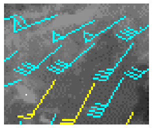
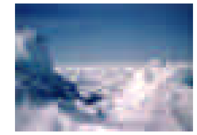


Winds in the Polar Regions from MODIS and Their Impact on NWP

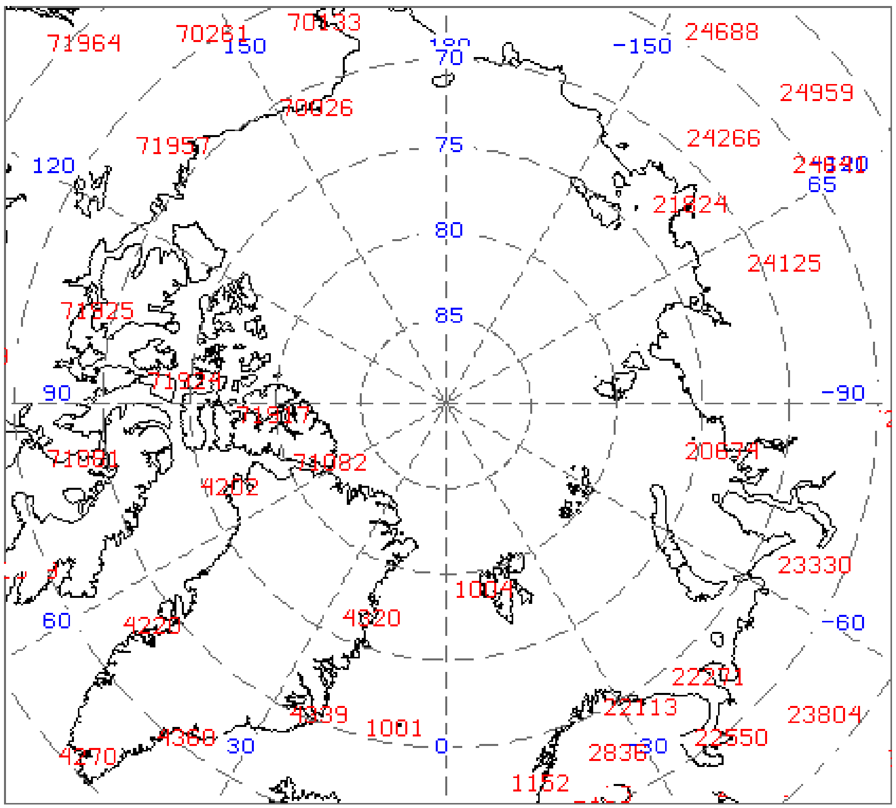


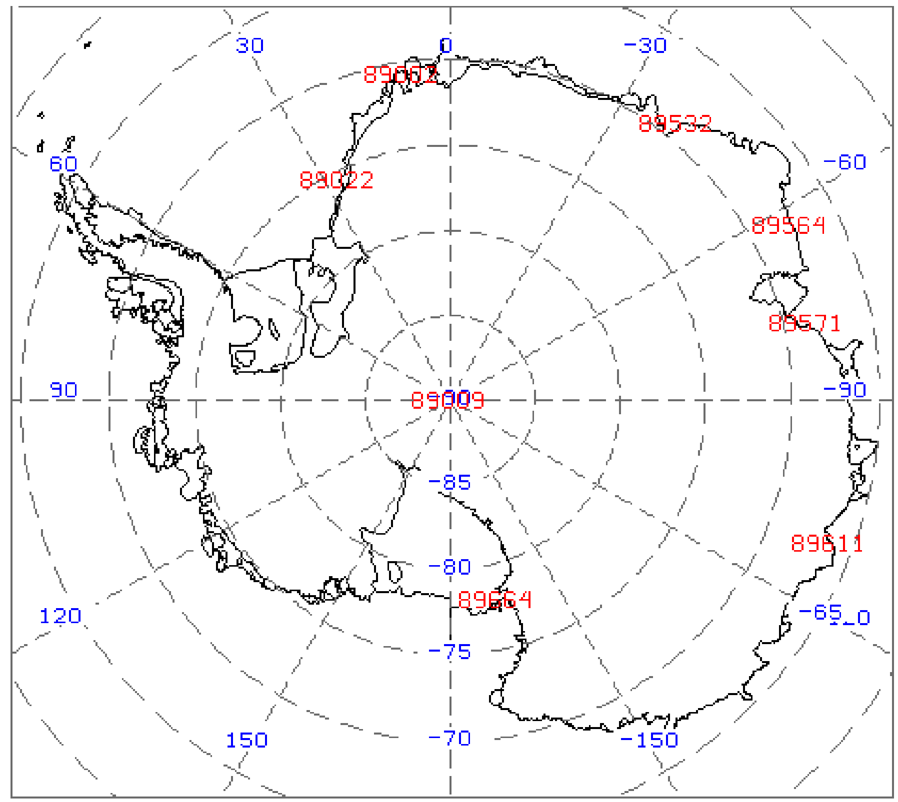
Jeff Key[1], Dave Santek[2], Chris Velden[2], and Paul Menzel[1]

[1]Office of Research and Applications, NOAA/NESDIS, Madison
[2]Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin

Sparse Observation Network

Arctic and Antarctic Rawinsonde Distribution



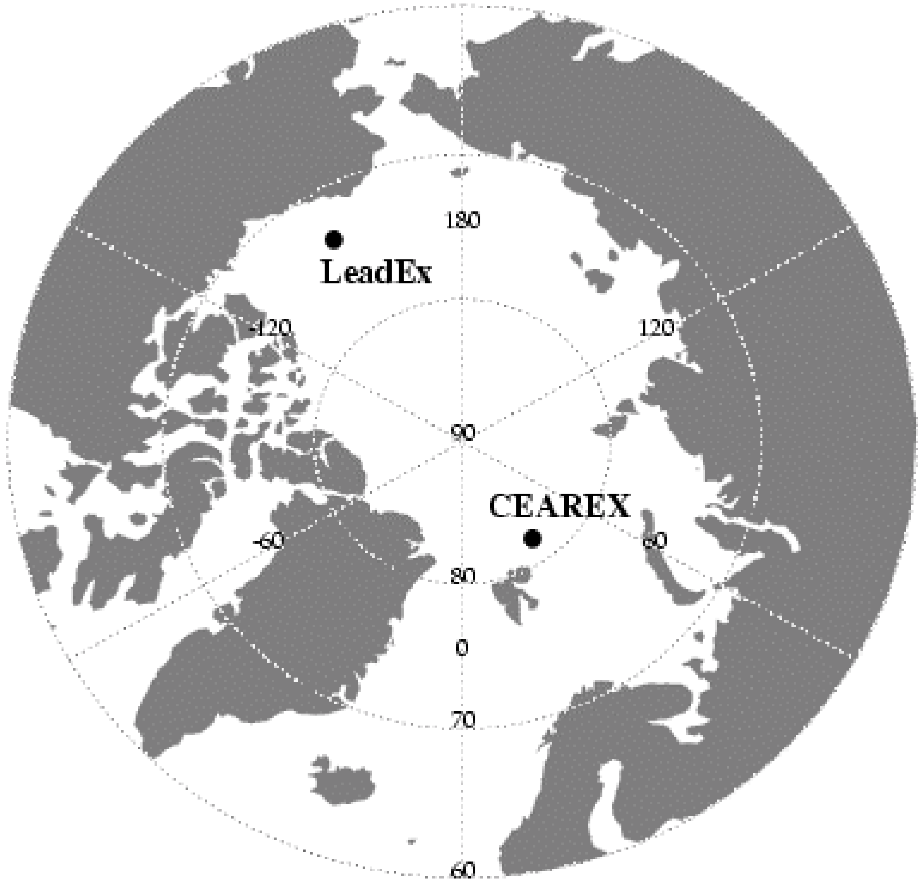


Raob locations are indicated by their WMO station numbers.

Model Wind Errors

Francis, 2002 (GRL, accepted) examined differences between NCEP/NCAR and ECMWF Reanalysis winds and raob winds for raobs that were not assimilated in the reanalysis, from the LeadEx (1992) and CEAREX (1988) experiments.

It was found that both reanalyses exhibit large biases in zonal and meridional wind components, being too westerly and too northerly. Winds are too strong by 25-65%.

