Superobbing vs. Thinning Atmospheric Motion Vectors: An evaluation of Methods Used at FNMOC and ECMWF

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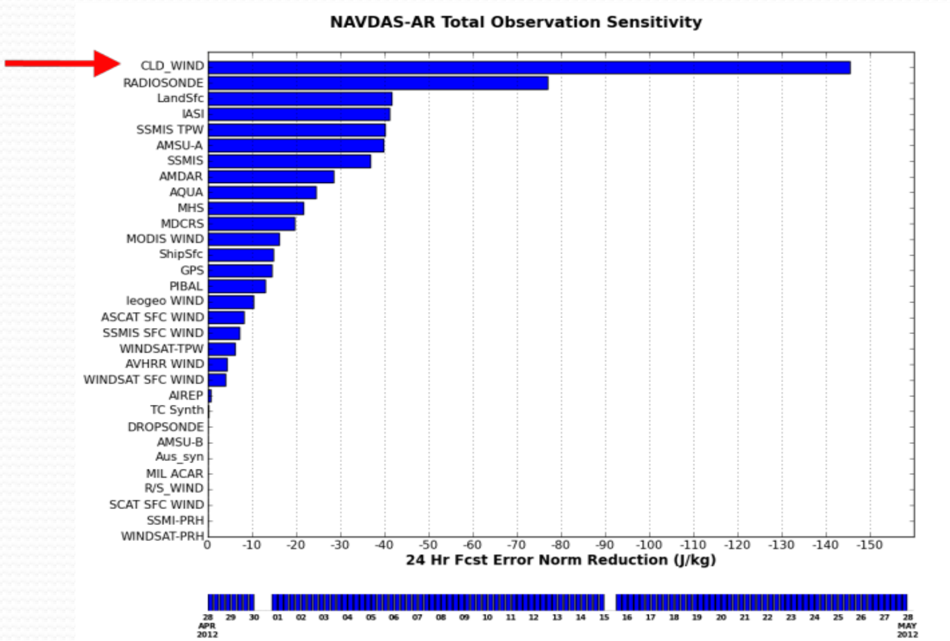
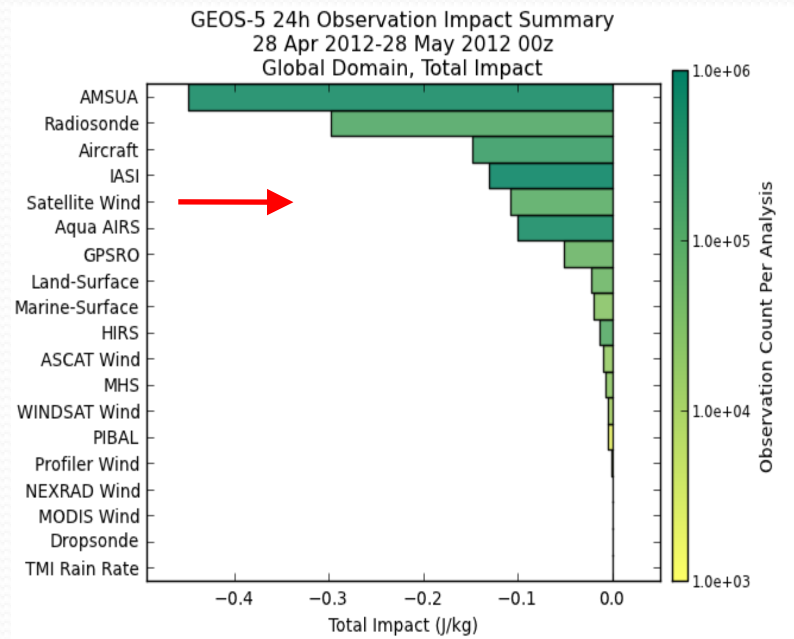
Ninth Annual Symposium on Future Operational Environmental Satellite Systems

FNMOC and GMAO Observation Impact Monitoring

Current Operations





http://www.nrlmry.navy.mil/metoc/ar_monitor/

http://gmao.gsfc.nasa.gov/products/forecasts/systems/fp/obs_impact/

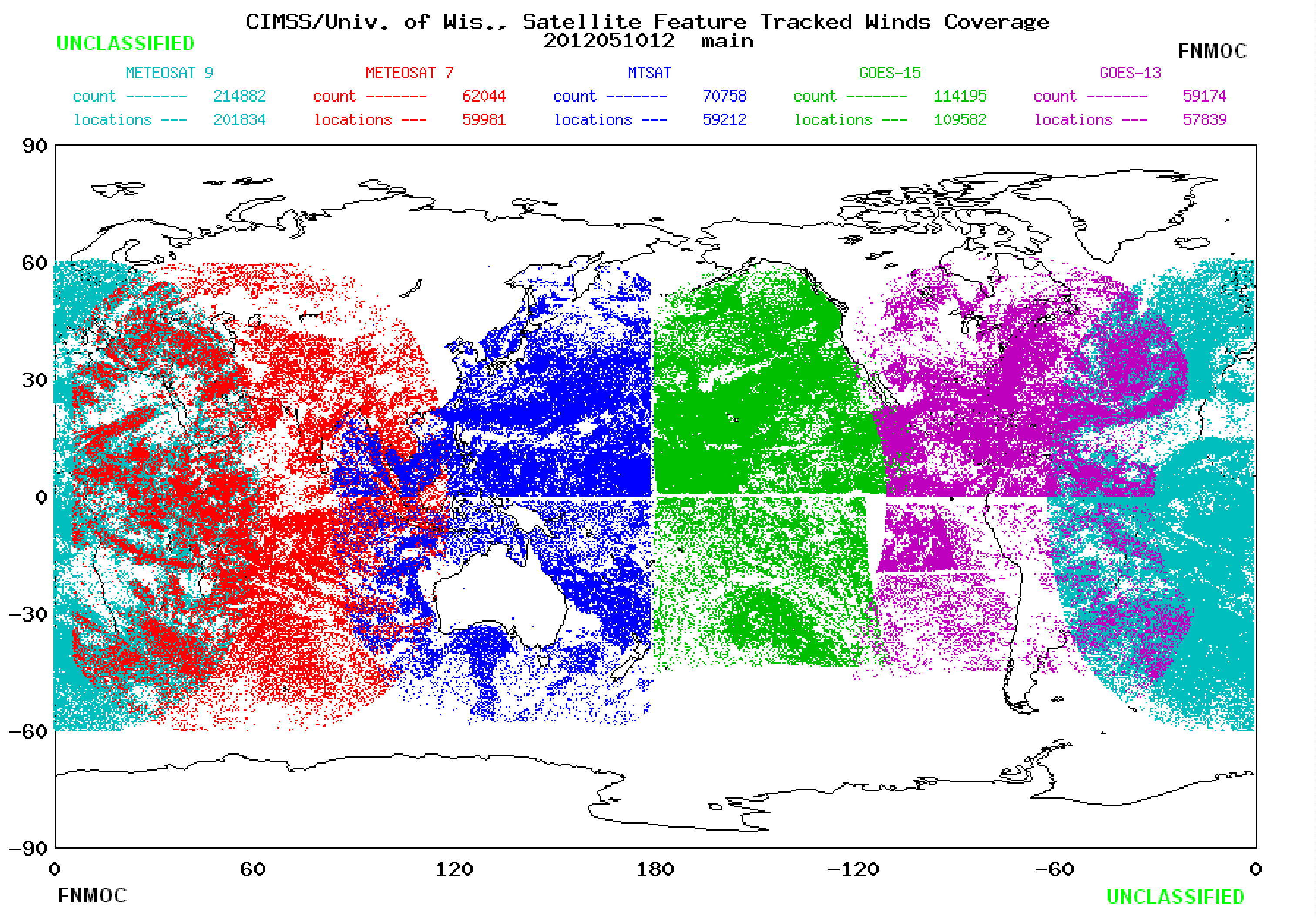
→ Much larger relative impact of AMVs in Navy system

Motivation

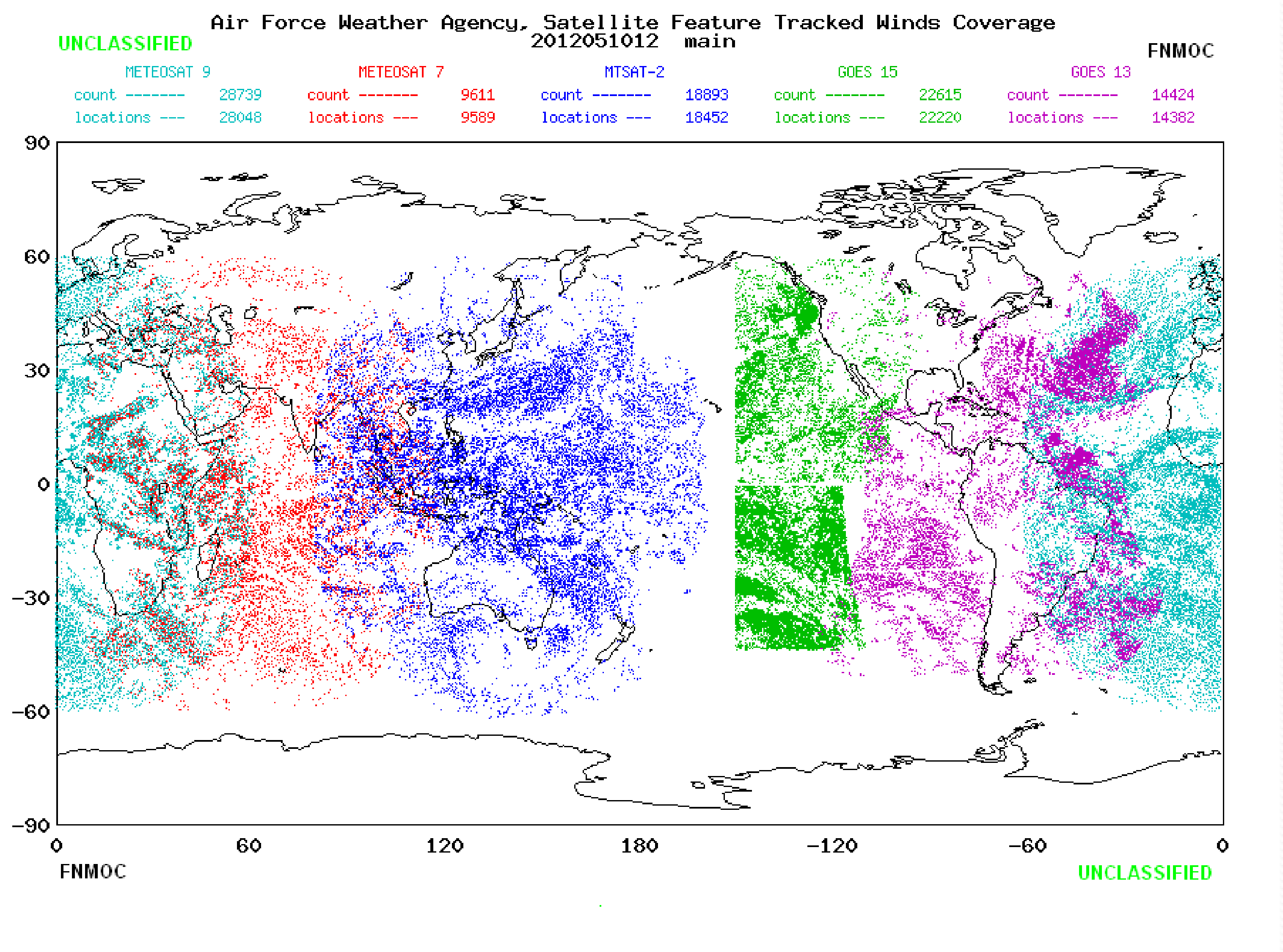
Why does NRL/FNMOC appear to obtain more benefit from AMVs than other NWP centers?

