Construction of High Spatial Resolution IR bands from Imager-Sounder Data Fusion

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Imager-Sounder Data Fusion:

Construction of IR bands based on imager-sounder data fusion

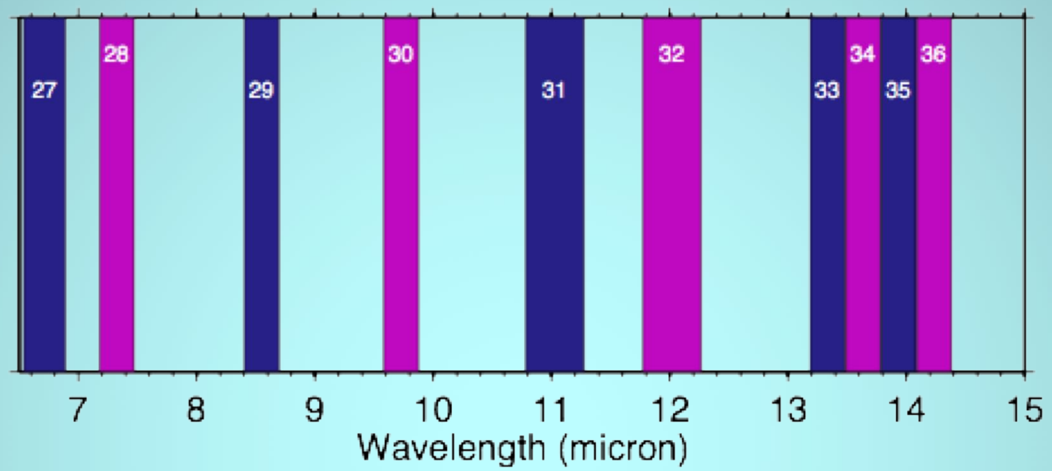
Compare measured to constructed (fusion) radiances (MODIS + AIRS)

Show global results for VIIRS+CrIS

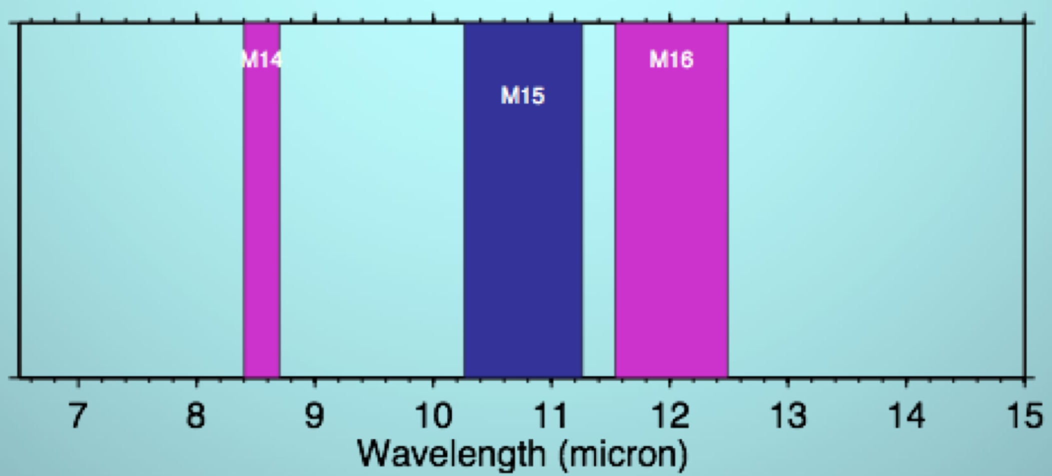
Ability to construct these channels for VIIRS+CrIS and AVHRR+HIRS/IASI

VIIRS and MODIS IR spectral bands

MODIS



VIIRS: M bands



Fusion Approach Links Imager and Sounder

Data fusion approach constructs IR bands at imager resolution

- IR absorption bands used in cloud property retrievals (e.g., cloud height, cloud thermodynamic phase, cloud mask), total precipitable water, polar winds, polar water vapor loops, …

Potential application to other polar-orbiting platforms

Sensor		Swath Width (km)
AVHRR	NOAA	2800
HIRS	NOAA	2200
MODIS	Aqua	2330
AIRS	Aqua	1650
VIIRS	S-NPP/NOAA-20	~3000
CrIS	S-NPP/NOAA-20	2200
AVHRR	Metop-A/B	2800
HIRS/IASI	Metop-A/B	2200

Statistical Reconstruction

Step 1: Based on a relationship (*k*-d tree) between split-window imager pixel radiances (single pixel and average of pixels within a sounder FOV), find *N* sounder FOVs that best match a given pixel

Step 2: For each of the *N* sounder FOVs assigned to a given pixel, apply a set of spectral response functions (SRFs) to the hyperspectral radiances and calculate narrowband radiances

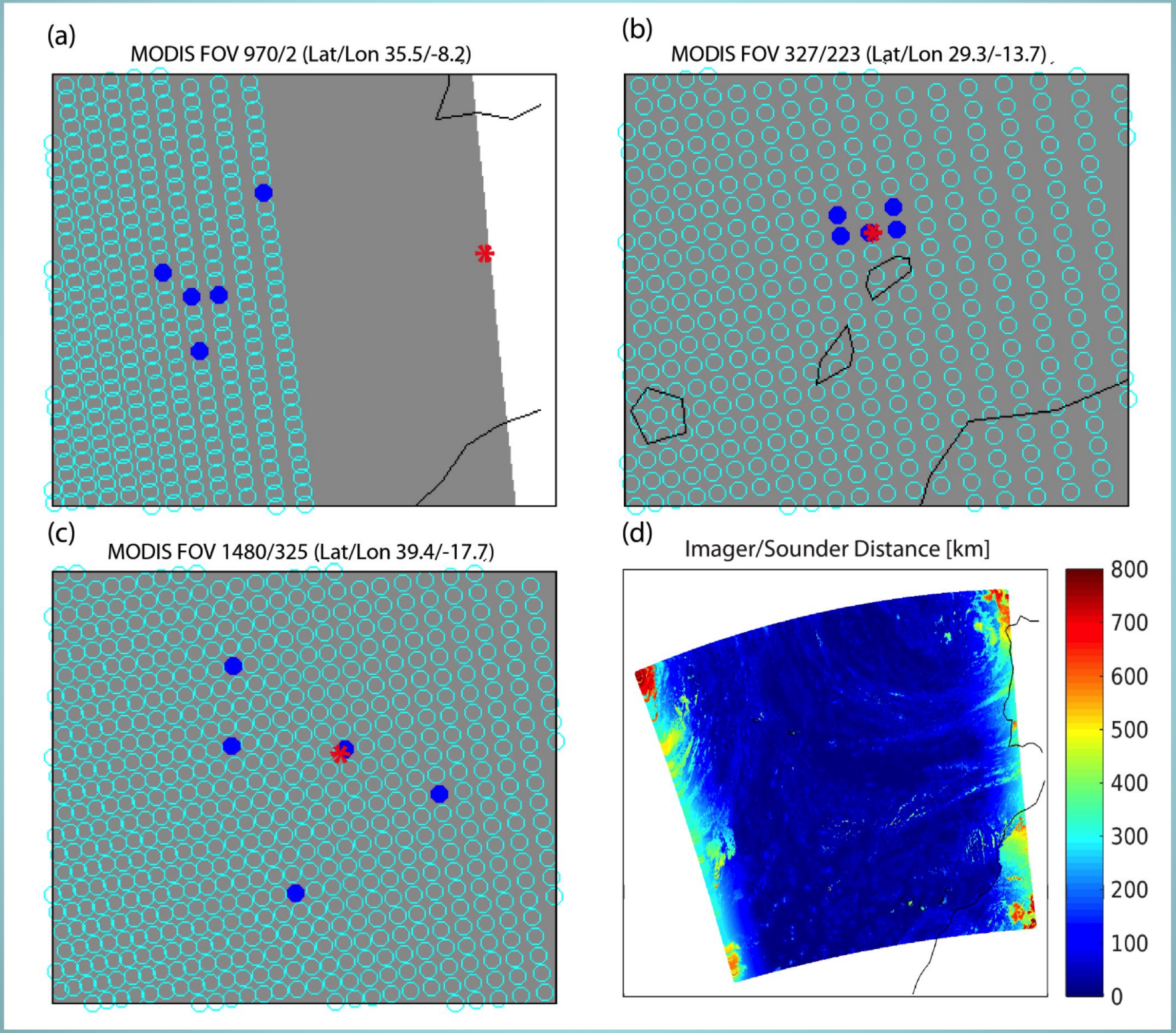
Step 3: Average the *N* narrowband radiances for each SRF and stamp on the pixel

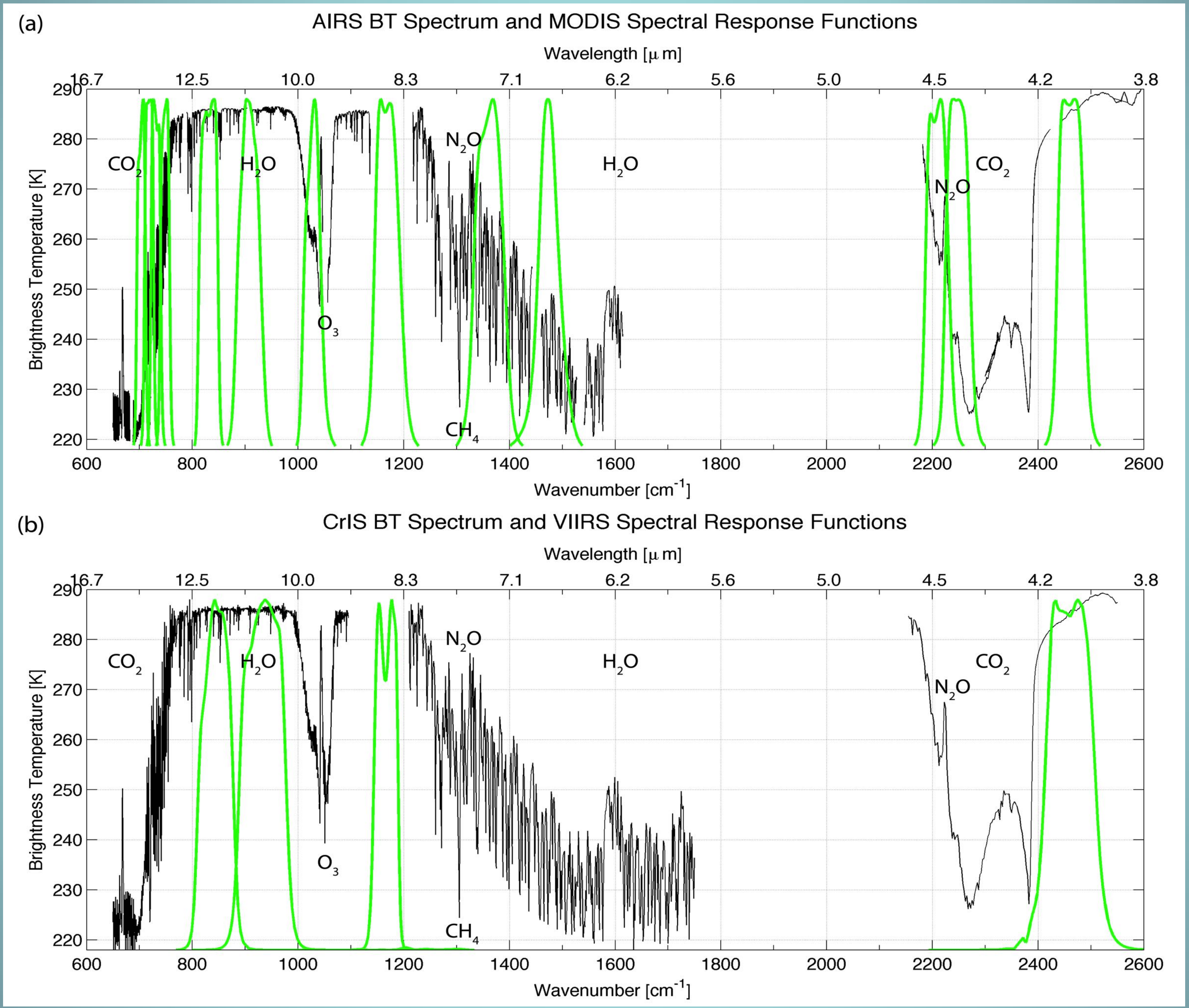
Cross et al., 2013: Statistical estimation of a 13.3-μm Visible Infrared Imaging Radiometer Suite channel using multisensor data fusion. *J. Appl. Remote Sens*. **7** (1), 073473, doi: 10.1117/1.JRS.7.073473.

