ARCSIX NASA P3-B Continuous Flow Diffusion Chamber measurements

Russell Perkins
Research Scientist
Colorado State University
Department of Atmospheric Science
1371 Campus Delivery, Fort Collins, CO 80526
russell.perkins@colostate.edu
https://orcid.org/0000-0002-2351-2362

Co-author: Ryan Patnaude
Postdoctoral Fellow
Colorado State University
Department of Atmospheric Science
1371 Campus Delivery, Fort Collins, CO 80526
ryan.patnaude@colostate.edu
https://orcid.org/0000-0003-3129-8279

1.0 Data Set Overview

These measurements were part of the Arctic Radiation-Cloud-Aerosol-Surface Interaction eXperiment (ARCSIX). The overarching goal of ARCSIX is to quantify the contributions of surface properties, clouds, aerosol particles, and precipitation to the Arctic summer surface radiation budget and sea ice melt during the early melt season (May through mid-July). PI Perkin's group is focused on interaction between clouds and aerosols and deployed instrumentation for measuring ice nucleating particles (INPs). These measurements of a key aerosol class are one piece to be able to better parameterize the life-cycle of clouds and the formation of ice crystals and precipitation. This archive is for the Colorado State University continuous flow diffusion chamber (CFDC) instrument that was onboard the NASA P3-B aircraft. The CFDC was used to measure the variability of INPs throughout the boundary layer and free troposphere, both inside and out of clouds. Flights were based from Pituffik Greenland.

2.0 Instrument Description:

The Colorado State University (CSU) Continuous Flow Diffusion Chamber (CFDC) is an ice-thermal gradient diffusion chamber that optically detects the freezing of single aerosol particles from air after exposure to controlled temperature and humidity conditions, including following liquid cloud particle activation. The operating principles of the vertically-oriented, cylindrical-walled CFDC is described in the earlier works of Rogers (1988), Rogers et al. (2001) and Eidhammer et al. (2010). The "HIAPER" version of the CFDC (CFDC-1H) that flew during ARCSIX has a total residence time of approximately 7s, during which INPs are activated and grown as ice crystals for optical detection as distinct from activated cloud droplets (DeMott et al., 2015). Practical operation for measuring INP concentrations of relevance to mixed-phase cloud conditions involve setting the relative humidity with respect to water to values exceeding 100%, typically in the range of 105%, and this was the case for ARCSIX. This emphasizes condensation and immersion freezing ice nucleation. Low free-tropospheric INP concentrations during ARCSIX and the low flow rate (1.5 vlpm) of the CFDC meant that measurements were focused between –30 °C and –20 °C or lower. Sampling occurred at various times from an Isokinetic (ISK) inlet based on the port front of the P3-B and from the counterflow virtual impactor (CVI) inlet also at the port front of the P3-B. The use of the CVI entails a particle enhancement factor due to the aerodynamics of cloud particle separation that the inlet effects. The CFDC sampled from the CVI in the standard mode to capture cloud particle residuals. Aerosol particles larger than 2.4 µm were removed from air entering the CFDC by a set of impactors prior to the chamber inlet in order to eliminate misidentification of large aerosol particles as ice crystals, which are detected at grown sizes >4 µm.

In an effort to limit sampling uncertainties, and account for very low concentrations of INPs in the Arctic (typically < 0.1 L^{-1} above –20 ºC) often below the detection limit, particle concentrations in the sample flow will be enhanced upstream of the CFDC using an aerosol concentrator. This technique was been used previously (Tobo et al., 2013; McCluskey et al. 2017) on the ground, but never for a full aircraft dataset, and increases the detection limit of the CFDC by concentrating a sample flow through a two-stage virtual impactor of ~250 to 1.5 L min^{-1}, thus increasing the number concentrations of large particles > 500 nm as much as ~100 fold. Due to this enhancement, INP measurements when sampling on the concentrator must be scaled based on a concentration factor (CF). The CF reported herein was calculated based on the ratio of the number of INPs when on and off of the aerosol concentrator. However, there were periods when the ambient INP concentration off concentrator was below detection limit. In these cases, the ratio of aerosol > 500 nm on and off the concentration was used to calculate the CF. A separate inlet was used for the aerosol concentrator and an autovalve located upstream of the CFDC was used to switch between concentrator and ISK or CVI.

