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

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Year 2 First-half Progress Report
June 2011 to December 2011

30 December 2011

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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 requires the strategies for use of the satellite-derived winds to be continually evaluated.

The focus of our proposal will be in three areas using AMVs generated from polar orbiting satellite data: (1) Quality control 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 future NPOESS Preparatory Project (NPP) and National Polar-Orbiting Operational Environmental Satellite System (NPOESS) satellites [now restructured as the Joint Polar Satellite System (JPSS)] .

Year 2 plans from the proposal:

Our second area of interest is the assimilation of polar winds derived from the AVHRR on the current NOAA satellites and the new Metop satellite series. This will be an important source of polar wind information as the NASA research satellites, Terra and Aqua, near the end of their lifetimes.

The NOAA AVHRR AMVs will result in additional spatial coverage (over what the MODIS currently provides) in the Arctic and Antarctic, with data available from up to four satellites. However, the satellite schedule may be problematic due to priority given to the operational satellites. Therefore, the actual availability of AMVs will be closely monitored with respect to cutoff times in the assimilation. Also, the thinning of the NOAA AVHRR AMVs using the EE will require investigation because of the lower resolution in the Global Area Coverage (GAC) data compared to MODIS.

The AMVs from the NOAA and Metop satellites have been routinely produced at CIMSS for several years, with a transition to NOAA operations planned by the end of 2009. Once the procedure is in NOAA operations, we expect the EE parameter will be included with the AVHRR polar winds, which we will use for screening and filtering in our experiments. We expect to begin this task in Year Two as the AVHRR polar winds product should be available in real-time from NOAA operations. In the event that it is not *available from NOAA in the expected timeframe, we at CIMSS are able to produce essentially the same product and we will use that for initial tests and experiments.*

The experiments using the AVHRR will be similar to those conducted for the MODIS polar winds: determining an optimal use of the EE for quality control and evaluating the forecast impact from two different seasons. We do not anticipate any problems transitioning the use of the AVHRR polar winds product into NCEP operations as it will be in the same format as the MODIS product, which has been in operations for many years.

Mid-year Progress

During the first six months of the second year of the project, these areas were addressed or identified:

- Problems with vapor
- Modify GSI code to import wind observations from text files
- Run additional control and experiments using the EE with MODIS winds
- Analyze forecast impact
- Investigate importing AVHRR polar winds
- Visit to ECMWF
- Planning transition to S4
- Subversion access
- Personnel changes

Problems with vapor

There were two issues on vapor over the last six months that affected this project. First, vapor was very unreliable for a few months, going down frequently with no notice and the disks filling causing problems with the archive. These problems required us to restart experiments many times (sometimes completely starting over) and to monitor the jobs daily so as not to lose output.

Second, from December 2010 into August 2011, the satwnd files on vapor did not contain the MODIS cloud-tracked winds. Brett discovered this and contacted Jim Jung, originally thinking there was a problem with his script. However, this was a problem with the dump archive script, which was corrected by NCEP for data files forward from August 2011; the previous satwnd files (back to December 2010) were not updated.

Run MODIS experiments

We ran control and EE threshold experiments using the MODIS AMVs for the dates:
24 August – 01 October 2010
01 January – 15 February 2011

These continued to use the same version of the GSI/GFS that we retrieved from nwprod in January 2011. We will update the code base when we move to S4.

Forecast impact

a) 01 January to 15 February 2011

Two-season experiments were to be performed. The first, August to October 2010, was run early in 2011 and the results were presented in the previous report. The second experiment was chosen to be January to February 2011. This was run in April 2011, but not analyzed until recently. Due to the MODIS winds missing in the satwnd files (described in *Problems with vapor*), the results of this experiment are not valid. Since the satwnd files for that time period was not corrected, a different winter experiment will be chosen. This will be run on S4 in early 2012.

b) Wind observation error experiment

All experiments to this point use the EE to quality control the input winds. This experiment uses all the winds, but the observation error is assigned the EE value. Typically, satellite winds are assigned an observation error of 7 ms^{-1}, so using the EE will set the observation error to a lower value in many cases and retain winds that may be otherwise discarded.

The EE ranges from 0 to 10 ms^{-1}; the observation error is set to this value, except values less than 3 ms^{-1} are set to 3.

The experiment was designed to run from 24 August to 1 October 2010. However, when it reached 21 September 2010 it stopped and we were not able to successfully restart the job. So as to include the results in this report, it was decided to analyze the experiment up to this point.

