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

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Year 3 First-half Progress Report
June 2012 through November 2012

28 December 2012

David Santek, PI

Proposed Work

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.

First Half of Third Year Progress

The primary effort during this six-month period was to finalize a new QC method for the MODIS winds based on the Expected Error (EE). Two experiments were run:

1. EE WOE: Assigning the wind observation error (WOE) the value of the EE.
2. EE Ratio: Discard MODIS AMVs if the EE Ratio is less than a specified threshold.

The EE Ratio gave the best results: For the six-week experiment in winter 2012 the impact compared to the control was generally neutral, except for a notable improvement in some dropout cases. Only the EE Ratio experiment is discussed further in this report.

Also, these areas were addressed or identified:

- Access to computing resources
- Importing AVHRR polar winds
- Subversion access
- Personnel status
- Conferences and papers

Access to computing resources

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

- Used the hybrid GDAS/GFS.
- Ran Quality Control experiments with the MODIS polar winds
- Setup code and experiments for assimilating AVHRR polar winds.
- Ran the GSI in Fortran debug mode to detect Fortran run-time errors. This was my suggestion to Jim to assist in tracking down some last remaining bugs on s4. Nothing serious was found in the code, except the the following *variables* were not always initialized (reported to J. Jung):
    - read_obs.F90*:* *satid*
    - read_prepbufr.f90: *pflag*
    - read_satwnd.f90: *pflag*

MODIS experiment

The operational quality control and previous experiments run under this project using the EE as a quality control resulted in many of the high-speed winds being thinned. This was considered a possible reason that the impact of the MODIS winds is generally neutral. While the satellite sounder radiances provide much information on atmospheric structure in regions that are clear, the impact of the MODIS winds can complement by providing information in highly dynamic, cloudy regions of the troposphere. However, the quality of these high-speed winds has been in question. The following experiment is designed to evaluate these previously discarded winds using a new QC method: EE Ratio.

The EE Ratio experiment eliminates MODIS AMVs if the EE Ratio (defined as EE/observation_speed) is less than a specified threshold. The threshold used was 1.3367, which was empirically determined to result in approximately the same number of rejections as the control. Over the six-week period, 3 million observations were accepted; 250,000 rejected. However, the experiment accepted about 36,000 (1%) more observations than the control. The following sections detail the assimilation impact, characterization of these newly retained winds, and the forecast impact.

Assimilation impact

Figure 1 is a frequency plot of the Observation minus Background (OmB) for two weeks in January 2012 for the MODIS IR AMVs. The green curves are the control; the red curves the EE Ratio experiment. Generally, these curves are coincident except for some small differences at large speed departures for the northern hemisphere. The bias and standard deviation are the same for both the control and experiment: -0.36 +/- 2.67 ms^{-1}. The distribution for the MODIS water vapor winds is similar (not shown). This is encouraging as accepting higher speed winds, with perhaps larger errors, have not affected the OmB statistics.

