High-resolution Atmospheric Motion Vectors (AMVs) for application in high-impact weather events in the GOES-R era

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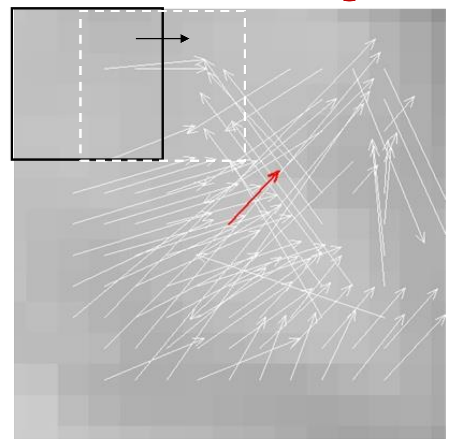
Introduction

The GOES-R Algorithm Working Group and Risk Reduction activities are supporting the development, validation and model impact testing of high-resolution (space and time) AMVs derived from rapid-scans for applications in high-impact weather events such as hurricanes and severe weather. This includes the testing of new AMV production algorithms expected to be operational in the GOES-R era, and numerical model data assimilation experiments designed to exploit the full information content of the high-resolution data in mesoscale analyses. Processing algorithms are reconfigured in order to optimize AMVs for these scales, that is, the 'full disk' AMVs coming out of the GOES-R ground system on day 1 will not be sufficient for this application. Examples from Hurricane Sandy (2012) and a severe weather event in 2014 are presented.

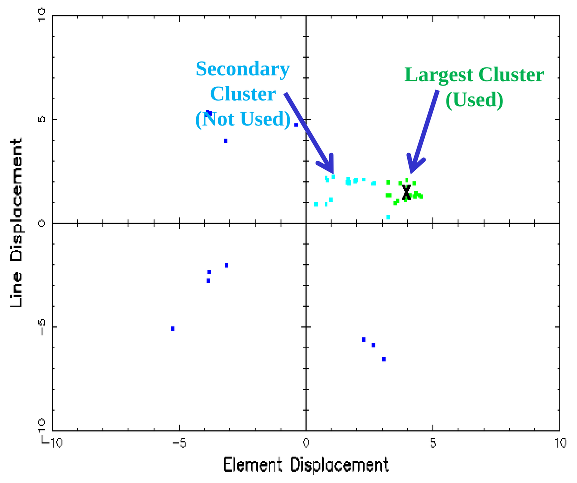
AMV Processing Methodologies

1) Heritage algorithm – NESDIS operational, adapted to mesoscale processing ("benchmark")
2) Developmental algorithm – GOES-R ("experimental"); 2 major innovations briefly described below

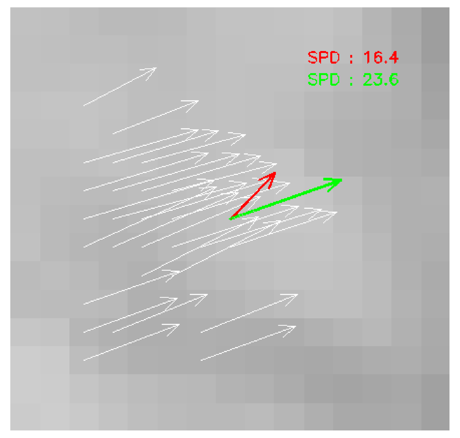
• **Novel nested tracking and clustering approach to determine most coherent cloud displacements**



Step 1: Generate field of local motion vectors (in white) by tracking 5x5 sub-regions of larger target scene. Red arrow shows average motion vector from all displacements.

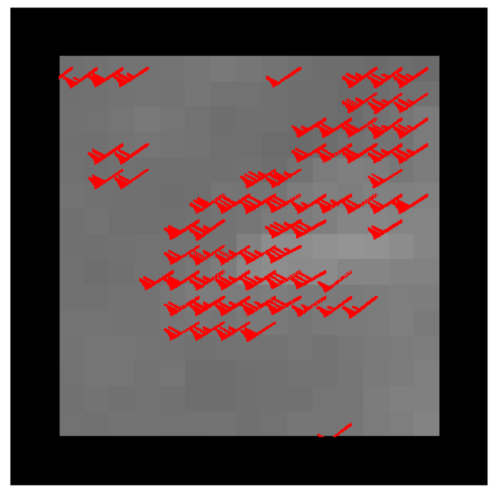


Step 2: Analyze displacements to find major motion clusters. Clusters can result from different cloud motions at different tropospheric levels within the target scene.

