Evolution of Biomass Burning Aerosols: a Model Comparison to the LASIC and ORACLES Observations

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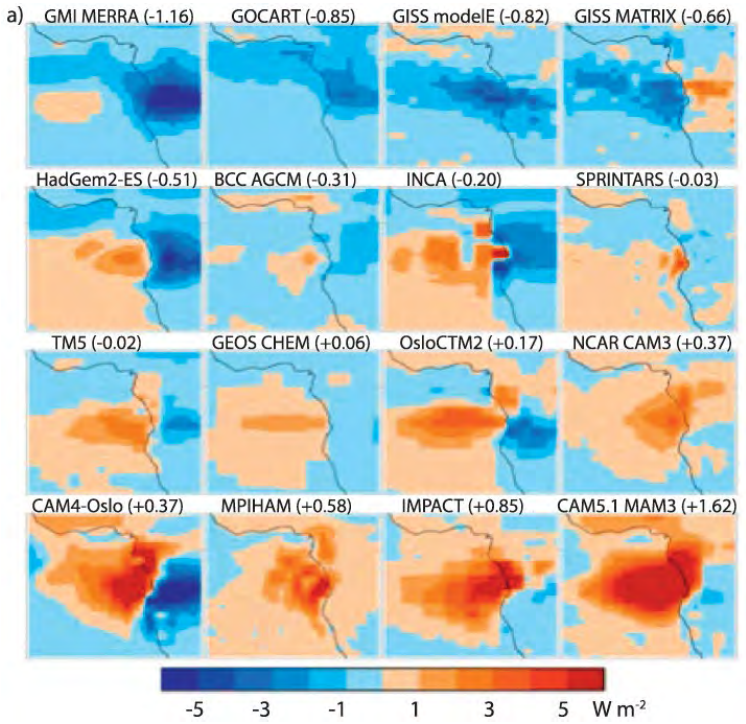
Introduction

- There is a large uncertainty in model estimated direct radiative effect (DRE) of **biomass burning (BB)** aerosols over the southeast Atlantic ocean: [-1.16 to +1.62] Wm^{-2}

- Factors that influence the calculation of aerosol DRE include:
  - Emission -> concentration
  - Optical properties
  - Vertical distribution

- Do the regional and global models capture the evolution of biomass burning aerosol properties in transport?

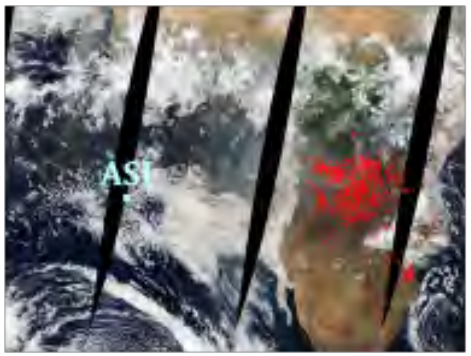
- Implication on aerosol DRE



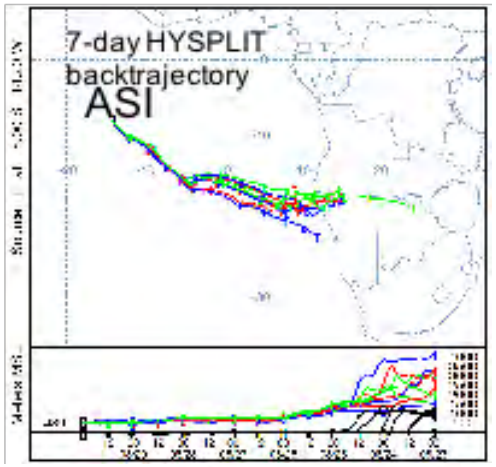
(Zuidema et al., 2016)

Approach

- Observations: (1) DOE AMF-1 LASIC and (2) NASA/ORACLES
- Models: DOE-E3SM, WRF-CAM5, GEOS-5, GEOS-CHEM, Unified Model, ALADIN
- Time periods: seasonal cycle (2016-2017) and case study: Sep 2016



