# Processing of the NGEE-Barrow Eddy Covariance Data:

This document is intended as a top to bottom description of what happens to data, collected by the UNL-LBNL eddy covariance flux system deployed at the Barrow, AK Barrow Ecological Observatory (BEO) as part of the Next Generation Ecosystem Experiment (NGEE-Arctic) (2012 – 20??). During this experiment, raw eddy covariance data are collected by a program called HuskerFlux, version 3.02 (or later). This program runs on a small, single-board computer (SBC), under wither the Microsoft Windows XP (SP2) operating system. The data are logged into day-long files that begin and end at midnight. The computer clocks are set to UTC. There are 4 files associated with each day. They all have the same file name: NGEE-barrow-ddd where ddd is the day-of-year. The 4 file name extensions are .eyy, .iyy, .oyy, or .ryy where yy are the last two digits of the year. The .eyy file contains information about certain errors that occur during operation, the .iyy file contains non-error information, the .oyy file contains human-readable output of averages, fluxes, covariances, etc. and the.ryy file contains the raw, high-frequency data. This is the most important of the four files. The data are uploaded to a server in Lincoln, NE every night where they are archived, processed (daily to weekly), and sent to various data archives (NGEE, AmeriFlux, etc) (for details of the data flow and processing, see the document "Processing-details-NGEE"). Output file names follow the following convention (except the a0 level): the name is structured as: NGEE-site-level-year.dat where "site" refers to the particular flux tower such as "barrow" or "council", "level" refers to the processing level such as "a1" or "b1", and "year" is the year of the data. The a1 level files contain one row of data for each averaging period that raw data was available. The b1 and c1 level products contain rows for every averaging period in the year. If no data were collected, -9999 is entered in the data spaces and the appropriate QC flag is set. Examples of file names are:
NGEE-barrow-b1-2012.dat and NGEE-barrow-c1-2013.dat

## I.) Raw Data (a0 level) and Initial Processing With HuskerProc (a1 level)

Raw data are stored in binary files (named as above) as 4-byte (single precision) real numbers, and represent the 10 Hz outputs of the Gill R3-50 sonic anemometer, the LiCor LI-7500A open-path IRGA ($CO_2$ and $H_2O$), and the LiCor LI-7700 $CH_4$ open-pathTDLS. The high frequency data (a0 level) are post-processed by a system called HuskerProc which we describe here. One of the parameters input to HuskerProc through its setup file is the averaging period length. 30 minutes will be used throughout this project. When HuskerFlux is started (and at every subsequent midnight), a full-day data file (for the next day) is generated and filled with zeros. As raw data (from the instruments) comes in, the zeros are over-written in the appropriate locations. Each location (or "line" of data) represents a clock tick of 0.1 seconds. Because of this structure, if the program is started at a time other than midnight or is started and stopped, there may be gaps in the data. The first task that HuskerProc performs is to examine the data file and mark the individual averaging periods (as determined by the setup file) as either complete or incomplete. An incomplete period is defined as one in which 2% or more of the data are missing. HuskerProc then performs a "circular covariance" calculation and determines an optimum delay time (between the vertical wind speed and the covariance "partner") for each covariance (or flux) requested in the set up file and shifts the data appropriately, correcting for time lags between instruments. This can be overridden with an appropriate switch in the set up file to use a specified delay. Next, any voltages or other quantities read from the raw data file are converted to appropriate units according to one of several algorithms selected in the set up file. After this, HuskerProc does a quality check of the data. A moving window (of length specified in the set up file) is passed over the data, and spikes or out-of-range values (as determined by parameters in the set up file) are replaced with the mean value from the current window. The three orthogonal wind speeds are then rotated into a coordinate system where the vertical and cross wind mean velocities are zero.

The heart of HuskerProc is the statistical analysis of the time series collected by HuskerFlux. Because this usually involves the summations of large numbers of data points, several steps have been taken to assure the best precision and to minimize round-off errors. First, all statistical calculations are performed in "double precision" arithmetic… that is, as 8-byte real numbers. Second, variances are computed using the "corrected two-pass algorithm" as described in Numerical Recipes in Fortran (NRF). Statistical descriptors (skewness and kurtosis) are also calculated as described in NRF. Covariances are calculated in this step. To provide an estimate of the flux uncertainty, the variance of covariances are calculated (*Billesbach 2011*, *Finkelstein and Sims 2001*). Another estimate (Random Shuffle) is also calculated (*Billesbach 2011*).

