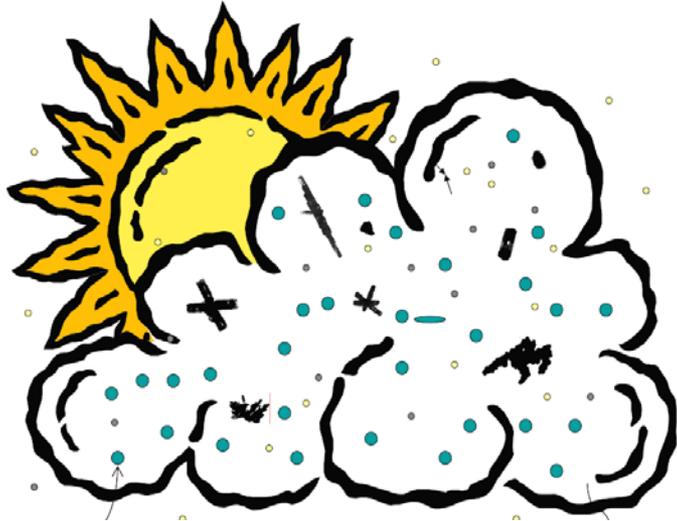


Heterogeneity of Ice Nuclei in the Arctic



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Acknowledgements:

Andrew Glen TAMU
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Anne Marie MacDonald
Alla Zelenyuk

The pilots and crew of the CONVAIR 580

DOE ARM and NSF CAREER

What drives ice nucleation in Arctic?

Previous
Measurements:
Large variations in IN
Seasonality

What new insight can
be gained from ISDAC?

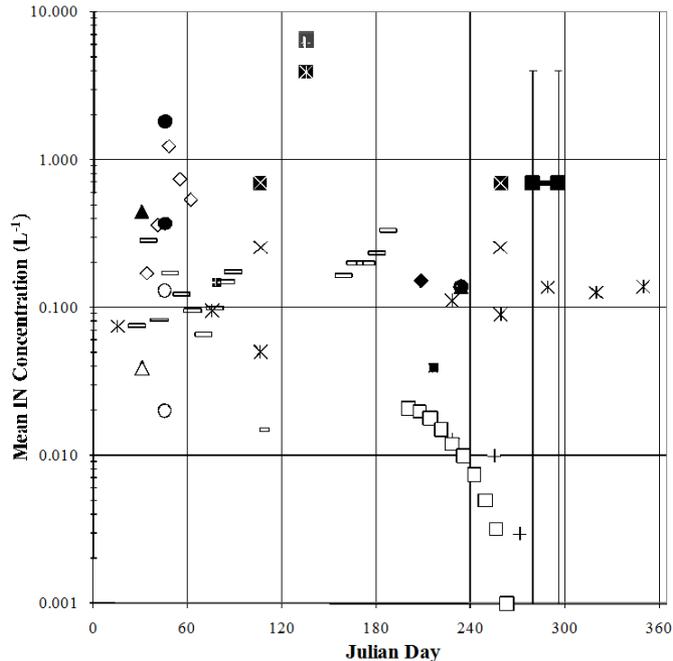


Figure 1. Previous measurements of Arctic IN at -15 °C: (Jayaweera and Ohtake, 1973) (×); (Isono et al., 1971) (◇); (Bigg and Stevenson, 1970) (○); (Bigg, 1996) (+); (Schnell and Delany, 1976) (Δ); (Borys, 1989) (-); (Bigg and Leck, 2001) (□); (Rogers et al., 2001) (⊗); at -20 °C: (Jayaweera and Ohtake, 1973) (⊠); (Flyger et al., 1973) (◆); (Bigg and Stevenson, 1970) (●); (Schnell and Delany, 1976) (▲); (Radke et al., 1976) (⊞); (Flyger et al., 1976) (■); (Fountain and Ohtake, 1985) (*); (Rogers et al., 2001) (⊛); at -21 °C: (Hobbs et al., 1971) (—); and for this study (■—■). Error bars for this study are

Prenni et al, 2008

IN as function of aerosol physical and chemical properties

Continuous Flow Diffusion Chamber (CFDC) Measurements of Ice Nucleating Concentration



Concentrations of Ice-Nucleating Aerosol (IN) as a function of Operating Temperature and %Supersaturation

Concentration of Ice-Nucleating Aerosol (IN)

Factors which impact IN concentration

1. CFDC operating conditions:

Temperature

%Supersaturation with respect to ice

% Supersaturation with respect to water

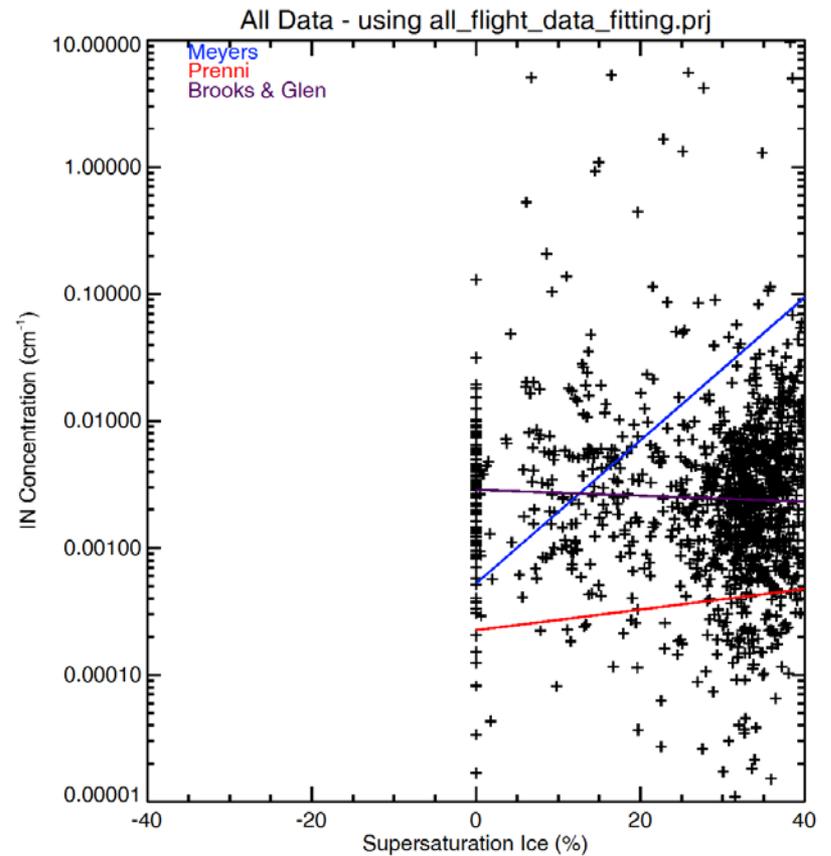
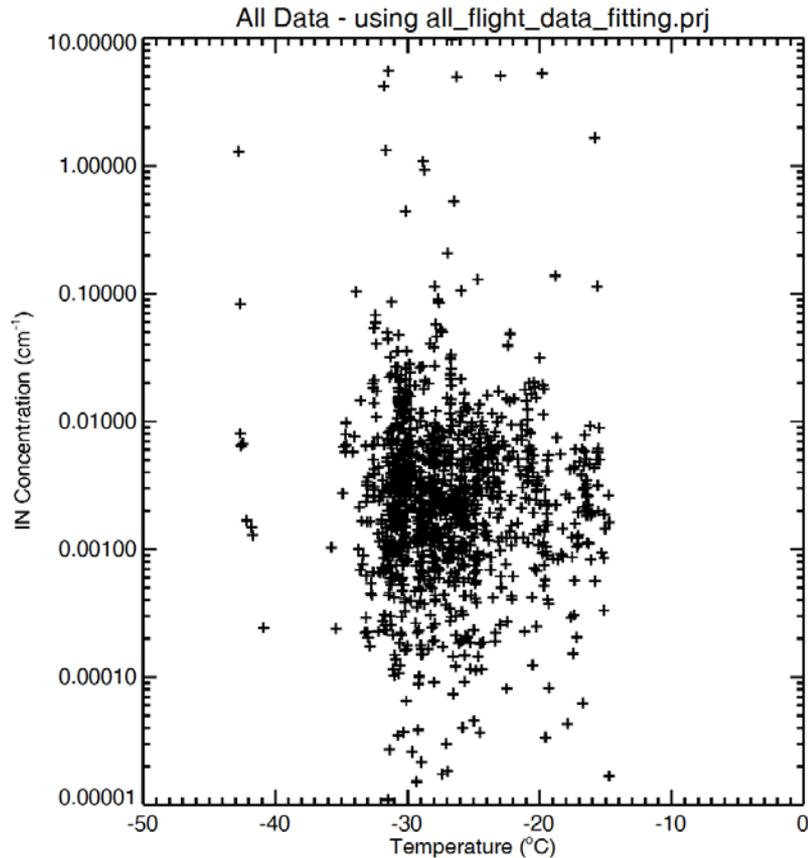
2. Aerosol properties:

