Aerosols in Troposphere and UTLS Simulated by a Sectional Aerosol Model

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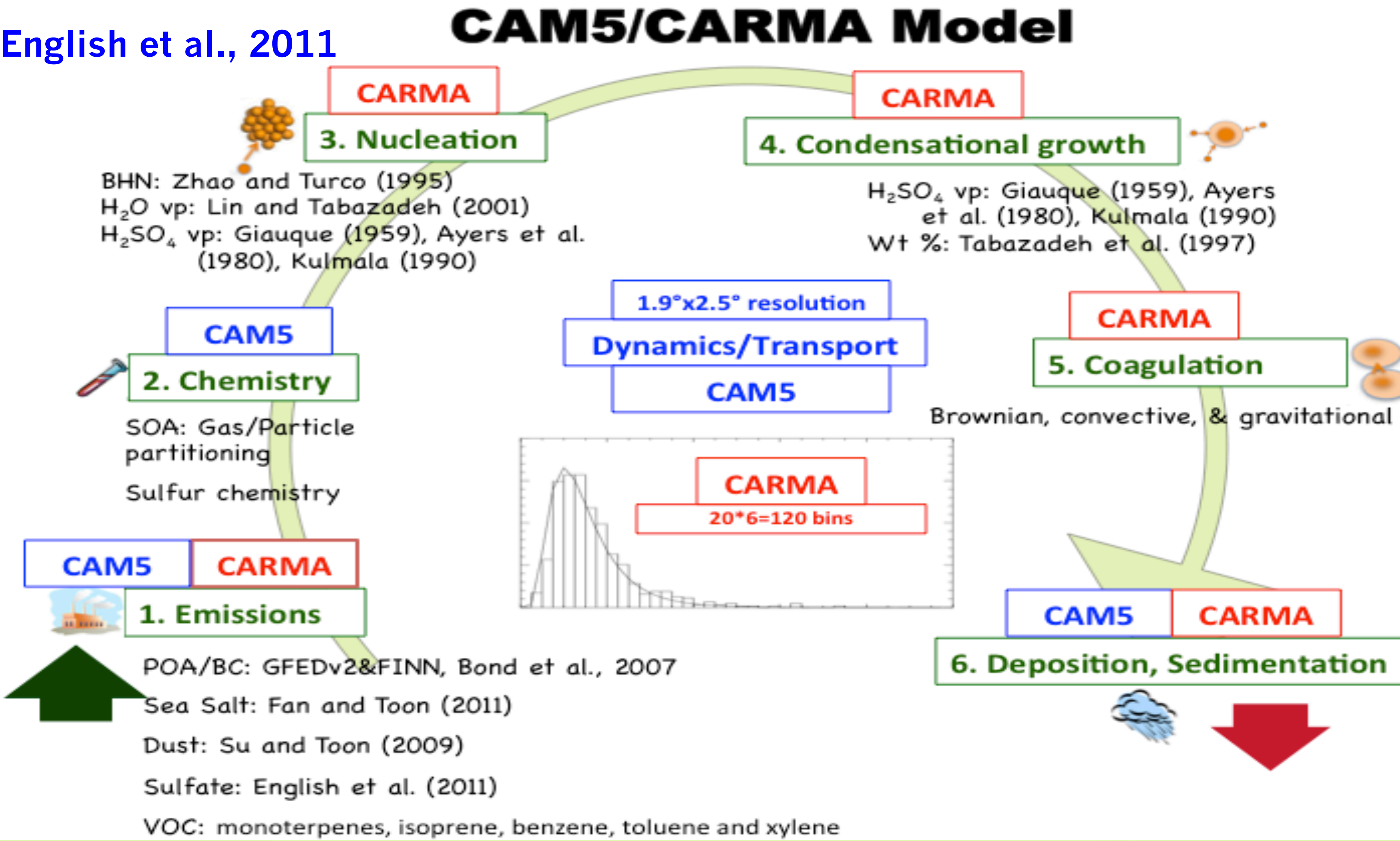
CARMA is a Sectional Aerosol Microphysics/ radiation model coupled with CAM5

English et al., 2011



CARMA is coupled with CAM5 by Charles Bardeen, ACD, NCAR

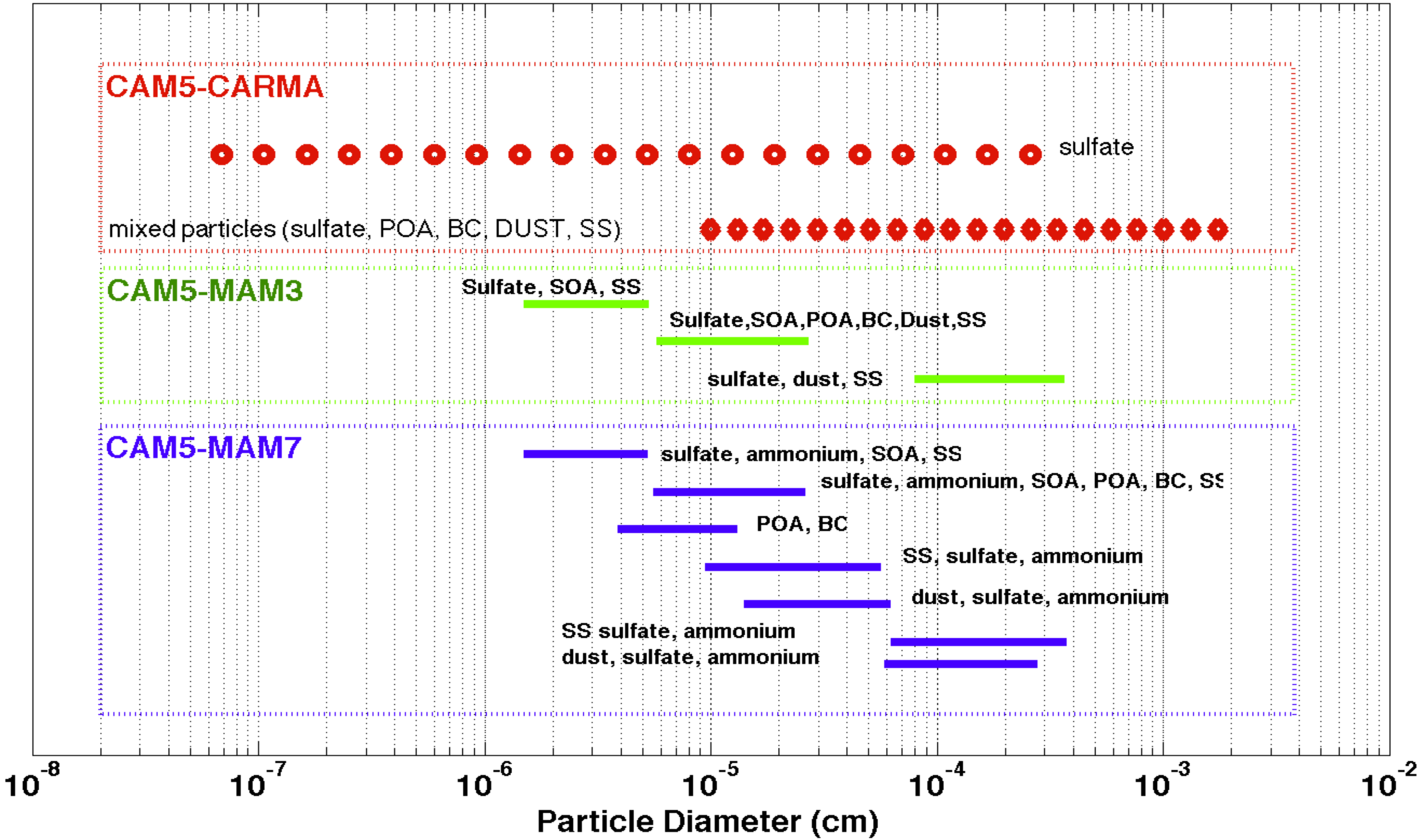
Compare sulfur chemistry in CAM5 aerosol models

CARMA	Default Modal	Bulk
H2SO4 + hv -> SO3 + H2O		
SO2 + hv -> SO + O		
SO3 + hv -> SO2 + O		
OCS + hv -> S + CO		
SO + hv -> S + O		
DMS + OH -> .5 * SO2 + .5 * HO2	DMS + OH -> SO2; DMS + OH -> .5 * SO2 + .5 * HO2	DMS + OH --> a*SO2 + (1-a)*MSA
DMS + NO3 -> SO2 + HNO3	DMS + NO3 -> SO2 + HNO3	DMS + NO3 --> SO2
OCS + O -> SO + CO	SO2 + OH -> H2SO4	SO2 + OH + M --> SO4 + M
OCS + OH -> SO2 + C + H		
S + OH -> SO + H		
S + O2 -> SO + O		
S + O3 -> SO + O2		
SO + OH -> SO2 + H		
SO + O2 -> SO2 + O		
SO + O3 -> SO2 + O2		
SO + NO2 -> SO2 + NO		
SO2 + OH + M -> HSO3 + M		
HSO3 + O2 -> SO3 + HO2		
SO3 + H2O -> H2SO4		
S(IV) + H2O2 --> SO4	S(IV) + H2O2 --> SO4	S(IV) + H2O2 --> SO4
S(IV) + O3 --> SO4	S(IV) + O3 --> SO4	S(IV) + O3 --> SO4

