

COMPARISONS BETWEEN SATELLITE-DERIVED ATMOSPHERIC MOTION VECTORS, RAWINSONDES, AND NOAA WIND PROFILER OBSERVATIONS

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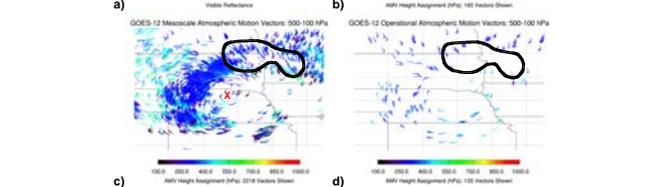
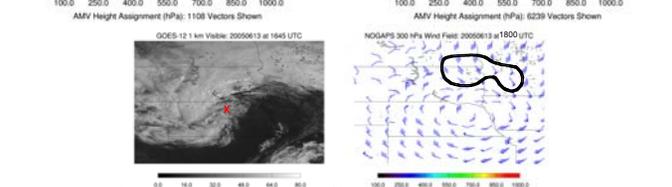
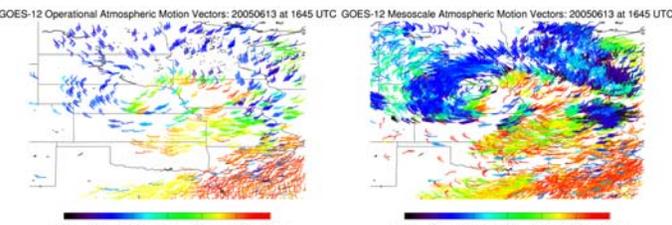
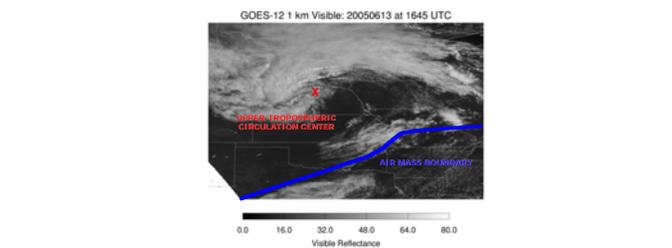
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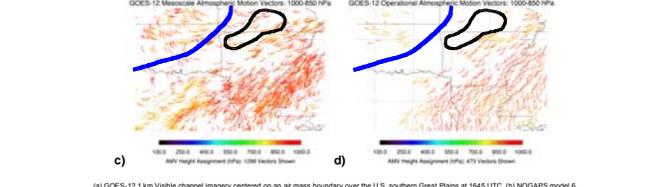
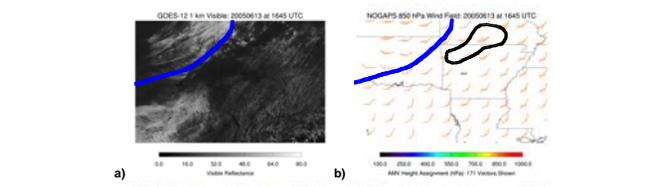
Project Description

Geostationary satellite-derived atmospheric motion vectors (AMVs) have been used over several decades in a variety of meteorological applications. The ever-increasing horizontal and vertical resolution of numerical weather prediction models puts a greater demand on satellite-derived wind products to monitor flow accurately at smaller scales and higher temporal resolution. The focus of this presentation is to evaluate the accuracy and potential application of a newly-developed experimental mesoscale AMV product derived from GOES imagery. The mesoscale AMV product is derived through a variant on processing methods used within the UW-CIMSS AMV algorithm, and features greatly increased vector density throughout the troposphere and lower-stratosphere over current NOAA/NESDIS processing methods for GOES-12 Imager data. The primary objectives of this study are to: 1) highlight applications of experimental GOES mesoscale AMVs toward weather diagnosis and forecasting; 2) compare the coverage and accuracy of mesoscale AMVs to the UW-CIMSS auto-edited NOAA/NESDIS operational AMV (OPER) product and 3) demonstrate the utility of 6-minute NOAA Wind Profiler network observations for satellite-derived AMV validation.

