The Polar Wind Product Suite

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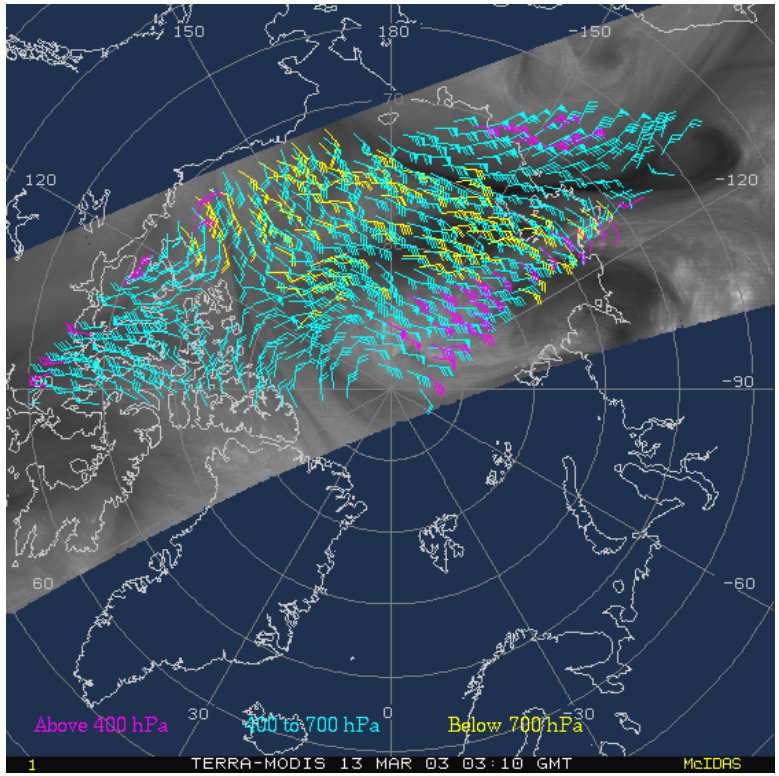
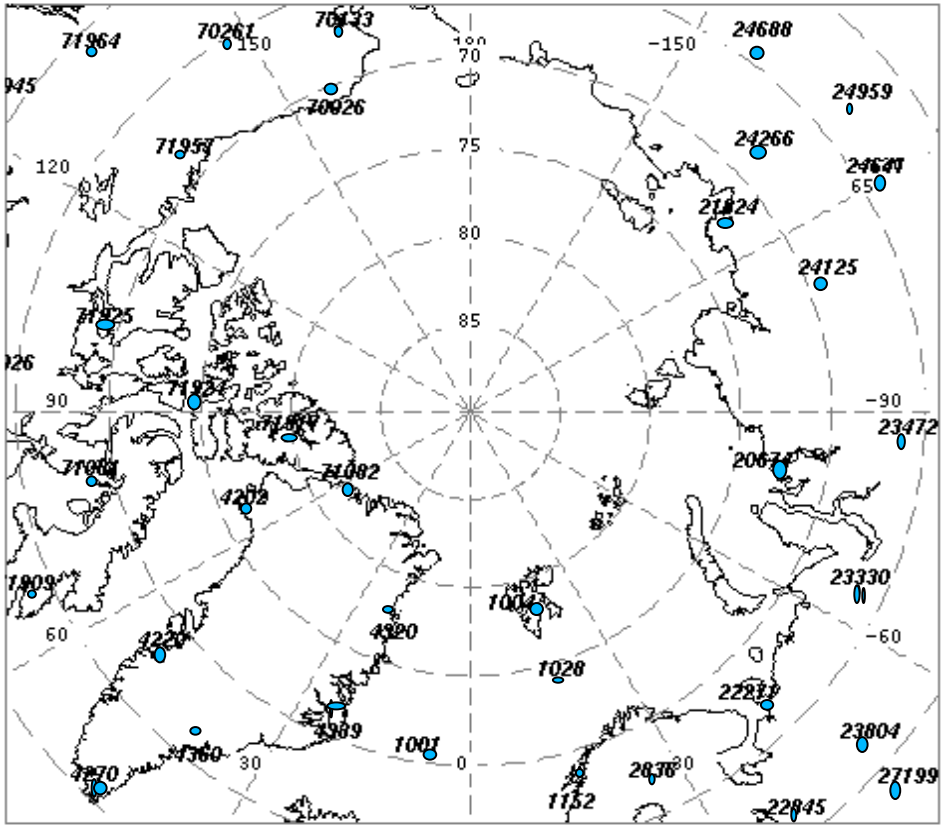
Objectives:

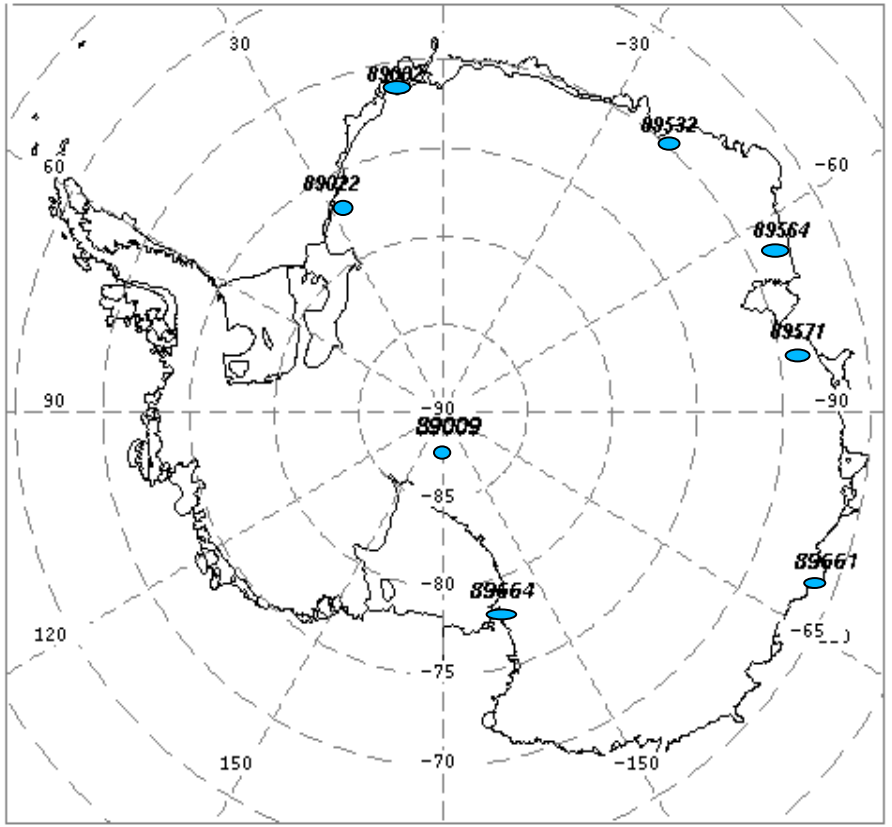
1. To describe the suite of satellite-derived polar wind products.
2. To solicit feedback on desirable products, enhancements, and problems.



Motivation

Sparse Observing Network





Regularly reporting radiosonde stations in the Arctic and Antarctic.

Positive Impact on Forecasts

Model impact studies have shown that the polar winds have a positive impact on weather forecasts not just in the polar regions, but globally.

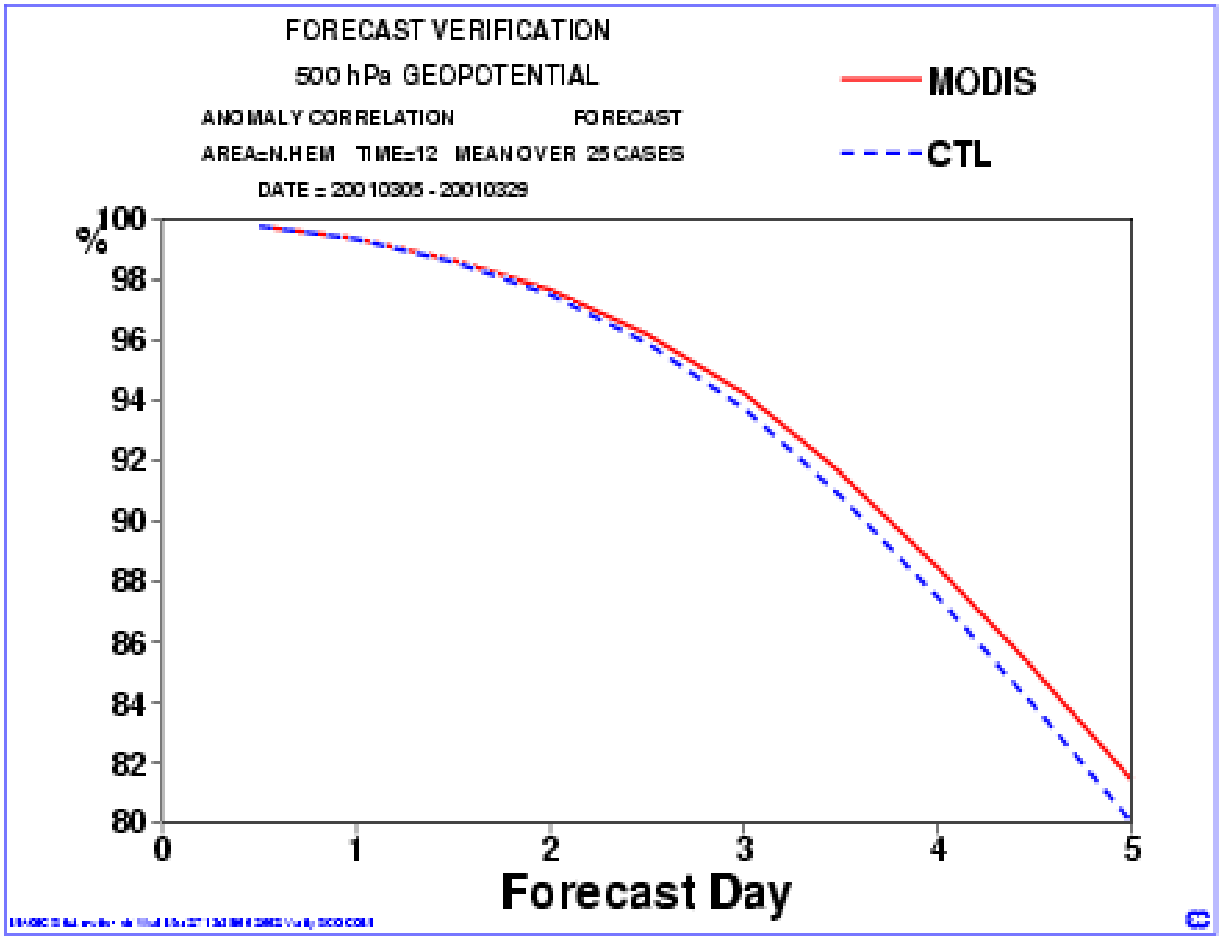


Figure: Anomaly correlations as a function of forecast range for the 500 hPa geopotential over the Northern Hemisphere extratropics (north of 20 degrees latitude). The study period is 5-29 March 2001. Including the MODIS winds in the model (red line) extends the 5-day forecast at a given accuracy by 3-6 hrs.