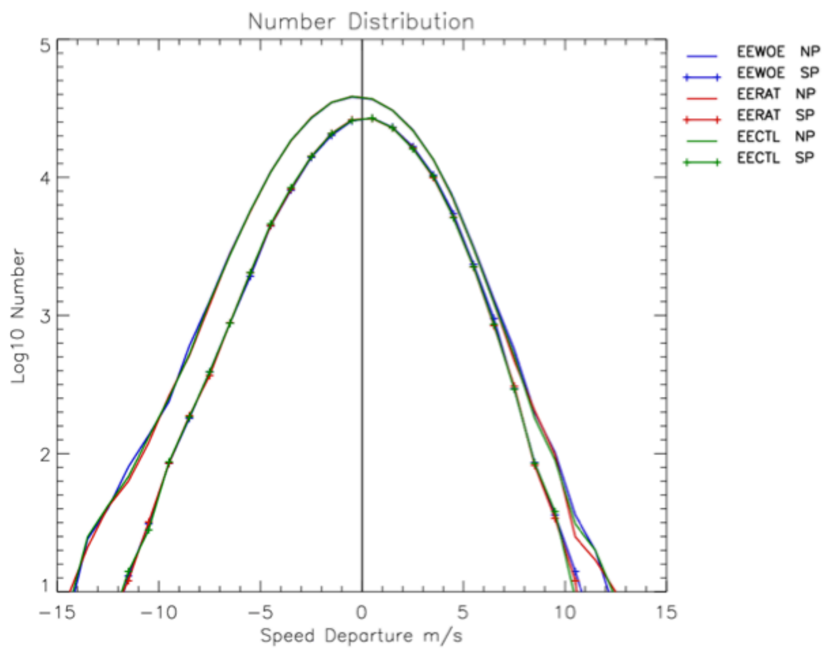

Figure 1. MODIS IR AMVs Observation minus Background (OmB) distribution for 2-18 January 2012. The solid lines are northern hemisphere; with tick marks for southern hemisphere. Shown are the control (green), EE WOE (blue), and EE Ratio (red).

Figure 2 is a density plot of the normalized background speed departure vs. EE Ratio for the MODIS IR winds in January 2012. The three curves represent the mean normalized speed departure (middle) and +/- one standard deviation. Since the standard deviation decreases with smaller EE Ratio (the lines converge from right to left), the EE Ratio does show some skill in reducing the spread of the normalized OmB distribution. Therefore, this is a reasonable candidate for QC screening.

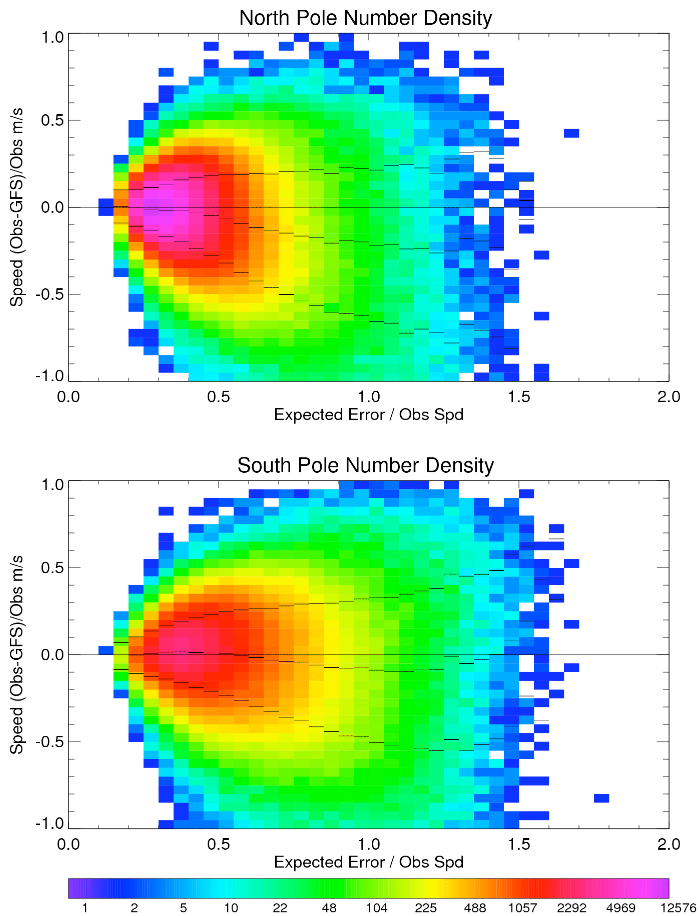

Figure 2. Normalized background speed departure vs. EE Ratio for the MODIS IR winds in January 2012 for the northern hemisphere (top) and southern hemisphere (bottom). The three curves represent the mean normalized speed departure (middle) and +/- one standard deviation.

Figure 3 is a frequency plot of the Observation minus Analysis (OmA) for the same time period as Figure 1. Again, the bias and standard deviation are the same for both the control and experiment: 0.08 +/- 2.12 ms^{-1}. And, it's encouraging to see the bias nearly zero and a smaller standard deviation compared to the OmB. Moreover, it is evident from Figure 3 that EE Ratio experiment (red) is allowing AMVs with higher speed departures to be retained compared to the control (green) for the northern hemisphere.

