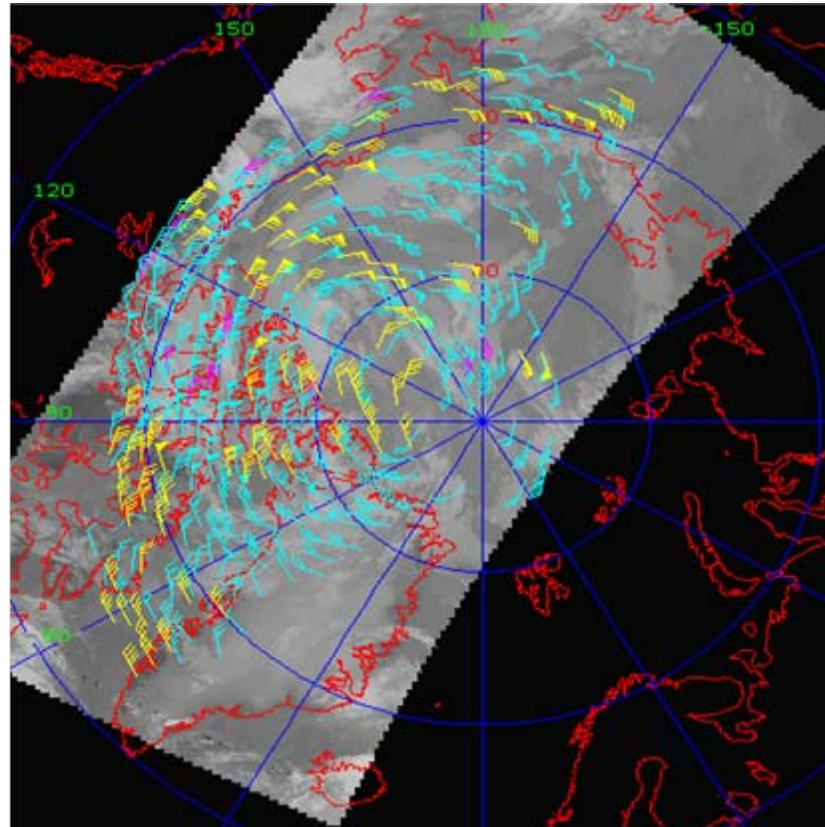


# A 20-Year Record of Satellite-Derived Polar Winds for Climate Studies



Richard Dworak, Jeff Key<sup>\*</sup>, Dave Santek, and Chris Velden

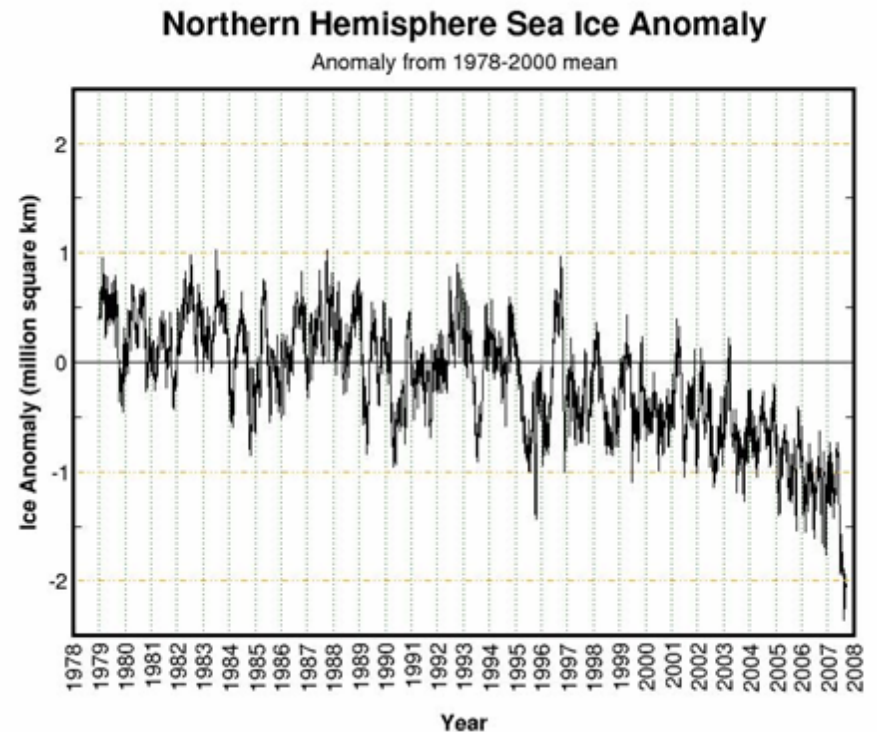
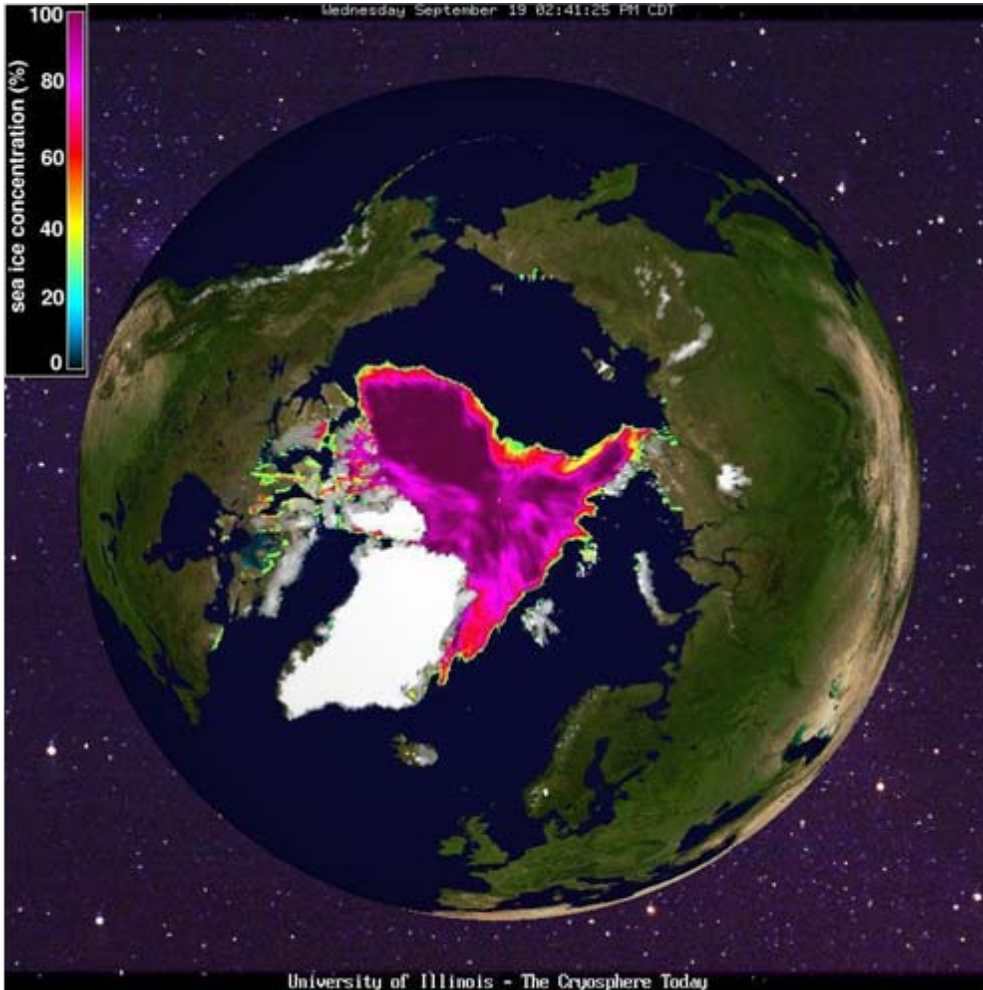
Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin

