The Impact of Satellite Atmospheric Motion Vectors in the U.S. Navy Global Data Assimilation System: The Superob Procedure

Patricia M. Pauley[1], Nancy L. Baker[1], Rolf Langland[1], Liang Xu[1], and Chris Velden[2]

[1]Marine Meteorology Division, Naval Research Laboratory, Monterey, California
[2]University of Wisconsin—Cooperative Institute for Meteorological Satellite Studies, Madison, Wisconsin

Acknowledgements: Office of Naval Research

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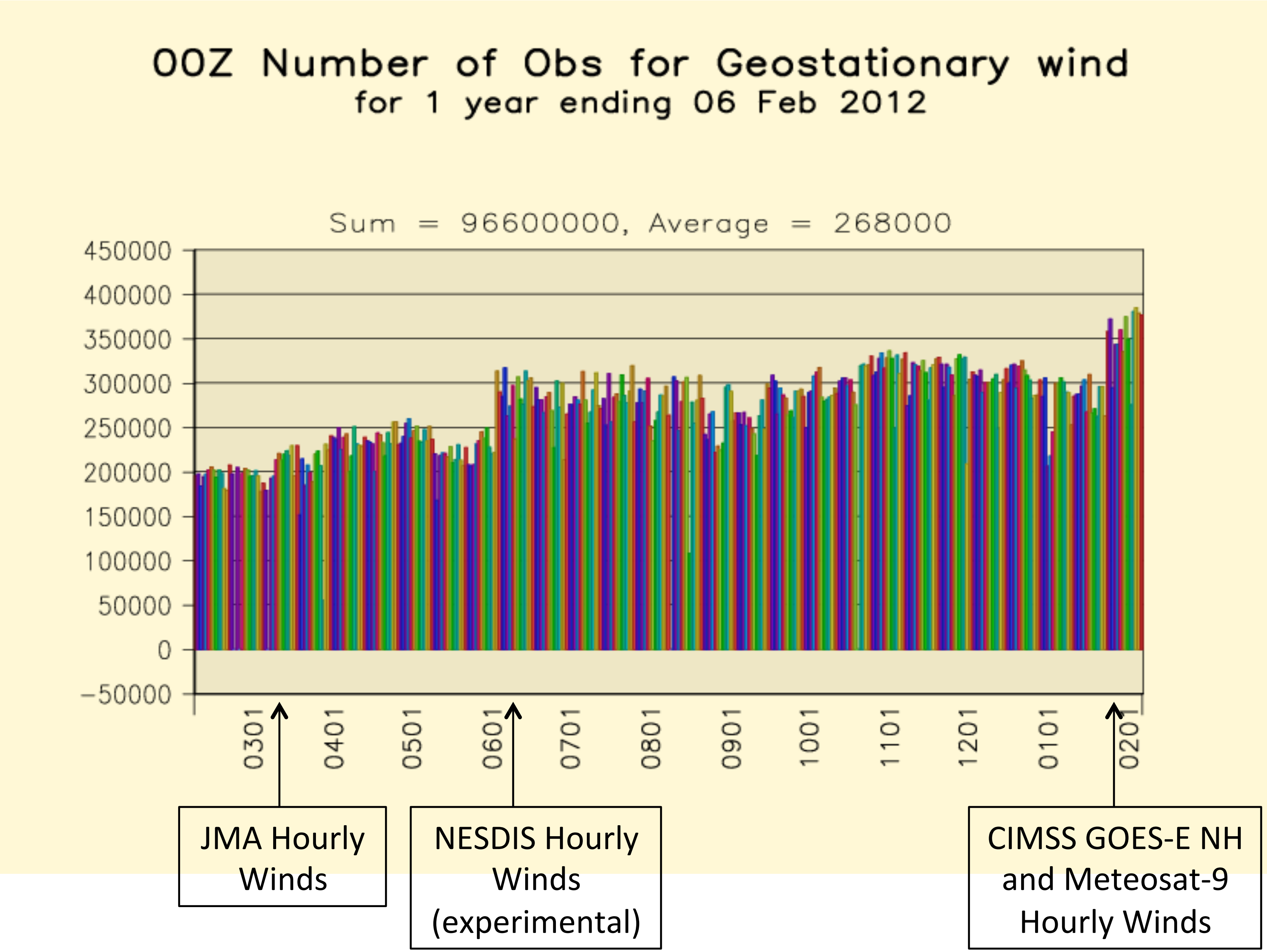
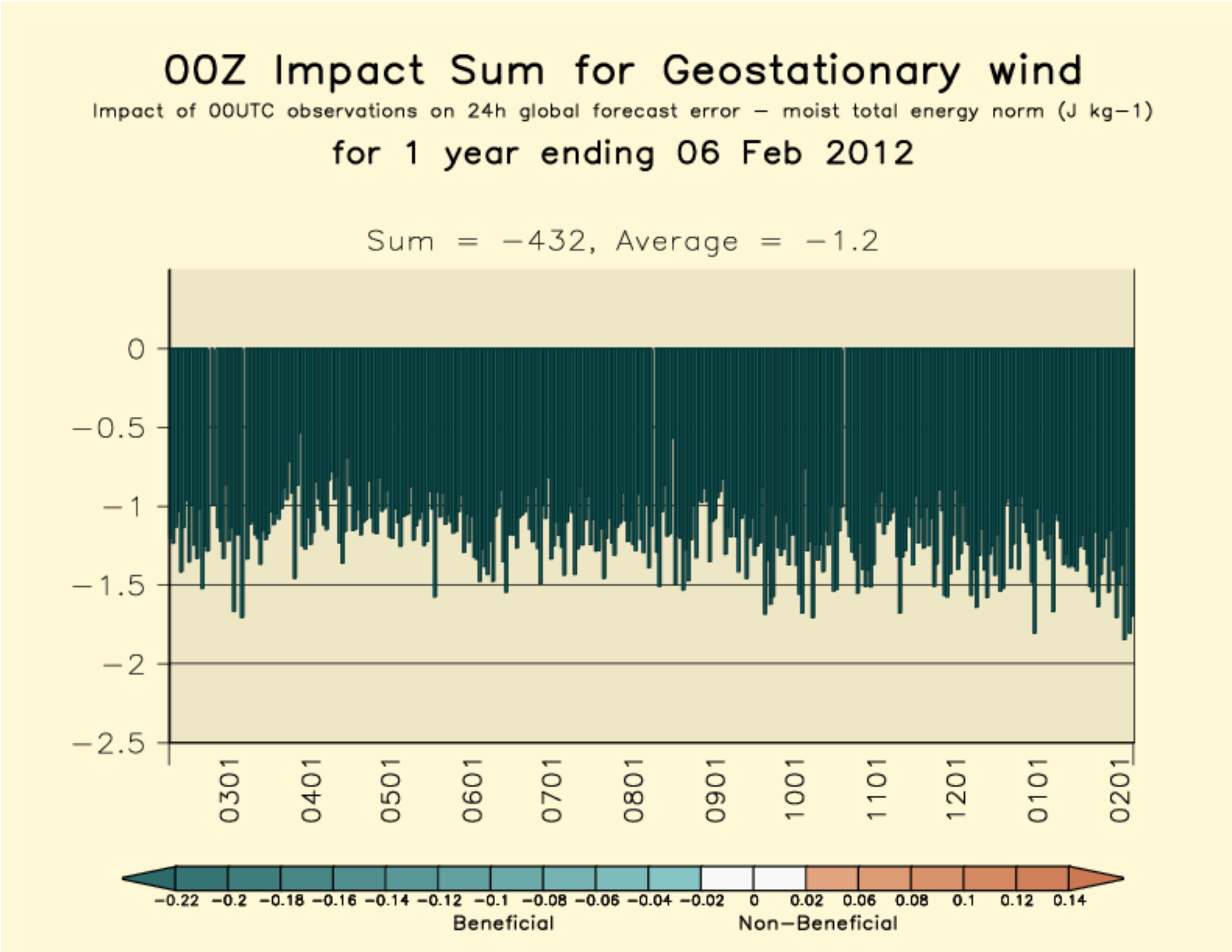
Experiment Goals

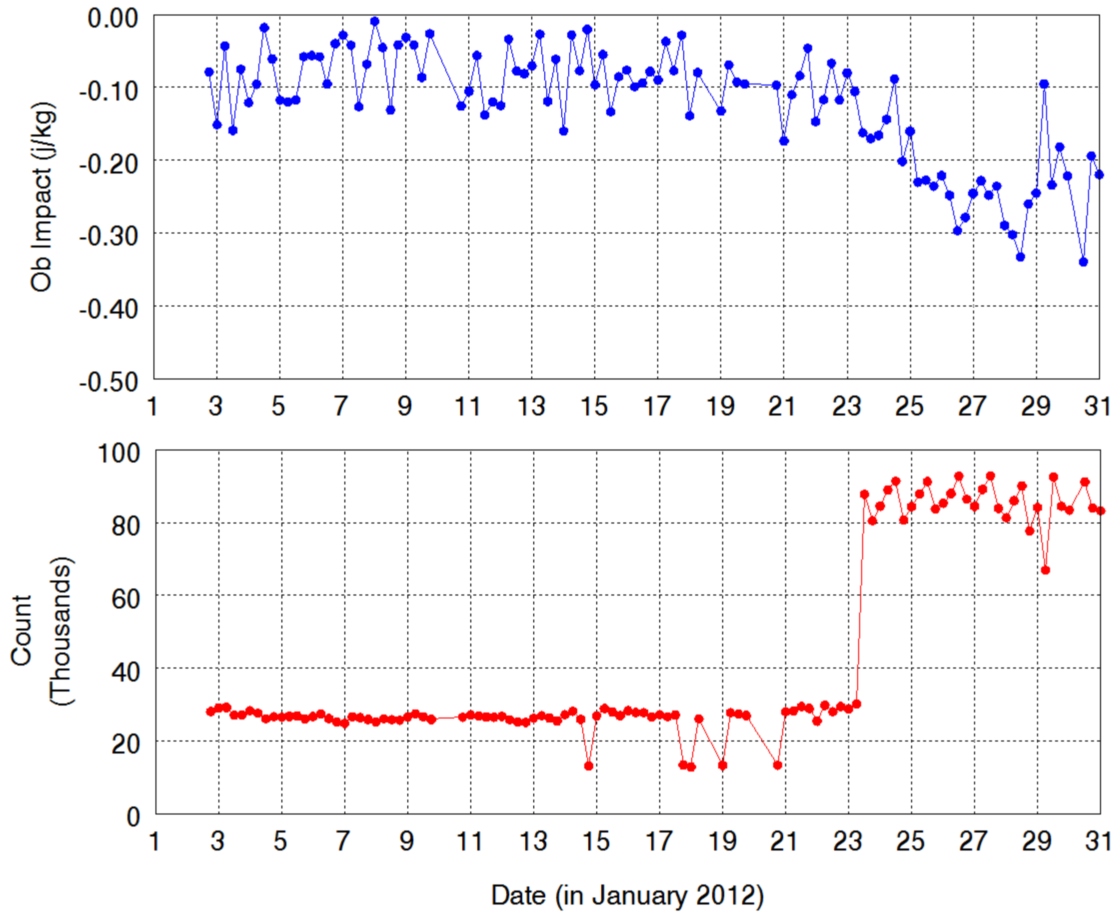
- Examine the impact of geostationary atmospheric motion vectors (AMVs) on numerical weather prediction (NWP) analysis and forecast skill
- Examine the impact of polar and composite ("LeoGeo") AMVs on NWP analysis and forecast skill
- Investigate why NRL/FNMOC appears to obtain more benefit from AMVs than other NWP centers
  - Superobbing vs. thinning
  - Assimilating geostationary winds from both CIMSS and NESDIS/EUMETSAT/JMA—two datasets for each satellite
  - Assimilating hourly winds where available


00Z Number of Obs for Geostationary wind
for 1 year ending 06 Feb 2012
Sum = 96600000, Average = 268000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
−50000
0301
0401
0501
0601
0701
0801
0901
1001
1101
1201
0101
0201
JMA Hourly Winds
NESDIS Hourly Winds (experimental)
CIMSS GOES-E NH and Meteosat-9 Hourly Winds



