The dependence of arctic mixed-phase stratus ice cloud microphysics on aerosol concentration using observations acquired during ISDAC

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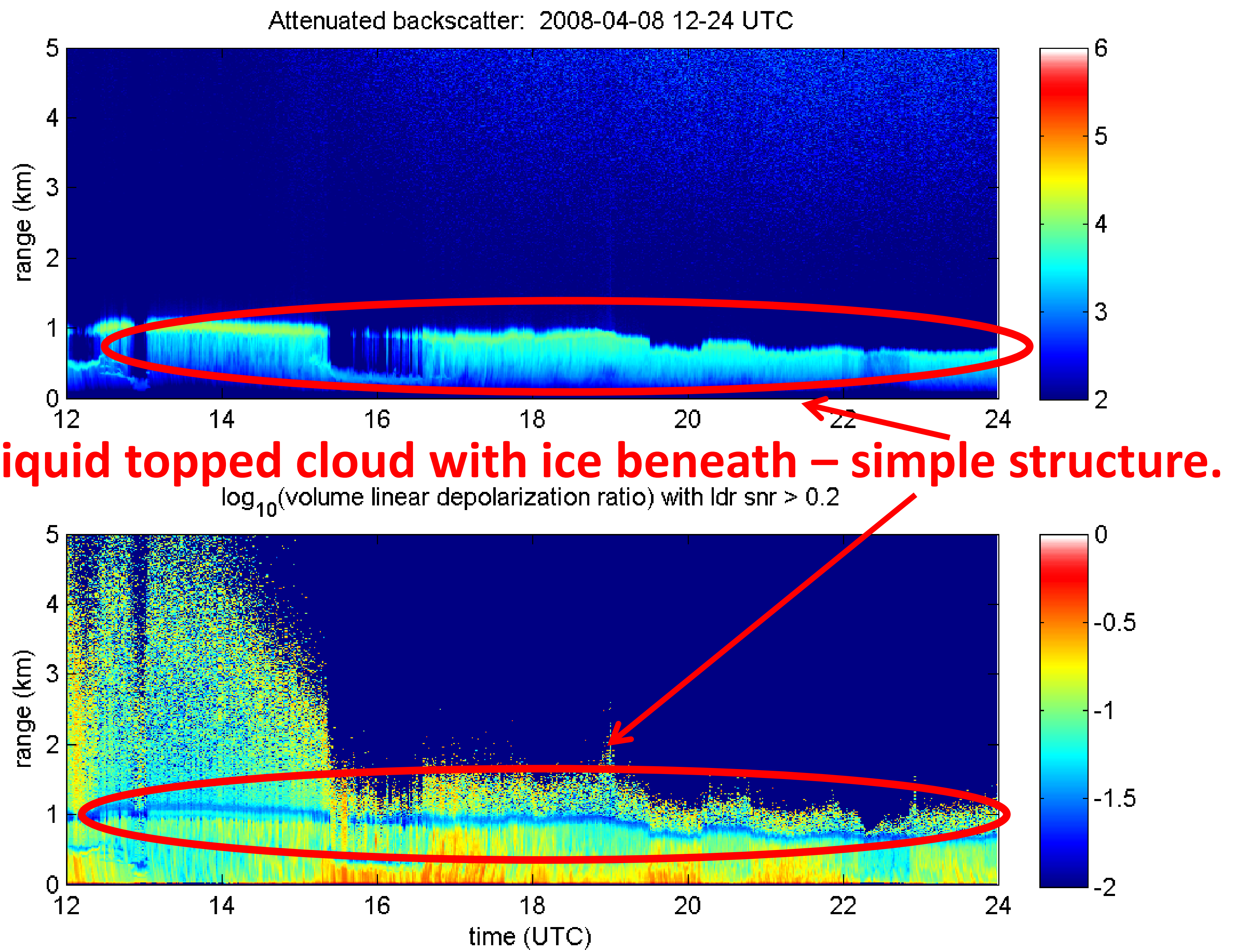


Attenuated backscatter: 2008-04-08 12-24 UTC
range (km)
Liquid topped cloud with ice beneath – simple structure.
log10(volume linear depolarization ratio) with ldr snr > 0.2
range (km)
time (UTC)

Overview

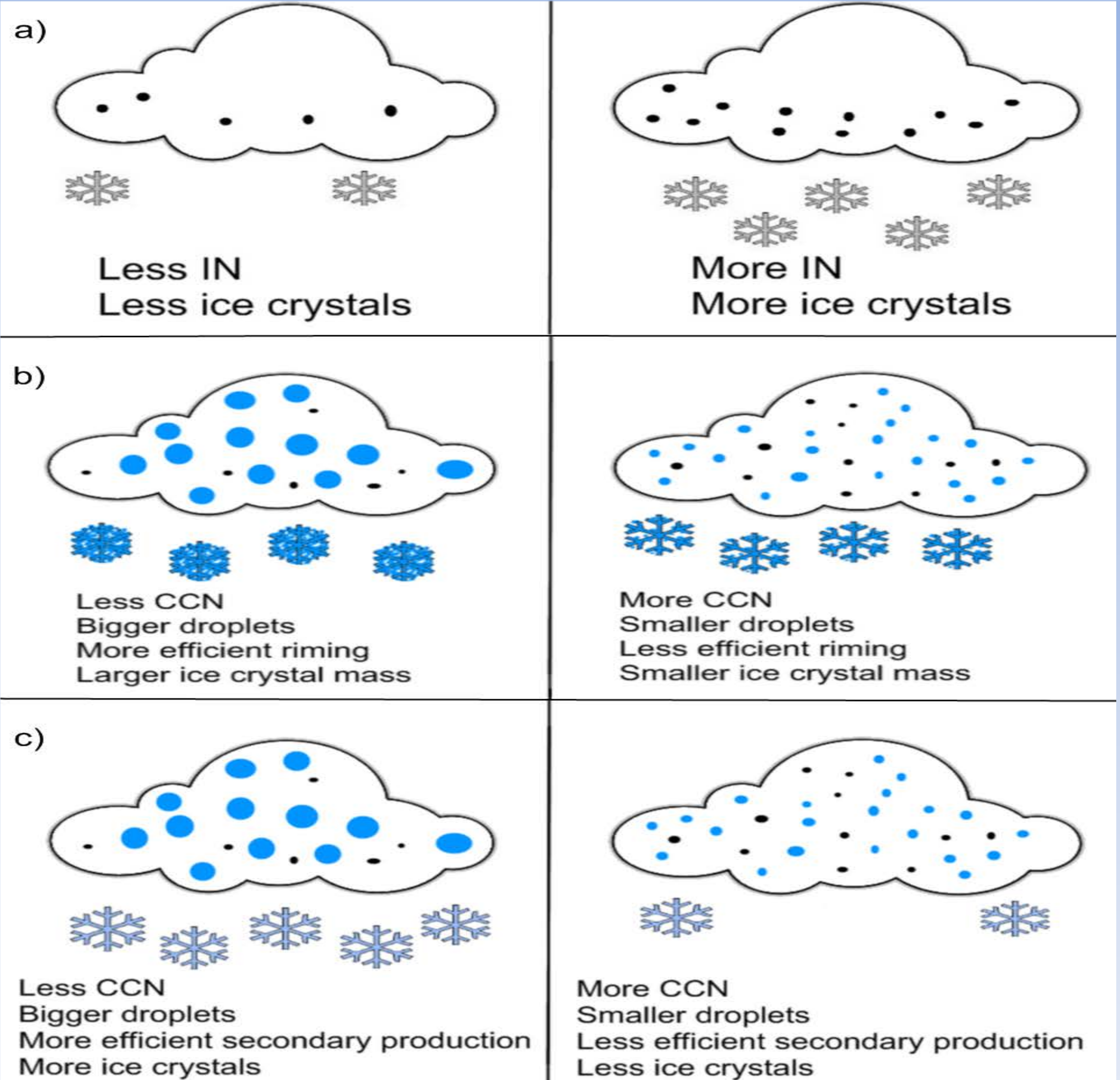
1. **Motivation**
   - What different effects can aerosols have on mixed-phase clouds?

2. **ISDAC Data**
   - Development of value added cloud product

3. **Observed Aerosol-Cloud Relations**
   - What do correlations between cloud μphysics & aerosols tell us about indirect effects?

4. **Comparison of ISDAC/M-PACE Data**
   - Impact of varying surface & aerosol conditions

5. **Future investigations**
   - ISDAC/M-PACE data ideal for examining impact of surface, meteorological & aerosol conditions



Glaciation indirect effect (Lohmann 2002)

Riming indirect effect (Borys et al. 2004)

Cold 2nd indirect effect (Rangno & Hobbs 2001; Lance et al. 2011

Development of Integrated Cloud Product

- Have probe specific information

- Developed integrated cloud product to derive cloud parameters by:
1) Compare N(D) in overlapping size ranges
2) Conduct mass closure tests

