UPDATE ON UW-CIMSS ATMOSPHERIC MOTION VECTOR RESEARCH AND DEVELOPMENT

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ABSTRACT

The expanding AMV user community includes operational, experimental and research sites. The mature Fortran version of the UW-CIMSS AMV tracking code is constantly being updated to remain current with new satellites/sensors and science developments. A new C version of the code is evolving toward full compliance with the Fortran version, with added features designed to ease algorithm implementation into new environments. Additions and modifications to both versions since the last IWW are summarized in this paper.

Incursion into new areas continues to expand the applications and impact of AMV. Recent projects at UW-CIMSS and collaborations have explored the utility of AMV from new sensors (GOES 3.9 micron, simulated GIFTS, Terra/MODIS) and modalities (i.e., rapid-scan). In addition, new innovative ways of visualizing the data are being investigated, with emphasis on 3-D displays.

A portal for accessing UW-CIMSS AMV data, code, updates and information will come online soon with the implementation of a dedicated web site. Still in the planning stages, suggestions will be solicited from interested users regarding content and format. In addition to real-time data access, a short-term online AMV archive will be maintained. The UW-CIMSS AMV tracking code (C version) will be made available in the form of source code and compiled binaries for several common computing platforms. Additional features of this web site will include FAQ, AMV community email lists, documentation, and contact information.

1. Introduction

The UW-CIMSS AMV tracking algorithm has pioneered many of the advances in AMV derivation from satellites over the past 2 decades. It is constantly evolving in response to emerging technologies and improved understanding of the processes involved. With new/improved satellites and sensors, advancing algorithms, and global coverage, the impact of AMV continues to expand. New applications, field experiments, and user requirements drive the evolutionary process.

2. Algorithm Status and Users

UW-CIMSS supports two developmental versions of AMV tracking software. The original Fortran version is the more mature algorithm. The newer C language version has rapidly advanced to include the same capabilities, but in a more portable package. Operational sites, including NOAA/NESDIS and the Australian Bureau of Meteorology (using code originally derived from the CIMSS algorithm) produce real time AMV using the Fortran version. The United States Navy and Air Force have begun using a prototype C version operationally. The two versions have been carefully compared and provide virtually identical results.

Collaborations have also been undertaken with operational data processing sites interested in testing the algorithm experimentally. The Indian Meteorological Department and the Japan Meteorological Agency have obtained copies of the UW-CIMSS software for use with satellite imagery from INSAT and GMS, respectively. And EUMETSAT is testing elements of the code for possible implementation into the operational processing of AMV from the Meteosat satellites.

Finally, CIMSS has begun to distribute the code to interested researchers for use in technique development, case studies, and new applications. See the articles by Campbell, Rabin, and Santek in this volume.

3. Recent Algorithm Upgrades

Since the last IWW, numerous upgrades and additions have been made to the UW-CIMSS AMV tracking package. The C version has caught up to the Fortran version in its ability to process AMV from GMS and Meteosat satellites. GOES-8 through -12 capability is currently being added.

A new module called JETCK has been added as a final post-processing step in the production stream of both the C and Fortran versions. The purpose of this procedure is to reinstate high-speed, upper-level winds (pressures 100-300 hPa, speeds 60-130 m/s) which were rejected by internal quality control due to large deviations from the guess field in speed but not direction. This procedure is designed to rectify situations in and around jet cores where important information was being lost. An appropriate identification tag is attached to reinstated winds.

The AMV targeting algorithm was adapted to permit analysis of images from the GOES 3.9 µm shortwave infrared (SWIR) channel. This channel is susceptible to contamination from reflected visible light, so potential targets are checked for position relative to the day/night terminator, and only nighttime targets (low-level) are processed. Applications of these data are described further in the next section and in a paper by Dunion and Velden, this volume.

In collaboration with NOAA/NESDIS, several major enhancements have been made to the Fortran code which have been, or are in the process of being, mirrored in the C code. In addition to the traditional method of identifying targets on the first image of the triplet and seeking correlations on the succeeding two, a middle-image targeting mode has been developed. In this mode, targets identified on the middle image are tracked backward/forward on the first/third images to produce vector pairs. Additional modifications have been made for GOES 11/12 processing, including use of the PLOD transmittance model for cloud height assignment (i.e. C02 slicing method).

The Quality Indicator (QI) scheme developed by Holmlund has been implemented into the UW-CIMSS package as an additional postprocessing step. The version which excludes the first guess test is also being implemented.

