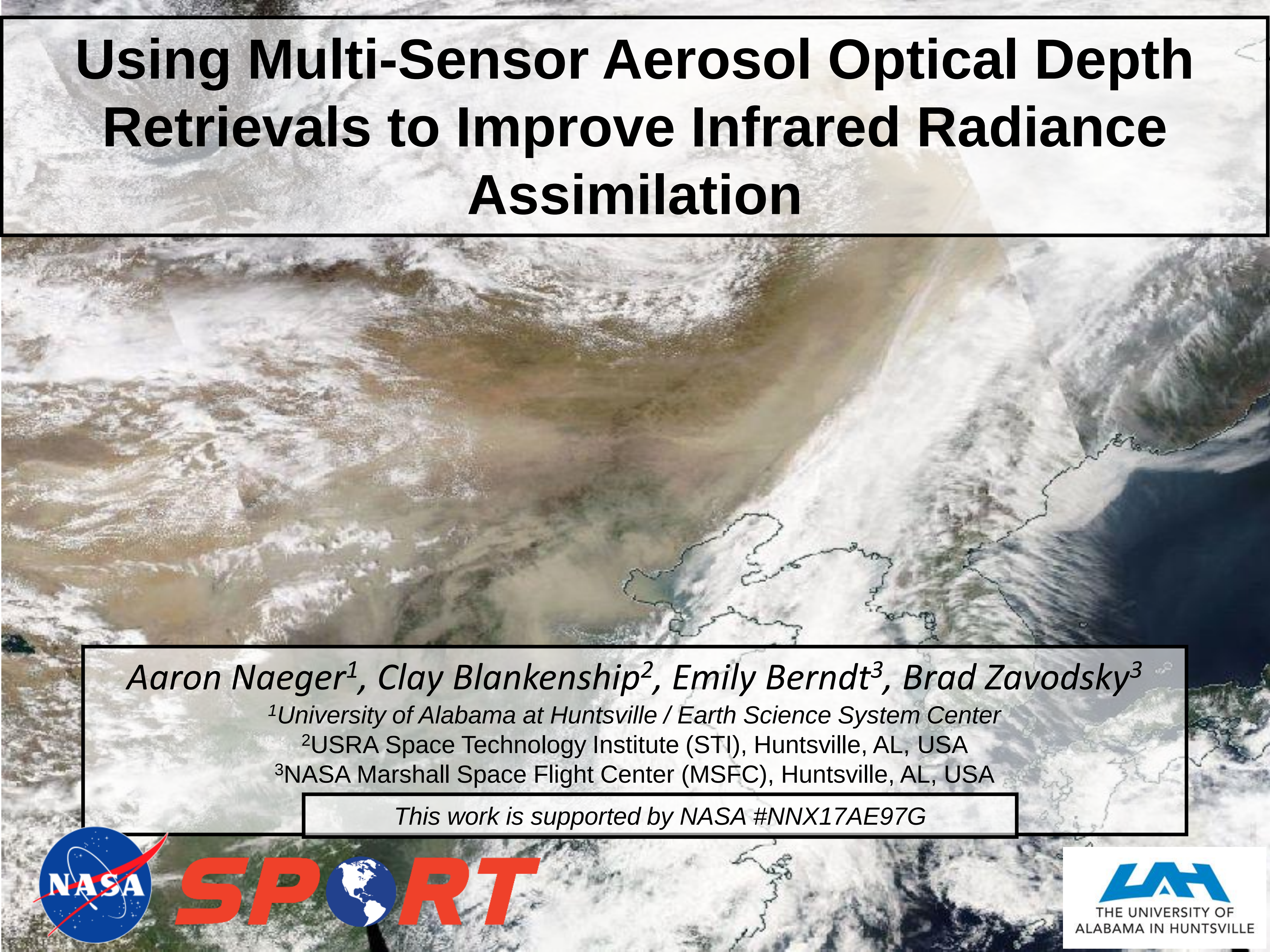
Using Multi-Sensor Aerosol Optical Depth Retrievals to Improve Infrared Radiance Assimilation



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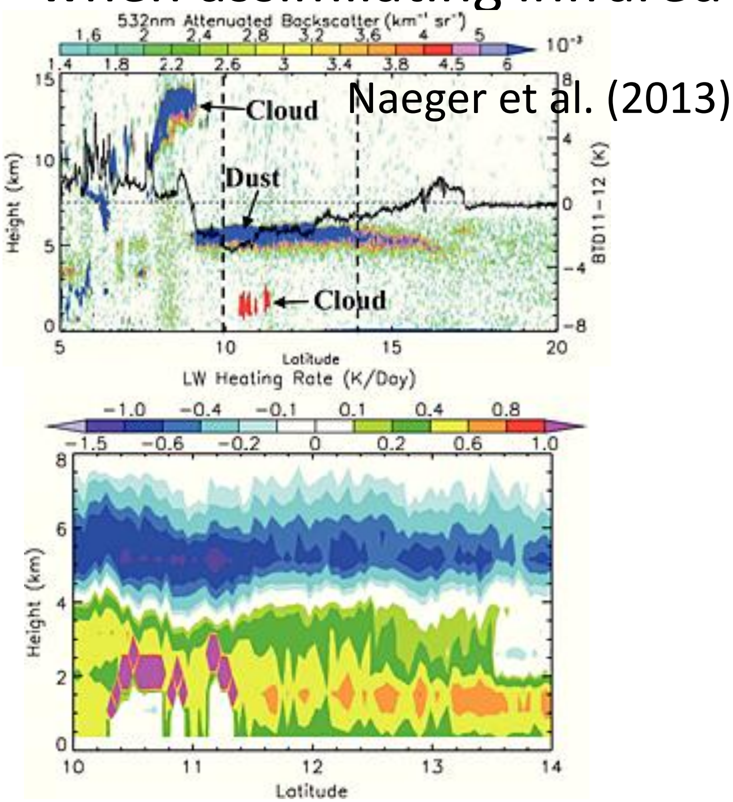
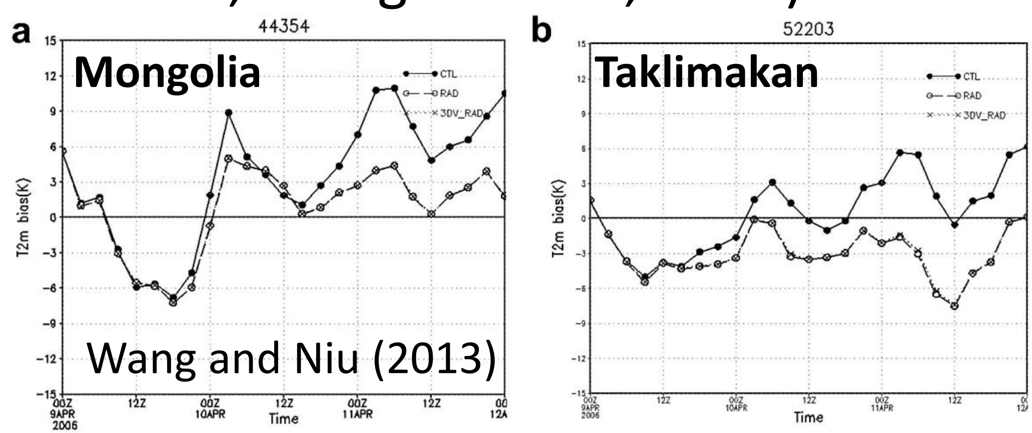
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Motivation

