New Particle Formation in CAM5

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7-Mode Modal Aerosol Module (MAM) in CAM5

Liu et al., *GMD*, 2012

Aitken
number
sulfate
ammmonium
secondary OM
sea salt

Accumulation
number
sulfate
ammonium
secondary OM
hydrophobic OM
BC
sea salt

Fine Soil Dust
number
soil dust
sulfate
ammonium

Fine Sea Salt
number
sea salt
sulfate
ammonium

coagulation
condensation

Primary Carbon
number
hydrophobic OM
BC

Coarse Soil Dust
number
soil dust
sulfate
ammonium

Coarse Sea Salt
number
sea salt
sulfate
ammonium

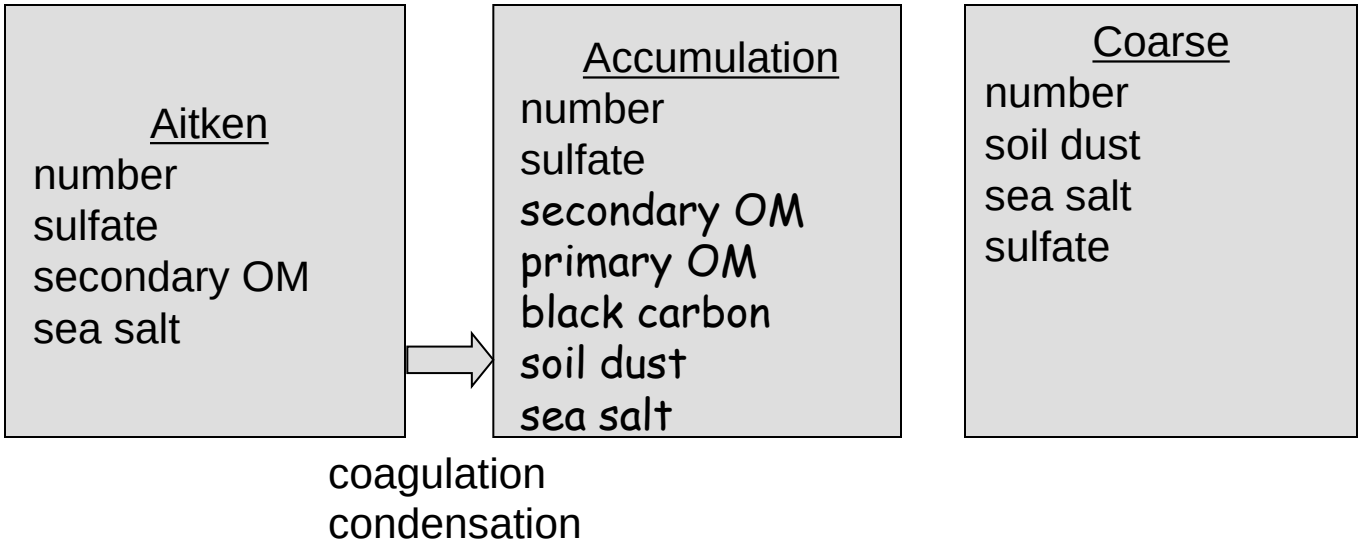
All modes log-normal with prescribed width.

Total transported aerosol tracers: 31

Cloud-borne aerosol and aerosol water predicted but not transported.

