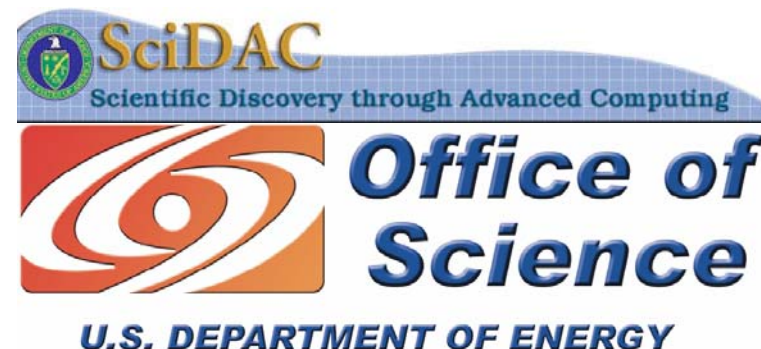


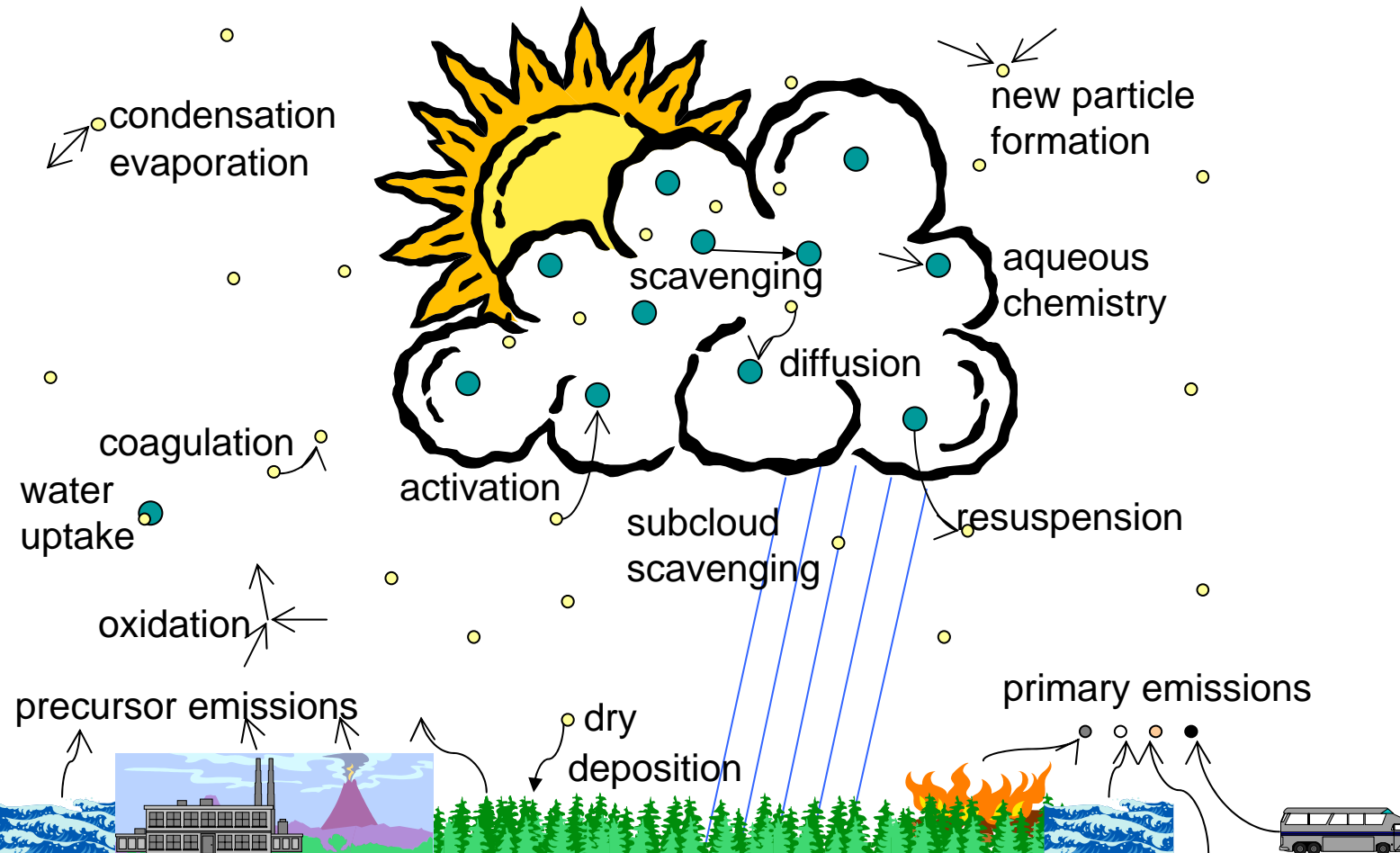
Progress on Application of Modal Aerosol Dynamics to CAM

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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

Current Weaknesses in CAM

- Aerosol species are externally mixed (individual particles are composed of only a single species).

