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

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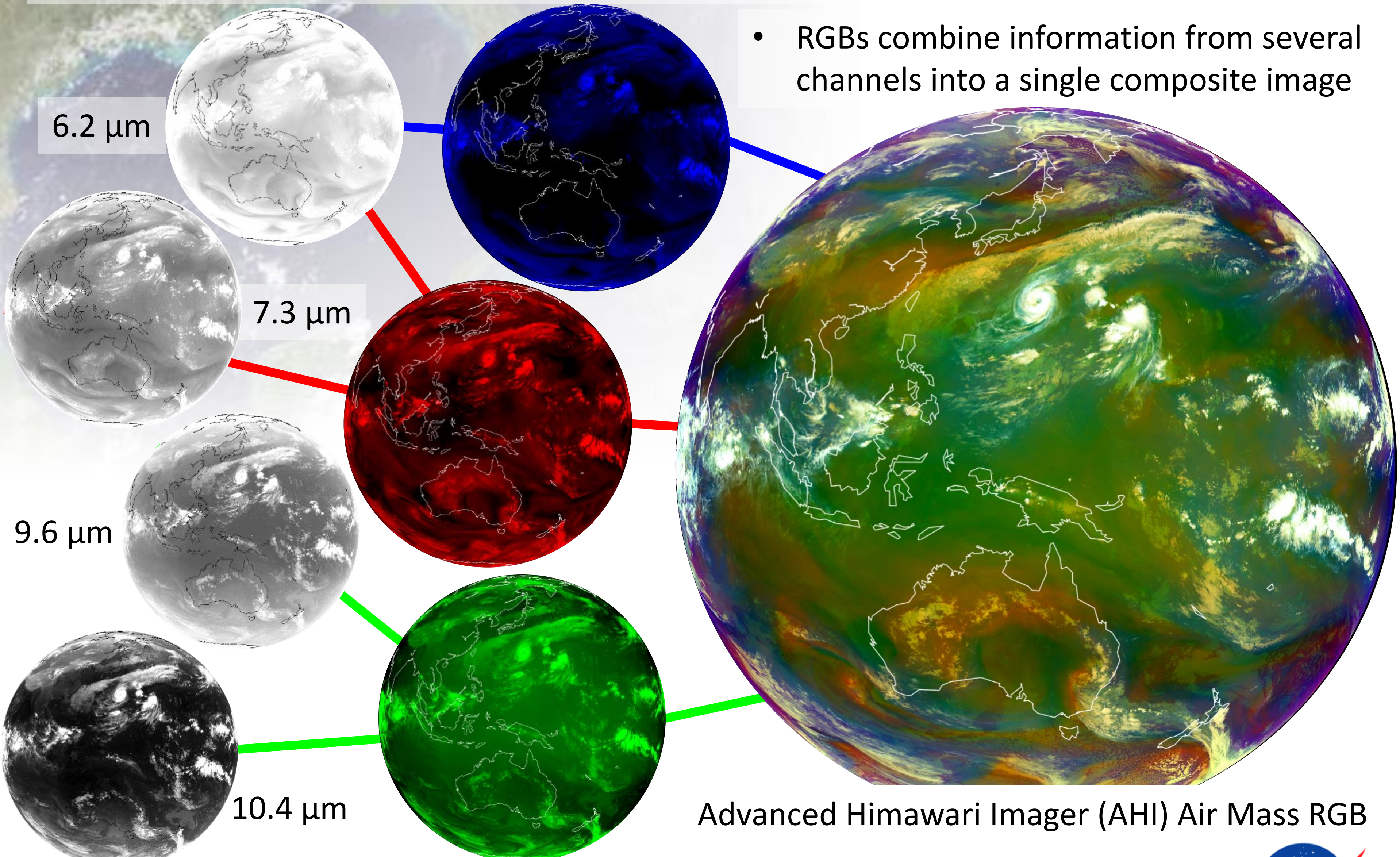
RGB Composites

