Analysis and Mitigation of Atmospheric Crosstalk

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Introduction

- What is crosstalk?
  - When a retrieval algorithm aliases unrelated geophysical signals into the retrieval
- Why is understanding crosstalk important?
  - Can mask important modes of variability (e.g., El Nino)
  - Can produce spurious trends on decadal time scales
- What are primary crosstalk sources for IR SST retrievals?
  - Clouds, water vapor, aerosols
- Why is quantifying IR SST crosstalk difficult?
  - Vapor is correlated with SST, and this correlation is a function of time scale
  - Vapor and cloud are correlated
  - Clouds have significant horizontal, vertical, and microphysical variability
  - Aerosols have a variety of radiative properties and lack unique spectral signature

Objectives

1. Develop a better understanding the effects of water vapor, aerosols, and clouds on VIIRS SST retrievals
2. Develop and implement two VIIRS SST algorithms
   - Physically parameterized statistical algorithm (PPSA)
     - Weighted least-squares algorithm, parameterized in terms of physical quantities
     - Tunable, like a statistical algorithm, by adjusting the a priori values and uncertainties
   - Combined VIIRS and AMSR2 algorithm
     - Uses AMSR2 in specifying a priori values and uncertainties
     - Additional cloud clearing based on AMSR2
     - Identifying and mitigating aerosol effects by comparing AMSR2 and VIIRS
3. Provide a characterization of uncertainties in SST retrievals

Preliminary Results

- Downloaded SDR data from VIIRS SIPS FTP at University of Wisconsin Space Science and Engineering Center
  - SVM12, SVM13, SVM15, SVM16, GMTCO
    - Does cloud clearing require other channels?
  - One granule = 52 MB
  - One day = 52 GB
  - One year = 19 TB
- Our project will be delivering software to VIIRS Ocean SIPS to run the SST algorithms
  - Is this the dataset I should be using for algorithm development?
- Also using RSS AMSR2 retrievals of SST, wind, vapor, cloud, and rain
  - Data available at www.remss.com
  - Resolution: twice daily, 0.25-deg grid
  - Validation of AMSR2 SST: Gentemann and Hilburn, 2015, JGR-O, accepted
  - Intercomparison of RSS and JAXA calibrations: Hilburn and Gentemann, 2015, JGR-O, submitted
  - Note: VIIRS starts October 2011, AMSR2 starts July 2012

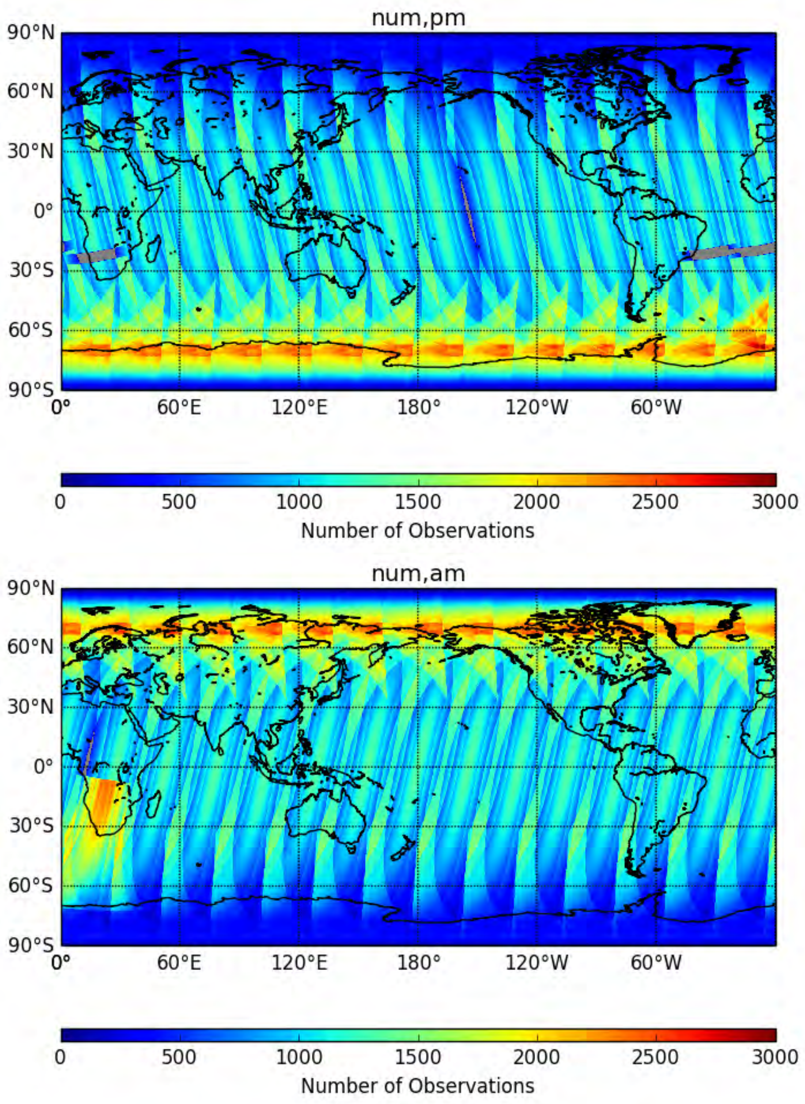
Table 1. VIIRS channels.

