CAPI Ice Nucleation Report

Thanks to ice nucleation breakout session participants and ASR community interest groups.

Ice Nucleation interest group:

Xiaohong Liu, Gourihar Kulkarni, Paul DeMott, Zhien Wang, Matthew Shupe, Ann Fridlind, Raymond Shaw, Gijs de Boer, David Mitchell, Daniel Knopf, Joyce Penner, Jiwen Fan, Ryan Muffet, Rachel Sellon, Mary Gilles, Andy Heymsfield, Tim Onasch, Sonia Kreidenweis, Markus Petters

- Highlights from this week breakout session
- Top priority questions
- Key questions

Monday 4:00-6:00 CAPI Ice Nucleation Breakout Session

4:00-4:15 Paul DeMott: Field and Laboratory Explorations of Marine Ice Nuclei

4:15-4:30 Gourihar Kulkarni: Ice nucleating properties of bare, coated, oxidized, coagulated, and thermally treated diesel soot particles

4:30-4:45 Daniel Knopf: What individually identified ice nuclei tell us about the atmospheric glaciation process

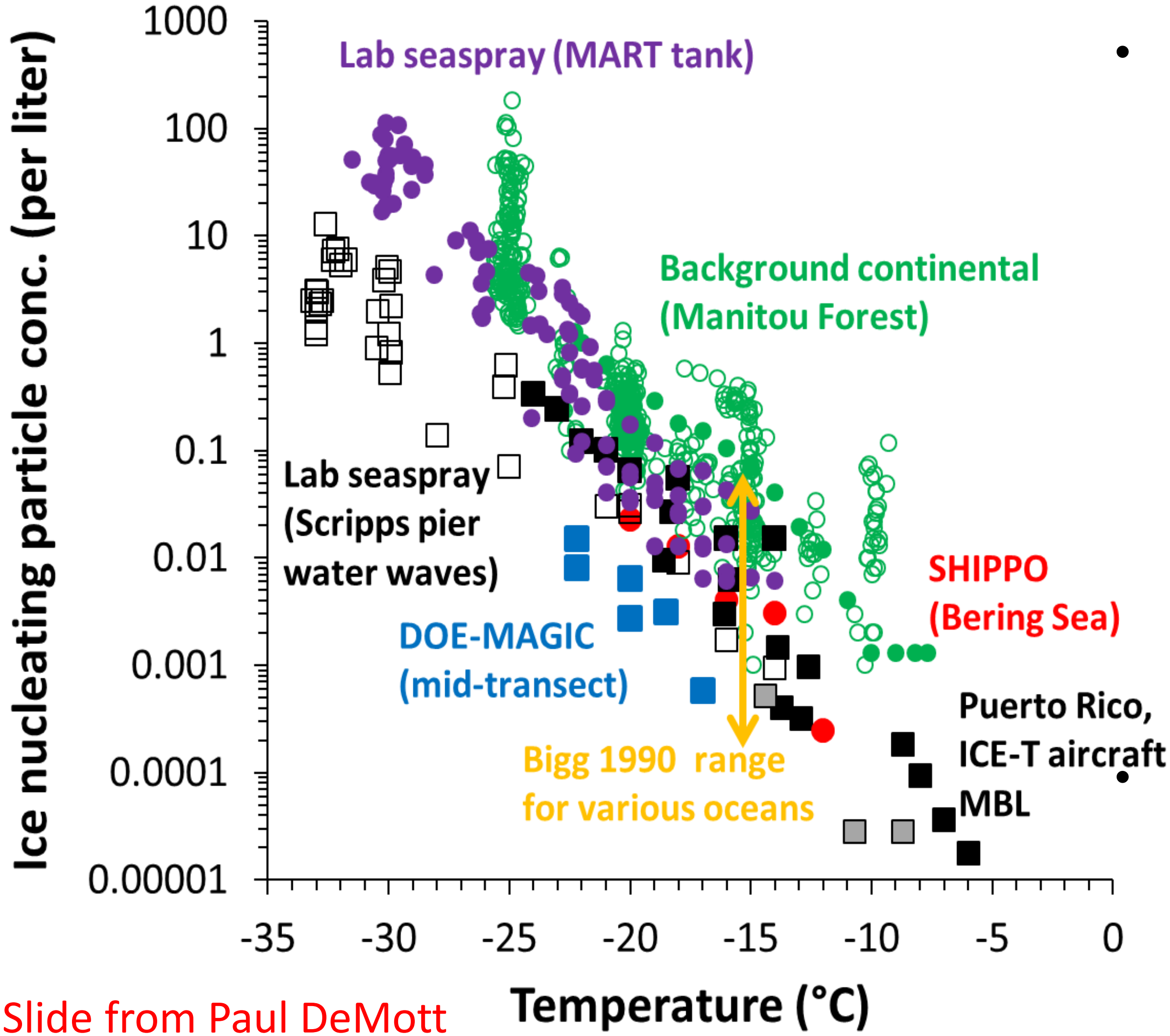
4:45-5:00 Damao Zhang: Seasonal Variations of Ice Number Concentration in Stratiform Mixed-phase Clouds over ACRF NSA site