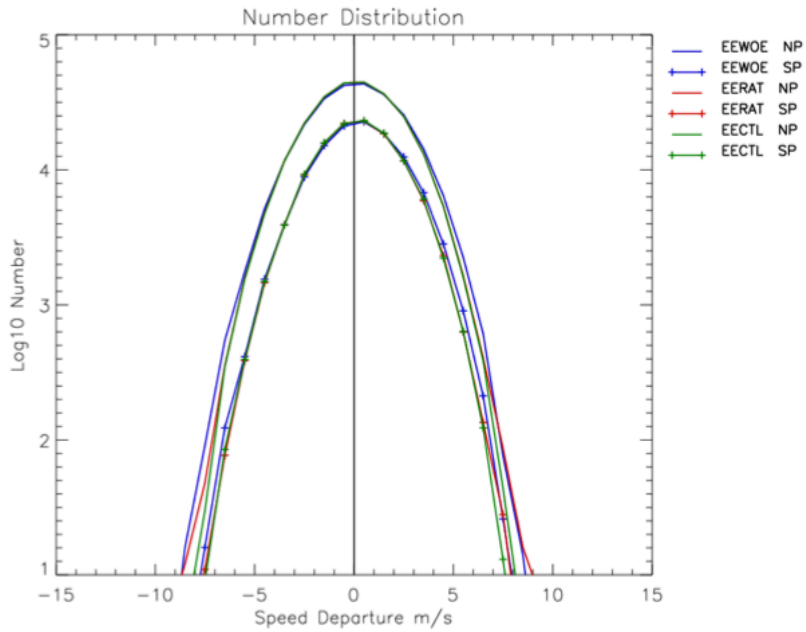

Figure 3. Same as Figure 1, except for Observation minus Analysis (OmA).

To examine more closely the characteristics of the AMVs with large departures from the analysis, difference histograms were generated for various parameters. These are shown in Figures 4 and 5. Essentially, histograms of the control were subtracted from the experiment histograms. Therefore, when the frequency is *above* the zero line, the experiment is *allowing* more observations of that type. Conversely, when the frequency is *below* the zero line, the experiment is *rejecting* more observations of that type. These plots are from 172 analysis periods.

In summary:

- More winds are retained with EE > 5 ms^{-1} (Figure 4 left). We had used this threshold in previous experiments, which resulted in a very neutral impact.
- More winds are retained in the 250-450 hPa (Figure 4 right). These are at the level of the polar jet.
- More slow winds (5 ms^{-1}) are rejected; more mid-speed winds retained (Figure 5 left).
- Few additional winds are rejected that deviate < 7 ms^{-1} from background. More are accepted when OmB > 7 ms^{-1} (Figure 5 right). This is the threshold used by the control, meaning the experiment is allowing more winds in that would have previously been rejected.

