Global Impacts of Dust Speciation on Mixed-Phase Clouds Through Ice Nucleation

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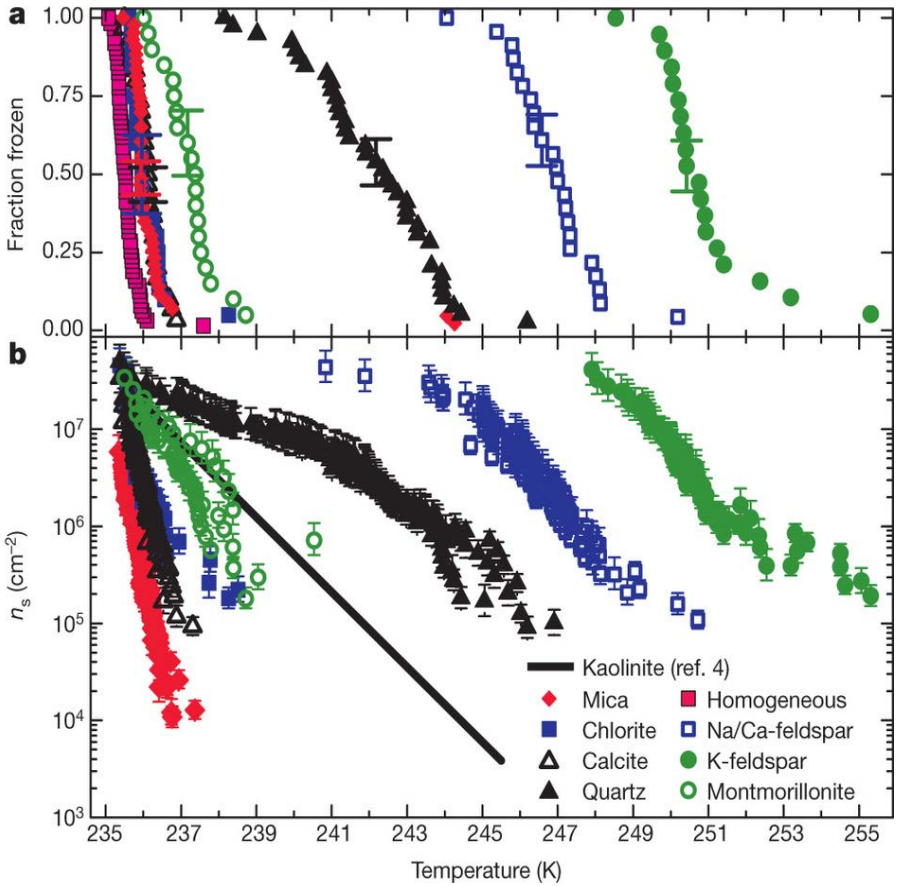
The role of dust

- Dust is one of the most abundant aerosol species in the atmosphere in terms of emitted mass [Forster et al., 2007].
- Dust has important climatic effects
  - Scattering and absorbing solar and terrestrial radiation
  - Influencing cloud radiative and microphysical properties as CCN and IN
  - Fertilizing oceans with iron dust
  - etc.

