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Development of new computationally efficient treatments of secondary organic aerosols (SOA) for E3SM v3: Sensitivity of SOA to emissions, chemistry, and vertical resolution

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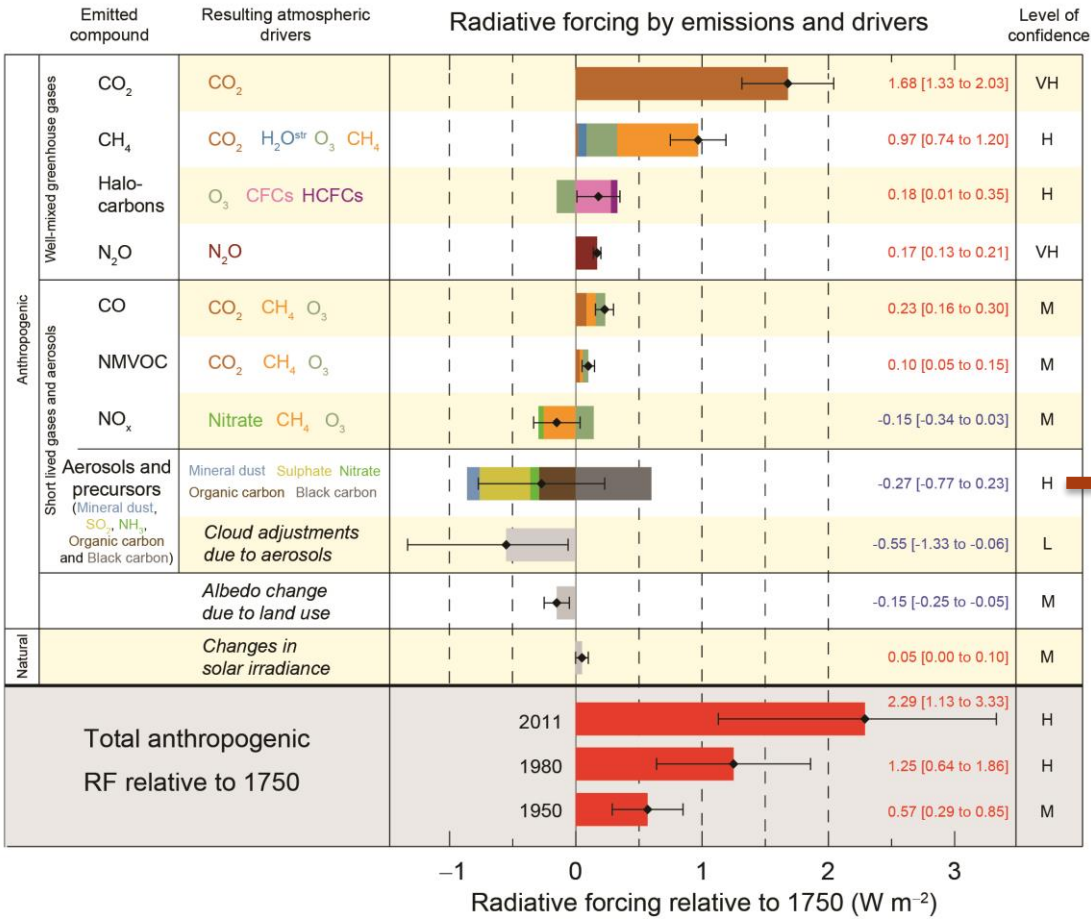
E3SM
Energy Exascale Earth System Model

