Aerosol Impact on the GEOS-5 Meteorological Analysis

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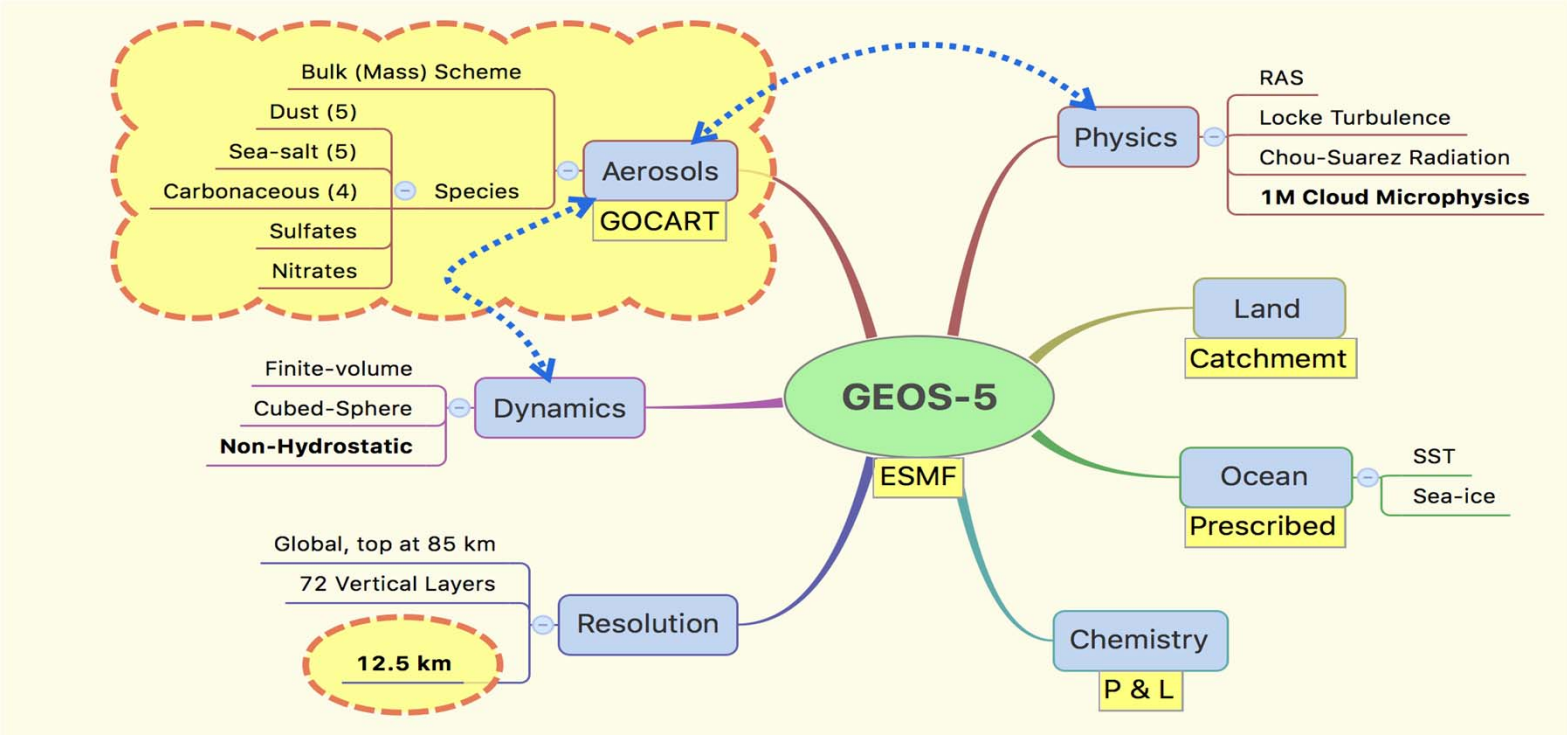
Outline

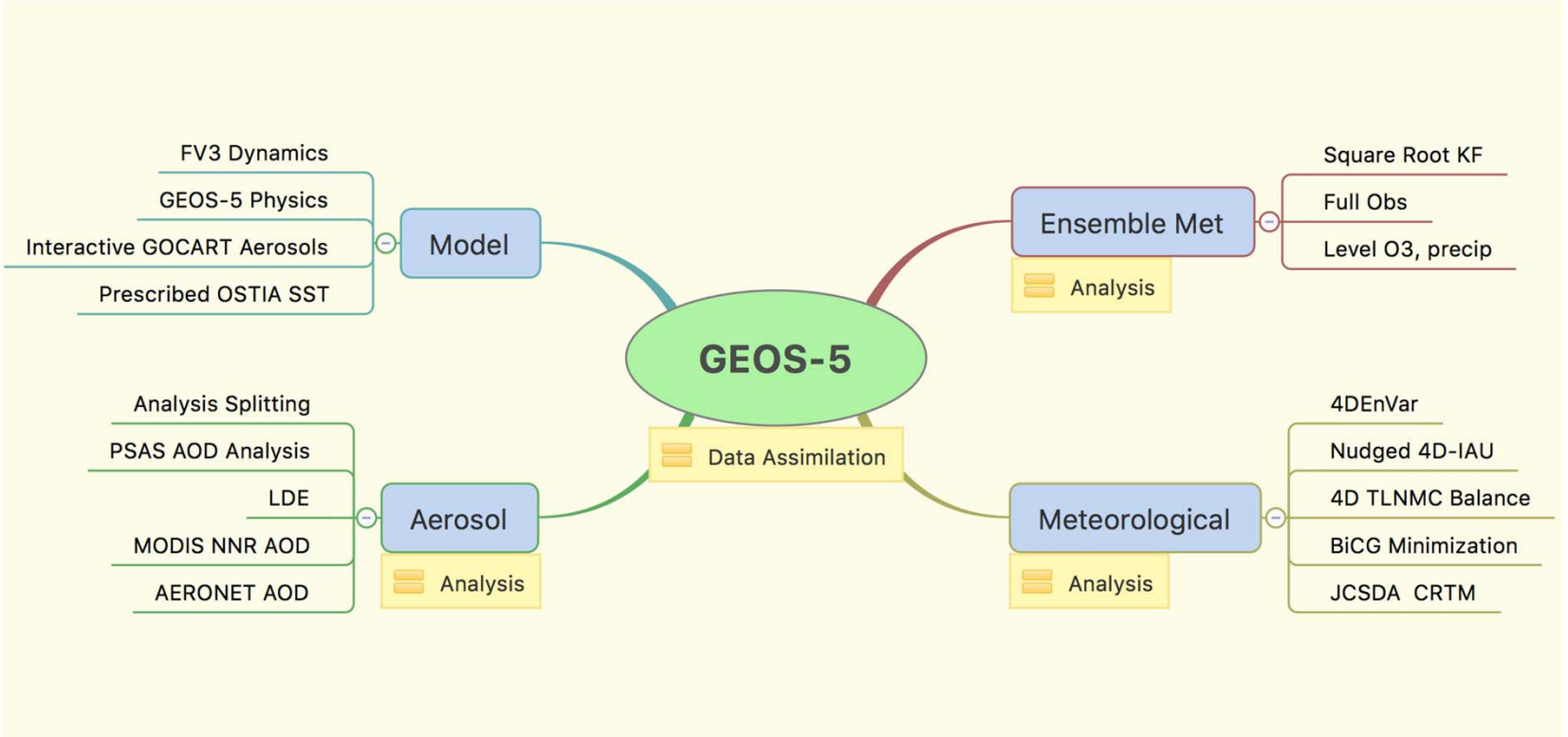
- **Aerosol Data Assimilation in GEOS-5**
- **The GEOS-5 Meteorological Data Assimilation**
- **Prescribed aerosol optical properties in the IR**
- **Impact of aerosols on the innovations of IR sensors**
  - AIRS, IASI, CRIS, HIRS
- **Impact on SST and upper temperature analysis**
- **Impact on the assimilation system~~, interaction with bias correction~~**
- **Concluding remarks**

