Radiative Heating from Biomass Burning Aerosol and its Impact on Cloud Structure in the Southeast Atlantic

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RUTGERS
Institute of Earth, Ocean, and Atmospheric Sciences

ASR Atmospheric System Research

USRA

Motivation

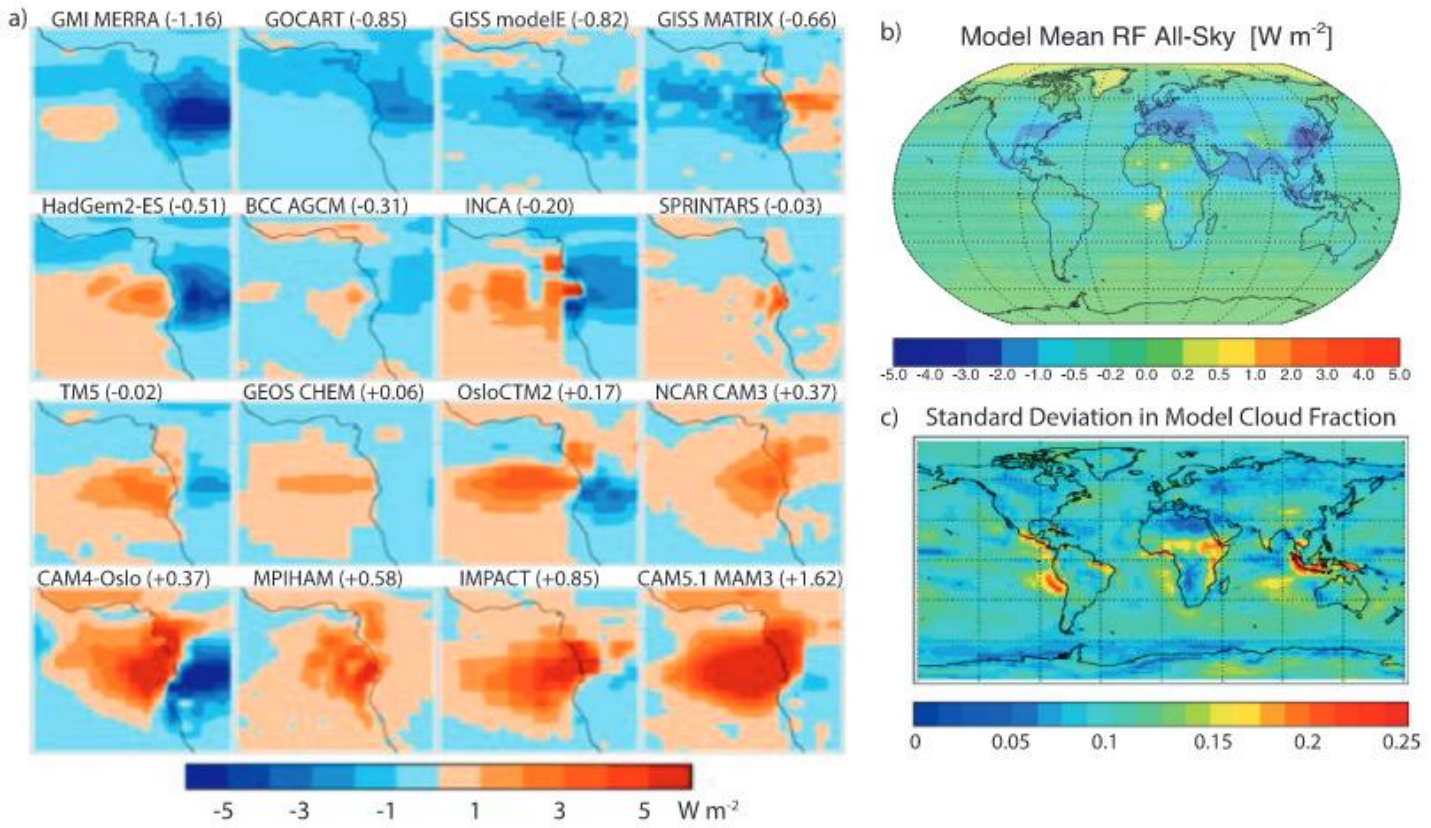
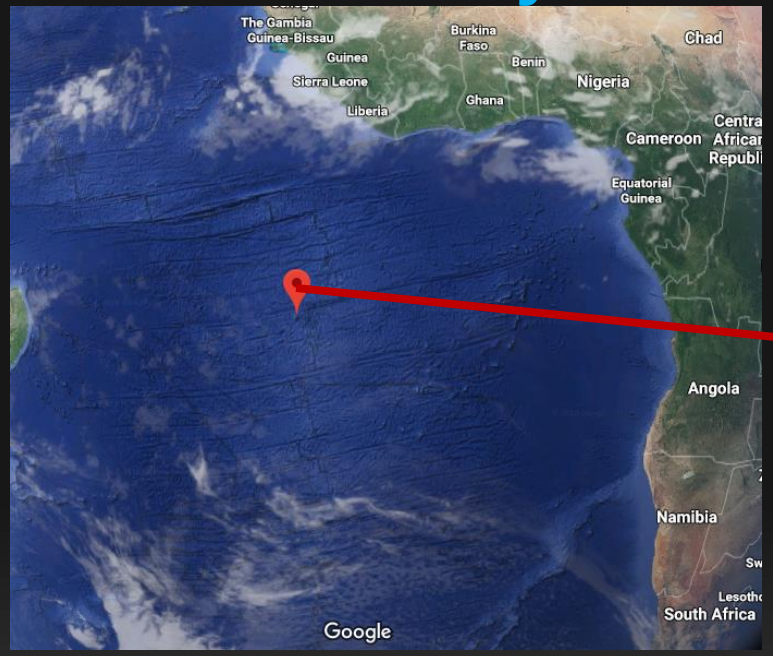


