Simulation of Biomass Burning Aerosol Transport Over the South African-Atlantic Region

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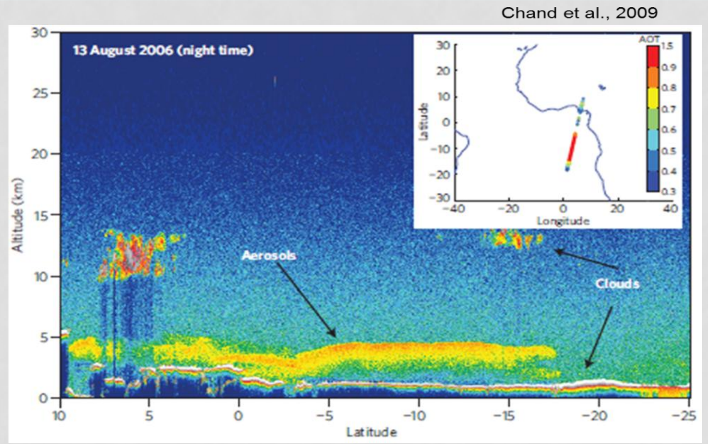
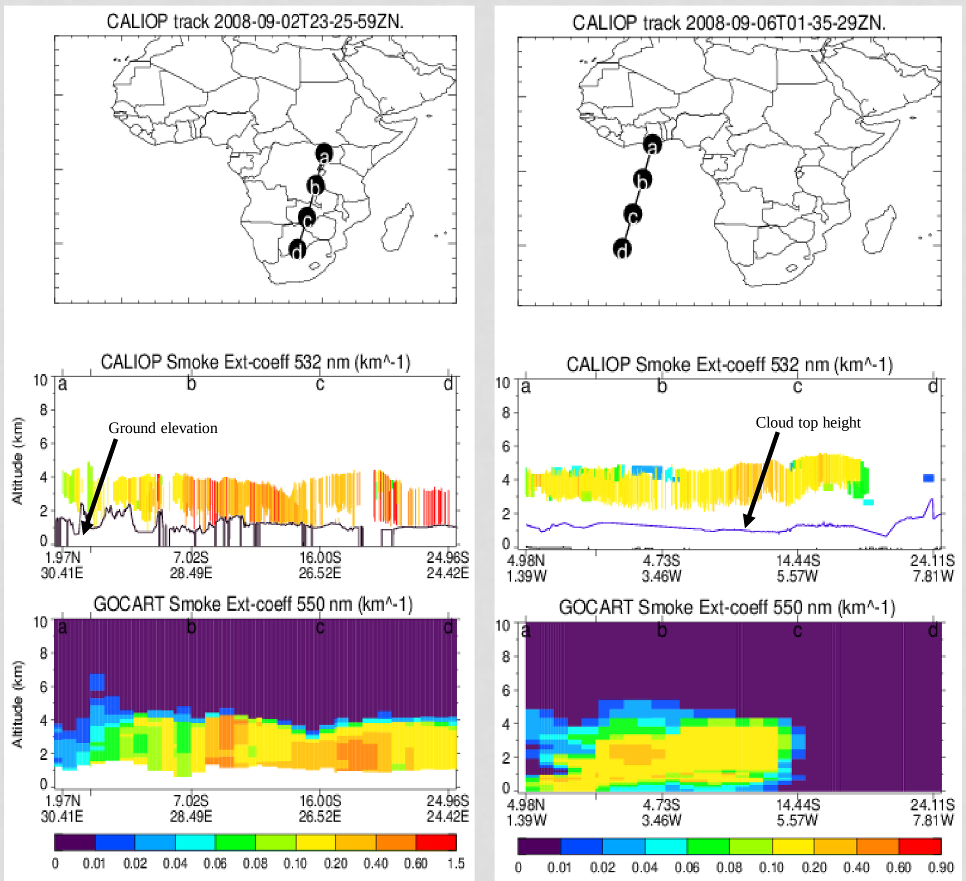
1 | Introduction