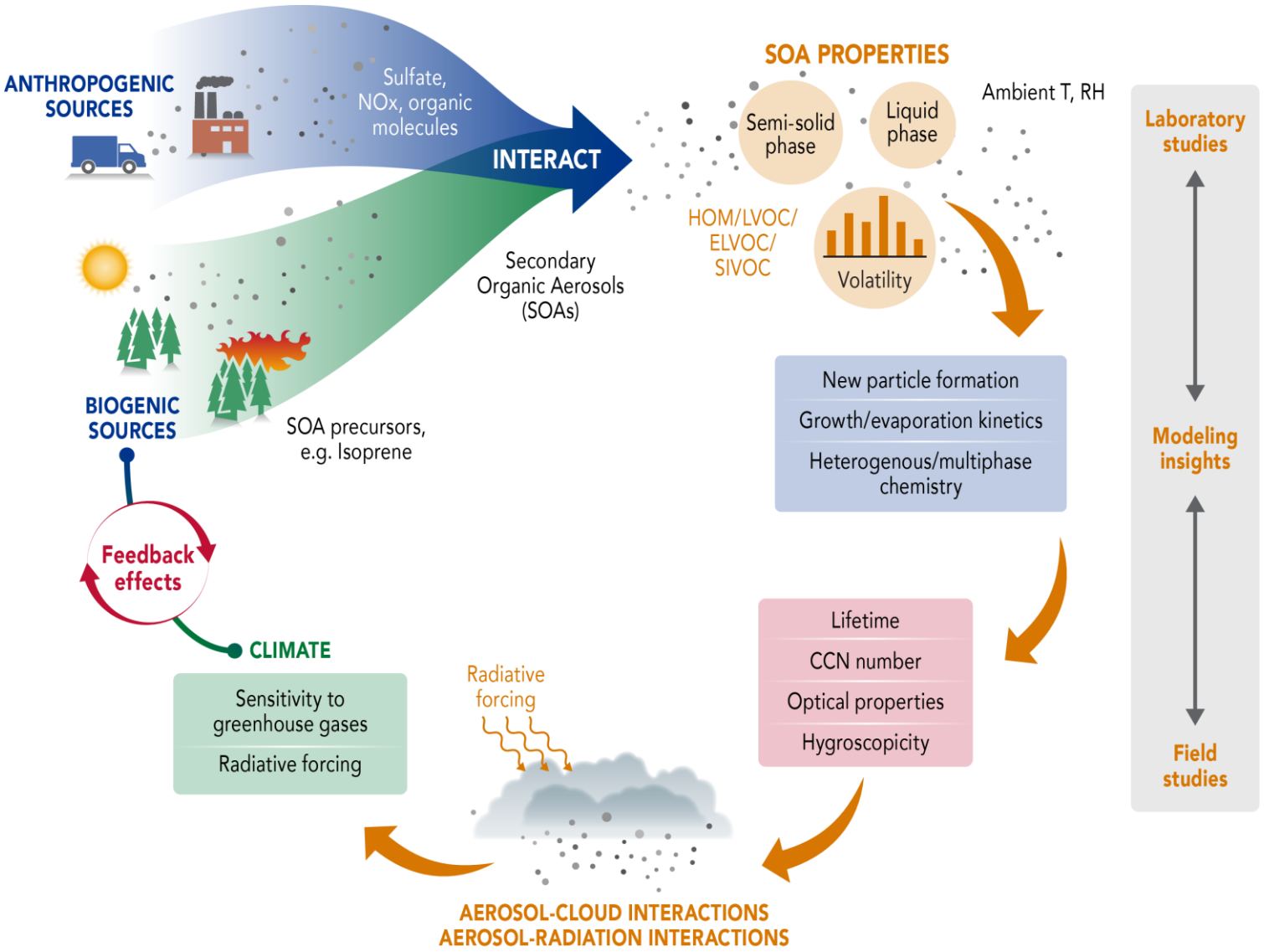
Radiative forcing of aerosols more uncertain than reported in IPCC AR5



IPCC, 2013

- Organic aerosols include 1000's of species whose chemical compositions and properties change dynamically in the atmosphere
- Organic aerosol is represented too simplistically in climate models
- Aerosol radiative forcing is more uncertain than reported in IPCC since
- Latest E3SM results show that SOA itself has a DRF of -0.7 to -1 W/m2

Complex SOA physical and chemical processes still uncertain and are not included in climate models



Shrivastava et al. 2017, Reviews of Geophysics

Multiple generations of aging in the atmosphere change SOA formation and volatility distribution


Multigenerational aging not explicitly included in global climate models

Primary VOC: biogenic, traffic/power plant, biomass burning

Species functionalizing & fragmenting

Smog chamber fit (Initial yields: OH, ozone, nitrate & NOx-dependent)

Functionalization (decreasing volatility)

Fragmentation (increasing volatility)