GEOS-5 Model Configuration for current NRT System

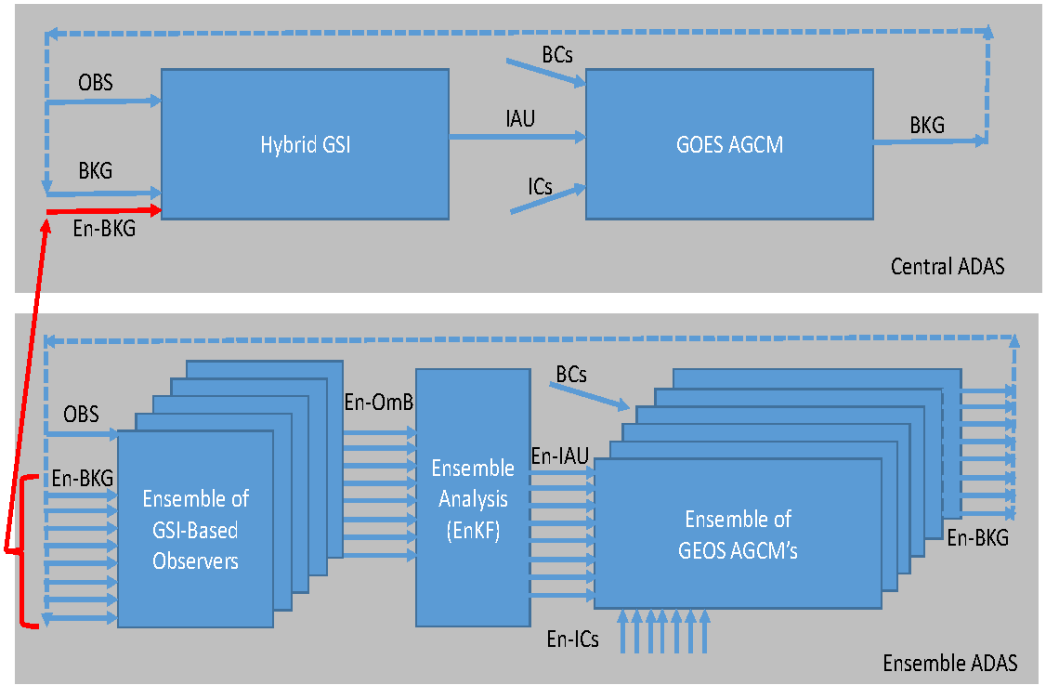


Global, 12.5 km, 72 Levels, top at 0.01 hPa

GEOS-5 Data Assimilation: Standard Configuration



GEOS-5 Hybrid Data Assimilation



Remark: Ensemble analyses are not re-centered around central (top) DAS analysis.

Aerosol Analysis: Splitting

2D AOD ANALYSIS

- Observable 550 nm AOD is 2D
  - Constrains column averaged optics
  - Cannot constrain speciation or vertical distribution
- Analysis in observation space:

$$\tau^a \equiv Hq^a = H\left(q^b + \delta q^a\right)$$
$$= \tau^b + \delta\tau^a$$

GOING TO 3D CONCENTRATIONS

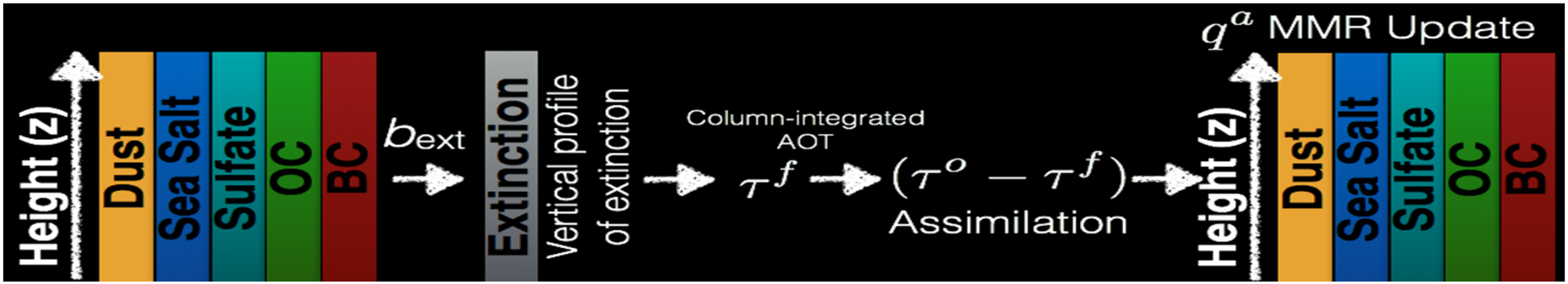
- Based on error covariances:

$$\delta q^a = BH^T\left(HBH^T\right)^{-1}\delta\tau^a$$

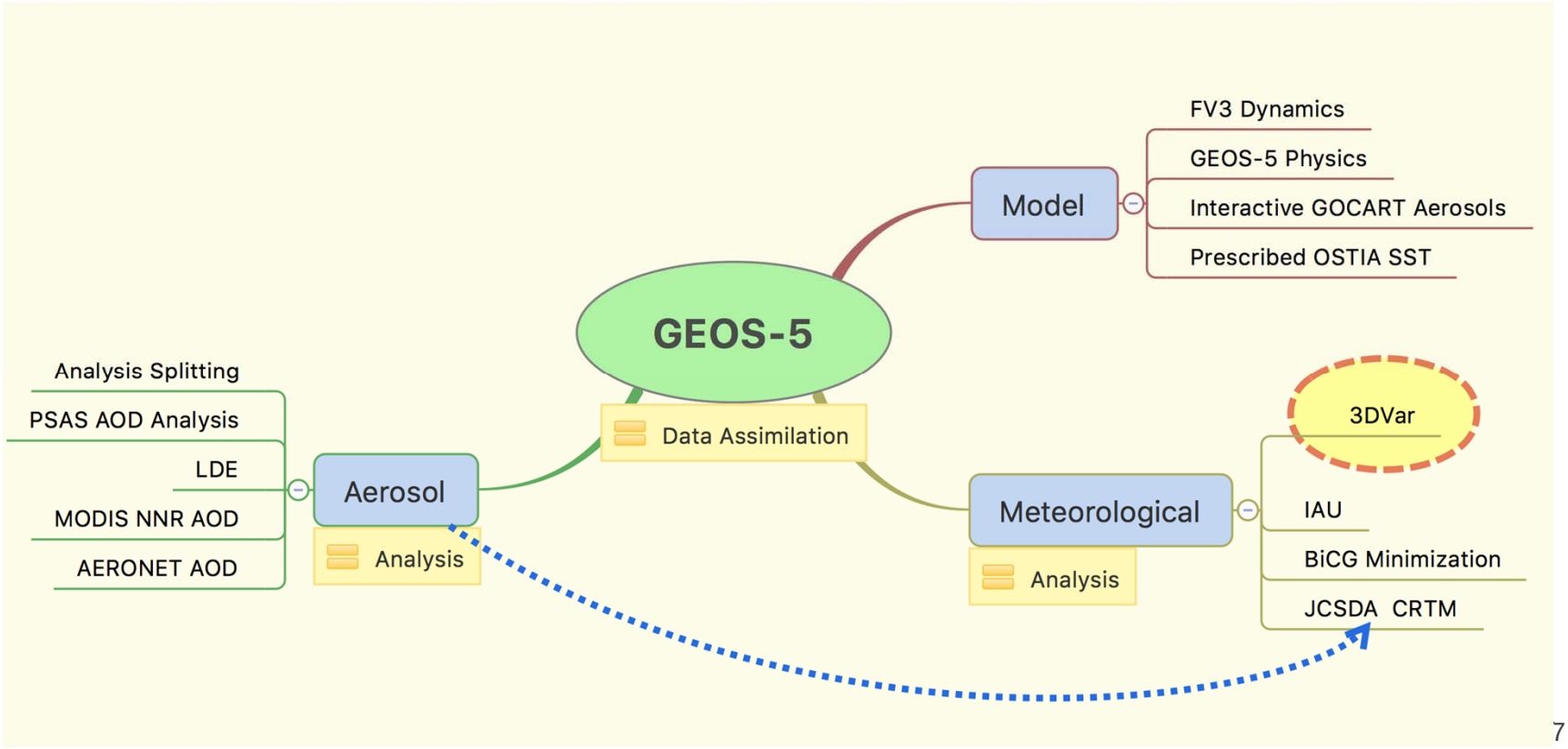
- Using ensemble perturbations,

$$\delta q^a = XY^T\left(YY^T\right)^{-1}\delta\tau^a$$

- NRT GEOS-5 uses Local Displacement Ensembles (LDE), in 1D



GEOS-5 Data Assimilation Experiment: Aerosol Impact on IR Sensors



Aerosols in GSI

- CRTM allows for the inclusion of (GOCART) aerosols
- The GEOS-5 GOCART aerosol species have been introduced as *state variables* in GSI
  - No aerosol increments for now
  - Aerosol effects included in the observation operators for AIRS, HIRS, IASI, CRIS, SEVIRI, AVHRR
- Optical properties hardwired inside CRTM
  - Inconsistent with GEOS-5 VIS channels but
  - OK for IR channels

Aerosol Contamination of GSI Radiances

CONTROL EXPERIMENT

- Aerosols fully interactive in GEOS-5
  - Standard, decoupled AOD assimilation
- Standard GSI global analysis
- Period
  - August 2016
- Resolution:
  - C360 (~25 km)

