Atmospheric ice nuclei concentrations and characteristics constraining the role of biological ice nuclei

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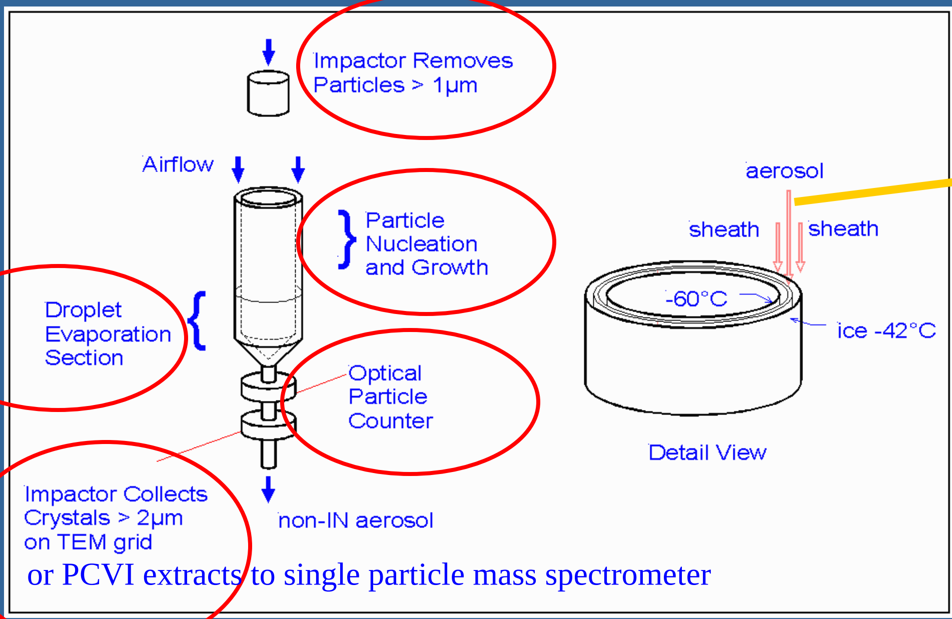
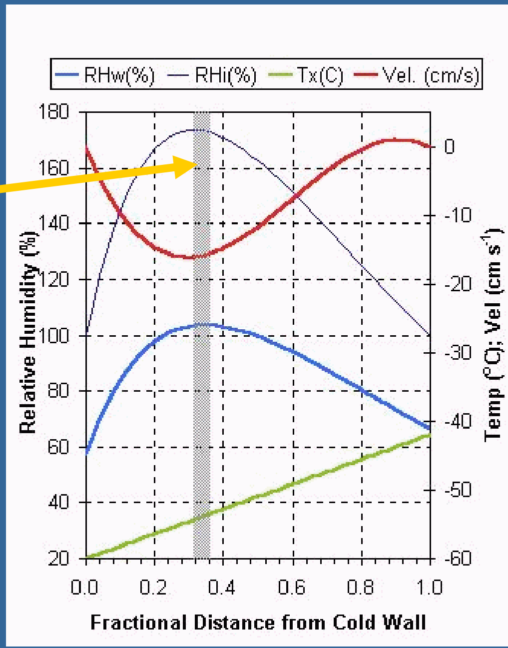
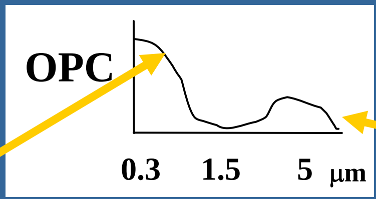
Overview of Today's Talk

- How we measure ice nuclei and infer sources and characteristics in the atmosphere
- The characteristics of ice nuclei based on measurements over the last decade or so
  - Concentrations
  - Sizes
  - Compositions
- Some present limitations on assessing the likelihood that bio-aerosols play a role as ice nuclei (sizes measured, appearance, where/when sampled)

Measuring ice nuclei: Continuous flow diffusion chamber (CFDC)







aerosol

Activated IN

What ice nucleation mechanisms do we measure?

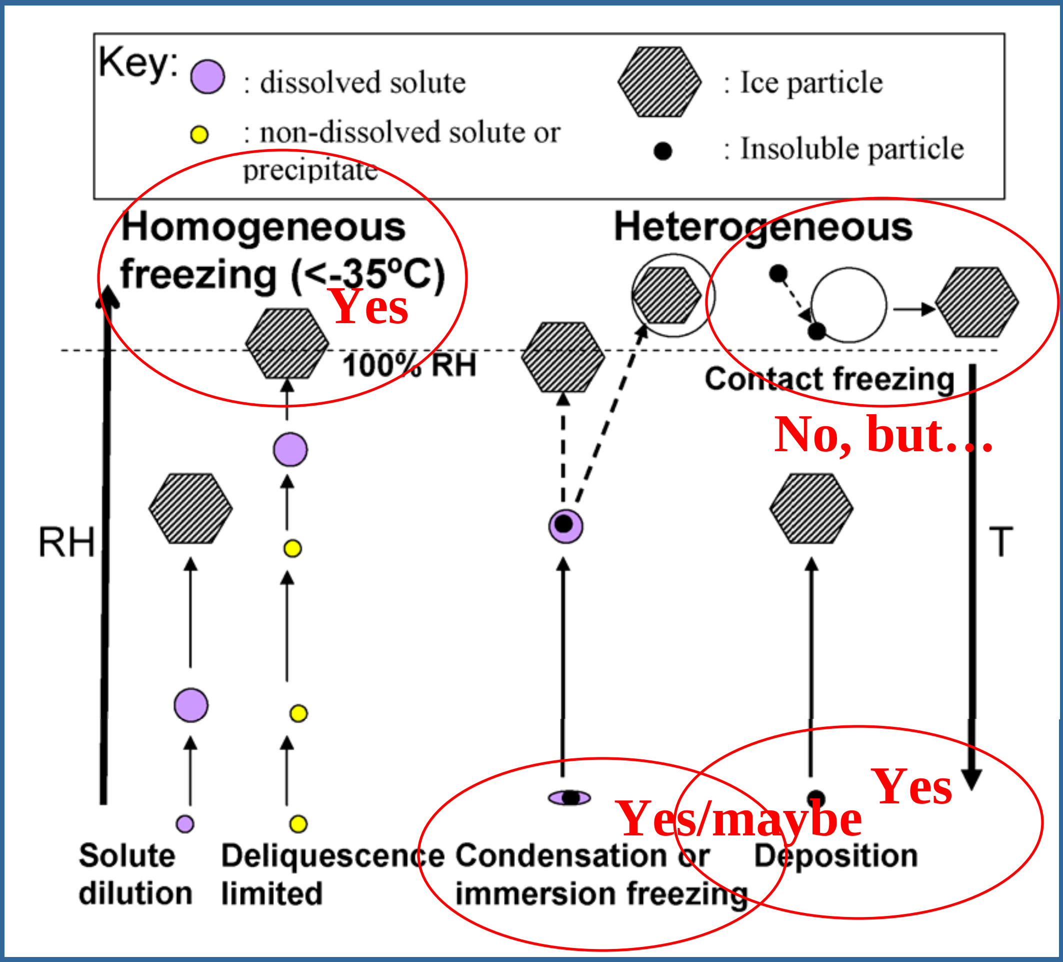
Aerosols nucleate ice by varied mechanisms, most depending on T, some on RH as well

No instrument yet capable of measuring all mechanisms

What can a CFDC measure?

Is immersion freezing a singular process on the time scale of measurement?

Contact freezing nuclei should be defined by the total numbers of immersion freezing nuclei active at somewhat lower temperature?



Sampling in various locations in various seasons from the surface and from aircraft

raft aerosol sample inlet

CVI inlet (aerosol from evaporated cloud particles)

