Analysis and Applications of Water Vapor-derived Multispectral Composites for Geostationary Satellites

Gary Jedlovec[1], Emily Berndt[1], Kevin Fuell[2], Frank J. LaFontaine[3], and Nicholas Elmer[2]

[1]Earth Science Branch, NASA / Marshall Space Flight Center, [2]Earth System Science Center, University of Alabama - Huntsville, [3]Raytheon, Huntsville, Alabama

Introduction/Focus

Analysis of multispectral (red-green-blue, RGB) satellite image composites can be used to improve understanding of thermodynamic and / or dynamic features associated with the development of significant weather events (cyclones, hurricanes, intense convection, turbulence, etc.). These composites minimize the need for a more time consuming analysis of multiple images and can provide additional insight not available from a single channel. The enhanced water vapor imaging capabilities of the Advanced Baseline Imager on GOES-16,-17 satellites provide a unique opportunity to demonstrate this capability through a comparison of the Air Mass and Differential Water Vapor RGB image products for several case studies.

Multispectral Image Composites

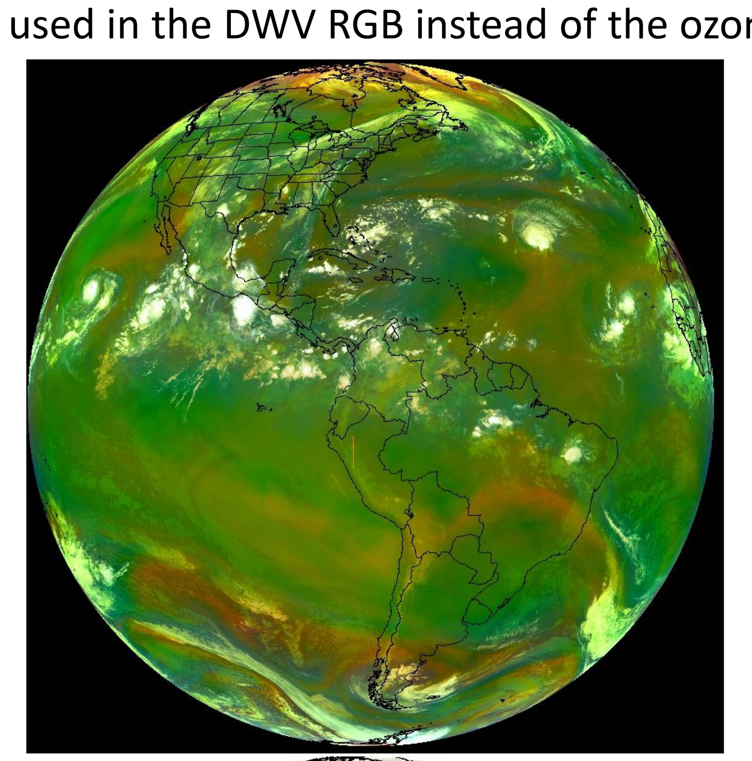
The Air Mass (AM) RGB, developed by the European Organization for Meteorological Satellites, composite product is often used to evaluate temperature and moisture characteristics of the environment surrounding developing synoptic weather systems by combining water vapor, ozone, and infrared window channel measurements into a single composite image. The channel formulation of this product is presented in the table below. Primarily warm, tropical air masses will appear green and cold polar air masses are blue. Dominance of green colors in the images indicate regions with a relatively high tropopause with low total ozone content, indicative of warm, moist tropical air masses. These tropical air masses can appear more olive in color with decreasing moisture content typical of large scale subsidence zones. More dominance of red / orange can indicate decreasing upper level moisture and warm dry ozone-rich descending stratospheric air associated with jet streams and potential vorticity anomalies. An increased absorption path length with off-nadir viewing can drastically change the colors and therefore the interpretation of this product. Therefore all images have been limb corrected for this effect.

