Ice nuclei measurements during the ICE-T (Ice in Clouds – Tropical) study

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The short story…

- ICE-T IN sampling occurred by multiple methods, on the ground and during flights, from ambient and CVI inlets.
- Technical issues and lack of pre-concentration made assessment of real-time IN number concentrations at modest supercooling impossible. FRIDGE measurements suffered a sea salt artifact and cannot be trusted. Filters for immersion freezing measurements filled the gap somewhat.
- Nevertheless, a typical IN spectrum was obtained and a clear dust impact on IN was verified.
- Three papers will come from the study: a basic one on the measurements, and paper using some of the data toward parameterization development, and a paper incorporating multiple data sets describing marine boundary layer IN characteristics

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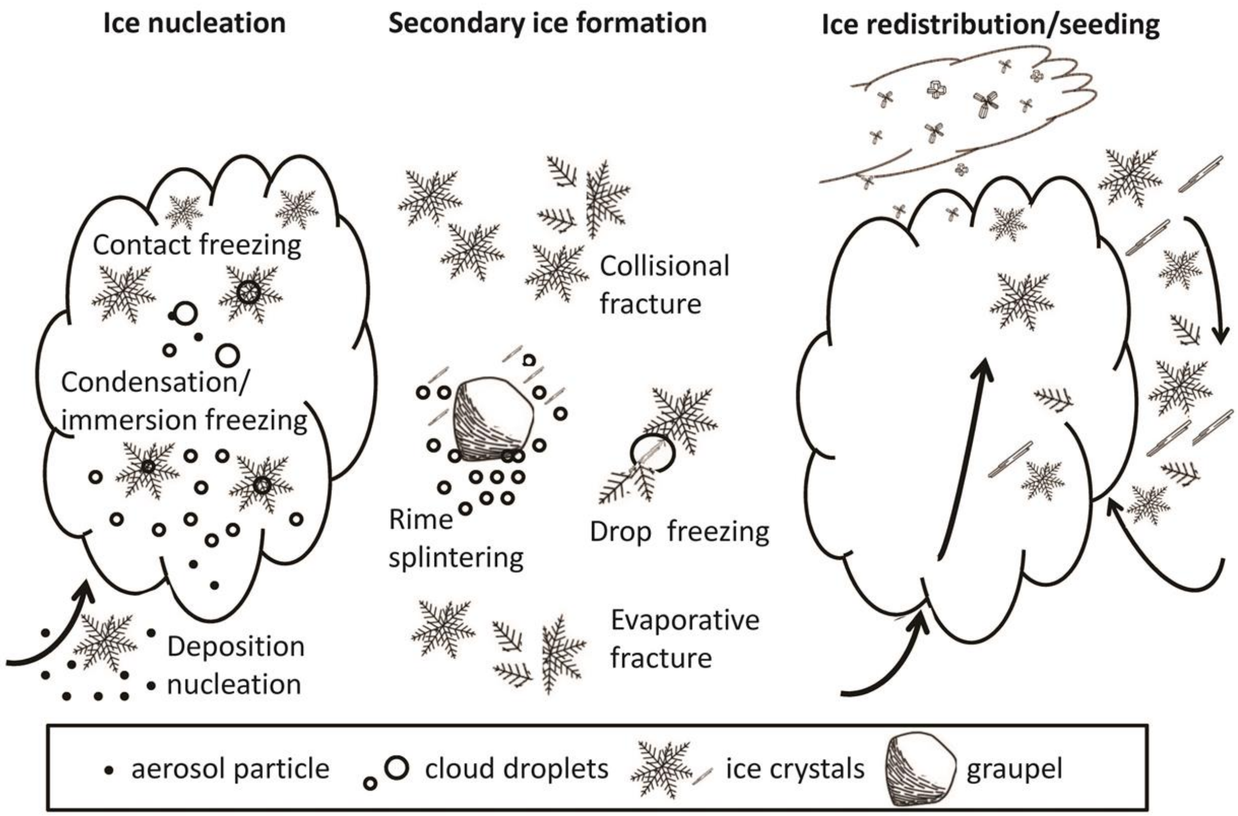
Motivation for ICE-T



Heterogeneous ice nuclei (IN) are usually responsible for first ice formation. Mineral dust particles are a key IN source, but biological ice nuclei (mixed with dust or from ocean and land sources) may play role, especially in warmest temperature ice formation.

Ice nuclei measurement methods

On-line method

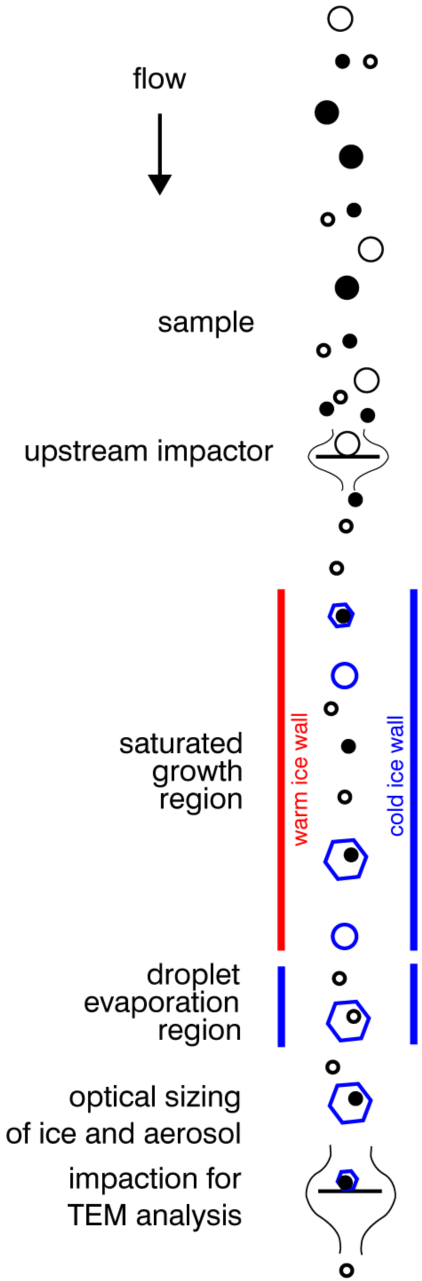
CSU continuous flow diffusion chamber (CFDC)

Rogers et al., JAOT, 2001
Prenni et al., Nature Geo, 2009

Sensitive to deposition and condensation/ immersion nucleation modes

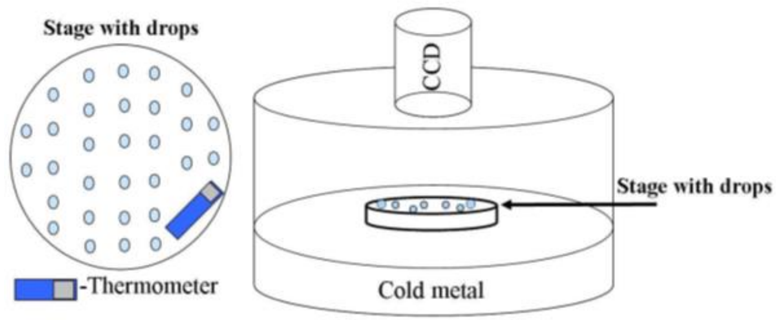
Sample temperature range approx. -12 to -40 C