Weisz, E., B. A. Baum, and W. P. Menzel, 2017: Fusion of satellite-based imager and sounder data to construct supplementary high spatial resolution narrowband IR radiances. *J. Appl. Remote Sens*. **11** (3), 036022, doi: 10.1117/1.JRS.11.036022

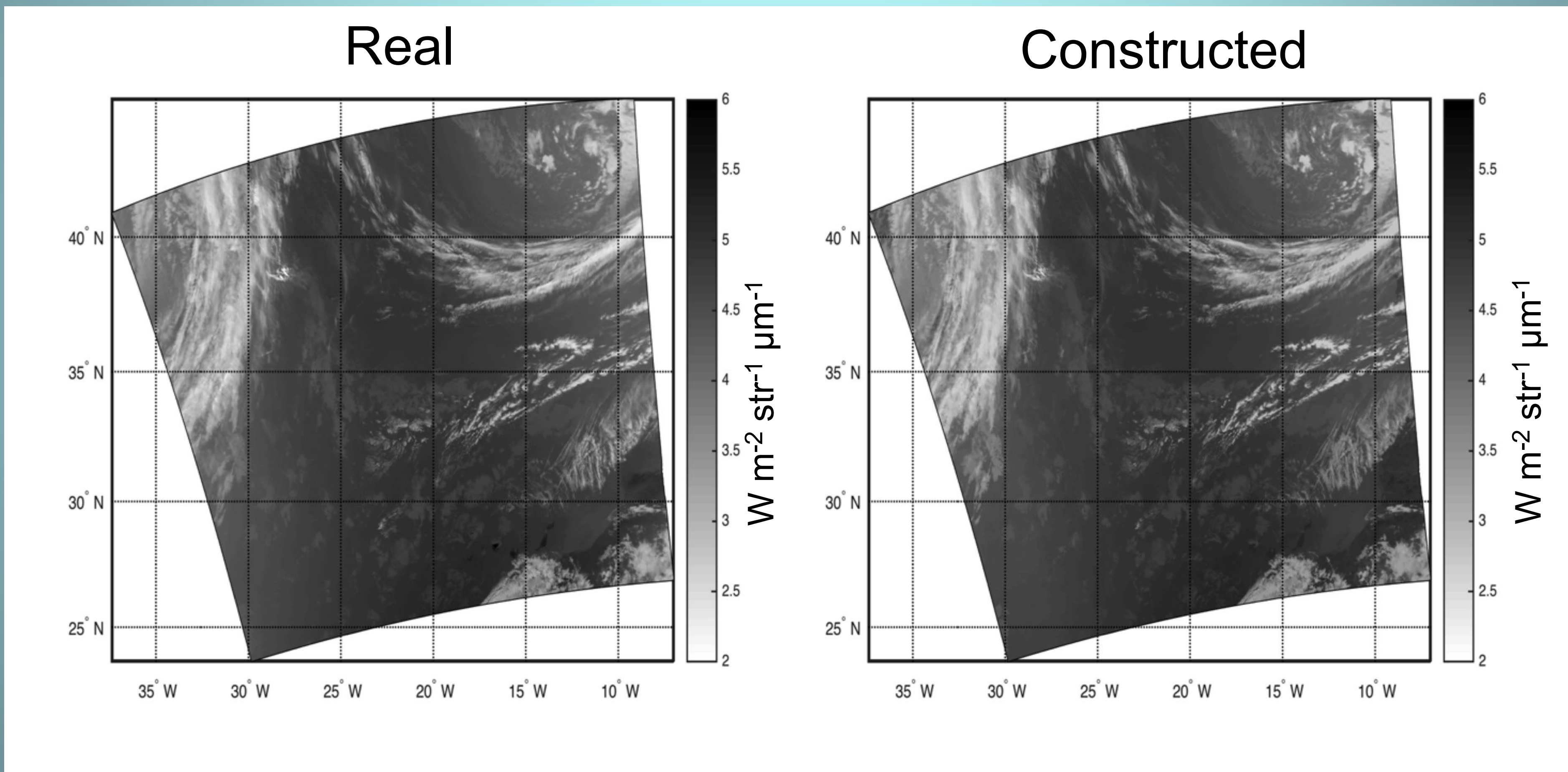
Collocation of *N* FOVs for a given imager pixel

Sounder FOV   Selected imager pixel.   Selected sounder FOV



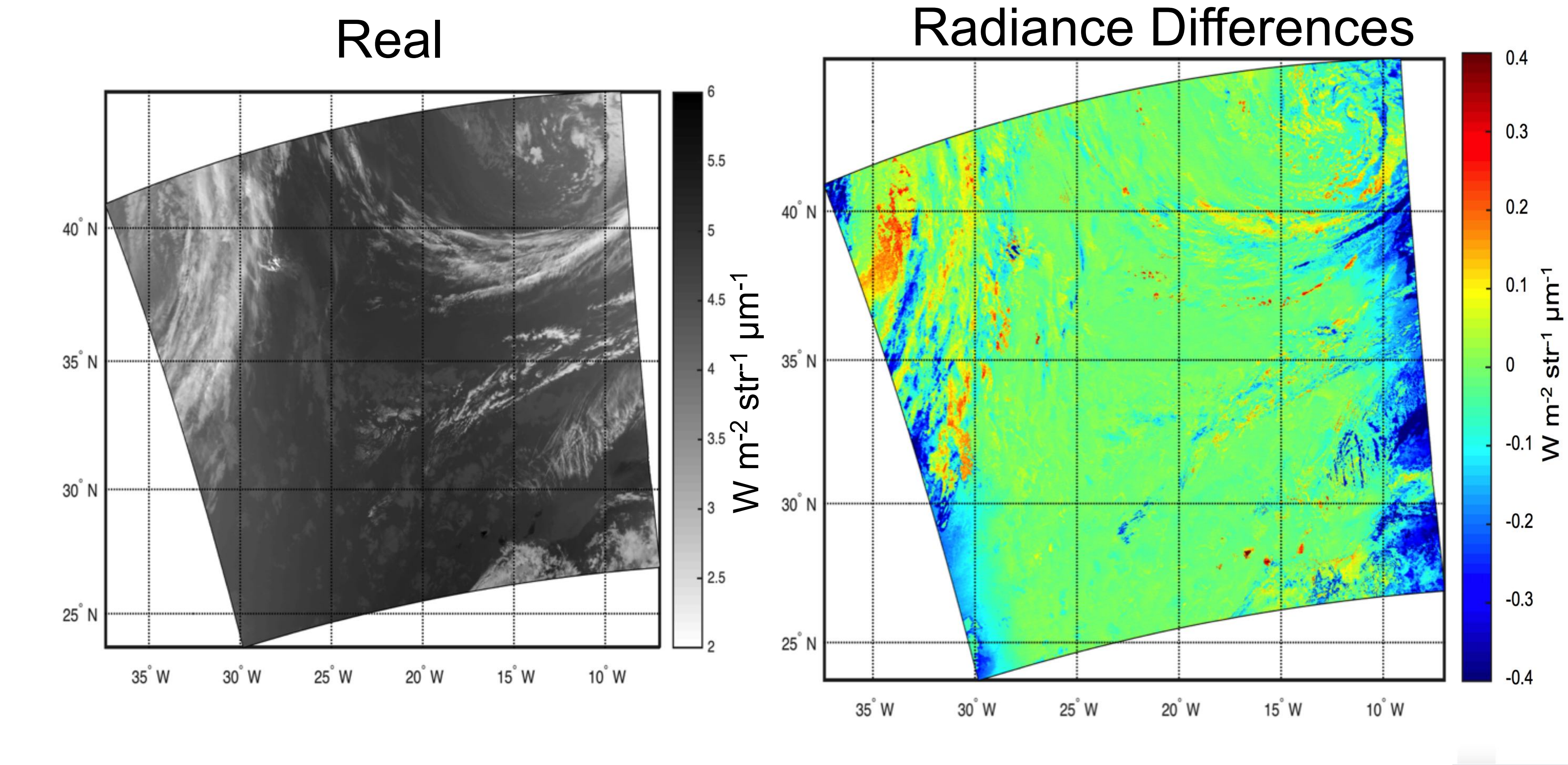

(a)
AIRS BT Spectrum and MODIS Spectral Response Functions
Wavelength [μ m]
16.7 12.5 10.0 8.3 7.1 6.2 5.6 5.0 4.5 4.2 3.8
Brightness Temperature [K]
220 230 240 250 260 270 280 290
CO2
H2O
O3
N2O
CH4
H2O
N2O
CO2
600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600
Wavenumber [cm-1]
(b)
CrIS BT Spectrum and VIIRS Spectral Response Functions
Wavelength [μ m]
16.7 12.5 10.0 8.3 7.1 6.2 5.6 5.0 4.5 4.2 3.8
Brightness Temperature [K]
220 230 240 250 260 270 280 290
CO2
H2O
O3
N2O
CH4
H2O
N2O
CO2
600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600
Wavenumber [cm-1]

Statistical construction of a high spatial resolution 13.3-μm MODIS channel from AIRS

