Current State of Atmospheric Motion Vector (AMV) Algorithm Development at NOAA/NESDIS in Preparation for the Future GOES-R Advanced Baseline Imager (ABI)

Summary and Purpose of Document

This paper reports on NOAA/NESDIS' current and planned AMV development work in preparation for the future GOES-R Advanced Baseline Imager (ABI). Part of this development work involves AMV height assignment derived from cloud property information retrieved at the pixel-level and is the focus of this report.

Current State of Atmospheric Motion Vector (AMV) Algorithm Development at NOAA/NESDIS in Preparation for the Future GOES-R Advanced Baseline Imager (ABI)

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1 INTRODUCTION

This paper describes the current state of the Atmospheric Motion Vector (AMV) algorithm developed for the future GOES-R Advanced Baseline Imager (ABI) by the GOES-R Algorithm Working Group (AWG) Wind Team. While the various algorithm components of the AMV derivation process will be described, this paper focuses on the AMV height assignment approach that will be used in the GOES-R era. Some preliminary results are given and plans for the future work are described.

2 GOES-R AMV HEIGHT ASSIGNMENT ALGORITHM APPROACH

GOES-R AMV software development and testing is being done within a common processing framework that supports a tiered algorithm processing approach that allows the output of lower-level algorithms to be available to subsequent higher-order algorithms while supplying needed data inputs to all algorithms through established data structures. This is illustrated in Figure 1. The framework efficiently provides routine services to algorithms that are easily plugged into the framework. The reading in and handling of calibrated/navigated radiances and ancillary data are performed by the framework. These data are then loaded into established data structures that can be accessed by all algorithms. Other established data structures enable the output of the lower-level algorithms to be accessible by higher-level algorithms.

