First CLARREO Mission Study Team Meeting

Newport News

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NASA-GISS

CLARREO Science Objectives

CLARREO

THE THREE MOST SIGNIFICANT ACHIEVABLE SCIENCE OBJECTIVES

1. ASSESS GLOBAL CLIMATE CHANGE

Detection, measurement, attribution of climate change
Obtain decadal-length records of key climate variables
AS IN 100+YR SURFACE TEMPERATURES, KEELING CO_2 RECORD

2. PERFORM CLIMATE GCM VALIDATION

Comprehensive end-to-end validation of climate GCMs
Field testing of climate GCM climate prediction accuracy
Simultaneous checks on radiative and physical variables

a. **Cloud, aerosol radiative parameters, indirect effect**
b. **Temperature, water vapor profiles, surface albedo**
c. **LW, SW radiative fluxes, heating / cooling rates**

MOST COMPREHENSIVE CLIMATE GCM VALIDATION EVER PROPOSED

3. PROVIDE RETRIEVAL INTERCALIBRATION

Improve calibration of operational satellite retrievals
Establish accurate satellite retrieval benchmarks: a., b., c.
MOST EFFECTIVE MEANS TO IMPROVE OPERATIONAL RETRIEVALS

CLARREO

vs

GLOBAL CLIMATE CHANGE

(decadal-length records of climate variables)
(detection, measurement, attribution)

WHAT NEEDS TO BE MEASURED ?

A. Direct Radiative Forcings

1. **Solar irradiance** (operational measurement)
2. **LW - GHGs** (direct sampling / operational measurement)
3. **SW - Aerosols, surface albedo** (poorly defined)

B. Climate Feedbacks / Natural Variability

1. **LW - Temperature, water vapor, clouds, GHGs**
2. **SW - Clouds, aerosols, surface albedo, indirect effect**

C. Nadir Spectral Intensity / Polarization

REQUIRED INSTRUMENTATION

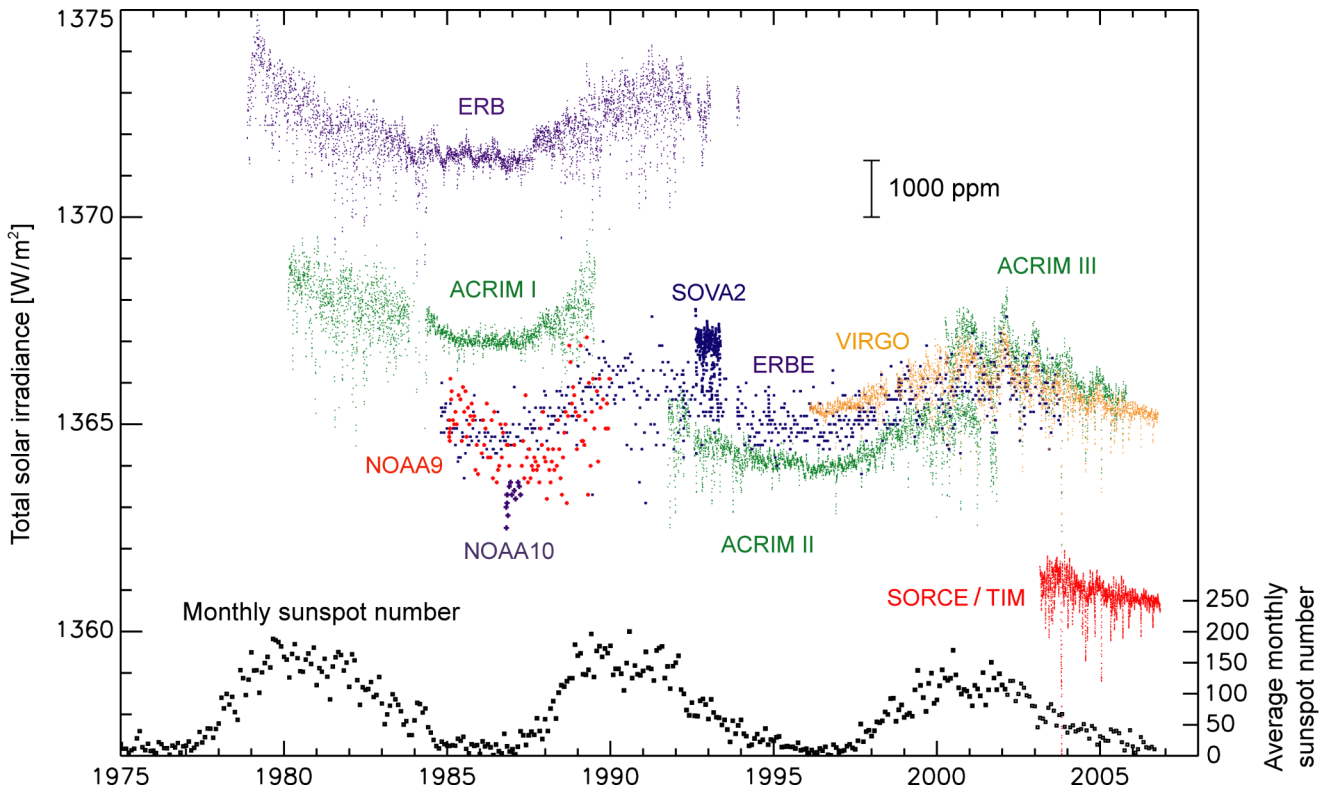
A. TSIS - Total Solar Irradiance

B. LW - Michelson Interferometer

1. **Temperature profile** (surface temperature, emissivity)
2. **Water vapor profile** (strat-trop differentiation)
3. **Cloud information** (height, phase, size, optical depth)
4. **LW Radiative fluxes** (heating / cooling rate profiles)

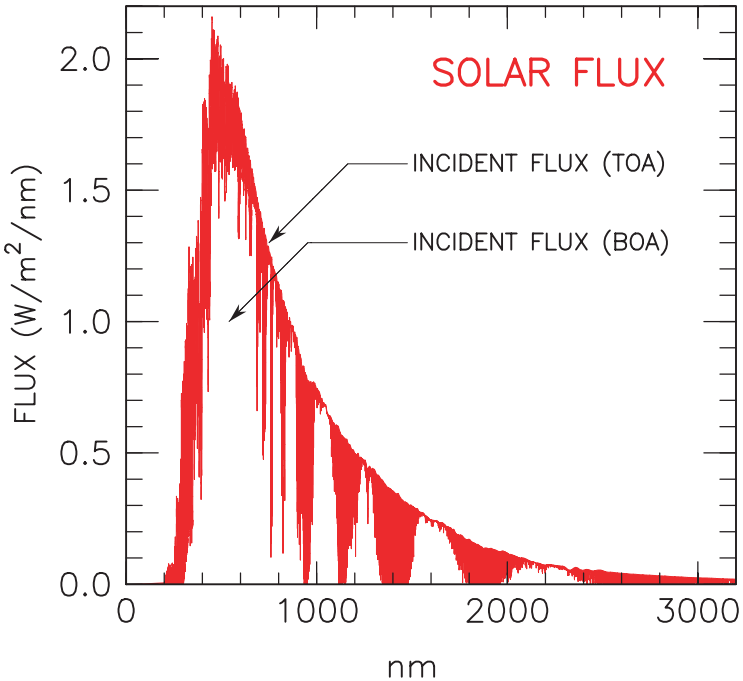
C. SW - Polarimeter / Spectrometer

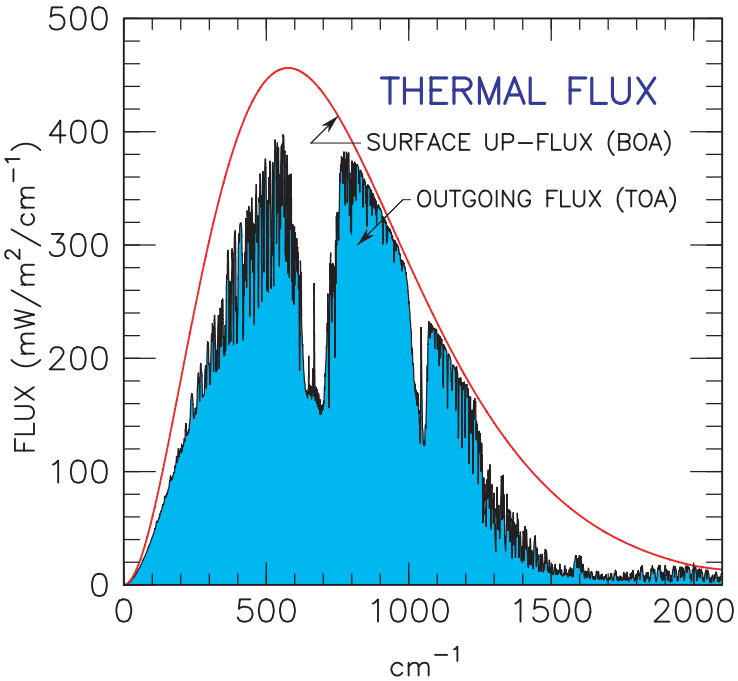
1. **Aerosol properties** (optical depth, size, composition, ω_o)
2. **Surface albedo** (spectral dependence)
3. **Clouds** (phase, size, optical depth, indirect effect)
4. **SW Radiative fluxes** (heating rate profiles)



The spaceborne TSI record is due to several instruments, which fortunately have sufficient overlap to provide continuity despite the relatively large differences between each instrument on an absolute scale. Correlations with sunspot number provide a proxy to extend TSI estimates back 400 years.

Solar and Thermal Radiation in a Climate GCM





(A) Spectral distribution of incident solar radiation at Top-of-Atmosphere (TOA) and at ground surface (BOA).

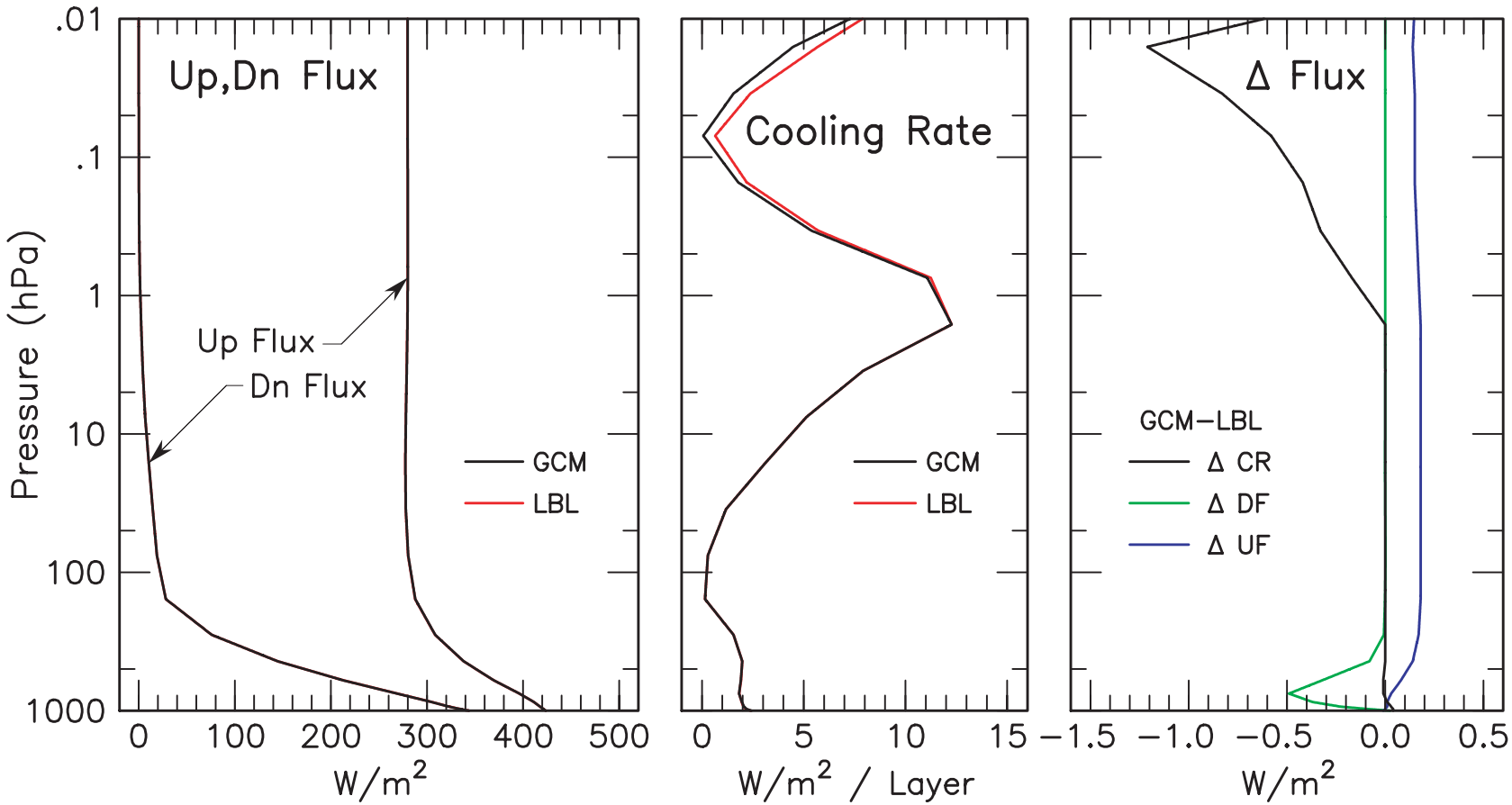
(B) Spectral distribution of thermal radiation at Top-of-Atmosphere (TOA) and at ground surface (BOA).

The global-mean absorbed Solar Radiation by the Earth (surface + atmosphere) is approximately 240 W/m^2.