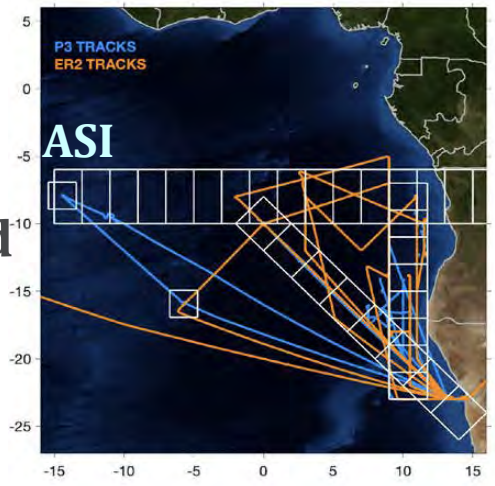
(NASA/Worldview)

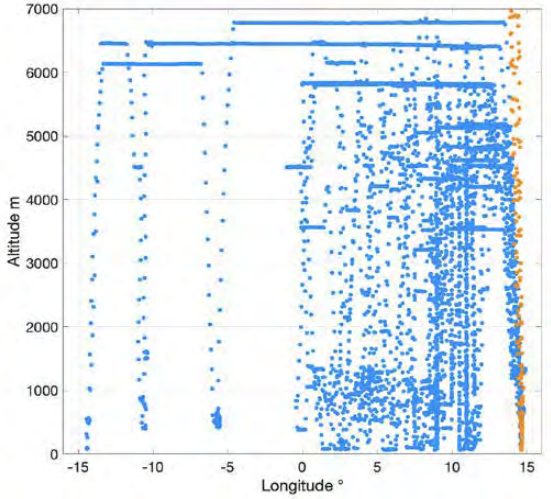


LASIC: **aged** (3~7 days)

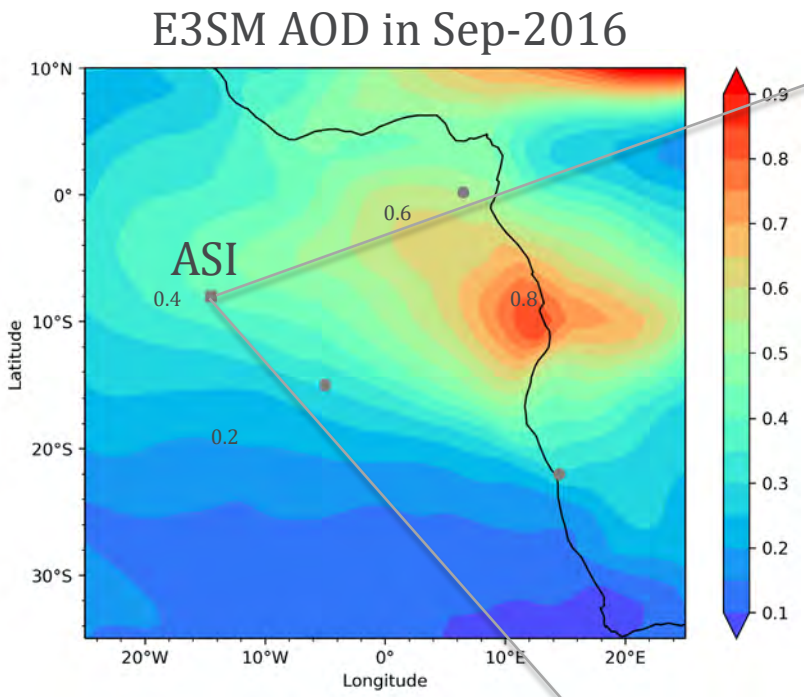
ORACLES: **moderately aged**

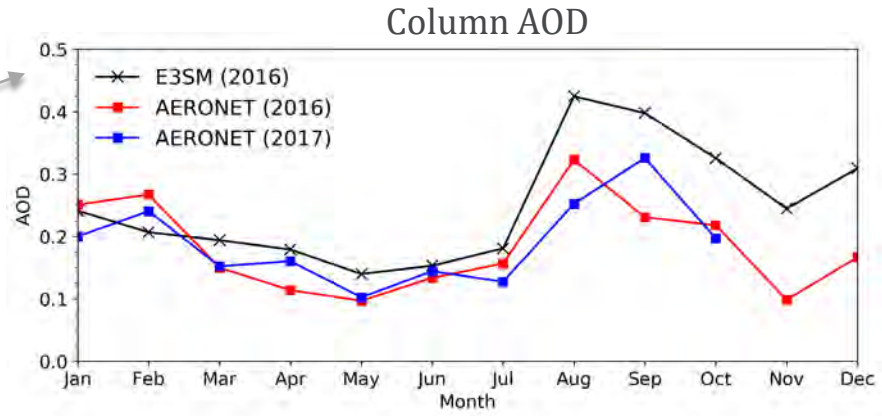
(Shinozuka et al., ACPD, 2020)