5:00-5:15 David Mitchell: Globally mapping regions of homo- and heterogeneous nucleation as a function of latitude and season: A potential strategy using CALIPSO

5:15-5:30 Xiaohong Liu: Effect of aerosols on the phase partitioning of mixed-phase clouds through comparison of Community Atmospheric Model (CAM5) and CALIPSO observation

5:30-6:00 DISCUSSION

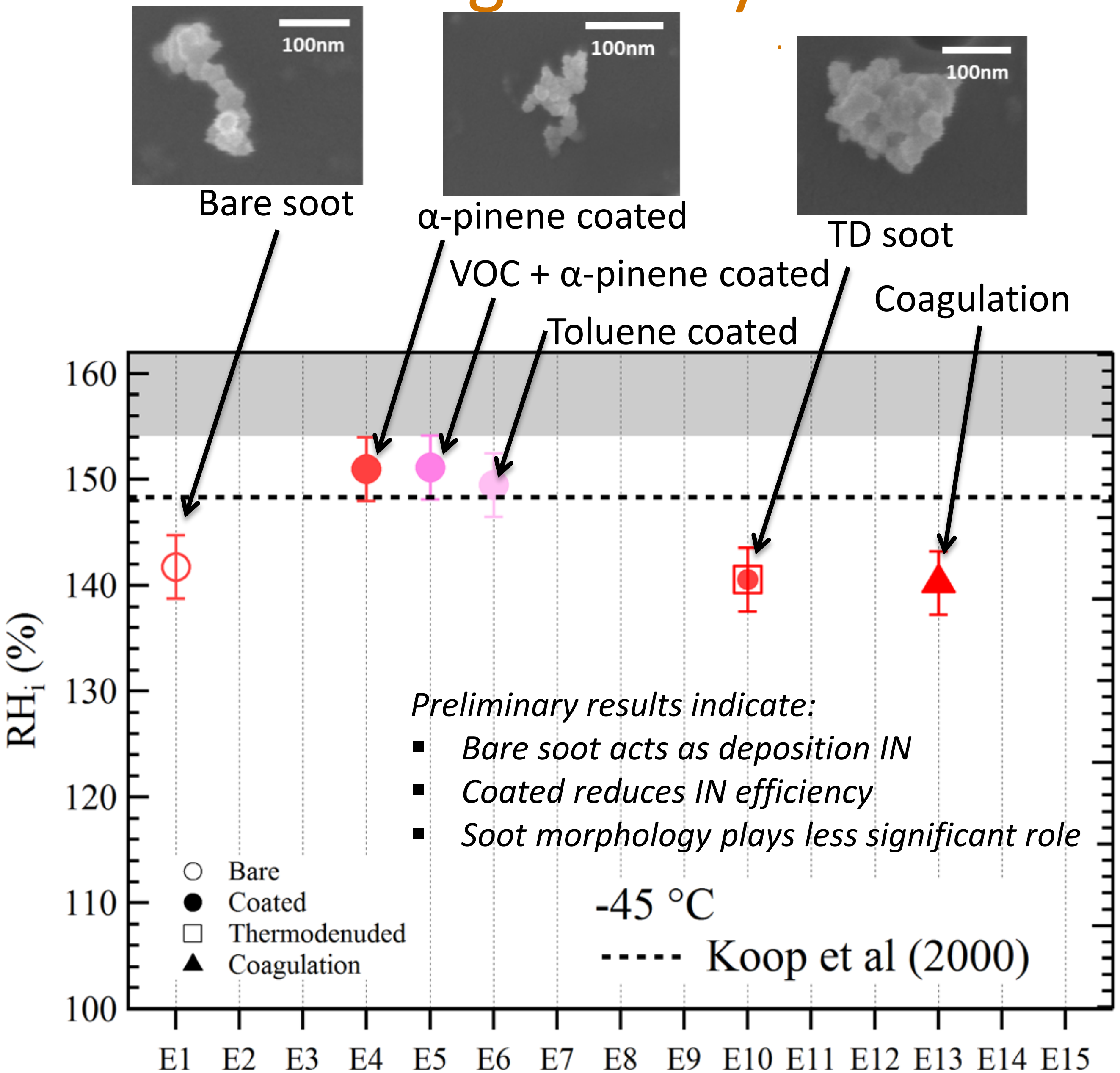
Comparison of all studies to remote continental INP data → weaker marine INP sources

