

Satellite-derived Wind, Cloud, and Surface Products at Direct Broadcast Sites in the Antarctic and Arctic

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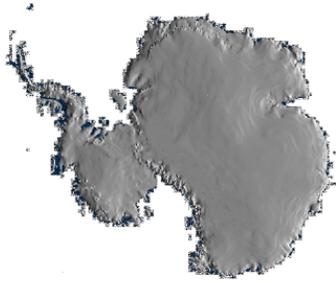


Objectives

- Provide an overview of the products generated on-site at the Direct Broadcast site at McMurdo, Antarctica
- Provide an overview of future sites and products

Motivation

- ❖ The need for more timely MODIS polar winds data by NWP centers motivated the development of a direct broadcast winds system.
- ❖ Other products were developed and became available as potential uses for them appeared.



McMurdo Station, Antarctica



Raytheon
Polar Services

The National Science Foundation installed an L/S/X-band ground station at McMurdo station in January 2005.

- The system is a SeaSpace design with a 2.4 meter dish, three computing systems with powerful processing capability.
- The system is one of the first to be able to capture all telemetries available: L-band NOAA, S-band DMSP and X-Band AQUA/TERRA.



The McMurdo L/S/X-band system



Capabilities:

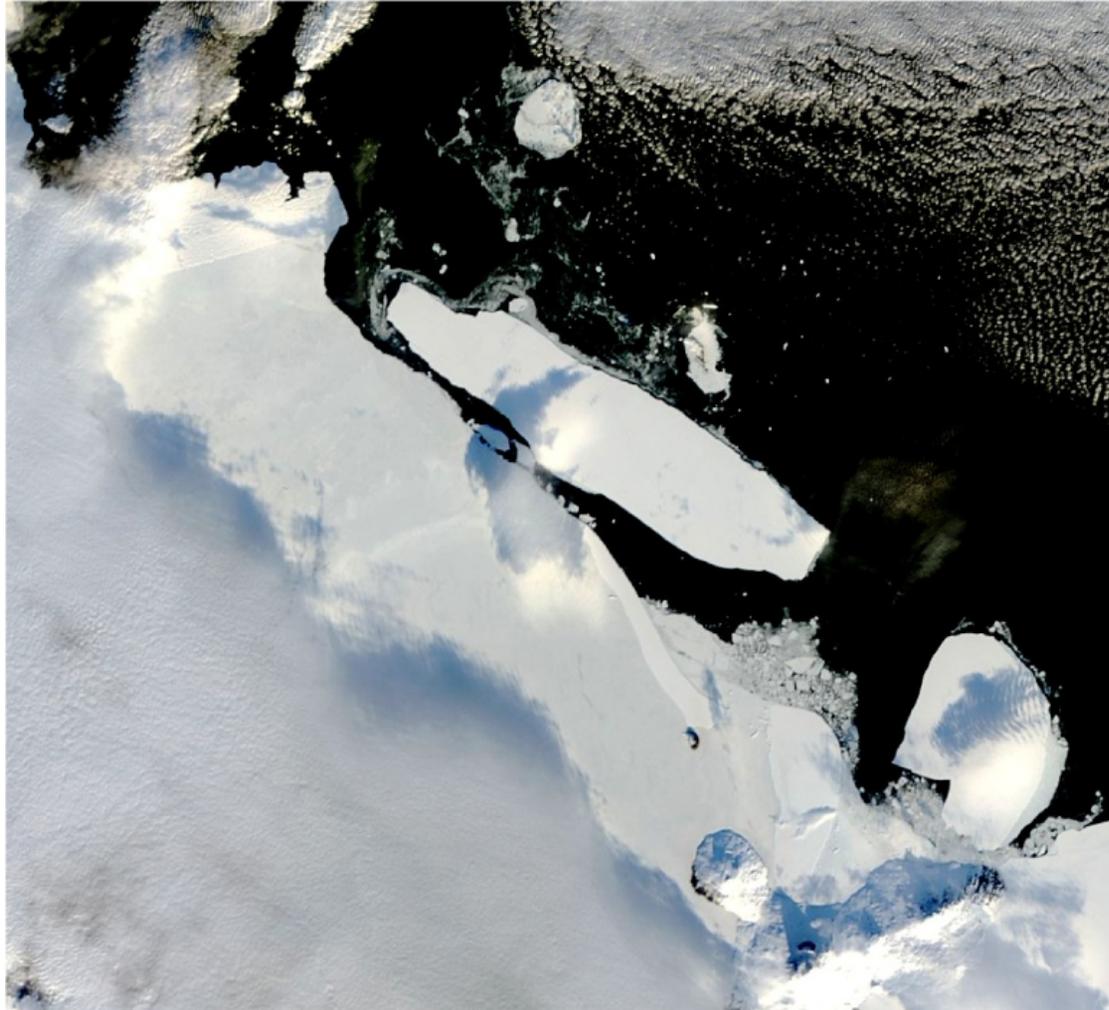
- DMSP S-Band
- NOAA L-Band
- MODIS AQUA and TERRA

Uses of Satellite Data Collected at McMurdo:

- **Flight forecasting and field operations.**
- **Weather prediction and planning.**
- Sea ice monitoring and research.
- **Cloud physics**
- Animal tracking (indirect) - seals and penguins.
- Operations in sea ice for ship navigation.
- Ocean color, chlorophyll and primary production.



