P1.16

Improving Aviation Weather Diagnostics and Forecasting Using Future Generation GOES-R Data

Wayne F. Feltz*, Kristopher M. Bedka*, Michael J. Pavolonis#, Christopher S. Velden*, Steven A. Ackerman*, John Mecikalski$, John J. Murray%, and David B. Johnson^

*Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin-Madison, #NOAA/NESDIS/STAR

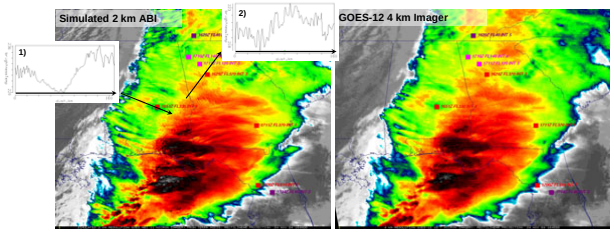
$University of Alabama in Huntsville, %NASA Langley Research Center, ^NCAR Research Applications Laboratory

Introduction

Hazardous weather conditions for the aviation industry are produced by a diverse set of atmospheric phenomena, ranging from mountain wave induced turbulence, volcanic ash detection, and newly developing to mature convective storms. Each category of these aviation hazards has unique temporal, spatial, and spectral characteristics that can be exploited to produce optimal aviation-weather diagnostics and forecasts. The suite of instruments included on the next generation GOES-R satellite will collect an unprecedented array of measurements of the Earth's atmosphere, which can be combined to improve aviation safety and efficiency. Higher temporal and spatial resolution measurements by the GOES-R ABI can be used to better monitor and forecast rapidly evolving phenomena such as convective storms and their associated mesoscale flows. Higher spectral resolution measurements from a hyperspectral instrument could be used to observe and characterize the structure of turbulent mountain and convectively-induced gravity waves as well as the composition of volcanic ash plumes. The focus of this presentation is to demonstrate the potential capability of the GOES-R ABI and a future hyperspectral sounding instrument (the high-spectral HES instrument will not be an operational instrument on the GOES-R series) for improved monitoring of hazardous aviation weather. This will be done through the use of current generation aircraft-based, geostationary, and polar-orbiting instrumentation that have similar characteristics and capabilities to instruments proposed to fly on GOES-R. This research has been conducted as part of the Advanced Satellite Aviation-weather Product (ASAP) and Satellite-based Nowcasting and Aviation Applications Program (SNAAP) at UW-CIMSS, which is focused on using current and future generation satellite instrumentation to study and better understand hazardous aviation weather phenomena.

Turbulence

Convectively-Generated Gravity Waves



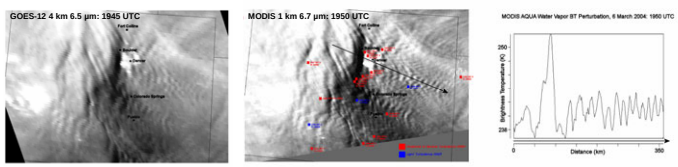
• Wave structures with several different orientations and wavelengths were generated by severe convection on 24 November 2004. 2 km GOES-R ABI 11 µm imagery is simulated using 1 km MODIS imagery at 1640 UTC.

• 4 km GOES-12 imagery at 1645 UTC is shown to demonstrate that these highly detailed wave features associated with aircraft turbulence cannot be seen with current generation satellite instrumentation.

• Wave features highlighted by transects 1 and 2 have differing orientations and wavelengths, but both were responsible for producing light to moderate turbulence.

• The GOES-12 4 km IR imagery does not capture either set of waves discussed above. Thus, higher spatial resolution imagery from GOES-R ABI will provide improved recognition of turbulent convectively-generated wave features.

Clear Air Turbulence from Mountain Waves



• Uhlenbrock et al. (2006) describes a technique for nowcasting mountain wave turbulence using MODIS water vapor (6.7 µm) imagery over the Front Range of Colorado.

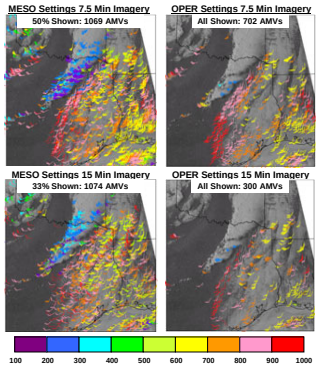
• Approximately 75% of the severely turbulent days during 2004, as indicated by pilot reports, had wave signatures in the water vapor imagery. The wave signatures on the severely turbulent days had different characteristics in the imagery than the signatures on days that were less turbulent.

