Predicting global atmospheric ice nuclei distributions and their impacts on climate

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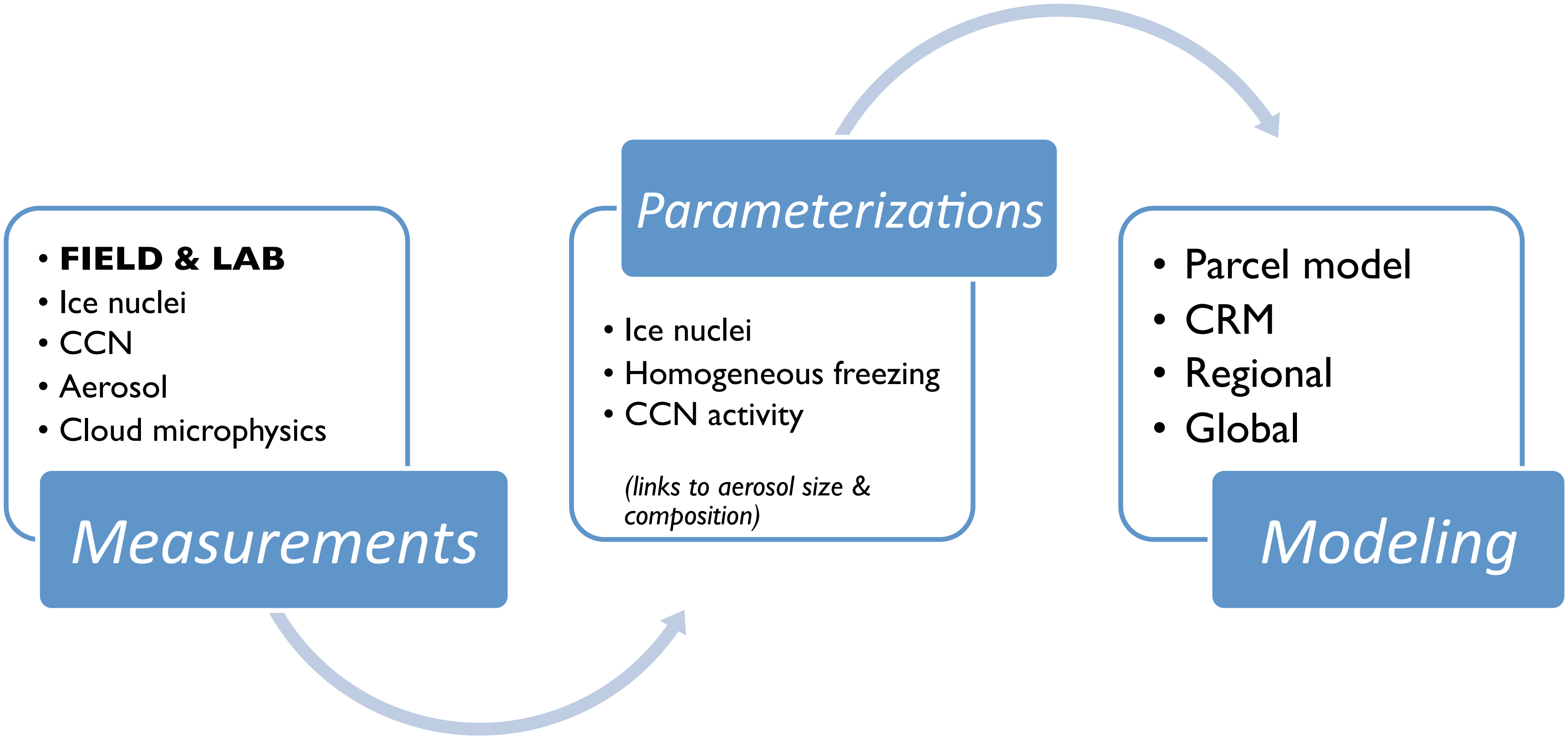
Approach


• **FIELD & LAB**
• Ice nuclei
• CCN
• Aerosol
• Cloud microphysics
Measurements
Parameterizations
• Ice nuclei
• Homogeneous freezing
• CCN activity
(links to aerosol size & composition)
• Parcel model
• CRM
• Regional
• Global
Modeling

