Limb Correction of Infrared Imagery in Cloudy Regions for the Improved Interpretation of RGB Composites

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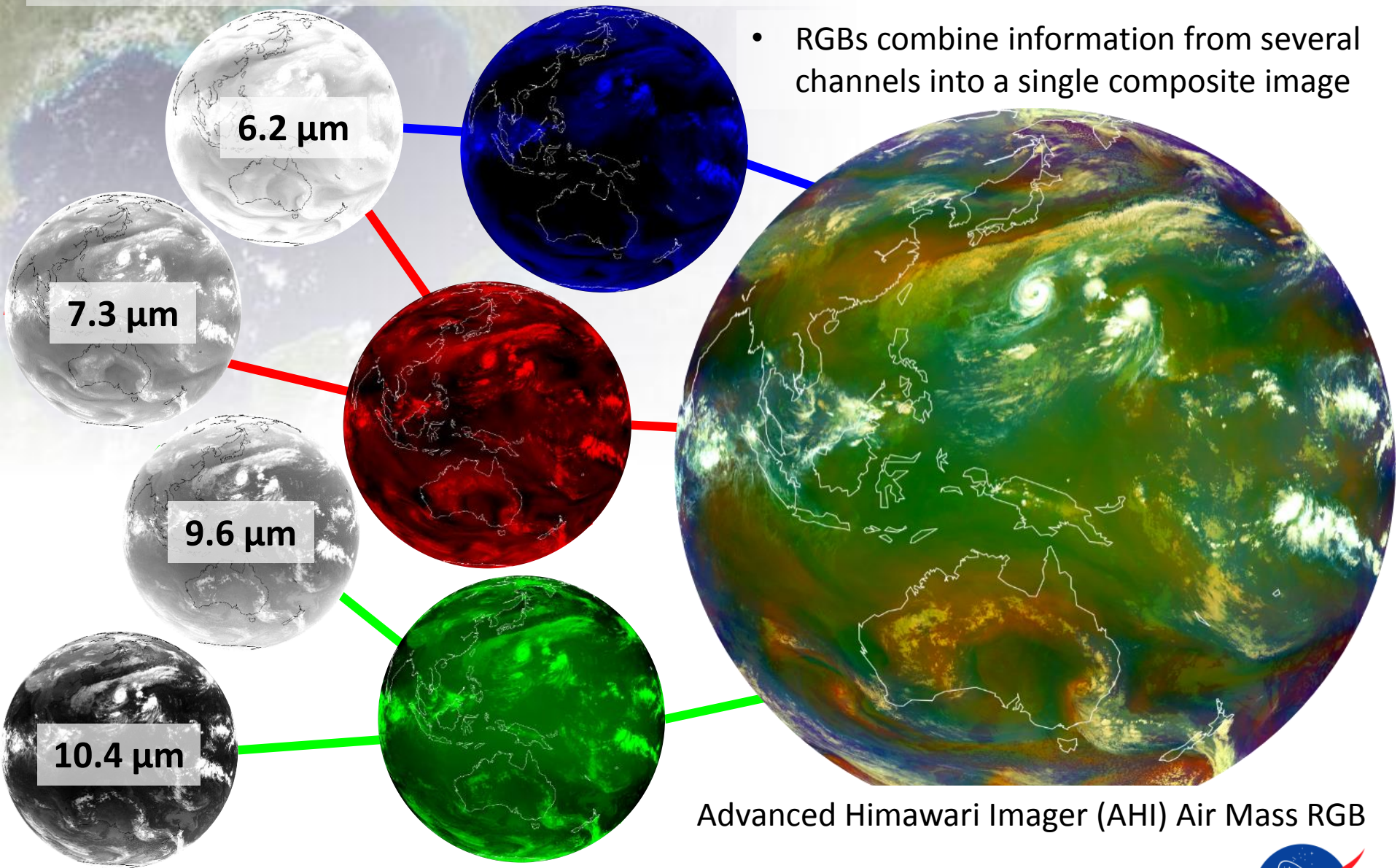
RGB Composites

- RGBs combine information from several channels into a single composite image



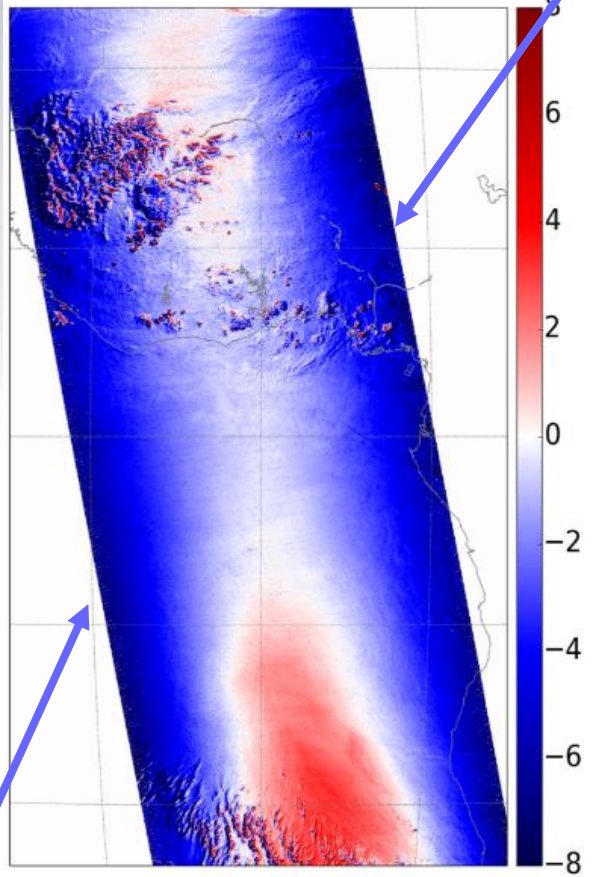
Advanced Himawari Imager (AHI) Air Mass RGB

