AMV RESEARCH USING SIMULATED DATASETS

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Abstract

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) continues to conduct research on satellite derived atmospheric motion vectors (AMVs) using simulated atmospheric datasets. The simulations, produced by numerical weather prediction (NWP) model output, serve as a "true" atmospheric state and provide the unique opportunity to compare AMVs derived from the simulated image sequence with the "true" model winds. This paper will briefly summarize the past CIMSS research on utilizing constant-pressure moisture analyses produced from simulated single field of view retrievals from hyperspectral sounders for 'height-resolved' AMV derivation. A more recent effort uses the current version of the CIMSS/NESDIS AMV retrieval code to experiment with simulated GOES-R Advanced Baseline Imager (ABI) datasets delivered by the GOES-R Algorithm Working Group (AWG) Proxy data team. Top of Atmosphere (TOA) Radiances for ABI channels 8 through 16 (6.19 μm – 13.3 μm), with 2 km horizontal resolution over the CONUS domain were output for a 6-hour period at 5/15/30 minute intervals. Example AMVs computed from heritage channels (IRW and WV) are shown. Another effort employed simulated Meteosat-8 images derived from the European Center for Medium-Range Weather Forecasts (ECMWF) global model. The images were simulated from a T_L2047 forecast run of the model. TOAs were output every 15 minutes for 6 hours. AMVs were then calculated in both the simulated 10.8 μm (IR) and 6.2 μm (WV) micron channels using processing strategies currently employed on actual Meteosat-8 data at CIMSS. Examples are shown, and the implications of this study are discussed in a related paper in this volume.

INTRODUCTION

In preparation for the launch of the next generation of U.S. geostationary operational environmental satellites (GOES-R series), CIMSS is involved in both the GOES-R risk reduction effort and the GOES-R Algorithm Working Group (AWG) through demonstration studies of algorithm development. The risk reduction program is designed to investigate optimal processing methods to insure products can be applied to the future hyperspectral imagers and sounders. The AWG was created to leverage developments in Risk Reduction and heritage algorithms. Atmospheric Motion Vectors (AMVs) is one of 15 product teams of the AWG. These algorithms will be required to work in an operational demonstration environment.

To ready the AMV algorithms for expected GOES-R inputs, we employ proxy datasets in the form of simulations produced by numerical weather prediction (NWP) model output. The model output can be converted to the form of simulated radiances and images, which can provide the unique opportunity to compare AMVs derived from the simulated image sequence with the "true atmospheric state" model winds.

HYPERSPECTRAL SOUNDER -- REVIEW

Several steps are involved in order to produce clear sky AMV profiles from proposed geostationary hyperspectral sounders. Mesoscale models are used to generate simulated atmospheric profiles with detailed horizontal and vertical resolution. TOA radiances simulated for a specified future hyperspectral environmental sounder, such as the Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS) or the Hyperspectral Environmental Suite (HES) are determined using these profiles along with the GIFTS forward radiative transfer model. Single field of view vertical temperature and water vapor retrievals are calculated from the TOA radiances (Otkin et al. 2007; Olson et al. 2006; Li et al. 2004). Moisture profiles from the retrievals are analyzed on constant pressure levels, and converted to images. Clouds are masked, and these pixels are not used in the targeting/tracking process. The water vapor amount is stretched over a range of 0 to 255 greyscale values in these images to enhance gradients for targeting. A sequence of three images (30 minutes to an hour apart) is then employed in an attempt to successfully track the targeted features. The height of the AMV is pre-determined by the pressure surface being tracked. Hence, height assignment errors that afflict current AMV production should be mitigated. The hyperspectral information (retrievals at 101 pressure levels) allows AMV production at multiple vertical levels throughout the troposphere as long as targetable moisture features are present. In comparison, current GOES imager clear sky water vapor winds are constrained mainly to the upper troposphere.

This project first demonstrated results at the 7th International Winds Workshop in Helsinki, Finland (Velden et al. 2004). Another presentation followed at the 8th International Winds Workshop in Beijing, China (Wanzong et al. 2006) that included a simulation from the Atlantic THORpex Regional Experiment (ATReC). The ATReC simulation was the first test using the Weather Research and Forecasting (WRF) NWP model. The AMV results were mixed, primarily due to the presence of significant cloud cover. The next simulation, named OCEANWINDS, was specifically chosen for clear sky temperature and moisture retrieval and AMV production. Fig. 1 is an example of what can be achieved with a high-resolution simulation (~3 km) and ½ hour temporal imagery.

