Testing a new aerosol-dependent ice nucleation parameterization for predicting ice nuclei and simulating mixed-phase clouds during ISDAC

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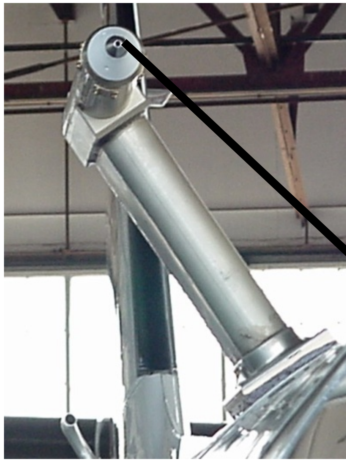
Overview

- Merged aerosol and ice nuclei (IN) data sets from multiple field programs toward a parameterization of ice nucleation as it depends on aerosols and thermodynamic conditions.
- Compare and contrast IN predictions versus TAMU IN data collected during the Indirect and Semi-Direct Aerosol Campaign (ISDAC)
- Incorporate parameterization into cloud resolving model simulations of single layer Arctic clouds during ISDAC

Sampling methods (CSU in various studies, TAMU in ISDAC)

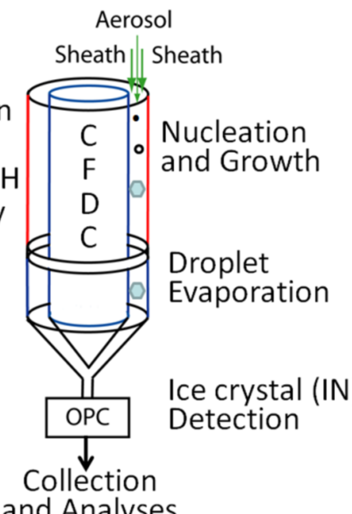


CVI inlet (aerosol from evaporated cloud particles when in clouds)