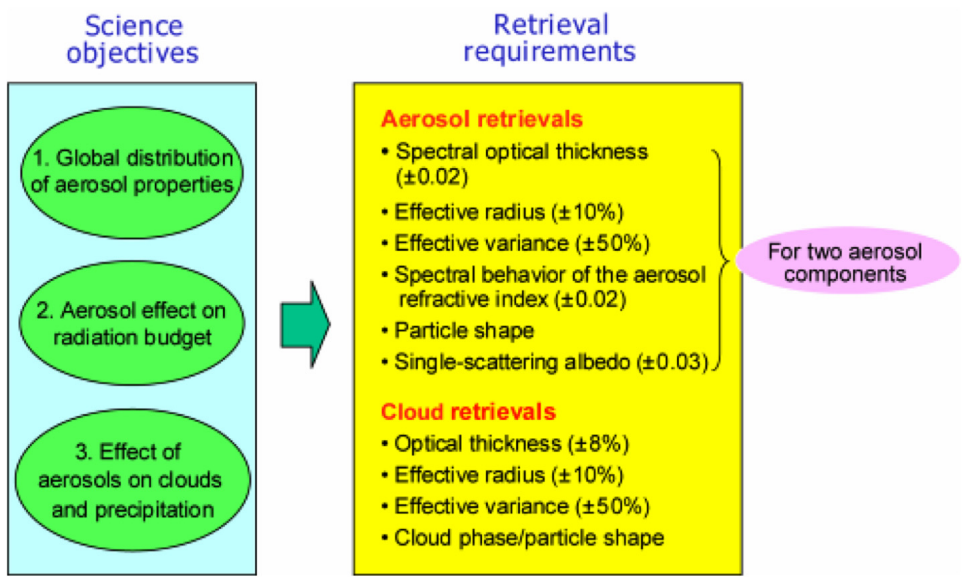
Global energy balance requires that the global-mean Thermal Radiation emitted to space is also 240 W/m^2.

Line-by-Line calculations of the SW and LW spectra use the HITRAN database of over 10^6 spectral lines and provide a Reference Benchmark for verifying the GCM radiation model accuracy.

Mid-Latitude Summer: GCM, LBL Flux, Cooling Rate



Radiative flux and cooling rate comparison between GCM (black) and Line-by-Line (red) calculations for a clear-sky Midlatitude Summer Standard Atmosphere. The cooling rate is the net flux divergence in a 23-layer atmosphere. GCM-LBL differences of the cooling rate, downwelling and upwelling flux are shown in the right hand panel.



Flowdown of science objectives into specific retrieval requirements

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LW SPECTRAL SIGNATURES

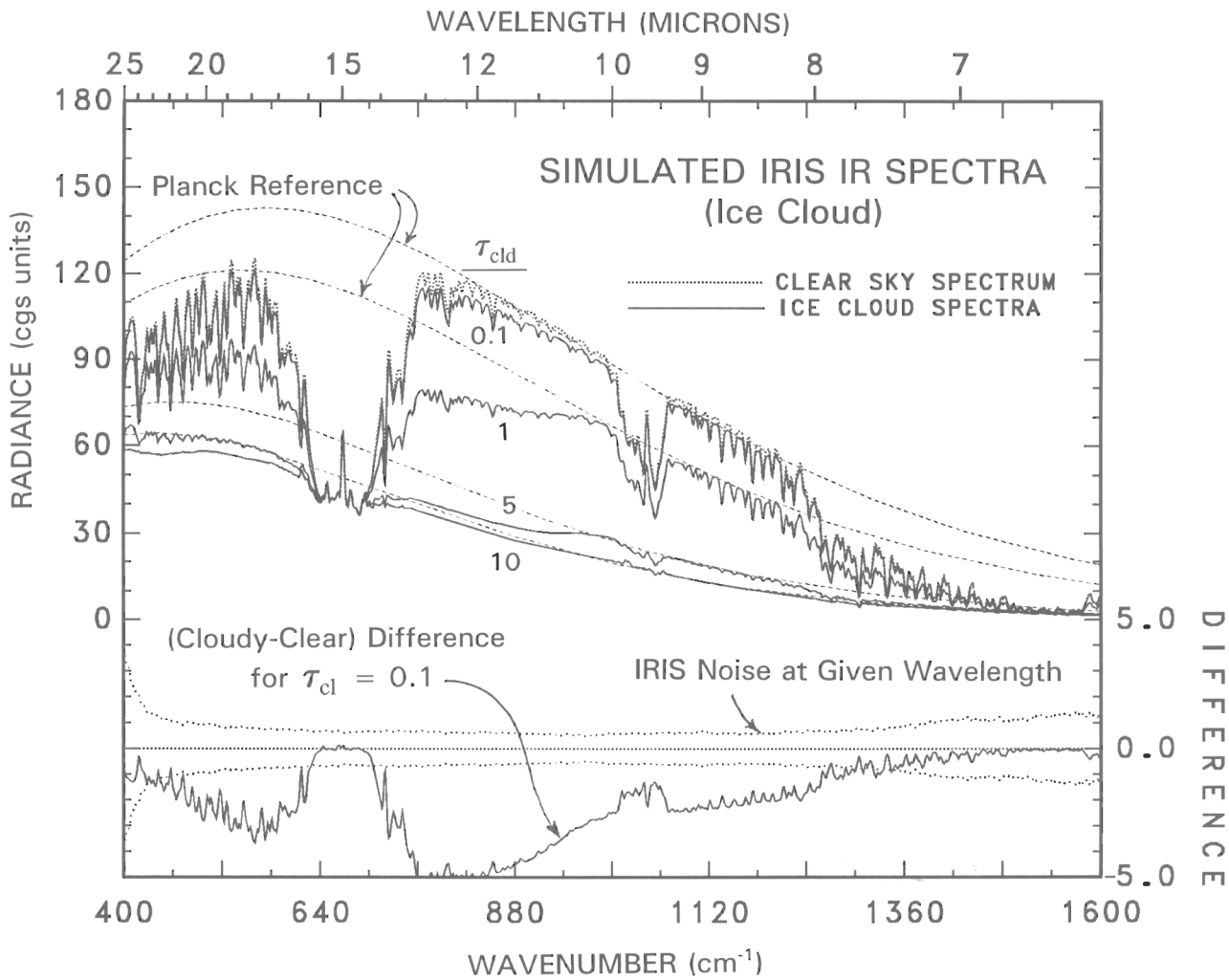
OF

KEY CLIMATE VARIABLES

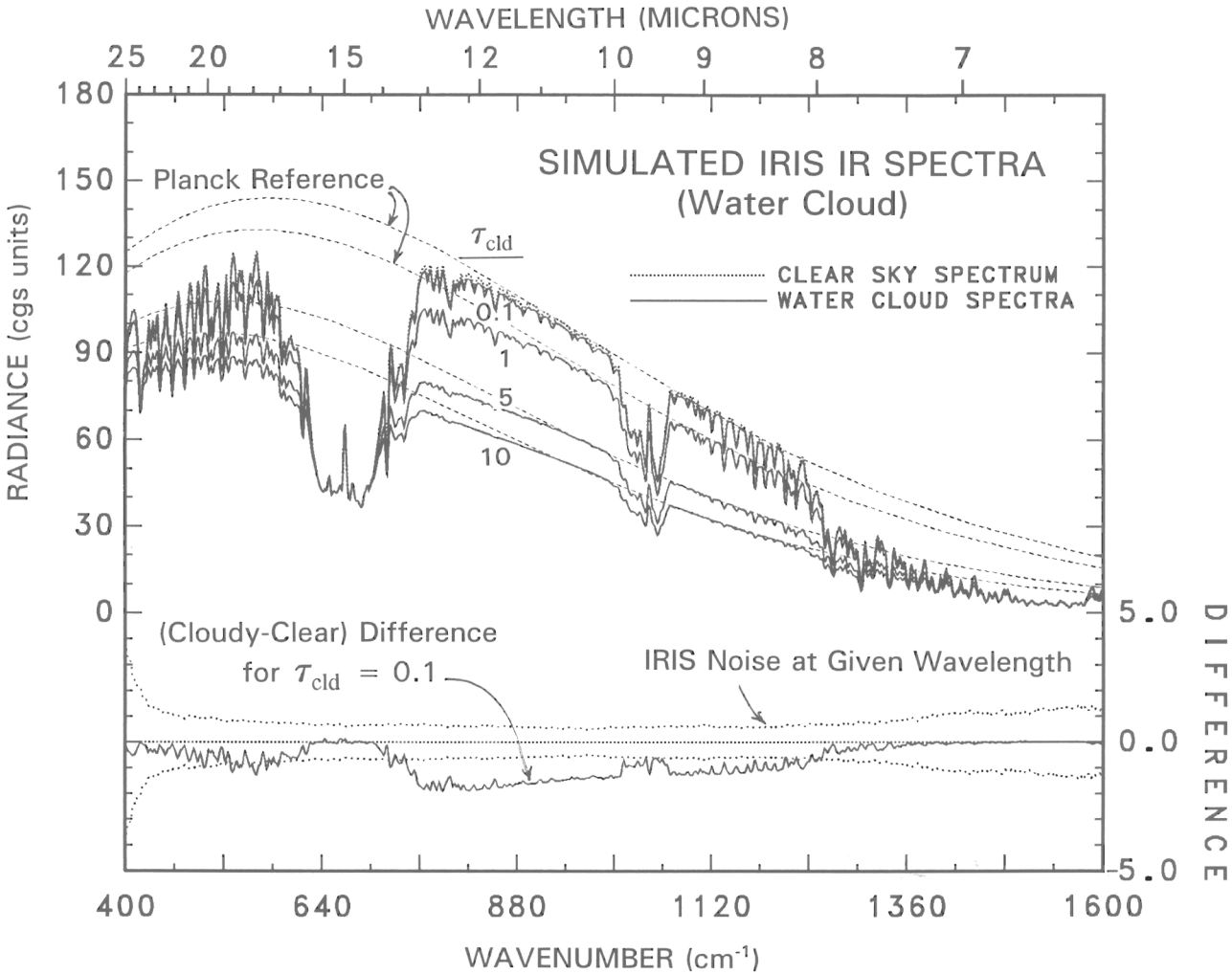
ENCOUNTERED IN

PRINCIPAL CLARREO LW APPLICATIONS

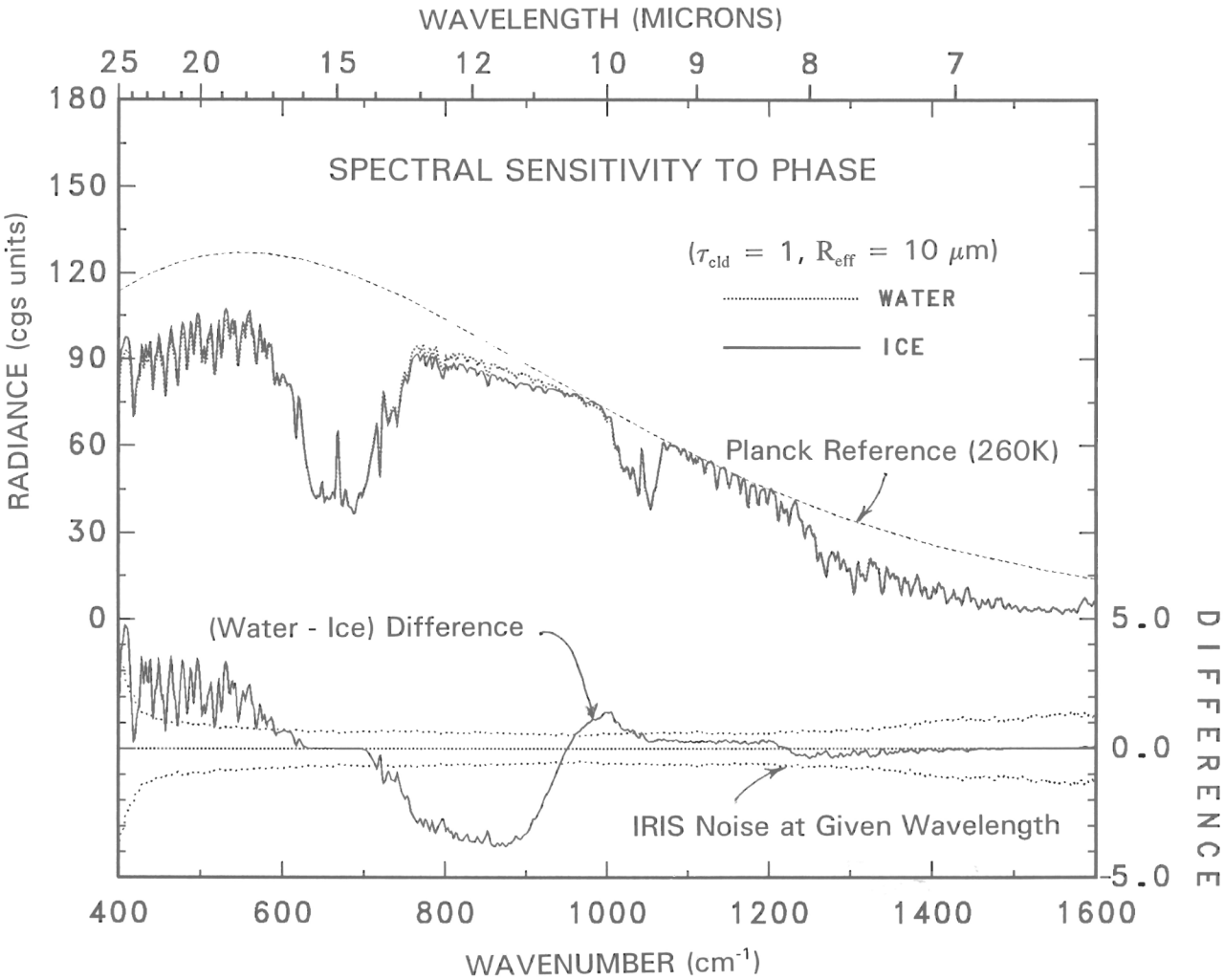
1. DECADAL CLIMATE RECORD INFORMATION CONTENT
2. EXPECTED CLARREO RETRIEVAL DATA PRODUCTS
3. GCM PERFORMANCE VALIDATION COMPARISON DATA
4. OPERATIONAL SATELLITE RETRIEVAL CALIBRATION DATA



