WE-CAN C-130 Continuous Flow Diffusion Chamber measurements

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1.0 Data Set Overview

These measurements were part of the Western Wildfire Experiment for Cloud Chemistry, Aerosol Absorption, and Nitrogen (WE-CAN). The goal of the WE-CAN campaign is to understand wildfire chemistry from emissions near the plume source and follow its evolution with aging. PI DeMott's group is focused on the question of interaction between smoke and clouds and deployed instrumentation for measuring ice nucleating particles (INPs), cloud condensation nuclei (CCN), and other aerosol properties. This archive is for the Colorado State University continuous flow diffusion chamber (CFDC) instrument that was onboard the NSF/NCAR C-130. The CFDC was used to measure the variability of INPs throughout the different plumes, clouds, and air masses sampled during the campaign to determine INP relations to fire fuel type and smoke processing with time, as well as to investigate cloud processing of INPs. Flights were based from Boise, Idaho. The time period covered is July 24 to August 28, 2018. A total of 16 research flights were flown with the CFDC instrument operational at latitudes between 37.1 and 48.1 degrees and longitudes -125.6 to -109.4 degrees, and a maximum altitude of 6422 meters. 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 WE-CAN 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 WE-CAN. This emphasizes condensation and immersion freezing ice nucleation. Low free-tropospheric INP concentrations during WE-CAN and the low flow rate (1.5 vlpm) of the CFDC meant that measurements were focused around -25°C or lower. Sampling occurred at various times from an SDI inlet based at the starboard front of the C-130 and from the counterflow virtual impactor (CVI) inlet also at the starboard front of the C-130. 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.

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 (e.g., 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 are INP concentrations for integrated periods, the 95% confidence bounds applicable to each record, the applicable CFDC temperature, water supersaturation (RH – 100%) conditions, and position and altitude information. Finally, data flags are used to indicate INP concentration data passing the significance test, and the best indication of sample type for each record. 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 period filtering the sample air for on the order of 5 minutes. Sample period concentrations are calculated from the subtraction of the adjacent filter period's Poisson rate, which is then converted to a concentration from the associated volumetric flow rate. The 95% confidence bounds and significance are determined using the moment confidence interval (Krishnamoorthy and Lee., 2012). Concentrations are considered significant if they have a calculated Z value of greater than 1.6449, which corresponds to the Z statistic at 95% confidence for a one-tailed distribution. The filter period also must have a t*λ of greater than or equal to 5 and the sample period must have a t*λ of greater than or equal to 10 to be considered significant, where t is the sample period time in seconds and λ is the calculated Poisson rate in counts per second. All INP concentrations and uncertainty data are reported at standard temperature and pressure (0°C, 1013.5 mb).

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.

Mid_UTC, seconds, Time_Mid, Seconds from 00:00 UTC at average time of each sample
Lat, Degrees, Latitude, Aircraft Latitude at average time of each sample
Lon, Degrees, Longitude, Aircraft Longitude at average time of each sample
Alt, Meters, AltitudePressure, Aircraft Pressure Altitude at average time of each sample
N_INP_STP, number per standard liter, NumberINP, number of ice nucleating particles per standard liter of air (1013.5 mb, 0C)
Lower_CI, number per standard liter, LowerUncertainty, 95% lower bound on number of ice nucleating particles per standard liter of air (1013.5 mb, 0C)
Upper_CI, number per standard liter, UpperUncertainty, 95% upper bound on number of ice nucleating particles per standard liter of air (1013.5 mb, 0C)
SSw_CFDC, percent, Supersaturation, percent supersaturation with respect to water
T_CFDC, degrees Celsius, Temperature, Temperature in CFDC column
sig_flag, none, SignificantData, 1=data is significant at 95% confidence 0=data not significant at 95% confidence
sample_type_flag, none, SampleType, 0=other/aged smoke 1=plume background 2=plume 3=on CVI inlet 4=below cloud 5=above cloud

The file names archived as “preliminary” are:

WECAN_CFDC_C130_RF01_07242018_R1.ict
WECAN_CFDC_C130_RF02_07262018_R1.ict
WECAN_CFDC_C130_RF03_07302018_R1.ict
WECAN_CFDC_C130_RF04_07312018_R1.ict
WECAN_CFDC_C130_RF05_08022018_R1.ict
WECAN_CFDC_C130_RF06_08032018_R1.ict
WECAN_CFDC_C130_RF07_08062018_R1.ict
WECAN_CFDC_C130_RF08_08082018_R1.ict
WECAN_CFDC_C130_RF09_08092018_R1.ict

WECAN_CFDC_C130_RF10_08132018_R1.ict
WECAN_CFDC_C130_RF11_08152018_R1.ict
WECAN_CFDC_C130_RF12_08162018_R1.ict
WECAN_CFDC_C130_RF13_08202018_R1.ict
WECAN_CFDC_C130_RF14_08232018_R1.ict
WECAN_CFDC_C130_RF15_08262018_R1.ict
WECAN_CFDC_C130_RF16_08282018_R1.ict

Final file versions will have a different version extension. Missing or erroneous values are reported as -9999.

5.0 Data Remarks

Data are not continuous, but the records are listed in chronological order. Midpoint time of each sample period is provided, and the representative average conditions for that record are listed. CVI factors for inlet enhancement and cloud number fraction sampled are already accounted for in the reported INP concentration data. It is highly recommended that only data passing the statistical significance test be used for science investigations. The non-significant data are reported for the sake of completeness, to acknowledge a positive-valued measurement of INP concentration that is not necessarily different from the lowest value resolvable by the CFDC. A non-significant value 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.

A known issue in the first version of the data is the need for reprocessing the INP concentrations for potential vapor depletion from too high of aerosol loading during some wildfire plumes. Final values will be reported in the final archive.

6.0 References

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