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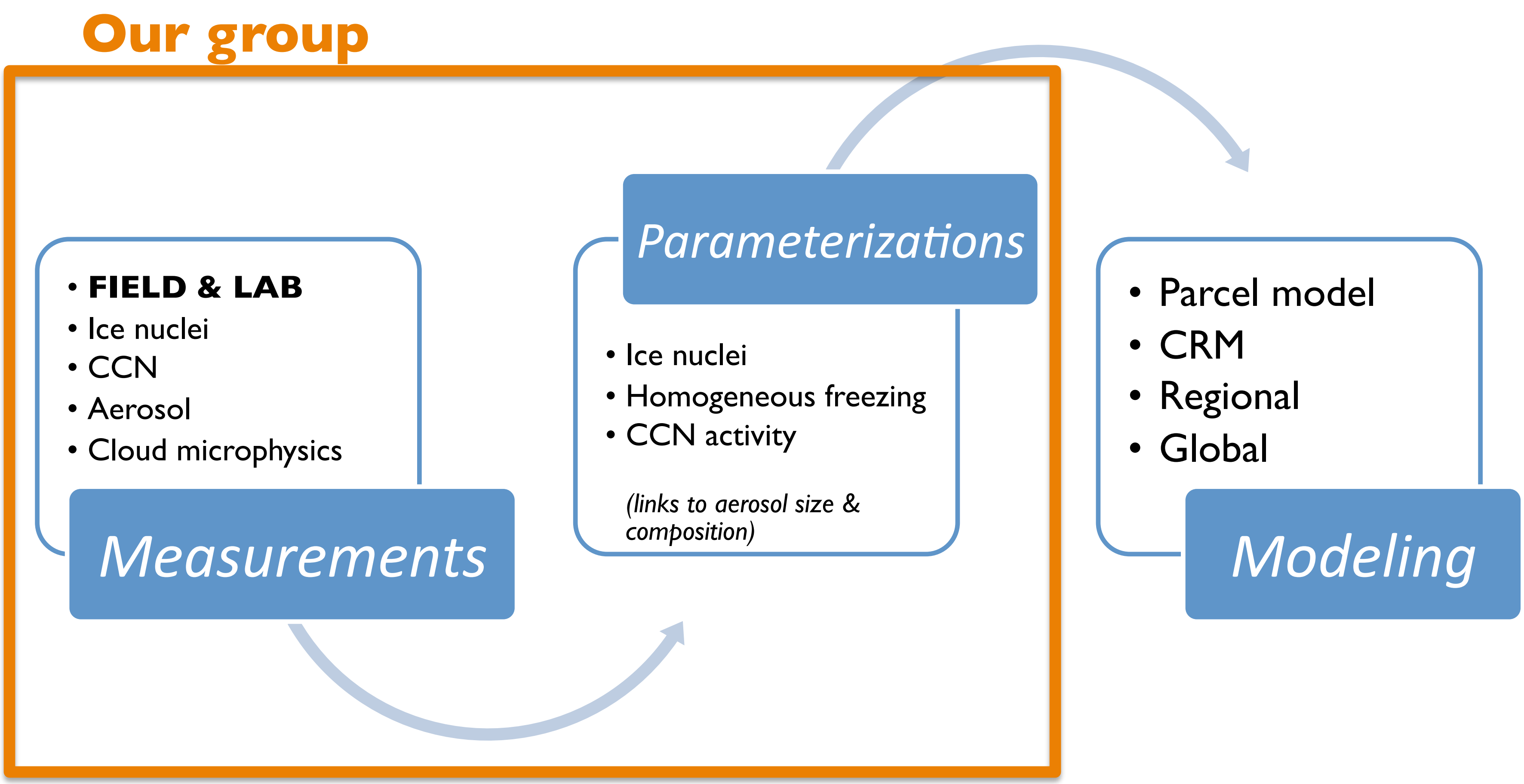
Our group
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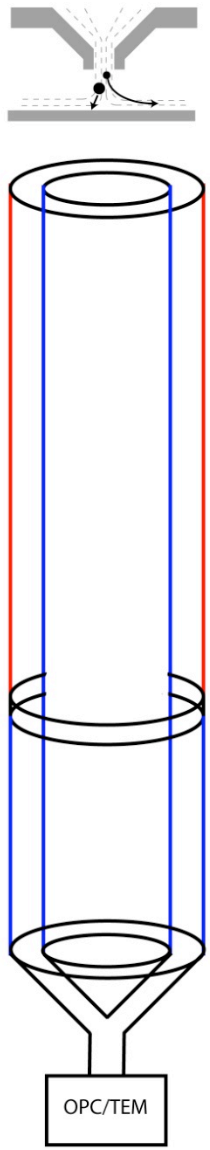
Real-time atmospheric measurement of IN - Continuous flow diffusion chamber (CFDC)