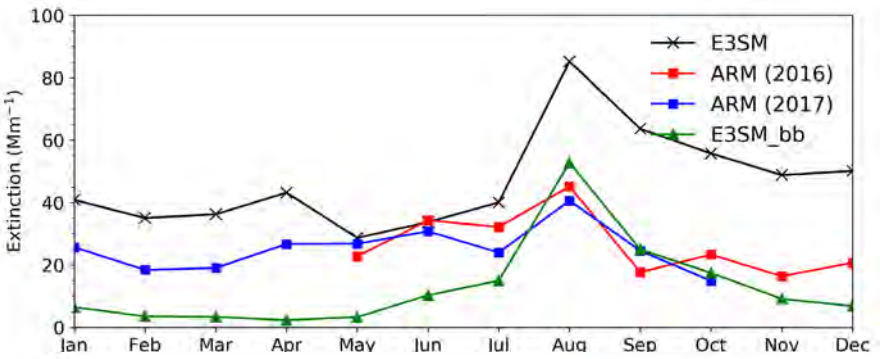


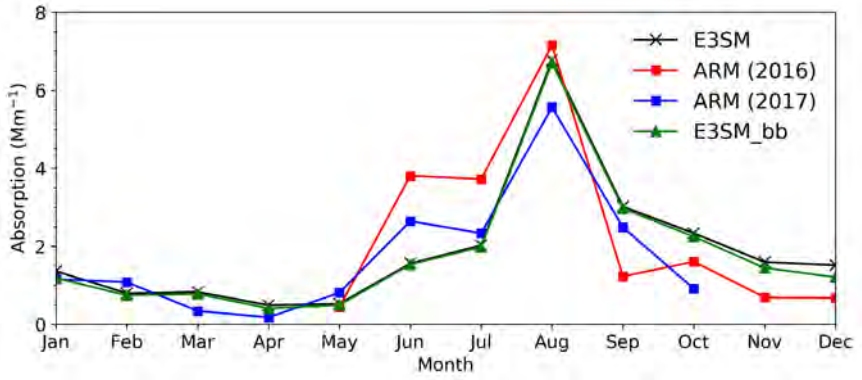


LASIC: Aged Aerosol Optical Properties







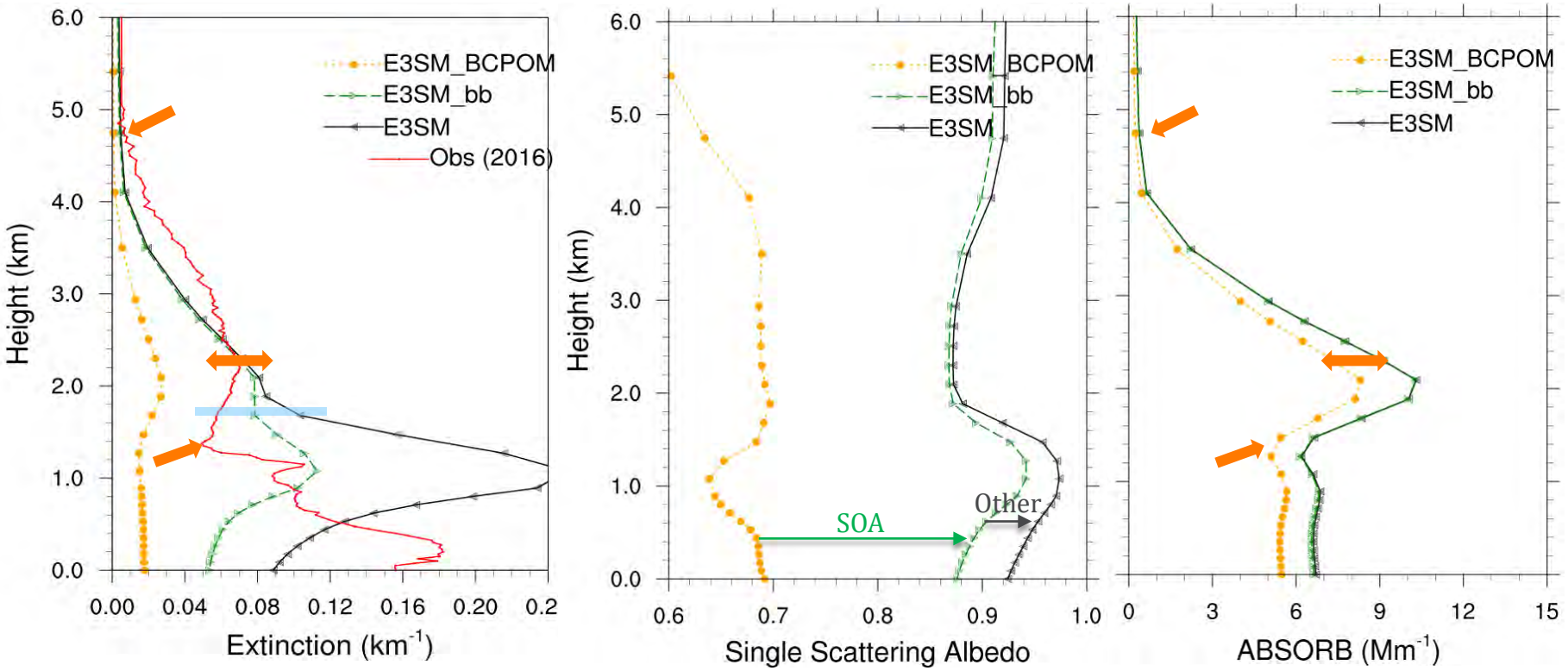


- AOD peaks in BB peak season (Aug-Sep), increasing by a factor of 3 from no-burning times
- The simulated surface aerosols are less absorbing than obs due to larger extinctions in the ambient RH

  Aug: SSA = 0.92 (model) > 0.84 (obs)
- Aged BB aerosols dominate the surface absorption all year round but for extinction only in peak burning season