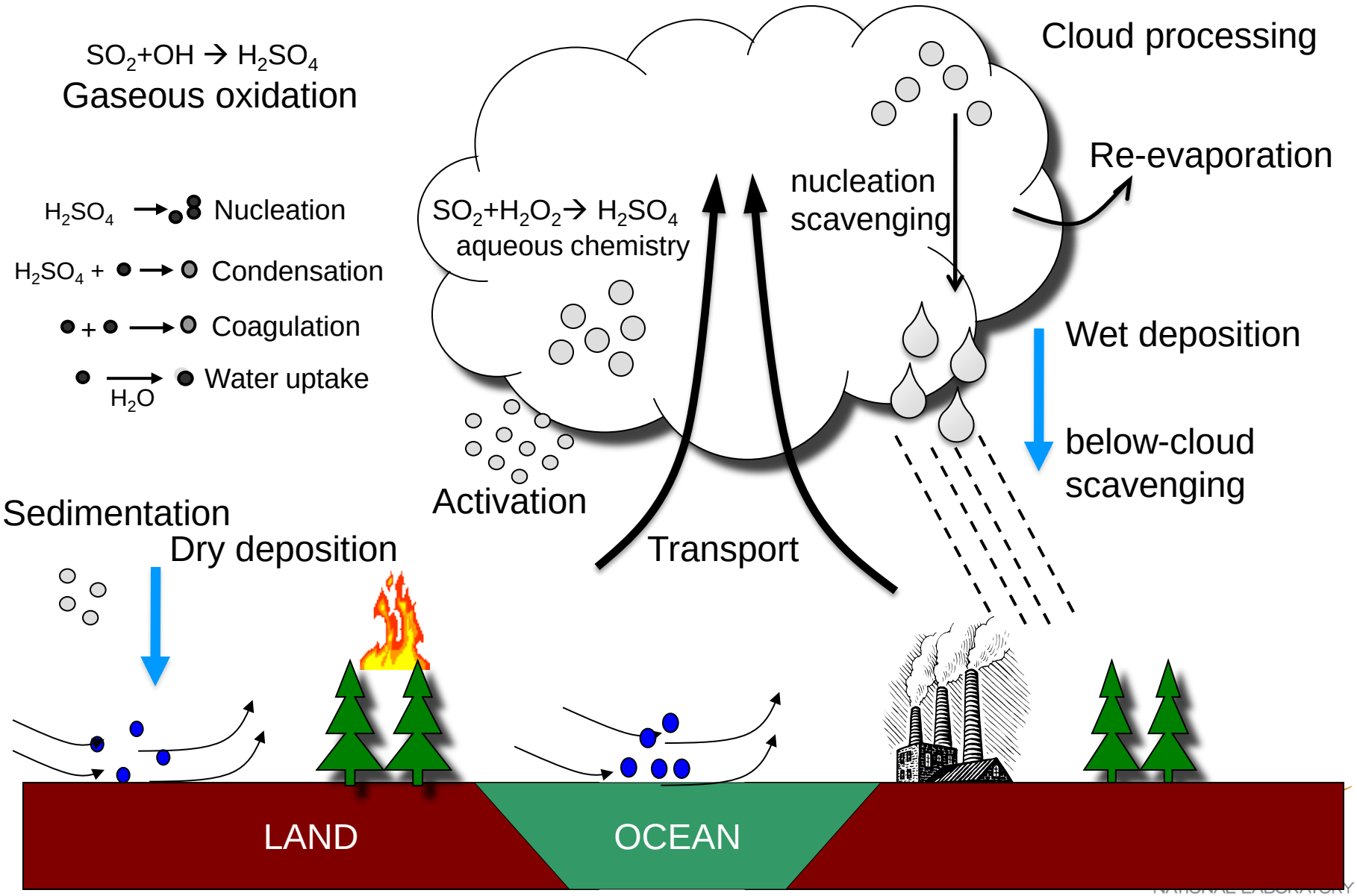
Simplified 3-mode version of MAM in CAM5

Assume primary carbon is internally mixed with secondary aerosol.
Sources of dust and seasalt are geographically separate
Assume ammonium neutralizes sulfate.



Total transported aerosol tracers: 15

Global Aerosol Cycles



Aerosol Nucleation in CAM5

- Ternary H_2SO_4-NH_3-H_2O nucleation in MAM7 (Merikanto et al, 2007) Binary H_2SO_4-H_2O nucleation in MAM3 (Vehkamaki et al. 2002);

- Boundary layer nucleation: empirical 1st order nucleation rate in H_2SO_4 (Sihtp et al., 2006) with the rate coefficient of 1.0×10^{-6} s^{-1};

- Kerminen and Kulmala (2002) approach used to account for coagulation loss of new particles as they grow from critical cluster size (~1 nm) to Aitken mode size.

Issues with current nucleation treatment in CAM5

- Contribution of organics (SOA) to particle nucleation/growth not considered.
- Calculation is time (sequentially)-split by processes (chemical production, condensation and nucleation). Produce numeric errors due to large model time steps.
- Fresh particles are grown to Aitken size using current time-step conditions, accounting for coagulation losses. Growth time often exceeds model time step. This may overestimate the growth rate of fresh particles to Aitken size.