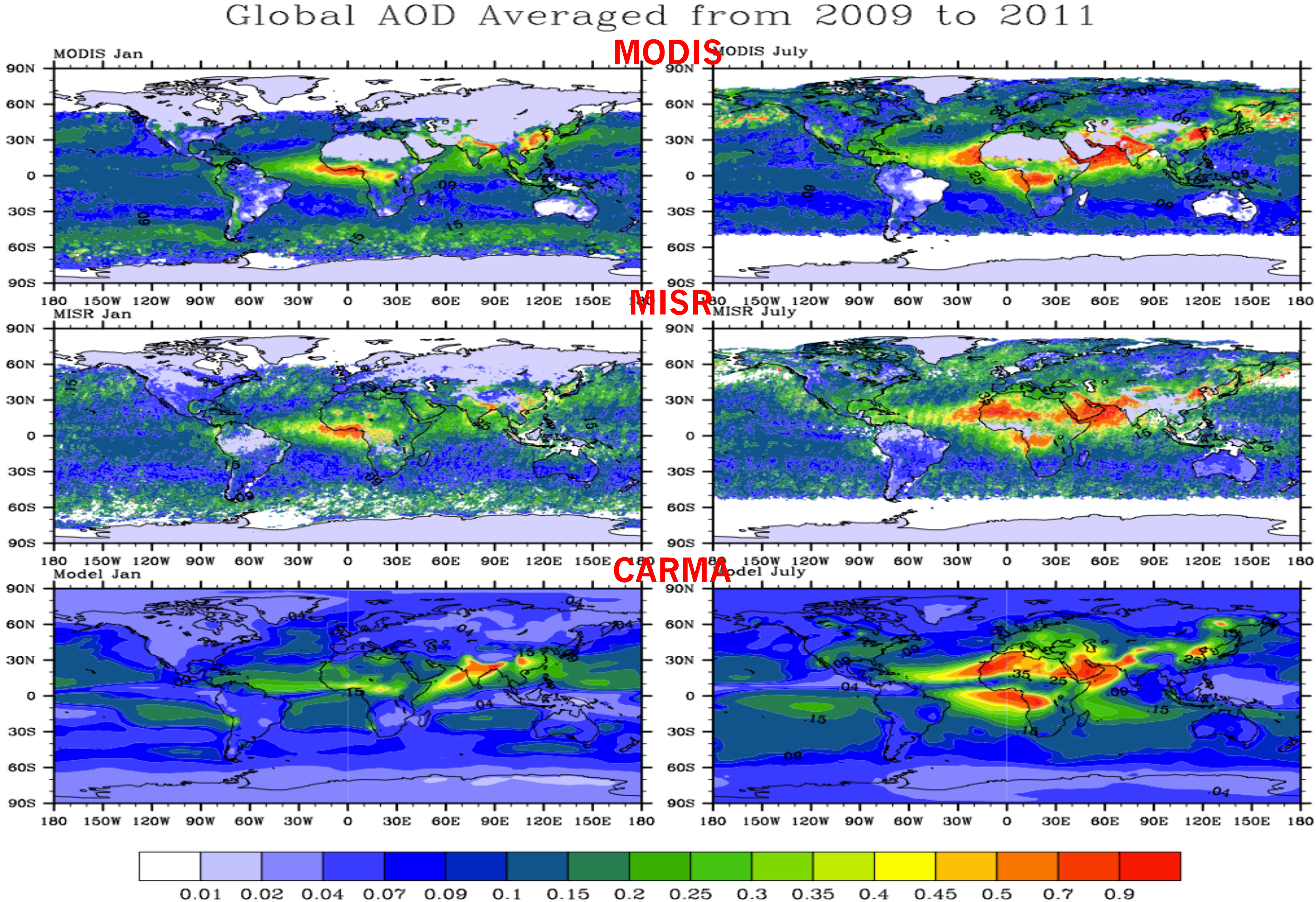
Sulfur Chemistry in CAM5/CARMA is developed by Mike Mills

CARMA has wider size range of aerosols than MAM

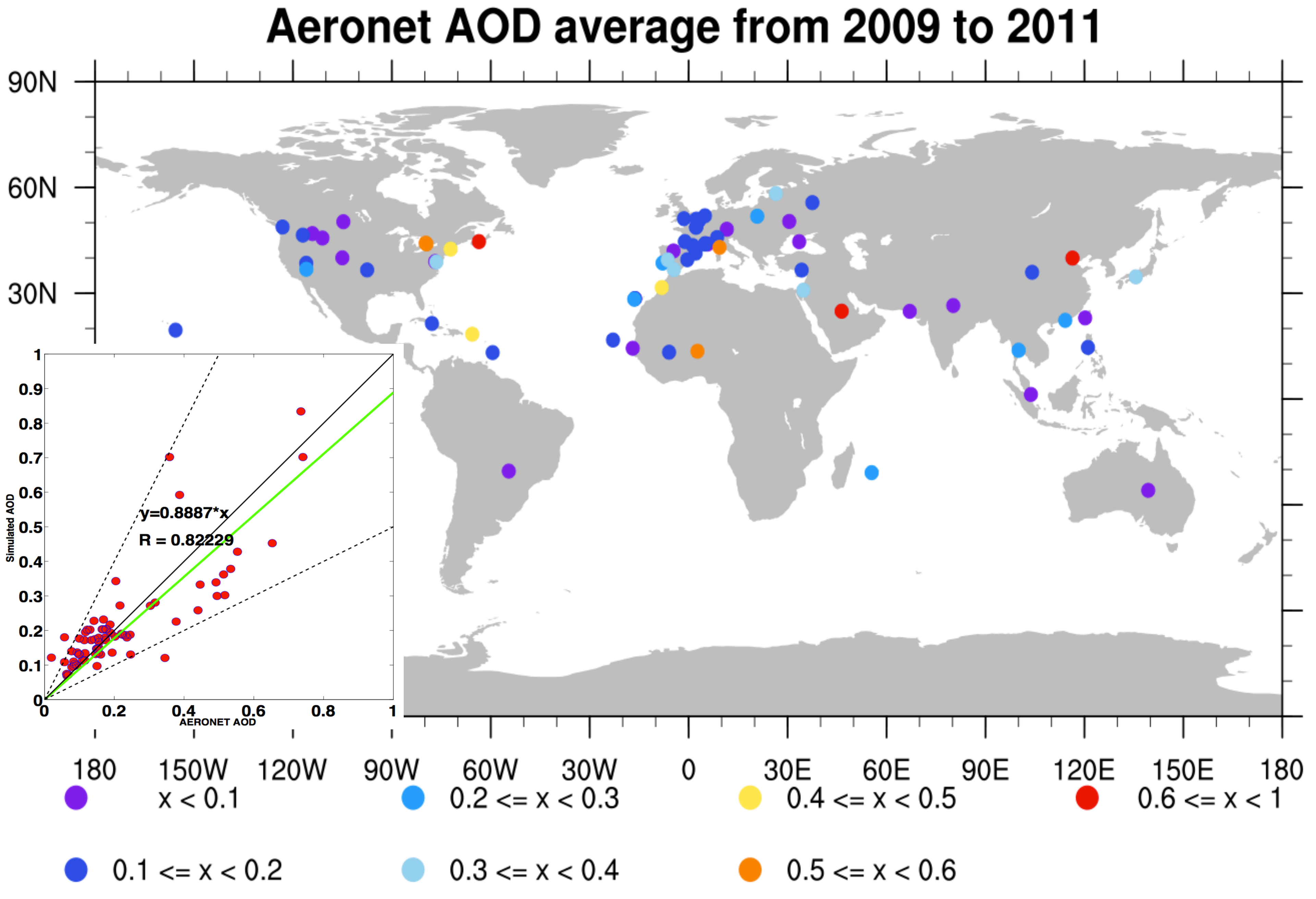
POA includes biomass burning organics, anthropogenic organics, marine organics and biological particles.



Model Captures Aerosol Optical Depth distribution



Model captures 89% of AeRoNet AOD on average



P1. CARMA Applied to UTLS:

- **Aerosol composition in UTLS and above:**

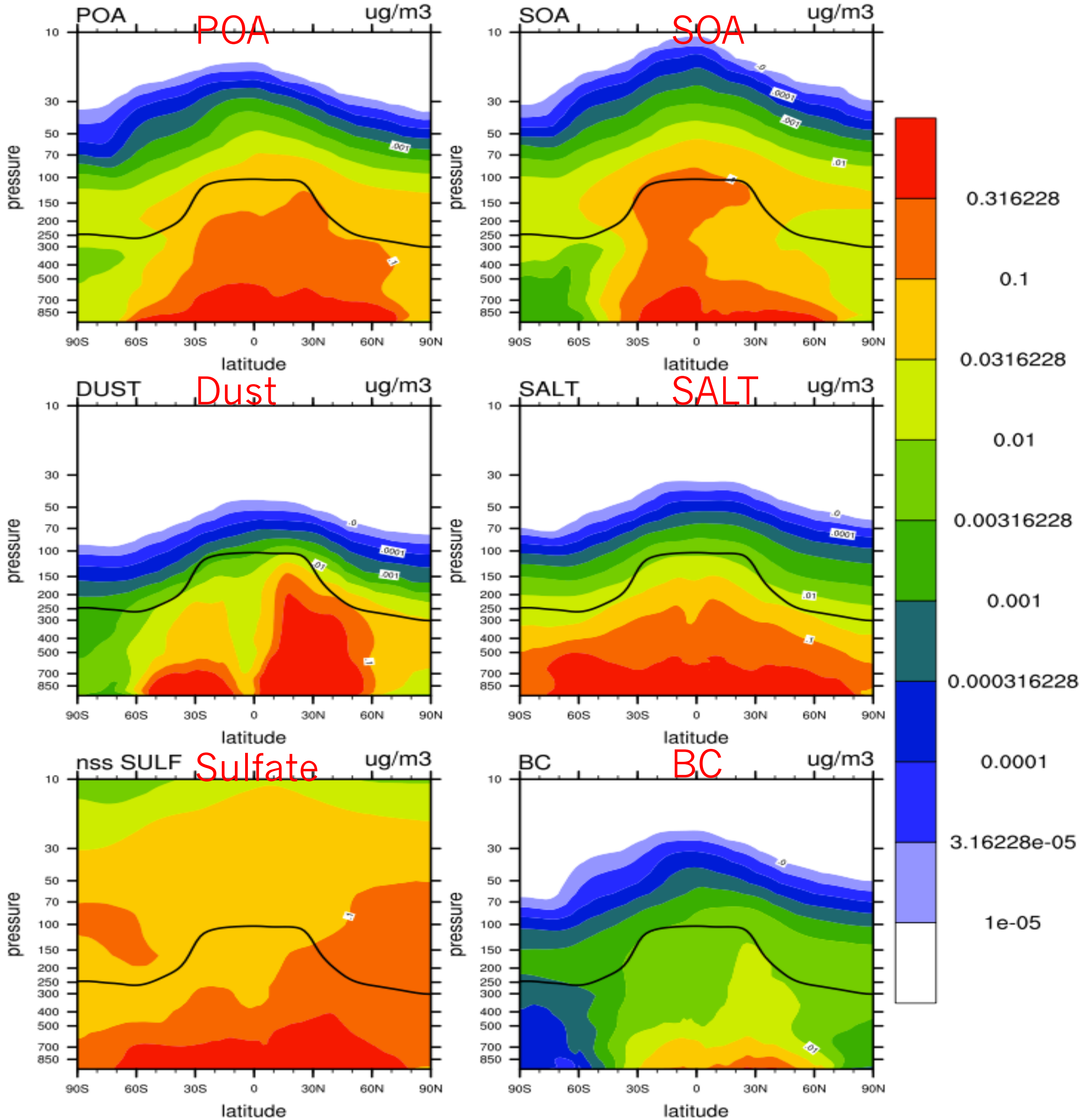
  Sulfate ≈ Organics @ UTLS

- **Aerosol properties in UTLS and above**

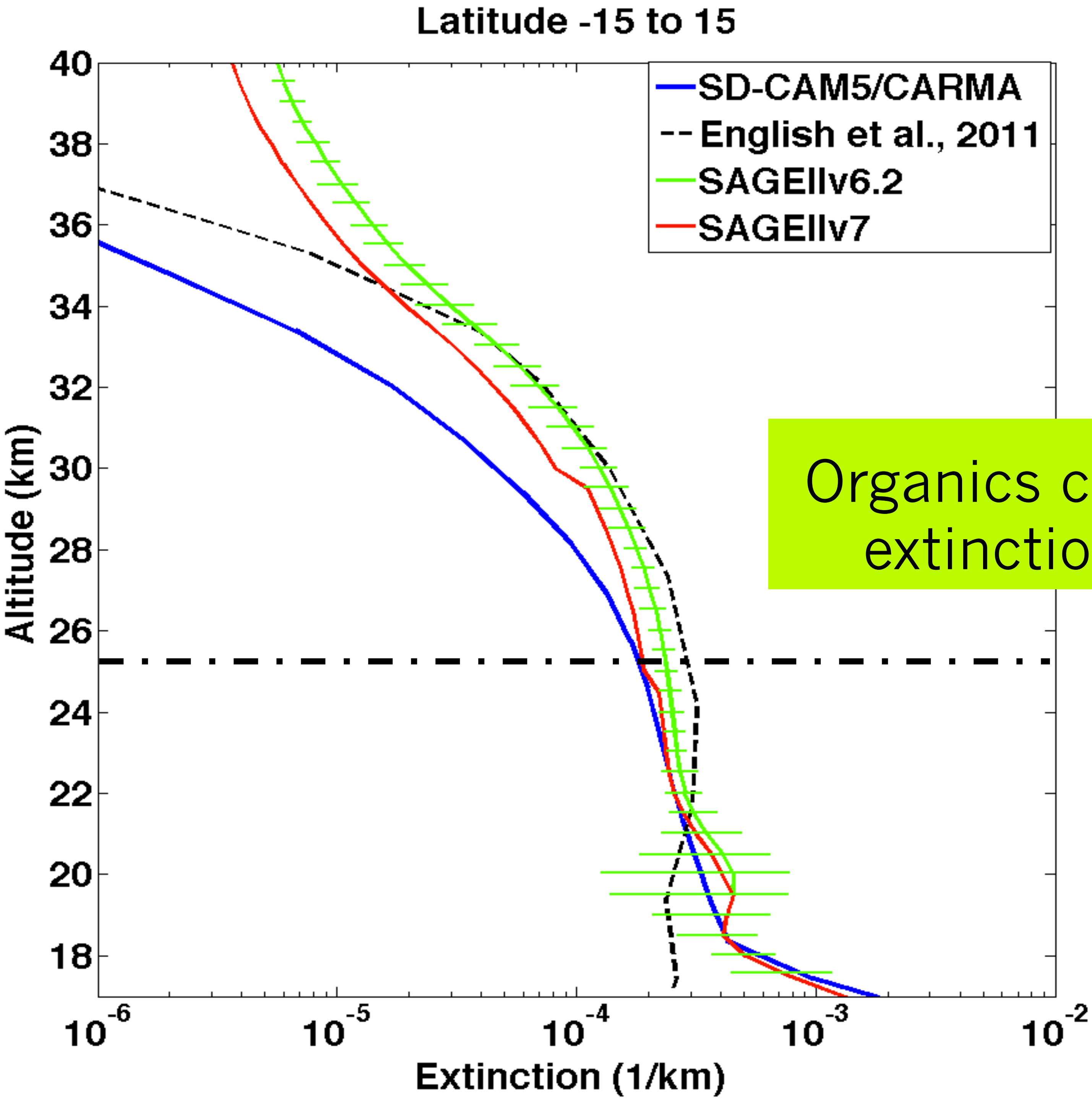
  Size distribution, Effective Radius

- **ATAL, NATAL**

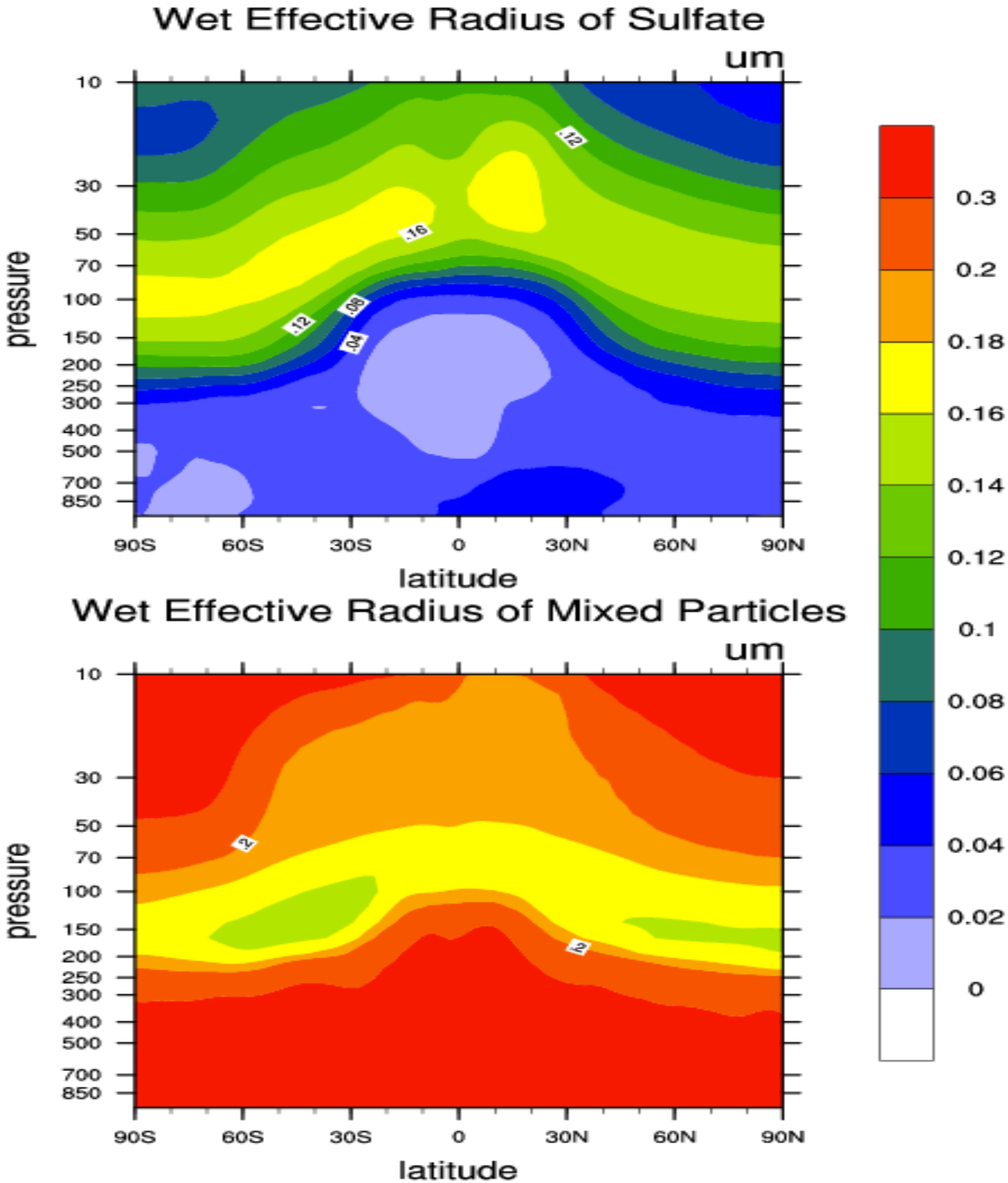
  Aerosol composition



In the UTLS, organics and sulfate dominate



Organics contributes to extinction at UTLS

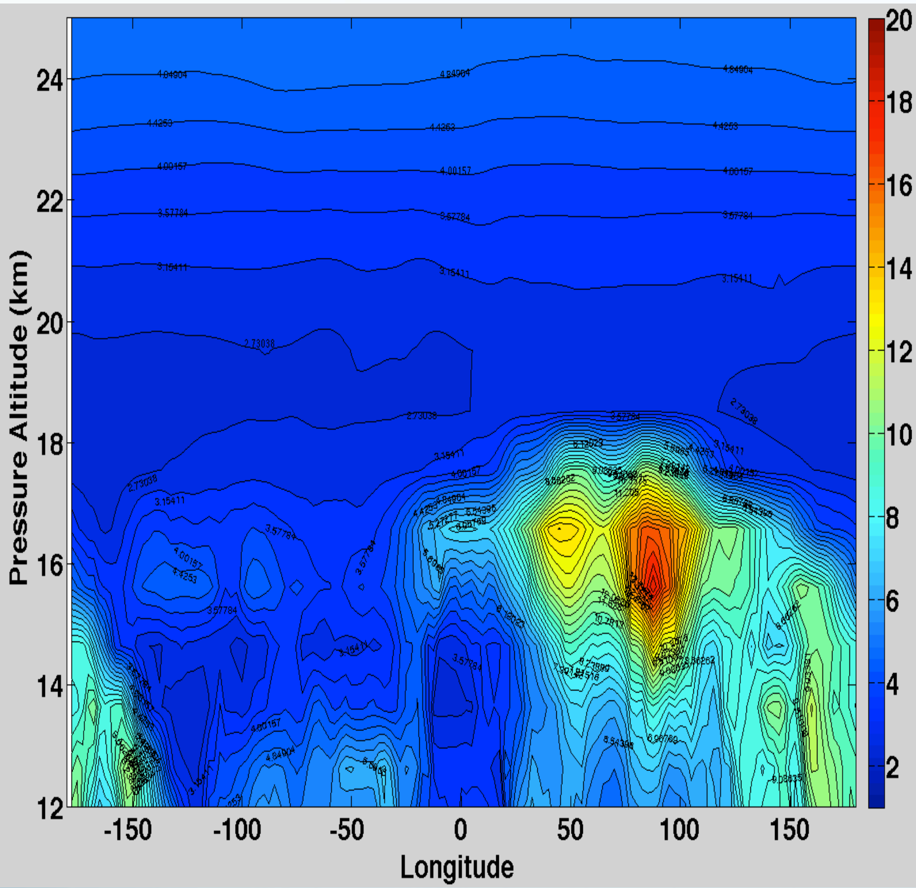