Concentration

Size

Composition

COMPOSITE ISDAC DATA



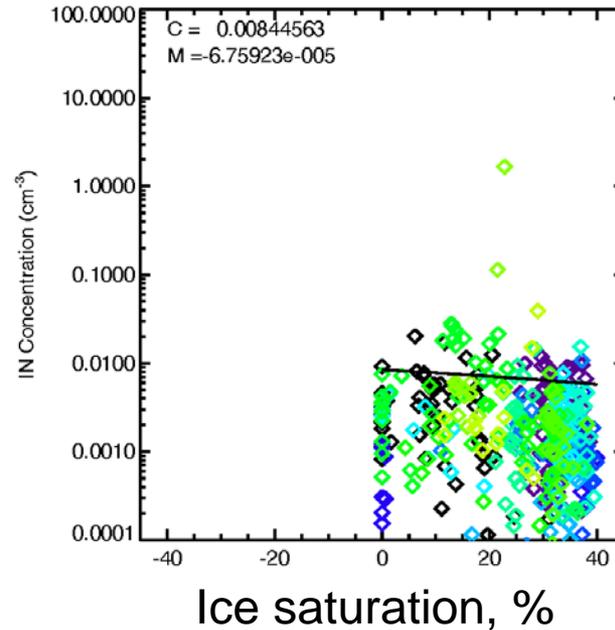
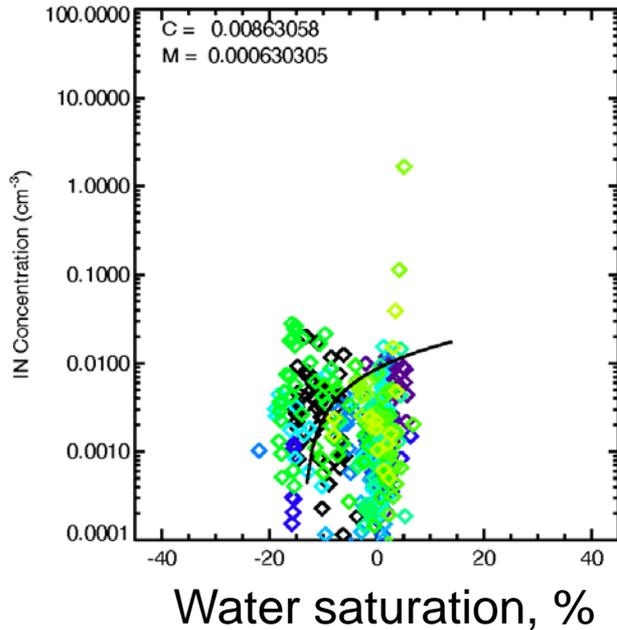
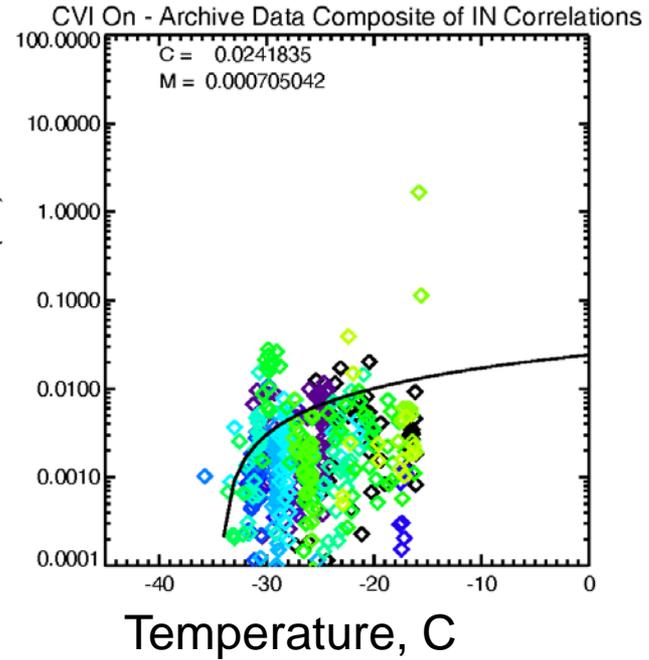
Overall, no clear trend in IN concentration with temperature or saturation.

