Characterization of Aerosol Above-cloud Incidence and Optical Properties over the Southeastern Atlantic

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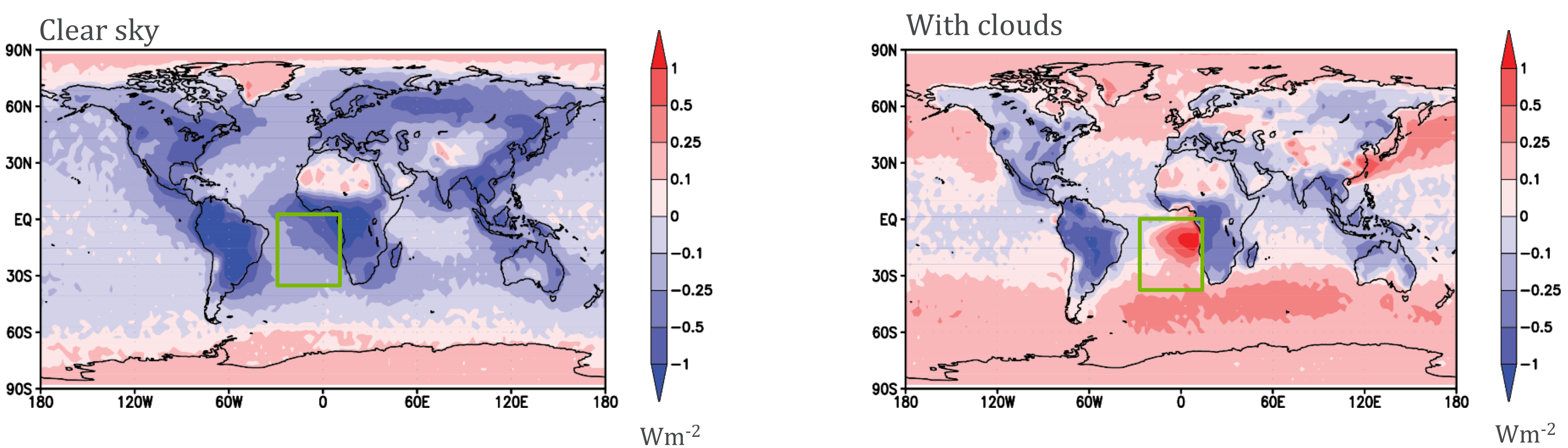
Motivation

- A major source of uncertainty in aerosol climate effects is related to the aerosol vertical distribution with respect to clouds.

- Above-Cloud Aerosols (ACA), especially those that are light-absorbing, can result in an amplification of aerosol absorption, leading to an extra positive direct radiative effect

- What is the seasonal variability of the ACA over the southeast Atlantic Ocean? in terms of optical properties and vertical distribution. How well are they represented in models?

Direct Radiative Effect of Organic Aerosols



(Feng et al., 2013)

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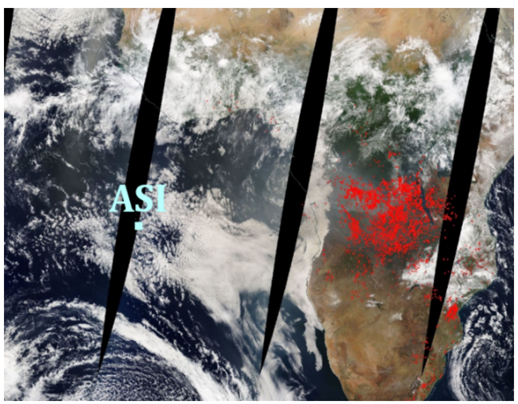
Approach

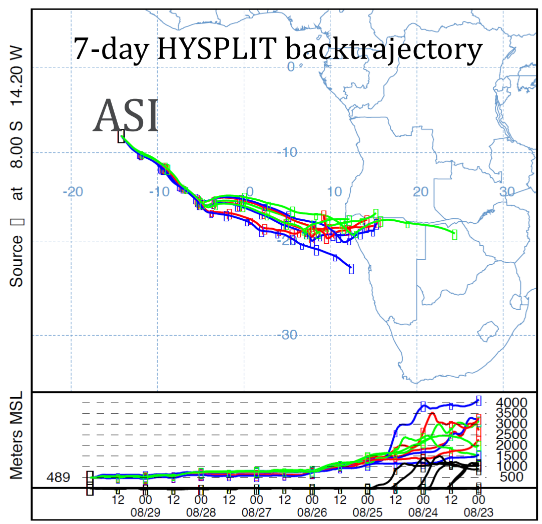
- ❑ Analyze the ARM Mobile Facility 1 (AMF-1) measurements on Ascension Island (ASI) during the DOE LASIC campaign (May 2016 - Oct 2017: 18 months)

- ❑ Use the DOE Energy Exascale Earth System model (E3SM) simulations (~1° and 72 layers)

Aug 10, 2016



(NASA/Worldview)



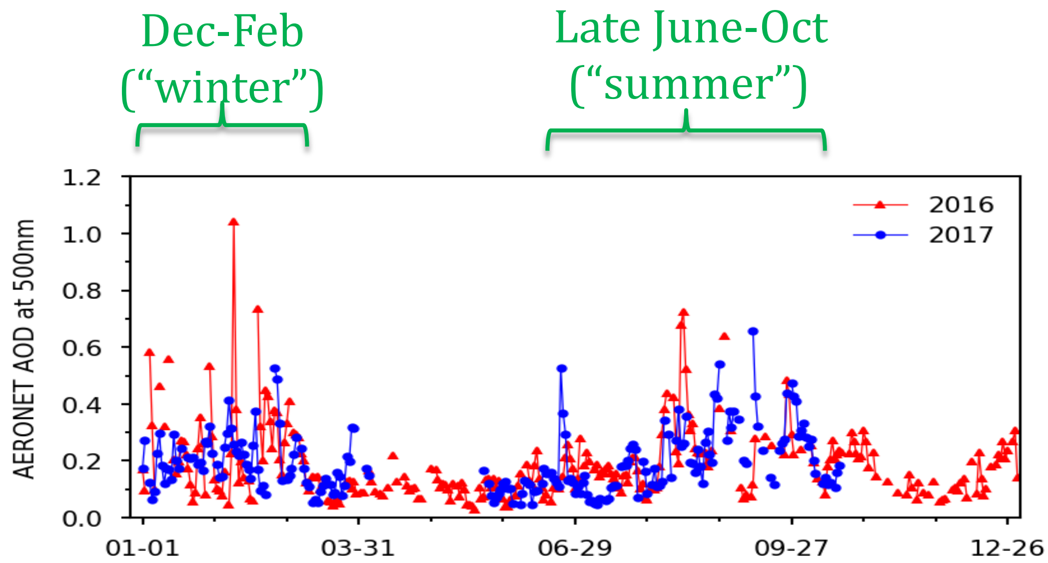
Ascension

(Zuidema et al., 2018)

Instrument	Measurements	Site
AOS	Surface aerosol properties	AMF M1
MPL	Aerosol extinction profiles	AMF M1
MFRSR	AOD	AMF M1
AERONET	AOD	NASA
Sonde	Boundary layer height	AMF S1
Ceilometer	Boundary layer height	AMF M1/S1