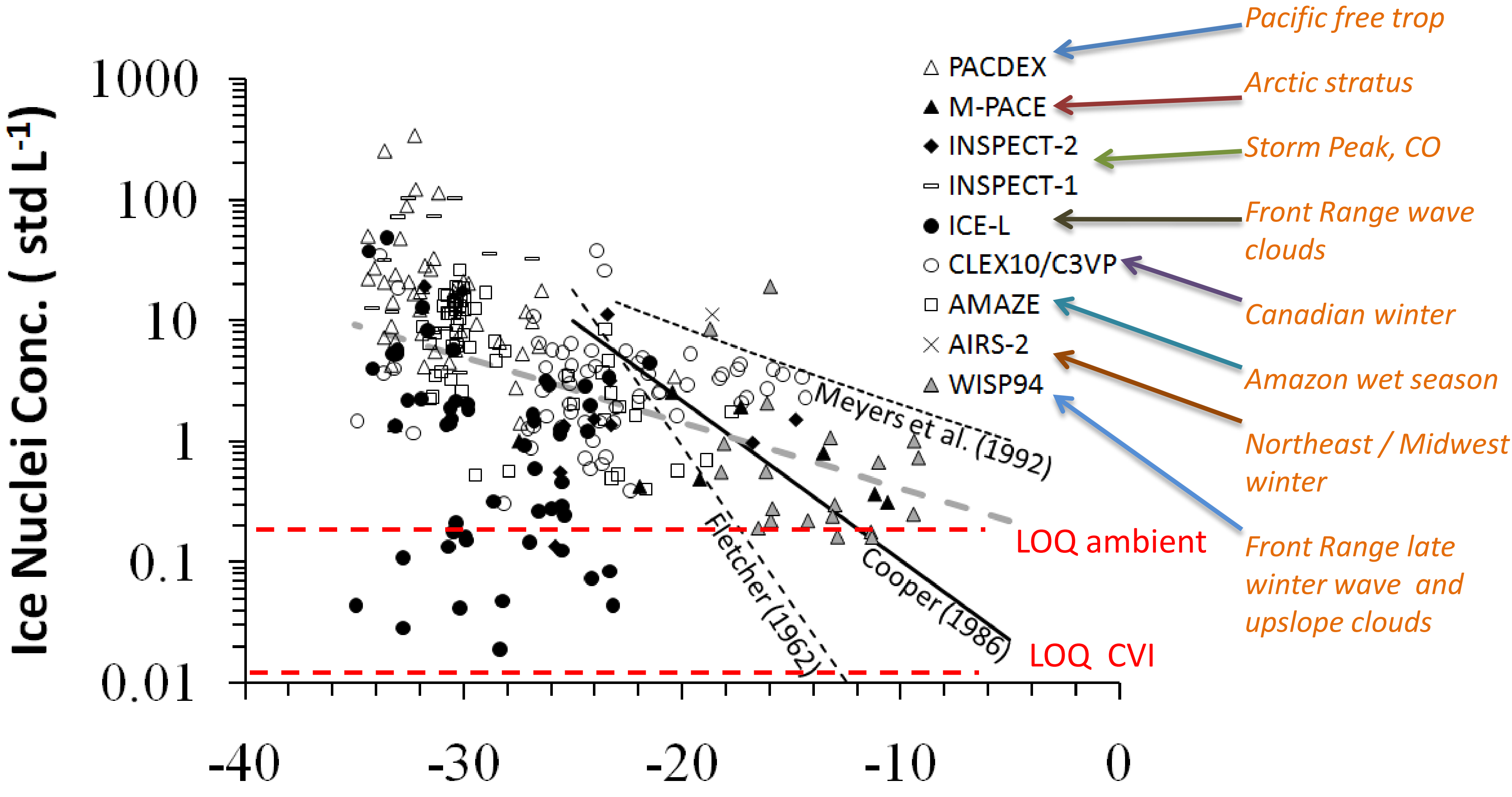
aircraft aerosol sample inlet

Continuous flow diffusion chamber (CFDC) in aircraft

Small fraction of particles freeze at T, RH controlled by ice coated warm and cold walls

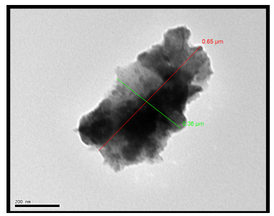


Ice nuclei concentrations (RH_w>100%) in projects over 14 years (292, **10-30 min**. averages, coincident aerosol data)

