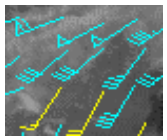


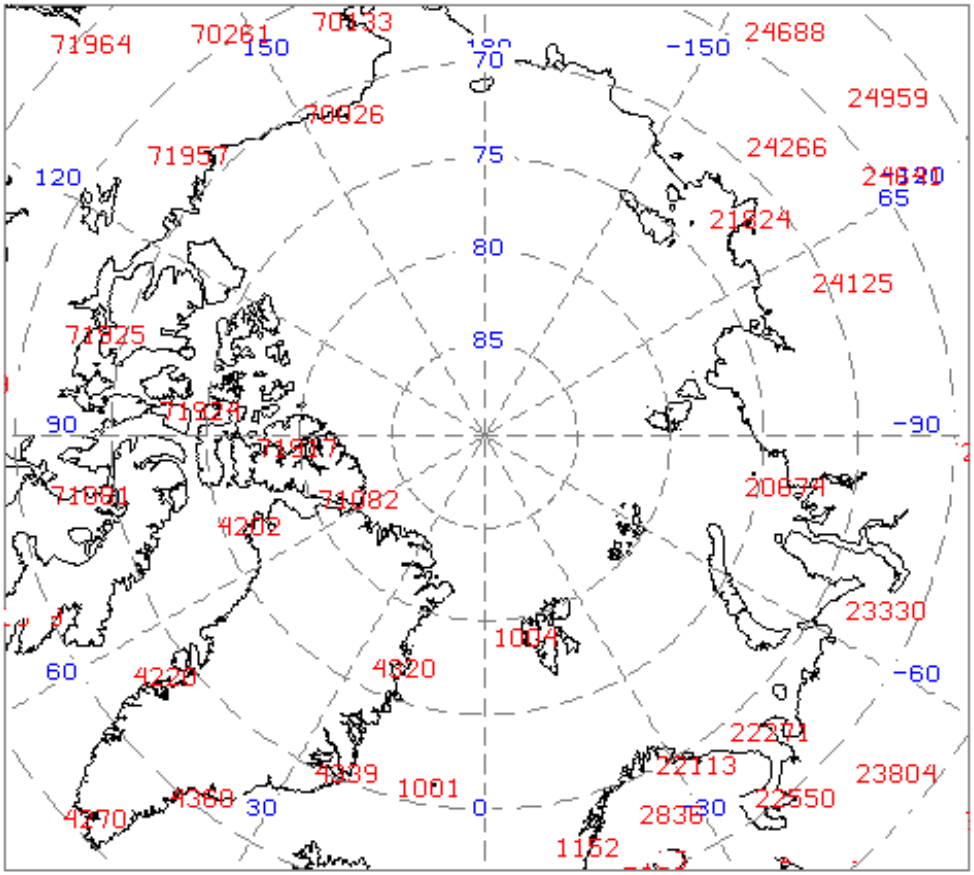
Polar Winds from Satellite Imagers and Sounders

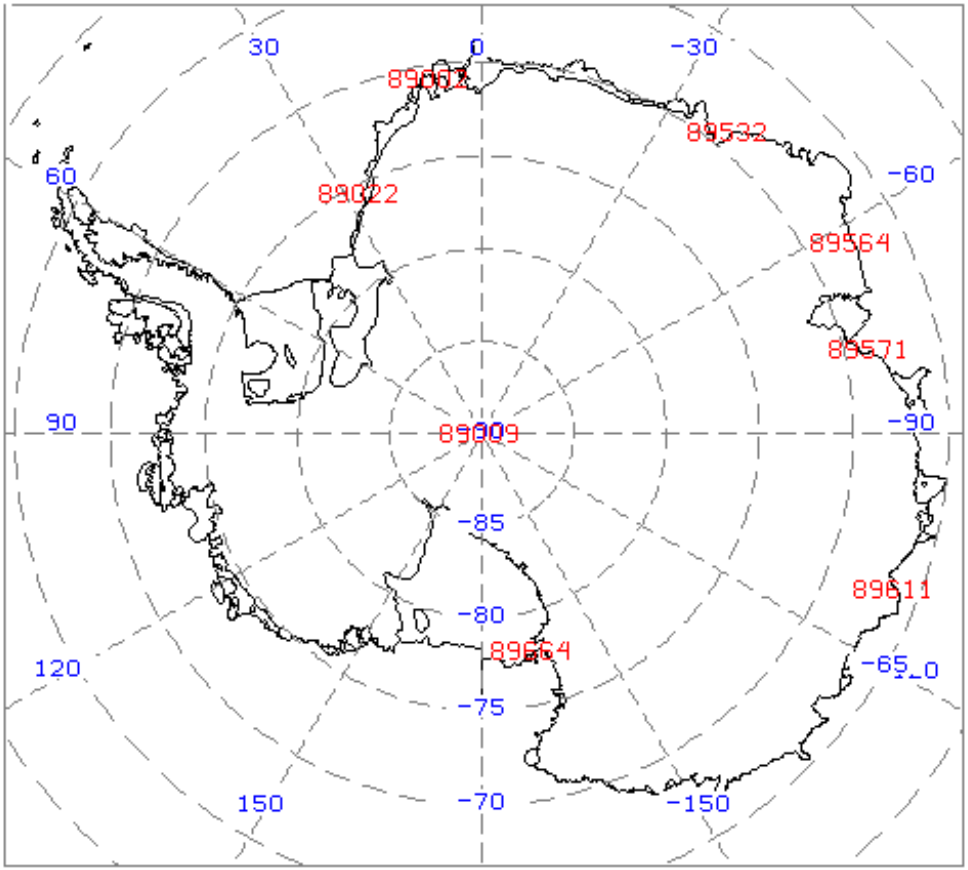
Jeffrey Key[1], David Santek[2], Christopher Velden[2], Lars Peter Riishojgaard[3], Cheng-Zhi Zou[1], Mark DeMaria[1], Jennifer Francis[4], and Mike Van Woert[1]

[1]Office of Research and Applications, NOAA/NESDIS
[2]Cooperative Institute for Meteorological Satellite Studies (CIMSS), Madison
[3]NASA Global Modeling and Assimilation Office
[4]Rutgers University

Sparse Observation Network

Arctic and Antarctic Rawinsonde Distribution





Raob locations are indicated by their WMO station numbers.

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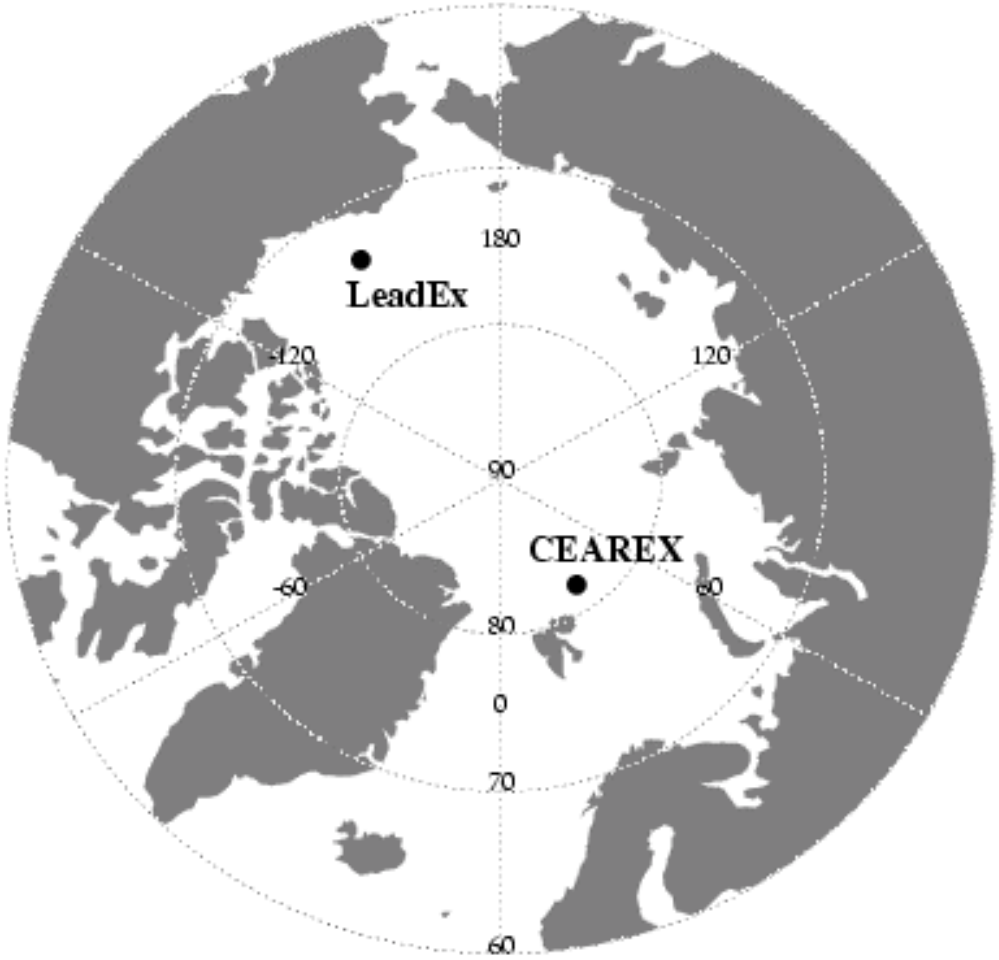
Model Wind Errors

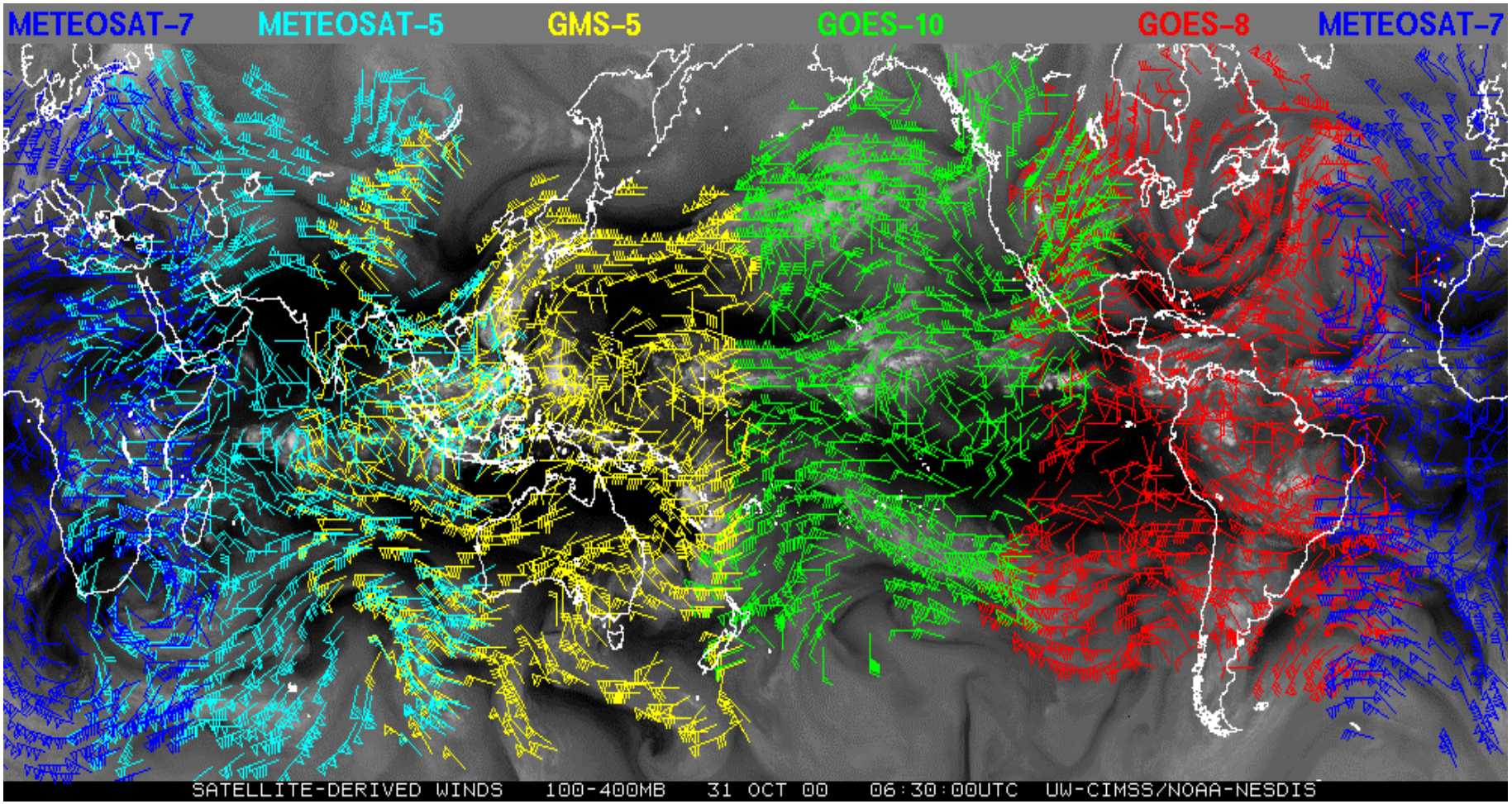
Francis, 2002 (GRL) examined differences between NCEP/NCAR and ECMWF Reanalysis winds and raob winds for raobs that were not assimilated in the reanalysis, from the LeadEx (1992) and CEAREX (1988) experiments.