- Biomass burning is a major source of trace gases and aerosols in the atmosphere
- The large-scale transport of aerosol plumes originating from seasonal (August-October) burning of agricultural residue in the southwestern African Savannah region gives rise to a unique situation that merits special scrutiny
- Many observational studies [1] showed that instead of intermingling with clouds, the plume gives rise to a non-interacting aerosol layer and resides over vast stretches of marine stratus clouds in the Atlantic
- Accurate simulations of the existence, location and properties of these aerosols is necessary to determine the magnitude and sign of aerosol direct, indirect and semi-direct effects



2| Background and Motivation

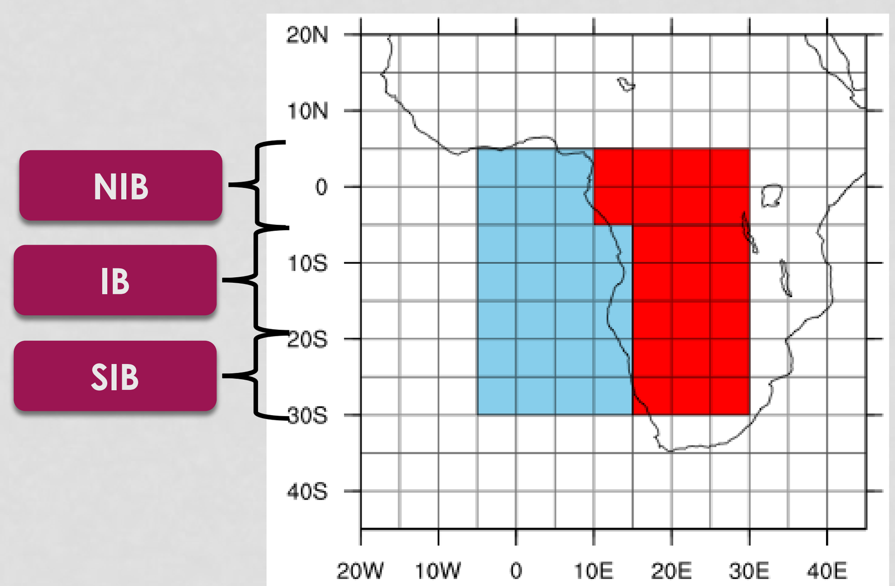


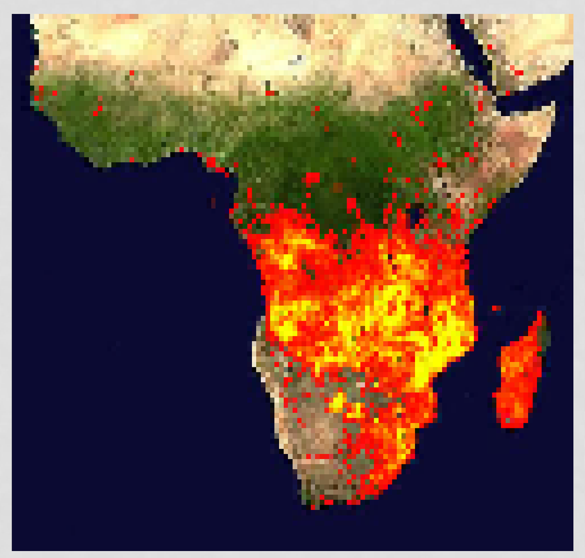
- The vertical smoke extinction profiles from CALIOP (satellite measurement) and GOCART (a global chemistry transport model) were compared along the satellite tracks
- The figure illustrates example of two tracks, one over the burning source region (left) and the other after a transport period of ~ four days, over the ocean (right)
- There is a reasonable agreement over the source region between the model and observations, but over the ocean, the non-interacting (with clouds) feature of the smoke layer is missing in the model
- The resolution of this discrepancy is important because the reduction/enhancement of cloud cover due to the semi-direct effect depends on the altitude of aerosol layer relative to clouds [3]