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

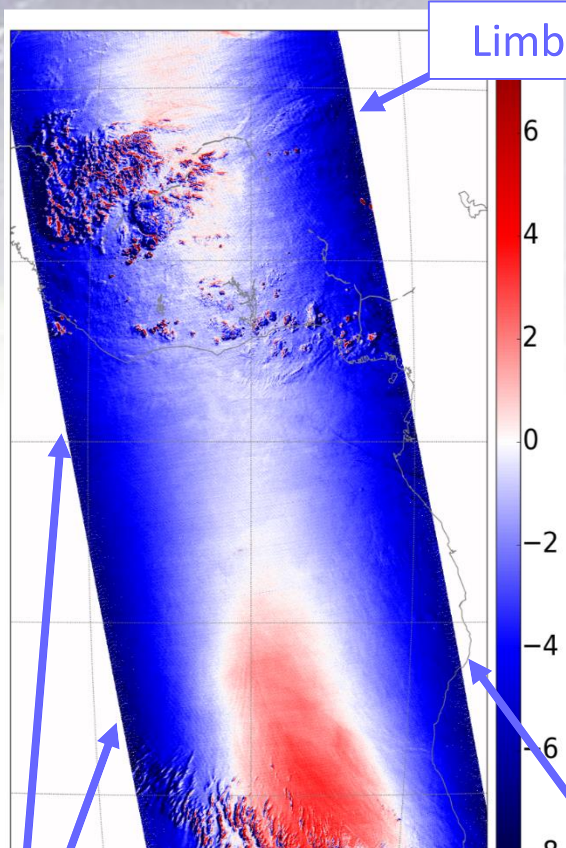


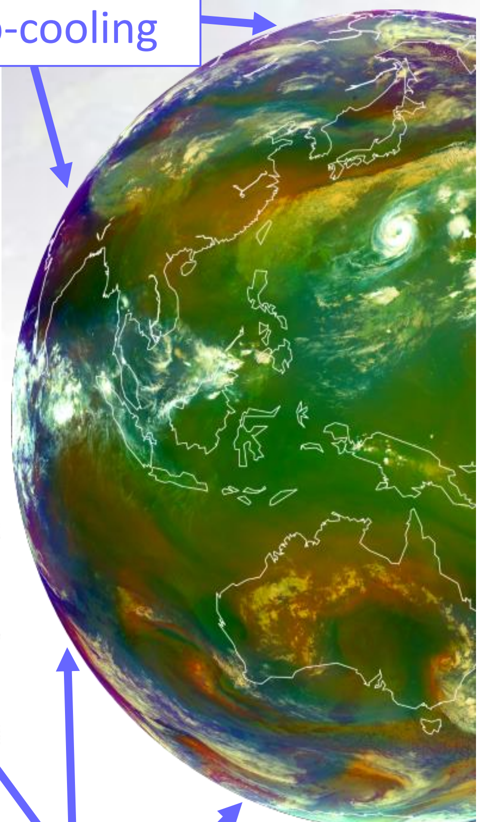
Advanced Himawari Imager (AHI) Air Mass RGB

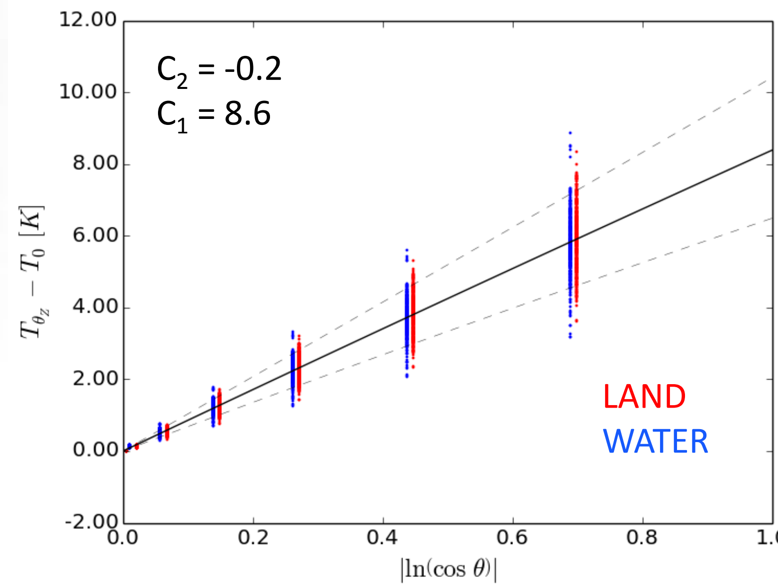
Limb Effect (Limb-Cooling)

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

- Infrared imagery from both polar-orbiting and geostationary sensors is affected by limb effects, which Interferes with qualitative interpretation of RGB composites at large scan angles