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%.

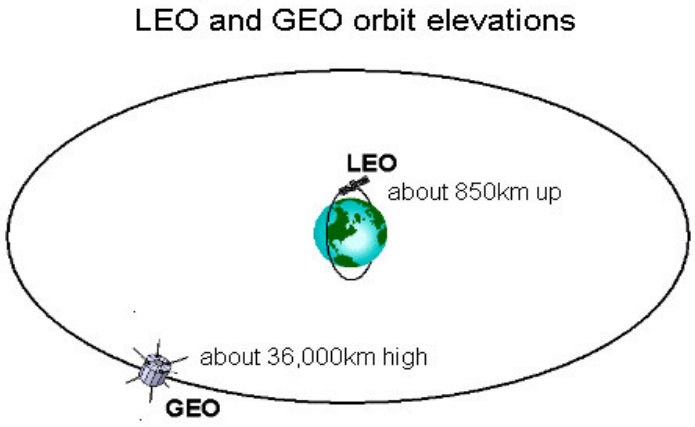


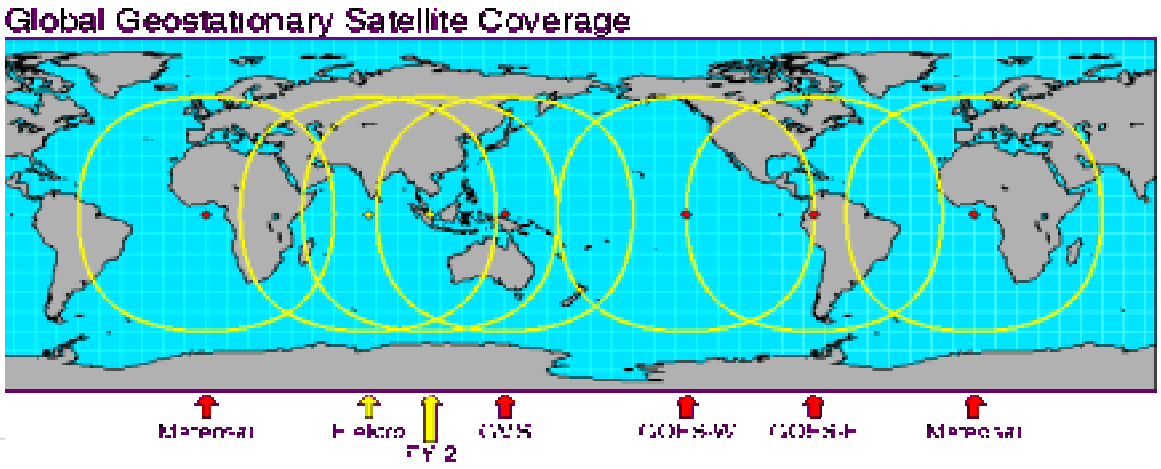
Geostationary Cloud Motion Vectors

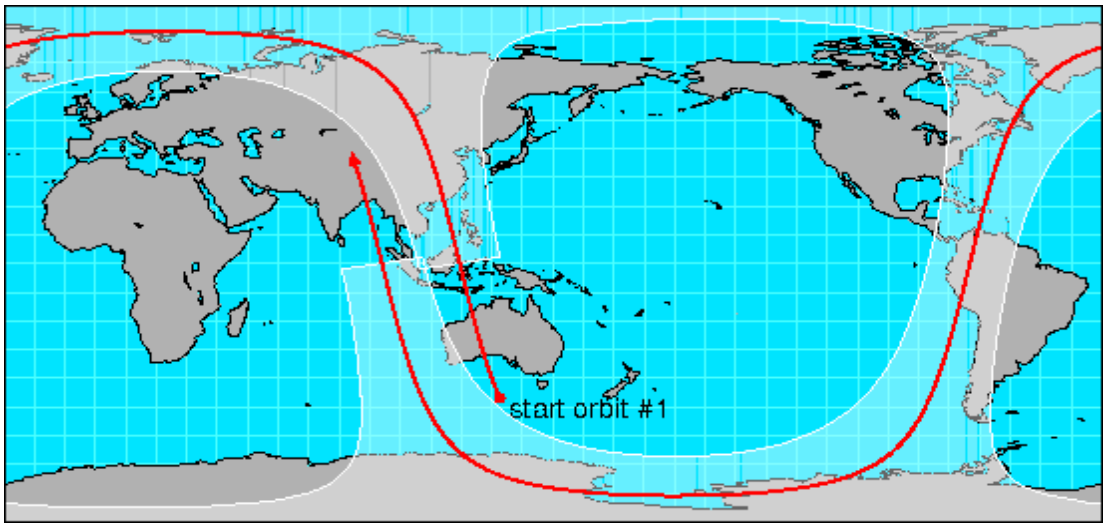
Five geos provide coverage for winds in the tropics and mid-latitudes. However, the total number of wind vectors drops off steadily beyond a 30 degree view angle, with a sharp drop off beyond 60 degrees. The success rate (#vectors/total possible) drops off beyond 50 degrees. Winds from polar orbiters can help fill the high-latitude areas between geos where view angles are large.