From these covariances, fluxes are calculated using standard definitions. HuskerProc will also read an (optional) meteorology file that, if present, is used to adjust several "constants" such as the latent heat of vaporization, specific heat of air, air density, etc. This information is also used to calculate several ancillary quantities such as saturation vapor pressure, vapor pressure deficit, etc. This information is culled from the slow response data file. If this file is not present, HuskerProc uses a set of standard default values (P=96.0 kPa, T=20.0 C, RH=40%). During this step, certain, routine corrections are applied to appropriate fluxes such as humidity corrections to sensible heat. Note that the Gill R3-50 applies the cross-wind temperature correction internally.

A set of corrections and other quantities are also calculated. These include the full set of Webb-Pearman-Leuning terms (*Webb et al, 1980*), frequency corrections (*Moore, 1986*) (which are only applied in the cumulative b1 and c1 files), spectroscopic corrections (A, B, C for the LI-7700 *LiCor, 2011*), friction velocity (u*), the Monin-Obuknov stability parameter (z/L), and the roughness length (zo).

All of these are output into a human-readable file, and to a comma separated text file (csv) as determined by an output setup file (a1 level). The following table describes the columns in the a1 file:

| Col. | Variable | Col. | Variable |
|---|---|---|---|
| 1 | Time of Year (days) (UTC) | 88 | Mean $T_{LI\text{-}7700}$ rot (ºC) |
| 2 | Day of Year (days) (UTC) | 89 | Var $T_{LI\text{-}7700}$ rot (ºC$^2$) |
| 3 | Time stamp (CSI format) (UTC) | 90 | Skew $T_{LI\text{-}7700}$ rot |