Qualitative AMV Comparisons



The images above focus on mid- to upper-level AMV flow patterns associated with a well-defined cyclonic circulation over the central Great Plains. Analysis of animated multispectral satellite imagery by a human expert indicates the presence of a light cyclonic circulation centered at the red 'X'. This is depicted very well by the MESO field, but much less so by OPER, which portrays a much broader, elongated circulation covering much of Eastern NE and SD. The NOGAPS 6 hour forecast wind field, used as a first guess within the OPER method, also depicts a tight circulation with a position a bit further to the east than that shown by MESO. The difference in position can be attributed to the ~1 hour time difference between the NWP and AMV fields. As this circulation is depicted fairly well by the first guess, the results suggest that the OPER IR and WV targeting settings (15x15 pixels=80 km²) were too large to capture this mesoscale circulation feature. By contrast, smaller targets (5x5 pixels=5 km² for VIS and 16 km² for IR and WV) tracked in the upper-troposphere by MESO were able to resolve the closed low center. The MESO field also depicted a region of enhanced wind speed across western MN and the Eastern Dakotas outlined by the black line, which is represented in the NOGAPS field but absent from OPER.



Low-level flow within the warm sector of this system from MESO, OPER, and NOGAPS is highlighted above. A surface boundary, shown by the blue line, is the primary feature of interest in this domain, as it was the focus for severe thunderstorm development from 1900-2100 UTC. Southerly winds of 5 to 10 kts are represented in both AMV types across eastern TX, LA, and MS to the southeast of the boundary, a bit slower than those from the NOGAPS. Flow of higher speed is found across northern AR and southern MO for both AMV types and NOGAPS. MESO depicts a narrow corridor of highly variable wind speed, outlined in black, with several vectors exceeding 40 kts. The NOGAPS forecast shows a region of enhanced speed across southern AR, but does not extend this speed maximum to the SW as depicted by MESO. The location of this narrow low-level jet is highly correlated with thunderstorms featuring severe winds, with storms producing severe hail found to the SW in a region of weaker flow. Also isolated to this corridor were several tornado reports, indicating that the MESO product may have depicted a localized region of enhanced low-level wind shear.

Another significant difference between MESO and OPER is found along and to the north of the surface boundary in OK. MESO depicts low-level flow from the NW with numerous vectors. This flow is not represented by either the OPER or NOGAPS forecast. These vectors are reasonable because MESO has targeted fine NW to SE oriented cumulus cloud streets in central OK and studies have indicated that boundary layer flow is often nearly parallel to these structures. The Lamont, OK NOAA Wind Profiler (not shown) validated the NW flow in this region at this time. Interestingly, the cloud street features, and northwesterly MESO flow extend to the south the surface boundary, suggesting some tilting of the boundary with height. OPER is unable to depict this flow because it deviates significantly from the NOGAPS forecast.

Data and Methodology

From April 2005-2006, GOES-12 IR, WV, and VIS MESO AMVs were computed every 30 mins from 1200 to 0300 UTC (the following day) over the Southern U.S. for use in convective storm nowcasting applications. AMVs within 25 km of the Lamont, OK NOAA Wind Profiler are collected from each algorithm run, providing 15332 mesoscale AMVs during this period.