**ISDAC
sampling:**

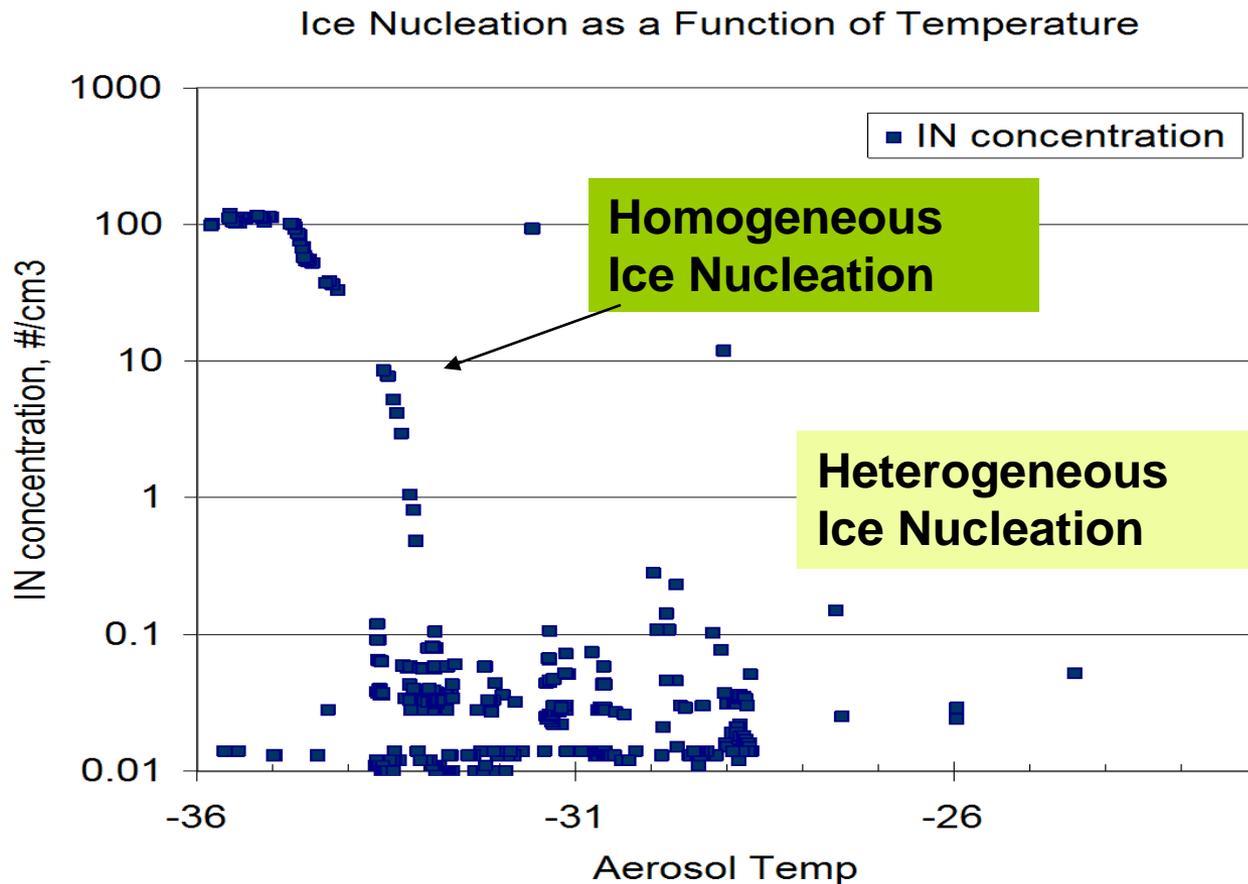
**Alternate
Ambient
and CVI**

- f16
- f17
- f18
- f19
- f20
- f21
- f22
- f23
- f24
- f25
- f26
- f27
- f28
- f29
- f30
- f31
- f32
- f33
- f34

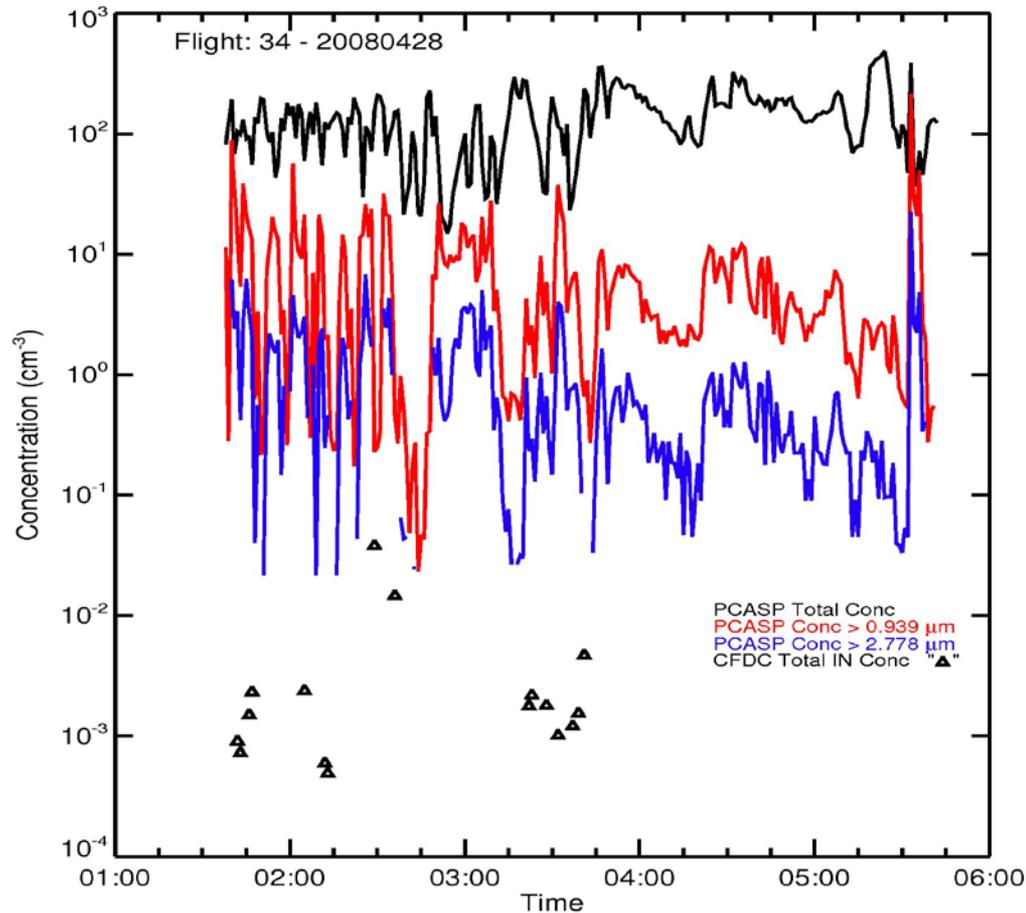
**Cloud Droplet
Residuals
(CVI)**



Dependence of IN concentration on CFDC operating temperature.



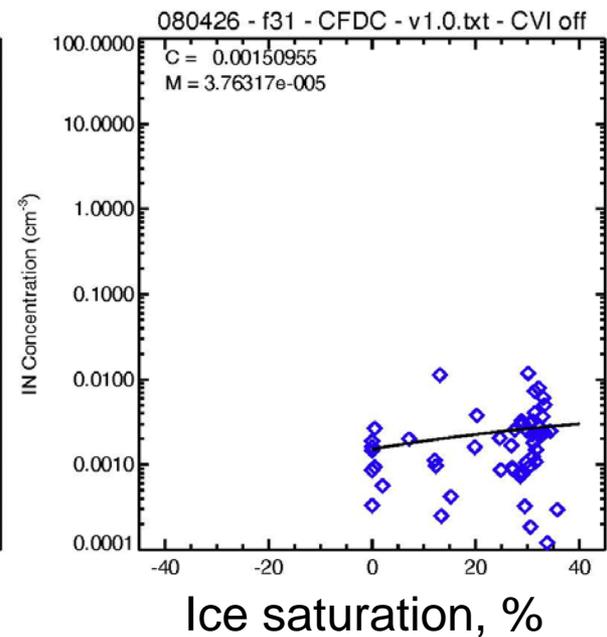
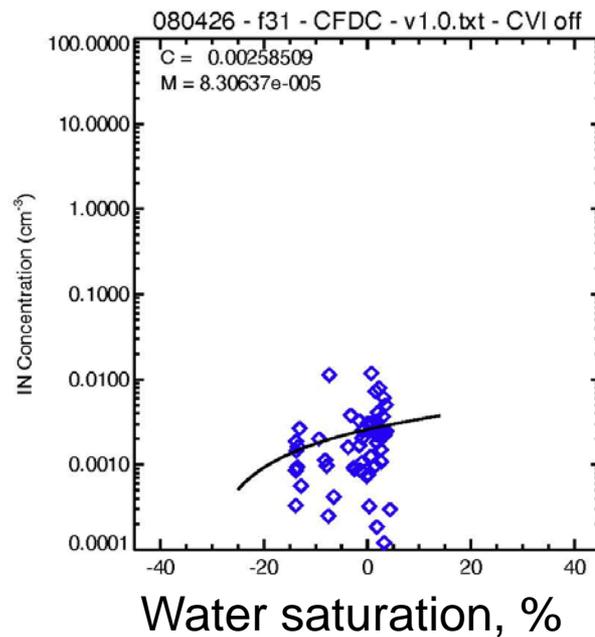
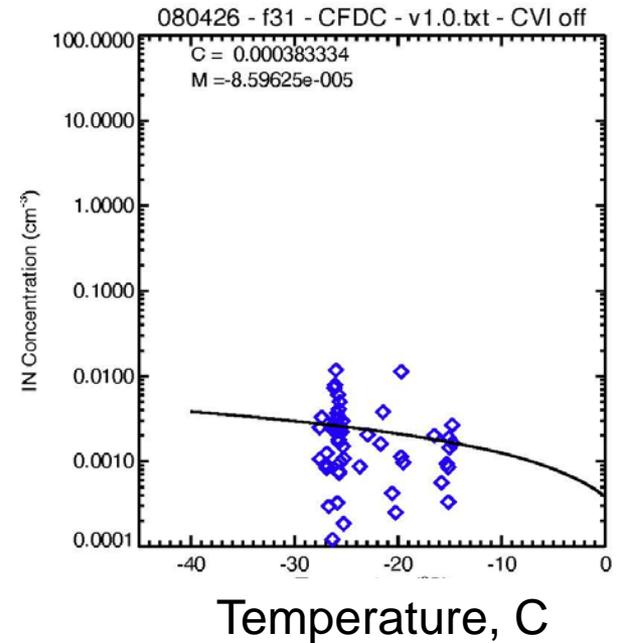
In Heterogeneous Regime, even “high” Ice Nucleation concentrations occur on a small fraction of aerosol



Aerosol concentration and size play a role in IN concentration.

