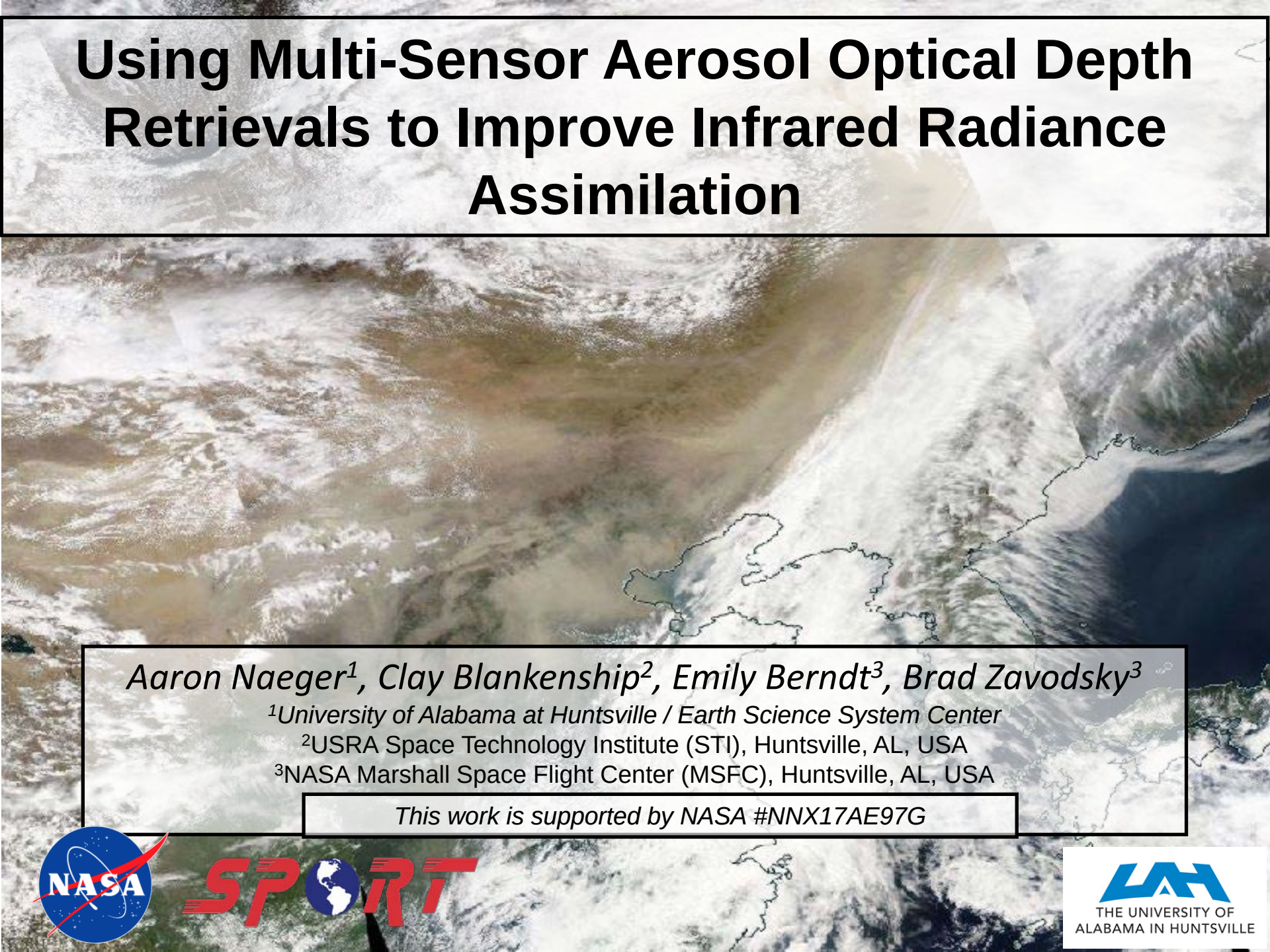
Using Multi-Sensor Aerosol Optical Depth Retrievals to Improve Infrared Radiance Assimilation



