MODIS- and AVHRR-derived Polar Winds Experiments
using the NCEP GDAS/GFS

NA10NES4400011

Year 3 Second-half Progress Report
December 2012 through May 2013

28 June 2013

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Proposed Work

From the proposal:
Atmospheric Motion Vectors (AMV) are routinely generated from geostationary and polar orbiting satellites and they are incorporated into most global numerical weather prediction models throughout the world. However, advances to the AMV derivation process together with changes to assimilation systems and forecast models require the strategies for use of the satellite-derived winds to be continually evaluated.

The focus of the proposal is in three areas using AMVs generated from polar orbiting satellite data: (1) Quality control (QC) and thinning using the Expected Error; (2) Experiments assimilating polar winds derived from Advanced Very High Resolution Radiometer (AVHRR) images; and, (3) Experiments designed to simulate winds from the Visible/Infrared Imager/Radiometer Suite (VIIRS) instrument onboard the Suomi NPP satellite.

Second Half of Third Year Progress

When this proposal was first written and during the first years of the project, the Expected Error (EE) appeared to be a good candidate for screening AMVs. Results from experiments presented at the 2012 JCSDA Workshop were very encouraging when using the EE scaled by the observation speed. However, recent developments have us reconsidering the use of the EE:

1. For the polar winds, the EE does not appear to be related to any measure of quality.
2. The EE is apparently not available for the AVHRR winds.

These two factors have convinced us to investigate a different method for quality control that can be used for all the polar winds products, including VIIRS in the future.

Also, these areas were addressed or identified:

- Access to computing resources
- MODIS polar winds experiments
- AVHRR polar winds experiments
- VIIRS polar winds status
- Subversion source control
- Personnel status
- Conferences and papers
- Project extension

Expected Error issues

When the proposal was written, the Expected Error correlated well with improved Observation Minus Background (OMB) statistics for geostationary winds. We expected a similar relationship would follow for the polar winds. However, that does not appear to be the case for the following reasons:

- We did an analysis of both polar and geostationary satellite winds using several weeks of observations, to determine if there is a correlation between winds-related parameters and the EE. For the geostationary winds, the majority of the variance in the correlation is explained by the QI (without forecast), wind speed, and background departure (OMB). Higher quality EE values are associated with higher QI, lower wind speed, and lower OMB. However for the polar winds, the better EE values are correlated with lower wind speed and higher pressure. Unlike the geostationary winds, no measure of quality (e.g., QI or OMB) correlates with the EE for polar winds.
- The EE coefficients, derived from a multi-variable regression with RAOBs, vary widely in value between different satellites (Aqua and Terra) and hemisphere (northern and southern). This is unexpected since the MODIS instrument is well calibrated and the performance is very similar between the two satellites. We suspect there is a sampling issue due to very few RAOBs being available for determining the coefficients: less than 5% of the MODIS winds are in the vicinity of a RAOB station.

Three other factors contributed to our abandoning the Expected Error:

- Our inspection of the BUFR files containing AVHRR winds did not reveal an EE value. Emails to Xiujuan Su, Jim Jung, Jaime Daniels, and Dennis Keyser could not resolve the issue of why the EE apparently was not contained in the files. It was also learned that if the EE was present, it would be based on the MODIS EE coefficients.
- One of the terms in the calculation of the EE is the AMV Quality Indicator (QI) that is dependent on the forecast. From a data assimilation point of view, the AMVs and associated quality information should be independent of the model.
- When the VIIRS winds are first available, it is unlikely there will be an EE associated with the AMVs. If there is, it will be using the coefficients from MODIS. Also, based on the earlier arguments, it will be difficult to compute reliable EE coefficients for VIIRS due to the scarcity of RAOBs.

New quality control

Discussions with Jim Jung and Li Bi about her encouraging results using a normalized OMB vector difference for OSCAT winds resulted in our investigating a similar measure for quality control for the polar winds. However, recognizing that wind speed has a range that covers three orders of magnitude (1, 10, 100 ms^{-1}), we elected to normalize the vector departure by the logarithm of the observation speed. The Log Normalized Vector Departure (LNVD) is defined as:

$$\mathrm{SQRT}\ (\ (U_o-U_b)2 + (\ V_o - V_b)2\ )\ /\ \log(\mathrm{ObsSpd})$$

where U_o, V_o is the observed u- and v- components; U_b, V_b is the background; ObsSpd is the AMV speed.