Figures 1 (northern hemisphere) and 2 (southern) depict the AC die-off curves and the daily variation for a two-week time period. Through Day 5 there is a neutral impact in both hemispheres, which is a somewhat surprising result given the significant change to how the satellite winds are included and observation error assigned. We will rerun for a longer time period and perform a detailed analysis on which winds are included versus a control run. One area that we know is a problem is that high speed winds are usually assigned a large EE, which in this case could potentially assign the observation error to a larger value than the default 7 ms^{-1}, resulting in a reduced impact.

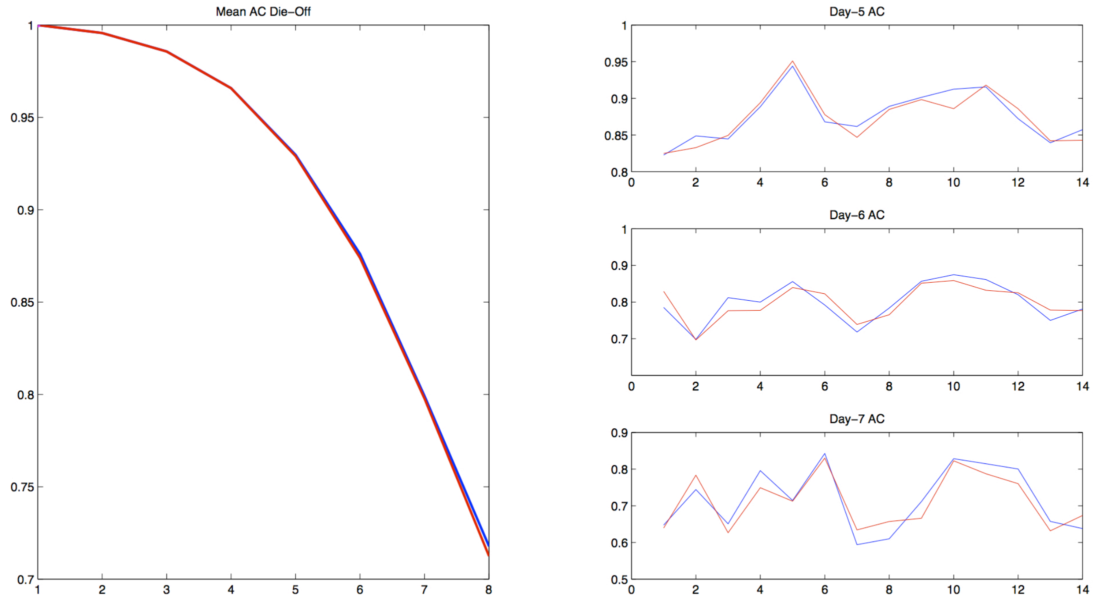

Figure 1. Anomaly Correlation scores averaged over 2 weeks (left) and the daily scores for Day-5, -6, and -7 on the right. Date: 08 – 21 September 2010. Scores are computed for 500 hPa geopotential heights over the northern hemisphere (20N-80N) for the control (blue) and the experiment (red), using the EE as the observation error.

