Ice Nucleation in Mixed-Phase Clouds and Climate Impacts

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Goal: Understand the Role of Ice Nucleation on Arctic Clouds and Climate

- **Tools: single column model version of CAM3 (SCAM3)**
- **Forcing data from ECMWF**
- **High-resolution simulations: 60 vertical levels**
- **Evaluation data: ISDAC measurements**

Observations show large variability

IN concentrations measured by CFDC from 9 field studies

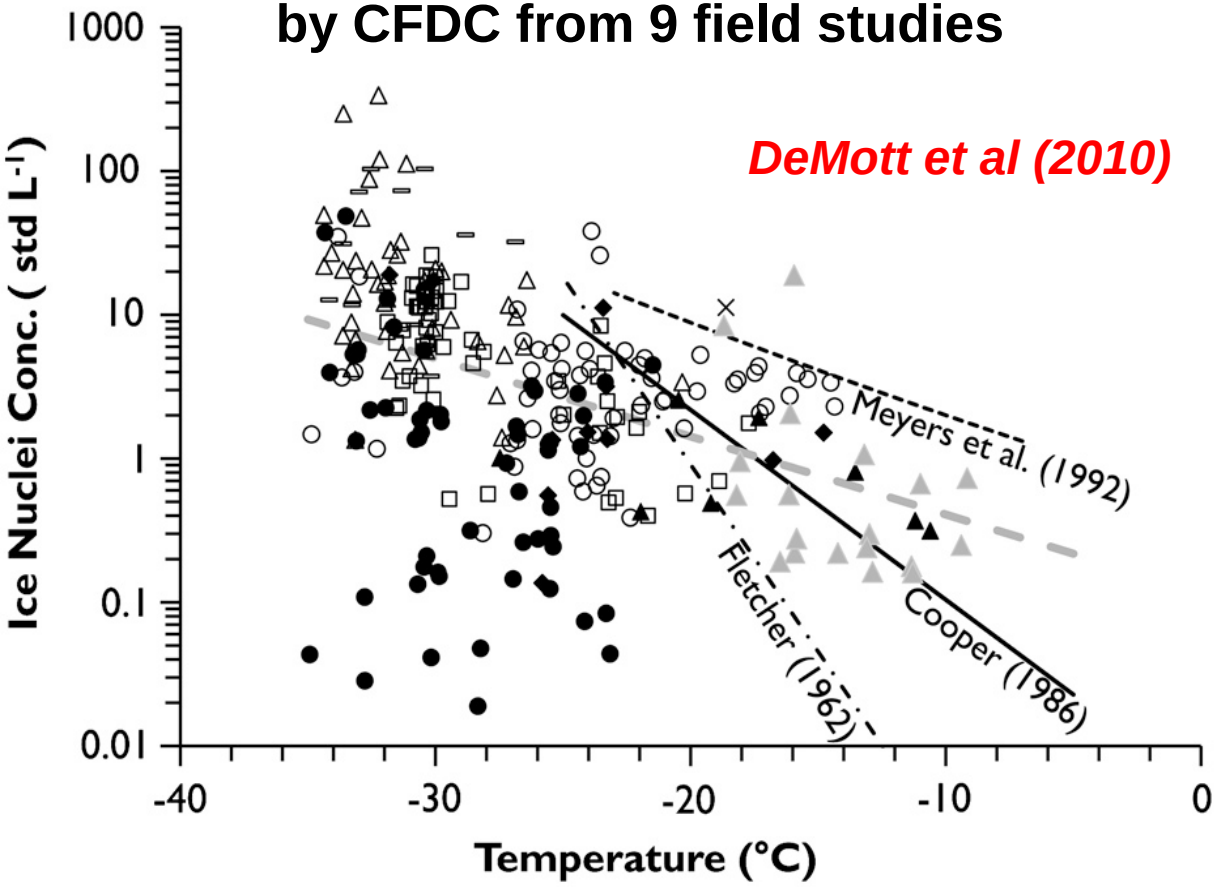

Figure adapted from DeMott et al. (2010)

- **Large variability in time, space, and temperature**
- **Earlier schemes are best fits to the specific data used and will have large disagreement with the compiled dataset**

