The impact of size-resolved aerosol microphysics on cloud properties and photochemistry in CESM

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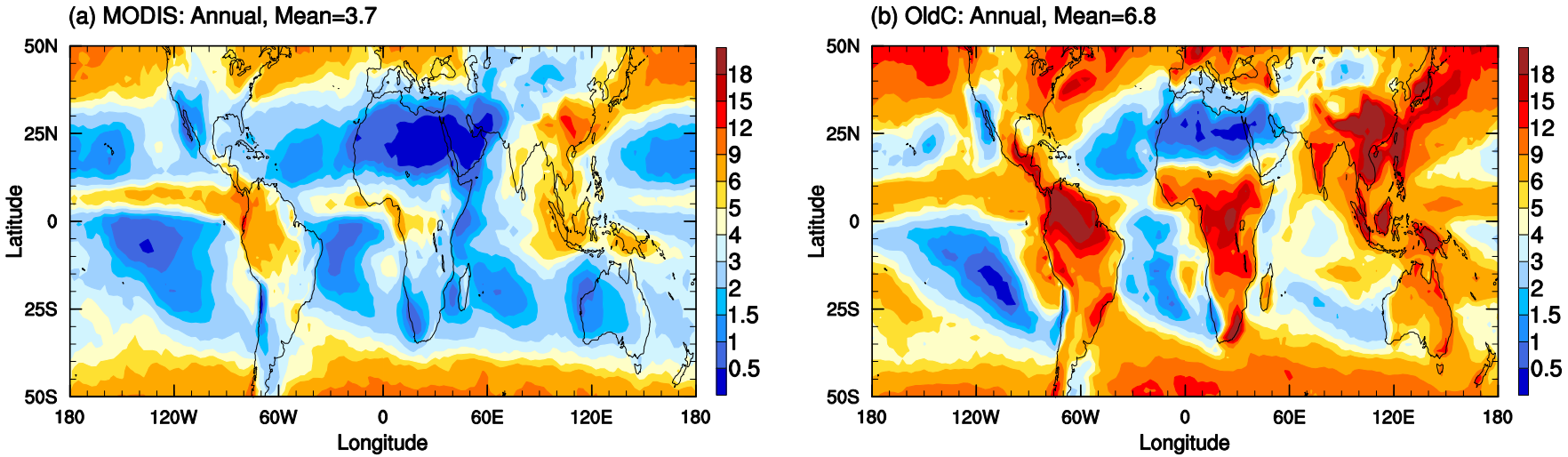
Introduction

By scattering and absorbing solar radiation, clouds modify photochemistry reaction rate

COD used for CAM-Chem photochemistry (OldC)

$$COD_{in} = \frac{3}{2}\frac{CWP}{\rho_{water} \cdot r_e}$$ **Slingo and Schrecker, 1982**

$$COD_r = COD_{in} \cdot CF^{\frac{3}{2}}$$ **Briegleb, 1992**

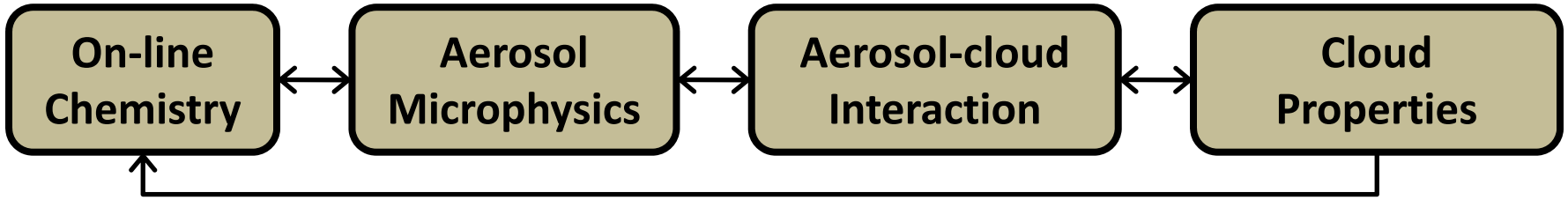


The Biases are large

- **Can we improve the agreement of COD by considering the impact of aerosol microphysics on cloud properties?**
- **How does it impact photochemistry and [OH]?**

Incorporation of sectional aerosol microphysics in CESM

Provide a new method which can represent the relationships among aerosol, droplet, COD, and tropospheric photochemistry



1. **On-line chemistry: MOZART + 2 product SOA scheme**
2. **Aerosol microphysics: the Advanced Particle Microphysics (APM)**

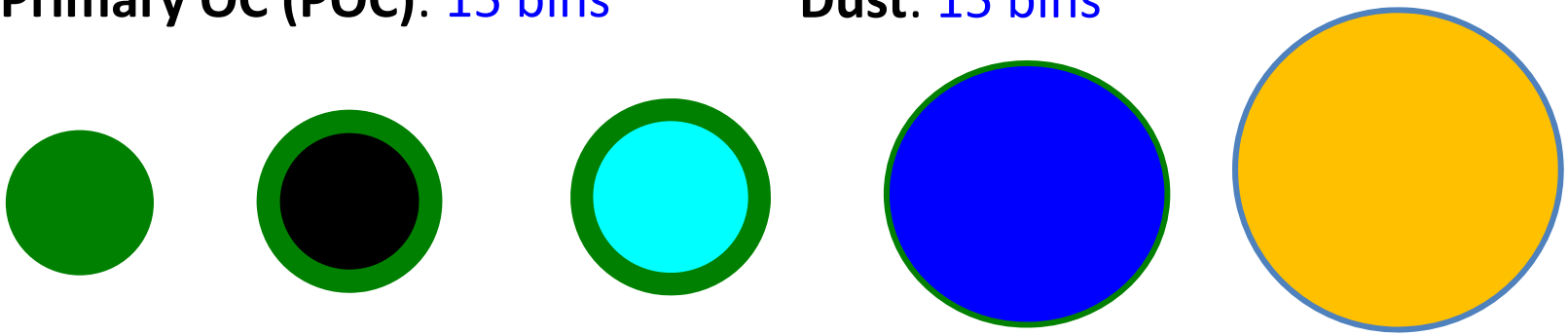
Secondary particles (SP) : **40** bins, composed of SO4, NIT, NH4, SOA

