

JPL Project

# Arctic Energy Balance Dataset

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# 1. INTRODUCTION

This document provides an overview of the data sources and averaging methods used to construct Arctic energy balance dataset. A suite of satellite observations are utilized to construct a comprehensive dataset for the community to provide easier access to study multiple, and often complex, processes and interactions over the arctic region. With the dramatic decline in sea ice and snow extent in previous years it is essential to characterize the surface energy budget to gain a better understanding of how Arctic amplification of temperature may manifest in the future.

This dataset offers a multi-composite index of cloud properties (horizontal and vertical cloud fraction, cloud phase, precipitating, non-precipitating, ect) to study how these properties vary over a seasonal cycle or with other parameters such as sea ice extent, and meteorology, to name a few. In addition, this dataset can enable inter-comparison amongst various derived products from different satellite sensors as well as to be used to evaluate Arctic cloud processes and feedbacks in Global Circulation Models (GCMs). In addition, the integrated products can be evaluated with several provided ground-based facilities. The majority of the data products used to construct this integrated dataset have been developed and published in peer-review journals. We encourage users of this data to familiarize themselves with pertinent documentation provided by each data product contained here.

## 1.1. Data sources

Data is acquired from multiple satellite/sensors that include: MODIS (MODerate Resolution Imaging Spectroradiometer), CERES (Clouds and the Earth's Radiant Energy System), and AIRS (Atmospheric Infrared Sounder) on the Aqua satellite; Cloud Profiling Radar (CPR) on CloudSat, Lidar on CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations), Global Energy and Water Cycle Experiment-Surface Radiation Budget (GEWEX-SRB), and the twin satellites from the GRACE (Gravity Recovery and Climate Experiment) mission. Re-analysis data includes MERRA (Modern Era Retrospective-Analysis for Research and Applications), NCEP (National Centers for Environmental Prediction), ECMWF-Interim (European Centre for Medium-Range Weather Forecasting), MACC (Monitoring Atmospheric Composition and Climate), and ASR (Arctic System Reanalysis) is also provided. Finally, ground based observations from the Atmospheric Radiation Measurement (ARM) site on the North Slope of Alaska and 23 instruments scattered throughout the Greenland Climate Network (GCNET) is carefully screened and provided. Table 1 summarizes the datasets used here.

Table 1. Summary of products used to construct the Arctic Energy Budget Dataset.

| Dataset                   | Primary Variables | Product | Period | Native Resolution | Note | Acquisition |
|---------------------------|-------------------|---------|--------|-------------------|------|-------------|
| <i>Satellite Products</i> |                   |         |        |                   |      |             |

|              |                                   |                        |             |        |  |  |
|--------------|-----------------------------------|------------------------|-------------|--------|--|--|
| AIRS         | meteorology & cloud               | AIRX3STM               | 2002 – 2013 | 14 km  | high spectral resolution spectrometer              | <a href="http://disc.sci.gsfc.nasa.gov/AIRS/data-holdings">disc.sci.gsfc.nasa.gov/AIRS/data-holdings</a>                 |
| CERES        | radiation                         | EBAF V2.7              | 2002 – 2013 | 20 km  | broadband scanning radiometer                      | <a href="http://ceres.larc.nasa.gov">ceres.larc.nasa.gov</a>   |
| CloudSat     | cloud, radiation, & precipitation | geoprof, flxhr, ect    | 2006 – 2011 | 1.4 km | radar & lidar (CALIPSO)                            | <a href="http://cloudsat.cira.colostate">cloudsat.cira.colostate</a>   |
| CloudSat-ERB | radiation                         | FLXHR-LIDAR            | 2006 – 2011 | 1.4 km | radar & Lidar (CALIPSO)                            | contact Tristan L'Ecuyer   |
| MODIS        | cloud                             | MYD08_M3               | 2002 – 2013 | 1 km   | scanning spectroradiometer                         | ftp:<br><a href="http://ladsweb.nascom.nasa.gov">ladsweb.nascom.nasa.gov</a>   |
| GEWEX-SRB    | radiation                         | REL3.1 LW<br>REL3.0 SW | 1983-2008   | 1°     | ISCCP cloud and GMAO input to radiation algorithm. | <a href="https://eosweb.larc.nasa.gov/project/srb/srb_table">https://eosweb.larc.nasa.gov/project/srb/srb_table</a>      |
| GRACE        | water storage                     | CSR, JPL, GFZ          | 2003 – 2013 | 1°     | ranging polar orbiting twin-satellites             | <a href="http://grace.jpl.nasa.gov/data/gracemonthlymassgridsland">grace.jpl.nasa.gov/data/gracemonthlymassgridsland</a> |
| NSIDC        | snow & ice                        | EASE-Grid              | 2002 – 2013 | 25 km  | passive microwave: Nimbus-7, SMMR, and SSM/I       | <a href="http://nsidc.org">nsidc.org</a><br>ftp://n4ftl01u.ecs.nasa.gov/SAN/M OST  |
| CMAP         | precipitation                     | standard               | 1979-2011   | 2.5°   | GPI,OPI,SSM/I scattering, SSM/I emission and MSU   | <a href="http://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html">www.esrl.noaa.gov/psd/data/gridded/data.cmap.html</a> |
| GPCP         | precipitation                     | V2.2                   | 1979-2010   | 2.5°   | gauge + GPI,OPI,SSM/I, & MSU                       | <a href="http://www.esrl.noaa.gov/psd/data/gridded/data.gpcp.html">www.esrl.noaa.gov/psd/data/gridded/data.gpcp.html</a> |

#### *Reanalysis Products*

|       |            |                  |           |       |                     |   |
|-------|------------|------------------|-----------|-------|---------------------|---|
| ASR   | everything | Interim          | 2000-2010 | 30 km | WRF-VAR & PWRP      | <a href="https://climatedataguide.ucar.edu/climate-data/arctic-system-reanalysis-asr">https://climatedataguide.ucar.edu/climate-data/arctic-system-reanalysis-asr</a> |
| ECMWF | everything | Interim          | 2002-2013 | 0.75° | 2-times Daily Data  | <a href="http://apps.ecmwf.int/datasets/data/interim_full_mnth/">http://apps.ecmwf.int/datasets/data/interim_full_mnth/</a>   |
| MERRA | everything | IAU 2D           | 1980-2013 | 1.25° | Monthly Data        | <a href="http://disc.sci.gsfc.nasa.gov/daac-bin/FTPSubset.pl?LOOKUPID_List=MAI3CPASM">http://disc.sci.gsfc.nasa.gov/daac-bin/FTPSubset.pl?LOOKUPID_List=MAI3CPASM</a> |
| NCEP  | everything | DOE-Reanalysis 2 | 2000-2013 | 1.25° | Daily Averaged Data | <a href="http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis2.html">http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis2.html</a>               |

#### *Assimilated (Satellite + Reanalysis) Products*

|       |              |               |           |       |              |   |
|-------|--------------|---------------|-----------|-------|--------------|---|
| GLDAS | water budget | NOAH025_M.020 | 2002-2013 | 0.25° | Monthly Data | <a href="http://disc.sci.gsfc.nasa.gov/services/grads-gds/gldas">http://disc.sci.gsfc.nasa.gov/services/grads-gds/gldas</a> |
| MACC  | aerosol      | ECMWF         | 2006-2013 | 1.25° | 6x daily     | <a href="http://data-portal.ecmwf.int/data/d/macc_reanalysis/">http://data-portal.ecmwf.int/data/d/macc_reanalysis/</a>     |

#### *Ground Observations*

|     |                    |               |           |     |                              |  |
|-----|--------------------|---------------|-----------|-----|------------------------------|--|
| ARM | radiation & clouds | ARMBE<br>ARSL | 1998-2011 | N/A | North Slope Alaska at Barrow | <a href="http://www.archive.arm.gov/armlogin/login.jsp">www.archive.arm.gov/armlogin/login.jsp</a> |
|-----|--------------------|---------------|-----------|-----|------------------------------|--|

|                                    |                 |         |           |       |                          |   |
|------------------------------------|-----------------|---------|-----------|-------|--------------------------|---|
| GCNET                              | Radiation       |         | 1996-2013 | N/A   | 23 Gauges over Greenland | <a href="http://cires.colorado.edu/science/groups/steffen/gcnet/">cires.colorado.edu/science/groups/steffen/gcnet/</a>      |
| GPCC                               | precipitation   | Full V6 | 1901-2010 | 0.5°  | rain gauge network       | <a href="http://www.esrl.noaa.gov/psd/data/gridded/data.gpcc.html">www.esrl.noaa.gov/psd/data/gridded/data.gpcc.html</a>    |
| AMVER                              | ship inventory  | N/A     | 2006-2010 | 0.25° | daily data               | <a href="http://www.amver.com">www.amver.com</a> . Upon request.  |
| <i>Climate Variability Indices</i> |                 |         |           |       |                          |   |
| NOAA                               | Climate Indices | N/A     | 1885-2013 | N/A   | Monthly Data             | <a href="http://www.esrl.noaa.gov/psd/data/climateindices/list/">http://www.esrl.noaa.gov/psd/data/climateindices/list/</a> |

### 1.2. Averaging Scheme

The period we choose for most of the datasets spans the same duration of the MODIS sensor on satellite *Aqua* (2002 to present). This period is used because the *Aqua* satellite was launched first, prior to CloudSat and CALIPSO. Due to the temporal sampling, missing values are used to fill the arrays containing CloudSat and CALIPSO data (i.e., 2002 to June 2006, with gaps in 2011 and 2012). In total, 79 months of data spanning from 2006 to 2013 are used in this product.

Data is monthly averaged into  $2.5^\circ \times 2.5^\circ$  latitude/longitude bins extending from  $60^\circ$  N to the pole. Because the A-Train is in a sun-synchronous orbit, the number of observations increases towards the poles. Therefore, the  $2.5^\circ \times 2.5^\circ$  boxes at higher latitudes are smaller due to the curvature of the earth but get more satellite passes per unit area. Figure 1 demonstrates this effect whereby the total number of CloudSat profiles are shown for each region for January 2008. Each region contains a minimum of 700 CloudSat profiles. The satellites range is  $82^\circ$  N/S and above this latitude CloudSat and CALIPSO do not provide retrievals. Because the imager of MODIS, AIRS, and CERES span wider swaths, complete coverage over the poles is provided by these additional sensors. In total, there are 144 longitude and 12 latitude bins averaged into 79 monthly bins. Table 2 summarizes the spatial and temporal variables.

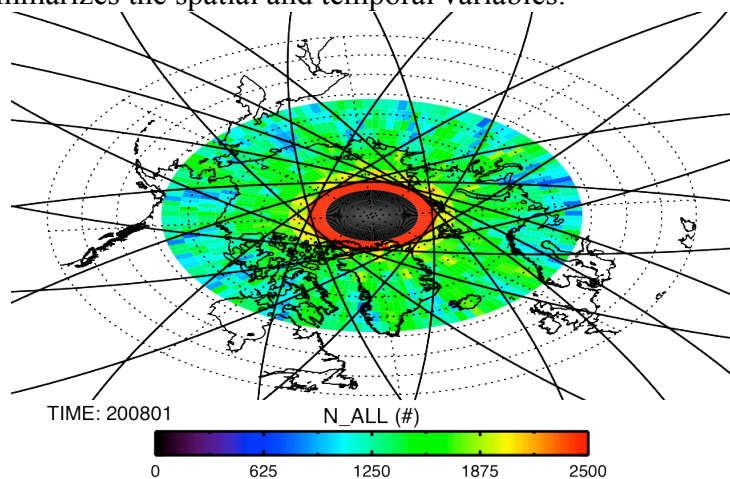


Figure 1. Number of CloudSat profiles binned by 2.5x2.5 regions for January 2008. Black lines are individual orbits made by CloudSat for one day of observations.

Table 2. NetCDF output file header information.

| Variable | Description                 | Dimensions | Units  |
|----------|-----------------------------|------------|--------|
| lat      | Latitude                    | 12         | Deg.   |
| lon      | Longitude                   | 144        | Deg.   |
| time     | Day number since 2002-01-01 | 79         | Day #  |
| month    | Month number                | 79         | Mon. # |
| year     | Year number                 | 79         | Year # |
| lev      | Vertical Level              | 125        | km     |

## 2. Data Products

Data is stored in a netCDF (version 4) file format listed under the primary name of the mission (e.g., CloudSat.nc4). Where possible the following components of the Earth-Atmosphere system are included: (1) surface properties, (2) atmospheric aerosol, (3) meteorology, (4) cloud and radiation properties derived from CloudSat observations, (5) cloud and radiation properties derived from MODIS & CERES observations, and (6) precipitation measurements from multiple sensors and models. We have also included a land/ocean/region mask data file that is available for easier analysis for specific regions of interest.