Band number/gain	VIIRS wavelength (μm)	VIIRS nadir pixel size along track × cross track (km)	Primary application
M1, dual	0.412	0.742 × 0.259	Ocean color, aerosols
M2, dual	0.445	0.742 × 0.259	Ocean color, aerosols
M3, dual	0.488	0.742 × 0.259	Ocean color, aerosols
M4, dual	0.555	0.742 × 0.259	Ocean color, aerosols
I1, single	0.640	0.371 × 0.387	Imagery, vegetation
M5, dual	0.672	0.742 × 0.259	Ocean color, aerosols
M6, single	0.746	0.742 × 0.776	Atmospheric correction
I2, single	0.865	0.371 × 0.387	Vegetation
M7, dual	0.865	0.742 × 0.259	Ocean color, aerosols
DNB, multiple	0.7	0.742 × 0.742	Imagery
M8, single	1.24	0.742 × 0.776	Cloud particle size
M9, single	1.38	0.742 × 0.776	Cirrus cloud cover
M10, single	1.61	0.742 × 0.776	Snow fraction
I3, single	1.61	0.371 × 0.387	Binary snow map
M11, single	2.25	0.742 × 0.776	Clouds
M12, single	3.70	0.742 × 0.776	Sea surface temperature (SST)
I4, single	3.74	0.371 × 0.387	Imagery, clouds
M13, dual	4.05	0.742 × 0.259	SST, fires
M14, single	8.55	0.742 × 0.776	Cloud-top properties
M15, single	10.76	0.742 × 0.776	SST
I5, single	11.45	0.371 × 0.387	Cloud imagery
M16, single	12.01	0.742 × 0.776	SST

