Summit, Greenland, Measurements from Fog Monitor 100: 2011-2014

Summit, Greenland, Meteorology and Snow Temperatures: 2011-2014

Author(s):

David C. Noone (P.I., corresponding author)
Associate Professor
College of Earth, Ocean, and Atmospheric Sciences
Oregon State University
104 CEOAS Administration Building
Corvallis, OR 97331
dcn@coas.oregonstate.edu

Christopher J. Cox
Research Scientist
Cooperative Institute for Research in Environmental Sciences (CIRES) / University of Colorado & NOAA Physical Sciences Division (PSD)
R/PSD3
335 Broadway
Boulder, CO 80305
(303) 497-4518
christopher.j.cox@noaa.gov

Max Berkelhammer
Assistant Professor
Dept. Earth and Environmental Sciences
University of Illinois, Chicago
(312) 413-8271
berkelha@uic.edu

Michael O'Neill
Formerly, CIRES/NOAA-ESRL

Funding Source and Grant Number:

NSF #1023574

Dataset Overview:

The data set consists of precipitation and cloud particle distribution measurements made by Droplet Measurement Technologies (DMT) Fog Monitor 100s (FM100) and Meteorological Particle Spectrometers (MPS) acquired from June 2011 through June 2014 at Summit Station, Greenland (72 ºN, -38 ºW, 3209m). The data was collected as part of the NSF funded project "Closing the Isotope Hydrology at Summit: Measurements of Source Regions, Precipitation and Post-deposition Processes". The purpose of the data set is to complement observations of isotopic composition of surface accumulation and vapor, ultrasonic wind measurements, meteorology and the properties of the snow surface.

A pair of FM100s and MPSs were installed to two heights on a tower facing into the predominant wind direction (southwest). Due to accumulation, the instruments were installed above their nominal heights of ~10 m and 2 m. In 2012 they were approximately 12 m and 3 m and by spring 2014 were approximately 11 m and 2 m above the surface. The uptimes for both instruments are shown in **Figure 1.** Examples of particle size distributions collected by the probes are shown in **Figure 2.**

The data were processed following Spiegel et al. (2012). The details of the processing can be found in the main text and Supplementary information of Cox et al. (2019). Other useful publications include Pinnick and Auvermann (1979); Dye and Baumgardner (1984); Borrmann et al. (2000); and Berkelhammer et al. (2016).

Important! Please Read! There are a number of important notes on interpretation of the data that must be considered both use of the data. See **Data Collection, Processing, Methodology & other Remarks**, below.

Platform(s):

- The data were collected by instruments mounted on a 50 m tower located on the southeast side of Summit Station. The instruments were mounted to the south side of the tower, facing into the prevailing wind as shown in the schematic in **Figure 3.**

Instrument(s):

- Fog Monitor 100: Droplet Measurement Technologies (http://www.dropletmeasurement.com/sites/default/files/ManualsGuides/Hardware%20Manuals/Fog%20Monitor.pdf)

Data Format:

File Information & Organization

- Data file type: netCDF (daily)
- File naming convention: smtFMAA.qc.YYYYMMDD.HHMMSS.cdf
    - AA = 02 (2 m installation) or 10 (10 m installation)
- Data format and file contents:

base_time: [1x1 single]
long_name: 'Time since 1970-01-01 00:00:00'
units: 'seconds
time_offset: [1440x1 double]
long_name: 'Time since base_time'
units: 'seconds'

lat: [1x1 single]
long_name: 'north latitude'
units: 'degrees'
lon: [1x1 single]
long_name: 'east longitude'
units: 'degrees'
alt: [1x1 single]
long_name: 'altitude'
units: 'meters above Mean Sea Level'
size: [1x1 single]
long_name: ‘Bin center’
units: 'microns'
PAS: [1x1 single]
long_name: ‘Probe air speed (PAS)’
units: 'm/s'
particle_count: [1x1 single]
long_name: ‘Particle counts, corrected for sampling biases’
units: 'unitless'
number_conc: [1x1 single]
long_name: ‘number concentration, corrected for sampling biases’
units: '#/m^3'
LWC: [1x1 single]
long_name: ‘Liquid water content (LWC), corrected for sampling biases’
units: 'g/m^3'
ED: [1x1 single]
long_name: ‘Effective diameter, ratio of the 3rd to 2nd moments of the size distribution, corrected for sampling biases’
units: 'micron'
flag_qc1: [1x1 single]
long_name: ‘Quality control flag for missing data: 1 = missing data’
units: '[]'
flag_qc2: [1x1 single]
long_name: ‘Quality control flag for laser current: 1 = removed data’
units: '[]'
flag_qc3: [1x1 single]
long_name: ‘Quality control flag for PAS out of range: 1 = removed data’
units: '[]'
flag_qc4: [1x1 single]
long_name: ‘Quality control flag for recovery temp: 1 = removed data’
units: '[]'
flag_qc5: [1x1 single]
long_name: ‘Quality control flag for north winds (defined (292.5-130 deg): 1 = north winds’
units: '[]'
flag_recalc: [1x1 single]
long_name: ‘Flag for PAS recalculations: 1 = data was recalculated’
units: '[]'
flag_md_corr: [1x1 single]
long_name: ‘Flag for missing data in sampling bias calculation. Where missing ntot set to 1’
units: '[]'

flag_Vs: [1x1 single]
long_name: ‘Sample volume’
units: 'cm^3'
theta_S: [1x1 single]
long_name: ‘Sampling angle, theta_s (-180 to 180 deg)
units: 'degrees'
U: [1x1 single]
long_name: ‘Ambient wind velocity into inlet’
units: 'm/s'
eta_total: [1x1 single]
long_name: ‘Sampling efficiency, total
units: 'unitless'
inst_Ht: [1x1 single]
long_name: ‘FM height above surface’
units: 'cm'

Parameters, Flags & Codes

- Missing data or data removed during quality control set to -9999. See above for flags.