### 2.1. CloudSat: Instantaneous Cloud Properties and Radiation

Level-2 CloudSat data products are binned according to the grid in Fig. 1 and Table 2. The word “*instantaneous*” in this context means that the monthly averages are constructed from observations at the local equator crossing times of approximately 1:30 pm and 1:30 am. These observations include both day and night retrievals and no diurnal corrections to the radiative fluxes are made (these corrections are made in CloudSat-L3 and discussed in the next section). For detailed calculations a separate set of CloudSat files were also produced for day and night conditions separately (e.g., CloudSat-Day.nc4 and CloudSat-Night.nc4). Cloud radiative effect from the 2B-FLXHR-LIDAR product is composited by all-sky, precipitating, raining, and snowing conditions separately using the precipitation estimates from the 2C-Rain-Profile and 2C-Snow-Profile products. When the rain and snow rates equal 0 the profile is considered non-precipitating. Top of atmosphere and bottom of atmosphere radiative fluxes are provided for all-sky and clear-sky conditions separately.

Frequency of cloud, precipitation, rain, and snow occurrence is provided for each region. In addition, cloud fraction is binned vertically into 125 bins following the standard heights used in CloudSat data. Here, the total number of instances in which cloud extends over each 240 m vertical bin is provided for each monthly time-step. The fraction is simply computed by normalizing this number by the total number CloudSat

profiles. Because multiple cloud layers can exist in a profile, the total number of clouds can in principal be larger than the total number of profiles. We provide the frequency of cloud occurrence based the number of profiles. In addition the total number of clouds under various conditions (liquid, ice, stratocumulus, cirrus, ect) is also provided. We leave the normalization method up to the user, (e.g., normalize cloud frequency by total number of clouds or by total number of profiles). Lastly, monthly mean precipitation rates are provided for each region. Liquid precipitation is given by the 2C-RAIN-PROFILE. Surface snowfall is re-gridded from the 2C-SNOW-PROFILE. Data for these variables is provided in the ArcticDB\_CloudSat.nc4 file. Separate calculations are also provided for land-only (CloudSat-Land.nc4) and ocean-only (CloudSat-Ocean.nc4) composites.

## *2.2. EBAF Cloud Properties and Radiation*

Radiative fluxes are provided by level-3 type data from CERES-EBAF, CloudSat-L3 (FLXHR-LIDAR), and GEWEX-SRB as well as in Re-analysis products. Radiative fluxes are adjusted in these products so that equal weighting is applied over the diurnal cycle over each region. The Energy Balanced And Filled (EBAF) data concept is also applied to CloudSat data. Here, the radiative fluxes include a varying solar zenith angle that effectively samples the entire diurnal cycle. Potential sampling biases due to the effects of missing granules are also corrected by renormalizing all shortwave fluxes to the appropriate monthly-mean solar insolation for each latitude band.

Cloud properties (effective radius, optical depth, cloud fraction, ect for liquid and ice clouds) are binned from monthly level-3 AIRS, CloudSat, and MODIS data.

## *2.3. Surface Properties*

Numerous sensors and products are utilized to provide a comprehensive assessment of the surface properties of the Arctic. AIRS (AIRX3STM data) and re-analysis products provide temperature and humidity information at the surface as well as that in a vertical profile. Total water storage above land is also inferred using GRACE data. Surface backscattering cross-section at 94-GHz can be used to infer snow and vegetation changes over land using the cloud profiling radar on CloudSat. Sea ice and snow extent is re-binned from weekly measurements of combined microwave satellite sensors used in the NSIDC weekly EASE product.

## *2.4 Aerosol*

Aerosol column optical depth at 550 and 865 nm is binned using monthly mean MODIS level-3 retrievals in MYD08\_M3 product. These variables are also provided in the MACC dataset, which assimilates total AOD from satellite retrievals into the ECMWF aerosol transport model. This model includes several aerosol species including black carbon, dust, organic carbon, sea salt, and sulphate. While MACC data extends back to 2003, we have only incorporated data from June 2006 to present. Prior data is planned to be assimilated at a later point.



## 2.5. Meteorology

AIRS and Reanalysis data products are used to provide vertical profiles of temperature and humidity. It's noteworthy that AIRS does not retrieve horizontal and vertical wind profiles. Seventeen vertical levels sorted by air pressure are provided in the NCEP dataset (variable NCEP\_Lev). Some variables (e.g., the vertical pressure velocity; omega) are only provided for the 12 lowest vertical levels. Therefore, some levels are filled with missing data values (i.e., -999). Retrievals using AIRS data contain 24 vertical levels. Vertical levels are identical between AIRS and NCEP re-analysis data.

The convergence of moisture plays a significant role in precipitation and heat exchange in the atmosphere. In addition to the previous datasets, we have also added convergence of moisture, wind, and heat and precipitation minus evaporation data labeled as QBudget. The product uses water vapor from AIRS level 3 gridded retrieval data and winds from MERRA to calculate the convergence of moisture, winds, ect. Users should consult Sun Wong (sun.wong@jpl.nasa.gov) before publishing data using this product. Details about this data can be found in Wong et al. (2011).

## 2.6. Precipitation

Precipitation falling to the Earth's surface is essential for characterizing the surface water budget. Measurements are obtained either directly at the surface using rain gauges or by retrieval using satellite observations. Precipitation data is provided from multiple data sources all of which are summarized in Table 3. Precipitation is reported as the accumulated amount for the month (e.g., or as a rate such as in mm/month). The number of days in each month is provided so that this parameter can easily be converted to a precipitation rate (e.g., convert to mm/day).

A global network of rain gauges are used in GPCC (Global Precipitation Climatology Centre) to construct monthly accumulated precipitation rates at 0.5 degree spatial resolution over the period 1901-present.

The GPCP (Global Precipitation Climatology Project) combines gauge and satellite precipitation measurements into 2.5 degree global grids. The assimilated satellite data comes from estimates derived from SSM/I emission and scattering data, Geostationary Satellite Precipitation (GPI) data, and NASA/GSFC Satellite Applications Office (TOVS) data.

The CMAP (CPC Merged Analysis of Precipitation) data is derived from 5 kinds of satellite estimates (GPI, OPI, SSM/I scattering, SSM/I emission and MSU). Note, the enhanced product assimilates NCEP reanalysis data while the standard uses satellite data only. Enhanced data is not valid after January 2008.

The final hybrid product we incorporate is the GLDAS (Global Land Data Assimilation System), which uses advanced land surface modeling and data assimilation techniques to generate optimal fields of land surface states and fluxes. We have incorporated the GLDAS-2.1 data that is forced with a combination of model and observation based forcing datasets.

CloudSat (previously) discussed uses a 94-GHz cloud profiling radar which measures cloud reflectivity and path integrated attenuation. These measurements are used

in 2 standard products where rain rates are provided by 2C-RAIN-PROFILE, and snowfall rates by 2C-SNOW-PROFILE products. For CloudSat products estimates of accumulated precipitation (e.g., variables labeled as prate, rrate, and srate), intensity based on precipitation falling from precipitating clouds (e.g., variables labeled as rrate\_precip and srate\_precip), frequency of precipitation for rain (rf) and snow (sf). Accumulated precipitation is simply the product of the intensity and frequency (e.g., for accumulated rain rate: rain intensity \* #raining profiles / #total profiles). These estimates are provided in mm accumulated over the month (or mm/month).

Precipitation is not provided by GRACE (Gravity Recovery and Climate Experiment) but can be inferred using the total water storage measurements in the approach outlined in Seo et al. (2010). In general, during winter when runoff and evapotranspiration rates are negligible over land, the difference in total water storage anomalies between two consecutive months provide an accurate estimate of solid phase precipitation. While solid phase precipitation derived from GRACE is possible we leave the calculation and assumptions up to the user.

Table 3. Precipitation products derived from ground and satellite observations.

| Dataset  | Platform                                       |
|----------|--|
| GPCC     | gauge  |
| GPCP     | gauge+satellite (GPI,OPI,SSM/I,&MSU)           |
| CMAP     | satellite (GPI,OPI,SSM/I, MSU)                 |
| GLDAS    | NOAH model + Obs [CMAP, GDAS, MODIS, & AGRMET] |
| CloudSat | satellite (cloud profiling radar)              |
| GRACE    | ranging polar orbiting twin-satellites         |

### 2.7. Reanalysis Products

Numerous studies use reanalysis data for scientific applications and intermodal comparisons. Here, we integrate MERRA, ECMWF-Interim, NCEP, and ASR products. “The (ASR) is produced using a high-resolution version of the Polar Weather Forecast Model (PWRF) and the WRF-VAR and High Resolution Land Data Assimilation (HRLDAS) data assimilation systems that have been optimized for the Arctic.” ASR-Interim is re-binned from 30 km to match the resolution of the Arctic dataset project resolution. Data spans from 2002 to 2011.

Because the reanalysis products described here can have a wide array of variables some of which are calculated in different ways and represented using different units our goal is to provide a standard set for consistency across all products. Key variables we chose to include are the following: (1) radiation fluxes at the top and base of the atmosphere, (2) all-sky cloud coverage, (3) meteorology [e.g., temperature, humidity, and wind profiles], and (4) surface properties [e.g., surface fluxes, precipitation, snow and ice extent, and albedo].

## 2.8. ARM Surface Measurements

Data collected by the ARM (Atmospheric Radiation Measurement) central facility (C1) located on the North Slope Alaska (NSA) in Barrow (71 N 156 W) is merged into the temporal sampling strategy used in this Arctic dataset. Due to the relatively high temporal sampling of the ARM site, averaging is performed over daily and monthly timescales.

### 2.8.1. Cloud and Radiation Measurements

ARM Best Estimate data products (ARMBE) is a collection of data that represents “best estimates” derived from several instruments and/or Value-Added Products (VAP). Cloud cover fraction is measured using cloud radar, lidar, and total sky imager from the ARM site at the surface. A microwave radiometer is used to estimate liquid and precipitable water paths. Downwelling shortwave radiation is measured using a pyranometer and longwave radiative fluxes are measured using a pyrgeometer at 1 minute resolution. Detailed information for the **ARMBECLDRAD** can be found in Xie et al. (2009). For more information please visit <http://www.arm.gov/data/vaps/armbe>.

The Actively Remotely-Sensed Cloud Locations (ARSCL) VAP product combines data from ceilometer, micropulse lidar, and cloud radar (35 GHz) to determine cloud base height, precipitation and fall velocity, and reflectivity. The dataset uses Clothiaux algorithms and observations are provided as a function of height above the surface every hour. The product called **ARSCL1CLOTH** and described in further detail here: <http://www.arm.gov/data/vaps/arscl/arscl1cloth>.

### 2.8.2. Aerosol Optical Thickness Data

Aerosol optical properties are derived from sun-and-sky scanning radiometer measurements from the cimel sunphotometer. Aerosol optical depth is provided hourly at multiple wavelengths. For comparison with MODIS, we chose to integrate retrievals at 555 nm and 865 nm and the associated angstrom exponent. Solar zenith angle is also provided. For more information about the **CSPHOT** product please visit: <http://www.arm.gov/instruments/cspshot>.

## 2.9 GC-NET Surface Measurements

The Greenland Climate Network (GCNET) provides surface radiation measurements from over 20 sites located throughout Greenland. Measurements are taken hourly at each location and then merged into the temporal sampling strategy (monthly) used in this Arctic dataset. Sites are listed in Table 5 and plotted in Figure xx. Radiation

fluxes are provided for downwelling shortwave, upwelling shortwave, and net radiation at the surface for each site. Stations are not included if the sensors operated prior to 2002.

Table 4. GCNET list of stations used in this dataset

| Site ID | Site Name      | Latitude | Longitude |
|---------|----------------|----------|-----------|
| 01      | Swiss Camp     | 69.56    | -49.3     |
| 02      | Crawford Point | 69.87    | -46.9     |
| 05      | Humboldt       | 78.52    | -56.8     |
| 06      | Summit         | 72.57    | -38.5     |
| 07      | Tunu-N         | 78.01    | -33.9     |
| 08      | DYE-2          | 66.48    | -46.3     |
| 09      | JAR-1          | 69.49    | -49.7     |
| 10      | Saddle         | 65.99    | -44.5     |
| 11      | South Dome     | 63.14    | -44.8     |
| 12      | NASA-E         | 75.00    | -29.9     |
| 14      | NGRIP          | 75.09    | -42.3     |
| 15      | NASA-SE        | 66.48    | -42.49    |
| 17      | JAR-2          | 69.41    | -50.09    |

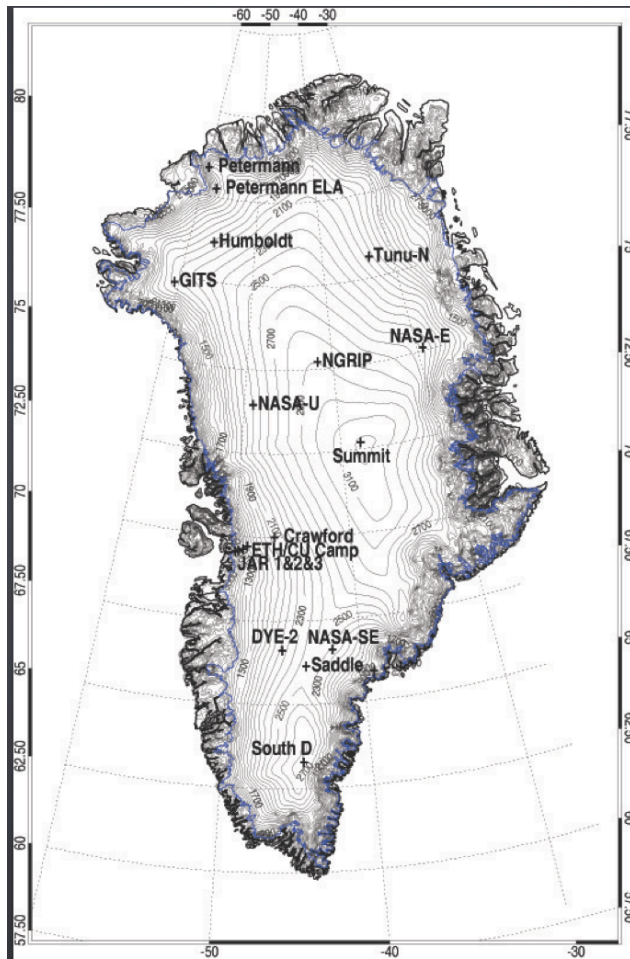


Figure 2. GC-Net ground based site locations, image obtained from <http://cires.colorado.edu/science/groups/steffen/gcnet/>.