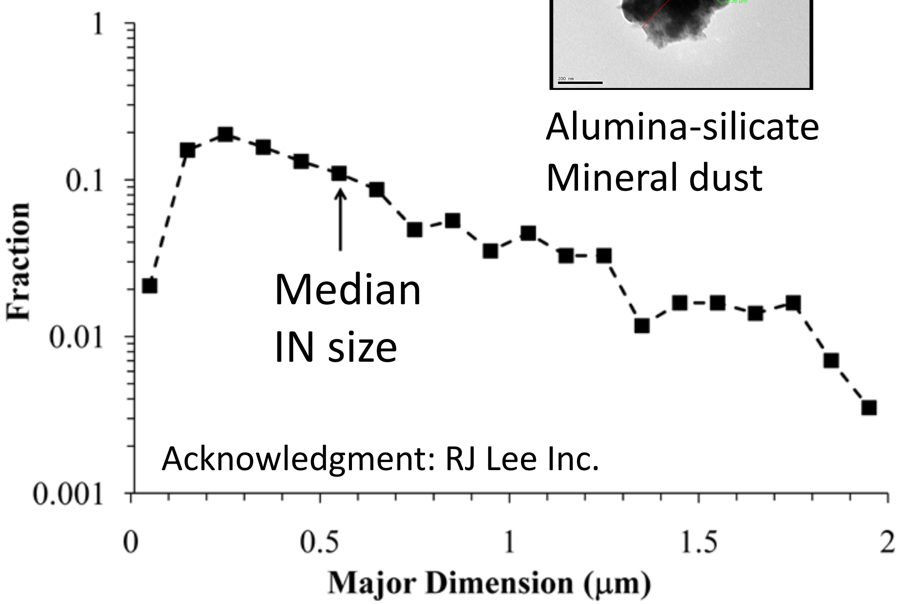


[*DeMott et al., 2010;* PNAS]

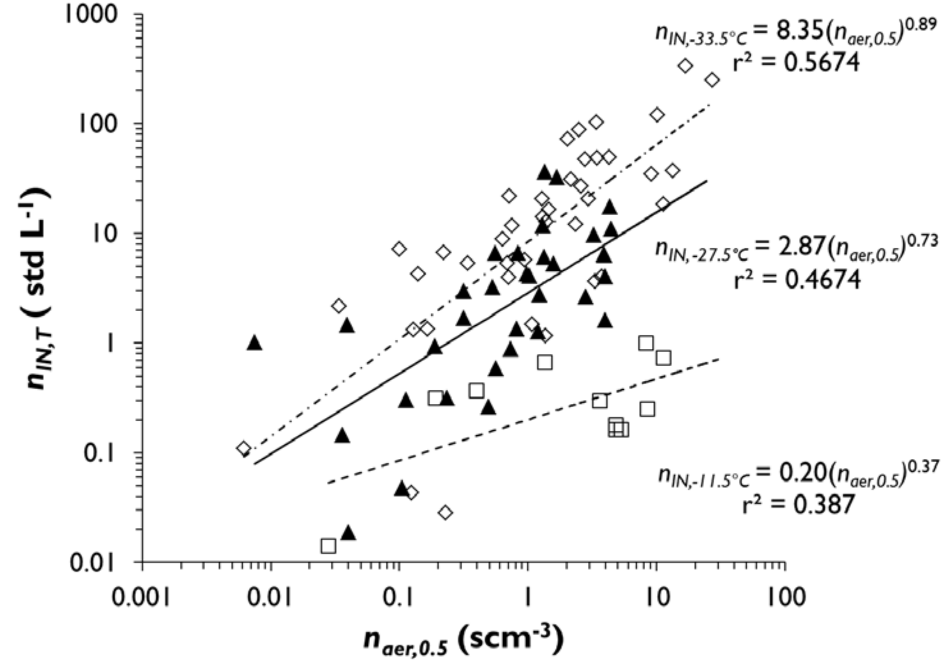
Noted sizes of collected ice nuclei translates to noted concentration sensitivity to concentrations of aerosols > 0.5 μm



Alumina-silicate
Mineral dust



Acknowledgment: RJ Lee Inc.