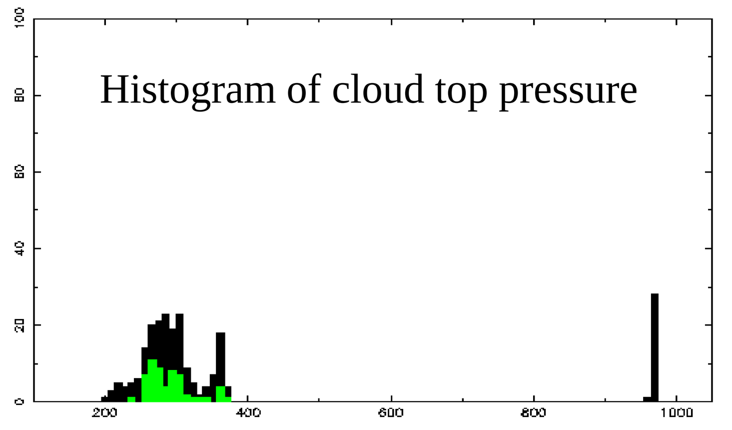


Step 3: Compute final motion estimate of points from largest cluster. Green arrow shows the average vector of points from largest cluster (spd = 23.6 m/sec) is significantly different from average motion in full target scene (red arrow, 16.4 m/sec).

• **New vector height assignment approach uses single pixel heights provided by GOES-R AWG Cloud Team algorithm. It also uses only the pixels matched to the largest tracking cluster.**



Local motion vectors associated with largest cluster.

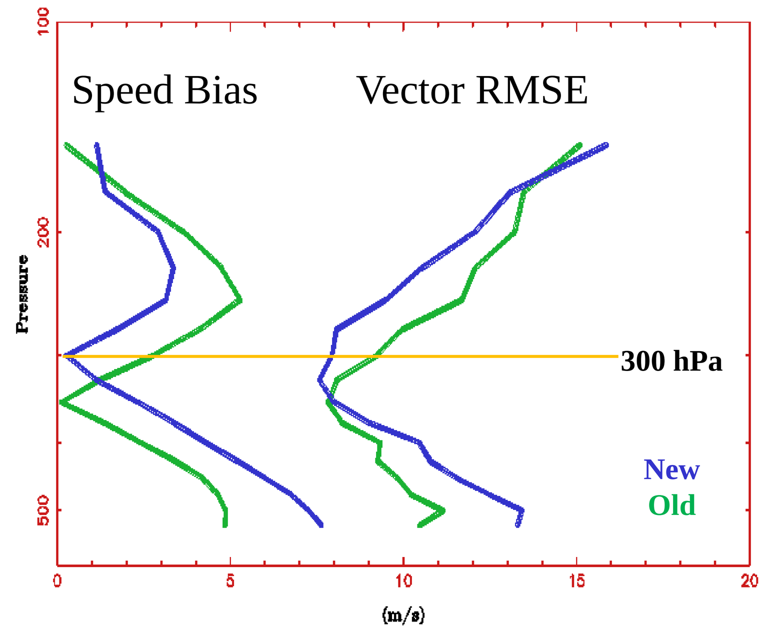


Black histogram is the distribution for the entire scene at left, green histogram is the distribution of largest cluster. Final associated AMV height is median value of largest cluster.

Validation of new methods

A large sample (2-month period) of AMVs are processed with and without the above new approaches. As an example of the impact, all AMVs assigned to 300 hPa from each processing method are compared against their respective collocated (space and time) rawinsonde wind profiles. The resulting error profiles are shown to the right for the AMVs without (green) and with (blue) the new innovations.