| | | | |
|---|---|---|---|
| 4 | Wind dir (º) | 91 | Kurt $T_{LI-7700}$ rot |
| 5 | Theta rot. (º) | 92 | # bad $T_{LI-7700}$ |
| 6 | Phi rot. (º) | 93 | Mean $T_{LI-7700}$ bad (ºC) |
| 7 | Mean u rot (m $s^{-1}$) | 94 | Mean $T_{LI-7700}$ unrot (º$C^2$) |
| 8 | Var u rot ($m^2$ $s^{-2}$) | 95 | Mean $P_{LI-7700}$ rot (kPa) |
| 9 | Skew u rot | 96 | Var $P_{LI-7700}$ rot ($kPa^2$) |
| 10 | Kurt u rot | 97 | Skew $P_{LI-7700}$ rot |
| 11 | # bad u | 98 | Kurt $P_{LI-7700}$ rot |
| 12 | Mean u bad (m $s^{-1}$) | 99 | # bad $P_{LI-7700}$ |
| 13 | Mean u unrot (m $s^{-1}$) | 100 | Mean $P_{LI-7700}$ bad (kPa) |
| 14 | Mean v rot (m $s^{-1}$) | 101 | Mean $P_{LI-7700}$ unrot ($kPa^2$) |
| 15 | Var v rot ($m^2$ $s^{-2}$) | 102 | Mean $Status_{LI-7700}$ rot |
| 16 | Skew v rot | 103 | Var $Status_{LI-7700}$ rot |
| 17 | Kurt v rot | 104 | Skew $Status_{LI-7700}$ rot |
| 18 | # bad v | 105 | Kurt $Status_{LI-7700}$ rot |
| 19 | Mean v bad (m $s^{-1}$) | 106 | # bad $Status_{LI-7700}$ |
| 20 | Mean v unrot (m $s^{-1}$) | 107 | Mean $Status_{LI-7700}$ bad |
| 21 | Mean w rot (m $s^{-1}$) | 108 | Mean $Status_{LI-7700}$ unrot |
| 22 | Var w rot ($m^2$ $s^{-2}$) | 109 | Separator (always -9999) |
| 23 | Skew w rot | 110 | uw flux rot () |
| 24 | Kurt w rot | 111 | uw flux rot (uncert.) () |
| 25 | # bad w | 112 | uw covar rot ($m^2$ $s^{-2}$) |
| 26 | Mean w bad (m $s^{-1}$) | 113 | uw covar rot (uncert.) ($m^2$ $s^{-2}$) |
| 27 | Mean w unrot (m $s^{-1}$) | 114 | uw covar unrot ($m^2$ $s^{-2}$) |
| 28 | Mean $T_{sonic}$ rot (ºC) | 115 | uv flux rot () |
| 29 | Var $T_{sonic}$ rot (º$C^2$) | 116 | uv flux rot (uncert.) () |
| 30 | Skew $T_{sonic}$ rot | 117 | uv covar rot ($m^2$ $s^{-2}$) |
| 31 | Kurt $T_{sonic}$ rot | 118 | uv covar rot (uncert.) ($m^2$ $s^{-2}$) |
| 32 | # bad $T_{sonic}$ | 119 | uv covar unrot ($m^2$ $s^{-2}$) |
| 33 | Mean $T_{sonic}$ bad (ºC) | 120 | vw flux rot () |
| 34 | Mean $T_{sonic}$ unrot (º$C^2$) | 121 | vw flux rot (uncert.) () |
| 35 | Mean $CO_2$ density rot (mg $m^{-3}$) | 122 | vw covar rot ($m^2$ $s^{-2}$) |
| 36 | Var $CO_2$ density rot ($mg^2$ $m^{-6}$) | 123 | vw covar rot (uncert.) ($m^2$ $s^{-2}$) |
| 37 | Skew $CO_2$ density rot | 124 | vw covar unrot ($m^2$ $s^{-2}$) |
| 38 | Kurt $CO_2$ density rot | 125 | H flux rot (W $m^{-2}$) |
| 39 | # bad $CO_2$ density | 126 | H flux rot (uncert.) (W $m^{-2}$) |
| 40 | Mean $CO_2$ density bad (mg $m^{-3}$) | 127 | $wT_{sonic}$ covar rot (ºC m $s^{-1}$) |
| 41 | Mean $CO_2$ density unrot (mg $m^{-3}$) | 128 | $wT_{sonic}$ covar rot (uncert.) (ºC m $s^{-1}$) |
| 42 | $CO_2$ density delay (sec) | 129 | $wT_{sonic}$ covar unrot (ºC m $s^{-1}$) |
| 43 | Mean $H_2O$ density rot (g $m^{-3}$) | 130 | LE flux rot (W $m^{-2}$) |
| 44 | Var $H_2O$ density rot ($g^2$ $m^{-6}$) | 131 | LE flux rot (uncert.) (W $m^{-2}$) |
| 45 | Skew $H_2O$ density rot | 132 | $wH_2O$ dens covar rot (g $m^{-2}$ $s^{-1}$) |
| 46 | Kurt $H_2O$ density rot | 133 | $wH_2O$ dens covar rot (uncert.) (g $m^{-2}$ $s^{-1}$) |
| 47 | # bad $H_2O$ density | 134 | $wH_2O$ dens covar unrot (g $m^{-2}$ $s^{-1}$) |
| 48 | Mean $H_2O$ density bad (g $m^{-3}$) | 135 | NEE flux rot (µmol $m^{-2}$ $s^{-1}$) |
| 49 | Mean $H_2O$ density unrot (g $m^{-3}$) | 136 | NEE flux rot (uncert.) (µmol $m^{-2}$ $s^{-1}$) |
| 50 | $H_2O$ delay density (sec) | 137 | $wCO_2$ dens covar rot (mg $m^{-2}$ $s^{-1}$) |
| 51 | Mean $T_{LI-7500}$ rot (ºC) | 138 | $wCO_2$ dens covar rot (uncert.) (mg $m^{-2}$ $s^{-1}$) |
| 52 | Var $T_{LI-7500}$ rot (º$C^2$) | 139 | $wCO_2$ dens covar unrot (mg $m^{-2}$ $s^{-1}$) |
| 53 | Skew $T_{LI-7500}$ rot | 140 | $CH_4$ flux rot (nmol $m^{-2}$ $s^{-1}$) |
| 54 | Kurt $T_{LI-7500}$ rot | 141 | $CH_4$ flux rot (uncert.) (nmol $m^{-2}$ $s^{-1}$) |
| 55 | # bad $T_{LI-7500}$ | 142 | $wCH_4$ dens covar rot (mg $m^{-2}$ $s^{-1}$) |
| 56 | Mean $T_{LI-7500}$ bad (ºC) | 143 | $wCH_4$ dens covar rot (uncert.) (mg $m^{-2}$ $s^{-1}$) |