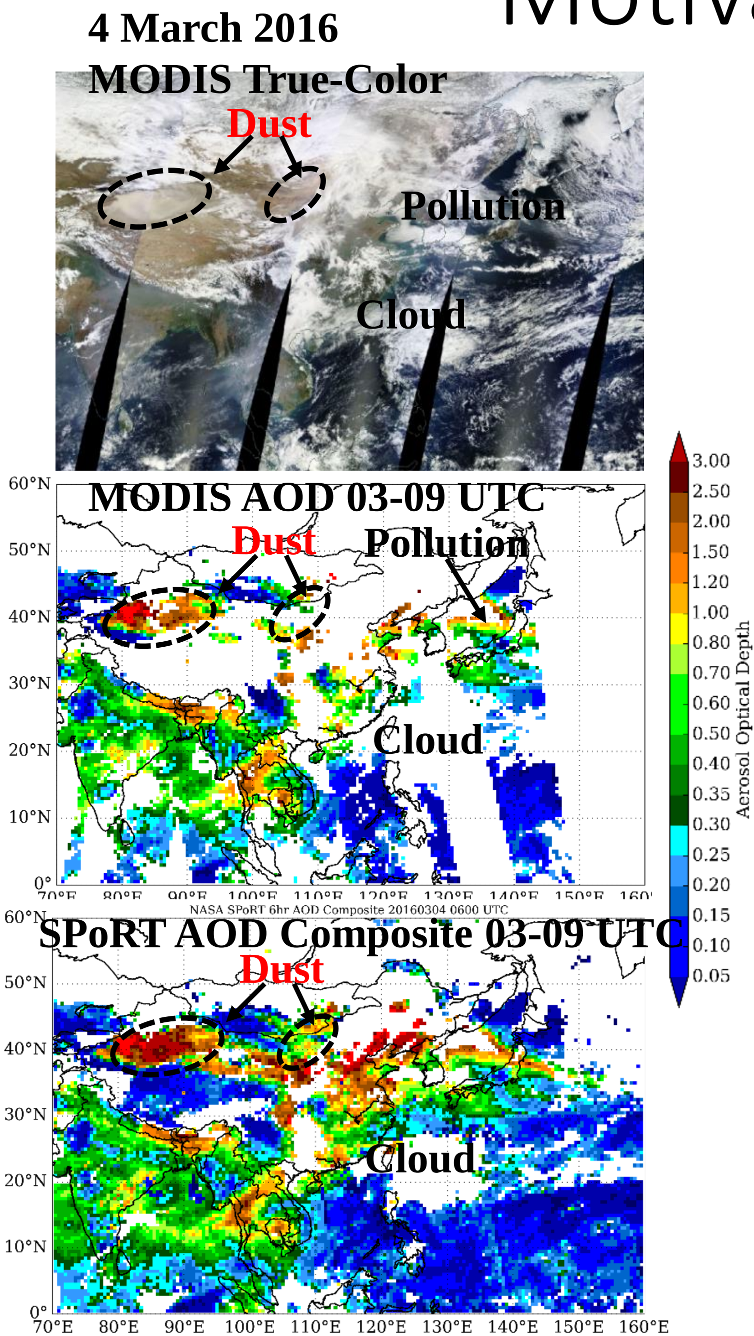
- Coarse dust aerosols absorb terrestrial radiation leading to significant longwave heating/cooling rates (Huang et al., 2009; Naeger et al., 2013)
- Modules accounting for aerosol impacts on radiation have been implemented into CRTM framework (Liu and Boukabara, 2014), but operational centers continue to assume aerosol-free conditions when assimilating infrared radiances into NWP models.



- **This assumption can introduce significant biases in analysis fields** (temp, moisture, etc.), which can **reduce forecast skill** (Perez et al., 2006; Wang and Niu, 2013)