From Lee et al. (2006), *BAMS*

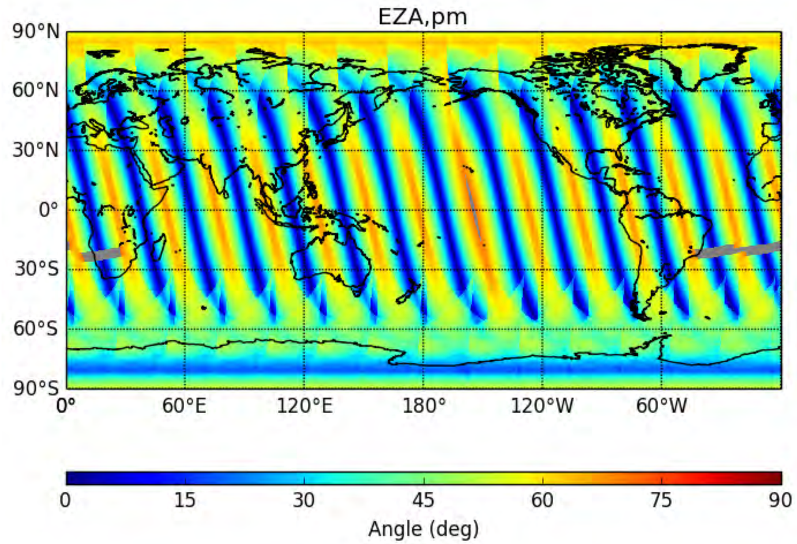
Sampling Patterns

- Maps show the number of observations falling in 0.25-deg Earth grid, for one day, separated local AM/PM
- VIIRS resolution = 0.7 km
- Thus, in the swath center the typical number of observations is
  - 25 km (1440 x 720) gives 1225 obs
  - 12.5 km (2880 x 1440) gives 289 obs
  - 9 km (4096 x 2048) gives 144 obs
  - 5 km (7200 x 3600) gives 49 obs
- Sampling patterns are complicated along swath edges because
  - Adjacent passes overlap (increases number of observations)
  - Mitigation of bow-tie effect (decreases number of observations, for two distinct scan angle ranges)
- To handle the TB-scale data volume, our project is to use VIIRS files that are pre-processed onto Earth grids
  - Is there compelling reason to chose particular grid resolution?
  - Since Earth zenith angle increases with scan angle, is there a maximum scan angle beyond which retrieval is not advisable?
  - Avoid high latitude overlap by making each map one orbit?

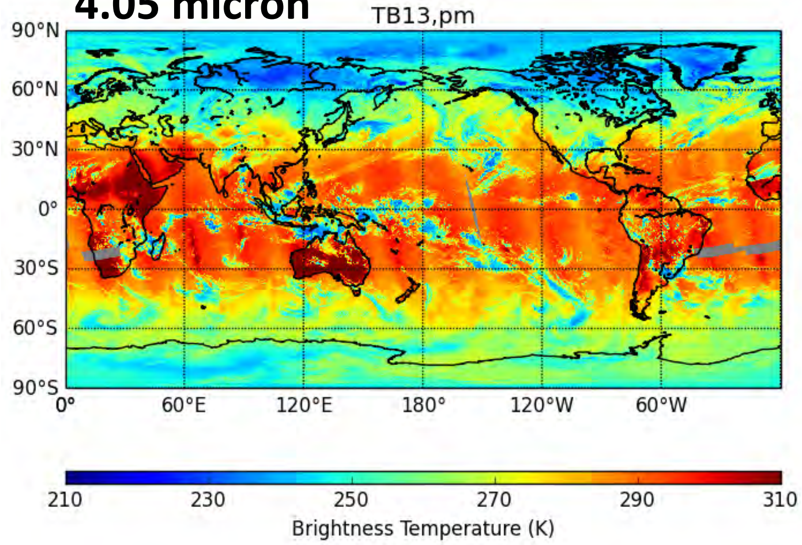


Viewing Geometry

- The Earth zenith angle varies from 0 deg at swath center to 70 deg at swath edges
- At swath edge, path through atmosphere is 2.9 x longer than swath center
- At 4.05 micron there is clear zenith angle dependence
  - Warmer at zenith angles of 0 deg
  - Cooler at zenith angles of 70 deg