| | | | |
|---|---|---|---|
| 57 | Mean $T_{LI-7500}$ unrot (ºC$^2$) | 144 | w$CH_4$ dens covar unrot (mg $m^{-2}$ $s^{-1}$) |
| 58 | Mean $P_{LI-7500}$ rot (kPa) | 145 | w$CH_4$ mixing ratio flux rot (ppmv $m^{-2}$ $s^{-1}$) |
| 59 | Var $P_{LI-7500}$ rot (kPa$^2$) | 146 | w$CH_4$ mixing ratio flux rot (uncert.) (ppmv $m^{-2}$ $s^{-1}$) |
| 60 | Skew $P_{LI-7500}$ rot | 147 | w$CH_4$ mixing ratio covar rot (ppmv $m^{-2}$ $s^{-1}$) |
| 61 | Kurt $P_{LI-7500}$ rot | 148 | w$CH_4$ mixing ratio covar rot (uncert.) (ppmv $m^{-2}$ $s^{-1}$) |
| 62 | # bad $P_{LI-7500}$ | 149 | w$CH_4$ mixing ratio covar unrot (ppmv $m^{-2}$ $s^{-1}$) |
| 63 | Mean $P_{LI-7500}$ bad (kPa) | 150 | Friction velocity (u*) (m $s^{-1}$) |
| 64 | Mean $P_{LI-7500}$ unrot (kPa$^2$) | 151 | Friction velocity (u*) (uncert.) (m $s^{-1}$) |
| 65 | Mean $Status_{LI-7500}$ rot | 152 | z/L |
| 66 | Var $Status_{LI-7500}$ rot | 153 | Displacement height (zo) (m) |
| 67 | Skew $Status_{LI-7500}$ rot | 154 | Sonic T correction |
| 68 | Kurt $Status_{LI-7500}$ rot | 155 | VPD (kPa) |
| 69 | # bad $Status_{LI-7500}$ | 156 | WPL (H) (NEE) (µmol $m^{-2}$ $s^{-1}$) |
| 70 | Mean $Status_{LI-7500}$ bad | 157 | WPL (H) (NEE) (uncert.) (µmol $m^{-2}$ $s^{-1}$) |
| 71 | Mean $Status_{LI-7500}$ unrot | 158 | WPL (LE) (NEE) (µmol $m^{-2}$ $s^{-1}$) |
| 72 | Mean $CH_4$ mixing ratio rot (ppbv) | 159 | WPL (LE) (NEE) (uncert.) (µmol $m^{-2}$ $s^{-1}$) |
| 73 | Var $CH_4$ mixing ratio rot (ppbv$^2$) | 160 | WPL (H) ($CH_4$ flux) (nmol $m^{-2}$ $s^{-1}$) |
| 74 | Skew $CH_4$ mixing ratio rot | 161 | WPL (H) ($CH_4$ flux) (uncert.) (nmol $m^{-2}$ $s^{-1}$) |
| 75 | Kurt $CH_4$ mixing ratio rot | 162 | WPL (LE) ($CH_4$ flux) (nmol $m^{-2}$ $s^{-1}$) |
| 76 | # bad $CH_4$ mixing ratio | 163 | WPL (LE) ($CH_4$ flux) (uncert.) (nmol $m^{-2}$ $s^{-1}$) |
| 77 | Mean $CH_4$ mixing ratio bad (ppbv) | 164 | Frequency correction ($CO_2$/LE) |
| 78 | Mean $CH_4$ mixing ratio unrot (ppbv) | 165 | Frequency correction (H) |
| 79 | $CH_4$ mixing ratio delay (sec) | 166 | Frequency correction ($CH_4$) |
| 80 | Mean $CH_4$ density rot (mg $m^{-3}$) | 167 | Frequency correction (u*) |
| 81 | Var $CH_4$ density rot (mg$^2$ $m^{-6}$) | 168 | Spectroscopic coefficient A (LI-7700) |
| 82 | Skew $CH_4$ density rot | 169 | Spectroscopic coefficient B (LI-7700) |
| 83 | Kurt $CH_4$ density rot | 170 | Spectroscopic coefficient C (LI-7700) |
| 84 | # bad $CH_4$ density | 171 | Random shuffle uncert. (w$H_2O$ density) (g $m^{-2}$ $s^{-1}$) |
| 85 | Mean $CH_4$ density bad (mg $m^{-3}$) | 172 | Random shuffle uncert. (w$T_{sonic}$ density) (ºC $m^{-2}$ $s^{-1}$) |
| 86 | Mean $CH_4$ density unrot (mg $m^{-3}$) | 173 | Random shuffle uncert. (NEE) (µmol $m^{-2}$ $s^{-1}$) |
| 87 | $CH_4$ density delay (sec) | 174 | Random shuffle uncert. ($CH_4$ flux) (nmol $m^{-2}$ $s^{-1}$) |

