LIMB CORRECTION OF POLAR-ORBITING IMAGERY FOR THE IMPROVED INTERPRETATION OF RGB COMPOSITES

In response to CGMS action A43.12

Presented to CGMS-44 Group II session, WP-03, agenda item WGII/8

Coordination Group for Meteorological Satellites

NEED FOR LIMB CORRECTION OF RGB COMPOSITES

- Multispectral and hyperspectral satellite sensors incorporate channels in both visible and infrared (IR) wavelengths to gather useful information about atmospheric and surface conditions.
- Red-Green-Blue (RGB) composites are derived from combinations of individual channels
  - RGB composites designed to address a specific forecast problem, such as identifying general air mass characteristics, airborne dust, or low-level clouds and fog
  - Contain more qualitative information than single channel imagery alone.
  - RGB composites allow forecasters to quickly gather the information they need, enhancing their situational awareness and enabling them to make decisions in a more efficient and timely manner.

- ***However, the interpretation of RGB composites derived from polar orbiting or geostationary satellite imagery can be problematic, particularly at large scan or view angles because of the increased atmospheric absorption in individual channels away from nadir viewing.***

METHODOLOGY – LIMB CORRECTION OF INDIVIDUAL CHANNELS

- Account for the absorption and scattering effects of the atmosphere path from the surface to the satellite – minor in window channels, large in water vapor and ozone channels
- Earlier studies (e.g., Soden and Bretherton 1993, 1996; Joyce and Arkin 1997; Joyce et al. 2001) calculated the change in brightness temperature (BT) from nadir to the limb using collocated geostationary satellite pairs.
- Use simulated top of atmosphere (TOA) brightness temperatures (BT) at varying angles derived from JCSDA CRTM using profiles of temperature, ozone mass mixing ratio, and specific humidity from the RCMWF global reanalysis.
    - A total of 12,657 profiles representative of clear scenes from March 2013 through February 2014 were used to represent variations temperature, water vapor, ozone
    - Profiles / TBs were separated by land (3670) and water (8987) locations
    - CRTM BTs were binned by latitude (15° intervals) and month to account for latitudinal and seasonal variability, but longitudinal variability was ignored

METHODOLOGY – LIMB CORRECTION OF INDIVIDUAL CHANNELS

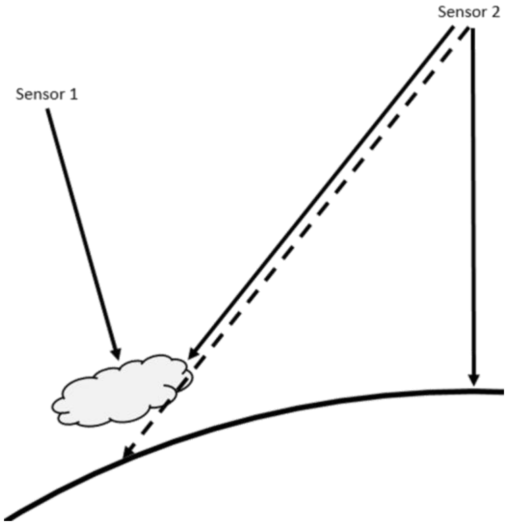
- Limb correction coefficients, which account for the increasing optical path length, were derived based on the CRTM simulated brightness temperatures.
- The quadratic equation,

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

  is used to describe the θz-BT relationship, where T_{θ} is the TCRTM at nadir, $T_{\theta z}$ is the TCRTM at θz, and the quadratic best fit parameters, C2 and C1, are defined as the limb correction coefficients, which vary latitudinally and seasonally.
- The yearly correlation for water vapor bands is greater than 0.96, however the average correlation of the monthly data was 0.99, indicating that the spread was primarily due to seasonal variability.

METHODOLOGY – CLOUDY REGIONS

- Clouds decrease the optical path length and limb correction scaling factors (Q) are calculated from the CRTM layer optical depth from the cloud to the satellite.
- Not all clouds are opaque with an emissivity of 1.0, but the assumption provides an acceptable approximation for correcting for most cloud effects.