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

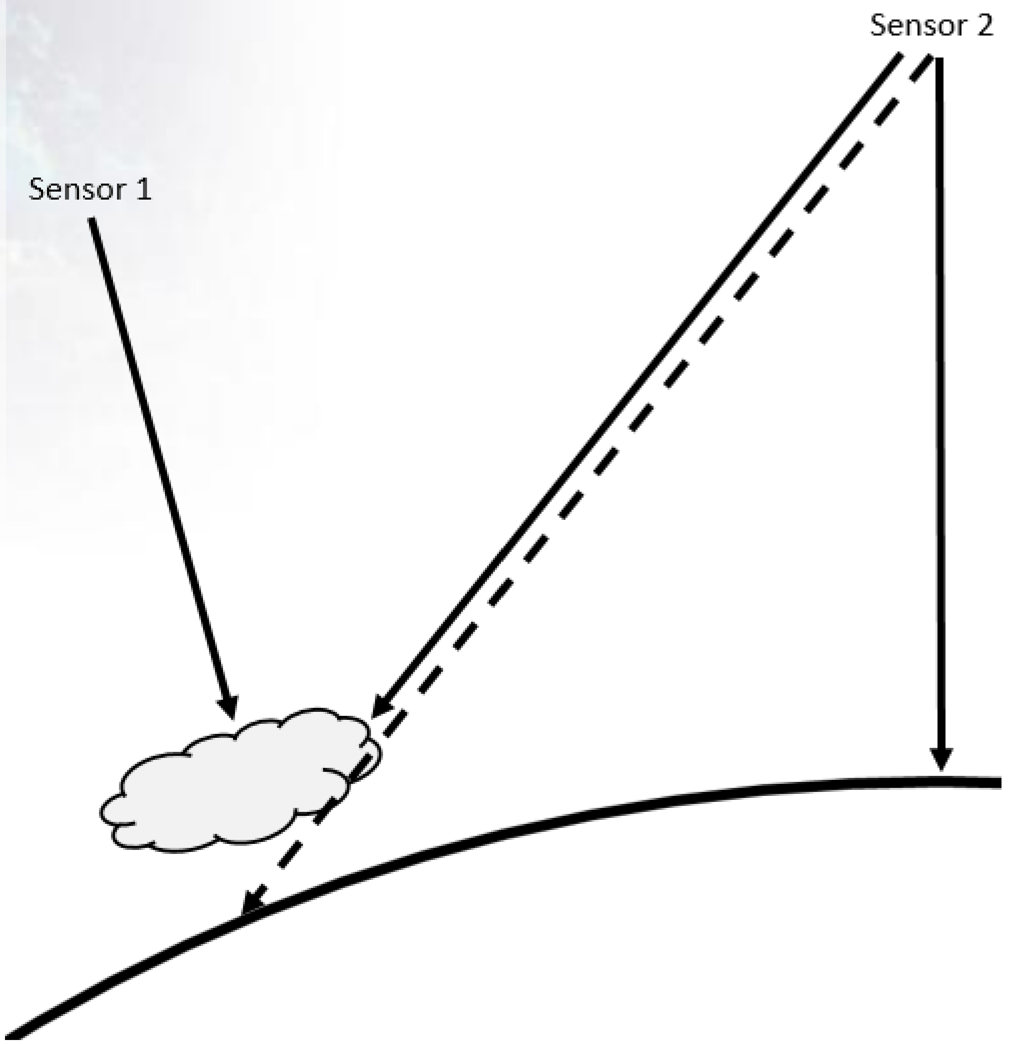
$$T_{\theta_Z} - T_0 = C_2|\ln(cos\theta_Z)|^2 + C_1|\ln(cos\theta_Z)|$$

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

Transitioning unique data and research technologies to operations

Cloud Effects

- Clouds contribute to limb effect
- Cloudy scene has shorter optical path length than clear scene
- Different parts of cloud likely have different temperatures and emissivities
- If limb effects are corrected in imagery without accounting for clouds, the limb correction will be inaccurate