MODIS Data



January 2005

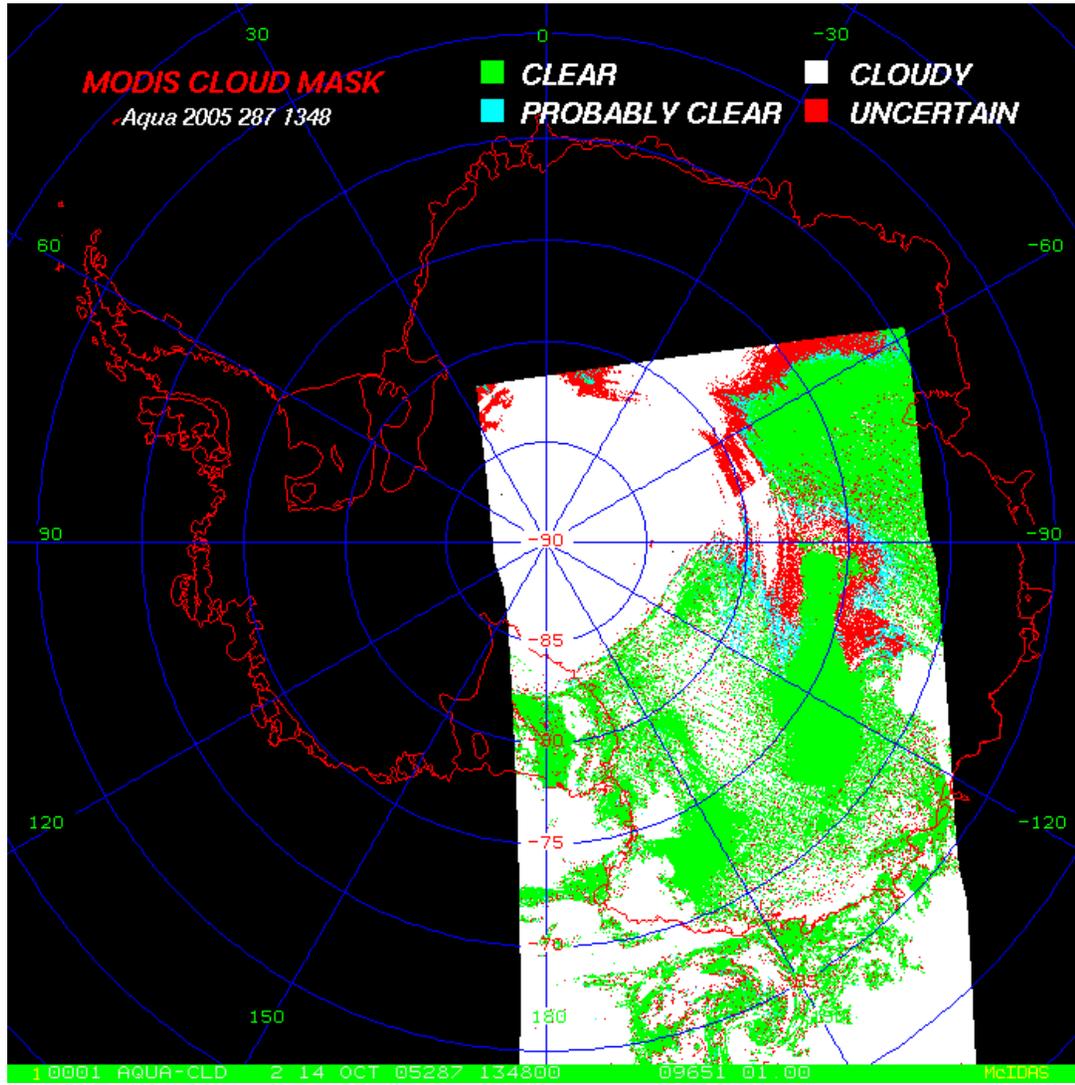
Current MODIS-derived products available from McMurdo DB site

- Cloud mask*
- Cloud pressure*
- Cloud phase*
- Total precipitable water*
- Inversion strength
- Inversion depth
- Ice/snow surface temperature
- Ice/snow albedo
- Water vapor/ IR Winds

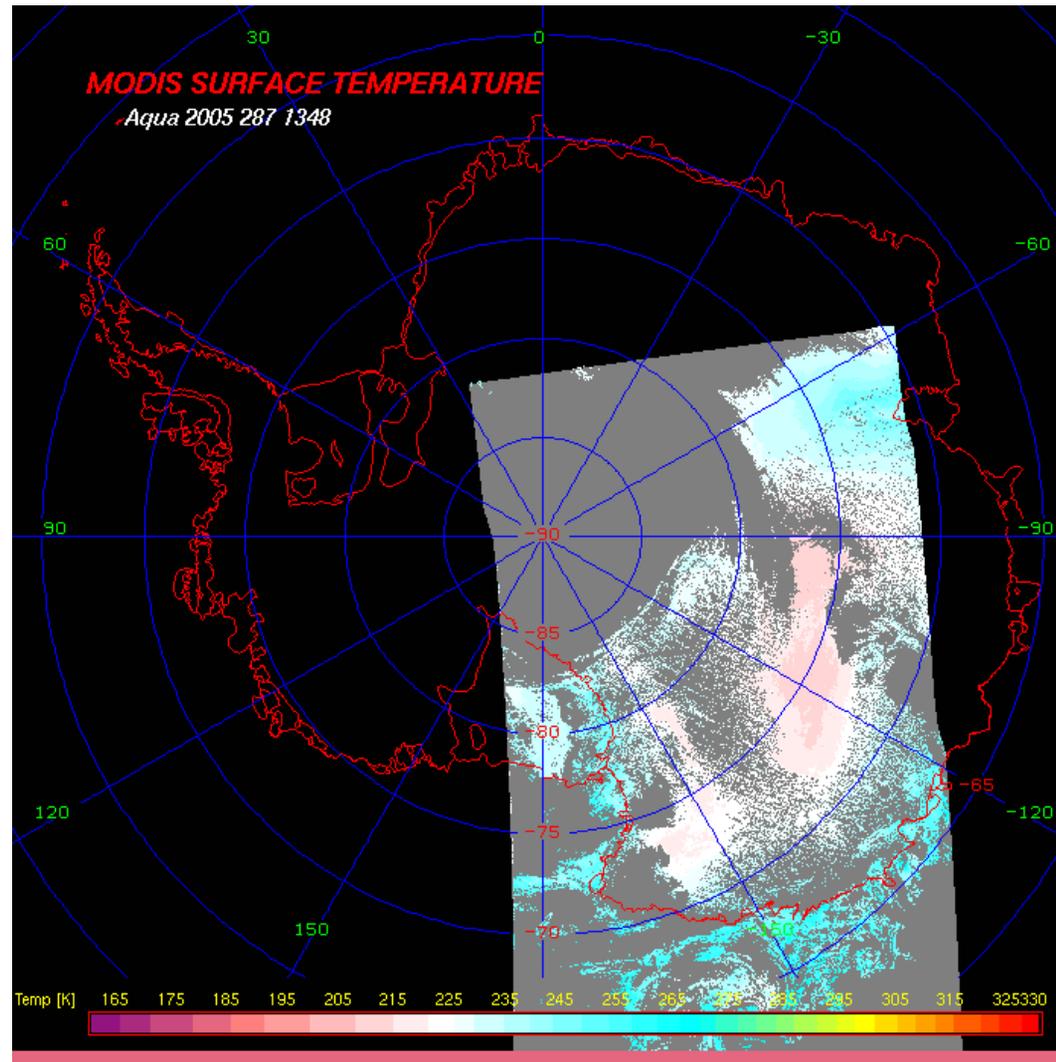
Plots generated and displayed using the Man computer Interactive Data Access System (McIDAS; Lazzara et al., 1999) and then saved to the real time web page.

