TOVS Pathfinder Path-P Daily and Monthly Polar Gridded Atmospheric Parameters, Version 1

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Francis, J. A. and A. J. Schweiger. 1999, updated 2008. *TOVS Pathfinder Path-P Daily and Monthly Polar Gridded Atmospheric Parameters, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/7L44Z9QVXUNL. [Date Accessed].

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National Snow and Ice Data Center

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1   DETAILED DATA DESCRIPTION

The NOAA/NASA Pathfinder Program was initiated to provide scientists with global-scale remote sensing data ahead of NASA's Earth Observing System satellite launches. The Pathfinder concept involved careful reprocessing of existing data sets which could be made readily available as high quality products for global change research. Because the polar regions hold special significance in the climate system, the Polar Pathfinders have established a cooperation to maximize the scientific potential of their data sets.

The TIROS TOVS has flown on NOAA polar-orbiting satellites since 1978 and has generated one of the longest and most complete satellite data records in existence. Radiances from the global TOVS data set have been subsetted and processed for the Arctic region, and the retrieved products are presented on a regular grid in a user-friendly format.

The TOVS Path-P provides users with gridded daily Arctic atmospheric soundings. These data were obtained to identify geophysical parameters in snow- and ice-covered areas (Francis 1994). The data set has been designed to address the particular needs of the polar research community including quantities used to compute surface turbulent fluxes and to drive ocean models.

The modified 3I algorithm (Chedin et al. 1985) is applied to the TOVS high-resolution infrared radiation sounder (HIRS) and the microwave sounding unit (MSU) level-1b radiances to generate daily gridded Arctic atmospheric variables. (Radiances were obtained from the National Environmental Satellite Data Service Division and the National Center for Atmospheric Research.) The grids have a spatial resolution of 100 km, and use observations from areas poleward of 60° N and 60° S. The 3I method combines statistical and physical techniques to estimate these geophysical quantities, which are then averaged over a 24-hour period centered at 12:00 Coordinated Universal Time (UTC) to produce one Arctic-wide field per day. Estimates are then organized onto a rectangular grid using a "drop-in-the-bucket" approach.

The data are gridded to the EASE-Grid (Armstrong and Brodzik 1995) equal-area azimuthal projection centered on the North and South Poles. This facilitates combining TOVS data set with other data sets, and opens the door to studies using data from a variety of sources (such as SSM/I and AVHRR data).

The algorithm used to generate these atmospheric variables has been validated directly through comparisons with surface observations from the Coordinated Eastern Arctic Experiment (CEAREX), North Polar drifting station data, and with radiosonde data from Russian ice stations. Comparisons with other TOVS retrieval algorithms provided further validation.

1.1 File Information

1.1.1 File Format

Data are stored in Hierarchical Data Format (HDF), developed by the National Center for Supercomputing Applications (NCSA), and they follow standards and recommendations outlined in the EOSDIS Version 0 Data Product Implementation Guidelines. TOVS Path-P data can be read by analysis tools capable of reading HDF data or using supplied sample programs.

Each daily and monthly file contains a group of 16 HDF Scientific Data Sets. Metadata are implemented as global attributes containing information about the data set dates and times. Much of this information may not be relevant to the user, but it is included for production and archiving purposes. The metadata consist of 25 global attributes.

The grid dimensions of the sixteen Scientific Data Sets for the Northern Hemisphere are 67 rows by 67 columns and for the Southern Hemisphere are 89 rows by 89 columns. Only two Scientific Data Sets are structured as three-dimensional arrays. The three-dimensional field TEMP has 10 levels in the vertical dimension, while WVAPOR has 5 layers. All data sets are represented as 32-bit floating point values. For more information, see Appendix A: Data Dictionary and Appendix B: Geometry Class.

1.1.2 Directory Structure

The TOVS data are available from the HTTPS site in two directories divided up by region: north and south. Within the north directory, the data are further subdivided into daily and monthly directories. Within the south directory, the data are further subdivided into a daily directory. These directories are in turn subdivided into annual directories of the form yyyy. A tools directory is also provided which includes scripts for viewing and accessing the data. See the Software and Tools section of this document for more information about these tools. Figure 1 displays the directory structure.
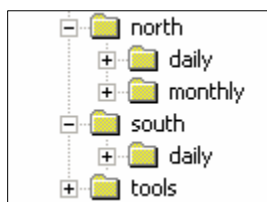

Figure 1. HTTPS
Directory Structure

1.1.3 File Naming Convention

The data files are named according to the following convention and as described in Table 1.

Daily: `tpp_Nss_h100_yyyyddd_daily.vx-y.hdf`

Monthly: `tpp_Nss_h100_yyyymm_monthly.vx-y.hdf`

Table 1. File Naming Convention Description

Variable	Description
tpp	Indicates this is TOVS Path-P data
N	Indicates NOAA satellite
ss	2-digit NOAA satellite identifier (06, 07, 09, 10, 11, 12, or 14)
h	Hemisphere (n: Northern Hemisphere or s: Southern Hemisphere) Note: There are no monthly files for the Southern Hemisphere
100	Indicates 100 km gridded data
yyyy	4-digit year
ddd	3-digit day of year (daily files only)
mm	2-digit month (monthly files only)
daily	Indicates this is a daily data file
monthly	Indicates this is a monthly data file
vx-y	two-part version number (for example, v3-4)
.hdf	File extension indicates an HDF file

For example, tpp_N06_s100_1987294_daily.v3-3.hdf or tpp_N14_n100_200412_monthly.v3-4.hdf.

Note: The transition of data collection from NOAA 10 to NOAA 11 occurred during the month of September 1991. The file name for the September 1991 monthly data file contains both satellite identifiers as N10N11 indicating that data in this file came from both satellites.

1.2 Spatial Information

1.2.1 Coverage

Northern Hemisphere files: 60° N to 90° N
Southern Hemisphere files: 60° S to 90° S

1.2.2 Resolution

Nominal grid spacing of the TOVS Path-P products is 100.2701 km. The TOVS EASE-Grid spacing is not exactly 100 km because the grid, originally designed for the 25 km Special Sensing

Microwave/Imager (SSM/I), required a slightly larger actual cell size (C=25.067525 km) to exactly span the equator. For sake of data product consistency, this cell size was used for all other EASE-Grid products. Of course, few cells actually have these dimensions, but they all have the same area.

1.2.3   Projection

The north and south EASE-Grids are based on an equal area azimuthal projection, centered on the North and South Poles, respectively. Grid spacing of the TOVS products is 100.2701 km, resulting in a 67-row by 67-column grid size for the Northern Hemisphere and an 89-row by 89-column grid size for the Southern Hemisphere.

The grid coordinates, r and s, are defined with axes parallel to the rows (s) and columns (r) of the grid and units equal to the sampling interval. The grid sample locations (grid-cell centers) are then the integer coordinate points. The coordinate system starts at the top left corner with r increasing to the right, and s increasing downward. A grid cell (j,i) in the r,s coordinate system is defined as the area between grid coordinates i-0.5 and i+0.5, and j-0.5 and j+0.5. The lower bound is included in the grid cell, while the upper bound is not; i and j are zero-based array indices for this grid cell. This definition means that the grid cells are referenced in r and s by their grid cell center coordinate.

Figure 2 shows the equations to convert between latitude and longitude coordinates and r,s grid coordinates.

Forward equations to convert from (λ, ϕ) **to (r,s):**

$$r = \rho \sin(\lambda) + r_0$$
$$s = \rho \cos(\lambda) + s_0$$

$$\rho = \left(\frac{2R}{C}\right) \sin\left(\frac{\pi}{4} - \frac{\phi}{2}\right)$$

where:

R (Earth radius)   = 6371.228 km
C (Grid cell size)   = 100.27 km
r_0, s_0 (grid origin in r,s)   = 33.0, 33.0
λ Longitude
ϕ Latitude