FIG. 2. Modeled Aug–Sep direct aerosol radiative forcing in (a) individual AeroCom models ordered by their regional- and annual-average difference from the (b) ensemble mean indicating the regional hotspot for BB aerosol forcing over the southeast Atlantic. (c) indicates the large diversity in the models' cloud fraction. The cloud fraction helps determine if the aerosol shortwave absorption influences the climate more than the aerosol scattering. More model details can be found in Stier et al. (2013).

(Zuidema et al., 2016)

- GCMs and reanalyses underestimate cloud fraction in the SE Atlantic (Klein et al., 2013; Dolinar et al., 2015)
- Warm marine stratocumulus
  - too optically thin in GCMs
  - underestimates of albedo and LWP (Lin et al., 2014; Rapp 2015)
  - Transition to cumulus poorly represented in models (Teixeira et al. 2011; Ahlgrimm and Forbes, 2016)
- These issues can be further complicated by aerosols!

LASIC: Layered Atlantic Smoke Interactions with Clouds



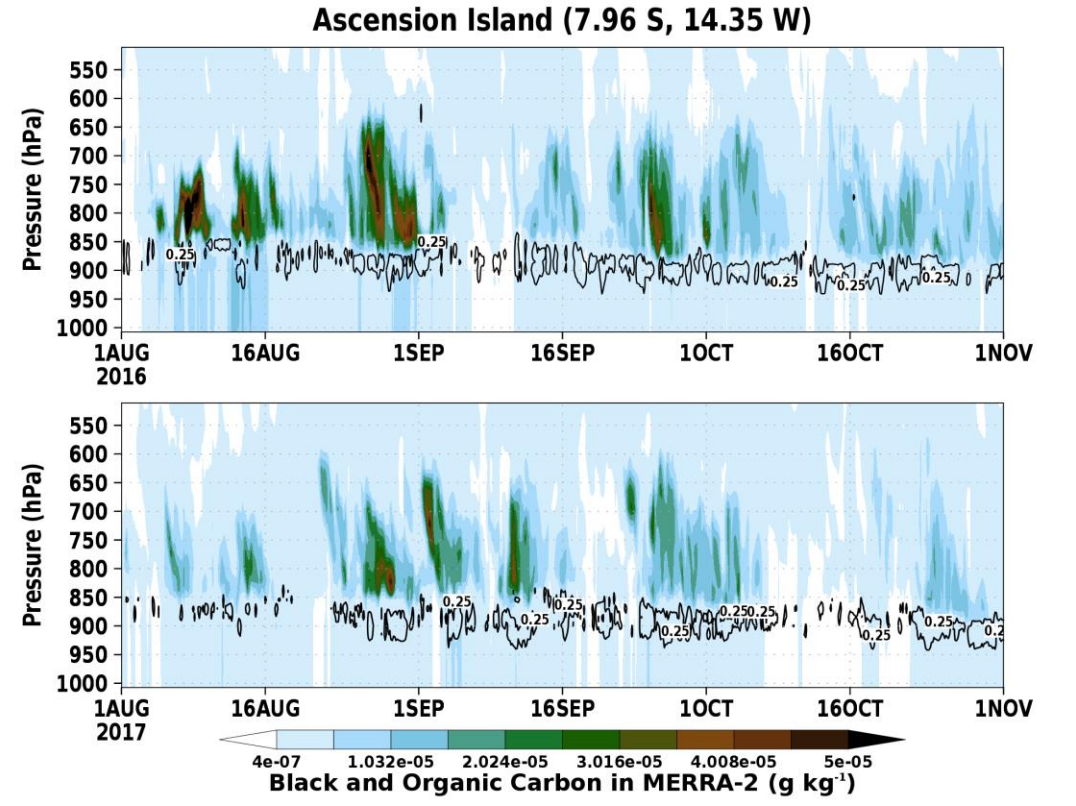
(Zuidema, 2016)