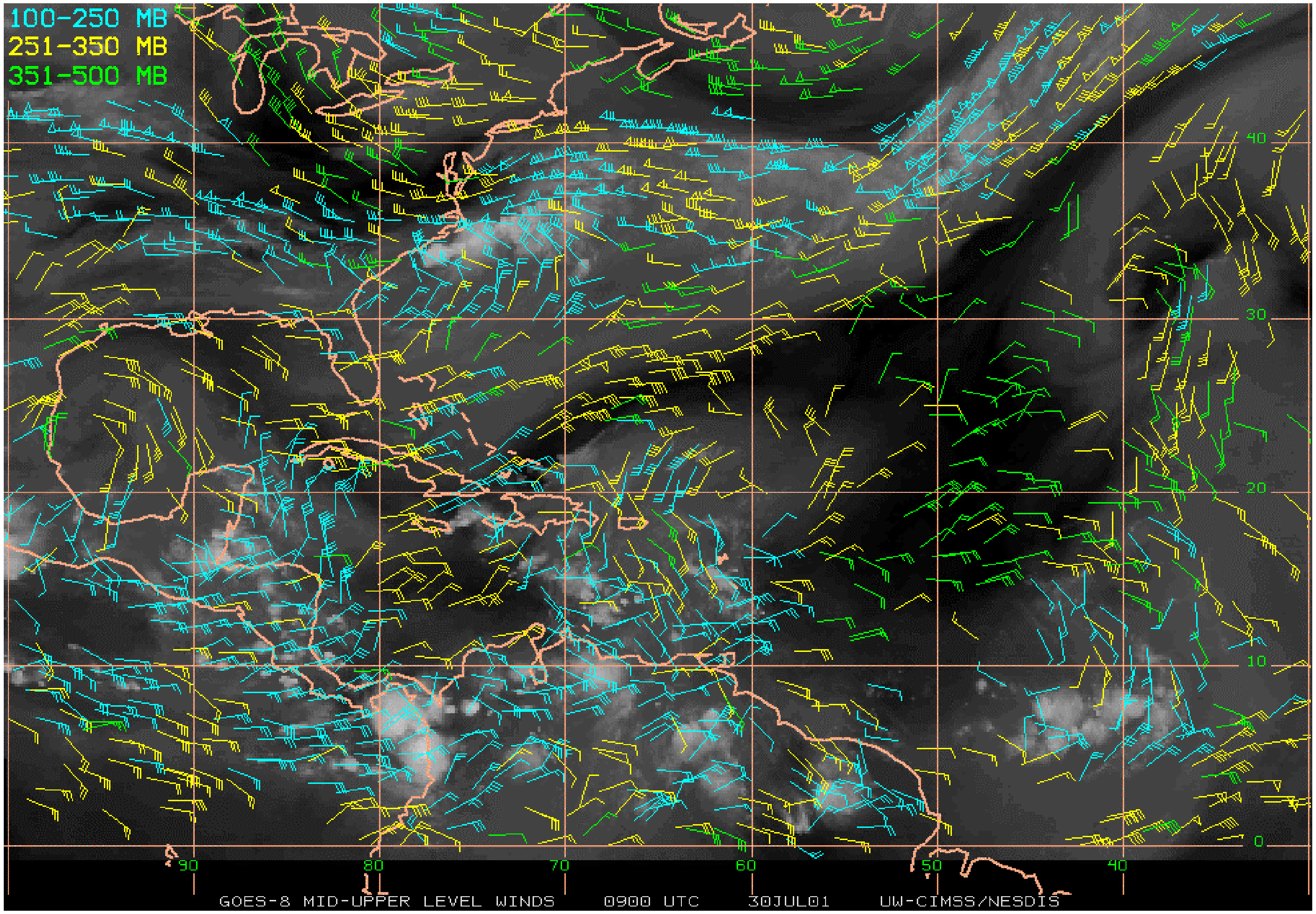


Winds Heritage

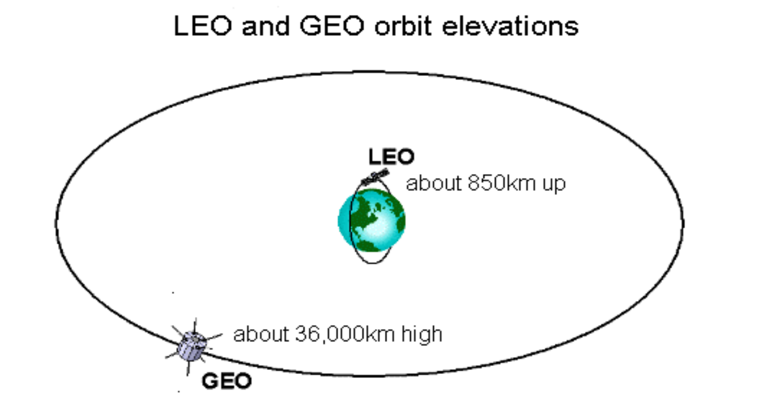
The polar winds work is building on the long history of geostationary wind retrievals at CIMSS.

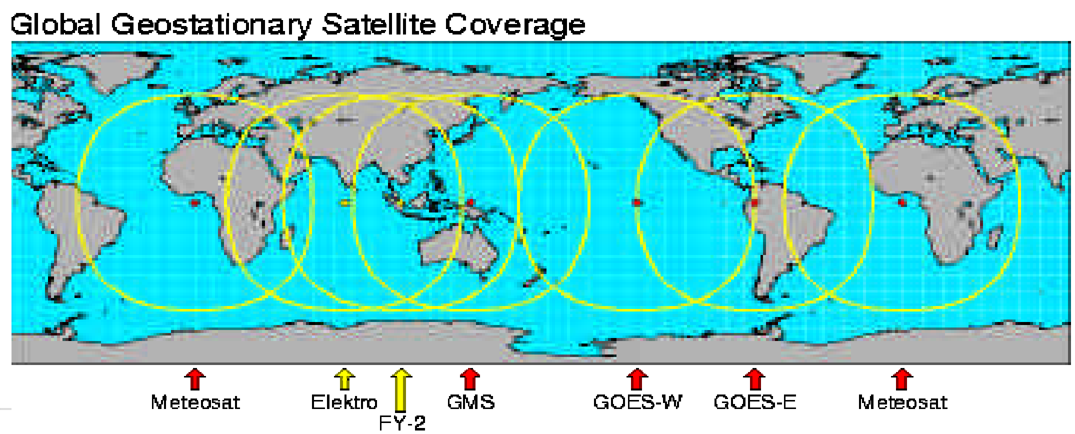
The geostationary method is based on cloud and water vapor feature tracking in a sequence of images.

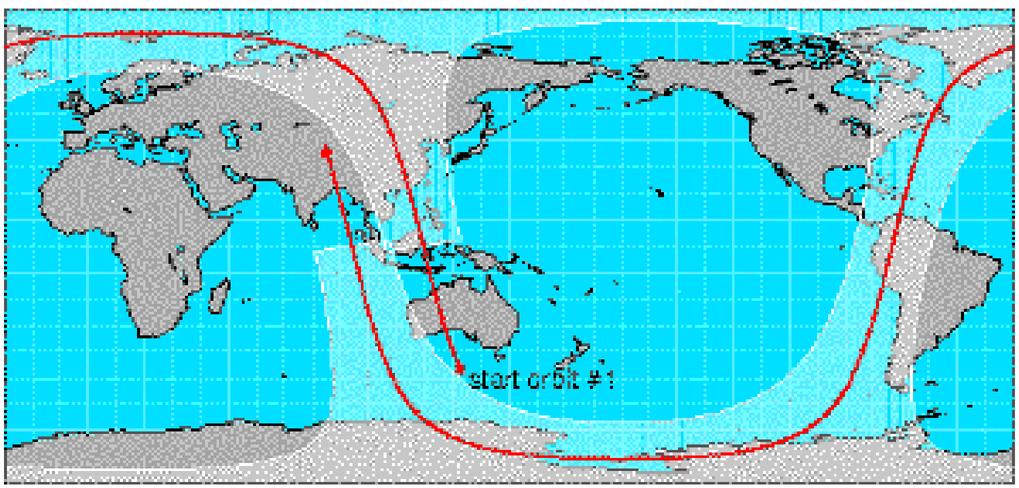
The geostationary wind code has been adapted and extended for use with polar orbiting satellites.