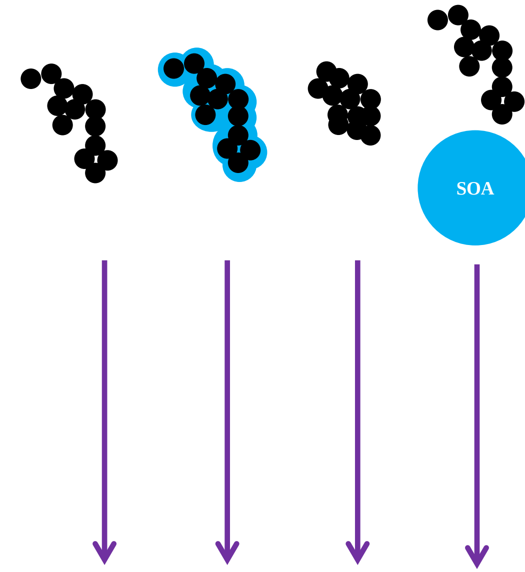


- Ice nuclei measurements from sea spray directly in lab and from near-surface marine aerosols
  - Reasonable consistency with previous measurements over oceans
  - Typically $INP_{Ocean} < INP_{land}$
  - Varied labile fraction of IN > -20˚C, but importance of small organic INP mixed with sea salt particles is suggested
  - Need further compositional data isolating INP units (underway)
- Next steps: More lab studies, MAGIC analyses, numerical modeling collaborations, new oceanic studies (e.g., SOCRATES), first INP mass spectra collected in last 3 weeks at Bodega Bay.

Slide from Paul DeMott (unpublished)

Ice Nucleating activity of diesel soot particles





Ice Nuclei ????

Slide from G. Kulkarni (unpublished)