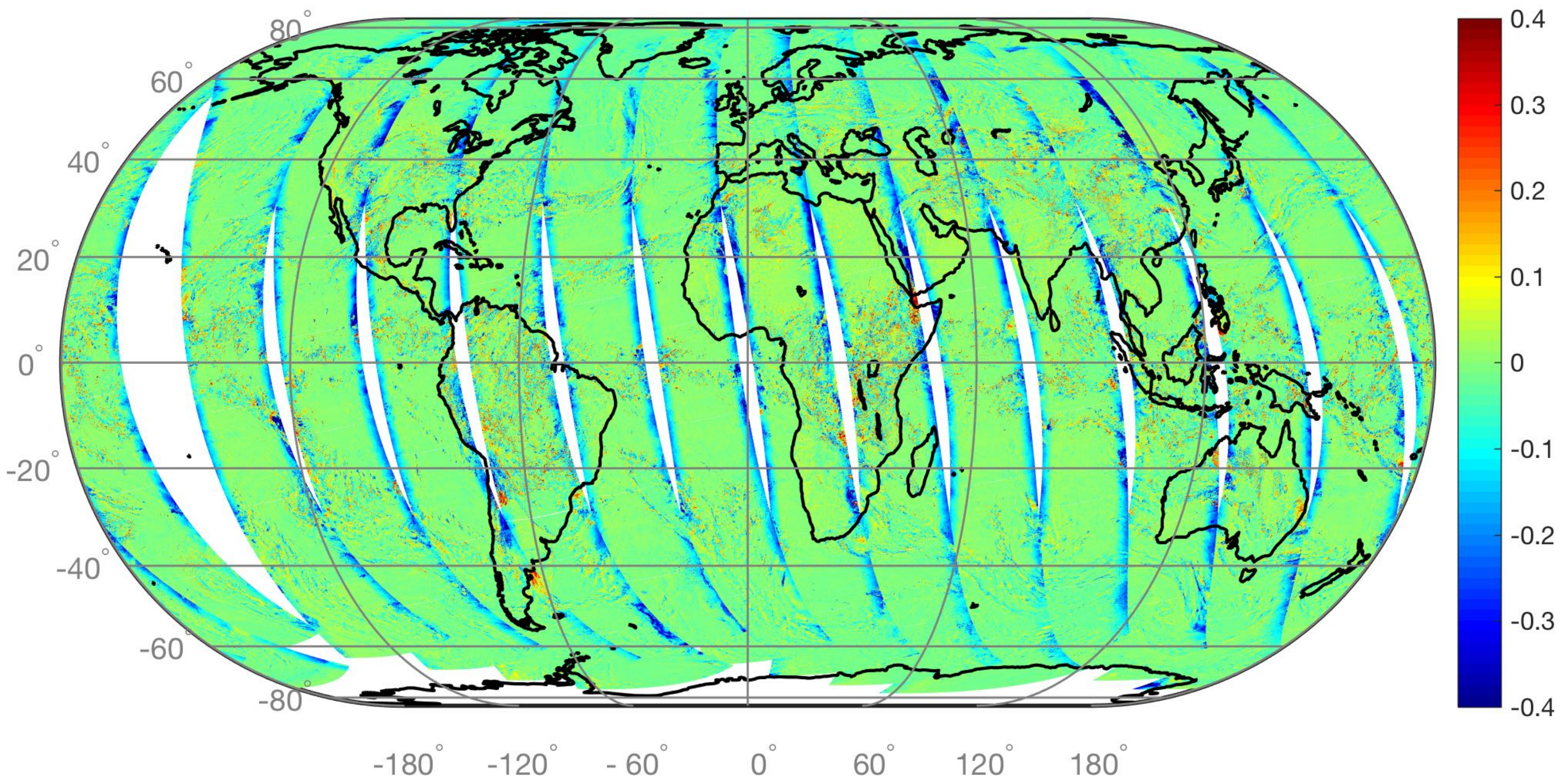


Scene over eastern Atlantic Ocean on April 17, 2015 at 1435 UTC

Radiance Differences Between Real and Constructed 13.3-μm channel

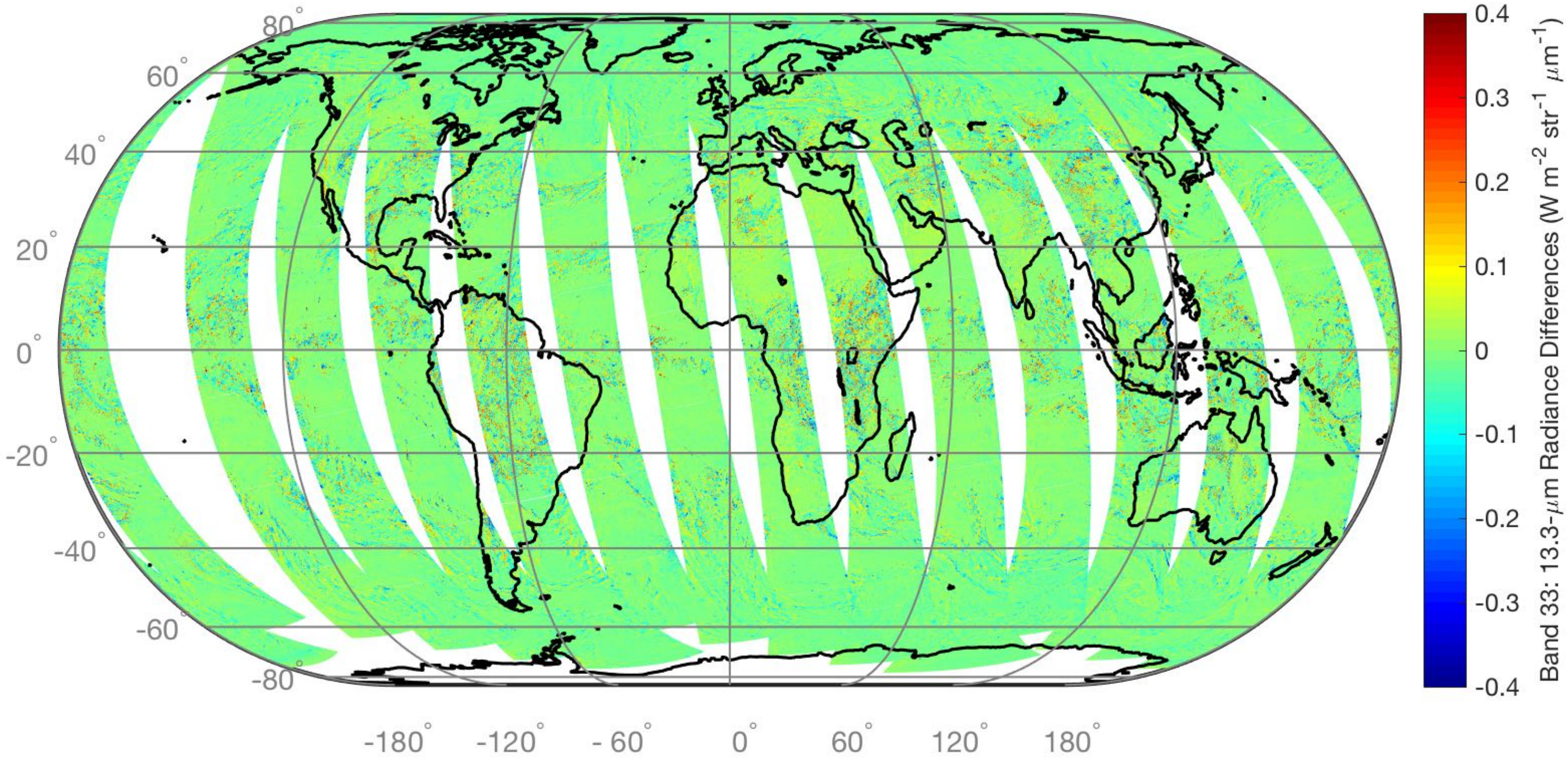


Full day of Radiance Differences Between Real and Constructed (Fusion) 13.3-μm channel MODIS+AIRS



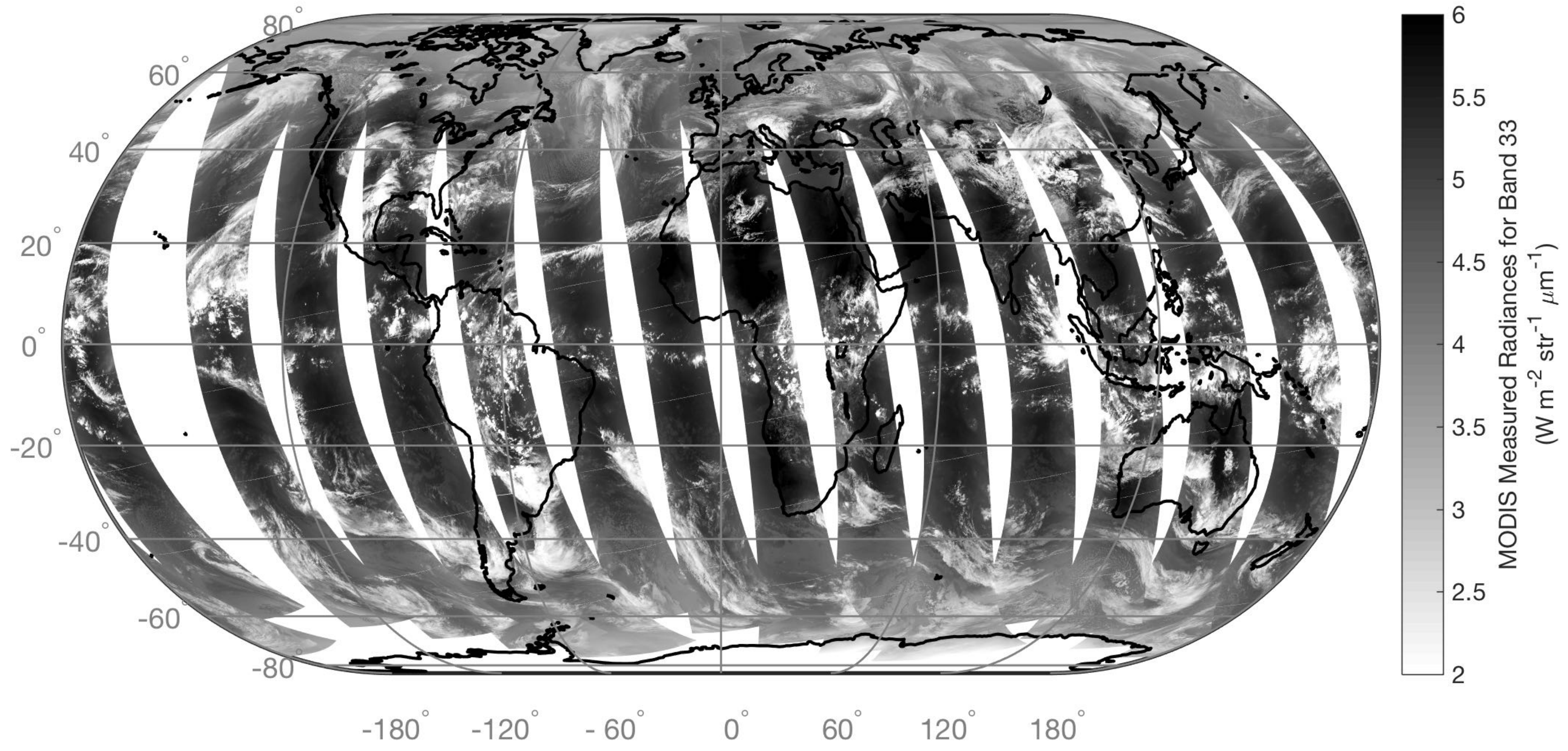
There is no adjustment for atmospheric absorption outside the range of the sounder swath (high scan angles).

Daytime (measured–fusion) 13.3-μm radiance differences
Sensor zenith angle ≤ 57°
MODIS+AIRS