http://www.nrlmry.navy.mil/obsenar/fnmoc/

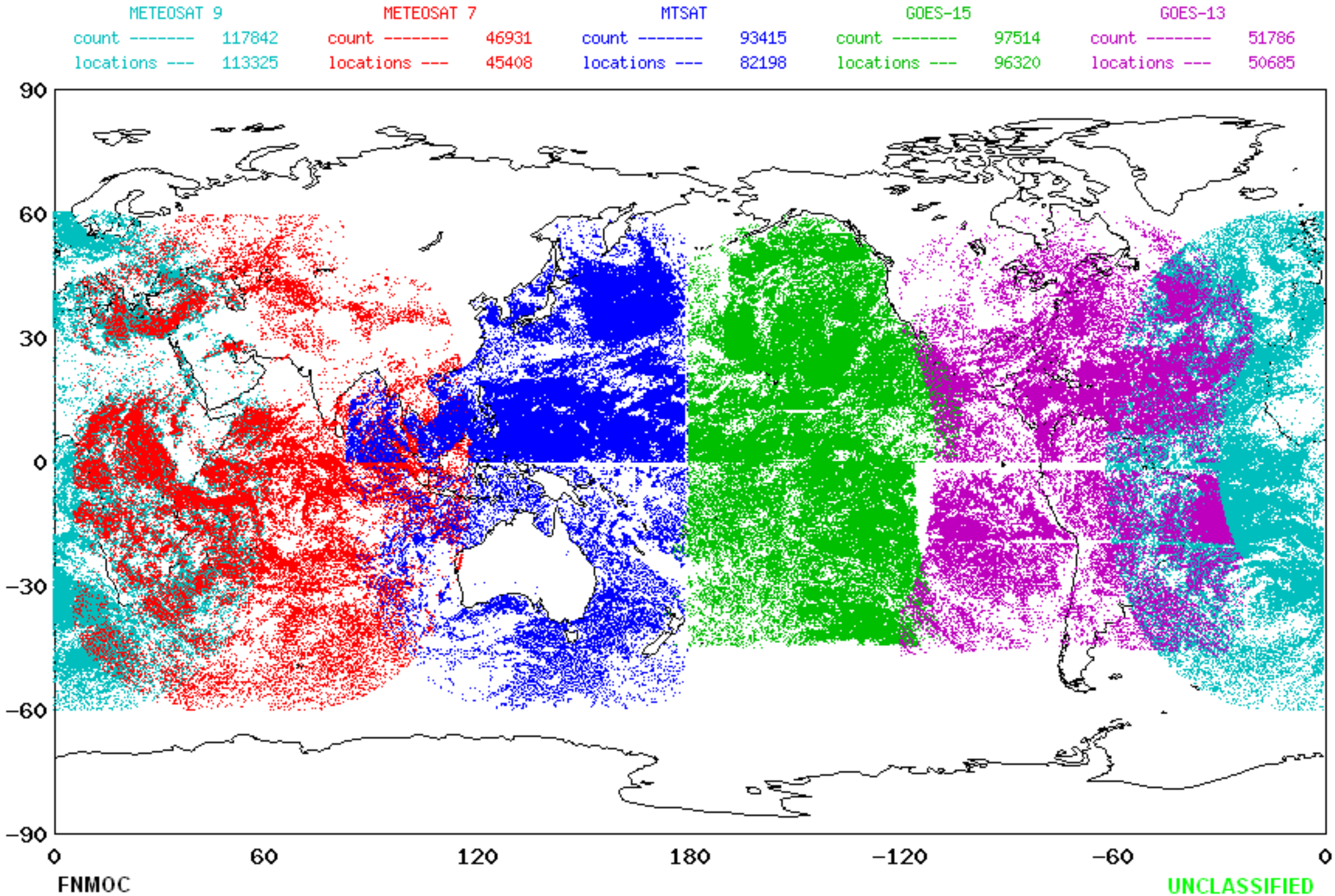
January 2012 Ob Impact
CIMSS Meteosat-9



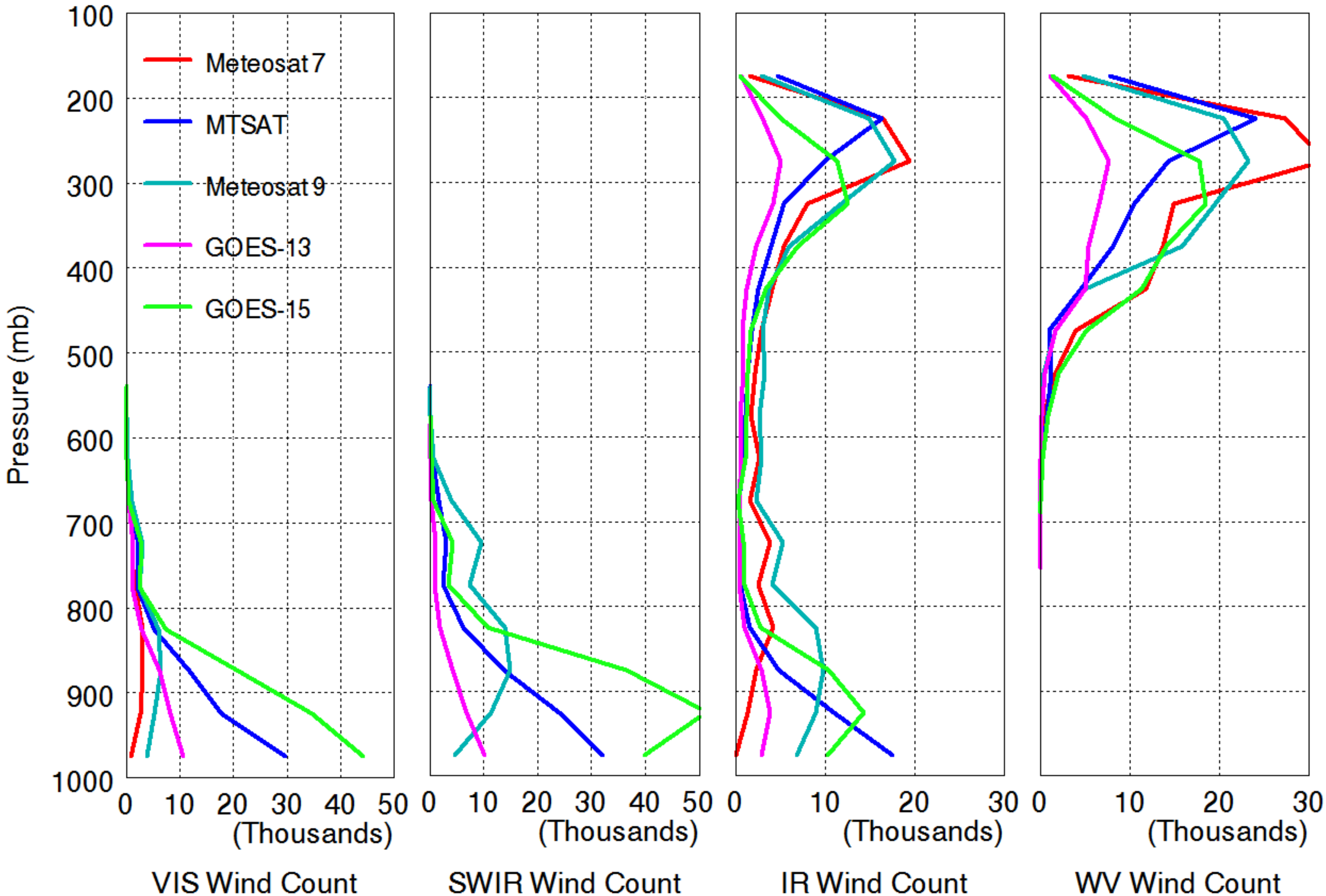
Negative values
Less error

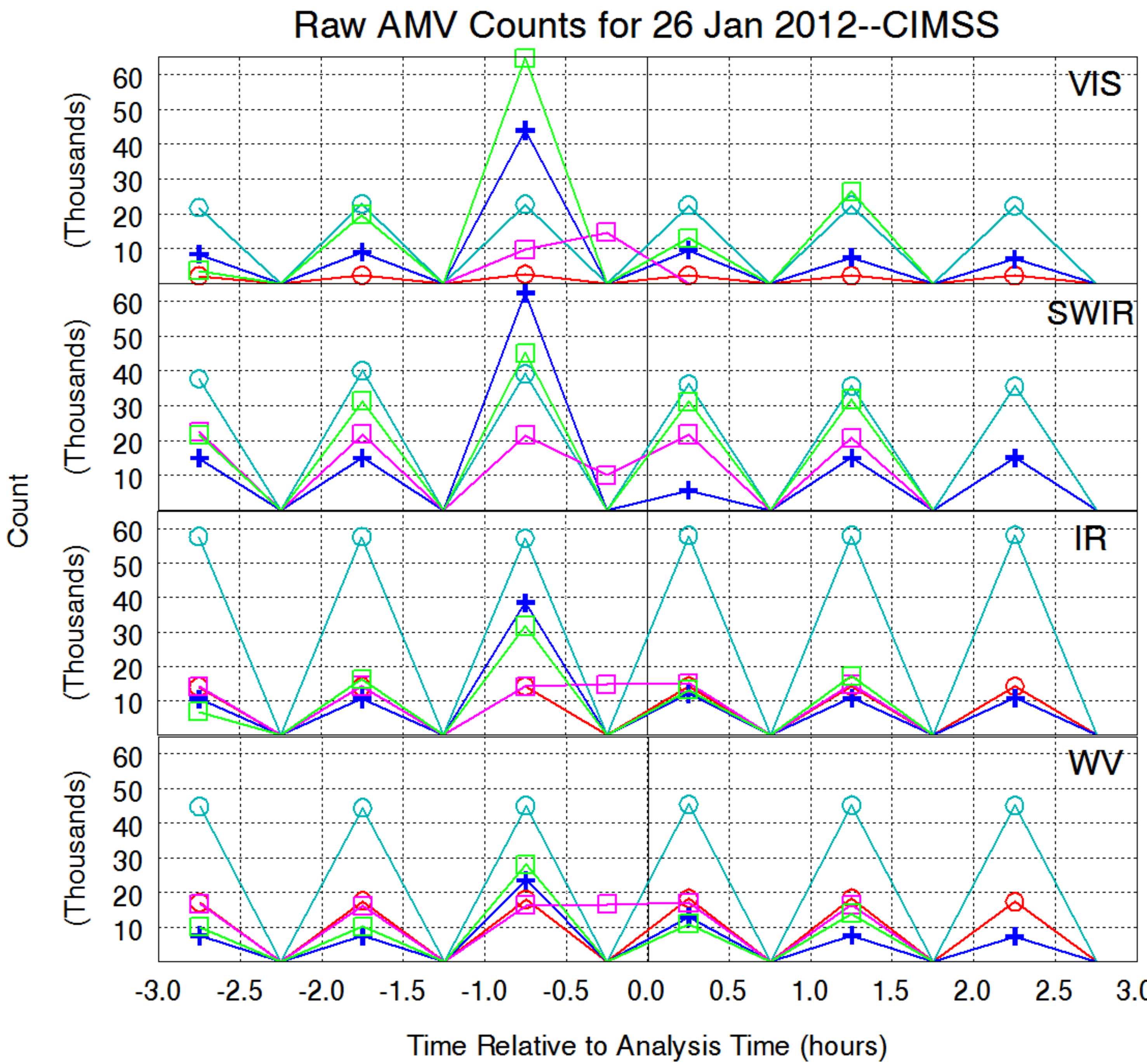
CIMSS Meteosat-9 winds became available on 23 Jan 2012. This figure shows the increased ob impact (decreased forecast error) that accompanied the increase in superob counts.

Data Overview—CIMSS/UW Winds

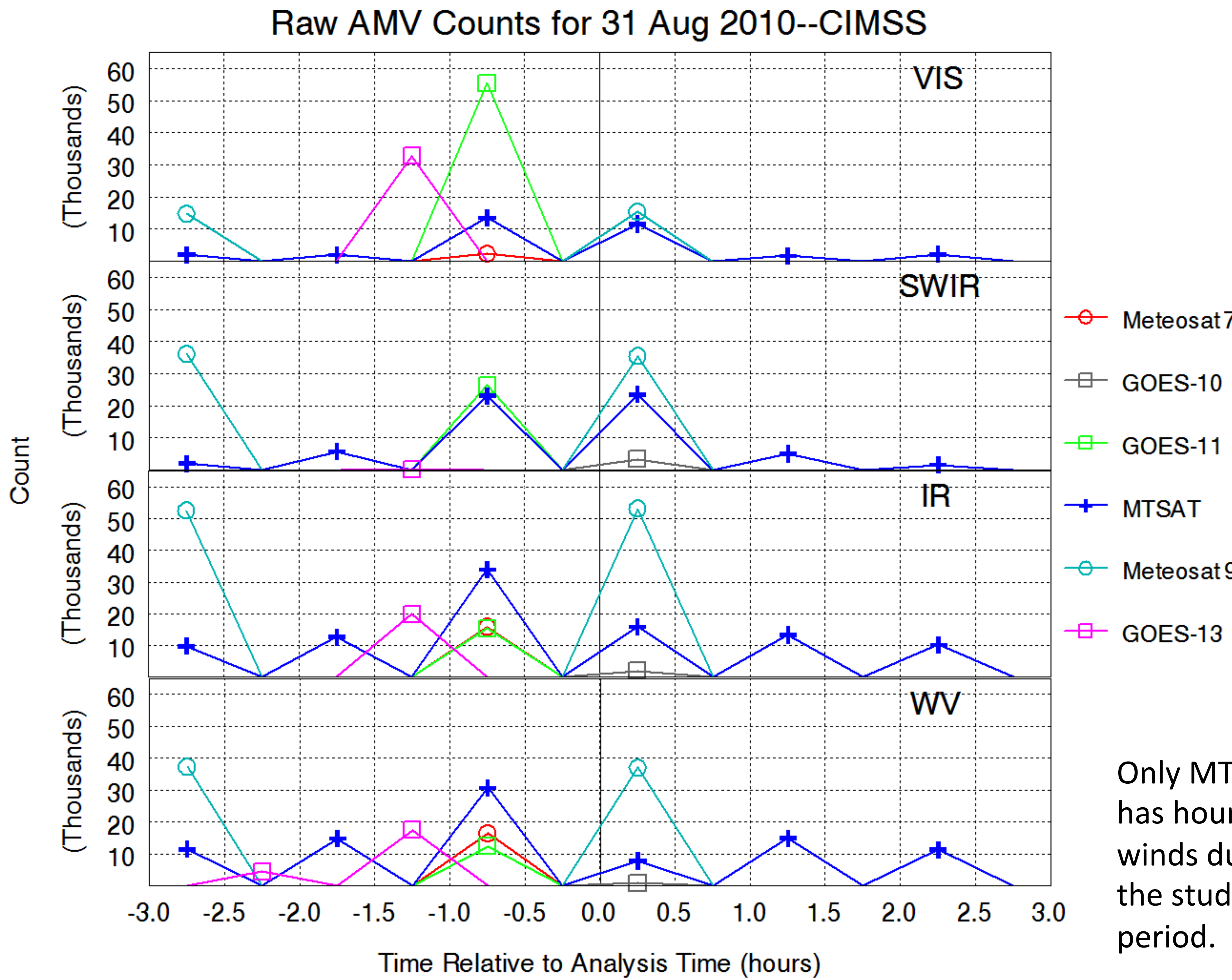


Raw AMV Counts for 16 January 2012 -- CIMSS



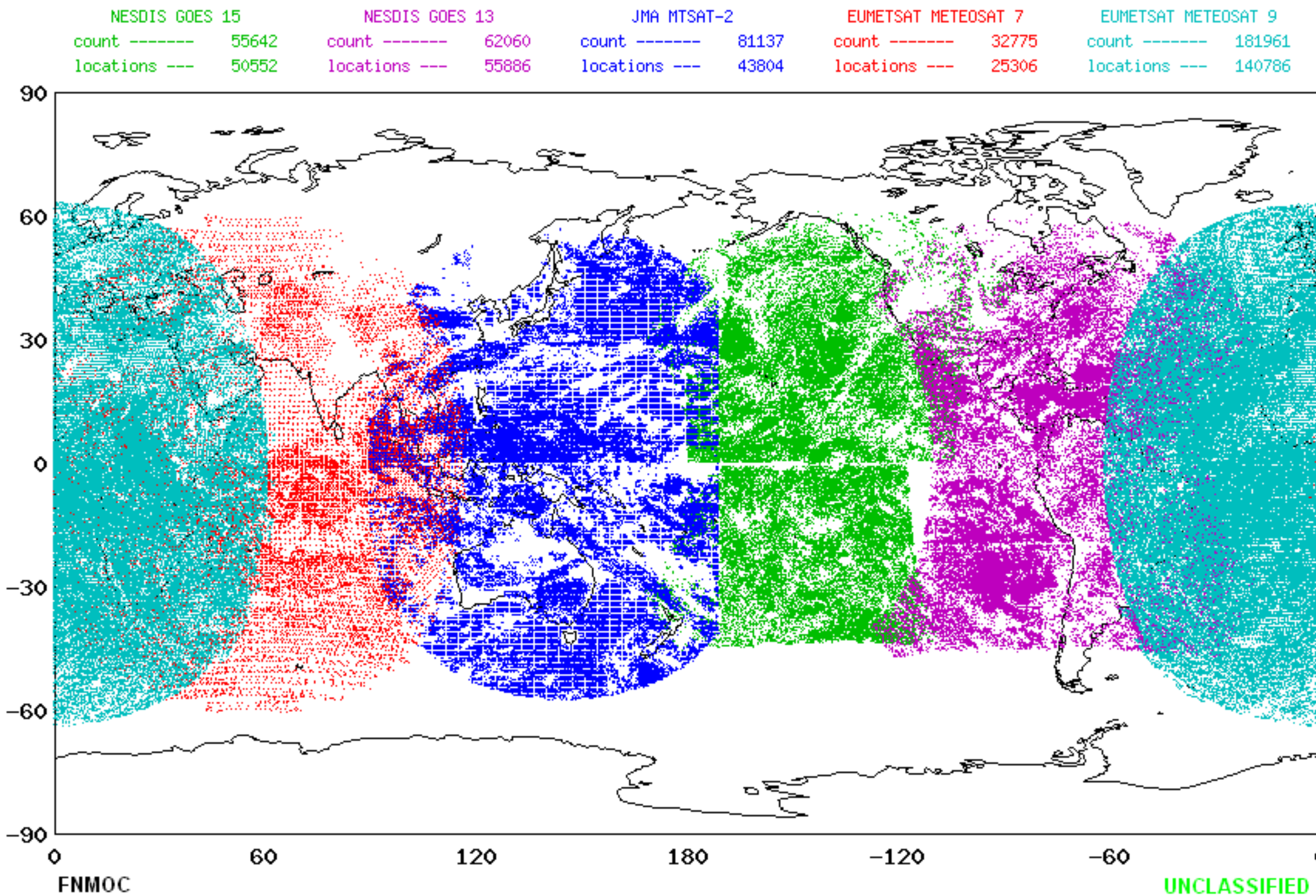


Hourly winds available from CIMSS for Meteosat-9 and GOES-13 starting on 23 Jan 2012.

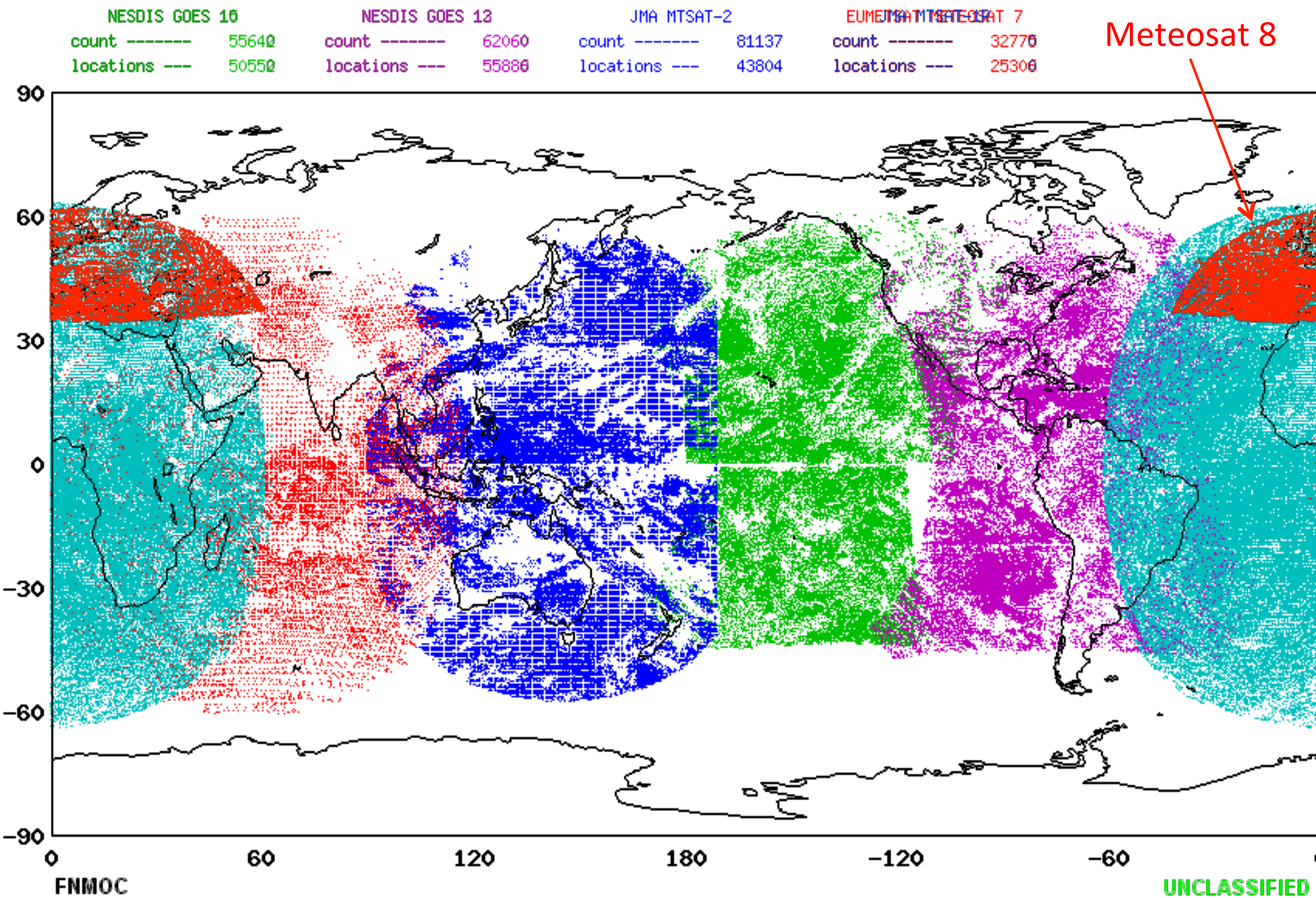


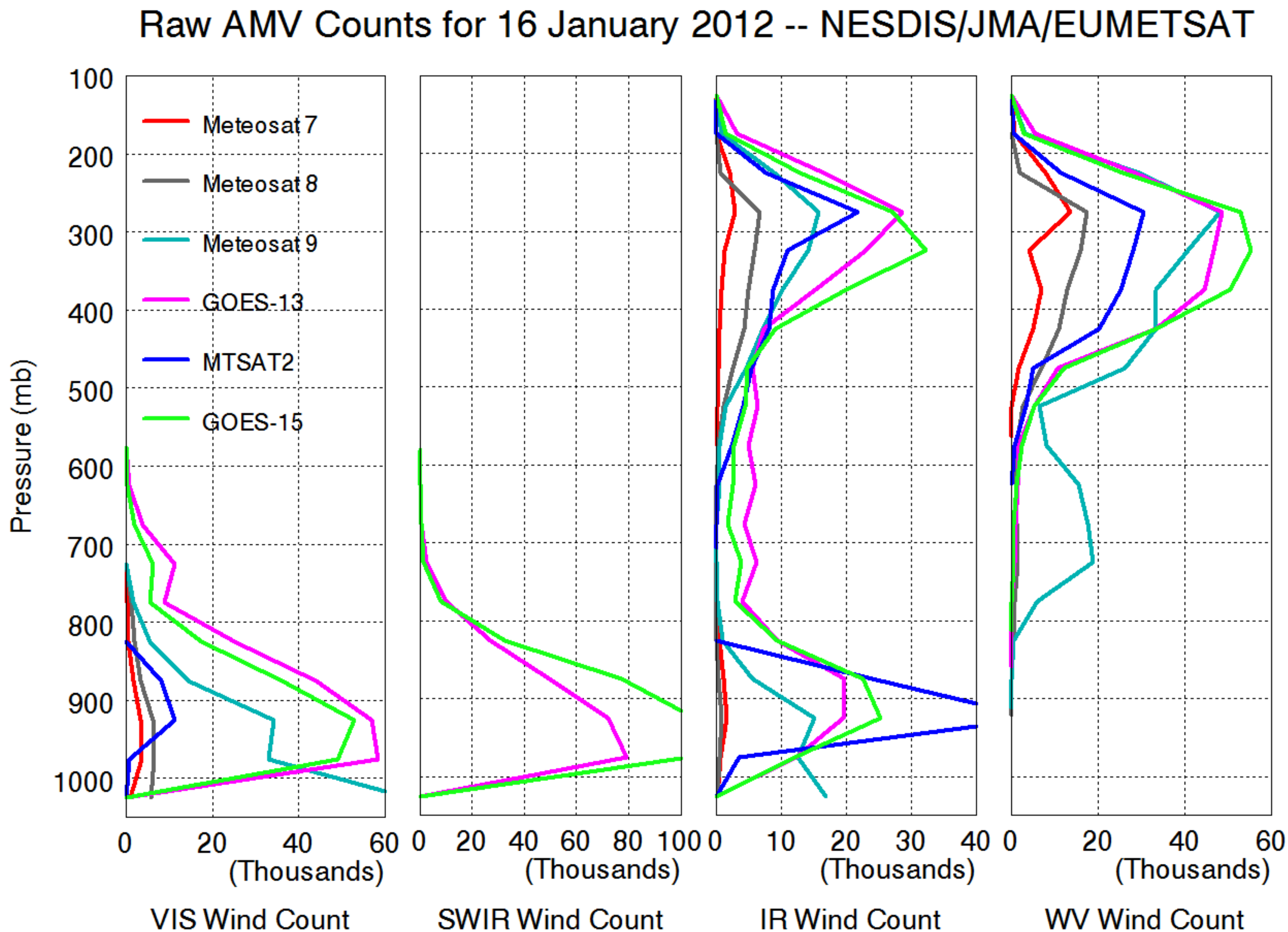
Only MTSAT has hourly winds during the study period.

