Overview of Satellite-Derived Winds in NAVGEM

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Outline

- Overview of satellite-derived winds used in NAVGEM
- Overview of superobbing procedures
- Forecast Sensitivity Observation Impacts (FSOI)
- Future work

Satellite-Derived Wind Datasets

NAVGEM uses the following satellite-derived winds operationally:

- Geostationary AMVs
  - GOES-13 and GOES-15 (NESDIS and CIMSS)
  - Meteosat-7 and Meteosat-10 (EUMETSAT and CIMSS) (and EUMETSAT Meteosat-9)
  - Himawari-8 (JMA and CIMSS)
- Polar AMVs
  - MODIS—Aqua and Terra (CIMSS and NESDIS)
  - AVHRR—METOP A and B; NOAA 15, 18, 19 (CIMSS and NESDIS)
  - VIIRS (CIMSS and NESDIS)
  - LeoGeo (CIMSS)
  - Global AVHRR (EUMETSAT)
- Surface winds
  - WindSat
  - ASCAT
  - RapidScat (KNMI)
  - SSMIS windspeeds

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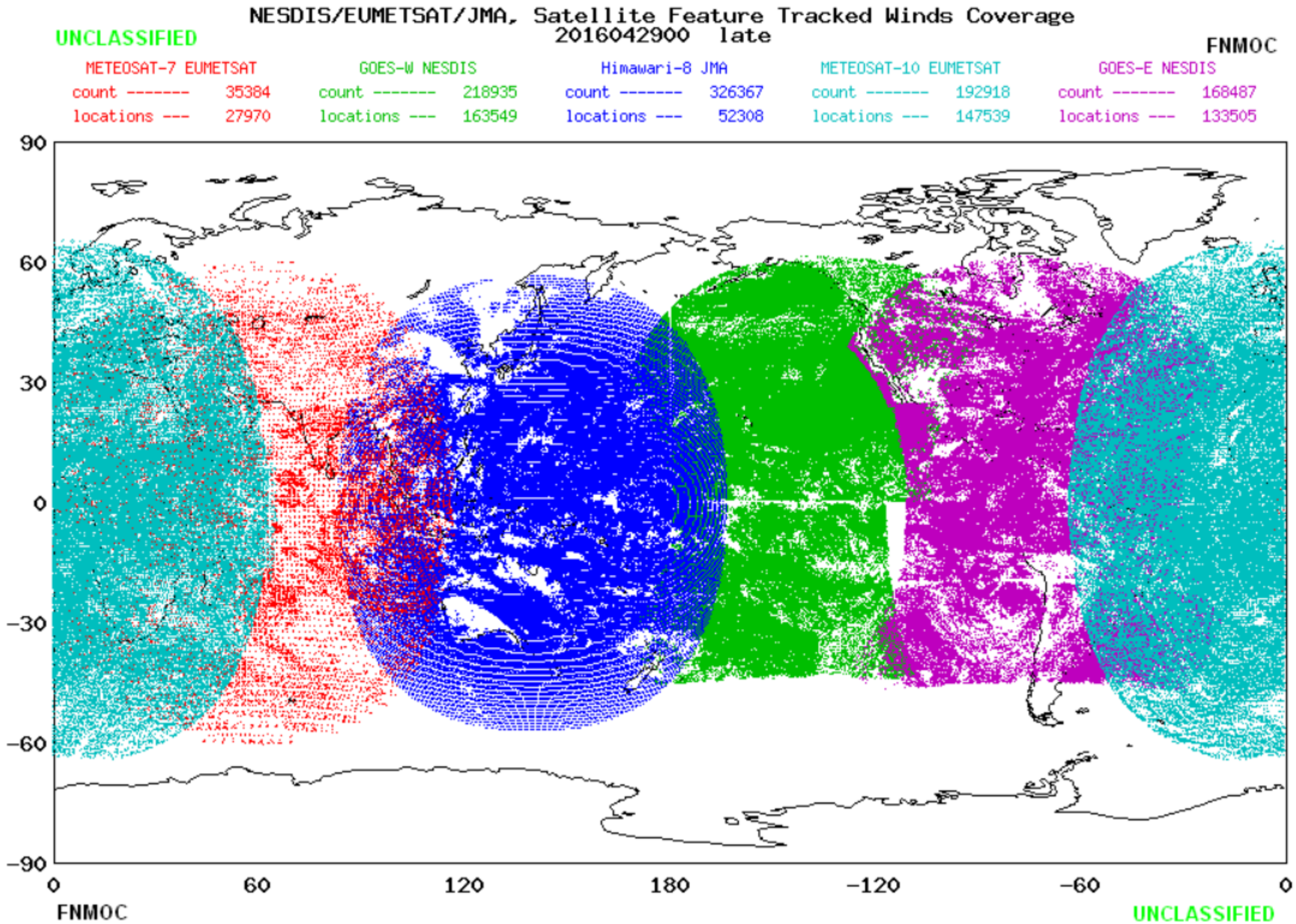
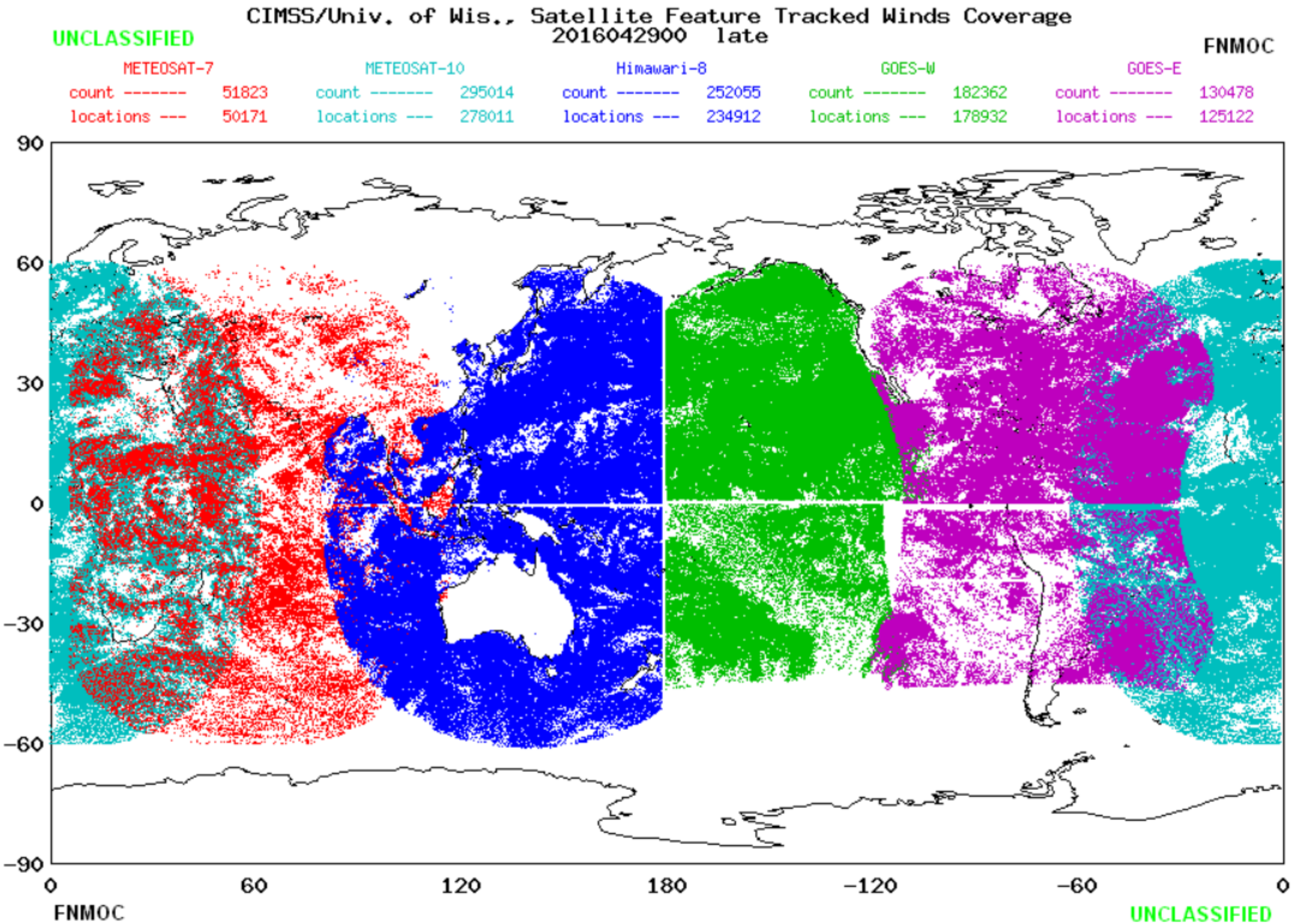
Geostationary Winds—NES/EU/JMA



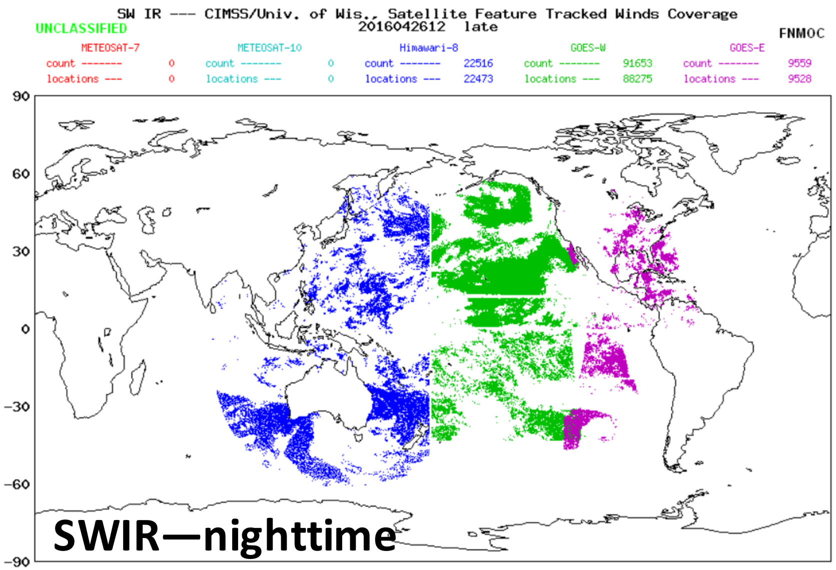
Geostationary winds from the operational providers (NESDIS, EUMETSAT, JMA)