Sulfate effective radius is between 0.1 to 0.18 um in stratosphere

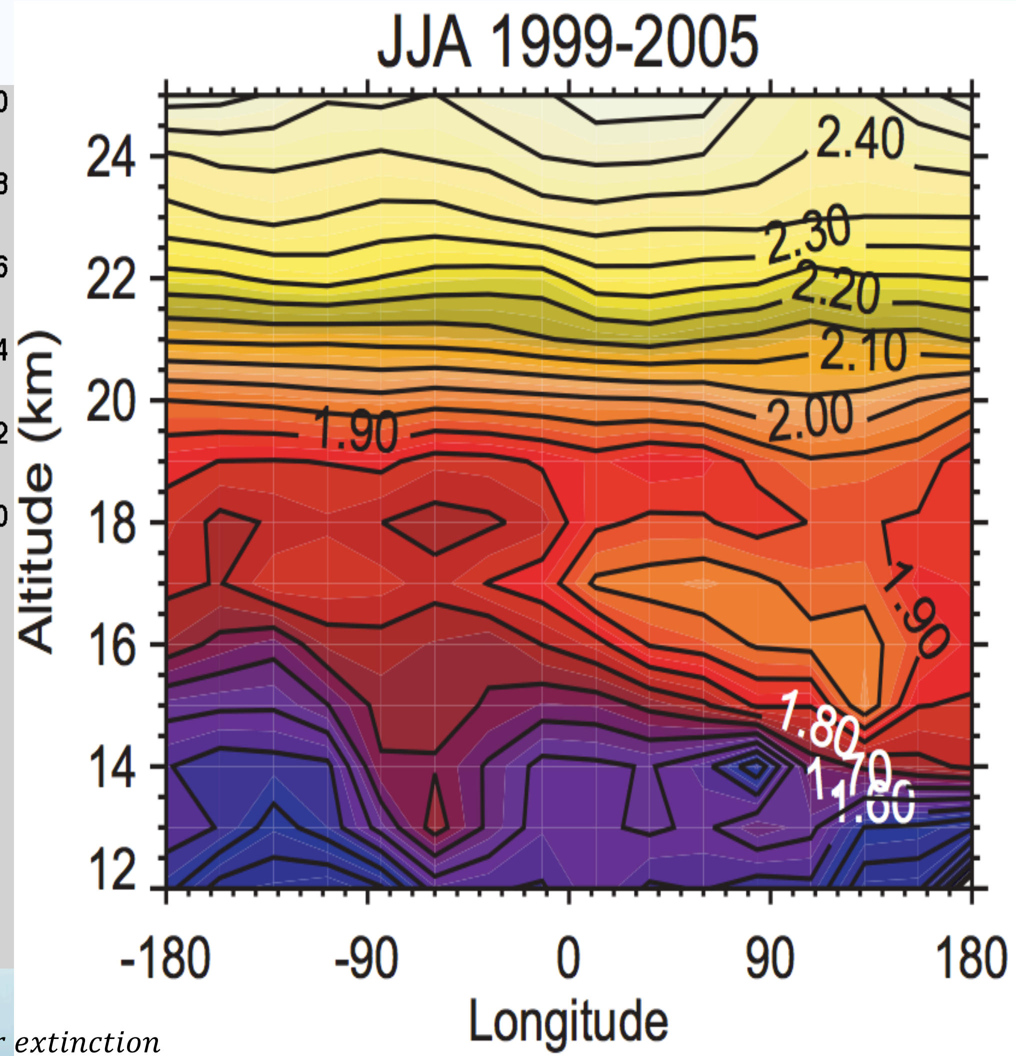
Mixed particles effective radius at UTLS is 0.16 um

CARMA predicts aerosol layer in UTLS over Asia and North America

Extinction Ratio at 1020 nm

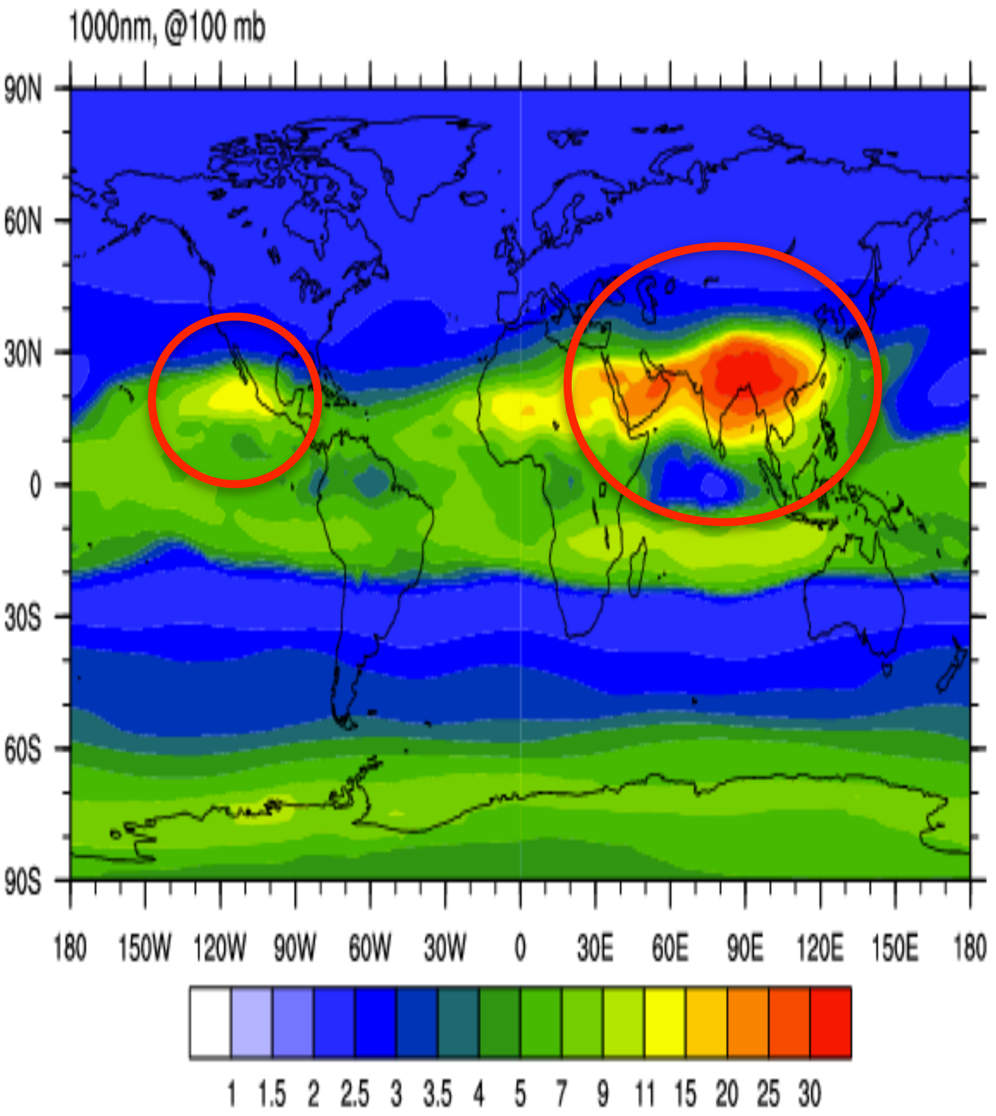


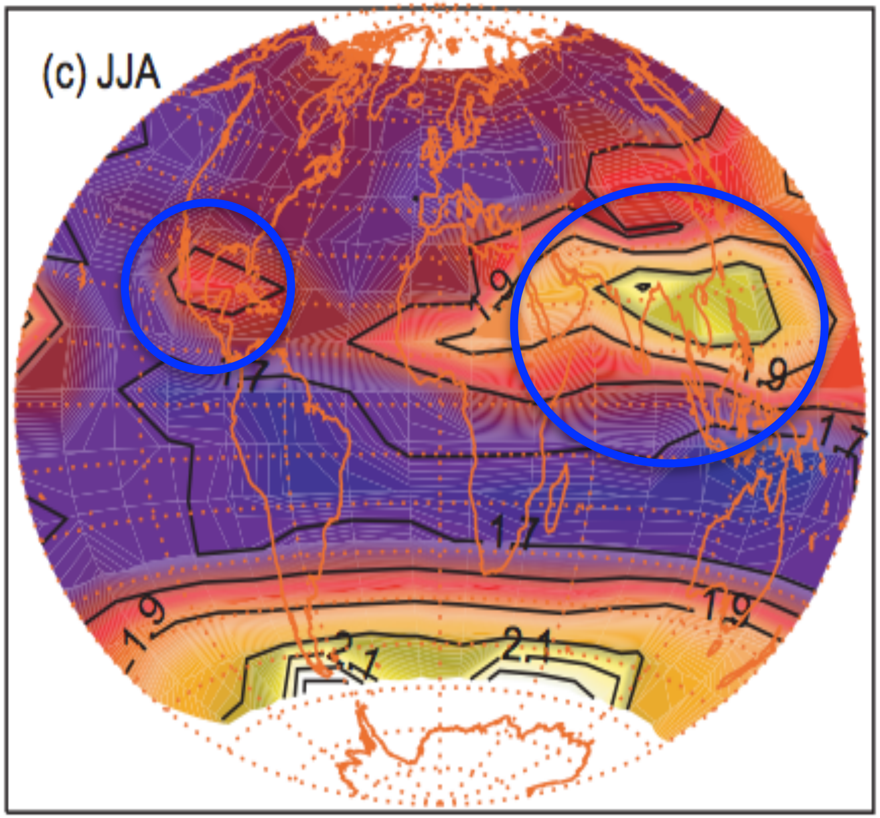
Total extinction/molecular extinction



$$\text{Extinction Ratio} = \frac{aerosol\ extinction + molecular\ extinction}{molecular\ extinction}$$