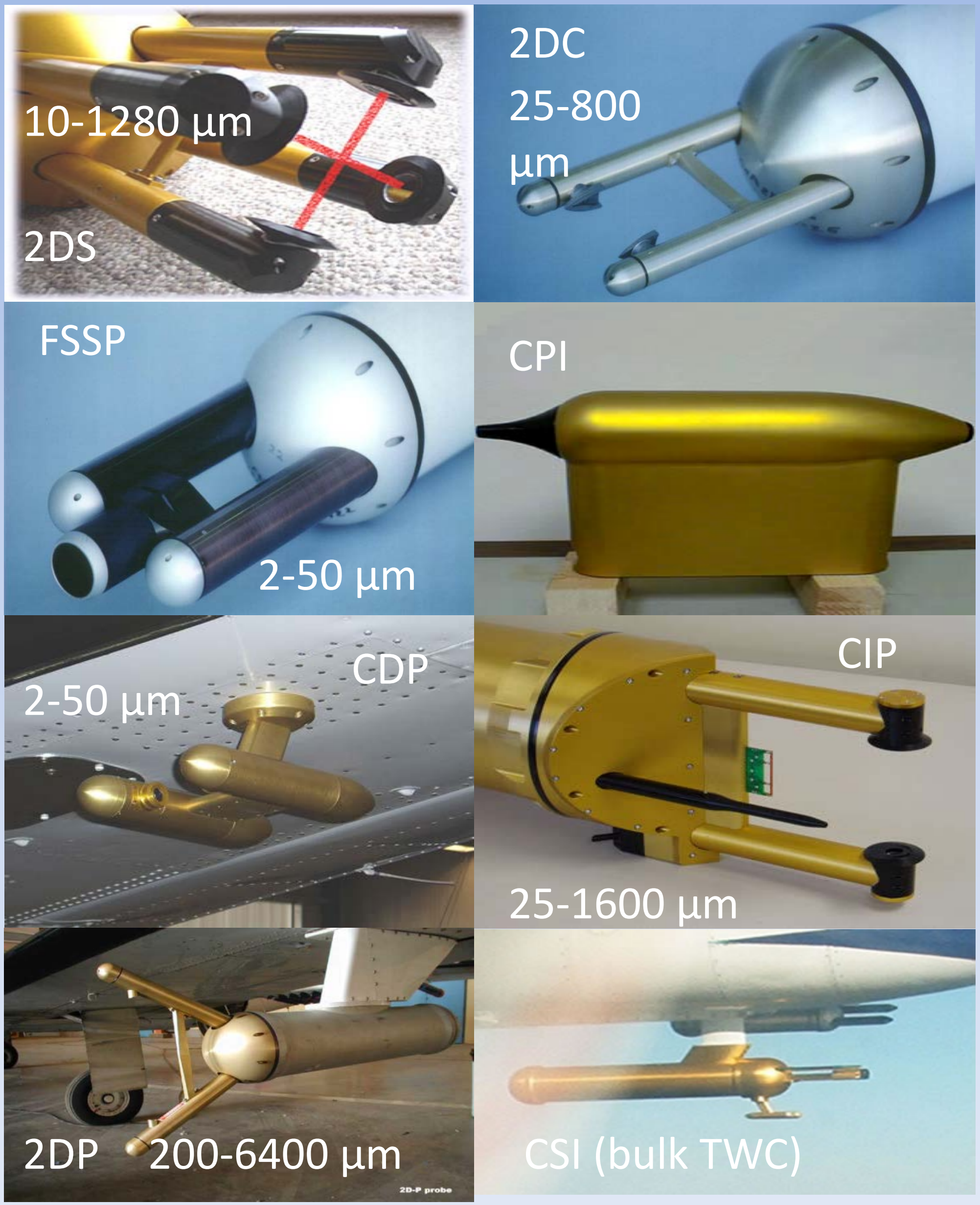



Image of single-layer cloud sampled on 8 April
Korolev and Strapp

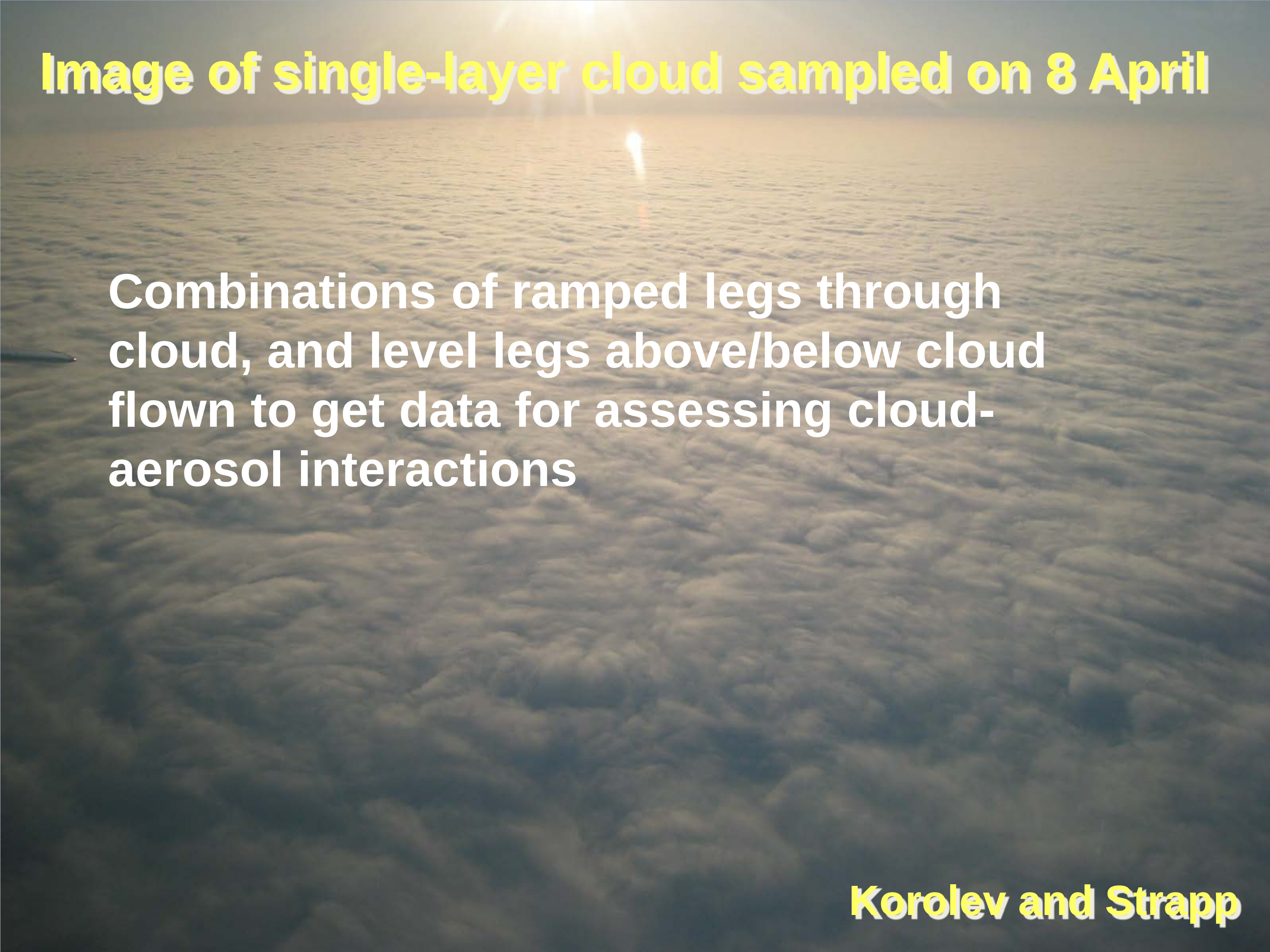
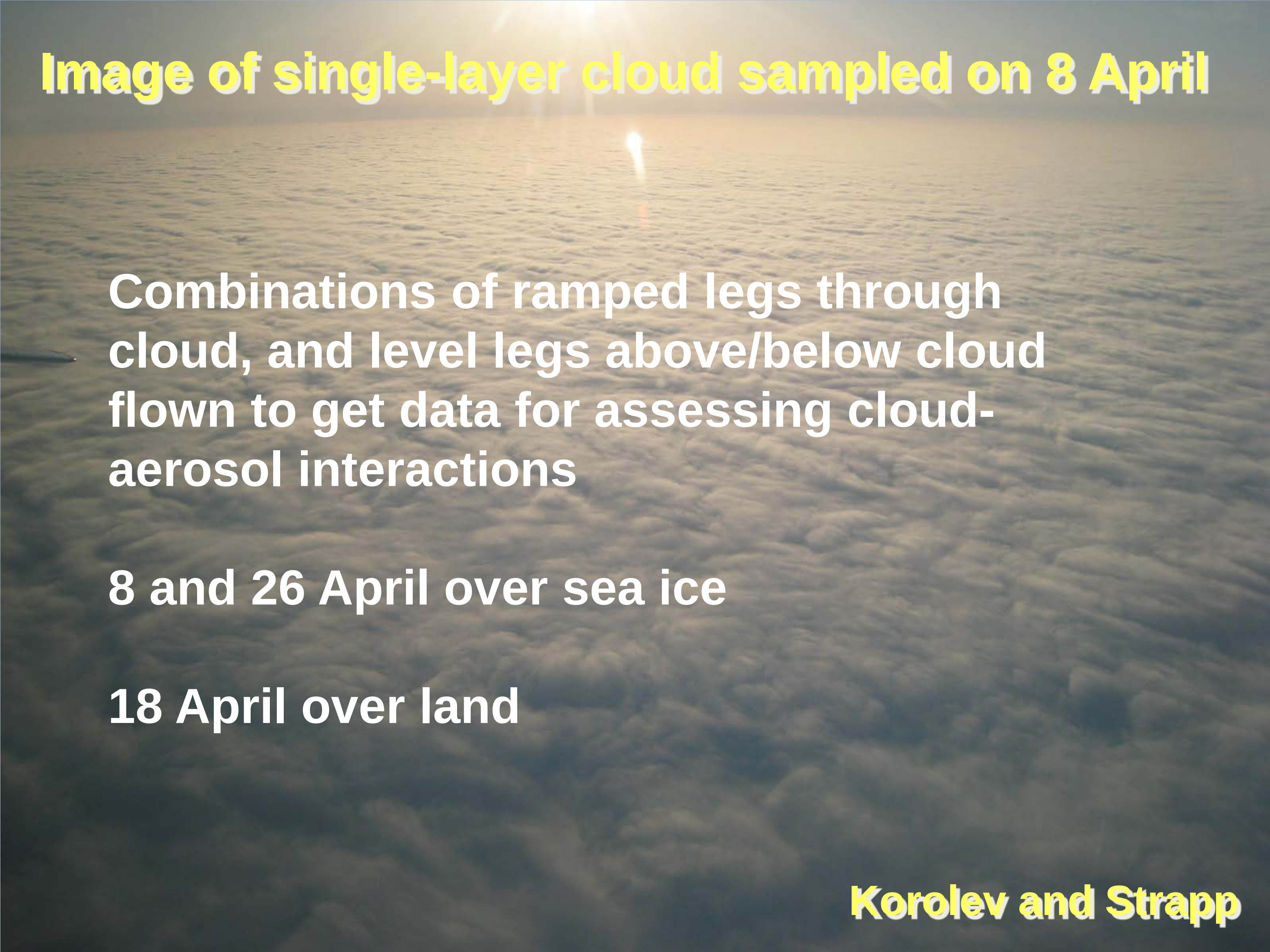


Image of single-layer cloud sampled on 8 April
Combinations of ramped legs through cloud, and level legs above/below cloud flown to get data for assessing cloud-aerosol interactions
Korolev and Strapp

Image of single-layer cloud sampled on 8 April



Combinations of ramped legs through cloud, and level legs above/below cloud flown to get data for assessing cloud-aerosol interactions