Objective

To investigate the relative roles of emission inventory, chemistry and dynamics in accurate simulation of the location and optical thickness of absorbing aerosol layer over clouds in the South Atlantic

3| Methods





- GOCART model was run in 'online mode' , i.e. the aerosol fields from GOCART were dynamically and radiatively interactive with the GEOS-5 AGCM (Atmospheric General Circulation Model)
- Figure above (right) shows the locations of the fires detected by MODIS (28 Aug- 06Sep '08), which is also representative of the typical burning pattern for the entire season of August-October. The color ranges from red where the fire count number is low to yellow where number of fires is large
- On left, the larger region of interest is divided into primarily land (red) and ocean (blue) regions, with further divisions into intense burning (IB), south of intense burning (SIB) and north of intense burning (NIB) sub-regions.
- GOCART and CALIOP aerosol extinction values are averaged (weighted by their occurrence) over each 5 x 5 degree box within each sub-region. The averaging duration is Aug to Sep 2008 for GOCART and Aug to Sep 2008 and 2009 for CALIOP. Additional year is included to make the satellite dataset representative of each box.
- CALIOP extinction values at 1064 nm were converted to 550 nm using angstrom exponent (=1.8) for 440-1020 nm wavelength interval, derived using measurements from AERONET sites over the source region. This was to account for the underestimation of AOD at 532 nm by CALIOP [2]
- While calculating probability of occurrence of aerosols and clouds from CALIOP measurements for each box, aerosol/cloud samples were discriminated from clear air samples using CALIOP feature type flag

4|Results and Discussion

- The transport and transformation of aerosol from land to ocean is characterized by the shape of the aerosol profile
- Each 5° x 5° box is representative of the typical aerosol profile that would exist at that location during the burning season
- The vertical concentration profiles of an inert tracer gas, carbon monoxide (CO), which is simultaneously emitted with aerosol during BB, were also compared to get insights about the role of model chemistry (dry and wet deposition for aerosols) during the transport process
- Simulated transport process exhibits distinct patterns for the three sub-regions. Examples from each are shown in figures below
- For each figure, top panel shows the probability of occurrence of aerosols (and clouds over ocean) measured by CALIOP for each 5x5 box; middle panel is the comparison of mean extinction coefficient profiles from GOCART and CALIOP, weighted by their occurrence; bottom panel is the mean concentration profiles of CO along the plume transport direction

Fig 1. Example of a SIB region: 25 S to 20 S from land (east) to ocean (west)

