Aerosol Radiative Effects over Ascension Island using LASIC Observations and MERRA-2

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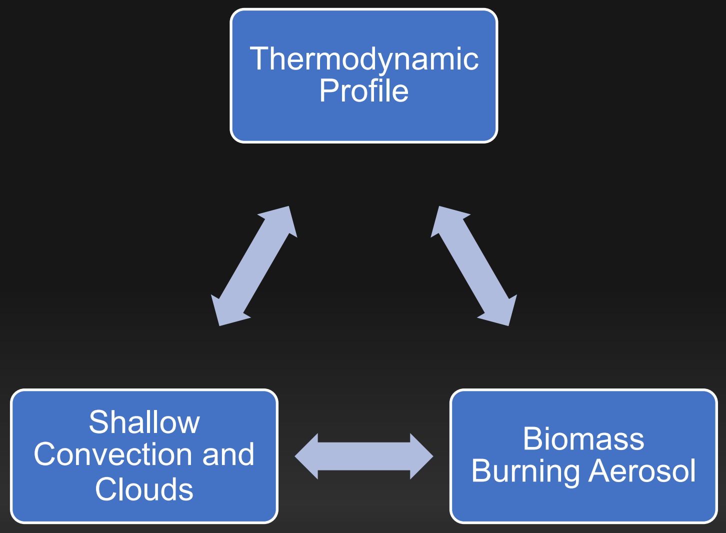
Rutgers Institute of Earth, Ocean, and Atmospheric Sciences

ASR Atmospheric System Research

USRA

Our Project – "Connecting the Radiative Influences of Aerosol upon the Mass Flux Profiles of Shallow Cumuli across the Central Atlantic Ocean Basin and its Boundaries"



Hypotheses:

1) Observable relationships exist between M, CAPE, CIN, etc and these relationships are sensitive to biomass burning aerosol
2) Biomass burning aerosol impacts the parameterization of shallow convection in models by altering grid-scale moist TKE and CIN
3) Initiation of shallow moist convection redistributes biomass burning aerosol in the atmosphere and in models

$$M = 0.4\rho\sqrt{e}\,\exp\left(-\frac{CIN}{e}\right)$$

= mass flux closure in U of Washington shallow convective scheme

M= mass flux, e = Turbulent Kinetic Energy

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

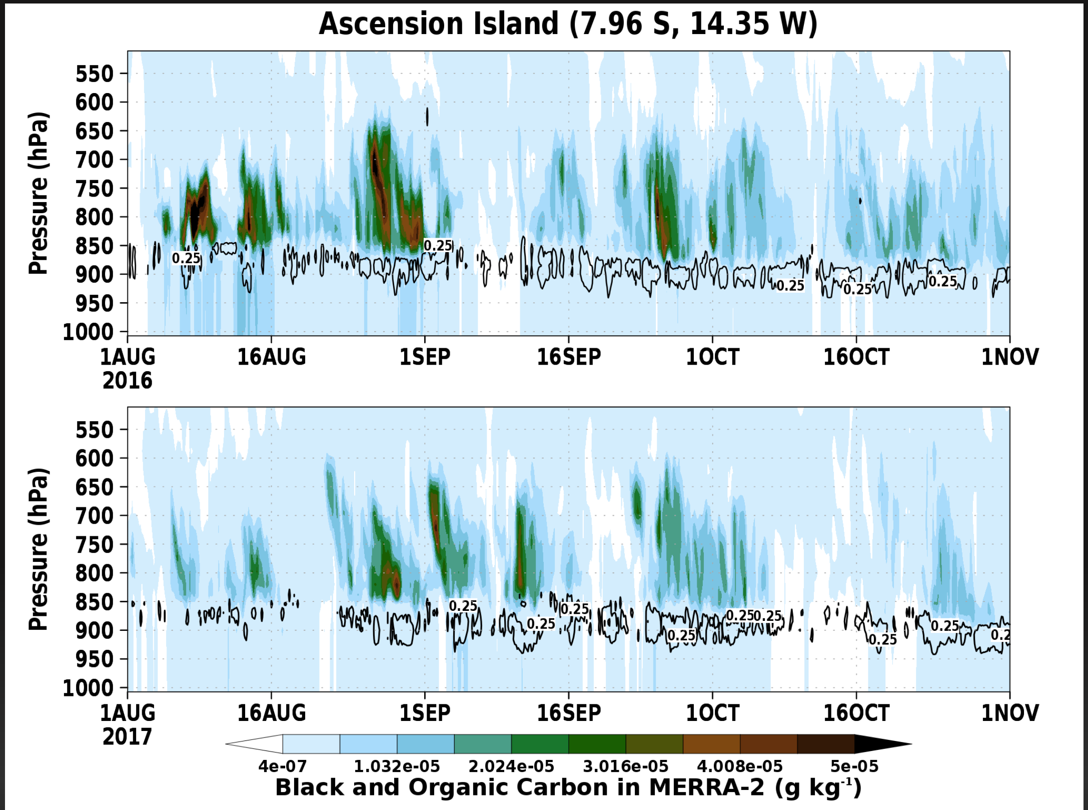
- Vertical profile of
  - Upwelling SW
  - Downwelling SW
  - Net SW
  - Diffuse vs Direct SW
  - Heating Rate