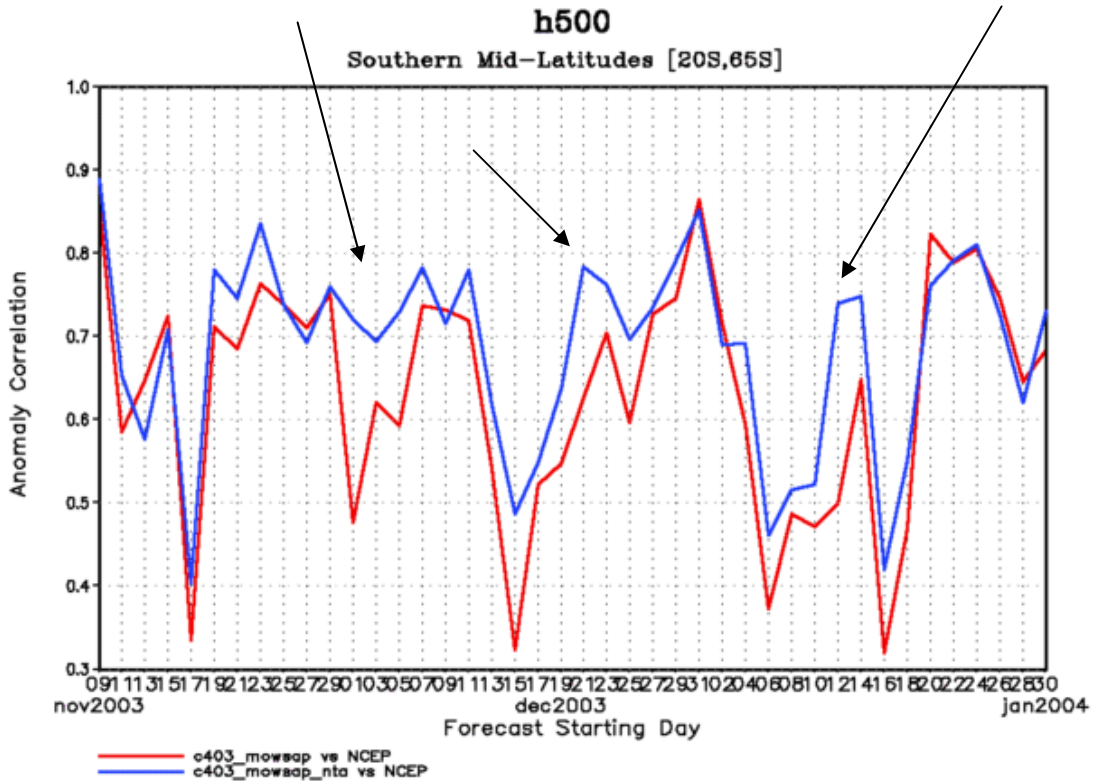
Forecast scores (anomaly correlations) are the correlation between the forecast geopotential height anomalies, with and without the MODIS winds, and their own analyses.

(Courtesy of ECMWF)

Forecast Busts

While the overall impact of the MODIS winds is positive, the impact at any given time may be positive, negative (occasionally), or neutral. What's important, however, is that the MODIS winds significantly reduce the likelihood and magnitude of forecast "busts", as shown below in time series of anomaly correlations.

Southern Hemisphere Extratropics



Blue is forecast with MODIS winds; red is control run

(Courtesy of GMAO)

Hurricane Track Forecasts

Average hurricane track errors (nm)

13.2	66.5	102.8	301.1	Cntrl
11.4	60.4	89.0	252.0	Cntrl + MODIS
74	64	52	34	Cases (#)
00-h	24-h	48-h	120-h	Time

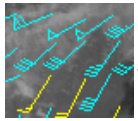
In both tables, the forecast time is the bottom row. The control run (Cntrl) did not assimilate the MODIS winds.

Frequency of superior hurricane performance

48.9	44.8	39.6	29.4	Cntrl
51.1	55.2	60.4	70.6	Cntrl + MODIS
74	64	52	34	Cases (#)
00-h	24-h	48-h	120-h	Time

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.

(Courtesy of JCSDA)



Polar Wind Product Suite

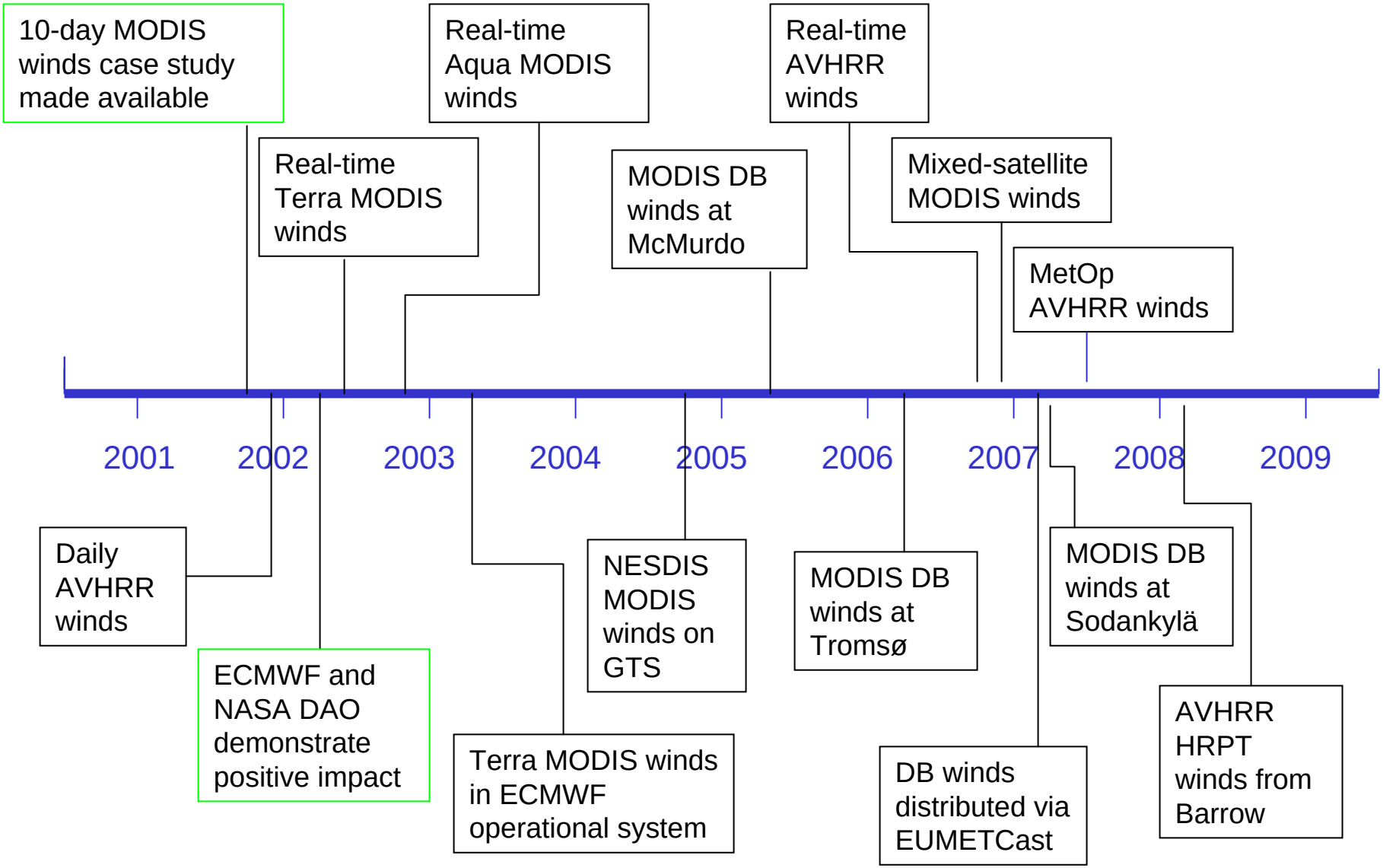
MODIS Polar Winds

- Aqua and Terra separately, bent pipe data source
- Aqua and Terra combined, bent pipe
- Direct broadcast (DB) at
  - McMurdo, Antarctica (Terra and Aqua separately)
  - Tromsø, Norway, antenna on Svalbard (Terra only)
  - Sodankylä, Finland (Terra only)
  - Fairbanks, Alaska (Aqua only, not yet mature). *Terra planned.*

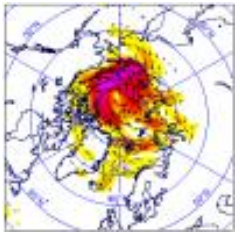
AVHRR Polar Winds

- Global Area Coverage (GAC) for NOAA-15, -16, -17, -18
- MetOp
- HRPT (High Resolution Picture Transmission = direct readout) at
  - Barrow, Alaska
  - *Planned Antarctic sites: Casey or Davis (Australia) and Rothera or Halley (UK).*
- Historical GAC winds, 1982-2002. *Extension/enhancement planned.*