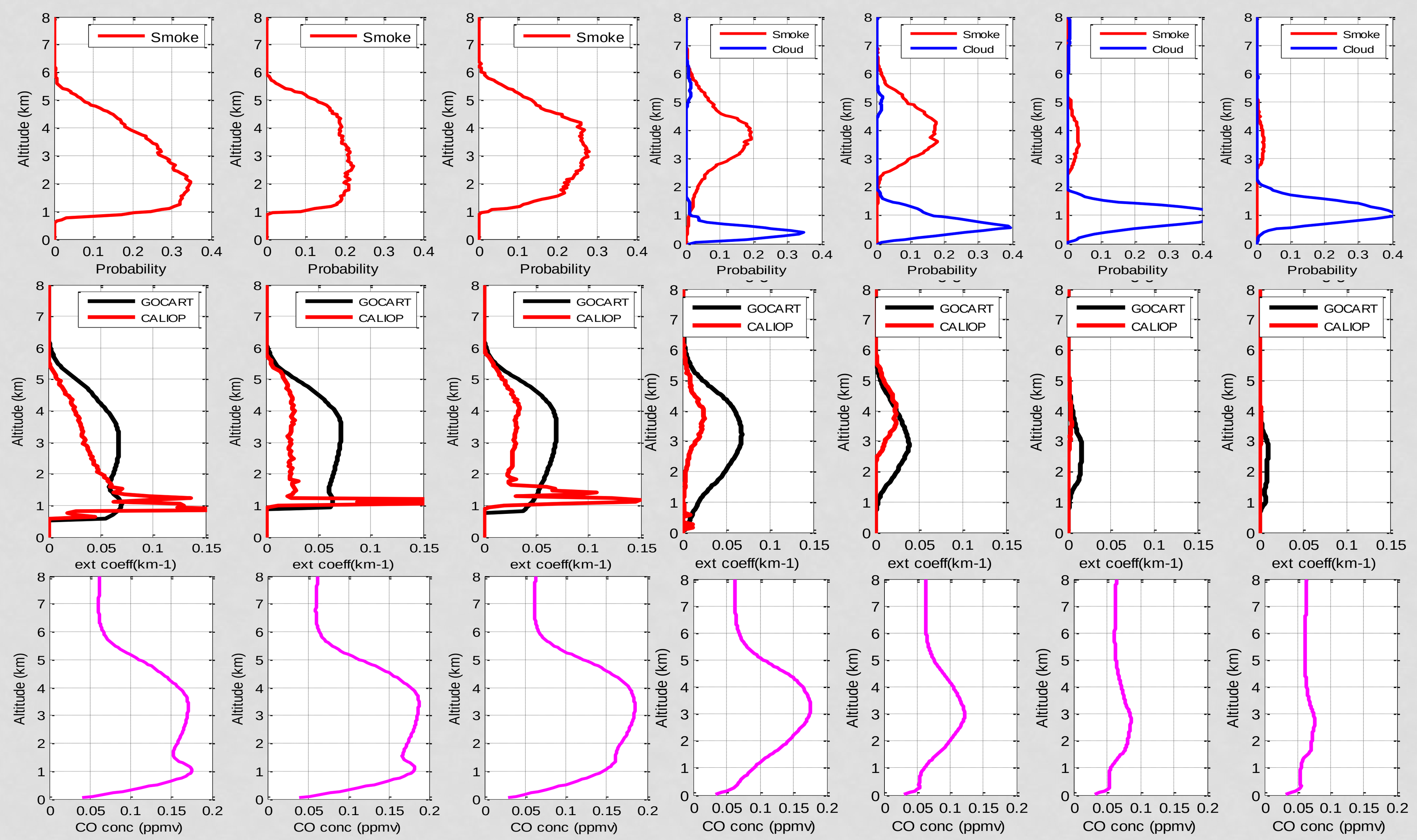


Fig 2. Example of an IB region: 15 S to 10 S from land (east) to ocean (west)