<sup>\*</sup>NOAA/NESDIS at CIMSS



# Motivation for More Polar Products: The Arctic is changing fast and we need to know why!

Arctic Sea Ice Extent on 19 Sept 2007

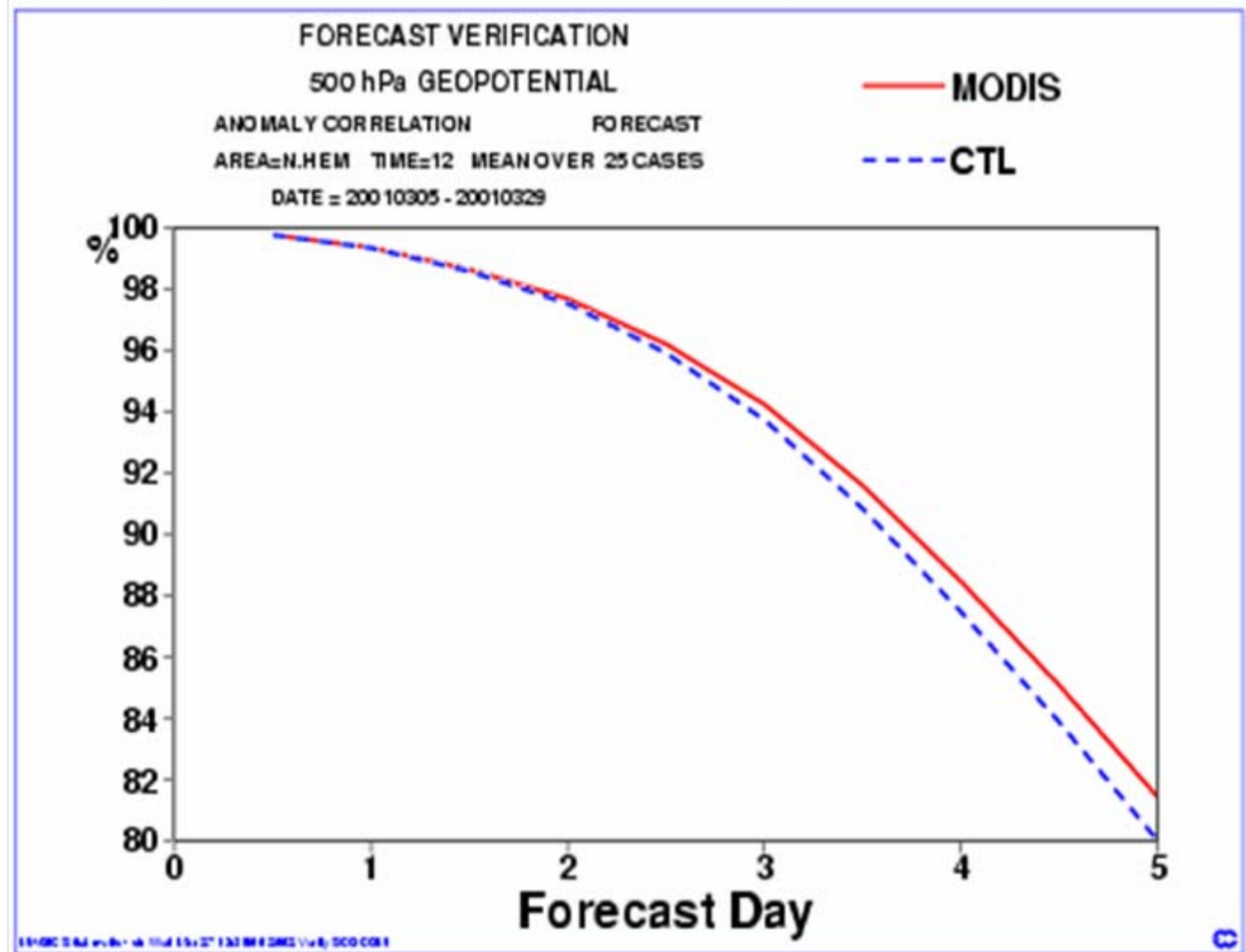




# Motivation for Polar Wind Data: Positive Impact

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

The MODIS winds are now used operationally by 10 NWP centers in 6 countries.

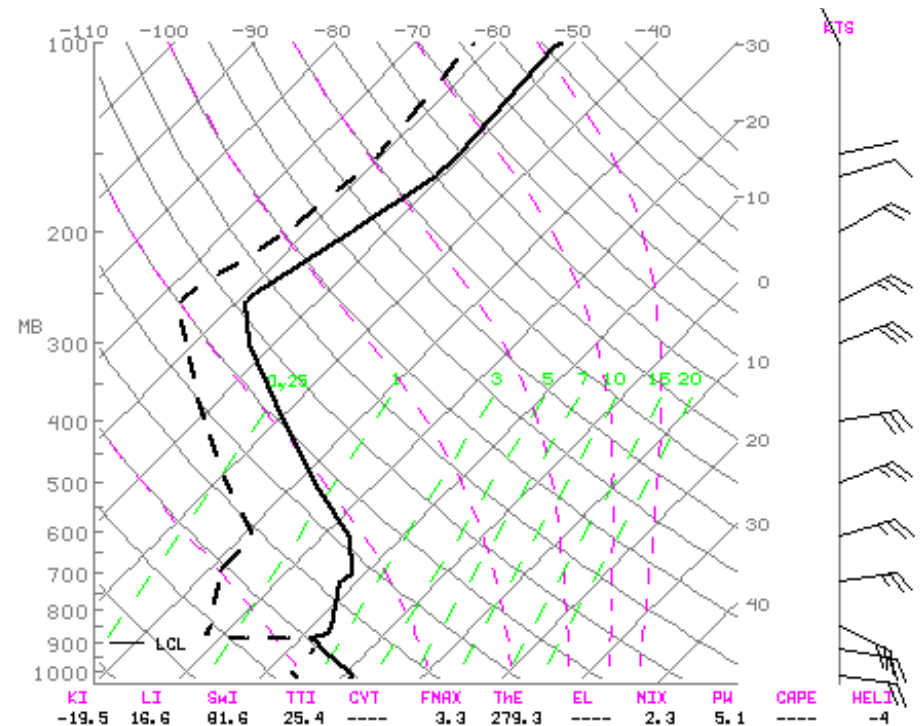


Anomaly correlations as a function of forecast range for the 500 hPa geopotential over the Northern Hemisphere extratropics (north of 20 degrees latitude). The study period is 5-29 March 2001. Forecast scores are the correlation between the forecast geopotential height anomalies, with and without the MODIS winds, and their own analyses.