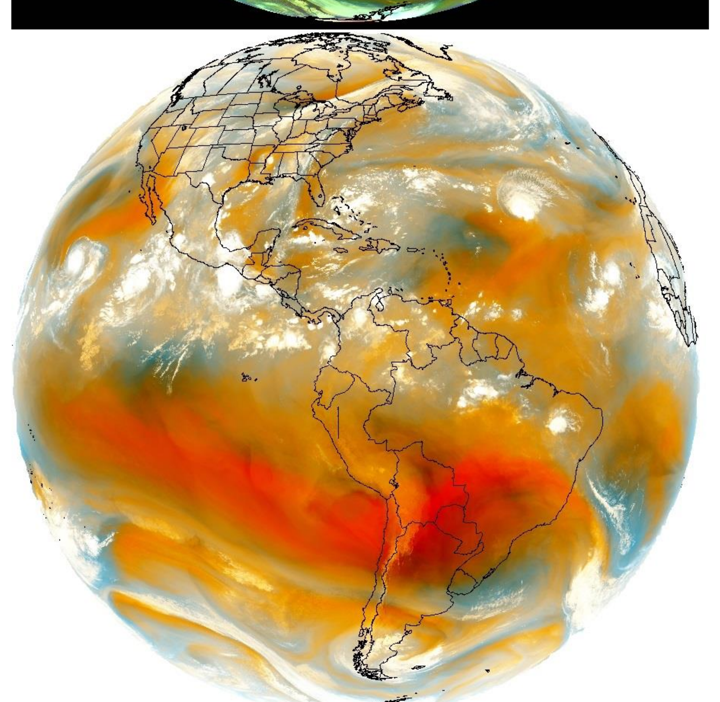
The Differential Water Vapor (DWV) RGB, developed by Japan Meteorological Agency, is used to understand variations in mid-upper level water vapor, horizontal moisture boundaries, trough / ridge patterns, and for assistance in predicting changes in hurricane intensity. The composite uses the same two water vapor channels as in the AM RGB but in a slightly different way to differentiate the vertical changes in moisture (see table below). Red / orange colors indicate dry upper levels with the lighter orange color indicating increasing levels of low and mid-level moisture. Dark blue colors indicate regions of upper-level moisture with a dry layer below, and light blue / grey colors a deeper layer of mid- and upper-level moisture.

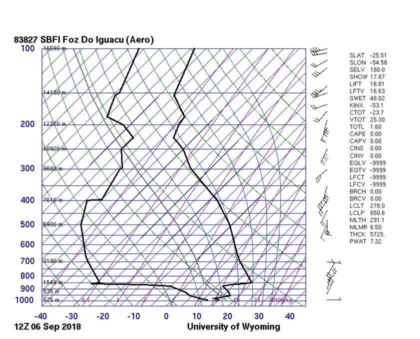
Note that the formulation of these two RGB products is not that different. They both use the same water vapor channels in a channel difference formulation (red RGB channel) and the 6.2um band for the blue RGB channel. The mid-tropospheric water vapor band (7.3um) is used in the DWV RGB instead of the ozone / infrared window band difference (9.6 – 10.3um) in the AM RGB.

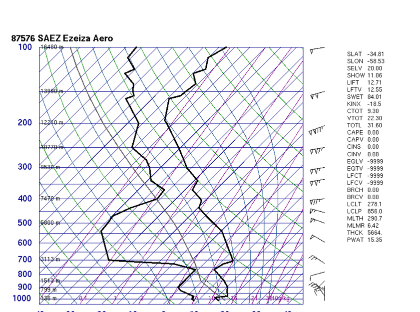
		Air Mass RGB	
Channel Color		Band/ Band Difference (um)	Temperature Range (min to max, C); gamma
Red		6.2 – 7.3	-26.2 to 0.6; 1.0
Green		9.6 – 10.3	-43.2 to 6.7; 1.01.0
Blue		6.2 (inverted)	-29.2 to (-64.6); 1.0

		Differential Water Vapor RGB	
Channel Color		Band/ Band Difference (um)	Temperature Range (min to max, C); gamma
Red		7.3 – 6.2	30.0 to 3.0; 0.26
Green		7.3 (inverted)	5.0 to -60; 0.40
Blue		6.2 (inverted)	-29.2 to (-64.6); 0.40







