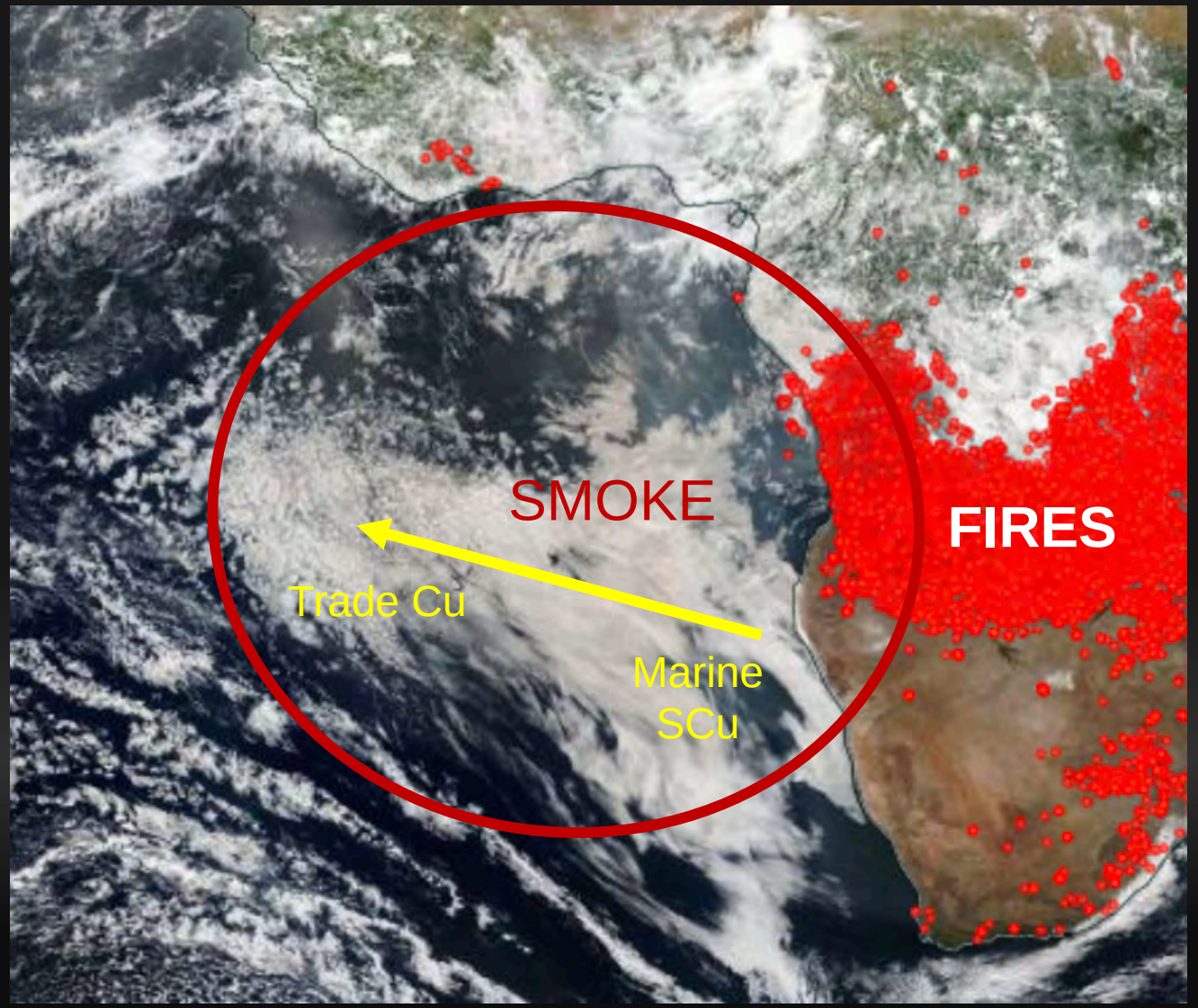
Radiative Heating Rate Profiles over the Southeast Atlantic Ocean during the 2016 and 2017 Biomass Burning Seasons

Allie Collow[1,2]
Mark Miller[3], Lynne Trabachino[3], Mike Jensen[4], and Meng Wang[4]
[1]Universities Space Research Association
[2]NASA Global Modeling and Assimilation Office
[3]Rutgers University
[4]Brookhaven National Laboratory

RUTGERS
Institute of Earth, Ocean, and Atmospheric Sciences

ASR Atmospheric System Research

USRA



NASA Worldview Image for 26 August 2016

How does biomass burning aerosol impact the radiative heating profile as the aerosol plume travels across the ocean in the presence of clouds?

- What is the aerosol radiative effect (ARE)?
- What is the uncertainty in SW radiative heating?

