

Limb Correction and Adjustments Applied to Imagery Derived from Differing Sensors to Improve Comparison of RGBs

NASA Short-term Prediction Research and Transition Center (SPoRT)
Marshall Space Flight Center; Huntsville, Alabama, United States of America

Gary Jedlovec, Emily Berndt , Nicholas Elmer, Kevin Fuell, Kevin McGrath

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Introduction/Motivation

- Limb effects can interfere with qualitative interpretation at high viewing angles
 - Limits use of polar-orbiting swaths
 - Can lead to misinterpretation of features (i.e. Tropical Air appears blue not green in the Air)

Advantages of Limb-Corrected RGBs

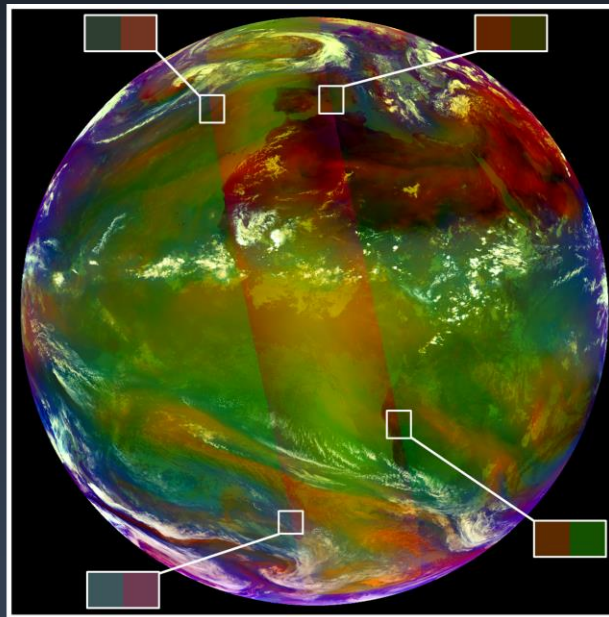
Improved forecaster situational awareness

Increased confidence in interpretation of RGB features

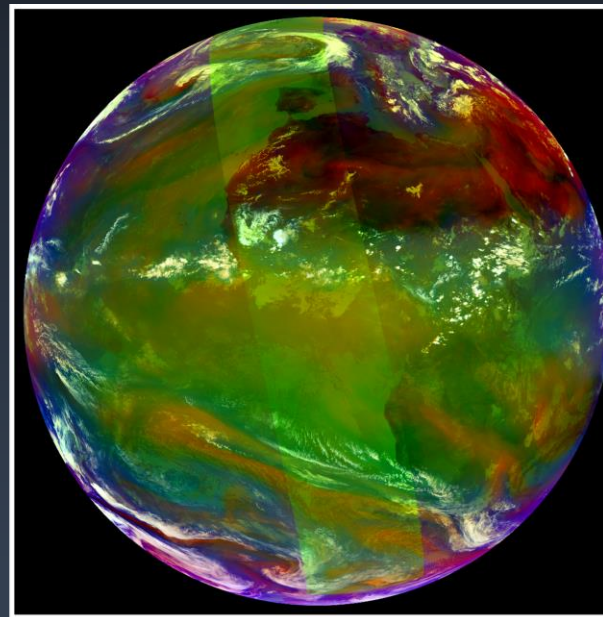
More accurate representation of atmosphere and surface on the limb

Ability to utilize the full satellite image, rather than just part of the image close to nadir

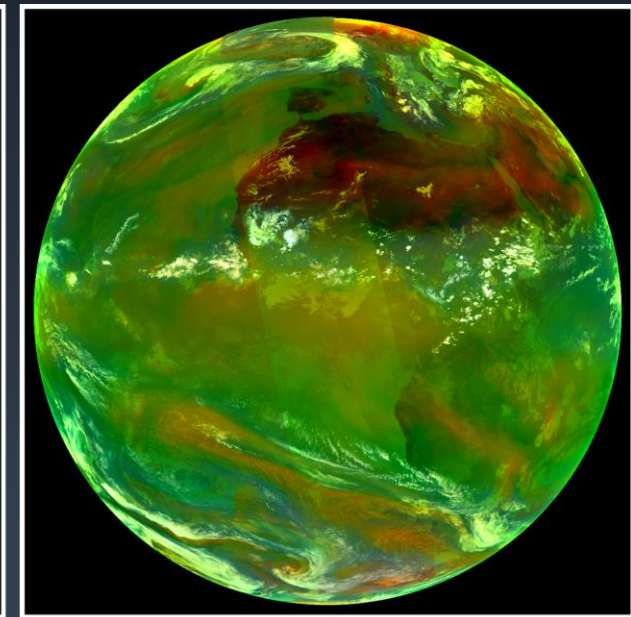
Improved transition between overlaid RGB composites



**Uncorrected MODIS
Uncorrected SEVIRI**



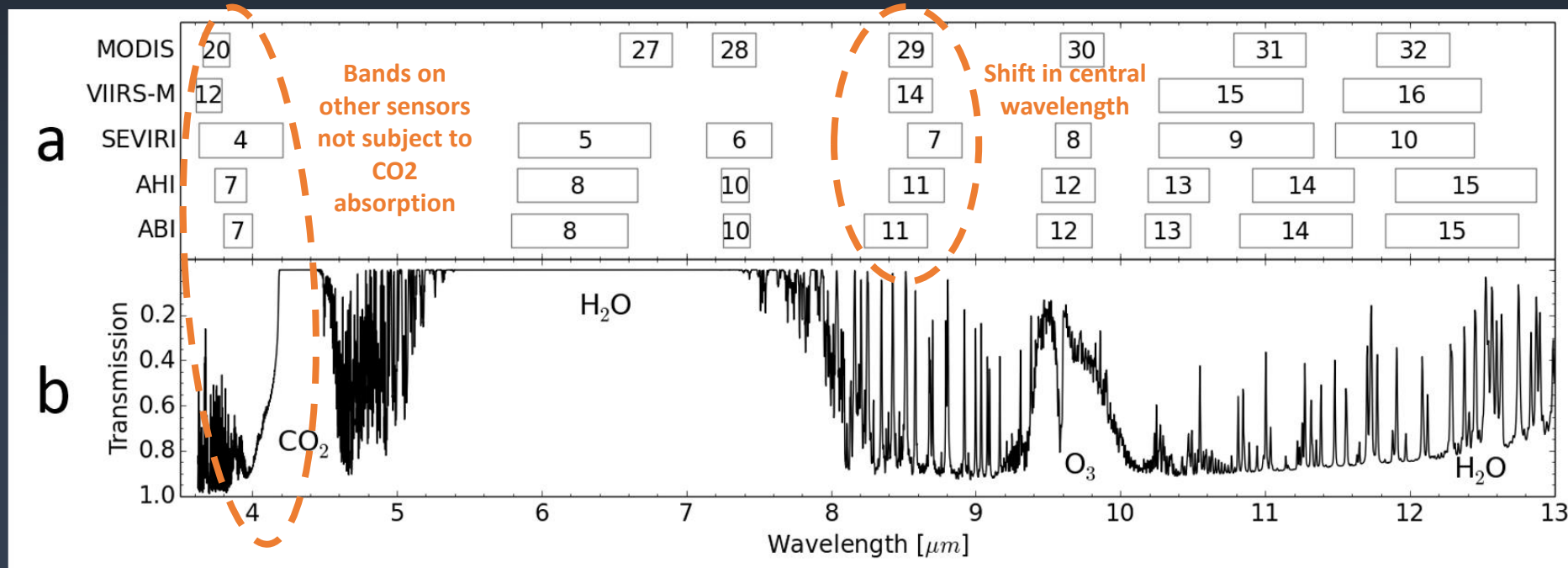
**Limb-corrected MODIS
Uncorrected SEVIRI**