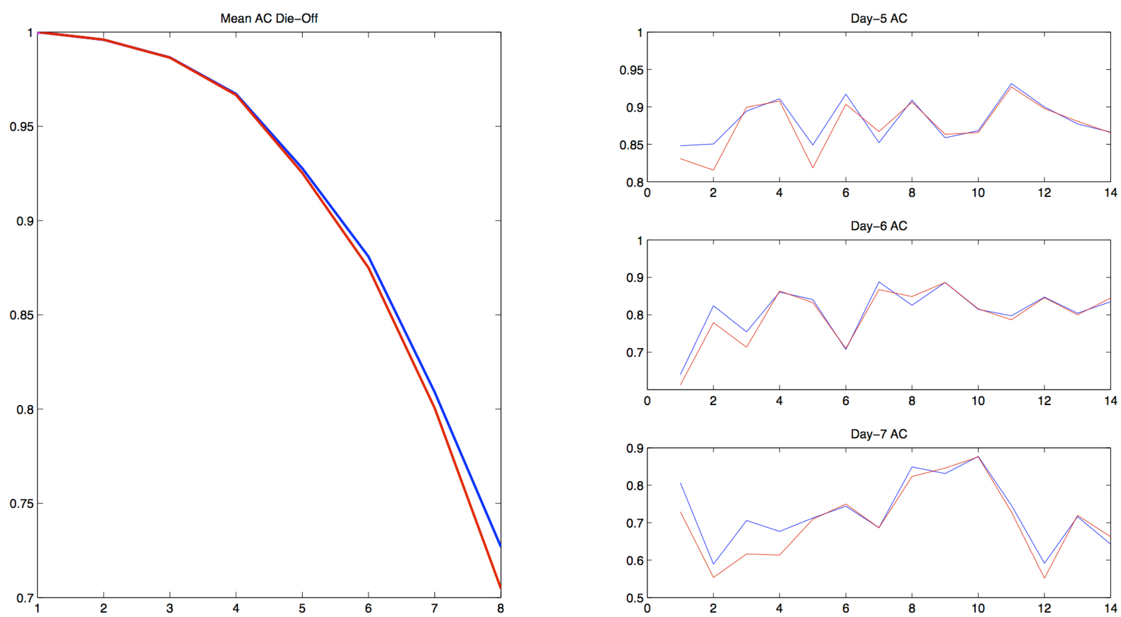

Figure 2. Anomaly Correlation scores averaged over 2 weeks (left) and the daily scores for Day-5, -6, and -7 on the right. Date: 08 – 21 September 2010. Scores are computed for 500 hPa geopotential heights over the southern hemisphere (20S-80S) for the control (blue) and the experiment (red), using the EE as the observation error.

c) Situation-dependent EE threshold

The number of MODIS polar AMVs available to the analysis is highly variable from analysis period to analysis period, as is the quality of those observations as measured by the expected error. Typically, it was found that if a large number of observations were available at the analysis time, their expected error distribution was characterized by a narrow tail of low EE winds and a steady widening of the distribution curve toward a very wide tail of high EE winds. Such a distribution contains many poor observations, and a quality control cutoff of EE<5 m/s may be expected to improve the analysis. By contrast, when fewer observations were available at the analysis time, the EE distribution was narrow, peaking near the EE=5 m/s range and quickly tapering off in both directions. In such a scenario, a cutoff of EE<5 m/s is draconian and serves to effectively eliminate all MODIS polar AMV data, which can deteriorate the analysis and forecast.

In fact, we can calculate the difference in Day-7 AC between the experiment and the control and regress it onto these very characteristics (Figure 3).

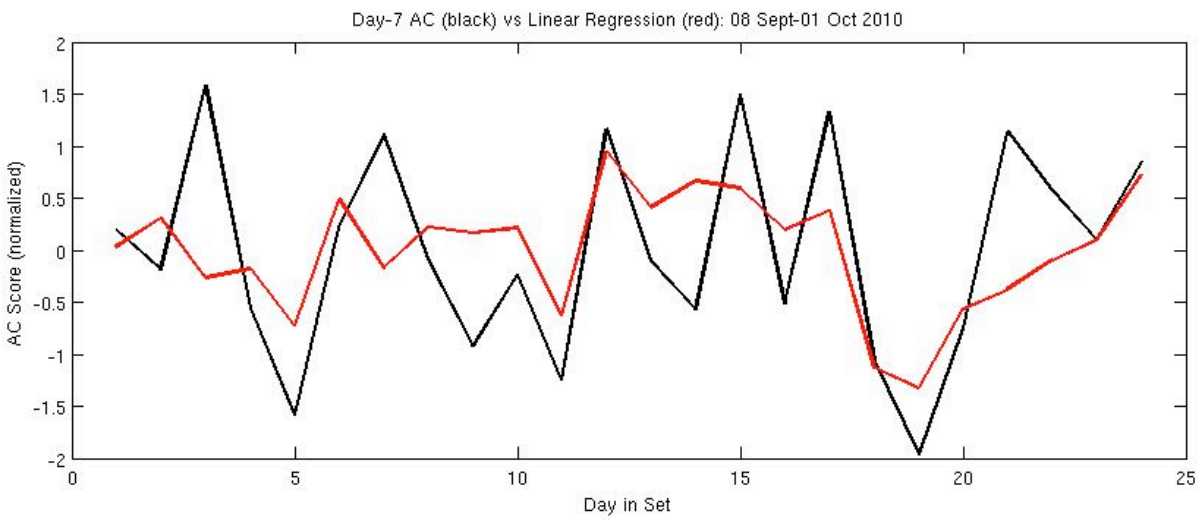

Figure 3. Timeseries of difference in Day-7 AC score (experiment – control) for 24 forecasts between 08 September 2010 and 01 October 2010. Calculated difference in AC (black) and linear regression (red) based on four characteristics of observations: total number of observations, mean expected error, standard deviation of expected error, and number of observations with EE > 7.5 ms^{-1} normalized by the total.