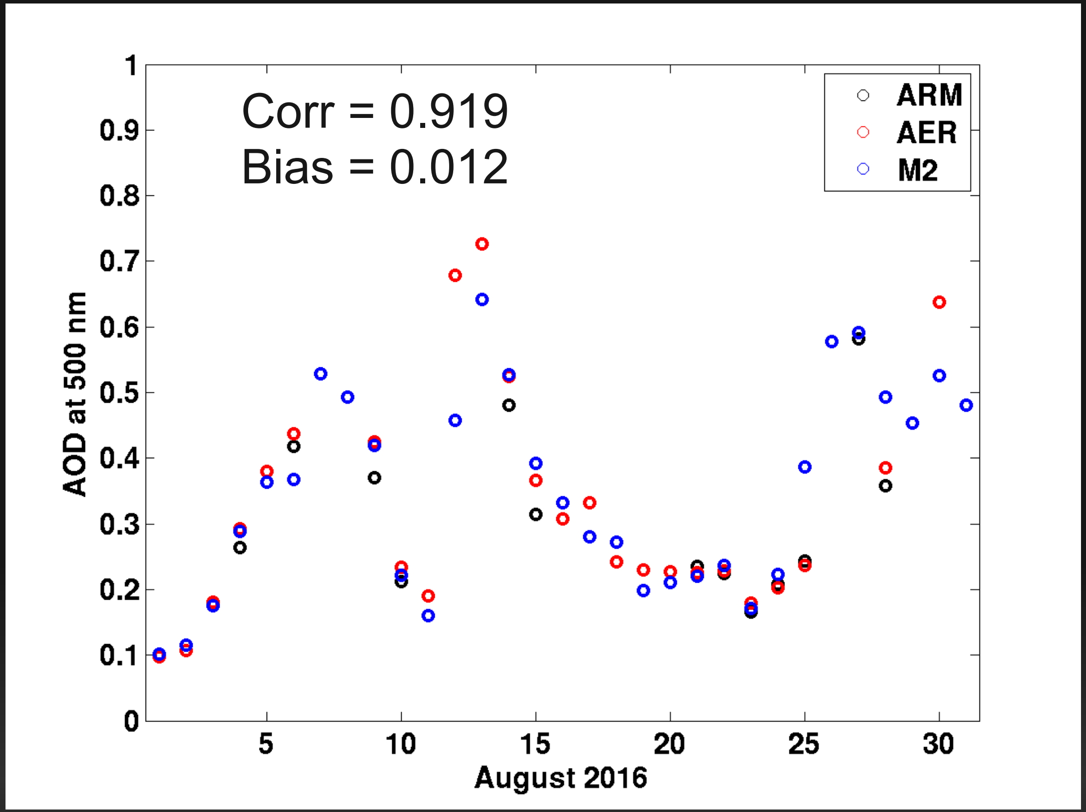
Note: As of this time, the LW version does not include aerosols

Due to the interaction of clouds and aerosols, we need a set of 6 idealized experiments:

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)