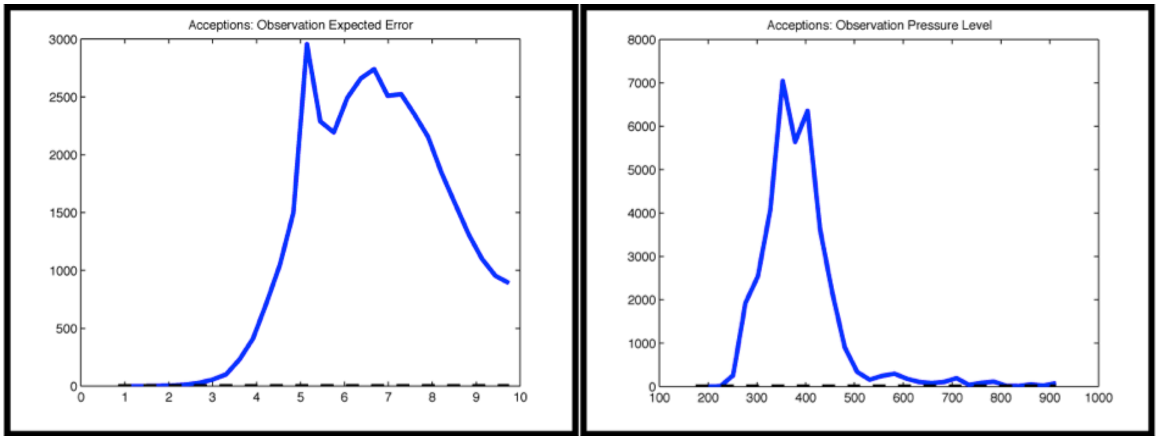

Figure 4. Difference (experiment – control) histogram for the Expected Error (left) and for the AMV pressure level (right). Above the zero line: The experiment is allowing more observations of that type.

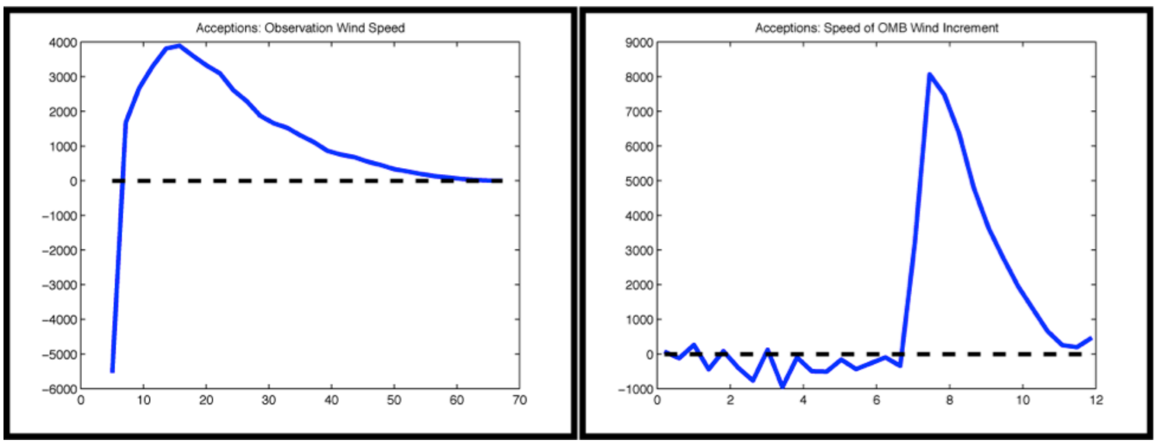

Figure 5. . Difference (experiment – control) histogram for the AMV speed (left) and for the AMV OmB increment (right). Above the zero line: The experiment is allowing more observations of that type. Below the zero line: The experiment is rejecting more observations of that type.

Based on the above analysis, the selection of an EE Ratio threshold based on a similar number of rejections as the control, results in accepting more higher speed winds at the jet level, while rejecting more slow winds. Also, these additionally accepted winds deviate more from the background than the operational QC would allow. However, since the additional winds are small in number, OmB and OmA statistics remain the same. The following discusses the forecast impact.

Forecast impact

Figures 6 and 7 show forecast impact of this new 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 6 and 7) is for 35 days from mid-January to late-February 2012. The daily scores are in the right panels for Day-5, -6, and -7 forecasts.

The averaged scores for the northern hemisphere (Figure 6) are neutral for this time period. However, there is a substantial improvement in a couple of dropout events near day 30 (circled in Figure 6 right panels), where the experiment (red) out-performed the control (blue).