AEROSOL IMPACT EXPERIMENT

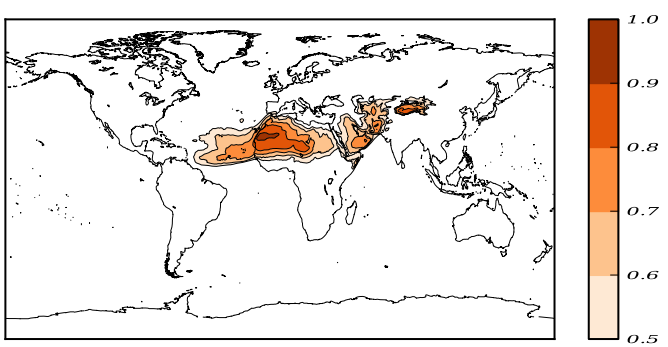
- Aerosols fully interactive in GEOS-5
  - Standard AOD assimilation
- GSI observation operators:
  - 15 GOCART species
  - Concentration
  - Effective radius
  - Optical parameters internally determined by CRTM

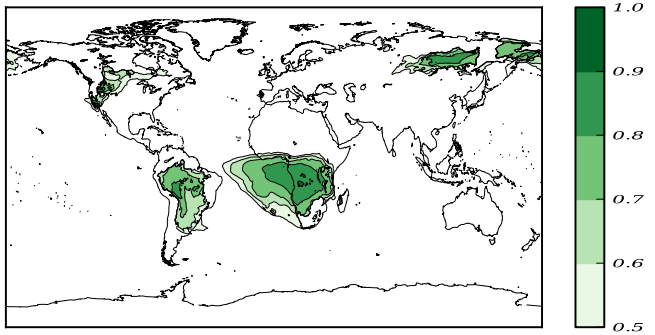
Non-cycling Experiment

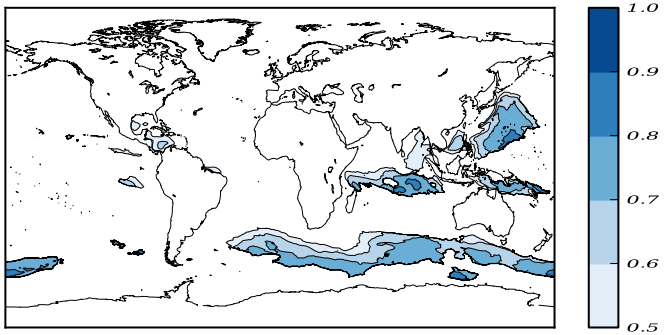
IMPACT OF AEROSOLS ON SIMULATED BRIGHTNESS TEMPERATURE