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

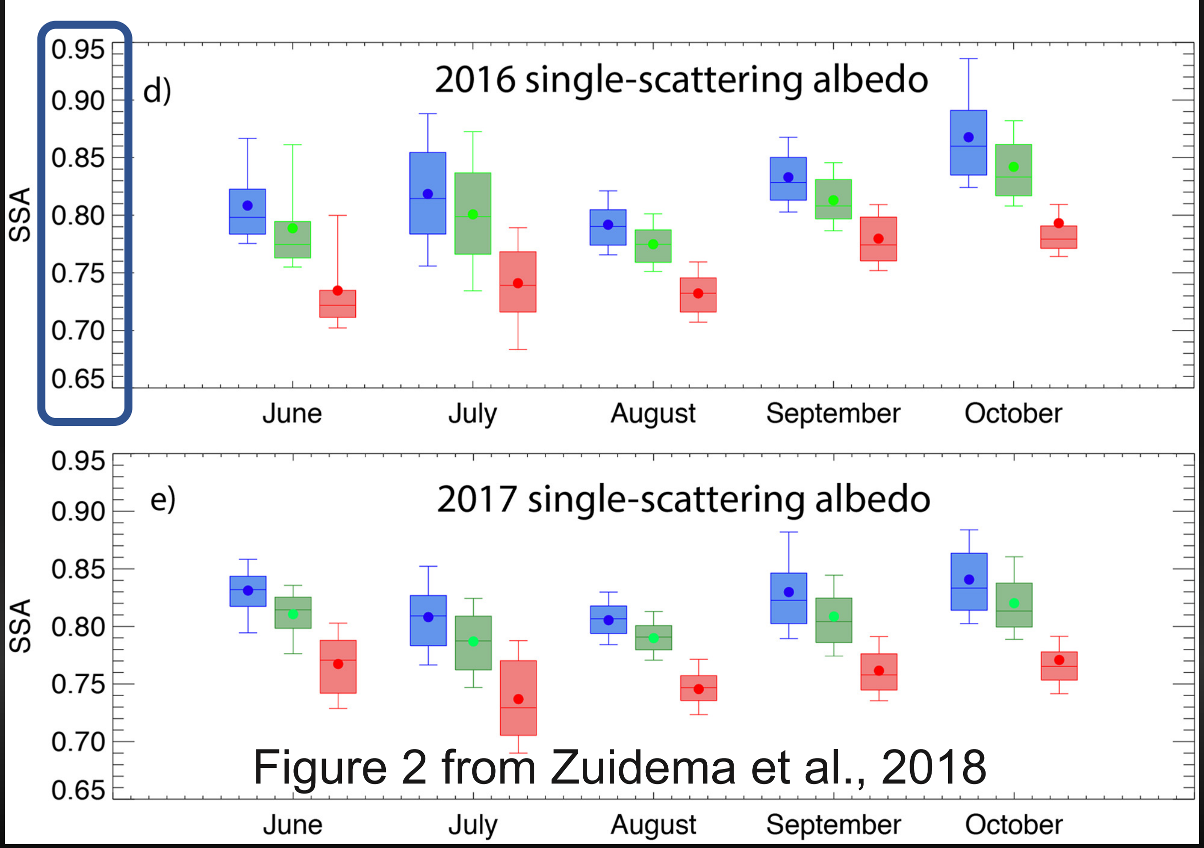


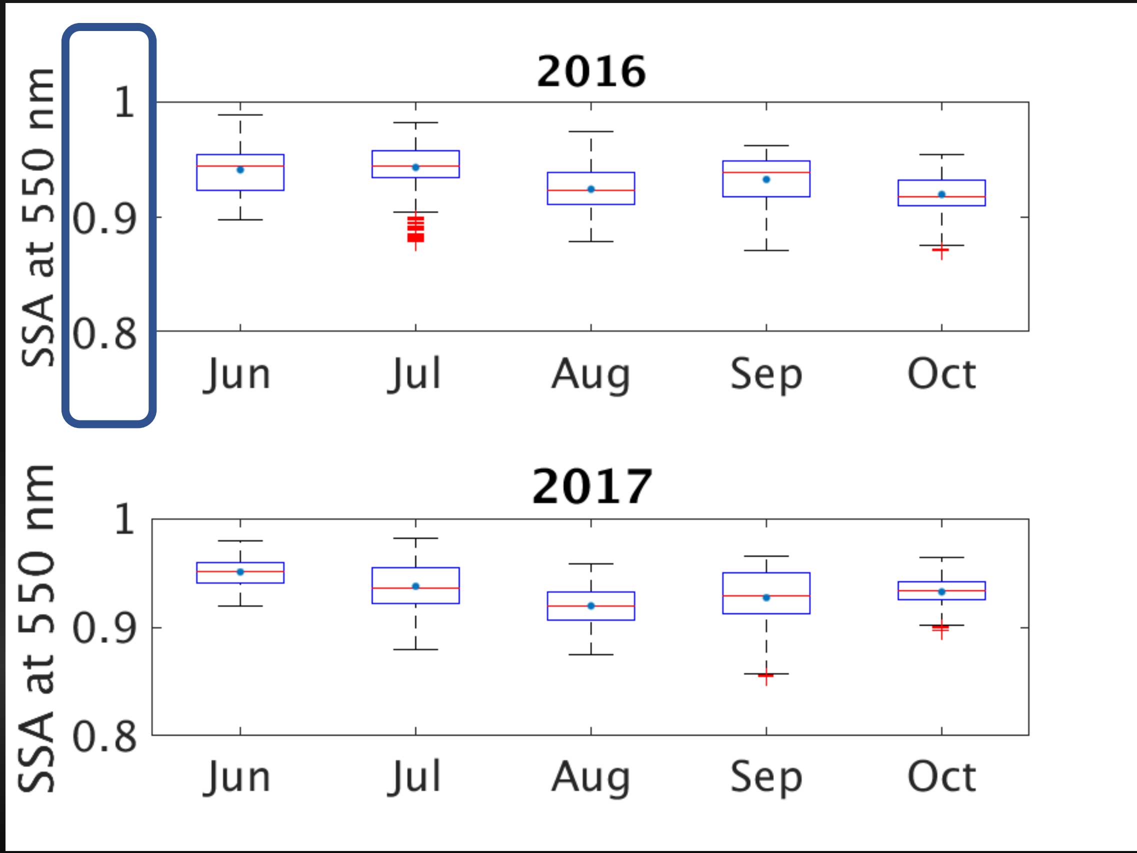


- Black contours = 25% cloud fraction
- Highest AODs occurred in August 2016, followed by September 2017
- As in the lidar observations, aerosol tends to be above the clouds, but does get mixed down to the surface