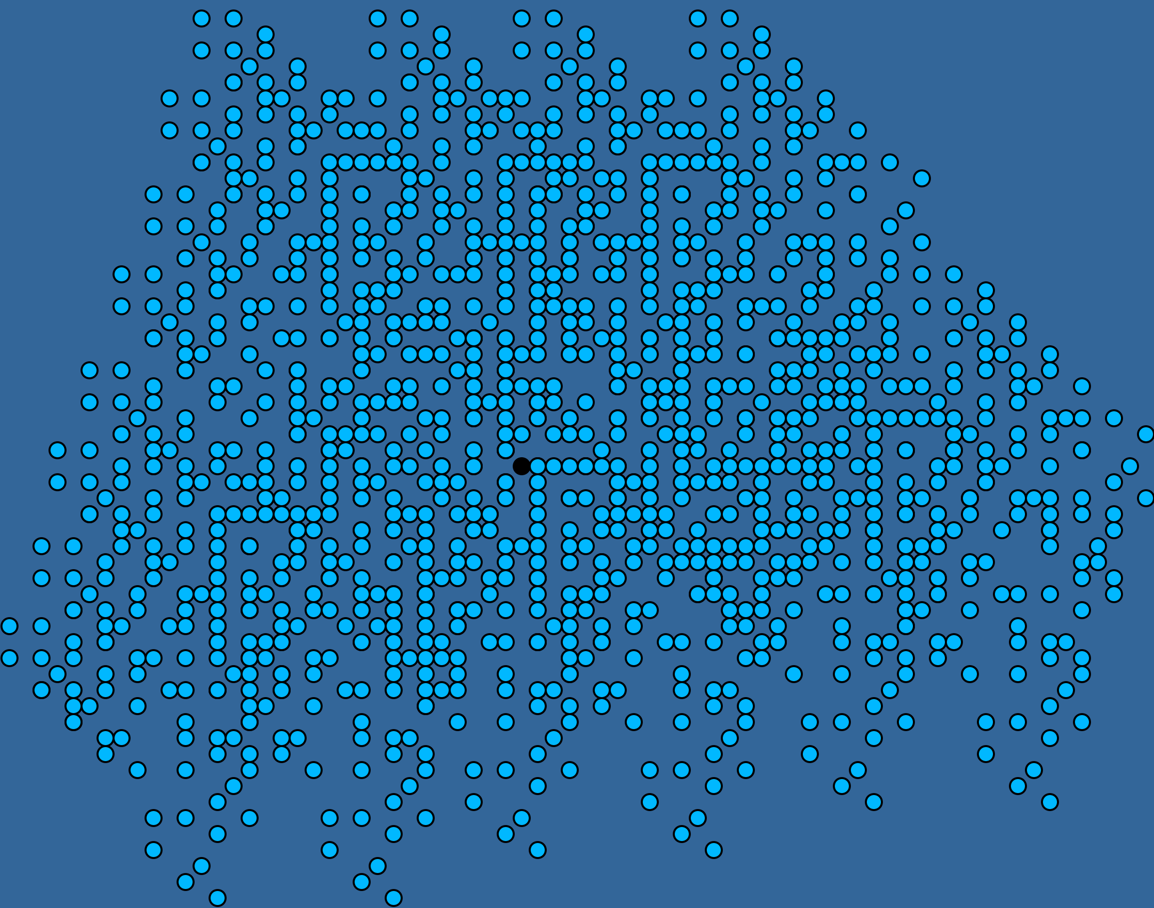
Compact instrument certified for sampling on any aircraft platform

Sampling at surface sites

Perugia, Italy

Author: Paul DeMott

What are the concentrations of ice nuclei in the atmosphere?



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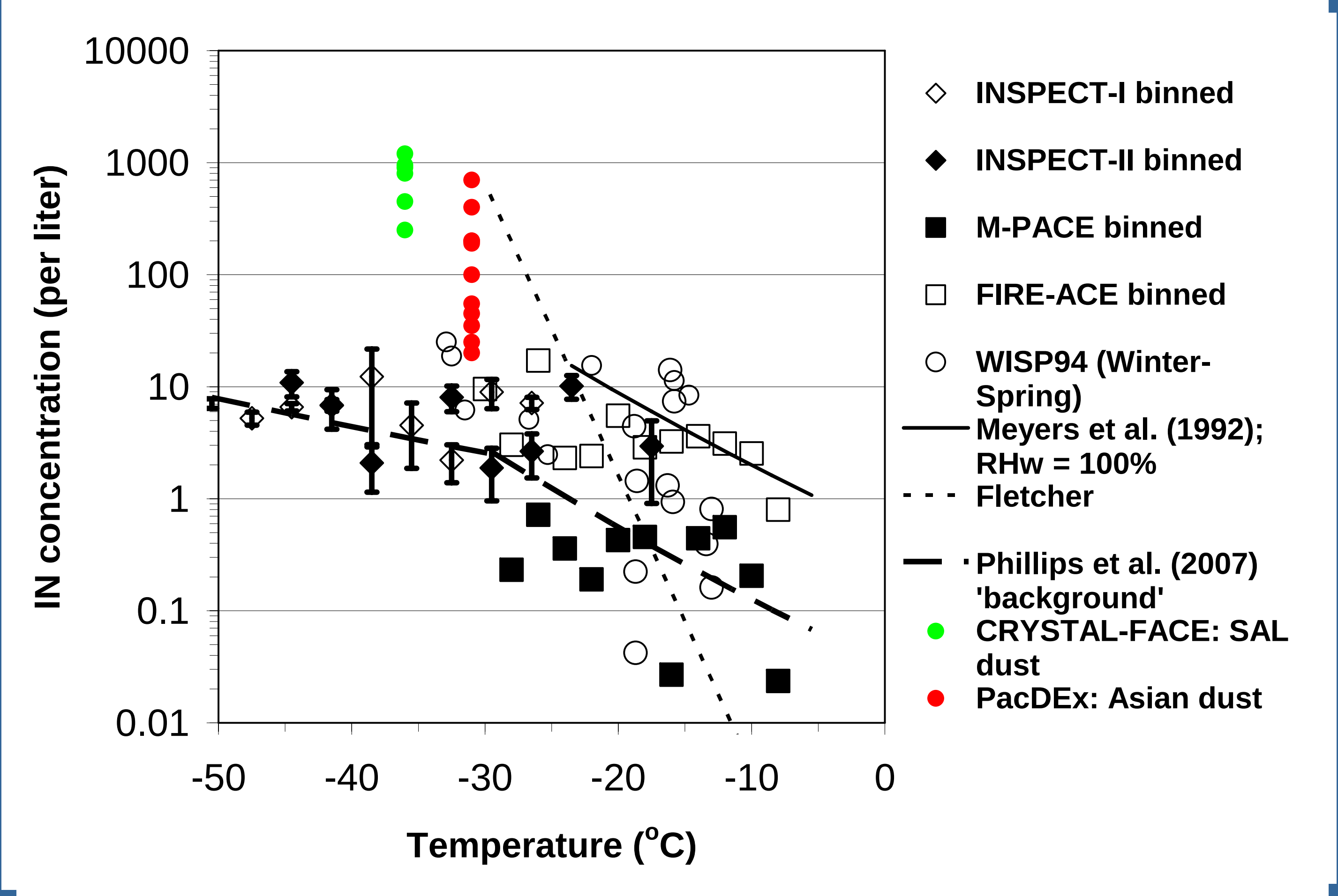
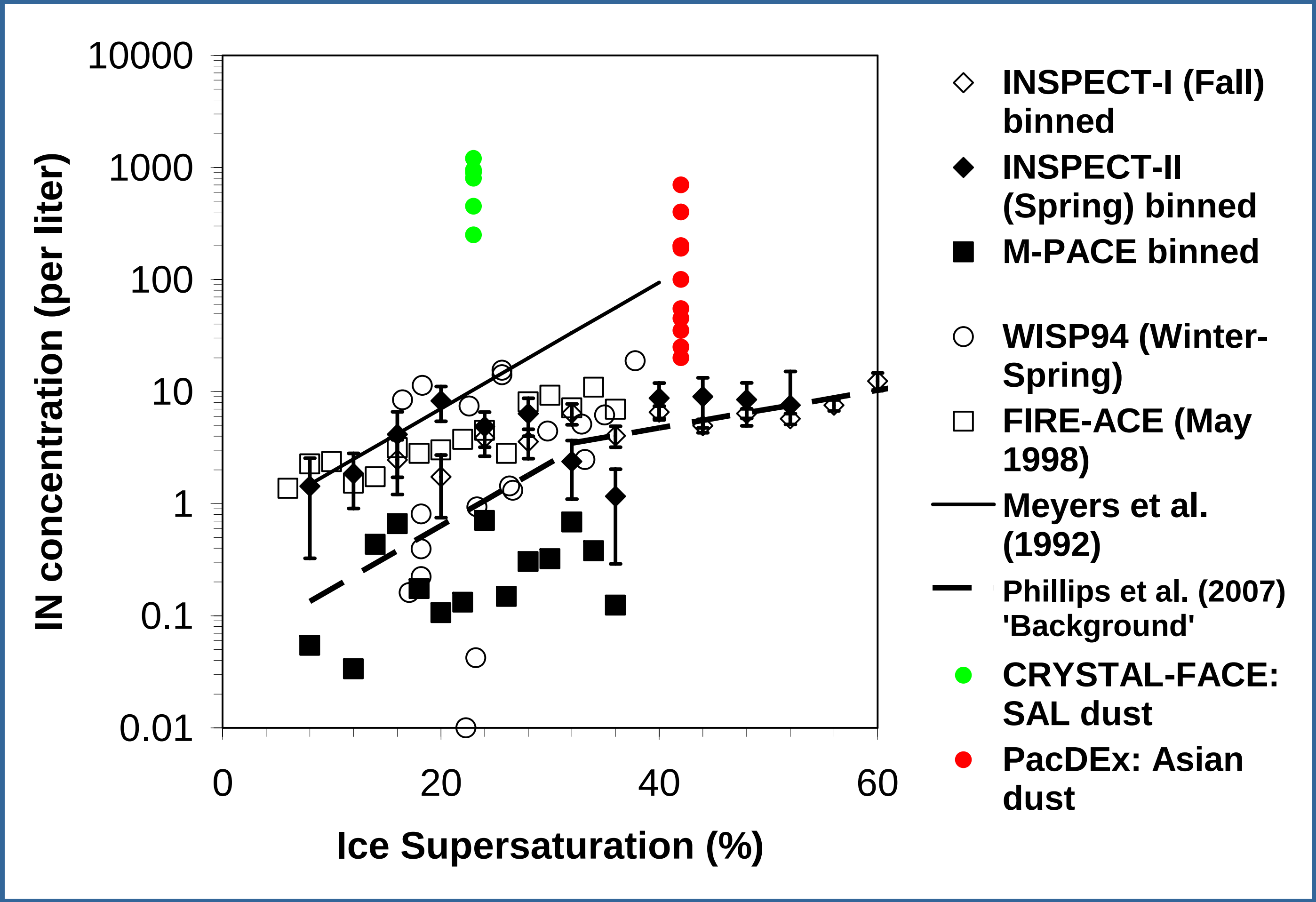
Perugia, Italy