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

↓

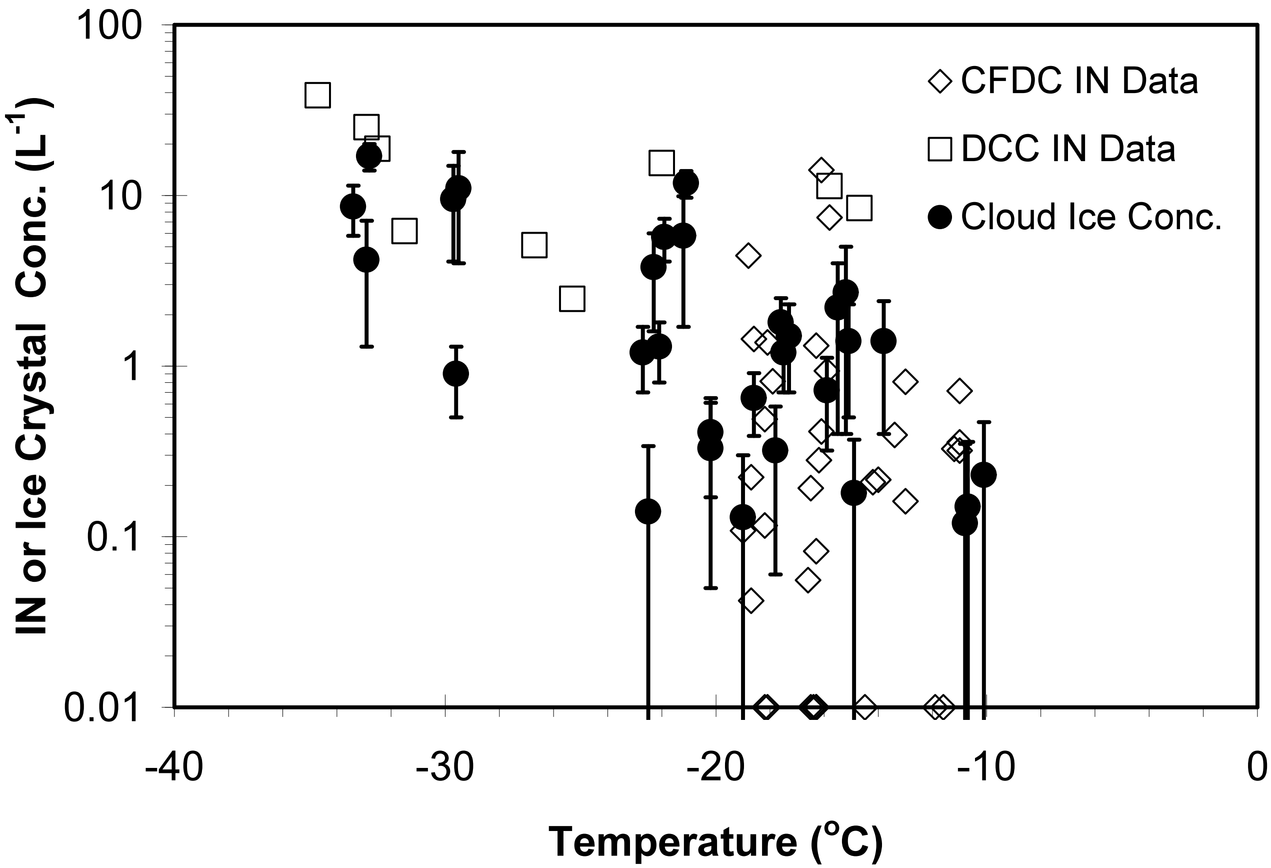
evaporation section deactivating liquid droplets

↓

optical detection of ice crystals and impaction for chemical TEM analysis

Total residence time ~6s

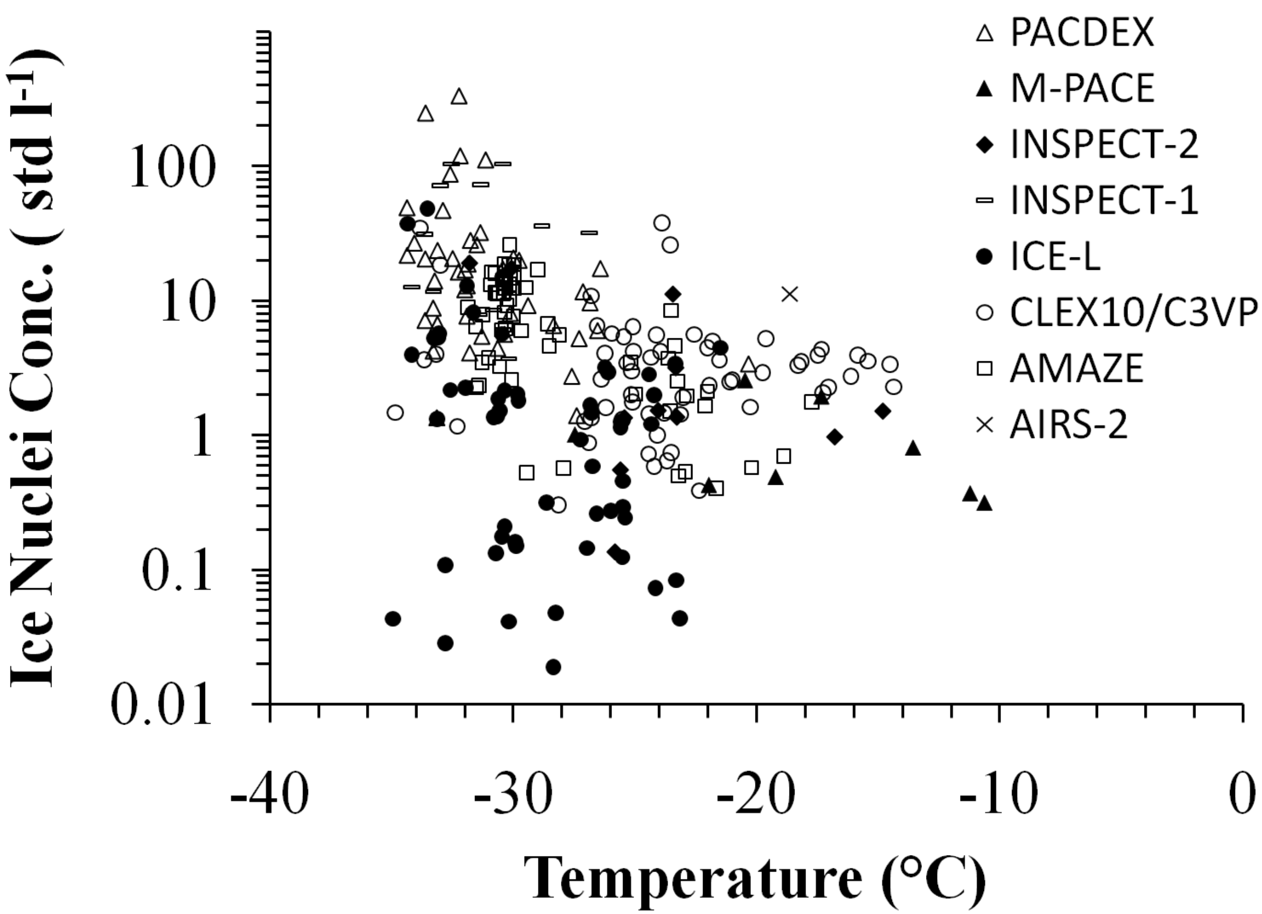
IN that we measure **DO** represent (primary) ice concentrations in clouds