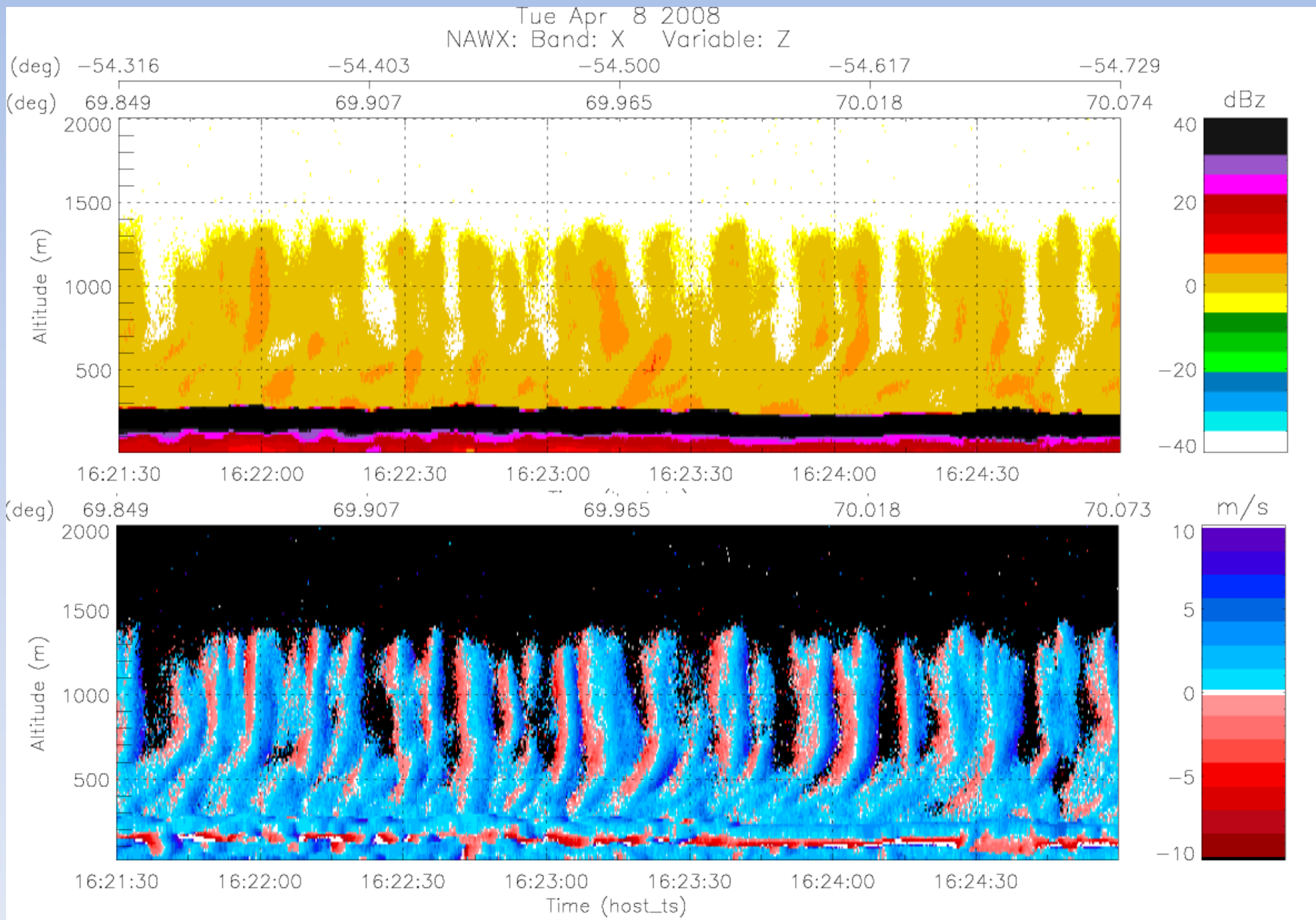
8 and 26 April over sea ice

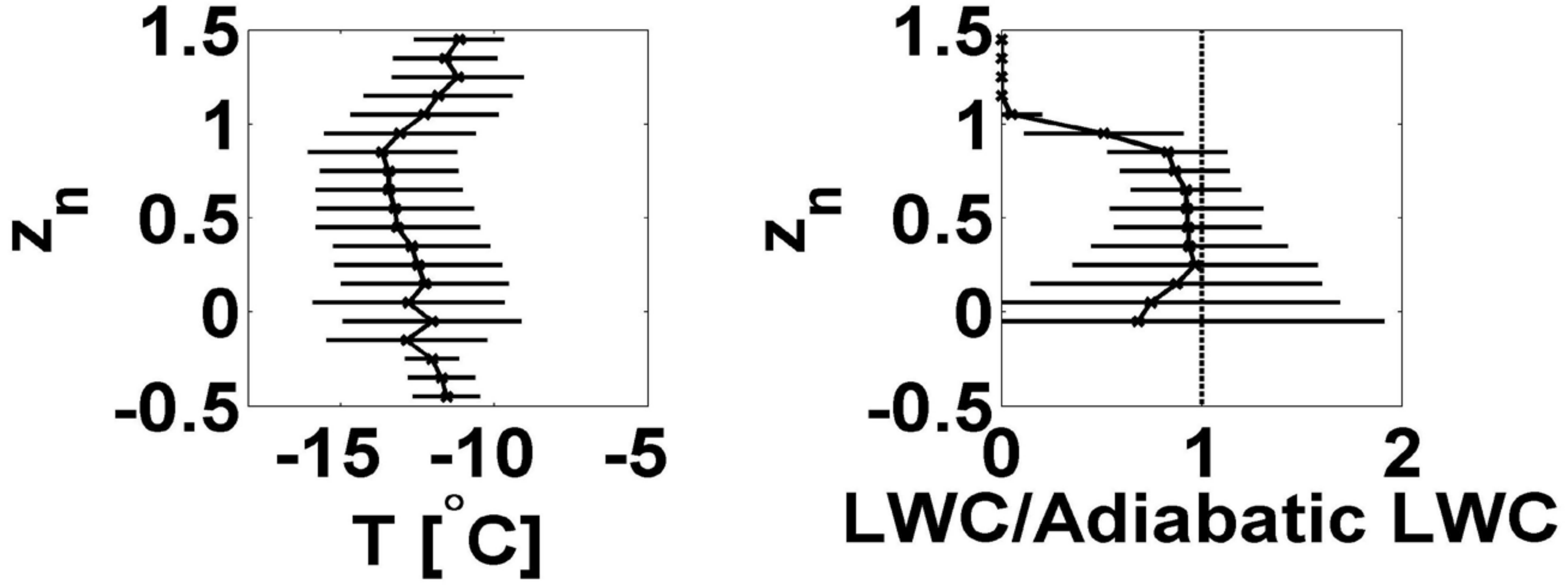
18 April over land

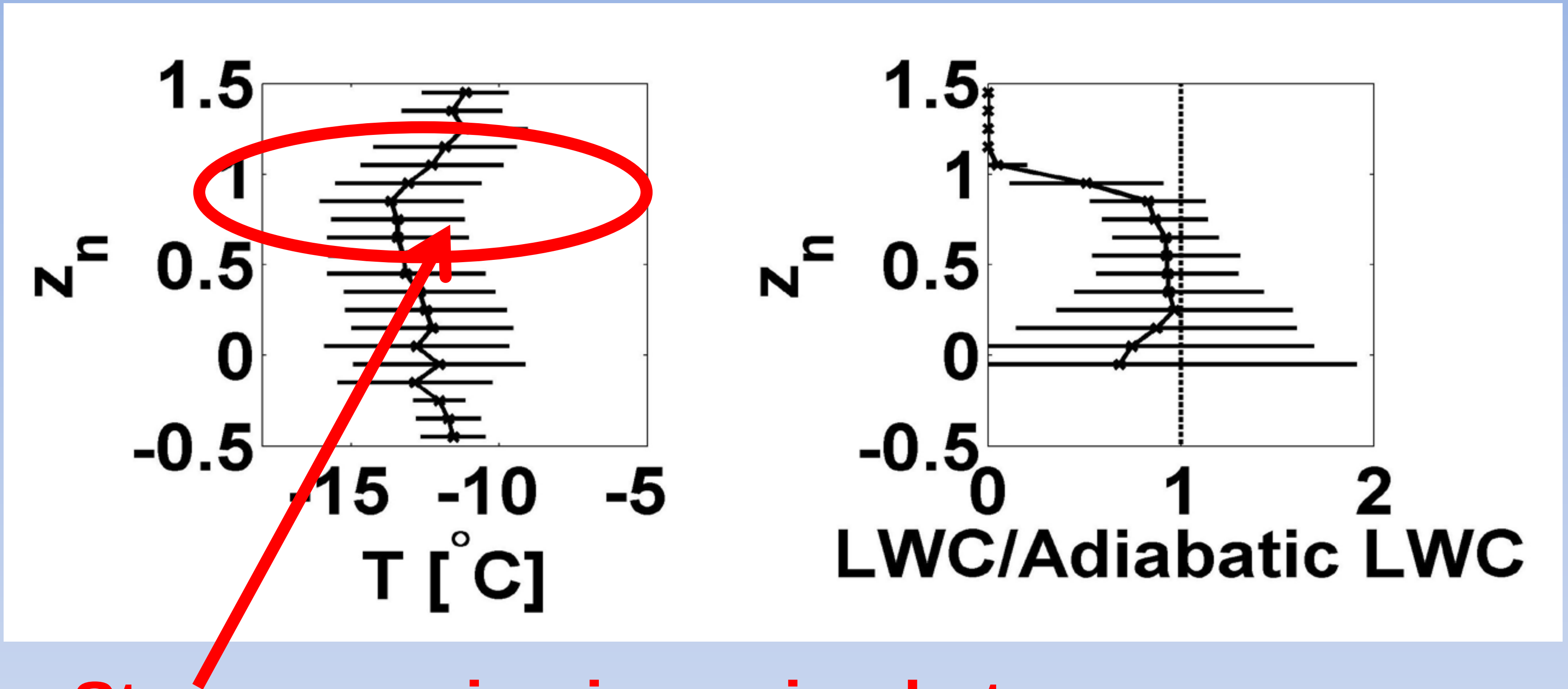
Korolev and Strapp

NRC NAX radar

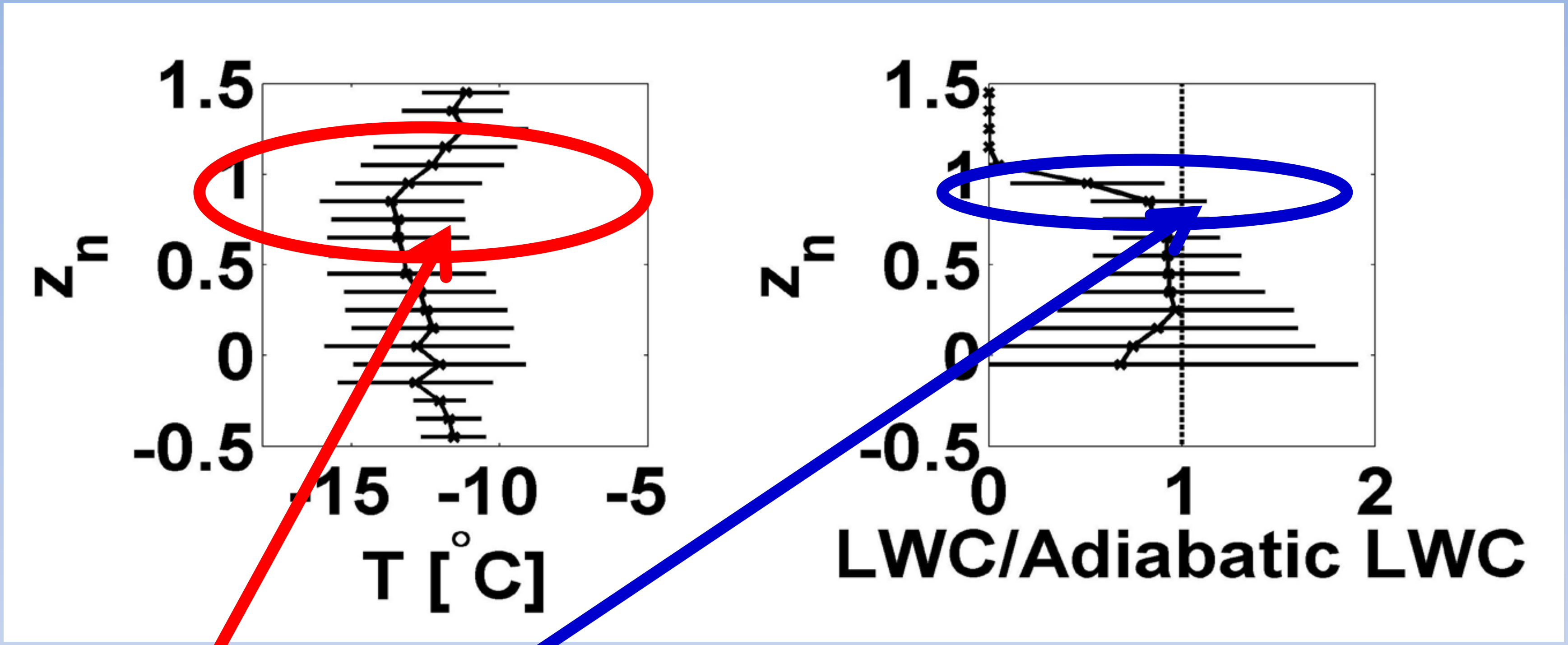
X band radar Z and V_d crossections




1.5
1
0.5
0
-0.5
z_n
-15
-10
-5
T [°C]
1.5
1
0.5
0
-0.5
z_n
0
1
2
LWC/Adiabatic LWC