Annual Cycle of Column and Surface Aerosols

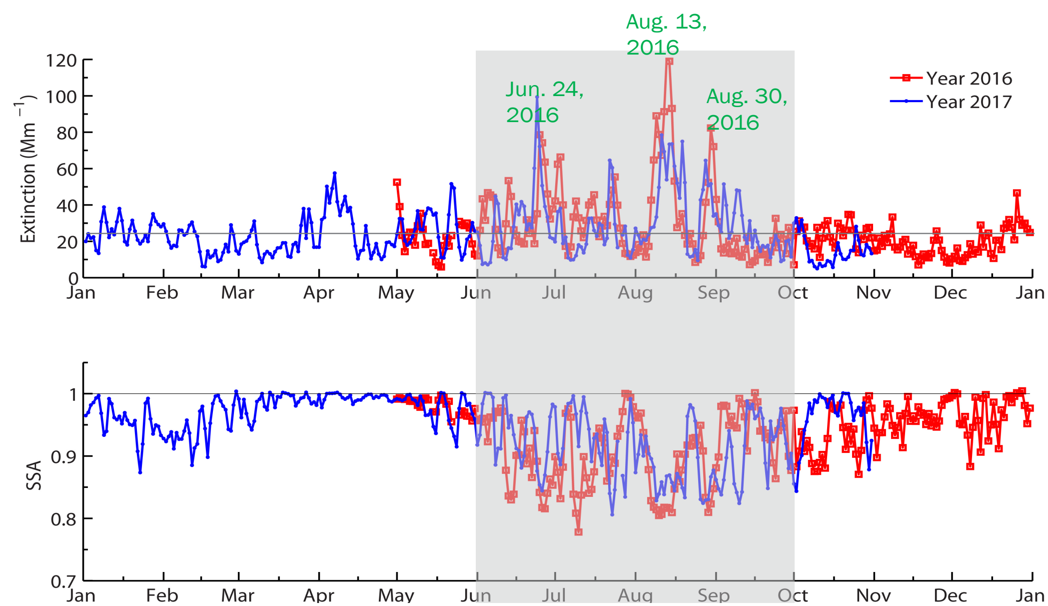
Column AOD



AOD peaks in
Feb and Aug, 2016
Feb and Sep, 2017

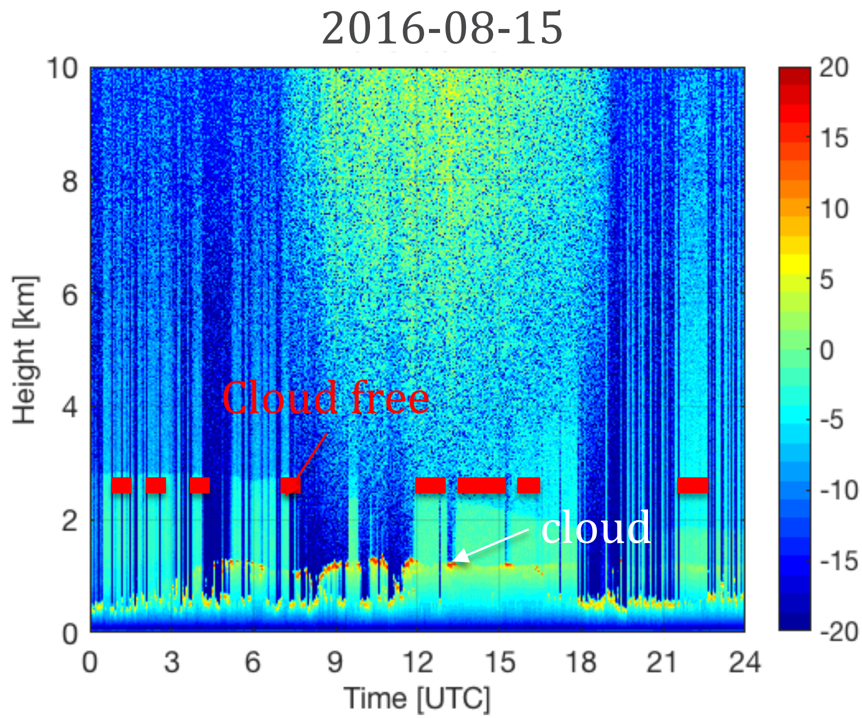
Surface aerosol extinction

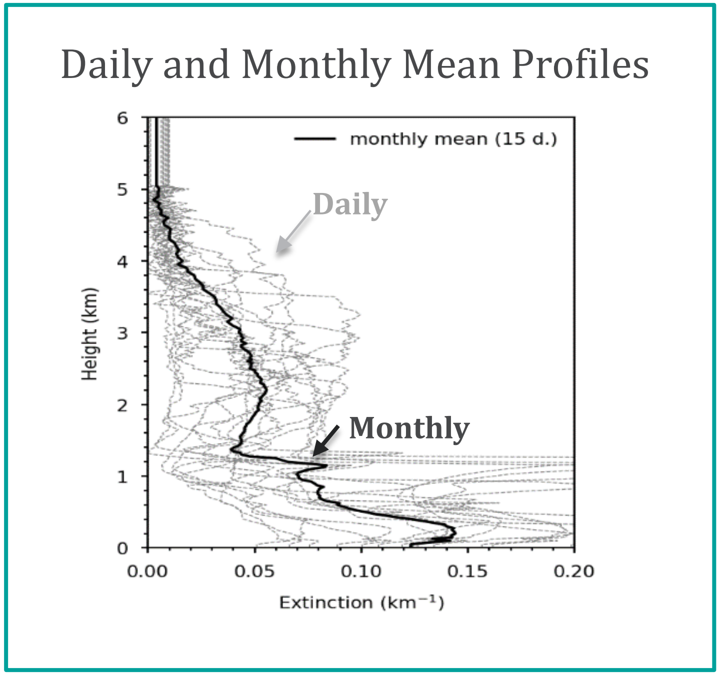
Surface single scattering albedo (SSA)

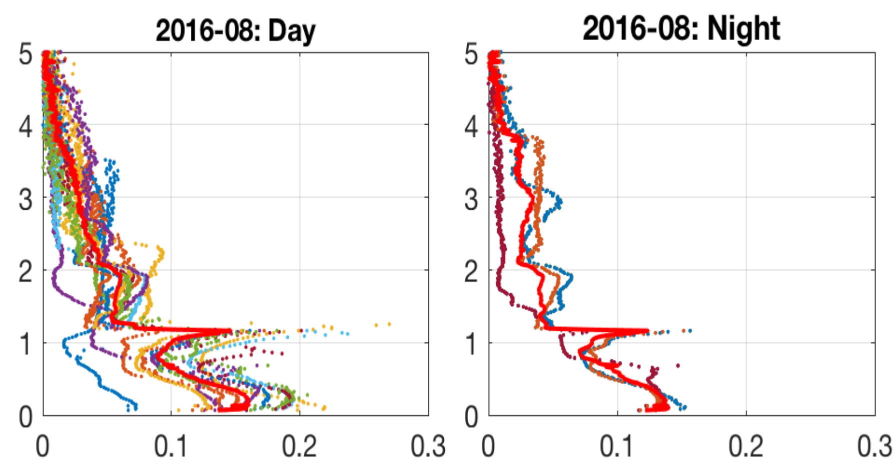


Zuidema et al., (2018) suggest that summer aerosols at surface are from biomass burning