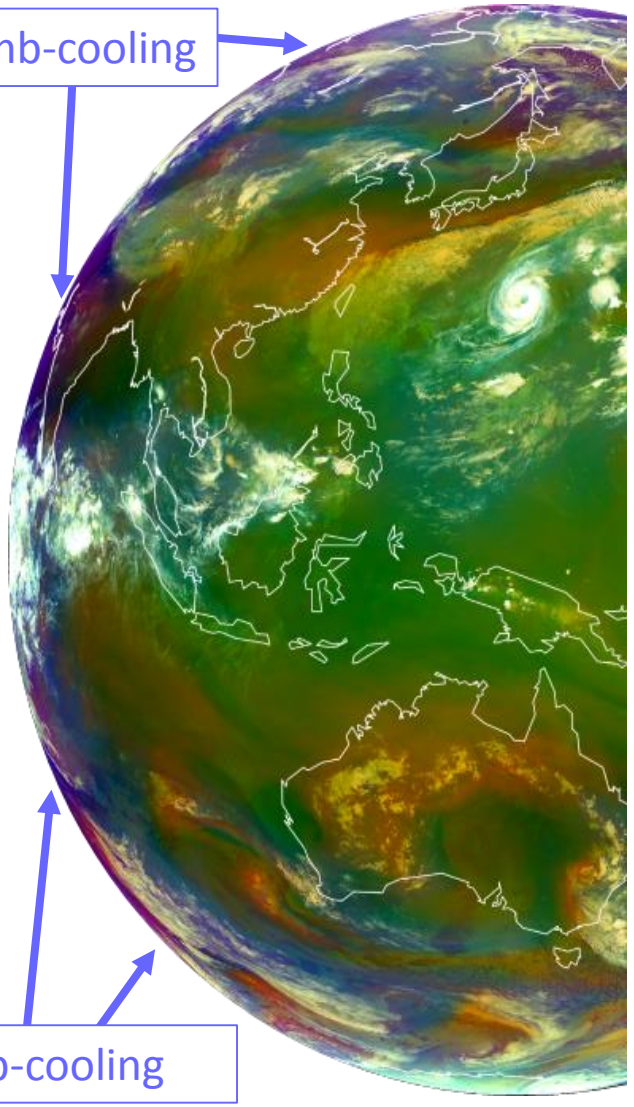
Limb Effect (Limb-Cooling)

- **Limb-cooling** occurs as the viewing zenith angle (θ_Z) increases, increasing the optical path length of the absorbing atmosphere (Goldberg et al. 2001; Joyce et al. 2001; Liu and Weng 2007)

- Limb effects interfere with qualitative interpretation of RGB composites at large θ_Z (both polar-orbiting and geostationary sensors)

Aqua MODIS minus SEVIRI brightness temperature difference (6.7 µm)



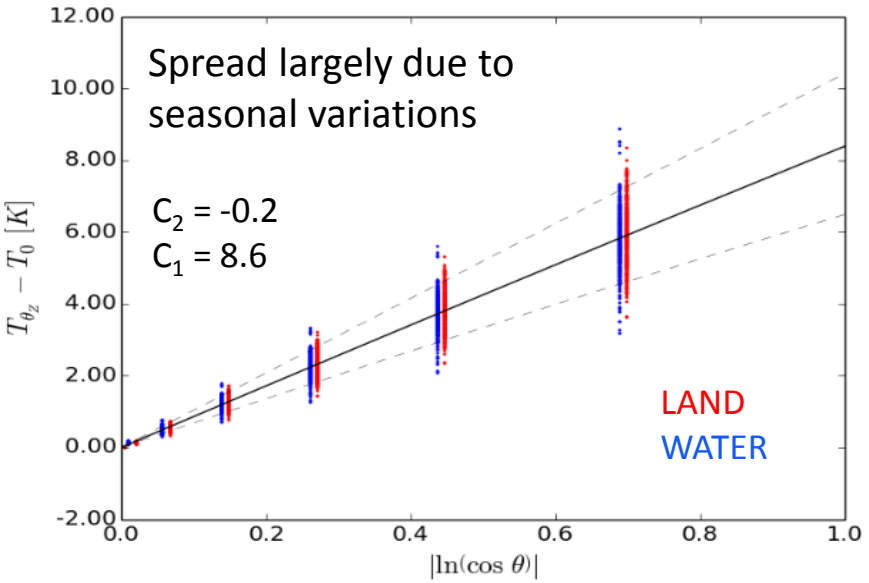


Limb-cooling

Limb-cooling

Limb-cooling

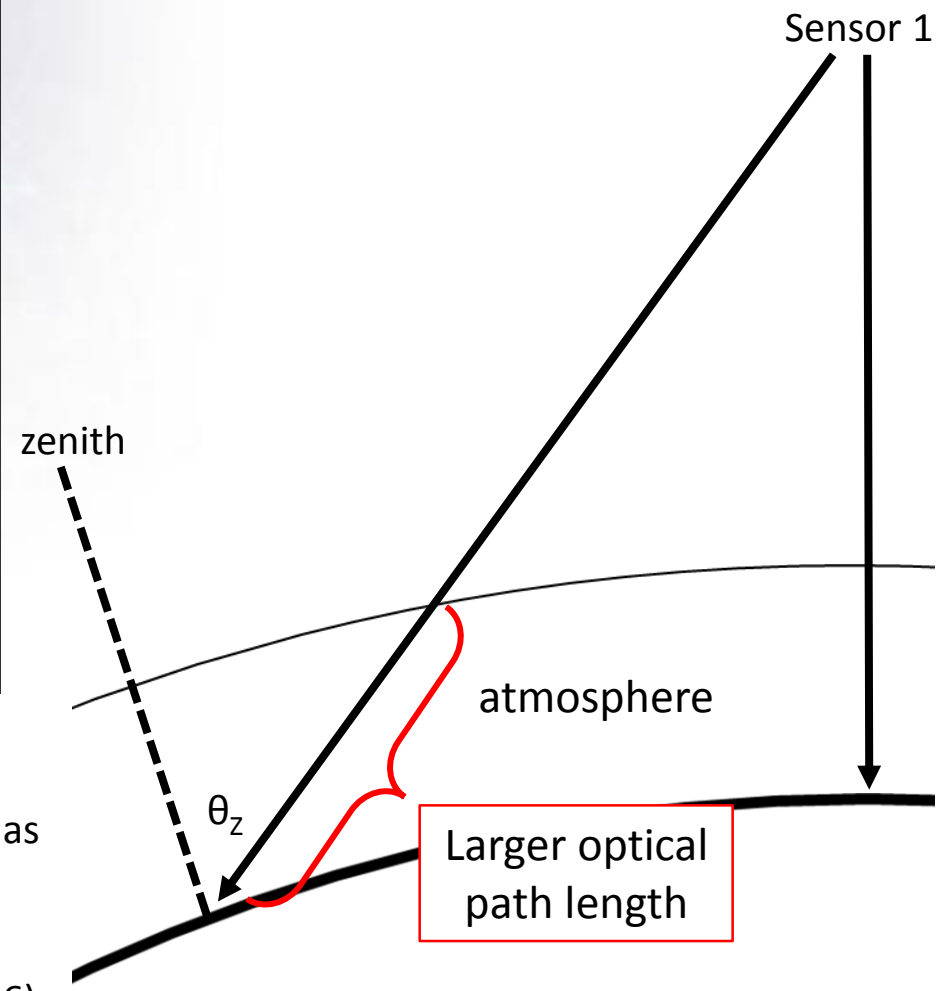
Limb Correction in Clear Regions



Limb-cooling in MODIS band 27 (6.7 µm) for midlatitudes (45°-60°)