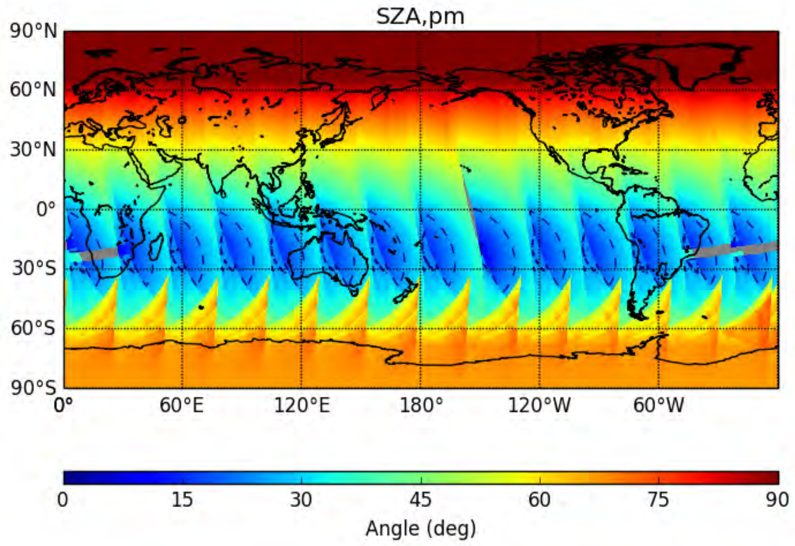


4.05 micron

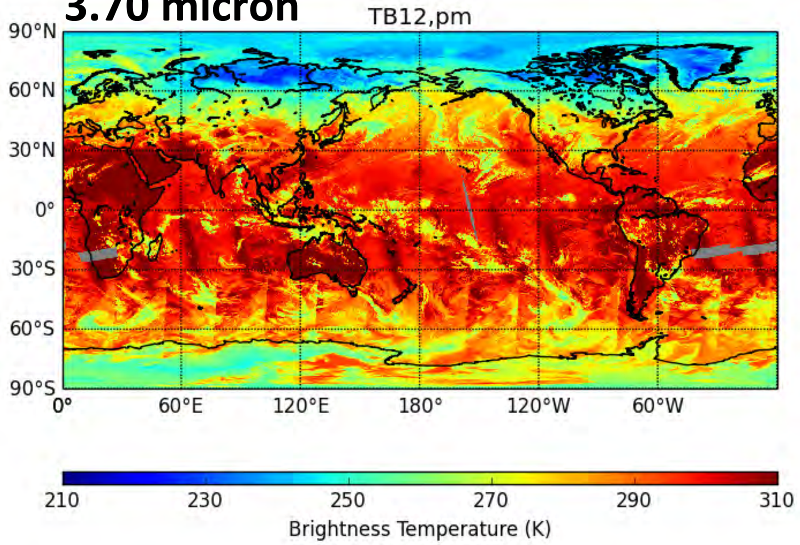


Solar Geometry

- Areas with solar zenith angle less than 25 deg are highlighted with dashed contours
- These correspond to hot areas in the 3.70 micron TB
- Would be preferable to examine sun-glint angle, which is angle between sun reflection vector and boresight vector