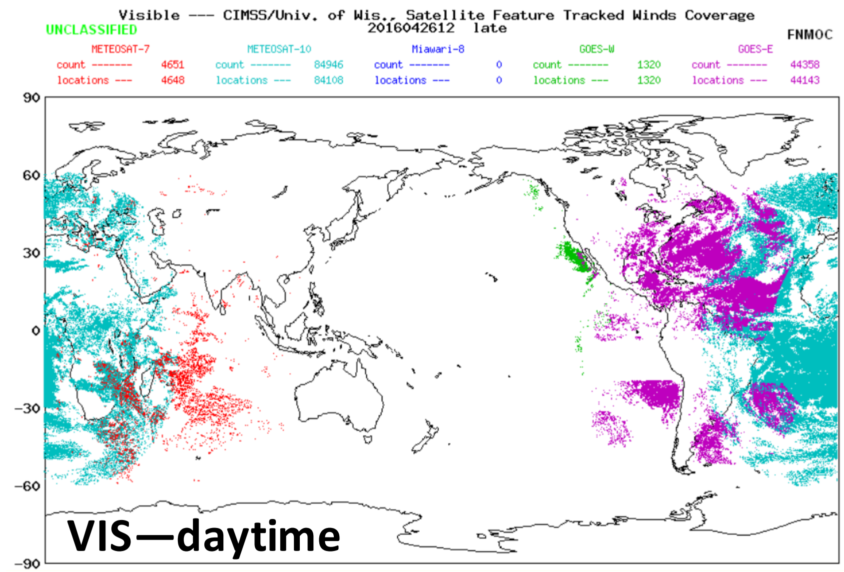
Geostationary Winds—CIMSS

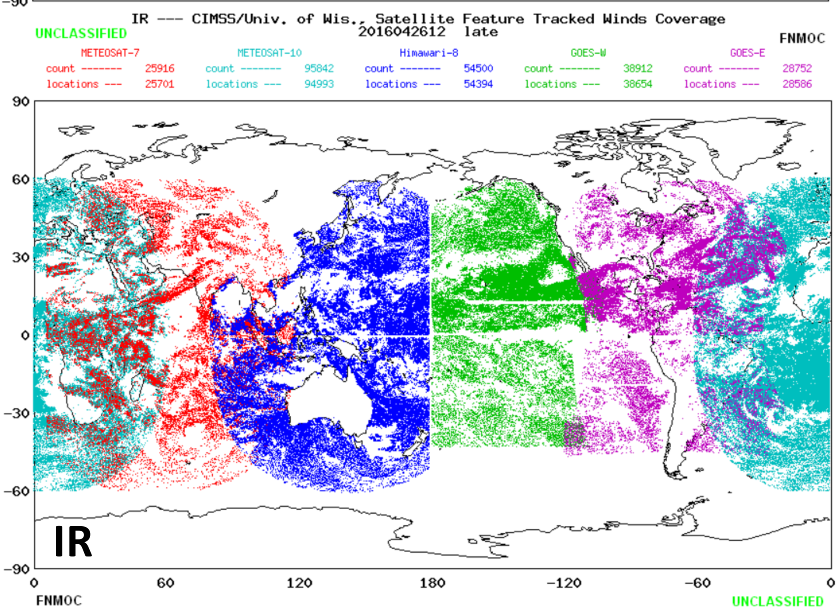


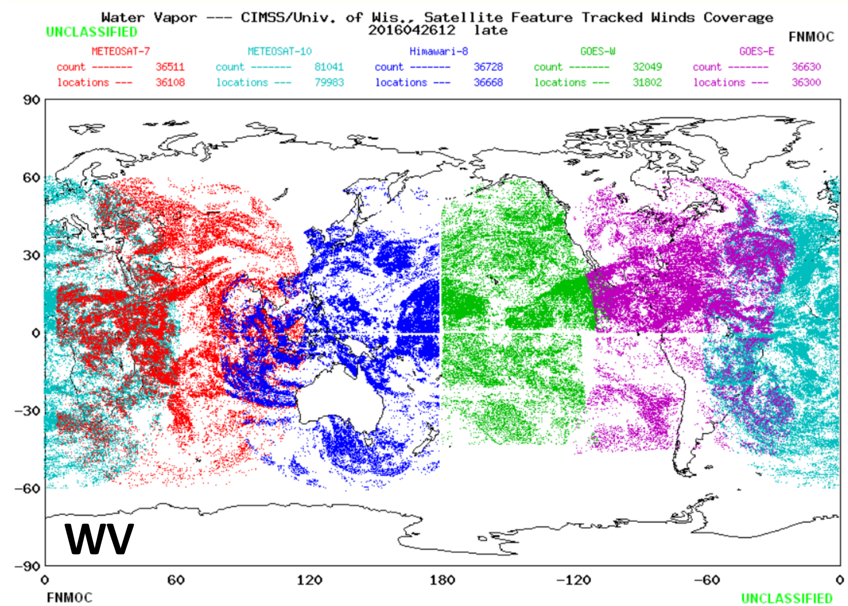
Geostationary winds from CIMSS (University of Wisconsin)

Geostationary Winds by Channel

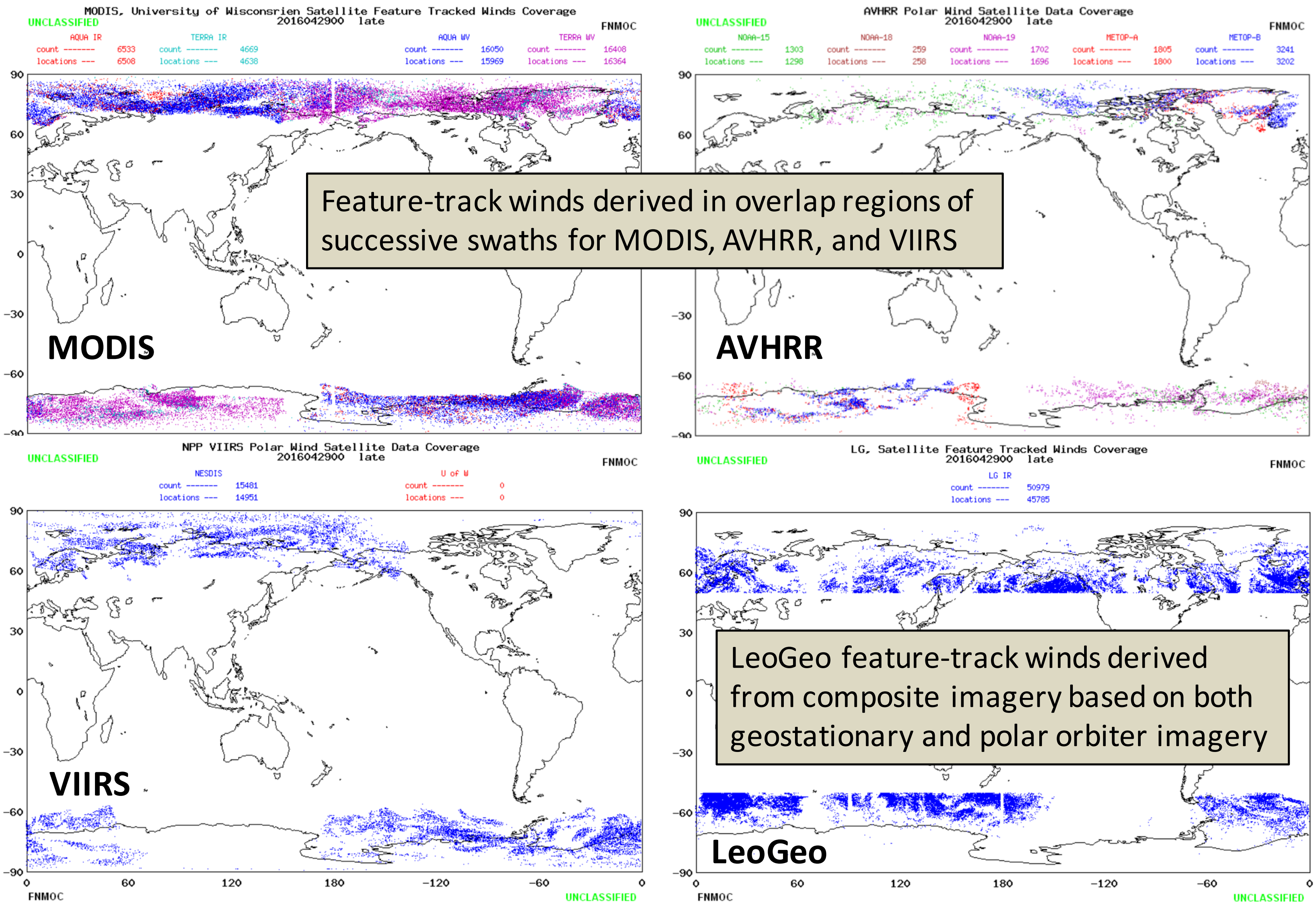








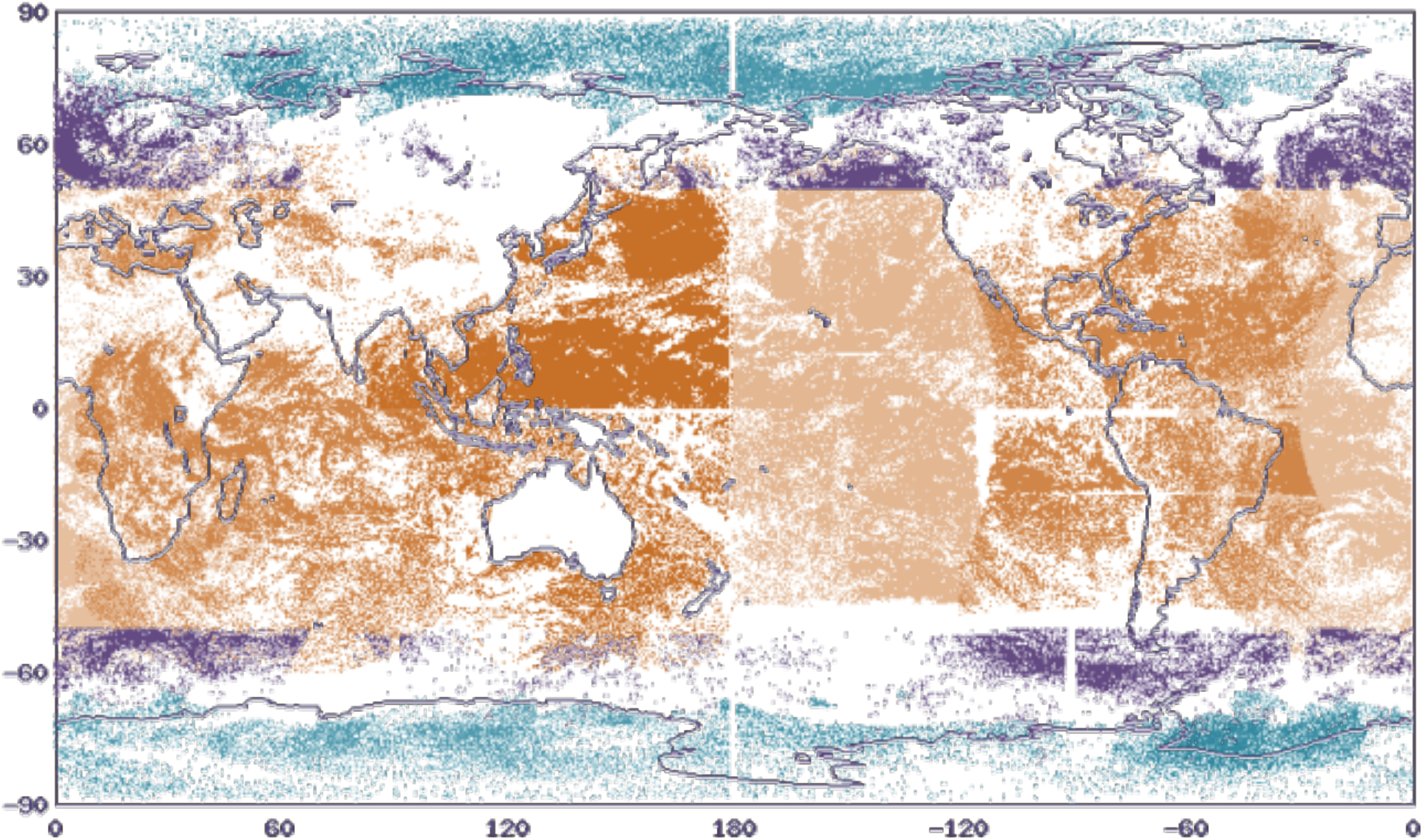
Polar Winds



Feature-track winds derived in overlap regions of successive swaths for MODIS, AVHRR, and VIIRS

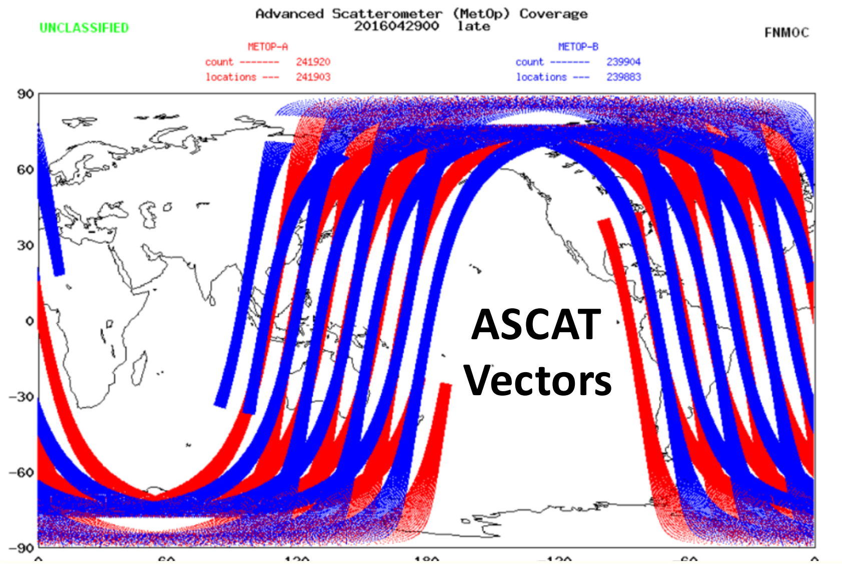
LeoGeo feature-track winds derived from composite imagery based on both geostationary and polar orbiter imagery

