An Aerosol Package for NCAR CAM4

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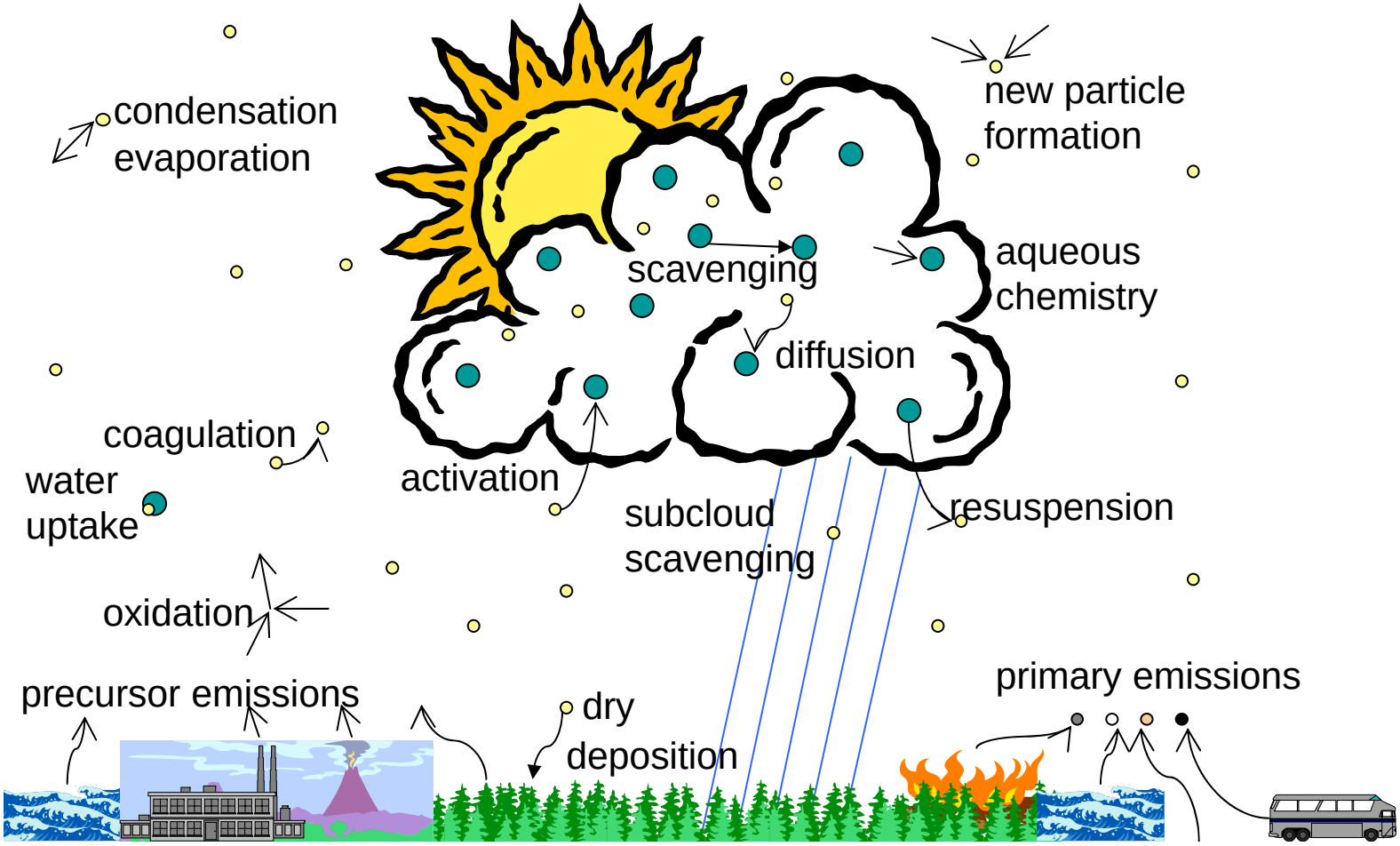
Goal: Develop a complete and computationally efficient representation of the aerosol for exploring the competing and complementing mechanisms by which natural and anthropogenic aerosols influence clouds and the cycles of water and energy.



