R: New treatments of aerosol formation, resuspension, ice nucleation, and light-absorption in snow/ice

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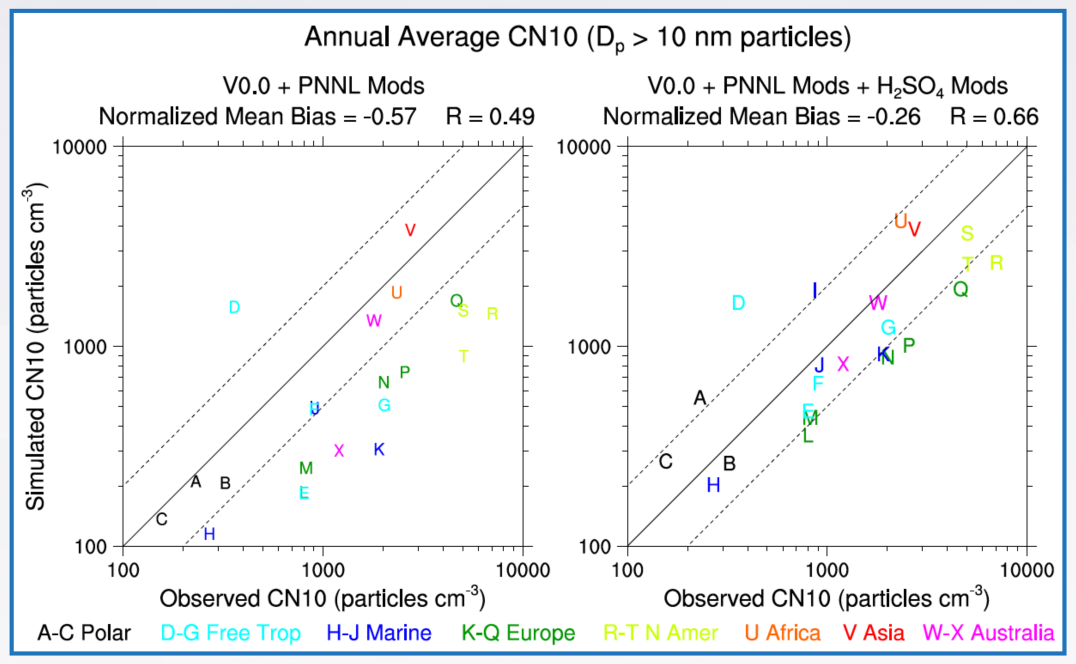
New aerosol particle formation

Objective:

Improve the MAM (Modal Aerosol Module) treatment of new particle formation and model simulation of smaller aerosol particles (diameter < 100 nm)

Approach:

The MAM treatments of H_2SO_4 vapor production and loss have been modified to use a parallel time-split approach, instead of a serial time-split approach. The H_2SO_4 vapor concentration is sensitive to the time splitting because of its short lifetime, and this strongly affects new particle formation.



Impact:

- Simulated aerosol number concentrations are now in much better agreement with observations, and the new treatment noticeably reduces the low bias and gives a moderately better correlation.
- The new treatment should also reduce the sensitivity of simulated nucleation to model time step.
- Much of the MAM higher-level code for gas condensation to aerosols, new particle formation, and coagulation was re-engineered to make it easier to understand, maintain, and extend (e.g., add aerosol modes and/or species). This has already benefited another task involving incorporation of primary marine organic aerosols into MAM.