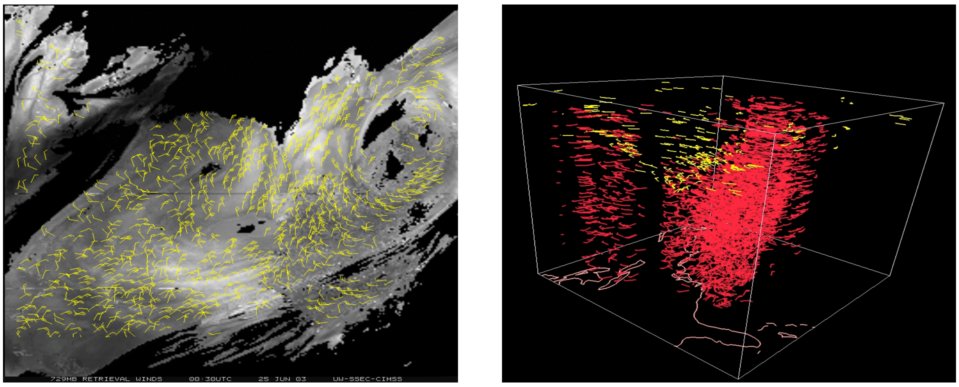

***Figure 1*: At left, hyperspectral retrieval AMVs at 729 hPA. Note the well-defined low-level circulation in the northeast section of the image. At right and in red are the retrieval AMVs at all available levels with enough water vapor to track (300 hPa to 986 hPa). In yellow are the operational clear sky AMVs from the GOES-12 Imager.**

GOES-R ABI SIMULATION

In recent months, the focus on GOES-R risk reduction and AMV algorithm demonstration has shifted to the ABI. The AWG Proxy Data team has created several ABI simulations. This section details work on a CONUS simulation which mimics one of the proposed scan segments on the future ABI. The creation of the simulation is very similar to the process described in the HES section above. In this case, TOA radiances are directly used in the AMV processing algorithms. Two flexible scanning scenarios are currently under review for the ABI. The first mode allows the ABI to scan the full disk (FD) every 15 minutes, allow 3 CONUS scenes, and scan a 1000 km x 1000 km selectable area every

30 seconds. A second mode would program the ABI to scan the FD every 5 minutes (Schmit et al. 2005). Fig. 2 shows an example of simulated ABI and corresponding real GOES-12 IR/WV images.