Importance of dust speciation

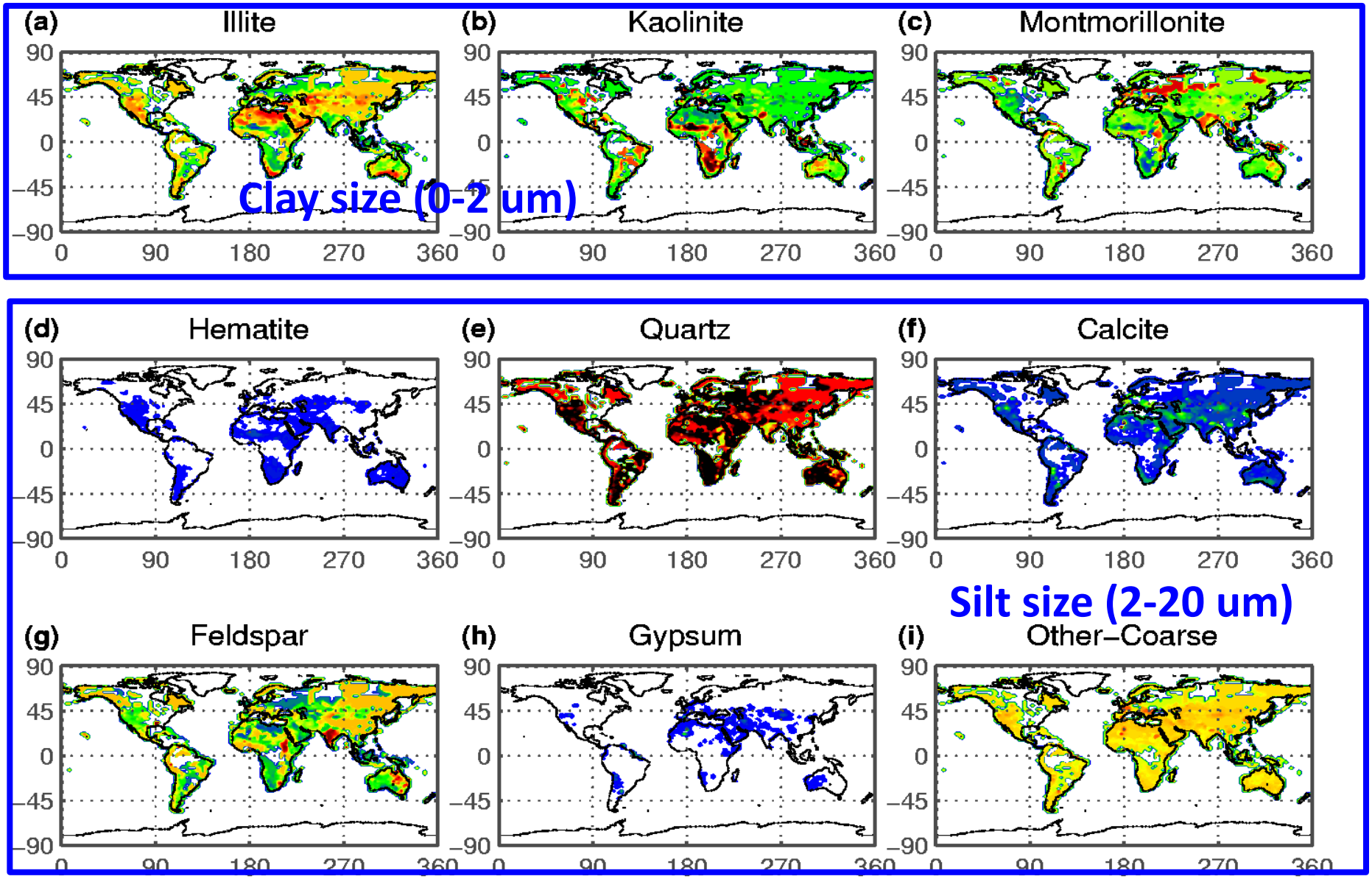
- Dust absorption strongly depends on dust composition
- Dust ice nuclei (IN) efficiency is sensitive to dust types (e.g., kaolinite vs. feldspar)
- Dust ocean fertilization relies on dust iron (e.g., hematite)



Experimental freezing results for the individual minerals.

(Atkinson et al. 2013)

Mineralogical composition of soil



Claquin et al. (1999)

Community Atmospheric Model (CAM5)

- Modal Aerosol Module (MAM, *Liu et al. 2012)*
  - Predicting aerosol mass, number and size distribution
- Two-moment stratiform microphysics (*Morrison & Gettelman 2008; Gettelman et al. 2010*)
- Cloud liquid droplet activation (*Abdul-Razzak & Ghan 2000*)
- Cloud ice crystal nucleation (*Liu et al. 2007*)
  - *Mixed-phase clouds*:

  Meyers et al. (1992) for deposition/immersion freezing of cloud droplets; Young (1974) for contact freezing of cloud droplets by dust

- Dust speciation – mineralogical composition of soil (Claquin et al. 1999); dust optical properties (Scanza et al. 2012)