Idealized Simulations with the Rapid Radiative Transfer Model (RRTM)

Inputs
- Vertical profile of
  - Temperature (INTERPSONDE)
  - Humidity (INTERPSONDE)
  - Cloud fraction, total water path, ice fraction, effective radius (ARSCL + MICROBASE)
  - Aerosol optical depth, single scatter albedo, asymmetry parameter (MERRA-2)

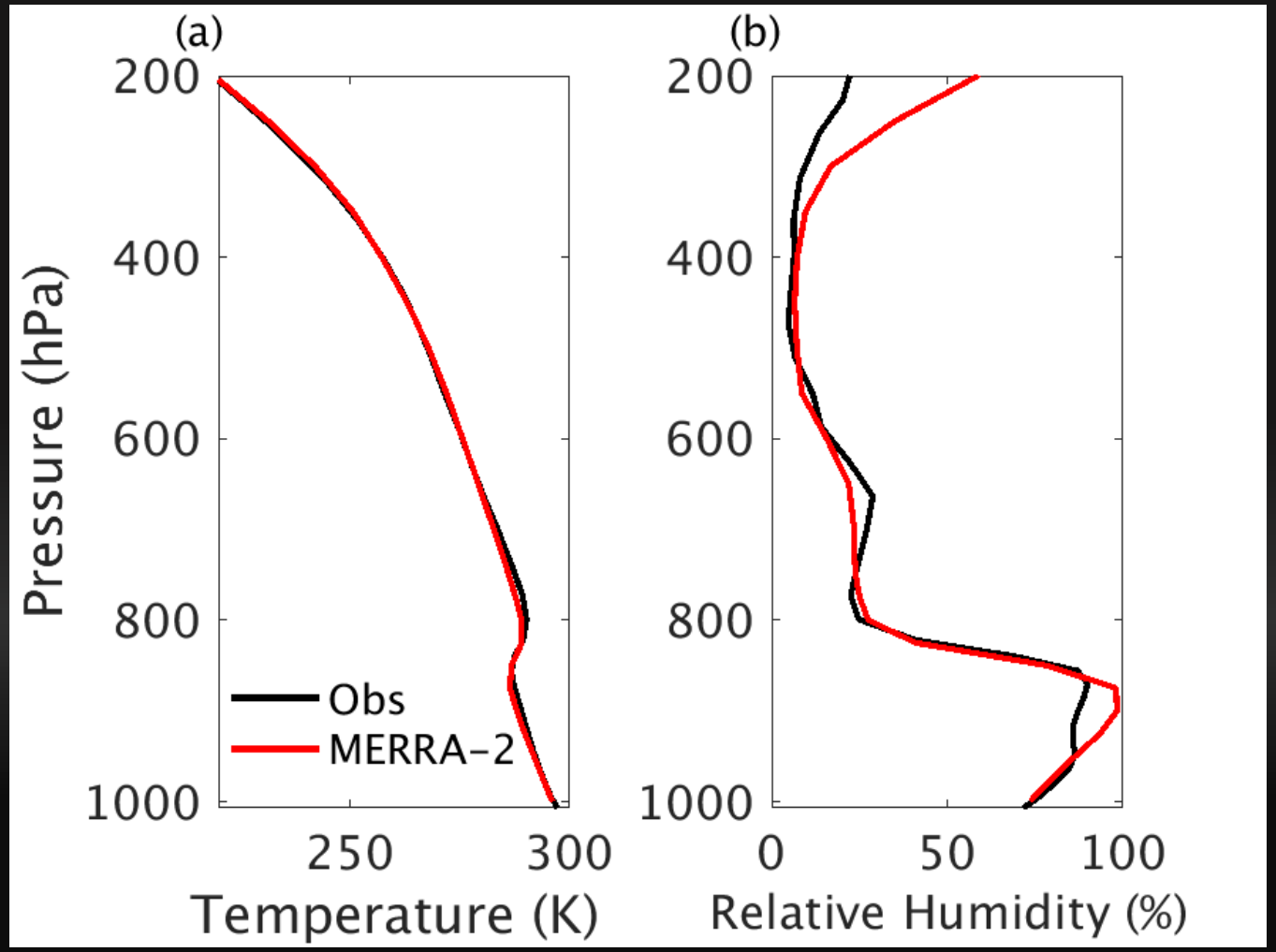
Outputs
- Vertical profile of
  - Upwelling SW
  - Downwelling SW
  - Net SW
  - Diffuse vs Direct SW
  - Heating Rate

Experiment
1. Control (T and RH profiles only)
2. Aerosols (1 plus all species in MERRA-2)
3. No black carbon (2 minus black carbon)
4. Clouds (1 plus cloud properties)
5. Aerosols and Clouds (2 + 4)
6. Aerosols, Clouds, No black carbon (3 + 4)

SSA Sensitivity Experiment
1. Original MERRA-2 SSA
2. MERRA-2 SSA scaled to observed RH using the MERRA-2 aerosol lookup table
3. MERRA-2 Organic Carbon SSA * 0.85