CFDC: Continuous Flow Diffusion Chamber

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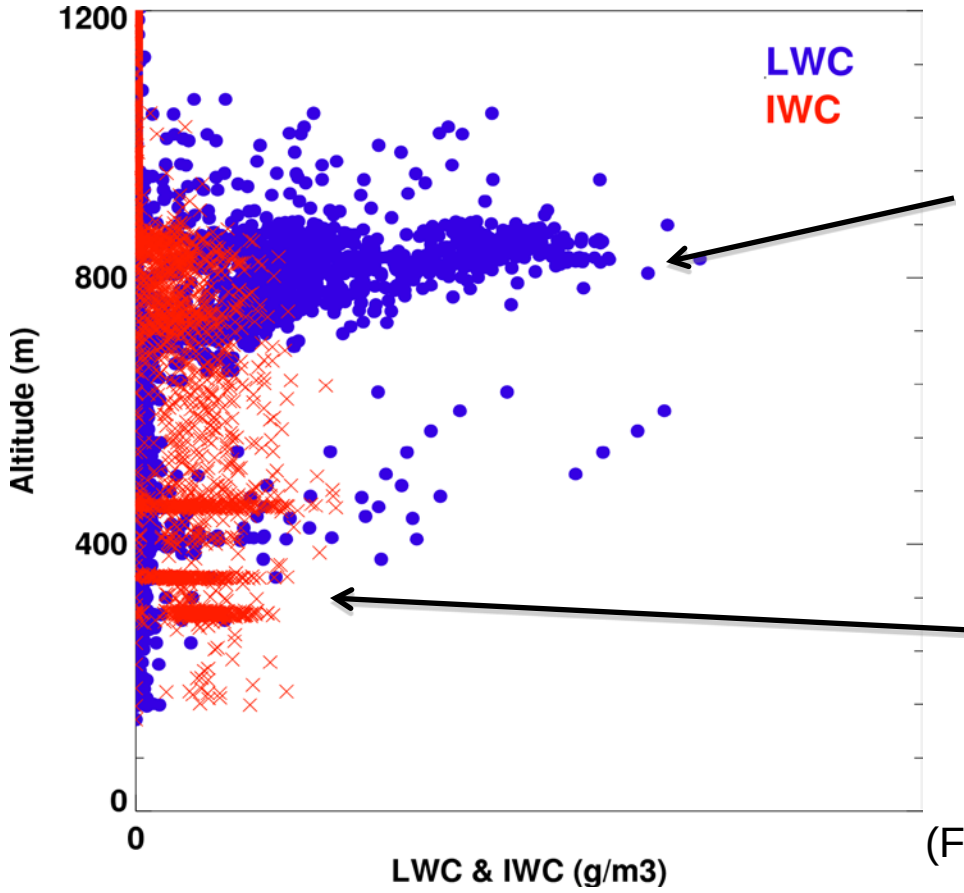
CAM3 Microphysical Schemes

- **Cloud microphysics (SCAM-ICE) : Liu et al (2007)**
  - **Double-moment, liquid/ice partition determined by microphysical processes (Bergeron-Findeisen, Rotstayns et al., 2000)**
- **Test mixed-phase cloud ice nucleation parameterizations in SCAM-ICE:**
  - **Meyers et al. (1992): N_{IN}~f(Si);**
  - **DeMott et al. (2009): N_{IN}~f(number of dust with D>0.5 um) (based on CFDC)**
  - **Phillips et al. (2008): N_{IN}~f(dust/BC/OC surface area) (based on CFDC)**

Aircraft Measured Cloud Water Content

Apr. 26, 2008 – A "golden" day of ISDAC



A strong liquid layer occurred near cloud top at 850m

Ice crystals in the liquid cloud layer and precipitating ice crystals beneath

(From A. Korolev)

For mixed-phase clouds, the range of cloud temperature is from -12 C ~ -15 C (600-900 m)

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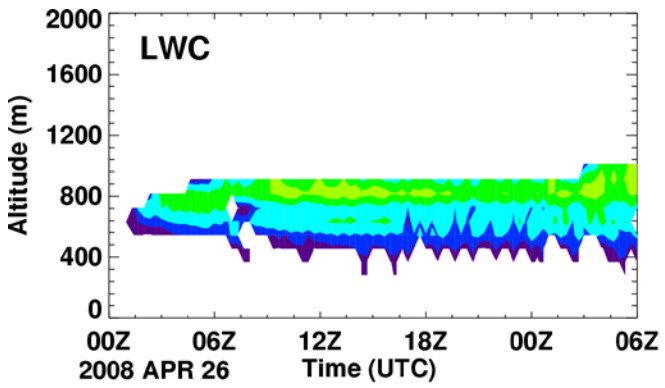
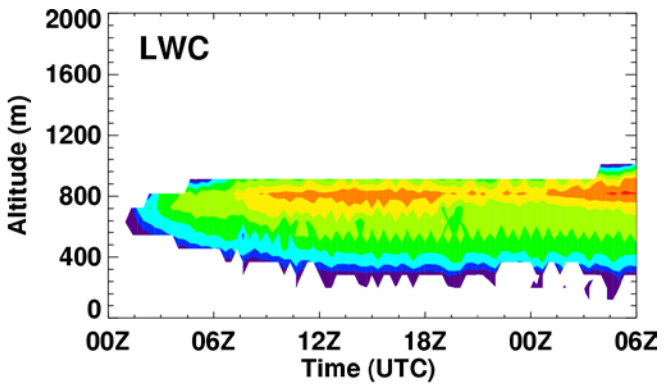
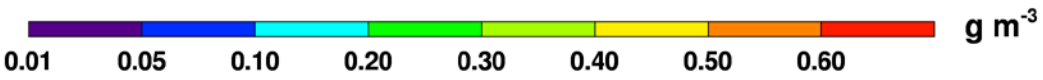
SCAM60L-ICE (Meyers vs Phillips) of ISDAC

