tracks for the North Atlantic Ocean from 1899 through 1989 were used. The tracking charts for this time period distinguish tropical storms tracks from hurricane tracks as required for the derivation of data group TC50.

3. *A Compilation of North Atlantic, Eastern North Pacific, Central North Pacific, and Western North Pacific Tropical Cyclone Data (TD-9697); and Consolidated Worldwide Tropical Cyclones (TD-9636)* [Part 1, Sect. 7.4, No. (3)]. These data sources were used for the period 1965 through 1986 in the Eastern North Pacific and Central North Pacific (data available for the areas of interest before 1965 were excluded because storm track records prior to that date were incomplete). The data sources consist of digital information on tropical cyclones (no tracking charts were provided). The numerical information provided storm positions, intensities, and forward movement data necessary to create tracking charts and conduct analyses for data variables TS, TY, STY, and TCV.

4. *Monthly Weather Review*, Vols. 116-118 [Part 1, Sect. 7.4, No. (4)]. These data sources provided tracking charts and statistical information (e.g., maximum winds) that were used for data variables TS, TY, STY, and TCV. The tracking charts indicate the location and intensity (through hurricane stage but not super typhoon stage) of each tropical cyclone throughout all stages of its life cycle. The data sources describe all tropical cyclone occurrences in the Eastern North Pacific Ocean from 1987 through 1989 east of 140°W.

5. *1970-1979 Annual Typhoon Reports* and *1980-1989 Annual Tropical Cyclone Reports* [Part 1, Sect. 7.4, No. (5)]. These data sources provided tracking charts and numerical information on tropical cyclones. Both tracking charts and numerical

information were interactively used to obtain a more accurate analysis of the tropical cyclones being studied. The data sources cover tropical cyclone occurrences in the Western North Pacific Ocean. Also covered are tropical cyclones in the North Indian Ocean (1975-1989), South Pacific Ocean (1985-1989), and South Indian Ocean (1985-1989). These data sources supplied information for data variables TS, TY, STY, and TCV.

6. *Tropical Cyclones in the Southwest Pacific: November 1969 to April 1979* [Part 1, Sect. 7.4, No. (6)]. The data source provided tropical cyclone tracking charts showing intensity stages for tropical storms and hurricanes from 150° W to 150° E in the South Pacific Ocean. The tracking charts provided information to update data variables TS and TY from mid-1969 to mid-1979.

7. *Forecast Verification and Reconnaissance Data for Southern Hemisphere Tropical Cyclones (July 1980 through June 1982)* and *Forecast Verification and Reconnaissance Data for Southern Hemisphere Tropical Cyclones (July 1982 through June 1984)* [Part 1, Sect. 7.4, No. (7)]. These data sources included both tropical cyclone tracking charts and numerical information. The numerical information provided the intensity classes and locations of the tropical cyclones. Tracking charts were used when necessary to verify the positions of the tropical cyclones provided by the numerical information. These data sources supplied information for data variable STY in the Southern Hemisphere from July 1980 through June 1984.

8. Unpublished works used are *Tropical Cyclone Statistics of the July 1989-June 1990 Southern Hemisphere Tropical Cyclone Season*, compiled by F.H. Wells (1990), and *Statistics of Central North Pacific Tropical Cyclones 1987-1989*, compiled by J.D. Elms (1990). Tropical cyclone tracking charts showing storm positions and intensities were used from the Central North Pacific data source. The information was used to improve the accuracy of data variables TS, TY, STY in the Central North Pacific (140° W to 180° W longitude). Numerical data were used from the Southern Hemisphere data source to construct tracks and revise data variables TS, TY, STY, and TCV through 1989, and through mid-1990 in a few regions.

The data sources for data group TC50 were obtained in three forms: (1) digital probabilities of occurrence for 5° x 5° grid cells; (2) tropical cyclone tracking charts; and (3) digital tapes with data on the characteristics, intensities, stages, and locations of tropical cyclones. The first data format used forms the basis of data group TC50. The remaining data sources expand, revise, and update the information provided in Data Source (1) through 1989, and in some regions through mid-1990.

Some overlap of tropical cyclone tracks and/or numerical data among the data sources exists in places of adjacent tropical cyclone basins (for example, where the Western North Pacific and Eastern North Pacific meet at 180° E/W). In such cases, data sources from all basins concerned were checked to ensure that all known tropical cyclones are represented in the data values. This means that Eastern North Pacific data sources were checked for information on tropical cyclones moving through the Western North Pacific and vice versa. This procedure was repeated for North Atlantic-Eastern North Pacific overlaps, Western North Pacific-North Indian overlaps, etc.

In a few cases, overlapping data sources provided conflicting information. When this occurred, the information from the newest data source was used. Two different situations usually created conflicting information: (1) a given storm was missing from one data source but indicated by another or (2) data sources disagreed on the location or intensity of the same storm.

The definitions of data variables TS, TY, and STY were held as constant as possible between the various data sources. Only the South Indian Ocean has some data values with somewhat inconsistent definitions. A small but significant portion of the data for data variables TS and TY in the South Indian Ocean contains a discrepancy in the maximum wind speed used to define the transition from a tropical storm to a hurricane. Throughout data group TC50, the point at which a tropical cyclone becomes a hurricane is 33 m/s. However, for a few tropical cyclones in the South Indian Ocean, the point of transition was defined as occurring at 28.8 m/s. The minor discrepancy between definitions (4.2 m/s) was ignored because of the relatively small number of storms affected. It is felt that the use of these data does not introduce a significant amount of error into the South Indian Ocean data values.

The Data Variables

Aside from the differences in the intensities of the tropical cyclones classified, data variables TS and TY were derived by the same methods. Data variables STY and TCV were calculated using different procedures.

All analyses of tropical cyclone data sources are a result of manual inspection. No computer processing was used in the analysis of digital information, tropical cyclone tracking charts, or numerical tropical cyclone data, and none of the data values in the data group were corrected for latitudinal differences in the sizes of 5° x 5° grid cells.

Data variables TS, TY, STY, and TCV contain no zero data values. After data derivation and analysis, data that resulted in zero values were flagged with either a "no data" value of 999 or an estimated data value of 200-299, where the hundreds digit flags the data as being estimated. Estimated data values for tropical storm, hurricane, or super typhoon probabilities of occurrence or mean forward velocities of tropical cyclones were interpreted based on the best available information and from averaging of cells with data that surrounded the "no data" cell.

The derivation method(s) used for a given data value and a given data variable depended on the available data sources for the region under analysis. (See Appendix C for a listing of the data sources used for each individual 5° x 5° grid cell.)

Discussions of the different data derivation methods used for each data variable follows.

Data Variables TS and TY.

Data derivation began initially by obtaining the data values for each 5° x 5° grid cell from the Data Source (1). Data Source (1) provided data values only in whole numbers (such as 26%, 30%, etc.). Using information on the period of record for a given grid cell, the numbers, in the form of percentages, from Data Source (1) were extended from the "ones" digit to the "tenths" digit. For example, assume that the period of record for a given grid cell was 14 years and Data Source (1) provided an original tropical storm occurrence data value of 7%. The actual data value for the cell, if only one tropical storm occurred during the period of record, is 7.1%.

Two additional data derivation methods were used to update the data values obtained above. A discussion of these two methods can be found under Data Derivation Methods 1 and 2 in the text of data group TC10. The general guidelines found in those sections also apply here. Note that the information in Data Derivation Methods 1 and 2 of the data group TC10 text should be interpreted for 5° x 5° grid cells when using those sections for data group TC50.

In some regions, information from Data Source (1) was not available. In these cases, the data derived are solely from the data sources used in Data Derivation Methods 1 and 2 in data group TC10.

After the probabilities of occurrence for data variables TS and TY were derived from each data source (for different periods of record), the data values provided by each data source were combined to obtain a single data value for each data variable in each 5° x 5° grid cell in the following manner (this example applies to both data variables).

Given three data sources with different periods of record,

	TS probability	Period of record	Years
Source 1:	34%	1899-1945	47
Source 2:	72%	1946-1957	12
Source 3:	18%	1958-1989	32

The TS probability and the years of record would be entered into the following equation to determine the final percentage for the entire period of record (i.e., 1899-1989).

$$\text{Final TS} = \frac{[(34\% * 47) + (72\% * 12) + (18\% * 32)]}{47 + 12 + 32}$$

Final TS = 33.4%

In circumstances in which a multiple number of data sources were used during a single period of record, the information from the data sources involved was combined before obtaining the TS probability for the entire period of record.

Data Variable STY (Super Typhoons).

The procedures for deriving data values for STY are identical to those for data variables TS and TY with the following exceptions:

1. Only tropical cyclones having maximum sustained winds of 67 m/s or greater were analyzed for data variable STY.

2. Data Derivation Methods 1 and 2 were used to obtain the data for variable STY.

Data Variable TCV (Mean Forward Velocities of Tropical Cyclones).

Data variable TCV defines the mean forward motion of all tropical cyclones moving through a given 5° x 5° grid cell for the given period of record. The data sources provided the mean forward motion of tropical cyclones in knots; however, the data values were changed to meters per second for their use in data variable TCV.

Data Source (1) provided information on mean forward velocities of tropical cyclones; however, unlike data for the other data variables in data group TC50, the mean forward velocities of tropical cyclones (data variable TCV) were not available in digital form.

Digital values were derived from contour maps that were available for most areas on the globe. Data derivation methods for areas of tropical cyclone occurrence that were not covered by the available contour maps will be explained later.

The contour map was converted to a 5° x 5° grid cell map (digital format) of data values in order to provide a format more compatible with the remainder of this NDP. The procedures used for converting the contour map into digital data values are as follows (see also Fig. A-4).

1. The contour map from Data Source (1) was divided into 5° x 5° grid cells coincident with those used for data variables TS, TY, and STY.

2. The contour lines (showing mean forward velocities of tropical cyclones) crossing over each grid cell were noted. A contour line was considered to cross over a grid cell if it was present in the interior of a grid cell or if the contour line at least touched a corner or side of the grid cell. A contour line crossing the same grid cell in two or more discontinuous segments was considered two or more separate lines.

3. The contour lines crossing over a given grid cell were summed using the data values of each contour line. The differing lengths of the particular contour lines within a given grid cell were not taken into account.

4. A summation resulting from (3) was then divided by the number of contour lines contained within each grid cell. The resulting number yielded the mean forward velocity in knots for all tropical cyclones within a given 5° x 5° grid cell.

5. If a 5° x 5° grid cell contained no contour lines on or within its boundaries, then the location of the given grid cell with respect to the nearest contour lines was noted. The contour interval in which the given grid cell was located was estimated to obtain a single data value for the given grid cell. For example, if a given grid cell was located between 7.5 kt and 10 kt contour lines, then the given grid cell was given a value of 8.75 kt.

6. Finally, data values were converted to meters per second (1 knot = 0.5144 m/s).

Alternate data sources were used for the regions not encompassed by the contour maps. One procedure used data on storm center time and location to determine tropical cyclone movement velocities, and the second procedure used preexisting statistics on the mean forward velocities of tropical cyclones. The general procedure for both of the approaches is outlined here. Note that the first procedure uses all of the outlined steps, whereas the second procedure uses only Step (4).

1. Storm center times and locations were noted for each 5° x 5° grid cell.

2. The actual great circle distance (distance on the earth's surface) was computed between each of the storm center locations.

3. By noting the time that each storm center required to move from location to location (derived by observing the time of each storm position given in the data source), one could determine the mean forward motion of the storm center between each of the storm center locations.

4. Finally, all movement velocity values between various points along all tropical cyclone tracks for a given 5° x 5° grid cell were averaged and converted from knots to meters per second. The results are the data values for data variable TCV.

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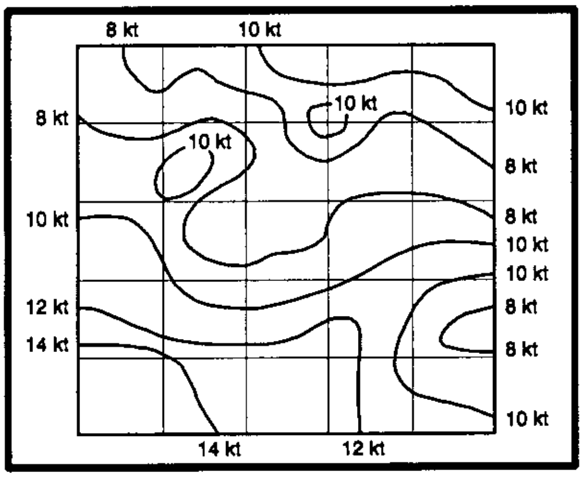

a

8.0	8.0	9.3	9.3	9.0
9.0	8.5	8.7	8.7	8.0
10.0	9.0	8.0	9.0	9.3
13.0	12.0	11.0	10.7	9.0
14.0	14.0	13.0	11.0	10.0

b

Fig. A-4. A sample conversion of contour map data into digital data according to the methods used for data variable TCV. (a) Contour map of the type used for data derivation; (b) resultant digital values in knots for each 5° x 5° grid cell.

DATA GROUP HCSTATE

Data group HCSTATE contains five data variables: C1 (Saffir-Simpson Category 1 Hurricanes), C2 (Saffir-Simpson Category 2 Hurricanes), C3 (Saffir-Simpson Category 3 Hurricanes), C4 (Saffir-Simpson Category 4 Hurricanes), and C5 (Saffir-Simpson Category 5 Hurricanes).

Information About the Data Sources

Specific information concerning the characteristics and use of the data sources for data group HCSTATE are described below. Data source documents are listed by number and title. For a fuller citation for each reference, see Part 1 as noted in brackets.

1. *Tropical Cyclones of the North Atlantic Ocean, 1871-1986* [Part 1, Sect. 8.3, No. (1)]. The table entitled "Number of hurricanes (direct hits) affecting U.S. and individual states 1899-1986 according to Saffir/Simpson Hurricane Scale" provided the primary information for the data variables. The data source gave the number of hurricanes for each Saffir-Simpson category striking various states and substates along the U.S. Atlantic and Gulf coasts.

2. *Monthly Weather Review*, Vols. 116-118 [Part 1, Sect. 8.3, No. (2)]. These data sources provided tracking charts and information for individual hurricanes striking U.S. Atlantic and Gulf coast states during the period 1987 through 1989. The tracking charts indicated the states or substates affected by the storms. The individual storm reviews from the data sources used provided information about the Saffir-Simpson intensity class assigned to each hurricane strike.

The Data Variables

All five data variables (C1, C2, C3, C4, and C5) of data group HCSTATE were initially constructed through the direct transfer of data values for each Saffir-Simpson category provided by Data Source (1). The data values for each data variable were then updated as necessary as a result of information obtained from Data Source (2).

The data values of C1, C2, C3, C4, and C5 were done using the following procedure.

1. Tracking charts from Data Source (2) were visually checked to determine states and substates directly hit by hurricanes from 1987 through 1989.

2. The storm reviews in Data Source (2) for these hurricanes were consulted. From these reviews, the Saffir-Simpson intensity class of each hurricane at the time of landfall on a given state or substate was determined.

3. Data values for all states or substates affected by hurricanes from 1987 through 1989 were then updated.

No corrections were applied to the data variables that would adjust data values for differences in the coastline lengths of the various states and substates. These data values should be standardized before an intercomparison of data values is made.

DATA GROUP XCNORTH

Data group XCNORTH contains 26 data variables: CGJA (January extratropical cyclogenesis), CFJA (January extratropical cyclone occurrence), CGFE (February extratropical cyclogenesis), CFFE (February extratropical cyclone occurrence), CGMR (March extratropical cyclogenesis), CFMR (March extratropical cyclone occurrence), CGAP (April extratropical cyclogenesis), CFAP (April extratropical cyclone occurrence), CGMY (May extratropical cyclogenesis), CFMY (May extratropical cyclone occurrence), CGJN (June extratropical cyclogenesis), CFJN (June extratropical cyclone occurrence), CGJL (July extratropical cyclogenesis), CFJL (July extratropical cyclone occurrence), CGAG (August extratropical cyclogenesis), CFAG (August extratropical cyclone occurrence), CGSP (September extratropical cyclogenesis), CFSP (September extratropical cyclone occurrence), CGOB (October extratropical cyclogenesis), CFOB (October extratropical cyclone occurrence), CGNV (November extratropical cyclogenesis), CFNV (November extratropical cyclone occurrence), CGDC (December extratropical cyclogenesis), CFDC (December extratropical cyclone occurrence), CGAN (annual extratropical cyclogenesis), and CFAN (annual extratropical cyclone occurrence).

Information About the Data Source

Specific information concerning the use of the data source for data group XCNORTH is described below. The data source is listed by number and title. For a fuller citation of the reference, see Part 1 as noted in brackets.

1. *Atlas of Northern Hemisphere Extratropical Cyclone Activity: 1958-1977* [Part 1, Sect. 9.3, Data Source (1)]. The number of extratropical cyclogeneses and extratropical cyclone occurrences were provided by this data source in digital format for each 5° x 5° grid cell of latitude-longitude between 20°N and 85°N.

The Data Variables

All extratropical cyclone occurrence data variables (those having names starting with CF) were generated by transferring data values directly from the data source. The extratropical cyclogenesis data variables (those having names starting with CG) were directly transferred from the data source except for data values representing 5° x 5° grid cells located above 65°N.

The authors of the data source (Horn and Whittaker, 1982) suggested leaving these data uncorrected for latitudinal differences in grid cell sizes. As a result, most of the data variables in data group XCNORTH are uncorrected for differences in grid cell sizes. Although it is desirable to have data values that represent grid cells of equal size, the required adjustments sometimes distort the information in the data.

Regions with no data are flagged with data values of either 888 or 999. 5° x 5° grid cells located between 0°N and 20°N are designated as being in the tropical portion of the Northern Hemisphere and were labeled with data values of 888. All others 5° x 5° grid cells outside the Northern Hemisphere were labeled with data values of 999 (i.e., "no data") for all of the data variables.

Other procedures used in developing extratropical cyclogenesis data variables and extratropical cyclone occurrence data variables are described in the following.

Data Variables CGJA, CGFE, CGMR, CGAP, CGMY, CGJN, CGJL, CGAG, CGSP, CGOB, CGNV, CGDC, and CGAN (extratropical cyclogenesis data variables).

Correction for varying grid cell size was possible for the extratropical cyclogenesis data variables without distorting the data information. This is because the extratropical cyclogenesis data values represent the number of points of extratropical cyclone origin within a given 5° x 5° grid cell. Therefore, changing the area of analysis for a given grid cell only transfers points of extratropical cyclogenesis origin from one grid cell to another. This could be advantageous in areas of low extratropical cyclogenesis. If the 5° x 5° grid cells were too small for the low frequency of extratropical cyclogenesis, the resulting data values for the data variables could misrepresent the actual distribution of the extratropical cyclogenesis. Thus, longitudinally increasing the grid cell size could make the data more representative of the actual distribution of storms in high latitudes.

Because 5° x 5° grid cells become smaller as the latitude increases, 5° x 5° grid cells centered above 65°N in the original data source were grouped in pairs for the purpose of recording data. This procedure decreases the analysis-induced unevenness of the data at high latitude and also makes the 5° x 5° grid cells representative of an area closer in size to 5° x 5° grid cells at lower latitudes. Each 5° x 5° grid cell above 65°N still maintains its identity and data values in data group XCNORTH; however, the data values given for each 5° x 5° grid cell were actually derived from the given 5° x 5° grid cell and one of its neighboring 5° x 5° grid cells. For example, if a pair of given 5° x 5° grid cells above 65°N latitude have July extratropical cyclogenesis values of 3 and 4, respectively, then the same two 5° x 5° grid cells would both have data values of 7 for data variable CGJL (July extratropical cyclogenesis) in this data group.

The specific groupings of 5° x 5° grid cells above 65°N for data analysis of extratropical cyclogenesis are paired according to the ARC/INFO™ grid cell identification numbers 0073-0074, 0075-0076, 0077-0078, 0079-0080, and so on through 0287-0288.

Data Variables CFJA, CFFE, CFMR, CFAP, CFMY, CFJN, CFJL, CFAG, CFSP, CFOB, CFNV, CFDC, and CFAN (extratropical cyclone occurrence data variables).

The extratropical cyclone occurrence data variables are influenced by linear features (storm tracks). This factor seems to make the data variables in question more vulnerable to distortion when attempts are made to correct for differences in the sizes of grid cells used. As a result, no area corrections for differences in grid cell sizes were attempted for these data variables. The extratropical cyclone occurrence values for 5° x 5° grid cells in the data source were simply transferred to their respective data variables in data group XCNORTH.

DATA GROUP POLARLOW

Data group POLARLOW contains three data variables: COMMA (mean number of polar lows per winter month of types 6, 7, and 21), SPIRAL (mean number of polar lows per winter month of type 22), and POLARLOW (mean number of polar lows per winter month of types 6, 7, 21, and 22).

Information About the Data Sources

Specific information concerning the characteristics and use of the data sources of data group POLARLOW is described in the following. Data source documents are listed by number and title. For a fuller citation of each reference, see Part 1 as noted in brackets.

1. A computer listing of Polar-Low observation data, compiled by B. Yarnal and K. G. Henderson (1989), [Part 1, Sect. 10.3, Data Source (1)]. This data source provided data on specific observations of polar lows and other types of cyclones. Observation data included information on cyclone type, cyclone stage, and cyclone location. Only data on polar lows in the formation and mature stage were used for analysis of polar lows in this NDP. This data source provided information on polar lows in the North Pacific Ocean [defined here as a box with corners having the latitude-longitude coordinates (70°N,110°E), (70°N,120°W), (20°N,120°W), and (20°N,110°E)] for the months November through March and for the winter seasons 1976-77 through 1982-83. The area of the North Pacific Ocean covered by this box is illustrated in Fig. 8 of Part 1.

2. *Satellite Climatology of "Polar Lows" and Broadscale Climatic Associations for the Southern Hemisphere* [Part 1, Sect. 10.3, Data Source (2)]. This data source provided the observed locations of developing and mature polar lows during the period of record. Polar lows (of type 6, 7, and 21) were grouped as one item (i.e., comma-form polar lows) in the data source. The locations of all polar lows identified in the data source were used to derive the necessary information for data group POLARLOW. The data source provided data on polar low occurrences in the Southern Hemisphere for June through September for the winter seasons of 1977 through 1983.

Explanations of polar lows and the several identified types 6, 7, 21, 22, etc. are in Appendix F.

Some satellite images were missing from the analysis periods of both data sources. However, the small percentage of missing images is not likely to significantly affect the data values here.

The Data Variables

The methods used to calculate the data variables COMMA, SPIRAL, and POLARLOW varied according to the data source used. The data values for 5° x 5° grid cells outside the Southern Hemisphere and the North Pacific Ocean are flagged with values of 999, indicating "no data." These two areas are defined in greater detail in Fig. 8 of Part 1.

Data derivation techniques used for the data variables are discussed by data source in the following.

Data Variables COMMA, SPIRAL, and POLARLOW from Data Source (1) of Part 1, Sect. 10.3 (North Pacific Ocean).

The data values for the region of the North Pacific Ocean for all of the data variables were compiled as follows.

1. Polar-low observations were separated from other cyclone observations in the data source through the use of a computer program written in C for this purpose.

2. The polar-low observations were sorted according to the 5° x 5° grid cell in which they were observed. The procedure placed each polar-low observation into one of 260 possible 5° x 5° grid cells bounded by the latitude-longitude box defined in the preceding Data Source (1) listing. Polar-low observations recorded exactly on the border between two 5° x 5° grid cells were counted in both of the grid cells. Also, polar-low observations recorded exactly on the corner between four 5° x 5° grid cells were counted in all four grid cells.

3. After sorting, the polar-low occurrences observed in each 5° x 5° grid cell were counted in three categories (representing the three data variables). This included counting: (1) the total number of comma-form polar lows (types 6, 7, and 21) observed in the given grid cell, (2) the total number of spiral-form polar lows (type 22) observed in the given grid cell, and (3) the total number of polar lows (types 6, 7, 21, and 22) observed in the given grid cell.

4. Finally, the resulting data values for data variables COMMA, SPIRAL, and POLARLOW for each 5° x 5° grid cell were adjusted to represent the area of a 5° x 5° grid cell of latitude-longitude centered at 45°N/S. Above 65°N/S, 5° x 5° grid cells were grouped in pairs. In those circumstances, the area of each pair of grid cells was then adjusted to represent the area of a 5° x 5° grid cell centered at 45°N/S. Although each grid cell in a given pair maintains its own identity in data group POLARLOW, both grid cells in the pair have the same data values for a given data variable. The ARC/INFO™ polygon ID numbers of the Northern Hemisphere 5° x 5° grid cell pairs are 0001-0002, 0003-0004, 0005-0006, and so on through ARC/INFO™ Polygon IDs 0359-0360. Table A-2 lists the coefficients used to adjust the data values of each 5° x 5° grid cell for area.

Table A-2. Coefficients used to adjust 5° x 5° grid cell data values to data values representing the area of a 5° x 5° grid cell centered at 45°N/S

Grid cell latitude zone	Coefficient	Grid cell latitude zone	Coefficient
0°-20°N/S	None[a]	50°-55°N/S	1.1588
20°-25°N/S	0.7685	55°-60°N/S	1.3114
25°-30°N/S	0.7998	60°-65°N/S	1.5244
30°-35°N/S	0.8403	65°-70°N/S	0.9188[b]
35°-40°N/S	0.8923	70°-75°N/S	1.1685[b]
40°-45°N/S	0.9590	75°-80°N/S	1.6224[b]
45°-50°N/S	1.0454	80°-90°N/S	None[a]

[a]Data in these zones do not require area correction since data values either equal zero or are not available.
[b]Coefficient is for area correction of a 5° x 5° grid cell pair.

Data Variables COMMA, SPIRAL, and POLARLOW from Data Source (2) of Part 1, Sect. 10.3 (Southern Hemisphere).

All data values for the Southern Hemisphere's data variables were derived as follows:

1. The polar-low observations were sorted according to the 5° x 5° grid cell of latitude-longitude in which they were observed. This was accomplished by visually observing the locations of polar-low occurrence in the Data Source (2) figures. Each polar-low observance was assigned to the particular 5° x 5° grid cell in which it occurred. In some cases, a polar-low observation occurred on a border between two 5° x 5° grid cells or on a corner between four 5° x 5° grid cells. Under these circumstances, the polar-low observance was counted in all 5° x 5° grid cells involved. (A reprint of the data source for the Southern Hemisphere including the figures from which the Southern Hemisphere data were derived, is in Appendix F).

2. After Step (1), the procedure for deriving data values for data variables COMMA, SPIRAL, and POLARLOW in the Southern Hemisphere is identical to that described in Steps (3) and (4) under Data Source (1) (North Pacific data source), except that the ARC/INFO™ grid cell IDs of 5° x 5° grid cell pairs of the Southern Hemisphere below 65°S latitude are 2233-2234, 2235-2236, 2237-2238, and so on through ARC/INFO™ grid cell IDs 2591-2592).

DATA GROUP LOWPC

Data group LOWPC contains 19 data variables that are known as ZONE (climate zone), LOWNJA (mean number of cyclones in January; Northern Hemisphere), LOWNJL (mean number of cyclones in July; Northern Hemisphere), LOWNAN (mean number of cyclones annually; Northern Hemisphere), LOWSJA (mean number of cyclones in January; Southern Hemisphere excluding Australian Region), LOWSJL (mean number of cyclones in July; Southern Hemisphere excluding Australian Region), LOWSAN (mean number of cyclones annually; Southern Hemisphere excluding Australian Region), LOWS2JA (mean number of hours of cyclonicity in January; Southern Hemisphere excluding Australian Region), LOWS2JL (mean number of hours of cyclonicity in July; Southern Hemisphere excluding Australian Region), LOWS2AN (mean number of hours of cyclonicity annually; Southern Hemisphere excluding Australian Region), LOWAJA (mean number of cyclones in January; Australian Region), LOWAJL (mean number of cyclones in July; Australian Region), LOWAAN (mean number of cyclones annually; Australian Region), LOWA2JA (mean number of hours of cyclonicity in January; Australian Region), LOWA2JL (mean number of hours of cyclonicity in July; Australian Region), LOWA2AN (mean number of hours of cyclonicity annually; Australian Region), CYCJA (relative number of cyclones in January; global), CYCJL (relative number of cyclones in July; global), and CYCLONE relative number of cyclones annually; global). See Parts 1 and 2 of this NDP for specific definitions of each data variable.

Information About the Data Sources

Specific information concerning the characteristics and use of the data sources of data group LOWPC are described below. Data source documents are listed by number and title. For a fuller citation of each reference, see Part 1 as noted in brackets.

1. *Principal Tracks and Mean Frequencies of Cyclones and Anticyclones in the Northern Hemisphere, Research Paper No. 40* [Part 1, Sect. 11.3, Data Source (1)]. This data source provided 12 charts of cyclone occurrence in the Northern Hemisphere for each month of the year. The period of record was 1899 through 1938. Each chart provided the number of cyclone occurrences in each 5° x 5° grid cell for the period of record during the given month. The number of cyclone occurrences recorded for each 5° x 5° grid cell is based on surface analysis charts using 5-hPa isobar intervals and observations taken at 1230 UTC each day of the period of record. The data source provided data in digital form.

2. Unpublished digital-form cyclonicity data for the Southern Hemisphere for January and July obtained from R.M. Leighton (1990). [Part 1, Sect. 11.3, Data Source (2)]. This data source provided charts of cyclone occurrence data in digital form for January and July. The digital values provided for each 5° x 5° grid cell were based on surface analysis charts using 4-hPa isobar intervals in the Australian Region and 10-hPa isobar intervals in the remainder of the Southern Hemisphere. [The Australian Region is enclosed by a latitude-longitude box defined by the corner coordinates (10°S,90°E), (10°S,180°E),(55°S,180°E), and (55°S,90°E)]. The

digital data provided by the data source were based on cyclone tracks that were interpolated from observations taken at 00 UTC and 12 UTC each day of the period of record. The period of record was 1965 through 1987 for the Australian Region and 1973 through 1987 for the remainder of the Southern Hemisphere.

3. Unpublished digital-form cyclonicity data for the Australian Region for all 12 months of the year, obtained from R.M. Leighton (1990). [Part 1, Sect. 11.3, Data Source (3)]. This data source provided information in the same format as described for Data Source (2), except for the following: (1) digital data were provided for each of the 12 months of the year, (2) data encompassed the Australian Region only, and (3) the period of record is 1965 through 1987 for all data.

4. *Goode's World Atlas* [Part 1, Sect. 11.3, Data Source (4)]. This data source provided a global climate classification map by G.T. Trewartha (modified and simplified from the Köppen climate classification).

5. Unpublished interpretations of the climate classification provided in Data Source (4). This data source subjectively interprets Data Source (4) for the purpose of segregating extratropical regions from tropical regions.

The data sources consist of two types. The first three data sources [Data Sources (1), (2), and (3)] are those used to derive the cyclonicity data for data group LOWPC. The remaining two data sources [Data Sources (4), and (5)] were used as an aid in deriving data variable ZONE. Data variable ZONE is not a cyclonicity data variable but is provided to allow the user the option of segregating tropical and extratropical regions for the purpose of helping to distinguish areas dominated by different cyclone types.

The Data Variables

A variety of methods were used to derive the data variables of data group LOWPC. As a result, each data variable is discussed separately when necessary.

Data Variable ZONE

Data variable ZONE is a global data variable. All 2,592 5° x 5° grid cells contain actual data values. Data variable ZONE is in essence a "dummy" variable. Data values can be only one of three integers (0, 1, or 2). Each integer represents the definitions "no data," "tropical," and "extratropical," respectively.

Data variable ZONE is derived partly from a global climate classification map. The complete derivation process for the data variable follows.

1. Data Source (4) was initially used to separate tropical and extratropical regions. This was accomplished by the designation of certain climate zones [as defined by Data Source (4)] as "tropical" or "extratropical." Climate zones Af, Am, Aw, As, BWh, BS, BShw, BSh, and BShs were defined as "tropical." All other climate zones were defined as "extratropical."

2. Tropical-extratropical boundaries were drawn across a world map according to the definitions in Step (1). These boundary lines were then modified to make them conform to the boundaries of the nearest 5° x 5° grid cell.

3. The resulting tropical-extratropical boundaries were then further modified in certain areas through subjective interpretation [Data Source (5)]. This means that for some areas, the tropical-extratropical boundaries were adjusted for several 5° x 5° grid cells in which special conditions were known to exist. Special conditions might include the presence of mountains that could change a climate classification. Another special condition might be the knowledge that a particular grid cell experiences certain storm events during a given season that would warrant a change of identity from dominantly tropical to dominantly extratropical or vice versa. Any adjustments made to the tropical-extratropical boundary always maintained borders along the boundaries of 5° x 5° grid cells of data group LOWPC.

4. Finally, each 5° x 5° grid cell on the tropical side of the tropical-extratropical boundary was designated "tropical" with a data value of 1. Likewise, each 5° x 5° grid cell on the extratropical side of the boundary was designated "extratropical" with a data value of 2. The derived tropical-extratropical boundary is illustrated in Fig. A-5.

Data Variables LOWNJA and LOWNJL

Data variables LOWNJA and LOWNJL are Northern Hemisphere data variables. Real data values are confined to 5° x 5° grid cells north of the equator. Data values for 5° x 5° grid cells in the Southern Hemisphere have the value 999, indicating "no data."

Data variables LOWNJA and LOWNJL were derived exclusively from Data Source (1). Both data variables were derived using the following procedures:

1. Real data values for each 5° x 5° grid cell were obtained through the direct transfer of the appropriate digital values from Data Source (1).

2. Because the data source's period of record was 40 years, the data values were divided by 40 to obtain data values that represented cyclone occurrences on a per year basis. Thus, data values in data variable LOWNJA describe the mean number of cyclone occurrences per January. Likewise, the data values in data variable LOWNJL describe the same for July.

The Data Source (1) data have already been adjusted for latitudinal differences in the areas of 5° x 5° grid cells before their use for data group LOWPC. Thus, the data values of data variables LOWNJA and LOWNJL are corrected for area. All of the data values represent an area equal to that of a 5° x 5° grid cell centered at 45°N/S.

The data values for 5° x 5° grid cells above 65°N were derived by Data Source (1) in a slightly different manner from those located below 65°N. Above 65°N, 5° x 5° grid cells were grouped for the purpose of recording data. These groups of grid cells were then area-corrected to represent an area equal to a 5° x 5° grid cell centered at 45°N/S. Such a procedure results in duplication of data values for numerous 5° x 5° grid cells above 65°N. (Although many 5° x 5° grid cells above 65°N contain duplicate values, all

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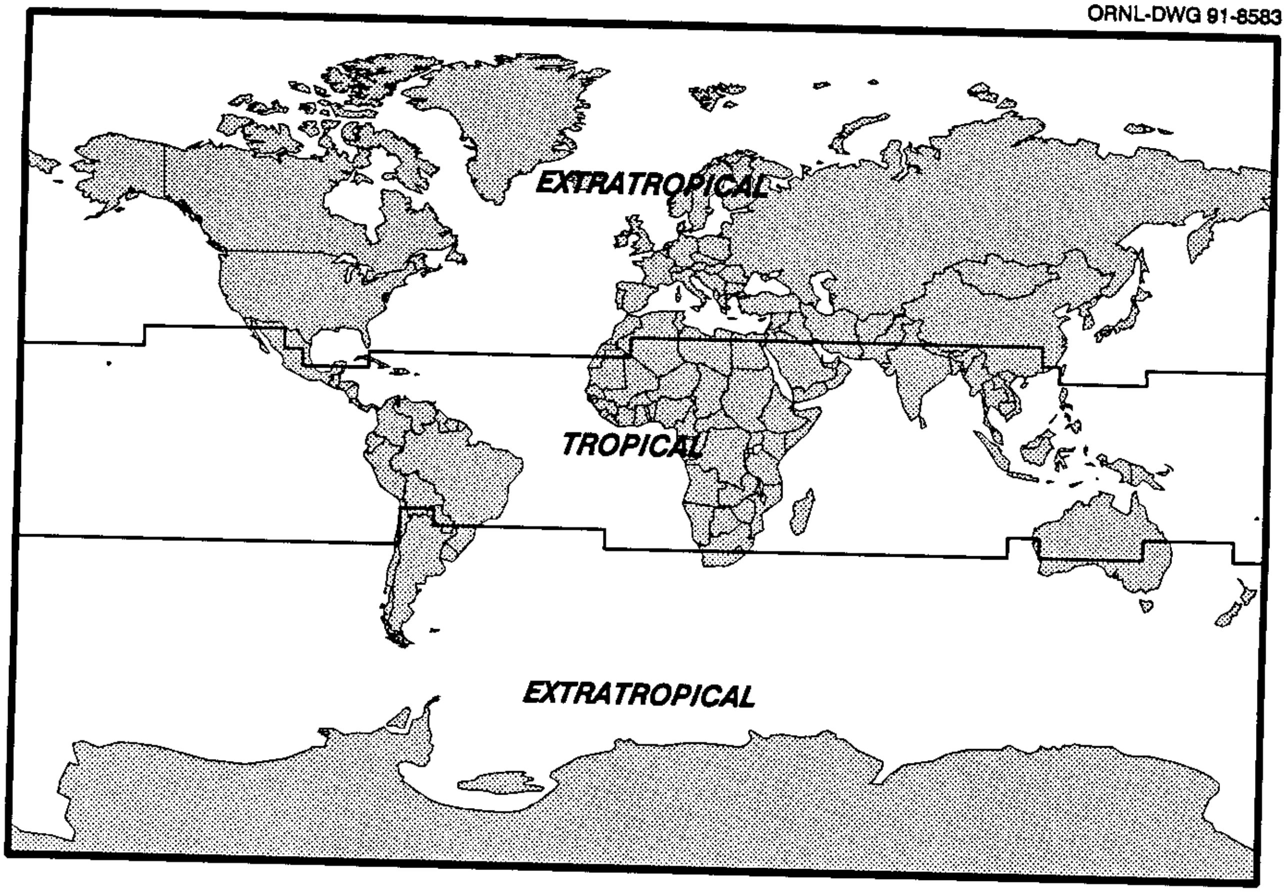

Fig. A-5. Tropical and extratropical areas as defined by data variable ZONE.

of the grid cells maintain separate identities as individual polygons). This procedure increases the data's integrity by preventing data analysis for grid cells that are too small. Groups of 5° x 5° grid cells that were analyzed together in data computations for Data Source (1)'s data are identified by their ARC/INFO™ grid cell ID numbers in Table A-3.

Table A-3. ARC/INFO™ grid cell IDs of 5° x 5° grid cells grouped together in the Data Source (1) analysis

Grid cell latitude zone	Number of grid cells per group	ARC/INFO™ grid cell IDs for each group
85°-90°N	18	0001-0018, 0019-0036, 0037-0054, 0055-0072
80°-85°N	6	0073-0078, 0079-0084, through 0139-0144
75°-80°N	3	0145-0147, 0148-0150, through 0214-0216
70°-75°N	2	0217-0218, 0219-0220, through 0287-0288
65°-70°N	2	0289-0290, 0291-0292, through 0359-0360

Data Variable LOWNAN.

Data variable LOWNAN is a Northern Hemisphere data variable. Real data values are confined to 5° x 5° grid cells north of the equator. All data values for 5° x 5° grid cells in the Southern Hemisphere have the value 999, indicating "no data."

Data variable LOWNAN was derived exclusively through Data Source (1). The following procedures were used.

1. Data values for each 5° x 5° grid cell for each month of the year were transferred from Data Source (1) charts to another chart. This procedure placed 12 data values for each 5° x 5° grid cell onto one chart.

2. The 12 data values for each 5° x 5° grid cell were summed to obtain 1 data value for each grid cell.

3. Because the data source's period of record was 40 years, the data values were divided by 40 to obtain data values that represented cyclone occurrences on a per year basis. Thus, data values in data variable LOWNAN describe the mean number of cyclone occurrences per year.

As was done for data variables LOWNJA and LOWNJL, Data Source (1) has corrected data variable LOWNAN for latitudinal differences in the areas of 5° x 5° grid cells. Each data value represents the area of a 5° x 5° grid cell centered at 45°N/S. The special procedure for data values of 5° x 5° grid cells above 65°N for data variables LOWNJA and LOWNJL also applies to data variable LOWNAN.

Note that data variable LOWNAN is not based strictly on information from data variables LOWNJA and LOWNJL, rather, it is based on data from all 12 months of the year.

Data Variables LOWSJA, LOWSJL, LOWS2JA, and LOWS2JL.

Data variables LOWSJA, LOWSJL, LOWS2JA, LOWS2JL are Southern Hemisphere data variables. Real data values are confined to 5° x 5° grid cells south of the equator and outside the Australian Region. (See the listing of Data Source (2) earlier in this data group discussion for a definition of the Australian Region.) Data values for 5° x 5° grid cells in the Northern Hemisphere have the value 999 indicating "no data."

Data variables LOWSJA, LOWSJL, LOWS2JA, and LOWS2JL are based strictly on information from Data Source (2). These data variables were derived using the following procedures.

1. Data values for each 5° x 5° grid cell between the equator and 55°S were obtained through the direct transfer of the appropriate digital values from Data Source (2) to the given data variable. The data source provided data values as annual probabilities over the period of record.

2. Data values for each 5° x 5° grid cell poleward of 55°S were obtained through the transfer of the appropriate digital value from a given 5° x 10° grid cell from Data Source (2) to the appropriate pair of 5° x 5° grid cells of data group LOWPC for the given data variable. Note that each 5° x 5° grid cell in data group LOWPC maintains its separate identity as a polygon. The 5° x 5° grid cell pairs deriving data values from the same original 5° x 10° grid cells in Data Source (2) are identified by ARC/INFO™ grid cell IDs 2089-2090, 2091-2092, 2093-2094, and so on through 2591-2592.

3. The data values for these data variables were not corrected for area by Data Source (2). Therefore, corrections for latitudinal differences in 5° x 5° grid cell areas were applied by multiplying data values by the coefficients listed in Table A-4. Area corrections for 5° x 5° grid cell data values south of 55°S latitude were based on the original 5° x 10° grid cells used to derive the data values.

Table A-4. Coefficients used to adjust Southern Hemisphere 5° x 5° grid cell data values to data values representing an area equal to that of a 5° x 5° grid cell centered at 45°S

Grid cell latitude zone	Coefficient	Grid cell latitude zone	Coefficient
0°-10°S	None[a]	45°-50°S	1.0454
10°-15°S	0.7283	50°-55°S	1.1588
15°-20°S	0.7451	55°-60°S	1.3114
20°-25°S	0.7685	60°-65°S	1.5244
25°-30°S	0.7998	65°-70°S	0.9188[b]
30°-35°S	0.8403	70°-75°S	1.1685[b]
35°-40°S	0.8923	75°-80°S	1.6224[b]
40°-45°S	0.9590	80°-85°S	2.6892[b]
	85°-90°S	None[a]	None[a]

[a]Data in these zones do not require area correction because data values either are equal to zero or are not available.
[b]Coefficient is for area correction of a 5° x 5° grid cell pair.

Data Variable LOWSAN.

Data variable LOWSAN is a data variable for the Southern Hemisphere. Real data values are confined to 5° x 5° grid cells south of the equator and outside the Australian Region. [See the listing of Data Source (2) earlier in this data group discussion for a definition of the Australian Region.] Data values for 5° x 5° grid cells in the Northern Hemisphere have the value 999, indicating "no data."

Data variable LOWSAN is based on data variables LOWSJA and LOWSJL. The data value for each grid cell x for variable LOWSAN was calculated by entering data values from the data variables LOWSJA and LOWSJL into the following equation.

$$\mathrm{LOWSAN}(x) = 12 * \frac{[\mathrm{LOWSJA}(x) + \mathrm{LOWSJL}(x)]}{2}$$

Data variable LOWSAN estimates the mean annual number of cyclone occurrences for each 5° x 5° grid cell in the Southern Hemisphere, based on the data provided by data variables LOWSJA and LOWSJL (mean number of cyclone occurrences for each 5° x 5° grid cell in the Southern Hemisphere for January and July, respectively).

Data Variable LOWS2AN.

Data variable LOWS2AN is a data variable for the Southern Hemisphere. Real data values are confined to 5° x 5° grid cells south of the equator and outside the Australian Region. [See the listing of Data Source (2) earlier in this data group discussion for a definition of the Australian Region.] Data values for 5° x 5° grid cells in the Northern Hemisphere have the value 999, indicating "no data."

Data variable LOWS2AN is based on data variables LOWS2JA and LOWS2JL. The data values for each grid cell x for variable LOWS2AN was calculated by entering the data values from the data variables LOWS2JA and LOWS2JL into the following equation:

$$LOWS2AN(x) = 12 * \frac{[LOWS2JA(x) + LOWS2JL(x)]}{2}$$

Data variable LOWS2AN estimates the mean annual number of hours that cyclones were present in each 5° x 5° grid cell in the Southern Hemisphere, based on the data provided by data variables LOWS2JA and LOWS2JL (mean number of hours that cyclones were present in each 5° x 5° grid cell in the Southern Hemisphere for January and July, respectively).

Data Variables LOWAJA, LOWAJL, LOWA2JA, and LOWA2JL.

Data variables LOWAJA, LOWAJL, LOWA2JA, LOWA2JL are Australian Region data variables. Real data values are confined to 5° x 5° grid cells inside the Australian Region. [See the listing of Data Source (2) earlier in this data group discussion for a definition of the Australian Region.] Data values for 5° x 5° grid cells outside this region have the value 999, indicating "no data."

Data variables LOWAJA, LOWAJL, LOWA2JA, and LOWA2JL are based strictly on information from Data Source (3). These data variables were derived using the following procedures:

1. Data values for each 5° x 5° grid cell were obtained through the direct transfer of the appropriate digital values from Data Source (3) to the given data variable. The data source provided data values in the desired per month format (i.e., for January or July).

2. The data values for these data variables were not corrected for area by Data Source (3). Therefore, corrections for latitudinal differences in 5° x 5° grid cell areas were applied by multiplying data values by the appropriate coefficients in Table A-4.

Data Variables LOWAAN and LOWA2AN.

Data variables LOWAAN and LOWA2AN are data variables for the Australian Region. Real data values are confined to 5° x 5° grid cells inside the Australian Region. (See the listing of Data Source (2) earlier in this data group discussion for a definition of the Australian Region.) The 5° x 5° grid cells outside the Australian Region have the value of 999 indicating "no data."

Data variables LOWAAN and LOWA2AN were derived using Data Source (3). The following procedures were used for both data variable LOWAAN and LOWA2AN.

1. Data values for each 5° x 5° grid cell for each month of the year were transferred from the Data Source (3) charts to another chart. This procedure placed 12 data values for each grid cell onto one chart.

2. In many of the 5° x 5° grid cells, data for some months of the year were lacking. In these cases, data values for the given data variable were estimated using the best available data. If a 5° x 5° grid cell had data for at least 8 months of the year and no more than 2 consecutive months was missing data, then missing monthly values for the given data variable were estimated by interpolating values for the missing months from the adjacent months that contained real data. This procedure resulted in 12 monthly values (either real or estimated) for each grid cell. If a given 5° x 5° grid cell was provided with less than 8 monthly values from Data Source (3), then the given 5° x 5 grid cell was assigned estimated values for the 12 months. Each of the 12 monthly values were equal to one another and was derived from the average of the real data provided for January and July. (All 5° x 5° grid cells analyzed for the given data variable were provided with data for January and July.)

3. The 12 data values for each 5° x 5° grid cell were summed to obtain 1 data value for each grid cell.

4. The data values for these data variables were not corrected for area by Data Source (3). Therefore, area corrections for latitudinal differences in 5° x 5° grid cells were applied by multiplying data values by the appropriate coefficients in Table A-4.

Note that for many 5° x 5° grid cells analyzed for data variable LOWAAN or data variable LOWA2AN, the resulting data values are not based strictly on information from January and July; rather, they are based on data from all 12 months of the year. The 5° x 5° grid cells having 12-month based data values for LOWAAN and LOWA2AN are identified by ARC/INFO™ grid cell IDs 1795-1799, 1859-1871, 1928-1944, 2000-2016, and 2073-2084.

Data Variables CYCJA and CYCJL.

Data variables CYCJA and CYCJL are global data variables representing the global distribution of cyclones in January and July, respectively. All 2,592 5° x 5° grid cells contain real data. There are no flagged data values in these data variables.