Updates in CAM5 Aerosol Nucleation Work

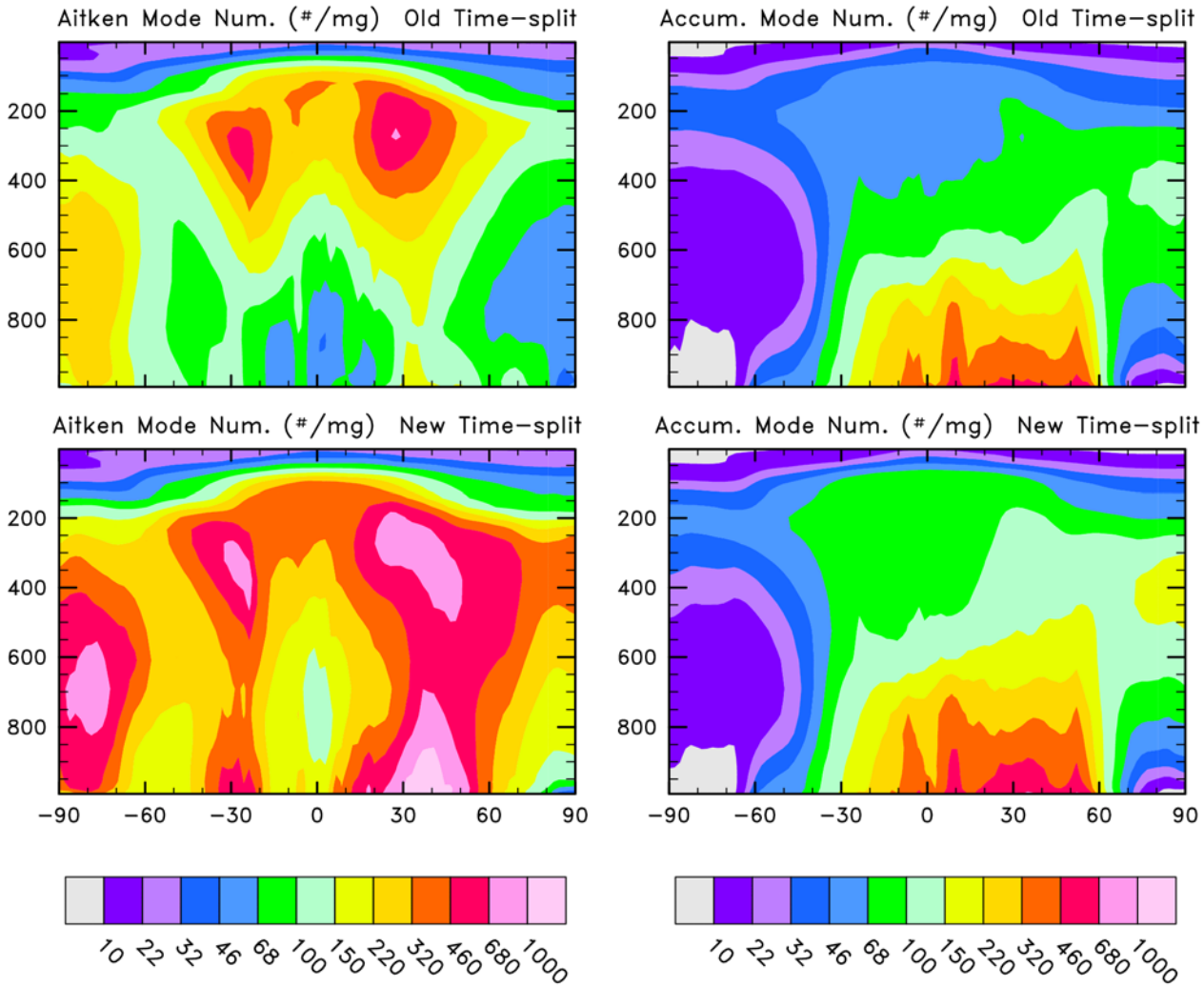
- Treats aerosol microphysics module for condensation, nucleation, and coagulation processes in a more integrated manner.
  - *Sub-time stepping*

- Improve time-splitting for H_2SO_4 production and loss.
  - *H_2SO_4 production by gas phase chemistry is applied simultaneously with H_2SO_4 condensation loss*

- Better represent H_2SO_4 concentration under fractional cloudiness conditions.
  - *Separate clear-sky (for aerosol nucleation) and in-cloud (for scavenging) potion of model grid*