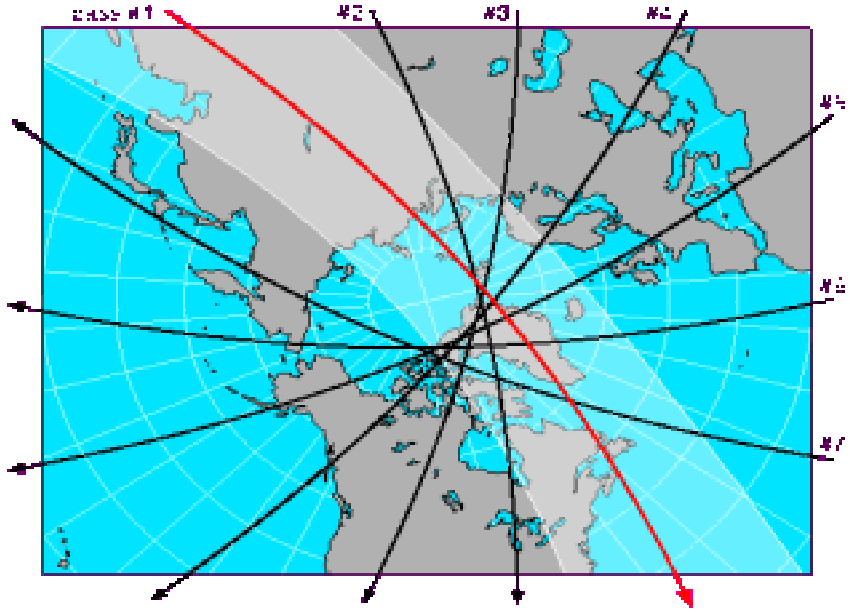


Orbits



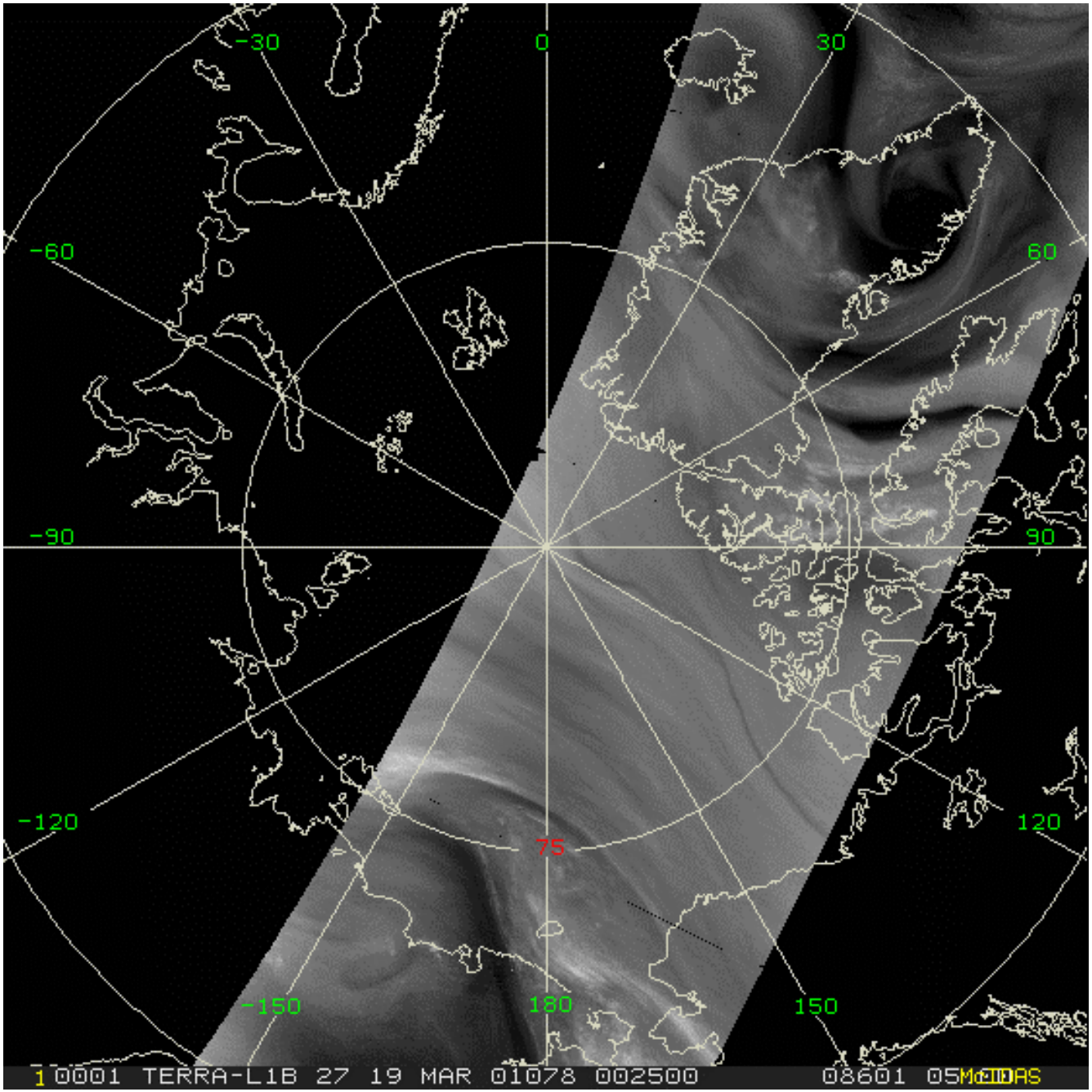




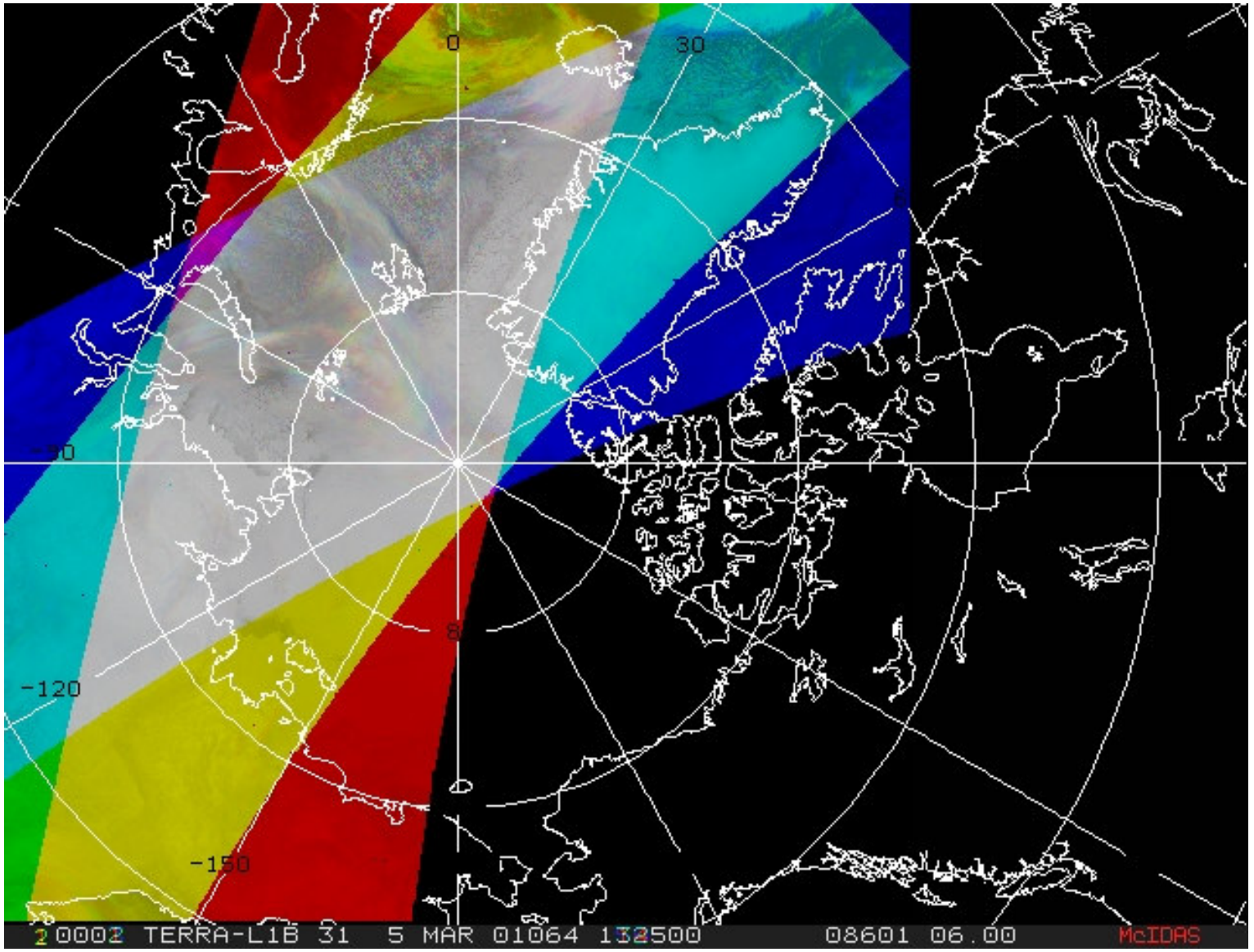


Figures from http://www.rap.ucar.edu/~djohnson/satellite/coverage.html

One Day of Arctic Orbits

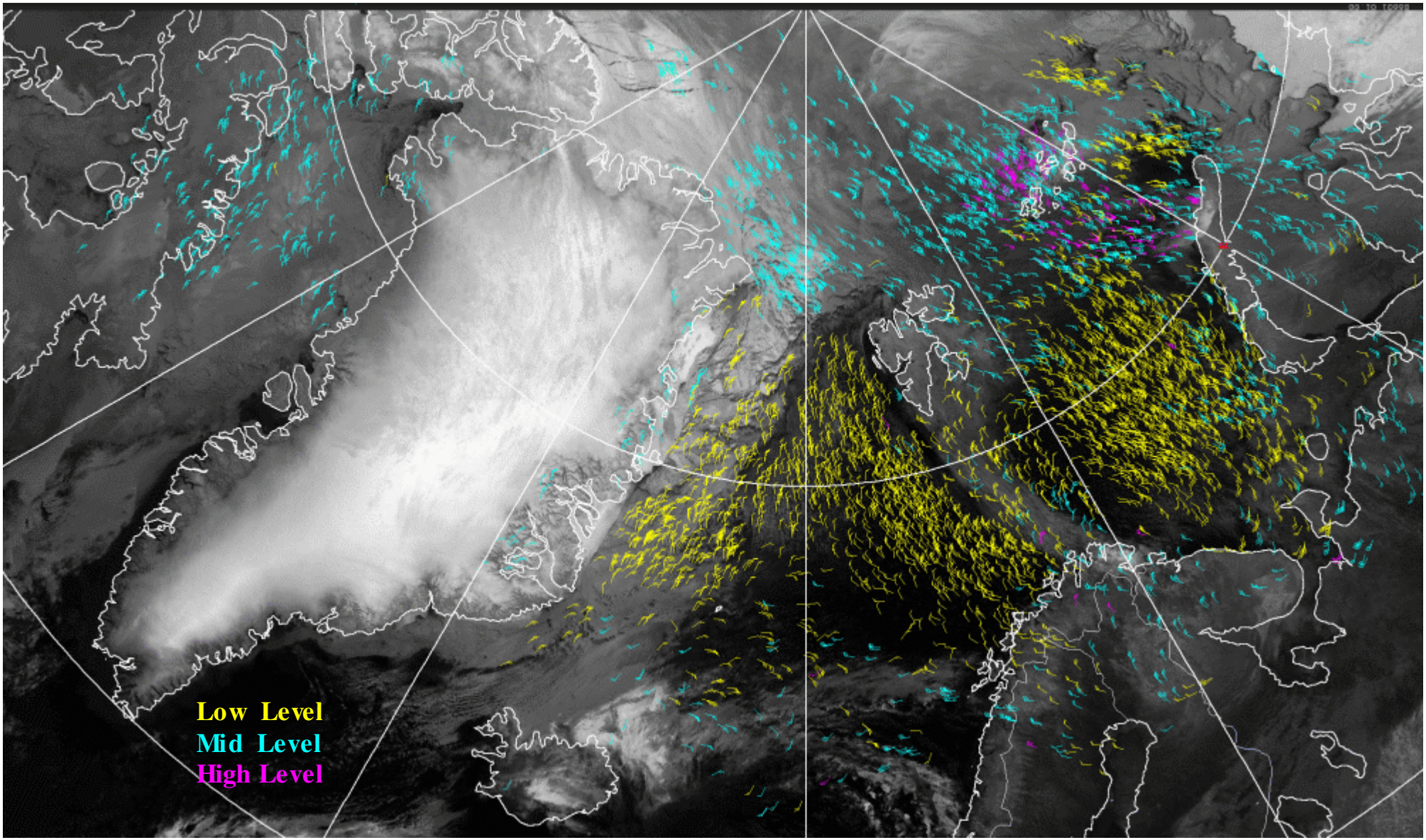


MODIS band 27 (6.7 μm)



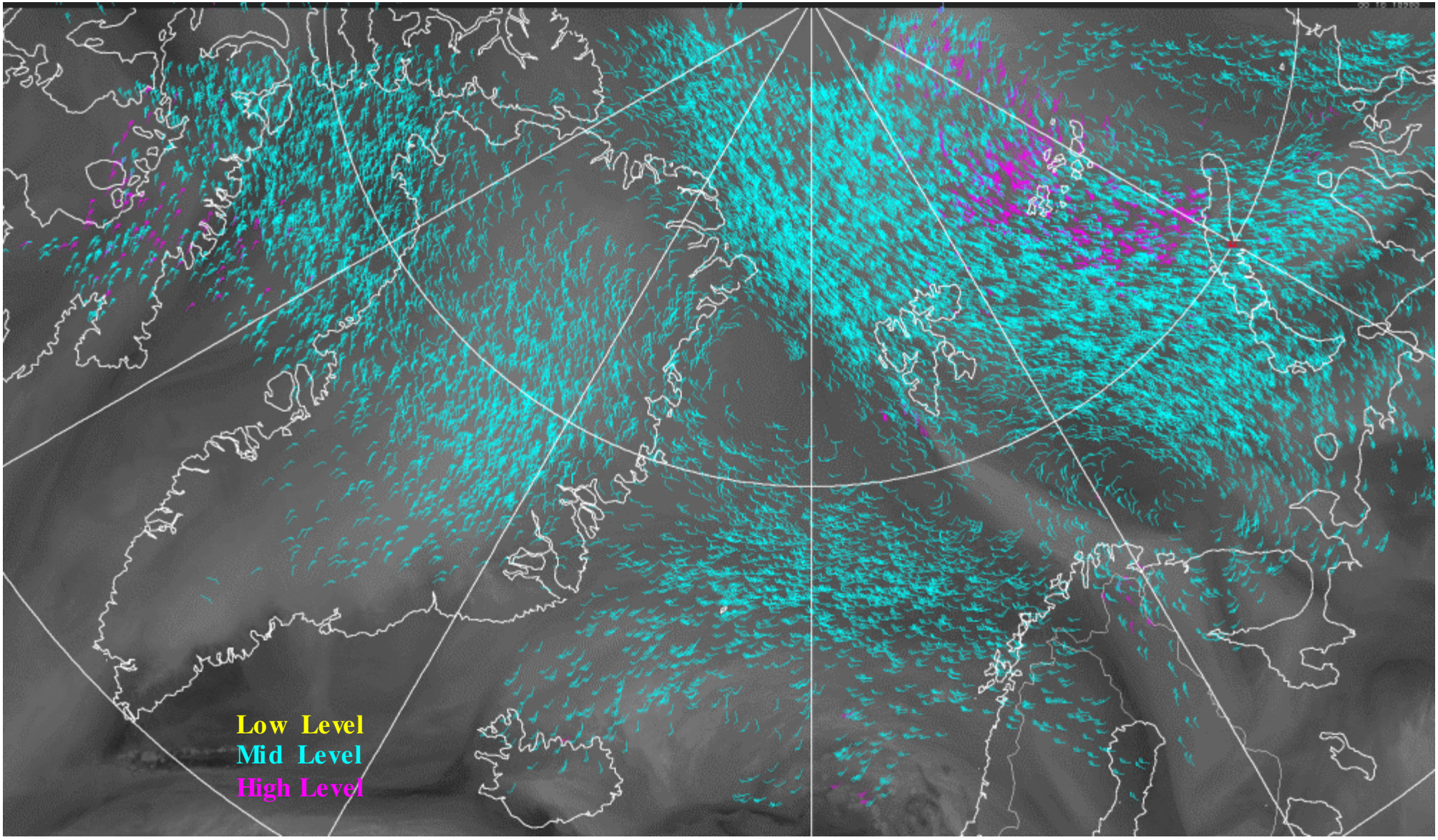
Unlike geostationary satellites at lower latitudes, it is not be possible to obtain complete polar coverage at a snapshot in time with one or two polar-orbiters. Instead, winds must be derived for areas that are covered by two or three successive orbits, an example of which is shown here. The whitish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