- Superobbing vs. thinning
- Assimilating more winds
  - Assimilating geostationary winds from NESDIS/EUMETSAT/JMA and from CIMSS/AFWA—two datasets for each satellite
  - Making separate superobs for each processing center, satellite, and channel
  - Assimilating hourly winds where available
- Assimilating fewer satellite radiance obs with less impact

Data Overview—CIMSS/UW Winds

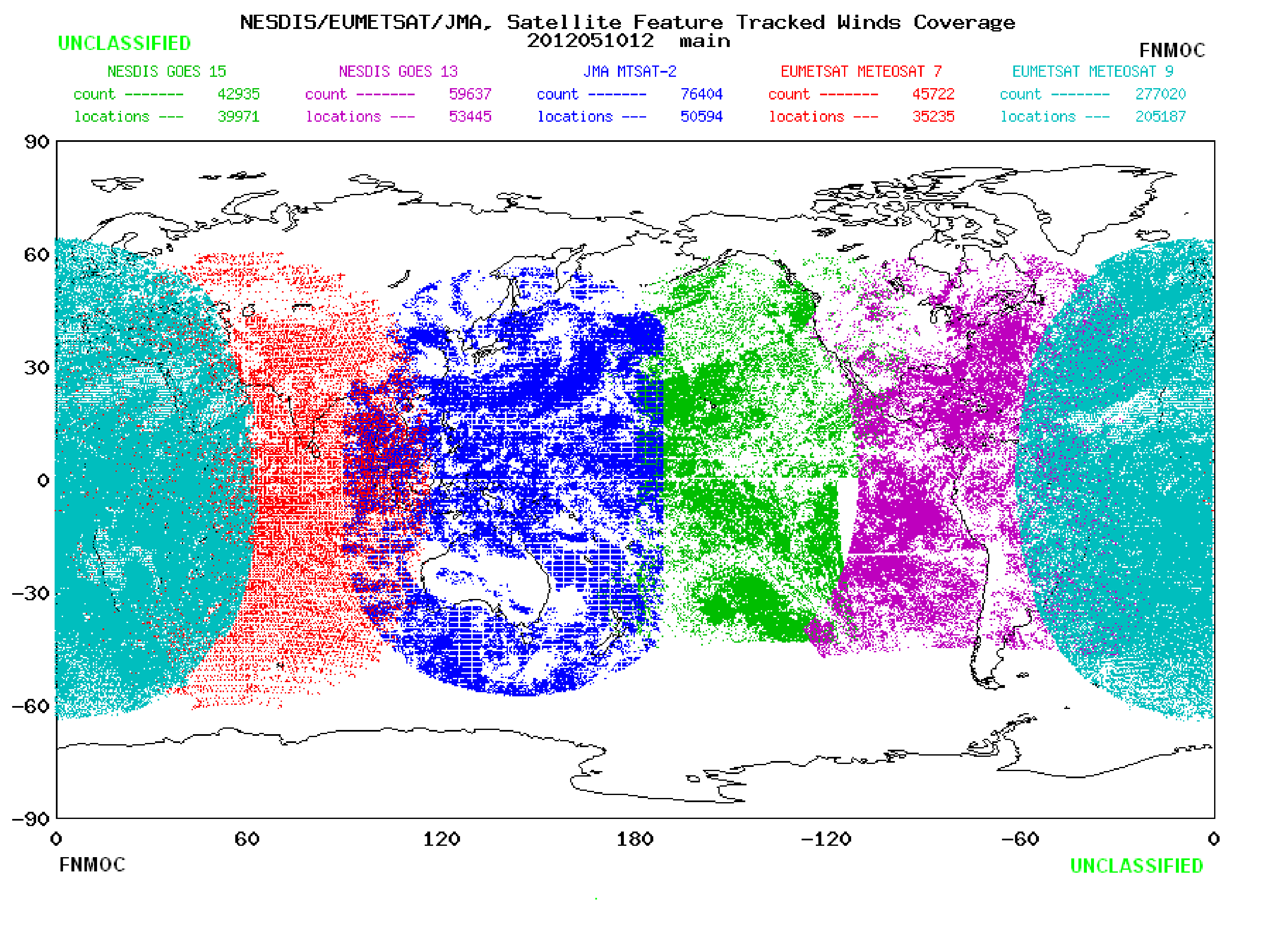


AFWA Winds

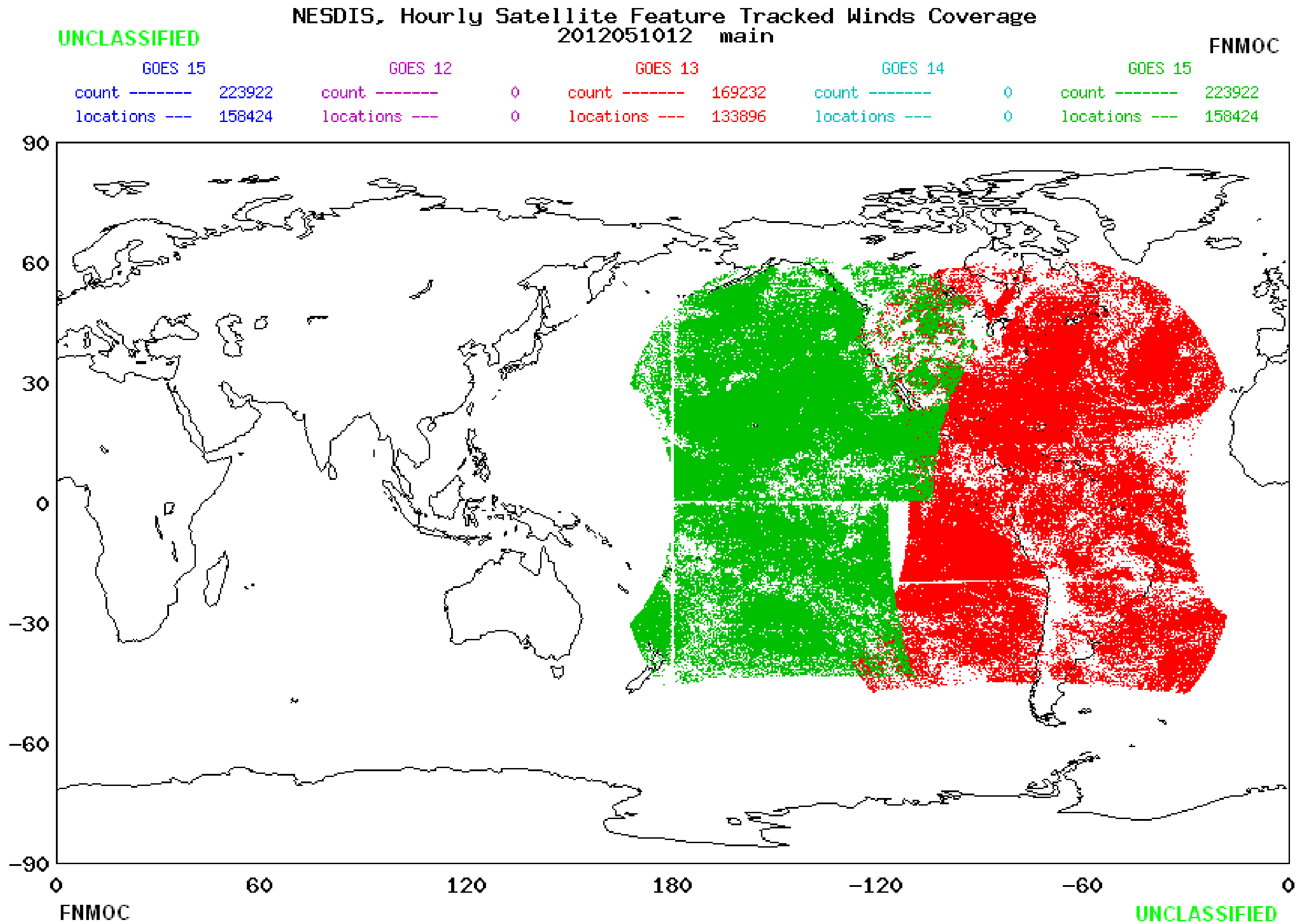


Air Force Weather Agency, Satellite Feature Tracked Winds Coverage
2012051012 main
UNCLASSIFIED
FNMOC
METEOSAT 9
count ------- 28739
locations --- 28048
METEOSAT 7
count ------- 9611
locations --- 9589
MTSAT-2
count ------- 18893
locations --- 18452
GOES 15
count ------- 22615
locations --- 22220
GOES 13
count ------- 14424
locations --- 14382
90
60
30
0
-30
-60
-90
0
60
120
180
-120
-60
0
FNMOC
UNCLASSIFIED

NESDIS/EUMETSAT/JMA Winds



NESDIS Hourly Winds



Motivation

In experiments using satwinds processed by NRL in the GMAO system, Gelaro et al. found:

- NRL AMVs provided a substantially increased beneficial impact and an improvement in overall forecast skill in the GMAO system, compared to using the NCEP AMVs.
- The greater volume of NRL AMVs appeared to be the primary reason for the larger impact.
- Superobbing also appears to be beneficial, although secondary to the influence of data volume.
- The smaller impact of NRL AMVs in the GMAO system compared to their impact in the NRL system appears to result from the larger number of satellite radiances used in the GMAO system.

From “Impact of Satellite Atmospheric Motion Vectors in the GMAO GEOS-5 Global Data Assimilation System”, by Gelaro, Merkova, McCarty, and Tai, presented at the 5th WMO Workshop on the Impact of Various Observing Systems on NWP, Sedona, AZ, May 2012 .