New Ice Nucleation Parameterizations in Mixed-Phase Clouds

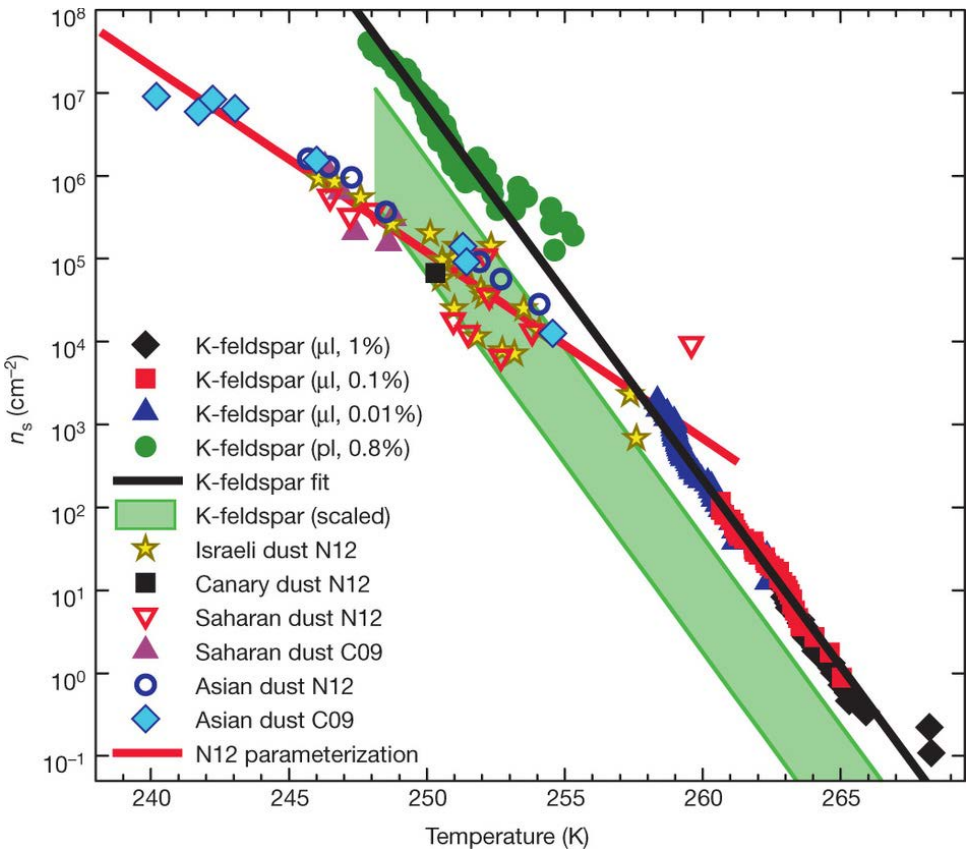
- Atkinson et al. (2013) – immersion on K-feldspar

$$n_s(T) = \exp(-1.038T + 275.26) \quad \text{for} \quad 248 < T < 268K$$

- Niemand et al. (2012) & DeMott et al. (2010) – immersion on "natural dust"

$$n_s(T) = \exp(-0.517(T - 273.15) + 8.934)$$

$$N_{IN} = a*(273.16-T)^b (N_{aer,0.5})^{(c*(273.16-T)+d)}$$



Atkinson et al. (2013)