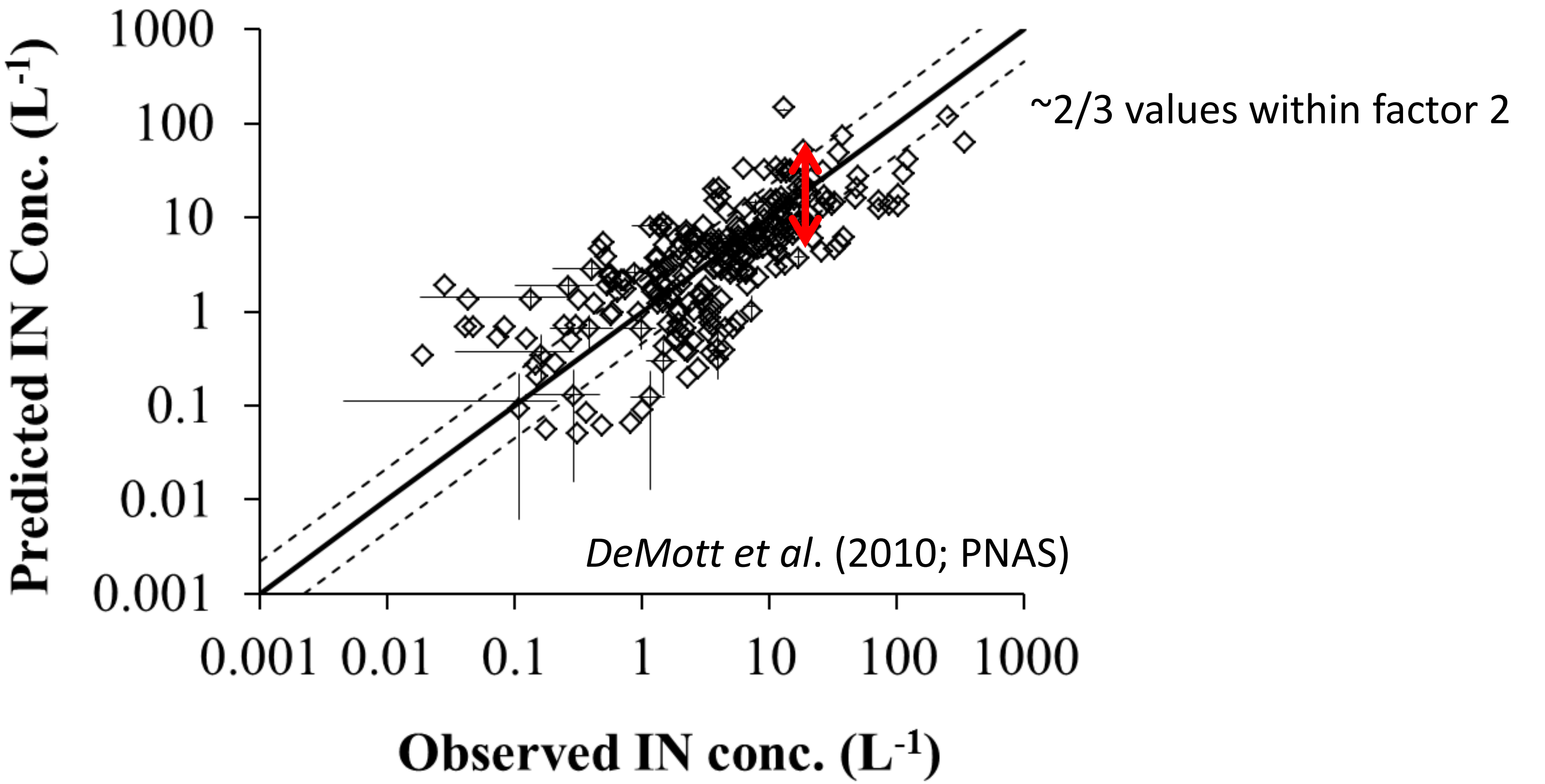


Parameterization of ice formation in mixed-phase clouds

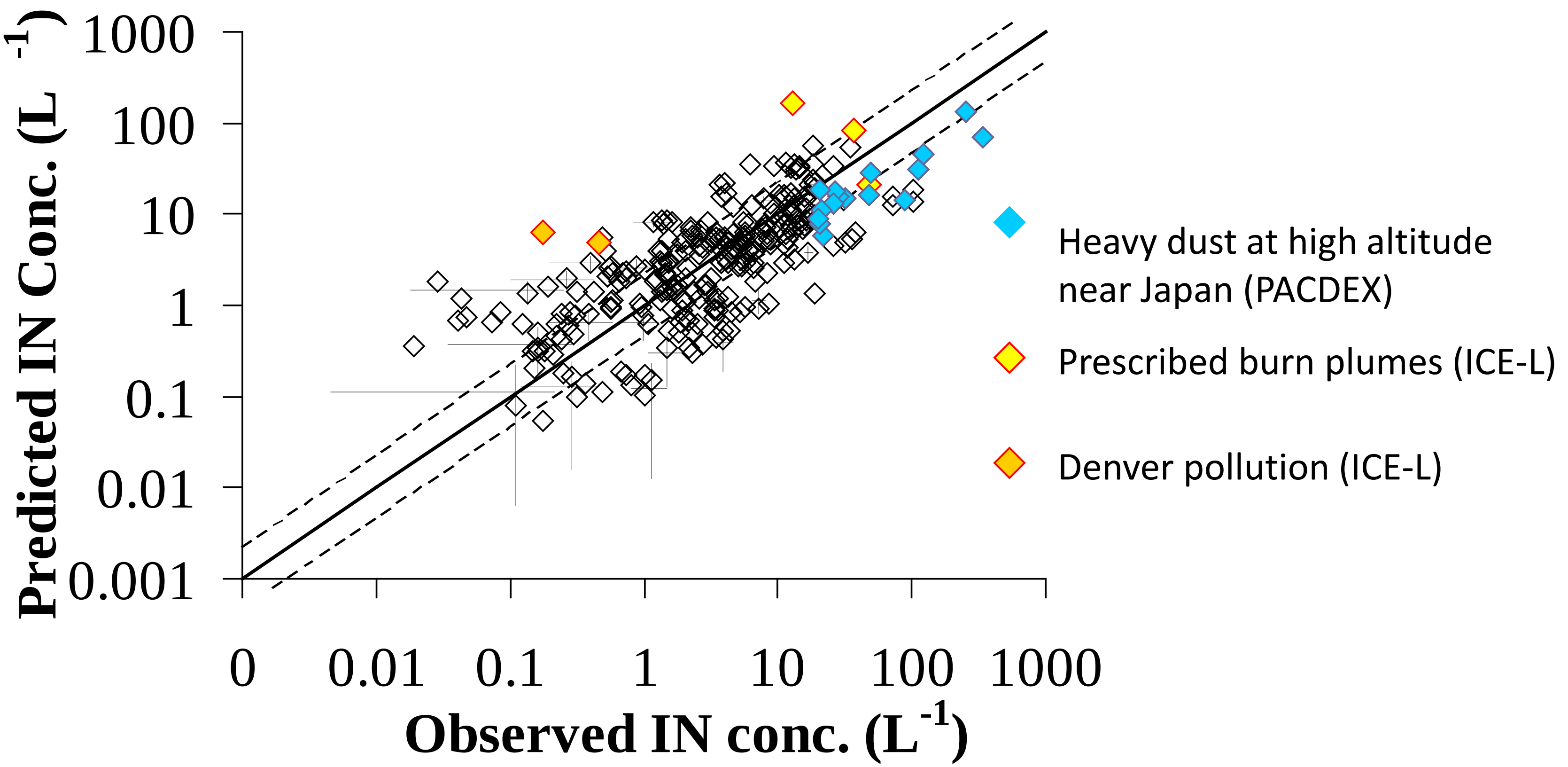
$$n_{IN,T_k} = a\left(273.16 - T_k\right)^b (n_{aer,0.5})^{(c(273.16-T_k)+d)}$$

- T_k is cloud temperature in degrees Kelvin
- $n_{aer,0.5}$ is the number concentration (scm^{-3}) of aerosol particles with diameters larger than 0.5 μm
- n_{IN} is ice nuclei number concentration (std L^{-1}) at T_k
- **Valid only in mixed phase conditions, ignores any IN dependence on RH_w>100%, no sampling represented under sea salt influences**

Account for particle size and T-dependencies reduces variability within ~1(O) magnitude

