Evaluation and Quality Control of Nested Tracking Approach for Atmospheric Motion Vectors (AMVs)

Sharon Nebuda¹, Jim Jung¹², Dave Santek¹, Jamie Daniels³, and Wayne Bresky⁴

¹Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin-Madison, WI
²Joint Center for Satellite Data Assimilation, Camp Spring, MD
³NOAA/NESDIS, Center for Satellite Applications and Research Camp Springs, MD
⁴I.M. Systems Group (IMS), Rockville, MD

Abstract

GOES-R Algorithm Working Group Winds team continues to assess the performance of the Atmospheric Motion Vectors (AMVs) algorithm designated for the GOES-R Advanced Baseline Imager (ABI). The AMVs algorithm uses a nested approach to define a field of wind vectors based on cloud features tracked in smaller target boxes contained within a larger scene. Using density based cluster analysis, the appropriate, average wind vector for the large scene is determined by isolating the dominant cluster from the field of wind vectors. Height assignment is also limited to the mean pressure of the cluster's cloud top pressure. This approach was designed to address the slow bias seen in the mid to upper level AMVs located in the extra-tropics for the current operational algorithm.

To test this new approach for GOES-R ABI, proxy data was created using imagery from Meteosat-9 Spinning Enhanced Visible Infra-Red Imager (SEVIRI). The initial validation of the AMVs against rawinsonde observations has been completed. Evaluation continues with comparisons of AMVs with the background assimilation state of the NCEP Global Forecast System (GFS). Examination of the statistics of the difference between the AMVs and the GFS background state will reveal appropriate quality control procedures for this new wind product. Parameters unique to this nested tracking approach algorithm such as uncertainties of the height assignment, sample size of the dominant cluster, cloud type of the cluster, will be included for consideration when determining quality control procedures.

Results will be shown of the algorithm AMVs as compared to the GFS data assimilation system (GDAS) background state including a focus on the AMVs in the mid to upper levels of the extra-tropical atmosphere. An assessment of algorithm parameters as candidates for use in quality control procedures will also be presented. Future work will include GFS forecast impact studies for this nested tracking approach algorithm.

INTRODUCTION

Statistics of AMVs produced by the Nested Tracking Algorithm (Daniels and Bresky, 2010) compared to the NCEP GFS background winds have been computed for 25 July to 2 August 2011 for ABI channel 14 proxy data. A second data set for 14-26 December 2011 has also been completed and is currently under analysis which includes the four ABI channels: 2, 7, 8, and 14; channel 14 is presented in this document. The purpose of the two GFS simulations is to compute statistics of the departure of AMVs from the GFS background state. Using these statistics various parameters, current quality metrics as well as algorithm parameters, were examined. Once candidate quality control measures are determined, two different seasons will be simulated while assimilating the proxy data allowing a statistical analysis of the difference of the AMVs and the assimilation state and evaluation of impact on forecast skill of GFS.
OMB STATISTICS

Statistics of the AMV observations minus the GFS background state (OMB) have been computed for the July and December data. Figures 1 and 2 present the zonal mean speed bias and magnitude of the direction bias for the two time periods. All proxy data is included in this calculation; no data is rejected based on quality control. Please note that the sample size is larger for December due to the longer simulation time. The number distribution of AMVs is shown as well; a minimum of 50 AMVs were required within the latitude and pressure bin to compute the bias.

![Figure 1](image1.png)  
**Figure 1:** Zonal mean of speed bias, magnitude of direction departure, and number of AMVs for 25 July – 2 August, 2011 ABI Channel 14.

![Figure 2](image2.png)  
**Figure 2:** Same as Figure 1 for 14-26 December, 2011 ABI Channel 14.

The zonal speed bias for both data sets shows a tendency for positive bias for midlevel AMVs and negative bias for high level AMVs. Upper level, northern hemisphere winter extra-tropical AMVs show a negative bias for the AMVs. Examining the upper level wind components for the December data reveals the zonal component is weaker than the GFS background wind while the meridional component is stronger. The same behavior was present in the July data, more so in the winter hemisphere. Low level clouds over the Atlantic ocean have a negative speed bias where the majority of AMVs are located near 900 hPa. The difference in wind direction between the AMVs and the GFS background are largest for the upper level tropics with a zonal mean average of the magnitude of the direction difference at approximately 20°-30°. The direction difference is smaller for the extra-tropics (5-15°) and low level AMVs (5-10°).

The larger departures for tropical AMVs with respect to direction is also highlighted in the regional vertical profiles shown in Figures 3 and 4. The normalized vector difference RMS is largest for the tropics at levels near 400 hPa and but reduces in magnitude as AMV height increases. The profile of AMV number indicates most tropical AMVs are located above this level closer to 200 hPa.
Figure 3: Regional averages for number of AMVs, normalized speed bias, normalized vector difference RMS for 25 July – 2 August, 2011 ABI Channel 14. The tropics (red), summer extra-tropics (green), and winter extra-tropics (purple) are shown as a function of pressure.