Motivation and Goals

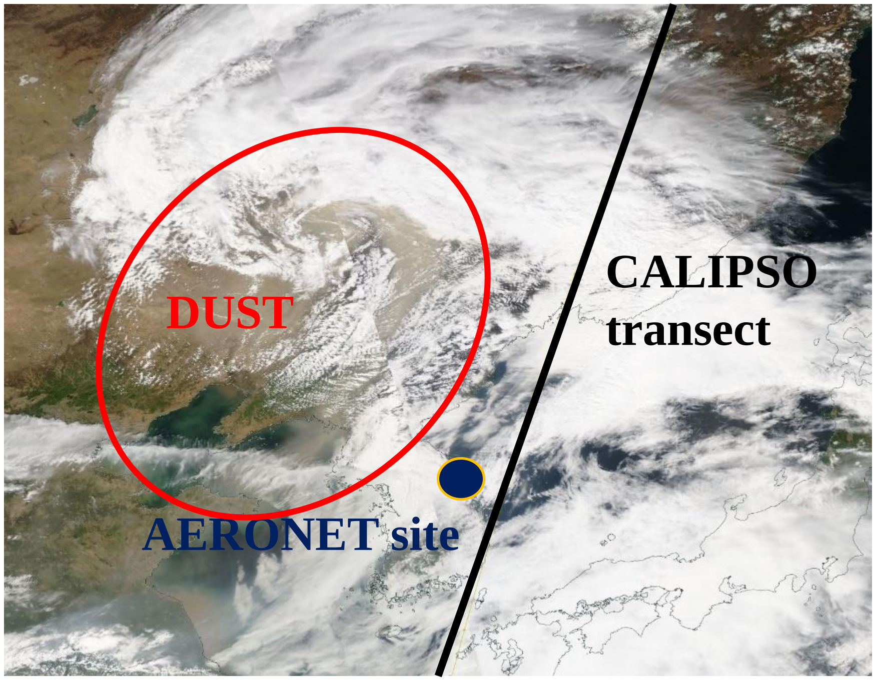


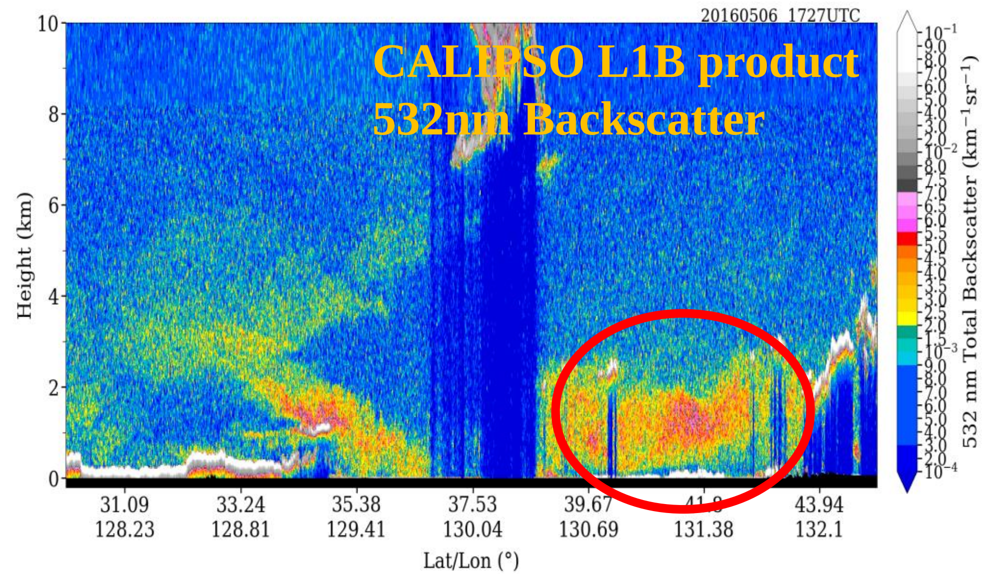
- Naeger et al. (2016) developed comprehensive AOD product by merging GEO (i.e.,MTSAT) and LEO sensors
- Use of LEO sensors alone can limit AOD spatial coverage
- Updated AHI AOD retrieval algorithm using improved aerosol models, quality control, and cloud masking technique, is currently being developed and validated
- **Goal: Improve assimilation of aerosol-affected radiances into NWP models within GSI by reducing forward model error via incorporation of SPoRT AOD as input into CRTM**

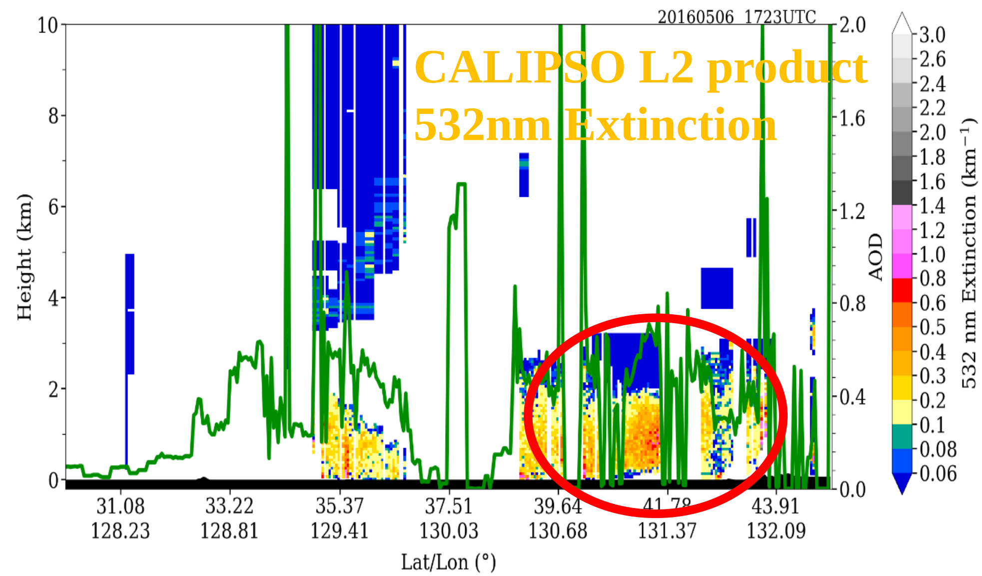
Motivational Questions

1. **How well can current aerosol modules in the CRTM simulate the satellite infrared radiances of coarse mode aerosols?**
2. **What is the overall impact of dust on satellite infrared radiances from the CRTM?**
3. Does the assimilation of aerosol-affected radiances lead to a reduction in error in the model analysis fields? What is the overall impact on the forecast?