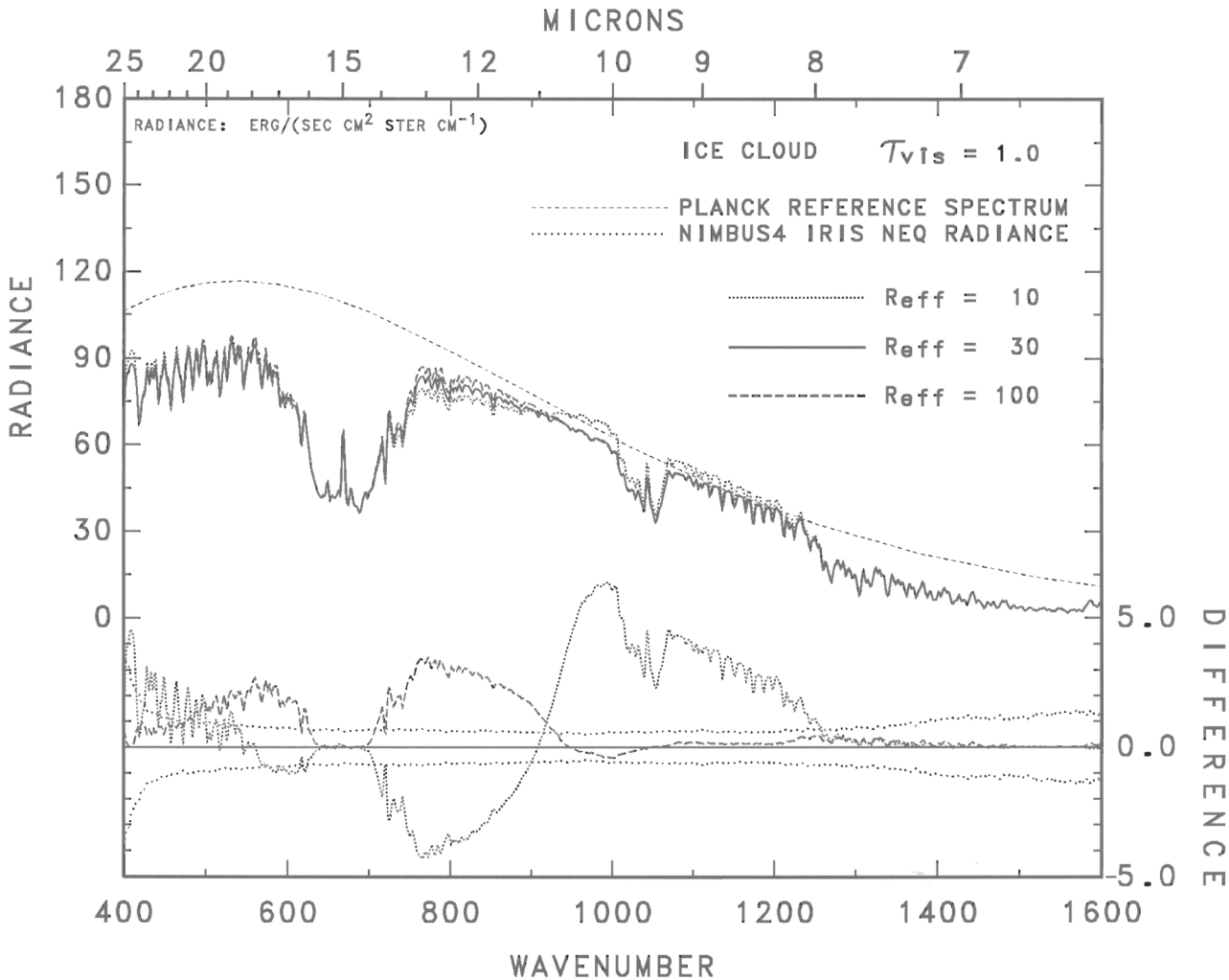
Spectral signature of ice cloud optical depth



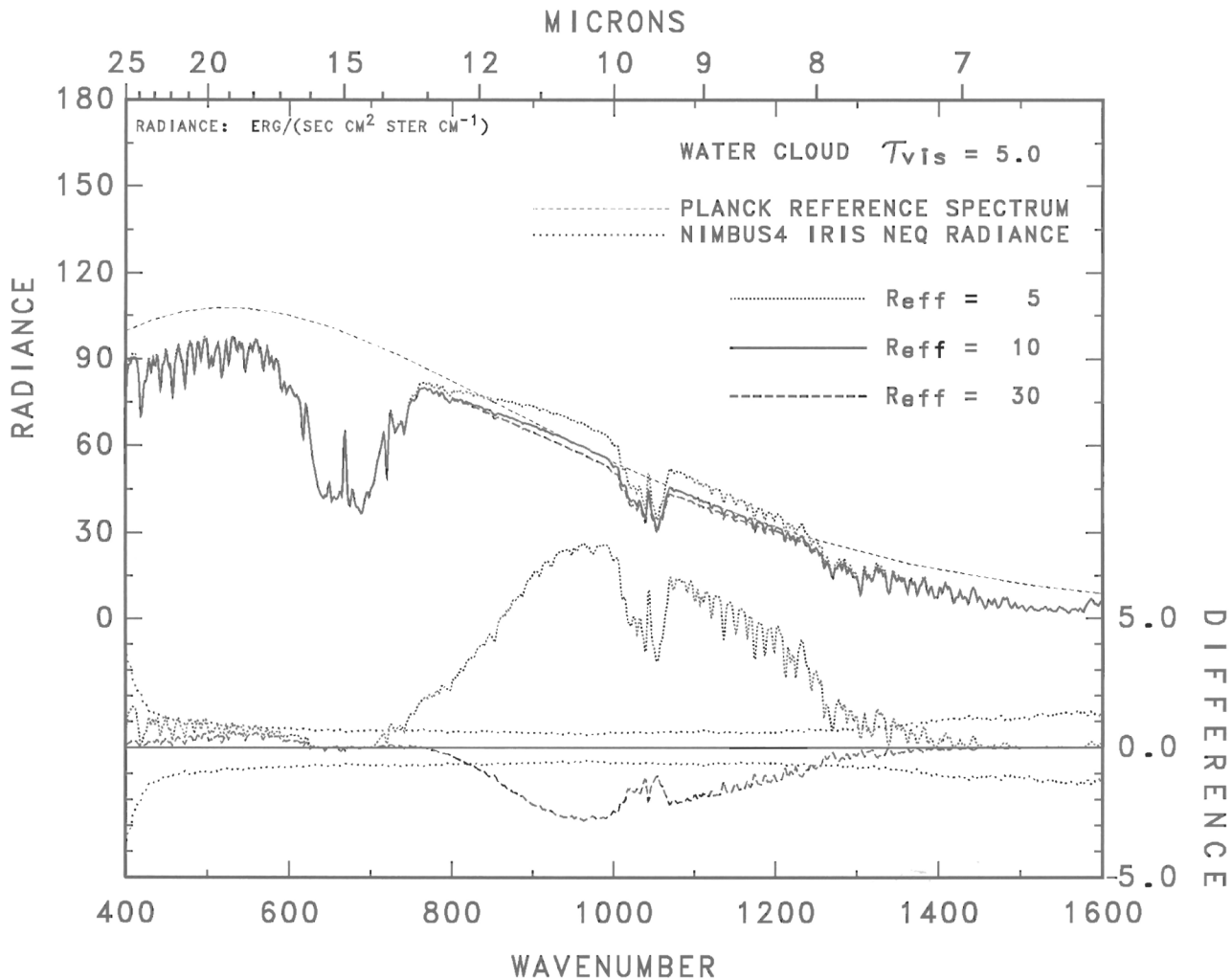
Spectral signature of water cloud optical depth



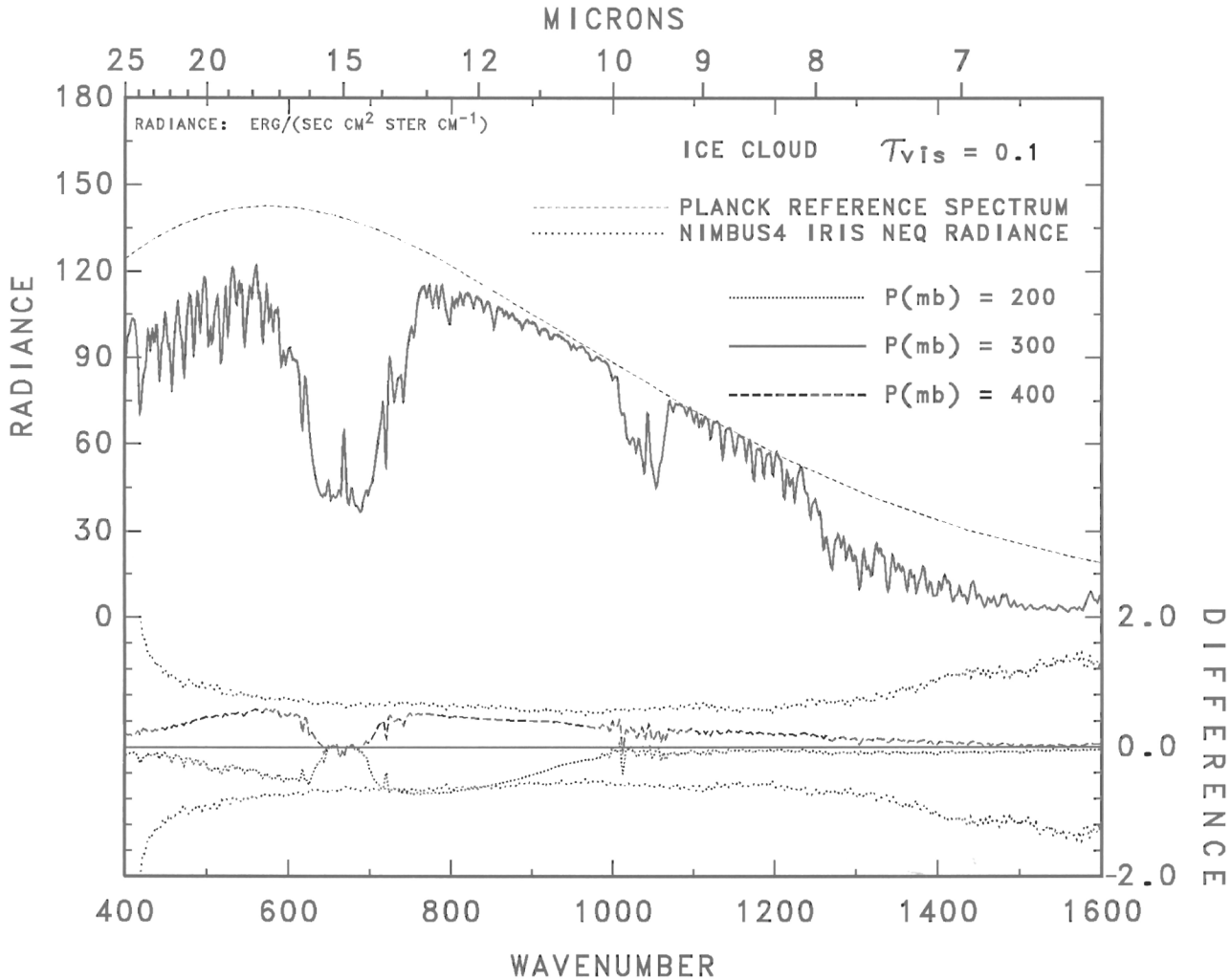
Spectral signature of cloud ice / water phase