Objective

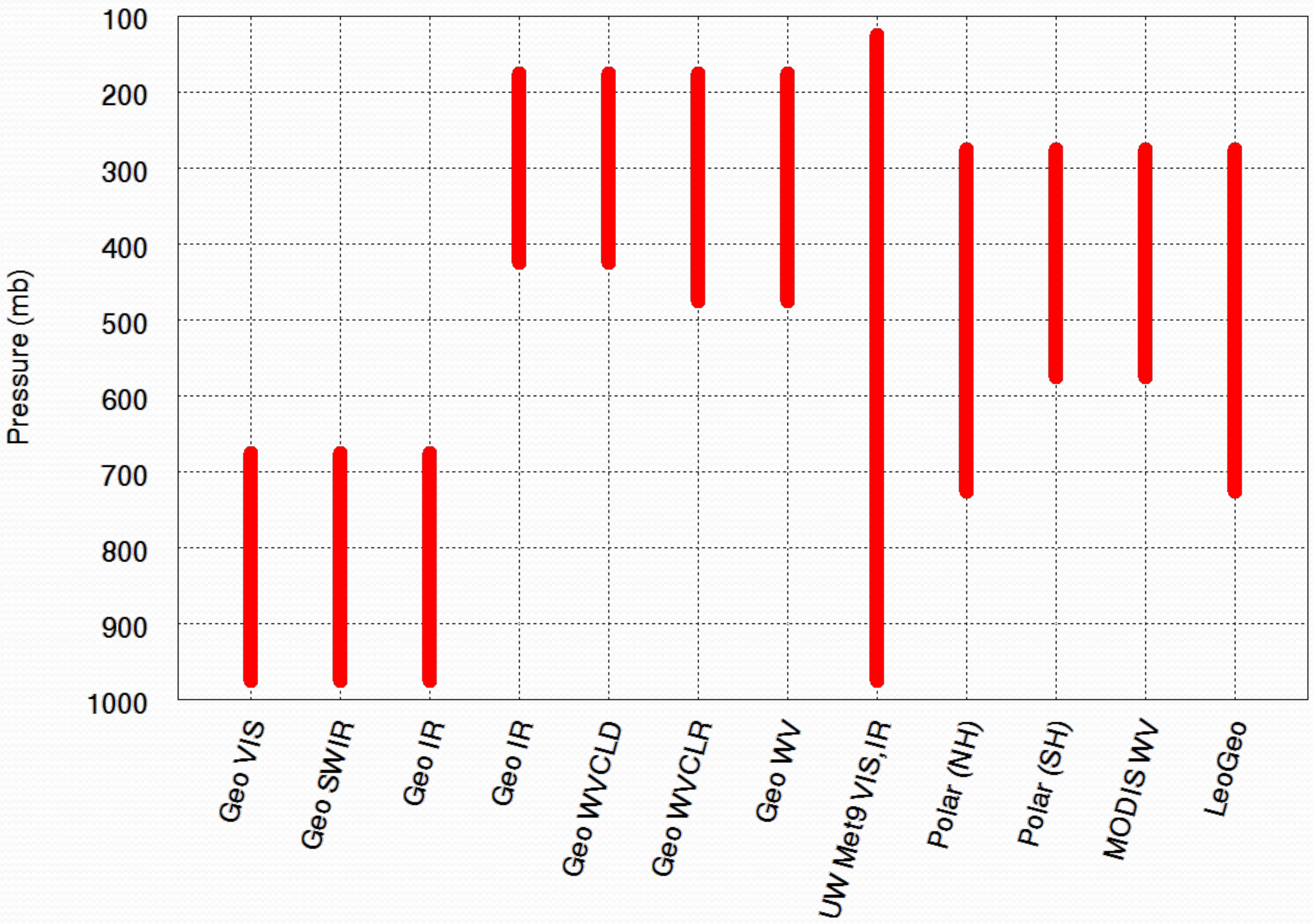
Examine the degree to which superobbing provides a benefit over thinning

- NAVGEM (Navy Global Environmental Model)
  - 4DVAR data assimilation system (NAVDAR-AR)
  - T359L50 (approx. 35 km resolution), model top at .04 hPa
- Superobbing experiment (FNMOC ops configuration):
  - Equal-area prisms (2° lat x 2° lon at the equator), 50 mb deep, within 1 hr
  - Obs from the same satellite, channel, processing center used in superobs
  - Prisms with winds that vary more than thresholds subjected to outlier rejection and/or horizontal quartering
  - No superobs made in prisms with large variability in the winds
- Thinning experiment:
  - Same prisms, ob grouping
  - Ob with the highest QI selected from same subset of obs that are used to form superobs, but without quartering

AMV Superob Processing

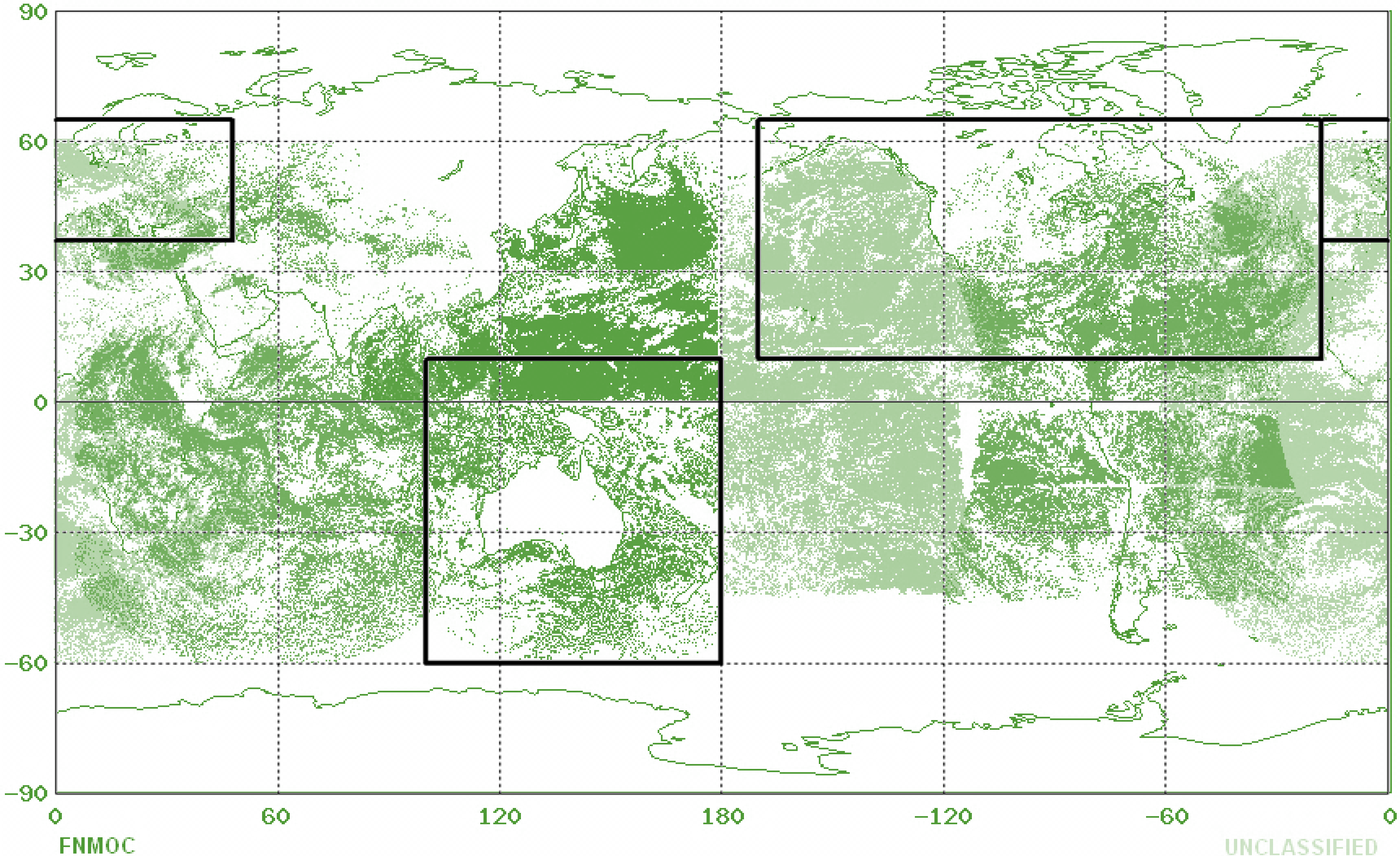
- Perform QC on individual observations
  - Exclude invalid observations with missing position, time, background
  - Exclude observations flagged as bad or having low confidence or quality
    - EUMETSAT/JMA confidence value less than provided threshold
    - NESDIS QI values less than 60
    - CIMSS RFF values less than 40 or CIMSS QI values less than 50
  - Impose vertical limits as a function of channel
  - Impose land-masking in selected regions
  - Exclude exact duplicates
  - Exclude winds with large vector innovations (ob minus background)