Sub- and super-saturated conditions w/ respect to water

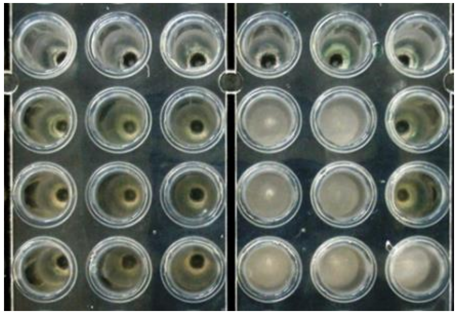


Off-line methods

FRIDGE-UF, FRIDGE-Wiz/TAU



Drop freezing (U. of Wyoming)



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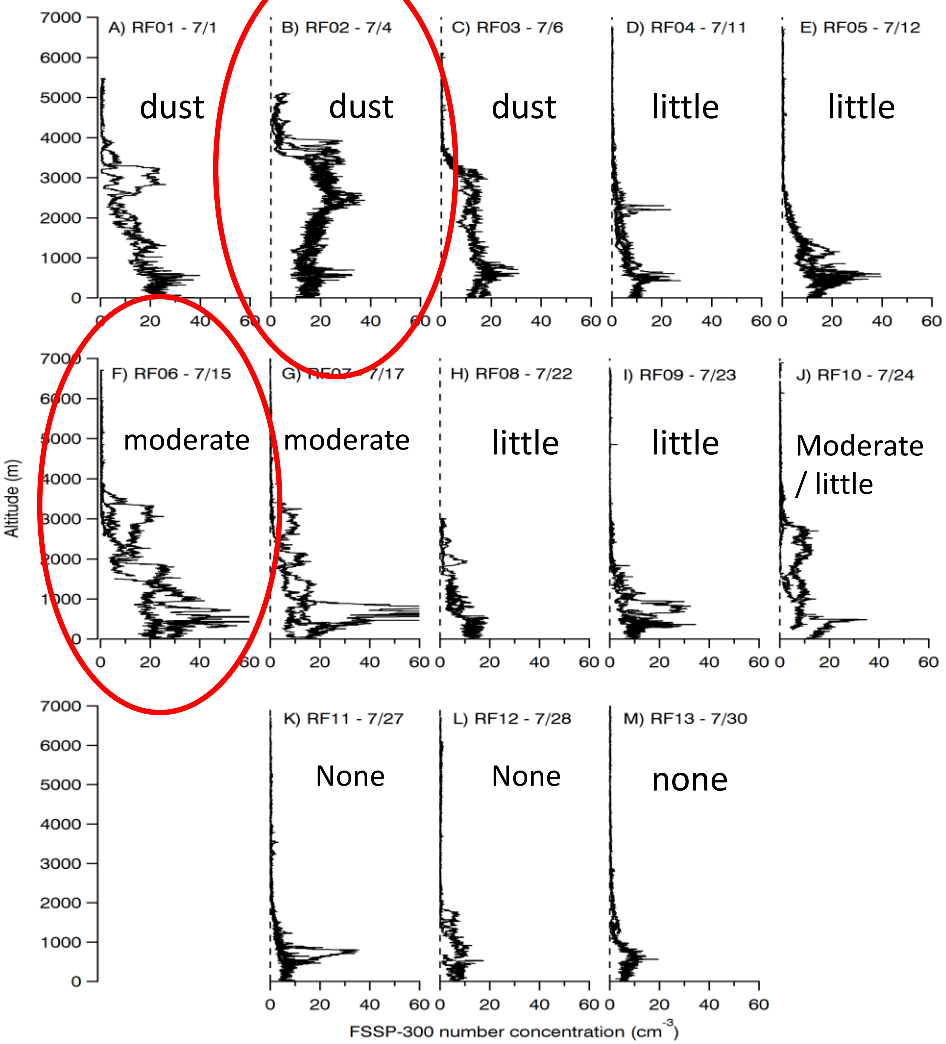
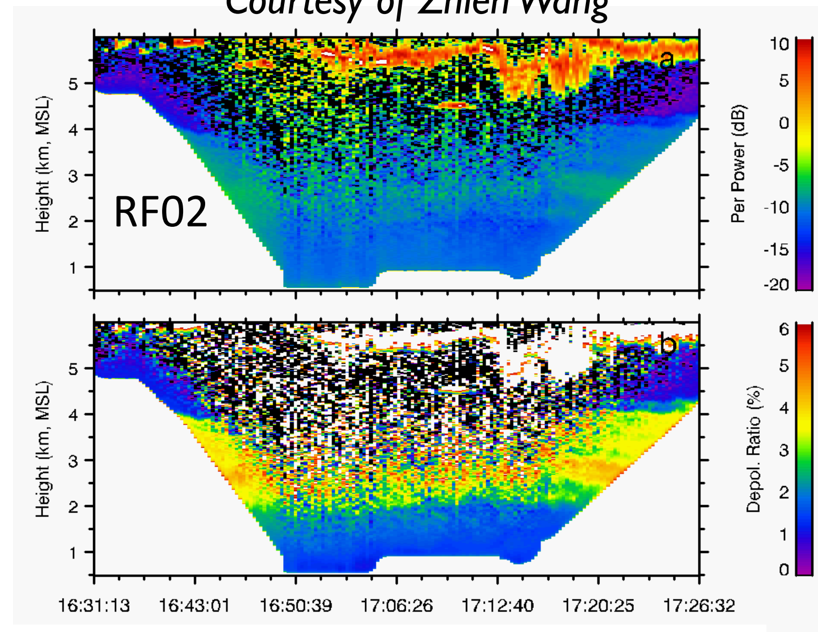
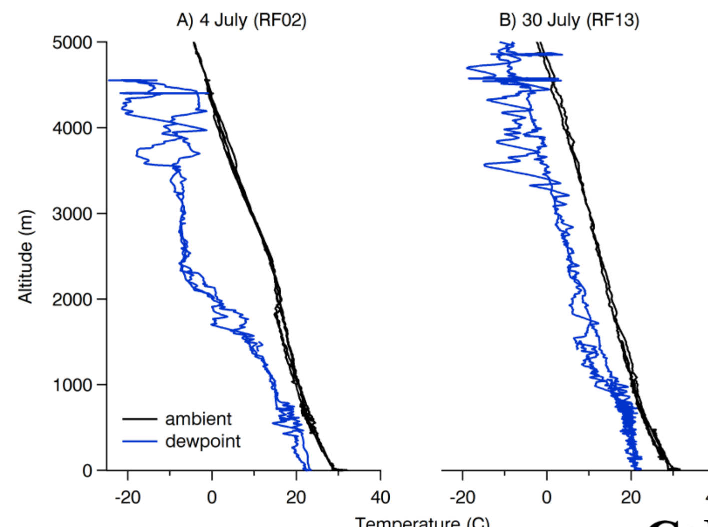
African dust during ICE-T