Author: Paul DeMott

IN concentration dependence on temperature



IN concentration dependence on supersaturation with respect to ice

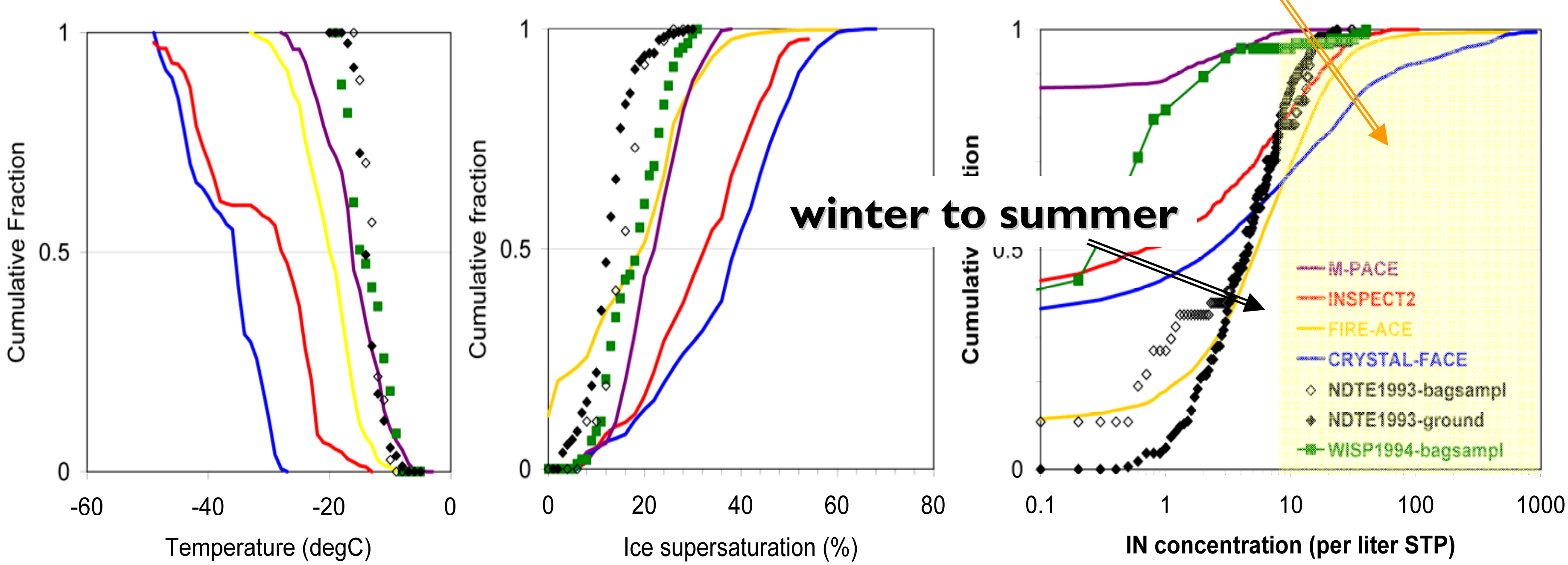


Cumulative distribution of [IN] and sampling conditions in many projects

MPACE: Arctic Fall
FIRE-ACE: Arctic Spring

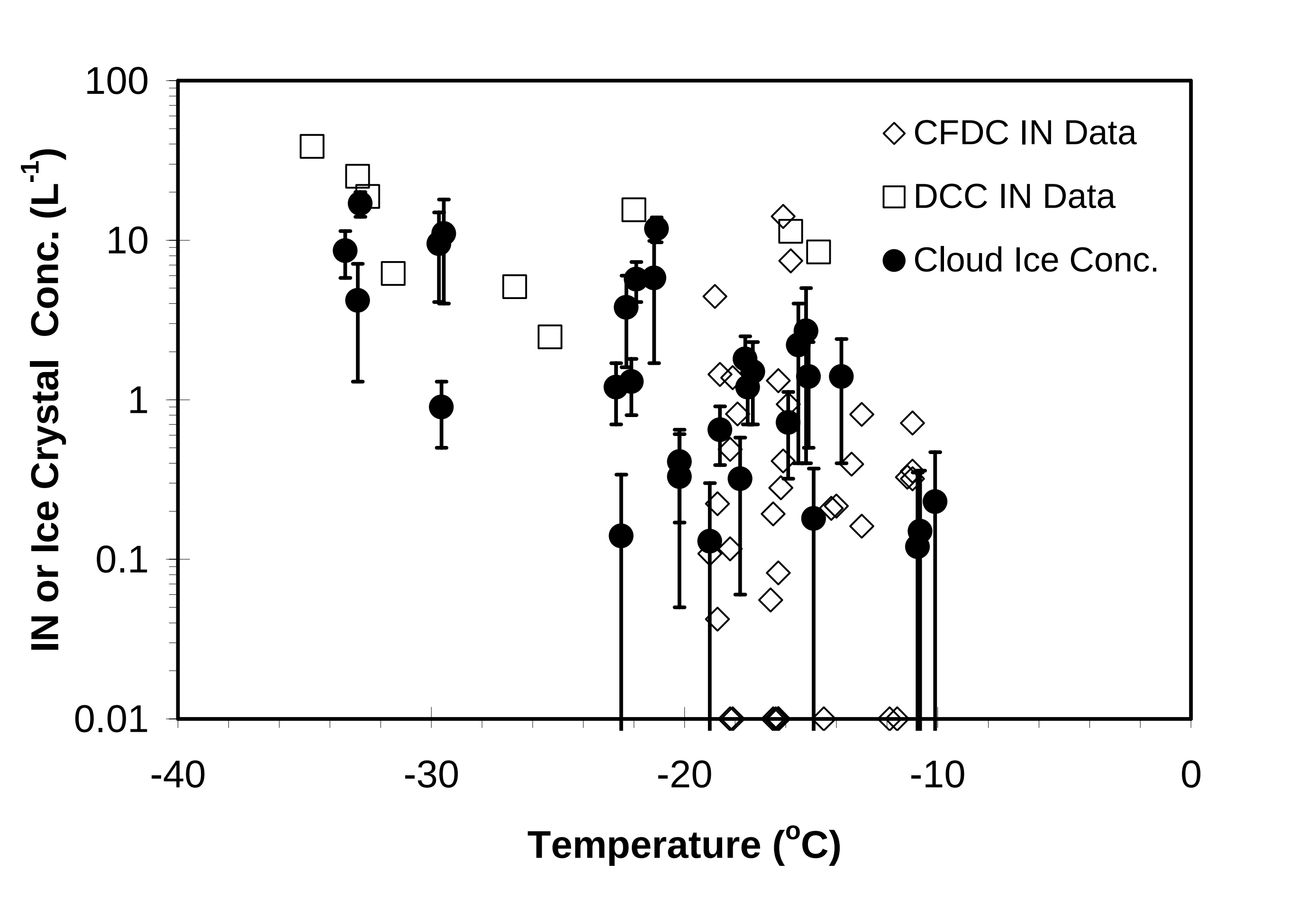
INSPECT-2: Western U.S. Spring
CRYSTAL-FACE: Florida July