Retrieval of Aerosol Extinction Profiles from ARM Micro-Pulse Lidar (MPL)

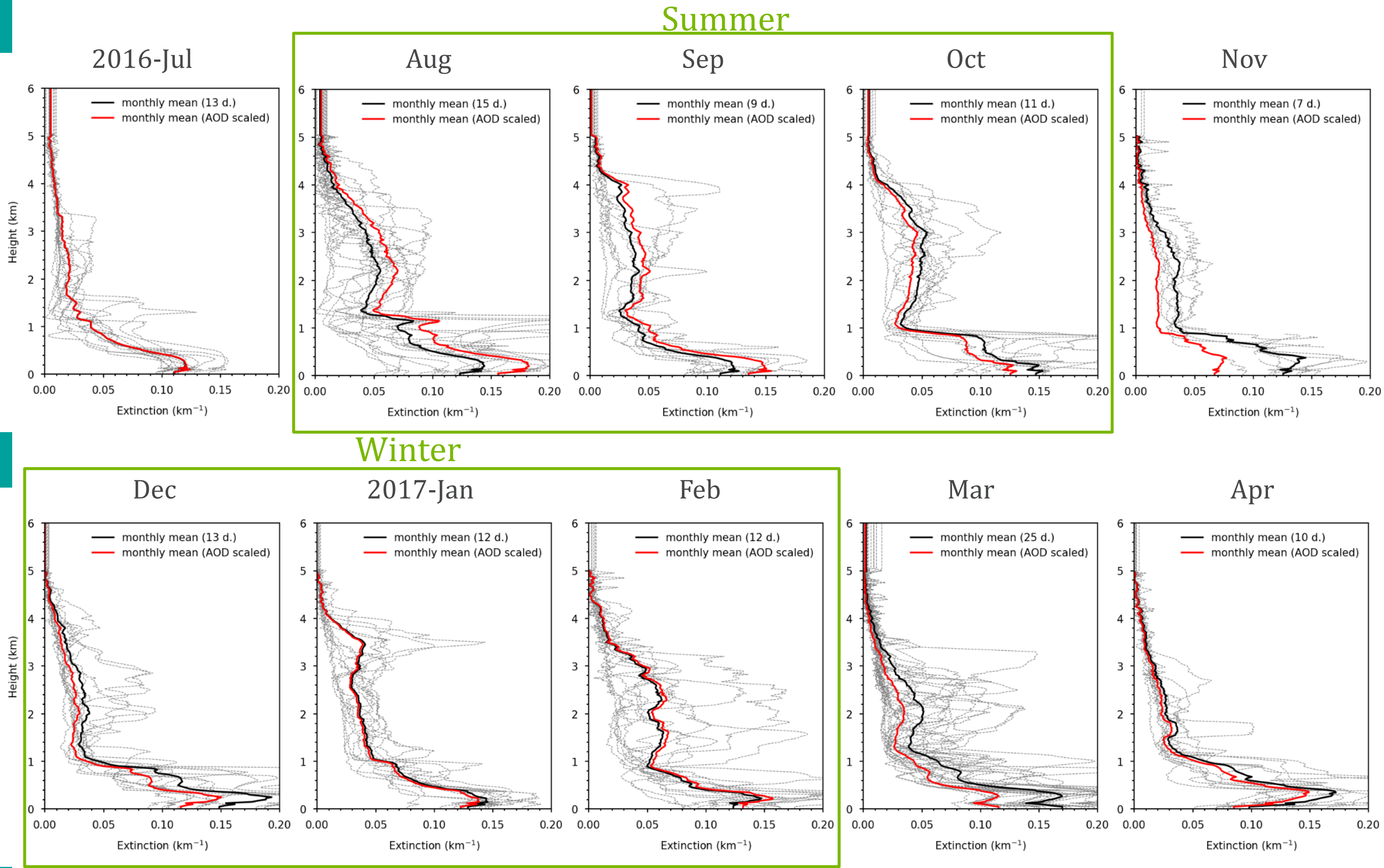






- ❑ Aerosol extinction profiles (532 nm) are retrieved from the AMF-1 MPL on ASI: hourly->daily->monthly
- ❑ No significant differences in extinction profiles between daytime and nighttime

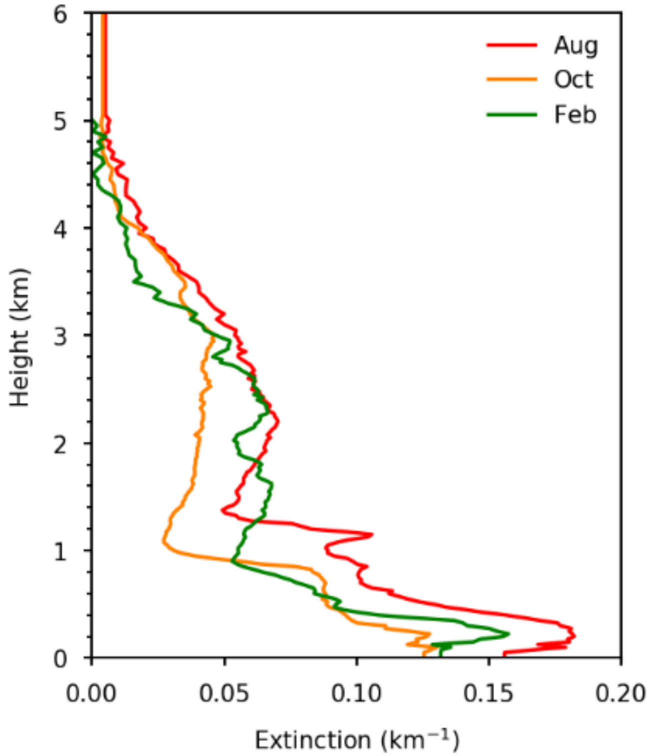
MPL-retrieved Aerosol Extinction Profiles



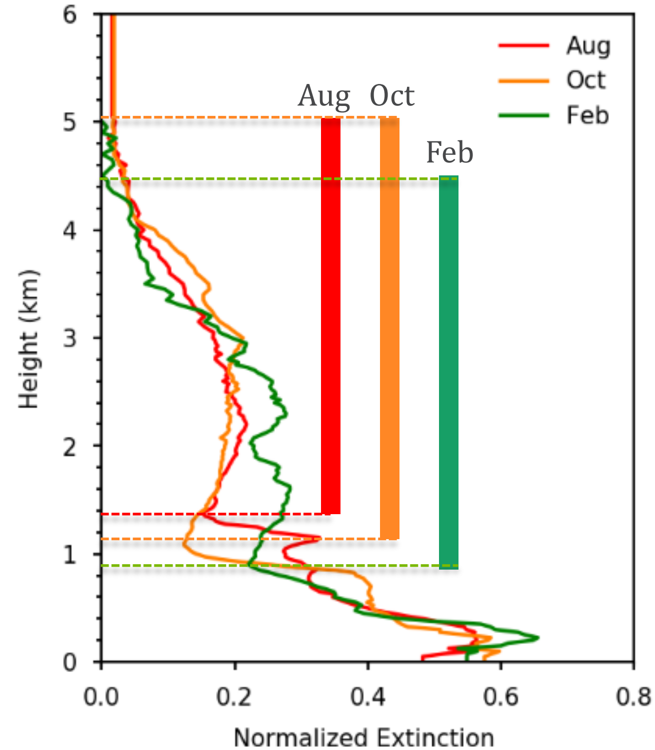
Gray: daily; **Black**: monthly; **Red**: monthly scaled by AERONET AOD