Shrivastava et al. 2015, JGR

Results: Decreasing fragmentation increases SOA burdens

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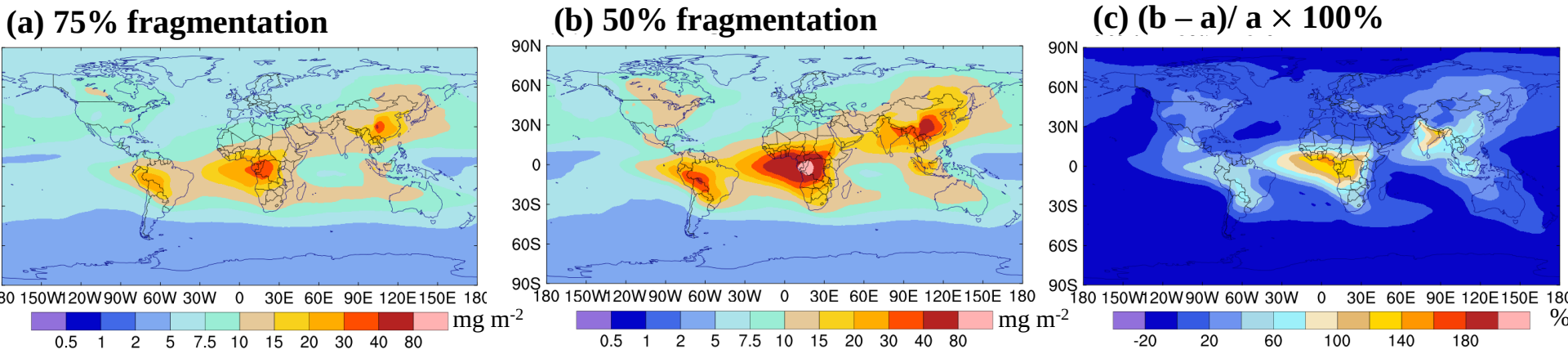
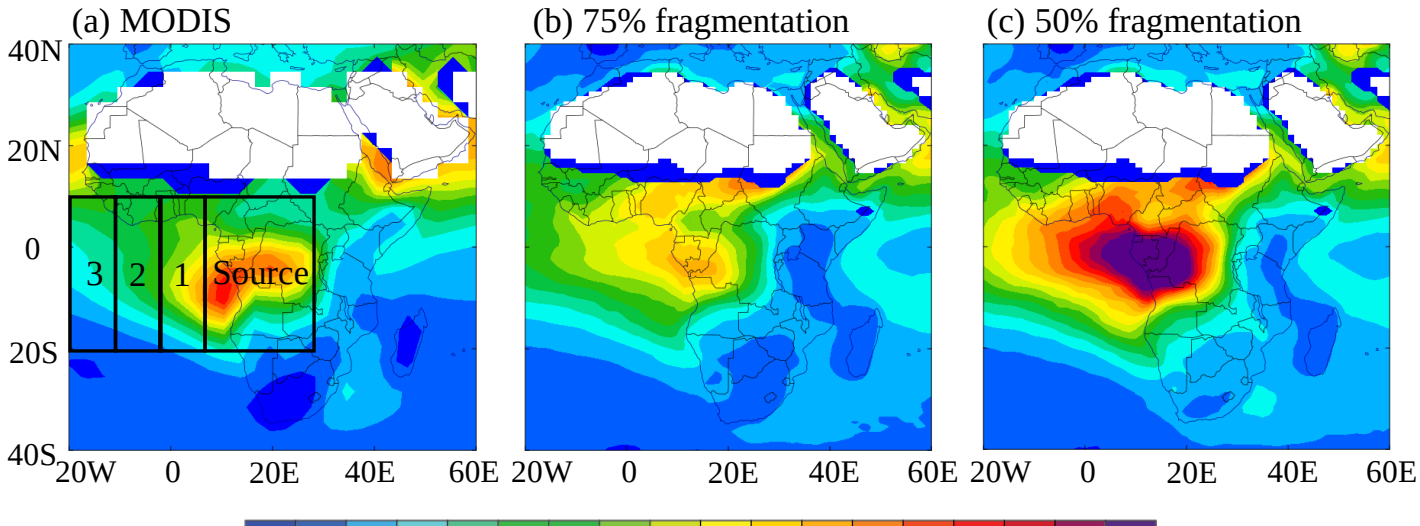
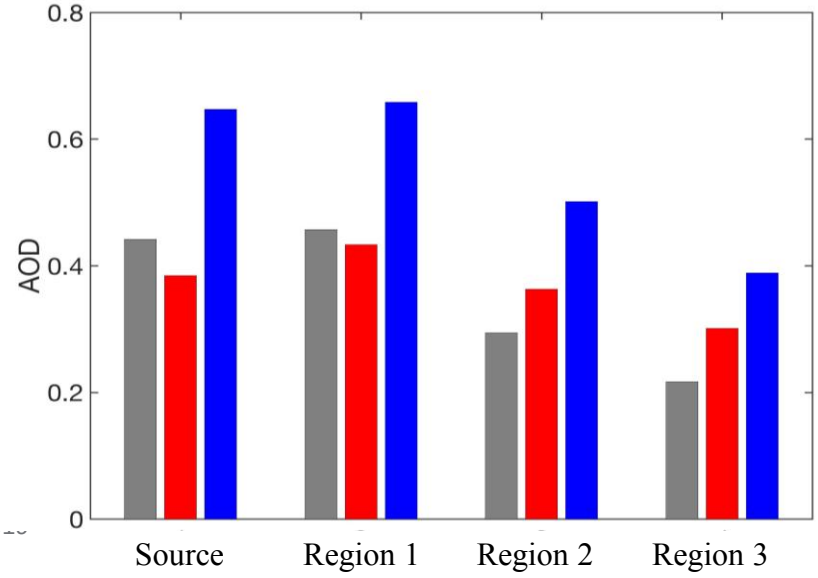