Increasing dust particle impacts

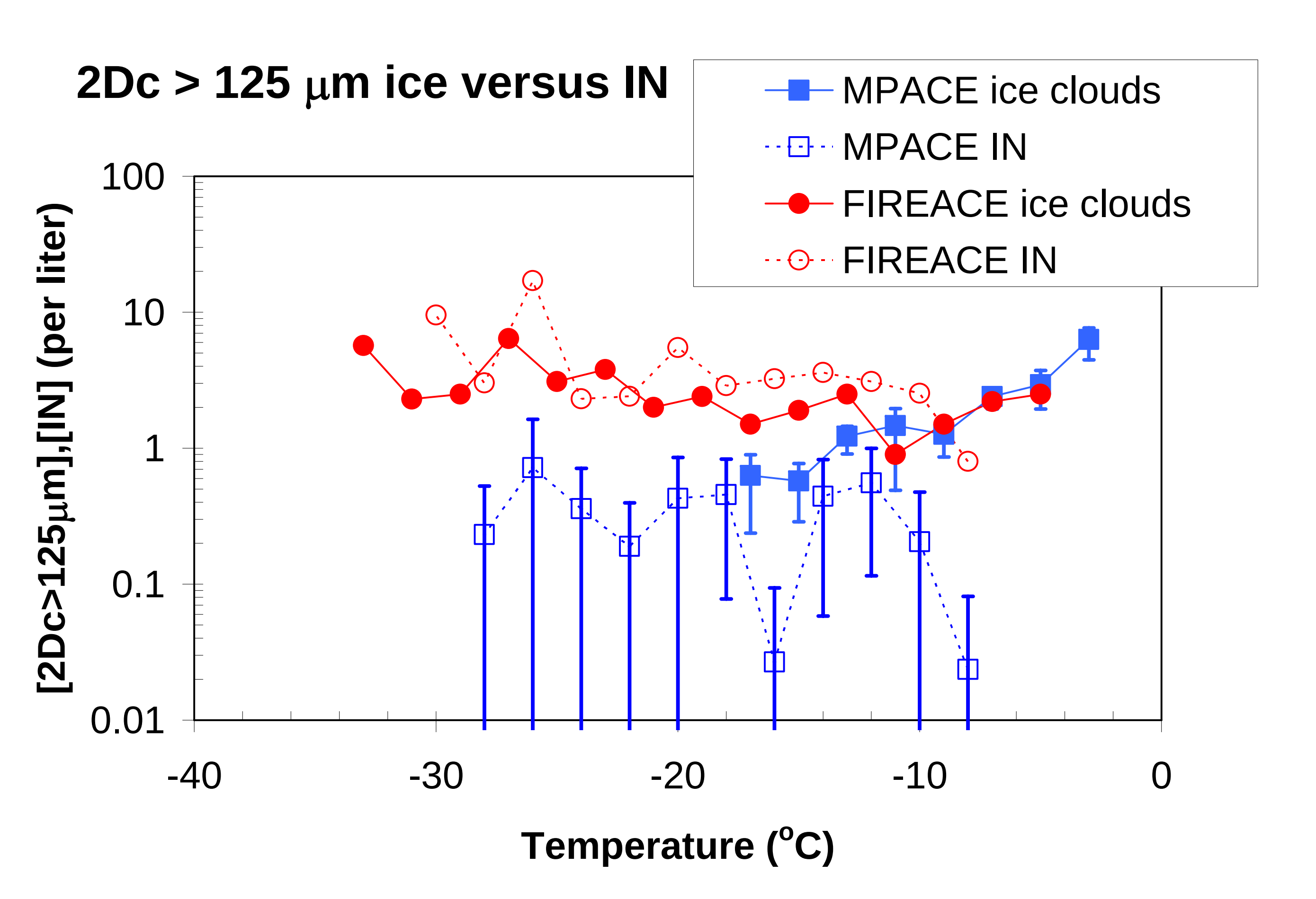


Do ice nuclei relate to ice in clouds?

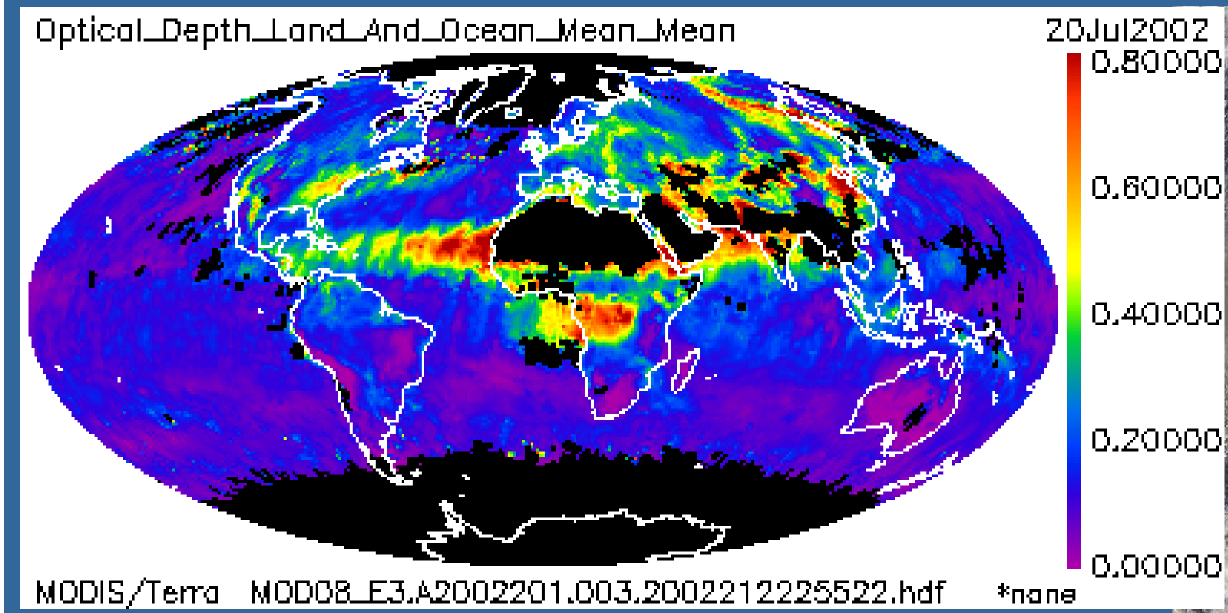
Winter Icing in Storms Project (1994) wave cloud [ice (>50 μm)] versus [IN]

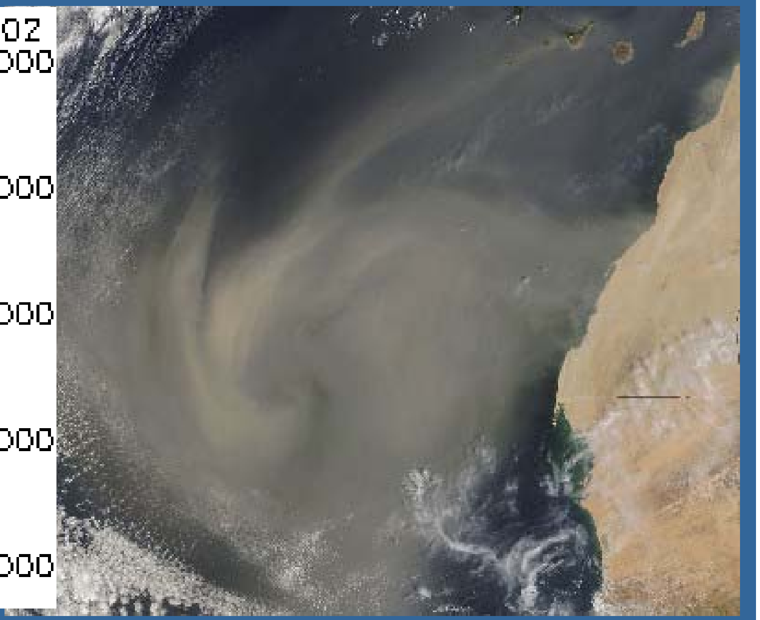


IN data versus ice in clouds for Arctic stratus (spring versus fall seasons)



Where do IN come from? What are their physical and chemical characteristics?