Limb-corrected MODIS Limb-corrected SEVIRI

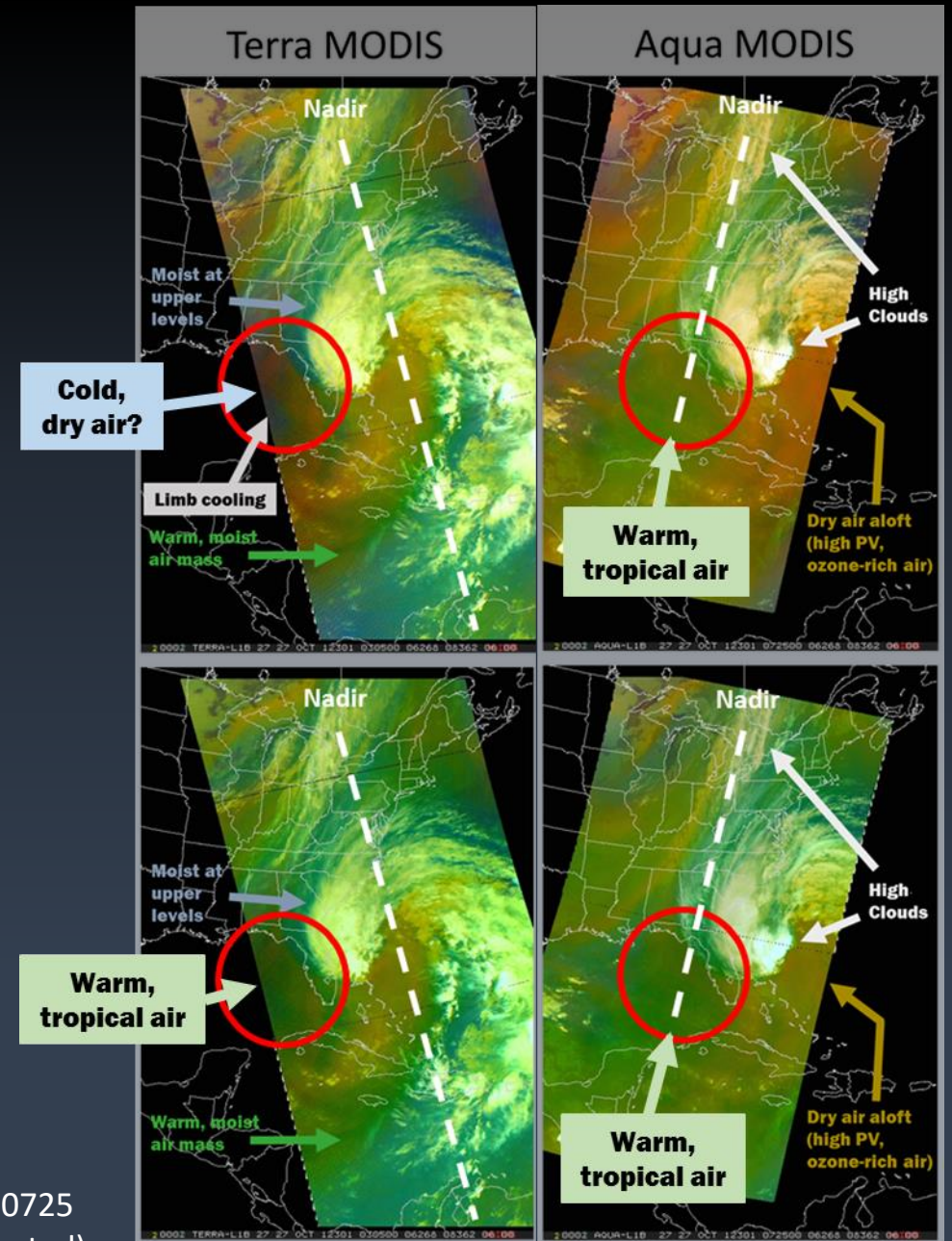
Introduction/Motivation

- Comparing RGBs across different sensors can be problematic
 - Differences in spectral characteristics of band (i.e. central wavelength, spectral bandwidth, spectral response function)
 - Differences in absorption characteristics (i.e. SEVIRI 3.9 μm band influenced by CO_2 absorption)
 - These differences can lead to inconsistent coloring and impact interpretation