These data (a0 and a1 levels) are only available from the flux tower technical lead (Billesbach). This is due to the fact that there are many caveats involved in their interpretation and use.

**II). Quality Control and Meshing With Slow Response Data. (b1 level)**

In the next processing step, the eddy covariance a1 data are combined with data from the slow response system, and a set of quality control parameters are generated. This process results in the b1 product which is the most highly processed product sent to the NGEE archive. The b1 files produced in this step contain lines for every data period in the year.

The QC flag bits are defined as follows:

0 ➔ no issues
1 ➔ missing data
2 ➔ value below minimum or above maximum
4 ➔ dependency failure
8 ➔ large variance

16 ➔ u*<0.10 m $s^{-1}$ or u<1.5 m $s^{-1}$
32 ➔ other problem

QA/QC values (where appropriate) for means, variances, and uncertainties are determined by the maximum and minimum allowed values for that quantity. For quantities (such as fluxes or corrected sonic temperature) that depend on other variables, these dependencies are also checked for validity. Fluxes are also flagged if the variances of their components are excessive. Finally fluxes are flagged if there is insufficient turbulence or wind speed. The "other" category is used with fluxes that are derived from the LI-7700 and LI-7500A. This flag is set when the status words from these instruments indicate a problem.

As with the a1 level files, the b1 level files are in CSV format. The table below defines the variable names for the columns of the b1 files as the max and min values.

| Col. | Variable | Min value | Max value |
|---|---|---|---|
| 1 | Index | N/A | N/A |
| 2 | Time Stamp (yyyydddhhmm) (start time, UTC) | N/A | N/A |
| 3 | Day Of Year (days) (UTC) | N/A | N/A |
| 4 | Time Of Year (days) (UTC) | N/A | N/A |
| 5 | Day/Night (0=day, 1=night) | N/A | N/A |
| 6 | Latitude (degrees North) | N/A | N/A |
| 7 | Longitude (degrees West) | N/A | N/A |
| 8 | Elevation (meters above sea level) | N/A | N/A |
| 9 | Height of flux instruments (meters above ground) | N/A | N/A |
| 10 | Height of radiation instruments (meters above ground) | N/A | N/A |
| 11 | Height of T/RH sensor (meters above ground) | N/A | N/A |
| 12 | Height of soil heat flux sensors (meters above ground) | N/A | N/A |
| 13 | Horiz. wind speed mean u (m $s^{-1}$) | -50 | 50 |
| 14 | Horiz. wind speed variance u ($m^2$ $s^{-2}$) | 0 | 100 |
| 15 | Horiz. wind speed u QC value | N/A | N/A |
| 16 | Cross wind speed mean v (m $s^{-1}$) | 0 | 0.001 |
| 17 | Cross wind speed variance v ($m^2$ $s^{-2}$) | 0 | 100 |
| 18 | Cross wind speed v QC value | N/A | N/A |
| 19 | Vert. wind speed mean w (m $s^{-1}$) | 0 | 0.001 |
| 20 | Vert. wind speed variance w ($m^2$ $s^{-2}$) | 0 | 20 |
| 21 | Vert. wind speed w QC value | N/A | N/A |
| 22 | Wind direction mean (º) | 0 | 360 |
| 23 | Wind direction variance (º) | N/A | N/A |
| 24 | Wind direction QC | N/A | N/A |
| 25 | Phi rotation mean (º) | -20 | 20 |
| 26 | Phi rotation variance (º) | N/A | N/A |
| 27 | Phi rotation QC | N/A | N/A |
| 28 | T sonic mean (ºC) | -50 | 40 |
| 29 | T sonic variance (º$C^2$) | 0 | 100 |
| 30 | T sonic QC value | N/A | N/A |
| 31 | $CO_2$ density mean (μmol $m^{-3}$) | 500 | 1100 |
| 32 | $CO_2$ density variance (μ$mol^2$ $m^{-6}$) | 0 | 100 |
| 33 | $CO_2$ density QC value | N/A | N/A |