6 May 2016 Asian Dust Case







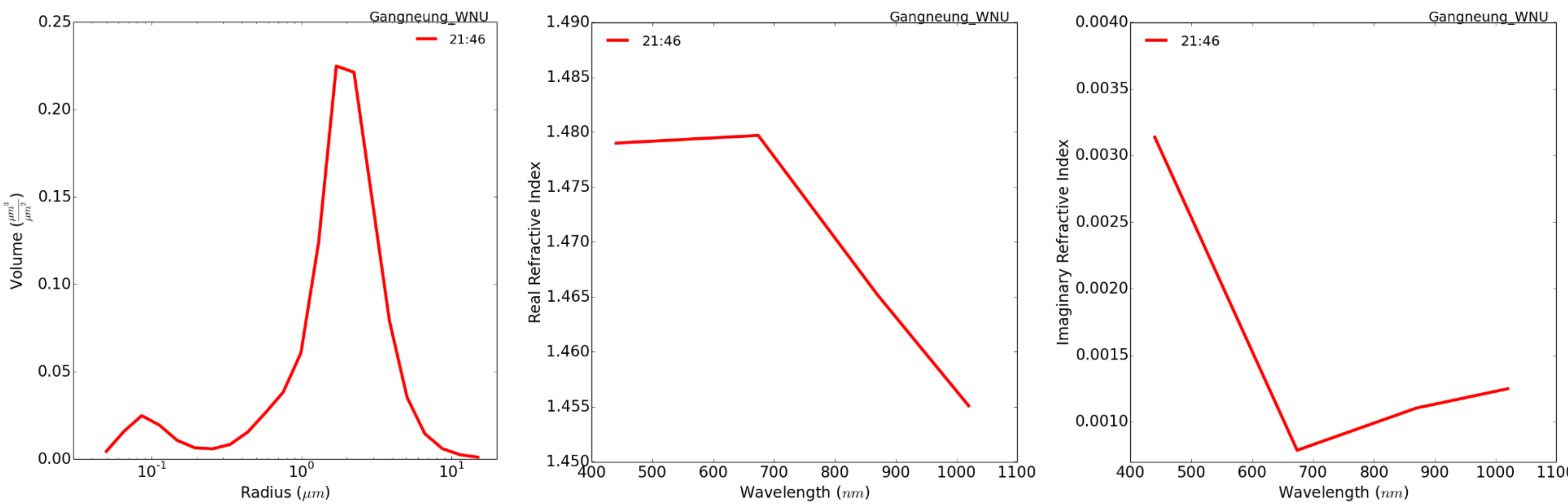
- Quantify uncertainty associated with CRTM aerosol modules using “best case” dust storms
- Nighttime CALIOP measures a lofted dust plume over the Sea of Japan
- Nearby AERONET sites provide detailed aerosol retrievals

Calculating CRTM input parameters

- Use nearby AERONET retrievals to determine realistic extinction efficiency (*Q*) from Mie calculations
- Calculate mass concentration (*M*) profiles for input into CRTM

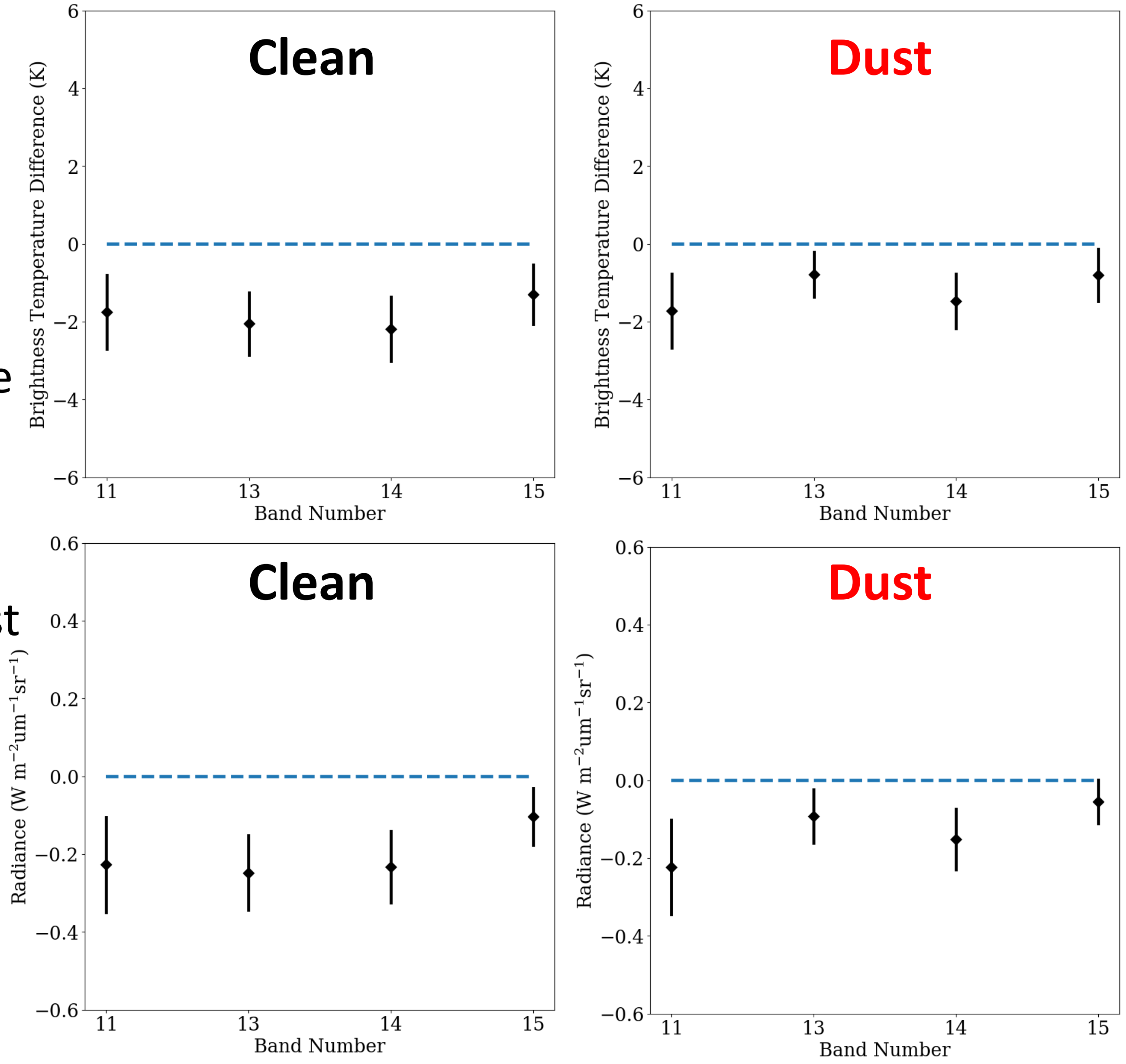
$$M = \frac{1.33 * \rho * AOD * r_e}{Q}$$

- CALIOP extinction retrieval profiles are converted to *AOD* from mass concentration calculation
- AERONET provides columnar measurements; therefore, assume constant size distribution and effective radius (r_e) throughout the column