Effect of Time Splitting on Zonal Annual Average Number Concentrations

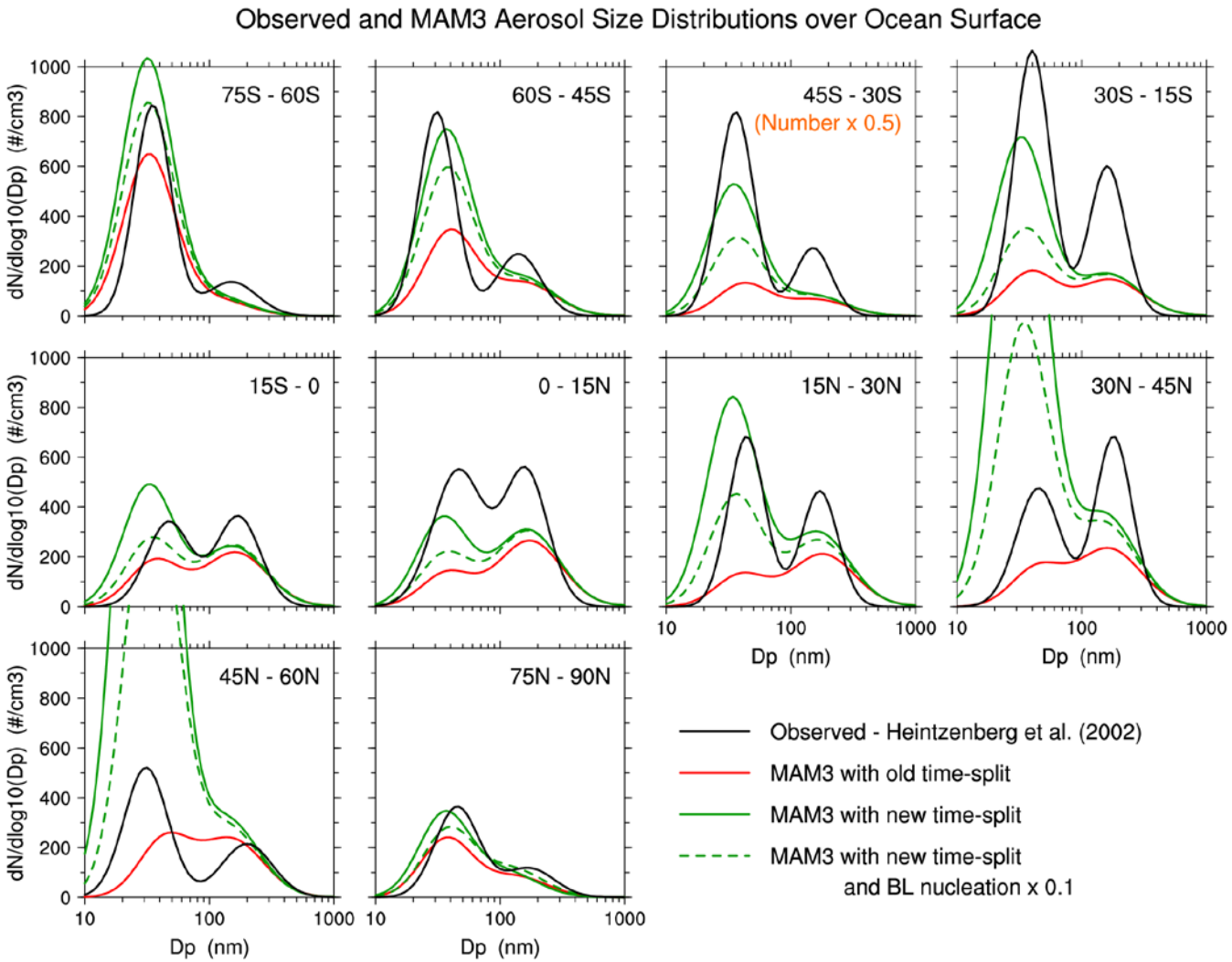
112% increase globally



27% increase globally

Eliminating time-split of H_2SO_4 production and condensation significantly increases nucleation. New particle formation up 400% globally, Aitken number up 112%, accumulation number up 27%.