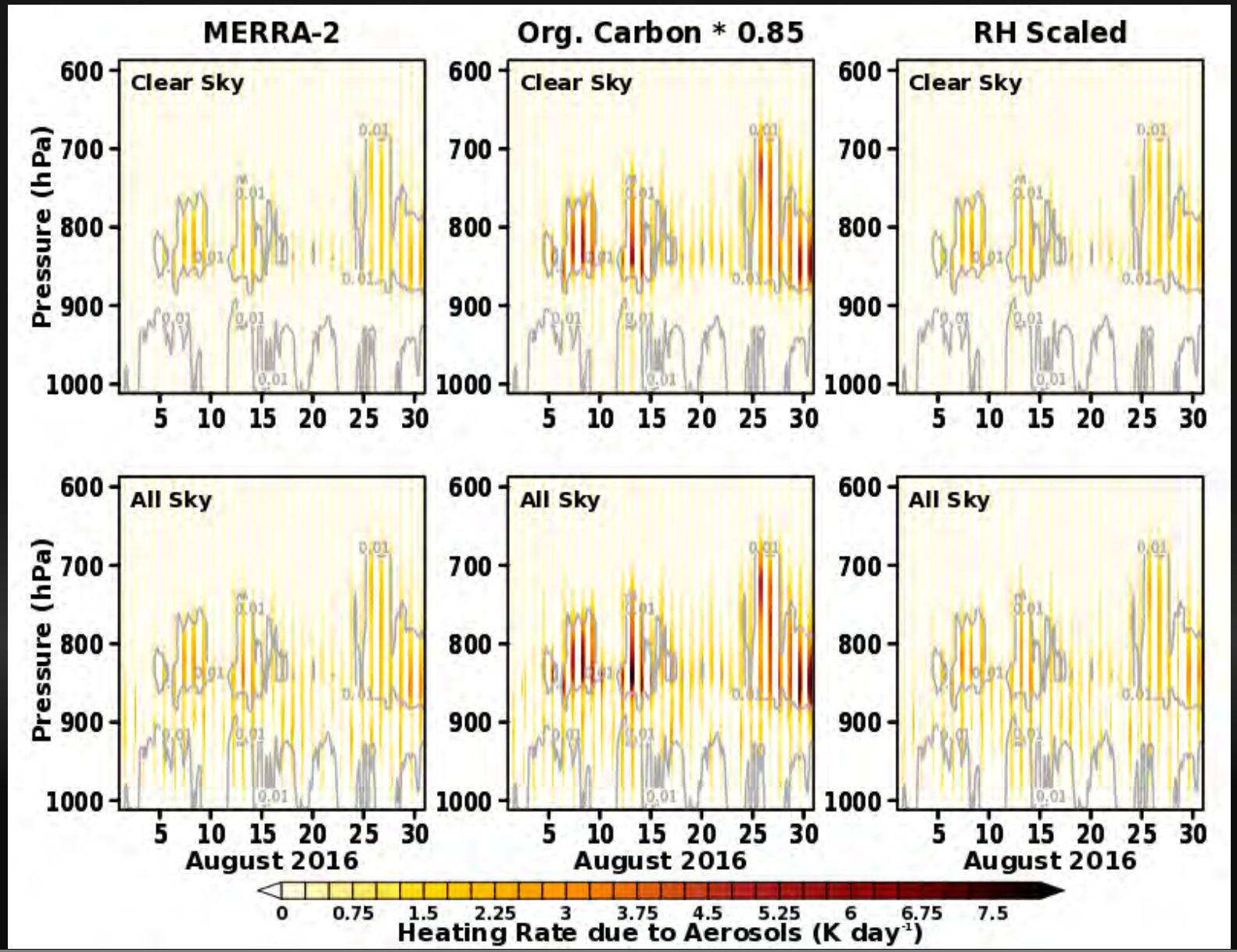
Note: As of this time, the LW version does not include aerosols

Evaluation of Thermodynamics; MERRA-2 vs AMF1



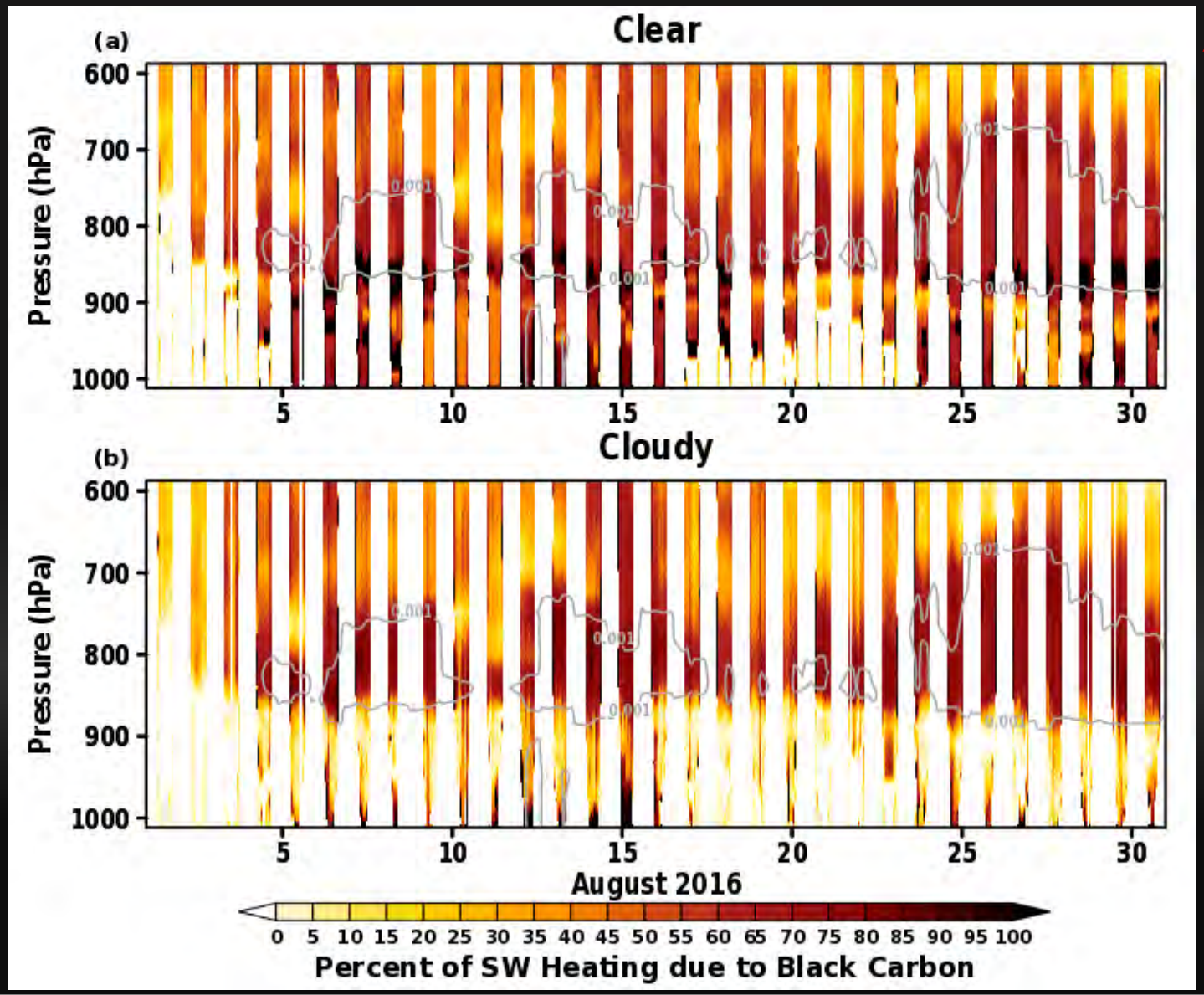
- Obs suggest more decoupled boundary layer than MERRA-2
- Cool temperatures at the top of the BL lead to overestimated RH