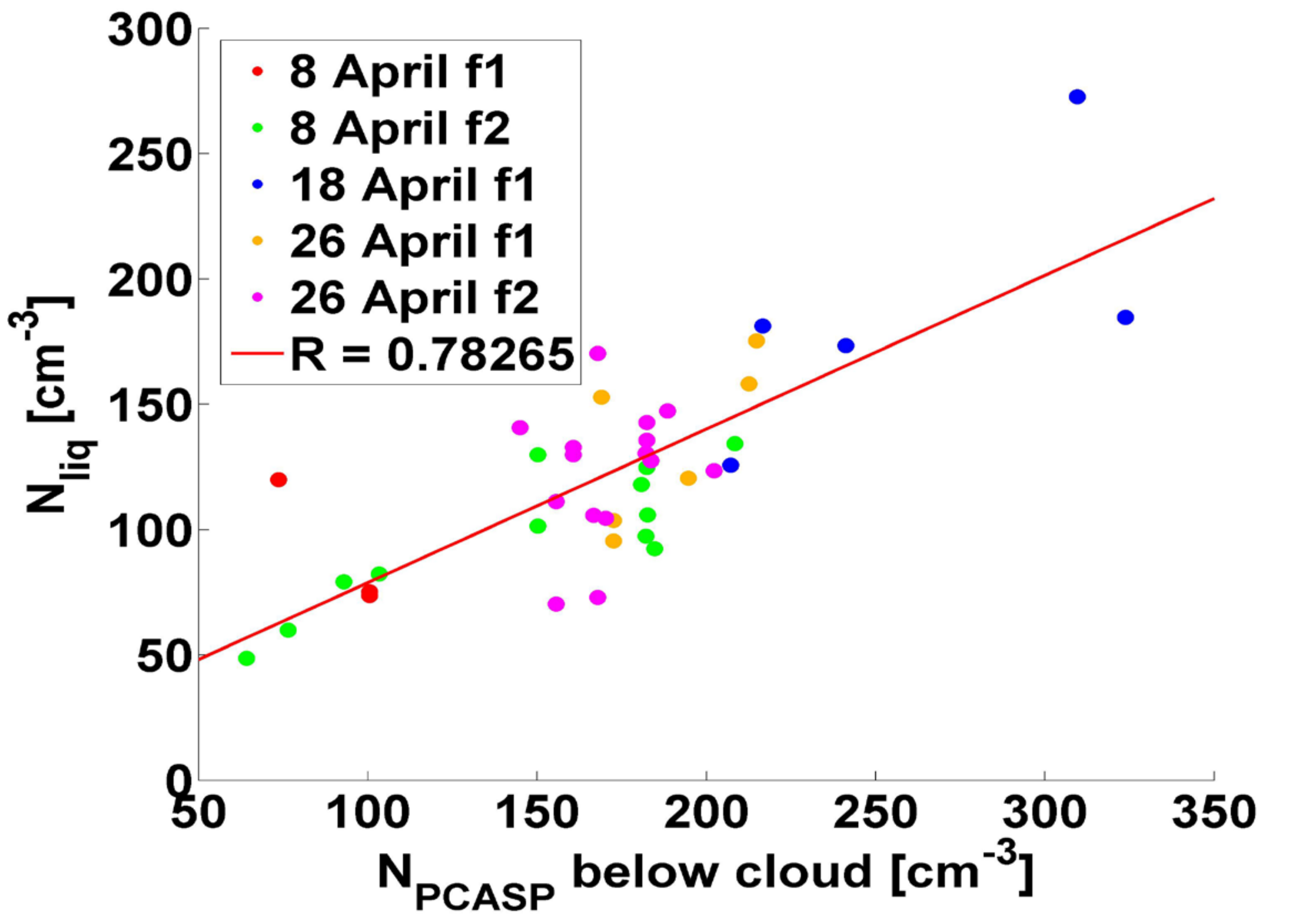


Strong capping inversion between normalized altitude (z_n) of 0.8 to 1.2

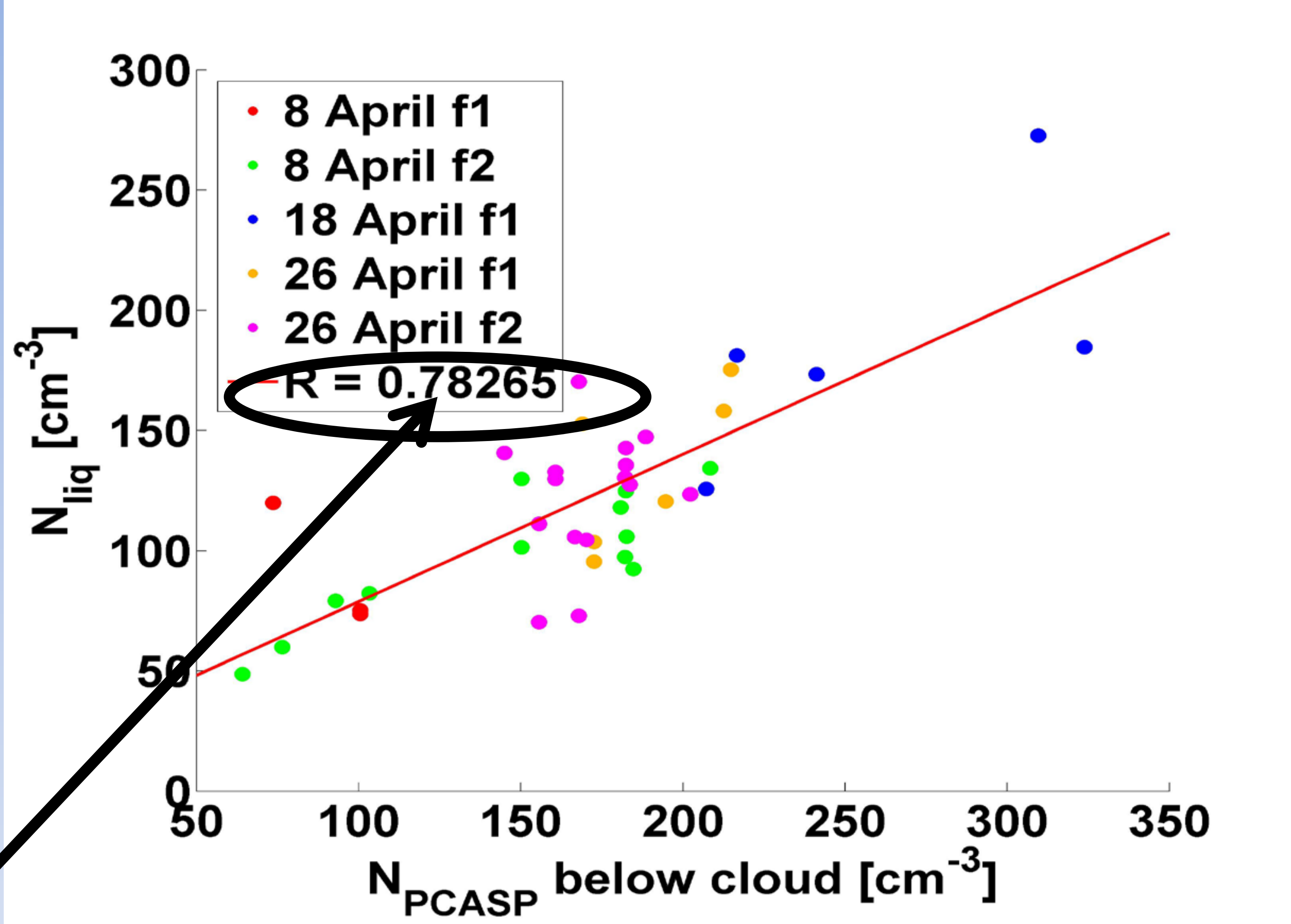


Strong capping inversion between normalized altitude (z_n) of 0.8 to 1.2

Subadiabatic LWC for z_n > 0.8 consistent with entrainment of dry air above cloud top or growth of ice at expense of liquid water



8 April f1
8 April f2
18 April f1
26 April f1
26 April f2
R = 0.78265
300
250
200
150
100
50
0
50
100
150
200
250
300
350
N_{liq} [cm^{-3}]
N_{PCASP} below cloud [cm^{-3}]



Strong correlation suggests aerosols in accumulation mode measured by PCASP were nucleated near cloud base

Ice cloud properties not well correlated with PCASP concentrations below cloud → look at how correlated with above cloud aerosol

How does this relate to #s of IN?

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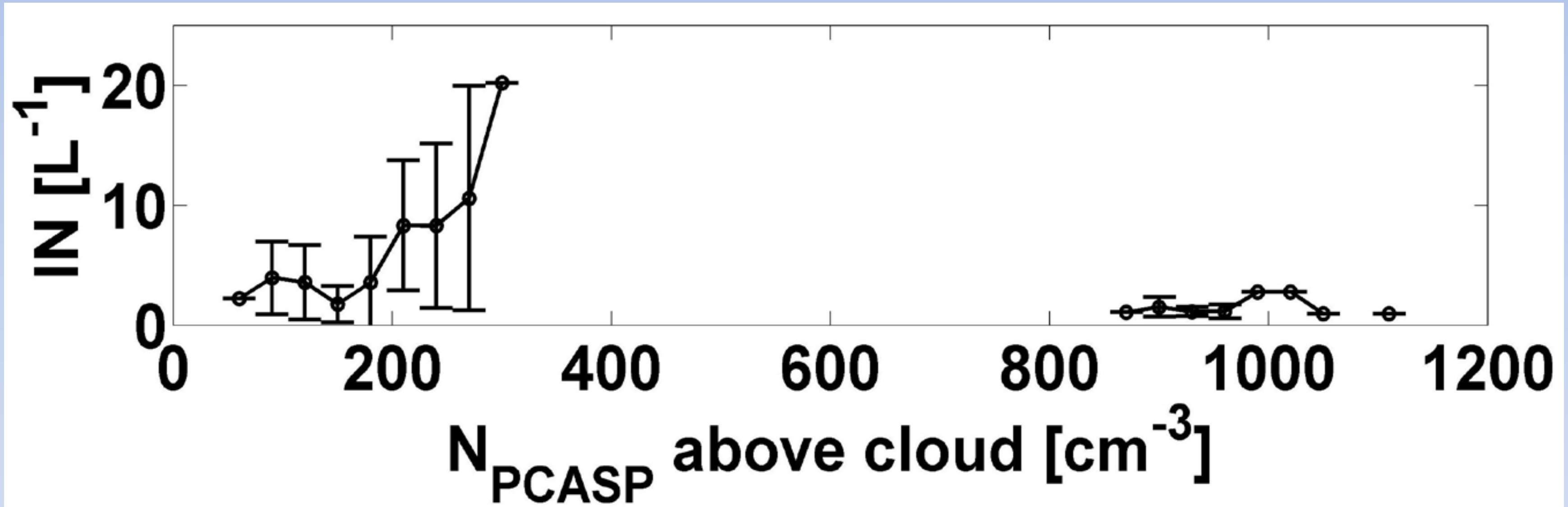
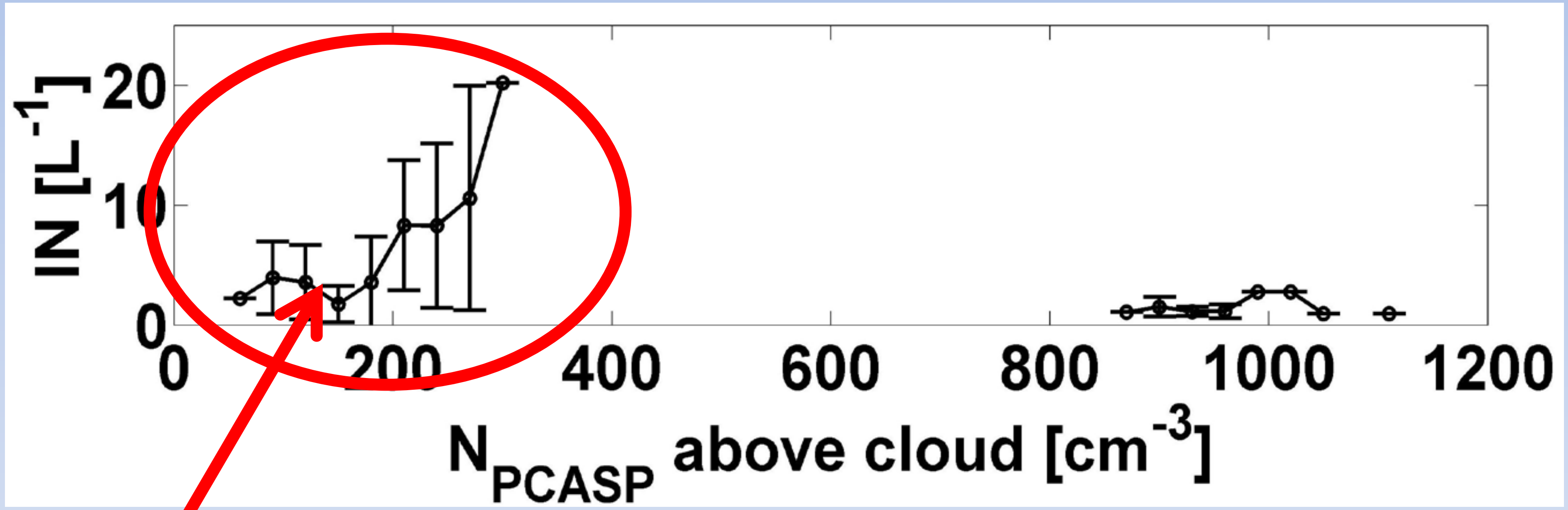