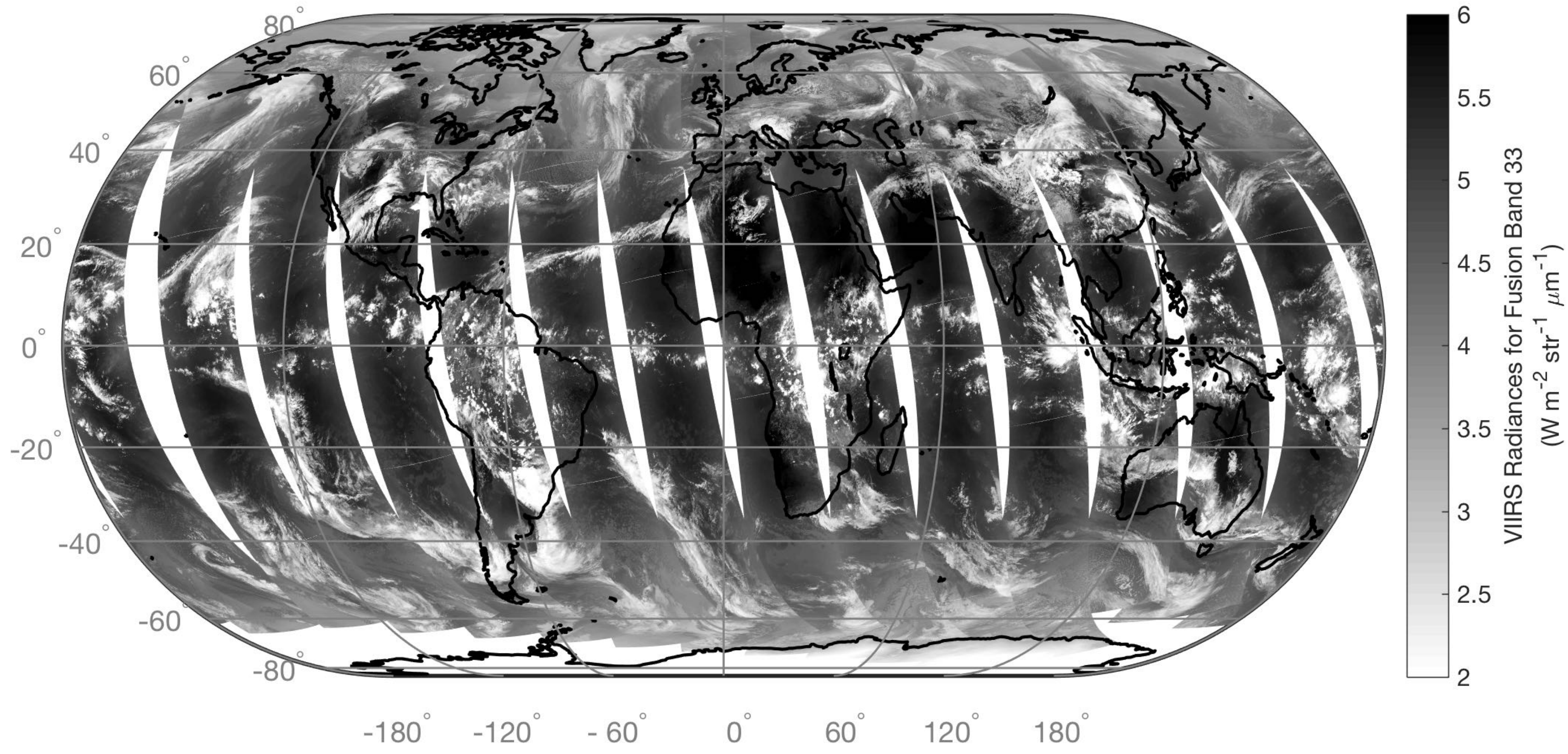


Sensor zenith angle ≤ 57°

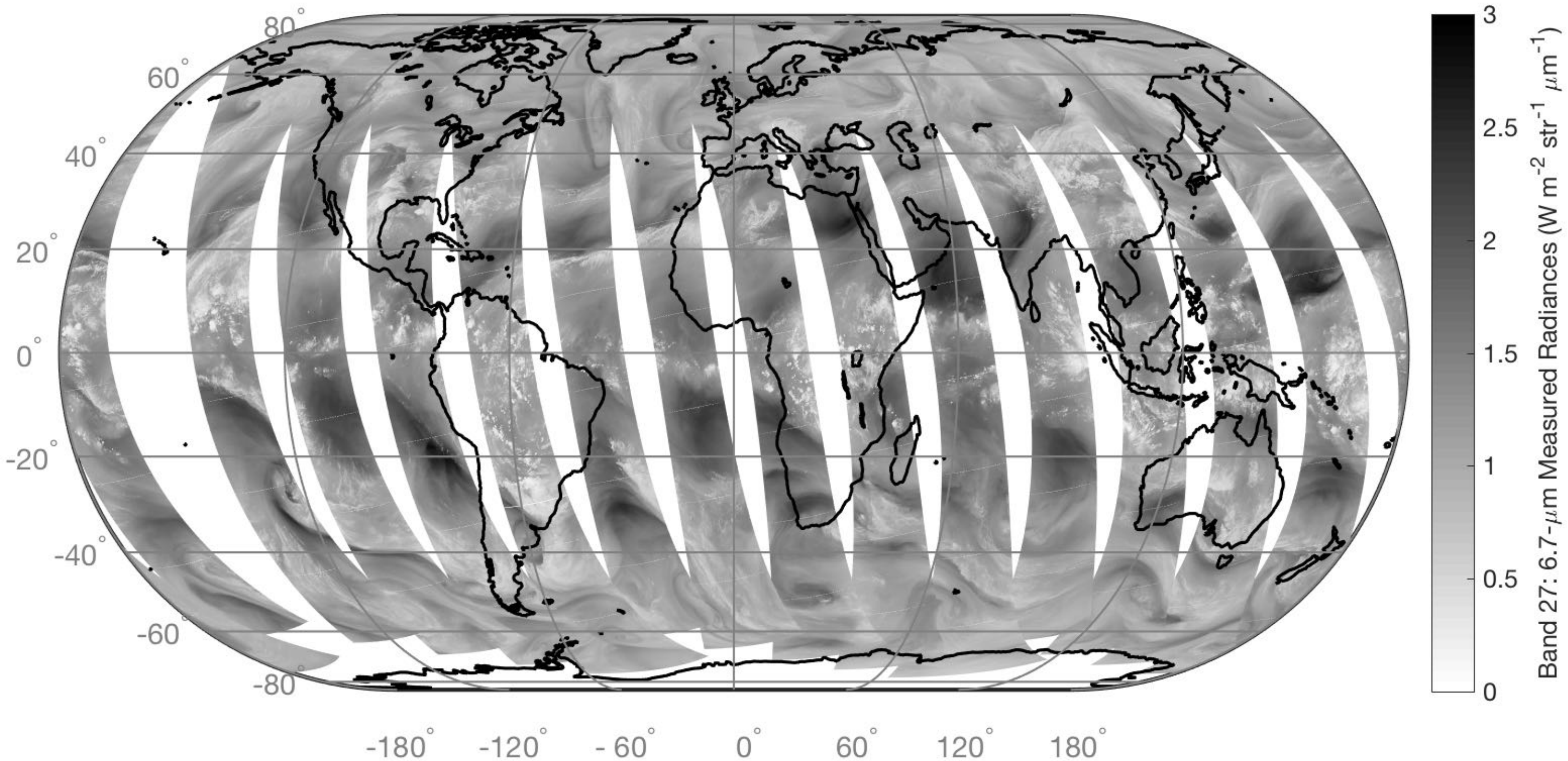
Daytime MODIS measured 13.3-μm band radiances
Sensor zenith angle ≤ 57°



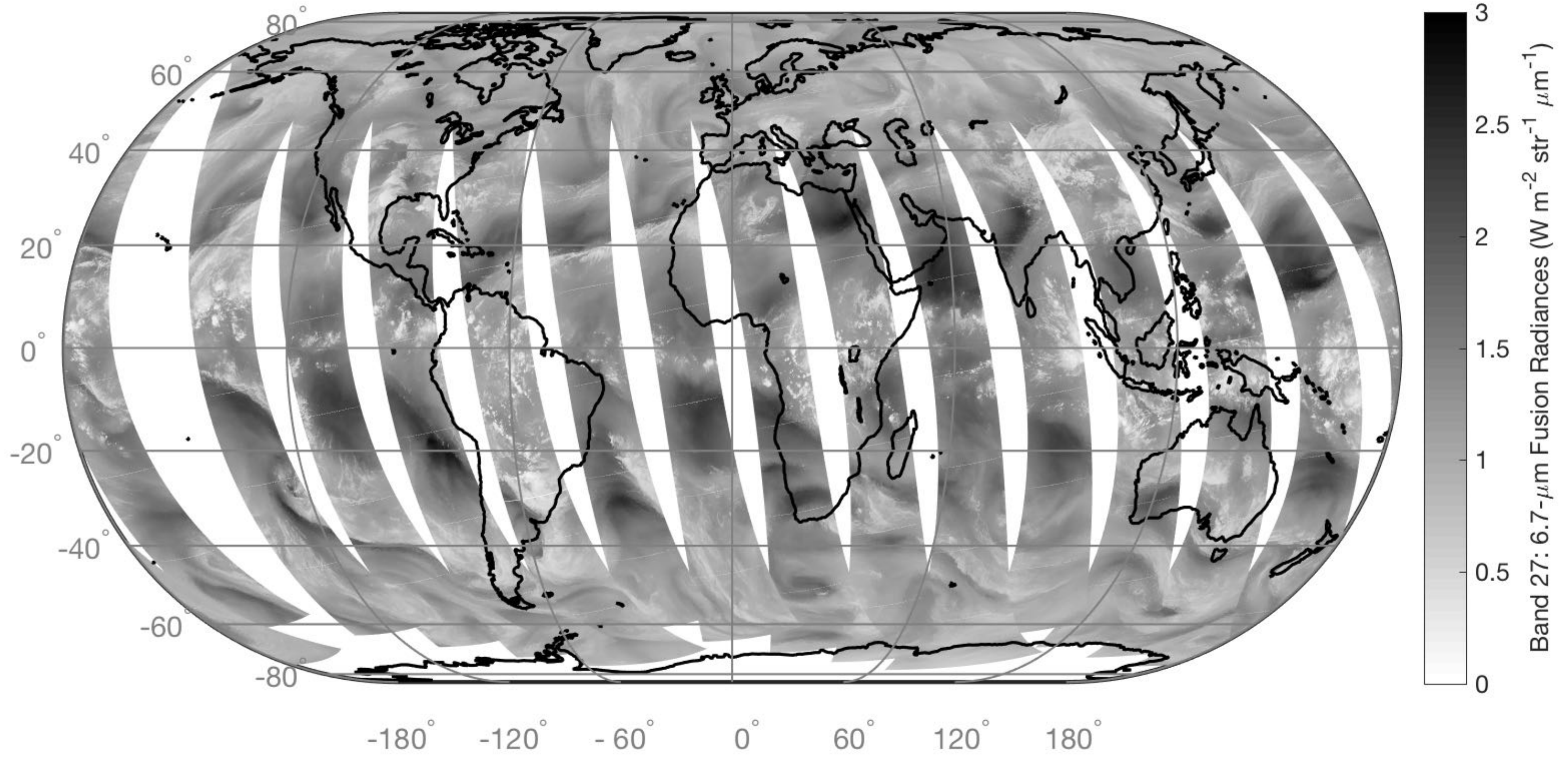
Daytime VIIRS-CrIS fusion 13.3-μm band radiances
No MODIS data used; only the relevant SRF
Sensor zenith angle ≤ 60˚



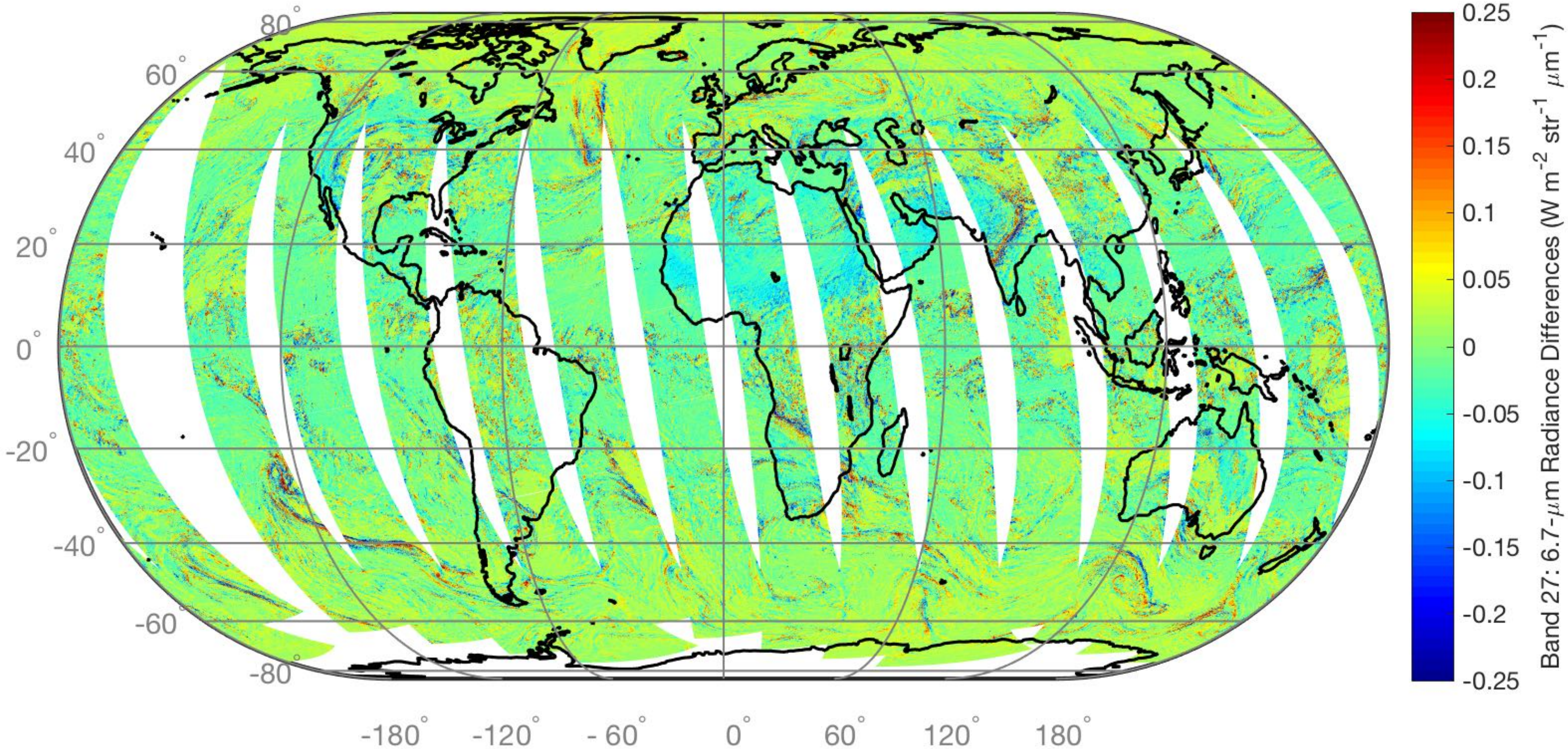
Daytime MODIS measured 6.7-μm band radiances
Sensor zenith angle ≤ 57˚