Vertical Limits by Data Type

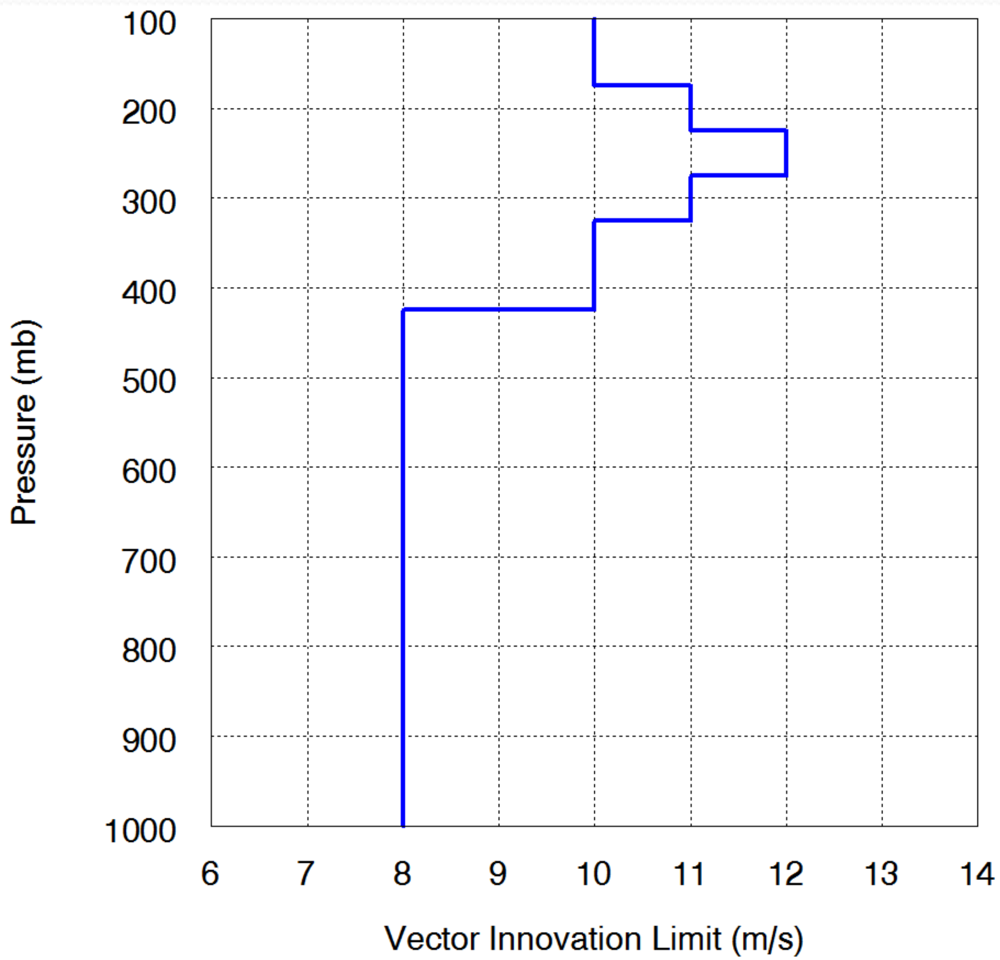


Land Masking

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



AMV Limits on Vector Innovations

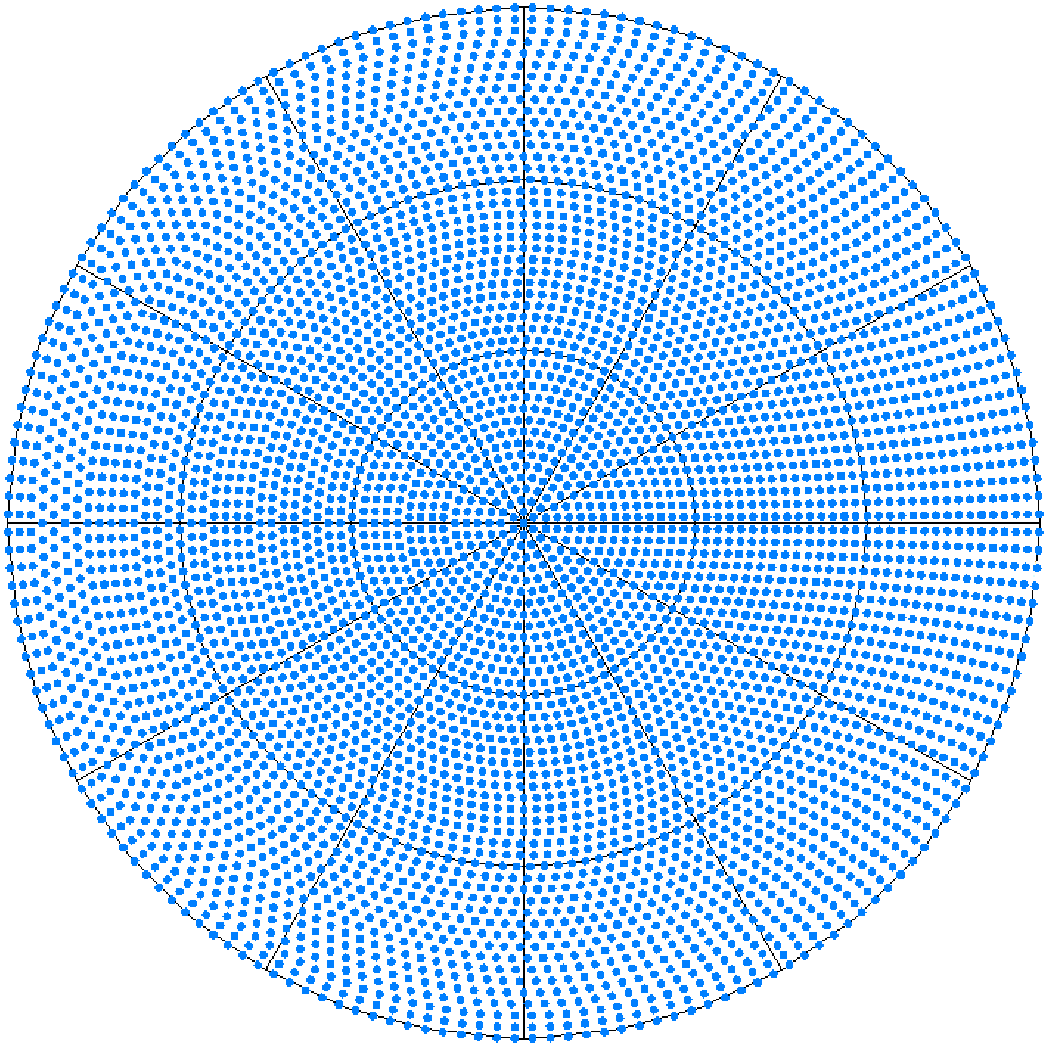


Winds having large vector innovation (ob minus background values) magnitudes are rejected.

AMV Superob Processing

- Bin winds into latitude-longitude "prisms" in 50 mb layers
- Examine obs in a prism layer from a particular satellite, channel, and processing center, and superob if criteria met
  - Speeds (or innovations) within 7-14 m/s depending on speed
  - Directions (or innovations) within 20° or u and v within 5 m/s
  - At least two AMVs are required in a prism
- Reject 1 or 2 outliers to meet criteria if necessary
- Quarter superob horizontally and attempt superobs in each quarter if the above is unsuccessful
- Adjust u and v superobs so that the magnitude of the superob wind vector is equal to the mean speed ob the individual obs

Northern Hemisphere 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.

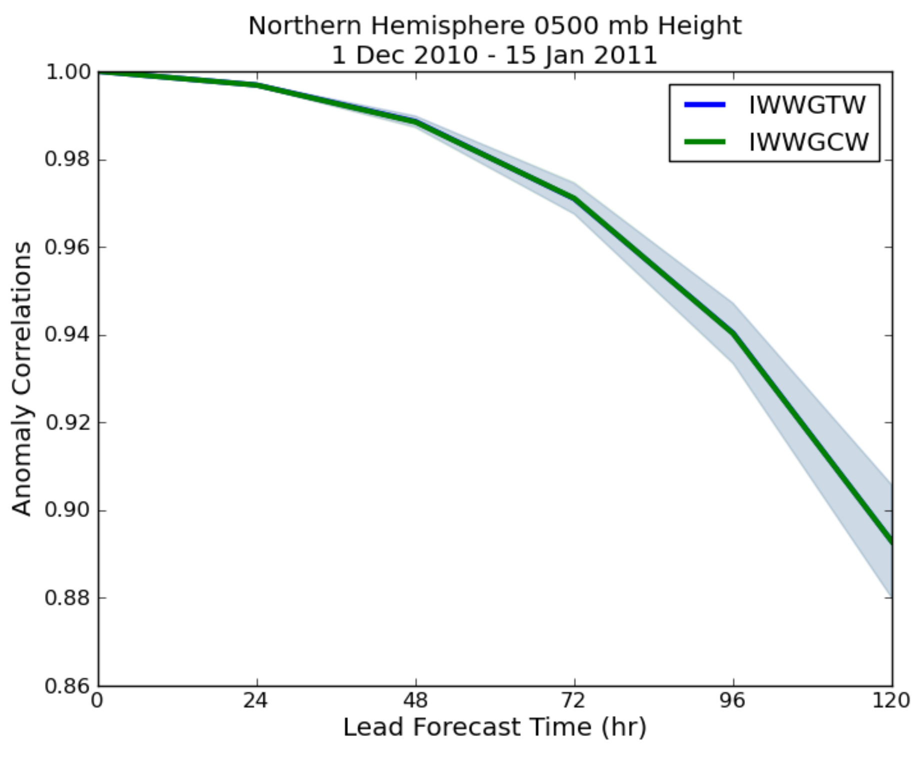
The circles in this figure at located at prism centers.

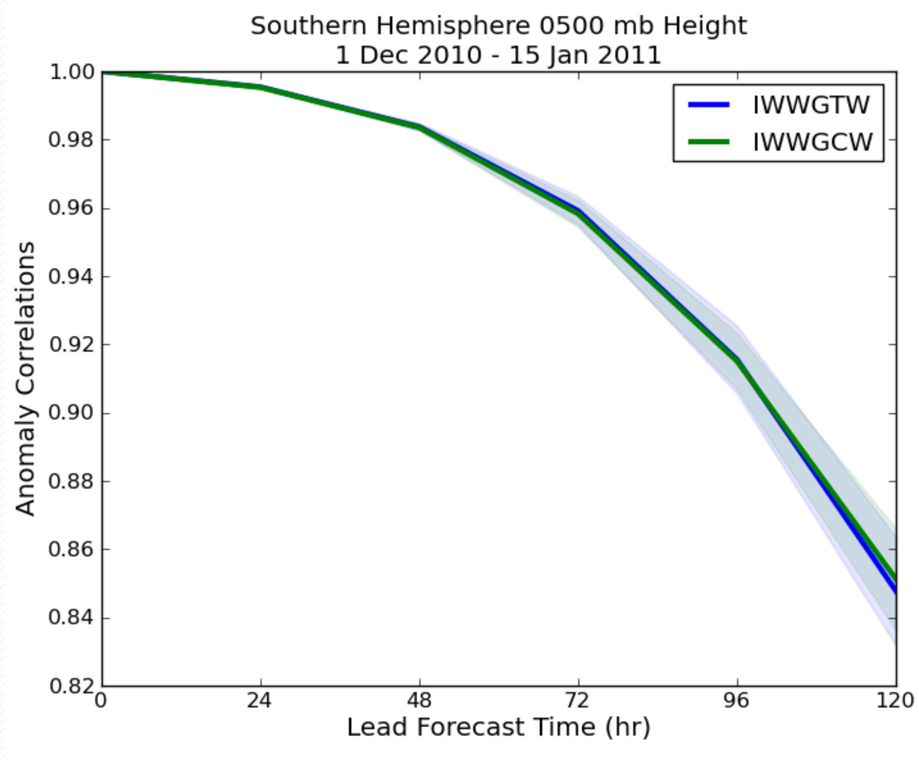
Thinning vs. Superobbing

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

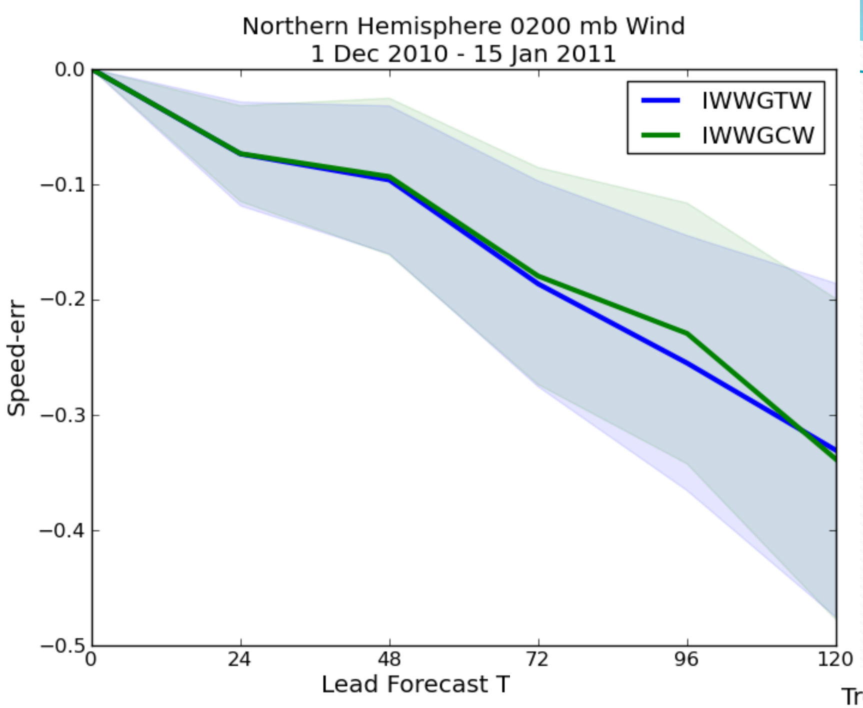
- Superobbing experiment—operational processing as previously described
- Thinning experiment
  - Process AMVs to generate superobs as previously described
  - Replace each superob by the unrejected observation closest in space to the superob, selected from the observations that were used to form the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

