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


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Liquid topped cloud with ice beneath – simple structure.
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 microphysics & 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

Combinations of ramped legs through cloud, and level legs above/below cloud flown to get data for assessing cloud-aerosol interactions.
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8 and 26 April over sea ice

18 April over land
NRC NAX radar
X band radar $Z$ and $V_d$ crossections
Strong capping inversion between normalized altitude ($z_n$) of 0.8 to 1.2
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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.
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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How does this relate to #s of IN?

IN sampled at ~-25°C at water sub-saturation
Ice cloud properties not well correlated with PCASP concentrations below cloud $\rightarrow$ look at how correlated with above cloud concentration

How does this relate to #s of IN?

IN sampled at $\sim$-25°C at water sub-saturation

IN increase with $N_{PCASP} < 400 \text{ cm}^{-3}$
Strong correlation of $N_{\text{ice}}$ & $N_{\text{PCASP}}$ consistent with glaciation indirect effect, possibly from IN entrained above cloud.
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 ISDACL (dirtier, less open water)
LWC < for ISDAC than M-PACE, consistent with more open water during M-PACE
$N_{\text{liq}} >$ for ISDAC than M-PACE, consistent with presence of more aerosols/CCN
$r_{el} <$ for ISDAC than M-PACE,
ISDAC

M-PACE

\( N_{\text{ice}} < \) for ISDAC than M-PACE, consistent with cold 2\textsuperscript{nd} 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
  – Rimming 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