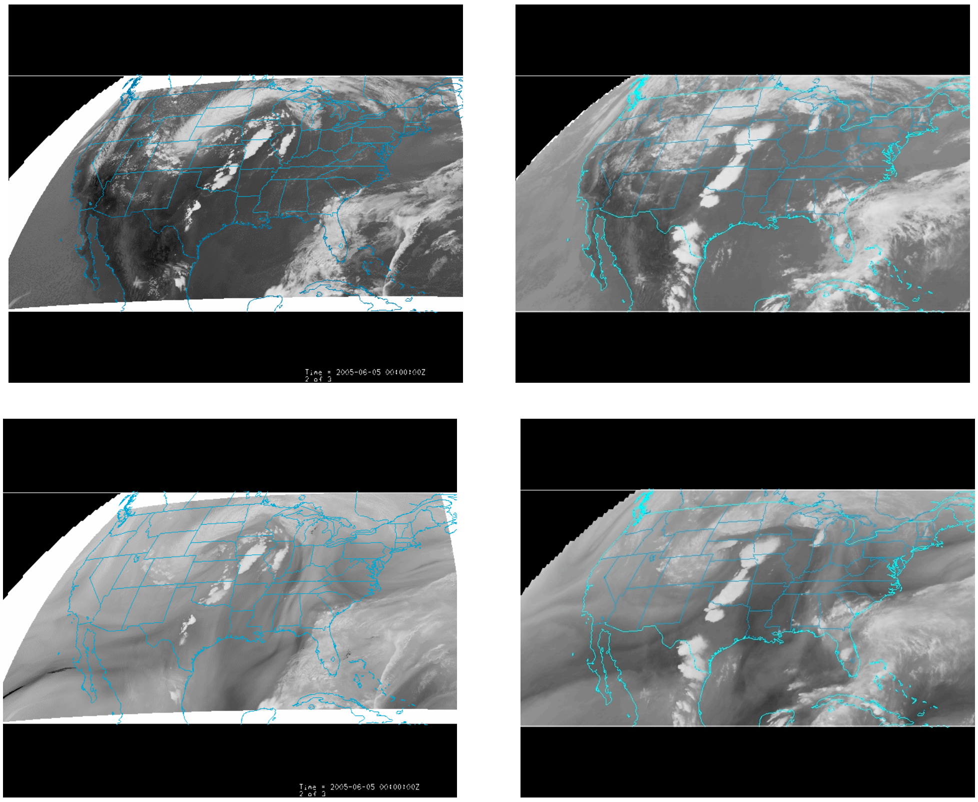

***Figure 2*: At left and top, simulated 11.2 μm imagery from the GOES-R ABI. At right and top, 10.7 μm imagery from the GOES-12 imager. Bottom left, simulated 6.19 μm imagery from the ABI. Bottom right, 6.5 μm imagery from the GOES-12 imager. The simulated data captures the general features and locations well. Differences can be observed in the cloud structures.**

To address this flexibility in potential scanning modes, AMVs were calculated on the CONUS sector in Fig. 2 with a 5-minute, 15-minute, and 30-minute time step between the sequence of 3 images. The current NOAA/NESDIS/CIMSS AMV retrieval code (Nieman et al. 1997; Velden et al. 2005) was used to calculate wind sets in the 6.19 μm and 11.2 μm wavelength regions. The full suite of quality control (QC) algorithms was applied to these data sets. Figure 3 below shows the results of the 5-minute time step example.

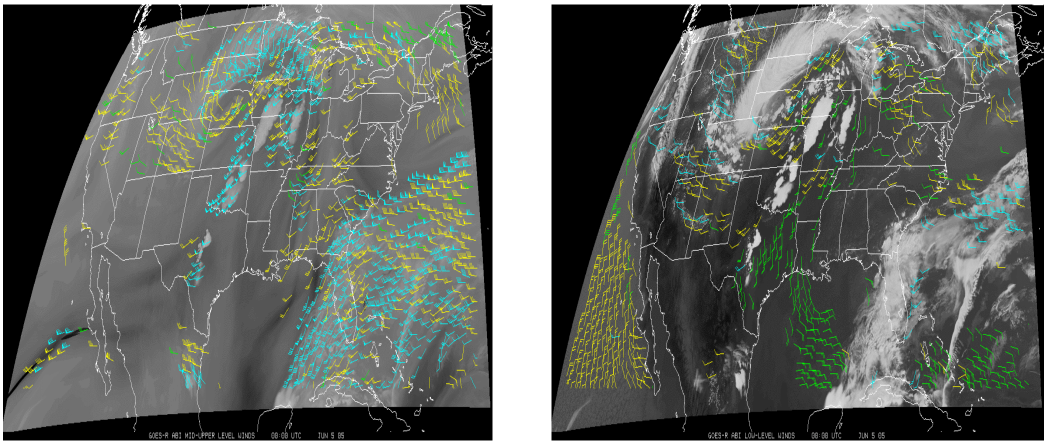

***Figure 3*: At left, mid to upper level IR-WV AMVs from simulated 5-minute ABI IR and WV imagery. At right, mid to low level IR AMVs from simulated 5-minute ABI imagery.**

A 10% drop in the quantity of AMVs was observed between the 5-minute and 15-minute time steps. A 30% decrease was observed between the 5-minute and 30-minute time step AMVs. Clearly, more rapid image refresh produces greater coherent vector quantities. To assess the quality of the AMV datasets, comparisons between the calculated AMVs and the model ('true') winds were performed. The results are shown in Tables 1 and 2.