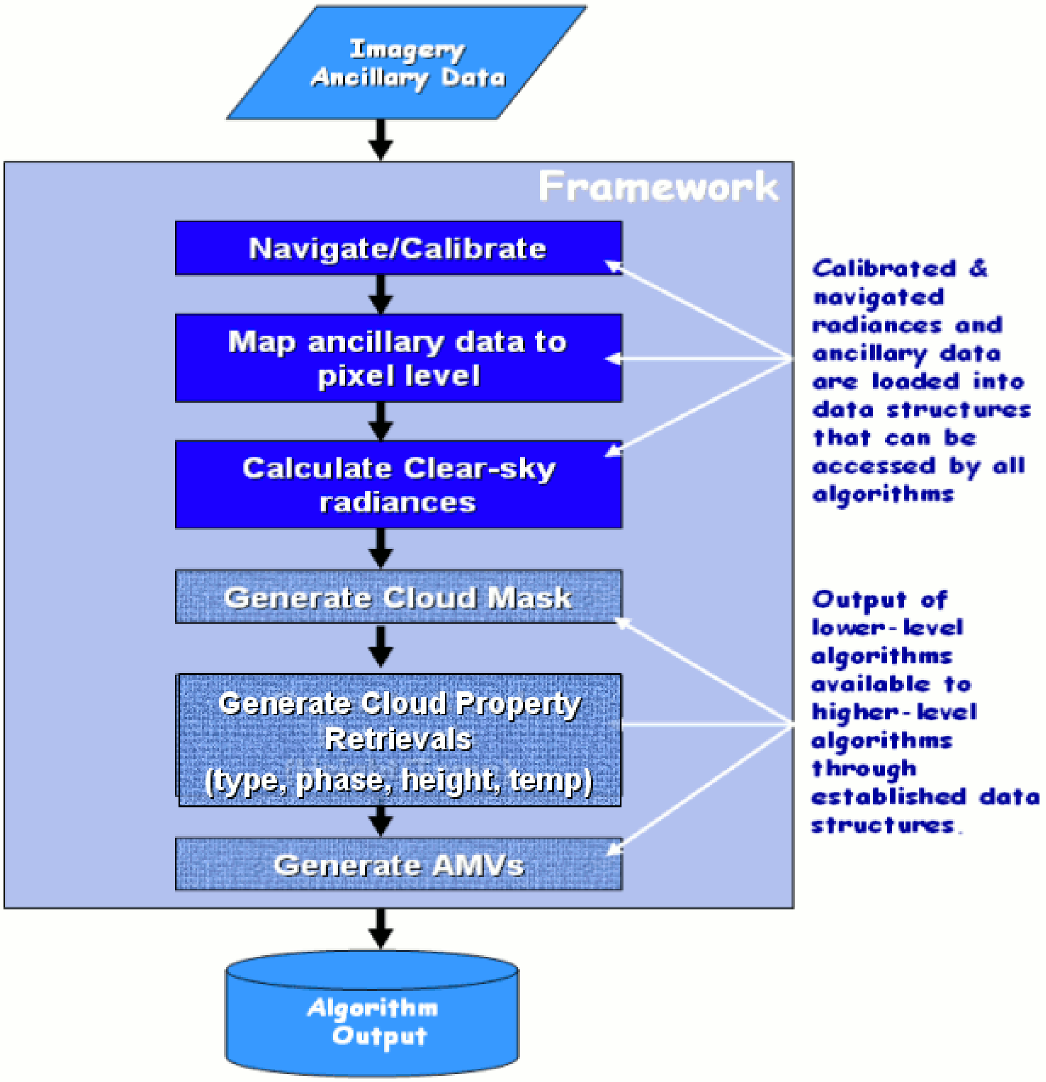

Figure 1. GOES-R Level-2 Product Processing framework has been developed to support a tiered algorithm processing approach.

The future GOES-R AMV target selection, feature tracking, and quality control algorithms (Daniels, et al, 2009) draw on the heritage algorithms used operationally today (Nieman et al, 1997) at NESDIS. The manner in which AMVs will be height assigned in the GOES-R era, however, will change dramatically from what is done operationally today. As shown in Figure 1, cloud property retrieval products that include cloud phase, cloud type, cloud-top temperature, and cloud-top height will be generated prior to the execution of the AMV algorithm. These cloud products will be generated for each ABI pixel (2km resolution at nadir) *prior to* execution of the GOES-R ABI AMV algorithm.

The GOES-R AWG cloud application team is responsible for the development of the cloud property retrieval algorithms (Heidinger, 2009; Pavolonis, 2009) which include cloud type, cloud phase, cloud-top height/pressure, cloud-top temperature, cloud optical depth, and cloud particle size distribution. The GOES-R ABI cloud type algorithm is responsible for the initial cloud type field for all ABI pixels. The current cloud type design calls for a total of 6 cloud types. In addition, the cloud phase output is divided into 4 different classifications. The cloud type categories are: warm liquid water cloud, supercooled liquid water, mixed phase, opaque ice, cirrus (e.g. semi-transparent ice clouds), and multilayered cloud. The cloud phase categories are: warm liquid water phase, supercooled water phase, mixed phase, and ice phase. The cloud phase output is consistent with heritage products such as those from Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Very High Resolution Radiometer (AVHRR). The cloud type product contains some additional information on multilayered clouds and cirrus that is useful to higher-level algorithms such as the cloud top height retrieval. The physical basis of the ACT was partially inspired by cloud type/phase algorithms developed for the AVHRR via the CLAVR-x system (NESDIS), as well as development performed for MODIS (NASA) and VIIRS (NESDIS). The AVHRR Extended (CLAVR-x) cloud type product inspired the ABI cloud type categories.

The current version of the GOES-R ABI cloud height algorithm draws on the following heritage algorithms:

- CLAVR-x split-window cloud height from NESDIS (Heidinger and Pavolonis. 2009)
- The MODIS MOD06 cloud height algorithm (Menzel, Frey, Baum & Zhang, 2006)

Since the cloud property retrieval algorithms all execute prior to the execution of the GOES-R AMV algorithm, it will have a plethora of cloud property information within each target scene available to it. This situation provides a unique opportunity to improve upon the AMV target selection and height assignment; one that the GOES-R AMV algorithm will exploit.