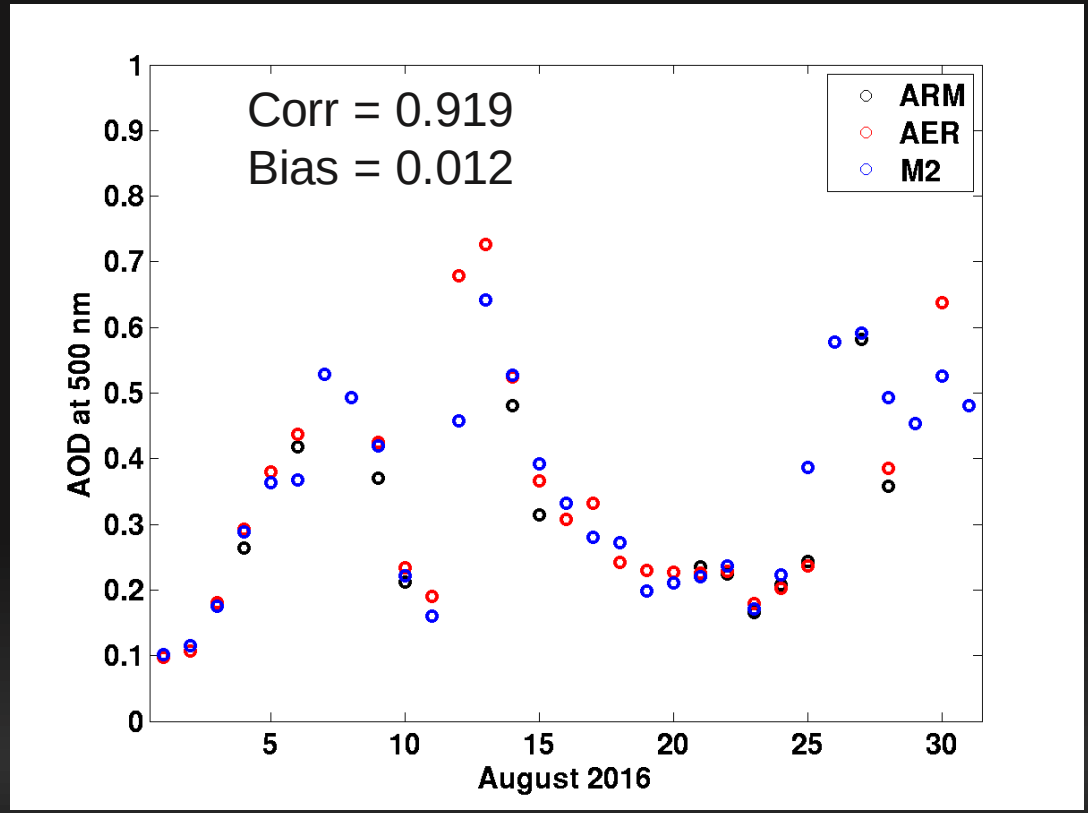
(ARM Flickr)

Ascension Island
1 June 2016 – 31 October 2017
Two biomass burning seasons

- How does biomass burning aerosol impact clouds?
- NASA conducted ORACLES, DOE loaded an island with instruments!
- Merge DOE observations with MERRA-2 reanalysis

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

Single Scatter Albedo

Observations (Zuidema et al., 2018)

