Predicting global atmospheric ice nuclei distributions and their impacts on climate


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Approach

Measurements
- FIELD & LAB
  - Ice nuclei
  - CCN
  - Aerosol
  - Cloud microphysics

Parameterizations
- Ice nuclei
- Homogeneous freezing
- CCN activity
  (links to aerosol size & composition)

Modeling
- Parcel model
- CRM
- Regional
- Global
Approach

Our group

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  - Ice nuclei
  - CCN
  - Aerosol
  - Cloud microphysics

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Parameterizations

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Modeling

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Real-time atmospheric measurement of IN - Continuous flow diffusion chamber (CFDC)

Temperature controlled walls to select processing temperature

-6 < T < -40°C

inertial impactor removes particles larger than 1.5 μm

supersaturated region all aerosols activate into cloud droplets

some fraction of droplets freezes forming a mixed phase cloud

evaporation section deactivating liquid droplets

optical detection of ice crystals and impaction for chemical TEM analysis

Total residence time ~6s
IN that we measure DO represent (primary) ice concentrations in clouds

Cloud ice based on 2D-C probe > 50 µm
Ice nuclei concentrations over several projects (10-30 min. averages)

[DeMott et al., 2009]
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IN trend with aerosol concentrations when stratified by size and temperature

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Ice nucleation parameterizations

• Meyers et al. (1992): \( n_{in} = \exp(12.96(S_i - 1) - 0.639) \)  
  (no links to aerosol properties)

• Phillips et al. (2008): \( n_{IN,X} = \alpha_X H_X \left( S_{i,v}, T \right) \xi(T) \left( \frac{n_{IN,1.5,*}(T, S_{i,v})}{\Omega_{X,1.5,*}} \right) \Omega_X \)  
  \( \alpha_X = f_{dust} f_{BC} f_{bio} \)  
  Lab based corrections  
  Scaling to “baseline” IN conc. and sfc. area

• DeMott et al. (2009): \( n_{IN,T_k} = a \left( 273.16 - T_k \right)^{3.6434} \left( n_{aer,0.5} \right)^{b(T_k)} \)  
  \( (T, n_{aer} > 0.5 \mu m \text{ diameter}) \)
Regional impacts – Arctic stratus single column global model (SCAM3)

DeMott et al., 2009

Liu et al. 2-moment microphys. + Meyers →

As above, BUT new IN param →

[DeMott et al., 2009]
Global model (CAM3) 5-year simulations, annual averages

- Total liquid water path
- SW cloud forcing
- Total cloud cover
- Surface downwelling SW

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Summary

- IN measurements relate directly to first ice formation (clear from wave cloud studies, other studies where secondary ice processes can be separated) → important for predicting phase in many clouds!

- IN concentrations in mixed-phase cloud T regime can be related to the number concentrations of particles larger than ~0.5 μm → useful in models that carry some information on particle size, eventually particle type

- Global model simulation sensitivity to IN formulation is quite strong → our new parameterization yields more water clouds and less ice, especially in Arctic & midlatitude storm tracks
Future work

• For CMMAP, implement the parameterization into the SAM model
  – Case studies for different locations
  – Use of CloudSat simulator to compare with obs

• Implementation in the MMF
  – Once aerosols are included!