FSSP-300 (D > 0.3 μm)



Courtesy of Zhien Wang





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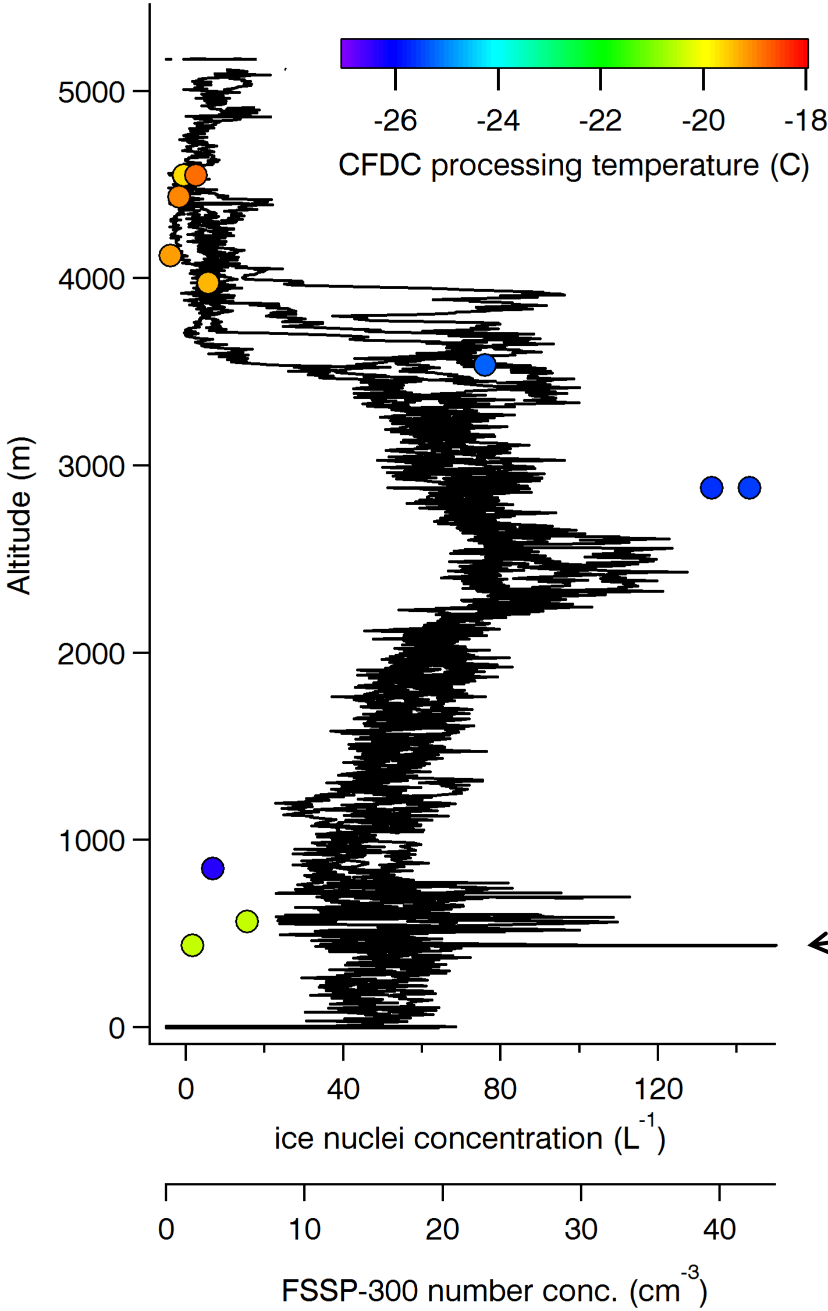
IN varied with altitude during dust events



Layers with strong depolarization signal

(5 minute integrated IN conc.)

Marine boundary layer

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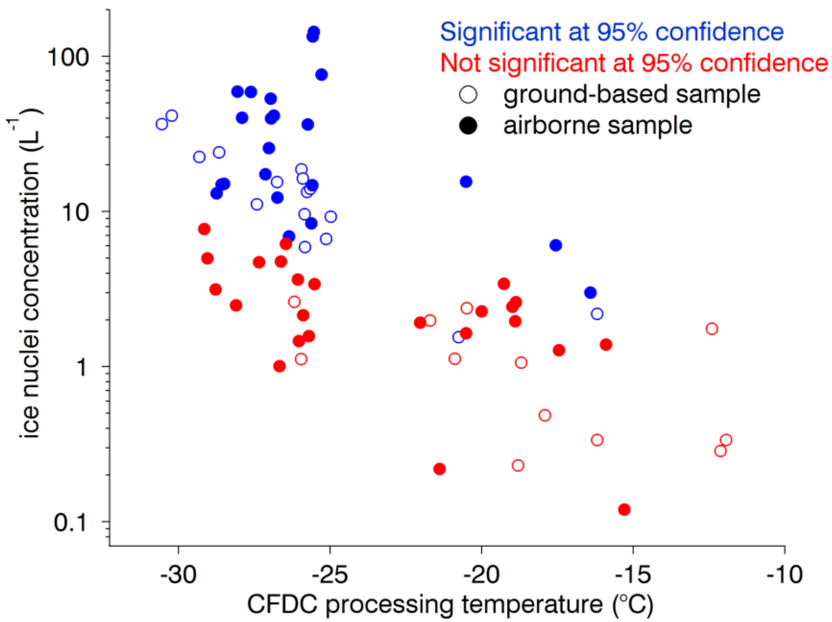
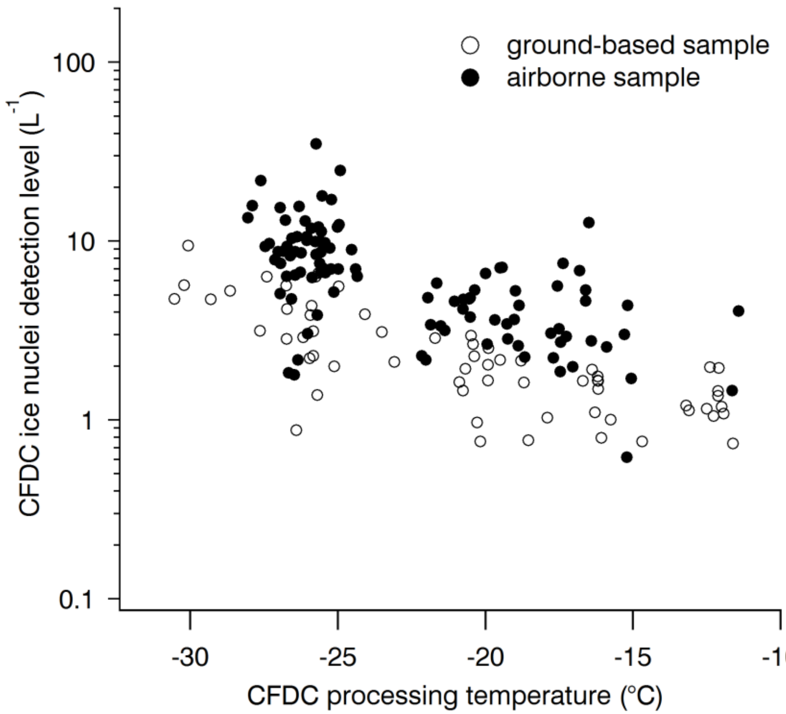
CFDC measurement summary of IN-T via condensation/immersion freezing, detection limits, and significant versus non-significant results