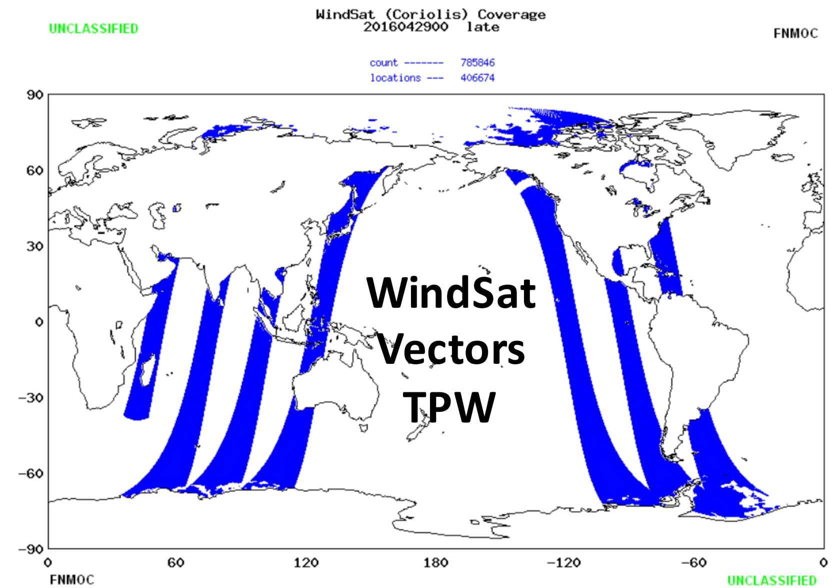
Combined AMV Dataset

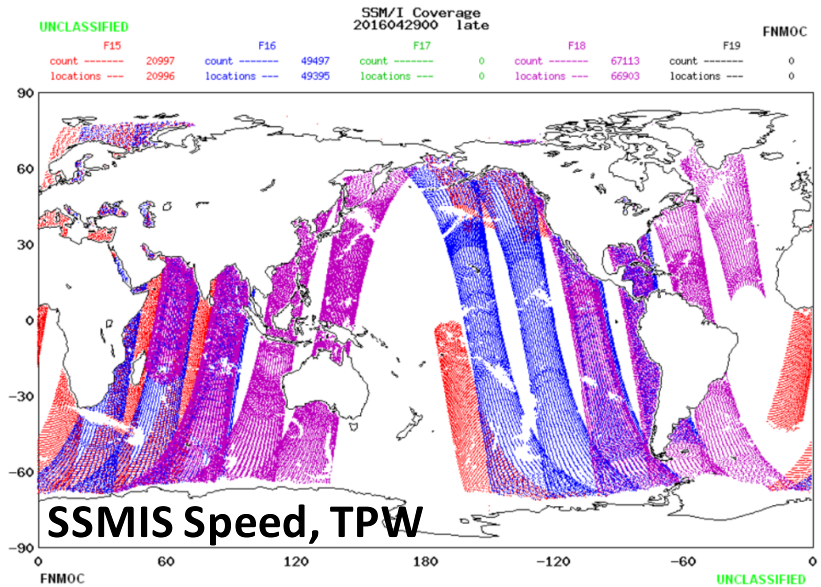


Geostationary winds (orange), polar winds (aqua), LeoGeo winds (purple)

Ocean Surface Winds







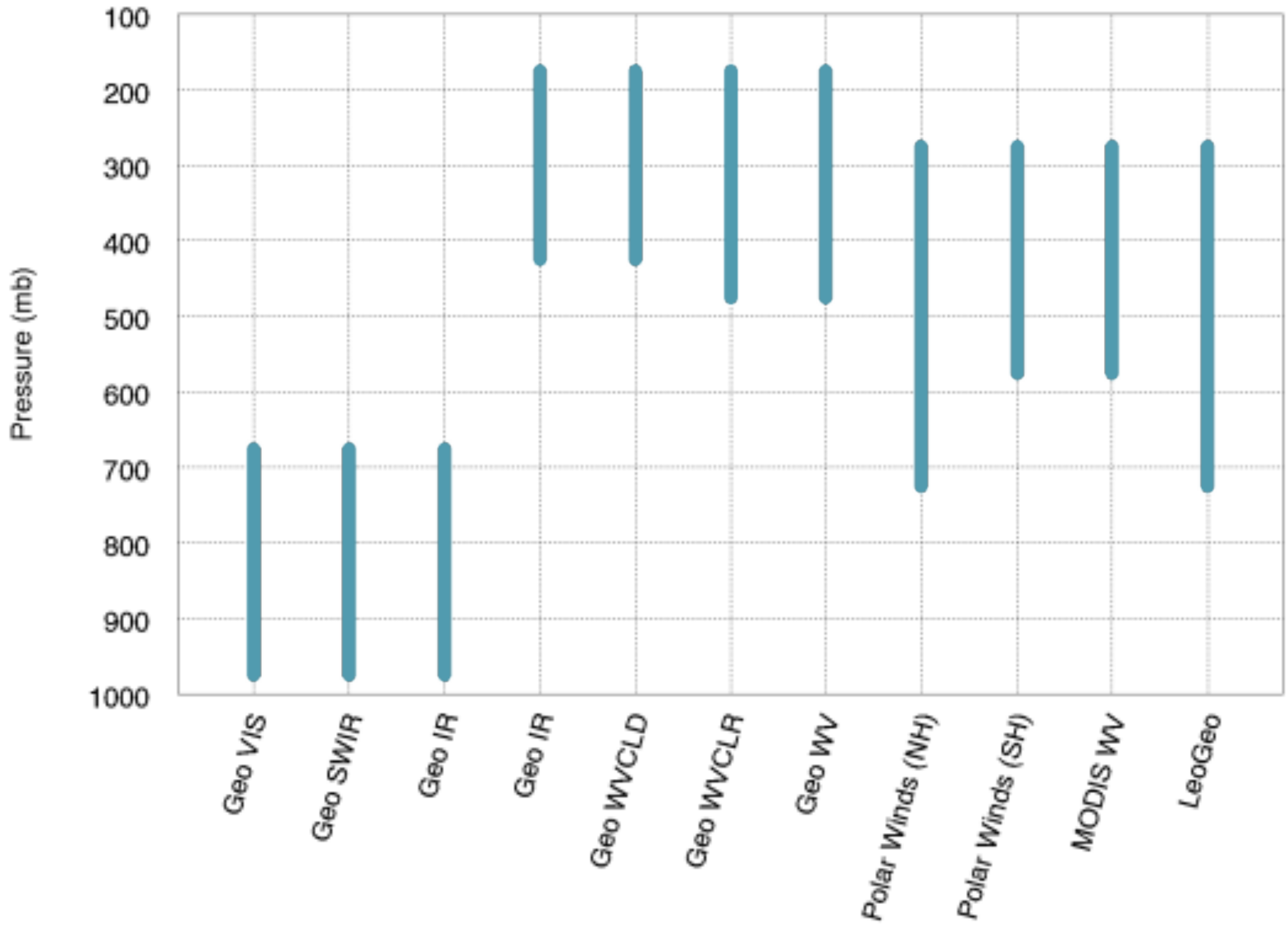
Basic Superobbing Philosophy

- Satellite-derived winds contain horizontally correlated errors that the data assimilation system assumes are not present.
- 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

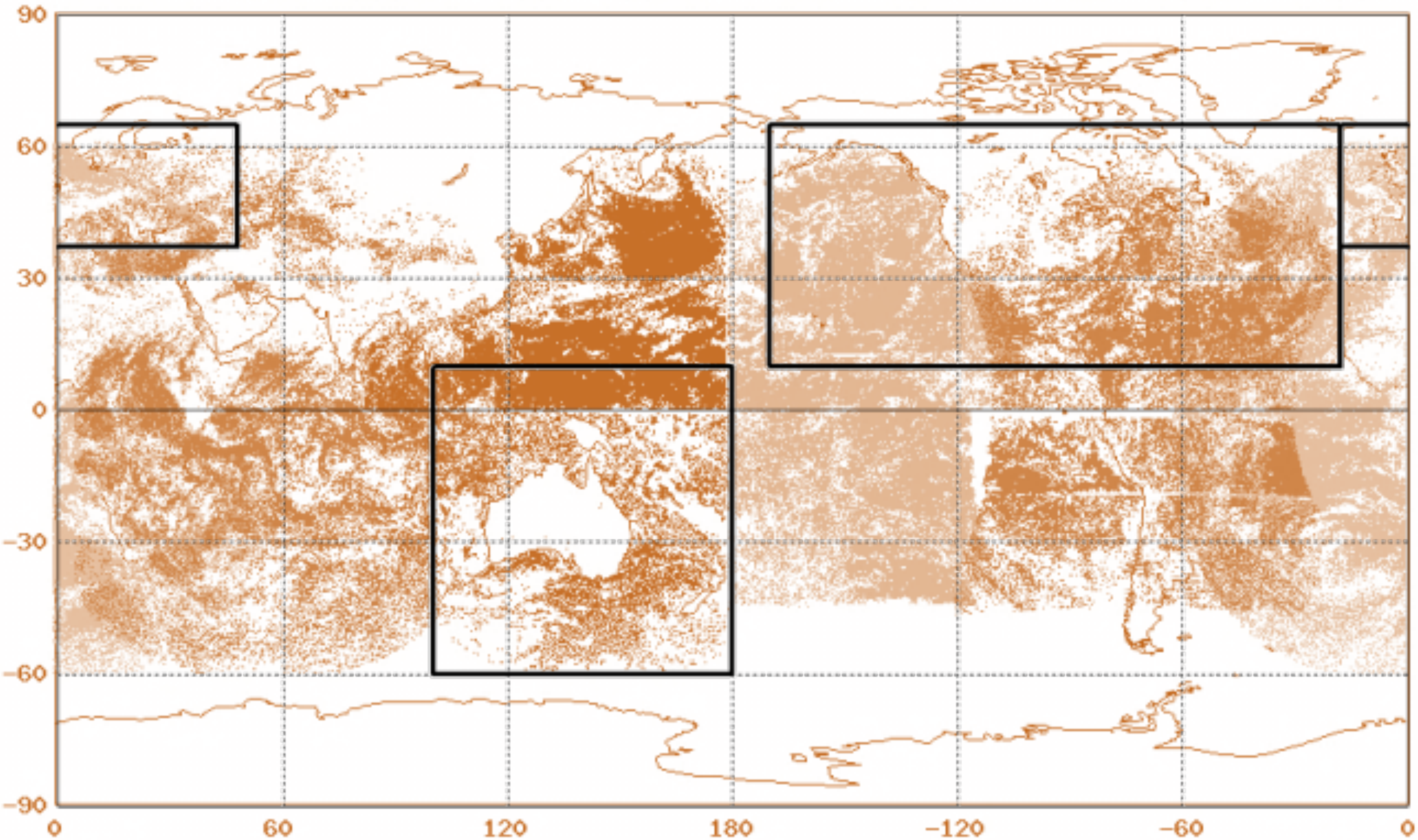
- Read data and convert direction, speed to u, v components
- Assign observation errors
- Read background fields and interpolate to observation locations
- Perform QC on individual observations
  - Exclude invalid observations
    - Missing latitude, longitude, pressure, or time
    - Missing background 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 and
  - Impose land-masking in selected regions