Data variables CYCJA and CYCJL are based on information from all three cyclonicity data sources [Data Sources (1), (2), and (3)]. The global data variables were created in an attempt to combine all available data into one standardized set of data values. Standardization is necessary because the data sources used different periods of record as well as different levels of detail in data analysis. The standardized global data variables (CYCJA and CYCJL) were created using the following procedures.

1. The mean and standard deviation were found for each of the three data sources.

2. The data values for data variables LOWNJA, LOWSJA, and LOWAJA for each 5° x 5° grid cell were copied and merged into the data variable CYCJA. Note that real data values for data variables LOWNJA, LOWSJA, and LOWAJA do not spatially overlap one another.

3. The following calculation was then performed to obtain variable CYCJA for each grid cell.

$$\text{CYCJA}(x) = \frac{[\text{CYCJA}(x) - \text{Mean of given data source}]}{\text{Standard deviation of given data source}}$$

4. Steps (2) and (3) above were repeated for the creation of data variable CYCJL from data variables LOWNJL, LOWSJL, and LOWAJL.

As a result of the standardization process, the data values obtained for the CYCJA and CYCJL are not expressed as the number of cyclone occurrences in each 5° x 5° grid cell. Instead, each data value is expressed as the deviation from the mean of the given source data variable (LOWNJA, LOWSJA, or LOWAJA in the case of data variable CYCJA; LOWNJL, LOWSJL, or LOWAJL in the case of data variable CYCJL) for each 5° x 5° grid cell. The actual means and standard deviations used in the calculations of data variables CYCJA, CYCJL, and CYCLONE from Data Sources (1), (2), and (3) are given in Table A-5.

A given data value may be reconverted to an actual number of cyclone occurrences by inverting the equation in Step (3) above and using the means and standard deviations in Table 5.

Table A-5. Means and standard deviations used to calculate data values for data variables CYCJA, CYCJL, and CYCLONE for Date Sources (1), (2), and (3)

Data region mean and std. dev.	Data variable CYCJA	Data variable CYCJL	Data variable CYCLONE
Northern hemisphere:			
Mean	0.360	0.400	4.730
Std. dev.	0.420	0.496	5.054
Southern hemisphere:			
Mean	0.844	1.019	11.175
Std. dev.	1.194	1.305	14.290
Australian region:			
Mean	1.340	1.211	14.257
Std. Dev.	1.321	1.324	11.170

Data Variable CYCLONE.

Data variable CYCLONE is a global data variable representing the annual global distribution of cyclones. All 2,592 5° x 5° grid cells contain real data. There are no flagged data values in this data variable.

Data variable CYCLONE is based on data variables CYCJA and CYCJL before standardizations. Each of the data values for data variable CYCLONE was calculated by entering data value for each grid cell x from data variables CYCJA and CYCJL into the following equation.

$$\text{CYCLONE}(x) = \frac{\dfrac{[\text{CYCJA}(x) + \text{CYCJL}(x)]}{2} - \text{Average of January and July mean for given data source}}{\text{Average of January and July standard deviation for given data source}}$$

Data variable CYCLONE provides an estimate of the relative number of cyclone occurrences per year for each 5° x 5° grid cell on the globe.

DATA GROUP MONSOON.

Data group MONSOON contains one data variable identified by the name MONSOON. This variable is an index of the influence of winds on coastlines in the African, Asian, and Australian monsoon regions.

Information About the Data Sources

Specific information concerning the characteristics and use of the data sources for data group MONSOON is described in the following. Data source documents are listed by title. For a fuller citation of each reference, see Part 1 as noted in brackets.

1. *Marine Climatic Atlas of the World, Vol. IX: World-wide Means and Standard Deviations* [Part 1, Sect. 12.3, Data Source (1)]. This data source provided contour maps of mean wind speed for the world for each month of the year. The wind-speed contours were given in knots and spaced at 2-knot intervals. The contour maps provided the information for the digital wind speed values compiled for 5° x 5° grid cells in the monsoon region defined for data group MONSOON.

2. *AWSTR 215* (Resultant Gradient-Level Wind); Charts 1-24 [Part 1, Sect. 12.3, Data Source (2)]. This data source provided streamlines for mean wind direction for all latitudes between 35°N and 35°S. The streamline charts also identified anticyclonic, cyclonic, and equatorial circulation systems. The spacing of the wind-direction streamlines varied from location to location but was sufficient to interpret mean wind direction for 1° x 1° grid cells in the monsoon region defined for data group MONSOON.

The computation process was done by hand for data variable MONSOON. All analysis involved visual and/or manual interpretation of the data sources.

The Data Variable

Data variable MONSOON was created by modifying and combining data from both data sources. The monsoon region, as modified to conform to the boundaries of 5° x 5° grid cells, for data group MONSOON is illustrated in Fig. 10 of Part 1 of this document. The latitude-longitude coordinates of the corners of the polygon defining the monsoon region are listed in Table A-6.

Table A-6. Latitude-longitude coordinates of the corners of the polygon defining the monsoon region in Fig. 10

Point number	Latitude-longitude	Point number	Latitude-longitude
(1)	35°N,115°E	(27)	0°N, 65°E
(2)	30°N,115°E	(28)	5°S, 65°E
(3)	30°N,130°E	(29)	5°S, 60°E
(4)	25°N,130°E	(30)	10°S, 60°E
(5)	25°N,135°E	(31)	10°S, 55°E
(6)	20°N,135°E	(32)	20°S, 55°E
(7)	20°N,145°E	(33)	20°S, 35°E
(8)	15°N,145°E	(34)	0°S, 35°E
(9)	15°N,150°E	(35)	0°S, 30°E
(10)	10°N,150°E	(36)	0°N, 30°E
(11)	10°N,155°E	(37)	0°N, 15°E
(12)	5°N,155°E	(38)	5°N, 15°E
(13)	5°N,160°E	(39)	5°N, 0°E
(14)	10°S,160°E	(40)	0°N, 0°E
(15)	10°S,155°E	(41)	0°N, 10°W
(16)	15°S,155°E	(42)	5°N, 10°W
(17)	15°S,150°E	(43)	5°N, 20°W
(18)	20°S,150°E	(44)	10°N, 20°W
(19)	20°S,115°E	(45)	10°N, 15°W
(20)	15°S,115°E	(46)	15°N, 15°W
(21)	15°S,110°E	(47)	15°N, 5°E
(22)	10°S,110°E	(48)	20°N, 5°E
(23)	10°S,100°E	(49)	20°N, 50°E
(24)	5°S,100°E	(50)	30°N, 50°E
(25)	5°S, 90°E	(51)	30°N, 75°E
(26)	0°N, 90°E	(52)	35°N, 75°E

None of the 1° x 1° grid cells (that comprise the area with data values for data variable MONSOON) used in data group MONSOON were corrected for latitudinal differences in the areas of 1° x 1° grid cells.

The 1° x 1° grid cells that were not included in the data analysis region for data group MONSOON in the flat ASCII data file have a data value of 999. Further derivation procedures for data variable MONSOON are discussed by data source in the following.

Data Source (1).

To place data group MONSOON into a grid-based system like most other data groups in this NDP, it was necessary to convert the contoured wind-speed information into a digital format. Contour lines were converted to digital values using the following process.

1. Each of the 12 contour maps (representing each month of the year) from Data Source (1) was divided into 5° x 5° grid cells. Only 5° x 5° grid cells contained in the general area defined as a monsoon region were analyzed (see Fig. 10 of Part 1 for an illustration of the monsoon region for data group MONSOON). All of the 5° x 5° grid cells have boundaries that are multiples of 5 (e.g., 25°N, 15°S, and 100°E, not 27°N, 13°S, or 101°E).

2. The contour lines (showing mean wind speeds for the month of a given contour map) crossing over each grid cell were noted. A contour line was considered to cross over a grid cell if it existed in the interior of a grid cell or if the contour line at least touched a corner or side of the grid cell. A contour line crossing the same grid cell at two separate times was considered to be two separate lines.

3. The data values for each of the contour lines crossing over a given 5° x 5° grid cell were added together. The differing lengths of the particular contour lines within a given 5° x 5° grid cell were not taken into account.

4. The sum resulting from Step (3) was then divided by the number of contour lines contained within the given 5° x 5° grid cell. The resulting number yielded the mean wind speed in knots for the month of a given contour map within a given 5° x 5° grid cell.

5. Steps (1) through (4) were repeated for each month of the year with the Data Source (1) contour maps.

6. A slightly different approach was followed for 5° x 5° grid cells that contained two or more significant and separate coastlines having highly contrasting wind speed contours between the various coastlines. In these cases, each coastline was treated separately (as if the given coastline were a complete 5° x 5° grid cell) and the procedures outlined in Steps (1) through (5), above. Afterwards, the results for each coastline in the 5° x 5° grid cell were averaged together for each month.

An example of a wind-speed contour map and the resulting digital data values are provided in Fig. A-6.

The conversion of the 12 wind speed contour maps resulted in 12 digital values (one for each month of the year) for each 5° x 5° grid cell in data group MONSOON. The digital values derived from Data Source (1) for each 5° x 5° grid cell along with a 12-month annual sum are listed in Tables A-7 and A-8.

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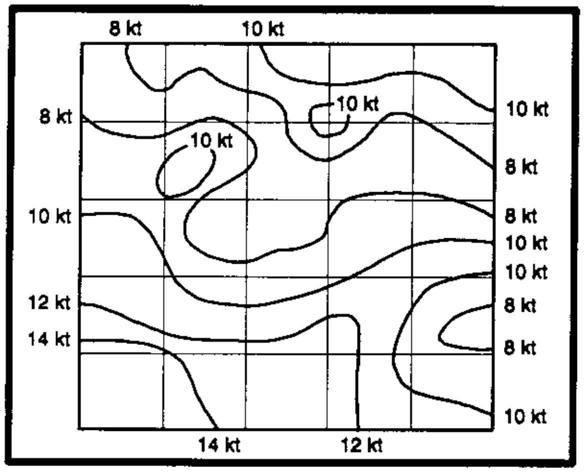

a

8.0	8.0	9.3	9.3	9.0
9.0	8.5	8.7	8.7	8.0
10.0	9.0	8.0	9.0	9.3
13.0	12.0	11.0	10.7	9.0
14.0	14.0	13.0	11.0	10.0

b

Fig. A-6. A sample conversion of a wind-speed contour map into digital data according to the derivation procedures used for data variable MONSOON. (a) Contour map of the type used for data derivation; (b) resultant digital values in knots for each 5° x 5° grid cell.

Table A-7. Digital values in knots derived from Data Source (1) for each 5° x 5° grid cell in the monsoon region of data group MONSOON (Each grid cell is identified by the latitude-longitude of its center.) for January through June

Grid cell location	JAN	FEB	MAR	APR	MAY	JUN
12.5°N,012.5°W	6.0	7.0	7.0	7.0	7.0	7.0
07.5°N,012.5°W	6.0	6.0	6.0	6.0	7.0	9.0
07.5°N,007.5°W	5.0	7.0	6.0	6.0	7.0	9.0
02.5°N,007.5°W	7.0	6.0	7.0	7.0	9.0	10.0
07.5°N,002.5°W	6.0	6.0	6.0	7.0	7.0	8.0
02.5°N,002.5°W	7.0	6.0	7.0	8.0	8.0	9.0
07.5°N,002.5°E	7.0	7.0	8.0	7.0	8.0	8.0
07.5°N,007.5°E	7.0	7.0	8.0	7.0	8.0	9.0
17.5°N,037.5°E	10.0	10.0	10.0	9.0	8.0	8.0
02.5°S,037.5°E	9.0	9.0	7.0	8.0	11.0	10.0
07.5°S,037.5°E	9.0	9.0	7.0	8.0	12.0	10.0
12.5°S,037.5°E	9.0	9.0	7.0	9.0	12.0	11.0
17.5°S,037.5°E	12.0	10.0	9.0	9.0	10.0	9.0
17.5°N,042.5°E	11.0	10.0	10.0	10.0	7.0	8.0
12.5°N,042.5°E	13.3	13.3	14.0	12.0	7.0	6.7
02.5°N,042.5°E	12.0	11.0	9.0	9.0	10.0	13.0
02.5°S,042.5°E	11.0	10.0	8.0	8.0	11.0	12.0
12.5°S,042.5°E	10.0	9.0	8.0	10.0	11.0	11.0
17.5°S,042.5°E	10.0	9.0	10.0	10.0	10.0	10.0
12.5°N,047.5°E	11.0	12.0	10.0	9.0	6.0	8.0
07.5°N,047.5°E	14.0	11.0	10.0	7.0	12.0	16.0
02.5°N,047.5°E	13.3	10.0	9.0	8.0	11.0	15.0
07.5°S,047.5°E	9.0	9.0	7.0	9.0	14.0	13.0
12.5°S,047.5°E	9.0	9.0	8.0	10.0	13.0	13.0
17.5°S,047.5°E	10.0	10.0	10.0	10.0	10.0	11.0
27.5°N,052.5°E	10.0	10.0	11.0	8.0	8.0	9.0
22.5°N,052.5°E	9.0	11.0	11.0	9.0	8.0	10.0
17.5°N,052.5°E	9.0	7.0	8.0	8.0	7.0	13.0
12.5°N,052.5°E	11.0	9.0	8.0	8.0	9.0	17.0
07.5°N,052.5°E	13.0	10.0	10.0	6.0	12.7	21.0
02.5°S,052.5°E	10.0	9.0	7.0	6.0	13.0	14.0
07.5°S,052.5°E	10.0	9.0	7.0	9.0	14.0	14.0
12.5°S,052.5°E	10.0	9.0	8.0	10.0	14.5	14.0
17.5°S,052.5°E	10.0	10.0	10.0	10.0	12.0	13.0
27.5°N,057.5°E	8.0	9.0	10.0	8.0	7.0	7.0
22.5°N,057.5°E	8.0	8.0	8.0	7.0	10.0	12.0
17.5°N,057.5°E	10.0	8.0	7.0	6.0	11.0	20.0
02.5°S,057.5°E	8.0	9.0	7.0	6.0	9.0	11.0
07.5°S,057.5°E	8.0	9.0	7.0	9.0	12.0	13.0
27.5°N,062.5°E	8.0	8.0	9.0	8.0	9.0	10.0

Table A-7 (continued)

Grid cell location	JAN	FEB	MAR	APR	MAY	JUN
27.5°N,067.5°E	9.0	7.0	9.0	9.0	12.0	14.0
22.5°N,067.5°E	10.0	8.0	8.0	8.0	11.3	16.0
22.5°N,072.5°E	9.0	8.0	9.0	10.0	11.0	14.0
17.5°N,072.5°E	8.0	8.0	8.0	9.0	9.0	15.0
12.5°N,072.5°E	8.0	8.0	7.0	6.0	8.0	14.0
07.5°N,072.5°E	8.0	8.0	6.0	6.0	9.0	12.0
02.5°N,072.5°E	8.0	7.0	6.0	6.0	10.0	10.0
12.5°N,077.5°E	9.0	7.0	7.0	6.0	11.0	12.0
07.5°N,077.5°E	9.0	9.0	6.0	6.0	11.0	11.3
17.5°N,082.5°E	9.0	6.0	7.0	8.0	13.0	15.0
12.5°N,082.5°E	9.0	7.0	7.0	7.0	13.0	15.0
07.5°N,082.5°E	10.0	9.0	6.0	7.0	14.0	15.0
22.5°N,087.5°E	6.0	6.0	8.0	10.0	13.0	14.0
17.5°N,087.5°E	9.0	6.0	7.0	8.0	12.0	16.0
22.5°N,092.5°E	6.0	6.0	8.0	9.0	11.0	14.0
17.5°N,092.5°E	8.0	7.0	6.0	7.0	11.0	15.0
12.5°N,092.5°E	10.0	8.0	6.0	6.0	11.0	15.0
07.5°N,092.5°E	9.0	7.0	6.0	6.0	9.0	12.0
17.5°N,097.5°E	7.0	6.0	6.0	7.0	9.0	12.0
12.5°N,097.5°E	7.0	6.0	7.0	6.0	8.0	11.0
07.5°N,097.5°E	8.0	6.0	7.0	6.0	7.0	10.0
02.5°N,097.5°E	7.0	6.0	6.0	6.0	6.0	7.0
02.5°S,097.5°E	8.0	7.0	7.0	7.0	7.0	7.0
12.5°N,102.5°E	9.0	9.0	8.0	7.0	8.0	10.0
07.5°N,102.5°E	9.0	8.0	7.0	6.0	6.0	9.0
02.5°N,102.5°E	8.0	8.0	6.0	6.0	5.0	6.0
02.5°S,102.5°E	8.0	6.0	7.0	6.0	7.0	7.0
12.5°S,102.5°E	10.0	8.0	9.0	10.0	11.0	11.0
22.5°N,107.5°E	11.0	12.0	11.0	11.0	11.0	10.0
17.5°N,107.5°E	12.0	12.0	12.0	10.0	11.0	10.0
12.5°N,107.5°E	15.0	12.0	12.0	8.0	8.0	11.0
07.5°N,107.5°E	13.0	12.0	9.0	6.0	7.0	10.0
02.5°N,107.5°E	11.0	9.0	6.0	6.0	6.0	7.0
02.5°S,107.5°E	8.0	8.0	6.0	6.0	6.0	8.0
07.5°S,107.5°E	10.0	8.0	9.0	10.0	10.0	11.0
22.5°N,112.5°E	15.0	14.0	12.0	11.0	9.0	10.0
17.5°N,112.5°E	15.0	14.0	12.0	10.0	9.0	11.0
07.5°N,112.5°E	14.0	12.0	7.0	6.0	7.0	9.0
02.5°N,112.5°E	13.0	10.0	7.0	5.0	5.0	6.0
02.5°S,112.5°E	9.0	7.0	7.0	6.0	7.0	8.0
07.5°S,112.5°E	9.0	8.0	9.0	9.0	9.0	10.0
27.5°N,117.5°E	17.0	17.0	15.0	11.0	11.0	9.0

Table A-7 (continued)

Grid cell location	JAN	FEB	MAR	APR	MAY	JUN
22.5°N,117.5°E	16.0	16.0	13.0	11.0	10.0	10.0
17.5°N,117.5°E	15.0	15.0	11.0	10.0	9.0	12.0
12.5°N,117.5°E	14.0	12.0	10.0	8.0	8.0	11.0
02.5°N,117.5°E	10.0	11.0	9.0	6.0	7.0	8.0
02.5°N,117.5°E	9.0	8.0	7.0	5.0	5.0	5.0
02.5°S,117.5°E	8.0	7.0	6.0	5.0	6.0	6.0
07.5°S,117.5°E	8.0	8.0	7.0	7.0	8.0	8.0
12.5°S,117.5°E	11.0	10.0	9.0	9.0	10.0	12.0
27.5°N,122.5°E	16.0	13.0	14.0	12.0	10.0	10.0
22.5°N,122.5°E	17.0	16.0	13.0	12.0	10.0	10.0
17.5°N,122.5°E	15.0	15.0	11.0	10.0	10.0	10.0
12.5°N,122.5°E	12.0	12.0	9.0	8.0	8.0	8.0
07.5°N,122.5°E	9.0	9.0	8.0	6.0	6.0	6.0
02.5°N,122.5°E	7.0	8.0	6.0	5.0	5.0	5.0
02.5°S,122.5°E	7.0	7.0	6.0	5.0	6.0	6.0
07.5°S,122.5°E	8.0	8.0	6.0	6.0	8.0	9.0
12.5°S,122.5°E	10.0	10.0	8.0	7.0	10.0	11.0
17.5°S,122.5°E	11.0	10.0	10.0	8.0	10.0	10.0
27.5°N,127.5°E	16.0	14.0	14.0	12.0	10.0	10.0
22.5°N,127.5°E	16.0	14.0	13.0	12.0	10.0	10.0
12.5°N,127.5°E	13.0	12.0	11.0	9.0	8.0	8.0
07.5°N,127.5°E	9.0	11.0	9.0	7.0	6.0	6.0
02.5°N,127.5°E	8.0	8.0	7.0	5.0	5.0	5.0
02.5°S,127.5°E	7.0	7.0	6.0	5.0	7.0	8.0
07.5°S,127.5°E	8.0	8.0	7.0	6.0	8.0	9.0
12.5°S,127.5°E	9.0	9.0	8.0	7.0	9.0	10.0
17.5°S,127.5°E	9.0	9.0	9.0	7.0	9.0	10.0
07.5°N,132.5°E	11.0	11.0	10.0	8.0	7.0	6.0
02.5°N,132.5°E	8.0	8.0	8.0	6.0	6.0	5.0
02.5°S,132.5°E	8.0	7.0	8.0	6.0	8.0	8.0
07.5°S,132.5°E	8.0	8.0	8.0	7.0	10.0	11.0
12.5°S,132.5°E	9.0	9.0	9.0	8.0	10.0	10.0
12.5°N,132.5°E	15.0	14.0	14.0	12.0	10.0	9.0
07.5°N,137.5°E	11.0	11.0	11.0	9.0	9.0	6.0
02.5°S,137.5°E	8.0	7.0	8.0	6.0	7.5	6.0
07.5°S,137.5°E	9.0	8.0	9.0	7.0	11.0	12.0
12.5°S,137.5°E	9.0	9.0	9.0	9.0	11.0	11.0
22.5°S,137.5°E	9.0	9.0	9.0	9.0	11.0	9.0
17.5°N,142.5°E	15.0	14.0	14.0	12.0	11.0	10.0
12.5°N,142.5°E	15.0	14.0	14.0	12.0	11.0	9.0
07.5°N,142.5°E	11.0	12.0	12.0	11.0	9.0	7.0
02.5°S,142.5°E	7.0	7.0	7.0	6.0	5.0	6.0

Table A-7 (continued)

Grid cell location	JAN	FEB	MAR	APR	MAY	JUN
07.5°S,142.5°E	8.0	7.0	9.0	8.0	11.0	12.0
12.5°S,142.5°E	9.0	7.0	10.0	9.0	11.0	11.0
17.5°S,142.5°E	9.0	9.0	10.0	9.0	11.0	10.0
12.5°N,147.5°E	14.0	15.0	15.0	13.0	12.0	10.0
07.5°N,147.5°E	12.0	13.0	13.0	11.0	9.0	7.0
02.5°N,147.5°E	8.0	9.0	9.0	8.0	6.0	6.0
02.5°S,147.5°E	7.0	8.0	7.0	6.0	5.0	7.0
07.5°S,147.5°E	8.0	6.0	8.0	7.0	8.0	10.5
12.5°S,147.5°E	8.0	7.0	10.0	11.0	11.0	12.0
17.5°S,147.5°E	10.0	9.0	12.0	10.0	11.0	11.0
07.5°N,152.5°E	12.0	13.0	13.0	11.0	9.0	9.0
02.5°N,152.5°E	9.0	10.0	9.0	8.0	7.0	6.0
02.5°S,152.5°E	7.0	8.0	8.0	6.0	5.0	6.0
07.5°S,152.5°E	7.0	7.0	7.0	8.0	8.0	9.0
12.5°S,152.5°E	8.0	8.0	9.0	11.3	10.0	12.0
02.5°N,157.5°E	9.0	11.0	10.0	9.0	7.0	8.0
07.5°S,157.5°E	7.0	6.0	7.0	8.0	7.0	9.0

Table A-8. Digital values derived from Data Source (1) for each 5° x 5° grid cell in the monsoon region of data group MONSOON (Each grid cell is identified by the latitude-longitude of its center.) for July through December and the year

Grid cell location	JUL	AUG	SEP	OCT	NOV	DEC	ANN
12.5°N,012.5°W	9.0	11.0	7.0	5.0	5.0	6.0	84.0
07.5°N,012.5°W	11.0	12.0	8.0	7.0	6.0	6.0	90.0
07.5°N,007.5°W	9.0	10.0	8.0	7.0	7.0	6.0	90.0
02.5°N,007.5°W	10.0	10.0	9.3	9.0	9.0	8.0	101.3
07.5°N,002.5°W	8.0	8.0	7.0	7.0	7.0	5.0	82.0
02.5°N,002.5°W	9.3	9.3	9.3	9.0	8.0	7.0	96.9
07.5°N,002.5°E	9.0	9.0	8.0	8.0	7.0	7.0	93.0
07.5°N,007.5°E	11.0	10.0	9.0	7.0	7.0	7.0	97.0
17.5°N,037.5°E	9.0	9.3	7.0	6.0	8.0	9.0	103.3
02.5°S,037.5°E	11.0	10.0	9.0	7.0	7.0	7.0	105.0
07.5°S,037.5°E	11.0	10.0	9.0	7.0	7.0	7.0	106.0
12.5°S,037.5°E	11.0	11.0	9.0	7.0	7.0	7.0	109.0
17.5°S,037.5°E	10.0	9.0	10.0	10.0	10.0	10.0	118.0
17.5°N,042.5°E	9.0	9.0	6.0	8.0	11.0	13.0	112.0
12.5°N,042.5°E	9.0	9.0	6.0	10.4	15.0	15.0	130.7
02.5°N,042.5°E	14.0	13.0	12.0	9.0	8.0	11.0	131.0
02.5°S,042.5°E	13.0	12.0	11.0	8.0	7.0	9.0	120.0
12.5°S,042.5°E	11.0	10.0	10.0	9.0	8.0	7.0	114.0
17.5°S,042.5°E	10.0	10.0	10.0	9.0	9.0	8.0	115.0
12.5°N,047.5°E	12.0	9.0	6.7	7.0	10.0	10.0	110.7
07.5°N,047.5°E	17.0	17.0	16.0	9.0	10.0	14.0	153.0
02.5°N,047.5°E	16.0	16.0	15.0	9.0	7.0	12.0	141.3
07.5°S,047.5°E	15.0	14.0	13.0	11.0	9.0	7.0	130.0
12.5°S,047.5°E	14.0	13.0	12.0	10.0	9.0	7.0	127.0
17.5°S,047.5°E	12.0	10.0	11.5	10.0	8.0	9.0	121.5
27.5°N,052.5°E	6.0	6.0	6.0	6.0	8.0	9.3	97.3
22.5°N,052.5°E	7.0	7.0	6.0	7.0	8.0	8.0	101.0
17.5°N,052.5°E	15.0	15.0	10.0	6.0	8.0	10.0	116.0
12.5°N,052.5°E	19.0	18.6	13.6	7.0	9.0	12.0	141.2
07.5°N,052.5°E	22.3	21.0	17.0	8.0	10.0	13.0	164.0
02.5°S,052.5°E	14.0	15.0	13.0	10.0	6.0	8.0	122.0
12.5°S,052.5°E	16.0	17.0	14.0	12.0	9.0	7.0	138.0
17.5°S,052.5°E	17.3	16.0	14.0	12.0	11.0	8.0	143.8
17.5°S,052.5°E	14.0	14.0	13.0	10.0	9.0	8.0	133.0
27.5°N,057.5°E	6.7	6.0	6.0	6.0	6.0	8.0	87.7
22.5°N,057.5°E	13.0	13.0	8.0	6.0	6.0	8.0	107.0
17.5°N,057.5°E	22.0	21.0	14.0	6.0	9.0	9.0	143.0
02.5°S,057.5°E	10.0	13.0	11.0	9.0	9.0	8.0	110.0
07.5°S,057.5°E	13.0	17.0	13.0	12.0	6.0	7.0	126.0
27.5°N,062.5°E	10.0	10.0	9.0	6.0	6.0	7.0	100.0

Table A-8 (continued)

Grid cell location	JUL	AUG	SEP	OCT	NOV	DEC	ANN
27.5°N,067.5°E	12.0	12.0	11.0	7.0	7.0	7.0	116.0
22.5°N,067.5°E	17.0	16.0	11.0	8.0	8.0	8.0	129.3
22.5°N,072.5°E	19.0	14.0	10.0	8.0	8.0	8.0	128.0
17.5°N,072.5°E	18.0	14.0	10.0	8.0	7.0	8.0	122.0
12.5°N,072.5°E	16.0	13.0	9.0	7.0	7.0	8.0	111.0
07.5°N,072.5°E	12.0	11.0	8.0	9.0	6.0	8.0	113.0
02.5°N,072.5°E	9.0	9.0	8.0	9.0	7.0	7.0	96.0
12.5°N,077.5°E	11.0	11.0	9.0	6.0	7.5	10.0	106.5
07.5°N,077.5°E	11.0	11.3	11.0	9.0	8.0	10.0	112.6
17.5°N,082.5°E	15.0	13.0	10.0	9.0	10.0	12.0	127.0
12.5°N,082.5°E	14.0	13.0	11.0	9.0	10.0	11.0	126.0
07.5°N,082.5°E	15.0	13.0	13.0	11.0	10.0	10.0	133.0
22.5°N,087.5°E	15.0	12.0	10.0	8.0	8.0	8.0	118.0
17.5°N,087.5°E	16.7	15.0	10.0	9.0	10.0	11.0	129.7
22.5°N,092.5°E	14.0	11.0	8.0	8.0	8.0	8.0	111.0
17.5°N,092.5°E	15.0	13.0	10.0	8.0	9.0	11.0	120.0
12.5°N,092.5°E	15.0	13.0	11.0	8.0	9.0	11.0	123.0
07.5°N,092.5°E	14.0	12.0	11.0	9.0	8.0	8.0	111.0
17.5°N,097.5°E	13.0	12.0	8.0	6.0	7.0	8.0	101.0
12.5°N,097.5°E	13.0	11.0	9.0	6.0	7.0	8.0	99.0
07.5°N,097.5°E	9.0	8.0	8.0	6.0	7.0	8.0	90.0
02.5°N,097.5°E	8.0	7.0	7.0	7.0	7.0	7.0	81.0
02.5°S,097.5°E	8.0	9.0	8.0	9.0	8.0	8.0	93.0
12.5°N,102.5°E	10.0	10.0	10.0	8.0	9.0	10.0	108.0
07.5°N,102.5°E	9.0	8.0	8.0	7.0	9.3	10.0	96.3
02.5°N,102.5°E	7.0	8.0	8.0	6.0	9.0	8.0	85.0
02.5°S,102.5°E	8.0	9.0	9.0	9.0	8.0	7.0	91.0
12.5°S,102.5°E	12.0	13.0	13.0	14.0	12.0	9.0	132.0
22.5°N,107.5°E	10.0	10.0	10.0	12.0	12.0	12.0	132.0
17.5°N,107.5°E	11.0	10.0	10.0	12.0	13.0	14.0	137.0
12.5°N,107.5°E	13.0	12.7	10.0	11.0	14.0	16.0	142.7
07.5°N,107.5°E	11.0	11.0	9.0	9.0	12.0	13.0	122.0
02.5°N,107.5°E	8.0	8.0	8.0	6.0	9.0	10.0	94.0
02.5°S,107.5°E	9.0	10.0	10.0	7.0	6.0	8.0	92.0
07.5°S,107.5°E	12.0	11.5	12.0	11.0	10.0	9.0	123.5
22.5°N,112.5°E	10.0	10.0	12.0	14.0	15.0	16.0	148.0
17.5°N,112.5°E	13.0	11.0	11.0	14.0	17.0	17.0	154.0
07.5°N,112.5°E	11.0	11.0	8.0	9.0	11.0	13.0	118.0
02.5°N,112.5°E	8.0	8.0	6.0	6.0	8.0	11.0	93.0
02.5°S,112.5°E	10.0	9.0	10.0	6.0	6.0	8.0	93.0
07.5°S,112.5°E	10.7	11.0	10.7	9.0	8.0	9.0	112.4

Table A-8 (continued)

Grid cell location	JUL	AUG	SEP	OCT	NOV	DEC	ANN
27.5°N,117.5°E	9.0	8.0	13.0	20.0	17.0	20.0	167.0
22.5°N,117.5°E	10.0	11.0	12.0	17.0	19.0	20.0	165.0
17.5°N,117.5°E	12.0	12.0	12.0	14.0	17.2	17.2	156.2
12.5°N,117.5°E	11.0	11.0	10.0	10.0	13.0	14.0	132.0
02.5°N,117.5°E	10.0	10.0	8.0	8.0	8.0	10.0	105.0
02.5°N,117.5°E	7.0	7.0	6.0	6.0	5.0	8.0	80.0
02.5°S,117.5°E	9.0	8.0	8.0	6.0	5.0	7.0	81.0
07.5°S,117.5°E	11.0	11.0	9.3	8.0	5.0	8.0	98.3
12.5°S,117.5°E	12.0	11.0	9.0	8.0	9.0	10.0	120.0
27.5°N,122.5°E	11.0	10.0	11.0	15.7	14.0	18.0	154.7
22.5°N,122.5°E	11.0	10.0	13.0	18.0	18.0	19.0	157.0
17.5°N,122.5°E	11.0	12.0	12.0	13.0	16.0	17.0	152.0
12.5°N,122.5°E	8.0	9.0	8.0	9.0	10.0	11.0	112.0
07.5°N,122.5°E	7.0	7.0	6.0	6.0	7.0	8.0	85.0
02.5°N,122.5°E	8.0	7.0	5.0	6.0	5.0	6.0	73.0
02.5°S,122.5°E	9.0	8.0	6.0	6.0	4.0	6.0	76.0
07.5°S,122.5°E	10.0	9.0	6.0	6.0	5.0	8.0	89.0
12.5°S,122.5°E	10.0	9.0	6.0	8.0	7.0	9.0	105.0
17.5°S,122.5°E	10.0	8.0	8.0	8.0	9.0	9.0	111.0
27.5°N,127.5°E	12.0	12.0	13.0	15.0	15.0	17.0	160.0
22.5°N,127.5°E	12.0	12.0	13.0	15.0	17.0	18.0	162.0
12.5°N,127.5°E	8.0	9.0	9.0	9.0	10.0	12.0	118.0
07.5°N,127.5°E	7.0	8.0	7.0	7.0	6.0	8.0	91.0
02.5°N,127.5°E	8.0	8.0	6.0	6.0	6.0	6.0	78.0
02.5°S,127.5°E	10.0	9.0	7.0	7.0	4.0	6.0	83.0
07.5°S,127.5°E	10.0	8.0	7.0	6.0	4.0	7.0	88.0
12.5°S,127.5°E	10.0	8.0	6.0	6.0	6.0	7.0	95.0
17.5°S,127.5°E	9.0	7.0	7.0	6.0	7.0	7.0	96.0
07.5°N,132.5°E	8.0	9.0	8.0	8.0	8.0	9.0	103.0
02.5°N,132.5°E	8.0	8.0	7.0	6.0	6.0	6.0	82.0
02.5°S,132.5°E	10.0	9.0	9.0	7.0	6.0	6.0	92.0
07.5°S,132.5°E	12.0	10.0	9.0	7.0	5.0	7.0	102.0
12.5°S,132.5°E	11.0	9.0	9.0	6.0	6.0	7.0	103.0
12.5°N,137.5°E	10.0	10.0	10.0	10.0	11.0	13.0	138.0
07.5°N,137.7°E	8.0	8.0	8.0	8.0	8.0	9.0	106.0
02.5°S,137.5°E	6.7	10.0	7.0	7.0	6.0	7.0	86.2
07.5°S,137.5°E	13.0	12.0	7.0	9.0	6.0	7.0	110.0
12.5°S,137.5°E	12.0	11.0	6.0	9.0	6.0	7.0	109.0
17.5°S,137.5°E	11.0	9.0	7.0	9.0	7.0	7.0	106.0
17.5°N,142.5°E	10.0	10.0	12.0	12.0	14.0	16.0	150.0
12.5°N,142.5°E	10.0	10.0	10.0	10.0	11.0	13.0	139.0
07.5°N,142.5°E	8.0	8.0	8.0	8.0	8.0	10.0	112.0

Table A-8 (continued)

Grid cell location	JUL	AUG	SEP	OCT	NOV	DEC	ANN
02.5°S,142.5°E	7.0	8.0	7.0	6.0	7.0	7.0	80.0
07.5°S,142.5°E	14.0	12.0	11.0	11.0	8.0	7.0	118.0
12.5°S,142.5°E	13.0	11.0	10.0	10.0	8.0	8.0	117.0
17.5°S,142.5°E	11.0	9.0	11.0	9.0	7.0	7.0	112.0
12.5°N,147.5°E	9.0	8.0	9.0	10.0	11.0	14.0	140.0
07.5°N,147.5°E	8.0	8.0	8.0	8.0	8.0	11.0	116.0
02.5°N,147.5°E	7.0	7.0	7.0	7.0	7.0	8.0	89.0
02.5°S,147.5°E	9.0	8.0	7.0	8.0	7.0	7.0	86.0
07.5°S,147.5°E	13.0	11.0	9.5	8.0	7.0	7.0	103.0
12.5°S,147.5°E	13.3	11.0	10.0	9.0	8.0	7.0	117.3
17.5°S,147.5°E	11.0	9.0	9.0	9.0	9.0	8.0	118.0
07.5°N,152.5°E	8.0	7.0	7.0	8.0	9.0	11.0	117.0
02.5°N,152.5°E	7.0	7.0	7.0	7.0	7.0	9.0	93.0
02.5°S,152.5°E	9.0	8.0	7.0	7.0	7.0	7.0	85.0
07.5°S,152.5°E	11.0	10.0	9.0	8.0	8.0	7.0	99.0
12.5°S,152.5°E	14.0	13.0	11.0	10.0	9.0	8.0	123.3
02.5°N,157.5°E	7.0	7.0	7.0	7.0	8.0	9.0	99.0
07.5°S,157.5°E	10.0	10.0	9.0	8.0	8.0	6.0	95.0

Data Source (2).

Data Source (2) was analyzed using 1° x 1° grid cells based on whole numbers of latitude and longitude (i.e., 1° x 1° borders are 37°N, 104°E, 5°S, etc.). All of the 1° x 1° grid cells analyzed for data group MONSOON contain significant coastlines. Also, all of the analyzed 1° x 1° grid cells are inside the boundaries of the 5° x 5° grid cells analyzed for wind speeds in Data Source (1).

For each 1° x 1° grid cell, the streamline gradient wind-flow charts were visually interpreted using the following steps.

1. The mean wind direction over a given 1° x 1° grid cell was determined by visually inspecting the wind-flow streamlines over the grid cell. This process was repeated for each of the 12 months of the year.

2. Each result from Step (1) was compared with the mean coastline orientation in the given 1° x 1° grid cell. The mean orientation of a given coastline in the given 1° x 1° grid cell was determined by visual interpretation of a map for the given coastline. The map used for the wind-flow streamline charts in Data Source (2) was also used for the interpretation of coastline orientation.

If the coastline within a given 1° x 1° grid cell contained highly irregular orientations (i.e., widely varying coastline directions within a given 1° x 1° grid cell), then the orientation of the largest portion of coastline comprising a consistent coastline orientation was taken to represent the coastline orientation for the given 1° x 1° grid cell.

3. For coastlines representing islands, 1° x 1° grid cells containing the islands were always designated as having onshore wind flow. For the purposes of data group MONSOON, an island was defined as any landmass having an area smaller than a 1° x 1° grid cell at the latitude of the given landmass.

4. After the mean wind direction and coastline orientation for a nonisland 1° x 1° grid cell were determined for a given month, the mean wind direction and coastline orientation were compared with respect to the compass. If the given mean wind direction was determined to be within 90° of moving directly toward the given coastline orientation, then the given 1° x 1° grid cell was designated as having onshore wind flow during the month in question. Conversely, if the given mean wind direction was determined to be within 90° of moving directly away from the given coastline orientation, then the given 1° x 1° grid cell was designated as having offshore wind flow during the month in question. This process was repeated for all 12 months of the year. The onshore and offshore designations derived for each 1° x 1° grid cell are given for each month in Table A-7.

5. For each 1° x 1° grid cell, months having onshore winds were separated from those having offshore winds. The wind-speed values obtained for each month in Data Source (1) were then consulted for the Data Source (1) 5° x 5° grid cell containing the 1° x 1° grid cell in question. Wind-speed values for each month having onshore winds in the 1° x 1° grid cell were summed to obtain a single numerical value. Wind speed values for offshore wind months in the given 1° x 1° grid cell were not used. The resulting sum of wind speed values for months having onshore wind flow became the data value for data variable MONSOON in the given 1° x 1° grid cell.

Figure A-7 illustrates the process of converting the wind-flow streamline charts of Data Source (2) into onshore and offshore wind-flow indicators for 1° x 1° grid cells.

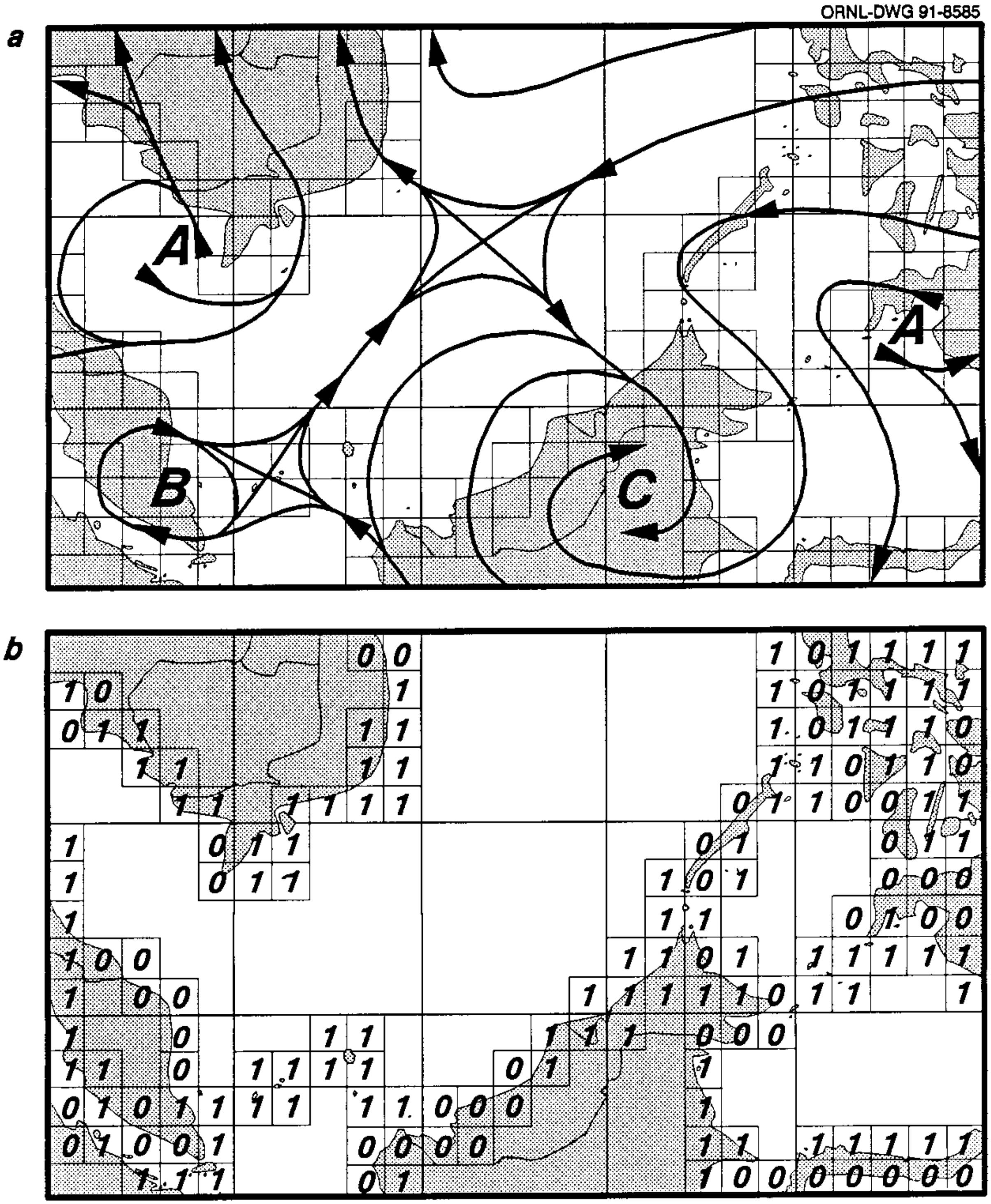

Fig. A-7. A sample conversion of a wind-flow streamline chart into digital onshore and offshore values, according to the procedures used for data variable MONSOON (The figure is theoretical and does not indicate the specific interpretations for actual data values in data variable MONSOON). (a) Wind-flow streamline chart of the type used for data derivation; (b) resultant digital values for each 1° x 1° grid cell ("1" identifies an onshore wind flow; "0" identifies an offshore wind flow).