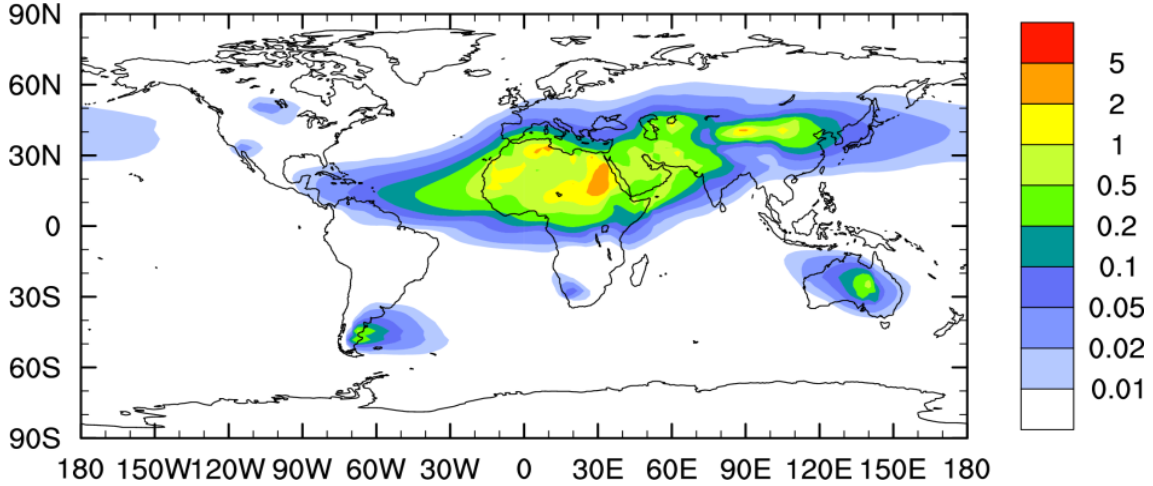
Model Experiments

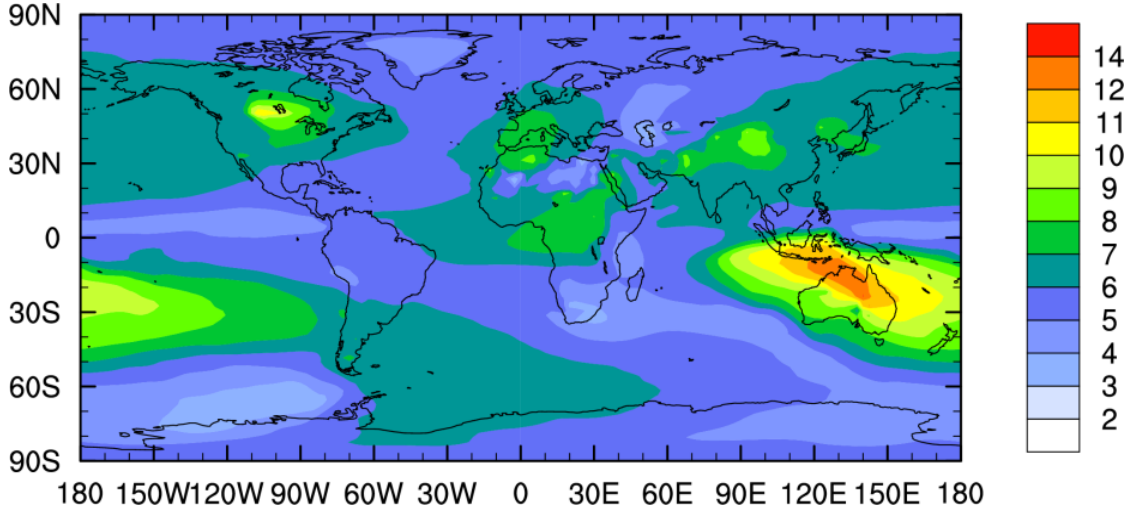
- CAM5 with FV dynamic core, 1.9° x 2.5°, 30 levels
- 6-yr climate runs with prescribed SST and sea ice (AMIP II type of run)

o Meyers et al. (1992) (default): IN no relation to dust (MEY)
o Atkinson et al. (2013) : IN link to dust mineralogy (ATK)
o Niemand et al. (2012) : IN relation to natural dust (NIE)
o DeMott et al. (2010) : IN relation to natural dust (DEM)