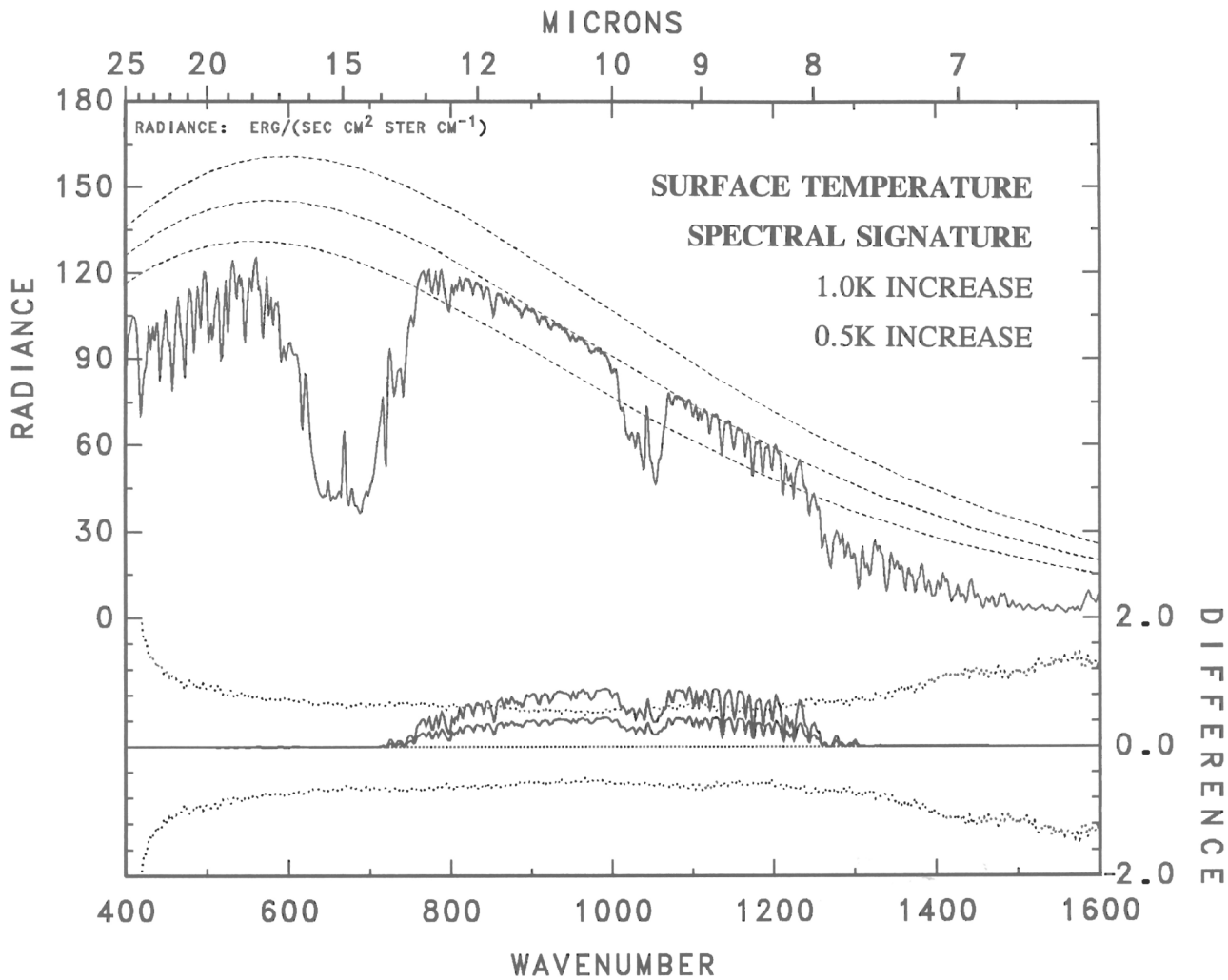
Spectral signature of ice cloud particle size



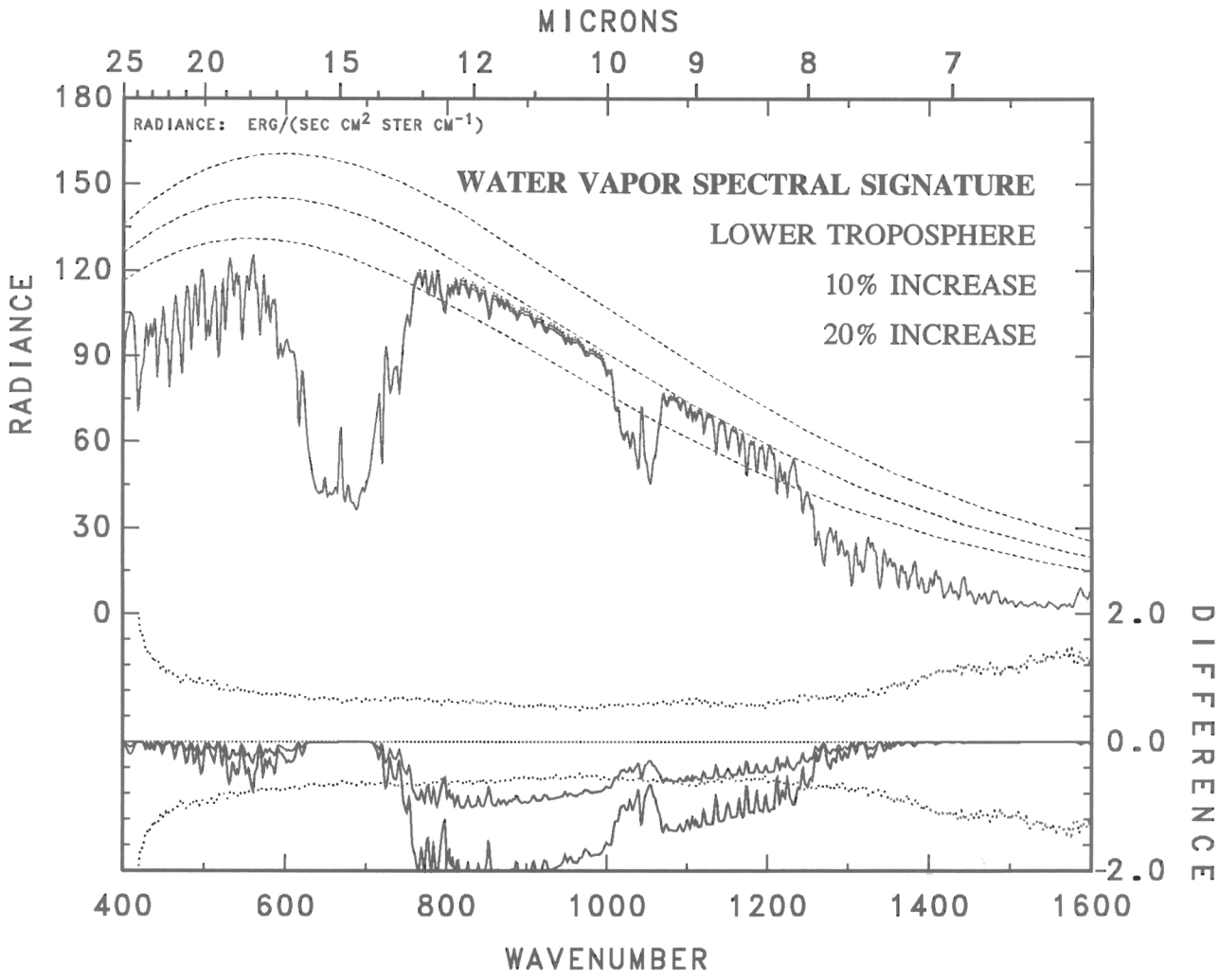
Spectral signature of water cloud particle size



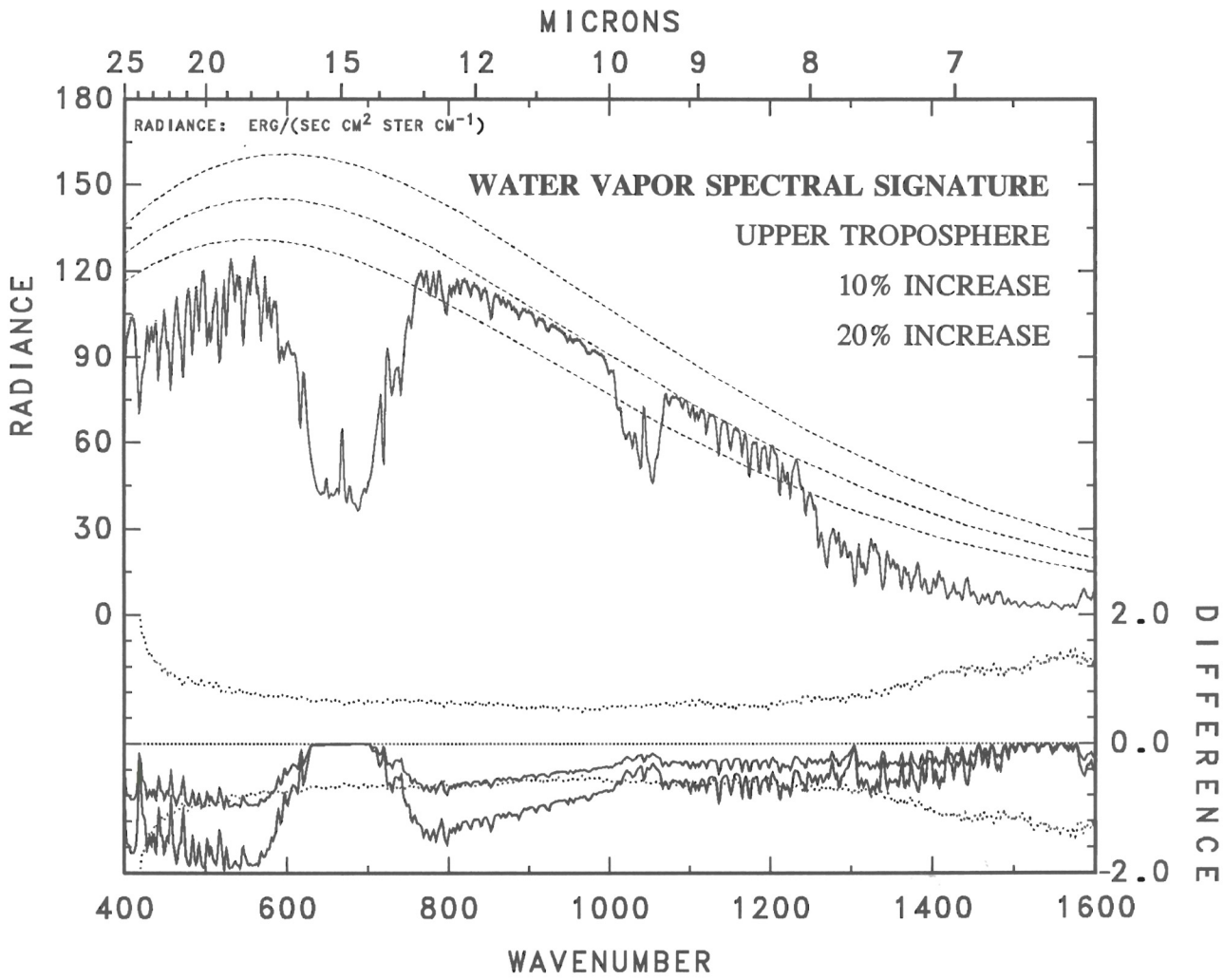
Spectral signature of ice cloud height change



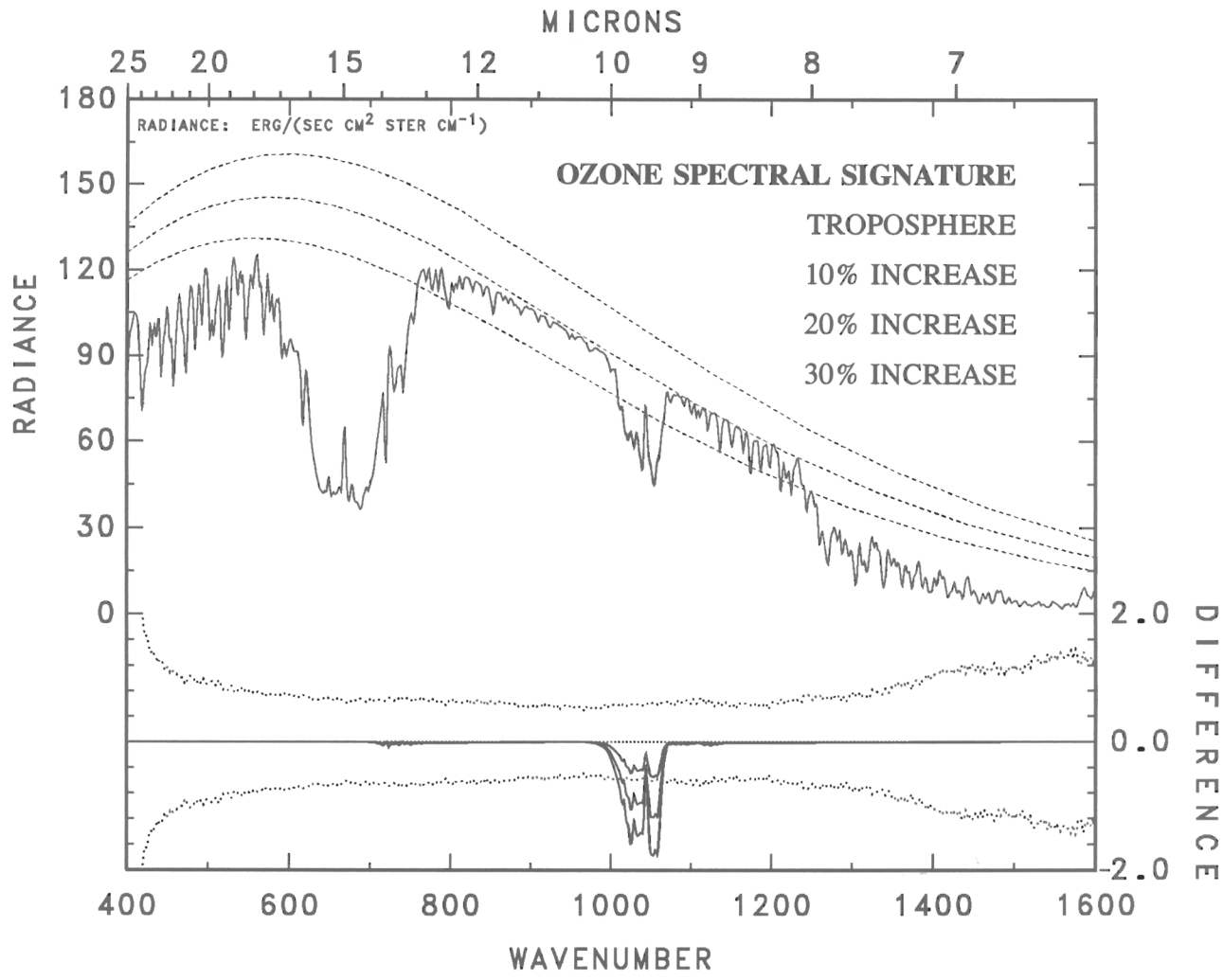
Spectral signature of surface temperature increase



