Contribution of biomass burning aerosols to above-cloud aerosol optical depth over the SE Atlantic

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Motivation: The abundance of above-cloud aerosols over the SE Atlantic influenced by BB activities is crucial to our understanding of the differences in the model estimates of aerosol radiative effects .

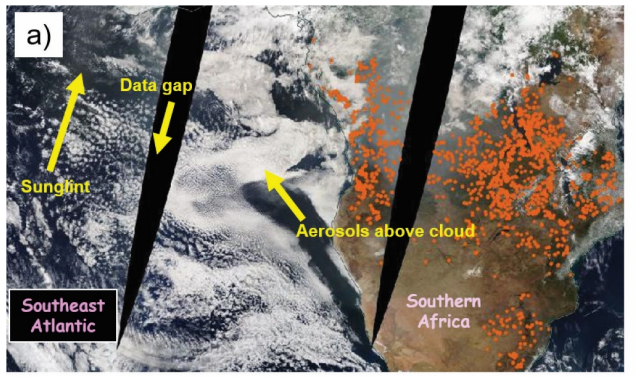
Questions: Do models capture the BB aerosols above clouds ? What are the main uncertainties?

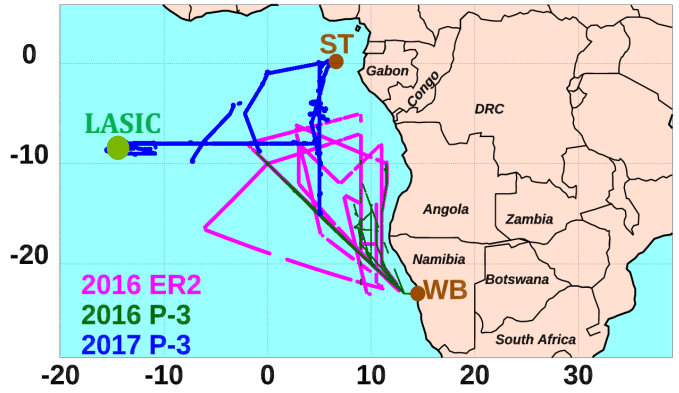
Approach: We examine differences among various models and aircraft-based (NASA/ORACLES) and surface (LASIC) measurements in:

(1) total column AOD;
(2) AOD fraction in FT; and
(3) FT or above-cloud AOD.

Models: Total 7 models, including 3 regional models.

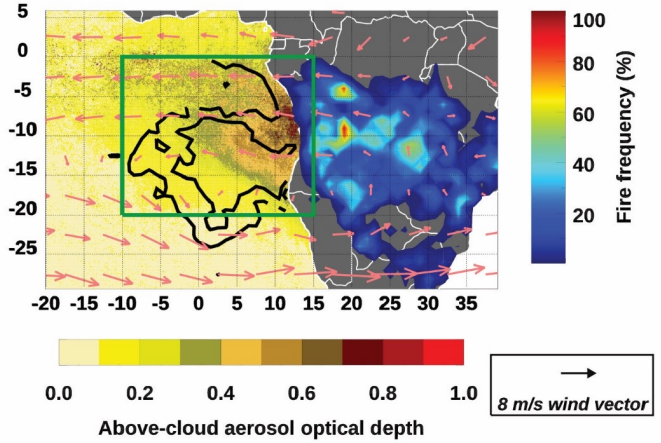
- DOE E3SMv1/ EAM (Wang et al. 2019; Feng et al. 2022)





ORACLES Flight tracks

MODIS above-cloud AOD August 2017



Chang et al. (2022)

Data:

(1) Aircraft measurements available in September 2016 & August 2017

- HSRL-2 (2016 ER2 & 2017 P-3): FT and total column AOD;
- 4STAR (P-3): FT AOD

(2) LASIC AMF-1 (June 2016 – Oct 2017): column AOD, FT AOD

Chang et al., *On the differences in the vertical distribution of modeled aerosol optical depth over the southeast Atlantic, Atmos. Chem. Phys. Discuss. [preprint], https://doi.org/10.5194/acp-2022-496, in review, (2022).*