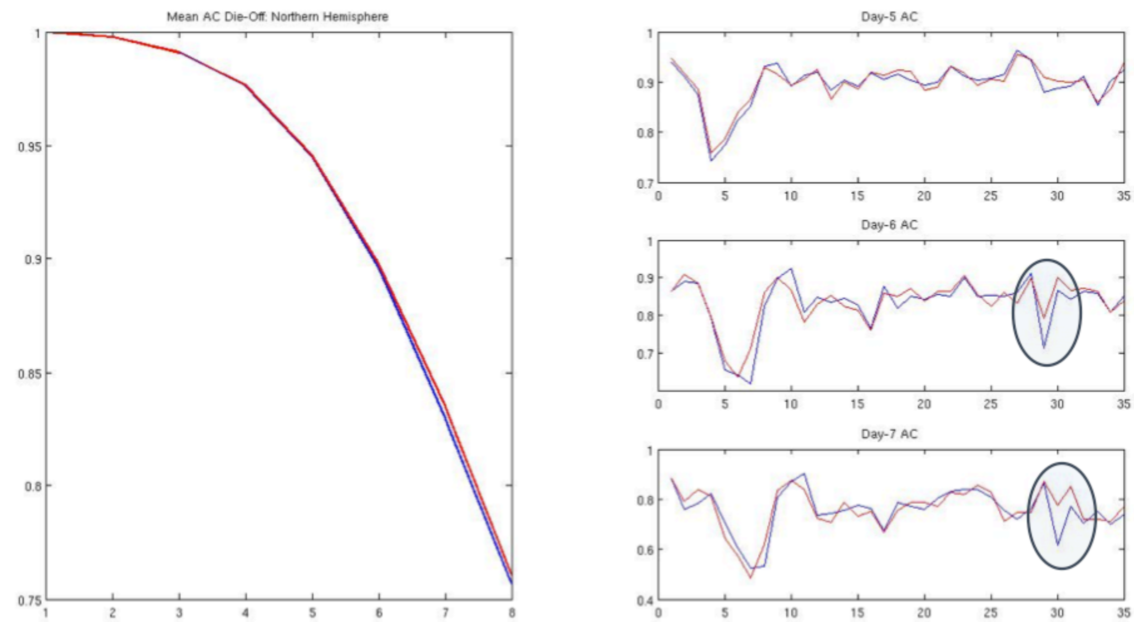

Figure 6. Anomaly Correlation (AC) scores averaged over five weeks (left) and the daily scores for Day-5, -6, and -7 (right). Date: mid-January to late-February 2012. Scores are computed for 500 hPa geopotential heights over the northern hemisphere (20N-80N) for the control (blue) and the experiment (red), using the EE Ratio. Improvements in selected dropout events are circled.

Similarly, the averaged scores for the southern hemisphere (Figure 7) are generally neutral, although by Day-7 and -8 the experiment is out-performing the control. Again, there is a substantial improvement in a couple of dropout events, this time near day 17 and 18 (circled in Figure 7 right panels), where the experiment (red) out-performed the control (blue).

See the December 2012 JCSDA newsletter article, *Polar Atmospheric Winds and Forecast Busts*, for a discussion on the dropout improvements (or lack thereof) as related to different flow regimes.