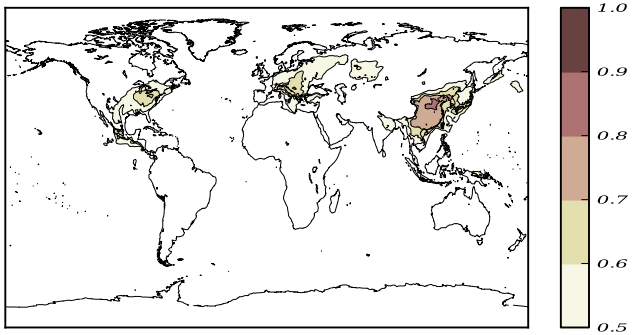
Goddard SPACE FLIGHT CENTER

Aerosol AOD Speciation: Aug 2016



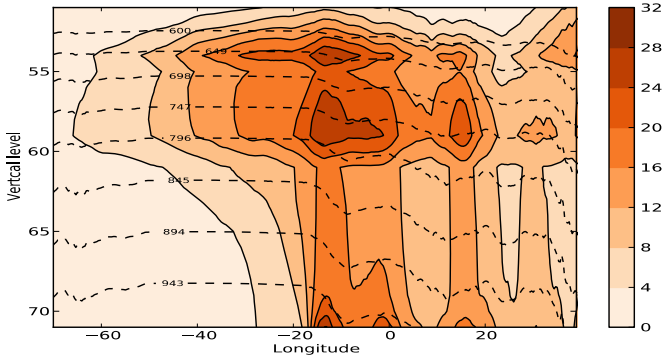




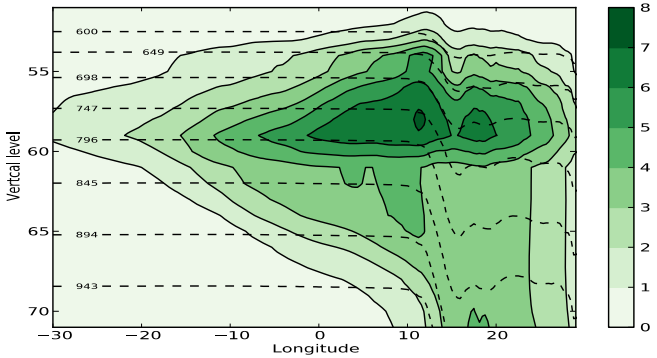


GOCART Aerosol IR Optical Properties

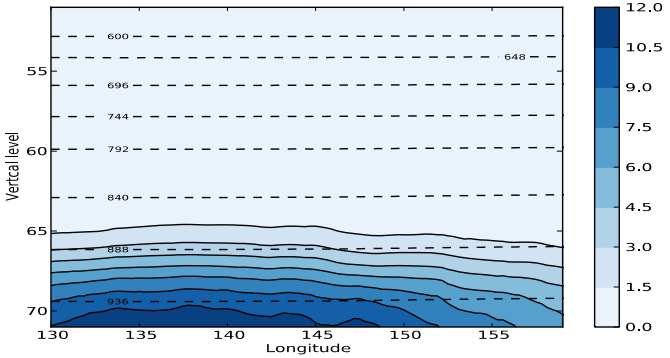
DUST



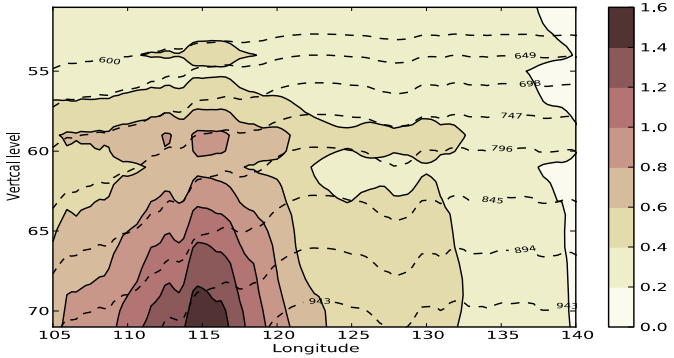
OC+BC



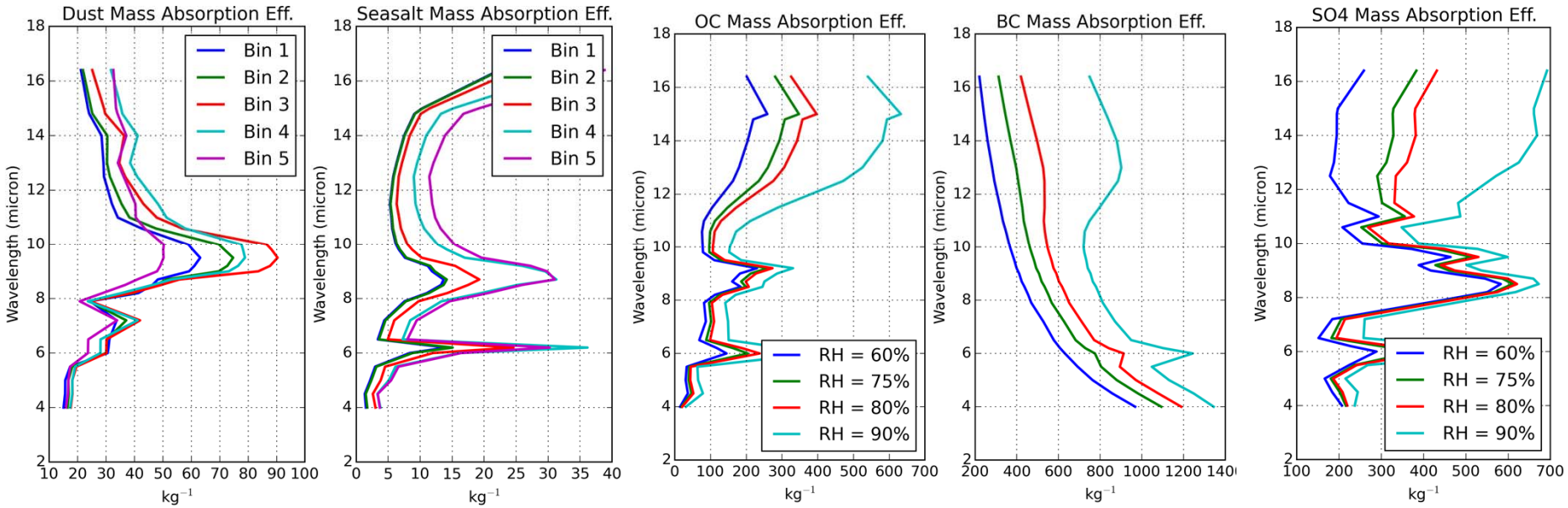
SEASALT



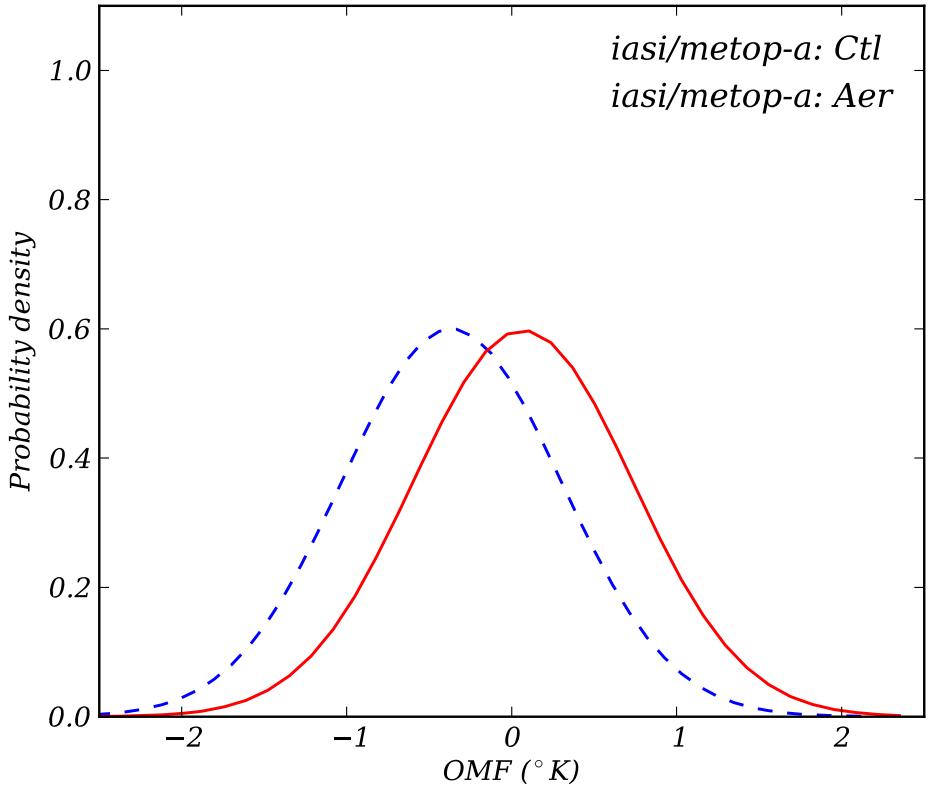
SO4



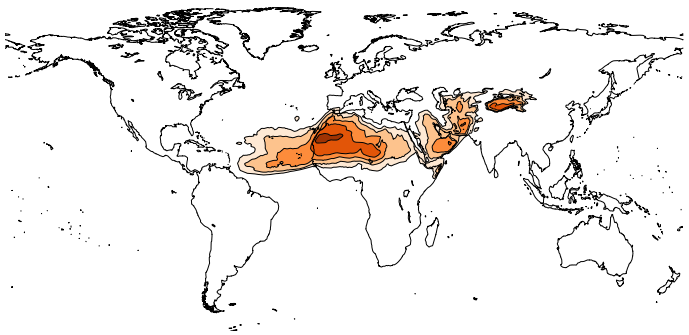
OPAC Aerosol Optical Properties

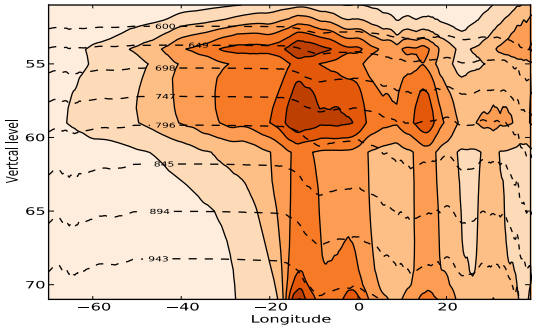


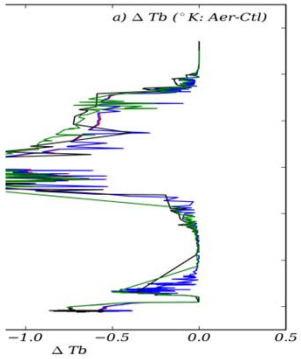
IASI Innovations

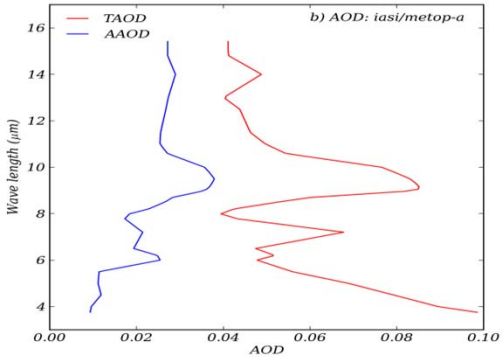


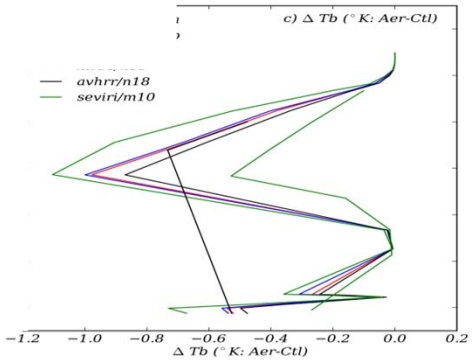
Dusty Pixels: T_b(aer) – T_b(ctl)

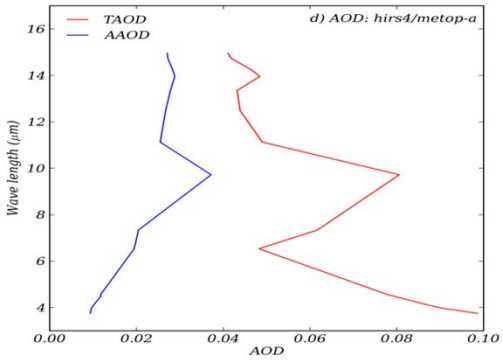




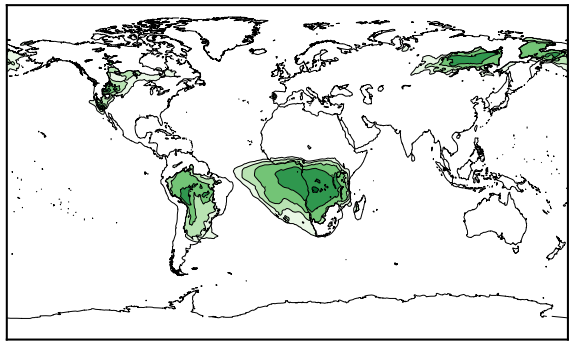


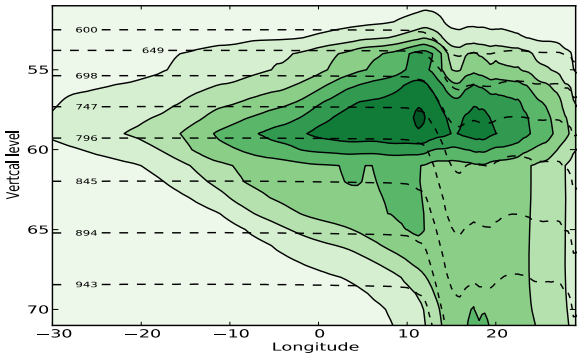


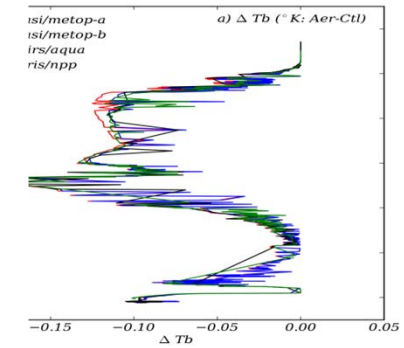


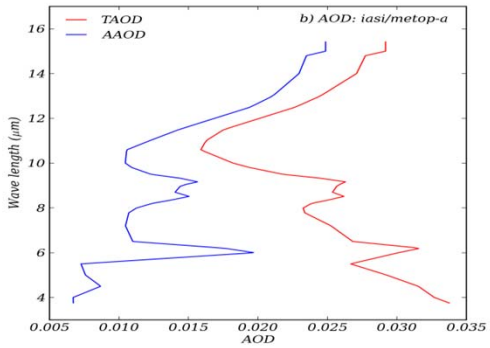


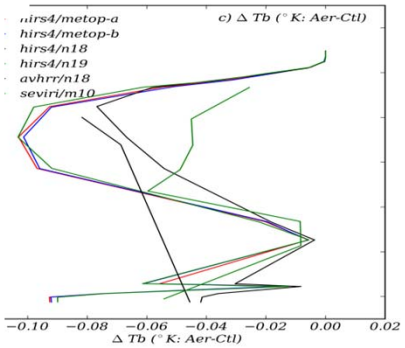
Smoky Pixels: T_b(aer) – T_b(ctl)