## *2.10. Ship Traffic*

As sea ice continues to melt more of the Arctic Ocean will be navigable for oceangoing vessels. Concern over the emitted particles from vessels into this region demands close monitoring of any changes in ship activity. Sponsored by the United States Coast Guard, AMVER is a voluntary global ship reporting system that was established in 1958. Its primary purpose is used for aiding in search and distress calls out over the ocean. It accounts for roughly 1/3 of the world fleet of merchant ships. Global distributions of ship density were determined from the AMVER ship inventory database. AMVER data is provided by the Amver Team USCG Operations Systems Center; binned by 2.5° x 2.5° regions.

## *2.11. Climate Variability*

### *2.11.1. Solar Radiation and Sunspot Activity*

Sunspot activity has been monitored for over 150 years at the Royal Observatory in Greenwich. This dataset has been made available by the US Air Force (USAF) and continued with the help of the US National Oceanic and Atmospheric Administration (NOAA). Sunspots follow a cycle that repeats roughly 11 years. The variation caused by the sunspot cycle to solar output is on the order of 0.1% of the solar constant or an approximate amplitude of 1.3 W/m<sup>2</sup> compared to the average solar constant of 1366 W/m<sup>2</sup>. Even though it only accounts for a minuscule fraction of total solar radiation, the impact of solar UV radiation on the Earth's upper atmosphere is profound having a variation of over 400% in a given sunspot cycle. This is a major driver for stratospheric chemistry with potential coupling to troposphere cloud dynamics. These influences are poorly understood particularly on the climatology of Arctic clouds.

### *2.11.1. NOAA Climate Indices*

Oscillations in the climate system can have significant impact on interannual climate variability. NOAA provides dozens of indices covering many atmospheric phenomena including the El Nino Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and the Quasi-Biennial Oscillation (QBO) to name a few. These indices have been standardized and re-binned in this dataset. Visit <http://www.esrl.noaa.gov/psd/data/climateindices/list/> for a description of this dataset.

## 2.12. Region Mask

Several masks are provided for analyzing specific regions in the Arctic. Firstly, the NCEP re-analysis land mask is re-gridded and added to this dataset. Secondly, several of the listed regions were identified visually and logged by hand. Coastlines were included if the grid-box was at least 50% filled. Bitmasks are dimensioned 144 x 12. A value of 1 indicates that the grid-box is located inside the area of interest, a value of 0 is outside the region. The following regions were identified in ArcticDB\_RegionMask.nc4: America, Arctic Ocean, Baffin Bay, Barents Sea, Eurasia, Greenland, Greenland Sea, and Siberia. Also included is the surface area (A) of each grid-box calculated using the following equations,

$$A = R^2 * [\phi_1 - \phi_0] * [\cos\theta_0 - \cos\theta_1] \quad (1)$$

$$R = \text{Radius of earth} = 6378.1 \text{ km} \quad (2)$$

$$\theta = \text{latitude} * \pi/180 \quad (3)$$

$$\phi = \text{longitude} * \pi/180 \quad (4)$$

## 3 File Naming Convention

A standard set of variable names is used across all datasets. This is needed because variables of the same type are often given a variety of names. For example, the “clear-sky downwelling shortwave radiation at the bottom of atmosphere” has been labeled as: FD\_DN (FLXHR-LIDAR), sfc\_sw\_down\_clr\_mon (CERES-EBAF), clr\_sw\_sfc\_dn (GEWEX-SRB), swgntclr (MERRA), ssrc (ECMWF-Interim), and SWUPBC (ASR) in various products. Therefore, when assimilating all of these products we have adopted a standard naming convention for each variable, and for this particular example the variable is called “boa\_swdn\_clr” where, boa stands for bottom of atmosphere, swdn stands for downwelling shortwave radiation, and clr stands for clear. Table 5 shows the naming convention for most of the standard variables used in this dataset.

Table 5. Naming convention given for standard variables

| Radiative Fluxes                           |                |                  |  |
|--|----------------|------------------|--|
| Long Name                                  | Var. Name      | Units            | Data Sets  |
| <i>Top of atmosphere</i>                   |                |                  |  |
| Incident shortwave radiation               | toa_swdn_all   | W/m <sup>2</sup> |  |
| Outgoing longwave radiation (all-sky)      | toa_lwup_all   | W/m <sup>2</sup> | CERES-EBAF, CloudSat-L3, MERRA, NCEP, ECMWF, ASR |
| Outgoing longwave radiation (clear-sky)    | toa_lwup_clear | W/m <sup>2</sup> |  |
| Longwave cloud radiative effect            | toa_cre_lw     | W/m <sup>2</sup> |  |
| Outgoing shortwave radiation (all-sky)     | toa_swup_all   | W/m <sup>2</sup> |  |
| Outgoing shortwave radiation (clear-sky)   | toa_swup_clear | W/m <sup>2</sup> |  |
| Shortwave cloud radiative effect           | toa_cre_sw     | W/m <sup>2</sup> |  |
| <i>Bottom of atmosphere</i>                |                |                  |  |
| Downwelling longwave radiation (all-sky)   | boa_lwdn_all   | W/m <sup>2</sup> |  |
| Downwelling longwave radiation (clear-sky) | boa_lwdn_clear | W/m <sup>2</sup> |  |

|   |                |                  |
|---|----------------|------------------|
| Upwelling longwave radiation (all-sky)      | boa_lwup_all   | W/m <sup>2</sup> |
| Upwelling longwave radiation (clear-sky)    | boa_lwup_clear | W/m <sup>2</sup> |
| Downwelling shortwave radiation (all-sky)   | boa_swdn_all   | W/m <sup>2</sup> |
| Downwelling shortwave radiation (clear-sky) | boa_swdn_clear | W/m <sup>2</sup> |
| Upwelling shortwave radiation (all-sky)     | boa_swup_all   | W/m <sup>2</sup> |
| Upwelling shortwave radiation (clear-sky)   | boa_swup_clear | W/m <sup>2</sup> |

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### Cloud Fraction

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| Long Name                   | Var. Name | Units         | Data Sets                               |
|-----------------------------|-----------|---------------|---|
| Total cloud fraction        | cf_tot    | none<br>(0-1) | AIRS, MODIS, MERRA, NCEP,<br>ECMWF, ASR |
| Liquid cloud fraction       | cf_liq    | none          | AIRS, MODIS                             |
| Ice cloud fraction          | cf_ice    | none          | AIRS, MODIS                             |
| Undetermined cloud fraction | cf_und    | none          | AIRS, MODIS                             |

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### Meteorology

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| Long Name                                | Var. Name      | Units         | Data Sets                  |
|--|----------------|---------------|----------------------------|
| Pressure Level                           | lev            | hPa           | AIRS, MERRA, NCEP, & ECMWF |
| Air Temperature                          | t              | K             | AIRS, MERRA, NCEP, & ECMWF |
| Specific Humidity                        | qv             | g/kg          | AIRS, MERRA, NCEP, & ECMWF |
| Relative Humidity                        | rh             | none<br>(0-1) | AIRS, MERRA, NCEP, & ECMWF |
| Geopotential Height                      | h              | m             | AIRS, MERRA, NCEP, & ECMWF |
| U-wind                                   | u              | m/s           | MERRA, NCEP & ECMWF        |
| V-wind                                   | v              | m/s           | MERRA, NCEP & ECMWF        |
| convergence (water vapor, momentum, ect) | divhflx, ect.. | g/kg/s        | QBudget                    |
| Vertical Velocity                        | omega          | hpa/s         | NCEP                       |

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### Surface Properties

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| Long Name                      | Var. Name   | Units         | Data Source            |
|--------------------------------|-------------|---------------|------------------------|
| <i>Meteorology</i>             |             |               |                        |
| Surface Level Pressure         | psfc        | hPa           | MERRA, AIRS, NCEP, ASR |
| Skin Temperature               | T_skin      | K             | MERRA, AIRS, NCEP, ASR |
| Surface Air Temperature        | T_2m        | g/kg          | AIRS, NCEP, ASR        |
| Surface Specific Humidity      | QV_2m       | none<br>(0-1) | NCEP, ASR              |
| U-wind                         | U_10m       | m             | NCEP, ASR              |
| V-wind                         | V_10m       | m/s           | NCEP, ASR              |
| Momentum flux (zonal)          | Uflx        |               | NCEP                   |
| Zonal gravity wave stress      | Ugwd        |               | NCEP                   |
| Momentum flux (meridional)     | Vflx        |               | NCEP                   |
| Meridional gravity wave stress | Vgwd        |               | NCEP                   |
| <i>Soil Layer Properties</i>   |             |               |                        |
| Soil moisture (0 – 10 cm)      | soilw_10cm  |               | NCEP                   |
| Soil moisture (10 – 200 cm)    | soilw_200cm |               | NCEP                   |
| Temperature of 0-10 cm layer   | soilt_10cm  | K             | MERRA, NCEP            |
| Temperature of 20-200 cm layer | soilt_200cm | K             | MERRA, NCEP            |

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### Surface Water Budget

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|   |               |                  |   |
|---|---------------|------------------|---|
| Accumulated precipitation                 | prate         | mm/mo            | NCEP, ECMWF, GPCC, CloudSat, GPCP, CMAP |
| Accumulated rainfall                      | rrate         | mm/mo            | CloudSat, GLDAS, MERRA, ASR             |
| Accumulated snowfall                      | srate         | mm/mo            | CloudSat, GLDAS, MERRA                  |
| Rain rate intensity                       | rrate_precip  | mm/mo            | CloudSat                                |
| Snow rate intensity                       | srate_precip  | mm/mo            | CloudSat                                |
| Rain frequency                            | rf            | 0-1              | CloudSat,                               |
| Snow frequency                            | sf            | 0-1              | CloudSat                                |
| Potential evaporation rate                | Pevap         | mm/mo            | NCEP                                    |
| Runoff                                    | runof         | mm/mo            | MERRA, NCEP, GLDAS, ASR                 |
| Ice concentration                         | icec          | 0-1              | NCEP, ECMWF, NSIDC, ASR                 |
| water equivalent of snow depth            | weasd         | mm               | MERRA, NCEP, ECMWF, GLDAS               |
| snow covered land                         | snowc         | 0-1              | NSIDC                                   |
| liquid water equivalent thickness anomaly | lwe_thickness | mm               | GRACE                                   |
| <i>Aviation</i>                           |               |                  |   |
| Ship Count                                | n_ships       | none             | AMVER                                   |
| <i>Surface Fluxes</i>                     |               |                  |   |
| Ground Heat Flux                          | grfl          | W/m <sup>2</sup> | NCEP, ECMWF, ASR                        |
| Latent Heat Flux                          | lhfl          | W/m <sup>2</sup> | MERRA, NCEP, ECMWF, ASR                 |
| Sensible Heat Flux                        | shfl          | W/m <sup>2</sup> | MERRA, NCEP, ECMWF, ASR                 |

| <b>Cloud Optical Properties</b>    |                                    |                  |                                  |
|------------------------------------|------------------------------------|------------------|----------------------------------|
| Long Name                          | Var. Name                          | Units            | Data Source                      |
| <i>Cloud optical depth</i>         |                                    |                  |                                  |
| Total, liquid, ice, & undetermined | cod_tot, cod_liq, cod_ice, cod_und | none             | CloudSat, MODIS, AIRS (ice only) |
| <i>Cloud effective radius</i>      |                                    |                  |                                  |
| Total, liquid, ice, & undetermined | cre_tot, cre_liq, cre_ice, cre_und | micron           | CloudSat, MODIS, AIRS (ice only) |
| <i>Cloud water path</i>            |                                    |                  |                                  |
| Total, liquid, ice, & undetermined | cwp_tot, cwp_liq, cwp_ice, cwp_und | g/m <sup>2</sup> | CloudSat, MODIS                  |
| Cloud top pressure (total)         | ctp                                | hPa              | MODIS, AIRS (ice only)           |
| Cloud top temperature (total)      | ctt                                | K                | MODIS, AIRS (ice only)           |

| <b>Aerosol</b>               |           |       |             |
|------------------------------|-----------|-------|-------------|
| Long Name                    | Var. Name | Units | Data Source |
| <i>Aerosol optical depth</i> |           |       |             |
| 550 nm                       | aod550    | none  | MODIS, MACC |
| 865 nm                       | aod865    | none  | MODIS, MACC |
| black carbon                 | bcaod     | none  | MACC        |
| dust                         | duaod     | none  | MACC        |
| organic matter               | omaod     | none  | MACC        |



|                   |             |      |       |
|-------------------|-------------|------|-------|
| sea salt          | ssaod       | none | MACC  |
| sulphate          | suaod       | none | MACC  |
| Angstrom exponent | ang_550_865 | none | MODIS |