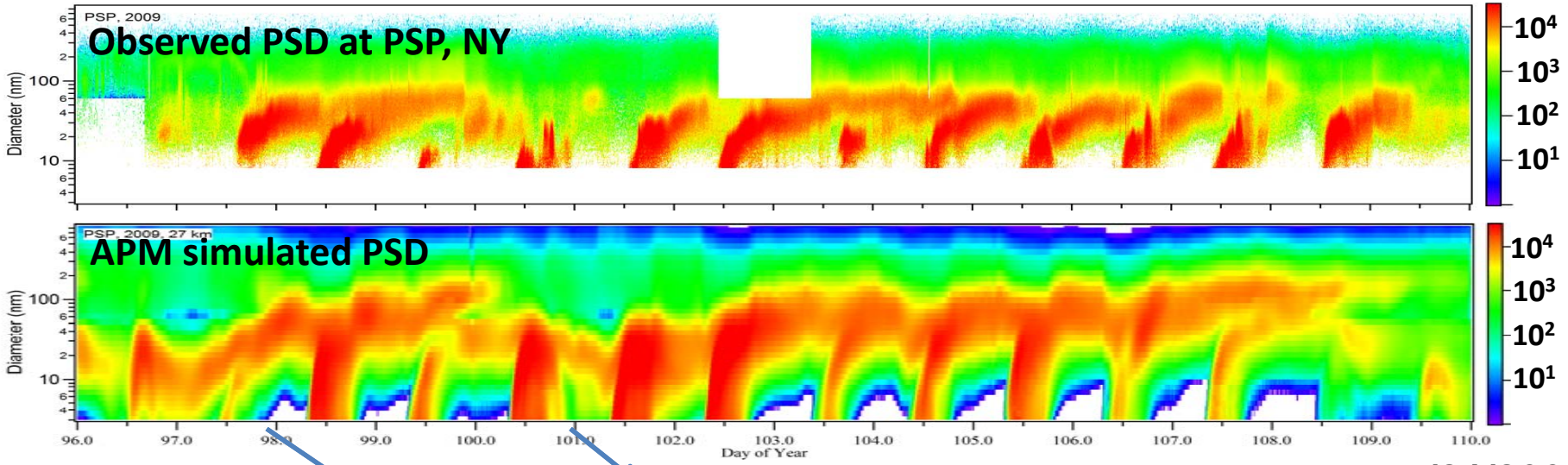
Black Carbon (BC): 15 bins

Primary OC (POC): 15 bins

Sea salt (SS): 20 bins

Dust: 15 bins





4/7/2009

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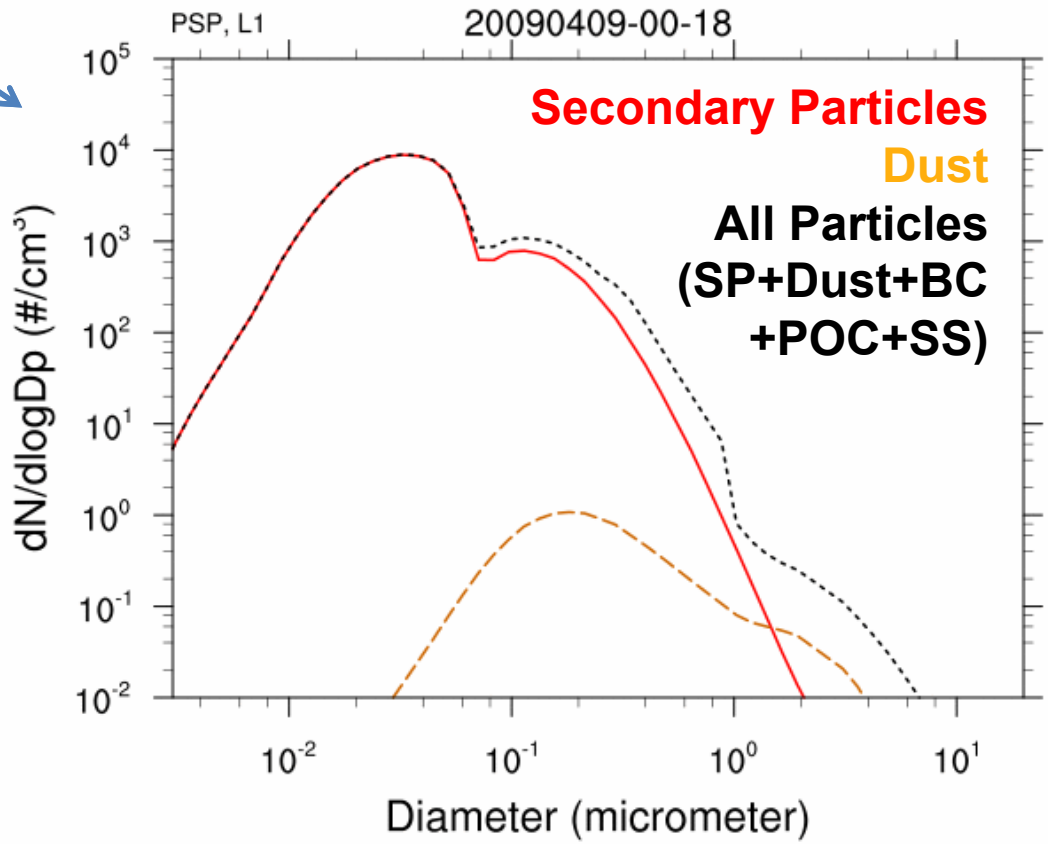
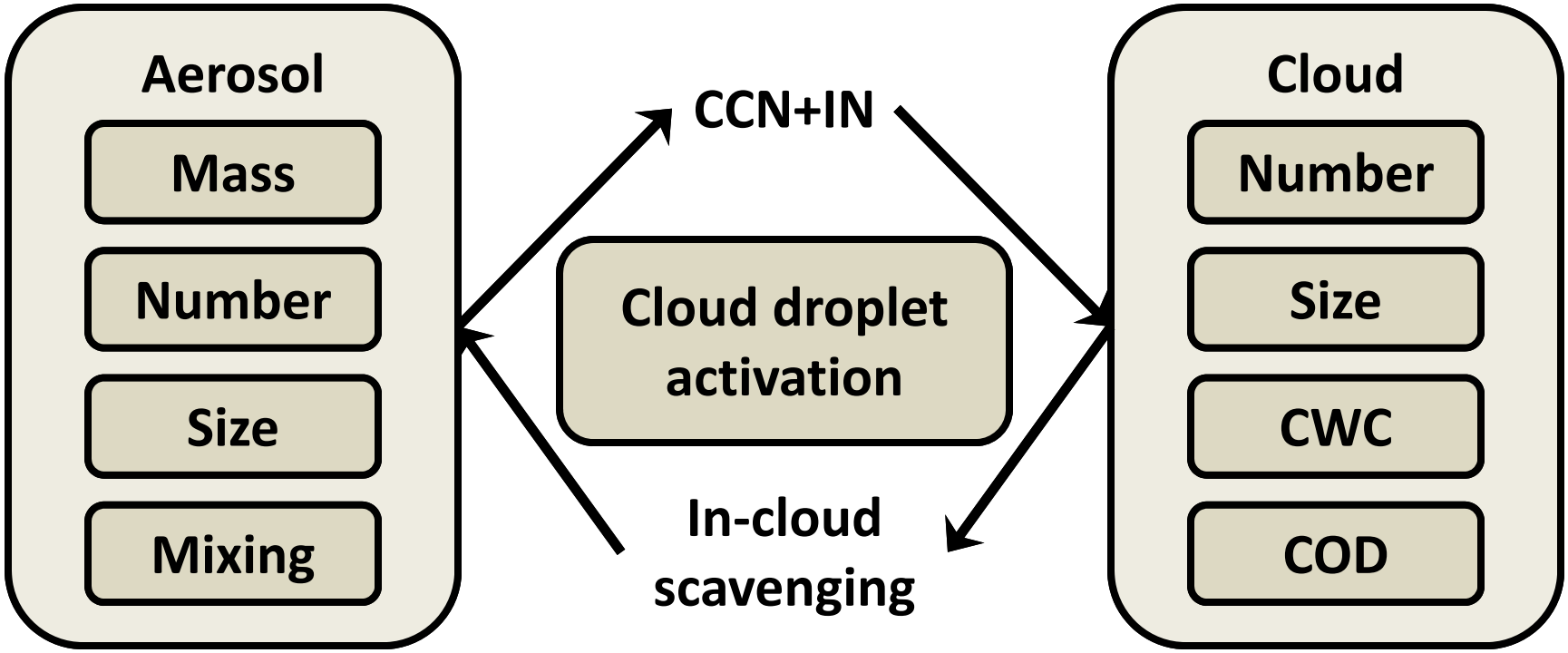
Particle formation, growth and contribution to CCN