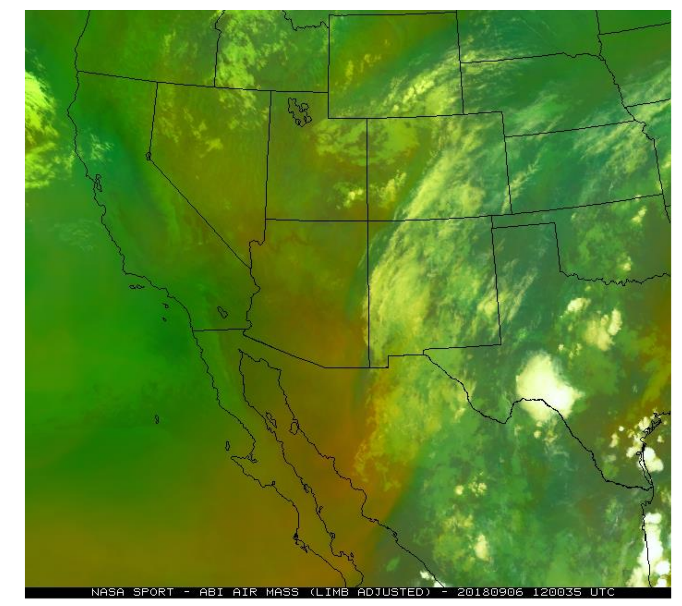


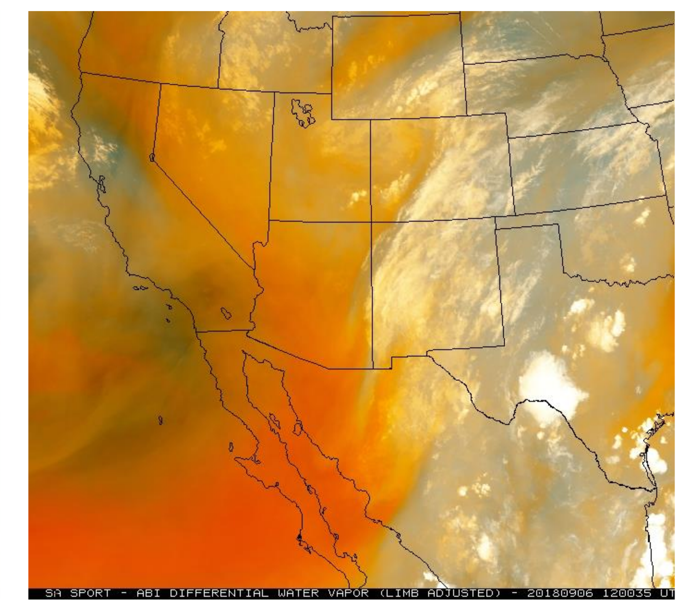
9/6/2018 Global

The AM and DWV full disk RGB image products for 6 September 2018 @ 1200UTC can be used to illustrate some of these capabilities. Dense cloud cover appears as white in each composite and associated circulation systems can be inferred from the changing colors in each RGB. A dominant feature in the southern hemisphere is the low pressure system over the tip of South America. The dark green (olive) region in the AM composite over Argentina, Uruguay, and Paraguay suggests a large region of tropical subsiding air with little moisture aloft. The DWV composite shows an red / blue couplet over this region inferring a large dry region consistent with the AM composite but with and influx of upper level moisture (blue) over Uruguay and the adjacent ocean region. This inference is substantiated by radiosonde profiles over SBFI (Paraguay) and SAEZ (Uruguay) points A and B in the images respectively. It is clear that the AM composite alone may not be sufficient to detect this increase in upper level moisture.

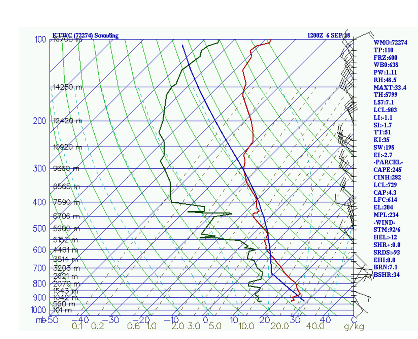
9/6/2018 Regional - NH

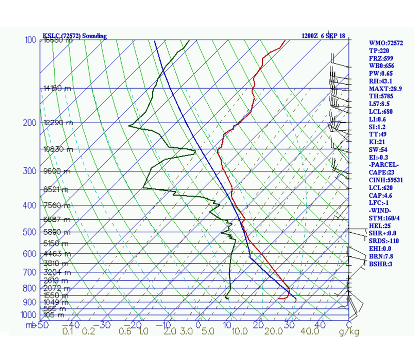
A greater understanding of variations in water vapor highlighted by the composite RGB images for September 6, 2018 in the Northern Hemisphere can be obtained by examining data over the western portion of the United States. Looking at the AM RGB, the large area of green in the cloudless region over southern California and the adjacent ocean region indicates a warm tropical air mass. The color change reflecting more orange tones over Baja, western Mexico, and southern Arizona indicate a decrease in upper-level moisture.