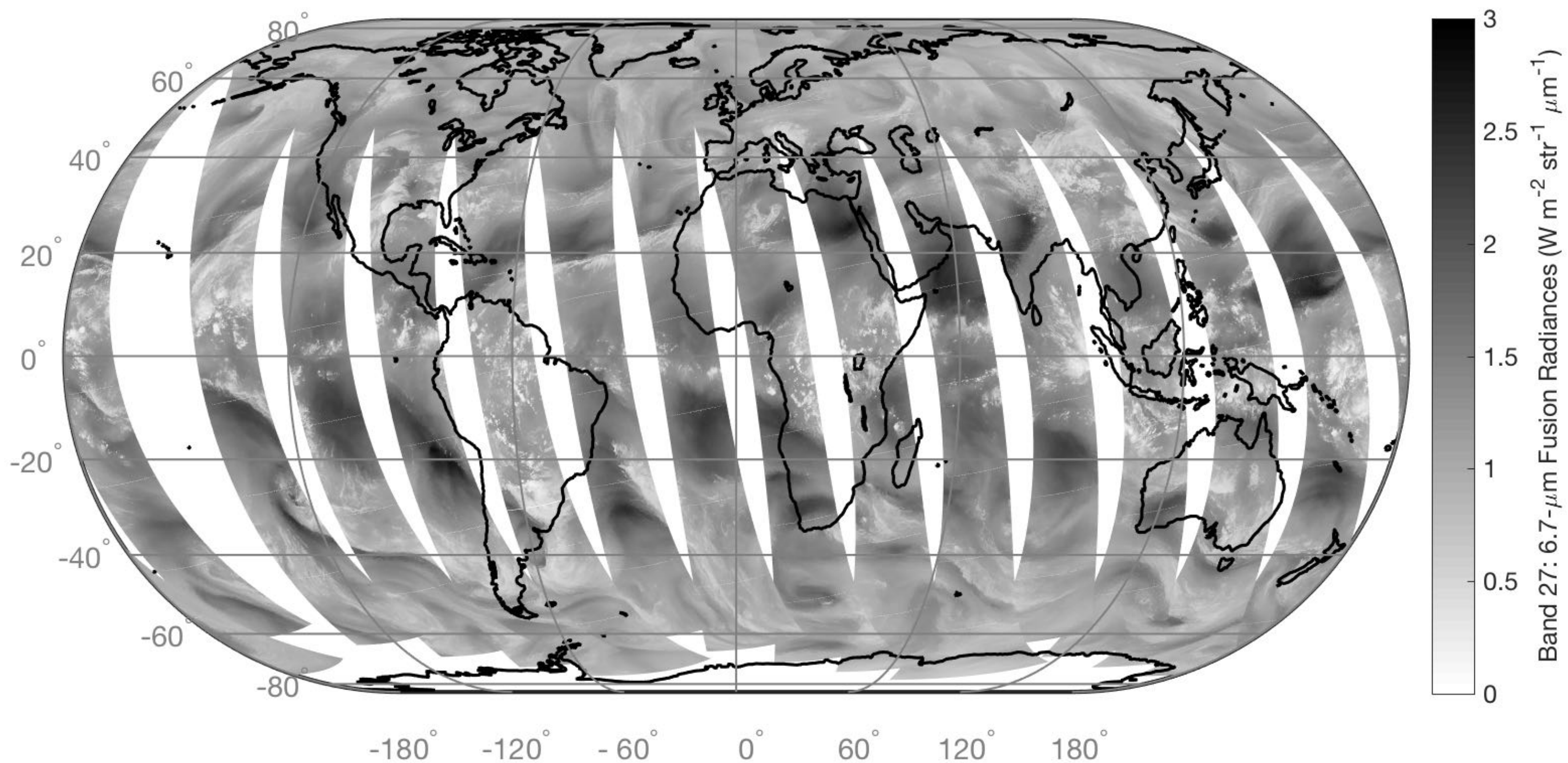
Daytime fusion 6.7-μm band radiances
Sensor zenith angle ≤ 57˚



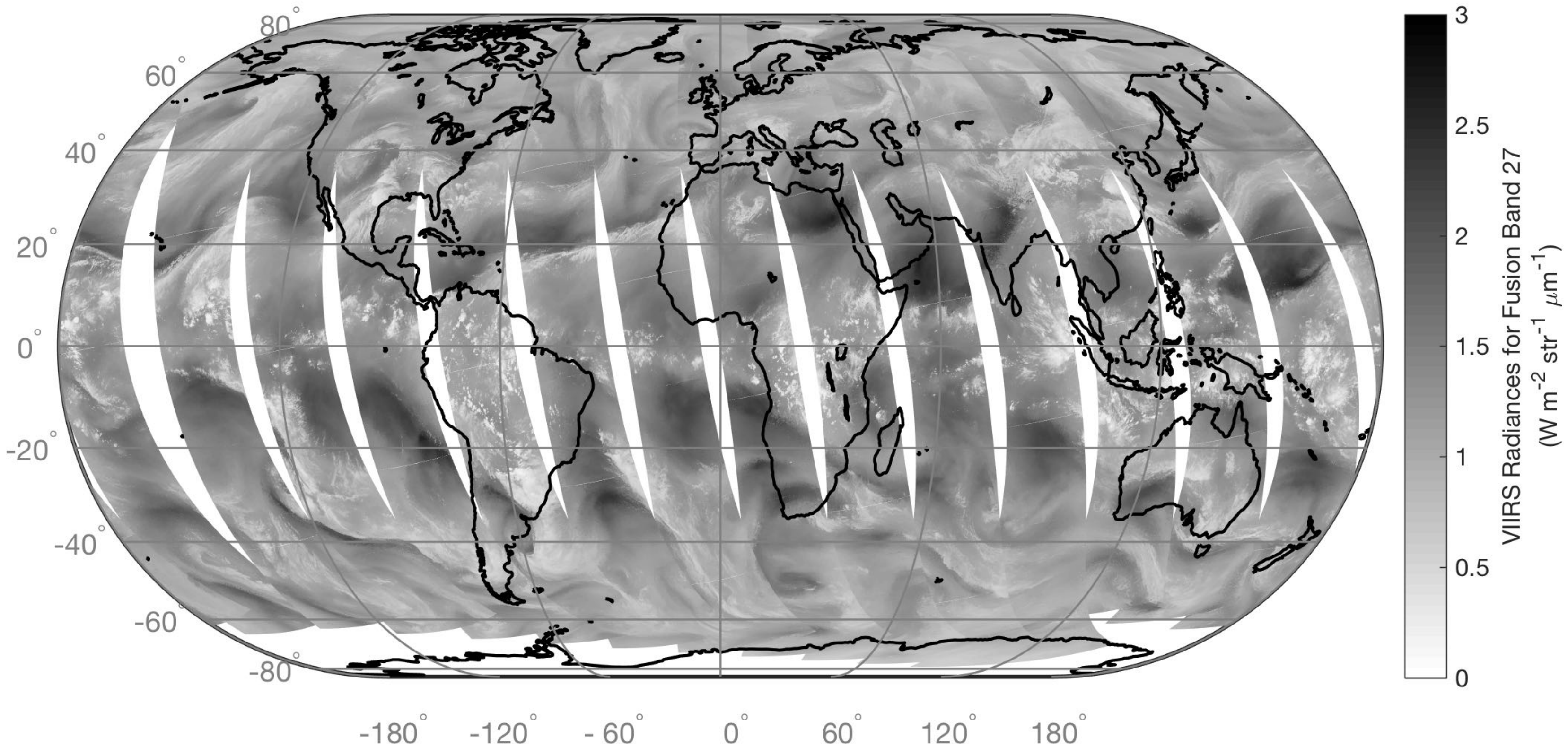
Daytime (measured–fusion) 6.7-μm radiance differences
Sensor zenith angle ≤ 57°



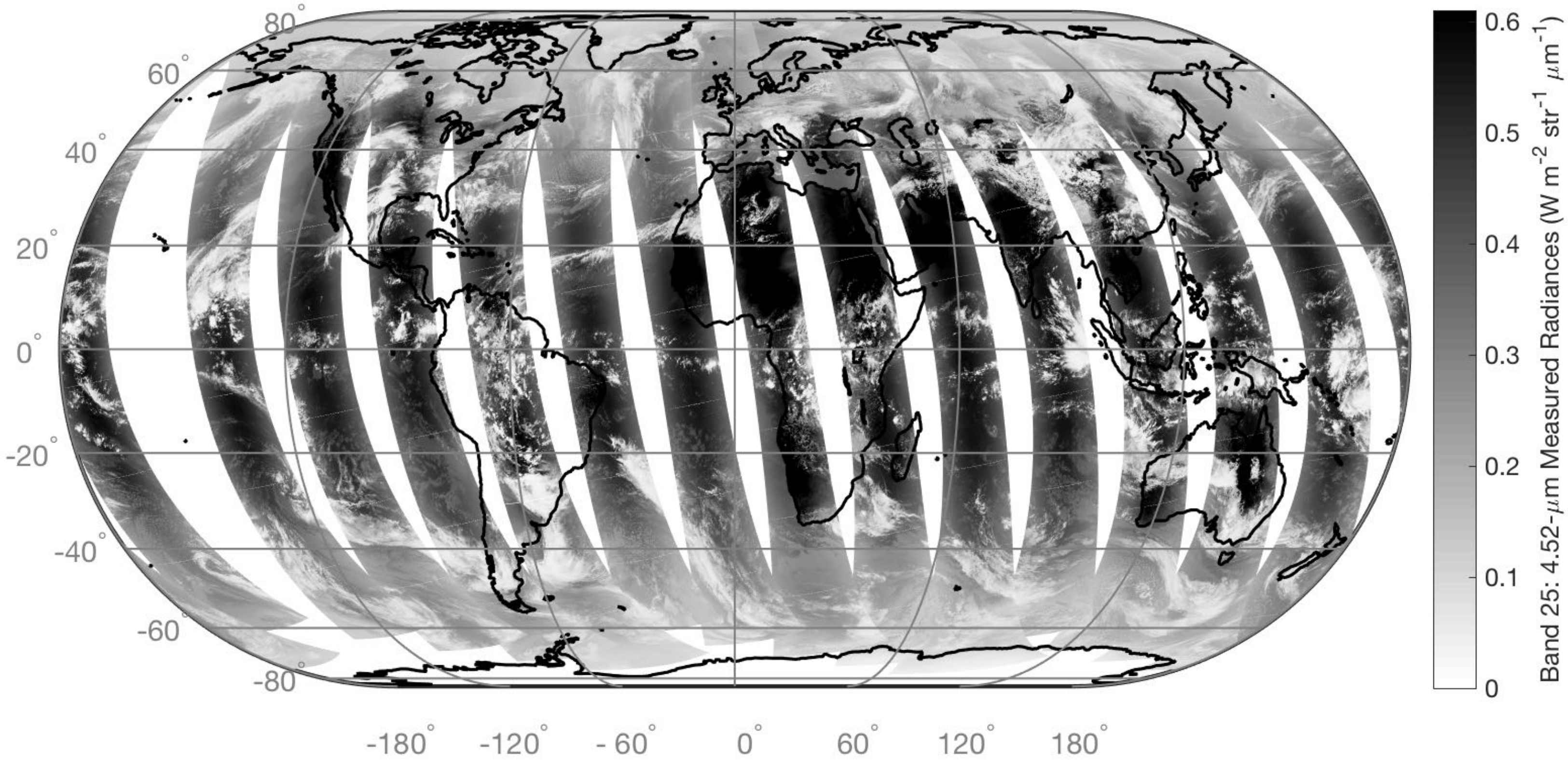
Daytime MODIS measured 6.7-μm band radiances
Sensor zenith angle ≤ 57°