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

Observations vs MERRA-2 Single Scatter Albedo

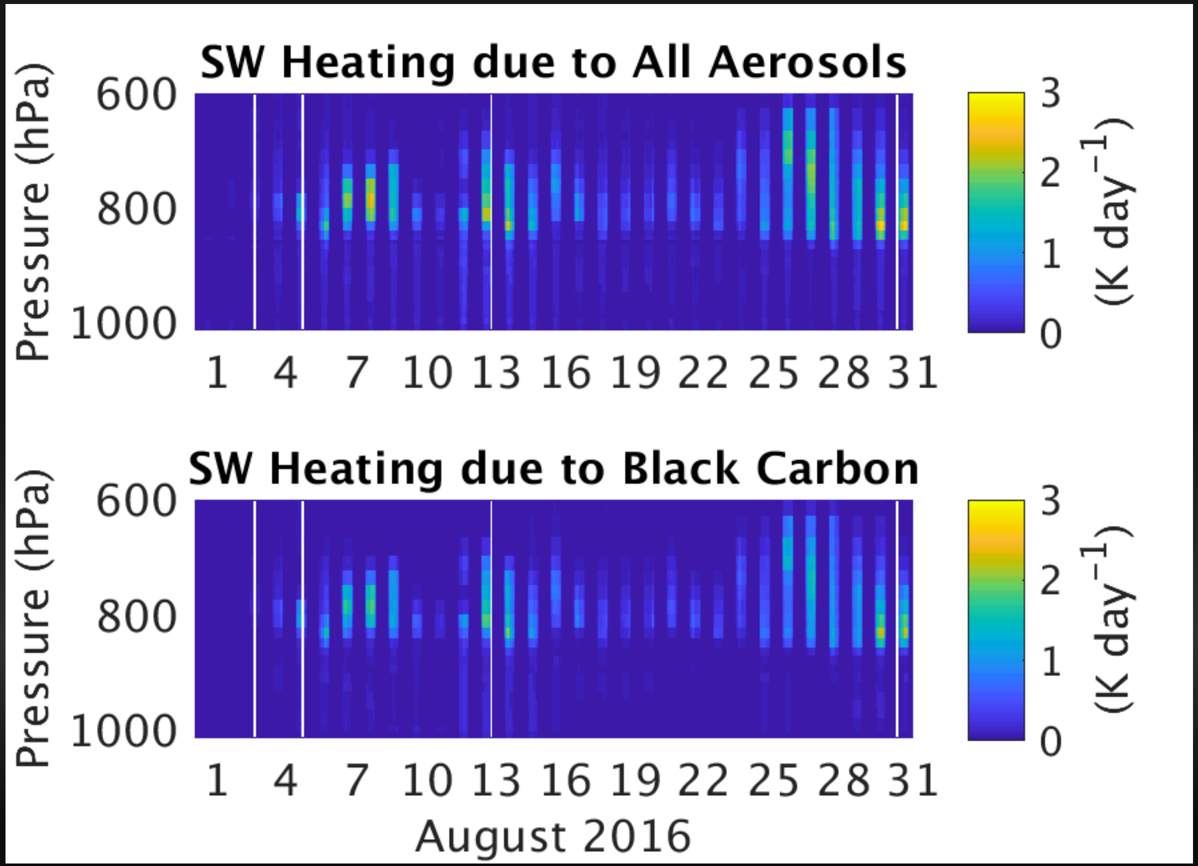


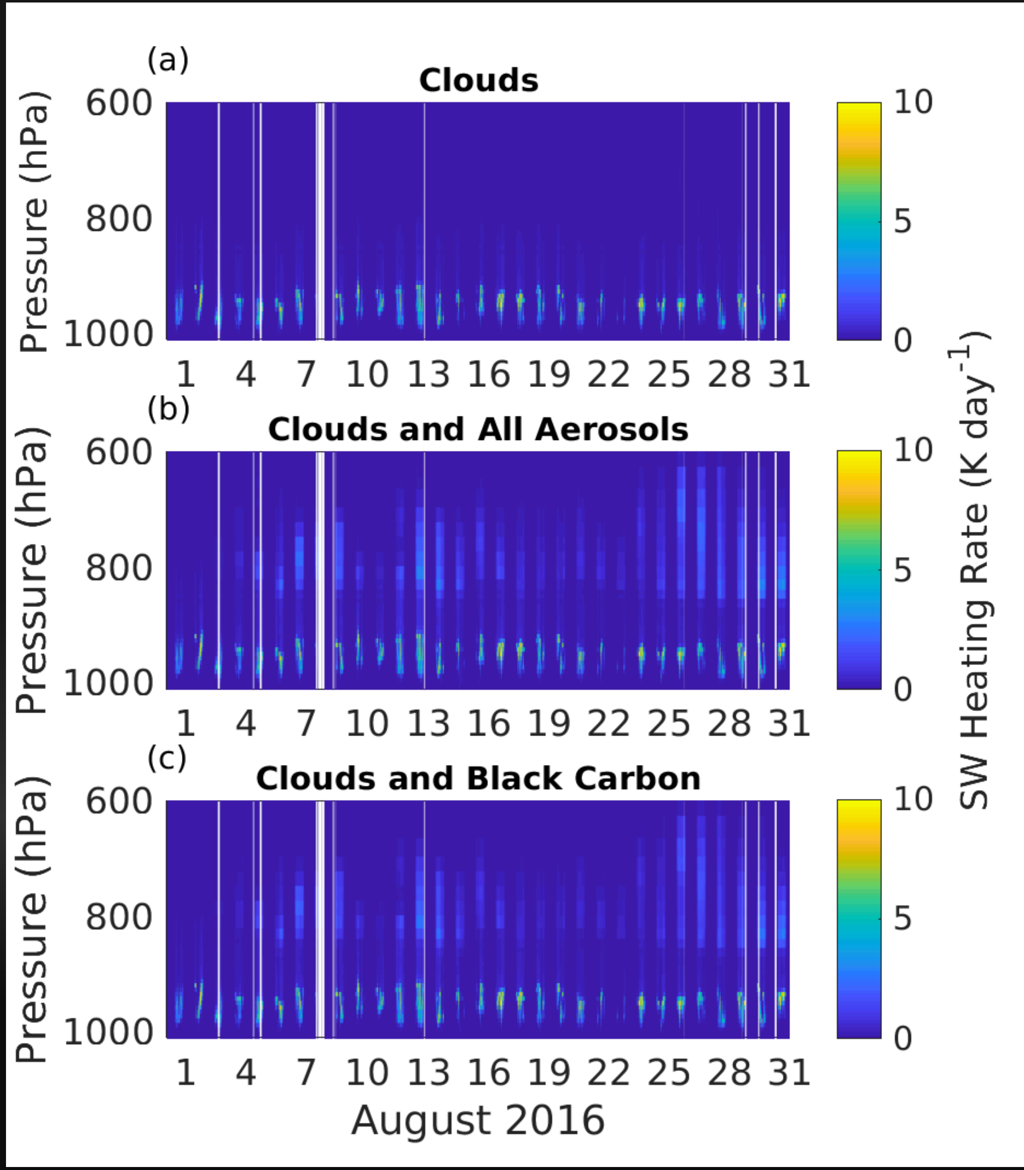


Possible Explanations: 1) Humidity; 2) No brown carbon in GEOS (yet)

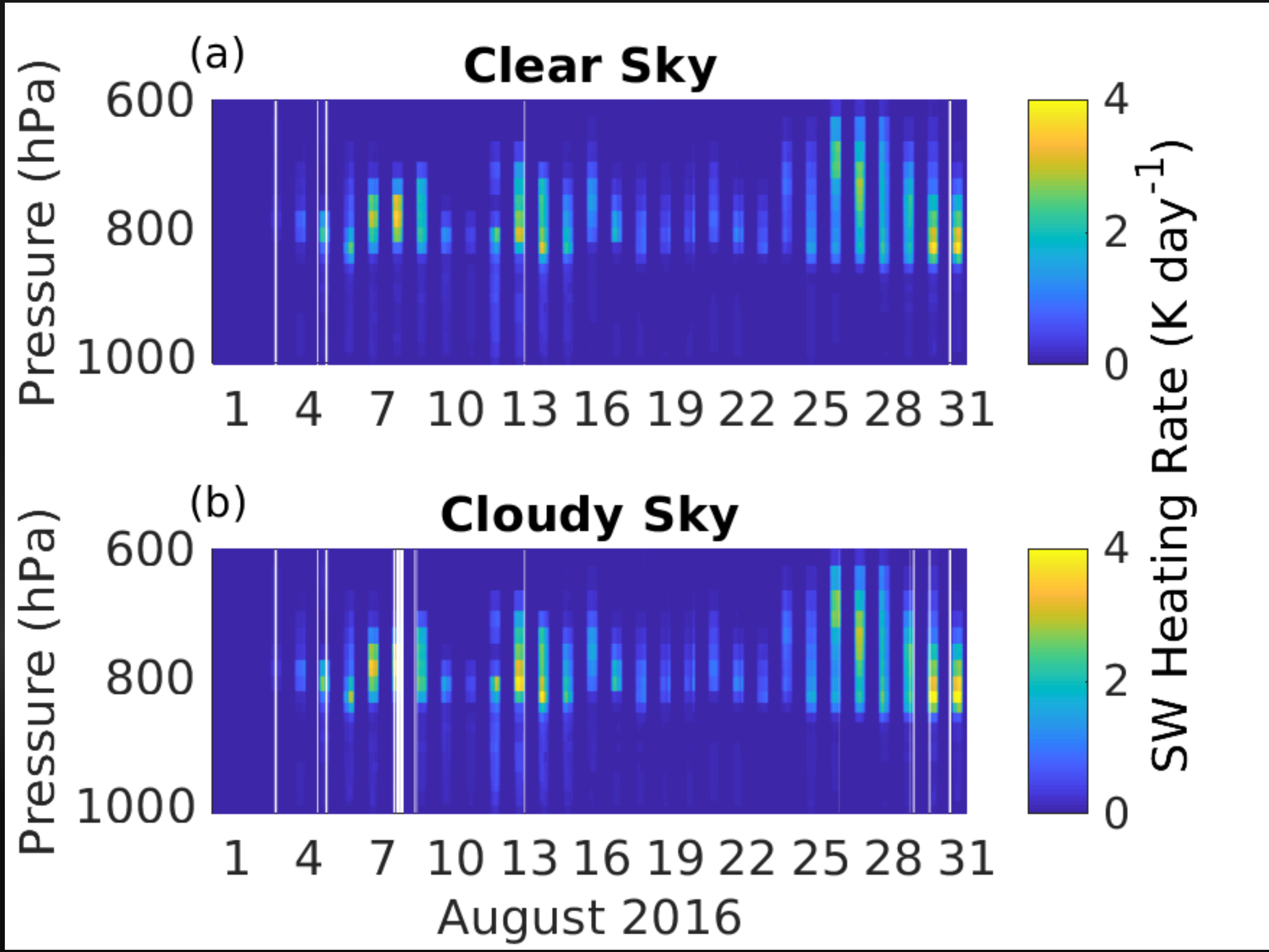
Initial Results on SW Aerosol Radiative Effect

