WE-CAN C-130 Ice Spectrometer 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 relates to the Colorado State University Ice Spectrometer (IS) instrument that utilized filters collected onboard the NSF/NCAR C130 during WE-CAN to measure the immersion freezing temperature spectra of ambient particles. Collections were from the SDI inlet, mounted on the front starboard side of the C-130, adjacent to the rack that held filter holders. The IS was used to measure INP number concentrations from filters collected during approximately level-leg transects in Western U.S. wildfire smoke, "background" air with respect to plumes, and above and below clouds 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 done with filter collections at latitudes between 37.2 and 47.6 degrees, longitudes between -125.6 to -109.4 degrees, and a maximum altitude of 5291 meters.

2.0 Instrument Description:

The Colorado State University Ice Spectrometer (IS) emanates from the developments of Hill et al. (2014; 2016) and is described in the approximate present form by Hiranuma et al. (2015) and DeMott et al. (2018). Immersion freezing temperature spectra are obtained in the IS following dispensing 32 or 48 aliquots of 50 µL suspensions of aerosols into sterile wells that are isolated in a cooled device that is 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 of approximately -28°C. Cumulative numbers of INPs mL^{-1} of suspension are estimated on the basis of Vali (1971) using,

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

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,

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

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). Seven filter blanks were collected and processed in a similar manner as aerosol samples to obtain a mean background INP spectrum.

Filter samples were obtained on the C-130 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 SDI inlet (same as used for the CFDC) at all times. After flights, filters were transferred using clean protocol and stored frozen at -20°C before transport frozen to CSU. For re-suspension of particles, filters are placed in sterile pre-rinsed 50 mL Falcon polypropylene tubes and 7 mL of suspension solution (0.1 µm filtered deionized water) is added. Particles are re-suspended by tumbling end-over-end at 60 cycles min^{-1} for 20 min. Ultra-filtered water used in experiments contained on average 1.2 INPs mL^{-1} at -25°C, and this sets typical lower detection limits. Correction is then applied for the number of INPs processed from rinsed filter blanks that were carried onto the C-130 during several flights.

A filter rinse produces sufficient volume for standard processing as described above, and alternate treatments prior to freezing tests to give inference to INP compositions, which will be provided in a later update. 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 plume, plume background, or below and above cloud 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. Using this formula, a single well frozen out of 32 aliquots the $\mathrm{CI}_{95\%}$ ranges from 18% to 540% of the estimated INP concentration, while for 16/32 wells frozen it is 68-132% of the INP concentration.

4.0 Data Format:

IS data are reported in non-standard ICARTT format to account for the fact that filters were often integrated over multiple passes at different locations to increase sample volumes representative of the plume, plume background, or below and above cloud air. Bounding times, latitudes and longitudes are provided for each filter collection, but not for the specific times that the filter was turned on and off. The primary variables and units are given in the data file header but are repeated here. Processed data appear as arrays, led by a list of secondary overall filter start and stop times (not continuous sampling), and maximum and minimum location and altitude variables. Additionally, 2 flags are also included for determined sample type and if enough air was filtered to see a distinguishable signal over background (more in section 5.0). These lines, one for each filter collected on a flight:

Start_UTC, seconds, Time_Start, Seconds from 00:00 UTC at first start of filter collection
Stop_UTC, seconds, Time_Stop, Seconds from 00:00 UTC at final stop of filter collection
Lat_min, Degrees, Latitude, Minimum aircraft Latitude during filter collection
Lat_max, Degrees, Latitude, Maximum aircraft Latitude during filter collection
Lon_min, Degrees, Longitude, Minimum aircraft Longitude during filter collection
Lon_max, Degrees, Longitude, Maximum aircraft Longitude during filter collection
Alt_min, Meters, AltitudePressure, Minimum aircraft Pressure Altitude during filter collection
Alt_max, Meters, AltitudePressure, Maximum aircraft Pressure Altitude during filter collection

Total_volume_filtered, Standard Liters, FilteredVolume, Total volume of air through filter
Sample_type_flag, none, SampleType, 0=other/aged smoke 1=plume background 2=plume 3=below cloud 4=above cloud
Insufficient_collection_flag, none, CollectionFlag, 0=False 1=True (clean air/too little time in plume)
TempC[], degrees Celsius, Temperature, Temperature of IS
N_INP_STP[], number per standard liter, NumberINP, number of ice nucleating particles per standard liter of air (1013.5 mb, 21.1C)
Lower_CI[], number per standard liter, LowerUncertainty, 95% lower confidence width for number of ice nucleating particles per standard liter of air (1013.5 mb, 21.1C)
Upper_CI[], number per standard liter, UpperUncertainty, 95% upper confidence width for number of ice nucleating particles per standard liter of air (1013.5 mb, 21.1C)

All INP concentrations are at STP conditions (21.1 °C, 1013.5 mb).

The file names archived as “preliminary” are:
WECAN_IS_C130_RF01_07242018_R1.ict
WECAN_IS_C130_RF02_07262018_R1.ict
WECAN_IS_C130_RF03_07302018_R1.ict
WECAN_IS_C130_RF04_07312018_R1.ict
WECAN_IS_C130_RF05_08022018_R1.ict
WECAN_IS_C130_RF06_08032018_R1.ict
WECAN_IS_C130_RF07_08062018_R1.ict
WECAN_IS_C130_RF08_08082018_R1.ict
WECAN_IS_C130_RF09_08092018_R1.ict
WECAN_IS_C130_RF10_08132018_R1.ict
WECAN_IS_C130_RF11_08152018_R1.ict
WECAN_IS_C130_RF12_08162018_R1.ict
WECAN_IS_C130_RF13_08202018_R1ict
WECAN_IS_C130_RF14_08232018_R1.ict
WECAN_IS_C130_RF15_08262018_R1.ict
WECAN_IS_C130_RF16_08282018_R1.ict

Final file versions will have a different version extension. Values that are below the detection limit of the IS are reported as -8888. For example, after background (blank) correction, some IS INP concentrations became slightly negative, meaning that they were not resolvable at greater than blank INP concentrations.

5.0 Data Remarks

The complex and integrated nature of the IS samples has been discussed above. Due to the extremely low INP concentrations and the limited volumes of samples compared to ship or fixed-site collections that typically last for 24 hours or more, background corrections are significant for this data set. While CI widths are provided as for all past archived IS data, a flag to indicate if not enough volume was collected for a particular sampling condition is also included. Examples of this being true are for sampling in clean plume background air or too little time spent in a particular plume to get a clear, resolvable signal above field blanks and instrument background. Therefore, caution should be exercised and use of these filters' INP values and temperature spectra to make conclusions is not advised. Additionally, we are evaluating an appropriate statistical test for determining significance above instrument background. This is especially relevant to consider the significance of the rare first well or two freezing in advance of the majority of the wells.

6.0 References

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