The Use and Impact of Satellite-derived Atmospheric Motion Vectors in Numerical Models

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Second Asia/Oceania Meteorological Satellite Users' Conference
Tokyo, Japan
9 December 2011

Outline

1. Mixed Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO) winds

2. Geostationary Winds from Rapid Scan satellite images

3. Tracking humidity features from AIRS retrievals

1. Mixed Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO) Winds

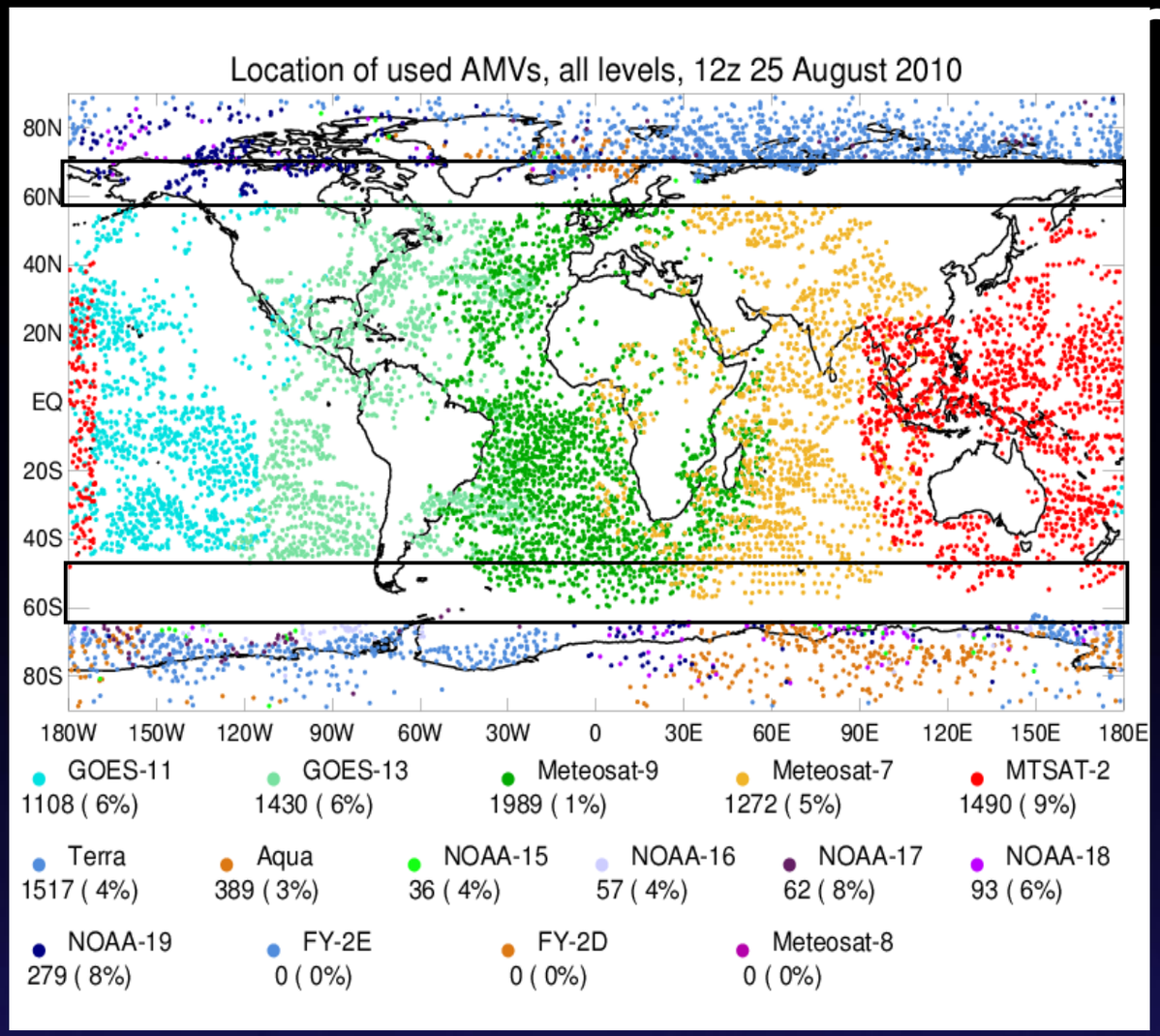
1) Address gap in global AMV coverage that is the band from 60˚ to 70˚ latitude

2) Create composites satellite images from geostationary and polar orbiting satellite images using the highest resolution pixels within a time window

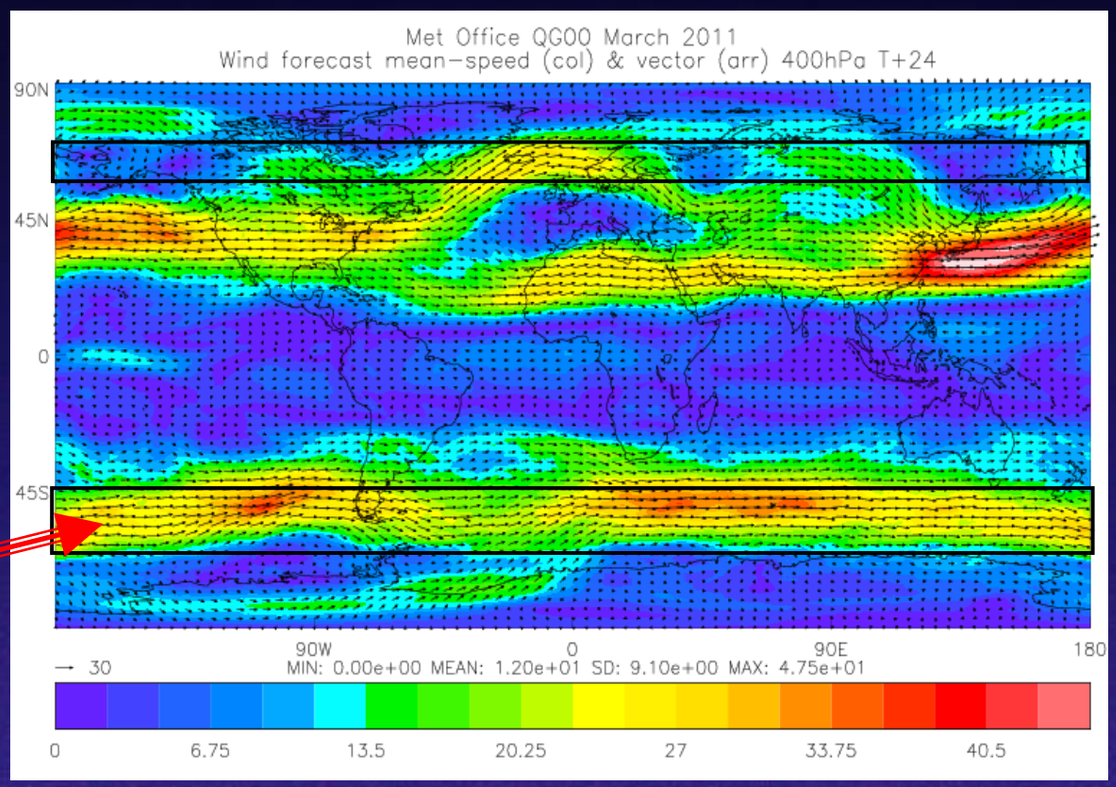
3) Maximize the use of higher resolution polar data with the time continuity of the geostationary data

