Sensitivity of CAM5 cloud simulation to ice-nucleation parameterizations and its implication to climate

Shaocheng Xie[1], Xiaohong Liu[2]

Chuanfeng Zhao[1], Yuying Zhang[1]

[1]Lawrence Livermore National Laboratory

[2]Pacific Northwest National Laboratory

Tested IN schemes

1. **Meyers et al. (1992): widely used in current climate models, inclduing CAM5; an empirical formulation developed based on midlatitude measurements of ice nuclei concentrations, which are generally much larger than Arctic IN concentration.**

2. **DeMott et al. (2010): link IN to aerosol particles (dust) large than 0.5 um based on more than 14-year observations over many regions of globe, which generally gives much lower IN number concentrations than Meyers et al. (1992).**

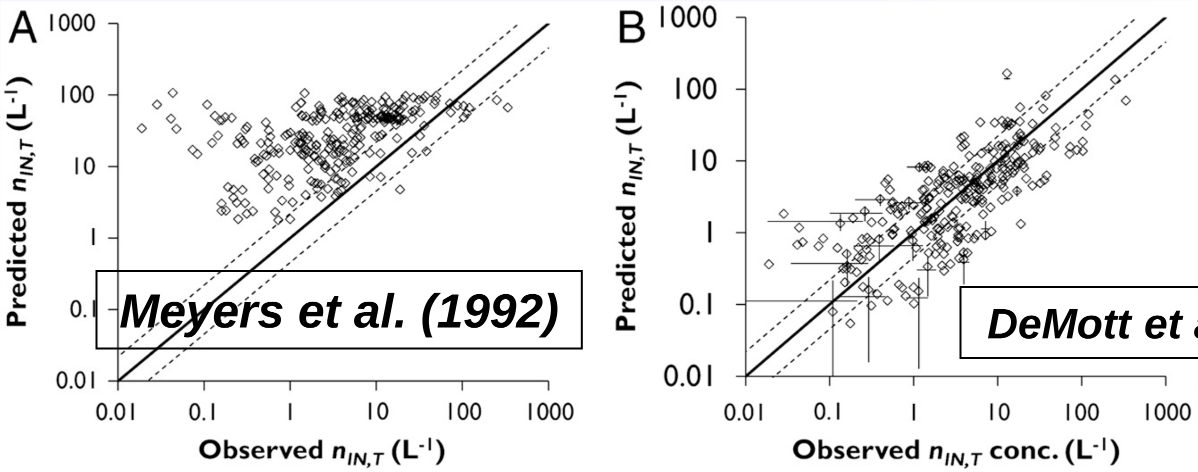


Figure adapted from DeMott et al. (2010)

How are these schemes used in CAM5?

- **A double-moment cloud microphysical scheme - Morrison and Gettelman (2008)**
- **Ice crystal nucleation scheme - Liu et al. (2007)**
  - **For Ice clouds ($T<-37^{0}C$): homogeneous freezing on sulfate aerosol competing with heterogeneous immersion nucleation on mineral dust in ice clouds.**
  - **For the mixed phase clouds ($-37<T<0^{0}C$): Meyers et al. (1992) is used for deposition/condensation nucleation, with a constant nucleation rate for $T < -20^{0}C$. Young (1974) used for contact nucleation by mineral dust.**