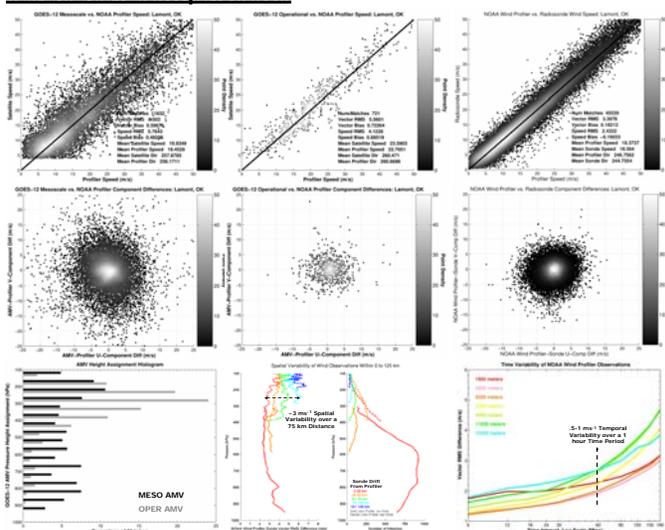
NOAA NESDIS OPER AMVs are processed every 3 hours for both day and night. OPER vectors within 25 km of the Lamont, OK Wind Profiler are also collected, providing 1132 AMVs during the 1-year study period.

6-minute observations from the 404 MHz NOAA Wind Profiler at Lamont, OK (LMNO2) are used as a "truth" dataset for comparison to satellite AMVs. The 6-min data are averaged over a 30 min period to best match the GOES imagery (three 15-min images) used to compute AMVs. An additional quality control criterion, described by Petersen and Bedka (2006), is imposed to ensure better time coherency of Profiler wind data. Profiler observations must fall within 10 hPa of the AMV height assignment to be considered a match.

Vaisala RS-92 rawinsondes are launched four times daily (additional sondes are also launched during IOPs) from the DOE ARM SGP Central Facility at Lamont, OK. Data from 1628 rawinsondes are included here to evaluate the relative accuracy of 6-min Profiler data. As wind observations are collected every 2 seconds by rawinsonde, Profiler data for each of the 72 vertical levels can be compared to the nearest sonde observation in height and time, resulting in 45539 matches during the 1-year period. The match criteria are 2 hPa in the vertical and +/- 3 minutes in the horizontal. The natural spatial variability of atmospheric wind is analyzed by separating Profiler-sonde differences into distance bins as the sonde drifts far away from the Profiler.

- Summary of Modifications to NOAA/NESDIS Operational Processing Settings by BM05**
- 1) Target box sizes reduced to 5x5 pixels, compared to 15x15 pixels in NOAA/NESDIS operations for VIS, IR, and WV channels AMVs.
 - 2) Targets in the visible (VIS) channel tracked from 1000-100 hPa, compared to an upper limit of 600 hPa in NOAA/NESDIS operations.
 - 3) Recursive fit (RFF) analysis score reduced to 0.1 versus 5 in NOAA/NESDIS operations, reflecting that a lesser agreement between AMV and NWP wind analysis is required in BM05 mesoscale processing.
 - 4) Comparison between AMV and NWP removed from Quality Indicator (QI) analysis, required QI score reduced to 50 versus 60 in NOAA/NESDIS operations.
 - 5) Gross error check tests are turned off in mesoscale processing, which automatically remove AMVs deviating by 10 m/s or 60 from the NWP model forecast.
 - 6) Maximum temperature of targets in IR window imagery increased from 250 K in NOAA/NESDIS operations to 285 K.

