CAPRICORN-2 RV *Investigator* Ice Spectrometer 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 aerosol filters installed on the MNF RV *Investigator* during CAPRICORN-2. These filters were analyzed for INP concentration using the CSU Ice Spectrometer (IS) following the conclusion of the campaign to determine INP temperature spectra and INP type, and 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 Ice Spectrometer (IS) emanates from the developments of Hill et al. (2014; 2016) and is described in its 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 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 -29°C. Cumulative numbers of INPs mL^{-1} of suspension are estimated based on Vali (1971) using:

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

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:

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

where V_{imp} is the total volume of water used to resuspend a collected filter (mL), f accounts for any dilution of the suspension (f = 1 for undiluted), and V_a is the air volume collected on the filter (L).

3.0 Data Collection and Processing:

Aerosols were collected onto pre-sterilized 0.2 µm, 47mm track-etched polycarbonate membrane filters in open-faced Nalgene filter units on an upper deck of the R/V *Investigator*, approximately 23 m above sea level. Filter units were opened on deck and mounted beneath a rain hat for alternating 24-48 hr periods. In order to limit ship exhaust contamination, the filter pump was powered with a sector sampler, which provided power to the pump only when the wind speed relative to the ship was between 10 and 80 kn, the ship-relative wind direction was from the forward 90° (relative wind directions greater than 45° and less than 315°), and the total particle concentrations measured by a CPC were stable and less than 2000 cm^{-3}.

Filters were stored and returned frozen to Colorado State University (CSU), where immersion freezing measurements over a range from 0 to -28°C were made using the CSU Ice Spectrometer (IS). Collected particles from each filter were resuspended in filtered, deionized water, and then dispensed into the IS and cooled to obtain cumulative INP temperature spectra. Five filter blanks were collected and processed in a similar manner as aerosol samples to obtain a mean background INP spectrum. Aliquots of suspensions from selected samples were also heat treated (95 °C for 20 min) to denature and deactivate biological INPs and/or digested in 10% H_2O_2 at 95 °C under UV-B for 20 min to remove all organic carbon INPs, prior to measurement using the IS (Suski et al., 2018). The results of these sample pre-treatments will be reported in a later update.

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):

$$CI_{95\%} = \left(\hat{p} + \frac{1.96^2}{2n} \pm 1.96\sqrt{\left[\hat{p}(1-\hat{p}) + {1.96^2}/{4n}\right]/n}\right) / \left(1 + {1.96^2}/{n}\right) \quad (3)$$

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 gives a CI95% ranging 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:

The data is presented as an array (using ICARTT format) of INP concentrations per standard liter of air (100 kPa and 0 °C) as a function of temperature. 95% 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. A flag, 0, 1, or 2, in the final column of the array indicates whether the sample suspension had been measured without treatment (0), after heat treatment at 95 °C for 20 min (1), or after digestion in 10% hydrogen peroxide at 95 °C under UV-B for 20 min (2). The arrays are preceded by associated data on the dates, times and volume of collection. The minimum and maximum latitude reached by the RV *Investigator* during each filter collection are also listed. A metadata header is included in each file, where each file represents a single filter collected over approximate 24 or 48-hour periods. Any notes specific to a single collection are noted in the header.

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
Num_Temps, unitless, none, Number of temperatures in data record
Total_Vol, standard liters, Total_Volume_Filtered, Total volume of air passed through filter (100 kPa, 0 degrees C)
LAT_Min, degree, Platform_Latitude_InSitu_None, Minimum latitude during filter collection
LAT_Max, degree, Platform_Latitude_InSitu_None, Maximum latitude during filter collection
LON_Min, degree, Platform_Longitude_InSitu_None, Minimum longitude during filter collection
LON_Max, degree, Platform_Longitude_InSitu_None, Maximum longitude during filter collection
IS_Temp_C[], degrees Celsius, AerMP_INP_Insitu_Bulk_NumConcSTP, Measurement temperature of IS
IS_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)
IS_Lower_CI[], number per standard liter, AerMP_INP_Insitu_Bulk_NumConcSTP, 95% lower confidence interval width array for number of ice nucleating particles per standard liter of air (100 kPa, 0 degrees C)
IS_Upper_CI[], number per standard liter, AerMP_INP_Insitu_Bulk_NumConcSTP, 95% upper confidence interval width array for number of ice nucleating particles per standard liter of air (100 kPa, 0 degrees C)
IS_Treatment_Flag[], unitless, none, 0=Untreated, 1=Heat Treated (95 degrees C for 20 minutes), 2=Peroxide Treated (10% H2O2 at 95 degrees C for 20 minutes under UV-B, then H2O2 decomposed with catalase)

The file names archived as “preliminary” are:
CAPRICORN-2-IS_20180112_R0_INP 1.ict
CAPRICORN-2-IS_20180115_R0_INP 2.ict
CAPRICORN-2-IS_20180116_R0_INP 3.ict

CAPRICORN-2-IS_20180118_R0_INP 4.ict
CAPRICORN-2-IS_20180119_R0_DNA 5.ict
CAPRICORN-2-IS_20180121_R0_INP 6.ict
CAPRICORN-2-IS_20180122_R0_INP 7.ict
CAPRICORN-2-IS_20180124_R0_INP 8.ict
CAPRICORN-2-IS_20180126_R0_INP 9.ict
CAPRICORN-2-IS_20180127_R0_INP 10.ict
CAPRICORN-2-IS_20180129_R0_INP 11.ict
CAPRICORN-2-IS_20180130_R0_INP 12.ict
CAPRICORN-2-IS_20180201_R0_INP 13.ict
CAPRICORN-2-IS_20180202_R0_INP 14.ict
CAPRICORN-2-IS_20180204_R0_INP 15.ict
CAPRICORN-2-IS_20180205_R0_INP 16.ict
CAPRICORN-2-IS_20180208_R0_INP 18.ict
CAPRICORN-2-IS_20180210_R0_INP 19.ict
CAPRICORN-2-IS_20180211_R0_INP 20.ict
CAPRICORN-2-IS_20180213_R0_INP 21.ict
CAPRICORN-2-IS_20180214_R0_INP 22.ict
CAPRICORN-2-IS_20180216_R0_INP 23.ict
CAPRICORN-2-IS_20180218_R0_INP 24.ict
CAPRICORN-2-IS_20180219_R0_INP 25.ict
CAPRICORN-2-IS_20180219_R0_INP 26.ict

Final file versions will have a different version number (Rx). Values that are below the detection limit of the IS are reported as -8888, and any missing values are reported as -9999.

5.0 Data Remarks

The complex and integrated nature of the IS samples has been discussed above. Due to the extremely low INP concentrations present over the Southern Ocean, background corrections are significant for filters with lower accumulated volumes, but have not yet been applied in this version of the data. Background-corrected concentrations will be reported in the next update of this dataset, along with heat and peroxide treatments on selected samples. Therefore, caution should be exercised when using this dataset, and it is encouraged to reach out to the PI before use.

6.0 References

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