



Satellite-derived Mountain Wave Turbulence Interest Field Detection



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Project Description

Mountain, or lee waves are caused when air flows over mountain ridges within a stably stratified atmosphere. Mountain waves can be an aviation hazard because of their strong updrafts and downdrafts which may force aircraft out of their assigned altitudes, and may also generate severe turbulence in regions of wave breaking. MODIS water vapor brightness temperature imagery has indicated the presence of wave structures over and downwind of mountain ranges. Research has been conducted to categorize the wave structure by using frequency of pilot turbulence reports, often occurring within cloud-free atmosphere. In the cases we examined, the reports of severe turbulence were associated with complex interfering wave patterns that extended downwind from the mountain ridge for a significant distance. The events that were less turbulent, as reported by pilots, had wave signatures with simpler patterns such as linear features orthogonal to the wind flow oriented parallel to one another. Synthetic MODIS 6.7 um water vapor imagery was derived from Weather Research and Forecasting (WRF) model thermodynamic fields to examine the NWP-simulated satellite imagery fidelity versus MODIS water vapor imagery. This poster presents wave structure classification results from the water vapor imagery, comparisons to NWP simulated water vapor imagery, and objective quantification techniques for detecting wave structures in the water vapor imagery coincident with observations of mountain wave turbulence.

Data and Methodology

Uhlenbrock et al 2007 indicated 6.7 um MODIS water vapor interference or crossing wave patterns which were more likely to contain moderate or severe pilot reports of turbulence while other simpler linear features orthogonal to the wind patterns indicated little or no pilot reports of turbulence.

Uhlenbrock, N. L., K. M. Bedka, W. F. Feltz, and S. A. Ackerman, 2007: Mountain Wave Signatures in MODIS 6.7 um Imagery and Their Relation to Pilot Reports of Turbulence. *Wea. Forecasting*, 22, 662-670.

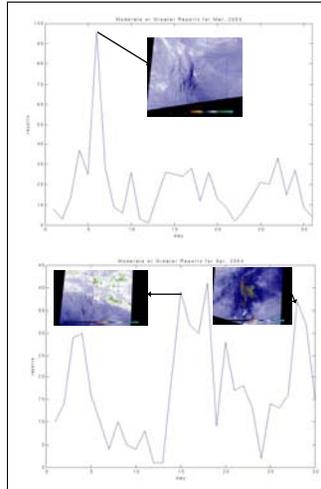


Figure 1. Number of moderate or greater turbulence reports for March (top) and April (bottom) 2004 with water vapor images for selected days.

The wave patterns seen in the imagery were correlated with pilot reports of turbulence. Approximately 90% of the severely turbulent days had wave signatures in the water vapor imagery. The wave signatures on these turbulent days exhibited complex wave patterns with apparent interference and crossing wave fronts that extended downwind from the mountains for a significant distance. Figure 1 shows an example of this analysis. The days that were less turbulent showed wave signatures that were simpler, patterns that were linear in orientation and shape.

Pilot reports (PIREPS) were analyzed to show the number of turbulence occurrences and intensities for each day to identify the most turbulent days. Those days were then compared to the satellite imagery to look for correlation with the wave signatures. Figure 1 shows examples of this analysis.

Wave patterns were correlated with the PIREP reports of turbulence. Figure 2 shows MODIS scans over Colorado that correspond to days that were very turbulent. Wave signatures are clearly present, and appear to be complex in nature.

Often when wave signatures were present in the water vapor channel, they were not present in the visible or infrared window channels. Figure 2 shows three MODIS 6.7 water vapor and visible IR case studies in demonstrating the lack of evidence of the mountain waves as seen within visible imagery.

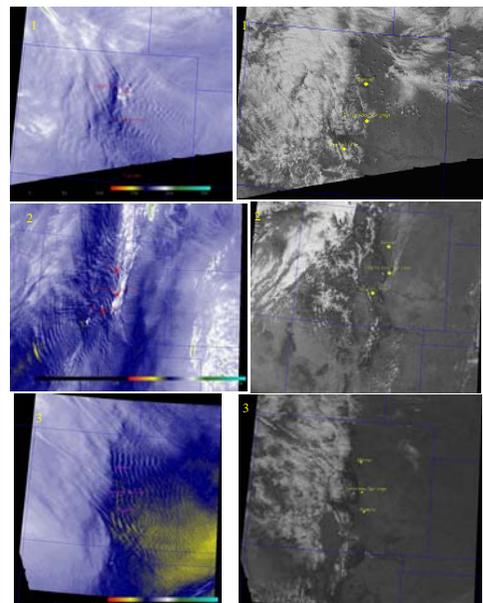


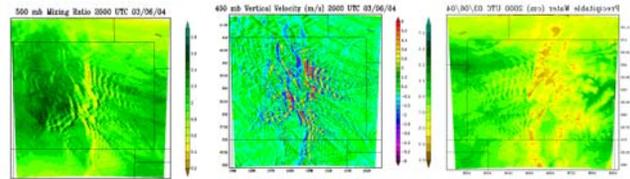
Figure 2. Aqua MODIS channel 27 (6.7 um water vapor) and channel 1 (visible) at 1) 06 March at 1950Z, 2) 05 May at 1800Z, and 3) 30 December at 1930Z. All images are from 2004 and over Colorado, U.S.