NOAA GOES-R Risk Reduction Program: NA06NES4400002

Current AMV data ...rage

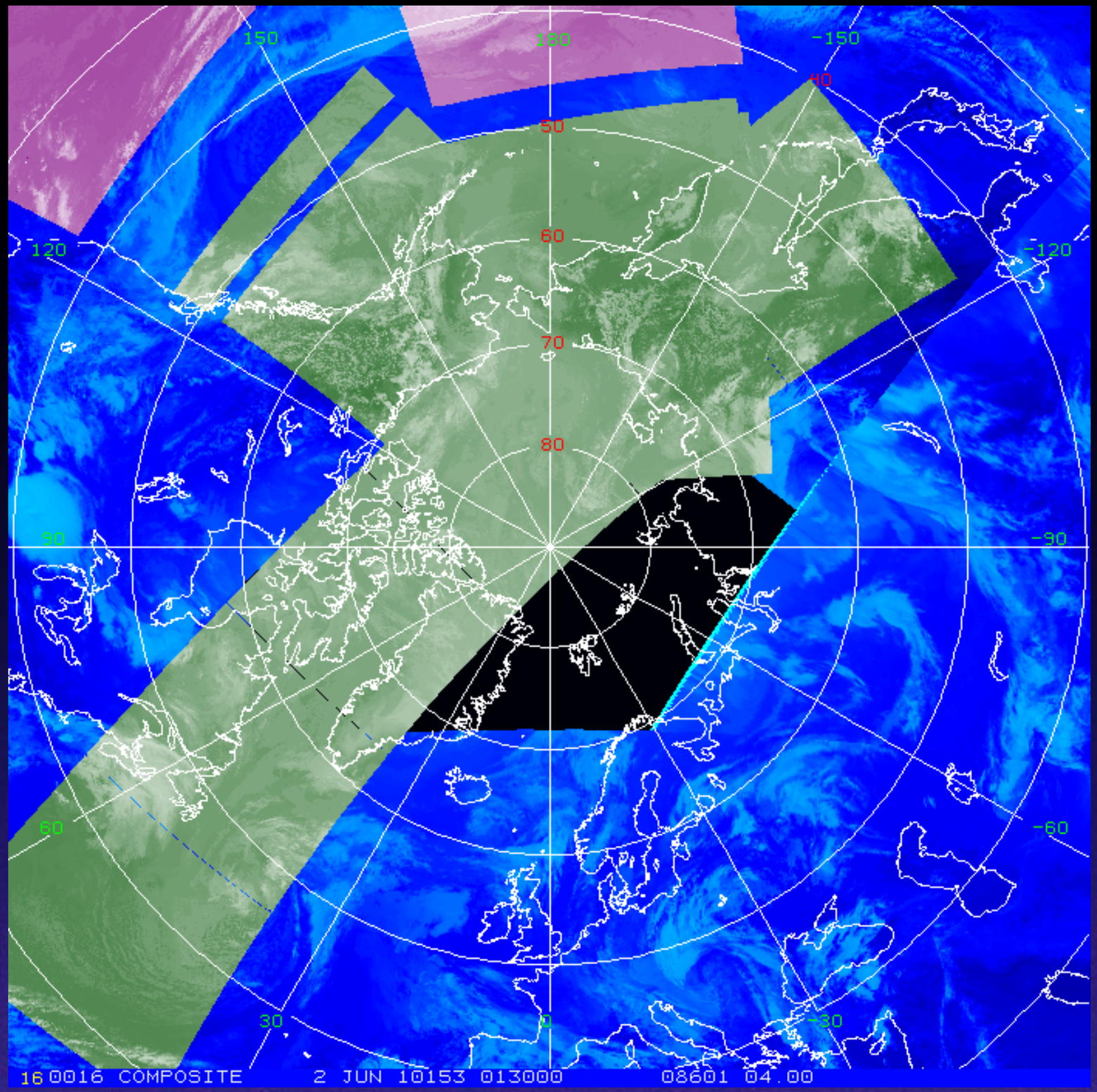


AMV data gap between polar orbiting and geostationary winds



Useful for constraining polar front jets

Mixed LEO/GEO Images



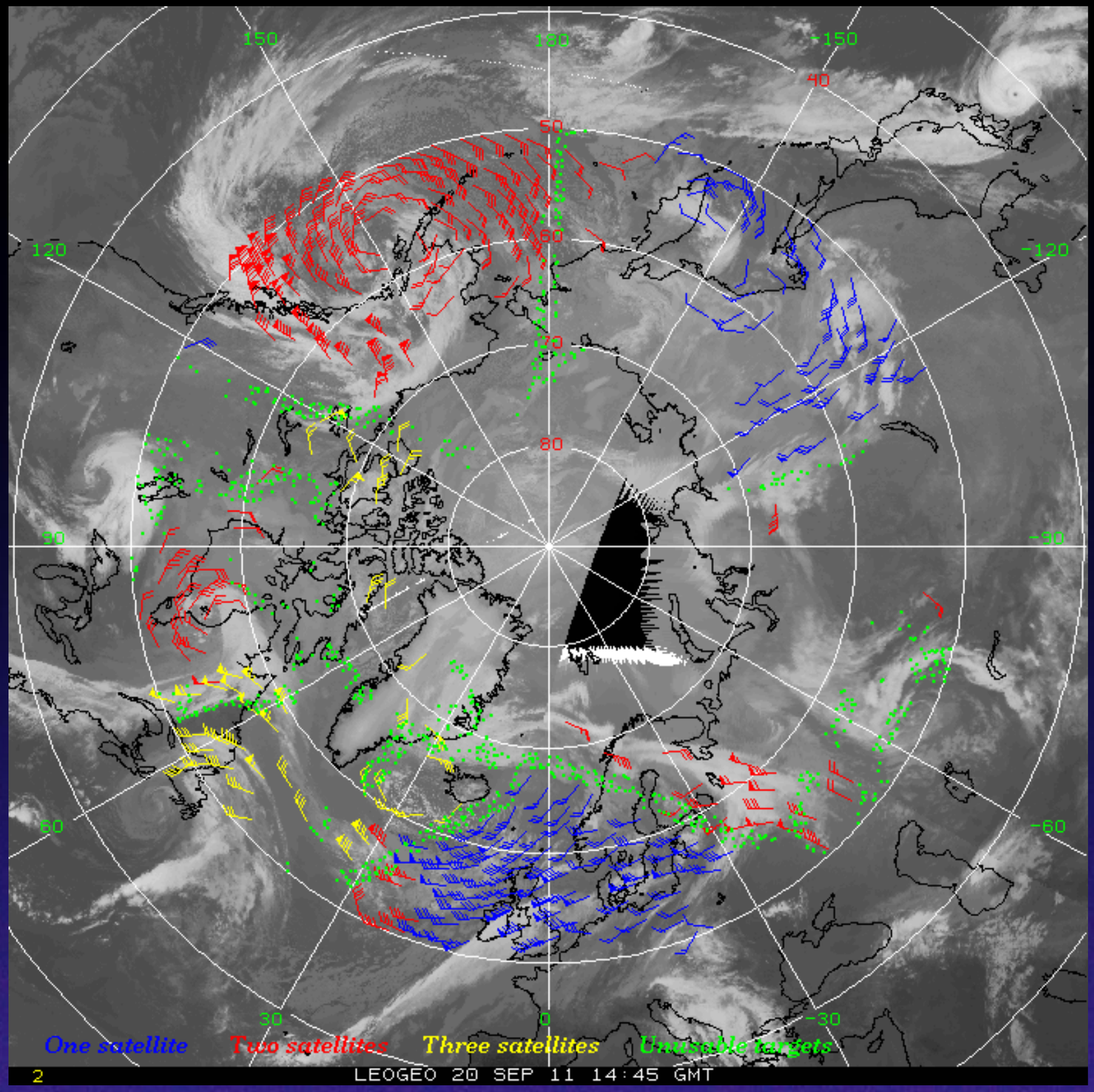
Mixed LEO/GEO Winds

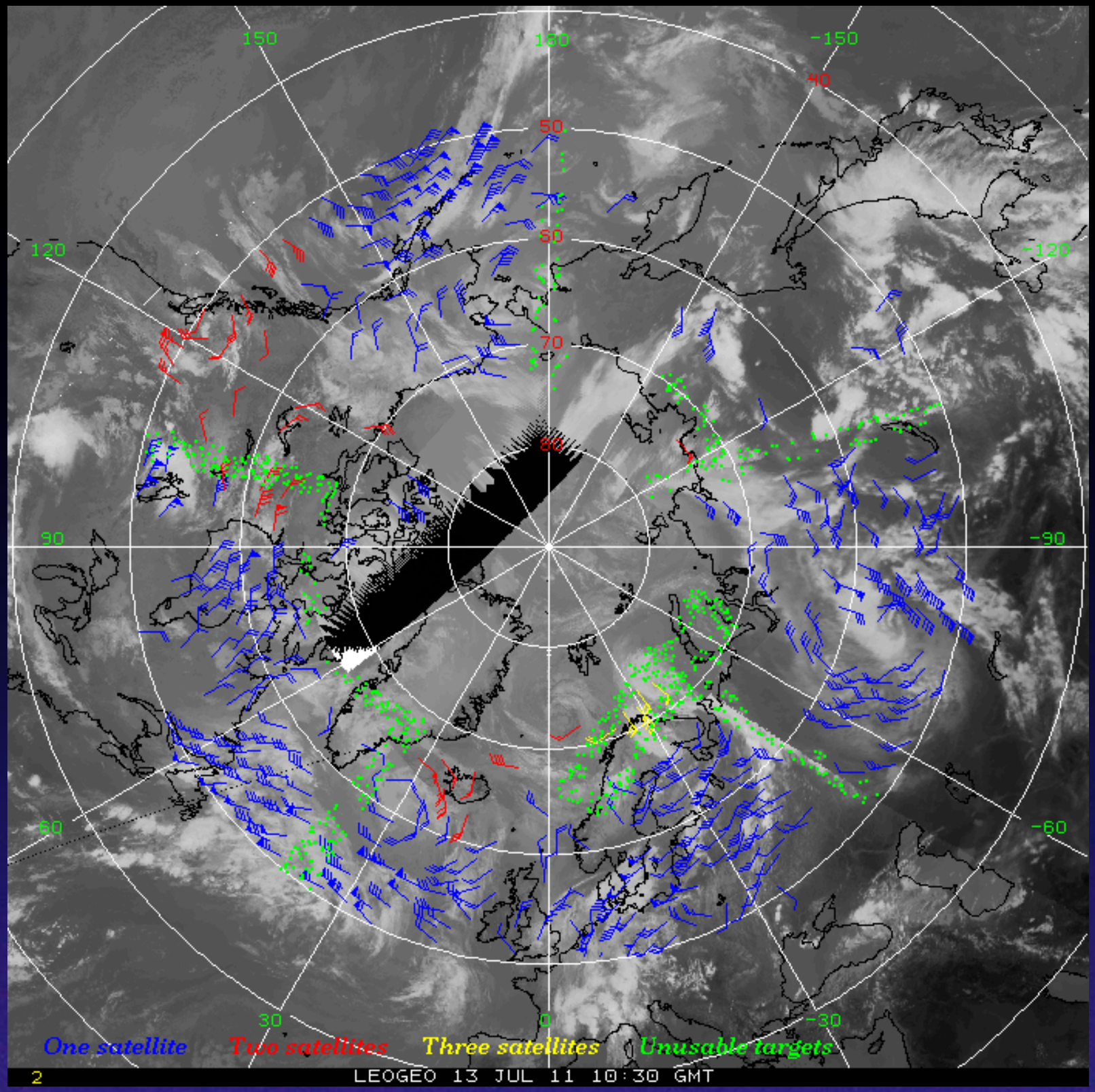
Vectors are generated from either single satellite or by mixing two or three satellites.

Tracking can use data from different satellites in the 3 images (accounts for the time and parallax information at each pixel)

Target/search box in each individual image must be from a single satellite

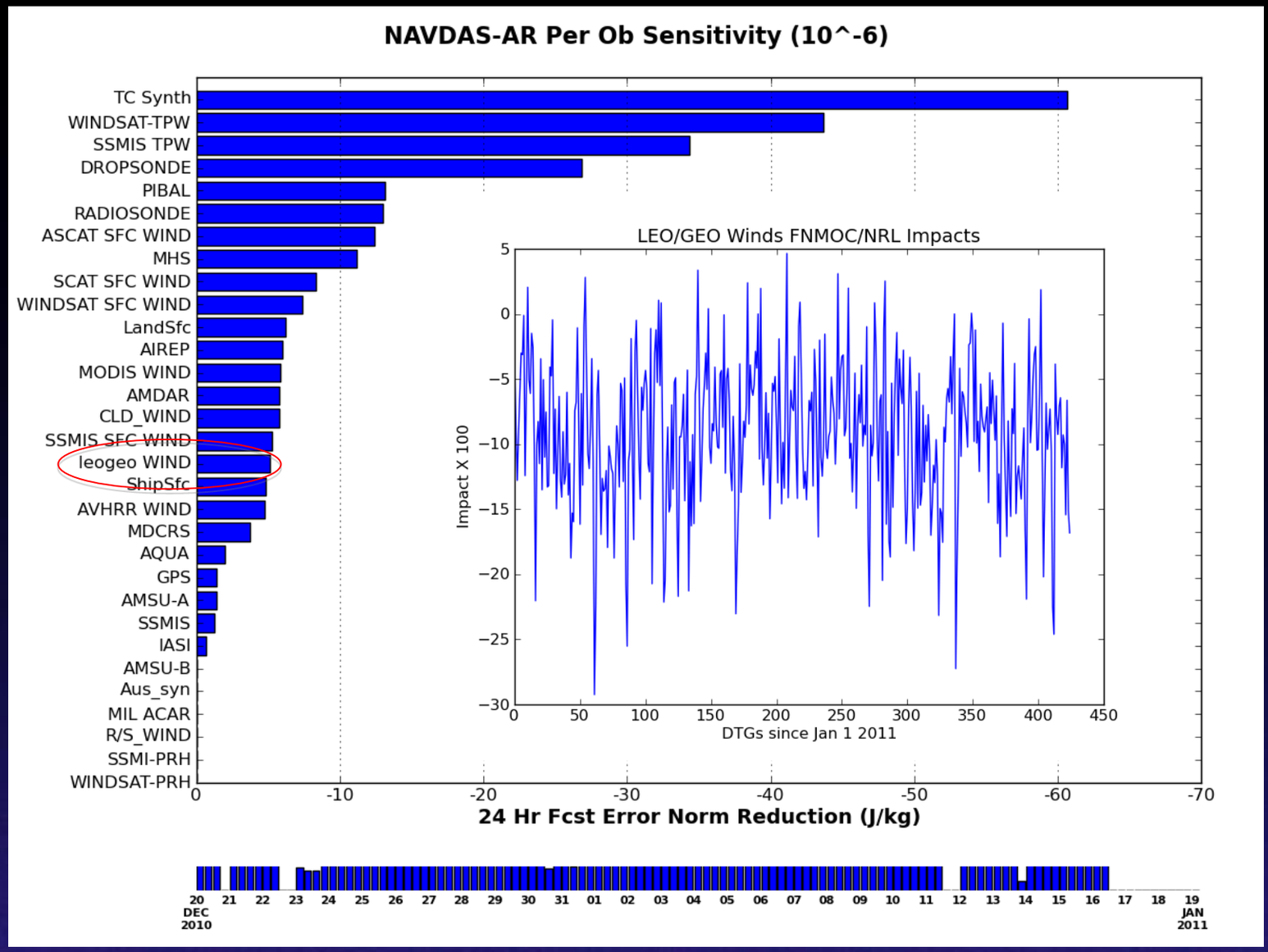
Potential targets that cannot be tracked