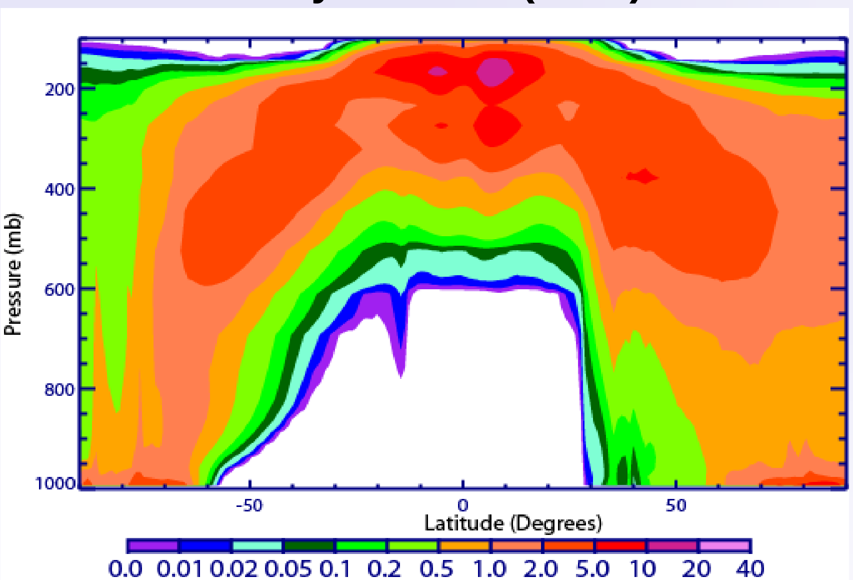
In the sensitivity tests, DeMott et al. (2010) is used to replace Meyers et al. (1992) to treat deposition/condensation nucleation.

Model experiment

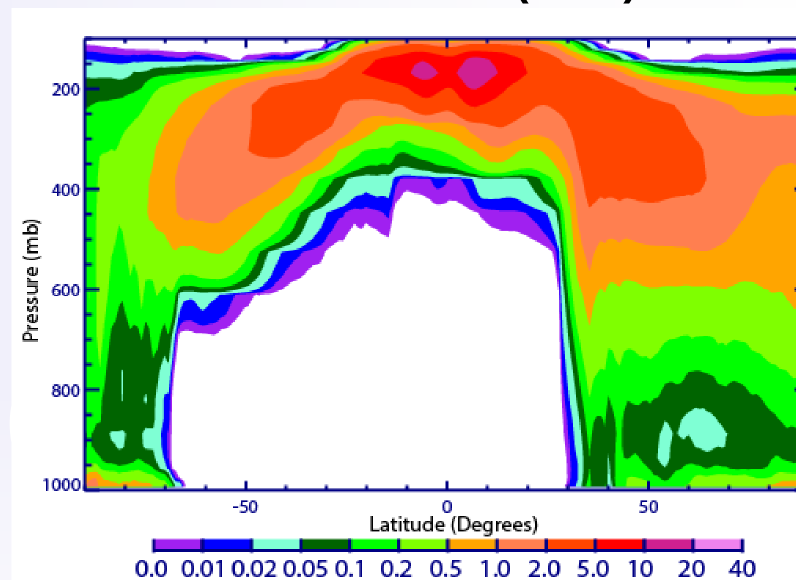
- CAM5 with its fv dynamic core, 0.9 x 1.25 (Deg), 30 levels
- 6-yr climate run with prescribed SST and sea ice (AMIP II type of run)

CAM5: **Ice crystal Concentration**

Meyers et al. (1992)



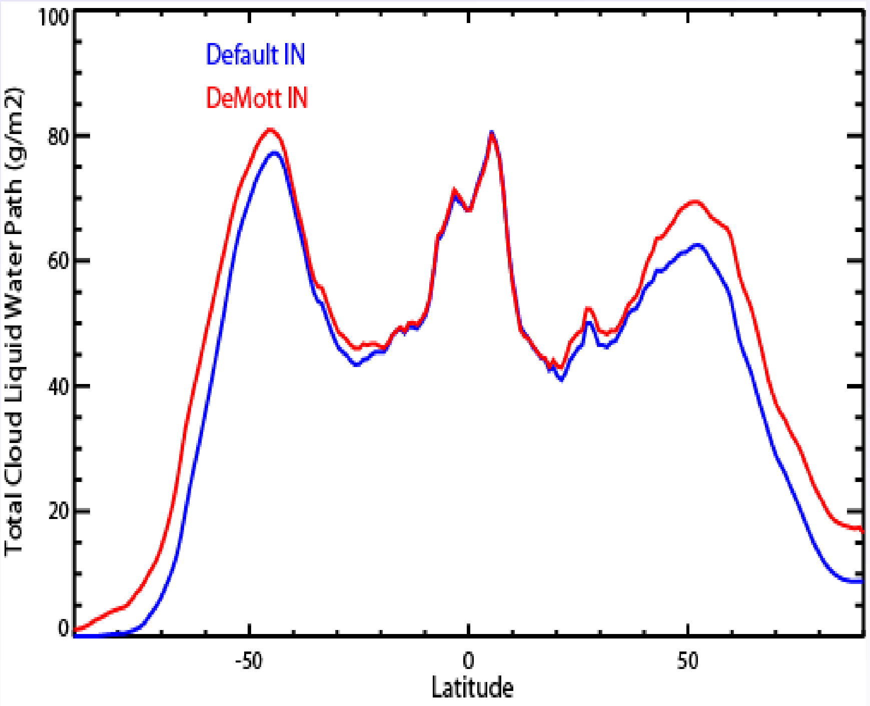
DeMott et al. (2010)