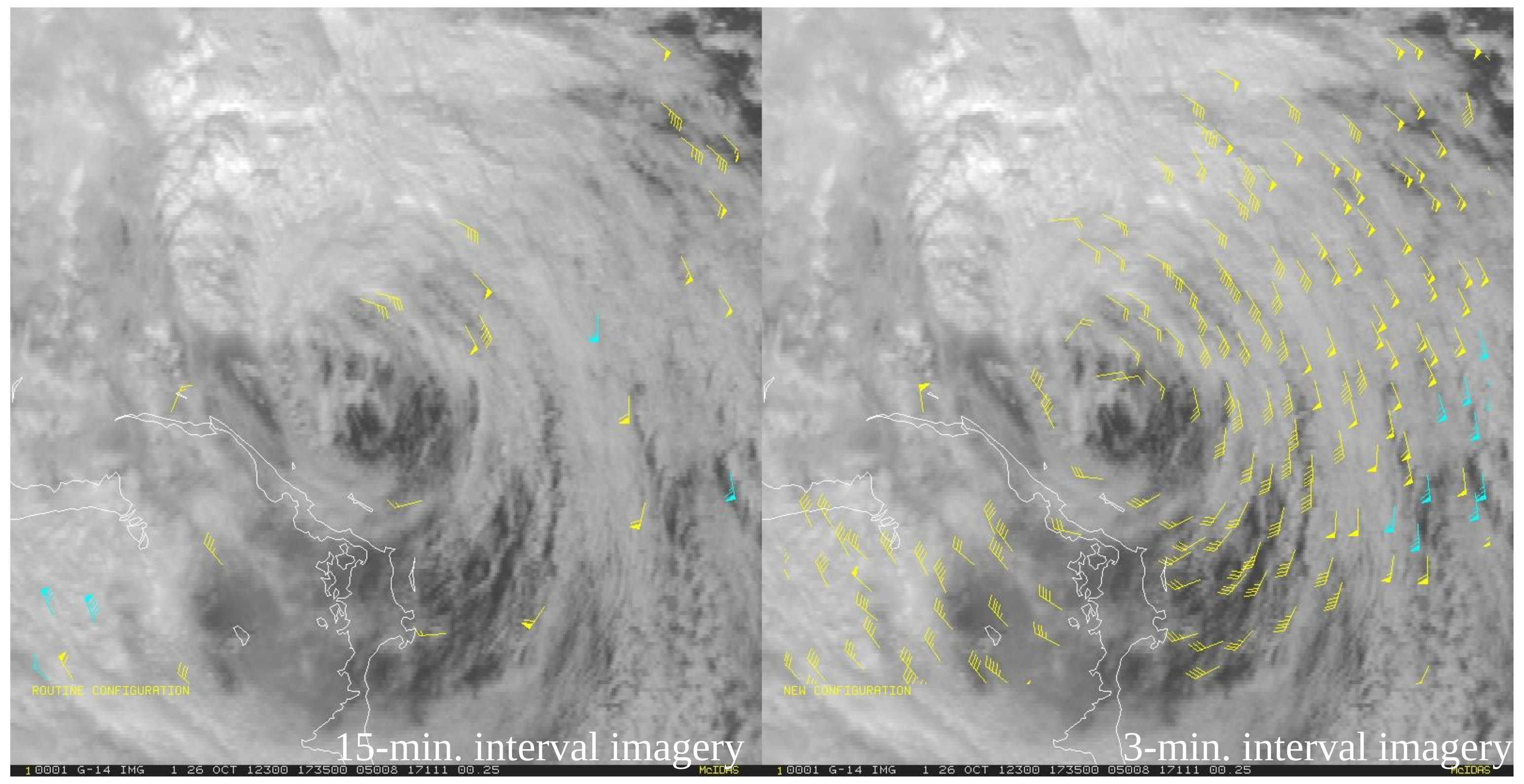
The new AMV methods show better agreement with minimum error values suggesting a closer link between tracking and height assignment.



Hurricane Sandy

Hurricane Sandy (2012) was identified as our initial tropical cyclone test case. Not only was Sandy an event of historic proportions, but GOES-14 was in SRSO mode with continuous 1-min. sampling for 5 days before/during landfall. This high rate of image refresh allows us to test AMV derivation in a simulated way to what GOES-R will provide.