Array indices i,j are found from r,s by rounding to the nearest integer

Inverse equations to convert from (r,s) to (λ,ϕ):

$$\kappa = \sqrt{x^2 + y^2}$$

if $\kappa \neq 0$:

$$\phi = asin(\cos c)$$

$$\lambda = atan \frac{x}{y}$$

$$c = 2\ asin\left(\frac{\kappa}{2R}\right)$$

where:

$$x = (r - r_0)\ C$$
$$y = (s - s_0)\ C$$

if $\kappa = 0$:

$$\phi = \frac{\pi}{2}$$
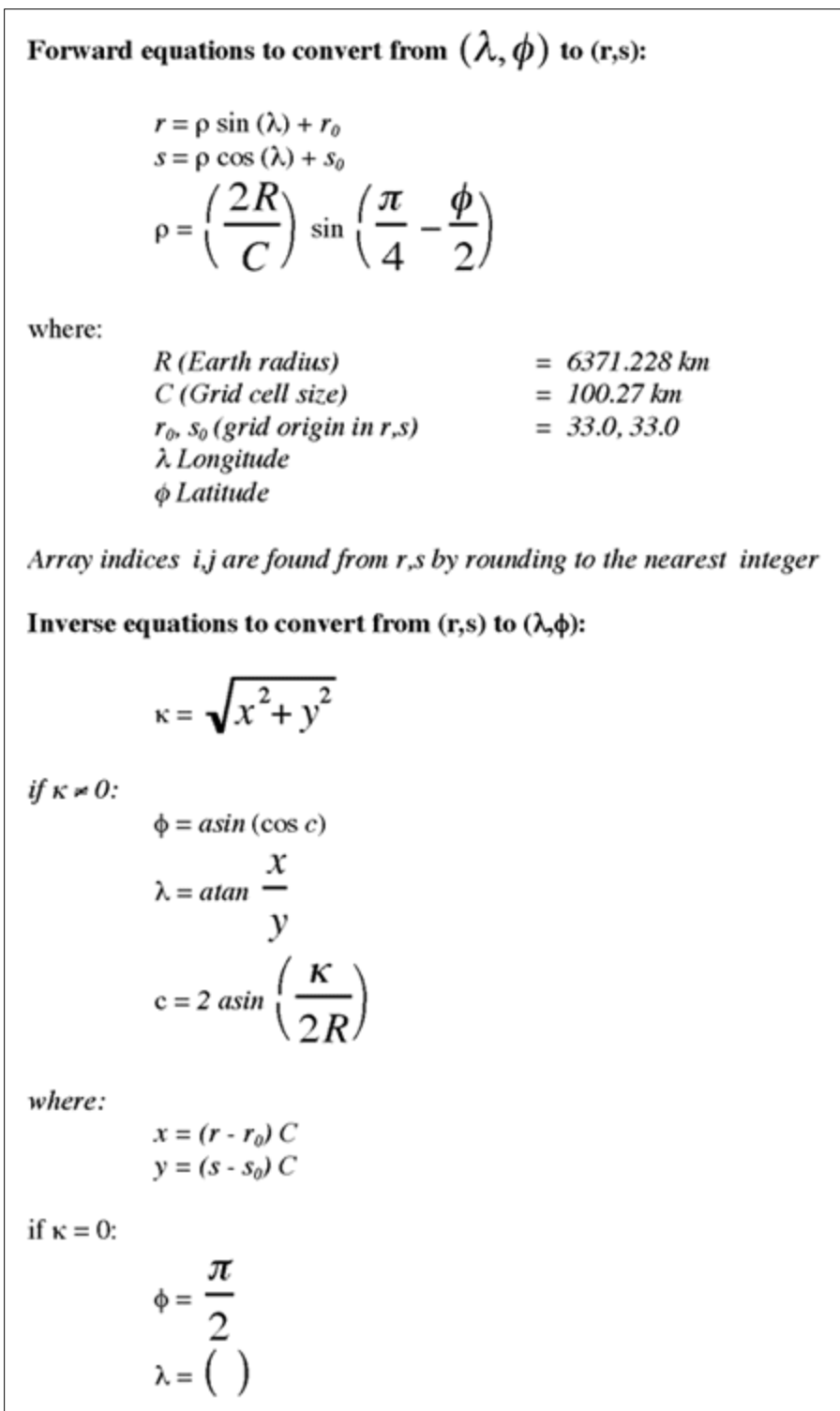
$$\lambda = (\ )$$

Figure 2. Equations to convert between latitude and longitude coordinates
and r,s grid coordinates.

Note: Latitude and longitude coordinates for each of the Path-P grid cells are included with the data set as well as elevation information and a land mask in ancillary data files: tpp_n100_9999999_ancil.hdf for the Northern Hemisphere and tpp_s100_9999999_ancil.hdf for

the Southern Hemisphere. For more information see the Software and Tools section of this document.

1.2.4   Grid Description

The TOVS Path-P EASE-Grids are based on an azimuthal equal-area projection for the Northern and Southern Hemispheres, with a grid resolution of 100 km. Please see All about EASE-Grid for more information on the EASE-Grid projection parameters and grid definitions.

1.3 Temporal Information

1.3.1   Coverage

For the Arctic (north), data exists from 1 January 1979 to 31 December 2005. For Antarctica (south), data exists from 1 July 1979 to 31 December 2001.

For some days, TOVS Level 1b data were either unavailable or of insufficient quality to ingest into the Path-P processing algorithm. When this occurred, files are available for these days but contain no data. See the Missing Data Files list under the Support tab for the specific dates.

1.3.2   Resolution

Daily data are linear averages of retrievals from all orbits for a single day, defined from 00:00:00 UTC to (excluding) 00:00:00 UTC of the following day. Users will also find files that are very small in size. Data were not available from NOAA for certain orbits but to maintain chronological integrity, files have been added as placeholders to complete the time series.

1.4 Parameter

Table 2 summarizes the parameters in this data set.

Table 2. Summary of Data Set Parameters

Variable	Description	Units
TEMP	Temperatures at pressure levels: 50, 70, 100, 300, 400, 500, 600, 700, 850 and 900 mb	kelvins
WVAPOR	Precipitable water in layers bounded by: 300-400, 400-500, 500-700, 700-850, 850-900 mb	millimeters
SKTEMP	Surface Skin Temperature	kelvins

Variable	Description	Units
HIRS_CLDY	Fraction of cloudy pixels per III retrieval box	percent
FCLD	Total effective cloud fraction	percent
CLPRESS	Cloud-top pressure	millibars (hectopascals)
CLTEMP	Cloud-top temperature	kelvins
EMISS	Emissivity at 50 GHz	none
ISICE	Surface Type Flag	0 = Open 1 = ice 3 = land 10 = last orbit showed open water, but changed from orbit to orbit 11 = last orbit showed ice, but changed from orbit to orbit 13 = last orbit showed land, but changed from orbit to orbit
SOLZEN	Average solar zenith angle (daily only)	degrees
PRESS	NCEP sea level pressure	millibars
PBLSTRAT	Boundary layer bulk stratification	kelvins
Cg	Geostrophic drag coefficient over sea ice (daily only)	none
ALPHA	Turning angle between geostrophic wind and the surface wind over sea ice (daily only)	degrees

WVAPOR

The weighting functions of the CO_2 absorption bands used by the TOVS retrieval algorithms limit the vertical resolution of the water vapor retrievals to 5 layers between the surface and 300 mb.

ISICE

Surface classifications may differ from orbit to orbit resulting in examples of daily averaged ice warmer than 273.15 K and water colder than 271.3 K.

SOLZEN

The solar zenith angle is the integral from sunrise to sunset divided by the time from sunrise to sunset. This integral is not just a function of solar zenith angle but also a function of day length.

PBLSTRAT

The bulk stratification parameter is defined as the difference in potential temperature between the 1000 and 900 mb levels. It provides a measure of the boundary layer stability. This value tends to

be more negative during the winter when surface inversions are common in the Arctic, than in warmer months.

PBLSTRAT is used to compute the geostrophic drag coefficient and a surface stress turning angle based on the parameterization developed by Overland and Davidson (1992) and Overland and Colony (1994). These parameters are useful for estimating near-surface winds, surface stress, and turbulent fluxes.

PBLSTRAT describes the difference in potential temperature between the 1000 and 900 mb levels, and provides a bulk measure of the stratification in the atmospheric boundary layer. In grid boxes with a sea-ice surface, this value is used to compute Cg, the geostrophic drag coefficient, and ALPHA, the turning angle between the geostrophic wind and the surface stress, using an empirically derived relationship.

Cg

The geostrophic drag coefficient can vary in space and time by a factor of 2 owing to differences in the strength of near-surface temperature inversion. Thus, large spatial variations in Cg may occur and correspond to surface pressure features.

SKTEMP

Surface skin temperature is the radiating temperature of the surface, which may differ from the actual surface temperature if the surface emissivity is less than unity. For more information see Francis and Schweiger 1999.

HIRS_CLDY and FCLD

Two measures of cloud fraction are available within a grid box. The first, FCLD or the effective cloud fraction, is the product of the cloud cover in a grid box and cloud emissivity. Although useful for some studies, it proves difficult to validate with surface observations when clouds are not optically thick in the infrared spectral region. Thin clouds are common in the Arctic, thus FCLD and HIRS_CLDY, the fraction of HIRS fields-of-view within a grid box that are identified as cloudy, can be significantly different from each other.