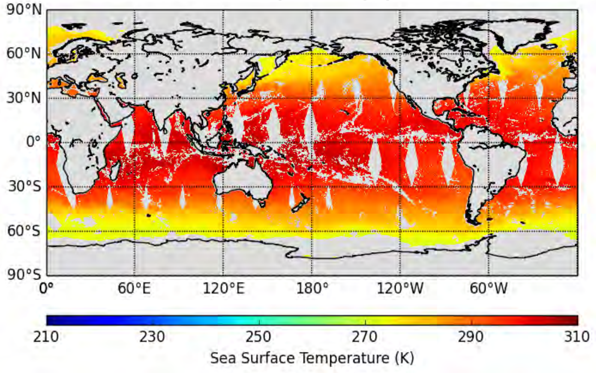
3.70 micron

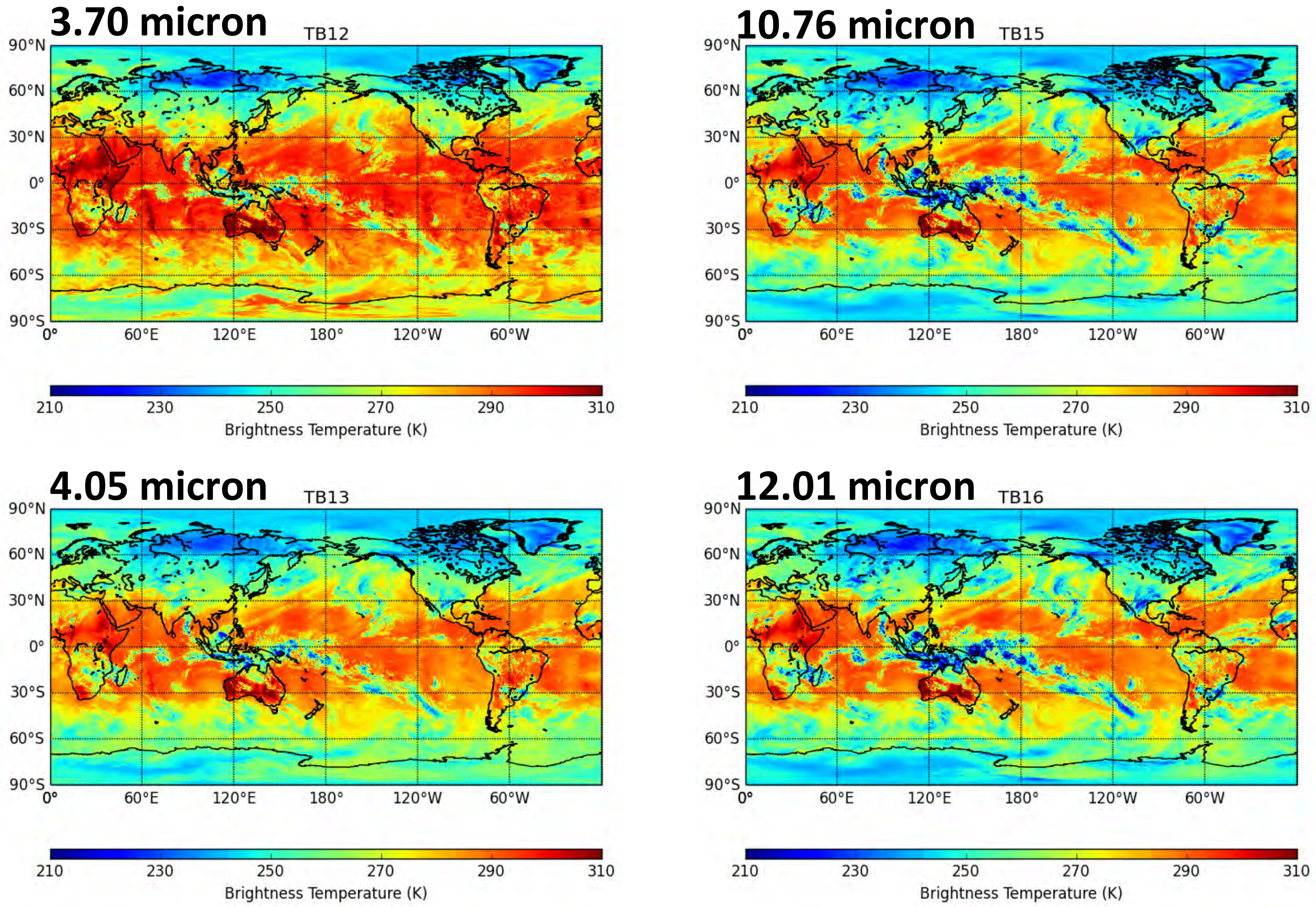


Daily Average TB

- Temperatures range from about 260 K over high-latitude ocean to 300 K over tropical ocean
- Areas with TB below 250 K are tall clouds with cold cloud tops, and are most prominent in longer wavelengths
- The 3.70 micron channel most closely resembles SST

