Limb Correction of Individual Infrared Channels Used in RGB Composite Products

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ATMOSPHERIC SCIENCE

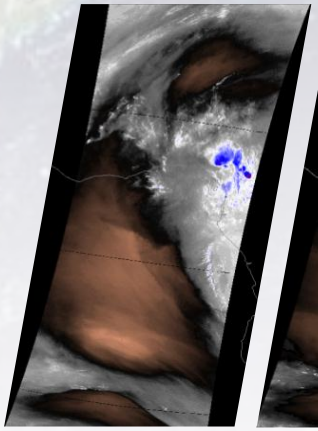
Transitioning unique data and research technologies to operations

Motivation

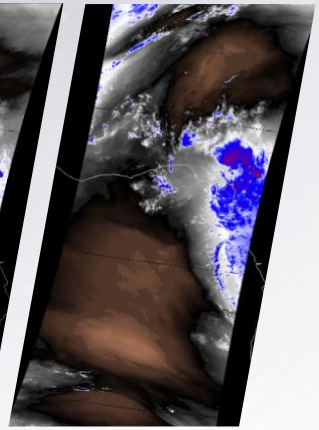
- Satellites monitor multiple spectral channels, but it is difficult to use all of these channels operationally, due to the vast amount of imagery available
- RGB (Red-Green-Blue) products aid the operational forecast community by **combining information from several channels** into one composite image, which **contains more qualitative information** than visible or infrared imagery alone and **enhances situational awareness**
- In preparation for GOES-R, RGB products derived from polar-orbiters are being used as proxy products
- Infrared imagery, particularly from polar-orbiters, is affected by limb effects, which prevents confident interpretation of RGB features at large scan angles
- Subtle channel differences between sensors can further complicate interpretation of RGB composites
- **To fully exploit the advantages of RGB products, it is necessary to correct the individual infrared channels for limb effects prior to creating the composites**

RGB Composites

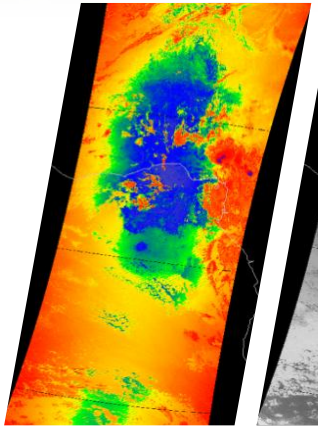
Original Channels



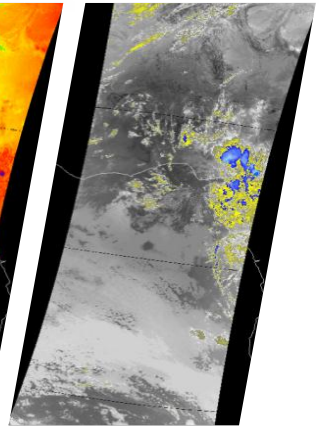
Water Vapor (6.7 µm)



Water Vapor (7.3 µm)



Ozone (9.7 µm)



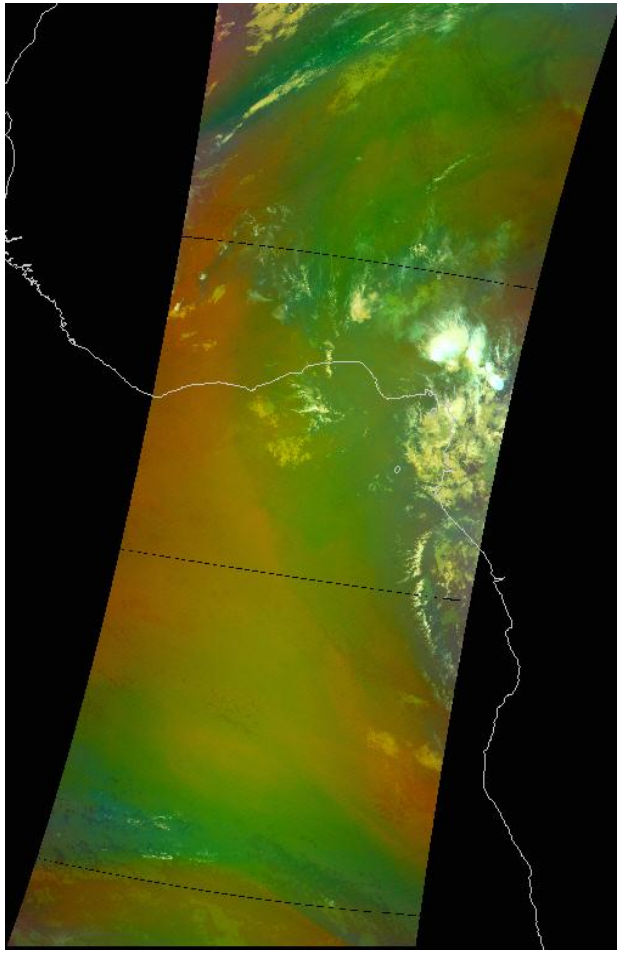
Infrared (11.0 µm)

- Combine information from several channels into one composite image
- Address specific forecast problem (e.g., airmass characteristics, airborne dust, low clouds/fog, etc.)
- Aid in quick analysis of atmospheric features

Air Mass RGB Recipe

Color	Band / Band Diff.	Physically Relates to….
Red	6.7 – 7.3	Vertical water vapor difference
Green	9.7- 10.7	Estimate of tropopause height based on ozone. Polar (tropical) air has higher (lower) ozone concentrations
Blue	6.7	Water Vapor in layer from ~200 – 500 mb