Most of the products listed above are standard atmospheric variables, but a few, surface skin temperature, cloud fraction and the potential temperature between 1000 and 900 mb, were added specifically for polar research and require some explanation.

Note

Designed so that all parameters are filtered by elevation, the modified 3I algorithm (Chedin et al. 1985) causes footprints with surface elevations of 1000 meters or more to be marked as missing for all parameters. (Consequently, most of Greenland's ice appears as missing.) For elevations

less than 1000 m, a daily average is computed across all footprints and orbits for that grid cell. The footprint location changes with each scan, for each pass, although all footprint locations fall within the same grid box. As such, elevations appear to vary greatly from day to day. Users may apply the elevation mask provided to ensure the same area is masked every day.

The reason the retrieval is limited to elevations less than 1000 m is that the weighting functions for some of the channels that peak low in the atmosphere become window channels over high elevations (peak of weighting function at the surface), and the algorithm does not take this into account, especially over the high ice sheets of Greenland and Antarctica. Thus, to be on the safe side, retrievals above 1000m were excluded.

The sample file below is composed of sensor data from nine satellite orbits. Each orbit is composed of up to 2500 individual sensor scans, along the orbital track. Each scan contains parameter values and location information for the footprint. Throughout the day, a particular grid cell may be passed over a number of times. For example, four passes occurred in the sample below. Choosing a grid cell location of column 17 and row 45, the following are orbital data for this day, per orbit:

```
lat  long  column  row   elevation  orbit   scan number
72   -53   17      45    597        2       604
72   -54   17      45    428        3       498
72   -52   17      45    993        4       143
72   -52   17      45    858        5       477
```

1.5 Sample Data Record

Appendix C shows sample images for the available data parameters and sample data values from 10 April 1996 (tpp_n100_1996100_daily.v3-3.hdf). For the binary subset version there is one file per day per parameter. The binary file names are prefixed with subset_ and end with an extension that reflects the parameter. For example, the file containing cloud fraction data for 10 April 1996 (day 100) is named: subset_tpp_n100_1996100_daily.v3-3.FCLD.

1.5.1   Sample Values from HDF or Binary Data Files

```
Row 32, Column 28 for IDL or C programs;
Row 33, Column 29 for Fortran programs

TEMP-50         226.683
TEMP-70         225.740
TEMP-100        224.263
TEMP-300        219.452
TEMP-400        230.288
TEMP-500        240.738
TEMP-600        248.602
TEMP-700        254.337
```

```
TEMP-850       258.343
TEMP-900       258.722
WVAPOR-300     0.0600000
WVAPOR-400     0.190000
WVAPOR-500     1.30500
WVAPOR-700     1.63000
WVAPOR-850     1.61500
SKTEMP         251.050
HIRS_CLDY      55.3333
FCLD           106.750
CLPRESS        568.750
CLTEMP         247.292
EMISS          0.751667
ISICE          1.00000
SOLZEN         82.3043
PRESS          1024.21
PBLSTRAT       -16.3351
Cg             0.0265637
ALPHA          26.2023
```

1.6 Error Sources

Users should be aware of potential inter-satellite calibration problems. Removal of such systematic biases required the development of an automatic correction scheme. The correction procedure used satellite and radiosonde data sets from NOAA/NESDIS as inputs to the forward model to accurately account for and eliminate biases caused by the radiative transfer model, the instrument or unexpected events, such as the Mt. Pinatubo eruption. However, this method may not fully address all of the inter-satellite calibration problems.

1.6.1 Other Known Problems

Elevation and surface type may vary from orbit to orbit, as reported by the satellites. Because surface classifications may differ from orbit to orbit, grid cells classified as ice may have temperatures warmer than freezing, and grid cells classified as water may have temperatures colder than freezing. Examples:

```
Ice temperature warmer than freezing (272°K):

  Date            Row         Column        ISICE        SKTEMP
-------         ---        ------       -------      -------
1997172          11           37        1.00000      280.900
1997190          23           49        1.00000      289.900
1998199          37           52        1.00000      292.500


Water temperature colder than freezing (272°K):
  Date            Row         Column        ISICE        SKTEMP
-------         ---        ------       -------      -------
1997021          37           26        0.00000      248.700
1997318          27           20        0.00000      252.040
1998294          54           21        0.00000      257.500
```

Furthermore, the cloud parameter value (FCLD) may be unrealistically high because no upper bound is imposed to ensure that the data are not artificially biased when averaged. Values of 199 have been observed, which may indicate the occurrence of only one retrieval with a value of 199 percent, or that all retrievals had values near 200 percent.

The boundary layer stratification (PBLSTRAT) data may have unrealistically large values. Most, but not all, of these values were filtered out.

A few instances have been noticed where the cloud top pressure (CLPRESS) is greater than the surface pressure, sometimes by more than 5mb. Example:

```
Surface Pressure less than cloud pressure:
 Date            Row         Column       CLDPRS       SURFACE PRESS
-------         ---        ------       -------      -------
1997010          47           46        976.750      969.586
1998087          64           24        984.000      982.692
1998351          61           23        984.000      974.951
```

Finally, the Southern Hemisphere grids reveal some false sea ice, which is likely caused by poor weather/cloud filtering.

1.7 Quality Assessment

The algorithm used to generate these grids has been validated directly through comparisons with surface observations from the CEAREX experiment and with radiosonde data from Soviet ice stations. Comparisons with other TOVS retrieval algorithms provided further validation. Additionally, Schweiger et al. (1999) found a strong correlation between the TOVS Path-P data and surface cloud observations obtained from the North Polar drifting meteorological stations, which indicates that the TOVS data effectively represent annual cloud cover. Table 3 provides an initial assessment of the accuracy of some variables included in the Path-P products. Not all variables

could be verified and validation of the following Path-P variables has been performed only for sea level.

Table 3. Estimated Accuracy of Path-P Level 3 Variables

Parameter	Description	Units	Estimated Accuracy
TEMP	Level temperatures	K	3K
WVAPOR	Layer Precipitable water	mm	~30%
SKTEMP	Surface Skin Temperature	K	3K
FCLD	Effective Cloud Fraction	%	30%
CLTEMP	Cloud-top temperature	K	TBD
CLPRESS	Cloud-top pressure	mb	TBD
EMISS	Surface Emissivity (50 GHz)		5%
PBLSTRAT	Boundary Layer Stratification	K	5K
C_g	Geostrophic drag coefficient		~30%
ALPHA	Turning angle	Deg	~10 deg
HIRS_CLDY	Fraction of cloudy pixels per III retrieval box	Percent	20%

2   SOFTWARE AND TOOLS

Tools for browsing the TOVS Path-P data are available in the tools folder. To accompany the Polar Pathfinder Product, NSIDC created a TOVS Path-P IDL Tools Tutorial that describes how to use the IDL tools to browse TOVS Path-P data files (available under the Support tab). Additionally, Fortran and C programs for reading Path-P daily data files have been provided by the University of Washington. Static ancillary HDF data files provide elevation, latitude, longitude, and land mask data. They are described in Table 4.

Table 4. Ancillary HDF Data Files Description

File Name	Description
tpp_n100_9999999_ancil.hdf	• Northern Hemisphere Ancillary File: Center latitude of grid cell is in 100ths of a degree. Divide by 100.0 to get units of degrees. Range of values is 0 to 90. • Center longitude of grid cell is in 100ths of a degree. Divide by 100.0 to get units of degrees. Range of values is -180 to +180. • Percent of grid cell covered by land in %. Range of values is 0 to 100. • Elevation in 10ths of meters. Divide by 10.0 to get units of meters.
tpp_s100_9999999_ancil.hdf	• Southern Hemisphere Ancillary File: Center latitude of grid cell is in 100ths of a degree. Divide by 100.0 to get units of degrees. Range of values is 0 to 90. • Center longitude of grid cell is in 100ths of a degree. Divide by 100.0 to get units of degrees. Range of values is -180 to +180. • Land Mask: ocean=0, land=1. • Elevation in 10ths of meters. Divide by 10.0 to get units of meters.

3   DATA ACQUISITION AND PROCESSING

These data were developed at the University of Washington's Applied Physics Laboratory with funding from Polar Exchange at the Sea Surface (POLES), a NASA EOS interdisciplinary project.

3.1 Source or Platform Description

The TOVS scanner was flown aboard several NOAA Polar Operational Environmental Satellites (POES), as shown in Table 5.