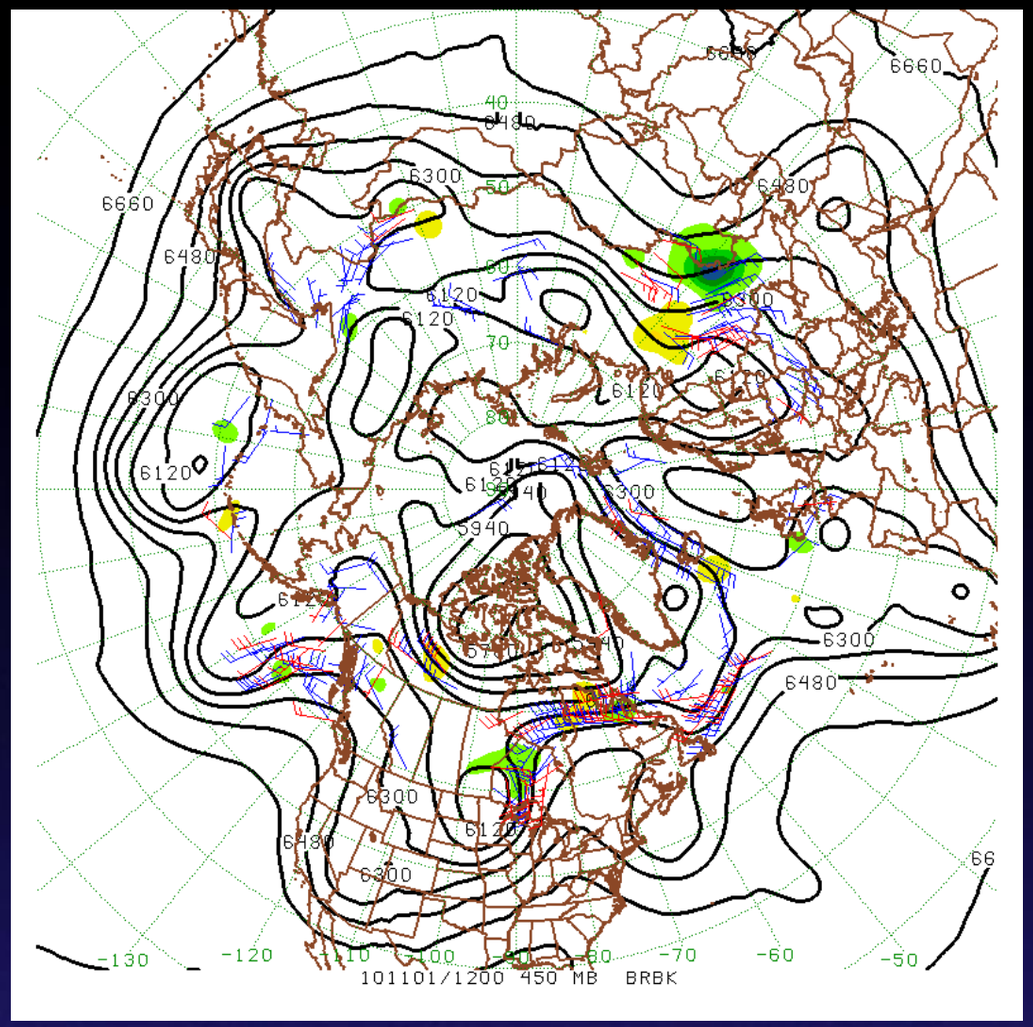

150
180
-150
40
50
60
120
-120
70
80
90
-90
60
-60
30
0
-30
One satellite
Two satellites
Three satellites
Unusable targets
2
LEOGEO 13 JUL 11 10:30 GMT

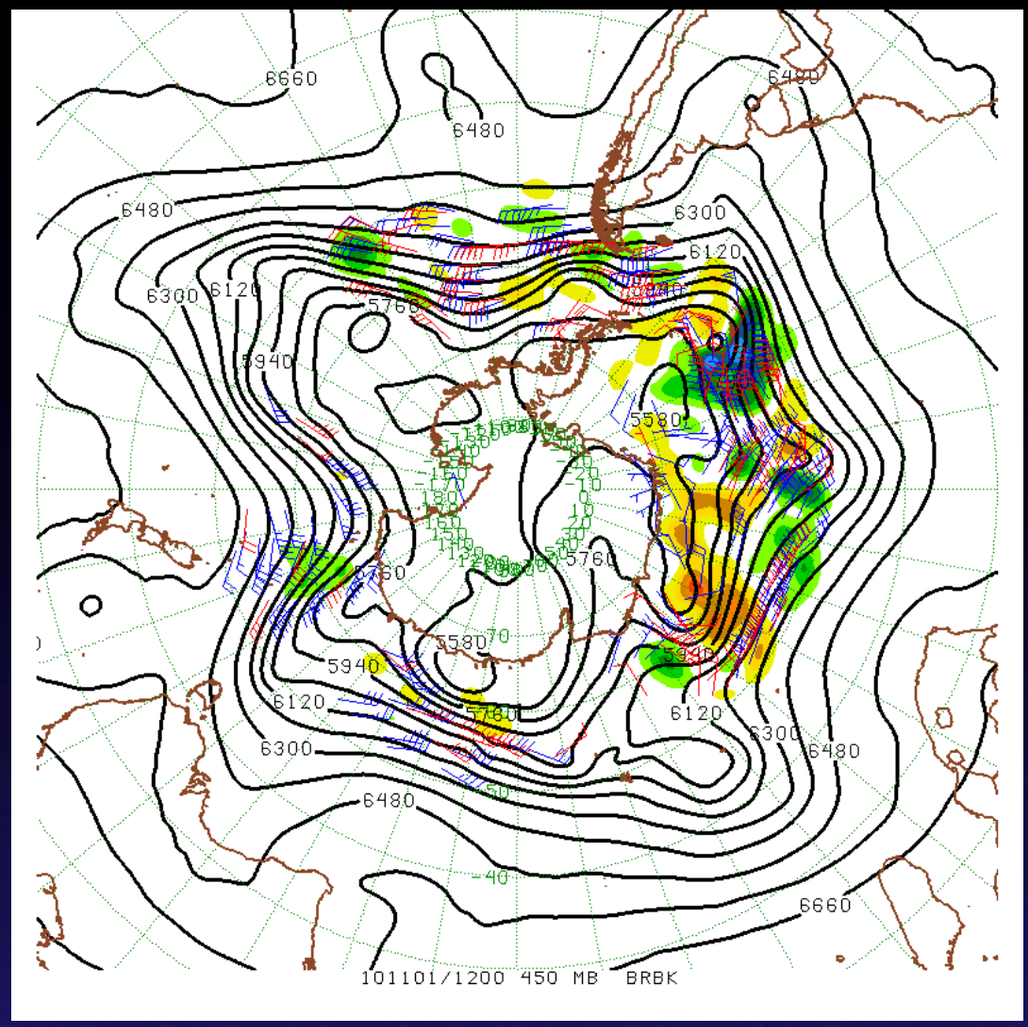
Impact of LEO/GEO AMVs
NOGAPS FNMOC/NRL

- 24-hr error reduction in the FNMOC model for various observation types.
- The reduction in error resulting from the incorporation of the LEO/GEO wind product is equivalent to that for the MODIS winds.
- This wind product is incorporated into FNMOC's operational system.



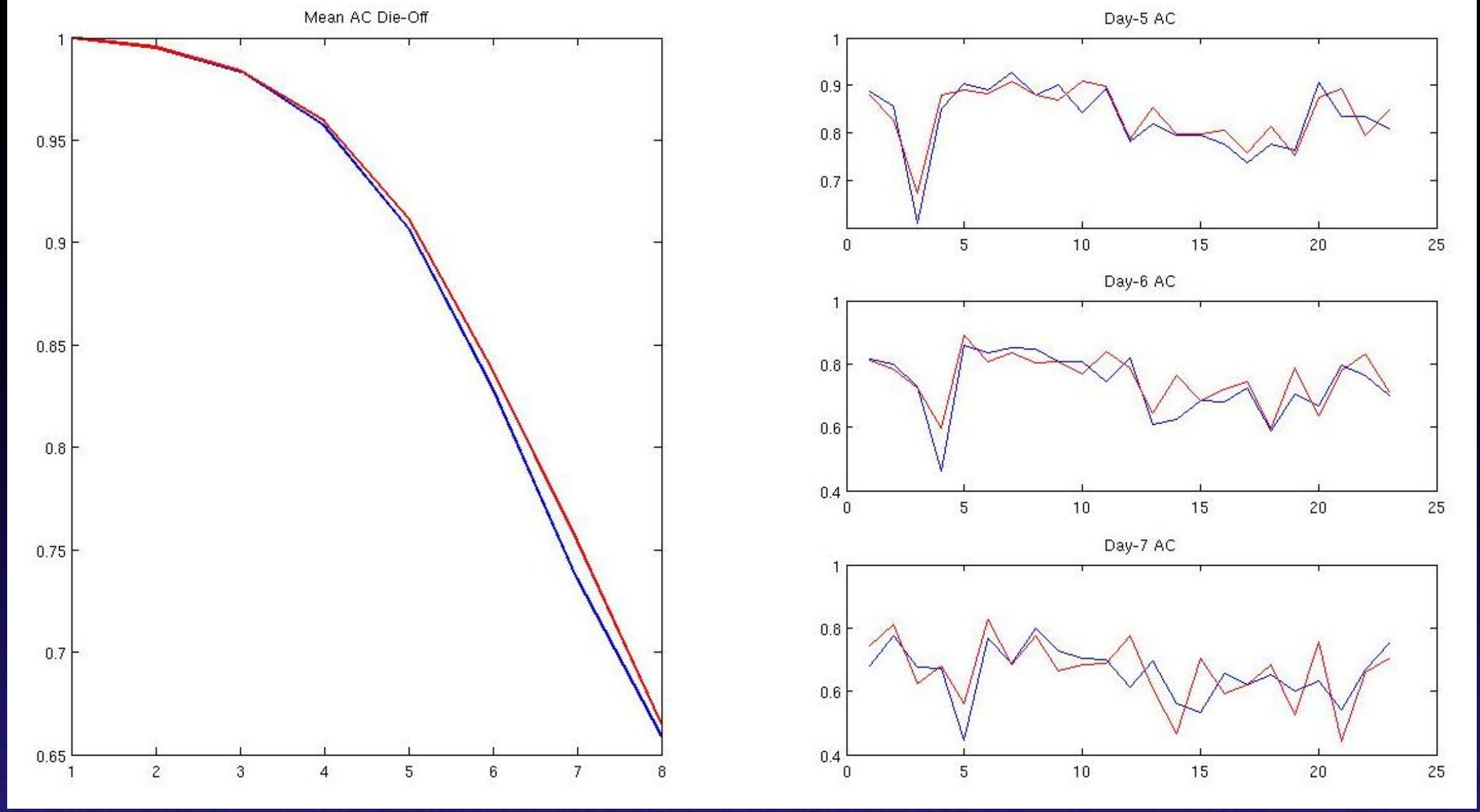
Assimilation Impact
NCEP GSI/GFS





450 hPa heights and Leo/Geo winds between 400-500 hPa (blue accepted; red rejected). Fill-pattern is the difference between the analyses with and without the Leo/Geo winds.