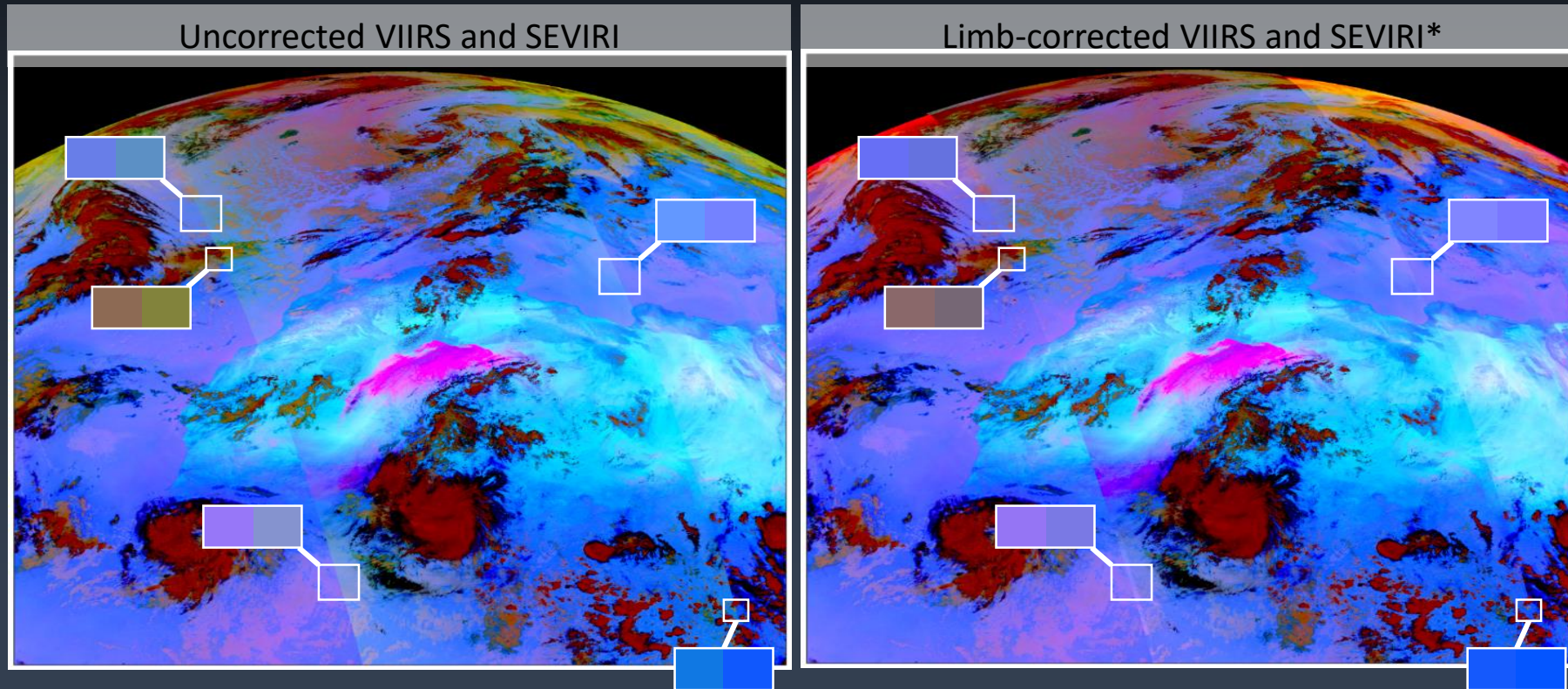
Limb Correction

- Elmer et al. (2016) developed limb correction technique to remove limb effects from Terra/Aqua MODIS and Suomi-NPP VIIRS infrared channels in real-time
 - Valid in both clear and cloudy regions
 - Function of latitude, Julian day, SZA, and cloud top pressure (for cloudy regions only)
 - Correction applied to all RGBs using longwave infrared bands



2012 October 27 Terra (0305 UTC) and Aqua (0725 UTC) MODIS Air Mass RGBs (original and corrected) showing a developing Hurricane Sandy.

Limb Correction



1245 UTC 3
September
2015 VIIRS and
SEVIRI Dust
RGB

*Cloud effects not
accounted for in SEVIRI
imagery

Technical Approach

- Brightness temperatures (T_B) simulated at varying satellite zenith angles using JCSDA Community Radiative Transfer Model (CRTM)
- Cloud-free atmospheric profiles of temperature, water vapor, and ozone obtained from global annual subset of ECMWF profiles used as input to CRTM
- The change in T_B from nadir to the limb ($T_{B_{NADIR}} - T_{B_{LIMB}}$) and the natural log of the cosine of the satellite zenith angle (θ) are related by a quadratic function:

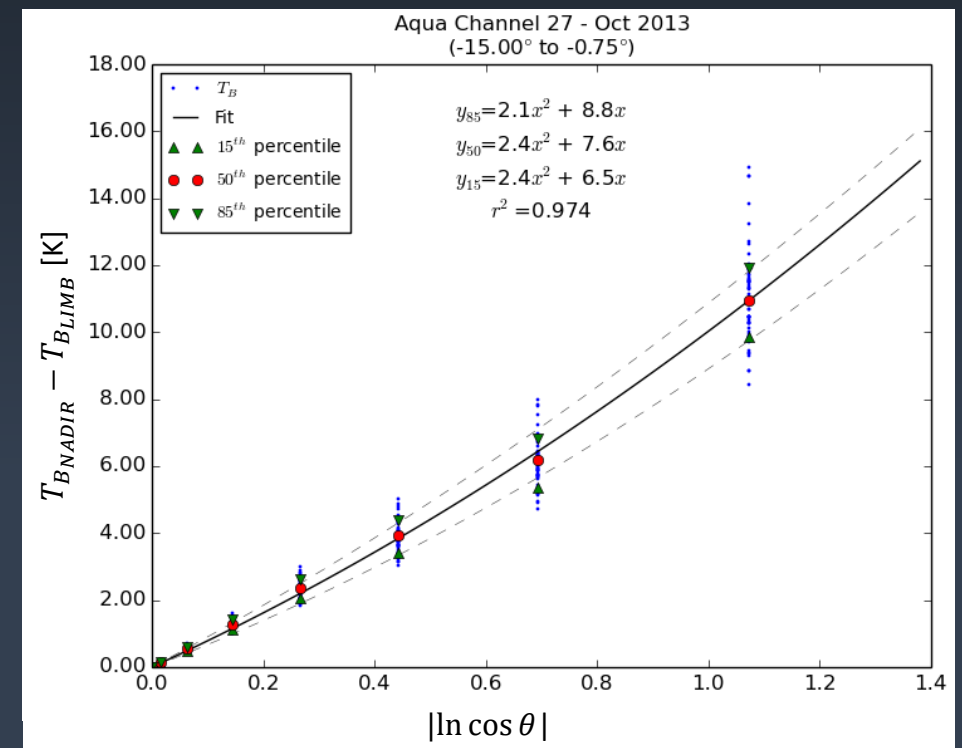
$$y = C_2x^2 + C_1x$$

- Least-square fit parameters, C_1 and C_2 , are defined as the limb correction coefficients
- Changing C_1 and C_2 by a value of 1 corresponds to change in $T_{B_{LIMB}}$ of 0.7 K and 0.5 K, respectively, at $\theta=60^\circ$

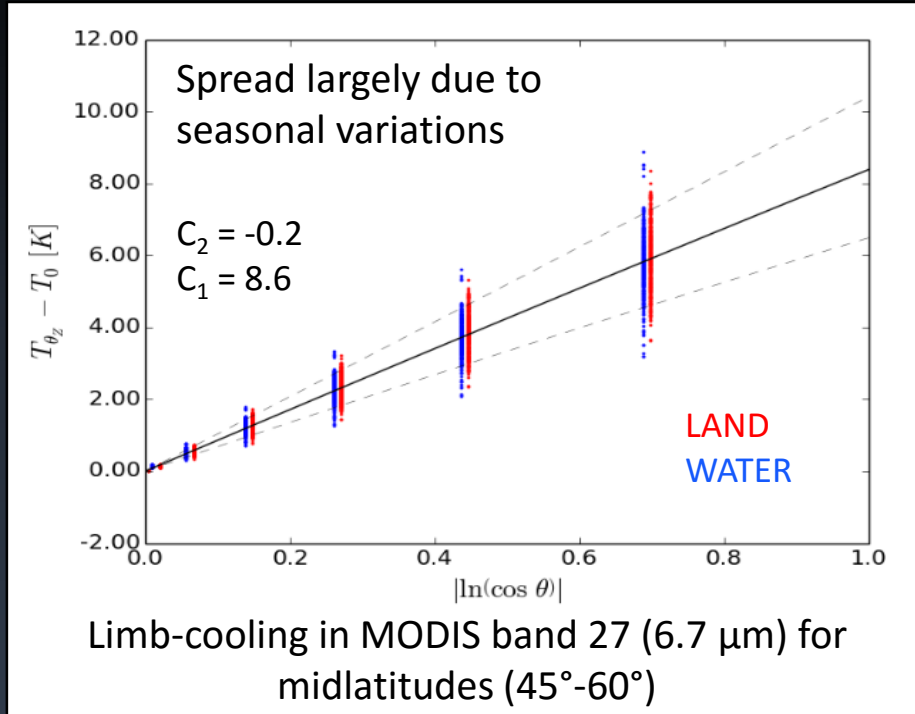
- The limb-corrected T_B (T_{corr}) can be calculated from the uncorrected T_B (T_{raw}) given θ :