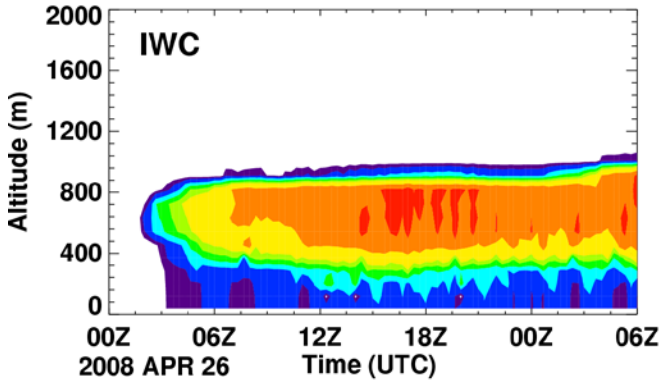
SCAM60L-ICE (Meyers)

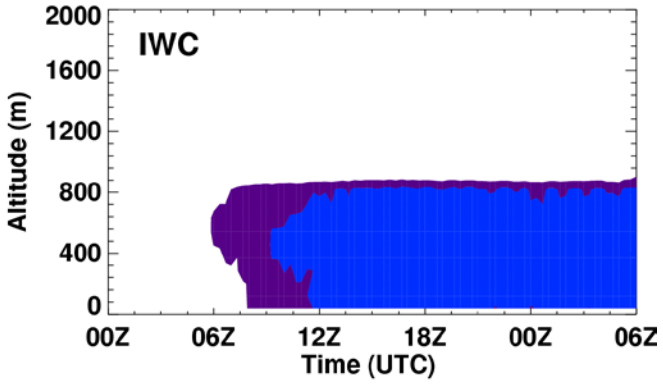


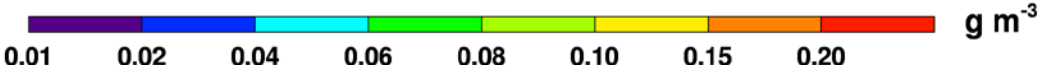
SCAM60L-ICE (Phillips)











- ***Obs:***
  H_{top}=850 m
  H_{base}=650 m
  LWC_{max}=0.1-0.15 g/m³
  IWC=0.01-0.04 g/m³

- ***IN number (CFDC, S. Brooks): 0.1-10/L***
  N_i = 0.3~0.5/L (size>100 um, A. Korolev)

- ***SCAM60L-ICE (Meyers) gives IN=2-4/L***

- ***SCAM60L-ICE (Phillips) gives IN=0.1-0.2/L and IWC much lower (by 5-6 times)***

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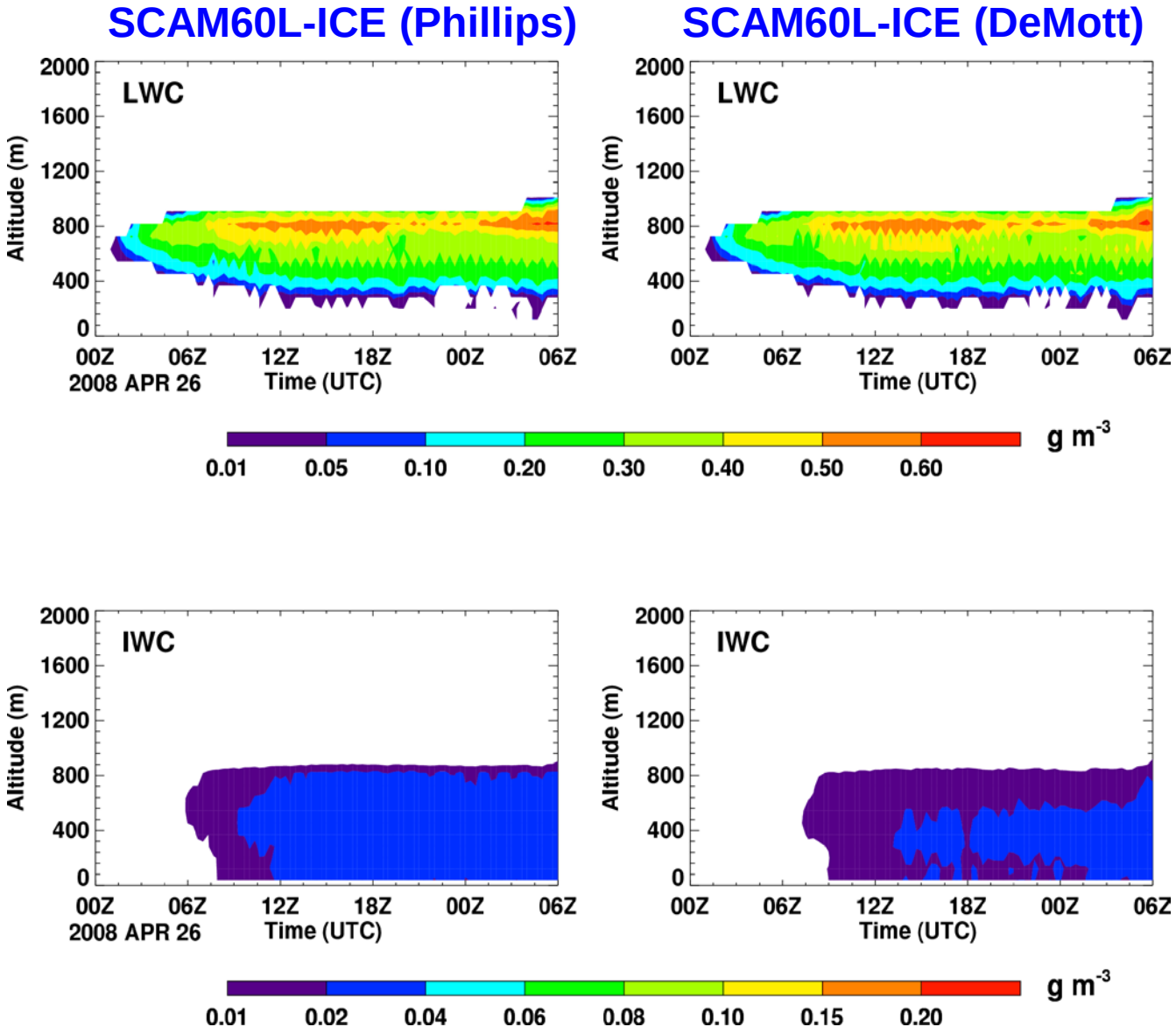
SCAM60L-ICE (Phillips vs DeMott) of ISDAC