Impact of SSA on SW Heating



- Figure shows all aerosols – clean sky; gray contours = AOD at 1 μm
- Clouds enhance heating due to aerosol: scattering from clouds -> increased upwelling SW -> 2nd chance for photons to be absorbed by aerosol
- SSA has a lot of influence on heating rates
  - MERRA-2 SSA: 2-3 K/day
  - RH Scaled SSA: 2-3 K/day
  - Org. Carbon SSA x 0.85: 6-8 K/day
- Actual heating is likely somewhere in between

How Much of the SW Heating is Due to Black Carbon?



ARE for Black Carbon ÷ ARE for All Aerosols (RH scaled case)

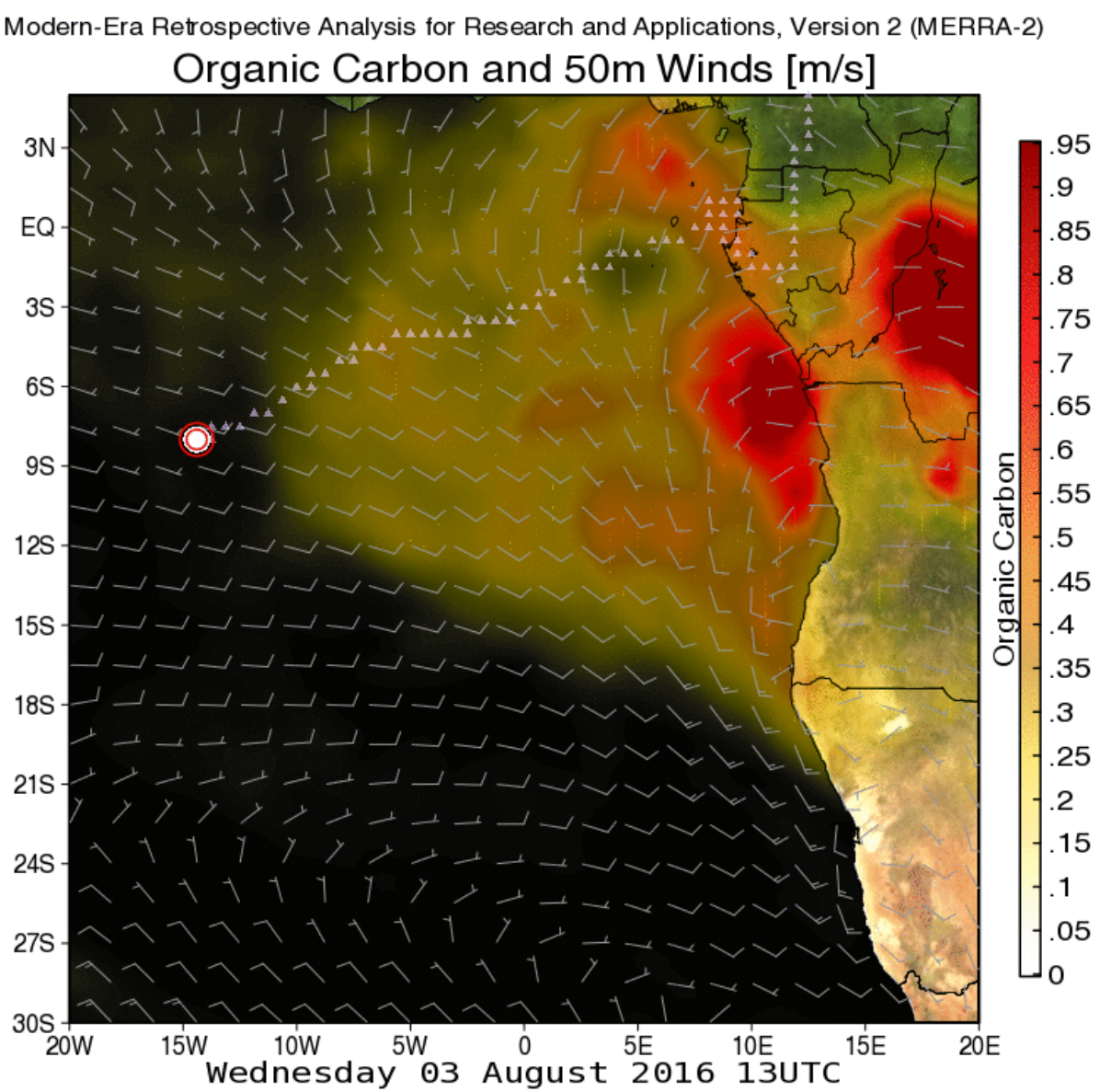
~80%

All!

Dependent on mixing into BL, thermo profile; Note the sinusoidal pattern at top of BL

~80%

~15% -> clouds block photons from reaching surface



Back Trajectory of Biomass Burning Aerosol

- Shading = Organic Carbon AOD from MERRA-2
- White triangles = Back trajectory from HYSPLIT originating within the aerosol layer above Ascension Island at 13z on 13 August 2016 (date with max AOD)
- Purple Triangle = Parcel location at time of AOD

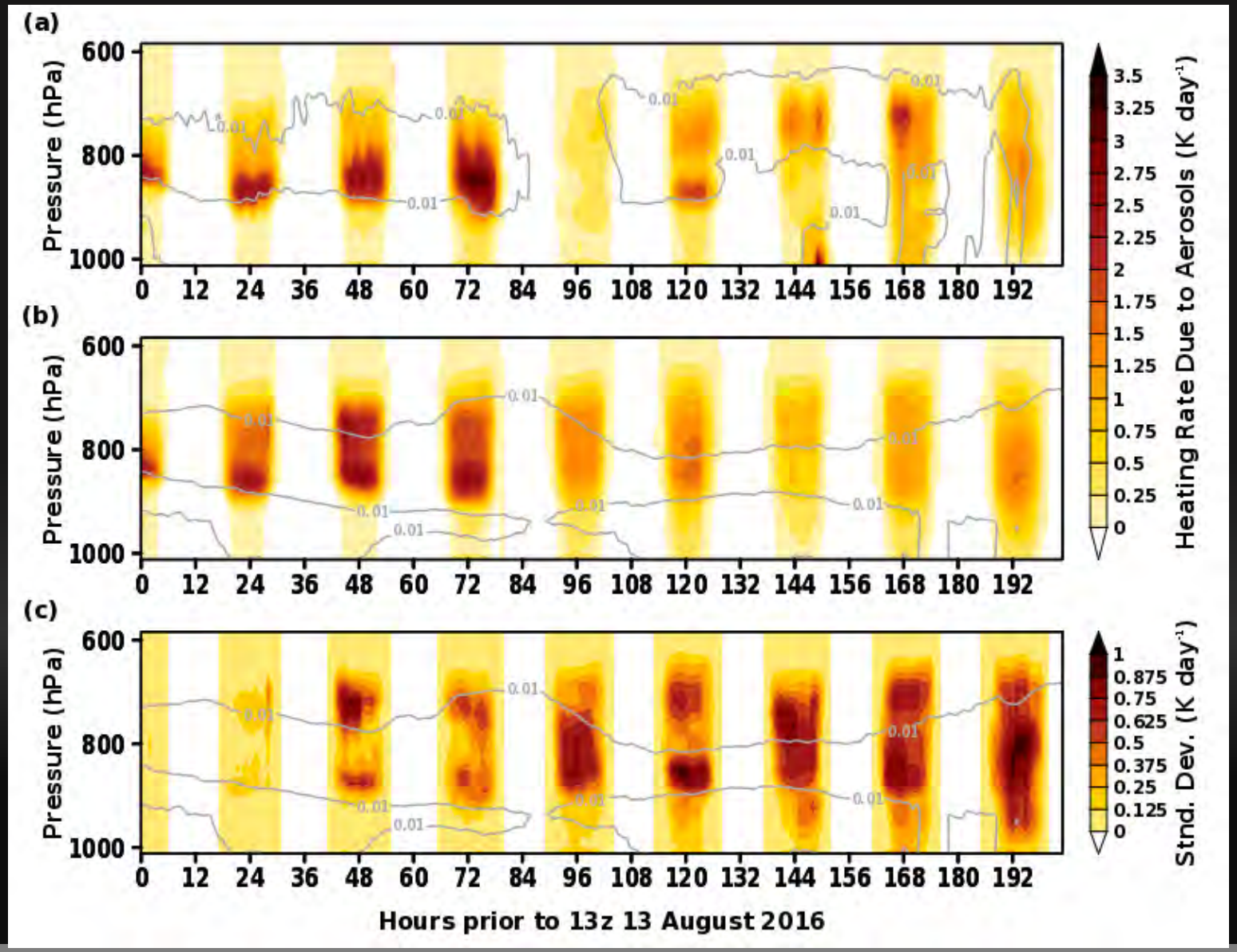
- Jumps in AOD = assimilation from MODIS