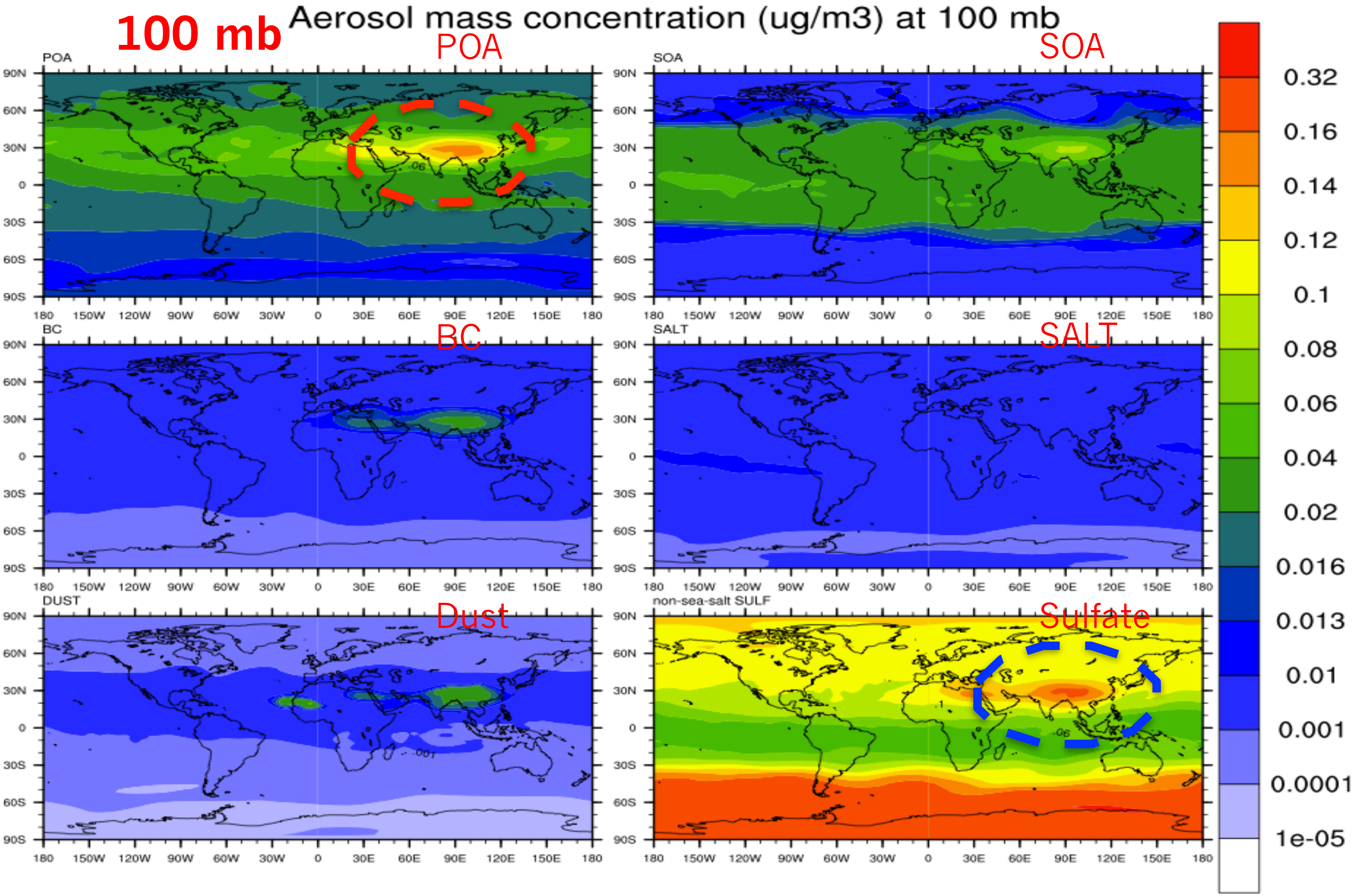
CARMA extinction ratio has maximum in ATAL and NATAL



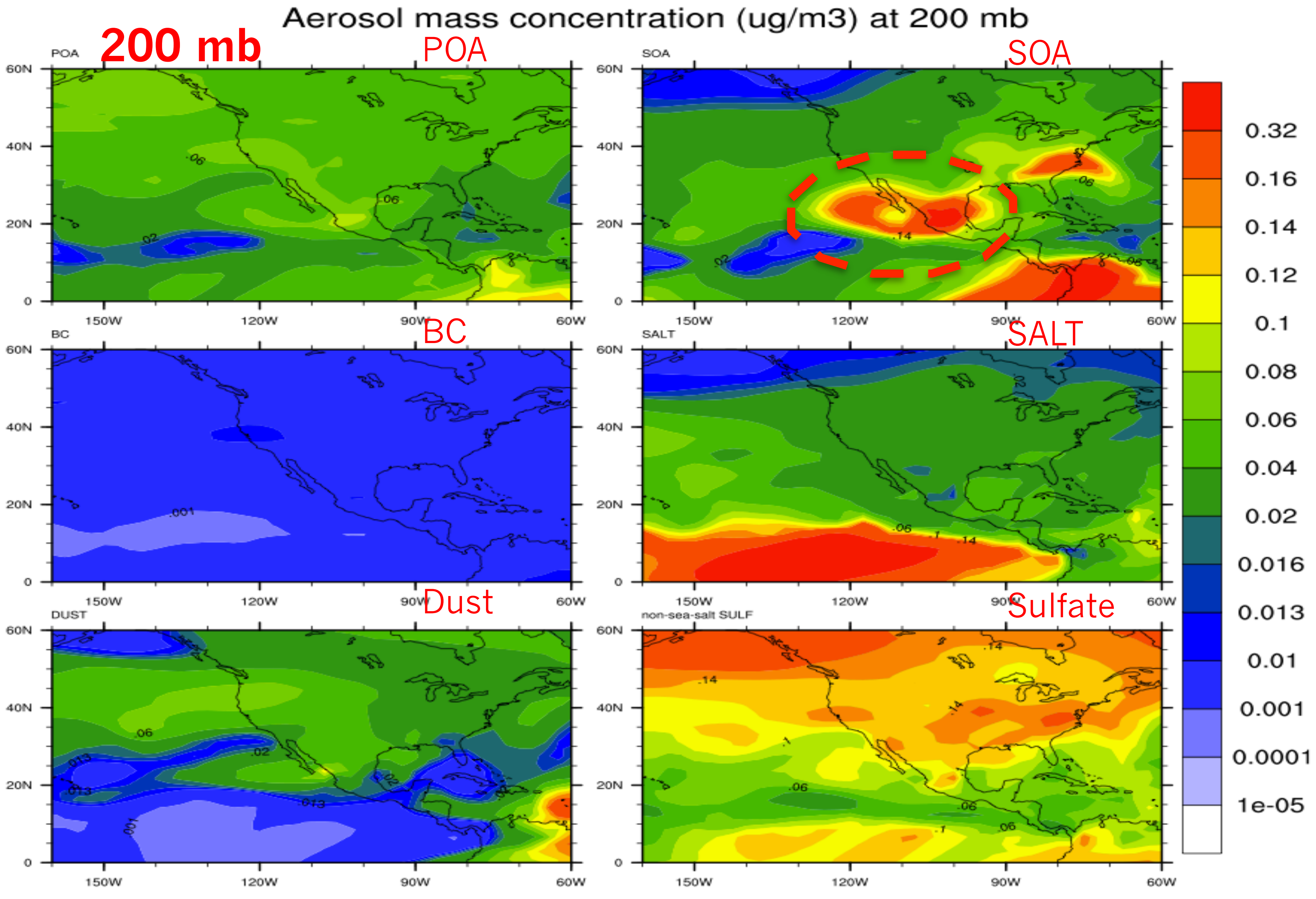


Extinction Ratio at 1020 nm

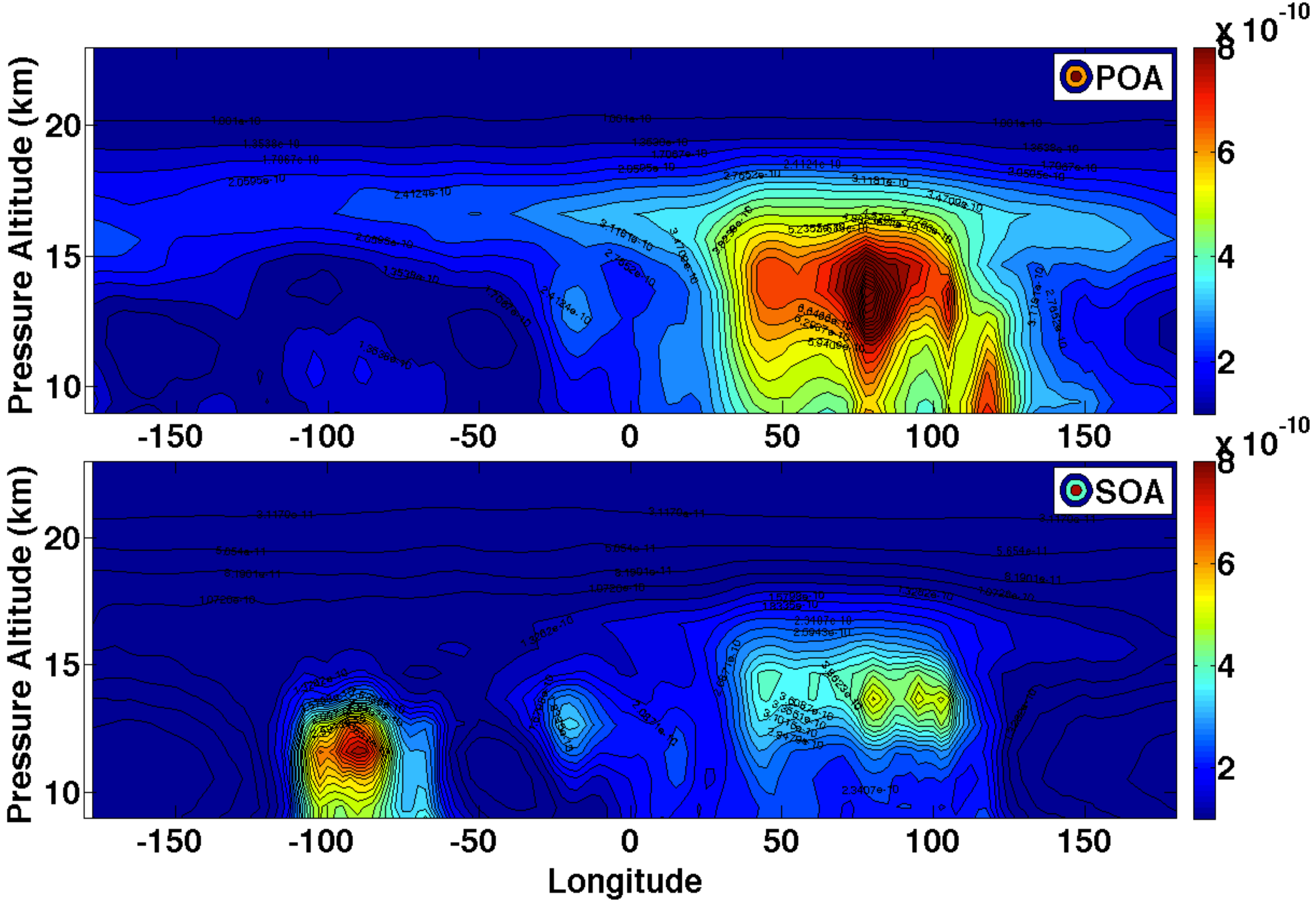
Asian Tropopause Aerosol Layer is mainly composed of POA and sulfate