WISP-1994 data shown as example

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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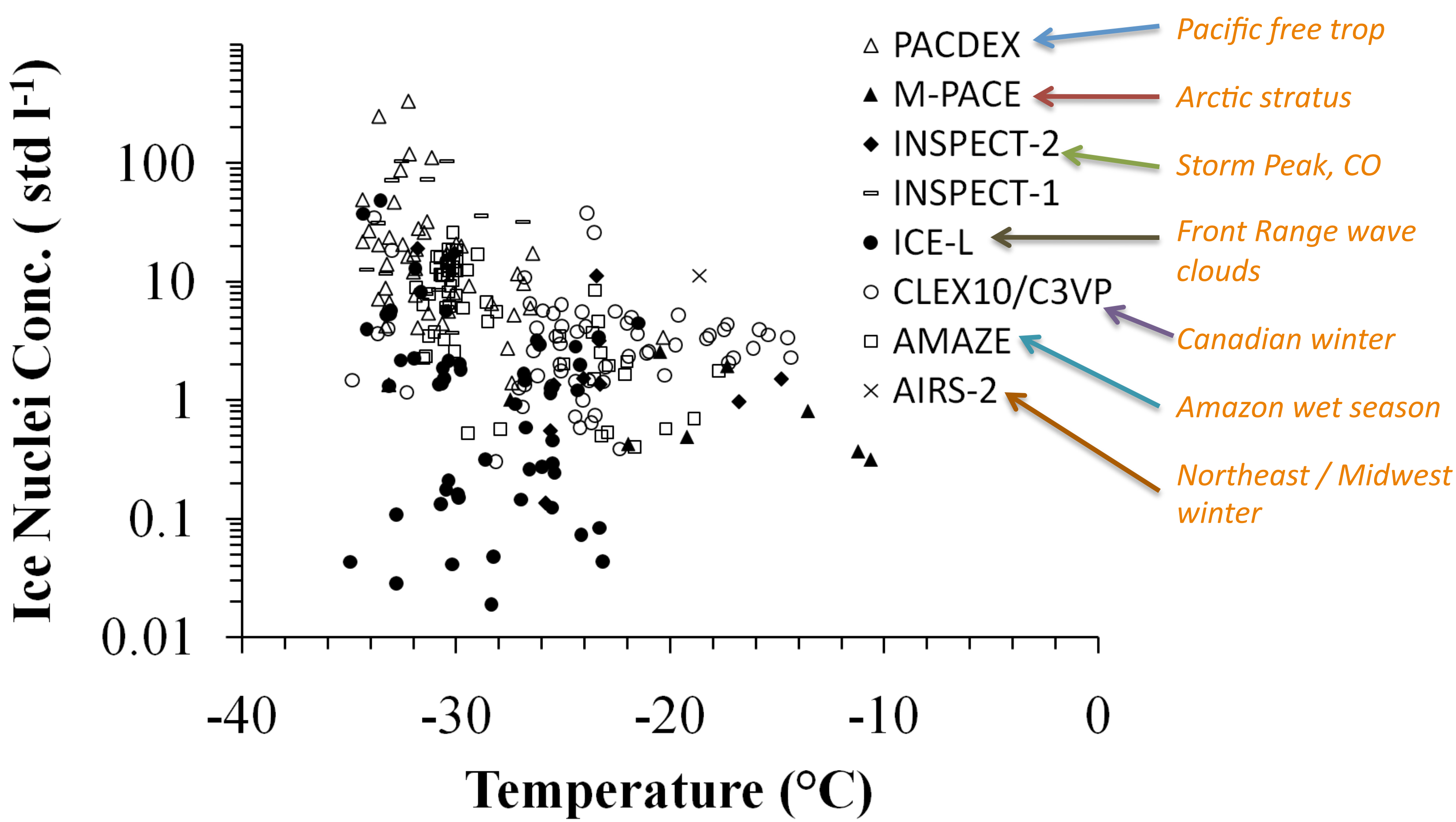
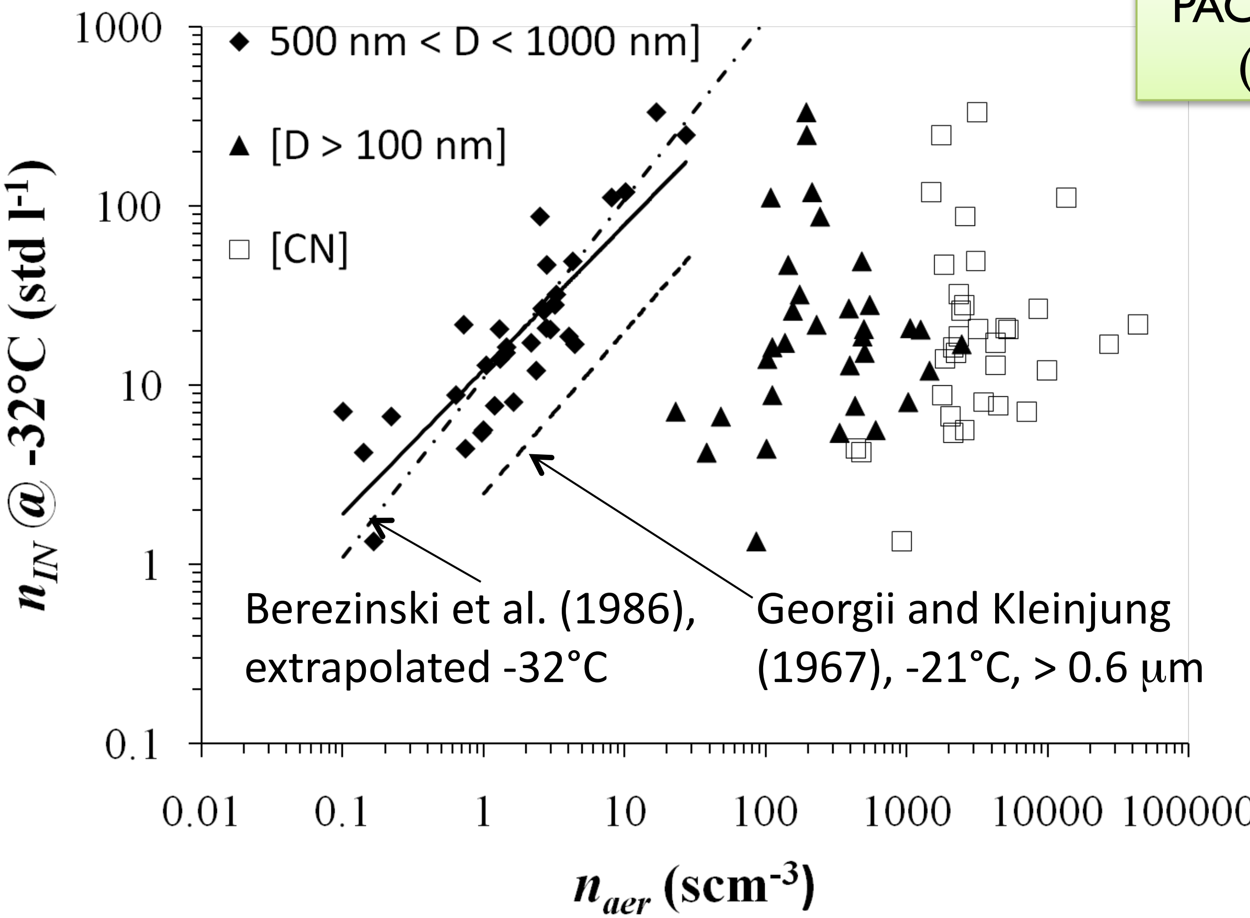