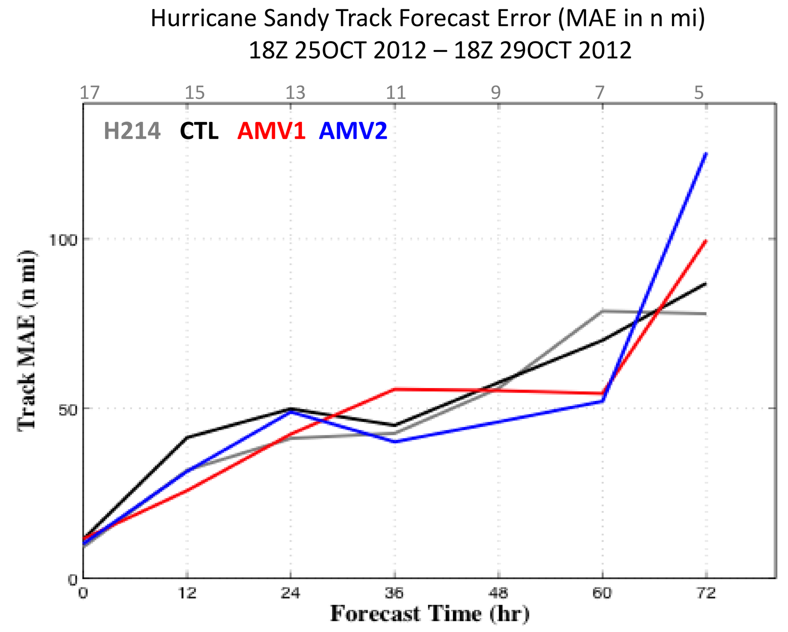
Exploit higher temporal sampling to generate higher-density AMV coverage

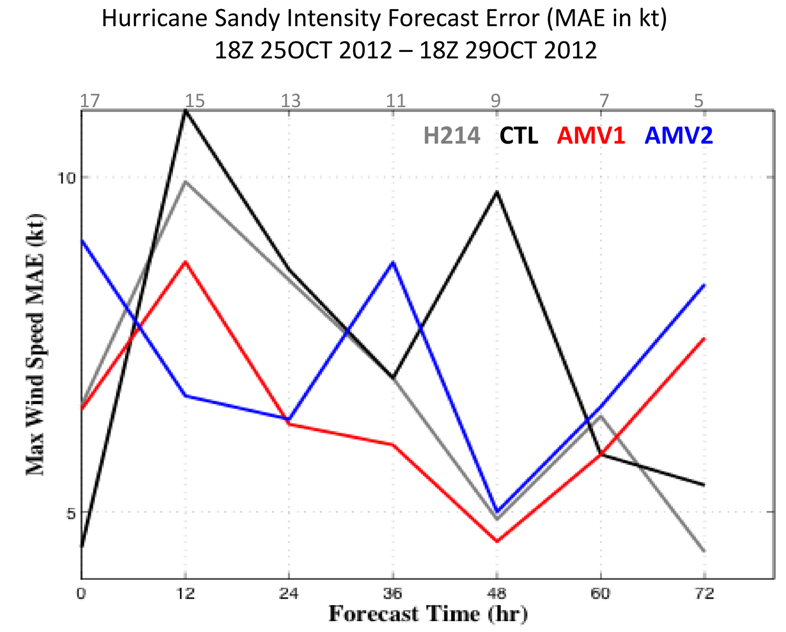


Low-level AMV output for Hurricane Sandy using heritage methodology and 15-minute VIS imagery (left), and new methodologies with 3-minute VIS imagery (right). Cyan vectors show hurricane force winds.