IN sampled at ~-25˚C at water sub-saturation

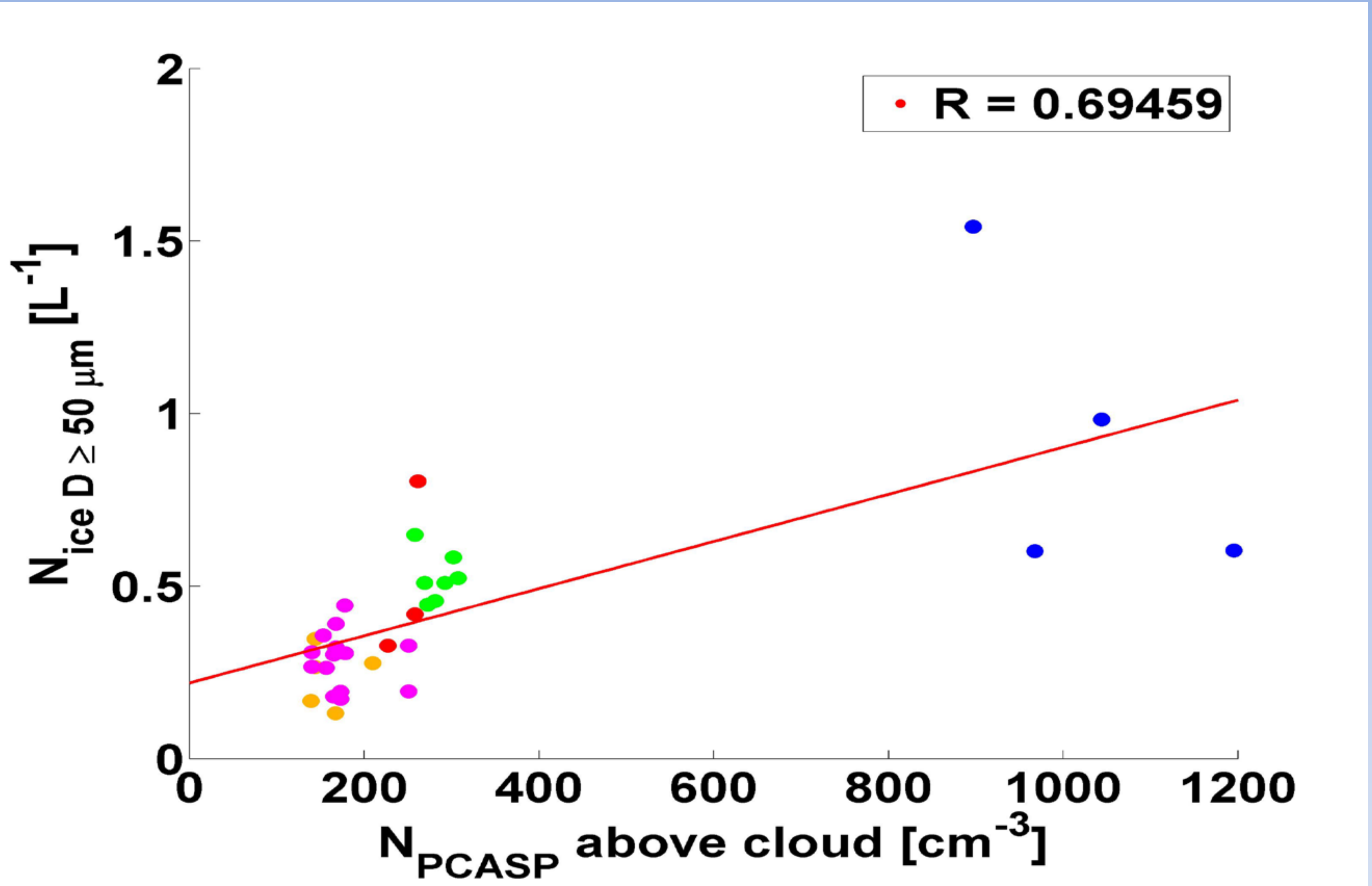
Ice cloud properties not well correlated with PCASP concentrations below cloud → look at how correlated with above cloud concentration

How does this relate to #s of IN?

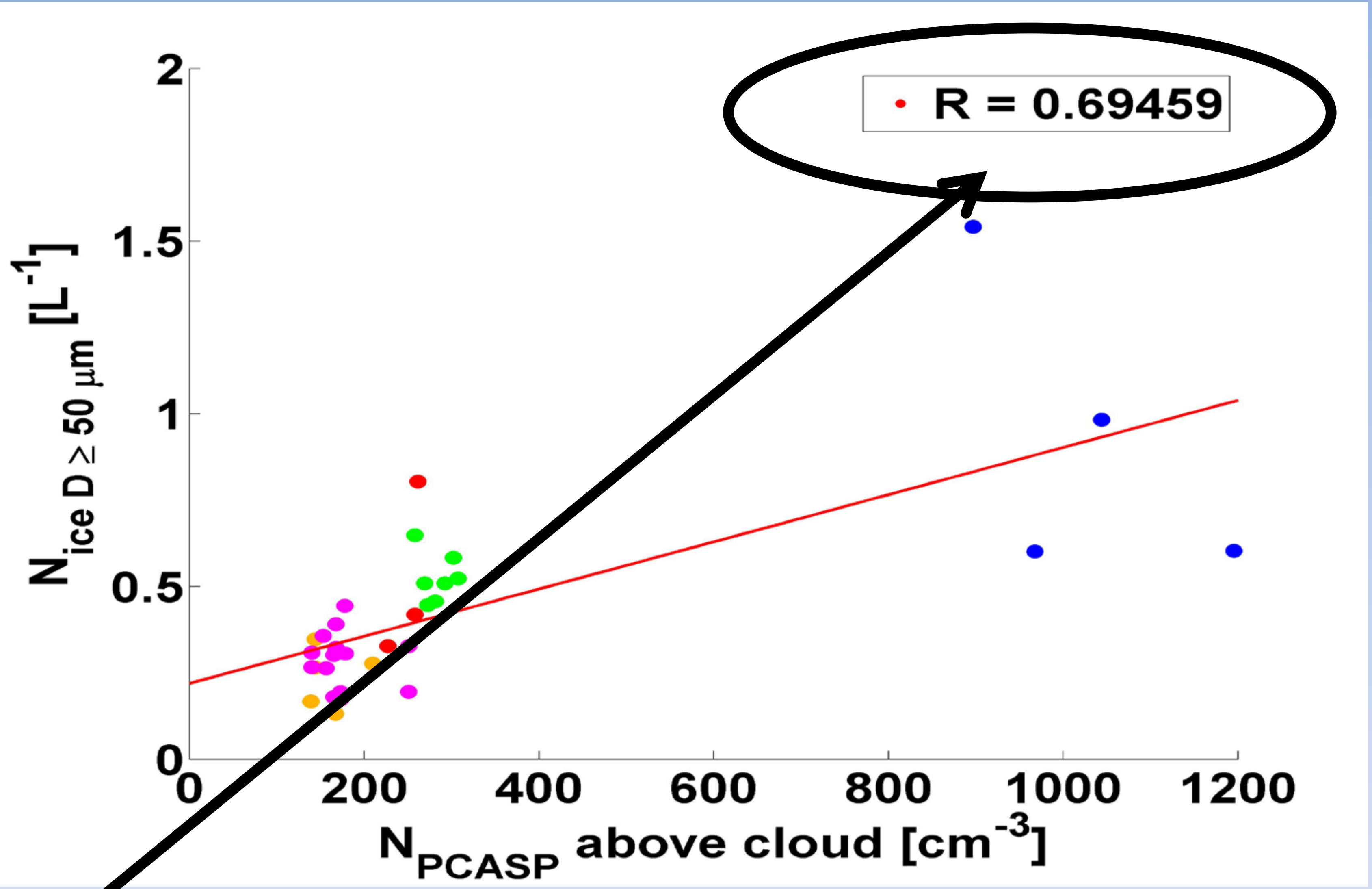


IN sampled at ~-25˚C at water sub-saturation

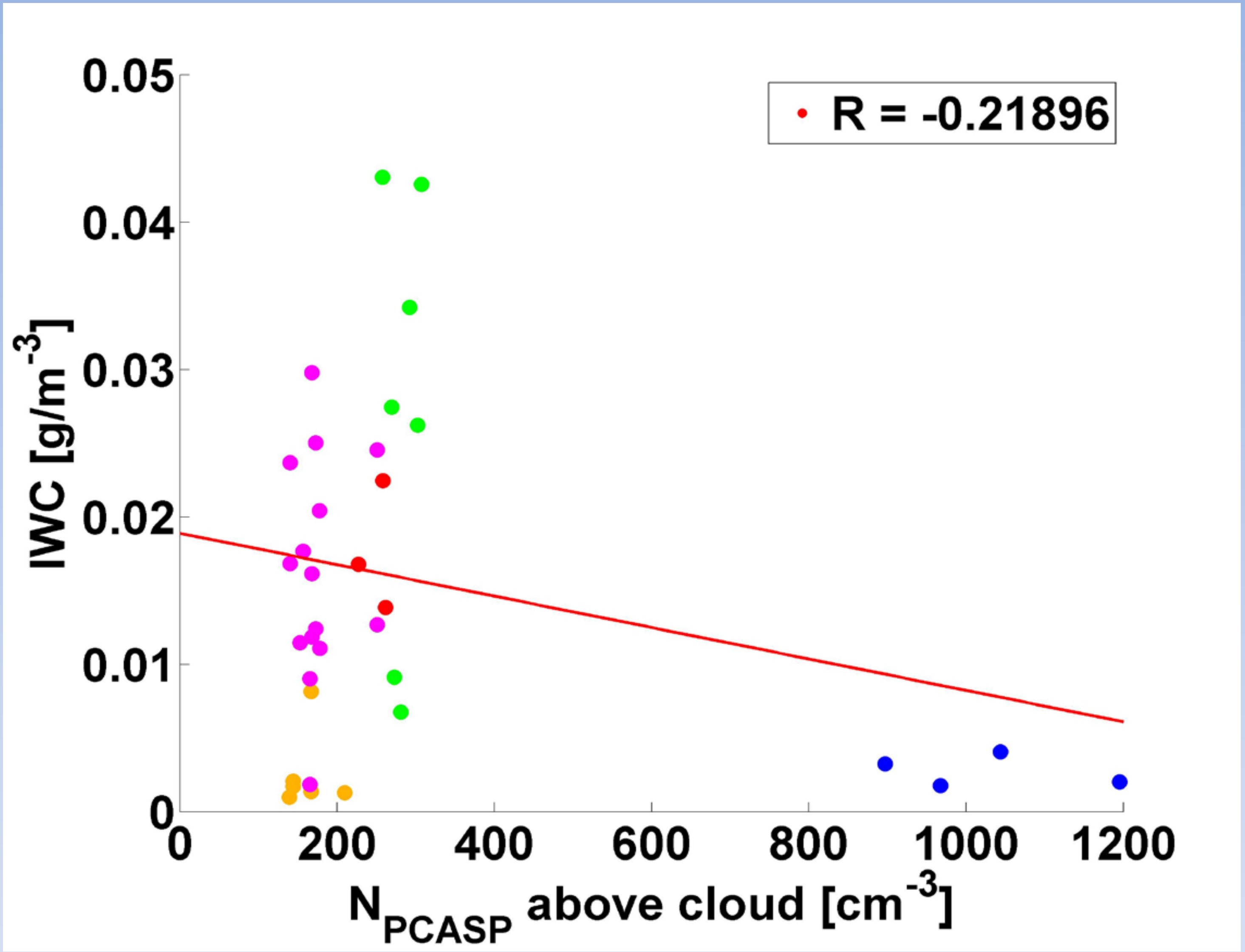
IN increase with N_{PCASP} < 400 cm^{-3}