Final Product: Air Mass RGB



2014 October 29 0110 UTC
Aqua MODIS Air Mass RGB

Air Mass RGB Interpretation

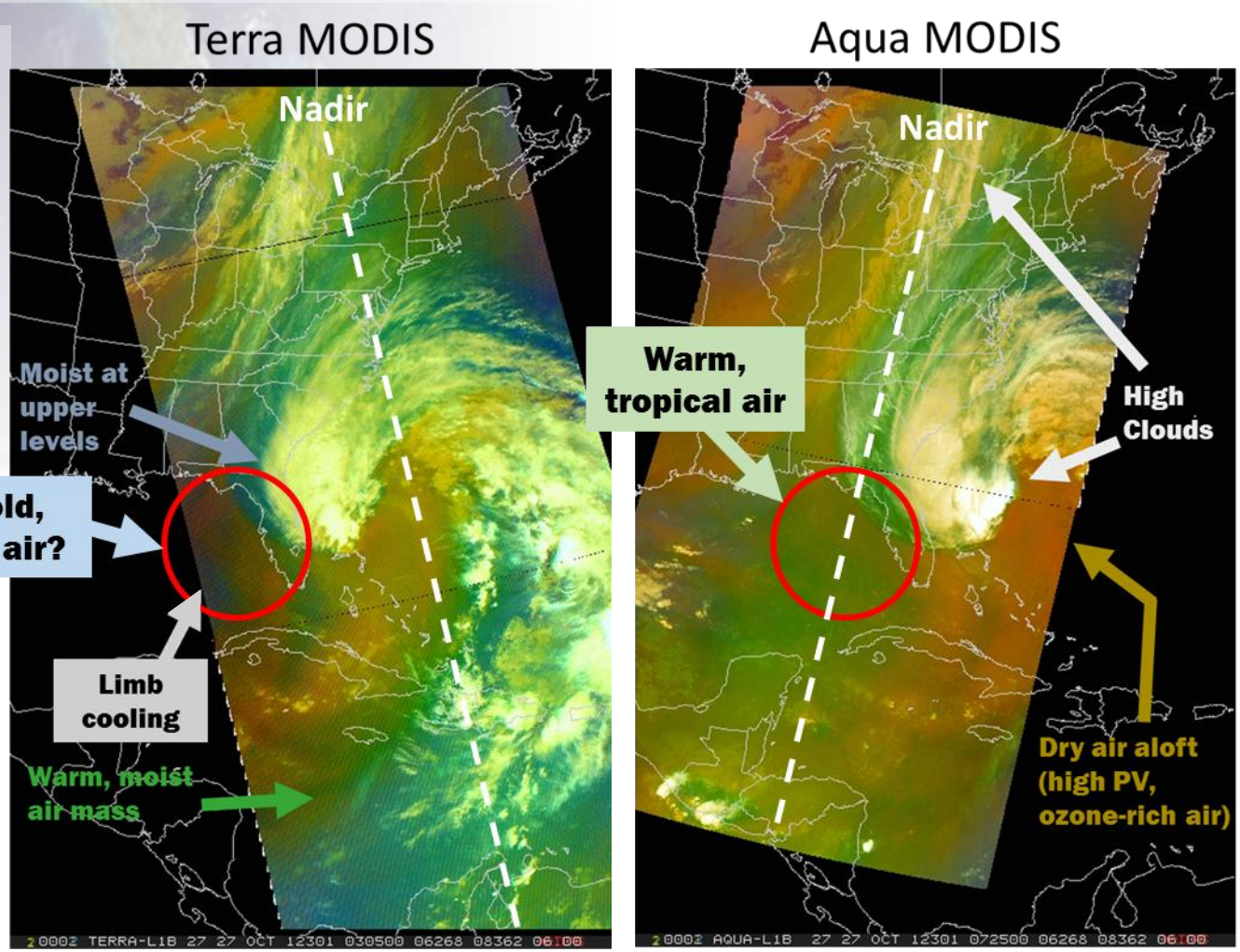
- Atmospheric and geometric effects (limb-cooling) prevent correct interpretation of features at large scan angles

  Ex. cold, dry air instead of warm, tropical air

- Forecasters may misinterpret these features

- Product can only be reliably interpreted close to nadir

- Subtle channel differences between sensors make comparison difficult



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

Limb Effect (Limb-Cooling)

Limb-cooling occurs as the satellite scans from nadir to the limb, increasing the optical path length of the absorbing atmosphere

Interferes with qualitative interpretation of RGB composites at large scan angles

