ARCSIX P-3 Ice Spectrometer measurements

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1.0 Data Set Overview

Measurements were part of the Arctic Radiation-Cloud-Aerosol-Surface Interaction Experiment (ARCSIX). PI Perkins's group was focused on measuring ice nucleating particles (INPs) during above and below cloud, clear air, and other relevant conditions pre- and post-melt. This archive relates to the Colorado State University Ice Spectrometer (IS) instrument that utilized filters collected onboard the NASA P-3 during ARCSIX to measure the immersion freezing temperature spectra of ambient particles. Collections were from the isokinetic inlet. The IS was used to measure INP number concentrations from filters collected during approximately level-leg transects above cloud, below cloud, and in sampled aerosol layers. Flights were based out of Pituffik Space Base, Greenland. The time period covered is May 28 to August 15, 2024. A total of 19 research flights were done with 42 filter collections.

2.0 Instrument Description:

The Colorado State University Ice Spectrometer (IS) developed from Hill et al. (2014; 2016) and is described in the present form in DeMott et al. (2025).

Filter samples were obtained on the P-3 using 47-mm diameter in-line aluminum filter holders fitted with a 0.2 μm diameter pore Nuclepore polycarbonate membranes. These were located within the CFDC instrument rack. Sampling was from the isokinetic inlet at all times. After flights, filters were transferred using clean protocol and stored frozen at -20°C before transport frozen to CSU with dry ice.

For re-suspension of particles, filters were placed in sterile pre-rinsed 50 mL Falcon polypropylene tubes and 6 mL of suspension solution (0.1 µm filtered deionized water) was added. Particles were re-suspended by tumbling end-over-end at 60 cycles min^{-1} for 20 min.
48 aliquots of 50 µL filter suspensions were dispensed into sterile wells that are isolated in a cooled device purged by ultra-clean nitrogen gas. Temperature is lowered at 0.33°C min^{-1} and frozen wells are counted at 0.2-1°C degree intervals to a limit as cold as -30 °C. Cumulative numbers of INPs mL^{-1} of suspension are estimated on the basis of Vali (1971) using,

$$c_{IN}(T) = -\frac{\ln(f_{unfrozen}(T))}{V_{drop}} \tag{1}$$

where $c_{IN}(T)$ is the concentration of INPs per unit volume of water (mL^{-1}), $f_{unfrozen}$ is the fraction of unfrozen drops at T, and V_{drop} is the population-median drop volume. Volumetric INP concentrations in air ($C_{INP}(T)$) are calculated via,

$$c_{INP}(T) = \frac{c_{IN}(T) \cdot f \cdot V_{imp}}{V_a} \tag{2}$$

where V_{imp} is the total volume rinsed from a collection filter (mL), f accounts for any dilution of the suspension (f = 1 for undiluted), and V_a is the air volume collected into liquid (L). Filter blanks were collected and processed in a similar manner as aerosol samples to obtain a mean background INP spectrum and for sample corrections.

Alternate treatments prior to freezing tests to give inference to INP compositions. These treatments include thermal exposure of suspensions at 95°C for 20 minutes to destabilize biological ice nucleating proteins (typically destroying their activity as INPs while not affecting inorganic INPs) or digestion of all organic carbon through application of hydrogen peroxide (Suski et al., 2018). The latter test distinguishes total organic versus inorganic INPs.

3.0 Data Collection and Processing:

IS filter collections represent integrated volumes collected over extended times of sampling at standard flow rates that varied by altitude from several to 15 lpm. Oftentimes, collections included multiple passes at altitudes and locations considered representative of the below cloud, above cloud, or aerosol layer air.

The primary data are INP concentrations as a function of temperature and the 95% negative and positive confidence widths. Binomial sampling confidence intervals (95%) are derived for all data using the formula (no. 2) recommended by Agresti and Coull (1998):

$$\mathrm{CI}_{95\%} = \left(\hat{p} + \frac{1.96^2}{2n} \pm 1.96\sqrt{\left[\hat{p}(1-\hat{p}) + {1.96^2}/{4n}\right]/n}\right) / \left(1 + {1.96^2}/{n}\right)$$

where $\hat{p}$ is the proportion of droplets frozen and n is the total number of droplets.

4.0 Data Format:

IS data are reported in text format to account for that filters were often integrated over multiple passes at different locations to increase sample volumes representative of the below cloud, above cloud, or aerosol layer air. The start and stop times, latitude, longitude, altitude, and leg type flag (0=below cloud, 1=above cloud, 2=aerosol layer, 3=low/mid level, 4=high level) are given for each period that the filter was turned on and off, as well as an overall accumulated volume. INP concentrations are at STP conditions (0 °C, 1013.5 mb) and a corresponding treatment flag (0=Untreated, 1=heat treated, 2=peroxide treated) is given. All variables and corresponding units are detailed in each data file header.

The file names archived are:
ARCSIX-INP-IS_P3B_RF01_20240528_R1.txt
ARCSIX-INP-IS_P3B_RF02_20240530_R1.txt
ARCSIX-INP-IS_P3B_RF03_20240531_R1.txt
ARCSIX-INP-IS_P3B_RF04_20240603_R1.txt
ARCSIX-INP-IS_P3B_RF05_20240605_R1.txt
ARCSIX-INP-IS_P3B_RF06_20240606_R1.txt
ARCSIX-INP-IS_P3B_RF07_20240607_R1.txt
ARCSIX-INP-IS_P3B_RF08_20240610_R1.txt
ARCSIX-INP-IS_P3B_RF09_20240611_R1.txt
ARCSIX-INP-IS_P3B_RF10_20240613_R1.txt
ARCSIX-INP-IS_P3B_RF11_20240725_R1.txt
ARCSIX-INP-IS_P3B_RF12_20240729_R1.txt
ARCSIX-INP-IS_P3B_RF13_20240730_R1.txt
ARCSIX-INP-IS_P3B_RF14_20240801_R1.txt
ARCSIX-INP-IS_P3B_RF15_20240802_R1.txt
ARCSIX-INP-IS_P3B_RF16_20240807_R1.txt
ARCSIX-INP-IS_P3B_RF17_20240808_R1.txt
ARCSIX-INP-IS_P3B_RF18_20240809_R1.txt
ARCSIX-INP-IS_P3B_RF19_20240815_R1.txt

Values that are below the detection limit of the IS are reported as -8888.

5.0 References

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