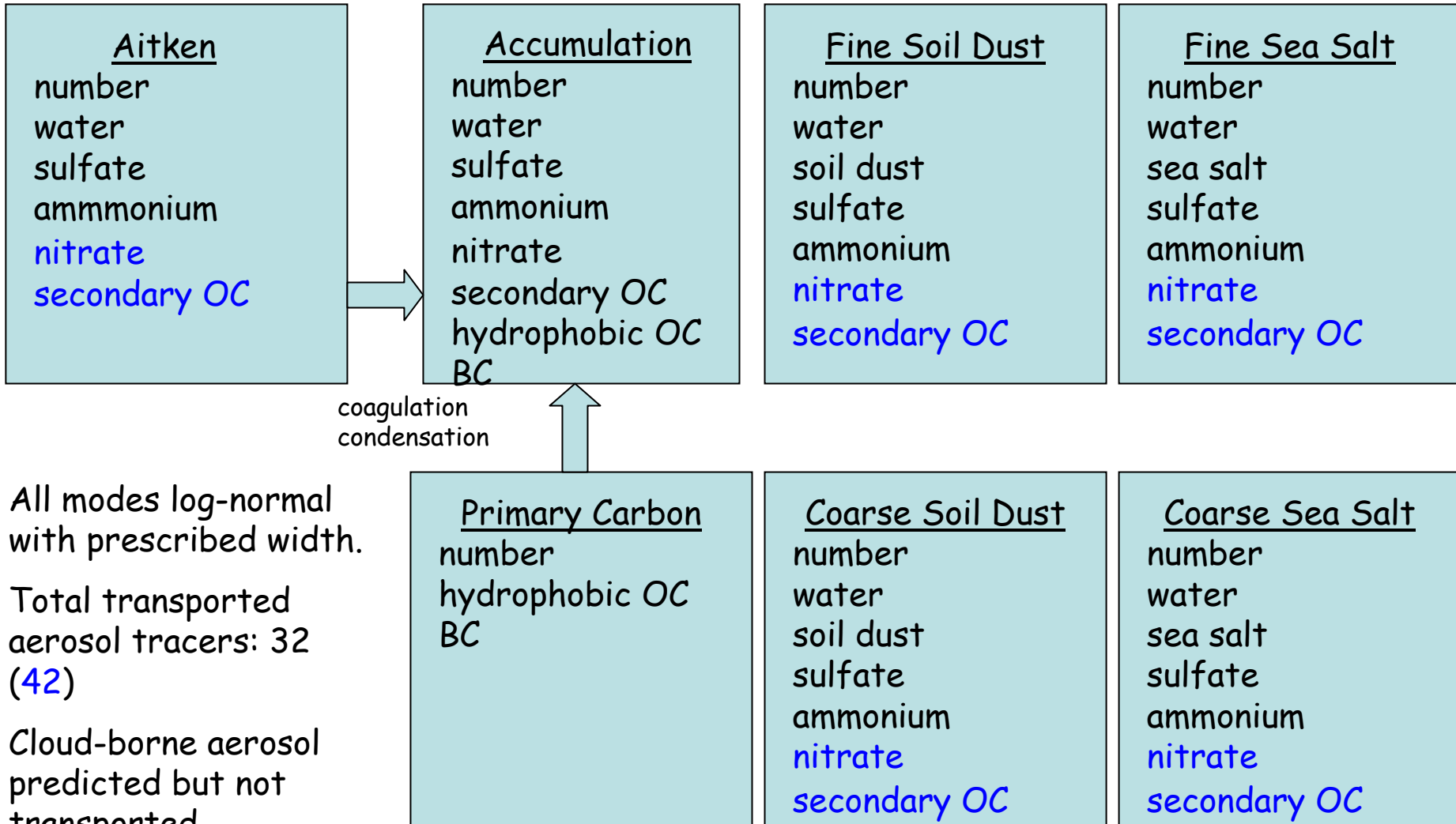
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- Aerosol species are externally mixed (individual particles are composed of only a single species).
- Their size distribution is prescribed (number is diagnosed from the predicted mass).
 - Processes that should only affect mass (condensation, chemistry) also affect number.
 - Processes that only affect number (nucleation, coagulation) are neglected.