**IMAPP/MODIS Science Team products*

IMAPP Cloud Product Example



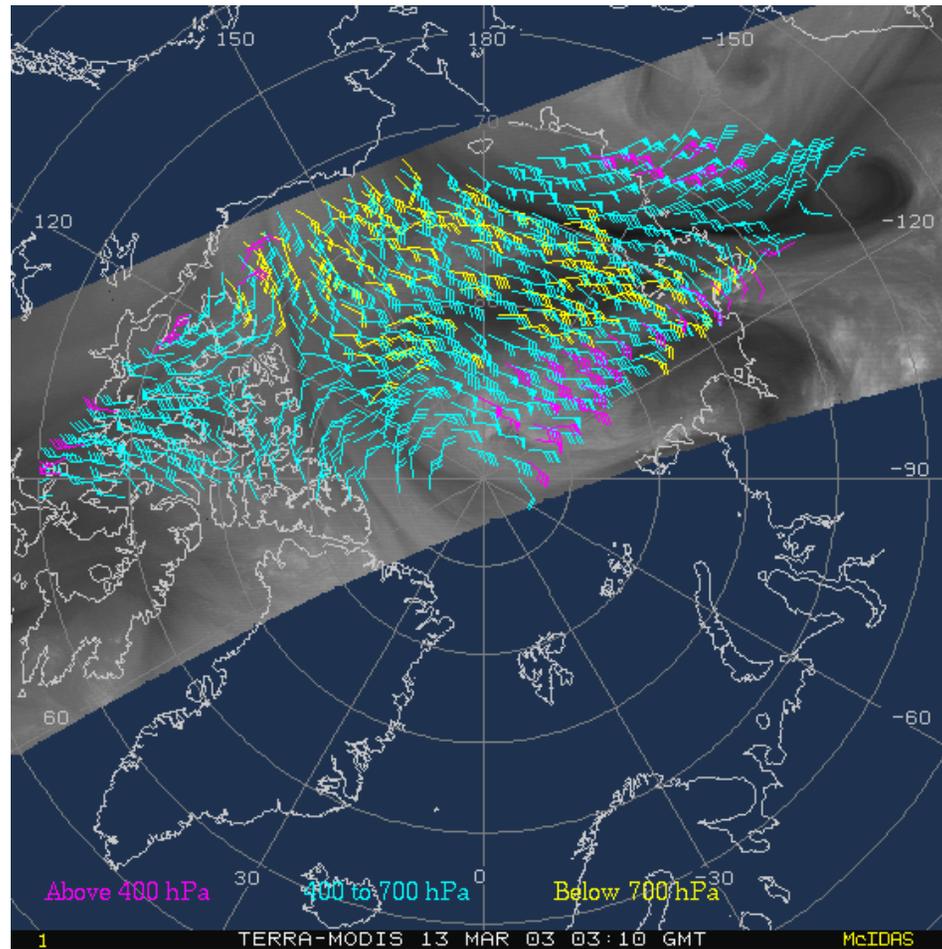
Surface Temperature example



MODIS Derived Winds

- Satellite-derived winds are important in the initialization of NWP
- The derivation of the polar winds from MODIS data is based on the established procedure used for the Geostationary Operational Environmental Satellite (GOES).
- Features from both the infrared window band at 11 μm and the water vapor band at 6.7 μm band are tracked over three consecutive orbits.
 - The majority of the wind vectors are derived from the water vapor channel because winds can be estimated in both clear and cloudy conditions.

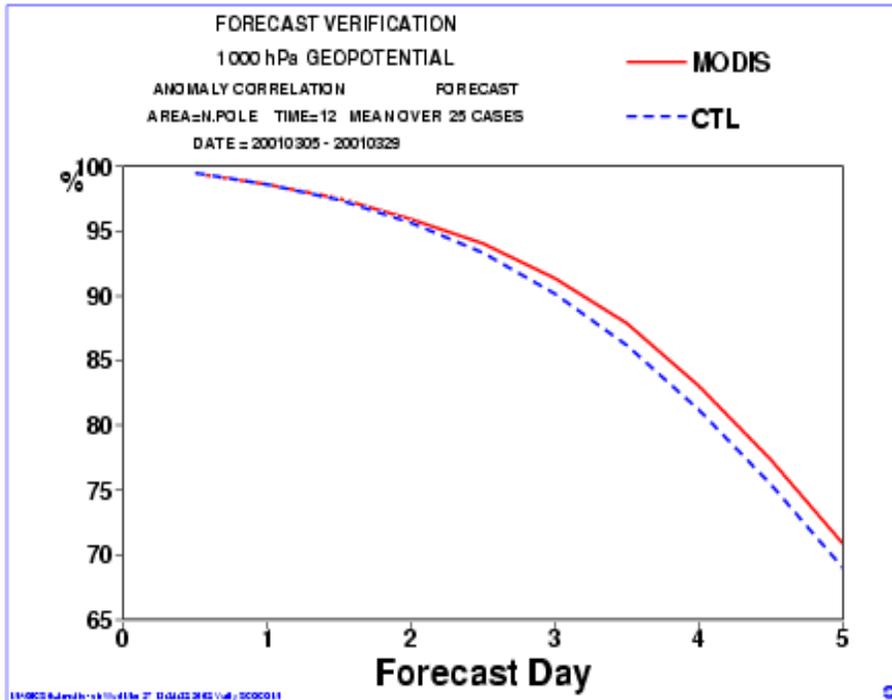
One Day of Arctic Orbits and Winds Terra MODIS



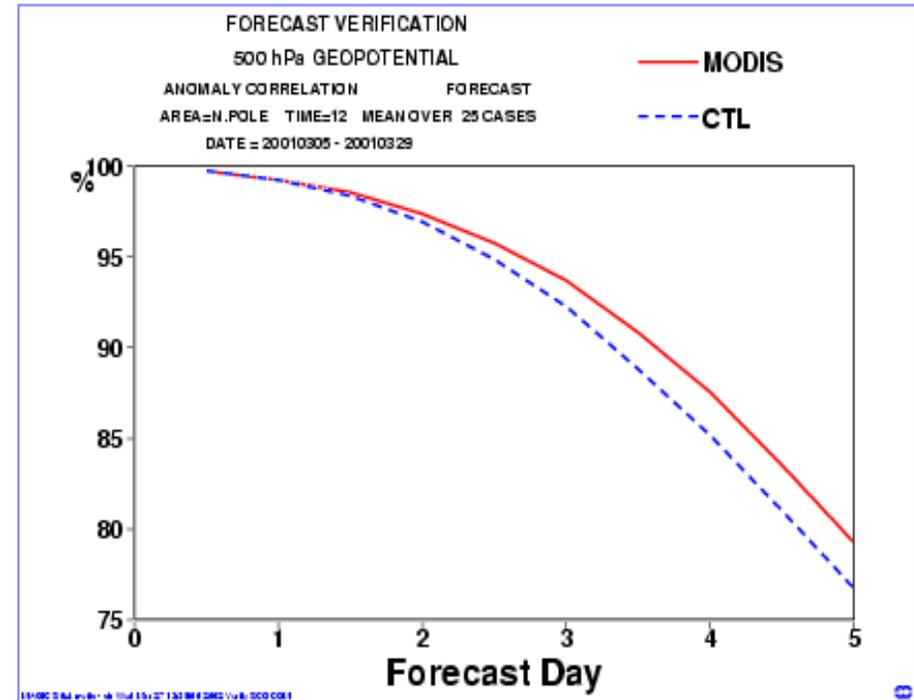
NOAA “bent pipe” data source.

ECMWF Model Impact: Arctic

1000 hPa



500 hPa



Forecast scores (anomaly correlations) as a function of forecast range for the geopotential at 1000 hPa (left) and 500 hPa (right). Study period is 5-29 March 2001. Forecast scores are the correlation between the forecast geopotential height anomalies, with and without the MODIS winds, and their own analyses. The Arctic (“N. Pole”) is defined as north of 65 degrees latitude.

There is a significant positive impact on forecasts of the geopotential from the assimilation of MODIS winds, particularly for the Arctic, but also for the Northern Hemisphere. This is also true for the Antarctica and Southern Hemisphere.