Statistical Comparisons



Comparison Type	Number of Vectors	Direction RMS	Wind Speed RMS	Wind Speed RMS	Vector Bias	Vector RMS
OPER AMV						
All Vectors	721	19.98	.885	4.12	.722	5.56
VIS/IR/WV 1000-701 hPa	27	30.53	-1.24	3.19	3.34	5.93
VIS/IR/WV 700-401 hPa	108	24.36	-.57	4.08	.97	5.42
VIS/IR/WV 400-100 hPa	586	16.01	1.25	4.17	1.19	5.57
VIS only	31	32.39	-1.03	3.9	3.21	6.66
IR only	308	15.29	.17	4.01	.23	5.35
WV only	382	19.04	1.60	4.25	1.39	5.64
50 s QI score < 75	105	29.07	54	5.37	1.04	7.44
75 s QI score < 90	120	14.13	-10	4.19	2.20	5.35
90 s QI score	281	9.18	1.06	3.60	1.02	4.63
50 s RF indicator < 75	455	16.96	73	4.15	.69	5.59
75 s RF indicator	36	7.73	-.06	3.09	2.20	3.85
MESO AMV						
All Vectors	11832	34.02	.48	5.78	.60	8.50
VIS/IR/MW 1000-851 hPa	1227	51.10	-.23	5.17	2.77	9.86
VIS/IR/MW 850-701 hPa	2108	40.09	1.54	5.20	.45	7.91
VIS/IR/MW 700-400 hPa	3686	36.73	.78	5.50	.70	8.68
VIS/IR/MW 400-100 hPa	4811	21.10	-.04	6.31	.77	8.58
VIS only	9515	36.42	.44	5.41	.80	8.36
IR only	1091	26.84	.24	6.17	.32	10.30
WV only	1163	15.42	1.12	6.10	.80	7.89
50 s QI score < 75	6216	39.74	.17	5.95	1.06	8.98
75 s QI score < 90	2625	30.79	.71	5.69	.41	8.33
90 s QI score	2991	25.40	.82	5.47	.15	7.46

A summary of match statistics over the one year study period is provided the tables above. Increased MESO AMV errors between 1000-850 hPa are likely associated with questionable Profiler wind observations (see upper right panel) in this layer. RF indicator values were only preserved for OPER AMVs, as MESO settings do not have use for this parameter in determining vector quality. QI values were missing during 2 months of the study period. It is important to note that OPER AMVs are processed every 3 hours, whereas MESO are processed every 30 mins. If we were to multiply the OPER match total by 6 to reach the equivalent processing interval of MESO, 4326 OPER vectors might have been produced, only 36% of the MESO total.

Conclusions

The results demonstrate that OPER AMVs exhibit closer agreement with Profiler observations than individual MESO for all height layers, GOES-12 spectral channels, and AMV algorithm quality statistic values. This study shows that MESO AMVs provided "good" wind estimates (less than 5 ms⁻¹ VRMS differences) for 43% of the total vector matches (5087 out of 11832 vectors), compared to 65% (469 out of 721 vectors) for the OPER method. The higher degree of AMV error could be attributed to target assignment of smaller 1 km VIS targets, differences in measurement of boundary layer flow between AMV and profiler, and the effect of reduced quality control constraints on MESO flows. Agreement between AMV and Profiler observations is much closer though when MESO and OPER vectors derived from near identical scenes are similar. Comparison between Profiler and co-located sonde indicates that 6-min Profiler can be considered a reliable validation dataset above 850 hPa. But one must be careful in selecting dataset match criteria, as significant spatial (3 ms⁻¹ over ~100 km distance) and temporal (.5 ms⁻¹, height dependent) variability exists in the atmospheric wind field, which can greatly impact the results of a validation study.

Although the more conservative OPER AMV product exhibits closer statistical agreement to Profiler observations than the MESO product, the case study example shown here and other previous studies illustrate that spatial patterns in the MESO field can provide useful indications of low-level convergence, vertical wind shear, and mid- to upper-level divergence and vorticity patterns, benefiting the diagnosis and forecasting of mesoscale weather phenomena. Thus, while individual experimental MESO AMVs may sacrifice some absolute accuracy, they show promise in providing greater temporal and spatial flow detail which could benefit diagnosis of upper-air flow patterns in near real-time. Assimilation of sets of MESO into a regional NWP model could provide positive impact on due to a more detailed representation of upper-air conditions at the mesoscale. Future work will focus on this topic as well the development of an AMV quality control scheme better suited to operate on flow of the MESO product density. This new QC method could focus on combining nearby MESO to get an "ensemble average" observation, which should improve the overall accuracy and representativeness of the resulting AMV field.

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