Polar Wind Product History



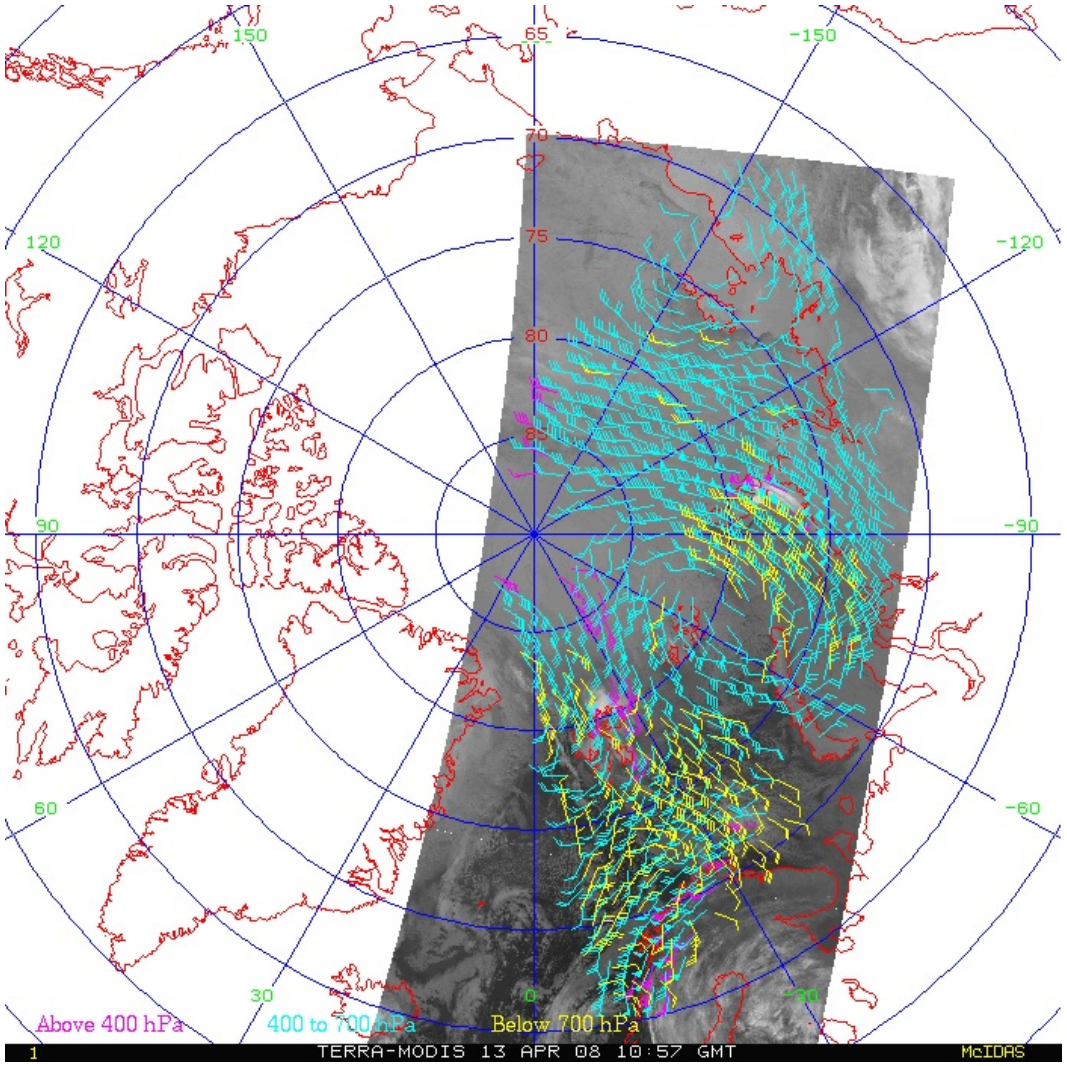
MODIS Winds in NWP



Current <u>Operational</u> Users:

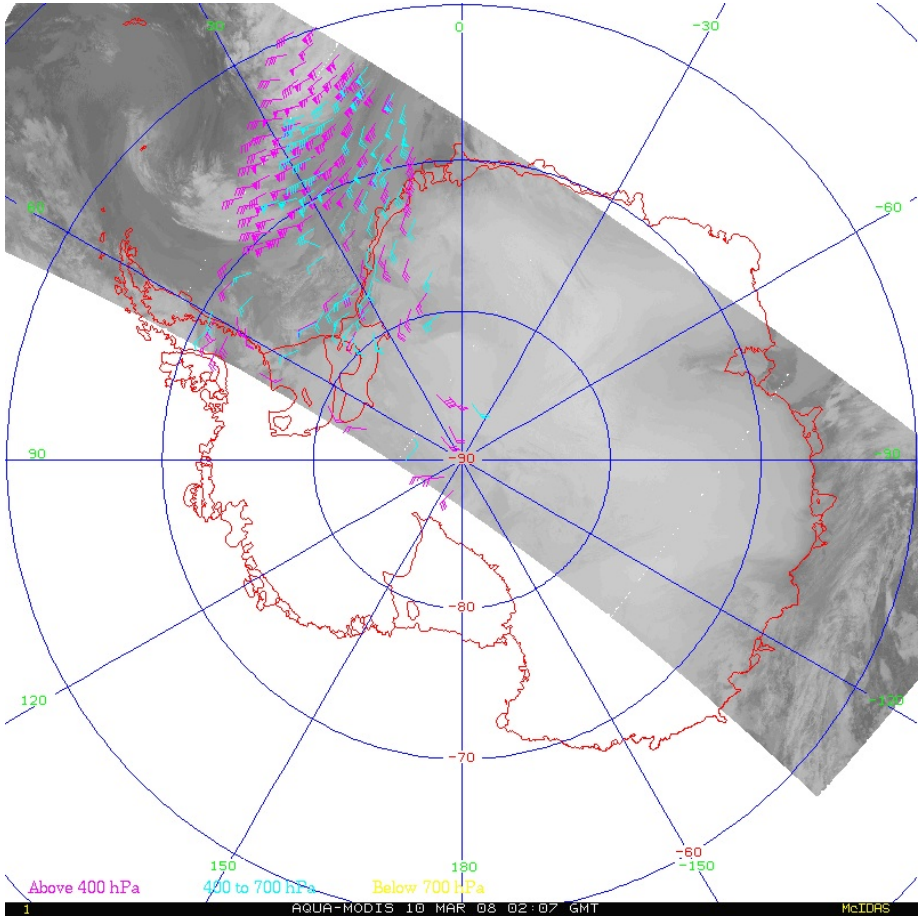
- European Centre for Medium-Range Weather Forecasts (ECMWF) - since Jan 2003.
- NASA Global Modeling and Assimilation Office (GMAO) - since early 2003.
- Deutscher Wetterdienst (DWD) – since Nov 2003.
- Japan Meteorological Agency (JMA), Arctic only - since May 2004.
- Canadian Meteorological Centre (CMC) – since Sept 2004.
- US Navy, Fleet Numerical Meteorology and Oceanography Center (FNMOC) –since Oct 2004. DB winds since Apr 2006. AVHRR GAC and MetOp since Nov 2007.
- UK Met Office – since Feb 2005. DB winds (experimentally) since Jun 2006. AVHRR GAC (experimentally) since ?.
- National Centers for Environmental Prediction (NCEP) and the Joint Center for Satellite Data Assimilation - since Nov 2005.
- MeteoFrance - since Jun 2006.
- National Center for Atmospheric Research (NCAR), Antarctic Mesoscale Model (AMPS) - since Oct 2006.
- Australian Bureau of Meteorology - since Sept (?) 2007

MODIS Winds: Single Satellite

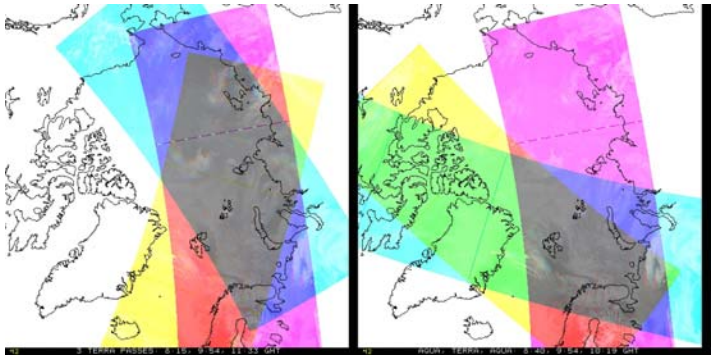


- Aqua and Terra winds are generated separately
- Data from the NOAA Real-Time System (aka “bent pipe”), composites of two or three 5-min granules.
- 1 km MODIS product (MOD021KM) is remapped to 2 km
- Cloud-track and water vapor winds
- NCEP’s GFS is used as the background
- Pros: Complete polar coverage
- Cons: Some MODIS granules arrive (very) late

MODIS Winds: Mixed Satellite (Aqua and Terra)