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

- 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)



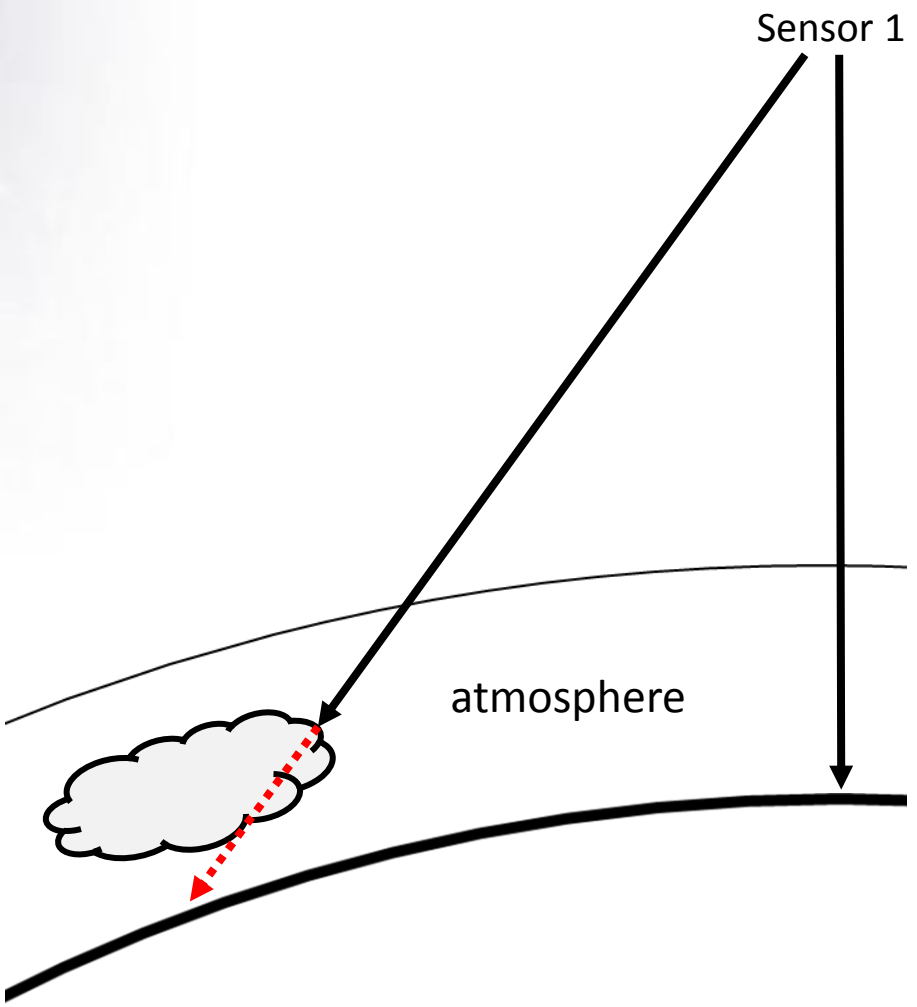
Cloud Effects

- Clouds contribute to limb effect:

  1) **Cloudy scenes have shorter optical path length than clear scenes**

  2) Different parts of cloud likely have different emissivities and temperatures

- If limb correction performed without accounting for cloud effects, limb correction will be inaccurate in cloudy regions



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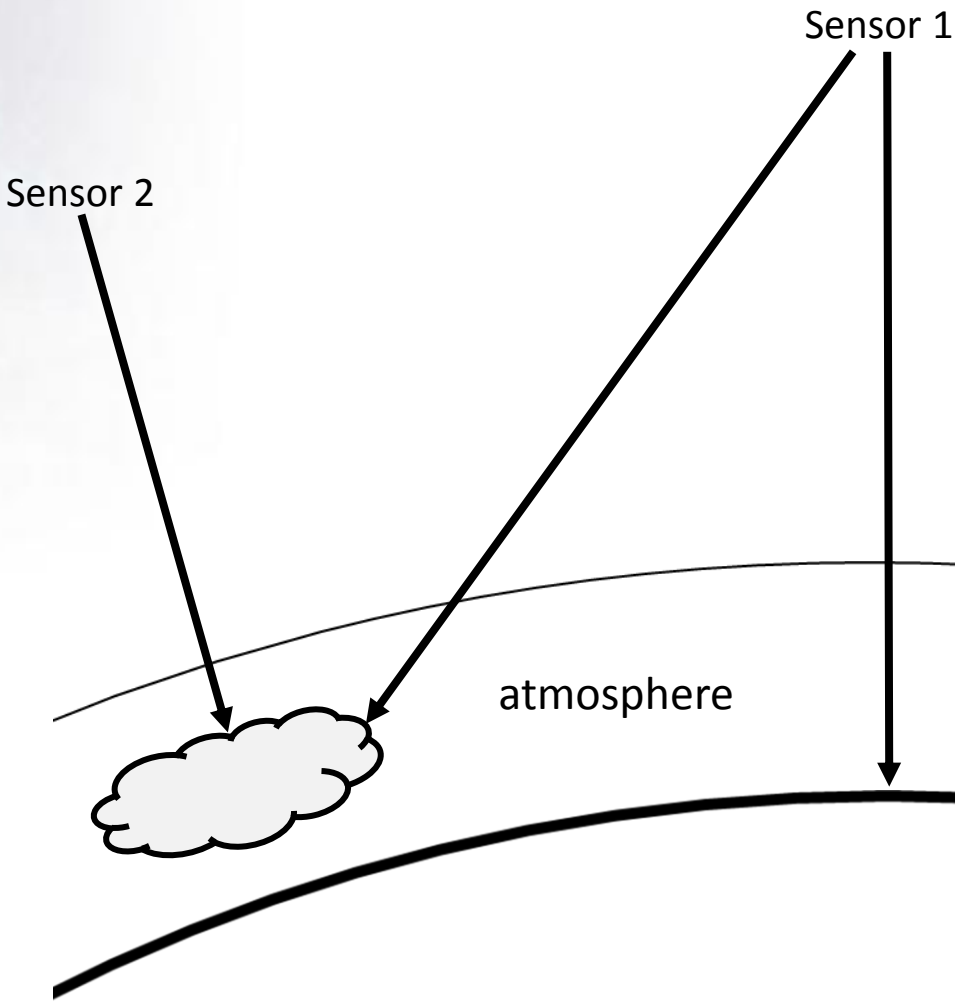