- *Obs:*
  H_{top}=850 m
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  LWC_{max}=0.1-0.15 g/m^3
  IWC=0.01-0.04 g/m^3

- *IN number (CFDC, S. Brooks): 0.1-10/L*
  N_i = 0.3~0.5/L (size>100 um, A. Korolev)

- *SCAM60L-ICE (Phillips & DeMott) gives IN=0.1-0.2/L, and LWC/IWC similar*

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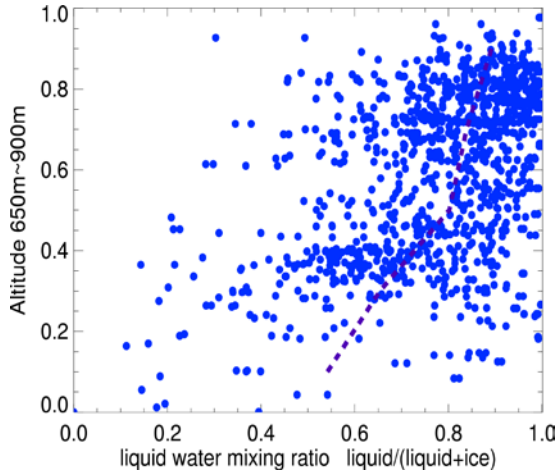
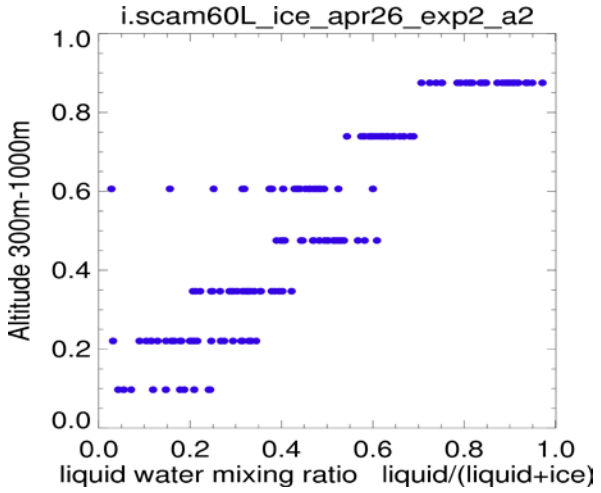
Boundary Layer Mixed-Phase clouds (April 26)

Model vs. Aircraft Data

Obs

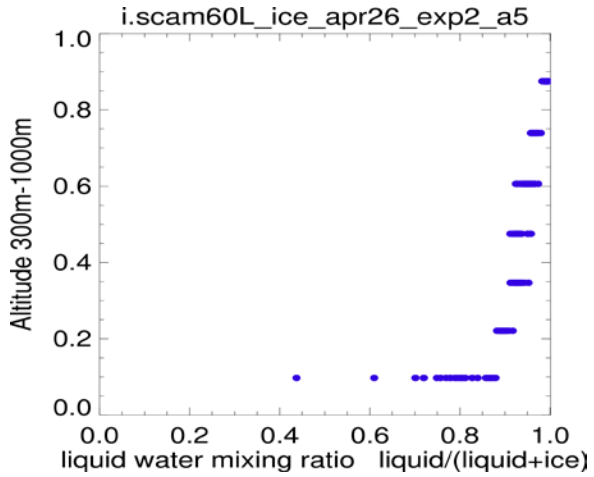


SCAM60L-ICE (Meyers)