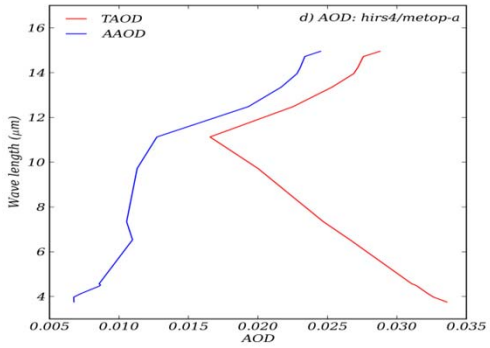




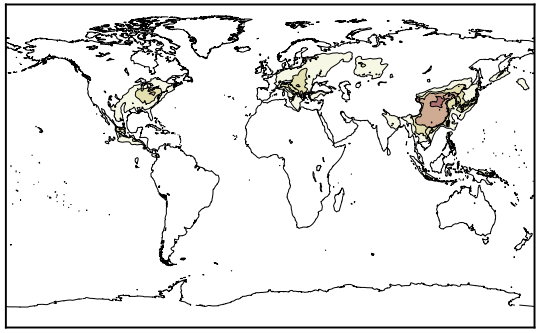


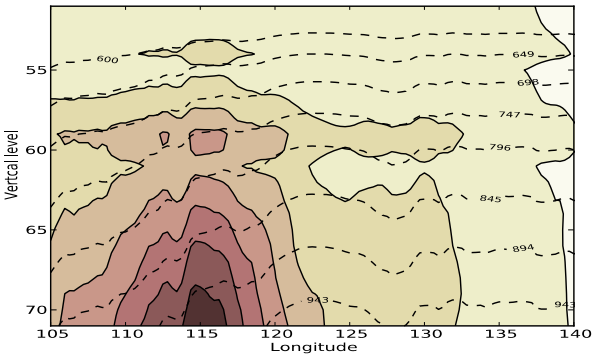


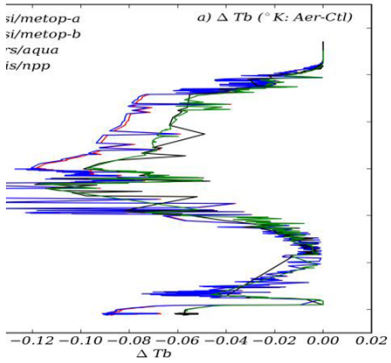


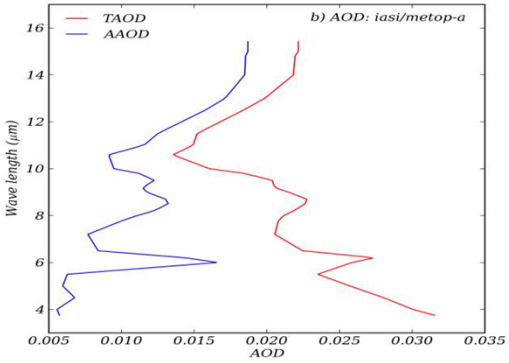


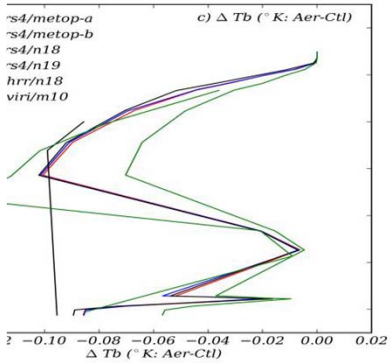
Sulfate Pixels: T_b(aer) – T_b(ctl)

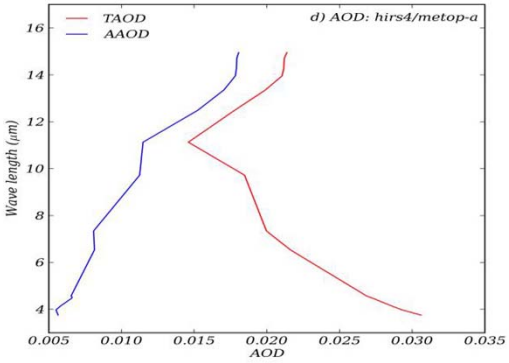




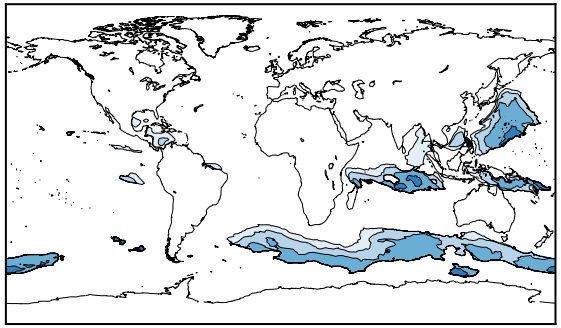


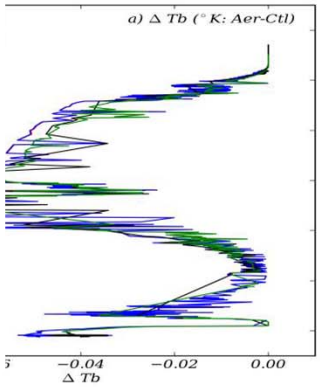


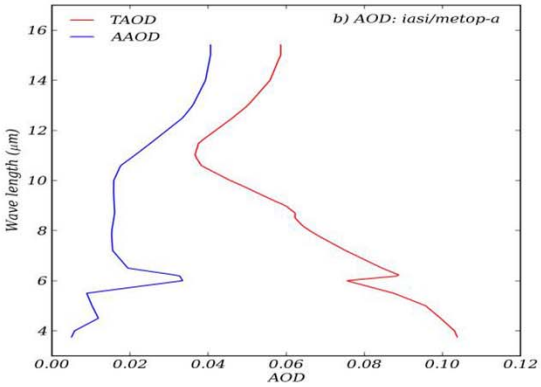


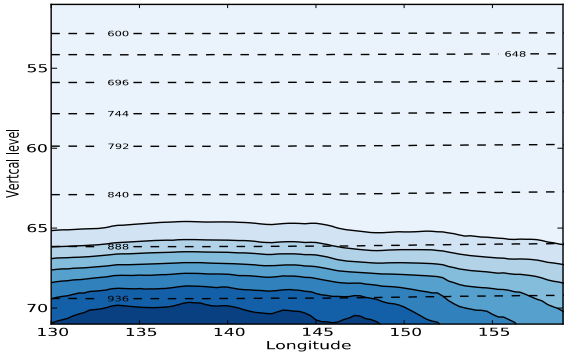


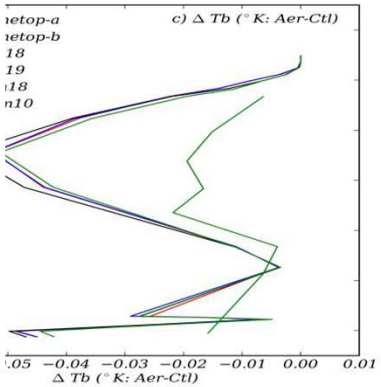
Salty Pixels: T_b(aer) – T_b(ctl)