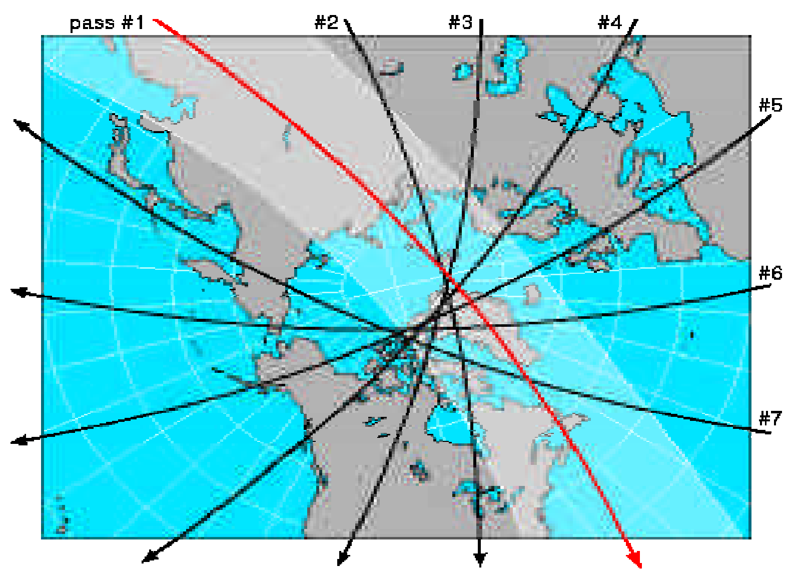


Orbits



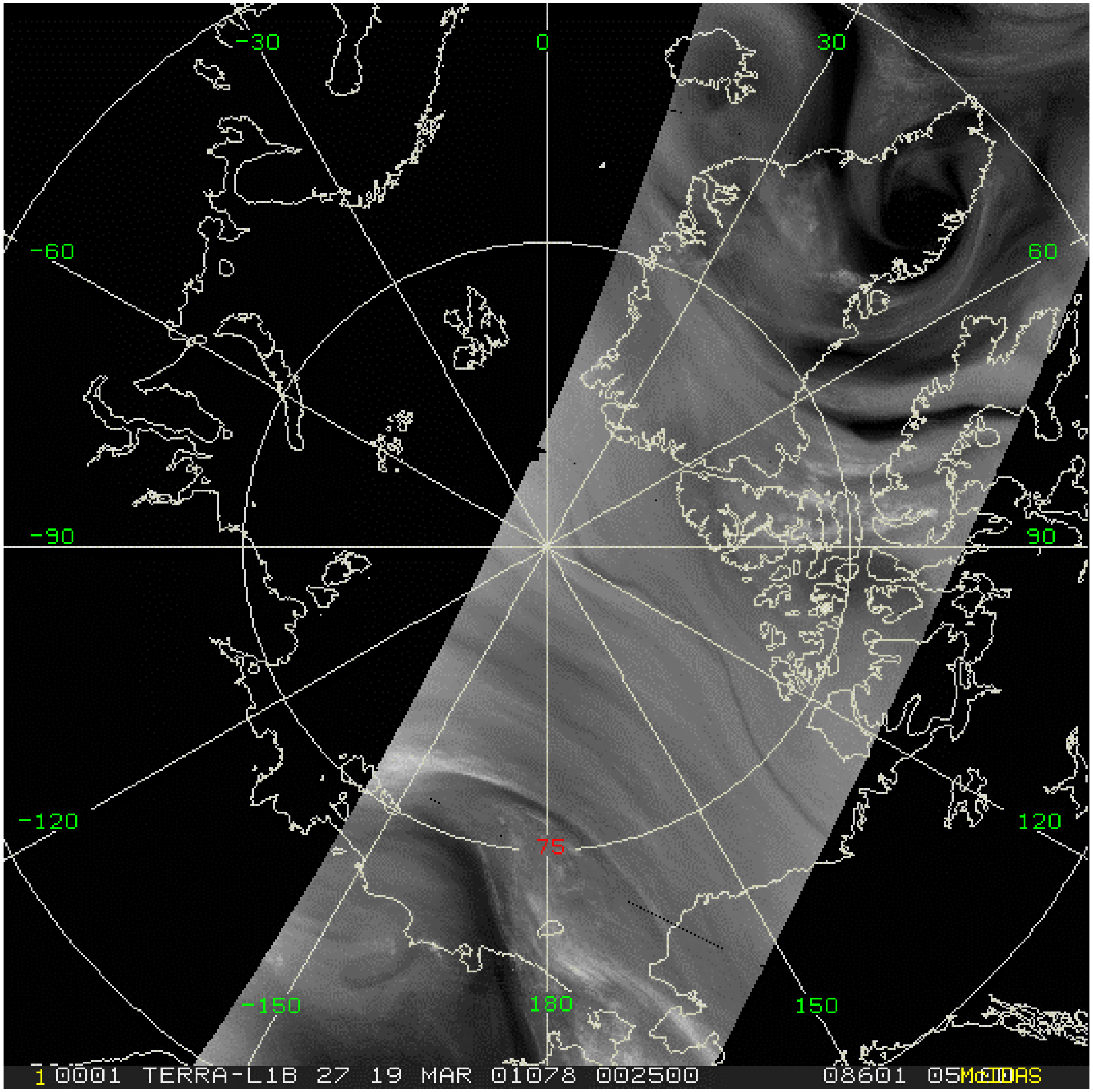






Figures from http://www.rap.ucar.edu/~djohnson/satellite/coverage.html

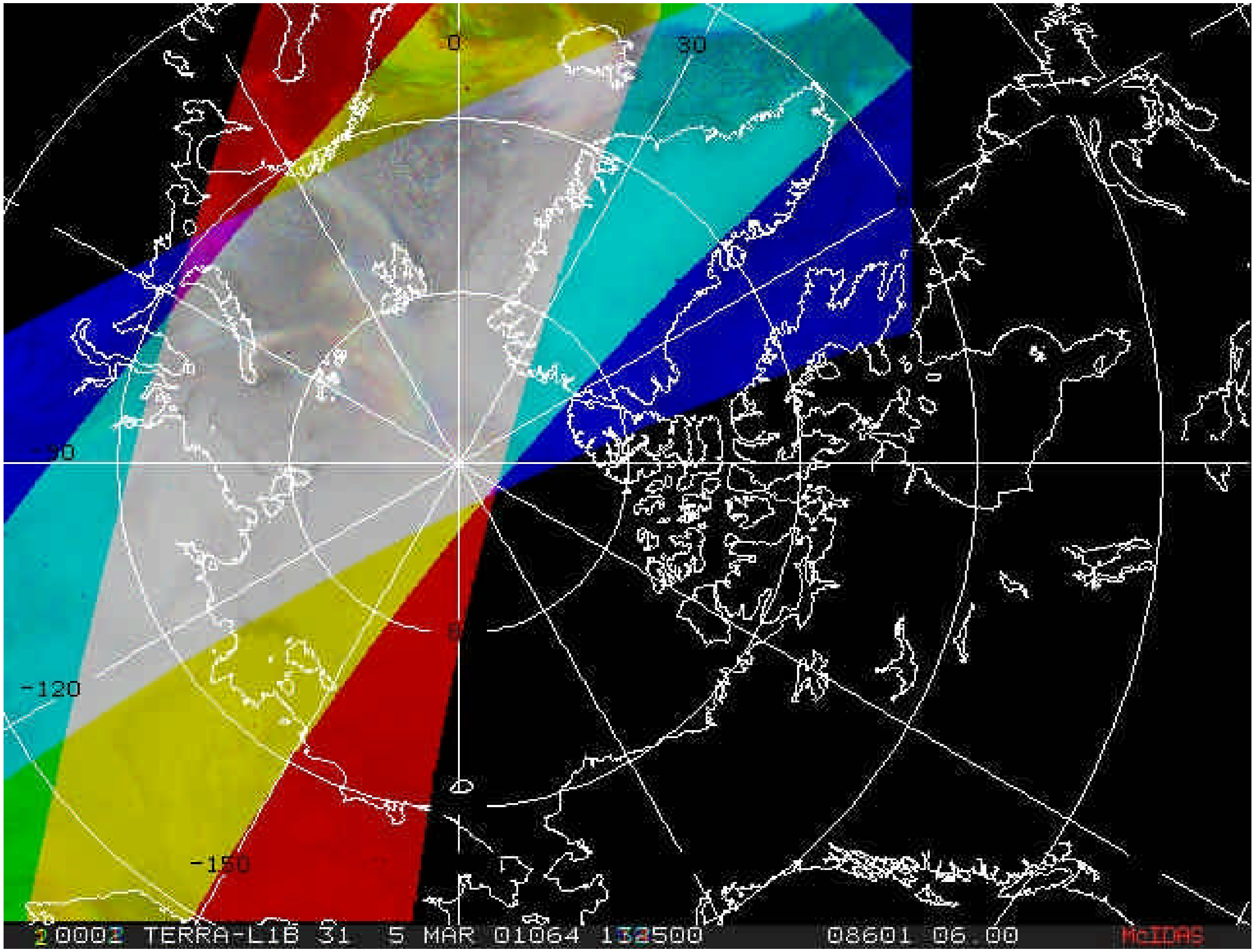
One Day of Arctic Orbits



MODIS band 27 (6.7 µm)

Wind Retrieval Methodology

- Targeting
  - - clouds in the IR window channel 11 µm
  - - water vapor features in 6.7 µm
- Tracking
  - - cross-correlation technique
  - - NWP grids as first guess
  - - image triplets (rather than pairs) used for consistency check
- Wind height assignment: IR window, CO_2-slicing, or H_2O-intercept