4. Recent Projects

4.1 Field Experiments

Real time field experiments provide excellent testing opportunities for AMV. Recently, CIMSS has played an important role in providing high-resolution winds from GOES-10 7.5 minute rapid-scan visible and infrared imagery in support of GWINDEX/PACJET (GOES rapid scan WINDs Experiment, PACific landfalling JETs experiment, January-March, 2001) and GWINDEX2/PACJET (January-March, 2002). The datasets were evaluated in real time by NWS forecasters, and also assessed through impact studies using the Rapid Update Cycle (RUC) model short-term forecasts. These experiments showed a positive impact of the rapid-scan AMV for both mission planning and RUC forecasts. The rapid-scan data are more coherent (as expected), and the number of vectors produced vastly exceeds those produced routinely using traditional image intervals. Figure 1 is an example from the GOES-10 GWINDEX data set for 1800 UTC, 25 February 2001.

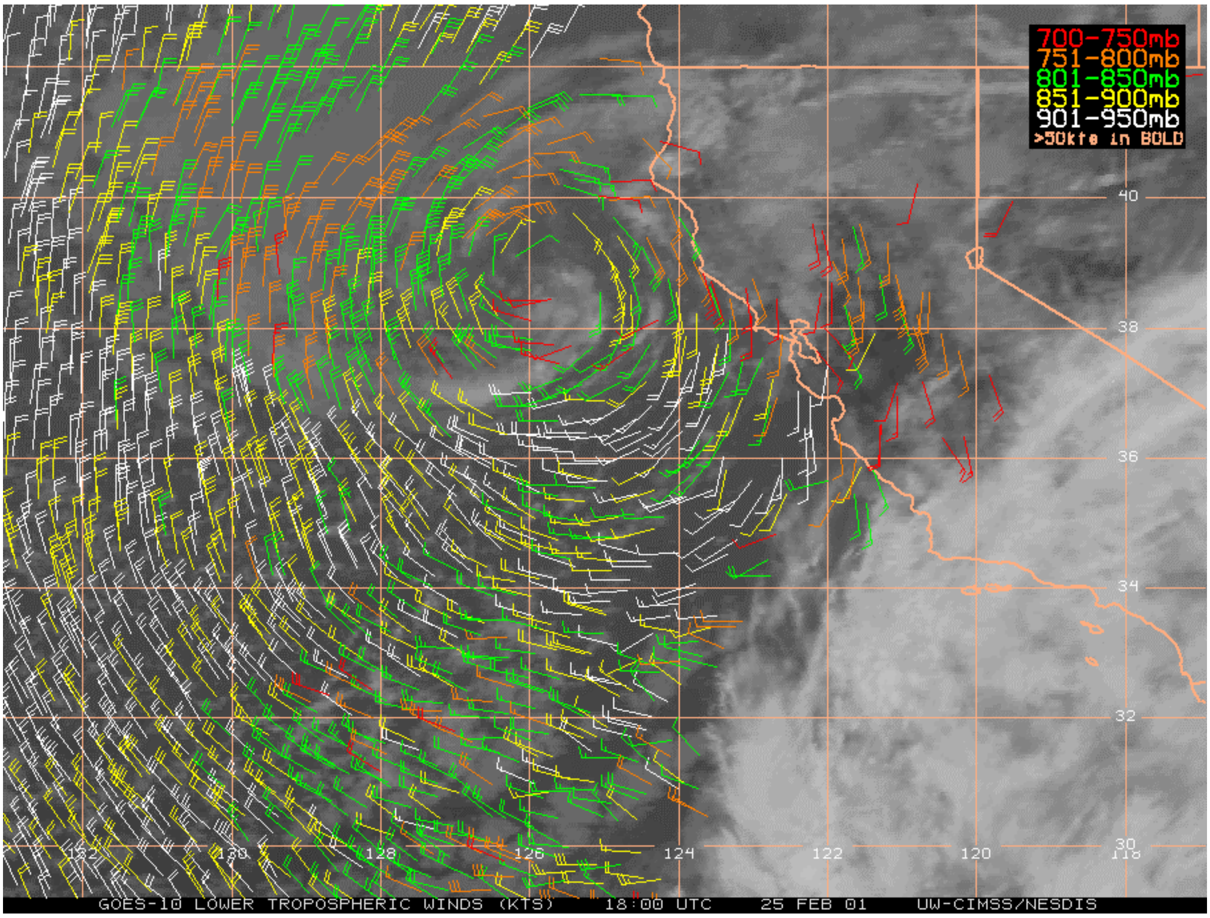

Figure 1. High-resolution, lower-tropospheric GOES-10 AMV from GWINDEX, 25 February 2001, 1800 UTC.