# Motivation for Historical Wind Data: Reanalysis Wind Errors

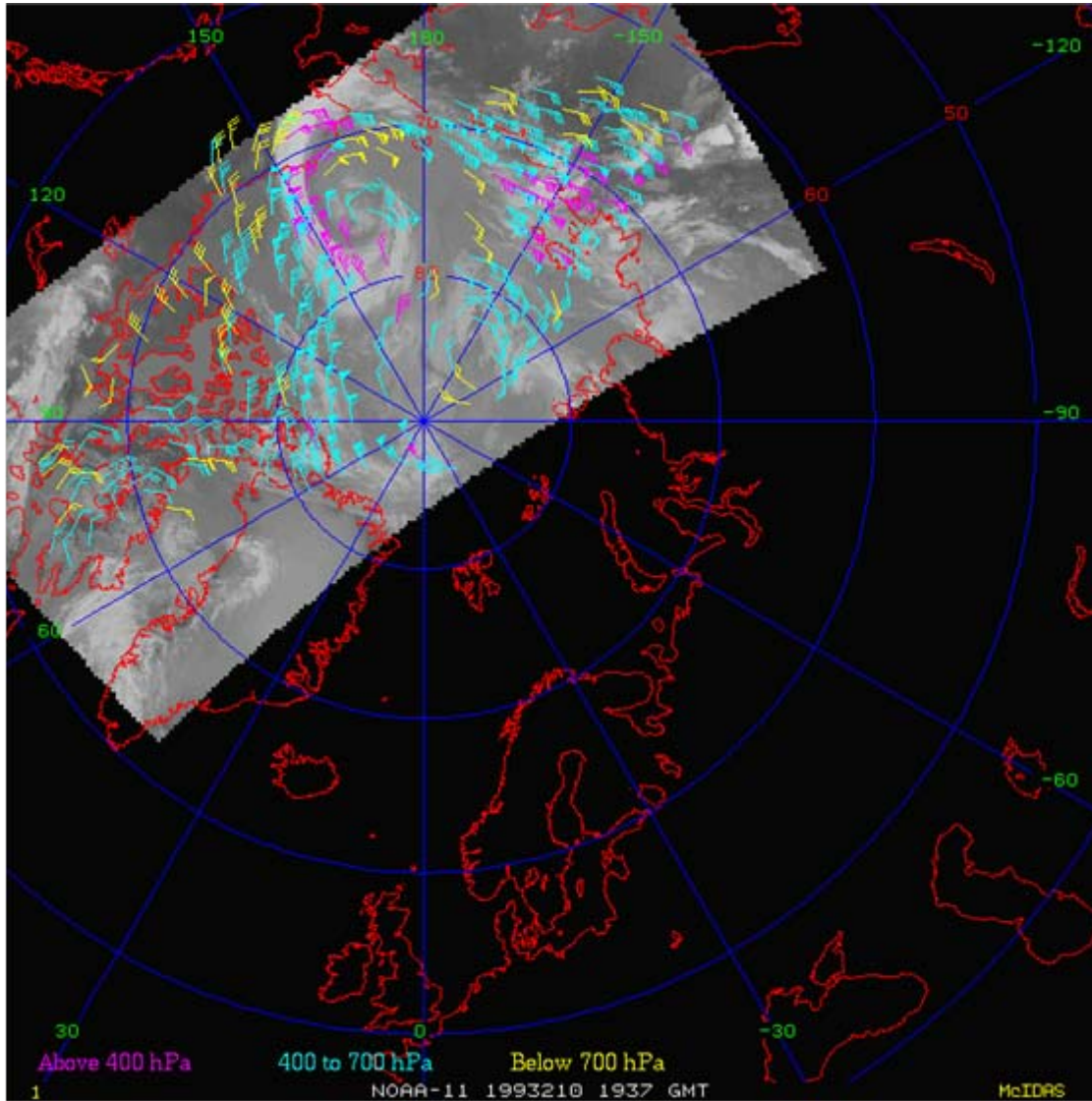
Francis (2002) examined differences between NCEP/NCAR and ECMWF Reanalysis winds and rawindsonde (“raob”) winds that were **not** assimilated into the reanalysis, from the LeadEx (1992) and CEAREX (1988) field experiments.

**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%.**



The result is meridional temperature gradients that are too strong, overly intense, narrow jet stream and/or cyclonic disturbances, and semi-permanent features in the upper-level circulation that are misplaced. Heat and moisture advection are too small in the poleward sense.