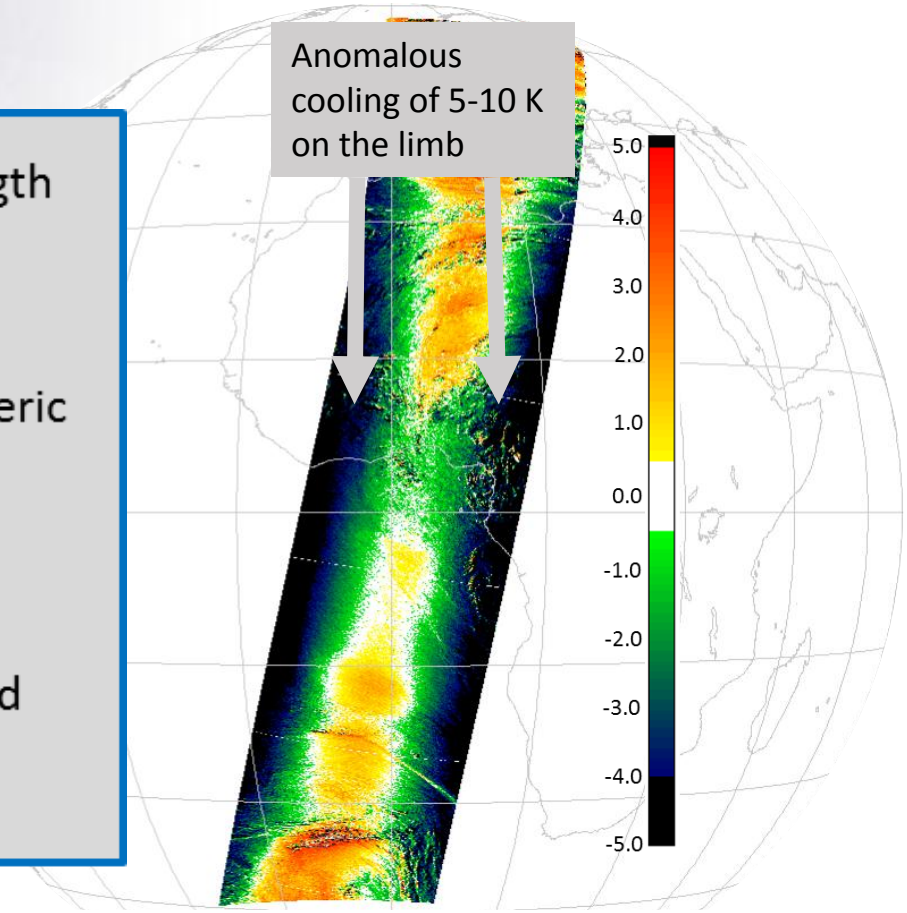
Longer Path Length

↓

Greater atmospheric absorption

↓

Lower measured brightness temperature



2014 Oct 29 0130 UTC Brightness Temperature Difference (BTD) between Aqua MODIS 6.7 µm (bias-corrected) and SEVIRI 6.3 µm

Limb Effect (Limb-Cooling)

- 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:

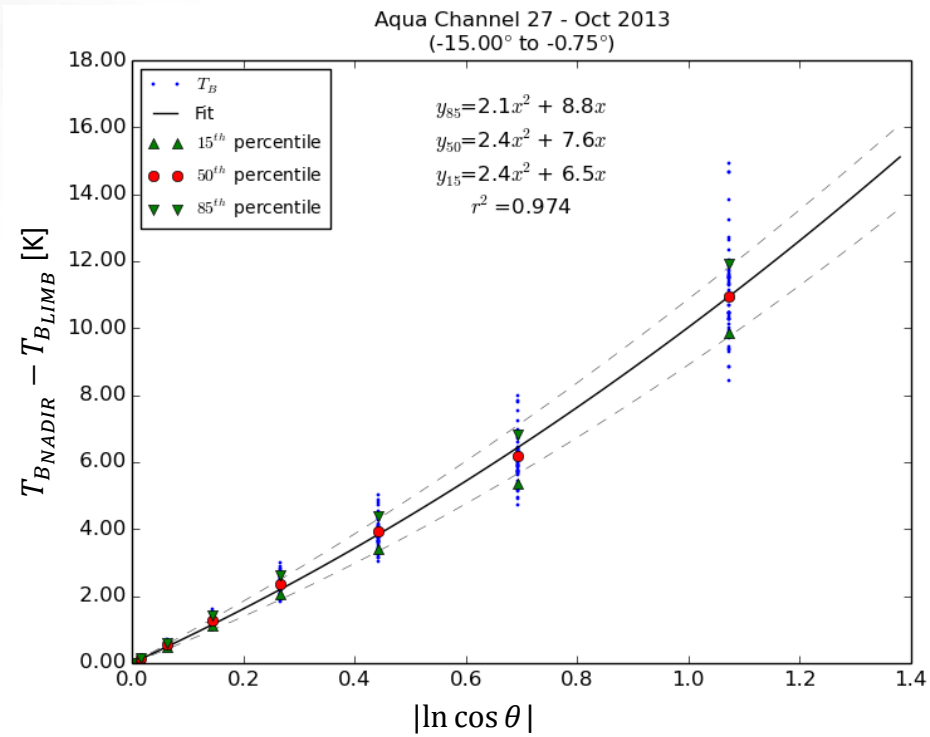
$$\mathbf{y = C_2 x^2 + C_1 x}$$

- 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 θ=60°

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

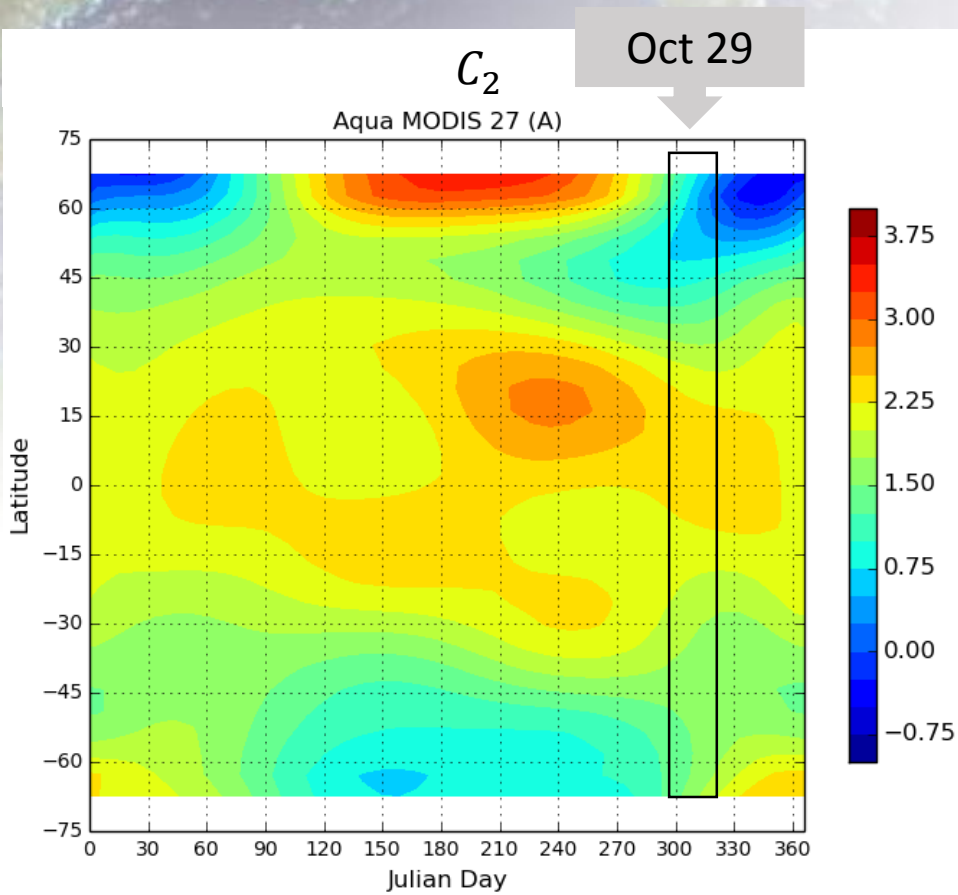
$$\mathbf{T_{corr} = T_{raw} - C_1 \ln(\cos\theta) - C_2 \ln(\cos\theta)^2}$$