Interval periods of operation in which aerosol particles are filtered from the incoming air stream are used to determine background frost influences on ice particle counts, as described in prior publications (Barry et al., 2021). Temperature uncertainty is ± 0.5°C at the reported CFDC lamina processing temperature. RHw uncertainty depends inversely on temperature, and has been estimated as ± 1.6, 2 and 2.4 % at -20, -25, and -30°C, respectively (Hiranuma et al., 2015).

3.0 Data Collection and Processing:

Data were collected continuously in real-time with the CFDC at a rate of 1 Hz. However, to obtain INP concentrations and to improve the signal to noise ratio, measurements are averaged over one to several minute periods. The data is presented as an array (using ICARTT format) of INP concentrations per standard L of air (100 kPa and 0 °C) as a function of temperature. 90 % confidence interval widths (positive and negative, to be added to and subtracted from the measured concentration to obtain confidence interval upper and lower bounds) are also given (Barry et al. 2021). The start, midpoint, and end time of each sample period are listed, as are the mean supersaturation with respect to water, measurement temperature, and pressure, in addition to the length of the sample period in seconds. Positional information is reported as the midpoint latitude, longitude and altitude of the aircraft. The concentrations reported here represent a mean over the reported sampling periods.

4.0 Data Format:

CFDC data are reported in standard ICARTT format. The list of variables and units are given in the data file header but are repeated here.

Time_Start, seconds, Time_Start, seconds_past_midnight_UTC
Time_Stop, seconds, Time_Stop, seconds_past_midnight_UTC
Time_Mid, seconds, Time_Mid, seconds_past_midnight_UTC
CFDC_N_INP, number per liter, AerMP_INP_Insitu_Bulk_NumConcSTP, Number of ice nucleating particles per liter of air (ambient temperature and pressure)
CFDC_Lower_CI, number per liter, AerMP_INP_Insitu_Bulk_NumConcSTP, 90 lower confidence interval width for number of ice nucleating particles per liter of air (ambient temperature and pressure)
CFDC_Upper_CI, number per liter, AerMP_INP_Insitu_Bulk_NumConcSTP, 90 upper confidence interval width for number of ice nucleating particles per liter of air (ambient temperature and pressure)
CFDC_Sample_Length, seconds, Sample_Length_s, Length of sample period in seconds
CFDC_SSw, percent, Supersaturation, Mean sample period supersaturation with respect to water in the CFDC
CFDC_Temp, degrees Celsius, Temperature, Mean sample period temperature of the CFDC aerosol lamina
CFDC_Pressure, mb, Pressure, Mean sample period pressure inside the CFDC chamber
Conc_Flag, unitless, Concentrator_Flag, whether sample period measurement was made with an aerosol concentrator upstream of CFDC: 0=False 1=True
CFDC_Conc_Factor, unitless, none, Concentration factor applied to data collected with aerosol concentrator to correct CFDC_N_INP to ambient INP levels
LAT, degree, Platform_Latitude_InSitu_None, Midpoint sample period latitude
LON, degree, Platform_Longitude_InSitu_None, Midpoint sample period longitude
ALT, meter, Platform_AltitudeMSL_InSitu_None, Midpoint aircraft altitude (meters ASL) during sample period
CFDC_Sample_Type_Flag, unitless, none, 0=ISK(Ambient) 1=CVI

The file names archived as “preliminary” are:

ARCSIX-INP-CFDC_P3B_20240528_RA_RF01.ict
ARCSIX-INP-CFDC_P3B_20240530_RA_RF02.ict
ARCSIX-INP-CFDC_P3B_20240531_RA_RF03.ict
ARCSIX-INP-CFDC_P3B_20240603_RA_RF04.ict
ARCSIX-INP-CFDC_P3B_20240607_RA_RF07.ict

Final file versions will have a different version number (Rx). Missing or erroneous values are reported as -9999.

5.0 Data Remarks

Data are not continuous, but the records are listed in chronological order. Start, end and midpoint times of each sample period are provided, and the representative average conditions for each record is listed. The non-significant data are not reported as these data may reflect both an unresolvable INP concentration or simply the operational quality of the CFDC processing conditions at the time of sampling. For example, while background frost concentrations are optimally less than 1 per liter, values exceeding 10 per liter could occur in some flight circumstances, limiting assessment of INP concentrations even for longer sampling intervals. Additionally, the use of the aerosol concentrator creates additional uncertainties in the INP measurements. However, the reported upper and lower 90 % confidence intervals were also scaled only by the CF. Future data versions will be reported that accounts for additional uncertainties. Lastly, CFDC data sampled from the CVI are preliminary, and the CVI enhancement factor has yet to be applied. Future data versions will include this correction.

6.0 References

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