06 March 2004 WRF-ARW Turbulence Simulation

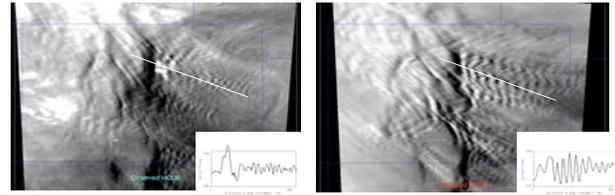
To better understand the 6.7 um water vapor wave pattern development, the WRF model was used to provide a 1-km spatial resolution and 30-min temporal resolution temperature and water vapor structure on 06 March 2004 case study. The 6 March 2004 case study was selected because it exceeded the mean number of daily 2004 pilot turbulence reports by over six standard deviations. Simulated atmospheric fields were generated using version 2.2 of the WRF model (ARW core). The simulation was initialized at 00 UTC on 06 March 2004 with 1° GFS data and then run for 24 hours. The simulation contains 2 domains with 5-km and 1-km horizontal grid spacing, respectively. The simulation employed the following parameterization schemes:

- * Thompson microphysics
- * Eta planetary boundary layer
- * RRTM/Dudhia radiation
- * Noah land-surface model
- * Explicit convection (i.e. no cumulus parameterization)

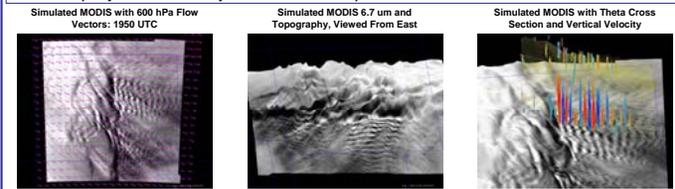
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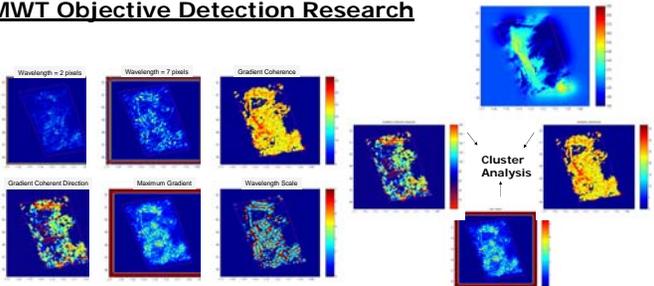
Wave structure apparent in total precipitable water field indicative of high amplitude wave persistence and organization



- * Combination of simulated satellite imagery and 3-D NWP information allows us to gain a better understanding of patterns observed in real-time imagery. WRF simulation indicated complex wave interference pattern caused by interaction between cold front and mountain wave train.
- * Simulation allows synthetic GOES-R Advanced Baseline Imager radiance calculation to provide insight into what future water vapor imagery will look like with improved ABI horizontal and temporal resolution
- * Provides a proxy data set to test objective detection techniques described below



MWT Objective Detection Research



Pattern recognition techniques are being investigated to objectively isolate destructive wave interference patterns, including wave length, orientation, coherence, and gradient. Since mountain wave turbulence is directly connected to orography and wind field, the detection methodology only needs to execute over limited geographical areas. The end product would be a satellite-based pattern recognition methodology resulting in an interest field of mountain wave turbulence location.

Conclusions

- Uhlenbrock et al. 2007 indicated that unique interference patterns occur within MODIS 6.7 um water vapor imagery which are highly correlated to numerous pilot reports of turbulence
- Since MODIS provides only single time step image at high horizontal resolution, a 1-km horizontal WRF simulation was performed to address need for ABI-like data set and to understand pattern origin
- Using both MODIS and WRF synthetic data, an objective wave pattern detection approach is being investigated. Plans for MSG SEVIRI and AIRS/IASI/CrIS data set investigations are also being developed.

Acknowledgments: This work was funded by the NASA Applied Sciences Program through the NASA Advanced Satellite Aviation-weather Products (ASAP) project.

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