Image Interval (Minutes)	# Matches	Speed Bias (m/s) (AMV - WRF)	V_{RMS} (m/s) (AMV - WRF)
5	3041	-0.06	5.15
15	2693	0.06	4.70
30	2124	0.07	5.00

***Table 1*: Comparison between simulated clear and cloudy sky WV AMVs and the WRF model winds.**

Image Interval (Minutes)	# Matches	Speed Bias (m/s) (AMV - WRF)	V_{RMS} (m/s) (AMV - WRF)
5	4157	-0.36	4.45
15	3754	0.56	4.01
30	2484	0.50	4.02

***Table 2*: Comparison between simulated IRW AMVs and the WRF model winds.**

The above tables show very good agreement between the calculated AMVs and model winds. The background model first guess used by the tracking algorithm employed the Navy's Operational Global Atmospheric Prediction System (NOGAPS). The simulation imagery was derived using the WRF. Figure 4 shows the calculated AMVs, from NOGAPS, overlaid on the WRF model streamlines. In general, the wind barbs overlay quite well with the WRF model streamlines. This makes the case that the AMV retrieval software is relatively insensitive to model background type. This is also observed in the Meteosat-8 simulation discussed below.

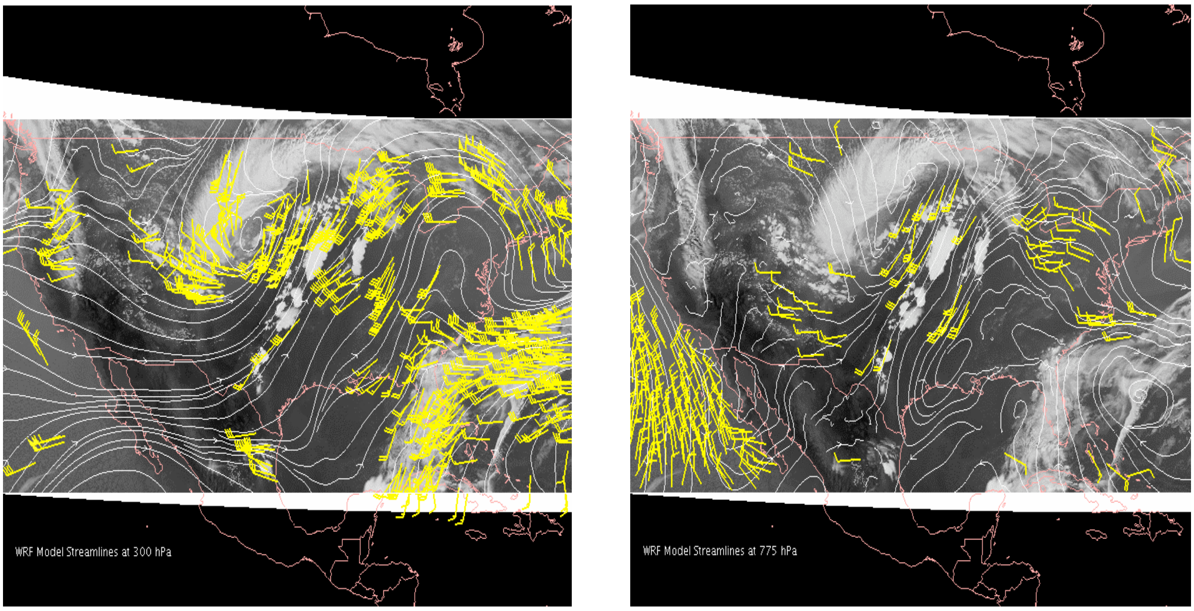

***Figure 4*: At left, simulated IR/WV AMVs (wind barbs) from 5 minute ABI imagery overlaid on WRF model wind streamlines at 300 hPA. At right, simulated IR AMVs (wind barbs) from 5-minute ABI imagery overlaid on WRF model streamlines at 775 hPA.**

The GOES-R Analysis Facility for Instrument Impacts on Requirements (GRAFIIR) uses component algorithms to analyze sensor measurements with different elements of sensor characteristics (i.e. noise, navigation, band-to-band co-registration, diffraction, etc.) and its potential impact on derived products. The CONUS simulation and GRAFIIR are used to test the sensitivity of instrument noise on AMVs. Table 3 shows the results of taking 3 times the proposed specifications for instrument effects, in combination (i.e. specs for the above instrument characteristics are all tripled). The AMV retrieval algorithms are able to function on the degraded data, but at a severe cost to the quality. This is the type of information that will be useful to the GOES-R decision-makers when instrument design and precision requirements are finalized.