Limb Correction in Cloudy Regions

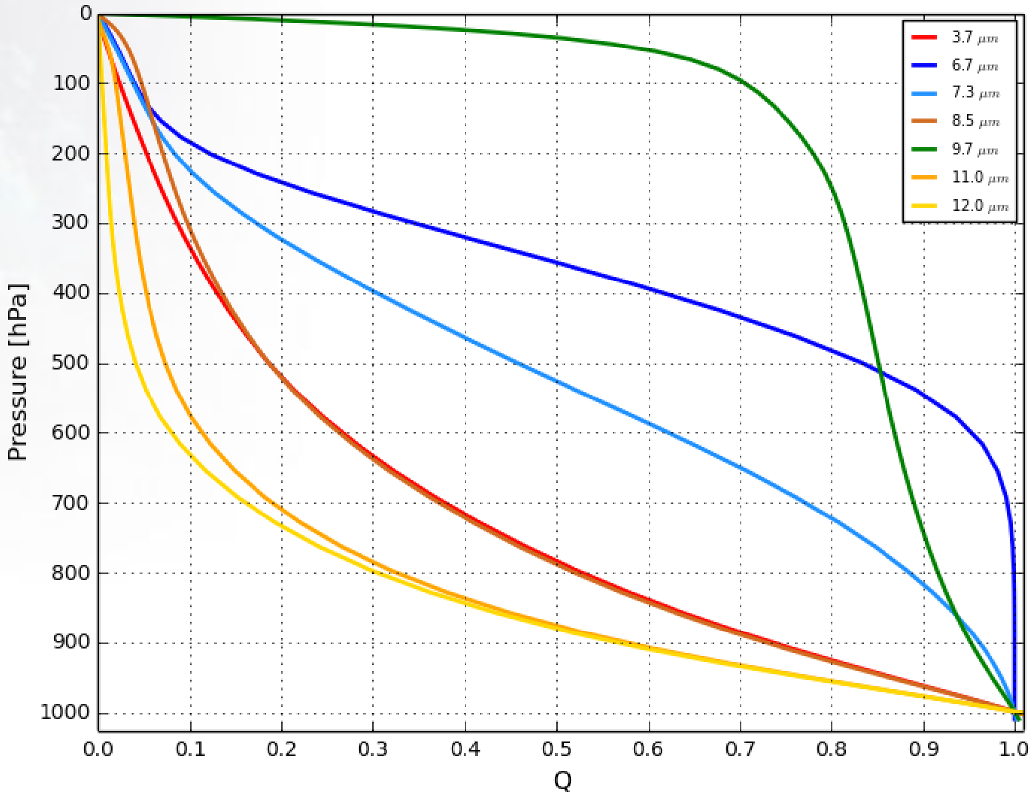
- Layer optical thickness (τ_l) calculated from JCSDA Community Radiative Transfer Model (CRTM; Han et al. 2006)
- Cloud correction coefficient (Q) calculated from τ_l using the equations:

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

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

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

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



Latitudinally and seasonally averaged Q values

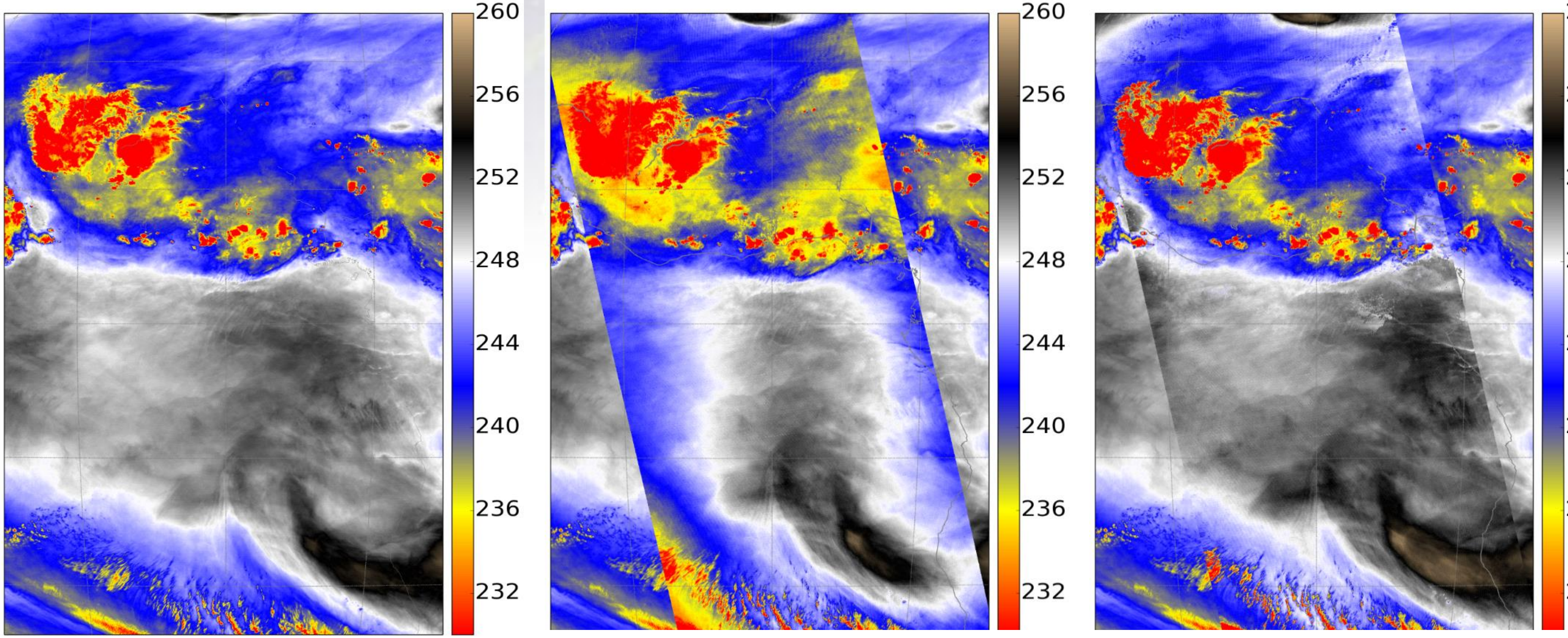
Limb Correction

- Limb Correction Equation:

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



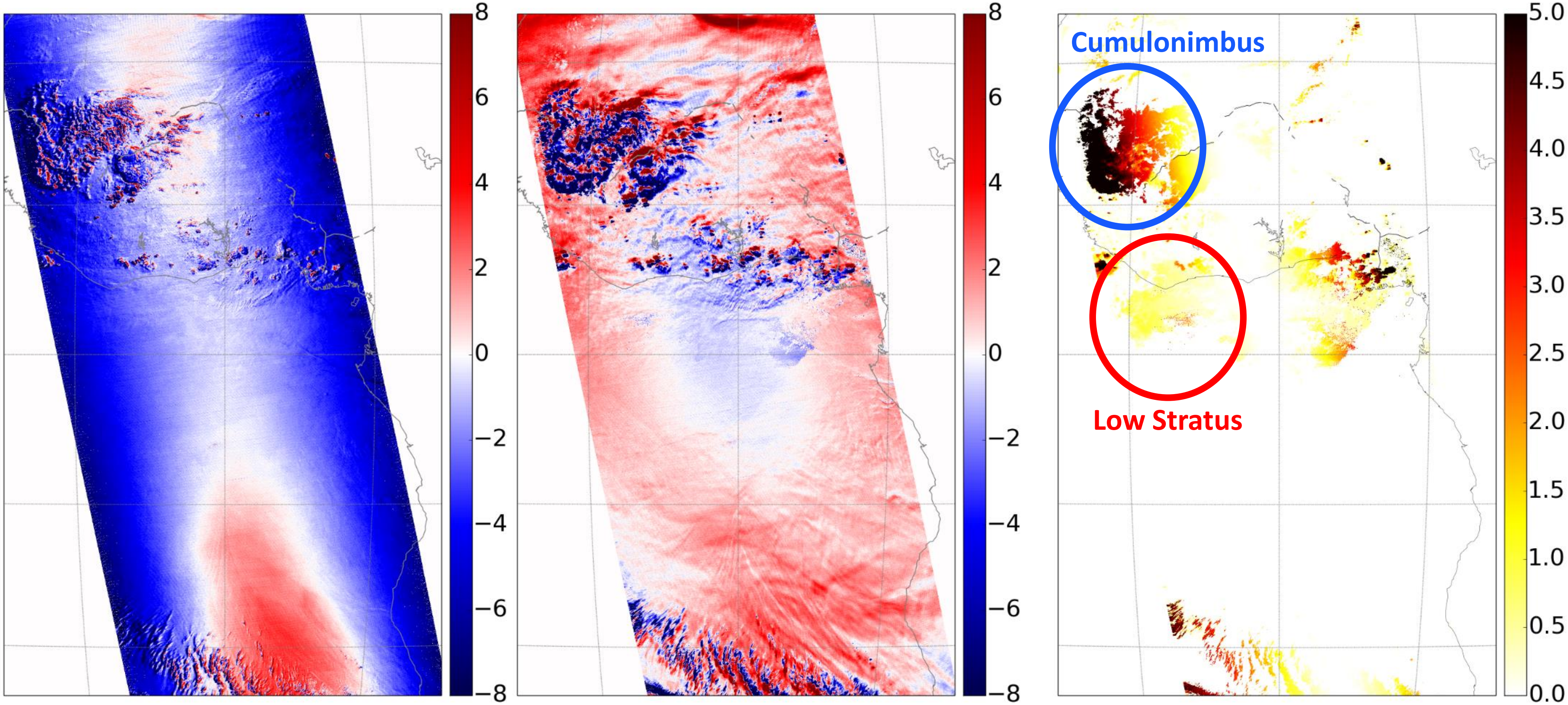
1330 UTC 28 June 2015 Aqua MODIS 6.7 µm and SEVIRI 6.2 µm brightness temperature

Limb Correction

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

Original Aqua MODIS minus SEVIRI

Corrected Aqua MODIS minus SEVIRI



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

Correction in cloudy regions

Air Mass RGB Aqua MODIS/ SEVIRI

- Limb correction of Aqua MODIS Air Mass RGB in cloudy regions improves interpretation of both high and low clouds

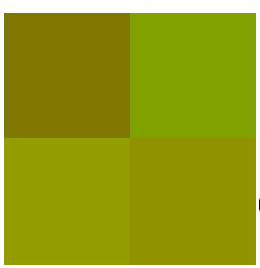
Cumulonimbus

(220,255,255) (223,255,226)