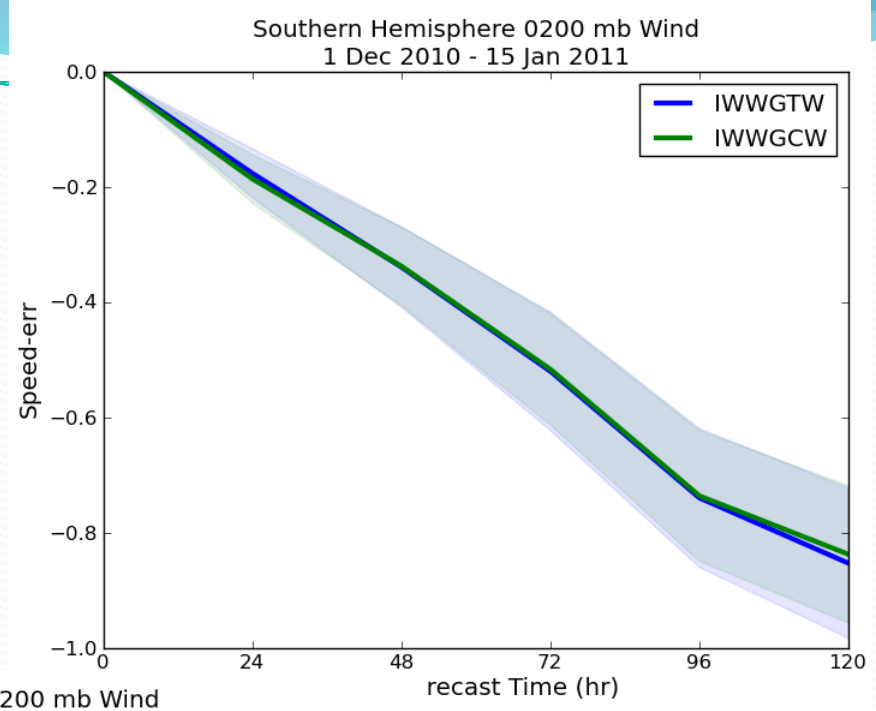
Experiment Results

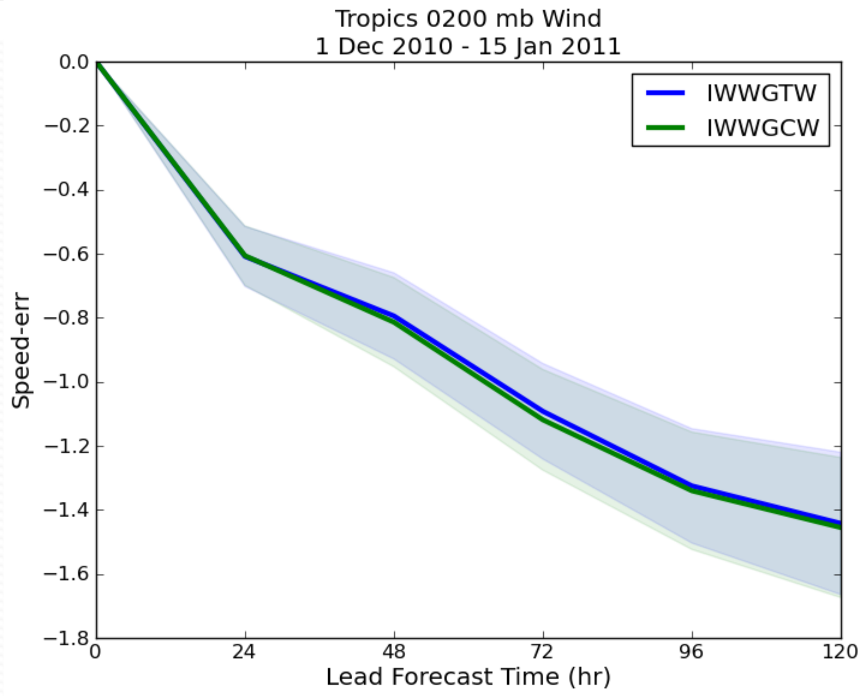




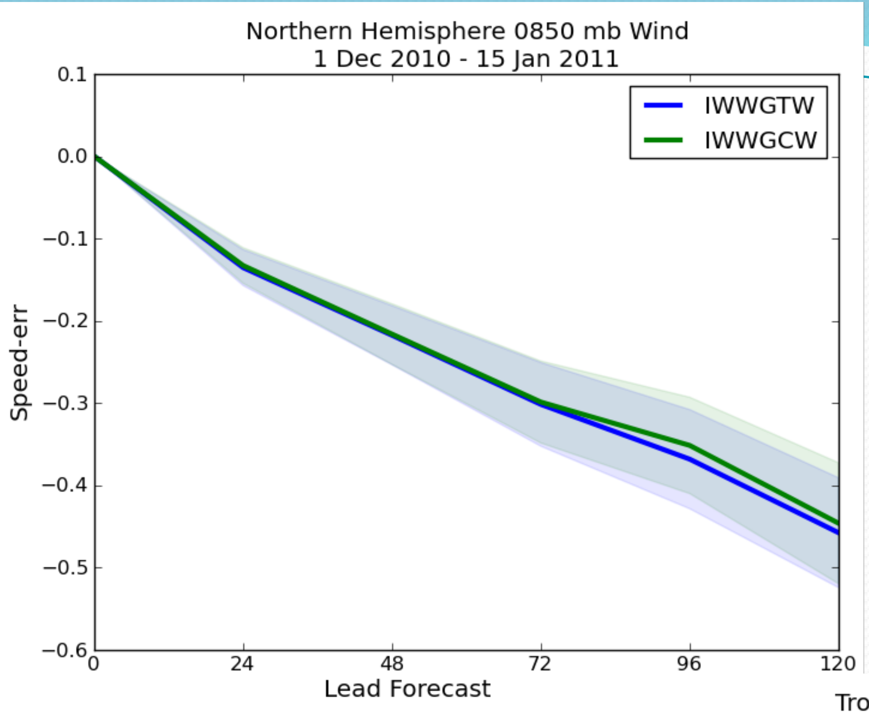
Results are comparable in terms of 500 mb anomaly correlation, with superobbing (green) having a slight advantage at longer forecast ranges in the Southern Hemisphere.

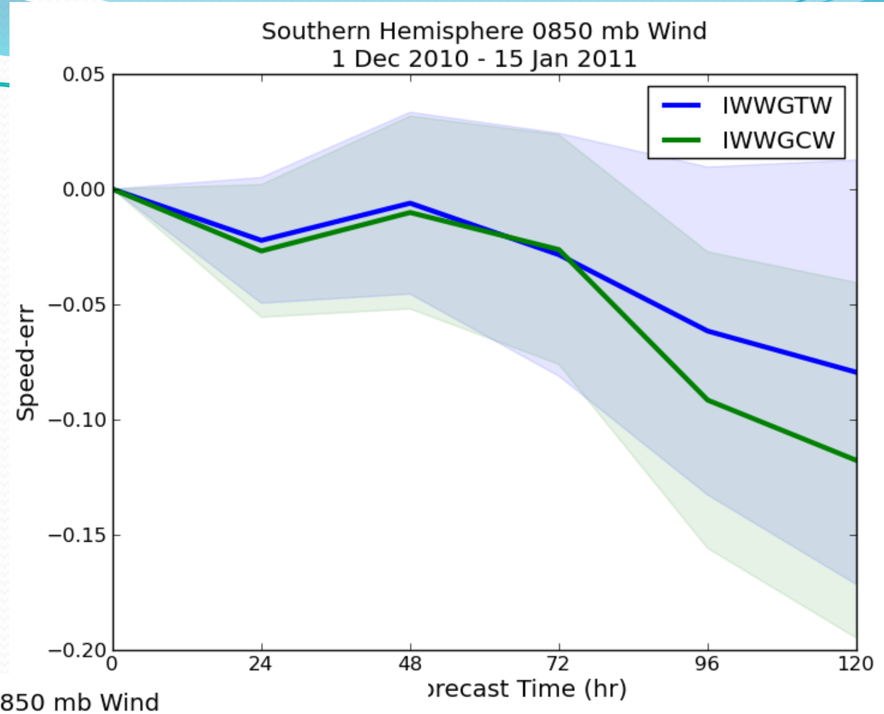


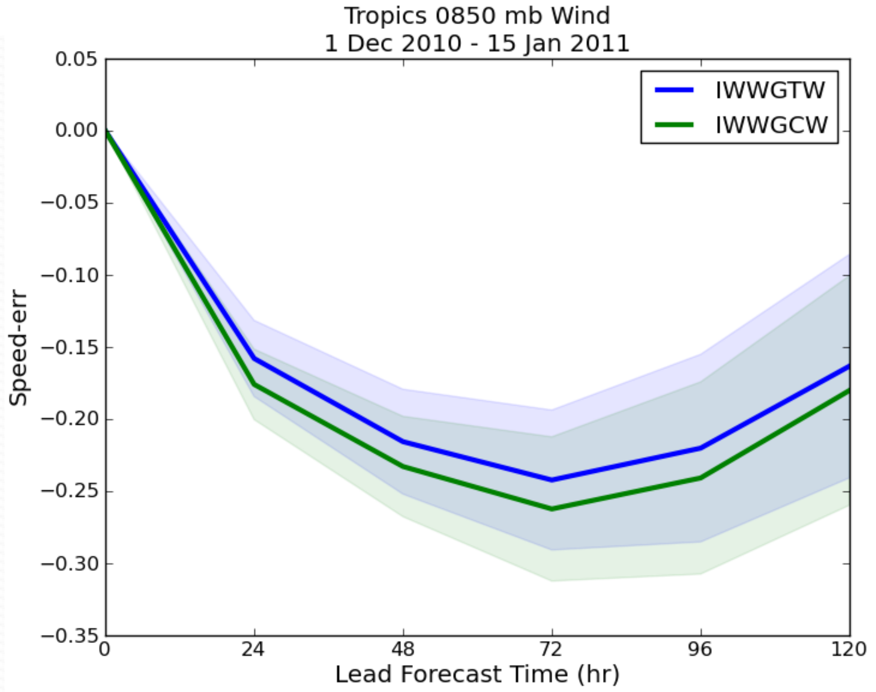




The 200mb speed error is slightly less negative for superobbing (green) compared to thinning (blue) except in the tropics where thinning is slightly better.