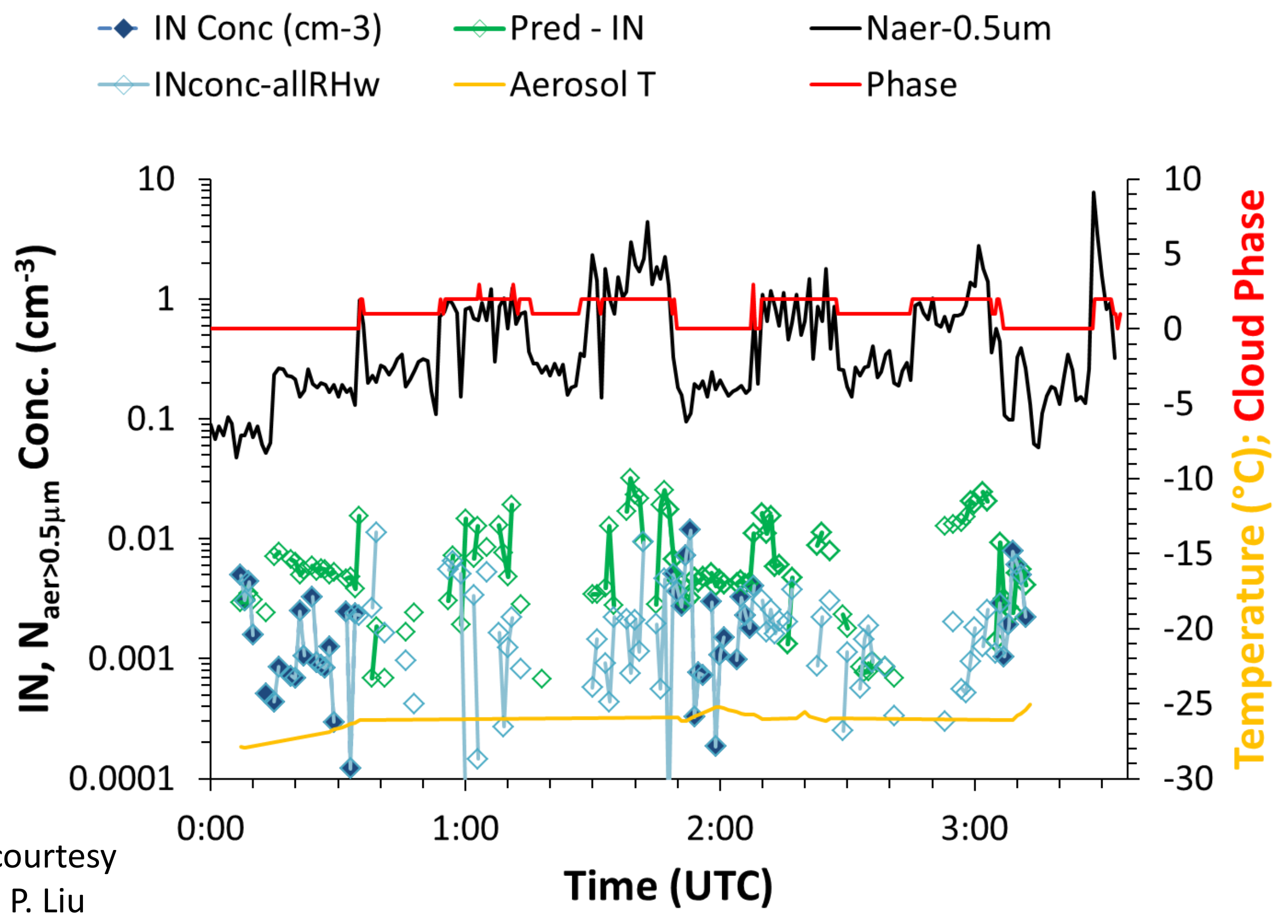


Chemistry or processing impacts on IN variability likely exist and require further research



Use of ISDAC PCASP number concentrations to predict IN number concentrations

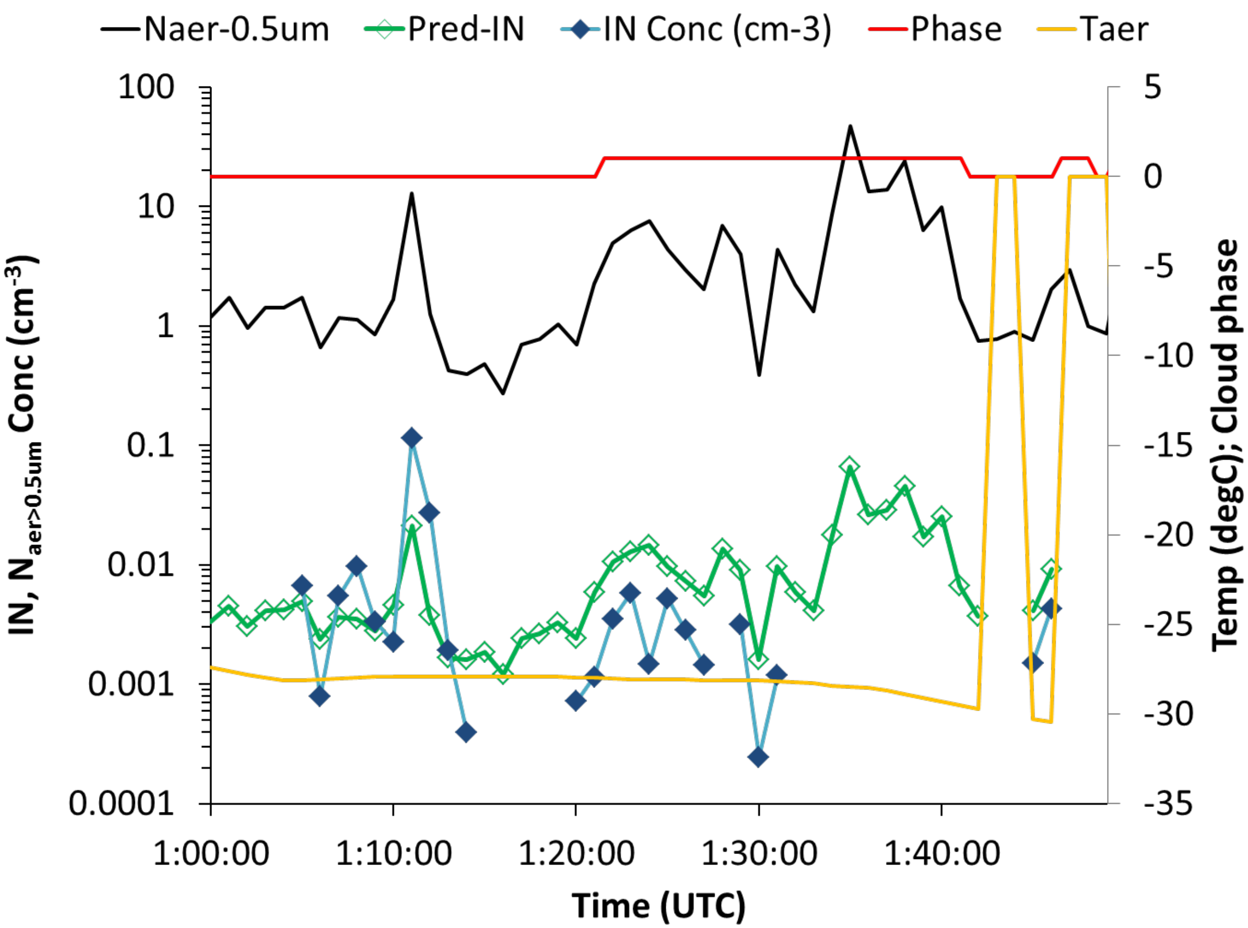
Flight 31 (April 26, 2008) – **1 min** IN for $RH_{TAMU-CFDC}$ > 100%