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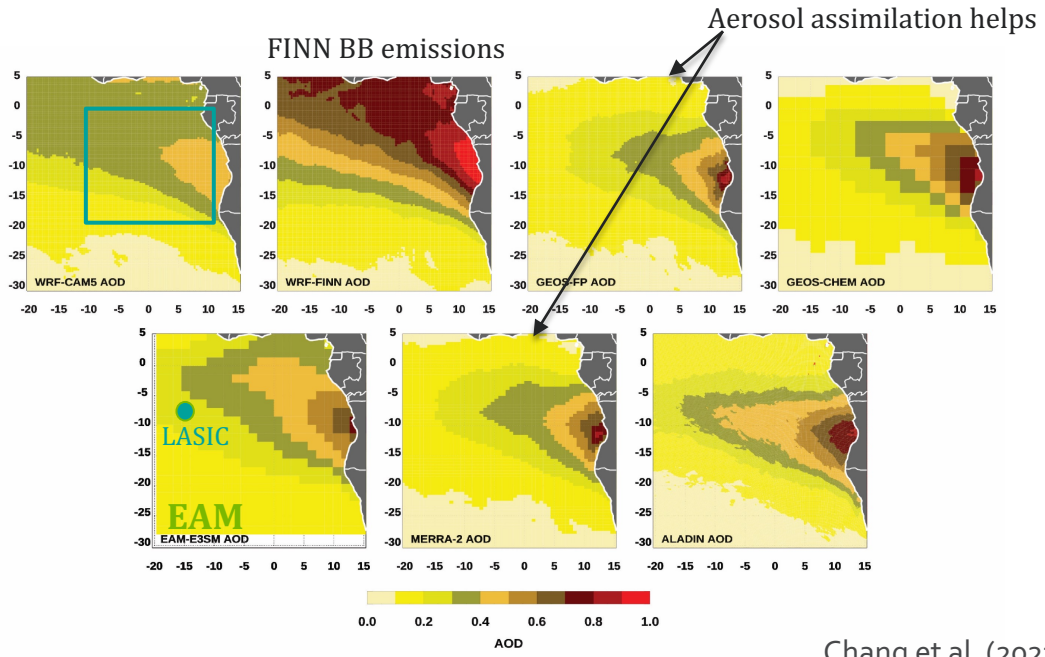
Column AOD is underestimated in most models near sources and for large AOD values, including EAM.

Contributing factors

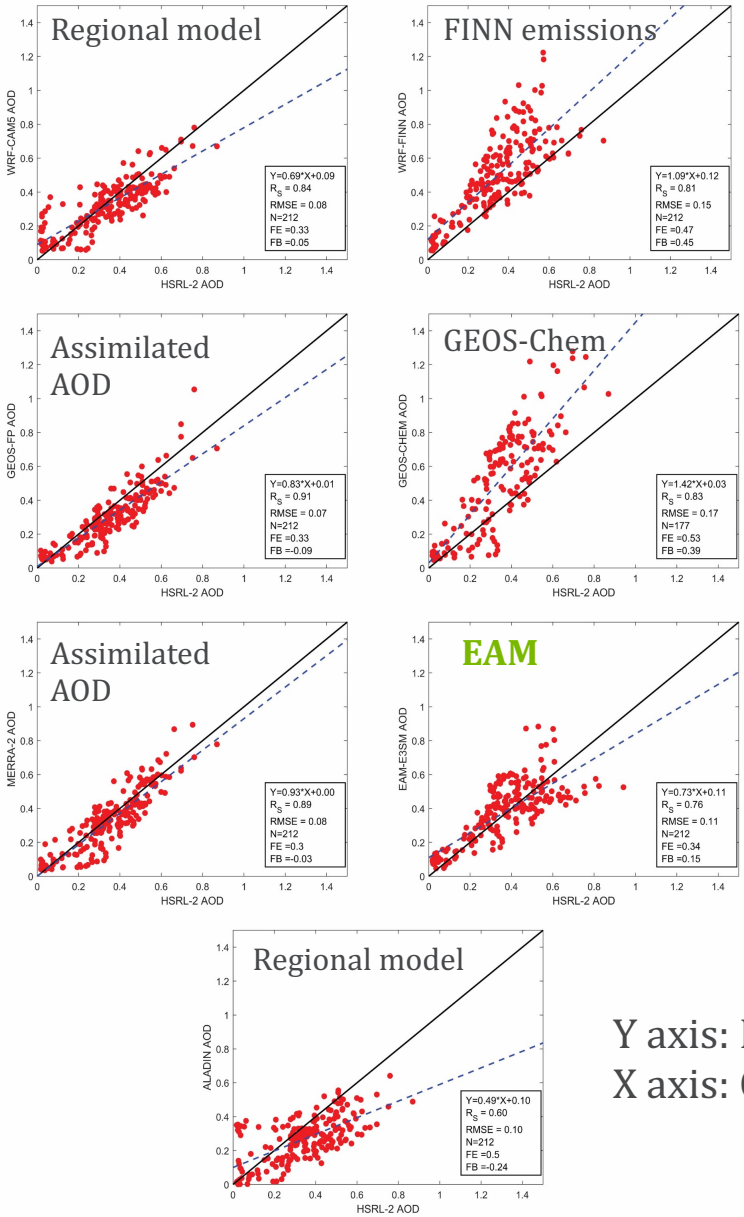
- BB emissions (sources)
- Aerosol assimilation (sources)
- Meteorology (transport)
- Aerosol removal (transport)