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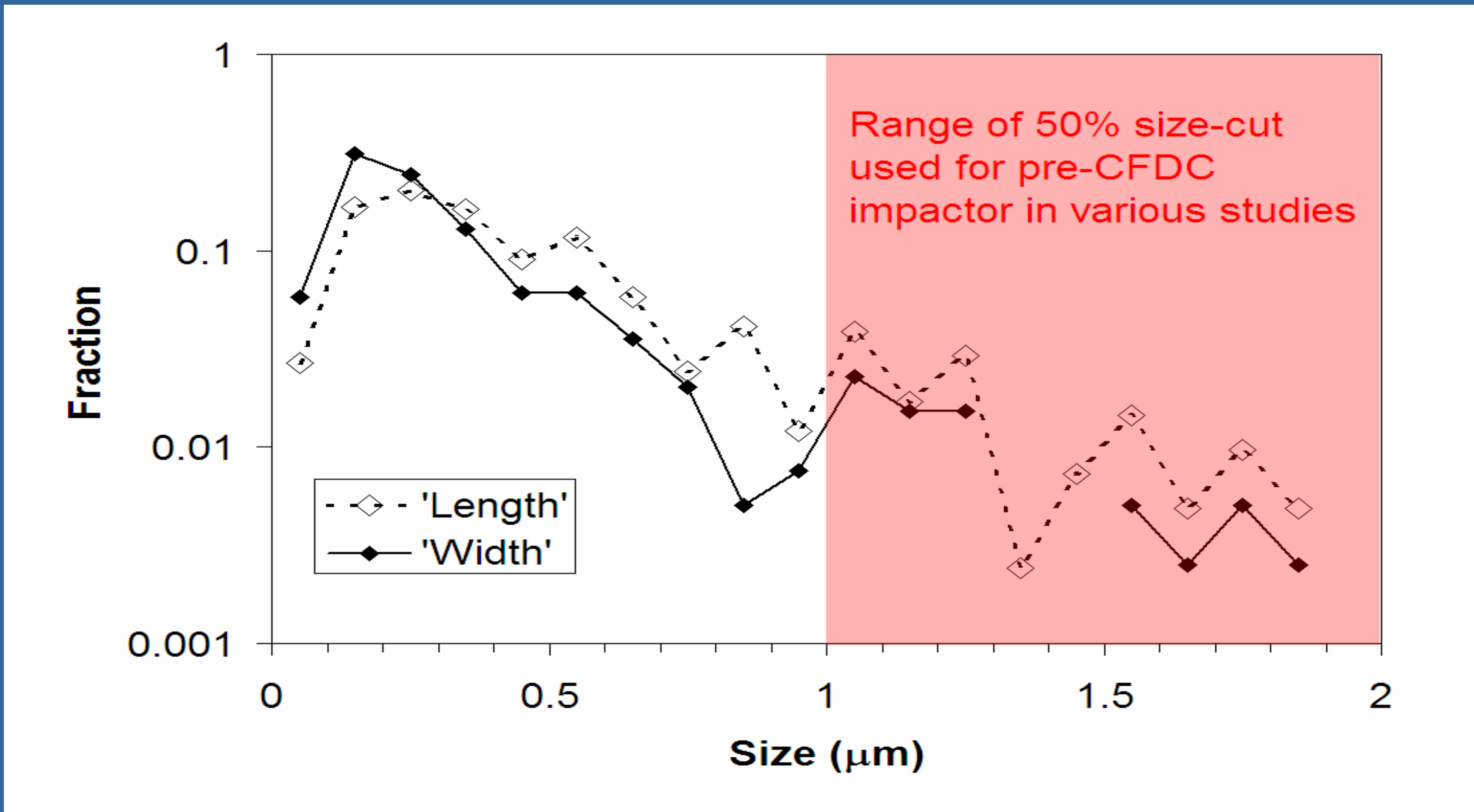
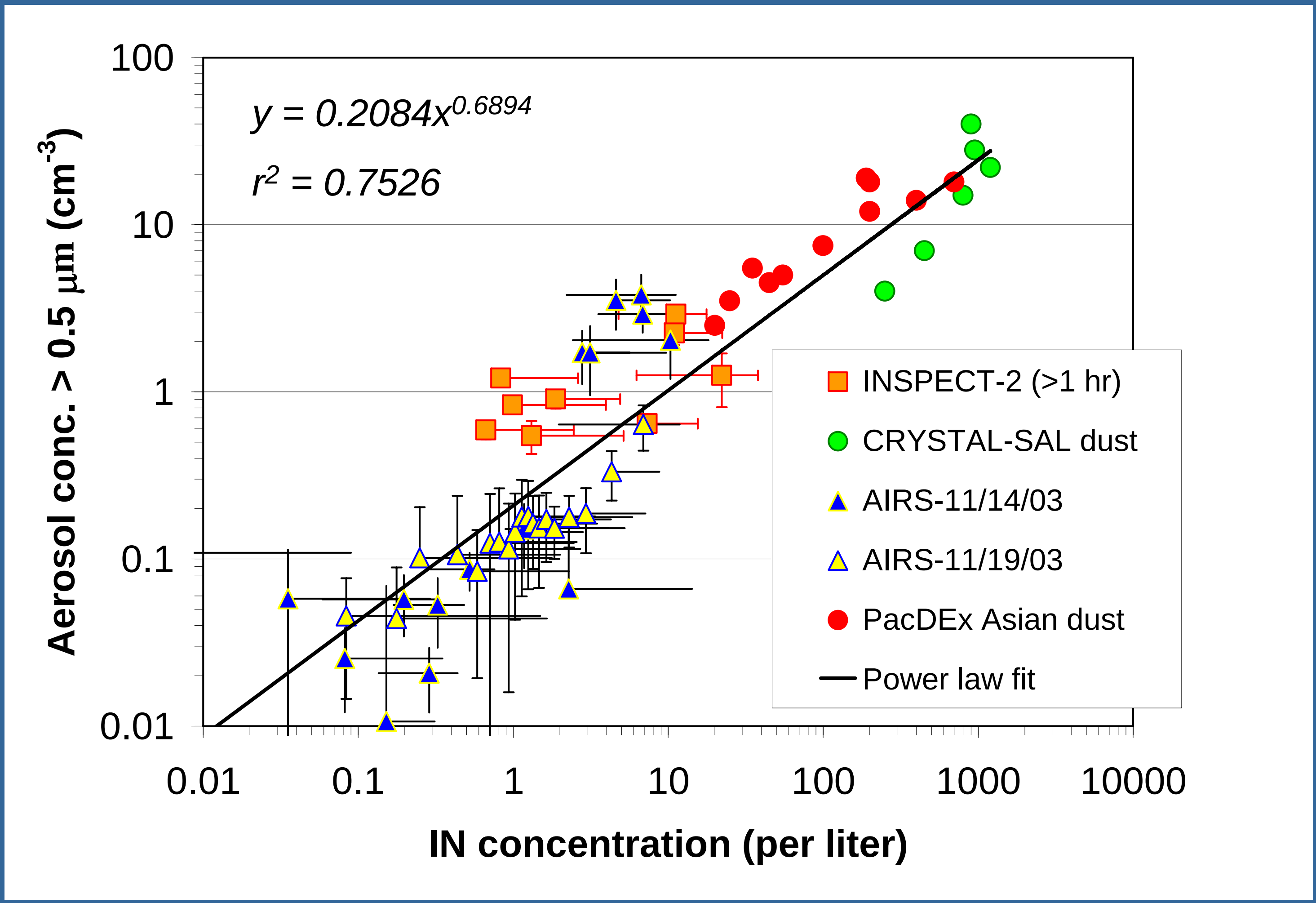
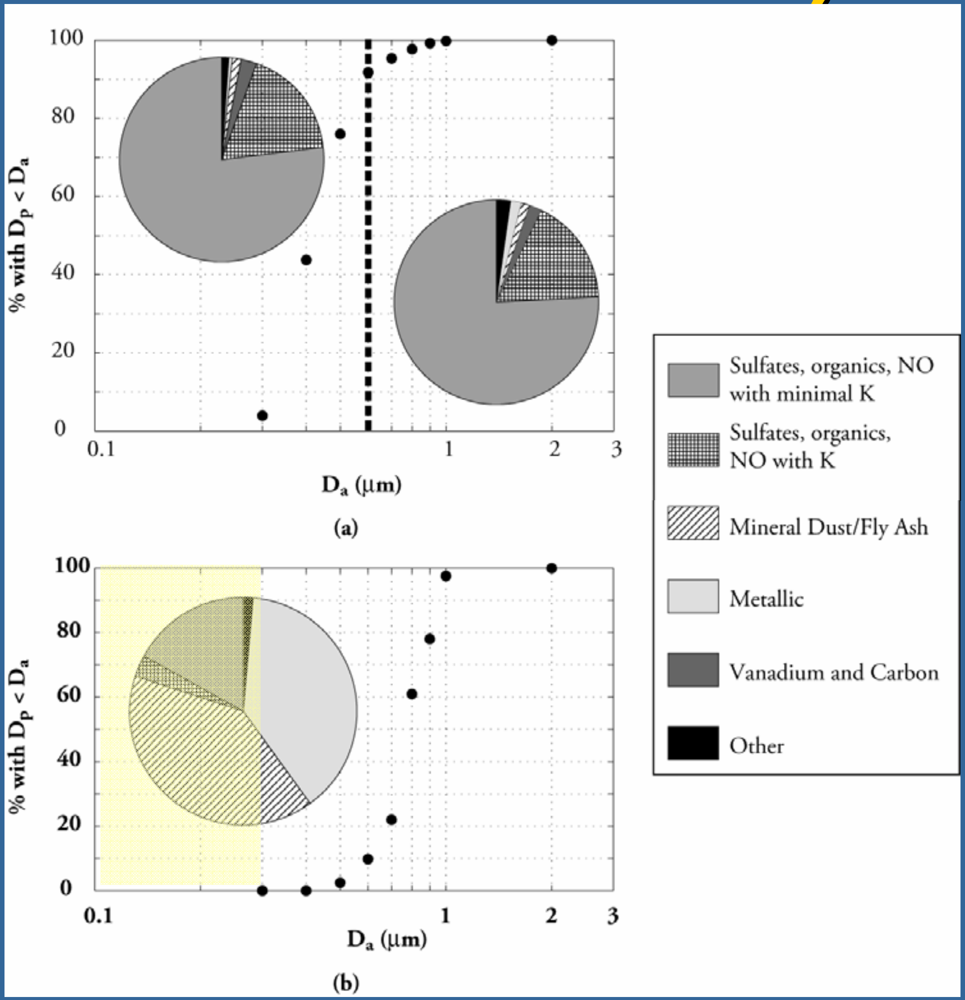
Ice nuclei physical size from TEM analyses in several programs