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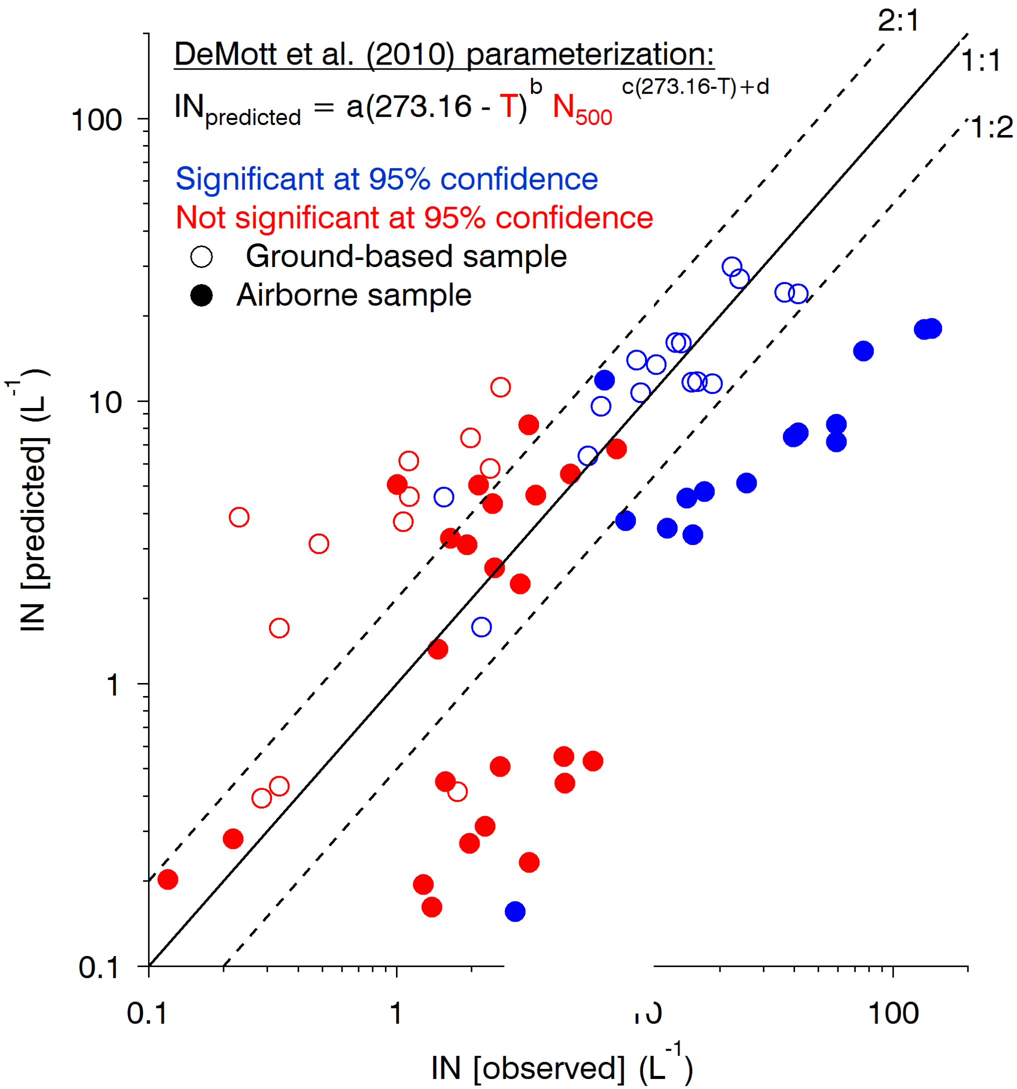
Dust data during ICE-T stand out in comparison to "global" IN parameterization of T, size dependence

DeMott et al. (PNAS, 2010) developed parameterization for IN based on processing temperature and aerosol concentrations (D > 500 nm).

Empirical fit based on collection of previous IN measurements in a range of environments.