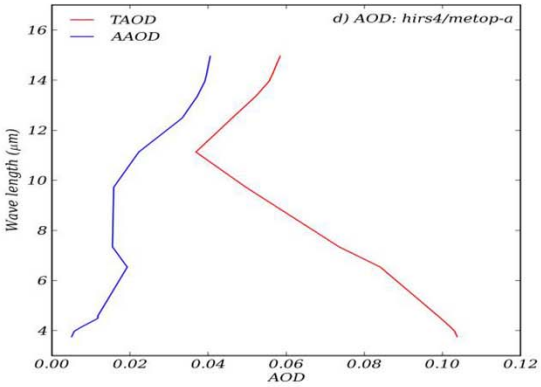












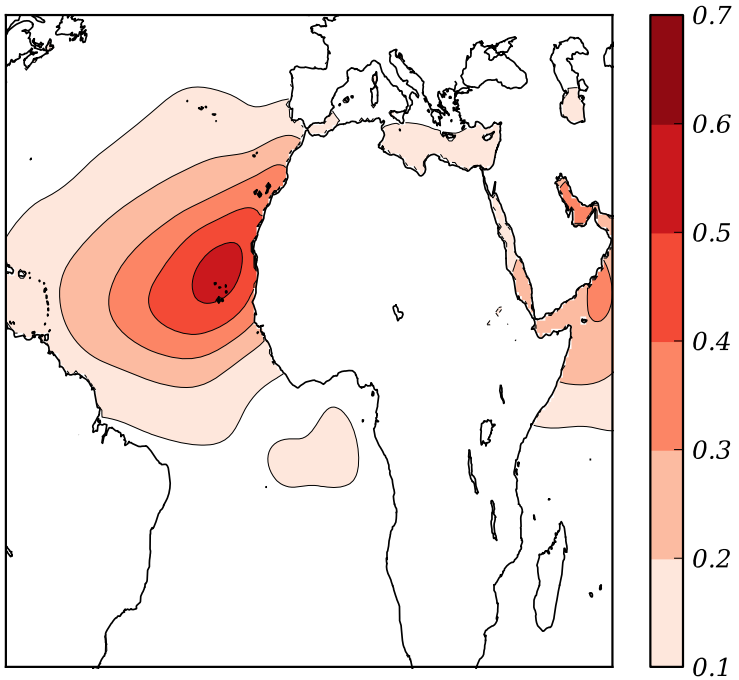
Non-cycling Experiment

IMPACT OF AEROSOLS ON METEOROLOGICAL ANALYSIS

Goddard SPACE FLIGHT CENTER

Impact on Temperature Analysis

SST



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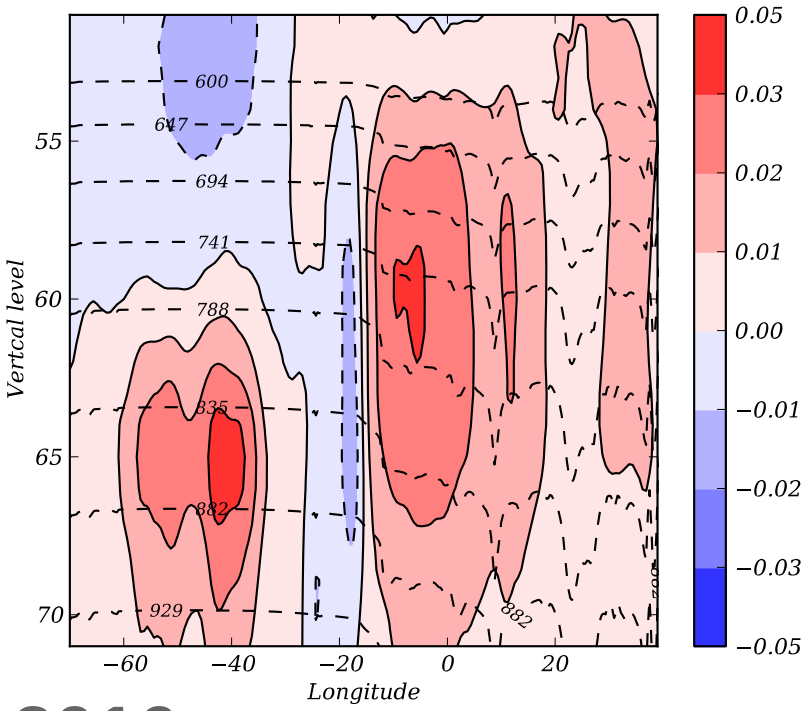


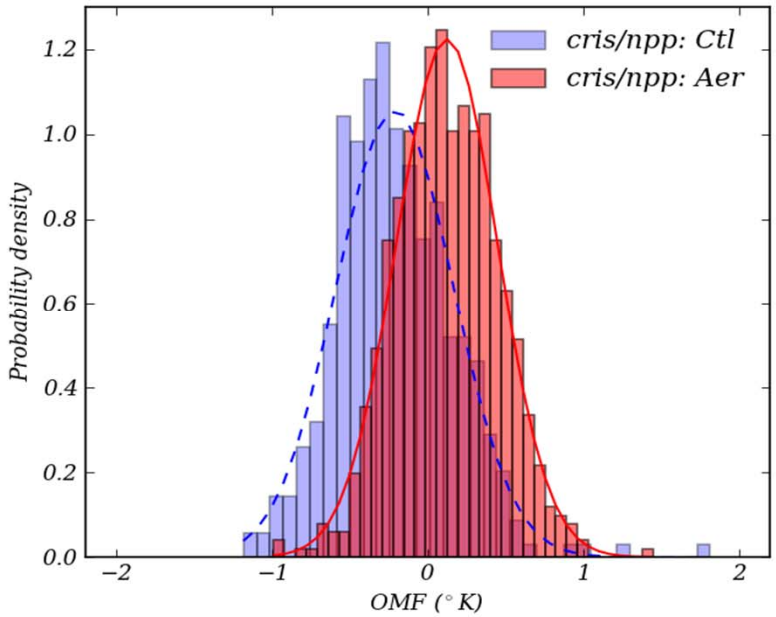
Aug 2016

Cycling Experiment: July 2015 & August 2016

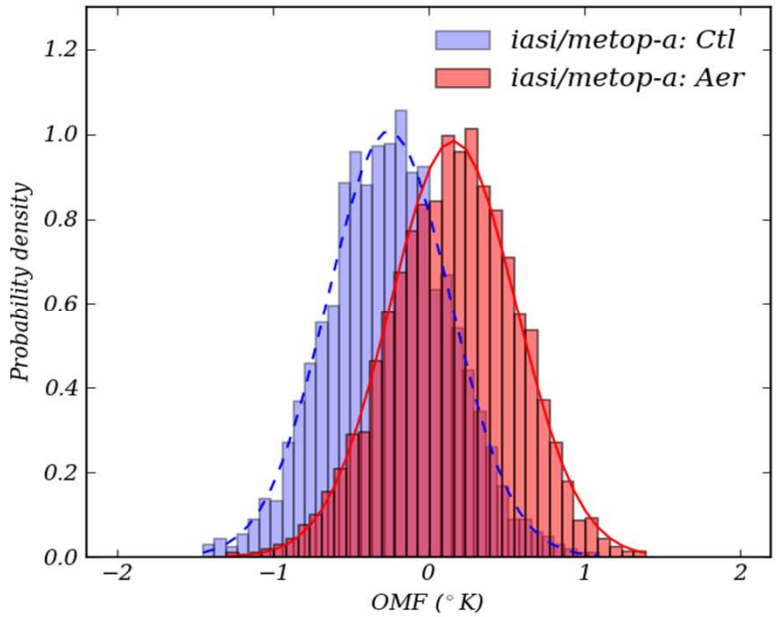
IMPACT OF AEROSOLS ON METEOROLOGICAL ASSIMILATION

Impact on Innovations (After QC & VBC)

CRIS (10.5μm)

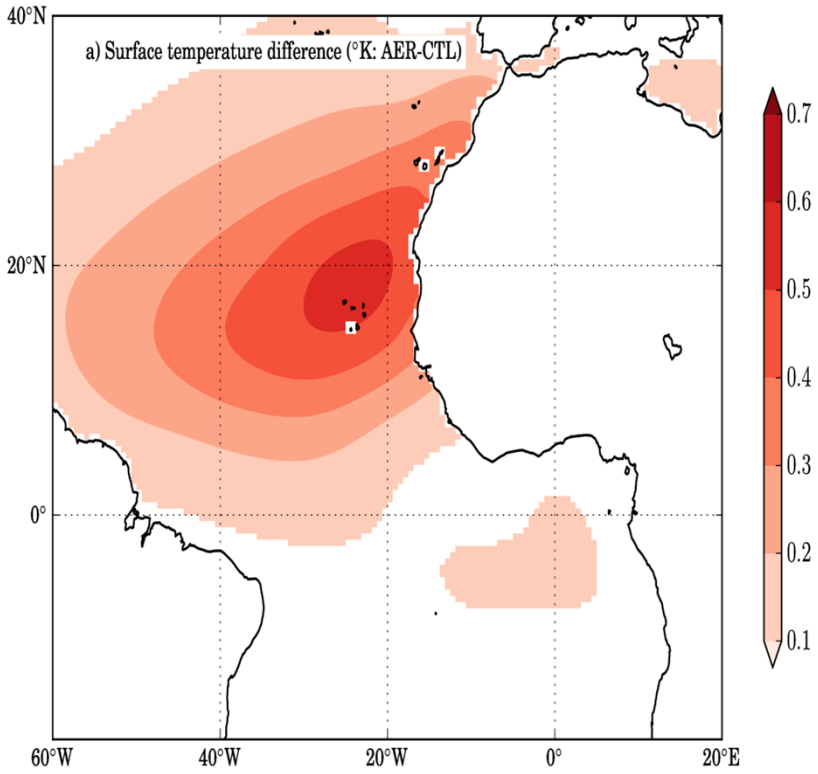


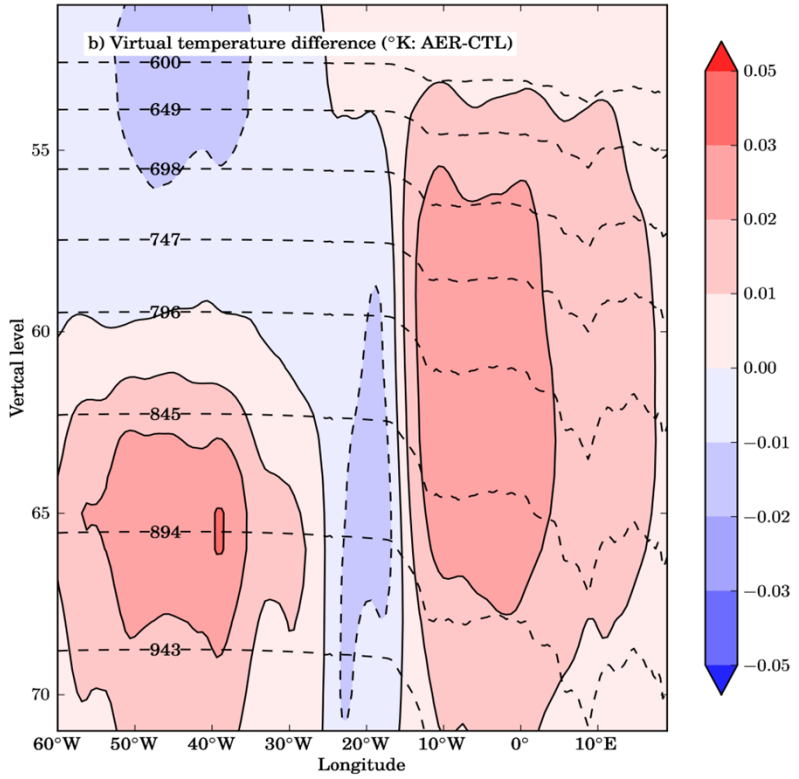
IASI (10.4μm)