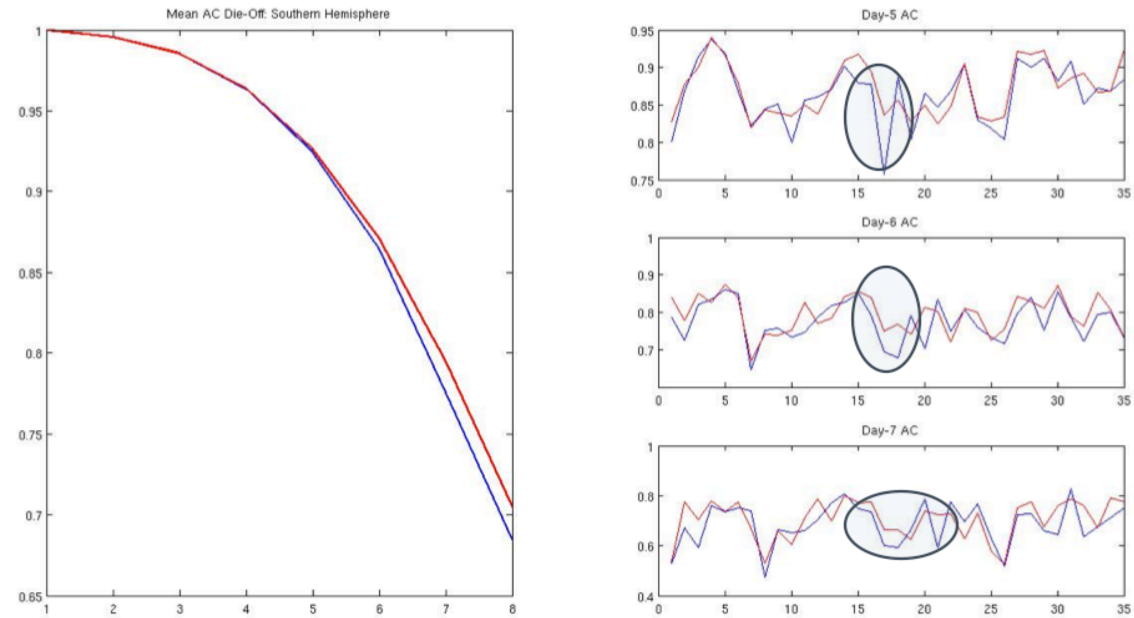

Figure 7. Same as Figure 6, except for the southern hemisphere.

Another way to evaluate the improvement in the ACC is to examine those cases in the control that perform at a standard deviation lower than its mean or less (i.e., the worst cases). Figures 8 (northern hemisphere) and 9 (southern hemisphere) depict the AC die-off curves for the worst cases during the five-week time period. Through Day 6 in the northern hemisphere, there is a neutral impact. In the day-7 and -8 forecasts, the EE Ratio performs slightly better on average. In the southern hemisphere, the improvement using the EE Ratio is substantial for all forecast time periods. Due to the small sample size, the differences are not statistically significant. However, we have seen similar improvements in other cases (see the June 2012 report).

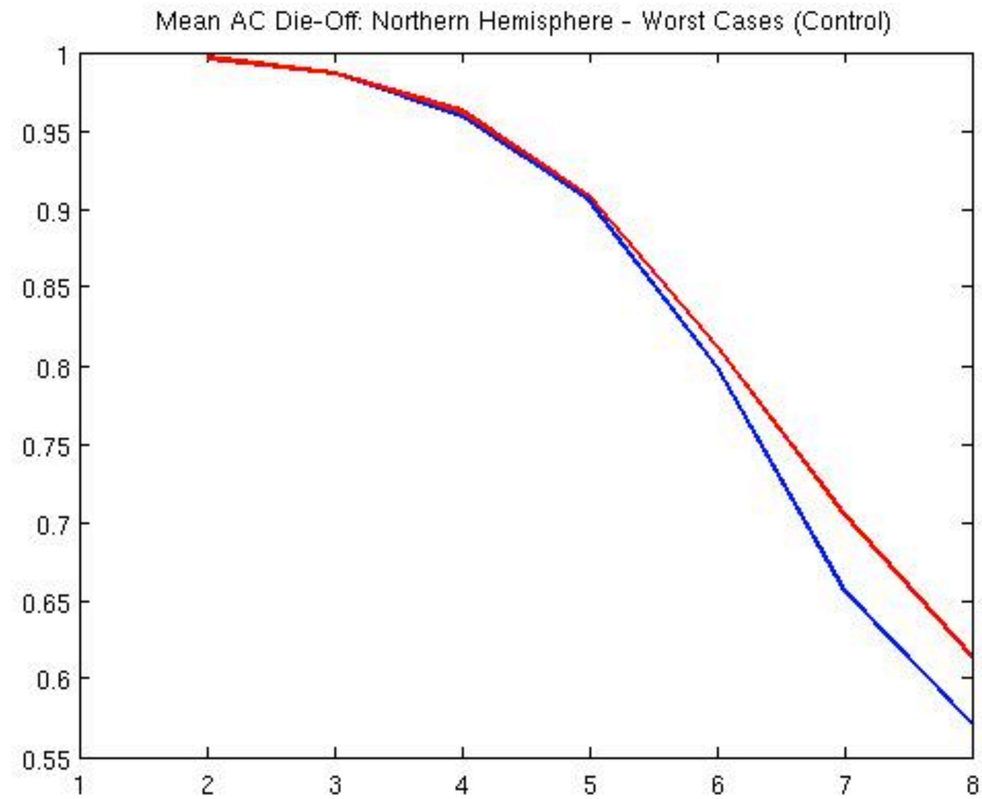

Figure 8. AC scores averaged for the worst cases during the five weeks. The worst cases are defined as control scores below one standard deviation from the mean. Date: mid-January to mid-February 2012. Scores are computed for 500 hPa geopotential heights over the northern hemisphere (20N-80N) for the control (blue) and the experiment (red), using the EE Ratio. There are 4-6 cases represented in these averaged AC scores.