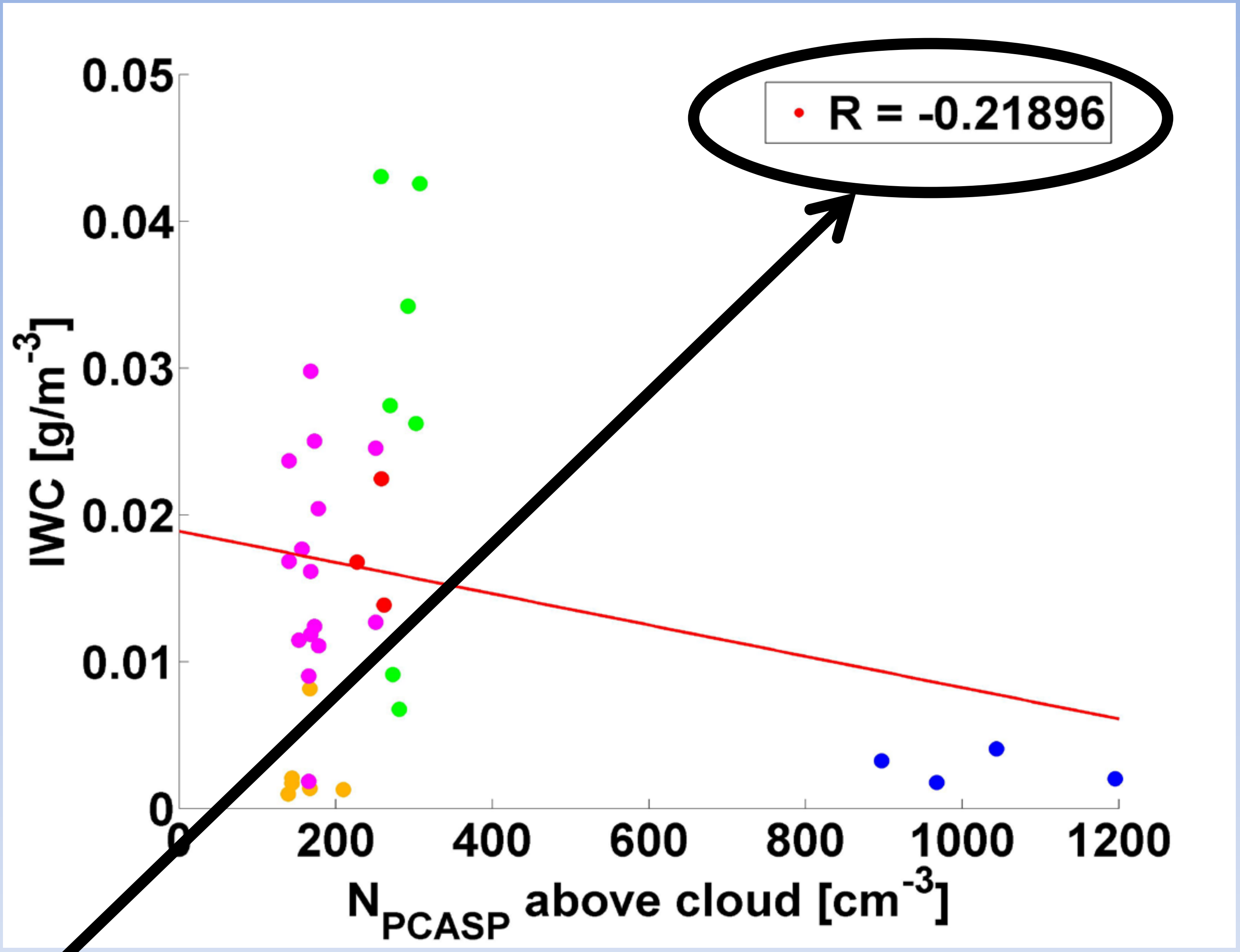
R = 0.69459
$N_{ice\ D \geq 50\ \mu m}$ [L^{-1}]
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
N_{PCASP} above cloud [cm^{-3}]



Strong correlation of N_{ice} & N_{PCASP} consistent with glaciation indirect effect, possibly from IN entrained above cloud



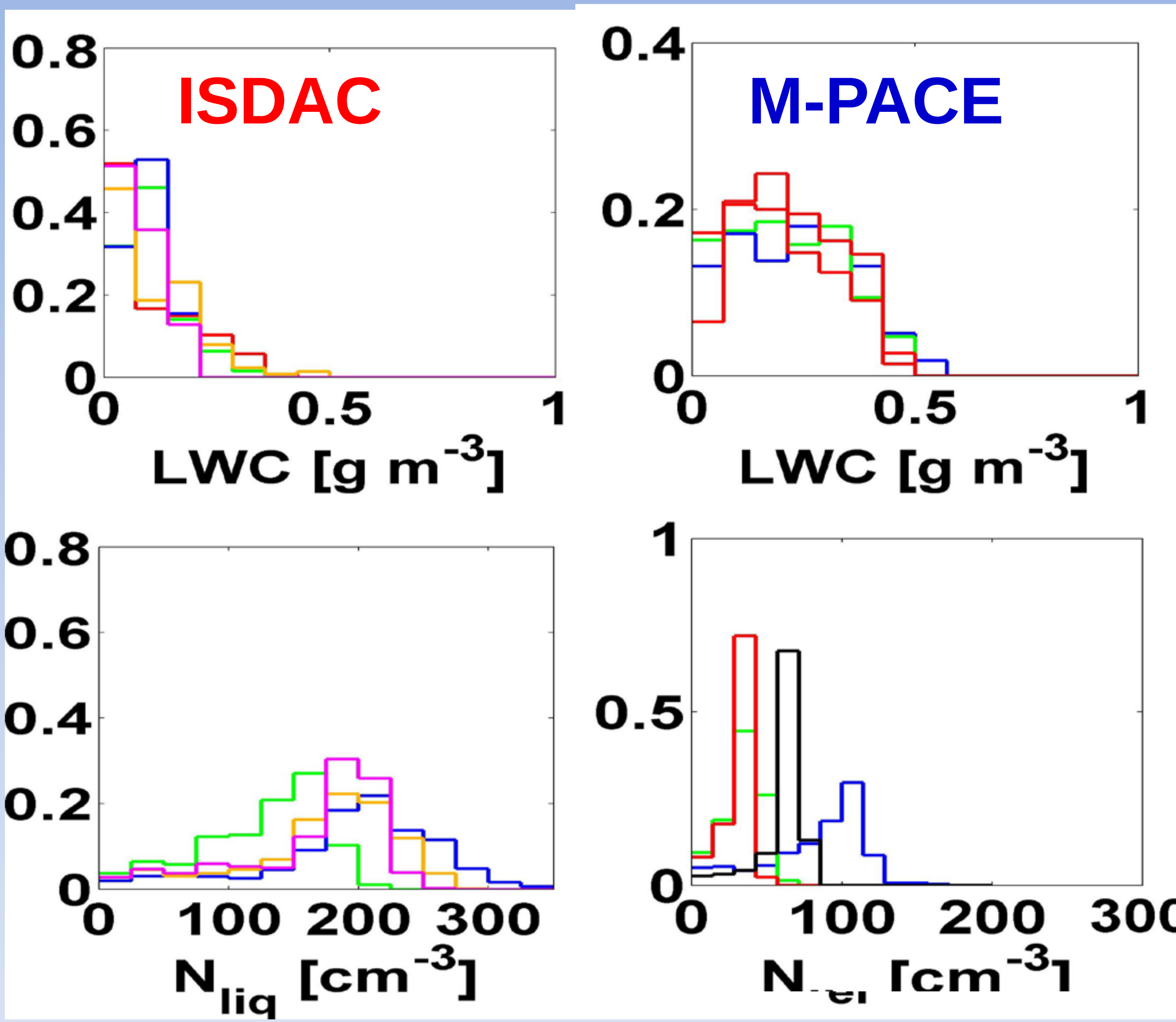
R = -0.21896
0.05
0.04
0.03
0.02
0.01
0
IWC [g/m-3]
0
200
400
600
800
1000
1200
N PCASP above cloud [cm-3]