Forecast Impact
NCEP GSI/GFS



500 hPa Anomaly Correlation for the Southern Hemisphere
9 – 31 May 2011. Control in blue; with LEO/GEO winds in red.

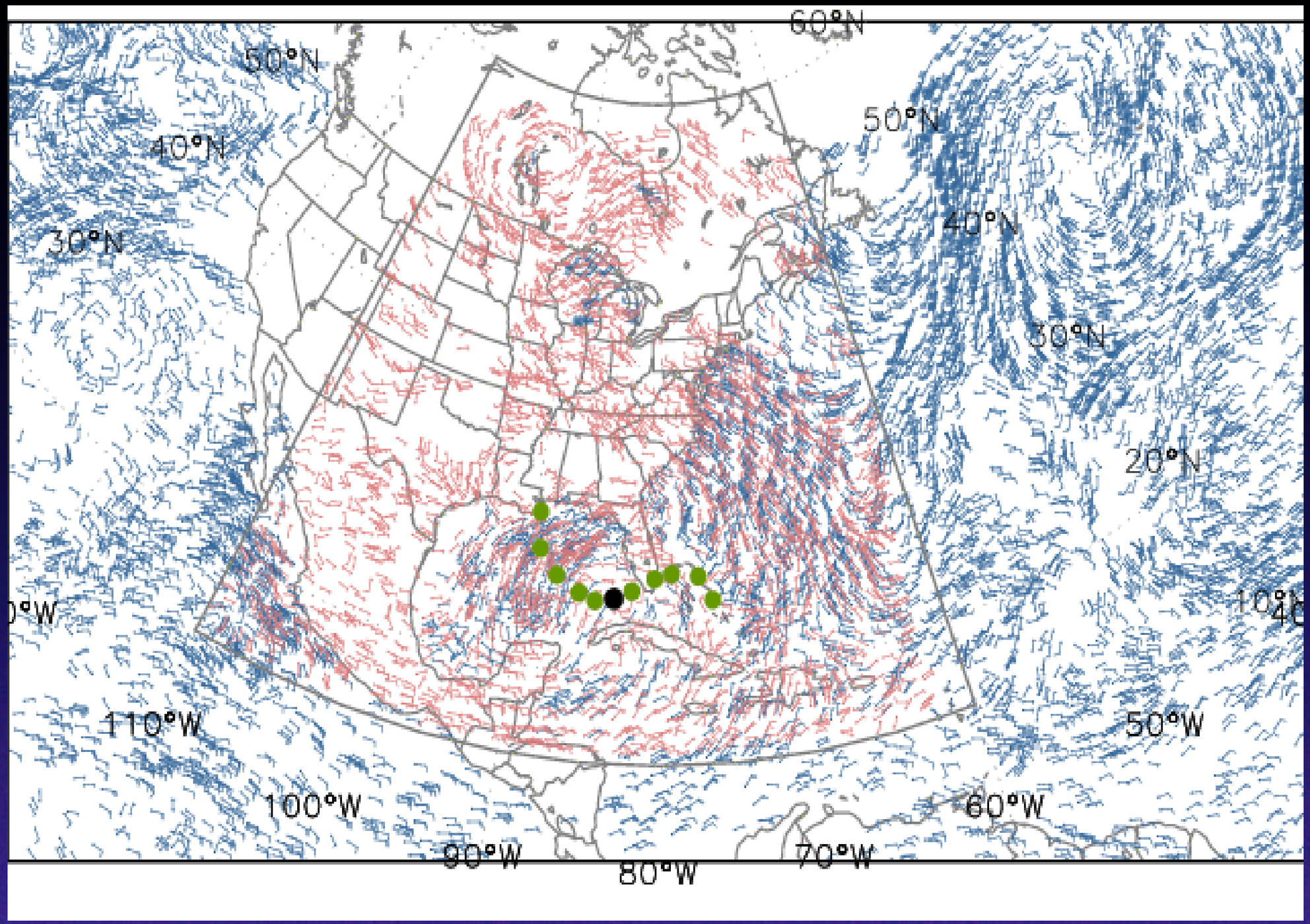
2. Geostationary Winds from Rapid Scan satellite images

1) Determine impact in tropical cyclone forecasts by using hourly winds and, when available, winds derived from rapid scan satellite images

2) NOGAPS forecast of Hurricane Katrina (August 2005)

3) NOGAPS forecast during the Thorpex - Pacific Asian Regional Campaign (T-PARC), including Typhoon Sinlaku (September 2008)

Katrina Case Study – Impact of GOES Rapid-Scan AMVs on NOGAPS Track Forecasts



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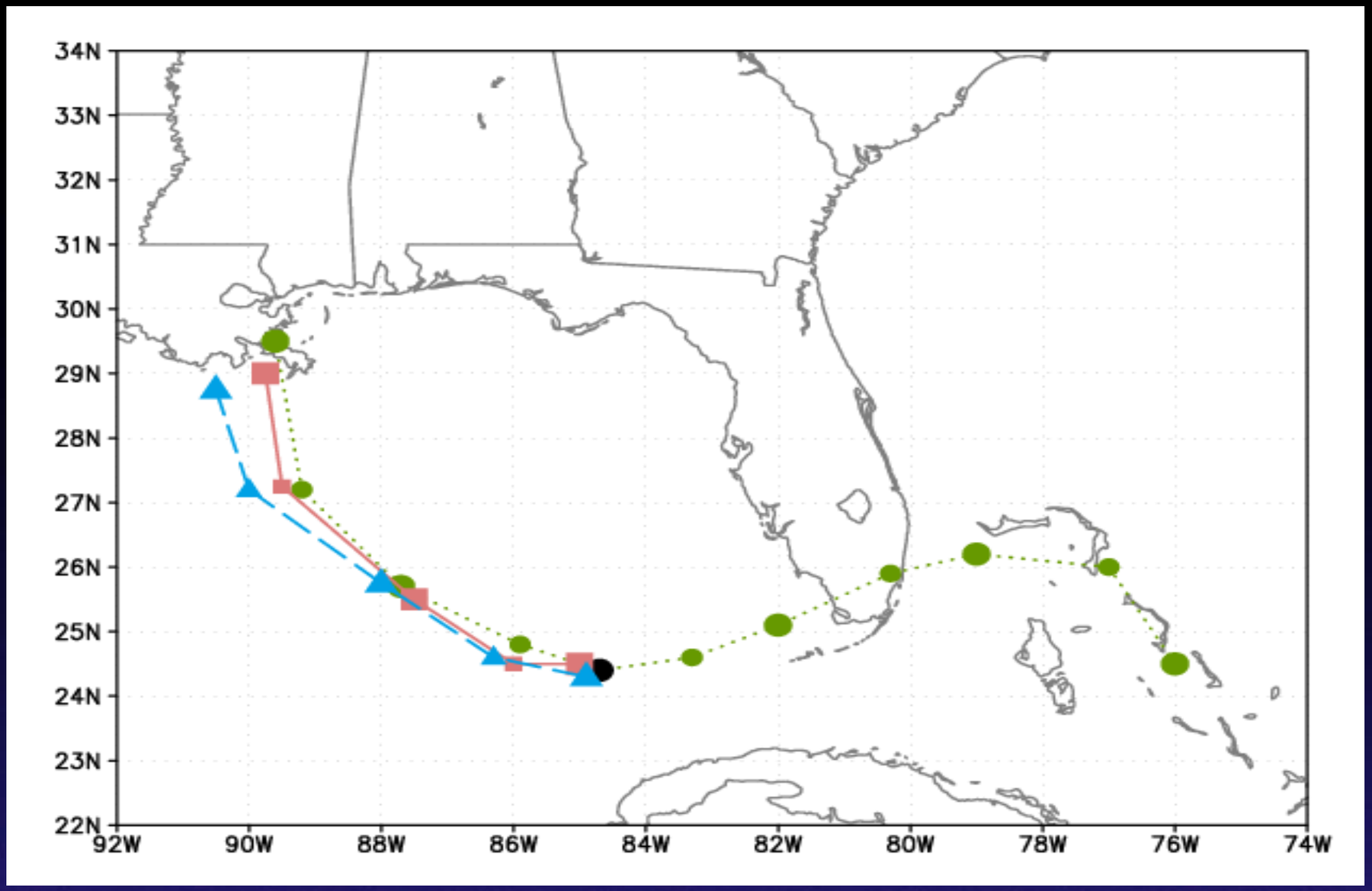
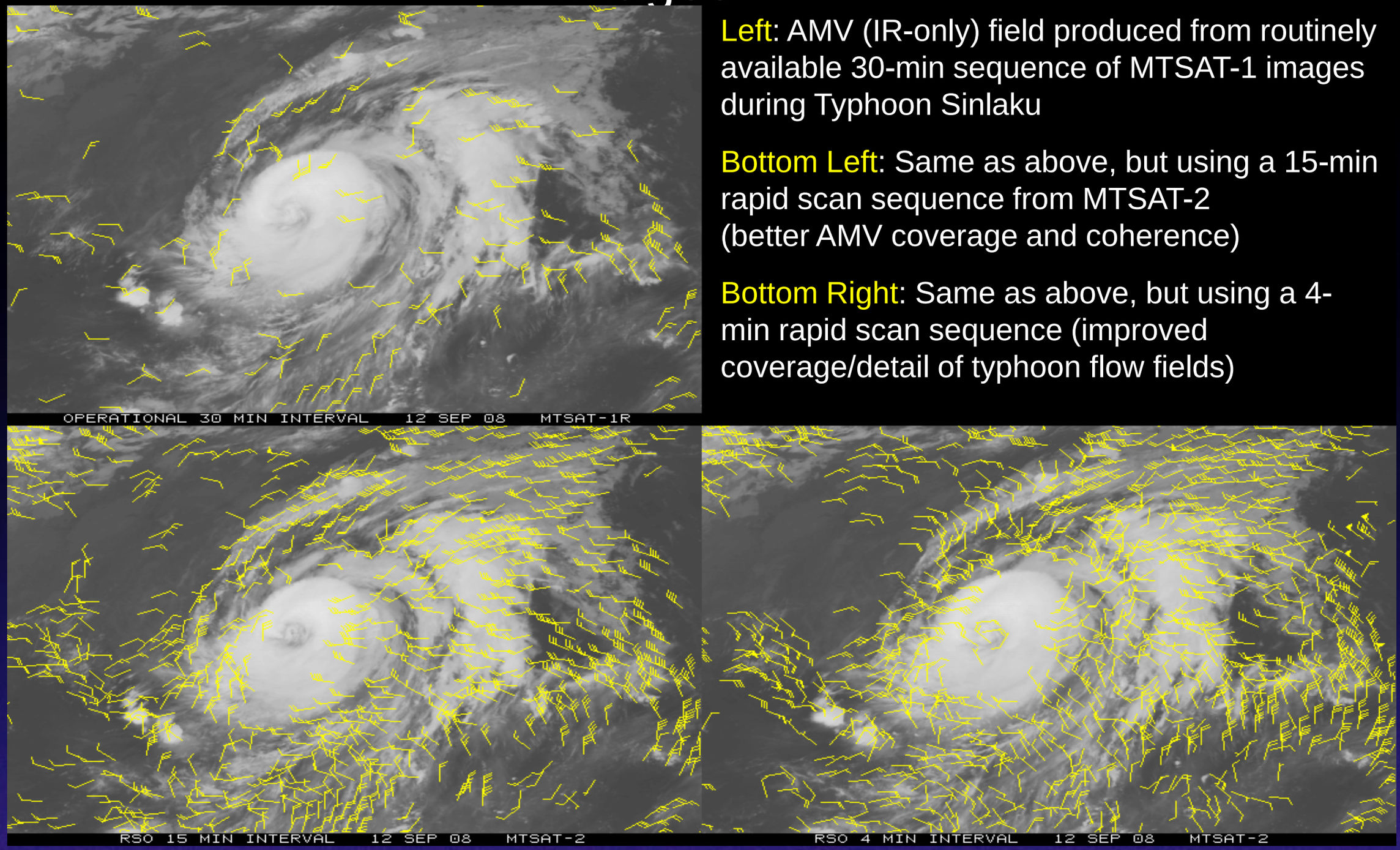