Impact in Tropics: GFS Model

Impact of MODIS winds on hurricane track forecasts from the Joint Center for Satellite Data Assimilation

Average hurricane track errors (nm)

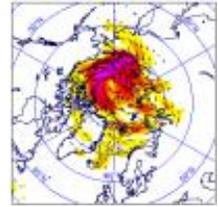
13.2	66.5	102.8	301.1	Cntrl
11.4	60.4	89.0	252.0	Cntrl + MODIS

Frequency of superior hurricane performance

48.9	44.8	39.6	29.4	Cntrl
51.1	55.2	60.4	70.6	Cntrl + MODIS

Percent of cases where the specified run had a more accurate hurricane position than the other run. Note: These cases are for hurricanes in the subtropics during 2004.

MODIS Winds in NWP

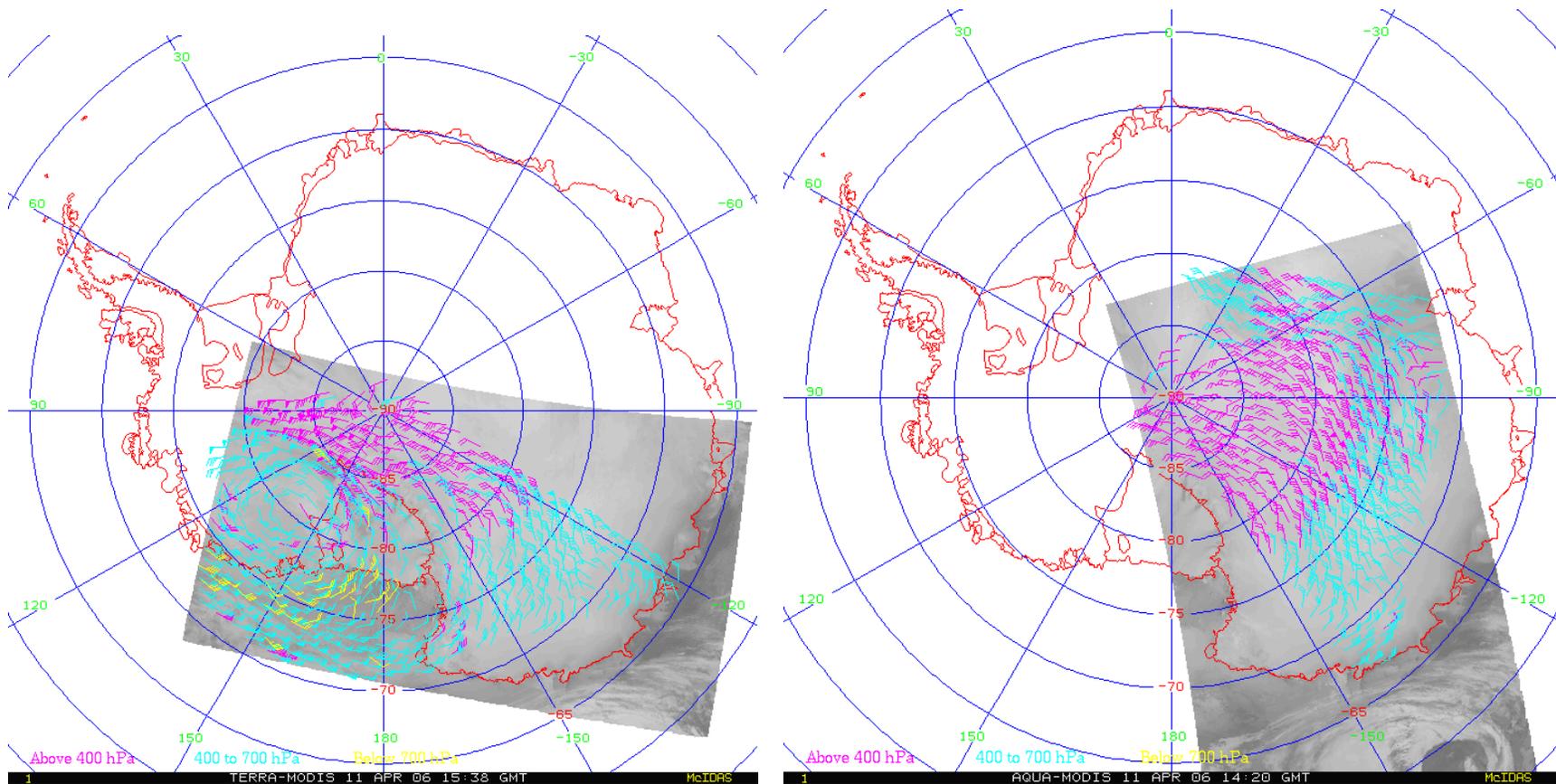


Current Operational Users:

- European Centre for Medium-Range Weather Forecasts (ECMWF) - since Jan 2003.
- NASA Global Modeling and Assimilation Office (GMAO) - since 2003.
- Deutscher Wetterdienst (DWD) – since Nov 2003.
- Japan Meteorological Agency (JMA), Arctic only - since May 2004.
- Canadian Meteorological Centre (CMC) – since Sept 2004.
- US Navy, Fleet Numerical Meteorology and Oceanography Center (FNMOC) –since Oct 2004.
- UK Met Office – since Feb 2005.
- National Centers for Environmental Prediction (NCEP) and the Joint Center for Satellite Data Assimilation - since Nov 2005.
- NCAR Antarctic Mesoscale Model (AMPS) ?

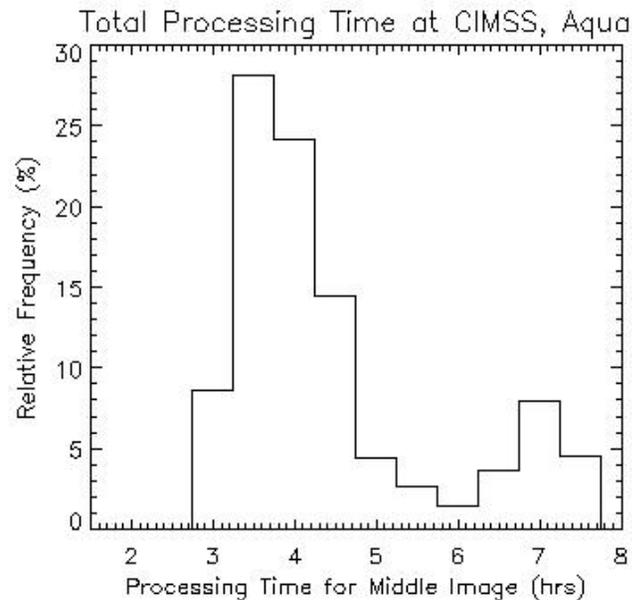
McMurdo MODIS Winds

MODIS winds system installed in November 2004. Antenna installed in January 2005. Wind production began in April 2005.