High-resolution winds from GOES-8 7.5 minute rapid-scan visible and infrared imagery were similarly produced in support of NASA's *CAMEX*-4 (*C*onvection *A*nd *M*oisture *Ex*periment, July-September, 2001). Hurricanes were specifically targeted during this field program. Application of this data to hurricane model forecasts is discussed by Berger, this volume.

4.2 Demonstrations and New Developments

UW-CIMSS AMV fields and resulting analyses are also used in support of developing research projects and quasi-operational application demonstrations. AMVs and diagnostic fields derived from them over tropical regions are routinely used in support of tropical cyclone analyses at the National Hurricane Center and the Joint Typhoon Warning Center. In polar regions, the UW-CIMSS code has been adapted to work with polar-orbiter data. Preliminary assessment on the impact of AMVs derived from MODIS and AVHRR imagery is very encouraging (see papers by Santek and Key, this volume).

Low-level cloud-drift winds derived from the 3.9 µm SWIR channel on GOES-8/10 have been developed for nighttime coverage to compliment the daytime visible winds produced operationally at NOAA/NESDIS. Because this near-infrared channel provides a cleaner atmospheric window than the operational 11 µm longwave IR channel (LWIR), superior low-level cloud detection is possible with the SWIR. Only nighttime SWIR winds are produced because of contamination at 3.9 mm from reflected sunlight. By enhancing (stretching) the warmer end of the brightness temperature range in the 3.9 channel, the gradients are sharpened prior to input into the AMV tracking algorithm.

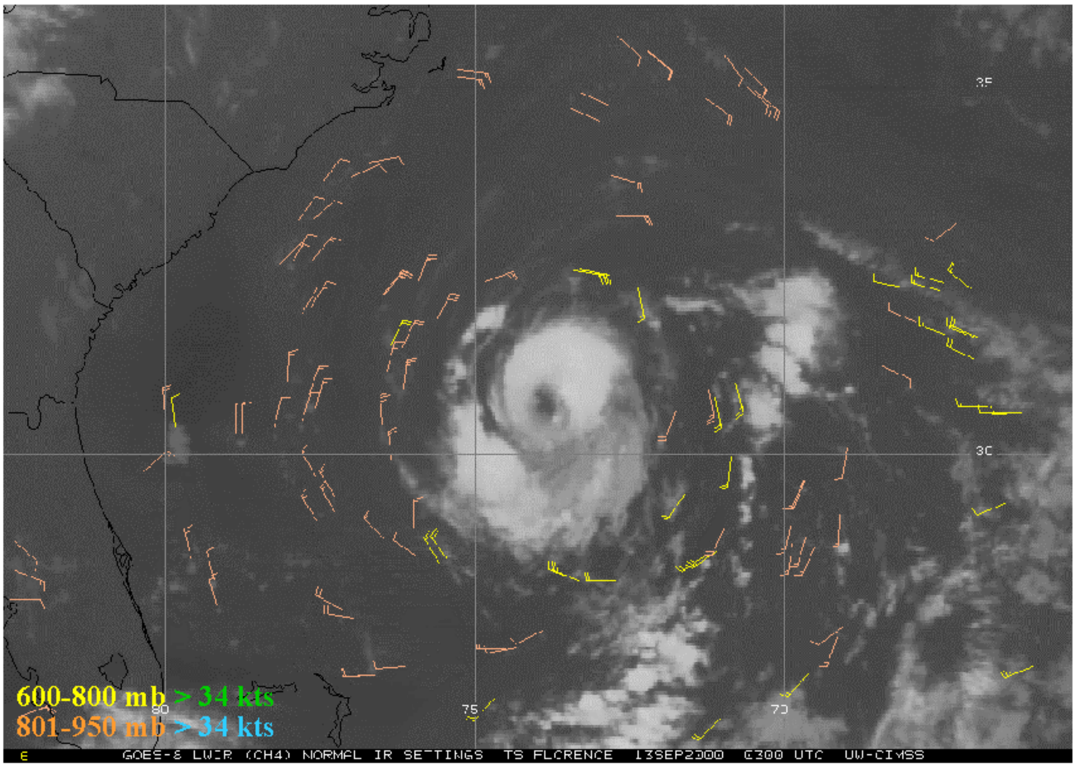

Figure 2. Traditional low-level AMV from the 11 µm longwave IR channel (LWIR) during Tropical Storm Florence, 13 September 2000, 0300 UTC.