Table A-9. Onshore and offshore wind-flow designations by month for the 1° x 1° grid cells analyzed in data group MONSOON. A wind-flow designation of "1" indicates onshore winds and a wind-flow designation of "0" indicates offshore winds. Consecutively numbered grid cells having identical data values for all 12 months are grouped in the table

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0001	1	1	1	1	1	1	1	1	1	1	1	1
0002-0003	0	0	0	0	1	0	1	1	1	1	1	0
0004	1	1	1	1	1	1	1	1	1	1	1	1
0005	1	1	1	1	0	1	1	1	0	0	1	1
0006	1	1	1	1	1	1	1	1	0	1	1	1
0007	1	1	1	1	0	0	1	1	1	1	1	0
0008-0009	1	1	1	1	0	1	1	1	1	1	1	0
0010-0012	1	1	1	1	1	1	1	1	1	1	1	1
0013	0	1	1	1	0	0	0	0	0	0	0	0
0014	1	1	1	1	1	1	0	1	0	0	0	0
0015	1	1	1	1	0	0	1	1	0	0	0	0
0016	1	1	1	1	1	0	0	0	0	0	0	0
0017	0	0	0	0	1	0	1	1	1	1	1	0
0018	0	0	0	0	1	1	1	1	1	1	1	0
0019-0020	1	1	1	1	1	1	1	1	1	1	1	1
0021	0	0	0	0	0	0	0	0	1	1	0	0
0022	1	1	1	1	1	1	1	1	1	1	1	1
0023	1	1	1	1	1	1	0	1	1	1	1	1
0024	1	1	1	1	1	1	1	1	0	0	0	0
0025	0	0	0	1	0	0	0	0	0	0	0	0
0026	0	0	0	0	0	0	0	0	0	0	0	0
0027	1	1	1	1	1	1	1	1	1	1	0	0
0028	0	1	1	0	1	1	1	1	0	1	1	1
0029-0030	0	0	1	0	1	0	1	1	1	1	1	0
0031-0035	1	1	1	1	1	1	1	1	1	1	1	1
0036	1	0	1	1	1	1	1	1	1	1	1	1
0037	0	1	0	0	0	0	0	0	1	0	0	0
0038-0041	1	1	1	1	1	1	1	1	1	1	1	1
0042	0	0	0	0	0	0	0	0	1	0	0	0
0043	0	1	1	1	1	1	1	1	0	1	0	1
0044	0	0	0	0	0	0	0	0	0	1	0	0
0045	0	0	0	1	1	0	1	0	0	1	0	0
0046-0048	0	0	0	0	1	0	1	0	0	1	0	0
0049-0051	0	0	0	0	1	0	1	0	0	0	0	0
0052	0	1	1	1	1	1	1	1	1	1	0	0
0053	0	0	0	1	1	1	1	0	1	0	0	0

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0054-0055	0	1	1	0	1	1	1	1	1	1	1	0
0056	1	1	0	0	1	0	0	0	0	1	1	0
0057	1	1	1	0	0	0	0	0	1	1	1	1
0058-0059	1	1	1	1	1	1	1	1	1	1	1	1
0060	0	0	0	0	0	0	0	0	1	1	1	1
0061	1	1	1	0	1	1	1	0	1	1	1	1
0062	1	1	1	0	1	1	1	1	1	1	1	1
0063-0064	1	1	1	1	1	1	1	1	1	1	1	1
0065	0	0	0	0	0	0	0	0	1	0	1	1
0066	0	0	1	0	0	1	0	0	0	0	1	1
0067-0068	1	1	1	1	1	1	1	1	1	1	1	1
0069	0	0	0	1	1	1	1	0	1	0	0	0
0070	0	1	1	1	1	1	1	1	1	1	0	0
0071-0073	0	1	0	1	0	1	1	1	1	1	1	0
0074	1	0	0	0	1	0	0	0	0	0	0	0
0075	1	1	1	0	0	0	0	1	1	1	1	1
0076-0079	1	1	1	1	1	1	1	1	1	1	1	1
0080	0	0	0	0	0	0	0	0	1	1	1	1
0081	1	1	1	0	1	1	1	0	1	1	1	1
0082	1	1	1	0	1	1	1	1	1	1	1	1
0083	1	1	1	1	1	1	1	1	1	1	1	1
0084	0	0	0	0	0	0	0	0	0	0	1	1
0085-0086	1	1	1	0	0	1	0	0	0	0	1	1
0087	0	0	1	0	0	0	0	0	0	0	1	1
0088	0	0	0	0	1	1	1	1	1	0	0	0
0089	0	0	1	1	1	1	1	1	1	0	0	0
0090-0091	0	0	0	0	0	0	1	0	0	0	0	0
0092	1	1	1	1	1	1	1	1	1	1	1	1
0093	0	1	1	1	1	1	1	1	1	0	0	0
0094	0	1	1	1	1	1	1	1	1	0	1	0
0095	1	1	0	1	1	1	1	1	1	1	1	0
0096	No data values calculated											
0097	0	1	1	1	1	1	1	1	1	1	1	1
0098	0	0	0	0	1	0	1	0	0	0	0	0
0099	1	1	1	0	0	0	0	1	1	1	1	1
0100	0	0	1	0	0	0	0	0	0	0	1	1
0101	0	0	0	0	1	1	1	1	1	0	0	0
0102	1	1	1	1	1	1	1	1	1	1	0	1
0103	0	1	1	1	1	1	1	1	1	1	0	0
0104	0	0	0	0	0	1	1	1	0	0	0	0

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0105	0	0	0	0	0	1	1	1	1	1	0	0
0106	0	0	0	0	1	1	1	1	1	0	0	0
0107	0	0	0	0	1	1	1	1	1	1	0	0
0108	0	0	0	0	1	1	1	1	1	1	1	0
0109	0	1	1	1	1	1	1	1	1	0	0	0
0110	0	1	1	1	1	1	1	1	1	0	0	0
0111	1	1	1	1	1	1	1	1	1	0	0	0
0112-0113	0	1	1	1	1	1	1	1	1	0	0	0
0114	0	1	1	1	1	1	1	1	1	0	1	0
0115	1	1	1	1	1	1	1	1	1	1	1	1
0116	0	1	0	1	1	1	1	1	0	0	0	0
0117	1	1	1	1	1	1	0	1	1	1	1	1
0118-0119	0	0	0	0	0	0	0	0	0	0	0	0
0120-0121	0	0	0	0	1	1	1	1	1	0	0	0
0122	0	0	0	0	0	0	0	0	0	0	1	1
0123	0	1	1	1	1	1	1	1	1	0	0	0
0124	0	0	0	0	0	0	0	0	0	1	0	1
0125	0	0	0	0	0	1	1	1	1	1	0	0
0126	0	0	0	0	1	1	1	1	1	0	0	0
0127	0	0	0	0	1	1	1	1	1	1	0	0
0128	0	0	0	0	1	1	1	1	1	1	0	0
0129-0130	1	1	1	1	1	1	1	1	1	0	0	1
0131	1	1	1	1	1	1	1	1	1	1	1	1
0132	0	1	1	1	1	1	1	1	0	1	0	0
0133	0	0	1	1	1	1	1	1	0	0	0	0
0134	1	1	1	1	1	1	1	1	0	1	0	0
0135	0	1	1	1	1	1	1	1	0	0	0	0
0136-0137	0	1	1	1	1	1	1	1	1	0	0	0
0138	1	1	1	1	1	1	1	1	1	1	1	1
0139	1	0	1	0	0	0	0	0	0	0	0	0
0140	1	1	1	0	0	0	0	0	0	0	0	0
0141	0	0	0	0	1	1	1	1	1	0	0	0
0142	0	0	0	0	0	0	0	0	0	0	1	1
0143	0	1	1	1	1	1	1	1	1	0	0	0
0144	0	0	0	0	0	0	0	0	0	1	0	0
0145	0	0	0	0	0	0	0	0	0	1	1	0
0146	1	1	1	1	1	1	1	1	1	0	0	1
0147	0	1	1	1	1	1	1	1	1	0	0	0
0148	0	1	0	1	1	1	1	1	1	0	0	0
0149	1	1	1	1	0	1	1	1	1	1	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0150-0151	1	1	1	1	1	1	1	1	1	1	1	1
0152	No data values calculated											
0153	0	0	1	1	1	1	1	1	0	0	0	0
0154	1	1	1	1	0	0	0	0	1	1	1	1
0155-0156	1	1	1	1	1	1	1	1	1	1	1	1
0157	1	1	1	1	1	0	0	0	0	1	1	1
0158	1	1	1	1	1	1	1	1	1	1	1	1
0159-0160	0	0	0	0	0	1	1	1	0	0	0	0
0161	1	1	1	0	0	0	0	0	0	0	1	0
0162	0	0	0	1	1	1	1	1	1	0	0	0
0163	1	0	0	1	0	0	0	0	0	1	1	1
0164	0	0	0	1	1	1	1	0	0	0	0	0
0165	0	0	0	0	0	0	0	0	0	1	0	0
0166	0	1	1	1	1	1	1	1	1	0	0	0
0167	1	1	1	1	1	1	1	1	1	1	0	0
0168	1	1	1	1	0	0	0	0	1	1	1	1
0169	1	1	1	1	1	1	1	0	1	1	1	1
0170-0171	0	0	0	0	0	0	0	0	0	0	0	1
0172	1	1	1	1	1	1	1	1	1	1	1	1
0173	1	1	1	1	0	1	0	1	1	1	1	1
0174-0175	1	1	1	1	1	1	1	1	1	1	1	1
0176-0177	1	1	1	1	1	1	0	1	0	1	1	1
0178	1	1	1	1	1	1	1	1	1	1	1	1
0179	0	0	0	0	0	1	1	1	1	0	0	0
0180	1	1	1	0	0	0	0	0	0	0	0	0
0181	0	0	0	1	0	1	1	1	1	1	0	0
0182	0	0	0	1	1	1	1	1	1	0	0	0
0183	0	1	1	1	0	0	0	0	0	0	1	1
0184	0	0	0	1	0	0	0	0	0	1	1	1
0185	0	1	1	1	1	1	1	1	1	1	0	0
0186	0	1	1	1	1	1	1	1	1	0	0	0
0187-0188	1	1	0	0	0	0	0	0	1	1	1	1
0189	0	0	1	1	1	1	1	1	1	0	0	0
0190	1	1	1	1	1	1	1	1	1	1	1	0
0191	1	1	1	1	1	1	1	1	1	1	1	1
0192	1	0	1	0	1	0	1	0	0	1	1	1
0193	1	1	1	0	0	0	0	0	0	1	1	1
0194	1	1	1	1	1	0	1	1	1	1	1	1
0195	1	1	1	1	1	1	0	0	0	1	1	1
0196	1	1	1	1	1	0	0	0	0	1	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0197	1	1	1	1	1	1	1	1	1	1	1	1
0198	0	0	0	0	0	0	1	0	1	0	1	0
0199	0	0	0	1	0	1	1	1	1	0	0	0
0200-0201	0	0	0	1	0	1	1	1	1	1	0	0
0202	1	1	1	1	0	0	0	0	0	1	0	0
0203	1	0	1	1	0	1	1	1	1	1	0	0
0204-0205	0	0	0	0	1	1	1	1	1	0	0	0
0206	0	1	1	1	1	0	0	0	0	0	1	1
0207	0	1	1	1	0	0	0	0	0	1	1	1
0208-0210	0	1	1	1	1	1	1	1	1	0	0	0
0211	1	1	0	0	0	0	0	0	0	1	1	1
0212	0	0	0	0	1	1	1	1	0	0	0	0
0213	No data values calculated											
0214	1	1	1	1	1	0	1	0	1	1	1	1
0215-0216	1	1	1	1	1	0	0	0	0	1	1	1
0217-0218	1	1	1	1	1	1	1	1	1	1	1	1
0219	0	0	0	1	0	1	1	1	1	0	0	0
0220	0	1	1	1	0	1	1	1	1	1	0	0
0221-0222	0	0	0	1	0	1	1	1	1	1	0	0
0223	1	1	1	1	0	0	0	0	0	1	0	0
0224	0	0	0	1	1	1	1	1	1	0	0	0
0225	1	1	1	1	0	0	0	0	0	0	0	1
0226	0	1	1	1	1	0	0	0	0	0	0	0
0227	1	1	1	1	0	0	0	0	0	1	1	1
0228-0229	0	1	1	1	1	1	1	1	1	0	0	0
0230	1	0	0	0	0	0	1	0	0	1	1	1
0231	1	0	0	0	1	1	1	0	1	1	1	1
0232	0	1	1	1	1	1	1	1	1	0	0	0
0233-0235	1	1	0	0	0	0	0	0	0	1	1	1
0236-0237	1	1	1	1	1	1	1	1	1	1	1	1
0238	0	0	0	0	0	0	0	1	1	0	0	0
0239	0	0	0	0	1	1	1	1	1	0	0	0
0240	1	1	1	1	1	1	1	1	0	1	1	0
0241	1	1	1	1	1	1	1	1	0	1	1	1
0242	1	1	1	1	1	1	0	1	0	1	1	1
0243	1	1	1	1	1	1	0	0	0	1	1	1
0244	1	1	1	1	1	1	1	1	1	1	1	1
0245	0	0	0	1	0	1	1	1	1	0	0	0
0246	0	1	1	1	0	1	1	1	1	1	0	0
0247	0	1	1	1	0	0	1	1	1	1	0	0

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0248	1	1	1	1	0	0	0	0	0	1	1	0
0249	0	0	0	0	1	1	1	1	1	0	0	0
0250	1	1	1	1	0	0	0	0	0	1	1	1
0251	0	1	0	1	1	1	1	1	1	0	0	0
0252	0	0	0	1	1	1	1	1	1	1	0	0
0253	1	0	0	0	0	0	0	0	0	1	1	1
0254	No data values calculated											
0255	0	0	1	1	1	1	1	1	1	0	0	0
0256-0257	1	1	1	1	0	0	0	0	0	1	1	1
0258	1	1	1	1	1	1	1	1	1	1	1	1
0259	0	0	0	0	1	1	1	1	1	0	0	0
0260	0	0	0	0	1	1	1	1	1	0	0	0
0261	1	1	1	1	1	1	0	0	0	1	1	1
0262	1	1	1	1	1	1	0	1	1	1	1	1
0263	1	1	1	1	1	1	0	0	1	1	1	1
0264-0265	0	0	0	1	0	1	1	1	1	0	0	0
0266	0	1	1	1	0	0	0	1	1	1	0	0
0267-0270	0	1	1	1	0	1	1	1	1	1	0	0
0271-0272	0	0	0	0	1	1	1	1	1	0	0	0
0273-0274	1	1	1	1	0	0	0	0	0	1	1	1
0275	1	1	1	1	1	1	1	1	1	1	1	1
0276	0	0	1	1	1	1	1	1	1	0	0	0
0277	0	0	0	1	1	1	1	1	1	0	0	0
0278-0279	1	1	1	1	0	0	0	0	0	1	1	1
0280	0	0	0	0	0	1	1	1	1	0	0	0
0281	0	0	0	0	1	1	1	1	1	0	0	0
0282	1	1	1	1	1	1	0	0	0	1	1	1
0283-0284	1	1	1	1	1	0	0	0	0	1	1	1
0285	1	1	1	1	1	1	0	0	0	1	1	1
0286-0287	1	1	1	1	1	1	1	1	1	1	1	1
0288	1	1	1	1	1	1	0	0	1	1	1	1
0289	1	1	1	1	1	0	0	0	0	1	1	1
0290	0	0	0	1	0	1	1	1	1	0	0	0
0291	1	1	1	1	1	0	0	0	0	1	1	0
0292	0	1	1	1	0	1	0	1	1	1	0	0
0293	0	1	1	1	0	0	0	1	1	1	0	0
0294	0	1	1	1	0	1	1	1	1	1	0	0
0295	0	0	0	1	1	1	1	1	1	0	0	0
0296	1	1	1	1	0	0	0	0	0	1	1	1
0297-0298	1	1	1	1	1	1	1	1	1	1	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0299	0	0	1	1	1	1	1	1	1	0	0	0
0300	0	0	0	1	1	1	1	1	1	0	0	0
0301	1	1	0	1	0	0	0	0	0	1	1	1
0302-0303	0	0	1	1	1	1	1	1	1	0	0	0
0304	1	1	1	1	0	0	0	0	0	1	1	1
0305-0306	1	1	1	1	1	1	1	1	1	1	1	1
0307-0308	0	1	0	0	1	1	1	1	1	0	0	0
0309	1	0	1	1	1	1	1	1	0	1	1	1
0310	1	1	1	1	1	1	0	0	0	1	1	1
0311	1	1	1	1	1	1	1	1	1	1	1	1
0312	0	0	0	1	0	1	1	1	1	1	1	1
0313	1	1	1	1	1	0	0	0	0	1	1	1
0314	1	1	1	1	1	0	0	0	1	1	1	0
0315	1	1	1	1	1	0	0	0	0	1	1	0
0316-0319	1	1	1	1	1	1	1	1	1	1	1	1
0320	0	0	0	1	1	1	1	1	1	1	0	0
0321	0	0	0	0	1	1	1	1	1	1	0	0
0322-0323	1	1	1	1	0	0	0	0	0	0	1	1
0324-0325	1	1	1	1	1	1	1	1	1	1	1	1
0326	1	1	1	1	1	1	1	1	1	1	1	1
0327	0	0	0	1	1	1	1	1	1	0	0	0
0328	1	1	0	1	0	0	0	0	0	1	1	1
0329	0	0	1	1	1	1	1	1	1	0	0	0
0330	0	1	1	1	1	1	1	1	1	0	0	0
0331	0	0	1	1	1	1	1	1	1	0	0	0
0332-0333	1	1	1	1	1	0	0	0	0	1	1	1
0334-0336	1	1	1	1	1	1	1	1	1	1	1	1
0337	1	1	0	0	1	1	1	1	1	1	1	1
0338	1	1	0	0	1	1	1	1	1	0	1	1
0339	0	0	1	1	0	0	0	0	0	1	1	1
0340	1	1	1	1	1	1	0	0	0	0	1	1
0341	0	0	0	0	0	1	1	1	1	0	0	0
0342-0343	1	1	1	1	1	0	0	0	0	1	1	1
0344	No data values calculated											
0345	0	0	0	0	0	0	1	0	0	0	1	1
0346	1	1	1	0	0	0	0	0	0	1	1	1
0347	1	1	1	0	0	0	0	0	0	1	1	1
0348	1	0	0	0	0	0	0	0	0	1	1	1
0349	1	0	0	0	0	1	0	0	0	1	1	1
0350	1	1	1	1	0	0	0	0	0	1	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0351-0352	1	1	1	1	1	1	1	1	1	1	1	1
0353-0354	0	0	0	1	1	1	1	1	1	1	0	0
0355	1	1	1	1	0	0	0	0	0	0	1	1
0356-0358	1	1	1	1	1	1	1	1	1	1	1	1
0359	0	0	0	1	1	1	1	1	1	0	0	0
0360	1	1	0	1	0	0	0	0	0	1	1	1
0361-0362	0	0	0	1	1	1	1	1	1	0	0	0
0363-0364	1	1	1	1	1	0	0	0	0	1	1	1
0365	1	1	1	1	0	0	1	1	1	1	1	1
0366	1	1	1	1	1	1	1	1	1	1	1	1
0367	1	1	1	0	1	1	1	1	1	1	1	1
0368-0369	1	1	1	1	1	1	1	1	1	1	1	1
0370	0	0	0	0	0	1	1	1	1	1	1	1
0371	1	1	1	1	1	1	0	0	0	0	1	1
0372	0	0	0	0	0	1	1	1	1	0	0	0
0373	0	0	0	0	1	1	1	1	1	0	0	0
0374	1	1	1	1	1	0	0	0	0	1	1	1
0375	1	0	1	0	1	0	0	0	0	1	1	1
0376	0	0	0	0	0	1	1	0	0	0	0	0
0377	1	0	0	0	0	0	0	0	0	1	1	1
0378	1	1	1	0	0	0	0	0	0	1	1	1
0379	1	1	1	0	0	0	0	0	0	1	1	1
0380-0381	1	1	1	1	0	0	0	0	0	1	1	1
0382-0384	1	1	1	1	1	1	1	1	1	1	1	1
0385-0386	0	0	0	1	1	1	1	1	1	1	0	0
0387	1	1	1	1	0	0	0	0	0	0	1	1
0388-0389	1	1	1	1	1	1	1	1	1	1	1	1
0390	0	0	0	0	1	1	1	1	1	0	0	0
0391	1	1	1	1	0	0	0	0	0	1	1	1
0392-0393	0	0	1	1	1	1	1	1	1	0	0	0
0394-0395	0	1	1	1	1	0	0	0	0	0	0	0
0396	0	0	1	1	1	0	0	0	0	0	0	0
0397	1	1	1	1	1	1	1	1	1	1	1	1
0398	0	0	0	0	0	0	1	1	1	0	0	1
0399	1	1	1	1	1	1	1	0	0	0	1	1
0400	1	1	1	1	1	1	1	1	1	1	1	1
0401	1	1	1	0	1	1	1	1	1	1	1	1
0402	1	0	0	1	1	1	1	1	1	1	1	1
0403	1	1	1	1	1	1	1	1	1	1	1	1
0404	0	1	1	1	1	1	1	1	1	1	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
	Wind-flow designations											
0405-0406	1	1	1	1	1	1	0	0	0	0	1	1
0407	1	1	1	1	1	1	1	1	1	1	1	1
0408	0	0	0	0	0	1	1	1	1	0	0	0
0409	0	0	0	1	1	1	1	1	1	0	0	0
0410	1	1	1	1	0	0	0	0	0	1	1	1
0411	1	1	1	1	1	1	1	1	1	1	1	1
0412-0413	0	0	0	1	1	1	1	1	1	1	0	0
0414	1	1	1	1	0	0	0	0	0	0	1	1
0415	0	0	0	1	1	1	1	1	1	1	0	0
0416	1	1	1	0	0	0	0	0	0	0	1	1
0417-0418	1	1	1	1	1	1	1	1	1	1	1	1
0419	0	0	0	0	1	1	1	1	1	1	0	0
0420	1	1	1	1	0	0	0	0	0	0	1	1
0421	1	1	1	1	1	1	1	1	1	1	1	1
0422	0	0	0	0	1	1	1	1	1	0	0	0
0423	0	1	1	1	1	0	0	0	0	0	0	0
0424	1	1	1	1	1	0	0	0	0	0	0	1
0425	0	0	0	0	0	1	1	1	1	0	0	0
0426	1	1	1	1	1	0	0	0	0	1	1	1
0427	No data values calculated											
0428	0	0	0	0	1	1	1	1	1	1	1	1
0429	1	1	1	1	1	1	1	1	1	1	1	1
0430	1	1	1	1	0	1	1	1	1	1	1	1
0431	0	0	0	0	0	0	1	1	1	1	0	0
0432	1	1	1	1	1	1	0	0	0	0	1	1
0433-0434	1	1	1	1	1	1	1	1	1	1	1	1
0435-0436	0	0	1	1	1	1	1	1	1	0	0	0
0437-0438	1	1	1	1	0	0	0	0	0	1	1	1
0439-0440	1	1	1	1	1	1	1	1	1	1	1	1
0441	0	0	0	1	1	1	1	1	1	1	0	0
0442	0	1	0	1	1	0	0	0	0	0	1	0
0443	1	1	1	1	0	0	0	0	0	0	1	1
0444	0	0	0	1	1	1	1	1	1	1	0	0
0445-0446	1	1	1	0	0	0	0	0	0	0	1	1
0447-0448	1	1	1	1	1	1	1	1	1	1	1	1
0449	0	0	0	0	1	1	1	1	1	1	0	0
0450-0451	1	1	1	1	0	0	0	0	0	0	1	1
0452	0	0	0	0	1	1	1	1	1	0	0	0
0453	0	1	1	1	1	0	0	0	0	0	0	1
0454	1	1	1	1	1	1	1	1	1	1	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0455	0	0	0	1	0	1	1	1	1	1	1	1
0456	1	1	1	1	1	1	0	1	1	1	1	1
0457	1	1	1	1	1	1	0	0	0	1	1	1
0458	1	1	1	1	0	0	0	0	0	1	1	1
0459	1	1	1	1	1	0	0	0	0	1	1	1
0460	1	0	1	0	0	0	1	1	1	1	1	1
0461	1	1	1	1	0	1	0	0	0	0	0	0
0462	1	1	1	1	1	1	0	0	0	0	1	1
0463	1	1	1	1	1	1	1	1	1	1	1	1
0464-0465	0	0	1	1	1	1	1	1	1	1	0	0
0466-0467	1	1	1	1	0	0	0	0	0	1	1	1
0468-0469	1	1	1	1	1	1	1	1	1	1	1	1
0470	0	0	0	1	1	1	1	1	1	1	1	0
0471	No data values calculated											
0472	1	1	1	0	0	0	0	0	0	0	1	1
0473	1	1	1	1	1	1	1	1	1	1	1	1
0474-0475	0	0	0	0	1	1	1	1	1	1	0	0
0476	1	1	1	1	0	0	0	0	0	0	1	1
0477	1	1	1	1	1	1	1	1	1	1	1	1
0478	1	1	1	1	1	1	1	1	0	1	1	
0479	0	0	0	0	0	0	1	1	1	1	1	0
0480	1	1	1	1	1	1	0	1	0	0	0	0
0481	0	0	0	0	1	1	1	1	1	1	0	0
0482	0	0	0	0	0	1	1	1	1	1	0	0
0483	1	1	1	1	1	1	0	0	0	0	0	0
0484	1	1	1	1	1	1	0	0	0	0	1	1
0485-0488	1	1	1	1	1	1	1	1	1	1	1	1
0489-0490	0	0	1	1	1	1	1	1	1	1	0	0
0491	1	1	1	1	1	1	1	1	1	1	1	1
0492	1	1	1	1	1	1	1	1	1	1	1	0
0493-0494	0	1	1	1	1	1	1	1	1	1	1	0
0495	0	1	1	1	1	1	1	1	1	1	0	0
0496-0497	1	1	1	1	0	0	0	0	0	0	1	1
0498-0499	1	1	1	1	1	1	1	1	1	1	1	1
0500	0	0	0	1	1	1	1	1	1	1	1	0
0501	0	0	1	1	1	1	1	1	0	1	0	0
0502	1	1	1	1	0	0	0	0	0	0	0	0
0503	1	1	1	1	1	1	1	1	1	1	1	1
0504	0	0	0	0	1	1	1	1	1	1	0	0
0505	0	1	0	1	1	1	1	1	1	1	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0506-0507	1	1	1	1	0	0	0	0	0	0	1	1
0508-0509	1	0	0	0	0	1	1	1	1	1	0	0
0510-0511	1	1	1	1	1	0	0	0	0	0	1	1
0512	1	1	1	1	1	1	1	1	1	1	1	1
0513	0	1	1	1	1	1	1	1	1	1	1	1
0514	0	0	0	1	1	1	0	1	0	1	0	0
0515-0516	0	0	0	0	0	1	1	1	1	1	0	0
0517	1	1	1	1	1	0	0	0	0	0	1	1
0518	1	1	1	1	1	1	0	0	0	0	1	1
0519-0520	0	0	1	1	1	1	1	1	1	1	0	0
0521	0	1	1	1	1	1	1	1	1	1	0	0
0522	1	1	1	1	1	1	1	1	1	1	1	1
0523	0	1	1	1	1	1	1	1	1	1	1	1
0524-0525	0	1	1	1	1	1	1	1	1	1	1	0
0526	0	1	1	1	1	1	1	1	1	1	1	1
0527-0530	1	1	1	1	1	1	1	1	1	1	1	1
0531-0532	0	1	1	1	1	1	1	1	1	1	0	0
0533-0534	1	1	1	1	0	0	0	0	0	0	1	1
0535-0536	1	1	1	1	1	1	1	1	1	1	1	1
0537	0	0	1	1	1	1	1	1	0	1	0	0
0538	1	1	1	1	0	0	0	0	0	0	0	0
0539	1	1	1	1	1	1	1	1	1	1	1	1
0540	1	1	1	1	0	0	0	1	1	1	1	1
0541-0542	1	1	1	1	0	0	0	0	0	1	1	1
0543	0	0	0	0	1	1	1	1	1	1	0	0
0544	No data values calculated											
0545-0546	1	1	1	1	0	0	0	0	0	0	1	1
0547	1	0	1	1	0	1	1	1	1	1	0	0
0548	1	0	0	0	0	1	1	0	1	0	0	0
0549	1	0	0	0	0	1	1	1	1	0	0	0
0550	1	1	1	1	0	0	0	0	0	0	1	1
0551	1	1	1	1	1	0	0	0	0	0	1	1
0552-0554	1	1	1	1	1	1	1	1	1	1	1	1
0555	No data values calculated											
0556	0	0	0	0	0	1	1	1	1	1	0	0
0557	1	1	1	1	1	1	0	0	0	0	0	1
0558-0559	1	1	1	1	1	1	1	1	1	1	1	1
0560	0	1	1	1	1	1	1	1	1	1	1	0
0561-0563	1	1	1	1	1	1	1	1	1	1	1	1
0564	0	1	1	1	1	1	1	1	1	1	1	0

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0565-0566	0	1	1	1	1	1	1	1	1	1	1	1
0567-0568	1	1	1	1	1	0	0	0	0	0	1	1
0569-0571	1	1	1	1	1	1	1	1	1	1	1	1
0572	0	0	0	0	1	1	1	1	1	1	0	0
0573	0	0	0	1	1	1	1	1	1	1	0	0
0574-0575	1	1	1	1	0	0	0	0	0	0	1	1
0576	0	0	0	0	1	1	1	1	1	1	0	0
0577	1	1	1	0	0	0	0	0	0	0	1	1
0578-0579	1	1	1	1	1	1	1	1	1	1	1	1
0580	1	0	0	1	0	1	1	1	1	1	0	0
0581	1	0	1	1	0	0	0	0	0	0	0	0
0582	1	0	0	1	0	0	0	0	0	0	0	0
0583	No data values calculated											
0584-0585	0	0	0	0	1	1	1	1	1	1	0	0
0586-0588	1	1	1	1	1	1	1	1	1	1	1	1
0589-0590	1	1	1	1	1	0	0	1	1	1	1	1
0591-0593	1	1	1	1	1	1	1	1	1	1	1	1
0594-0595	0	0	0	1	1	1	1	1	1	1	0	0
0596-0597	1	1	1	1	0	0	0	0	0	0	1	1
0598-0599	0	0	0	0	1	1	1	1	1	1	0	0
0600	1	1	1	0	0	0	0	0	0	0	1	1
0601-0604	1	1	1	1	1	1	1	1	1	1	1	1
0605	1	1	1	1	0	0	0	0	0	0	0	0
0606	1	0	0	1	0	1	1	1	1	1	0	0
0607	1	1	1	1	1	0	0	0	0	0	0	1
0608-0611	1	1	1	1	1	1	1	1	1	1	1	1
0612	1	1	1	1	1	1	1	1	1	1	1	1
0613	1	1	1	1	1	0	1	1	1	1	1	1
0614-0615	1	1	1	1	1	1	1	1	1	1	1	1
0616-0617	1	1	1	1	1	1	1	1	1	1	1	1
0618	0	0	0	1	1	1	1	1	1	1	1	0
0619	0	0	0	1	1	1	1	1	1	1	0	0
0620-0621	1	1	1	1	0	0	0	0	0	0	1	1
0622	0	0	0	0	1	1	1	1	1	1	0	0
0623	0	0	0	0	1	1	1	0	1	1	0	0
0624	1	1	1	0	0	0	0	0	0	0	1	1
0625-0627	1	1	1	1	1	1	1	1	1	1	1	1
0628	No data values calculated											
0629	1	1	1	1	1	1	1	1	1	1	1	1
0630	1	1	1	1	0	0	0	0	0	0	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0631	1	1	0	1	1	1	0	1	1	1	1	1
0632	1	1	1	1	0	0	1	0	0	0	0	1
0633	1	1	1	1	0	0	0	0	0	0	0	0
0634	1	1	1	1	0	0	0	0	0	0	0	1
0635	1	1	1	1	1	1	1	1	1	1	1	1
0636	No data values calculated											
0637	1	1	1	1	0	0	0	0	0	0	1	1
0638-0644	1	1	1	1	1	1	1	1	1	1	1	1
0645	0	0	0	1	1	1	1	1	1	1	1	0
0646	No data values calculated											
0647-0648	1	1	1	1	0	0	0	0	0	0	1	1
0649	0	0	1	1	1	1	1	1	1	1	1	0
0650	0	0	0	1	0	1	0	1	1	1	1	0
0651	1	1	1	0	0	0	0	0	0	0	0	1
0652	1	1	1	1	1	1	1	1	1	0	1	1
0653	1	1	1	1	0	0	1	0	0	0	0	1
0654	1	1	0	1	1	0	0	0	0	0	0	1
0655	1	1	0	1	0	0	1	0	0	0	0	1
0656-0657	1	1	1	1	0	0	0	0	0	0	0	1
0658	1	1	1	1	0	0	0	0	0	0	1	1
0659	1	1	1	1	0	0	0	0	0	0	0	1
0660-0661	1	1	1	0	0	0	0	0	0	0	0	1
0662	1	1	1	1	0	0	0	0	0	0	1	1
0663	1	1	1	1	1	1	1	1	1	1	1	1
0664	0	1	1	0	1	1	1	1	0	0	0	0
0665	1	1	1	0	1	0	0	0	0	0	1	1
0666-0670	1	1	1	1	1	1	1	1	1	1	1	1
0671	1	1	1	1	1	1	1	1	1	1	1	1
0672	1	0	1	1	1	1	1	1	1	1	1	1
0673	1	0	0	1	1	1	1	1	1	1	1	0
0674	No data values calculated											
0675-0676	1	1	1	1	0	0	0	0	0	1	1	1
0677	1	1	1	1	1	1	1	1	1	1	1	1
0678-0679	0	1	1	1	1	1	1	1	1	1	1	1
0680	0	0	0	0	0	0	1	1	1	0	0	0
0681	0	0	0	0	1	0	1	1	1	1	1	0
0682	1	1	1	1	1	0	0	0	0	1	1	1
0683-0684	0	0	0	0	1	1	1	1	1	1	1	0
0685	0	0	0	1	1	1	1	1	1	1	1	0

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0686	1	1	1	1	1	1	1	1	1	1	1	0
0687	0	0	0	0	1	1	1	1	1	1	0	0
0688	1	1	1	1	1	0	0	0	0	0	1	1
0689	0	0	0	0	1	1	1	1	1	1	1	0
0690-0693	1	1	1	1	1	1	1	1	1	1	1	1
0694	1	0	1	1	1	1	1	1	1	1	1	1
0695	1	1	1	1	1	1	1	1	1	1	1	1
0696	0	0	0	0	0	0	0	1	1	1	0	1
0697-0699	1	1	1	1	1	1	1	1	1	1	1	1
0700-0701	0	0	0	0	0	0	1	1	1	1	0	0
0702	No data values calculated											
0703	1	1	1	1	1	0	0	1	0	1	1	1
0704	0	0	0	0	0	0	0	0	0	0	0	0
0705	1	1	1	1	1	0	0	0	0	0	1	1
0706	1	1	1	1	0	0	0	0	0	0	0	1
0707	0	0	1	0	0	0	0	0	1	0	0	0
0708-0709	1	1	1	1	1	1	1	1	0	0	1	1
0710	0	0	1	0	0	1	0	1	1	1	0	0
0711	1	1	1	1	1	1	1	1	1	0	1	1
0712	1	1	1	1	0	0	0	0	0	0	0	1
0713-0714	1	1	1	0	0	1	0	0	1	0	0	1
0715	0	1	0	1	0	1	0	1	1	1	0	1
0716-0717	1	1	1	1	1	1	1	1	1	1	1	1
0718-0723	1	1	1	1	1	1	1	1	1	1	1	1
0724	0	0	1	0	0	0	0	0	0	0	0	1
0725	0	0	0	0	0	1	1	0	1	0	0	0
0726	1	1	1	1	1	0	0	0	0	0	1	1
0727	0	1	0	0	0	0	0	0	0	0	0	0
0728-0729	1	1	1	1	1	1	1	1	1	1	1	1
0730-0731	0	0	0	0	0	0	1	1	1	1	0	0
0732	1	1	1	1	1	0	0	0	0	0	1	1
0733	1	1	1	1	0	0	0	0	0	0	0	0
0734	1	0	0	1	1	1	1	1	1	1	1	0
0735	0	0	0	0	0	1	1	1	1	1	0	0
0736	1	1	0	1	1	1	1	1	1	1	1	0
0737	1	1	1	1	1	1	1	1	1	1	1	1
0738-0742	1	1	1	1	1	1	1	1	1	1	1	1
0743	1	1	1	1	1	0	1	1	0	0	1	1
0744	0	0	0	1	1	0	1	1	0	1	1	0
0745	No data values calculated											

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0746	0	0	0	0	0	1	0	0	1	0	0	0
0747	0	0	0	0	1	1	1	1	1	1	0	0
0748	1	1	1	1	1	1	1	1	1	1	1	1
0749	1	1	1	1	0	1	0	0	1	1	1	1
0750	1	1	1	1	0	1	0	0	0	0	1	1
0751	1	1	1	0	1	1	0	0	1	1	0	1
0752-0756	1	1	1	1	1	1	1	1	1	1	1	1
0757	1	1	1	1	0	1	1	1	1	1	1	1
0758	0	1	1	0	0	0	0	0	0	0	0	0
0759	1	0	1	1	1	1	1	1	1	1	1	1
0760	0	0	0	0	0	0	0	0	0	0	0	0
0761-0762	1	1	1	1	1	1	1	1	1	1	1	1
0763	1	1	1	1	1	0	0	1	0	0	1	1
0764	0	1	1	1	1	0	1	1	1	1	1	0
0765-0766	0	0	0	1	1	1	1	1	1	1	1	0
0767-0768	0	0	0	0	0	1	1	1	1	1	0	0
0769	No data values calculated											
0770-0771	1	1	1	1	0	0	0	0	0	0	1	1
0772	0	0	0	0	0	1	1	1	1	1	1	0
0773-0774	0	0	0	0	0	1	1	1	1	1	0	0
0775-0776	1	1	1	1	1	1	1	1	1	1	1	1
0777-0779	1	1	1	1	1	1	1	1	1	1	1	1
0780-0781	1	1	1	1	0	0	0	0	0	0	0	1
0782	1	1	1	1	1	1	1	1	1	0	1	1
0783	1	1	1	1	1	0	1	0	0	0	1	1
0784	0	0	0	1	0	0	0	0	0	1	1	1
0785	0	0	1	0	0	0	0	0	1	0	1	1
0786	0	0	0	0	1	1	1	1	1	1	0	1
0787-0789	1	1	1	1	0	0	0	0	0	0	1	1
0790	1	1	1	0	1	1	0	0	0	1	0	1
0791-0793	1	1	1	0	1	1	0	0	0	1	1	1
0794-0803	1	1	1	1	1	1	1	1	1	1	1	1
0804	1	1	1	1	0	1	0	1	1	0	1	1
0805	1	1	1	1	0	0	0	1	1	1	1	1
0806	0	0	0	0	1	1	0	1	1	1	0	0
0807	0	0	1	1	1	1	1	1	1	1	1	1
0808-0809	1	1	1	1	1	1	1	1	1	1	1	1
0810	0	0	0	1	1	1	1	1	1	1	1	0
0811	0	0	1	1	1	1	1	1	1	1	1	1
0812	0	0	0	1	1	1	1	0	0	0	0	0

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0813	0	0	1	1	1	1	1	0	0	0	0	0
0814	1	1	1	1	1	0	0	0	0	0	0	1
0815	0	0	0	0	1	1	1	1	1	0	0	0
0816	0	0	0	0	1	1	1	1	1	1	0	0
0817	1	1	1	1	0	0	0	0	0	0	1	1
0818	1	1	1	0	0	0	0	1	0	0	1	1
0819	1	1	1	0	1	1	1	1	1	1	1	1
0820	1	1	1	0	0	0	0	0	0	0	1	1
0821	0	0	0	0	0	1	1	1	1	1	0	0
0822	1	1	1	1	1	1	1	1	1	1	1	1
0823	No data values calculated											
0824-0825	1	1	1	1	1	1	1	1	1	1	1	1
0826	1	1	1	1	1	1	1	1	0	0	1	1
0827	1	0	0	1	1	1	1	1	0	0	1	0
0828	0	0	0	1	1	1	1	1	0	0	1	0
0829	1	0	1	0	0	1	1	1	1	0	0	0
0830	1	1	1	1	1	1	1	1	0	0	1	1
0831	1	1	1	1	1	0	1	0	0	0	1	1
0832	0	1	1	1	1	0	1	1	0	0	1	1
0833	0	0	0	0	1	1	1	1	1	1	0	0
0834	1	1	1	1	0	0	0	0	0	0	1	1
0835	No data values calculated											
0836-0837	1	1	1	0	1	1	0	0	0	1	1	1
0838	1	0	1	0	1	1	1	1	1	1	0	0
0839	1	1	1	1	0	0	1	0	0	1	0	0
0840-0846	1	1	1	1	1	1	1	1	1	1	1	1
0847	1	1	1	1	0	0	0	1	1	0	1	1
0848	1	1	1	1	0	0	0	0	1	0	1	1
0849	0	0	0	1	1	1	0	1	1	1	0	0
0850	0	0	0	1	1	1	1	1	1	1	1	0
0851-0852	1	1	1	1	1	1	1	1	1	1	1	1
0853	1	1	1	1	0	0	0	0	0	0	1	1
0854	0	0	0	1	1	1	1	1	1	1	0	0
0855	1	1	1	0	0	0	0	0	0	0	1	1
0856	0	0	1	0	0	1	1	1	1	1	1	0
0857	1	1	1	1	1	1	1	1	1	1	1	1
0858	1	1	1	1	1	1	1	1	0	0	1	1
0859	1	1	1	1	1	0	0	0	0	0	1	1
0860	0	0	0	0	1	1	1	1	1	1	1	0
0861	0	1	1	1	1	0	1	0	0	0	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
	Wind-flow designations											
0862	0	0	0	0	1	1	1	1	0	0	1	0
0863	0	0	0	1	1	1	1	1	0	0	1	0
0864	0	0	1	1	1	1	1	0	0	0	1	0
0865-0866	0	0	0	0	1	1	1	1	1	1	0	0
0867	1	1	1	1	1	1	0	1	1	1	1	1
0868	1	1	1	1	1	1	1	1	1	1	1	1
0869	1	1	1	1	1	0	0	1	1	1	0	1
0870	1	1	1	1	0	0	0	0	0	0	0	1
0871	1	1	1	1	1	1	1	1	1	1	1	0
0872-0876	1	1	1	1	1	1	1	1	1	1	1	1
0877	1	1	1	1	0	0	0	0	1	0	1	1
0878	1	1	1	1	0	0	0	1	1	0	1	1
0879	0	0	0	1	1	1	0	1	1	1	0	0
0880	1	1	1	0	0	0	0	0	0	0	0	0
0881	0	1	1	0	0	0	0	0	0	0	0	0
0882	1	1	1	1	1	1	1	1	1	1	1	1
0883	1	1	1	0	0	1	0	1	1	0	1	1
0884	0	0	0	1	1	1	1	1	1	1	0	0
0885	1	1	1	1	1	1	1	1	0	1	1	1
0886	1	1	1	1	1	1	1	1	1	1	1	0
0887-0888	1	1	1	1	1	1	1	1	1	1	1	1
0889-0891	1	1	1	1	1	1	1	1	1	1	1	1
0892	0	0	0	1	1	1	1	0	0	0	1	0
0893	1	1	1	1	1	1	1	0	0	0	1	0
0894	1	1	1	0	0	0	0	0	0	0	0	1
0895	0	0	0	0	1	1	1	1	0	1	0	0
0896	0	0	0	0	1	1	1	1	1	1	1	0
0897	1	1	0	1	0	0	1	1	1	1	1	1
0898	1	0	0	1	1	1	1	1	1	1	1	1
0899-0900	1	0	0	0	1	1	1	1	1	1	1	0
0901-0902	0	1	1	1	1	1	1	1	1	1	1	1
0903-0904	1	1	1	1	1	1	1	1	1	1	1	1
0905	1	1	1	1	1	1	1	0	1	1	1	1
0906	1	1	1	1	0	0	1	0	0	0	1	1
0907	0	1	1	0	0	0	0	0	0	0	0	1
0908	1	1	1	0	0	0	0	0	0	1	0	0
0909	0	1	1	0	0	0	0	0	0	0	0	0
0910	0	1	0	1	0	1	1	1	1	1	0	0
0911	0	1	1	0	0	0	0	0	0	0	0	0
0912	1	1	1	0	0	0	0	0	0	0	0	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
	Wind-flow designations											
0913	0	1	0	1	0	1	1	1	1	1	0	0
0914	1	1	1	0	0	0	0	0	0	0	0	0
0915	1	1	1	0	0	0	0	0	0	0	1	0
0916	1	1	1	1	1	1	1	1	1	1	1	0
0917-0918	1	1	1	1	1	1	1	1	1	1	1	1
0919	No data values calculated											
0920-0924	1	1	1	1	1	1	1	1	1	1	1	1
0925	1	1	1	0	0	0	0	0	0	0	0	1
0926	0	0	0	0	1	1	1	1	0	1	0	0
0927	0	0	0	0	1	1	1	1	1	1	1	0
0928	1	1	0	1	0	0	1	1	1	1	1	1
0929	0	0	0	1	1	1	1	1	1	1	1	1
0930-0931	0	0	0	0	1	1	1	1	1	1	1	0
0932-0936	1	1	1	1	1	1	1	1	1	1	1	1
0937	0	0	1	1	0	1	0	1	0	0	1	1
0938-0941	1	0	1	1	1	1	1	1	1	1	1	1
0942	1	0	1	0	1	1	1	1	1	1	1	1
0943	No data values calculated											
0944	1	0	0	0	1	1	1	1	1	1	0	0
0945	1	0	0	0	0	0	1	1	0	0	0	0
0946	0	0	0	1	1	1	1	1	1	1	1	0
0947-0958	1	1	1	1	1	1	1	1	1	1	1	1
0959-0960	1	1	1	0	0	0	0	0	0	0	0	1
0961	0	1	1	0	0	0	0	0	0	0	0	1
0962	0	0	0	1	1	1	1	1	1	1	1	0
0963	0	0	1	1	1	1	1	1	1	1	0	0
0964	0	0	0	1	1	0	1	1	1	1	0	0
0965	0	0	0	0	1	0	1	0	1	1	0	0
0966	0	0	1	1	1	1	1	1	0	1	1	1
0967-0972	1	1	1	1	1	1	1	1	1	1	1	1
0973-0975	1	0	1	1	1	1	1	1	1	1	1	1
0976	1	1	1	1	1	1	0	1	1	1	1	1
0977	0	1	1	1	1	0	0	1	1	1	1	1
0978	1	1	1	1	1	1	1	1	1	1	1	1
0979	0	1	1	0	1	1	1	0	1	1	0	1
0980	0	0	0	1	1	1	1	1	1	1	1	1
0981	1	1	1	1	0	1	1	1	1	1	1	0
0982	1	1	1	1	1	0	1	1	1	1	1	1
0983	0	1	0	0	1	0	1	1	1	1	1	0
0984	0	1	1	1	1	1	1	1	1	1	1	0

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
0985	0	0	1	1	1	1	1	1	1	0	1	0
0986	1	1	1	1	1	1	1	1	1	1	1	1
0987	1	1	1	1	1	1	1	1	0	1	1	1
0988	1	1	1	0	0	0	0	0	0	0	0	1
0989	0	0	0	1	1	1	0	0	0	0	1	1
0990	0	0	0	1	1	1	1	1	1	1	1	1
0991-0994	1	1	1	1	1	1	1	1	1	1	1	1
0995	1	1	1	0	0	0	0	0	0	0	0	1
0996-0997	0	0	0	1	1	1	1	1	1	1	1	0
0998	1	1	1	0	0	0	0	0	0	0	0	0
0999-1000	0	0	0	1	1	1	1	1	1	1	1	1
1001	0	1	1	1	1	1	1	1	1	1	1	1
1002	0	0	0	1	1	0	1	1	1	1	0	0
1003	1	1	1	0	0	0	0	0	0	0	0	0
1004	0	0	1	0	1	1	0	1	0	1	1	1
1005	0	0	0	1	1	1	1	1	1	1	0	1
1006-1012	1	1	1	1	1	1	1	1	1	1	1	1
1013	1	1	0	1	1	1	1	1	1	1	1	1
1014-1015	1	1	1	1	1	1	1	1	1	1	1	1
1016	1	1	1	1	1	1	1	1	1	1	1	1
1017	0	1	0	1	1	1	1	0	1	1	1	0
1018	1	1	1	0	0	0	0	0	0	1	0	1
1019	1	1	1	0	0	0	0	0	0	1	1	1
1020	1	0	0	0	1	1	0	1	0	1	1	0
1021	1	0	0	0	1	1	0	1	0	1	1	1
1022	No data values calculated											
1023-1024	1	1	1	0	0	0	0	0	0	0	0	1
1025-1026	0	0	0	1	1	1	1	1	1	1	1	0
1027	1	1	1	1	0	0	0	0	0	0	0	0
1028-1030	0	0	0	1	1	1	1	1	1	1	1	1
1031-1032	1	1	1	0	0	0	0	0	0	0	0	0
1033	0	0	0	1	1	0	0	0	0	1	0	1
1034	1	1	1	1	0	0	0	1	0	0	0	1
1035-1040	1	1	1	1	1	1	1	1	1	1	1	1
1041	1	1	0	0	0	0	0	1	1	1	1	1
1042	1	1	0	0	0	0	1	1	1	1	1	1
1043-1045	1	1	1	1	1	1	1	1	1	1	1	1
1046	1	1	1	0	0	0	0	0	0	0	0	1
1047	0	0	0	1	1	1	1	1	1	1	1	1
1048	1	1	1	1	1	1	1	1	1	1	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
1049	1	1	1	1	0	0	0	0	0	0	0	1
1050	0	1	0	1	1	1	1	1	1	1	1	0
1051	0	0	0	1	1	1	1	1	1	1	1	0
1052	1	1	1	0	0	0	0	0	0	1	1	1
1053-1054	1	1	1	1	1	1	1	1	1	1	1	1
1055	1	1	0	0	0	0	0	0	0	0	0	0
1056	0	0	0	1	1	1	1	1	1	1	1	1
1057-1058	0	0	0	1	1	1	1	1	1	1	1	0
1059	1	0	0	1	1	1	1	1	1	1	1	0
1060	0	0	0	1	1	1	1	1	1	1	1	1
1061-1062	1	1	1	1	1	1	1	1	1	1	1	1
1063	0	0	0	1	1	1	1	1	1	1	1	1
1064-1067	1	1	1	1	1	1	1	1	1	1	1	1
1068	1	1	1	0	0	0	0	0	0	0	0	1
1069-1070	1	1	1	1	1	1	1	1	1	1	1	1
1071-1072	1	1	1	0	0	0	0	0	0	1	1	1
1073	1	1	0	1	1	1	1	1	1	1	1	0
1074	1	1	1	0	0	0	0	0	0	1	1	1
1075-1076	0	1	1	0	0	0	0	0	0	1	1	1
1077	1	1	1	0	0	0	0	0	0	0	0	1
1078	1	1	1	1	1	1	1	1	1	1	1	1
1079	1	1	0	0	0	0	0	0	0	0	0	0
1080-1081	0	0	0	1	1	1	1	1	1	1	1	1
1082-1084	1	1	1	1	1	1	1	1	1	1	1	1
1085	0	0	0	1	1	1	1	1	1	1	1	1
1086-1089	1	1	1	1	1	1	1	1	1	1	1	1
1090	No data values calculated											
1091	1	0	0	0	0	0	0	0	0	0	0	0
1092	0	1	1	1	1	1	1	1	1	1	1	1
1093-1094	1	1	1	1	1	1	1	1	1	1	1	1
1095	1	1	1	0	0	0	0	0	0	1	1	1
1096	0	1	1	1	0	1	0	1	1	1	1	1
1097	1	1	1	0	0	0	0	0	0	1	1	1
1098	0	0	1	0	0	0	0	0	0	1	1	1
1099	1	1	1	0	0	0	0	0	0	1	1	1
1100	1	1	1	0	0	0	0	0	0	0	0	1
1101	0	0	1	1	1	1	1	1	1	1	1	1
1102	1	1	0	0	0	0	0	0	0	0	0	0
1103-1104	0	0	1	1	1	1	1	1	1	1	1	1
1105	0	0	0	1	1	1	1	1	1	1	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
1106	1	0	0	0	0	0	0	0	0	0	0	0
1107	1	1	0	0	0	0	0	0	0	0	0	1
1108	0	1	1	1	1	1	1	1	1	1	1	1
1109	1	1	1	1	1	1	1	1	1	1	1	1
1110	1	1	1	0	0	0	0	0	0	0	0	1
1111	0	0	1	1	0	0	0	0	0	0	0	1
1112	0	0	1	1	1	1	1	1	1	1	1	0
1113-1114	1	1	1	0	0	0	0	0	0	0	1	1
1115-1117	0	0	1	1	1	1	1	1	1	1	1	1
1118	0	1	0	0	0	0	0	0	0	0	0	0
1119	1	0	1	1	1	1	1	1	1	1	1	1
1120	0	0	0	1	1	1	1	1	1	1	1	1
1121-1122	1	0	0	0	0	0	0	0	0	0	0	0
1123	No data values calculated											
1124	1	1	1	1	1	1	1	1	1	1	1	1
1125	1	1	1	0	0	0	0	0	0	0	0	1
1126	1	1	1	1	0	0	0	0	0	0	0	1
1127	0	0	0	1	1	1	1	1	1	1	1	0
1128	0	0	1	0	1	1	1	1	1	1	0	0
1129	1	1	1	0	0	0	0	0	0	0	0	1
1130	0	0	1	1	1	1	1	1	1	1	1	1
1131	0	0	0	1	1	1	1	1	1	1	1	1
1132	1	0	1	1	1	1	1	1	1	1	1	1
1133	0	0	0	0	0	0	0	0	0	0	0	0
1134-1136	1	0	1	1	1	1	1	1	1	1	1	1
1137	0	0	1	1	1	1	1	1	1	1	1	1
1138	0	0	0	0	0	0	0	0	0	0	0	1
1139	0	0	0	0	0	0	0	0	0	0	0	1
1140	1	0	0	0	0	0	0	0	0	0	0	1
1141	1	1	1	1	1	1	1	1	1	1	1	1
1142	1	1	1	1	1	1	1	1	1	1	1	1
1143	1	1	1	1	1	1	1	1	1	1	1	1
1144	1	1	1	0	0	0	0	0	0	0	0	1
1145	1	1	0	0	0	0	0	0	0	0	0	1
1146	0	0	0	1	1	1	1	1	1	1	0	0
1147	1	1	1	0	0	0	0	0	0	0	1	1
1148	0	1	1	0	0	0	0	0	0	1	1	1
1149-1151	1	1	1	1	1	1	1	1	1	1	1	1
1152	0	0	0	0	0	0	0	0	0	0	0	0
1153-1154	1	1	1	1	1	1	1	1	1	1	1	1

Table A-9 (continued)

ARC/INFO™ grid cell ID no.	Wind-flow designations											
	JA	FE	MR	AP	MY	JN	JL	AG	SP	OC	NV	DC
1155-1156	1	1	1	1	1	1	1	1	1	1	1	1
1157	0	0	1	1	1	1	1	1	1	1	1	1
1158	1	1	1	1	1	1	1	1	1	1	1	1
1159-1160	0	0	0	0	0	0	0	0	0	0	0	0
1161-1162	1	1	1	1	1	1	1	1	1	1	1	1
1163-1164	1	1	0	0	0	0	0	0	0	0	1	1
1165	1	1	1	0	0	0	0	0	0	0	1	1
1166	1	0	1	0	1	1	1	1	1	1	1	1
1167	1	1	1	1	1	1	1	1	1	1	1	1
1168	1	1	1	1	0	1	0	0	0	1	1	1
1169	1	1	1	1	1	1	1	1	1	1	1	1
1170-1171	0	0	0	0	0	0	0	0	0	0	0	0
1172-1173	1	1	1	1	1	1	1	1	1	1	1	1
1174	1	1	1	1	1	1	1	1	1	1	0	1
1175-1176	1	1	1	1	1	1	1	1	1	1	0	0
1177-1178	1	1	1	1	1	1	1	1	1	1	1	1
1179-1180	0	0	0	0	0	0	0	0	0	0	0	0
1181	1	1	1	1	1	1	1	1	1	1	1	1
1182-1183	1	1	0	0	0	0	0	0	0	0	1	1
1184	0	0	0	0	1	1	1	1	0	0	1	0
1185	1	1	1	1	0	1	1	1	1	1	1	1
1186	1	1	1	1	1	1	1	1	1	1	1	1
1187	0	0	0	0	0	0	0	0	0	0	0	0
1188-1192	1	1	1	1	1	1	1	1	1	1	1	1
1193-1194	0	0	0	0	0	0	0	0	0	0	0	0
1195	1	1	1	1	1	1	1	1	1	1	1	1
1196-1196	1	1	0	0	0	0	0	0	0	0	1	1
1198-1201	1	1	1	1	1	1	1	1	1	1	1	1
1202	0	0	0	0	0	0	0	0	0	0	0	0
1203-1204	1	1	1	1	1	1	1	1	1	1	1	1
1205-1206	0	0	0	0	0	0	0	0	0	0	1	1
1207	1	1	1	1	1	0	0	1	0	1	1	1
1208-1209	1	1	1	1	1	1	1	1	1	1	1	1

Computing Data Variable MONSOON

The derivation of a given data value number for data variable MONSOON can be better understood by using the data in Tables A-7, A-8, and A-9. For a given 1° x 1° grid cell, multiplying the 12 wind-speed values from Tables A-7 and A-8 by the appropriate monthly onshore or offshore values (1 or 0) in Table A-9 will result in the data value for variable MONSOON. For example, the 1° x 1° grid cell having ARC/INFO™ Grid Cell ID no. 239 is inside the 5° x 5° grid cell centered at 17.5°N latitude and 122.5°E longitude. Therefore, this 1° x 1° grid cell inherits monthly wind speed values of 15, 15, 11, 10, 10, 10, 11, 12, 12, 13, 16, and 17 for the months of the year. The corresponding onshore and offshore wind-flow designations for the given months in the same order are 0, 0, 0, 0, 1, 1, 1, 1, 1, 0, 0, and 0. Thus, the monsoon index value for data variable MONSOON in grid cell 239 equals:

$$\text{Cell (239)} = [(15 * 0) + (15 * 0) + (11 * 0) + (10 * 0) + (10 * 1) + (10 * 1) + (11 * 1) + (12 * 1) + (12 * 1) + (13 * 0) + (16 * 0) + (17 * 0)]$$

$$\text{Cell (239)} = 55.$$

DATA GROUP SEAICE

Data group SEAICE contains one data variable known as ICE (mean annual sea-ice concentration).