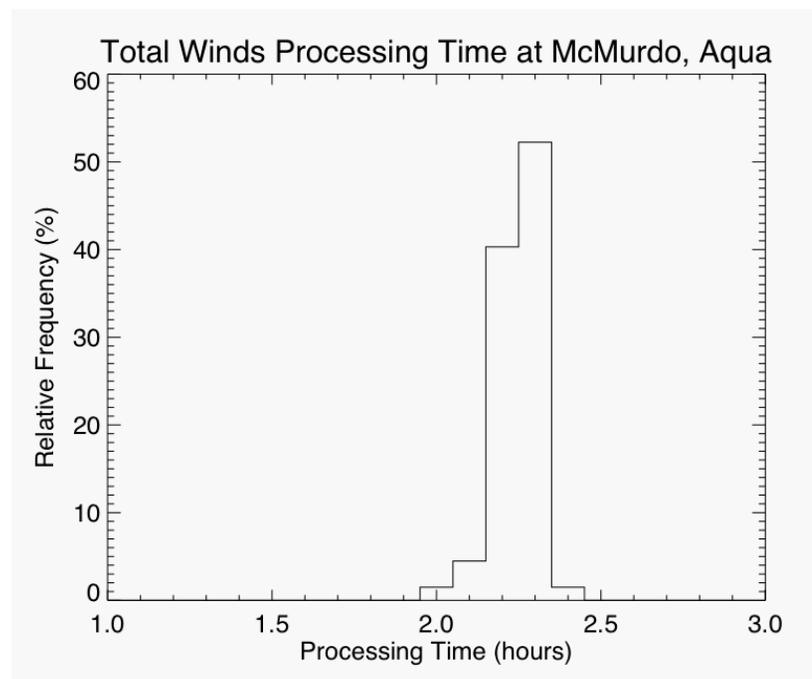
MODIS Derived Winds

- Currently, the conventional MODIS data source, the NOAA real-time system (or “bent pipe”), the polar winds product is typically available 3-5 hours after MODIS views the earth. This processing time is for the middle image in a 3-orbit triple
- This can be to the 3-hour cutoff time typical of regional weather forecast models.



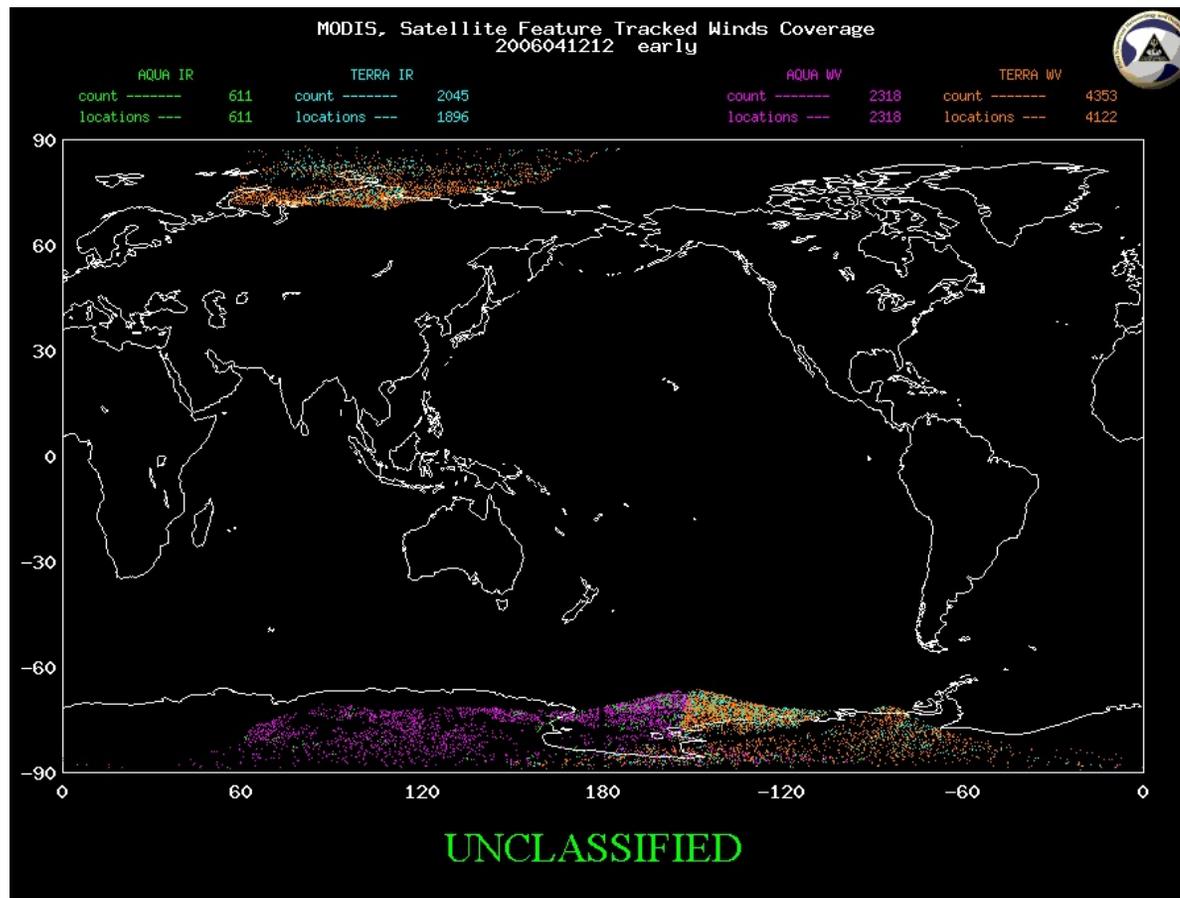
MODIS Derived Winds

- With the DB system, the wind product is generated in 2.0-2.5 hours, well within 3 hour cutoff time typical of regional weather forecast models.
- MODIS images are available (image acquisition to level 1b) in about 25 minutes.
- Winds processing takes an addition 10-15 minutes.
- Difference between DB and bent-pipe winds: ~1hr



Operational Use by Fleet Numerical Meteorology and Oceanography Center

FNMOC began using the McMurdo DB winds in March (2006) and the Tromsø winds in April. For their early model runs (1:10 cutoff), the DB winds are often the only winds available for the polar regions.



MODIS Winds Formats

Winds available via FTP (on request):

- McIDAS MD
- ASCII TXT
- BUFR

Product display and availability

- Currently, the products are being displayed on the WWW in near real time at:

<http://stratus.ssec.wisc.edu/products/db/> (click on which DB site you wish)

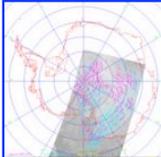
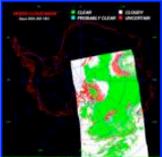
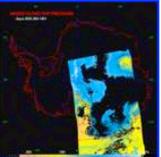
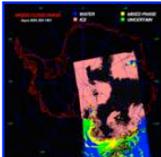
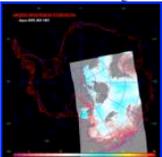
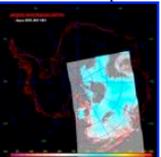
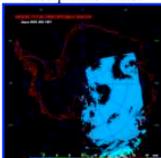
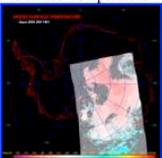
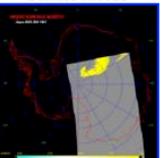
- It is hoped that a display will be installed in the McMurdo Forecasting Office next season so forecasters can use these products operationally

- Winds available via FTP (on request)

Real-Time MODIS Products from McMurdo

A number of MODIS products are generated on-site at McMurdo, Antarctica, using data from the National Science Foundation's direct broadcast system. Here are the most recent images for each product. **Click on the product links at left for more images of a specific product.** The purpose of this direct broadcast real-time system is two-fold: (1) to generate polar wind and other information more quickly than is done with our current system, so that numerical weather prediction centers can assimilate more polar data in their model runs, and (2) to provide an additional source of information, primarily winds, for weather forecasters in Antarctica.