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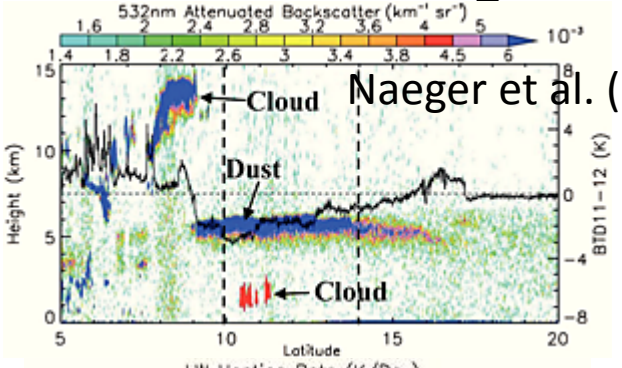
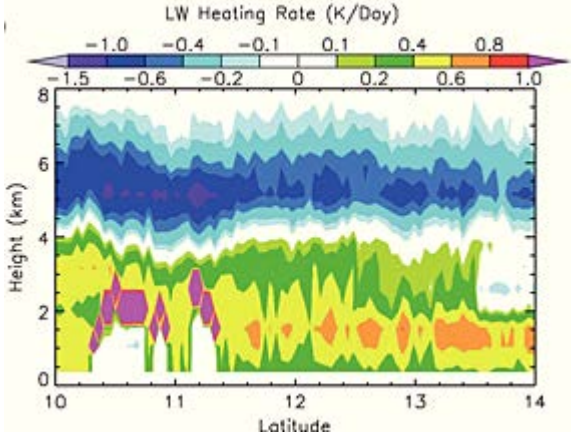
Motivation

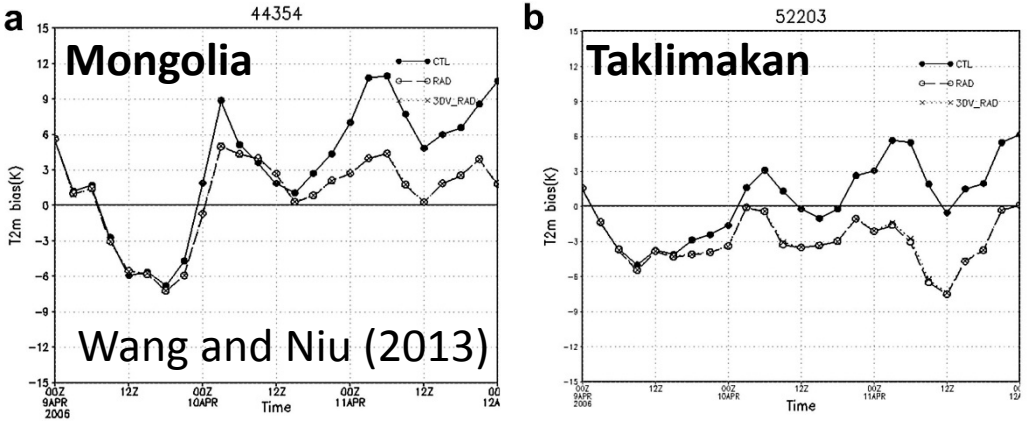
- Coarse dust aerosols absorb terrestrial radiation leading to significant longwave heating/cooling rates (Huang et al., 2009; Naeger et al., 2013)
- Modules accounting for aerosol impacts on radiation have been implemented into CRTM framework (Liu and Boukabara, 2014), but operational centers continue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



Naeger et al. (2013)