Infrared Winds



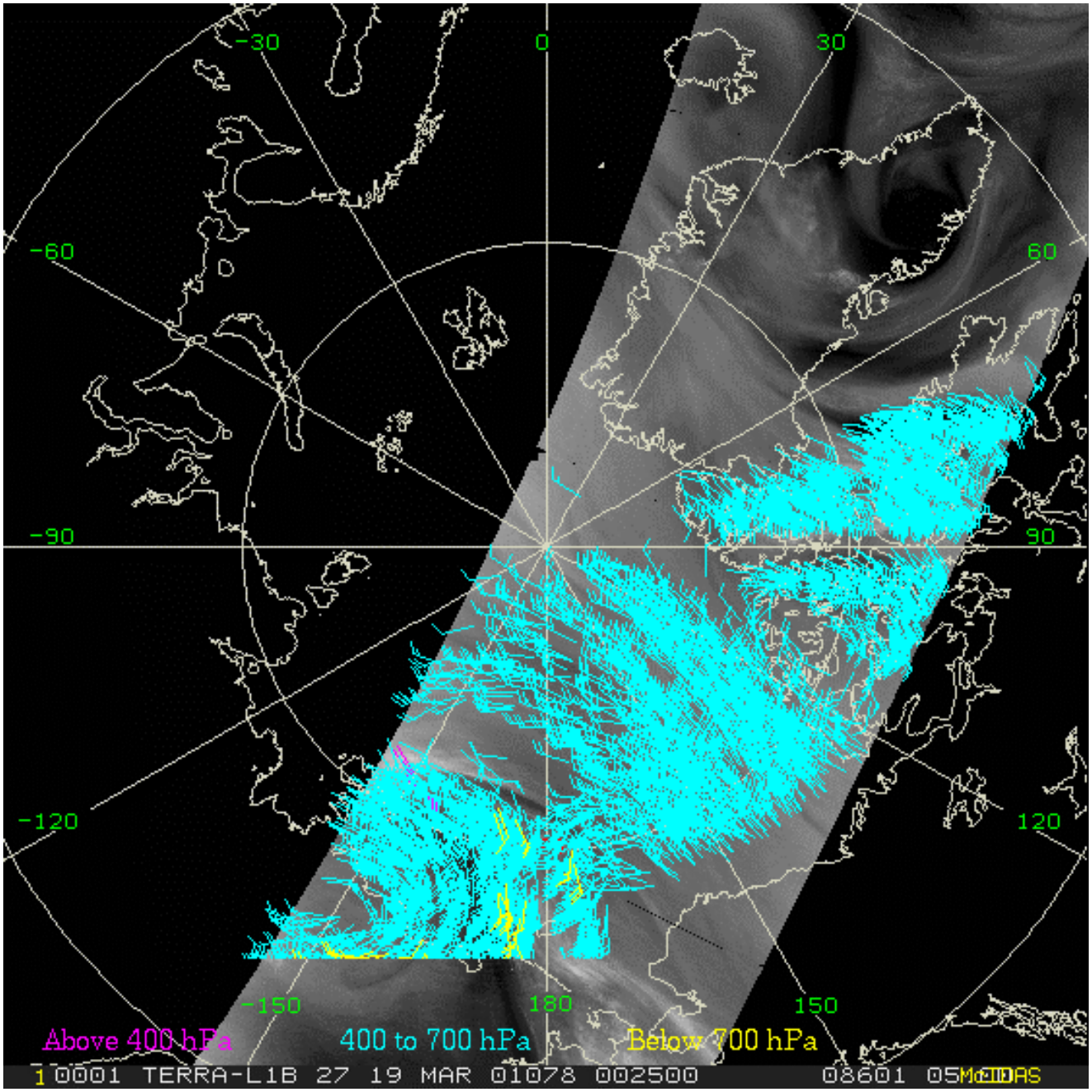
05 March 2001: Daily composite of 11 micron MODIS data over half of the Arctic region. Winds were derived over a period of 12 hours. There are about 4,500 vectors in the image. Vector colors indicate pressure level - yellow: below 700 hPa, cyan: 400-700 hPa, purple: above 400 hPa.

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

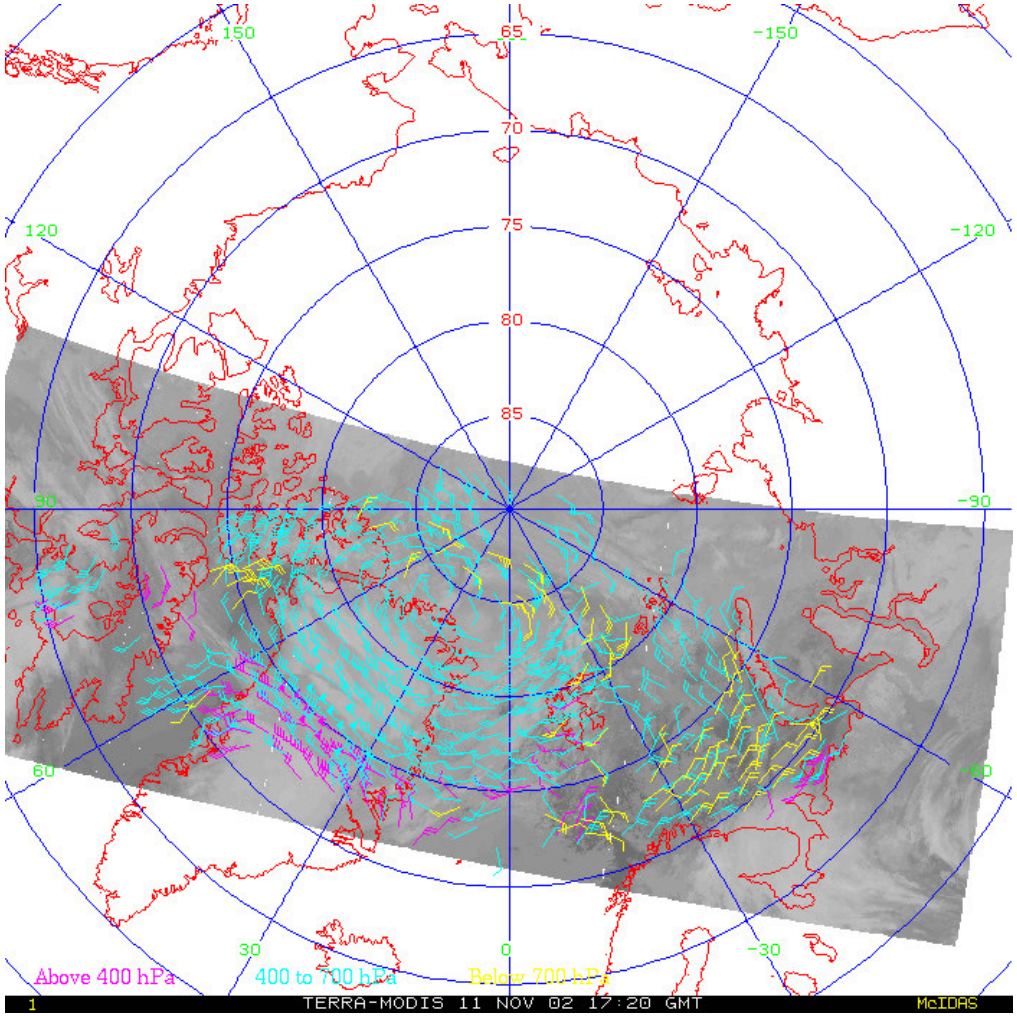


MODIS band 27 (6.7 μm)

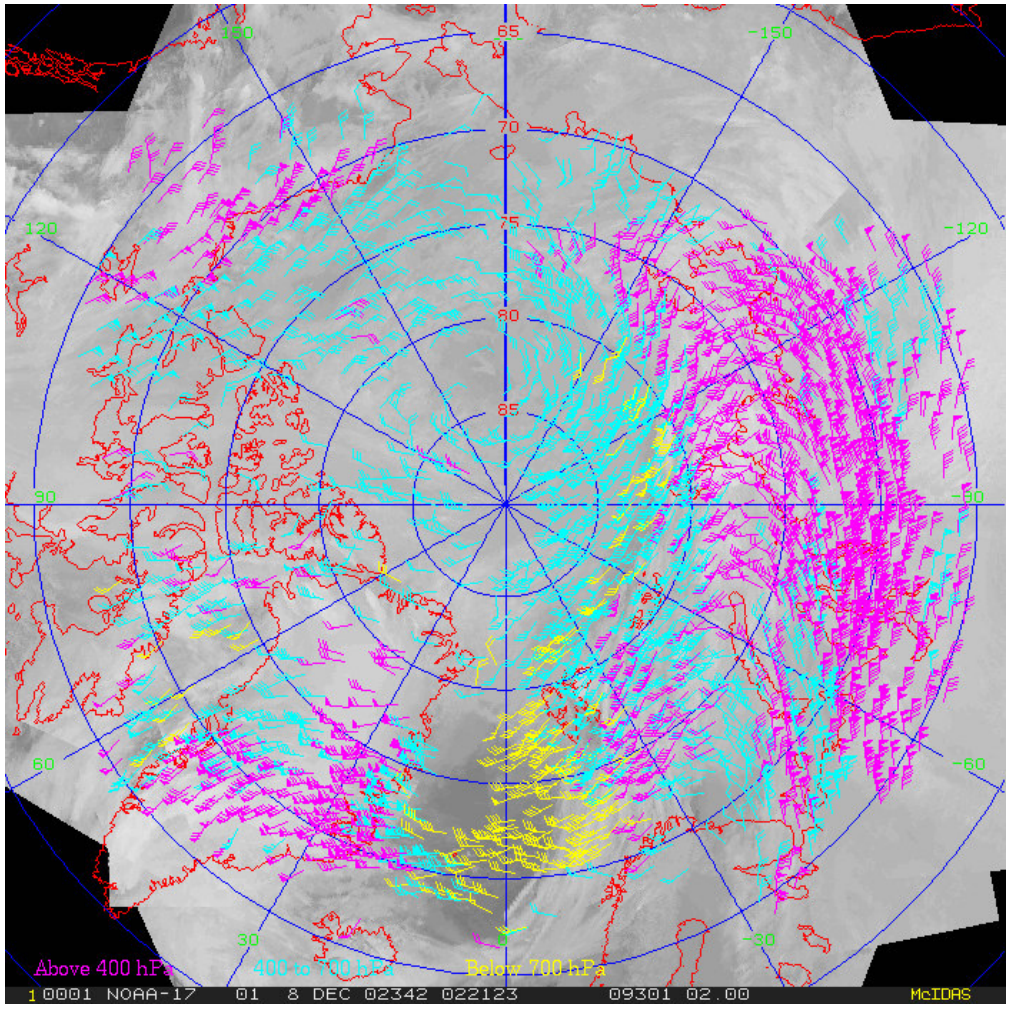
Near Real-Time Winds Examples

MODIS winds are generated and made available in real-time for each 200 minute triplet. AVHRR GAC winds are generated in near real-time and are presented on the Web as composites over the day. Both are available at http://stratus.ssec.wisc.edu/products/rtpolarwinds.