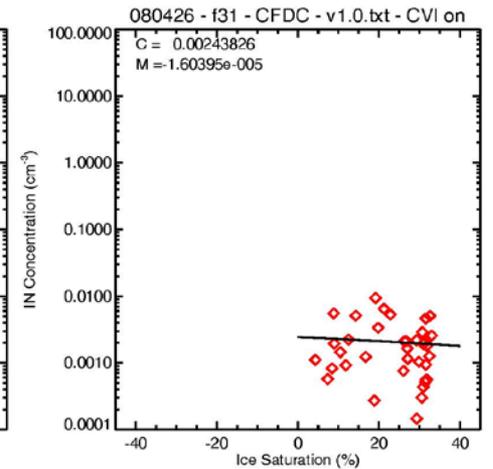
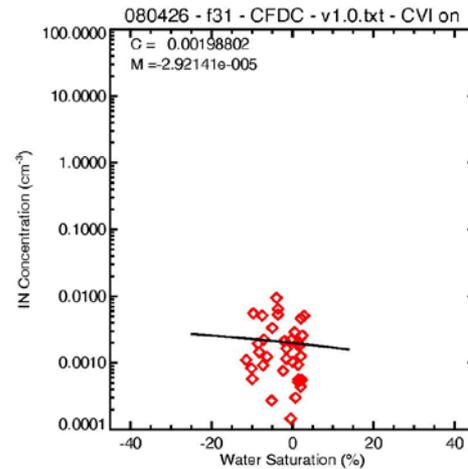
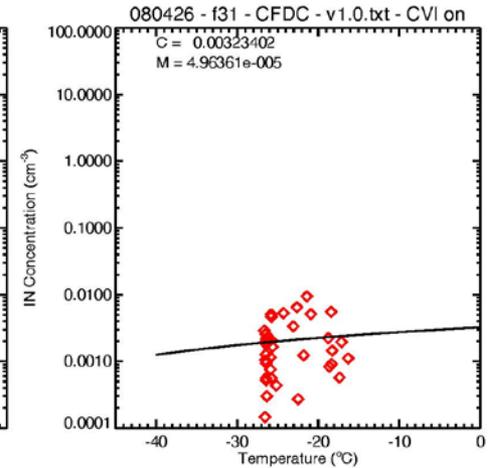
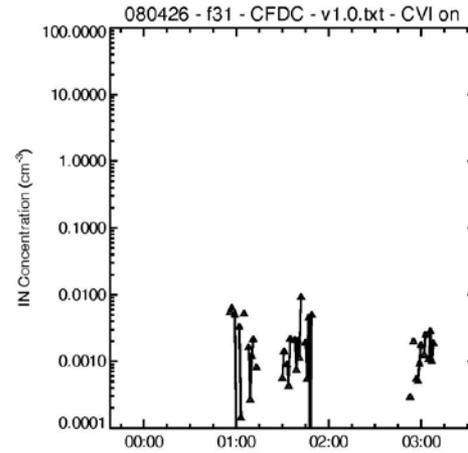
Individual days show trends in heterogeneous freezing

ambient sampling



Individual days show trends in heterogeneous freezing

CVI residuals



Observed IN concentrations are highly variable

Why?

Episodes of Highly IN-active aerosols sampled during ISDAC?

or

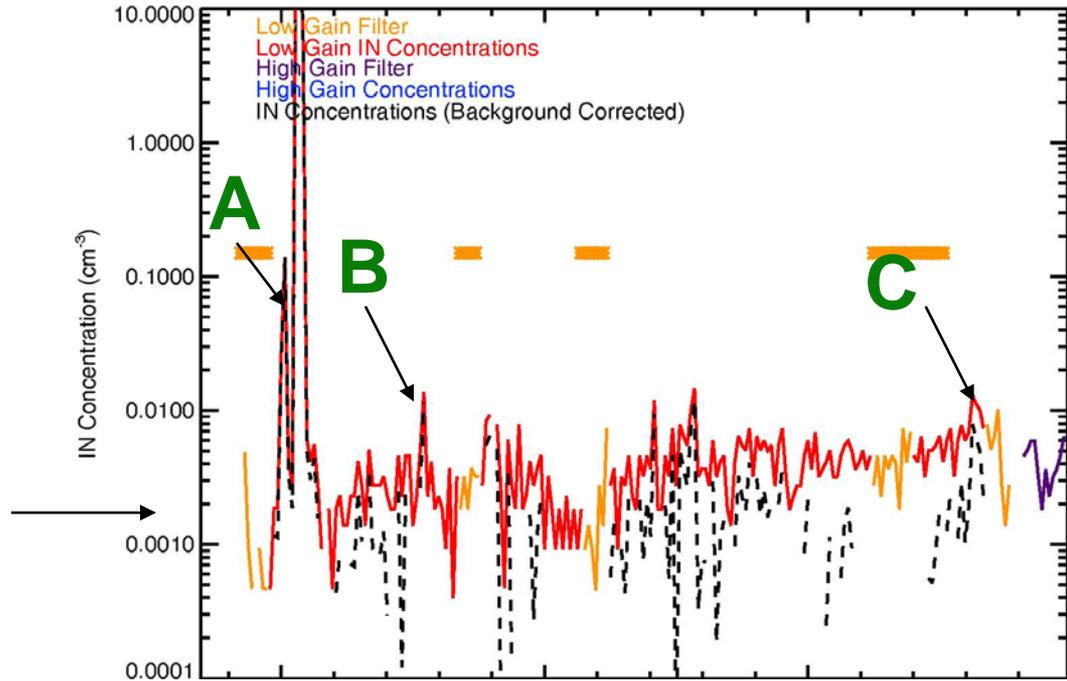
Are we overcounting IN?

-IN mixed phase could the CFDC counting droplets as IN?

-Are we counting large soot particles from biomass burning as IN?