Model predictions of AOD in September 2016



Chang et al. (2022)

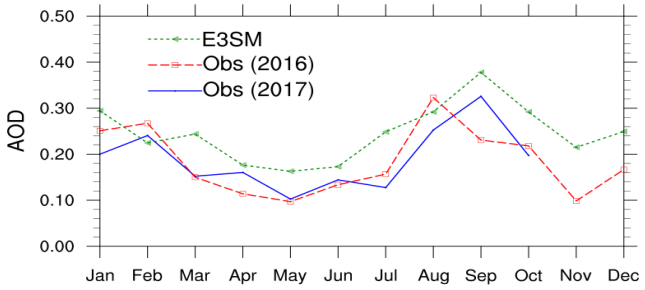
Comparison with HSRL-2 clear-sky AOD



Y axis: Models
X axis: Obs

- EAM overpredicts the AOD at Ascension, implying a possible weak aerosol removal in transport.

Ascension Island (LASIC)



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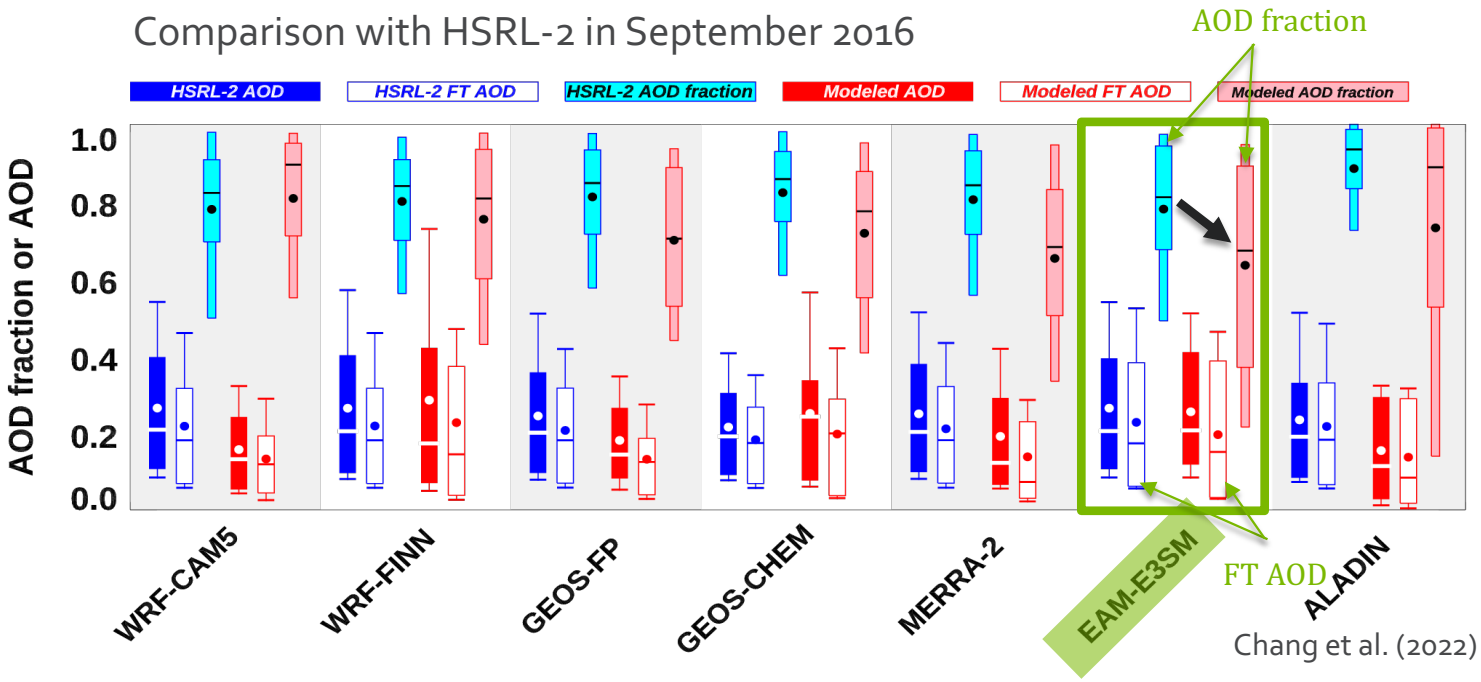
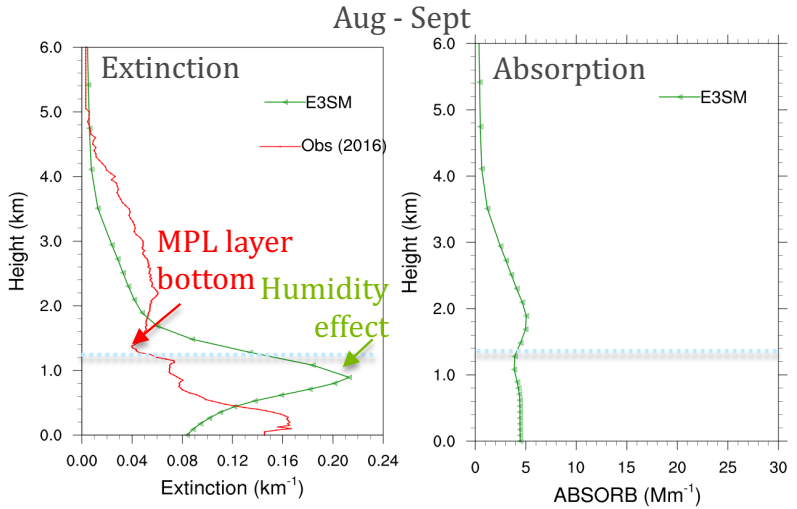
Most models also underestimate the AOD fraction in the free troposphere (FT), thus resulting in even larger underestimation in the FT AOD.