[*DeMott et al., 2009*]

IN trend with aerosol concentrations when stratified by **size** and **temperature**

PACDEX project
(-32±2°C)



DeMott et al. (2009)

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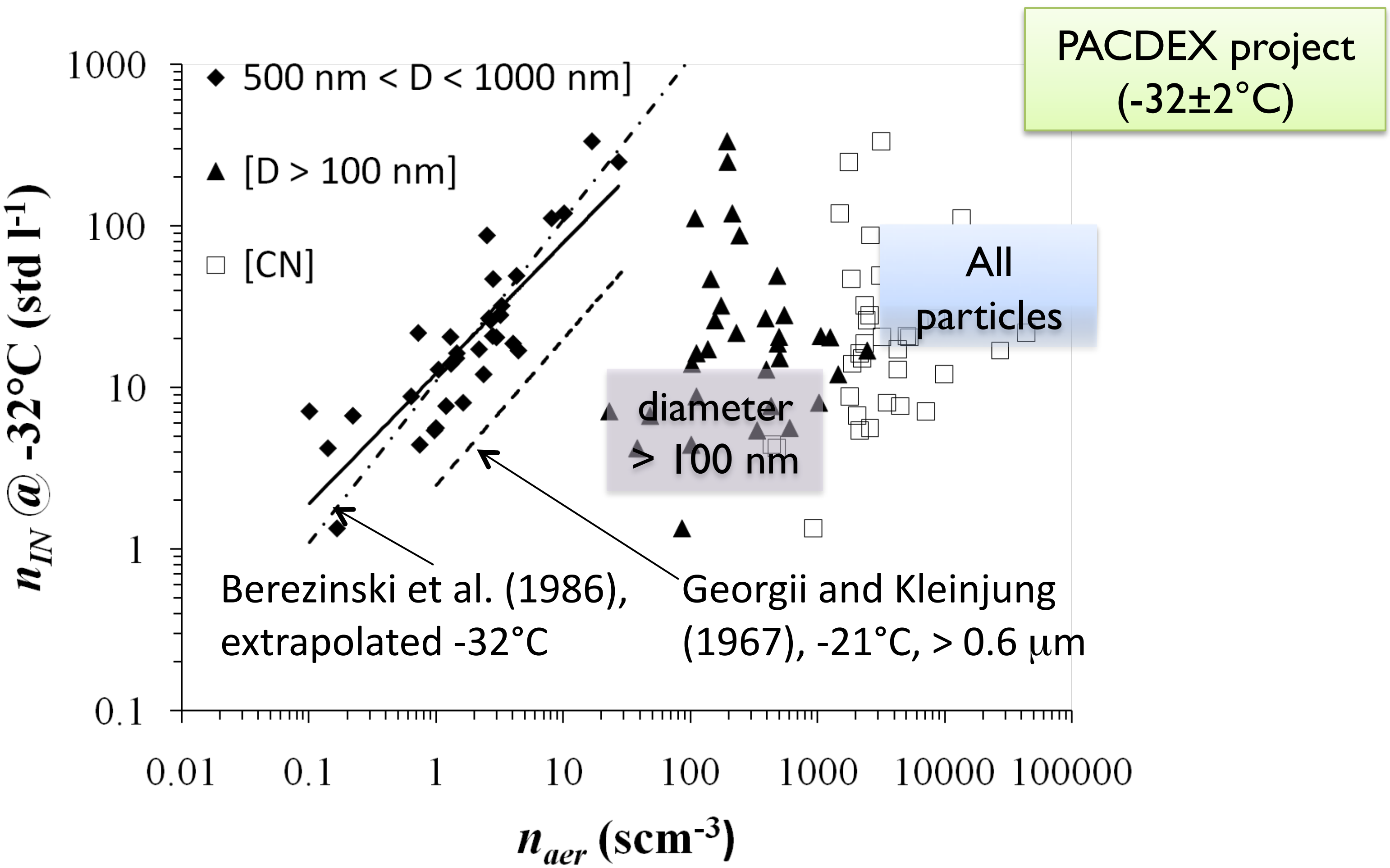

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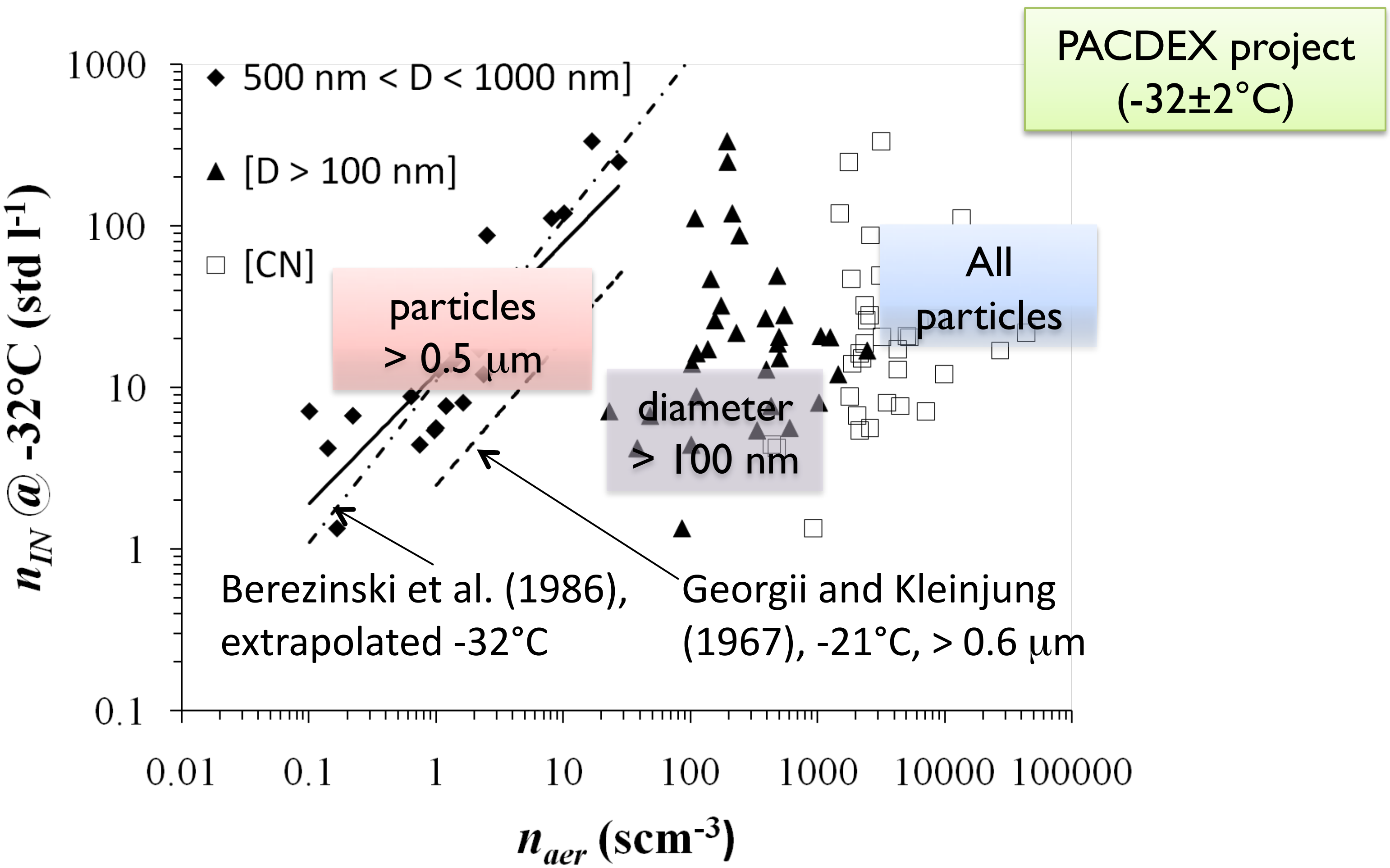