Column concentration of dust & feldspar fraction

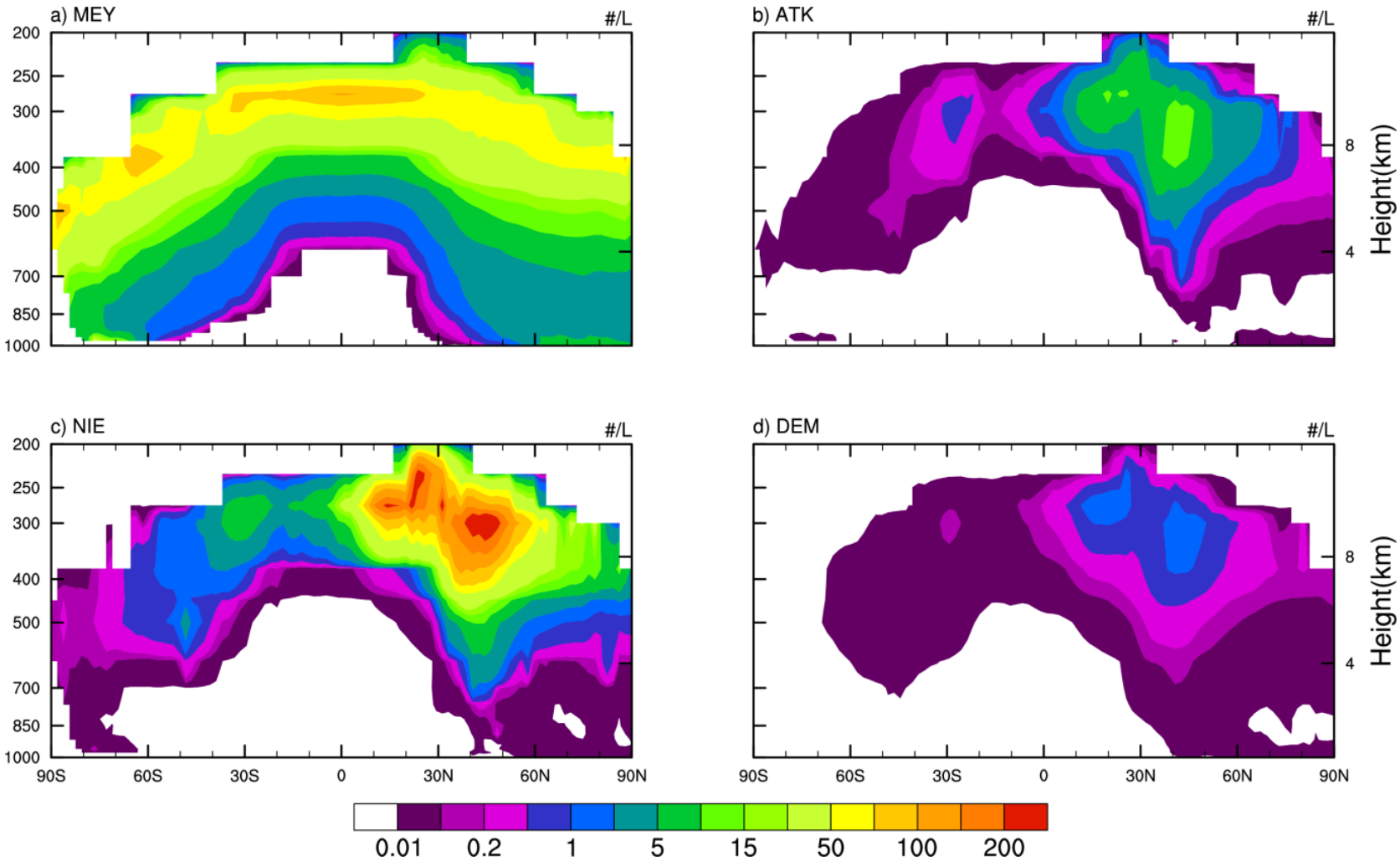
Dust mass loading (g/m2)