For the initial evaluation of the LNVD, we determined a threshold that would result in the same number of discarded winds as the control and EE ratio experiment. A LNVD threshold of 3 is equivalent to EE ratio of 1.33, and the LNVD has a similar effect as the EE ratio by discarding more slow winds and retaining higher speed winds. Figure 1 illustrates the change in distribution of the winds retained by the LNVD (red) compared to the control (blue): the dashed black line shows many more winds < 10 ms^{-1} are removed, while retaining more winds in the range 10-40 ms^{-1}.

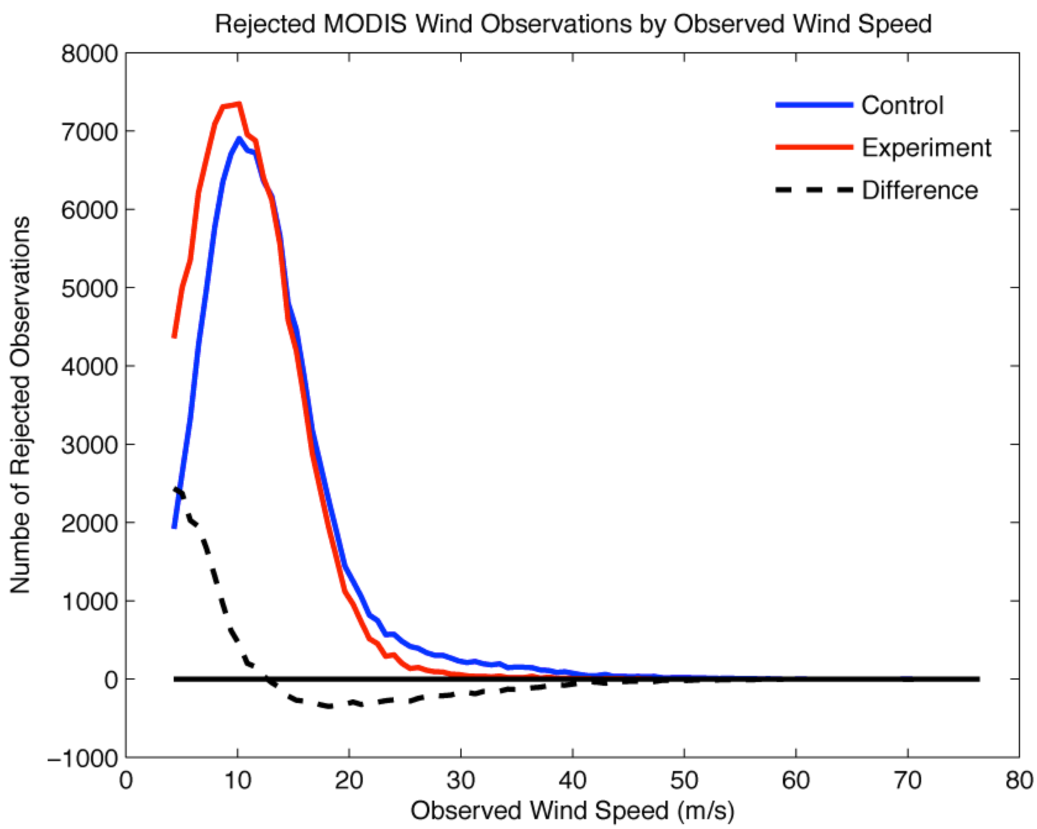

Figure 1. Histogram of rejected AMVs binned by observed wind speed for the control (blue) and LNVD experiment (red) for 9 – 26 October 2012. In the experiment, winds are discarded if the LNVD > 3.

The following table shows how the allowed vector departure can increase for faster winds to be retained with the LNVD method. Recall, the operational screening discards AMVs if the u- or v- component differs by more than 7 ms^{-1} from the background. Therefore, most slow winds (< 5 ms^{-1}) are retained in the control because they will not exceed the 7 ms^{-1} threshold, even though they may be pointed in the opposite direction! On the other end of the scale, the LNVD < 3 will allow a 50 ms^{-1} wind to deviate from the background by 11.7 ms^{-1} and still be retained.