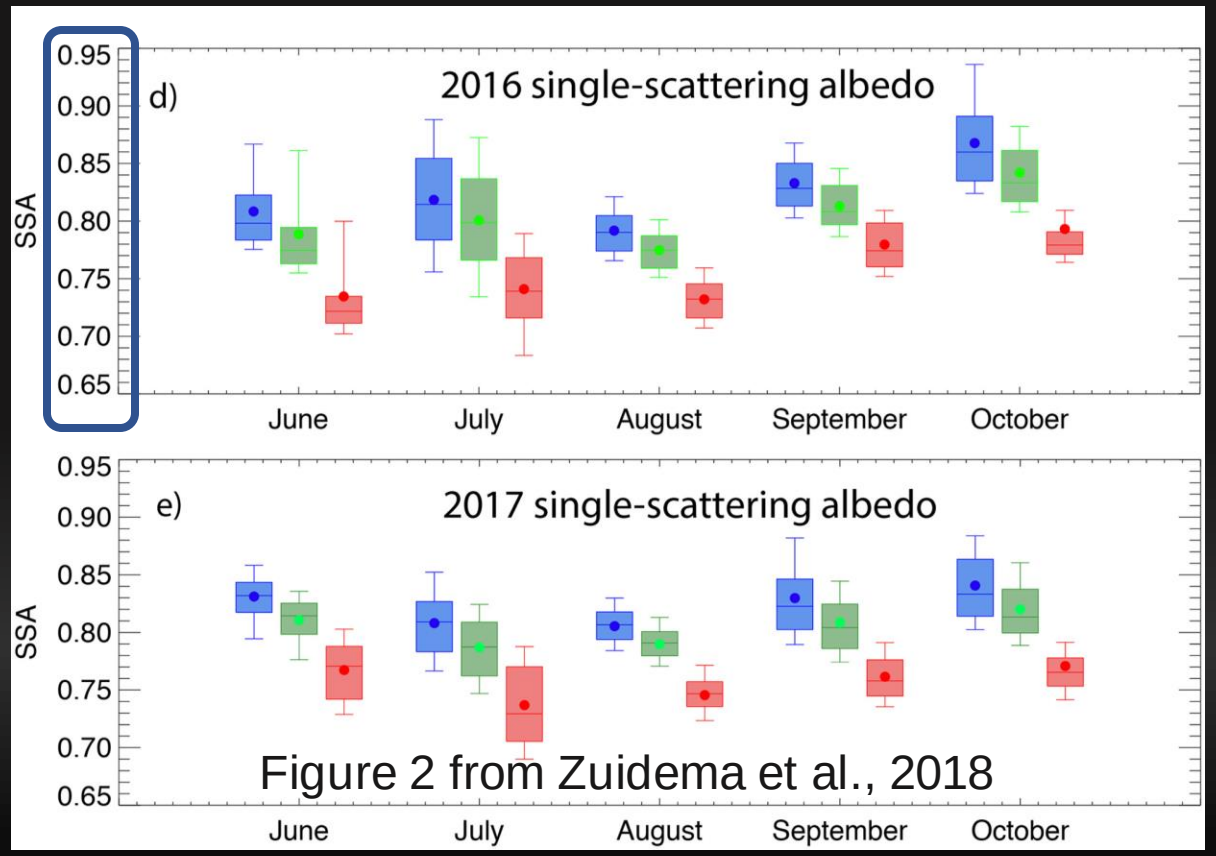
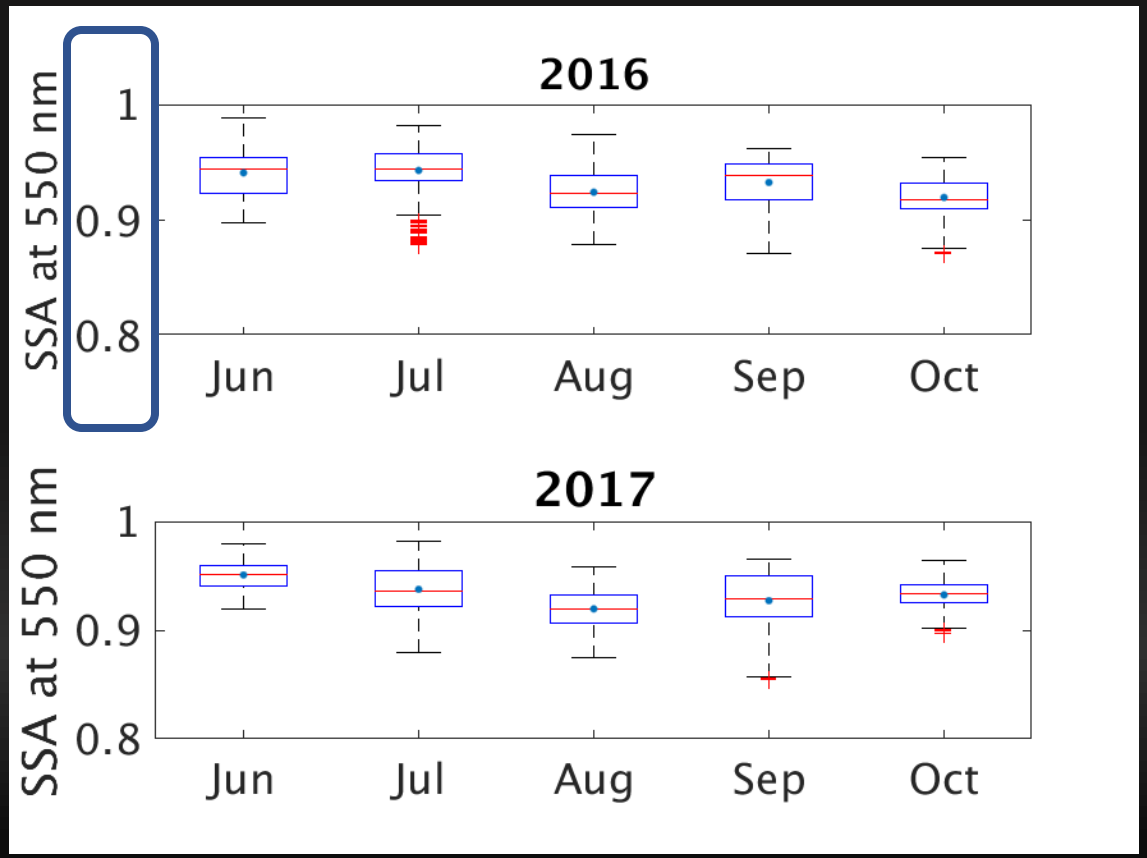