Data Overview—NESDIS/JMA/EUMETSAT Winds

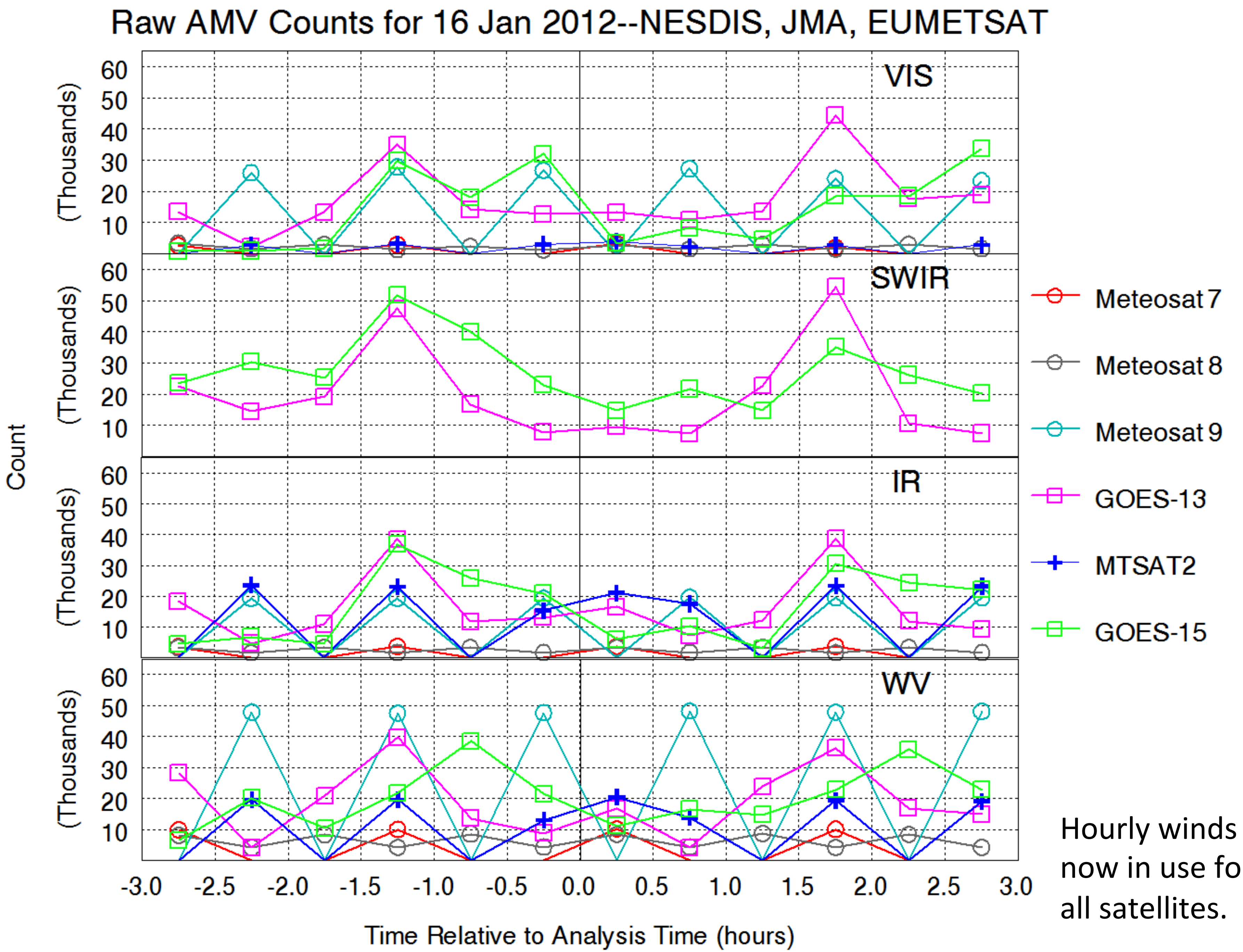


Data Overview—NESDIS/JMA/EUMETSAT Winds

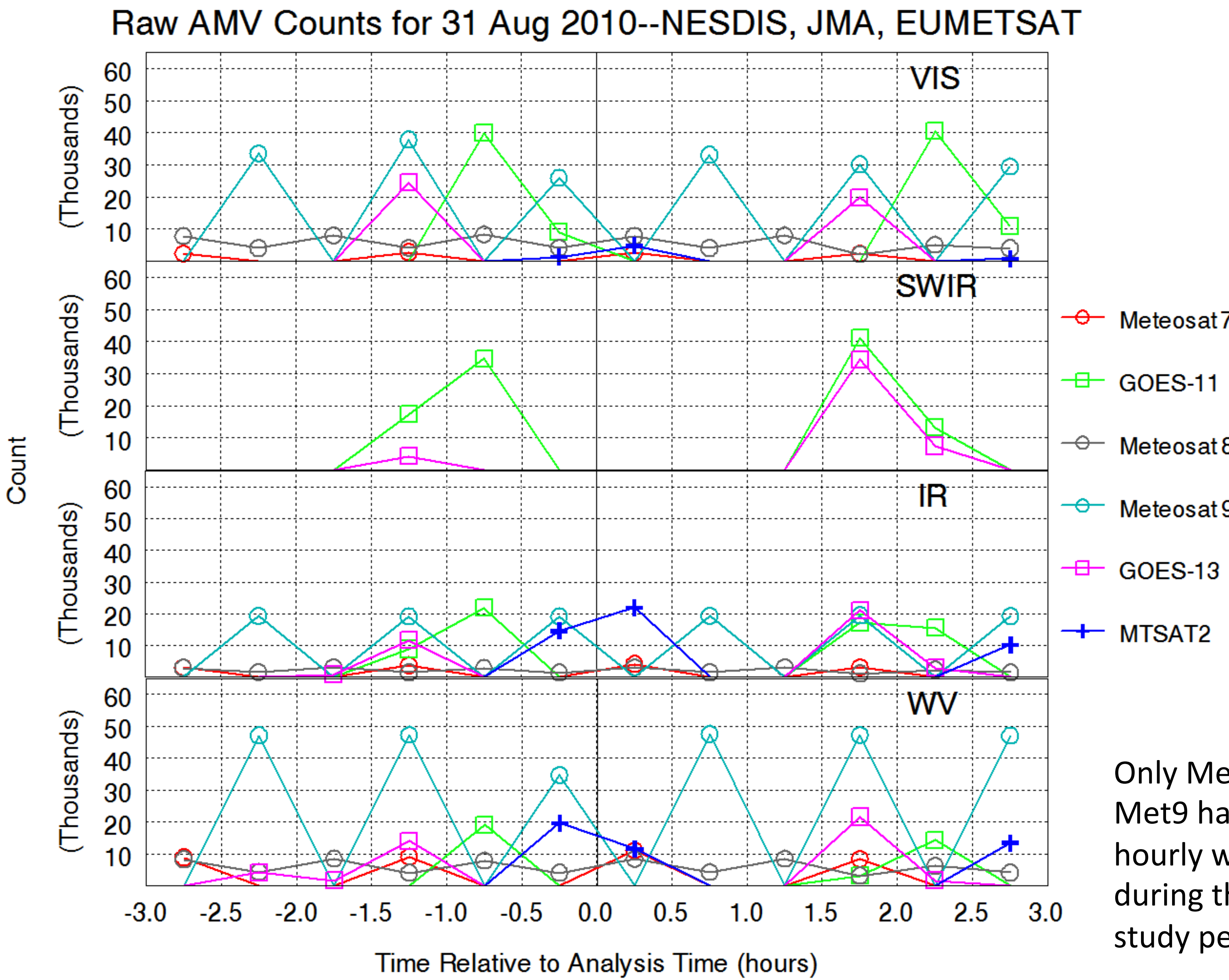




Raw AMV Counts for 16 January 2012 -- NESDIS/JMA/EUMETSAT
Pressure (mb)
100
200
300
400
500
600
700
800
900
1000
Meteosat 7
Meteosat 8
Meteosat 9
GOES-13
MTSAT2
GOES-15
0
20
40
60
(Thousands)
VIS Wind Count
0
20
40
60
80
100
(Thousands)
SWIR Wind Count
0
10
20
30
40
(Thousands)
IR Wind Count
0
20
40
60
(Thousands)
WV Wind Count



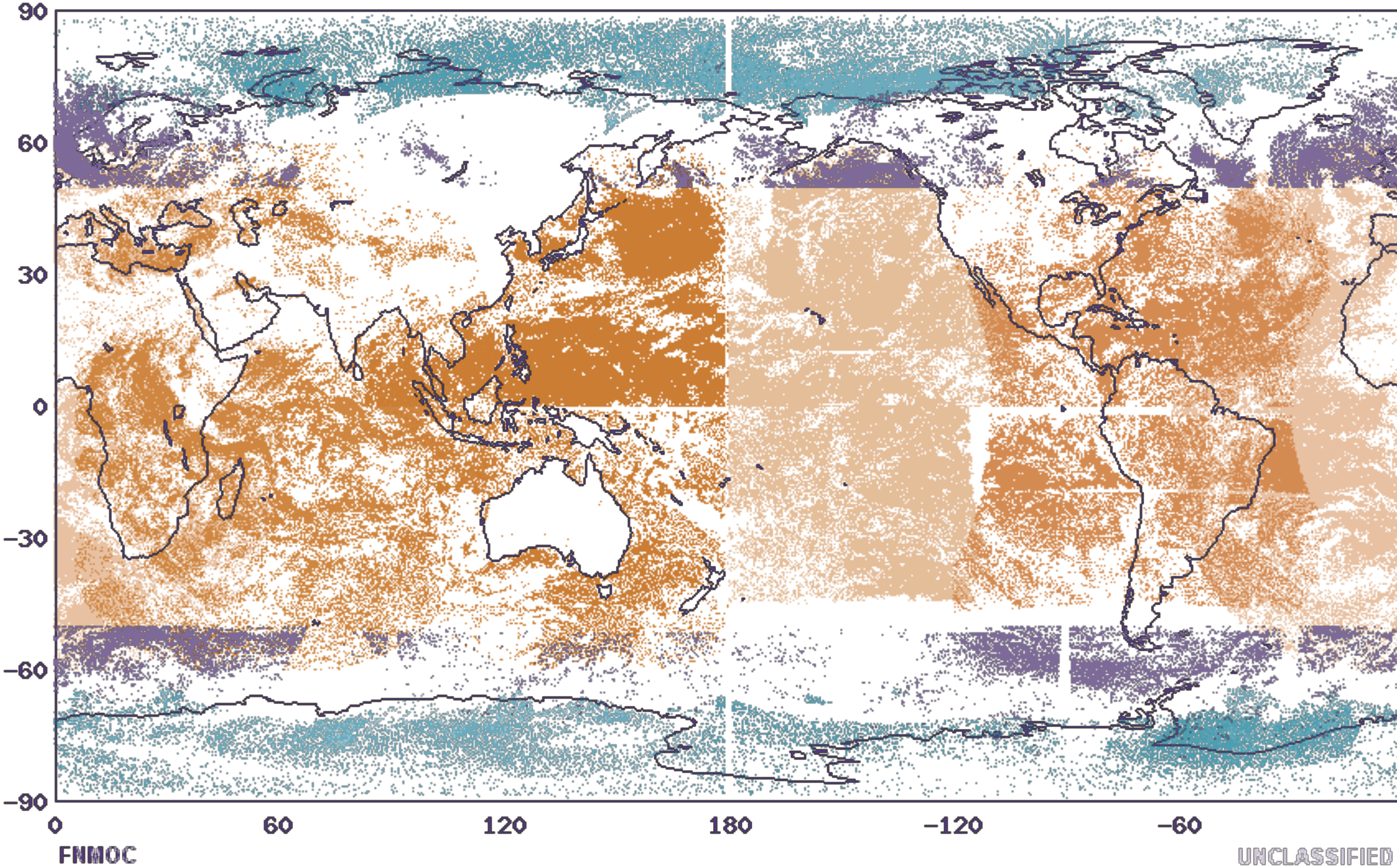
Hourly winds now in use for all satellites.



Only Met8 and Met9 had hourly winds during the study period.

Data Overview—CIMSS/UW Polar/LeoGeo Winds

Geostationary winds—orange
Polar winds—aqua (MODIS operational in Oct 2004, AVHRR operational in Nov 2007)
LeoGeo winds—purple (operational in Nov 2010)—based on composite imagery



Basic Philosophy

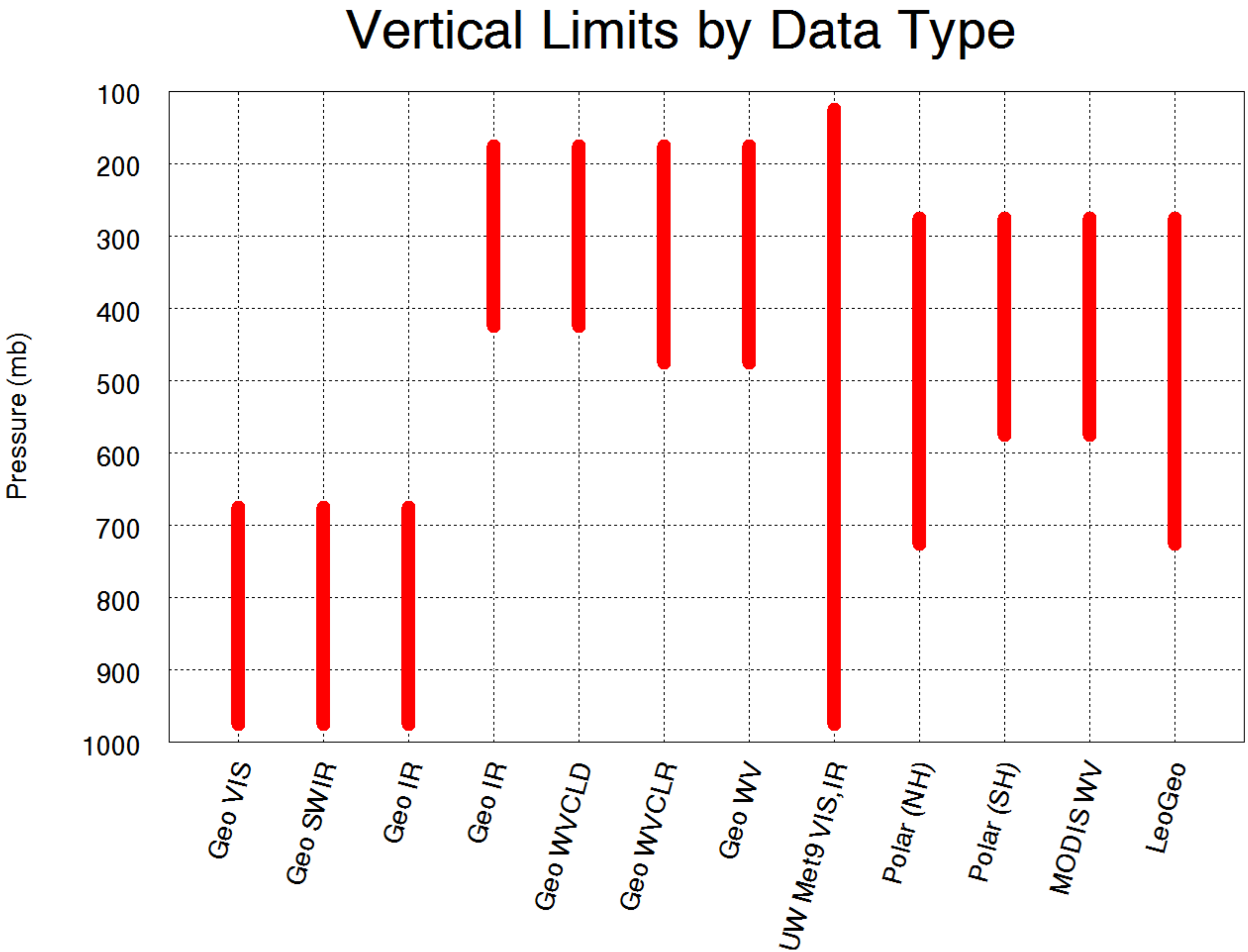
- Satellite-derived winds contain horizontally correlated errors.
- But, the data assimilation system assumes that observation errors are not horizontally correlated.
- Thinning or averaging ("superobbing") is performed to mitigate this problem.
- NRL philosophy: Only superob similar observations.
  - Same satellite, channel, processing center
  - Similar wind direction and speed (or u and v components)
  - Similar time