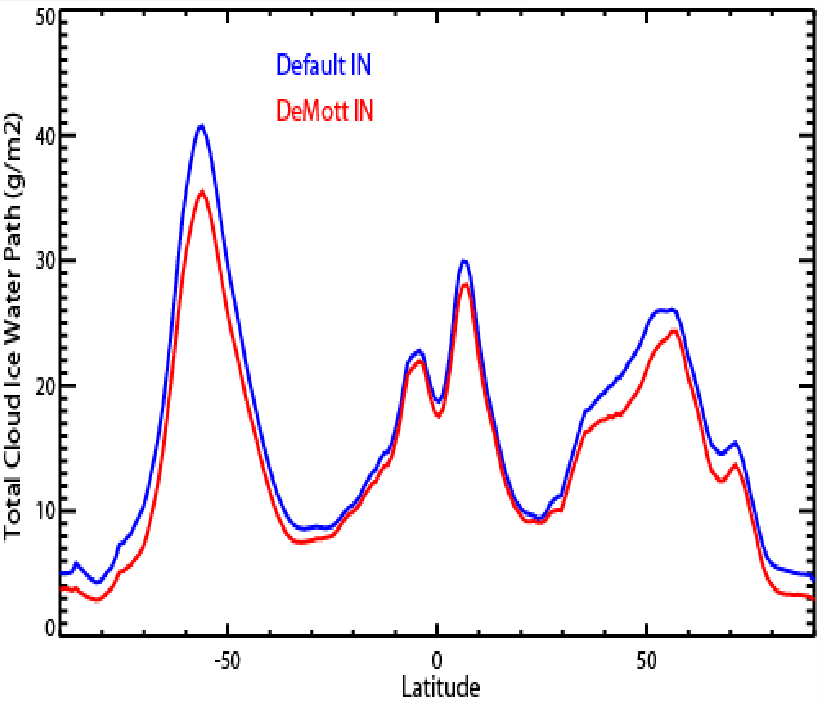
Meyers et al. (1992) produces larger IN number concentration than DeMott et al. (2010), especially in the middle and high latitudes in 6-year AMIP runs.