- The limb correction equation for cloudy regions is given by

$$T_{CORR} = T_B - T_{OFFSET} + Q\left(C_2(\phi,\delta)\ln(\cos\theta_z)^2 - C_1(\phi,\delta)\ln(\cos\theta_z)\right)$$

where the optical path length limb correction scaling factor (Q) is a function of cloud height and varies between 0 for high clouds and 1 for no clouds.

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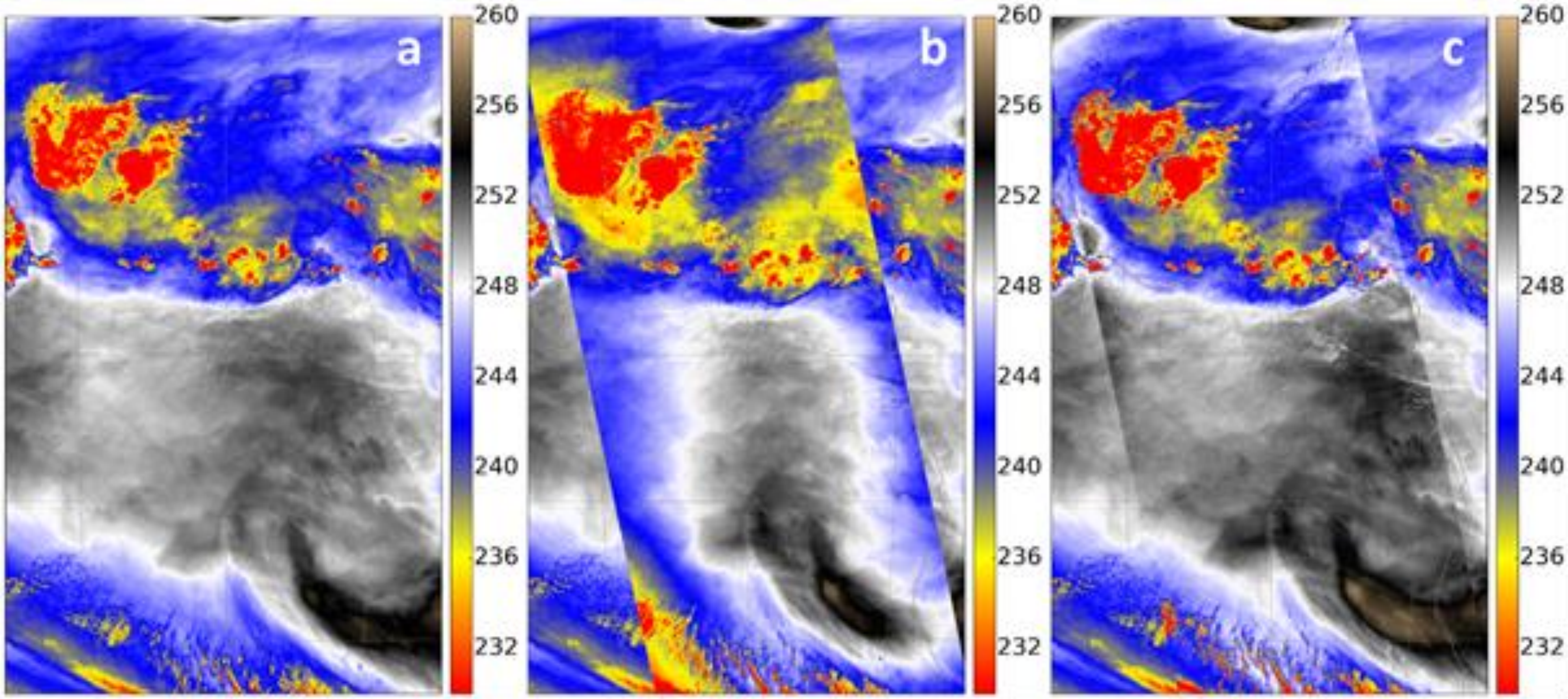
APPLICATION OF LIMB CORRECTION TECHNIQUE

