

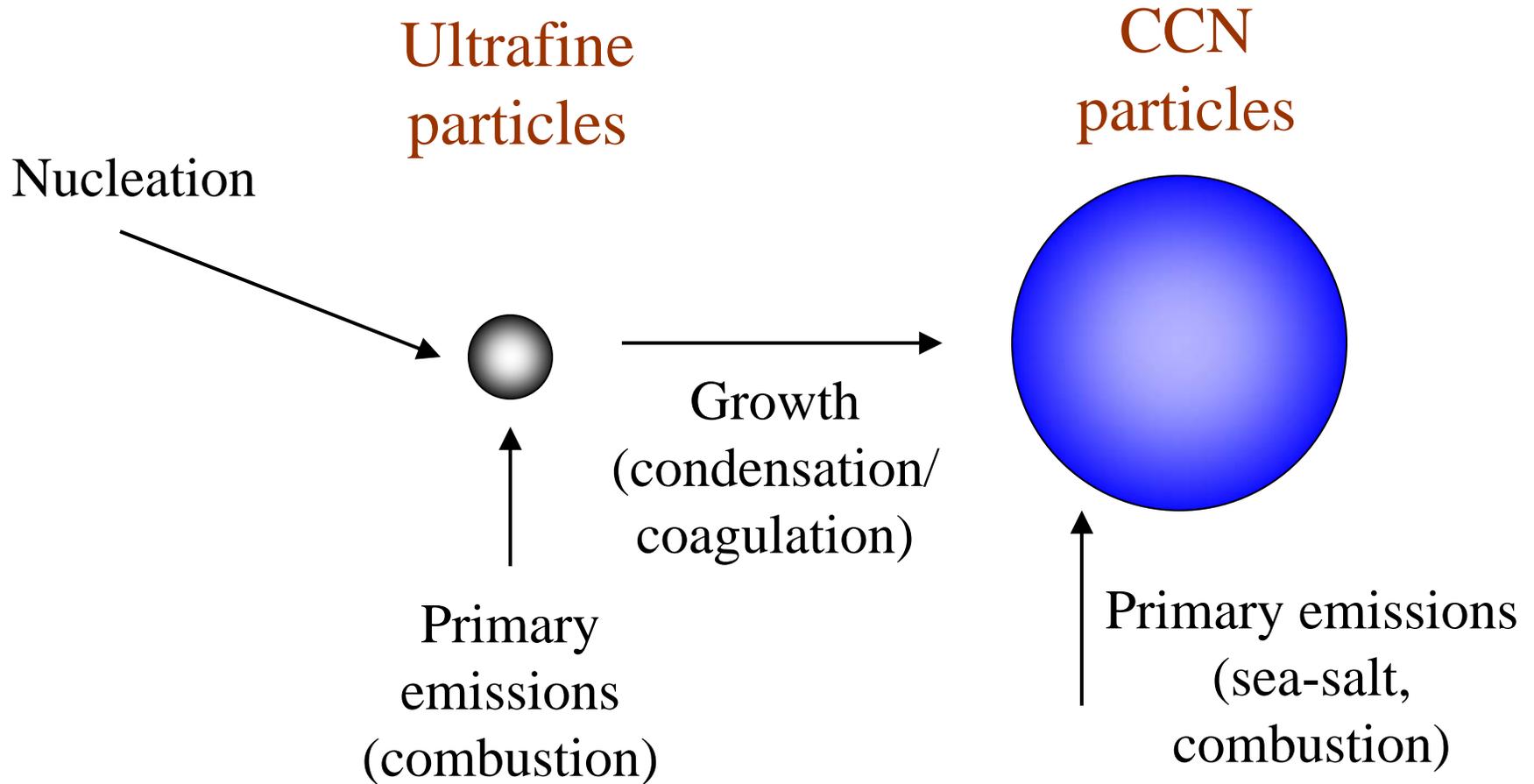
TOMAS Global Aerosol Microphysics Model

GMI Meeting
12 January 2006

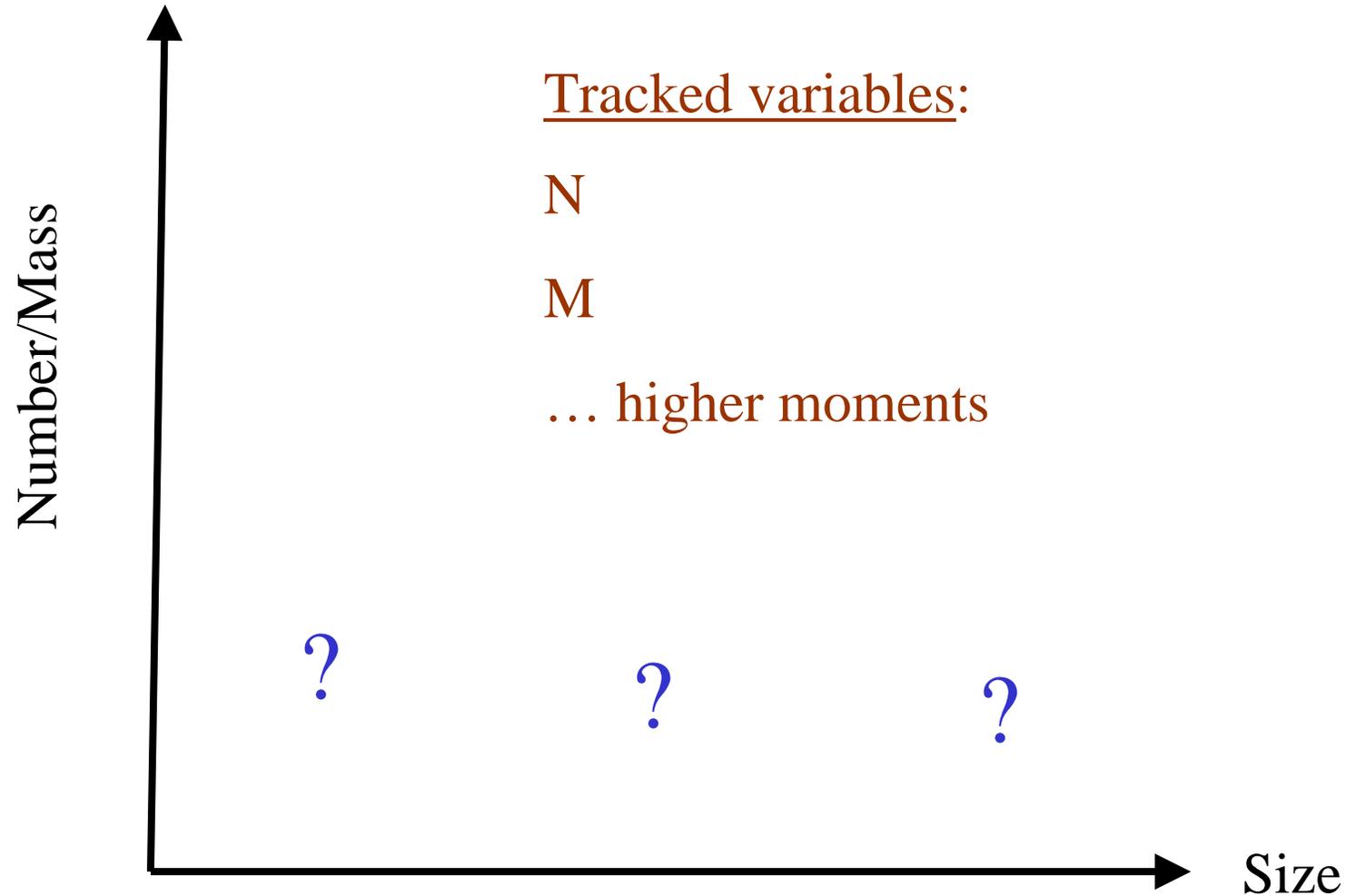
Goals

- Overall: reduce uncertainty in indirect effect
- Develop capability to predict cloud condensation nuclei (CCN) in global models
- Understand sources/sinks of CCN
- Need to predict size-resolved aerosol
 - number
 - mass
 - composition