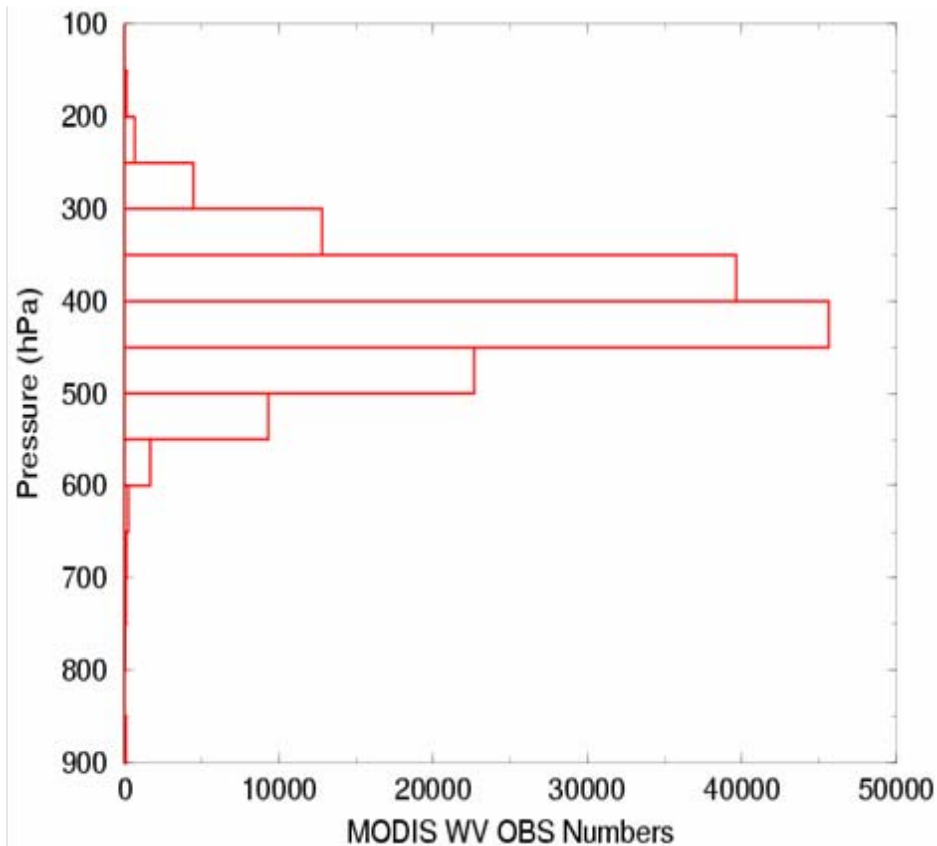
# Historical AVHRR Polar Winds



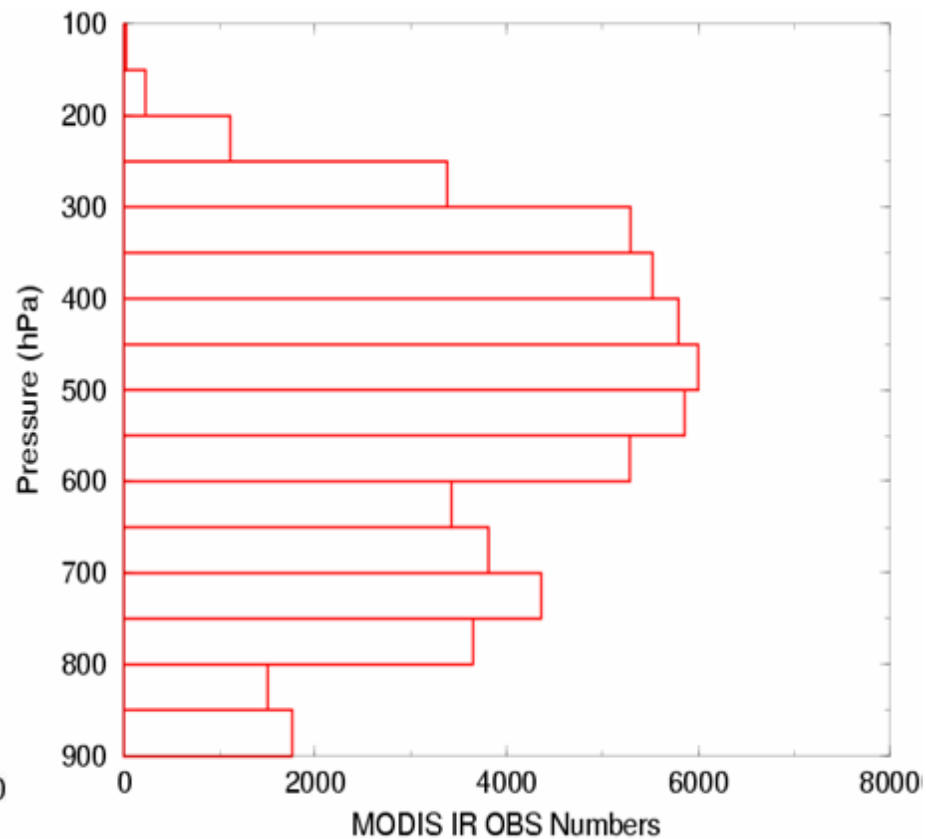
- January 1, 1982 to August 31, 2002.
- One satellite at any given time, NOAA-7, -9, -11, -14.
- Global Area Coverage (GAC) data gridded at 4 km.
- Cloud-track winds only (no water vapor channel).
- ERA-40 used as background. ERA-40 is ECMWF's 1957-2002 reanalysis product.
- Available in BUFR and text formats.