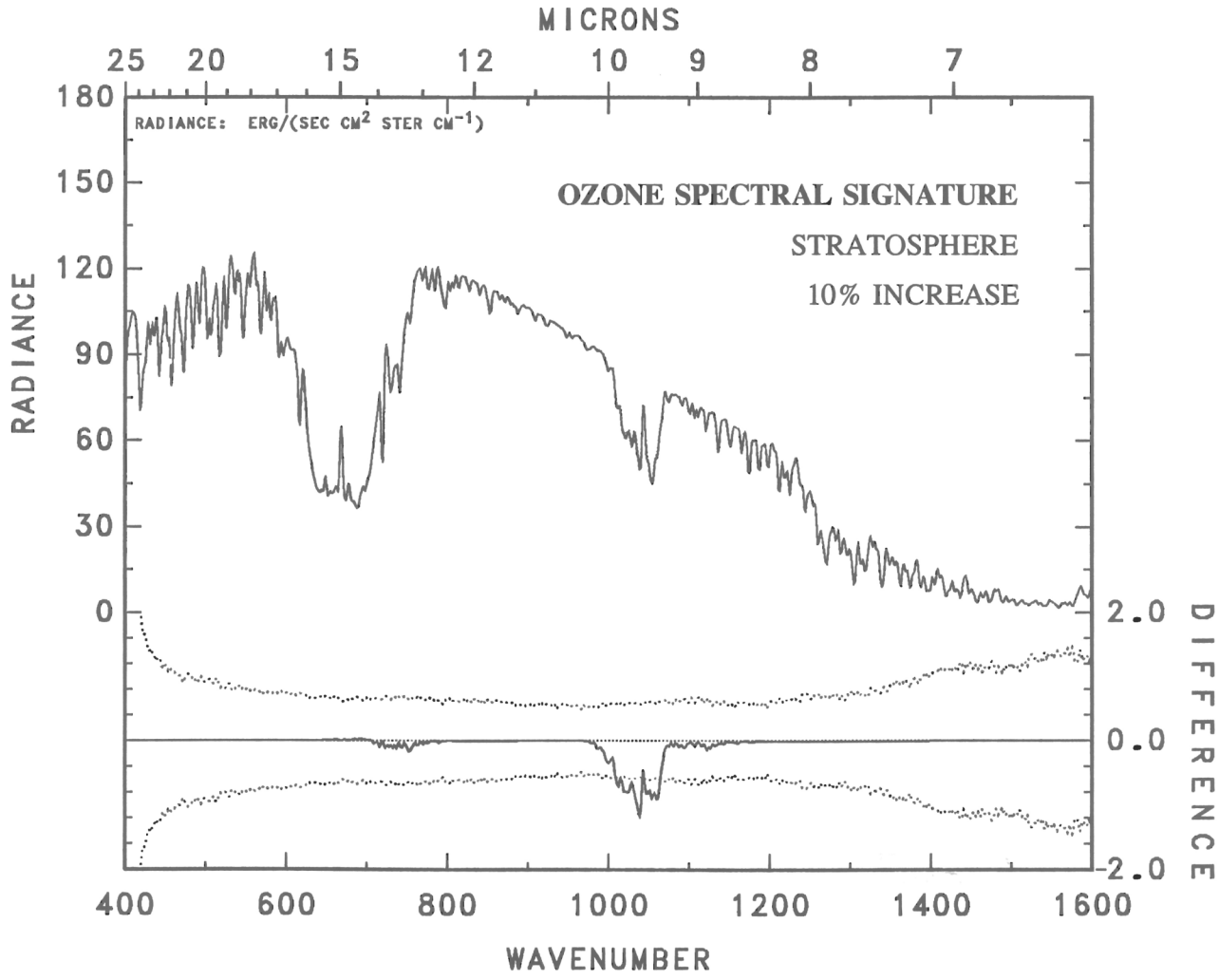
Spectral signature of lower tropospheric water vapor



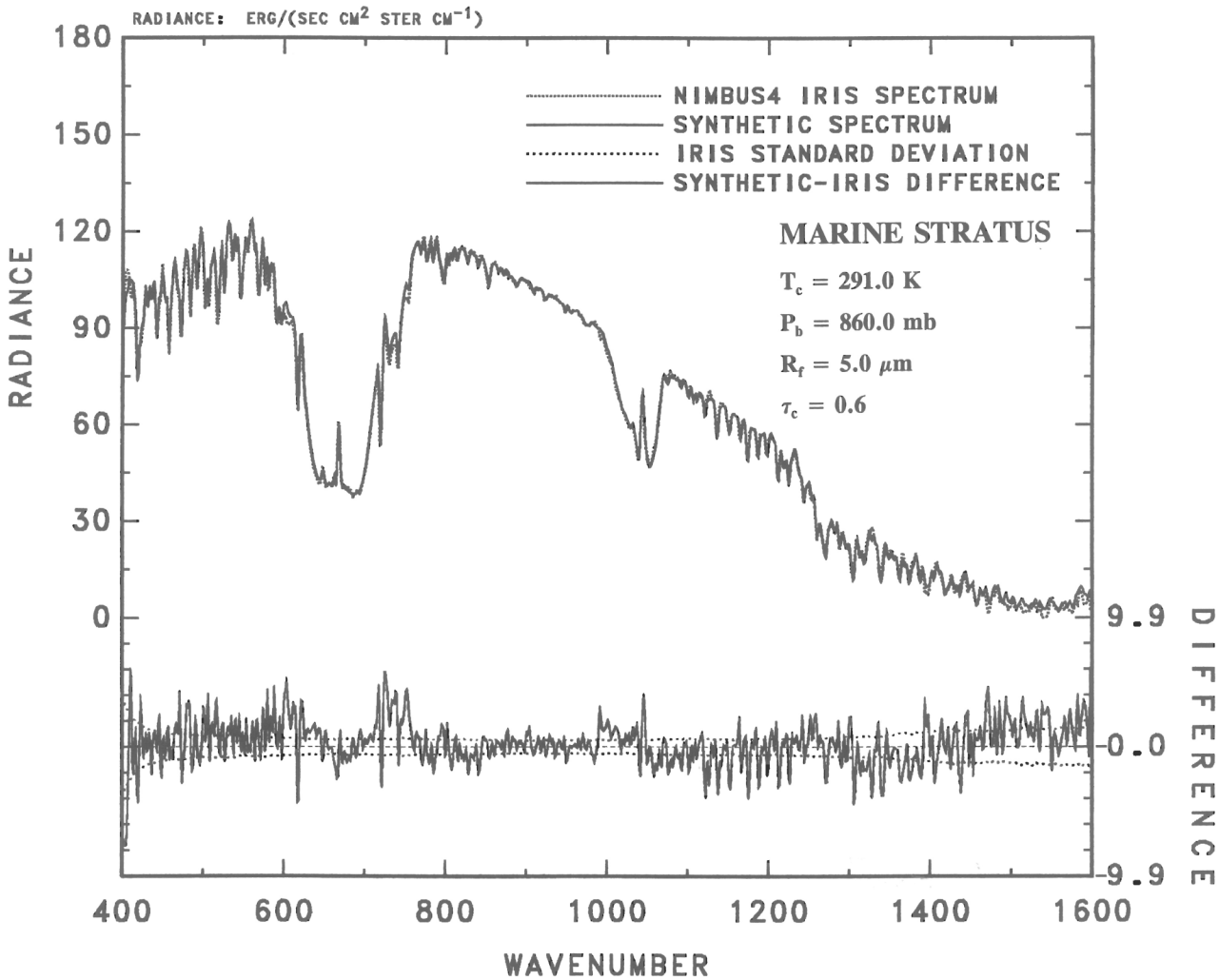
Spectral signature of upper tropospheric water vapor



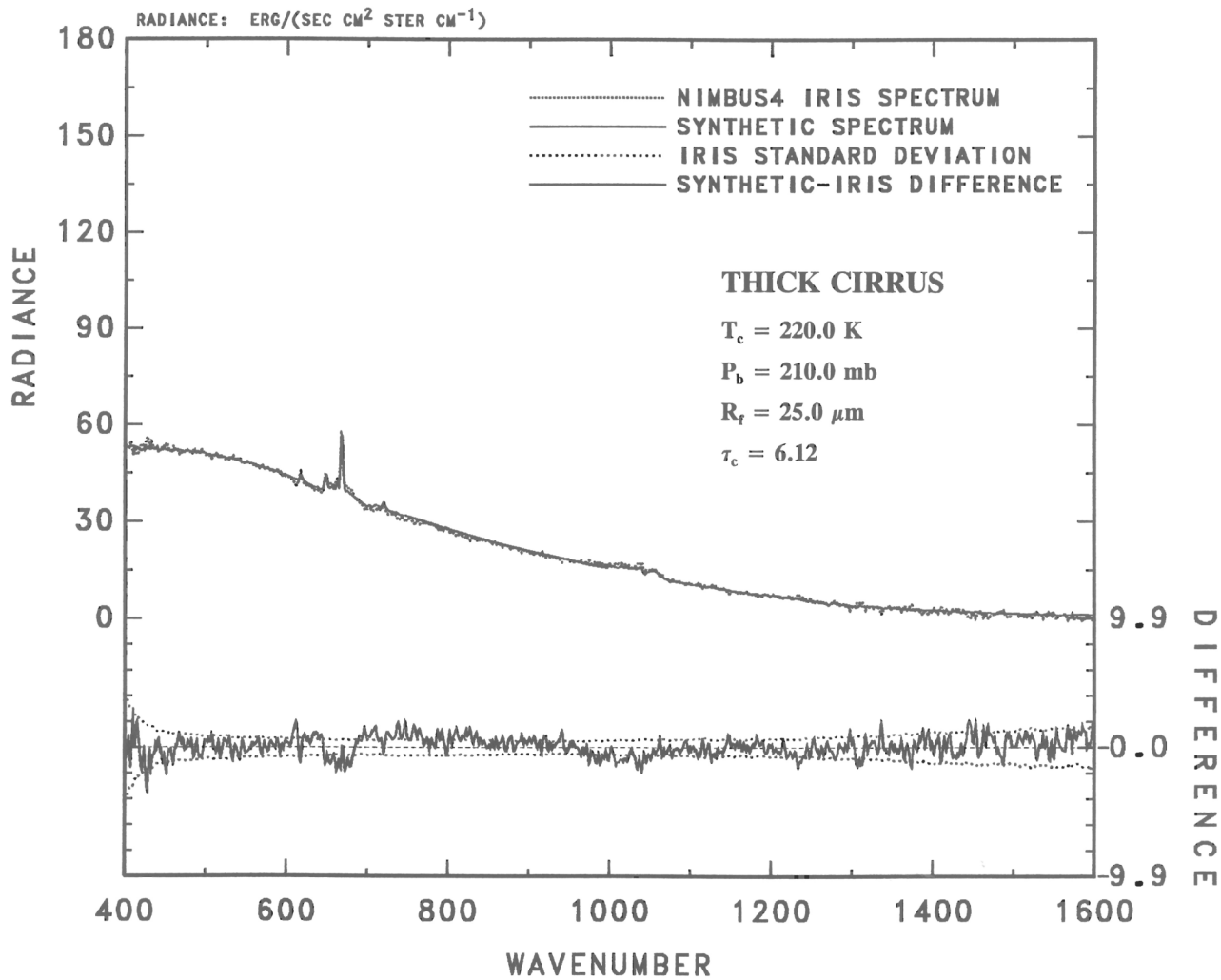
Spectral signature of tropospheric ozone