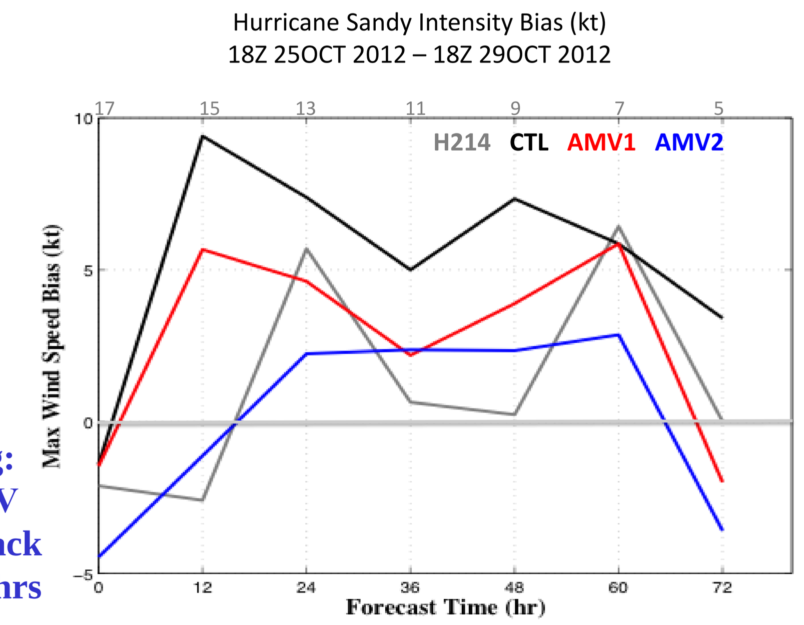
Impact of AMVs assimilated into a hurricane forecast model

Both "Benchmark" and "Experimental" AMV datasets were produced and assimilated into the NCEP operational HWRF/GSI for the Hurricane Sandy case. The system configuration employed is what is used operationally at NCEP, and all experiments were coordinated with our NCEP/EMC project partner Vijay Tallapragada. The only deviation from operational practice was to disable the GSI functions that thin and QC the AMV data. The period of evaluation covers the time GOES-14 was in SRSO mode during Sandy: roughly 4.5 days before landfall. The assimilation cycle was every 6 hours. A control run (CTL) used only radiosonde data and GFS analyses as background fields.





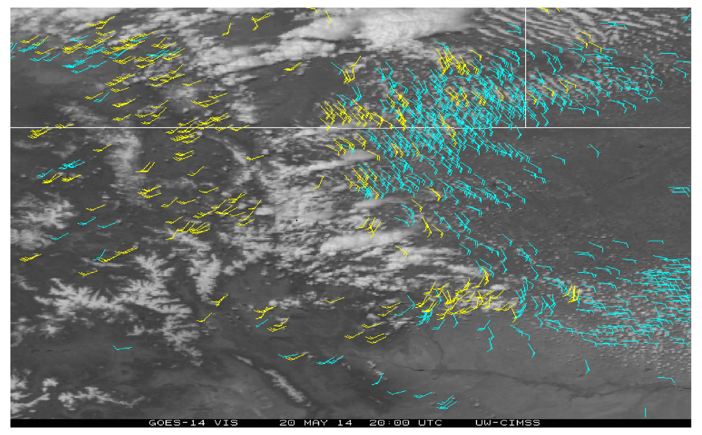
Results of forecast impact experiments for Hurricane Sandy (2012), where MAE is the Mean Absolute Error. CTL is our Control run with only radiosondes assimilated. H214 is the operational HWRF run with full complement of data including reconnaissance aircraft dropsondes and radar wind data (but no AMVs in core region). AMV1 is the CTL plus GOES AMVs assimilated, and represents the "Benchmark" GOES AMV datasets processed with the heritage algorithm. AMV2 represents the "Experimental" GOES AMVs processed using the new GOES-R algorithm. The number of verifying forecasts for each forecast time is listed across the top of the graph.



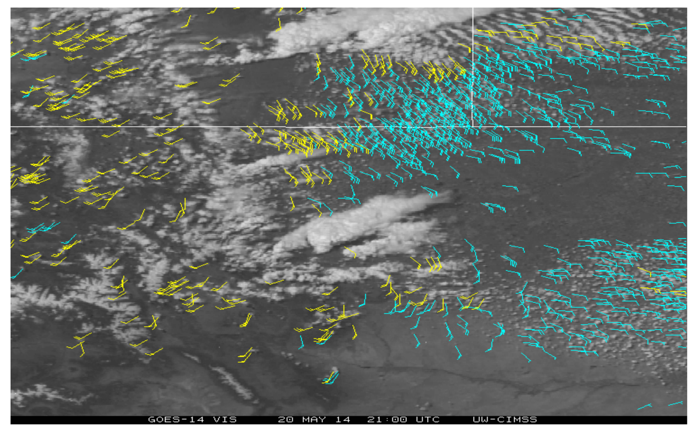
The runs assimilating the AMVs are encouraging: Both the "Benchmark" and "Experimental" AMV forecast errors are lower than the CTL for both track and intensity at almost all forecast times except 72hrs and are comparable to the full data assimilation operational run (H214). These results are particularly impressive given the already relatively low HWRF forecast errors from the CTL and H214 for Sandy.