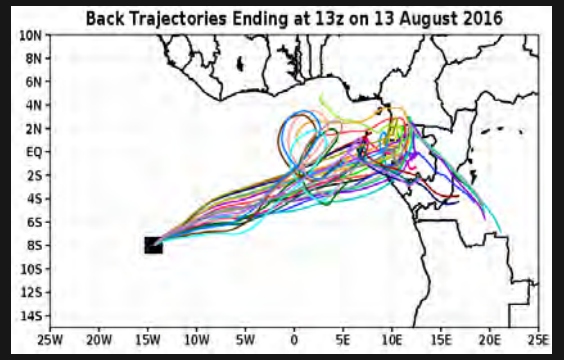
Clear Sky SW Heating Due to Aerosols Along the Back Trajectory

MERRA-2 Back Trajectory

Mean of GDAS Ensemble Back Trajectories

Standard Deviation of GDAS Ensemble Back Trajectories





- MERRA-2 does not include necessary cloud optical properties for RRTM ☹
- Aerosol plume endures multiple days of heating at a rate > 2 K per day
- Uncertainty exists in the heating rate due to uncertainty in the back trajectory

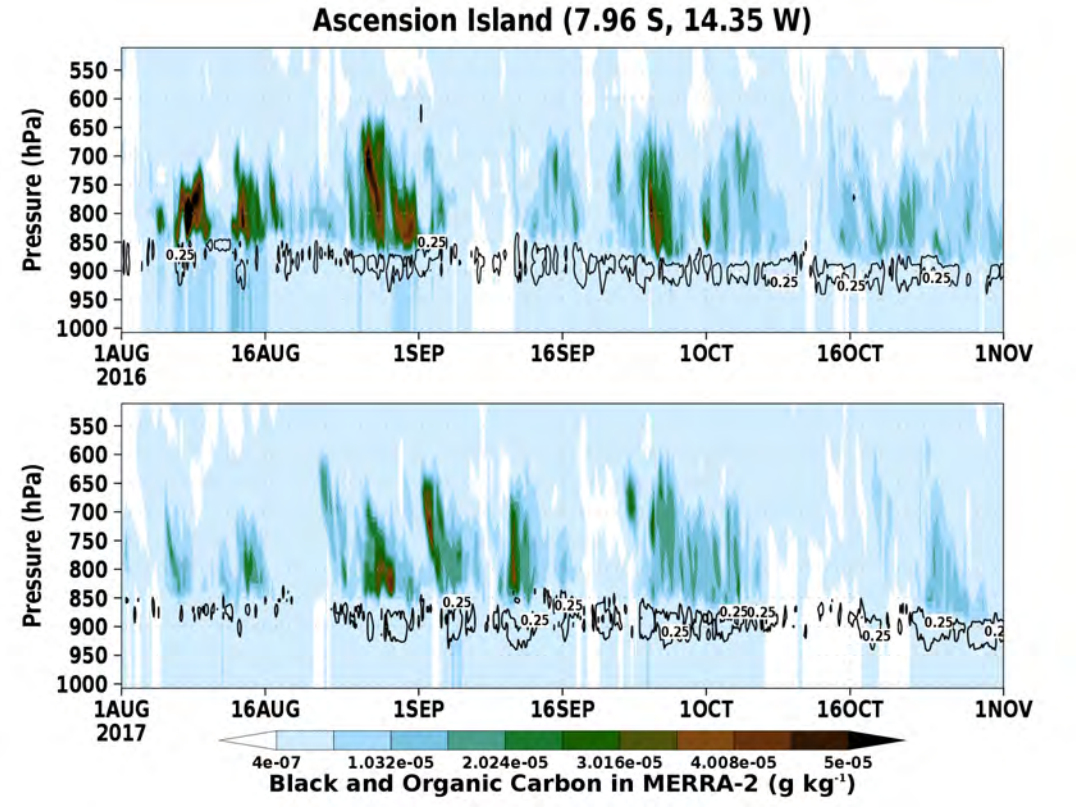
Conclusions

- Aerosol optical properties in MERRA-2 are okay to use, but SSA over the site is too high
- Aerosols result in ~2-8 K/day SW heating locally, but also impact heating rates elsewhere in the column
- This SW heating is enhanced by clouds on the order of a few tenths of a K per day, dependent on the location and thickness of the cloud as well as the AOD
- Black carbon is responsible for ~80% of the SW heating within the aerosol plume
- As the aerosol plume approaches Ascension Island, it encounters multiple days of SW aerosol heating on the order of ~2 K/day, but uncertainties in the back trajectory lead to uncertainties in the heating rate
- LW cooling CANNOT offset the daytime SW aerosol heating (not shown today)

