# Fast-2DC Data Processing Software

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## Introduction

The Fast-2DC data processing software is designed to produce particle size distributions and derived quantities from raw Fast-2DC image data.  The software is installed on the RAF/EOL network and can be run from a terminal or console command line.  The latest C++ source code is available in the EOL Subversion Repository at /trunk/instruments/pms2d/process2d.

## Running the Software

The Fast-2DC processing software can be called as follows from a UNIX/LINUX command prompt:

```
procf2dc [filename.2d] <options>
```

where "filename.2d" is the raw image data file.  The software may be run with a number of processing options which are listed below.

```
OPTIONS:
  -starttime [hhmmss]
     Specify start time in format hhmmss, default is first available time
  -stoptime [hhmmss]
     Specify stop time in format hhmmss, default is last available time
  -xsize
```

Use x-sizing (across the array), use of -allin highly recommended

-ysize

Use y-sizing (with the airflow)

-allin

Require particles to be fully imaged

-noshattercorrect

Turn off shattering rejection and corrections

-verbose

Send extra output to console

-o file_name

Specify output file, instead of default output name

Example: procf2dc myfile.2d -start 123000 -stop 140000 -xsize -allin

If no additional options are listed, the default options will apply. Default options are:

| | |
|---|---|
| *start time* | First available time in the raw data file |
| *stop time* | Last available time in the raw data file |
| *particle sizing method* | Diameter of smallest circle that encloses the particle |
| *partially imaged particles* | Allowed |
| *shattering corrections* | On |
| *output file* | Create a new netCDF file with Fast-2DC data only |

When the software has finished processing, the data will be written to a netCDF file with either the default filename or a user-specified file name as indicated by the “-o” option.

*If the filename specified by the “-o” option already exists, the existing file will be preserved and the Fast-2DC data will be added to this file. Adjustments to the start and stop time will be made automatically to match the existing file.

## Processing Details

The Fast-2DC software processes and writes data with two particle populations, round particles and all particles. The "round particle" population is intended to represent liquid water particles. The "all particle" population follows the more traditional method of processing 2D image data, placing both round and irregularly shaped particles together into the same particle size distribution. Both of these populations are processed for the entire duration of the raw data file. The applicability of these populations will change based on many factors, and the decision of which population is most appropriate is left to the discretion of the end-user.

*Part 1: Particle Sizing and Sample Area*

Particles can be measured by three methods, circle-fit, sizing across the array (x-size) and sizing with the airflow (y-size).

The circle-fit method is the default sizing method. It simply fits the smallest possible circle around a particle image and uses the diameter of that circle as the diameter of the particle. This method is used for its computational efficiency, as well as its ability to produce a clean comparison of the area of particle to the area of the circle. This area ratio is used for subsequent particle rejection, roundness detection, and may also be used for computing such parameters as fall velocity and optical extinction.

The x-size and y-size methods measure the maximum difference between shaded pixels in their respective directions. X-size may be useful for spinning disc calibrations, or for any time where the probe's timing did not match the particle speed resulting in distorted images.

In the case of particles flagged as "round" a sizing correction is applied following Korolev (2007). This correction is based on the size of the Poisson spot seen when imaging liquid particles, and indicates magnification of a particle due to its position in the depth of field. If a Poisson spot is detected, its area is measured and compared to the area of the complete particle.

The ratio of these two areas is used to find a correction factor, which reduces the size measurement to its expected pre-magnification value.

In all sizing methods, partially imaged particles which touch either or both ends of the diode array are allowed by default. The sample area of the probe is computed following the "reconstruction" method in Equation 17 of Heymsfield and Parrish (1978). If the user elects to reject partially imaged particles, the sample area is computed following Equation 4 of the same reference.

*Part 2: Shattering Corrections*

Large particles that impact on the forward surface of a probe arm can break into many pieces and then be imaged by the Fast-2DC probe. This results in an overestimate of the concentration of small particles. Since these small particles appear in clusters, the time between neighboring particles, or interarrival time, may be used to detect suspected shattering events. The Fast-2DC software corrects for shattering events using the methods described in Field, et al. (2006), which are briefly described below.

The Fast-2DC software maintains a circular buffer of the last 400 interarrival times measured. For each 1Hz time period, a histogram of these interarrival times is compiled. If there are very few shattering events, the histogram will resemble a Poisson distribution. If there are many shattering events the distribution will have a double-Poisson shape with two distinct peaks, one for the natural particle population and one for the shattered particle population. A non-linear least squares double-Poisson fit is made for each of these distributions. The interarrival time of each peak of the double-Poisson shape is then found, and an appropriate cutoff is determined to distinguish between the natural population and the shattered population. At this point all particles, and their preceding neighbor, with an interarrival time below this cutoff time are rejected. This method also rejects naturally-occurring particles that may have short interarrival times, so a statistical correction is made to account for these particles.