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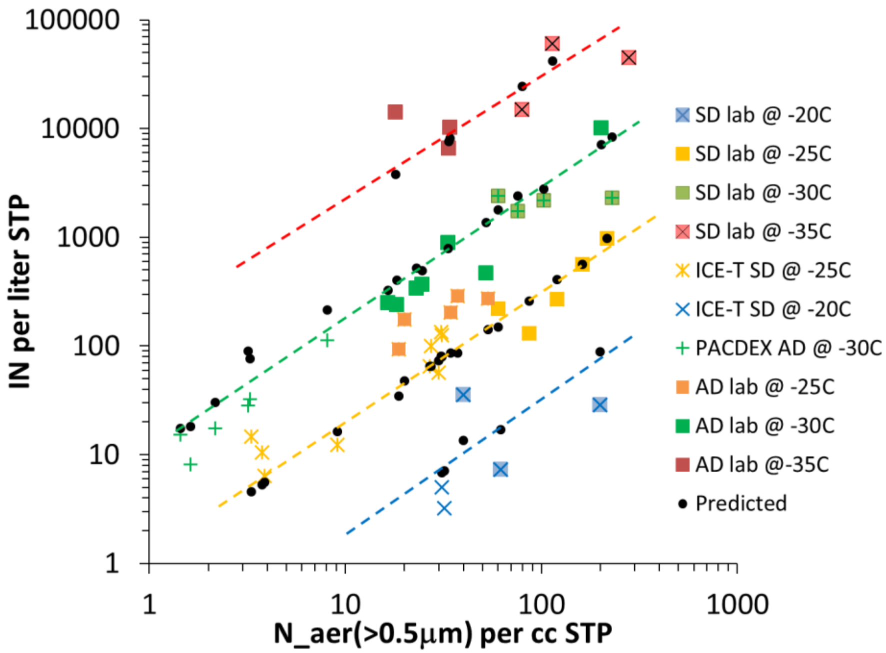
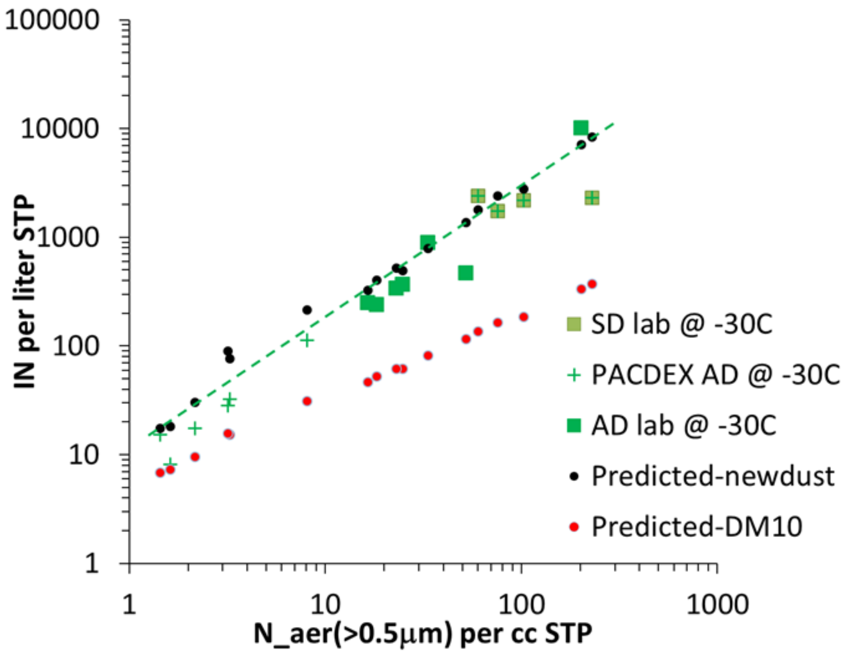
Use of ICE-T data with PACDEX data and CFDC lab data to show uniformity of dust IN for parameterization

New-dust param: $n_{INP,T_k} = (CF)\,(n_{a>0.5\mu m})^{(\alpha(273.16-T_k)+\beta)} \exp(\gamma(273.16-T_k)+\delta)$





n_{IN,T_k}(STP) is referenced to RH_w = 105% here, as the typical value used in field situations

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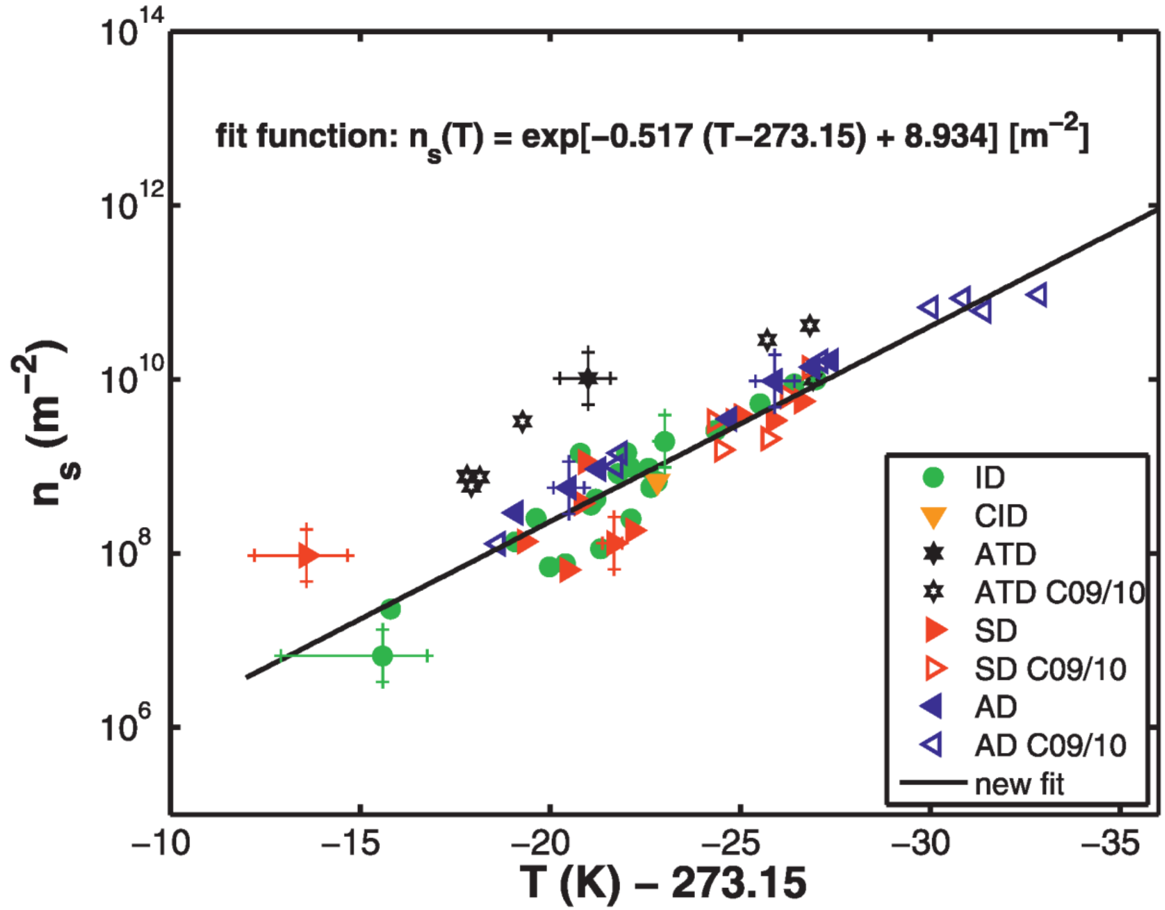
Niemand et al (2012): similar result in parameterizing IN surface site density