Severe Storm Event

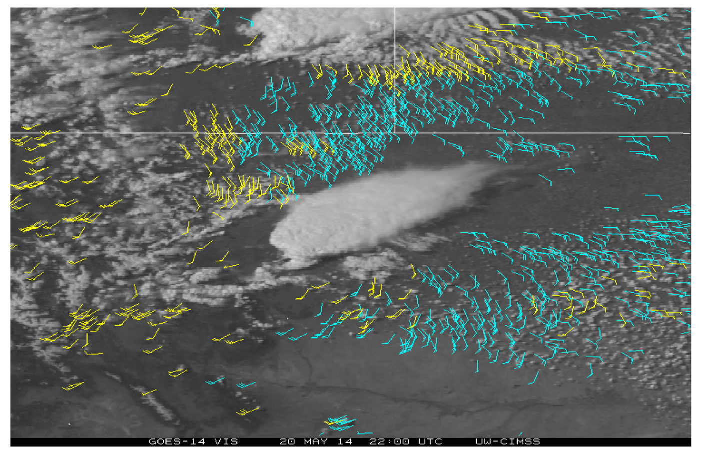
The GOES-14 1-min. super-rapid-scan-operations sampling also provides a testbed for tuning mesoscale AMV datasets with applications to severe storms. For selected cases during the activation period in May of 2014, UW-CIMSS processed AMV fields using the heritage algorithm and with processing settings tuned to achieve high-density vector coverage. Examples are shown in the figures below. No attempt has been made yet to reprocess AMVs with the GOES-R algorithm for a severe weather case.



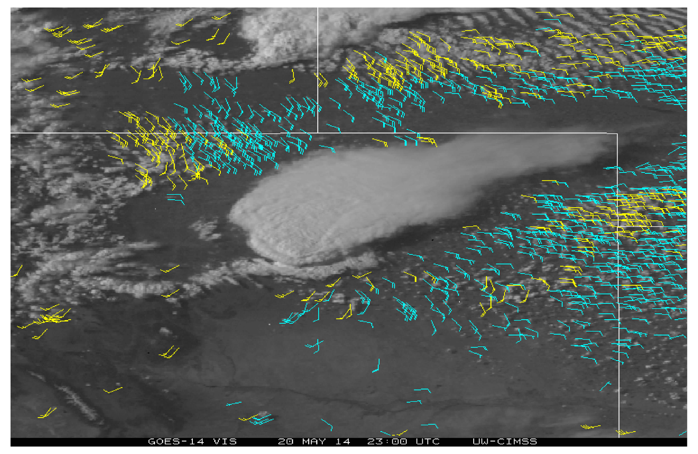
Developing cell in Colorado (image center) at 20:00UTC on May 20, 2014. Low-level AMVs are plotted, with assigned vector heights in the 600-800hPa layer in yellow, 801-999hPa in cyan.



Cell continues to develop/grow at 21:00UTC.



By 22:00UTC on 20 May, 2014, becoming a supercell with elongated anvil.



Large hail with tornado warnings being issued about this time: 23:00UTC 20 May, 2014.

We plan to produce AMVs for this case with the new processing methodology, and run data assimilation and forecast impact experiments using the High-Resolution Rapid Refresh (HRRR) model with our project partners at ESRL.

Future Work

Continue to adapt and tune the new GOES-R AMV processing algorithm for higher-resolution datasets

Examine additional hurricane cases toward assessing optimal AMV data assimilation and model impacts

Apply the new GOES-R AMV algorithm to severe storm events

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