NOGAPS 48hr forecast of Hurricane Katrina positions verifying at 12 UTC 29 August 2005.
Rapid Scan AMV forecast (red) and Control forecast (blue). Observed track (green). All positions indicated at 12-hr intervals.

Langland, R., C. Velden, P. Pauley, H. Berger, 2009: Impact of Satellite-Derived Rapid-Scan Wind Observations on Numerical Model Forecasts of Hurricane Katrina. Mon. Wea. Rev., 137, 1615–1622.

Example of AMVs from MTSAT-2 Rapid Scan images



Left: AMV (IR-only) field produced from routinely available 30-min sequence of MTSAT-1 images during Typhoon Sinlaku

Bottom Left: Same as above, but using a 15-min rapid scan sequence from MTSAT-2 (better AMV coverage and coherence)

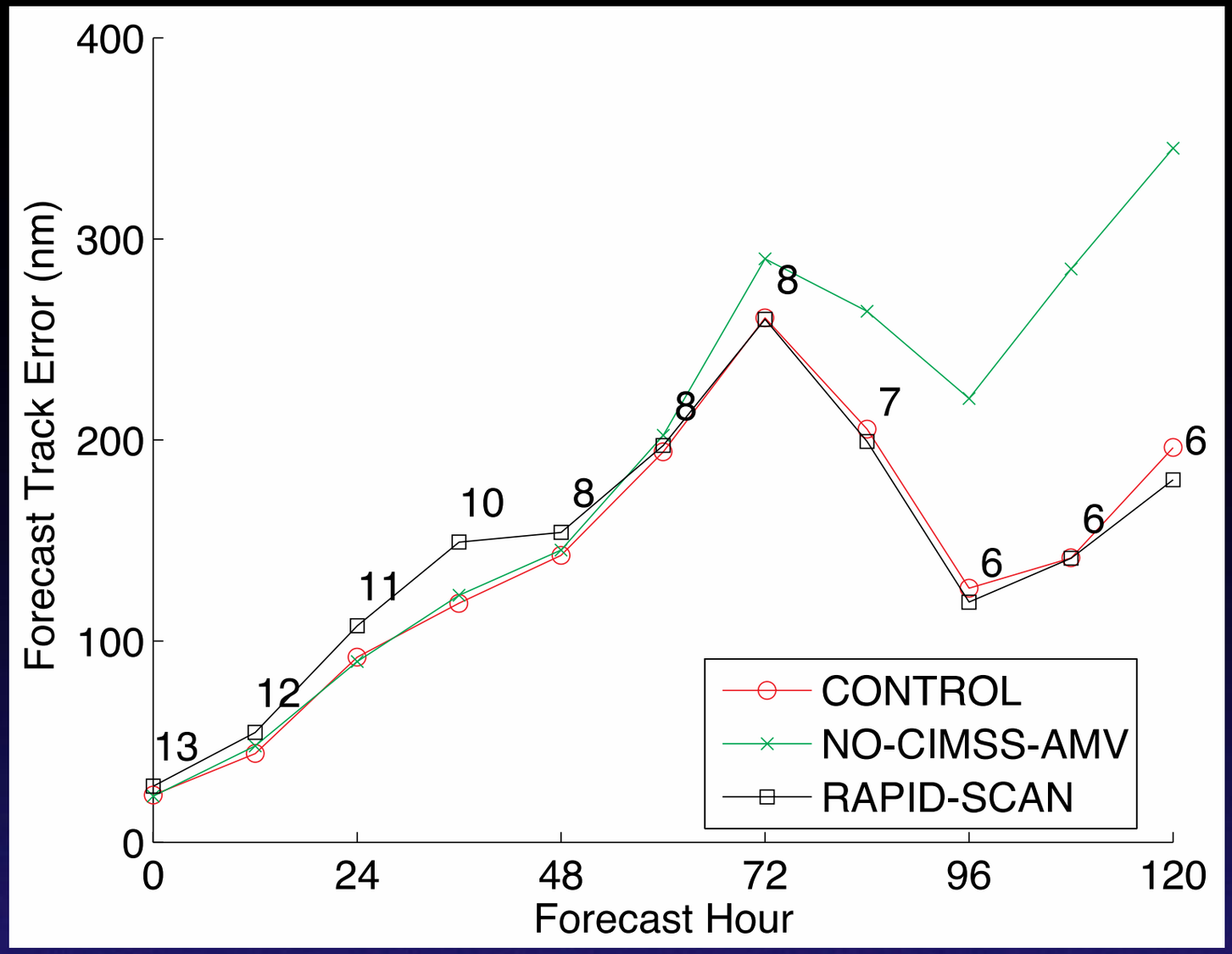
Bottom Right: Same as above, but using a 4-min rapid scan sequence (improved coverage/detail of typhoon flow fields)

Typhoon Sinlaku: 12 Sep 2008

NOGAPS Track Forecasts Error (nm) during T-PARC (August – October 2008)

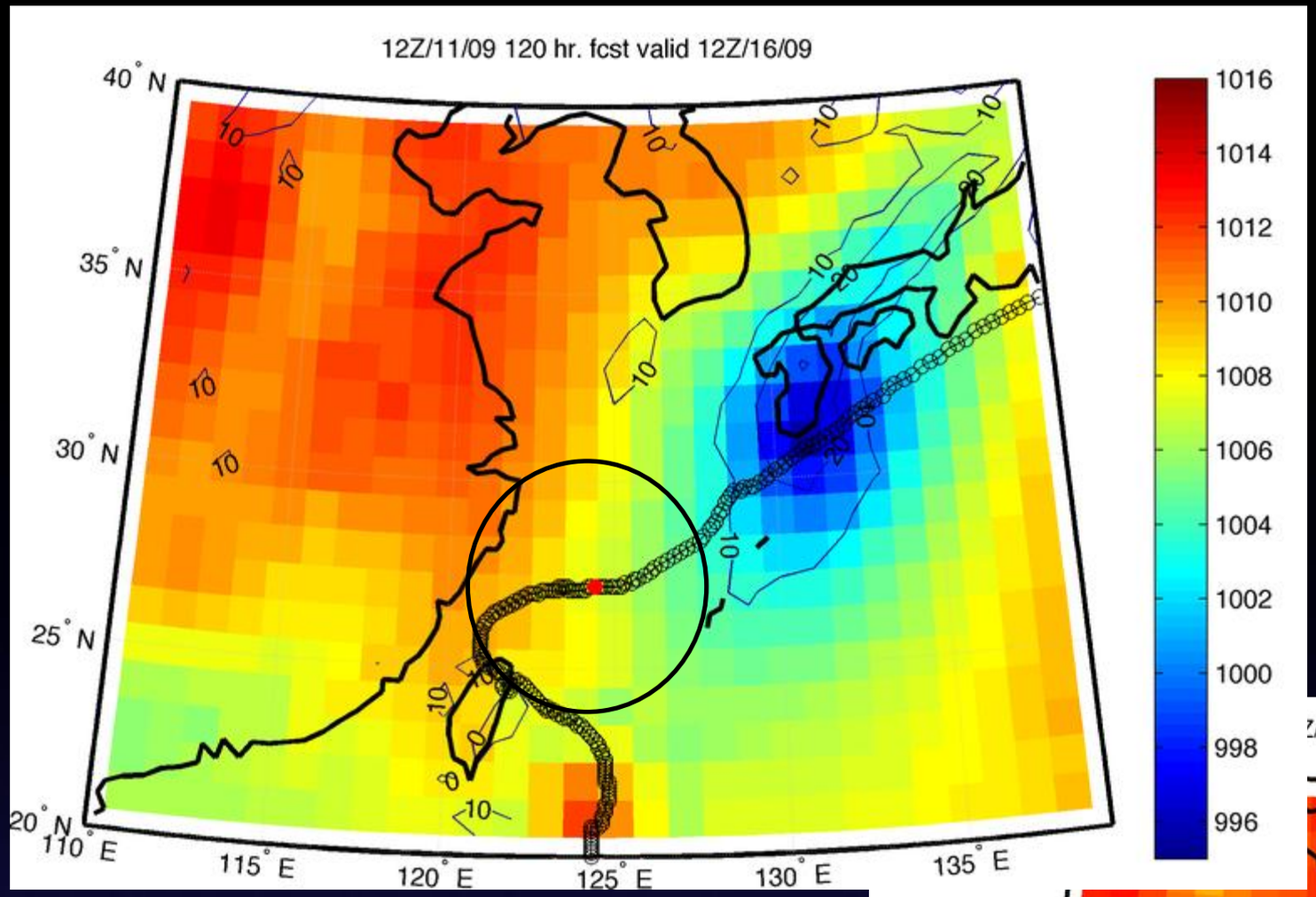
- Continuously assimilate all hourly MTSAT AMV datasets using NRL 4DVAR during the 2-month T-PARC period