Vertical Limits by Data Type



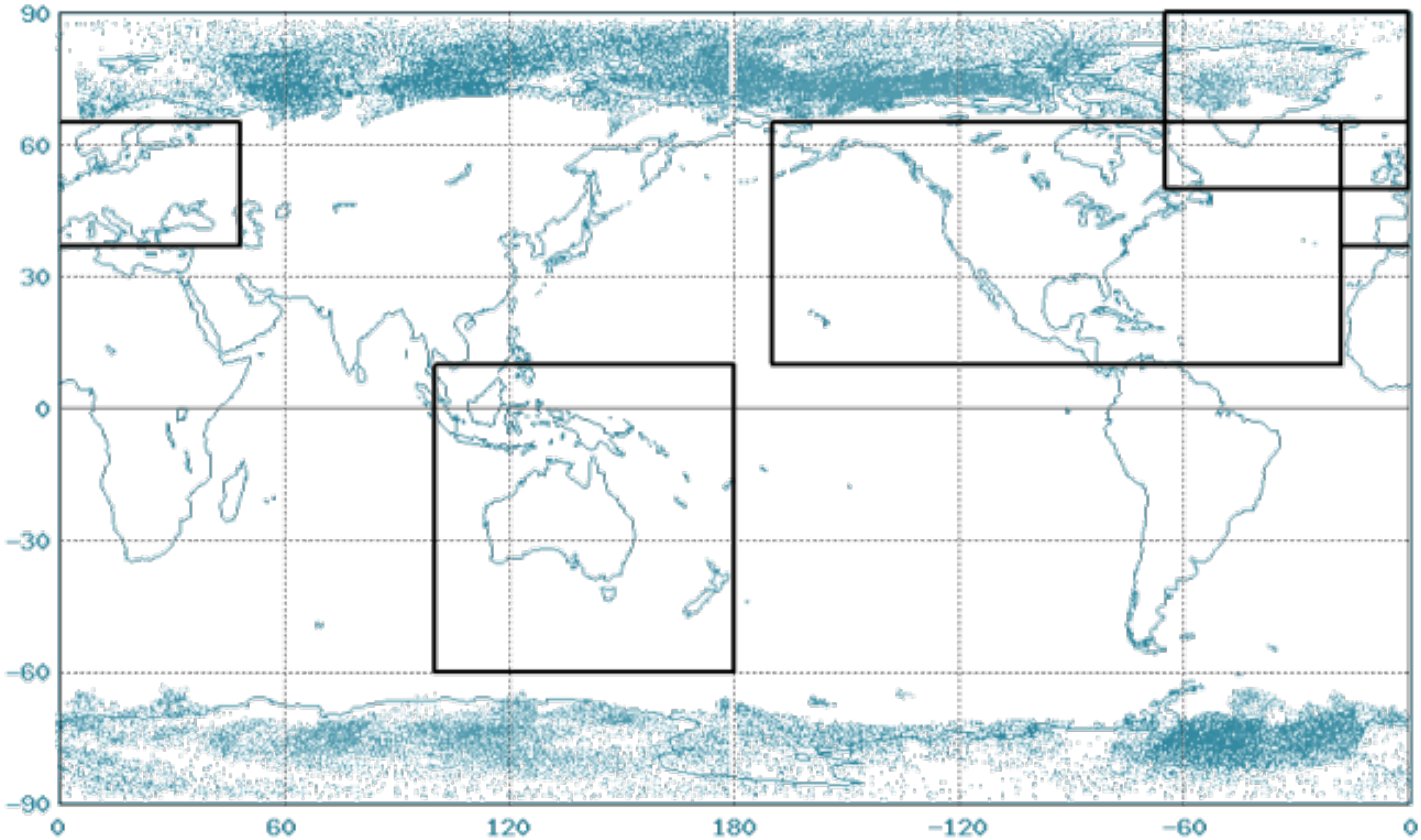
Winds used only within the indicated vertical ranges

Land Masking—Geostationary Winds



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

Land Masking—Polar Winds



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

AMV Processing

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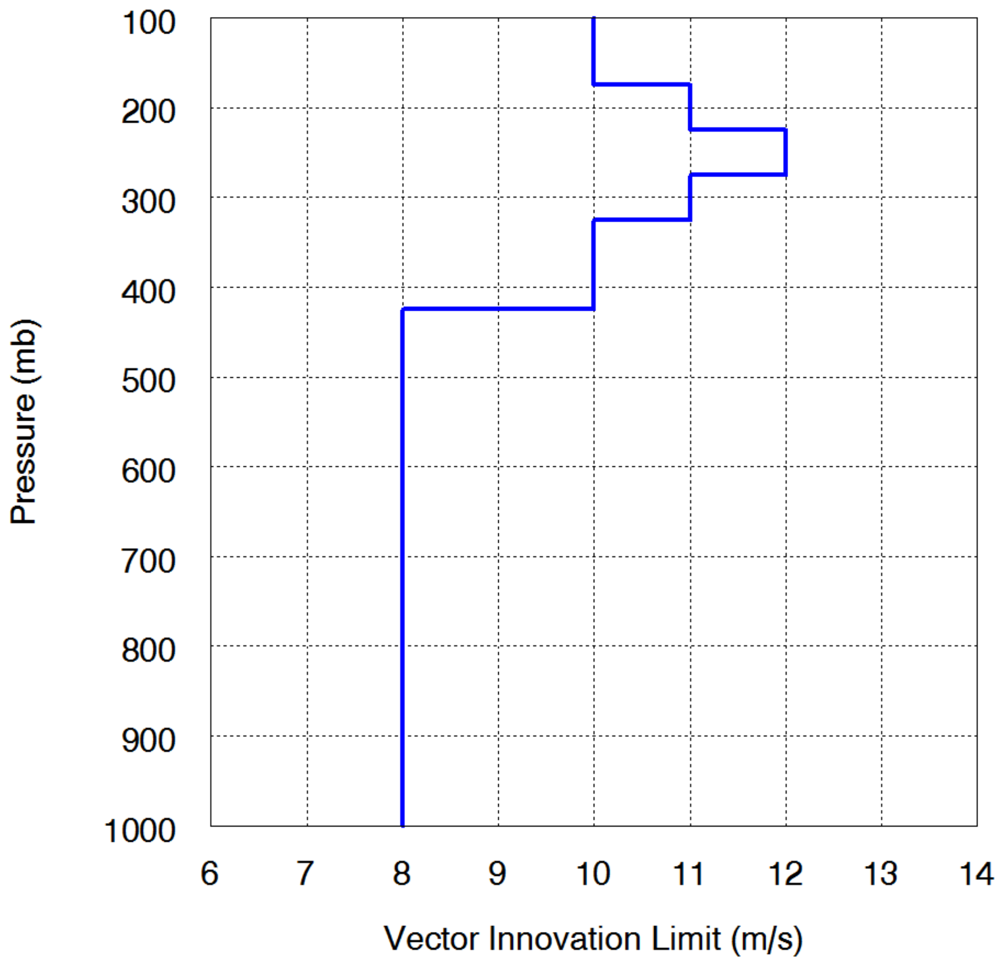
- Assign observation errors
- Read background fields and interpolate to observation locations
- Perform QC on individual observations
  - Exclude invalid observations
  - Exclude observations flagged as bad or having low confidence or quality
  - Impose vertical limits
  - Impose land-masking in selected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

Limits on Vector Innovations



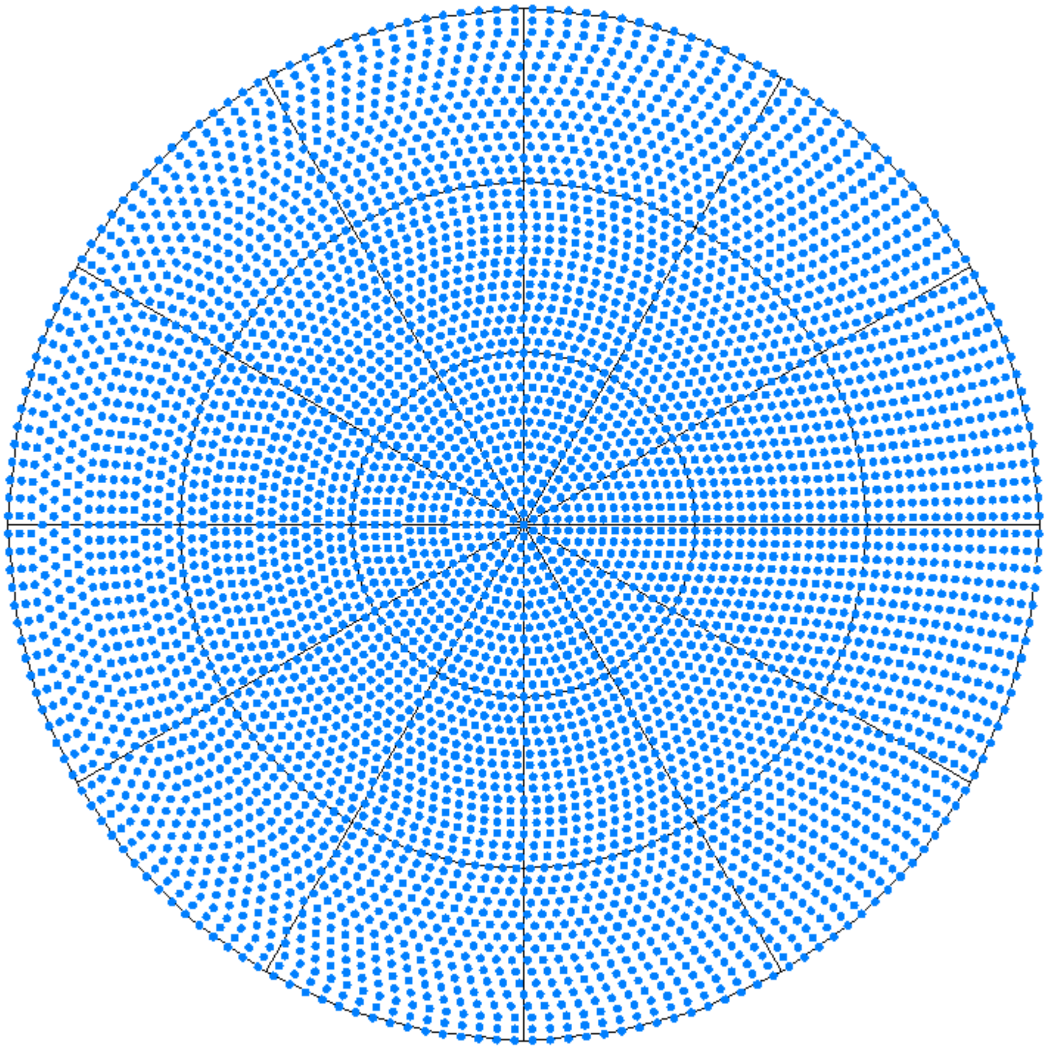
Innovation = Ob - Bk

Winds with vector innovations larger than limits 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

Superob Prism Distribution



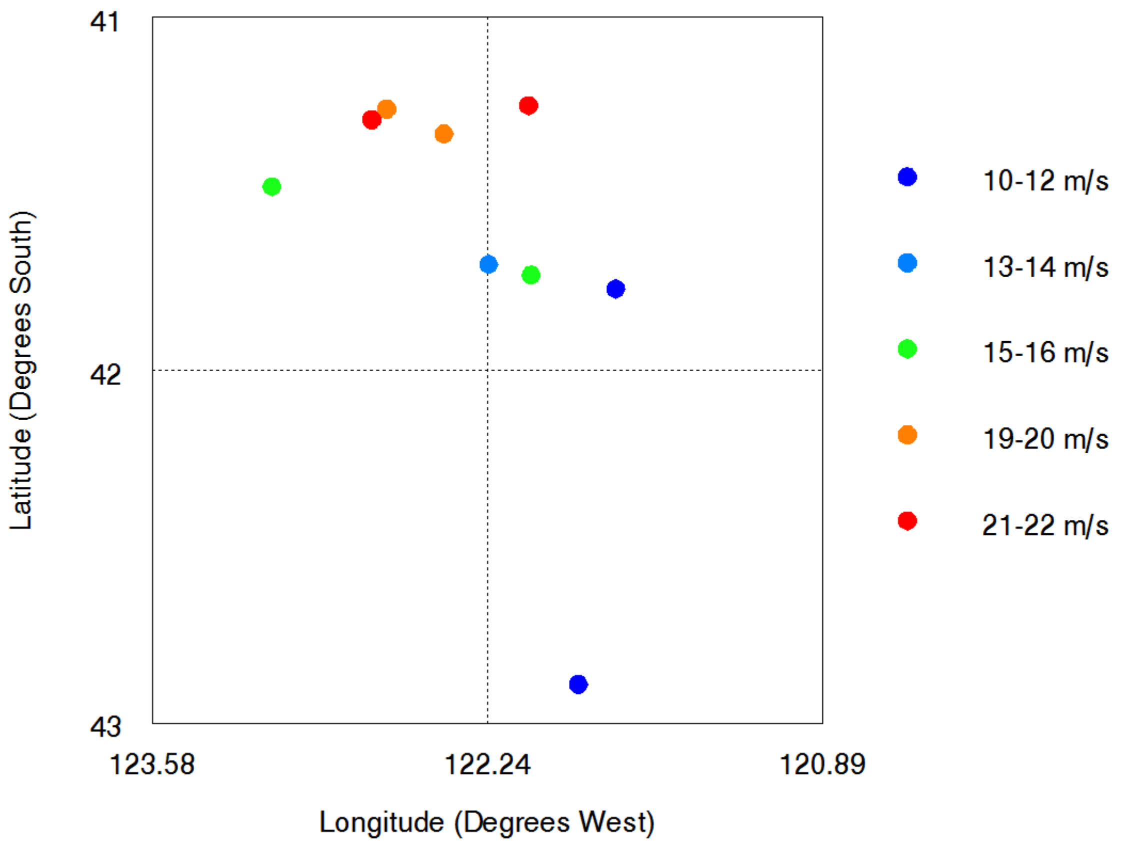
Dots indicate the centers of superob prisms in a hemisphere