Relation of IN to larger aerosol using a variety of data sets



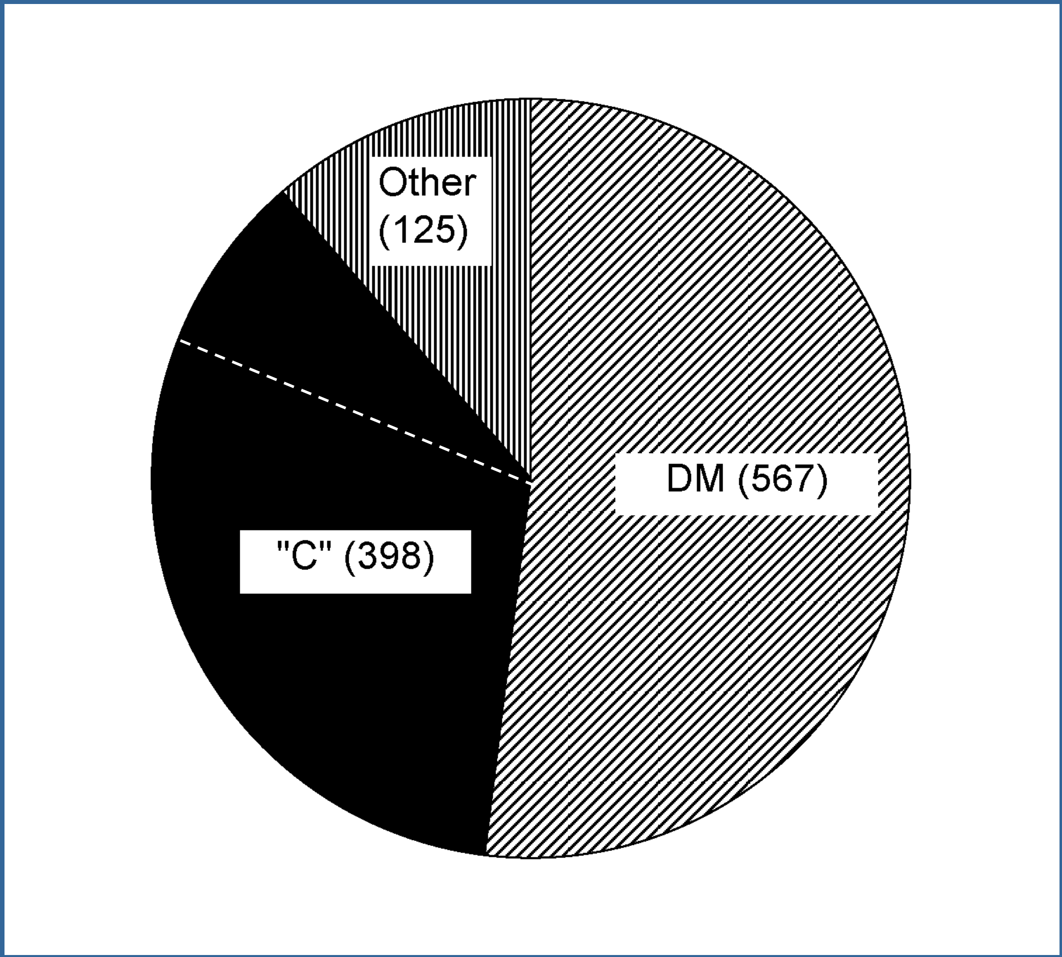
Mineral dust and metallic particles dominate IN compositions (Cziczo et al. 2003; Richardson et al. 2007)



Results from PALMS (Particle Ablation Laser Mass Spectrometry) analysis of ambient aerosol particles

PALMS analyses of IN (residues of ice crystals) activated in the CFDC and aerodynamically extracted from flow.

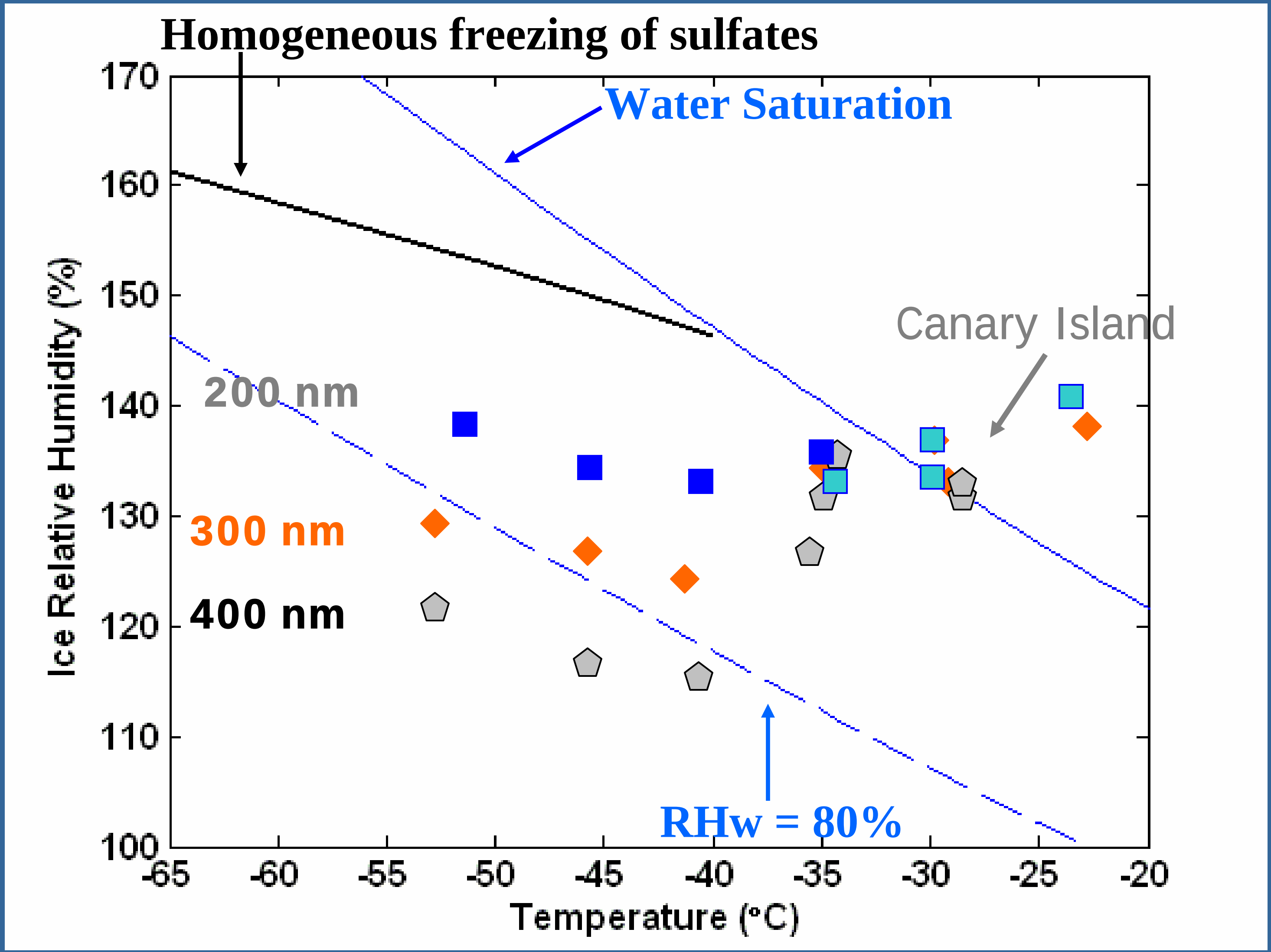
IN composition (TEM/EDS) in several studies (arctic, subtropics, midlatitudes represented)



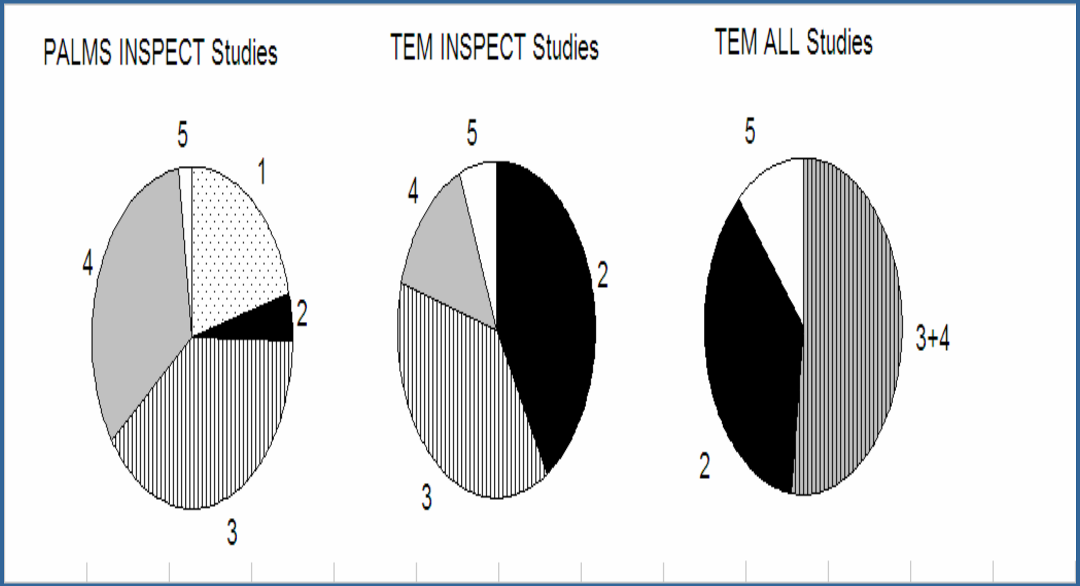
C: Carbonaceous as inferred by absence of elemental signature

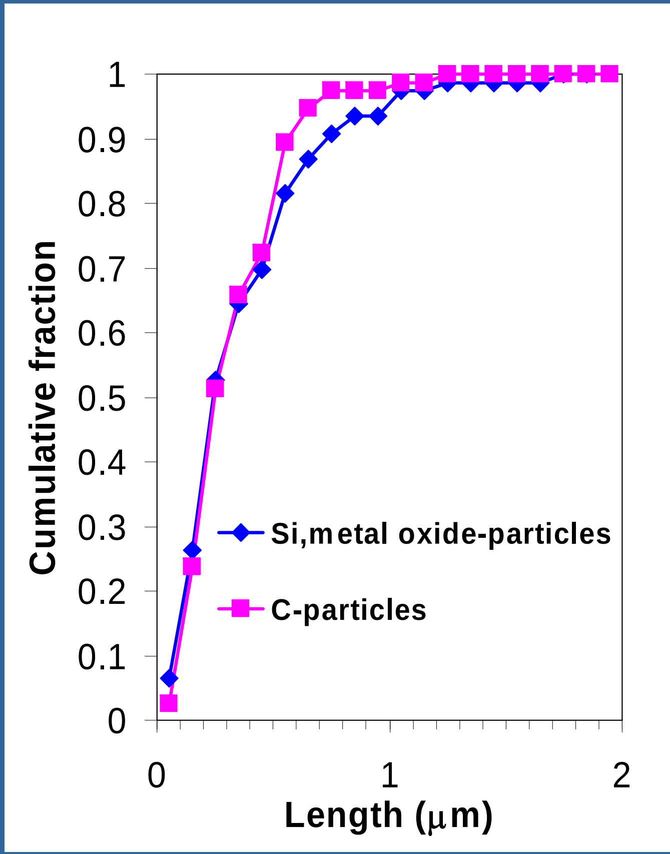
DM: dust and metallic (some oxides and some not)