# MODIS vs AVHRR Winds: Vertical Frequency of Water Vapor and IR Winds

Water vapor from MODIS only

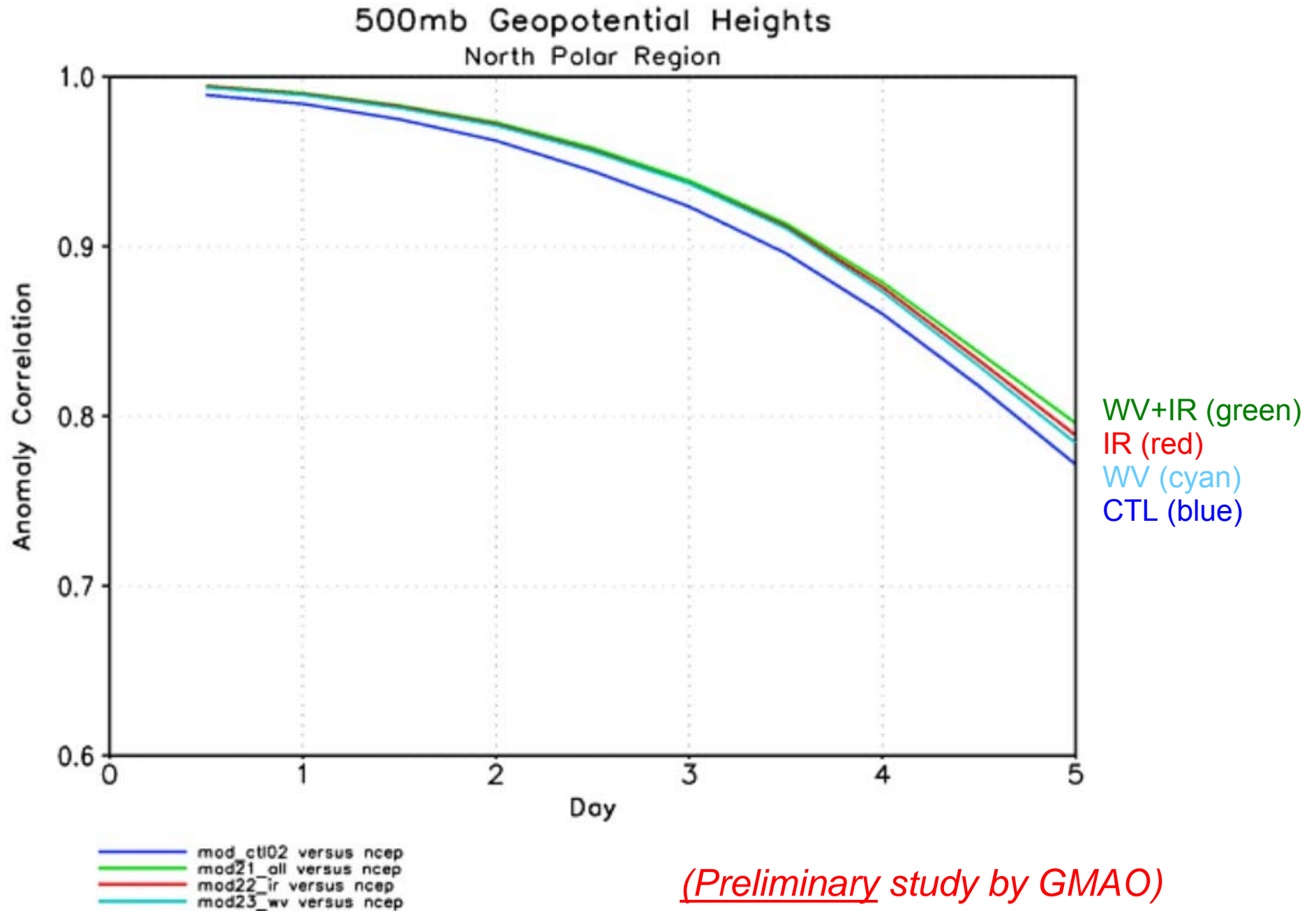


Cloud-track from MODIS and AVHRR



*(Courtesy of GMAO)*

# MODIS vs AVHRR Winds: NWP Impact



*(Preliminary study by GMAO)*

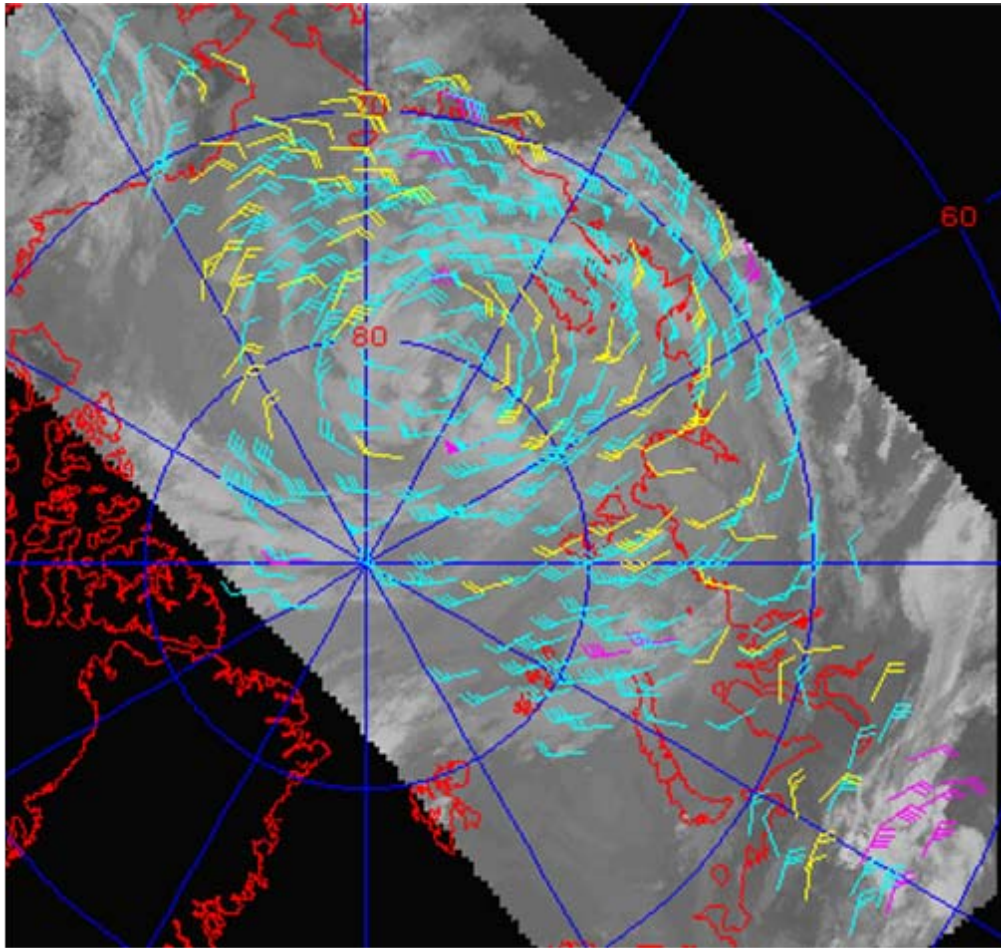


# AVHRR and ERA-40 Winds

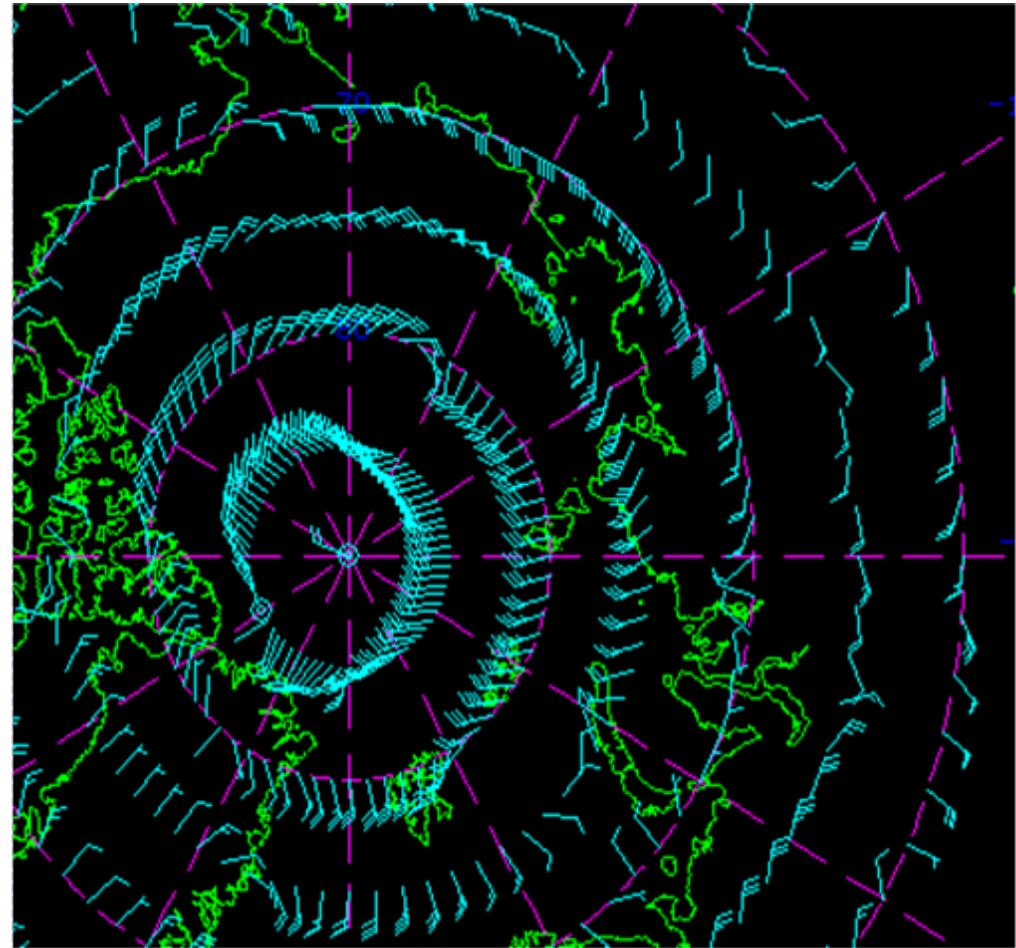
The following analyses were performed:

- Compare AVHRR and ERA-40 winds to each other.
- Compare AVHRR and ERA-40 winds to rawinsonde winds.
- Examine where, meteorologically, differences between AVHRR and ERA-40 winds occur.