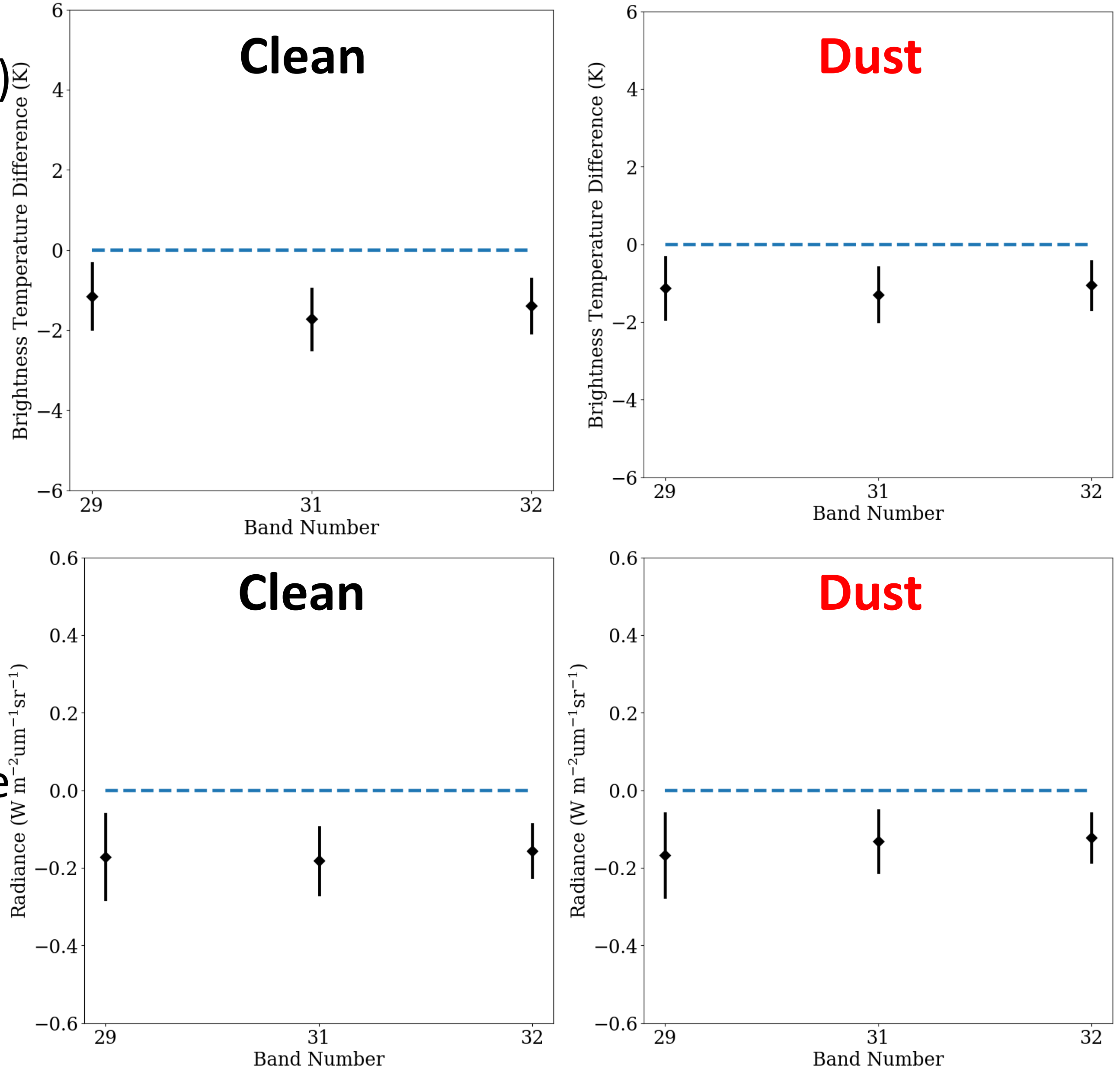
Observed vs Simulated AHI

- Run CRTM with clean and dusty profiles, along with same meteorology from MERRA reanalyses
- Simulated AHI BTs are still underestimated when accounting for dusty atmosphere
- Almost negligible dust impacts at 8.6 μm (Band 11) according to CRTM simulations
- CRTM underpredicts dust impacts in infrared bands