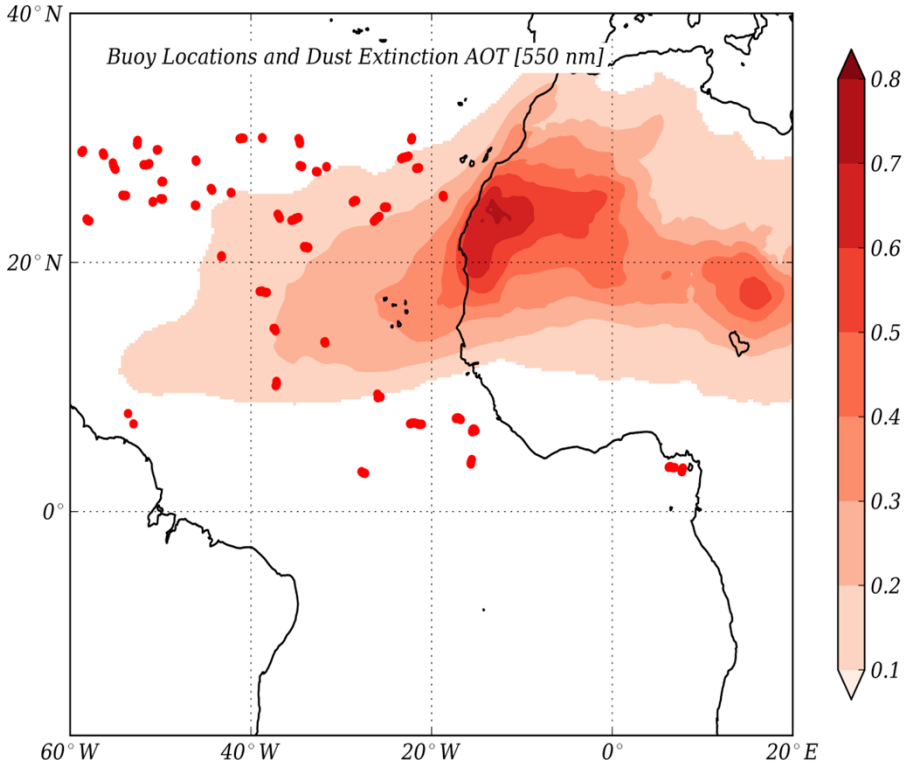
Aug 2016

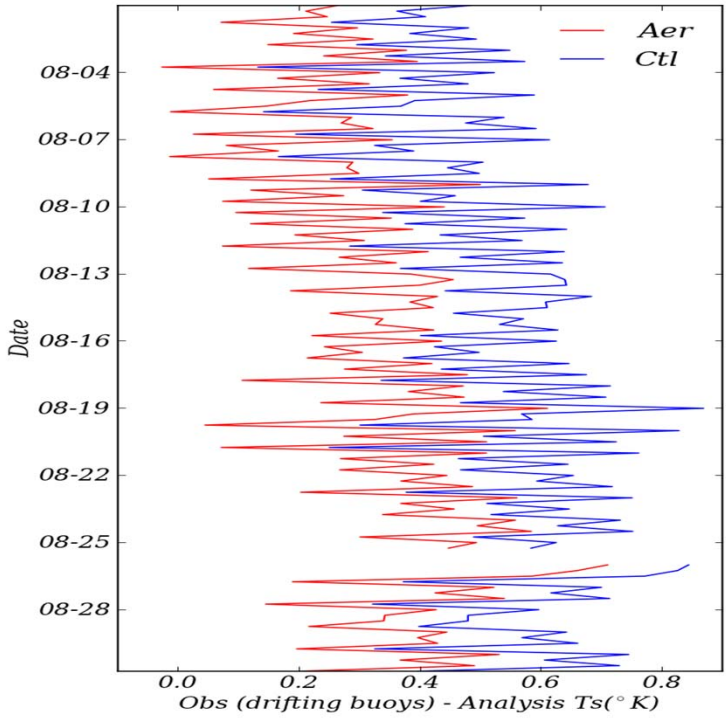
ΔSST Analysis (Aer-Ctl): Aug 2016



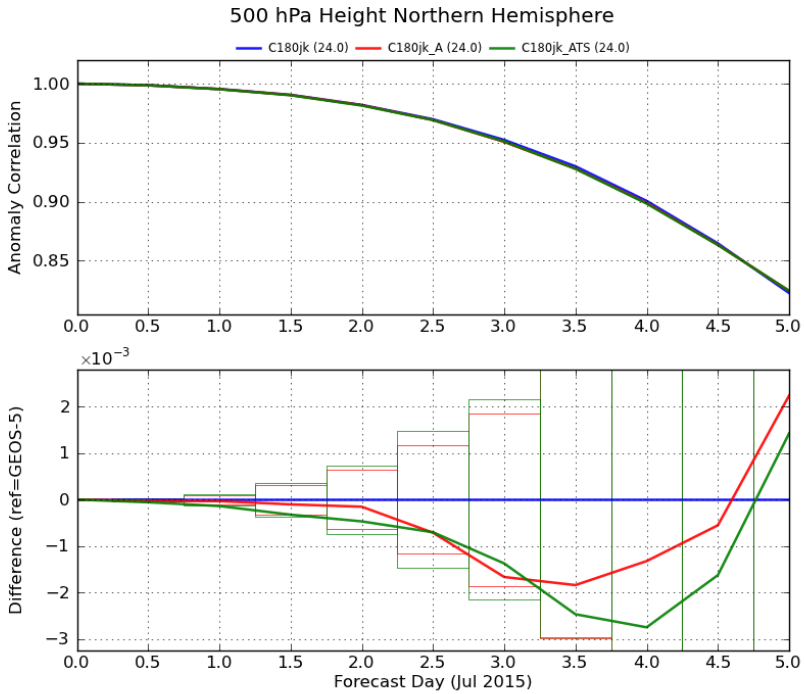


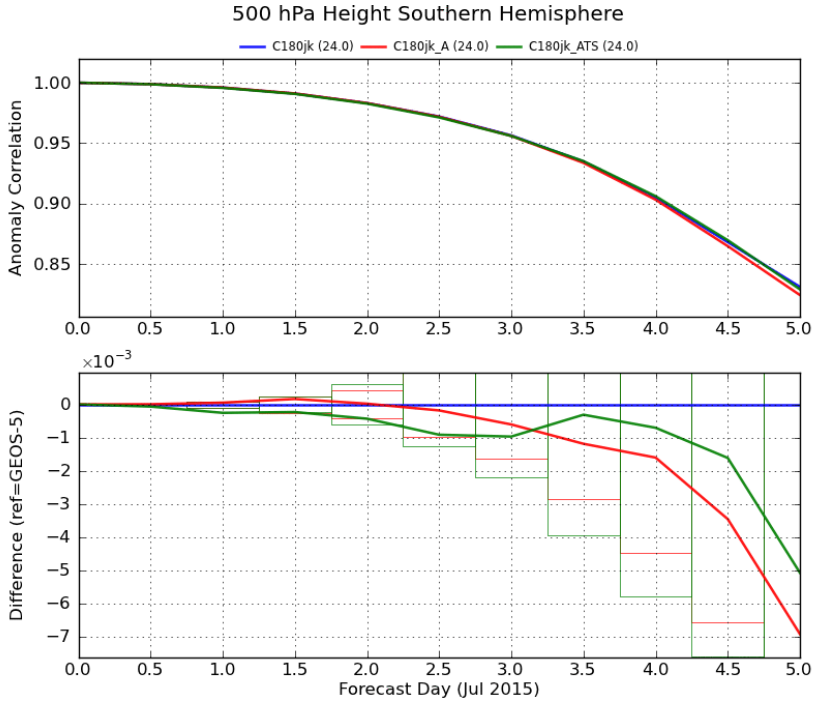
SST: Comparison to Buoys: Aug 2016



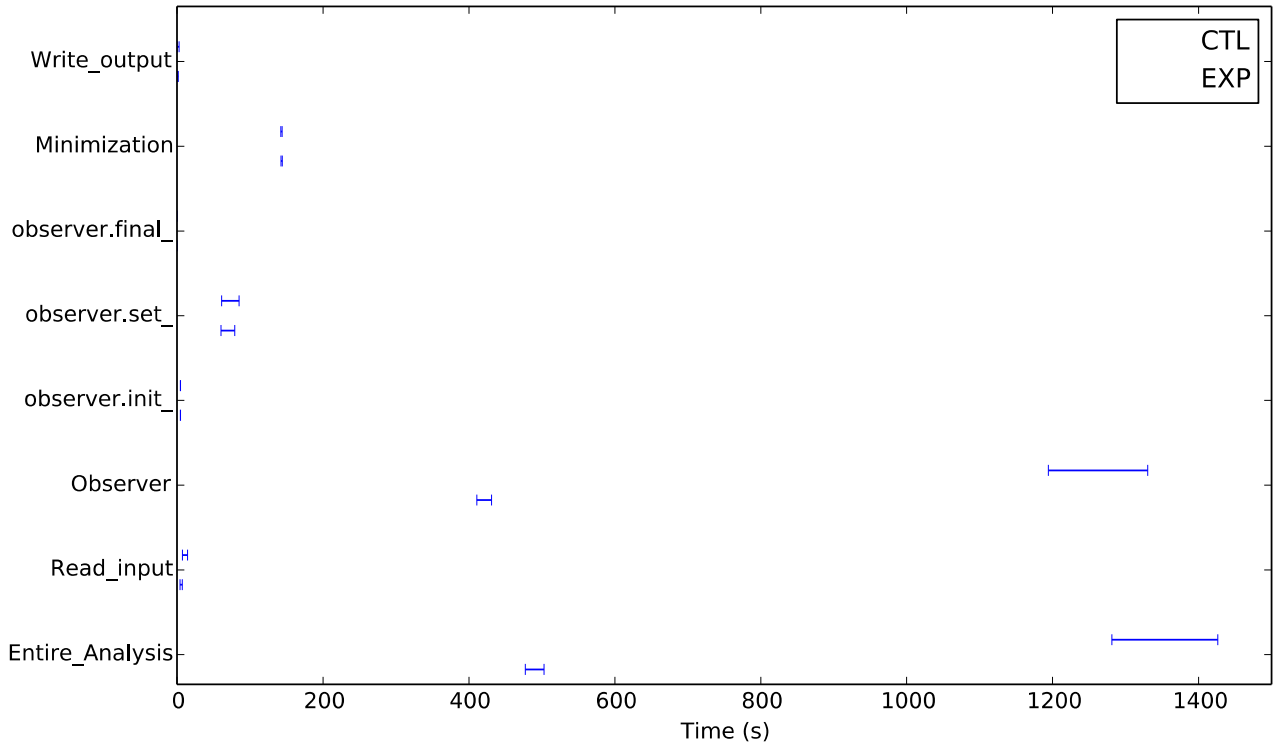


500 hPA Anomaly Correlation





Computational Cost

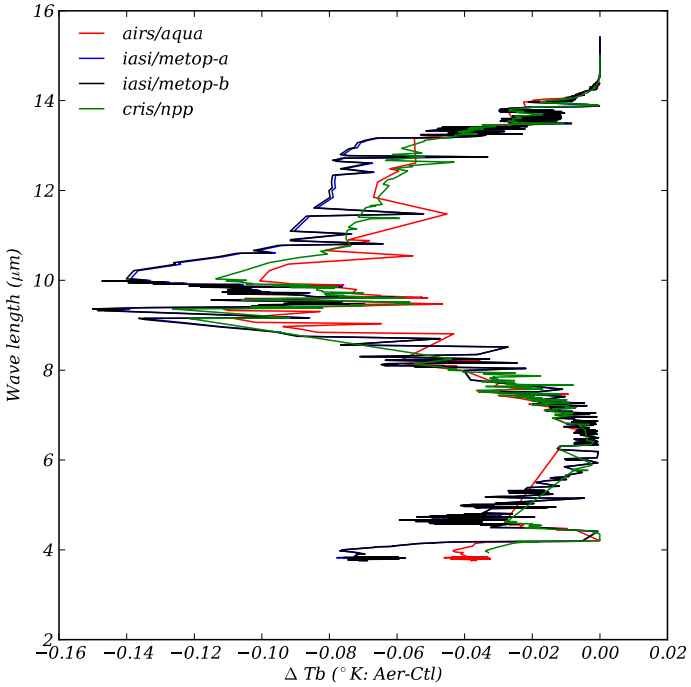


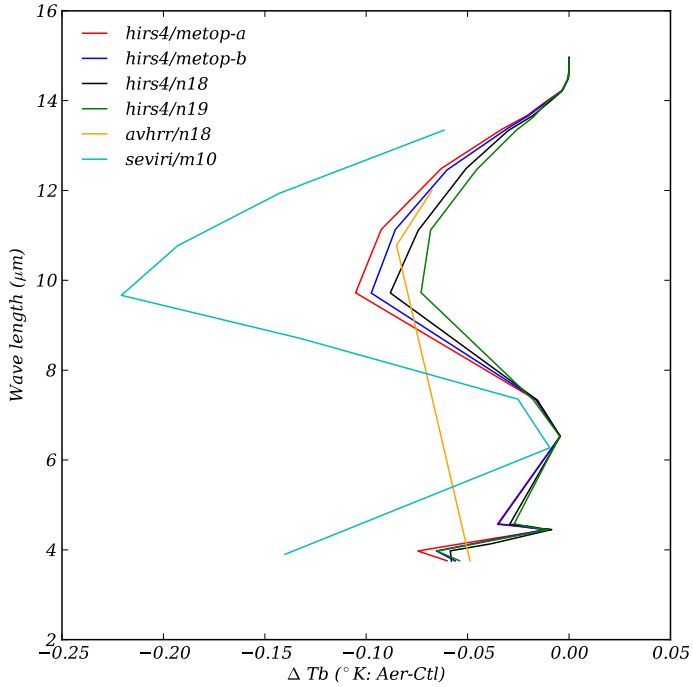
Concluding Remarks

- **The impact of the GEOS-5 assimilated aerosols on meteorological assimilation has been examined**
  - One way interaction: 3D aerosol concentrations impact on the CRTM calculation of IR BTs
- **Larger effect over predominantly dusty pixels**
- **Cooling effect of aerosols on T_b calculation leads to warming in SST analysis**
  - Nearly 1K effect on SST analysis over the Saharan dust plume
- **Impact on 5-day forecast skill is negligible**
- **Slightly more data were accepted in the cycled experiments: HIRS, AIRS, IASI, CRIS**
- **SST verification against drifting buoy indicates that the aerosol experiments had slightly improved surface temperature in the tropical Atlantic**