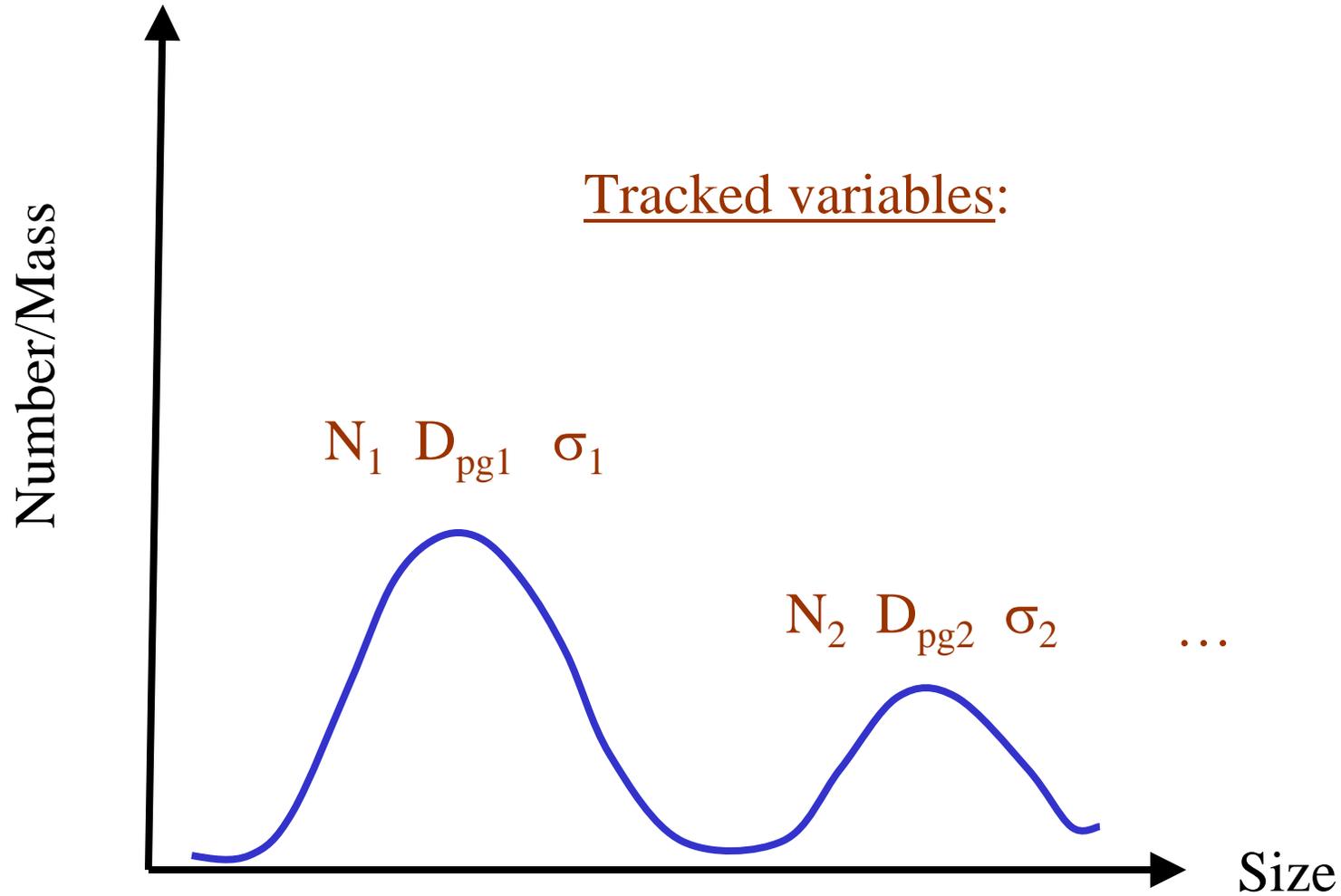
CCN Formation



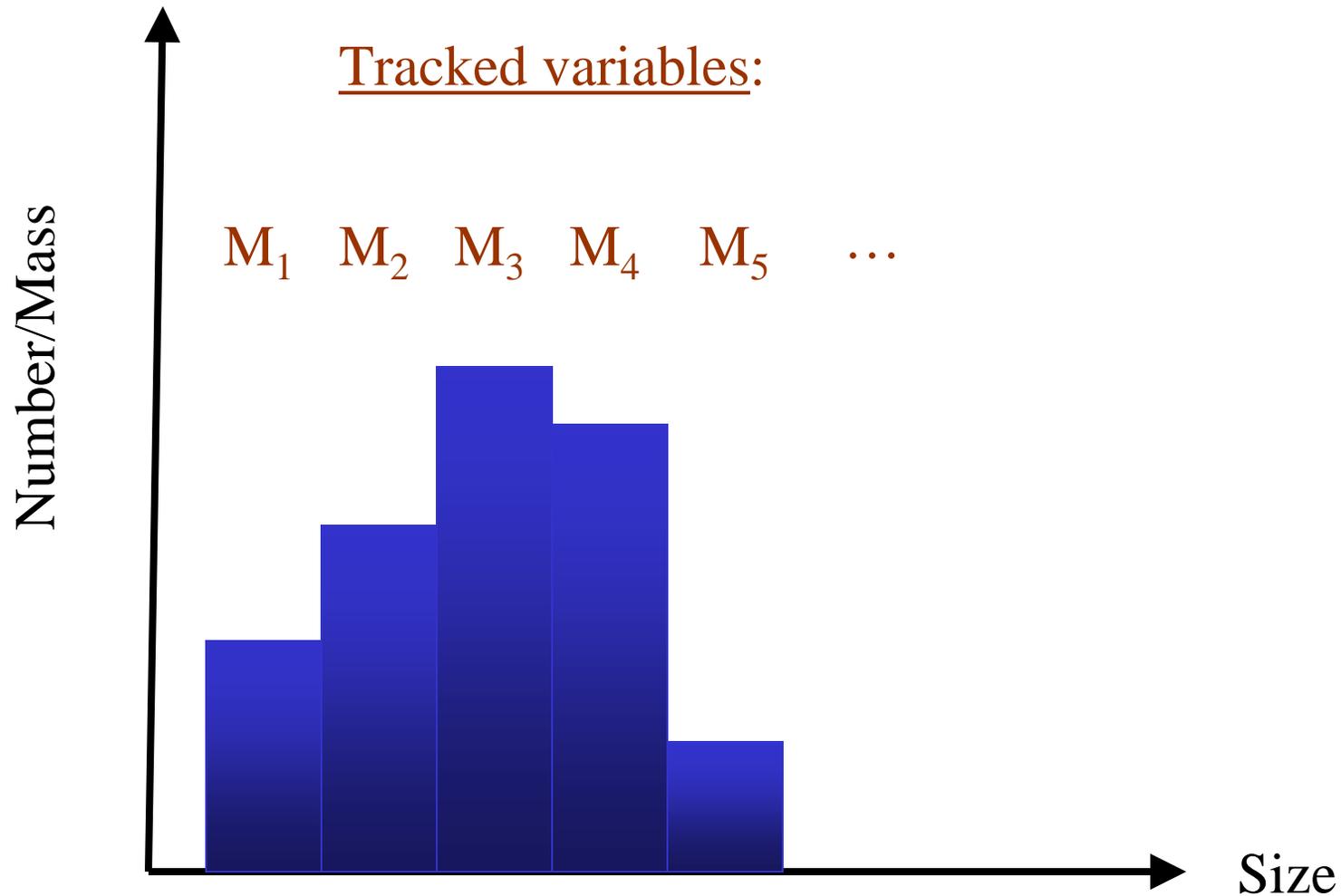
Moment-based Algorithms



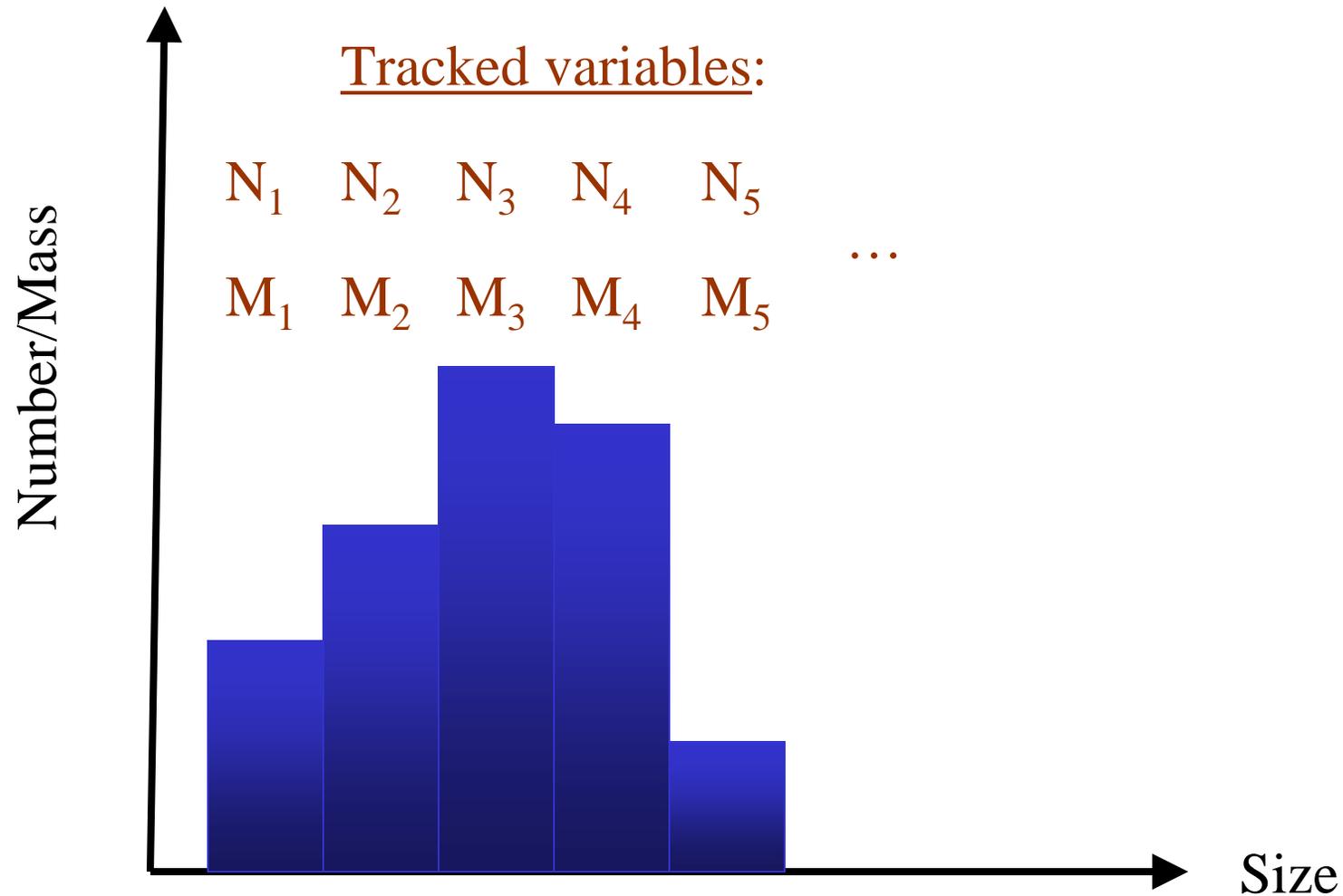
Modal Algorithms



Traditional Sectional Algorithms

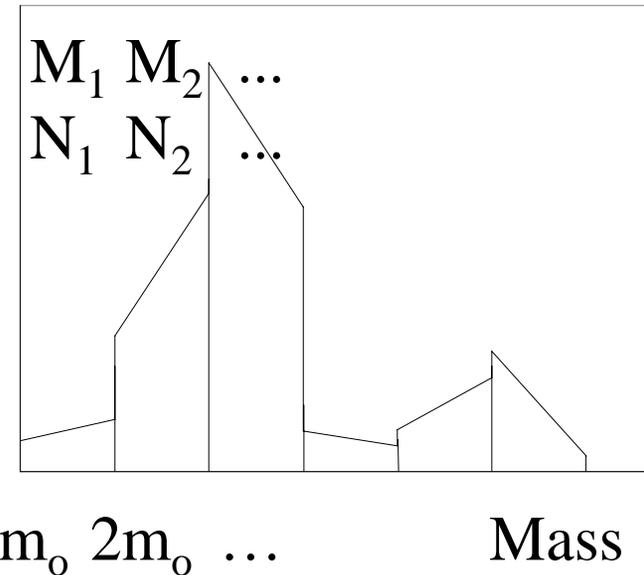


Two-Moment Sectional Algorithms



Two-Moment Aerosol Sectional (TOMAS) Model

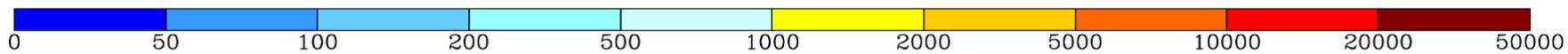
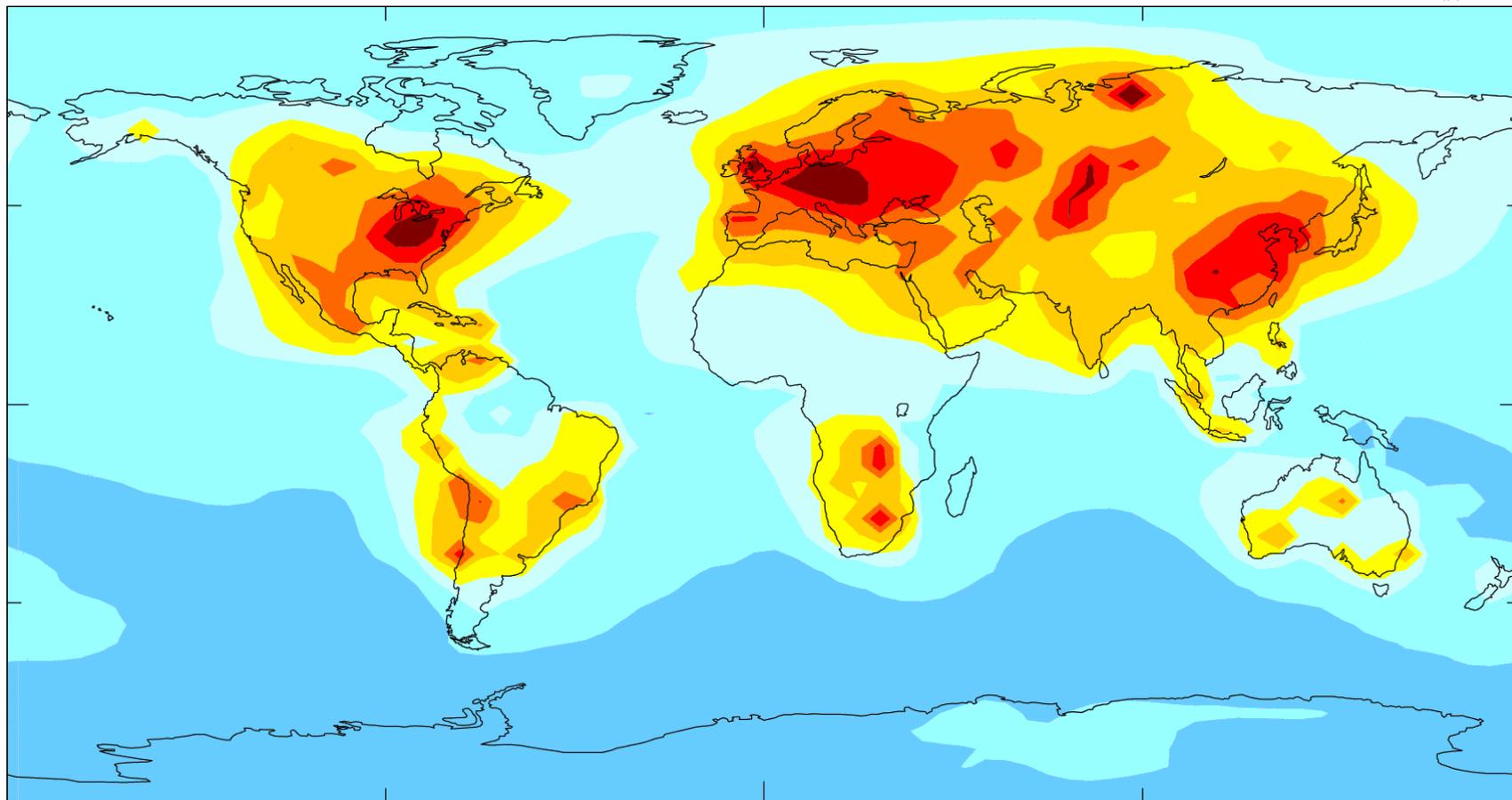
- Two moments of the size distribution (mass and number) are tracked for each size bin.
- The average size of particles in a given section is not constant with time
- Two-moment method conserves both mass and number precisely
- Prevents numerical diffusion present in single-moment methods
- Excellent size resolution: 30 sections from $.01 \mu\text{m}$ to $10 \mu\text{m}$