Limb Correction in Cloudy Regions

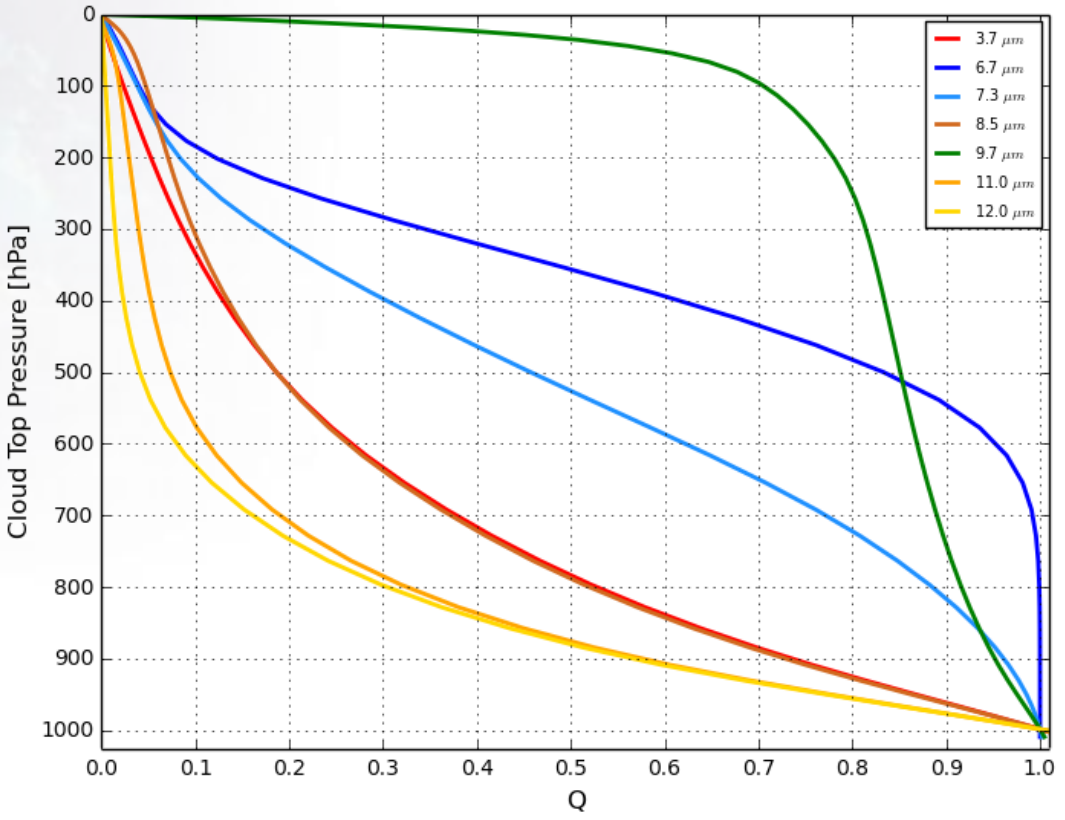
- Layer optical thickness (τ_l) calculated from JCSDA Community Radiative Transfer Model (CRTM; Han et al. 2006)
- Cloud correction coefficient (Q) calculated from τ_l :

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

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

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

- For clear regions, Q=1
- **Q varies latitudinally and seasonally**, similar to limb correction coefficients C_1 and C_2



Cloud correction coefficient (annual global mean)