AMV Processing

- Read data and convert direction, speed to u, v components
- Assign observation errors (2.8 to 5.2 m/s depending on level)
- Read background fields and interpolate horizontally, vertically, and temporally to observation locations

AMV Processing

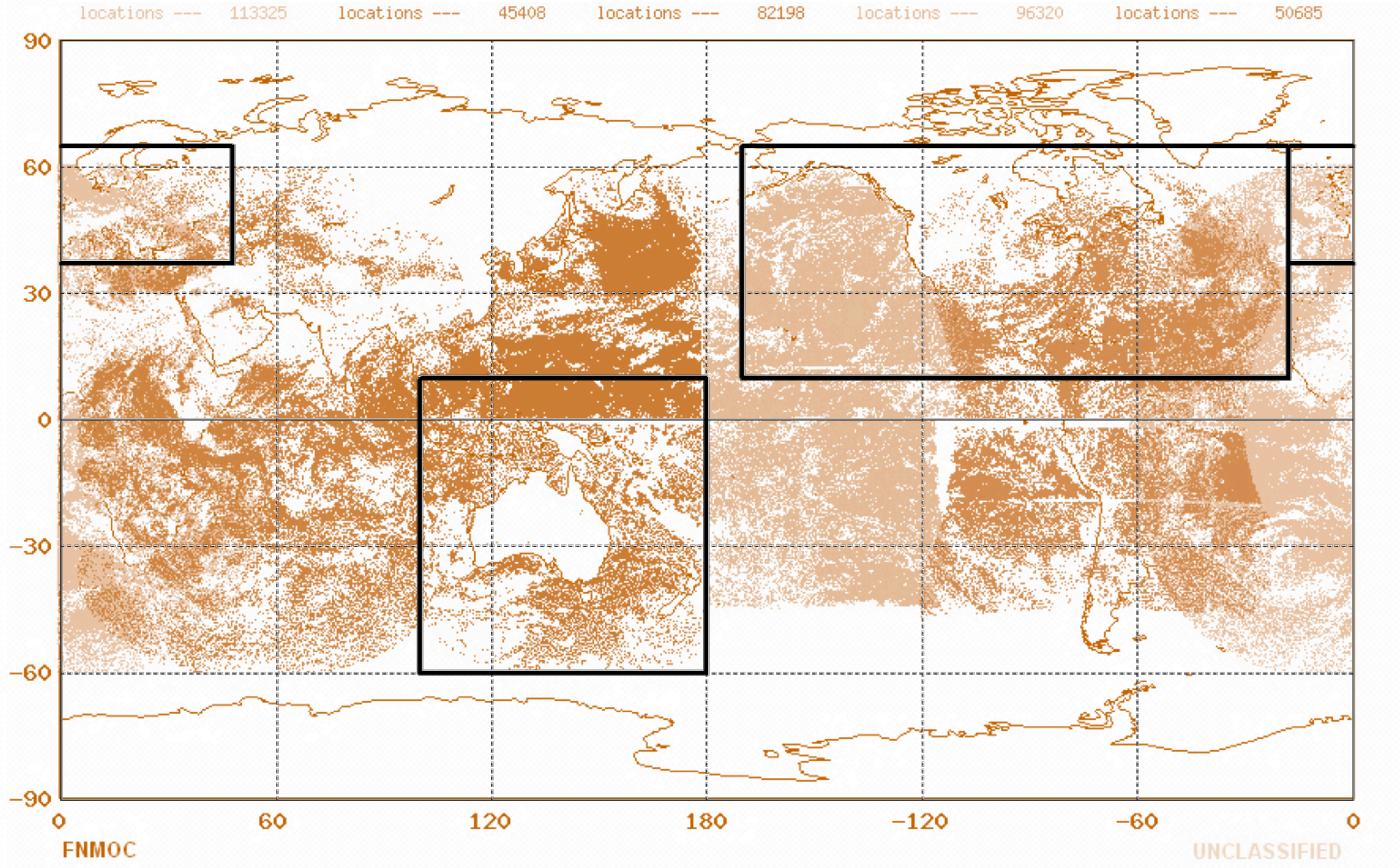
- Read data and convert direction, speed to u, v components
- Assign observation errors
- Read background fields and interpolate to observation locations
- Perform QC on individual observations
  - Exclude invalid observations
    - Missing latitude, longitude, pressure, or time
    - Missing background value
  - Exclude observations flagged as bad or having low confidence or quality
    - EUMETSAT confidence value less than provided threshold
    - CIMSS RFF values less than 40
    - CIMSS QI values less than 50 (60 for polar and LeoGeo winds)
  - Impose vertical limits
  - Impose land-masking in selected regions



Vertical Limits by Data Type
Pressure (mb)
100
200
300
400
500
600
700
800
900
1000
Geo VIS
Geo SWIR
Geo IR
Geo IR
Geo WVCLD
Geo WVCLR
Geo WV
UW Met9 VIS,IR
Polar (NH)
Polar (SH)
MODIS WV
LeoGeo

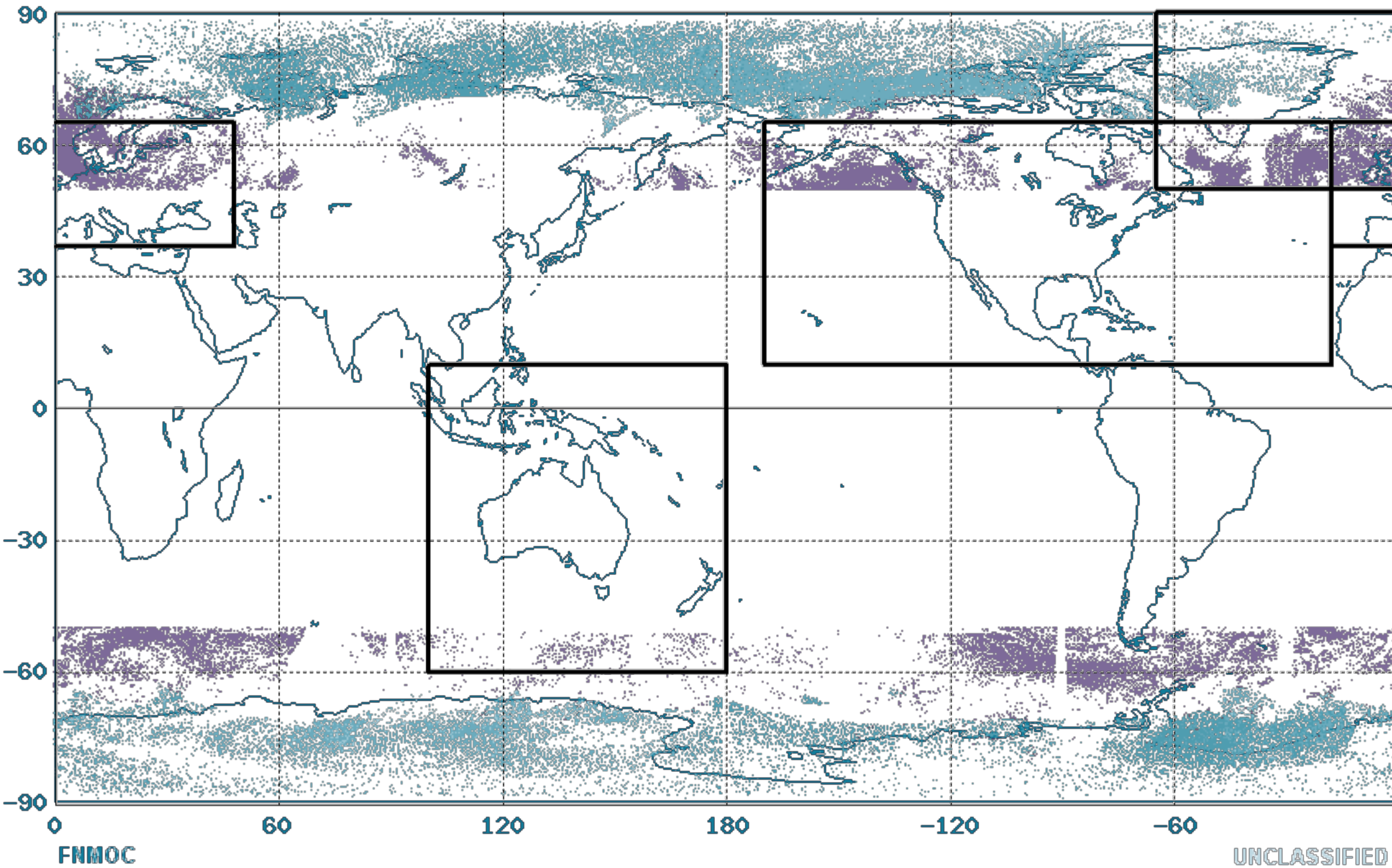
Land Masking with Geostationary Winds

Winds at land points within the North America, Western Europe, and Australia latitude-longitude boxes are excluded from use.



Land Masking with MODIS/AVHRR/LeoGeo Winds

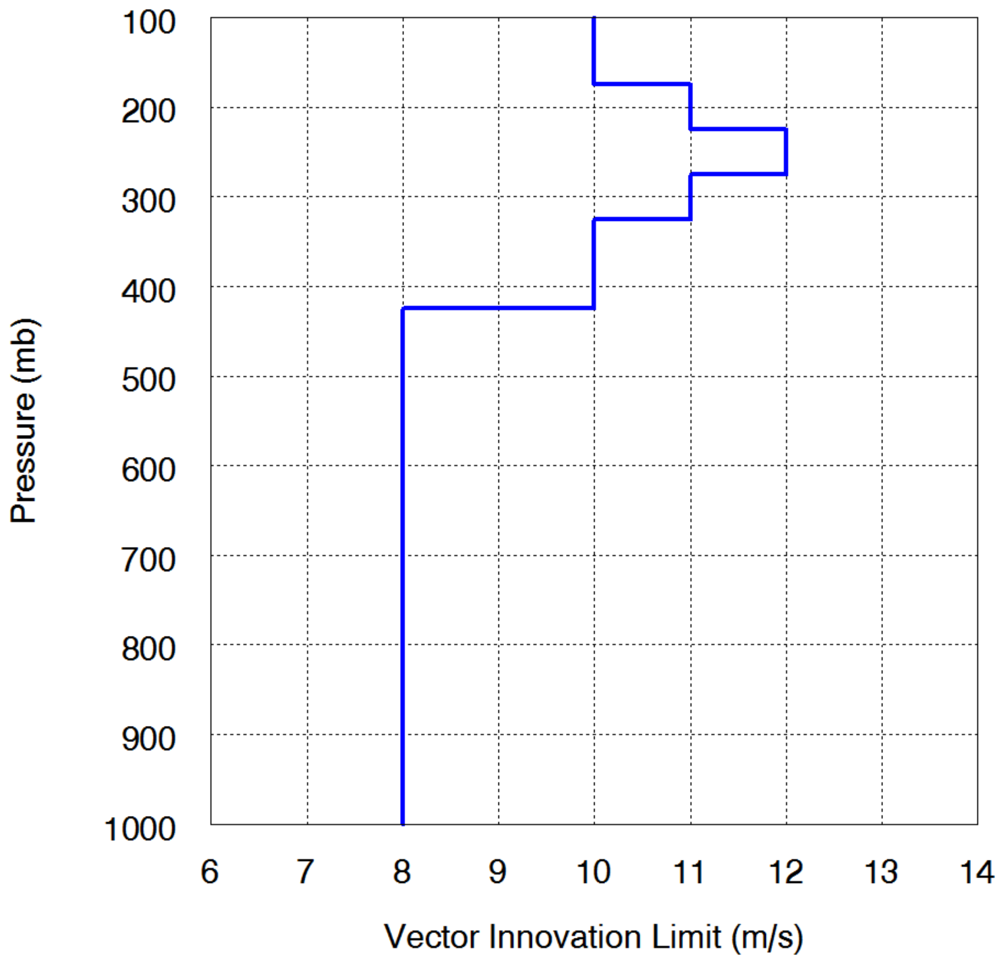
Polar and LeoGeo winds are subjected to the same land masking as geostationary winds, with an additional masking performed for Greenland.



AMV Processing

- Read data and convert direction, speed to u, v components
- Assign observation errors
- Read background fields and interpolate to observation locations
- Perform QC on individual observations
  - Exclude invalid observations
  - Exclude observations flagged as bad or having low confidence or quality
  - Impose vertical limits
  - Impose land-masking in selected regions
  - Exclude exact duplicates
  - Exclude winds with large vector innovations (ob minus background)

AMV Limits on Vector Innovations

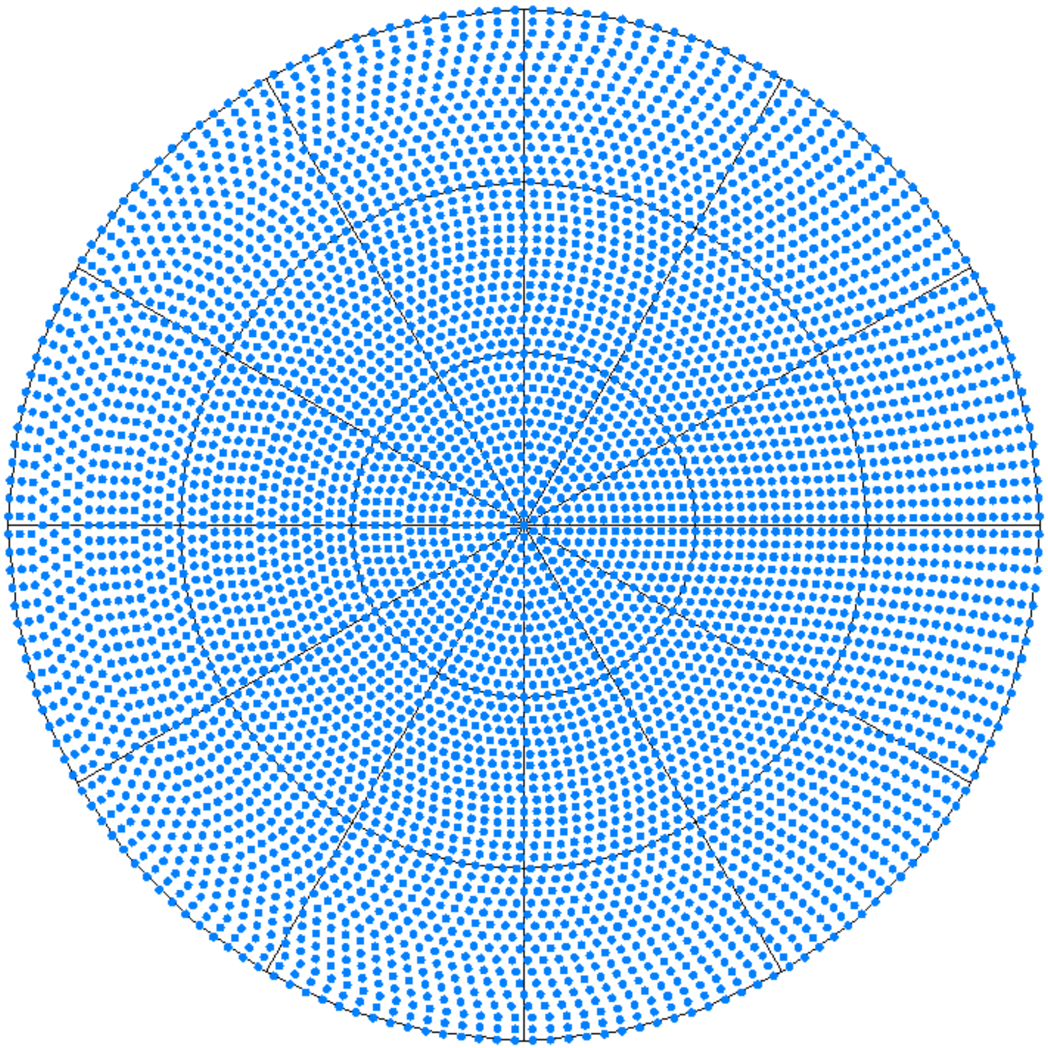


Winds having large vector innovation (ob minus background values) magnitudes are rejected.

AMV Processing

- Read data and convert direction, speed to u, v components
- Assign observation errors
- Read background fields and interpolate to observation locations
- Perform QC on individual observations
- Bin winds into latitude-longitude “prisms” in 50 mb layers

Northern Hemisphere Superob Prism Distribution



Superobs are formed in "prisms" that are 2° latitude by 2° longitude at the equator. Although the latitudinal extent of each prism is kept fixed at 2°, the longitudinal extent is allowed to vary, keeping the area of the prisms approximately equal while also keeping an integer number of prisms in a latitude band.

The circles in this figure at located at prism centers.