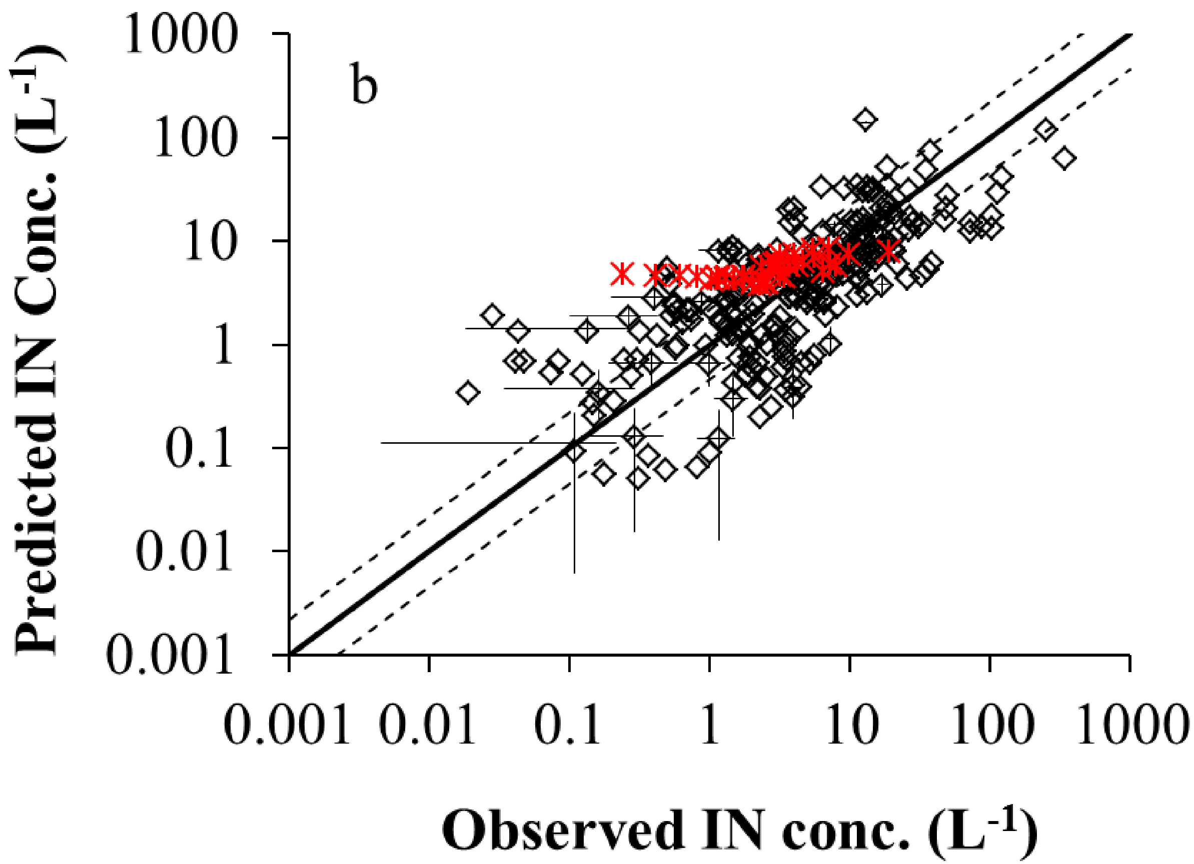
PCASP data courtesy of W. Strapp, P. Liu