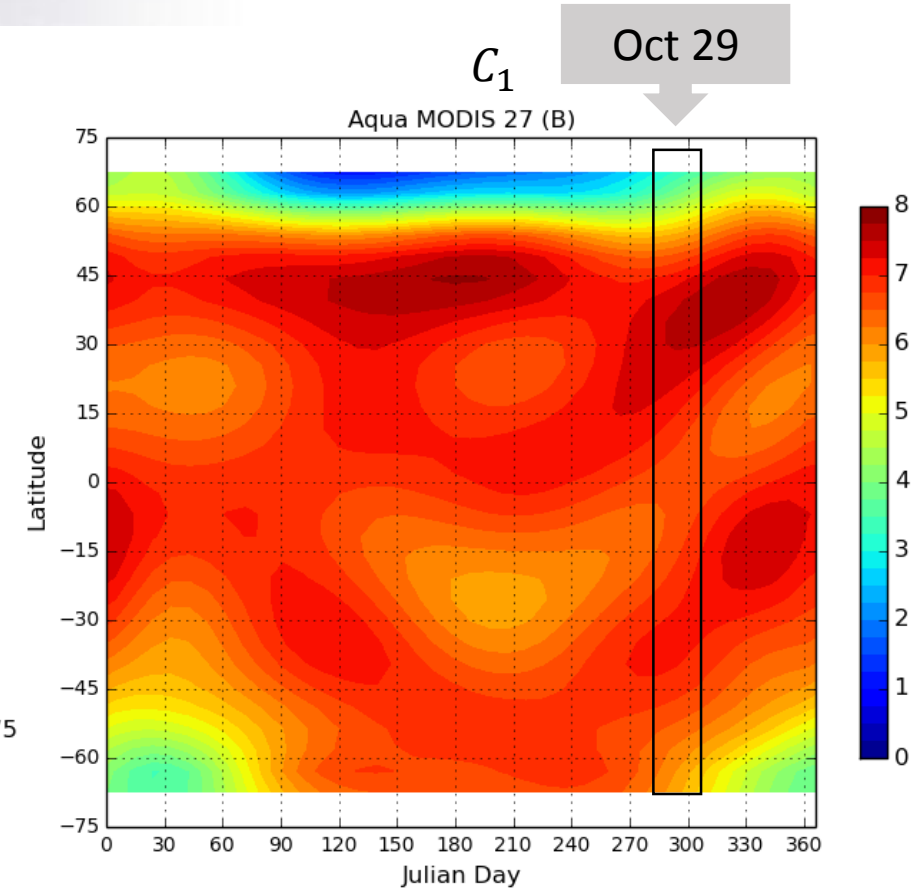
- **Correction coefficients vary latitudinally and seasonally!**



Correction Coefficients

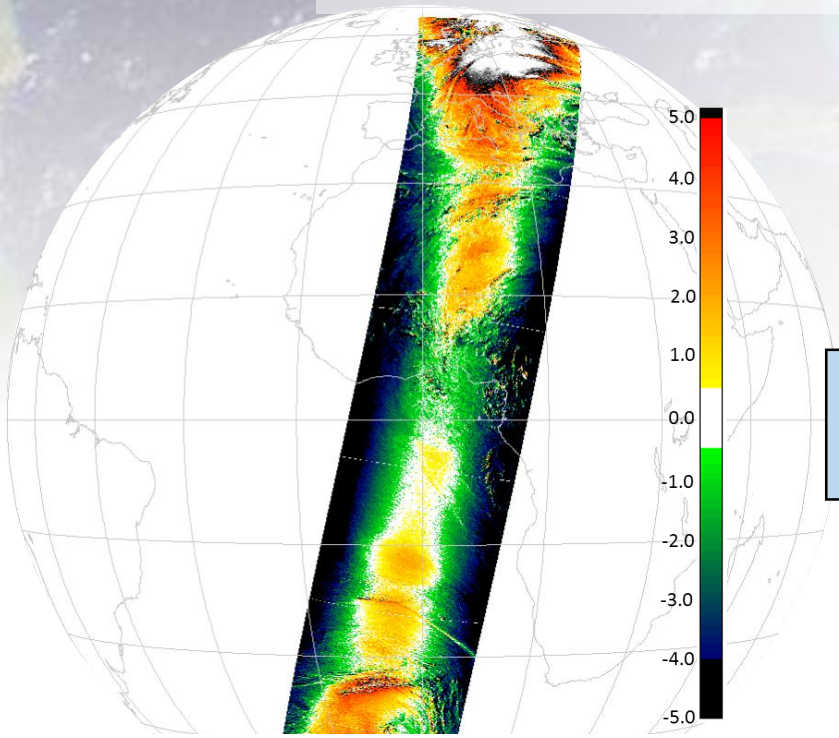
Correction coefficients are latitudinally and seasonally dependent!