LASIC: Vertical Profiles of Optical Properties

August 2016

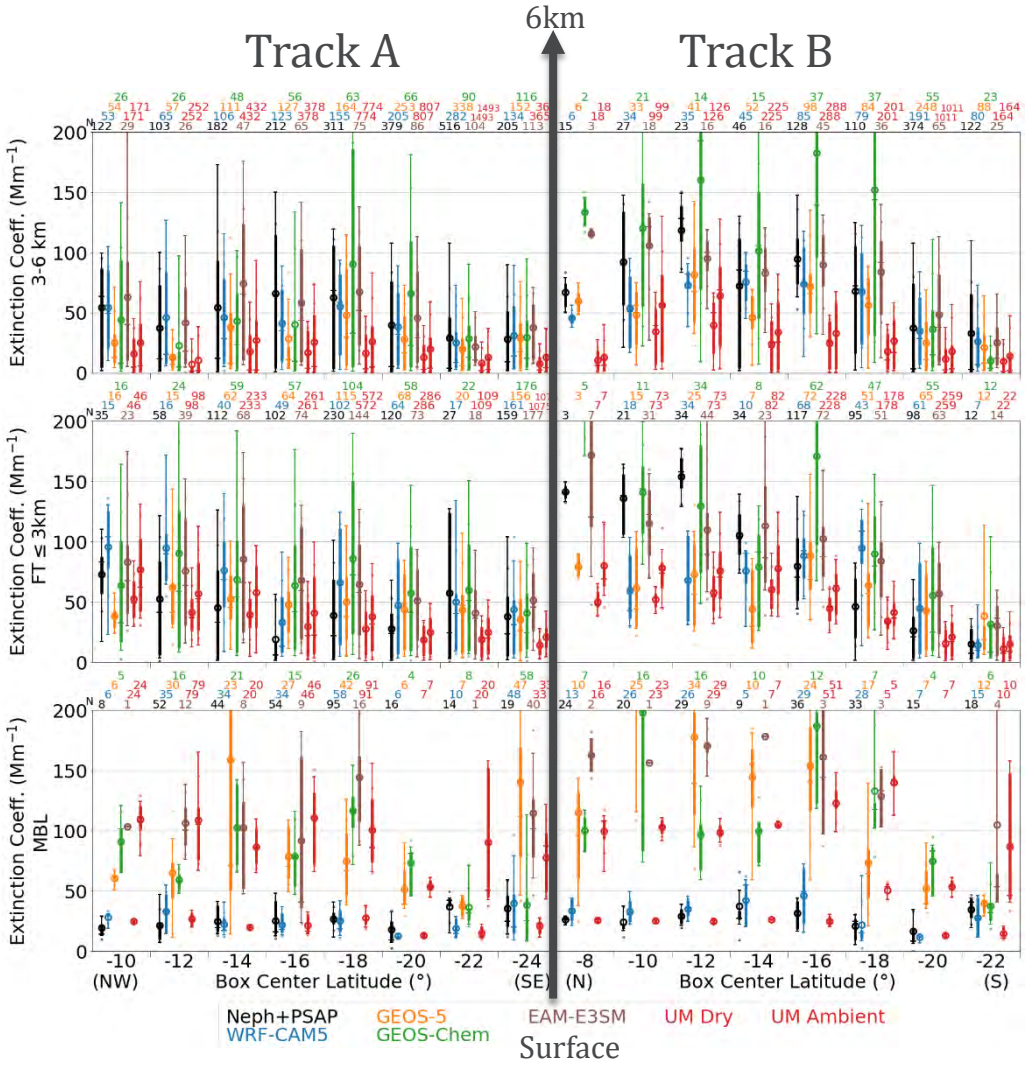


Obs: ARM MPL retrieved aerosol extinction profile on ASI (Muradyan et al.); clear-sky only
E3SM, E3SM_bb and E3SM_BCPOM: model simulations of all aerosols; BB aerosols (BC+POM+SOA), and BB BC+POM

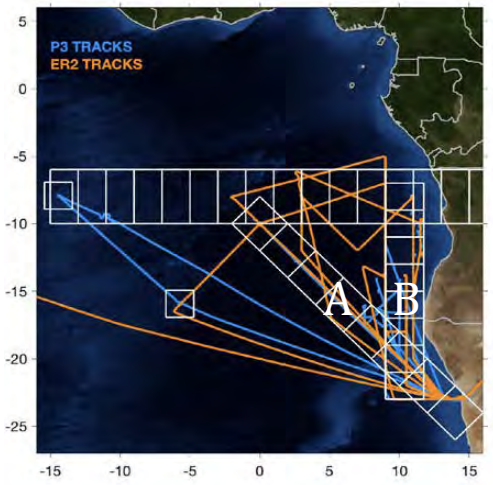
- Simulated aerosol extinction profile is heavily influenced by high RHs at the cloud levels, but dominated by BB aerosols above BL. Extinction above BL: ~70 (obs) vs 90 (E3SM) km^{-1}
- The observed BB layer is about 3 km thick, with layer top and bottom simulated by E3SM; the predicted layer center is slightly lower
- The aged BB has similar absorption efficiency near surface and in the free troposphere (SSA=0.87)

ORACLES: Moderately Aged Aerosol Properties

September 2016



(Shinozuka et al., 2020)