$$T_{corr} = T_{raw} - C_1 \ln(\cos \theta) - C_2 \ln(\cos \theta)^2$$

- Correction coefficients vary latitudinally and seasonally!**

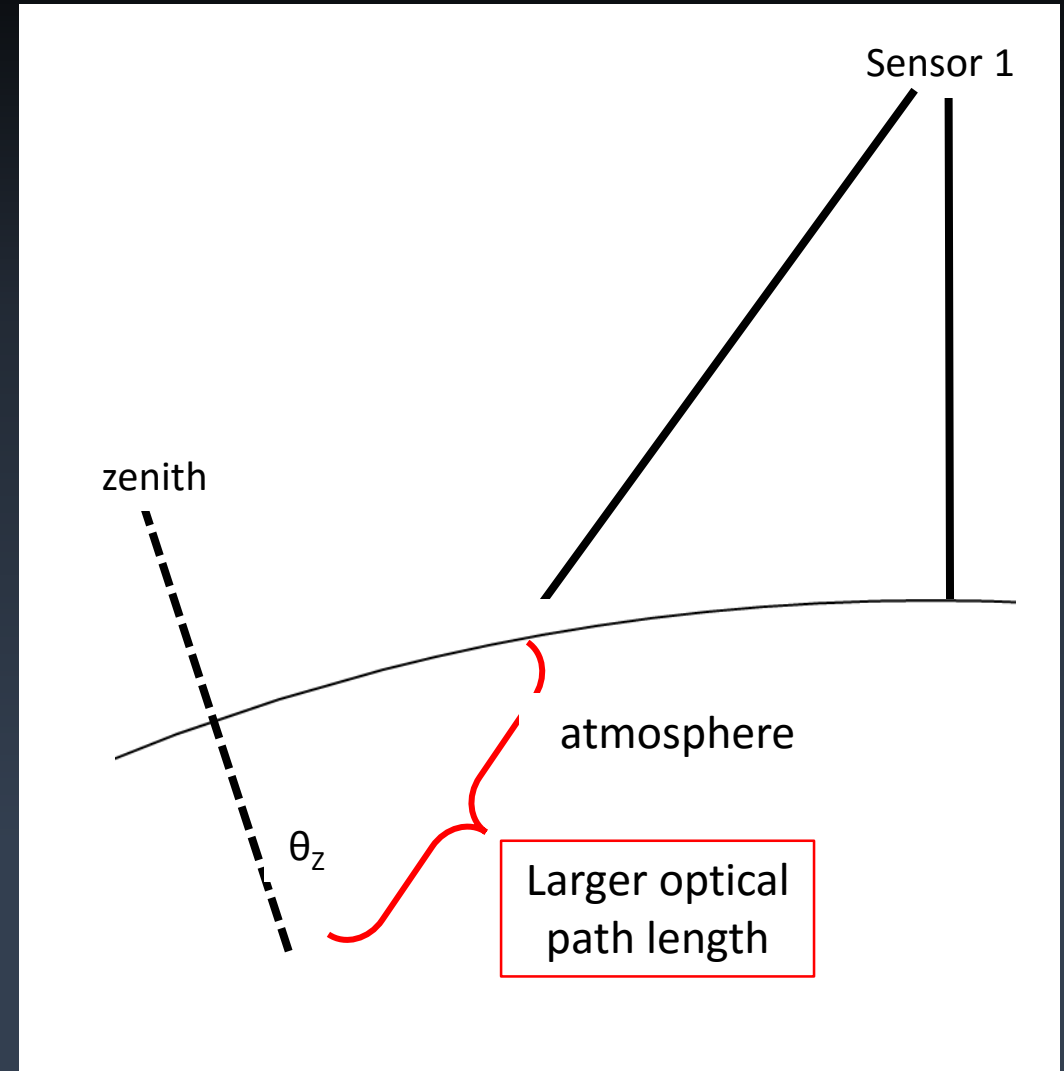


Limb Correction in Clear Regions



$$T_{\theta_z} - T_0 = C_2 |\ln(\cos \theta_z)|^2 + C_1 |\ln(\cos \theta_z)|$$

- Least-square fit parameters, C_1 and C_2 , are defined as the limb correction coefficients
- **Correction coefficients vary latitudinally and seasonally** (Joyce et al. 2001; Elmer et al. 2015, 2016)



Limb Correction in Cloudy Regions

- Layer optical thickness (τ_l) calculated from JCSDA Community Radiative Transfer Model (CRTM; Han et al. 2006)
- Cloud correction coefficient (Q) calculated from τ_l :

$$t_l(p) = e^{-\tau_l(p)}$$

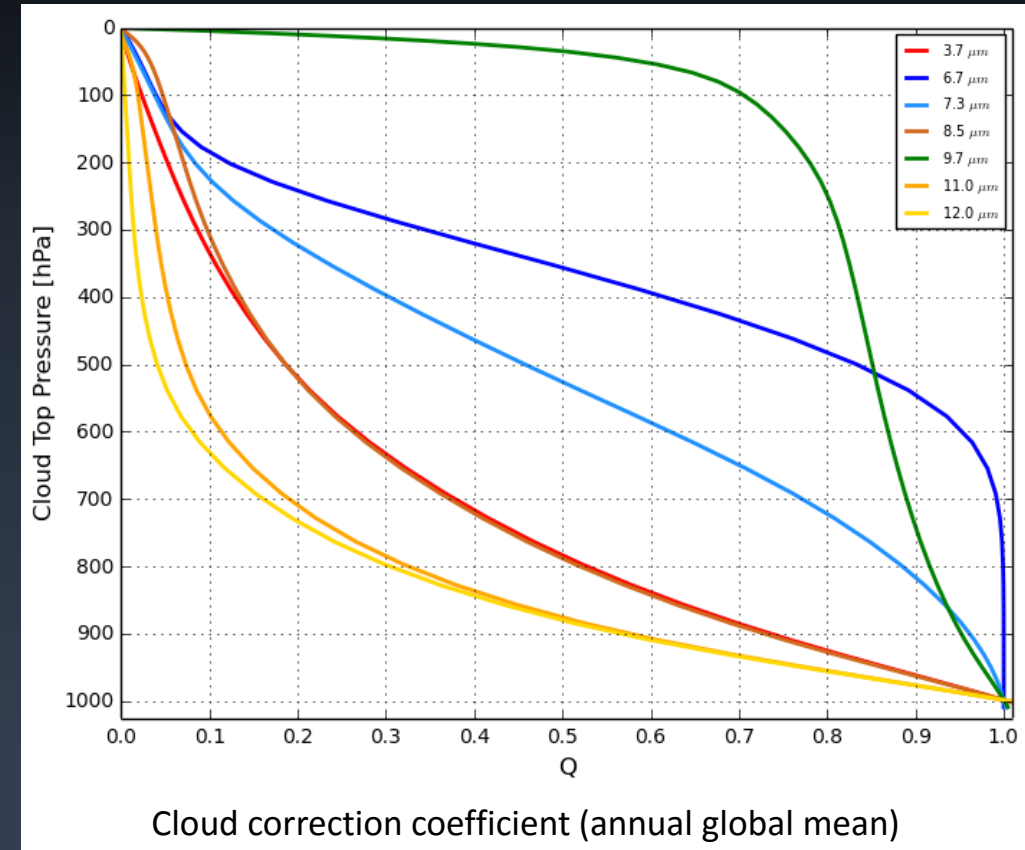
$$t(p) = t_l(p) t(p - 1)$$

$$Q(p) = \frac{t(0) - t(p)}{t(0) - t(p_s)}$$

- **Q varies latitudinally and seasonally**, similar to limb correction coefficients C_1 and C_2 , $Q = 1$ in clear regions
- Limb Correction Equation:

$$T_{CORR} = T_B + Q [C_2 \ln(\cos\theta_Z)^2 - C_1 \ln(\cos\theta_Z)]$$

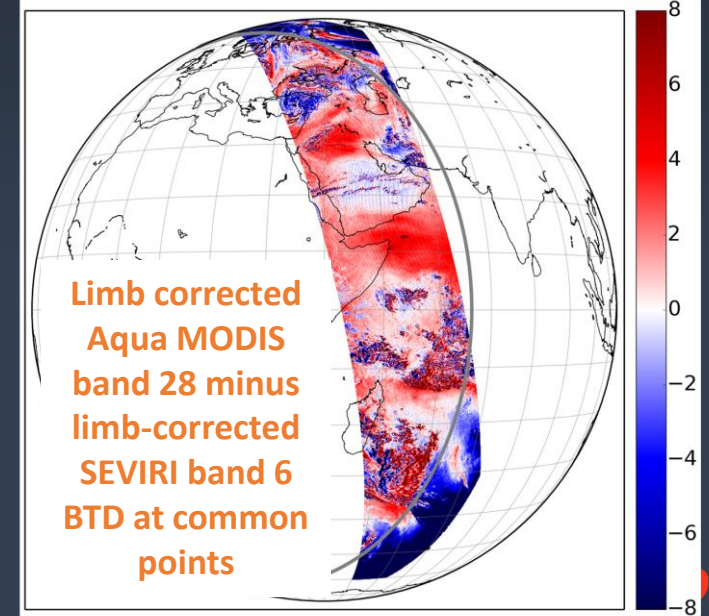
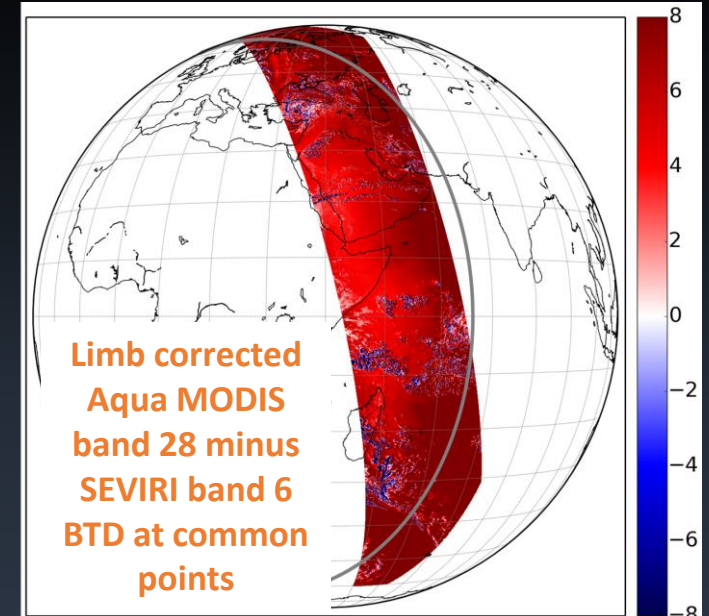
- Applicable to polar-orbiting and geostationary sensors



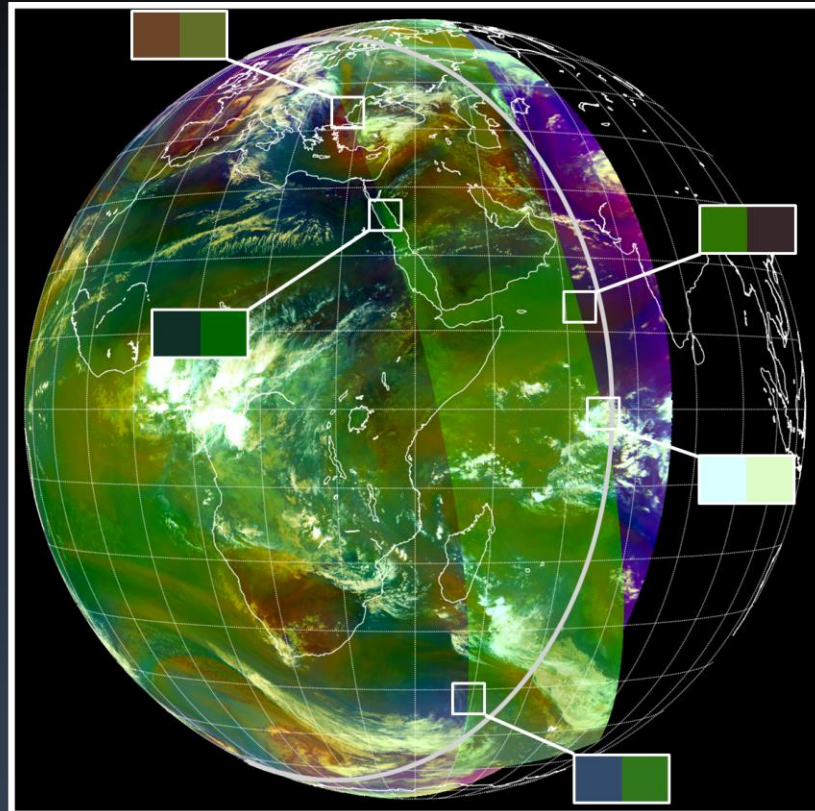
(Elmer et al. 2016)