Table 5. TOVS Satellites and Operational Periods

Satellite	Time Period
NOAA-6	12 Jul 1979 to 31 Dec 1982
NOAA-7	01 Jan 1983 to 31 Dec 1984
NOAA-9	01 Jan 1985 to 31 Dec 1986
NOAA-10	01 Jan 1987 to 16 Sep 1991
NOAA-11	17 Sep 1991 to 31 Dec 1994
NOAA-12	01 Jan 1995 to 31 Dec 1996
NOAA-14	01 Jan 1997 to most recent data

3.2 Sensor or Instrument Description

The TOVS scanner aboard the NOAA polar orbiters includes three sensors, the HIRS/2, MSU and Stratospheric Sounding Unit (SSU). The MSU is a scanning microwave radiometer with four channels in the 50 to 60 GHz oxygen region. The MSU sensors consist of two four-inch diameter antennas, each having an instantaneous field of view (IFOV) of 7.5 degrees.

The 109-km IFOV resolution at nadir creates an underlap, or gap, of approximately 115 km between adjacent scan lines. The MSU data output represents uncorrected brightness temperatures after a 1.84 second integration period (i.e., how long the instrument collects signal from a given position) per step of the scanning antenna.

The MSU has no special calibration sequence to interrupt normal scanning. Calibration data are included in a scan line of data. Each MSU data set normally contains an individual satellite recorder playback. Data with each MSU data set are in chronological order with one record for each MSU scan.

HIRS is a 20 channel scanning radiometer with channels in the 15 micrometer and four micrometer regions. The data are recorded onboard satellite for readout on command. TOVS data are used operationally by NESDIS to produce vertical profiles of temperature and moisture, and to derive other atmospheric variables.

SSU data are not used for this data set.

A summary of the HIRS and MSU instruments' parameters is given in Table 6.

Table 6. HIRS and MSU Instrument Parameters

Instrument Parameters	HIRS/2	MSU
Cross-track scan angle (from nadir)	49.5°	47.35°
Scan time	6.4 seconds	25.6 seconds
Ground IFOV at nadir	17.4 km	109.3 km
Ground IFOV at end of scan (cross-track)	58.5 km	323.1 km
Ground IFOV at end of scan (along-track)	29.9 km	178.8 km
Distance between IFOV centers (along-track)	42.0 km	168.1 km
Swath width	+/-1120 km	+/-1174 km
Data precision	13 bits	12 bits
Time between start of each scan line	6.4 seconds	25.6 seconds

For more instrument information see the NOAA Polar Orbiter Data Users Guide.

3.3 Data Source

TOVS level 1b radiances for the regions poleward of 60° N and 60° S were obtained from the Satellite Data Services Division (SDSD) of the National Oceanographic and Atmospheric Administration (NOAA) and from the National Center for Atmospheric Research (NCAR). Level 1b data files contain raw, quality-controlled radiances as well as calibration and navigation information (Francis 1994).

3.4 Derivation Techniques and Algorithms

"The 3I algorithm uses HIRS and MSU measurements to deduce the three-dimensional thermal structure of the atmosphere through inversion of the radiative transfer equation. Physical inversion methods consist of solving the radiative transfer equation iteratively until agreement is found between observed and calculated radiances. The 3I algorithm improves upon other iterative methods by including more physics than do purely statistical models. For this application distinctly polar characteristics and the unique physical aspects of snow and ice have been considered. The 3I algorithm also makes use of a library (called TIGR, TOVS Initial Guess Retrieval) of some 1800 atmospheric profiles culled from a global set of more than 150,000 radiosonde measurements. The library acts as a "look-up" table, speeding the computational process. To build the library, a forward radiative transfer model was developed for each of the 1800 profiles and used to calculate

brightness temperatures for each HIRS and MSU channel, the Jacobians of the partial derivatives of the radiances B with respect to temperature T and moisture q at each level, and the temperature and radiance means and covariance matrices. Calculations were performed for 10 viewing angles, 19 surface pressures, and two surface emissivities (Francis 1994).

3.5 Processing Steps

Below are the steps used in the data retrieval process:

- Navigate and calibrate the radiances.
- Detect clouds and remove their effects.
- Select the first-guess profile from TIGR and retrieve final temperature profile.
- Retrieve cloud-top pressure and cloud fraction.
- Retrieve relative humidity, surface temperature, and total precipitable water.

For elevations greater than 1000 meters, all parameters are marked as bad for that orbit. Since each orbital footprint has a unique position, and though several orbits may fall into the same 100 x 100 grid cell, their elevation information is coming from different parts of that cell, and therefore giving different elevations. Thus, regions defined as being higher than 1000 meters vary from day to day due to varying satellite input data.

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6 DOCUMENT INFORMATION

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APPENDIX A – DATA DICTIONARY

The data dictionary in this section describes the elements associated with the two Scientific Data Set (SDS) objects contained in the TOVS Path-P files. The first SDS object is Global Attributes which defines attributes that describe an individual Path-P file and contains information common to all of the data set arrays in the file. The other SDS object is Scientific Data Sets which describes the individual scientific data arrays and their associated metadata.

The attributes that comprise the Global Attributes object are defined by the following elements:

```
Element
  Parameter Name      = PROJECT
  Definition          = Name of project
  Format              = string
  Type                = character
  Length              = Max 256
  Range               =
  Comment             = Current Value is "TOVS PATHFINDER PATHP"

 Element
  Parameter Name      = DATASET_NAME
  Definition          = Producer's name of data set
  Format              = string
  Type                = character
  Length              = Max 256
  Range               =
  Comment             = Possible values for this project are
                        "Gridded Daily Arctic Atmospheric Data from TOVS(PathP)"
                        "Gridded Monthly Arctic Atmospheric Data from TOVS(PathP)"

 Element
  Parameter Name      = SOURCE_NAME
  Definition          = Satellite Platform
  Format              = string
  Type                = character
  Length              = Max 256
  Range               = NOAA-10
  Comment             =

 Element
  Parameter Name      = PROCESSING_LEVEL
  Definition          = Level of Processing Number
  Format              = string
  Type                = character
  Length              = Max 256
  Range               =
  Comment             = Value is "3"

 Element
  Parameter Name      = REFERENCE_DATE
  Definition          = Date or time period for which this granule is
                        representative
  Format              = yyyy-mm-dd
  Type                = character
  Length              = Max 256
  Range               =
  Comment             =

 Element
  Parameter Name      = START_DATE
  Definition          = Date and time of first datapoint in granule
  Format              = yyyy-mm-ddTHH:MM:SS
  Type                = character
  Length              = Max 256
  Range               =
```

```
      Comment            = Example of this attribute is "1987-10-01T01:41:51"

  Element
   Parameter Name       = STOP_DATE
   Definition           = Date and time of last datapoint in granule
   Format               = yyyy-mm-ddTHH:MM:SS
   Type                 = character
   Length               = Max 256
   Range                =
   Comment              = Example of this attribute is "1987-10-01T22:41:51"

  Element
   Parameter Name       = POSITION_TYPE
   Definition           = A type of spatial object defined in the NSIDC IMS Server
   Format               =
   Type                 = character
   Length               = Max 256
   Range                =
   Comment              = Value of this attribute is "FIXED GRID"

  Element
   Parameter Name       = GRID_TYPE
   Definition           = Northern or Southern Hemisphere
   Format               =
   Type                 = character
   Length               = 1
   Range                =
   Comment              = Possible values are "N" or "S"

  Element
   Parameter Name       = GRID_NAME
   Definition           = Name of Grid
   Format               = string
   Type                 = character
   Length               = Max 256
   Range                =
   Comment              = Value for this attribute is "EASE GRID"

  Element
   Parameter Name       = PROJECTION
   Definition           = Geographical projection of the grid
   Format               = string
   Type                 = character
   Length               = Max 256
   Range                =
   Comment              = Value for this attribute is "Azimuthal Equal Area"

  Element
   Parameter Name       = EASE_GRD
   Definition           = Grid parameter file used by NSIDC gridding software
   Format               = string
   Type                 = character
   Length               = Max 256
   Range                =
   Comment              = This file defines the parameters required by the
                          gridding software developed by NSIDC.

  Element
   Parameter Name       = EASE_MPP
   Definition           = Map projection parameter file used by NSIDC
                          projection software
   Format               = string
   Type                 = character
   Length               = Max 256
   Range                =
   Comment              = This file defines the parameters of the EASE-Grid
                          map projection required by the projection software
                          developed by NSIDC.

  Element
   Parameter Name       = LATITUDE
   Definition           = Latitude of the corner points of the grid
   Format               = f6.3
```

```
 Type                    = float32
 Length                  = 4 * float32 (16 bytes)
 Range                   = (-90,90)
 Comment                 = Array of latitude values corresponding to the
                            x,y grid coordinates [0,0], [0,66], [66,66], [66,0]

Element
 Parameter Name          = LONGITUDE
 Definition              = Longitude of corner points of the grid
 Format                  = f6.3
 Type                    = float32
 Length                  = 4 * float32 (16 bytes)
 Range                   = (-180,180)
 Comment                 = Array of longitude values corresponding to the
                            x,y grid coordinates [0,0], [0,66], [66,66], [66,0]

Element
 Parameter Name          = Temporal_Res
 Definition              = Temporal resolution of the data set
 Format                  = string
 Type                    = character
 Length                  = Max 256
 Range                   =
 Comment                 = Possible values are "daily" or "monthly"

Element
 Parameter Name          = Spatial_X_Res
 Definition              = Spatial resolution of data set in x direction
 Format                  = string
 Type                    = character
 Length                  = Max 256
 Range                   = 100.27 km
 Comment                 =

Element
 Parameter Name          = Spatial_Y_Res
 Definition              = Spatial resolution of data set in y direction
 Format                  = string
 Type                    = character
 Length                  = Max 256
 Range                   = 100.27 km
 Comment                 =

Element
 Parameter Name          = PRODUCER_GRANULE_ID
 Definition              = Name of granule when generated on production system
 Format                  = string
 Type                    = character
 Length                  = Max 256
 Range                   =
 Comment                 = Unix system file name generated on POLES SCF system

Element
 Parameter Name          = PRODUCER_DATE
 Definition              = Date granule was produced
 Format                  = string
 Type                    = character
 Length                  = Max 256
 Range                   =
 Comment                 = Example of value used for this attribute is
                            "Mon May 16 11:21:38 1994"

Element
 Parameter Name          = PRODUCER_PROGRAM
 Definition              = RCS header for production software
 Format                  = string
 Type                    = character
 Length                  = Max 256
 Range                   =
 Comment                 = Example of a value for this attribute is
                            "$Header: /home/n1/PathP/development/src/l3
                             /gridgen/RCS/PPgridL2.c, v1.1 1994/05/11/23:08:09
                             axel Exp axel $"
```

```
Element
 Parameter Name        = PRODUCER_REVISION_DATE
 Definition            = Date of last modification to production program
 Format                = string
 Type                  = character
 Length                = Max 256
 Range                 =
 Comment               = Example of value for this attribute is
                         "Mon May 16 11:14:23 1994"

Element
 Parameter Name        = PRODUCER_ARCHITECTURE
 Definition            = Production machine architecture and Operating System
 Format                = string
 Type                  = character
 Length                = Max 256
 Range                 =
 Comment               = Example of the information provided by this
                         attribute is "SunOS.4.1.3_UI node: nansen"

Element
 Parameter Name        = PRODUCER_COMMENT
 Definition            = Any comment the producer feels necessary to add
 Format                = string
 Type                  = character
 Length                = Max 256
 Range                 =
 Comment               = Example of the information provided by this
                         attribute is "SunOS.4.1.3_UI node: nansen"

Element
 Parameter Name        = PRODUCER DOCUMENT
 Definition            = Document that describes this data set
 Format                = string
 Type                  = character
 Length                = Max 256
 Range                 =
 Comment               = Value for this attribute is "PATH-P_USERS_GUIDE.TXT"
```