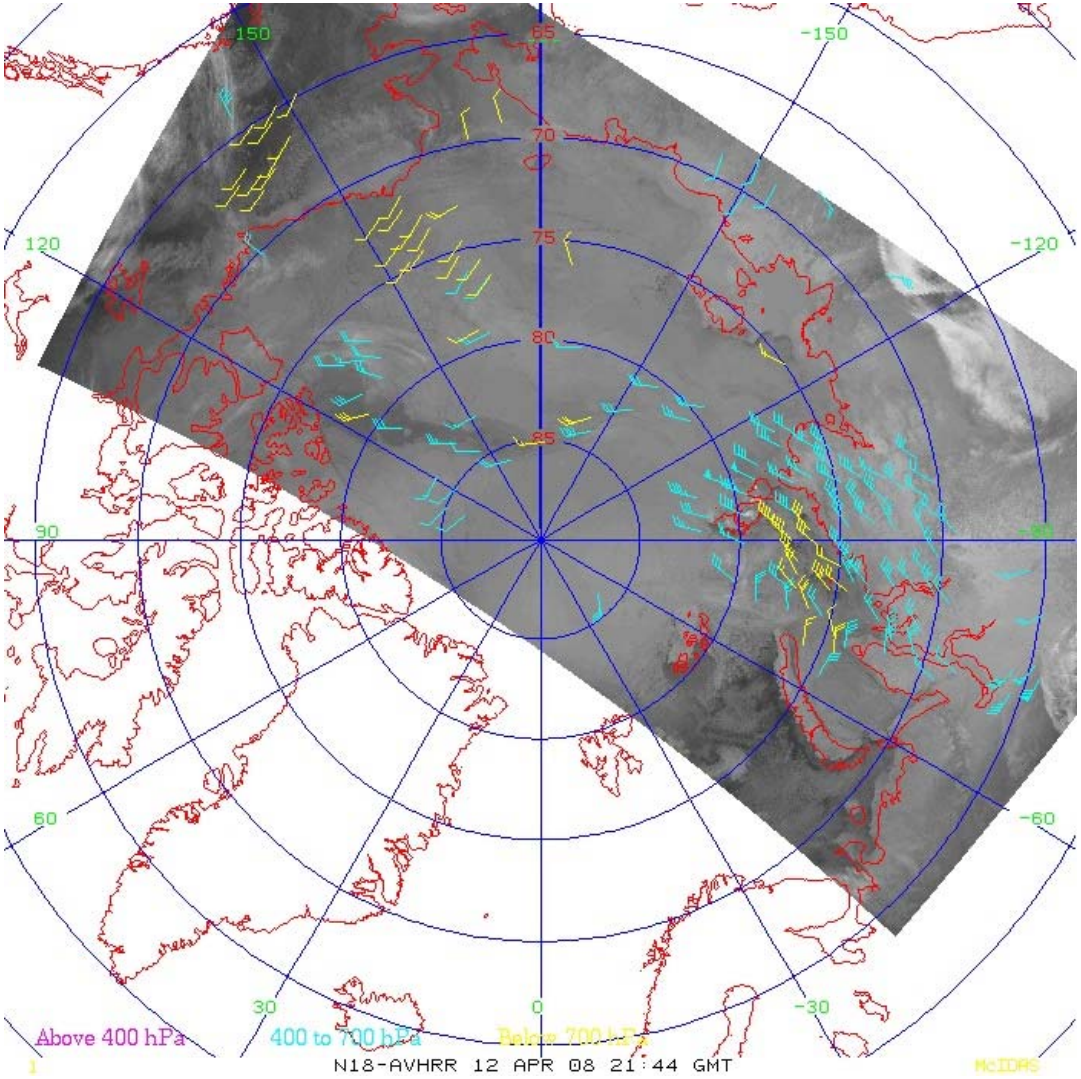
Terra only



Aqua, Terra, Aqua

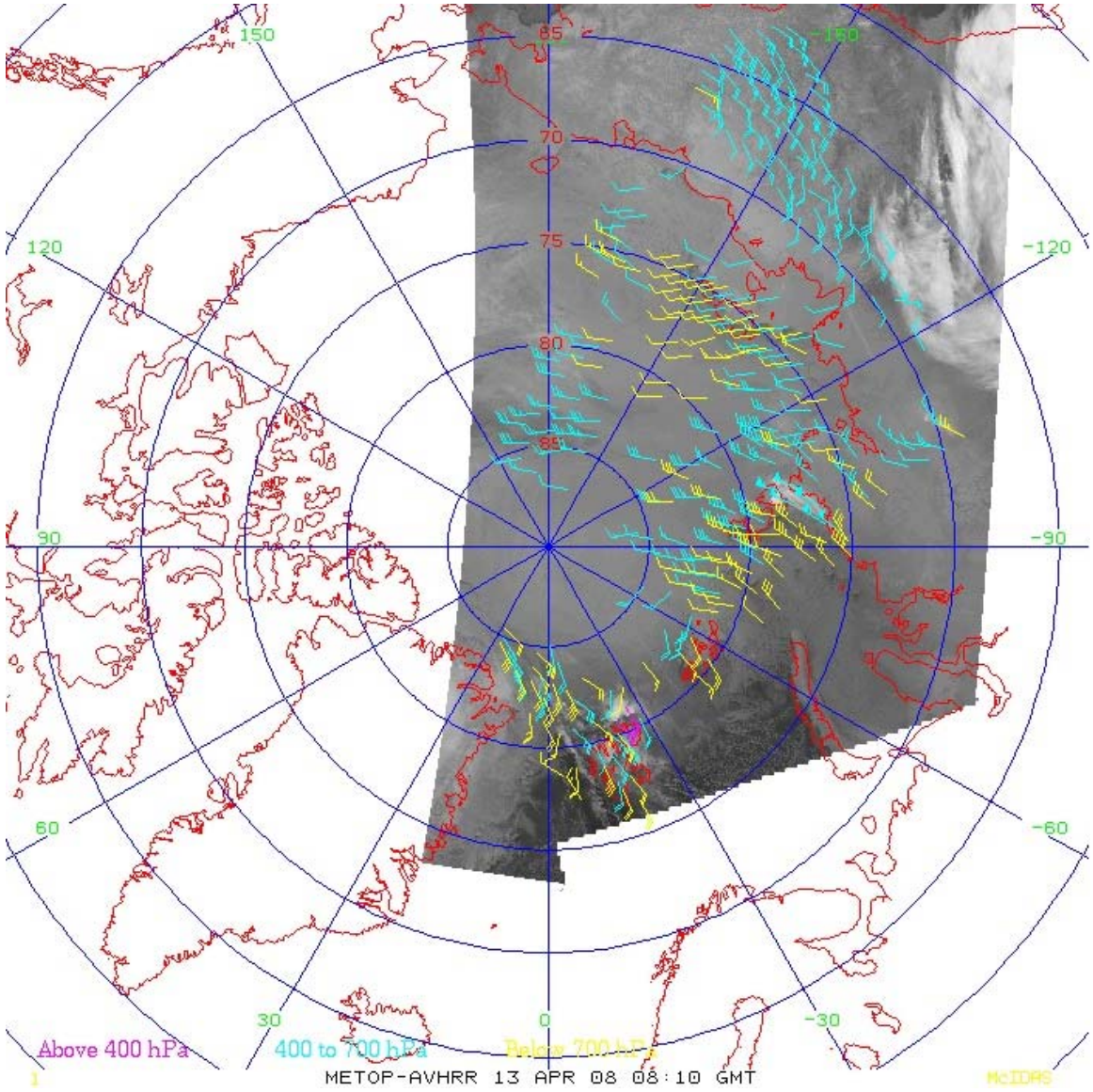
- Aqua and Terra data streams combined
- Data from the NOAA Real-Time System (aka “bent pipe”), composites of two or three 5-min granules.
- 1 km MODIS product (MOD021KM) remapped to 2 km
- Cloud-track and water vapor winds
- NCEP’s GFS is used as the background.
- Pros: Complete polar coverage; lower latency (100 min rather than 200 for a triplet); somewhat lower latitude coverage (poleward of 65 degrees).
- Cons: Smaller area of overlap so fewer vectors each pass. Parallax is a problem.

AVHRR GAC Winds



- Four satellites: NOAA-15, -16, -17, -18
- 4 km
- Cloud-track winds
- NCEP's GFS is used as the background.
- Pros: Complete polar coverage; excellent temporal sampling with 4 satellites. Good preparation for NPOESS VIIRS.
- Cons: No water vapor clear winds (no clear sky). Lower spatial resolution yields fewer vectors. Height assignment uncertainty for thin clouds.

MetOp AVHRR Winds

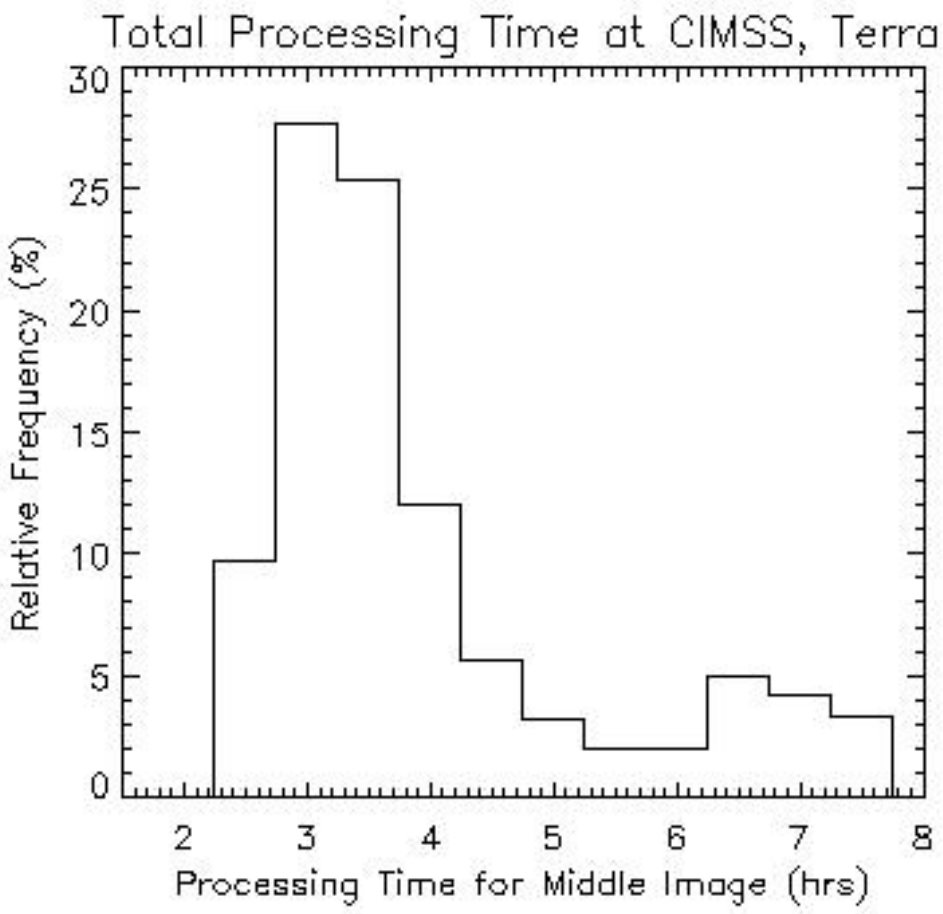


- 1 km data remapped to 2 km.
- Cloud-track winds
- NCEP's GFS is used as the background.
- Collaborating with EUMETSAT. Parallel products planned.
- Pros: Complete polar coverage. Higher resolution than GAC = more accurate and more vectors. Good preparation for NPOESS VIIRS.
- Cons: No water vapor clear winds (no clear sky). Height assignment uncertainty for thin clouds.