Strength, Height and Thickness of Elevated Aerosol Layer

Extinction Profiles

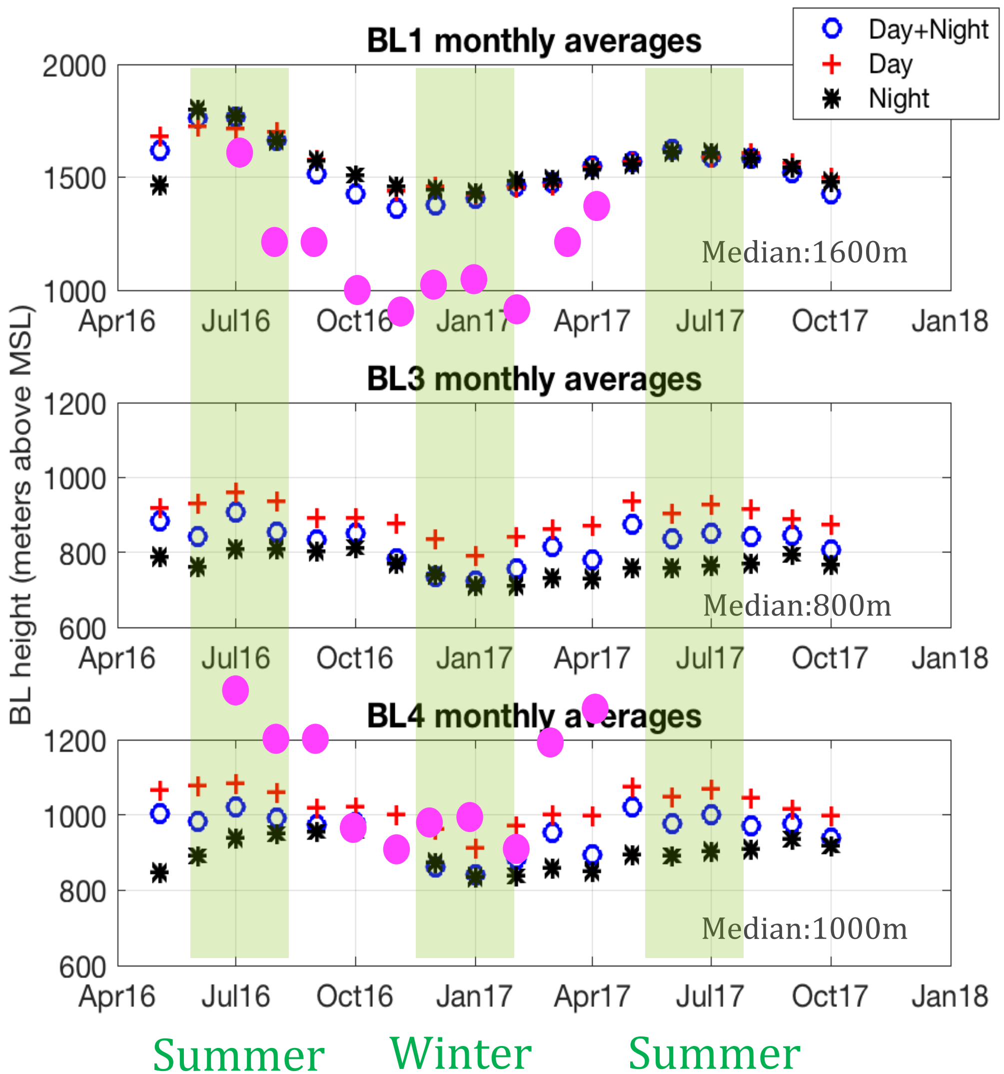


Normalized Profiles to AOD=1



- ❑ The strength of the aerosol aloft does not vary with AOD proportionally
- ❑ Both the layer bottom and top of aerosol layer are the lowest in Feb, where Aug's layer bottom is the highest but with the same top level as Oct
- ❑ Oct and Feb have elevated aerosol layers thicker than Aug

MPL Aerosol Layer Bottom, Boundary Layer Height, and Cloud Top



ASI sonde boundary layer height (BLH) estimates:

- BL1 Heffer (1980) method
- BL3 Bulk Richardson number using critical threshold of 0.25
- BL4 Bulk Richardson number using critical threshold of 0.50

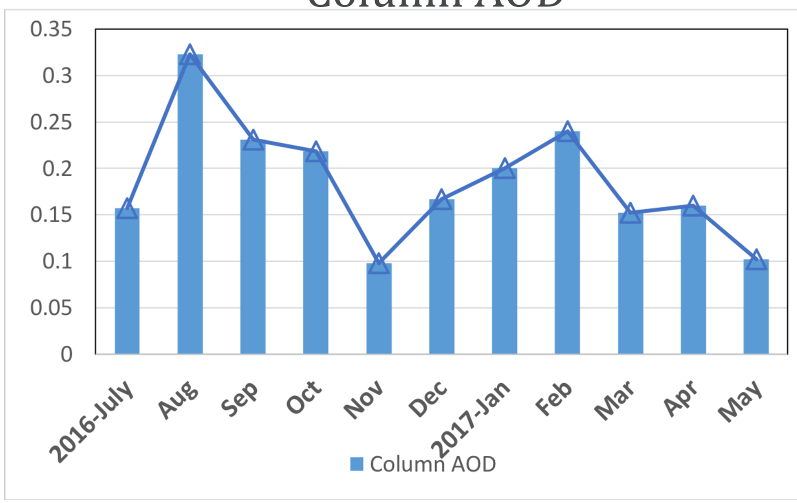
❑ BLH estimates show clear seasonality

❑ The location of aerosol layer bottom from MPL profiles coincides with BL top

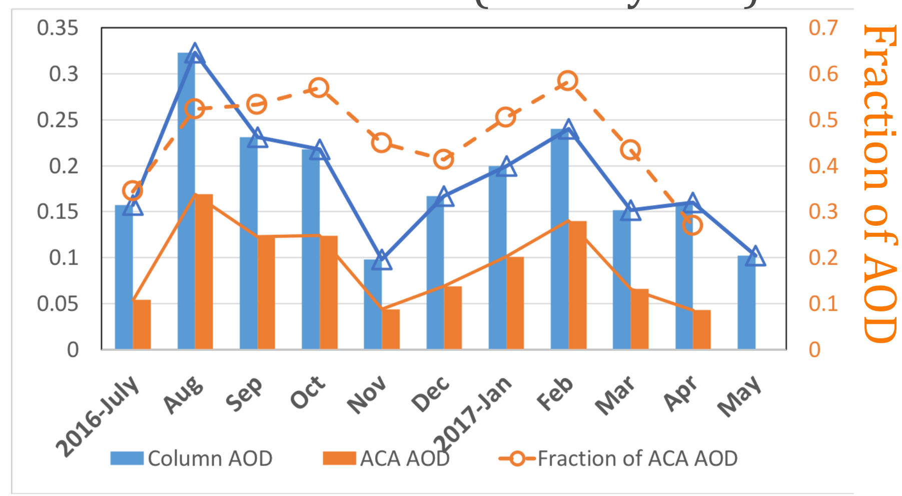
❑ Both of BLH and MPL layer bottom are used to derive above-cloud aerosols (ACA)