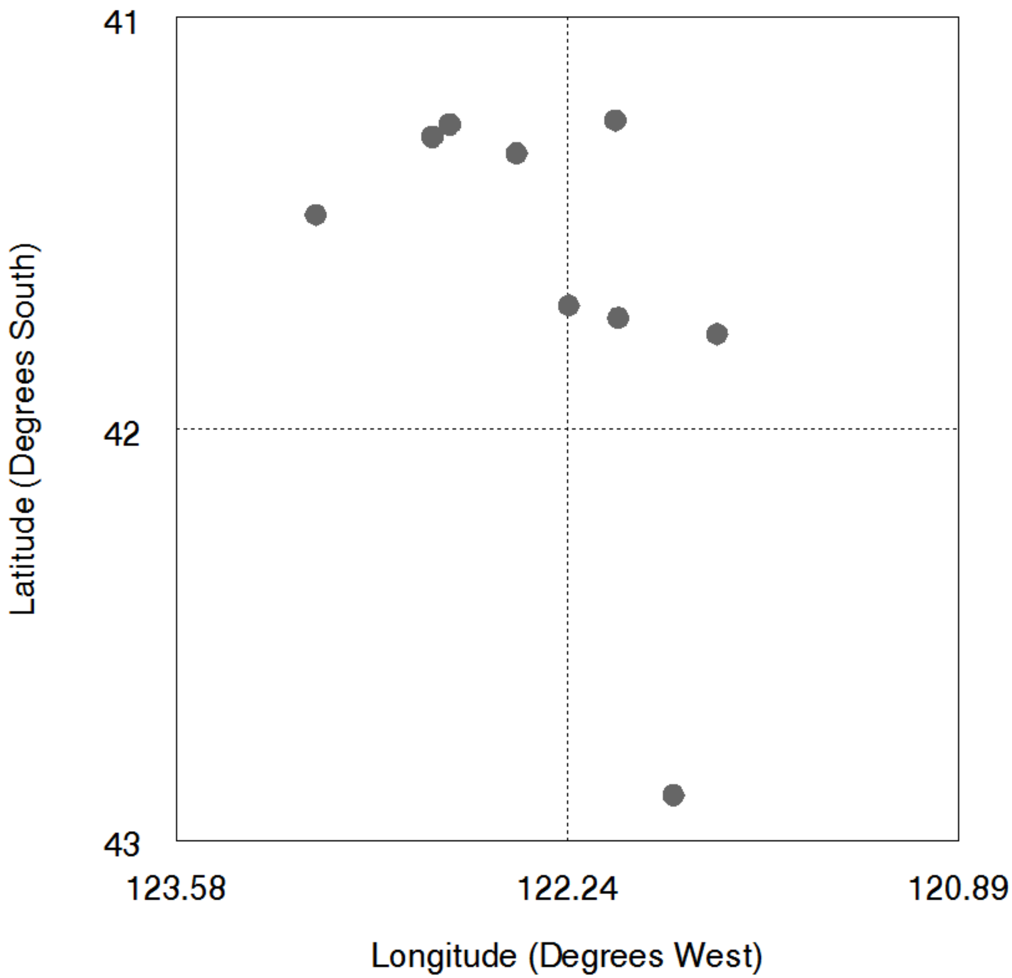
AMV Processing

- Read data and convert direction, speed to u, v components
- Assign observation errors
- Read background fields and interpolate to observation locations
- Perform QC on individual observations
- Bin winds into latitude-longitude "prisms" in 50 mb layers
- Examine obs in a prism layer from a particular satellite, channel, and processing center
  - Superob (average) if criteria met
  - Save superob to innovation vector file if successful
- Assimilate AMV superobs using NAVDAS-AR

Superobbing Rules

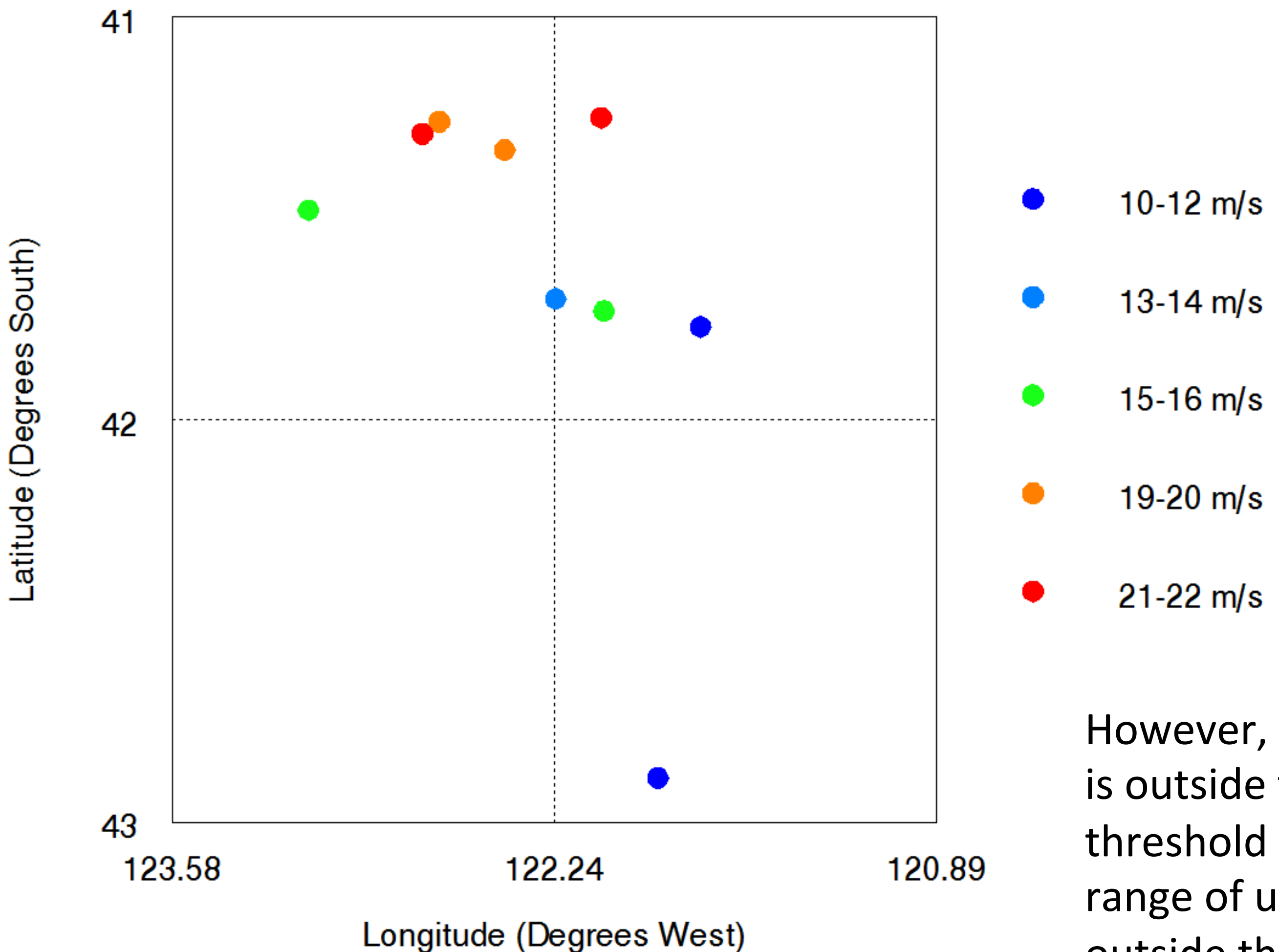
- Winds to be superobbed are required to be:
  - in the same prism and 50 mb layer
  - generated by the same processing center
  - from the same satellite and channel
  - with times within one hour.
- At least two AMV obs are required (except for Meteosat).
- The winds to be superobbed must be within thresholds:
  - Speeds (or speed innovations) within 7 to 14 m/s depending on speed, and
  - Directions (or direction innovations) within 20° or u and v components (or u and v innovations) within 5 m/s.
- One or two outliers can be rejected to meet the thresholds if sufficient obs are present.
- Prism is quartered and superobbing is attempted in each quarter if necessary.
- Superob values are corrected so that the magnitude of the superob wind vector is equal to the mean speed of the obs used to form the superob.

Superob Example



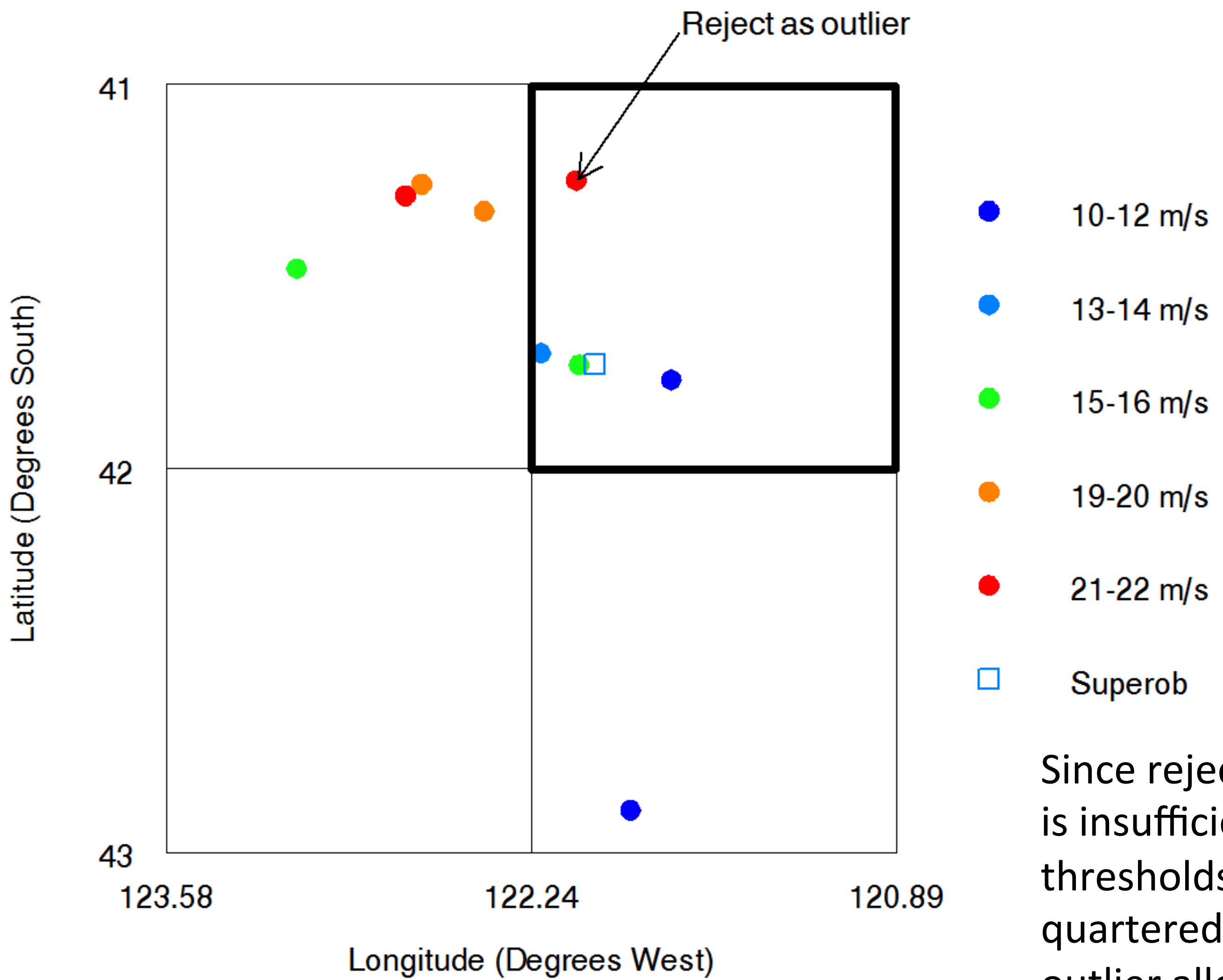
This example shows GOES-11 wind obs from 1722 UTC 31 August 2010 in a particular prism. The directions range from 281° to 296°, within the 20° threshold.

Superob Example



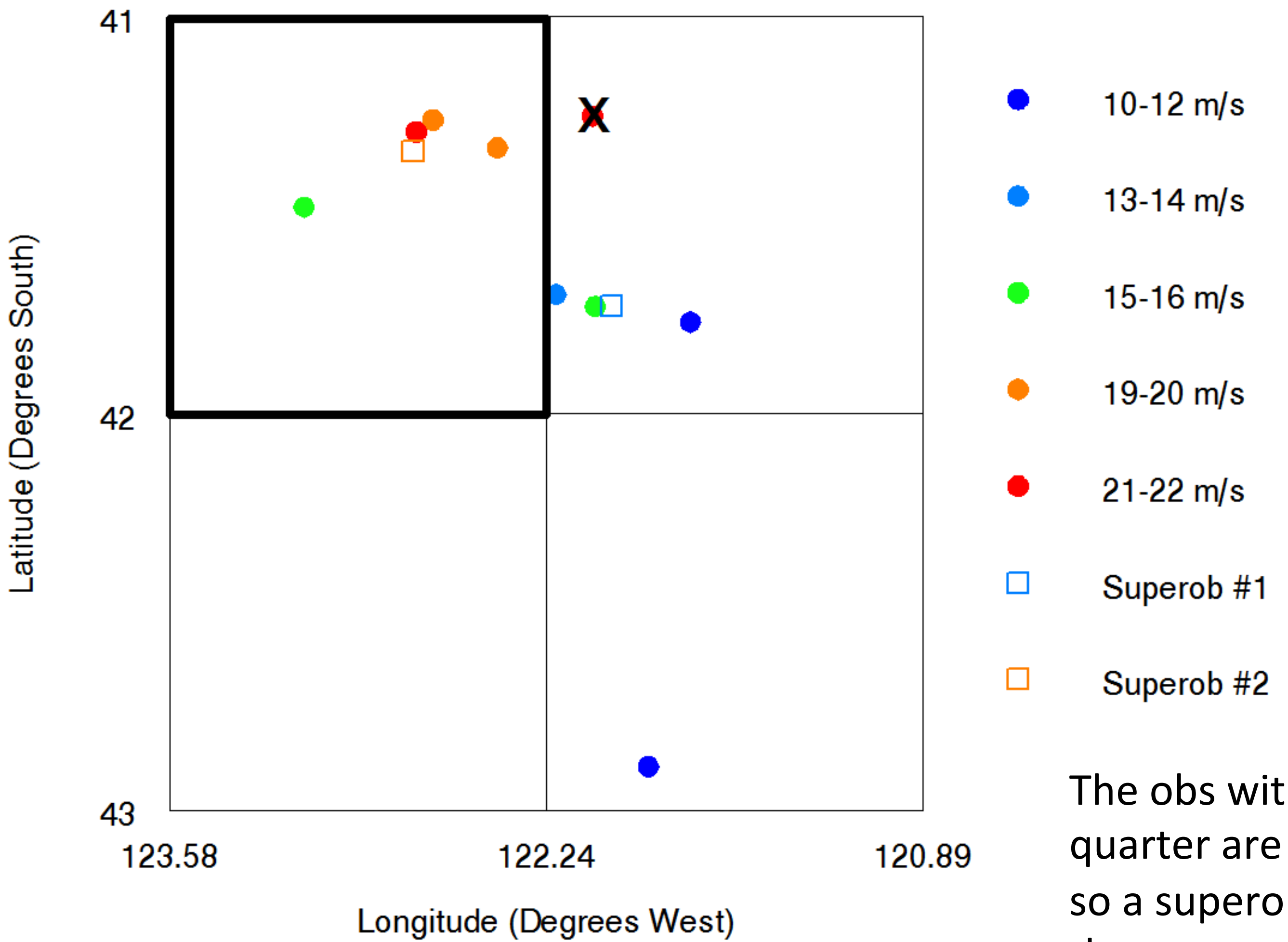
However, the range of speeds is outside the 7.071 m/s threshold (or equivalently, the range of u or v components is outside the 5 m/s threshold).

Superob Example



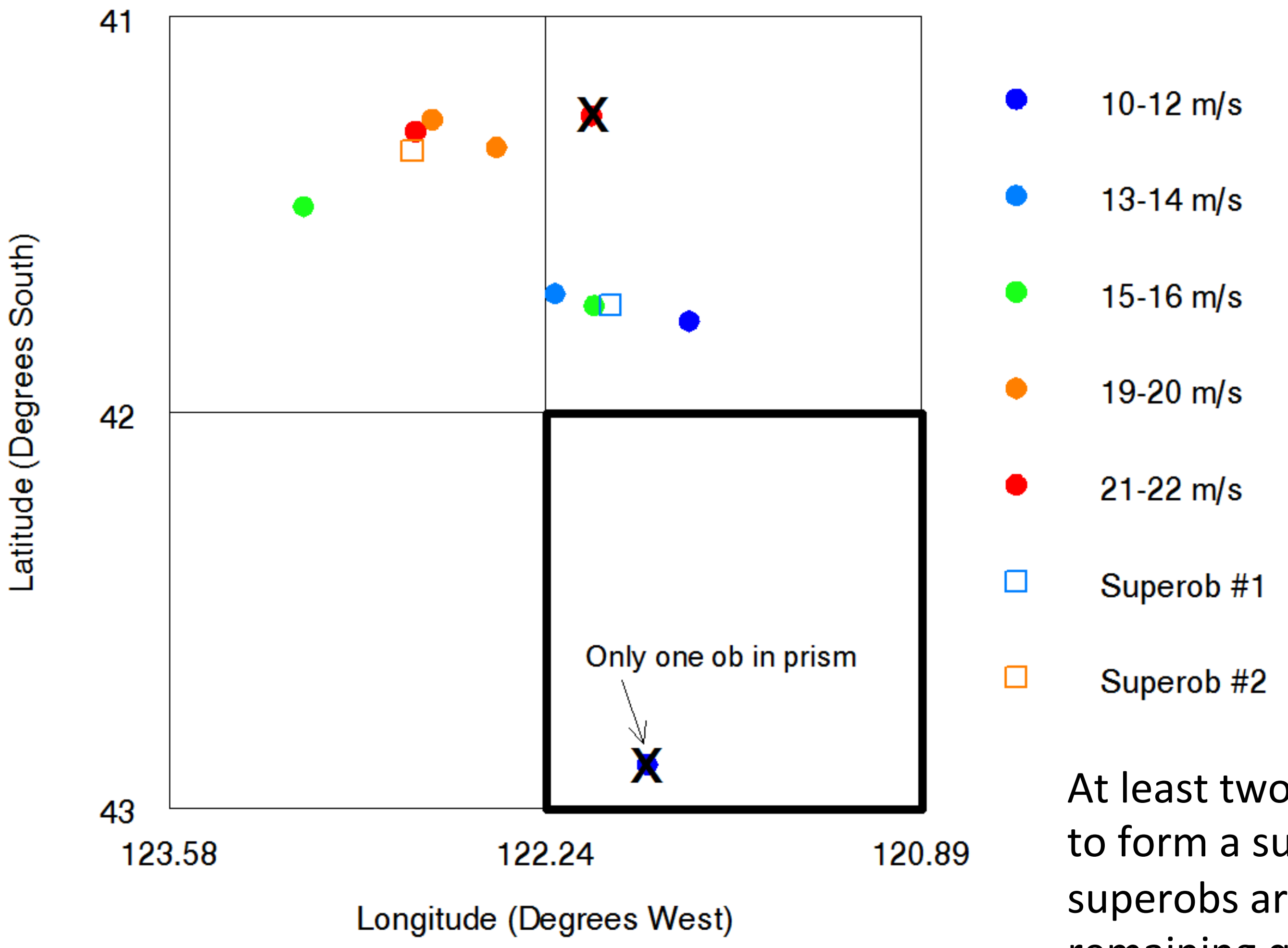
Since rejecting 1 or 2 outliers is insufficient to meet the thresholds, the prism is quartered. Rejecting one outlier allows a superob to be formed in the first quarter.

Superob Example



The obs within the second quarter are within thresholds, so a superob is also formed there.