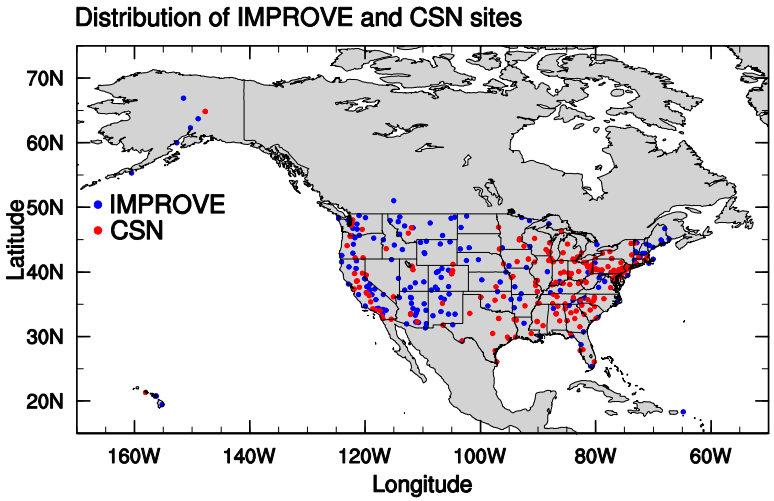
Incorporation of sectional aerosol microphysics in CESM

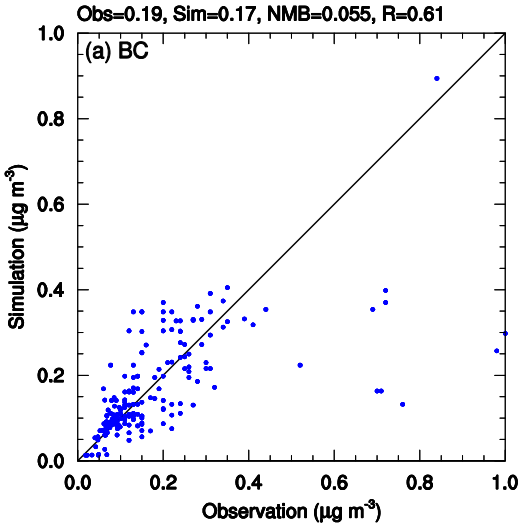
3. Aerosol-cloud interaction

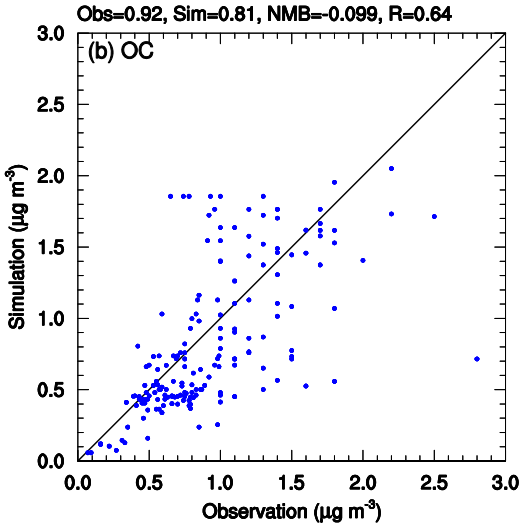


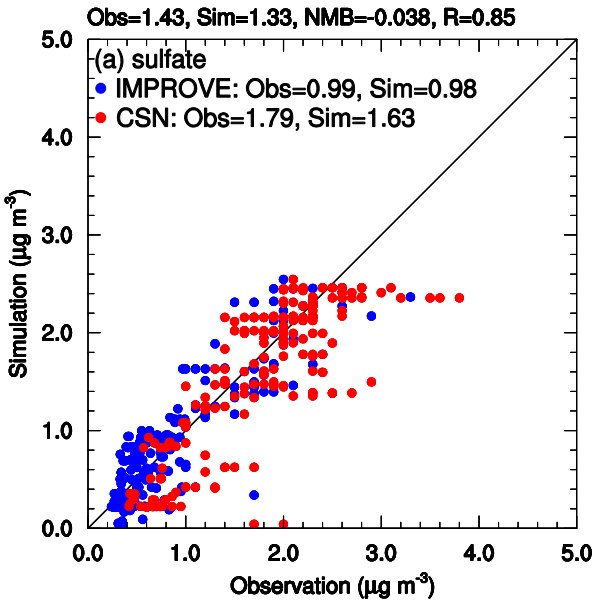
4. Cloud properties and impacts on atmospheric chemistry
   a. Cloud Water Content ⇨ aqueous chemistry
   b. Cloud Optical Depth ⇨ photolysis rate ⇨ SP precursors