NA "Tropopause" Aerosol Layer is mainly composed of SOA

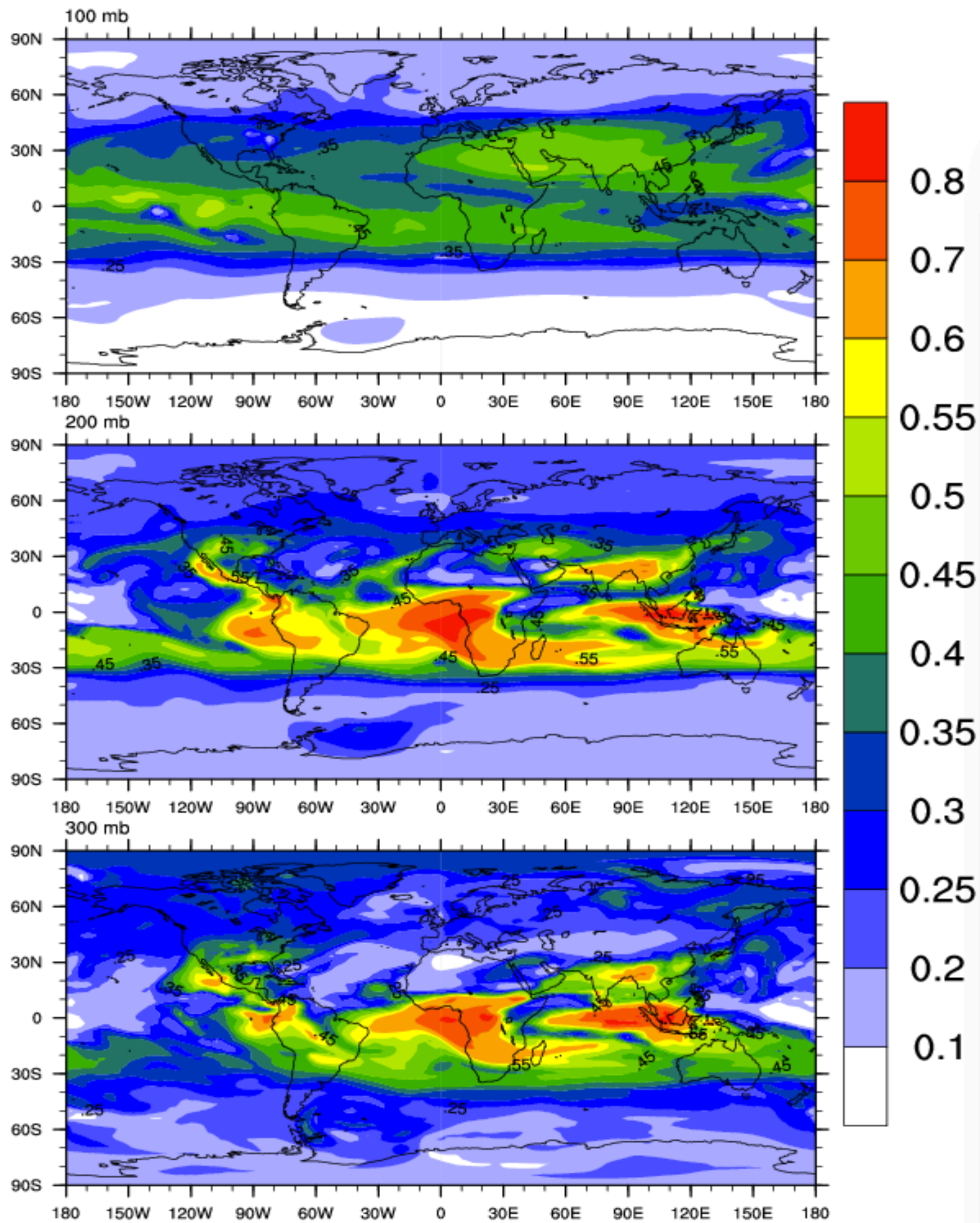


ATAL is composed of POA; NATAL is composed of SOA



Strong gradient of organic mass fraction from Europe to India/China in upper troposphere

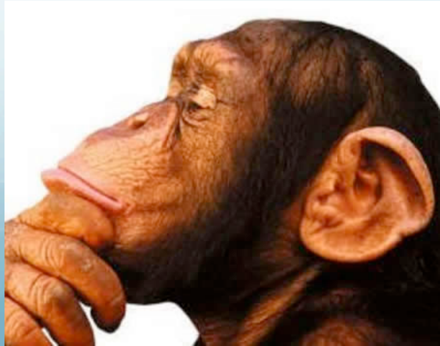
Organics/Sulfate mass fraction at multiple pressure levels



$$\frac{organics}{organics + sulfate}$$

Conclusions P1

- At UTLS, sulfate mass ≈ organics mass; above UTLS, sulfate dominates;
- Sulfate effective radius is roughly 0.1~0.18 um in stratosphere;
- Mixed particle effective radius is roughly 0.16 um in UTLS;
- CARMA does predict ATAL and NATAL during JJA;
- ATAL is mostly composed of organics and sulfate;
- NATAL is mostly composed of SOA, with sulfate as background;



P2. CARMA applied to SEAC^{4}RS

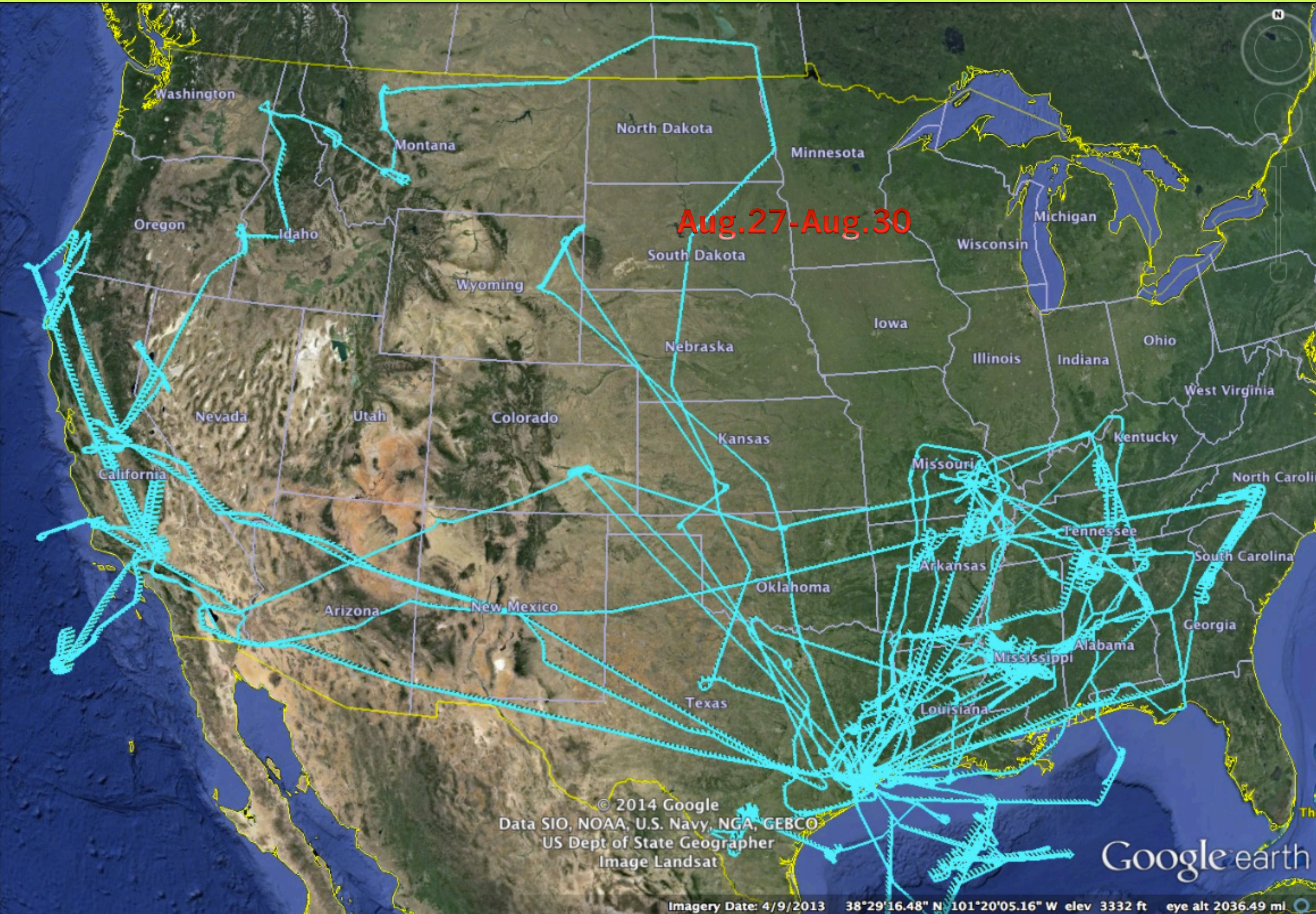
- Aerosol compositions during SEAC^{4}RS:

  Sulfate, Organics, Black Carbon

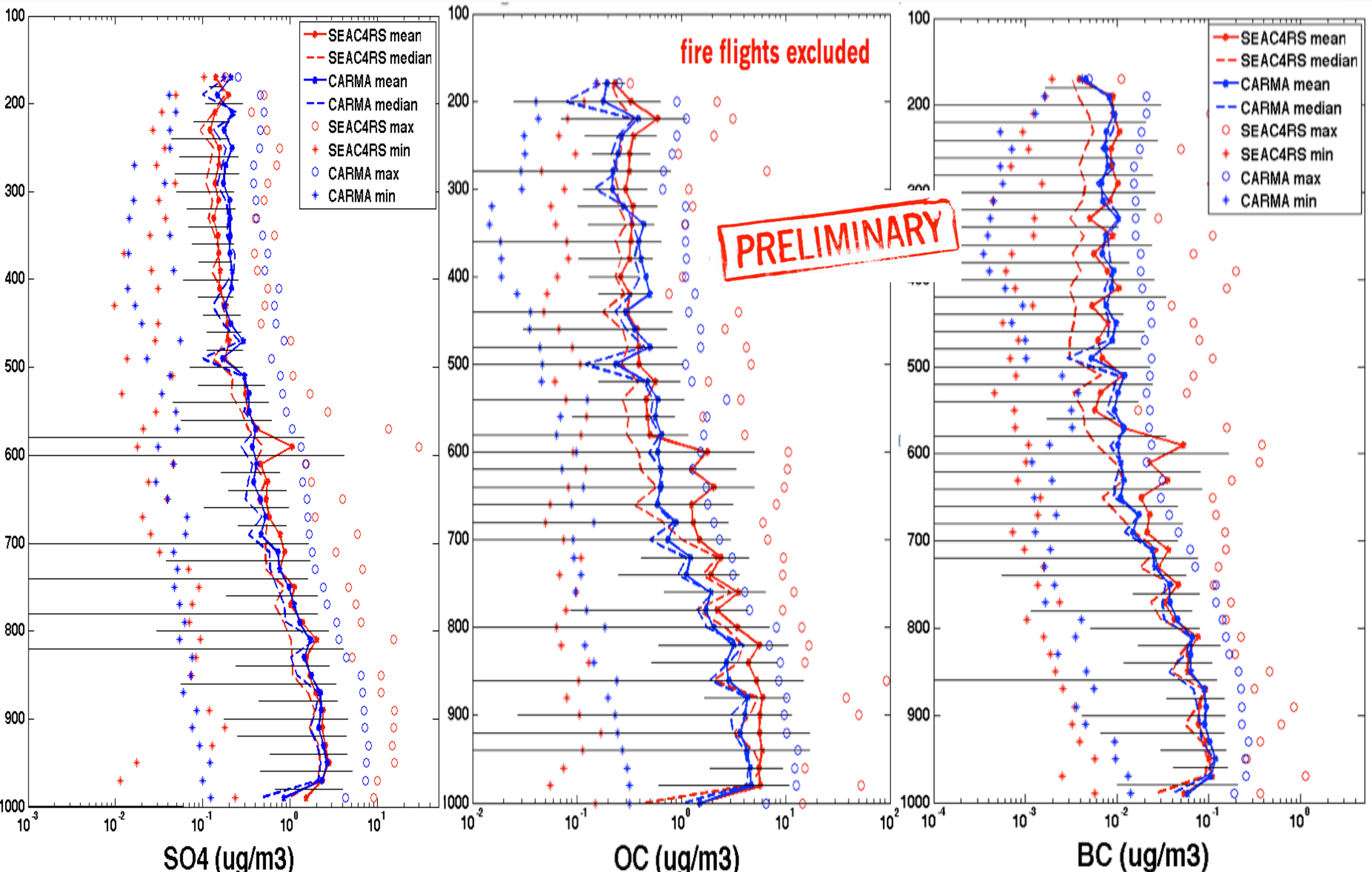
- Aerosol properties

  size distribution, Optics, $OC:SO_4^{-2}$

SEAC^{4}RS - Southeast US: Aug-Sep, 2013



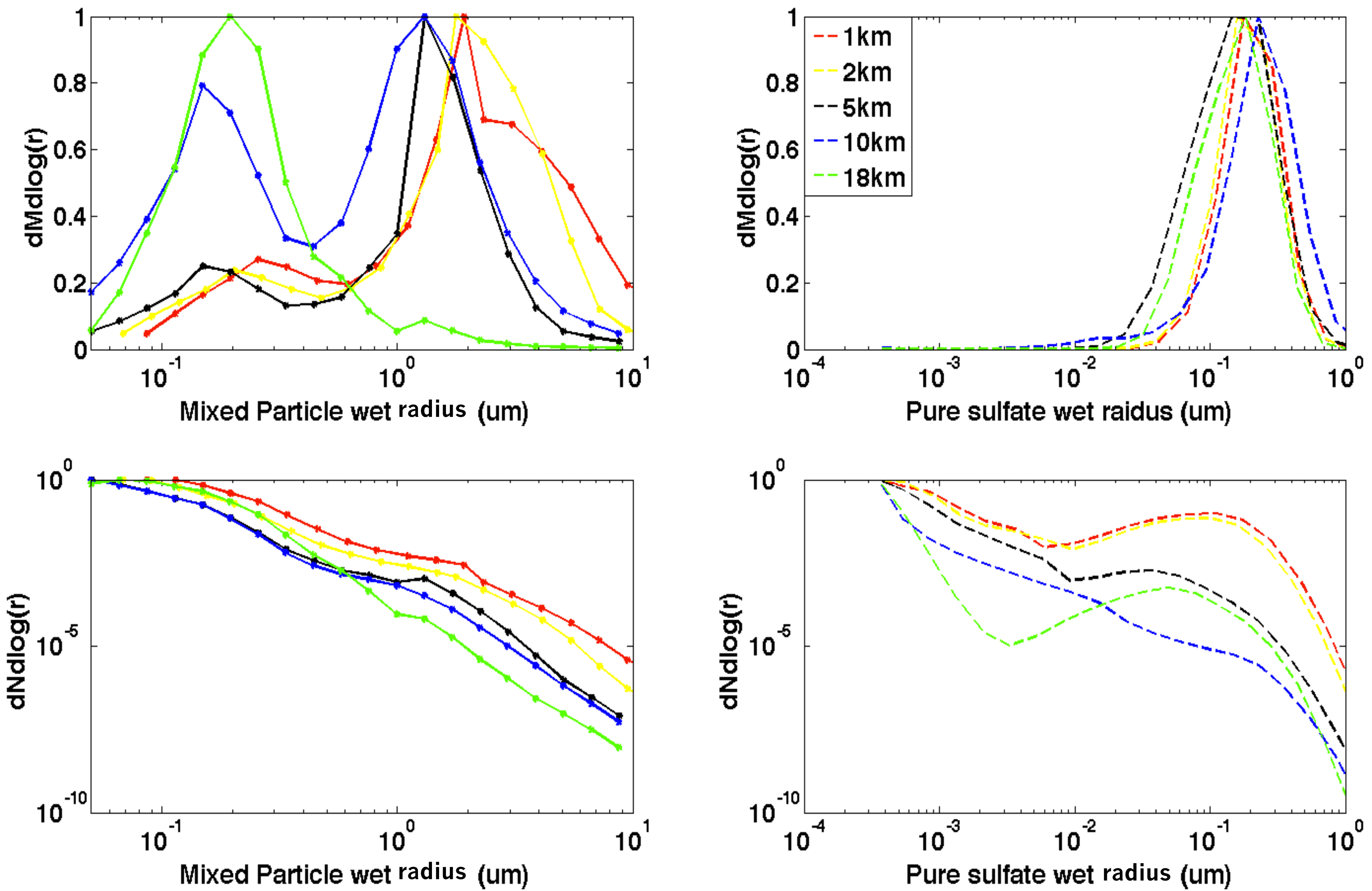
Model captures SO_4/OC/BC in troposphere