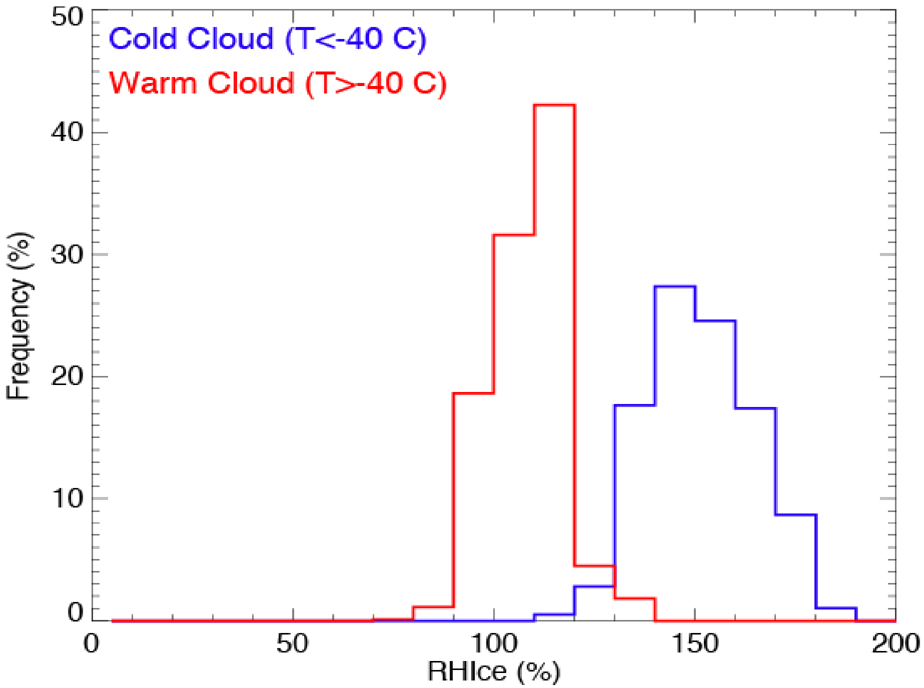
Globally mapping regions of homo- and heterogeneous nucleation as a function of latitude and season: A potential strategy using CALIPSO

Proposed Strategy for Global Mapping of Ice Nucleation Regimes

1. Identify nucleation modes in cirrus sampled during recent field campaigns (e.g. SPARTICUS, MACPEX) using in situ microphysical & RH measurements

2. Calculate the microphysical parameter (β) for cirrus dominated by either homo- or heterogeneous nucleation based on measured PSD

3. Identify flight segments corresponding to A-train overpasses and compare in-situ measurements of β with retrieved β corresponding to thin cirrus (ε < 0.5)

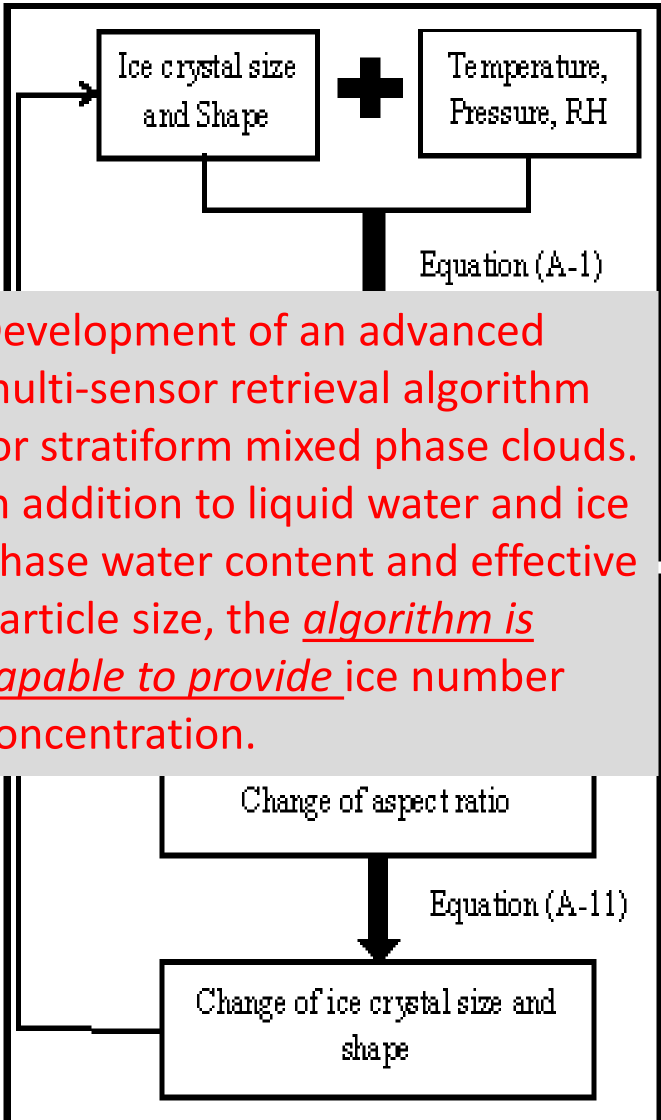


4. If corresponding retrieved & in situ measurements of β compare reasonably well, use the above information to develop an algorithm for estimating the ice nucleation regime (homogeneous, heterogeneous or mixed)