CAM5: **Cloud Properties**

LWP

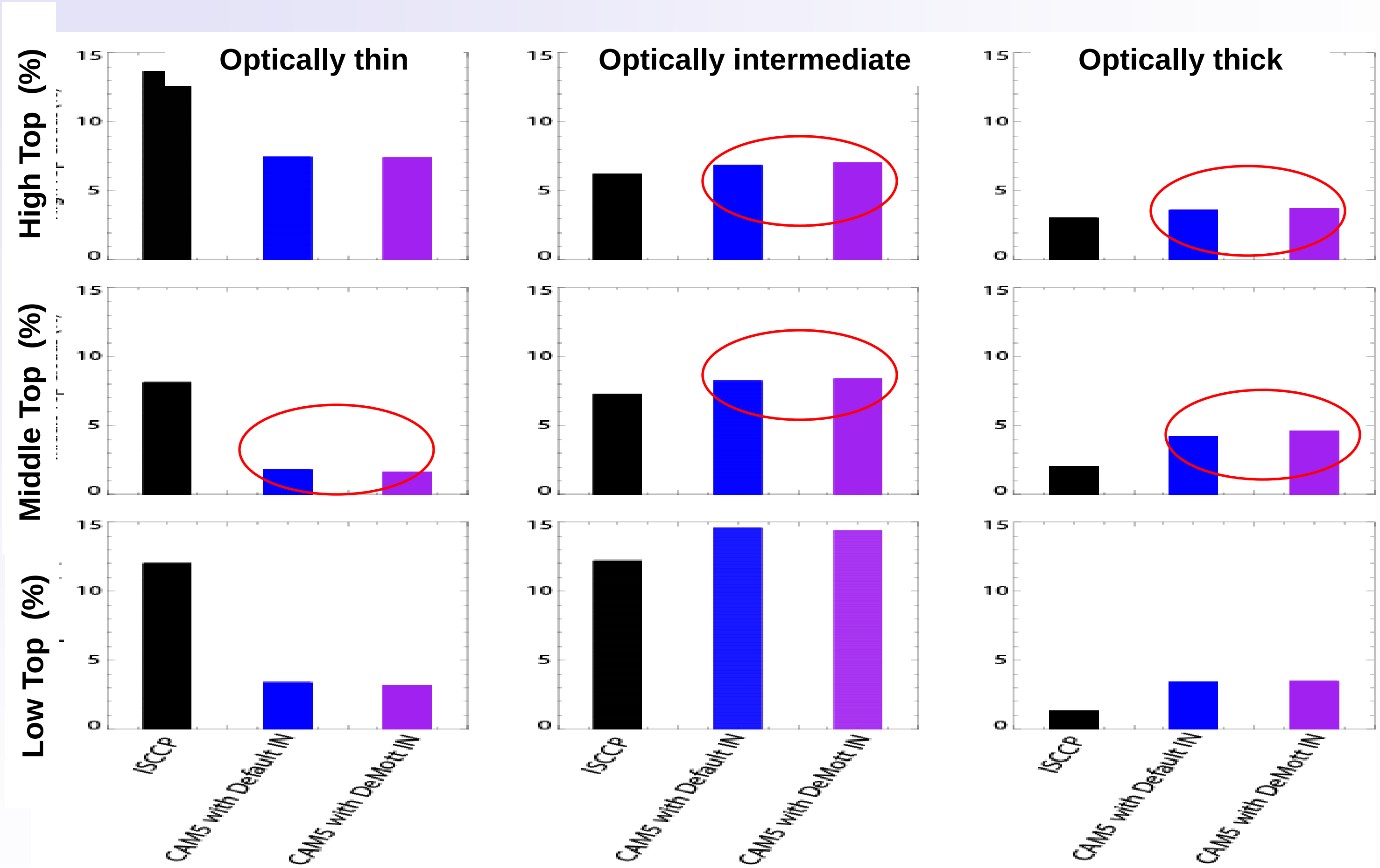


IWP



Larger difference seen in the higher latitudes between Meyers et al. (1992) and DeMott et al. (2010). As expected, Meyers et al. (1992) has smaller LWP and larger IWP compared to DeMott et al. (2010) because the larger IN concentration is produced in the default scheme.