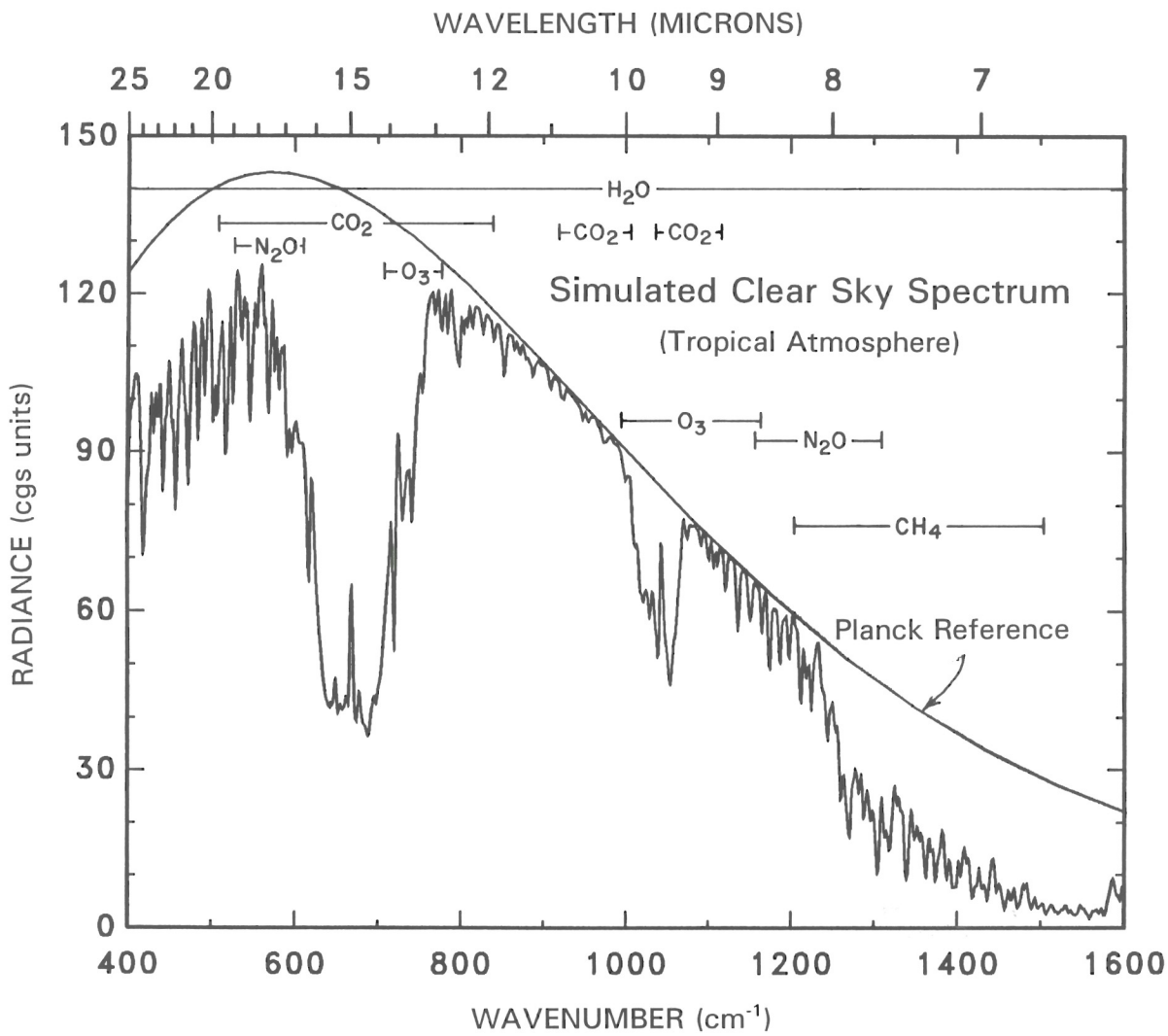
Spectral signature of stratospheric ozone



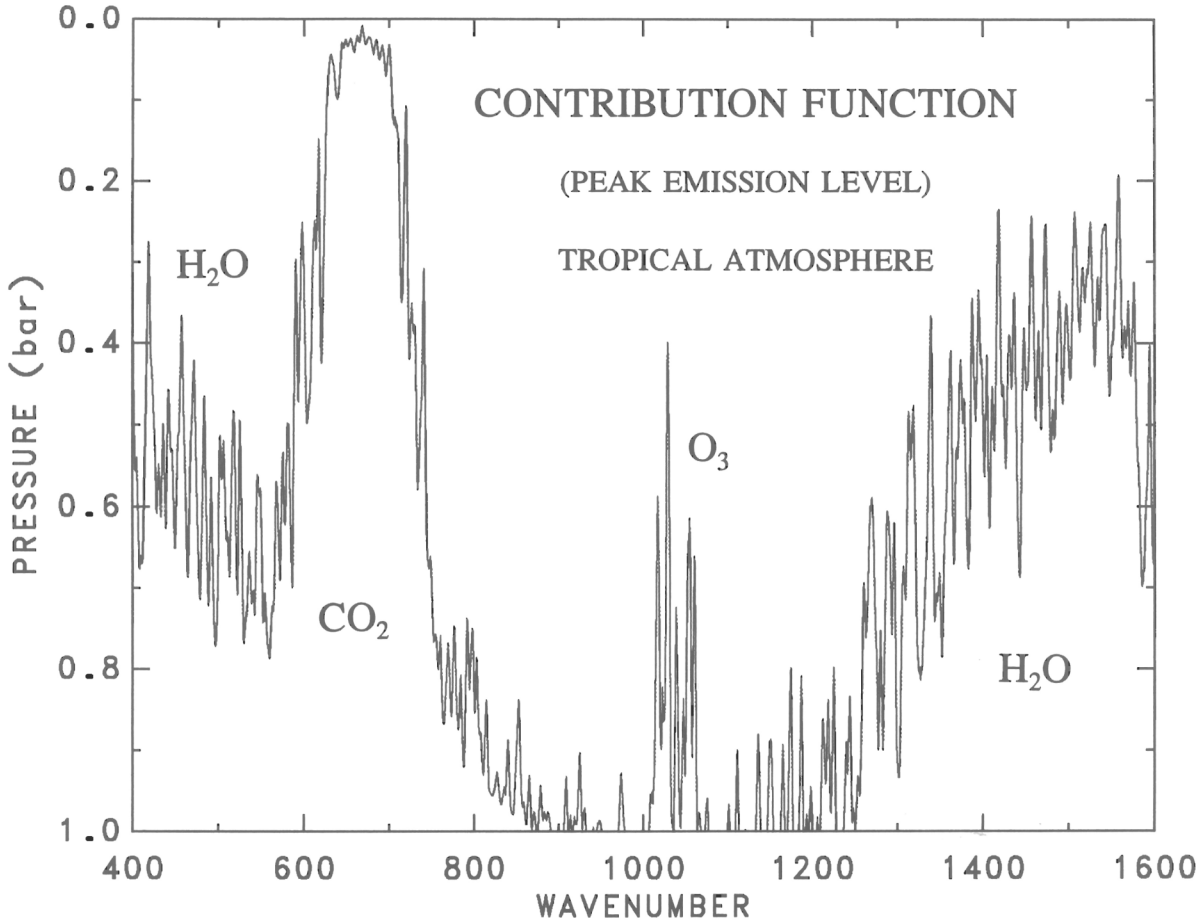
NIMBUS-4 IRIS sample retrieval - marine stratus



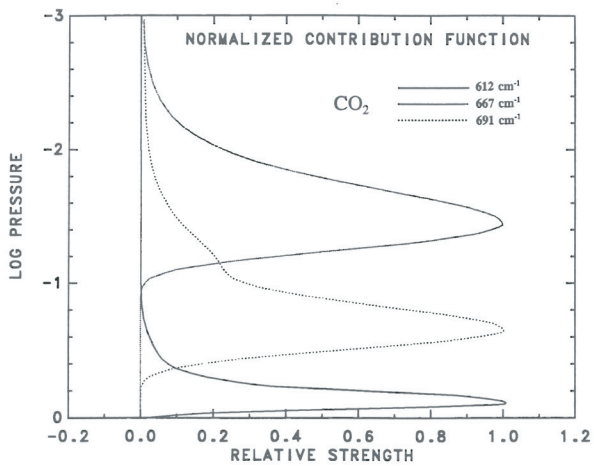
NIMBUS-4 IRIS sample retrieval - thick anvil cirrus

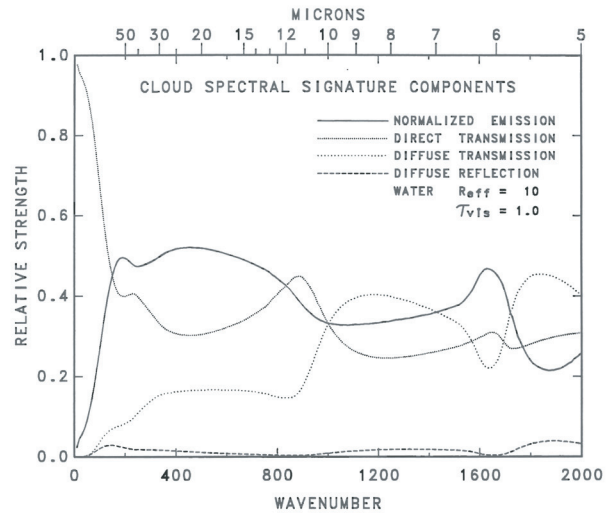


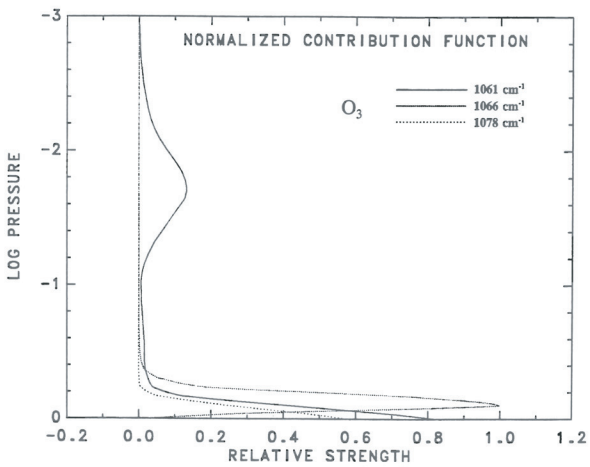
Spectral location of principal GHG absorption bands

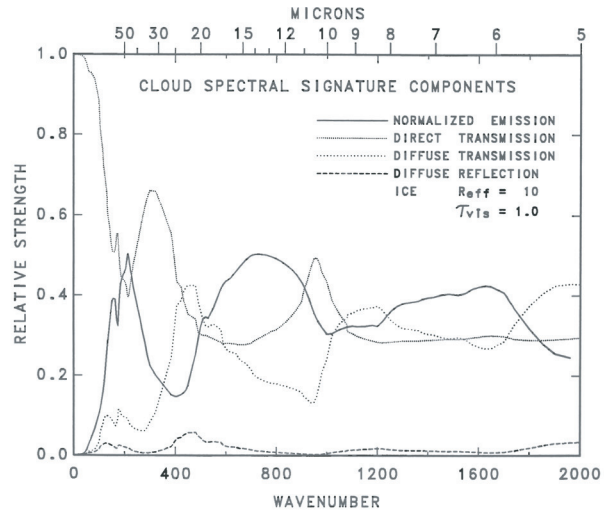


NIMBUS-4 IRIS peak emission level



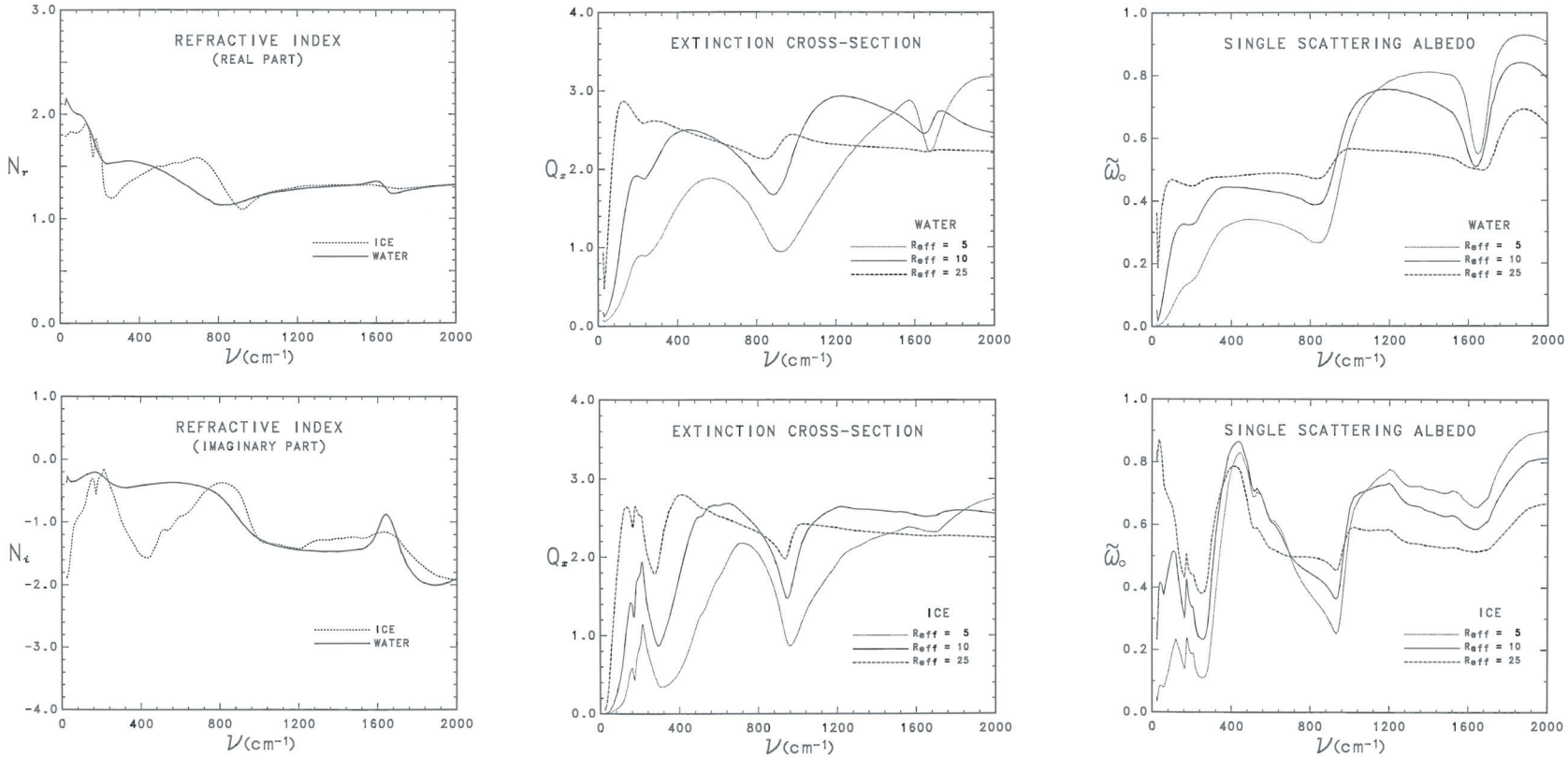






Left: Normalized sample spectral GHG contribution functions.