MODIS Polar Winds Real-Time Processing Delays

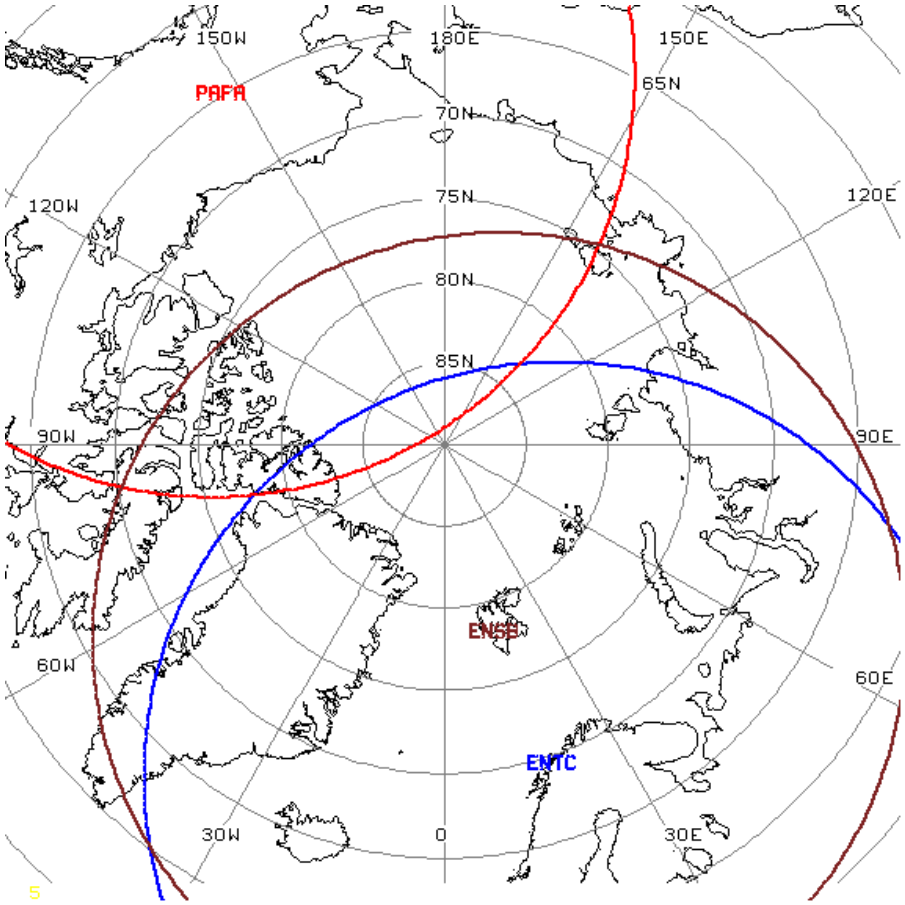
With an average delay of 3-5 hours, MODIS and AVHRR GAC winds do not meet the 3-hr (or less) cutoff for early model runs.

Possible solution: Generate winds with direct broadcast data on site.

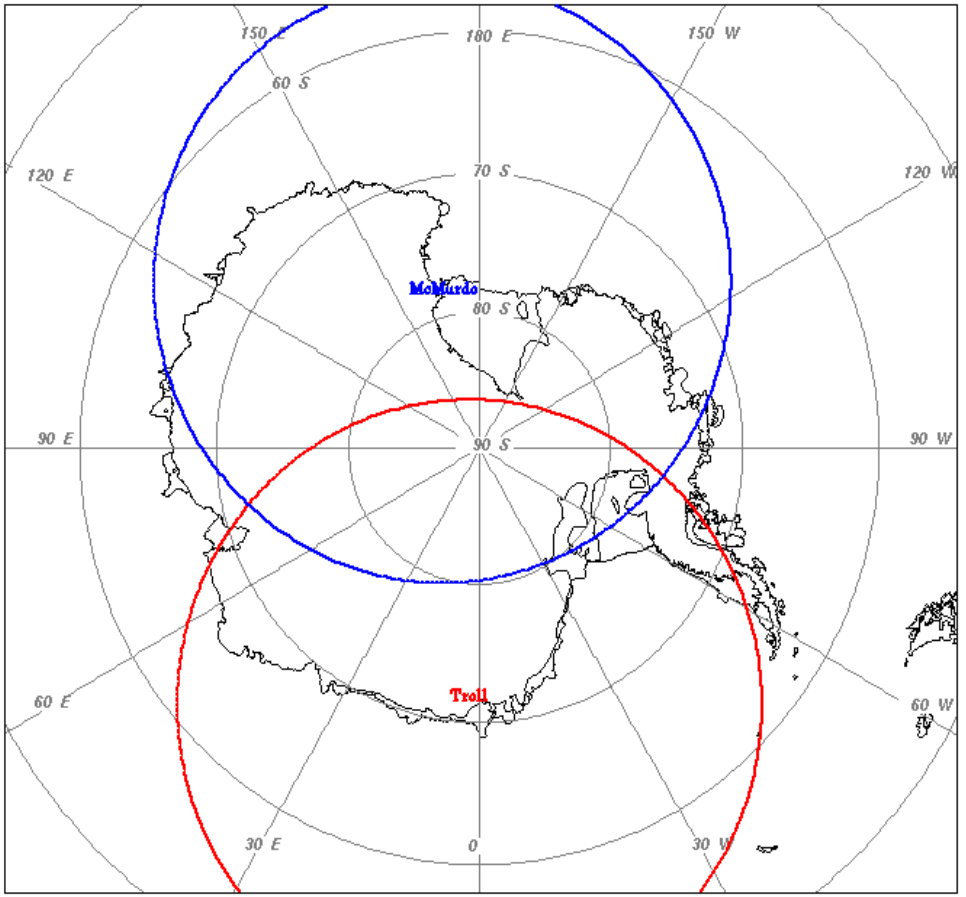


Processing times are for the middle image in a 3-orbit triplet. Actually processing time from image acquisition to availability of wind vectors is 100 minutes (1.67 hrs) less than shown.

Some Receiving Station Masks in the Arctic and Antarctic

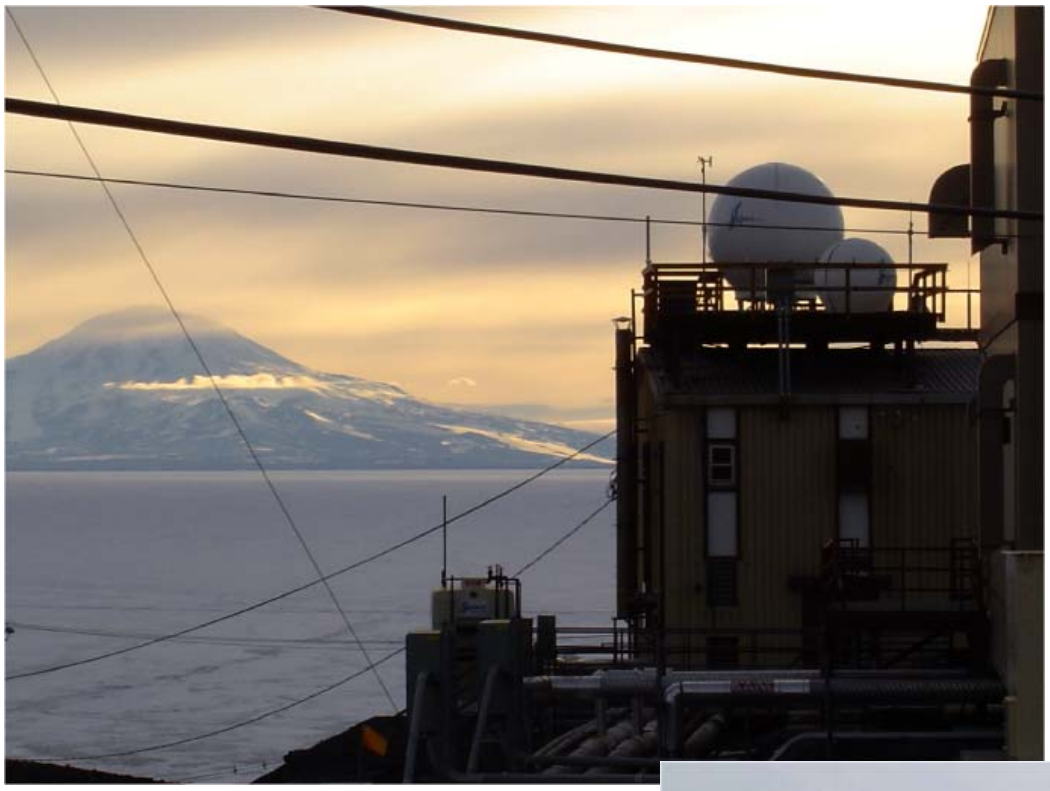


Station masks for
- Fairbanks, Alaska
- Tromsø, Norway
- Svalbard



Station masks for
- McMurdo
- Troll (Norway)

DB Sites: McMurdo and Tromsø



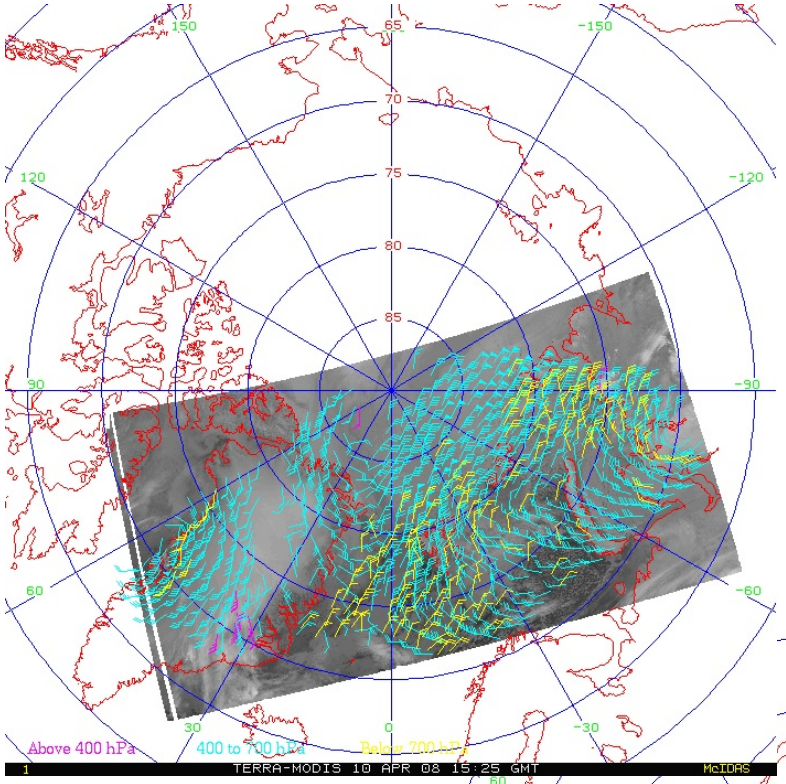
McMurdo (at left): National Science Foundation