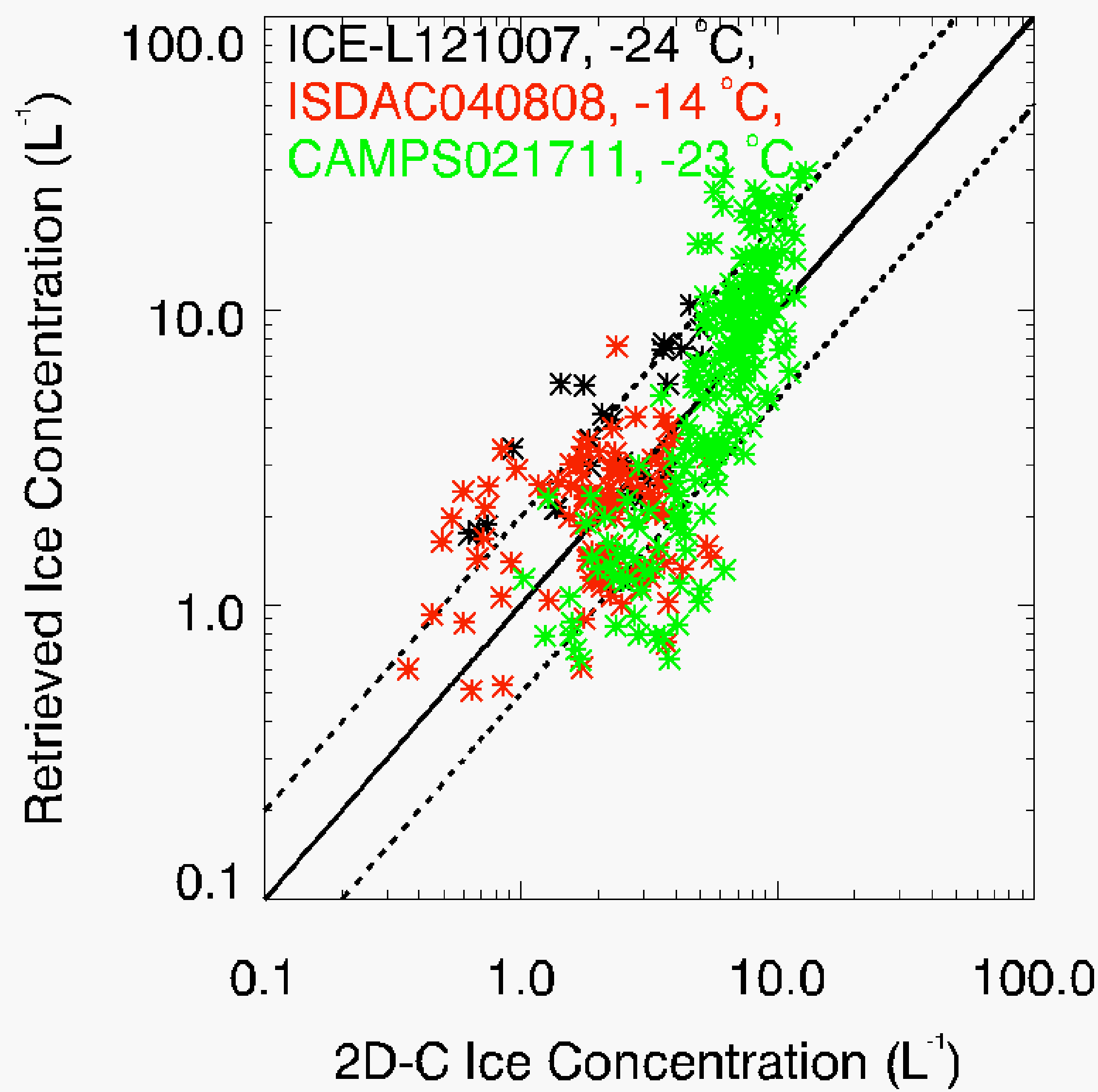
5. Apply algorithm to archived β data to evaluate the dependence of homo- and heterogeneous nucleation on latitude and season.