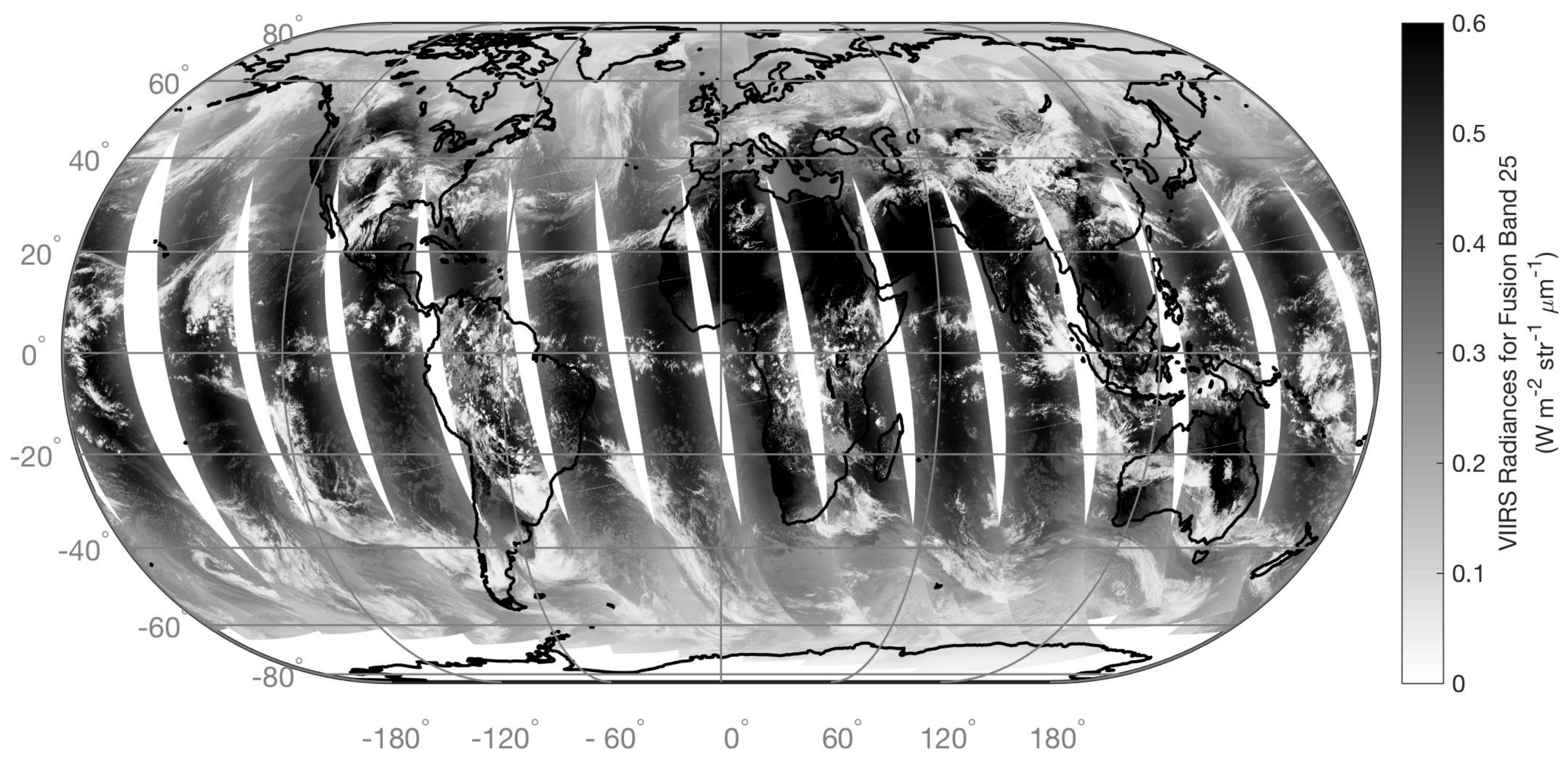
Daytime VIIRS-CrIS fusion 6.7-μm band radiances
No MODIS data used; only the relevant SRF
Sensor zenith angle ≤ 60˚



Daytime MODIS measured 4.52-μm band radiances
Sensor zenith angle ≤ 57°



Daytime VIIRS-CrIS fusion 4.52-μm band radiances
No MODIS data used; only the relevant SRF
Sensor zenith angle ≤ 60˚



Availability of the MODIS-AIRS fusion product

A month of the AIRS/MODIS fusion MYD021KM granules is available for April 2015 at the Atmosphere SIPS:

ftp://sips.ssec.wisc.edu/products/fusion_matlab/airs-modis/aqua/2015/

In this product the relevant MODIS IR radiances are simply replaced with the fusion radiances. The use of scaling factors is the same as with the original granule (HDF4). Looks just like the original granule format.

The fusion radiances are based on use of the Aqua MODIS response functions for channels 23-25 (CO_2), 27-28 (H_2O), 30 (O_3), and 33-36 (CO_2)

Availability of the VIIRS-CrIS fusion product

The VIIRS-CrIS fusion product is available at the Atmosphere SIPS; the record begins 01 January 2018 and is produced in forward stream:

ftp://sips.ssec.wisc.edu/dev/viirs/snpp/VNP02FSN/1.0dev3/2018/

The relevant Aqua MODIS-like IR radiance channels (MODIS channels 23-25, 27, 28, 30, 33-36) are added to the VIIRS Level 1b granule (NetCDF4).

Additionally, fusion channels are included for VIIRS M15 and M16 so a user can gain a sense of fusion-based construction errors.

The size of each granule is roughly double that of the "standard" L1b granule.

Global ascending/descending browse imagery for 6.7- and 13.3-μm channels is provided for each day.

To date, fusion process runs successfully for 98.6% of granules (of which 4 days account for most of the failures)

About the statistical construction approach

Pros:

- No detector striping or other artifacts
- Spectral response functions same as for MODIS-Aqua, i.e., they are known
- In fact, you can apply any response functions to construct new bands including those where lines of strong trace gas absorption are omitted
- Hyperspectral IR data are well calibrated
- Can apply MODIS retrieval algorithms to any platform with minor changes
- Can extend beyond the sounder swath but need to account for increased water vapor (and trace gas) absorption

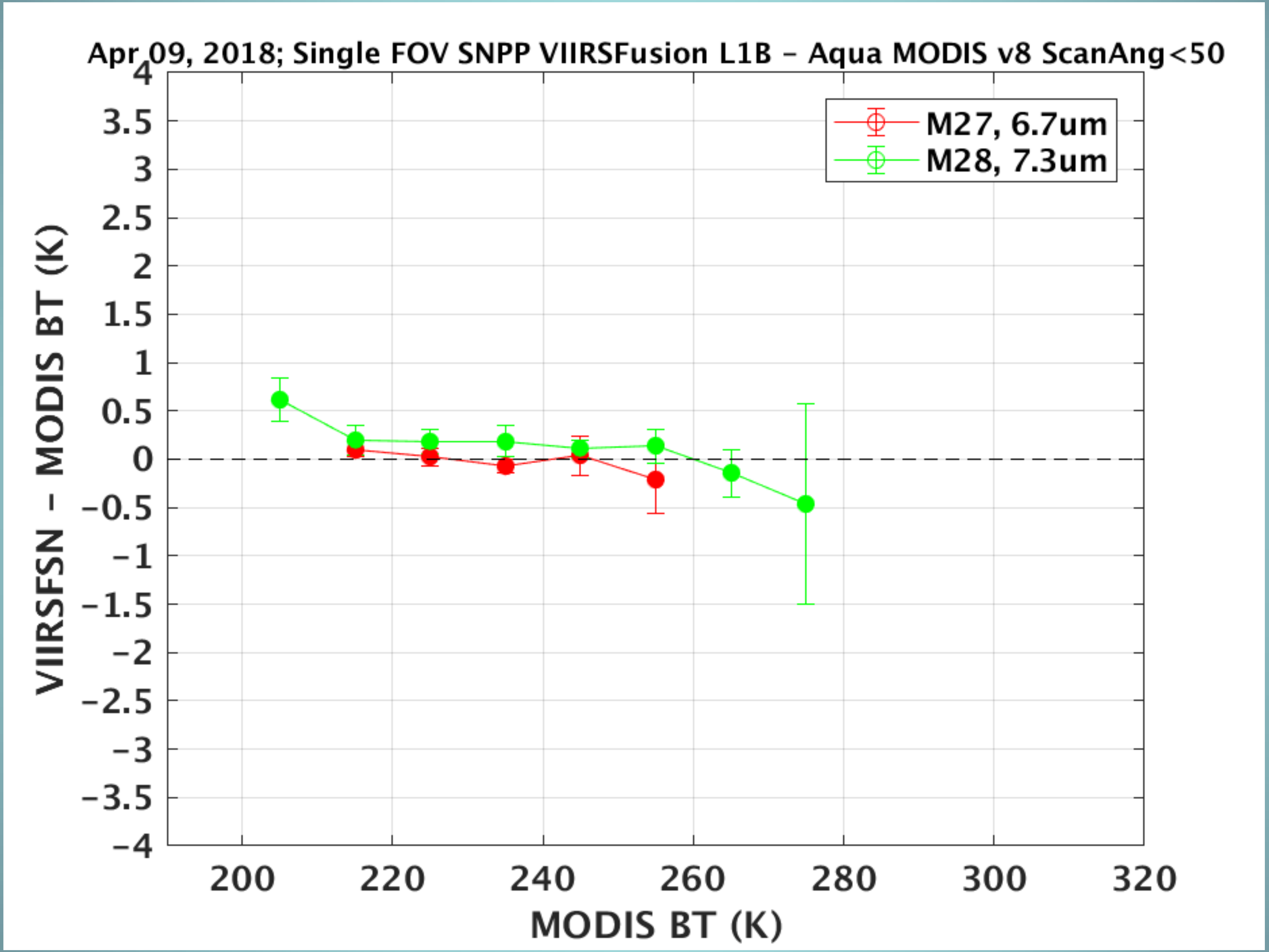
Cons:

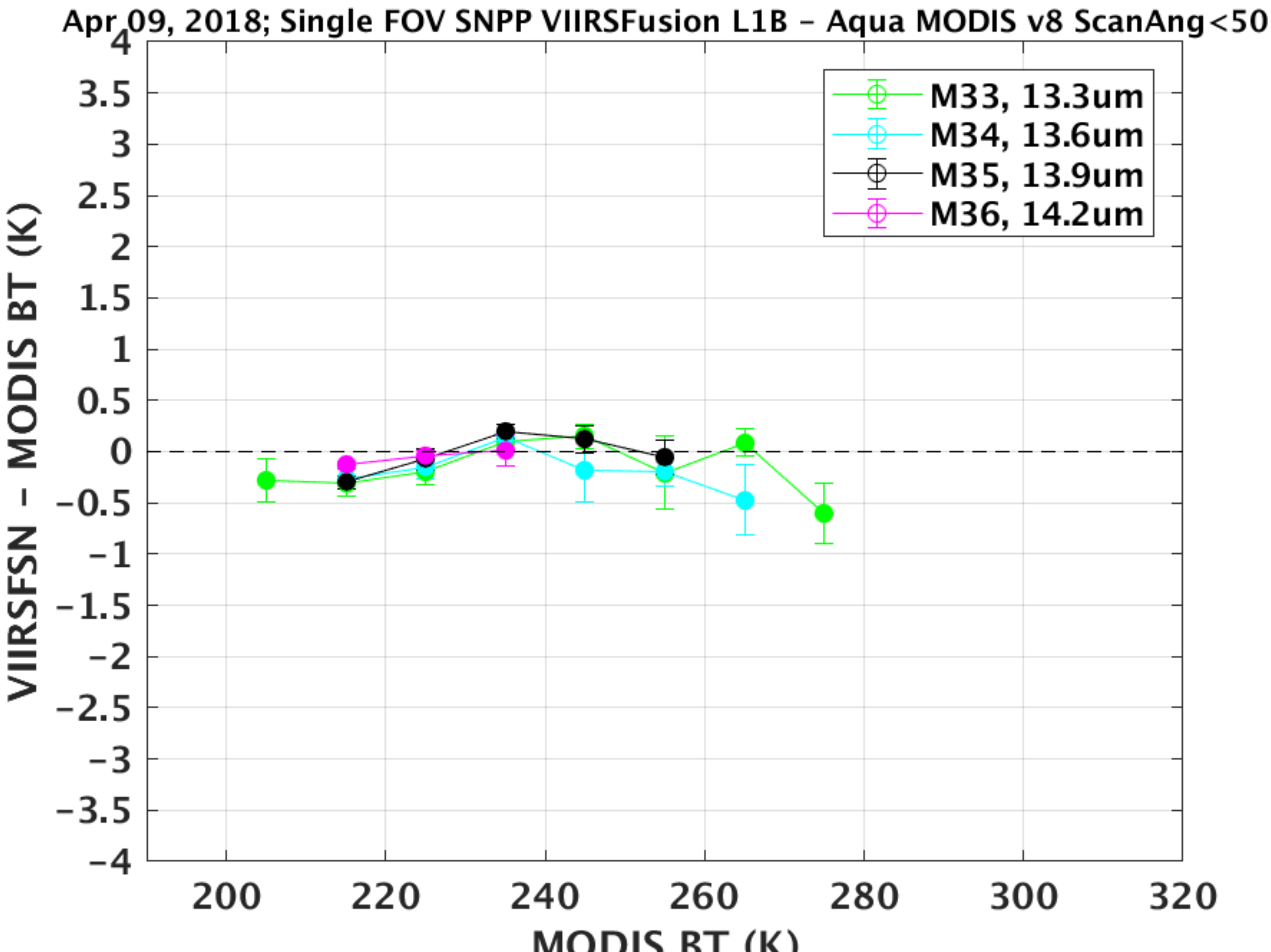
- Radiance differences increase outside of sounder swath
- Higher noise around edges of rapidly changing radiance fields
- May have more noise than an algorithm requires for accuracy
- Suspect that surface emissivity might be playing a small role in clear-sky conditions

Radiance differences are about 1-2% of the total (~1-3K/typical scene)

VIIRS Fusion and Aqua MODIS Matchups April 09, 2018

- Global matchups abundant on this day
- Analysis limited to matchups where only one VIIRS measurement falls within the MODIS pixel field-of-view.
- Matchups filtered using cloud mask (99% confident clear only).
- Matchups include day+night, all surfaces