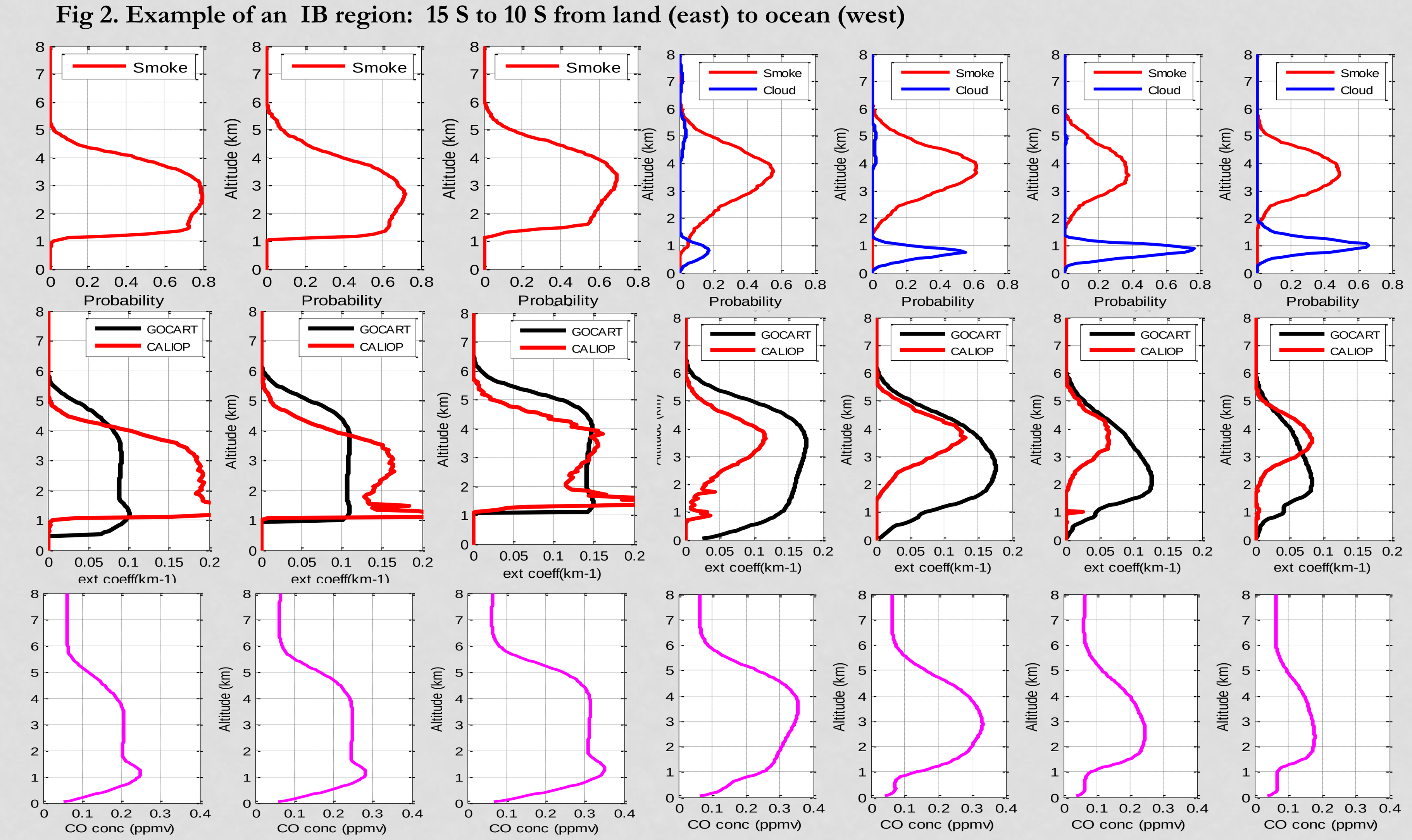


Fig 3. Example of a NIB region: 5 S to 0 N from land (east) to ocean (west)