A linear regression of four observation characteristics onto the Day-7 AC score yields regression coefficients (normalized):

1. Total number of observations: 0.57
2. Mean expected error: -2.06
3. Standard deviation of expected error: -1.17
4. (Number of obs. EE > 7.5 ms^{-1} / total): 2.98

When a threshold of EE<5 m/s is used, the experiment tends to outperform the control when there are a large number of observations, the mean EE is low, the standard deviation is low, and there are many bad observations that need to be removed. Likewise, the experiment tends to underperform the control when there are few observations, the mean EE is higher, the distribution is wider, but there are few poor observations.

Performing this experiment, it becomes clear that the appropriate EE threshold for quality control of MODIS polar AMVs is context sensitive; a threshold value may cut an appropriate percentage of the total wind observations away in one analysis when there are many observations to choose from, but when that same threshold is applied to an analysis with fewer observations, the change is too drastic. It is clear that an appropriate quality control mechanism will have to rely on more information than simply choosing a threshold EE value and assuming it will be appropriate for all situations.

An experiment was performed wherein the linear regression of observation characteristics (above) was used to determine whether a strict (EE<5 m/s) or generous (EE<8.5 m/s) threshold should be used at each analysis time, and while it was an improvement over the EE<5 m/s experiment, the results are still not optimal. Other characteristics may need to be taken into consideration, such as the fact that a high-velocity wind observation (e.g. obs taken near a jet core) may have a high EE, but the value is small compared to the total wind speed. Likewise, an observation may have an EE that is low, but is on par with the velocity of the observation itself, which may be considered a "bad" observation despite having a low EE.

d) Other EE experiments

As noted above, screening the winds using a low EE value has resulted in high-speed winds being discarded compared to the control. Since there is evidence that the polar satellite winds are the most valuable in dynamic and ageostrophic regions in the atmosphere (Santek, 2010), we designed an experiment to retain winds with a higher EE and reject those observations with velocities less than 50% of EE. However, that experiment needs to be rerun because an archive was not retained in the middle of the experiment. This experiment will be run in parallel with several thresholds to test the sensitivity of the experiment.

<u>Import AVHRR winds</u>

In preparation for incorporating AVHRR satellite-derived winds, we began investigating different methods of reading in additional wind observations without relying on NCEP personnel to make the winds part of the usual dataset. We were successful in modifying the read_prepbufr.f90 routine to read in satellite-derived winds from text files. This has been tested with some limited experiments for the leo/geo and GOES-R winds projects.

When we move to S4, we will use the latest version of the GSI, which includes substantial changes by XiuJuan Su for the satellite winds. Depending on the availability of NESDIS-supplied AVHRR winds, we may need to use the CIMSS-generated winds (requiring the ability to read the winds from text files).

As we understand it, two issues remain with NESDIS operational AVHRR winds as of December 2011:

1. The EE is not being computed
2. There is a gap in the wind coverage near 00 UTC

Changes to the processing are in testing, but currently not in operations.

After we transition to S4 (which is expected in late January 2012), we will revisit the source of the AVHRR winds. If the AVHRR winds from NESDIS have the above issues resolved, we will use those. If not, we will use the CIMSS AVHRR winds and modify the GSI code to read them in from text files.

Visit to ECMWF

I was invited to visit ECMWF for two weeks to work on a small project on the assimilation impact of GOES hourly winds, which included examining the EE. While there, I learned in more detail of their efforts to provide situation-dependent estimates of the errors (SOE) in AMVs being developed at the Met Office and ECMWF (Salonen and Bormann 2011). Here, the error is split into a height assignment error in terms of pressure (dependent on satellite, channel, pressure level, height assignment error) and a vector error. The height assignment error is estimated using best-fit pressure statistics from NWP, and is later translated to a wind error using the variation of the wind profile around the assigned pressure taken from a forecast wind profile. At ECMWF, the vector error is estimated from departure statistics in regions where the wind shear is small.

An evaluation of the EE and SOE shows that both quantities successfully identify AMVs with larger errors and therefore larger departures against the short-term forecast. The SOE tends to estimate smaller errors than the EE, and there is some indication that the SOE with the current parameterization investigated at ECMWF underestimates small errors. While the SOE and EE have similar components in their formulation (e.g., the dependence on wind shear), the correlation between the two quantities is not very strong (Figure 4).