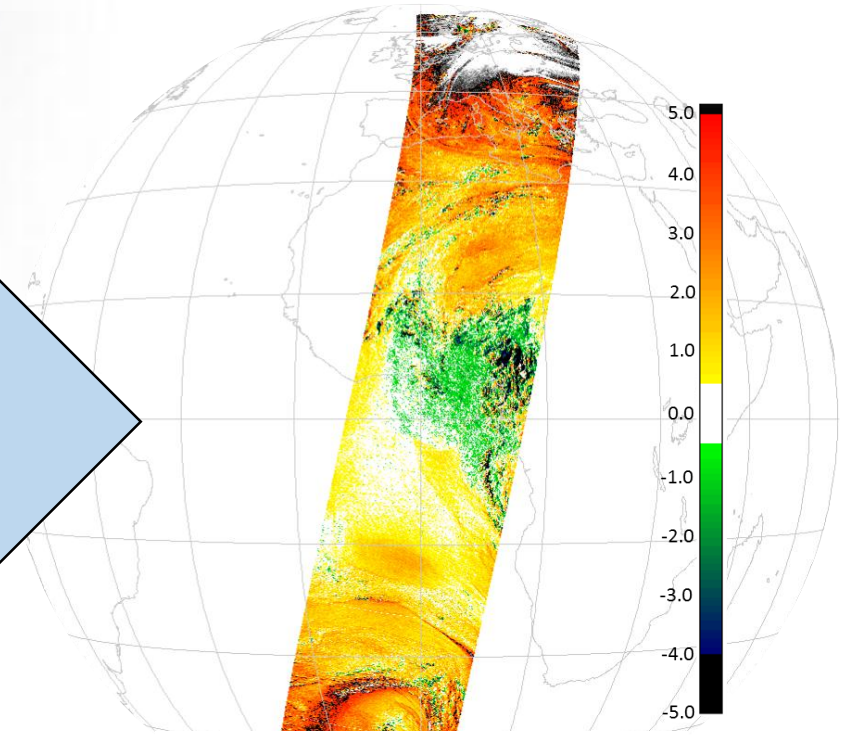
Limb Correction

- Bias correction already applied to account for channel differences
- Less than 1 K difference between SEVIRI and Aqua at the limb
- N-S variations due to SEVIRI limb-cooling