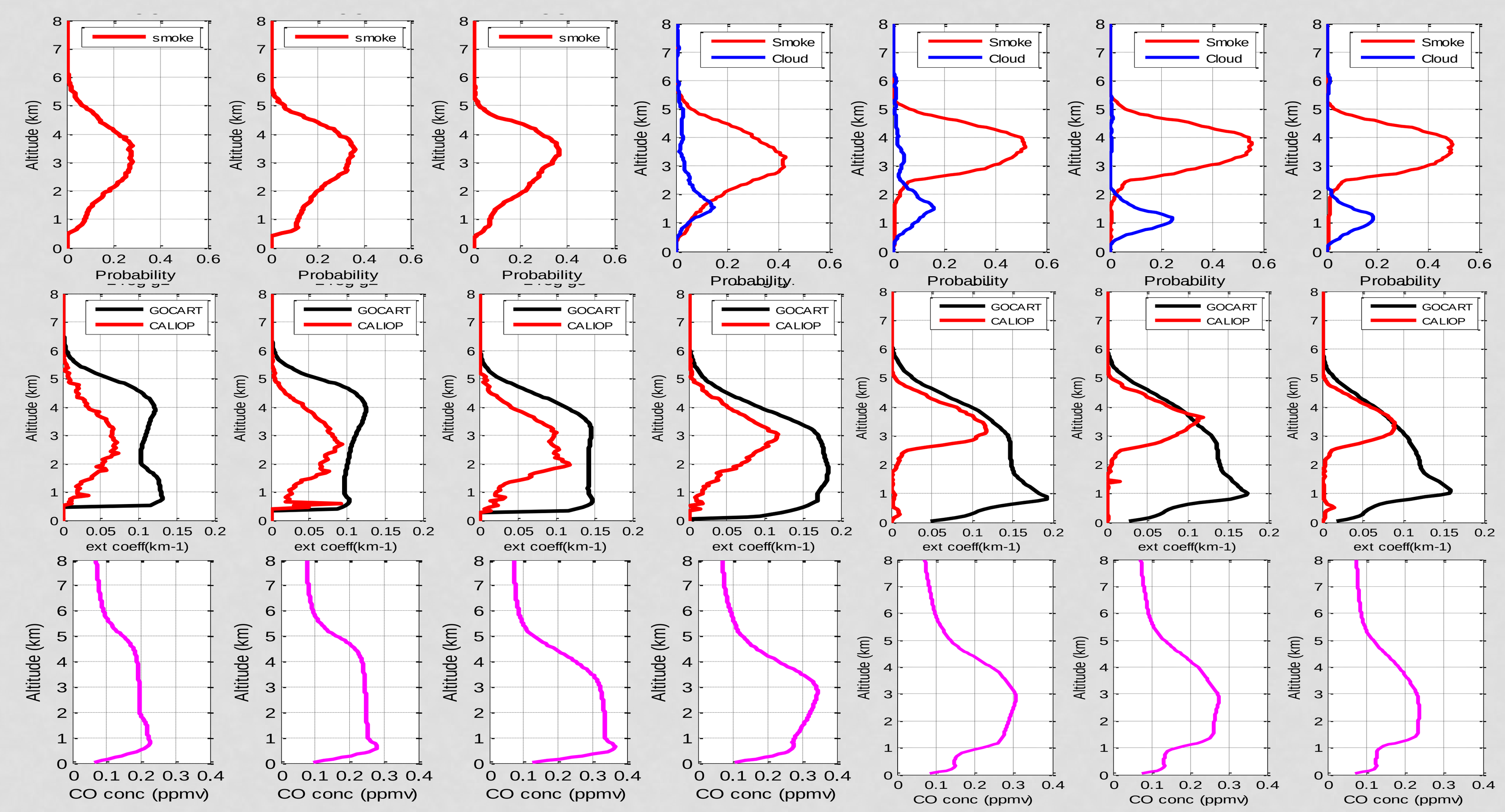
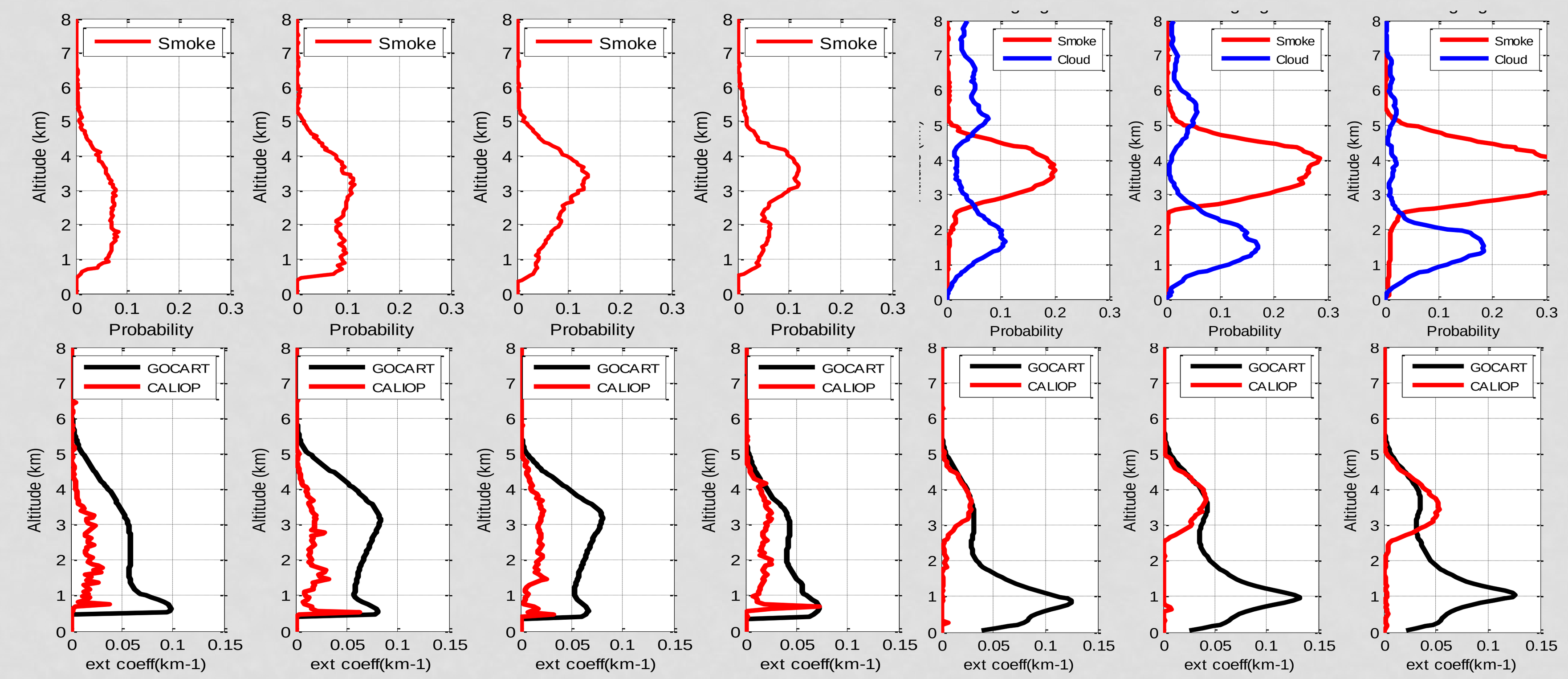