Figure 2 from Zuidema et al., 2018

MERRA-2



- MERRA-2 overestimates SSA
- Possible Explanations: 1) Humidity; 2) No brown carbon in GEOS (yet)

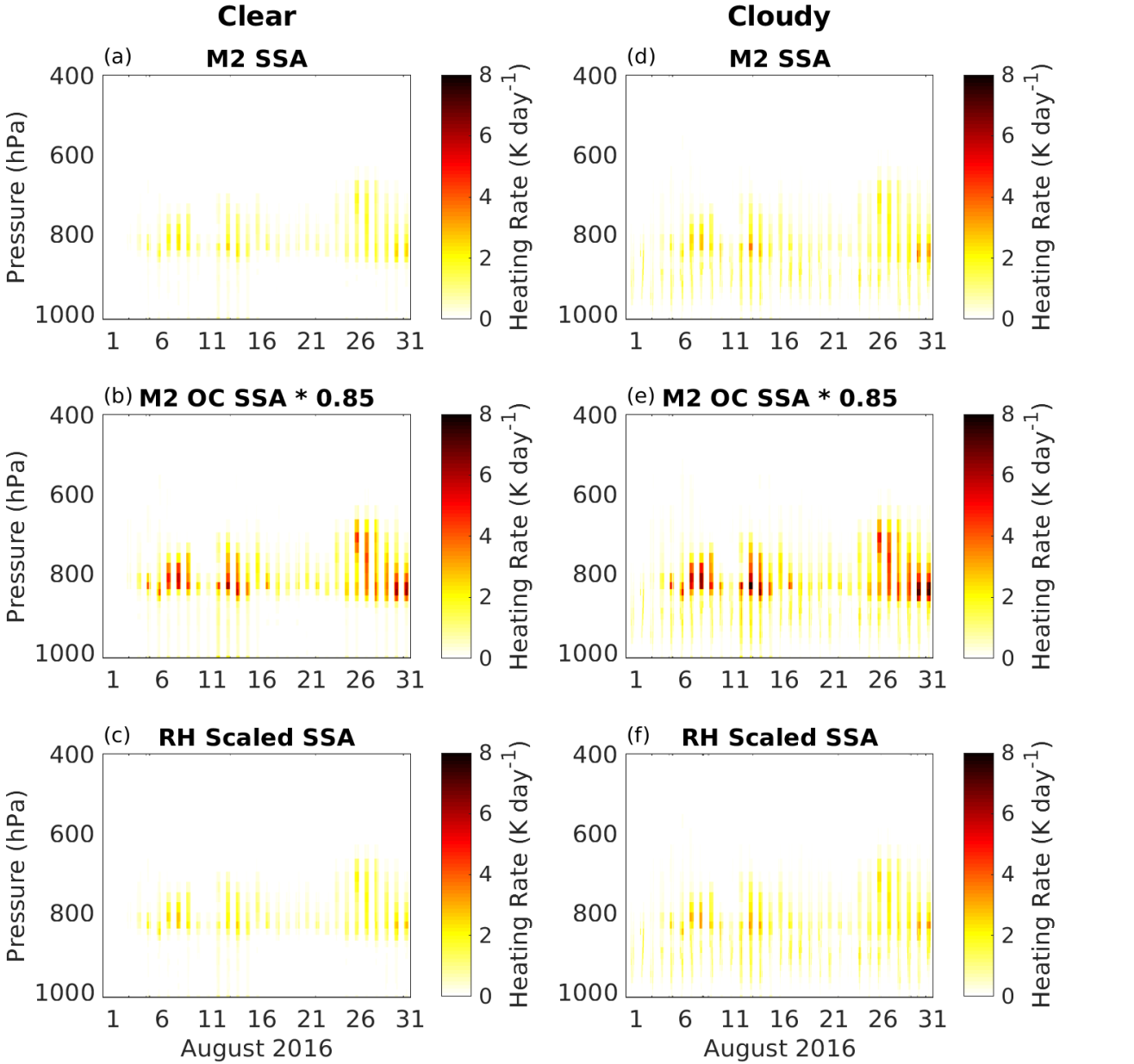
Idealized Simulations with the Rapid Radiative Transfer Model (RRTM)