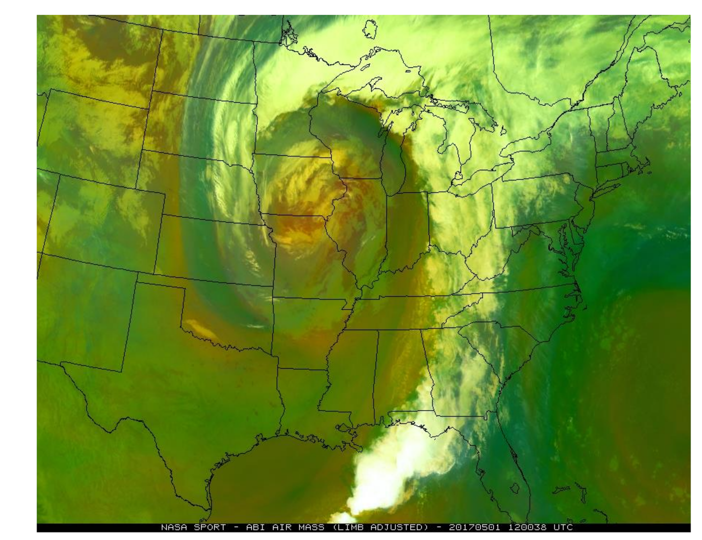
The DWV RGB shows similar large scale water vapor features but with subtle differences. The large warm, moist tropical air mass in the AM RGB is represented by the orange and blue colors in the DWV image, the blue indicating upper level moisture over a thick dry layer. This information about the underlying dry air cannot be inferred from the AM RGB. The deep orange-red color of the Baja peninsula indicates a deep layer of dryness in the mid- and upper-troposphere. Lighter orange colors over Arizona imply increasing mid-tropospheric moisture as seen in the Tucson, Arizona radiosonde for the same time and the increase olive and orange tones in the AM RGB correlate with decreasing moisture. Over Utah, the AM RGB indicates smaller-scale horizontal variations in moisture with likely low and mid-level cloud contamination (likely coming from the window channel imagery used in the composite). The DWV RGB indicates light orange, blue, and gray tones in this region indicating increasing mid- and upper-level water vapor content as confirmed with the Salt Lake City, Utah, sounding. The water vapor channels used in this product do not see the lowest layers of the atmosphere and are not affected by the clouds (now known to be low level) present in the AM RGB product.