- All prisms are 2° lat "tall"
- Prisms at the equator are 2° lon "wide"
- Width varies to approximate equal area
- Each latitude band has an integer number of prisms

AMV Processing

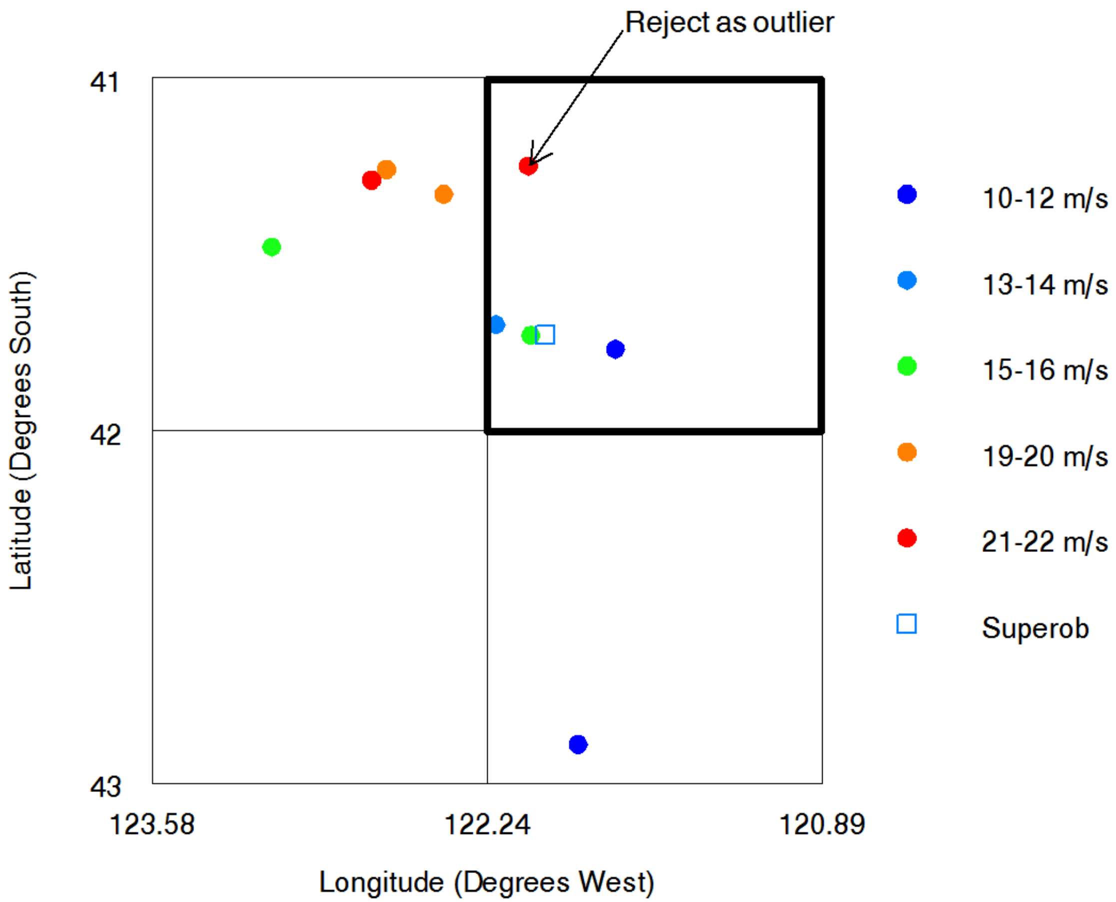
- Read data and convert direction, speed to u, v components
- Assign observation errors
- Read background fields and interpolate to observation locations
- Perform QC on individual observations
- Bin winds into latitude-longitude “prisms” in 50 mb layers
- Examine obs in a prism layer from a particular satellite, channel, and processing center
  - Superob (average) winds if criteria are met

Superob Example



- GOES-11 example from 1722 UTC 31 August 2010
- Directions range from 281° to 296°, within the 20° threshold
- Speed range exceeds the 7 m/s threshold, even if 1 or 2 outliers are rejected

Superob Example



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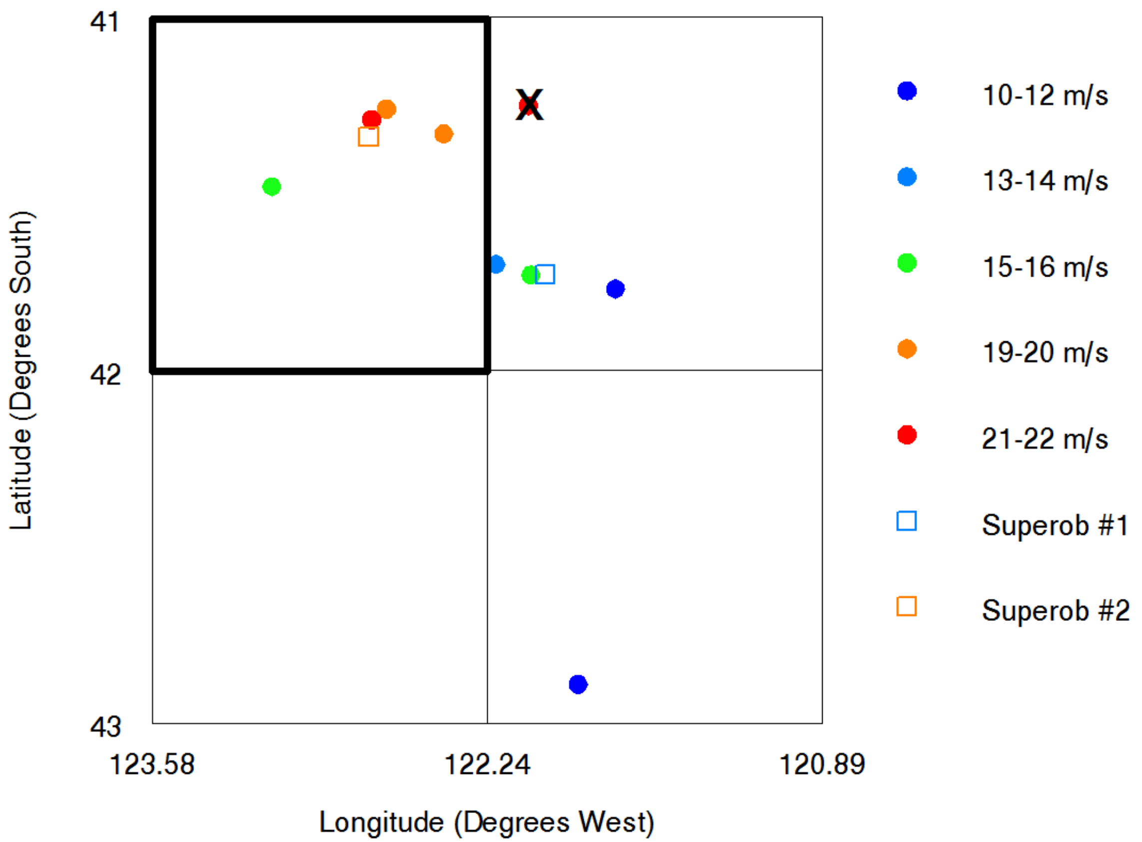
- Superob prism is quartered
- Rejecting one outlier allows a superob to be formed in the first quarter

Superob Example



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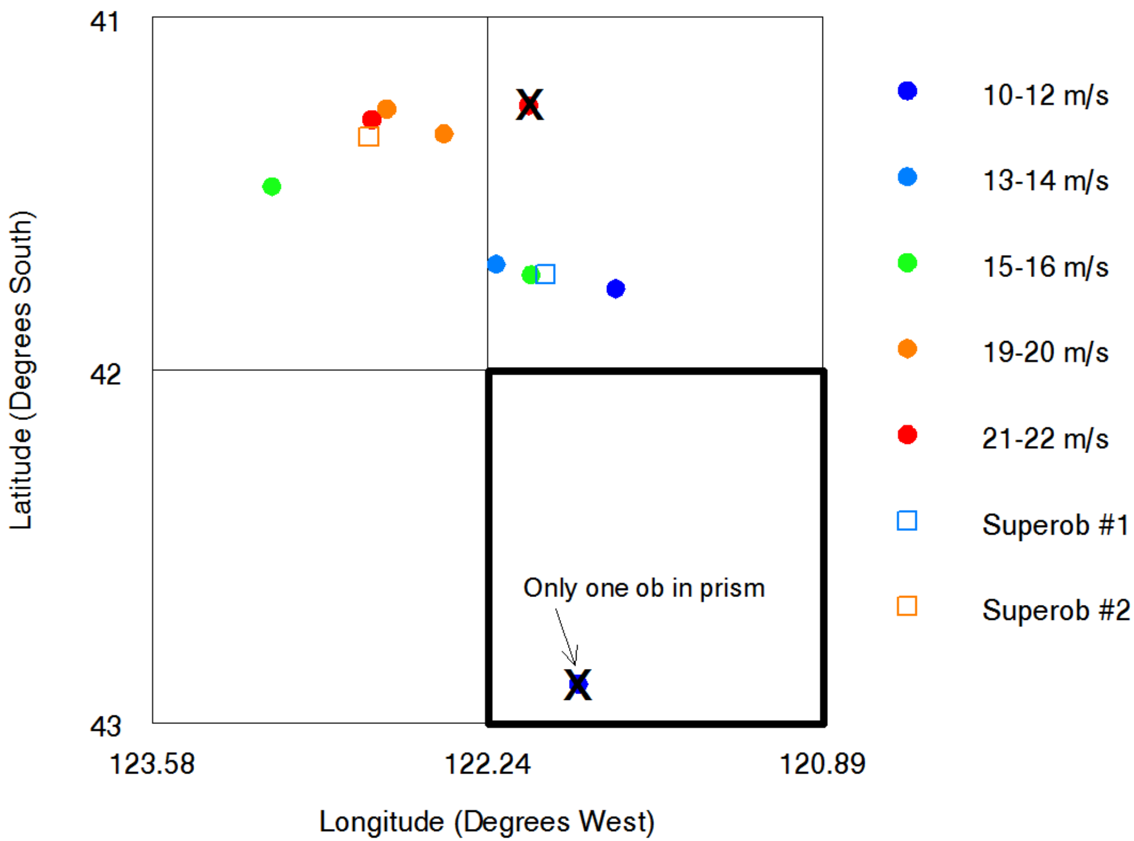
- Obs in the second quarter are within the threshold so a superob is formed