The current version of the GOES-R AMV height assignment algorithm uses the pixel-level cloud-top height and temperature products within each target scene (currently a 15x15 pixel scene) to arrive at a height for the AMV that is representative of the target scene being tracked. Deriving a representative height for each target from available pixel-level cloud-top information is achieved through the following approach. A 1-D histogram of the 11 um channel brightness temperature values is first constructed. The cloud-top pressures associated with the coldest 25% of the cloudy and probably cloudy pixels (as determined from pixel-level cloud mask) are then sorted so that the median cloud-top pressure can be extracted. The median pressure then serves as the representative height for the target scene.

3 PRELIMINARY RESULTS

Meteosat Second Generation (MSG) SEVIRI instrument, the current GOES-imager, and simulated ABI data are all being used as proxy datasets for GOES-R ABI AMV development, testing, and validation activities. The SEVIRI imager on MSG offers 11 ABI channels at 3km horizontal resolution with a temporal resolution of 15 minute for full disk coverage making it the best proxy data available today for our needs.

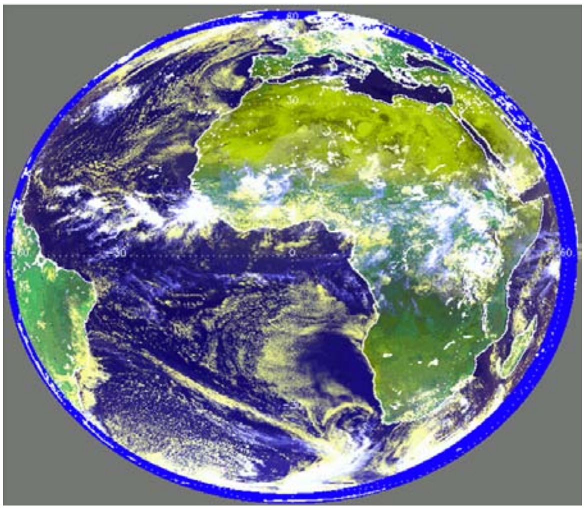

Figure 2a. False color image of Meteosat-8 SEVIRI image on 04 August 2006 at 12:15 UTC

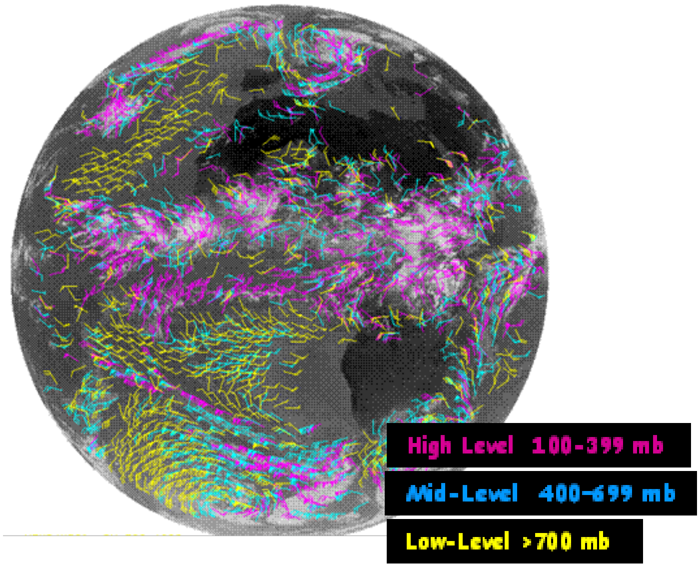

Figure 2b. Cloud-drift AMVs derived derived from a Meteosat-8 SEVIRI image triplet centered at 12:15 UTC on 04 August 2006

