SOCRATES GV Continuous Flow Diffusion Chamber measurements

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1.0 Data Set Overview

These measurements were part of the Southern Ocean Clouds Radiation Transport Aerosol Transport Experimental Study (SOCRATES). The main objective of the SOCRATES 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 flown onboard the NSF/NCAR HIAPER G-V during SOCRATES. The CFDC was used to measure horizontal and vertical 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. Flights were based from Hobart, Tasmania. The time period covered is January 15 to February 24, 2018. A total of 15 research flights were flown with the CFDC instrument operational at latitudes between -42.5 and -62.5 degrees and longitudes 134 to 163 degrees, and altitudes within the lower 6 km of the Earth's atmosphere. 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 flew during SOCRATES 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 SOCRATES. This emphasizes condensation and immersion freezing ice nucleation. Low INP concentrations during SOCRATES and the low flow rate (1.5 vlpm) of the CFDC meant that measurements were focused below -25°C, and typically around -30°C. Sampling occurred at various times from a devoted HIMEL inlet based underneath the G-V and from the counterflow virtual impactor (CVI) inlet, also mounted on the underside of the G-V. The use of the CVI entails a particle enhancement factor due to the aerodynamics of cloud particle separation that the inlet effects. The CVI was used in two modes during SOCRATES: in standard mode to capture cloud particle residuals or in “total” mode (without counterflow) to capture ambient aerosol particles. Enhancements of particle concentrations also occur under non-isokinetic CVI sampling in total mode, but are less than for counterflow operation. The CFDC sampled from the CVI in both modes at times, since it was advantageous to remain on the CVI inlet after descending through clouds into the marine boundary layer. Aerosol particles larger than 2.4 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 and altitude information. Finally, data flags are used to indicate the sample type for each record (HIMIL/ambient or CVI inlet). 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.

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
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=Ambient 1=CVI

The CFDC_Sample_Type_Flag “ambient” label (0) refers to the HIMIL inlet. The file names archived as “preliminary” are:
SOCRATES-CFDC_20180119_R1_RF02.ict
SOCRATES-CFDC_20180123_R1_RF03.ict
SOCRATES-CFDC_20180124_R1_RF04.ict
SOCRATES-CFDC_20180125_R1_RF05.ict

SOCRATES-CFDC_20180129_R1_RF06.ict
SOCRATES-CFDC_20180131_R1_RF07.ict
SOCRATES-CFDC_20180204_R1_RF08.ict
SOCRATES-CFDC_20180205_R1_RF09.ict
SOCRATES-CFDC_20180218_R1_RF12.ict
SOCRATES-CFDC_20180219_R1_RF13.ict
SOCRATES-CFDC_20180221_R1_RF14.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 flight circumstances, limiting assessment of INP concentrations even for longer sampling intervals.

CFDC data sampled from the CVI are very preliminary, and the CVI enhancement factor has yet to be applied. Future data versions will include this correction, as well as indicating measurements collected with the CVI in “standard mode” (collecting cloud droplet residuals) vs “total mode” (without counterflow). A known issue with this (R1) version of the dataset is that measurements made using the HIMIL inlet have not yet been manually screened to ensure periods of drizzle or light cloud are removed. Additionally, the data has not been time shifted to account for the transit time between the exterior inlet and the instrument (~17 seconds, but varies by flight, altitude, and inlet).

This version (R1) improves the background correction and uncertainty calculation of the initial dataset (R0).

6.0 References

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