Superob Example



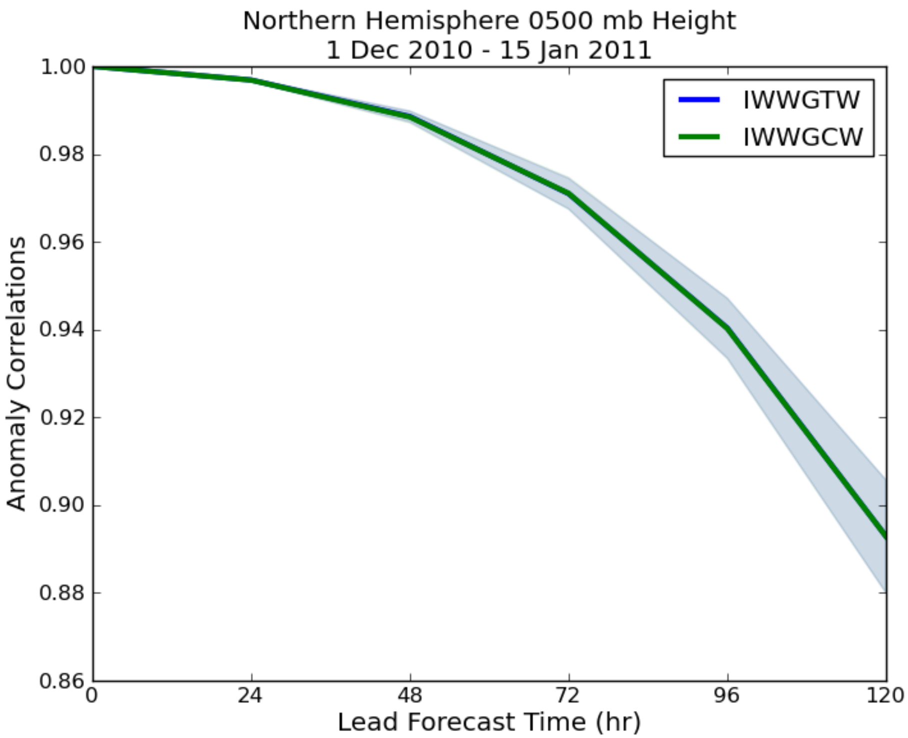
At least two obs are required to form a superob, so no superobs are formed in the remaining quarters.

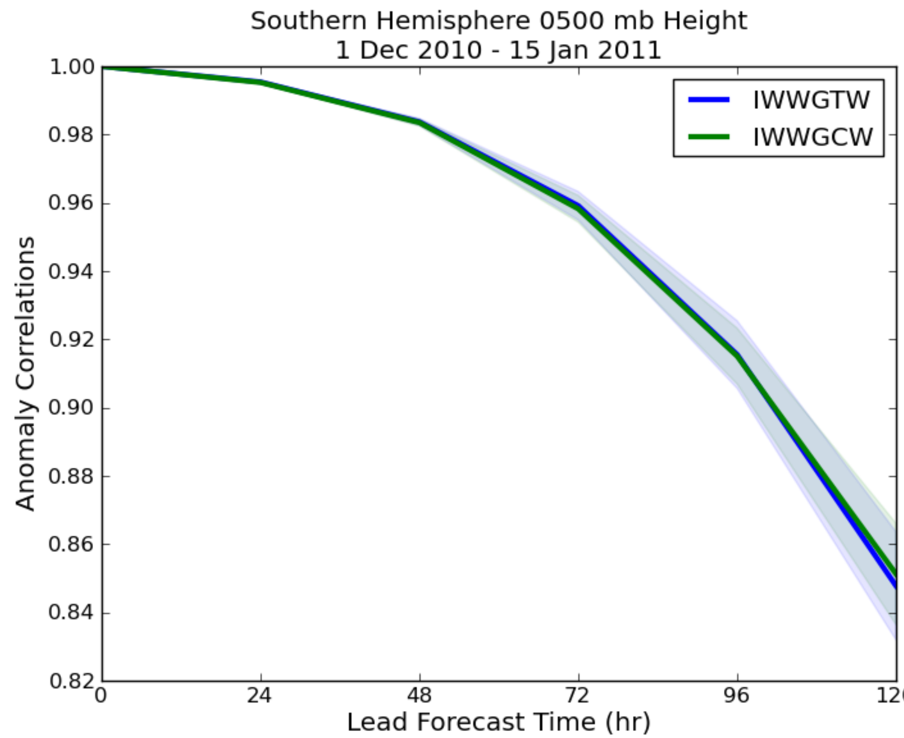
Thinning vs. Superobbing

The goal of this investigation is to compare simple thinning to superobbing without changing the spatial and temporal distribution of observations and without changing the number of observations.

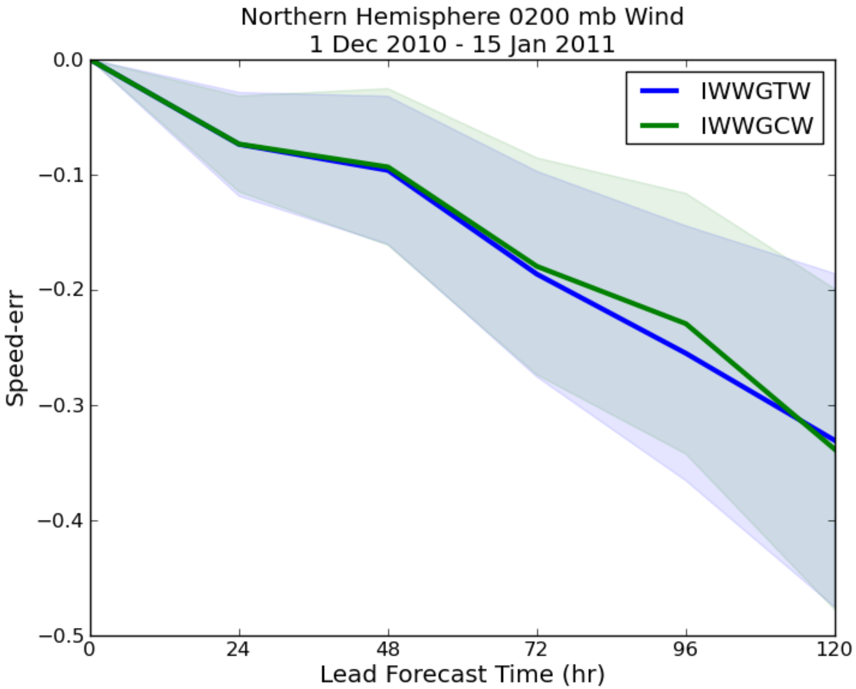
- Superobbing experiment—operational processing as previously described
- Thinning experiment
  - Process AMVs to generate superobs as previously described
  - Replace each superob by the unrejected observation closest in space to the superob, selected from the observations that were used to form the superob

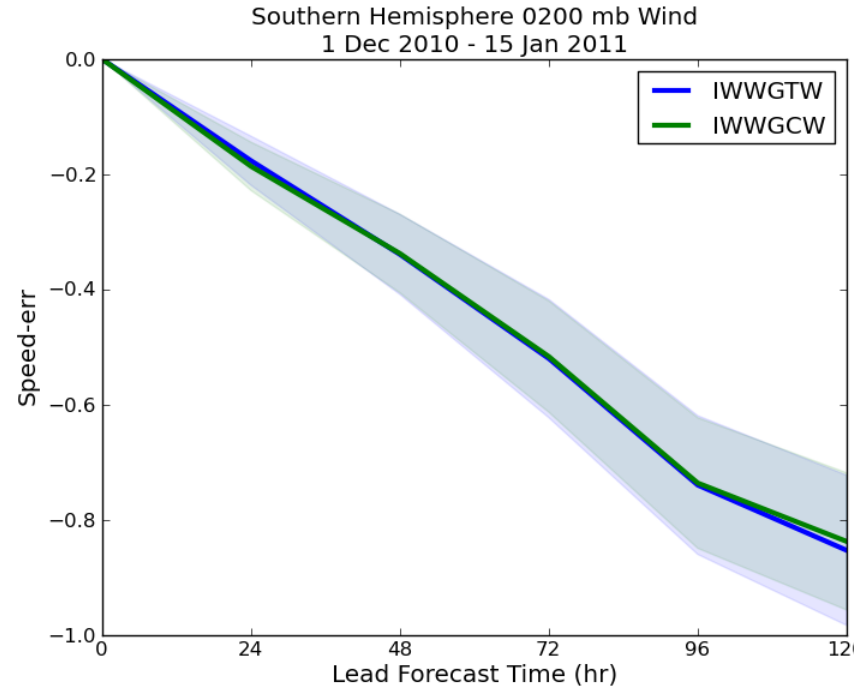
Experiment Results

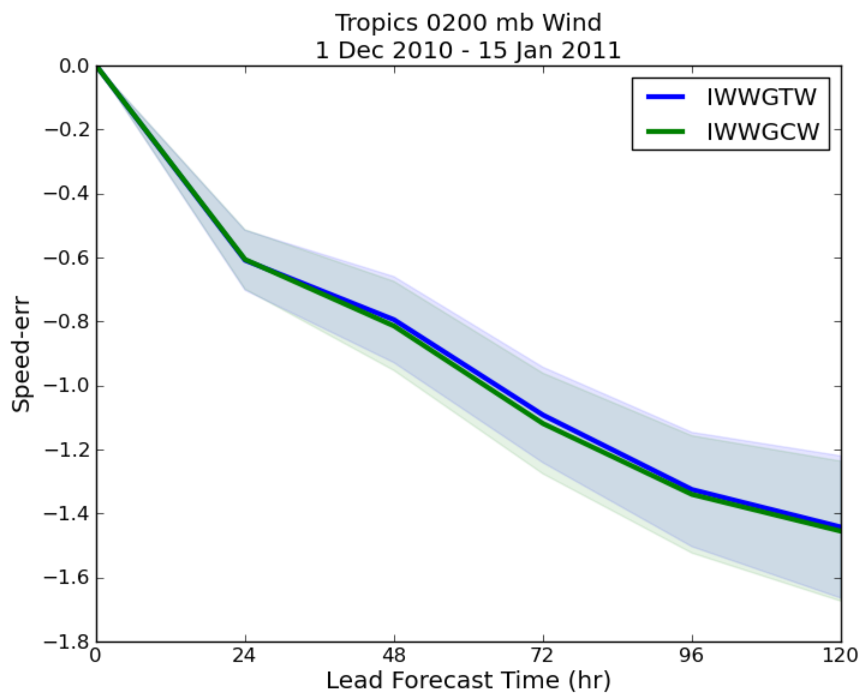




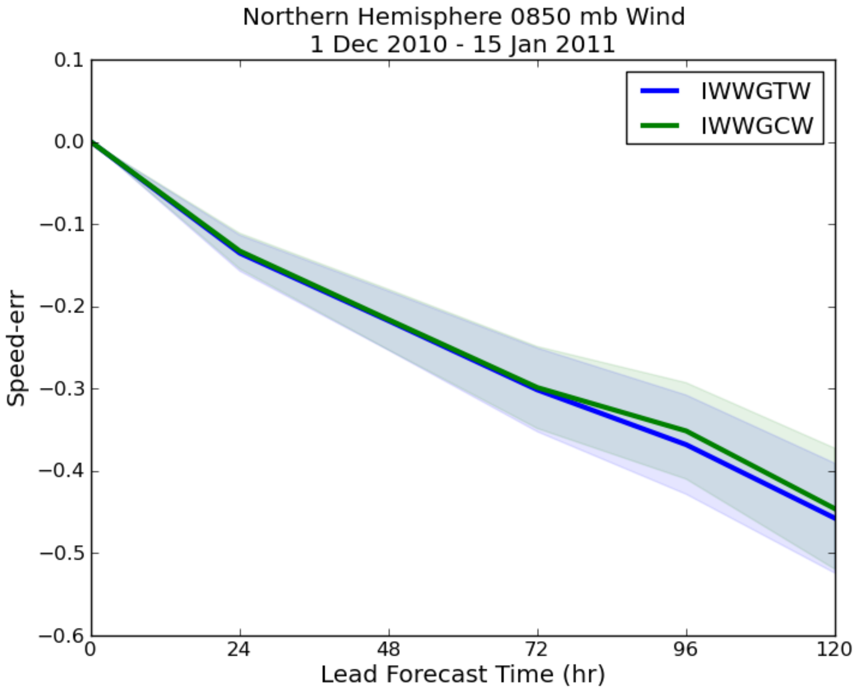
Results are comparable in terms of 500 mb anomaly correlation, with superobbing (green) having a slight advantage at longer forecast ranges in the Southern Hemisphere.

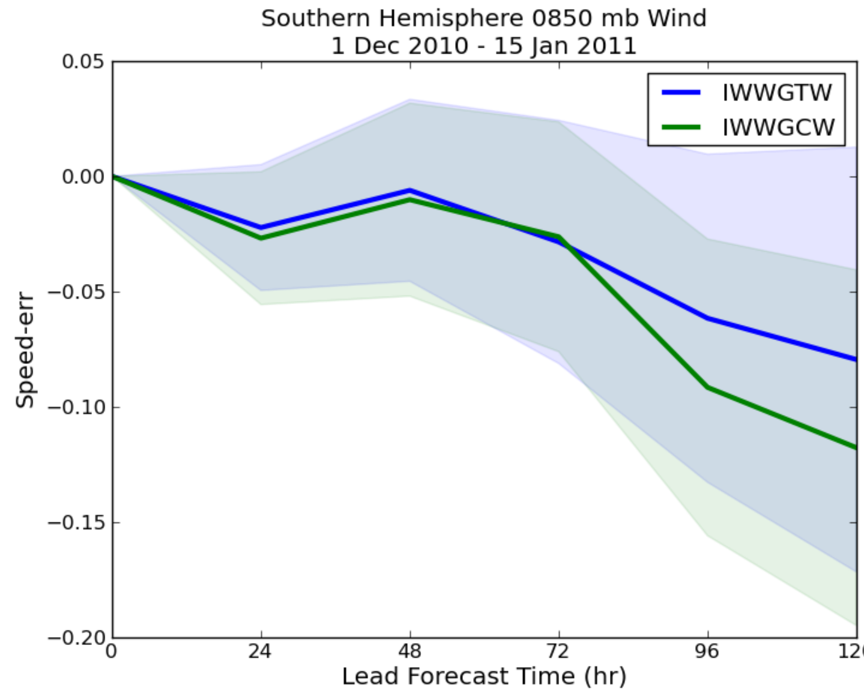


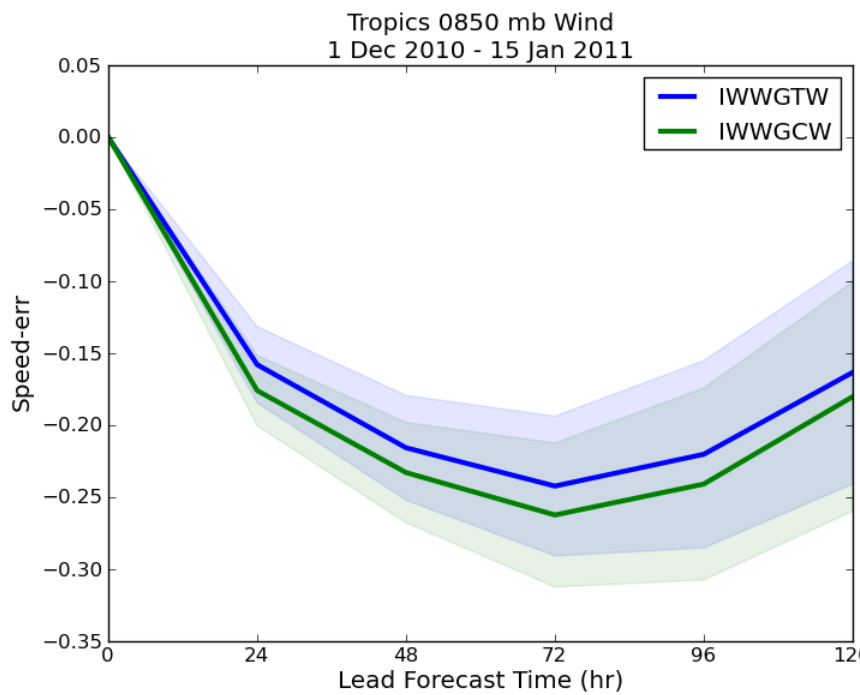




The 200mb speed error is slightly less negative for superobbing (green) compared to thinning (blue) except in the tropics where thinning is slightly better.







The 850mb speed error is slightly less negative for superobbing (green) compared to thinning (blue) in the Northern Hemisphere, but thinning is slightly better in the tropics and Southern Hemisphere.

Questions?