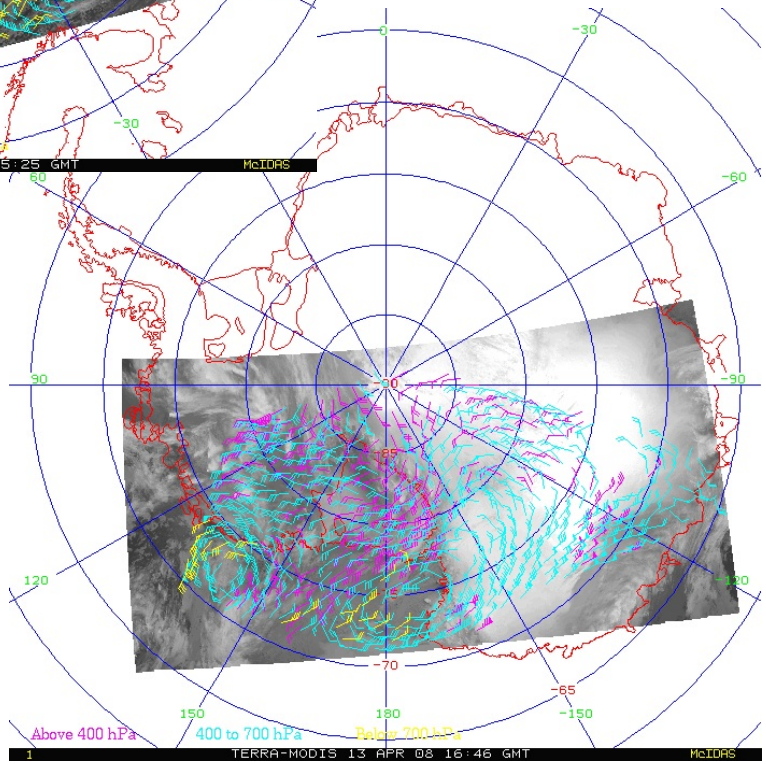
Raytheon
Polar Services

KONGSBERG

Tromsø (Svalbard pictured at right): Kongsberg Satellite Service and the US Integrated Program Office

MODIS Winds: Direct Broadcast





Above: Tromsø DB winds

Right: McMurdo DB winds

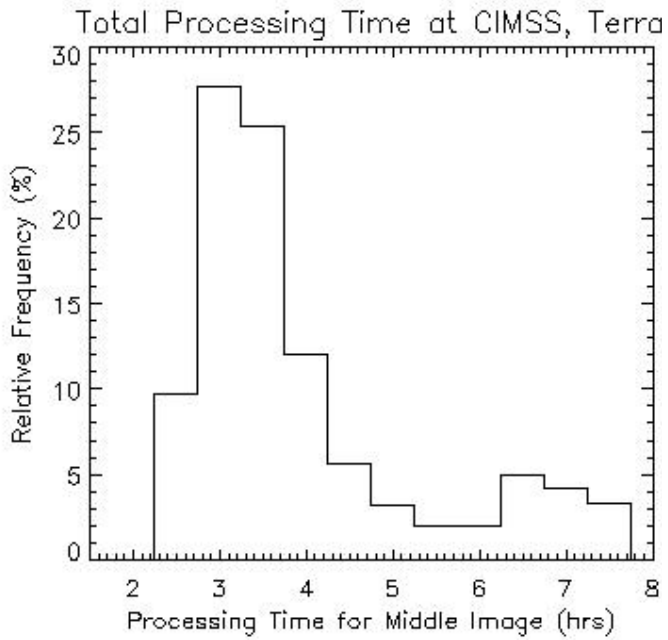
- Aqua and Terra winds are generated separately
- Data source is direct readout (broadcast)
- 1 km MODIS product (MOD021KM) is remapped to 2 km.
- Cloud-track and water vapor winds
- NCEP's GFS is used as the background.
- Pros: Low latency; high resolution.
- Cons: Incomplete polar coverage.

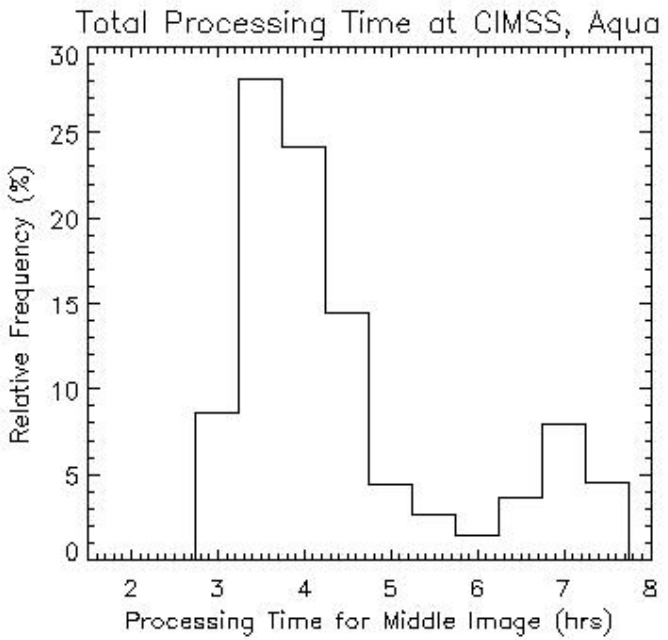
MODIS Polar Winds Total Processing Time

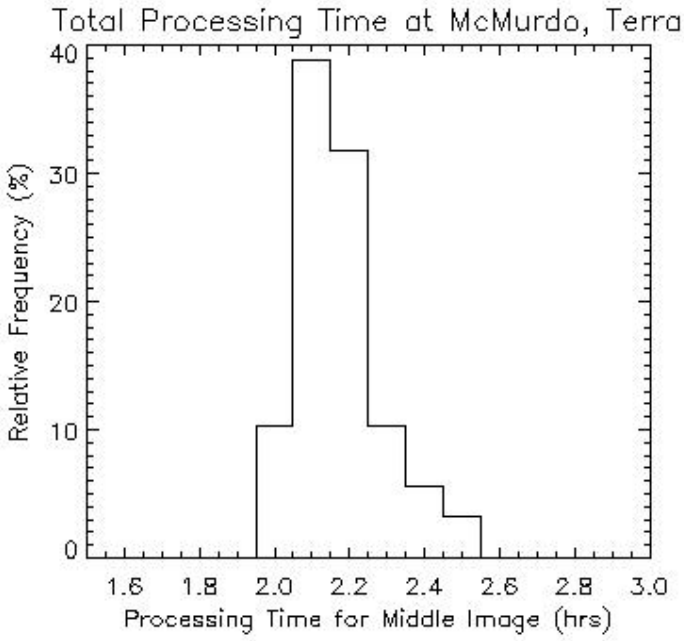
Bent pipe

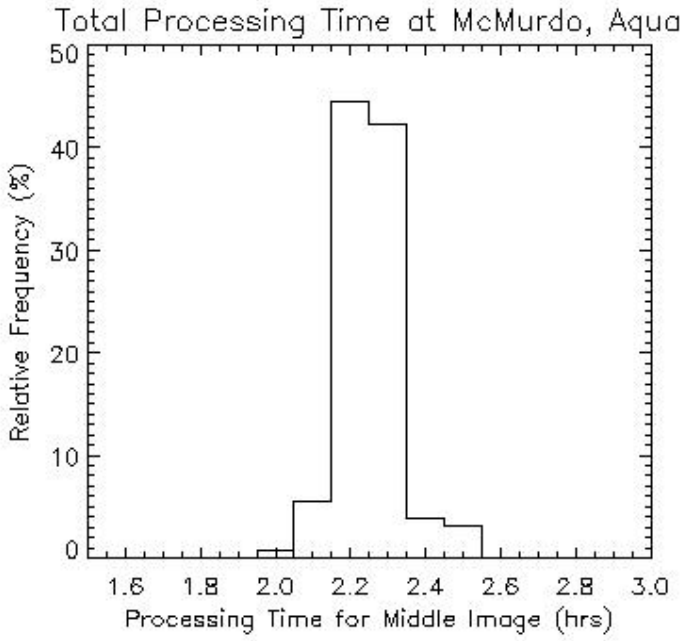
Processing times are for the middle image in a 3-orbit triplet. Actually processing time from image acquisition to availability of wind vectors is 100 minutes (1.67 hrs) less than shown.