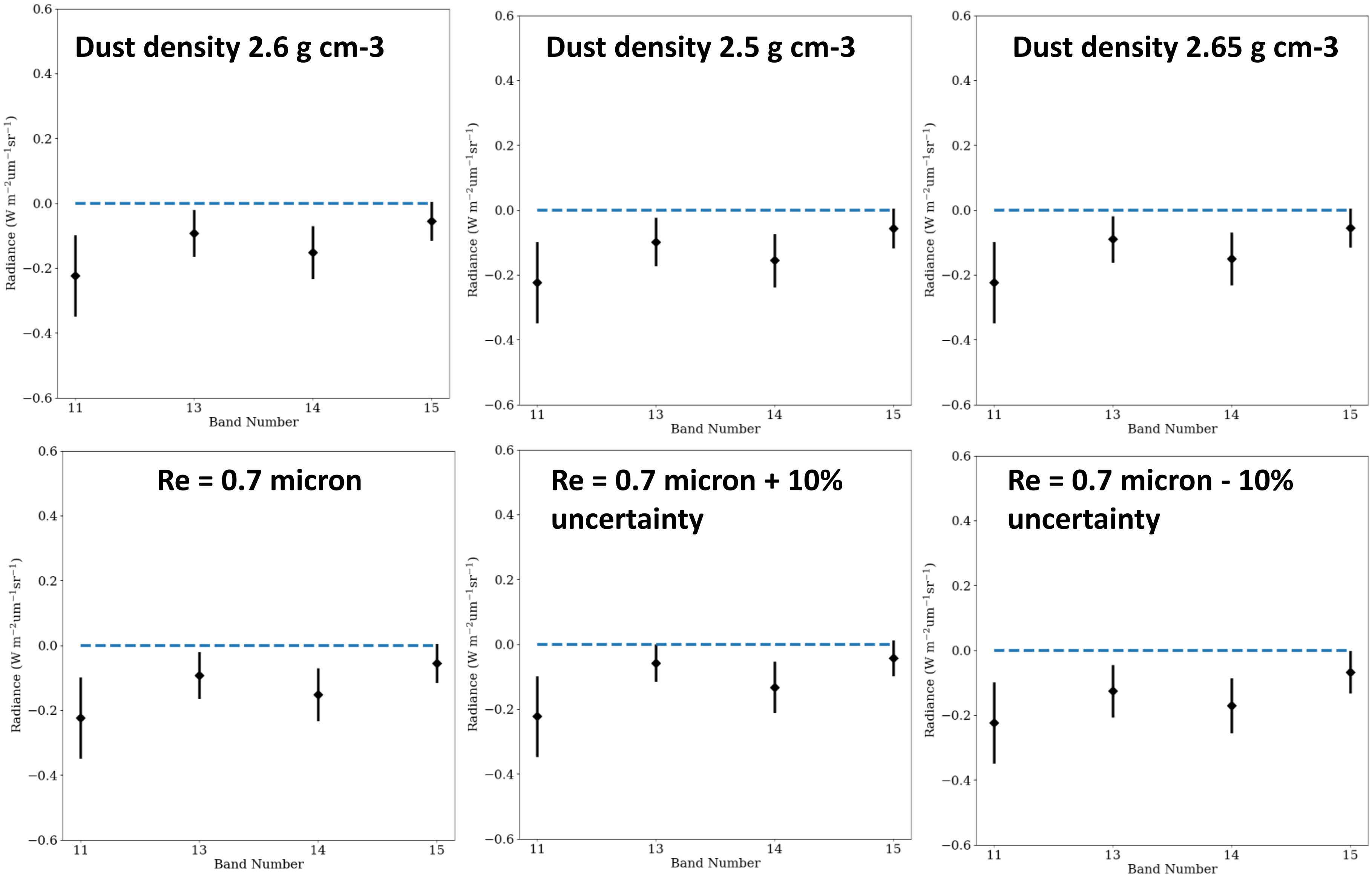


Observed vs Simulated MODIS

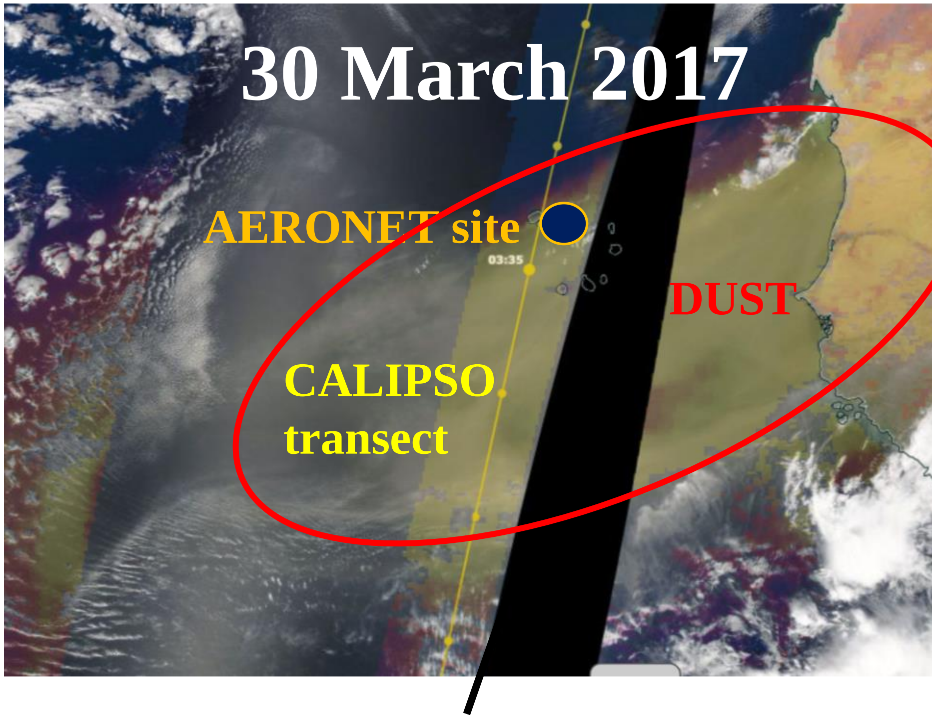
- MODIS 10.8 (Band 31) µm is less sensitive to dust than AHI 10.4 and 11.2 (Band 14) µm bands
- Overall MODIS simulated BTs are warmer than observed
- Suggests needed refinements to aerosol properties in CRTM aerosol module