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Table 6. List of **AIRS** rebinned  $1^{\circ} \times 1^{\circ}$  monthly mean variables.

| Variable Name | Long Name                                | Units                 | Orig. File: AIRX3STM<br>Orig. Variable Name              |
|---------------|--|-----------------------|--|
| lat           | Latitude                                 | degrees               | Center Latitude  |
| lon           | Longitude                                | degrees               | Center Longitude   |
| time          | Time                                     | Days Since 2002-01-01 | Day number referenced to 15th day of the month           |
| month         | Month Number                             | none                  | The number of the month of year (1-12)                   |
| year          | Year                                     | none                  | The year   |
| lev           | Pressure Levels                          | hPa                   | The vertical coordinate of the AIRS L3 monthly data      |
| h             | Geopotential Height                      | m                     | GPHeight_A   |
| t             | Air Temperature                          | K                     | Temperature_A  |
| qv            | Specific Humidity                        | g/kg                  | H2O_MMR_Lyr_A  |
| rh            | Relative Humidity                        | none                  | RelHum_A   |
| t_2m          | Air Temperature at 2 Meters              | K                     | SurfAirTemp_A  |
| psfc          | Surface Pressure                         | hPa                   | SurfPres_Forecast_A                                      |
| cod_ice       | Optical Thickness of Ice Clouds          | none                  | ice_cld_tau_all  |
| cre_ice       | Effective Particle Radius Ice Clouds     | microns               | ice_cld_de_all   |
| ctt_ice       | Cloud Top Temperature Ice Clouds         | K                     | ice_cld_top_temp_all                                     |
| cf_ice        | Cloud Fraction Ice Clouds                | none                  | ice_cld_freq_all   |
| cf_und        | Cloud Fraction Undetermined Phase Clouds | none                  | unk_cld_freq_all   |
| cf_liq        | Cloud Fraction Liquid Water Clouds       | none                  | liq_cld_freq_all   |
| cf_tot        | Total Cloud Fraction                     | none                  | ice_cld_freq_all<br>unk_cld_freq_all<br>liq_cld_freq_all |

Table 7. List of **AMVER** rebinned  $0.25^{\circ} \times 0.25^{\circ}$  daily report at 00:00 UTC variables.

| Variable Name | Long Name    | Units                 | Description   |
|---------------|--------------|-----------------------|---|
| lat           | Latitude     | degrees               | Center Latitude   |
| lon           | Longitude    | degrees               | Center Longitude  |
| time          | Time         | Days Since 2002-01-01 | Day number referenced to 15th day of the month          |
| month         | Month Number | none                  | The number of the month of year (1-12)                  |
| year          | Year         | none                  | The year  |
| n_ships       | Ship Count   | none                  | The number of ships detected by AMVER in the stated bin |

Table 8. List of **ASR** rebinned 30 km monthly mean variables.

| Variable Name         | Long Name  | Units                           | asr30km.fc3.mon<br>Orig. Variable Name                |
|-----------------------|--|---------------------------------|---|
| lat                   | Latitude   | degrees                         | Center Latitude                                       |
| lon                   | Longitude  | degrees                         | Center Longitude                                      |
| time                  | Time   | Days<br>Since<br>2002-<br>01-01 | Day number<br>referenced to 15th<br>day of the month  |
| month                 | Month Number   | none                            | The number of the<br>month of year (1-<br>12)         |
| year                  | Year   | none                            | The year  |
| seconds_per_m<br>onth | Seconds Per Month  | s                               | The number of<br>seconds in the<br>given month        |
| lev                   | Depth of Center of Soil Layers   | m                               | The vertical<br>coordinate of ASR<br>Soil Data        |
| n_points              | Number of Datapoints   | none                            | The number of ASR<br>grid points in the<br>stated bin |
| boa_lwdn_all          | Bottom of Atmosphere Downwelling Longwave<br>Radiation All-Sky Conditions    | W/m <sup>2</sup>                | LWDNB   |
| boa_lwdn_clear        | Bottom of Atmosphere Downwelling Longwave<br>Radiation Clear-Sky Conditions  | W/m <sup>2</sup>                | LWDNBC  |
| boa_lwup_all          | Bottom of Atmosphere Upwelling Longwave<br>Radiation All-Sky Conditions      | W/m <sup>2</sup>                | LWUPB   |
| boa_lwup_clear        | Bottom of Atmosphere Upwelling Longwave<br>Radiation Clear-Sky Conditions    | W/m <sup>2</sup>                | LWUPBC  |
| boa_swdn_all          | Bottom of Atmosphere Downwelling Shortwave<br>Radiation All-Sky Conditions   | W/m <sup>2</sup>                | SWDNB   |
| boa_swdn_clear        | Bottom of Atmosphere Downwelling Shortwave<br>Radiation Clear-Sky Conditions | W/m <sup>2</sup>                | SWDNBC  |
| boa_swup_all          | Bottom of Atmosphere Upwelling Shortwave<br>Radiation All-Sky Conditions     | W/m <sup>2</sup>                | SWUPB   |
| boa_swup_clear        | Bottom of Atmosphere Upwelling Shortwave<br>Radiation Clear-Sky Conditions   | W/m <sup>2</sup>                | SWUPBC  |
| gflux                 | Ground Heat Flux   | W/m <sup>2</sup>                | GRDFLX  |
| icec                  | Sea Ice Fraction   | none                            | SEAICE  |
| lhtfl                 | Latent Heat Flux   | W/m <sup>2</sup>                | LH  |
| pblh                  | Planetary Boundary Layer Height  | m                               | PBLH  |
| pevap                 | Accumulated Potential Evaporation  | W/m <sup>2</sup>                | POTEVP  |
| prate                 | Surface Precipitation Rate   | mm                              | RAINNC  |
| psfc                  | Surface Pressure   | hPa                             | PSFC  |
| qv_2m                 | Specific Humidity at 2 Meters  | g/kg                            | Q2  |
| runof                 | Surface Runoff   | mm                              | SFROFF  |
| shfl                  | Sensible Heat Flux   | W/m <sup>2</sup>                | HFX   |
| slp                   | Sea-Level Pressure   | hPa                             | SLP   |
| soilt                 | Soil Temperature   | K                               | TSLB  |
| soilw                 | Soil Moisture  | none                            | SMOIS   |

|                |  |                  |        |
|----------------|--|------------------|--------|
| sr             | Fraction of Frozen Precipitation                                       | none             | SR     |
| srate          | Surface Snowfall Rate  | mm               | SNOW   |
| toa_lwup_all   | Top of Atmosphere Upwelling Longwave Radiation All-Sky Conditions      | W/m <sup>2</sup> | LWUPT  |
| toa_lwup_clear | Top of Atmosphere Upwelling Longwave Radiation Clear-Sky Conditions    | W/m <sup>2</sup> | LWUPTC |
| toa_swdn_all   | Top of Atmosphere Downwelling Shortwave Radiation All-Sky Conditions   | W/m <sup>2</sup> | SWDNT  |
| toa_swdn_clear | Top of Atmosphere Downwelling Shortwave Radiation Clear-Sky Conditions | W/m <sup>2</sup> | SWDNTC |
| toa_swup_all   | Top of Atmosphere Upwelling Shortwave Radiation All-Sky Conditions     | W/m <sup>2</sup> | SWUPT  |
| toa_swup_clear | Top of Atmosphere Upwelling Shortwave Radiation Clear-Sky Conditions   | W/m <sup>2</sup> | SWUPTC |
| t_2m           | Air Temperature at 2 Meters  | K                | T2     |
| t_skin         | Surface Skin Temperature   | K                | TSK    |
| urunof         | Underground Runoff   | mm               | UDROFF |
| u_10m          | Zonal Wind at 10 Meters  | m/s              | U10    |
| v_10m          | Meridional Wind at 10 Meters   | m/s              | V10    |
| weasd          | Snow Mass  | mm               | SNOW   |

Table 9. List of **CERES-EBAF** rebinned 1°×1° over monthly data from version 2.7 data.

| Variable Name  | Long Name   | Units                           | Ed2.7<br>Orig. Variable Name                         |
|----------------|---|---------------------------------|--|
| lat            | Latitude  | degrees                         | Center Latitude                                      |
| lon            | Longitude   | degrees                         | Center Longitude                                     |
| time           | Time  | Days<br>Since<br>2002-<br>01-01 | Day number<br>referenced to 15th day<br>of the month |
| month          | Month Number  | none                            | The number of the<br>month of year (1-12)            |
| year           | Year  | none                            | The year   |
| toa_swdn_all   | Top of Atmosphere Downwelling Shortwave Radiation All-Sky Conditions      | W/m <sup>2</sup>                | solar_mon  |
| toa_swup_all   | Top of Atmosphere Upwelling Shortwave Radiation All-Sky Conditions        | W/m <sup>2</sup>                | toa_sw_all_mon                                       |
| toa_swup_clear | Top of Atmosphere Upwelling Shortwave Radiation Clear-Sky Conditions      | W/m <sup>2</sup>                | toa_sw_clr_mon                                       |
| toa_lwup_all   | Top of Atmosphere Upwelling Longwave Radiation All-Sky Conditions         | W/m <sup>2</sup>                | toa_lw_all_mon                                       |
| toa_lwup_clear | Top of Atmosphere Upwelling Longwave Radiation Clear-Sky Conditions       | W/m <sup>2</sup>                | toa_lw_clr_mon                                       |
| toa_cre_sw     | Top of Atmosphere Shortwave Cloud Radiative Effect                        | W/m <sup>2</sup>                | toa_cre_sw_mon                                       |
| toa_cre_lw     | Top of Atmosphere Longwave Cloud Radiative Effect                         | W/m <sup>2</sup>                | toa_cre_lw_mon                                       |
| boa_swdn_all   | Bottom of Atmosphere Downwelling Shortwave Radiation All-Sky Conditions   | W/m <sup>2</sup>                | sfc_sw_down_all_mon                                  |
| boa_swdn_clear | Bottom of Atmosphere Downwelling Shortwave Radiation Clear-Sky Conditions | W/m <sup>2</sup>                | sfc_sw_down_clr_mon                                  |
| boa_swup_all   | Bottom of Atmosphere Upwelling  | W/m <sup>2</sup>                | sfc_sw_up_all_mon                                    |

|                |   |                  |                     |
|----------------|---|------------------|---------------------|
|                | Shortwave Radiation All-Sky Conditions                                      |                  |                     |
| boa_swup_clear | Bottom of Atmosphere Upwelling<br>Shortwave Radiation Clear-Sky Conditions  | W/m <sup>2</sup> | sfc_sw_up_clr_mon   |
| boa_lwdn_all   | Bottom of Atmosphere Downwelling<br>Longwave Radiation All-Sky Conditions   | W/m <sup>2</sup> | sfc_lw_down_all_mon |
| boa_lwdn_clear | Bottom of Atmosphere Downwelling<br>Longwave Radiation Clear-Sky Conditions | W/m <sup>2</sup> | sfc_lw_down_clr_mon |
| boa_lwup_all   | Bottom of Atmosphere Upwelling<br>Longwave Radiation All-Sky Conditions     | W/m <sup>2</sup> | sfc_lw_up_all_mon   |
| boa_lwup_clear | Bottom of Atmosphere Upwelling<br>Longwave Radiation Clear-Sky Conditions   | W/m <sup>2</sup> | sfc_lw_up_clr_mon   |

Table 10. List of **CloudSat-L3-ERB** rebinned 1.4 km footprint monthly averaged variables.