Information About the Data Sources

Specific information concerning the characteristics and use of the data sources for data group SEAICE is described in the following. Data source documents are listed by number and title. For a fuller citation of each reference, see Part 1 as noted in brackets.

1. *Sea-Ice Climatic Atlas: Arctic East* [Part 1, Sect. 13.3, No. (1)]. This atlas provided contour-type sea-ice concentrations (in ranges of percent) for affected areas in the Northern Hemisphere east of 90° W and west of 90° E. Sea-ice concentrations were presented twice monthly (for a total of 24 observations per year). The contoured sea-ice bands (in ranges of percent) provided the basis of the digital data values provided by data variable ICE.

2. *Sea-Ice Climatic Atlas: Arctic West* [Part 1, Sect. 13.3, No. (2)]. This atlas provided contour-type sea-ice concentrations (in ranges of percent) for affected areas in the Northern Hemisphere east of 90° E and west of 90° W. Sea-ice concentrations were presented twice monthly (for a total of 24 observations per year). The contoured sea-ice bands (in ranges of percent) provided the basis of the digital data values provided by data variable ICE.

3. *U.S. Navy Marine Climatic Atlas of the World, Vol. I, The North Atlantic* [Part 1, Sect. 13.3, No. (3)]. This atlas provided contour-type sea-ice concentrations and was used to update data values for the U.S. Atlantic Coast. Specifically, contours indicating areas of extreme or rare sea-ice occurrence were used to update digital sea-ice data values from Data Source (1).

4. *U.S. Navy Marine Climatic Atlas of the World, Volume II, The North Pacific* [Part 1, Sect. 12.3, No. (4)]. This atlas provided contour-type sea-ice concentrations and was used to update data values for the U.S. Pacific Coast. Specifically, contours indicating areas of extreme or rare sea-ice occurrence were used to update digital sea-ice data values from Data Source (2).

The Data Variable

Data variable ICE was derived primarily by converting contour-type sea-ice data into a digital format. Data variable ICE provides a mean annual sea-ice concentration (in percent) for each 1° x 1° grid cell analyzed for data group SEAICE.

Depending on its location, each 1° x 1° grid cell's data value was derived primarily from either Data Source (1) or Data Source (2). In either case, the method used to derive the data is the same.

After deriving digital data values from Data Sources (1) and (2) (the primary data sources), Data Sources (3) and (4) were consulted. Data Sources (3) and (4) were used to derive data for areas experiencing infrequent but nonzero sea-ice occurrence. These areas generally failed to be adequately represented by the information in Data Sources (1) and (2).

All analyses of the data sources were manually performed by visual inspection of the data. The observations were then recorded in tables, where the data were converted to digital values for data variable ICE. The analysis steps used for each 1° x 1° grid cell follow. Figure A-8 illustrates the conversion of the contour-type data of the data sources into the digital form of data used to derive data variable ICE.

1. For each of the 24 data charts, contoured zones of sea-ice concentration were analyzed with respect to a given 1° x 1° grid cell in order to determine which of the zones encompassed at least some portion of the 1° x 1° grid cell. The fraction of area covered by a given sea-ice concentration zone in a given 1° x 1° grid cell was not a consideration in this or any of the following analysis steps.

2. The sea-ice concentration zones used by Data Sources (1) and (2) refer to ranges of sea-ice concentration (in percent); therefore, for the purposes of this analysis, each sea-ice concentration zone was assumed to represent a single midrange percentage of sea-ice concentration (i.e., a zone having percentage values of 80 to 100% became 90%, a 50 to 80% zone became 65%, etc.).

3. For each of the 24 data charts, the midrange values of the sea-ice concentration zones occupying areas within a given 1° x 1° grid cell were averaged to obtain a single value. This resulted in 24 digital sea-ice concentration values for each grid cell.

4. The 24 values obtained from Step (3) were then averaged to obtain a digital mean annual sea-ice concentration value (in percent) for each 1° x 1° grid cell.

5. The 1° x 1° grid cells having data values of zero after Steps (1) through (4) were analyzed further using Data Sources (3) and (4).

6. Contour maps showing the maximum extent of sea ice with a 10% or greater concentration were referenced from Data Sources (3) and (4) for each month of the year. For each month that the maximum 10% sea-ice contour crossed a given 1° x 1° grid cell, the grid cell was given an arbitrary data value of 2%. This resulted in 12 values for each 1° x 1° grid cell of either 2% or 0%.

7. The 12 values obtained in Step (6) were averaged to obtain a single digital data value for a given 1° x 1° grid cell. Data values resulting from Steps 5 through 7 all have final data values (data variable ICE) of 0.5% or less.

Note that all nonzero data values for data variable ICE derived their values from Data Sources (1) and (3) or Data Sources (2) and (4). Data values of 99 for data variable ICE indicate regions where no data were analyzed.

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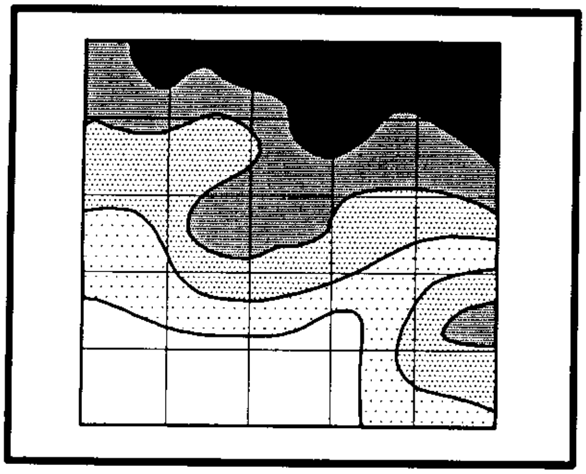

a

77.5	63.3	77.5	77.5	77.5
50.0	50.0	63.3	63.3	63.3
22.5	36.7	50.0	36.7	36.7
5.0	15.0	15.0	15.0	36.7
0.0	0.0	0.0	15.0	22.5

b

Key for Part a

- 80-100% zone of sea-ice concentration
- 50-80% zone of sea-ice concentration
- 20-50% zone of sea-ice concentration
- 0-20% zone of sea-ice concentration
- Open water

Fig. A-8. Sample conversion of sea-ice contour zones into digital data, according to the derivation procedures used for data variable ICE. (a) Contour-type map of the type used for data derivation; (b) resultant digital values in percent for each 1° x 1° grid cell.

APPENDIX B

LATITUDE-LONGITUDE REFERENCE COORDINATES FOR SELECTED GRID CELLS

APPENDIX B

LATITUDE-LONGITUDE REFERENCE COORDINATES FOR SELECTED GRID CELLS

Specific latitude-longitude locations for any of the grid cells in this data set can be deduced using Tables B-1 through B-4. The latitudes and longitudes of several grid cells in data groups TC10, TC50, XCNORTH, POLARLOW, LOWPC, MONSOON, and SEAICE are identified. Each of the identified positions refer to the upper left corner of the given grid cell. Note, however, that data values provided in the forementioned data groups refer to an entire grid cell or polygon (i.e., not to a single point). Since all these data groups contain either 1° x 1° or 5° x 5° grid cells of latitude-longitude, the user can determine the coordinates of any of the other grid cells within a given data group based on the reference locations in this appendix. The figures in Part 1 of this document may be used to help identify the locations of grid cells. For each grid cell listed, Tables B-1 through B-4 identify the ARC/INFO™ polygon ID number, ASCII file ID number, page number location for the figures in Part 1, and latitude-longitude coordinates. Each table addresses a different set of data groups.

Table B-1. Locations of selected grid cells in data group TC10

ARC/INFO™ polygon ID	ASCII file ID	Page no.	Latitude-longitude
657	23411	45	24°N, 170°W
1166	32051	45	11°N, 170°W
79	14456	46	50°N, 125°W
556	21296	46	31°N, 125°W
607	22042	47	29°N, 99°W
520	20619	47	33°N, 82°W
1	10916	48	60°N, 65°W
65	14155	48	51°N, 163°W
480	19903	49	35°N, 78°W
525	20635	50	33°N, 65°W
783	25385	50	20°N, 76°W
785	25312	50	20°N, 69°W

Table B-2. Locations of selected grid cells in data groups TC50, XCNORTH, POLARLOW, and LOWPC

ARC/INFO™ polygon ID	ASCII file ID	Page no.	Latitude-longitude
1	1	51	90°N, 180°W
24	24	51	90°N, 65°W
2521	2521	51	85°S, 180°W
2544	2544	51	85°S, 180°W
25	25	52	90°N, 60°W
48	48	52	90°N, 55°E
2545	2545	52	85°S, 60°W
2568	2568	52	85°S, 55°E
49	49	53	90°N, 60°E
72	72	53	90°N, 175°E
2569	2569	53	90°N, 175°E

Data group HCSTATE does not consist of uniform grid cells as do the other data groups. The latitude-longitude coordinates for the polygons in data group HCSTATE are located in HCSTATE.BNA (File 14) on the magnetic tape. A sample of the contents of HCSTATE.BNA is in Sect. 20, p. 99, of this document.

Table B-3. Locations of selected grid cells in data group MONSOON

ARC/INFO™ polygon ID	ASCII file ID	Page no.	Latitude-longitude
341	28246	62	12°N, 15°W
532	30426	62	6°N, 5°E
157	25418	63	20°N, 37°E
314	27945	63	13°N, 44°E
667	32263	63	1°N, 42°E
690	32622	64	0°N, 41°E
846	34076	64	4°S, 55°E
1142	38031	64	15°S, 50°E
1	21831	65	30°N, 50°E
221	26514	65	17°N, 53°E
91	24011	66	24°N, 70°E
107	24390	66	23°N, 89°E
670	32293	66	1°N, 72°E
252	26915	67	16°N, 94°E
171	25490	67	20°N, 109°E
679	32330	67	1°N, 109°E
693	32679	68	0°N, 98°E
1019	35940	68	9°S, 119°E
2	21902	69	30°N, 121°E
4	21910	69	30°N, 129°E
95	24058	70	24°N, 117°E
552	30540	70	6°N, 119°E
704	32701	71	0°N, 120°E
1110	37386	71	13°S, 125°E
407	28670	72	11°N,139°E
286	27325	72	15°N, 144°E
610	31272	72	4°N, 132°E
488	29852	72	8°N, 151°E
792	33441	73	2°S, 140°E
1187	38841	73	17°S, 140°E

Table B-4. Locations of selected grid cells in data group SEAICE

ARC/INFO™ polygon ID	ASCII file ID	Page no.	Latitude-longitude
237	13313	74	53°N,172°E
7	6858	75	71°N,163°E
255	13681	75	52°N,180°W
10	6861	76	71°N,160°W
130	10821	76	60°N,160°W
121	10481	77	61°N,140°W
280	17745	78	41°N,76°W

APPENDIX C

DATA SOURCES USED FOR EACH GRID CELL OR POLYGON BY DATA VARIABLE

APPENDIX C

DATA SOURCES USED FOR EACH GRID CELL OR POLYGON BY DATA VARIABLE

The following tables and discussions indicate the data sources used to derive data values for all grid cells (polygons) or coastal segments in this NDP for each of the 61 data variables.

The tables list grid cells according to their respective ARC/INFO™ grid cell (polygon) ID numbers. Corresponding ASCII file ID numbers can be determined using the figures in Part 1. Each data source is identified on the basis of the number assigned to it in Part 1. For example, the "2" listed in the first line of Table C-1 refers to Data Source (2) of Part 1, Sect. 7.4 (*Tropical Cyclones of the North Atlantic Ocean: 1871-1986*). Many grid cells having identical data sources are grouped in the tables. If the source is listed as "None", then no data were available for the given grid cell; however, these cells may contain estimated data values and are indicated as such by the use of flags.

By referencing the period of record information in Part 1 with the tables and discussions that follow, the specific time period of use for a specific data source can be determined for most grid cells and polygons.

Table C-1. Part 1, Sect. 7.4 data sources for each grid cell of data group TC10

ARC/INFO™ Cell ID	Data variable TS	Data variable TY
0001-0078	2	2
0079-0093	3,4	3,4
0094-0111	2	2
0112-0126	3,4	3,4
0127-0147	2	2
0148-0162	3,4	3,4
0163-0184	2	2
0185-0199	3,4	3,4
0200-0219	2	2
0220-0234	3,4	3,4
0235-0248	2	2
0249-0263	3,4	3,4
0264-0276	2	2
0277-0291	3,4	3,4
0292-0304	2	2
0305-0319	3,4	3,4
0320-0322	2	2
0323-0337	3,4	3,4
0338-0343	2	2
0344-0358	3,4	3,4

Table C-1 (continued)

ARC/INFO™ Cell ID	Data variable TS	Data variable TY
0359-0365	2	2
0366-0380	3,4	3,4
0381-0385	2	2
0386-0400	3,4	3,4
0401-0405	2	2
0406-0420	3,4	3,4
0421-0424	2	2
0425-0439	3,4	3,4
0440-0443	2	2
0444-0458	3,4	3,4
0459-0462	2	2
0463-0477	3,4	3,4
0478-0482	2	2
0483-0497	3,4	3,4
0498-0504	2	2
0505-0519	3,4	3,4
0520-0526	2	2
0527-0541	3,4	3,4
0542-0555	2	2
0556-0570	3,4	3,4
0571-0656	2	2
0657-0676	3,4	3,4
0677-0682	2	2
0683-0782	3,4	3,4
0783-0791	2	2
0792-0811	3,4	3,4
0812-0818	2	2
0819-0838	3,4	3,4
0839-0845	2	2
0846-1185	3,4	3,4

Table C-2. Part 1, Sect. 7.4 data sources for each grid cell of data group TC50

ARC/INFO™ polygon ID	Data variable TS	Data variable TY	Data variable TCV	Data variable STY
0001-0380	None	None	None	None
0381-0396	2	2	3,4	3,4
0397-0452	None	None	None	None
0453-0468	2	2	3,4	3,4
0469-0487	None	None	None	None
0488-0504	3,5	3,5	3,5	3,5
0505-0512	1,3,8	1,3,8	1	3,8
0513-0516	1,3,4	1,3,4	1	3,4
0517-0540	1,2	1,2	1	3,4
0541-0559	None	None	None	None
0560-0576	1,3,5	1,3,5	3,5	3,5
0577-0584	1,3,8	1,3,8	1	3,8
0585-0588	1,3,4	1,3,4	1	3,4
0589-0612	1,2	1,2	1	3,4
0613-0631	None	None	None	None
0632-0648	1,3,5	1,3,5	3,5	3,5
0649-0656	1,3,8	1,3,8	1	3,8
0657-0660	1,3,4	1,3,4	1	3,4
0661-0684	1,2	1,2	1	3,4
0685-0703	None	None	None	None
0704-0720	1,3,5	1,3,5	1	3,5
0721-0728	1,3,8	1,3,8	1	3,8
0729-0733	1,3,4	1,3,4	1	3,4
0734-0756	1,2	1,2	1	3,4
0757-0775	None	None	None	None
0776-0792	1,3,5	1,3,5	1	3,5
0793-0800	1,3,8	1,3,8	1	3,8
0801-0806	1,3,4	1,3,4	1	3,4
0807-0828	1,2	1,2	1	3,4
0829-0835	None	None	None	None
0836-0846	5	5	1	5
0847	3,5	3,5	1	3,5
0848-0864	1,3,5	1,3,5	1	3,5
0865-0872	1,3,8	1,3,8	1	3,8
0873-0879	1,3,4	1,3,4	1	3,4
0880-0900	1,2	1,2	1	3,4
0901-0907	None	None	None	None
0908-0918	5	5	1	5
0919	3,5	3,5	1	3,5
0920-0936	1,3,5	1,3,5	1	3,5

Table C-2 (continued)

ARC/INFO™ polygon ID	Data variable TS	Data variable TY	Data variable TCV	Data variable STY
0937-0944	1,3,8	1,3,8	1	3,8
0945-0951	1,3,4	1,3,4	1	3,4
0952	1,2,3	1,2,3	1	3,4
0953-0972	1,2	1,2	1	3,4
0973-0979	None	None	None	None
0980-0989	5	5	1	5
0990-0991	3,5	3,5	1	3,5
0992-1008	1,3,5	1,3,5	1	3,5
1009-1016	1,3,8	1,3,8	1	3,8
1017-1024	1,3,4	1,3,4	1	3,4
1025	1,2,3	1,2,3	1	3,4
1026-1044	1,2	1,2	1	3,4
1045-1051	None	None	None	None
1052-1062	5	5	1	5
1063	3,5	3,5	1	3,5
1064-1080	1,3,5	1,3,5	1	3,5
1081-1088	1,3,8	1,3,8	1	3,8
1089-1098	1,3,4	1,3,4	1	3,4
1099	1,2,3	1,2,3	1	3,4
1100-1116	1,2	1,2	1	3,4
1117-1123	None	None	None	None
1124-1134	5	5	1	5
1135	3,5	3,5	1	3,5
1136-1152	1,3,5	1,3,5	1	3,5
1153-1160	1,3,8	1,3,8	1	3,8
1161-1171	1,3,4	1,3,4	1	3,4
1172-1188	1,2	1,2	1	3,4
1189-1195	None	None	None	None
1196-1206	5	5	1	5
1207	3,5	3,5	1	3,5
1208-1224	1,3,5	1,3,5	1	3,5
1225-1232	3,8	3,8	1	3,8
1233-1243	3,4	3,4	1	3,4
1244-1260	2	2	1	3,4
1261-1267	None	None	None	None
1268-1278	5	5	1	5
1279-1296	3,5	3,5	1	3,5
1297-1302	1,3,5,6,8	1,3,5,6,8	1	3,5,7,8
1303-1309	3,5,8	3,5,8	3,5,8	3,5,7,8
1310-1337	None	None	None	None

Table C-2 (continued)

ARC/INFO™ polygon ID	Data variable TS	Data variable TY	Data variable TCV	Data variable STY
1338-1362	1,3,5,8	1,3,5,8	1	3,5,7,8
1363-1374	1,3,5,6,8	1,3,5,6,8	1	3,5,7,8
1375-1381	3,5,8	3,5,8	3,5,8	3,5,7,8
1382-1409	None	None	None	None
1410-1434	1,3,5,8	1,3,5,8	1	3,5,7,8
1435-1446	1,3,5,6,8	1,3,5,6,8	1	3,5,7,8
1447-1453	3,5,8	3,5,8	3,5,8	3,5,7,8
1454-1481	None	None	None	None
1482-1506	1,3,5,8	1,3,5,8	1	3,5,7,8
1507-1518	1,3,5,6,8	1,3,5,6,8	1	3,5,7,8
1519-1525	3,5,8	3,5,8	3,5,8	3,5,7,8
1526-1553	None	None	None	None
1554-1578	1,3,5,8	1,3,5,8	1	3,5,7,8
1579-1590	1,3,5,6,8	1,3,5,6,8	1	3,5,7,8
1591-1597	3,5,8	3,5,8	3,5,8	3,5,7,8
1598-1625	None	None	None	None
1626-1650	1,3,5,8	1,3,5,8	1	3,5,7,8
1651-1662	1,3,5,6,8	1,2,5,6,8	1	3,5,7,8
1663-1669	3,5,8	3,5,8	3,5,8	3,5,7,8
1670-1697	None	None	None	None
1698-1722	1,3,5,8	1,3,5,8	1	3,5,7,8
1723-1734	1,3,5,6,8	1,3,5,6,8	1	3,5,7,8
1735-1741	3,5,8	3,5,8	3,5,8	3,5,7,8
1742-1769	None	None	None	None
1770-1794	1,3,5,8	1,3,5,8	1	3,5,7,8
1795-1806	1,3,5,6,8	1,3,5,6,8	1	3,5,7,8
1807-1813	3,5,8	3,5,8	3,5,8	3,5,7,8
1814-1841	None	None	None	None
1842-1866	1,3,5,8	1,3,5,8	1	3,5,7,8
1867-1878	1,3,5,6,8	1,3,5,6,8	1	3,5,7,8
1879-1885	3,5,8	3,5,8	3,5,8	3,5,7,8
1886-1913	None	None	None	None
1914-1938	1,3,5,8	1,3,5,8	1	3,5,7,8
1939-1946	1,3,5,6,8	1,3,5,6,8	1	3,5,7,8
1947-1950	1,3,5,8	1,3,5,8	1	3,5,7,8
1951-1957	3,5,8	3,5,8	3,5,8	3,5,7,8
1958-1985	None	None	None	None
1986-2010	1,3,5,8	1,3,5,8	1	3,5,7,8
2011-2016	1,3,5,6,8	1,3,5,6,8	1	3,5,7,8
2017-2029	3,5,8	3,5,8	3,5,8	3,5,7,8

Table C-2 (continued)

ARC/INFO™ polygon ID	Data variable TS	Data variable TY	Data variable TCV	Data variable STY
2030-2072	None	None	None	None
2073-2088	3,5,8	3,5,8	3,5,8	3,5,7,8
2089-2592	None	None	None	None

Part 1, Sect. 8.3 data sources for each polygon in data group HCSTATE

All polygons (ARC/INFO™ polygon IDs 1 through 42) use Data Sources (1) and (2) for all data variables in this data group (data variables C1, C2, C3, C4, and C5).

Part 1, Sect. 9.3 data sources for each grid cell in data group XCNORTH

All grid cells (ARC/INFO™ grid cell IDs 1 through 2592) use Data Source (1) for all data variables in this data group (data variables CGJA, CFJA, CGFE, CFFE, CGMR, CFMR, CGAP, CFAP, CGMY, CFMY, CGJN, CFJN, CGJL, CFJL, CGAG, CFAG, CGSP, CFSP, CGOB, CFOB, CGNV, CFNV, CGDC, CFDC, CGAN, and CFAN).

Table C-3. Part 1, Sect. 10.3 data sources for each grid cell of data group POLARLOW (Data source is the same for all data variables in a given grid cell.)

ARC/INFO™ polygon ID	Data variables COMMA, SPIRAL, and POLARLOW	ARC/INFO™ polygon ID	Data variables COMMA, SPIRAL and POLARLOW
0000-0288	None	0661-0706	None
0289-0300	1	0707-0732	1
0301-0346	None	0733-0778	None
0347-0372	1	0779-0804	1
0373-0418	None	0805-0850	None
0419-0444	1	0851-0876	1
0445-0490	None	0877-0922	None
0491-0516	1	0923-0948	1
0517-0562	None	0949-0994	None
0563-0588	1	0995-1008	1
0589-0634	None	1009-1296	None
0635-0660	1	1297-2592	2

Table C-4.1. Part 1, Sect. 11.3 data sources for each grid cell of data group LOWPC

ARC/INFO™ polygon ID	Data variable ZONE	Data variable LOWNJA	Data variable LOWNJL	Data variable LOWNAN
0001-1296	4,5	1	1	1
1297-2592	4,5	None	None	None

Table C-4.2. Part 1, Sect. 11.3 data sources for each grid cell of data group LOWPC

ARC/INFO™ polygon ID	Data variables LOWSJA, LOWS2JA	Data variables LOWSJL, LOWS2JL	Data variables LOWSAN, LOWS2AN
0001-1296	None	None	None
1297-1495	2	2	2
1496-1512	None	None	None
1513-1567	2	2	2
1568-1584	None	None	None
1585-1639	2	2	2
1640-1656	None	None	None
1657-1711	2	2	2
1712-1728	None	None	None
1729-1783	2	2	2
1784-1800	None	None	None
1801-1855	2	2	2
1856-1872	None	None	None
1873-1927	2	2	2
1928-1944	None	None	None
1945-1999	2	2	2
2000-2016	None	None	None
2017-2071	2	2	2
2072-2088	None	None	None
2089-2592	2	2	2

Table C-4.3. Part 1, Sect. 11.3 data sources for each grid cell of data group LOWPC

ARC/INFO™ polygon ID	Data variables LOWAJA, LOWA2JA	Data variables LOWAJL, LOWA2JL	Data variables LOWAAN, LOWA2AN
0001-1495	None	None	None
1496-1512	3	3	3
1513-1567	None	None	None
1568-1584	3	3	3
1585-1639	None	None	None
1640-1656	3	3	3
1657-1711	None	None	None
1712-1728	3	3	3
1729-1783	None	None	None
1784-1800	3	3	3
1801-1855	None	None	None
1856-1872	3	3	3
1873-1927	None	None	None
1928-1944	3	3	3
1945-1999	None	None	None
2000-2016	3	3	3
2017-2071	None	None	None
2072-2088	3	3	3
2089-2592	None	None	None

Table C-4.4. Part 1, Sect. 11.3 data sources for each grid cell of data group LOWPC

ARC/INFO™ polygon ID	Data variable CYCJA	Data variable CYCJL	Data variable CYCLONE
0001-1296	1	1	1
1297-1495	2	2	2
1496-1512	3	3	3
1513-1567	2	2	2
1568-1584	3	3	3
1585-1639	2	2	2
1640-1656	3	3	3
1657-1711	2	2	2
1712-1728	3	3	3

Table C-4.4 (continued)

ARC/INFO™ polygon ID	Data variable CYCJA	Data variable CYCJL	Data variable CYCLONE
1729-1783	2	2	2
1784-1800	3	3	3
1801-1855	2	2	2
1856-1872	3	3	3
1873-1927	2	2	2
1928-1944	3	3	3
1945-1999	2	2	2
2000-2016	3	3	3
2017-2071	2	2	2
2072-2088	3	3	3
2089-2592	2	2	2

Part 1, Sect. 12.3 data sources for each polygon in data group MONSOON.

All grid cells (ARC/INFO™ grid cell IDs 1 through 1210) in data group MONSOON use Data Sources (1) and (2) for the only data variable (MONSOON).

Part 1, Sect. 13.3 data sources for each grid cell in data group SEAICE.

Table C-5. Part 1, Sect. 13.3 data sources for each grid cell of data group SEAICE

ARC/INFO™ polygon ID	Data variable ICE	ARC/INFO™ polygon ID	Data variable ICE
001-224	2,4	258-297	1,3

APPENDIX D

THE DATA GROUPS: A QUICK REFERENCE

APPENDIX D

THE DATA GROUPS: A QUICK REFERENCE

A listing of the data variables and other pertinent information for each of the eight data groups follows. Each of these data groups also contains system variables created by the ARC/INFO™ system. The system variables are AREA, PERIMETER, an internal polygon identifier, and an external polygon identifier.

1. **DATA GROUP TC10:** Tropical Storm and Hurricane Probabilities of Occurrence for Coastal Areas of the United States, Canada, and Bermuda (1° x 1° Grid Cells).

Data Variables

TS - the probability in percent of having at least one tropical cyclone center per year in a given 1° x 1° grid cell with maximum sustained winds greater than 17.5 m/s but less than 33 m/s.

TY - the probability in percent of having at least one tropical cyclone center per year in a given 1° x 1° grid cell with maximum sustained winds of 33 m/s or greater.

Data Coverage - All coastal areas of the United States, Canada, and Bermuda affected by tropical storms and hurricanes.

Data Format - ARC/INFO™ coverage with data values for each 1° x 1° latitude-longitude grid cell.

File Storage - ARC/INFO™ coverage name is **TC10.E00** (File 4).
ASCII file name is **TC10.ASC** (File 5).

(18)	20°S,130°E	(44)	10°N, 20°W
(19)	20°S,115°E	(45)	10°N, 15°W
(20)	15°S,115°E	(46)	15°N, 15°W
(21)	15°S,110°E	(47)	15°N, 5°E
(22)	10°S,110°E	(48)	20°N, 5°E
(23)	10°S,100°E	(49)	20°N, 50°E
(24)	5°S,100°E	(50)	30°N, 50°E
(25)	5°S, 90°E	(51)	30°N, 75°E
(26)	0°N, 90°E	(52)	35°N, 75°E

None of the 1° x 1° grid cells (that comprise the area with data values for data variable MONSOON) used in data group MONSOON were corrected for latitudinal differences in the areas of 1° x 1° grid cells.

The 1° x 1° grid cells that were not included in the data analysis region for data group MONSOON in the flat ASCII data file have a data value of 999. Further derivation procedures for data variable MONSOON are discussed by data source in the following.

ORNL-DWG 8584

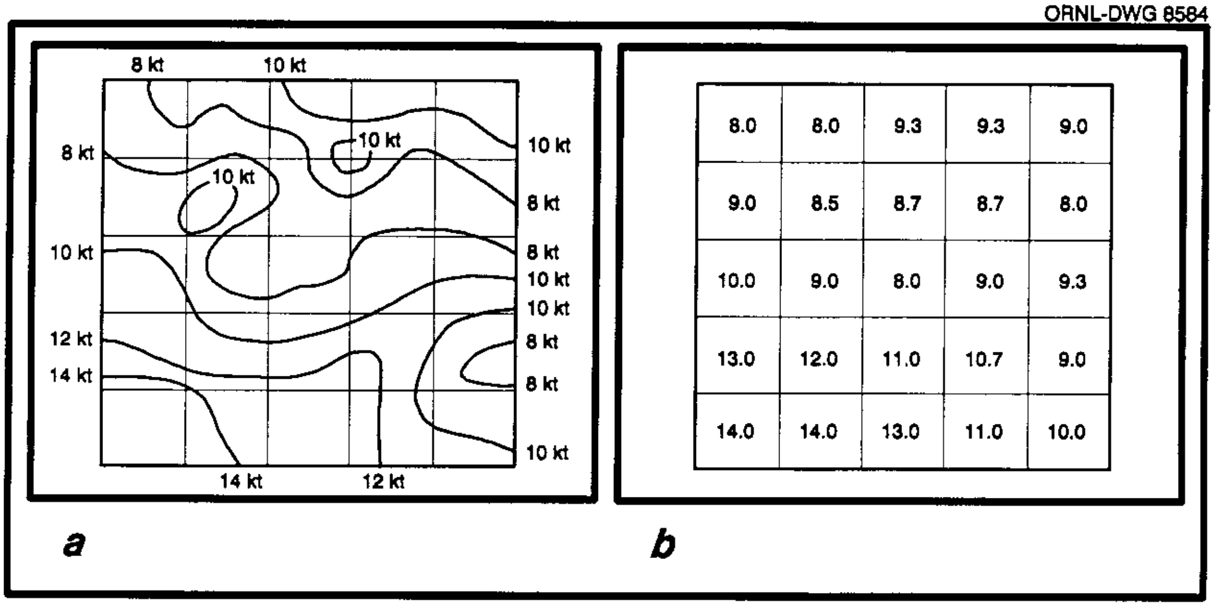

Fig. A-6. A sample conversion of a wind-speed contour map into digital data according to the derivation procedures used for data variable MONSOON. (a) Contour map of the type used for data derivation; (b) resultant digital values in knots for each 5° x 5° grid cell.

3. **DATA GROUP HCSTATE:** Number of Hurricane Strikes for the U.S. Atlantic and Gulf Coasts by State and Saffir-Simpson Category

Data Variables

C1 - Number of hurricanes of Saffir-Simpson Hurricane Category 1 having crossed a given state or substate coastline with maximum sustained surface winds of 33.0 to 42.5 m/s.

C2 - Number of hurricanes of Saffir-Simpson Hurricane Category 2 having crossed a given state or substate coastline with maximum sustained surface winds of 42.5 to 49.2 m/s.

C3 - Number of hurricanes of Saffir-Simpson Hurricane Category 3 having crossed a given state or substate coastline with maximum sustained surface winds of 49.2 to 58.1 m/s.

C4 - Number of hurricanes of Saffir-Simpson Hurricane Category 4 having crossed a given state or substate coastline with maximum sustained surface winds of 58.1 to 69.3 m/s.

C5 - Number of hurricanes of Saffir-Simpson Hurricane Category 5 having crossed a given state or substate coastline with maximum sustained surface winds of 69.3 m/s or more.

Data Coverage - Coastlines of the U.S. Atlantic and Gulf Coast states.

Data Format - ARC/INFO™ coverage with data values for each polygon. Note that data values should be adjusted on the basis of the coastline length of each represented state or substate polygon before data values between states and/or substates are compared.

File Storage - ARC/INFO™ coverage name is **HCSTATE.E00** (File 12).
ASCII file name is **HCSTATE.ASC** (File 13).
Vector coordinate file name is **HCSTATE.BNA** (File 14).

4. **DATA GROUP XCNORTH:** Mean Number of Extratropical Cyclogeneses by Month and Year in the Northern Hemisphere (5° x 5° Grid Cells); and Extratropical Cyclone Occurrences by Month and Year in the Northern Hemisphere (5° x 5° Grid Cells)

Data Variables

CGJA - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for January.

CFJA - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for January.

CGFE - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for February.

CFFE - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for February.

CGMR - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for March.

CFMR - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for March.

CGAP - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for April.

CFAP - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for April.

CGMY - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for May.

CFMY - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for May.

CGJN - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for June.

Data Variables (continued)

CFJN - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for June.

CGJL - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for July.

CFJL - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for July.

CGAG - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for August.

CFAG - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for August.

CGSP - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for September.

CFSP - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for September.

CGOB - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for October.

CFOB - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for October.

CGNV - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for November.

CFNV - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for November.

CGDC - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell for December.

Data Variables (continued)

CFDC - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for December.

CGAN - the mean number of extratropical cyclones with centers originating in a given 5° x 5° grid cell per year.

CFAN - the mean number of extratropical cyclones with centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell per year.

Data Coverage - 5° x 5° grid cells in the Northern Hemisphere located between latitudes of 20°N and 85°N. 5° x 5° grid cells between 0°N and 20°N are designated as tropical (not significantly affected by extratropical cyclones).

Data Format - ARC/INFO™ coverage with data values for each 5° x 5° latitude-longitude grid cell.

File Storage - ARC/INFO™ coverage name is **XCNORTH.E00** (File 17).
ASCII file name is **XCNORTH.ASC** (File 18).

5. **DATA GROUP POLARLOW:** Mean Number of Polar Lows per Winter Month for the North Pacific Ocean and Southern Hemisphere (5° x 5° Grid Cells)

Data Variables

COMMA - the area-adjusted mean number of polar-low centers (types 6, 7, and 21) occurring per winter month in a given 5° x 5° grid cell.

SPIRAL - the area-adjusted mean number of polar-low centers (type 22) occurring per winter month in a given 5° x 5° grid cell.

POLARLOW - the area-adjusted mean number of polar-low centers (types 6, 7, 21, and 22) occurring per winter month in a given 5° x 5° grid cell.

The polar-low types mentioned in the above definitions refer to the polar-low classification system used by the data sources. (See Appendix F for pertinent literature reprints.)

Data Coverage - North Pacific Ocean (110°E eastward to 120°W longitude, 20°N to 70°N latitude) and the entire Southern Hemisphere.

Data Format - ARC/INFO™ coverage with data values for each 5° x 5° latitude-longitude grid cell.

File Storage - ARC/INFO™ coverage name is **POLARLOW.E00** (File 21).
ASCII file name is **POLARLOW.ASC** (File 22).

6. **DATA GROUP LOWPC:** Mean and/or Relative Number of Cyclones for January, July, and the Year for the World (5° x 5° Grid Cells); and Mean Number of Hours of Cyclone Occurrence for January, July, and the Year for the Southern Hemisphere (5° x 5° Grid Cells)

Data Variables

ZONE - indicates the climate zone to which the given 5° x 5° grid cell is assigned. Two climate zones are possible: tropical and extratropical. This data variable is not a cyclonicity value. Rather, it is intended to assist the user of cyclonicity data in the segregation of tropical and extratropical cyclone types.

LOWNJA - the area-adjusted mean number of cyclone centers occupying a position at 1230 GMT within a given 5° x 5° grid cell for January.

LOWNJL - the area-adjusted mean number of cyclone centers occupying a position at 1230 GMT within a given 5° x 5° grid cell for July.

LOWNAN - the area-adjusted mean number of cyclone centers occupying a position at 1230 GMT within a given 5° x 5° grid cell for the year.

LOWSJA - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for January (based on multiple daily observations for a 15-year period and 10-hPa isobar intervals).

LOWSJL - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for July (based on multiple daily observations for a 15-year period and 10-hPa isobar intervals).

LOWSAN - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for the year (based on multiple daily observations for a 15-year period and 10-hPa isobar intervals).

LOWS2JA - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell for January (based on multiple daily observations for a 15-year period and 10-hPa isobar intervals).

LOWS2JL - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell for July (based on multiple daily observations for a 15-year period and 10-hPa isobar intervals).

Data Variables (continued)

LOWS2AN - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell for the year (based on multiple daily observations for a 15-year period and 10-hPa isobar intervals).

LOWAJA - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for January (based on multiple daily observations for a 23-year period and 4-hPa isobar intervals).

LOWAJL - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for July (based on multiple daily observations for a 23-year period and 4-hPa isobar intervals).

LOWAAN - the area-adjusted mean number of cyclone centers existing (originating, passing through, or terminating) in a given 5° x 5° grid cell for the year (based on multiple daily observations for a 23-year period and 4-hPa isobar intervals).

LOWA2JA - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell for January (based on multiple daily observations for a 23-year period and 4-hPa isobar intervals).

LOWA2JL - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell for July (based on multiple daily observations for a 23-year period and 4-hPa isobar intervals).

LOWA2AN - the area-adjusted mean number of hours that cyclone centers were present in a given 5° x 5° grid cell for the year (based on multiple daily observations for a 23-year period and 4-hPa isobar intervals).

CYCJA - the area-adjusted statistically standardized data value representative of the average number of cyclones for each 5° x 5° grid cell in January.

CYCJL - the area-adjusted statistically standardized data value representative of the average number of cyclones for each 5° x 5° grid cell in July.

CYCLONE - the area-adjusted statistically standardized data value representative of the number of cyclones for each 5° x 5° grid cell for an average year.

Data Coverage - Northern Hemisphere for data variables LOWNJA, LOWNJL, and LOWNAN; Australian region [defined by the box formed by the following coordinates: (10°S, 90°E), (10°S, 180°E), (55°S, 180°E), and (55°S, 90°E)] for data variables LOWAJA, LOWAJL, LOWAAN, LOWA2JA, LOWA2JL, and LOWA2AN; Southern Hemisphere, excluding the Australian Region as defined above, for data variables LOWSJA, LOWSJL, LOWSAN, LOWS2JA, LOWS2JL, and LOWS2AN; Global for data variables ZONE, CYCJA, CYCJL, and CYCLONE.

Data Format - ARC/INFO™ coverage with data values for each 5° x 5° latitude-longitude grid cell.

File Storage - ARC/INFO™ coverage name is **LOWPC.E00** (File 25).
ASCII file name is **LOWPC.ASC** (File 26).

7. **DATA GROUP MONSOON:** Index of the Influence of Winds on Coastlines in the African, Asian, and Australian Monsoon Regions (1° x 1° Grid Cells)

Data Variable

MONSOON - A numeric index of the relative influence of onshore winds on coastlines in monsoon regions for 1° x 1° grid cells. Numbers range from 0 to 154. The larger the number the greater the influence of onshore winds on the given coastal areas.

Data Coverage - All coastlines of the monsoon regions of Africa, Asia, and Australia.

Data Format - ARC/INFO™ coverage with data values for each 1° x 1° latitude-longitude grid cell.

File Storage - ARC/INFO™ coverage name is **MONSOON.E00** (File 29).
ASCII file name is **MONSOON.ASC** (File 30).

8. **DATA GROUP SEAICE:** Mean Annual Sea-Ice Concentrations for Alaskan and U.S. Atlantic Coastal Areas (1° x 1° Grid Cells)

Data Variable

ICE - the mean annual concentration of sea ice for a given 1° x 1° grid cell. Data values are expressed as percentages.

Data Coverage - All coastal areas of the United States affected by sea ice.

Data Format - ARC/INFO™ coverage with data values for each 1° x 1° latitude-longitude grid cell.

File Storage - ARC/INFO™ coverage name is **SEAICE.E00** (File 33).
ASCII file name is **SEAICE.ASC** (File 34).

APPENDIX E

DEFINITIONS OF METEOROLOGICAL TERMS

APPENDIX E

DEFINITIONS OF METEOROLOGICAL TERMS

A listing of important meteorological terms found in this NDP follows. These terms are defined on the basis of the data sources used in this project whenever possible. As a result, these definitions may differ slightly from those obtained from other sources.

Anticyclone - An area of high atmospheric pressure characterized by outwardly spiraling winds. The direction of the spiraling wind movement is clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere.

Baroclinic - An atmospheric state in which surfaces of constant pressure intersect surfaces of constant density.

Baroclinic instability - Instability characterized by a meridional temperature gradient, strong vertical wind shear, temperature advection, and divergent wind flow aloft. The formation of an extratropical cyclone is often the result of baroclinic instability.

Cyclone center - The vertical axis or core of a cyclone, usually determined by cloud vorticity patterns, wind, and/or pressure distribution.

Circumpolar vortex - A jet stream characterized by a more or less continuous region of upper-level low pressure that encircles each pole. Wind flow is often intense and is from west to east in both hemispheres. These regions undergo little variation in intensity between summer and winter, but the latitudinal positions exhibit a semiannual oscillation.

Cold front - see Front.

Conditional instability of the second kind (CISK) - A process proposed by J. Charney and A. Ellassen to explain how cyclones form in a conditionally unstable atmosphere whose thermal structure is apparently unfavorable to convective circulations on the scale required for tropical cyclones. The CISK process postulates that cyclones may be intensified by a kind of secondary instability in which existing cumulus convection is augmented in regions of low-level horizontal convergence and quenched in regions of low-level divergence. Thus, cumulus and cyclone-scale motions are regarded as a cooperative effort in which the clouds supply latent heat energy and the cyclone supplies fuel in the form of moisture to the clouds. This type of interaction would, to a large scale, promote self-amplification of a depression.

Cyclogenesis - The initial formation of a low-pressure system.

Cyclone - An area of low atmospheric pressure characterized by inwardly spiraling winds. The direction of the spiraling wind movement is counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

Extratropical - A term used to indicate a cyclone with no tropical characteristics. The term implies both displacement from the tropics and the conversion of the cyclone's primary energy source from the release of latent heat of condensation to that of baroclinic processes. Tropical cyclones can become extratropical and still maintain winds of tropical storm or hurricane force.