Clear Sky



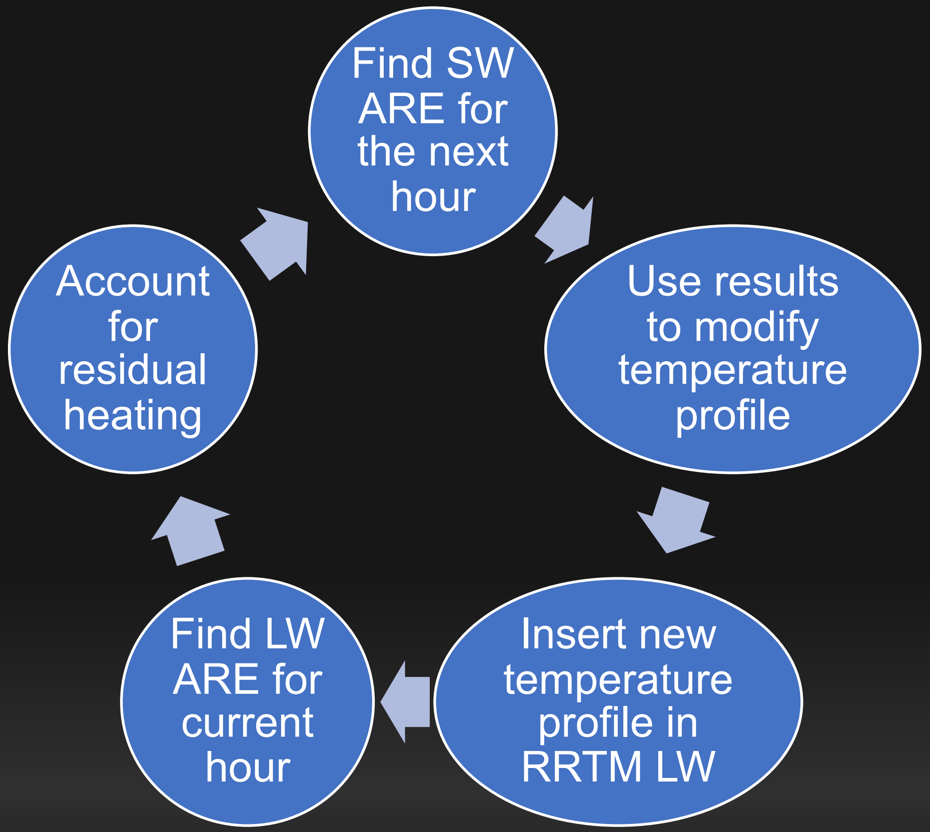


Impact of the SSA Discrepancy on SW Heating

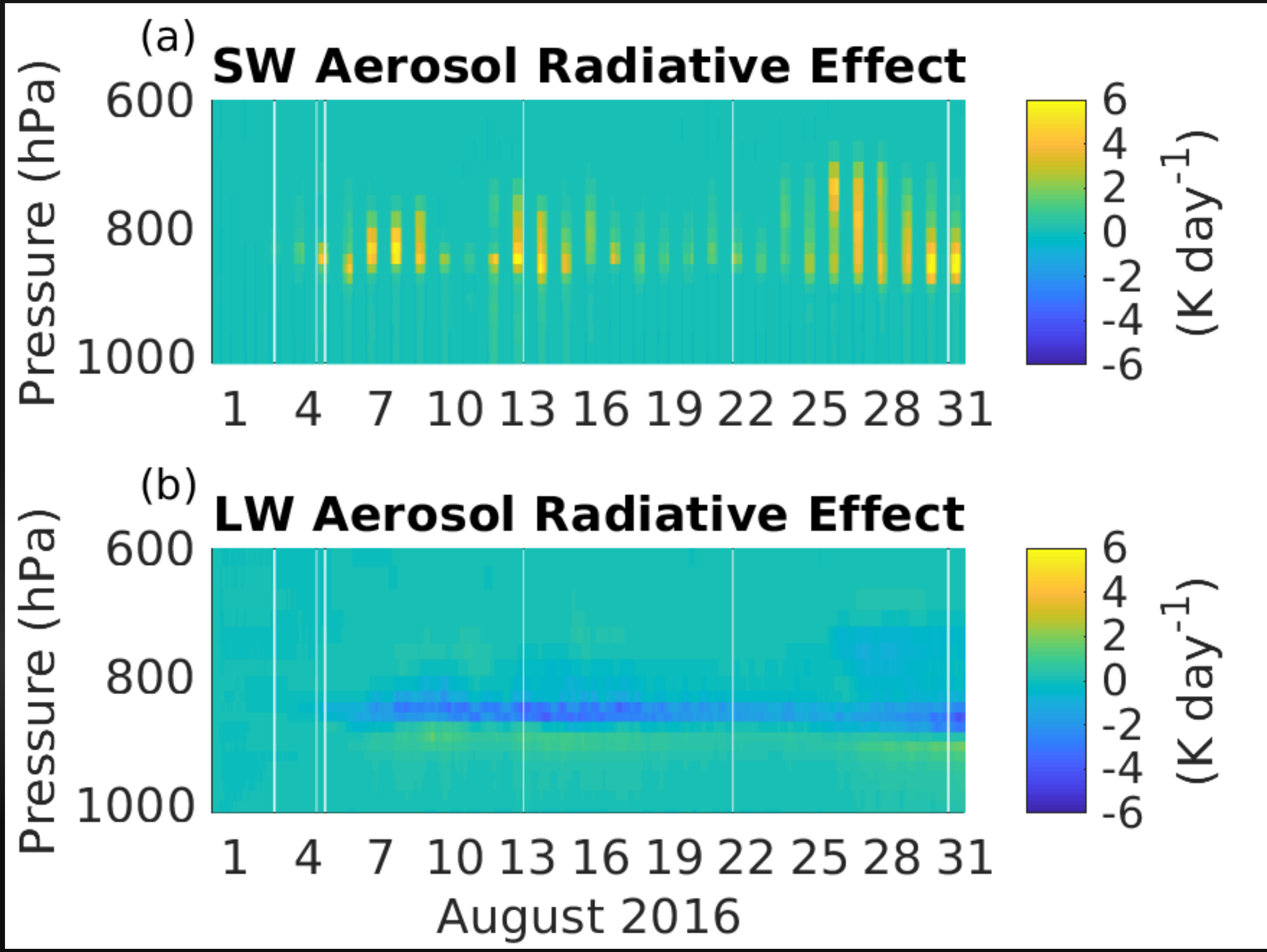


- Original RRTM run used SSA from MERRA-2
- Second run reduced SSA by 15% (average difference for the month)
- Lower SSA results in up to 4 K/day in additional SW heating within the aerosol layer
- This is on the order of the ARE with the original MERRA-2 SSA!
- As expected, the sensitivity to SSA is large