Model Output

959 mb

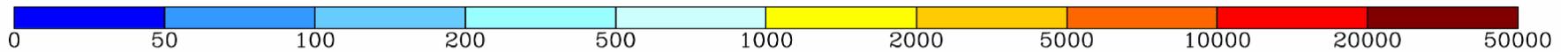
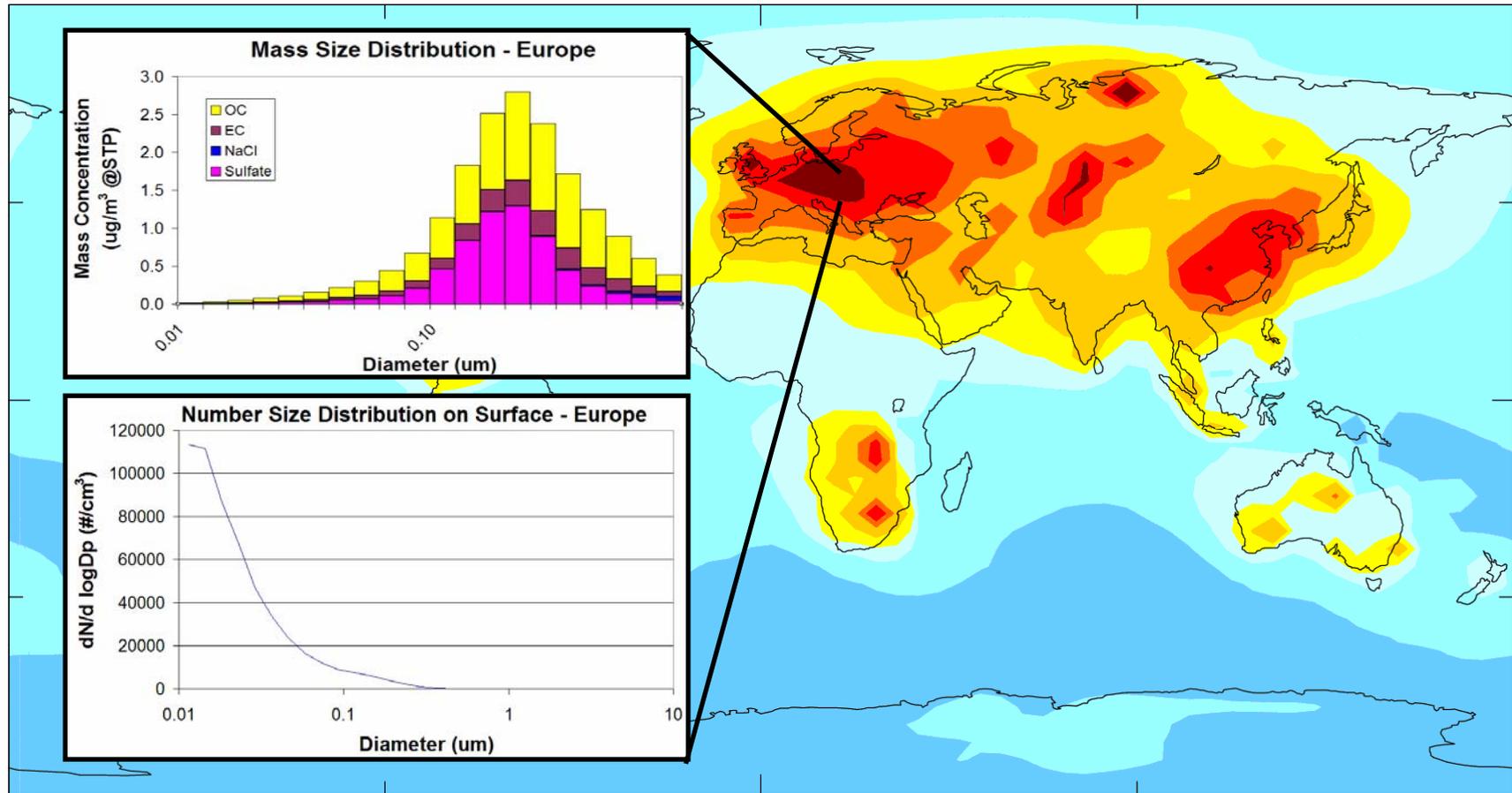
1420.40 #/cm³



Model Output

959 mb

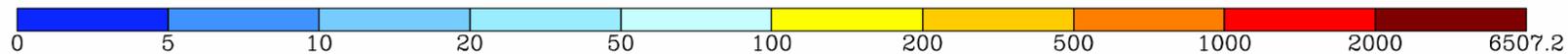
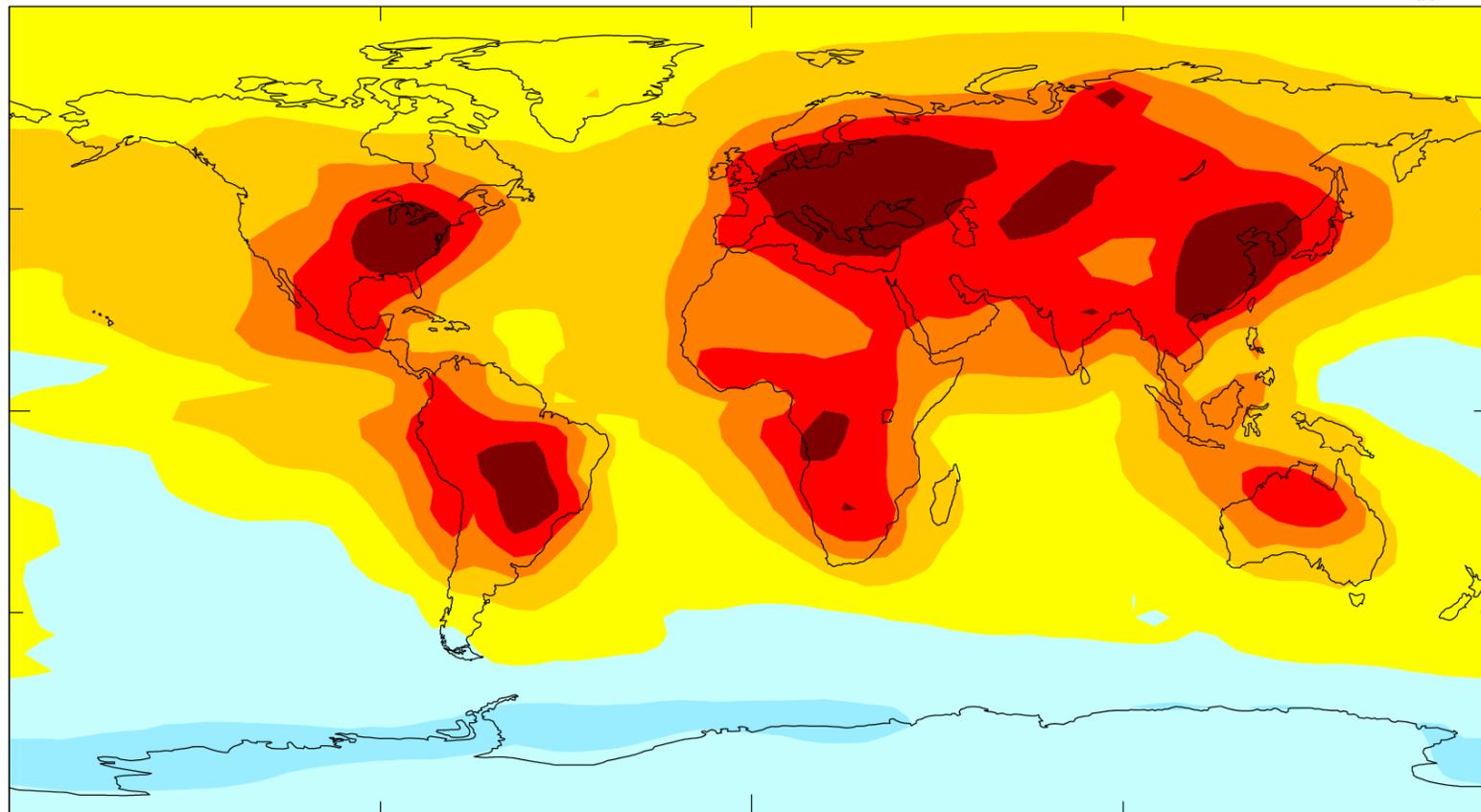
1420.40 #/cm³



CCN (0.2%) Distribution

959 mb

549.23 #/cm³



Platforms

MODULE DEVELOPMENT

- GISS GCM II-prime
- Sulfate: Adams and Seinfeld, 2002
- Sea-salt: Pierce and Adams, JGR in press
- EC/OC: Chen and Adams, JGR in press
- Dust: developed but under evaluation

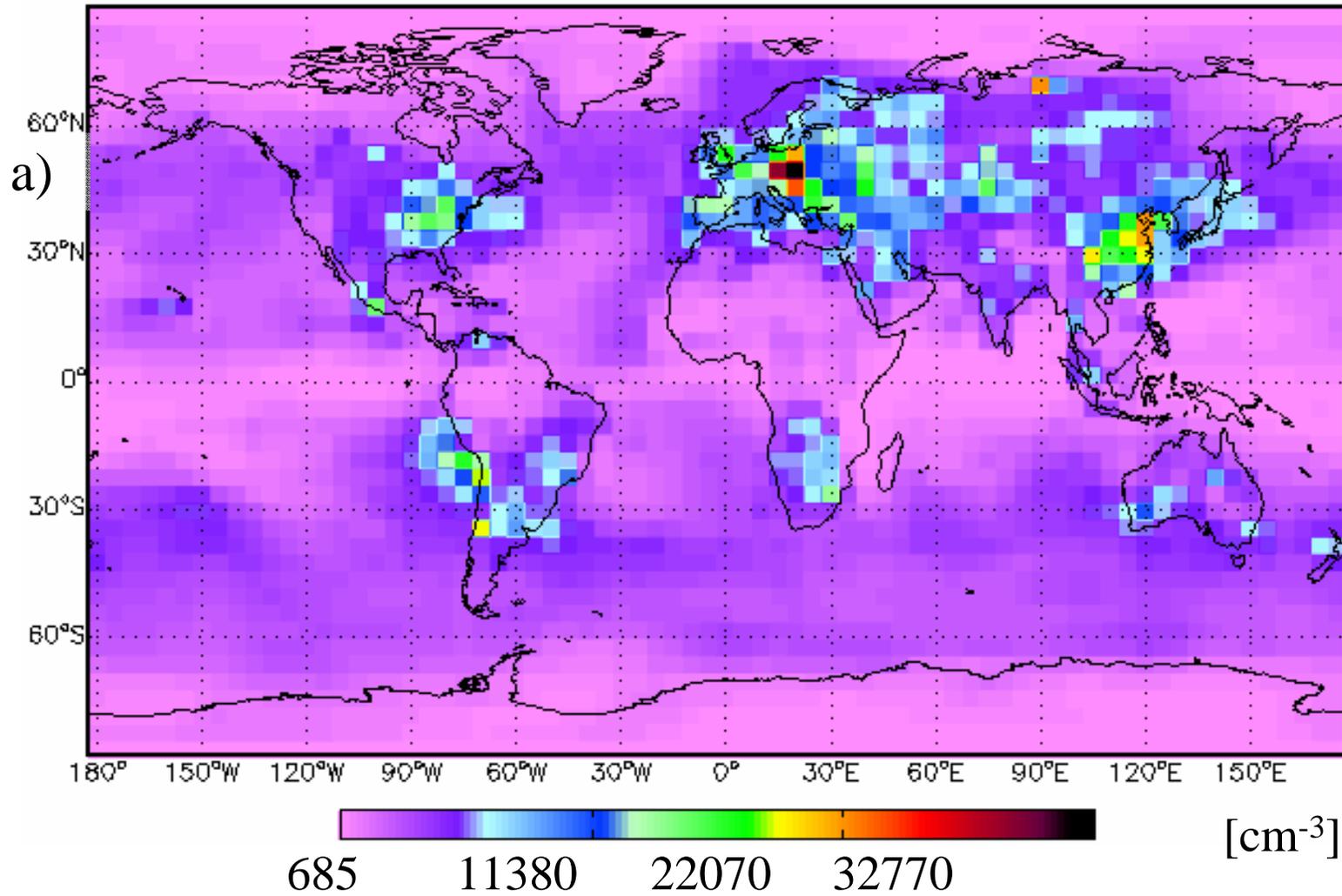
MODULE EVALUATION

- GEOS-CHEM
- Sulfate: Win Trivitayanurak, debugging
- Other species: future

MICROPHYSICS INTERCOMPARISON

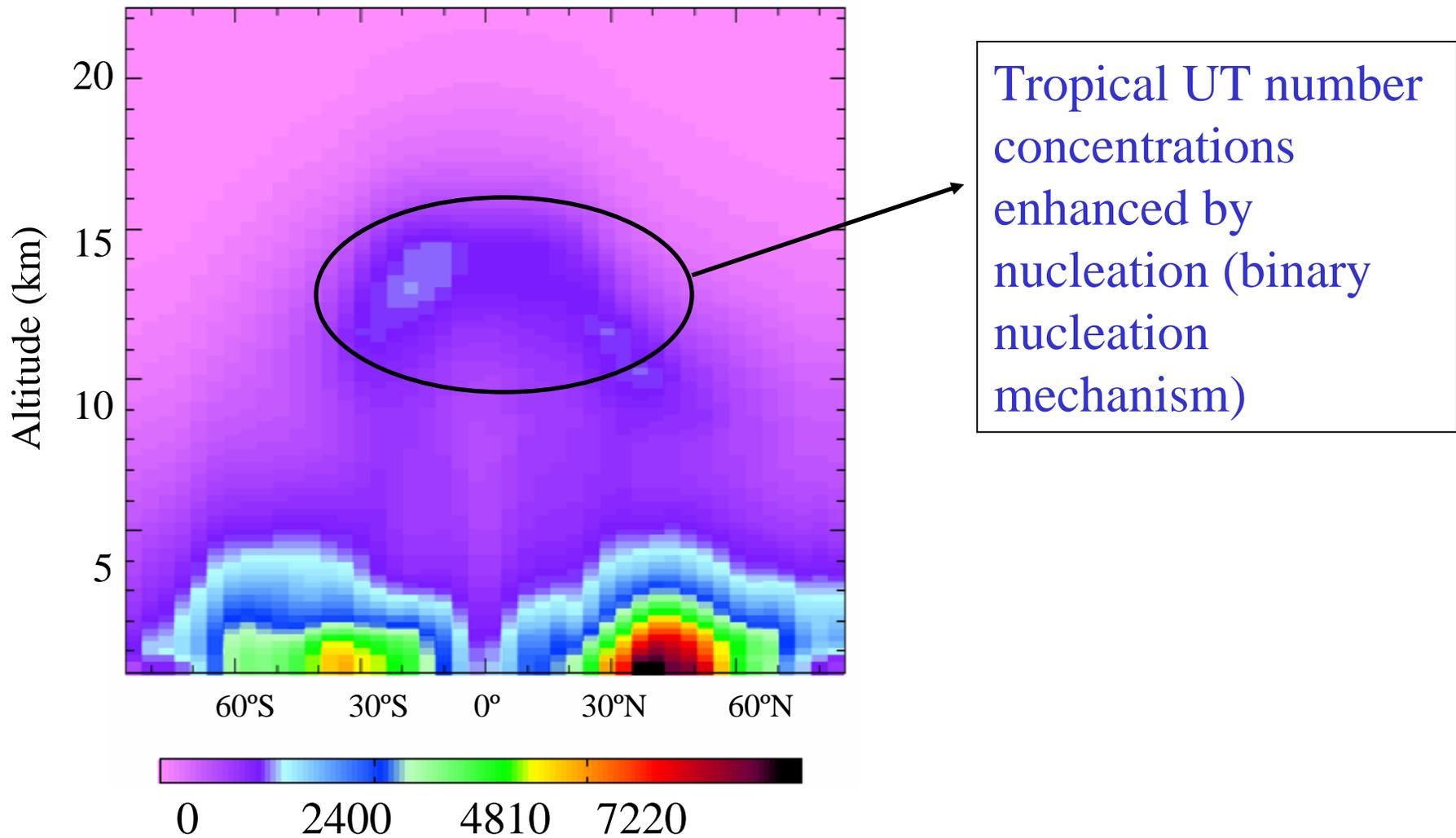
- GMI (proposed)