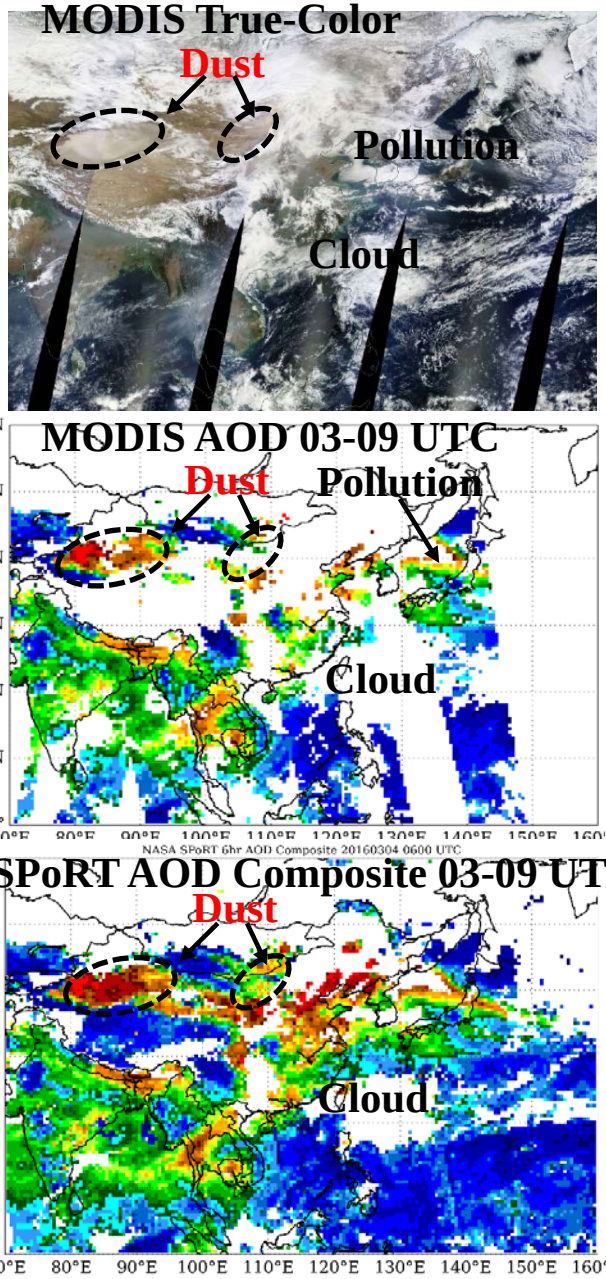


- **This assumption can introduce significant biases in analysis fields** (temp, moisture, etc.), which can **reduce forecast skill** (Perez et al., 2006; Wang and Niu, 2013)



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

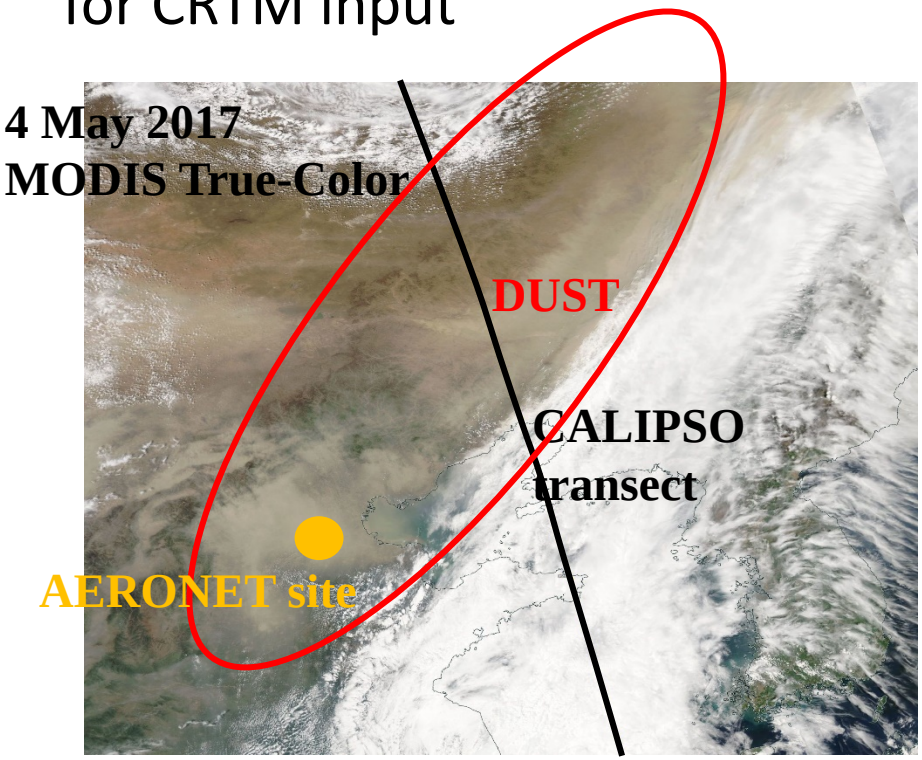
- How well can current aerosol modules in the CRTM simulate the satellite infrared radiances of coarse mode aerosols?
- What is the overall impact of dust aerosols on the satellite radiances from the CRTM? Does additional aerosol information in the CRTM lead to more accurate calculations of the aerosol-affected radiances and reductions in the RTM error?
- Does the assimilation of aerosol-affected radiances lead to a reduction in error in the model analysis fields? What is the overall impact of forecast?