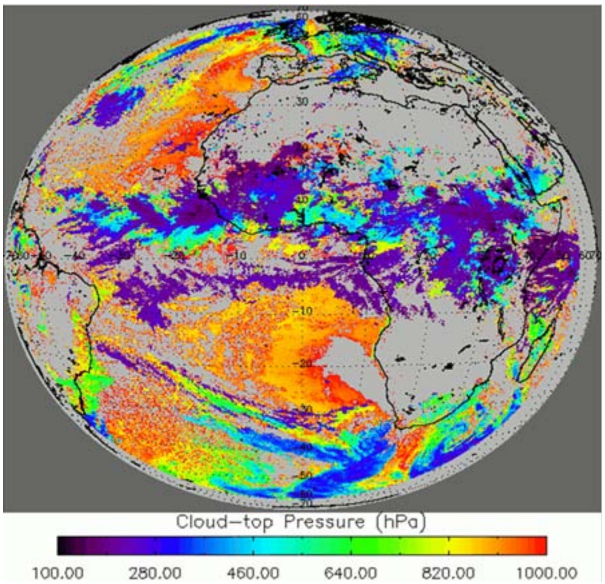

Figure 2c. Image of Meteosat-8 retrieved cloud-top pressure on 04 August 2006

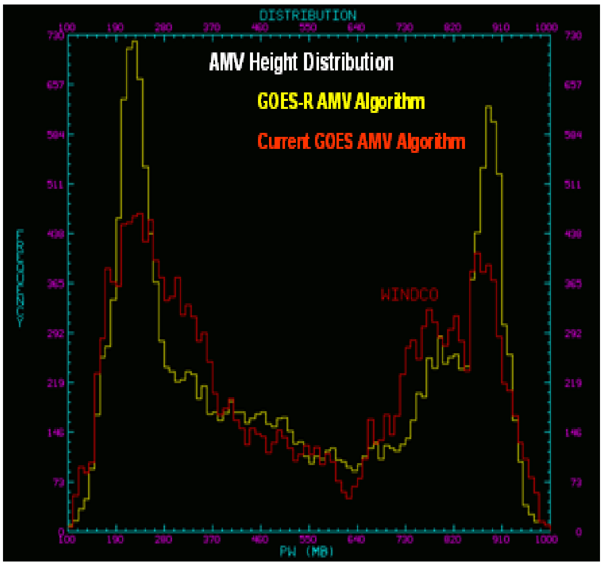

Figure 2d. Comparison of AMV height height distributions generated from the future GOES-R (yellow) and current GOES (red) height assignment algorithm algorithms on 04 August 2006 at 12:15 UTC

A comprehensive database of Meteosat-8 SEVIRI imagery, all ancillary data needed by the AMV algorithms, and validation datasets needed to validate the AMV algorithm output has been constructed. The entire full-disk Meteosat-8 SEVIRI imagery (all channels at 15 minute temporal resolution) is available for August 2006 and February 2007. The ancillary datasets needed to derive AMVs include short-term global forecasts from the National Weather Services (NWS) National Center for Environmental Prediction (NCEP) Global Forecast System (GFS), global topography, coastline mask, and a snow/ice mask, for example.

Validation datasets collected include: rawinsondes, GFS analyses, and AMVs generated from current operational NESDIS AMV algorithms.

Figures 2a shows a false-color image of Meteosat-8 SEVERI on 04 August 2006 at 1215 UTC and Figure 2b shows Cloud-drift AMVs derived from a Meteosat-8 SEVERI image triplet centered at 12:15 UTC on 04 August 2006. Figure 2c shows an image of the retrieved cloud-top pressures derived for the Meteosat-8 image shown in Figure 2a. Figure 2d, in turn, shows a shows a comparison of AMV height distributions between the new GOES-R and the current GOES AMV height assignment algorithms for the Meteosat-8 on 04 August 2006 12:15 UTC case. Both height distributions are bi-modal with the GOES-R distribution showing a sharper more defined peak at upper levels. At low levels, the GOES-R height distribution shows more heights at higher pressures. This behavior is a result of improved low cloud height assignment in regions where low-level temperature inversions exist.