LNVD threshold = 3		
ObsSpd	Log(ObsSpd)	VecDiff
3	1.1	3.3
10	2.3	6.9
50	3.9	11.7
100	4.6	13.8

A graphical depiction of the LNVD screening (Figure 2) shows that slow winds (3 ms^{-1}; upper left panel) can vary substantially from the background, but not in the opposite direction as the control would allow. For high-speed winds (60 ms^{-1}; lower right panel) the direction can not vary by much, but speeds from 50-73 ms^{-1} will be retained; a larger range than the control.

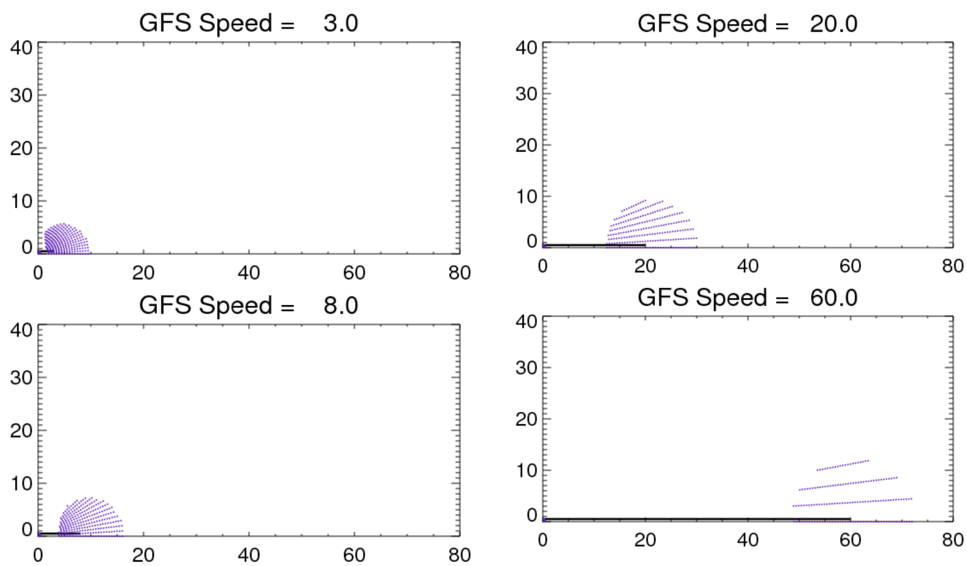

Figure 2. A graphical representation of retained winds with the threshold, LNVD = 3. The solid black line along the x-axis represents the wind vector at speeds: 3, 8, 20, 60 ms^{-1} shown in individual panels. The purple dots represent the end point of a vector (originating at 0,0) that will be retained.

Access to computing resources

We have access to zeus, jibb, and s4. We primarily run the hybrid GDAS/GFS on s4. Briefly, on s4 we:

- Used the latest version of the hybrid GDAS/GFS certified on s4
- Ran experiments using the MODIS polar winds
- Ran experiments using the AVHRR polar winds

MODIS experiment

The previous experiments run under this project using the EE ratio as a quality control resulted in retaining more high-speed winds and discarding more low-speed winds, compared to the control. For a one-season experiment, the results were very favorable, especially in some forecast dropout events (December 2012 JCSDA newsletter). The threshold for the EE ratio was determined, such that, the number of rejected observations was approximately the same in both the control and experiment, in this case 8%.

The new QC method, LNVD, has similar characteristics as the EE ratio: retaining more high-speed winds; discarding more low-speed winds. A threshold of 3 for the LNVD, results in a similar number of rejections as the control and EE ratio. This threshold will be used for the first set of experiments.

The following sections detail preliminary results of the assimilation impact and the forecast impact.

Assimilation impact

Figure 3 is a frequency plot of the OMB and Observation Minus Analysis (OMA) for 17 days in October 2012 for the MODIS IR AMVs. The red curves are OMB; the blue curves OMA. Generally, these curves are the same for the control (top) and experiment (bottom): the bias is nearly zero and the standard deviation is the same. The experiment OMB standard deviation is 2.44 ms^{-1}, which reduces to 2.10 ms^{-1} for OMA (i.e., the observations have an impact on the analysis).

Even though the LNVD method retains winds with a larger background departure, they are few in number so the bulk statistics are very similar to the control.