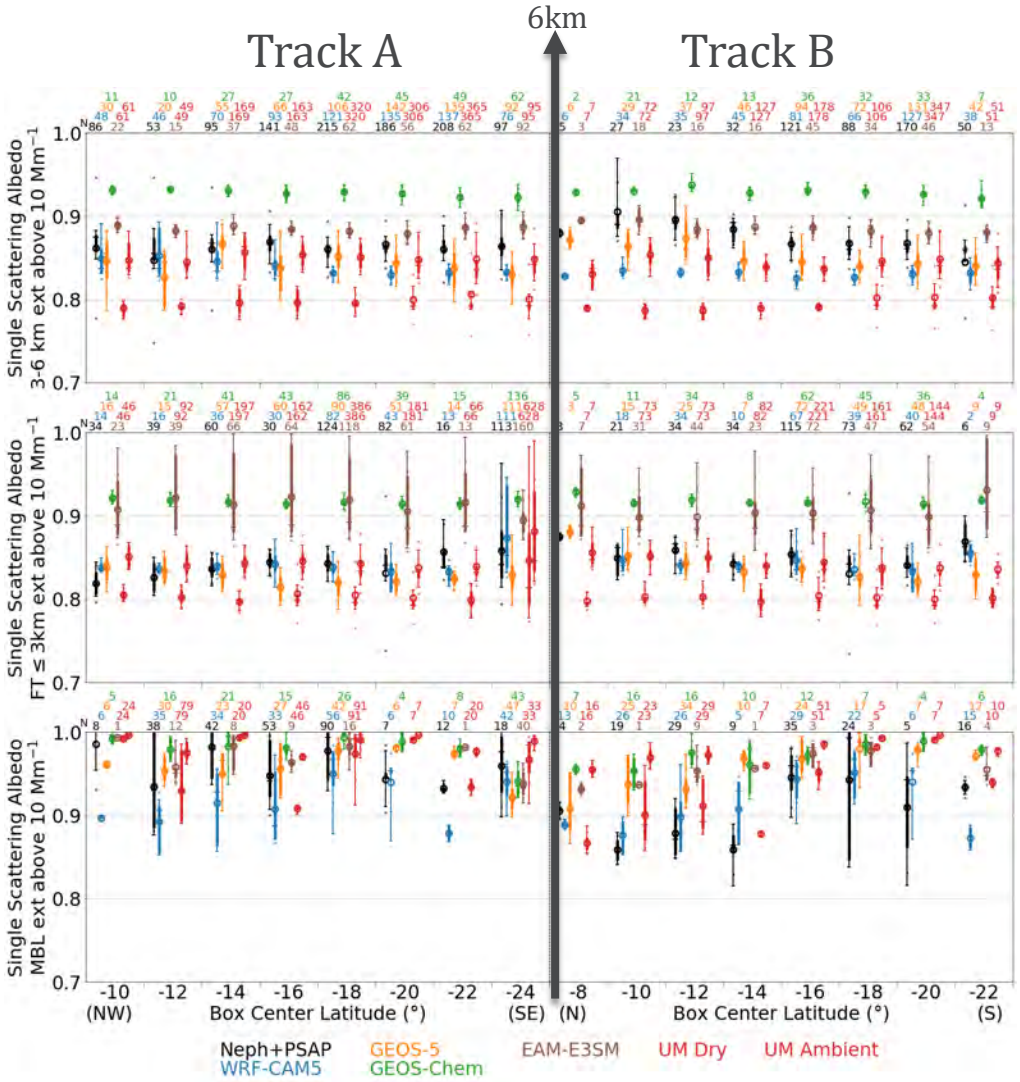
Above BL (RH<~60%)

- Lower extinctions away from sources simulated: Track B > Track A ~ on ASI (20~70 Mm^{-1})
- At lower latitudes <15°S, extinctions peak <3km as on ASI, while peak between 3-6km toward S
- Larger data-model and inter-model diversities in extinctions in MBL (RH?) than FT and along Track B (sources?) than A

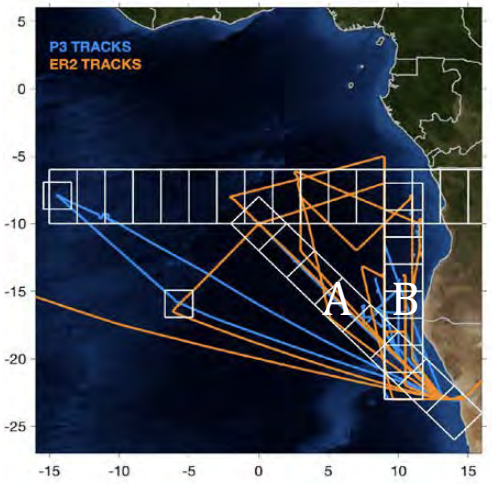
E3SM	Mean bias	RMSD	
3-6km	+6 (11%)	17 (28%)	'best'
FT(<3km)	+16 (24%)	28 (43%)	

ORACLES: Moderately Aged Aerosol Properties

September 2016



(Shinozuka et al., 2020)