Where are we now?
Determining whether SW warming is balanced by LW cooling



- Clear sky results shown here
- 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)



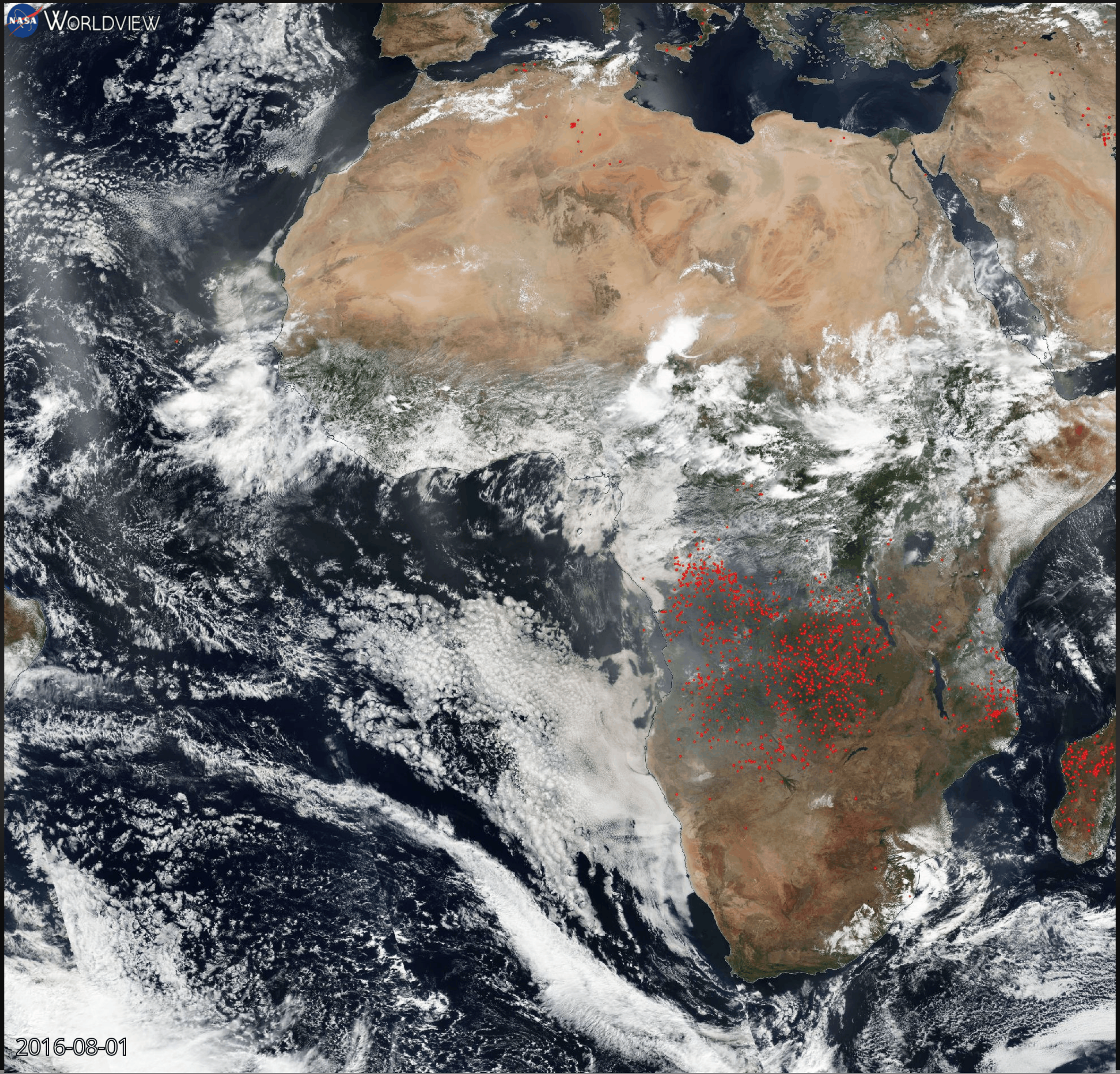
Conclusions

- 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
- Black carbon is responsible for ~4-6 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 in due to aerosols
- A nearly constant wind from the southwest mitigates direction island effect concerns, but a shallow internal boundary layer is present (not shown today)

Future Work

- Perform RRTM calculations along HYSPLIT back trajectories
- Further investigate the role of aerosols with respect to the U of W mass flux closure
- Repeat RRTM experiments with GEOS single column model or GEOS RadApp?