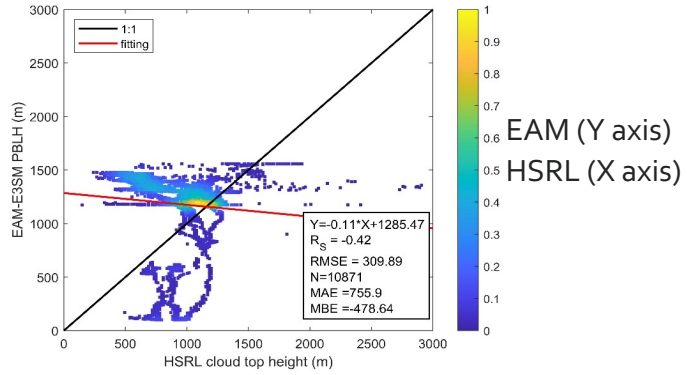


Chang et al. (2022)

EAM underestimates FT AOD and absorption at Ascension Island



PBLH: EAM vs HSRL



EAM PBLH based on specific humidity (q) profiles (Ryoo et al, 2022) is too high compared to HSRL cloud top height

- The underestimated FT AOD in EAM suggests that the strength of elevated BB aerosols is low-biased, possibly related to
  - insufficient vertical transport near the sources due to unresolved turbulent transport; and excessive aerosol dry deposition.
  - formation of secondary aerosols – SSA in FT too high (Shinozuka et al. 2020)
- The calculated AOD fraction in FT is sensitive to the model planetary boundary layer height (PBLH).

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Findings and on-going work

- Biomass burning aerosol plumes over the SE Atlantic are predominately elevated above the clouds (~70-88%) in observations.

- Models underestimate the above-cloud AOD (Chang et al., 2022), e.g., 60% with EAM, and absorption (high SSA; Shinozuka et al. 2020) due to BB aerosols.

- For E3SM-EAM, we are addressing these issues by
  - Reducing aerosol dry removal near sources (v3); Above-cloud AOD
  - Increasing wet deposition through cloud scavenging (v3); AOD in the remote ocean
  - Improving BrC aerosol absorption in BB with the improved POA/SOA scheme (v3): Absorption
    - BrC inserts a positive forcing: +0.05~0.34 Wm-2;

- Influence of BB aerosols on CCN during LASIC [**Poster #13: Session 1 Wed Morning 8-9:30am**]