CFDC Measurements April 26, Flight 31

**A closer look
at cases of
high IN
concentration**

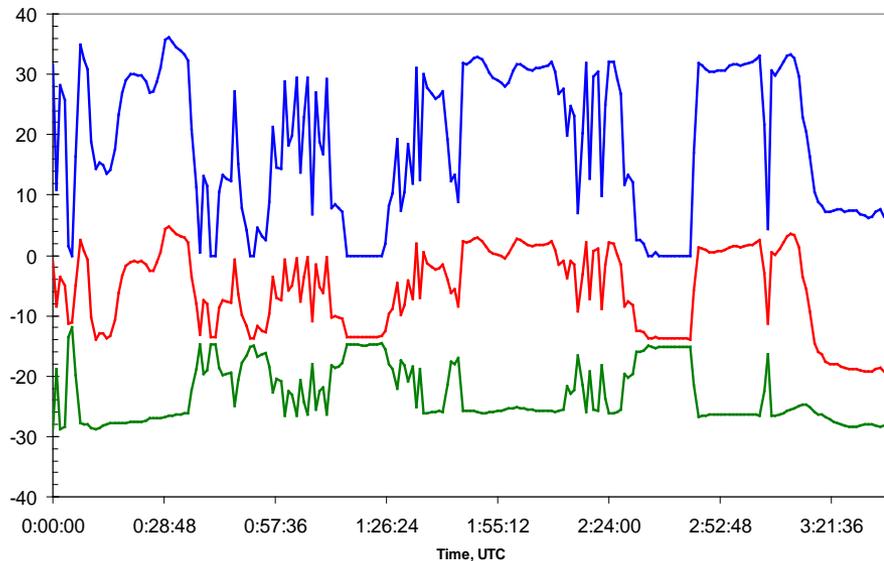


CFDC operating conditions

Supersaturation_ice, %

Supersaturation_water, %

Temperature, °C



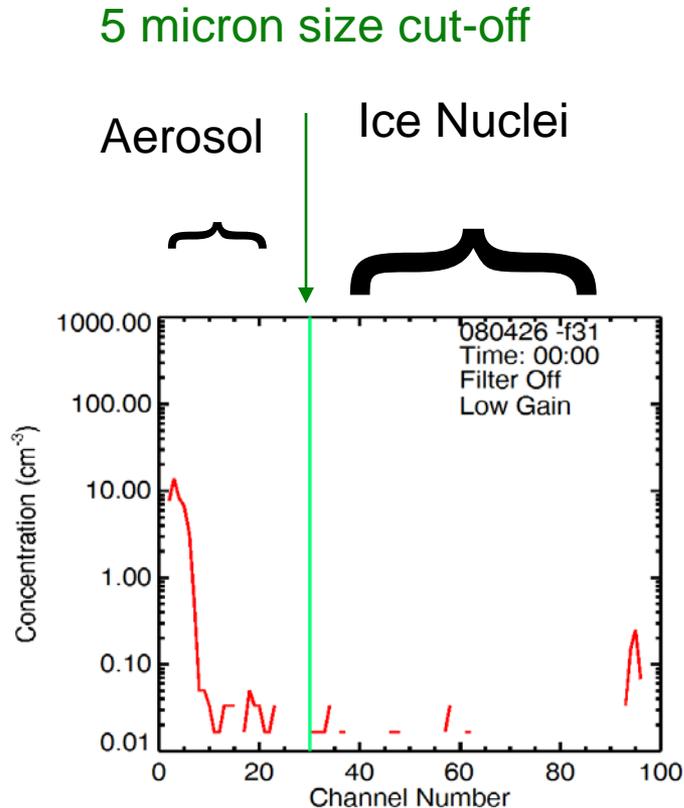
Case A

Comparing
CFDC detection of aerosols
and ice nuclei to
PCASP aerosol size
distributions

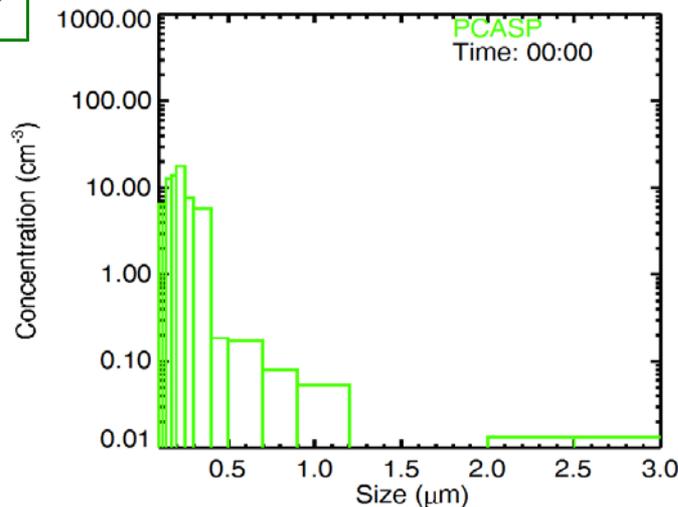
Here we see

1. Agreement between non-nucleating aerosol in CFDC and PCASP aerosol
2. Large aerosols are not falsely counted as IN.

CFDC



PCASP

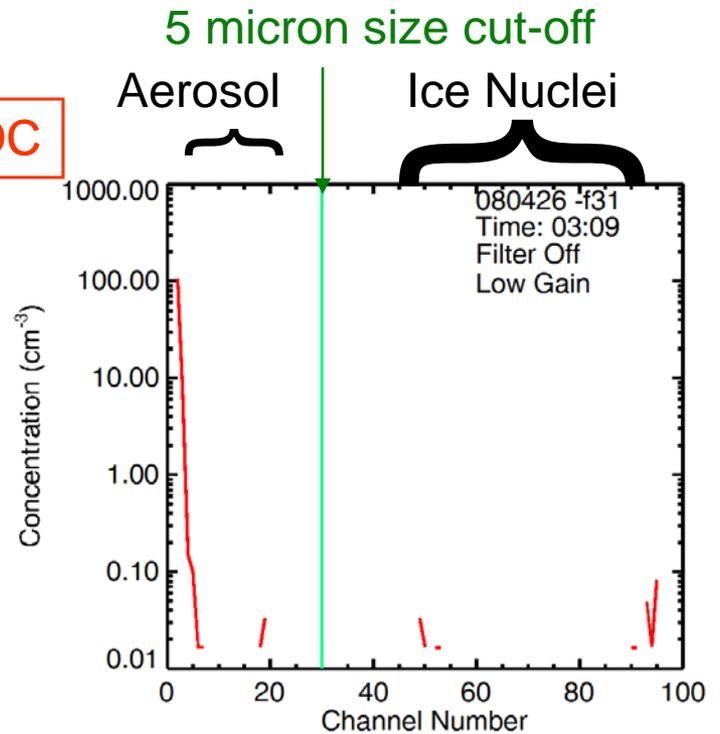


Case C

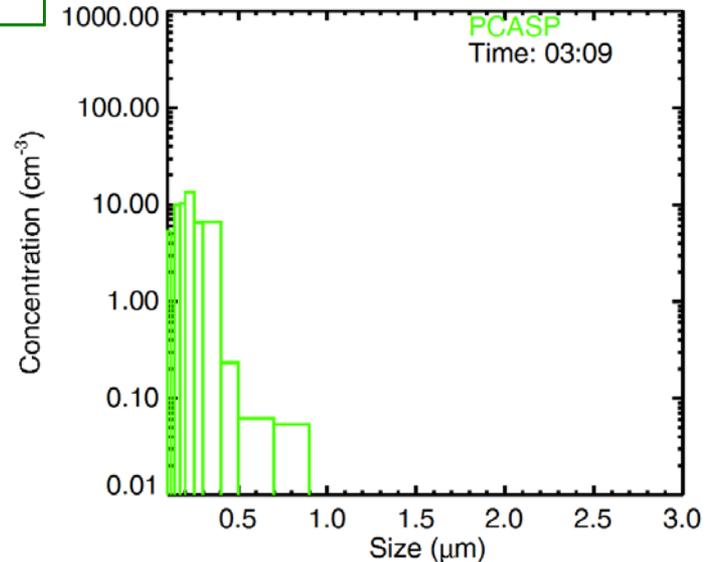
Very high concentrations of both submicron IN-active aerosols

and IN

CFDC



PCASP

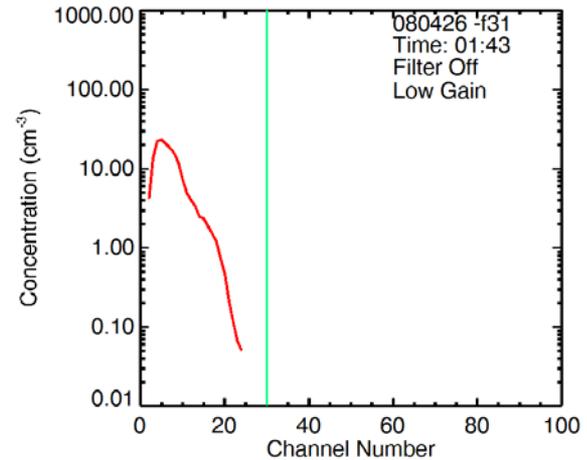
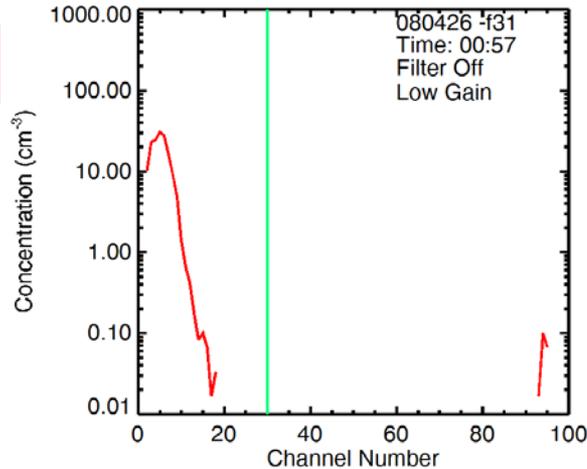