Above-cloud Aerosols (ACA) Show Different Seasonality from the Column AOD

Column AOD

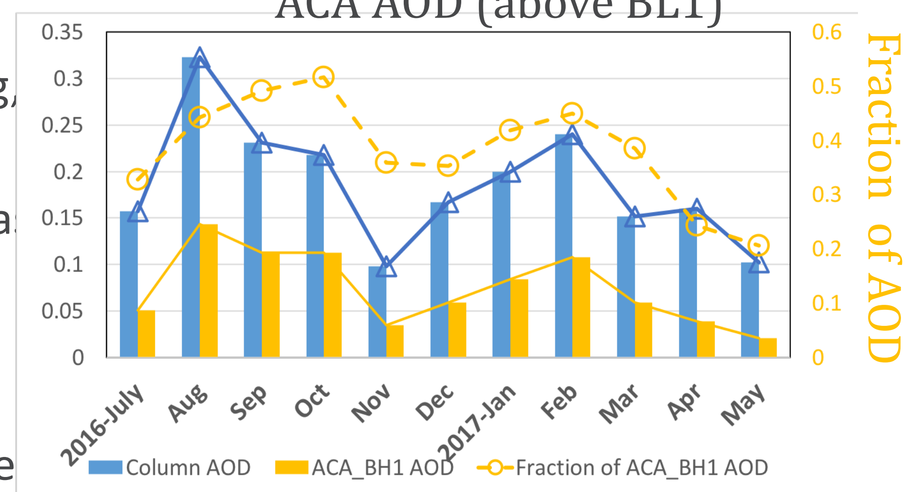


ACA AOD (MPL layered)



- ACA AOD increases due to <u>long-range transport of aerosols</u>, i.e., biomass burning, as the column AOD increases
- Smaller increase of ACA AOD off the bioma burning peak times (Oct and Feb) is compensated by <u>lower BL heights</u>
- The impact of BL changes on ACA is secondary but enhances the ACA incidence

ACA AOD (above BL1)



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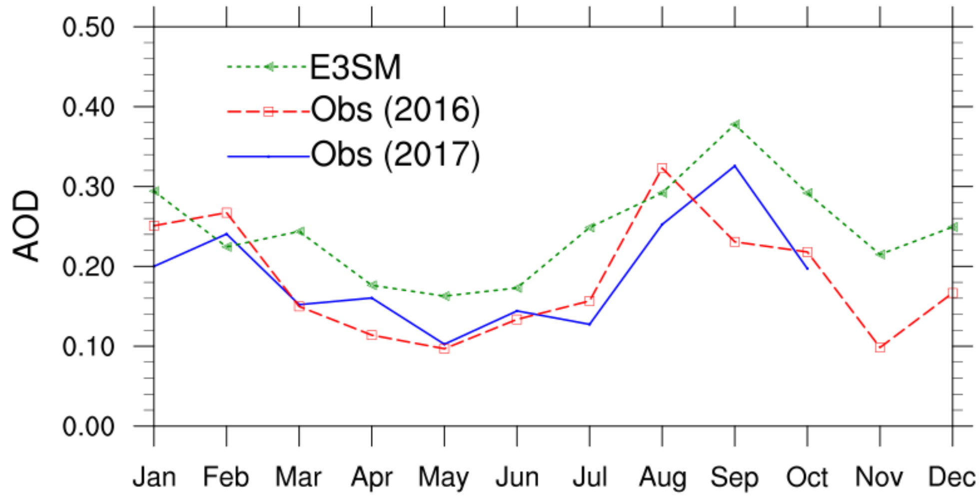
Annual Cycles of AOD and PBLH in E3SM

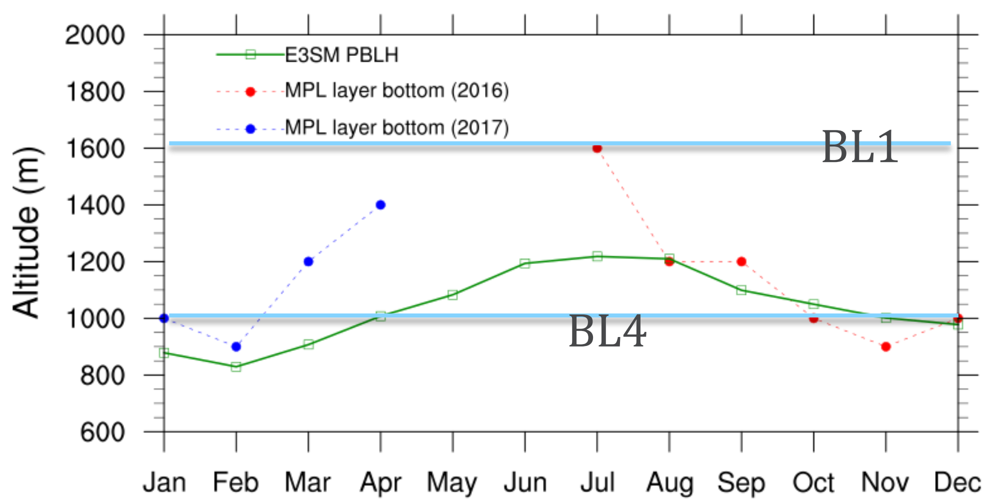
Column AOD



E3SM simulates the AOD seasonal variations

- ~1 degree, 72 layers
- Biomass burning emissions (1998-2002)
- Last 5-year averages of the 10-year free model run

PBLH



Model PBLH is similar to ARM sonde BL4 estimates

It agrees with the MPL-derived layer bottom from Aug-Feb but underestimates from Mar-Jul