Comparison to Observed Size Distributions in MBL



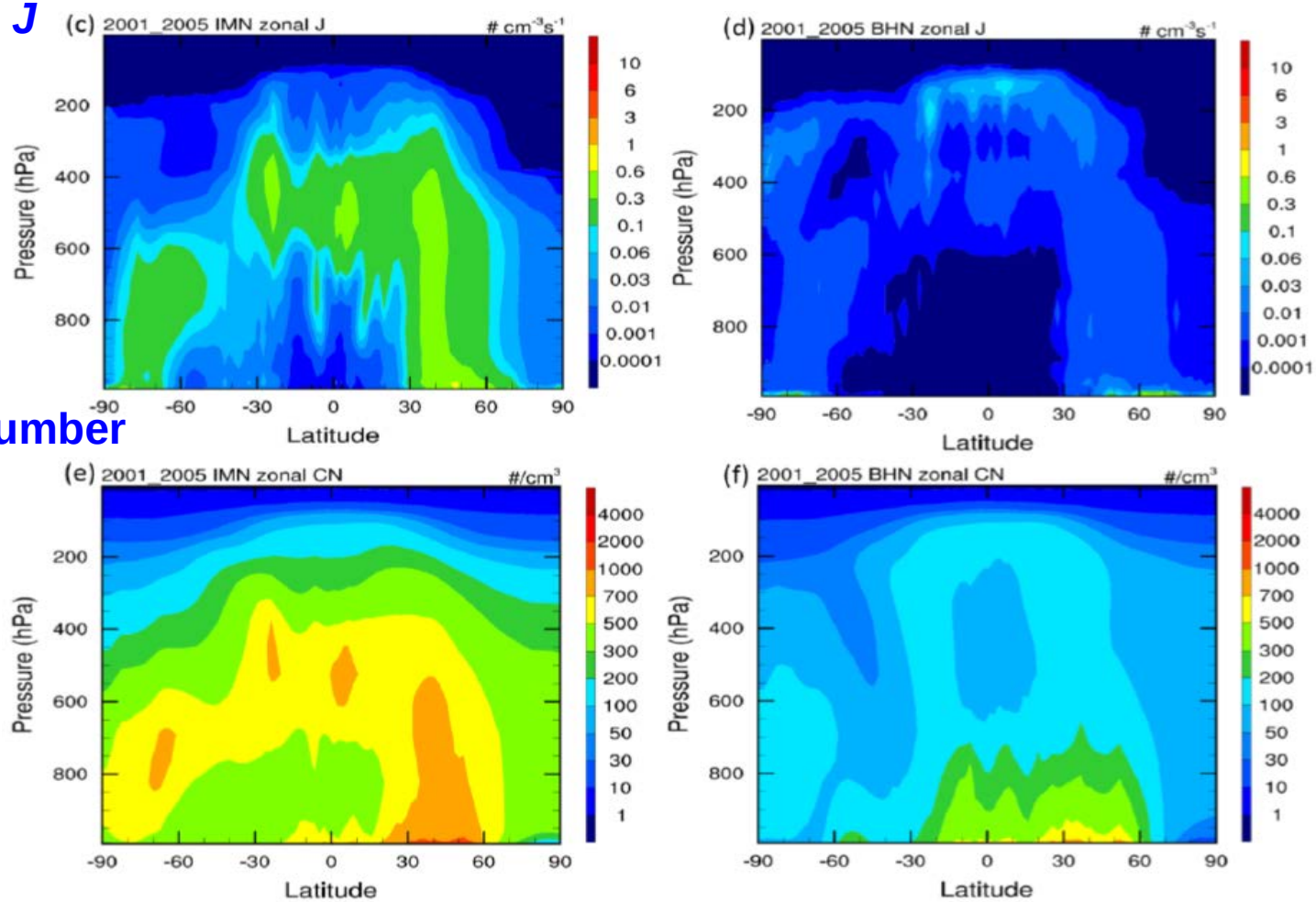
Aitken number evaluation (limited): Aircraft profiles improved; marine BL now too high.