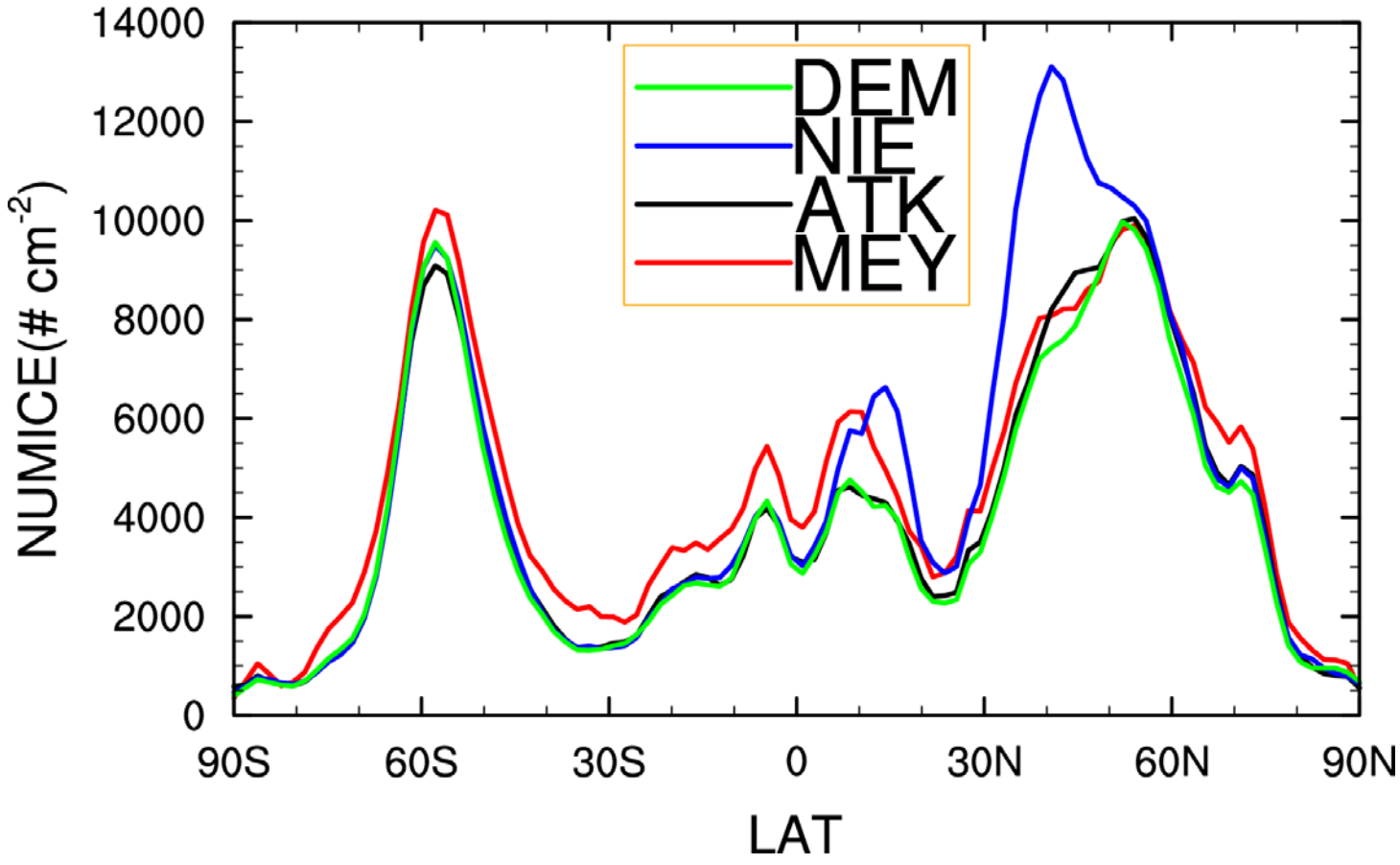


Feldspar mass fraction (%)

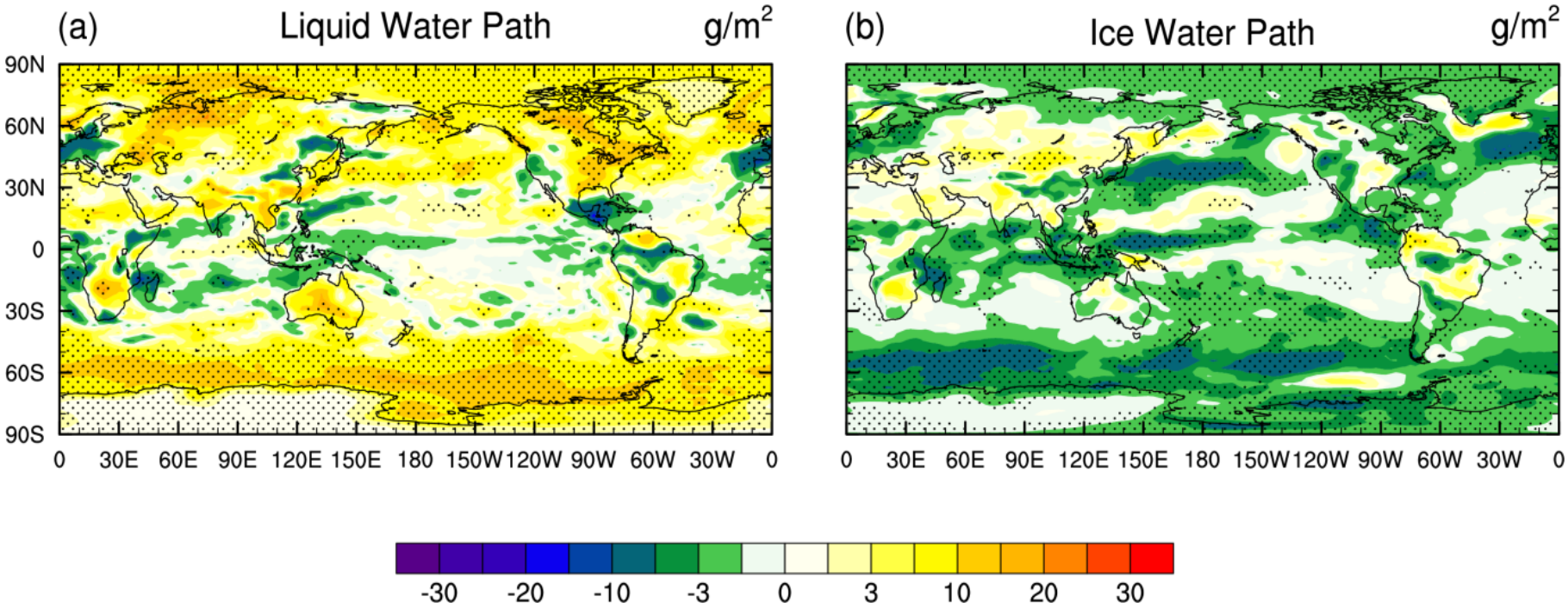
Ice nuclei number concentrations in mixed-phase clouds