| | | | |
|---|---|---|---|
| 34 | $H_2O$ density mean (mol $m^{-3}$) | 0 | 10 |
| 35 | $H_2O$ density variance ($mol^2$ $m^{-6}$) | 0 | 0.1 |
| 36 | $H_2O$ density QC value | N/A | N/A |
| 37 | $CH_4$ density mean (nmol $m^{-3}$) | 75 | 110 |
| 38 | $CH_4$ density variance ($nmol^2$ $m^{-6}$) | 0 | 20 |
| 39 | $CH_4$ density QC value | N/A | N/A |
| 40 | $CH_4$ mixing ratio mean (nmol $mol^{-1}$) | 1800 | 2500 |
| 41 | $CH_4$ mixing ratio variance ($nmol^2$ $mol^{-2}$) | 0 | 2500 |
| 42 | $CH_4$ mixing ratio QC value | N/A | N/A |
| 43 | NEE (µmol $m^{-2}$ $s^{-1}$) | -15 | 15 |
| 44 | NEE uncertainty (µmol $m^{-2}$ $s^{-1}$) | 0 | 4 |
| 45 | NEE QC value | N/A | N/A |
| 46 | Flux $CH_4$ (nmol $m^{-2}$ $s^{-1}$) | -200 | 500 |
| 47 | Flux $CH_4$ uncertainty (nmol $m^{-2}$ $s^{-1}$) | 0 | 15 |
| 48 | Flux $CH_4$ QC value | N/A | N/A |
| 49 | Flux $H_2O$ (mmol $m^{-2}$ $s^{-1}$) | -1.1 | 6.75 |
| 50 | Flux $H_2O$ uncertainty (mmol $m^{-2}$ $s^{-1}$) | 0 | 0.67 |
| 51 | Flux $H_2O$ QC value | N/A | N/A |
| 52 | ET (mm $30min^{-1}$) | -0.036 | 0.225 |
| 53 | ET uncertainty (mm $30min^{-1}$) | 0 | 0.022 |
| 54 | ET QC value | N/A | N/A |
| 55 | H (W $m^{-2}$) | -50 | 300 |
| 56 | H uncertainty (W $m^{-2}$) | 0 | 50 |
| 57 | H QC value | N/A | N/A |
| 58 | LE (W $m^{-2}$) | -50 | 300 |
| 59 | LE uncertainty (W $m^{-2}$) | 0 | 30 |
| 60 | LE QC value | N/A | N/A |
| 61 | u* (friction velocity) (m $s^{-1}$) | 0 | 10 |
| 62 | u* uncertainty (m $s^{-1}$) | N/A | N/A |
| 63 | u* QC value | N/A | N/A |
| 64 | Vapor pressure deficit (VPD) mean (kPa) | -2 | 10 |
| 65 | Vapor pressure deficit (VPD) variance ($kPa^2$) | N/A | N/A |
| 66 | Vapor pressure deficit (VPD) QC value | N/A | N/A |
| 67 | Monin-Obukhov stability (z/L) mean | -0.2 | 0.2 |
| 68 | Monin-Obukhov stability (z/L) variance | N/A | N/A |
| 69 | Monin-Obukhov stability (z/L) QC value | N/A | N/A |
| 70 | Roughness length (zo) mean (m) | 0 | 0.15 |
| 71 | Roughness length (zo) variance ($m^2$) | N/A | N/A |
| 72 | Roughness length (zo) mean (m) | N/A | N/A |
| 73 | Rad. short downwelling mean (W $m^{-2}$) | 0 | 1000 |
| 74 | Rad. short downwelling variance ($W^2$ $m^{-4}$) | N/A | N/A |
| 75 | Rad. short downwelling QC value | N/A | N/A |
| 76 | Rad. long downwelling mean(W $m^{-2}$) | 100 | 600 |
| 77 | Rad. long downwelling variance ($W^2$ $m^{-4}$) | N/A | N/A |
| 78 | Rad. long downwelling QC value | N/A | N/A |
| 79 | Rad short upwelling mean (W $m^{-2}$) | 0 | 1000 |
| 80 | Rad short upwelling variance ($W^2$ $m^{-4}$) | N/A | N/A |
| 81 | Rad short upwelling QC value | N/A | N/A |
| 82 | Rad long upwelling mean (W $m^{-2}$) | 100 | 600 |
| 83 | Rad long upwelling variance ($W^2$ $m^{-4}$) | N/A | N/A |
| 84 | Rad long upwelling QC value | N/A | N/A |
| 85 | Rad PAR downwelling mean (µmol $m^{-2}$ $s^{-1}$) | 0 | 1500 |
| 86 | Rad PAR downwelling variance ($µmol^2$ $m^{-4}$ $s^{-2}$) | N/A | N/A |