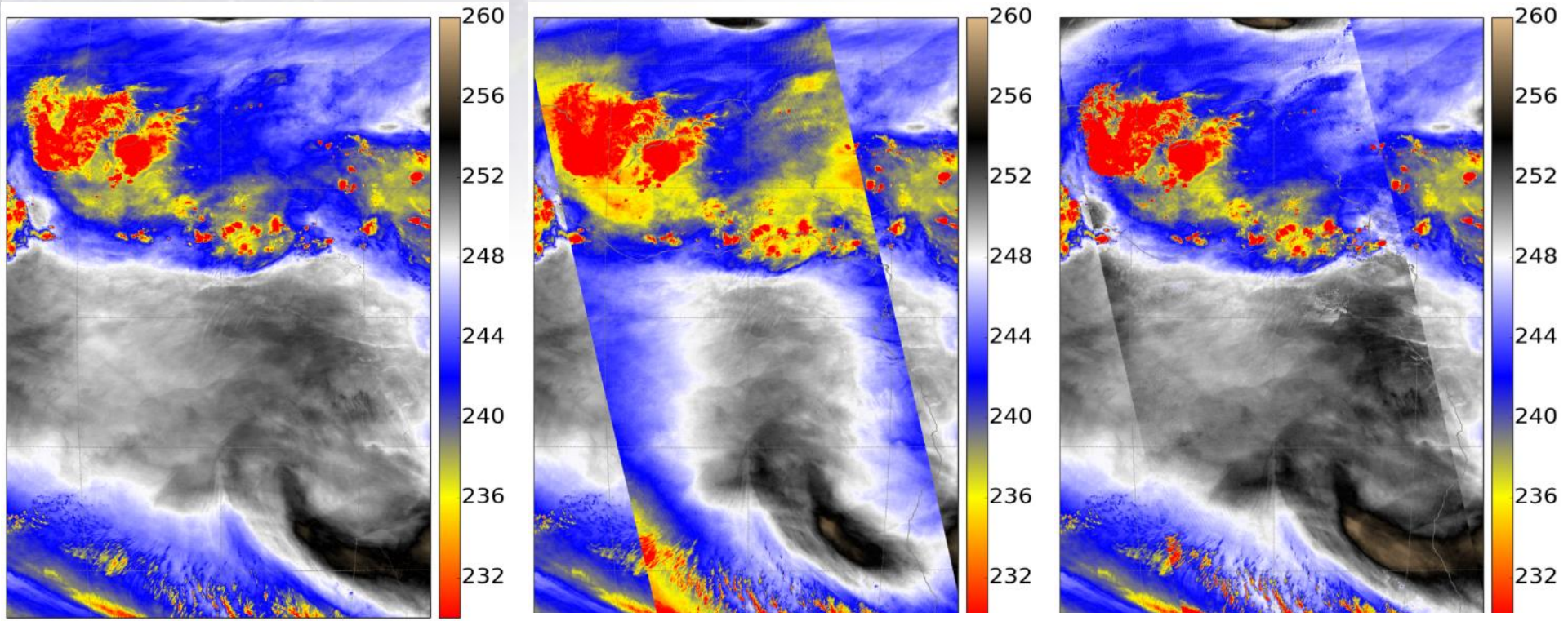
Limb Correction

- Limb Correction Equation:

$$T_{CORR} = T_B + Q\left[C_2\, ln(cos\theta_Z)^2 - C_1\, ln(cos\theta_Z)\right]$$ (Elmer et al. 2016)

- Applicable to both polar-orbiting and geostationary sensors

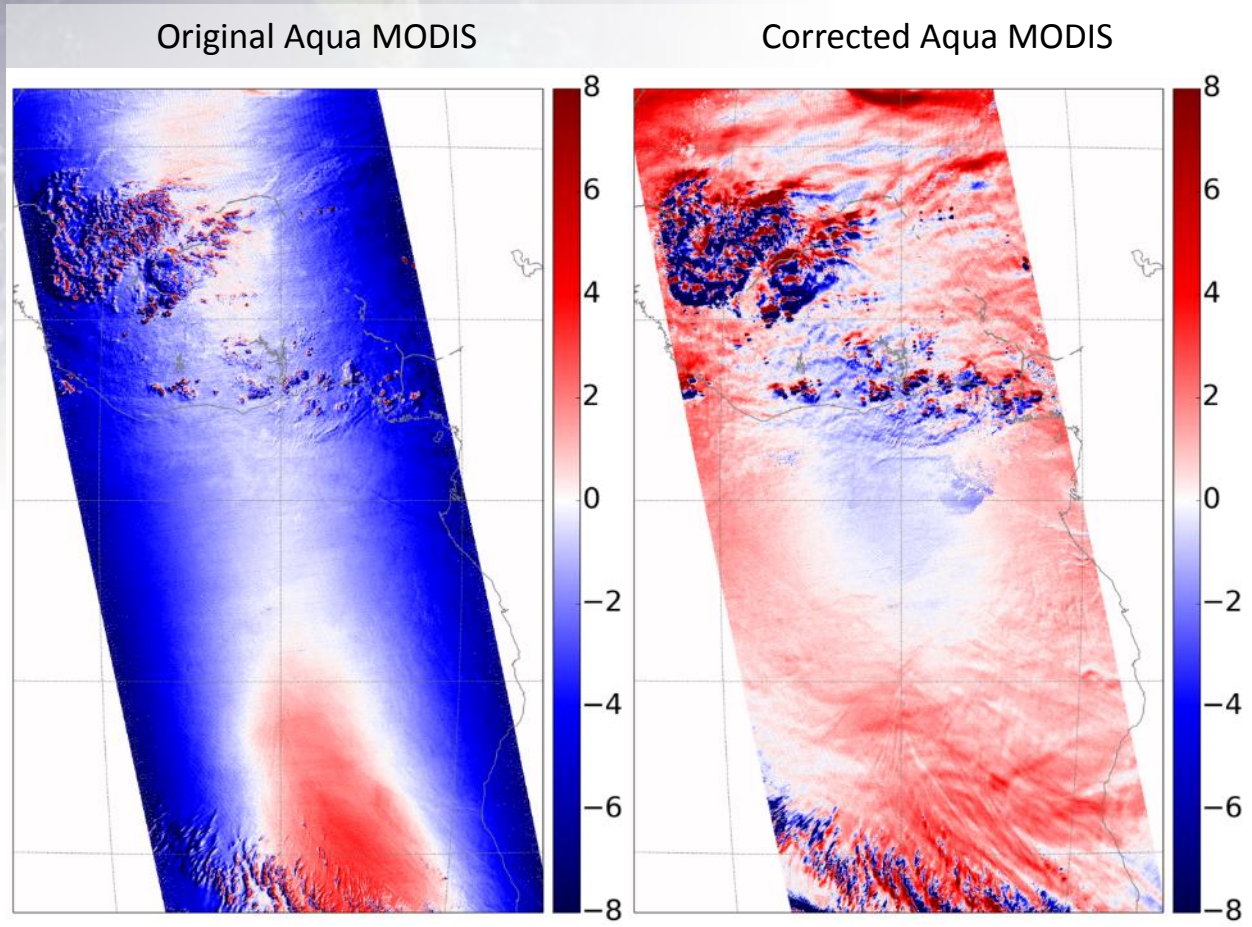
SEVIRI (6.2 µm) | Original Aqua MODIS (6.7 µm) | Corrected Aqua MODIS (6.7 µm)