Superob Example



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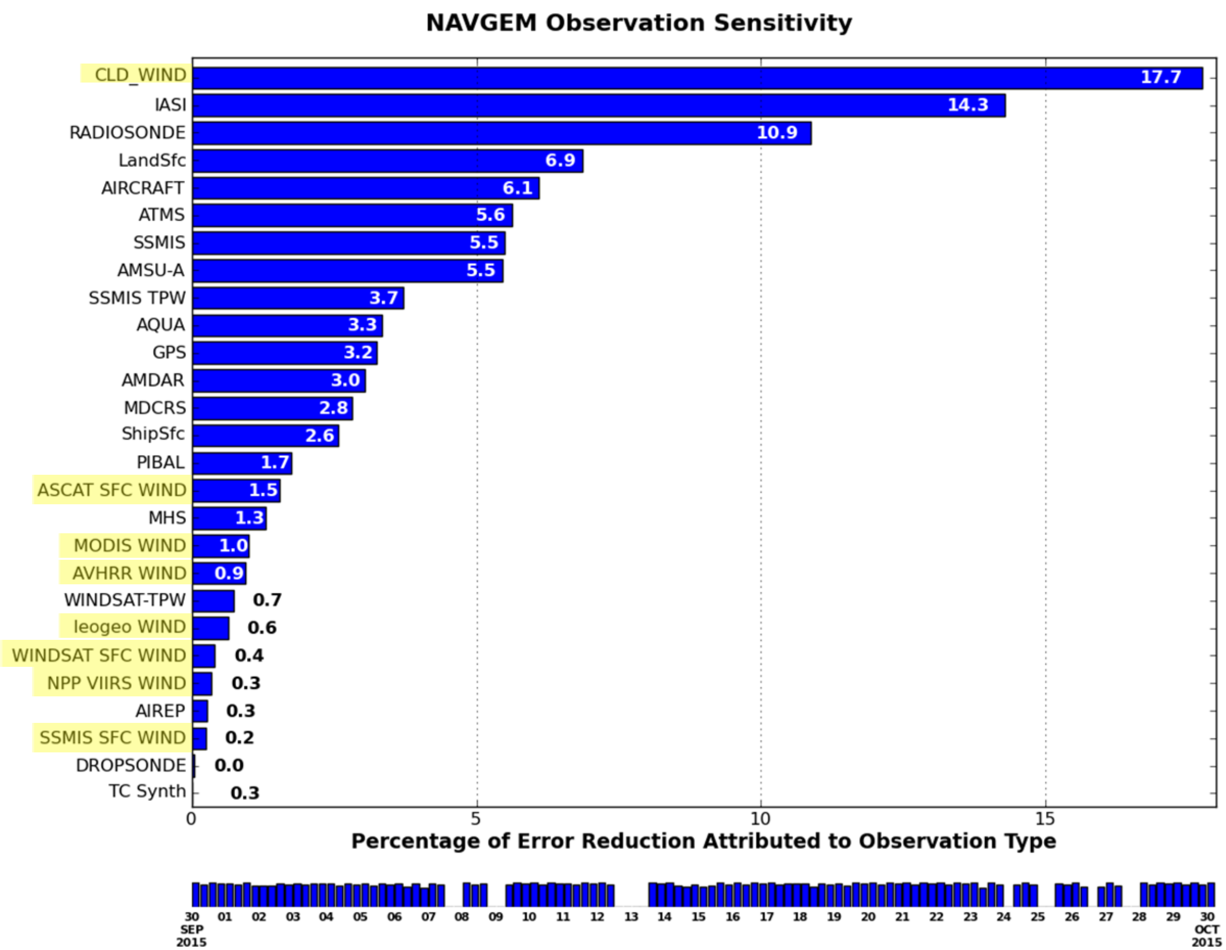
- Superob prism is quartered
- Rejecting one outlier allows a superob to be formed in the first quarter
- Obs in the second quarter are within the threshold so a superob is formed
- Fewer than two obs are in the remaining quarters, so no superobs are formed there

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
- Assimilate AMV superobs using NAVDAS-AR
  - 4DVAR uses winds throughout the 6-hr time window

Impact of AMVs on 24-hr Forecasts



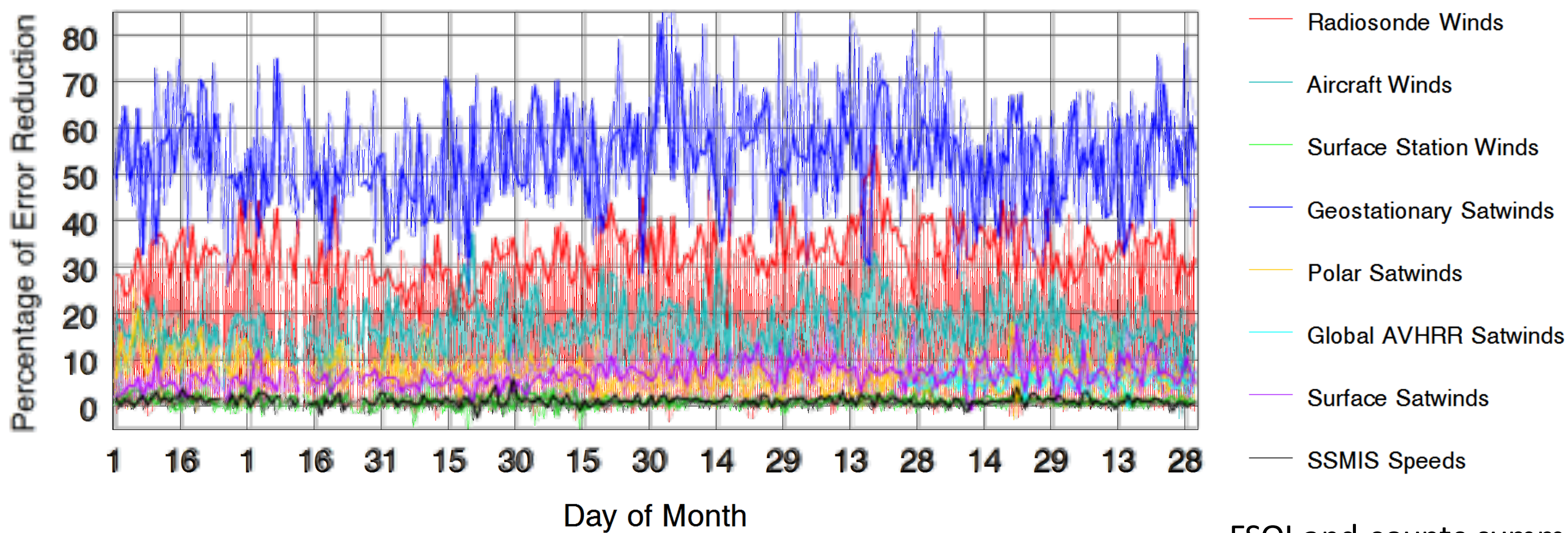
Forecast Sensitivity Observation Impact (FSOI) quantifies the contribution of observations to a reduction in the 24-hr forecast error as measured by the moist energy norm and is computed as part of NAVGEM.

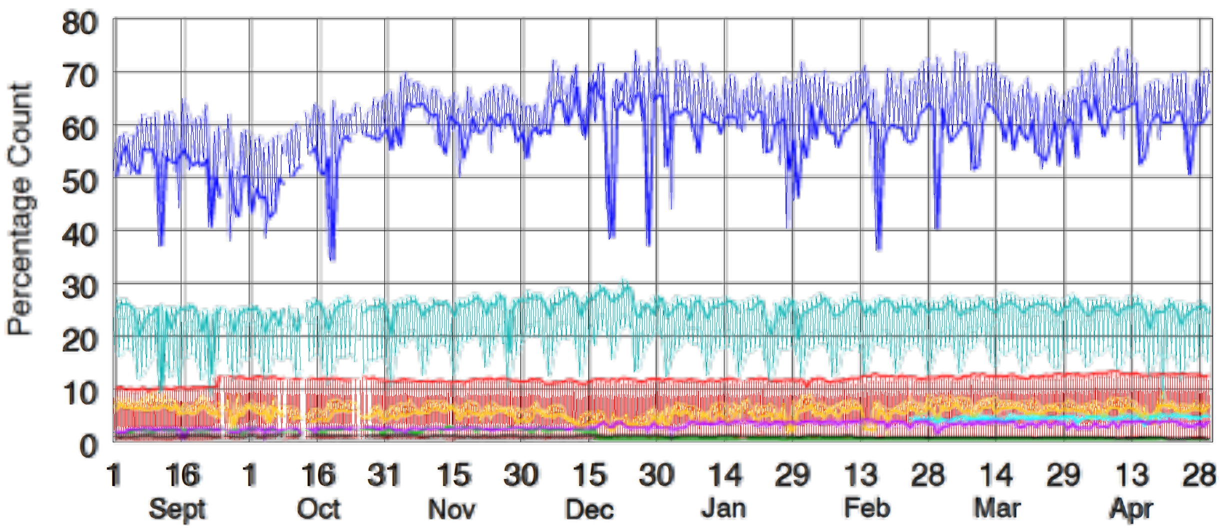
Percentage of error reduction for the operational NAVGEM run for October 2015, with data availability at the bottom of the graph. All variable types are included.

Satellite winds are one of the most critical data types in NAVGEM in terms of percentage error reduction:

- Geostationary feature-track winds ("CLD_WIND") – 18%
- Polar feature-track winds (MODIS, AVHRR, VIIRS winds) – 2.2%
- LeoGeo composite feature-track winds – 0.6%
- Surface satellite winds (ACSAT and WindSat wind vectors and SSMIS windspeeds) – 2.1%

Comparison of FSOI for Winds

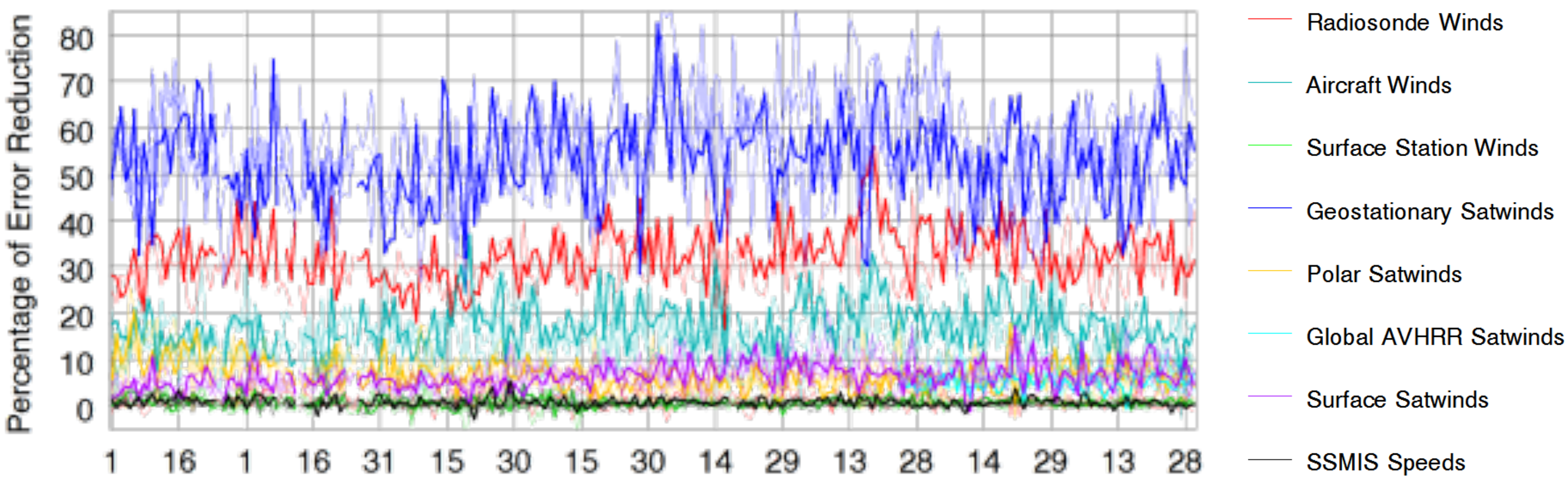


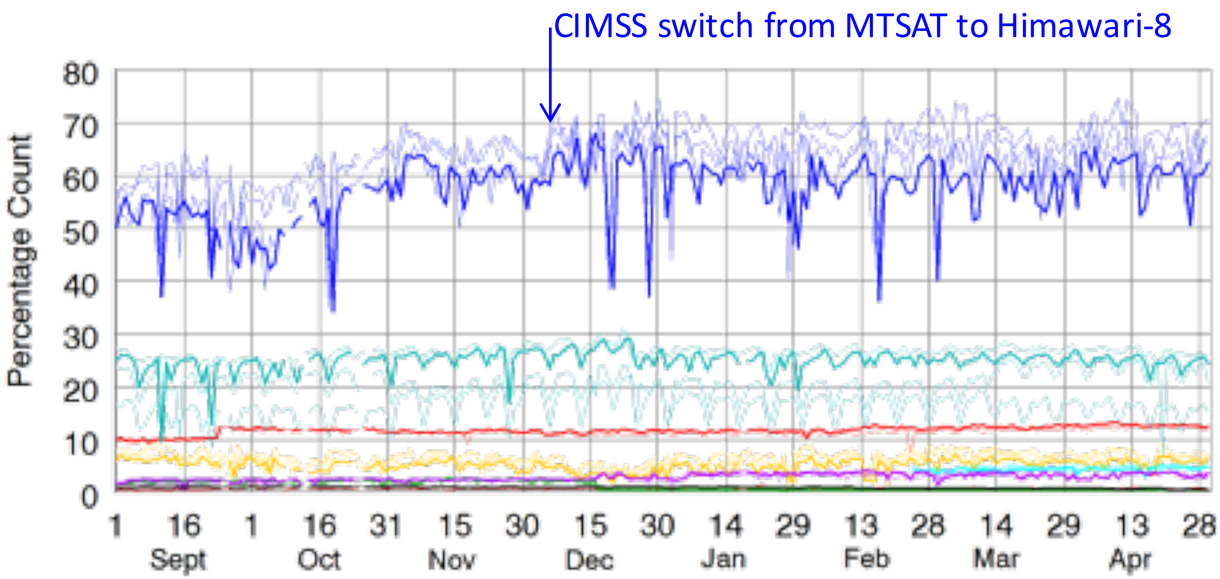


FSOI and counts summed for wind obs for Sept 2015 to April 2016

- Full time series depicted
- Bold line for forecasts from 0000 UTC
- Thin lines for forecasts from 0600, 1200, and 1800 UTC
- Percentages formed using the average total count (768582) and FSOI (-2.4012) per date-time group for the period