Other Work/Extra Slides

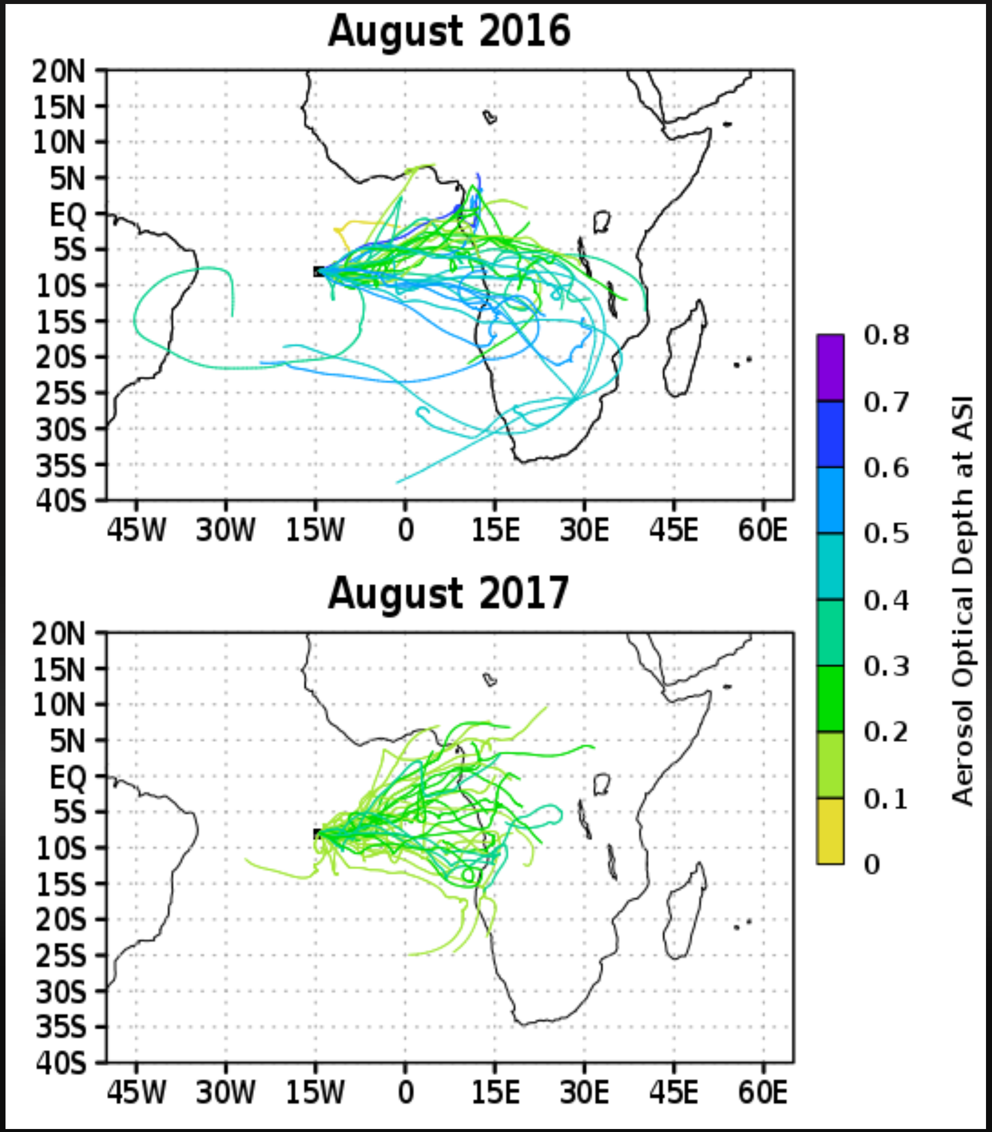


How does biomass burning aerosol impact the radiative heating profile as the aerosol plume travels across the ocean in the presence of clouds?

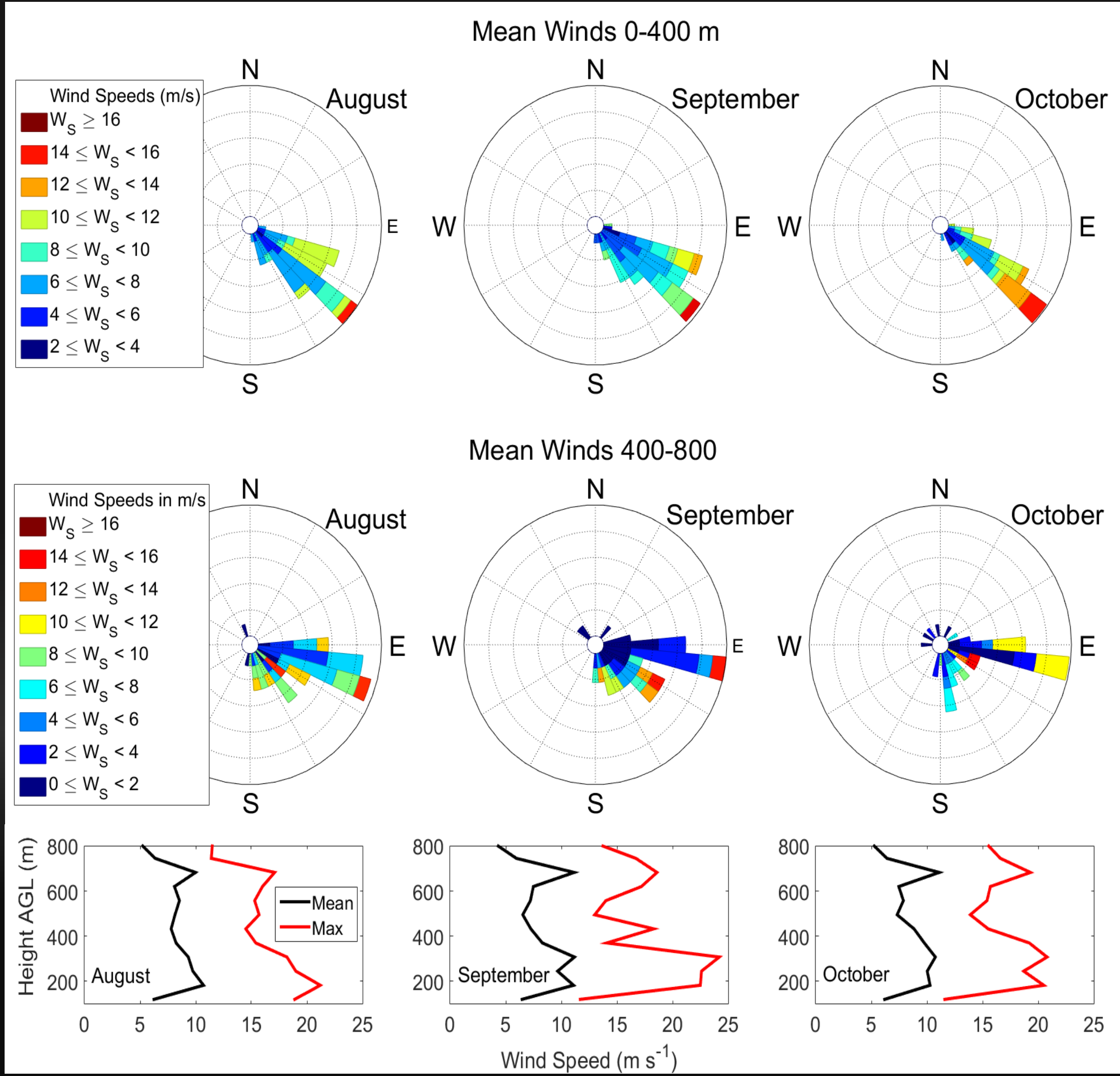
- Heating rate due to aerosol is ~1-2K per day…adds up over a week!