GEOS-CHEM Results (SO₄ Only)



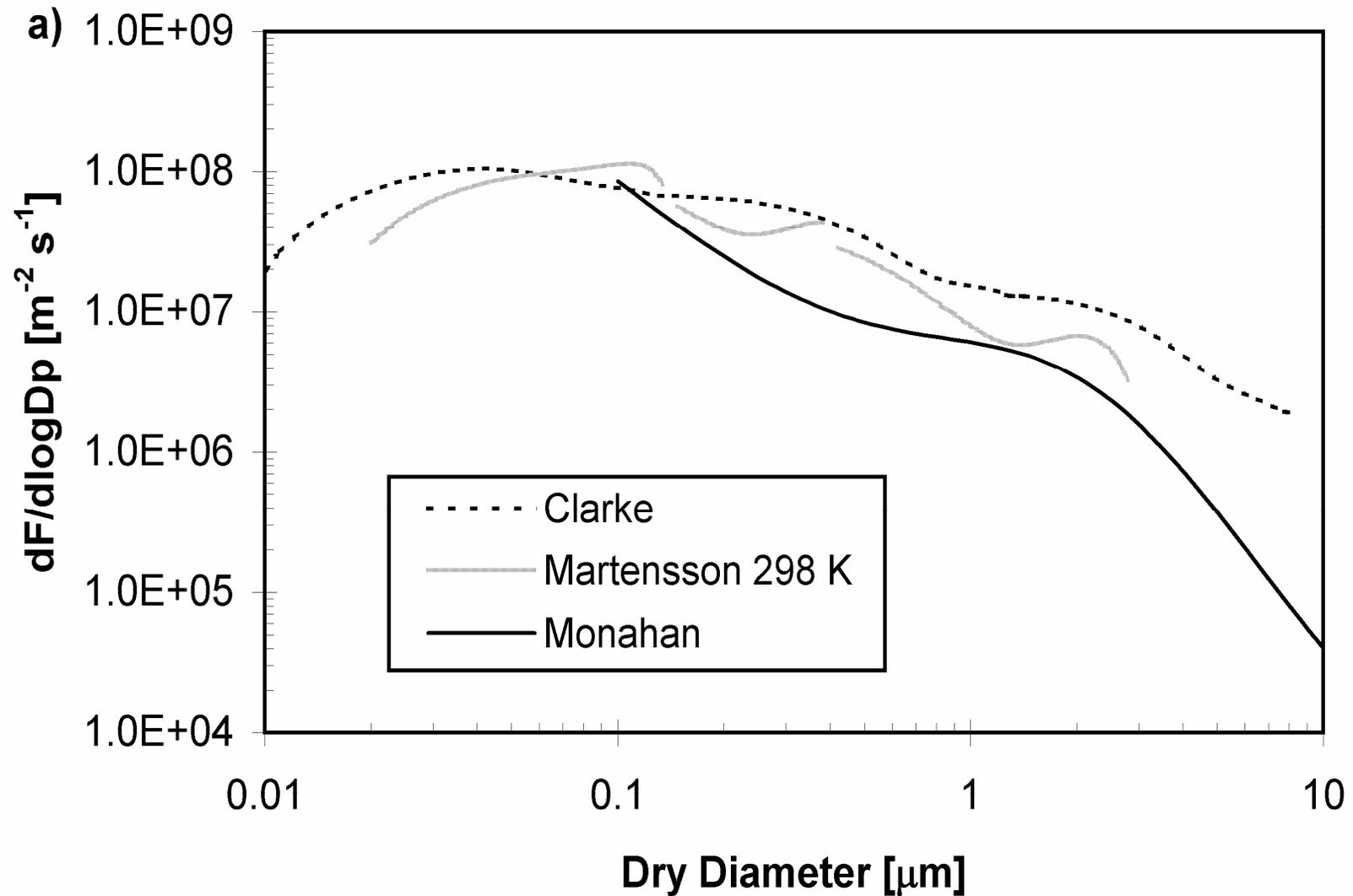
Aerosol Number Concentrations (April, 2001)

GEOS-CHEM Results (SO₄ Only)

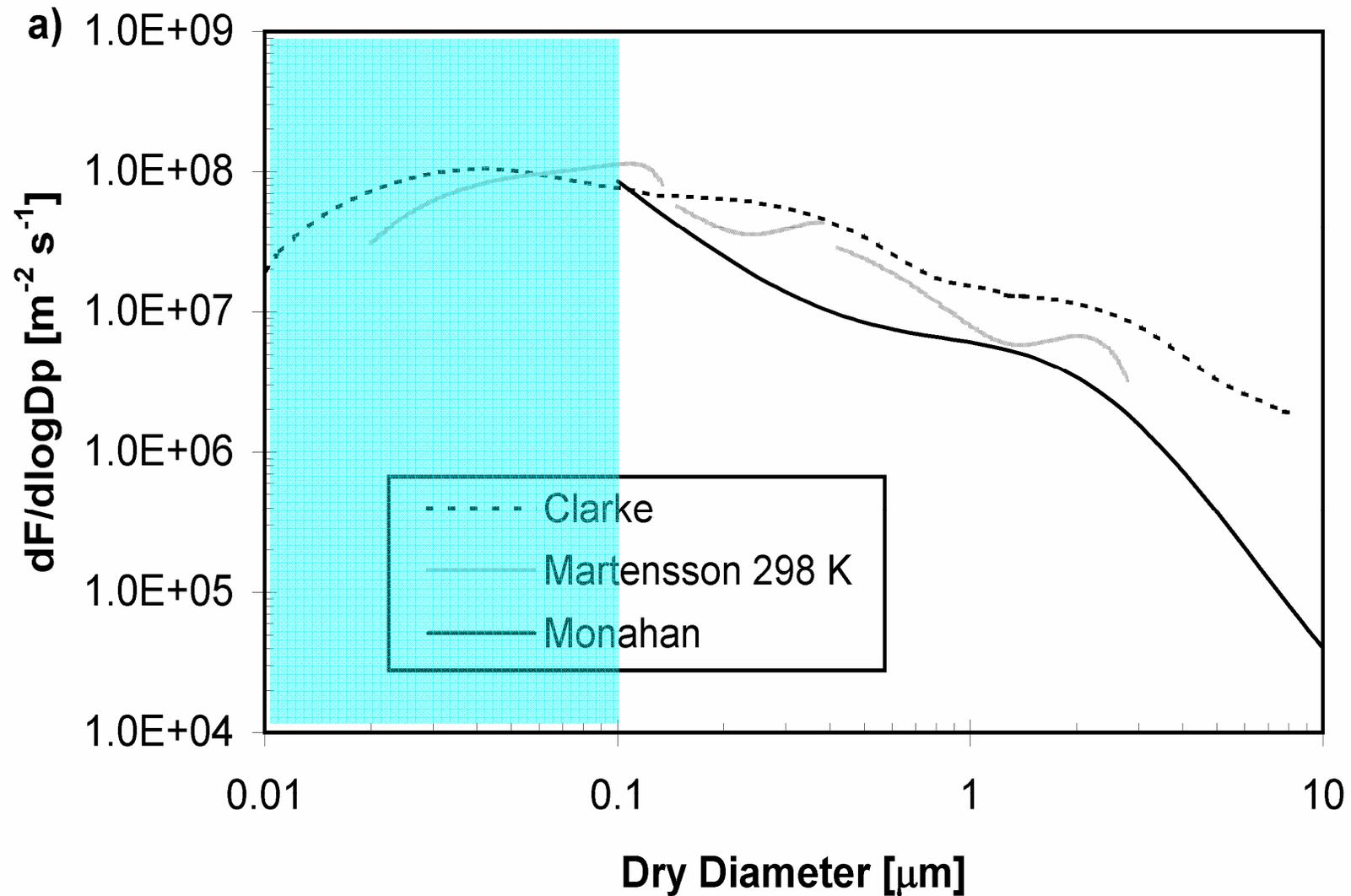


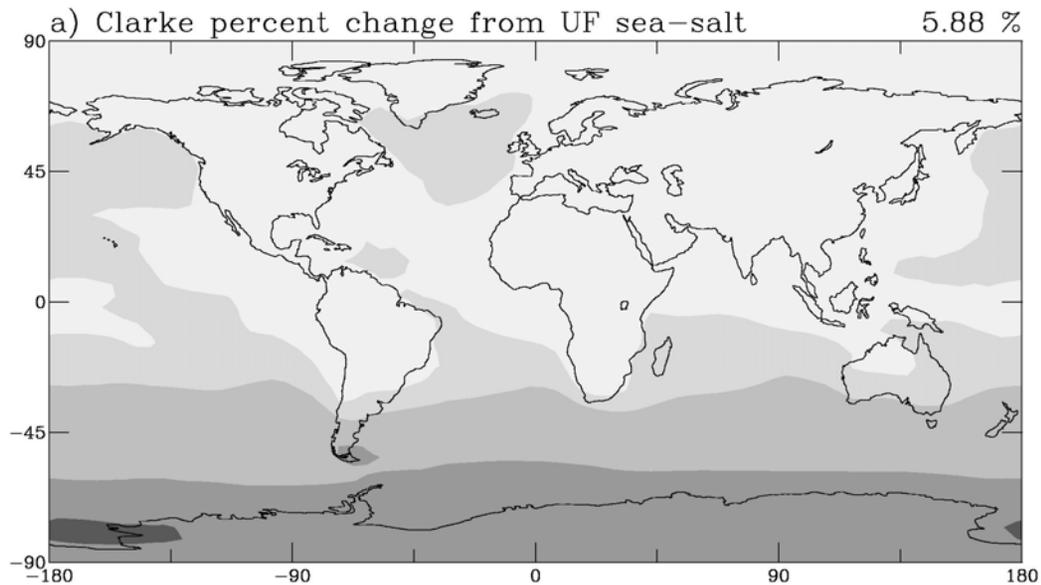
Aerosol Number Concentrations (April, 2001)