| | | | |
|---|---|---|---|
| 87 | Rad PAR downwelling QC value | N/A | N/A |
| 88 | Rad PAR upwelling mean (µmol $m^{-2}$ $s^{-1}$) | 0 | 1500 |
| 89 | Rad PAR upwelling variance ($µmol^2$ $m^{-4}$ $s^{-2}$) | N/A | N/A |
| 90 | Rad PAR upwelling QC value | N/A | N/A |
| 91 | Rad net SW (W $m^{-2}$) mean | -100 | 1000 |
| 92 | Rad net SW (W $m^{-2}$) variance | N/A | N/A |
| 93 | Rad net SW QC value | N/A | N/A |
| 94 | Rad net LW (W $m^{-2}$) mean | -100 | 1000 |
| 95 | Rad net LW (W $m^{-2}$) variance | N/A | N/A |
| 96 | Rad net LW QC value | N/A | N/A |
| 97 | Rad net all (W $m^{-2}$) mean | -100 | 1000 |
| 98 | Rad net all (W $m^{-2}$) variance | N/A | N/A |
| 99 | Rad net all QC value | N/A | N/A |
| 100 | Rad net PAR (µmol $m^{-2}$ $s^{-1}$) mean | -100 | 1500 |
| 101 | Rad net PAR (µmol $m^{-2}$ $s^{-1}$) variance | N/A | N/A |
| 102 | Rad net PAR QC value | N/A | N/A |
| 103 | Rad albedo SW mean | 0 | 1 |
| 104 | Rad albedo SW variance | N/A | N/A |
| 105 | Rad albedo SW QC value | N/A | N/A |
| 106 | Rad albedo LW mean | 0 | 1 |
| 107 | Rad albedo LW variance | N/A | N/A |
| 108 | Rad albedo LW QC value | N/A | N/A |
| 109 | Rad albedo all mean | 0 | 1 |
| 110 | Rad albedo all variance | N/A | N/A |
| 111 | Rad albedo all QC value | N/A | N/A |
| 112 | Rad albedo PAR mean | 0 | 1 |
| 113 | Rad albedo PAR variance | N/A | N/A |
| 114 | Rad albedo PAR QC value | N/A | N/A |
| 115 | T air mean (ºC) | -50 | 30 |
| 116 | T air variance ($ºC^2$) | N/A | N/A |
| 117 | T air QC value | N/A | N/A |
| 118 | RH mean (%) | 0 | 100 |
| 119 | RH variance ($\%^2$) | N/A | N/A |
| 120 | RH QC value | N/A | N/A |
| 121 | Air pressure mean (kPa) | 80 | 110 |
| 122 | Air pressure variance ($kPa^2$) | N/A | N/A |
| 123 | Air pressure QC value | N/A | N/A |
| 124 | T surface mean (ºC) | -50 | 30 |
| 125 | T surface variance ($ºC^2$) | N/A | N/A |
| 126 | T surface QC value | N/A | N/A |
| 127 | Mean soil heat flux mean G (W $m^{-2}$) | -100 | 100 |
| 128 | Mean soil heat flux variance G ($W^2$ $m^{-4}$) | N/A | N/A |
| 129 | Mean soil heat flux QC value | N/A | N/A |
| 130 | W'T' RS uncertainty | N/A | N/A |
| 131 | W'T' RS uncertainty | N/A | N/A |
| 132 | W'T' RS uncertainty QC value | N/A | N/A |
| 133 | W'Q' RS uncertainty | N/A | N/A |
| 134 | W'Q' RS uncertainty | N/A | N/A |
| 135 | W'Q' RS uncertainty QC value | N/A | N/A |
| 136 | NEE RS uncertainty | N/A | N/A |
| 137 | NEE RS uncertainty | N/A | N/A |
| 138 | NEE RS uncertainty QC value | N/A | N/A |
| 139 | Flux CH4 RS uncertainty | N/A | N/A |