AMSR2 SST



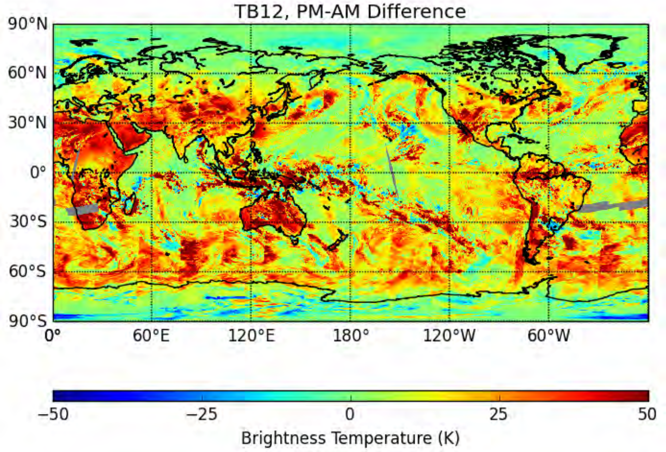


Daily average VIIRS TB from 2015/01/01

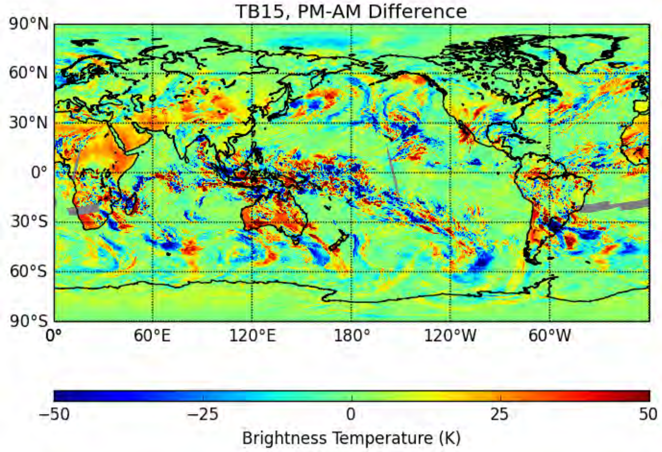
PM-AM TB Difference

- VIIRS on Suomi NPP satellite has ascending node time of 1:30 PM
- Over land, the increase in temperature from morning to afternoon is strongest at 3.70 micron, indicating the largest surface contribution
- 3.70 micron also has large (20-30 K) positive PM-AM differences over Southern Ocean – this example is from January: sun reflection
- Diurnal differences are on the order 10-20 K at 4.05 micron and are 10 K or less for 10.76 and 12.01 micron

