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

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Introduction

- 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.).
- 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 (AM) and Differential Water Vapor (DWV) RGB image products for several case studies.

RGB Imagery

Air Mass RGB:

- Developed by the European Organization for Meteorological Satellites
- Used to evaluate temperature and moisture characteristics of the environment surrounding developing synoptic weather systems

RGB Derivation

Color	Band / Band Diff. (µm)	Min – Max Gamma	Physically Relates to…	*Small input to pixel indicates…	*Large input to pixel indicates…
Red	6.2 – 7.3	-26.2 to 0.6 C 1	Vertical water vapor difference	Moist upper levels	Dry upper levels
Green	9.6 – 10.3	-43.2 to 6.7 C 1	Tropopause height based on ozone	Low trop and high ozone	High trop and low ozone
Blue	6.2 (inverted)	-29.25 to -64.65 C 1	Water vapor ~200-500 mb	Dry upper levels	Moist upper levels

Interpretation

- Jet stream; potential vorticity; dry upper levels
- Cold Air Mass
- Warm Air Mass
- Warm Air Mass, less moisture
- Limb Effects
- Warm Low-level Cloud
- Cold Low-level Cloud
- Mid-level Clouds
- Thick, high Clouds

Differential Water Vapor RGB:

- Developed by Japan Meteorological Agency
- Used to understand variations in mid-upper level water vapor, horizontal moisture boundaries, trough / ridge patterns

RGB Derivation

Color	Band / Band Diff. (µm)	Min – Max Gamma	Physically Relates to…	*Small contribution to pixel indicates…	*Large Contribution to pixel indicates…
Red	7.3 – 6.2 (inv)	30 to -3 C 0.2587	Vertical water vapor difference	Moist upper levels	Dry upper levels
Green	7.3 (inv)	5 to -60 C 0.4	Low level water vapor	Dry low levels	Moist lower levels
Blue	6.2 (inv)	-29.25 to -64.65 C 0.4	Upper level water vapor	Dry upper levels	Moist upper levels

Interpretation

- Very dry mid-upper level
- Dry mid-upper level
- Dry mid-upper level; Moist mid level; Mid level cloud
- Moderate moisture mid-upper level
- Moist upper level
- Thick, high clouds

Limb Corrected Imagery

- An increased atmospheric absorption path length with off-nadir viewing can drastically change the colors and interpretation of the product
- Limb effects create a false blue to purple in the AM RGB at high viewing angles (Fig. 1 and 2)
  - Cold, polar air is a similar color as limb effects
  - Green tropical air masses appear blue instead of green
- Limb effects create a false white, gray, and teal in the DWV RGB at high viewing angles (Fig. 3 and 4)
  - False sense of high, thick clouds
  - Dry air masses may be interpreted as moist
- Limb correction from Elmer et al. 2016, 2019 applied