Technical Approach: Geo Limb Correction

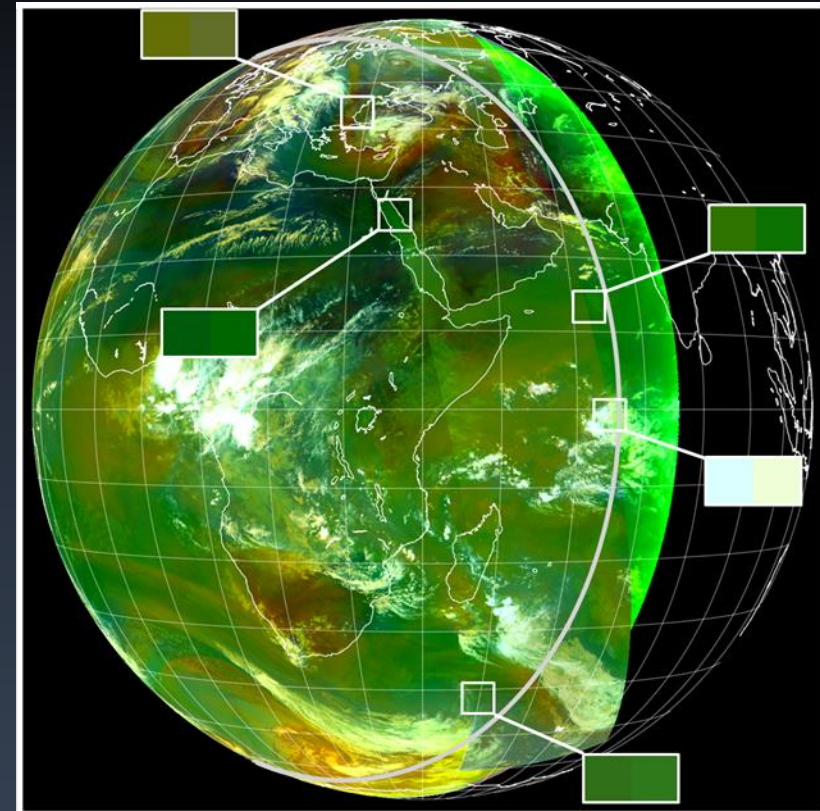
- Extend Elmer et al. (2016) limb correction technique to MSG SEVIRI
 - MSG Optimal Cloud Analysis (OCA; EUMETSAT 2016) provides cloud top pressure for SEVIRI for SZA < 75°
 - Limb-corrected Aqua MODIS used to validate SEVIRI limb correction
 - MODIS and inter-calibrated with SEVIRI prior to limb correction to account for sensor differences, following methodology in Elmer et al. (2016)



Limb Correction: Air Mass RGB



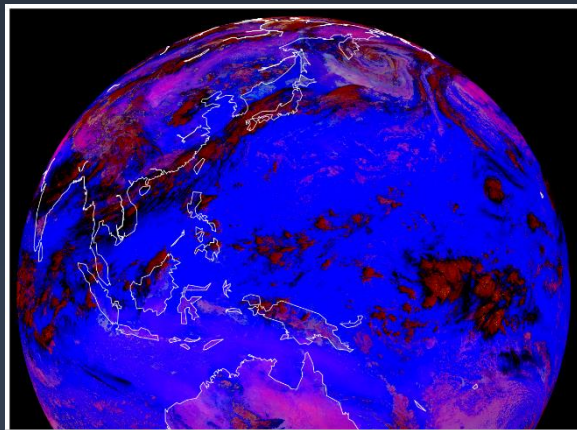
Corrected MODIS
Uncorrected SEVIRI
gray line SZA=75°



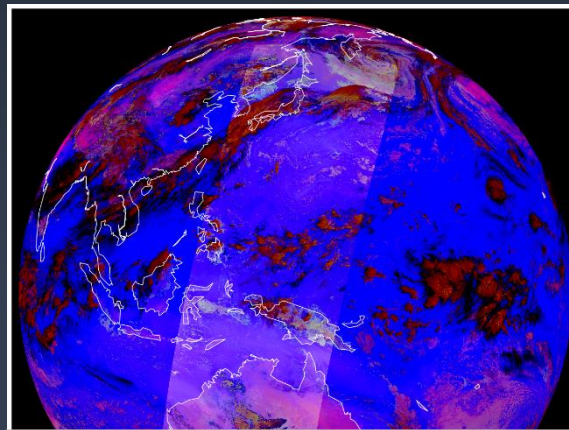
Corrected MODIS
Limb-corrected SEVIRI
(considering cloud effects)

Adjusting RGB Recipes

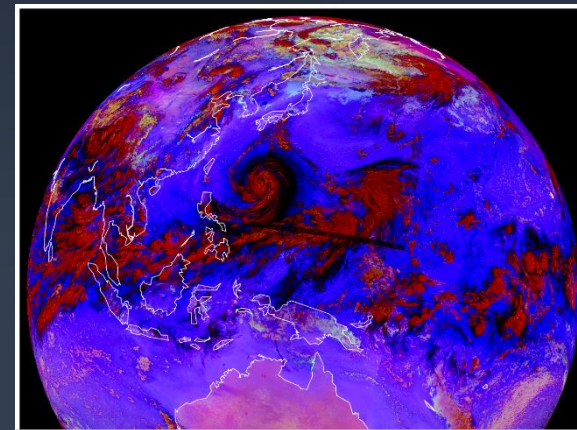
- Directly applying EUMETSAT recipes to sensors with different spectral and absorption characteristics can lead to color differences in the RGB imagery and impact interpretation.
- For example the EUMETSAT best practices recommend adjusting the RGB recipe when creating RGBs with instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS) due to differing spectral and absorption characteristics across sensors.
- JMA has pioneered work to adjust EUMETSAT recipes for advanced sensors such as AHI.
- This work extends JMA's approach to apply recipe adjustments to GOES-16 and -S and match RGBs derived from non-overlapping sensors.



**Night-time Microphysics
EUMETSAT Recipe
No Adjustment**



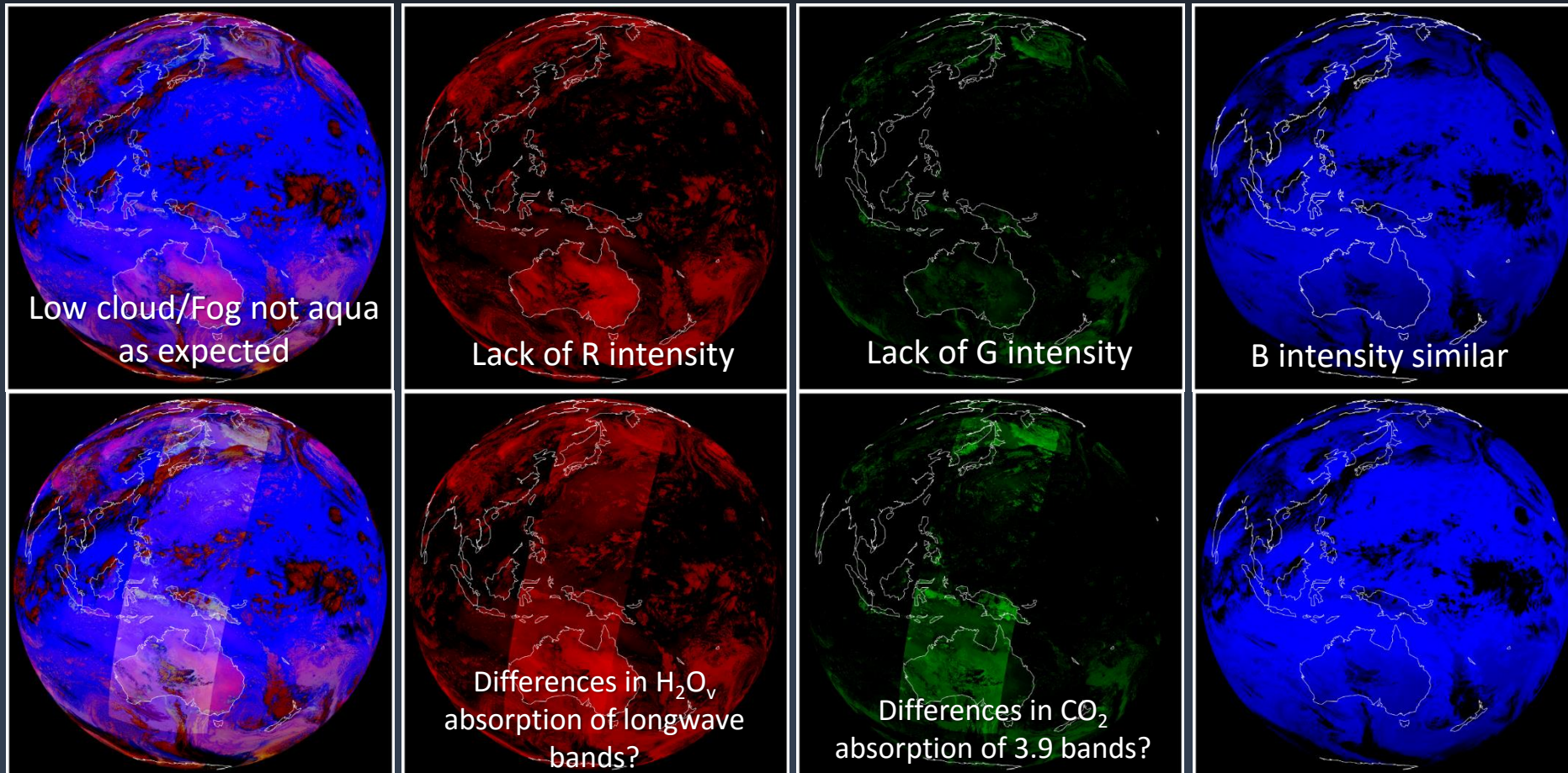
**Night-time Microphysics
EUMETSAT Recipe +
VIIRS as SEVIRI Proxy**