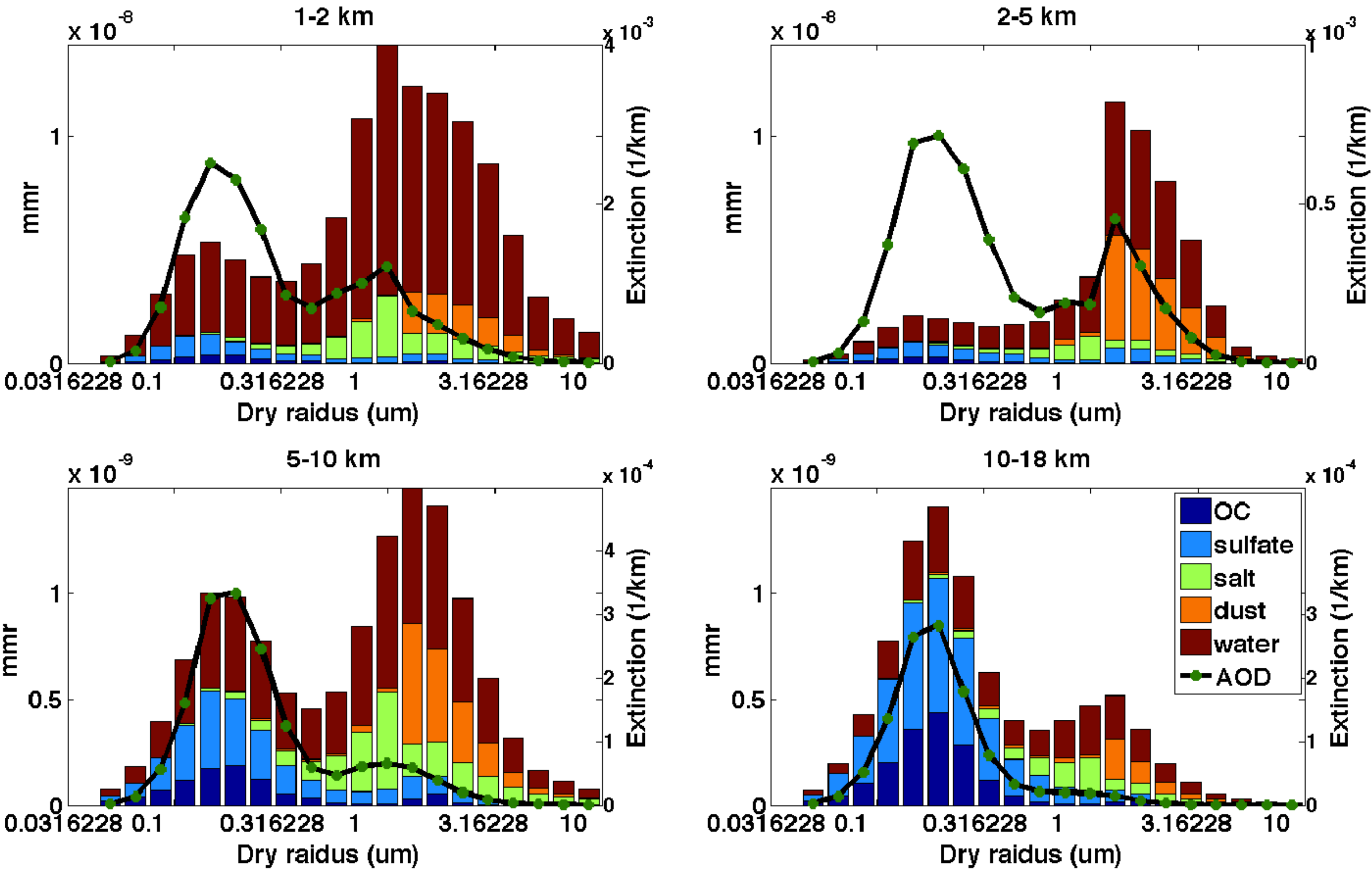
Boulder AMS, Dr Jose-Luis Jimenez

NOAA SP2, Dr Joshua Schwarz

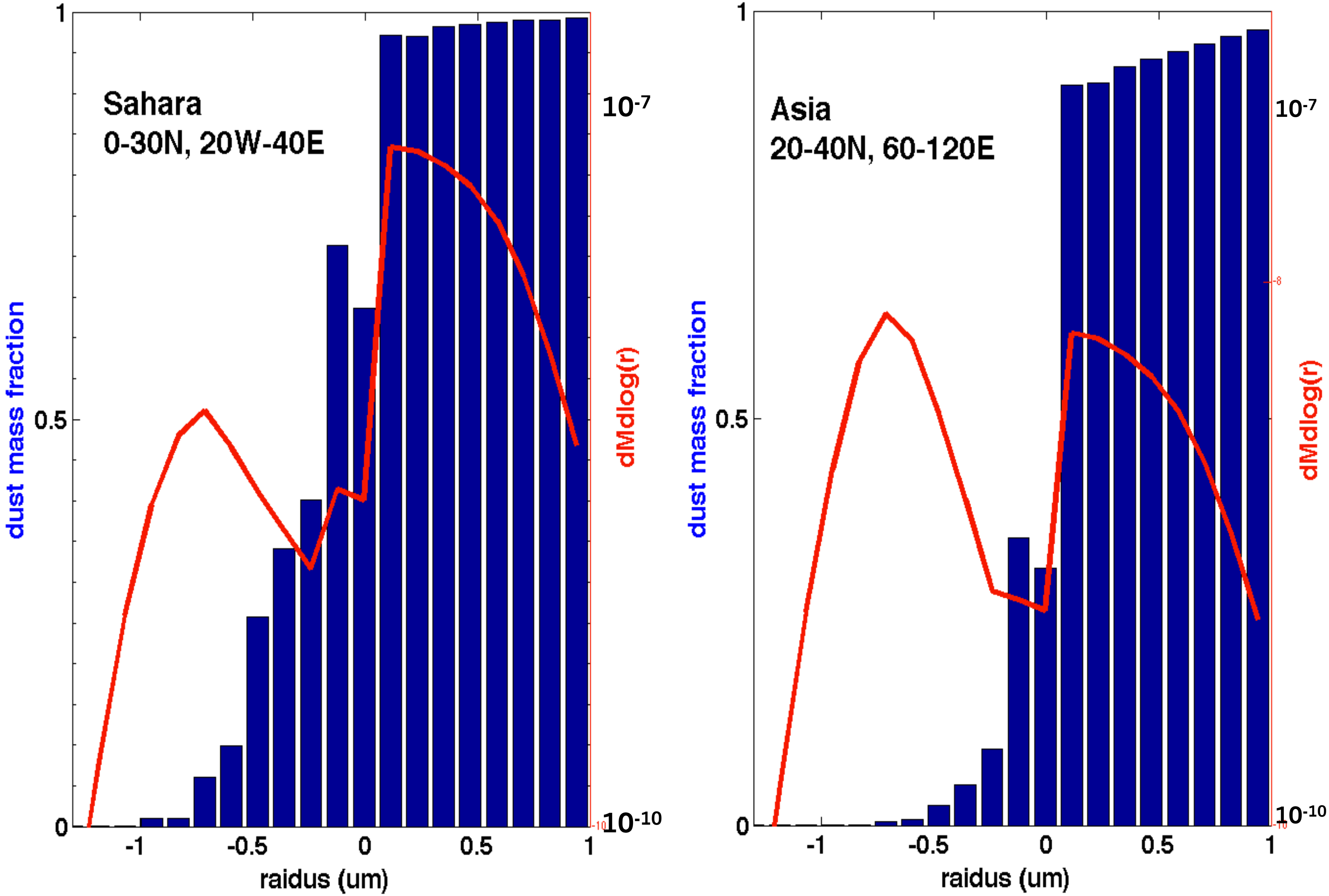
Normalized Size distribution changes with altitude over U.S, mode width changes with composition



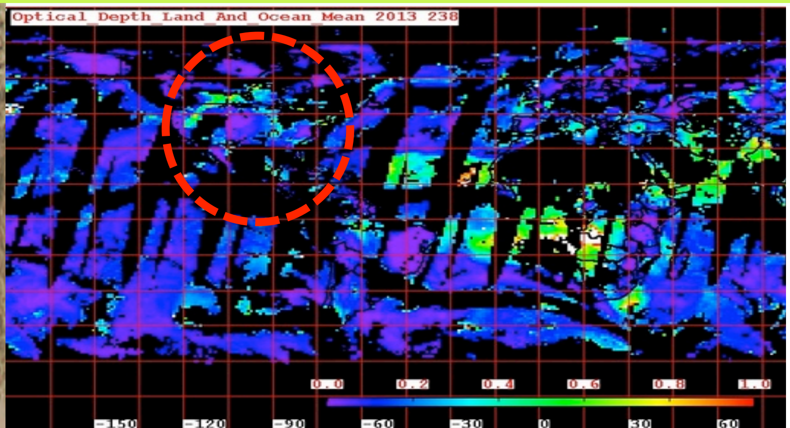
Sub-micron particles dominates optically, varies with altitude over U.S.



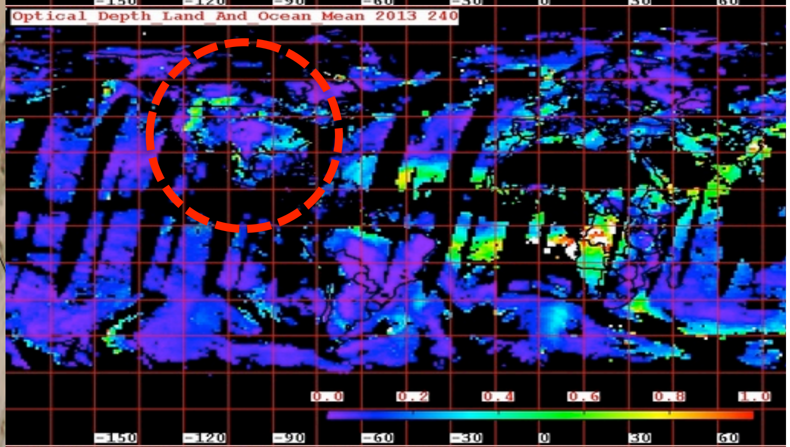
Size distribution over Sahara and Asia (July), dust dominates in super-micron modes



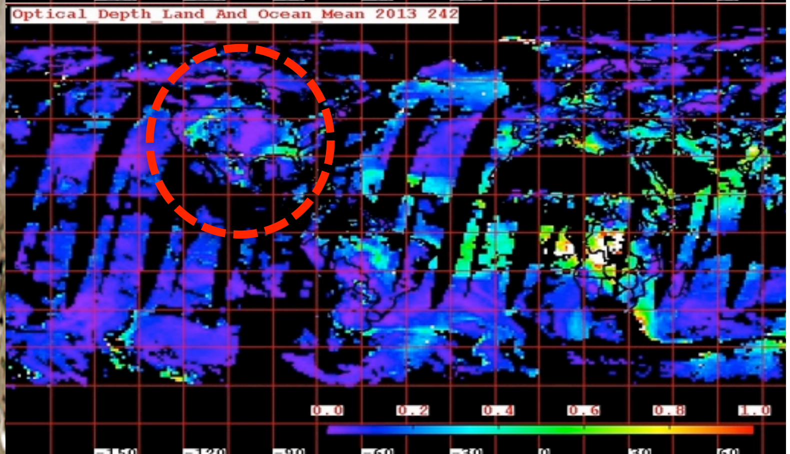
MODIS shows Rim Fire plumes, Aug.2013



Aug.26

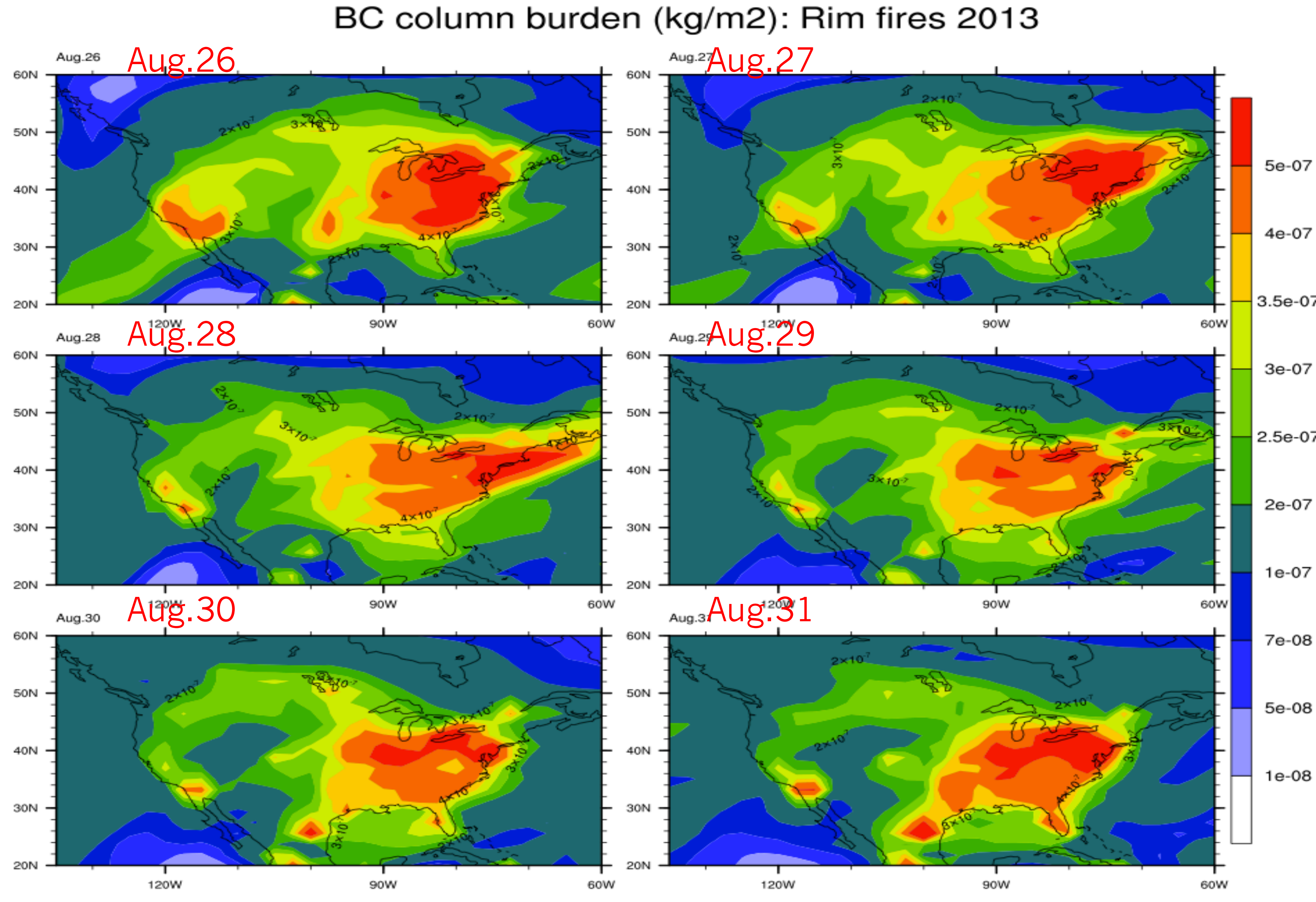


Aug.28



Aug.30

CARMA shows transport of Rim fire smoke



Conclusions P2

- CARMA can reproduce organics, black carbon and sulfate vertical distribution over U.S. within error bars;
- Particles size distribution varies with altitude;
- Sub-micron particles dominate optically in U.S.
- 2-degree climate model is not able to resolve aerosol intensity of smoke plumes;
- CARMA does show regional transport of smoke

Future work

1. Graduate
2. Add ammonium and nitrate
3. Climate forcing (direct)
4. Climate forcing (secondary)

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NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

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@ Houston, SEAC^{4}RS, Sep.2013