DeMott et al. (2009)

Ice nucleation parameterizations

- Meyers et al. (1992): $n_{in} = \exp(12.96(S_i\text{-}1)\text{- }0.639)$

(no links to aerosol properties)

↑ Ice supersaturation dependence only

- Phillips et al. (2008):

(surface area, **composition**, S_i, T)

$$n_{IN,X} = \alpha_X H_X(S_{i,v}, T)\xi(T)\left(\frac{n_{IN,1.5,*}(T, S_{i,v})}{\Omega_{X,1.5,*}}\right)\Omega_X$$

$\alpha_X = f_{dust}, f_{BC}, f_{bio}$

Lab based corrections

Scaling to "baseline" IN conc. and sfc. area

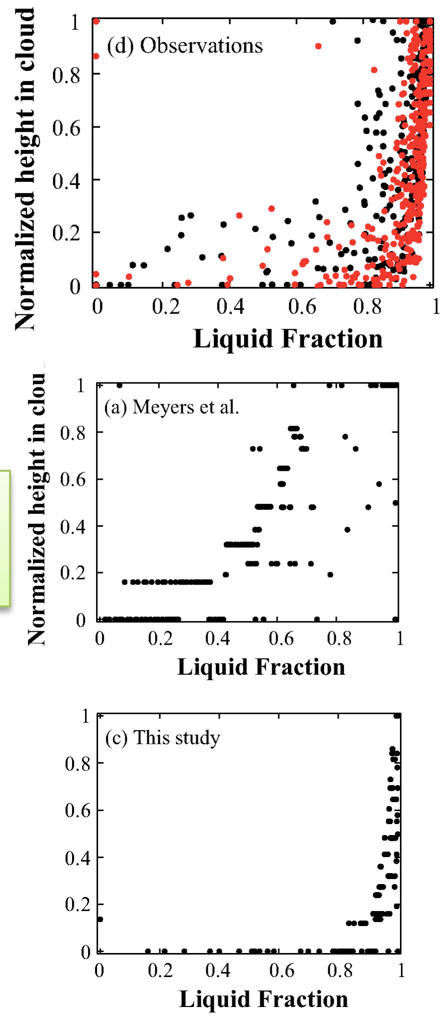
- DeMott et al. (2009): $n_{IN,T_k} = a(273.16 - T_k)^{3.6434}(n_{aer,0.5})^{b(T_k)}$

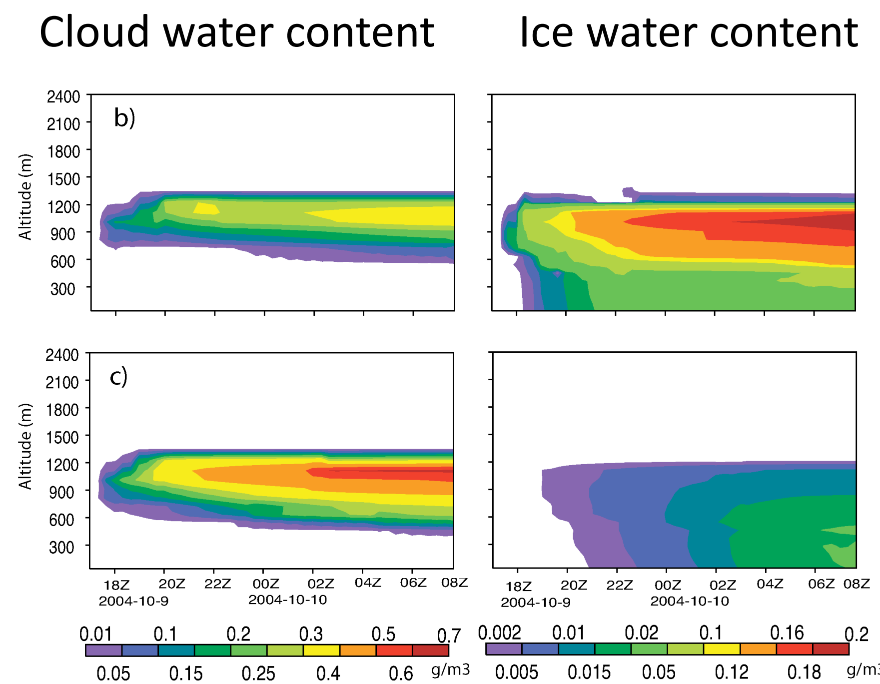
(T, n_{aer} > 0.5μm diameter)