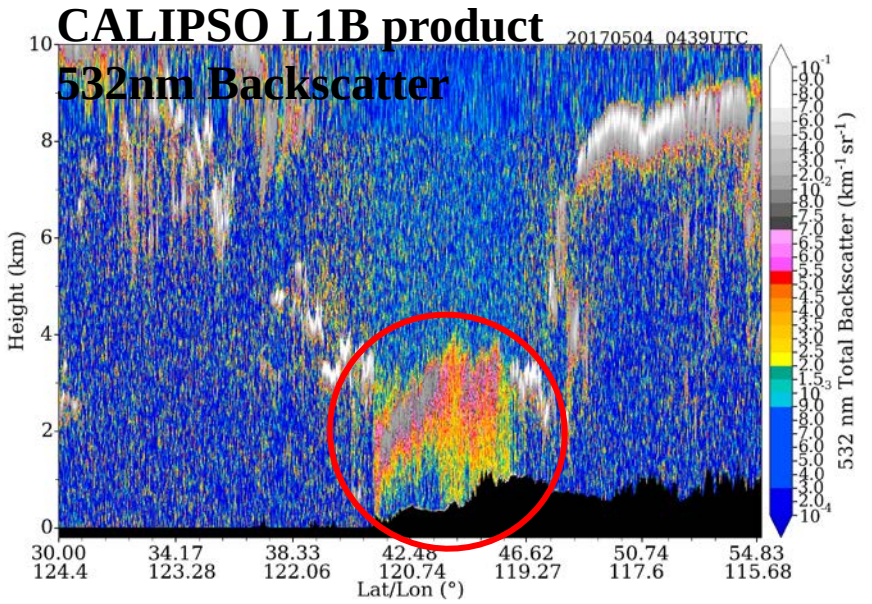
Project Tasks

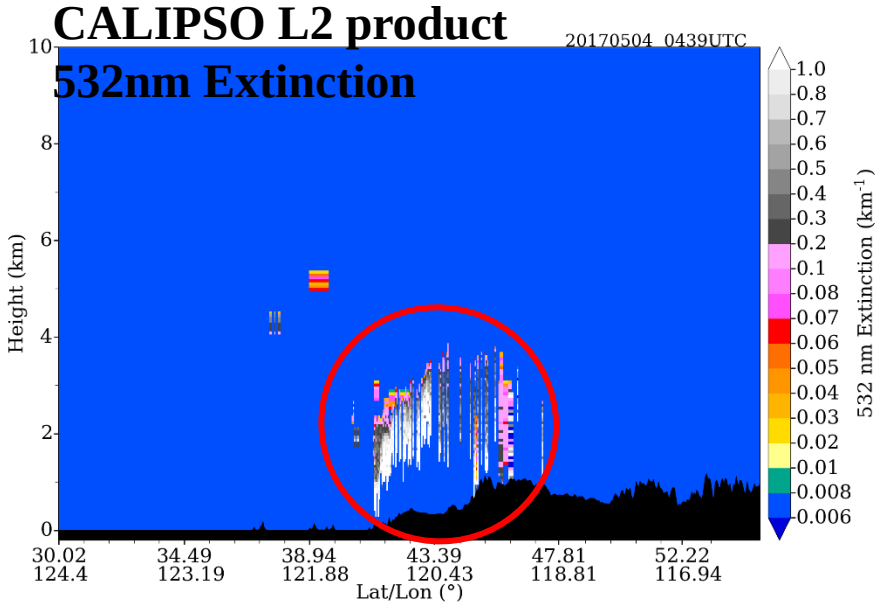
1. Fully diagnose CRTM forward modeling error by analyzing dust cases where intensive measurements were available (i.e., CALIOP, CATS, AERONET, etc.)…KORUS-AQ campaign.
2. Conduct experimental simulations for cases to diagnose overall impact on simulated aerosol-affected radiances. Use following as input into CRTM…
   - (1) CTRL run: only meteorological profiles, neglect aerosols
   - (2) EXP-GEOS: GEOS-5 aerosol analysis fields
   - (3) EXP-SPoRT: SPoRT AOD Composite product to update GEOS-5 aerosol fields.
3. Model analysis fields (temp, water vapor) from simulations will be evaluated against radiosondes for verifying error reduction due to aerosol-affected radiances. Perform 5-day simulation to confirm positive impact on forecast.

CRTM forward modeling error

- Quantify uncertainty associated with CRTM aerosol modules using “best case” dust storms
- CALIOP and CATS aerosol extinction retrieval products will be used for calculating realistic aerosol profiles for CRTM input