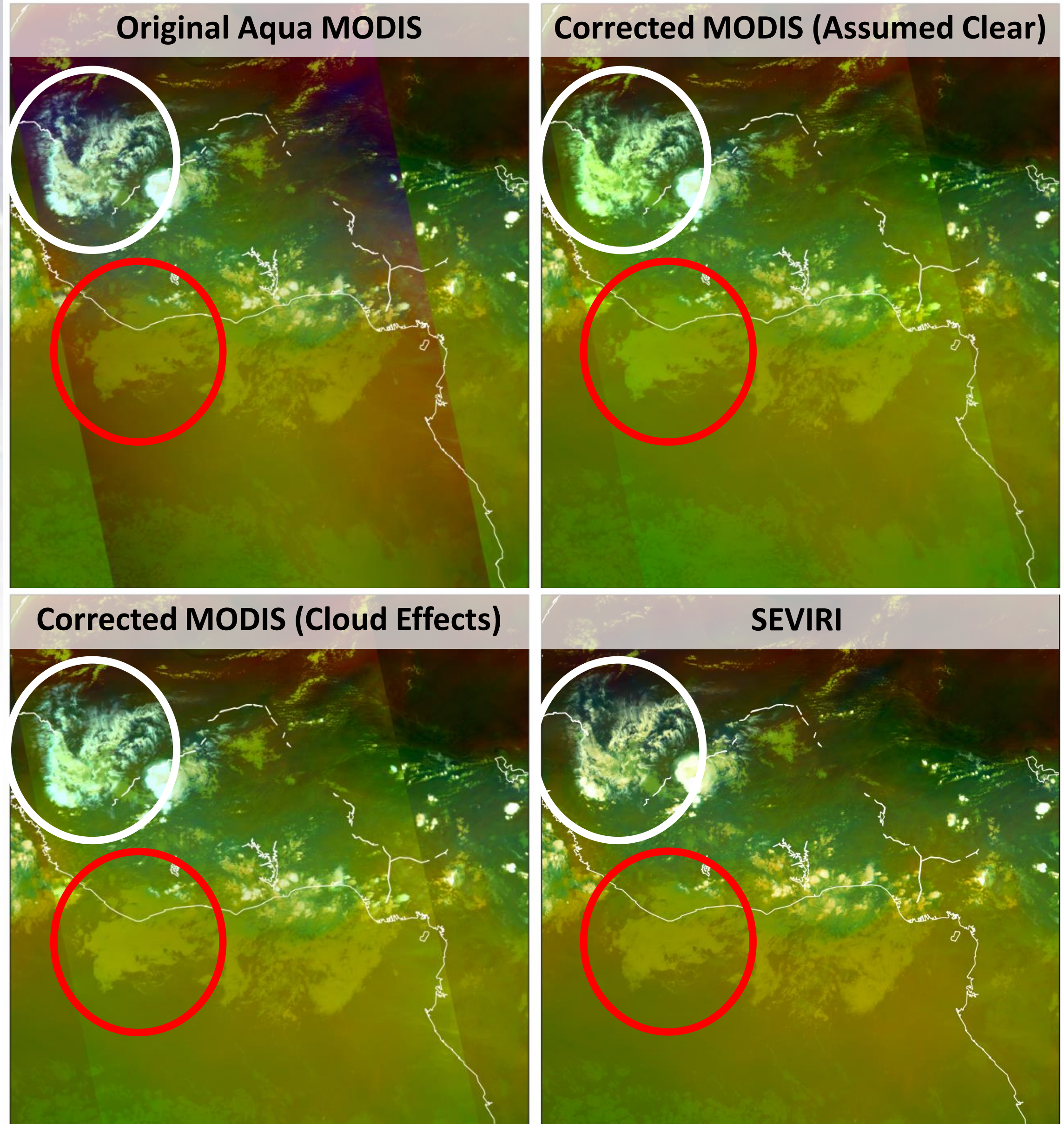
(222,255,255) (253,255,251)

Low Stratus

(128,119,0) (128,162,0)