Regional impacts – Arctic stratus single column global model (SCAM3)

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

As above, BUT new IN param →





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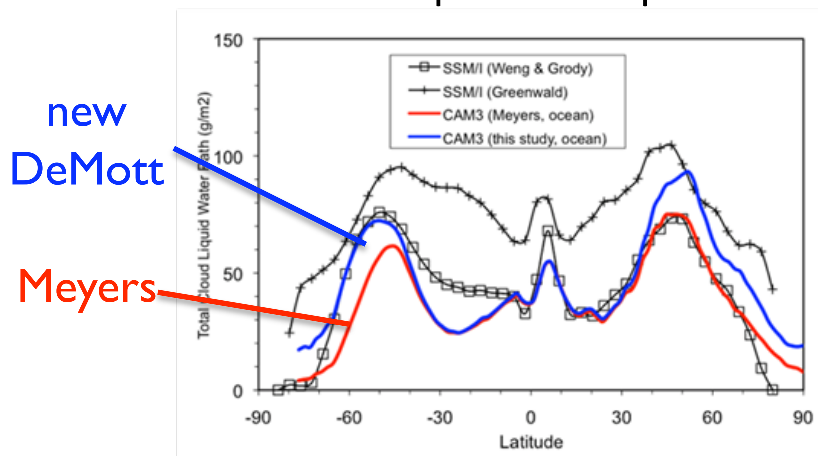
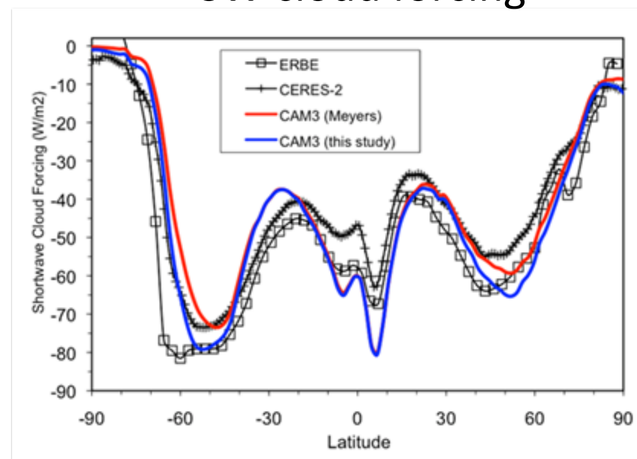
Global model (CAM3) 5-year simulations, annual averages

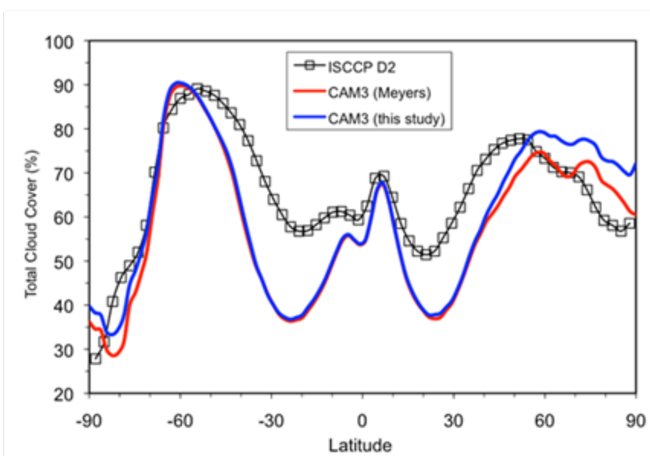
Total liquid water path



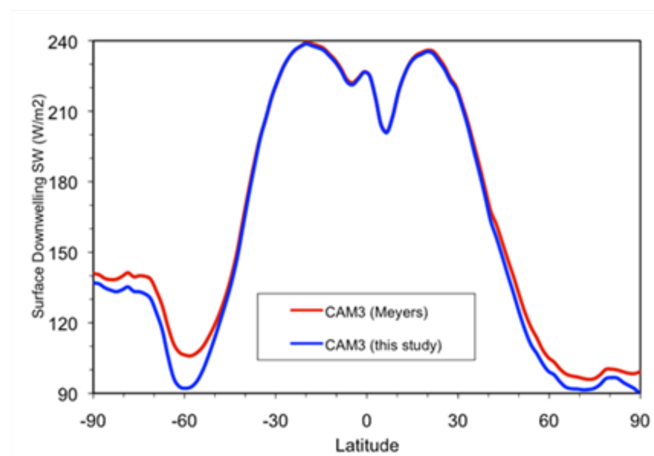
SW cloud forcing



Total cloud cover



Surface downwelling SW



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!