CAM5: **Annual Mean Cloud Fraction for Nine Cloud Types in ISCCP (60S-60N)**

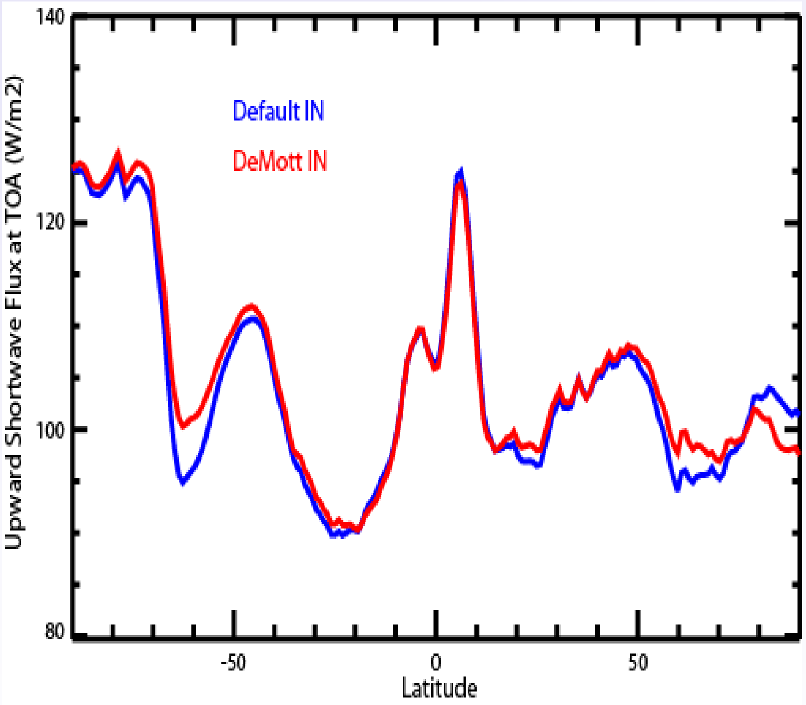


Overall, DeMott et al. produces slightly more optically intermediate and thick middle and high top clouds and less optically thin clouds globally → clouds are brighter!

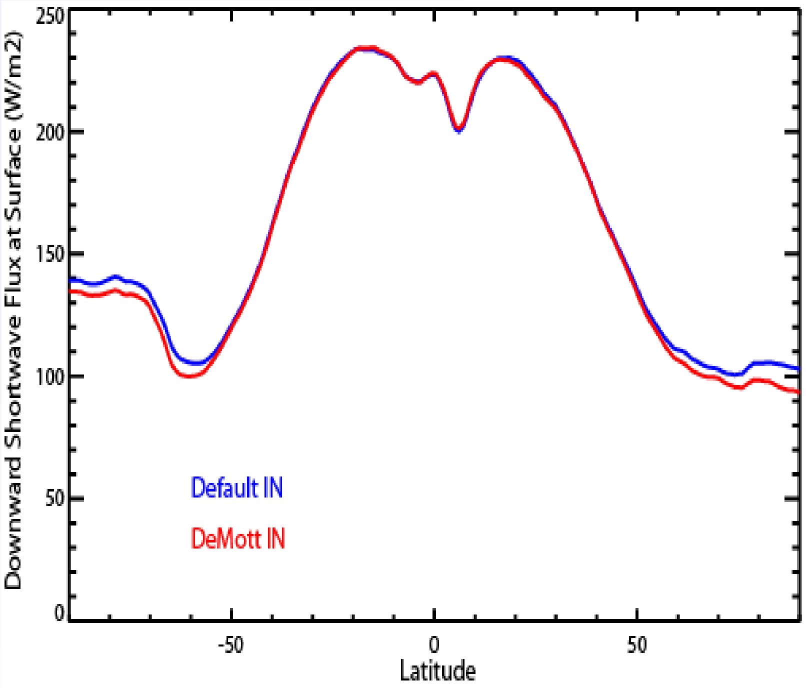
The largest changes are seen in the Arctic region where mixed-phase clouds dominate