# AVHRR vs ERA-40 Winds: An Arctic Example

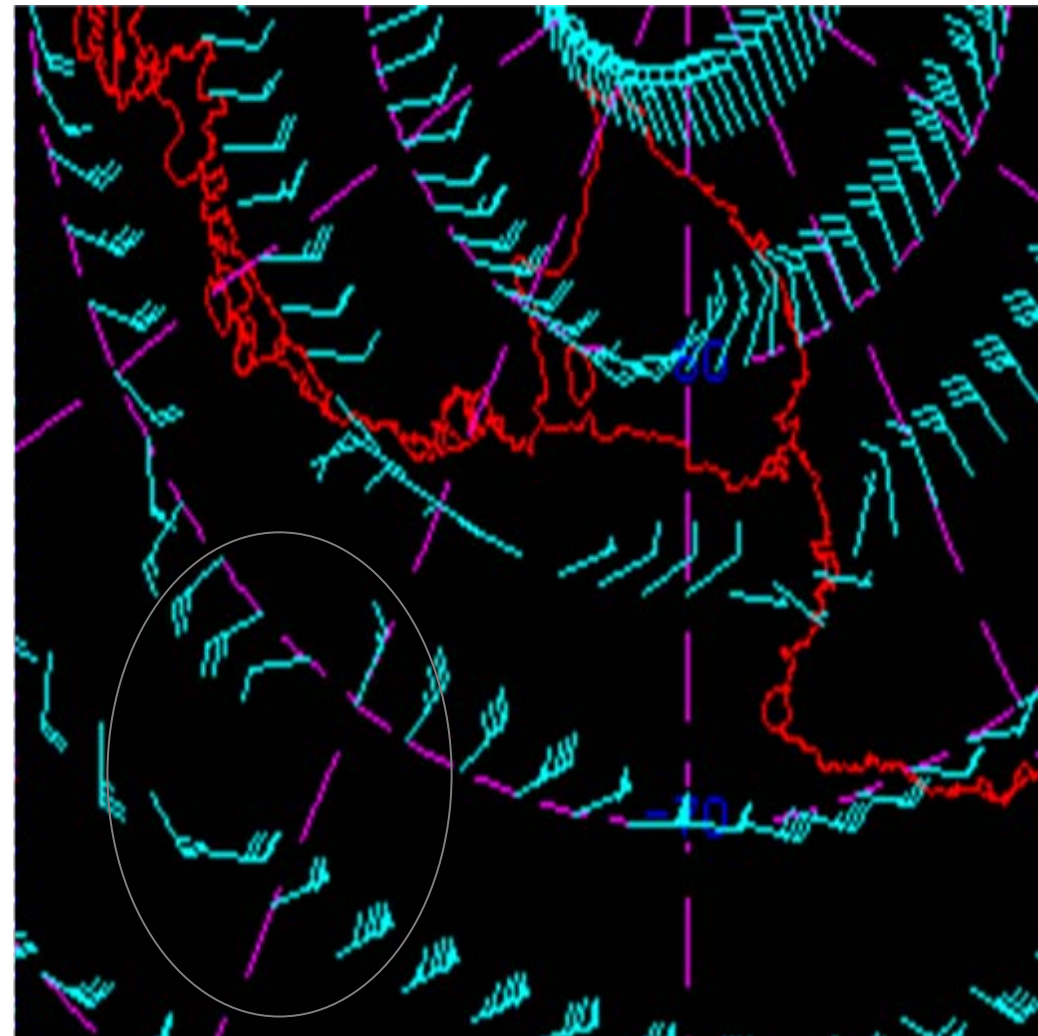
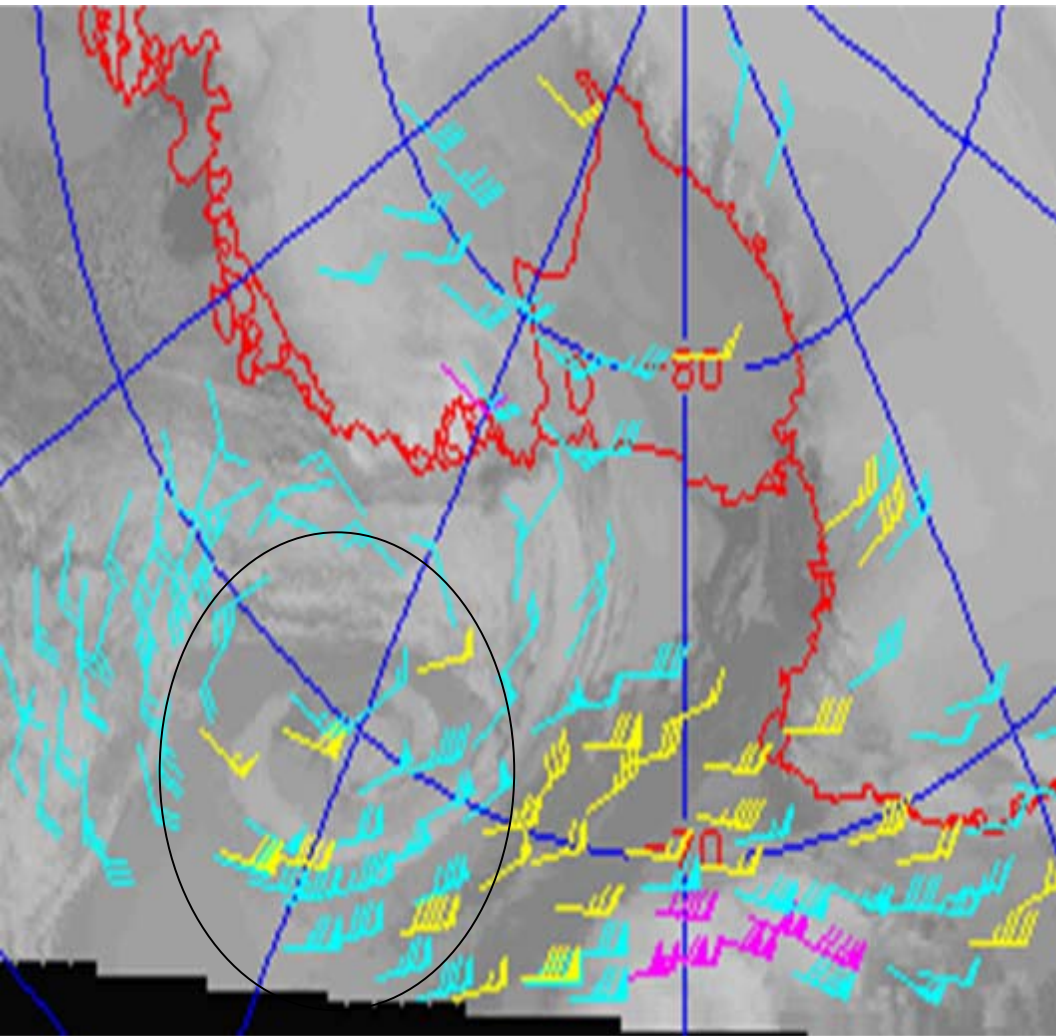


AVHRR



ERA-40

Largest differences seem to be in dynamically active areas.