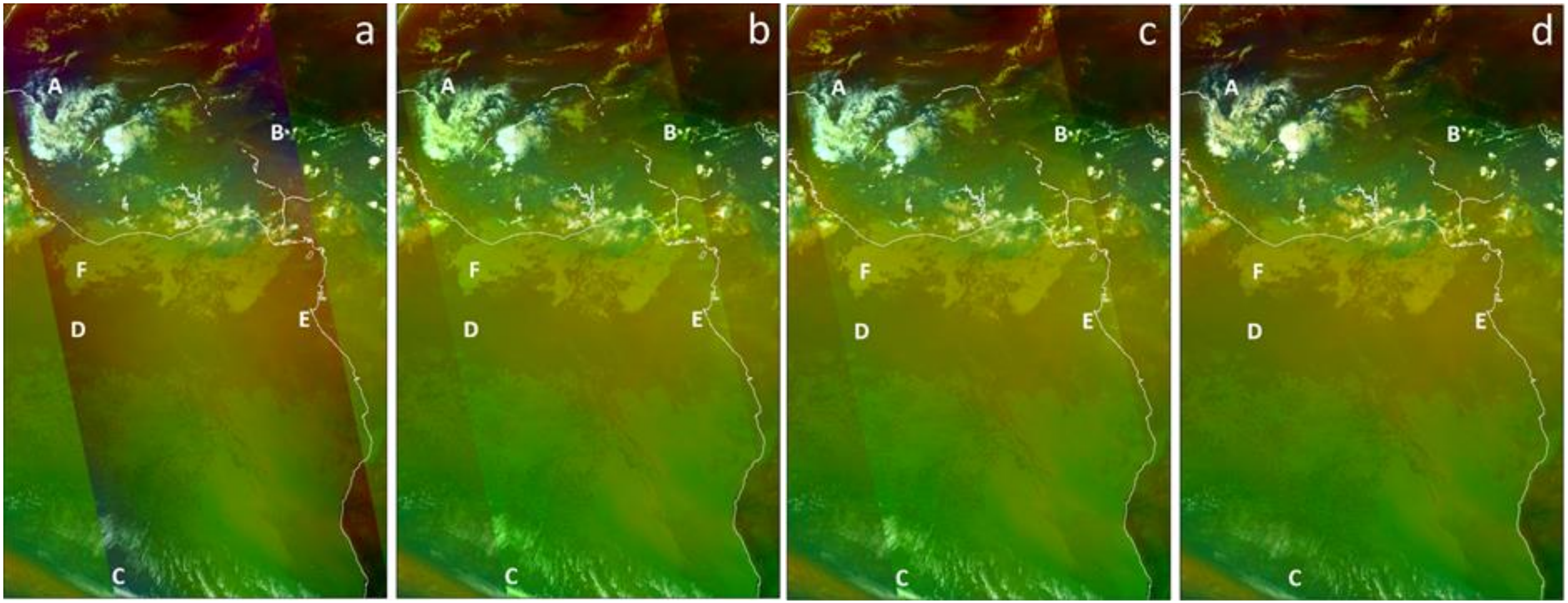
Limb-corrected MODIS imagery with SERVIRI



1330 UTC 28 June 2015 (a) SEVIRI band 5 (6.2 µm) brightness temperatures (K) overlaid with (b) uncorrected and (c) corrected (limb and cloud effects) Aqua MODIS band 27 (6.7 µm) brightness temperatures (K).