CAM5: SW radiation

Upward SW at TOA

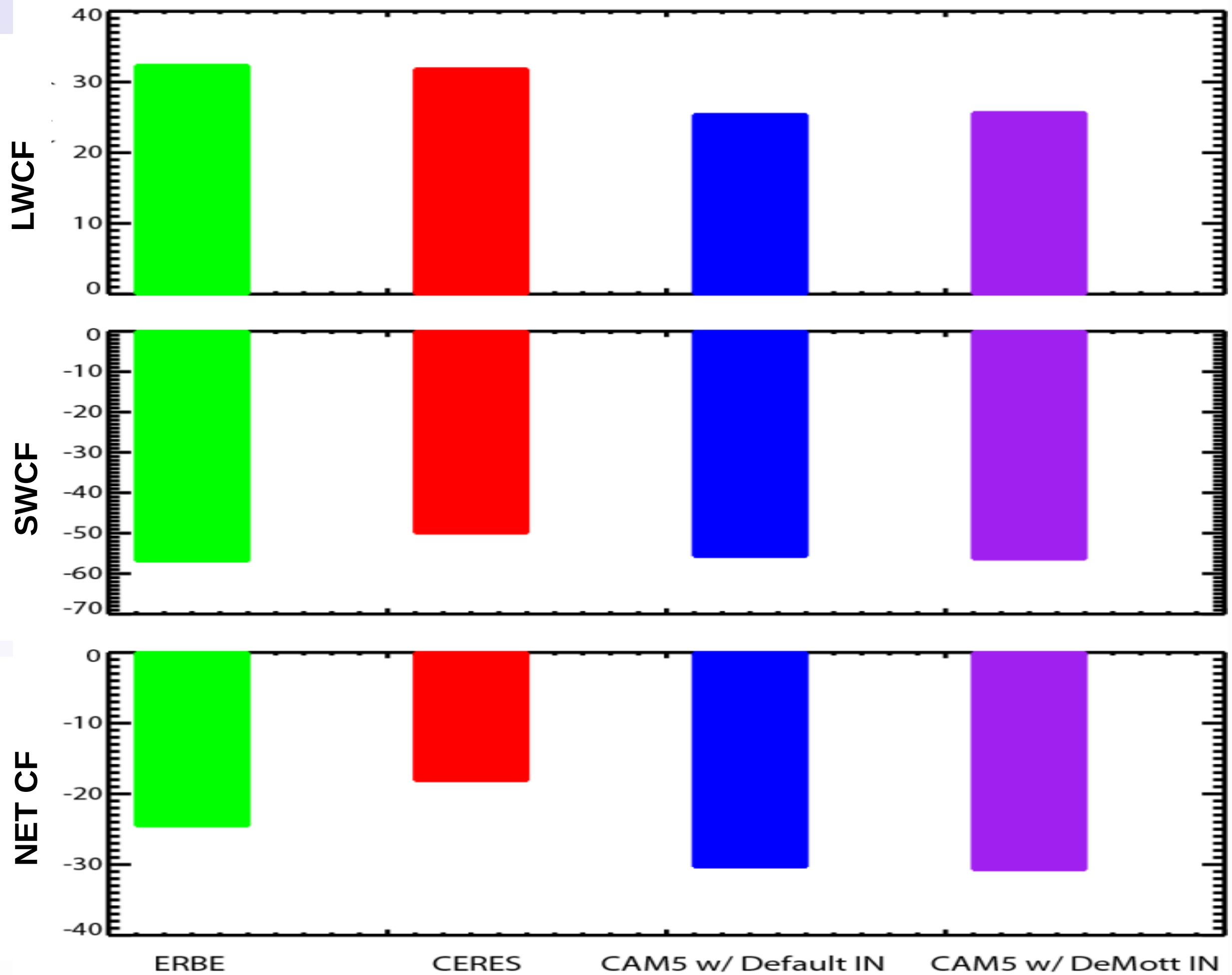


Downward SW at surface



Differences are seen in the higher latitudes, brighter clouds reflect more SW at TOA and less SW reaching the surface