Where are we headed?
Looking along Back Trajectories

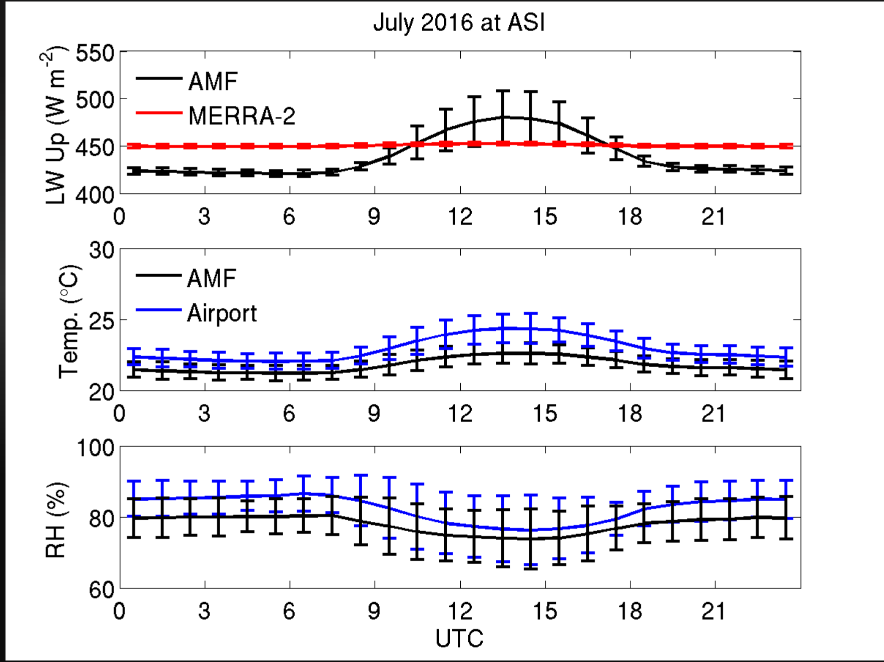
- HYSPLIT: Hybrid Single-Particle Lagrangian Integrated Trajectory model
- Forced with MERRA-2
- Initialized over the site (7.95S, 14.35W) every day at 12z for 3 different heights: 100 m (within boundary layer), 250 m (within the cloud layer), 2000 m (within the aerosol plume)
- Allowed back trajectories to run for 10 days



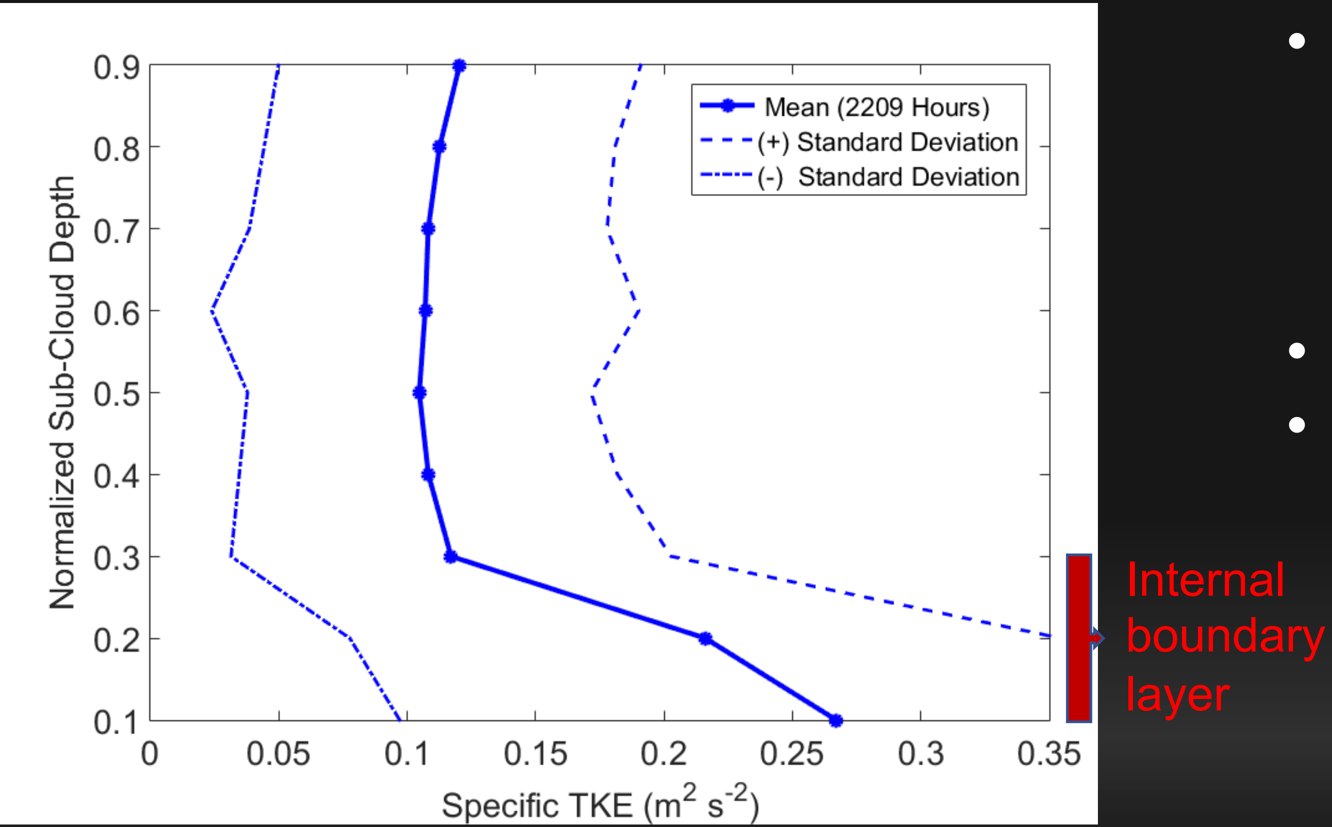
Diagnosing Island Effects



- Topography can impact the observations
- Being over land means that the results may not be representative for over the ocean
  - Surface based LCL can differ due to diurnal heating and cooling
  - The island can generate its own internal boundary layer
- Common solution: eliminate data points when the wind direction causes flow to span the island



Observations of Thermodynamics at ASI



- Profile of the vertical component of the sub-cloud specific Turbulent Kinetic Energy (TKE/m), where m is mass
- August-October 2016 and 2017.
- Heights normalized to be between 0 and 1, where 1 = cloud base height

- Sub-cloud TKE calculated based on Doppler Lidar observations
- using w $(w' = w - \overline{w})$ and $TKE = 0.5\,\overline{w'w'} = 0.5\,\overline{w'^2}$

where 30 minute averages are subtracted from the one second observations.

- Clouds base must be above 200 m to be included.