Implement ion-mediated nucleation scheme in CAM5

F. Yu (SUNY-Albany), X. Liu, R.C. Easter, S. Ghan (PNNL)

Nucleation rate *J*

Total particle number

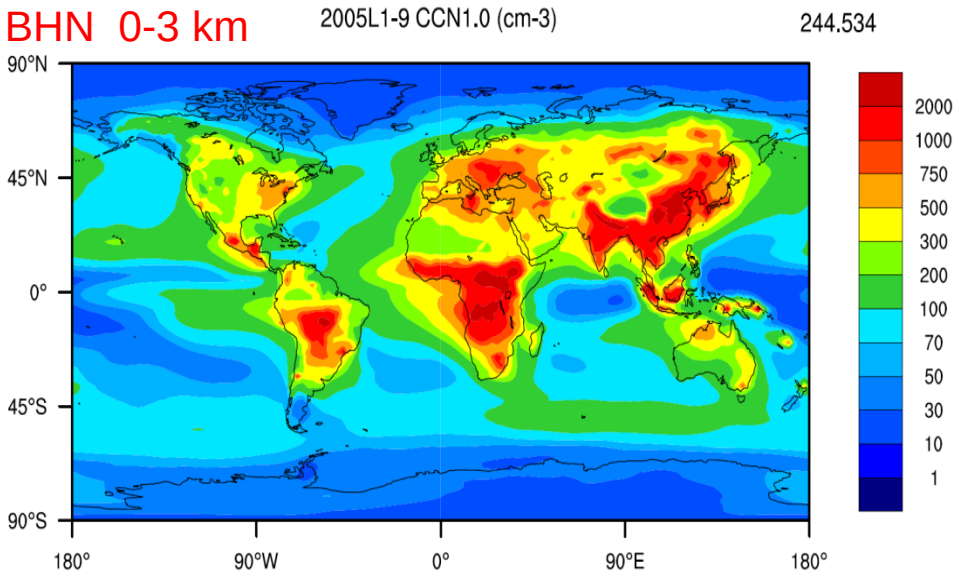


IMN BHN

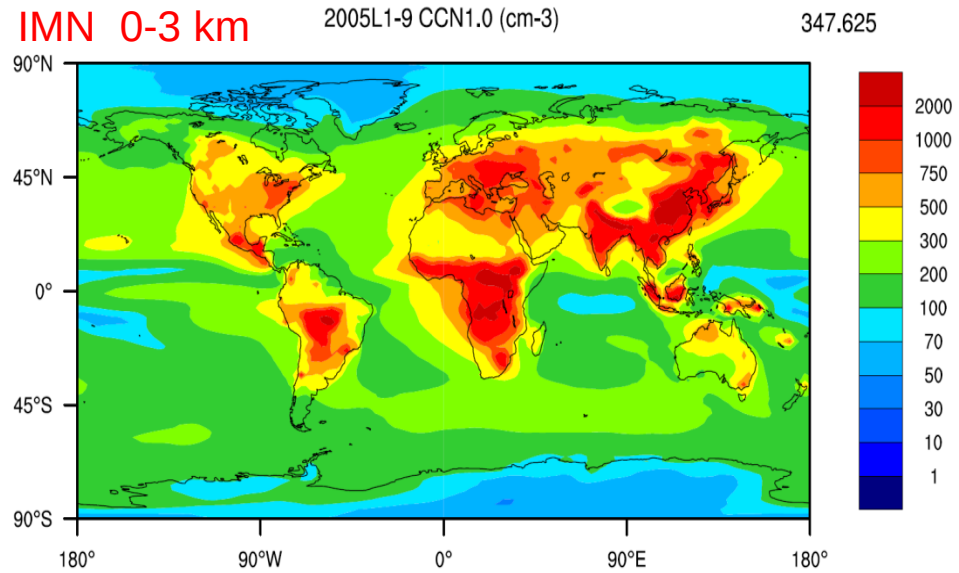
CCN @ S=1% (# cm^{-3})

244.5 — 42% — 347.6

BHN 0-3 km



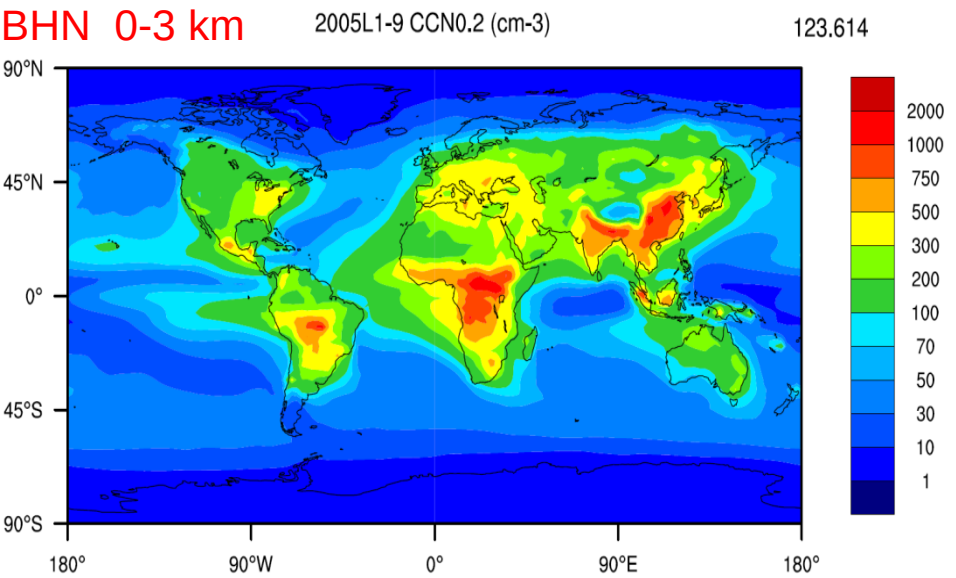
IMN 0-3 km



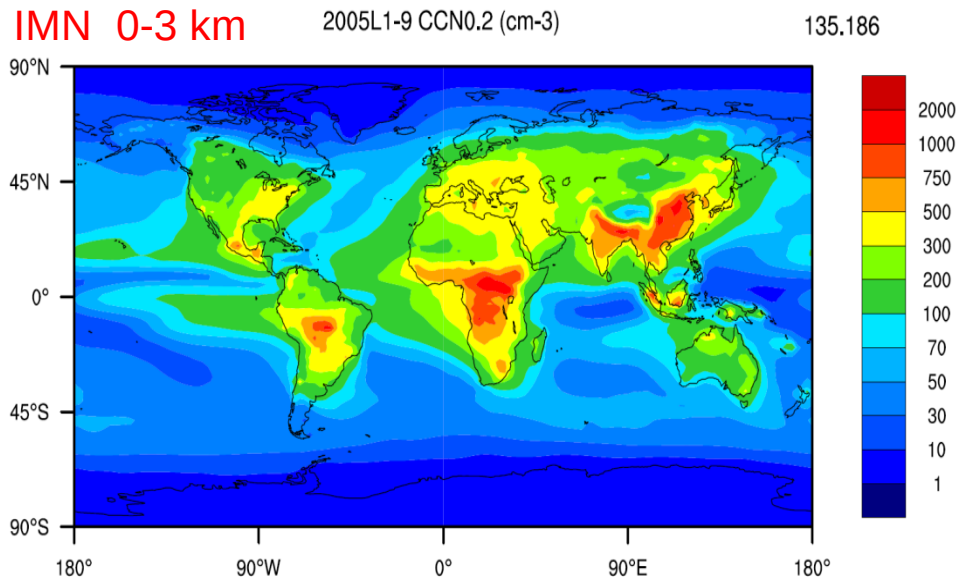
CCN @ S=0.2% (# cm^{-3})