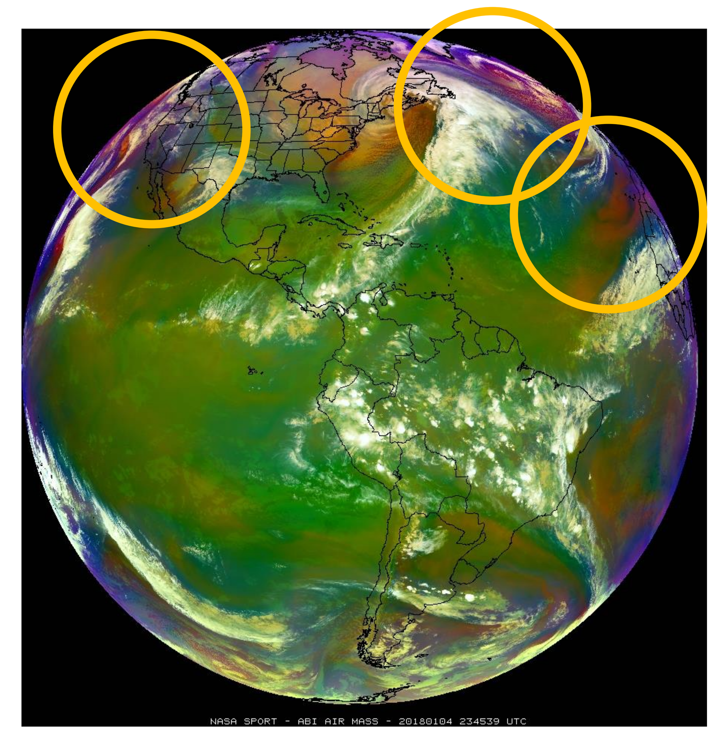

Fig. 1 Air Mass RGB 2345 UTC 04 January 2018

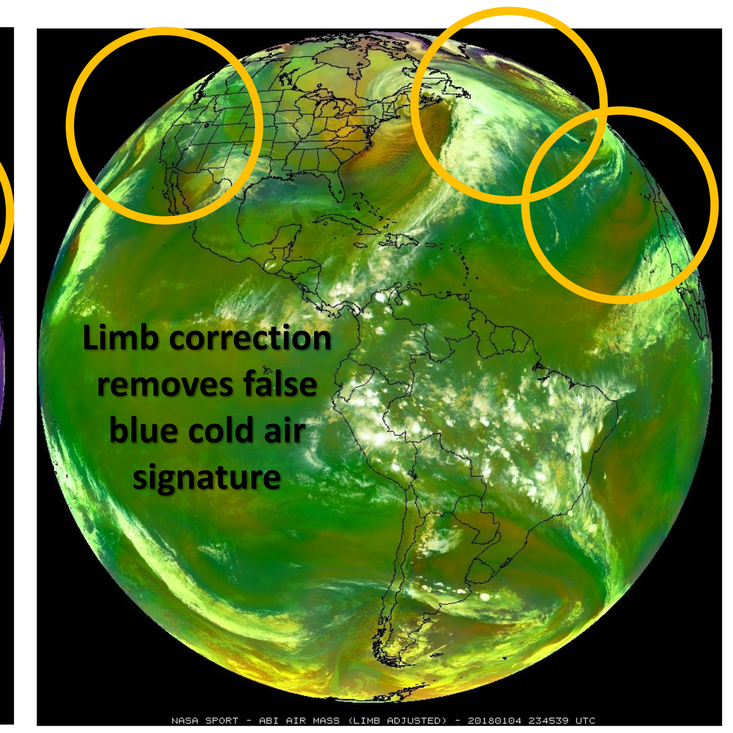

Fig. 2 Limb Corrected Air Mass RGB 2345 UTC 04 January 2018

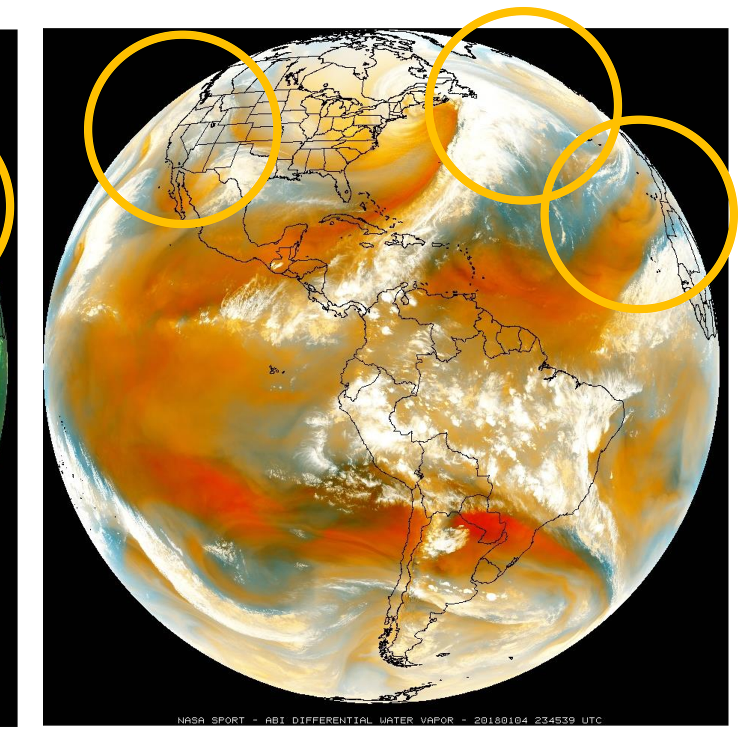

Fig. 3 Differential Water Vapor RGB 2345 UTC 04 January 2018

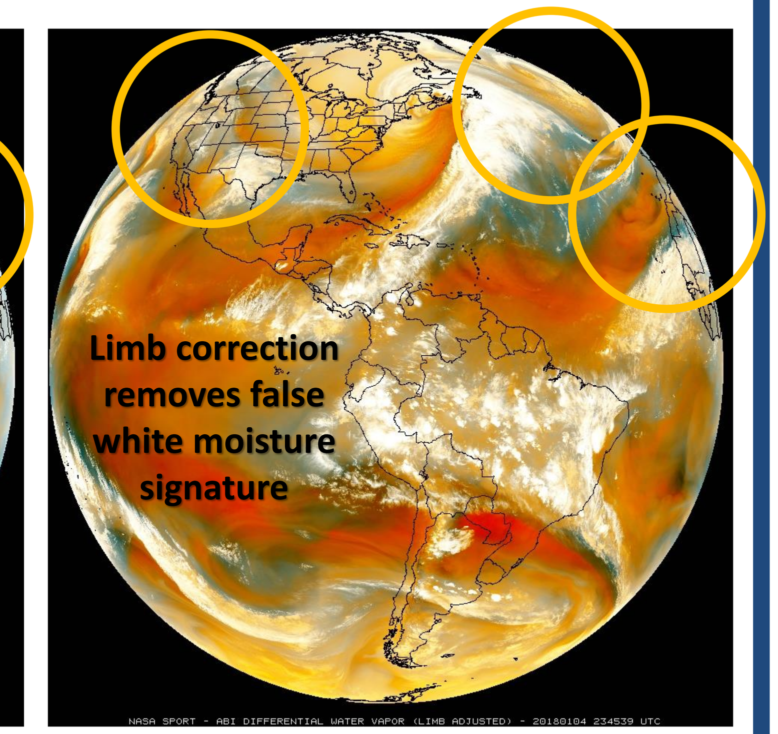

Fig. 4 Limb Corrected Differential Water Vapor RGB 2345 UTC 04 January 2018

Variations in Mid-Level Moisture

Air Mass RGB (Fig 5)

- Tucson, AZ (TWC): Warm, tropical air mass offshore and inland. More orange tones indicate a decrease in upper-level moisture within the same air mass.
- Salt Lake City, UT (SLC): Low to mid level clouds and green tones indicate more low to mid level moisture