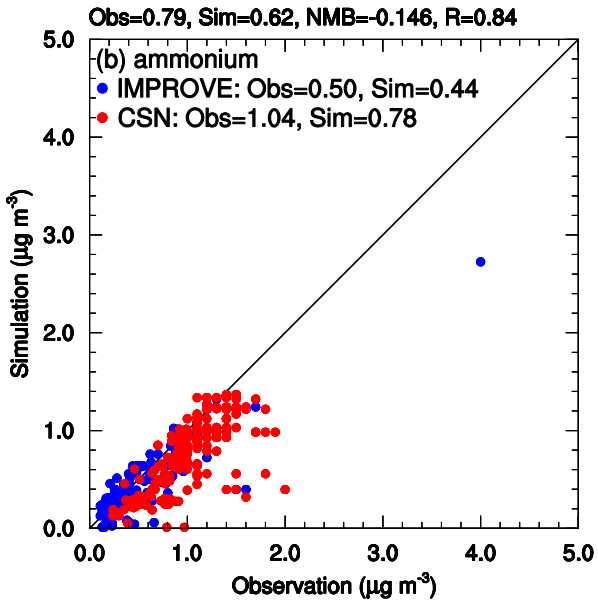
Validation of Aerosol Mass

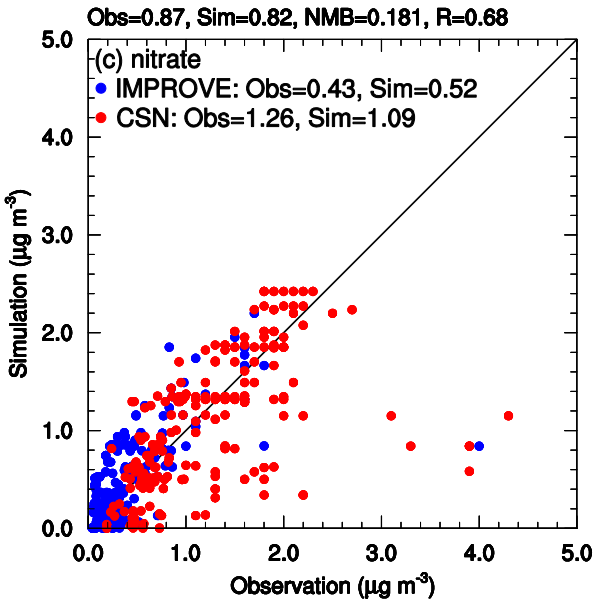




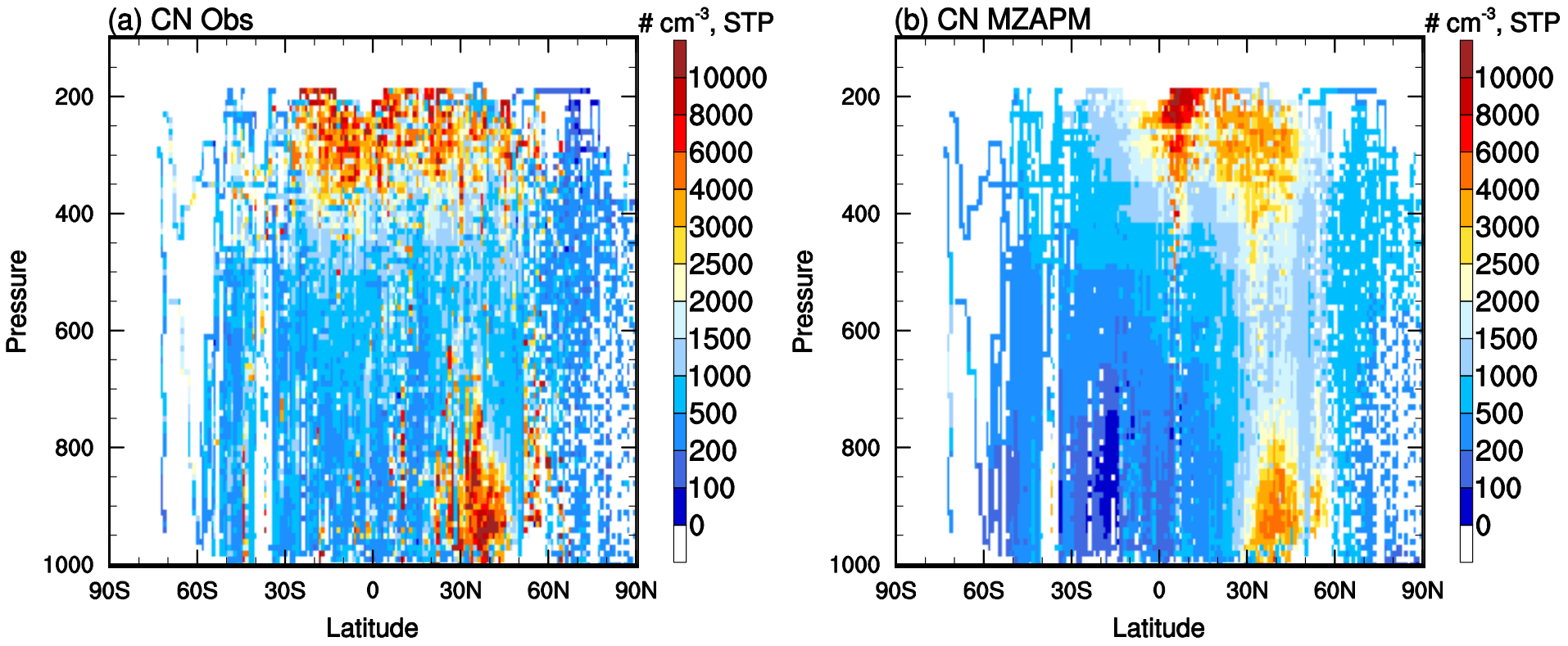






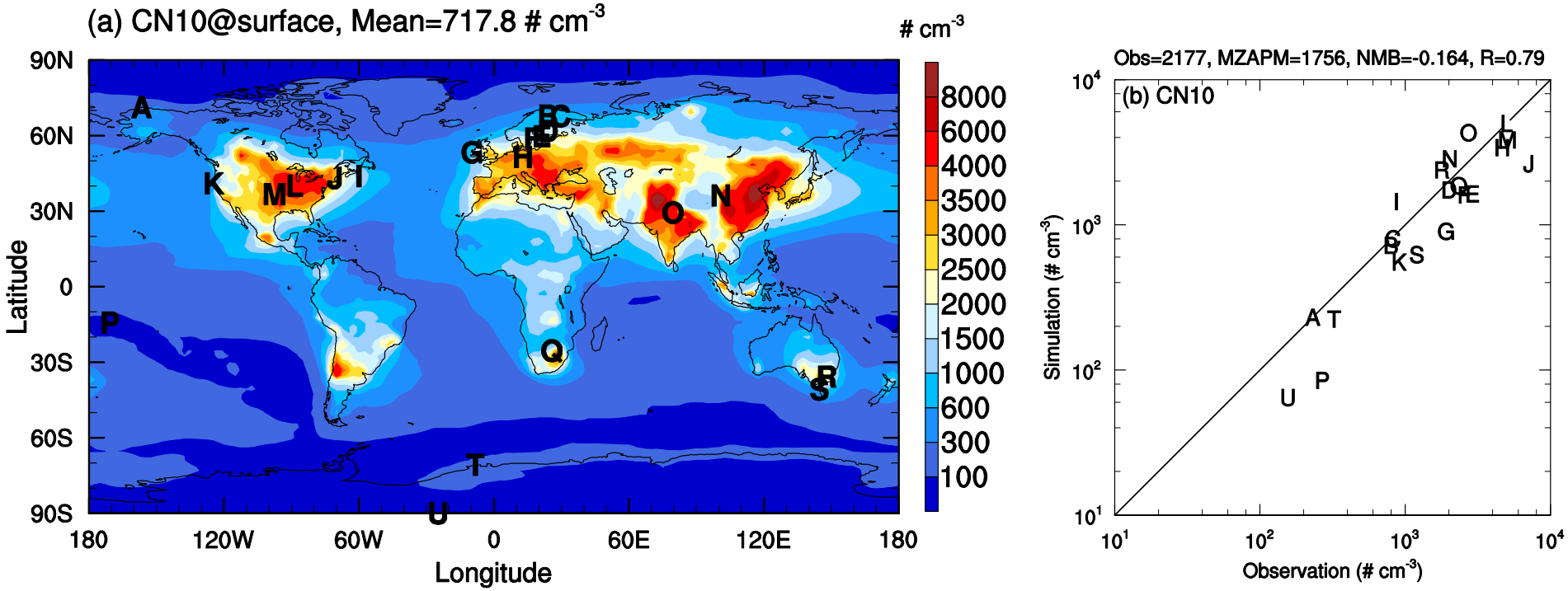


Validation of Ultra-fine Aerosol I: CN3 (Diameter > 3 nm)