Cloud phase data courtesy of R. Jackson and G. McFarquhar
- 0: clear
- 1: ice or sub-cloud precip.
- 2: mixed phase
- 3: liquid

Flight 17; April 8, 2008

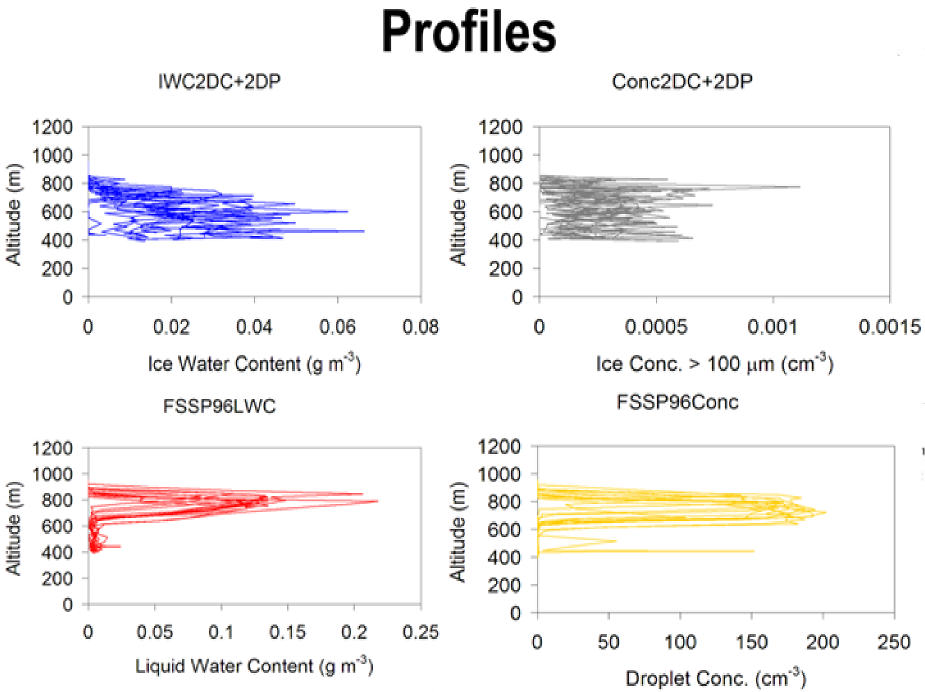


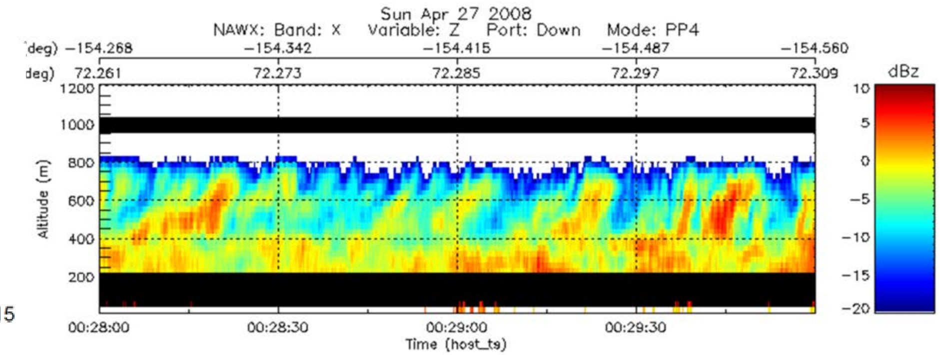
ISDAC IN – aerosol preliminary data for 2 days (5 minute averages)

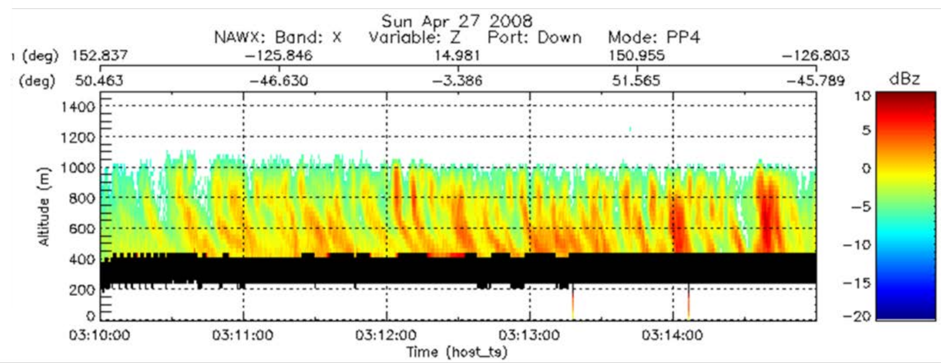


Springtime Arctic is not deficient in IN, at least at -25 to -32 C

Flight 31 (April 26, 2008) – single layer, upper-liquid and lower-ice dominated, precipitating ice at times