Extratropical cyclone - A cyclone that derives its primary energy from horizontal temperature gradients and/or other baroclinic processes. These processes tend to exist in the midlatitude and polar regions (thus the term "extratropical").

Fetch - The linear distance that winds blow over the sea at a relatively constant speed and direction. Generally, increases in fetch result in the generation of large waves.

Front - A zone of transition between two distinct air masses. Four major types of fronts are recognized: (1) cold front - indicates cold air is replacing warm air at the surface, (2) warm front - indicates warm air is replacing cold air at the surface, (3) stationary front - indicates that the transition zone between two distinct air masses is remaining in approximately the same location, and (4) occluded front - generally indicates that a cold front has overtaken a warm front that was moving in advance of the cold front (as a result, the warm air mass is forced aloft).

Gale - A strong wind ranging from 17.5 to 24.5 m/s.

High-pressure system - see Anticyclone.

Hurricane - A tropical cyclone with maximum sustained surface winds of 33 m/s or greater. In some parts of the world, hurricanes are known as typhoons, cyclones, etc.

Isobar - A line connecting points of equal atmospheric pressure.

Isotherm - A line connecting points of equal temperature.

Low-pressure system - see Cyclone.

Maximum sustained wind - The mean surface wind speed averaged over a 1-min period.

Mesoscale - Meteorological phenomena of a scale that ranges from a few kilometers to about 100 km in size. Some phenomena classified as mesoscale include local winds, thunderstorms, and tornadoes.

Monsoon - A wind system that affects large climatic regions and seasonally reverses direction, especially the Asiatic monsoon that produces dry and wet seasons in India, southern Asia, and parts of Africa.

Monsoon low - Weak low-pressure systems that tend to form as a result of a divergent flow aloft. The winds associated with the low-pressure system intensify monsoon winds and may enhance precipitation.

Occluded front - see Front.

Polar air cloud vortex - see Polar low

Polar low - A small-scale synoptic low-pressure system (usually about one-tenth the diameter of a typical extratropical cyclone system) that primarily forms in winter or spring behind the leading edge of an arctic or antarctic airstream over relatively warm water. Two types of formational processes seem to influence polar-low development. These are (1) conditional instability of the second kind (CISK), and (2) moist baroclinicity.

Saffir-Simpson scale - A scale used to estimate the destructive potential of a tropical cyclone having maximum sustained winds of 33 m/s or greater. The scale has five categories that classify tropical cyclone intensity primarily on the basis of maximum sustained wind speed. However, other factors such as central atmospheric pressure and storm surge may also be considered.

Stationary front - see Front.

Storm surge - An abnormal rise of ocean waters along a shoreline usually resulting from an intense cyclone. Tropical cyclones, for example, have caused storm surges exceeding 8 m to occur on the U.S. Gulf Coast.

Subtropical cyclone - A low-pressure system that forms over the ocean (usually in the subtropics) and is of upper cold-low or low-level baroclinic origins. This type of cyclone has many of the same characteristics as a tropical cyclone, and the system may be transformed into a tropical type cyclone if the storm moves toward the equator.

Super typhoon - Although the term originates from the Western North Pacific, super typhoon is used in this documentation for all tropical cyclones having maximum sustained surface winds of 67 m/s or greater.

Thermal lows - areas of low pressure that are vertically shallow and tend to occur over areas with relatively high surface temperatures.

Tropical cyclone - A nonfrontal, migratory low-pressure system, usually of synoptic scale, originating over tropical or subtropical waters and having an organized circulation. A tropical cyclone derives its energy primarily from latent heat of condensation by means of its uniformly warm vertical circulation. Thus, a tropical cyclone may also be identified as a warm-core low-pressure system.

Tropical depression - A tropical cyclone with maximum sustained surface winds less than 17.5 m/s.

Tropical disturbance - A discrete system of apparently organized convection, generally 180 to 525 km in diameter, originating in the tropics or subtropics, having a nonfrontal, migratory character, and having maintained its identity for 12- to 24-h. It may or may not be associated with a detectable perturbation of the wind field. It is the basic generic designation which, in successive stages of development, may be classified as a tropical depression, tropical storm, hurricane, or super typhoon.

Tropical storm - A tropical cyclone with maximum sustained surface winds of at least 17.5 m/s but less than 33 m/s.

Typhoon - see Hurricane.

Warm-core low - A low-pressure system that is characteristically warmer toward its center than at its periphery. This pattern is typical of tropical cyclones.

Warm front - see Front.

APPENDIX F

PERTINENT LITERATURE-REPRINTS

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A SATELLITE-DERIVED CLIMATOLOGY OF POLAR-LOW EVOLUTION IN THE NORTH PACIFIC

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ABSTRACT

A climatology of polar-low evolution for seven low-sun seasons (November to March) in the North Pacific is presented. The data were collected by the subjective interpretation of Defense Meteorological Satellite Program (DMSP) infra-red imagery, using a cloud vortex classification scheme designed especially for use with medium to high resolution imagery. For the study period, about two-thirds of all polar lows that formed over the North Pacific evolved to a higher stage. Approximately one-half of those (one-third of the total) passed through all stages of development from cyclogenesis to decay. The more common form of cyclogenetic polar low in the North Pacific, the comma cloud, continued to develop two-thirds of the time, while the less common spiraliform only evolved to a higher stage of development in two-fifths of the cases. Those polar lows that formed in certain key areas were likely to evolve to a higher stage, while other specific locations discouraged continued development. No readily discernible difference between gross size and cloud characteristics of evolving and non-evolving polar lows was present in the satellite data, suggesting that additional data are needed to forecast correctly which will develop into mature cyclones.

KEY WORDS Polar lows North Pacific Satellite climatology Subjective synoptic classification

INTRODUCTION

A number of factors make the polar low a unique type of cyclone. As their name implies, polar lows form in polar or arctic air masses poleward of major fronts, usually over oceans and seas. They are single air mass storms, appearing as comma- or spiral-shaped cloud masses on satellite imagery (Reed (1986), reported in Rasmussen and Lystad (1987)). These sometimes intense cyclones can be difficult to detect because they often have a life cycle as short as 6–24 h, are about one-tenth the diameter of a typical synoptic-scale frontal cyclone (and, therefore, can be smaller than standard synoptic grids), and occur over some of the most data-sparse areas of the globe (Lystad, 1986). Therefore, the importance of polar lows as a meso-alpha-scale (i.e. 100–1000 km) phenomenon has only become evident with the advent of medium to high resolution satellite imagery.

The sudden development of an intense polar low introduces the potential for interruptions of human activity, damage to structures and facilities, and loss of life. A clear need for improved forecasting of these cyclones on short time-scales is recognized (Rasmussen and Lystad, 1987). However, forecasting is hindered by the surprising lack of knowledge about polar lows, including such basic climatological information as where they form and, of those that do form, how many will continue to develop into mature storms. In a report on the forecasting of polar lows, Midtbo and Lystad (1986) state that the forecaster needs at least twice-a-day satellite coverage to detect incipient polar lows. Furthermore, they suggest that detection must be based

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in part on a climatological knowledge of those areas where polar lows are likely to form and develop into potentially destructive cyclones.

Yarnal and Henderson (1989) have recently documented the climatology of polar-low cyclogenesis in the North Pacific. Based on the subjective interpretation of satellite imagery, they found that the vast majority of polar lows form west of the International Date Line, with two nodal areas of cyclogenetic activity. The first runs along the east Asian coast from northern Japan to the western Bering Sea, while the second extends zonally eastward from northern Japan to about 180° longitude. As part of their work, they also related intra-annual and interannual variability of cyclogenesis to elements of the large-scale ocean–atmosphere environment. Pressure patterns, ocean currents, sea-surface temperature–air temperature differences and other large-scale factors all control those areas in which polar lows will form in the North Pacific basin.

An aspect of polar lows neglected by the satellite-derived climatology of Yarnal and Henderson (1989) concerns the evolution of these cyclones beyond the cyclogenetic stage. In this paper, the principal objective is to determine whether all polar lows that form in the North Pacific continue to develop into mature storms or not. Attention is given to the location and typical characteristics of evolving and non-evolving cyclogenetic polar lows. The frequency and distribution of a special category of evolving polar low, the instant occlusion, is also presented.

METHODOLOGY

The most difficult and time consuming aspect of this study was the subjective interpretation of the satellite mosaics. In the following, the methodology for classifying the polar low data is presented, including a discussion of the classification system itself, the data recorded, and the problems encountered. However, first the satellite imagery from which the polar low data was extracted is described.

Data used

The satellite data employed were the computer-processed infra-red (8–13 μm) 1:30 M half-hemisphere mosaics of the Defense Meteorological Satellite Program (DMSP) polar-orbiting system. The mosaics encompass the entire North Pacific basin and are assembled twice daily at approximately 12 h intervals. Visual products are not appropriate for study of wintertime features because of the pervasive darkness over the higher latitudes. Details of the DMSP satellite and data systems are given by Blankenship and Savage (1974). The DMSP archive is located at the National Snow and Ice Data Center (NSIDC), University of Colorado. Imagery may be purchased from the NSIDC or can be used at the archive.

The potential use of DMSP imagery in the climatological study of data-poor areas was first suggested by Streten and Downey (1977). Since then, in a series of papers dealing with aspects of the climatology of northern hemisphere cyclones, Carleton (1985a, b, 1987) has demonstrated the value of the DMSP products used here.

Mosaics for eight 5-month winter seasons, November to March, 1976–1977 to 1983–1984, were studied, although the last season was eliminated due to excessive amounts of missing data (see below). 1976–1977 was the first winter season that the DMSP data were available with continuous twice-a-day coverage, while years subsequent to 1983–1984 continued to have problems with missing data; hence, only the 7-year period contained the data needed for this study.

Cloud vortex classification

The cloud vortex classification system used in this research has evolved from the seminal work of Troup and Streten on early imagery of the southern hemisphere (i.e. Troup and Streten, 1972; Streten and Kellas, 1973; Streten and Troup, 1973). Carleton (1979, 1981a, b) applied an updated version of their classification to a more extensive and improved southern hemisphere data set, and subsequently further modified it for use with the DMSP imagery (Carleton, 1985a, b, 1987). That version of Carleton's classification system is modified slightly here as part of a collaborative global climatology of polar lows, where Carleton and Carpenter (1989a, b) have investigated these storms on DMSP imagery of the southern hemisphere and we have studied them in the North Pacific (Yarnal and Henderson. 1989. and this paper) using identical methodologies. The last part of the project. concerning the North Atlantic. is currently at the proposal stage.

The cloud vortex classification system and signature types for extratropical cyclones is presented in Figure 1 and Table I. Major extratropical fronts follow the sequence: type 1, type 4, type 5, type 7, type 8, type 9 and/or type 10, type 11. The evolutionary sequence of polar lows is quite similar, with any particular cyclogenetic polar low forming as either a comma cloud (type 21) or spiraliform (type 22), and potentially passing in turn through the developing (type 6), mature (types 7 and 8), dissipating (type 9 and/or type 10) and decaying (type 11) stages. From type 7 onward, evolving frontal waves and polar lows are often very similar morphologically, although they can usually be distinguished by means of their size and history.

In this study, the two key cyclogenetic polar-low signatures are those of the comma cloud (type 21) and spiraliform (type 22). As discussed in Yarnal and Henderson (1989), no consensus has been reached on the classification of these cyclones. For our purpose, which is the rapid identification of polar lows based on their size, shape, structure, and environmental context, these two types were believed sufficient. In most cases, comma clouds and spiraliforms are morphologically distinct, but considerable variation within the two types is possible (Forbes and Lottes, 1985) so that distinguishing these two forms from one another was sometimes quite subjective.

Continued development of the polar low results in the type 6, developing stage signature. This type is characterized by a slot of clear, relatively dry air near the central vortex. For the larger frontal bands, two types (4 and 5) are recognized based on the extent of dry-slot development.

The mature, fully developed stage is marked by signatures in which the slot of clear air forms a well-defined spiral around the nominal vortex centre. This stage is comprised of two types: 7 and 8. Type-7 cyclones possess a sharp hook and an incomplete (or semi-) spiral, while Type-8 storms have a clear slot that spirals into the centre of the vortex.

Dissipating cyclones (types 9 and 10), are somewhat distinct from one another and do not necessarily denote an evolutionary sequence (i.e. type 10 does not always follow type 9; Streten and Kellas, 1973). Type 9 occlusions are symmetric spirals, similar to the mature type 8 storms, except that the clear spiral bands are 'smudged' or filled in. Type 10 occlusions are asymmetric, huge features, with the distance across the head of the 'question mark' sometimes measuring as much as 15° of latitude for frontal storms. They can develop directly from type 8 cyclones, or from type 9. Often, they fragment into a number of smaller cyclones at all stages of development, from cyclogenetic to decaying.

Decaying cyclones (type 11), also known as dying vortices or dying spirals, tend to spin in one location for days and fragment into smaller cloud structures. Occasionally, some of the fragments have sufficient vorticity and moisture to develop into new cyclones. The clouds associated with decaying cyclones tend to be lower in level than those of the younger, more active systems from which they evolved (Carleton, 1985b).

Instant occlusions (Carleton, 1981b, 1985a) are included in this classification scheme as a special kind of cyclogenesis. This process takes place when a polar low in any stage of development (although usually cyclogenetic or developing) advances upon and interacts with a decelerating or stalled frontal wave. The effect of this combination is to cause a rapid cyclonic spin-up at the point of contact, appearing to occur 'instantly' between successive satellite images. As shown schematically in Figure 1, the satellite image may catch the resulting spin-up at any stage of development after initial contact, from a developing type 4 to a dissipating type 9 frontal cyclone.

Data recorded

Specific data were recorded for every polar low that occurred in the domain 20°–70°N latitude and 110°E–120°W longitude. Each system was given a number and was tracked through all stages of evolution in successive images. The date and time the mosaic was assembled was recorded. The latitude and longitude of the nominal vortex centre, marked by an 'x' in Figure 1, was noted, as was the radius in degrees latitude from the vortex centre to the leading edge of the storm. Signature type was recorded, as well as an indication as to whether this was the first image in which that cyclone was observed with that particular signature. The

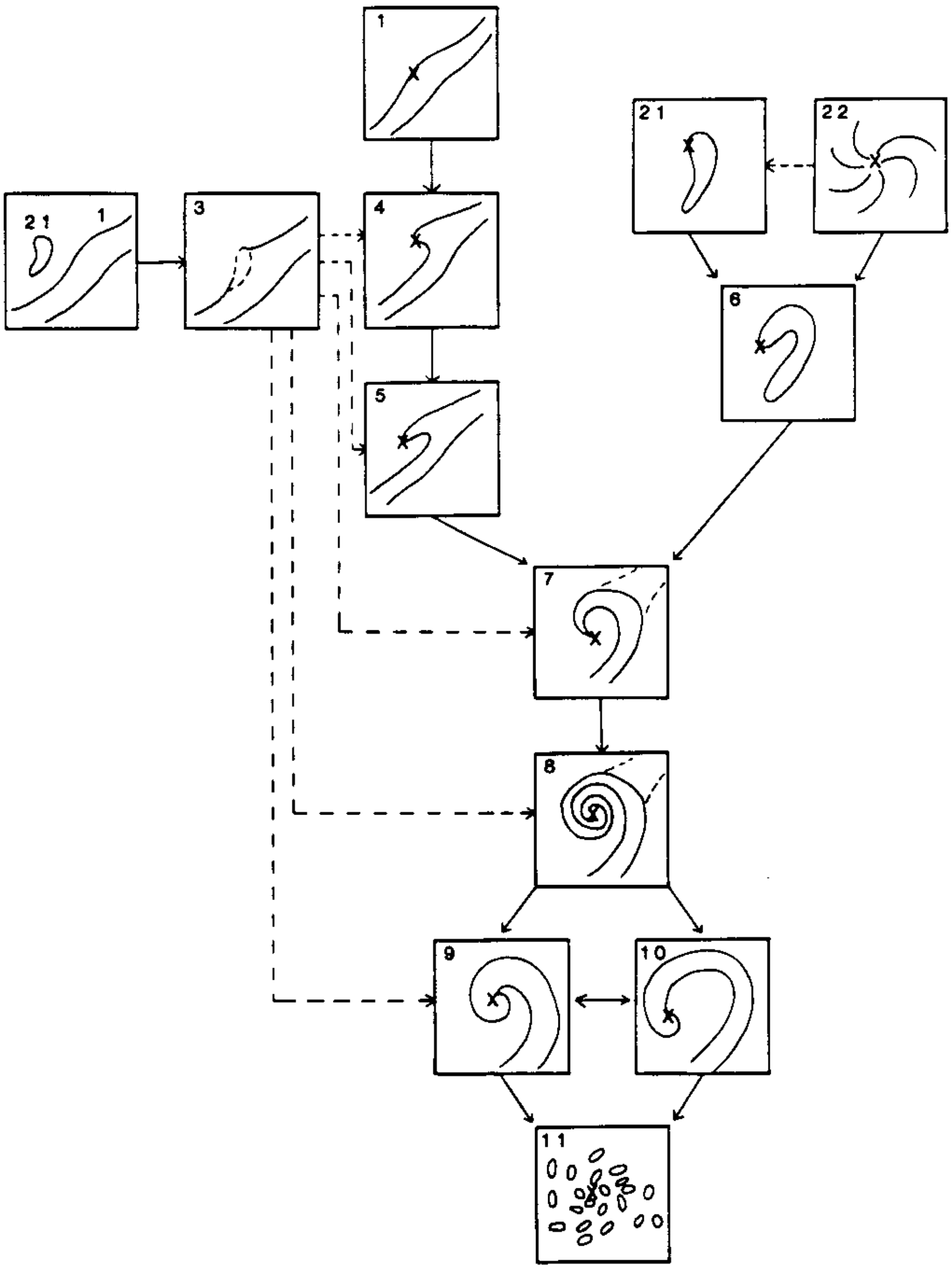

Figure 1. Cloud vortex signature types and their evolutionary sequence: 'x' indicates nominal vortex centre

Table I. Categories of model cyclone development*

Cyclone category	Carleton category	Cloud vortex type
1	A1a, A1b	Frontal wave
21, 22	A2i, A2ii	Comma and spiraliform polar lows
3	A3	Instant occlusion
F4, I4	B1a	Developing wave: incipient slot
F5, I5	B1b	Developing wave: marked slot
6	B2	Developing polar low
P7, F7, I7	C2	Mature hook
P8, F8, I8	C1	Mature spiral
P9, F9, I9	Da	Dissipating: symmetric cloud band
F10, I10	Db	Dissipating: asymmetric cloud band
P11, F11, I11	E	Decaying vortex spiral

P, denotes a cyclone developed from one of the polar low cyclogenetic types (21 or 22).
F, denotes cyclone developed from a frontal wave (type 1).
I, denotes a cyclone developed from an instant occlusion (type 3).
* Modified from Carleton (1985a).

following information was noted for types 21 and 22: cloud type (cumuliform or stratiform), cloud height (high/medium or low), and perceived cyclogenetic mode (mode 1 = land/ice edge cyclogenesis; mode 2 = formation in polar airstream over open water; mode 3 = development from a decaying vortex spiral (type 11). Tail lengths were measured in degrees latitude for cyclogenetic comma clouds (type 21).

Problems encountered

A few significant problems were encountered in the interpretation of the satellite imagery that placed limitations on the results of this study. The most serious was the often large number of missing mosaics (Table II). In the first seven seasons of the study, 1976–1977 to 1982–1983, an average of about 10 per cent of the images were missing, which caused some minor problems. These included such difficulties as following the progress of a storm when a missing image interrupted the sequence, cyclones appearing without passing through the cyclogenetic stage, and lows not reaching their ultimate stage of development because of a truncated sequence. Although these problems were frustrating and prevented the full assessment of all storms' evolution, they are believed to have little impact on the main results of this research. However, in the eighth year, 1983–1984, considerably more than 50 per cent of the mosaics were missing. An attempt was made to interpret the remaining images, but no confidence was placed in these data and, therefore, they were not included in the results that follow.

Mapping the distributions of the cyclones posed several problems that ultimately influenced the results. The first problem concerned the 'binning' of the data. In order to map the data, the geographical coordinates of each cyclone were fed into a computer mapping package. If each whole-numbered latitude–longitude pair over the domain of this study was used, 6681 points would have been evaluated by the package; this would have consumed extraordinary amounts of computer time and would have been prohibitively expensive. More importantly, so much smoothing would be required to make the maps intelligible that much of the detail in the data would be wasted. Therefore, it was desirable to place the data into latitude–longitude boxes (bins), with the centroid of the bin assigned the total number of cyclones appearing within that area during a specified period. The decision then became a compromise between computational efficiency and resolution of the data. In the literature, 2° by 2°, 5° by 5°, 5° by 10°, and 10° by 10° bins are commonly used. The 2° by 2° bins would have required the computer to handle 1625 points, still a fairly large and time consuming computational task, producing a highly detailed, difficult to read map. Alternatively, although computationally efficient, 5° by 10° and 10° by 10° bins would have provided poor spatial resolution and greatly

Table II. Inventory of DMSP 1:30 M infra-red mosaics of the North Pacific basin

Month/year	Usable	Missing*	Month/year	Usable	Missing*
Nov. 1976	47	13	Nov. 1980	56	4
Dec. 1976	59	3	Dec. 1980	58	4
Jan. 1977	61	1	Jan. 1981	60	2
Feb. 1977	49	7	Feb. 1981	53	3
Mar. 1977	60	2	Mar. 1981	60	2
1976–1977	276	26	1980–1981	287	15
Nov. 1977	52	8	Nov. 1981	57	3
Dec. 1977	57	5	Dec. 1981	59	3
Jan. 1978	55	7	Jan. 1982	54	8
Feb. 1978	52	4	Feb. 1982	32	24
Mar. 1978	54	8	Mar. 1982	55	7
1977–1978	270	32	1981–1982	257	45
Nov. 1978	57	3	Nov. 1982	59	1
Dec. 1978	37	25	Dec. 1982	55	7
Jan. 1979	61	1	Jan. 1983	48	14
Feb. 1979	50	6	Feb. 1983	46	10
Mar. 1979	60	2	Mar. 1983	52	10
1978–1979	265	37	1982–1983	260	42
Nov. 1979	57	3	Nov. 1983	22	38
Dec. 1979	54	8	Dec. 1983	24	38
Jan. 1980	60	2	Jan. 1984	54	8
Feb. 1980	54	4	Feb. 1984	37	21
Mar. 1980	56	6	Mar. 1984	32	30
1979–1980	281	23	1983–1984	169	135

* Includes mosaics where key satellite passes were missing

reduced information levels. Thus, the 5° by 5° bins were considered an acceptable compromise, with 260 points to contour and moderate spatial resolution.

The 'binning' also required decisions that influenced the displayed results. Whenever the geographical coordinate fell on the border between bins, each of the contiguous bins were arbitrarily assigned one-half cyclone each. If the coordinate was on the corner-point of four contiguous bins, each was assigned one-quarter cyclone. Cyclones falling on the outer borders of the study area were treated similarly.

Because of the convergence of meridians as the poles are approached, and because as part of the larger project some of the polar low data were to be related to other environmental parameters that are area dependent, all of the polar low frequency distributions were standardized to those of a bin centred on 45° latitude. For all of the data presented in this study, the correction was not necessary and produced slightly biased results, especially near the northern and southern margins of the study area. However, the overall effect was trivial and was kept to maintain comparability to those phases of the research where the correction was needed. The method of Taljaard (1967) was applied to this problem, in which:

$$X = N(4 \cos 45/\eta \cos \Psi)$$

where N is the number of vortices in each bin, η is the number of months of data and Ψ is the mid-latitude between each 5° parallel.

The last problem encountered in mapping had a subtle, but pervasive impact on the displayed results. The smoothing function and contour interval chosen could produce either a highly smoothed, very general cyclone distribution or an extremely detailed map that was very difficult to read. Again, a compromise between interpretability and level of information had to be struck. Unfortunately, one smoothing function and contour interval would not suffice for all maps, with any one selection producing a pleasing, informative map with one distribution, and either a busy, complicated figure or one devoid of information with another. Our solution was to maintain one 'best' smoothing function with any particular group of maps, but change (and report that change in the figure caption) the contour interval as necessary within that group.

RESULTS

There are two parts to this section. In the first, basic statistics and spatial distributions of evolving versus non-evolving cyclogenetic polar lows will be presented in order to determine if these two classes of cyclone can be distinguished from one another using our methodology. The second part consists of a brief look at the frequencies and distribution of instant occlusions in the North Pacific.

Evolving versus non-evolving cyclogenetic polar lows

Polar lows were classified as *evolving* if a given cyclogenetic comma cloud or spiraliform was observed to pass into a higher stage of development. In most cases, this would be type 6, although often these cyclones developed so quickly that this might be any of the higher order types (see Figure 1). In a very few cases, instant occlusions occurred before the incipient polar low could evolve further; these were excluded from this part of the analysis. *Non-evolving* polar lows were not observed to develop beyond the cyclogenetic stage.

Ratios of evolving versus non-evolving cyclogenetic polar lows are stratified by their form and cyclogenetic mode in Table III. Mode 1 or mode 2 comma clouds continue to evolve two-thirds of the time, whereas spiraliform polar lows evolve roughly one-third of the time. Approximately half of the polar lows formed from decaying vortices (mode 3) evolve to higher stages. The raw frequencies from which these ratios were derived are given in Table IV. These data demonstrate that not all polar lows evolve beyond the incipient stage. Nonetheless, in the North Pacific, about 100 to 150 do continue to develop each low-sun season.

Table III. Evolving: non-evolving ratios of cyclogenetic polar lows

	Polar-low class	
Cyclogenetic mode	Comma clouds	Spiraliforms
1	1·94	0.64·
2	1·95	0·53
3	1·08	0·83

Table IV. Frequencies (and percentages) of evolving and non-evolving cyclogenetic polar lows

Cyclogenetic mode	Evolving	Non-evolving
Comma clouds		
1	212 (14·0)	109 (7·2)
2	670 (44·3)	343 (22·7)
3	28 (1·9)	26 (1·7)
Spiraliforms		
1	29 (1·9)	45 (3·0)
2	10 (0·7)	19 (1·3)
3	10 (0·7)	12 (0·8)
All comma clouds	910 (60·1)	478 (31·6)
All spiraliforms	49 (3·2)	76 (5·0)

Maps of the total number of cyclogenetic, total evolving, and total non-evolving comma clouds and spiraliforms reveal useful information. In the case of the comma clouds (Figure 2), the largest number of non-evolving polar lows are found over the southern Kamchatka Peninsula, with a band of slightly lower frequencies extending south-eastward from there to the vicinity of the date line. Although the peak for continued development is found off the east coast of northern Japan, quite a few fail to develop in this region, as well. In addition, about half of those born over the eastern half of the basin do not evolve. For the spiraliforms (Figure 3), it appears that, in general, those that form away from the coast are least likely to evolve, whereas those that form immediately upon leaving the land/ice edge stand a much better chance of developing beyond the cyclogenetic stage. An interesting feature of the maps is the virtual total failure of the spiraliforms forming in the Gulf of Alaska to evolve.

The above data can be stratified further by cyclogenetic mode to bring out even more detail (Figure 4). Virtually all mode 1 comma clouds that form in the lee of the coastal mountains over the northern Sea of Japan continue to evolve, whereas most of those that form in the lee of the mountains of the extreme north-eastern USSR over the north-west Bering Sea fail to develop (Figure 4, a and b, respectively). Most of those that form in the lee of the southern tip of Sakhalin Island also tend to evolve. The rest of the mode 1 comma clouds either evolve or not in roughly the 2:1 ratio given in Table III. Mode 2 comma clouds exceed this ratio immediately to the east of Hokkaido, but tend to maintain the 2:1 proportion eastward across the North Pacific to about the date line (Figure 4, c and d). From that meridian, the likelihood of an incipient comma cloud continuing to evolve declines progressively as one moves eastward. A clear regional dichotomy can be seen in the spiraliform mode 1 maps (Figure 4, e and f). Virtually all of these polar lows that form to the north and east of the Kamchatka Peninsula fail to evolve, whereas those that form to the south and west of this area stand a chance of continued development. Like the mode 1 comma clouds, the mode 1 spiraliforms are most likely to survive the incipient state if they form over the Sea of Japan. To crudely summarize this group of maps, specific areas may favour or disfavour the continued development of certain types or modes of polar lows.

Basic statistics comparing the gross size and cloud conditions of evolving with those of non-evolving cyclogenetic polar lows are presented in Table V. In all but one case, no significant difference exists between the samples. The one exception is found in the percentage of medium to high cloud in the spiraliforms (Table V (d)), where the non-evolving cases tend to have far less vertical development. Thus, with the exception of this one tantalizing piece of evidence, there seems to be no easily observed difference between those storms that evolve and those that do not.

When a polar low evolves beyond the incipient, cyclogenetic stage, it may successively pass through the developing (type 6), mature (types 7 and 8), dissipating (types 9 and/or 10) and decaying (type 11) stages. However, just as all cyclogenetic polar lows do not evolve to higher forms, not all higher order polar lows continue to develop. Of the 1005 type-6 polar lows observed during the study period, only 438 completed their life cycle by evolving to type 11.

In summary, based on our results, only a few generalizations can be made on the likelihood of a North Pacific polar low's further development. Two-thirds of all comma clouds evolve beyond the cyclogenetic stage, while only one-third of all spiraliforms continue to develop. Certain geographic locations favour development at a rate greater than these proportions, while in other areas, any polar low that forms will almost certainly fail to evolve. However, for the bulk of the area in which polar lows form, the proportions given above are accurate. Statistics comparing evolving and non-evolving polar lows show no important differences between the two developmental classes in our satellite-derived data. Roughly one-third of all polar lows will pass through all stages of development from cyclogenesis to decay.

Forbes and Lottes (1985), in a detailed climatology of just 36 days' data, concluded that comma clouds and spiraliforms were the most likely of their polar vortices to evolve and were able to detect subtle differences in the synoptic-scale atmospheric environment, as measured by upper air analyses, associated with developing and non-developing polar lows. In contrast, based solely on observation of the DMSP imagery, we could not always tell which polar lows would continue to evolve. Therefore, except for those areas where polar lows almost always fail to develop, each incipient polar low should be watched carefully for signs of continued evolution by forecasters tracking these storms, and objective methods of discrimination based on variables

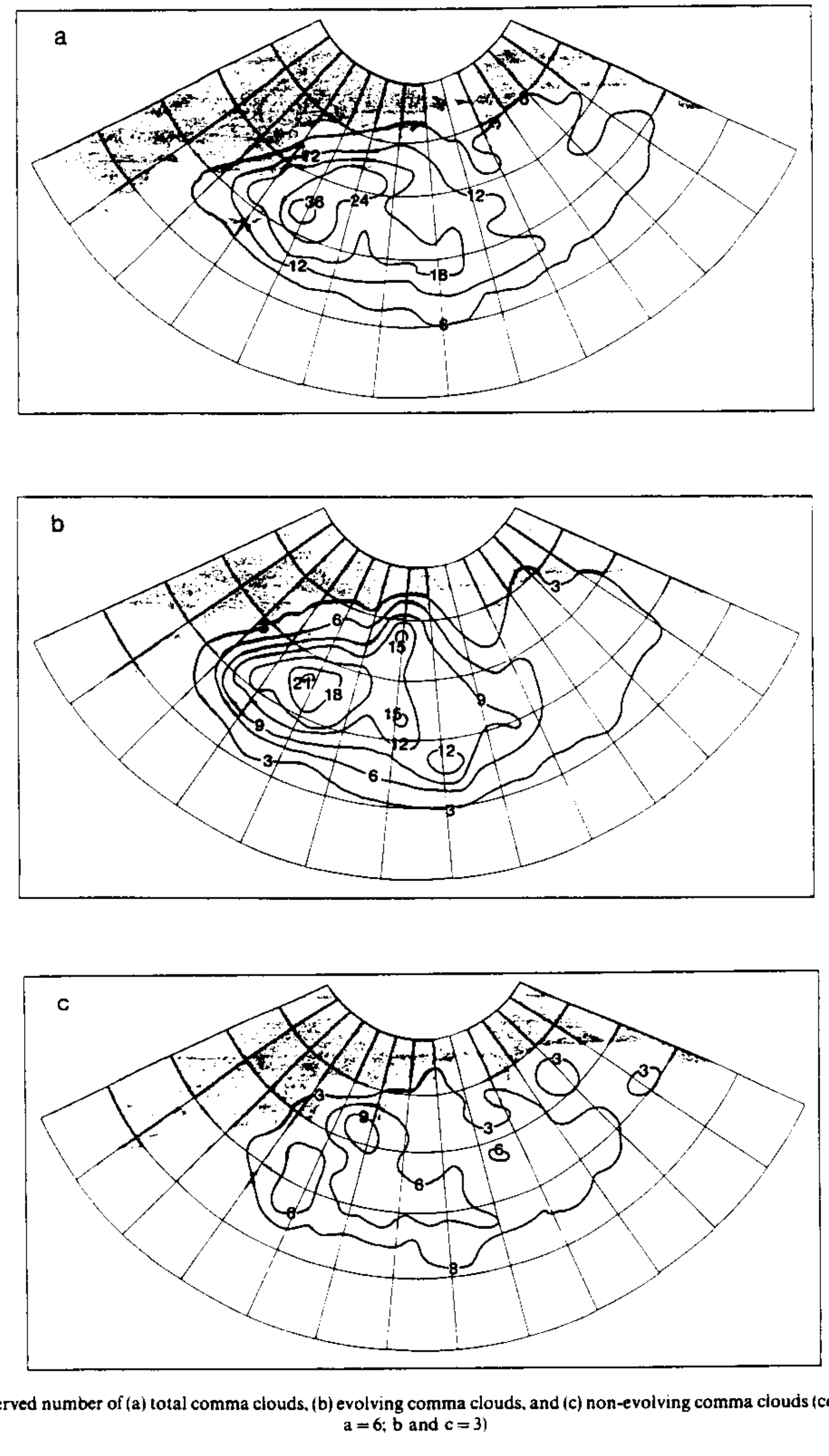

Figure 2. Observed number of (a) total comma clouds, (b) evolving comma clouds, and (c) non-evolving comma clouds (contour interval: a = 6; b and c = 3)

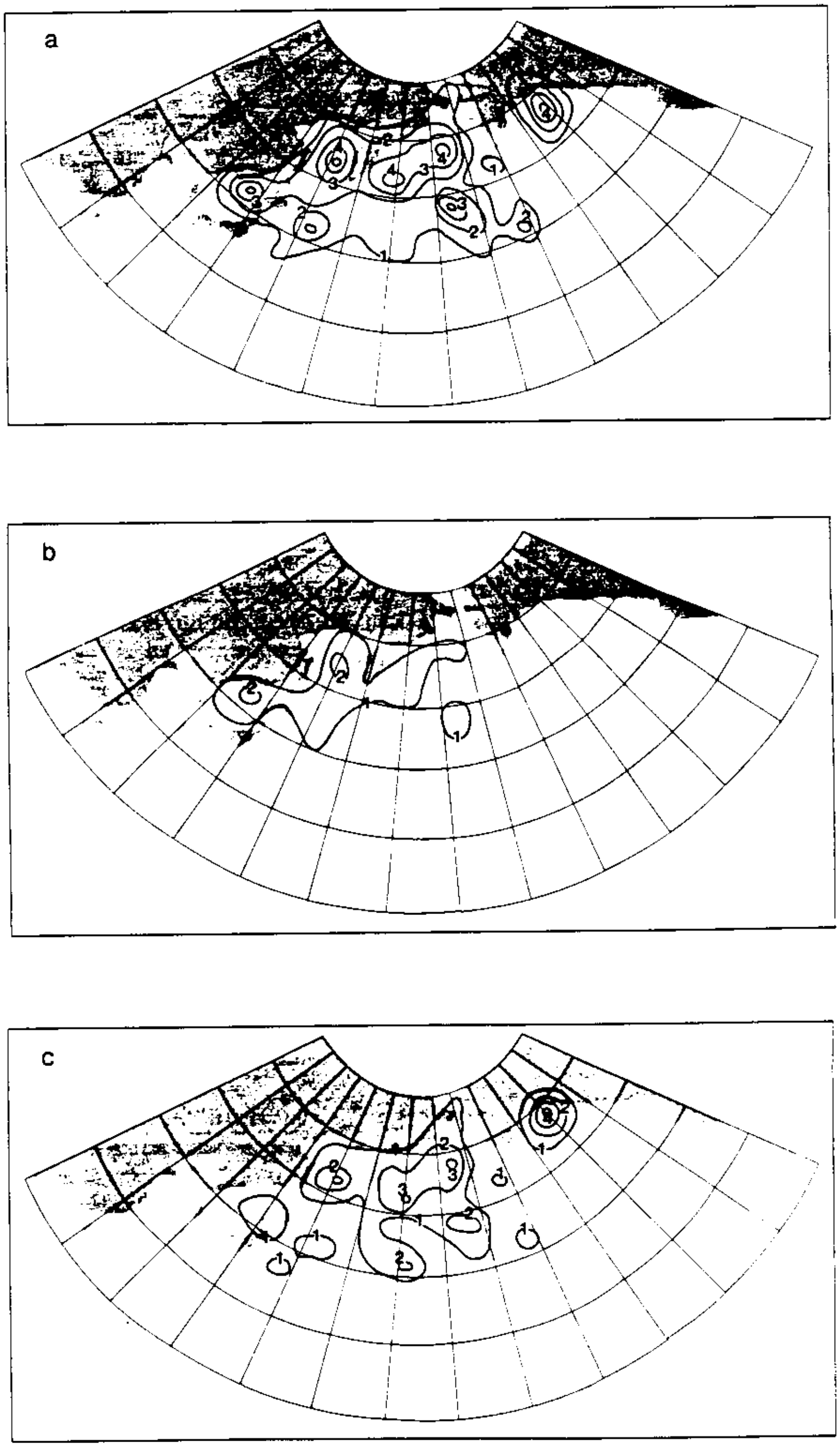

Figure 3. Observed number of (a) total spiraliforms, (b) evolving spiraliforms and (c) non-evolving spiraliforms (contour interval = 1)

Table V. Statistics of evolving and non-evolving cyclogenetic polar lows
(a) Radii

Polar-low type and mode	$\bar{X}$(°latitude)		$\hat{s}$(°latitude)	
	Evolving	Non-evolving	Evolving	Non-evolving
21-1	1·43	1·35	0·35	0·38
21-2	1·53	1·41	0·42	0·36
21-3	1·57	1·37	0·42	0·39
22-1	2·05	2·27	0·63	0·89
22-2	1·95	2·08	0·55	0·80
22-3	2·30	2·38	0·63	0·71
All 21s	1·50	1·40	0·41	0·37
All 22s	2·08	2·24	0·62	0·84

(b) Tail length

Polar-low type and mode	$\bar{X}$(°latitude)		$\hat{s}$(°latitude)	
	Evolving	Non-evolving	Evolving	Non-evolving
21-1	2·61	2·51	0·79	0·86
21-2	2·75	2·63	0·90	0·87
21-3	2·95	3·00	0·80	1·07
All 21s	2·72	2·62	0·87	0·88

(c) Percentage cumuliform cloud

Polar-low type and mode	Evolving	Non-evolving
21-1	84·0	80·7
21-2	93·1	89·5
21-3	89·3	76·9
22-1	89·7	88·9
22-2	100·0	89·5
22-3	100·0	83·3
All 21s	90·9	86·8
All 22s	93·9	88·2

(d) Percentage medium to high cloud

Polar-low type and mode	Evolving	Non-evolving
21-1	70·3	68·8
21-2	81·9	74·6
21-3	92·9	65·4
22-1	55·2	31·1
22-2	80·0	47·4
22-3	90·0	58·3
All 21s	79·6	72·8
All 22s	67·3	39·5

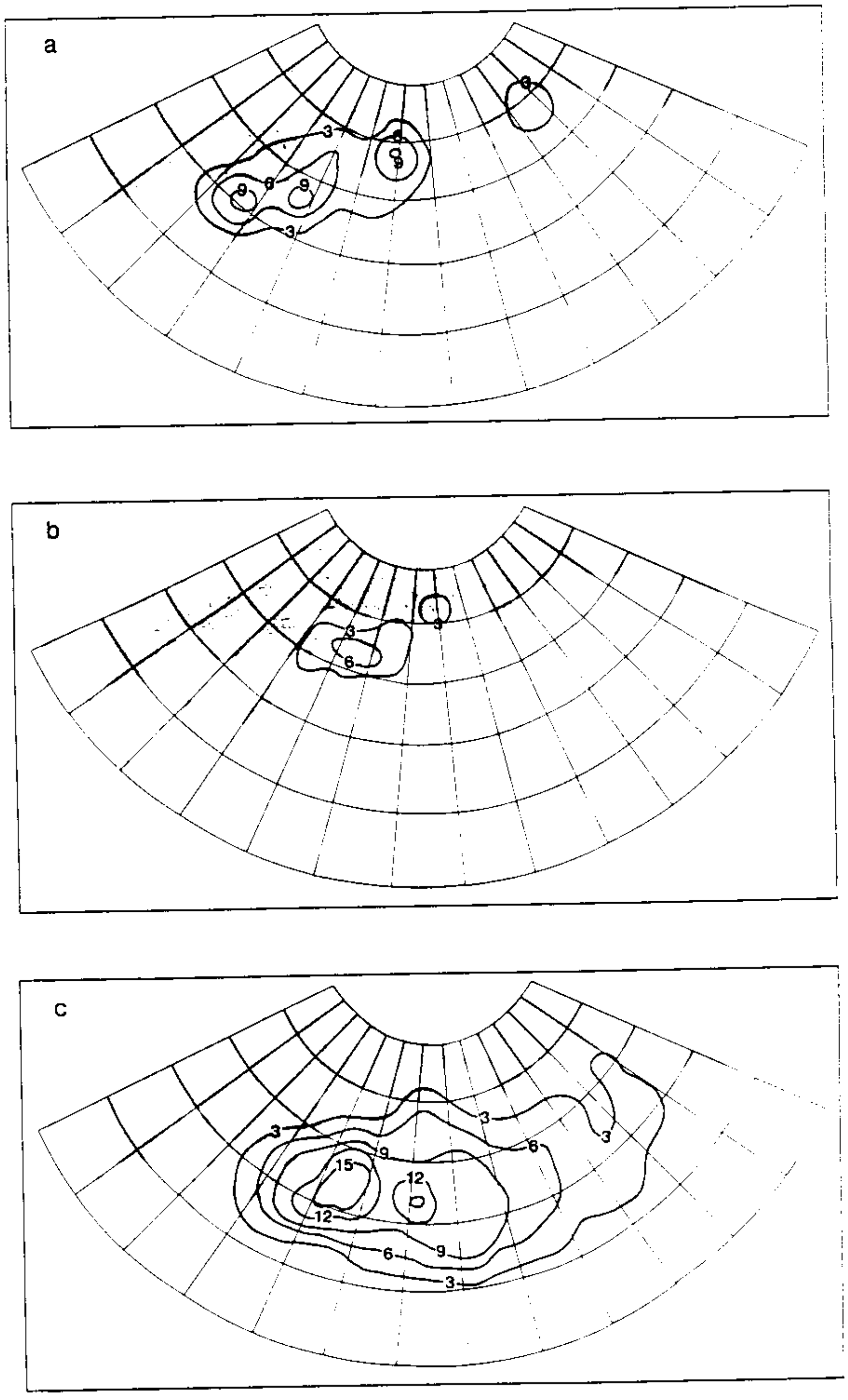

Figure 4. Observed number of evolving and non-evolving cyclogenetic modes: (a) evolving and (b) non-evolving mode 1 comma clouds; (c) evolving and (d) non-evolving mode 2 comma clouds; (e) evolving and (f) non-evolving mode 1 spiraliforms (contour interval: a, b, c and d = 3; e and f = 1)

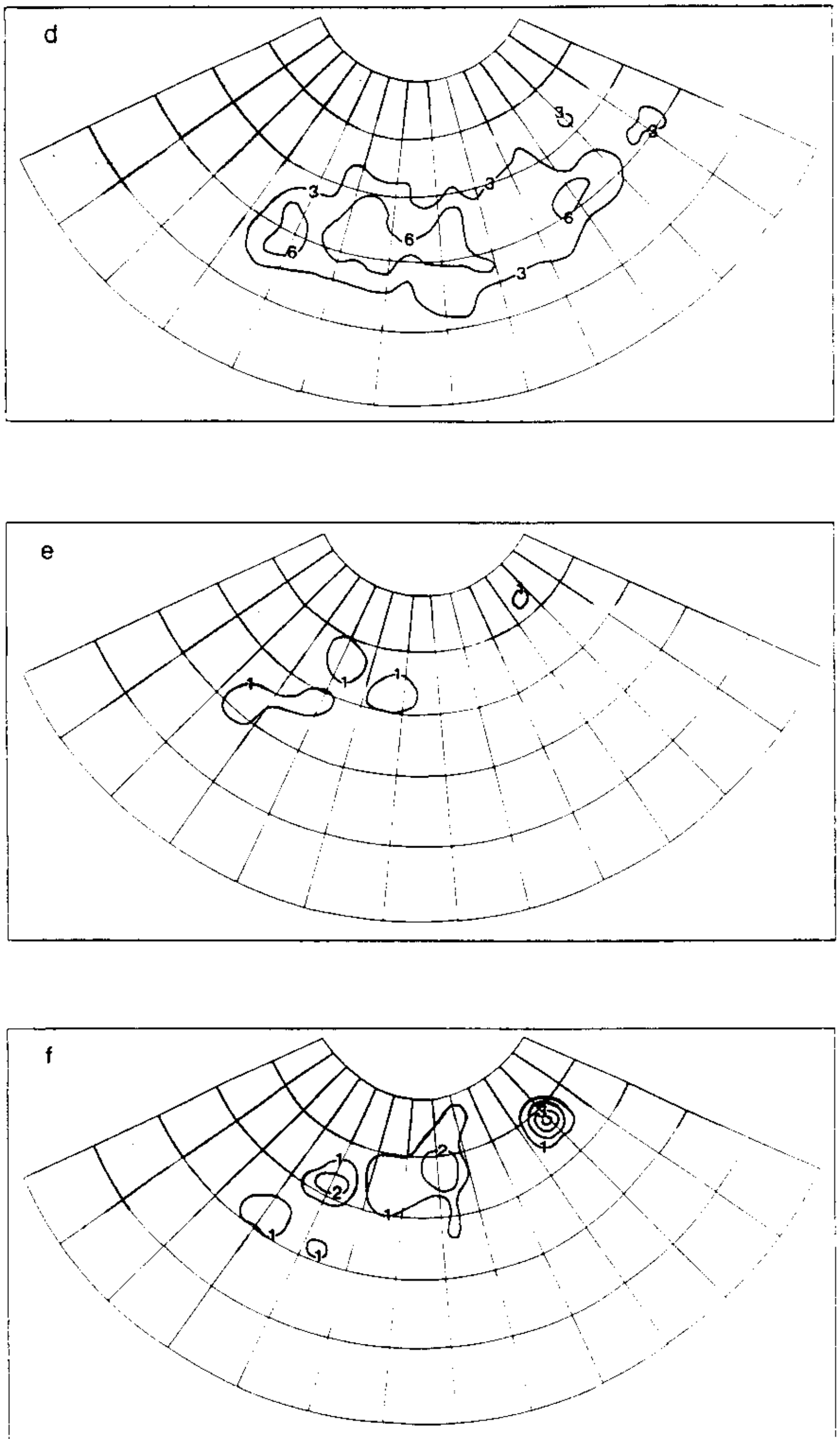

Figure 4 (*continued*)

such as horizontal temperature gradient, vertical wind-shear, lapse rate and, especially, vorticity advection (Forbes and Lottes, 1985) should be developed in order to determine those cyclones most likely to evolve.

Instant occlusions

At any stage of its development, a polar low can catch up to the frontal wave preceding it and initiate the instant occlusion process. In the seven seasons of this study, 81 instant occlusions were observed. They were almost always located where a blocking high had caused the frontal wave to stall, allowing an eastward-moving polar low to interact with the frontal wave. Given the large number of blocking ridges known to form over the extreme eastern North Pacific, the distribution of instant occlusions is expected (Figure 5).