Supplemental Slides

Geostationary and Polar-orbiting Atmospheric Motion Vectors

Imagery combined by selecting the coldest pixel

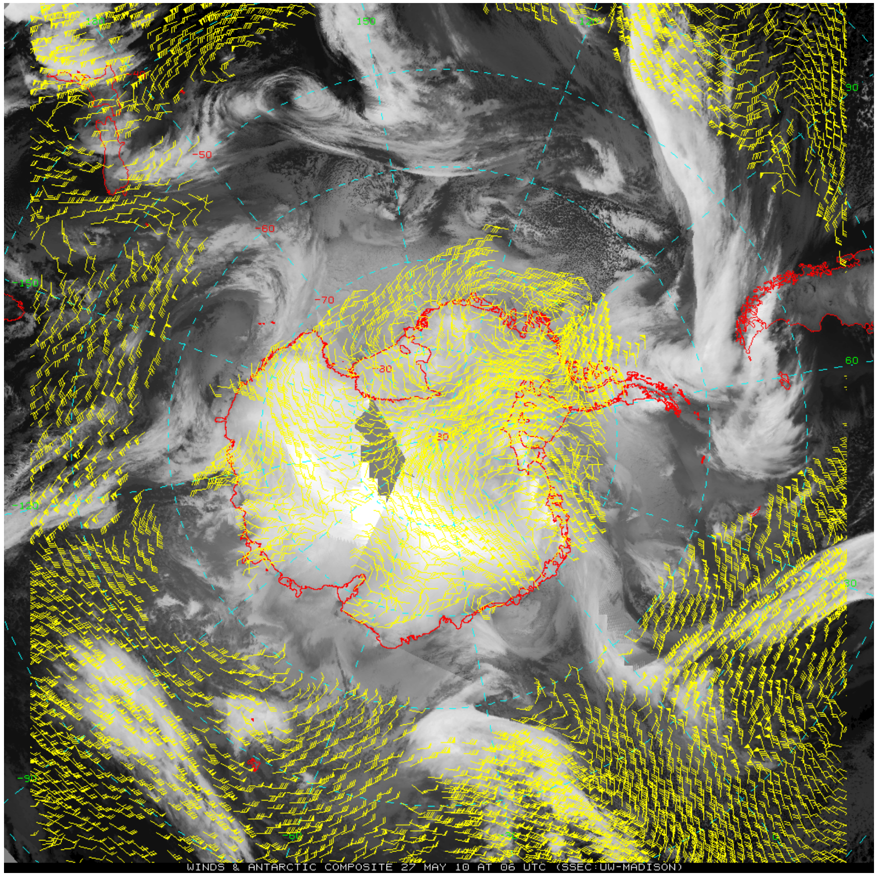
*Reduces limb darkening

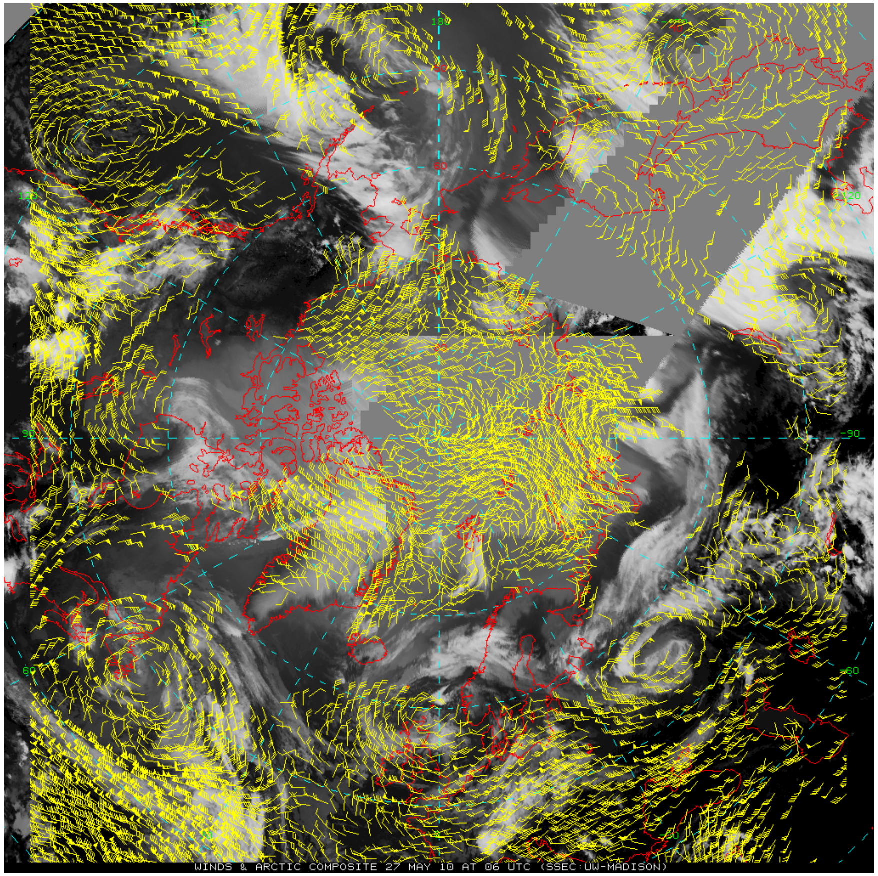
*Smooth transition between satellites

*Originally intended for visualization

*Geostationary: GOES, Meteosat, FY-2, MTSAT

*Polar-orbiting: *NOAA, MODIS, Metop

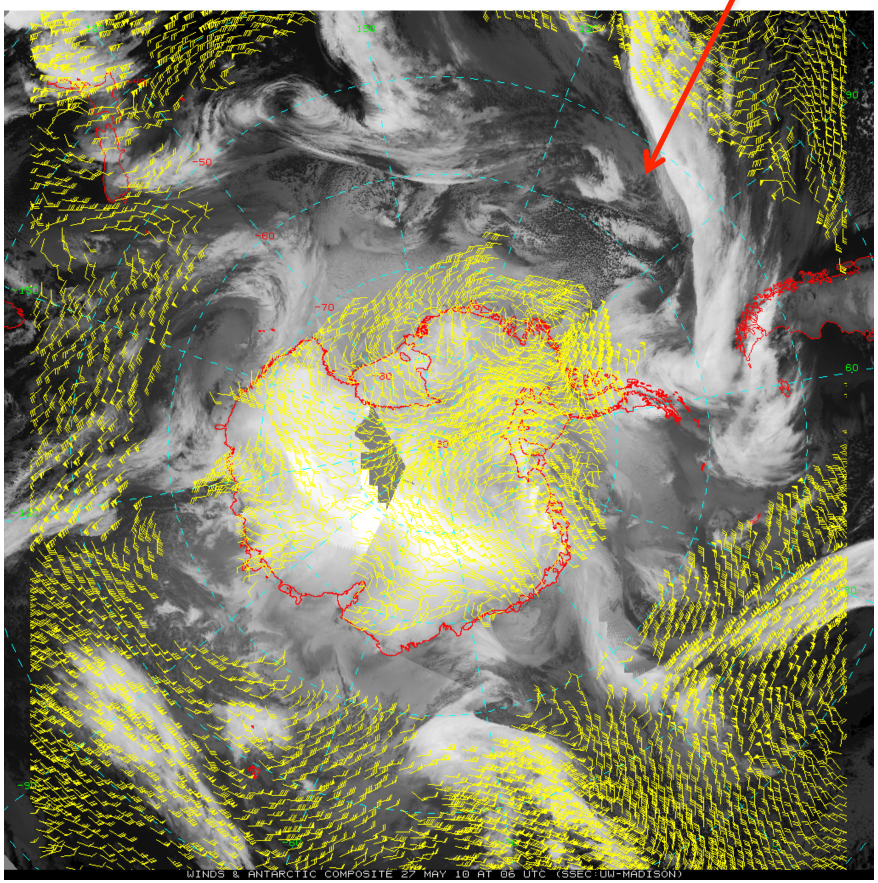


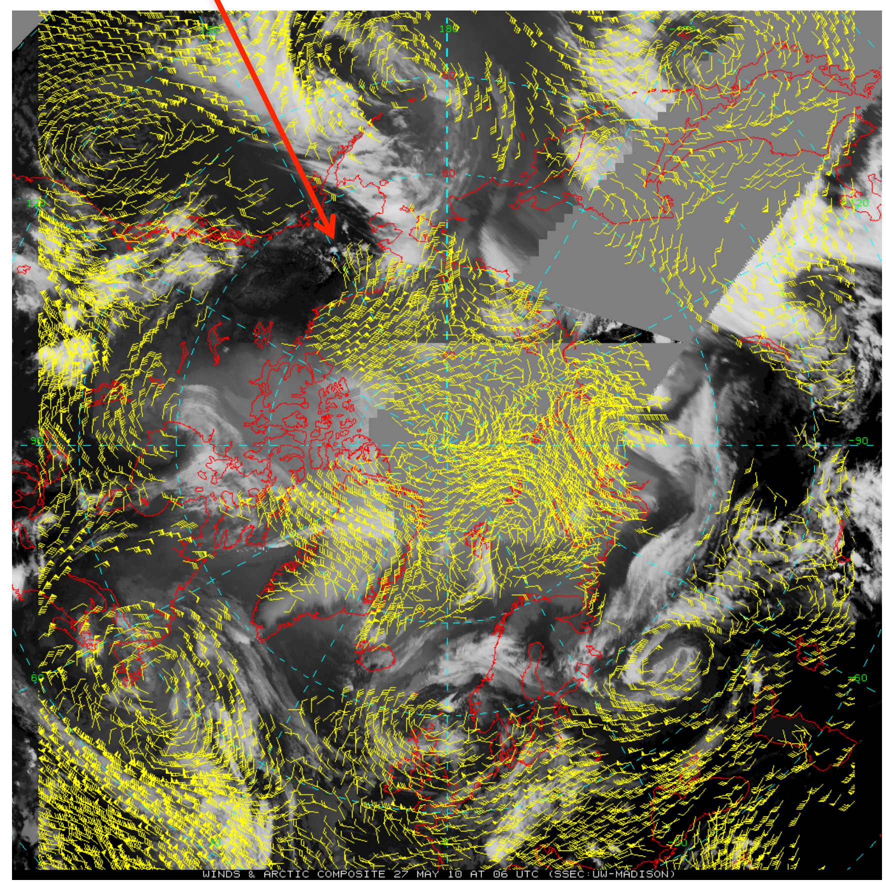


Geostationary and Polar-orbiting Atmospheric Motion Vectors

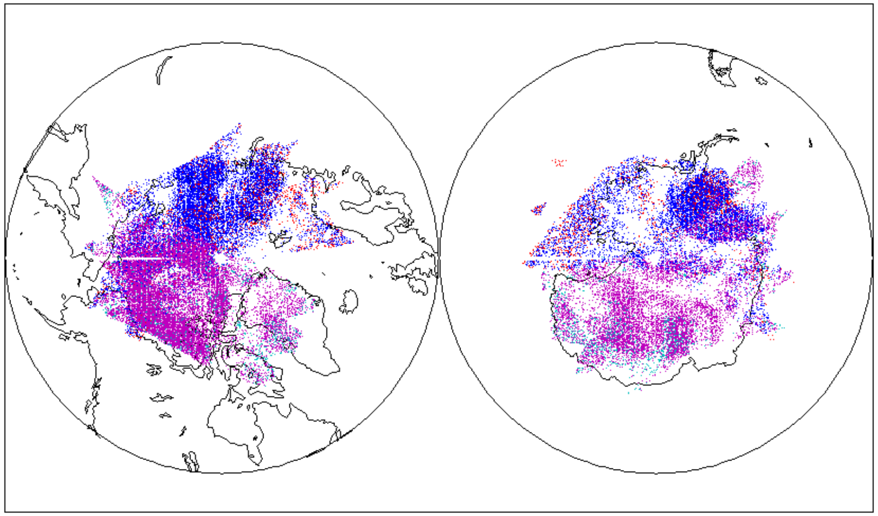
Missing winds – gap in coverage

- NWP centers: the polar jet stream can be located in this gap; improper model initialization can lead to errors in the forecasts.
- CIMSS research: the addition of the wind information is important in this region.

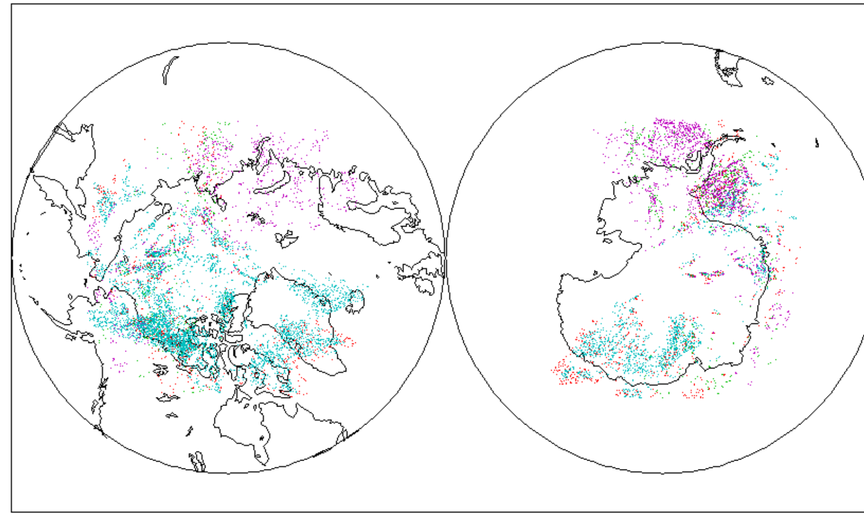




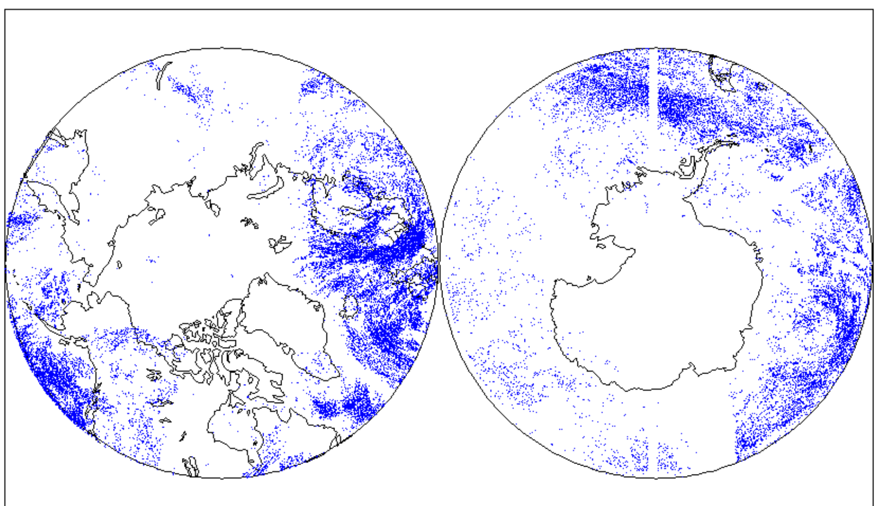
Data Overview—CIMSS/UW Polar/LeoGeo Winds



MODIS winds



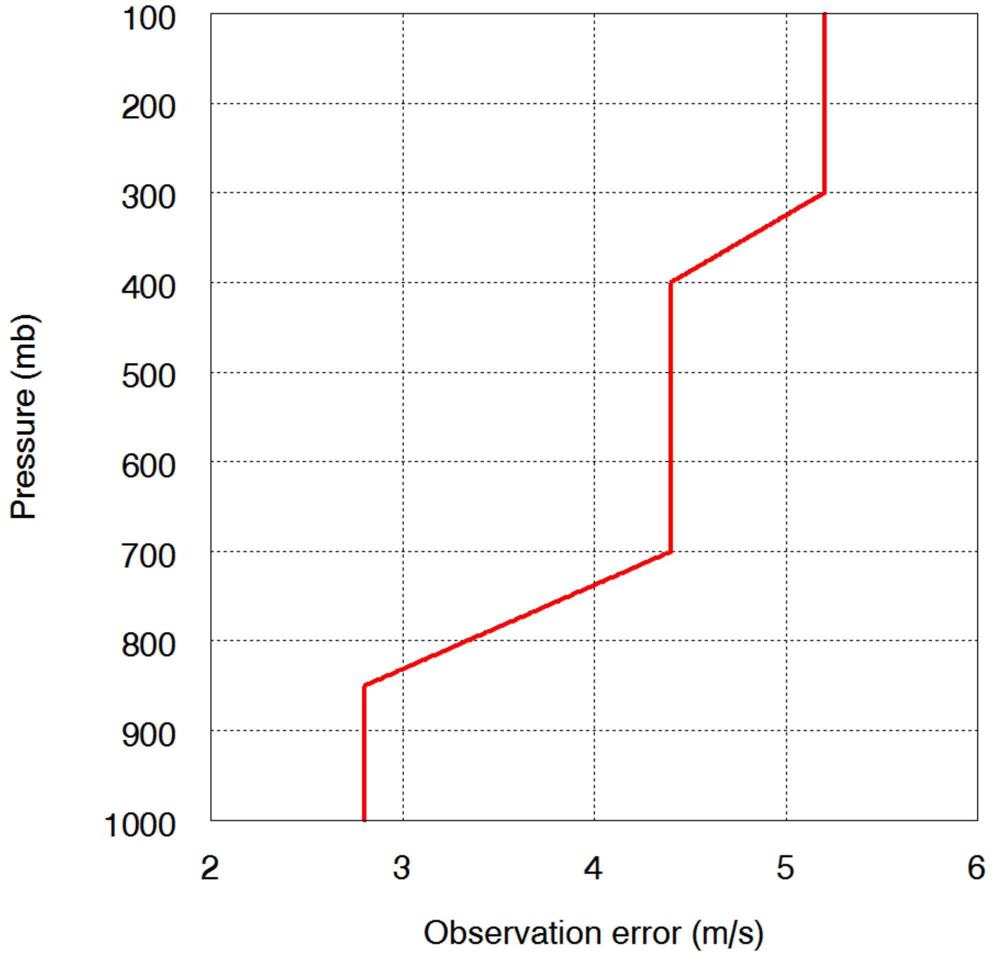
AVHRR winds



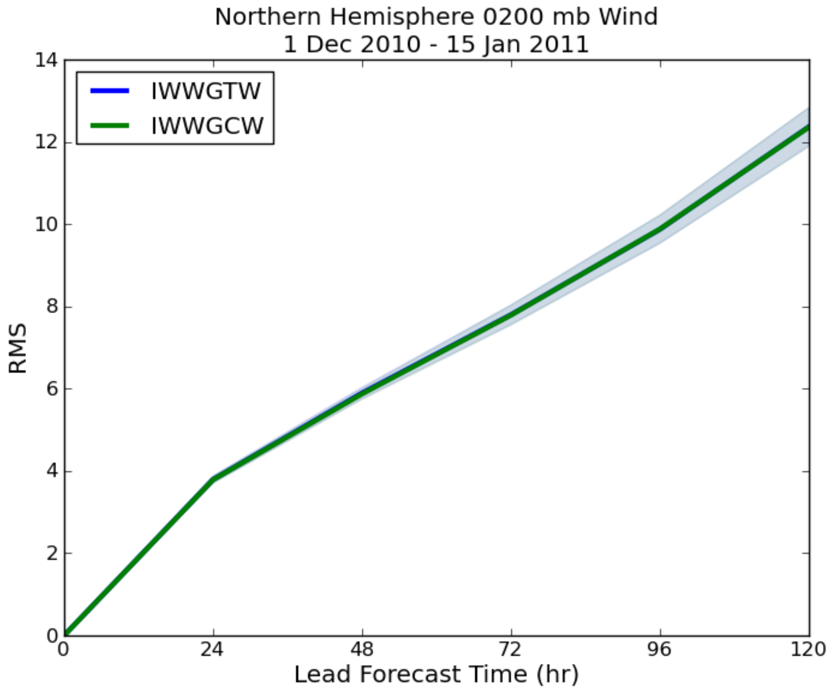
LeoGeo Winds

- MODIS and AVHRR winds are derived from images from successive overlapping passes of a given satellite.
- LeoGeo winds are derived from successive composite images made from geostationary and polar orbiter data from multiple satellites.
- LeoGeo winds “fill the gap” in coverage between geostationary and polar AMVs.