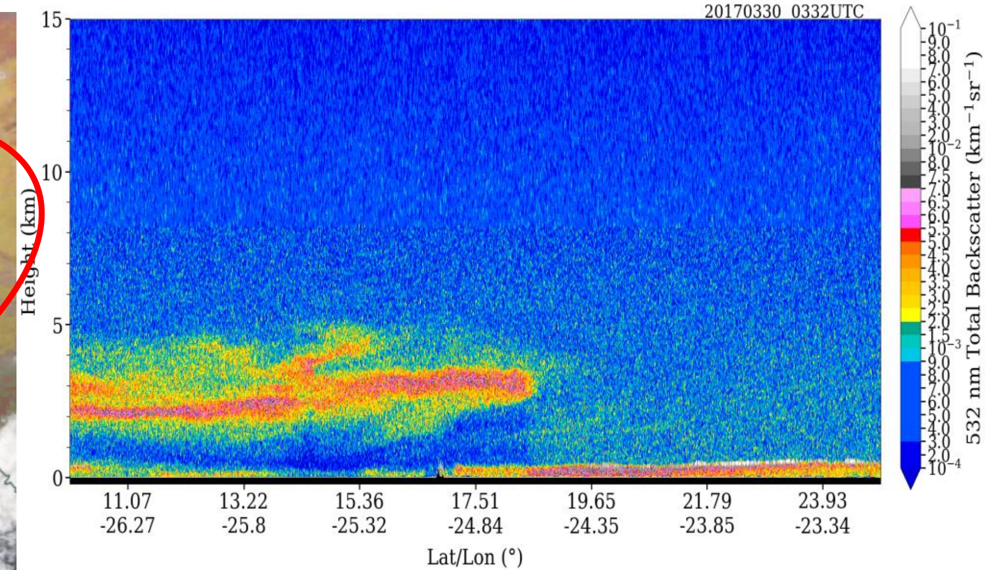


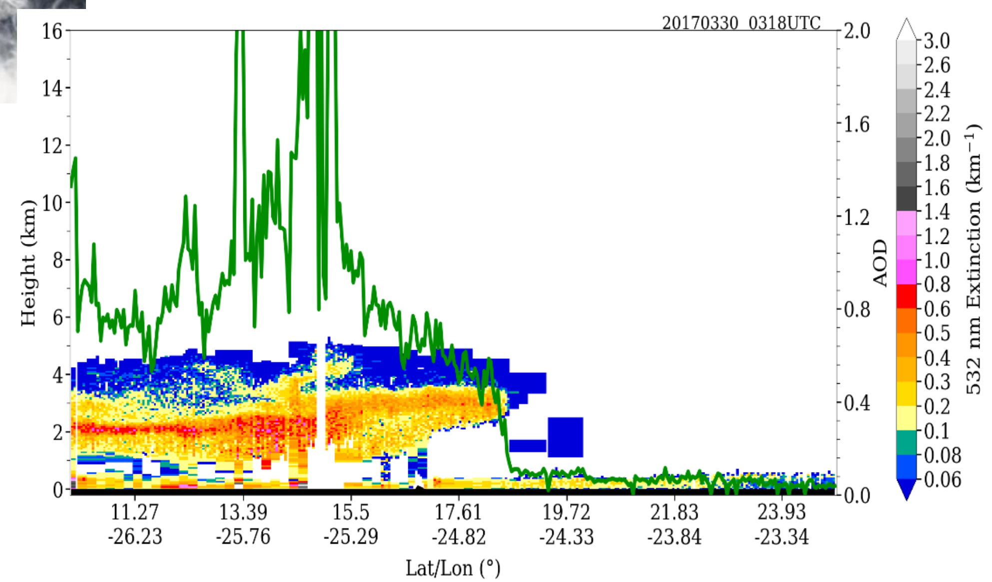
Sensitivity Tests with AHI



30 March 2017 Saharan Dust Case







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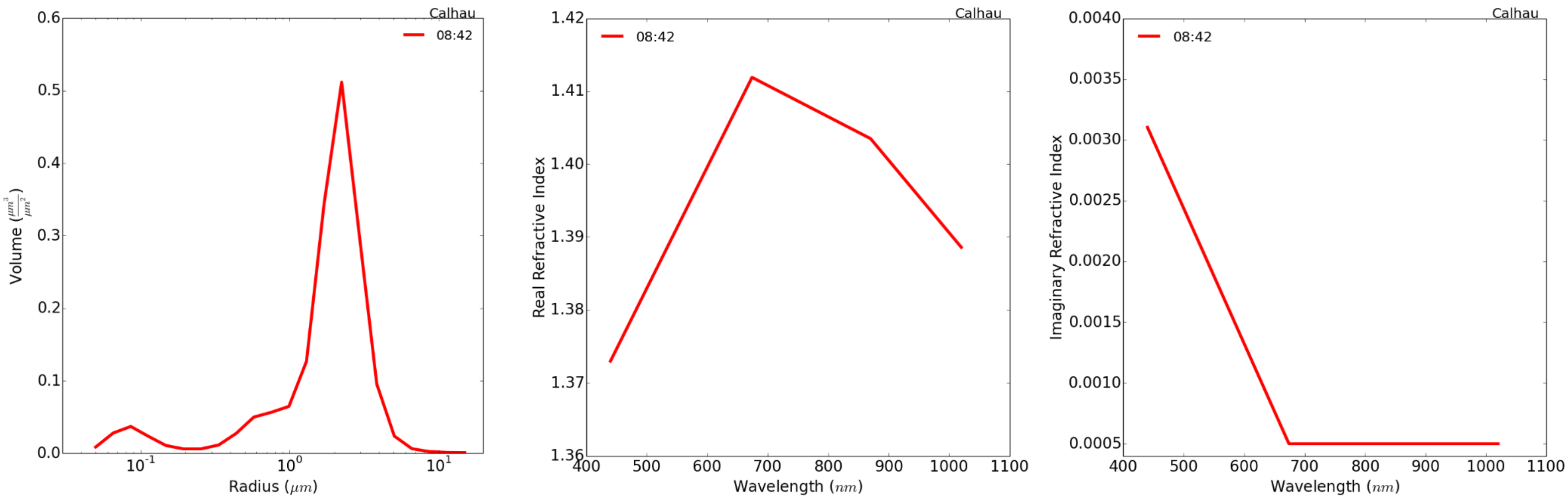
AERONET retrievals

- AERONET retrievals from Calhau site off West African coast

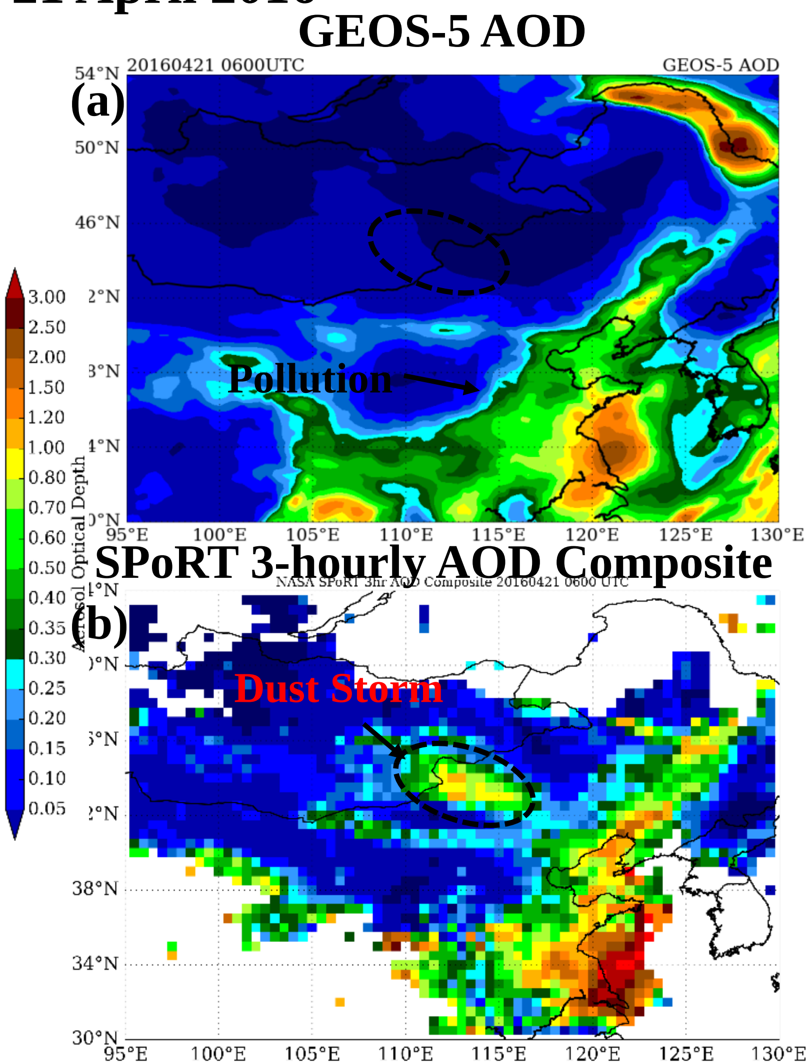


Simulation of infrared radiances using GEOS-5 fields

- Use 3-D meteorological and aerosol analysis fields from the GEOS-5 for input into the CRTM (conduct CTRL and EXP-GEOS runs)
- The GEOS-5 DAS uses GSI to combine observational information with a model state by minimizing a cost function that includes (1) departure of model fields from background and (2) departure of predicted (CRTM) from actual observations.
- GEOS-5 uses GOCART for predicting aerosol transport and physical processes …. 5 dust size bins (0.5, 1.4, 2.4, 4.5, 8.0 μm)