- Greatest effects of gas-phase fragmentation are over source regions including the South African biomass burning outflow, the Amazon (South America), and over India
- High latitudes such as the Arctic show much smaller effects of fragmentation on SOA burdens

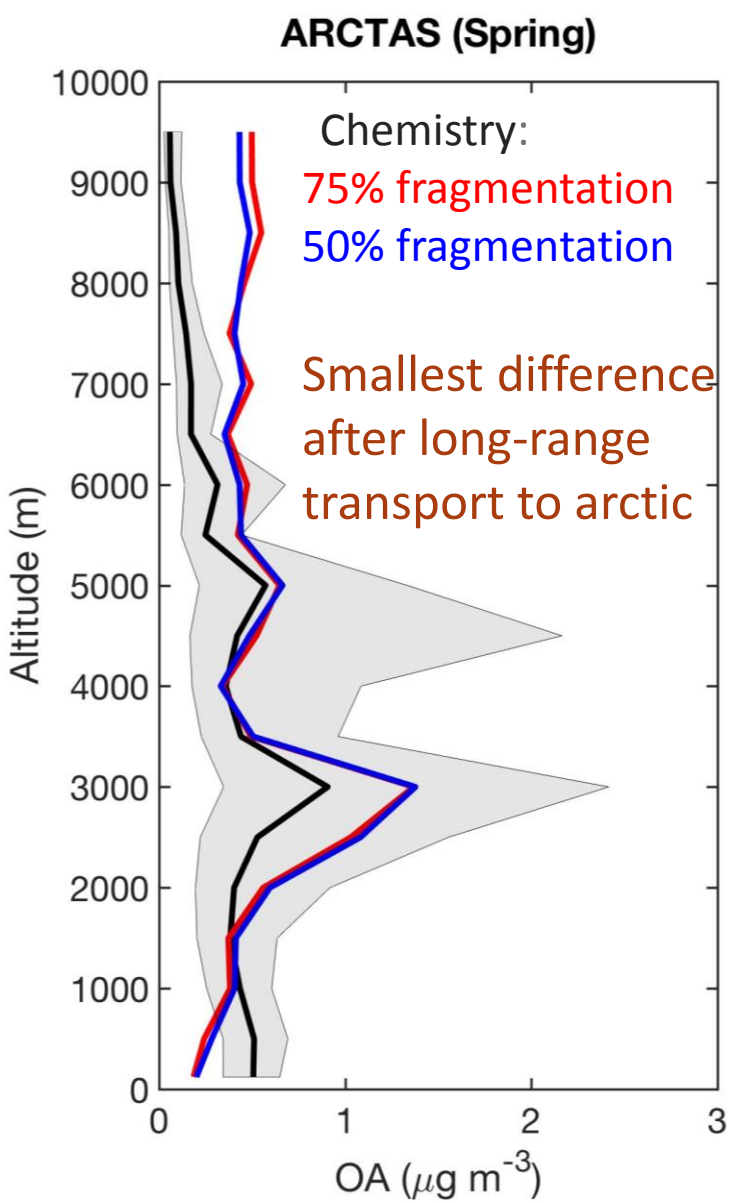
Simulated and satellite AOD over South African biomass burning outflow