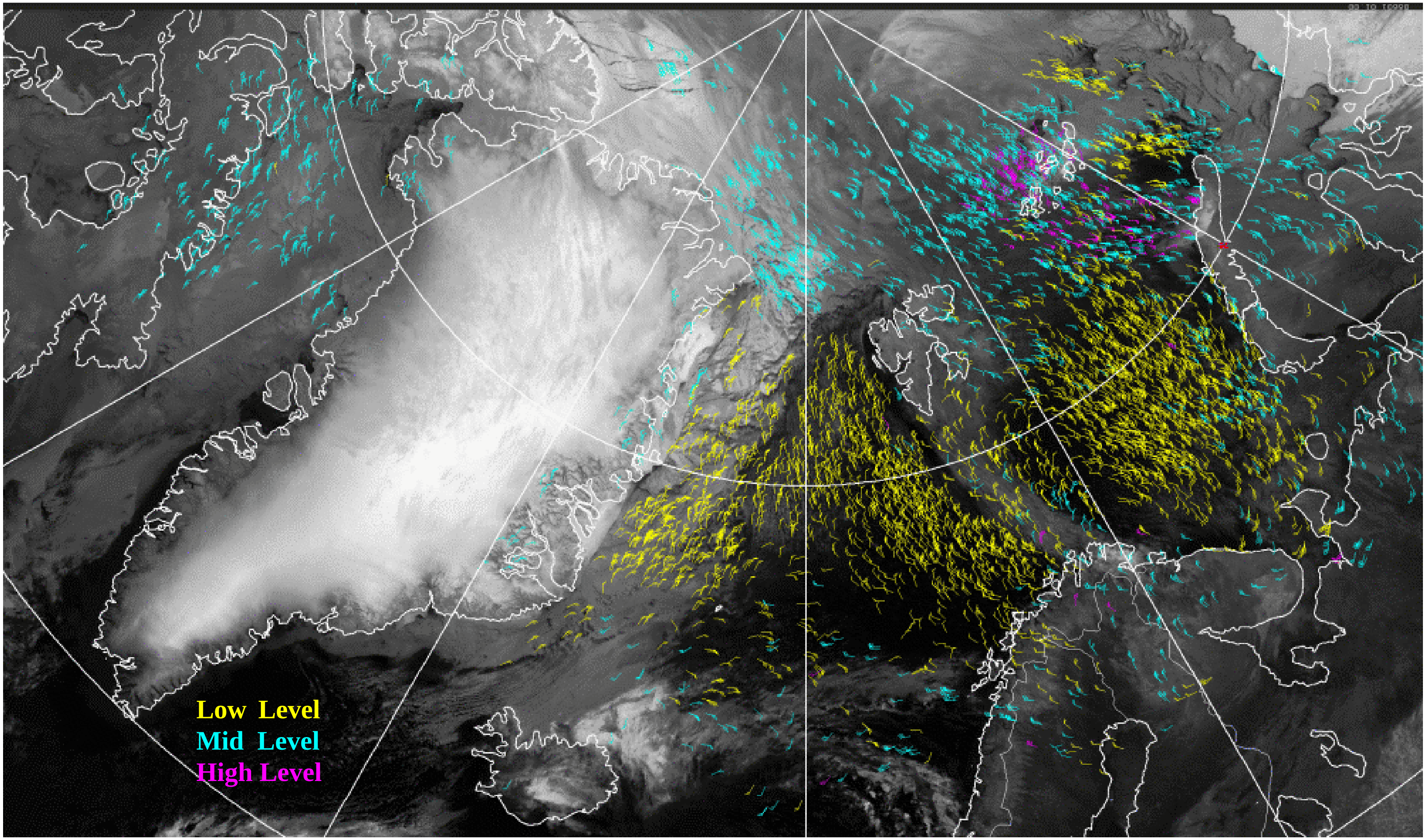
Unlike geostationary satellites at lower latitudes, it is not be possible to obtain complete polar coverage at a snapshot in time with one or two polar-orbiters. Instead, winds must be derived for areas that are covered by two or three successive orbits, an example of which is shown here. The whitish area is the overlap between three orbits.

A Case Study

- 30-day period: 05 March to 03 April 2001
- Both polar regions
- 1 km MODIS Level 1B data from Goddard Space Flight Center.
- Data were normalized and destriped.
- Two to four 5-minute granules from each orbit were remapped into a polar stereographic projection at 2 km resolution and composited with McIDAS. The resulting images are 2800x2800 pixels. (The next two slides show a 2800x1400 composite sector.)
- Winds were derived from successive image triplets of the water vapor (band 27) and IR window channels (band 31).

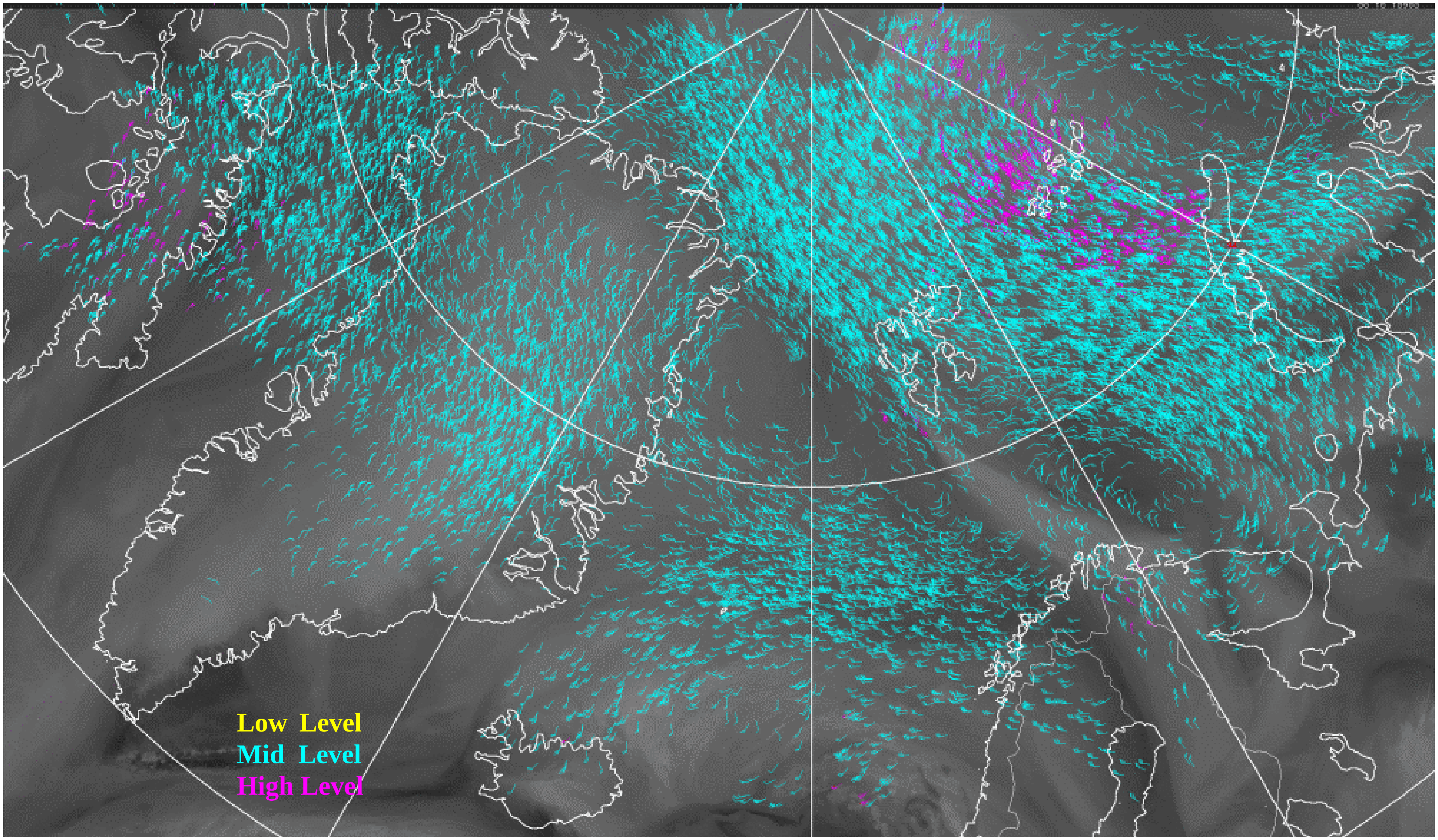
There are about 25,000 quality-controlled vectors per day at each pole.