More on that later...

# AVHRR vs ERA-40 Winds

## Arctic:

### Below 700 hPa

cases: 48,382

speed rms: 2.94 m/s

direction rms: 17.66°

mean speed diff: -0.32 m/s

mean direction diff: -0.47°

mean AVHRR: 12.35 m/s

mean ERA40: 12.67 m/s

### 700 – 400 hPa

cases: 224,952

speed rms: 2.93 m/s

direction rms: 14.16°

mean speed diff: 0.11 m/s

mean direction diff: 0.13°

mean AVHRR: 16.02 m/s

mean ERA40: 15.91 m/s

### Above 400 hPa

cases: 27,741

speed rms: 3.45 m/s

direction rms: 11.54°

mean speed diff: 0.34 m/s

mean direction diff: 0.51°

mean AVHRR: 25.36 m/s

mean ERA40: 25.02 m/s

- Overall, the AVHRR and ERA-40 wind fields are similar, with the direction root-mean-square error/difference (RMSE) less than 20 degrees and the speed RMSE less than 4 m/s.
- However, there are many instances of large differences in speed and direction. Generally, speed and direction differences between AVHRR and ERA-40 winds are larger in areas where there are no raobs.

# Validation with Raobs: LeadEx and CEAREX

- LeadEx took place over the Beaufort Sea 1992. CEAREX took place over the Barents and Greenland Seas 1988-89.
- The rawinsonde data were not assimilated in the reanalysis.
- RMSEs are similar for ERA-40 and AVHRR winds, but the speed bias is lower for AVHRR winds.
- The results generally confirm those of Francis (2002).



## ERA-40

**Speed RMSE: 6.86 m/s**

**Direction RMSE: 51.95°**

**Speed Bias: 1.36 m/s**

**Direction Bias: 2.34°**



## AVHRR

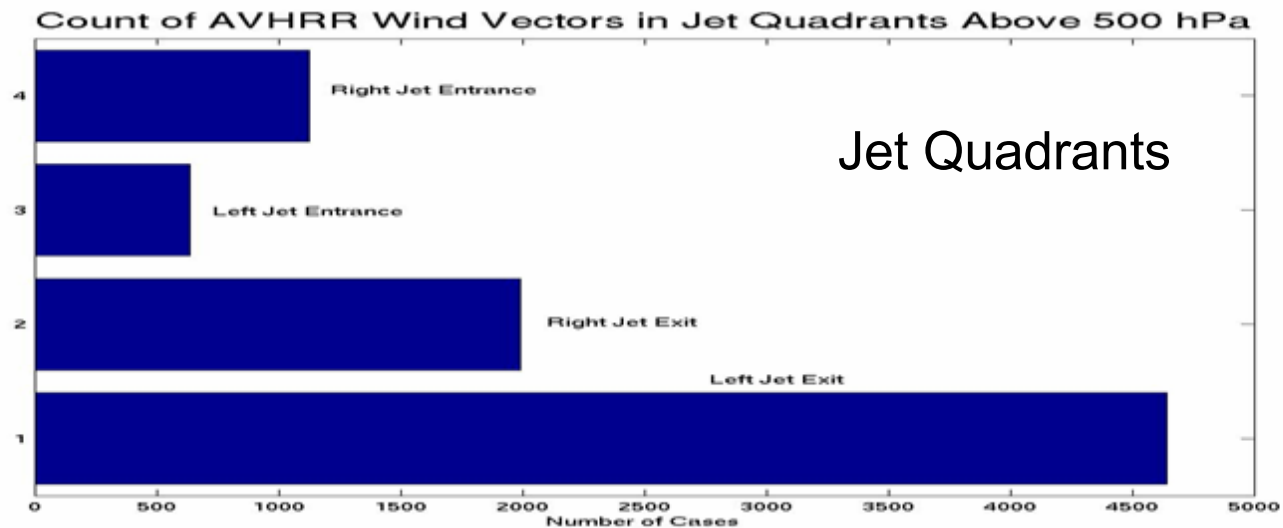
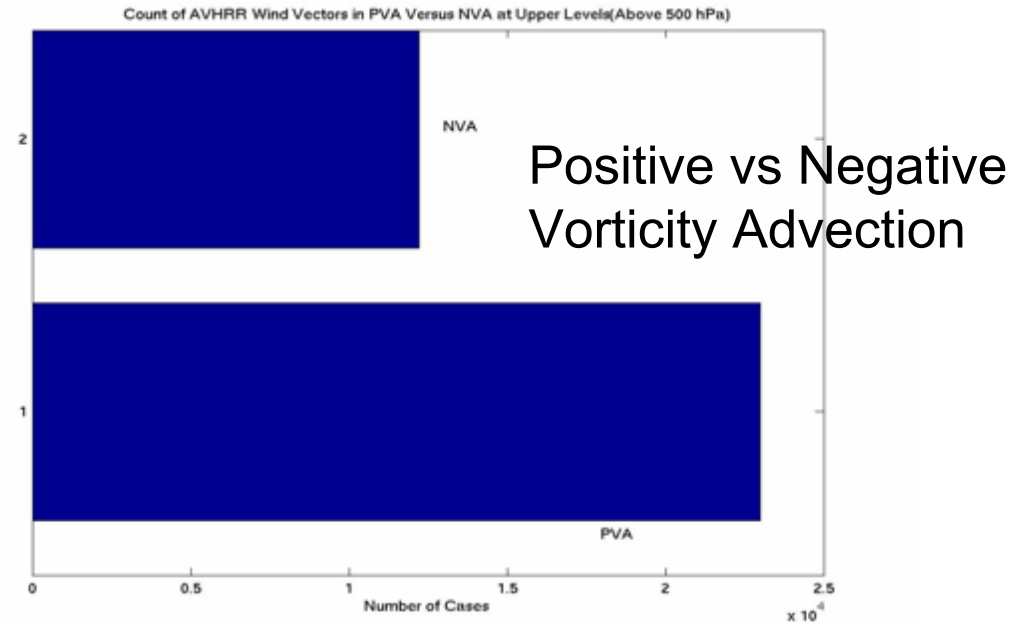
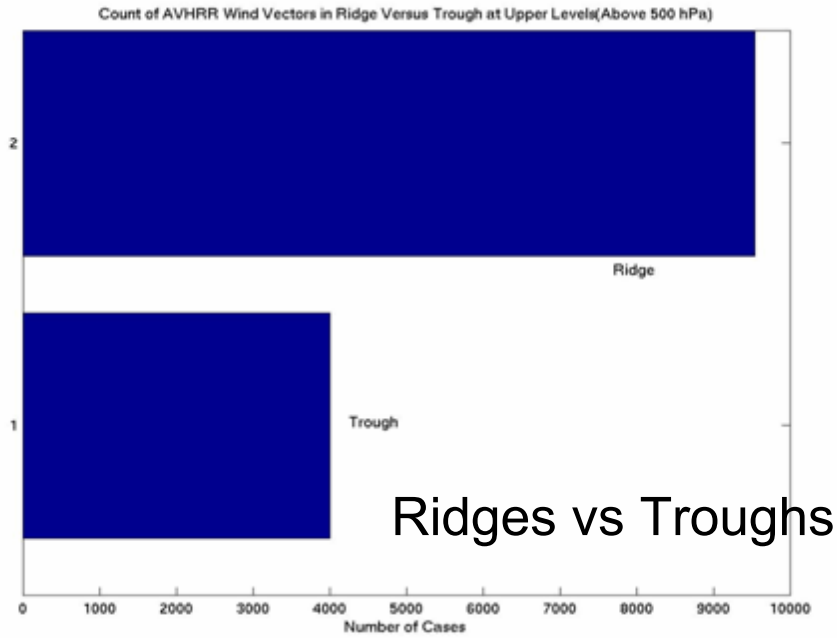
**Speed RMSE: 6.60 m/s**