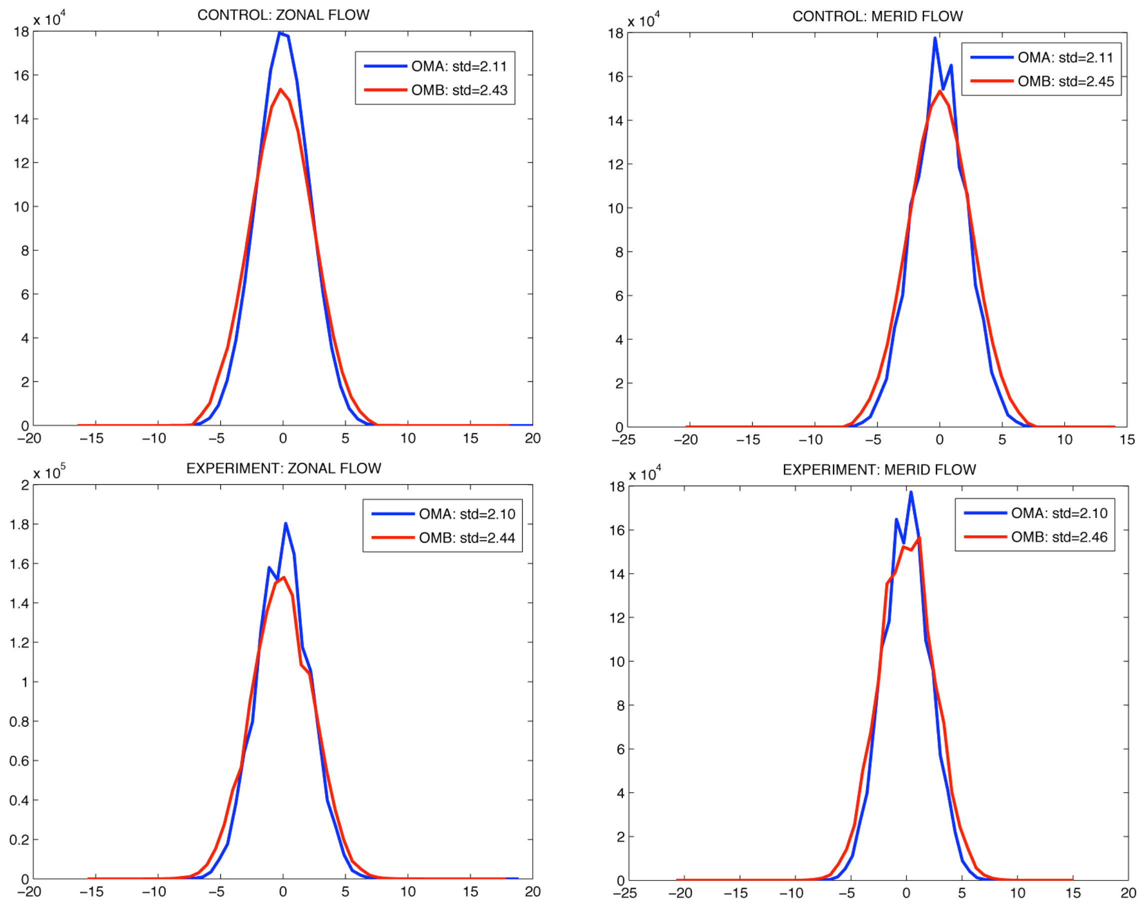

Figure 3. MODIS IR AMVs Observation Minus Background (OMB) and Observation Minus Analysis (OMA) distributions for 9 – 26 October 2012. The top panels are the control; the lower panels the experiment, for the u-component (left side) and v-component (right side) of the wind.

Forecast impact

Figures 4 and 5 show very preliminary forecast impact of the LNVD QC method compared to the control as measured by the hemispheric Anomaly Correlation (AC) at 500 hPa. The averaged AC score (left panels of Figures 4 and 5) is only for 11 days from mid-October 2012. The daily scores are in the right panels for Day-5, -6, and -7 forecasts.

The averaged scores for the northern hemisphere (Figure 4) are neutral for this short time period. This is expected, since generally the MODIS winds have a neutral impact except in some situation dependent flow regimes.