Apr 09, 2018; Single FOV SNPP VIIRSFusion L1B - Aqua MODIS v8 ScanAng<50
M27, 6.7um
M28, 7.3um
VIIRSFSN - MODIS BT (K)
MODIS BT (K)
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
200
220
240
260
280
300
320



Apr 09, 2018; Single FOV SNPP VIIRSFusion L1B - Aqua MODIS v8 ScanAng<50
M33, 13.3um
M34, 13.6um
M35, 13.9um
M36, 14.2um
VIIRSFSN - MODIS BT (K)
MODIS BT (K)
4
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
−3.5
−4
200
220
240
260
280
300
320

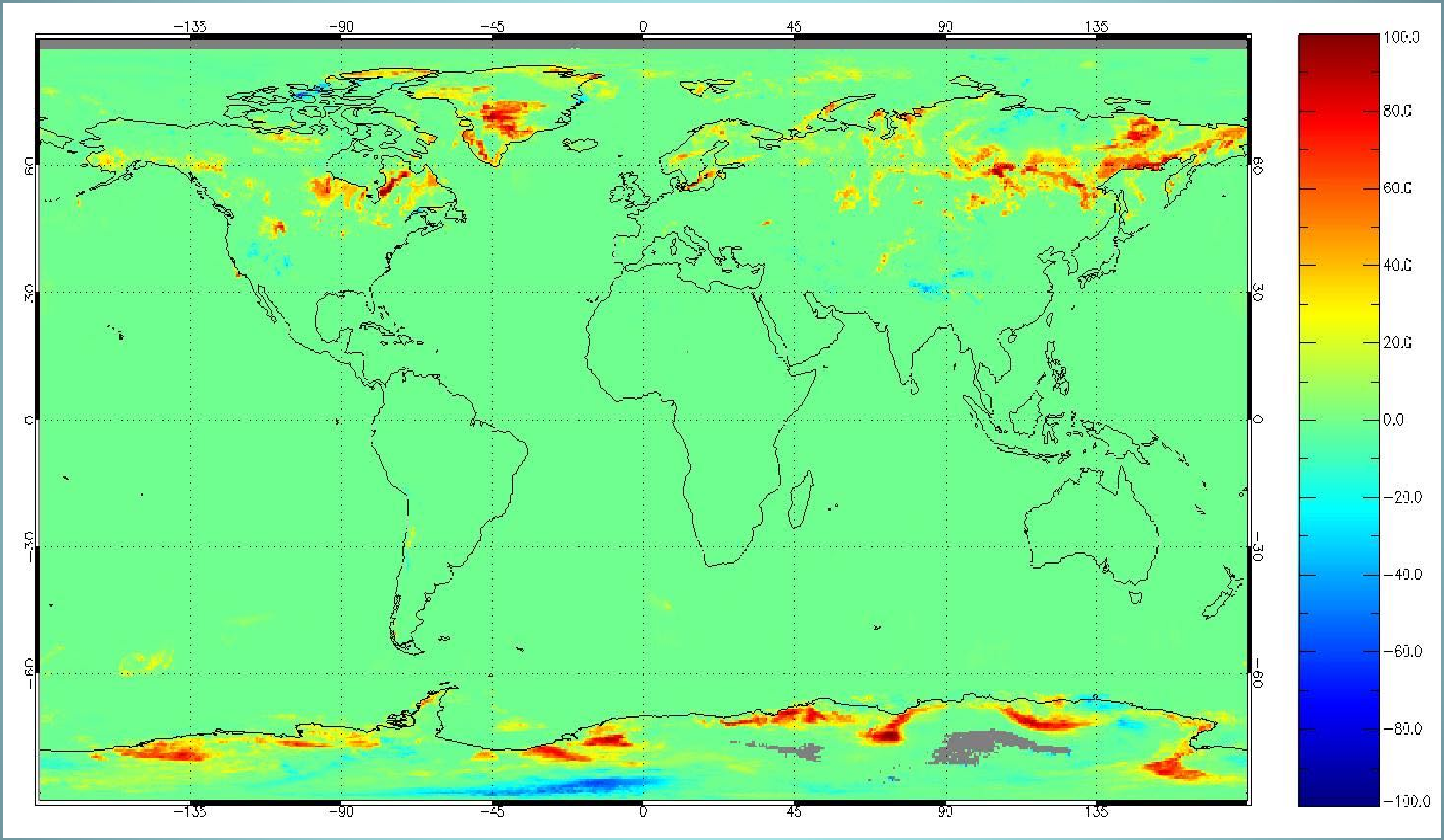
Test viability of constructed IR bands

Want to know two things:

a. does inclusion of IR bands provide useful information?

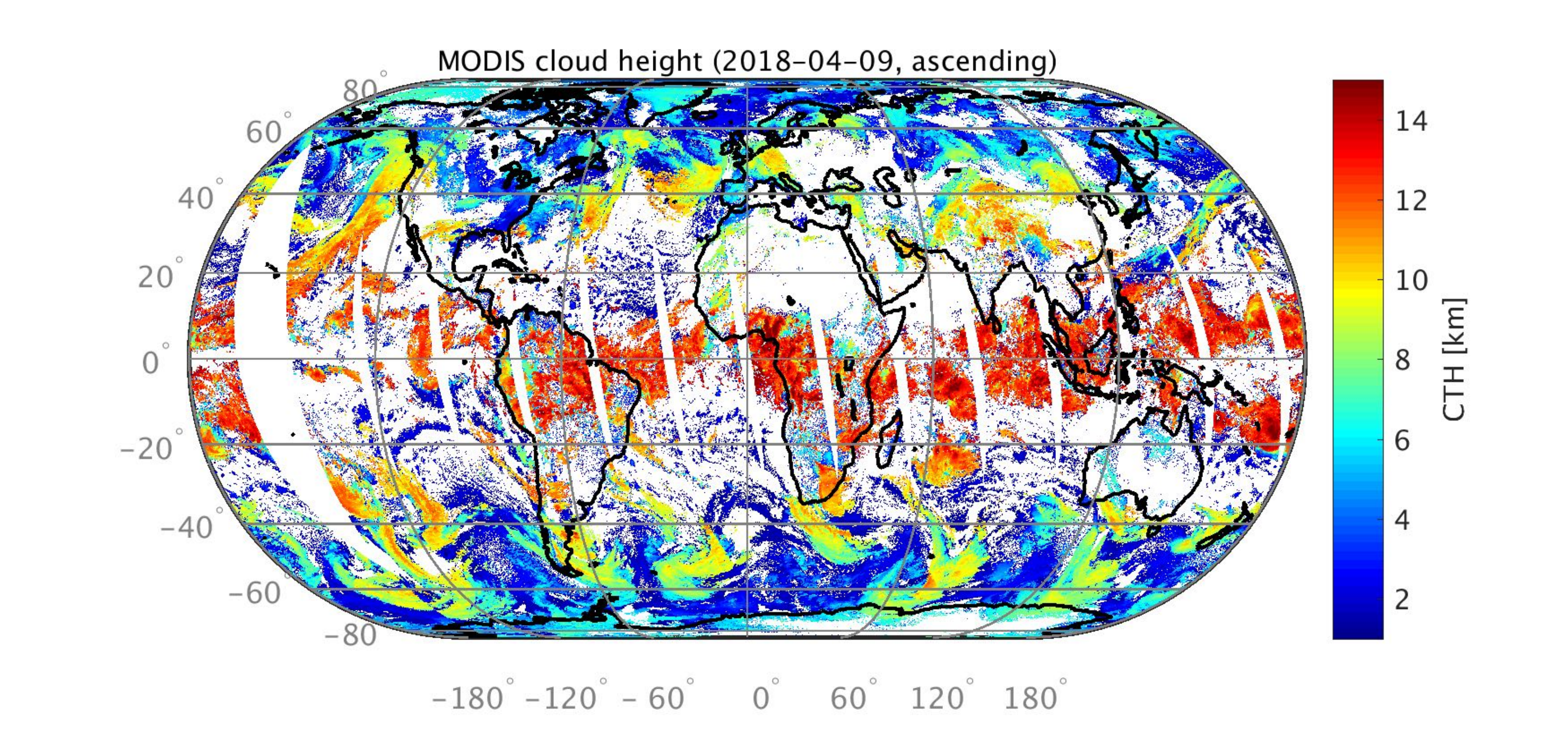
b. does inclusion of IR bands cause harm?

MVCM (Fusion – VIIRS) Nighttime Cloud Fraction Difference (%)
April 9, 2018



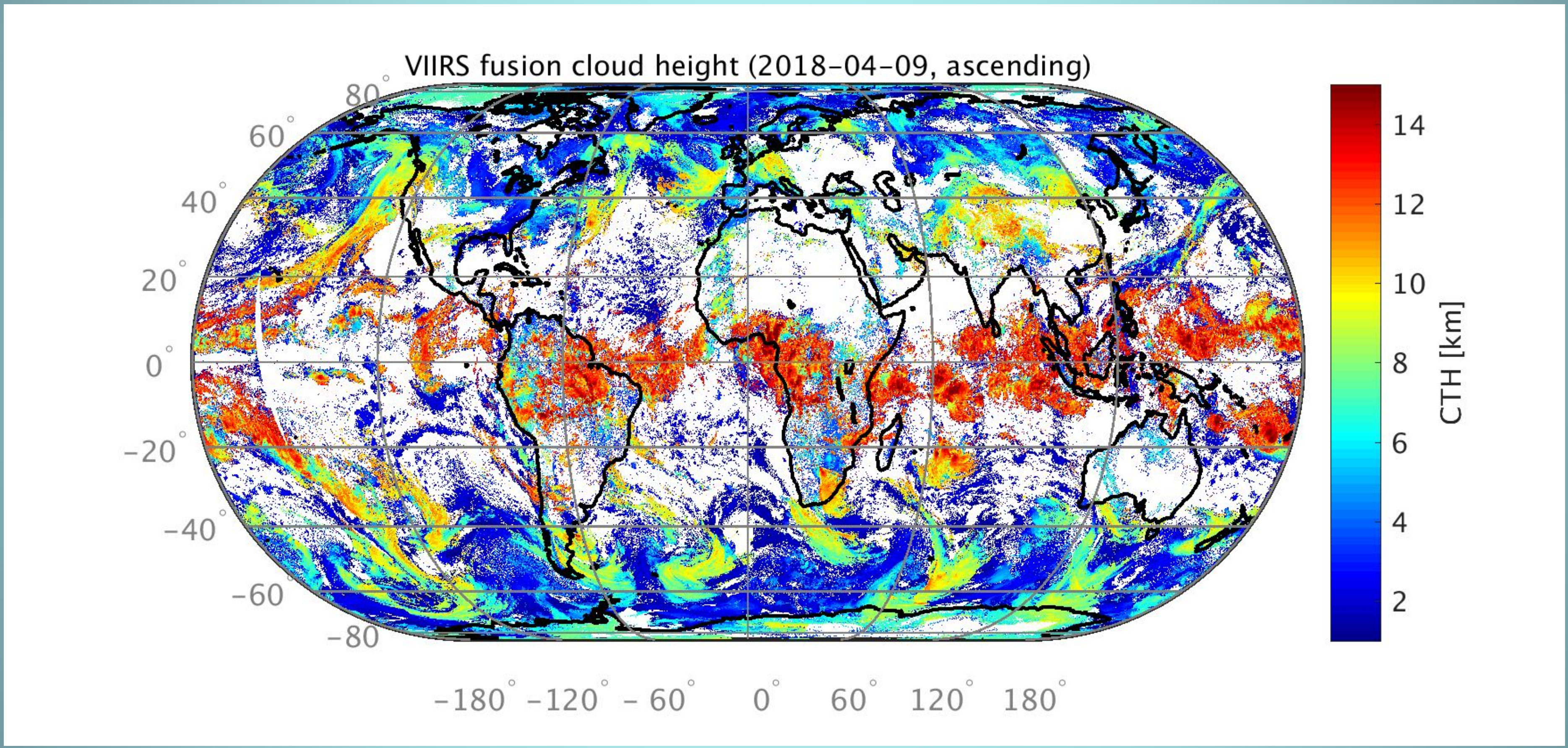
Additional MODIS-like cloud mask tests employed without "tweaking" any thresholds. Impact of fusion channels greater at night than daytime. Note that scale is ±100%.