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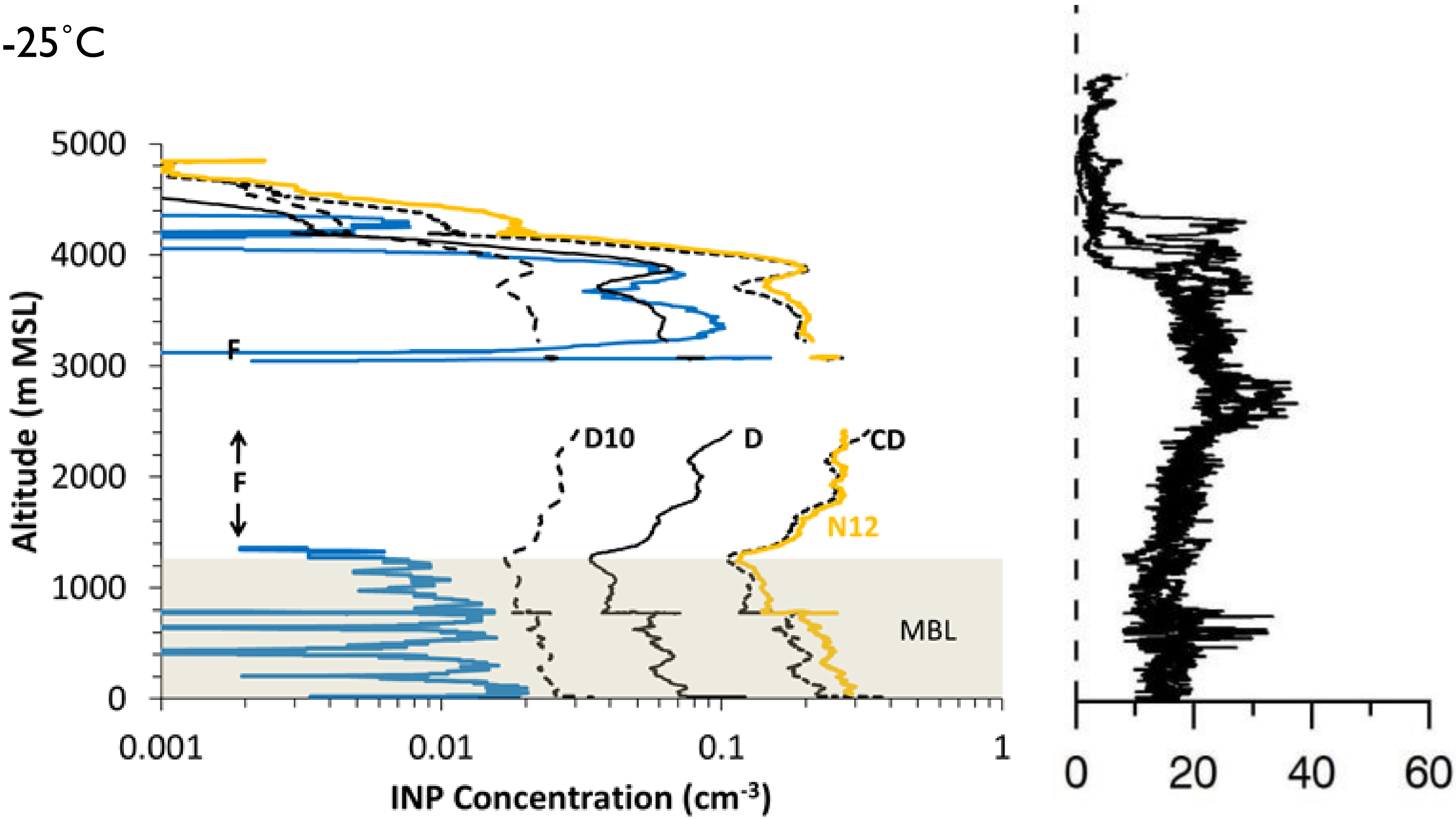
ICE-T RF4 profile through African dust layer and ice nuclei parameterizations

T = -25˚C



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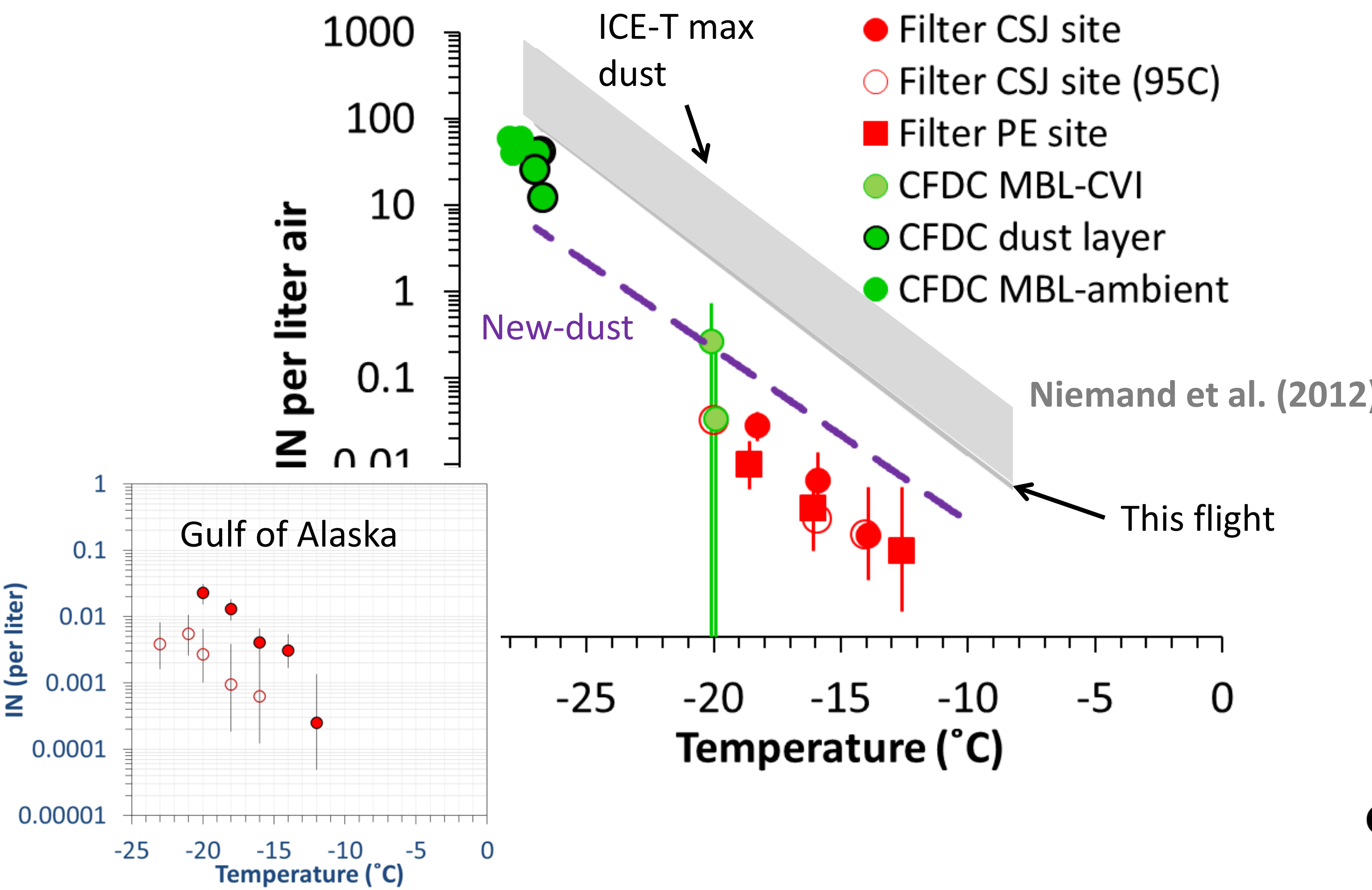
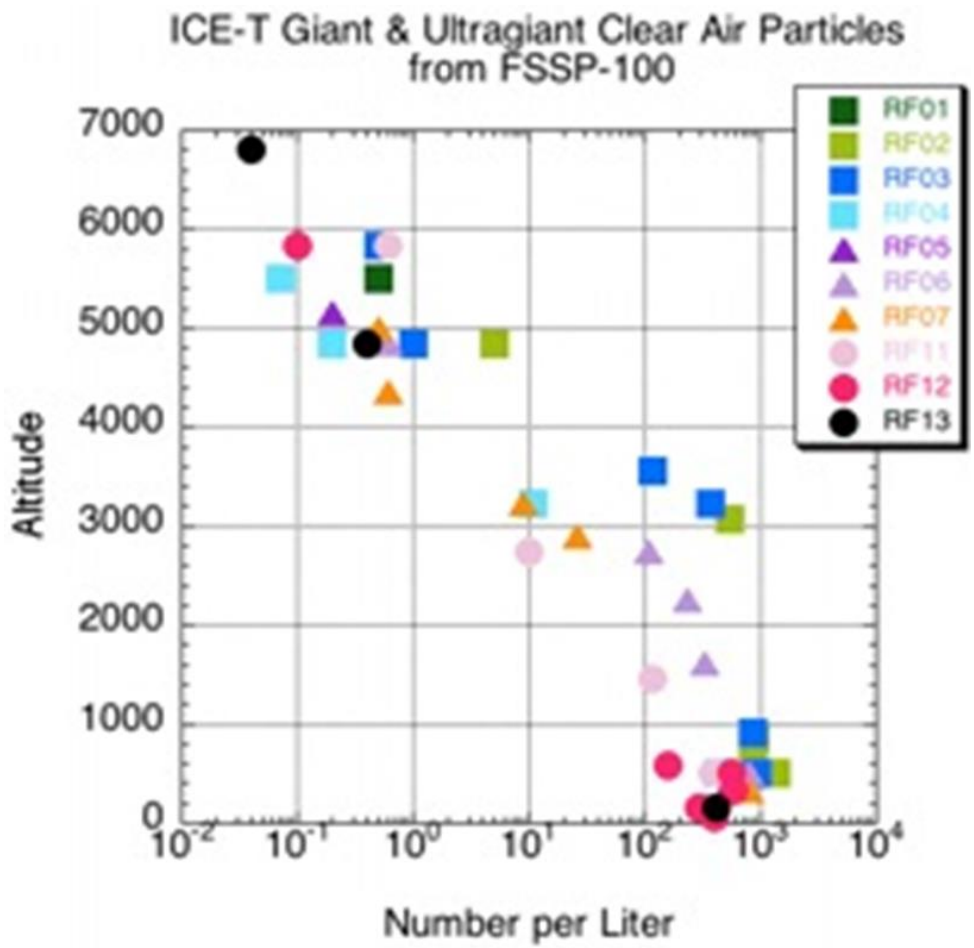
ICE-T RF6 ice nuclei concentration versus T