123.6 — 9.4% — 135.2

BHN 0-3 km



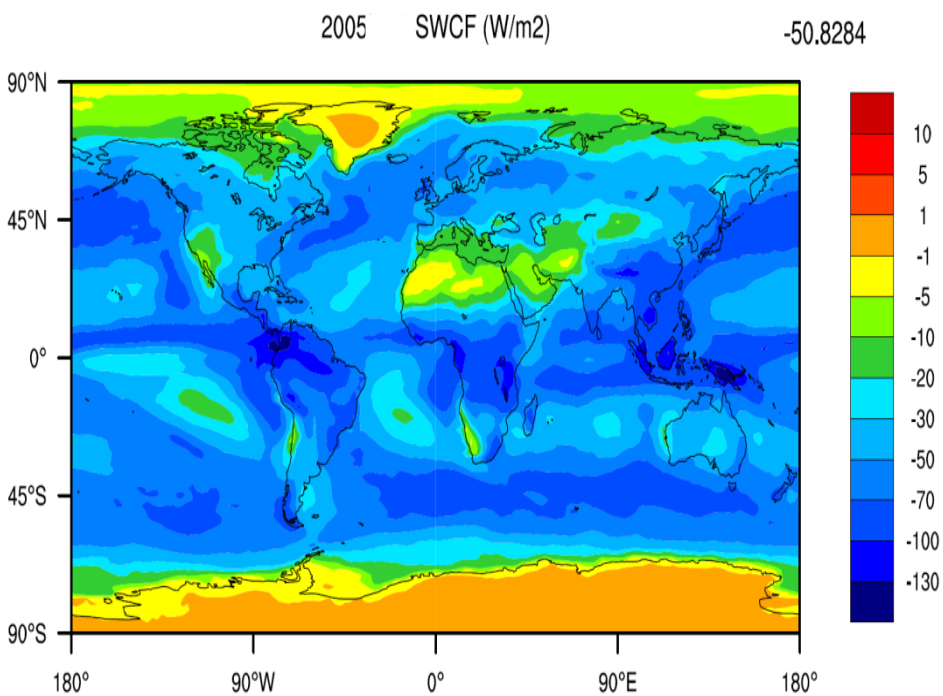
IMN 0-3 km



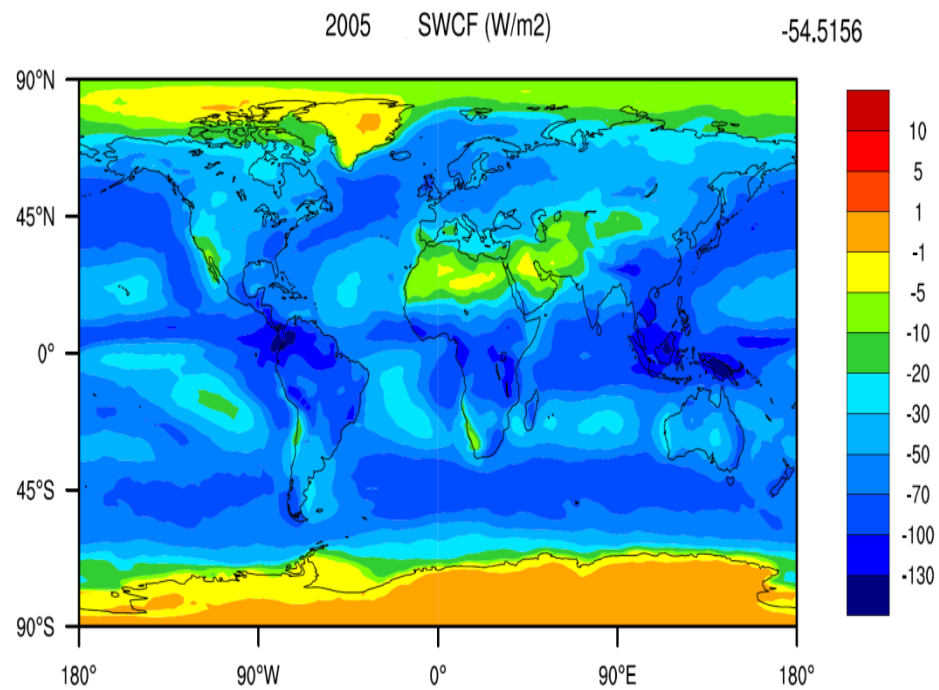
Effect of nucleation on shortwave cloud forcing