Case B

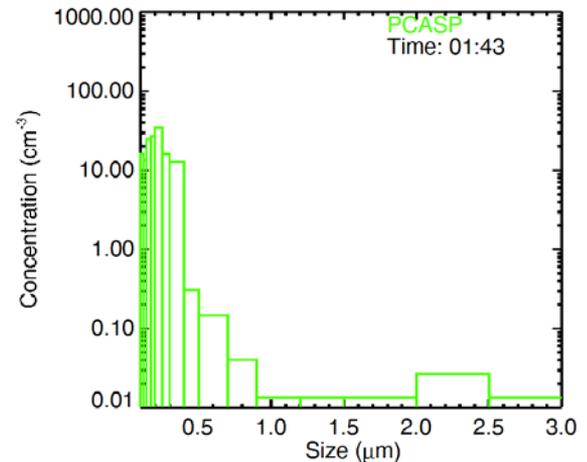
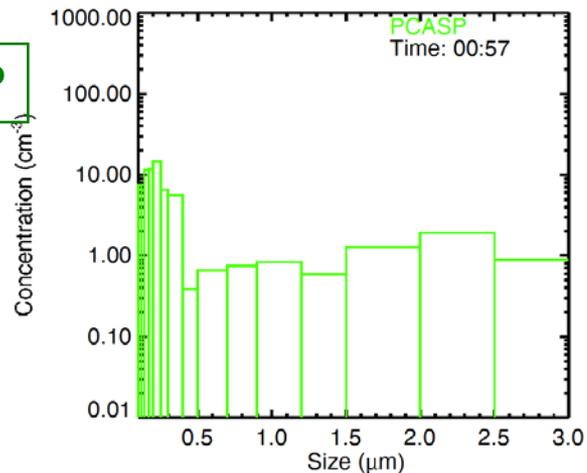
Droplets and Ice Nuclei