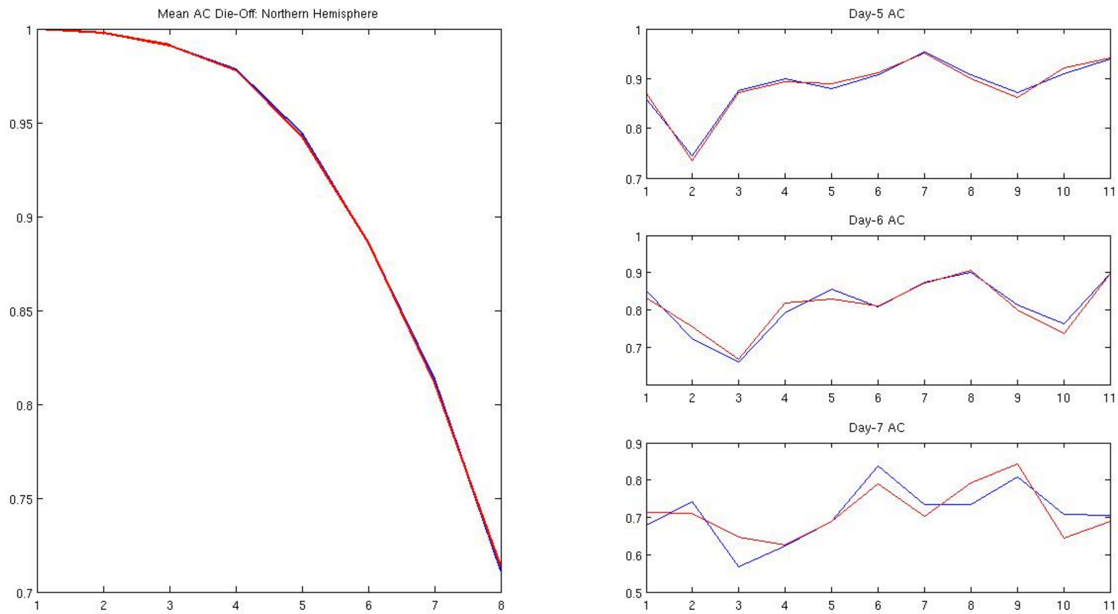

Figure 4. Very preliminary results of the Anomaly Correlation (AC) scores averaged over the first 11 days of the experiment (left) and the daily scores for Day-5, -6, and -7 (right). Scores are computed for 500 hPa geopotential heights over the northern hemisphere (20°N-80°N) for the control (blue) and the experiment (red), using the LNVD threshold of 3. Date: 9-20 October 2012.

Similarly, the averaged scores for the southern hemisphere (Figure 5) are generally neutral, although by Day-7 and -8 the experiment is out-performing the control. Because of the short time period, these results are not significant, although they are tending in the right direction.