Sea-salt Emissions Parameterizations



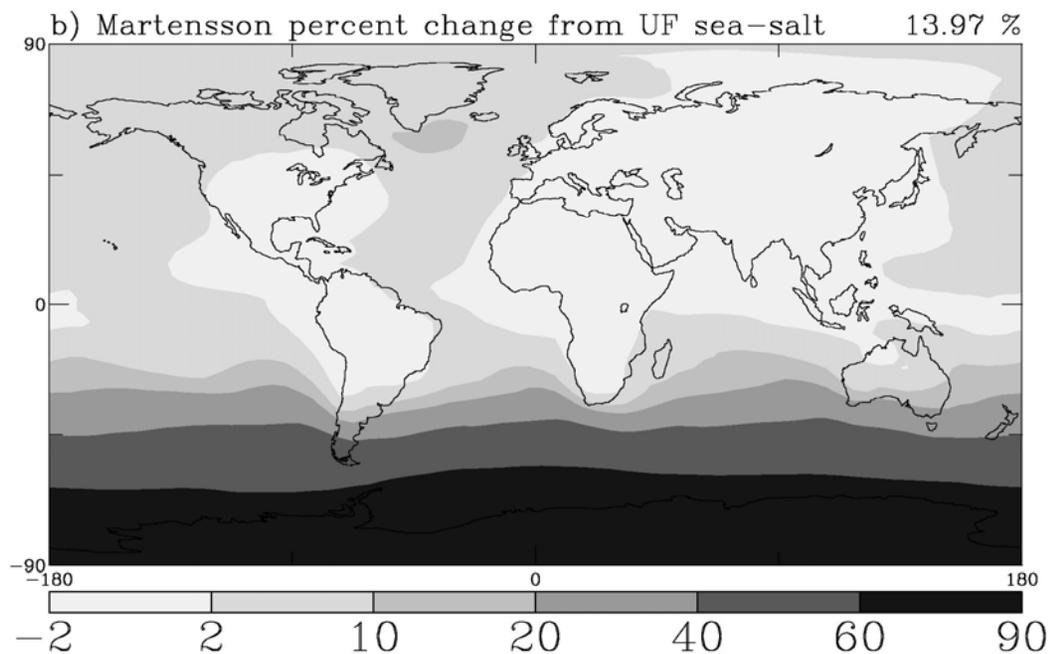
Sea-salt Emissions Parameterizations





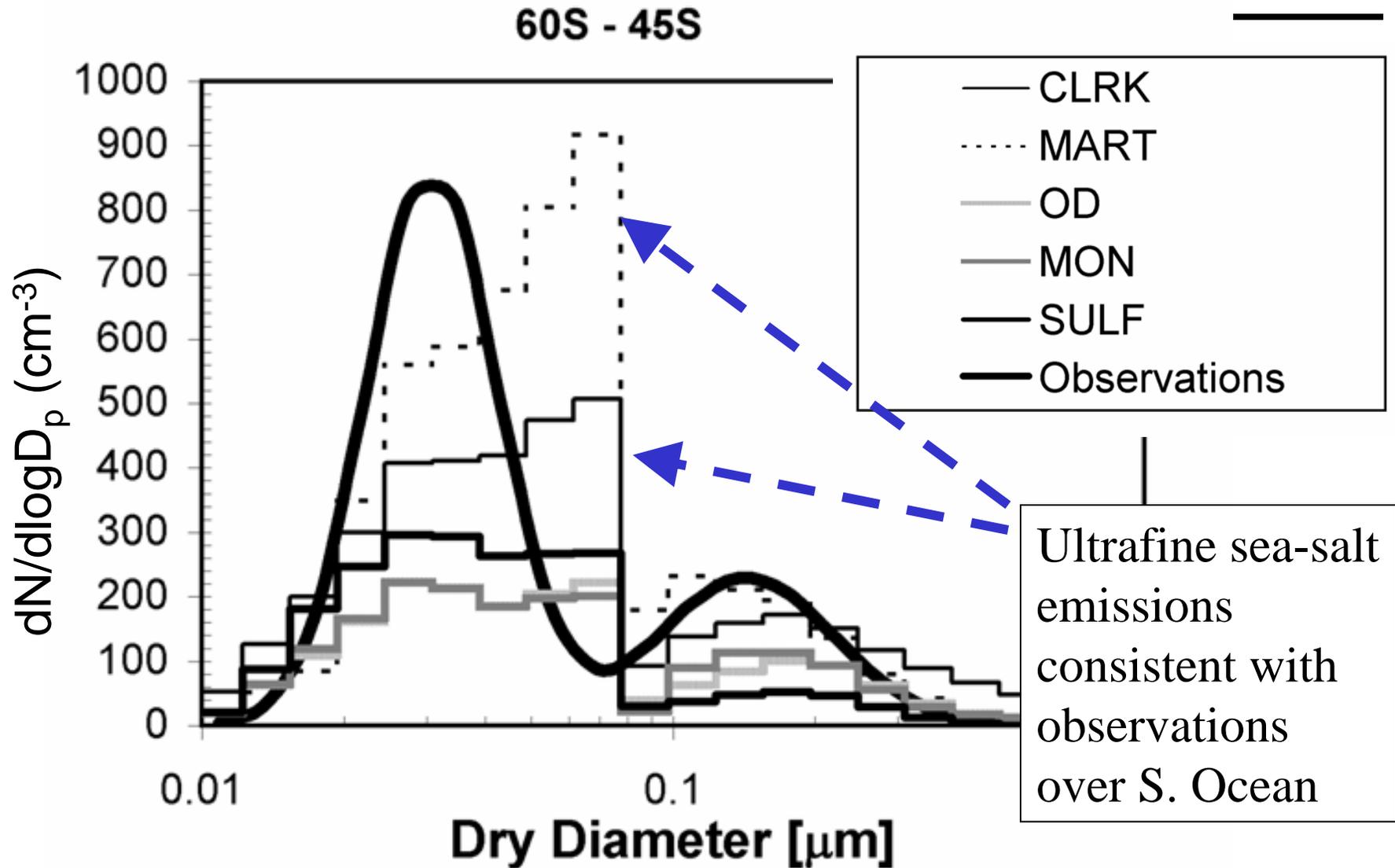
Clarke parameterization

Impact of Ultrafine Sea-Salt Emissions (% Increase in CCN 0.2)



Monahan parameterization

Observed Number Distributions



Observations from *Heintzenberg et al.* [2000]

Carnegie Mellon

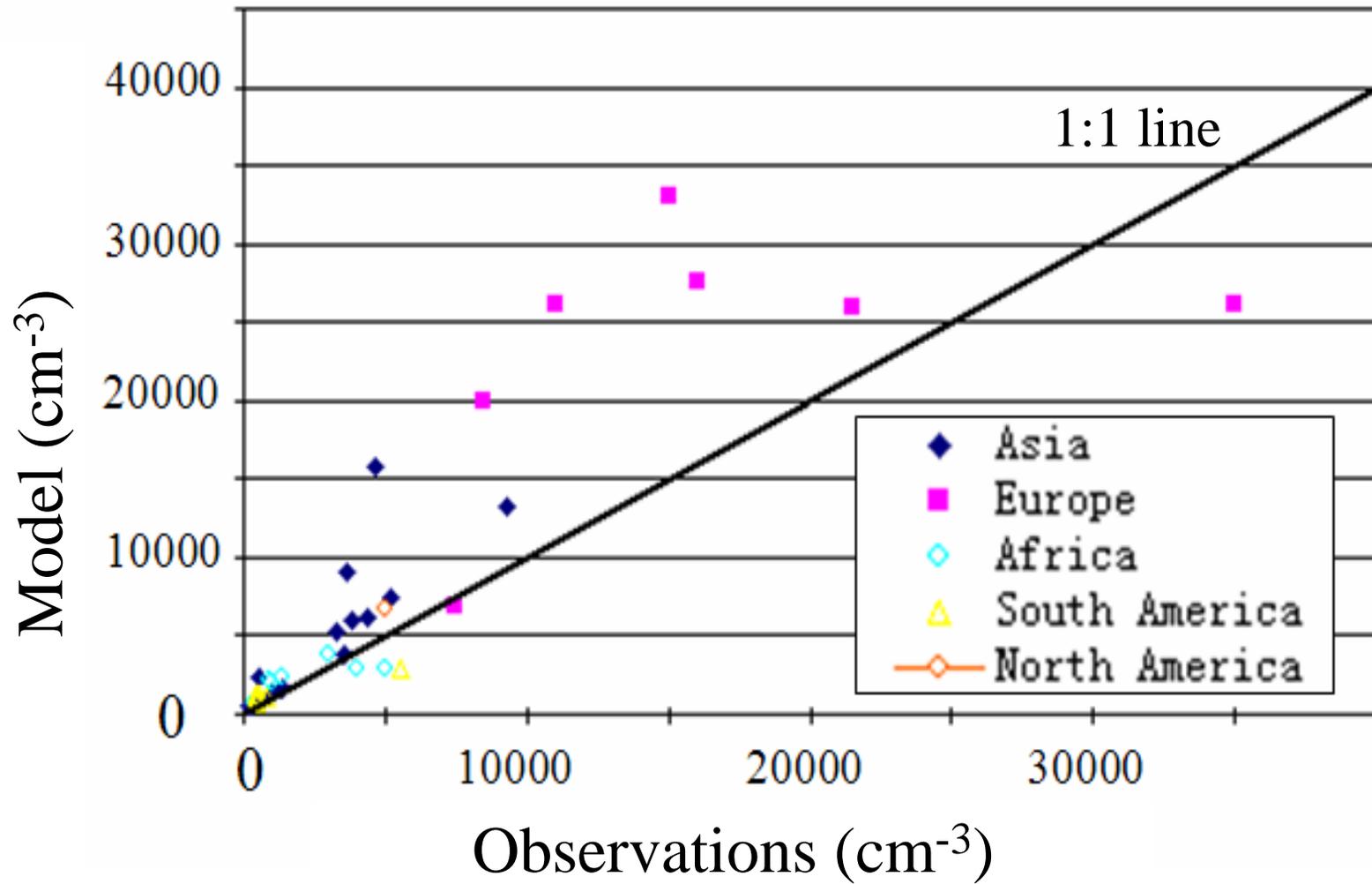
Carbonaceous Simulation

- Species: Sulfate, sea-salt, EC, OM
 - EC and OM are both divided into hydrophilic/hydrophobic fractions
- Emissions: Bond et al., 2004
 - EC: 8 Tg yr⁻¹ (80% hydrophobic initially)
 - OC: 33.9 Tg yr⁻¹ (50% hydrophobic initially)
- SOA: formation rate specified from Chung and Seinfeld, 2002
- Aging of hydrophobic to hydrophilic with
 - $\tau = 1.5$ days
- Primary emissions: assumed lognormal
 - D_{pg} (mass) = 100 nm and $\sigma = 2$
 - D_{pg} (number) = 30 nm

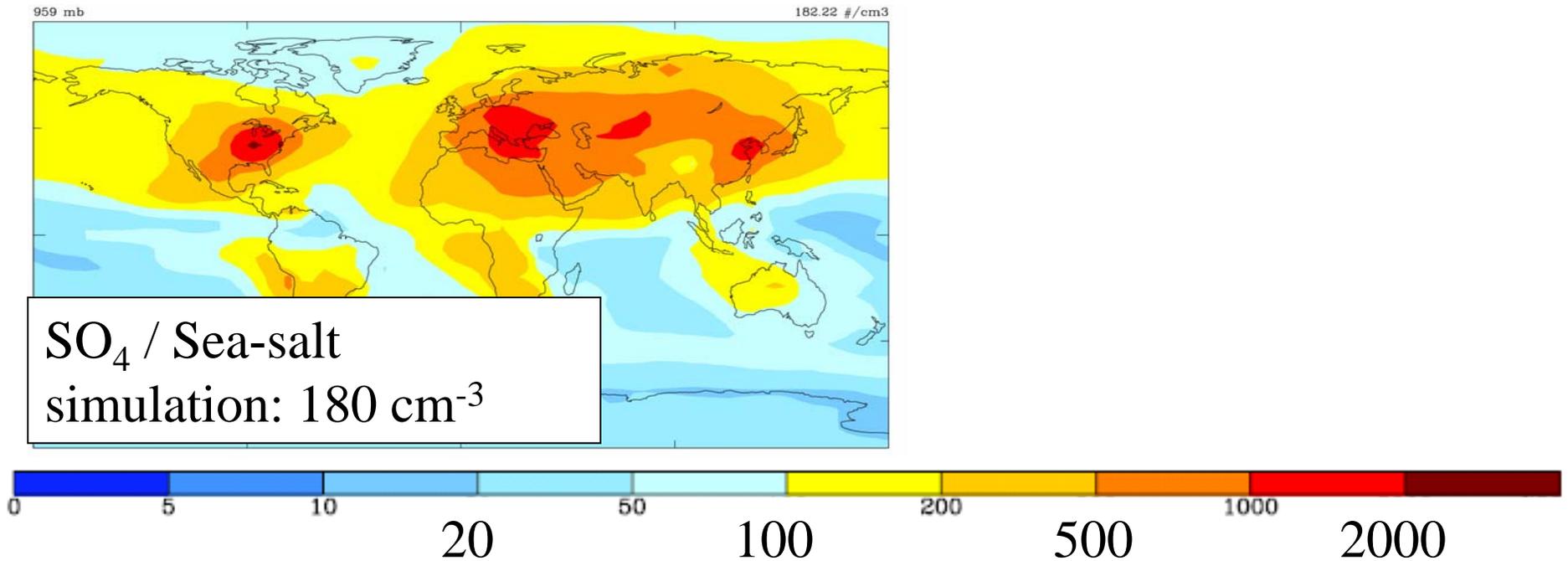
CCN Activity of EC/OC

- Modified Köhler theory
 - Slightly soluble species
 - Insoluble species
 - Surfactant effects not included
- Base case: assume two aerosol populations
 - Population 1: hydrophobic EC
 - Population 2: internal mixture of other species
 - Sulfate and sea-salt
 - Hydrophilic EC (insoluble core)
 - Hydrophobic OC (slightly soluble, 0.009 g /100 cm³ H₂O)
 - Hydrophilic OC ($D_{\text{crit}} = 45 \text{ nm}$ and 140 nm at $S = 1\%$ and 0.2%)