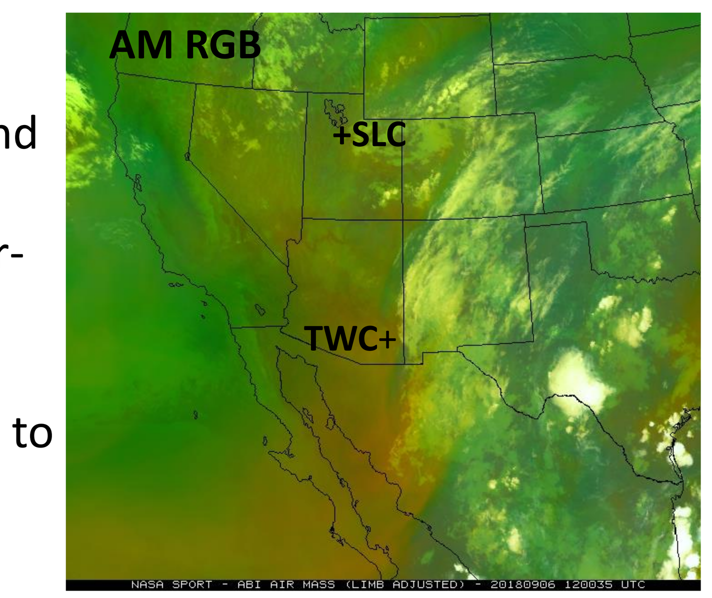

Fig. 5 Limb Corrected Air Mass RGB 1200 UTC 06 September 2018

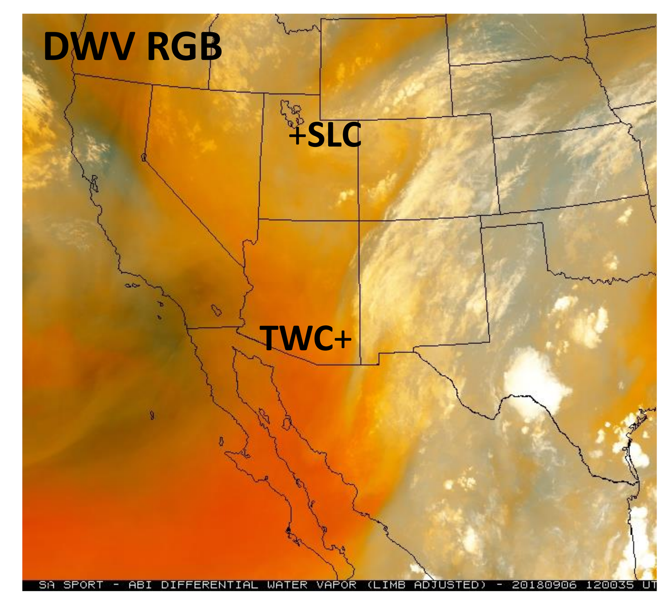

Fig. 6 Limb Corrected Differential Water Vapor RGB 1200 UTC 06 September 2018

Differential Water Vapor RGB (Fig. 6)

- Tucson, AZ (TWC): Orange and blue colors offshore indicating upper level moisture over a thick dry layer. Increasing deep layer dryness inland
- Salt Lake City, UT (SLC): lighter orange, blue, and gray tones indicate increasing mid to upper level moisture

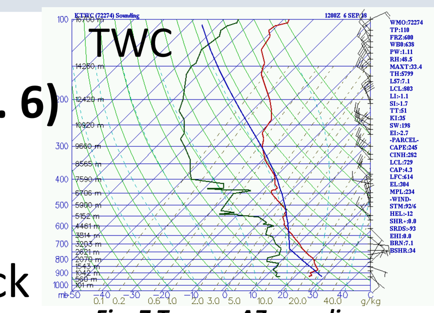

Fig. 7 Tucson, AZ sounding 1200 UTC 06 September 2018

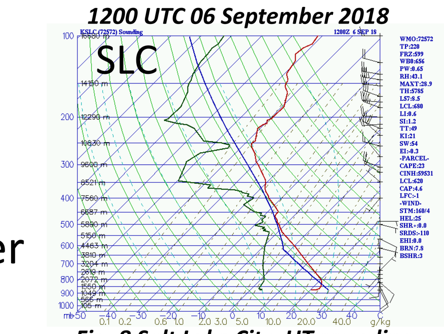

Fig. 8 Salt Lake City, UT sounding 1200 UTC 06 September 2018

- TWC radiosonde confirms the deep layer dryness indicated by the DWV RGB and decrease in moisture in the AM RGB
- SLC radiosonde confirms increasing mid- and upper level water vapor
- The AM RGB indicates the horizontal extent of the upper level dry air (olive) while the DWV RGB indicates regions with deep layer dry air (orange)
- Analyze the RGBs together to assess mid-level moist or dry layers that can impact stability of the pre-convective environment

Mid-Latitude Cyclone

Air Mass RGB (Fig. 9)

- Jackson, MS (JAN): warm, dry air in olive and orange tones representative of the dry slot
- Chanhassen, MN (MPX): increase in upper level moisture in green tones where the dry slot is not influencing the region
- Wallops Is, VA (WAL): warm, moist air offshore head of the advancing cold front