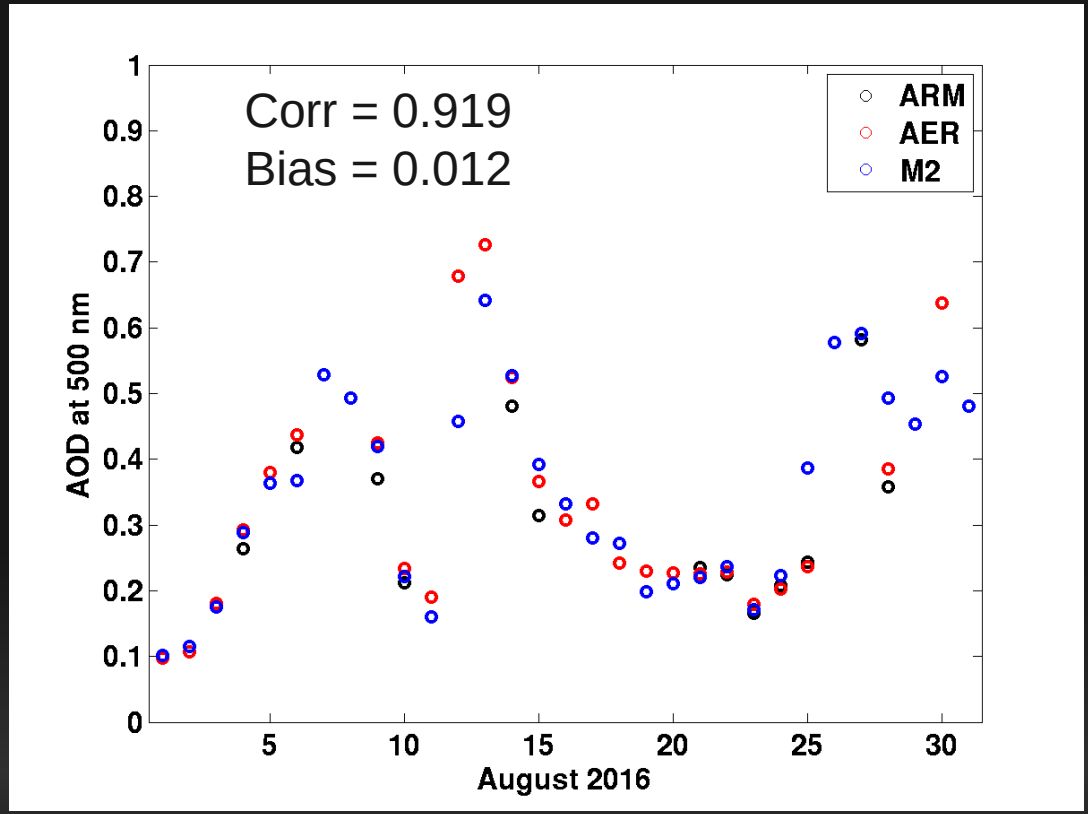
More Details

- ACP Discussion Paper - https://www.atmos-chem-phys-discuss.net/acp-2020-106/
- Revised version currently under review
- Also includes thermo discussion, LW calculation, speculations on impact on clouds

MERRA-2 Captures the Low-Level Clouds and Aerosol Structure!



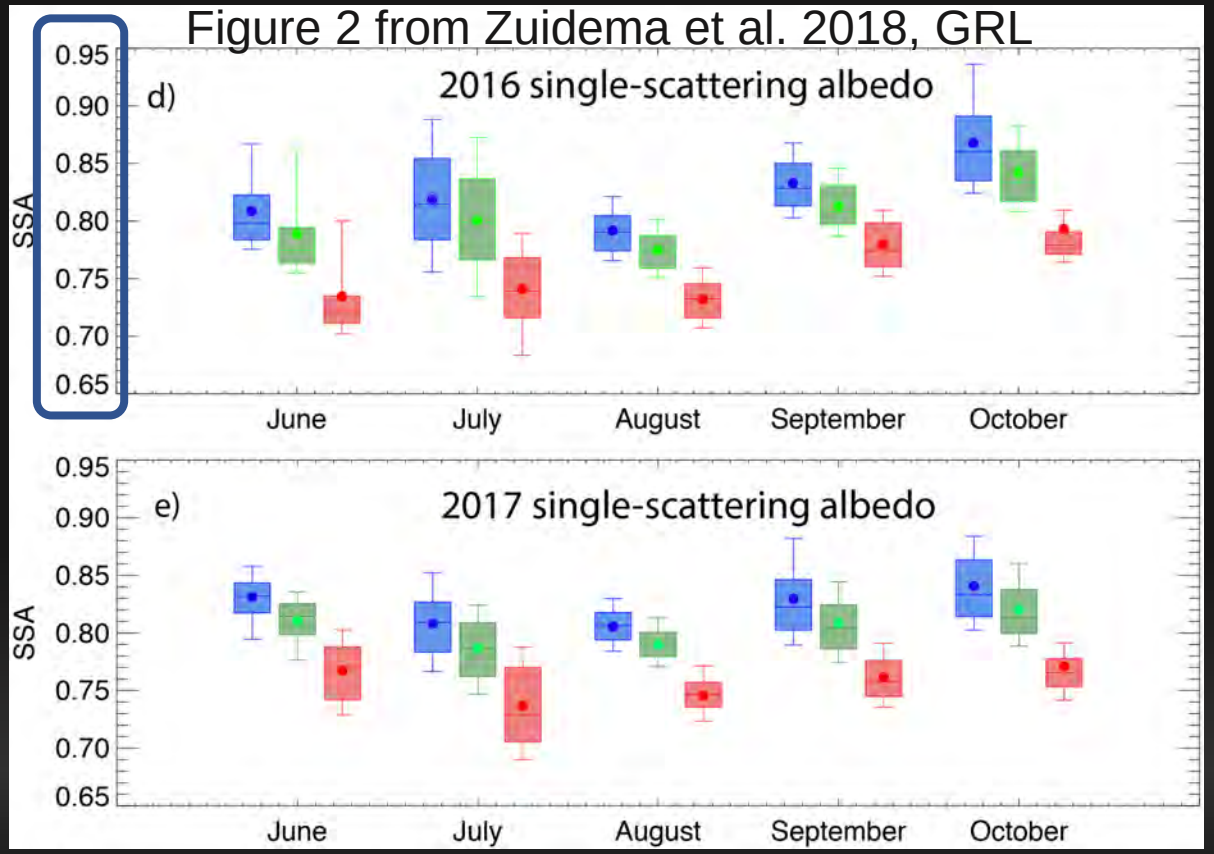
- Black contours = 25% cloud fraction
- Highest AODs occurred in August 2016, followed by September 2017
- As in the lidar observations, aerosol tends to be above the clouds, but does get mixed down to the surface