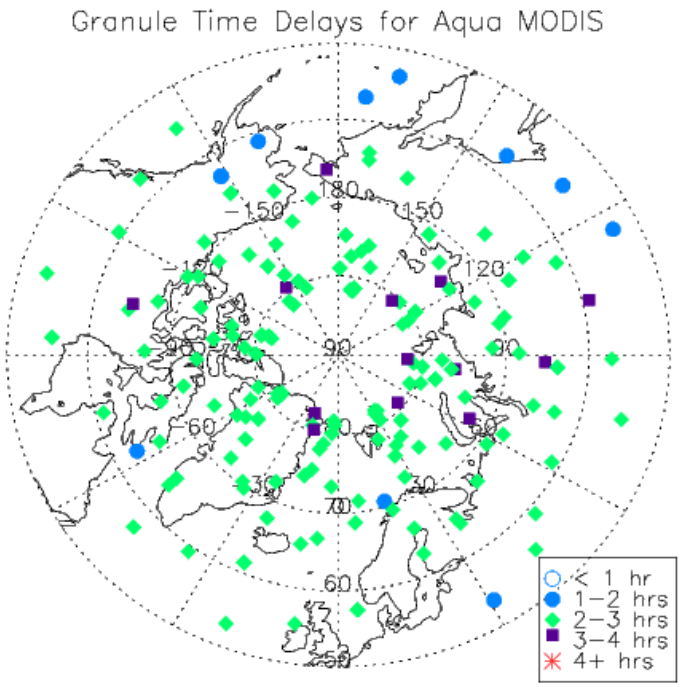
MODIS

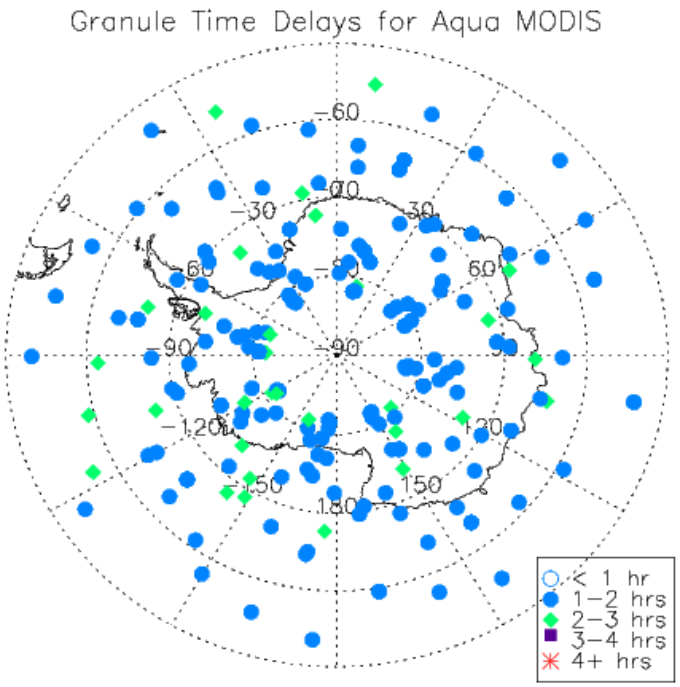


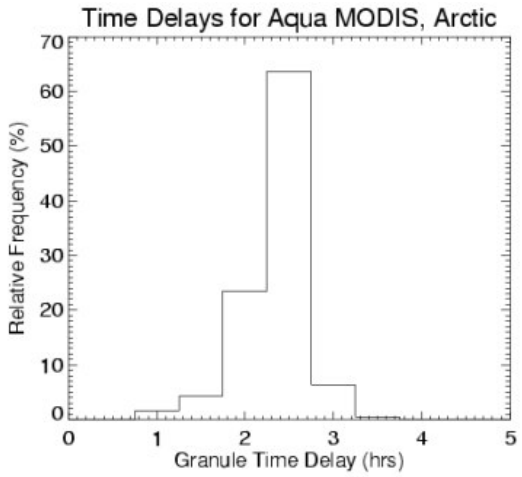
AVHRR

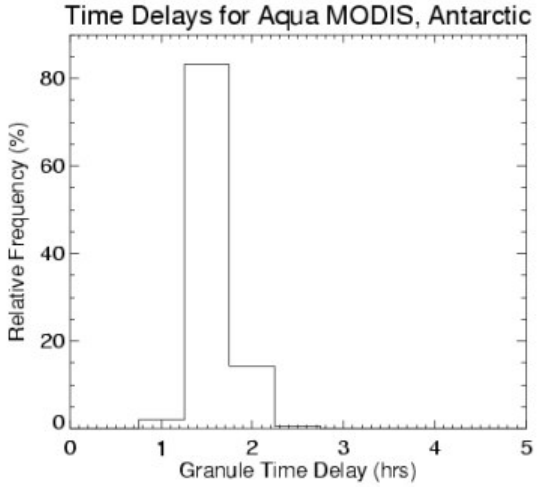


Aqua MODIS Data Acquisition Delays



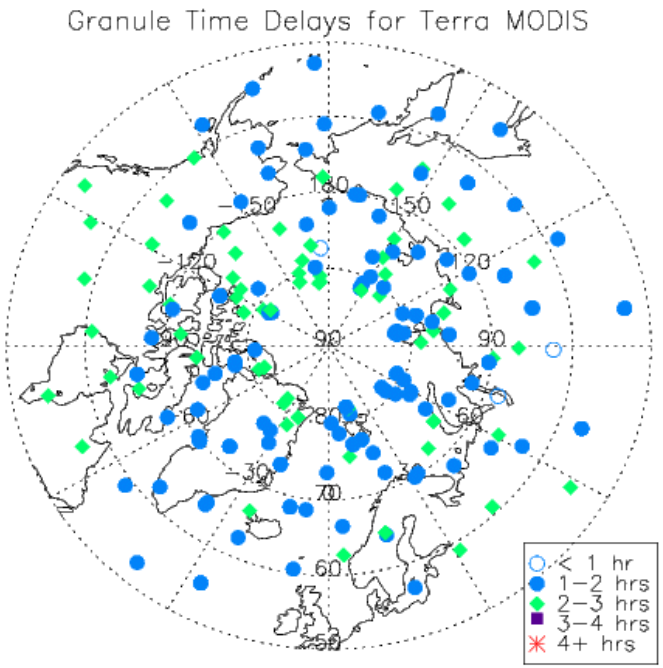


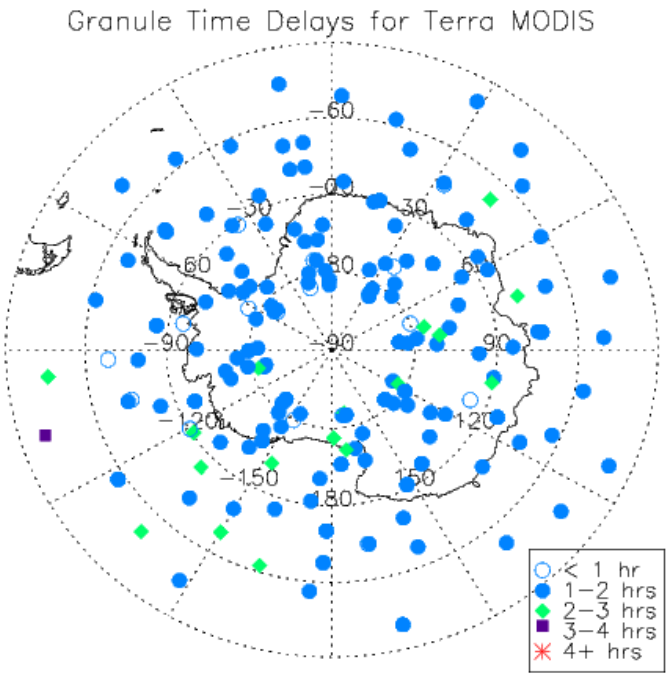


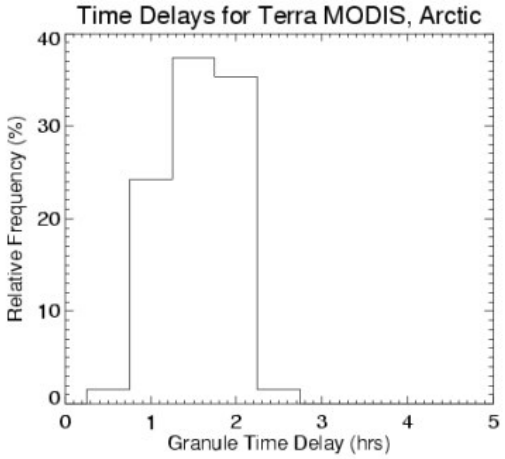


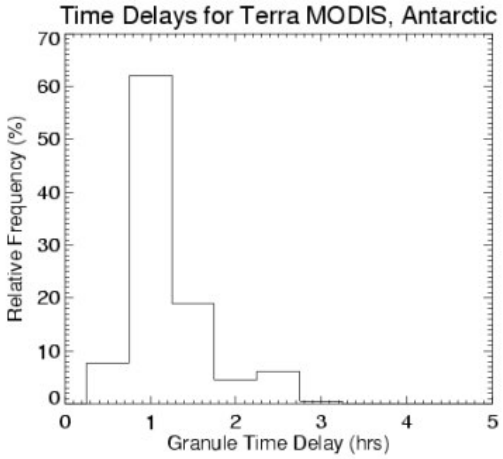
The figures above show the time delay in the availability of Aqua MODIS data, where the delay is the time between the image time and the time a granule is available on the NOAA "bent pipe". This histogram of time delays is for the south polar region.

Terra MODIS Data Acquisition Delays





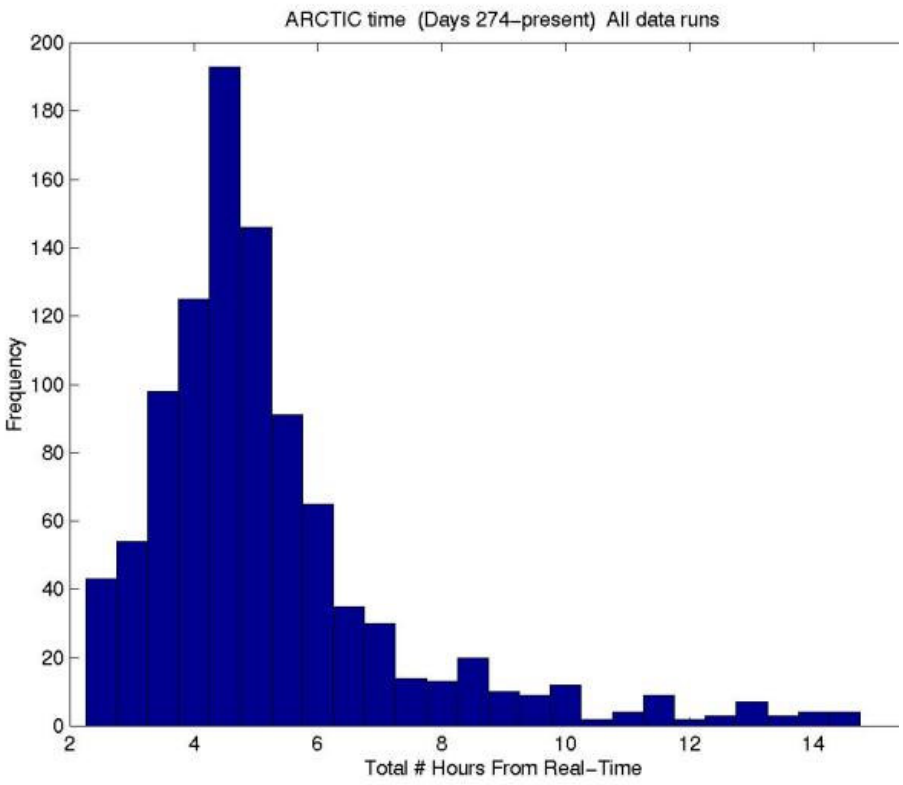




The figures above show the time delay in the availability of Terra MODIS data, where the delay is the time between the image time and the time a granule is available on the NOAA "bent pipe". This histogram of time delays is for the south polar region.

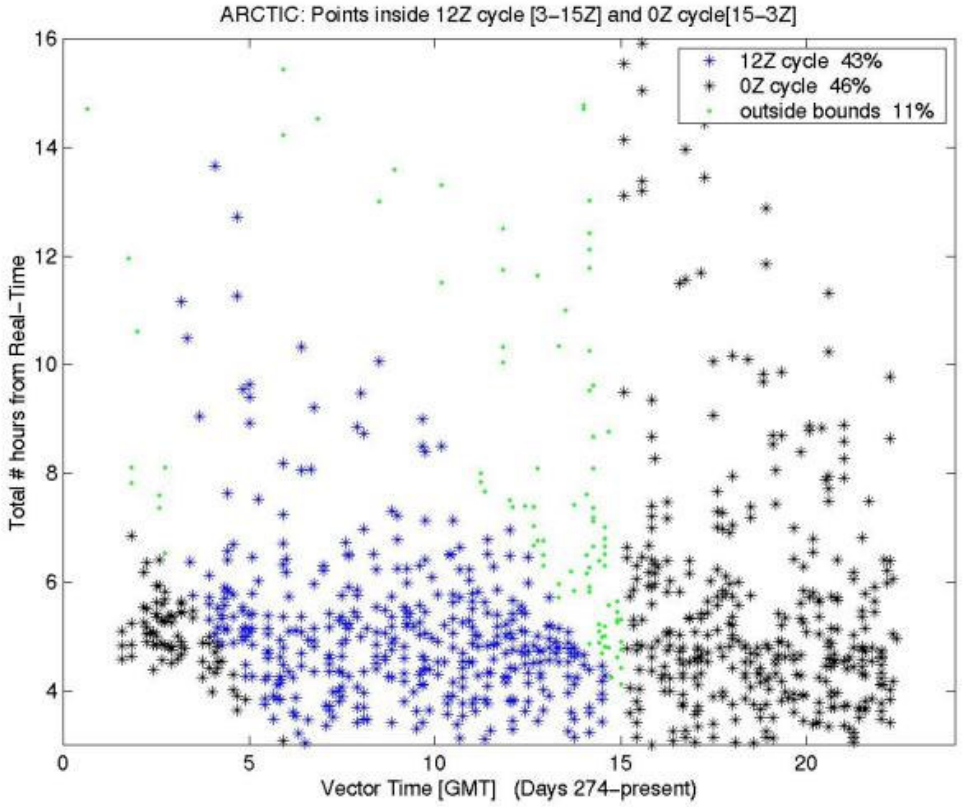
MODIS Polar Winds Real-Time Processing Delays

Frequency of Delays in Wind Retrievals



1-3 hrs before MODIS data is available + 1/5 hr to transfer data from GSFC to CIMSS + 1 hr to process winds + 1-1/2 hrs offset because we assign vector time to middle image = 3-6 hours total time