| Variable Name  | Long Name   | Units                    | Orig. Variable Name                                  |
|----------------|---|--------------------------|--|
| lat            | Latitude  | degrees                  | Center Latitude                                      |
| lon            | Longitude   | degrees                  | Center Longitude                                     |
| time           | Time  | Days Since<br>2002-01-01 | Day number<br>referenced to 15th day<br>of the month |
| month          | Month Number  | none                     | The number of the<br>month of year (1-12)            |
| year           | Year  | none                     | The year   |
| n_points       | Number of Datapoints  | none                     | ntotal   |
| n_clear        | Number of Clear-Sky Datapoints  | none                     | nclear   |
| n_cloudy       | Number of Cloudy-Sky Datapoints   | none                     | ncloudy  |
| cf_tot         | Total Cloud Fraction  | none                     | ncloudy/ntotal                                       |
| toa_swup_all   | Top of Atmosphere Outgoing Shortwave<br>Radiation All-Sky Conditions            | W/m <sup>2</sup>         | toa_swup_allsky                                      |
| toa_swdn_all   | Top of Atmosphere Incident Shortwave<br>Radiation                               | W/m <sup>2</sup>         | toa_swdn_allsky                                      |
| toa_lwup_all   | Top of Atmosphere Outgoing Longwave<br>Radiation All-Sky Conditions             | W/m <sup>2</sup>         | toa_lwup_allsky                                      |
| toa_swup_clear | Top of Atmosphere Outgoing Shortwave<br>Radiation Clear-Sky Conditions          | W/m <sup>2</sup>         | toa_swup_clearsky                                    |
| toa_lwup_clear | Top of Atmosphere Outgoing Longwave<br>Radiation Clear-Sky Conditions           | W/m <sup>2</sup>         | toa_lwup_clearsky                                    |
| boa_swup_all   | Bottom of Atmosphere Upwelling<br>Shortwave Radiation All-Sky Conditions        | W/m <sup>2</sup>         | boa_swup_allsky                                      |
| boa_swdn_all   | Bottom of Atmosphere Downwelling<br>Shortwave Radiation All-Sky Conditions      | W/m <sup>2</sup>         | boa_swdn_allsky                                      |
| boa_lwup_all   | Bottom of Atmosphere Upwelling<br>Longwave Radiation All-Sky Conditions         | W/m <sup>2</sup>         | boa_lwup_allsky                                      |
| boa_lwdn_all   | Bottom of Atmosphere Downwelling<br>Longwave Radiation All-Sky Conditions       | W/m <sup>2</sup>         | boa_lwdn_allsky                                      |
| boa_swup_clear | Bottom of Atmosphere Upwelling<br>Shortwave Radiation Clear-Sky<br>Conditions   | W/m <sup>2</sup>         | boa_swup_clearsky                                    |
| boa_swdn_clear | Bottom of Atmosphere Downwelling<br>Shortwave Radiation Clear-Sky<br>Conditions | W/m <sup>2</sup>         | boa_swdn_clearsky                                    |

|                |  |                  |                   |
|----------------|--|------------------|-------------------|
| boa_lwup_clear | Bottom of Atmosphere Upwelling Longwave Radiation Clear-Sky Conditions   | W/m <sup>2</sup> | boa_lwup_clearsky |
| boa_lwdn_clear | Bottom of Atmosphere Downwelling Longwave Radiation Clear-Sky Conditions | W/m <sup>2</sup> | boa_lwdn_clearsky |
| toa_cre_sw     | Top of Atmosphere Shortwave Cloud Radiative Effect                       | W/m <sup>2</sup> | toa_cre_sw        |
| toa_cre_lw     | Top of Atmosphere Longwave Cloud Radiative Effect                        | W/m <sup>2</sup> | toa_cre_lw        |

Table 11. List of **CloudSat** rebinned 1.4 km footprint instantaneous averaged variables from products: GEOPROF, GEOPROF-LIDAR, FLXHR-LIDAR, SNOW-PROFILE, RAIN-PROFILE, and CLDCLASS-LIDAR. Separate composites are provided for **Day-only**, **Night-only**, **Land-only**, and **Ocean-only**.

| Variable Name     | Long Name                                      | Units                 |
|-------------------|--|-----------------------|
| lat               | Latitude                                       | degrees               |
| lon               | Longitude                                      | degrees               |
| time              | Time   | Days Since 2002-01-01 |
| month             | Month Number                                   | none                  |
| year              | Year   | none                  |
| seconds_per_month | Seconds Per Month                              | s                     |
| lev               | Vertical Level                                 | km                    |
| vcf               | Vertical Cloud Fraction                        | none                  |
| n_profs_vcf       | Number of profiles in Vertical Cloud Fraction  | none                  |
| n_profs           | Number of Profiles                             | none                  |
| n_profs_cldclass  | Number of Profiles in CloudClass Data          | none                  |
| cf_ice            | Cloud Fraction Ice Clouds                      | none                  |
| cf_mixed          | Cloud Fraction Mixed Ice and Water Clouds      | none                  |
| cf_liq            | Cloud Fraction Liquid Water Clouds             | none                  |
| cf_unknown        | Cloud Fraction Unknown Clouds                  | none                  |
| cf_cirrus         | Cloud Fraction Cirrus Clouds                   | none                  |
| cf_altostratus    | Cloud Fraction Altostratus Clouds              | none                  |
| cf_altocumulus    | Cloud Fraction Altocumulus Clouds              | none                  |
| cf_st             | Cloud Fraction Stratus Clouds                  | none                  |
| cf_sc             | Cloud Fraction Stratocumulus Clouds            | none                  |
| cf_cumulus        | Cloud Fraction Cumulus Clouds                  | none                  |
| cf_nimbostratus   | Cloud Fraction Nimbostratus Clouds             | none                  |
| cf_deepconvection | Cloud Fraction Deep Convection Clouds          | none                  |
| cf                | Cloud Fraction                                 | none                  |
| clrf              | Clear Sky Fraction                             | none                  |
| n_clouds          | Number of points in Clouds                     | none                  |
| n_ice             | Number of points in Ice Clouds                 | none                  |
| n_mixed           | Number of points in Mixed Ice and Water Clouds | none                  |
| n_liq             | Number of points in Liquid Water Clouds        | none                  |
| n_unknown         | Number of points in Unknown Clouds             | none                  |
| n_cirrus          | Number of points in Cirrus Clouds              | none                  |
| n_altostratus     | Number of points in Altostratus Clouds         | none                  |

|                     |   |                  |
|---------------------|---|------------------|
| n_altocumulus       | Number of points in Altocumulus Clouds  | none             |
| n_st                | Number of points in Stratus Clouds  | none             |
| n_sc                | Number of points in Stratocumulus Clouds  | none             |
| n_cumulus           | Number of points in Cumulus Clouds  | none             |
| n_nimbostratus      | Number of points in Nimbostratus Clouds   | none             |
| n_deepconvection    | Number of points in Deep Convection Clouds  | none             |
| cf_lid_cloud_1km    | Cloud Fraction LIDAR detected Clouds under 1km  | none             |
| cf_cpr_cloud_20_1km | Cloud Fraction where CPR cloud mask is GE 20 in levels below 1km                              | none             |
| cf_cpr_cloud_30_1km | Cloud Fraction where CPR cloud mask is GE 30 in levels below 1km                              | none             |
| cf_cpr_cloud_20     | Cloud Fraction where CPR cloud mask is GE 20  | none             |
| cf_cpr_cloud_30     | Cloud Fraction where CPR cloud mask is GE 30  | none             |
| n_low               | Number of points in Low Clouds  | none             |
| n_cpr_cloud_30_low  | Cloud Fraction where CPR cloud mask is GE 30 and there are low clouds                         | none             |
| n_profs_precip      | Number of Profiles in Precipitation Data  | none             |
| n_missing_precip    | Number of Missing/Bad Profiles in Precipitation Data  | none             |
| n_valid_precip      | Number of Valid Profiles in Precipitation Data  | none             |
| n_rain              | Number of Raining Profiles in Precipitation Data  | none             |
| n_snow              | Number of Snowing Profiles in Precipitation Data  | none             |
| n_valid_strict      | Number of Valid Profiles in Precipitation Data (Strict Snow Retrieval)                        | none             |
| n_snow_strict       | Number of Snowing Profiles in Precipitation Data (Strict Snow Retrieval)                      | none             |
| n_precip            | Number of Precipitating Profiles in Precipitation Data  | none             |
| n_precip_free       | Number of Precipitation Free Profiles in Precipitation Data                                   | none             |
| n_rain_low          | Number of Raining Profiles with Low Clouds in Precipitation Data                              | none             |
| n_snow_low          | Number of Snowing Profiles with Low Clouds in Precipitation Data                              | none             |
| rrate               | Liquid Precipitation Rate   | mm               |
| rrate_uncertainty   | Liquid Precipitation Rate Uncertainty   | mm               |
| rrate_precip        | Liquid Precipitation Rate Precipitating-Sky Conditions  | mm               |
| rrate_precip_low    | Liquid Precipitation Rate Precipitating-Sky Conditions Low Clouds                             | mm               |
| rf                  | Rain Fraction   | none             |
| srate               | Surface Snowfall Rate   | mm               |
| srate_uncertainty   | Surface Snowfall Rate Uncertainty   | mm               |
| srate_precip        | Surface Snowfall Rate Precipitating-Sky Conditions  | mm               |
| srate_strict        | Surface Snowfall Rate Strict Criteria   | mm               |
| srate_precip_strict | Surface Snowfall Rate Precipitating-Sky Conditions Strict Criteria                            | mm               |
| srate_precip_low    | Surface Snowfall Rate Precipitating-Sky Conditions Low Clouds                                 | mm               |
| sf                  | Snow Fraction   | none             |
| prate               | Surface Precipitation Rate  | mm               |
| n_cwp_ice_precip    | Number of points in Cloud Water Path Ice Clouds Precipitating-Sky Conditions                  | none             |
| n_cwp_ice_no_precip | Number of points in Cloud Water Path Ice Clouds without Precipitating-Sky Conditions          | none             |
| n_cwp_liq_precip    | Number of points in Cloud Water Path Liquid Water Clouds Precipitating-Sky Conditions         | none             |
| n_cwp_liq_no_precip | Number of points in Cloud Water Path Liquid Water Clouds without Precipitating-Sky Conditions | none             |
| cwp_ice_precip      | Cloud Water Path Ice Clouds Precipitating-Sky Conditions                                      | g/m <sup>2</sup> |

|                   |   |                  |
|-------------------|---|------------------|
| cwp_ice_no_precip | Cloud Water Path Ice Clouds without Precipitating-Sky Conditions                      | g/m <sup>2</sup> |
| cwp_liq_precip    | Cloud Water Path Liquid Water Clouds Precipitating-Sky Conditions                     | g/m <sup>2</sup> |
| cwp_liq_no_precip | Cloud Water Path Liquid Water Clouds without Precipitating-Sky Conditions             | g/m <sup>2</sup> |
| n_flxhr_all       | Number of Profiles marked All-Sky Conditions  | none             |
| n_flxhr_cloud     | Number of Profiles marked Cloudy-Sky Conditions                                       | none             |
| n_flxhr_rain      | Number of Profiles marked Rainy-Sky Conditions  | none             |
| n_flxhr_snow      | Number of Profiles marked Snowy-Sky Conditions  | none             |
| n_flxhr_clear     | Number of Profiles marked Clear-Sky Conditions  | none             |
| n_flxhr_precip    | Number of Profiles marked Precipitating-Sky Conditions                                | none             |
| toa_swdn_all      | Top of Atmosphere Downwelling Shortwave Radiation All-Sky Conditions                  | W/m <sup>2</sup> |
| toa_swdn_cloud    | Top of Atmosphere Downwelling Shortwave Radiation Cloudy-Sky Conditions               | W/m <sup>2</sup> |
| toa_swdn_clear    | Top of Atmosphere Downwelling Shortwave Radiation Clear-Sky Conditions                | W/m <sup>2</sup> |
| toa_swup_all      | Top of Atmosphere Upwelling Shortwave Radiation All-Sky Conditions                    | W/m <sup>2</sup> |
| toa_swup_cloud    | Top of Atmosphere Upwelling Shortwave Radiation Cloudy-Sky Conditions                 | W/m <sup>2</sup> |
| toa_swup_clear    | Top of Atmosphere Upwelling Shortwave Radiation Clear-Sky Conditions                  | W/m <sup>2</sup> |
| toa_lwup_all      | Top of Atmosphere Upwelling Longwave Radiation All-Sky Conditions                     | W/m <sup>2</sup> |
| toa_lwup_cloud    | Top of Atmosphere Upwelling Longwave Radiation Cloudy-Sky Conditions                  | W/m <sup>2</sup> |
| toa_lwup_clear    | Top of Atmosphere Upwelling Longwave Radiation Clear-Sky Conditions                   | W/m <sup>2</sup> |
| toa_cre_sw_all    | Top of Atmosphere Effective Particle Radius of Shortwave All-Sky Conditions           | W/m <sup>2</sup> |
| toa_cre_sw_rain   | Top of Atmosphere Effective Particle Radius of Shortwave Rainy-Sky Conditions         | W/m <sup>2</sup> |
| toa_cre_sw_snow   | Top of Atmosphere Effective Particle Radius of Shortwave Snowy-Sky Conditions         | W/m <sup>2</sup> |
| toa_cre_sw_precip | Top of Atmosphere Effective Particle Radius of Shortwave Precipitating-Sky Conditions | W/m <sup>2</sup> |
| toa_cre_lw_all    | Top of Atmosphere Effective Particle Radius of Longwave All-Sky Conditions            | W/m <sup>2</sup> |
| toa_cre_lw_rain   | Top of Atmosphere Effective Particle Radius of Longwave Rainy-Sky Conditions          | W/m <sup>2</sup> |
| toa_cre_lw_snow   | Top of Atmosphere Effective Particle Radius of Longwave Snowy-Sky Conditions          | W/m <sup>2</sup> |
| toa_cre_lw_precip | Top of Atmosphere Effective Particle Radius of Longwave Precipitating-Sky Conditions  | W/m <sup>2</sup> |
| boa_swdn_all      | Bottom of Atmosphere Downwelling Shortwave Radiation All-Sky Conditions               | W/m <sup>2</sup> |
| boa_swdn_cloud    | Bottom of Atmosphere Downwelling Shortwave Radiation Cloudy-Sky Conditions            | W/m <sup>2</sup> |
| boa_swdn_clear    | Bottom of Atmosphere Downwelling Shortwave Radiation Clear-Sky Conditions             | W/m <sup>2</sup> |
| boa_swup_all      | Bottom of Atmosphere Upwelling Shortwave Radiation All-Sky                            | W/m <sup>2</sup> |