Did we miss the contributions of large IN not making it in the C-130 inlet?

Could be 100 per liter large aerosol not sampled effectively during RF13 or on most days without dust. It is extremely unlikely even 1% of these would be IN active based on our previous measurements over land or sea.



Courtesy of Sonia Lasher-Trapp

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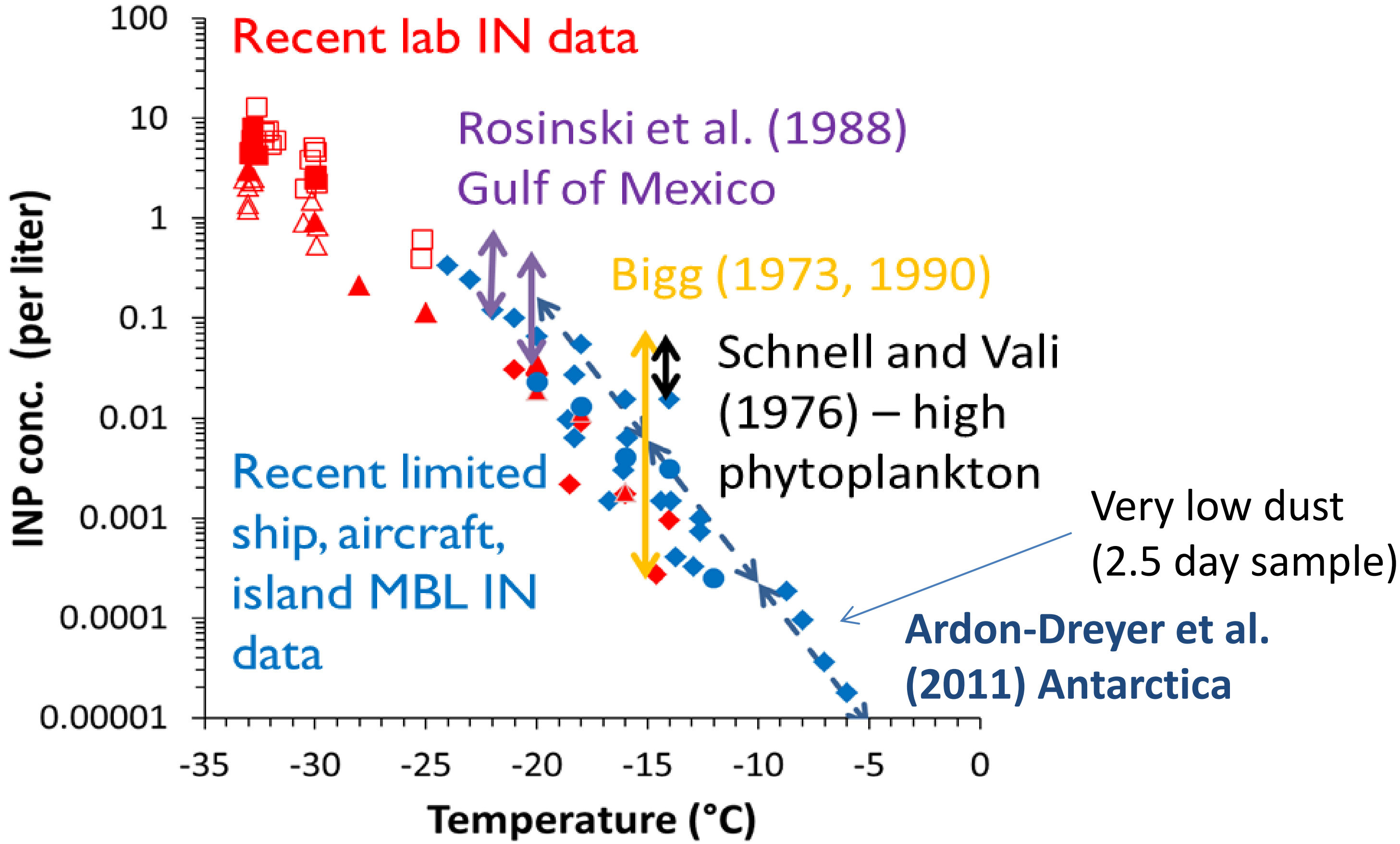
Ice nuclei from sea spray particles – lab and field data combined including ICE-T processed filters