All of these August 2006 and February 2007 data mentioned above have been staged and are actively being used for GOES-R AMV algorithm development and validation activities. These same datasets are also being used by the GOES-R AWG Cloud Application Team for the development and validation of the cloud mask and aforementioned cloud property algorithms. Presently, the Cloud Application Team is actively using Cloud-Aerosol Lidar and Infrared Pathfinder Satellite (CALIPSO) and CLOUDSAT data for their pre-launch cloud retrieval algorithm validation activities. CALIPSO and CLOUDSAT observations and derived cloud products are serving as a vital validation source for GOES-R cloud and AMV algorithms. Active interactions between the Wind Application and Cloud Application teams occur since the AMV target height assignment algorithm relies on using several of the pixel-level cloud products to generate representative target scene heights.

4 FUTURE PLANS

Future versions of the GOES-R AMV target selection and/or height assignment algorithms may include use of pixel-level cloud type and cloud microphysical property retrievals that are available within each AMV target scene. Exploitation of the temporal variation of this information within the timeframe spanning the image triplet will also be investigated.

More AMV validation work, particularly to better characterize the performance of the future GOES-R AMV height assignment schemes, is planned and includes some of the following:

- Capture cloud type and cloud property retrievals (and associated retrieval error estimates) associated with each derived AMV and carry it along in a comprehensive matchup database containing collocated satellite-based AMVs and reference (“truth”) wind observations (ie., radiosonde winds, GFS analysis/forecast winds)

- Compute comparison statistics, sorting on the various retrieved cloud parameters, to characterize AMV performance/quality as a function of various cloud scenes

- Collocate CALIPSO observations and cloud products to satellite-derived AMVs to understand true nature of the cloud field within the target scene being tracked. Perform individual case studies to analyze and understand the performance of the AMV height assignment algorithm.

Data assimilation impact studies using AMVs derived from Meteosat SEVIRI data using the future GOES-R AMV algorithm are also being planned. Special attention will be given to the use of cloud height retrieval uncertainties that fall out of the optimal estimation retrieval approach as a means to improve the use of the AMV products in NWP data assimilation with the goal of further improving NWP forecast skill.

5 REFERENCES

Daniels, J., W. Bresky, C. Velden, S. Wanzong, H. Berger, and I. Genkova, 2009: GOES-R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document For Derived Motion Winds.

Heidinger, A. K and M. J. Pavolonis, 2009: Gazing at clouds through a split-window for nearly 30 years. Part I: Methodology. *In press JAMC.*

Heidinger, A., 2009: GOES-R Advanced Baseline Imager (ABI) Cloud Top Height Algorithm Theoretical Basis Document

Menzel, W.P., A. Frey, B. A. Baum, and H. Zhang, "Cloud Top Properties and Cloud Phase - Algorithm Theoretical Basis Document. Products: 06-L2, 08-D3, 08-E3, 08-M3," NASA Goddard Space Flight Center, Tech. Rep. ATBD Reference Number: ATBD-MOD-05, 2006.

Nieman, S.J., W.P. Menzel, C. Hayden, D. Gray, S. Wanzong, C. Velden, and J. Daniels, 1997: Fully Automated Cloud-Drift Winds in NESDIS Operations. *Bull. Amer. Meteor. Soc.*, **78**, 1121–1133

Pavalonis, M., 2009: GOES-R Advanced Baseline Imager (ABI) Cloud Type/Phase Algorithm Theoretical Basis Document

Rodgers, C.D., 1976: Retrieval of atmospheric temperature and composition from remote measurements of thermal radiation. Rev. Geophys. Space Phys., 60, 609-624.