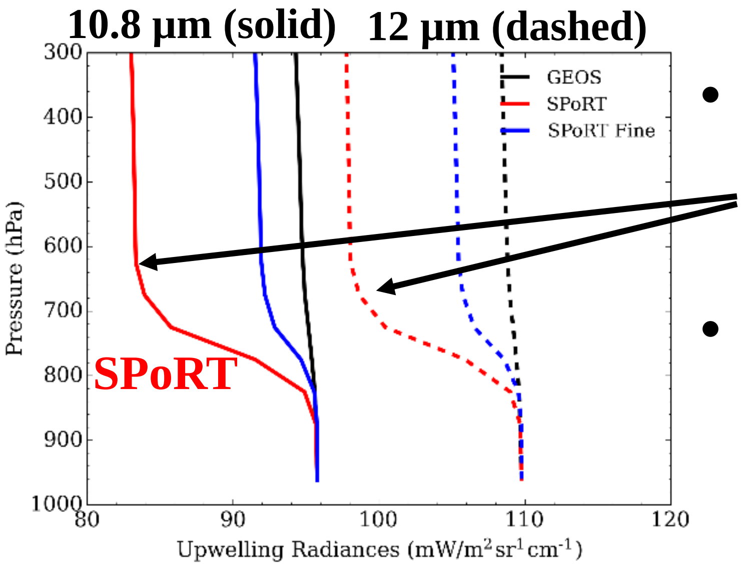
Simulation of infrared radiances using SPoRT AOD Composite

21 April 2016



- Utilize 3-hourly SPoRT AOD product for this work to emphasize aerosol retrievals closer to analysis time
- SPoRT product has better capability to depict dust storms due to high temporal resolution
- Our focus is not on aerosol assimilation; thus, a simple OA approach will be used to adjust the GEOS-5 mass concentrations
- We anticipate these EXP-SPoRT runs will lead to improved forecast skill
- However, errors in GEOS-5 will still translate to some errors here

Validation of simulated infrared radiances



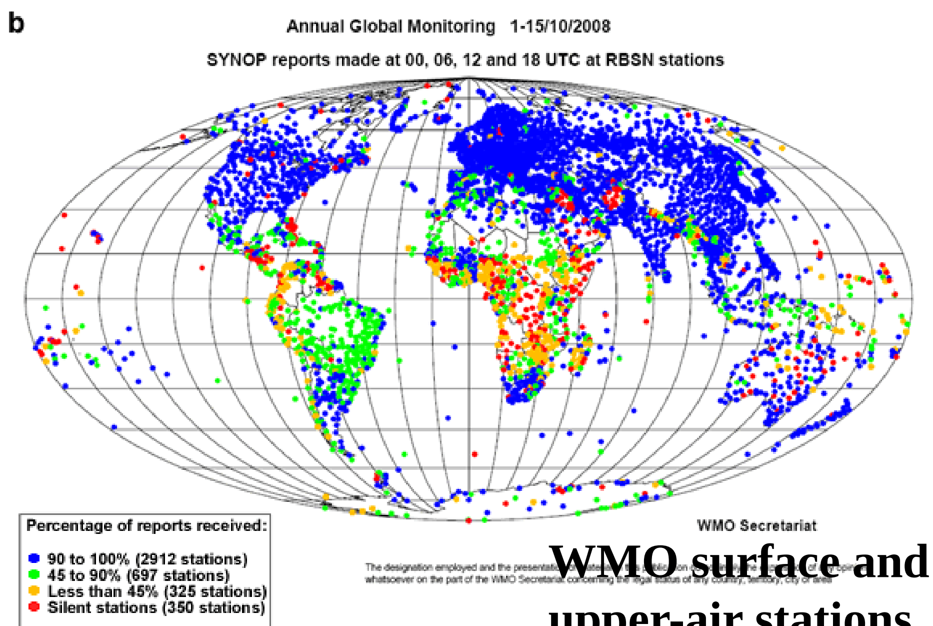
CRTM radiances for MODIS bands within dust storm on 21 April 2016

- Simulated radiances were significantly reduced due to larger mass concentrations from GEOS nudged to SPoRT AOD (SPoRT)
- Sensitivity run using small dust particles (0.5 µm; SPoRT Fine) showed much smaller impact on radiances, which highlights the importance of particle size

- Simulated AHI or ABI infrared radiances for each experiment will be evaluated against satellite observations.
- Focus on satellite bands centered near 3.9, 8.7, 11, and 12 µm, due to the influence of dust particles at these wavelengths.
- Assess each case individually to understand whether the impact of aerosol-affected radiances on forward model error can vary significantly on location and optical properties of dust storm

Evaluate impact on GEOS-5 forecast fields

- Perform 5-day GEOS-5 forecasts initialized with analysis fields from the CTRL, EXP-GEOS, and EXP-SPoRT for each dust case
- Work collaboratively with Will McCarty at GMAO to test our technique within their CRTM/GSI system
- Temp, dewpoint, and wind from the experiments will be validated against *in situ* observations from the WMO network of surface and upper air observations to verify positive impact on forecast fields
- Standard metrics of RMS errors for these meteorological fields will also be used for verification
- Quantify forecast impact in terms of whether changes in analysis fields persist in forecasts



WMO surface and upper-air stations

Summary and Future Work

- This project aims to advance current operational DA systems by implementing the framework for the assimilation of aerosol-affected radiances into these systems.
- This framework will reduce forward modeling error in regions of significant dust concentrations, improving the accuracy of DA, and ultimately, forecast error.
- Future work includes:
  - Implementing refinements within CRTM aerosol modules to further reduce forward modeling error.
  - Assessing impact of other aerosol types on infrared radiance assimilation…Does the coarse mode pollution aerosols often present across East Asia impact infrared radiances?

Thanks!
Questions/Comments

https://www.jcsda.noaa.gov/news.php

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