For comparison:
Case of droplets, and zero IN

CFDC



PCASP

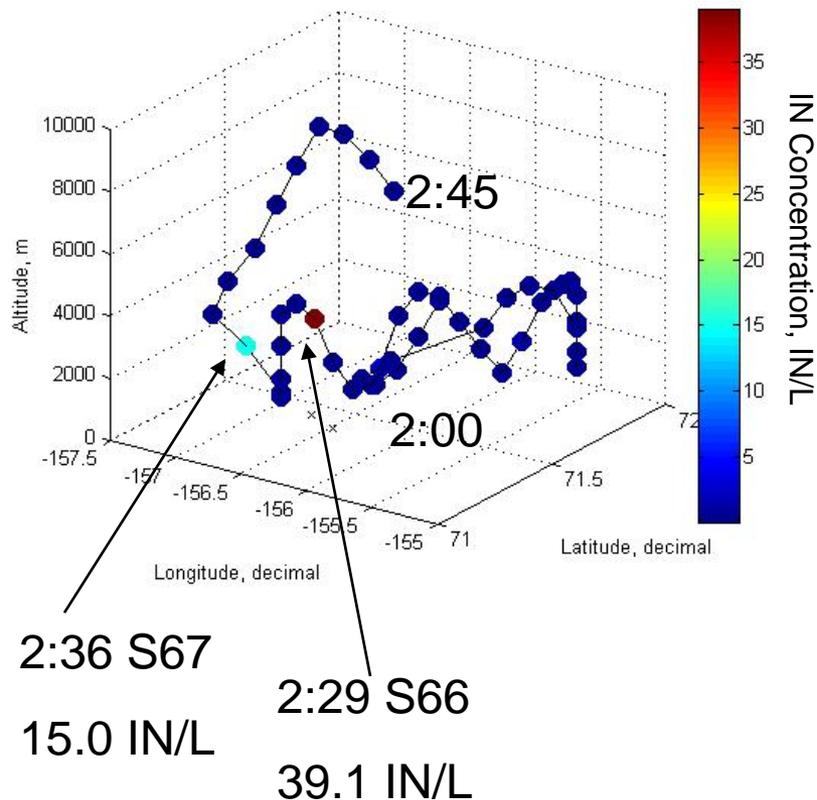


Droplets are not falsely counted as IN under ISDAC sampling conditions

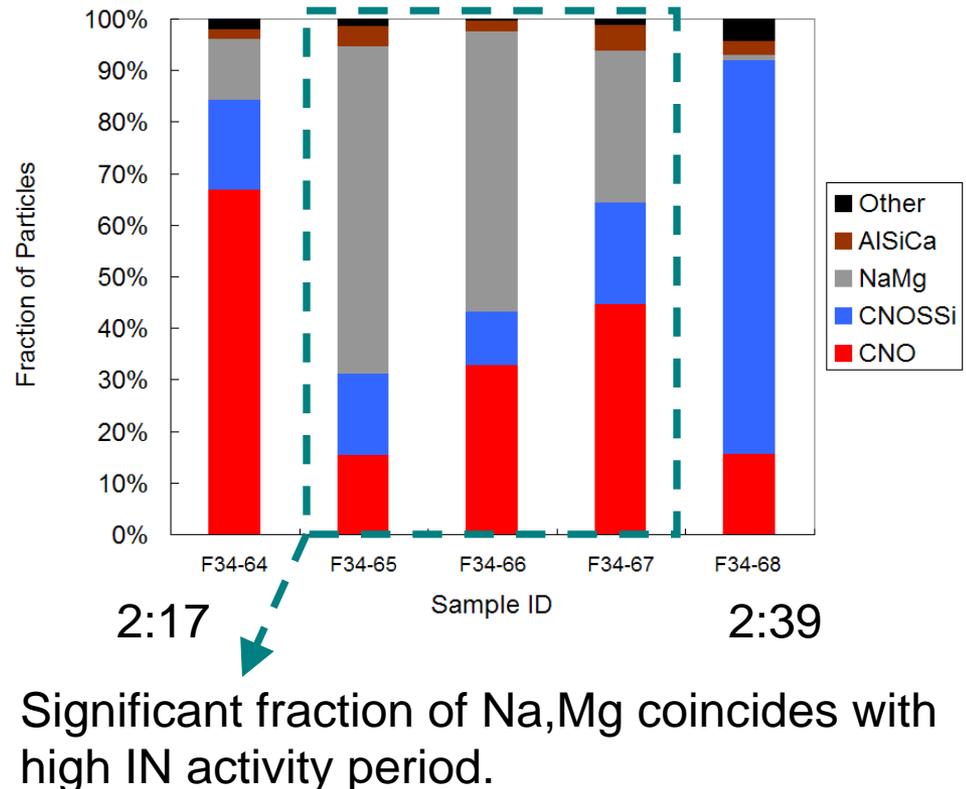
Aerosol Chemistry and Ice Nucleation

CCSEM-EDX Elemental Composition

IN spatial temporal plot

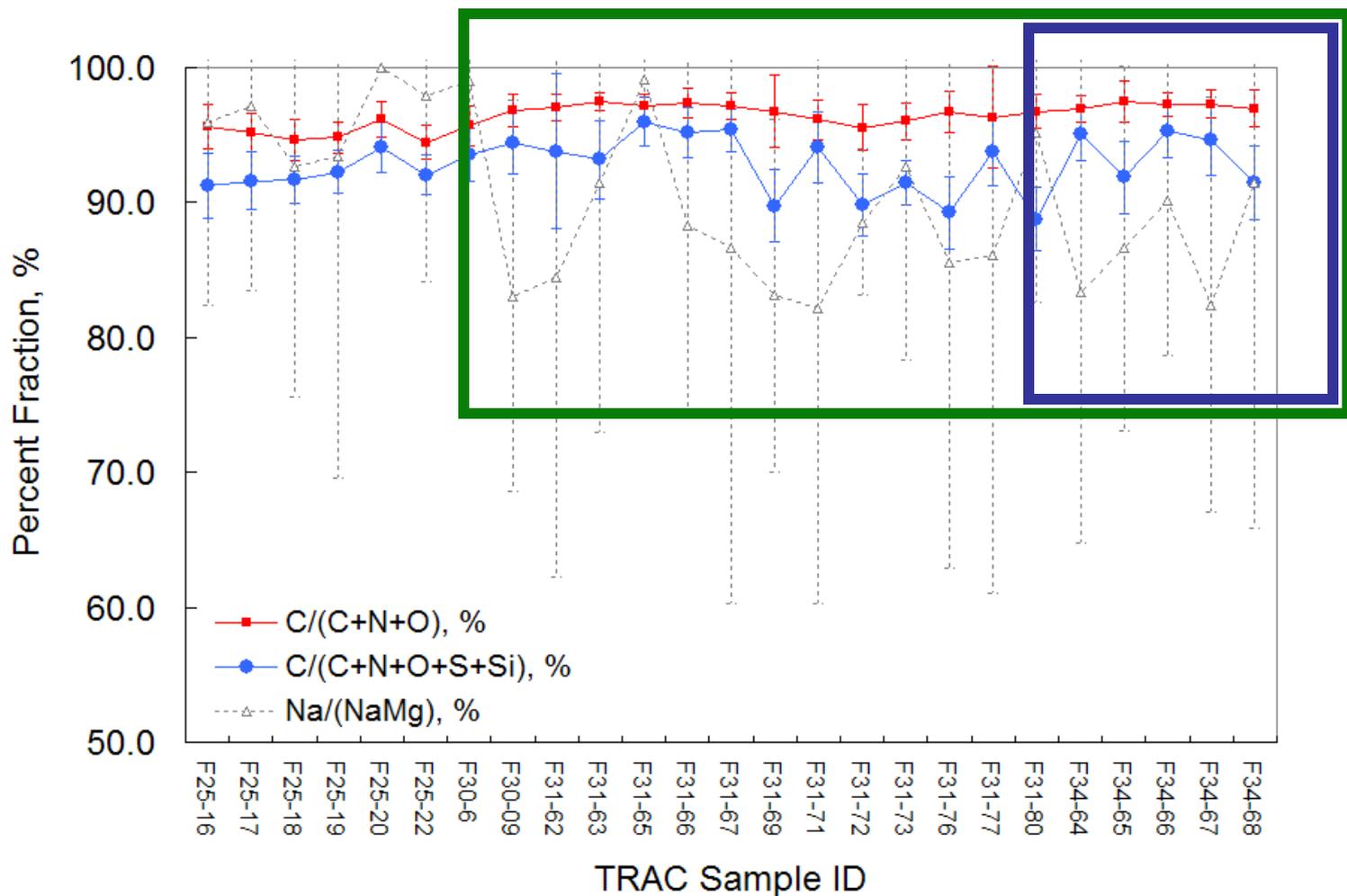


EDX Elemental compositions



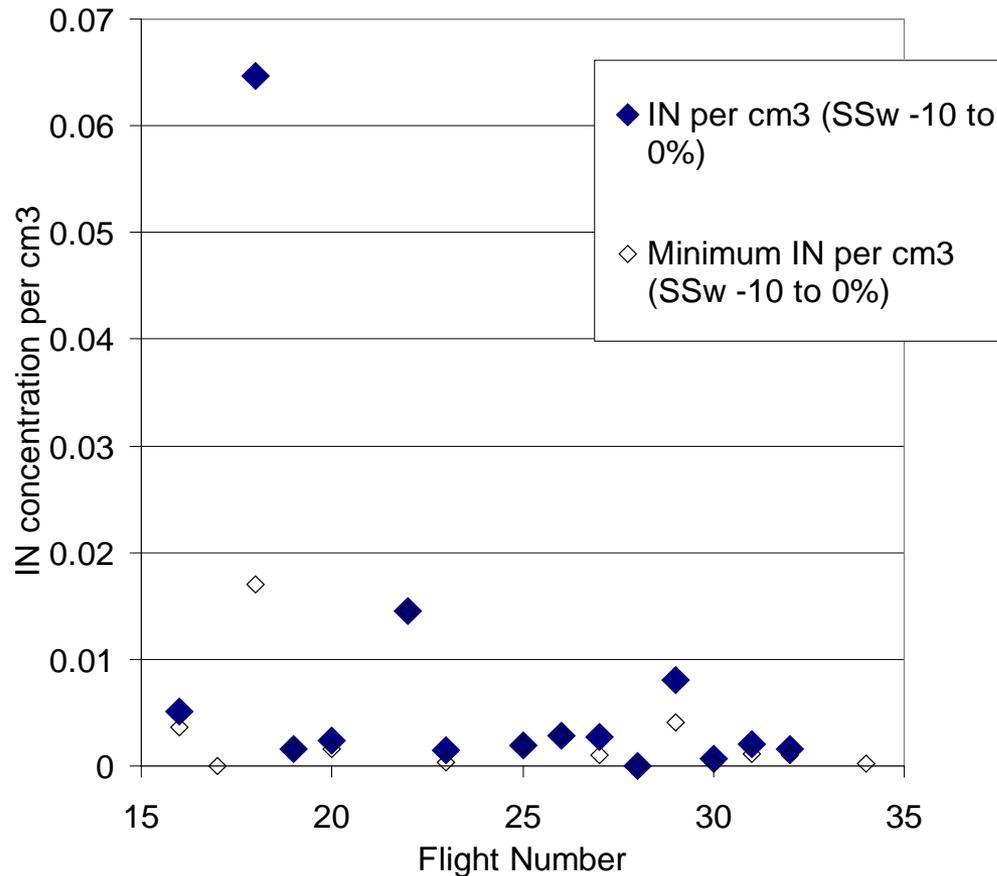
Significant fraction of Na,Mg coincides with high IN activity period.

Elemental ratios of C/(CNO), C/(CNOSi), and Na/(NaMg) measured by CCSEM/EDX analysis in biomass burning plume (F25), 2nd golden day mix-phase cloud (F30, F31), and high ice nucleation activity cloud (F34). F30-6, F31-62 to 67, F34-64 to 67 were collected when CVI was on. Error bars represent one standard deviation from mean.