Aircraft measurements: ~30,000 samples collected from GLOBE, ACE-1, PEM-Tropics A and B, TRACE-P, INTEX-A and B, NAMMA, TC-4, and ARCTAS

Validation of Ultra-fine Aerosol II: CN10 (Diameter > 10 nm)



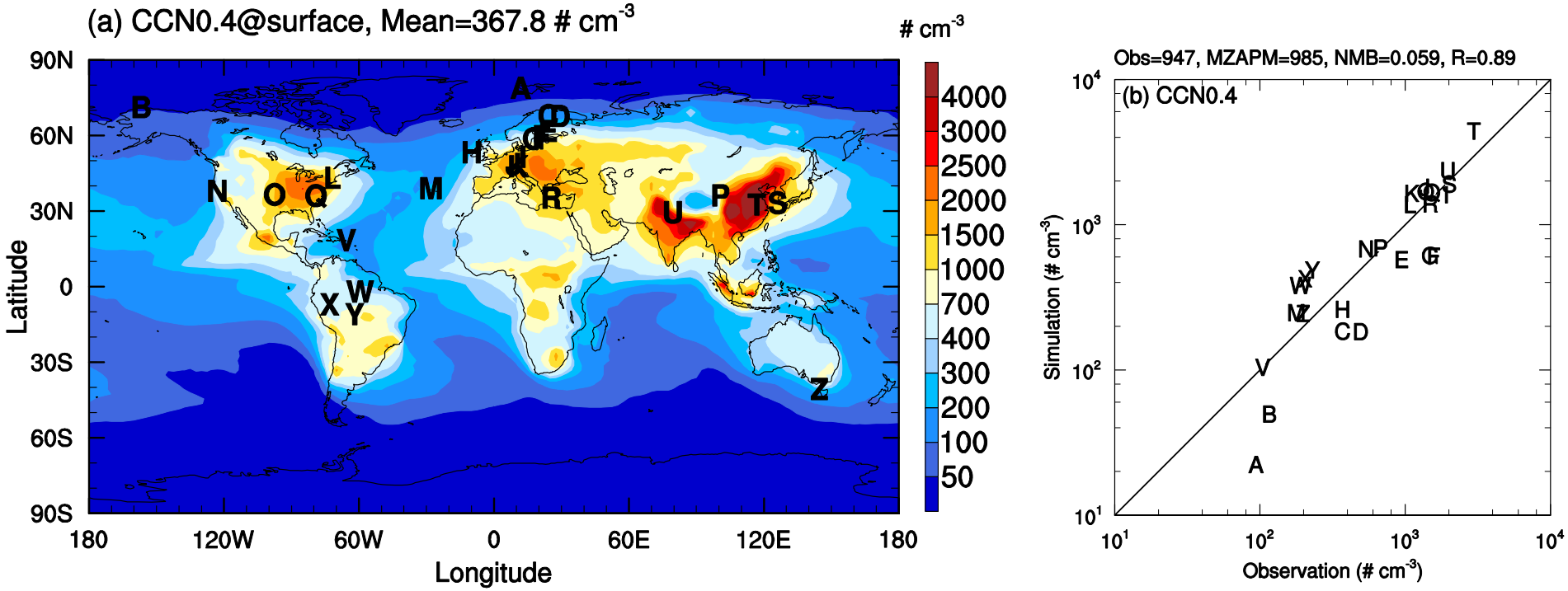
Long-term ground-based measurements of CN10 at 21 sites:

Obs: 2177 # cm^{-3}; Sim: 1756 # cm^{-3}; R=0.8

Underestimated at rural region (P, U) and coast region (G, J, K, S)

Global mean = ~700 # cm^{-3}

Validation of CCN0.4: CCN at supersaturation 0.4%



Ground-based measurements of CCN0.4 at 26 sites:

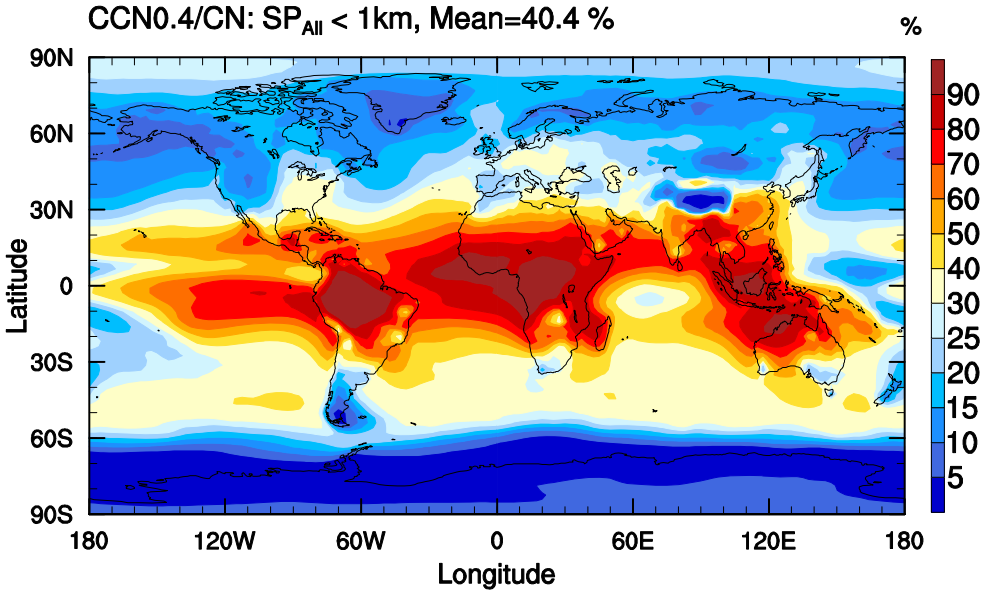
Obs: 947 # cm^{-3}; Sim: 965 # cm^{-3}; R=0.9

Underestimated at Arctic region (A, B, C, D)

Overestimated at Amazon (W, X, Y) and China (T)