Fig 4. Special case of 0 N to 5 N from land (east) to ocean (west)



5| Conclusions

- CO and aerosol profiles seem similar in shape, except in NIB region, where aerosols are probably being scavenged into the clouds due to wet deposition. This similarity is indicative of the larger role of model dynamics (than chemistry) in the disagreement of simulated transport process compared to observations
- GOCART profiles over ocean are most consistent with observations in SIB region but deviates as we go closer to the equator. However, between 0-5N, CALIOP and GOCART profiles are similar above the clouds
- This scenario may be partly due to overestimation of subsidence caused by aerosol feedback to meteorological fields. Increase in subsidence was observed for particularly 30S-0N when GEOS-5 AGCM was run with and without aerosol feedback respectively [4]
- Model aerosol extinction profiles using two different emission inventories (GFED and QFED) were also compared with observations. Results (not shown here) for QFED are more consistent with observed values, than for GFED

6|Future work

- Sensitivity study using no aerosol dynamical feedback to AGCM meteorological fields will be performed to test the increase in subsidence hypothesis
- Model vertical velocity fields, especially over the ocean, will be compared to other existing modeling studies for the region

7| References

[1] Chand et al.., 2009. Satellite-derived direct radiative effect of aerosols dependent on cloud cover. Nature Geoscience, 2 (March 2009): DOI: 10.1038/NGEO437
[2] Jethva et al., (2014), How do A-train sensors intercompare in the retrieval of above-cloud aerosol optical depth? A case study-based assessment, Geophys. Res. Lett., 41, 186–192, doi:10.1002/2013GL058405
[3] Koch and Del Genio (2010), Black carbon semi-direct effects on cloud cover: review and synthesis, Atmos. Chem. Phys., 10(16), 7685-7696, doi:10.5194/acp-10-7685-2010
[4] Randles et al.,(2013), Direct and semi-direct aerosol effects in the NASA GEOS-5 AGCM : aerosol-climate interactions due to prognostic versus prescribed aerosols, J. Geophys. Res. Atmos., 118, 149–169, doi:10.1029/2012JD018388.

8|Acknowledgement

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