2014 Oct 29 0130 UTC BTD between Aqua MODIS 6.7 µm (bias-corrected) and SEVIRI 6.3 µm

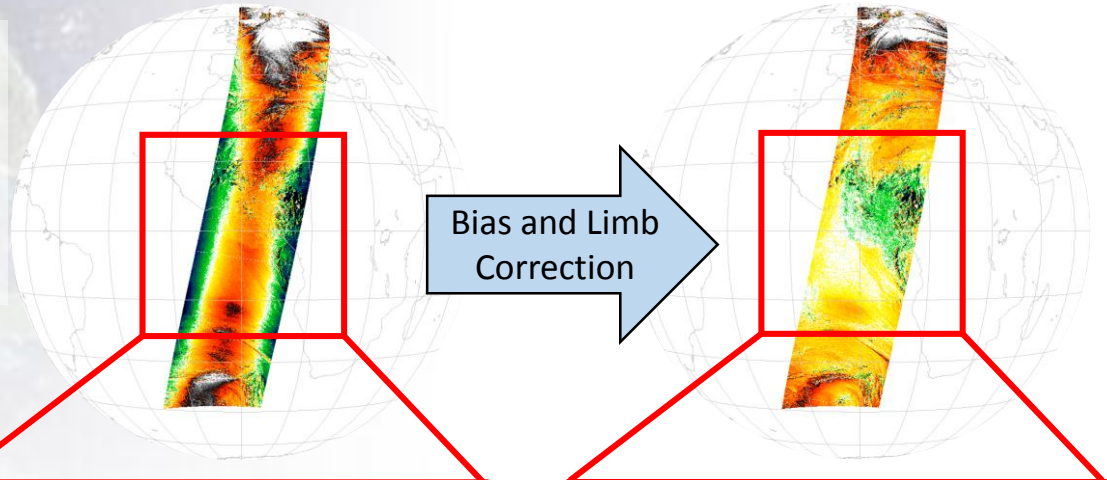
Limb Correction

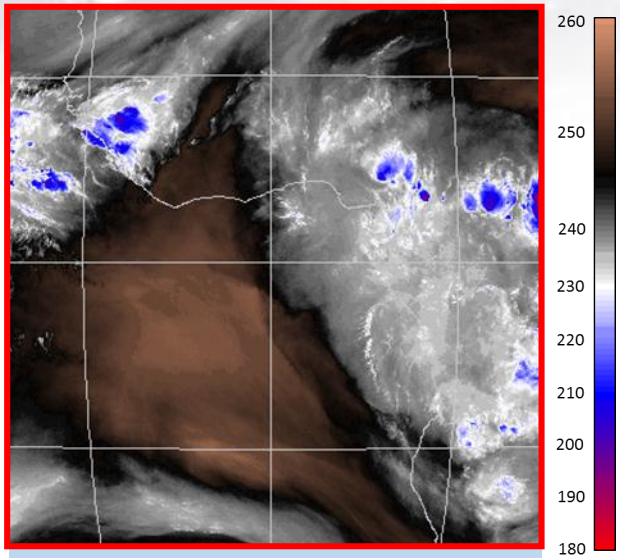


2014 Oct 29 0130 UTC BTD between Aqua MODIS 6.7 µm (limb-corrected) and SEVIRI 6.3 µm

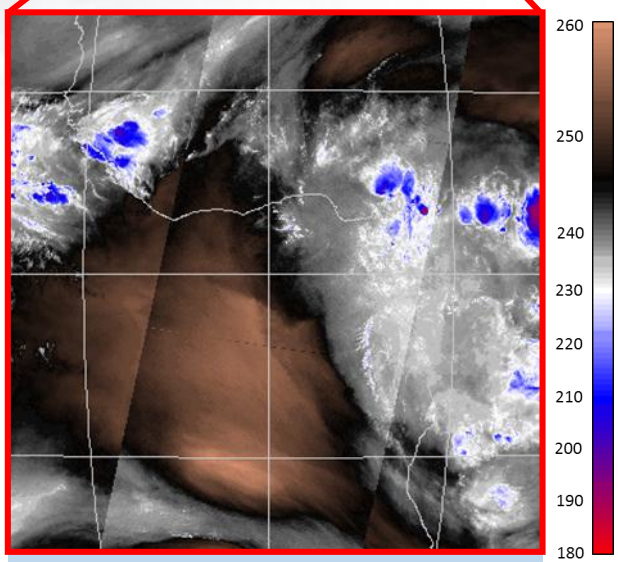
Results

- Correction removes cooling due to limb effect
- Corrected Aqua matches very closely with SEVIRI imagery

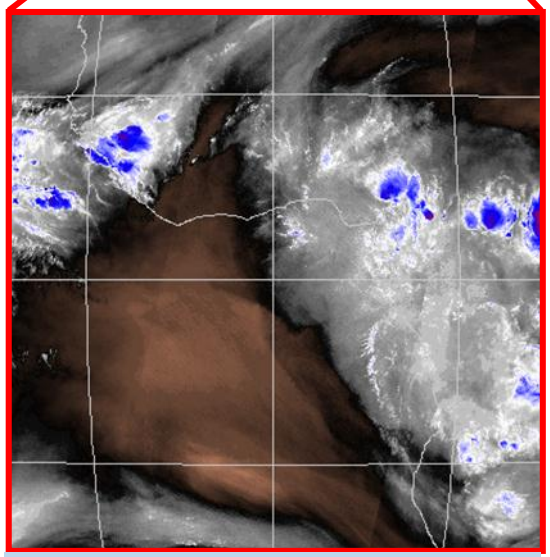




SEVIRI (6.3 µm)



Uncorrected Aqua MODIS (6.7 µm) merged with SEVIRI (6.3 µm)

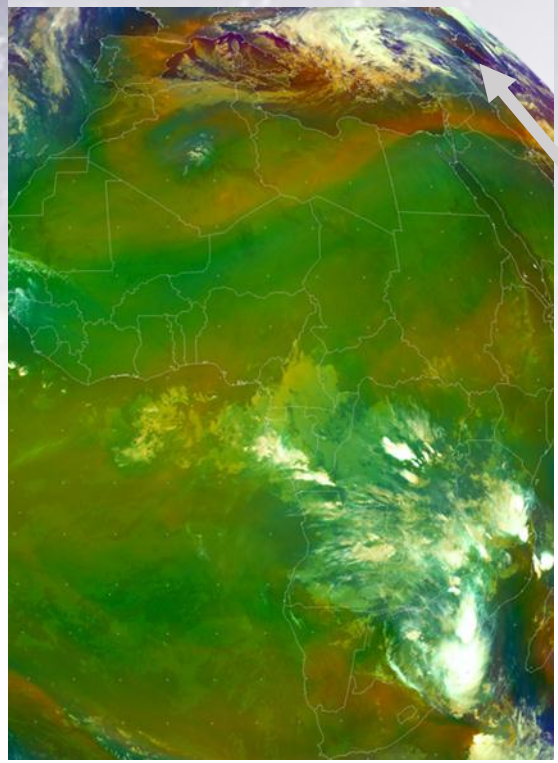


Corrected Aqua MODIS (6.7 µm) merged with SEVIRI (6.3 µm)

Air Mass RGB Example – Aqua/SEVIRI

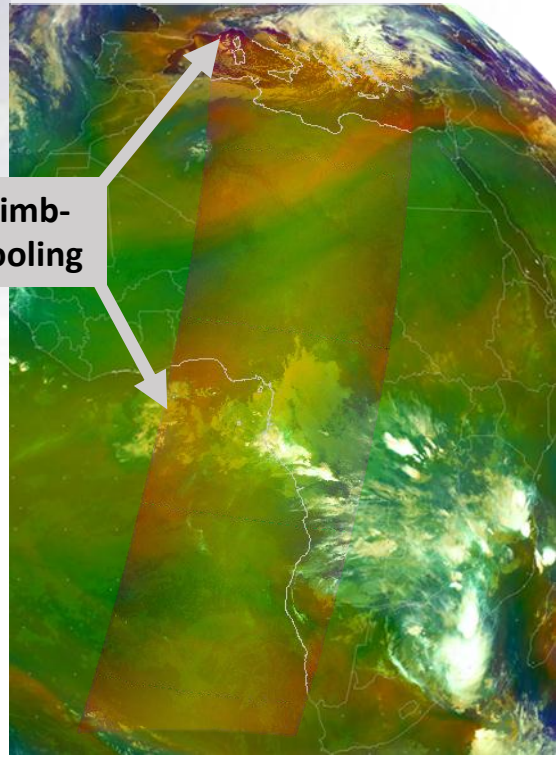
- Limb correction leads to significant improvement in ability to correctly interpret RGB product
- Slight over-correction in ozone channel