NAWX Airborne Radar Profiles courtesy of M. Wolde

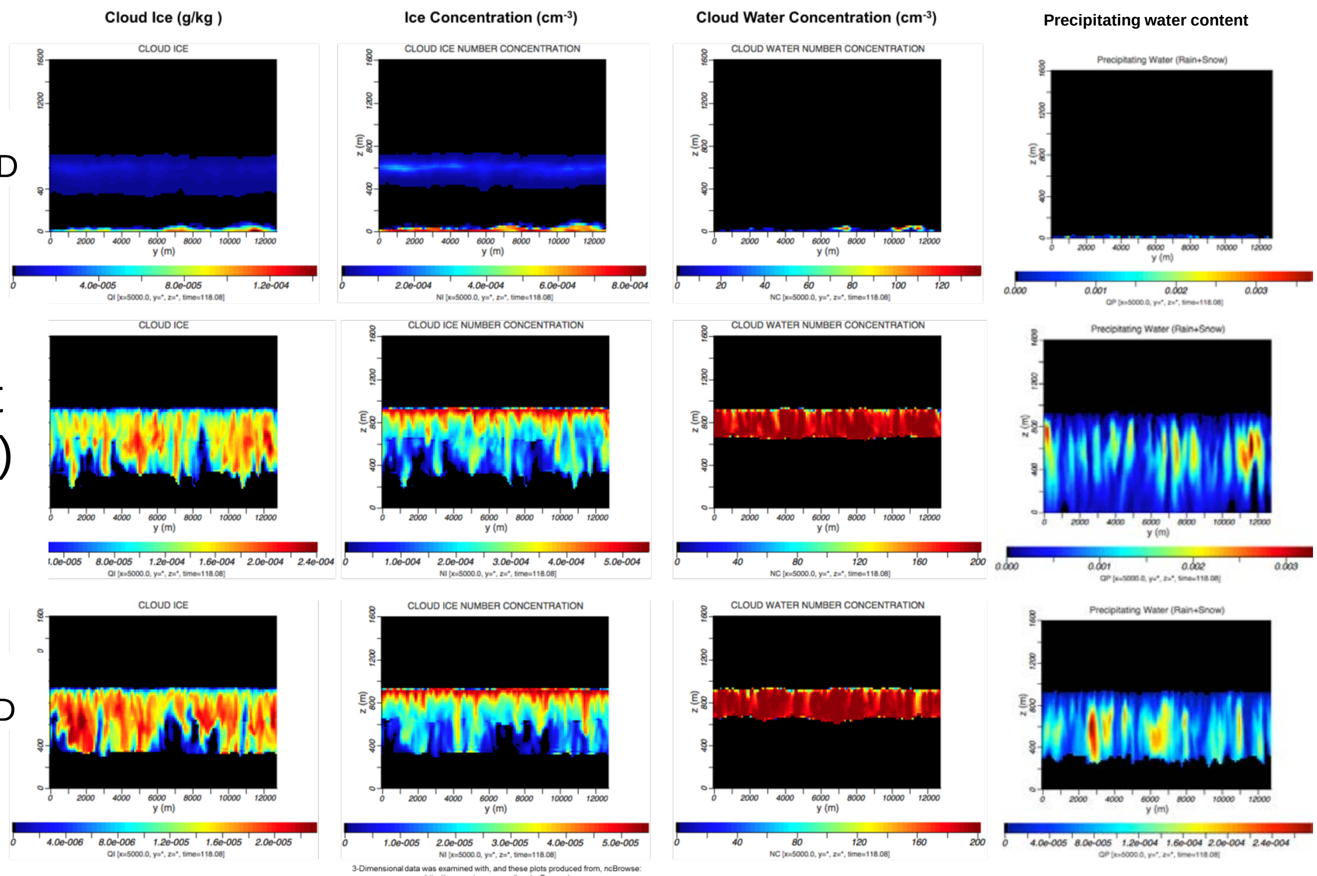
Cloud data courtesy of W. Strapp, A. Korolev

$N_1 = 206.9\ cm^{-3}$; $N_2 = 8.5\ cm^{-3}$
$s_1 = 1.50$; $s_2 = 2.45$
$d_1 = 0.2\ \mu m$; $d_2 = 0.7\ \mu m$

Acknowledgments to Mengistu Wolde, Mikhail Ovchinnikov, Michael Earle

Simulations and sensitivity studies using the System for Atmospheric Modeling (SAM v 6.8.2) CRM, Morrison 2-moment microphysics, “diagnostic” IN

12-Hour Simulation Results



$10 \times IN_D$ — Early glaciation of cloud water and early precipitation

IN_D (from DeMott et al. (2010)) — Ice conc. (0.2-0.3 L^{-1}) correct, and precipitation to surface

$0.1 \times IN_D$ — Ice conc. low by ~10; no precipitation to surface

Conclusions and outlook

- IN predicted by parameterization linking to aerosols (numbers and size) agrees within expectations with observed values during ISDAC – will be compiling a comprehensive comparison.
- Many characteristics of April 26 cloud case are well simulated using IN parameterization – need further analyses of simulation details (cloud water and ice distributions), comparison to remote sensing data.
- Case shows strong sensitivity of clouds to ice formation process. Will attempt prognostic IN implementation next.
- Simulate additional cases and participate in model inter-comparisons.