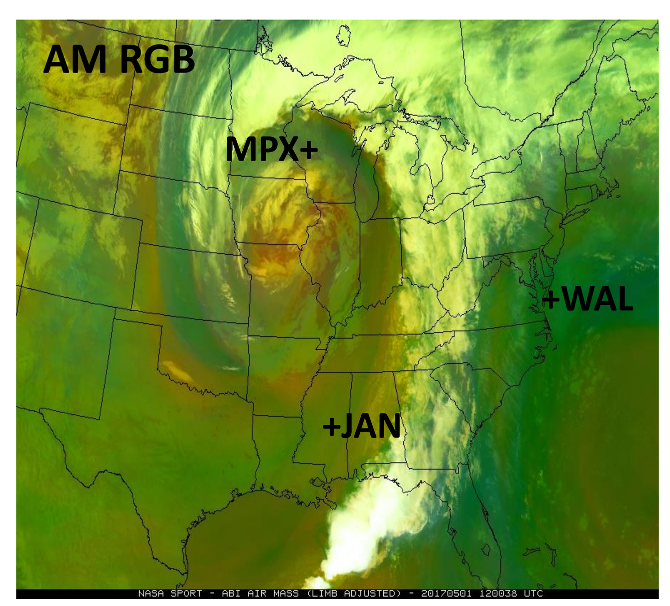

Fig. 9 Limb Corrected Air Mass RGB 1200 UTC 01 May 2018

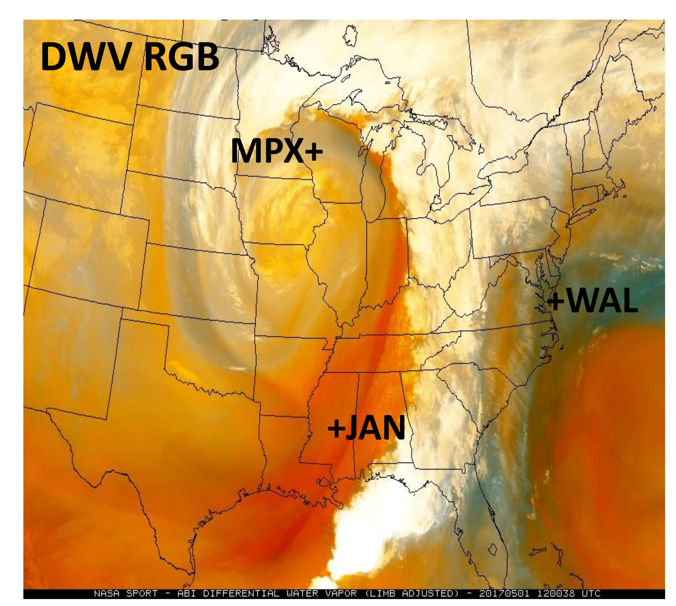

Fig. 10 Limb Corrected Differential Water Vapor RGB 1200 UTC 01 May 2018

Differential Water Vapor RGB (Fig. 10)

- Jackson, MS (JAN): Deep orange tones indicate deep layer dry air also in Fig. 11
- Chanhassen, MN (MPX): increased low to mid level moisture evidenced by the gray color and in Fig. 12
- Wallops Is, VA (WAL): moist upper levels with dry air below also see Fig. 13

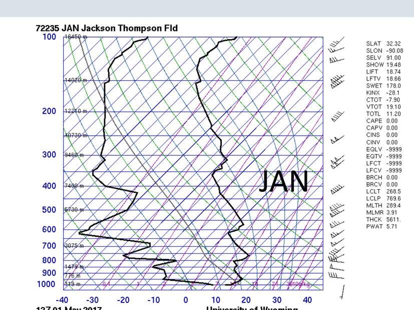

Fig. 11 Jackson, MS sounding 1200 UTC 01 May 2018

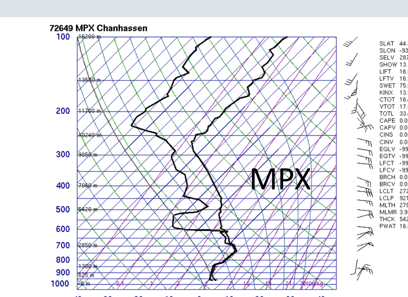

Fig. 12 Chanhassen, MN sounding 1200 UTC 01 May 2018

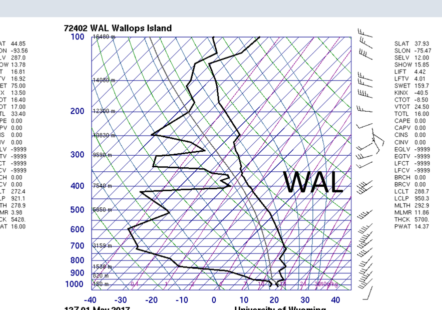

Fig. 13 Wallops Is., VA sounding 1200 UTC 01 May 2018

- The AM RGB indicates upper-level temperature and moisture characteristics and the DWV RGB provides information about the vertical distribution of the moisture
- Assessing the horizontal and vertical distribution of dry air associated with the dry slot is important for anticipating changes in cyclone intensity due to stratospheric air

Summary

- Combined analysis of AM and DWV RGB is useful for assessing mid- to upper- level horizontal/vertical variations in moisture that impact the stability of the pre-convective environment and changes in cyclone intensity
- Applying limb correction to water-vapor derived RGB images can remove the false signal at high viewing angles and potentially improve application an interpretation
- Future work includes verification of results with radiative transfer modeling and obtaining forecaster feedback on the utility of limb-corrected imagery and application of these RGB products as complimentary tools

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