1330 UTC 28 June 2015 Aqua MODIS 6.7 µm and SEVIRI 6.2 µm brightness temperature

Limb Correction

- Correction reduces errors due to limb and cloud effects in single band imagery

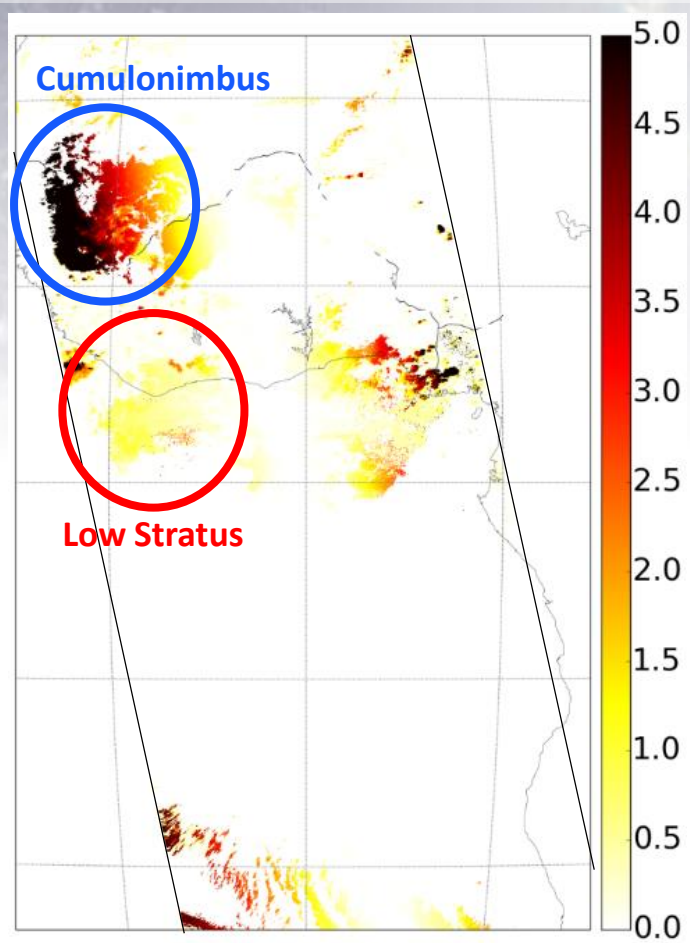


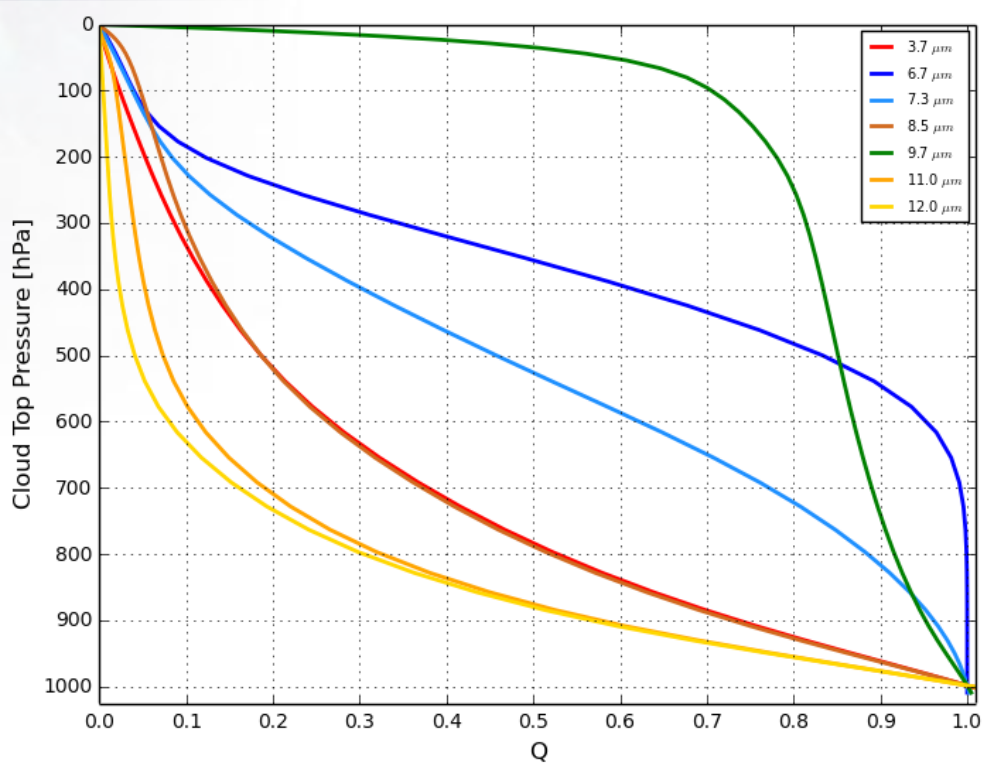
1330 UTC 28 June 2015 Aqua MODIS minus SEVIRI brightness temperature difference

Impact of Cloud Effects

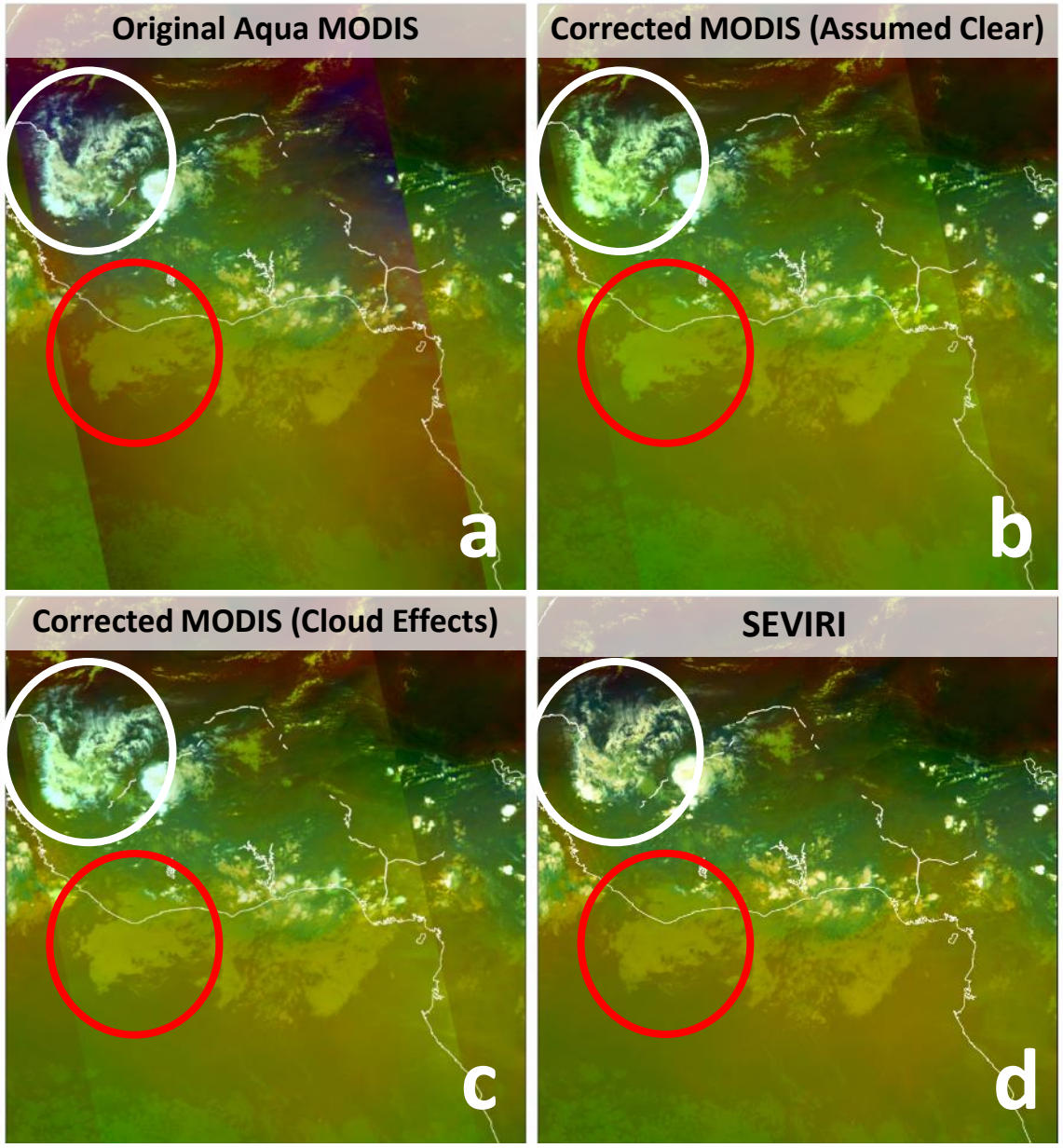
- Difference between correction with and without accounting for cloud effects, i.e.,