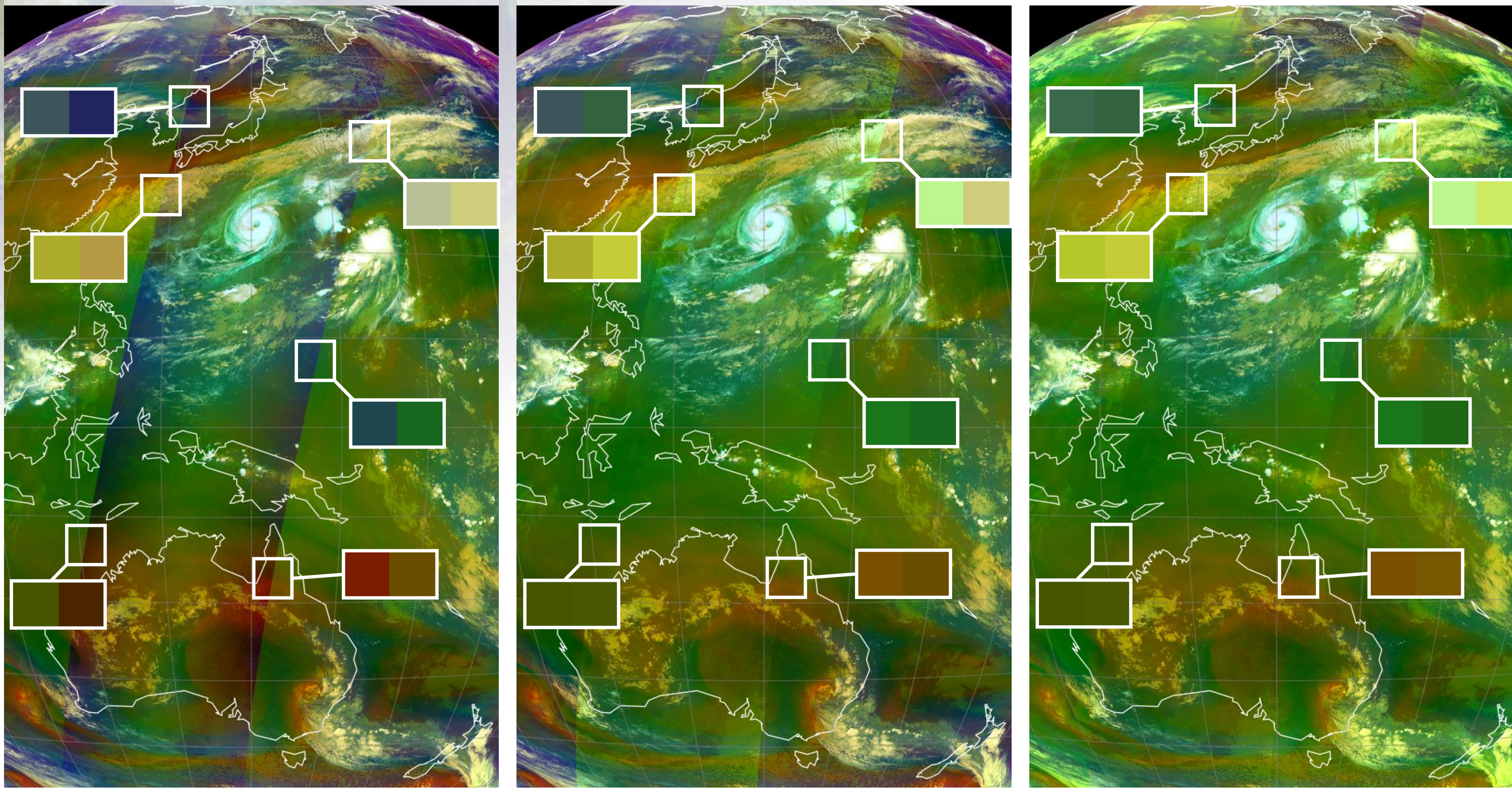
(148,157,0) (144,147,0)