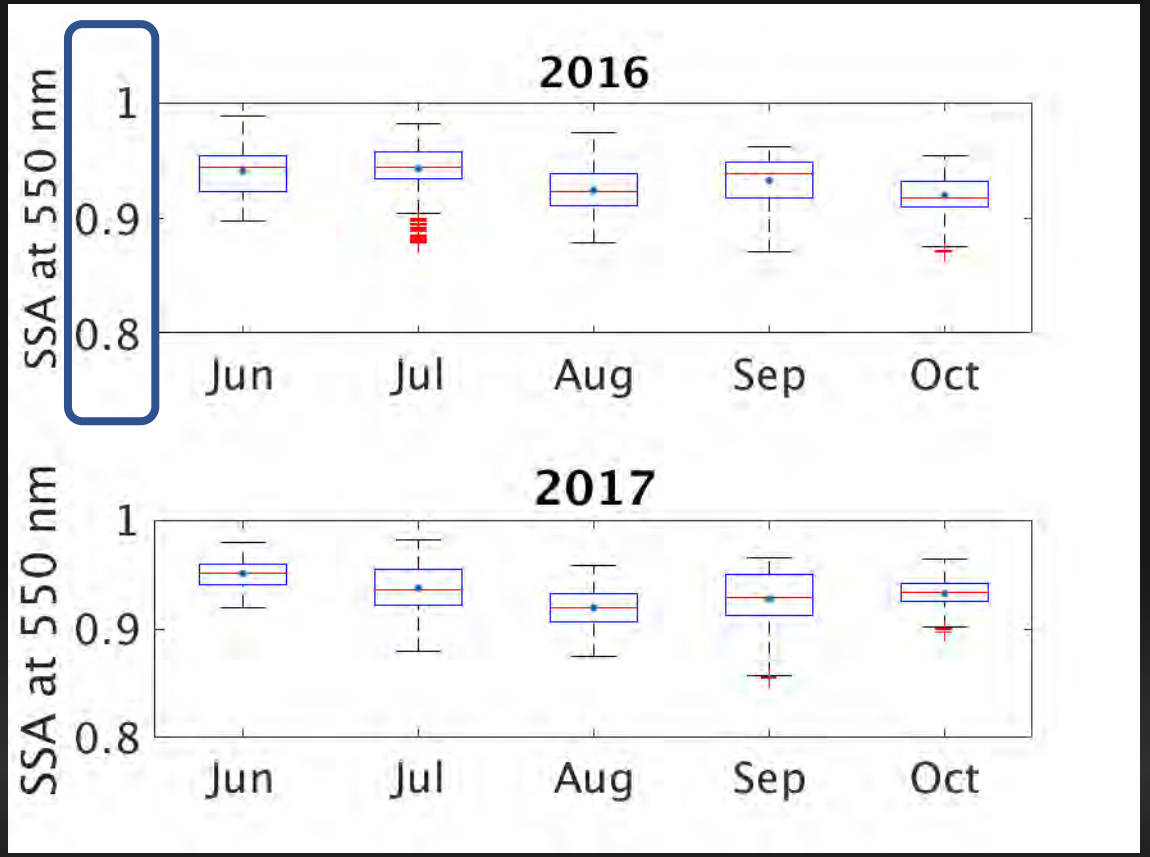


- Ascension Island happens to be an AERONET site -> two sources of AOD obs!
- Correlations are vs AERONET

Observations vs MERRA-2 Single Scattering Albedo

Figure 2 from Zuidema et al. 2018, GRL





- Different y axis on plots! SSA too high in MERRA-2
- Possible Explanations: 1) Humidity; 2) No brown carbon or aerosol aging in GEOS…yet
- SSA in MERRA-2 and GEOS is more in line with obs closer to the African coast (Shinozuka et al. 2019, ACP)