• Waves are present in both GOES and MODIS in the imagery above, but the higher spatial resolution MODIS imagery better captures the complex "herringbone"-type interference patterns, which are shown in the Uhlenbrock study to be highly correlated with a greater number of turbulence reports. The transect shows that the waves in the lee on this day have a horizontal wavelength of ~15 km and induce a ~4 K T_B fluctuation.

• With GOES-R ABI, we will better observe the spatial and temporal characteristics of mountain waves in water vapor imagery, which will improve clear-air turbulence diagnostics and forecasts.

Satellite Winds

High-Density Mesoscale Satellite Winds



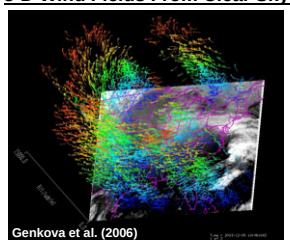
• The UW-CIMSS satellite wind were processed using two differing techniques, 1) Operational (OPER) settings (right, Velden et al. 1997) and 2) Experimental settings designed to capture detailed mesoscale (MESO) flow patterns (left, Bedka and Mecikalski 2005).

• Unique aspects of MESO processing include smaller wind targeting boxes, full-tropospheric VIS wind tracking, and a reduced dependence on a NWP model-based background wind analysis.

• As the time resolution between increases, greater mesoscale flow information is captured by both the OPER and MESO winds.

• GOES-R ABI will collect data every 5 mins with increased spatial resolution and could capture higher density mesoscale wind flow information than the MESO examples shown here, providing important upper-air wind information for data assimilation and operational weather forecasting.

3-D Wind Fields From Clear Sky Moisture Retrievals

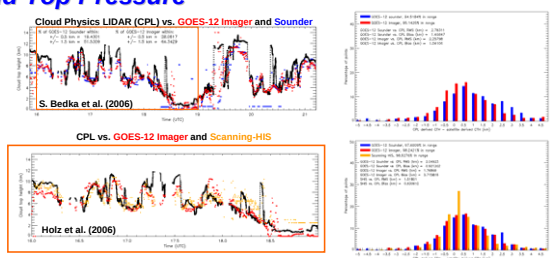


• The wind vectors shown here are computed through tracking hourly retrieved moisture fields at 10 km resolution from the GOES-12 Sounder instrument. Gradients in the retrieved moisture field can be tracked at each of the 40 retrieval levels over a 3-image sequence.

• Retrieval tracking minimizes the difficulty of vector height assignment, as retrievals are performed at discrete levels in the atmosphere. This contrasts with height assignment of Imager-based wind vectors, where cloud top and water vapor radiances are given heights using techniques such as IR window or CO_2 slicing, which are shown to exhibit errors proportional to those shown below.

• A hyperspectral sounding instrument could provide an unprecedented amount of atmospheric motion information, as 1) narrow hyperspectral weighting functions allow for more accurate moisture retrievals at a greater number of atmospheric levels and 2) higher temporal and spatial resolution allows for better tracking of coherent moisture features.

Cloud Top Pressure

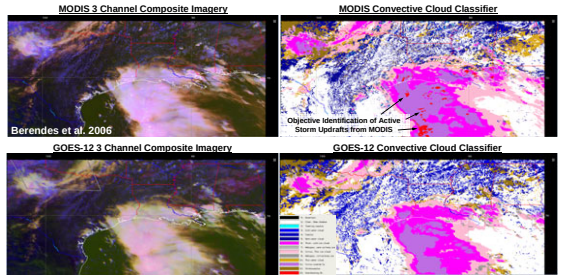


• The figures above compare single field of view cloud-top heights (CTH) from the GOES-12 Imager and Sounder, airborne Scanning High Resolution Interferometer Sounder (S-HIS), and the airborne Cloud Physics Lidar (CPL) during the Atlantic-THORPEX Regional Campaign (ATReC).

• The top panels show that the trend in CTH estimated by the CPL and both the GOES-12 Imager and Sounder are similar. However, the Sounder appears to consistently underestimate the cloud height with respect to the CPL, while the Imager, with its improved spatial resolution, captures some of the smaller features that are missed by the Sounder.

• The bottom panels demonstrate the improvement in CTH estimates that could be provided by a hyperspectral sounding instrument. These plots show that the S-HIS heights exhibit better agreement with the CPL, with S-HIS having the lowest RMS difference and bias. While further studies are necessary to fully assess the accuracy of these methods, these preliminary results show great promise for the use of hyperspectral technology in estimating cloud-top heights.