McMurdo DB





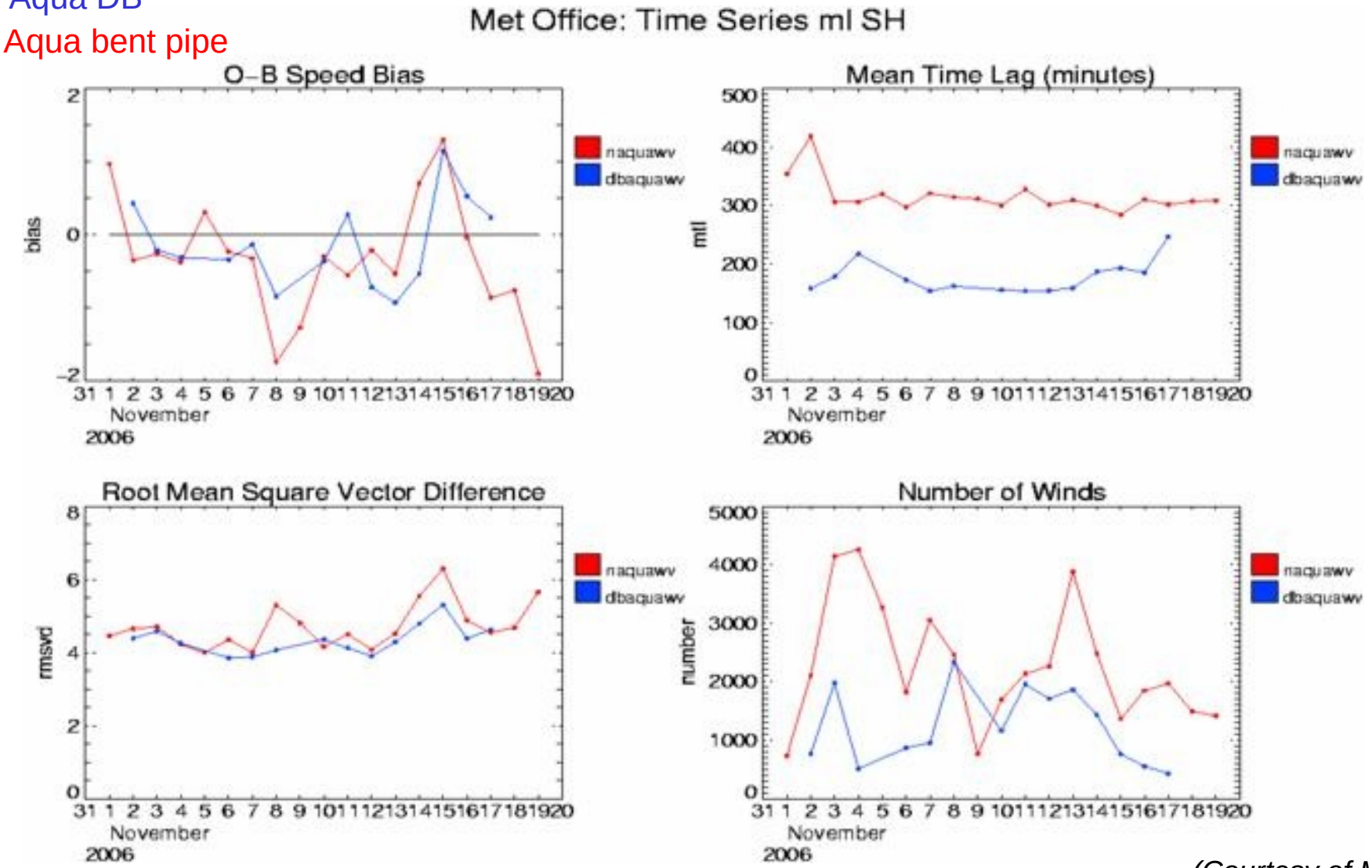




DB/Bent-Pipe Wind Comparison

Blue is Aqua DB

Red is Aqua bent pipe

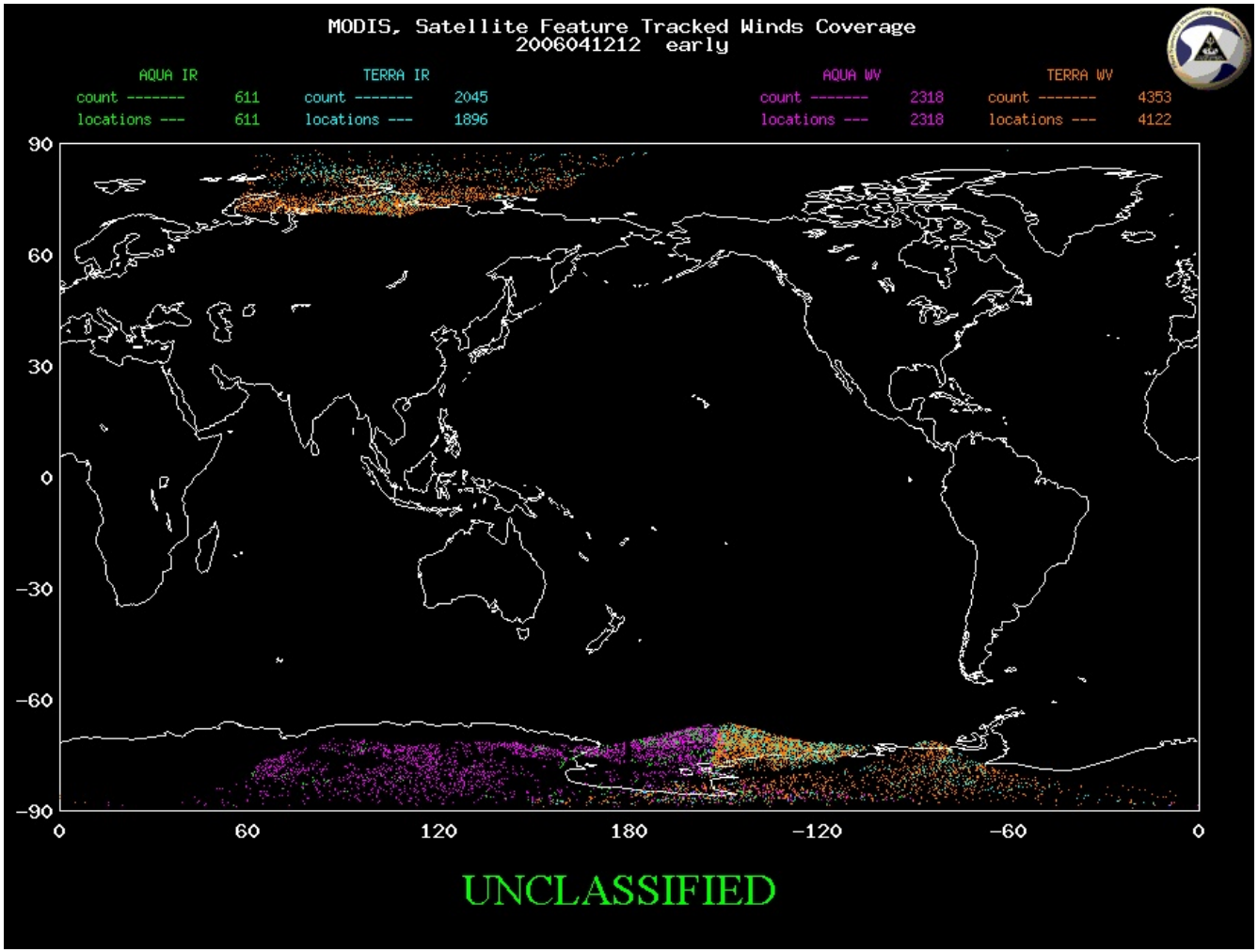


(Courtesy of Met Office)

The DB MODIS polar winds are similar in quality and number to the "bent-pipe" winds, but are available significantly faster (approximately 100 minutes). This example is for Aqua winds in the Southern Hemisphere. The Northern Hemisphere results are similar.

DB Wind Use at Fleet Numerical Meteorology and Oceanography Center

For FNMOC's early model runs (1:10 cutoff), the DB winds are often the only winds available for the polar regions.



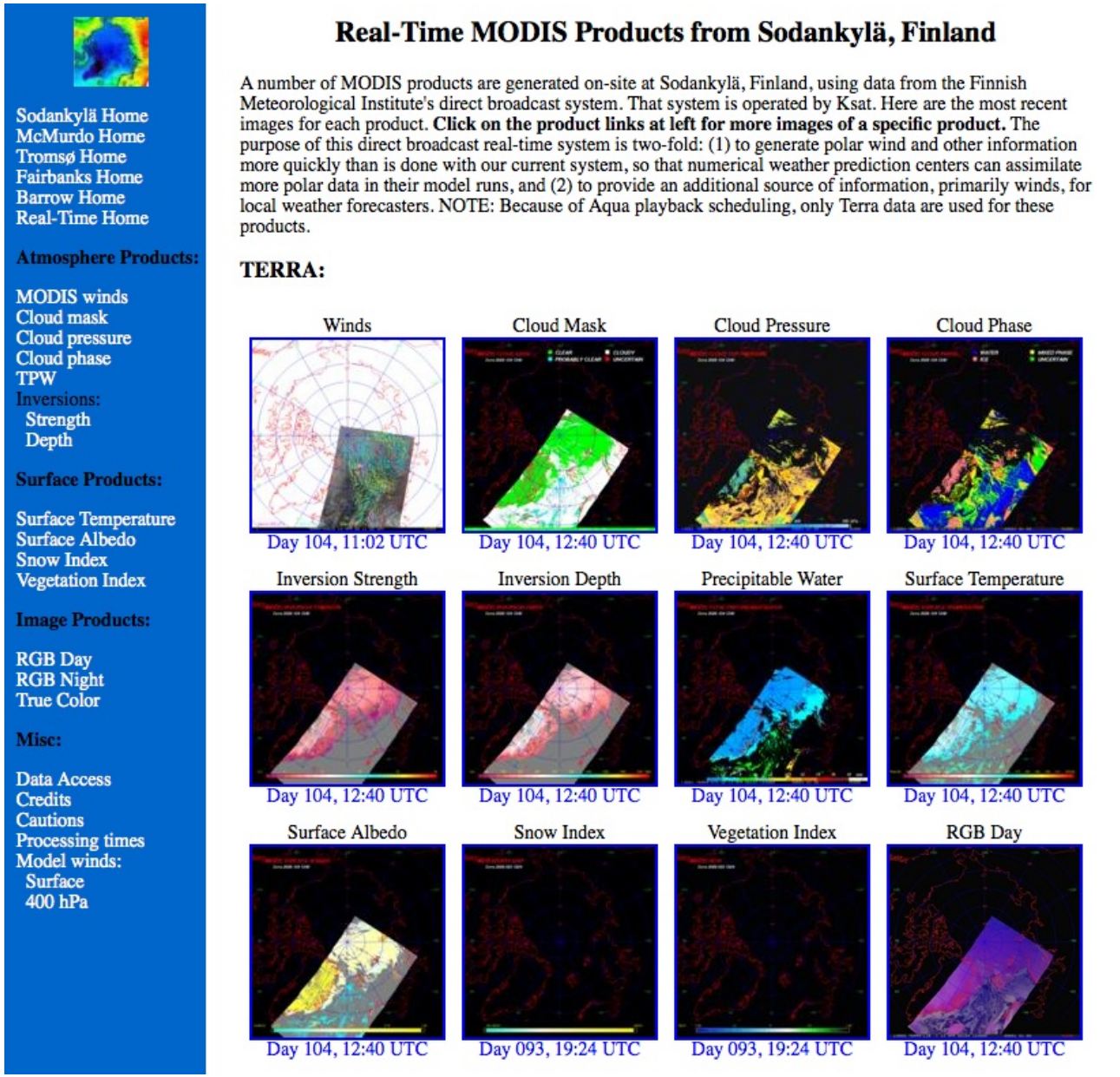
Other products are also generated at DB sites

Current DB Products (all MODIS):
Winds
Cloud mask*
Cloud pressure*
Cloud phase*
Total precipitable water*
Inversion strength
Inversion depth
Ice/snow surface temperature
Ice/snow albedo
Snow cover