Case Study: Infrared Winds



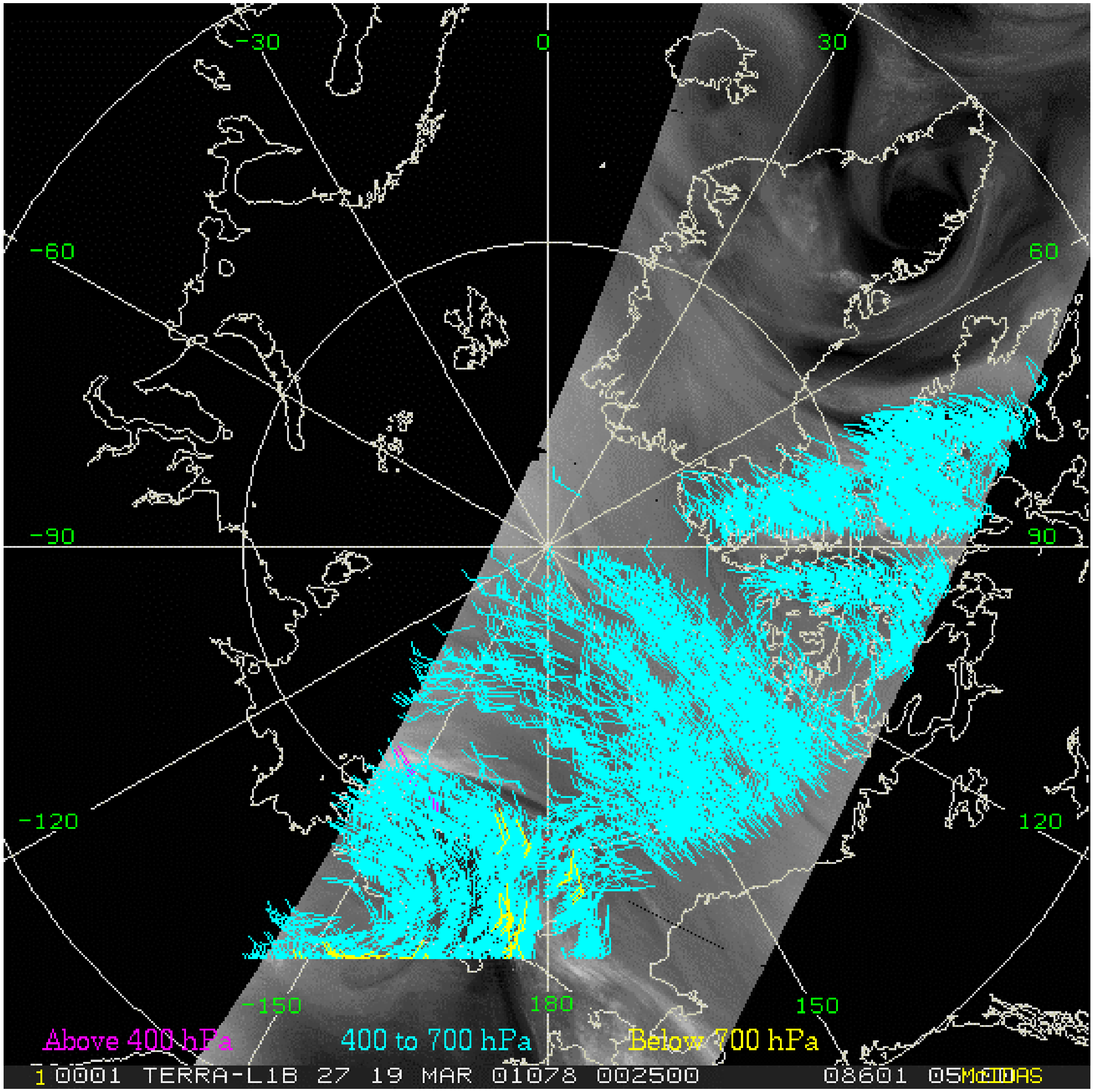
05 March 2001: Daily composite of 11 micron MODIS data over half of the Arctic region. Winds were derived over a period of 12 hours. There are about 4,500 vectors in the image. Vector colors indicate pressure level - yellow: below 700 hPa, cyan: 400-700 hPa, purple: above 400 hPa.

Case Study: Water Vapor Winds



05 March 2001: Daily composite of 6.7 micron MODIS data over half of the Arctic region. Winds were derived over a period of 12 hours. There are about 13,000 vectors in the image. Vector colors indicate pressure level - yellow: below 700 hPa, cyan: 400-700 hPa, purple: above 400 hPa.

One Day of Arctic Orbits



MODIS band 27 (6.7 µm)

Validation with Raobs:
30-Day Case Study Statistics for the Arctic

All Levels	**Sat**	**Guess**	**Raob**
NRMS difference	0.57	0.53	
RMS difference	8.11	7.29	
Average difference	6.87	6.10	
STD deviation	4.32	4.00	
Speed bias	-0.58	-1.14	
Speed	14.31	13.76	14.89

Sample size: 26959

Definitions:

$VD = sqrt[(u_{avg}-u)^2 + (v_{avg}-v)^2]$ VD is a measure of the uv vector difference

$RMS = sqrt(VD^2_{mean} + VD^2_{std})$

$NRMS = RMS/S_{avg}$ S is speed

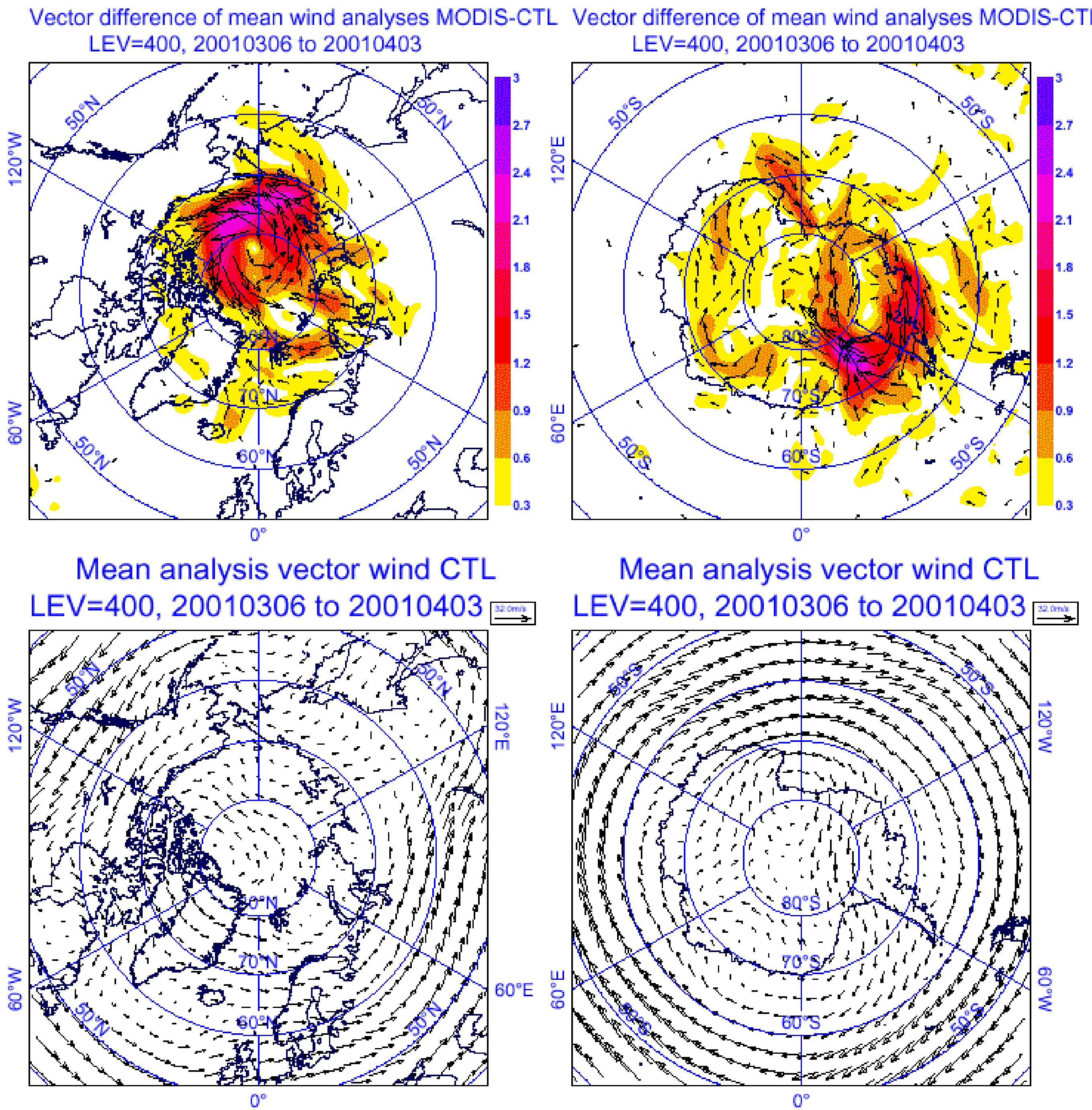
Note: There are very few raobs for comparison in the Antarctic.