Current Aerosol Treatment in CAM3

sulfate	hydrophobic black carbon	sea salt 1	soil dust 1
ammonium	hydrophobic organic carbon	sea salt 2	soil dust 2
nitrate	hydrophilic black carbon	sea salt 3	soil dust 3
secondary organic carbon	hydrophilic organic carbon	sea salt 4	soil dust 4

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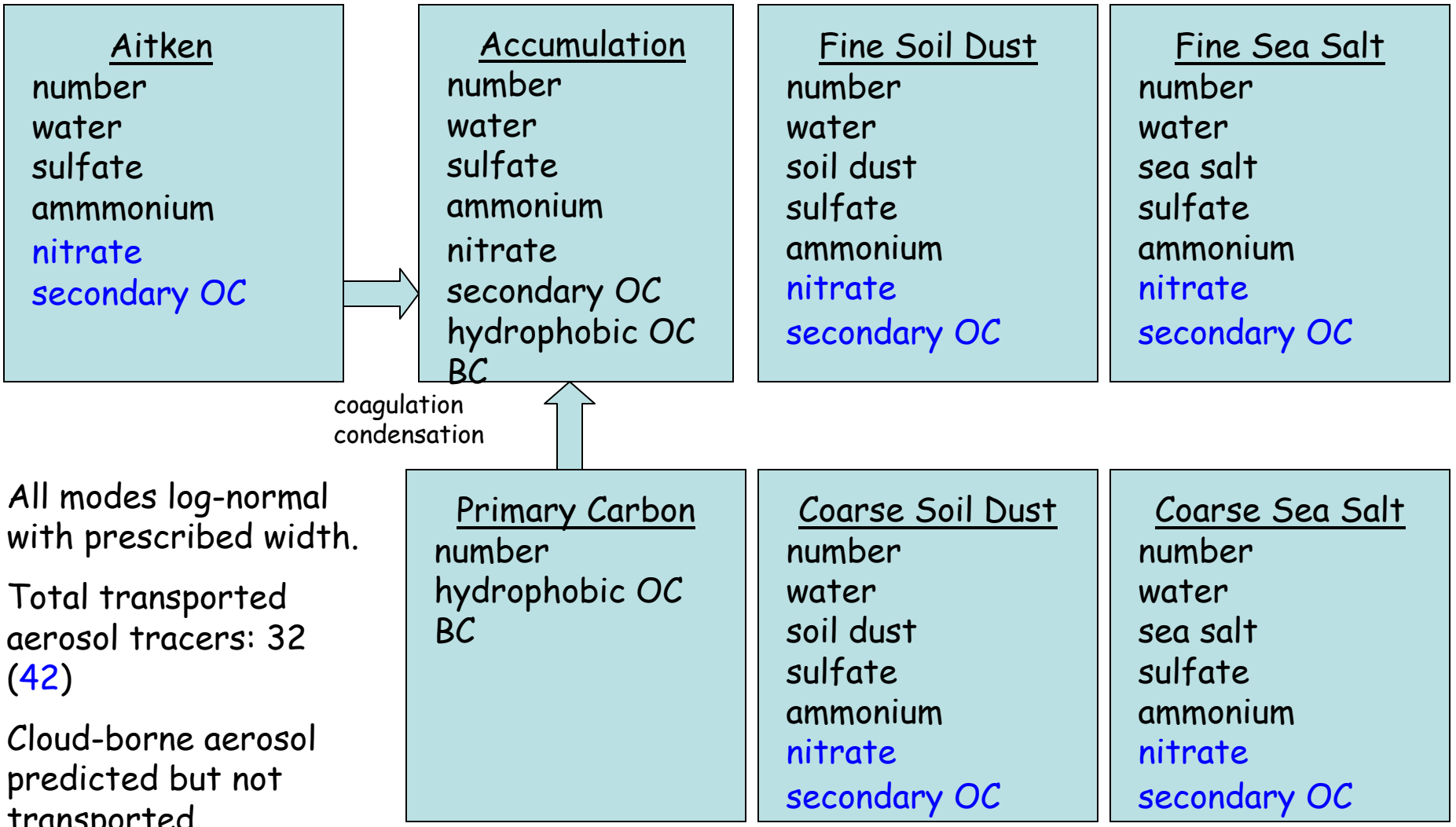
- Hydrophobic carbon ages to hydrophilic with prescribed timescale

Proposed Benchmark Aerosol Treatment for CAM4



All modes log-normal with prescribed width.

Total transported aerosol tracers: 32 (42)

Cloud-borne aerosol predicted but not transported.

Process and Property Treatment

- Primary emissions: size-resolved.
- New particle formation: ternary homogeneous nucleation.
- VOC oxidation and condensation separated.
- Condensation: mass transfer theory.
- Cloud chemistry: current CAM3 treatment (pH dependent)
- Coagulation: Brownian within, between modes.
- Intermode transfer due to condensation, coagulation, and cloud chemistry.
- Scavenging: in-cloud -- activation of number and mass for each mode, number depletion by droplet collision/coalescence; below-cloud -- by impaction; dry deposition
- Water uptake: Kohler theory for internal mixture, with hysteresis dependent on previous aerosol water.
- Optical properties: parameterization in terms of wet refractive index and wet surface mode radius.