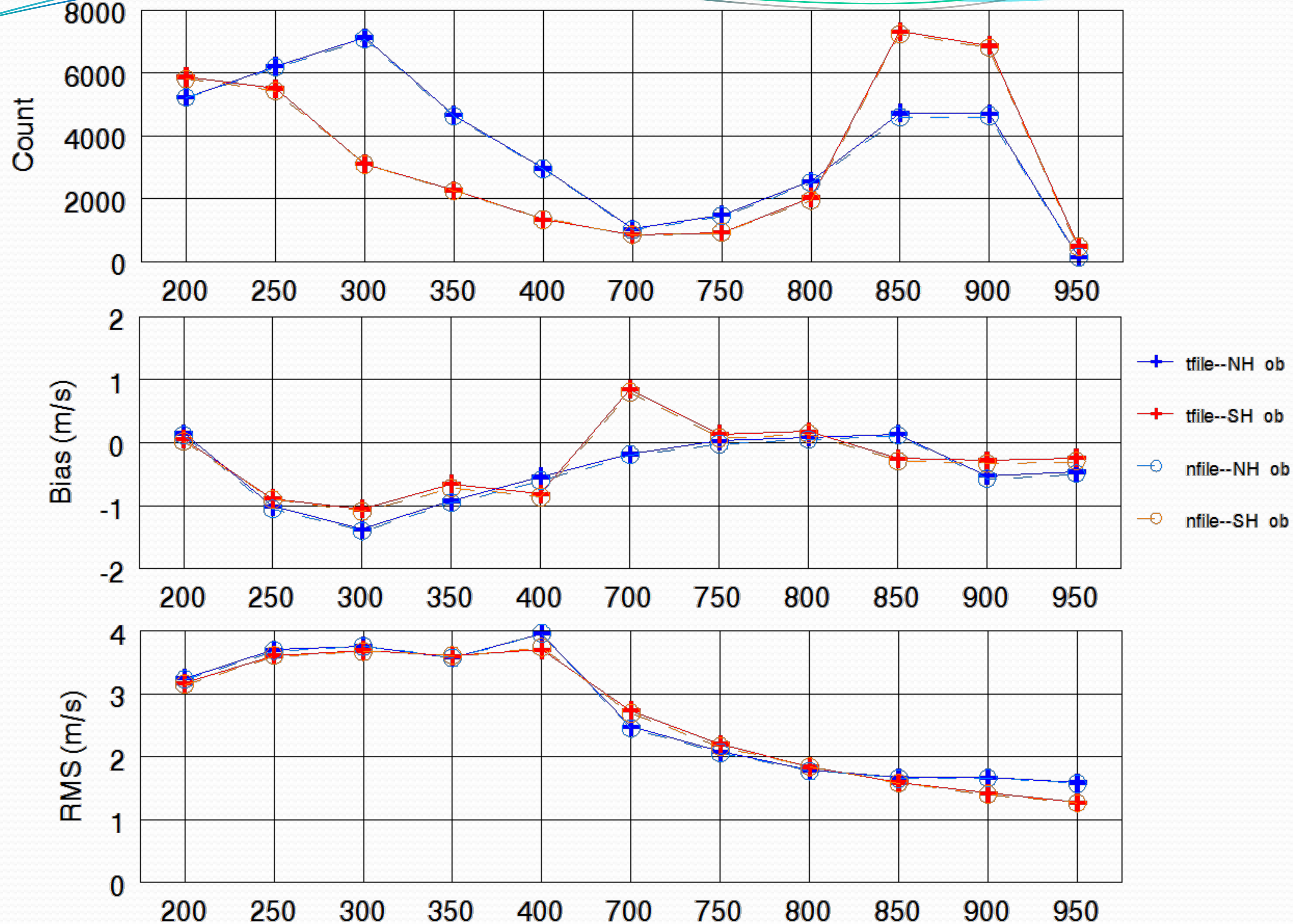
The 850mb speed error is slightly less negative for superobbing (green) compared to thinning (blue) in the Northern Hemisphere, but thinning is slightly better in the tropics and Southern Hemisphere.

Thinning vs. Superobbing

The goal of this test is to compare ECMWF-style thinning to superobbing without forcing the spatial and temporal distribution of observations and the number of observations to remain the same.

- Superobbing experiment—operational processing as previously described
- Thinning experiment
  - Process AMVs to QC and bin obs into prisms as previously described
  - In place of superobbing, select a single ob from each prism containing obs by choosing the ob with the highest QI value. If more than one ob has this QI, select the first one.

2012120900--Speed Innovation Statistics for IR Wind Obs and Superobs



No appreciable difference in the ob counts or statistics between the two file formats

Spatial Distribution of Superobs

```
70             .. ..          ..
                   .X 2    .       547
                       ..  .2     2   5QQ6
                      22    .222           2.
                        .2.    .254.2  .2
     ..                            .44.3QQQ73
      . 23                   .      .. 25 .2QQ538
      .. ..                             . 4.2.3.3.25       3
       X  2. ..3.                       2. .653554852892  4.   34
          ..22Q2..2.            .  2    .2   . .2..44585X3. 2      42
 60    2  . ...342.3..         . .3.2.   2..Q2. 23233..576742 2       24
              22       33         .24.2      .3.2.2  4.  .28X4X663      . 5
       ..   .      .   .34.          2.2.2....3.......2..   ..224555.     3.45
        ... .3.3 .2  .    X           24522... 3.Q22.. 3        2.  243.  .224453
         22.       .X.4.   23.        ..2..2..  2 .2244.          ..523465636346783
      . 2.. .        ..    .2222 . 2.  22.      22. .322      .   . .4752235332435.5.
      2..2        .3. . ..  ...43   574.       . 3.QQ452.    ..2 2  3248755246765.4432
     3 .  2       .  22       235Q.  3X44.       2 2344232.     .2.432.22546.  5423222
        .  .      . .. 3.    32322.2  4552  ..22 .2322233..      .33 2.22263  2
          22         2. ..2. 2.3.      9654222.22. . .2. .  2  ..  22      .  X      .353.. .
 50  . .....           . ....        .3  4222Q33.        ... .                . ..245365 ..
     5499.                       .2  2.2.732. 32. 222..  2    2                   33.73 .43.
     .3.32  ..            ..   . 2..  ...6  ..  .22Q3Q              3..                    .
      .26  .2  2.3 2        22.3....   .. .   22 2Q.233          2  24                 . ..22
       . . 2.2.  .  ..  .2.2 ..          .    .22  ..22      . 2.2.2Q343.2                 ..  .
     53        .  .  .                        2      .2.        ..223.2 2..    23.       265433
     46 .22    .....223..    .    .       . 2..Q. 2   2.       .   ...      .  .2         44544
     262         .   22  23.Q     .        . ....  . X               .     .               .32
      .5        .2 .. .22. .               32..   2 Q..     ..       .       . .         .2.2
        2      2... . ...2..   .             .2 ...22 X    . .     .   .               ..2323.
 40   2 2.2           .    .2  . 2   2..  2 .. .. .2.             333                   .523
       22  .               2    .2    ..2  2. ..2.3...      .  ..22.  2 . 222.2 .      43.
      .. 2322                   .  .  .. .  X222... .         .222..2.223..24.23.  .. .
     5..  .                  .  .  2  22. .2. ...2            . .. 55 265.2 27.
       .                            .  .      .....         .  ..222. .5443.5.
      .           ..              ... 3.                    .  4..42 ..7422345 .2
              2             . .   22.2.    .. .323    .       233242   33. 34245
                           .     . .     .. .  23  ..      3352.4      .. . 35
                        .    .    4       . .43.43.     232  ..2.   .2  .
            .           .       2..2      2..32 ..  .35            35222
 30         .   .2. . ....X2..X2   .  2 ...2.4.2..234.3..       ..653
     . .    . 3.3      ...3222..2  2  2 2  3222323226452     .  23
         . .2 .    ..23.2.42 .3232  ..  223343222444.       ..
      .  .2..       2 . 2422232 . .2     2  342.23..
     .233      .   2  23232.  .            32
     32.    ...  .   2.    .    .  .     23
                    2.       2
                           .    2
                            342
                       .22
 20                 .
```

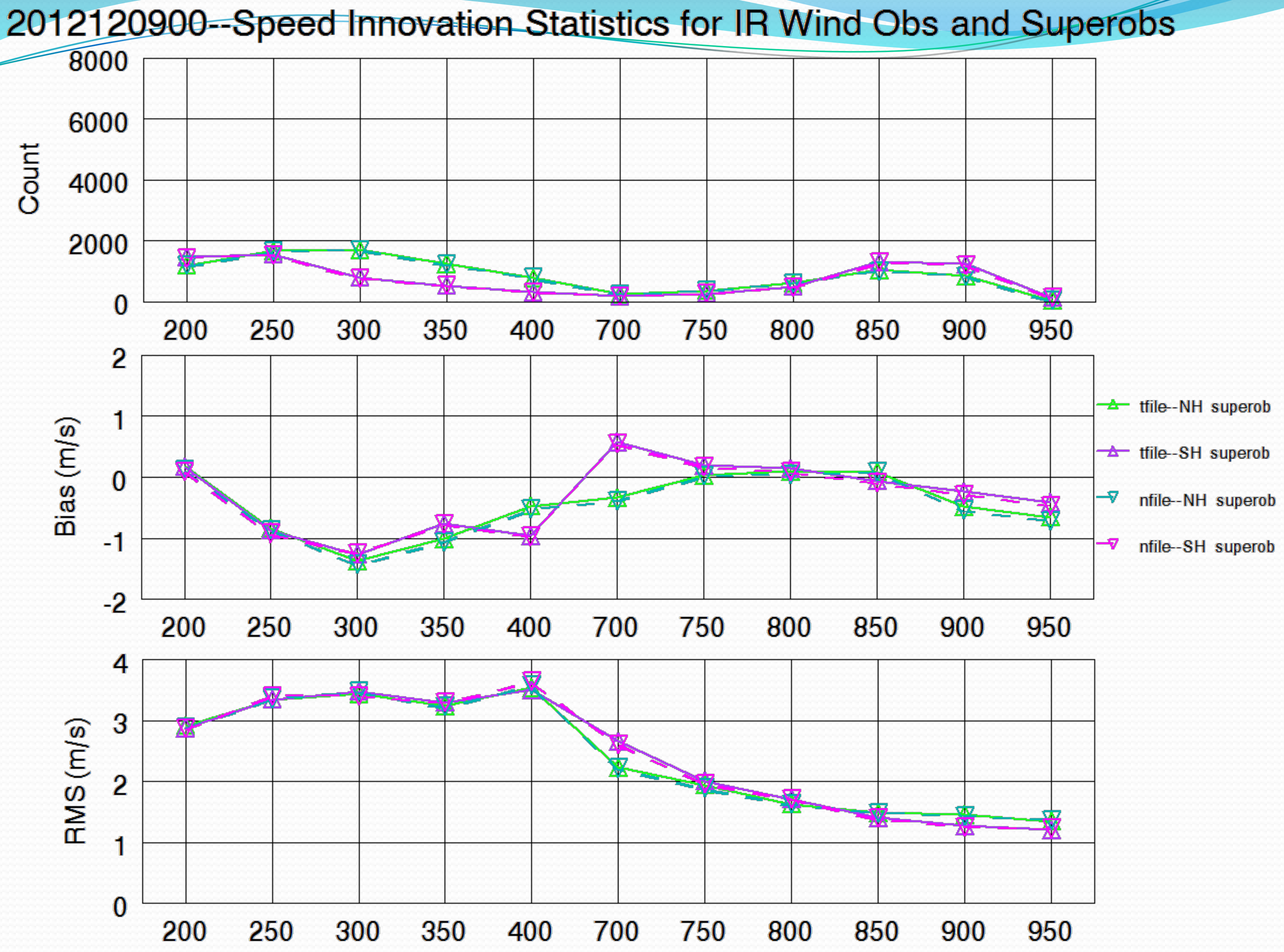
Legend:

Q Prism was quartered

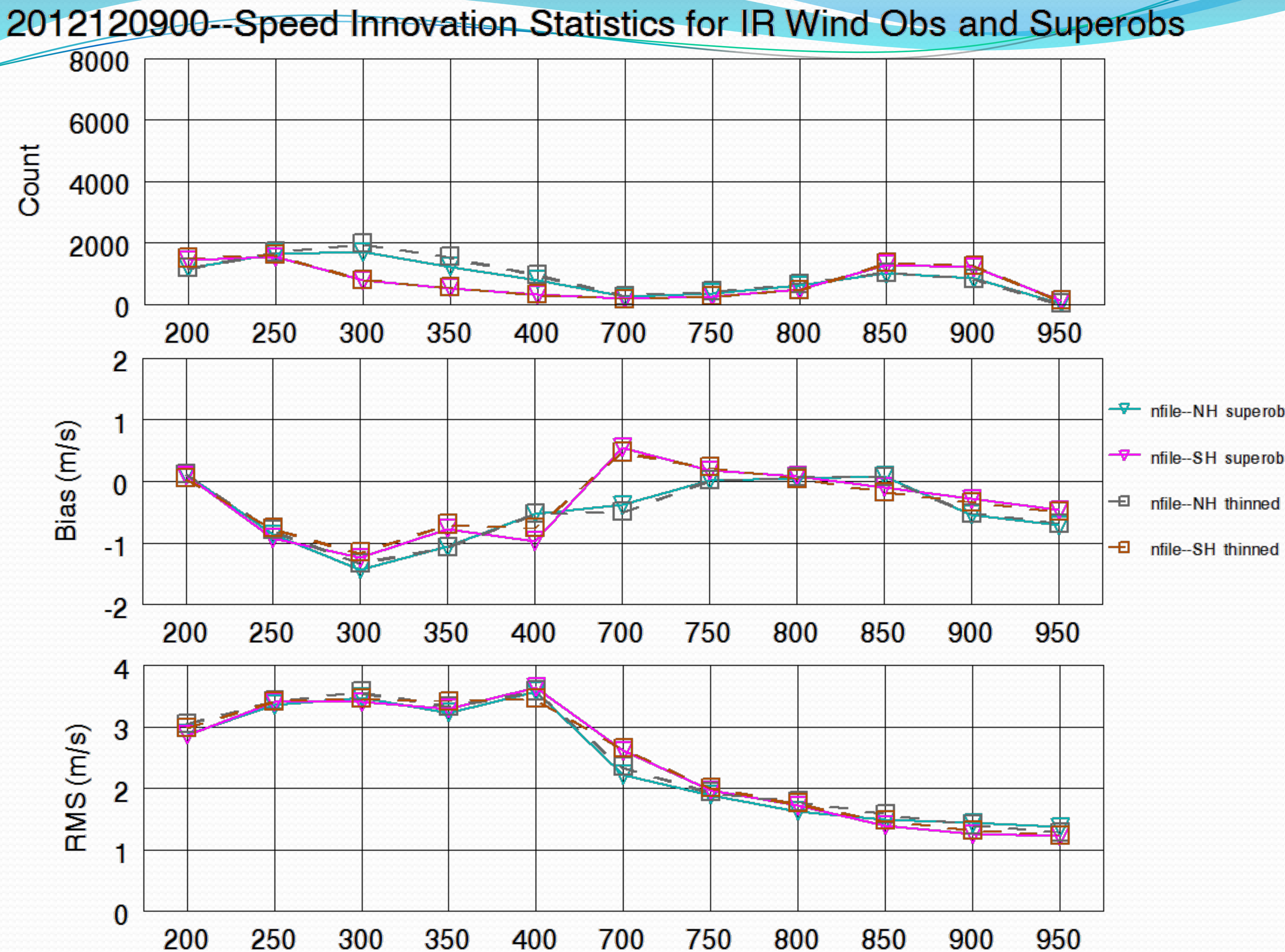
X No superob was made

. Isolated ob allowed

In the thinning experiment, no quartering is performed, but an ob is selected in every prism, changing the details of the spatial distribution relative to the superob experiment.

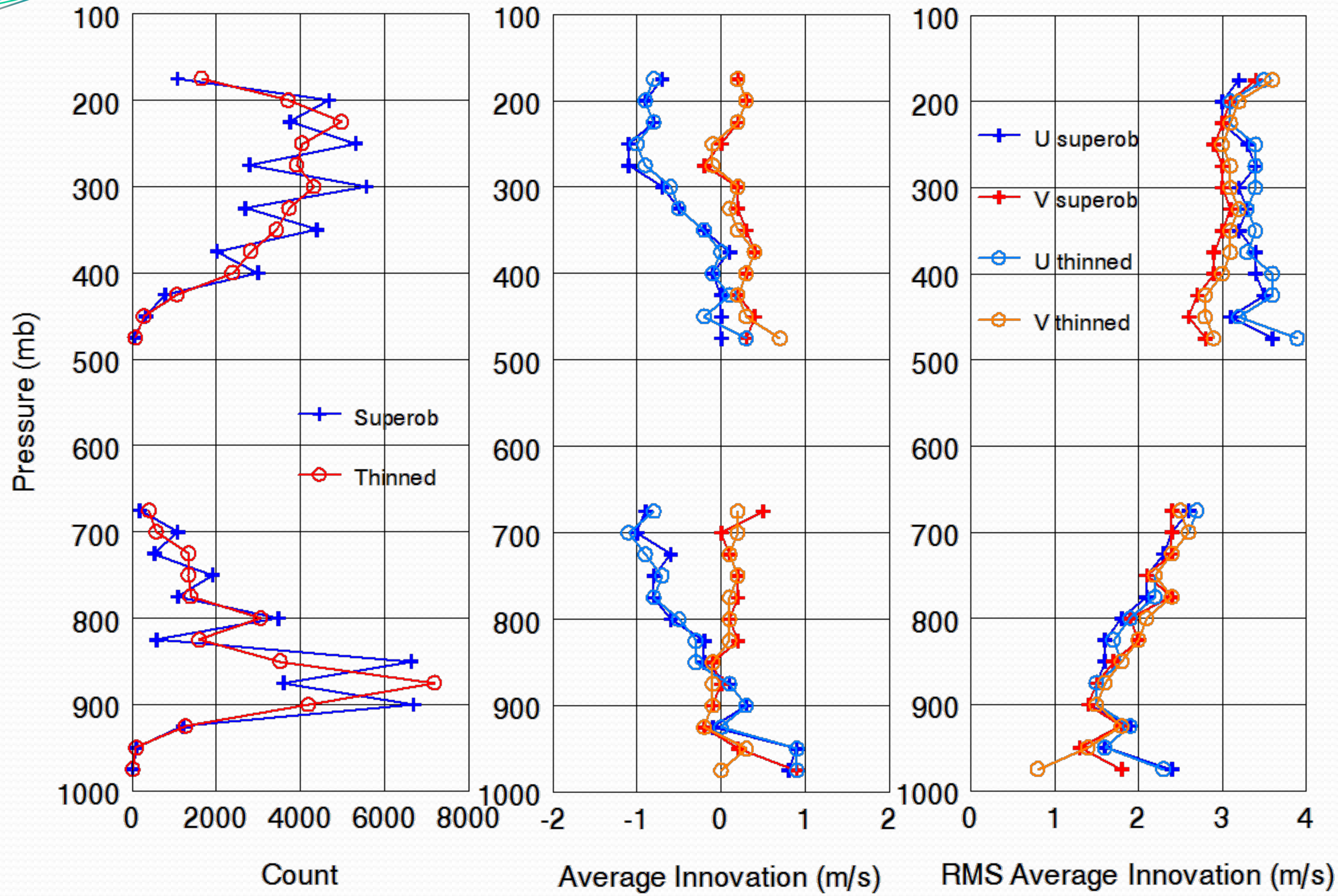


No appreciable difference in the superob counts or statistics between the two file formats

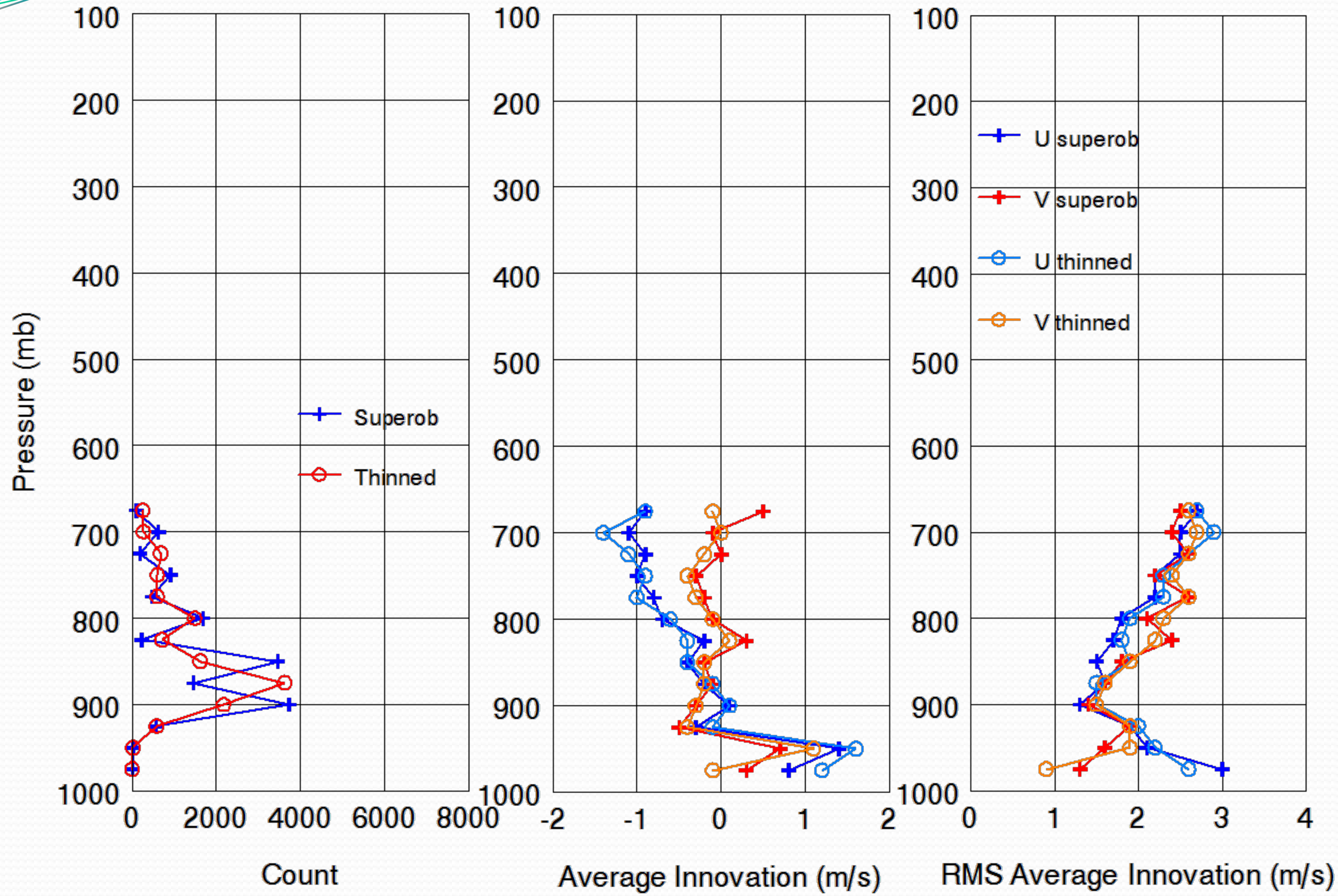


Only small differences in the superob counts and statistics between superobbing and thinn