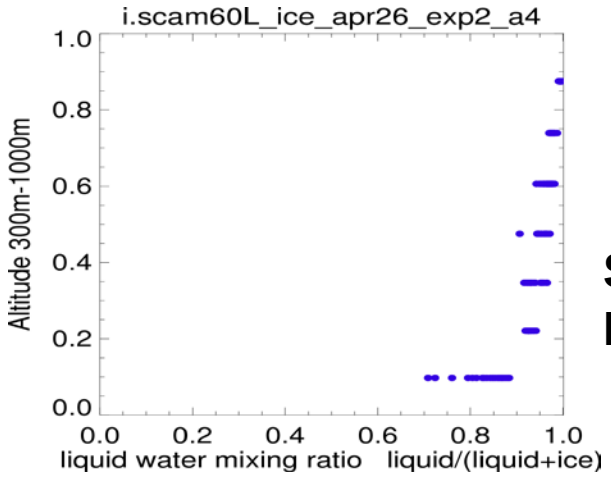


Normalized Height

SCAM60L-ICE (Phillips)



SCAM60L-ICE (DeMott)



Liquid water fraction, liq/(liq+ice)

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Climate Effects of Ice Nucleation in Mixed-Phase Clouds

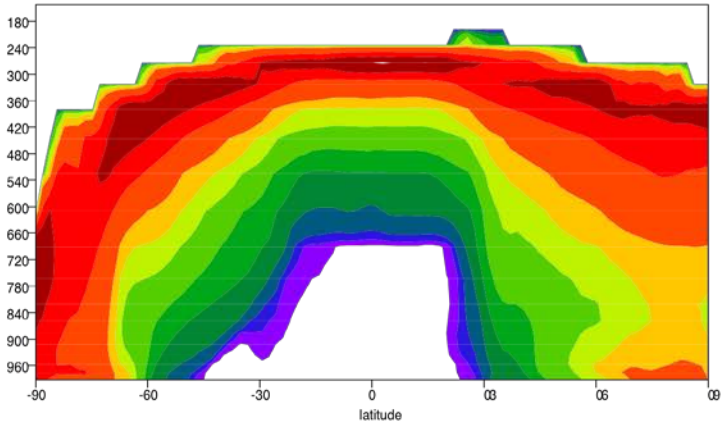
CAM5 Climate Simulations

- Double-moment MG cloud microphysics
- PNNL modal aerosol module (MAM)
- UW PBL + shallow Cu + cloud macrophysics
- RRTMG shortwave and longwave radiative transfer

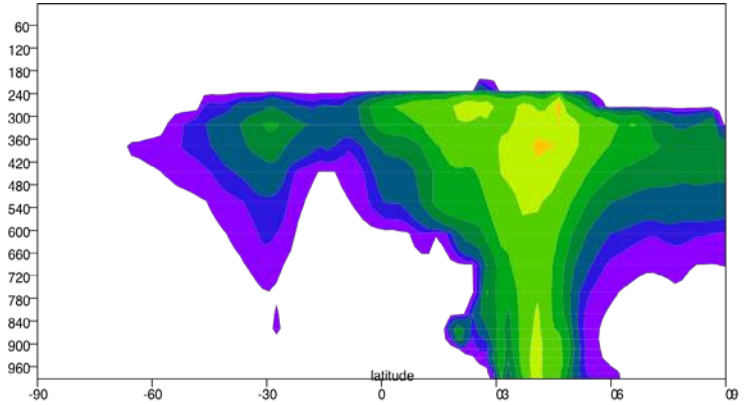
- 5 years at 1.9°x2.5° resolution

Ice Nuclei in Mixed-Phase Clouds from CAM

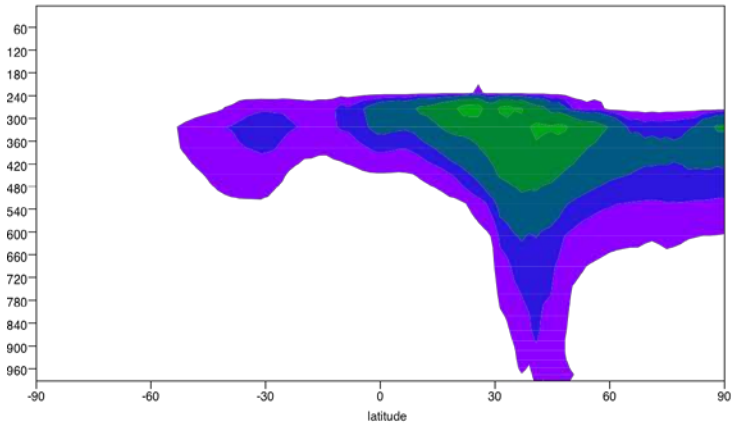
Meyers et al.