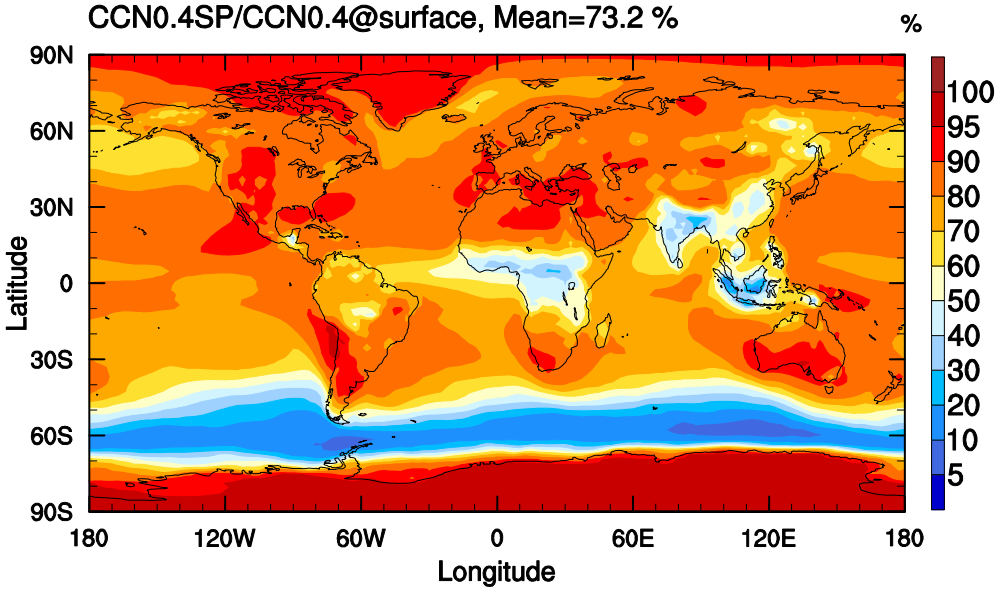
Global mean = ~370 # cm^{-3}

Characteristics of aerosol simulated by CAM-Chem/APM



40% of total particles are larger than CCN size

Tropics: 70-90%



Global aerosol number is dominated by SP: 73%

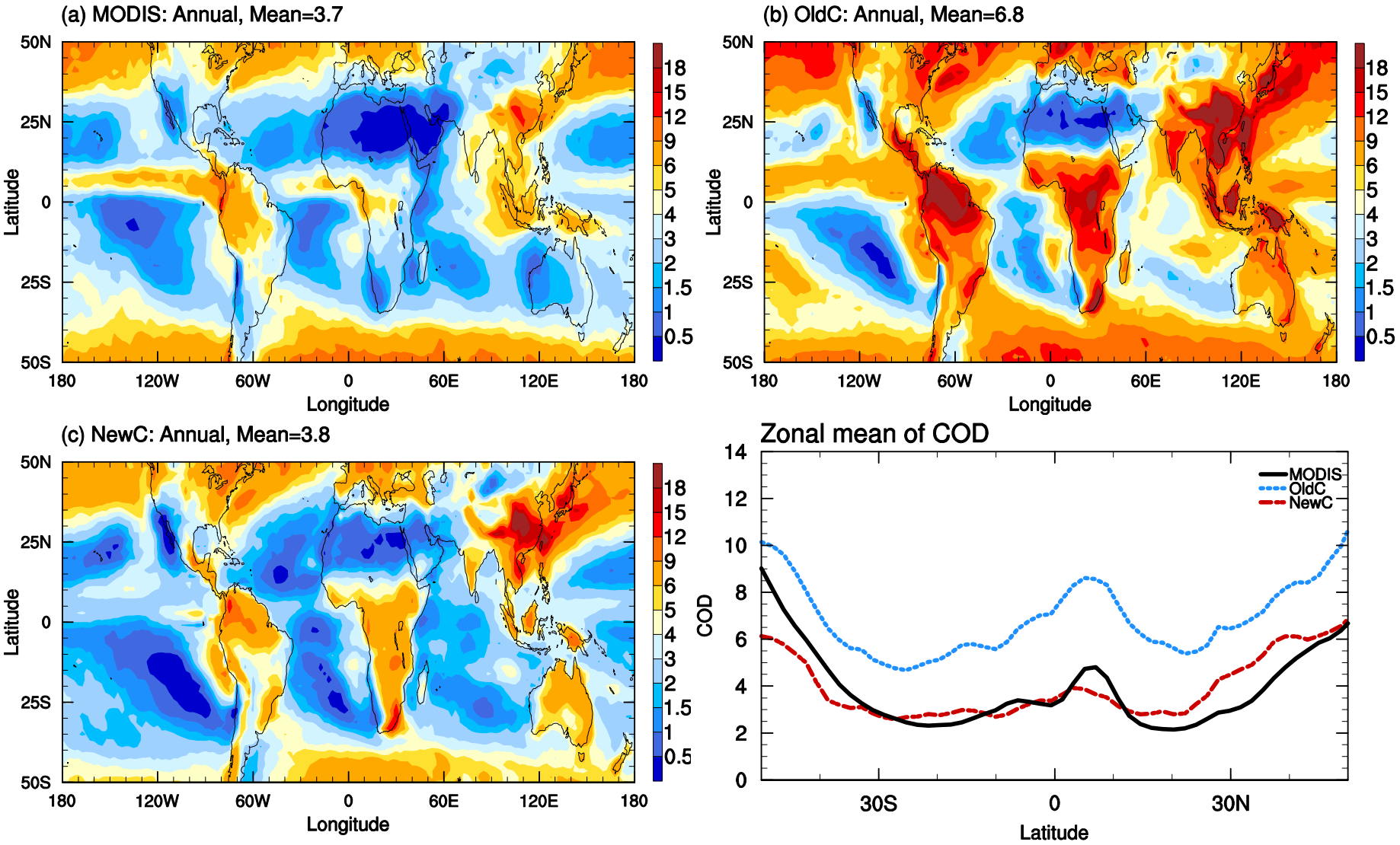
South Ocean: sea salt