**More Mg in cloud samples..
Active Ice Nuclei**

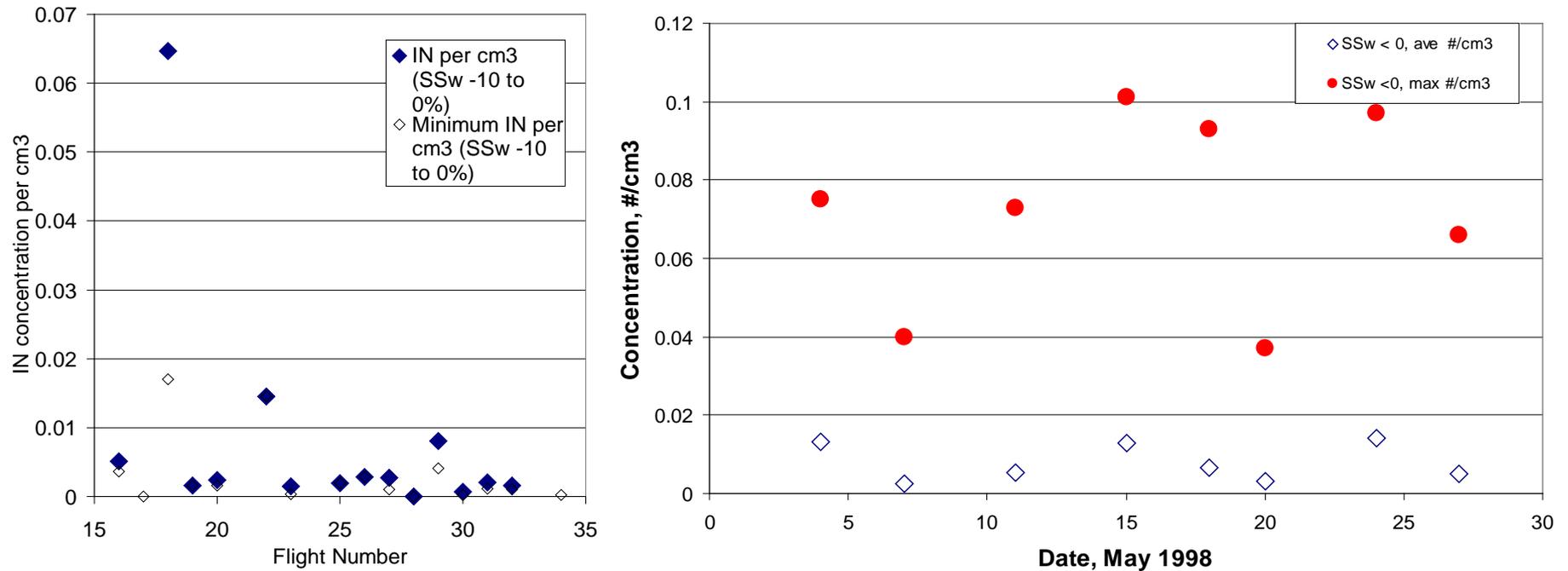
IN Time Variation during ISDAC



This is consistent with SHEBA IN measurements. (Spring)
Not with M-PACE (Fall)
Present of different aerosol composition in SPRING?

IN Time Variation during Arctic Springtime

Ice Nucleation during SHEBA, Springtime 1998



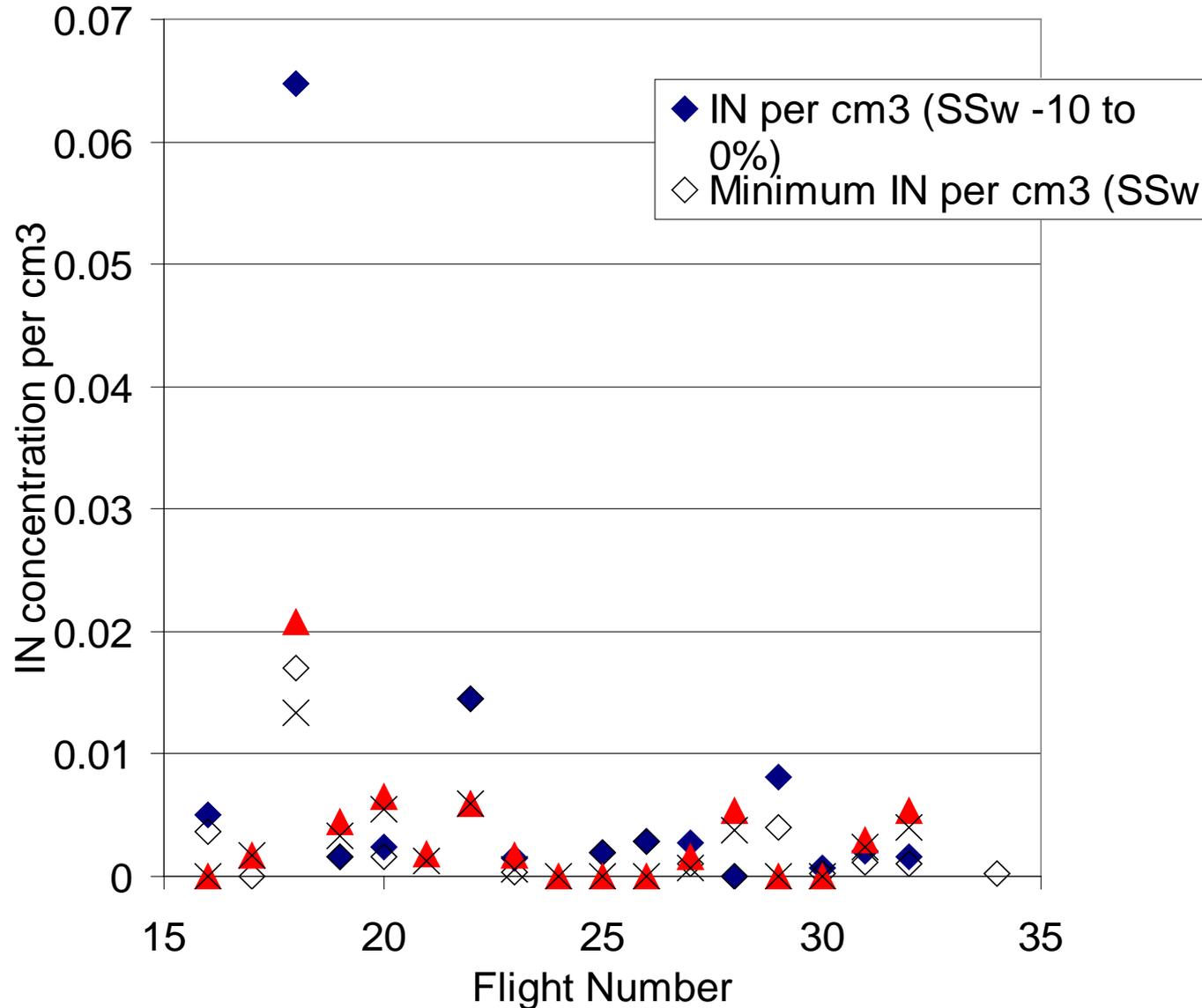
Rogers, 2001

This is consistent with SHEBA IN measurements. (Spring)

(Not with M-PACE (Fall))

Present of different aerosol composition in SPRING?

IN Time Variation during ISDAC



Conclusions

Observed CFDC IN concentrations – highly variable

IN concentrations must be considered in the context of other parameters

Seasonal variations in IN

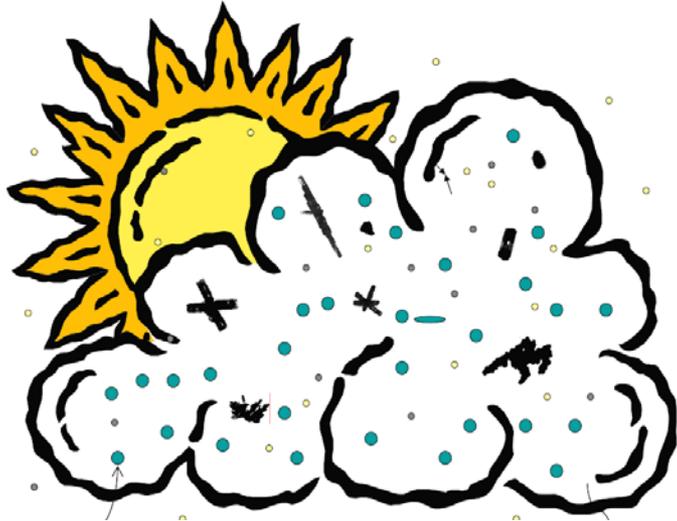
Next steps:

Further Correlations with aerosol composition

Further Testing of aerosol size and ice crystal size

Revisit ambient-CVI transitions

Out of cloud and in cloud comparisons



Acknowledgements:

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Mary Giles Berkeley Lab
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Peter Liu
Anne Marie MacDonald
Alla Zelenyuk

The pilots and crew of the CONVAIR 580

DOE ARM and NSF CAREER

080426 - f31 - CFDC - v1.0.txt - CVI off