Attributes that comprise the **Scientific Data Sets** object are defined by the following elements:

```
Element
 Parameter Name        = LATITUDE_GRID
 Definition            = Latitude coordinate of each grid point
 Format                = f6.3
 Type                  = 32 bit floating point Scientific Data Set
 Units                 = degrees
 Size                  = 67 x 67
 Comment               = This Scientific Data (SD) is stored in an external SD
                         file: LatGrd.exhdf

Element
 Parameter Name        = LONGITUDE_GRID
 Definition            = Longitude coordinate of each grid point
 Format                = f6.3
 Type                  = 32 bit floating point Scientific Data Set
 Units                 = degrees
 Size                  = 67 x 67
 Comment               = This Scientific Data (SD) is stored in an external SD
                         file: LonGrd.exhdf

Element
 Parameter Name        = TEMP
 Definition            = Temperatures [K] at pressure levels
                         50, 70, 100, 300, 400, 500, 600, 700, 850 millibars
 Format                = f6.3
 Type                  = 32 bit floating point Scientific Data Set
 Units                 = degrees of Kelvin
 Size                  = 9 x 67 x 67
```

```
 Comment                =

Element
 Parameter Name         = TEMP-SD
 Definition             = Time Standard Deviation of TEMP
 Format                 = f5.1
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = degrees of Kelvin
 Size                   = 9 x 67 x 67
 Comment                =

Element
 Parameter Name         = WVAPOR
 Definition             = Precipitable water [mm] of layers bounded by 300-400,
                          400-500, 500-700, 500-850, 850-1000 millibars
 Format                 = f6.3
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = mm
 Size                   = 5 x 67 x 67
 Comment                =

Element
 Parameter Name         = WVAPOR-SD
 Definition             = Time Standard Deviation of WVAPOR
 Format                 = f6.3
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = mm
 Size                   = 5 x 67 x 67
 Comment                =

Element
 Parameter Name         = SKTEMP
 Definition             = Surface skin temperature [K]
                          400-500, 500-700, 500-850, 850-1000 millibars
 Format                 = f5.1
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = degrees of Kelvin
 Size                   = 67 x 67
 Comment                =

Element
 Parameter Name         = SKTEMP-SD
 Definition             = Time Standard Deviation of SKTEMP
 Format                 = f5.1
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = degrees of Kelvin
 Size                   = 67 x 67
 Comment                =

Element
 Parameter Name         = FCLD
 Definition             = Total effective cloud fraction [%]
 Format                 = f5.1
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = percent
 Size                   = 67 x 67
 Comment                = Effective cloud fraction is the retrieved
                          radiatively effective cloud fraction and is the
                          product of the actual cloud fraction and the
                          cloud emissivity. This parameter corresponds to
                          the actual cloud fraction if clouds had unit
                          emissivity.

Element
 Parameter Name         = FCLD-SD
 Definition             = Time Standard Deviation of FCLD[%]
 Format                 = f5.1
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = percent
 Size                   = 67 x 67
 Comment                =

Element
```

```
Parameter Name          = CLPRESS
Definition              = Cloud top pressure [mb]
Format                  = f3.0
Type                    = 32 bit floating point Scientific Data Set
Units                   = millibars
Size                    = 67 x 67
Comment                 =

Element
 Parameter Name         = CLPRESS-SD
 Definition             = Time Standard Deviation of CLPRESS
 Format                 = f3.0
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = millibars
 Size                   = 67 x 67
 Comment                =

Element
 Parameter Name         = CLTEMP
 Definition             = Cloud top temperature [K]
 Format                 = f5.1
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = degrees of Kelvin
 Size                   = 67 x 67
 Comment                =

Element
 Parameter Name         = CLTEMP-SD
 Definition             = Time Standard Deviation of CLTEMP
 Format                 = f5.1
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = degrees of Kelvin
 Size                   = 67 x 67
 Comment                =

Element
 Parameter Name         = ZANGLE
 Definition             = Effective satellite zenith angle defined as the
                           arccosine of the average value of the cosines of
                           the cosines of the individual satellite zenith angles.
 Format                 = f5.2
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = degrees
 Size                   = 67 x 67
 Comment                =

Element
 Parameter Name         = ZANGLE-SD
 Definition             = Time Standard Deviation of ZANGLE
 Format                 = f5.2
 Type                   = 32 bit floating point Scientific Data Set
 Units                  = degrees
 Size                   = 67 x 67
 Comment                =

Element
 Parameter Name         = EMISS
 Definition             = Surface emissivity at 50 GHz (MSU Channel 1)
 Format                 = f3.0
 Type                   = 32 bit floating point Scientific Data Set
 Units                  =
 Size                   = 67 x 67
 Comment                = This variable may be used to provide a surface
                           type classification.

Element
 Parameter Name         = EMISS-SD
 Definition             = Time Standard Deviation of EMISS
 Format                 = f3.0
 Type                   = 32 bit floating point Scientific Data Set
 Units                  =
 Size                   = 67 x 67
 Comment                =
```

```
Element
 Parameter Name      = PBLSTRAT
 Definition          = Boundary layer bulk stratification (difference
                       in potential temperature between the surface and
                       at 900 mb.
 Format              = f5.1
 Type                = 32 bit floating point Scientific Data Set
 Units               = degrees of Kelvin
 Size                = 67 x 67
 Comment             =

Element
 Parameter Name      = PBLSTRAT-SD
 Definition          = Time Standard Deviation for PBLSTRAT
 Format              = f5.1
 Type                = 32 bit floating point Scientific Data Set
 Units               = degrees of Kelvin
 Size                = 67 x 67
 Comment             =

Element
 Parameter Name      = Cg
 Definition          = Geostrophic drag coefficient over sea ice
                        (Overland and Davidson, 1992).
 Format              = f3.0
 Type                = 32 bit floating point Scientific Data Set
 Units               =
 Size                = 67 x 67
 Comment             = This value is parameterized after Overland and
                        Davidson, 1992. This variable is calculated only
                        over sea ice.

Element
 Parameter Name      = Cg-SD
 Definition          = Time Standard Deviation for Cg
 Format              = f3.0
 Type                = 32 bit floating point Scientific Data Set
 Units               =
 Size                = 67 x 67
 Comment             =

Element
 Parameter Name      = ALPHA
 Definition          = Turning angle between the geostrophic wind and the
                        surface wind over sea ice (Overland and Davidson,
                        1992).
 Format              = f3.0
 Type                = 32 bit floating point Scientific Data Set
 Units               = degrees
 Size                = 67 x 67
 Comment             = This variable is based on the parameterization of
                        Overland and Davidson (1992) and is calculated only
                        over sea ice. Positive values represent counter
                        clockwise turning angles.

Element
 Parameter Name      = ALPHA-SD
 Definition          = Time Standard Deviation for ALPHA
 Format              = f3.0
 Type                = 32 bit floating point Scientific Data Set
 Units               = degrees
 Size                = 67 x 67
 Comment             =

Element
 Parameter Name      = IIIreject
 Definition          = Number of III rejections per grid cell
 Format              = f3.0
 Type                = 32 bit floating point Scientific Data Set
 Units               = counts
 Size                = 67 x 67
 Comment             = IIIreject is the number of retrievals rejected for
```

```
                                an individual grid cell by the algorithm. Under
                                certain conditions the processing algorithm is
                                not able to perform a retrieval. These conditions
                                are often associated with thick clouds. Only actual
                                rejections are counted. A value of zero (0) may mean
                                that no rejections occurred or that no observations
                                were available for the respective grid cell.

 Element
  Parameter Name        = OBS
  Definition            = Number of non-rejected observations per grid cell
  Format                = f3.0
  Type                  = 32 bit floating point Scientific Data Set
  Units                 = counts
  Size                  = 67 x 67
  Comment               = The number of valid observations per cell. By
                          examining the values of OBS and IIIreject, the
                          user can determine the fraction of rejected
                          observations. The derived fraction may provide
                          an indication of how well the retrieved values
                          represent atmospheric conditions for a given time
                          period.
```