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 - Processes that only affect number (nucleation, coagulation) are neglected.
- 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.

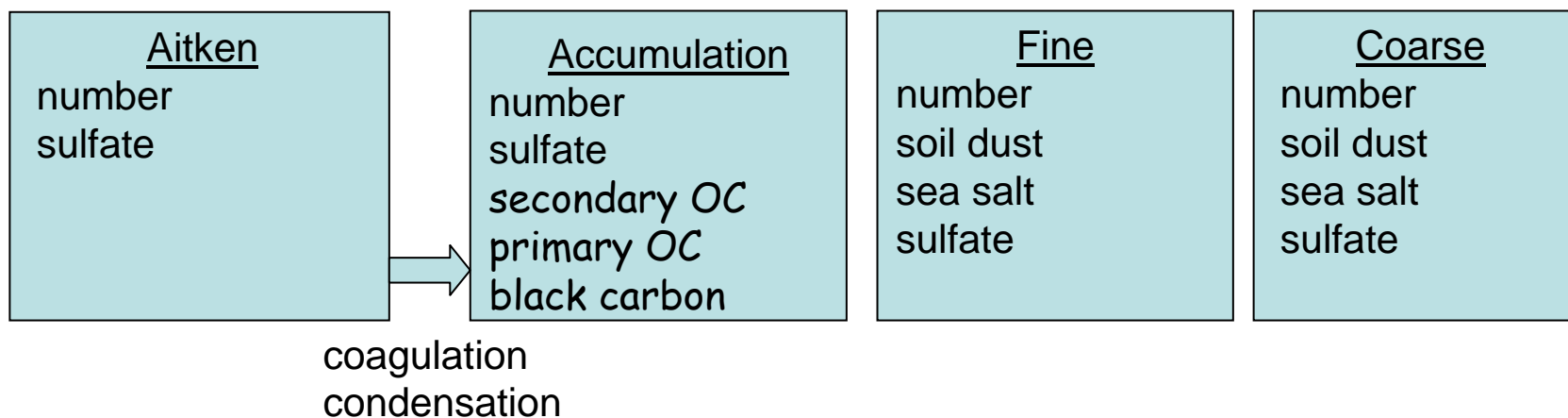
Proposed Simplified Aerosol Treatment for CAM4

Assume aerosol are hydrated for $RH > \text{crystalization } RH$.

Carry soil dust and sea salt in same mode because sources are separate.

Assume primary carbon is internally mixed with secondary aerosol.

Assume ammonium neutralizes sulfate, and neglect nitrate.



All modes are log-normal with prescribed width.

Total transported aerosol tracers: 15

Cloud-borne aerosol are predicted but not transported.

Process and Property Treatment

- Primary emissions: size-resolved.
- New particle formation: 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.

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

Progress

- Emissions (size-resolved) (done)
 - ✓ Fossil fuel SO₂ emissions over 0-100 m and >100 m based on EDGAR-2000;
 - ✓ 3% (by mole) of fossil fuel SO₂ emissions goes to SO₄ (Aitken & Accu. modes, mass & number, Whitby 1978);
 - ✓ OM and BC to primary carbon mode (mass & no.);
 - ✓ Sea salt emission based on Gong et al (1997) to fine and coarse sea salt modes (mass & no.);
 - ✓ Dust emissions to fine and coarse dust modes (mass & no.).

Progress

- Aerosol activation and droplet nucleation (Ghan scheme) (done)
- Wet scavenging (done)
 - ✓ In-cloud rainout based on activated aerosol;
 - ✓ Below-cloud impaction scavenging rates (mass & no.) using a look-up table (wet size, precipitation rate).
- Cloud sulfur chemistry (done)
 - ✓ Bulk sulfate chemistry based on calculated pH
 - ✓ Sulfate mass produced distributed to modes based on number of activated aerosols in modes.
 - ✓ Include contribution from H_2SO_4 (g) uptakes

Works in Progress

- New particle formation: homogeneous nucleation.
- Condensation: mass transfer theory.
- Coagulation: Brownian within, between modes.
- Dry deposition & gravitational settling.
- Intermode transfer due to condensation, coagulation, and cloud chemistry.
- VOC oxidation and condensation separated.
- 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.
- Update emissions: biomass burning carbon emissions (e.g., injection height, diurnal cycles), fine sea salt emissions from Clarke et al (2006)

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-indu., 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 simplified 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.