| | | | |
|---|---|---|---|
| 140 | Flux CH4 RS uncertainty | N/A | N/A |
| 141 | Flux CH4 RS uncertainty QC value | N/A | N/A |

We should note here that while we have calculated albedos from the various downwelling and upwelling radiation sensor pairs, these may not be accurate estimates of the actual albedos. This warning is in response to manufacturer's notes (for some of the sensors) that state they may not provide results (within specs) when looking at the ground. One reason for this is that down facing sensors (for upwelling radiation) may inadvertently see parts of the sky.

Notes:

1 The time stamp is a string of numbers that have the form: yyyydddhhmm and marks the beginning of the averaging interval. DOY is the Day Of Year for the beginning of the interval. All times are in UTC.
2 For fluxes, uncertainty values have been calculated and may be interpreted as confidence intervals for the reported flux value. For other quantities (where possible), statistical variances are reported.
3 Latent heat flux and ET are both calculated from the fundamental measurement of water vapor flux. Only the latent heat of vaporization for water (corrected for ambient temperature) is used in this (basically unit conversion) calculation. In Arctic ecosystems this can potentially result in errors when sublimation or frost formation occurs. The latent heat of vaporization (2 $\rightarrow$ 3 transformation) is approximately 2500 J $g^{-1}$ while the latent heat of sublimation (1 $\rightarrow$ 3 transformation) is approximately 50,900 J $g^{-1}$. At this time we don't know of a good method to estimate this error.

## III). Gap Filling. (c1 level)

For users who do not wish to do their own gap filling, we provide a gap filled product (c1 level). Because there are many approaches to gap filling, we recognize that many users may want to do this step themselves. We hope that the b1 level product will provide all of the information needed for this, and we encourage this group to contact us regarding their approach and implementation.
Our simple approach is statistically based and uses linear interpolation for short gaps (4 or fewer consecutive points). For larger gaps, the average of that particular time for the previous and following 7 days is used. When a value is gap filled, its QC value is multiplied by -1 to note the fact. The column definitions for the c1 product are the same as those of the b1 product.

## IV.) References:

Billesbach, DP (2011) Estimating Uncertainties in Individual Eddy Covariance Flux Measurements: a Comparison of Methods and a Proposed New Method. *Agric. For. Meterol.* **151**, 394 – 405

Finkelstein PL, and Sims PF (2001) Sampling Error in Eddy Correlation Flux Measurements. *J. Geophys. Res.* **D4 106**, 3503 – 3509

LiCor (2011) LI-7700 Open Path $CH_4$ Analyzer Instruction Manual. LiCor Biosciences, Lincoln, NE

Moore CJ (1986) Frequency Response Corrections for Eddy Covariance Systems. *Boundary-Layer Meteorol.* **37**, 17 – 35

Webb EK, Pearman GI, Leuning R (1980) Correction of Flux Measurements For Density Effects Due To Heat and Water Vapour Transfer. *Q J R Meteorol Soc* **106**, 85 – 100