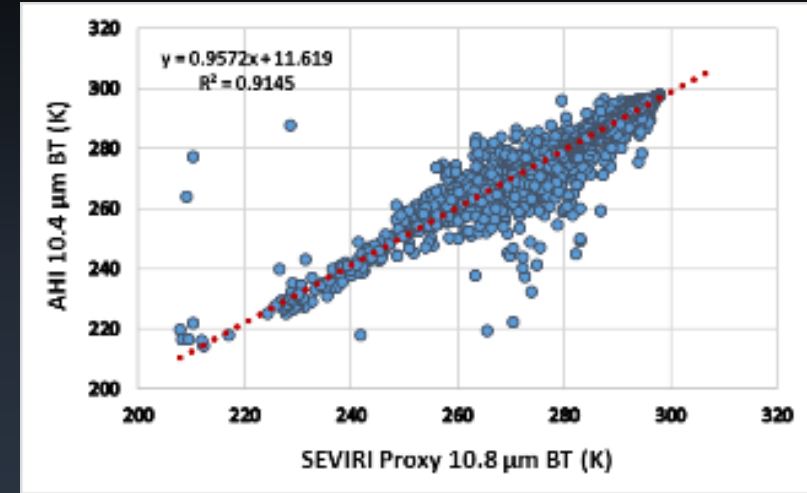
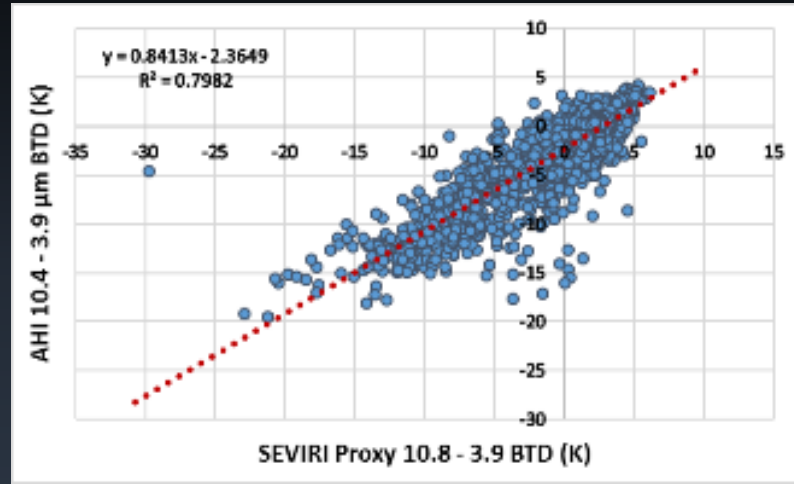
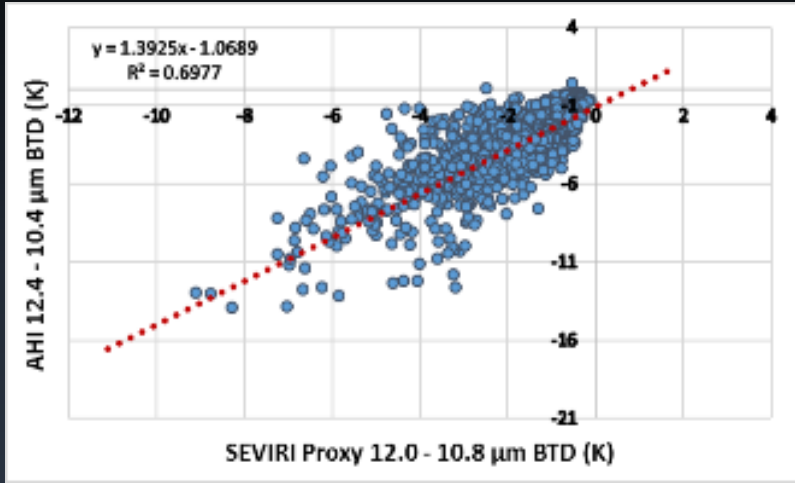
**Night-time Microphysics
Adjusted Recipe +
VIIRS as SEVIRI Proxy**

Night-Time Microphysics RGB

- AHI RGB coloring and component intensities differ from the SEVIRI proxy overlay



Recipe Adjustment



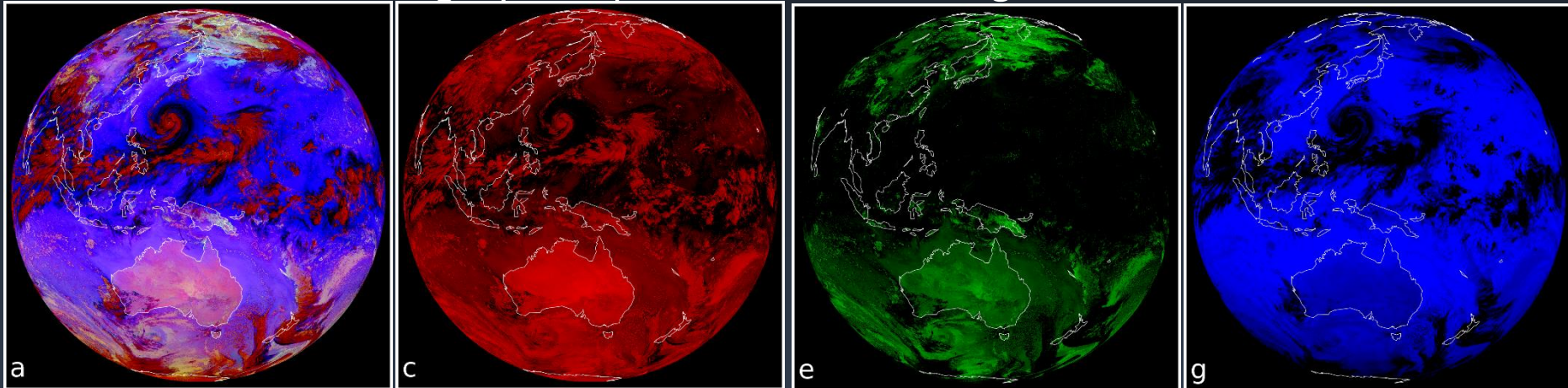
	Adjustment by SEVIRI Proxy Case 1 8/30/2015			Adjustment by SEVIRI Proxy Case 2 12/14/2016		
	Min (K)	Max (K)	Gamma	Min (K)	Max (K)	Gamma
R	-6.6	1.7	1	-6.8	2.4	1
G	-2.4	6.0	1	-2.5	6.3	1
B	244.2	292.1	1	243.9	291.3	1
	All 16 Cases			Adjustment by JMA		
	Min (K)	Max (K)	Gamma	Min (K)	Max (K)	Gamma
R	-7	2	1	-6.7	2.6	1
G	-2	6.0	1	-3.1	5.2	1
B	243	292	1	243.6	292.6	1