Slide from David Mitchell (unpublished)

Evaluations of the 1-D Ice Growth Model Simulations and the Retrieved N_i



Development of an advanced multi-sensor retrieval algorithm for stratiform mixed phase clouds. In addition to liquid water and ice phase water content and effective particle size, the *algorithm is capable to provide* ice number concentration.



Slide from Damao Zhang (submitted)

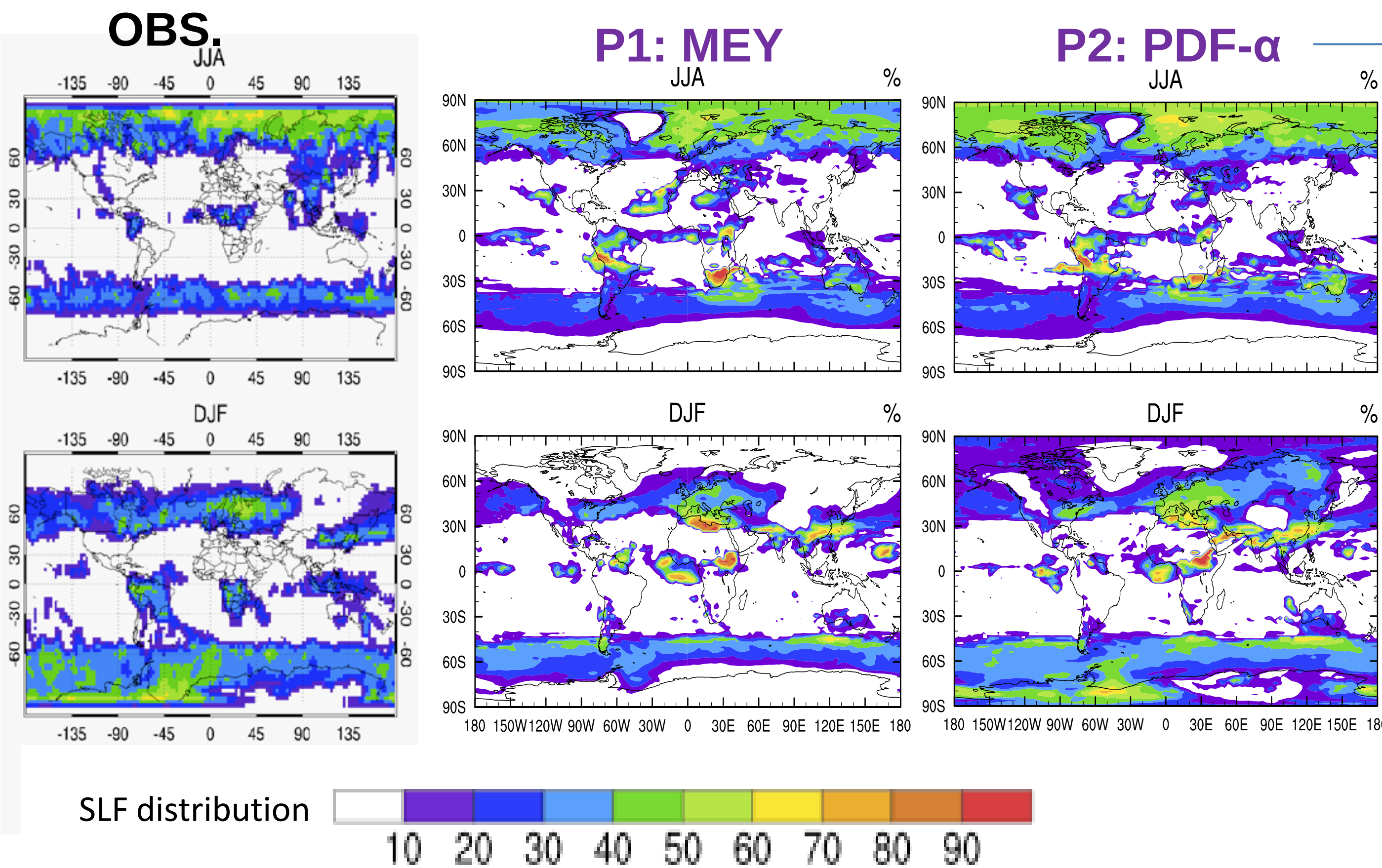
Impact of Ice Nucleation on Phase Partitioning in Mixed-Phase Clouds