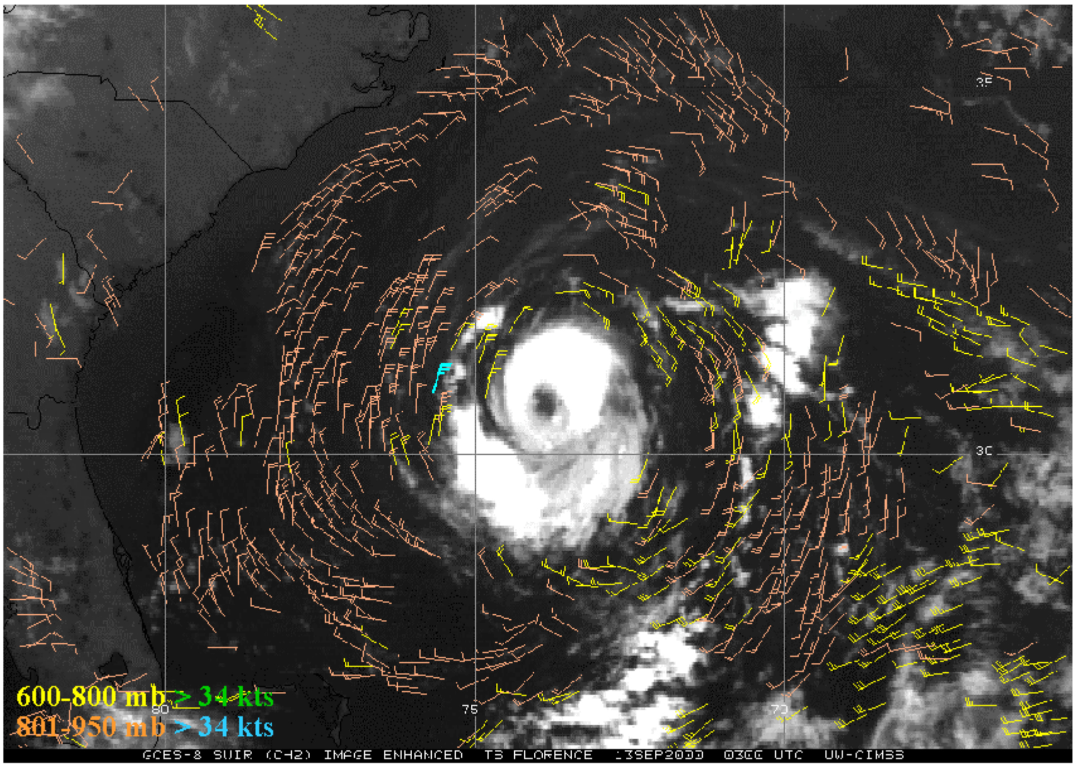

Figure 3. New low-level AMV from the GOES 3.9 µm shortwave IR channel (SWIR) during Tropical Storm Florence,13 September 2000, 0300 UTC.

Figures 2 and 3 show an example of low-level vectors derived simultaneously from LWIR and SWIR images, respectively. Improvement in coverage of vectors using SWIR is quite apparent. A brief statistical analysis of the SWIR/LWIR AMV vs. coincident rawinsondes over the CONUS region during December 2000 - January 2001 is given in Tables 1 and 2. A 30-40% increase in the number of resultant winds is indicated using enhanced SWIR compared to LWIR, with very little change in the quality of the winds. We conclude that using enhanced SWIR for low-level wind production during nighttime hours can drastically increase the density of coverage without sacrificing data quality.

Table 1. Vector quantity comparison for GOES-8 LWIR and enhanced SWIR, raw winds (prior to objective QC) and edited (after objective QC).

	LWIR	SWIR
RAW	33,945	56,479
EDITED	14,321	20,558

Table 2. Statistical evaluation of GOES-8 LWIR and enhanced SWIR winds (after objective QC) versus coincident rawinsondes. Values (except sample size) are in m/s.