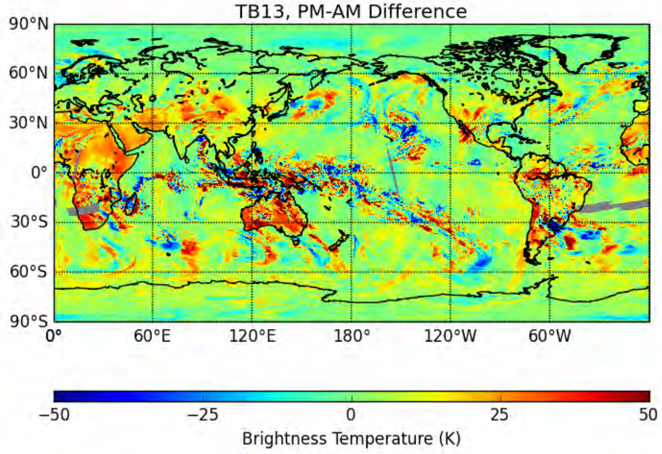
3.70 micron



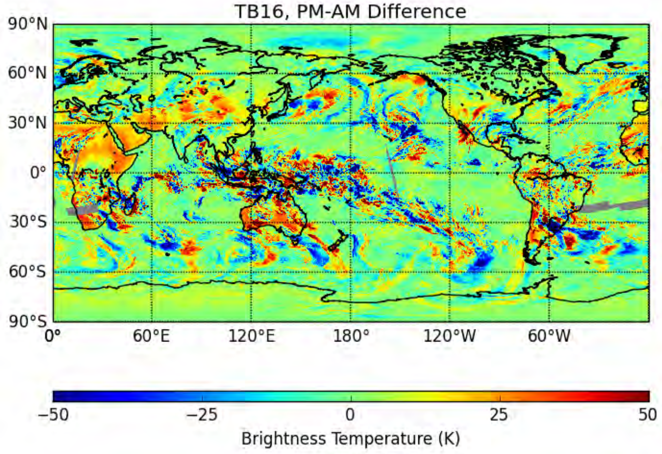
10.76 micron



4.05 micron



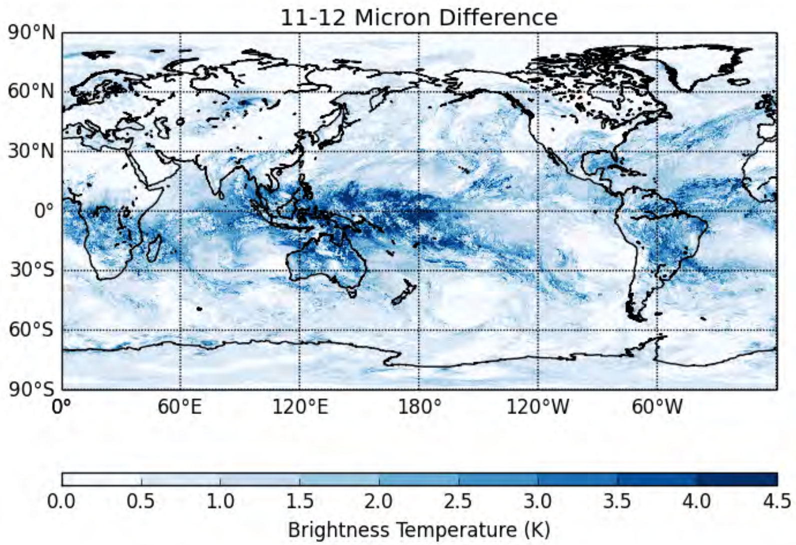
12.01 micron

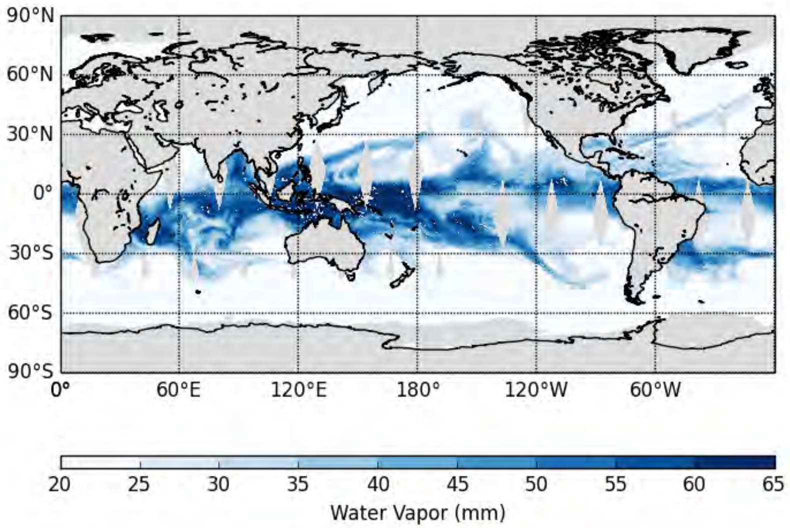


PM-AM (LT) VIIRS TB from 2015/01/01

11-12 Micron TB Difference and Vapor

- Overall, there is a positive correlation between the VIIRS TB difference (top) and AMSR2 total columnar water vapor (bottom)
- This is most evident in the western tropical Pacific
- Other areas with abundant water vapor, like the eastern tropical Pacific and Indian Oceans have a smaller TB differences
- In some areas, like the tropical Atlantic, larger TB differences can be found outside of high vapor areas
- Plumes of vapor that extend into mid-latitudes are sometimes evident in TB difference (north Atlantic), and other times not (northwestern Pacific)





Summary and Conclusions

- Performed initial exploration of VIIRS data and comparison with AMSR2
- There is a clear SST signal in VIIRS TBs
- There is also a clear signal from clouds
- Large TB-SST differences occur where water vapor is abundant
- Large differences also can occur where vapor is low
    - Suggests that effective air temperature also plays important role
- The relationship between 11-12 micron TB diff and vapor varies by region
- First order of business: to produce gridded VIIRS TB with clouds cleared
    - Q/C: sun glint, TB bounds check, scan angle threshold, number of obs threshold
    - Maps should also include time and Earth zenith angle