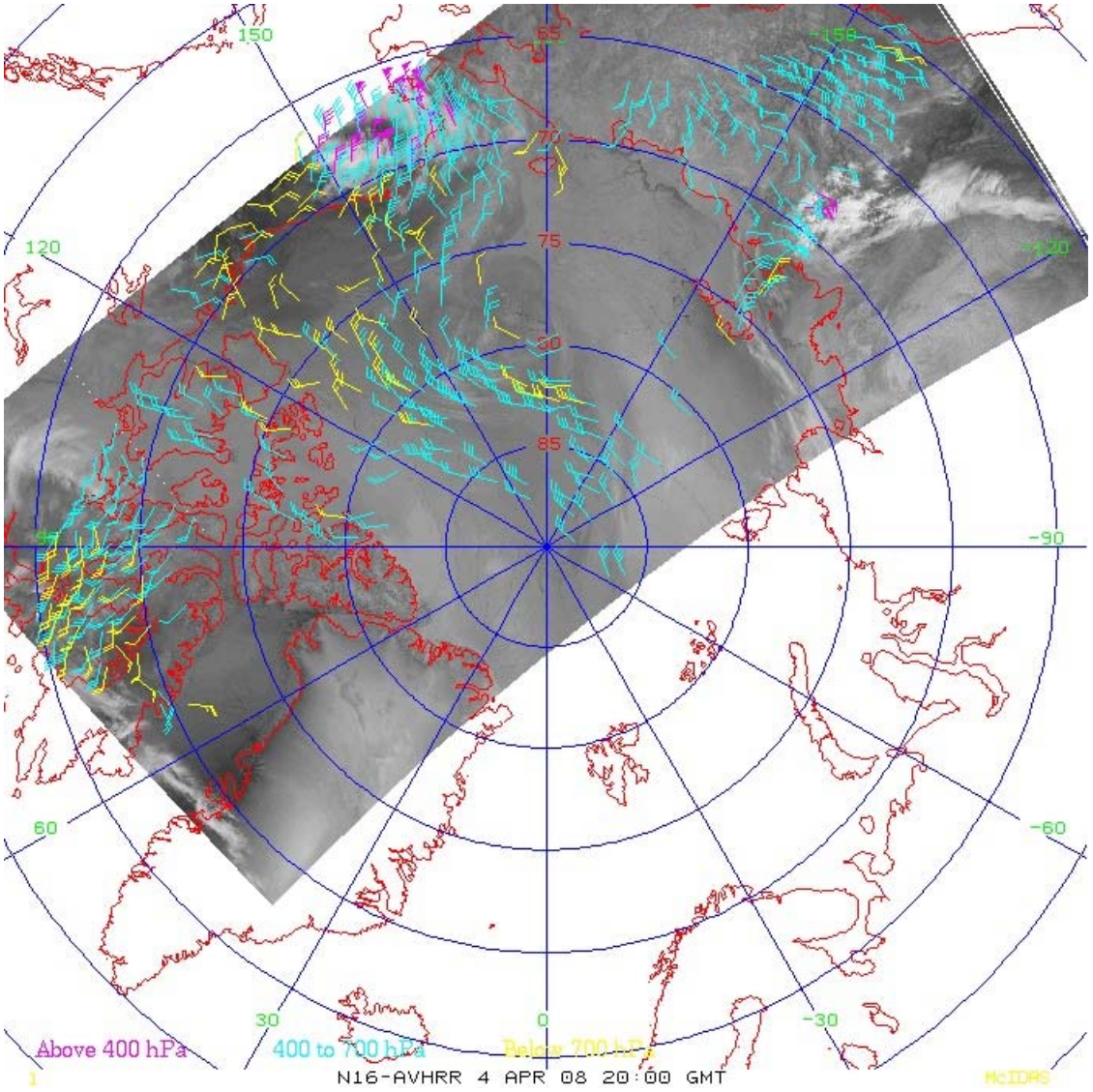
Planned products:
Ice motion (MODIS + AMSR-E)
Ice age
Ice concentration
Cloud optical properties

Similar plans for HRPT sites.

**IMAPP/MODIS Science Team products*

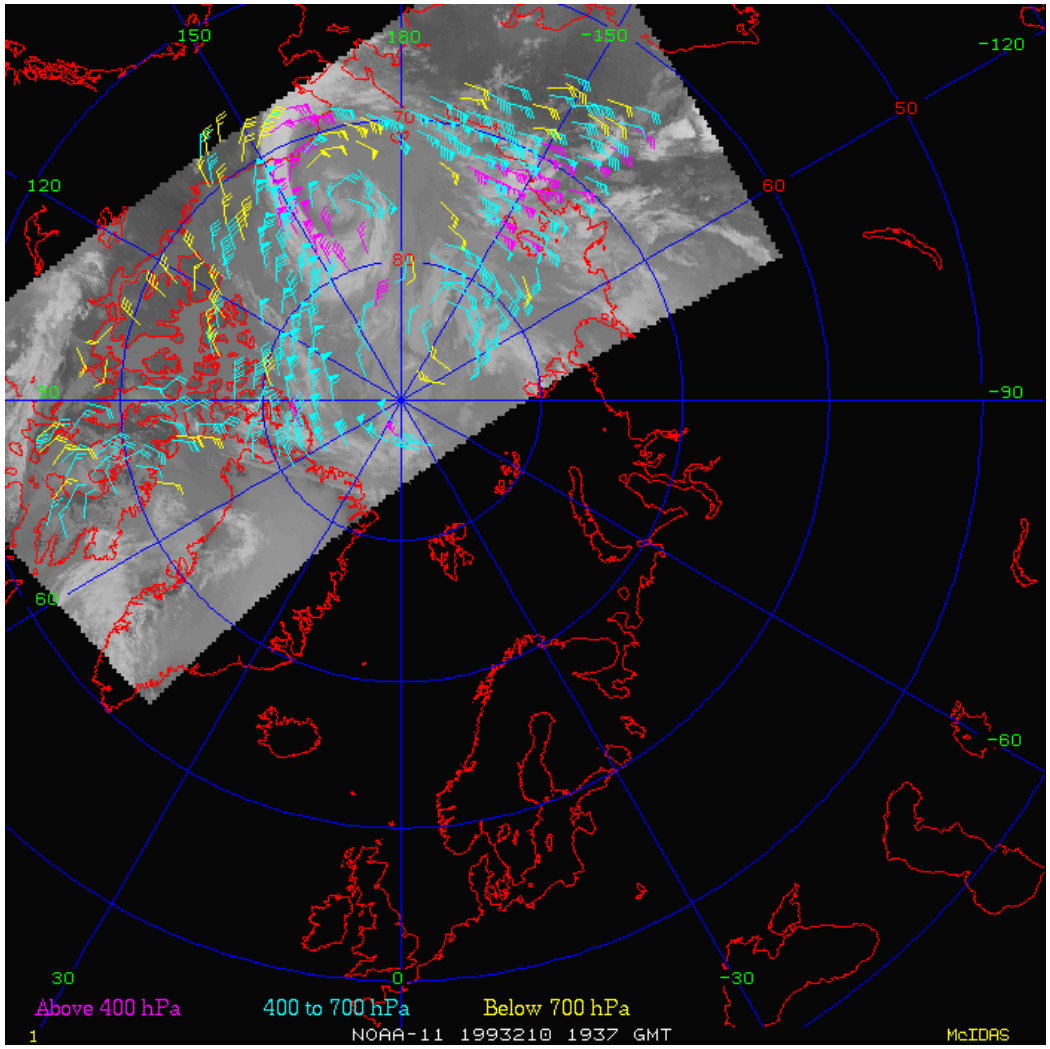


AVHRR HRPT Winds



- 1 km MODIS product (MOD021KM) remapped to 2 km.
- Cloud-track winds
- NCEP's GFS is used as the background.
- Pros: Hi-res, global; low latency. Good preparation for NPOESS VIIRS.
- Cons: No water vapor clear winds (no clear sky). Height assignment uncertainty for thin clouds.

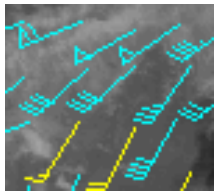
Historical AVHRR Polar Winds



- January 1, 1982 to August 31, 2002.
- One satellite at any given time, NOAA-7, -9, -11, -14, -16.
- Global Area Coverage (GAC) data gridded at 5 km.
- Cloud-track winds using IR channel only (no water vapor channel).
- ERA-40 used as background. ERA-40 is ECMWF's 1957-2002 reanalysis product.
- Pros: An essential product for reanalysis projects.
- Cons: Low resolution. Currently only one satellite at any given time. Height assignment uncertainty for thin clouds.

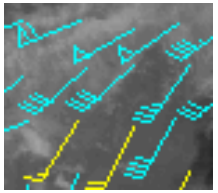
Product Comparison

Product/Feature	Spatial Coverage	Spatial Resolution	Latency (middle image)	Relative Accuracy	Operational NESDIS Product
MODIS, bent pipe, separate satellite	Entire Arctic and Antarctic	2 km	3-5 hrs	Similar to GOES	🗐
MODIS, bent pipe, combined Terra & Aqua	Entire Arctic and Antarctic	2 km	2-4 hrs	Similar to GOES (?)	🗐 (mid-2008)
MODIS DB, single satellite	Part of Arctic or Antarctic	2 km	2.2 hrs	Same as bent pipe winds	Maybe never
AVHRR GAC	Entire Arctic and Antarctic	4 km	3-5 hrs	Good, but not as good as MODIS bent pipe	🗐 (Apr 2008)
MetOp AVHRR	Entire Arctic and Antarctic	2 km	3-5 hrs	Same as bent pipe winds	🗐 (Mar 2009)
HRPT AVHRR	Part of Arctic or Antarctic	2 km	2.0 hrs	Same as bent pipe winds	Maybe never
Historical AVHRR	Entire Arctic and Antarctic	5 km	N/A	Good, but not as good as bent pipe	Never



Summary

- Development of the MODIS and AVHRR polar winds began in 2000, with test data and model impact studies in 2001.
- The single-satellite MODIS winds are used operationally by 10 NWP centers in six countries. MODIS DB and AVHRR winds are underutilized. Why?
- The need for more timely MODIS polar winds data by NWP centers motivated the development of a direct broadcast MODIS and AVHRR winds system and the mixed-satellite (Terra and Aqua) winds.
- AVHRR winds provide additional temporal coverage for cloudy areas (no WV channel). The GAC, HRPT, and MetOp winds set the stage for life without MODIS.
- Significant errors have been found in the reanalysis wind fields of both ERA and NCEP, providing the motivation for an historical AVHRR polar wind product.
- We would like to hear your thoughts on polar wind products, including current problems and future directions.



Acknowledgments

The success of the polar winds project is completely dependent upon the people at the NWP centers. In particular, we thank Niels Bormann, Lars Peter Riishojgaard, Mary Forsythe, Randy Pauley, John LeMarshall, Jim Jung, Real Sarrazin, Alexander Cress, Masahiro Kazumori, Christophe Payan, Yan-Qiu Zhu, Claire Delsol, Lueder von Bremen, and Antonio Irving. Paul Menzel suggested exploring MODIS polar winds in 2000, so it's all his fault.

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http://stratus.ssec.wisc.edu