- Assess impact on NRL/FNMOC NOGAPS TC forecasts:
  - Control: Includes hourly AMV datasets from MTSAT-1
  - No-CIMSS AMV: Control with hourly AMVs removed
  - Rapid-Scan: Control with Rapid-Scan AMVs included

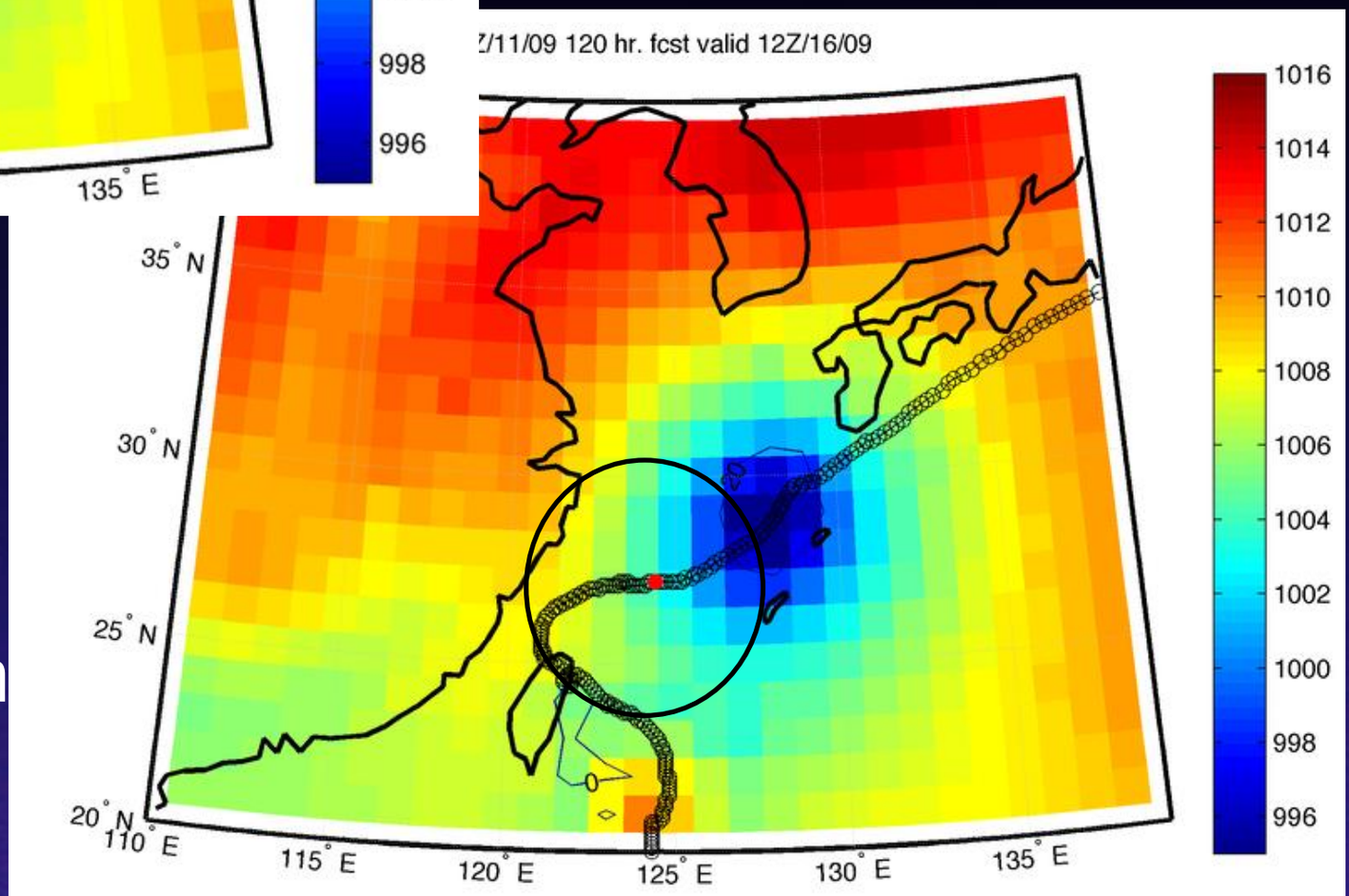


Typhoon Sinlaku
120-hr forecast on
11 Sept. 2008
1200 UTC

MSLP (hPa)



Control



Rapid-Scan

Influence of mid-latitude troughs?

3. Tracking humidity features from AIRS retrievals

1) Determine to what extent AIRS-derived AMVs can provide useful wind information. Advantages:
   a) Provide a 3-dimensional winds dataset
   b) Removes issues with AMV height determination
   c) Clear sky (and above cloud) wind information

2) Blend these AIRS moisture retrieval AMVs with the already proven MODIS AMVs to create 3-D polar wind fields.

3) Perform NWP experiments with the blended product to determine the overall impact on numerical forecasts, and the relative contributions of each data type (MODIS vs. AIRS). No results at this time.

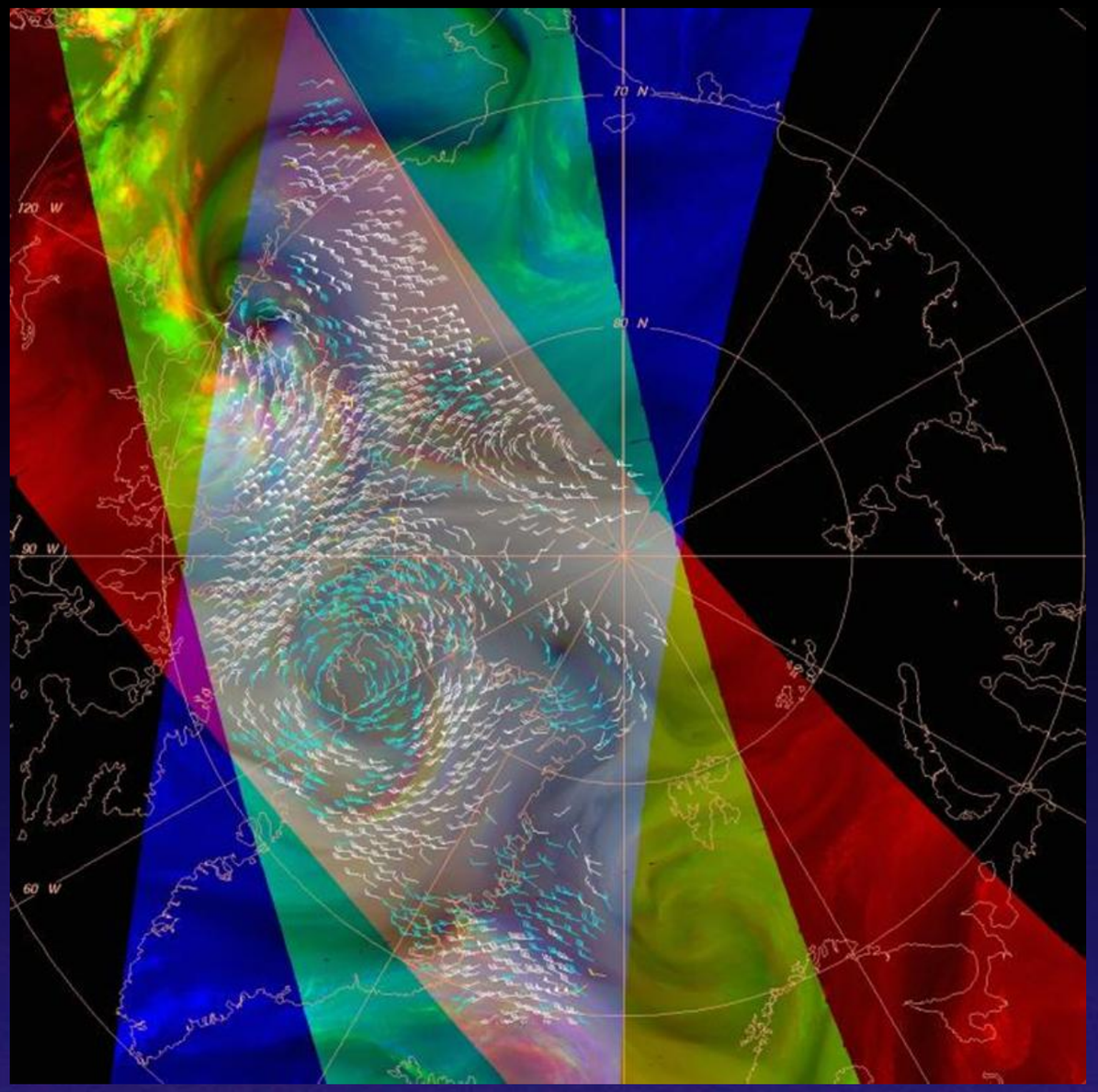
NASA ROSES: NNX11AE97G

Satellite-derived Polar Winds

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.

