GOES-R Overview of Aviation Applications for Detection of Convection, Turbulence, and Volcanic Ash

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## 1. INTRODUCTION

The GOES-R Aviation Algorithm Working Group was formed in November 2006 to assess meeting aviation related requirements as defined in the GOES-R Mission Requirements Document. A suite of aviation related products are in development and are being evaluated to assess meteorological hazards to aircraft in flight derived from the current generation of European Spinning Enhanced Visible and Infrared Imager (SEVIRI) imager data. This presentation will focus on GOES-R Advanced Baseline Imager (ABI) measurement requirements relating to satellite-based aviation convective, turbulence, and volcanic ash/SO2 products with a focus on South African geographical domain for testing and validation.

## 2. CONVECTIVE OVERSHOOTING-TOPS/THERMAL COUPLETS/NOWCASTING

Overshooting top (OT) detection is the process of identifying thunderstorm cloud tops with heights above the tropopause. OTs are important indicators of storm intensity, where the most intense radar reflectivity echoes are well correlated with overshooting top signatures observed in satellite imagery. OTs are also a significant aviation turbulence hazard, as a deep layer of strong vertical motions are required to penetrate the statically stable tropopause. Horizontally and vertically propagating gravity waves are generated as the overshooting cloud tops interact with the stable tropopause region, which can produce turbulence for aviation far from the convectively-generated gravity wave source region.

Anvil thermal couplets (ATC) are present in association with the “enhanced-V” signature in IR window channel imagery. Brunner et al. describe the relationship of storms exhibiting the enhanced-V signature to severe weather such as strong winds, large hail, and tornadoes [1]. Brunner et al. show that V-producing storms with a minimum IR window OT BT $\leq$ 205 K and a downstream warm region BT $\geq$ 212 K (i.e. an ATC $\geq$ 7 K) corresponded to severe weather 92% of the time during the 2003 and 2004 convective seasons. They also describe the broad range of morphologies of the enhanced-V signature in IR imagery, where the length of V pattern “arms” and the arm angular separation can vary significantly based upon the magnitude of the environmental wind field and other unknown factors. This suggests that objective detection of the V signature itself through pattern recognition would be very difficult and prone to false alarm. As every V-pattern contains a downstream warm region, accurate detection of the ATC is much more attainable and equally relevant, as the presence and magnitude of an ATC shows a direct relationship to severe weather occurrence at the surface.

Convective nowcasting using microphysical phase discrimination and infrared cooling rate has been demonstrated using SEVIRI data over S. Africa. This presentation will highlight some of this research.

## 3. SATELLITE-BASED TURBULENCE DETECTION

Detection of tropopause folds by using 6.7 um water vapor radiance gradients has been demonstrated by Wimmers and Moody, 2003 [2,3]. The accuracy of the tropopause-folding algorithm was improved by refining the criteria for satellite signatures corresponding to upper-tropospheric turbulence. Consideration of gradient feature size, aircraft angle of approach, and distance from the tropopause fold has been included in objective turbulence interest field product. Demonstration of this product and validation results will be presented which may have implications over European mid-latitudes where tropopause folds show direct correlation with aircraft turbulence reports.

Validation of the tropospheric fold algorithm with United Airlines Eddy Diffusion Rate (EDR) objective turbulence reports over eastern United States from 01 May 2004 - 30 April 2006 was accomplished. The validation from proxy GOES-12 data yielded successful results. Results were compiled in the following cross-sectional contour plots. The algorithm achieved a probability of detection of approximately 20% for Light-or-Greater turbulence observations. The algorithm showed a smaller area of 10% detection for the much less frequent Moderate-or-Greater turbulence cases. Also, the algorithm had little skill for the very infrequent Severe-or-Greater cases. The most robust prediction of turbulence occurred in the months of December – February. The high volume of data in the EDR reports enabled a determination of aircrafts' directional sensitivity to turbulence around the jet stream.

## 4. VOLCANIC ASH/SULFUR DIOXIDE DETECTION

Potential volcanic ash pixels are identified using a tri-spectral (8.5, 11, and 12 μm) cloud optical depth based approach. The cloud optical depth based approach improves upon traditional brightness temperature difference methods by 10% or more (in terms of skill score). This general approach was modified such that the result of the ash detection algorithm is expressed as a probability as opposed to a binary yes/no. In order to accomplish this, look-up tables, based on measured radiances from the SEVIRI, were created.

The $SO_2$ detection algorithm is now able to detect $SO_2$ contaminated ice clouds by exploiting a infrared 4-channel spectral (7.3, 8.5, 11, and 12 μm) signature. Similar to the volcanic ash detection, the measurements are converted to cloud optical depth and ratios of various optical depth pairs (termed β-ratios) are used to distinguish between $SO_2$ contaminated clouds and meteorological clouds. The 7.3 and 8.5 μm channels are sensitive to $SO_2$ absorption; the 11 and 12 μm channels are not. The 8.5, 11, and 12 μm channels are sensitive to the presence of small particles, which tend to be present in $SO_2$ contaminated ice clouds. Thus, the ratio of the 7.3 μm and the 11 μm optical depth is sensitive to $SO_2$ absorption, the ratio of the 8.5 μm and the 11 μm optical depth is sensitive is both $SO_2$ absorption and particle size, and the ratio of the 12 μm and the 11 μm optical depth is sensitive to the presence of small particles. This presentation will overview improvement is detection with very low false alarm rate using SEVIRI data.

## 5. SUMMARY

The GOES-R Aviation AWG is tasked to adapt the current suite of experimental and operational aviation product algorithms, with modifications and enhancements, for the GOES-R Advanced Baseline Imager (ABI) using European SEVIRI satellite data. This presentation will overview the aviation requirements being addressed and progress toward making them GOES-R ready for an anticipated 2016 launch..

## 6. REFERENCES

List and number all bibliographical references at the end of the paper. The references can be numbered in alphabetic order or in order of appearance in the document. When referring to them in the text, type the corresponding reference number in square brackets as shown at the end of this sentence [1].

[1] Brunner, J. C., S. A. Ackerman, A. S. Bachmeier, and R. M. Rabin, 2007: A Quantitative Analysis of the Enhanced-V Feature in Relation to Severe Weather. Wea. Forecasting, 22, 853-872.

[2] Wimmers, A. J. and J. L. Moody, Tropopause folding at satellite-observed spatial gradients: 1. Verification of an empirical relationship, *Journal of Geophysical Research – Atmospheres*, 109, art. no. D19306, 2004.

[3] Wimmers, A. J. and J. L. Moody, Tropopause folding at satellite-observed spatial gradients: 2. Development of an empirical model, *Journal of Geophysical Research – Atmospheres*, 109, art. no. D19307, 2004.