Figure 4: Same as Figure 1 for 14-26 December, 2011 ABI Channel 14.

Examining the OMB statistics did not reveal a dependence on surface type or zenith angle. The low level AMVs and mid-upper level, tropical AMVs have the best distribution of data for the range of possible zenith angles. The vector difference bias and RMS do not indicate a trend for OMB as a function of zenith angle. For surface type, the mean OMB for speed bias for all water and all land points are similar. Repeating this analysis for July in the tropics and 20-60S regions found larger difference in the means for land and water but no consistent conclusion. For mid-upper level, tropical data, the AMVs had a speed bias of 1.1 m s\(^{-1}\) for water and 0.4 m s\(^{-1}\) for land while the southern hemisphere mid-upper level AMVs had a speed bias of 0.5 m s\(^{-1}\) for water and 1.3 m s\(^{-1}\) for land. Direction statistics did not indicate a dependency either. Analysis will continue to confirm this conclusion.
QUALITY CONTROL

To identify candidate quality control parameters, the number distribution and OMB statistics were computed on binned AMVs for discrete ranges of parameter values. Existing quality control parameters include the Quality Indicator (QI) and its components (Holmlund, 1998) as well as the Expected Error (EE, Le Marshall et al. 2004). Algorithm parameters include cluster size, correlation, and standard deviation as well as number of clusters found in the target box. To determine the impact of these parameters on the OMB statistics, the binned statistics were plotted as a function of the various parameter values. For brevity, the normalized vector difference RMS for the December data is shown in Figures 5 and 6. Figure 5 suggests the current metrics of quality, QI and EE, apply well to this new AMV product. The components of QI that are not dependent on the background state are included as well. For QI values above 83, all bias and RMS statistics indicate AMVs are more similar to the background as QI increases. For EE values above 3, an increasing EE generally indicates an increasing bias and RMS for speed, direction, and vector difference.

Repeating this calculation for the algorithm parameters reveals some dependency with OMB statistics, which may be utilized for quality control. Figure 6 shows the normalized vector difference RMS for parameters related to the tracked cluster. The parameters shown are based on the first vector in the Nested Tracking algorithm; results were similar for the second vector. The OMB dependence on these algorithm parameters indicate that for smaller clusters, cluster selected from a box with many clusters, and AMVs with low standard deviations, the AMVs are the most different compared to the background state. Cluster correlation indicates a higher correlation score indicates an AMV with smaller departure from the background state. Analysis will continue with respect to these parameters as well as information about the cloud type associated with the cluster and its height uncertainty.
Figure 6: Normalized vector difference RMS as a function of first vector parameters NOC1: number of clusters, MX1: cluster size, COR1: cluster correlation, and SD1: standard deviation of the cluster pressure. Dependency plots are shown for the tropics (red), summer extra-tropics (green), winter extra-tropics (purple) for AMVs above 800mb as well as low level AMVs (blue) for 14-26 December, 2011 ABI Channel 14.

To demonstrate the impact of quality control on the OMB statistics, the zonal mean speed bias and direction magnitude difference for the December data is shown in Figure 7 with a simple threshold test based on quality indicator components that are independent of the forecast. AMVs with values of the quantity (QI1+QI2+QI3+2*QI6)/5 greater than 90 are included in the zonal mean calculation. Comparing Figure 7 with Figure 2 shows a reduction in zonal mean departure for both speed and direction for upper level AMVs.

Figure 7: Same as Figure 2 with a threshold quality control requirement for AMVs of (QI1+QI2+QI3+2*QI6)/5 > 90.
SUMMARY AND FUTURE PLANS

Results shown with the proxy GOES-R AMVs generated with the new Feature Tracking Algorithm highlight:

- Upper level tropical AMVs have the largest departures in direction
- Mid-level AMVs tend to have a positive speed bias while the highest AMVs tend to have a negative speed bias
- December AMVs in the northern hemisphere, extra-tropics have a negative speed bias but a positive meridional bias.
- Low level AMVs have a small negative speed bias

Quality metrics of QI and EE were shown to be good predictors of AMV performance compared to the GFS background state. OMB statistics dependence on the new algorithm parameters also indicates a potential to screen AMVs that would not be appropriate for assimilation in the GFS. Results were also shown to demonstrate the impact of a quality control measure on OMB statistics.

Work is ongoing and will be expanded to the ABI channels of 2, 7, and 8. Also, statistical analysis as a function of cloud type of the tracked cluster has begun. Cloud type is most strongly dependent on the location of the AMV and each region tends to have a dominant cluster cloud type. The combination of both July and December data sets may allow enough number to examine OMB statistics for the range of cluster cloud types identified within each region. Height uncertainty associated with the tracked cluster will also be investigated for the possibility to predict AMV quality. When the candidate quality control metrics are determined, they will be applied in the GFS Global Data Assimilation System to incorporate the GOES-R AMVs in the analysis. Statistics of observation minus the GFS assimilated state and forecast skill will be examined for two seasonal runs.

REFERENCES