-50.8 -54.5

-3.7 W/m^2



BHN



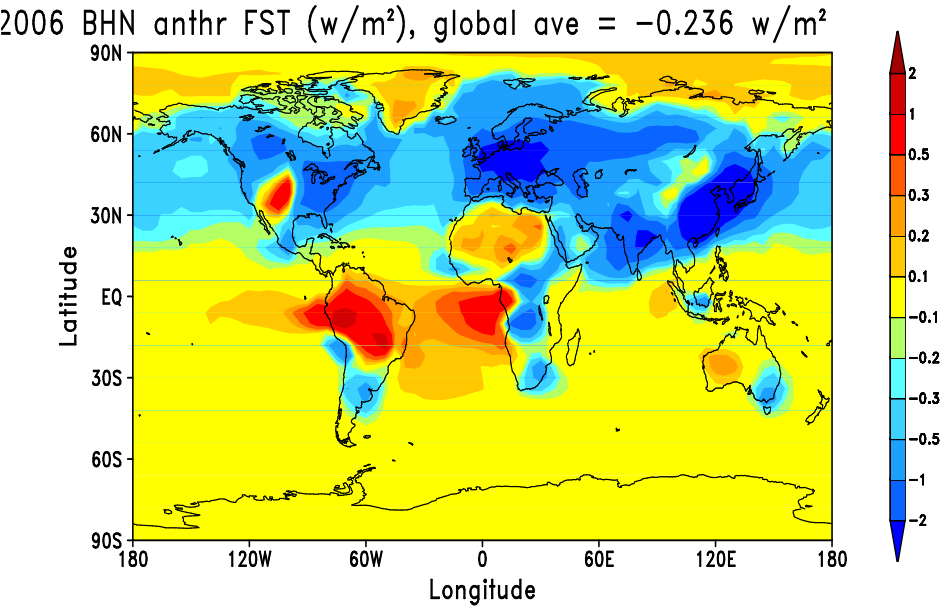
IMN

Planned improvement in CAM5 nucleation

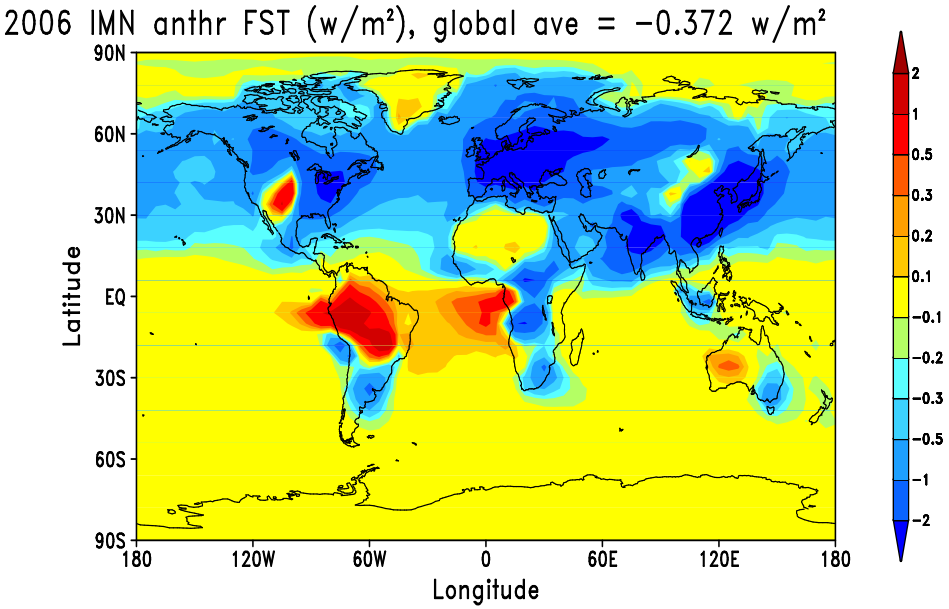
- Include an explicit “ultrafine” mode for fresh particles.
- Incorporate new findings for fresh particle growth rates (Kuang and Wang, BNL).
- Treat sub-grid variations in RH, T, H_2SO_4

Total anthropogenic aerosol all-sky TOA direct radiative forcing

BHN



IMN



-0.236 -0.14 W/m^2 -0.372