Right: Normalized spectral cloud signature components for water (top left) and ice (bottom right) clouds, respectively: (1) self emission, (2) direct transmission, (3) diffuse transmission, (4) reflection.



Left: Real (top) and imaginary (bottom) refractive index for water and for ice.

Center: Mie scattering extinction efficiency factor for water (top) and ice (bottom).

Right: Mie scattering single scattering albedo for water (top) and ice (bottom).

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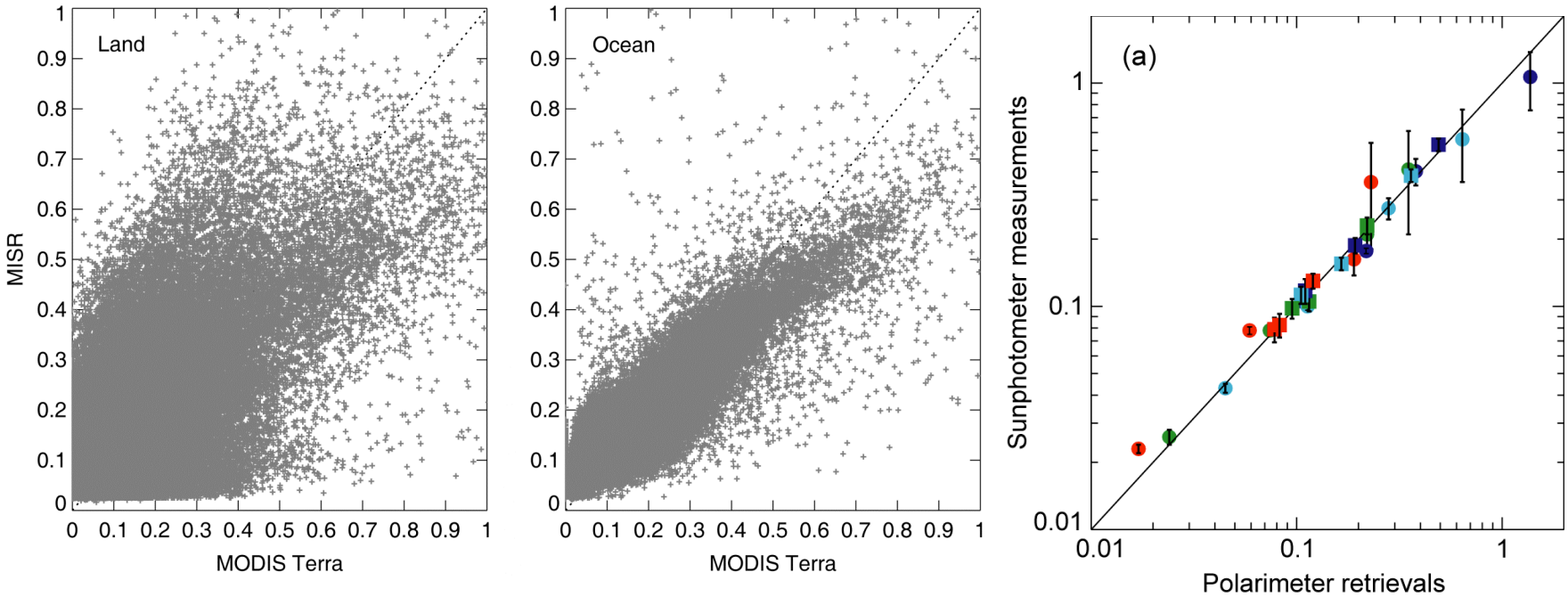
SW CLIMATE VARIABLES

RETRIEVAL LIMITATIONS OF INTENSITY ONLY MEASUREMENTS

1. Can’t measure global aerosol change
2. Can’t measure surface albedo change
3. Can’t address aerosol indirect effect

SW MEASUREMENT REQUIREMENT

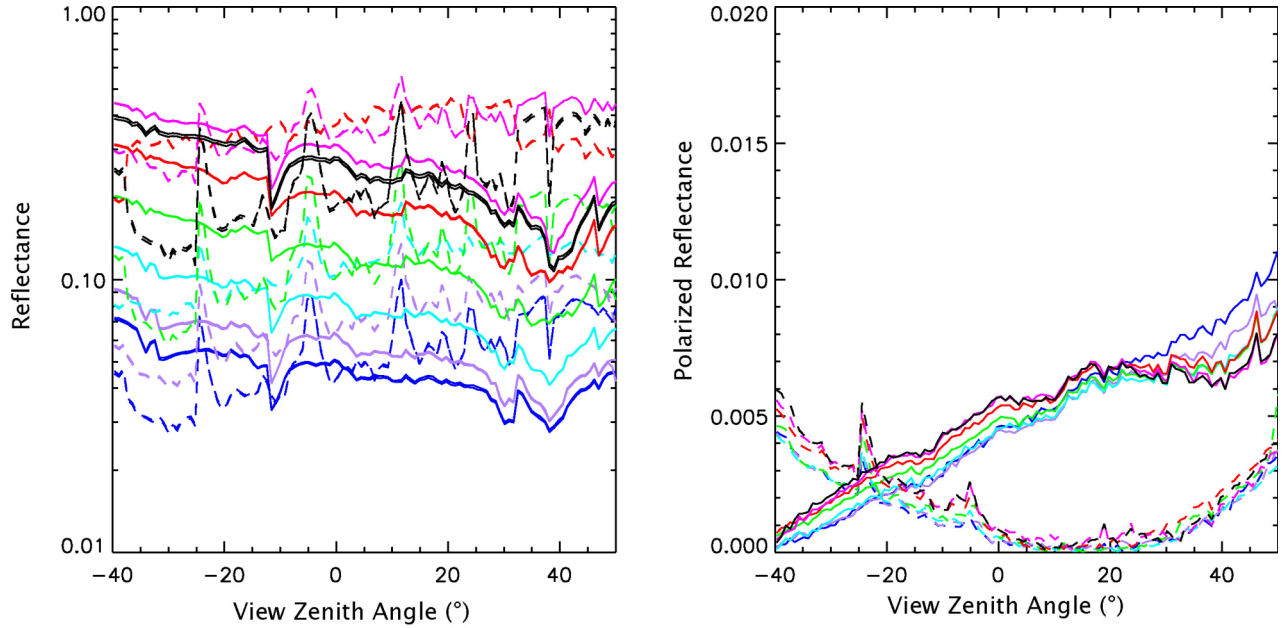
Polarimetric / Spectral Capability



Left: one month of MISR *vs* MODIS same-spacecraft, co-located pixel-level AOTs (January 2006). Right: Research Scanning Polarimeter (APS aircraft prototype) AOTs *vs* sunphotometer results over land (circles) and ocean (squares) at 410/443 (blue), 500 (turquoise), 673 (green), and 865 nm (red). The error bars correspond to sunphotometer measurement uncertainty.

Research Scanning Polarimeter in ALIVE

– Low altitude reflectance and polarized reflectance

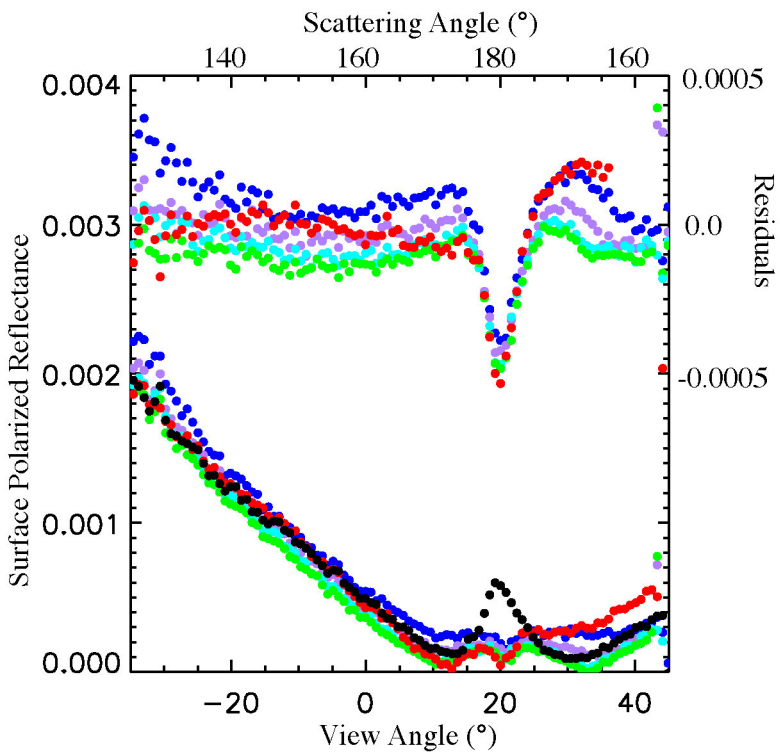


– Measurements of two different surface types at 410, 470, 555, 670, 865, 1590 and 2250 nm (blue, mauve, turquoise, green, red, magenta, black) with different viewing geometries.

- Solid lines are bare soil, dashed lines are vegetation. These are single aggregated scans of a single pixel. Imperfection are primarily due to yaw.
- Reflectances of different surface types show significant variations in color. Polarized reflectances of different surface types is dominated by geometry.

Research Scanning Polarimeter in ALIVE

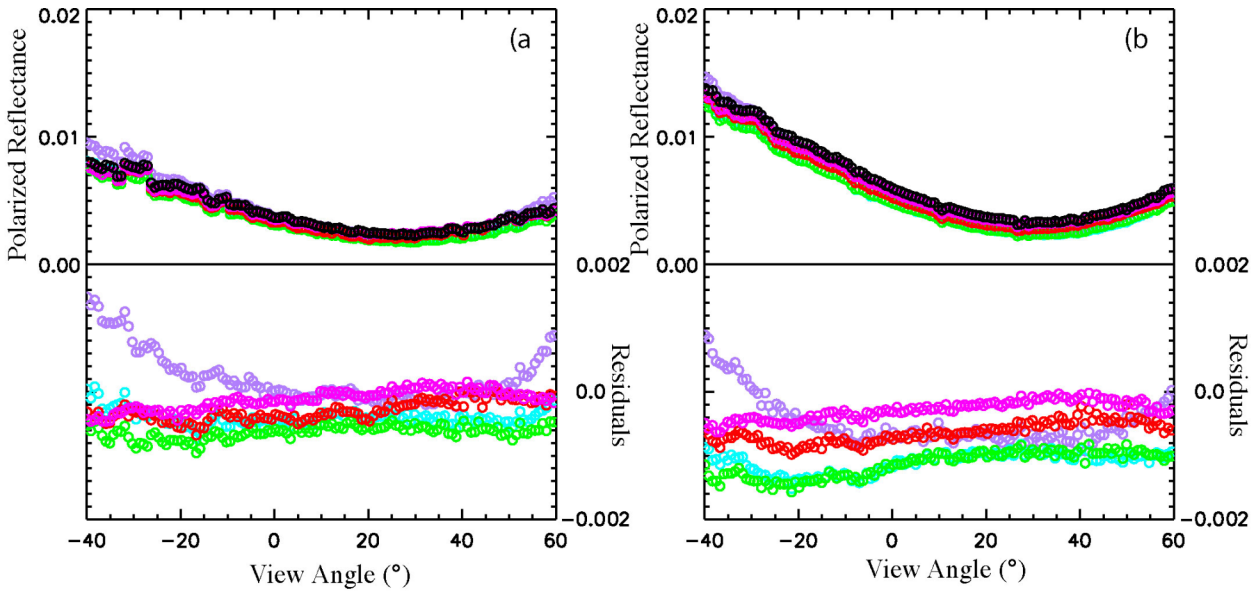
– Previous measurements over Dismal Swamp showed that at least heavily vegetated surface are relatively colorless in terms of their polarized reflectance.