Tropics: POC+BC

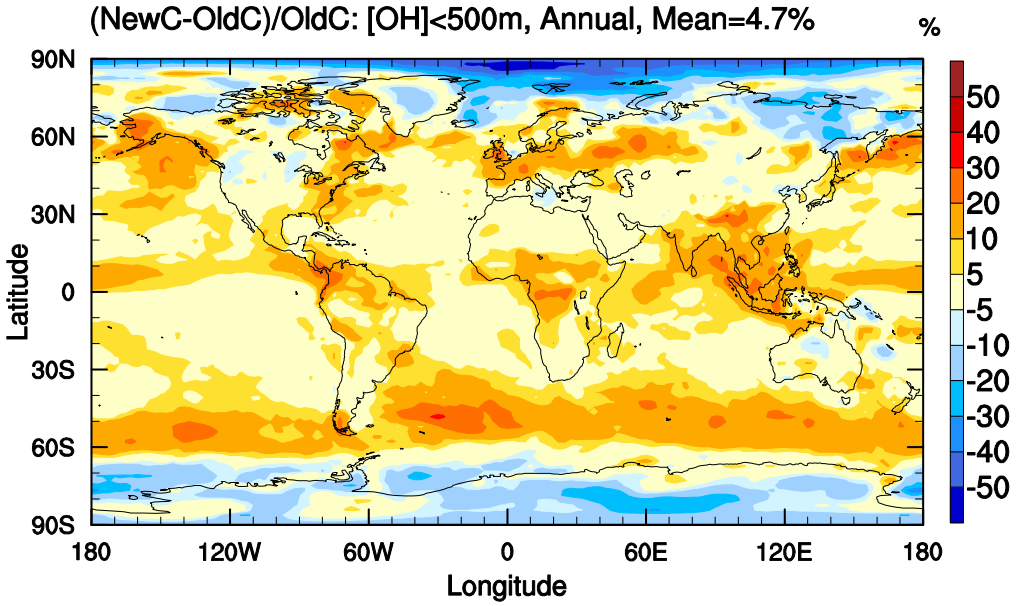
The Comparisons of COD: MODIS, OldC, NewC

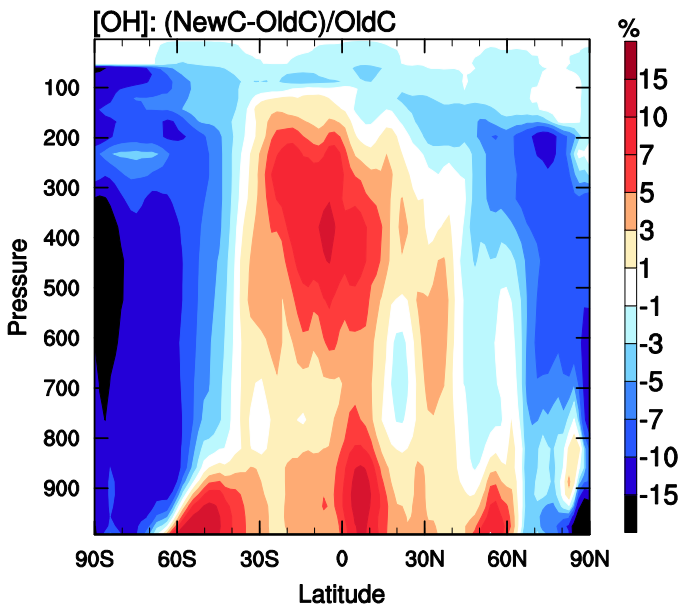
Cloud Optical Depth

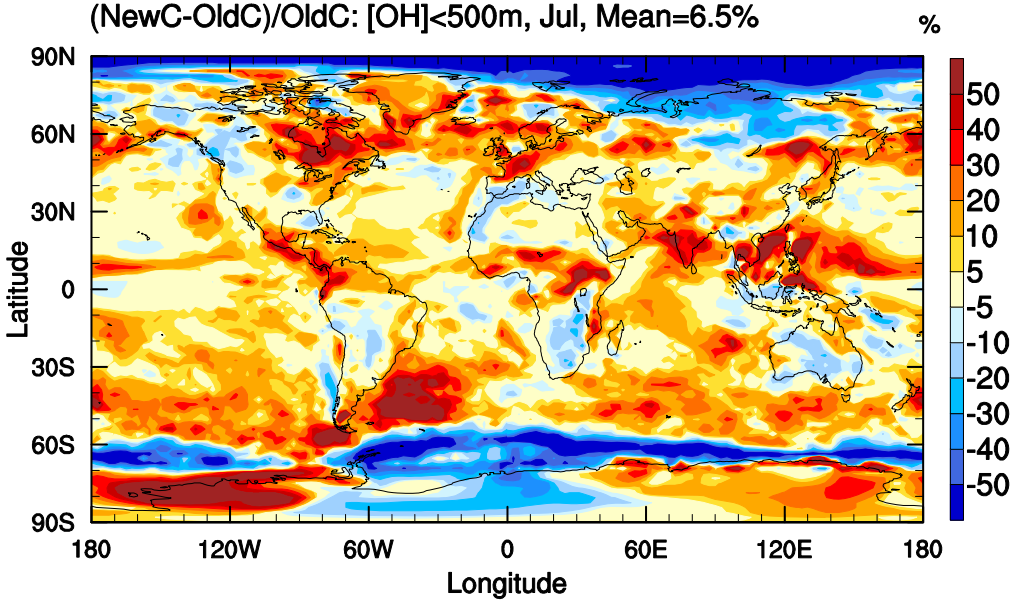
Aerosol Number ⇨ Droplet Number ⇨ Effective Radius + In Cloud Water Content ⇨ COD