Convection



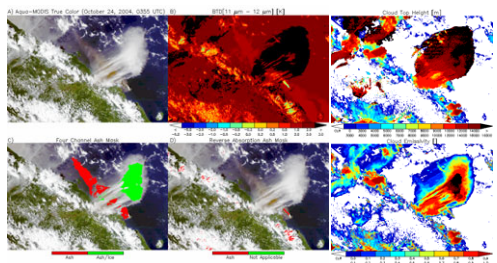
• A daytime unsupervised convective cloud classifier has been developed using GOES-12 (left) and MODIS (right) multispectral VIS and IR imagery. This product can be used to objectively recognize potential areas of convectively induced turbulence associated with convective outflow and storm updrafts, as well as to identify newly developing convective storms.

• The GOES-12 classifier is a 1 km resolution product that uses 1 km VIS reflectance and texture information, and 4 channel 4-8 km IR radiances and band differences as inputs.

• In addition to the GOES information above, the MODIS classifier uses reflectance and texture from three VIS channels (.4, .5, and .6 µm), and cloud-top microphysical information from 1.6 µm reflectance, 8.5 µm radiances, and the 8.5-11 µm channel difference to also produce a 1 km convective cloud classification.

• The increased IR resolution and cloud-top microphysical information from MODIS allows identification of overshooting convective cloud tops associated with the strongest thunderstorm updrafts, as well as a better depiction of cirrus covered convection. Comparable resolution and multispectral information will be available with GOES-R ABI, which will allow us to better objectively recognize regions with a higher likelihood for convectively-induced turbulence.

Volcanic Ash Detection



• The spatial resolution and spectral channels of the GOES-R ABI will allow for better ash vs. meteorological cloud discrimination.

• A hyperspectral sounding instrument could help identify the presence of volcanic gases such as SO_2.

• The ABI should improve estimation of ash cloud height and emissivity.

References

Bedka, K. M., and J. R. Mecikalski, 2005: Application of satellite-derived atmospheric motion vectors for estimating mesoscale flows. *J. Appl. Meteor.*, 44, 1761-1772.

Bedka, K. M., W. F. Feltz, J. R. Mecikalski, R. A. Petersen, and C. S. Velden, 2006: Statistical relationships between satellite-derived mesoscale atmospheric motion vector, rawinsonde, and NOAA Wind Profiler network observations. 12th Conf. on Aviation, Range, and Aerospace Meteorology, 29 Jan–2 Feb 2006, Atlanta, GA.

Bedka, S. T., W. F. Feltz, A. J. Schreiner and R. E. Holz., 2005: Satellite derived cloud top pressure product validation using aircraft based cloud physics lidar data from the AIREC field campaign. *International Journal of Remote Sensing*, In Press.

Berendes, T. A., J. R. Mecikalski, U. S. Nair, and K. M. Bedka, 2006: Convective cloud detection in satellite imagery using standard deviation limited adaptive clustering. In preparation for *J. Appl. Meteor.*

Genkova, I., C. S. Velden, and S. Wanzong, 2006: Satellite wind vectors from GOES Sounder moisture fields. Proc. of the 8th Intl. Winds Workshop, 24-28 April 2006, Bejing, China.

Holz, R.E., S. Ackerman, P. Antonelli, F. Nagle, M. McGill, D.L. Hlavka, and W. D. Hart, 2006: An improvement to the high spectral resolution CO2 slicing cloud top altitude retrieval, *J. Atmos. Ocean. Tech.*, *23*, 653-670.

Mecikalski, J. R., J. J. Murray, W. F. Feltz, D. B. Johnson, K. M. Bedka, S. M. Bedka, others, 2006: The Advanced Satellite Aviation Weather Products (ASAP) initiative: Phase I efforts to improve aviation safety using satellite remote sensing. Submitted to *Bull Amer. Meteor. Soc.*

Pavolonis, M.J., W.F. Feltz, A.K. Heidinger, and G.M. Gallina, 2006: A daytime compliment to the reverse absorption technique for improved automated detection of volcanic ash. *J. Tech.*, In press.

Uhlenbrock, N. L., K. M. Bedka, W. F. Feltz, and S. A. Ackerman, 2006: Mountain waves in MODIS water vapor imagery: Mountain wave signatures in MODIS 6.7 µm imagery and their relation to pilot reports of turbulence. In press.

Velden, C. S., C. M. Hayden, S. J. Nieman, W. P. Menzel, S. Wanzong, J. S. Goerss, 1997: Upper-tropospheric winds derived from geostationary satellite water vapor observations. *Bull. Amer. Meteor. Soc.*, 78, 173-195.

Acknowledgements: This research was supported by the NASA LaRC Subcontract #4400071484 and NOAA Grant #NA07EC0676.

More information about this research can be found at http://cimss.ssec.wisc.edu/asap/ or wayne.feltz@ssec.wisc.edu