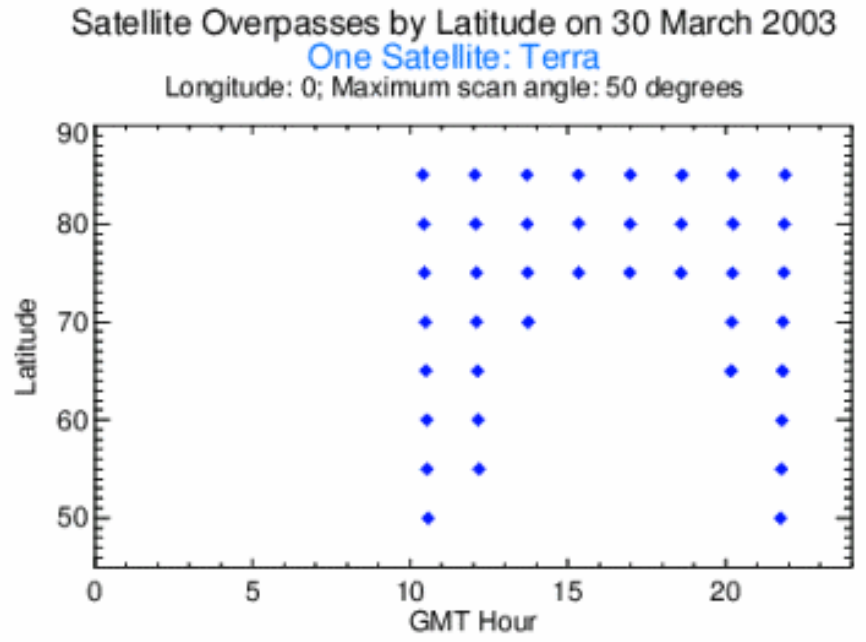
Relative to Two ECMWF Processing Cycles

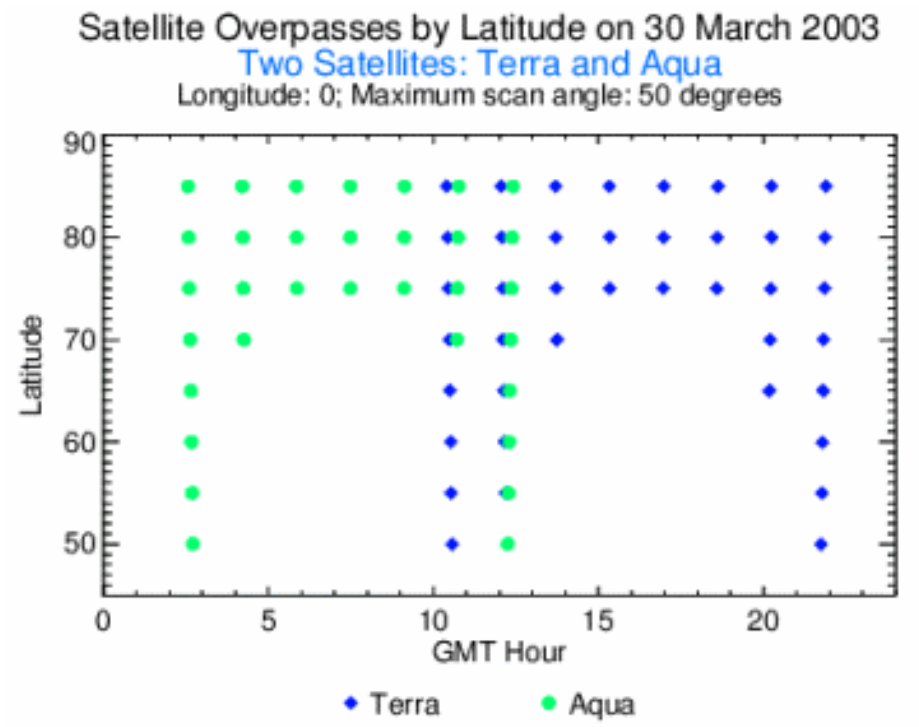


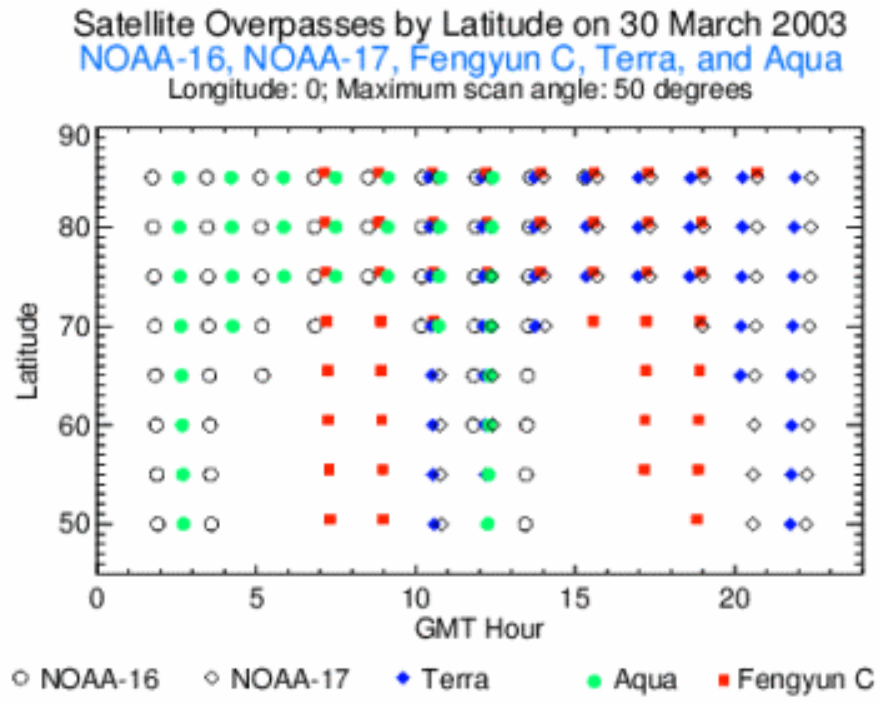
The blue points represent winds that will be included in the 12Z run; the black points represent winds that will be used in the 0Z run. The green points will not be used in either, as a result of the processing delay. The 12Z run is not done until 19Z; the 0Z run is done at 9Z.

Overpass Frequency

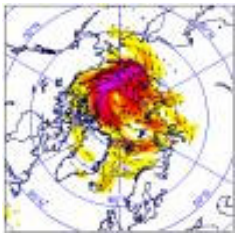
The figure at right shows the time of successive overpasses at a given latitude-longitude point on a single day with only the Terra satellite. The figure at the upper right shows the frequency of "looks" by two satellites: Terra and (the future) Aqua. The figure at the lower right shows the temporal sampling with five satellites.







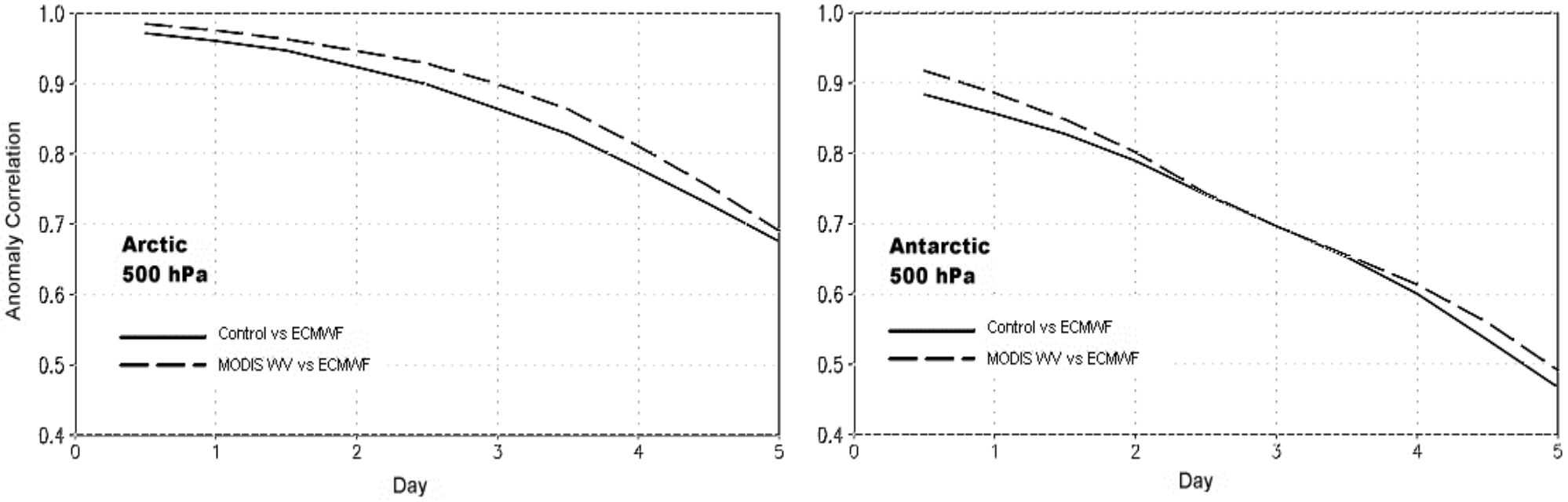
Model Impact Studies



Current Users:

- European Centre for Medium-Range Weather Forecasts (ECMWF; Lueder von Bremen and Jean-Noel Thepaut) - Using winds in operational system.
- NASA Global Modeling and Assimilation Office (GMAO; Lars Peter Riishojgaard and Yanqiu Zhu) - Using winds in operational system.
- Japan Meteorological Agency (JMA; Masahiro Kazumori) – Using winds in operational system (Arctic only)
- Canadian Meteorological Centre (CMC; Real Sarrazin) – Using winds in experimental system
- UK Met Office (Mary Forsythe and Howard Berger) – Using winds in experimental system
- Deutscher Wetterdienst (DWD; Alexander Cress) – Using winds in experimental system
- US Navy, Fleet Numerical Meteorology and Oceanography Center (FNMOC; Pat Pauley and Chuck Skupniewicz) – Using winds in experimental system
- NCEP/EMC has begun impact studies (Jim Jung)

DAO Model Impact Studies: Arctic and Antarctic

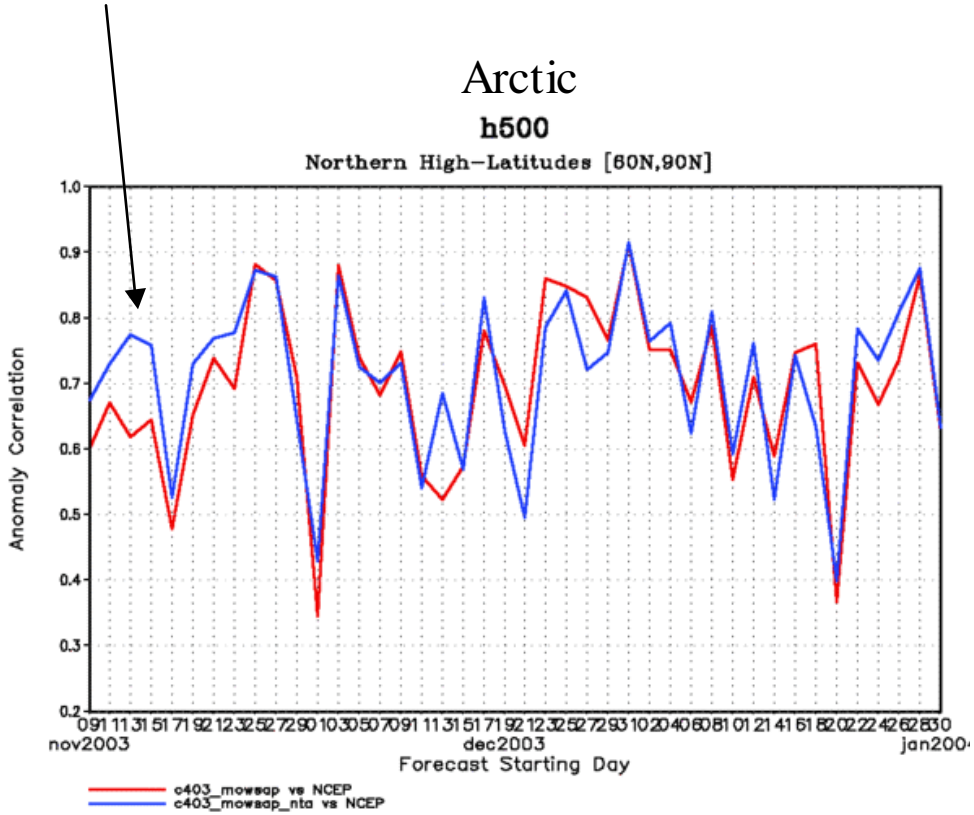


Forecast scores (anomaly correlations) as a function of forecast range for the 500 hPa geopotential over the Arctic (left) and Antarctic (right). The anomaly correlation is the correlation between the forecast geopotential height anomalies, with and without the MODIS winds, and ECMWF analyses. The Arctic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