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

Air Mass RGB – Aqua MODIS/AHI

Original | Corrected Aqua MODIS | Corrected Aqua MODIS/AHI*



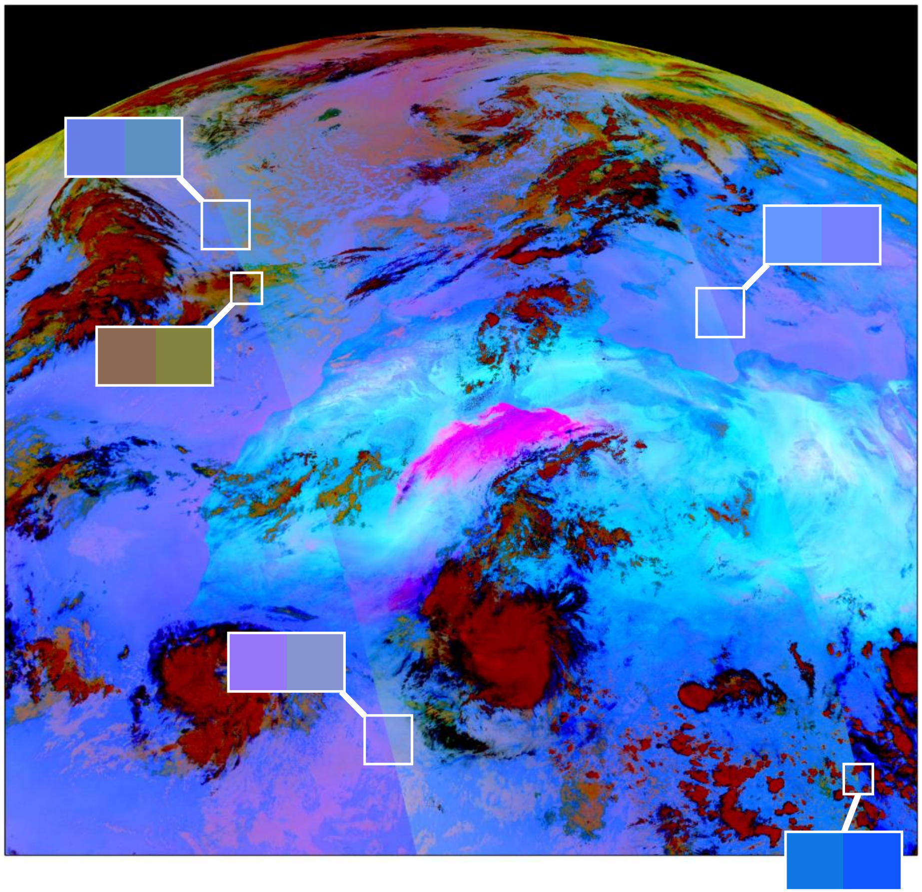
1640 UTC 21 October 2015 Aqua MODIS and AHI Air Mass RGB

*Cloud effects not accounted for in AHI imagery

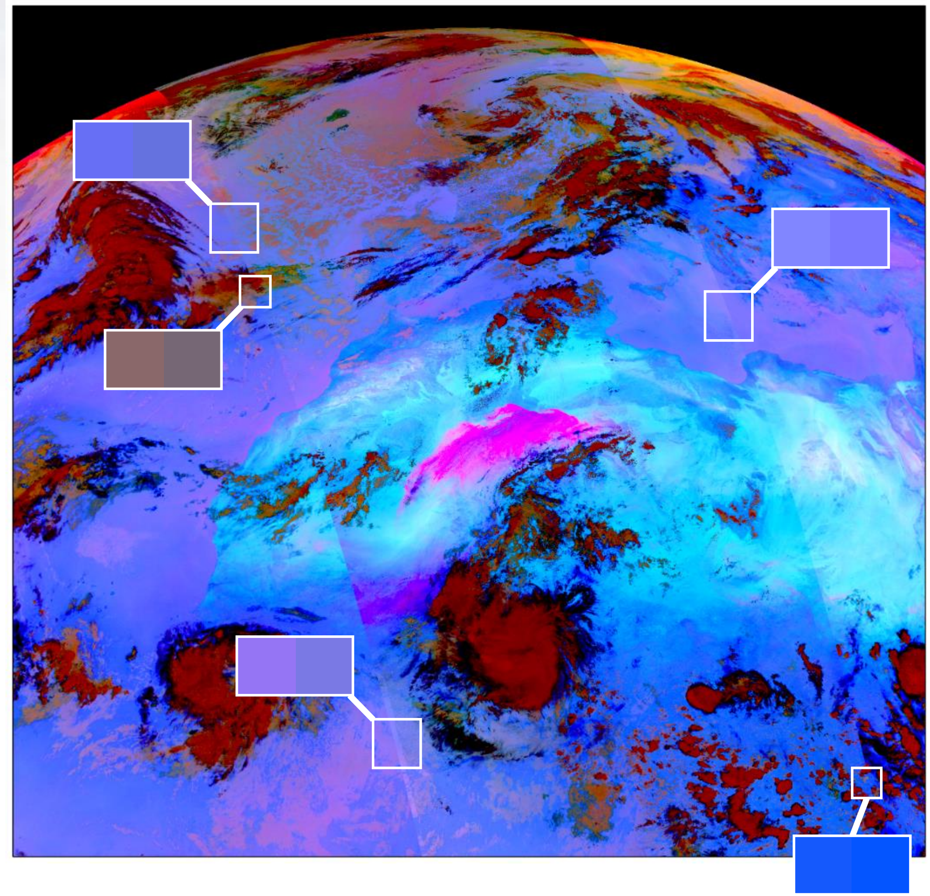
Dust RGB – VIIRS/SEVIRI

- Dust RGB 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 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
- Cloud effects were not addressed in imagery from geostationary sensors (future work)

Questions

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