The instant occlusion process has been identified by Mullen (1983) and Businger and Walter (1988) as a potential initiator of explosive cyclogenesis. Our results (Yarnal and Henderson, 1989 and this study) suggest that although the eastern North Pacific is an area of low polar low frequency, the potential for explosive cyclogenesis is much greater in this part of the basin because of the concentration of instant occlusions. Thus, the entire extratropical west coast of North America is exposed to the dangers of these storms.

CONCLUSIONS

The data on polar lows used in this research was derived from seven low-sun seasons of the medium resolution, twice-a-day DMSP mosaics of the North Pacific basin. The large amount of imagery interpreted did not allow a detailed climatological study such as that by Forbes and Lottes (1985; based on only 36 days' data), but did permit a number of generalizations to be made on the evolution of polar lows.

In the North Pacific, not all polar lows evolve beyond the incipient, cyclogenetic stage. Although a few areas favour continued development, and conversely a few discourage further evolution, most areas maintain the climatological ratios of evolving:non-evolving presented here. On average, about two-thirds of all polar lows that form will evolve to a higher stage, and approximately one-third will pass through all stages of development from cyclogenesis to decay. Two-thirds of all comma clouds, the more common form of polar low in the North Pacific, evolve beyond the incipient stage, whereas only two-fifths of the less common spiraliform polar lows develop beyond cyclogenesis.

No discernible, significant difference between gross size and cloud characteristics of evolving and of non-evolving polar lows was present in our data. Thus, based on just the observation of satellite imagery without support of upper air data, it may be difficult to predict which polar lows will continue to develop beyond the cyclogenetic stage. For forecasting purposes, once an incipient polar low has been identified on a satellite

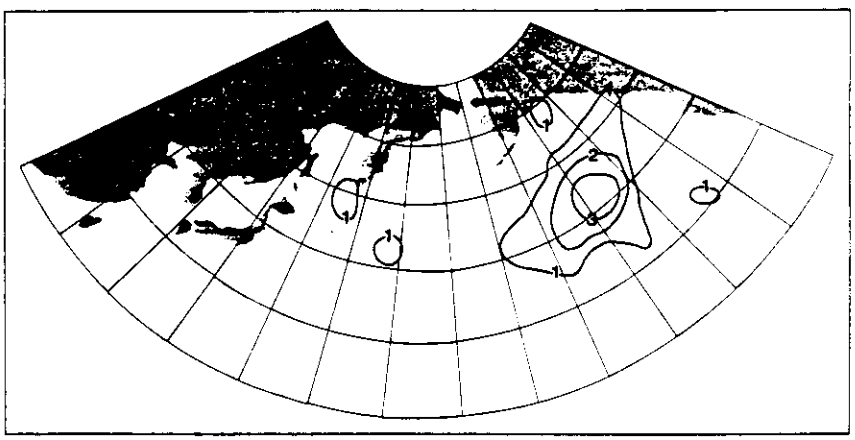

Figure 5. Observed number of instant occlusions (type 3) (contour interval = 1)

image, it is recommended that variables such as those studied by Forbes and Lottes (1985; e.g. horizontal temperature gradients, vorticity advection) be monitored in order to better predict the likelihood that one of these potentially destructive cyclones will continue to develop. Those specific areas where continued evolution beyond the cyclogenetic stage is favoured should be watched most carefully by forecasters.

When polar lows catch up to the frontal wave with which they are associated, an instant occlusion, and perhaps explosive cyclogenesis, will result. Instant occlusions form almost exclusively in the eastern extratropical North Pacific, putting the west coast of Anglo-America at risk to these potentially dangerous storms.

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REFERENCES

Blankenship, J. R. and Savage, R. C. 1974. 'Electro-optical processing of DAPP meteorological satellite data', *Bull. Am. Meteorol. Soc.*, **55**, 9–15.

Businger, S. and Walter, B. 1988. 'Comma cloud development and associated rapid cyclogenesis over the Gulf of Alaska: a case study using aircraft and operational data', *Mon. Wea. Rev.*, **116**, 1103–1123.

Carleton, A. M. 1979. 'A synoptic climatology of satellite-observed extratropical cyclone activity for the Southern Hemisphere winter', *Arch. Meteorol. Geophys. Bioklimatol.*, **27B**, 265–279.

Carleton, A. M. 1981a. 'Monthly variability of satellite-derived cyclonic activity for the Southern Hemisphere winter', *J. Climatol.*, **1**, 21–38.

Carleton, A. M. 1981b. 'Climatology of the "instant occlusion" phenomenon for the Southern Hemisphere winter', *Mon. Wea. Rev.*, **109**, 177–181.

Carleton, A. M. 1985a. 'Satellite climatological aspects of the "polar low" and "instant occlusion"', *Tellus*, **37A**, 433–450.

Carleton, A. M. 1985b. 'Synoptic cryosphere-atmosphere interactions in the Northern Hemisphere from DMSP image analysis', *Int. J. Remote Sensing*, **6**, 239–261.

Carleton, A. M. 1987. 'Satellite-derived attributes of cloud vortex systems and their application to climate studies', *Remote Sensing Environ.*, **22**, 271–296.

Carleton, A. M. and Carpenter, D. A. 1989a. 'Intermediate-scale sea ice-atmosphere interactions over high southern latitudes in winter', *Geojournal*, **18**, 87–101.

Carleton, A. M. and Carpenter, D. A. 1989b. 'Satellite-derived climatology of "polar lows" and broadscale climatic associations for the southern hemisphere', *Theor. Appl. Climatol.* (in press).

Forbes, G. S. and Lottes, W. D. 1985. 'Classification of mesoscale vortices in polar airstreams and the influence of the largescale environment on their evolution', *Tellus*, **37A**, 132–155.

Lystad, M. 1986. 'Project summary', in Lystad, M. (Ed.) *Polar Lows Project Final Report*, Norwegian Meteorological Institute, Oslo.

Midtbo, K. H. and Lystad, M. 1986. 'Polar low forecasting', in Lystad, M. (Ed.) *Polar Lows Project Final Report*, Norwegian Meteorological Institute, Oslo.

Mullen, S. L. 1983. 'Explosive cyclogenesis associated with cyclones in polar airstreams', *Mon. Wea. Rev.*, **111**, 1537–1553.

Rasmussen, E. and Lystad, M. 1987. 'The Norwegian Polar Lows Project: a summary of the International Conference on Polar Lows, 20–23 May 1986, Oslo, Norway', *Bull. Am. Meteorol. Soc.*, **68**, 801–816.

Reed, R. J. 1986. 'Baroclinic instability as a mechanism for polar low formation', *Proceedings of the International Conference on Polar Lows, Oslo, 1986*, Norwegian Meteorological Institute, Oslo.

Streten, N. A. and Downey, W. K. 1977. 'Defense Meteorological Satellite Program (DMSP) imagery: a research tool for the Australian region', *Aust. Meteorol. Mag.*, **25**, 25–35.

Streten, N. A. and Kellas, W. R. 1973. 'Aspects of cloud pattern signatures of depressions in maturity and decay', *J. Appl. Meteorol.*, **12**, 23–27.

Streten, N. A. and Troup, A. J. 1973. 'A synoptic climatology of satellite-observed cloud vortices over the Southern Hemisphere', *Q. J. R. Meteorol. Soc.*, **99**, 56–72.

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551.555.6:551.576.1:551.589.1:551.467 (215–13)

SATELLITE CLIMATOLOGY OF 'POLAR LOWS' AND BROADSCALE CLIMATIC ASSOCIATIONS FOR THE SOUTHERN HEMISPHERE

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ABSTRACT

A climatology of polar air cloud vortices (so-called 'polar lows') is derived for the Southern Hemisphere using sets of medium resolution (5·4 km) DMSP (Defense Meteorological Satellite Program) imagery. The climatology is for the winter season (June through to September) and covers the 7-year period 1977–1983. Both comma cloud and spiraliform polar air signature types are considered, as identified in recent satellite studies for the Northern Hemisphere. The comma clouds dominate over a wide range of ocean latitudes, whereas the spiraliform systems occur less frequently (about 1:10 for the hemisphere), and show maximum frequencies in sea ice latitudes around mid-winter (about 1:3).

Within-season variations in the locations of maximum occurrence of polar air systems are consistent with the large-scale changes in the longwaves associated with the semi-annual oscillation of surface pressures. Interannual variations in polar low occurrence for the seven winters appear connected, at least in part, with changes in the amplitude of sea-level pressure (SLP) wavenumber one. When the seasonal cycle is amplified, as in the year of a 'warm' ENSO (El Niño/Southern Oscillation) event (e.g. 1982), large numbers of polar lows are observed south-east of Australia and around New Zealand. This contrasts with the situation for year (−1) of a warm event (e.g. 1981), when the annual cycle of the trough is suppressed. At that time, reduced frequencies of cold air outbreaks in the New Zealand area are accompanied by fewer polar lows.

On a seasonally averaged basis, and in most winters, there is a positive relationship between the regional extent of the Antarctic sea ice, the longitudes of preferred occurrence of cold air outbreaks and the incidence of polar lows. This effect may be enhanced just downstream of areas of strongest oceanic heat loss to the atmosphere.

KEY WORDS Satellite climatology Synoptic climatology Southern Hemisphere Polar lows Antarctic sea ice

1. INTRODUCTION

The time and space scales of atmospheric motion detectable in meteorological satellite images range upwards from localized cumulus convection through to the synoptic-scale eddies associated with cyclones (Troup and Streten, 1972; Carleton, 1987a). Satellite-based climatologies have tended to emphasize the synoptic-scale and larger cloud systems (e.g. Streten and Troup, 1973; Carleton, 1979, 1981a, 1985a; McGuirk *et al.*, 1987). Circulation systems occupying the meso-alpha (or 'intermediate') range of atmospheric motions (length-scales about $0{\cdot}2$–2×10^3 km: Orlanski, 1975) have only quite recently gained attention. These include the meso-scale convective system (MCS) and the vortices occurring in cold air streams in the absence of pre-existing frontal cloud bands (polar air vortices, or 'polar lows'). They represent an interaction between local (mainly vertical) motions and the quasi-geostrophic flow characteristic of synoptic circulations. Both systems are important precipitation producers in middle latitudes (Browning, 1985). The 'polar low' appears most frequently over the middle and higher latitude oceans in the cool season of each hemisphere (Carleton, 1979; Reed, 1979), although cases of polar air cyclogenesis over land in winter have also been documented (Mullen, 1982). Prior to the advent of satellite data, polar lows were often assumed to be secondary cold fronts or 'back-bent'

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occlusions associated with synoptic-scale wave cyclones. Polar lows readily lend themselves to satellite climatological investigation since (i) they have characteristic cloud signatures (e.g., Carleton, 1985a, b), and (ii) there now exist sufficiently long-term archives of higher resolution cloud imagery from polar orbiters, such as the NOAA AVHRR (Advanced Very High Resolution Radiometer) and DMSP (Defense Meteorological Satellite Program) systems. Further, greater accuracy with numerical prediction models requires improved knowledge of subgrid-scale processes, and this is focusing increased attention on circulations in the meso-alpha range (Keyser and Uccellini, 1987).

The relatively small size of polar lows and their often rapid development over the ocean means that they may easily elude the conventional synoptic observing network until making landfall. Since they may be accompanied by high winds as well as heavy precipitation, polar lows may inflict substantial damage and cause loss of life along populated coastal areas (Kellogg and Twitchell, 1986). It has been shown (Mullen, 1983) that some of the explosive extratropical cyclogenesis events known as 'bombs' (Sanders and Gyakum, 1980) are polar lows. Polar lows continue to be the subject of intensive diagnostic research in the Northern Hemisphere (e.g. Sinclair and Elsberry, 1986), culminating recently in the North Atlantic 'Polar Lows Project' (Rasmussen and Lystad, 1987; Shapiro *et al.*, 1987). A satellite-based winter climatology of polar lows is now available for the North Pacific Ocean (Yarnal and Henderson, 1989).

Little detailed information is available concerning polar air cyclogenesis over the Southern Hemisphere oceans, except where conventional data permit in limited longitudinal sectors (Lyons, 1983; Auer, 1986; Sinclair, 1986; Turner and Warren, 1988). Previous studies of synoptic-scale cyclones in the Southern Hemisphere (Streten and Troup, 1973; Carleton, 1979, 1981a) indicate that polar air vortices may be a relatively frequent form of cyclogenesis over the higher latitude oceans (about 45–50 °S), especially in winter. These systems disrupt the otherwise simple pattern for frontal wave systems of cyclogenesis over middle latitudes, followed by maturity and dissipation at successively higher latitudes. The hemispheric mosaics used in the Streten and Troup (1973) and Carleton (1979, 1981a) cyclone climatologies did not have sufficient spatial or spectral resolutions to permit ready detection of smaller scale polar air vortices over the Southern Hemisphere, or to determine more precisely the frequency of high-latitude cyclogenesis. The latter has long been considered an uncommon phenomenon, although it now seems that meso-scale cyclogenesis events near coastal Antarctica may be relatively frequent (Bromwich, 1987).

The present paper presents a climatology of polar air cloud vortices for the Southern Hemisphere based on analysis of higher resolution polar orbiter satellite imagery. Studies for the Northern Hemisphere (Forbes and Lottes, 1982, 1985; Businger, 1985, 1987; Carleton, 1985b) suggest that polar lows indicate highly anomalous (frequently meridional) atmospheric circulation. This broadscale association is also examined in the present Southern Hemisphere research, since the satellite data span seven winters (1977–1983) that exhibit marked interannual variations of circulation. Finally, the general associations of polar lows with broadscale surface climate variables, primarily sea-surface temperatures (SSTs) and the Antarctic sea ice extent, are examined. These are known to interact with synoptic circulations (for reviews see Budd, 1982; Streten, 1982; Gillooly and Lutjeharms, 1984; Carleton, 1987b), but their specific relationships with polar lows are undocumented.

2. SATELLITE IMAGERY AND DATA ON SURFACE CLIMATE VARIABLES

2.1 DMSP imagery

The wintertime climatology of polar lows utilizes sets of medium resolution (5·4 km) thermal infra-red (IR: 8–13 μm) imagery acquired by the polar orbiting DMSP system. Since the IR data are available twice daily and provide radiance information for all latitudes irrespective of seasonal variations in solar illumination, they are used in preference to the only once-daily and lower latitude coverage afforded by the simultaneous broadband visible sensor. The twice-daily IR orbital swaths are computer processed by US Air Force Global Weather Central (AFGWC) into half-hemispheric mosaics that are mapped on to a polar stereographic base at a nominal scale of 1:30 million. Examples of polar air vortices appearing on DMSP imagery are presented in Figure 1(a–c). These are discussed in the context of the classification of polar air vortices in section 3.

Figure 1. DMSP infra-red examples of (a) comma cloud polar low (type 6) near centre of image that formed in a field of enhanced cumulus between two frontal wave cyclones (lower left and extreme right side of image). (b) Spiraliform polar low (type 22) located close to the marginal ice zone of Antarctica. The system is the small cumuliform spiral vortex (arrowed) in lower centre of the image, and is located south-east of a large dissipating frontal cyclone with an asymmetric cloud band (type [illegible]). Note also the area of enhanced convection in the extreme lower right of the image. (c) Serial polar lows (types 21 and 6) in a field of enhanced cumulus convection derived from a pre-existing vortex (type 11) near image centre. A dissipating frontal cyclone with symmetric cloud band (type 9) is evident at lower right in the image

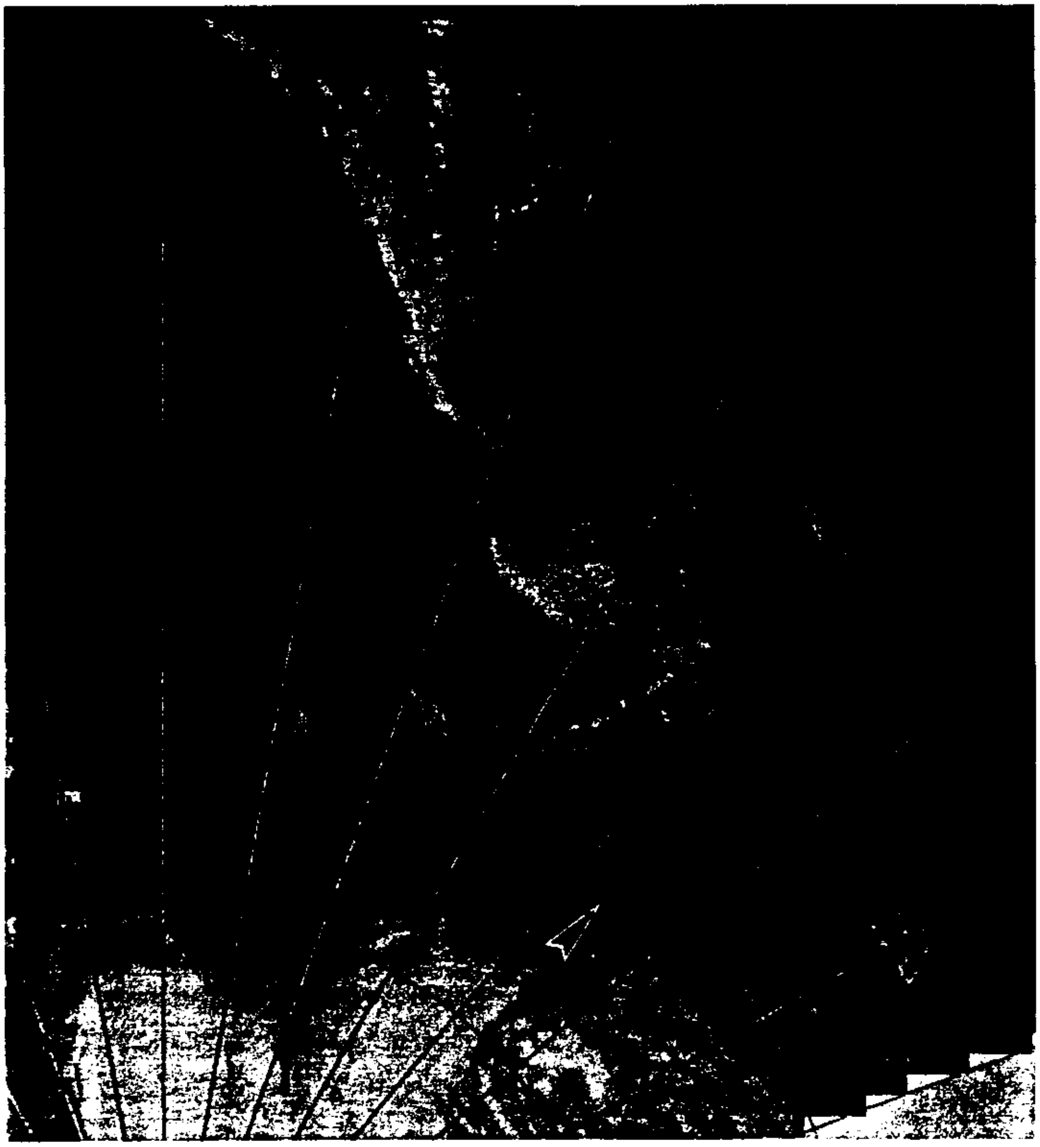


Figure 1(b)

As with most satellite data sets, the DMSP imagery contain temporal and spatial gaps. The twice-daily IR record for the Southern Hemisphere is most complete for the 7 years 1977–1983; hence, the choice of winters studied here. The occasional gaps in the DMSP record that exceed 2 days in duration were supplemented by twice-daily hemispheric IR mosaics derived from the SR (Scanning Radiometer) on board the NOAA polar orbiters. These data have a coarser resolution (about 8 km at nadir) than the DMSP sensor, and are mapped at a smaller scale. Accordingly, smaller polar lows occurring during these times are likely to be under-represented on the imagery, particularly over the marginal ice zone (MIZ) of Antarctica. Similarly, the failure of one of the DMSP satellites in the 1980–1982 period was compensated by computer compositing NOAA SR data into the resulting gaps. Spatial gaps in the DMSP mosaics tend to occur preferentially in the African sector and are due to the time cut-off for compositing the orbital data into mosaics. Despite these deficiencies, the large size of the DMSP mosaics and the long data record, coupled with their relatively high spatial

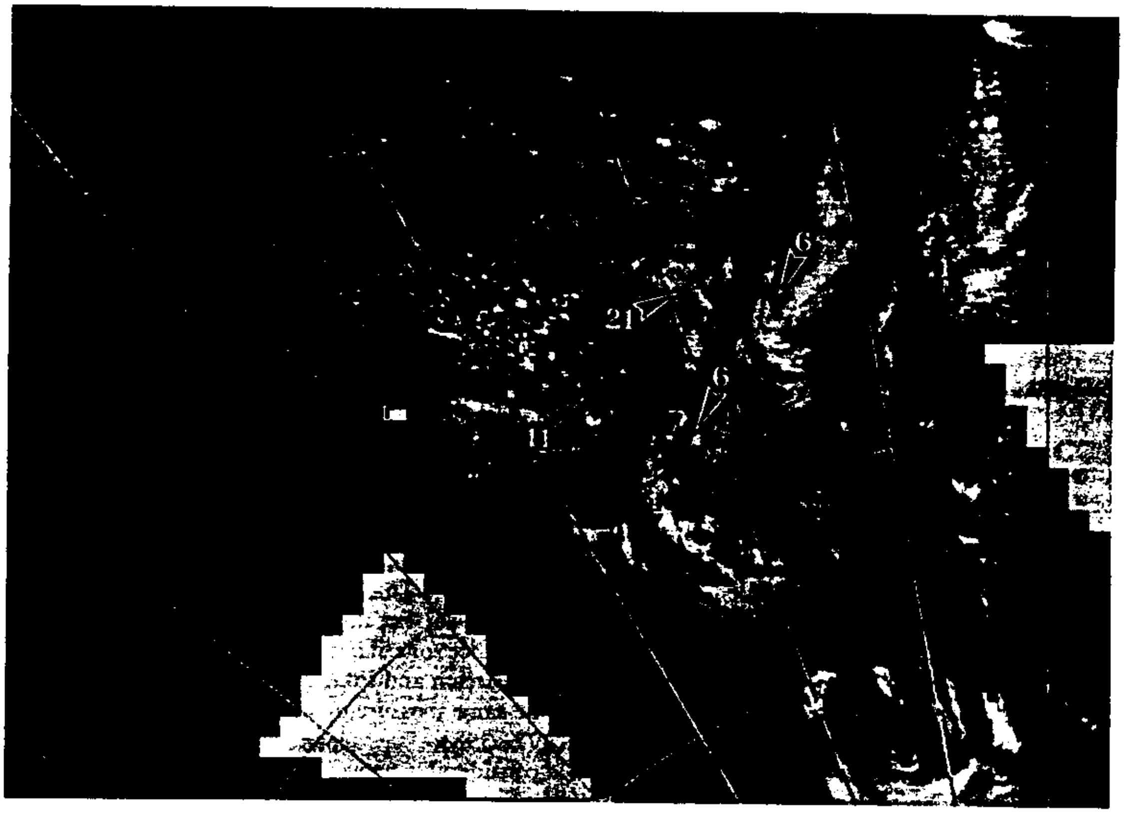


Figure 1(c)

resolution and high latitude coverage (refer Figure 1 (a–c)), optimize the detection of meso-scale cyclogenesis events over the Southern Hemisphere for the winter season.

2.2 *Sea-surface temperature data*

Northern Hemisphere studies indicate an association between polar lows and ocean–atmosphere interaction occurring via upward fluxes of sensible and latent heat. High resolution (2° × 2° latitude-longitude box) monthly summaries of observed and derived marine climate variables, particularly SSTs and marine air temperatures (MATs), have recently become available for the global ocean (Woodruff *et al.*, 1987). They comprise the COADS (Comprehensive Ocean–Atmosphere Data Set) that was developed as a cooperative effort of the US NOAA (National Oceanic and Atmospheric Administration), NCDC (National Climatic Data Center), CIRES (Cooperative Institute for Research in Environmental Sciences) and NCAR (National Center for Atmospheric Research) organizations. The COADS is a synthesis of multiple data sets containing weather observations from ships, and are available for the 1854–1986 period. These have been subjected to rigorous quality control (Woodruff *et al.*, 1987; Oort *et al.*, 1987), although fluctuations in the record arising from changes in observing practice are left uncorrected. These mainly affect the measurement of SST, and involve the changeover from uninsulated bucket to insulated bucket or engine intake that had occurred by about 1950 (Barnett, 1984; Wright, 1986). These changes are not a consideration in the present analysis for the 1977–1983 period.

While the COADS is considered to be an excellent data source for ocean-climate studies (Oort *et al.*, 1987), it is also acknowledged to contain deficiencies that may limit its full utility to studies of *interannual*, rather than interdecadal, climate variations (Wright, 1986). Again, this is not a concern for the present study. However, for most middle southern latitudes, particularly the 40–50° S band, the number of 2° × 2° boxes containing SST observations was actually greatest around the turn of the twentieth century in association with the whaling routes (Oort *et al.*, 1987, their figure 2; Woodruff *et al.*, 1987, their figure 5). This reduces the number of available SST and MAT observations in the recent part of the record and necessitates aggregating the monthly data into 10° × 10° boxes over a winter season for the present examination of SST influences on polar air vortex frequency variations. Rather than simply comparing the SST fields with polar-low activity, it was felt that the ocean–air temperature difference (i.e. SST − MAT = ΔT) would more clearly depict the role of boundary layer forcing for interannual polar low variations. A similar index was used to study the composite structure of mature satellite-observed synoptic-scale cyclones in the Southern Hemisphere (Zillman and Price, 1972).

2.3 *Antarctic sea ice data*

Data sets of the extent of the Antarctic pack ice, represented either as the latitude of the ice edge (e.g., Jacka, 1983) or as the total ice area (Naval Oceanography Command Detachment, 1985), are available since 1973. They are derived from combinations of satellite-sensed and conventional shore, ship and aircraft observations, and are compiled into 7-day averaged charts by the US Navy Fleet Weather Facility (FLEWEAFAC) Joint Ice Center (JIC). The equatorward boundary of the pack ice margin is considered important climatically since it is likely to be associated with strong thermal gradients in the lower troposphere. Its short-term advances and retreats are the result of differential dynamic (wind-induced) and thermodynamic (temperature) advection that appear highly dependent on season (Andreas, 1985). This climate sensitivity may be enhanced by cloud-radiation feedbacks in the MIZ (Cahalan and Chiu, 1986). For this reason, and since the ice edge is a relatively simple and reliable measure of the extent of the pack ice zone, it has often been used in synoptic-scale studies of Antarctic sea ice–atmosphere interactions (e.g. Streten and Pike, 1980a; Streten, 1983; Carleton, 1981b, 1983). The present investigation makes use of the same measure of sea ice extent using the JIC ice charts that have been digitized for the seven winters 1977–1983.

The analysis of the original JIC ice charts has varied considerably between studies, and the results are not strictly intercomparable (Sturman and Anderson, 1985). The only other digital archive of the Antarctic ice-edge latitude known to the authors is that of Jacka (1983), who registered the ice-edge latitude at every 10° of longitude. Given these constraints, and the fact that polar air systems are typically far smaller than 10° latitude in diameter (Carleton, 1987a, figure 5), it was decided to digitize the ice edge appearing on JIC analyses as a continuous line. Different ice concentrations and polynyas are not included in the data set. It is a relatively simple matter to plot the weekly locations of the ice edge and compute monthly, intraseasonal and interannual variations in Antarctic sea ice extent on a polar stereographic map base using this digital record. The ice conditions can then be compared with the incidence of polar lows for the required time period.

3. ANALYSIS OF DMSP IMAGERY FOR POLAR LOWS

The DMSP analysis of intermediate-scale polar air cloud vortices that develop in the absence of pre-existing frontal cloud bands ('polar lows'), necessarily makes use of subjective pattern recognition techniques similar to those employed in case study and climatological analyses for the Northern Hemisphere (e.g. Reed, 1979; Rasmussen, 1981; Zick, 1983; Forbes and Lottes, 1985; Carleton, 1985a,b, 1987a). Automated approaches to the primary level classification of cloud vortices hold promise for future satellite climatological investigations (Burfeind *et al.*, 1987). However, the subjective technique utilized in the present study permits differences in polar air systems to be discerned that may ultimately indicate differences in physical process (see Kellogg and Twitchell, 1986). In this regard, two major subclasses are the 'comma cloud' (Reed, 1979) and the spiraliform (or 'Arctic') polar lows (Rasmussen, 1981) (see figure 1 (a and b) for examples). Until quite recently (Sardie and Warner, 1983) it was believed that geographical variations in the relative frequencies of these two types for the Northern Hemisphere implied the dominance of two largely separate formation processes. This involves deep baroclinicity and strong positive vorticity advection in the case of comma clouds, but CISK (conditional instability of the second kind) probably being most important for spiraliform polar lows. However, more recent modelling studies and observations deriving, at least partly, from the Polar Lows Project, suggest that

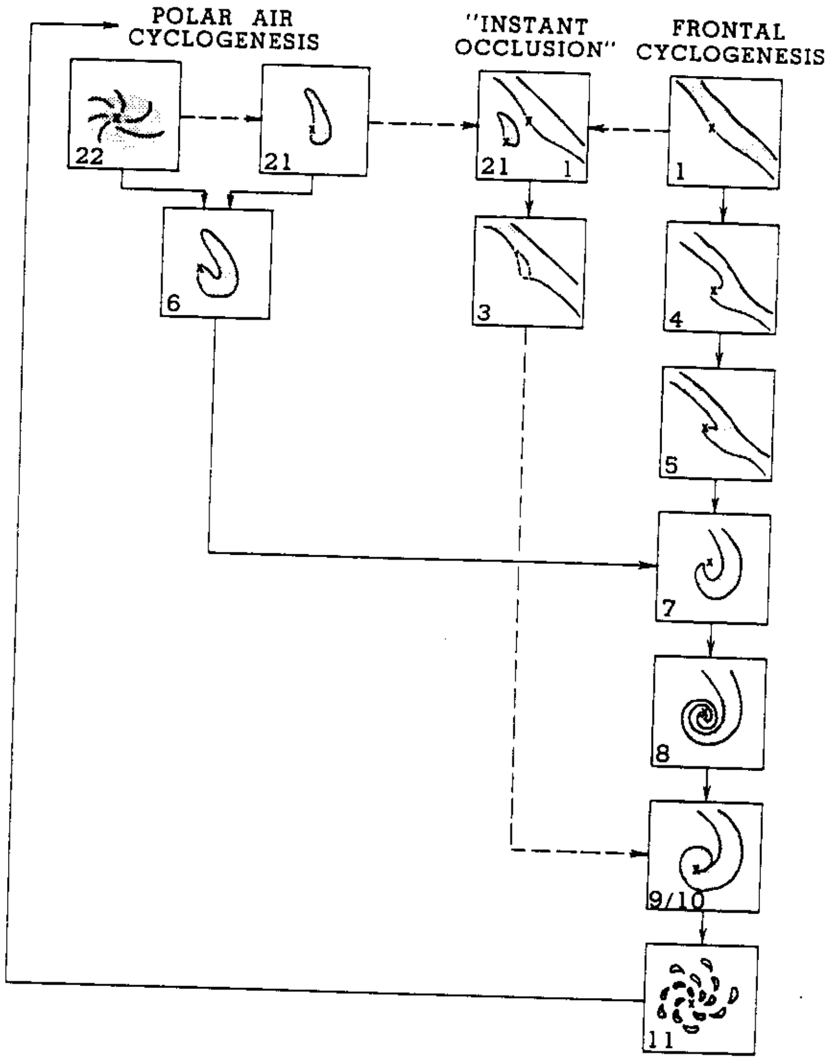


Figure 2. Classification scheme of cyclogenesis cloud vortices for the Southern Hemisphere, as modified from Carleton (1985a, b, 1987a). Refer to text and Table I for further explanation

these differences in formation process are less distinct. It appears that some degree of baroclinicity, generally at lower tropospheric levels, is required for initiation of spiral developments. This may explain their appearance close to the ice–ocean margin (Businger, 1985; Carleton, 1985b; Ese *et al.*, 1988). CISK contributes to further growth and development of both types of polar low, particularly the spirals (Sardie and Warner, 1985; Bonatti and Rao, 1987). While Southern Hemisphere polar lows have signatures resembling the Northern Hemisphere types designated as comma cloud and spiraliform (see Figure 1 (a–c)), no attempt is made here to interpret differences in frequency or preferred location of the two types in terms of likely physics. Such interpretations must await an intensive investigation of polar lows for the Southern Hemisphere where the satellite data may be augmented by conventional surface and upper air data. The cloud vortex classification scheme used here is essentially the same as that described by Carleton (1985a,b, 1987a), and is presented here as Figure 2 and Table I.

Table I. Morphometric classification of extratropical cyclogenesis[a]

Category (Figure 2)	Cyclogenesis type	Description
21	Polar air	Incipient comma cloud: no 'dry slot'
22	Polar air	Incipient spiraliform: banded
6	Polar air	Developed comma cloud with dry slot
1	Frontal	Incipient 'wave' on a cloud band
3	'Instant occlusion'	Fusion of types 21 and 1: incipient
4	Frontal	Developing wave: weak 'dry slot'
5	Frontal	Developed wave: marked dry slot
7	Frontal, polar air	Mature vortex: well-defined hook
8	Frontal, (polar air)[b]	Mature vortex: clear-air spiral
9/10	Frontal, polar air	Dissipating: cloudy or cloud-free vortex and loss of spiral
11	Frontal, polar air, Instant occlusion	Decaying; weakly banded. May generate new polar air vortices

[a] Modified from Carleton (1985a, b, 1987a).
[b] Indicates signature not often observed.

Figures 1 (a–c) and 2 give examples of the 'typical' signatures associated with polar air cyclogenesis in the Southern Hemisphere. Three main cyclogenetic signature types are identified on the DMSP imagery, following previous satellite studies for both hemispheres (e.g. Troup and Streten, 1972; Zillman and Price, 1972; Forbes and Lottes, 1985). These are the polar low, the frontal wave, and the cyclogenesis that results from the merger of these two formations (the 'instant occlusion': Carleton, 1981c, 1985b; Locatelli *et al.*, 1982; Mullen, 1983; Browning and Hill, 1985). Polar air systems are categorized either as comma clouds that develop in enhanced cumulus fields to the rear of a frontal cyclone (type 21 in Figure 2; also Figure 1(a and c)), as smaller spiraliform ('Antarctic') polar lows (type 22; Figure 1b), or as systems developing from weakly vortical cumulus fields remanent from decayed frontal systems (type 11; Figure 1c). The last is described in some detail for the North Atlantic sector by Zick (1983). The value of the higher resolution DMSP data for detecting the spiraliform (type 22) polar low is evident in Figure 1b. This triple classification of polar air vortices (types 11, 21, and 22) may seem simplistic given the resolution of the imagery, however, we felt that a conservative approach would be appropriate. While a finer classification of polar lows is possible (see Forbes and Lottes, 1985), most of the diffuse and smaller scale systems are typically transient and non-developing. Those polar lows that continue to develop can generally be placed into one of the three categories indicated above.

Continued development of the cyclogenetic vortices (both polar air and frontal) through the 'developing' (types 5 and 6) stages results in the mature (hook or spiral) systems (types 7 and 8 in Figure 2), followed by the dissipation (types 9 and 10 in Figure 1 (a and b)) and, ultimately, the decayed (type 11) stages (Figure 2, Table I). In the Southern Hemisphere, this evolution typically occurs as cyclones migrate from lower-middle to high latitudes. In the case of polar lows, it was often difficult to detect a distinct spiral vortex characteristic of mature frontal wave vortices (type 8). The cyclogenetic stages are emphasized in the present study.

The interpretation of twice-daily infra-red DMSP images according to the criteria just described also involved noting latitude/longitude positions of the cloud vortices, the dominant cloud type and level (e.g. stratiform; high), and the vortex location with respect to surface type (e.g., sea ice–ocean margin, open ocean). The last appears to be an important influence on mid-season cyclonic activity patterns in the Northern Hemisphere (Carleton, 1985a). Each system was assigned an identification number to facilitate tracking from image to image. The ability to track systems helps reduce bias that might result from the misidentification of a decaying frontal vortex as a polar low. A minimum size of 1° latitude radius was specified for a polar-low vortex to be recorded, since Forbes and Lottes (1985) note that systems smaller than this in the Northern Hemisphere frequently fail to develop further. Accordingly, a minimum duration of 24 h was set (ideally, two consecutive DMSP mosaics) for comma clouds. However, spiraliform systems were counted whenever they occurred owing to their frequently short life spans (average about 12–36 h in this study, compared with about 48–72 h for comma clouds). The climatological characteristics of Southern Hemisphere polar lows are now discussed.

4. WINTER SEASON CLIMATOLOGY OF POLAR LOWS, 1977–1983

4.1 Spatial patterns of polar air cyclones

The locations of all polar air vortices (inverted comma, spiraliform) in any stage of development for the seven winters 1977–1983, are shown in Figure 3(a–d). These are grouped according to month. The monthly maximum and minimum extents of the sea ice for those years are also plotted. In all months, the comma system (types 21, 6, and 7) is much more numerous than the spiraliform polar low (type 22), and occurs over a wide range of ocean latitudes. Part of this result derives from the longer duration of comma clouds, and also the fact that some spirals may evolve into systems resembling comma clouds (Figure 2).

Interestingly, maps of the *first-observed* locations of polar air vortices (Carleton and Carpenter, 1989, their figure 4) reveal a broadly similar disparity of numbers. For the hemisphere as a whole (poleward of 30°S) and for polar air vortices in all stages of development (types 11, 21, 22, 6, and 7), the spiraliform systems (type 22) comprise only about 10 per cent of the total population of polar lows for much of the winter. However, when considered by 10° latitude zones, the spiraliform type may comprise up to about 40 per cent of the total number of polar lows south of about 60°S in July (Carleton and Carpenter, 1989, their table 2). A similar high-latitude frequency maximum of the spiral systems is evident for the North Atlantic (Carleton, 1985b), often in association with the sea ice margin. Some of the spiral systems occur well within the Antarctic pack ice zone, particularly in July (Figure 3b). This suggests the possible influence of heat and moisture sources, such as polynyas, for high-latitude cyclogenesis. The maximum number of polar air vortices occurs in July (monthly mean = 43·6) with the minimum number in September (mean = 14.4). This coincides with the migration in latitude of the circumpolar trough (van Loon, 1967) that is associated with the semi-annual oscillation in surface pressures (below).

Some confirmation of the possible differences in physical processes related to polar-low type is afforded by Table II, which gives summary statistics of cloud type and height categories for comma (types 21, 6, and 7) and

Table II. Cloud type[a] and level[b] characteristics of polar lows in relation to mode of cyclogenesis

	Comma systems (type 21, 6, and 7)				Spirals (type 22)			
	Cloud form (per cent)		Cloud level (per cent)		Cloud form (per cent)		Cloud level (per cent)	
	Cumuliform	Stratiform	C_M, C_H	(C_L)	Cumuliform	Stratiform	C_M, C_H	(C_L)
Mode 1: ice edge	76·1	(23·9)	91·0	(9·0)	63·6	(36·4)	66·7	(33·3)
Mode 2: open ocean	54·9	(45·1)	90·6	(9·4)	50·0	(50·0)	75·0	(25·0)
Mode 3: pre-existing vortex (type 11)	80·0	(20·0)	93·3	(6·7)	37·5	(62·5)	87·5	(12·5)
Total	59·7	(40·3)	90·9	(9·1)	54·4	(45·6)	73·4	(26.3)

[a] Cloud type is determined from the morphology of cloud elements; cellular in the case of cumuliform clouds, amorphous or striated for stratiform clouds.

[b] Cloud level is determined using the dominant IR radiance of the clouds in relation to the temperature grey scale (latitude and height dependent).

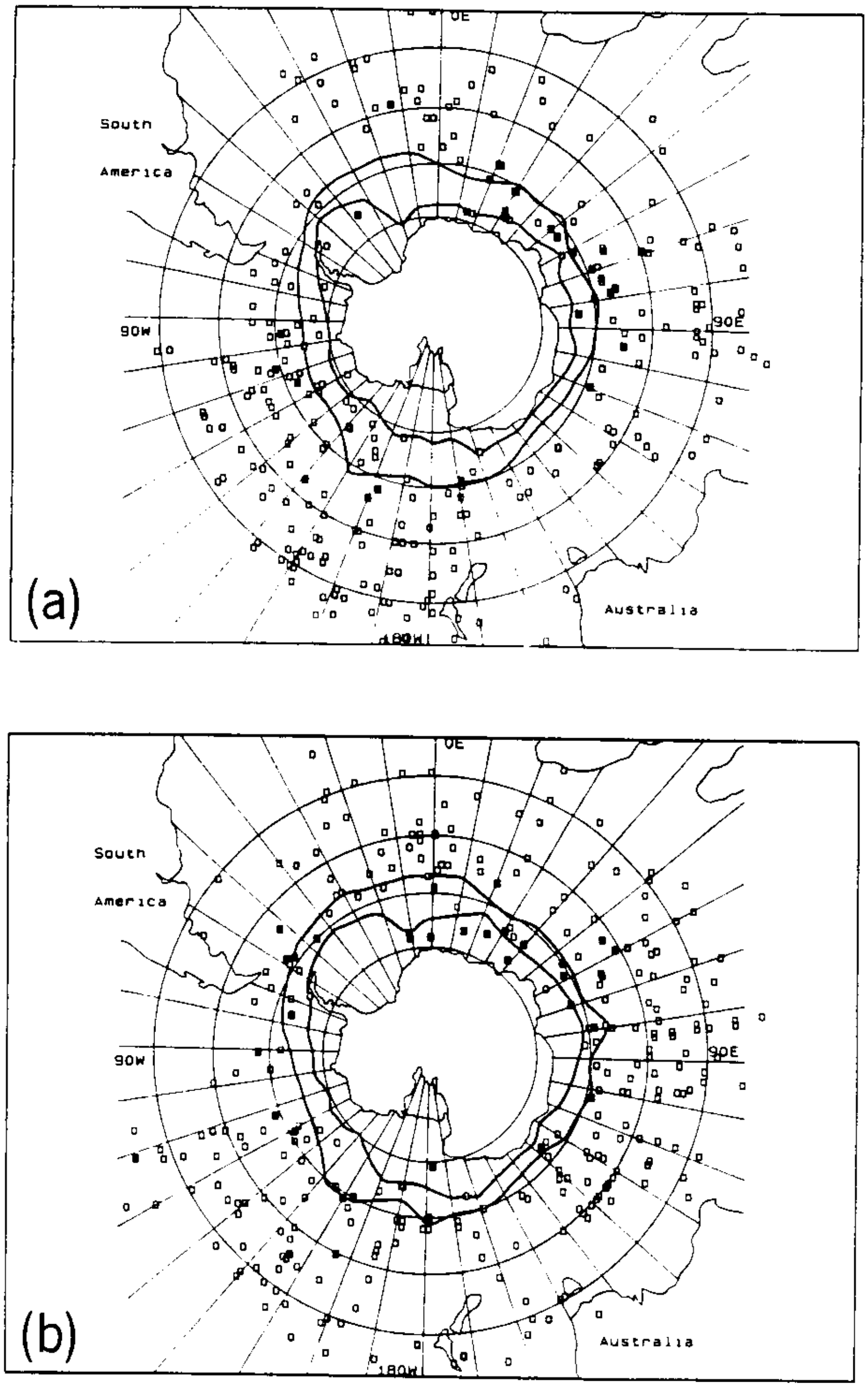


Figure 3. Monthly locations of polar air cloud vortices in any stage of development (types 21, 22, 6, and 7), winters 1977-1983, for (a) June, (b) July, (c) August, and (d) September. Types are indicated thus: comma clouds (open squares), spiraliform polar lows (filled squares). The maximum and minimum extents of the Antarctic sea ice in each month for the seven-winter period are shown by the heavy lines

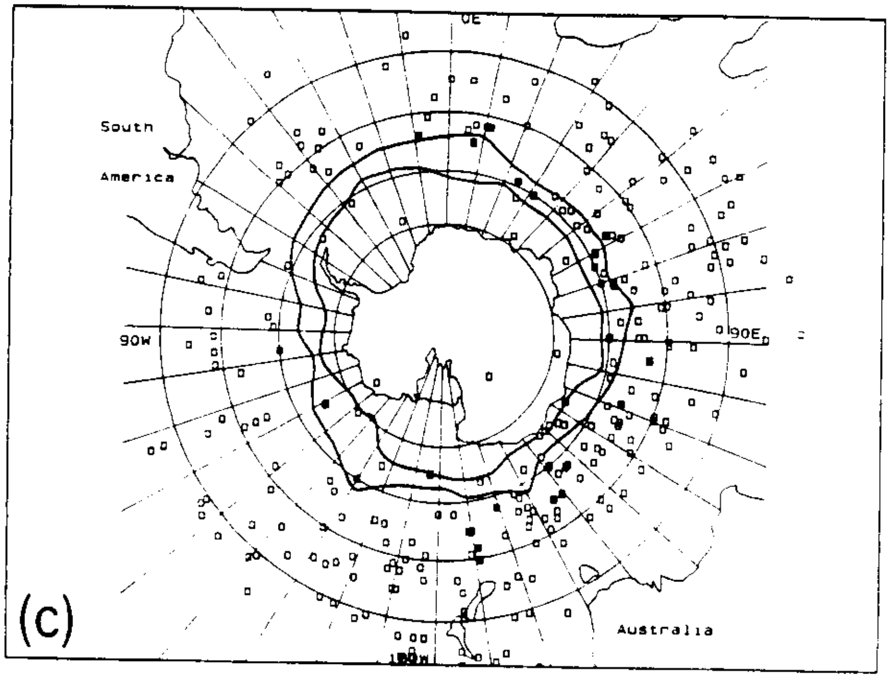


Figure 3(c)

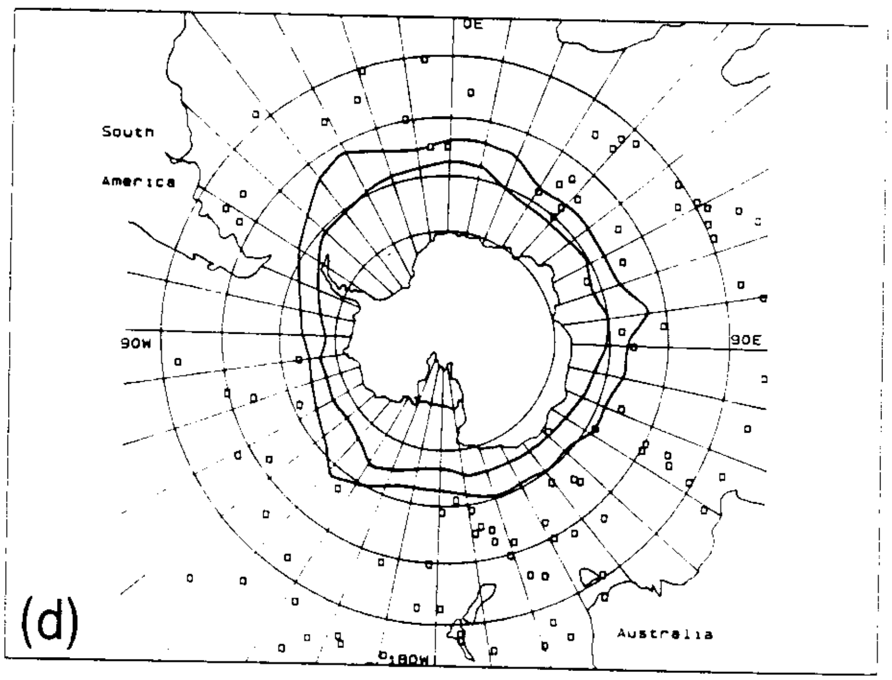


Figure 3(d)

spiraliform (type 22) polar lows with respect to mode of formation. Most comma clouds, particularly those evolving near the ice edge (mode 1) and those developing from decaying frontal vortices (mode 3), appear dominated by cumuliform clouds indicative of weak static stability. The situation is broadly similar for the spiraliform polar lows near the ice edge. A higher proportion of stratiform clouds characterize both comma clouds and spirals developing over the open ocean (mode 2). For all three development modes, comma clouds are dominantly deep cloud systems with very high frequencies of medium and high clouds. The reverse is the case for the spiraliform systems, indicating that these are more likely to be confined to the lower troposphere. These observations are generally consistent with observations of polar air cloud vortices made for the Northern Hemisphere.