AQUA:

Winds	Cloud Mask	Cloud Pressure
 Day 269, 12:22 UTC	 Day 269, 14:01 UTC	 Day 269, 14:01 UTC
Cloud Phase	Inversion Strength	Inversion Depth
 Day 269, 14:01 UTC	 Day 269, 14:01 UTC	 Day 269, 14:01 UTC
Precipitable Water	Surface Temperature	Surface Albedo
 Day 269, 14:01 UTC	 Day 269, 14:01 UTC	 Day 269, 14:01 UTC

TERRA:

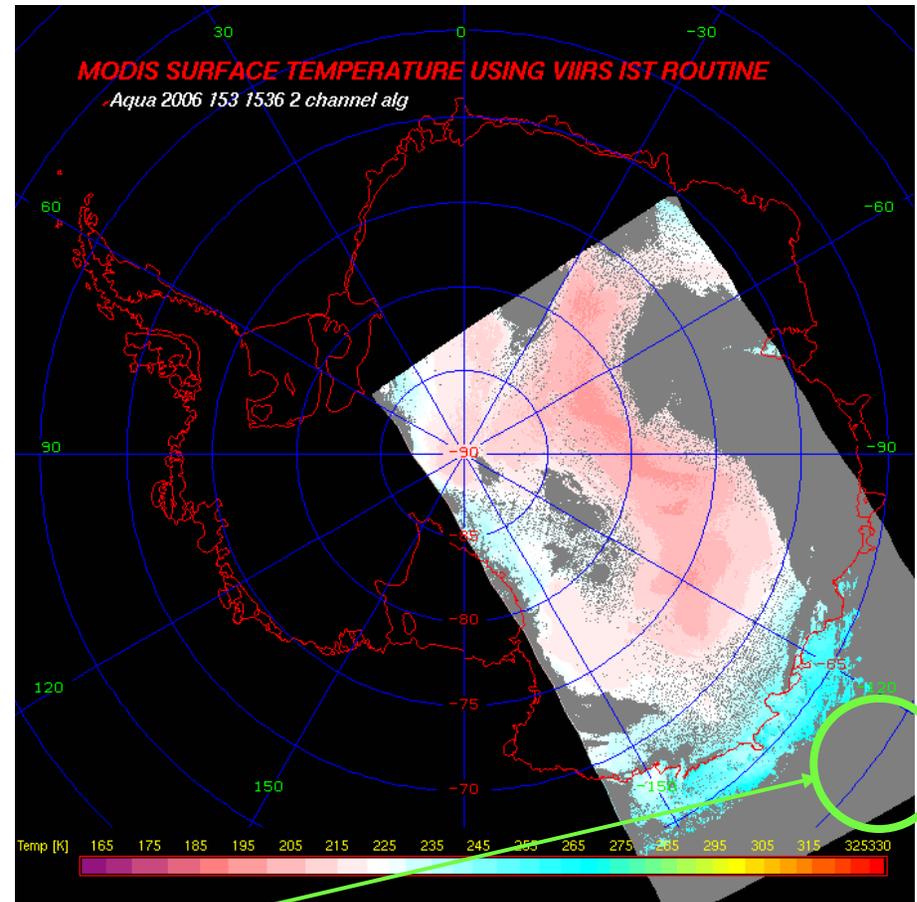
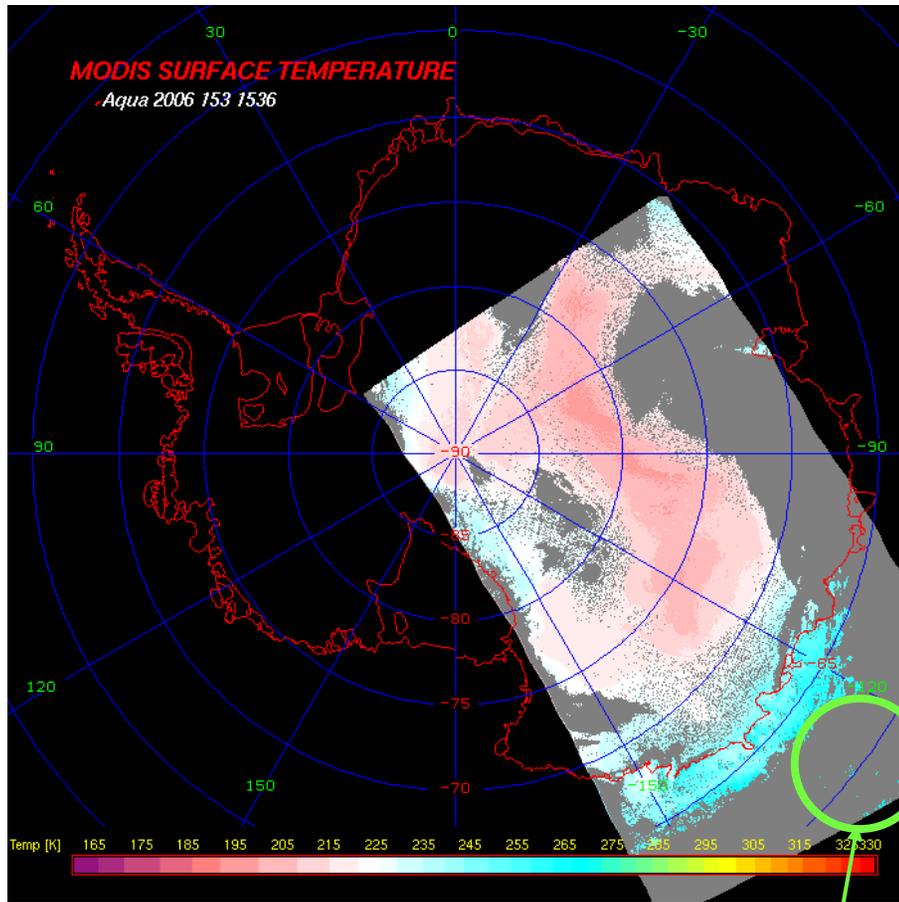
Note: The McMurdo system is currently experiencing a problem with Terra MODIS acquisition.