Phillips et al.



DeMott et al.



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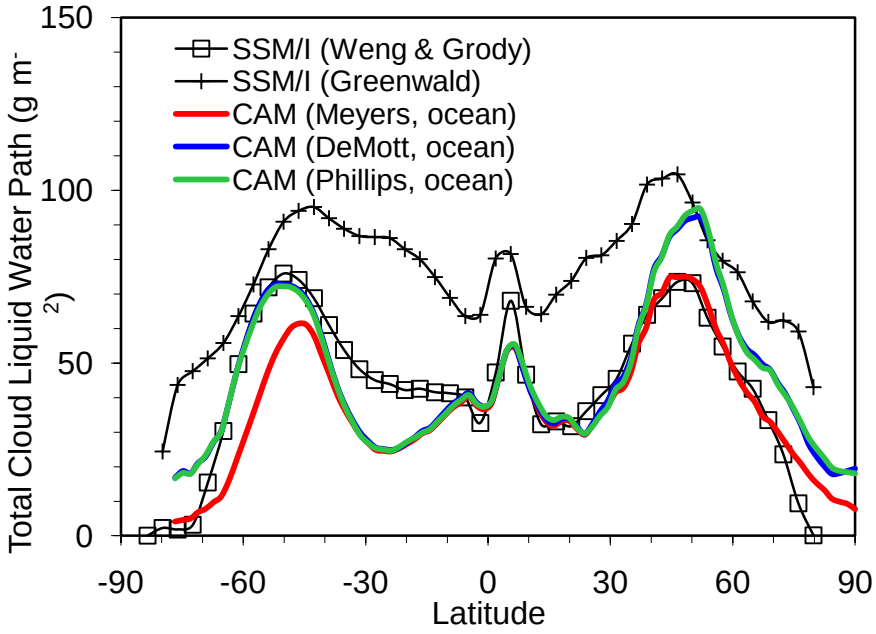
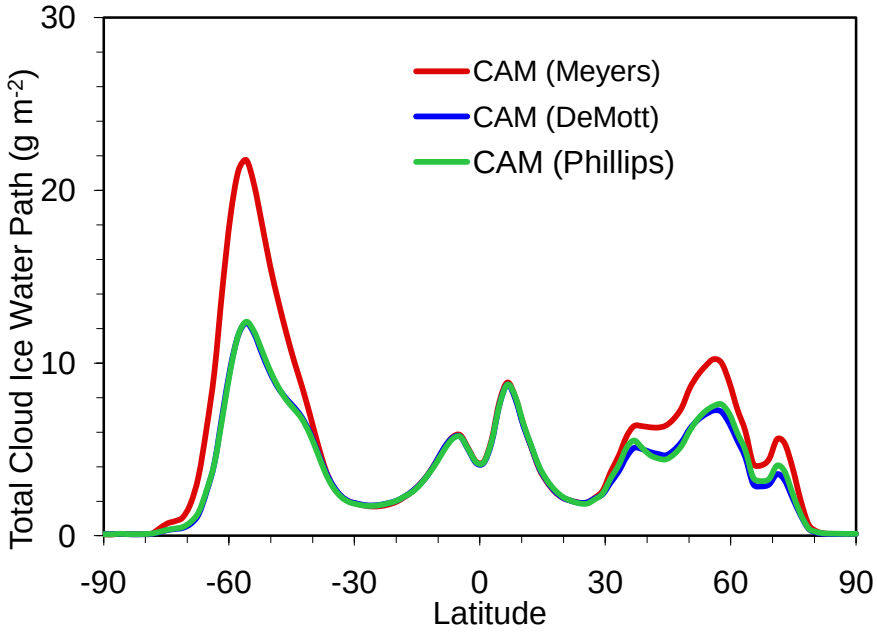
Climate Effects of IN Parameterizations