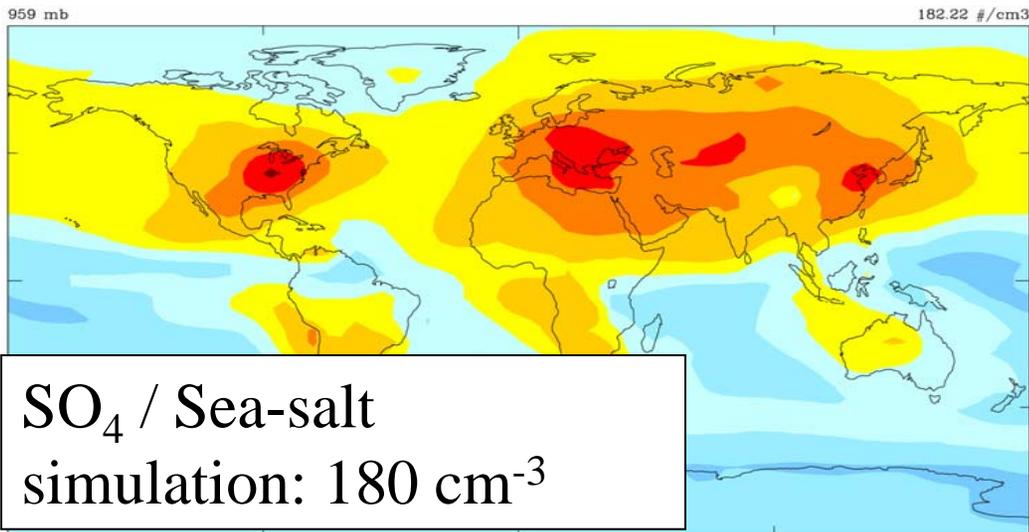
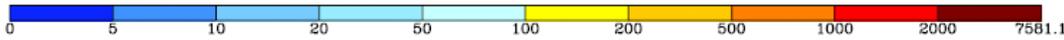
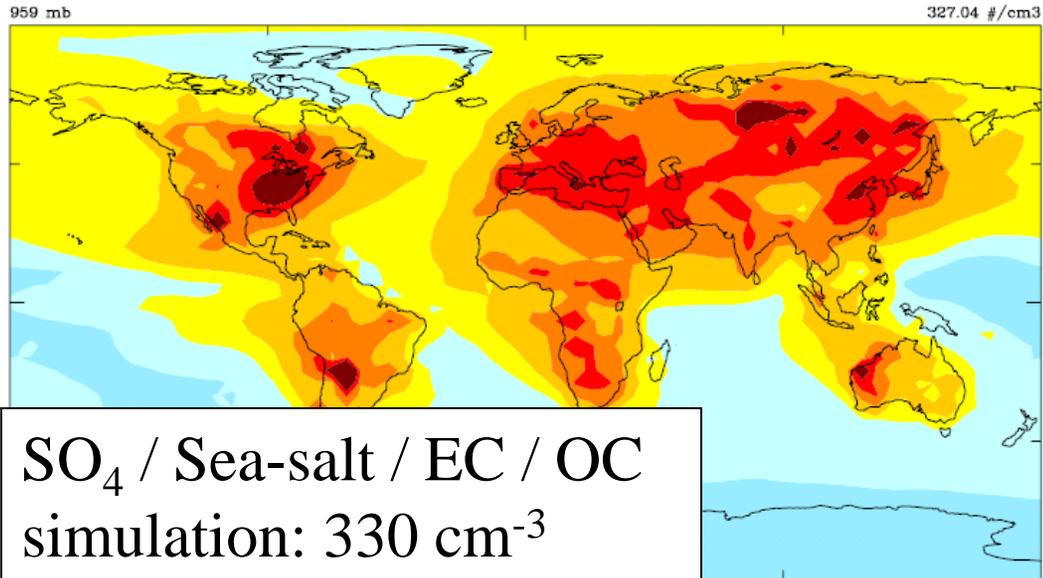
Aerosol Number: Observations



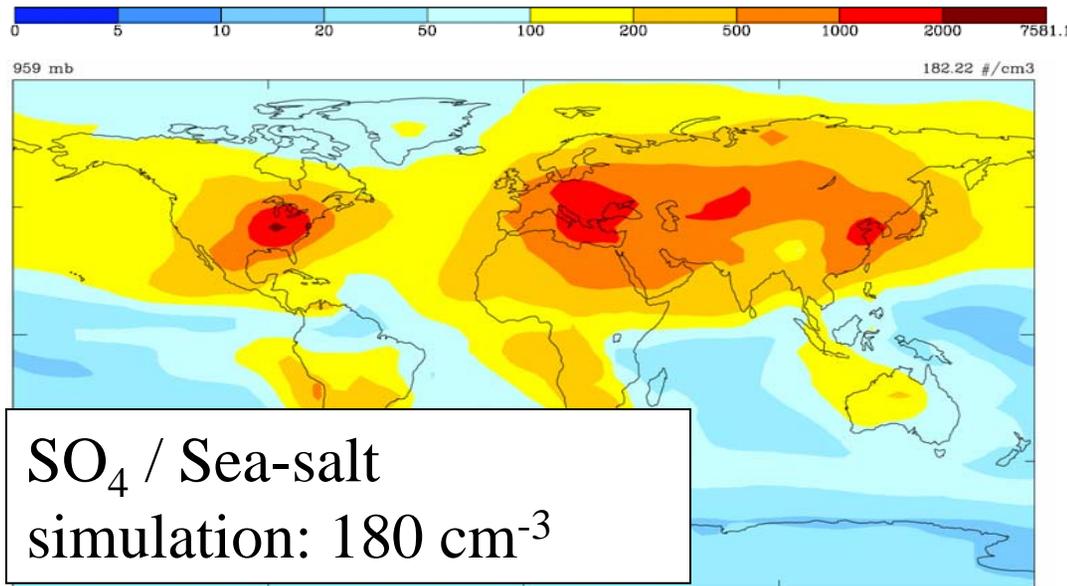
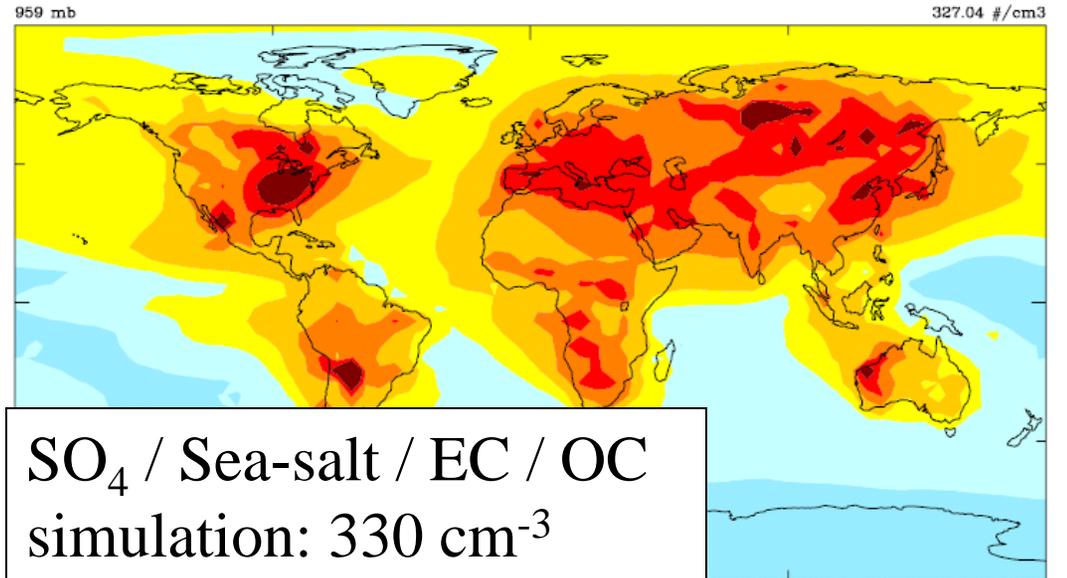
Impact of Carbonaceous Aerosol on CCN (0.2%)



Impact of Carbonaceous Aerosol on CCN (0.2%)



Impact of Carbonaceous Aerosol on CCN (0.2%)



- Primary EC/OC with original $D_p > 85$ nm accounts for only half this enhancement
- Growth of primary ultrafine EC/OC contributes significantly to CCN(0.2%)



Sensitivity to Mixing / Solubility

Offline calculations of CCN(0.2%) for alternative activation scenarios:

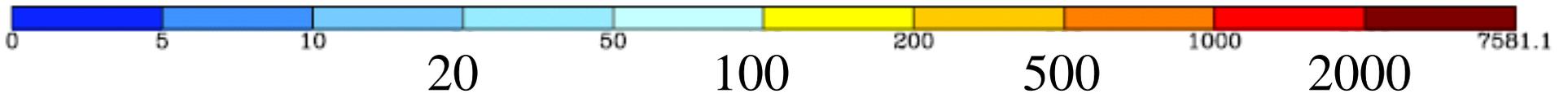
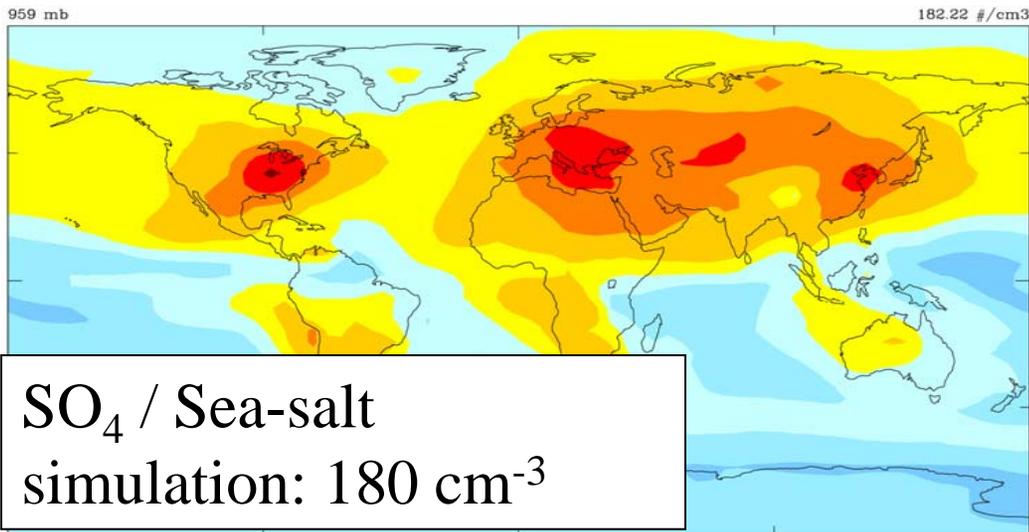
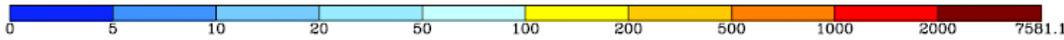
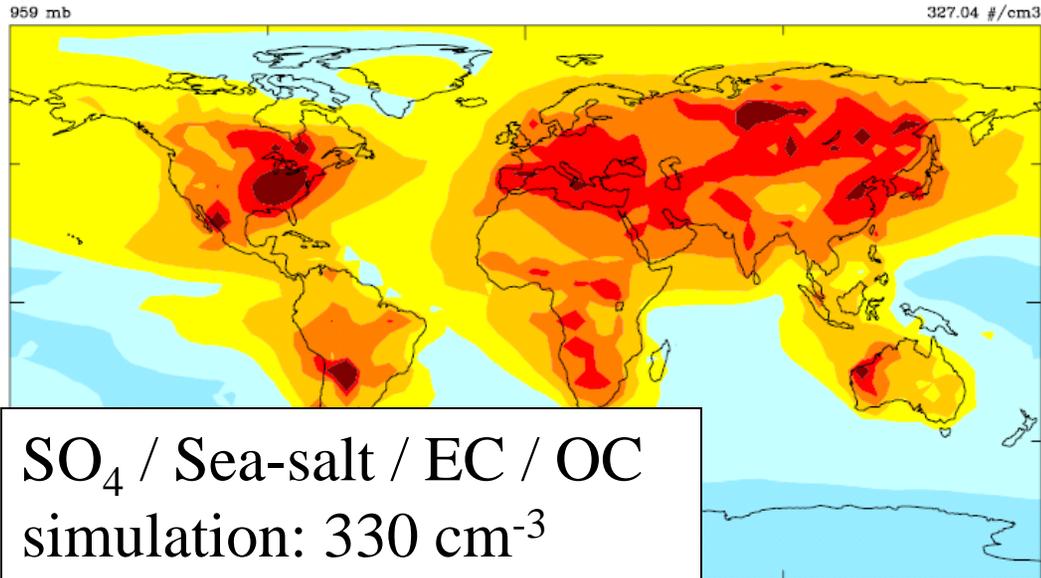
1) Insoluble:

- EC/OC are insoluble cores
- Internally mixed with sulfate/sea-salt

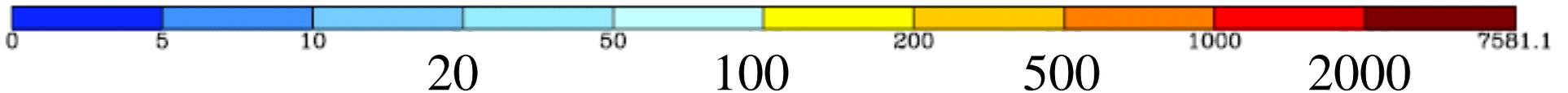
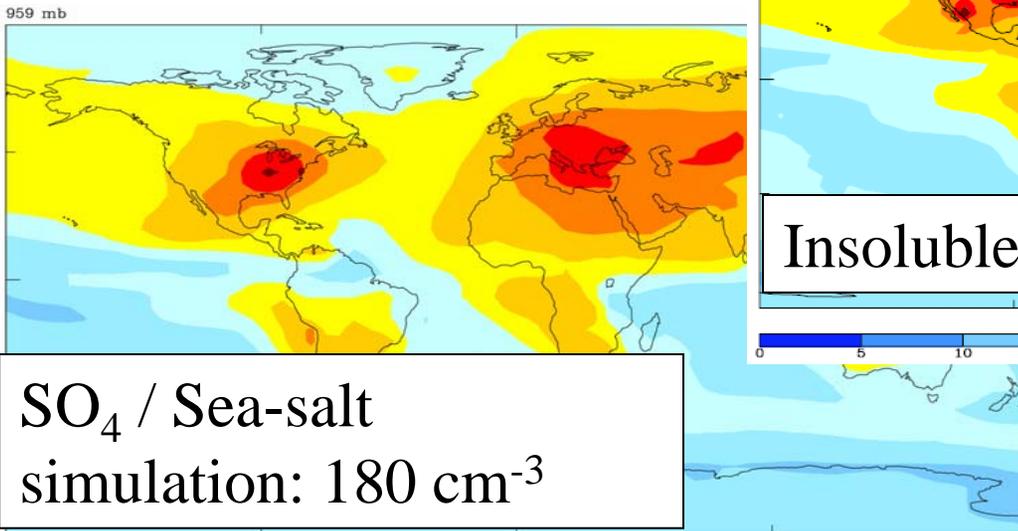
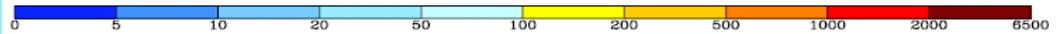
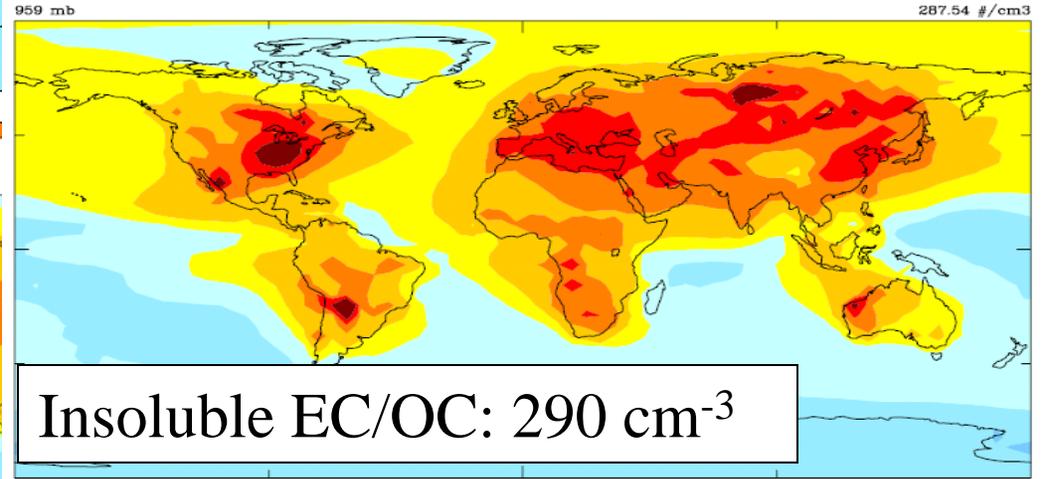
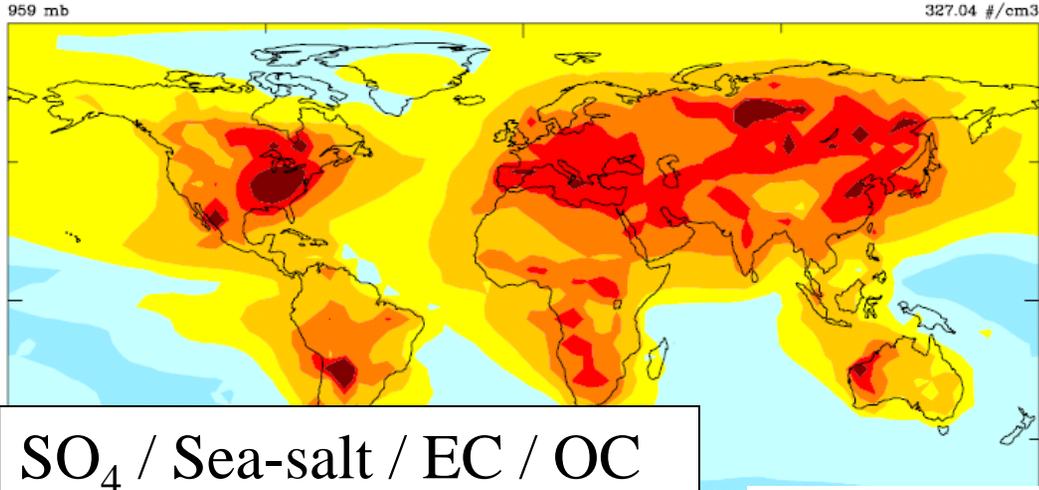
2) Externally-mixed:

- External mixtures: sulfate, sea-salt, EC/OC
- Solubility/activation same as base case

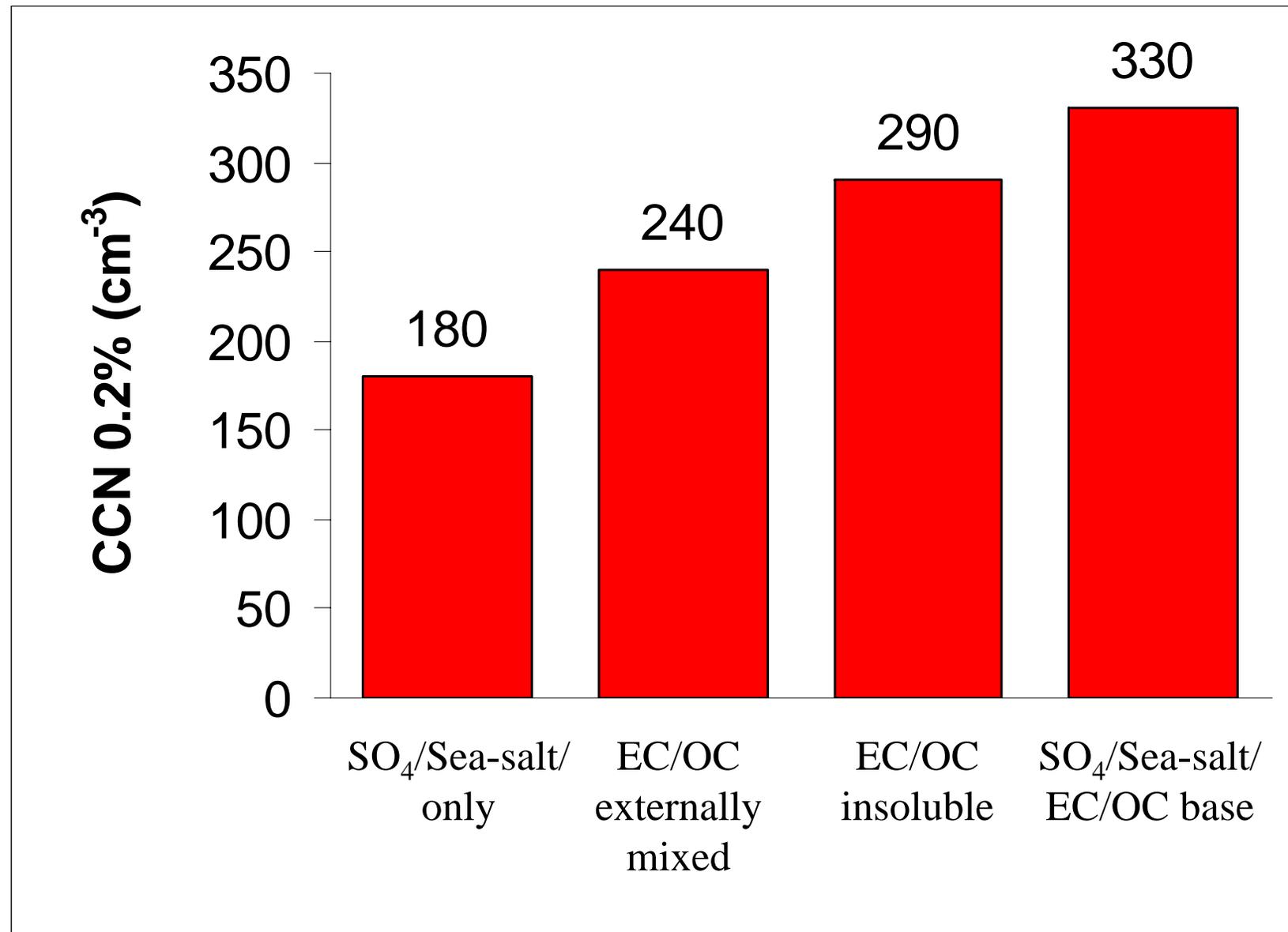
Impact of Carbonaceous Aerosol on CCN (0.2%)



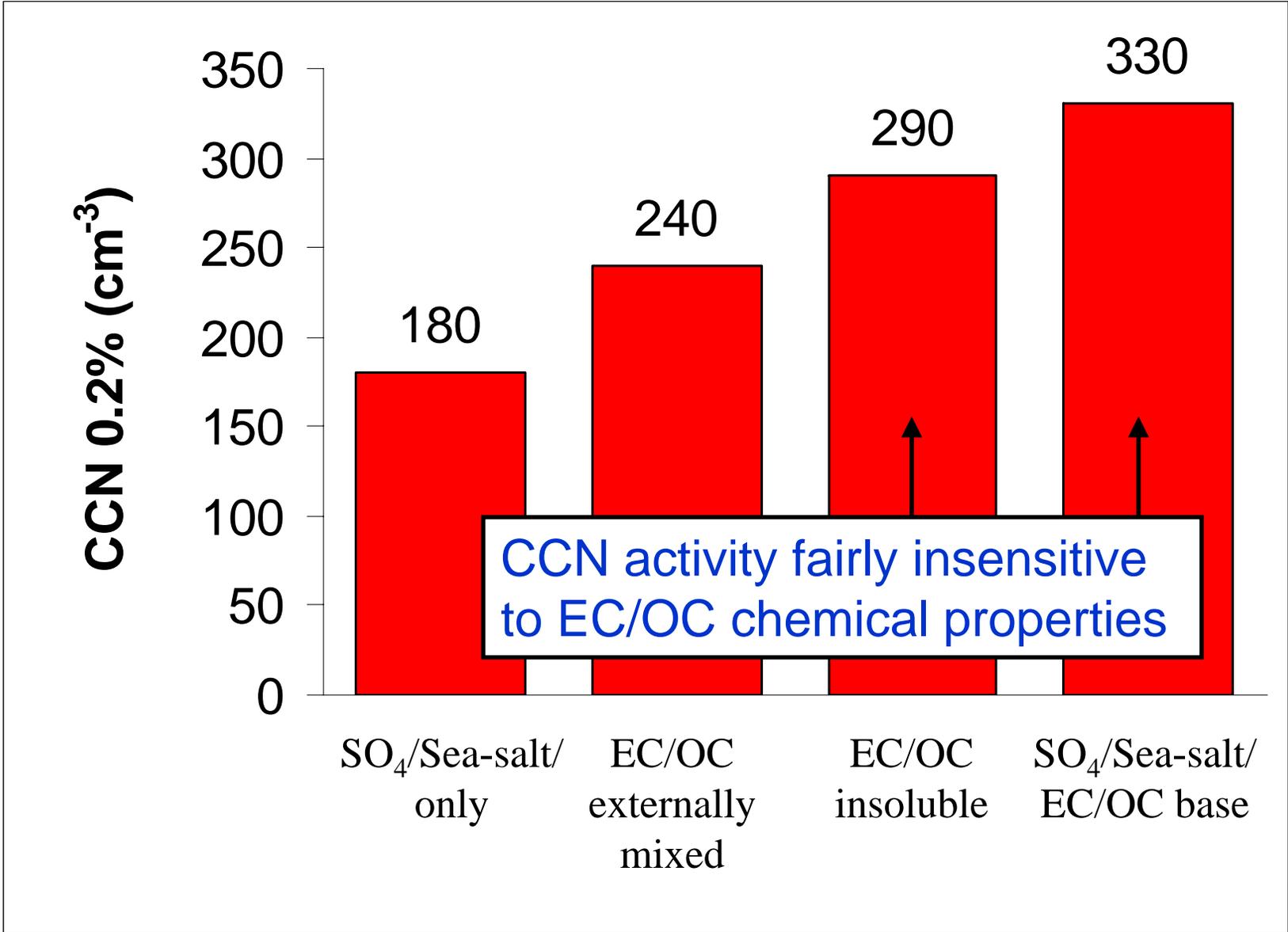
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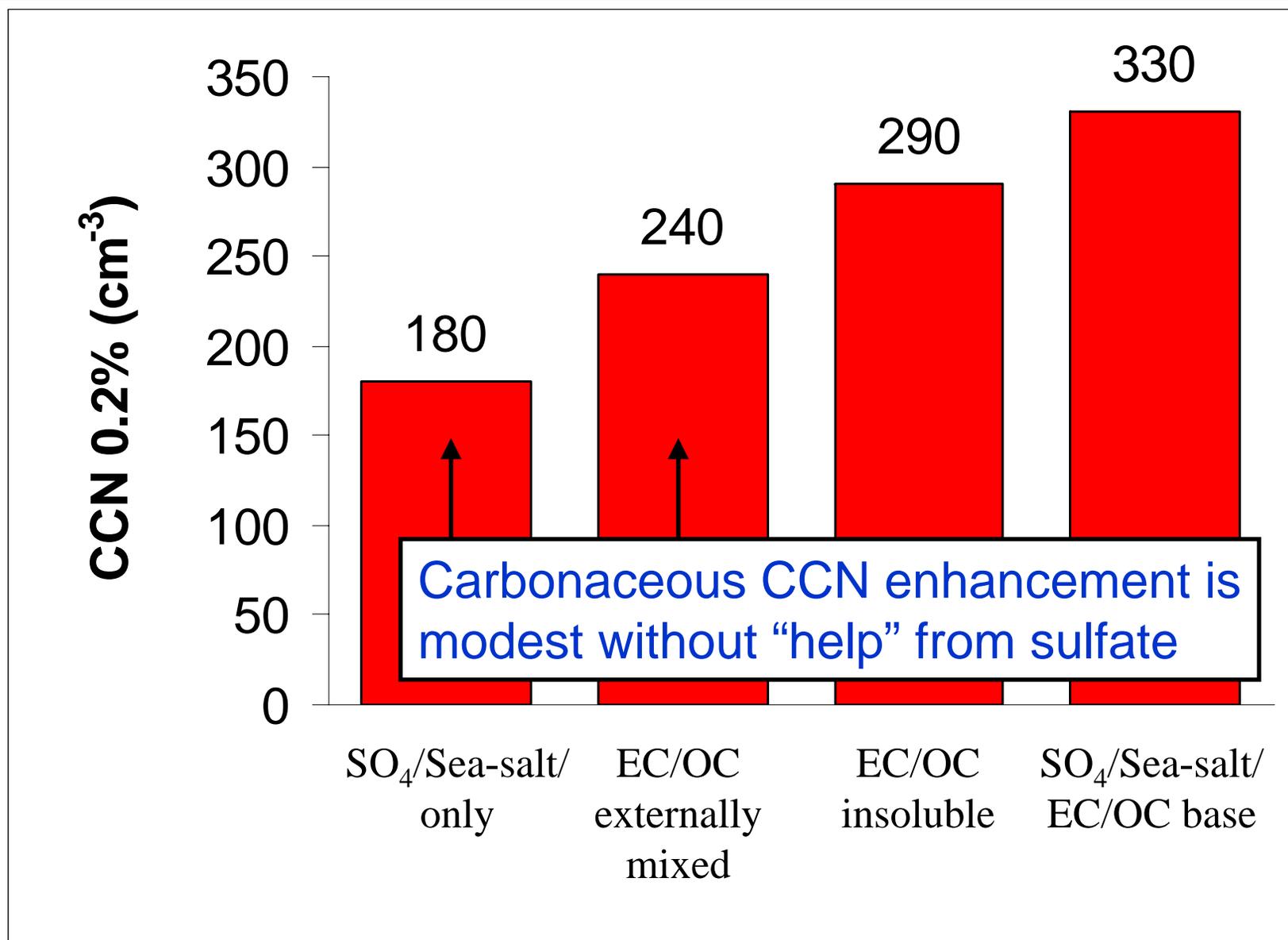
Sensitivity to Chemistry / Microphysics