|                   |  |                  |
|-------------------|--|------------------|
|                   | Conditions   |                  |
| boa_swup_cloud    | Bottom of Atmosphere Upwelling Shortwave Radiation Cloudy-Sky Conditions                 | W/m <sup>2</sup> |
| boa_swup_clear    | Bottom of Atmosphere Upwelling Shortwave Radiation Clear-Sky Conditions                  | W/m <sup>2</sup> |
| boa_lwup_all      | Bottom of Atmosphere Upwelling Longwave Radiation All-Sky Conditions                     | W/m <sup>2</sup> |
| boa_lwup_cloud    | Bottom of Atmosphere Upwelling Longwave Radiation Cloudy-Sky Conditions                  | W/m <sup>2</sup> |
| boa_lwup_clear    | Bottom of Atmosphere Upwelling Longwave Radiation Clear-Sky Conditions                   | W/m <sup>2</sup> |
| boa_lwdn_all      | Bottom of Atmosphere Downwelling Longwave Radiation All-Sky Conditions                   | W/m <sup>2</sup> |
| boa_lwdn_cloud    | Bottom of Atmosphere Downwelling Longwave Radiation Cloudy-Sky Conditions                | W/m <sup>2</sup> |
| boa_lwdn_clear    | Bottom of Atmosphere Downwelling Longwave Radiation Clear-Sky Conditions                 | W/m <sup>2</sup> |
| boa_cre_sw_all    | Bottom of Atmosphere Effective Particle Radius of Shortwave All-Sky Conditions           | W/m <sup>2</sup> |
| boa_cre_sw_rain   | Bottom of Atmosphere Effective Particle Radius of Shortwave Rainy-Sky Conditions         | W/m <sup>2</sup> |
| boa_cre_sw_snow   | Bottom of Atmosphere Effective Particle Radius of Shortwave Snowy-Sky Conditions         | W/m <sup>2</sup> |
| boa_cre_sw_precip | Bottom of Atmosphere Effective Particle Radius of Shortwave Precipitating-Sky Conditions | W/m <sup>2</sup> |
| boa_cre_lw_all    | Bottom of Atmosphere Effective Particle Radius of Longwave All-Sky Conditions            | W/m <sup>2</sup> |
| boa_cre_lw_rain   | Bottom of Atmosphere Effective Particle Radius of Longwave Rainy-Sky Conditions          | W/m <sup>2</sup> |
| boa_cre_lw_snow   | Bottom of Atmosphere Effective Particle Radius of Longwave Snowy-Sky Conditions          | W/m <sup>2</sup> |
| boa_cre_lw_precip | Bottom of Atmosphere Effective Particle Radius of Longwave Precipitating-Sky Conditions  | W/m <sup>2</sup> |
| n_profs_sigma0    | Number of profiles in Sigma-Zero   | none             |
| n_missing_sigma0  | Number of points in With Missing/Bad Data Sigma-Zero                                     | none             |
| n_sigma0_all      | Number of points in Sigma-Zero All-Sky Conditions  | none             |
| sigma0_all        | Sigma-Zero All-Sky Conditions  | dB               |
| sigma0_clear      | Sigma-Zero Clear-Sky Conditions  | dB               |
| n_sigma0_clear    | Number of points in Sigma-Zero Clear-Sky Conditions                                      | none             |

Table 12. List of **C**MAP rebinned 2.5°×2.5° monthly mean variables.

| Variable Name     | Long Name         | Units                 | Orig. Variable Name                            |
|-------------------|-------------------|-----------------------|--|
| lat               | Latitude          | degrees               | Center Latitude                                |
| lon               | Longitude         | degrees               | Center Longitude                               |
| time              | Time              | Days Since 2002-01-01 | Day number referenced to 15th day of the month |
| month             | Month Number      | none                  | The number of the month of year (1-12)         |
| year              | Year              | none                  | The year                                       |
| seconds_per_month | Seconds Per Month | s                     | The number of seconds in the given month       |

|                |  |    |                               |
|----------------|--|----|-------------------------------|
| prate_standard | Surface Precipitation Rate<br>(excludes NCEP Reanalysis I) | mm | excludes NCEP<br>Reanalysis   |
| prate_enhanced | Surface Precipitation Rate<br>(includes NCEP Reanalysis)   | mm | includes NCEP<br>Reanalysis I |

Table 13. List of **ECMWF-Interim** rebinned  $0.75^{\circ} \times 0.75^{\circ}$  variables for rebinned 2x daily average into monthly mean.

| Variable Name     | Long Name  | Units                           | Orig. Variable Name                                      |
|-------------------|--|---------------------------------|--|
| lat               | Latitude   | degrees                         | Center Latitude  |
| lon               | Longitude  | degrees                         | Center Longitude   |
| time              | Time   | Days<br>Since<br>2002-<br>01-01 | Day number<br>referenced to 15th day<br>of the month     |
| month             | Month Number   | none                            | The number of the<br>month of year (1-12)                |
| year              | Year   | none                            | The year   |
| seconds_per_month | Seconds Per Month  | s                               | The number of seconds<br>in the given month              |
| boa_lwdn_all      | Bottom of Atmosphere Downwelling<br>Longwave Radiation All-Sky Conditions  | W/m <sup>2</sup>                | strd   |
| boa_lwup_all      | Bottom of Atmosphere Upwelling<br>Longwave Radiation All-Sky Conditions    | W/m <sup>2</sup>                | str  |
| boa_swdn_all      | Bottom of Atmosphere Downwelling<br>Shortwave Radiation All-Sky Conditions | W/m <sup>2</sup>                | ssrd   |
| boa_swup_all      | Bottom of Atmosphere Upwelling<br>Shortwave Radiation All-Sky Conditions   | W/m <sup>2</sup>                | ssr  |
| toa_lwup_all      | Top of Atmosphere Upwelling Longwave<br>Radiation All-Sky Conditions       | W/m <sup>2</sup>                | ECMWF-Interim<br>Radiation negation of<br>variable: ttr  |
| toa_lwup_clear    | Top of Atmosphere Upwelling Longwave<br>Radiation Clear-Sky Conditions     | W/m <sup>2</sup>                | ECMWF-Interim<br>Radiation negation of<br>variable: ttrc |
| toa_swdn_all      | Top of Atmosphere Downwelling<br>Shortwave Radiation All-Sky Conditions    | W/m <sup>2</sup>                | tisr   |
| toa_swup_all      | Top of Atmosphere Upwelling Shortwave<br>Radiation All-Sky Conditions      | W/m <sup>2</sup>                | tsr  |
| toa_swup_clear    | Top of Atmosphere Upwelling Shortwave<br>Radiation Clear-Sky Conditions    | W/m <sup>2</sup>                | tsrc   |
| shfl              | Sensible Heat Flux   | W/m <sup>2</sup>                | sshf   |
| lhtfl             | Latent Heat Flux   | W/m <sup>2</sup>                | slhf   |
| cf_tot            | Total Cloud Fraction   | none                            | tcc  |
| sea_ice           | Sea Ice Cover  | none                            | ci   |
| weasd             | Snow Mass  | mm                              | sd   |
| prate             | Surface Precipitation Rate   | mm                              | tp   |
| srate             | Surface Snowfall Rate  | mm                              | sf   |
| rrate             | Liquid Precipitation Rate  | mm                              | tp - sf  |

Table 14. List of **GEWEX-SRB** rebinned  $1^{\circ} \times 1^{\circ}$  variables for rebinned 2x daily average into monthly mean.

| Variable Name  | Long Name   | Units                 | srb_rel3.0_shortwave_monthly_utc<br>srb_rel3.0_longwave_monthly_utc<br>Orig. Variable Name |
|----------------|---|-----------------------|--|
| lat            | Latitude  | degrees               | Center Latitude  |
| lon            | Longitude   | degrees               | Center Longitude   |
| time           | Time  | Days Since 1980-01-01 | Day number referenced to 15th day of the month   |
| month          | Month Number  | none                  | The number of the month of year (1-12)   |
| year           | Year  | none                  | The year   |
| boa_lwdn_all   | Bottom of Atmosphere Downwelling Longwave Radiation All-Sky Conditions    | W/m <sup>2</sup>      | lw_sfc_dn  |
| boa_lwdn_clear | Bottom of Atmosphere Downwelling Longwave Radiation Clear-Sky Conditions  | W/m <sup>2</sup>      | clr_lw_sfc_dn  |
| boa_lwup_all   | Bottom of Atmosphere Upwelling Longwave Radiation All-Sky Conditions      | W/m <sup>2</sup>      | lw_sfc_up  |
| boa_lwup_clear | Bottom of Atmosphere Upwelling Longwave Radiation Clear-Sky Conditions    | W/m <sup>2</sup>      | clr_lw_sfc_up  |
| boa_swdn_all   | Bottom of Atmosphere Downwelling Shortwave Radiation All-Sky Conditions   | W/m <sup>2</sup>      | sw_sfc_dn  |
| boa_swdn_clear | Bottom of Atmosphere Downwelling Shortwave Radiation Clear-Sky Conditions | W/m <sup>2</sup>      | clr_sw_sfc_dn  |
| boa_swup_all   | Bottom of Atmosphere Upwelling Shortwave Radiation All-Sky Conditions     | W/m <sup>2</sup>      | sw_sfc_up  |
| boa_swup_clear | Bottom of Atmosphere Upwelling Shortwave Radiation Clear-Sky Conditions   | W/m <sup>2</sup>      | clr_sw_sfc_up  |
| toa_lwup_all   | Top of Atmosphere Upwelling Longwave Radiation All-Sky Conditions         | W/m <sup>2</sup>      | lw_toa_up  |
| toa_lwup_clear | Top of Atmosphere Upwelling Longwave Radiation Clear-Sky Conditions       | W/m <sup>2</sup>      | clr_lw_toa_up  |
| toa_swdn_all   | Top of Atmosphere Downwelling Shortwave Radiation All-Sky Conditions      | W/m <sup>2</sup>      | sw_toa_dn  |
| toa_swup_all   | Top of Atmosphere Upwelling   | W/m <sup>2</sup>      | sw_toa_up  |

|                |  |                  |               |
|----------------|--|------------------|---------------|
|                | Shortwave Radiation All-Sky Conditions                               |                  |               |
| toa_swup_clear | Top of Atmosphere Upwelling Shortwave Radiation Clear-Sky Conditions | W/m <sup>2</sup> | clr_sw_toa_up |
| cf_tot         | Total Cloud Fraction   | none             | cld_frac      |

Table 15. List of **GLDAS** rebinned 0.25°×0.25° variables for rebinned monthly data.

| Variable Name     | Long Name  | Units                 | GLDAS_NOAH025_M.020 Orig. Variable Name        |
|-------------------|--|-----------------------|--|
| lat               | Latitude   | degrees               | Center Latitude                                |
| lon               | Longitude  | degrees               | Center Longitude                               |
| time              | Time   | Days Since 2002-01-01 | Day number referenced to 15th day of the month |
| month             | Month Number   | none                  | The number of the month of year (1-12)         |
| year              | Year   | none                  | The year                                       |
| seconds_per_month | Seconds Per Month  | s                     | The number of seconds in the given month       |
| runof             | Surface Runoff   | mm                    | Qs_GDS0_SFC                                    |
| runof_sbsfc       | Subsurface Runoff  | mm                    | Qsb_GDS0_SFC                                   |
| rrate             | Liquid Precipitation Rate                                | mm                    | Rainf_GDS0_SFC                                 |
| srate             | Surface Snowfall Rate                                    | mm                    | Snowf_GDS0_SFC                                 |
| prate             | Surface Precipitation Rate                               | mm                    |  |
| shfl              | Sensible Heat Flux                                       | W/m <sup>2</sup>      | Qh_GDS0_SFC_ave3h                              |
| lhtfl             | Latent Heat Flux   | W/m <sup>2</sup>      | Qle_GDS0_SFC_ave3h                             |
| soilw_10cm        | Soil Moisture between 0 and 2 cm Below Ground Level      | mm                    | SoilMoist1_GDS0_DBLV                           |
| soilw_200cm       | Soil Moisture between 0 and 200 cm Below Ground Level    | mm                    | SoilMoist1_GDS0_DBLV                           |
| soilt_10cm        | Soil Temperature between 0 and 10 cm Below Ground Level  | K                     | SoilTemp1_GDS0_DBLV                            |
| soilt_200cm       | Soil Temperature between 0 and 200 cm Below Ground Level | K                     | SoilTemp1_GDS0_DBLV                            |
| weasd             | Snow Mass  | mm                    | SWE_GDS0_SFC                                   |
| evapt             | Total Evapotranspiration                                 | mm                    | Evap_GDS0_SFC                                  |
| lat               | Latitude   | degrees               | Center Latitude                                |