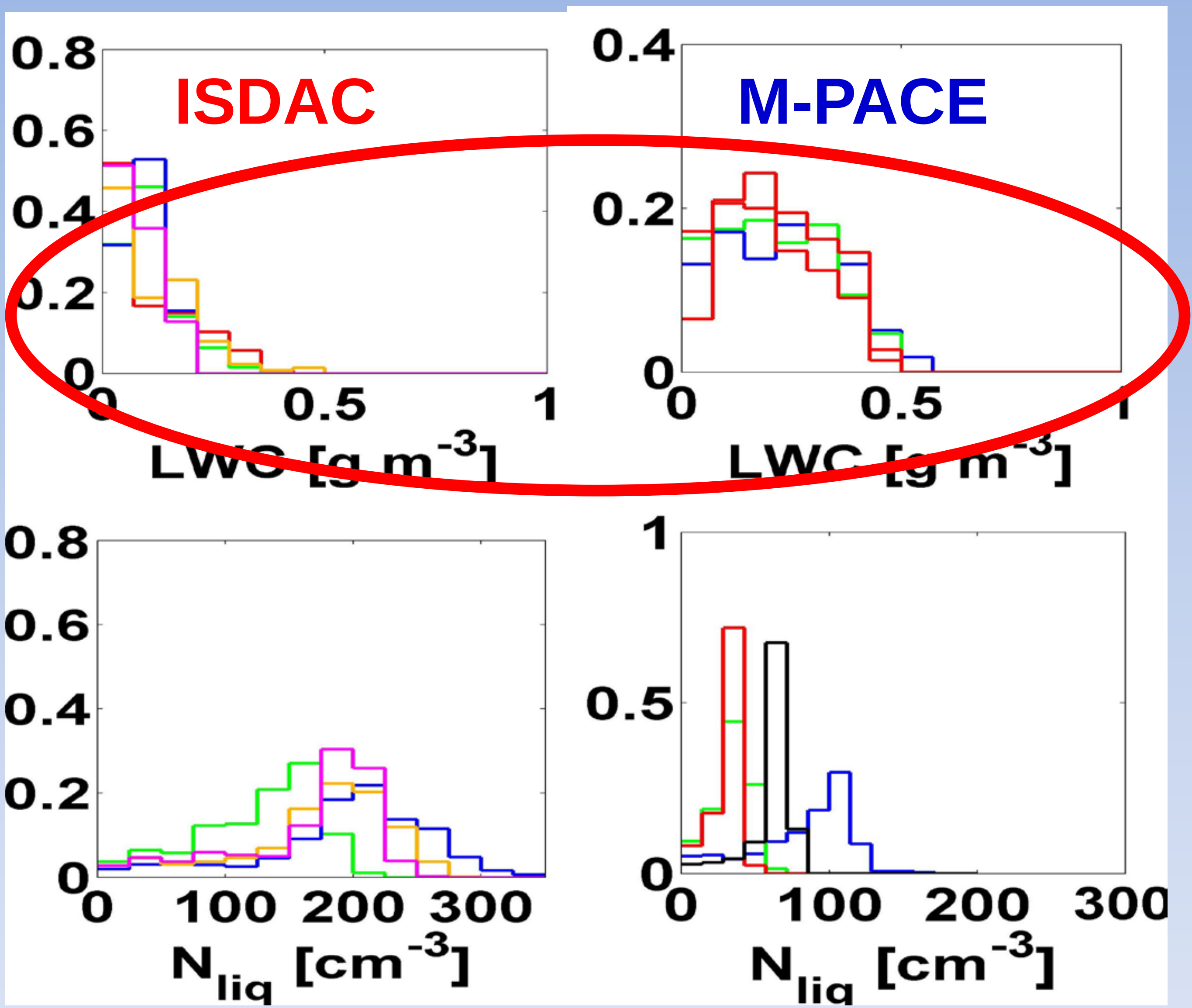


Little evidence of riming indirect effect, but liquid contents of cloud not sufficient for a lot of riming growth on most days

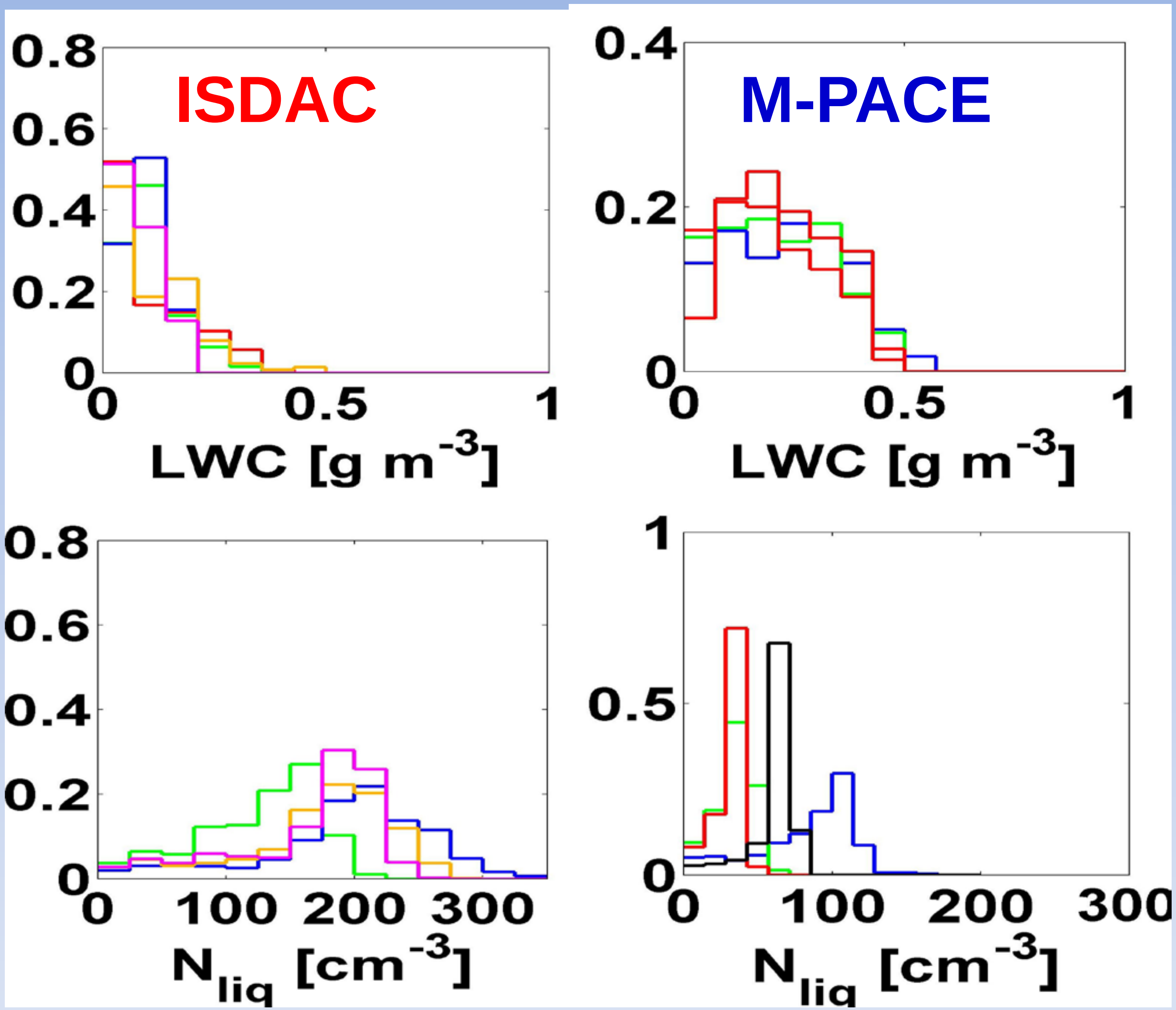
M-PACE/ISDAC

- **Compare frequency distributions of cloud properties from M-PACE (pristine, open water) and ISDAC (dirtier, less open water)**

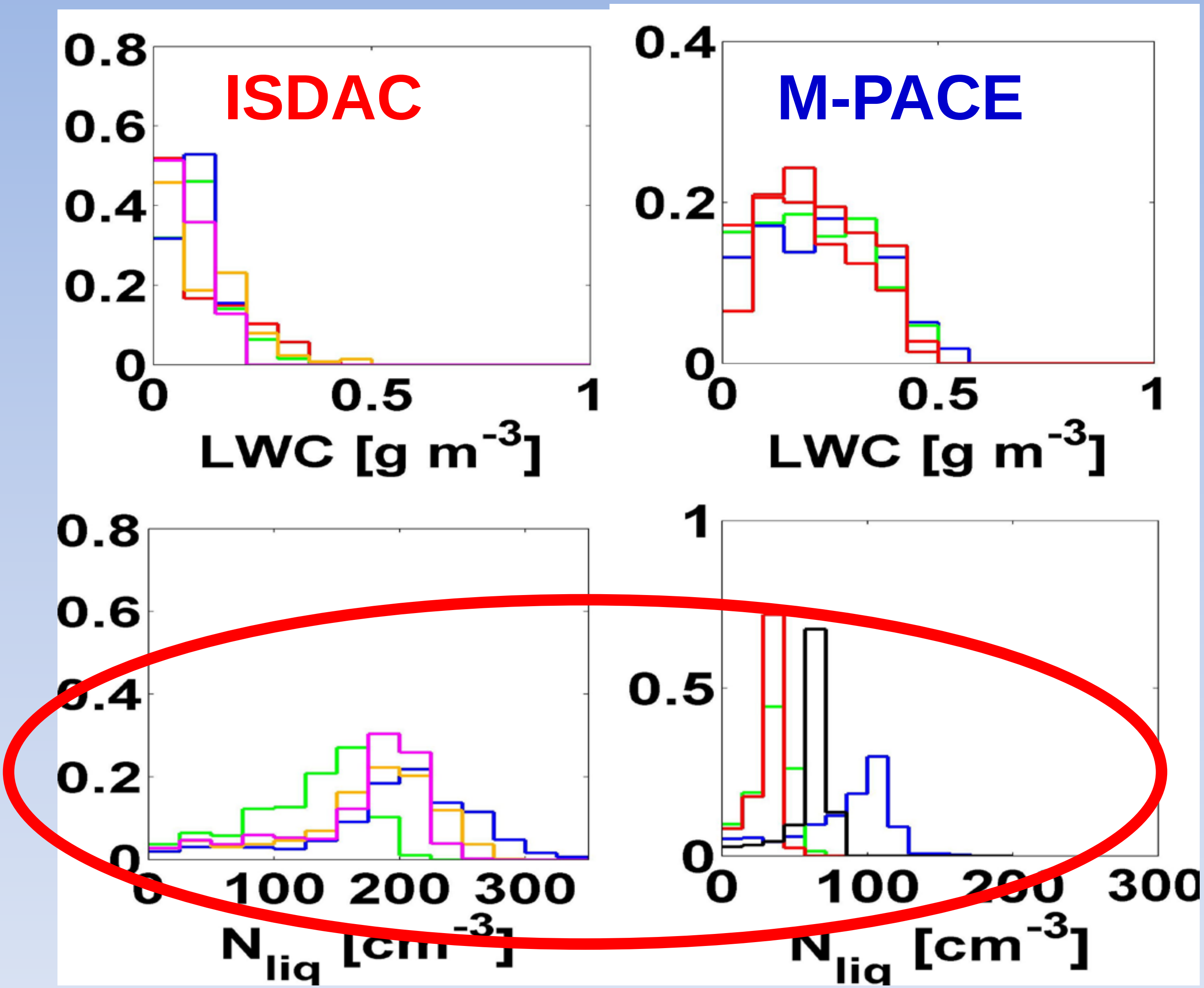

ISDAC
M-PACE
0.8
0.6
0.4
0.2
0
0.5
1
LWC [g m-3]
0.4
0.2
0
0.5
1
LWC [g m-3]
0.8
0.6
0.4
0.2
0
100
200
300
Nliq [cm-3]
1
0.5
0
100
200
300