APPLICATION - LIMB CORRECTED RGB COMPOSITES

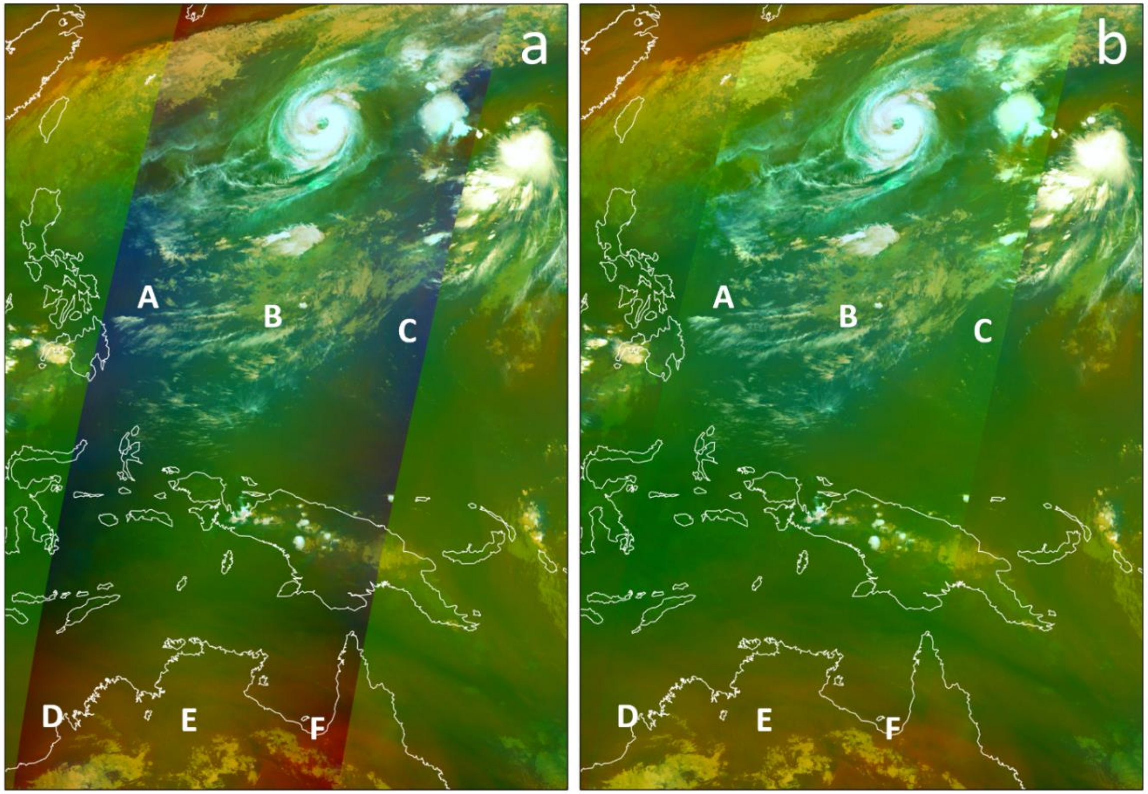
Limb-corrected MODIS Air Mass RGB imager with SERVIRI



1330 UTC 28 June 2015 (a) uncorrected, (b) corrected (limb effects only), and (c) corrected (limb and cloud effects) Aqua MODIS Air Mass RGB overlaying (d) the corresponding SEVIRI Air Mass RGB.

APPLICATION - LIMB CORRECTED RGB COMPOSITES

Limb-corrected MODIS Air Mass RGB image with AHI



1640 UTC 21 October 2015 (a) uncorrected and (b) corrected (limb and cloud effects) Aqua MODIS Air Mass RGB overlaying the corresponding AHI Air Mass RGB.

Summary

- Use of RGB composite imagery aid in the operational weather analysis. However, ***infrared channels are adversely affected by the limb effect, limiting the utility of the polar-orbiting composite products.***
- ***A limb cooling correction technique for individual IR channels has been developed*** and applied to polar-orbiting imagery before their combined to produce limb-corrected RGB composite image products.
- The approach
  - o develops latitudinally- and seasonally-varying correction coefficients from radiative transfer modeling and global weather forecast model data
  - o can be applied to infrared imagery from any polar-orbiting satellite
  - o used in clear and cloudy regions to produce a suite of limb-corrected RGB images
- ***Limb-corrected RGB composites increase confidence in interpretation of RGB features and improve situational awareness***
- Future work will address limb cooling and cloud effects in geostationary RGB composite imagery