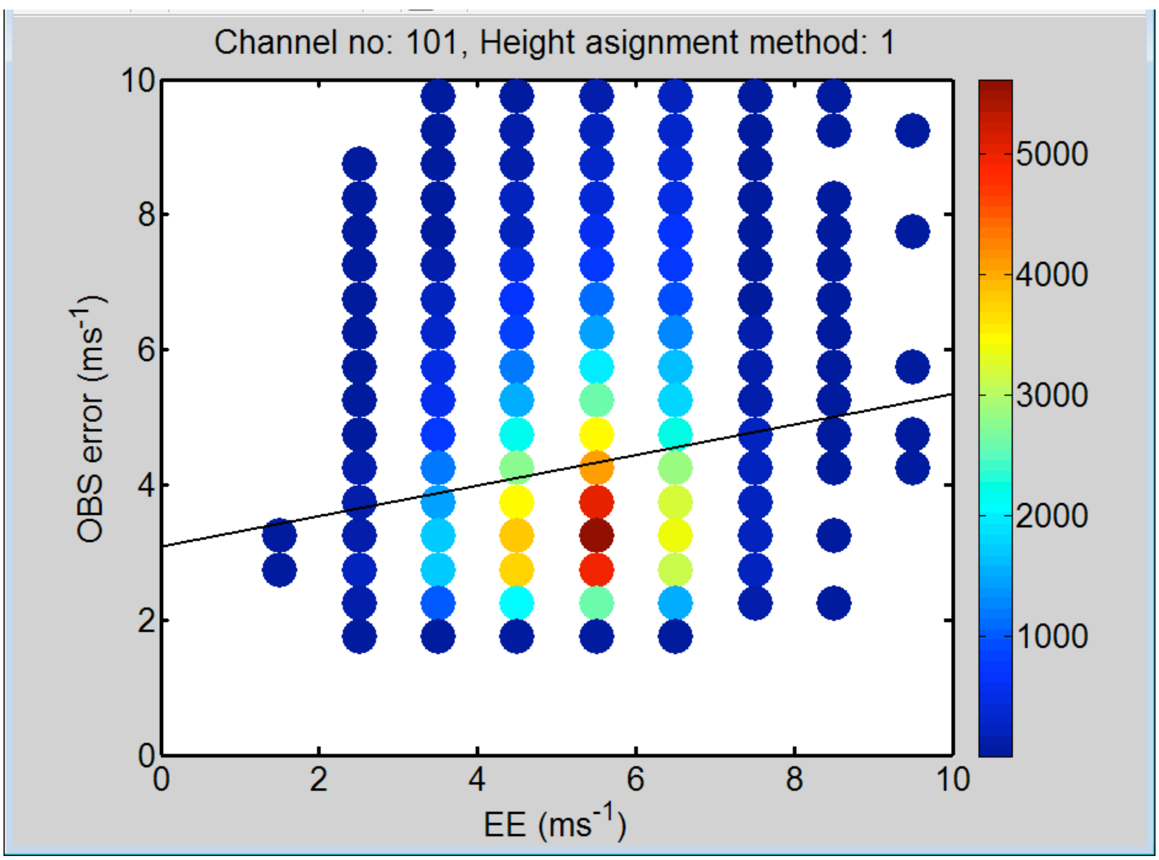

Figure 4: Histogram of SOE vs. EE for high-level GOES-11 IR cloud tracked winds with the brightness temperature height method, tropics only for the time period 8 August through 23 September 2011.

Transition to S4

There is a tentative plan in place for Jim Jung to visit CIMSS during the week of 30 January 2012 to train Sharon, Brett, and myself on running the GDAS/GFS on S4.

Subversion access

I have sent a request to John Derber to gain access to the GSI Subversion code base. This will include write access to the branches, but not the trunk.

Personnel changes

Brett Hoover began on this project in December 2010 as a postdoc. Over the last six months, he has reduced his time commitment to this project as other funding has come in for him.

Sharon Nebuda will be brought on in 2012, when the move to S4 is complete. She is currently working with Jim Jung and Jaime Daniels on impact studies for the GOES-R winds project.

References

Salonen, K. and N. Bormann, 2011. Accounting for the characteristics of AMV observation errors in data assimilation. *2011 EUMETSAT Meteorological Satellite Conference*. 5 – 9 September 2011. Oslo, Norway.

Santek, D., 2010: The impact of satellite-derived polar winds on lower-latitude forecasts. *Mon. Wea. Rev*. 138, 123–139.

Conferences and workshops

Santek, D., B. Hoover, J. Jung, 2011. Using the Expected Error in the quality control of satellite-derived polar winds. *2011 EUMETSAT Meteorological Satellite Conference*. 5 – 9 September 2011. Oslo, Norway.