		LWIR	SWIR
OVERALL	NRMS DIFFERENCE	0.38	0.40
	RMS DIFFERENCE	5.19	5.42
	AVG DIFFERENCE	4.48	4.68
	STD DEVIATION	2.62	2.73
	SPEED BIAS	-1.37	-1.59
	SPEED	14.17	13.51
	SAMPLE SIZE	1484.00	2394.00
MIDDLE (401-700 hPa)	NRMS DIFFERENCE	0.31	0.33
	RMS DIFFERENCE	5.04	5.27
	AVG DIFFERENCE	4.35	4.54
	STD DEVIATION	2.55	2.68
	SPEED BIAS	-1.04	-1.31
	SPEED	16.08	15.88
	SAMPLE SIZE	837.00	1169.00
LOW (701-1000 hPa)	NRMS DIFFERENCE	0.46	0.48
	RMS DIFFERENCE	5.38	5.56
	AVG DIFFERENCE	4.65	4.82
	STD DEVIATION	2.70	2.77
	SPEED BIAS	-1.81	-1.85
	SPEED	11.71	11.25
	SAMPLE SIZE	647.00	1225.00

The GIFTS (Geosynchronous Imaging Fourier Transform Spectrometer) is a proposed geostationary satellite sounder which will demonstrate advanced technologies for observing surface properties as well as atmospheric moisture, temperature and chemistry variables. Large area format Focal Plane detector Arrays (LFPAs) will provide near instantaneous coverage at 4-km horizontal resolution. A Fourier Transform Spectrometer (FTS) will enable collection of atmospheric radiance spectra simultaneously for all LFPA detector elements to provide temperature and moisture sounding information at high vertical resolution. The geosynchronous orbit of the satellite platform will enable near continuous imaging of the atmosphere's three-dimensional structure, allowing GIFTS to provide water-vapor image sequences for deriving winds at many levels throughout the troposphere. GIFTS is scheduled to be launched in 2005 as part of NASA's New Millennium Program (NMP) Earth Observing (EO-3) satellite mission, and will serve as the prototype for sounding systems to fly on future NOAA operational geosynchronous satellites. To get ready for this revolutionary event, UW-CIMSS is adapting the AMV tracking software to perform on simulated GIFTS data. AMV production will be demonstrated using three "imaging" modes for input data: (1) individual-channel hyperspectral images, (2) multi-channel averaged "superchannels" and (3) retrieved moisture fields.

The wealth and diversity of emerging new AMV datasets is placing increasing demands on methods to visualize and diagnose these data. UW-CIMSS is pioneering a new 3-dimensional visualization of AMV using VisAD (Visualization for Algorithm Development, developed by Bill Hibbard of UW-SSEC). Figures 4-6 show views of a high-resolution AMV dataset derived from GOES 3-minute rapid-scan imagery of Hurricane Keith in October 2000. Wind barbs are color coded by pressure altitude, from low-level (red) to high-level (blue). A satellite image underlay with base map is provided for orientation.

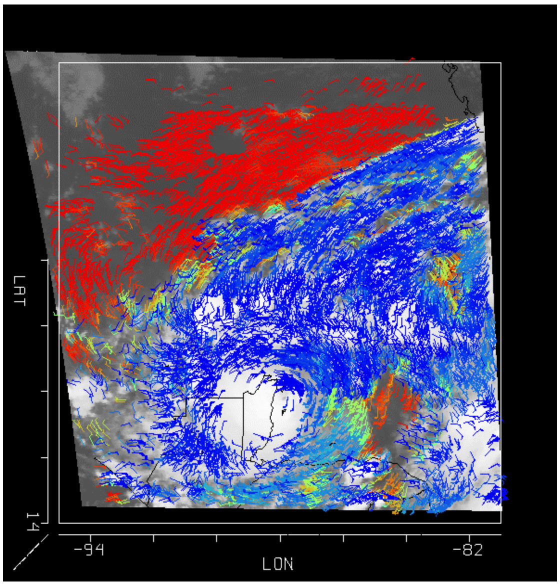

Figure 4. Satellite's view.