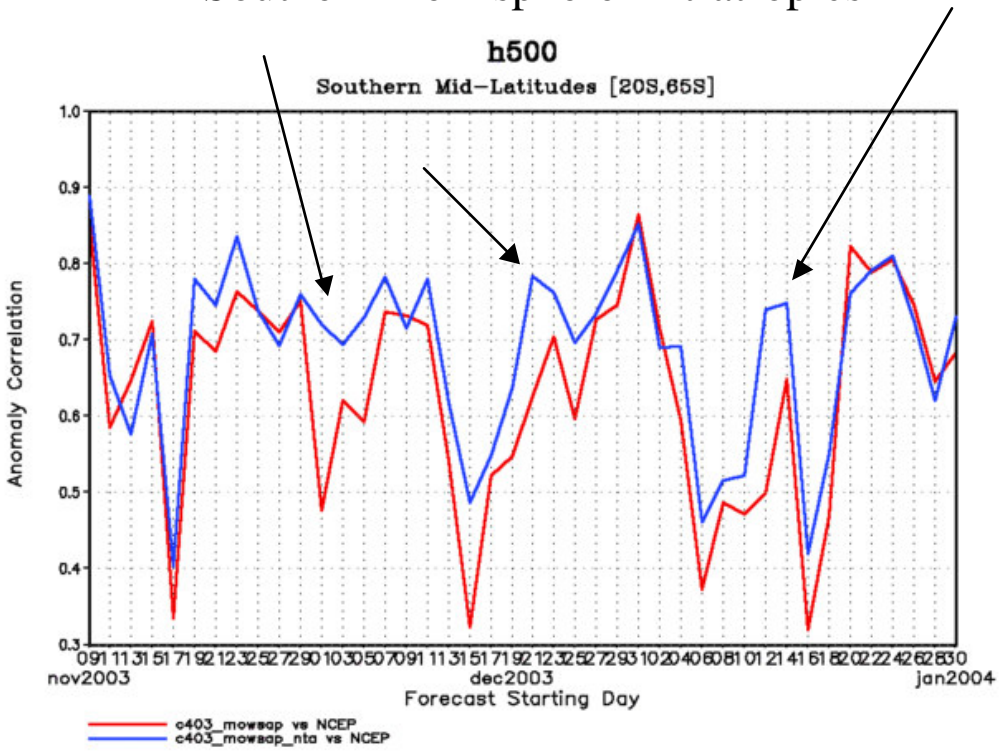
Over the Arctic the forecast impact is positive. Over the Antarctic the impact is neutral to positive.

Forecast Busts (GMAO)

Arctic



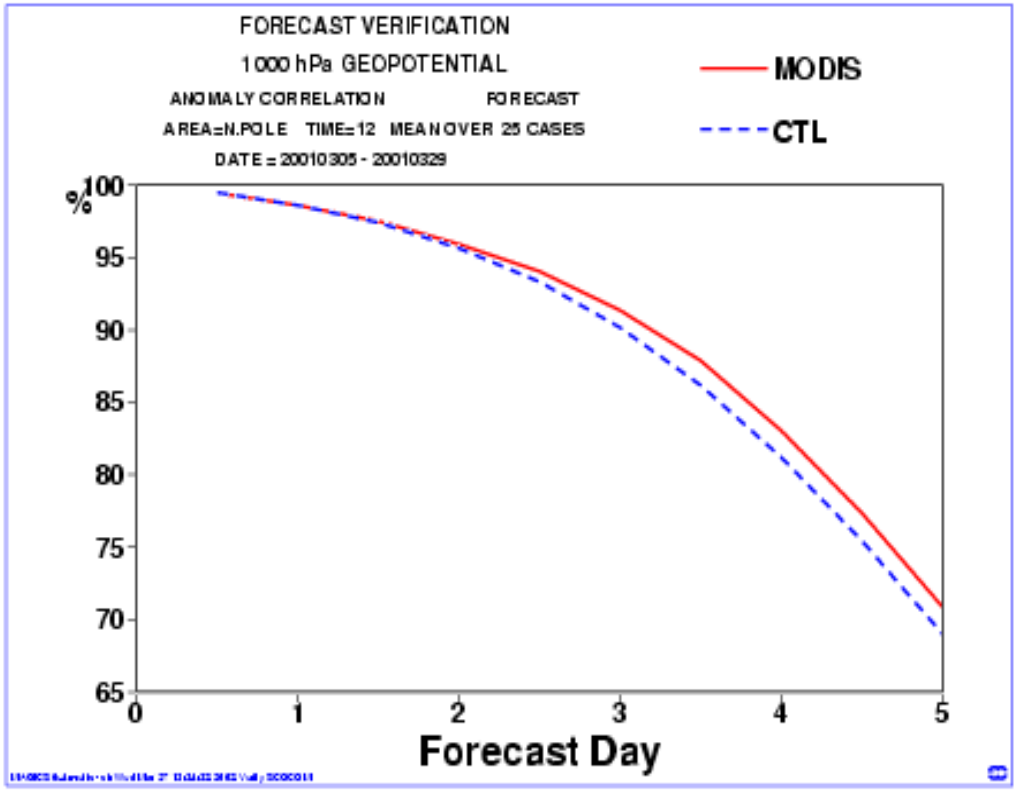
Southern Hemisphere Extratropics



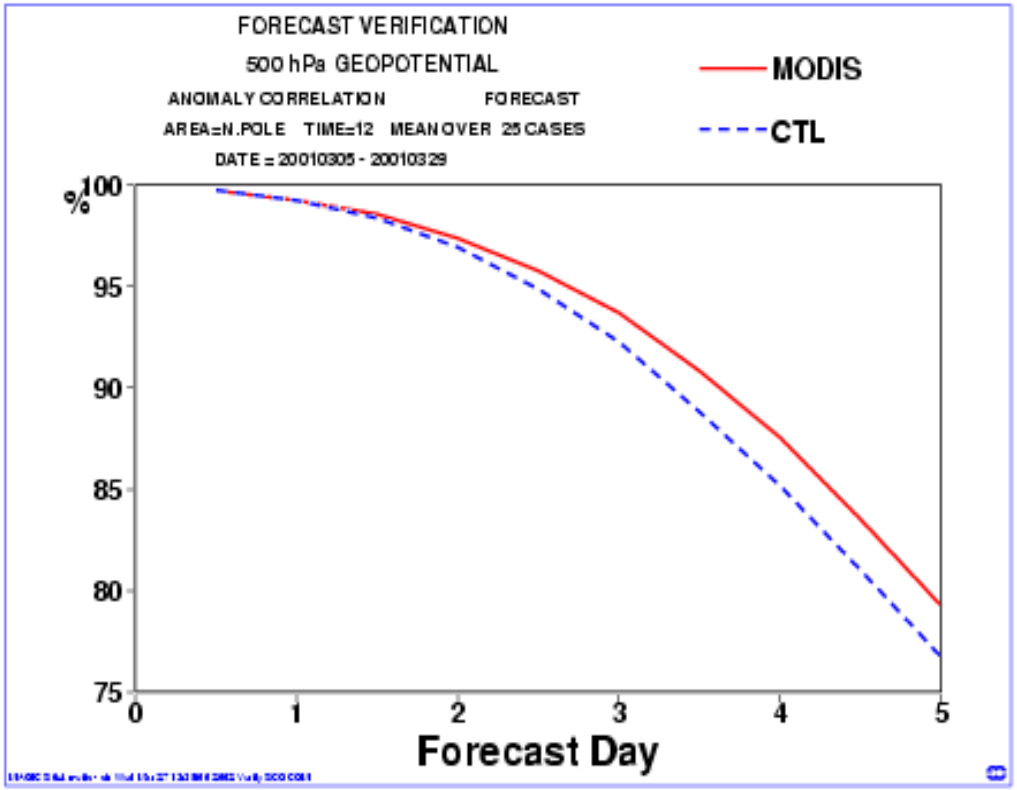
Blue is forecast with MODIS winds; red is control run

ECMWF Model Impact: Arctic

1000 hPa



500 hPa

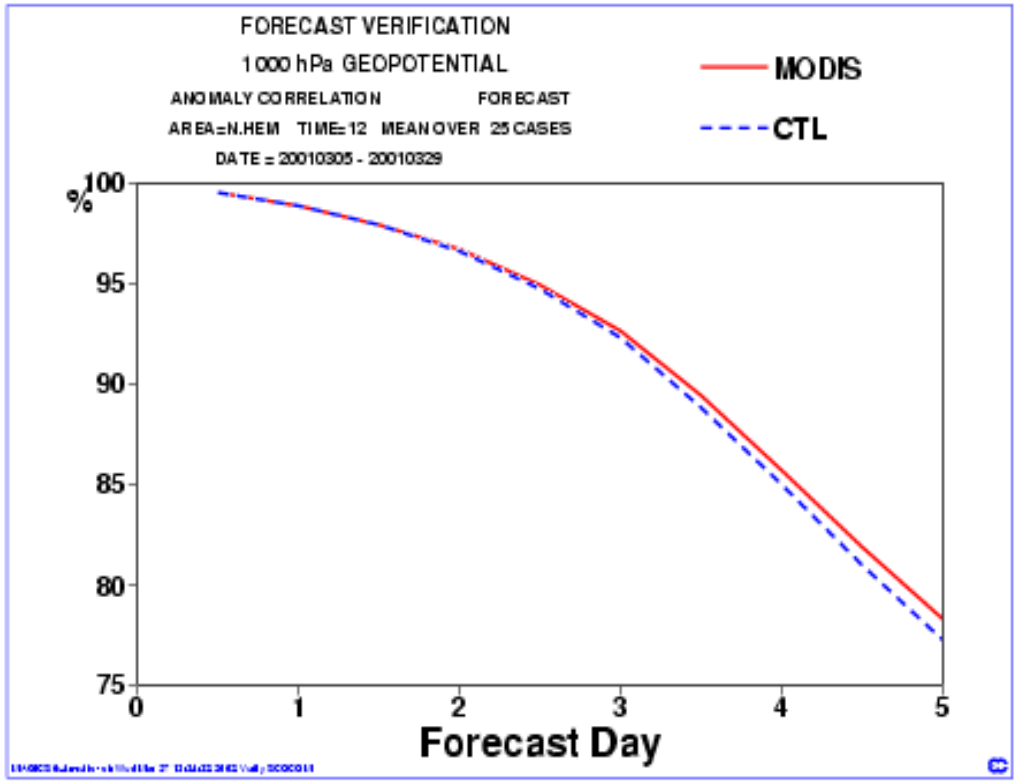


Forecast scores (anomaly correlations) as a function of forecast range for the geopotential at 1000 hPa (left) and 500 hPa (right). Study period is 5-29 March 2001. Forecast scores are the correlation between the forecast geopotential height anomalies, with and without the MODIS winds, and their own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

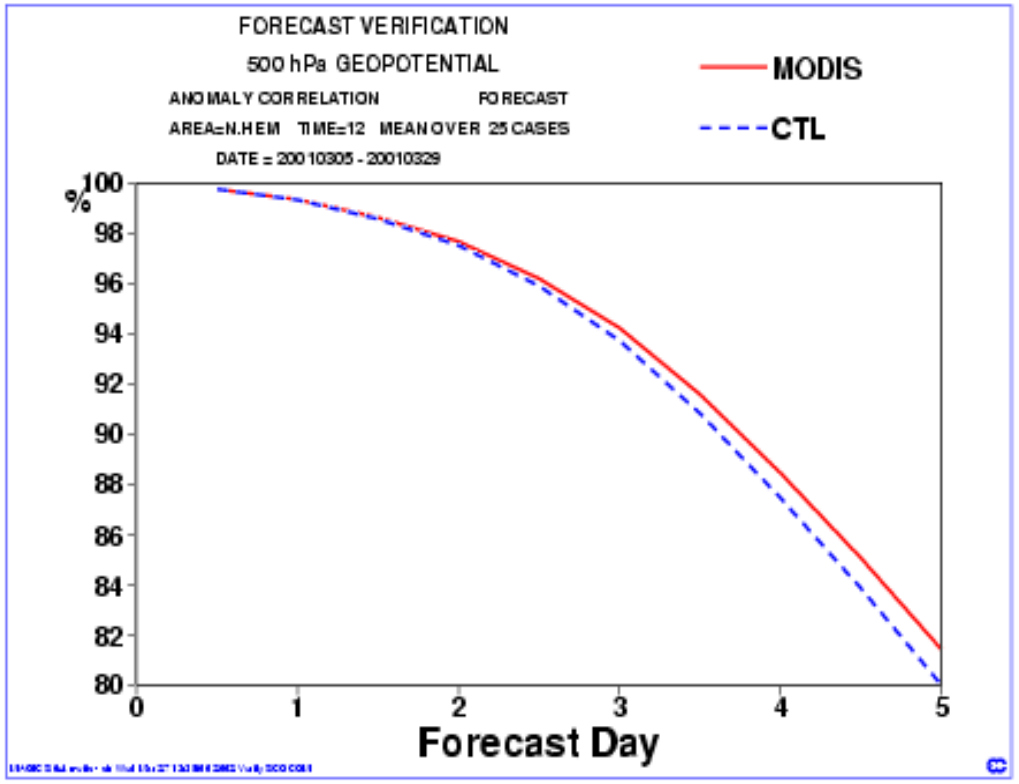
There is a significant positive impact on forecasts of the geopotential from the assimilation of MODIS winds, particularly for the Arctic. Forecast accuracy is extended by about 5 hrs.