Many laboratory studies support the role of mineral dusts as IN, but our data suggests larger dusts particles needed to account for ice formation at very warmest temperatures



Role of carbonaceous particles as IN (TEM vs PALMS apparent discrepancy)





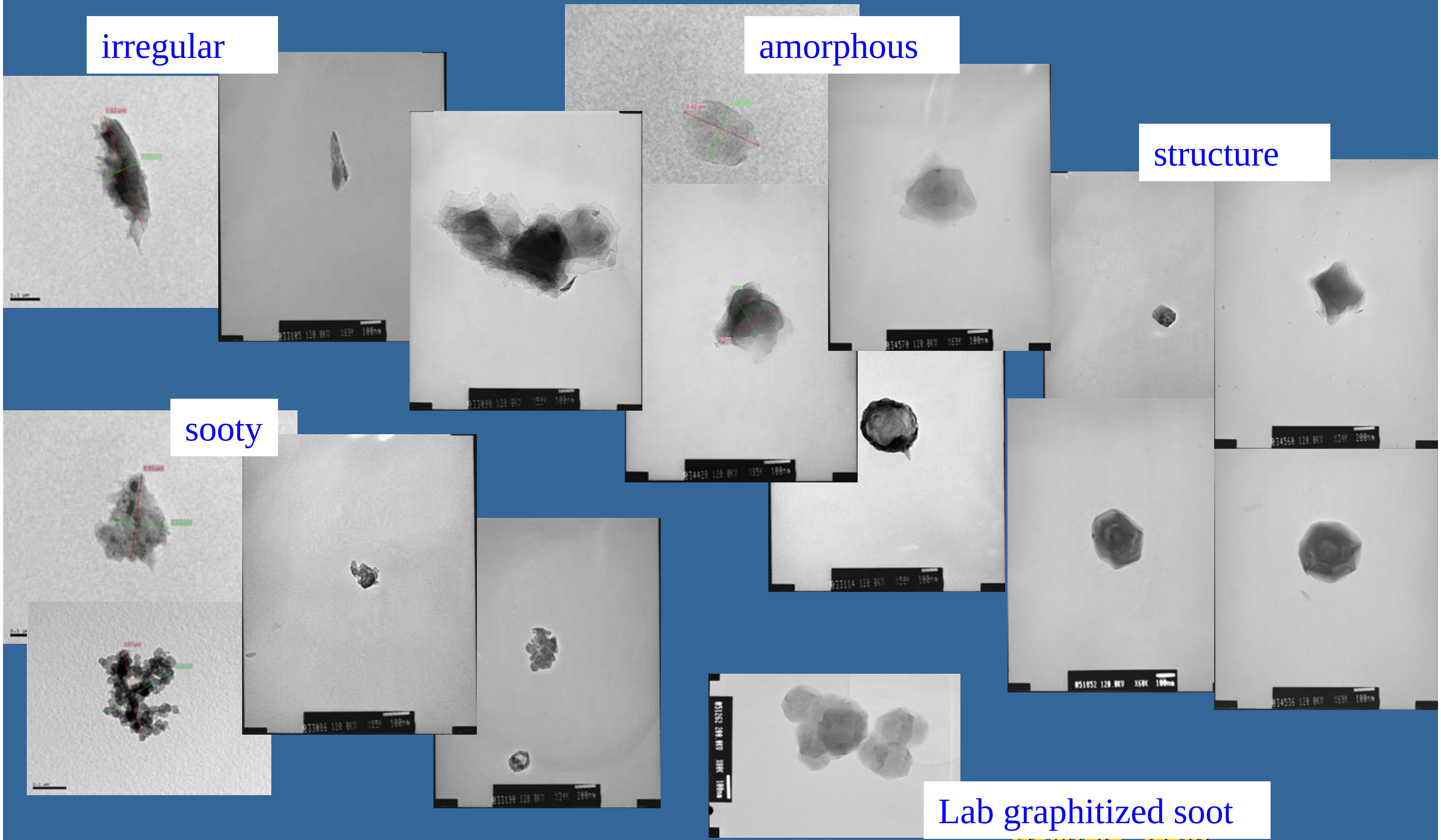
1 = sulfates+organics 5 = “other”

2 = carbonaceous

3 = minerals

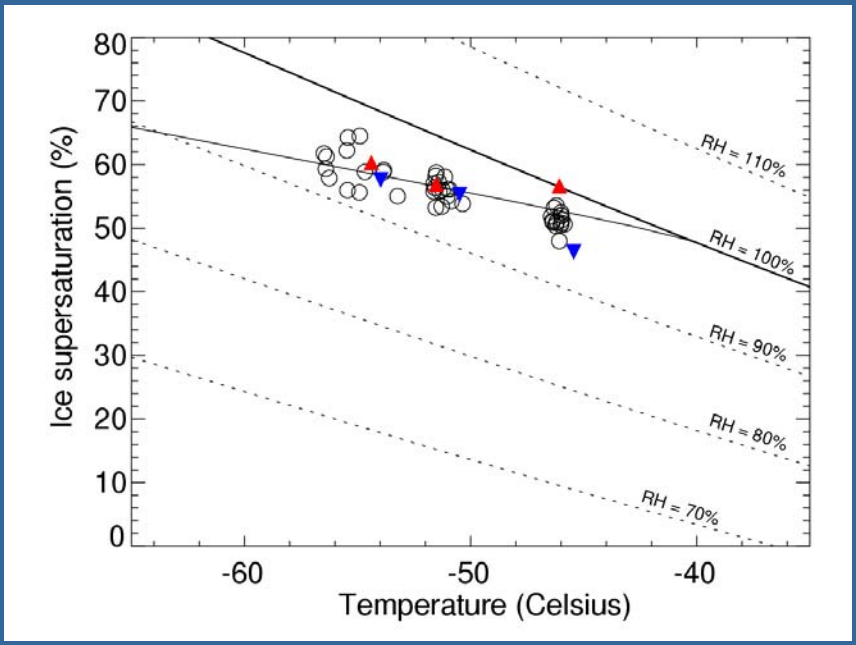
4 = metal (oxides)

What are these carbonaceous IN?

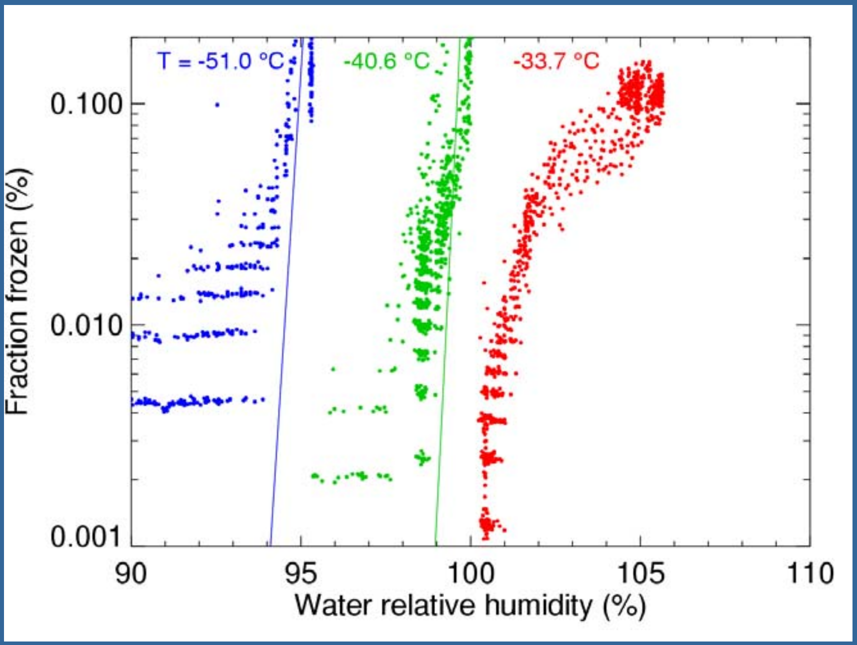


Biomass burning smoke particles tested in laboratory only rarely a source of measurable IN

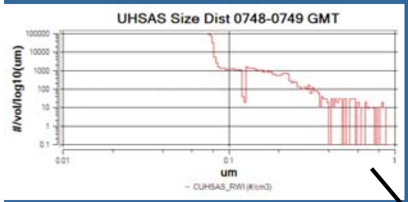
Most smokes froze at low temperature at the conditions identified for homogenoeus freezing of soluble haze particles