$$(1 - Q)\left[C_2\, ln(cos\theta_Z)^2 \; - \; C_1\, ln(cos\theta_Z)\right]$$





Cloud correction coefficient (annual global mean)



1330 UTC 28 June 2015 Aqua MODIS and SEVIRI Air Mass RGB

Air Mass RGB Aqua MODIS/ SEVIRI

- Limb correction in cloudy regions improves interpretation of both high and low clouds

Cumulonimbus

33	a	b	39
31	c	d	

Low Stratus

32	a	b	22
11	c	d	

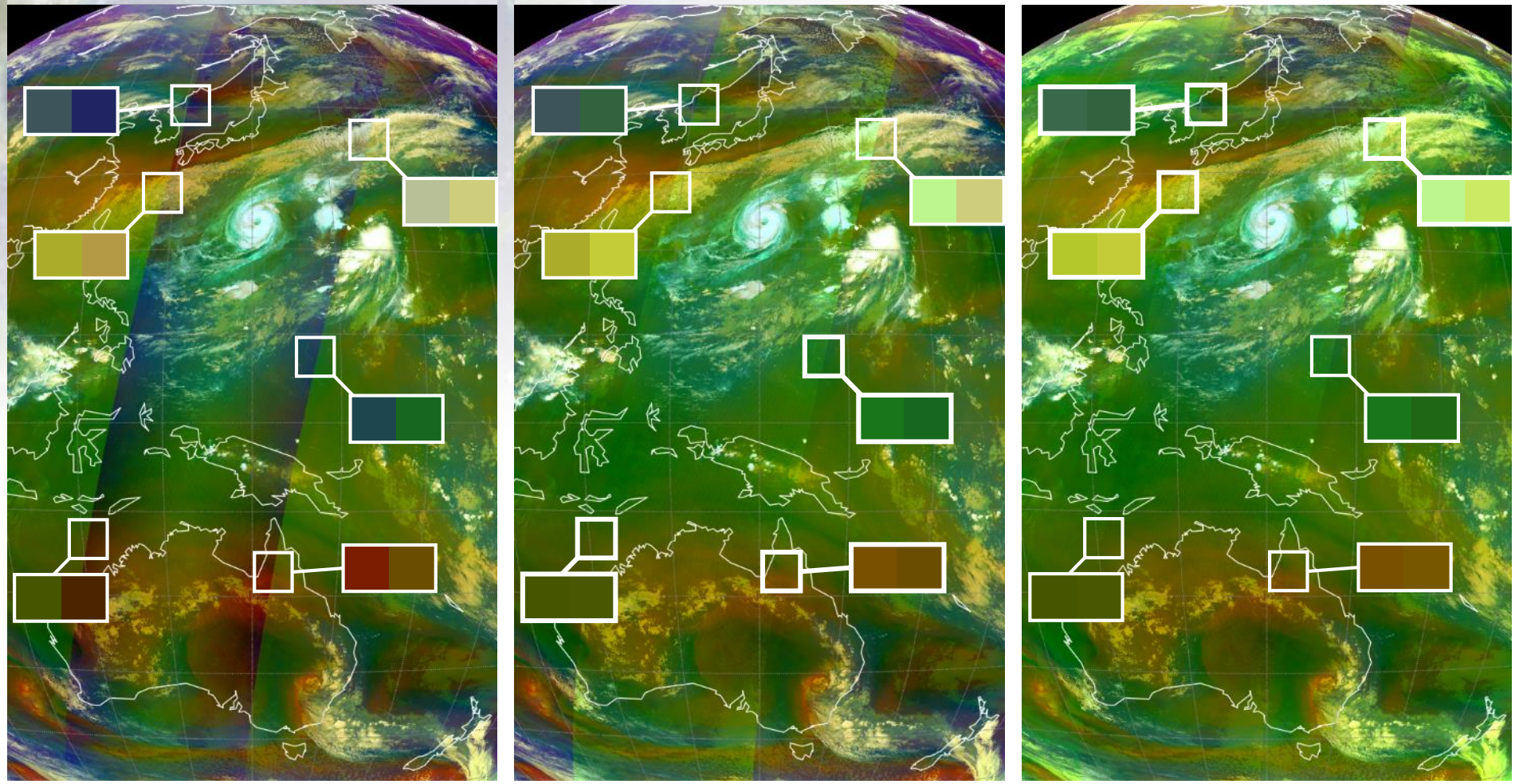
*Values indicate Euclidean distance from (d) in RGB space