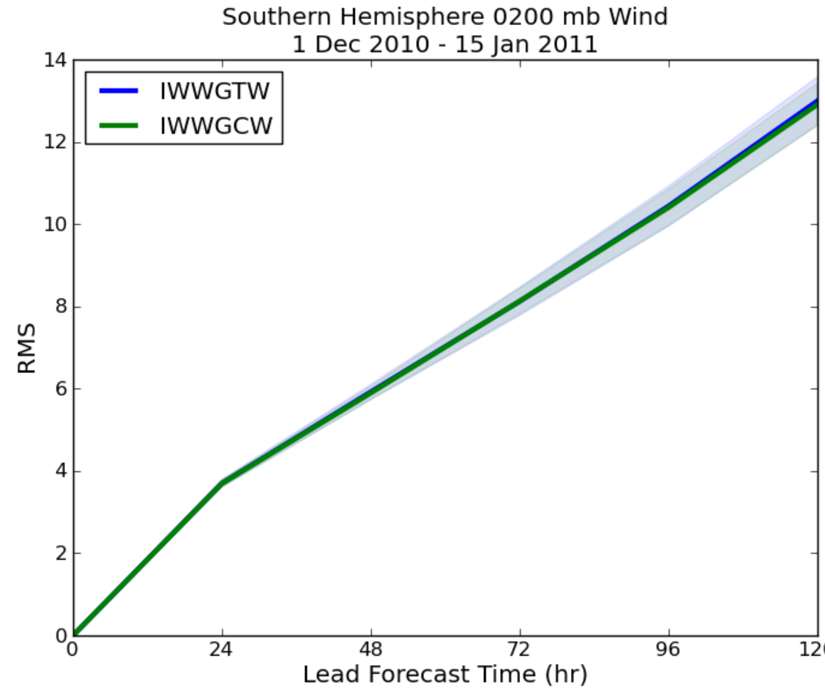
AMV Observation Errors for u and v Components



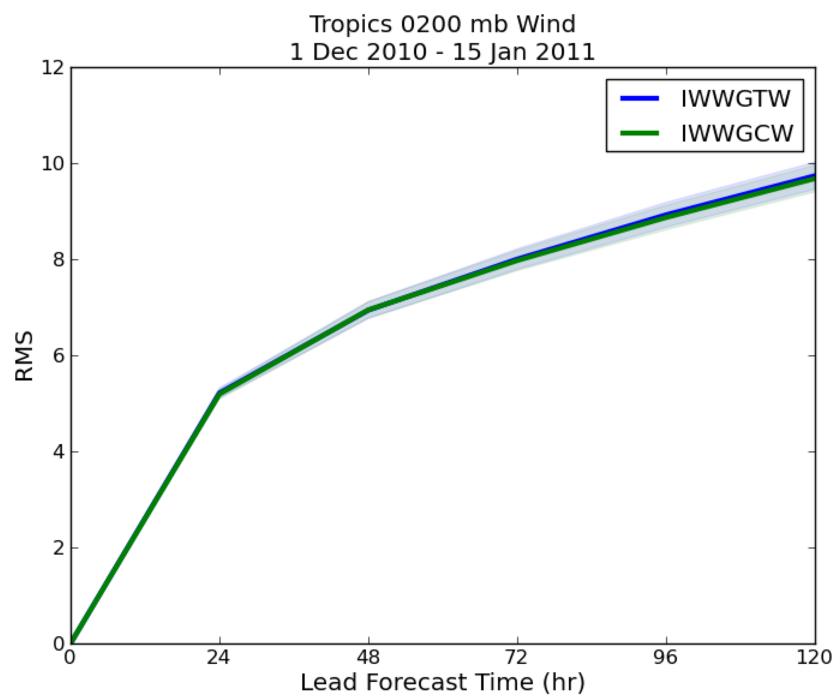
Ob errors are specified at mandatory pressure levels and interpolated linearly in pressure where necessary.



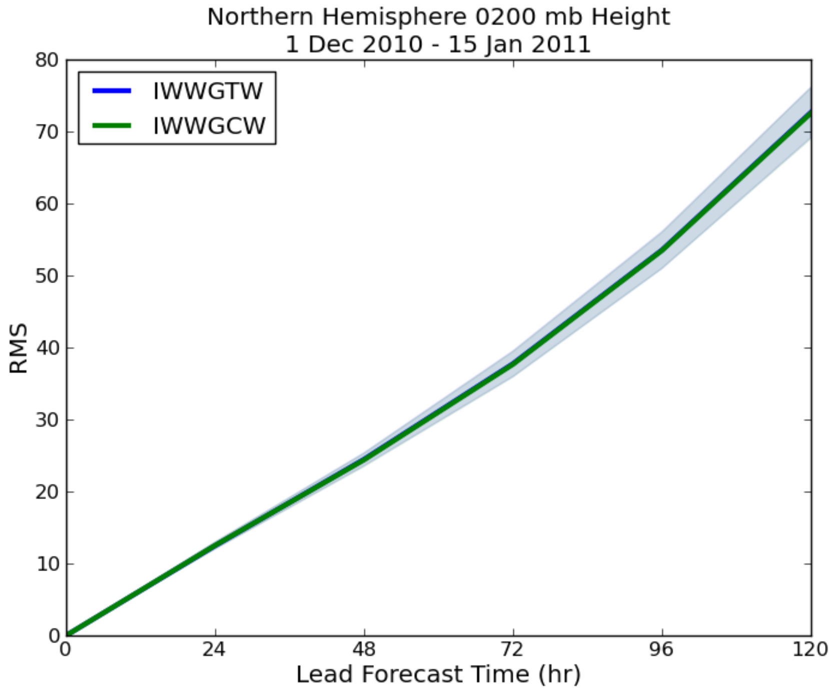
Northern Hemisphere 0200 mb Wind
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
Lead Forecast Time (hr)
0
24
48
72
96
120
2
4
6
8
10
12
14

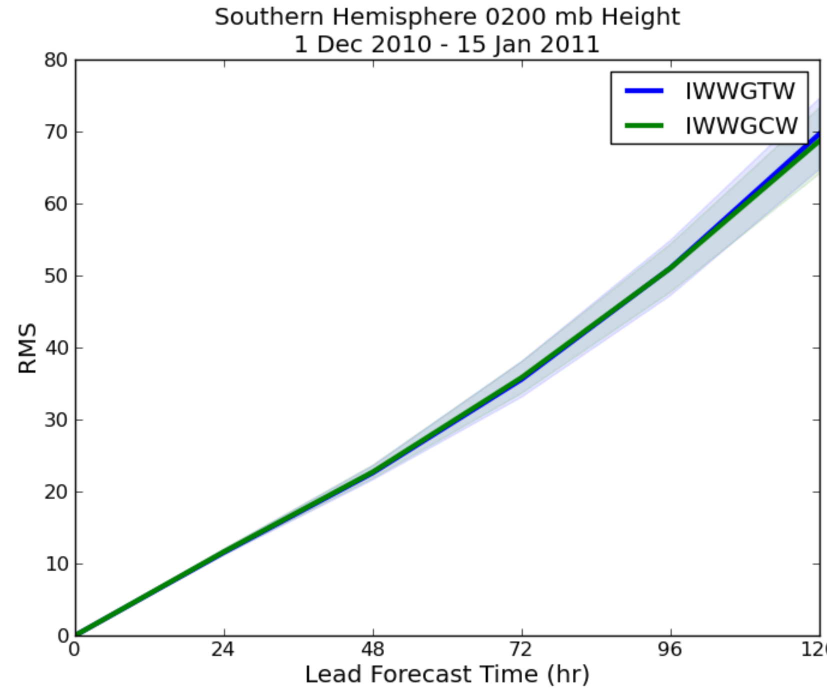


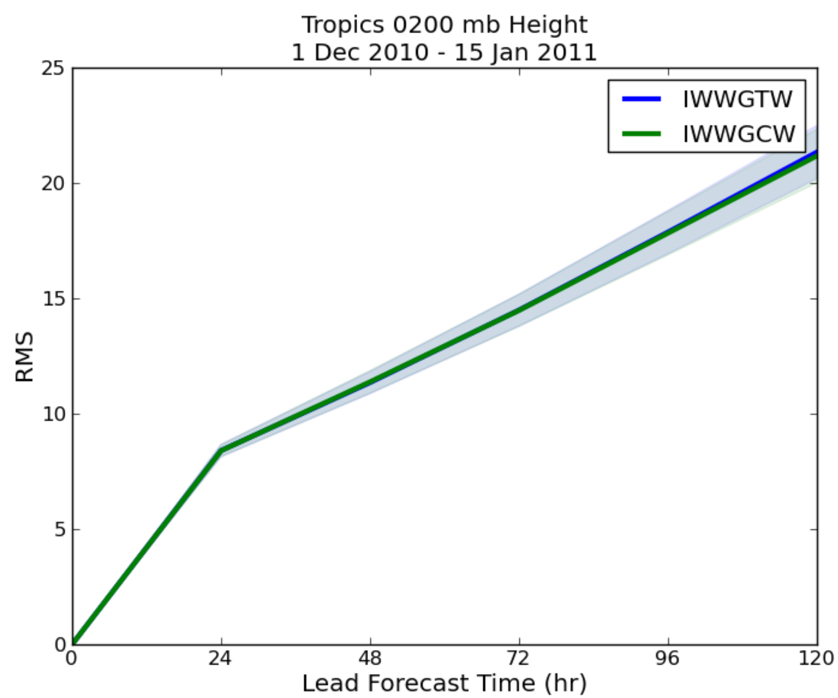
Southern Hemisphere 0200 mb Wind
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
Lead Forecast Time (hr)
0
24
48
72
96
120
2
4
6
8
10
12
14

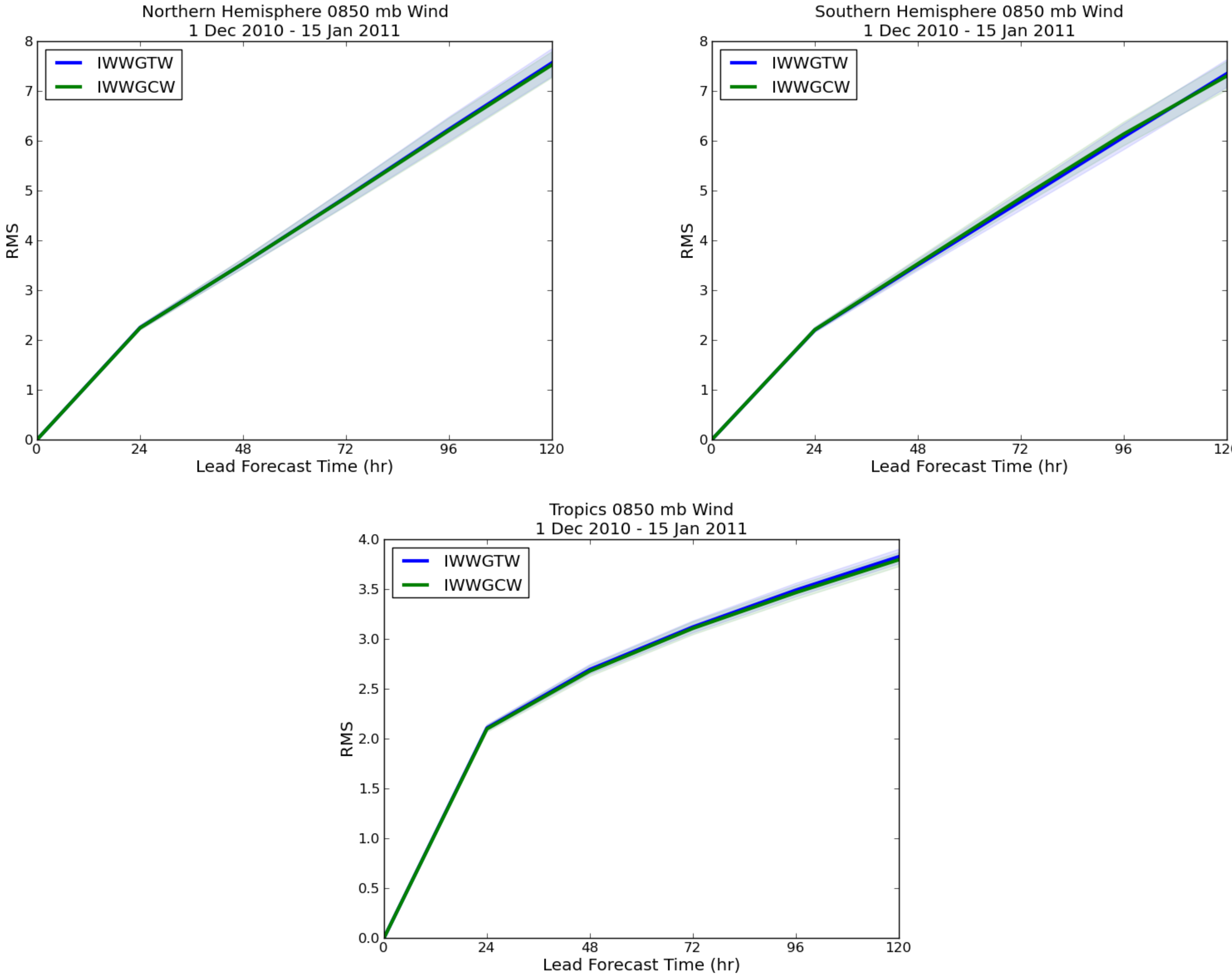


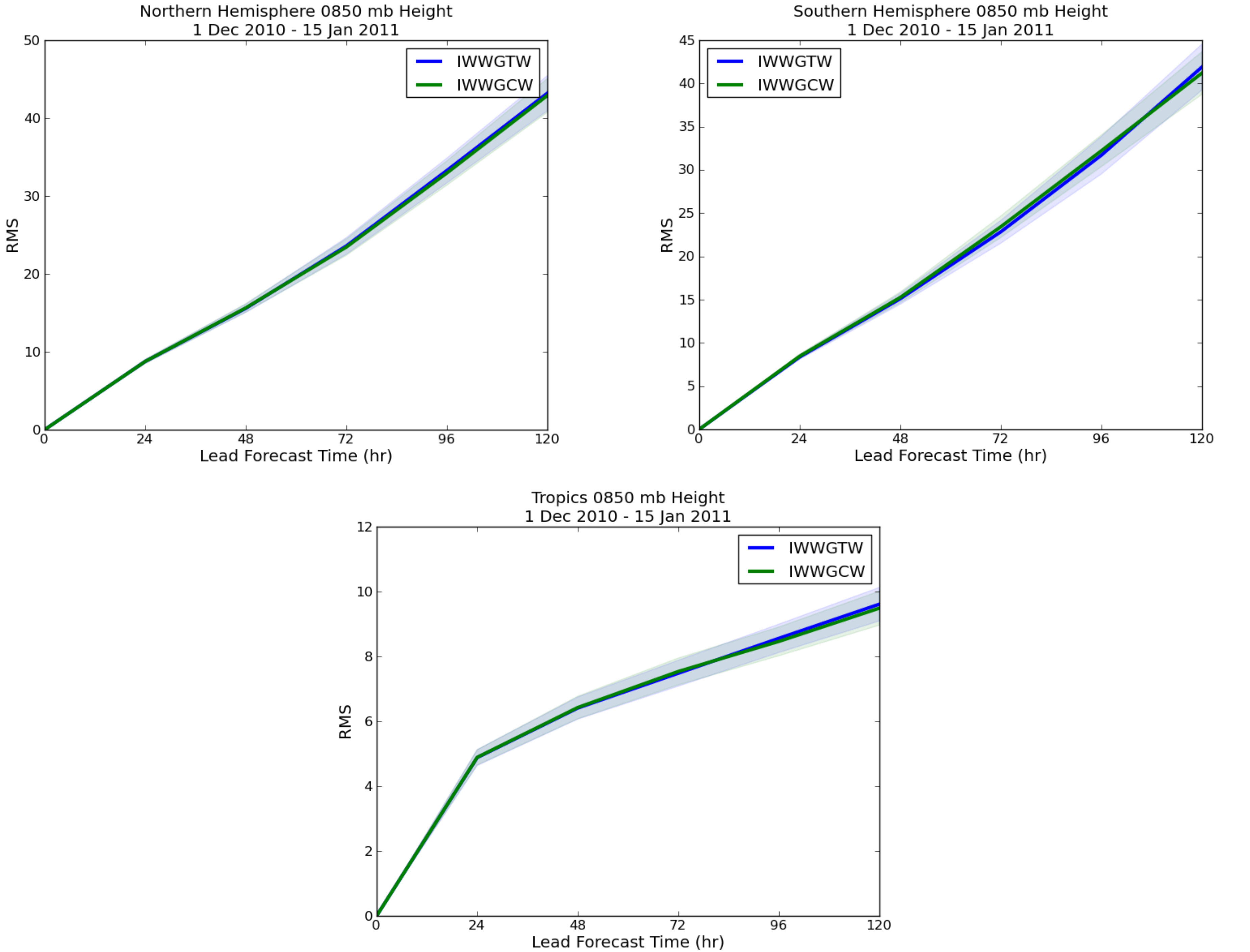
Tropics 0200 mb Wind
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
Lead Forecast Time (hr)
0
24
48
72
96
120
2
4
6
8
10
12


Northern Hemisphere 0200 mb Height
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
0
10
20
30
40
50
60
70
80
0
24
48
72
96
120
Lead Forecast Time (hr)


Southern Hemisphere 0200 mb Height
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
0
10
20
30
40
50
60
70
80
0
24
48
72
96
120
Lead Forecast Time (hr)


Tropics 0200 mb Height
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
0
5
10
15
20
25
0
24
48
72
96
120
Lead Forecast Time (hr)


Northern Hemisphere 0850 mb Wind
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
0
1
2
3
4
5
6
7
8
0
24
48
72
96
120
Lead Forecast Time (hr)
Southern Hemisphere 0850 mb Wind
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
0
1
2
3
4
5
6
7
8
0
24
48
72
96
120
Lead Forecast Time (hr)
Tropics 0850 mb Wind
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0
24
48
72
96
120
Lead Forecast Time (hr)


Northern Hemisphere 0850 mb Height
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
0
10
20
30
40
50
0
24
48
72
96
120
Lead Forecast Time (hr)
Southern Hemisphere 0850 mb Height
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
0
5
10
15
20
25
30
35
40
45
0
24
48
72
96
120
Lead Forecast Time (hr)
Tropics 0850 mb Height
1 Dec 2010 - 15 Jan 2011
IWWGTW
IWWGCW
RMS
0
2
4
6
8
10
12
0
24
48
72
96
120
Lead Forecast Time (hr)