Winds Cloud Mask Cloud Pressure

Future Products

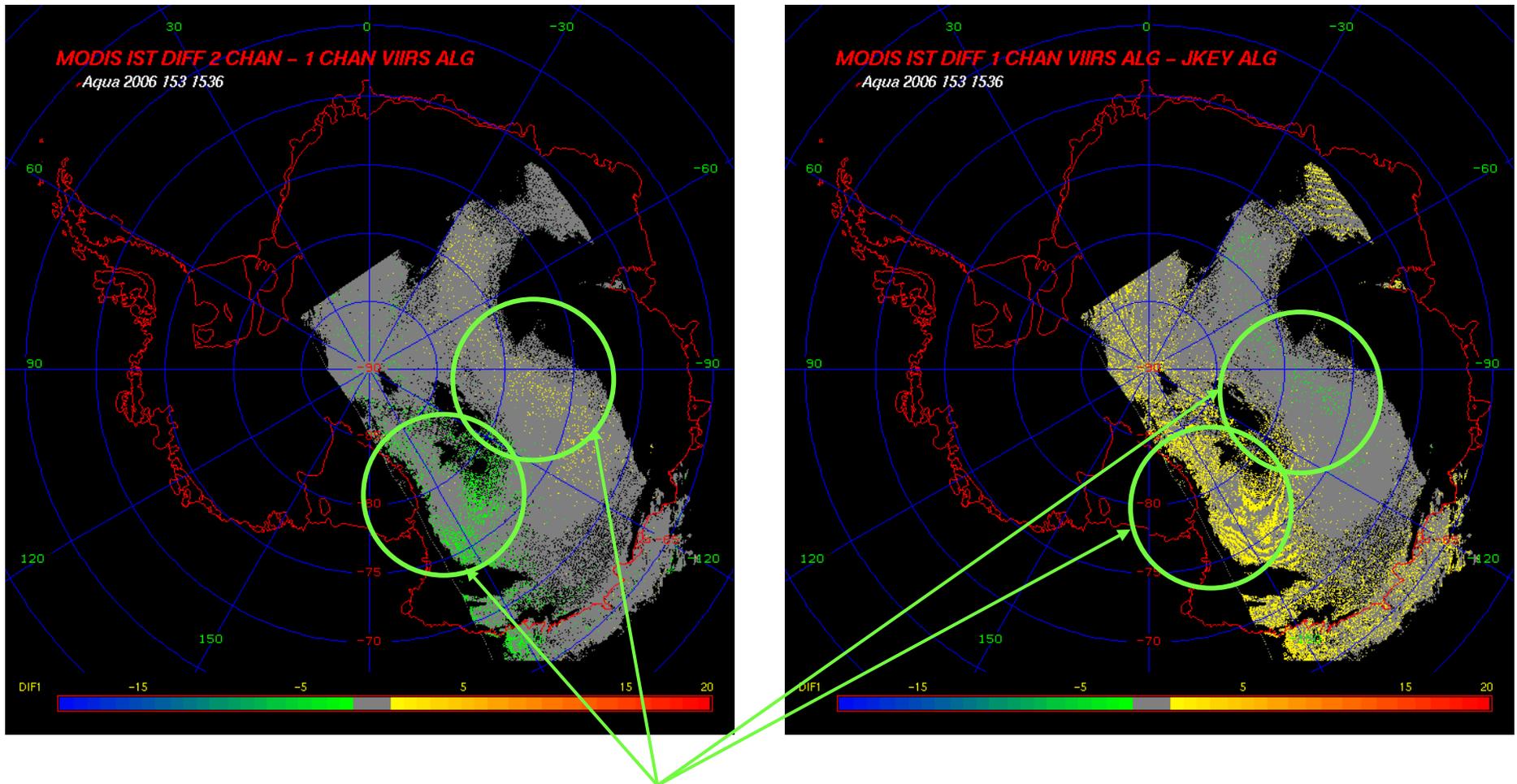
- Currently, 9 operational products are being derived and displayed.
- 4 new products are currently being planned to be performed
 - Ice motion (MODIS + AMSR-E)
 - Ice age
 - Snow cover
 - Cloud optical properties (optical thickness, cloud top effective radius)
- Other products will potentially use the DB sites as a testbed for the code used for the next generation of polar orbiters (NPP and NPOESS)
 - VIIRS 1 and 2 channel IST EDR operational May/June 2006
 - VIIRS Binary Snow Flag testing as of mid June 2006
 - Comparisons ongoing

IST Algorithm example



No ocean pixels used in comparison

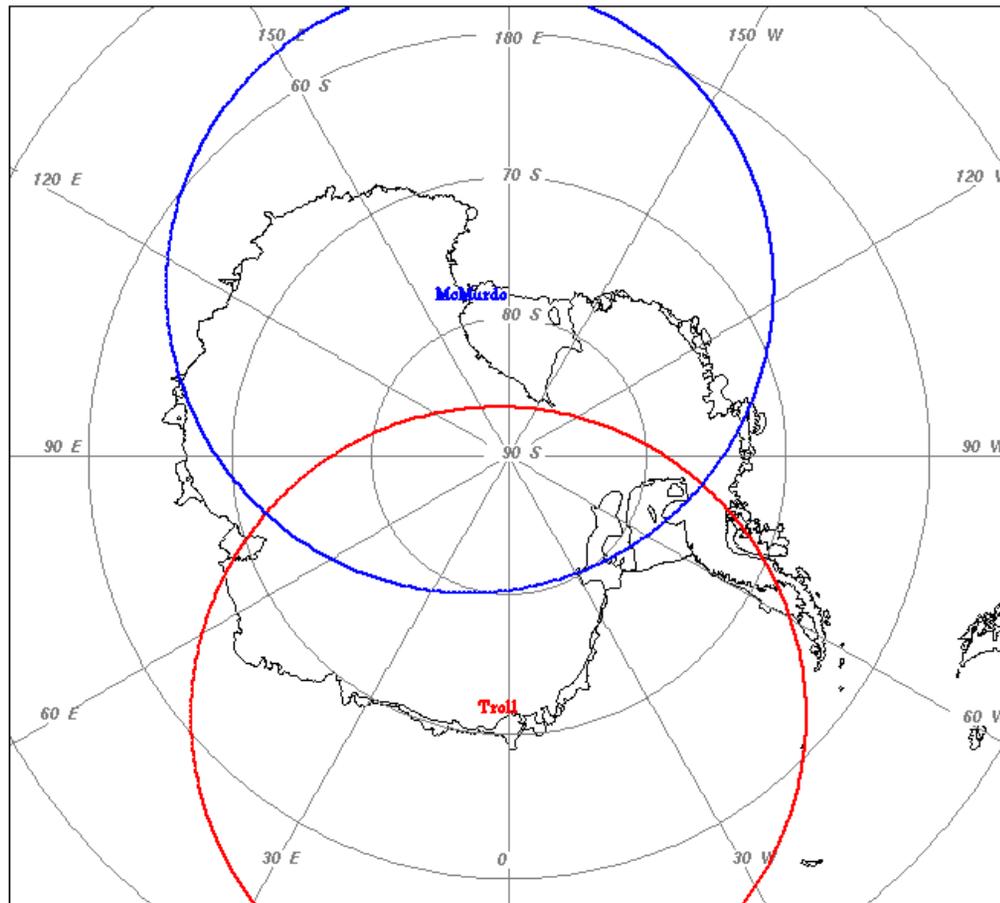
IST Algorithm difference example



Same areas and magnitudes of difference
(inversion caused by the way the math is done)