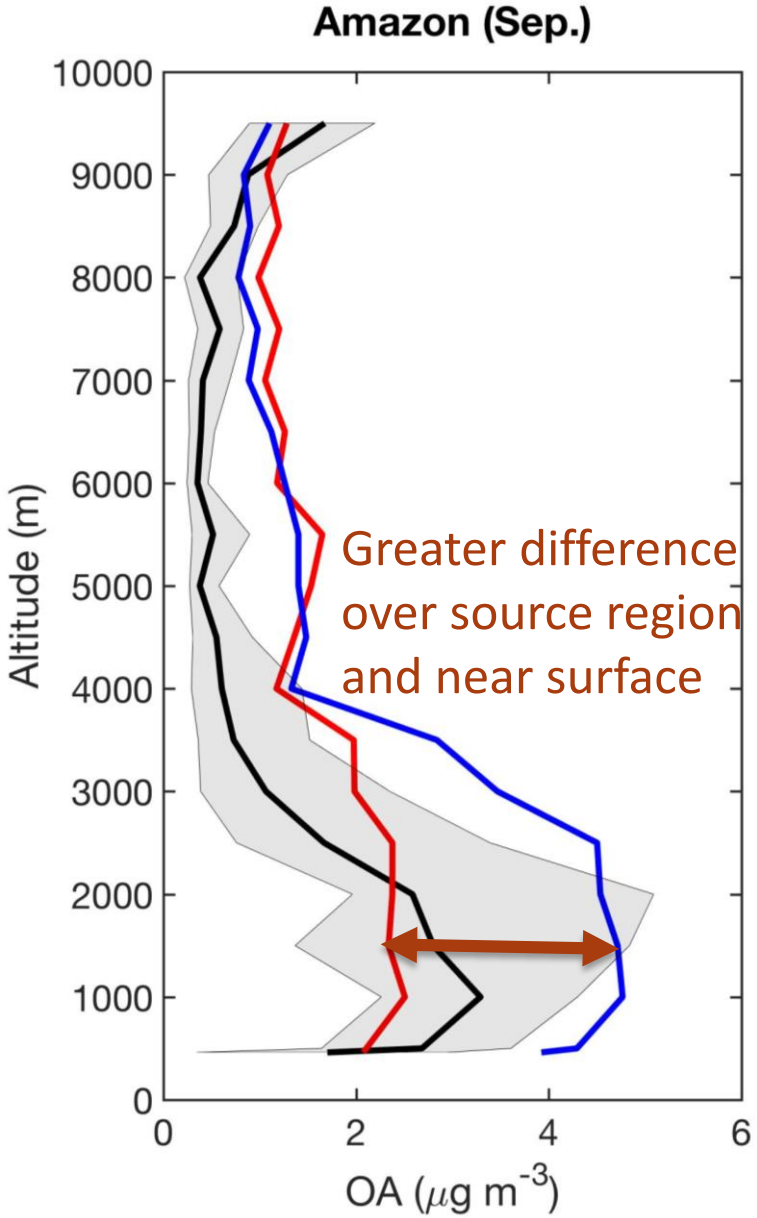




- Simulated AOD shows strong sensitivity to SOA
- High fragmentation case agrees better with MODIS AOD

Evaluate model predictions with aircraft measurements over Arctic and Amazon





Recent studies reflect large uncertainties in predicting SOA direct radiative forcing

- Previous estimates of SOA direct radiative forcing (DRF) differ by an order of magnitude

Studies	DRF (W m^{-2})
AeroCom Phase II Intercomparison experiments (Myhre et al. 2013)	-0.01 to -0.21 (mean: -0.06)
Spracklen et al. 2011 (observationally constrained but mostly near surface and in North Hemisphere)	-0.26±0.15 (anthropogenic controlled SOA)

- Direct radiative forcing using E3SM model: -0.7 and -0.9 W m^{-2} for 75% and 50% fragmentation
- Indirect forcing (PD-PI) is -1.2 W m^{-2} with upto 20% changes with SOA chemistry treatments