LWP



IWP



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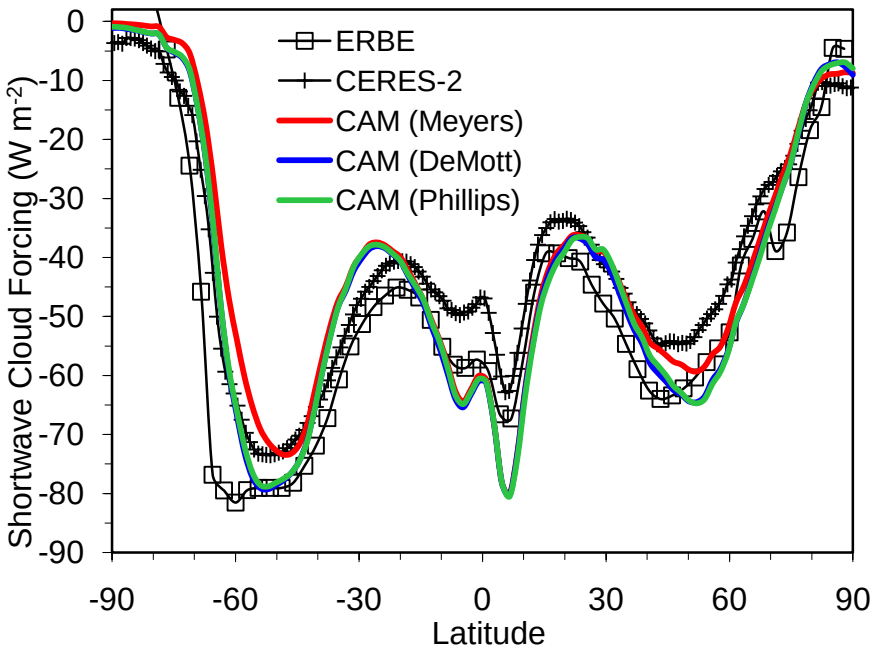
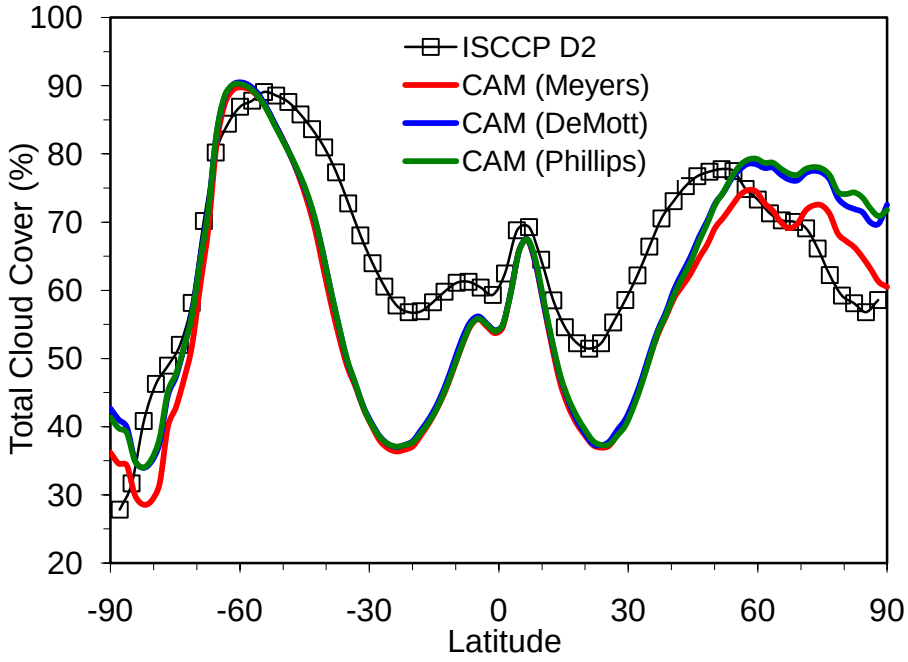
Climate Effects of IN parameterizations