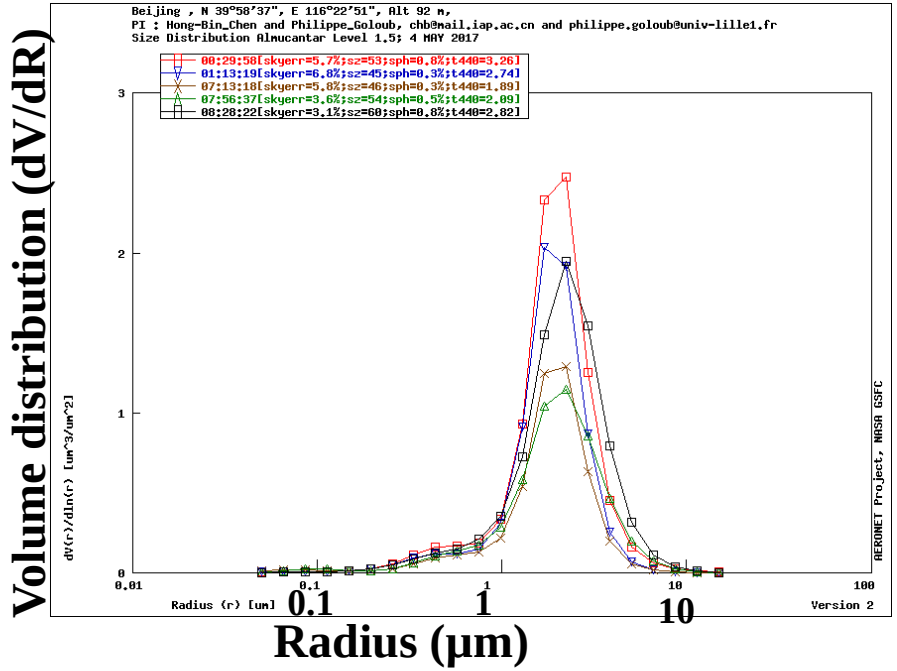
CRTM forward modeling error

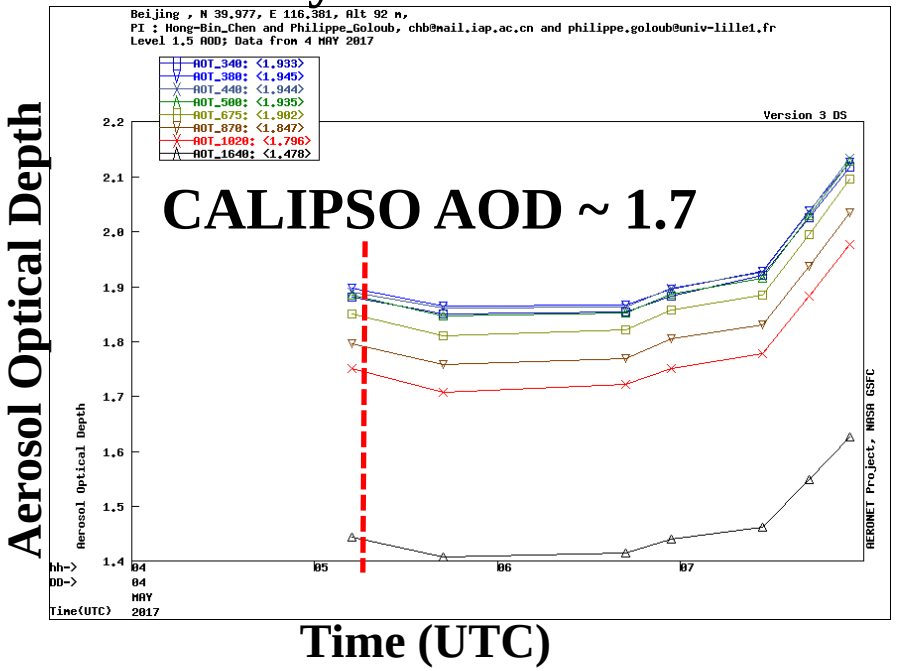
- CRTM requires mass concentration profiles, so use nearby AERONET retrievals of refractive indices and mean radii to determine realistic extinction efficiency (*Q*) from Mie calculations
- Calculate mass concentration (*M*) using following equation:

$$M^{type,size} = \frac{1.33 * \rho * AOD * r_e}{Q^{type,size}}$$

- Use AERONET AOD for verification of CALIOP/CATS column AOD to ensure accurate profile information is used for CRTM input

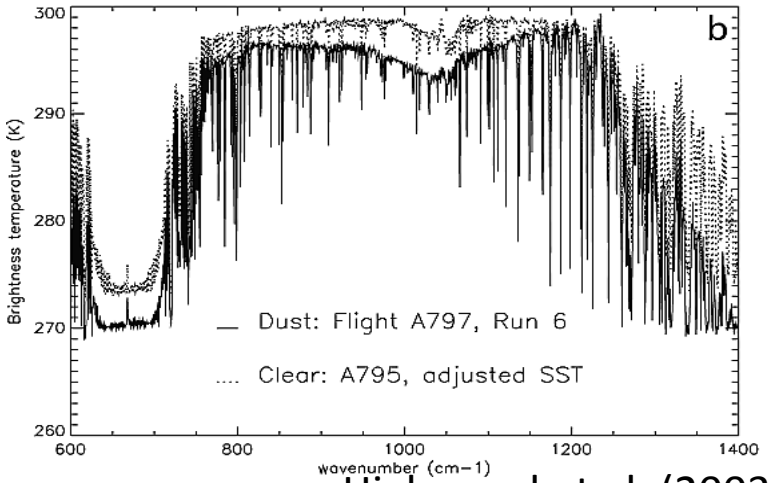
AERONET site retrievals - 4 May 2017





CRTM forward modeling error

- Focus on validating the simulated satellite infrared radiances near dust absorbing wavelengths of 3.9, 8.7, 11, and 12 µm
- Run CRTM for AHI, ABI, MODIS, and VIIRS sensors, since SPoRT AOD product utilizes all of these sensors
- Run CRTM for dust cases, and validate simulated satellite radiances and brightness temperatures against satellite observations to quantify forward modeling error
- What uncertainties are inherent to the CRTM aerosol modules? Does the dust spherical particle assumption lead to significant uncertainties?



Highwood et al. (2003)

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

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