- **Neural Net based approximations being investigated as a device to reduce cost**
  - Possibly a better parameterization for the variational bias correction

EXTRA SLIDES

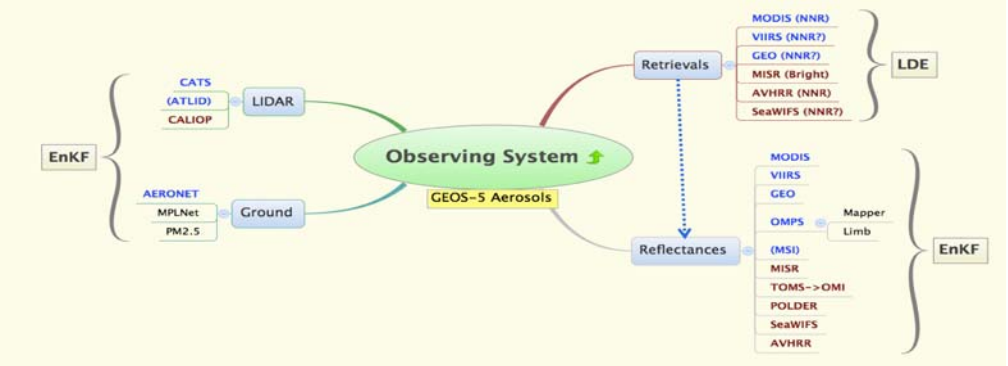
Global: T_b(ctl) – T_b(aero)





Aerosol Observing System

- **Aerosol Optical Depth (AOD) is the most commonly available observable**
  - Vertically integrated mass weighted by extinction coefficient, summed over multiple species: *low observability*
  - Available multi-spectral AOD measurements are not really measured
- **Radiance assimilation:**
  - Vector scattering calculations needed for UV-VIS measurements are not cheap
  - Surface BRDF characterization is a challenge
- **Surface PM 2.5**
  - Single level
  - Often plagued by representativeness



- **Lidar measurements provide vertical info**
  - Spatially coverage is poor (pencil thin)
  - Attenuated backscatter again requires optical assumptions which are not directly measured
    - » New HSRL concept is promising