MODIS Cloud Top Heights From ACHA (NOAA)
April 9, 2018
Ascending Orbits



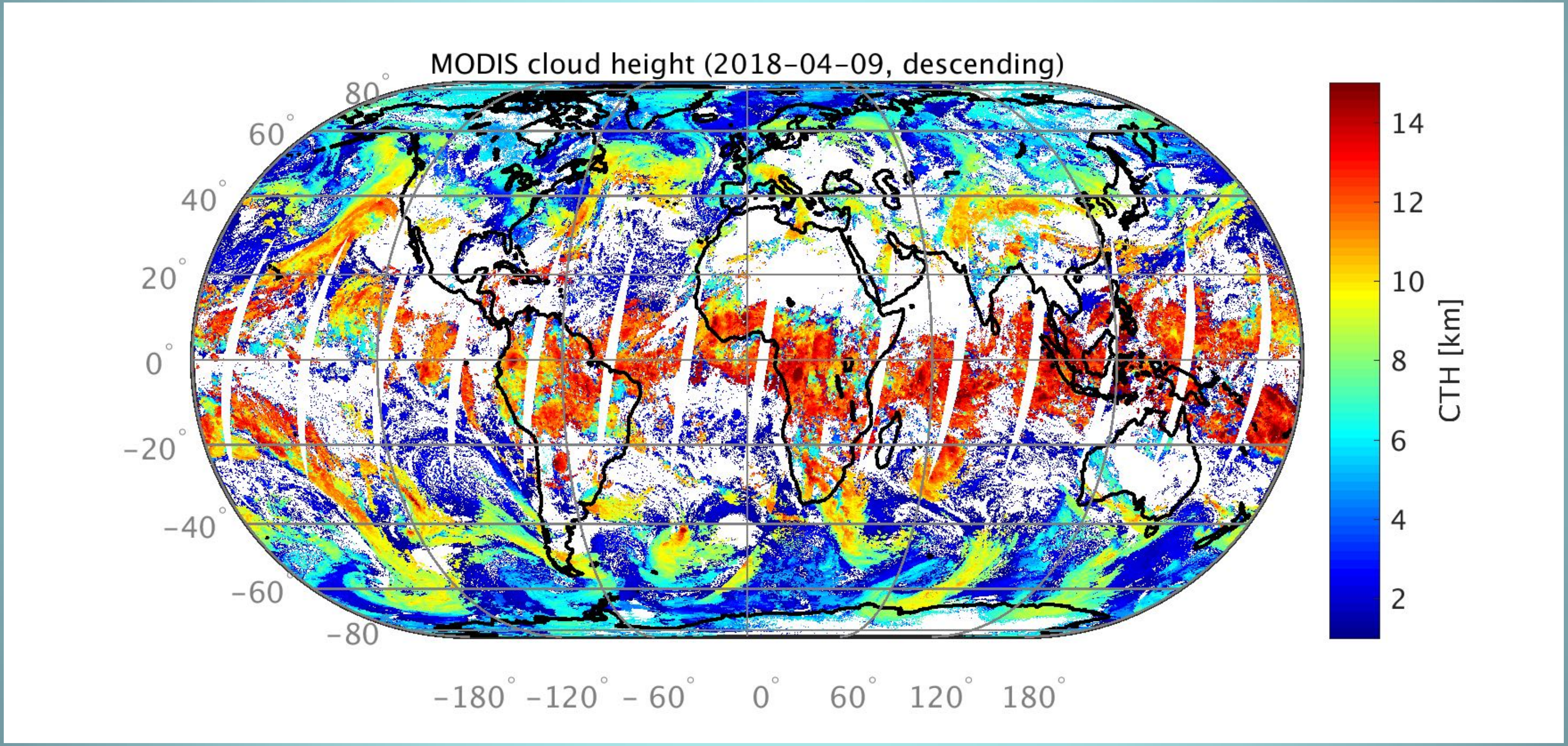
Courtesy of Yue Li (SSEC) and Andy Heidinger (NOAA)

VIIRS Fusion Cloud Top Heights From ACHA (NOAA)
April 9, 2018
Ascending Orbits



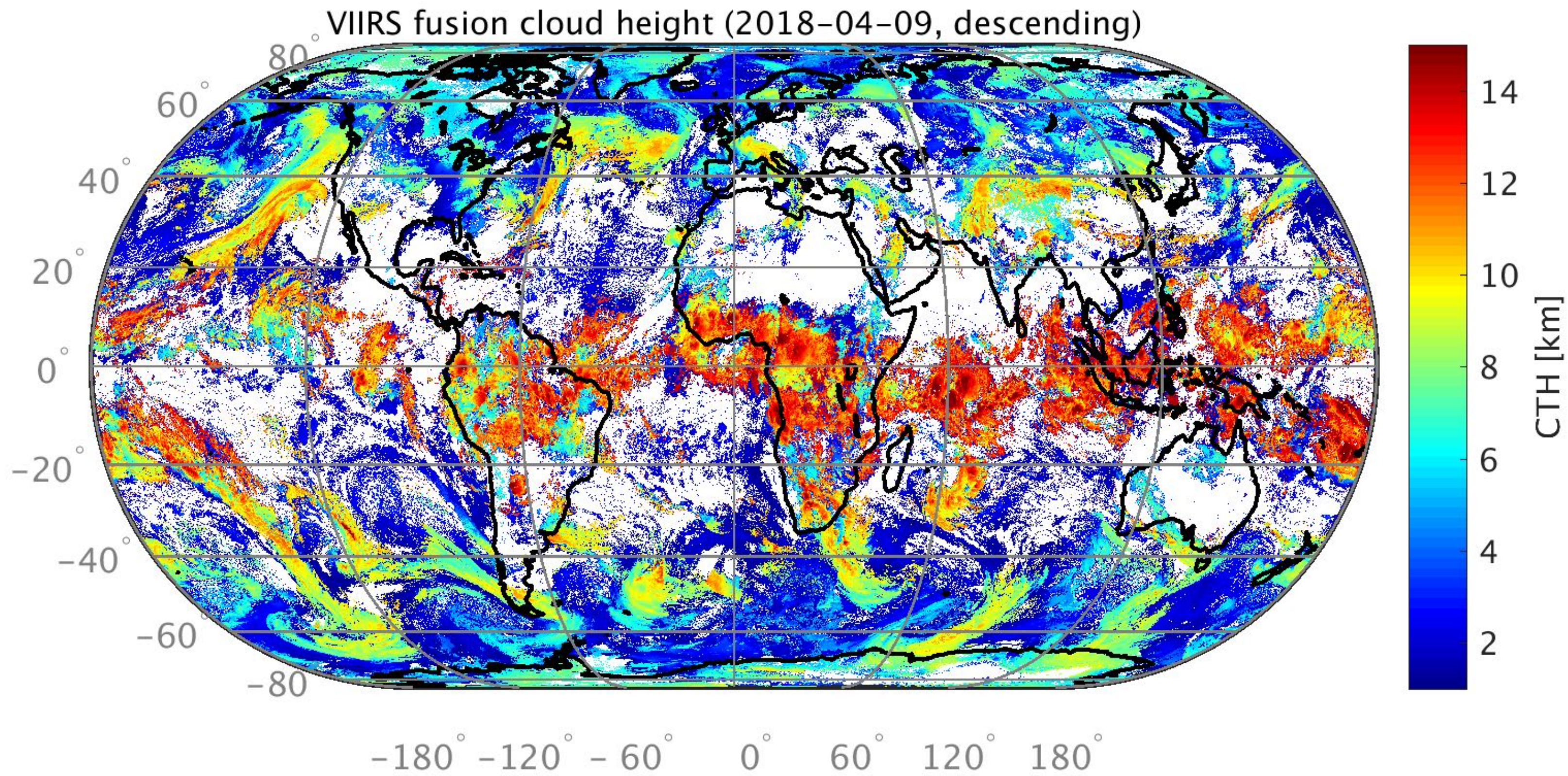
Courtesy of Yue Li (SSEC) and Andy Heidinger (NOAA)

MODIS Cloud Top Heights From ACHA (NOAA)
April 9, 2018
Descending Orbits



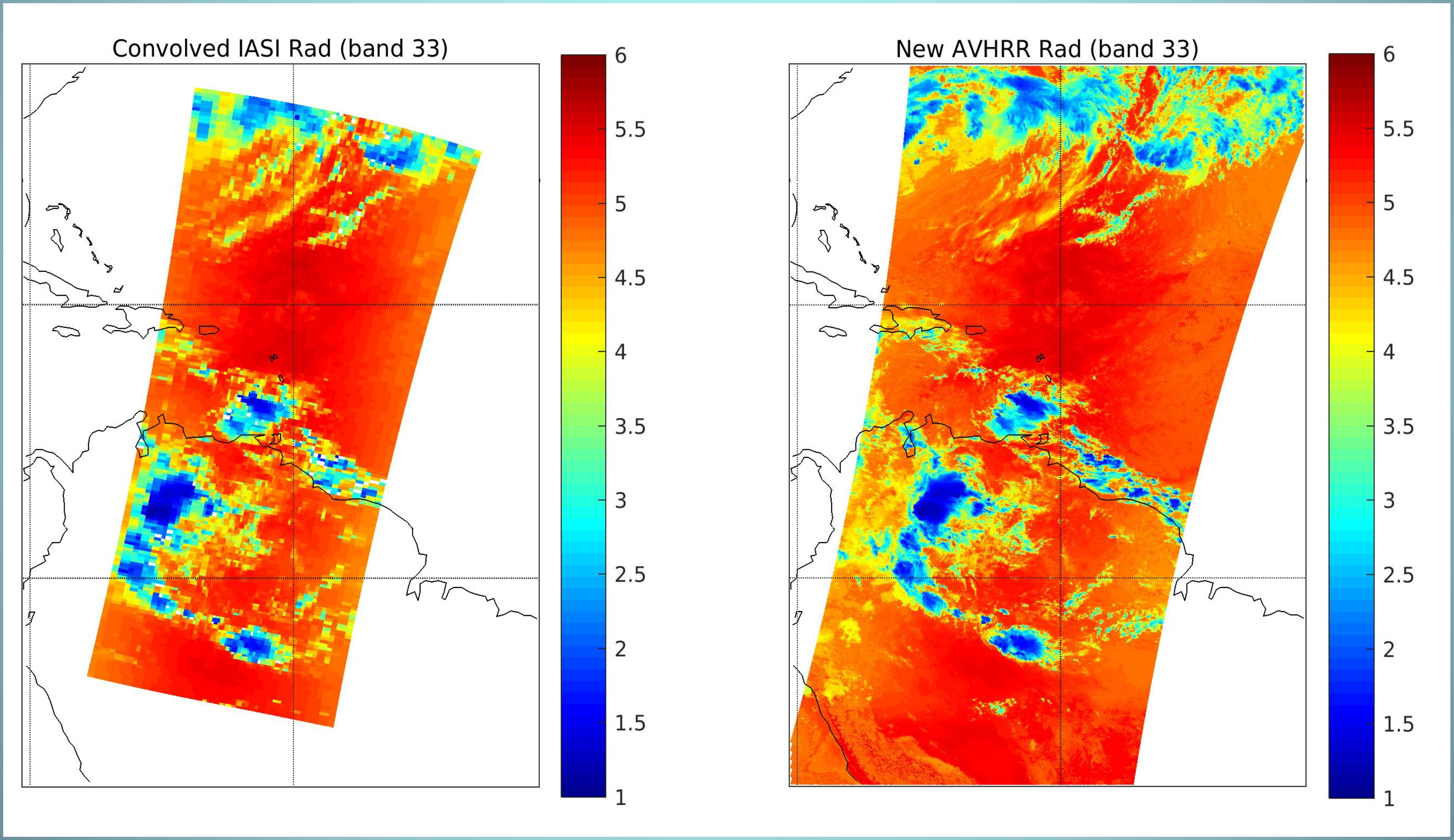
Courtesy of Yue Li (SSEC) and Andy Heidinger (NOAA)

VIIRS Fusion Cloud Top Heights From ACHA (NOAA)
April 9, 2018
Descending Orbits



Courtesy of Yue Li (SSEC) and Andy Heidinger (NOAA)

Construction of MODIS-like IR bands for AVHRR on Metop-B (AVHRR+IASI)



Summary

Demonstrated ability to construct IR radiances for imagers based on imager-sounder data fusion

Current application is to construct Aqua MODIS-like channels for VIIRS

Methodology expanded to AVHRR+IASI and AVHRR+HIRS

Capability to construct new channels, e.g., more H_2O channels with SRF overlap

Capability to construct channels with lines of strong trace gas absorption eliminated (would make forward modeling much faster)

Contact: babaum@stcnet.com

Cross et al., 2013: Statistical estimation of a 13.3-μm Visible Infrared Imaging Radiometer Suite channel using multisensor data fusion. *J. Appl. Remote Sens*. **7** (1), 073473, doi: 10.1117/1.JRS.7.073473.

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