4.2 *Spatial patterns of frontal cyclones*

In the context of the synoptic circulation of the Southern Hemisphere, it is instructive to compare the spatial patterns of polar low cyclogenesis (Figure 3(a–d)) with those for frontal wave cyclones occurring in the developing (type 1) through to mature (type 8) stages. These are presented for June and September only in Figure 4 (a and b). The greater frequencies of frontal cyclones in both months contrast with the polar air vortices for the hemisphere equatorward of about 55°S. This is confirmed in Table III, where it is seen that polar lows comprise between about 30 per cent and 50 per cent of frontal cyclones during the winter, a result that is in broad agreement with the earlier study for the 1973–1977 winters by Carleton (1979). Cyclogenesis over higher southern latitudes appears to be quite frequent and dominantly meso-scale, rather than frontal and synoptic. Table III also indicates that the within-season latitude changes of both polar lows and frontal cyclogenetic cloud vortices are statistically significant, and imply associations with the broadscale circulation patterns. These are discussed below. Detailed discussion of the seasonal climatologies of the synoptic-scale cloud vortices is given in Streten and Troup (1973) and Carleton (1979, 1981a,b).

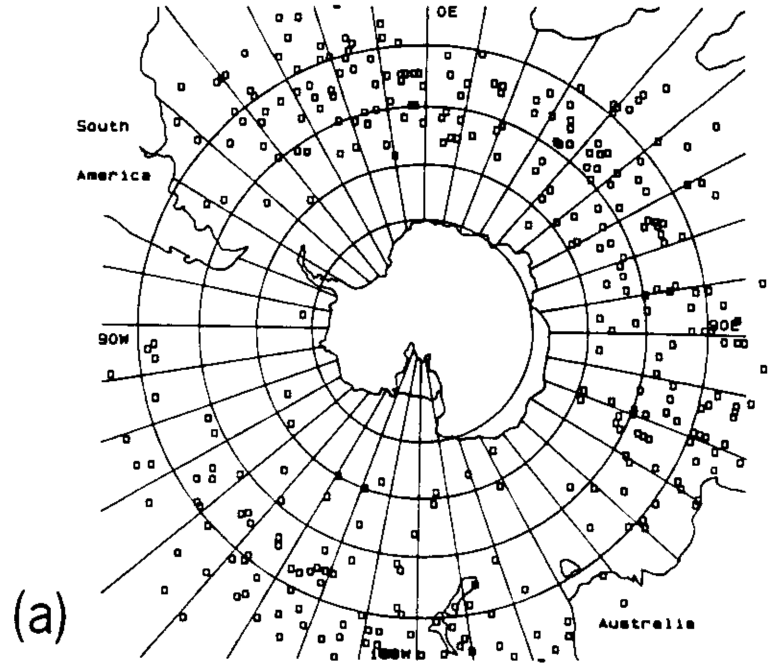
4.3 *Longitudinal variations of polar-low frequencies*

Even a cursory examination of Figure 3 (a–d) suggests a marked westward shift in the maximum frequency of polar air vortices (all types) from the South Pacific (90°W–180°) to the south-east Indian Ocean (180°–90°E) sectors between June and September. This impression is confirmed and shown to be statistically significant by

Table III. Hemispheric and latitude-band frequencies of polar air (types 21, 22, 6, and 7) and frontal wave cloud vortices (types 1–8), winters 1977–1983

	Number of polar/number of frontal lows (per cent)				Full season totals
	June	July	August	September	
All latitudes south of 30°S	277/439 (63·1)	305/859 (35·5)	270/709 (38·1)	102/340 (30·0)	954/2347 (40·7)
30°–40°S	38/158 (24·1)	41/268 (15·3)	43/275 (15·6)	29/150 (19·3)	151/851 (17·7)
40°–50°S	88/188 (46·8)	100/364 (27·5)	84/287 (29·3)	32/116 (27·6)	304/955 (31·8)
50°–60°S	92/82 (112·2)	121/194 (62·4)	113/135 (83·7)	35/67 (52·2)	361/478 (75·5)
60°–70°S	58/12 (483·3)	43/33 (130·3)	30/12 (250·0)	6/7 (85·7)	137/64 (214·1)

χ^2 for polar lows = 31·02 and for frontal lows = 28·46 (significant at $p \leq 0·001$ level with 9 degrees of freedom (critical value = 27·88)).



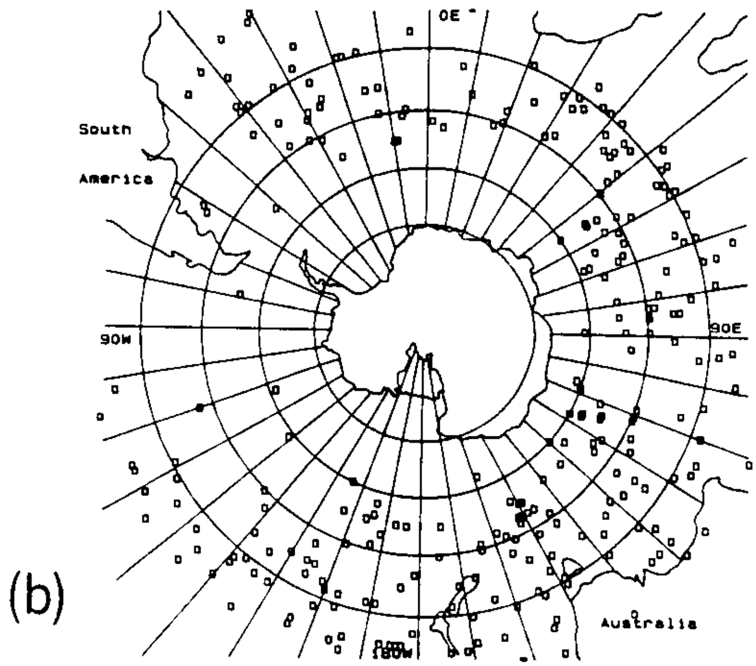


Figure 4. Locations of all frontal wave vortices in the genesis (type 1) through to mature (type 8) stages of development for (a) June and (b) September, winters 1977–1983

Table IV. Intraseason change in polar-low activity (types 21, 22, 6, and 7) between the South Pacific (90°W–180°) and south-east Indian (180°–90°E) Oceans

Month		South Pacific sector	South-east Indian Ocean sector
June $\sum$		123	54
Per cent $\sum_H$	(277)	44·4 per cent	19·5 per cent
July $\sum$		88	82
Per cent $\sum_H$	(305)	28·9 per cent	26·9 per cent
August $\sum$		69	99
Per cent $\sum_H$	(270)	25·6 per cent	36·7 per cent
September $\sum$		27	35
Per cent $\sum_H$	(102)	26·5 per cent	34·3 per cent

$\chi^2 = 31{\cdot}25$ with 3 degrees of freedom (significant at $p < 0{\cdot}001$)

Table IV. Maximum frequencies of polar lows occur in the south-west Pacific and Indian Ocean, and these are also the longitudes of largest interannual variability for these systems (section 5). The peaks of polar-low occurrence, such as between 60°E and 100°E and in longitudes of New Zealand (about 170°E–180°), coincide with or are displaced slightly to the west of, the longitudes of peak occurrence of frontal lows in most months (not shown). This is to be expected when considering that the majority of polar lows are comma clouds that develop in the cold air behind major frontal systems. Again, these results are in broad agreement with the previous study of synoptic-scale cloud vortices for the winter season undertaken by Carleton (1979). The increases (decreases) of polar lows in the Indian Ocean (western Pacific) between early and late winter months (Table IV) are less evident for frontal cyclogenesis (not shown).

4.4 Latitude variations of polar lows and frontal cyclones

Figure 5 shows the composite latitude variations of polar lows and frontal cyclones between early (June) and late (September) winter months over all longitudes. Polar air cyclogenesis increases dramatically just equatorward of the Antarctic continent in both months. Between June and September, large changes occur in the latitude preference of polar air systems. These changes are statistically significant (Table III), and possibly occur in association with the seasonal equatorward movement of the sea ice edge and sea surface isotherms noted by Budd (1982). However, in late winter particularly, these surface influences on polar-low development are complicated by the semi-annual oscillation in sea-level pressures (SLP) (van Loon, 1967; van Loon and Rogers, 1984; Carleton, 1987b). The semi-annual oscillation dominates over subantarctic latitudes and produces thickness gradient maxima in the equinoctial (March, September) months with minima in June and January. Marked changes in the phase and amplitude of the hemispheric longwaves are associated with the semi-annual oscillation. The latitude of maximum cyclone frequencies (and the circumpolar trough) shifts polewards after July at the same time as the zonally averaged Antarctic sea ice edge and sea surface isotherms are expanding equatorwards (see also van Loon, 1967). Longitudinal variations in the semi-annual oscillation related to cyclone frequencies also occur (Howarth, 1983), and are associated with out-of-phase changes in SLP between the three southern continents and their adjacent oceans (van Loon and Rogers, 1984). Sea-level pressure falls (rises) over the continents (oceans) between June and September, leading to amplification of the hemispheric waves (van Loon and Rogers, 1984, their figure 1). It was shown by Budd (1982, his figure 5) that, if considering only *cyclogenesis* (i.e. the formation of new lows), the semi-annual oscillation is not as apparent. Instead, the latitude zones of maximum cyclogenesis show a more simple annual variation resembling those of the sea-surface temperature isotherms and zonally averaged sea ice extent (Budd, 1982). The absence of a

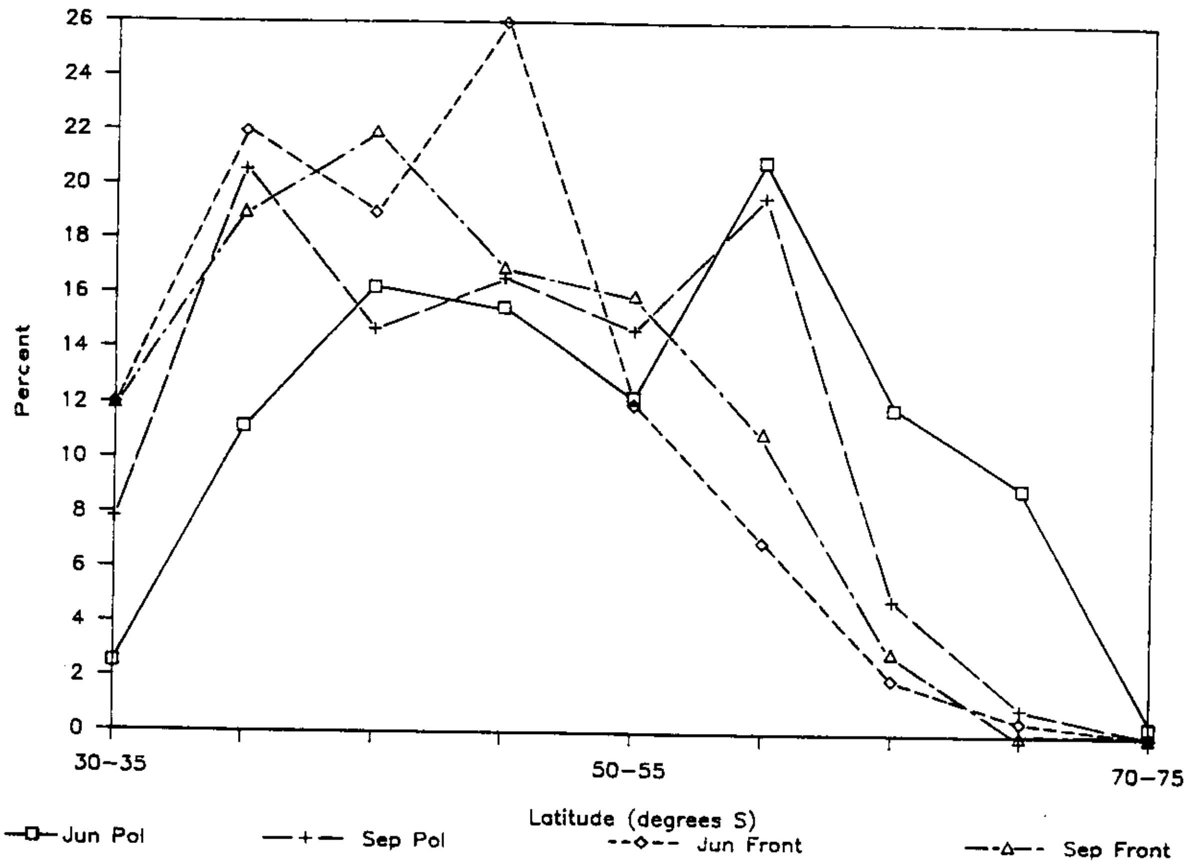


Figure 5. Latitude variations of polar lows (all types) in June (solid line, squares) and September (dashed line, + symbol), and frontal cyclones for June (dashed line, diamond) and September (chain line, triangle), for the 1977–1983 winters. Values are shown for each 5° latitude zone as the percentage of the total number for each type occurring in that month over all latitudes poleward of 30°S

strong semi-annual oscillation signal in the polar-low latitude variations (i.e. one in which there is a poleward shift in frequencies between June and September), contrasts with the situation for the frontal cyclones (Figure 5). This suggests that other controls, such as the Antarctic sea ice, may be at least partly involved in the intraseasonal variations of polar lows. On the other hand, an increase in comma clouds noted for the 35–40°S zone in September (Figure 5) seems unlikely to be due entirely to the migration of the sea-surface temperatures or sea ice edge. Part of this irregularity may relate to the substantial interannual variations in polar air cyclogenesis occurring for the seven winters and the associated large longitudinal variability, about which more is said below.

4.5 Interactions between the hemispheric waves and polar lows

A major feature of the spatial and longitudinal patterns of polar air cyclones (Figure 3; Tables III and IV) is the statistically significant westward shift in activity between the South Pacific (90°W–180°) and south-east Indian Oceans (180°–90°E) that occurs between early and late winter. Since the intraseasonal change in extent of the Antarctic sea ice between June and September is generally no more marked in the south Indian Ocean than it is, on average, in the south-west Pacific (Ropelewski, 1983, his figure 2 and table 2), the source for such a large-scale longitudinal shift in polar-low activity must be sought in the atmospheric longwaves and associated changes in the mean longitudes of cold air outbreaks.

Wavenumber one dominates the mean SLP fields (Trenberth, 1980) and also contributes substantially to the interannual variability of the zonal westerlies in the Southern Hemisphere (Rogers and van Loon, 1982). It shows a close relationship with the zonally asymmetric sea-surface temperature distribution of the Southern Hemisphere (Anderssen, 1965) and with local sea ice conditions in the Scotia Sea (Rogers and van Loon, 1982; Rogers, 1983). The month-to-month variations in wavenumber one can be described by a simple index of the normalized station SLP anomaly difference Hobart minus Stanley, known as the Trans-Polar Index (TPI) (Pittock, 1980, 1984). The TPI is represented in the second eigenvector of SLP (Rogers and van Loon, 1982). Positive (negative) values of the index indicate a trough displaced towards the South American (Australasian) sector. The TPI has recently been updated by the senior author for the period 1961–1981 (Carleton, 1989). Since the phase of the semi-annual oscillation between June and September is associated with pressure falls (rises) over the southern continents (oceans), an amplification of the trough is implied over and just west of Australia in late winter (van Loon and Rogers, 1984). This would be expected to change the longitudes of most frequent cold air outbreaks from the western Pacific in June to the south Indian Ocean in September, and explain the results in Figure 3. If this is the case, then the TPI should reveal the systematic change in the wave.

Table V shows the average monthly values of TPI for the five winters 1977–1981. Sea-level pressure data were not available for Stanley for the last 2 years of the analysis (1982 and 1983). As expected, there is a progressive change from positive to quite strongly negative TPI values between June and September (Table V), implying the amplification (weakening) of the trough in the Australian (South American) sectors. The mean change is −6·4 mbar, although the interannual variability, as given by the standard deviation, is also large. This change results in progressive reductions of cold air advection and the observed frequencies of polar lows over the South Pacific (90°W–180°) after early winter as winds take on more northerly components. The opposite is the case for the south-east Indian Ocean sector, and polar air vortices show a corresponding increase in frequency there (Figure 3).

Corroboration on a regional scale of this hemispheric circulation–polar low relationship is possible. Trenberth's (1976) M1 index is the SLP difference Hobart minus Chatham Island, and measures the trough in the Tasman Sea. This index was also updated through the period considered (1977–1983). The results appear in Table V, along with the relationships among TPI, M1, and Troup's Southern Oscillation Index (SOI) for the full 1951–1982 period. The Troup SOI is the SLP anomaly difference Tahiti minus Darwin, normalized to the standard deviations of the differences for a given record length (here, 1932–1977). TPI and M1 are

Table V. Southern Hemisphere 'polar low'-circulation index relationships

	Trans-polar index: Hobart minus Stanley SLP (1977–1981)				M1 index: Hobart minus Chatham Island (1977–1983)			
	June	July	August	September	June	July	August	September
$\bar{x}$(mbar)	+3·00	−2·23	−0·65	−3·38	+4·1	+4·0	+1·4	+1·7
s	5·17	2·36	0·60	3·78	5·3	4·0	3·8	6·5
	$\bar{\Delta}$ September–June: −6·38 mbar				$\bar{\Delta}$ September–June: −2·43 mbar			

Correlation matrix of annual index values (1951–1982)

	TPI	M1	SOI
TPI	1·00		
M1	0·514[a]	1·00	
SOI	−0·273	−0·466[a]	1·00

[a] Statistically significant at $p \leq 0.05$ level.

positively and significantly correlated for the full period, but M1 is significantly negatively correlated with SOI (see also van Loon, 1984). Table V shows that M1 becomes progressively less positive between June and September in the 1977–1983 period, indicating an amplification of the Tasman Sea trough. The positive relationship TPI–M1 therefore confirms the increased (decreased) incidence of cold air outbreaks and associated polar-low occurrences south-west (east) of Australia (New Zealand) by August, noted in Figure 3 and also Table IV.

5. INTERANNUAL VARIATIONS OF POLAR LOWS AND BROADSCALE CLIMATIC ASSOCIATIONS

Previous climatologies of extratropical cloud vortices for both hemispheres (e.g. Carleton, 1979, 1980, 1981a,b, 1983, 1987a; Streten, 1975) reveal the existence of large interannual variations in type frequencies and latitudes of maximum occurrence. These are consistent with the strong interannual variability of tropospheric height fields, thicknesses, and geostrophic winds, and also of surface variables important in climate. The latter include the extent of sea ice and snow cover (e.g., Carleton, 1983; Ropelewski, 1983; Zwally *et al.*, 1983; Walsh *et al.*, 1982), and sea-surface temperatures (Chiu and Newell, 1983). These coupled surface and atmosphere variations comprise distinctive teleconnection patterns, particularly the El Niño/Southern Oscillation (ENSO) (Chiu, 1983; Pan and Oort, 1983; Peng and Domros, 1987; Carleton, 1988). Thus, it is not surprising that the incidence of polar air cyclogenesis over the Southern Hemisphere also exhibits a large interannual variability for the seven winters studied here. At least part of this variation appears related to ENSO.

5.1 Polar-low variations 1977–1983

Table VI lists observed frequencies of polar lows for the Southern Hemisphere by winter. The greatest number of polar lows occurred in the winter of 1979, coincident with the intensive observing period known as FGGE (First GARP Global Experiment). The 1979 FGGE year was highly anomalous over middle and southern latitudes, both in terms of atmospheric circulation (strong westerlies, deep synoptic systems: Streten and Pike, 1980b; Guymer and LeMarshall, 1981; van Loon and Rogers, 1981) and also the Antarctic sea ice extent (Streten, 1983). While not representative of an ENSO event, the 1979 FGGE year has been described as resembling a combination of the two extreme phases of the Southern Oscillation, depending on the latitude zone considered (van Loon and Rogers, 1981). Figure 6 confirms the large numbers of polar lows over the southern oceans in winter 1979, and also reveals a lack of strong longitudinal dependence to the pattern: polar lows occur fairly uniformly over most sectors. Comparison of these results with maps of the departures of SLP from the long-term means for June, July and August 1979, presented in van Loon and Rogers (1981, their figure 5), shows that most of the polar lows occur in association with a strong west wind gradient between

Table VI. Hemispheric winter totals of polar air cloud vortices by type, 1977–1983

Year	Comma (types 21 and 6)	Spiral (type 22)	Totals
1977	82	4	86
1978	119	27	146
1979 (FGGE)	186	17	203
1980	78	11	89
1981 (ENSO year − 1)	118	11	129
1982 (ENSO year 0)	170	10	180
1983	115	8	123
$\bar{x}$	124	13	137
$\hat{s}$	41	7	44

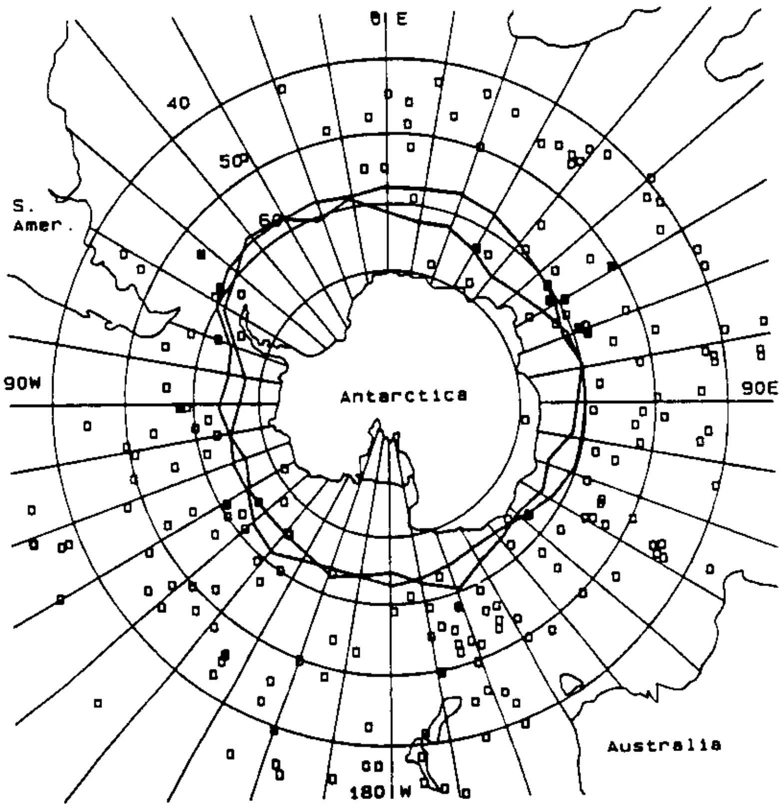


Figure 6. Locations of polar-low cloud vortices for the 1979 FGGE winter (June–July–August–September). Comma clouds (types 21, 6, and 7) are shown as open squares; spiraliform systems (type 22) as filled squares. The June and September sea ice extents are also shown

negative (positive) pressure anomalies over subantarctic (middle) latitudes. Both polar lows and the SLP anomaly gradient are at a maximum in the eastern hemisphere between 0° eastward through to about 130°W. Similarly, an examination of the broadscale pressure indices for the 1979 winter (Table VII) reveals minimal eccentricity to wavenumber one (TPI) for the season (mean = 0·3 mbar). The same is also true of the M1 index for the Tasman Sea sector (mean = 0·1 mbar). These results confirm the broadscale zonality of the FGGE winter and its representation in the largely undifferentiated distributions of polar lows.

The occurrence of the major 'warm' (El Niño) event of 1982–1983 during our period of study invites an examination of possible relationships between the broadscale atmospheric circulation changes and the polar low regimes. The winters of 1981 and 1982 correspond, respectively, to year (− 1) and year (0) of that event, as defined by van Loon and Shea (1985). These authors show that large changes in SLP occur between year (0) of an ENSO 'warm' event compared with the year before (year − 1). This feature is evidently not confined to low and middle southern latitudes (Carleton, 1988). Similarly, Streten (1975) has shown that substantial changes in the frequencies and longitudes of *synoptic* systems over the South Pacific occurred during the evolution of the 1972–1973 ENSO event. A comparison of the occurrences of polar lows in the winter year (0) of the event in 1982 with those for the year before (year − 1) in 1981 (Figures 7(a and b)) shows (i) considerably more polar lows in the 1982 winter than in 1981 (also Table VI), and (ii) distinct changes in their longitudes of occurrence. There is a marked peak in activity around the 90 °E meridian in 1981, but relatively little activity is noted for the New Zealand–west Pacific region at that time. The reverse is the case for 1982 (year 0), particularly west and south-west of New Zealand. Differences in sea ice extent seem to be partly involved in these changes (Figures 7(a and b)), as are the atmospheric waves. The intraseasonal change in the wave in the Tasman Sea,

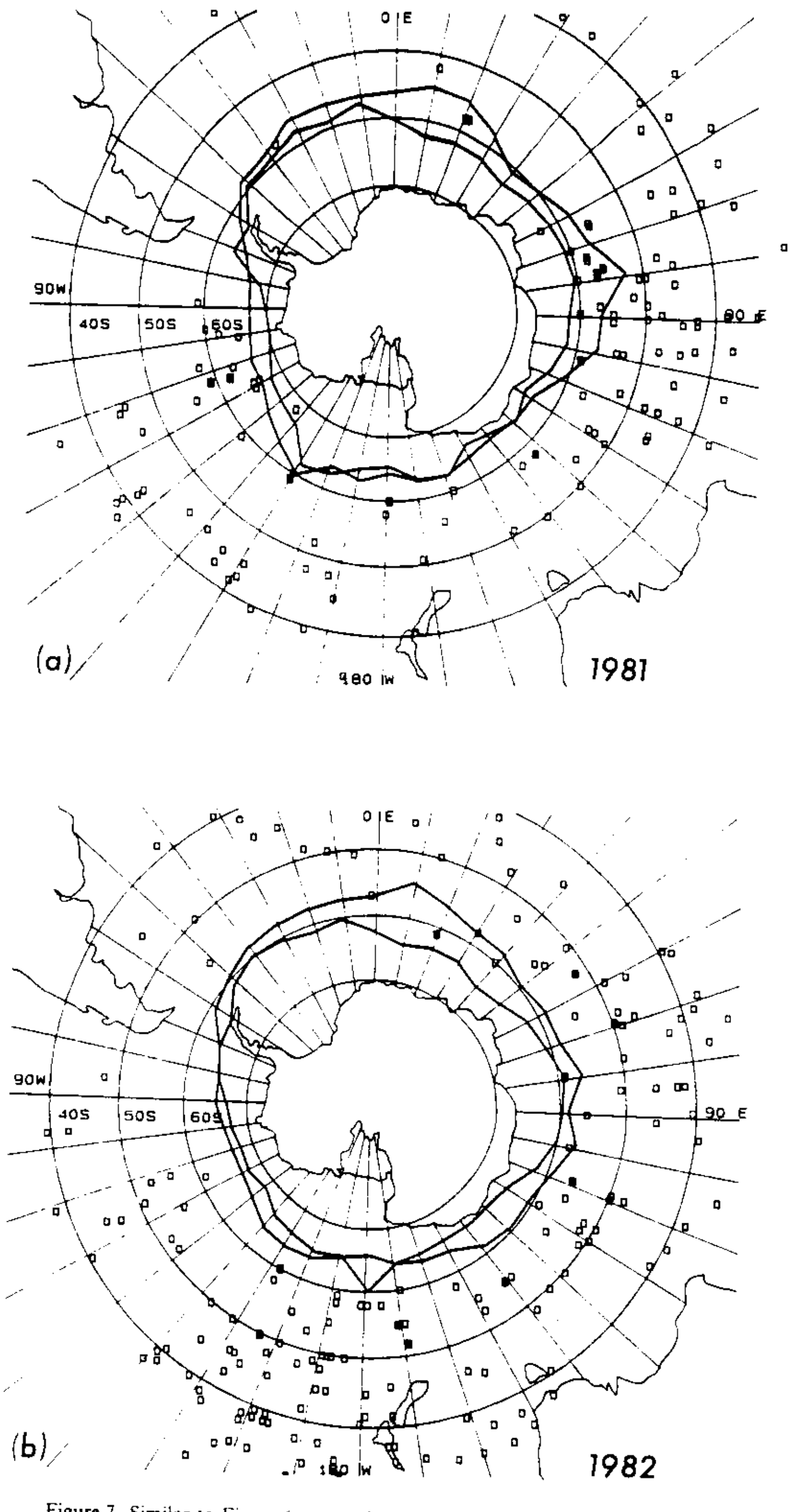


Figure 7. Similar to Figure 6, except for the (a) 1981 and (b) 1982 winters

Table VII. Southern Hemisphere circulation indices, 1977–1983.

	TPI (mbar)		M1 (mbar)		$SOI^{b}_{DJF_{-1}}$ (mbar)
	$\Delta_{Sept-June}$	$\bar{x}^{a}$	$\Delta_{Sept-June}$	$\bar{x}^{a}$	
1977	−3·2	1·7	5·4	4·1	4·3
1978	−14·0	−1·7	−19·0	1·9	1·5
1979	−7·7	0·3	3·1	0·1	4·3
1980	−11·6	−1·2	−4·3	3·9	4·0
1981	4·6	−3·3	11·0	2·9	4·1
1982	—	—	−8·7	4·3	5·2
1983	—	—	−4·5	2·3	−1·7

[a] Represents the winter season mean, June–July–August–September.
[b] Seasonal mean values (DJF_{-1}) taken from Parker (1983).

given by the M1 index, is strongly positive (+11·0 mbar) in 1981 but strongly negative (−8·7 mbar) in 1982 (Table VII). Thus, the reduced (increased) incidence of polar lows in the New Zealand sector in 1981 (1982) is consistent with the suppressed (enhanced) annual cycle of the trough noted by van Loon (1984). This is not to suggest that most of the interannual variability of polar lows in the southern Indian Ocean or South Pacific regions can be explained on the basis of the Southern Oscillation: other years that are adjacent exhibit large differences in polar-low frequencies unrelated to extremes in ENSO (Table VI). Examination of other factors possibly involved in these polar-low variations is now undertaken.

5.2 Polar-low relationships with cold air outbreaks and sea ice extent

The above results indicate a general relationship between polar-low activity and the broadscale atmospheric circulation of the Southern Hemisphere. Similar findings have been made for the Northern Hemisphere (e.g. Businger, 1985; Forbes and Lottes, 1985). The physical implications are that increased (decreased) frequencies of polar air cyclogenesis in particular longitude sectors coincide with a greater (reduced) incidence of southerly cold air outbreaks from higher latitudes and, correspondingly, reduced (enhanced) static stability. Thus, the degree of meridionality of the circulation seems to strongly determine the preferred longitudes of polar lows (cf. FGGE 1979, 1981, and 1982). These changes in the longitudes of maximum frequency of cold air outflows would also be expected to show a positive relationship with the regional extent of the Antarctic sea ice, since ice advance (new growth plus ice advection) is favoured to the west of longitudes of major cyclonic activity in the circumpolar trough (Streten and Pike, 1980a; Cavalieri and Parkinson, 1981). Thus, in the southern Indian Ocean between about 60°E and 100°E in 1981 (1982), polar lows increase (decrease) in association with greater (reduced) sea ice (Figure 7(a and b)). A similar relationship is apparent for the Weddell Sea sector in the 1978 winter (Figure 8a). Marked equatorward advances of the ice edge occur in the South Atlantic (near 0°) during the season and coincide with high frequencies of polar air vortices in those longitudes. However, in certain other winters (e.g. 1977, Figure 8b) the relationship is not at all evident. Large increases in sea ice extent in the Weddell Sea during the 1977 winter are accompanied by very few polar lows. In this case, the ocean circulation (Weddell Gyre) may be largely responsible for the marked seasonal ice increases occurring in that region (Hibler and Ackley, 1983), rather than sustained southerly air flow.

5.3 Polar-low relationships with SST patterns

Given the general association between cold air outbreaks and polar air vortices, and the occurrence of marked interannual variations in polar-low frequencies for the 1977–1983 period, an examination of polar-low relationships with seasonal patterns of sea–air temperature difference ($\overline{\Delta T}$) was made for key sectors. Positive

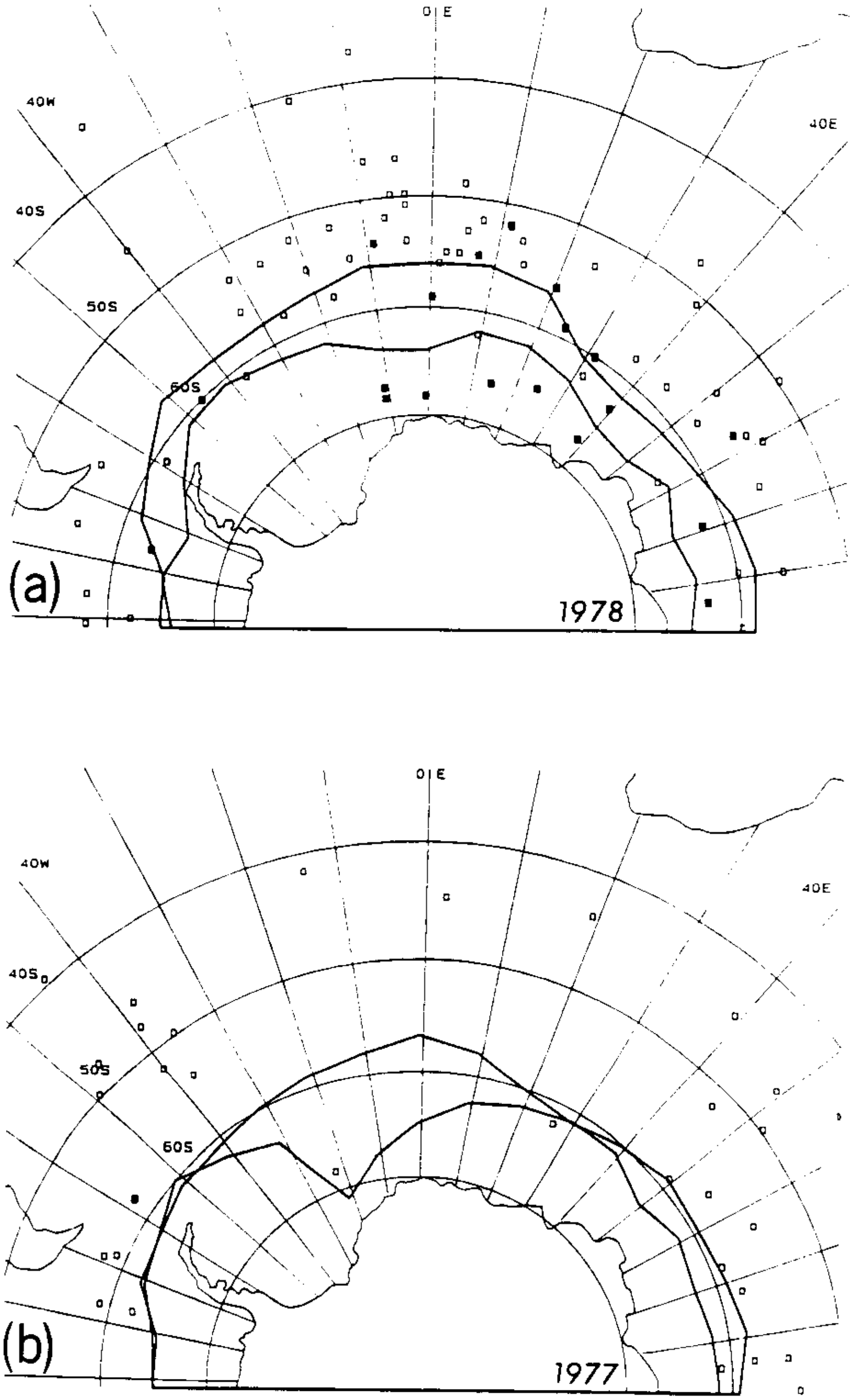
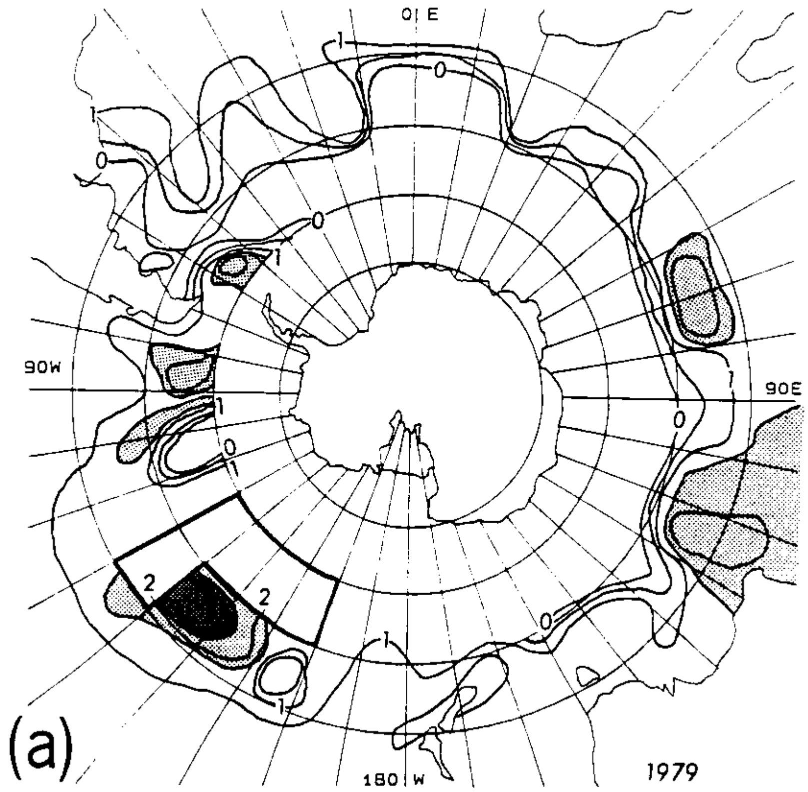


Figure 8. Similar to Figure 6, except for the South Atlantic sector in the (a) 1978 and (b) 1977 winters



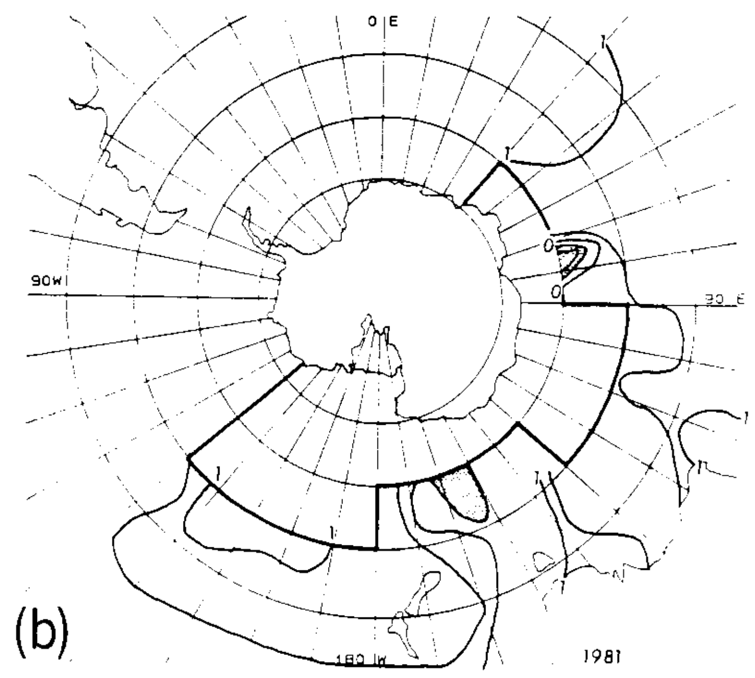


Figure 9. Seasonal (June–July–August–September) patterns of $\overline{\Delta T}$ (= SST – MAT) for the southern oceans in the (a) 1979, (b) 1981, and (c) 1982 winters. Positive (negative) values exceeding 1·5 °C (– 1·0 °C) are shown stippled (hatched). Areas lacking data are enclosed by solid lines

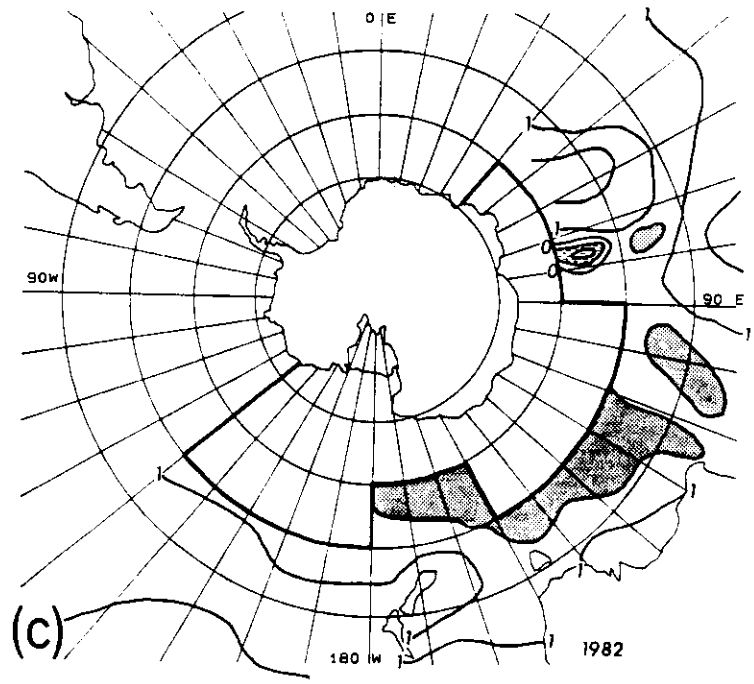
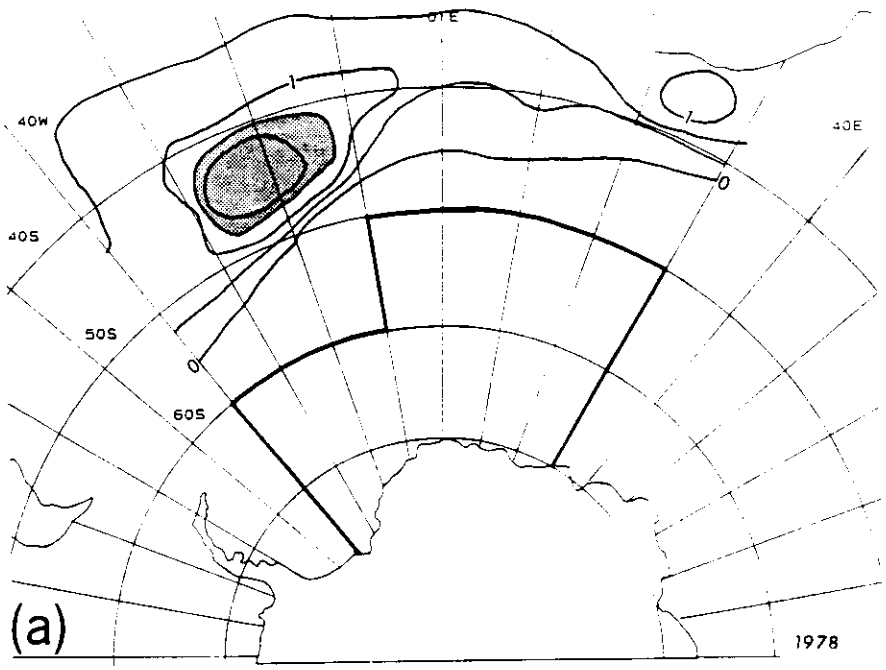


Figure 9(c)

(negative) values of $\overline{\Delta T}$ imply net heat gain (loss) by the boundary layer in that region over the course of a winter season. In general, a reasonably close association between areas of positive $\overline{\Delta T}$ and polar-low outbreaks is observed, with the former tending to lie slightly upstream of the latter. Thus, the high frequencies of polar lows for the hemisphere in the 1979 FGGE winter (Figure 6) occur at the same time as widespread positive $\overline{\Delta T}$ anomalies are observed, at least over those higher middle latitudes for which COADS is available (Figure 9a). Clusters of polar lows in the central South Pacific in that winter may be associated with the strongly positive $\overline{\Delta T}$ anomalies noted in that region and slightly to the westward. However, the relatively large numbers of these systems south-west of New Zealand may be associated more with the anomalous sea ice conditions in those longitudes (see Figure 6). Similarly, areas of positive $\overline{\Delta T}$ cannot account entirely for the major shifts in polar-low activity observed between the southern Indian Ocean (1981) and south-west Pacific (1982) associated with ENSO (year -1) and (year 0). Although positive $\overline{\Delta T}$ occur upstream of the large numbers of polar lows observed east of New Zealand in 1982 (Figure 9c) compared with 1981 (Figure 9b), the patterns in the southern Indian Ocean appear broadly similar between the two years. Again, a contributory influence on the larger numbers of polar lows in 1981 may be the greater regional extent of the sea ice in that winter. Further, since the majority of polar lows in the southern Indian Ocean in 1981 are comma clouds, surface–atmosphere thermal influences are likely to comprise only one factor in the spin-up of these systems. Mid-tropospheric vorticity maxima appear particularly important in the development of most comma cloud polar lows, at least in the Northern Hemisphere (e.g. Reed, 1979; Reed and Blier, 1986a), with low-level thermal forcing having a contributory effect (Reed and Blier, 1986b).

Further evidence for the complementary role of the sea ice extent in the polar low–SST relationship is given in Figure 10 (a and b) which shows $\overline{\Delta T}$ in longitudes of the South Atlantic for the 1977 and 1978 winters. Very few polar lows were observed in that region in 1977 compared with 1978 (see Figure 8), even though large areas of positive $\overline{\Delta T}$ occur in both winters (Figure 10). Thus, it is possible that the somewhat greater



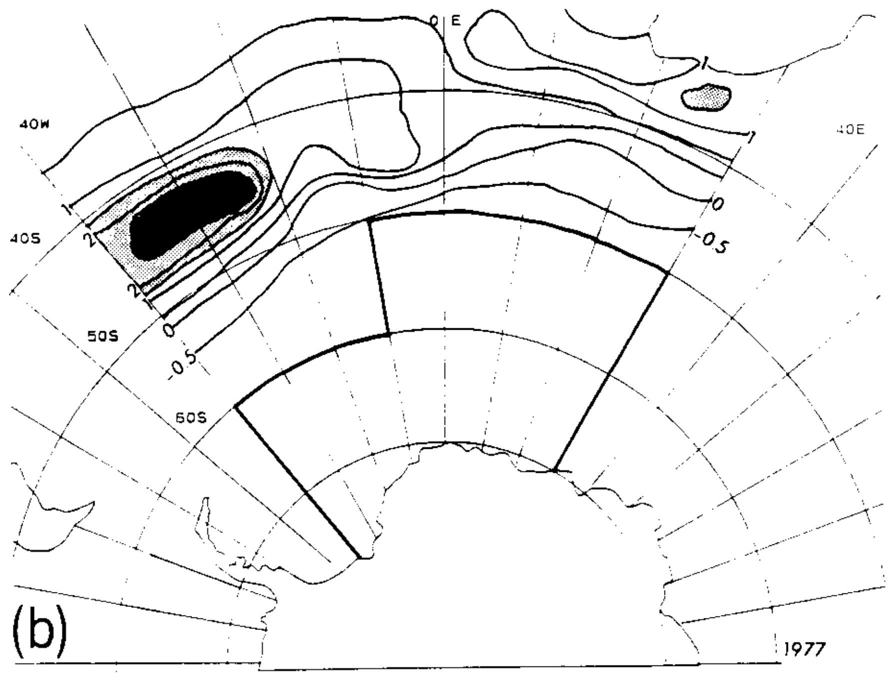


Figure 10. Similar to Figure 9, except for the South Atlantic in the (a) 1978 and (b) 1977 winters

latitudinal extent of the sea ice in the winter of 1978 was responsible for the large numbers of polar lows over the South Atlantic, in conjunction with high frequencies of cold southerly airflow at low levels and baroclinic processes aloft. Future diagnostic studies should address this question of the relative contributions of the lower level thermal (sea ice, SST) and upper level baroclinic processes for polar-low developments in the Southern Hemisphere as improved data become available. Preliminary steps in this direction have already been undertaken by Sinclair (1986) and Auer (1986) for polar lows in the New Zealand region. Studies of this type will enable fuller comparisons with the growing number of observational and modelled analyses of polar lows available for the Northern Hemisphere.

6. SUMMARY AND CONCLUDING REMARKS

A climatology of polar air cloud vortices for the Southern Hemisphere, derived using DMSP imagery for the seven winters 1977–1983, reveals the following:

(1) Both 'comma cloud' and 'spiral' (Antarctic) polar lows are evident, the latter occurring preferentially over and adjacent to the sea ice zone. For the hemisphere, the ratio of spiraliform (type 22) to comma cloud (types 21, 6, and 7) vortices is about 1:10, but this increases to around 1:3 at higher latitudes in mid-winter (July), which is also the time of maximum observed occurrences of polar lows. The quite frequent occurrence of spiral systems in ice-edge and higher latitudes may imply strong surface–atmosphere interaction on meso-scales (e.g. from polynyas) in conjunction with baroclinic conditions.