Image Interval (Minutes)	# Matches		Speed Bias		VRMS	
	Spec	3X Spec	Spec	3X Spec	Spec	3X Spec
5	3041	534	-0.06	1.66	5.15	6.11
15	2693	1189	0.05	1.68	4.70	5.29
30	2124	1217	0.07	1.40	5.00	4.84

***Table 3*: Comparison between simulated ABI clear and cloudy sky WV AMVs and the WRF model winds. Spec pertains to unaltered TOA radiances. 3X Spec refers to AMVs calculated from altered TOA radiances at 3 times specifications, using all sensor effects.**

The ABI will contain 16 spectral bands, including 6 visible/near-infrared channels. The CONUS simulation AWG proxy team has now made these bands available. Heritage bands yet to be explored for AMVs include the .64 μm, 3.90 μm, 6.95 μm and 7.34 μm. It will take a significant re-engineering to the current AMV retrieval code to take advantage of potentially interesting "new" bands such as the .87 μm (AMVs over water), 1.38 μm (very thin cirrus) and the Ozone channel (Figure 5). We plan to explore these bands for their potential to add AMV information.

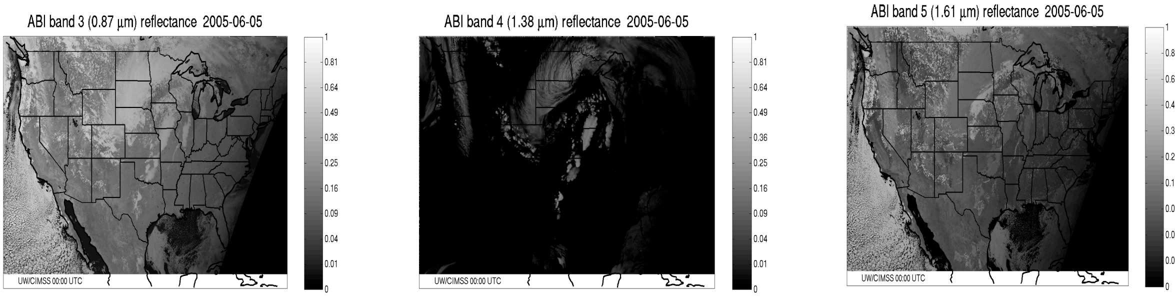

***Figure 5*: Potential non-heritage simulated ABI channels available for AMV processing. These channels draw upon heritage instruments on VIIRS and spectrally modified AVHRR.**

METEOSAT-8 SIMULATION

To better characterize the behavior of AMVs for data assimilation into the ECMWF global model, a study was conducted using simulated Meteosat-8 imagery. The Meteosat-8 simulation began with a high-resolution (T_L2047) run of the global ECMWF model. This forecast has an approximate 10 km resolution and is re-sampled to match the Meteosat-8 resolution of 3 km. Meteosat-8 radiances are simulated using the model profiles of temperature, specific humidity, cloud cover, ice water, and liquid water, and the Radiative Transfer for Television and Infrared Sounder (RTTOV) Cloud model. The model was allowed to run out to 24 hours. From hour 24 to hour 30, in 15-minute intervals (to mirror the operational Meteosat-8 (now -9) scanning mode), TOA radiances were supplied to the CIMSS/NESDIS AMV retrieval code. Simulated images are shown in Figure 6.