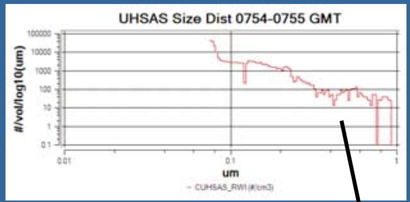


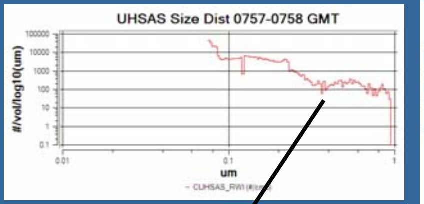
Utah sage/rabittbrush mix indicates apparent modest numbers of freezing nuclei (only one of more than 40 tested)

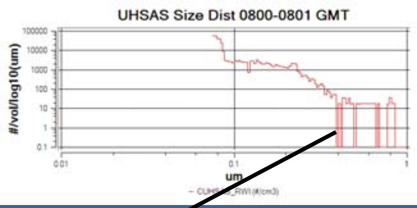


PACDEX vertical profile over Central Pacific Ocean (May 23, 2007)

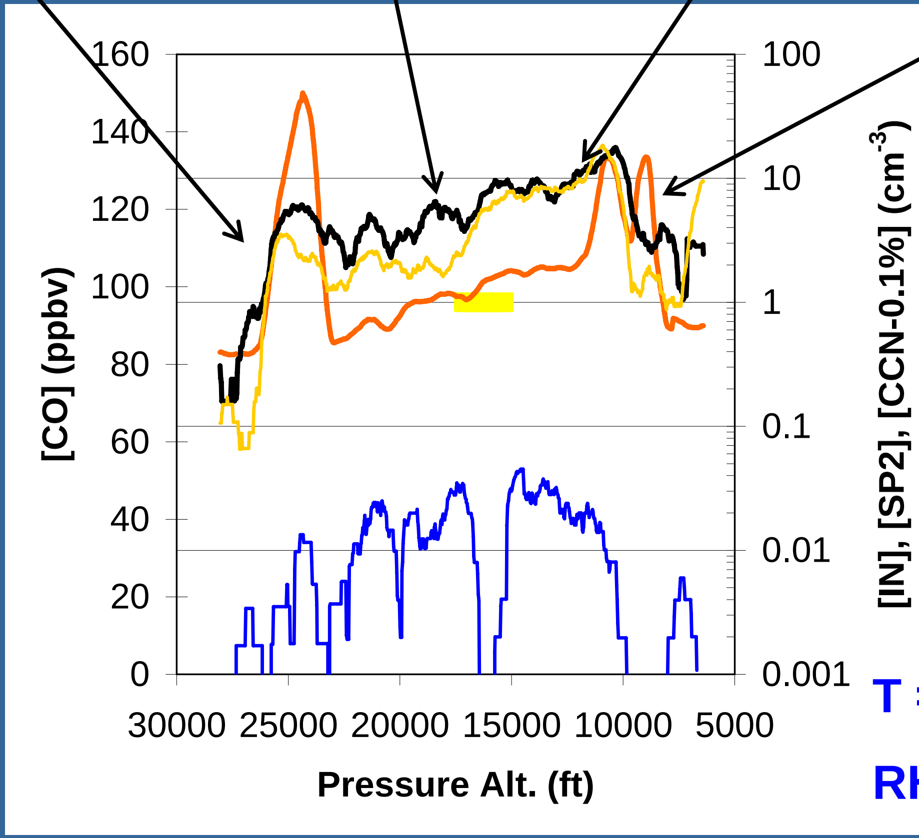


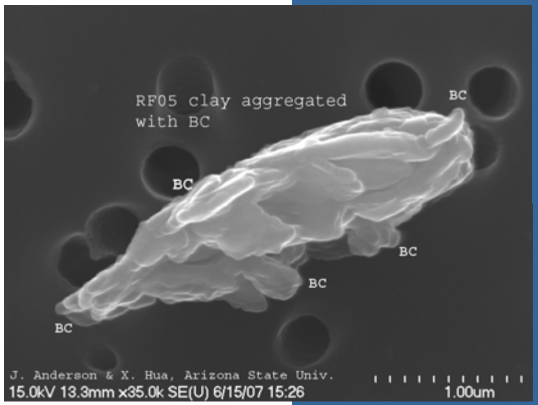






Likely dust plumes, but note rise of “black carbon” (SP-2) particle concentrations in hand with larger particles.





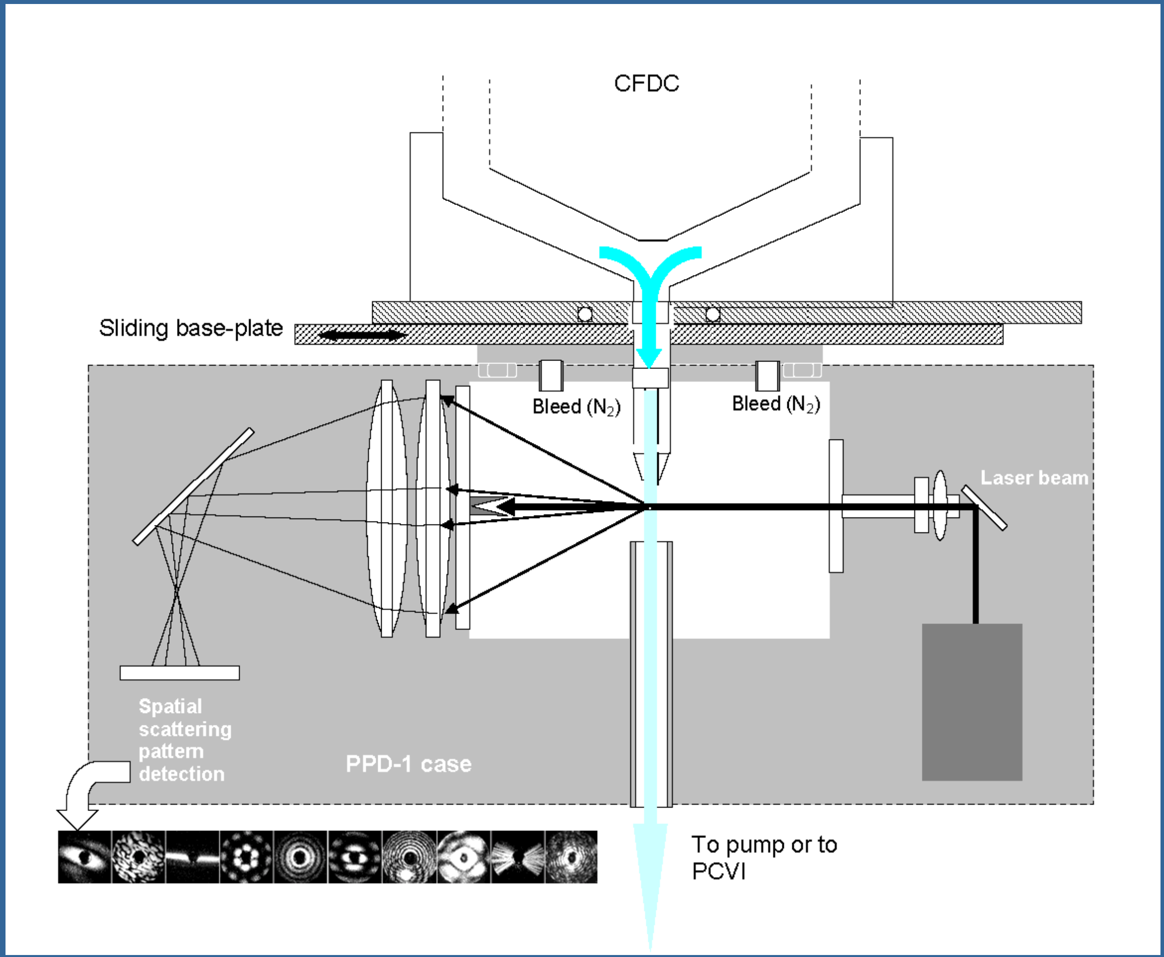
T = -32ºC;

RH = 100-103%

Some present limitations

- We are designing instruments to detect ice formation by larger aerosols, but by removing the distinction of ice and aerosol by size, how do we extract ice crystals to measure IN composition?

New detectors should allow elimination of activated IN detection by size alone



Some present limitations

- We are designing instruments to detect ice formation by larger aerosols, but by removing the distinction of ice and aerosol by size, how do we extract ice crystals to measure IN composition?
- We have not sampled much directly in regions likely to have strong biological inputs (lower altitude areas over oceans and source plant surfaces)
- How best to identify "biological" IN?

Summary

- IN concentrations in the atmosphere range from below 0.0001 cm^{-3} to as high as a few cm^{-3}. Nevertheless, typical values are 0.001 to 0.01 cm-3 and rarely exceed a 0.1cm^{-3}.
- Lower IN concentrations are found particularly in cold seasons/regions and at times through elevated layers of the atmosphere. Desert dust is usually responsible for highest [IN].
- IN compositional measurements confirm sources from mineral dusts, metallic particles (some may be anthropogenic) and substantial but variable and unidentified numbers of carbonaceous particles. Biomass smokes are mostly poor sources of IN.

Summary (continued)

- **IN, while having mode sizes between 0.2 – 0.5 μm, extend into the supermicron range where we have the weakest instrumental capabilities for identifying their compositions.**
- **Niether the apparent physical morphology, nor typical sizes of IN support a strong biological source, but measurements have not emphasized the expected size range of these and sampling has not focused very much on seasons and locations where a strong bio-input is most expected.**

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