(2) The polar-low winter regimes are quite different from those of frontal wave cyclones (genesis through to mature stages). Frontal cloud vortices predominate over middle latitudes (about 30–50°S), particularly in the eastern hemisphere, and show latitude variations related to the migration of the circumpolar trough associated with the semi-annual oscillation.

(3) Within-season changes of polar lows (mainly comma clouds) are dominated by a westward shift from the south-west Pacific to the southern Indian Ocean. These changes appear associated with the seasonal change in the longwaves associated with the semi-annual oscillation, and occur as surface pressures fall (rise) over the continents (adjacent oceans). Wavenumber one amplifies over the Australian sector between June and September, resulting in an increased incidence of polar lows south-west of that continent. The opposite tendency is observed for the area east of New Zealand.

(4) Anomalies in the regional extent of the Antarctic sea ice appear positively related to the longitudes of maximum frequency of polar lows when considered on a seasonal basis. This relationship evidently comes about via cold air outbreaks and enhanced ice advection. Major changes in polar-low activity occurred between the 1981 (ENSO year -1) and 1982 (year 0) winters and resulted in increases in the south-west Pacific. These appear connected with changes in the seasonal cycle of the trough characteristically ascribed to the evolution of ENSO events over middle southern latitudes.

(5) Interannual variations in the longitudes of maximum frequency of polar lows over ocean latitudes appear related to the distribution of areas of positive $\overline{\Delta T}$ (SST–MAT), and imply the contributory role of lower level thermal influences in spin-up of these systems. There is a tendency for positive $\overline{\Delta T}$ areas to be located both coincident with and slightly upstream (generally west) of the locations of maximum observed frequencies of polar lows. However, sea–air temperature forcing alone cannot explain large between-year fluctuations in polar-low occurrence when the locations of areas of positive $\overline{\Delta T}$ are similar. In those cases, substantial changes in the regional latitude extent of the sea ice may be important. These surface thermal factors are presumably augmented by mid-tropospheric vorticity.

The present broadscale study raises many additional questions pertaining to meso-scale cyclogenesis over higher southern latitudes that require investigation in future work. These include, but are not limited to, the need to examine the physical processes attending spin-up of spiraliform developments adjacent to the ice edge and also within the pack ice zone. In this regard, the occurrence of coastal polynyas and, by implication, the persistent katabatic wind regime of East Antarctica, may be crucial.

Both modelling and observational approaches offer prospects for improved understanding of the 'Antarctic' polar lows. The latter technique should utilize the high resolution digital data from the NOAA and

DMSP polar orbiters that are now acquired in real time at McMurdo Station and, shortly also, for Palmer. The Automatic Weather Station (AWS) data that are available for much of the Ross Sea area offer opportunities for detailed analysis of Antarctic polar lows in conjunction with the satellite data. Use of these data is particularly pertinent since case studies have shown that a well-developed cloud signature may not be apparent in the imagery until cyclogenesis is well under way (Bromwich, 1987).

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REFERENCES

Anderssen, E. C. 1965. 'A study of atmospheric long waves in the Southern Hemisphere', *Notos*, **14**, 57–65.

Andreas, E. L. 1985. 'Heat and moisture advection over Antarctic sea ice', *Mon. Wea. Rev.*, **113**, 736–746.

Auer, Jr., A. H. 1986. 'An observational study of polar air depressions in the Australian region', in *Second International Conference on Southern Hemisphere Meteorology*, 1–5 December, 1986, Preprint Volume. American Meteorological Society, Boston, MA, pp. 46–49.

Barnett, T. P. 1984. 'Long-term trends in surface temperature over the oceans', *Mon. Wea. Rev.*, **112**, 303–312.

Bonatti, J. P. and Rao, V. B. 1987. 'Moist baroclinic instability in the development of North Pacific and South American intermediate-scale disturbances', *J. Atmos. Sci.*, **44**, 2657–2667.

Bromwich, D. H. 1987. 'A case study of mesoscale cyclogenesis over the southwestern Ross Sea', *Antarct. J. U.S.*, **22**, 254–256.

Browning, K. A. 1985. 'Conceptual models of precipitation systems', *Meteorol. Mag.*, **114**, 293–319.

Browning, K. A. and Hill, F. F. 1985. 'Mesoscale analysis of a polar trough interacting with a polar front', *Q. J. R. Meteorol. Soc.*, **111**, 445–462.

Budd, W. F. 1982. 'The role of Antarctica in southern hemisphere weather and climate', *Aust. Meteorol. Mag.*, **30**, 265–272.

Burfeind, C. R., Weinman, J. A. and Barkstrom, B. R. 1987. 'A preliminary computer pattern analysis of satellite images of mature extratropical cyclones', *Mon. Wea. Rev.*, **115**, 556–563.

Businger, S. 1985. 'The synoptic climatology of polar low outbreaks', *Tellus*, **37A**, 419–432.

Businger, S. 1987. 'The synoptic climatology of polar-low outbreaks over the Gulf of Alaska and the Bering Sea', *Tellus*, **39A**, 307–325.

Cahalan, R. F. and Chiu, L. S. 1986. 'Large-scale short-period sea ice atmosphere interaction', *J. Geophys. Res.*, **91**, 10, 709–10, 717.

Carleton, A. M. 1979. 'A synoptic climatology of satellite-observed extratropical cyclone activity for the Southern Hemisphere winter', *Arch. Meteorol Geophys. Bioklimatol* **B27**, 265–279.

Carleton, A. M. 1980. 'Recent variations in winter extratropical cyclone activity for the Australian region', *Search*, **11**, 37–39.

Carleton, A. M. 1981a. 'Monthly variability of satellite-derived cyclonic activity for the Southern Hemisphere winter', *J. Climatol.*, **1**, 21–38.

Carleton, A. M. 1981b. 'Ice–ocean–atmosphere interactions at high southern latitudes in winter from satellite observation', *Aust. Meteorol. Mag.*, **29**, 183–195.

Carleton, A. M. 1981c. 'Climatology of the "instant occlusion" phenomenon for the Southern Hemisphere winter', *Mon. Wea. Rev.*, **109**, 177–181.

Carleton, A. M. 1983. 'Variations in Antarctic sea ice conditions and relationships with Southern Hemisphere cyclonic activity, winters 1973–77', *Arch. Meteorol. Geophys. Bioklimatol.*, **B32**, 1–22.

Carleton, A. M. 1985a. 'Synoptic cryosphere–atmosphere interactions in the Northern Hemisphere from DMSP image analysis', *Int. J. Remote Sensing*, **6**, 239–261.

Carleton, A. M. 1985b. 'Satellite climatological aspects of the "polar low" and "instant occlusion"', *Tellus*, 37A, 433–450.

Carleton, A. M. 1987a. 'Satellite-derived attributes of cloud vortex systems and their application to climate studies', *Remote Sensing Environ.*, **22**, 271–296.

Carleton, A. M. 1987b. 'Antarctic climates', in Oliver, J. E. and Fairbridge, R. W. (eds) *The Encyclopedia of Climatology*, Van Nostrand Reinhold, New York, pp. 44–64.

Carleton, A. M. 1988. 'Sea ice–atmosphere signal of the Southern Oscillation in the Weddell Sea, Antarctica', *J. Climate*, **1**, 379–388.

Carleton, A. M. 1989. 'Antarctic sea-ice relationships with indices of the atmospheric circulation of the Southern Hemisphere', *Climate Dynamics*, **3**, 207–220.

Carleton, A. M. and Carpenter, D. A. 1989. 'Intermediate-scale sea ice–atmosphere interactions over high southern latitudes in winter', in *Sea Ice–Atmosphere Interactions*, *GeoJournal*, **18**, 87–101.

Cavalieri, D. J. and Parkinson, C. L. 1981. 'Large-scale variations in observed sea ice extent and associated atmospheric circulation', *Mon. Wea. Rev.*, **109**, 2323–2336.

Chiu, L. S. 1983. 'Antarctic sea ice variation 1973–80', in Street-Perrott, F. A., Beran, M., and Ratcliffe, R. A. S. (eds.) *Variations in the Global Water Budget*, D. Reidel Publishing Co., Dordrecht Holland, pp. 301–311.

Chiu, L. and Newell, R. E. 1983. 'Variations of zonal mean sea surface temperature and large-scale air–sea interaction', *Q. J. R. Meteorol. Soc.*, **109**, 153–168.

Ese, T., Kanestrom, I. and Pedersen, K. 1988. 'Climatology of polar lows over the Norwegian and Barents Sea', *Tellus*, **40A**, 248–255.

Forbes, G. S. and Lottes, W. D. 1982. 'Characteristics and evolution of mesoscale cloud vortices occurring in polar airstreams', in *Conference on Cloud Physics*, Nov. 15-18, November 1982, Preprint Volume, American Meteorological Society, Boston, MA, pp. 310-313.

Forbes, G. S. and Lottes, W. D. 1985. 'Classification of mesoscale vortices in polar airstreams and the influence of the large-scale environment on their evolutions', *Tellus*, **37A**, 132-155.

Gillooly, J. F. and Lutjeharms, J. R. E. 1984. 'The ocean and climate: large-scale ocean-atmosphere interactions in the Southern Hemisphere', *S. Afr. J. Sci.*, **80**, 36-40.

Guymer, L. B. and LeMarshall, J. F. 1981. 'Impact of FGGE buoy data on Southern Hemisphere analyses', *Bull. Am. Meteorol. Soc.*, **62**, 38-47.

Hibler, W. D., III and Ackley, S. F. 1983. 'Numerical simulation of the Weddell Sea pack ice', *J. Geophys. Res.*, **88**, 2873-2887.

Howarth, D. A. 1983. 'An analysis of the variability of cyclones around Antarctica and their relationship to sea ice extent', *Ann. Assoc. Am. Geogr.*, **73**, 519-537.

Jacka, T. H. 1983. 'A computer data base for Antarctic sea ice extent', Antarctic Division, Australia, *ANARE Research Notes, No. 13*, 54 pp.

Kellogg, W. W. and Twitchell, P. F. 1986. 'Summary of the Workshop on Arctic Lows, 9-10 May 1985, Boulder, Colorado', *Bull. Am. Meteorol. Soc.*, **67**, 186-193.

Keyser, D. and Uccellini, L. W. 1987. 'Regional models: emerging research tools for synoptic meteorologists', *Bull. Am. Meteorol. Soc.*, **68**, 306-320.

Locatelli, J. D., Hobbs, P. V. and Werth, J. A. 1982. 'Mesoscale structures of vortices in polar air streams', *Mon. Wea. Rev.*, **110**, 1417-1433.

Lyons, S. W. 1983. 'Characteristics of intense Antarctic depressions near the Drake Passage', in *First International Conference on Southern Hemisphere Meteorology*, 31 July-6 August, 1983, Preprint Volume, American Meteorological Society, Boston, MA, pp. 238-240.

McGuirk, J. P., Thompson, A. H. and Smith, N. R. 1987. 'Moisture bursts over the tropical Pacific Ocean', *Mon. Wea. Rev.*, **115**, 787-798.

Mullen, S. L. 1982. 'Cyclone development in polar air streams over the wintertime continent', *Mon. Wea. Rev.*, **110**, 1664-1676.

Mullen, S. L. 1983. 'Explosive cyclogenesis associated with cyclones in polar air streams', *Mon. Wea. Rev.*, **111**, 1537-1553.

Naval Oceanography Command Detachment 1985. *Sea Ice Climatic Atlas, Vol. I. Antarctic*, NAVAIR 50-IC-540, prepared by Naval Oceanography Command Detachment, Asheville, NC, NSTL MS39529-5000.

Oort, A. H. Pan, Y. H., Reynolds, R. W. and Ropelewski, C. F. 1987. 'Historical trends in the surface temperature over the oceans based on the COADS', *Climate Dynamics*, **2**, 29-38.

Orlanski, I. 1975. 'A rational subdivision of scales for atmospheric processes', *Bull. Am. Meteorol. Soc.*, **56**, 527-530.

Pan, Y. H. and Oort, A. H. 1983. 'Global climate variations connected with sea surface temperature anomalies in the eastern equatorial Pacific Ocean for the 1958-73 period', *Mon. Wea. Rev.*, **111**, 1244-1258.

Parker, D. E. 1983. 'Documentation of a Southern Oscillation index', *Meteorol Mag.*, **112**, 184-188.

Peng, G. and Domros, M. 1987. 'Connections of the West Pacific subtropical high and some hydroclimatic regimes in China with Antarctic ice-snow indices', *Meteorol. Atmos. Phys.*, **37**, 61-71.

Pittock, A. B. 1980. 'Patterns of climatic variation in Argentina and Chile. I. Precipitation, 1931-60', *Mon. Wea. Rev.*, **108**, 1347-1361.

Pittock, A. B. 1984. 'On the reality, stability and usefulness of southern hemisphere teleconnections', *Aust. Meteorol. Mag.*, **32**, 75-82.

Rasmussen, E. 1981. 'An investigation of a polar low with a spiral cloud structure', *J. Atmos. Sci.*, **38**, 1785-1792.

Rasmussen, E. and Lystad, M. 1987. 'The Norwegian Polar Lows Project: a summary of the International Conference on Polar Lows, 20-23 May 1986, Oslo, Norway', *Bull. Am. Meteorol. Soc.*, **68**, 801-816.

Reed, R. J. 1979. 'Cyclogenesis in polar air streams', *Mon. Wea. Rev.*, **107**, 38-52.

Reed, R. J. and Blier, W. 1986a. 'A case study of comma cloud development in the eastern Pacific', *Mon. Wea. Rev.*, **114**, 1681-1695.

Reed, R. J. and Blier, W. 1986b. 'A further study of comma cloud development in the eastern Pacific', *Mon. Wea. Rev.*, **114**, 1696-1708.

Rogers, J. C. 1983. 'Spatial variability of Antarctic temperature anomalies and their association with the Southern Hemisphere atmospheric circulation', *Ann. Assoc. Am. Geogr.* **73**, 502-518.

Rogers, J. C. and van Loon, H. 1982. 'Spatial variability of sea level pressure and 500 mb height anomalies over the Southern Hemisphere', *Mon. Wea. Rev.*, **110**, 1375-1392.

Ropelewski, C. F. 1983. 'Spatial and temporal variations in Antarctic sea-ice (1973-82)', *J. Clim. Appl. Meteorol.*, **22**, 470-473.

Sanders, F. and Gyakum, J. R. 1980. 'Synoptic-dynamic climatology of the "bomb"', *Mon. Wea. Rev.*, **108**, 1589-1606.

Sardie, J. M. and Warner, T. T. 1983. 'On the mechanism for the development of polar lows', *J. Atmos. Sci.*, **40**, 869-881.

Sardie, J. M. and Warner, T. T. 1985. 'A numerical study of the development mechanisms of polar lows', *Tellus*, **37A**, 460-477.

Shapiro, M. A., Fedor, L. S. and Hampel, T. 1987. 'Research aircraft measurements of a polar low over the Norwegian Sea', *Tellus*, **39A**, 272-306.

Sinclair, M. R. 1986. 'Investigation of polar air stream cyclogenesis in the New Zealand area using quasi-Lagrangian diagnostics', in *Second International Conference on Southern Hemisphere Meteorology*, 1-5 December, 1986, Preprint Volume, American Meteorological Society, Boston, MA, pp. 50-51.

Sinclair, M. R. and Elsberry, R. L. 1986. 'A diagnostic study of baroclinic disturbances in polar air streams', *Mon. Wea. Rev.*, **114**, 1957-1983.

Streten, N. A. 1975. 'Satellite derived inferences to some characteristics of the South Pacific atmospheric circulation associated with the Nino event of 1972-73', *Mon. Wea. Rev.*, **103**, 989-995.

Streten, N. A. 1982. 'Exploring southern hemisphere climates', *Aust. Meteorol. Mag.*, **30**, 143-153.

Streten, N. A. 1983. 'Antarctic sea ice and related atmospheric circulation during FGGE', *Arch. Meteorol Geophys. Bioklimatol.*, **A32**, 231-246.

Streten, N. A. and Pike, D. J. 1980a. 'Characteristics of the broadscale Antarctic sea ice extent and the associated atmospheric circulation 1972-77', *Arch. Meteorol. Geophys. Bioklimatol.*, **A29**, 279-299.

Streten, N. A. and Pike, D. J. 1980b. 'Indices of the mean monthly surface circulation over the Southern Hemisphere during FGGE', *Aust. Meteorol Mag.*, **28**, 201-215.

Streten, N. A. and Troup, A. J. 1973. 'A synoptic climatology of satellite observed cloud vortices over the Southern Hemisphere', *Q. J. R. Meteorol. Soc.*, **99**, 56–72.

Sturman, A. P. and Anderson, M. R. 1985. 'A comparison of Antarctic sea ice data sets and inferred trends in ice area', *J. Clim. Appl. Meteorol.*, **24**, 275–280.

Trenberth, K. E. 1976. 'Fluctuations and trends in indices of the southern hemisphere circulation', *Q. J. R. Meteorol Soc.*, **102**, 65–75.

Trenberth, K. E. 1980. 'Planetary waves at 500 mb in the Southern Hemisphere', *Mon. Wea. Rev.*, **108**, 1378–1389.

Troup, A. J. and Streten, N. A. 1972. 'Satellite-observed Southern Hemisphere cloud vortices in relation to conventional observations', *J. Appl. Meteorol.*, **11**, 909–917.

Turner, J. and Warren, D. 1988. 'The structure of sub-synoptic-scale vortices in polar air-streams from AVHRR and TOVS data', in *Second Conference on Polar Meteorology and Oceanography, Madison*, WI, 29–31 March, 1988, Preprints Volume, American Meteorological Society, Boston, MA pp. 126–128.

van Loon, H. 1967. 'The half-yearly oscillations in middle and high southern latitudes and the coreless winter', *J. Atmos. Sci.*, **24**, 472–486.

van Loon, H. 1984. 'The Southern Oscillation. Part III: Associations with the Trades and with the trough in the westerlies of the South Pacific Ocean', *Mon. Wea. Rev.*, **112**, 947–954.

van Loon, H. and Rogers, J. C. 1981. 'Remarks on the circulation over the Southern Hemisphere in FGGE and on its relation to the phases of the Southern Oscillation', *Mon. Wea. Rev.*, **109**, 2255–2259.

van Loon, H. and Rogers, J. C. 1984. 'Interannual variations in the half-yearly cycle of pressure gradients and zonal wind at sea level on the Southern Hemisphere', *Tellus*, **36A**, 76–86.

van Loon, H. and Shea, D. J. 1985. 'The Southern Oscillation. Part IV. The precursors south of 15°S to the extremes of the Oscillation', *Mon. Wea. Rev.*, **113**, 2063–2074.

Walsh, J. E., Tucek, D. R. and Peterson, M. R. 1982. 'Seasonal snow cover and short-term climatic fluctuations over the United States', *Mon. Wea. Rev.*, **110**, 1474–1485.

Woodruff, S. D., Slutz, R. J., Jenne, R. L. and Steurer, P. M. 1987. 'A comprehensive ocean-atmosphere data set', *Bull. Am. Meteorol Soc.*, **68**, 1239–1250.

Wright, P. B. 1986. 'Problems in the use of ship observations for the study of interdecadal climate changes', *Mon. Wea. Rev.*, **114**, 1028–1034.

Yarnal, B. and Henderson, K. G. 1989. 'A satellite-derived climatology of polar-low evolution in the North Pacific', *Int. J. Climatol.* **9**, 551–566.

Zick, C. 1983. 'Method and results of an analysis of comma cloud developments by means of vorticity fields from upper tropospheric satellite wind data', *Meteorol. Rundsch.*, **36**, 69–84.

Zillman, J. W. and Price, P. G. 1972. 'On the thermal structure of mature Southern Ocean cyclones', *Aust. Meteorol. Mag.*, **20**, 34–48.

Zwally, H. J., Parkinson, C. L. and Comiso, J. C. 1983. 'Variability of Antarctic sea ice and changes in carbon dioxide', *Science*, **220**, 1005–1012.

Monthly anticyclonicity and cyclonicity in the Southern Hemisphere: averages for January and July

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ABSTRACT

The geographical distribution across the Southern Hemisphere of 15 year averages (23 year averages in the Australian Region) of monthly anticyclonicity and cyclonicity, as well as monthly anticyclone and cyclone immobility times, for the months of January and July for the years 1973-1987 (1965-1987 in the Australian Region) are presented in the form of maps. A comparison with an existing atmospheric climatology of the Southern Hemisphere presented by Le Marshall et al. in 1985 (i.e., derived from daily numerical analyses calculated for the period 1972-1982) is presented and some synoptic scale features of the climatology are briefly discussed.

1. Introduction

The methods currently in use for representing surface circulation for long periods (i.e., months, seasons, etc.) by charts of anticyclonicity and cyclonicity were first developed in 1951-1953 in connection with the problem of extended and long-range forecasting in Australia. Karelsky was one of the first to publish the results of these early tracking efforts, for example, Karelsky compiled charts of 7 year averages (1946-1952) and 15 year averages (1946-1960) of monthly and seasonal anticyclonicity and cyclonicity and published them in 1954 and 1961, respectively.

Since Karelsky (1961) published his 1946-1960 climatology satellite cloud photos have been added to the data sets available to the National Meteorological Centre, Australia. This paper presents the cyclonicity/anticyclonicity climatology for the period 1973-1987 (1965-1987 in the Australian Region) for the Southern Hemisphere for which cloud photographs were generally available.

Climatologies of synoptic systems, such as this, seem to be less common than conventional climatologies and to the author's knowledge similar studies to this have not been attempted elsewhere in the world. Information from the National Climatic Data Center, Asheville, North Carolina, supports this conclusion and suggest that this study is unique. It is hoped that the complementary nature of this study with conventional climatologies and general circulation statistics will help in providing a comprehensive picture of the Earth's climate.

2. Anticyclonicity and Cyclonicity

The term "anticyclonicity" ("cyclonicity") is defined as the time in hours during which anticyclone (cyclone) centres occupied a given 5° cell north of 55°S during a given period (i.e., week, month, season, etc.). South of 55°S cells are 5° latitude by 10° longitude.

Cyclonicity and anticyclonicity was computed from the plotted locations of cyclone (anticyclone) centres at 00 UTC and 12 UTC and, assuming a uniform speed of movement, the systems could be tracked. Single centres which were not part of a track were assigned a lifetime of 6 hours.

3. Charts of cyclonic (anticyclonic) immobility

Immobility of an cyclone (anticyclone) centre is defined as the time taken by the cyclone (anticyclone) centre to traverse a 5° cell. The average immobility of cyclone (anticyclone) centres across a 5° cell was calculated by dividing the cyclonicity (anticyclonicity) of a 5° cell by the number of cyclone (anticyclone) centres which have occupied that square during the same period.

Charts prepared by the National Meteorological Centre of the Bureau of Meteorology were used to obtain means of cyclonicity, anticyclonicity, and immobility for January and July from 1973-1987 (1965-1987 in the Australian Region). Charts of mean monthly anticyclonicity, cyclonicity, and cyclone immobilities are presented in Figures 1 and 2.

Figure 1. (b) January average anticyclone immobility index.

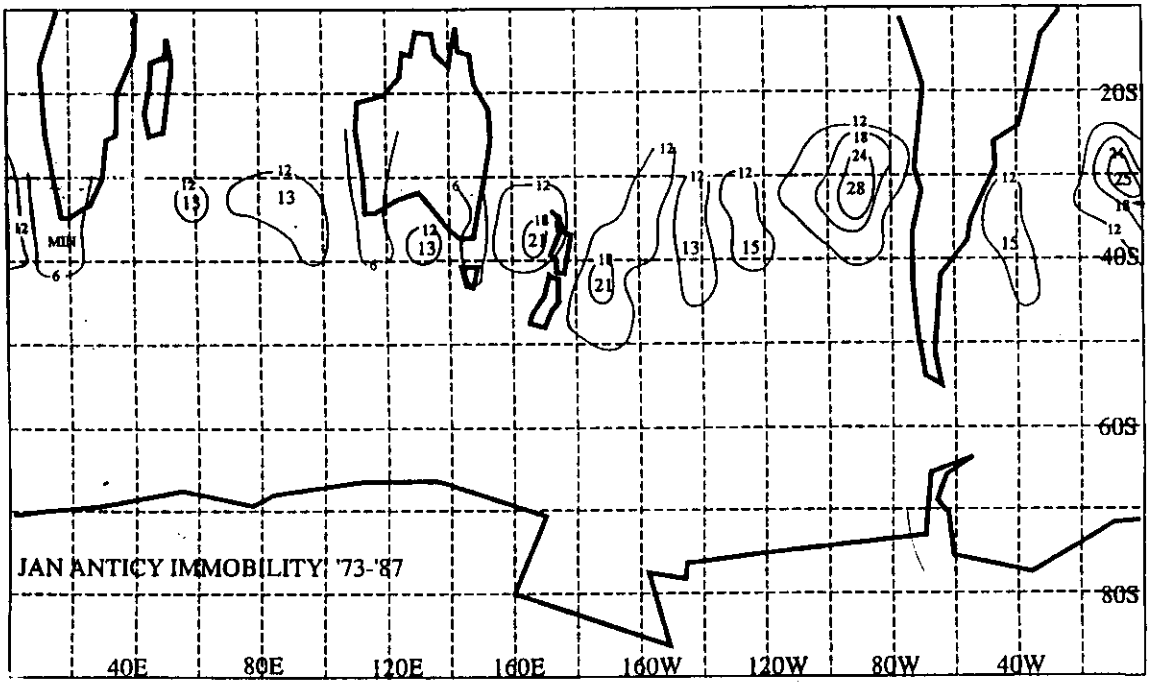


Figure 1. (c) January average cyclonicity, isopleths are in hours.

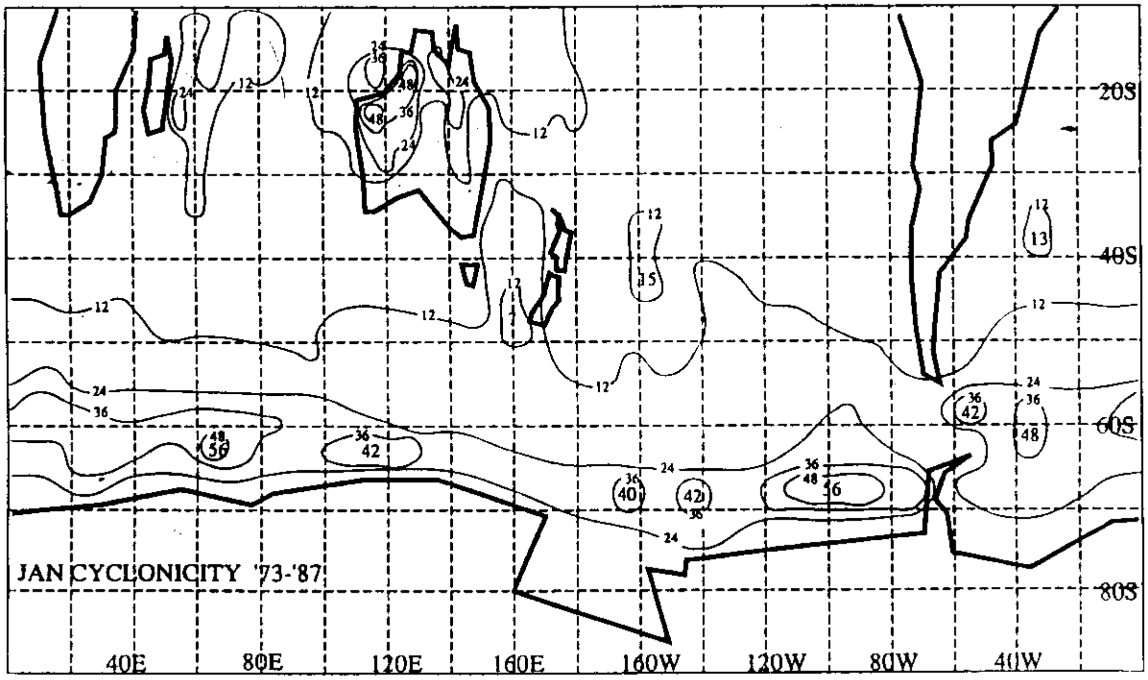


Figure 1. (d) January average cyclonic immobility index.

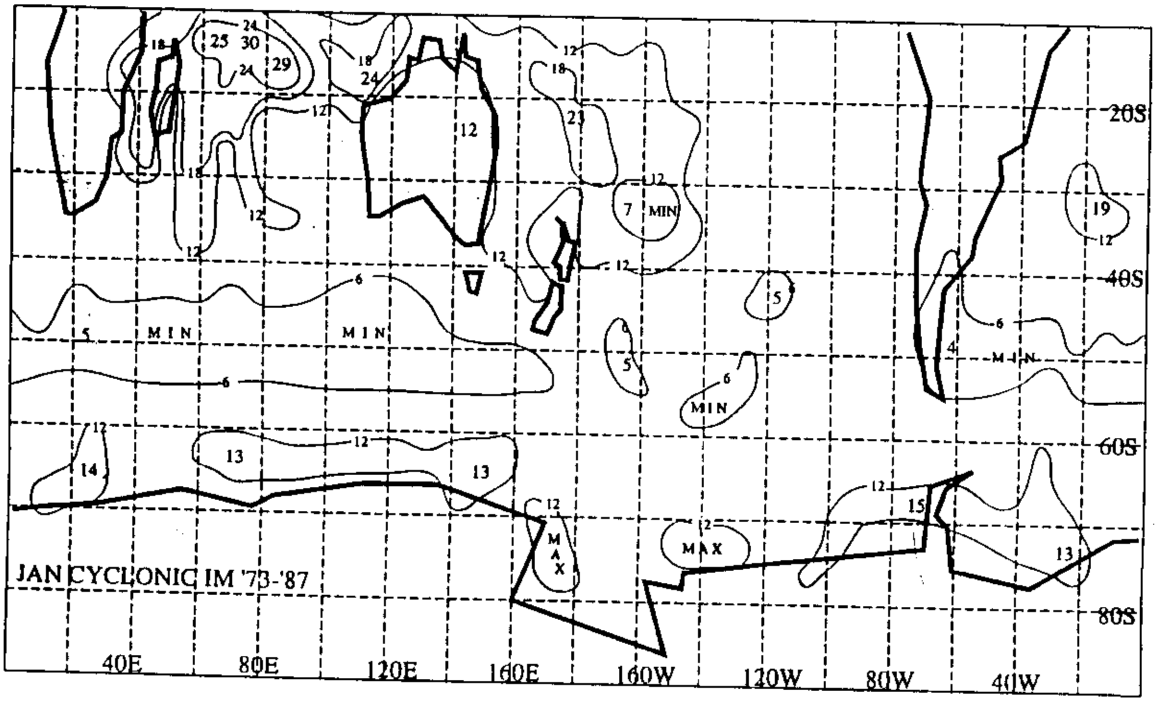


Figure 2. (a) July average anticyclonicity, isopleths are in hours.

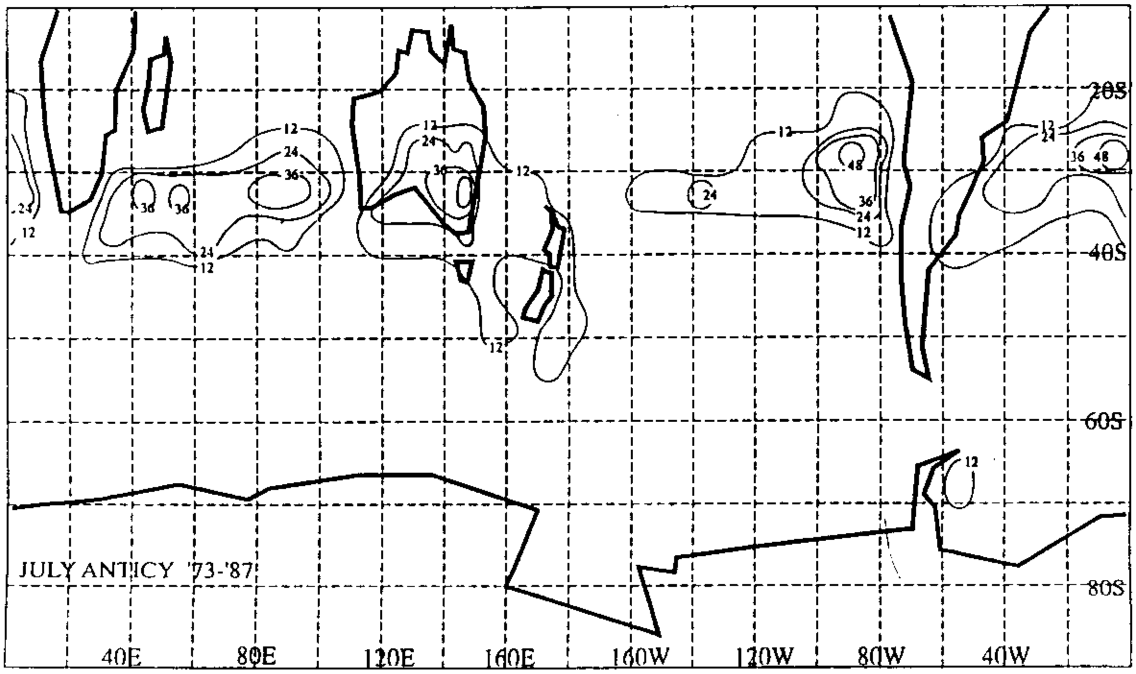


Figure 2. (b) July average anticyclone immobility index.

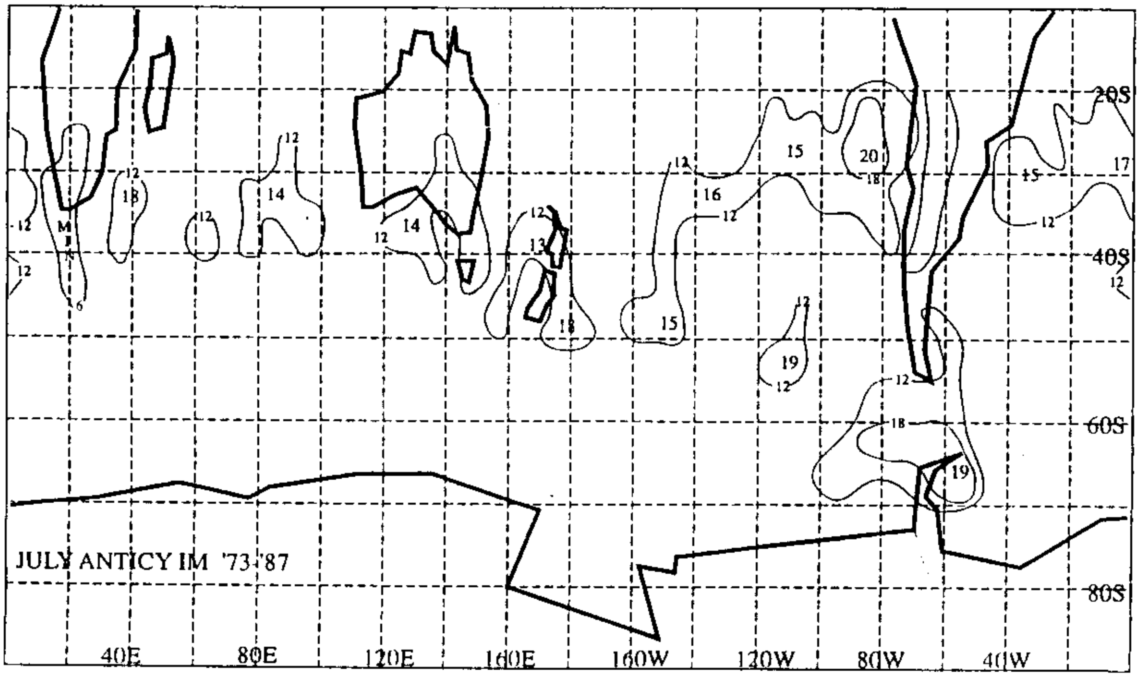


Figure 2. (c) July average cyclonicity, isopleths are in hours.

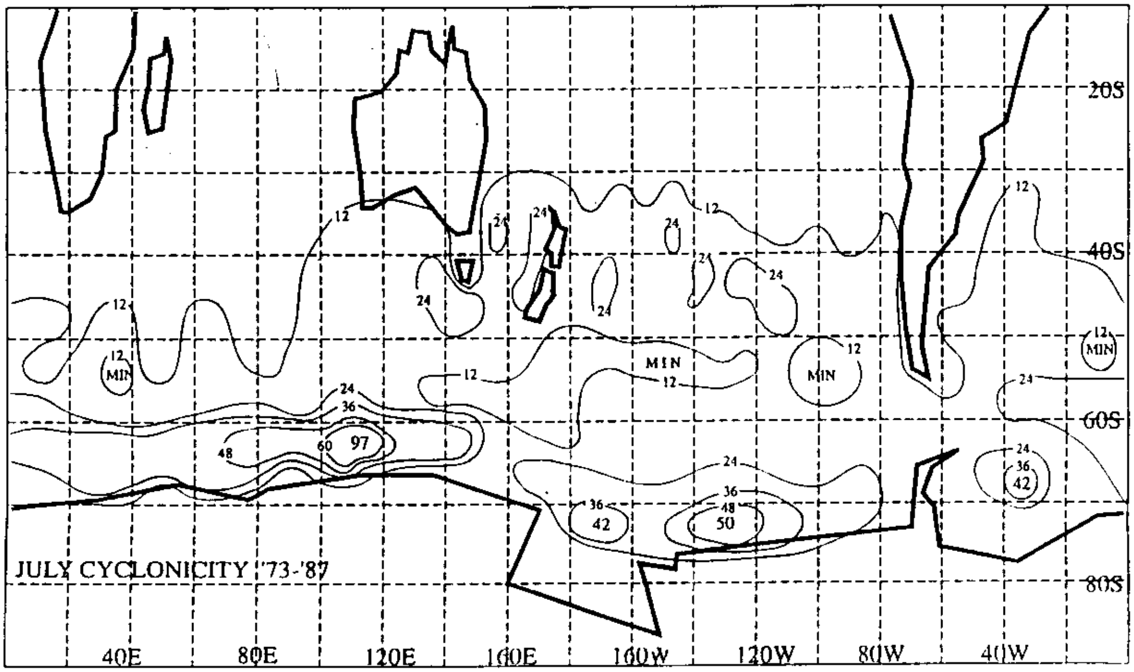
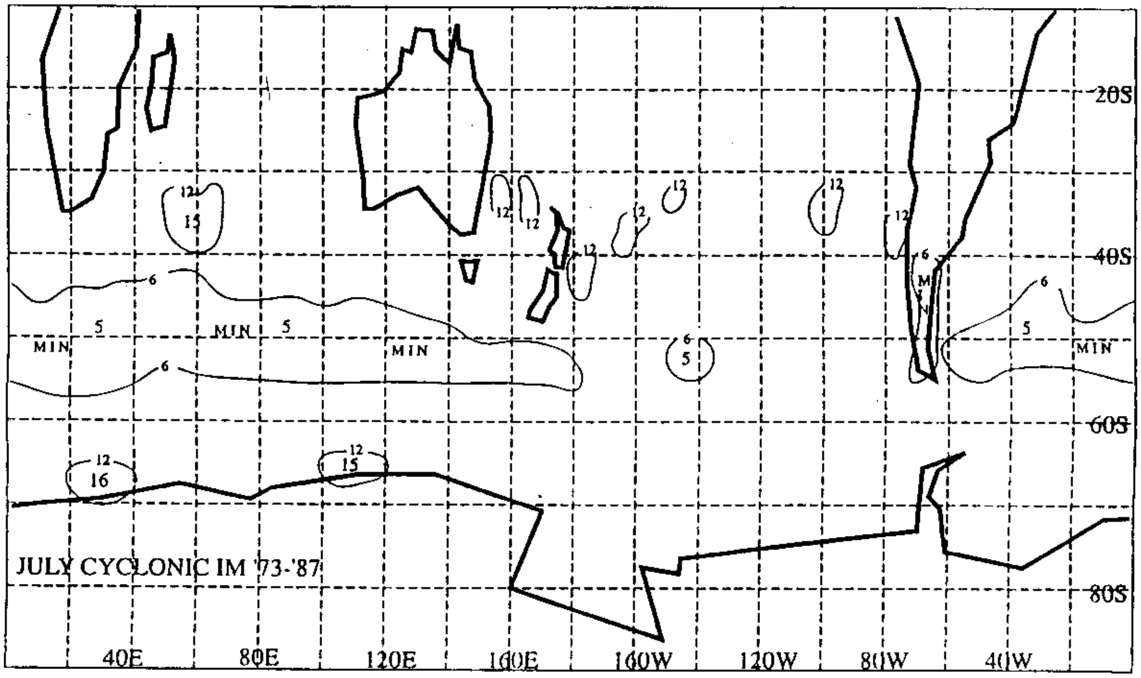


Figure 2. (d) July average cyclonic immobility index.



4. Accuracy of charts of anticyclonicity and cyclonicity

From 1965 cloud satellite photos were available for synoptic analyses for the Australian Region and from 1973 for the Southern Hemisphere. With this increase to the data base for the Australian Region and for the Southern Hemisphere the accuracy of surface analyses increased greatly. Drifting buoys deployed at various times since 1978 at differing positions in the oceans around the Southern Hemisphere have added to the data base also. The author feels that the ability of analysts to identify centres of lows from cloud photos could affect the accuracy of the charts. Wave lows forming under heavy cloud cover may not be obvious until the clouds display a definite wave or hook shape. Old lows can be difficult to access because an apparent circulation may remain visible in the cold air after the surface low itself has decayed. Lows situated under clouds associated with warm air advection may give no visible evidence of formation particularly in the initial stages of development. Surface lows in the monsoon trough are difficult to determine. Areas showing large cloud masses of convective activity in the tropics are regarded as suspicious for surface low development, however on occasions analyses identify ephemeral centres in these areas.

5. A comparison of (anti) cyclonicity with those presented by Le Marshall et al., 1985)

The ten yearly averaged hemispheric mean sea level pressure charts for January and July produce by Le Marshall et al. (1985) appear in Figure 3. Climatologies of synoptic systems add detail to the understanding of the overall climatology of a region and charts of (anti) cyclonicity show how the centres of pressure systems relate to the average pressure distribution and identifies areas of fast or slow centre movement, thus indicating favorable regions for synoptic blocking patterns to occur.

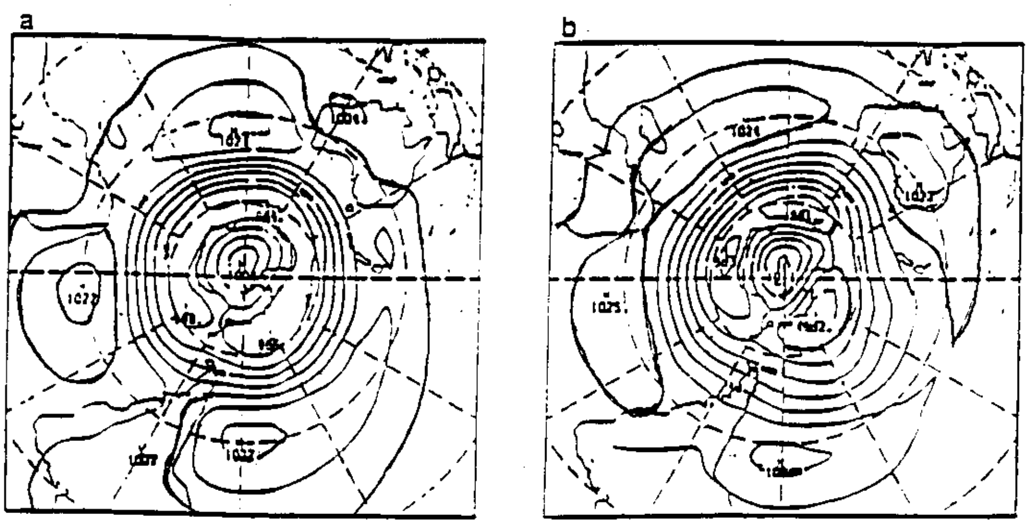


Figure 3. Ten-year monthly mean Australian southern hemisphere climatology mean sea level pressure (MSLP) for (a) January and (b) July (Source: Le Marshall et al., 1985).

For January Le Marshall et al. (1985) shows broad pressure ridges crossing the Oceans and the Australian Bight. Maximum pressure values are in the eastern Pacific, eastern Atlantic, and mid-eastern Indian ocean. The January anticyclonicity average has a strong maxima coinciding with the maximum pressure values in the eastern section of the oceans. The other anticyclonicity maxima, positioned in the pressure ridge, highlights where anticyclone centres are predominant.

Likewise the January cyclonicity chart show maxima in the low pressure trough which surrounds Antarctica. Across northwestern Australia the cyclonicity average has two heat low centres whereas Le Marshall suggest only one at the centre of lowest pressure. Across the tropics where there is no great change in average pressure cyclonicity defines the preferred location of low centres. In the Tasman Sea the region favorable for cyclones could not be deduced from Le Marshall.

In July the positions of the anticyclonicity maxima are further south than the mean ridge position given by Le Marshall in the Australian Region, western Pacific, Atlantic, and Indian Oceans. Possibly mobile westerly fronts, being more intense and frequent than troughs in easterlies, erode the southern portion of anticyclones leading to a lower mean pressure value than on the north side of the anticyclone centre. Across the Pacific Ocean Le Marshall indicates the presence of a broad trough with weak pressure gradients compared with a distinct minimum in cyclonicity between 50°S and 60°S. In the Tasman Sea Le Marshall shows a weak pressure gradient with possibly a weak blocking regime in the east Tasman/New Zealand sector. Anticyclonicity and cyclonicity maxima both occur in the Tasman Sea proving that the region is favorable for the location of both anticyclones and cyclones. The cyclonicity maximum in the western Tasman Sea could not be deduced from Le Marshall.

6. Synoptic scale features of the climatology

Anticyclonicity or cyclonicity maxima may or may not coincide with anticyclone or cyclone immobility maxima for the same period. If they coincide the surface systems can be slow moving crossing the anticyclonicity or cyclonicity maxima. If they do not coincide the anticyclone and cyclone immobility maxima indicate that the less common occurrences of surface systems placed outside the anticyclonicity and cyclonicity maxima can be slow moving.

For the two months (i.e., January and July) most anticyclone immobility maxima occur in or near anticyclonicity maxima. The size and nature of the immobility maxima may vary with each anticyclonicity maximum and most anticyclones move slowly when positioned near anticyclonicity maxima. For January a notable large immobility maximum at high latitudes occurs east of New Zealand and four quick moving or "jump" regions are evident below both Africa and Western Australia, and across southeastern Australia and New Zealand.

In January the cyclonicity maxima in the Kimberley and Hammersley regions of Western Australia represent heat lows. These regions do not have any associated immobility maxima.

Weak shallow lows draw over the northwest of Australia fluctuate with the time of day, being more common at 12 UTC than 00 UTC, hence high immobility figures do not appear there as the lows appear as separate systems each day. Also in January cyclonicity maxima with non coincident cyclone immobility maxima occur across tropical oceans due to the slow movement of tropical cyclones and depressions.

Across the southern ocean in both months the cyclone immobility maxima is low suggesting rapid movement of systems, although values increase near the coast of Antarctica. For both months the Tasman Sea also favors slow moving anticyclones suggesting this area is a favored longitude for blocking patterns.

7. Conclusion

(Anti)cyclonicity averages add to conventional climatologies by showing regions of slow and rapid movement of surface centres and the location of potential blocking areas, and as such, can be used as a guide for forecasting. The averages could be useful for verifying the realism of Numerical Weather Prediction, or Global models and the basic figures, being on a five degree grid, could be used as a data base in models. Anomalies can be calculated for ongoing current months and these would help in defining severe weather occurrences or possible climate change.

8. References

Karelsky, S., 1954, 'Surface circulation in the Australasian region', Bureau of Meteorology Study No. 3.

Karelsky, S., 1961, 'Monthly and seasonal anticyclonicity and cycloncity in the Australian region - 15 year average (1946-1960)', Bureau of Meteorolgy Study No. 13.

Le Marshall, et al., 1985, Australia Meteorological Magazine.

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