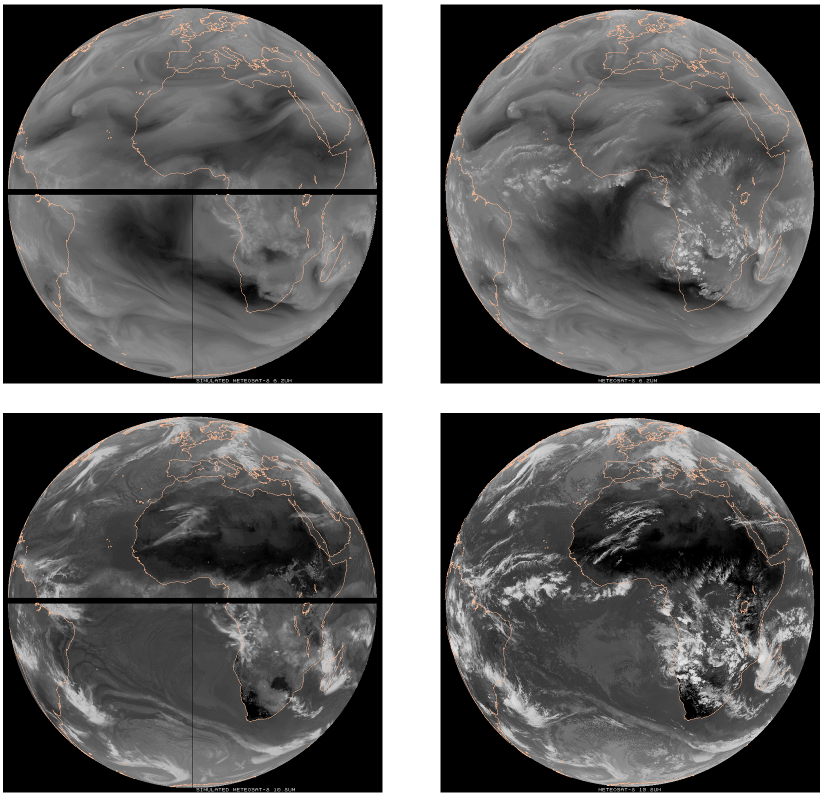

Figure 6: **At left and top, simulated 6.2 μm imagery from Meteosat-8. The observed banding is an artifact of the display software, not in the simulated TOA radiances. At right and top, real 6.2 μm imagery from Meteosat-8. At left and below, simulated 10.8 μm imagery from Meteosat-8. At right and below, real 10.8 μm imagery from Meteosat-8. Again, overall features are excellent, but some cloud structure is missing.**

From this simulated case, CIMSS supplied variants of 12 AMV datasets to ECMWF. Each AMV dataset was derived using either the NOGAPS or ECWMF as the model background in the processing. ECMWF-derived simulated imagery was used in every case. Using the ECMWF model as a background is unique, as it is the first time CIMSS AMVs have been generated with the forecast that created the simulation. In all cases, AMV datasets were supplied after each stage of the CIMSS/NESDIS post-processing to assess the quality control impacts (i.e., 'raw' winds, after the QI step, after the 'auto-editor' step). Some of the AMV dataset variants were calculated with gross error checks intentionally relaxed. A total of 120 BUFR files were supplied to ECMWF for evaluation. Examples of simulated AMVs are shown Figures 7 and 8.

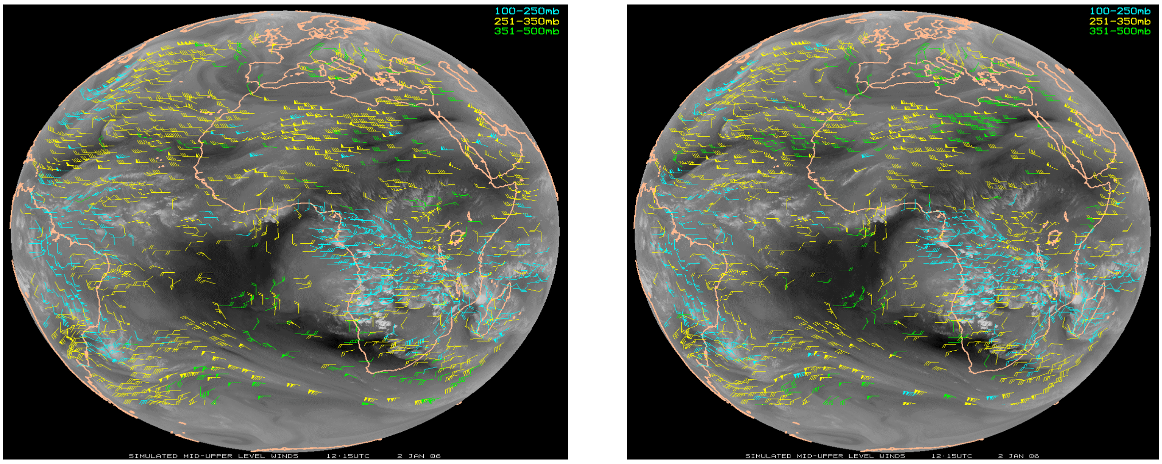

Figure 7: **At left, simulated Meteosat-8 mid to upper level IR-WV AMVs using the ECMWF model background in the processing. At right, using the NOGAPS model background.**