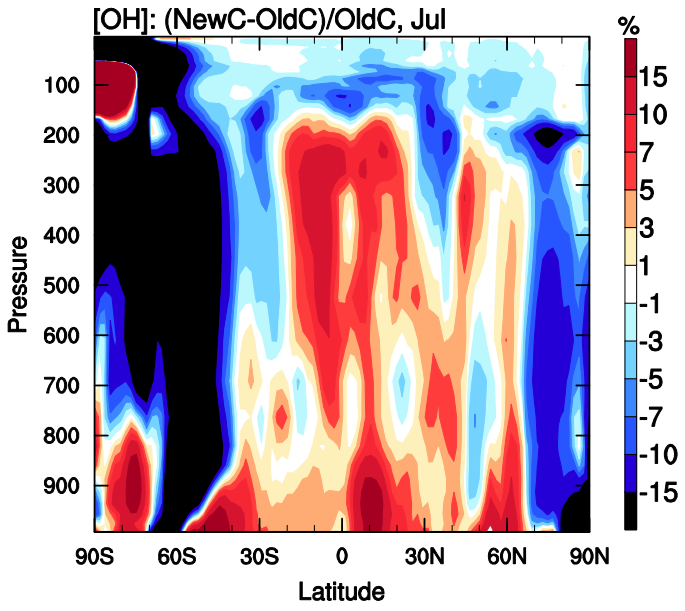


Impact on Photochemistry: Change OH Concentration

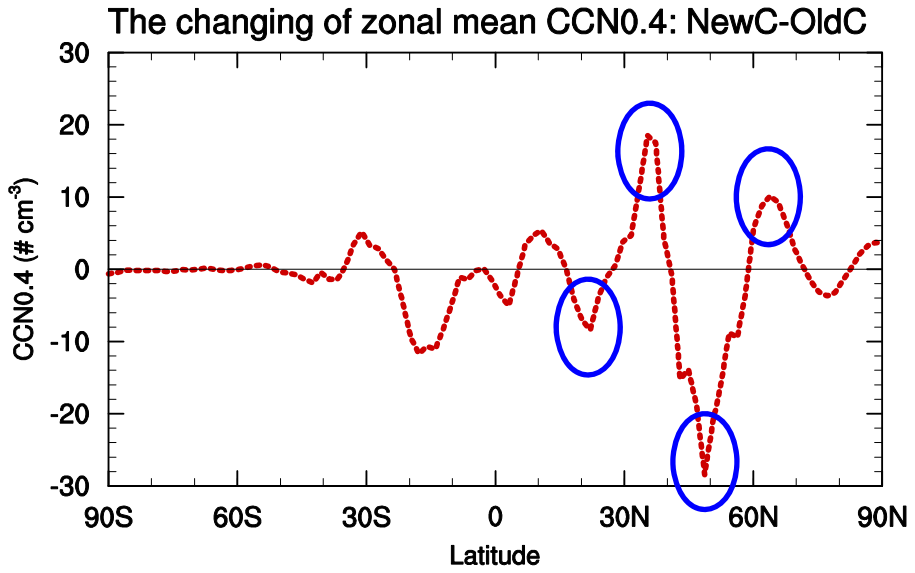


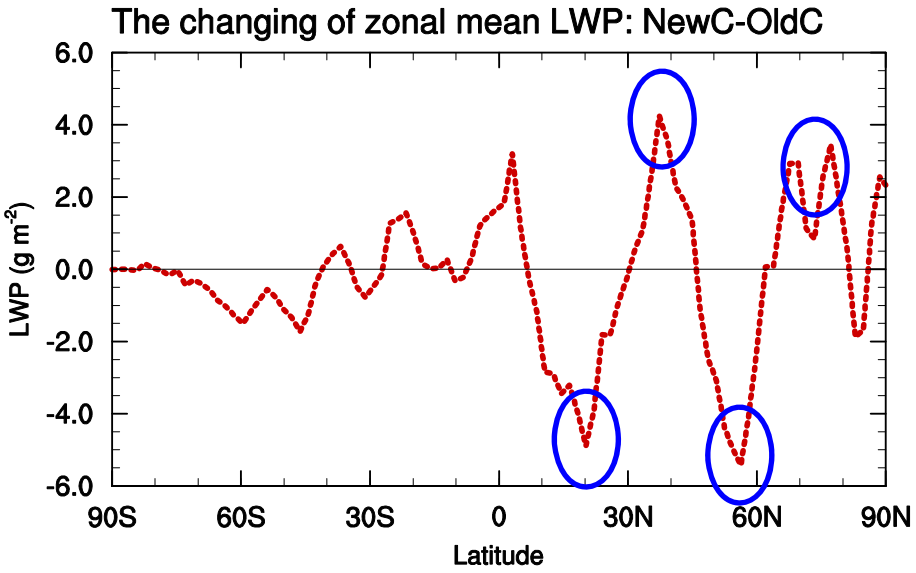


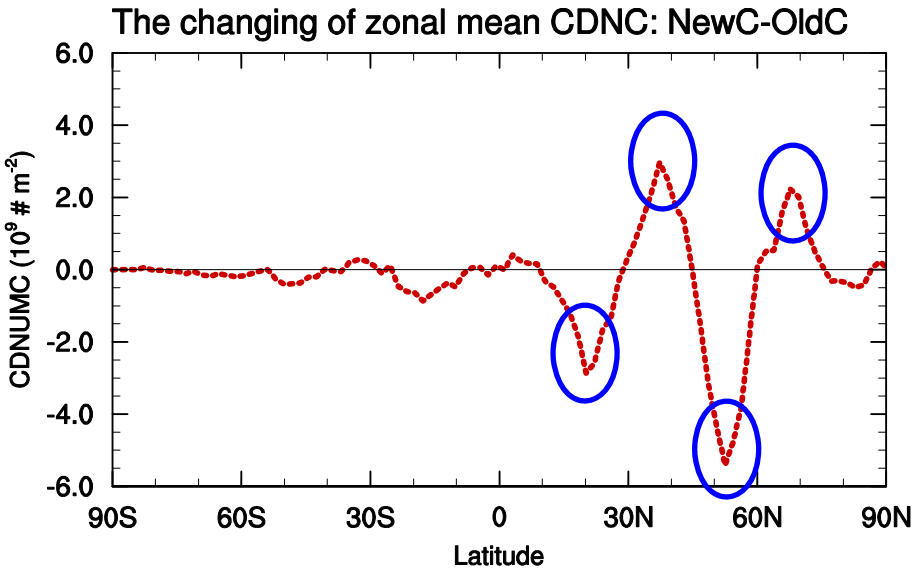


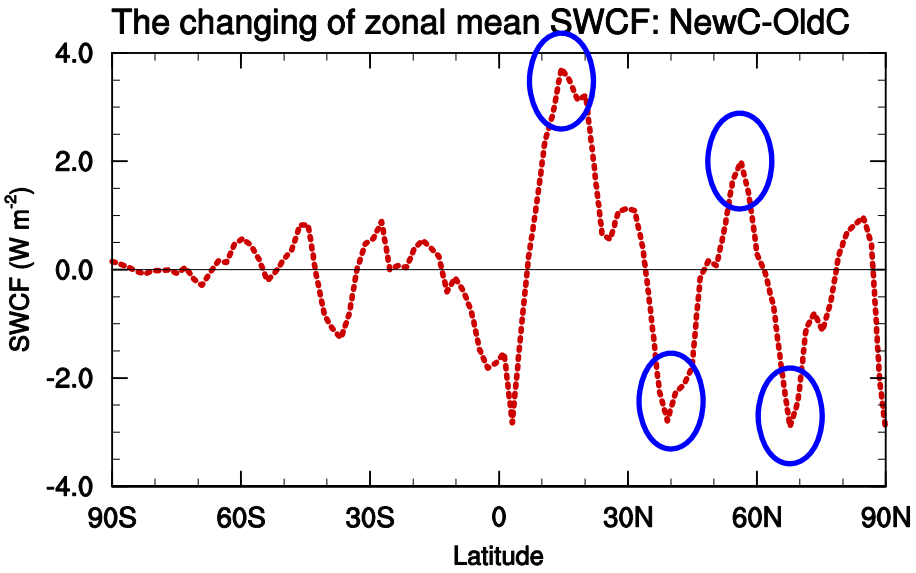


Impact on Cloud properties: CCN, CDNC, LWP, SWCF









Summary

- There are large biases of COD which are used for photochemistry in CAM-Chem
- By using cloud number and size predicted by the coupled aerosol and cloud microphysics, COD changes from 6.8 to 3.7 in CAM-Chem, which is closer to MODIS value of 3.6
- The reduced COD in CAM-Chem by using NewC:
  a. enhances global average low layer [OH]
     Annual: ~5%; Summer: ~7%
     Regional changes can be high up to 10-40%
  b. has large impact on CCN, CDNC, LWP, SWCF

The End

Thank You !