$$SLF = \frac{LWP}{LWP + IWP}$$

LWP: MODIS (MOD06) cloud product (King et al. 2003). Only for water and mixed-phase clouds.

IWP: Integration of IWC from CPR radar detected cloud base to top. Only for MP and ice clouds.

Global Supercooled Liquid Fraction (SLF) distributions



Getting better

JJA

DJF

Slide from X. Liu (unpublished)

Discussion Highlights/Science questions derived from this and previous ice nucleation breakout sessions.

Top priority:

- Long-term IN measurements at NSA (ARM super-site).
- Identify the IN measurement technique that can be automatic.
- IOP for IN closure

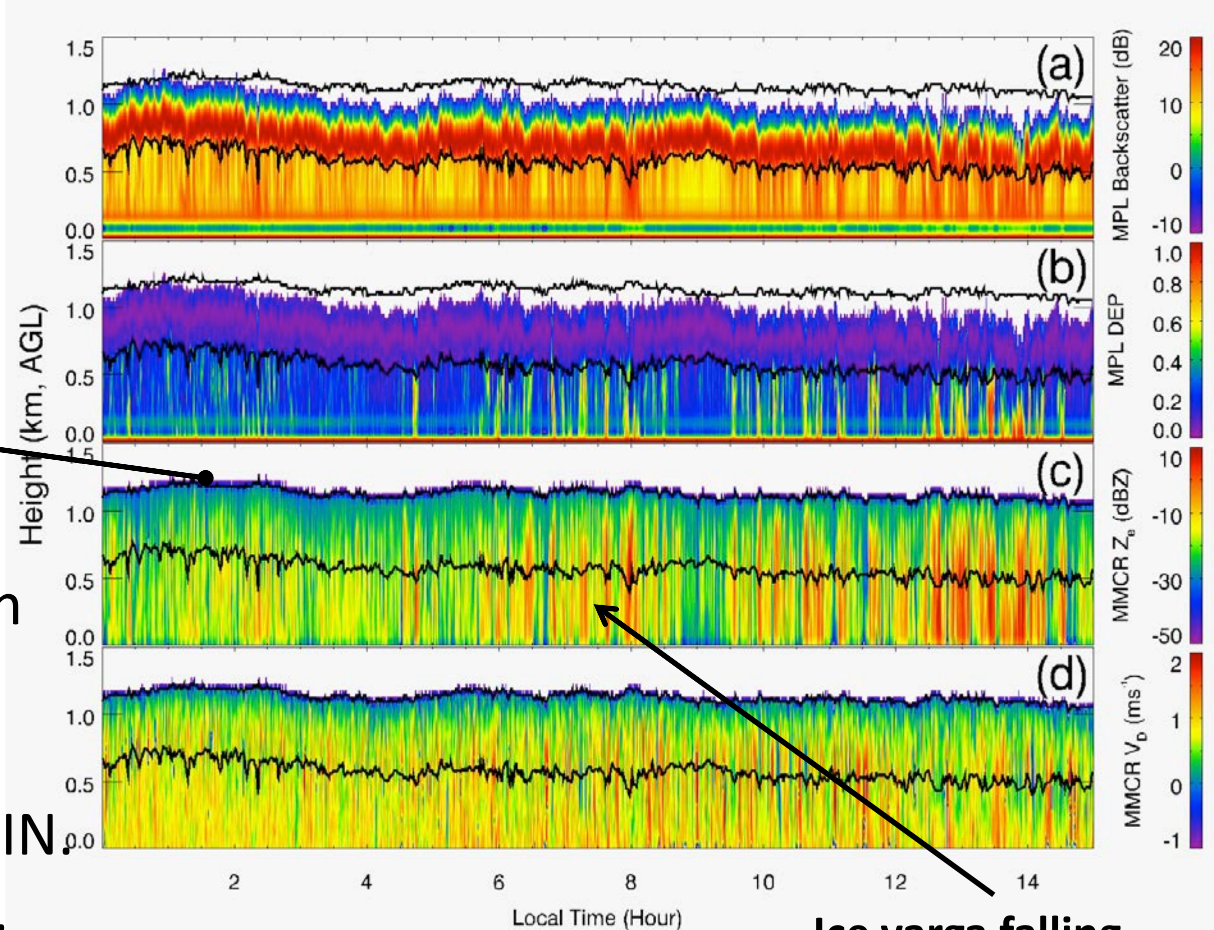
Why these are top priority questions? See next slide.