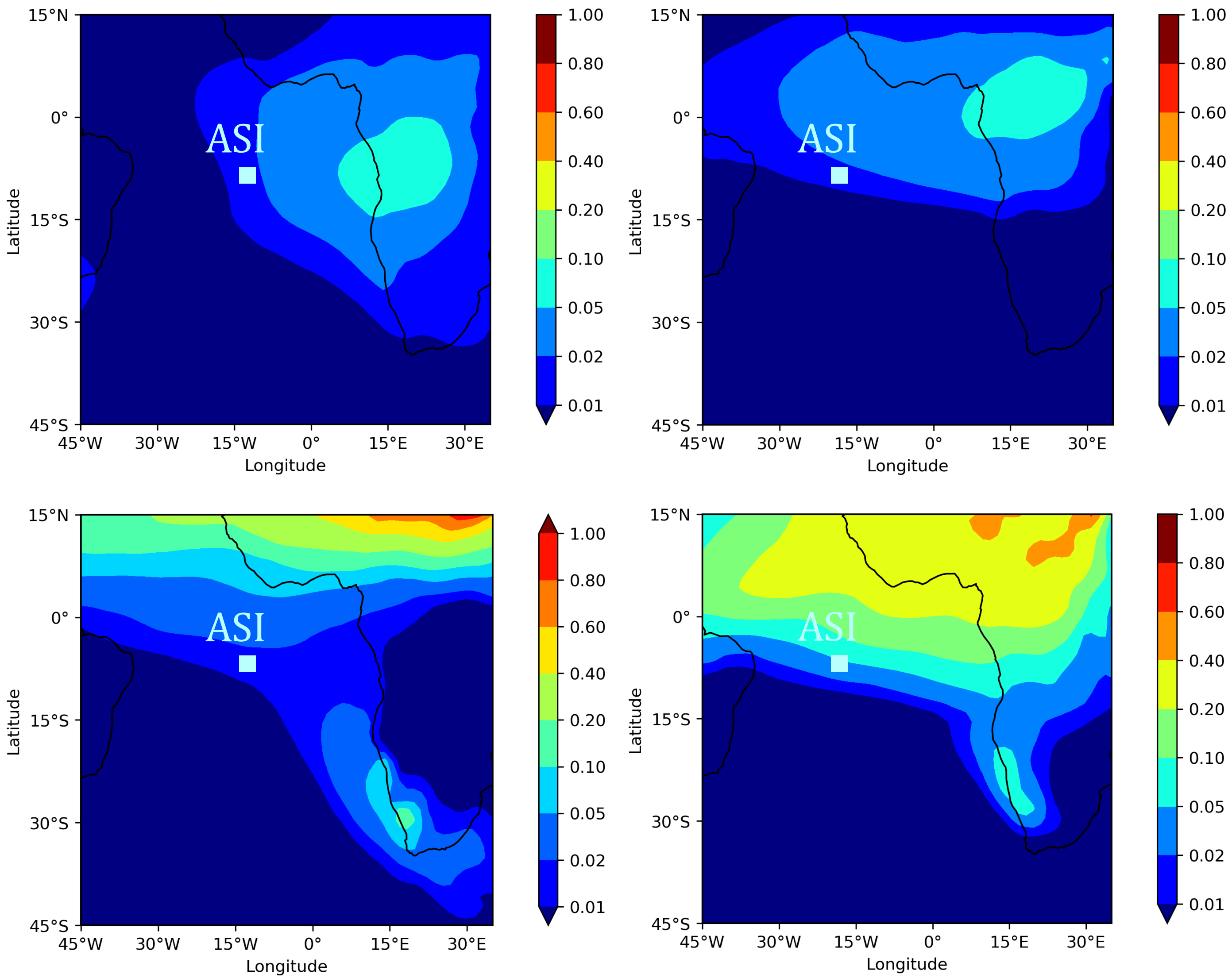
Larger Contribution from Dust to ACA in Winter