APPENDIX B – GEOMETRY CLASS

The Geometry data contained in the Path-P gridded products describe the parameters used by a set of the projection and gridding software developed at NSIDC for generating the Equal Area SSM/I Earth (EASE) Grid. These attributes are stored in the Path-P files as part of the processing history and are not required to access or use the scientific data sets.

Table B - 1. Geometry Attributes and Descriptions for the Path-P Products

Attribute	Value	Data Type
bin_meth	1	32-bit Integer
registration	1	32-bit Integer
map_origin_col	33.0	32-bit Float
map_origin_row	33.0	32-bit Float
cols_per_map_unit	100.27	32-bit Float
rows_per_map_unit	100.27	32-bit Float
cols	67	32-bit Integer
rows	67	32-bit Integer
lat0	90.0	32-bit Float
lon0	0.0	32-bit Float
lat1	-99999.0	32-bit Float
rotation	0.0	32-bit Float

APPENDIX C – SAMPLE DATA IMAGES
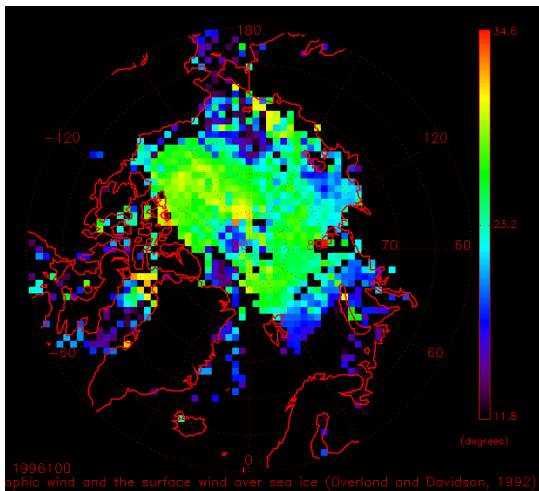
C - 1. Geostrophic Wind
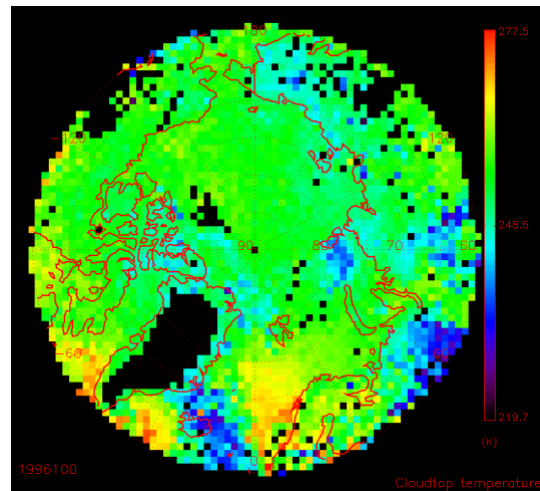
C - 4. Cloud Top Temperature
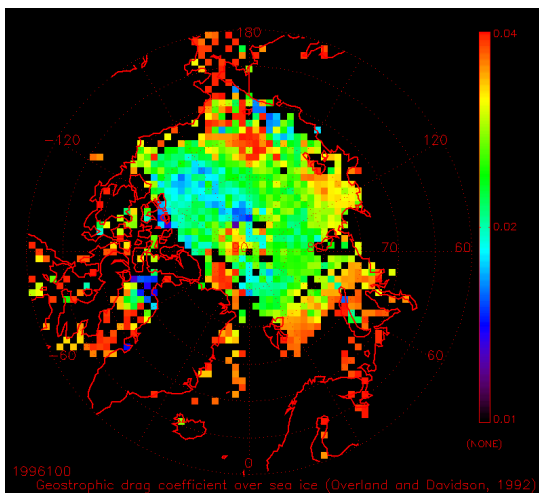
C - 2. Geostrophic Drag
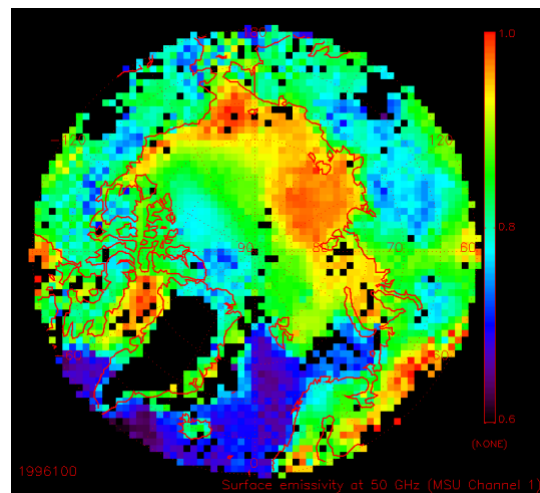
C - 5. Surface Emissivity
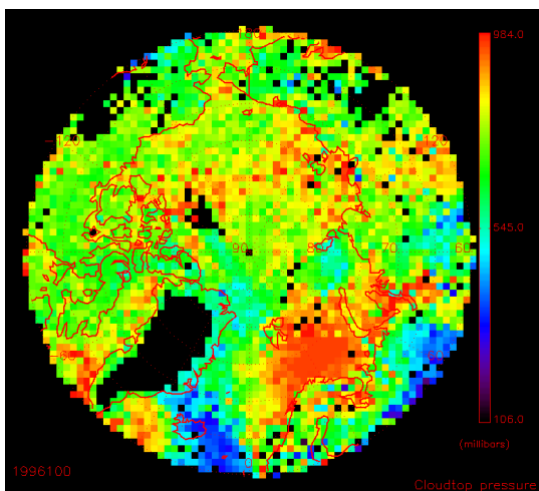
C - 3. Cloud Top Pressure
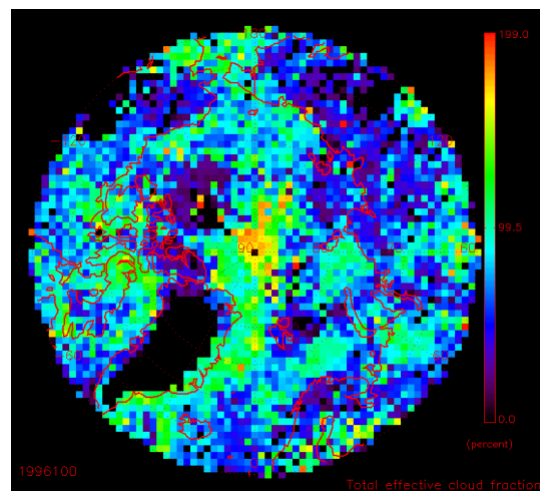
C - 6. Cloud Fraction
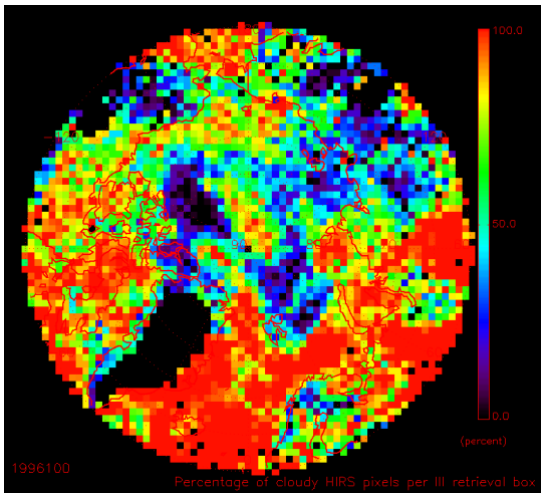
C - 7. HIRS Pixel
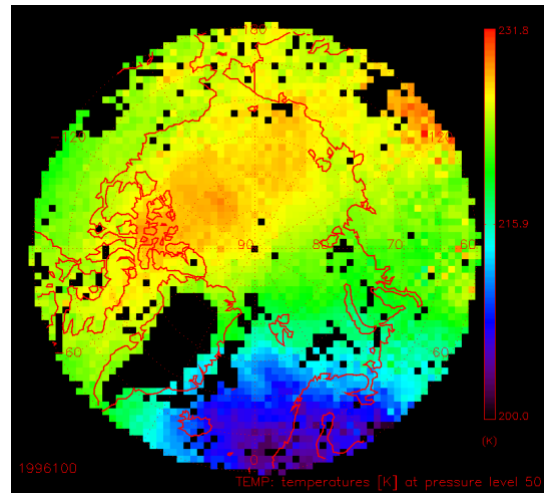
C - 10. Temperature at 50 Mb
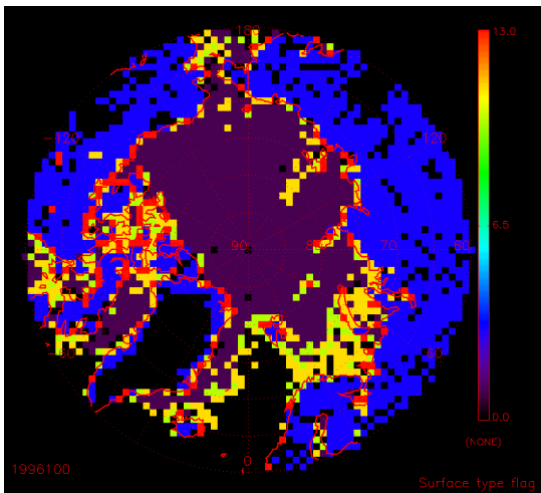
C - 8. Surface Type
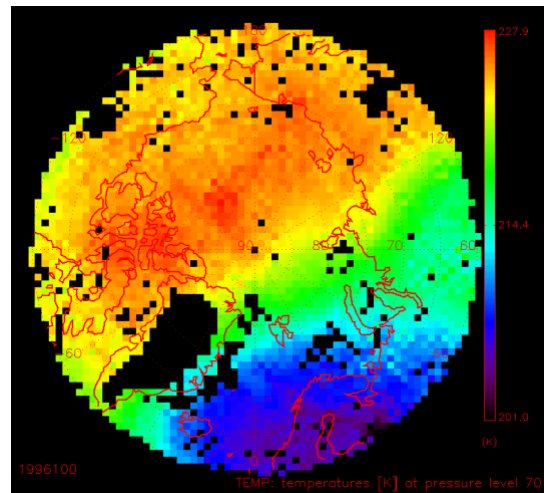
C - 11. Temperature at 70 Mb
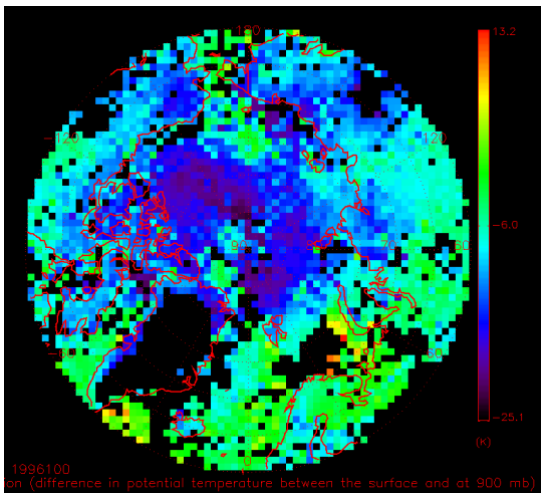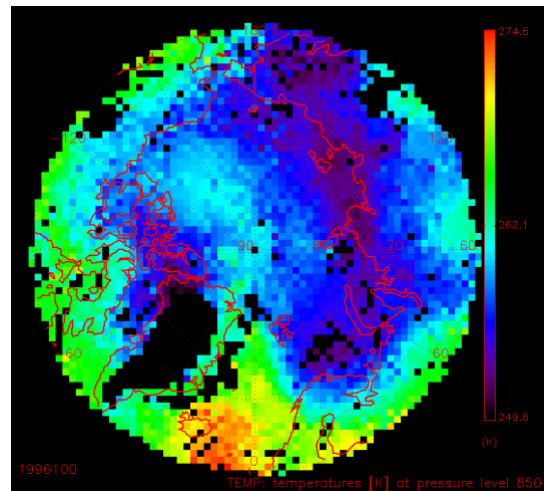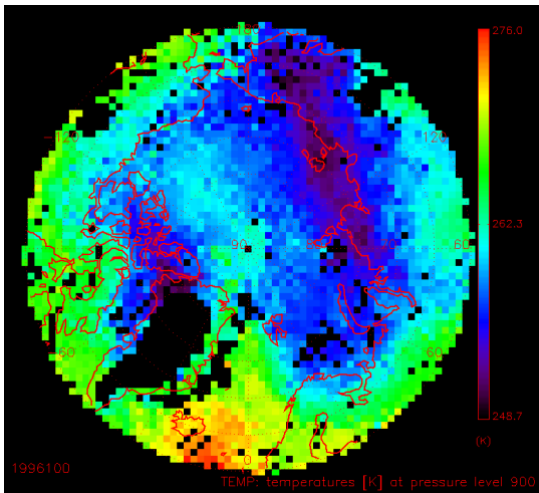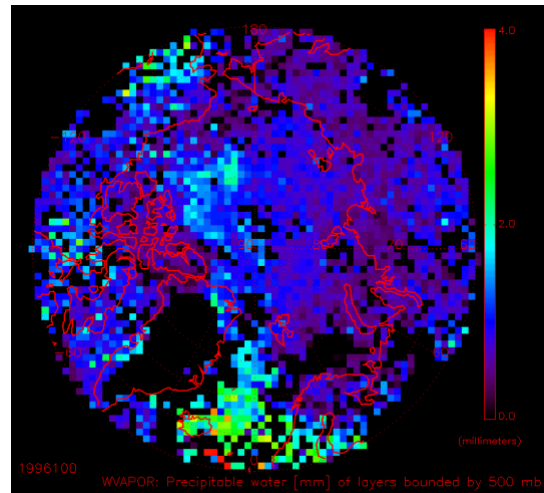