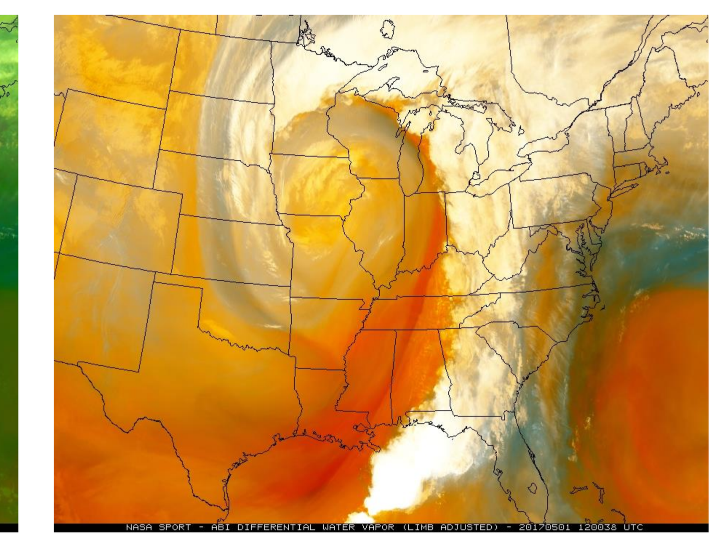


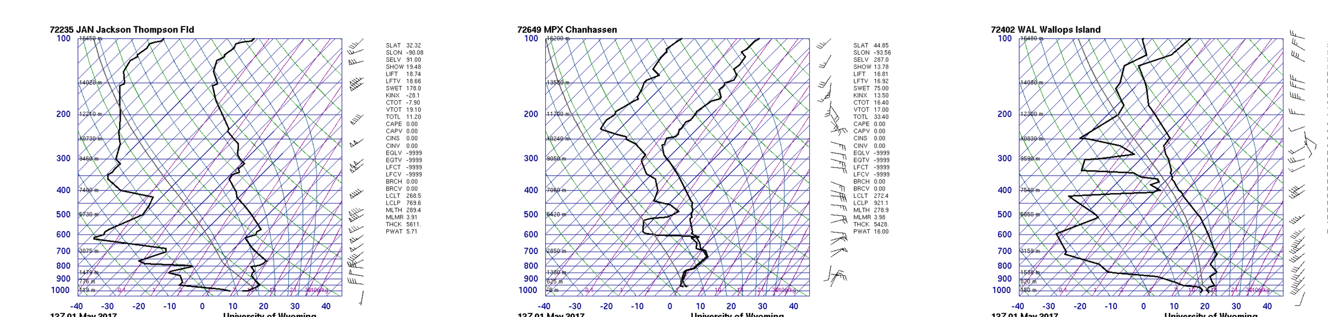


5/1/2018 Regional - NH

A comparison of the AM and DWV RGB composite products for a more dynamic situation is presented in the imagery for May 1, 2018 (below). Examining the prominent region of dry air in the dry slot near point x, the orange and olive tones indicate dry upper-level conditions. In this same region, deep orange tones in the DWV RGB indicate a deep layer of dry air, which is confirmed in the associated Jackson, Mississippi radiosonde at 1200 UTC. In this case the AM RGB is used to identify the presence and horizontal extent of the dry air, but the DWV RGB indicates the atmospheric column is dry. Identification of the extent and depth of the dry air is important for understanding the role of stratospheric air in cyclogenesis and associated hazards where high momentum dry air mixes to the surface to create high impact winds.







Another area of interest is north of the cyclone center near Wisconsin and Minnesota. Greener tones in the AM RGB are interpreted as regions with more moisture than in the orange or olive regions. This same region is represented by a gray color in the DWV RGB. The associated radiosonde at Chanhassen, Minnesota confirms a moderate amount of moisture in the mid- to upper-levels, indicating the deep layer dry air associated with the dry slot is not influencing this region yet. As the amount of moisture increases in the atmospheric column, the AM RGB colors become more green while the DWV RGB colors become more gray. The blue tones in the DWV RGB, such as those near point Z indicate moist upper-levels with dry air present underneath. The advantage of the DWV RGB is the identification of these regions where dry air is present below the moist-upper levels. The radiosonde at Wallops Island, Virginia confirms these conditions, knowing the thermodynamic conditions ahead of an approaching cold front are important for anticipating severe weather or precipitation type.

Summary

The use of RGB composite imagery highlights three-dimensional differences in the temperature and moisture structure associated with synoptic weather systems that may otherwise go unnoticed because of the complexity of manually evaluating many individual channels of data. While the air mass RGB composite alone highlights variations in tropopause height and upper-level water vapor variability, the differential water vapor RGB seems to highlight additional vertical variability in mid- and upper-tropospheric water vapor structure which may not be apparent in the air mass RGB imagery.

References

Elmer, N. J., E. Berndt, G. Jedlovec, and K. Fuell, 2019: Limb correction of geostationary infrared imagery in clear and cloudy regions to improve interpretation of RGB composites for real-time applications. J. Atmos. Ocean. Technol. (In review).

EUMETSAT User Services, 2009: Best practices for RGB compositing of multi-spectral imagery. Darmstadt, 8 pp. [http://oiswww.eumetsat.int/~idds/html/doc/best_practices.pdf].

Shimizu, A. and Y. Ioka, 2017: Newly proposed RGBs by Himawari-8 and some case studies. WMO RGB Experts and Developers Workshop, [http://www.wmo.int/pages/prog/sat/meetings/RGB-WS-2017.php]

Quick Guides for RGBs

https://nasasporttraining.wordpress.com/quick-guides/