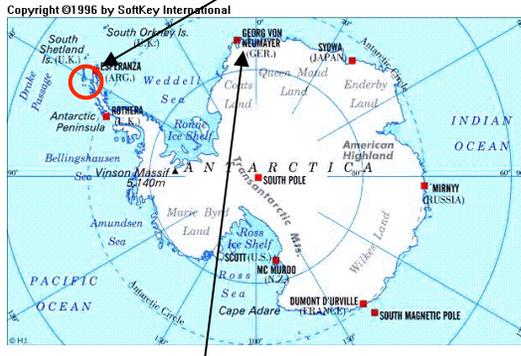
Future DB Sites (Antarctica)

Currently, MODIS data acquired at the McMurdo DB site provides extensive, but not complete coverage of the Antarctic. At least two DB sites on opposite sides of each polar region are needed for complete coverage



- Station masks for
- McMurdo Station (USA)
 - Trøll Station (Norway)

Another Potential Antarctic Site: Palmer Station is on the list for L/S/X



Trøll (Norway)





Arctic DB Site Tromsø, Norway



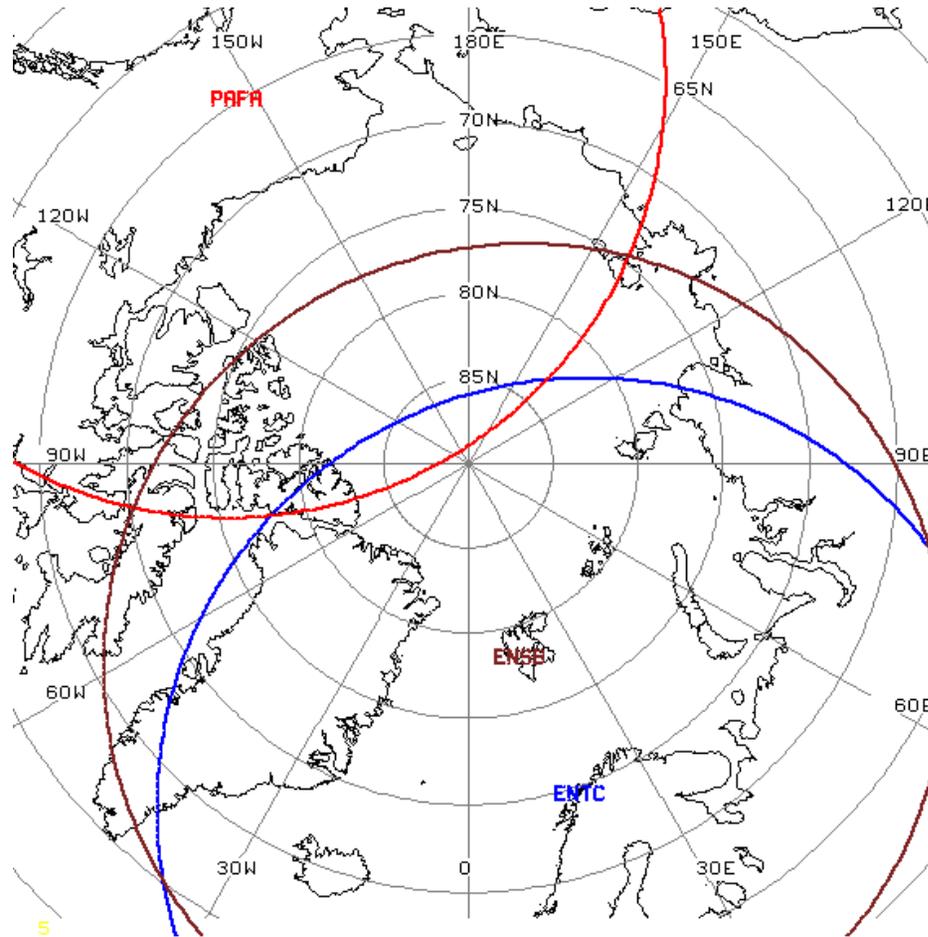
KONGSBERG

A polar winds system was installed at Tromsø, Norway, at the Kongsberg Satellite Services (Ksat) facility in February 2006. The MODIS data are currently acquired with the Integrated Program Office (IPO) antenna on Svalbard. At present, wind and product generation is from Terra only and is irregular due to antenna scheduling issues.



Arctic DB sites

- Other sites that are being considered include Fairbanks, Alaska and Sodankylä, Finland. Discussions are ongoing with the operators of those facilities (NOAA and the Finnish Meteorological Institute, respectively).



- Station masks for
- Fairbanks, Alaska
 - Tromsø, Norway
 - Svalbard

Summary

- ❖ The need for more timely MODIS polar winds data by NWP centers motivated the development of a direct broadcast winds system.
- ❖ Products using the MODIS data available at the direct broadcast sites allow for timely analysis of features such as cloud cover and surface temperature.
- ❖ DB products are currently generated on-site at McMurdo, Antarctica (Terra and Aqua, ~20 passes per day total), and Tromsø, Norway (Terra only, irregularly).
- ❖ DB winds are available 50-60 minutes after flyover. Add 100 minutes for the middle-image time. This is a time savings of 1-2+ hours over the bent-pipe winds.
- ❖ Wind data are sent back to CIMSS and can available for NWP usage
 - ❖ Currently data is being pushed to the U.S. Navy Fleet Numerical Meteorology and Oceanography Center (FNMOC).
 - ❖ Data can be made available on request to users
- ❖ Wind data available in MD, ASCII and BUFR formats.

Summary (continued)

- ❖ All data can be viewed via the WWW.
 - ❖ Potential for onsite display at McMurdo
 - ❖ New AMRC hardware
 - ❖ Distribution of data via LDM (Antarctic-IDD)

- ❖ Due to the coverage of each DB site, two sites on opposite sides of the pole are necessary to cover entire polar region

- ❖ Potential future Antarctic sites include Palmer Station (USAP) and Troll Station (Norway).

- ❖ Other potential Arctic sites include the NOAA system at Gillmore Creek, Alaska (Aqua only), and Sodankylä, Finland. Routine generation at Sodankylä is expected in Fall 2006.

Surface and Cloud Products

- MODIS Level 0 and Level 1b Product generated with SEADAS (NASA, Fu et al., 1998).
- Level 2 (MOD35 (Cloud mask), MOD06 and MOD07) products generated using the International MODIS/AIRS Processing Package (IMAPP)
 - The IMAPP MODIS Cloud Mask direct broadcast version of the GFSC DAAC MOD35 product (Ackerman et al., 1998).
 - Documentation on the IMAPP MODIS cloud mask is described in detail in Strabala et al. (2002) while the MODIS cloud top properties products (MOD06) are described in Menzel et al., 2002)
 - Cloud top pressure and cloud particle thermodynamic phase are the key parameters included in the MODIS cloud top properties product (Menzel et al., 2002; MOD06CT).
 - Total precipitable water is the only MOD07 product currently available.

Surface and Cloud Products

- Surface temperature, broadband albedo, inversion strength and depth are also derived.
 - The algorithms used were originally developed for use with Advanced Very High Resolution Radiometer (AVHRR) data and have been adapted for use with MODIS.
 - (Key et al., 1997; Key et al., 2001)
- Surface variables are calculated for each non-cloudy pixel, as determined from the MODIS cloud mask.
- The surface type is determined by the MOD35 processing flag