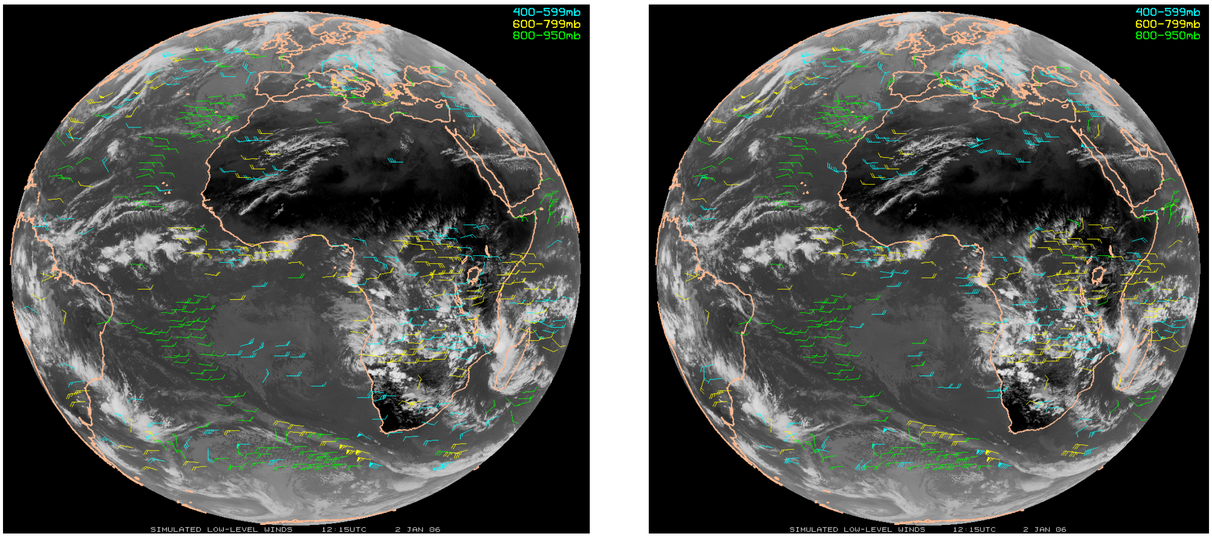

***Figure 8*: At left, simulated Meteosat-8 mid to low level IR AMVs using the ECMWF model background in the processing. At right, using the NOAGAPS model background.**

Very little difference is observed in the AMVs when switching between the differing model backgrounds in the processing step. The Meteosat-8 simulation is discussed in more detail within this volume (See “Evaluation of AMVs Derived From ECMWF Model Simulations”, by von Bremen et al.).

FUTURE WORK

A more detailed examination of the CONUS simulation will be investigated. Unexplored heritage channels are now available for testing. These include visible, short wave IR, and the mid- and low-level water vapor channels. The GOES-R AWG Proxy data team has also completed a Meteosat-8 simulation at the native horizontal resolution of 3 km. This may become the benchmark data set for future studies with ECMWF and EUMETSAT.

SUMMARY

To prepare for the GOES-R era, simulated datasets are being employed to ready the CIMSS/NESDIS AMV algorithms. Early results indicate that the simulated proxy (GOES-R/Meteosat-8) datasets can provide a good framework for advancing algorithm development. The proxy datasets can also be used to better understand the AMV algorithm behavior when compared to the simulation background.

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ACKNOWLEDGEMENTS

The authors wish to thank Jaime Daniels of NOAA/NESDIS and Wayne Bresky of IMSG for GOES-R AWG support. We also thank several members of ECMWF, including Lueder von Bremen, Niels Bormann, Mariano Hortal, Deborah Salmond, Jean-Noël Thépaut' and Peter Bauer for their support during the Meteosat-8 simulation study.