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

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

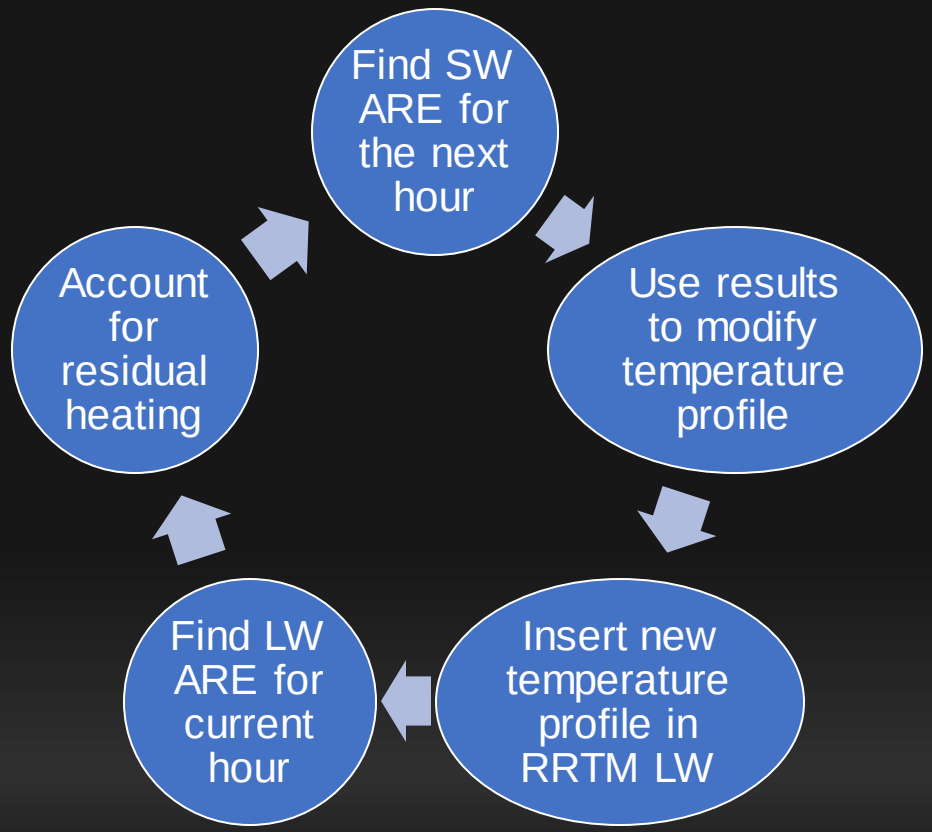


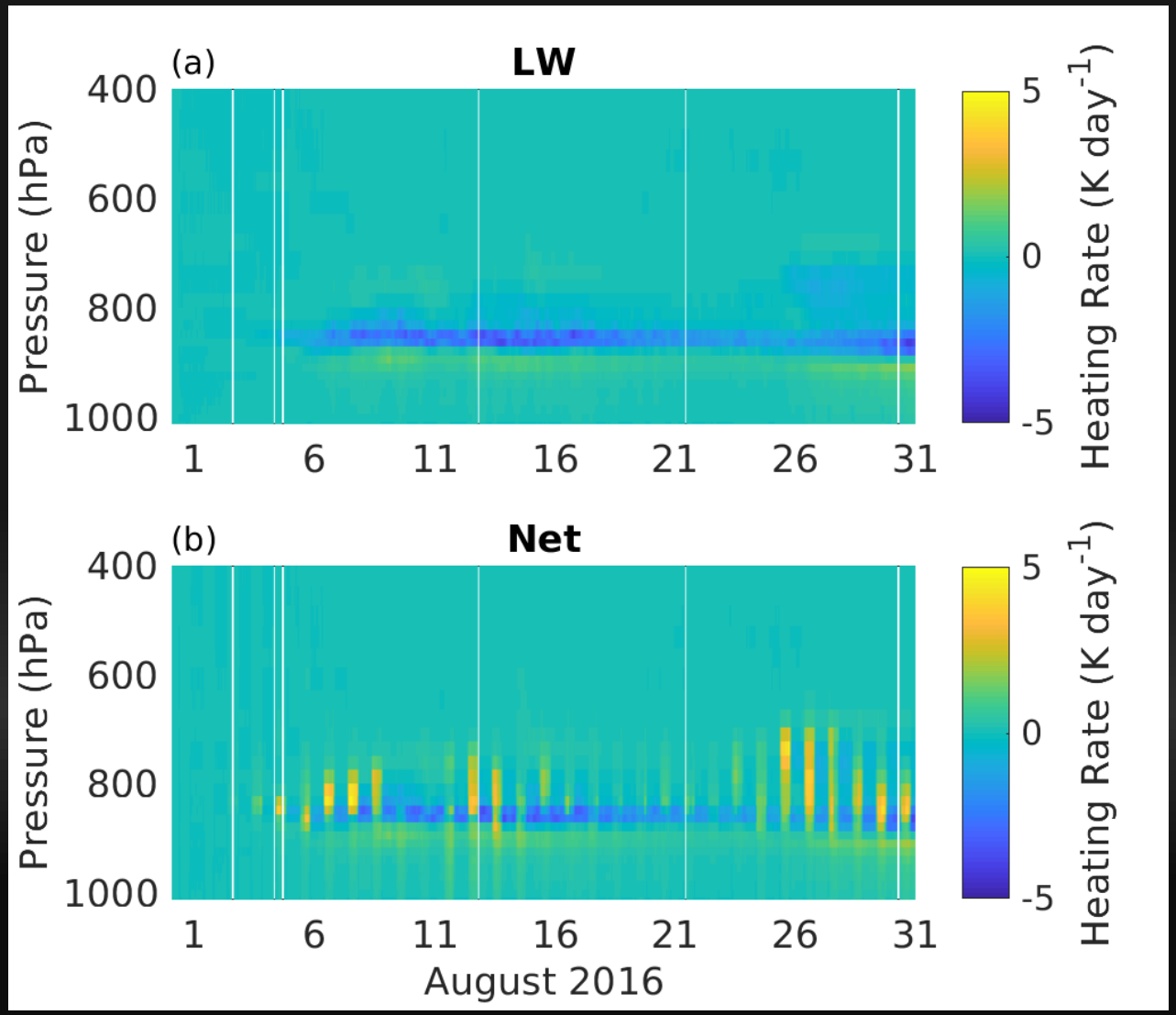
SW Heating Rate Due to Aerosols