Model Impact Studies:

European Centre for Medium-Range Weather Forecasts

NASA Data Assimilation Office

ECMWF Mean and Difference Wind Fields 400 hPa

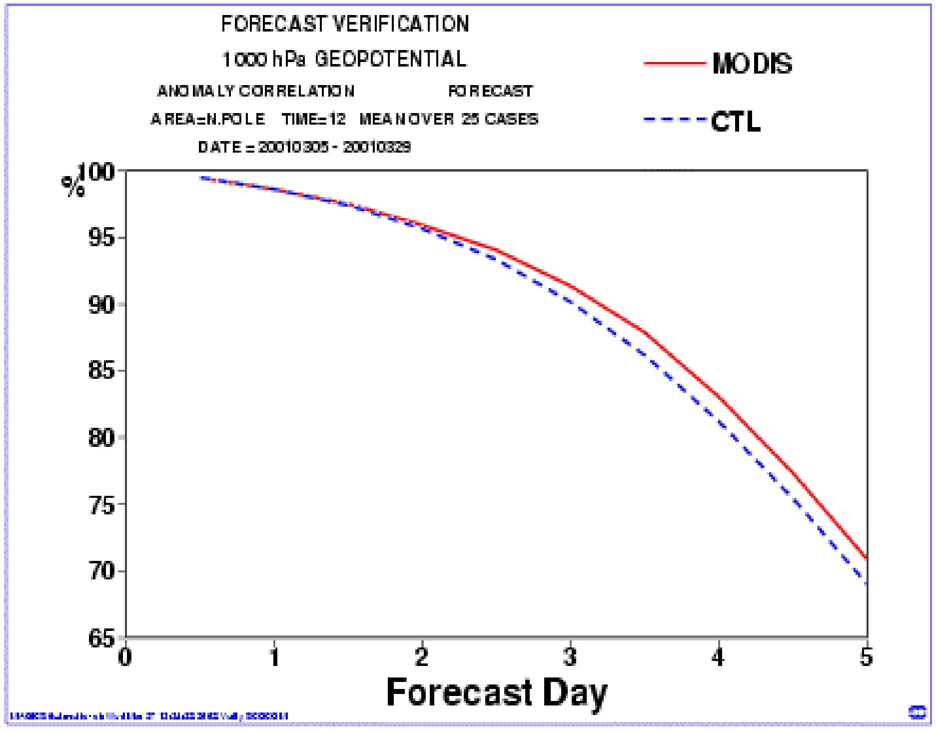


Arctic: MODIS winds act to strengthen the circulation at upper levels; at lower levels the difference field suggests a weakening of the local circulation.

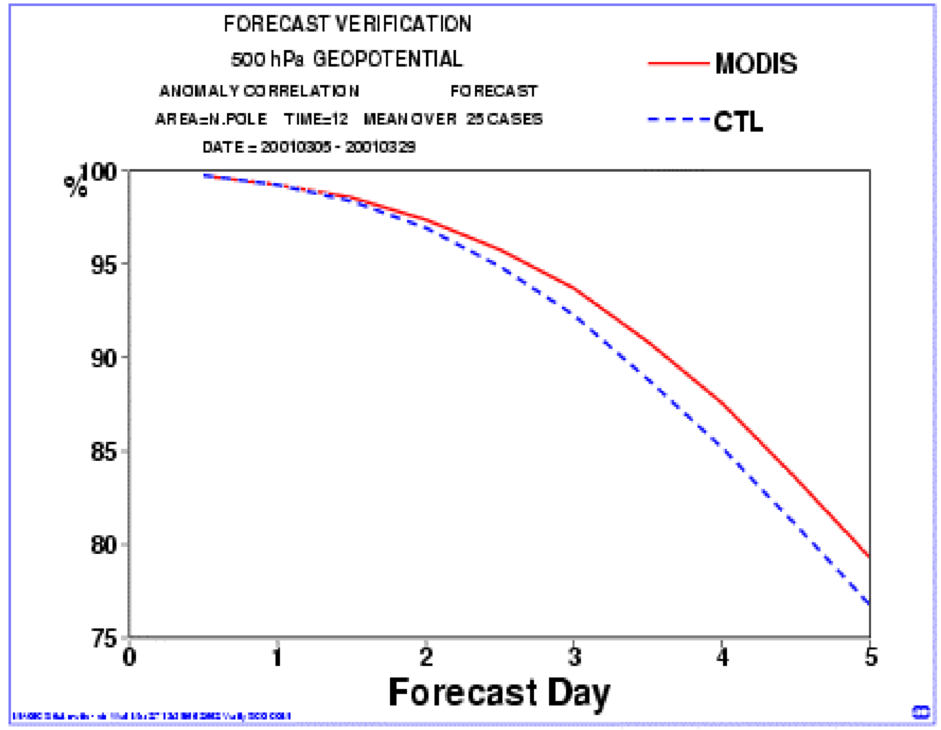
Antarctic: MODIS winds act to strengthen the flow around the Antarctic Peninsula.

ECMWF Model Impact: Arctic

1000 hPa



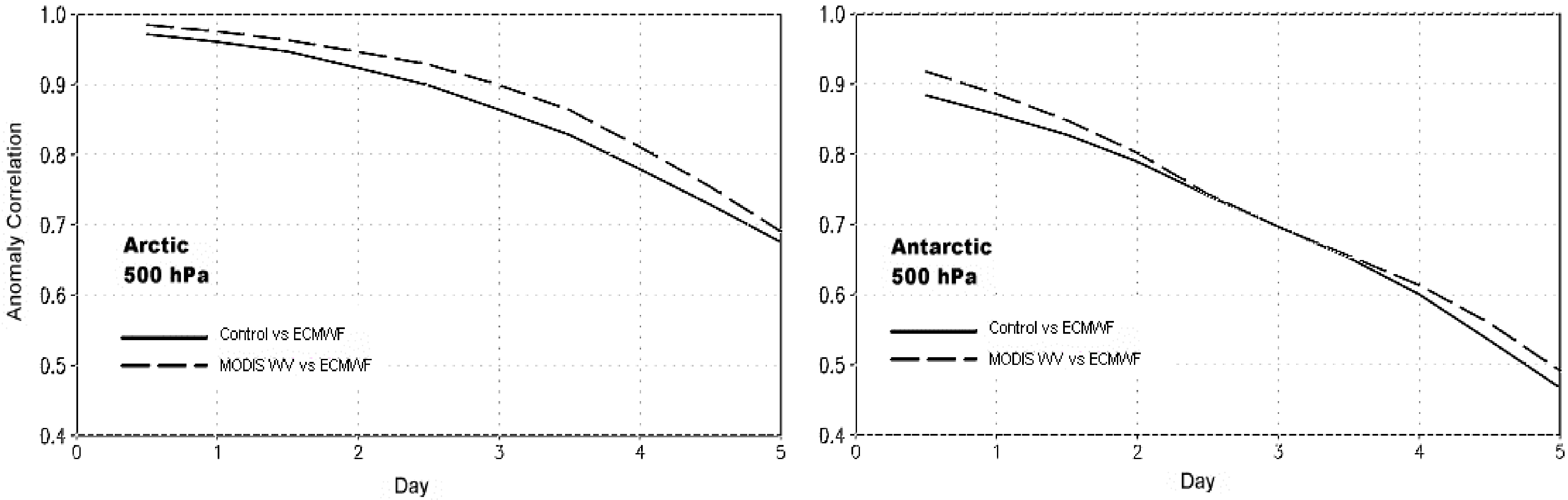
500 hPa



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. Forecast accuracy is extended by about 5 hrs.

DAO Model Impact Studies: Arctic and Antarctic

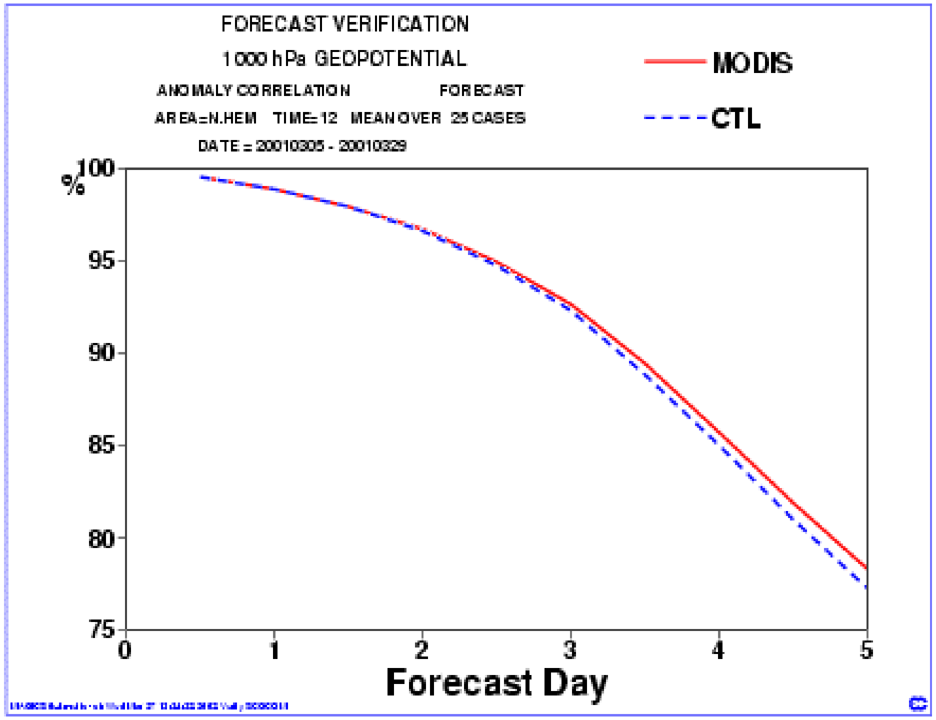


Forecast scores (anomaly correlations) as a function of forecast range for the 500 hPa geopotential over the Arctic (left) and Antarctic (right). The anomaly correlation is the correlation between the forecast geopotential height anomalies, with and without the MODIS winds, and ECMWF analyses. The Arctic and Antarctic are defined as poleward of 60 degrees latitude.