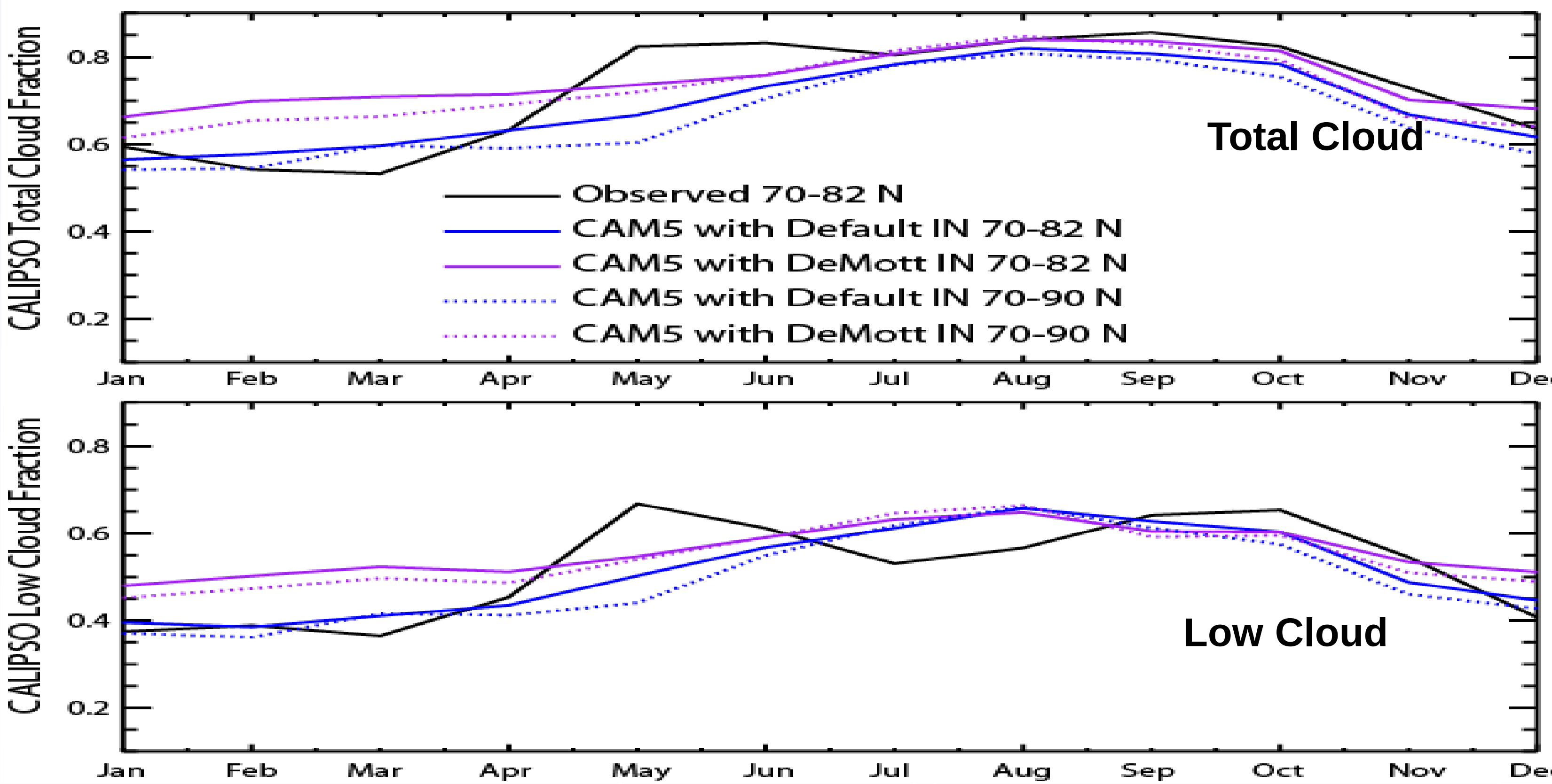
CAM5: **Cloud Radiative Forcing (60S-60N)**



Increased cloud forcing in the DeMott et al. (2010), specifically in SWCF due to brighter clouds

CAM5: **Cloud Fraction**

Seasonal Variation of Arctic Clouds from CALIPSO Simulator output



Overall, DeMott et al. produces more cloudness (mixed-phase clouds) than the Meyers et al. (1992) in the polar region, especially during the Spring season when the air is more polluted.

Summary

- IN number concentrations need to be accurately represented in climate models, but this is a very challenging task.
- Simulated cloud and climate is sensitive to IN parameterizations, especially in the Arctic region.
- Less IN –> larger LWP and smaller IWP; as well as more optically intermediate and thick clouds (brighter)
- The difference is larger during the polluted season than the clean reason in the Arctic
- More analyses need to be done