Comparison of FSOI for Winds

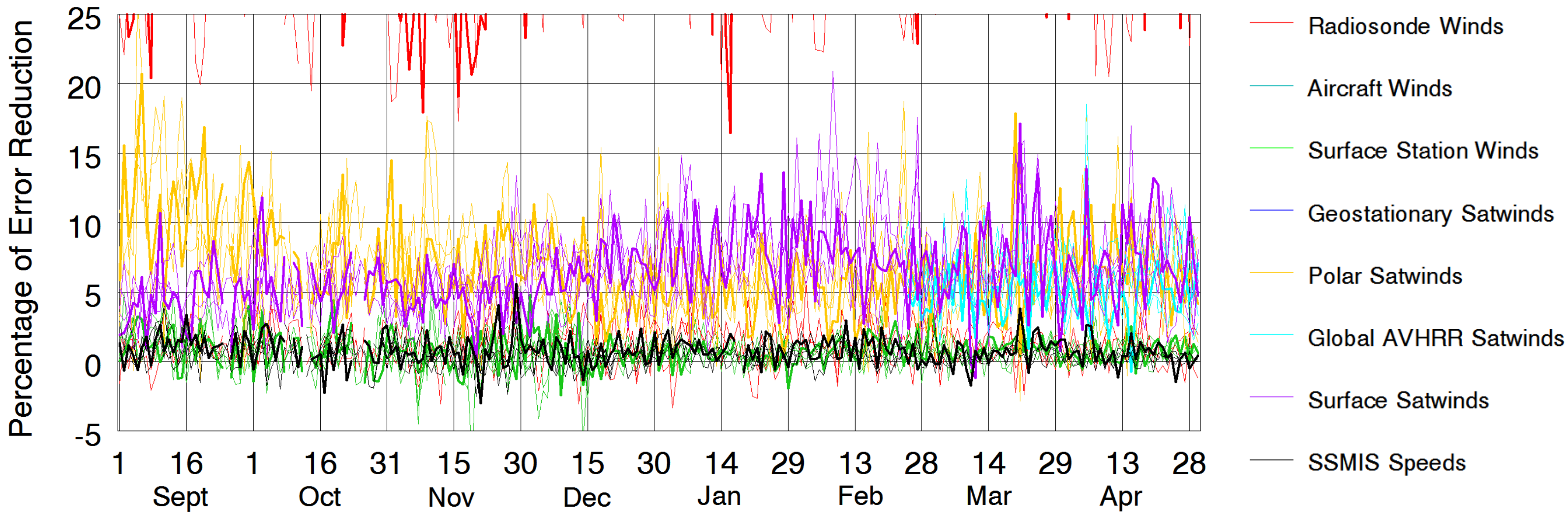


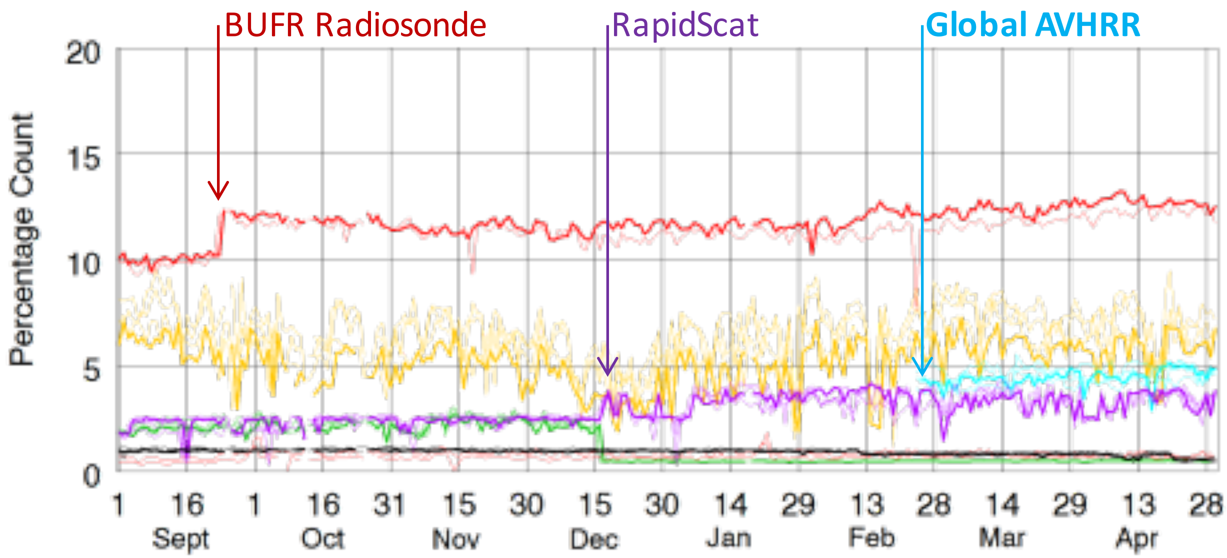


FSOI and counts summed for wind obs for Sept 2015 to April 2016

- Bold line for forecasts from 0000 UTC
- Thin lines for forecasts from 0600, 1200, and 1800 UTC
- Percentages formed using the average total count (768582) and FSOI (-2.4012) per 6-hrs for the period
- Significant variability by time of day

Comparison of FSOI for Winds

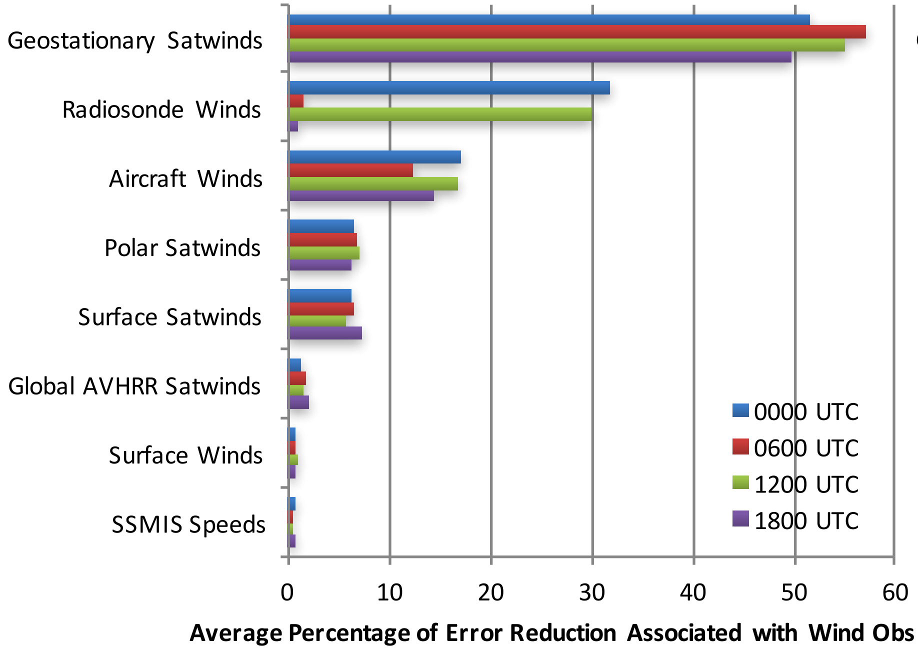


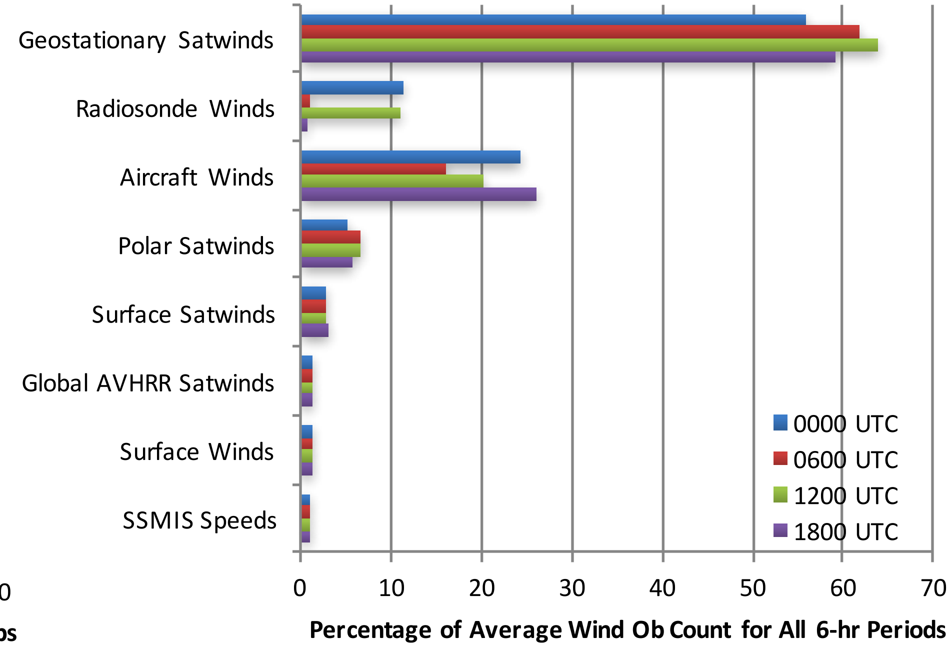


Expansion of previous graph to examine the details of the data types with lower counts

- Initial use of BUFR radiosonde (23 Sept), RapidScat (16 Dec-- included with surface satwinds) and Global AVHRR (24 Feb) indicated with arrows
- Beneficial impact of RapidScat and Global AVHRR shown in top graph