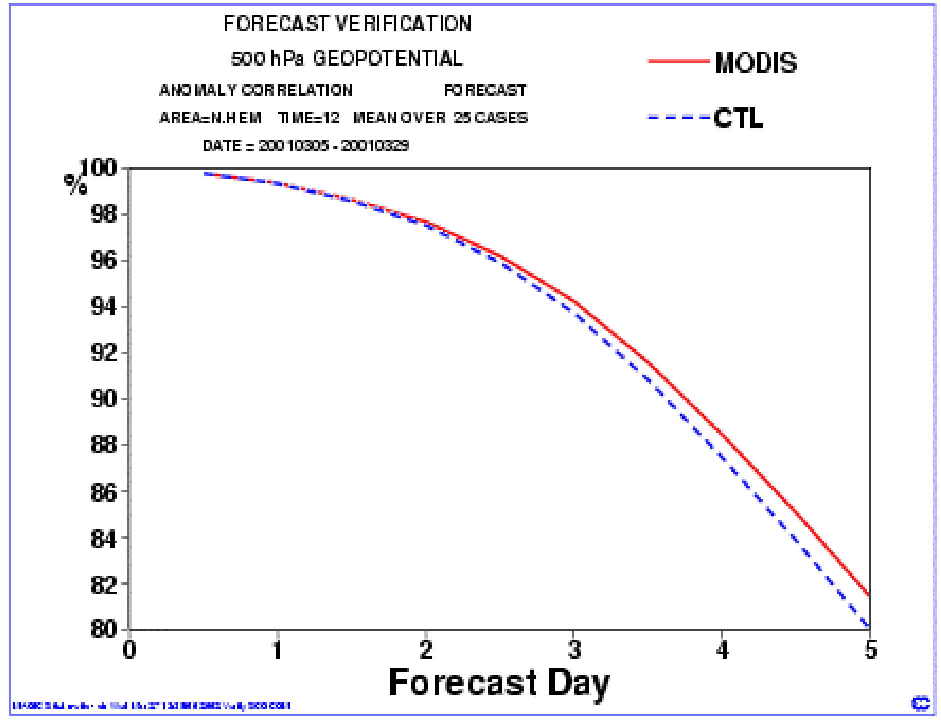
Over the Arctic the forecast impact is positive. Over the Antarctic the impact is neutral to positive.

ECMWF Model Impact: Northern Hemisphere

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 Northern Hemisphere is defined as north of 20 degrees latitude.

The improvements for the Northern Hemisphere are significant at the 2% or better level (t-test) for the forecast range of 2-5 days at most levels.

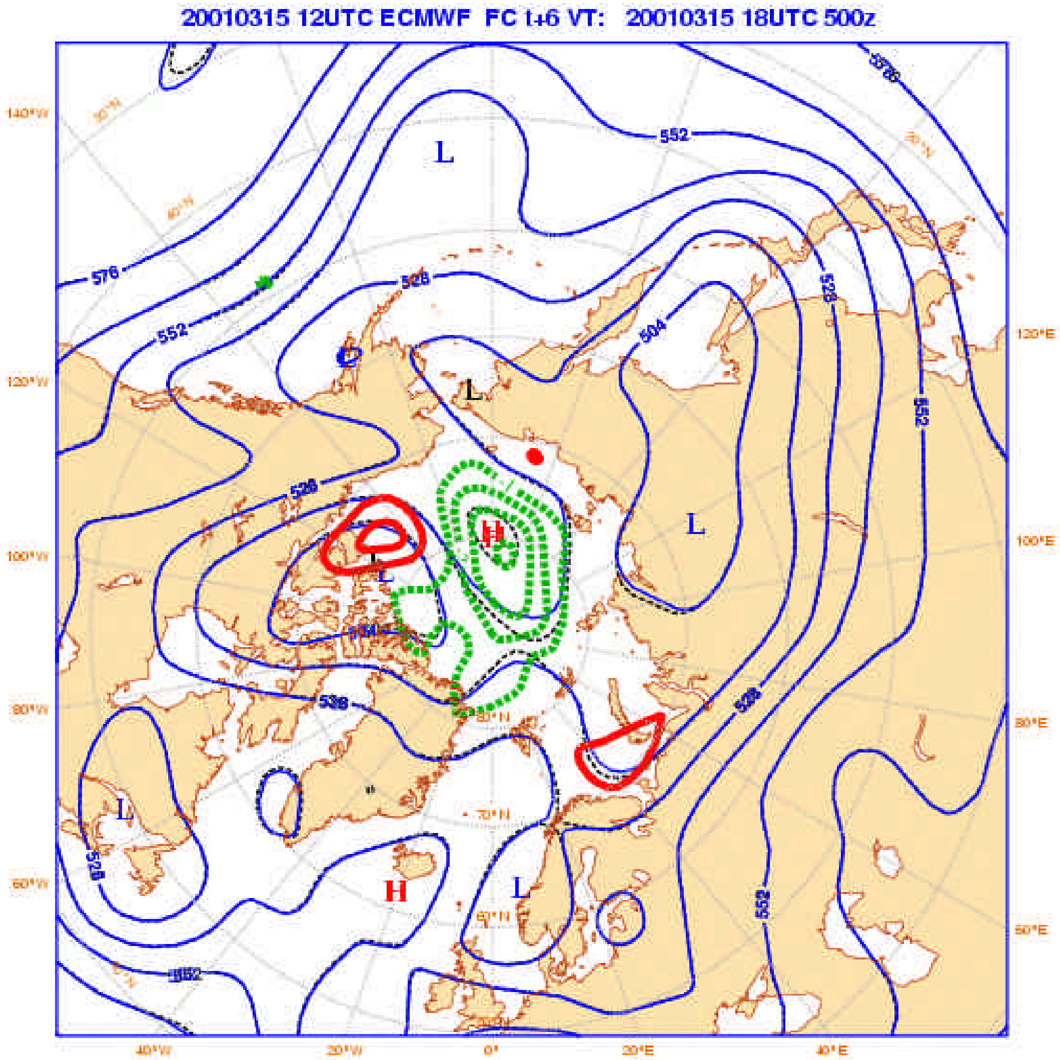
ECMWF: Error Propagation to the Midlatitudes

This animation illustrates the propagation of analysis errors from the poles to the midlatitudes for one case study. Each frame shows the 500 hPa geopotential height for forecasts from 1 to 5 days in 1 day increments. The solid blue line is the geopotential from the experiment that included MODIS winds; the **dashed black line** is the control (CTL) experiment without MODIS winds. Solid red lines show positive differences in the geopotential height (MODIS minus CTL), and **thick dashed blue lines** show negative differences.

The area of large positive differences near the Beaufort Sea (north of Alaska) moves southward over the 5-day period. The CTL run is forming a deeper trough over central Alaska and then over the Pacific south of Alaska than the MODIS run.

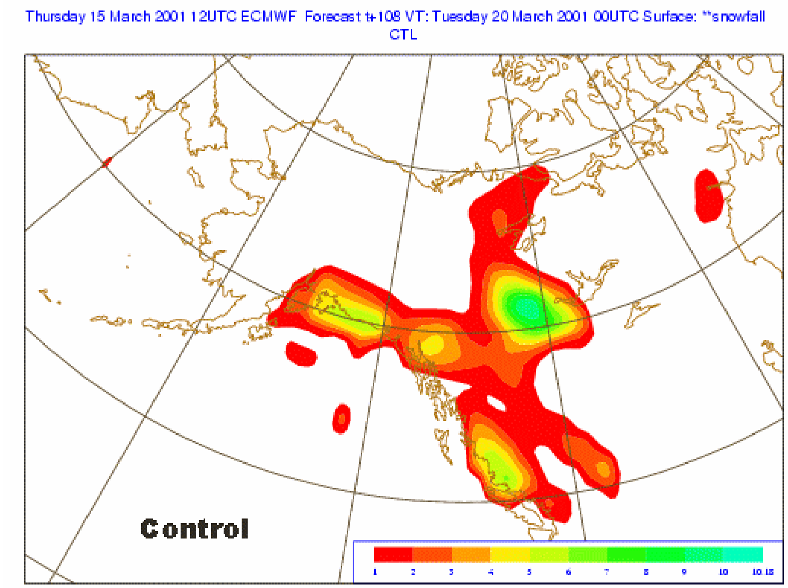
The 5-day MODIS forecast verifies better against the subsequent analysis (not shown), so the initial analysis for this MODIS forecast was closer to the "truth" than the CTL (positive impact on forecast). The propagation of differences is therefore also a propagation of analysis errors in the CTL forecast.