SWCF



Total Cloud Cover



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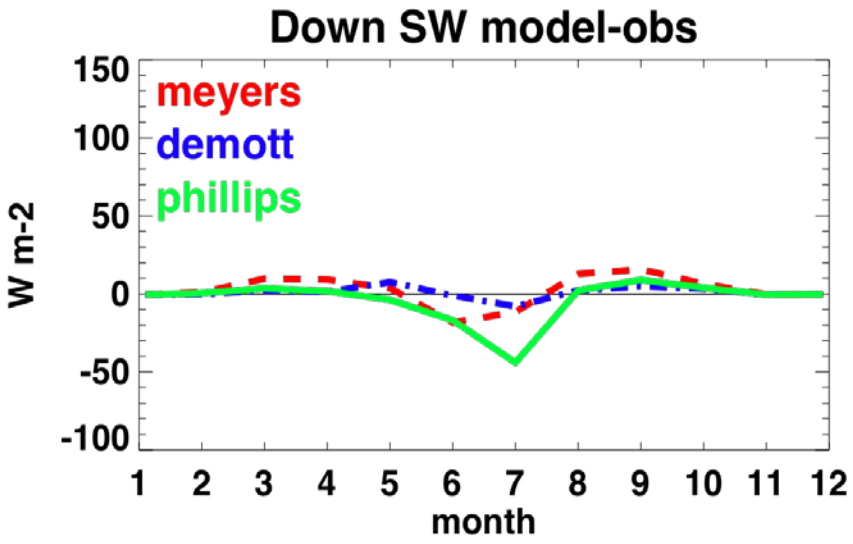
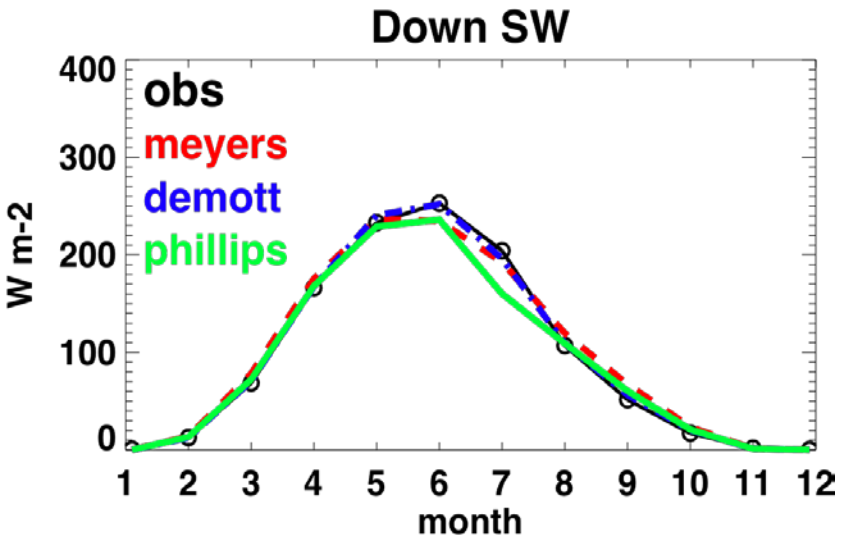
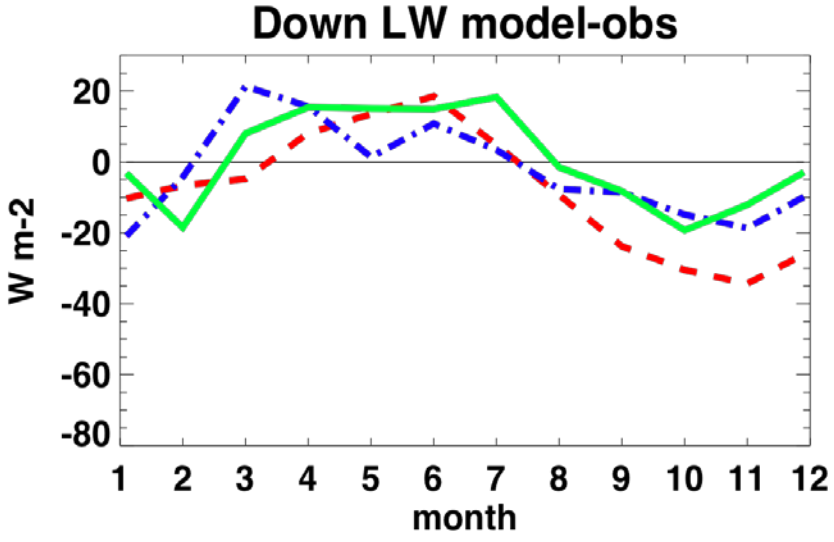
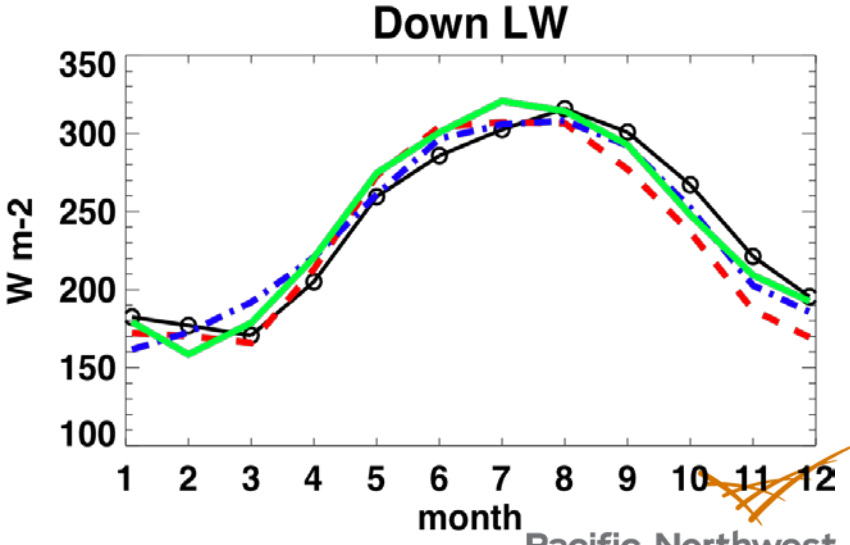
Comparison of Radiative Fluxes at Barrow (ARM)









Summary

- SCM testing for ISDAC shows that realistic treatment of mixed-phase cloud microphysics (ice nucleation and Bergeron-Findeisen process) is needed to reproduce cloud structure in Arctic mixed-phase clouds.

- Ice nucleation in mixed-phase cloud has important implication on regional (e.g., Arctic) and global climate.