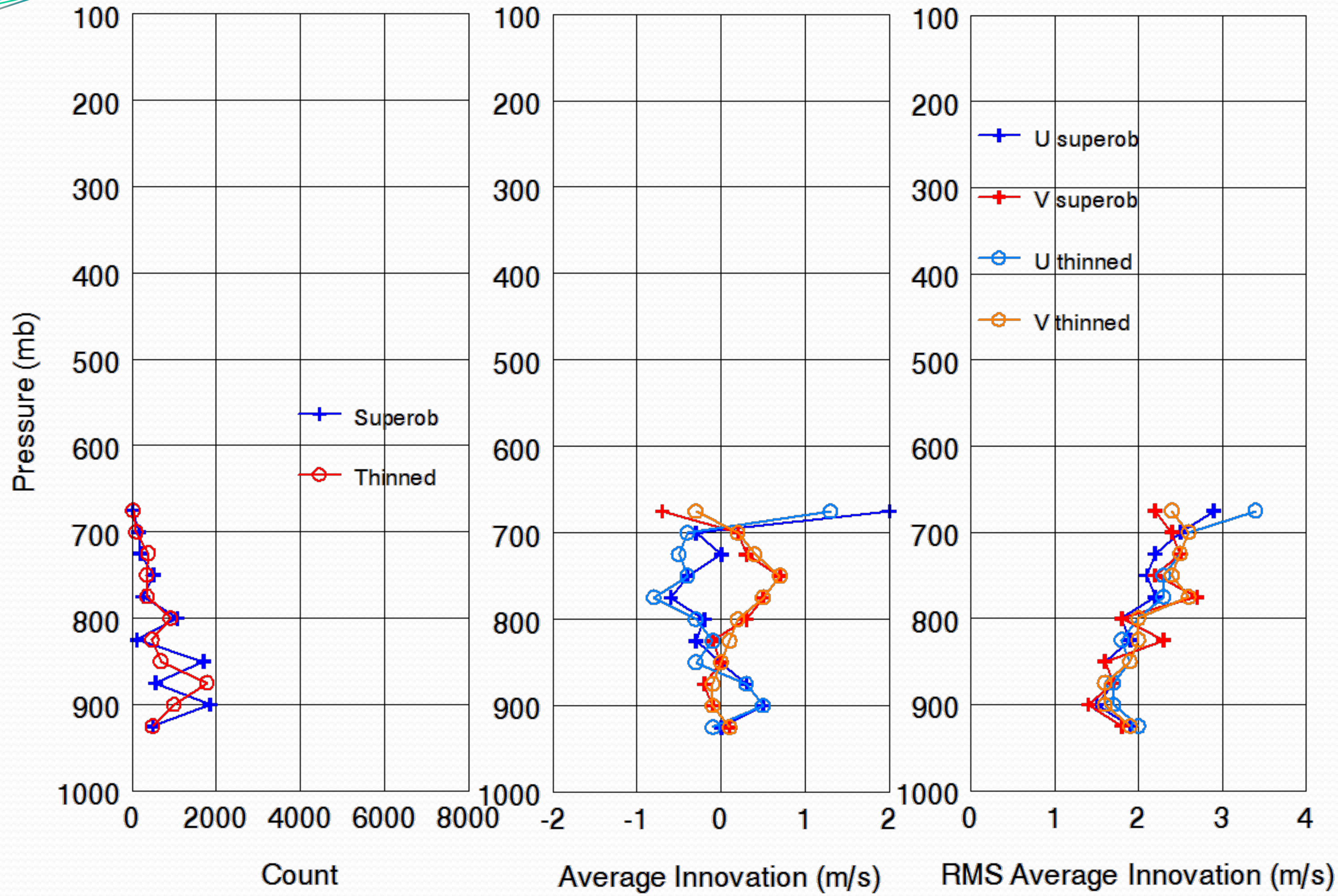
2012120900--All BUFR Winds



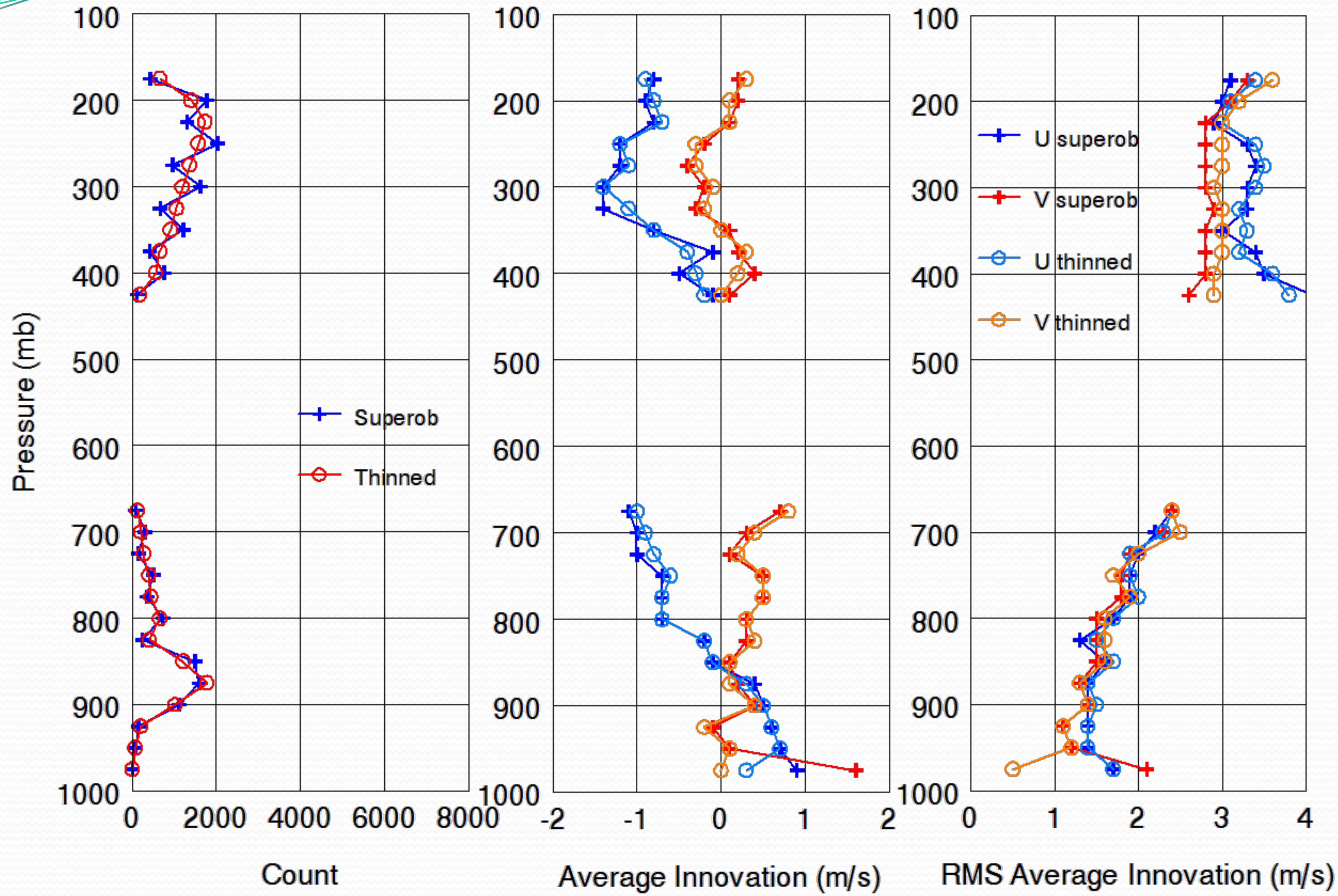
2012120900--All BUFR VIS Winds



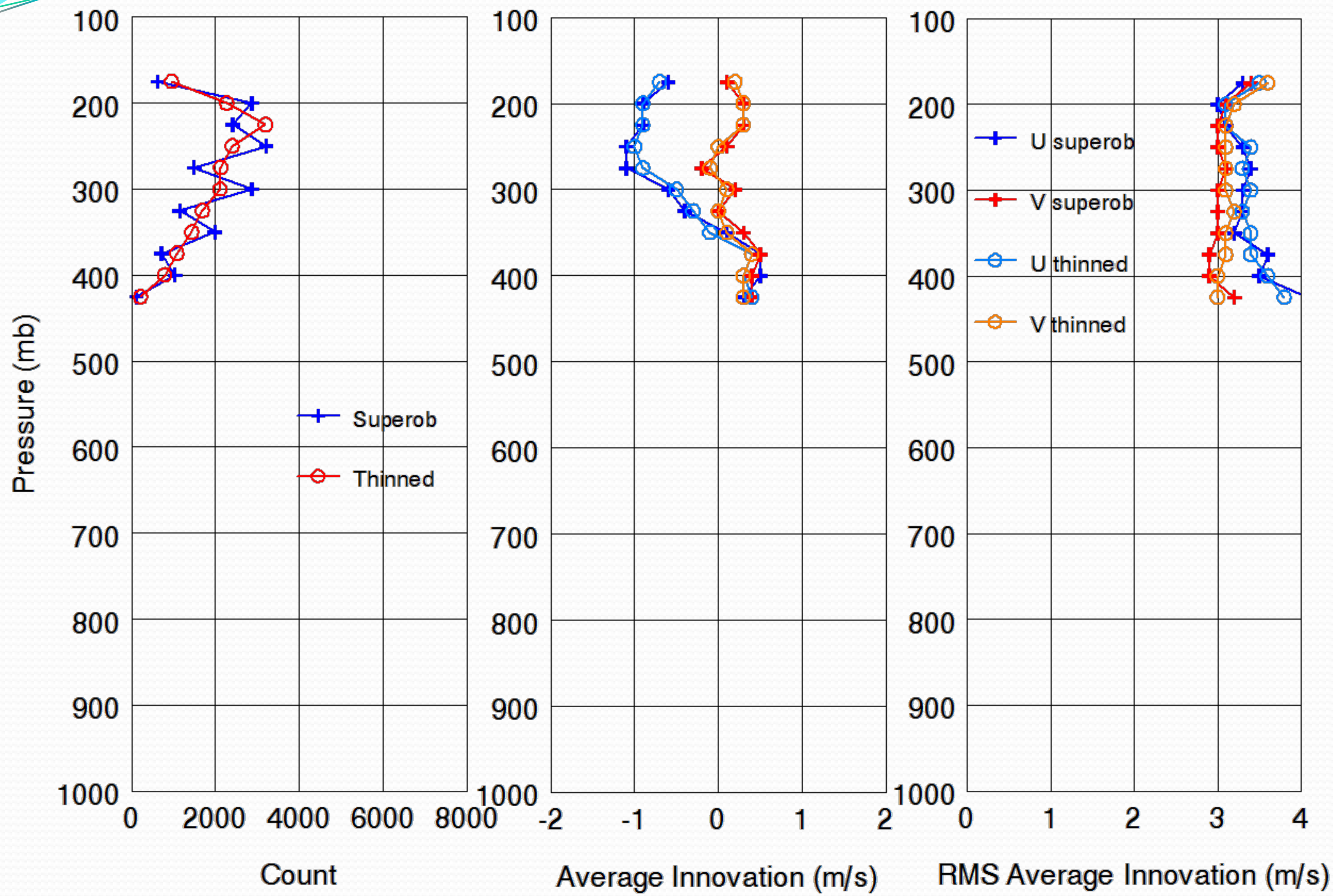
2012120900--All BUFR SWIR Winds



2012120900--All BUFR IR Winds



2012120900--All BUFR WVCLD Winds



2012120900--All BUFR WVCLR Winds