Column Ice Crystal Number Concentration in Mixed-Phase Clouds



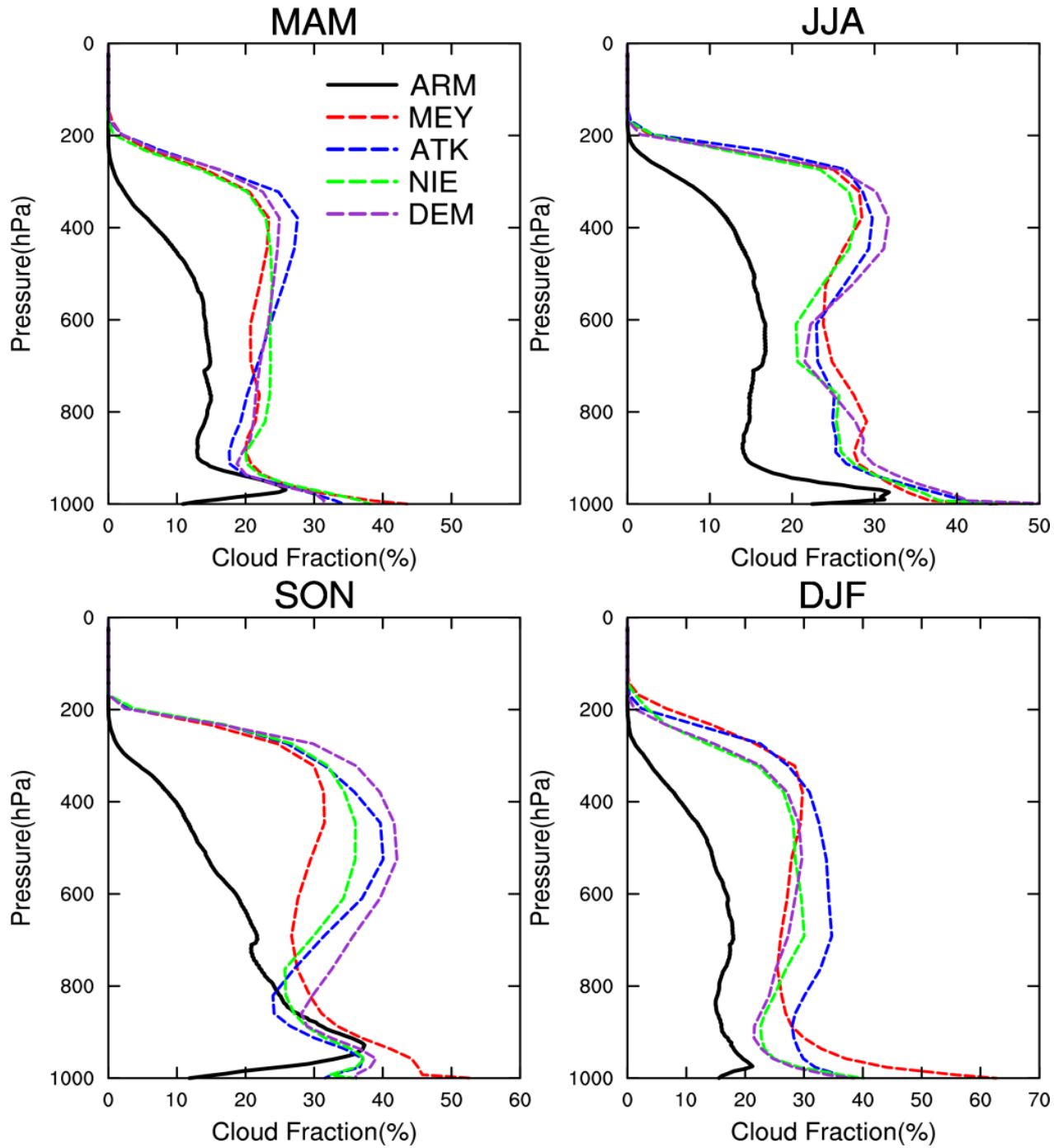
Difference in Cloud Water (ATK-MEY)