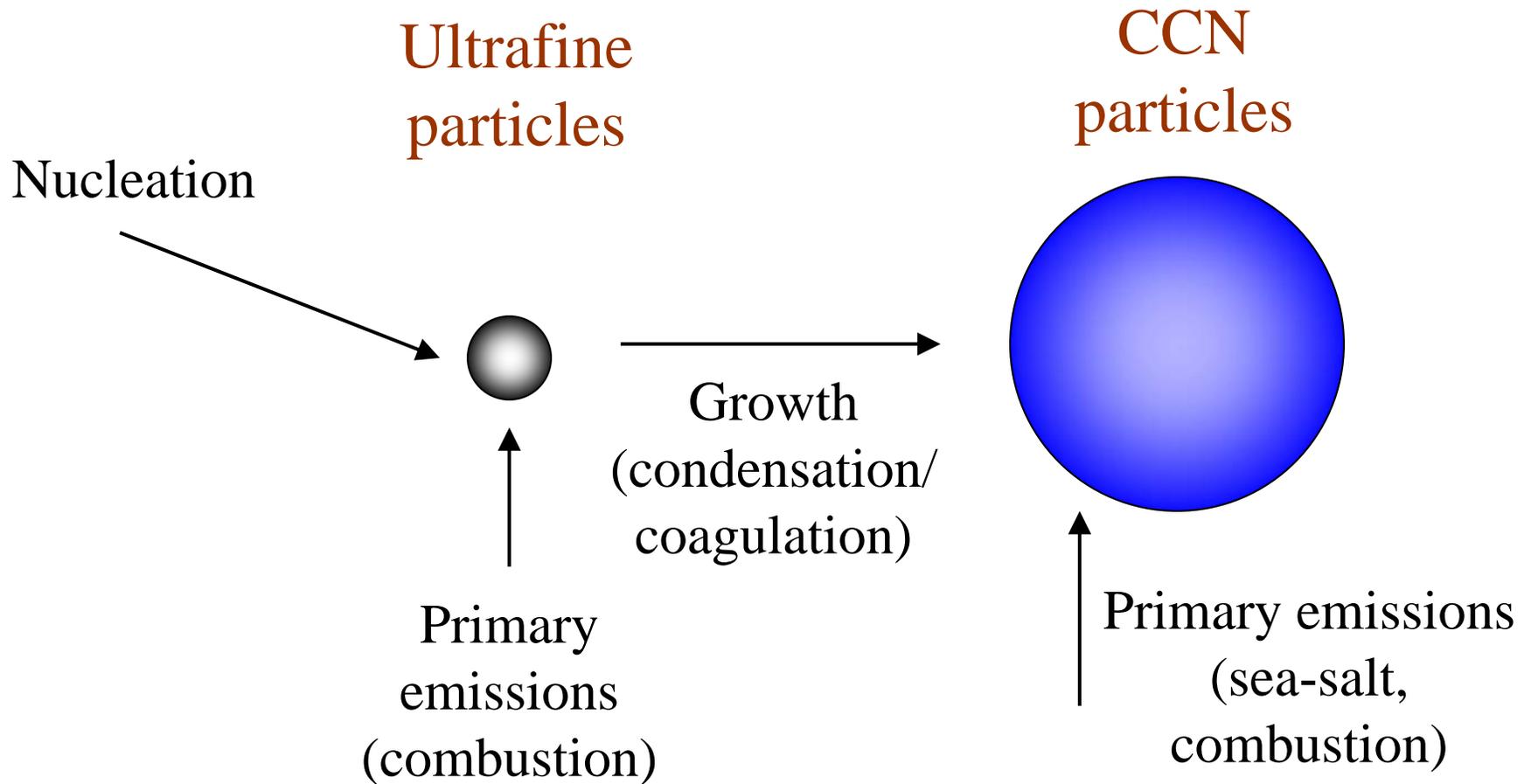
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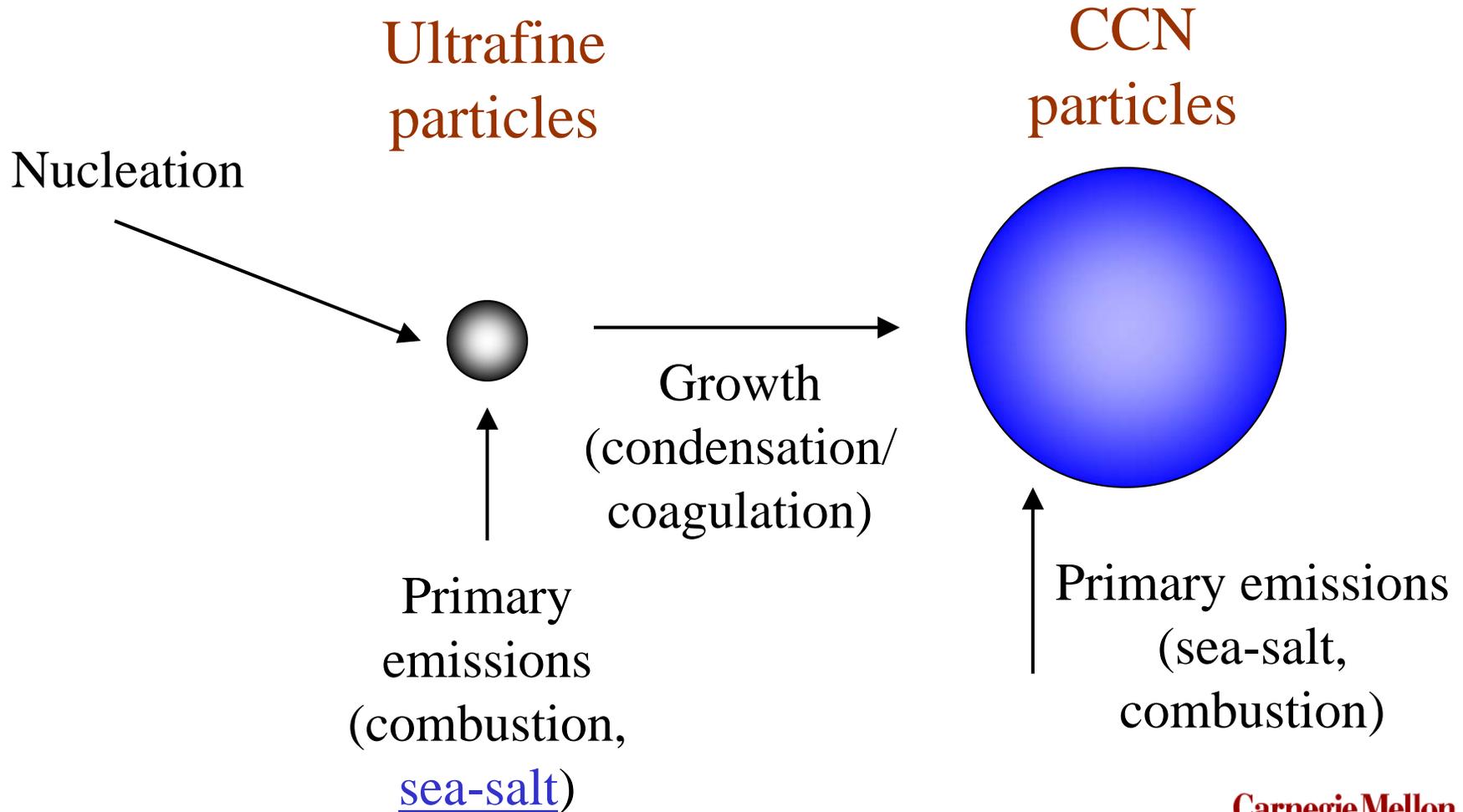
Sensitivity to Chemistry / Microphysics



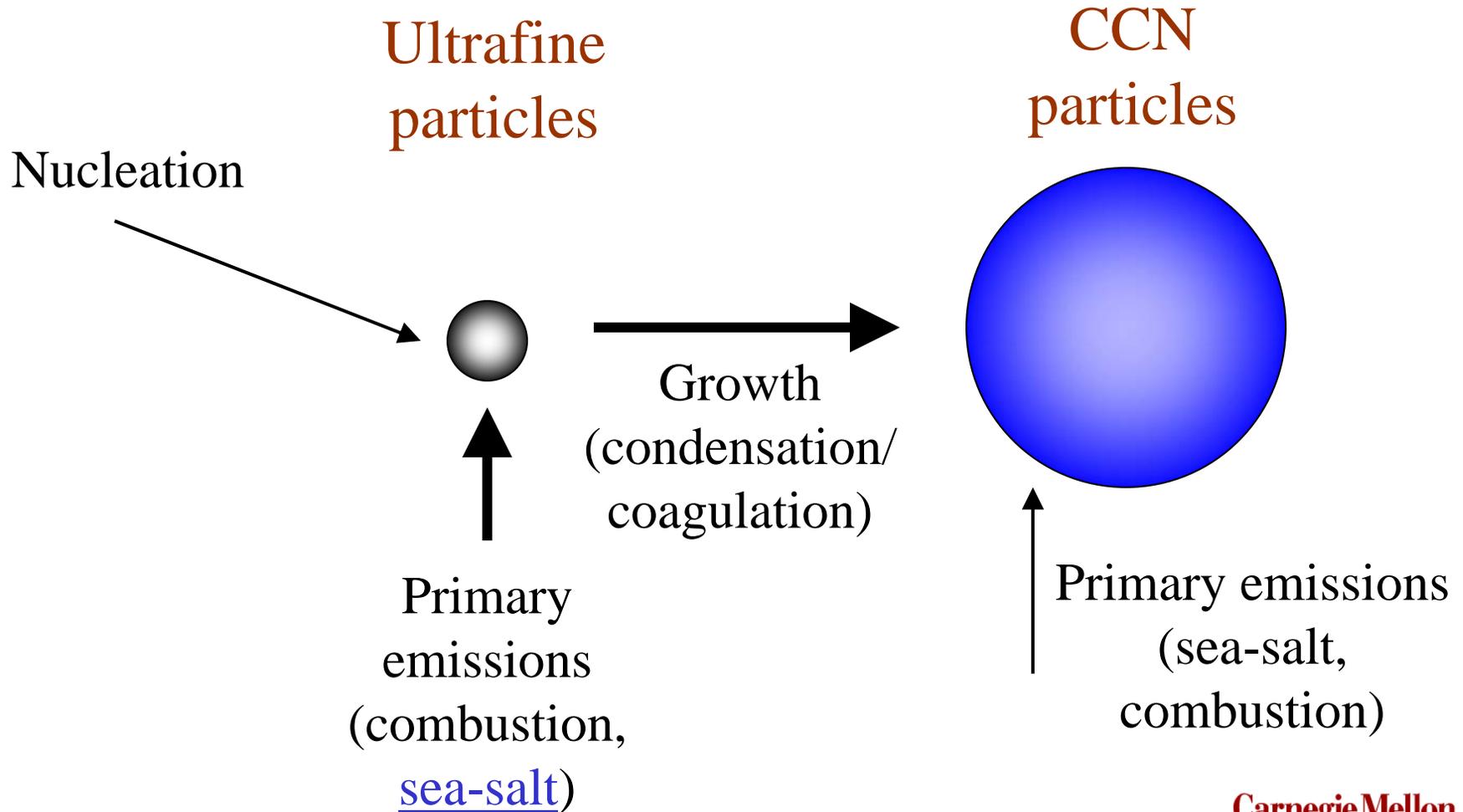
CCN Formation



CCN Formation



CCN Formation



GMI Activities

- Several microphysics schemes used in global models
 - Moment-based
 - Modal
 - Traditional sectional
 - Two-moment sectional
- Tradeoff between accuracy and computational time is mostly unexplored
- GMI is ideal platform for this intercomparison
 - Implement TOMAS
 - Invite participation of other schemes