C - 9. Boundary Layer
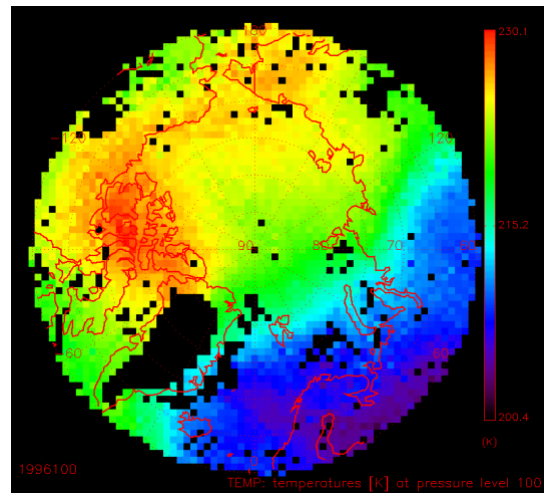
C - 12. Temperature at 100 Mb
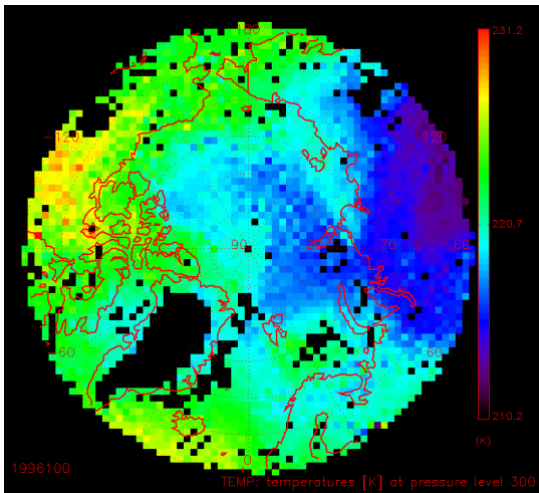
C - 13. Temperature at 300 Mb
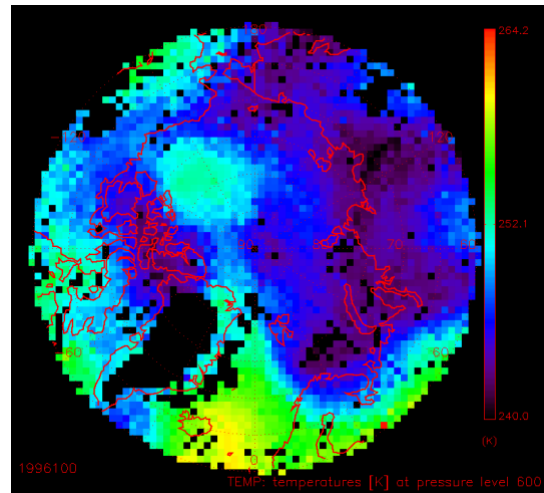
C - 16. Temperature at 600 Mb
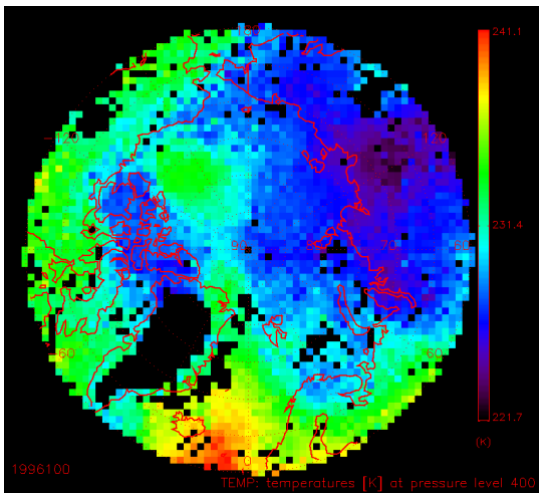
C - 14. Temperature at 400 Mb
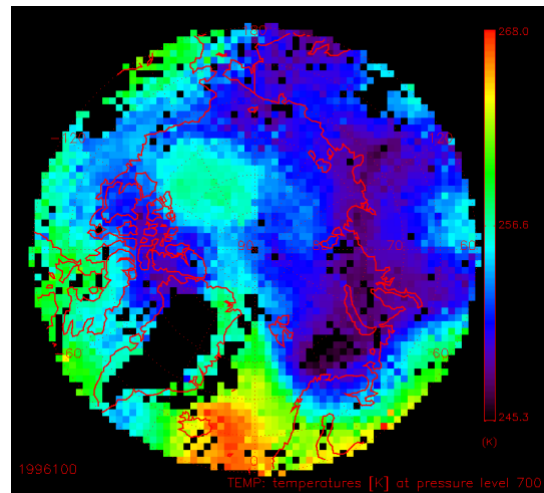
C - 17. Temperature at 700 Mb
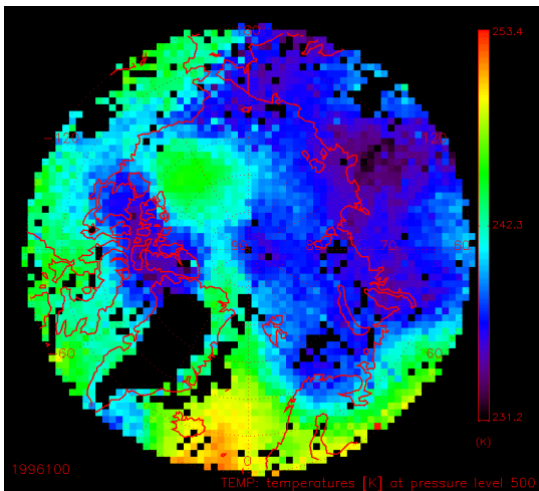
C - 15. Temperature at 500 Mb

C - 18. Temperature at 850 Mb
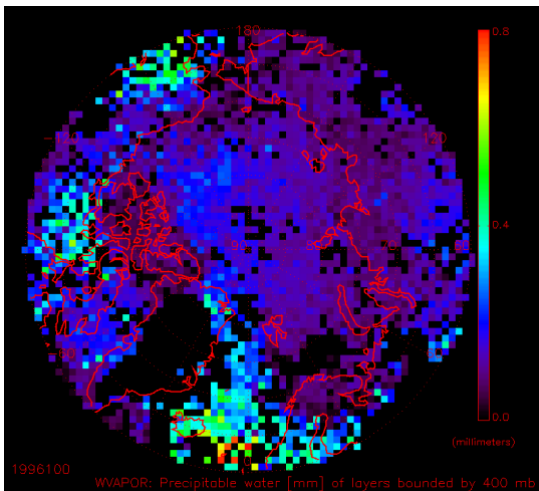
C - 19. Temperature at 900 Mb

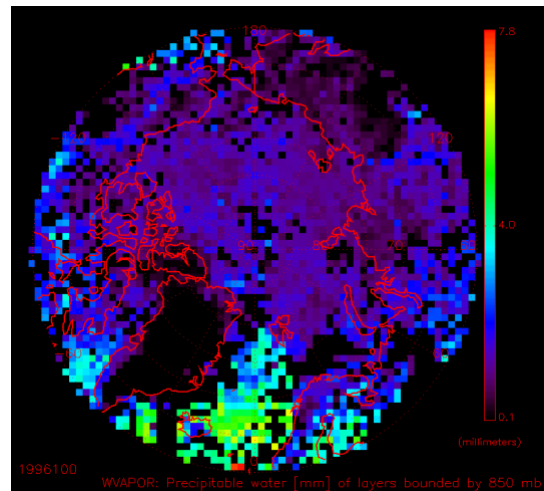C - 22. Water Vapor at 500 Mb
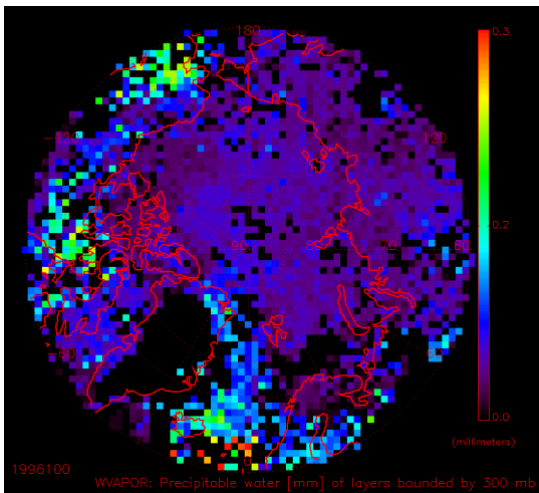
C - 20. Water Vapor at 300 Mb
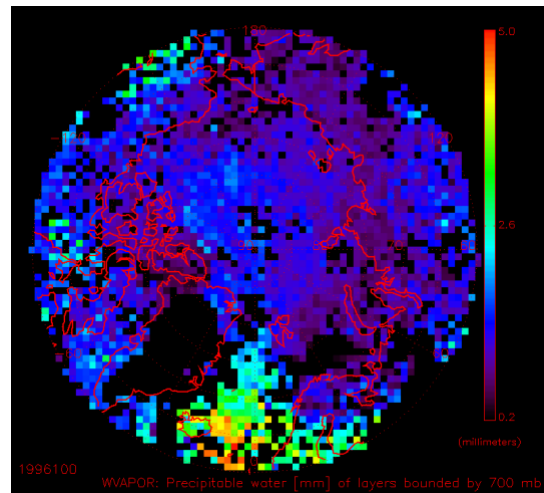
C - 23. Water Vapor at 700 Mb

C - 21. Water Vapor at 400 Mb

C - 24. Water Vapor at 850 Mb