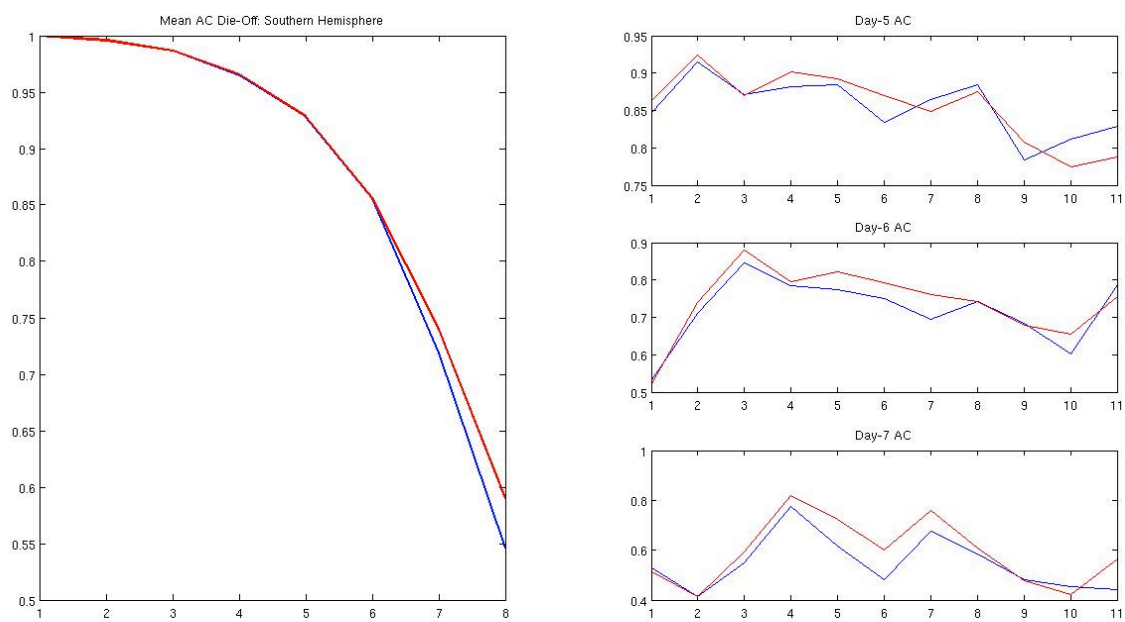

Figure 5. Same as Figure 4, except for the southern hemisphere.

We have restarted the experiment using a more recent version of the GSI, r29119, in preparation to check in code changes into subversion and changed the start date to 1 September 2012, due to a yet un resolved problem with the experiment near 26 October 2012.

AVHRR experiments

Experiments using AVHRR IR winds have begun using the same LNVD settings as MODIS. The real-time AVHRR winds are from NOAA-15, -16, -18, -19, and Metop-A for this time period. For the NOAA satellites, features are tracked in 4 km resolution images (compared to 2 km for MODIS). However, for the Metop satellite the resolution is the same as MODIS. This results in more AVHRR IR winds as compared to MODIS, but MODIS has a substantial contribution from water vapor winds.

In this first experiment, the AVHRR winds replace the MODIS winds and the statistics presented are compared to their respective background and analysis. This scenario is important as the MODIS instruments on Terra and Aqua are well-beyond their designed life-times, so AVHRR-only polar winds may be a reality in the near future.

Figures 6 and 7 show preliminary OMB and OMA statistics for AVHRR (green) as compared to MODIS IR (yellow). The shapes of the OMB curves are about the same, with a bias near zero and equivalent standard deviation (Figure 6).

