# Aerosol-Cloud Droplet Number Closure from ISDAC Observations

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## Overview

- Energy balance of Arctic region particularly sensitive to enhancements of natural and anthropogenic aerosol
- Associated aerosol indirect effects modulate formation and properties of clouds – significant impact on climate predictions
- Conducting aerosol-cloud droplet number closure study using aircraft/ground measurements in Arctic from DOE Indirect and Semi-Direct Aerosol Campaign (ISDAC)
  - Conducted in vicinity of Barrow, Alaska, in April, 2008
- Emphasis on improving representations of vertical (updraft) velocity for parameterizations of aerosol activation into cloud droplets and evaluating existing parameterizations (Abdul-Razzak and Ghan)

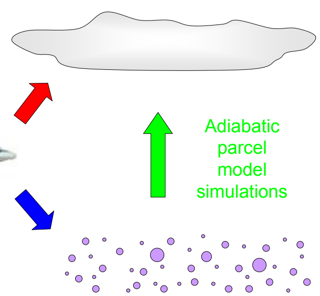
## Approach

**In-cloud measurements**

- T, P, RH, liquid/ice phase measurements
- Cloud droplet number concentration
  - Forward – Scattering Spectrometer Probe (FSSP-096)
  - Cloud Droplet Probe (CDP)
- Vertical (updraft) velocity


**Below – cloud aerosol measurements**

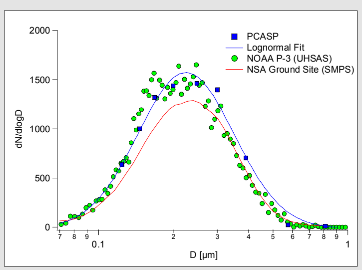
- Size-distributed aerosol number concentration
  - Passive Cavity Aerosol Spectrometer Probe (PCASP-100X)
- Size-distributed aerosol concentration and composition
  - Single-particle mass spectrometer (SPLAT)



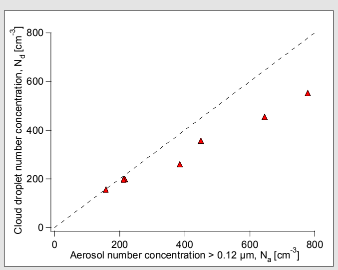

- Simulate cloud droplet activation using aircraft measurements in an adiabatic parcel model
- Compare measured and simulated cloud droplet number concentrations to assess representations of cloud droplet activation

## Aircraft Measurements

- Good agreement in Aerosol size distribution with NOAA-P3 and NSA ground measurements
  - Sub-linear relationship between PCASP and cloud droplet number concentrations

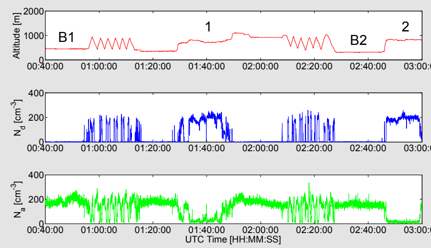



Comparison of aerosol size distributions from PCASP with independent measurements from NOAA P-3 aircraft and ARM North Slope of Alaska (NSA) ground site during a missed approach on April 20, 2008.

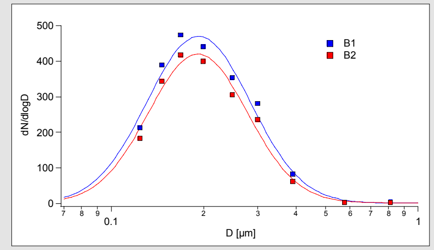



Cloud droplet number concentrations versus below-cloud aerosol (PCASP) concentrations for 7 identified cases from 6 flights during ISDAC.

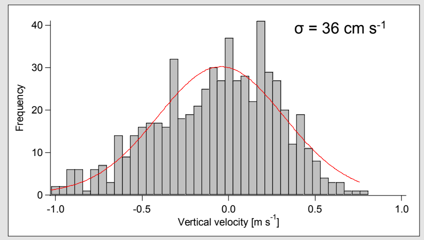
## Case Study: ISDAC Flight 31 (April 26, 2008)



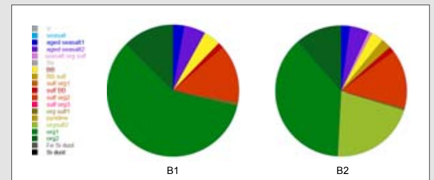

Selection of below- and in-cloud cases for parcel model analysis from time series of altitude, cloud droplet concentration ($N_d$), and aerosol particle concentration ($N_a$), during ISDAC flight 31 on April 26, 2008.




Aerosol size distributions and lognormal fits for below-cloud intervals B1 and B2.




Vertical velocity histogram for cloud interval 1. A Gaussian fit yields a standard deviation, σ, of 36 cm $s^{-1}$. Similar analysis for cloud interval 2 (not shown) yields σ = 41 cm $s^{-1}$.




Composition from SPLAT used to guide selection of hygroscopicity parameter, κ, for model runs

Aerosol particle composition determined using SPLAT for below-cloud intervals B1 and B2.

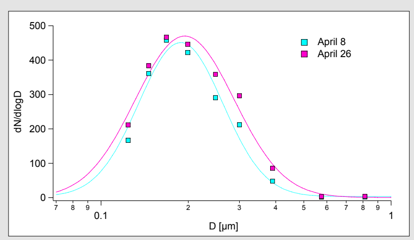
## Preliminary Results

- Parcel model analysis of this case indicates that updraft velocities of > 0.6σ give the same droplet number concentration
- For aerosol distributions such as these that are dominated by larger particles, the droplet number concentration is relatively more sensitive to the cloud-base aerosol concentrations than to the updraft speed

| Case | W [m $s^{-1}$] | $N_{calc}$ [$cm^{-3}$] | $N_{avg,obs}$ [$cm^{-3}$] | % Diff. (avg) | $N_{max,obs}$ [$cm^{-3}$] | % Diff. (max) |
|---|---|---|---|---|---|---|
| 1 | **>0.6σ** | 185 | 191 | **3** | 228 | **19** |
| 2 | **>0.6σ** | 160 | 190 | **16** | 215 | **26** |

Preliminary parcel model results for selected cases (above) during ISDAC flight 31. All simulations assume a mass accommodation coefficient, α, equal to 1. Calculated droplet concentrations are compared against average observed values $N_{avg,obs}$ and 95th percentile observed values, $N_{max,obs}$.

## Below-Cloud Aerosol Size Distributions for "Golden" Days




Best estimates of below-cloud aerosol size distributions for ISDAC 'golden' days, characterized by measurements below and in single-layer stratus clouds.

| Date | ISDAC Flights | D [μm] | $σ_g$ | N [$cm^{-3}$] |
|---|---|---|---|---|
| April 8 | 16 | **0.188** | **1.40** | **165** |
| April 26 | 30,31 | **0.194** | **1.48** | **199** |

Lognormal fitting parameters – mean diameter, geometric standard deviation, and number concentration – for best-estimate aerosol size distributions.

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