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.

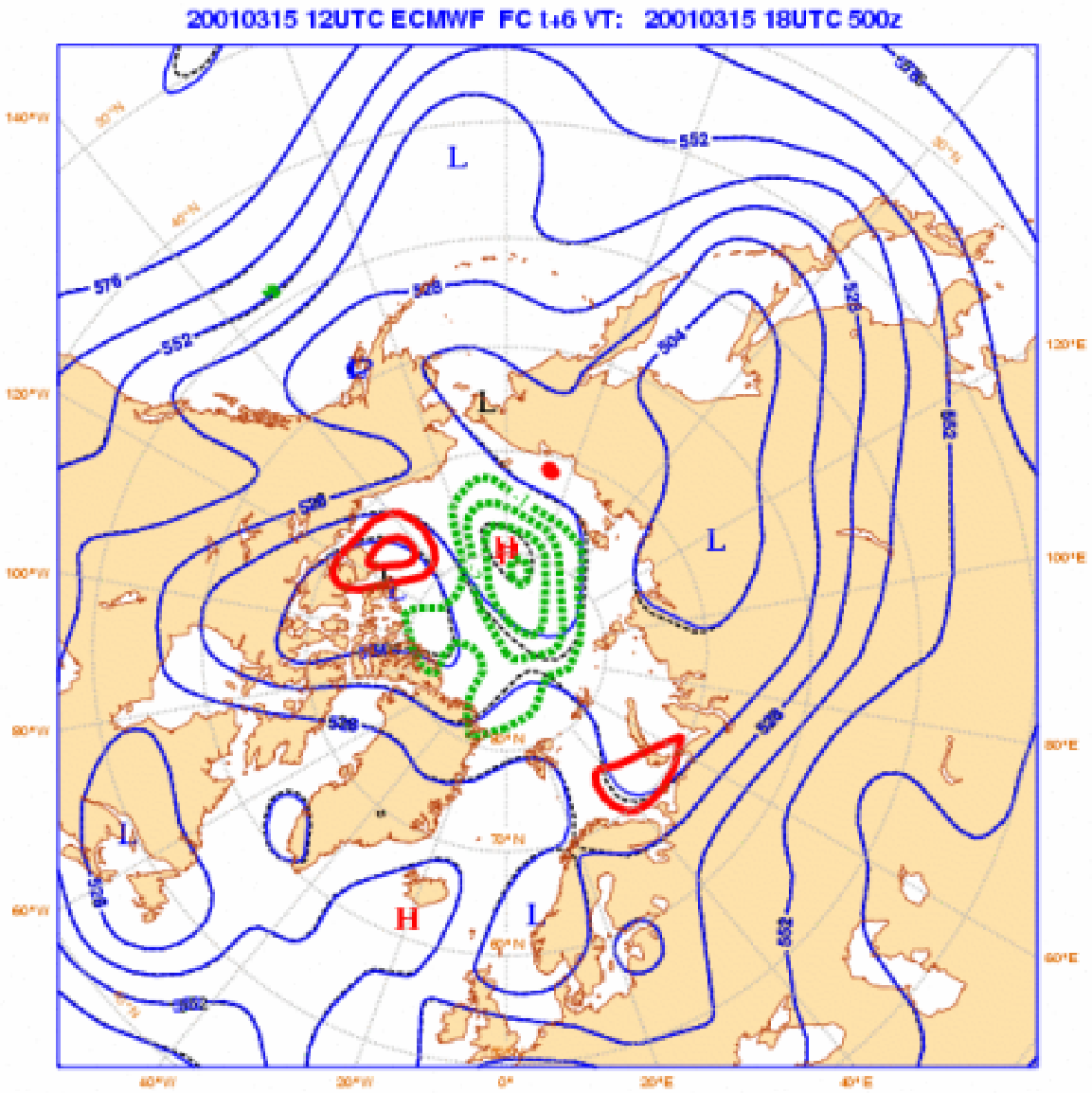
ECMWF: Error Propagation to the Midlatitudes

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 green 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.

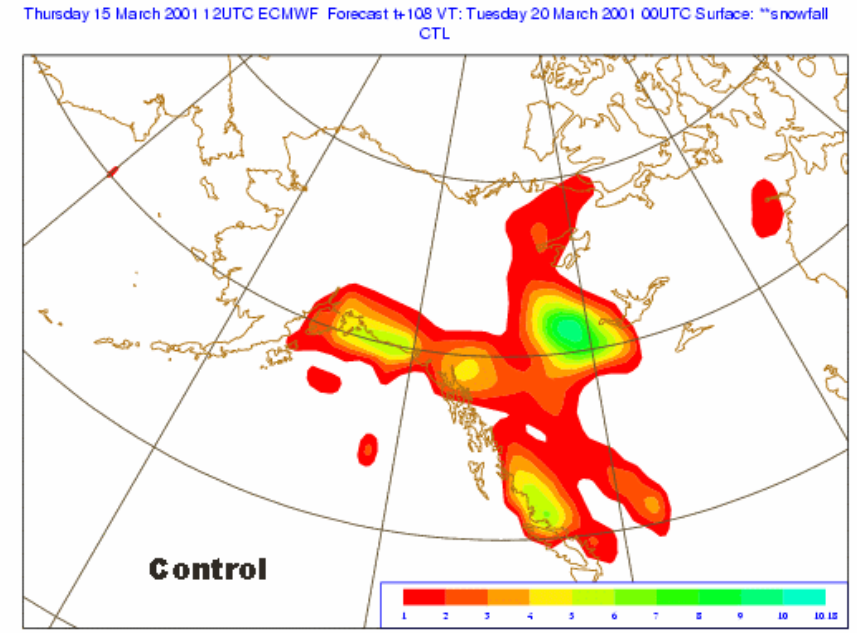
The 5-day MODIS forecast verifies better against the subsequent analysis (not shown), so the initial analysis for this MODIS forecast was closer to the "truth" than the CTL (positive impact on forecast). The propagation of differences is therefore also a propagation of analysis errors in the CTL forecast.

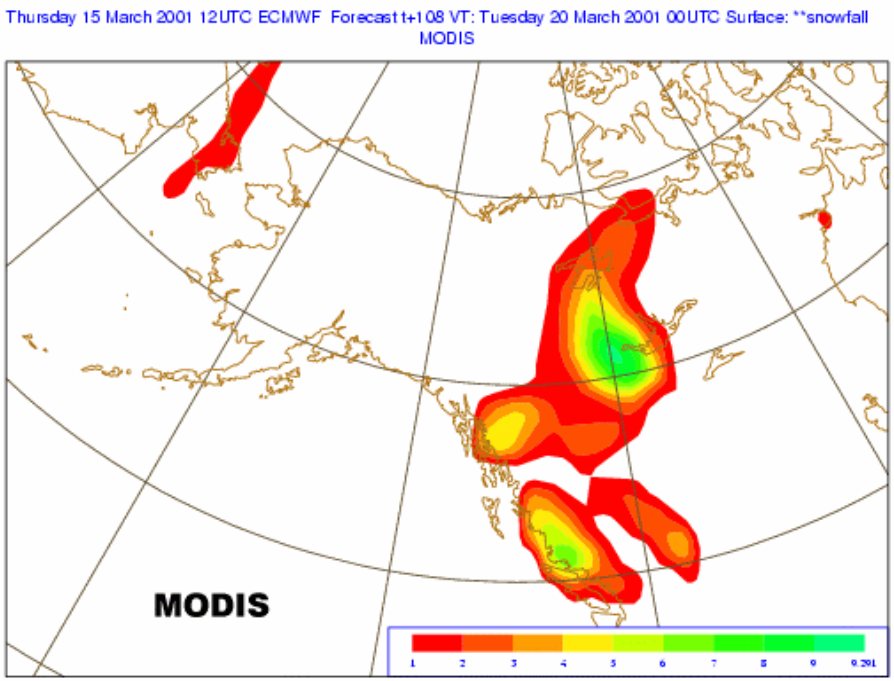
Better observations over the poles should improve forecasts in the midlatitudes.

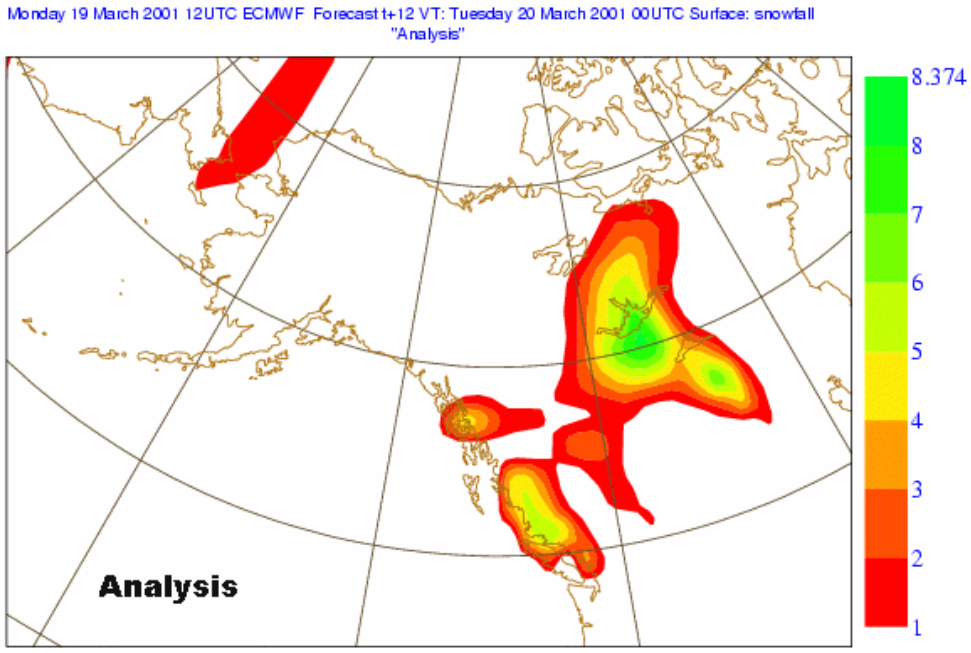


Error Propagation to the Midlatitudes: Snowfall

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.







Sounder Winds

The methodology for deriving winds from sounders involves estimating the temperature and moisture fields from retrievals, and then applying hydrostatic and dynamical balance constraints; i.e., calculate a thermal wind and correct for mass conservation. A surface wind from a model analysis or from satellite data (e.g., scatterometer) is used, and thermal winds are sequentially added upwards. Wind retrieval methods that have been developed for soundings from TOVS and AMSU will be applied to the polar regions. Improved soundings from AIRS will also be considered.

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Trends from TOVS

Thermal winds have been calculated for 22 years of TOVS data. This unique dataset can be used to examine trends in Arctic circulation, as illustrated below. Trends in total column u and v wind components for the period 1979-2001 show that the polar vortex has strengthened and shifted toward central Siberia.

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Plans

- MODIS winds:
  - Algorithm improvements - parallax correction, combine Terra and Aqua, improve height assignment, improve timing, additional bands
  - Model impact studies - 2nd special processing period, height assignment issues

- Sounder winds:
  - Investigate the specification of boundary conditions, variations in the vertical weighting function, and eddy winds
  - Adapt the AMSU nonlinear balance wind algorithm for the tropics to the polar regions

- Combine MODIS and sounder winds

- Complete the historical AVHRR and TOVS winds