CAPRICORN-2 RV *Investigator* Continuous Flow Diffusion Chamber measurements

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1.0 Data Set Overview

These measurements were part of the second Clouds, Aerosols, Precipitation, Radiation and atmospherIc Composition Over the southeRN ocean (CAPRICORN-2) campaign. The main objective of the CAPRICORN-2 experiment is to improve our understanding of aerosol-cloud interactions with respect to the major synoptic meteorological conditions in the Southern Ocean (SO) to reduce the uncertainties related to aerosols, clouds, and their feedbacks in our climate models. Specifically, PI DeMott's group deployed instrumentation for measuring ice nucleating particles (INPs) and bio-aerosols on multiple platforms. This archive relates to the Colorado State University continuous flow diffusion chamber (CFDC) instrument installed on the CSIRO MNF RV *Investigator* during CAPRICORN-2. The CFDC was used to measure horizontal spatial variability of INP number concentrations, to determine their relation to ocean sources and long-range transport of aerosol and cloud microphysical properties in the Southern Ocean region. The campaign was based out of Hobart, Tasmania. The time period covered is January 11 to February 22, 2018. The voyage covered latitudes from -66 to -42 degrees South and longitudes between 132 and 150 degrees East. Peculiarities and issues with use of these data are discussed briefly below.

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 was used during CAPRICORN-2 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 involves setting the relative humidity with respect to water to values exceeding 100%, typically in the range of 105%, and this was the case for CAPRICORN-2. This emphasizes condensation and immersion freezing ice nucleation. Low INP concentrations during CAPRICORN-2 and the low flow rate (1.5 vlpm) of the CFDC meant that measurements were focused below -25°C, and typically around -30°C. Air was sampled from a custom-designed aerosol sampling inlet, with the intake located approximately 18.4 m above sea level at the bow of the ship. The whole inlet is stainless steel, with an inner diameter of 16 cm, which tapers to a 4 cm conical intake. Ambient air is sampled into the conical intake section at ~440 L min^{-1}, which is oriented horizontally to limit the amount of precipitation entering the inlet, and automatically adjusts to orient into the wind (forward 180° only). The inlet then travels vertically down the foremast into the aerosol lab, which is located directly underneath the inlet at the bow of the ship, to minimize particle losses. Inside the aerosol lab, approximately 9 m from the intake, is a sample manifold with instrument pickoffs for aerosol sampling, from which the CFDC sampled. In addition to direct ambient measurements, an aerosol concentrator was also employed upstream of the CFDC to pre-concentrate ambient aerosol and enhance INP number concentrations prior to measurement. The aerosol concentrator inlet was constructed from 1” stainless steel tubing, and followed the same path described above for the main aerosol inlet. Aerosol particles larger than 1.5 µm were removed from the sample stream prior to entering the CFDC by a set of impactors upstream of the chamber inlet, in order to eliminate misidentification of large aerosol particles as ice crystals, which are detected at grown sizes >4 µm.

Interval periods of operation in which aerosol particles are filtered from the incoming air stream are used in order to determine background frost influences on ice particle counts, as described in prior publications (e.g. Barry et al. 2021, DeMott et al., 2015; Schill et al., 2016). 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).

Nucleated ice crystals were separated by aerodynamic impaction onto electron microscopy grids during select flights for subsequent chemical (energy dispersive x-ray) analyses. These analyses will be reported separately.

3.0 Data Collection and Processing:

Data were collected continuously in real-time with the CFDC at a rate of 1 Hz. The primary data reported are INP concentrations as a function of temperature, which are given per standard liter of air (100 kPa and 0 °C). Also reported are the 90% (2-tailed) confidence bound widths (Barry et al. 2021) applicable to each record, water supersaturation (RHw >100%) conditions for each measurement, measurement pressure, sample length, and position information. Finally, data flags are used to indicate the sample type for each record (ambient and concentrator), and the aerosol concentrator enhancement factor, if applicable. To obtain INP concentrations and to improve the signal to noise ratio, measurements are averaged over 2 to several minute periods. As much as possible, data were collected on inlet air for up to 10-minute intervals, bookended by periods filtering the sample air for on the order of 5 minutes in order to calculate the instrument background. The data reported here have been background-corrected using adjacent filtered-air periods, as described in Barry et al. 2021. The INP concentration factors for measurements made with the aerosol concentrator were calculated through comparison to ambient INP measurements made at the same temperature (±2 °C) and within 30 minutes. These concentration factors were used to scale measurements made with the aerosol concentrator to their equivalent ambient concentration. All INP measurements are reported at the ambient concentration level, and the concentration factor used to correct the aerosol concentrator measurements are reported in the dataset.

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 standard liter, AerMP_INP_Insitu_Bulk_NumConcSTP, Number of ice nucleating particles per standard liter of air (100 kPa, 0 degrees C)
CFDC_Lower_CI, number per standard liter, AerMP_INP_Insitu_Bulk_NumConcSTP, 90% lower confidence interval width for number of ice nucleating particles per standard liter of air (100 kPa, 0 degrees C)
CFDC_Upper_CI, number per standard liter, AerMP_INP_Insitu_Bulk_NumConcSTP, 90% upper confidence interval width for number of ice nucleating particles per standard liter of air (100 kPa, 0 degrees C)
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
CFDC_Conc_Factor, unitless, none, Concentration factor applied to data collected with aerosol concentrator to correct CFDC_N_INP to ambient INP levels (CFDC_Conc_Factor=1 indicates ambient sample)
LAT, degree, Platform_Latitude_InSitu_None, Midpoint sample period latitude
LON, degree, Platform_Longitude_InSitu_None, Midpoint sample period longitude

The “CFDC_Conc_Factor” variable is reported for all measurements, and is equal to 1 for concentrations measured directly (ambient inlet), and is greater than 1 if the aerosol concentrator was used. The file names archived as “preliminary” are:

CAPRICORN-2-CFDC_20180116_R0.ict
CAPRICORN-2-CFDC_20180117_R0.ict
CAPRICORN-2-CFDC_20180118_R0.ict
CAPRICORN-2-CFDC_20180119_R0.ict
CAPRICORN-2-CFDC_20180120_R0.ict
CAPRICORN-2-CFDC_20180123_R0.ict
CAPRICORN-2-CFDC_20180124_R0.ict
CAPRICORN-2-CFDC_20180126_R0.ict
CAPRICORN-2-CFDC_20180131_R0.ict
CAPRICORN-2-CFDC_20180203_R0.ict
CAPRICORN-2-CFDC_20180204_R0.ict
CAPRICORN-2-CFDC_20180205_R0.ict
CAPRICORN-2-CFDC_20180206_R0.ict
CAPRICORN-2-CFDC_20180207_R0.ict
CAPRICORN-2-CFDC_20180208_R0.ict
CAPRICORN-2-CFDC_20180211_R0.ict
CAPRICORN-2-CFDC_20180212_R0.ict
CAPRICORN-2-CFDC_20180214_R0.ict
CAPRICORN-2-CFDC_20180215_R0.ict
CAPRICORN-2-CFDC_20180217_R0.ict
CAPRICORN-2-CFDC_20180218_R0.ict
CAPRICORN-2-CFDC_20180219_R0.ict
CAPRICORN-2-CFDC_20180221_R0.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 either an unresolvable INP concentration or simply low 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 circumstances, limiting assessment of INP concentrations even for longer sampling intervals.

6.0 References

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