SEVIRI



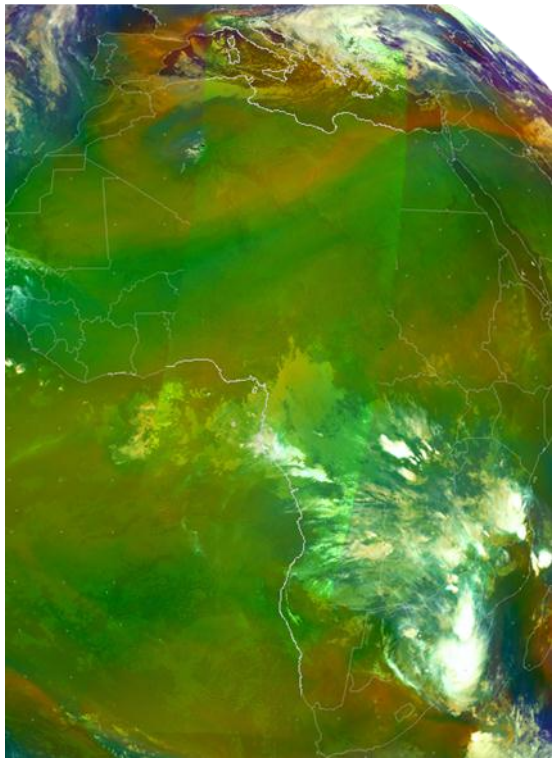
2014 December 29 SEVIRI (0100 UTC) Air Mass RGB

Original Aqua MODIS



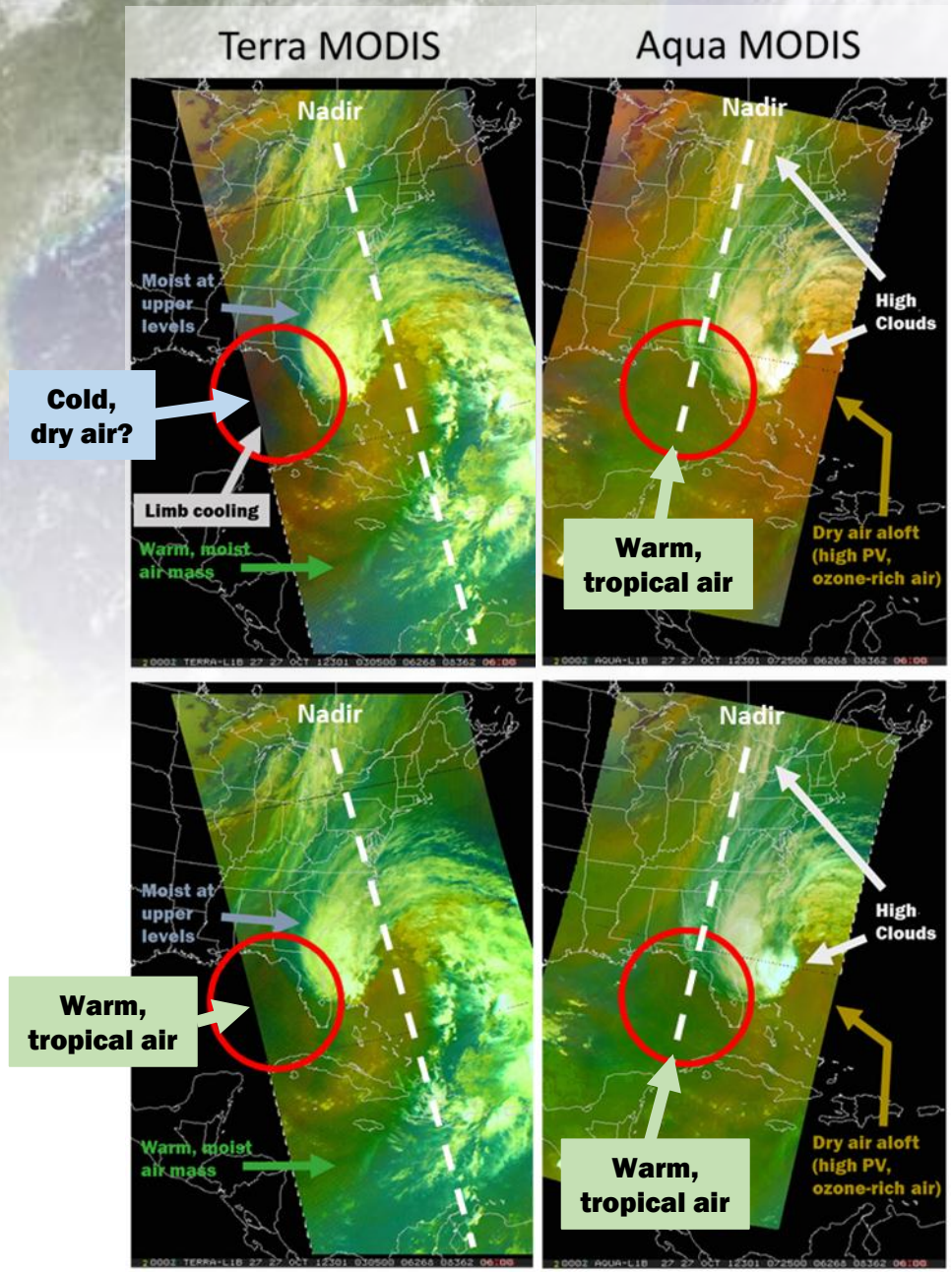
2014 December 29 Aqua MODIS Air Mass RGB (0045 UTC) merged with SEVIRI (0100 UTC) Air Mass RGB.