Table 16. List of **GPCC** rebinned 0.5°×0.5° monthly mean variables.

| Variable Name     | Long Name         | Units                 | Additional information<br>orig file: full_data_v6 |
|-------------------|-------------------|-----------------------|---|
| lat               | Latitude          | degrees               | Center Latitude                                   |
| lon               | Longitude         | degrees               | Center Longitude                                  |
| time              | Time              | Days Since 1900-01-01 | Day number referenced to 15th day of the month    |
| month             | Month Number      | none                  | The number of the month of year (1-12)            |
| year              | Year              | none                  | The year  |
| seconds_per_month | Seconds Per Month | s                     | The number of seconds in the given month          |

|          |                            |      |  |
|----------|----------------------------|------|--|
| prate    | Surface Precipitation Rate | mm   | GPCC Full Data Reanalysis Version 6<br>0.5x0.5 Monthly Means rebinned to ArcticTS grid |
| n_gauges | Number of Gauges per Grid  | none | GPCC Full Data Product version 6   |

Table 17. List of **GRACE** rebinned 1°×1° monthly mean variables.

| Variable Name             | Long Name   | Units                    | file: GRCTellus<br>Orig. Variable Name               |
|---------------------------|---|--------------------------|--|
| lat                       | Latitude  | degrees                  | Center Latitude                                      |
| lon                       | Longitude   | degrees                  | Center Longitude                                     |
| time                      | Time  | Days Since<br>2002-01-01 | Day number<br>referenced to 15th day<br>of the month |
| month                     | Month Number  | none                     | The number of the<br>month of year (1-12)            |
| year                      | Year  | none                     | The year   |
| time_bounds               | Time Bounds   | Days Since<br>2002-01-01 | The start and end day<br>of each time bin            |
| seconds_per_month         | Seconds Per Month   | s                        | The number of<br>seconds in the given<br>month       |
| lwe_thickness_csr         | Anomaly Liquid Water<br>Equivalent Thickness (csr)            | mm                       | lwe_thickness  |
| lwe_thickness_csr_scaled  | Anomaly Liquid Water<br>Equivalent Thickness (csr)<br>Scaled  | mm                       | lwe_thickness using<br>conservative scale<br>factor  |
| lwe_thickness_gfz         | Anomaly Liquid Water<br>Equivalent Thickness (gfz)            | mm                       | lwe_thickness  |
| lwe_thickness_gfz_scaled  | Anomaly Liquid Water<br>Equivalent Thickness (gfz)<br>Scaled  | mm                       | lwe_thickness using<br>conservative scale<br>factor  |
| lwe_thickness_jpl         | Anomaly Liquid Water<br>Equivalent Thickness (jpl)            | mm                       | lwe_thickness  |
| lwe_thickness_jpl_scaled  | Anomaly Liquid Water<br>Equivalent Thickness (jpl)<br>Scaled  | mm                       | lwe_thickness using<br>conservative scale<br>factor  |
| lwe_thickness_mean        | Anomaly Liquid Water<br>Equivalent Thickness<br>(Mean)        | mm                       | mean of CSR, GFZ, and<br>JPL lwe_thickness           |
| lwe_thickness_mean_scaled | Anomaly Liquid Water<br>Equivalent Thickness<br>(Mean) Scaled | mm                       | lwe_thickness using<br>conservative scale<br>factor  |
| leakage_error             | Leakage Error   | mm                       | leakage_error.                                       |
| measurement_error         | Measurement Error   | mm                       | measurement_error.                                   |

Table 18. List of **GPCP** rebinned 2.5°×2.5° monthly mean variables from V2.2.

| Variable Name | Long Name | Units   |
|---------------|-----------|---------|
| lat           | Latitude  | degrees |
| lon           | Longitude | degrees |

|                   |                                  |                       |
|-------------------|----------------------------------|-----------------------|
| time              | Time                             | Days Since 2002-01-01 |
| month             | Month Number                     | none                  |
| year              | Year                             | none                  |
| seconds_per_month | Seconds Per Month                | s                     |
| prate             | Surface Precipitation Rate       | mm                    |
| prate_error       | Surface Precipitation Rate Error | mm                    |

Table 19. List of **MACC** reanalysis rebinned  $1^{\circ} \times 1^{\circ}$  monthly mean variables.

| Variable Name | Long Name                            | Units                 | Orig. Variable Name                            |
|---------------|--------------------------------------|-----------------------|--|
| lat           | Latitude                             | degrees               | Center Latitude                                |
| lon           | Longitude                            | degrees               | Center Longitude                               |
| time          | Time                                 | Days Since 2002-01-01 | Day number referenced to 15th day of the month |
| month         | Month Number                         | none                  | The number of the month of year (1-12)         |
| year          | Year                                 | none                  | The year                                       |
| aod550        | Total Aerosol Optical Depth at 550nm | none                  | AOD550   |
| aod865        | Total Aerosol Optical Depth at 865nm | none                  | AOD865   |
| bcaod         | Black Carbon Aerosol Optical Depth   | none                  | BCAOD550                                       |
| duaod         | Dust Aerosol Optical Depth           | none                  | DUAOD550                                       |
| omaod         | Organic Matter Aerosol Optical Depth | none                  | OMAOD550                                       |
| ssaod         | Sea Salt Aerosol Optical Depth       | none                  | SSAOD550                                       |
| suaod         | Sulphate Aerosol Optical Depth       | none                  | SUAOD550                                       |
| ang_550_865   | Angstrom Exponent                    | none                  | derived from aod550 and aod865                 |

Table 20. List of **MERRA** reanalysis rebinned  $1.25^{\circ} \times 1.25^{\circ}$  monthly mean variables.

| Variable Name     | Long Name                | Units                 | Orig. Variable Name  |
|-------------------|--------------------------|-----------------------|--|
|                   |                          |                       | MERRA100.prod.assim.instM_3d_ana_Np<br>MERRA100.prod.assim.tavgM_2d_flux_Nx,<br>MERRA100.prod.assim.tavgM_2d_flux_Nx,<br>MERRA100.prod.simul.tavgM_2d_mld_Nx,<br>MERRA101.prod.assim.tavgM_2d_rad_Nx |
| lat               | Latitude                 | degrees               | Center Latitude  |
| lon               | Longitude                | degrees               | Center Longitude   |
| time              | Time                     | Days Since 1980-01-01 | Day number referenced to 15th day of the month   |
| month             | Month Number             | none                  | The number of the month of year (1-12)   |
| year              | Year                     | none                  | The year   |
| seconds_per_month | Seconds Per Month        | s                     | # sec in month   |
| lev               | Pressure Levels          | hPa                   | Pressure level   |
| t_skin            | Surface Skin Temperature | K                     | tavgM_2d_rad_Nx ts   |
| asfc              | Surface Albedo           | none                  | tavgM_2d_rad_Nx albedo   |

|                |  |                  |                          |
|----------------|--|------------------|--------------------------|
| boa_lwdn_all   | Bottom of Atmosphere<br>Downwelling<br>Longwave Radiation<br>All-Sky Conditions    | W/m <sup>2</sup> | tavgM_2d_rad_Nx lwgab    |
| boa_lwdn_clear | Bottom of Atmosphere<br>Downwelling<br>Longwave Radiation<br>Clear-Sky Conditions  | W/m <sup>2</sup> | tavgM_2d_rad_Nx lwgabclr |
| boa_lwup_all   | Bottom of Atmosphere<br>Upwelling Longwave<br>Radiation All-Sky<br>Conditions      | W/m <sup>2</sup> | tavgM_2d_rad_Nx lwgem    |
| boa_lwup_clear | Bottom of Atmosphere<br>Upwelling Longwave<br>Radiation Clear-Sky<br>Conditions    | W/m <sup>2</sup> | tavgM_2d_rad_Nx lwgntclr |
| boa_swdn_all   | Bottom of Atmosphere<br>Downwelling<br>Shortwave Radiation<br>All-Sky Conditions   | W/m <sup>2</sup> | tavgM_2d_rad_Nx swgdn    |
| boa_swdn_clear | Bottom of Atmosphere<br>Downwelling<br>Shortwave Radiation<br>Clear-Sky Conditions | W/m <sup>2</sup> | tavgM_2d_rad_Nx swgdnclr |
| boa_swup_all   | Bottom of Atmosphere<br>Upwelling Shortwave<br>Radiation All-Sky<br>Conditions     | W/m <sup>2</sup> | tavgM_2d_rad_Nx swgnt    |
| boa_swup_clear | Bottom of Atmosphere<br>Upwelling Shortwave<br>Radiation Clear-Sky<br>Conditions   | W/m <sup>2</sup> | tavgM_2d_rad_Nx swgntclr |
| toa_lwup_all   | Top of Atmosphere<br>Upwelling Longwave<br>Radiation All-Sky<br>Conditions         | W/m <sup>2</sup> | tavgM_2d_rad_Nx lwtup    |
| toa_lwup_clear | Top of Atmosphere<br>Upwelling Longwave<br>Radiation Clear-Sky<br>Conditions       | W/m <sup>2</sup> | tavgM_2d_rad_Nx lwtupclr |
| toa_swdn_all   | Top of Atmosphere<br>Downwelling<br>Shortwave Radiation<br>All-Sky Conditions      | W/m <sup>2</sup> | tavgM_2d_rad_Nx swtdn    |
| toa_swup_all   | Top of Atmosphere<br>Upwelling Shortwave<br>Radiation All-Sky<br>Conditions        | W/m <sup>2</sup> | tavgM_2d_rad_Nx swtnt    |
| toa_swup_clear | Top of Atmosphere<br>Upwelling Shortwave<br>Radiation Clear-Sky<br>Conditions      | W/m <sup>2</sup> | tavgM_2d_rad_Nx swtntclr |
| cod_high       | Optical Thickness of<br>High Clouds  | none             | tavgM_2d_rad_Nx tauhgh   |

|            |   |                  |                          |
|------------|---|------------------|--------------------------|
| cod_low    | Optical Thickness of Low Clouds                         | none             | tavgM_2d_rad_Nx taulow   |
| cod_mid    | Optical Thickness of Mid-Level Clouds                   | none             | tavgM_2d_rad_Nx taumid   |
| cod_tot    | Optical Thickness of All Clouds                         | none             | tavgM_2d_rad_Nx tautot   |
| cf_high    | Cloud Fraction High Clouds                              | none             | tavgM_2d_rad_Nx cldhgh   |
| cf_mid     | Cloud Fraction Mid-Level Clouds                         | none             | tavgM_2d_rad_Nx cldmid   |
| cf_low     | Cloud Fraction Low Clouds                               | none             | tavgM_2d_rad_Nx cldlow   |
| cf_tot     | Total Cloud Fraction                                    | none             | tavgM_2d_rad_Nx cldtot   |
| soilt_2cm  | Soil Temperature between 0 and 2 cm Below Ground Level  | K                | tavgM_2d_mld_Nx tsoil1   |
| soilt_10cm | Soil Temperature between 0 and 10 cm Below Ground Level | K                | tavgM_2d_mld_Nx tsoil2   |
| prate      | Surface Precipitation Rate                              | mm               | tavgM_2d_lnd_Nx prectot  |
| srate      | Surface Snowfall Rate                                   | mm               | tavgM_2d_lnd_Nx prec sno |
| rrate      | Liquid Precipitation Rate                               | mm               | tavgM_2d_lnd_Nx          |
| weasd      | Snow Mass   | mm               | tavgM_2d_lnd_Nx snodp    |
| runof      | Surface Runoff  | mm               | tavgM_2d_lnd_Nx runoff   |
| lhtfl      | Latent Heat Flux  | W/m <sup>2</sup> | tavgM_2d_flux_Nx eflux   |
| shfl       | Sensible Heat Flux                                      | W/m <sup>2</sup> | tavgM_2d_flux_Nx hflux   |
| pblh       | Planetary Boundary Layer Height                         | m                | tavgM_2d_flux_Nx pblh    |
| evap       | Surface Potential Evaporation                           | mm               | tavgM_2d_flux_Nx evap    |
| slp        | Sea-Level Pressure                                      | hPa              | instM_3d_ana_Np slp      |
| psfc       | Surface Pressure  | hPa              | instM_3d_ana_Np ps       |
| h          | Geopotential Height                                     | m                | instM_3d_ana_Np h        |
| t          | Air Temperature   | K                | instM_3d_ana_Np t        |
| u          | Zonal Wind  | m/s              | instM_3d_ana_Np u        |
| v          | Meridional Wind   | m/s              | instM_3d_ana_Np v        |
| qv         | Specific Humidity                                       | g/kg             | instM_3d_ana_Np qv       |
| o3         | Ozone   | g/kg             | instM_3d_ana_Np o3       |

Table 21. List of **MODIS-L3** rebinned 1°×1° monthly data.

