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

6.2 μm
7.3 μm
9.6 μm
10.4 μm

Advanced Himawari Imager (AHI) Air Mass RGB

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Limb Effect (Limb-Cooling)

- **Limb-cooling** occurs as the viewing zenith angle ($\theta_Z$) 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 $\theta_Z$ (both polar-orbiting and geostationary sensors)

Aqua MODIS minus SEVIRI brightness temperature difference (6.7 μm)
Limb Correction in **Clear Regions**

- **Spread largely due to seasonal variations**

  \[ C_2 = -0.2 \]

  \[ C_1 = 8.6 \]

- **Limb-cooling in MODIS band 27 (6.7 \( \mu \)m) 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 ($\tau_l$) calculated from JCSDA Community Radiative Transfer Model (CRTM; Han et al. 2006)

- Cloud correction coefficient ($Q$) calculated from $\tau_l$:

  \[
  t_l(p) = e^{-\tau_l(p)}
  \]
  
  \[
  t(p) = t_l(p) \cdot t(p - 1)
  \]
  
  \[
  Q(p) = \frac{t(0) - t(p)}{t(0) - t(p_s)}
  \]

- For clear regions, $Q=1$

- $Q$ varies latitudinally and seasonally, similar to limb correction coefficients $C_1$ and $C_2$
Limb Correction

• Limb Correction Equation:

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

• Applicable to both polar-orbiting and geostationary sensors

(Elmer et al. 2016)

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)
Air Mass RGB
Aqua MODIS/SEVIRI

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

Values indicate Euclidean distance from (d) in RGB space
Air Mass RGB – Aqua MODIS/AHI

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

*Cloud effects not accounted for in AHI imagery

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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

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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