Fewer Ni → More Liquid, Less Ice

through slowing down the Bergeron proces

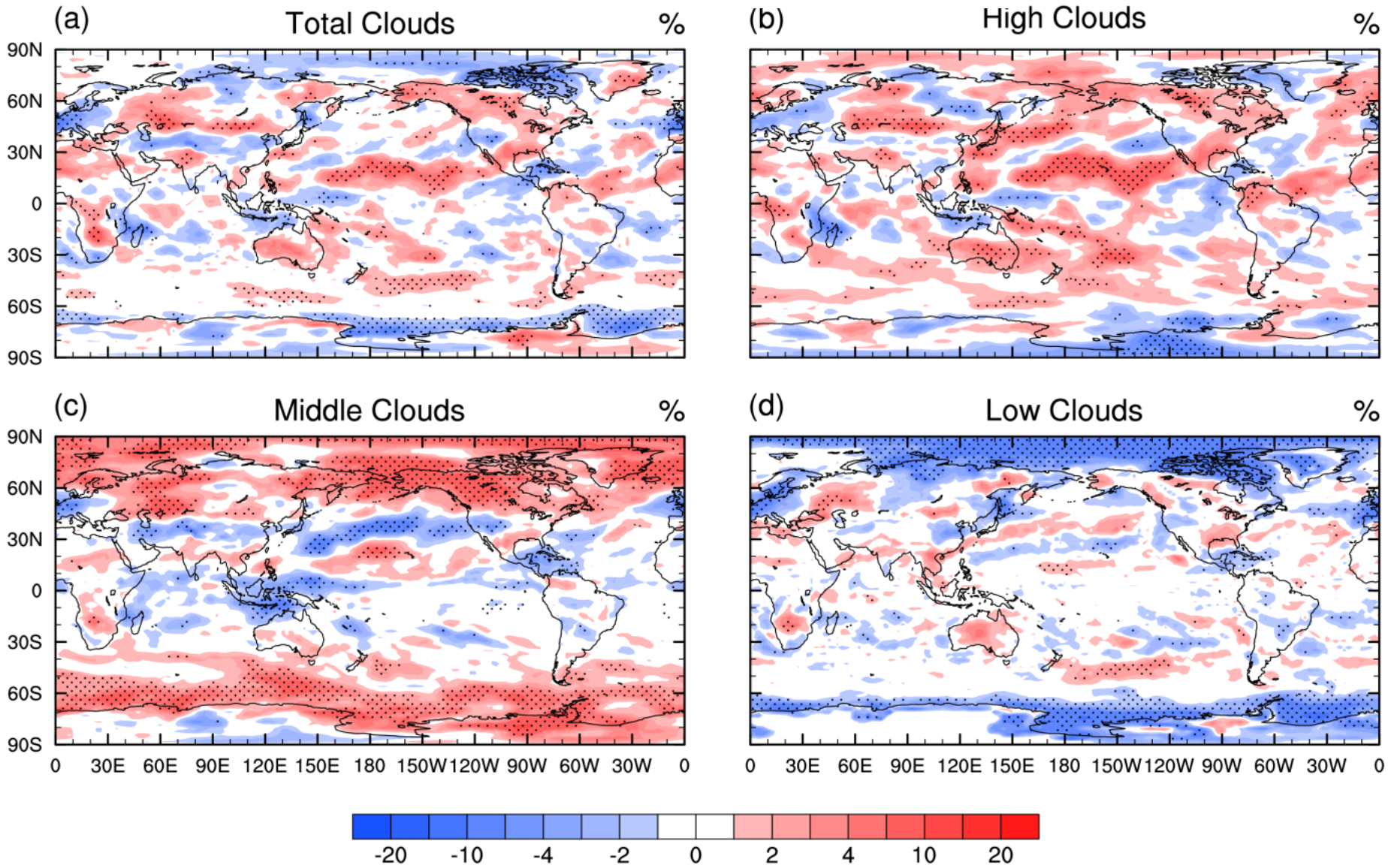
Cloud cover at ARM Barrow



LWP -> Ts -> LTS -> LLC -> RH -> MLC & HLC

Xie et al. (2013)

Summary

- Dust speciation (mineralogy) is implemented in CAM5, and linked to dust optical and IN properties
- Compared to Meyers et al. (default), new parameterizations has a significant effect on cloud water and cloud cover, especially in high latitudes:
  - Improved comparison with long-term ARM observations

Difference in Cloud Cover (MIX-MEY)