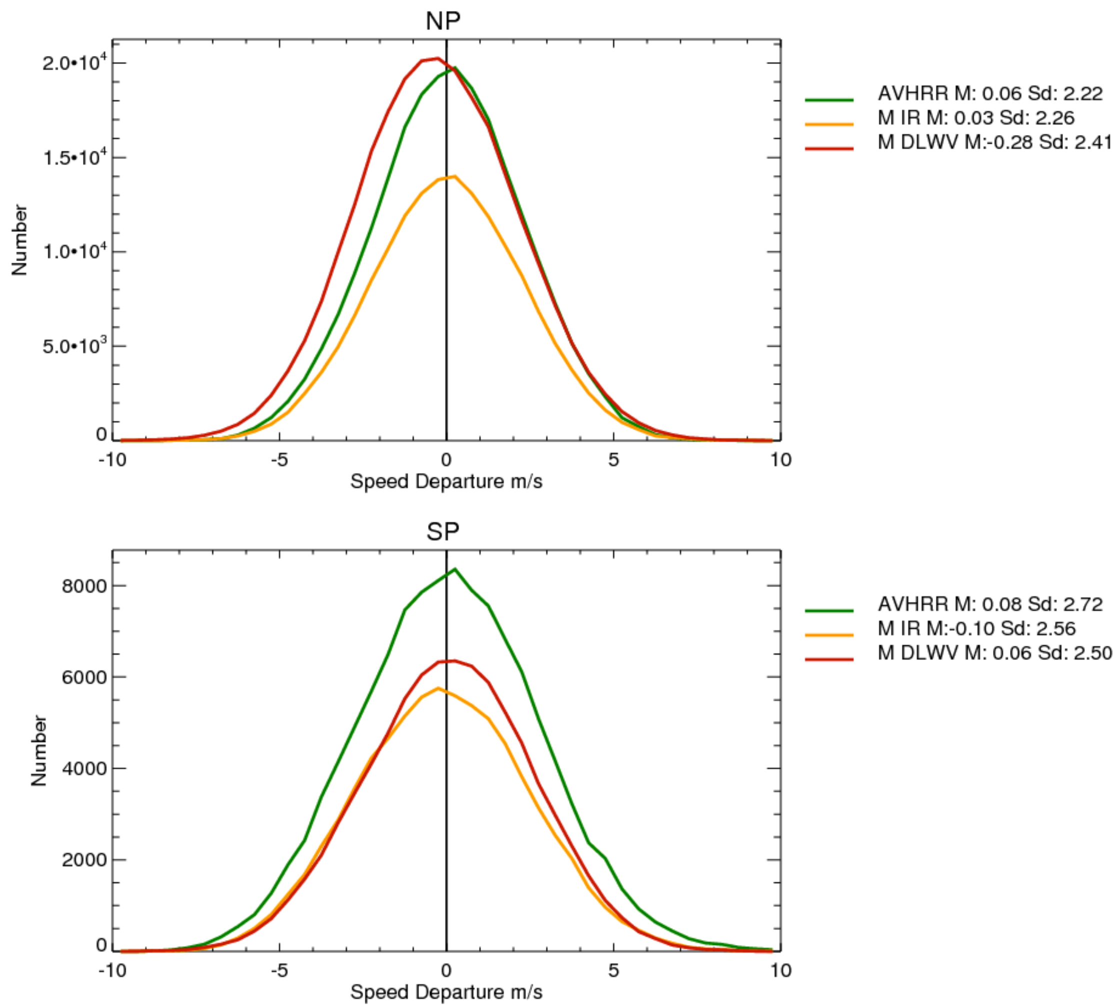

Figure 6. AVHRR IR AMVs OMB distributions for 9 – 26 October 2012. The top panel is the Arctic; lower panel the Antarctic. Green curve is AVHRR; yellow MODIS IR; red MODIS water vapor winds.

The OMA (Figure 7) statistics for AVHRR (green) as compared to MODIS IR (red) are also very similar, although a bias of 0.2 ms^{-1} is evident in the southern hemisphere which may be due to the small sample size at this time.