LWC < for ISDAC than M-PACE, consistent with more open water during M-PACE

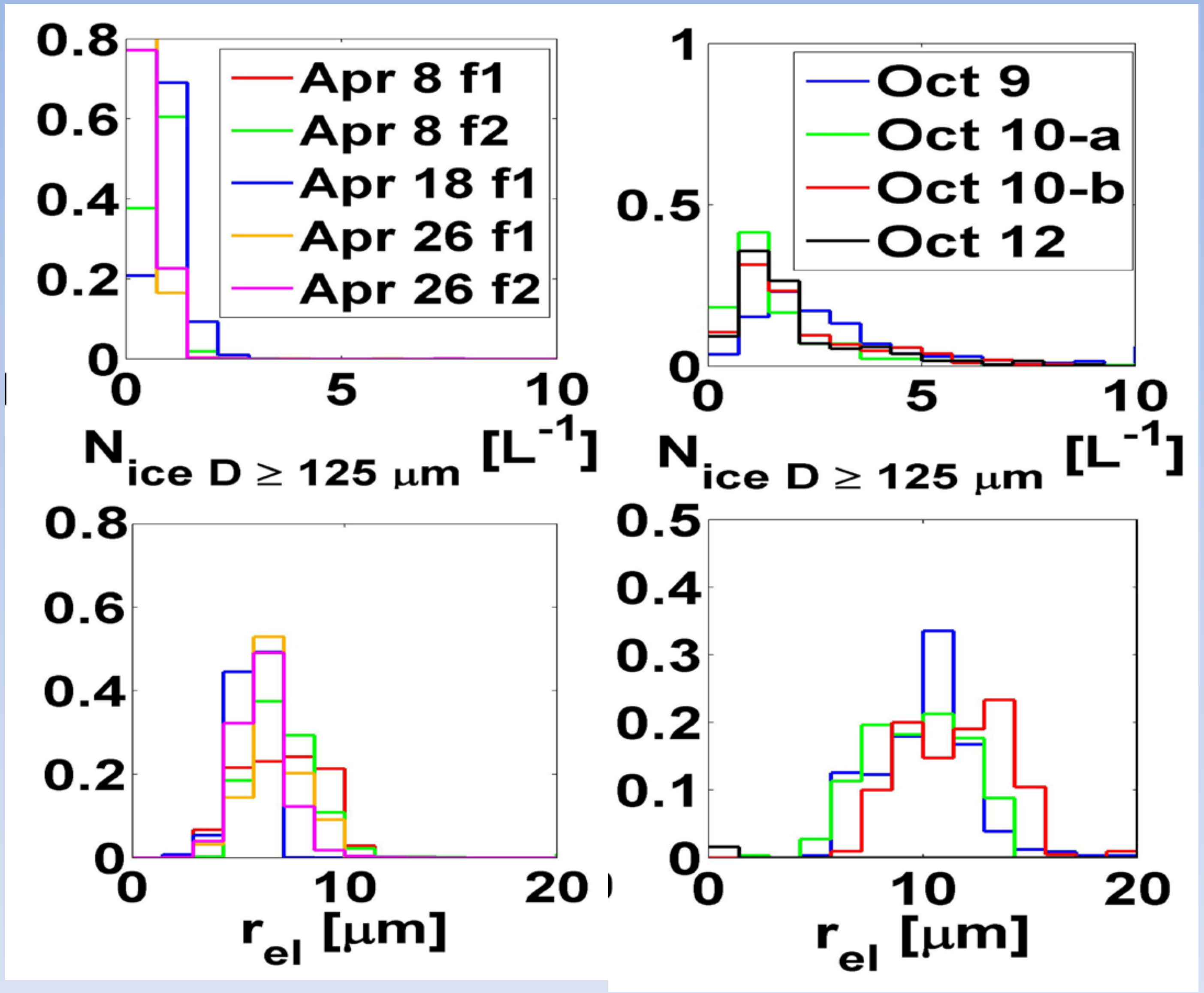


ISDAC
M-PACE
0.8
0.6
0.4
0.2
0
0.5
1
LWC [g m-3]
0.4
0.2
1
0.5
100
200
300
N liq [cm-3]



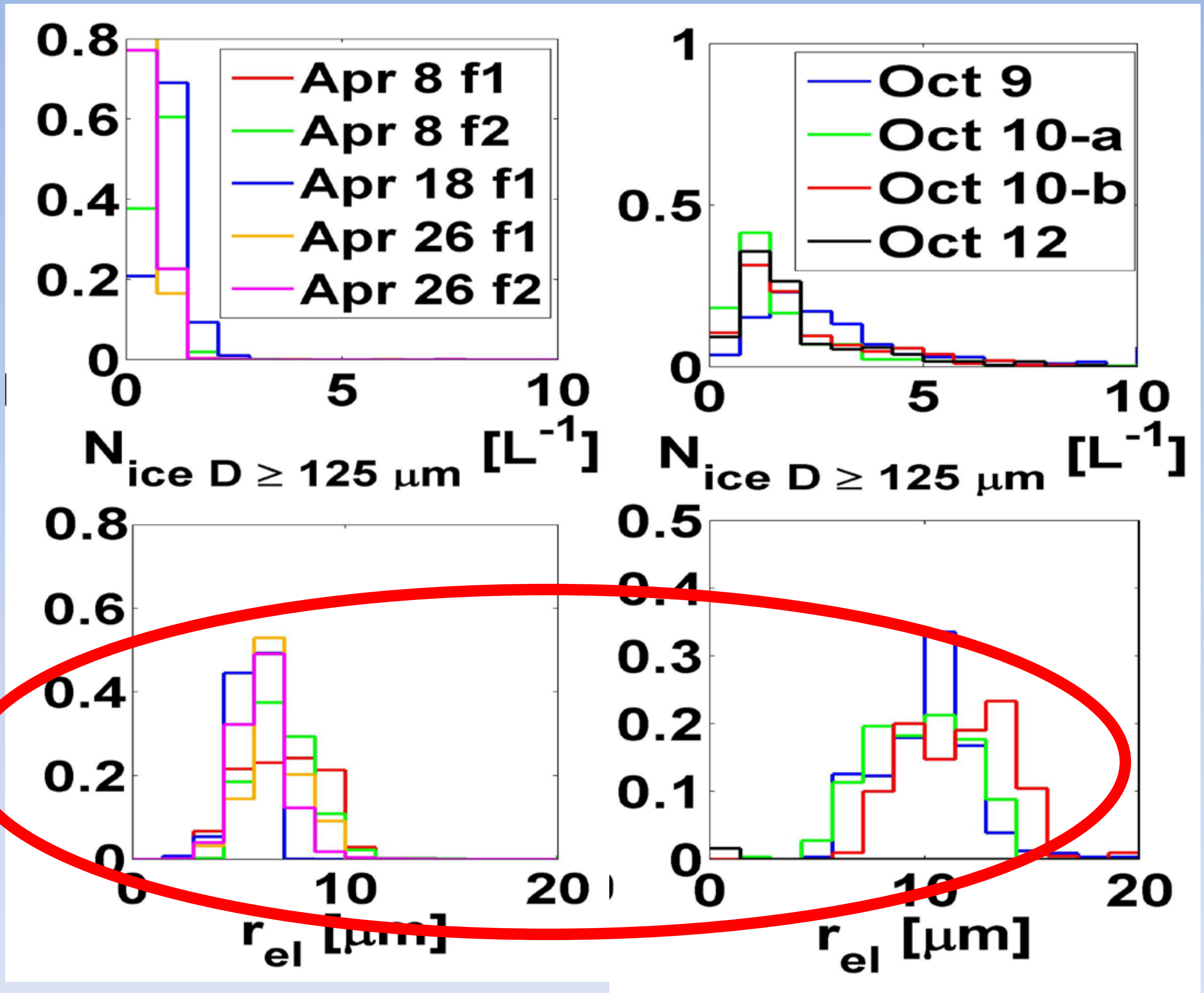
N_{liq} > for ISDAC than M-PACE, consistent with presence of more aerosols/CCN

ISDAC M-PACE



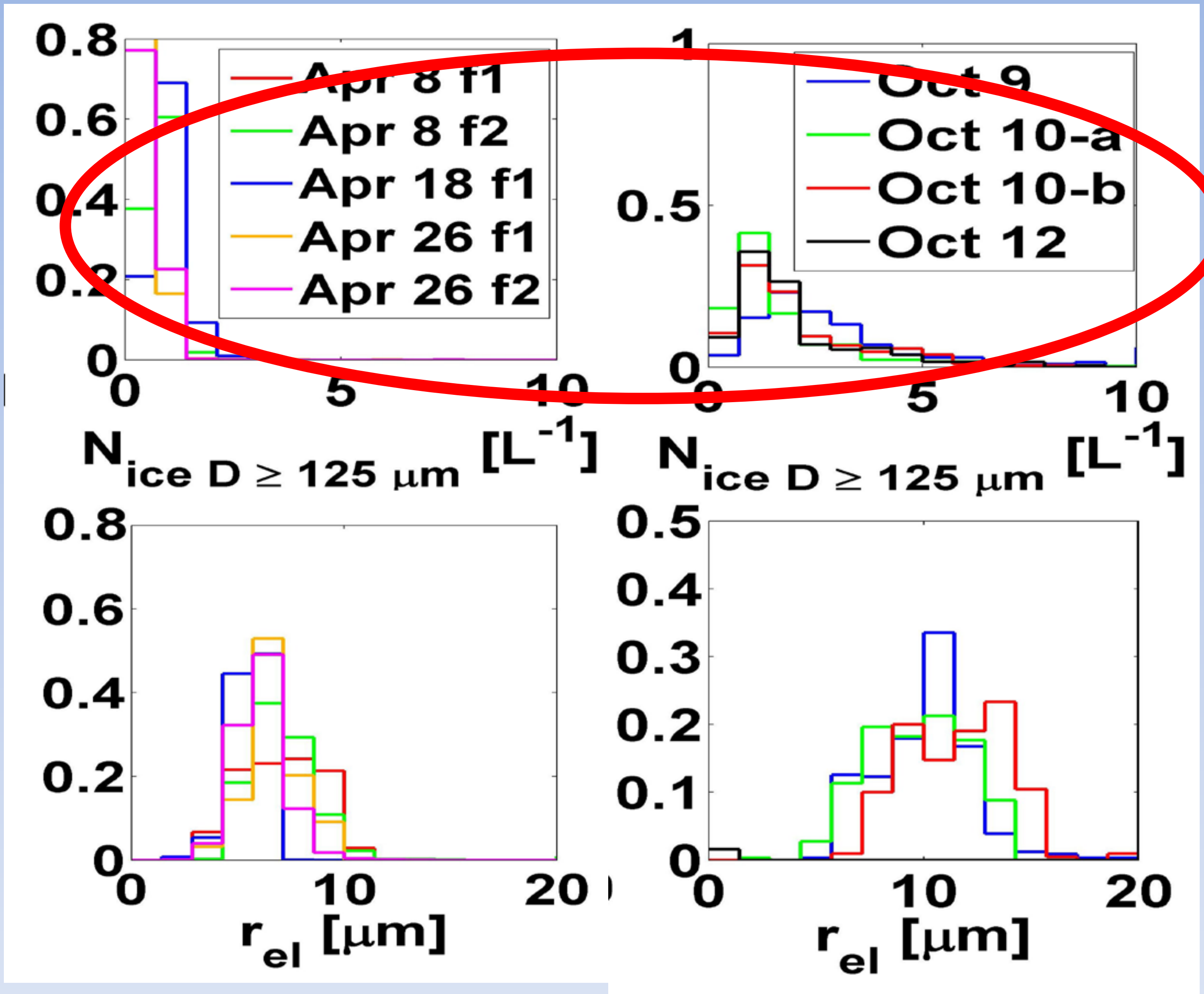
Apr 8 f1
Apr 8 f2
Apr 18 f1
Apr 26 f1
Apr 26 f2
Oct 9
Oct 10-a
Oct 10-b
Oct 12
N ice D ≥ 125 μm [L-1]
N ice D ≥ 125 μm [L-1]
r el [μm]
r el [μm]

ISDAC M-PACE



r_{el} < for ISDAC than M-PACE,

ISDAC M-PACE



N_{ice} < for ISDAC than M-PACE, consistent with cold 2nd indirect effect

Summary

- For ISDAC single-layer cases sampled:
  - Nucleation of liquid drops occurred near cloud base, N_l correlated with N_{PCASP} below cloud
  - Data consistent with glaciation indirect effect operating through entrainment of IN & dry air above cloud
  - Riming indirect effect did not play big role
- Difference between ISDAC & M-PACE data consistent with operation of cold 2nd indirect effect & greater surface fluxes in fall

Future Work

- Great data set for evaluation of models and remote sensing retrievals
- Future modeling studies should isolate how differences in ISDAC & M-PACE aerosol, surface & meteorological conditions cause changes in microphysical properties
- Need data in greater range of data for investigating different effects on cloud μphysics