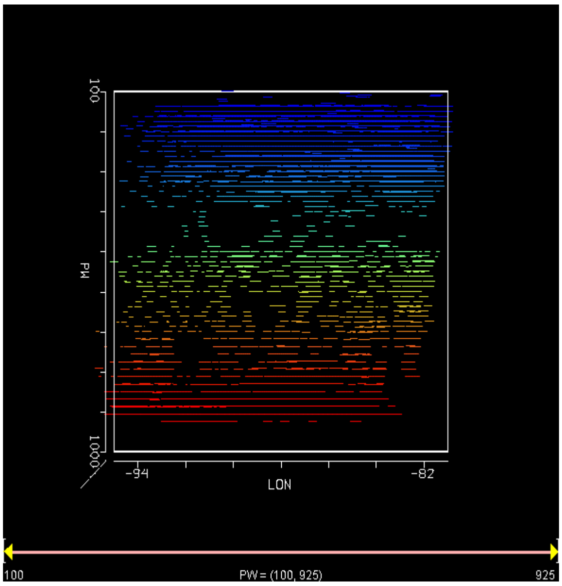

Figure 5. Vertical distribution.

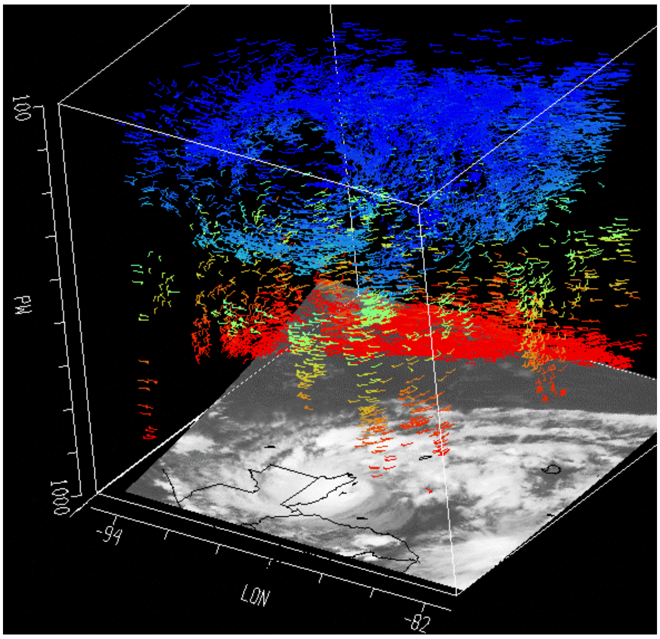

Figure 6. Rotated view.

5. Future Plans

Development of the C version of the UW-CIMSS AMV tracking algorithm will continue with emphasis on operating platform/environment independence. Algorithm upgrades will be an ongoing process, and increased efficiency will reduce system requirements and processing time. Modular design enhancement will better facilitate the addition of new satellites and sensors (e.g. MSG, MTSAT, GIFTS, MODIS), and generic data input and output formats will reduce dependency on McIDAS data structures. In this way, we hope to make the code more easily portable to the global user community.

Two efforts are being undertaken to facilitate access to the code. The first is construction of an optional AMV algorithm add-on to McIDAS. This version will be more suitable for small-scale AMV production and researchers. It will be available through the McIDAS User's Group (http://www.ssec.wisc.edu/mug/mug.html). For larger satellite data processing sites and those who do not use McIDAS, the C version of the code will be available on the UW-CIMSS AMV web page, which is currently under construction. Source code, compiled binaries for several common configurations, documentation and applications will be available for download.

Real-time AMV data plots and animations will be available for viewing and downloading via the UW-CIMSS web page. Limited historic data will be maintained in an online archive with a thumbnail browser. The web page will also feature FAQ about AMV, links to related sites, project news and status, facilities for contacting members of the UW-CIMSS winds team, and a subscriber mail list for users who wish to share questions, comments, tips and solutions with other members of the community. As this web site is still in the planning stages, the authors encourage input on content and format from potential users. We will also be happy to trade links with other AMV related sites.

6. Summary

With global production and dissemination of satellite AMVs now a routine part of our tropospheric observing system, the already considerable impact of AMVs is expected to increase in future years due to new satellites and sensors, improvements in processing strategies, and a growing base of applications. UW-CIMSS will continue to support the AMV user community with the latest advances in technology and derivation methodologies. We will strive to improve and expand upon the C version of the UW-CIMSS tracking software with generic input and output formats that will make it easier for users to adapt the code to their needs and add new satellite instrument capabilities. The UW-CIMSS algorithm will be distributed to the global community upon request as either a McIDAS add-on or as an independent application for Unix platforms. Code, data and support will be accessible via the new CIMSS AMV web page (under development).