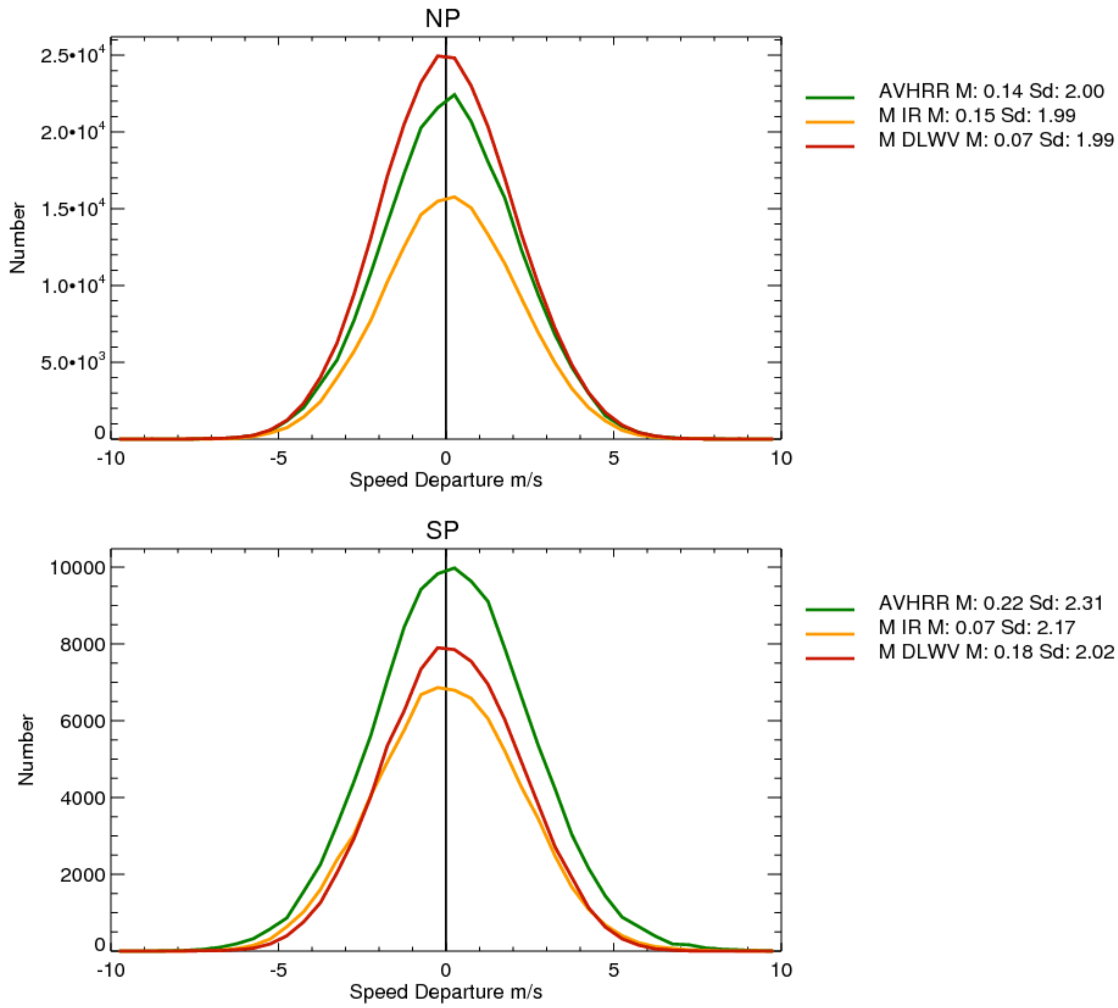

Figure 7. AVHRR IR AMVs OMA distributions for 9 – 26 October 2012. The top panel is the Arctic; lower panel the Antarctic. Green curve is AVHRR; yellow MODIS IR; red MODIS water vapor winds.

MODIS IR-only experiment

At this time, the MODIS winds are derived from the 11 µm and 6.7 µm bands resulting in IR, cloudy water vapor, and clear-sky water vapor AMVs. However, the Terra MODIS water vapor channel has only 2 good detectors out of 10, which impacts:

- Feature tracking in the water vapor images
- Cloud heights for AMVs from water vapor and IR (for the H_2O-intercept method)

Therefore, CIMSS is in the process of discontinuing the use of the Terra MODIS water vapor channel in polar winds production.

This experiment will quantify the impact due to the lack of water vapor winds, which is becoming a reality with Terra MODIS and for the follow on VIIRS instrument on the JPSS series.

Note: To fill the gap in clear-sky regions, CIMSS has a NASA project to investigate and evaluate tracking features from hyperspectral sounder retrievals of water vapor from

AIRS. If successful, the technique could be extended to retrievals from CrIS, IASI, and ATMS.

VIIRS polar winds

Polar winds from the VIIRS instrument are expected to be operational by the end of calendar year 2013. For the infrared winds, we expect better spatial coverage and higher quality winds over MODIS, for these reasons:

- The spatial resolution for VIIRS ranges from 750 m at nadir to 1.5 km at the swath edge; MODIS is 1km at nadir, degrading to 9 km at the edge
- The VIIRS has a wider swath than MODIS: 3000 km vs. 2320 km

However, with no water vapor channel on VIIRS:

- There will be no clear-sky water vapor winds
- The VIIRS polar wind coverage will be more similar to AVHRR than MODIS
- Cloud height options will be only from IR brightness temperature (no H_2O-intercept method)

The timeline for generating VIIRS polar winds, as of June 2013 (Jaime Daniels, personal communication):

- Routine production at STAR: late FY13Q4
- Routine production at OSPO: October 2013
- NESDIS Operational: December 2013

However, the details of providing these winds to NCEP operations for real-time assimilation into the GSI are not finalized.

Subversion source control

The subversion branch, SANTEK_POLAR_EE_AMV, was renamed to SANTEK_POLAR_AMV to remove the reference to EE, since it is unlikely that the Expected Error will be used for screening the polar winds.

Personnel status

Brett Hoover and Sharon Nebuda continue to work on this project; Jim Jung has a consulting role.

Conferences and papers

An oral presentation (*Status of improving the use of MODIS, AVHRR, and VIIRS polar winds in the GDAS/GFS*) was given at the 11th Annual JCSDA Workshop on Satellite Data Assimilation in June 2013.

An article (*Polar Winds and Forecast Busts*) was published in the December 2012 JCSDA Quarterly newsletter:
http://www.jcsda.noaa.gov/documents/newsletters/201212JCSDAQuarterly.pdf

Project extension

A one-year, no cost extension was requested:

A one-year extension is being requested for two reasons: (a) We were unable to run experiments when transitioning from vapor to S4 in 2012, and (b) We anticipate the production of VIIRS Atmospheric Motion Vectors (AMV) within the next few months and we would like to evaluate those, instead of proxy VIIRS AMVs which we proposed.

The request was granted; the project end date is now 31 May 2014.