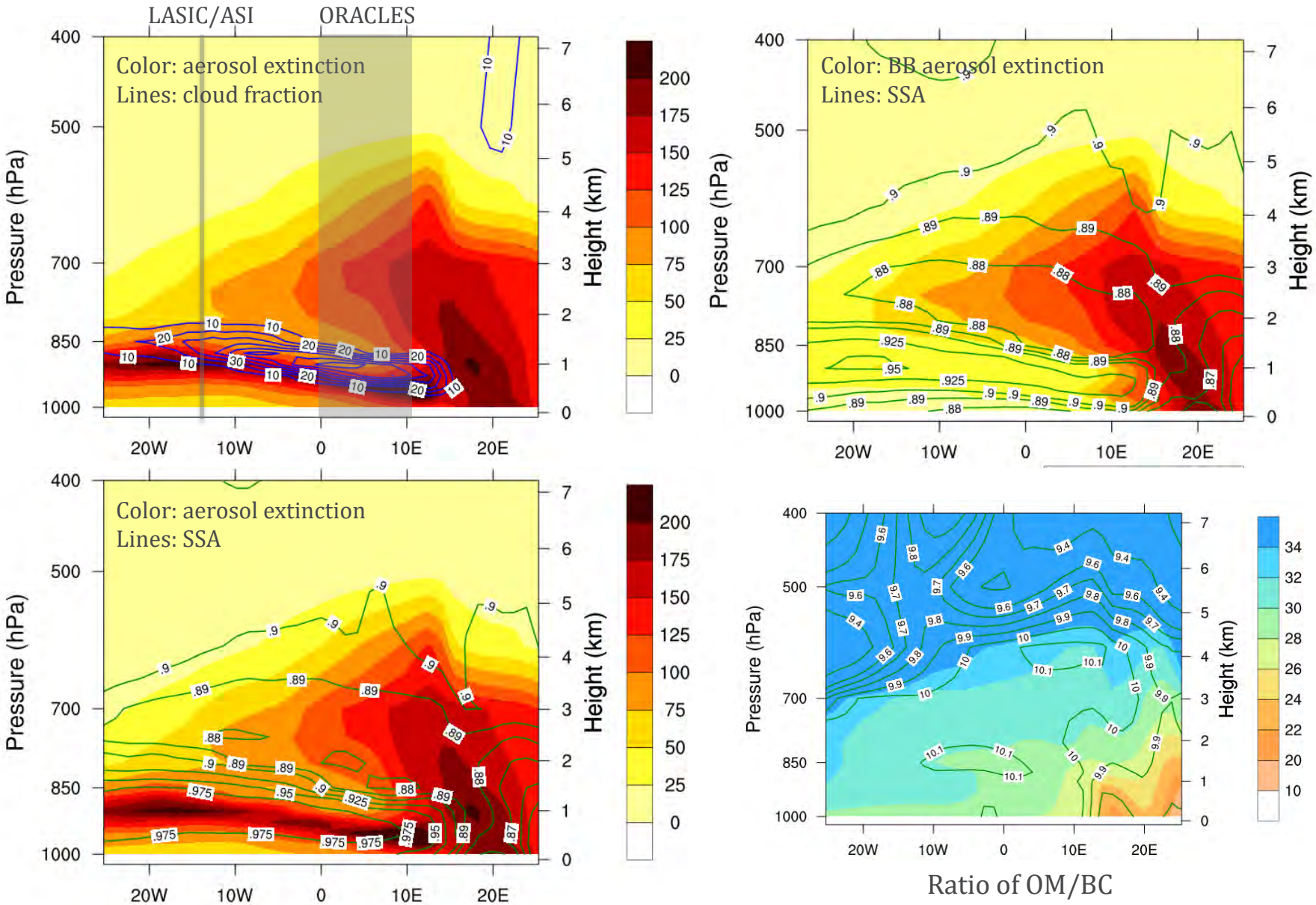
Above BL (RH<~60%)

- SSA (3-6km) > SSA (<3km) in obs, captured by few models, i.e., GEOS-5
- Large inter-model diversity in SSA
- E3SM overpredicts SSA <3km vs 0.85 (Obs), likely due to underestimated BC (-61%)

E3SM	Mean bias	RMSD	
3-6km	+0.02 (2%)	0.02 (2%)	'best'
FT(<3km)	+0.06 (8%)	0.07 (8%)	

A regional perspective

Cross section along 10°S for September 2016



Summary

- Biomass burning aerosols increase the AOD by a factor of 3 over the remote ocean (ASI). This seasonal cycle is simulated by E3SM
- Boundary layer aerosol optical properties are strongly influenced by relative humidity especially at the cloud levels. Caution on model-data comparison. There is a need of extinction measurements calibrated at ambient conditions
- Model simulations of well-aged BB aerosol over ASI suggest moderately absorbing in both surface and free troposphere (FT), with SSA of 0.87. The calculated SSA agrees with the ORACLES data in FT
- In addition to SSA, the vertical profile of elevated aerosol layer in models is also improved in terms of the layer location and thickness
- However, models still need better constraints of OM and BC for capturing the variability in SSA