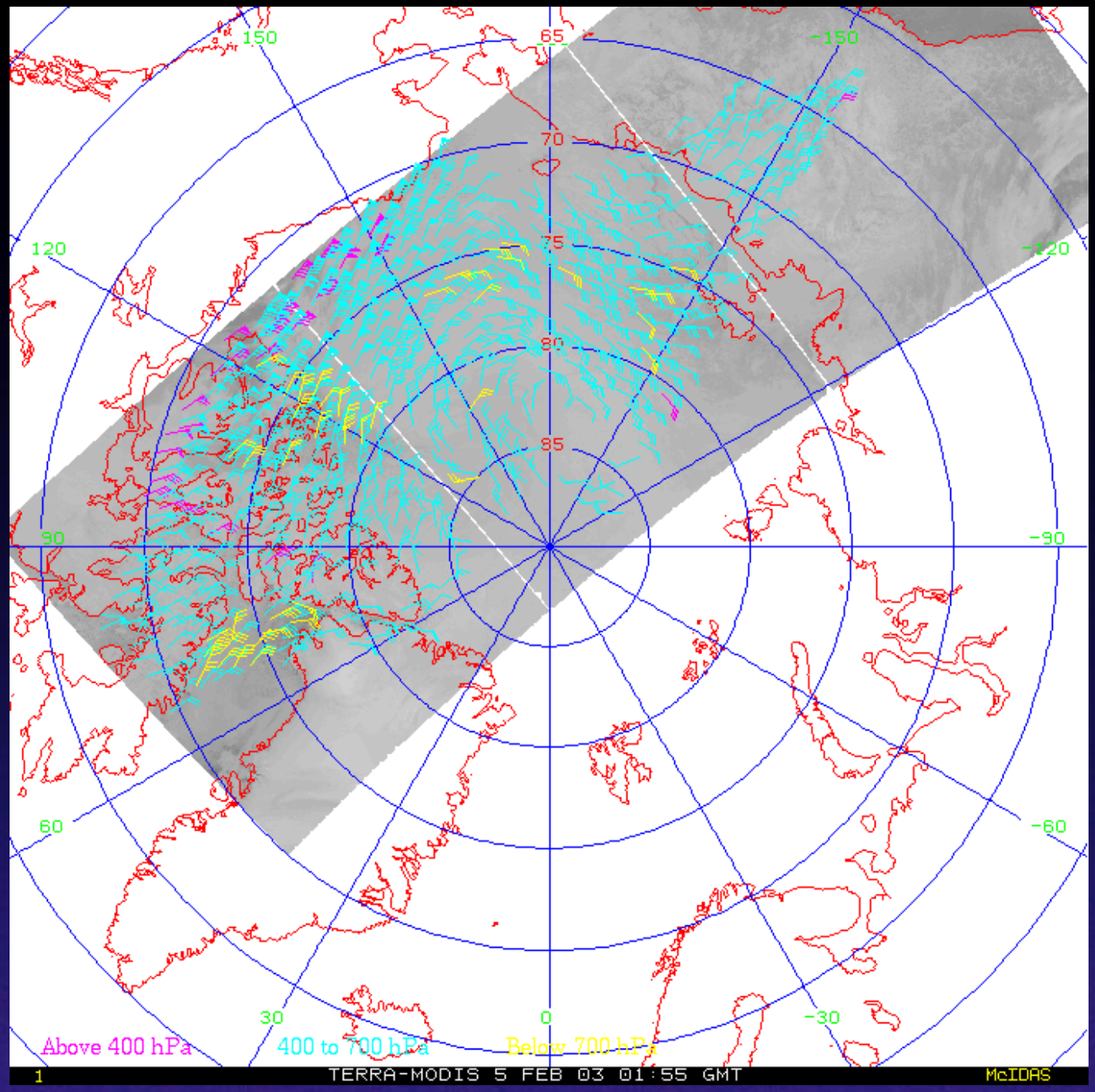
Winds must be derived for areas that are covered by three successive orbits

The gray area is the overlap between three orbits.



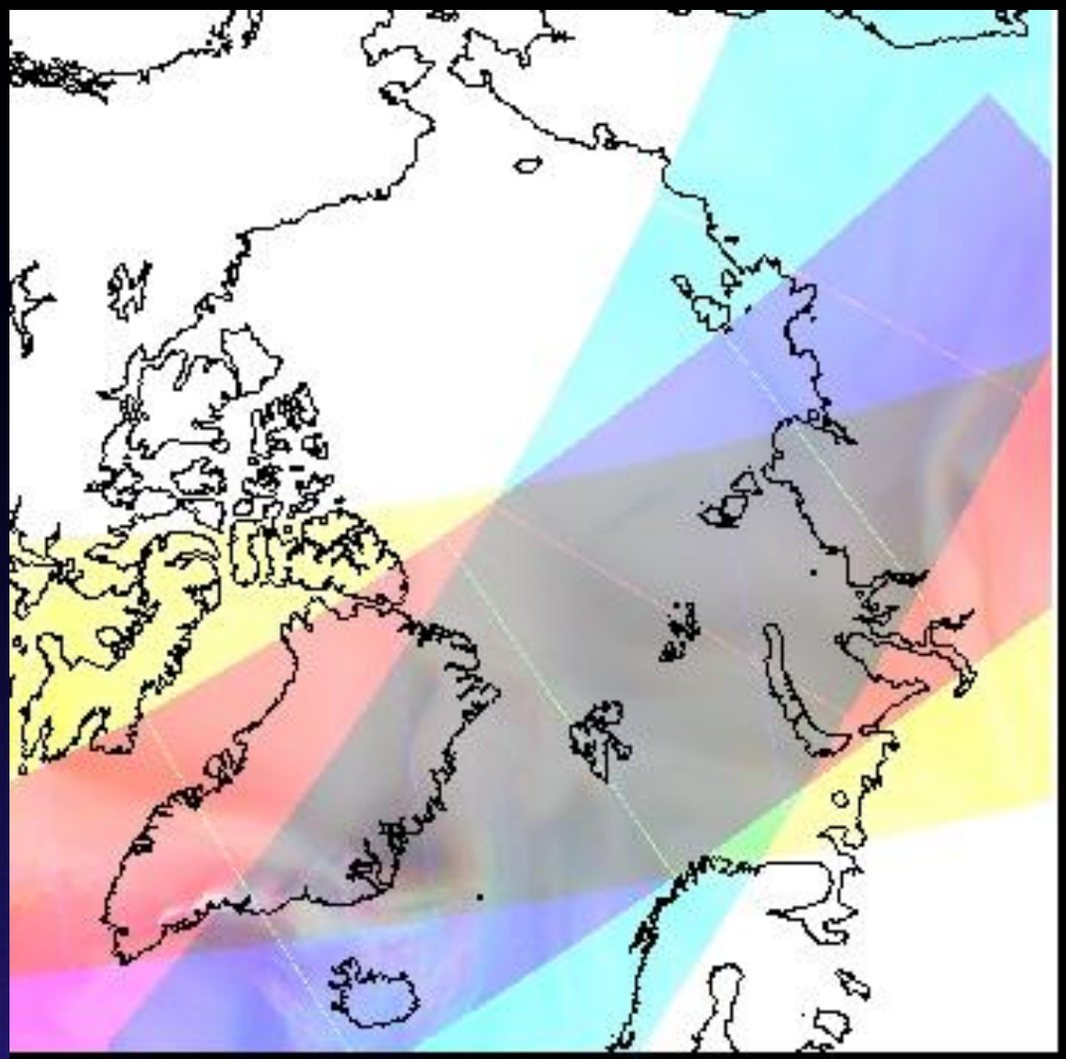
Three overlapping Aqua MODIS passes, with WV and IR winds superimposed. The white wind barbs are above 400 hPa, cyan are 400 to 700 hPa, and yellow are below 700 hPa.

One Day of Arctic Orbits
Terra MODIS

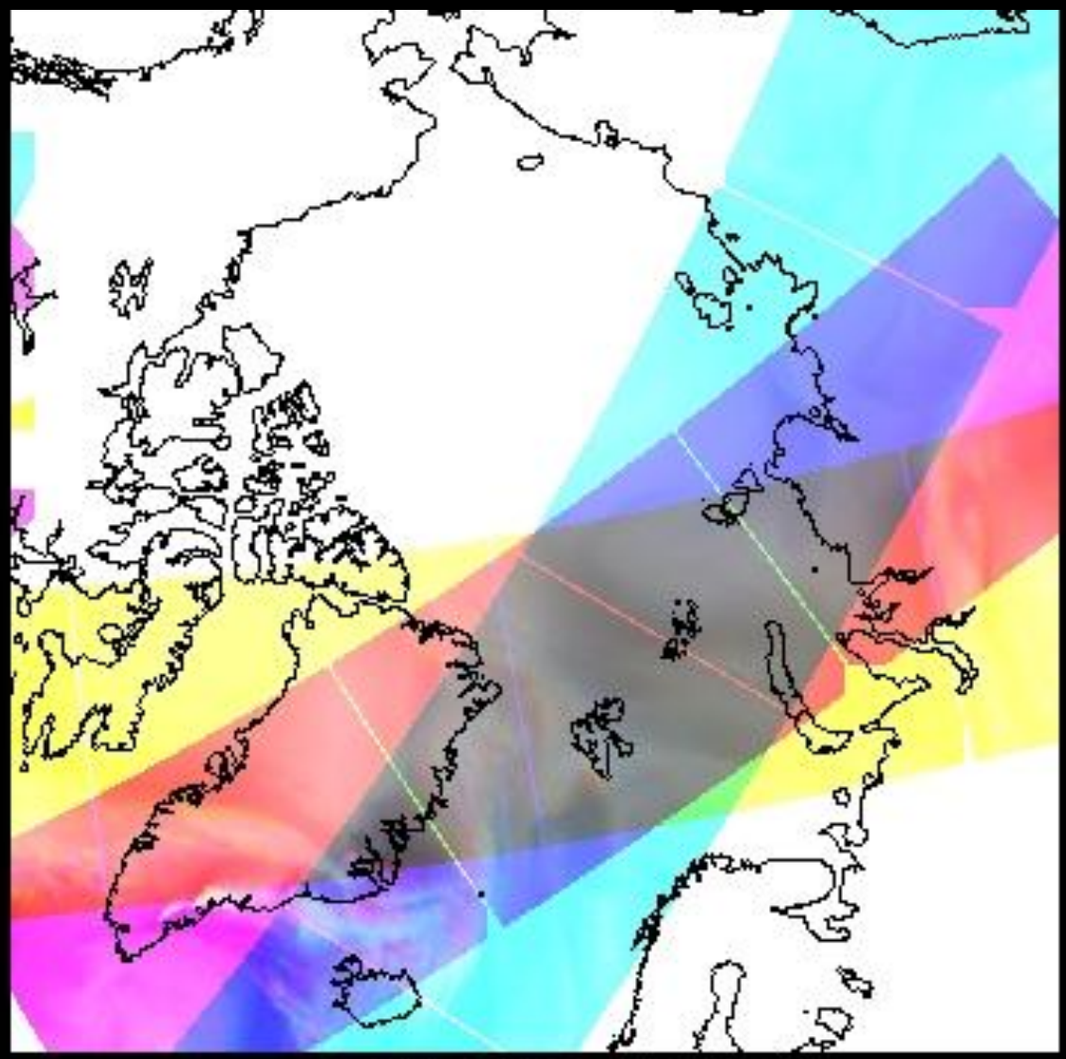


MODIS band 31 (11 μm)