Key issues are also identified…see next

Stratiform Mixed-phase Clouds (SMCs)

- Long-lived, high occurrence over the Arctic Region.
- Liquid dominated layer at the top, & ice below.

Supercooled liquid layer



Ice varga falling

<u>Questions are</u>:

- How they persist for such long period of time (hrs. to days).
- What are the sources of IN.
- Role of turbulent mixing.
- Ice nucleation is stochastic or deterministic or both?

Figure courtesy of D. Zhang

Strategy:

Field/Lab studies:

-Deploy IN measurement techniques at NSA

-Collect IN, aerosol and other meteorological field properties

-Develop/constrain IN parameterizations from this data set

In situ measurements:

-Detailed aerosol and cloud properties

This component is missing

Remote sensing:

-Identify a cloud case

-Retrieve corresponding cloud properties, confidence in interpreting the research results

Some of ASR scientists are working on this

However, without incorporating fundamental microphysical processes, these studies are incomplete

Cloud modeling:

-Sensitivity studies to various microphysical structures

-Provide feedback for further development of robust parameterizations

-Improved scientific understanding can be passed to other models (regional, global)

Key Issues identified

- Ice Nuclei (IN) budget in the atmosphere. What are the sources of IN in the atmosphere? This is needed to constrain the models and, also, the remote sensing retrievals.

- IN measurements are missing at DOE-ARM super-sites. These are CRITICALLY needed to advance the Ice Cloud research forward.

- Classify the IN concentration as a function of aerosol size, chemical mixing state, composition to better understand the ice nucleation processes.

- IN instrument comparison workshop to better understand the performance of IN instruments. European IN group is interested to collaborate with ASR IN group.

- Competition between heterogeneous and homogenous freezing in cirrus clouds.

Key Issues cont.

- Relative importance of Ice microphysical processes (ice nucleation, Bergeron-Findeison process, secondary ice formation etc.).

- Role of contact freezing in ice formation. Importance of this ice nucleation mechanism is unclear.

- Role of different aerosol size and chemistry (black carbon, biological, coated dust, organics) towards inducing ice. *Pre-activation/memory effect on ice nucleation.*

- Continuous collection of aerosol particles on filter/substrate at ARM sites, and analyzing these filter samples for ice nucleation and particle characterization. What are the pros and cons of this method?

- Rain/snow water collection and analyzing the residues.

Action Plan

Short Term Goals (0 to 2 years)

- ✓ Deploy IN instrument at Barrow ARM ground site, and start collecting IN data.
- ✓ Investigate filter/substrate based technique for IN measurement.
- ✓ Participate in the international IN instrument comparison workshop.
- ✓ Use IN measurements to explore remote sensing retrievals and to constrain the models.

Long Term Goals (2 to 5 years)

- ✓ IOP at Barrow for IN closure studies including in situ studies.
- ✓ Deploy IN instrument at ARM super-site (SGP, NSA).
- ✓ Participate in the proposed multi-agency Southern ocean field experiment (SOCRATES) to understand the importance of biological particles towards ice formation.