- Figure shows all aerosols – clean sky
- Clouds enhance heating due to 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

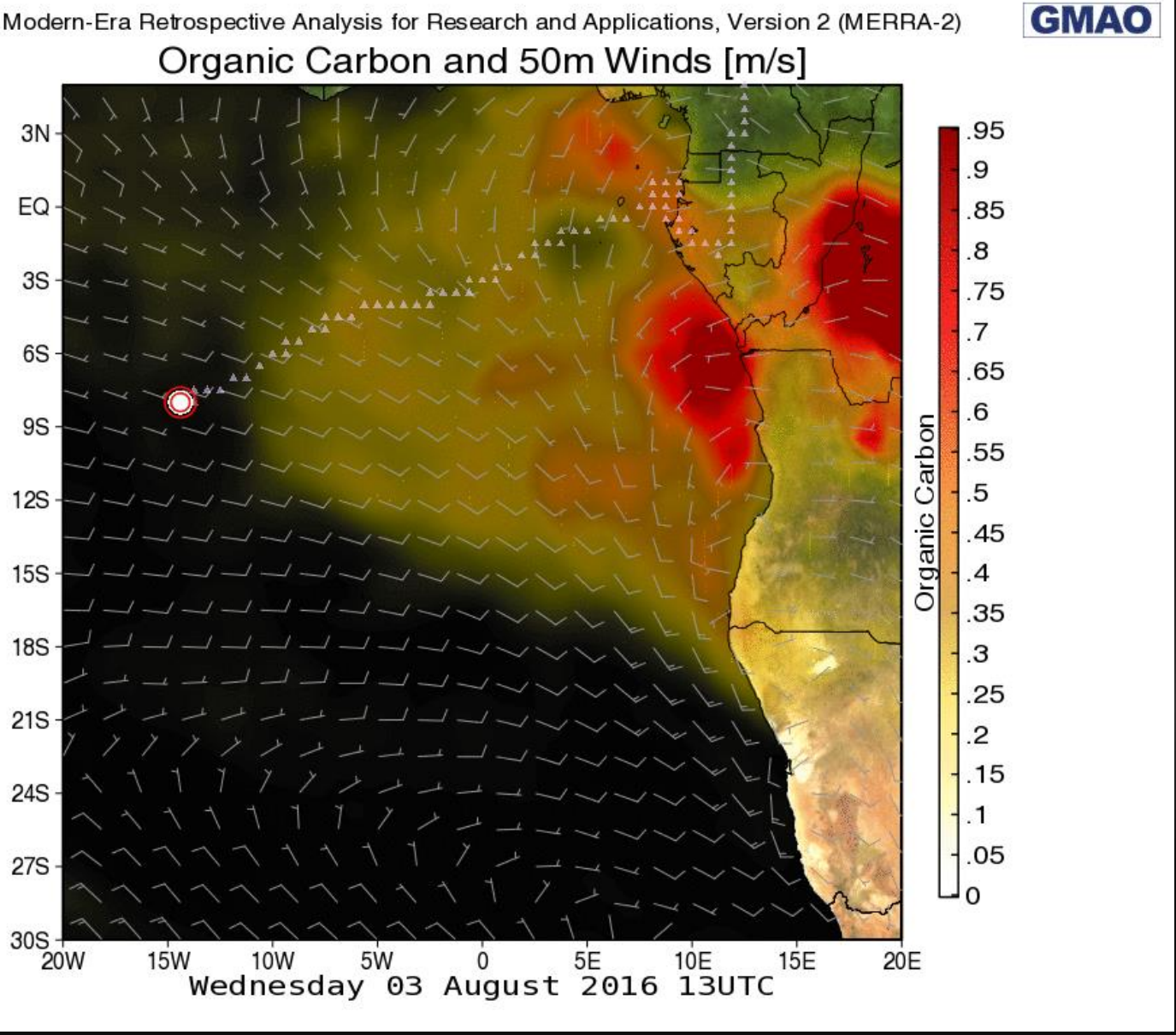
- Actual heating is likely somewhere in between