Air Mass RGB – Aqua MODIS/AHI

Original

Corrected Aqua MODIS

Corrected Aqua MODIS/AHI*



1640 UTC 21 October 2015 Aqua MODIS and AHI Air Mass RGB

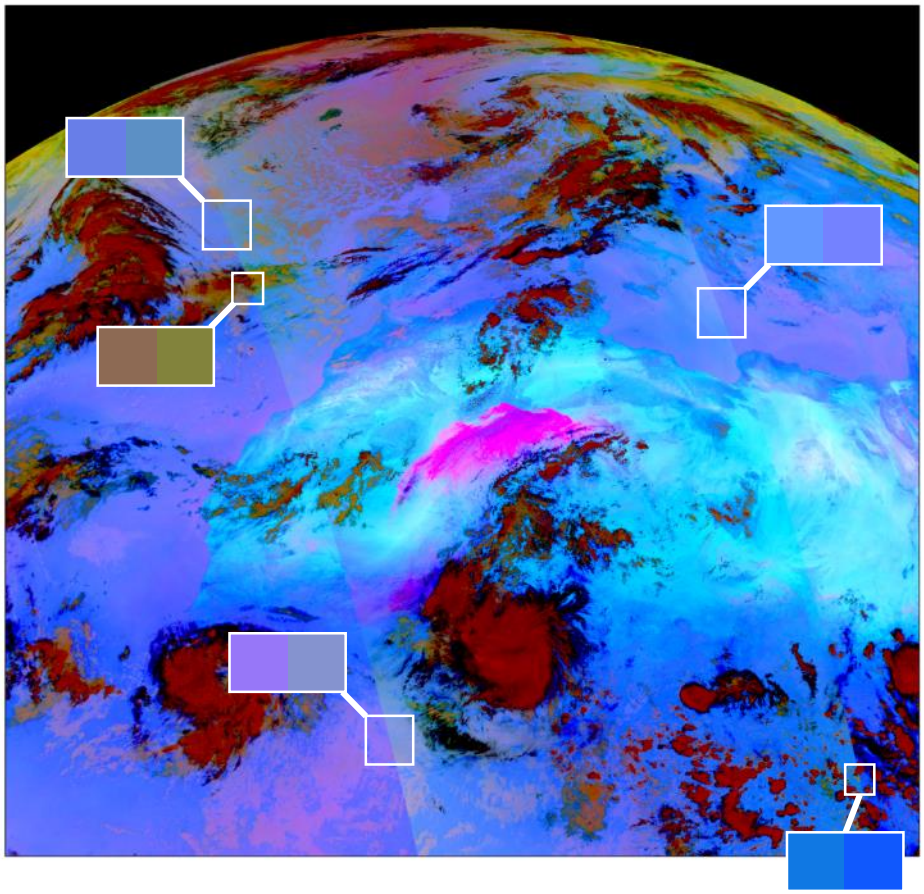
*Cloud effects not accounted for in AHI imagery

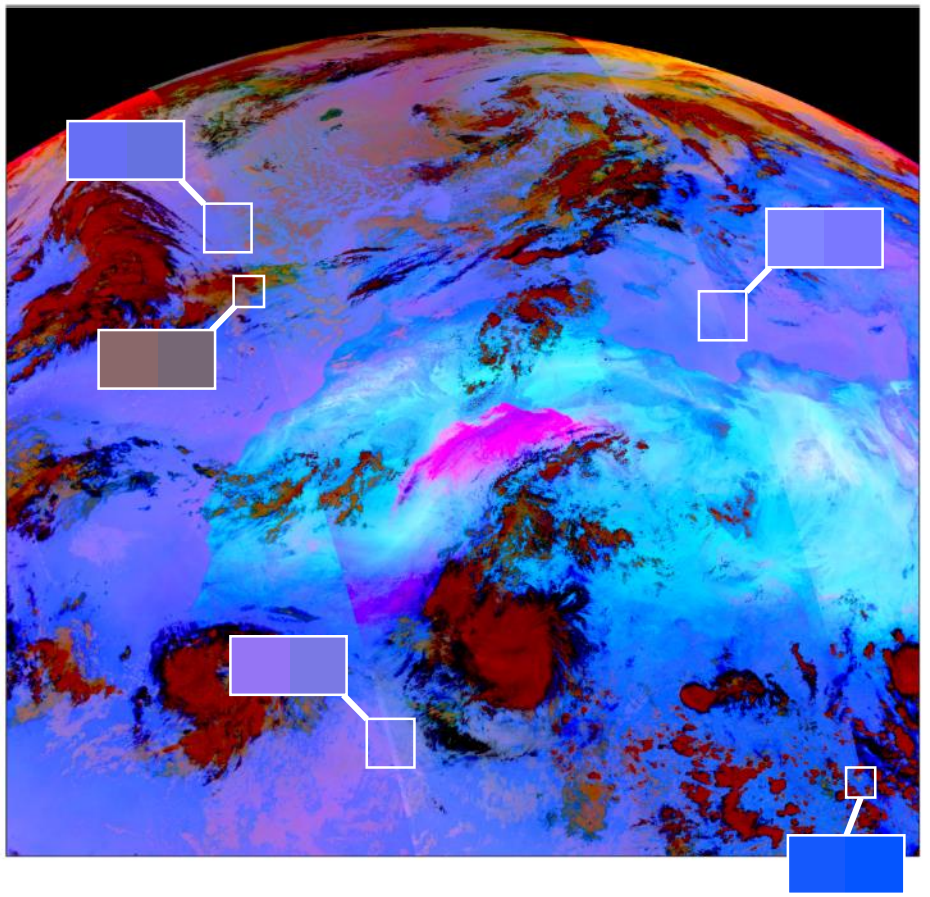
Dust RGB – VIIRS/SEVIRI

- Dust RGB (8.7, 11, 12 µm) less sensitive to limb effects, but correction still improves interpretation in clear and cloudy regions

Original

Limb-corrected*





1245 UTC 3 September 2015 VIIRS and SEVIRI Dust RGB

*Cloud effects not accounted for in SEVIRI imagery

Summary

- Limb effects and some cloud effects can be removed from infrared imagery using latitudinally and seasonally dependent correction coefficients
- Limb correction in cloudy regions is a function of atmospheric transmittance from cloud top to sensor
- Required parameters for limb correction: **viewing zenith angle, latitude, and cloud top pressure**
- Corrected RGB composites **increase confidence in interpretation of RGB features and improve situational awareness**
- Corrected MODIS and VIIRS RGB composites are currently produced by NASA SPoRT for operational use
- Correction can be easily applied to future sensors, including **GOES-R ABI** imagery when data becomes available

Questions

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References

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