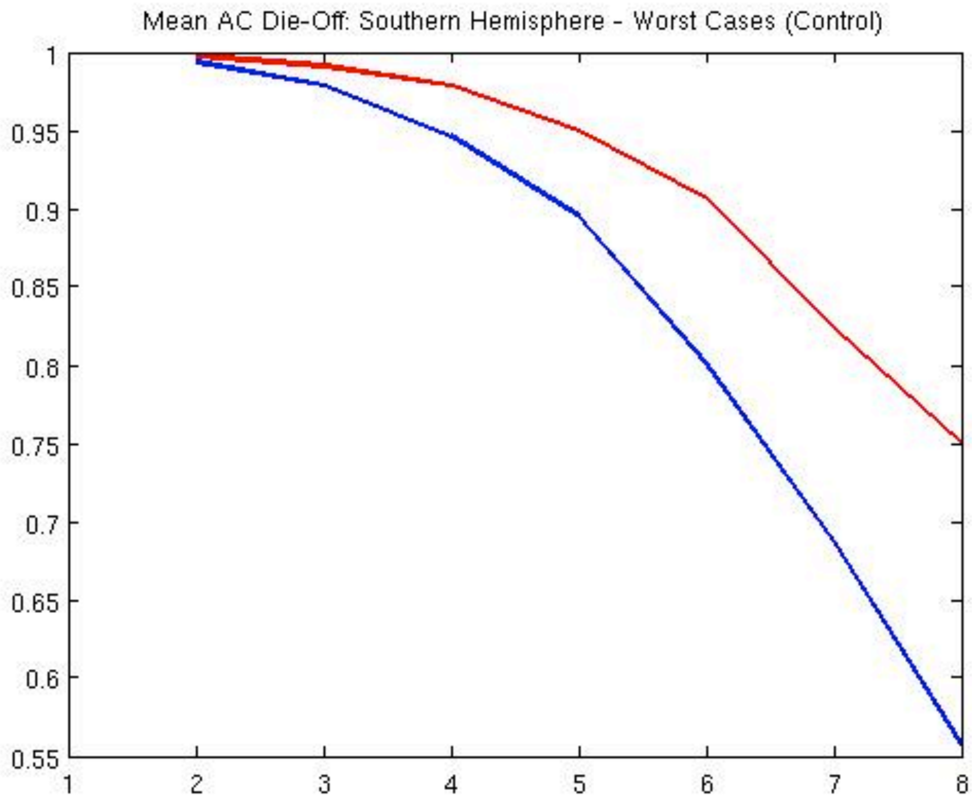

Figure 9. Same as Figure 8, except for the southern hemisphere. There are 5-8 cases represented in these averaged AC scores.

AVHRR experiments

NESDIS operations began sending AVHRR polar winds to NCEP in 2011. However, the dataset did not include the EE nor did it span the day boundary, until late June 2012. We have recently modified the code to include the AVHRR winds and are in the process of verifying the code is working as expected.

Subversion source control

A branch, SANTEK_POLAR_EE_AMV, was created from the GSI trunk. This branch will be used for all successive MODIS and AVHRR AMV experiments.

Personnel status

Brett Hoover and Sharon Nebuda continue to work on this project, with Jim Jung having a consulting role.

Conferences and papers

An oral presentation (*Quality control of MODIS and AVHRR polar winds in the GDAS/GFS: Status and plans*) was given at the 10th Annual JCSDA Workshop on Satellite Data Assimilation in October 2012.

An article (*Polar Atmospheric Winds and Forecast Busts*) was submitted in December 2012 for an upcoming JCSDA Newsletter.