Aug

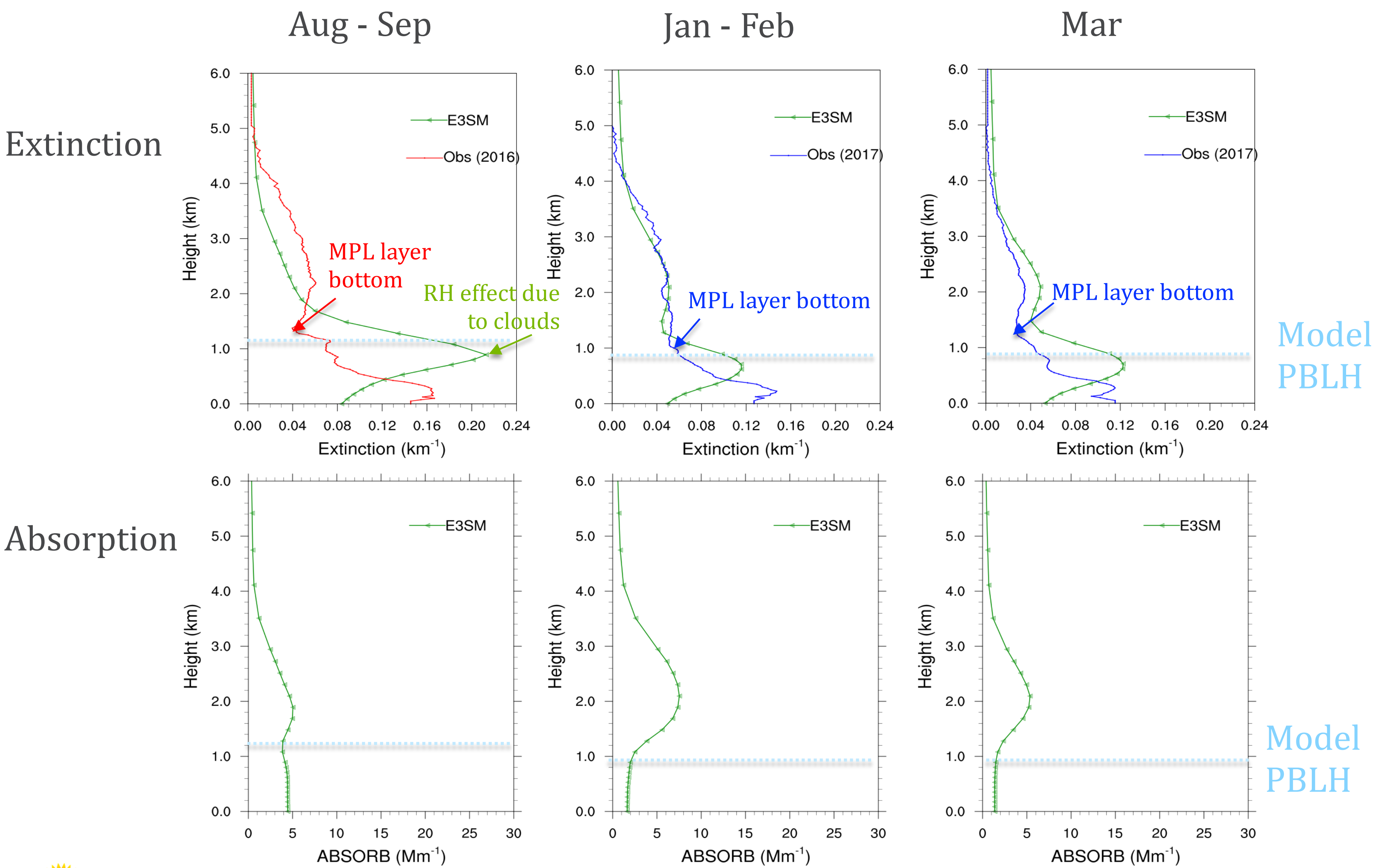
Feb

BC AOD

Dust AOD



Comparison of Aerosol Vertical Profiles vs MPL

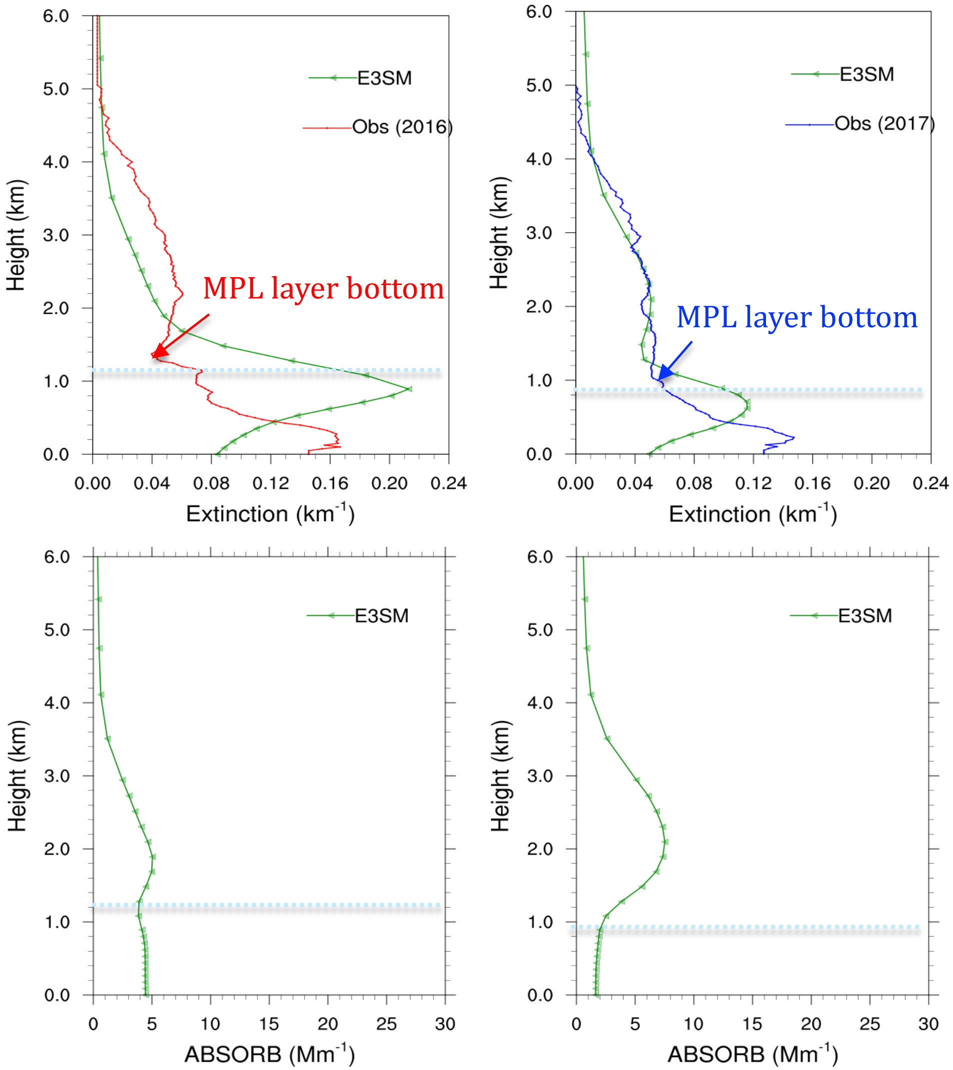


Comparison of Aerosol Vertical Profiles vs MPL

Aug - Sep | Jan - Feb

Extinction

Absorption



E3SM simulates the ACA extinctions in winter but underestimates the ACA from summer biomass burning

E3SM predicts the ACA layer height similar to the MPL profiles

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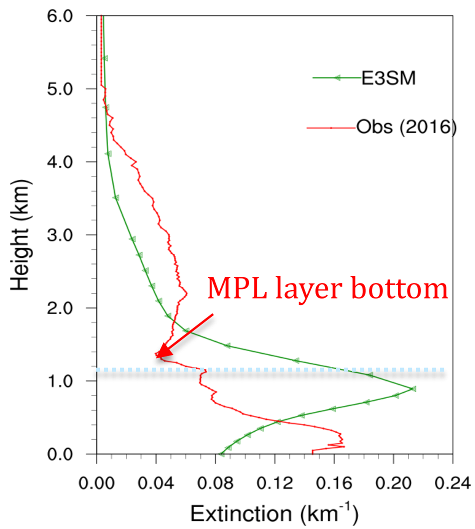
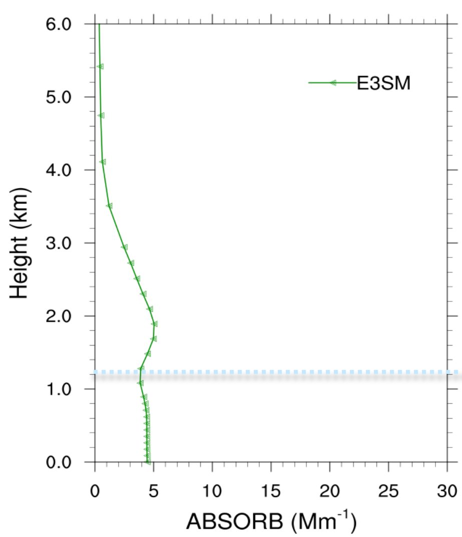
Comparison of Aerosol Vertical Profiles vs MPL

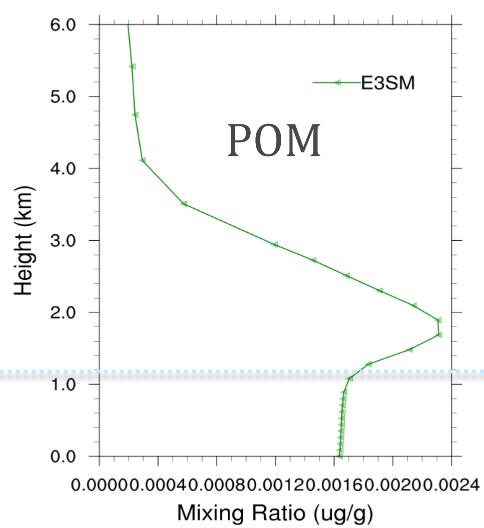
Aug - Sep

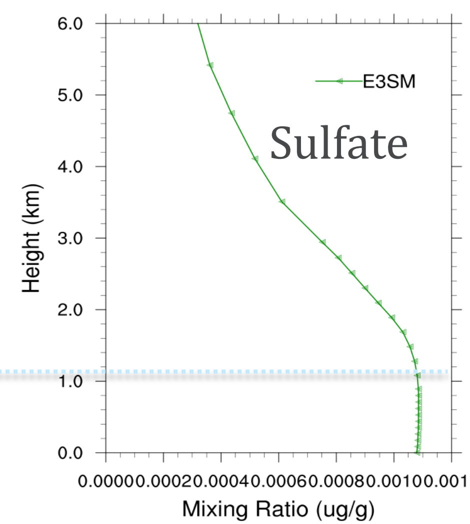
Extinction



Absorption







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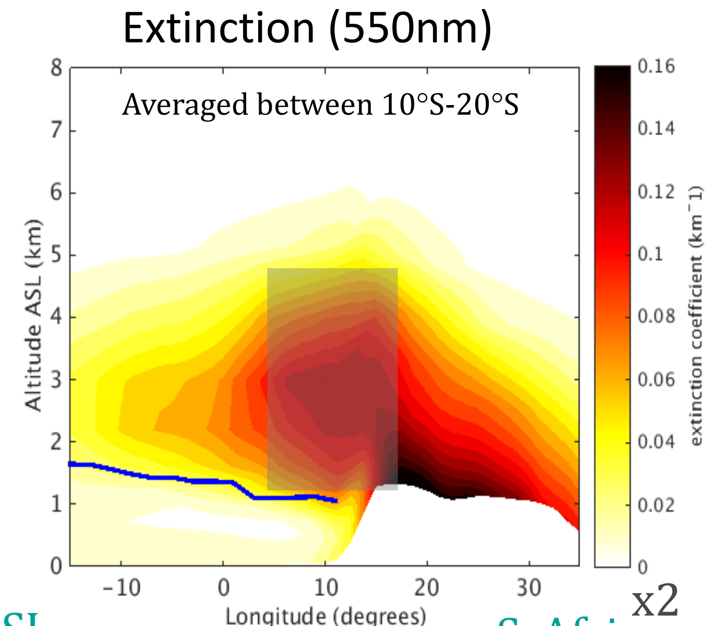
Transport of the Biomass Burning Aerosols