**Direction RMSE: 53.25°**

**Speed Bias : 0.22 m/s**

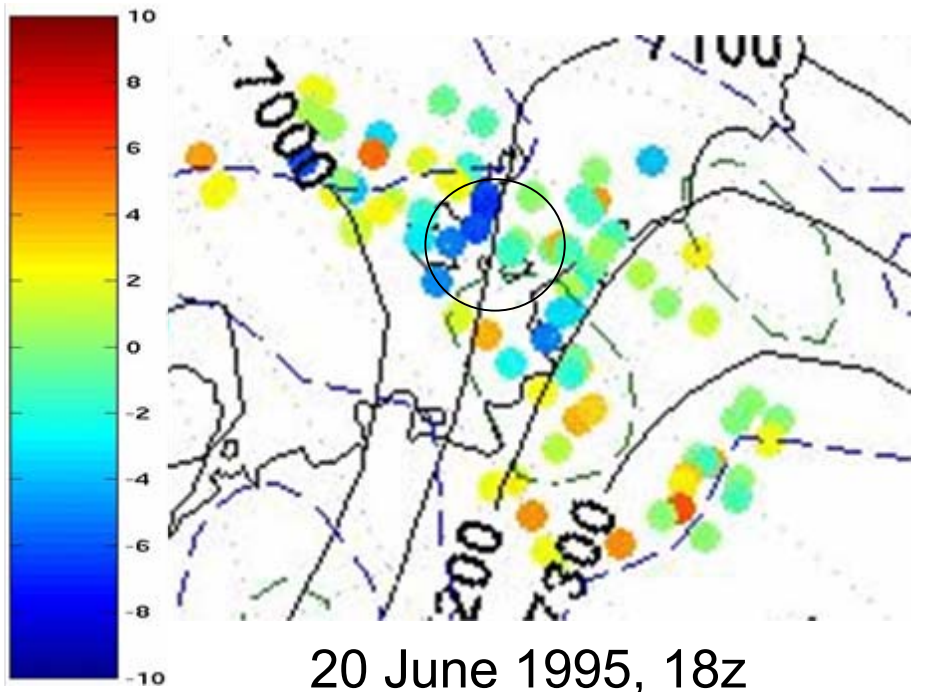
**Direction Bias: -2.46°**

# Synoptic Analysis: Where are the AVHRR winds?

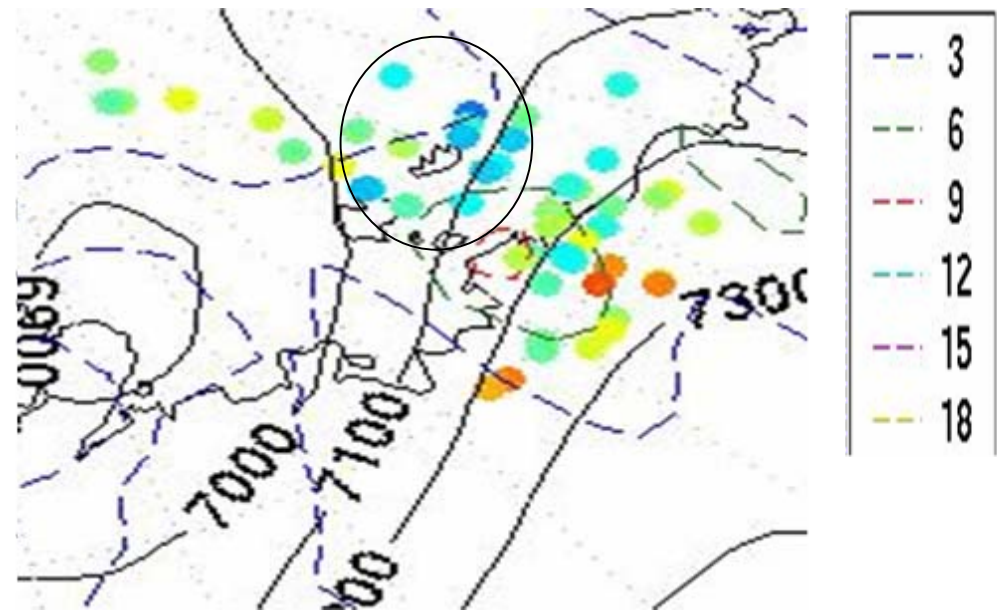


# Synoptic Analysis: Where are the Differences?

Correlations between AVHRR/ERA-40 wind differences and kinematic variables ( $V_a$ , divergence, vorticity, etc.) did not show any significant relationships. But...



20 June 1995, 18z



21 June 1995, 0z

Plots of geopotential height (solid) at 400 hPa, inertial advective component of the ageostrophic wind (dashed), and wind speed difference (dots).

Significant speed differences are seen in the left jet exit region, downstream of the trough. AVHRR wind vectors are slower and more clockwise (not shown) than ERA-40. This could be indication that ERA-40 is underestimating the deceleration of the flow and the ageostrophic component in the left jet exit region.



## Summary



- The two major reanalysis products have significant errors in winds over the Arctic where there are no radiosonde data.
- AVHRR GAC data were used to create a 20+ year polar wind product for the period 1982-2002.
- AVHRR and ERA-40 winds are similar overall, but exhibit significant differences in areas without raobs. Comparison with raobs not assimilated in ERA-40 indicate that the AVHRR winds have a lower bias. AVHRR-raob statistics are similar to those for MODIS.
- Synoptic analyses show that the greatest differences between AVHRR and ERA-40 winds occur near jet entrance and exit regions, as well as in high curvature flows around troughs and ridges.
- This data set is ideal for use in reanalyses.