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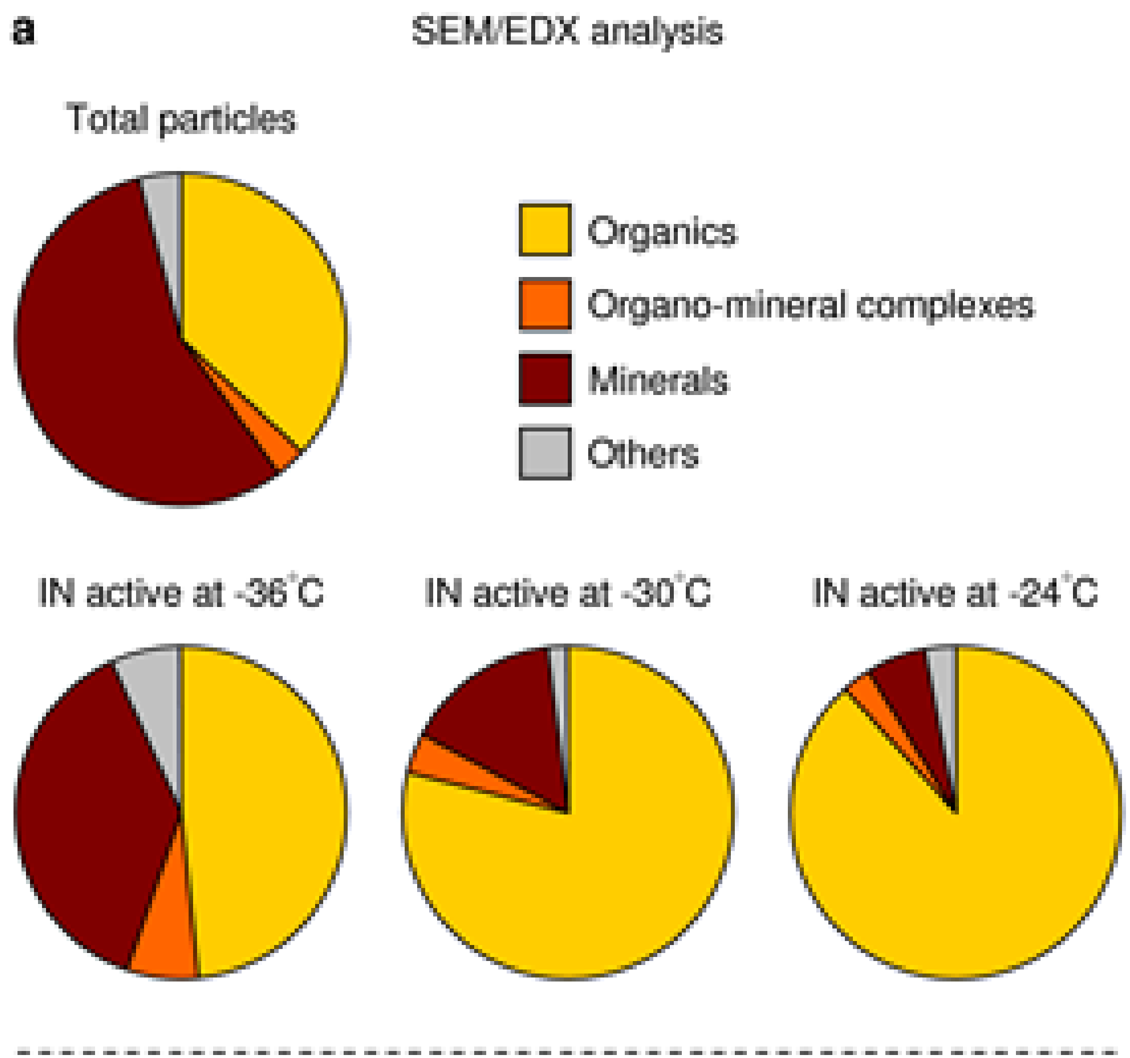
Aside – arable soil dust IN are largely organic C, not minerals (Tobo et al. 2013, in submission)



Summary

- ICE-T included periods with and without Saharan dust influence
- IN concentrations in the absence of dust were below CFDC detection limits (roughly 1 L-1) at temperatures warmer than -15 C. Suggests upper limit of IN on the order of 1 L-1 in pristine maritime conditions.
- Immersion freezing measurements suggest below 0.1 per liter at warmer T
- African dust layer-perturbed IN concentrations exceed the contributions typical of sea spray-produced IN by 1-2 orders of magnitude at -8 to -15˚C, and reach 150 L-1 at -25 ˚C. Stronger direct evidence via improved methods in regions of strong gradients is needed (ICE-D).
- Still examining (in)consistency between CFDC and off-line methods. Have not carefully analyzed CVI sample data toward objectives
- Modeling studies and further observations are needed to understand the dynamics of primary and secondary ice generation, CCN affects (warm-cold cloud interactions) etc, to predict precipitation impacts.

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Papers using ICE-T data

- McMeeking, G. R., P. J. DeMott, J. B. Snider, Z. Wang, T. C. Hill, G. D. Franc, M. Diaz Martinez, I. Venero, G. M. Santos, O. Mayol-Bracero, and S. M. Kreidenweis, 2013: Ice nuclei measurements in the Ice in Clouds – Tropical clouds (ICE-T) experiment. In preparation for submission to *J. Geophys. Res*.
- DeMott, P. J., A. J. Prenni, G. R. McMeeking, Y. Tobo, R. C. Sullivan, M. D. Petters, M. Niemand, O. Möhler, and S. M. Kreidenweis, 2013: A parameterization of freezing nucleation by mineral dust particles, In preparation for *Atmos. Chem. Phys. Disc*.
- DeMott, P. J., T. C. Hill, R. C. Sullivan, M. J. Ruppel, R. Mason, A. P. Ault, K. A. Prather, M. J, Kim, A. Bertram, T. Bertram, V. K. Grassian, T. Lee, C. Hwang, and G. D. Franc, 2013: Ice nuclei concentrations from marine sources: Laboratory and atmospheric measurements. In preparation for submission to *Nature Geosciences*.