HIWC-2022 Cloud Particle Probe Microphysics

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1. Dataset Description

This dataset consists of cloud particle size distributions (PSDs) and mass-size distributions (MSDs) derived from two wing-mounted instruments installed on the NASA DC-8 aircraft: the DMT Precipitation Imaging Probe (PIP), and the SPEC Two-Dimensional Stereo probe (2D-S). The data were collected during the High Ice Water Content (HIWC) field campaign from July 5-30, 2022, based out of Jacksonville, Florida. Research flights were conducted over the Gulf of Mexico, the Atlantic Ocean, and the Caribbean Sea, primarily focusing on areas of high ice water content at typical jet aircraft cruise altitudes. Additionally, most flights included a series of low-level flight legs to measure aerosol and microphysical profiles of oceanic towering cumulus clouds.

Previous PSD/MSD datasets from the HAIC (2014/2015) and HIWC-RADAR-I (2015) field campaigns were processed by the Centre National de la Recherche Scientifique Laboratoire de Météorologie Physique (CNRS). The HIWC-RADAR-II (2018) dataset was processed by NCAR. The data produced for this archive follow the processing methods and file formats that were used in these previous datasets as closely as possible, in order to maintain consistency across projects. See Leroy et al. (2016, 2017) for further details on the processing methodology.

2. Instrument Description

Both the 2D-S and PIP are two-dimensional optical array probes that record images of cloud particles as they travel through an illuminated sampling area between the probes' arms. The recorded images are then analyzed to produce particle size distributions (PSDs) from 10 microns to 7 centimeters in diameter. A mass-size parameterization is applied to the PSDs to provide estimates of the mass size distribution (MSD) over the same size range.

The 2D-S records particles from two separate channels, one with a vertical (top view) orientation, and one with a horizontal (side view) orientation. The vertical channel is used in the merged distributions in this dataset. The horizontal channel data are available separately on

request. The PIP has a single channel which was oriented vertically for all flights during the campaign. The 2D-S was installed in the inboard canister on the right wing of the DC-8, and the PIP was installed on the outboard canister of the right wing.

Probe specifications	Number of imaging elements	Resolution per element	Probe arm width	Recording rate	Data reporting rate
2D-S Horizontal	128	11 μm	6.3 cm	Asynchronous	5 seconds
2D-S Vertical	128	11 μm	6.3 cm	Asynchronous	5 seconds
PIP	64	100 μm	22.2 cm	Asynchronous	5 seconds

More information about these instruments is available at:
http://www.specinc.com/2d-s-stereo-probe-operation
https://www.dropletmeasurement.com/product/precipitation-imaging-probe/

3. Data Collection and Processing

Particle Measurement: Particle size and mass distributions are given in terms of equivalent-area particle diameter (D_{eq}), which is defined as the diameter of a circle with the same area (A) as the particle image:

$$D_{eq} = \sqrt{4/\pi\, A}$$

Area is measured directly for each individual particle image by counting the number of pixels occluded at the 50% or greater shadow level. An adjustment to A is applied for partially imaged particles that touch one or both of the array edges, using the estimated portion of the image outside of the array as determined by a circle fit. Particles are rejected if the center is determined to be outside of the image array ("center-in" method, Heymsfield and Parrish 1978). The final D_{eq} value is also adjusted to account for optical diffraction using the imaged area and the area of any enclosed interior voids found in the particle images (Korolev 2007).

Shattering and depth of field: Both the 2D-S and PIP were equipped with probe tips designed to minimize the amount of particle shattering. Post-processing corrections for residual shattering have been applied to the 2D-S data using the method described in Field et. al (2006). Optical depth of field for the PIP uses a constant of 3.0. Depth of field for the 2D-S is described in Lawson et al. (2006) with a constant of 8.12.

Particle Coincidence: When multiple particles are imaged in a single PIP frame, only the largest particle is measured and accepted. Multiple images in 2D-S frames are treated as a single particle.

Overload time: Both instruments record the time of arrival of each individual particle, and missing data is either flagged or can be determined by a particle counter. This information is used to compute the overload time when a probe is temporarily not recording data.

Binning: The 2D-S is used for all size bins smaller than 800 microns. The PIP is used for all size bins larger than 1200 microns. A blend between the 2D-S and PIP is used in the overlap range between 800-1200 microns, as described in Leroy et. al (2016). The final composite (merged 2D-S and PIP) distributions have been interpolated onto size bins with 10-micron intervals.

Mass estimation: Mass distributions are computed from the particle size distributions using a power-law relationship of the form $M = \alpha D^{\beta}$ (using cgs units). The β exponent is fixed at a value of 2.51. The α coefficient is adjusted dynamically to fit the value reported by the Isokinetic Total Water Content Evaporator Probe (IKP2). A default value of α=0.023 has been applied when adjustment of α is not possible, gives unreasonable values, or either the PIP or 2D-S is inoperational.

4. Data Format

Composite particle size distributions and mass distributions are given in bins ranging from 15 microns to 6995 microns in 10-micron increments. The bin center-points are listed in the first line of each file. In the following lines, the starting time of each interval is given (UTC seconds from midnight), followed by the particle size distribution or mass distribution for that time interval. Particle size distribution units are **#/L/micron**. Mass distribution units are **g/m^3/micron**. Poor or missing data are flagged with a value of -999.

A housekeeping file is available for each flight containing bulk parameters derived from the distribution data, including total number concentration (#/m^3), ice water content (g/m^3), and median mass diameter (microns). The α and β coefficients used to calculate the mass distribution are listed. Finally, a data quality flag, overload time, and end diode voltages are given for the 2D-S and the PIP.

All data files are in ASCII comma-separated value format and named with the following convention:

YYYYMMDD_Composite_Deq_2DS-PIP_V01.txt (Composite PSD file)
YYYYMMDD_MassSizeD_Deq_2DS-PIP_V01.txt (Composite MSD file)
YYYYMMDD_Housekeeping_2DS-PIP_V01.txt (Other data)

Selected particle images from the 2D-S and PIP are available as a series of PNG image files. Each file represents one minute of flight time, and the 60 panels show the first particle buffer available for each second. PNG files in clear air have been omitted from the archive. Many more particle images are not shown but are available on request:

YYYYMMDD_PIP_images.tar
YYYYMMDD_2DS_H_images.tar

YYYYMMDD_2DS_V_images.tar

5. Data Remarks

The PIP experienced poor image quality on several flights when the measured laser intensity dropped below the operational limit, which typically occurred at cold temperatures. The 2D-S experienced occasional brief outages during rapid descents to warmer temperatures or from data acquisition computer malfunctions. The data in the 2D-S and/or PIP size range during these outages have been flagged with a value of -999.0.

6. References

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7. Appendix (keywords)

CLOUDS
CLOUD MICROPHYSICS
PARTICLE SIZE DISTRIBUTION
HYDROMETEORS
CLOUD LIQUID WATER/ICE