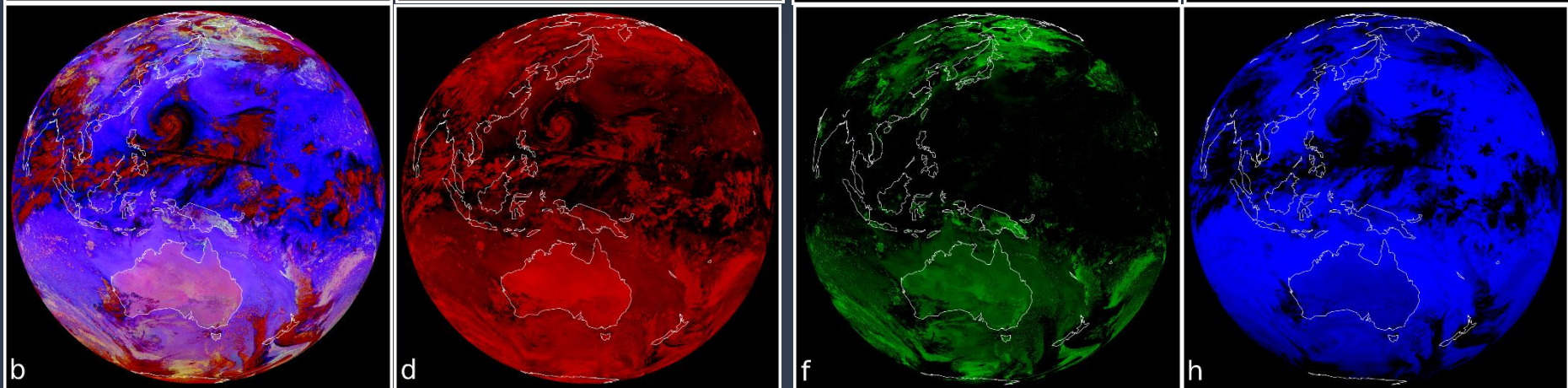
Adjusted Night-time Microphysics

- With the new adjustment RGB colors and component intensity are similar to the SEVIRI proxy overlay (SEVIRI overlay barely visible!)
- Adjustment improves the lack of red and green intensities noted earlier
- RGB colors are consistent with legacy interpretation and training

Night-time
Microphysics
Adjusted

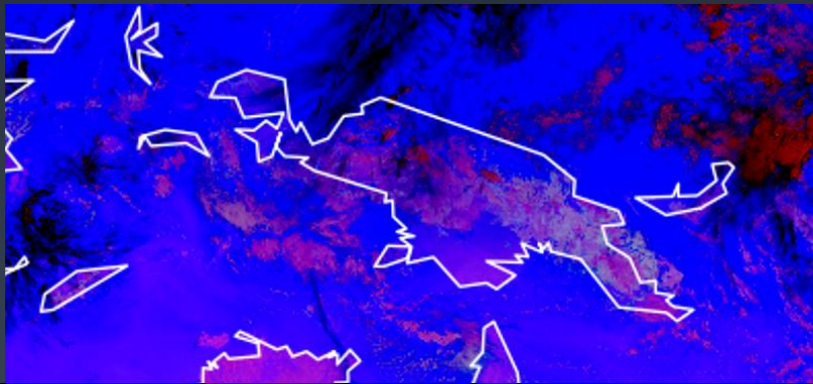


Night-time
Microphysics
Adjusted
+
SEVIRI
Proxy Overlay

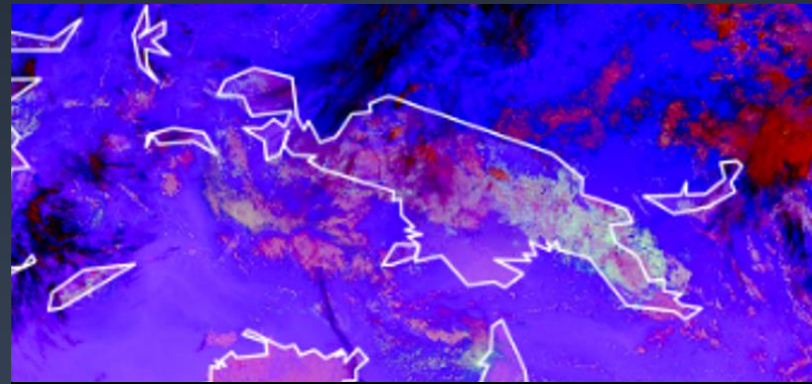


Adjusted Night-time Microphysics

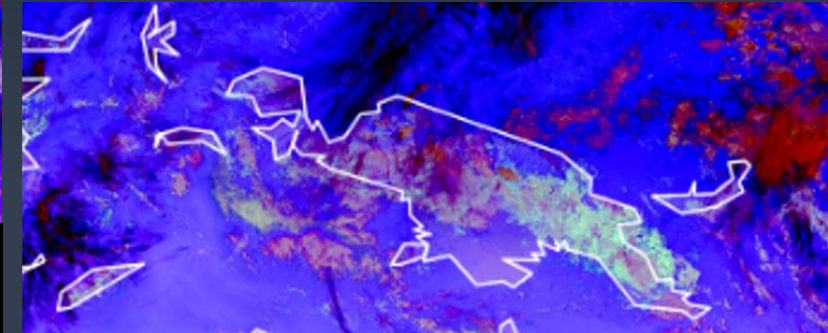
- The adjustment improves the aqua coloring of the low cloud/fog features
- Since the adjustment is similar to the JMA derivation for AHI, this research verifies work done by JMA and demonstrates a computationally inexpensive methodology to determine recipe adjustments for RGB imagery derived with GOES-R and GOES-S in the future
- Slight color differences between case study and JMA adjustments attributed to the ability to account for instrument bias, noise, and full atmospheric absorption when using real data



Unadjusted
Night-time Microphysics



Case Study Adjusted
Night-time Microphysics



JMA Adjusted
Night-time Microphysics