Shattering corrections may be turned off at the command line if the user wishes not to use them.

*Part 3: Particle Rejection Criteria*

The particle rejection criteria in the Fast-2DC software serve two purposes, to distinguish between “round” and “all” particles, and to remove image artifacts. Image artifact rejection is simply based on the ratio of the measured area of a particle (after holes are filled) to the area of the smallest circle that can enclose that particle. If this ratio falls below a certain threshold, the particle is rejected. Distinguishing between “round” and “all” particles is done in a similar manner, with the area ratio requirement raised to eliminate particles that do not meet a certain roundness. The rejection criteria details are as follows:

“All” particles rejected if:

Area ratio < 0.1

Particle size outside of size-bin range

“Round” particles rejected if:

Area ratio < 0.4

Area ratio < 0.5 for particles 10 pixels or larger

Size greater than 6mm

Corrected particle size outside of size-bin range

## File Output

After processing is complete, a new netCDF file will be created or variables will be added to an existing netCDF file. Units, descriptions, and other metadata may be found in the netCDF file itself. The variables created by the Fast-2DC software are:

| | |
|---|---|
| A2DCA | Fast 2DC Corrected Counts per Channel, All Particles |
| A2DCR | Fast 2DC Corrected Counts per Channel, Round Particles |
| C2DCA | Fast 2DC Concentration per Channel, All Particles |
| C2DCR | Fast 2DC Concentration per Channel, Round Particles |
| I2DCA | Interarrival Time Counts, All Particles Including Rejections |
| CONC2DCA | Total Fast 2DC Concentration, All Particles |
| CONC2DCR | Total Fast 2DC Concentration, Round Particles |
| PLWC2DCR | Fast 2DC Liquid Water Content, Round Particles |
| PLWC2DCA | Fast 2DC Liquid Water Content, All Particles |
| DBAR2DCR | Fast 2DC Mean Particle Diameter, Round Particles |
| DBAR2DCA | Fast 2DC Mean Particle Diameter, All Particles |
| DISP2DCR | Fast 2DC Dispersion, Round Particles |
| DISP2DCA | Fast 2DC Dispersion, All Particles |
| DBZ2DCR | Fast 2DC Calculated Reflectivity, Round Particles |
| DBZ2DCA | Fast 2DC Calculated Reflectivity, All Particles |
| REFF2DCR | Fast 2DC Effective Radius, Round Particles |
| REFF2DCA | Fast 2DC Effective Radius, All Particles |
| NACCEPT2DCR | Number of Particles Accepted, Round Particles |
| NACCEPT2DCA | Number of Particles Accepted, All Particles |
| NREJECT2DCR | Number of Particles Rejected, Round Particles |
| NREJECT2DCA | Number of Particles Rejected, All Particles |
| poisson_coeff1 | Interarrival Time Fit Coefficient 1 |
| poisson_coeff2 | Interarrival Time Fit Coefficient 2 |
| poisson_coeff3 | Interarrival Time Fit Coefficient 3 |
| poisson_cutoff | Interarrival Time Lower Limit |
| poisson_correction | Count/Concentration Correction Factor for Interarrival Rejection |
| SA | Sample area per channel |
| bin_endpoints | Size bin endpoints (microns) |
| bin_midpoints | Size bin midpoints (microns) |
| interarrival_endpoints | Interarrival bin endpoints (seconds) |

## References

Field, P. R., A. J. Heymsfield, A. Bansemer, 2006: Shattering and Particle Interarrival Times Measured by Optical Array Probes in Ice Clouds. J. Atmos. Oceanic Technol., 23, 1357–1371. doi: 10.1175/JTECH1922.1

Heymsfield, Andrew J., Joanne L. Parrish, 1978: A Computational Technique for Increasing the Effective Sampling Volume of the PMS Two-Dimensional Particle Size Spectrometer. J. Appl. Meteor., 17, 1566–1572.

Korolev, Alexei, 2007: Reconstruction of the Sizes of Spherical Particles from Their Shadow Images. Part I: Theoretical Considerations. J. Atmos. Oceanic Technol., 24, 376–389. doi: 10.1175/JTECH1980.1