Corrected Aqua MODIS



2014 December 29 Aqua MODIS Air Mass RGB (0045 UTC) merged with SEVIRI (0100 UTC) Air Mass RGB.

Air Mass RGB Example - Aqua/Terra

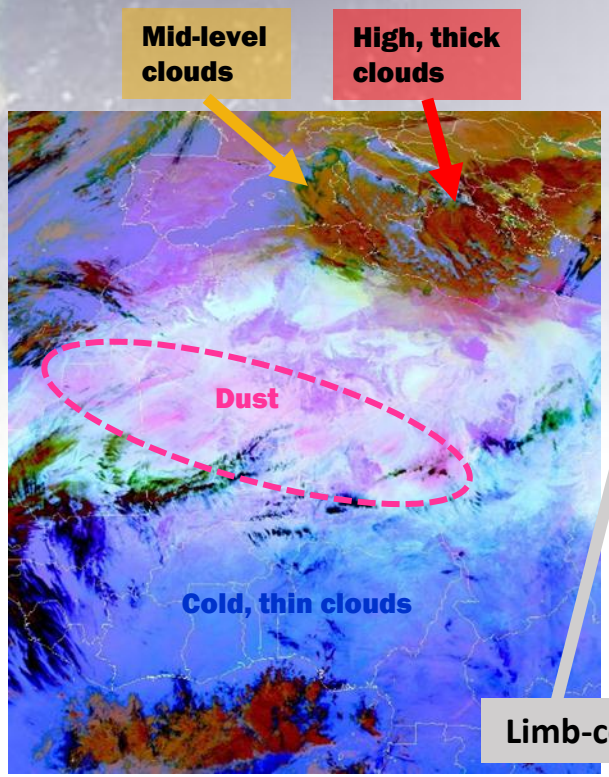


- Warm, tropical air can be properly identified in limb-corrected imagery, even at large scan angles
- Easy comparison of products from different sensors, enabling them to be used jointly for analysis
- Increased forecaster confidence in interpretation of RGB features

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

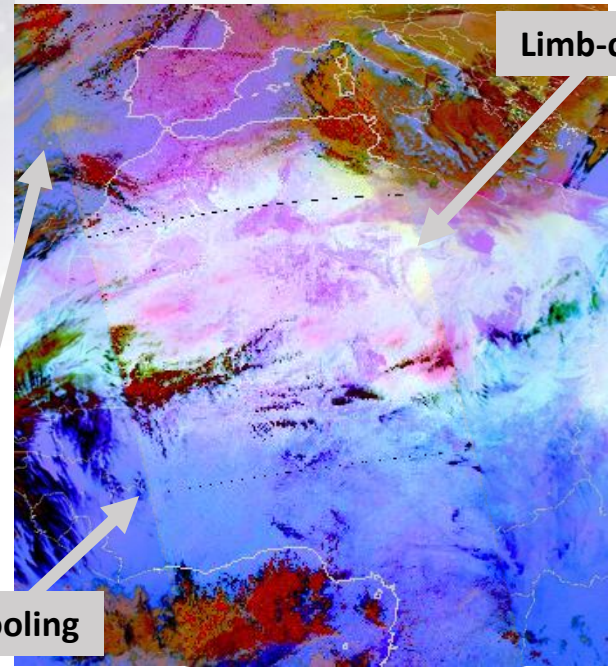
Dust RGB Example

- Impact of limb-cooling less significant than in Air Mass RGB, but still an issue
- Correction allows seamless transition between Aqua MODIS and SEVIRI Dust RGBs



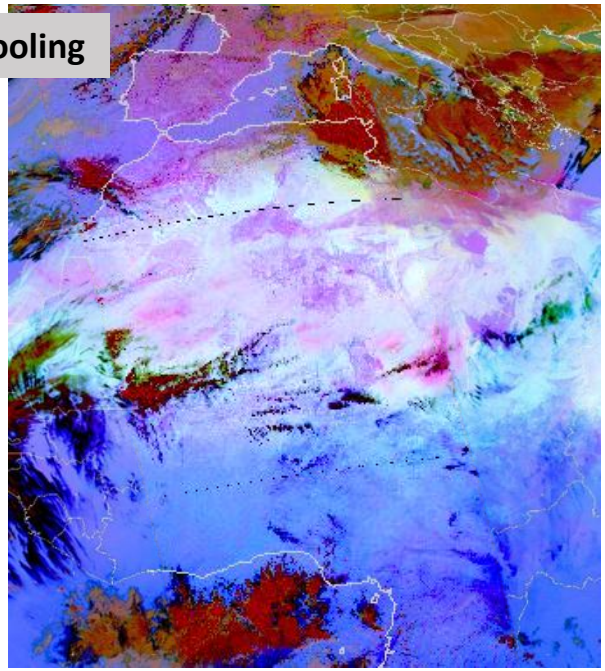
2014 December 31 SEVIRI (1315 UTC) Dust RGB

Original



2014 December 31 Aqua MODIS Dust RGB (1310 UTC) merged with SEVIRI (1315 UTC) Dust RGB.

Corrected



2014 December 31 Aqua MODIS Dust RGB (1310 UTC) merged with SEVIRI (1315 UTC) Dust RGB.

Summary

- Limb effects can be removed from infrared channels using latitudinally and seasonally dependent correction coefficients, which account for an increasing optical path length as scan angle increases
- Limb-corrected RGBs provide multiple advantages over uncorrected RGBs, including:
  - **increased confidence in interpretation of RGB features**
  - **improved situational awareness**
  - seamless transition between overlaid RGB composites
  - easy comparison of RGB products from different sensors
  - availability of high quality proxy products for GOES-R era
- Polar applications (Alaska Region) to provide GOES-R quality RGBs to high latitudes
- Limb correction can to applied to other RGBs, including RGBs from other instruments (e.g., Suomi NPP VIIRS)
- Future work will refine limb correction and bias correction through additional analysis

Questions

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<u>References</u>

Joyce, R., J. Janowiak, and G. Huffman, 2001: Latitudinally and Seasonally Dependent Zenith-Angle Corrections for Geostationary Satellite IR Brightness Temperatures. *J. Appl. Meteor.*, **40**, 689-703.

Soden, B.J., and F.P. Bretherton, 1993: Upper Tropospheric Relative Humidity from the GOES 6.7 µm Channel: Method and Climatology for July 1987. *J. Geophys. Res.*, **98**, 16669-16688.