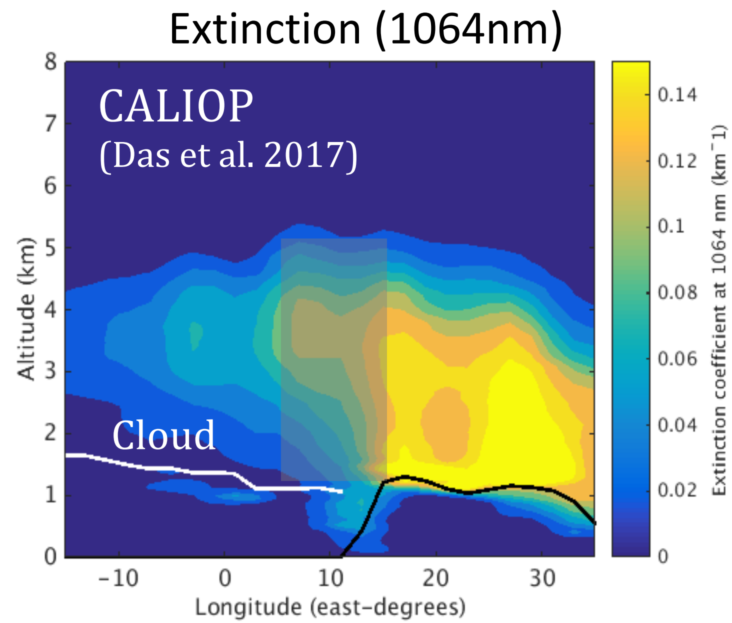
Model-Base Run (Sep)



ASI
-15°W

S. Africa
35°E

CALIOP (Sep)



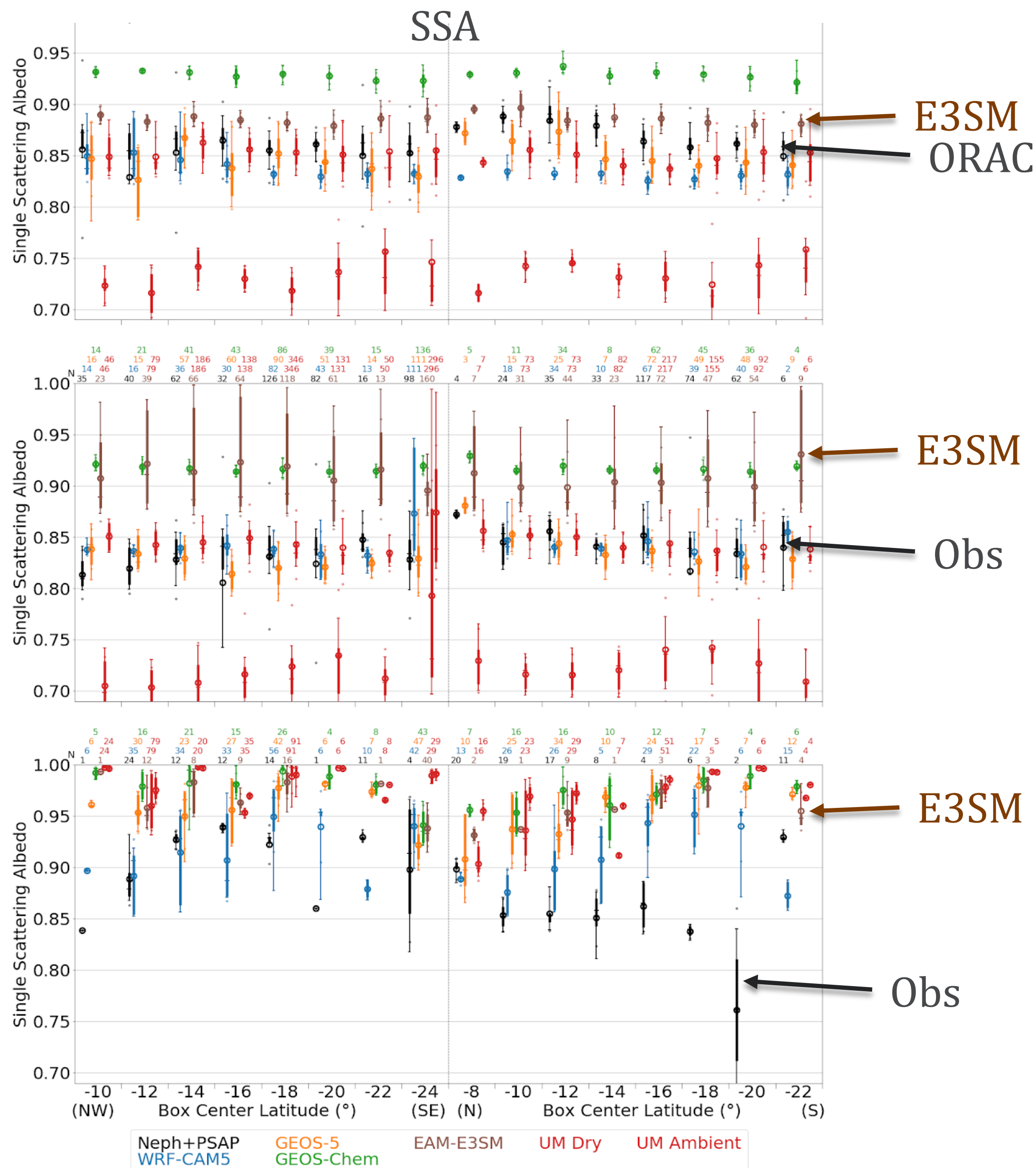
- Near the source region, the outgoing aerosol plume height in the model is low biased compared with the CALIOP data

Model Underestimation of the ACA SSA

3-6km

PBL top to 3 km

PBL



Manuscript in preparation by Shinozuka et al.

Conclusions

- Aerosol extinction profiles are retrieved from the ARM/MPL during LASIC for 18 months. That enables characterization of **seasonality in aerosol vertical distributions** over the remote southeastern Atlantic
  - → Column AOD shows a **second peak in winter**, which is **dominated by ACA**
  - → **Lower and more stable BL** in winter results in more aerosols above-cloud and less entrained to BL; and **lower layer bottom and top of ACA**
  - → **ACA layers** are largely about **3-4 km thick** from the BL top, and contribute to >50% column AOD in both summer and winter peak times
- The seasonal characteristics of ACA could be used to diagnose the transport of aerosols. The global model **E3SM** simulates the **ACA layer height and AOD in winter**, but **underestimates the ACA from summer biomass burning**. This could be related to the low-biased outgoing plume height from deep convection
- Ongoing work is to derive observational constraints of absorption for ACA from the in situ aircraft data overpassing the Ascension for constraining the annual cycle of direct and indirect radiative effects of ACA