Comparison with GMI aerosol microphysics

CAM4 aerosol

- 7 modes, internal mixing within modes, external mixing between modes.

GMI aerosol

- 2 modes for pure sulfate, non-sulfate aerosol (OC,BC,dust,ss), interaction of sulfate with non-sulfate aerosol.

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- Water in aerosol predicted

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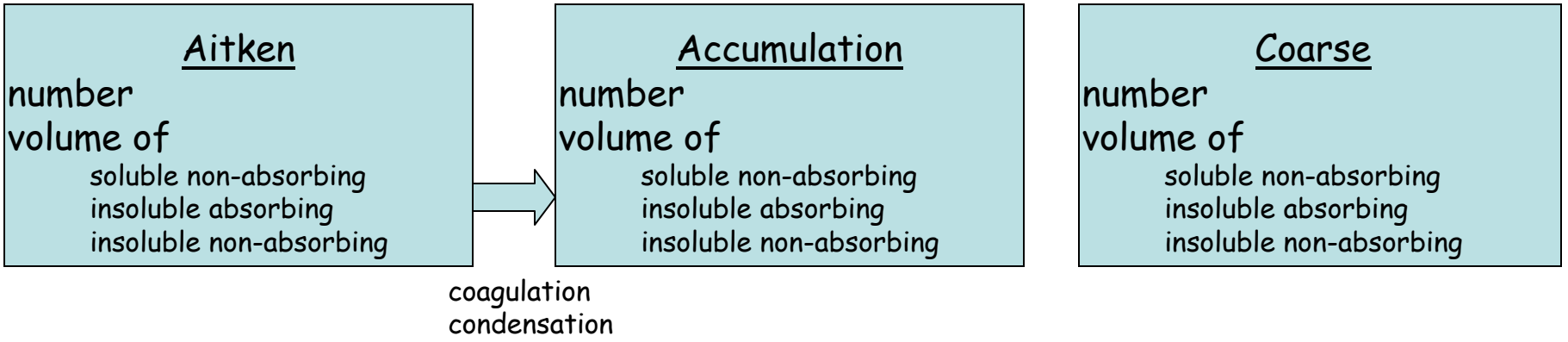
- Treatment of nitrate, ammonium
- Prescribed fraction -> wet removal
- Water in aerosol diagnosed

Proposed simplified Aerosol Treatment for CAM4

Treat only three aerosol types for each mode, distinguished by hygroscopicity and solar absorption.

Predict volume mixing ratio v of each type.



All modes log-normal with prescribed width.

Total transported aerosol tracers: 12

Cloud-borne aerosol predicted but not transported.

Hygroscopicity B and imaginary refractive index r of each aerosol type k are prescribed.

All sources are fully speciated.

Mass source q of each chemical specie i is partitioned across types to conserve hygroscopicity and refractive index.

$$\frac{dv_k}{dt} = \frac{1}{B_k} \sum_i \frac{B_i q_i}{\rho_i}$$

CAM Simulations

- Benchmark modal present-day
  - On-line oxidants (HO_x,O_3 chemistry)
  - Off-line oxidants (input HO_x,O_3)
- Benchmark modal pre-industrial
- Simplified modal present day, offline oxidants
- Simplified modal pre-industrial, offline oxidants
- Offline benchmark present day (interpolation from monthly mean of on-line benchmark)
- Offline benchmark pre-industrial

Testing

- Evaluate on-line benchmark treatment using *in situ* (surface and aloft) and remote aerosol measurements (mass, number, size, CCN, AOD, ...). Utilize AEROCOM and other model evaluation efforts.
- Evaluate approximations used in on-line simple treatment by comparing direct and indirect aerosol effects with on-line benchmark treatment.
- Evaluate off-line benchmark treatment by comparing with on-line benchmark treatment.

Collaboration

- PNNL: aerosol microphysics
  - Xiaohong Liu: integration, emissions, intermode transfer, simulations
  - Steve Ghan: scavenging, optics, simple treatment
  - Richard Easter: nucleation, coagulation, convection
  - Rahul Zaveri: water uptake, mass transfer, condensation
  - Yun Qian: evaluation, off-line treatment
- LLNL: evaluation
  - Cathy Chuang and Philip Cameron-Smith: AEROCOM diagnostics, satellite & other data
  - Cyndi Atherton, Peter Connell: VOC oxidation (leveraging ASP)
- NCAR: chemistry
  - Jean-Francois Lamarque: VOC oxidation and SOA formation
  - Natalie Mahowald: sea salt and soil dust emissions
  - Francis Vitt: preprocessor, merging

Schedule

- March 2007: Complete application and first benchmark simulation
- September 2007: Complete evaluation and refinement of benchmark
- December 2007: Complete evaluation of simplified and off-line treatments
- March 2008: Merge with developmental trunk