| Variable Name | Long Name    | Units                 | MODIS MYD08_M3 Orig. Variable Name             |
|---------------|--------------|-----------------------|--|
| lat           | Latitude     | degrees               | Center Latitude                                |
| lon           | Longitude    | degrees               | Center Longitude                               |
| time          | Time         | Days Since 2002-01-01 | Day number referenced to 15th day of the month |
| month         | Month Number | none                  | The number of the month of year (1-12)         |



|             |   |                  |  |
|-------------|---|------------------|--|
| year        | Year  | none             | The year                                       |
| cre_tot     | Effective Particle Radius of All Clouds   | microns          | Cloud_Effective_Radius_Combined_Mean_Mean      |
| cre_ice     | Effective Particle Radius of Ice Clouds   | microns          | Cloud_Effective_Radius_Ice_Mean_Mean           |
| cre_liq     | Effective Particle Radius of Liquid Water Clouds  | microns          | Cloud_Effective_Radius_Liquid_Mean_Mean        |
| cre_und     | Effective Particle Radius of Undetermined Phase Clouds  | microns          | Cloud_Effective_Radius_Undetermined_Mean_Mean  |
| cf_tot      | Total Cloud Fraction  | none             | Cloud_Fraction_Combined_FMean                  |
| cf_ice      | Cloud Fraction Ice Clouds   | none             | Cloud_Fraction_Ice_FMean                       |
| cf_liq      | Cloud Fraction Liquid Water Clouds  | none             | Cloud_Fraction_Liquid_FMean                    |
| cf_tot_mask | Total Cloud Fraction from Cloud Mask (count of lowest 2 clear sky confidence levels cloudy & probably cloudy / total count) | none             | Cloud_Fraction_Mean_Mean                       |
| cf_pix      | Total of Level-3 Input Pixel Daily Counts in Cloud Fraction   | none             | Cloud_Fraction_Pixel_Counts                    |
| cf_und      | Cloud Fraction Undetermined Phase Clouds  | none             | Cloud_Fraction_Undetermined_FMean              |
| cod_tot     | Optical Thickness of All Clouds   | none             | Cloud_Optical_Thickness_Combined_Mean_Mean     |
| cod_ice     | Optical Thickness of Ice Clouds   | none             | Cloud_Optical_Thickness_Ice_Mean_Mean          |
| cod_liq     | Optical Thickness of Liquid Water Clouds  | none             | Cloud_Optical_Thickness_Liquid_Mean_Mean       |
| cod_und     | Optical Thickness of Undetermined Phase Clouds  | none             | Cloud_Optical_Thickness_Undetermined_Mean_Mean |
| ctp         | Cloud Top Pressure  | hPa              | Cloud_Top_Pressure_Mean_Mean                   |
| ctt         | Cloud Top Temperature   | K                | Cloud_Top_Temperature_Mean_Mean                |
| cwp_tot     | Total Cloud Water Path  | g/m <sup>2</sup> | Cloud_Water_Path_Combined_Mean_Mean            |
| cwp_ice     | Cloud Water Path Ice Clouds   | g/m <sup>2</sup> | Cloud_Water_Path_Ice_Mean_Mean                 |
| cwp_liq     | Cloud Water Path Liquid Water Clouds  | g/m <sup>2</sup> | Cloud_Water_Path_Liquid_Mean_Mean              |

|          |  |                  |   |
|----------|--|------------------|---|
| cwp_und  | Cloud Water Path Undetermined Phase Clouds               | g/m <sup>2</sup> | Cloud_Water_Path_Undetermined_Mean_Mean   |
| aod550   | Total Aerosol Optical Depth at 550nm                     | none             | Optical_Depth_Land_And_Ocean_Mean_Mean    |
| n_aod550 | Number of points in Total Aerosol Optical Depth at 550nm | none             | Optical_Depth_Land_And_Ocean_Pixel_Counts |

Table 22. List of **NCEP** reanalysis 2 rebinned 1.25°×1.25° daily averaged variables

| Variable Name     | Long Name  | Units                 | Orig. File<br>Orig. Variable Name                                      |
|-------------------|--|-----------------------|--|
| lat               | Latitude   | degrees               | Center Latitude  |
| lon               | Longitude  | degrees               | Center Longitude   |
| time              | Time   | Days Since 2000-01-01 | Day number referenced to 15th day of the month                         |
| month             | Month Number   | none                  | The number of the month of year (1-12)                                 |
| year              | Year   | none                  | The year   |
| seconds_per_month | Seconds Per Month  | s                     | The number of seconds in the given month                               |
| lev               | Pressure Levels  | hPa                   | The vertical coordinate of NCEP in Pressure                            |
| h                 | Geopotential Height  | m                     | hgt  |
| t                 | Air Temperature  | K                     | air  |
| rh                | Relative Humidity  | none                  | rhum   |
| qv                | Specific Humidity  | g/kg                  | NCEP Reanalysis 2 Monthly Sampled derived from variables: air and rhum |
| u                 | Zonal Wind   | m/s                   | uwnd   |
| v                 | Meridional Wind  | m/s                   | vwnd   |
| omega             | Omega  | Pa/s                  | omega  |
| psfc              | Surface Pressure   | hPa                   | pres.sfc   |
| t_skin            | Surface Skin Temperature                                       | K                     | skt.sfc  |
| t_2m              | Air Temperature at 2 Meters                                    | K                     | air.2m   |
| t_min_2m          | Minimum Air Temperature at 2 Meters                            | K                     | tmin.2m  |
| t_max_2m          | Maximum Air Temperature at 2 Meters                            | K                     | tmax.2m  |
| t_above_freezing  | Fraction of Days Air Temperature at 2 Meters is Above Freezing | none                  | NCEP Reanalysis 2 Monthly Sampled derived from variable: air.2m        |
| qv_2m             | Specific Humidity at 2 Meters                                  | g/kg                  | shum.2m  |
| u_10m             | Zonal Wind at 10 Meters  | m/s                   | uwnd.10m   |
| v_10m             | Meridional Wind at 10 Meters                                   | m/s                   | vwnd.10m   |
| uflx              | Zonal Wind Momentum Flux                                       | N/m <sup>2</sup>      | uflx.sfc   |
| ugwd              | Zonal Gravity Wave Stress at Surface                           | N/m <sup>2</sup>      | ugwd.sfc   |
| vflx              | Meridional Wind Momentum Flux                                  | N/m <sup>2</sup>      | vflx.sfc   |
| vgwd              | Meridional Gravity Wave Stress at Surface                      | N/m <sup>2</sup>      | vgwd.sfc   |

|              |   |                  |                |
|--------------|---|------------------|----------------|
| soilw_10cm   | Soil Moisture between 0 and 2 cm Below Ground Level                     | none             | soilw.0-10cm   |
| soilw_200cm  | Soil Moisture between 0 and 200 cm Below Ground Level                   | none             | soilw.10-200cm |
| soilt_10cm   | Soil Temperature between 0 and 10 cm Below Ground Level                 | K                | tmp.0-10cm     |
| soilt_200cm  | Soil Temperature between 0 and 200 cm Below Ground Level                | K                | tmp.10-200cm   |
| icec         | Sea Ice Fraction  | none             | icec.sfc       |
| weasd        | Snow Mass   | mm               | weasd.sfc      |
| runof        | Surface Runoff  | mm               | runof.sfc      |
| prate        | Surface Precipitation Rate  | mm               | prate.sfc      |
| prate_conv   | Surface Convective Precipitation Rate                                   | mm               | cprat.sfc      |
| pevap        | Accumulated Potential Evaporation                                       | W/m <sup>2</sup> | pevpr.sfc      |
| gflux        | Ground Heat Flux  | W/m <sup>2</sup> | gflux.sfc      |
| lhtfl        | Latent Heat Flux  | W/m <sup>2</sup> | lhtfl.sfc      |
| shfl         | Sensible Heat Flux  | W/m <sup>2</sup> | shtfl.sfc      |
| cf_tot       | Total Cloud Fraction  | none             | tcdc.eatm      |
| boa_lwdn_all | Bottom of Atmosphere Downwelling Longwave Radiation All-Sky Conditions  | W/m <sup>2</sup> | dlwrf.sfc      |
| boa_lwup_all | Bottom of Atmosphere Upwelling Longwave Radiation All-Sky Conditions    | W/m <sup>2</sup> | ulwrf.sfc      |
| boa_swup_all | Bottom of Atmosphere Upwelling Shortwave Radiation All-Sky Conditions   | W/m <sup>2</sup> | uswrf.sfc      |
| boa_swdn_all | Bottom of Atmosphere Downwelling Shortwave Radiation All-Sky Conditions | W/m <sup>2</sup> | dswrf.sfc      |
| toa_lwup_all | Top of Atmosphere Upwelling Longwave Radiation All-Sky Conditions       | W/m <sup>2</sup> | ulwrf.ntat     |
| toa_swup_all | Top of Atmosphere Upwelling Shortwave Radiation All-Sky Conditions      | W/m <sup>2</sup> | uswrf.ntat     |
| toa_swdn_all | Top of Atmosphere Downwelling Shortwave Radiation All-Sky Conditions    | W/m <sup>2</sup> | dswrf.ntat     |

Table 23. List of **NOAA** Climate Index variables

| Variable Name    | Long Name                              |
|------------------|--|
| time             | Time (days since 1885-01-01)           |
| month            | Month Number                           |
| year             | Year                                   |
| n_sunspots       | Sunspot Count                          |
| n_days_reporting | Number days in Month with Sunspot Data |
| ao               | Arctic Oscillation                     |
| ea               | Eastern Asia/Western Russia            |
| epo              | East Pacific/North Pacific Oscillation |
| hurr             | Hurricane activity                     |
| mei              | Multivariate ENSO Index                |
| nao              | North Atlantic Oscillation             |
| noi              | Northern Oscillation Index             |

|       |                                  |
|-------|----------------------------------|
| pdo   | Pacific Decadal Oscillation      |
| pna   | Pacific North American Index     |
| qbo   | Quasi-Biennial Oscillation       |
| soi   | Southern Oscillation Index       |
| solar | Solar Flux (10.7cm)              |
| tna   | Tropical Northern Atlantic Index |
| tsa   | Tropical Southern Atlantic Index |
| whwp  | Western Hemisphere warm pool     |
| wp    | Western Pacific Index            |

Table 24. List of **NSIDC** rebinned 25 km spatial resolution weekly averaged variables from the National Snow & Ice Data Center EASE weekly product

| Variable Name | Long Name                          | Units                            |
|---------------|------------------------------------|----------------------------------|
| lat           | Latitude                           | degrees                          |
| lon           | Longitude                          | degrees                          |
| time          | Time                               | Days Since 2002-01-01            |
| month         | Month Number                       | none                             |
| year          | Year                               | none                             |
| n_points      | Number of Datapoints               | none                             |
| icec          | Sea Ice Fraction                   | none                             |
| snowc         | Snow Covered Land Fraction         | none                             |
| NH_ice_area   | Northern Hemisphere Sea Ice Area   | 10 <sup>6</sup> *km <sup>2</sup> |
| NH_ice_extent | Northern Hemisphere Sea Ice Extent | 10 <sup>6</sup> *km <sup>2</sup> |

Table 25. List of **QBudget** variables. Details about this data can be found in Wong et al. (2011).

| Variable Name     | Long Name                                   | Units                 |
|-------------------|---|-----------------------|
| lat               | Latitude                                    | degrees               |
| lon               | Longitude                                   | degrees               |
| time              | Time  | Days Since 2002-01-01 |
| month             | Month Number                                | none                  |
| year              | Year  | none                  |
| seconds_per_month | Seconds Per Month                           | s                     |
| lev               | Pressure Levels                             | hPa                   |
| qsrcsnk           | Water Vapor Divergence                      | g/kg/s                |
| quflx             | Zonal Water Vapor Flux                      | g/kg/s                |
| qvflx             | Meridional Water Vapor Flux                 | g/kg/s                |
| qwflx             | Vertical Water Vapor Flux                   | g/kg/s                |
| divhflx           | Horizontal Flux Divergence                  | g/kg/s                |
| divwflx           | Vertical Flux Divergence                    | g/kg/s                |
| qhadv             | Horizontal Water Vapor Advection            | g/kg/s                |
| qwadv             | Vertical Water Vapor Advection              | g/kg/s                |
| dqdt              | Water Vapor Tendency                        | g/kg/s                |
| qv                | Specific Humidity                           | g/kg                  |
| pmv               | Water Vapor Precipitation Minus Evaporation | g/kg                  |

|          |  |    |
|----------|--|----|
| pme_airs | AIRS Water Vapor Precipitation minus Evaporation | mm |
|----------|--|----|

Table 26. List of **RegionMask** variables.

| Variable Name     | Long Name                          | Units           |
|-------------------|------------------------------------|-----------------|
| lat               | Latitude                           | degrees         |
| lon               | Longitude                          | degrees         |
| grid_surface_area | The surface area in each grid box  | km <sup>2</sup> |
| elevation         | Elevation                          | m               |
| land_fraction     | Land Fraction                      | none            |
| america           | The region defining America        | none            |
| arctic_ocean      | The region defining Arctic Ocean   | none            |
| baffin_bay        | The region defining Baffin Bay     | none            |
| barents_sea       | The region defining Barents Sea    | none            |
| eurasia           | The region defining Eurasia        | none            |
| greenland         | The region defining Greenland      | none            |
| greenland_sea     | The region defining Greenland Sea  | none            |
| ncep_land_mask    | The region defining NCEP Land Mask | none            |
| siberia           | The region defining Siberia        | none            |