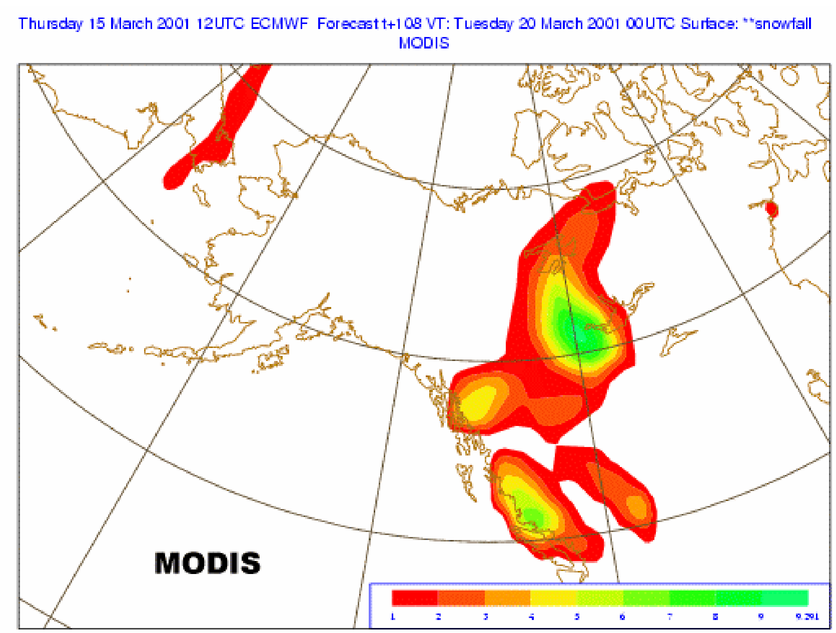
Better observations over the poles should improve forecasts in the midlatitudes.

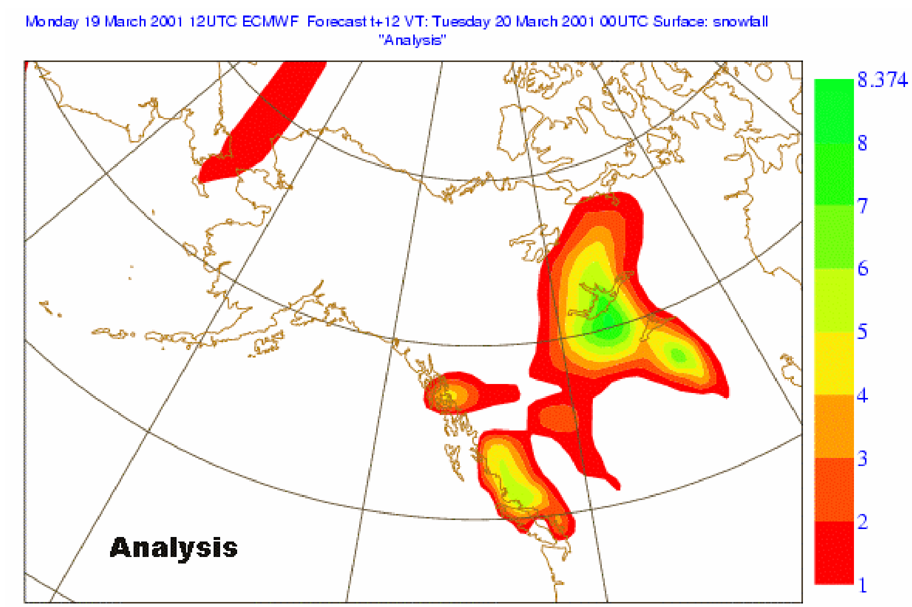


Error Propagation to the Midlatitudes: Snowfall

Accumulated snowfall forecasts (mm water equivalent) over Alaska for 03/20/02 (end of animation period). At right is the snowfall from the 5-day CTL forecast, below left is the snowfall from the 5-day MODIS forecast, below right is the snowfall from a 12-hr forecast for verification. The MODIS run verified better, and the CTL run produced spurious snowfall in southern Alaska.



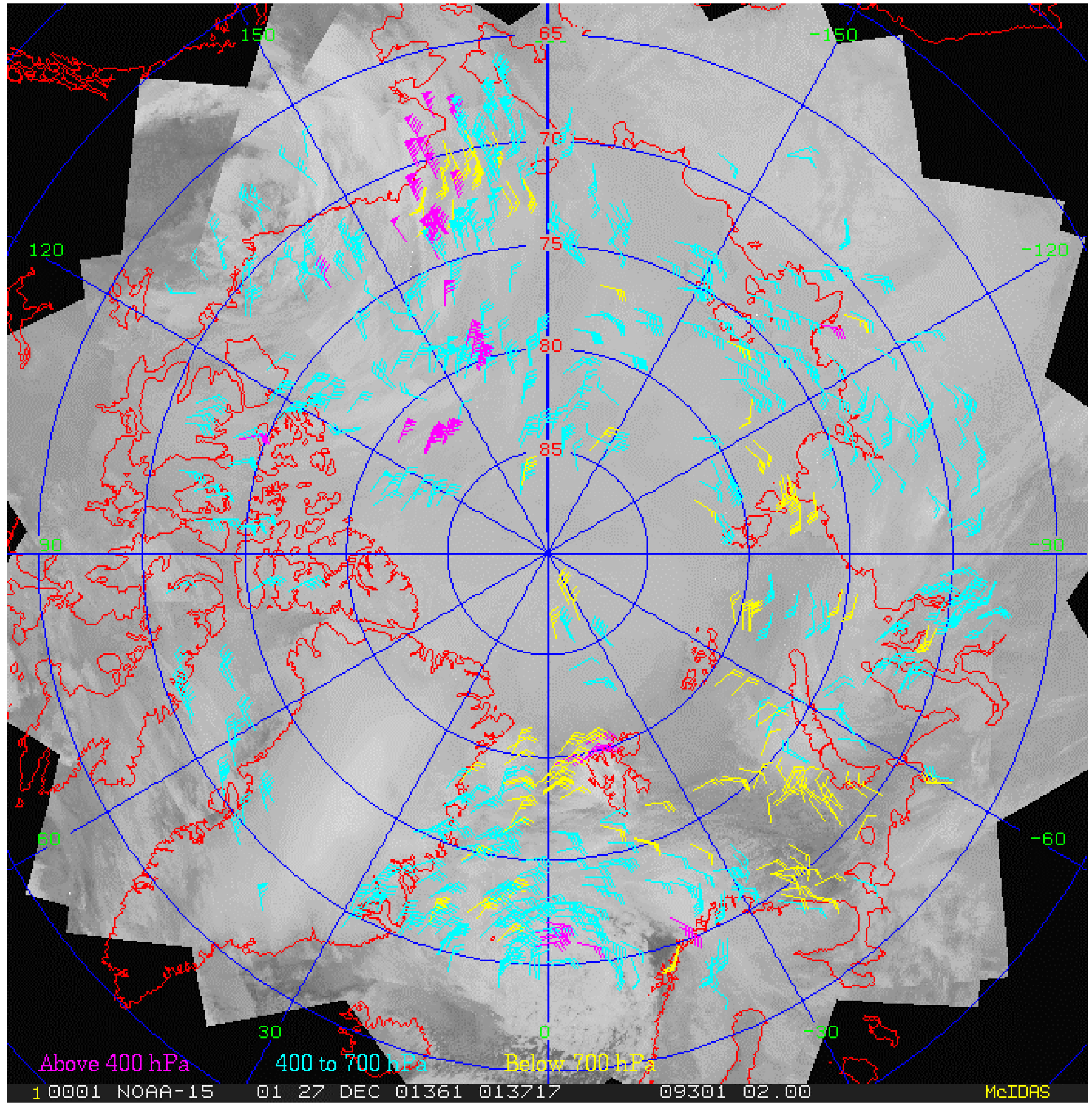




Near Real-Time AVHRR Winds

The polar winds procedure has been adapted for use with AVHRR GAC data and is processed in a near real-time mode. Daily composites of all winds obtained over a 24 hour period for both polar regions are generated and made available on the Web.

The entire procedure is automated. The figure at right gives an example of AVHRR winds over the Arctic on 1 December 2001. Note that the AVHRR does not have a water vapor channel so the number of wind vectors is far less than what would be obtained from MODIS.



http://stratus.ssec.wisc.edu/products/rtpolarwinds

Conclusions

This study has demonstrated the feasibility of deriving tropospheric wind information at high latitudes from polar-orbiting satellites. The methodology employed is based on the algorithms currently used with geostationary satellites, modified for use with the polar-orbiting MODIS instrument.

The project presents some unique challenges, including the irregularity of temporal sampling, varying viewing geometries, and the complexity of surface features. Height assignment, particularly for low clouds, is the area of largest uncertainty.

Model impact studies from two major NWP centers are encouraging (exciting!) and justify continued research.

MODIS polar winds are being retrieved in real-time (5-8 hour delay). They will be implemented in NESDIS operations in 2003.

Acknowledgements: Special thanks to Niels Bormann and Jean-Noel Thepaut (ECMWF) and Lars Peter Riishojgaard (DAO) for model impact studies.