Is SW warming balanced by LW cooling?





- Clear sky results shown here, using RH scaled SSA
- Net result: redistribution of heat; stabilizes the aerosol layer
- warming at the top of the aerosol layer (~ 3K/day), cooling at the bottom of the aerosol layer (~3K/day), warming just below (~1K/day)

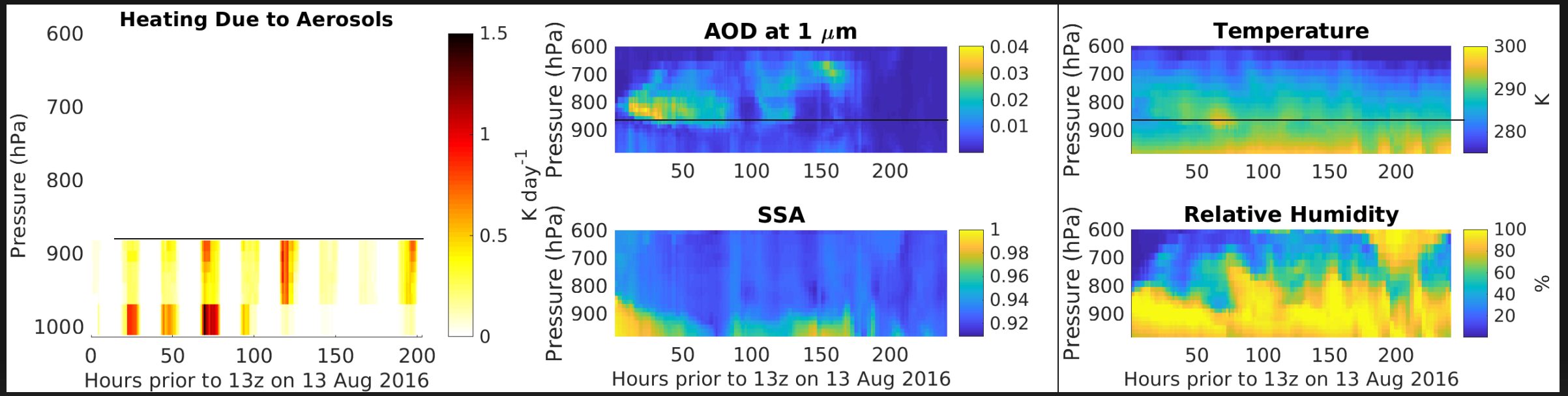


Back Trajectory of Biomass Burning Aerosol

- 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 = Particle location at time of AOD

- Jumps in AOD = assimilation from MODIS

Clear Sky SW Heating Along the Back Trajectory



- SSA within the SE Atlantic in GEOS was evaluated by Shinozuka et al. (ACP, 2019) and shown to be okay closer to the African coast
- Heating occurs below the inversion layer (artifact of the height of the boundary layer in MERRA-2) and at the surface

Conclusions

- Aerosol optical properties in MERRA-2 are okay to use, but SSA over the site is too high
- Some differences exist in the thermodynamic profiles between MERRA-2 and the observations – could be related to vertical resolution, boundary layer deficiencies
- Aerosols are responsible for ~2-8 K/day heating locally, but also impacts heating rates elsewhere in the column
- When LW cooling is accounted for, there is a net redistribution of heat within the column due to aerosols
- Heating due to aerosol occurs before the aerosol plume reaches the site

Future Work

•Perform RRTM calculations with clouds and in the LW along HYSPLIT back trajectories

•Further investigate the role of aerosols on cloud structure with respect to the U of W mass flux closure