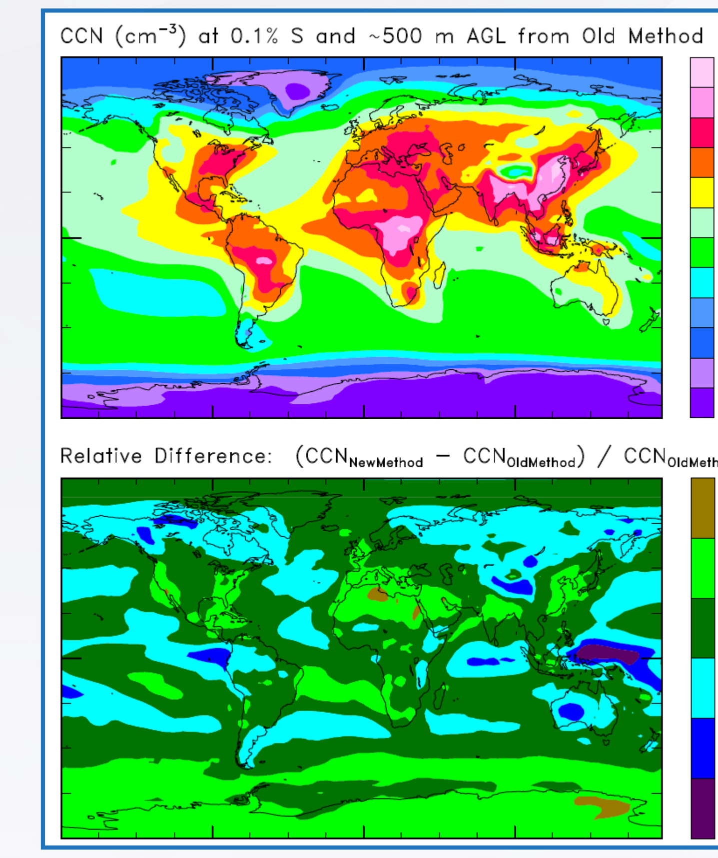
Aerosol resuspension

Objective:

Improve the MAM treatment of the release of scavenged aerosol material from evaporating drops

Approach:

A significant fraction of the aerosol that is wet-scavenged within clouds is released as aerosol particles when raindrops evaporate. The existing treatment releases particles back to their originating mode, rather than to the coarse mode as relatively large particles. The aerosol wet-scavenging modules are revised to use a more physically-based treatment of this release process, which requires a modest increase in the number of transported aerosol species (i.e., coarse mode BC, POA, and SOA).



Impact:

- CAM5.1 simulations show that releasing particles to the coarse mode has two main impacts: 1) the number of particles released is much less, so CCN and cloud droplet number concentrations are about 25% lower globally; 2) the released aerosol mass has a shorter lifetime, so burdens of sub-micron aerosol species are about 20% lower globally.
- The impacts on cloud liquid water path and shortwave cloud forcing are much smaller.
- These impacts, and those from other changes to ACME model physics, will likely require some retuning of the overall aerosol wet removal.

Ice nucleation schemes

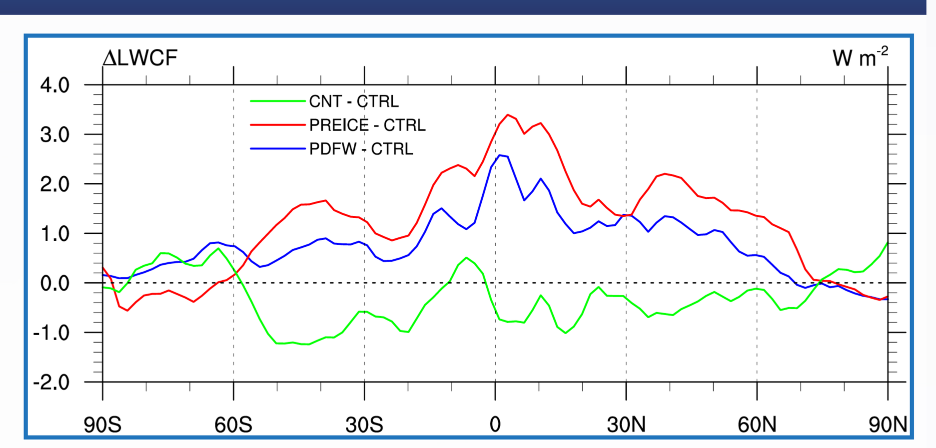
Objective:

Improve the simulation of ice clouds and their impacts on the radiation budget and hydrological cycle

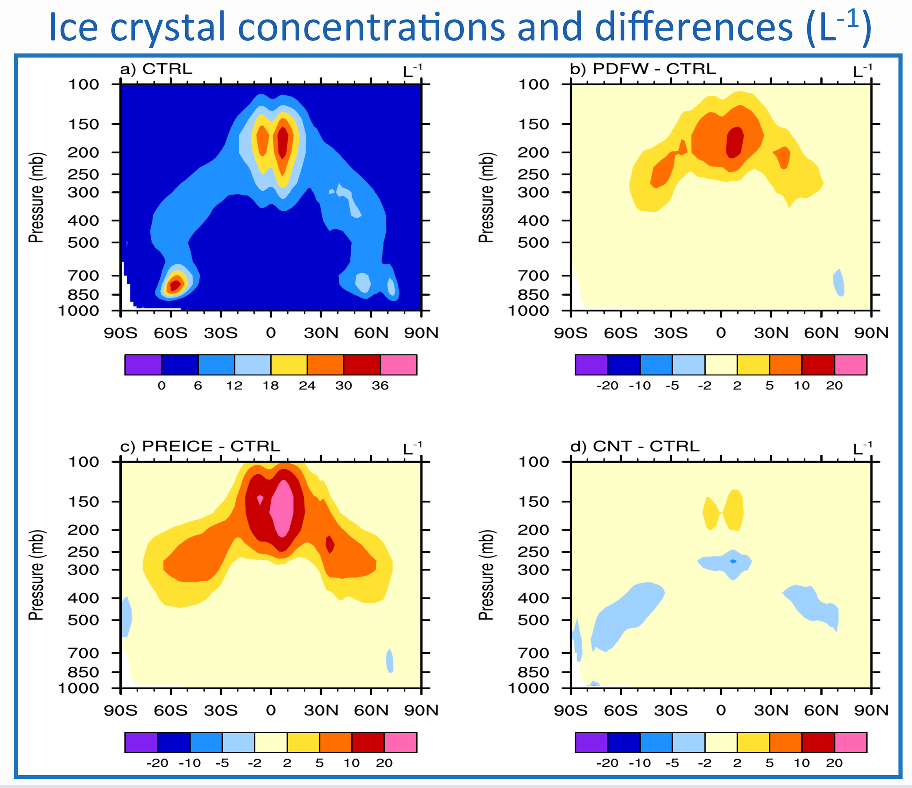
Approach:

Several modifications have been made to the ice cloud parameterizations in ACME, including

- a new treatment of the sub-grid updraft velocity (PDFW)
- an updated cirrus nucleation parameterization that considers the impact of pre-existing ice crystals (PREICE)
- a classical-nucleation-theory based heterogeneous ice nucleation scheme for mixed-phase clouds (CNT).



Ice crystal concentrations and differences (L^{-1})



Impact:

These new treatments remove some artificial thresholds applied in the existing ice nucleation schemes and improve the consistency between the representations of various ice nucleation modes.

Light-absorbing particles in snow and ice

Objective:

Improve the compatibility between MAM aerosols and light-absorbing particles (LAPs) deposited on snow/ice and model simulation of their impacts on radiation and snow/ice melting

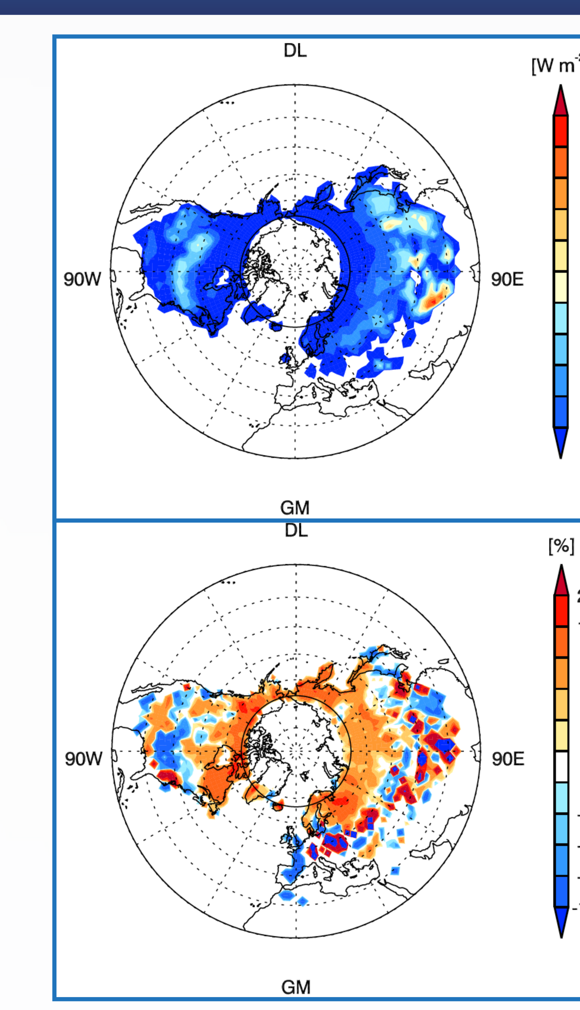
Approach:

The ACME model is being modified to

- couple MAM with the treatments of LAPs in snow and sea ice
- utilize new estimates of BC-in-snow optical properties that depend on snow grain size and BC particle size
- fix a bug in the calculation of snow grain size
- integrate other aerosol improvements for CAM with treatments of LAPs in snow/ice in CLM/CICE

Impact:

- Preliminary results show significant changes to aerosol-in-snow forcing due to the new treatments (see figures)
- The code is structured to function with future treatments of light-absorption by brown carbon particles in addition to BC and dust



January LAPs-in-snow radiative forcing in default model (top) and relative changes induced by new treatments (bottom)

ACME Accelerated Climate Modeling for Energy

For additional information, contact Hailong.Wang@pnnl.gov, or visit the ACME Confluence / Atmosphere Group Space / Atmosphere Tasks (P3,P4, M1)

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