Comparison of FSOI for Winds

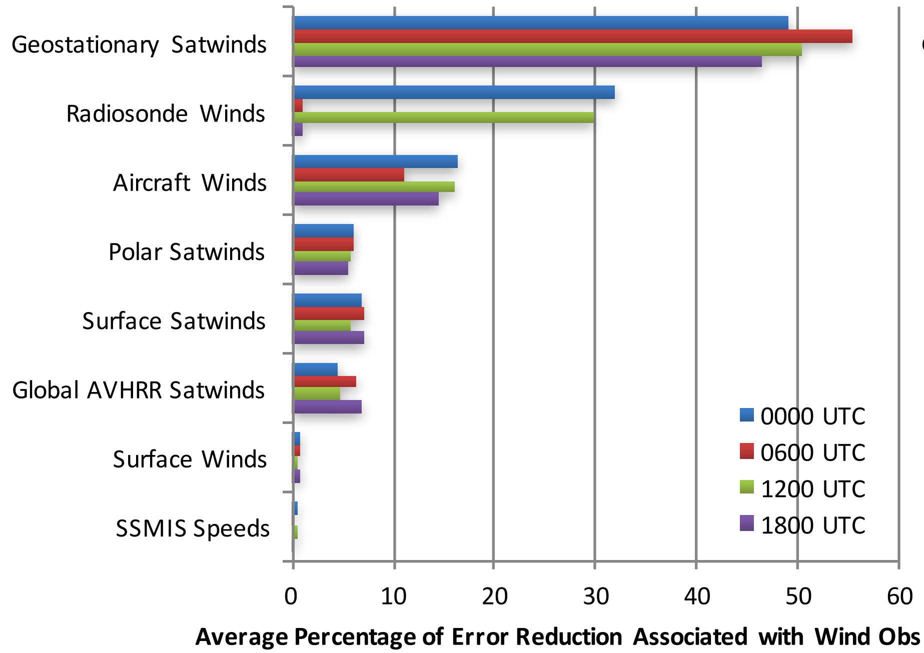


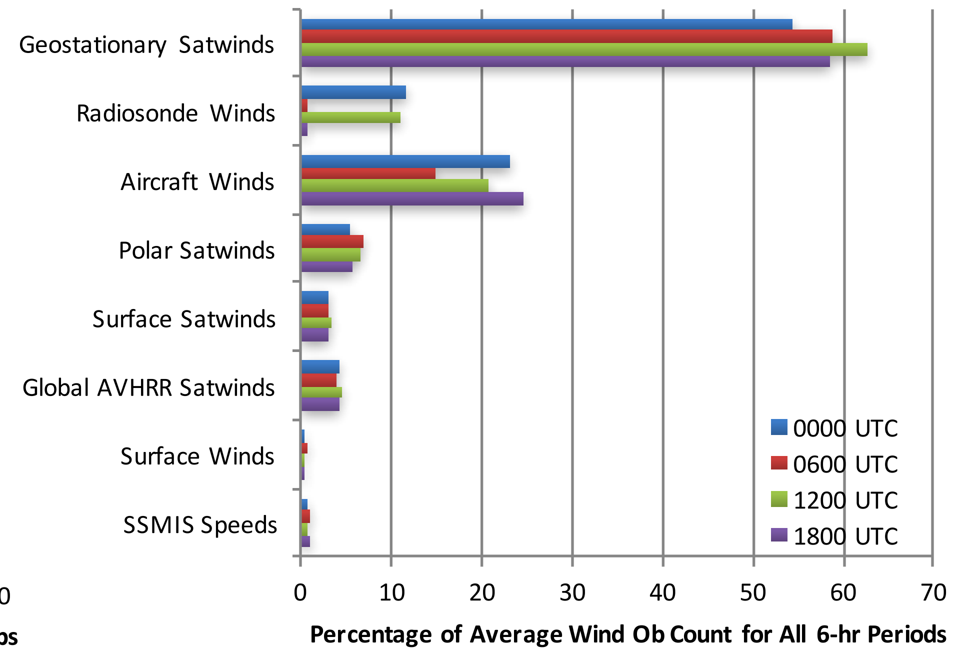


Comparison of wind observations for September 2015 – April 2016

- Some ob types have counts that vary with time of day, most notably radiosonde data
- The percentage of error reduction is related to the ob count, but also the distribution of those obs horizontally and vertically in comparison to other obs, for example:
  - Geostationary satwinds are most important at 0600 UTC—few radiosonde winds available and aircraft winds at a minimum
  - Global AVHRR and surface satwinds have increased impact at 0600 and 1800 UTC—ASCAT and Global AVHRR coverage over the Indian Ocean and Eastern Pacific

Comparison of FSOI for Winds

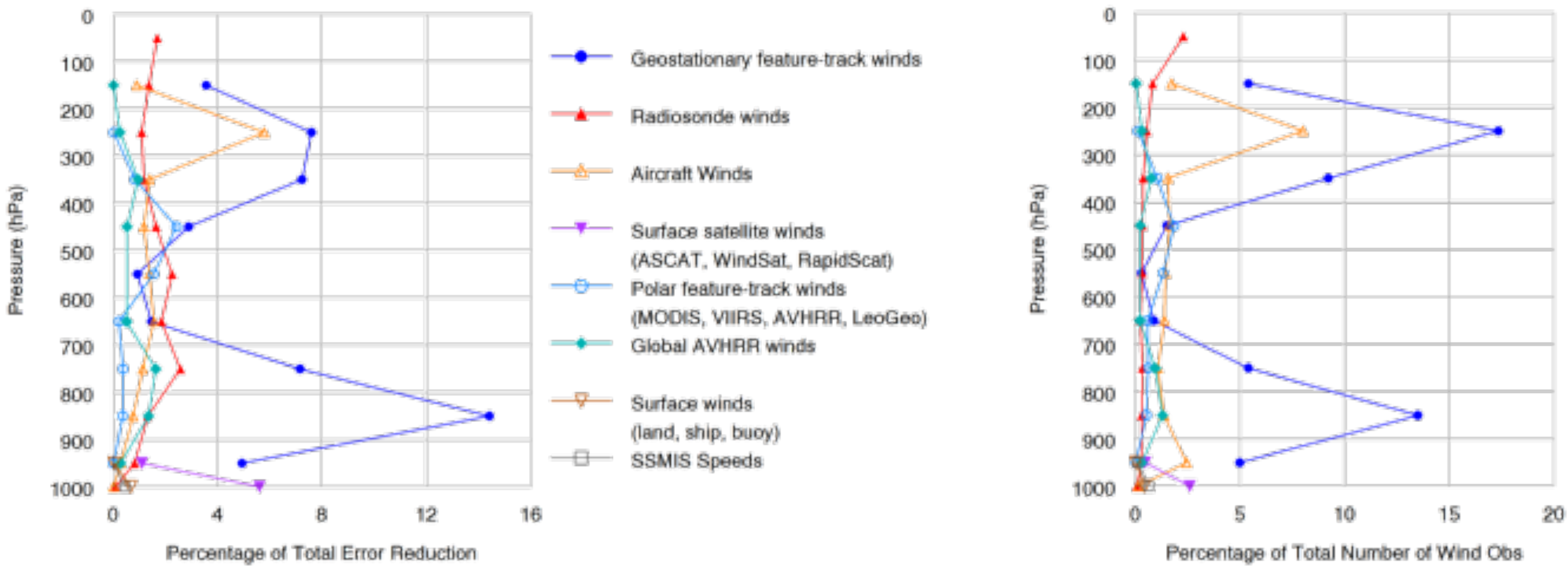




Comparison of wind observations for March – April 2016

- The March-April 2016 period is more representative of what NAVGEM ops currently sees.
- The Global AVHRR winds yield nearly as much error reduction as surface and polar satwinds, but this appears to be somewhat at the expense of the error reduction from geostationary satwinds, especially at 1200 and 1800 UTC.

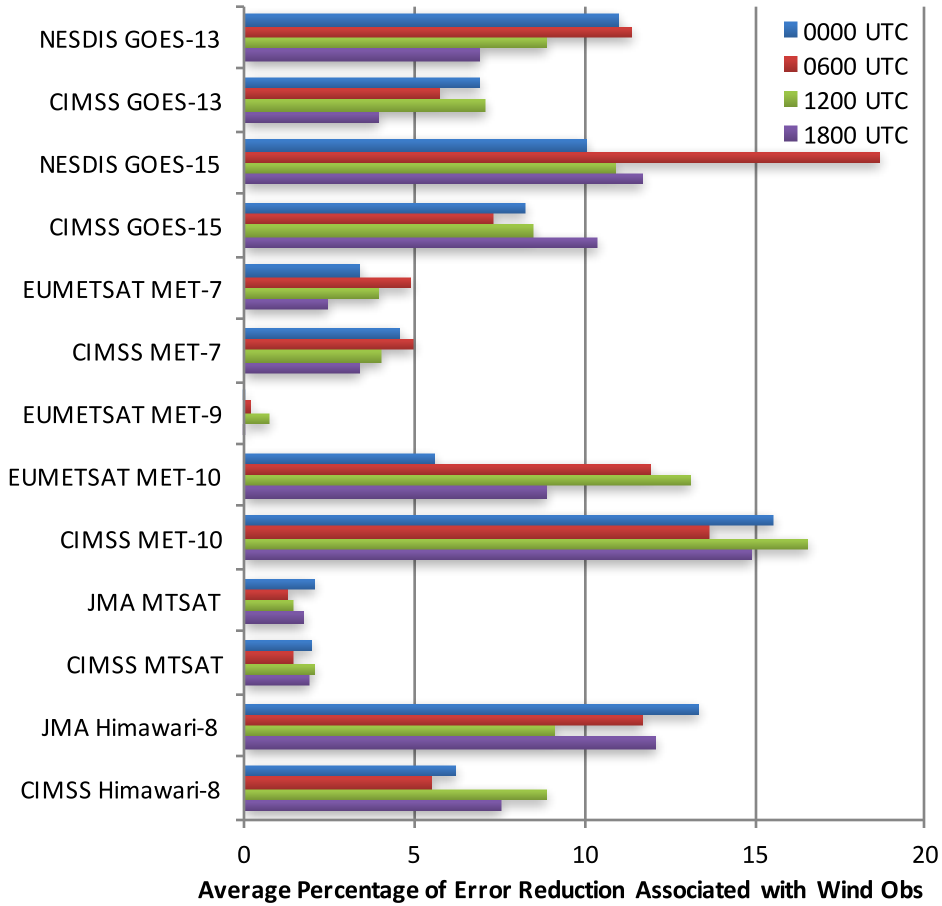
Comparison of FSOI for Winds

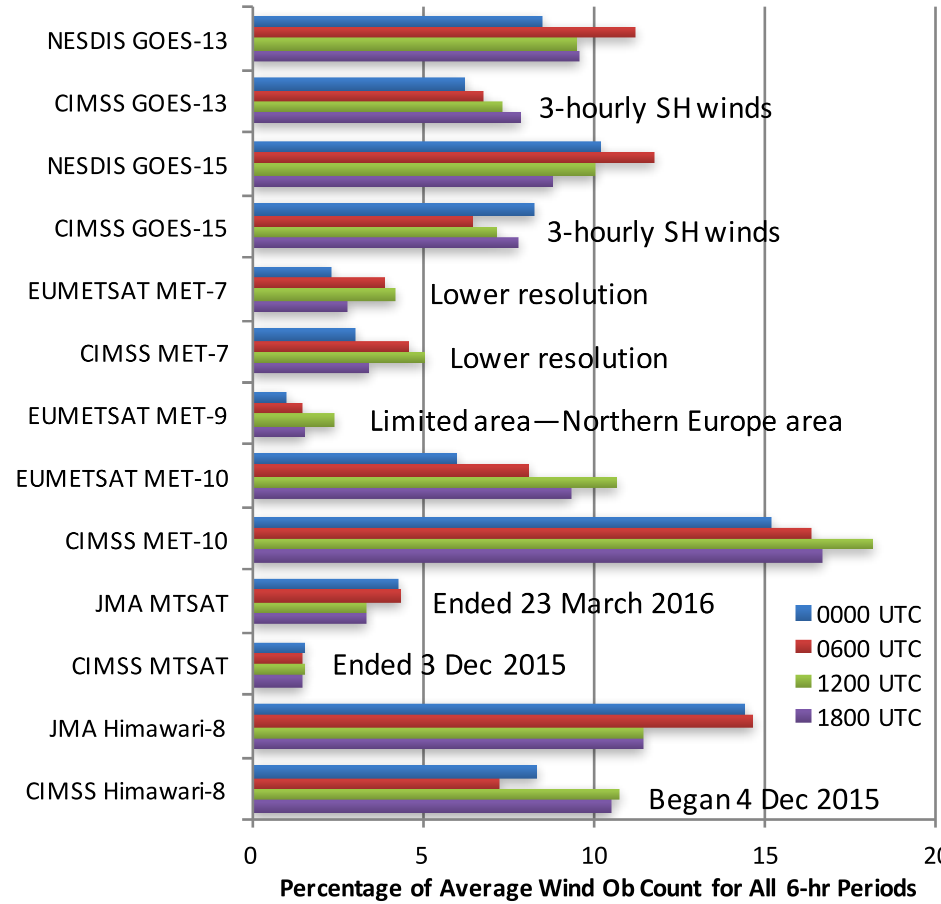


Contributions to error reduction by level for wind observations for Mar-Apr 2016

- Unique contribution by each observation type
- Lower-troposphere peak--primarily visible, infrared, and shortwave infrared geostationary winds
- Upper-troposphere peak--infrared and water-vapor geostationary winds and aircraft winds
- Radiosonde winds key at mid-levels (700-500 hPa) and above 100 mb where other winds are few
- Aircraft and radiosonde winds are assigned a lower ob error than satellite winds
- Surface satellite winds and surface winds important at the lowest levels
- Polar feature-track winds important regionally, especially at 600-300 hPa
- Global AVHRR winds important in lower and upper troposphere where available

Comparison of FSOI for Winds





Comparison of Geostationary satwinds for September 2015 – April 2016

- Some satellite wind sources provide more winds than others for indicated reasons.

Ongoing Work

- Evaluation of new satwind datasets
  – INSAT-3D
  – COMS
  – MISR
- Re-evaluation of aspects of superobbing
  – Discontinuing use of innovation limits prior to forming superobs
  – Allowing single obs to be used in prisms that only contain one ob
  – Decreasing size of superob prisms horizontally and/or vertically
  – Discontinuing use of land mask
  – Investigating the use of thinning rather than superobbing for surface satwinds

Questions?

Acronyms

- **NAVGEM** (NAVy Global Environmental Model)—the U.S. Navy's operational global modeling system
- **NAVDAS-AR** (Naval Research Laboratory Atmospheric Variational Data Assimilation System-Accelerated Representer)—the 4DVAR data assimilation system used in NAVGEM

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 CIMSS Meteosat, AVHRR, and global AVHRR).
- 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.