Polar Winds Coverage
MODIS vs. AIRS

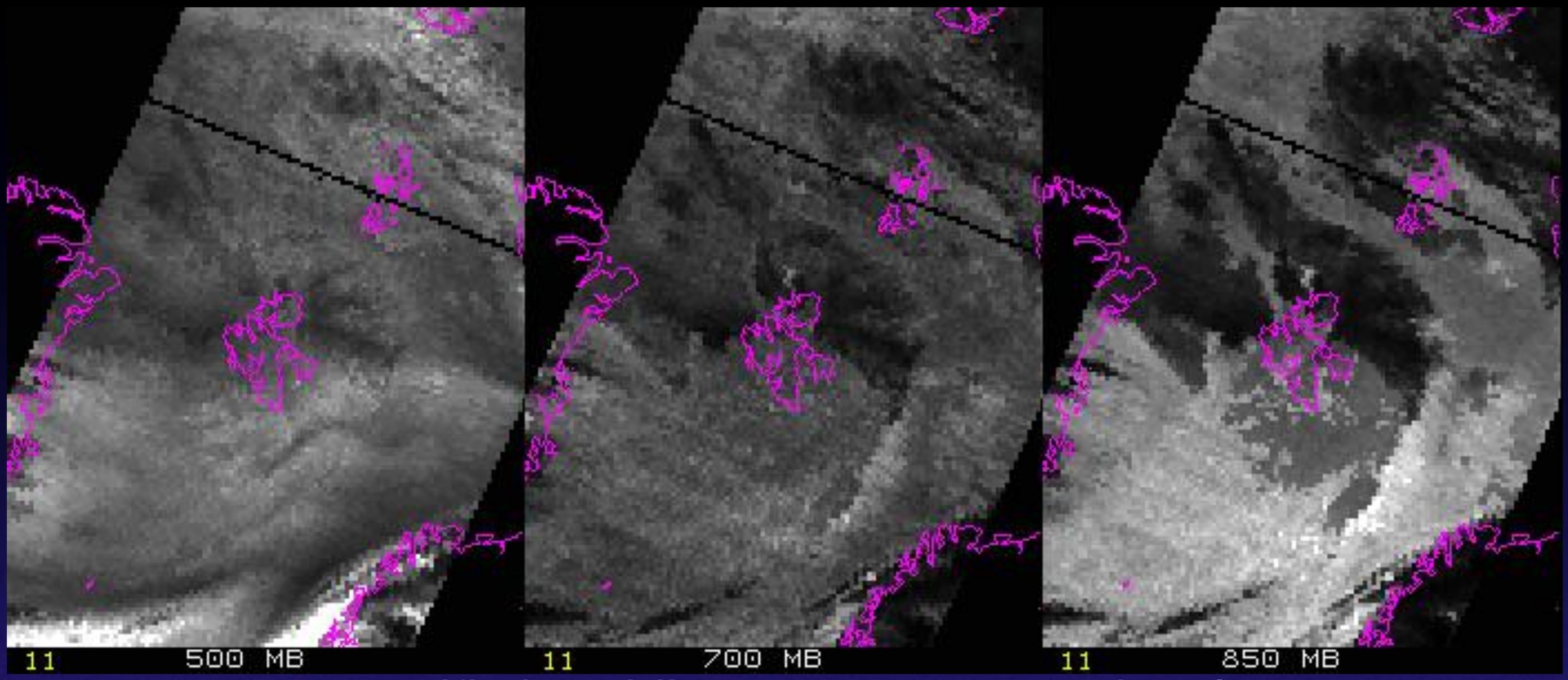


AQUA MODIS COVERAGE



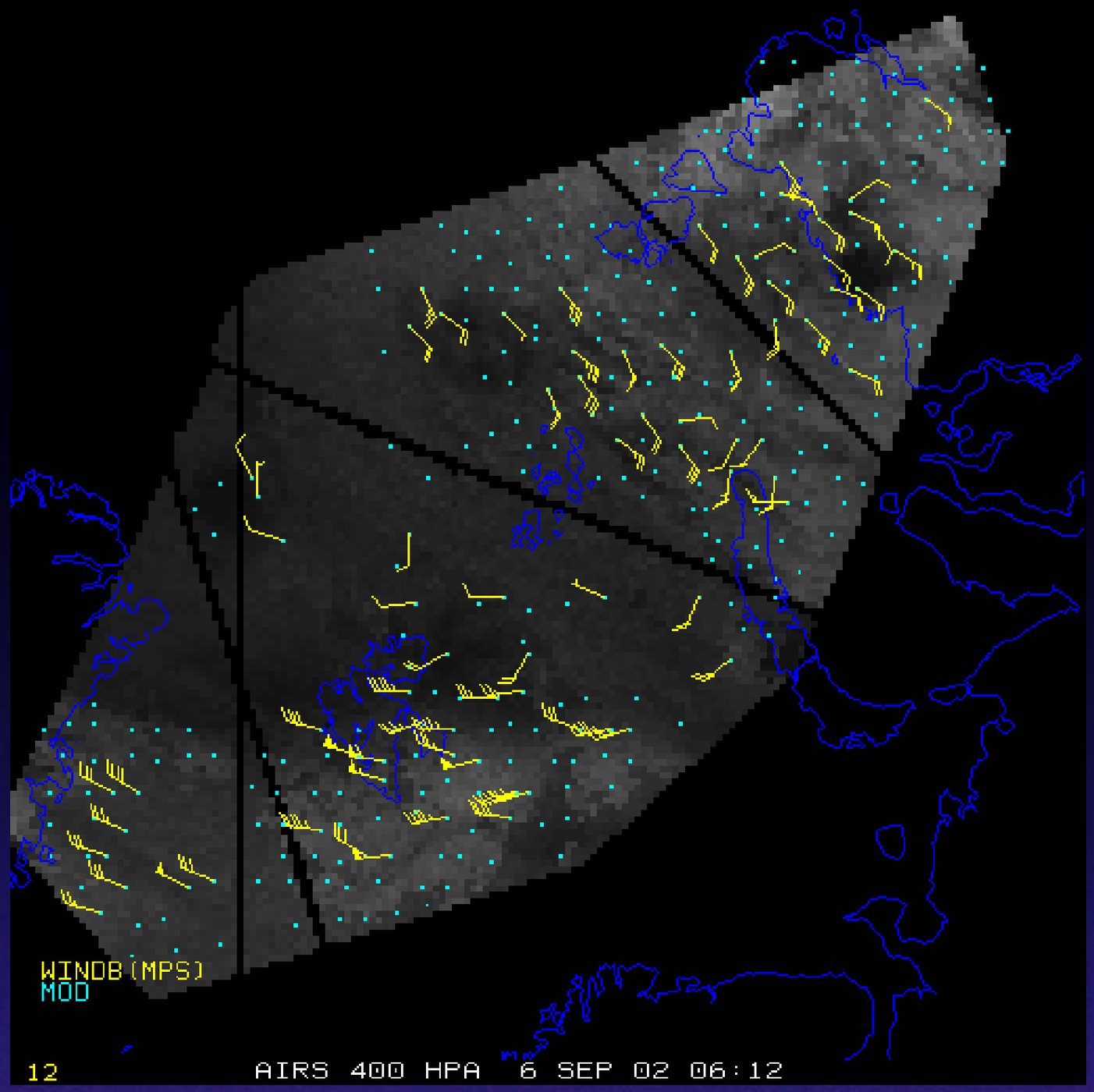
AQUA AIRS COVERAGE

AIRS Retrieval Images at 500, 700, 850 hPa



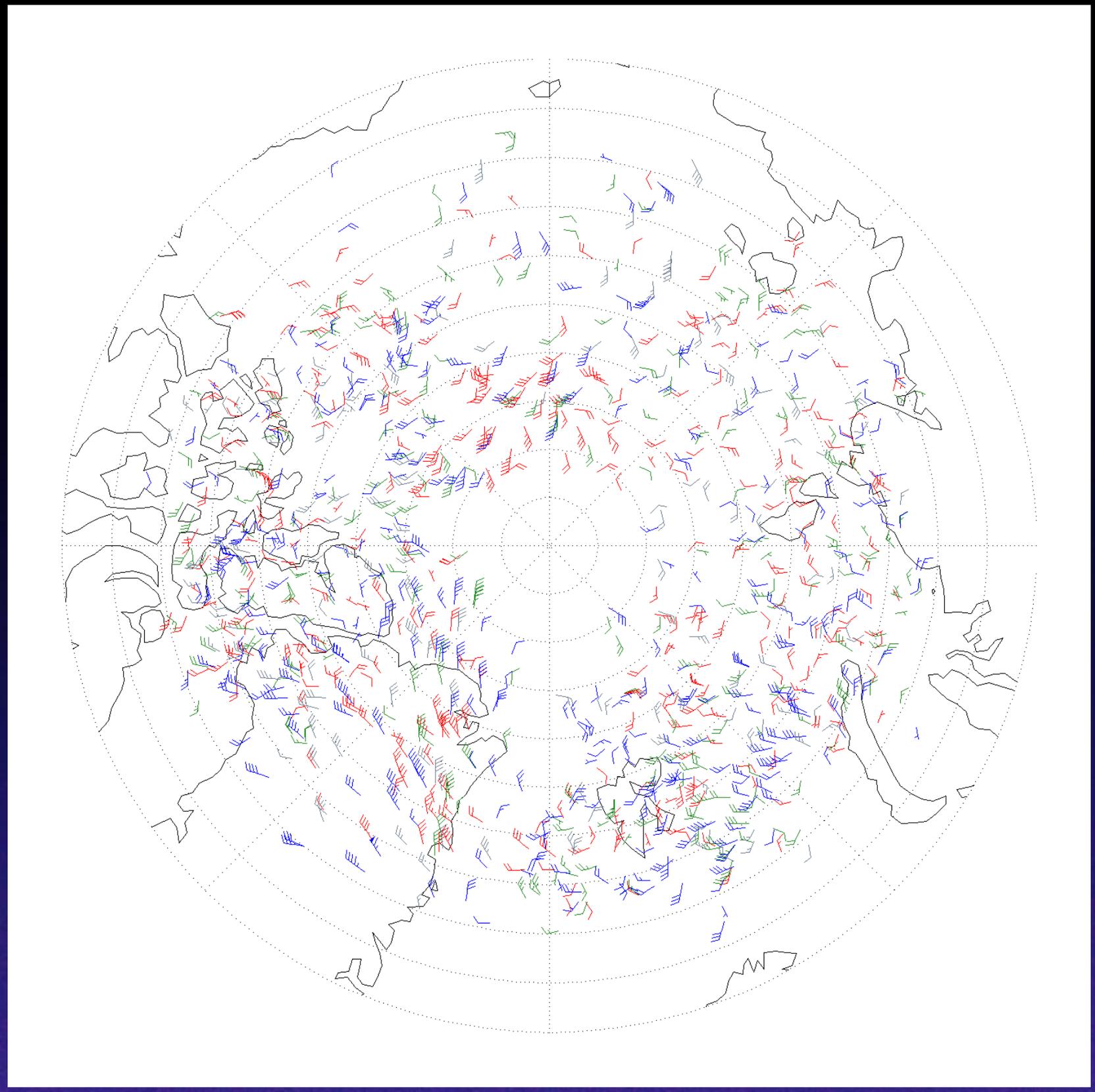
Specific humidity SFOV AIRS retrievals
Remapped composites at 16 km resolution

AIRS Retrieval Winds



Targets (cyan) and unedited winds (yellow) at 400 hPa.
Target size 5x5 pixels. Search box size 14x14.

Spatial distribution of AIRS retrieval winds for one day. North Pole region.



All derived winds from 5 January 2011. Color coded by level:

- 700 - 600 hPa (red)
- 550 - 450 hPa (green)
- 400 - 300 hPa (blue)
- 150 hPa ozone (gray)

Summary

1) Impact from global to synoptic scale (tropical cyclones)
2) Use of rapid scan images for higher temporal resolution winds datasets show value
3) New techniques are needed for future sensors:
   - No water vapor sensor after MODIS (polar satellites). Perhaps use the AIRS retrieval tracking method for IASI (Metop) and CrIS (NPP, JPSS)
   - More mixed satellite tracking to improve polar coverage (many satellites with AVHRR)
   - Use of other sensors (VIIRS Day/Night visible band for low light situations at the poles)

Thank you!

Any Questions?