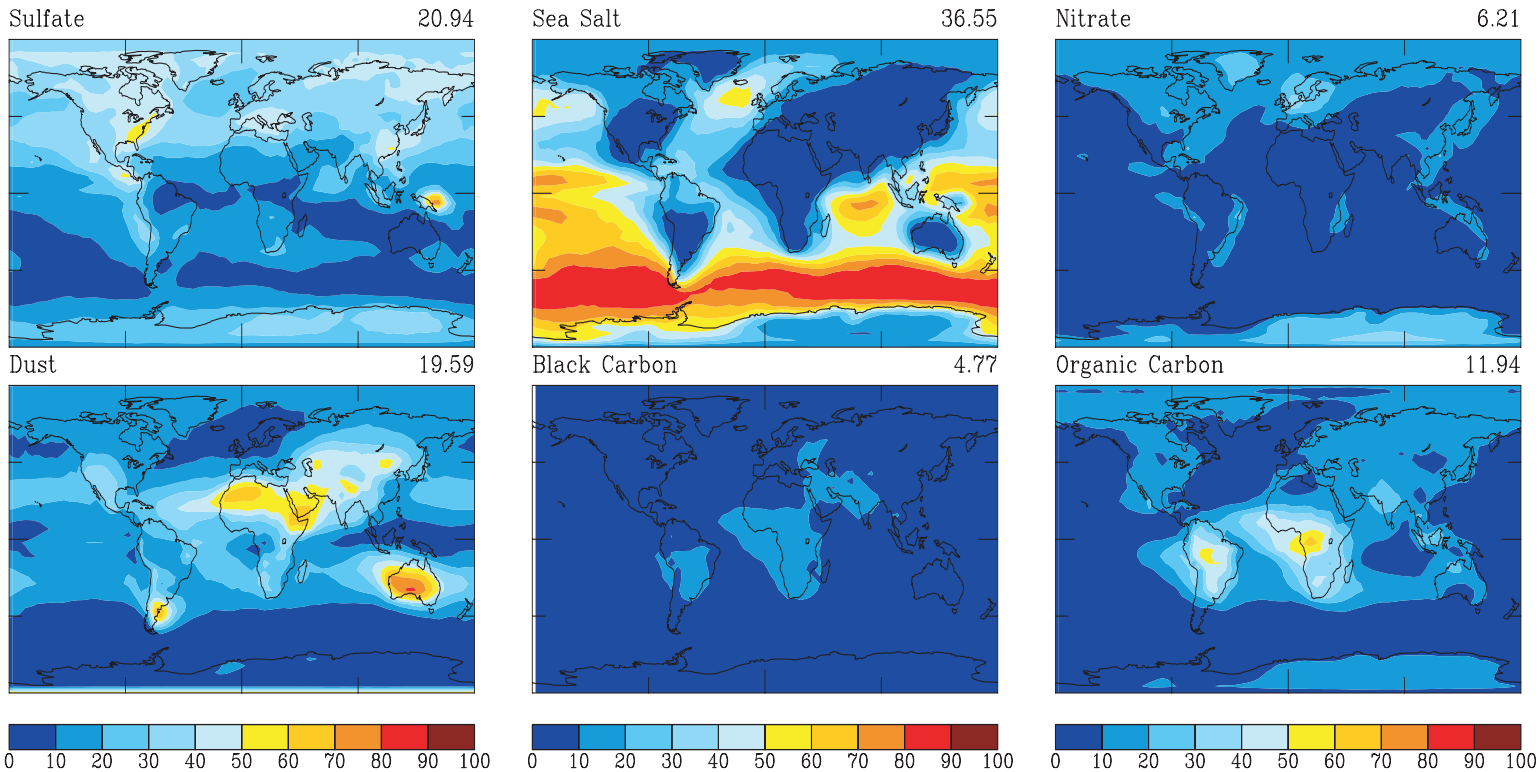
– Residuals are the difference between the other bands and the 2250 nm polarized reflectance.
– Planned aerosol retrieval will use 2250 nm polarized reflectance as a proxy for the surface polarized reflectance.
– Important to know how grey the surface polarized reflectance is and what viewing geometries should be excluded (e.g. backscatter).

Research Scanning Polarimeter in ALIVE

– ALIVE provides increased angular range of measurements and better atmospheric correction
  - Raman Lidar to determine burden between ground and plane, AATS to determine burden above and spatial gradients, CIMEL/MFR for size distribution/refractive index estimate.
  - Preliminary atmospherically corrected a) vegetation and b) soil polarized reflectance. AATS not incorporated and CIMEL is our analysis of sun/sky radiance Level 1 measurements.
  - Results may get better, or worse with more accurate (AATS) correction, but it is certainly the case that the surface polarized reflectance color is very weak.

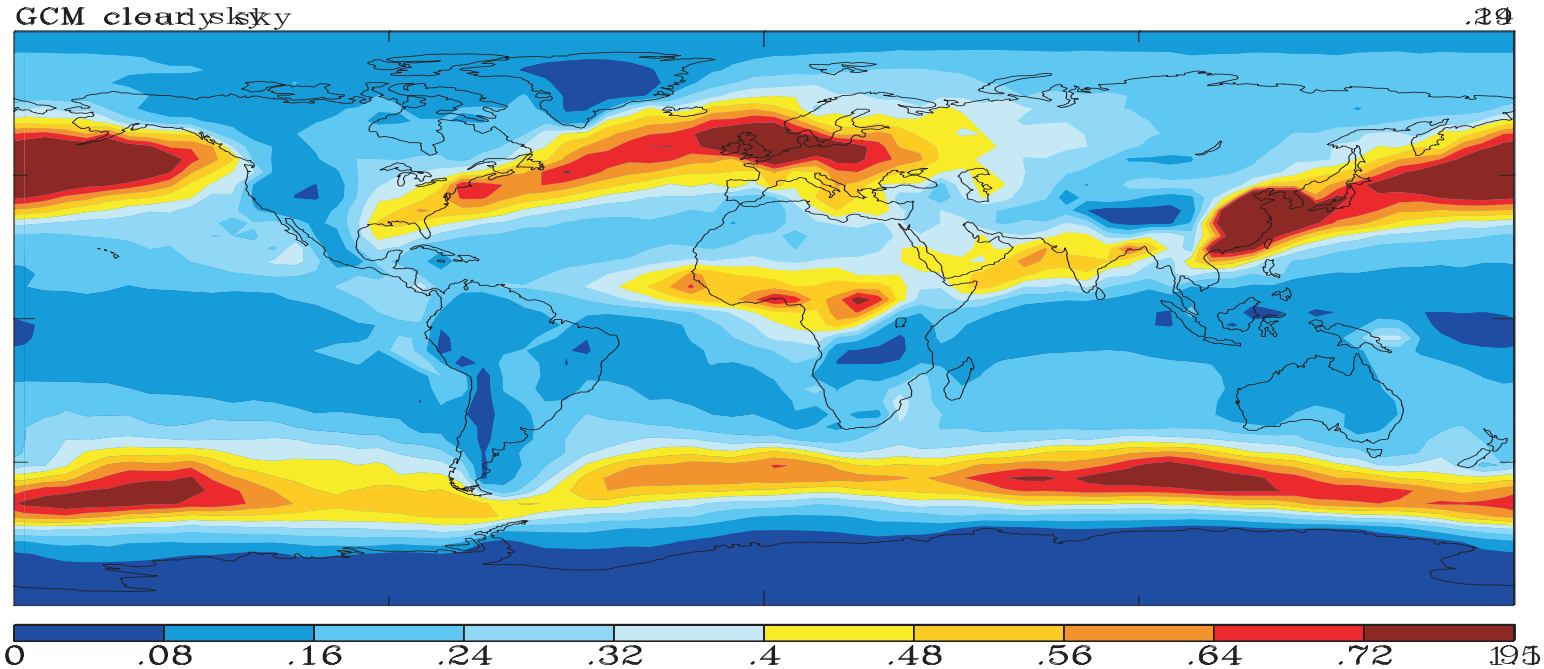


Principal GCM Aerosol Species



Global annual-mean distribution Sulfate, Sea Salt, Nitrate, Dust, Black Carbon, and Organic Carbon aerosols in the GISS ModelE aerosol climatology. Upper right hand numbers give global-mean per cent of each aerosol.

Each aerosol species incorporates a seasonally variable spatial and height distribution. Hygroscopic species (sulfate, nitrate, sea salt, and organic carbon) incorporate dependence of particle size and radiative parameters on the local relative humidity in accord with Tang and Munkelwitz [1991, 1994, 1996] laboratory measurements. There is a separate volcanic aerosol climatology (optical depth, size, and zonal mean height distribution of sulfuric acid aerosol) based on historical and satellite observational data [Sato et al., 1993].


GCM clearsky
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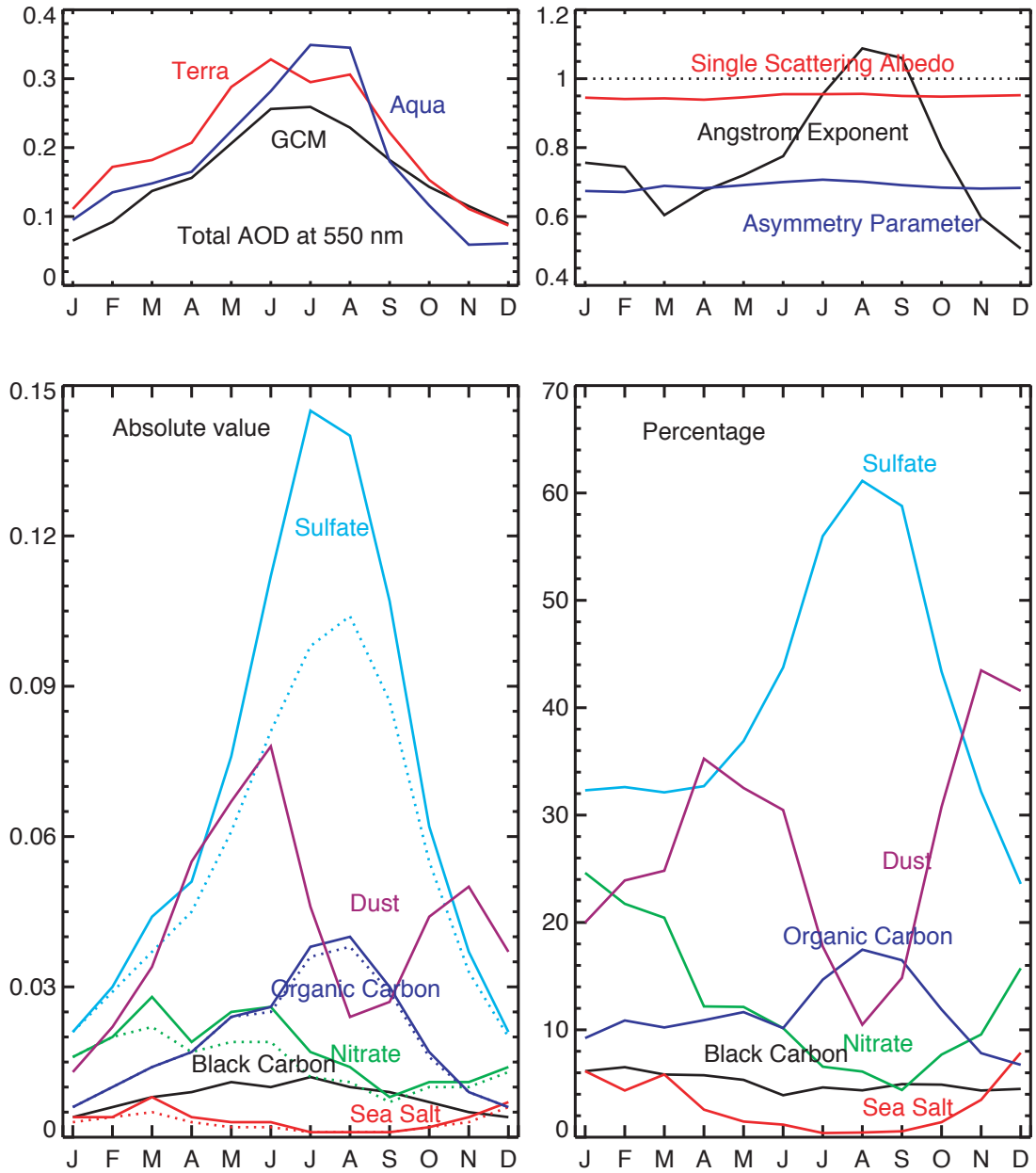
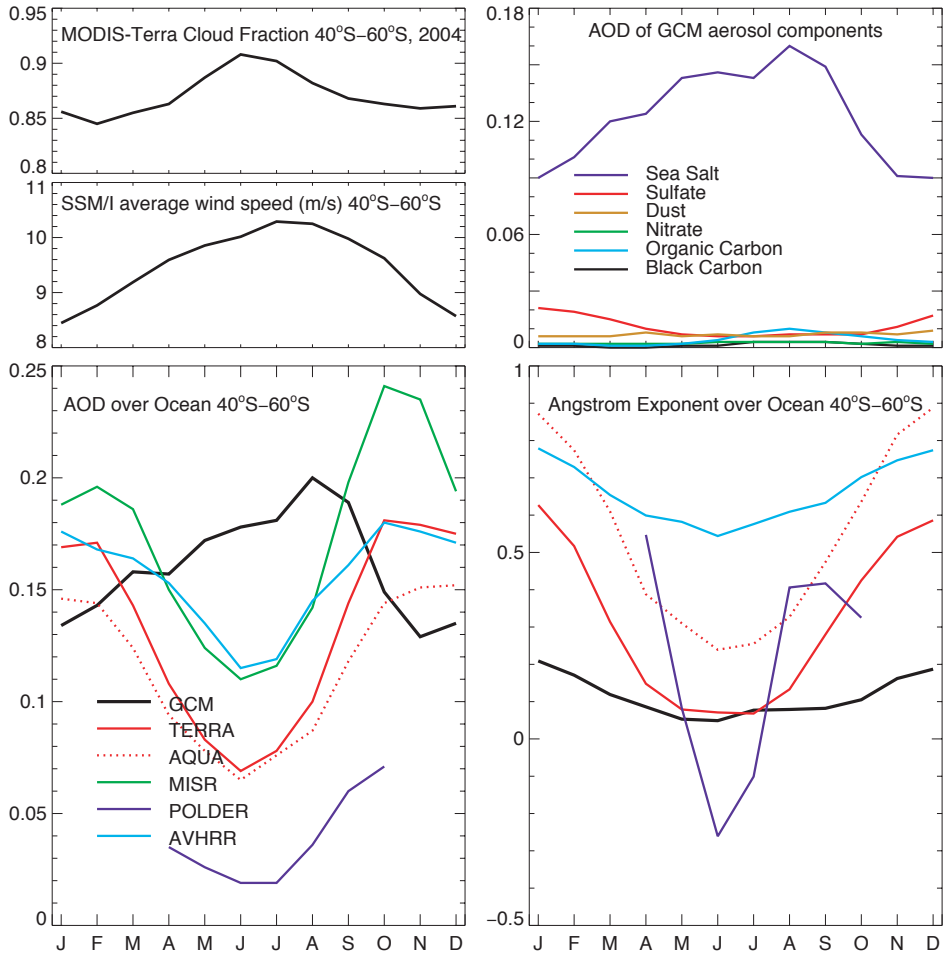


GISS GCM aerosol climatology at SGP site



Seasonal phase mismatch of aerosol optical depth variability between GCM (sea salt) and satellite observations - suggests retrieval problem.

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