Version

- Version 1. 30-May-2018

Data Collection, Processing, Methodology & other Remarks:

IMPORTANT!

- The FM100 is a scattering spectrometer and all particle detections a sized to be calibrated with the scattering properties of liquid droplets. Thus, all sizes should be interpreted as optically-equivalent liquid spheres! Nevertheless, many observations are of frozen hydrometeors, either frozen fog droplets, diamond dust, snow or blowing snow. These particles are ice and therefore have a different density than liquid, as well as exhibit a variety of non-spherical shapes. The sizing for these particles should not be treated as physical.

- Raw FM100 measurements are affected by two large sources of uncertainty.
  - (1) Sizing ambiguities arising from the non-monotonic nature of the Mie scattering functions used to relate measured voltage to size. The data in the files are presented in the binning native to the instrument. Several approaches have been proposed. Ambiguous bins can be identified and combined (Pinnick and Auvermann, 1979; Dye and Baumgardner, 1984). For the present data set we suggest combining bins between 4 and 10 µm and considering doing the same for bins near 23 µm. Refer to the Supplement to Cox et al. (2019) for further details.
  - (2) Sampling losses associated with the aspiration and transmission of particles, in particular in variable wind conditions. A method for correcting this bias was proposed by Spiegel et al. (2012) and adopted by Cox et al. (2019). “Corrected for sampling losses” in the data attributes indicates this correction was applied. However, the correction is only valid for wind directions (absolute value) relative to the inlet (θ_S or “theta_S”) < 90° and ***extreme caution*** should be exercised in interpreting data when $|\theta_S| > 50°$.

For more information see Cox et al., ACP, 2019.

References:

Berkelhammer, M., Noone, D. C., Steen-Larsen, H. C., Bailey, A., Cox, C. J., O'Neill, M. S., Schneider, D., Steffen, K., and White, J. W. C.: Surface-atmosphere decoupling limits accumulation at Summit, Greenland, Science Adv., 2, e1501704, doi:10.1126/sciadv.1501704, 2016.

Borrmann, S., Luo,B., and Mishchenki, M.: Application of the T-Matrix method to the measurement of aspherical (ellipsoidal) particles with forward scatting optical particle counters, J. Aerosol Sci., 31, 789-799, doi:10.1016/S0021-8502(99)00563-7, 2000.

Cox, C.J., Noone, D.C., Berkelhammer, M., Shupe, M.D., Neff, W.D., Miller, N.B., Walden, V.P., and Steffen, K.: Super-cooled liquid fogs over the central Greenland ice sheet, Atmos. Chem. Phys., in press, doi:10.5194/acp-2018-819, 2019.

Dye, J. E., and Baumgardner, D.: Evaluation of the forward scattering spectrometer probe, I: Electronic and optical studies, J. Atmos. Ocean Tech., 1, 329-344, doi:10.1175/1520-0426(1984)001<0329:EOTFSS>2.0.CO;2, 1984.

Pinnick, R. and Auvermann, H.: Response characteristics of Knollenberg light-scattering aerosol counters, J. Aerosol Sci., 10, 55-74, doi:10.1016/0021-8502(79)90136-8, 1979.

Spiegel, J. K., Zieger, P., Bukowiecki, N., Hammer, E., Weingartner, E., and Eugster, W.: Evaluating the capabilities and uncertainties of droplet measurements for the fog droplet spectrometer (FM-100), Atmos. Meas. Tech., 5, 2237-2260, doi:10.5194/amt-5-2237-2012, 2012.

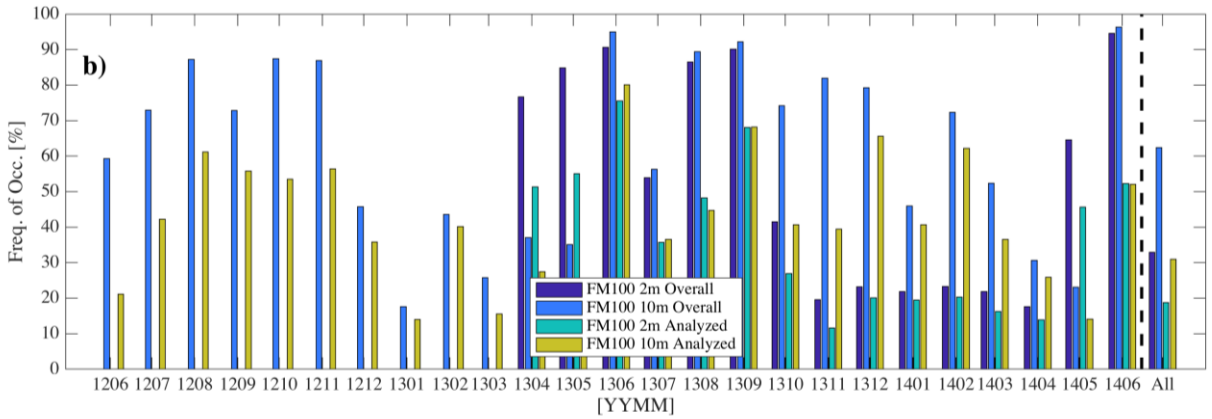

Figure 1. *Percent of available data for each month in the study period for FM100s at 10 m (dark blue/green) and 2 m (light blue/yellow). Blues show the amount of available data and yellow/green shows the amount of analyzed data after screening for wind direction and availability of ancillary measurements. Figure taken from Cox et al. (2019). Refer to that publication for further details.*

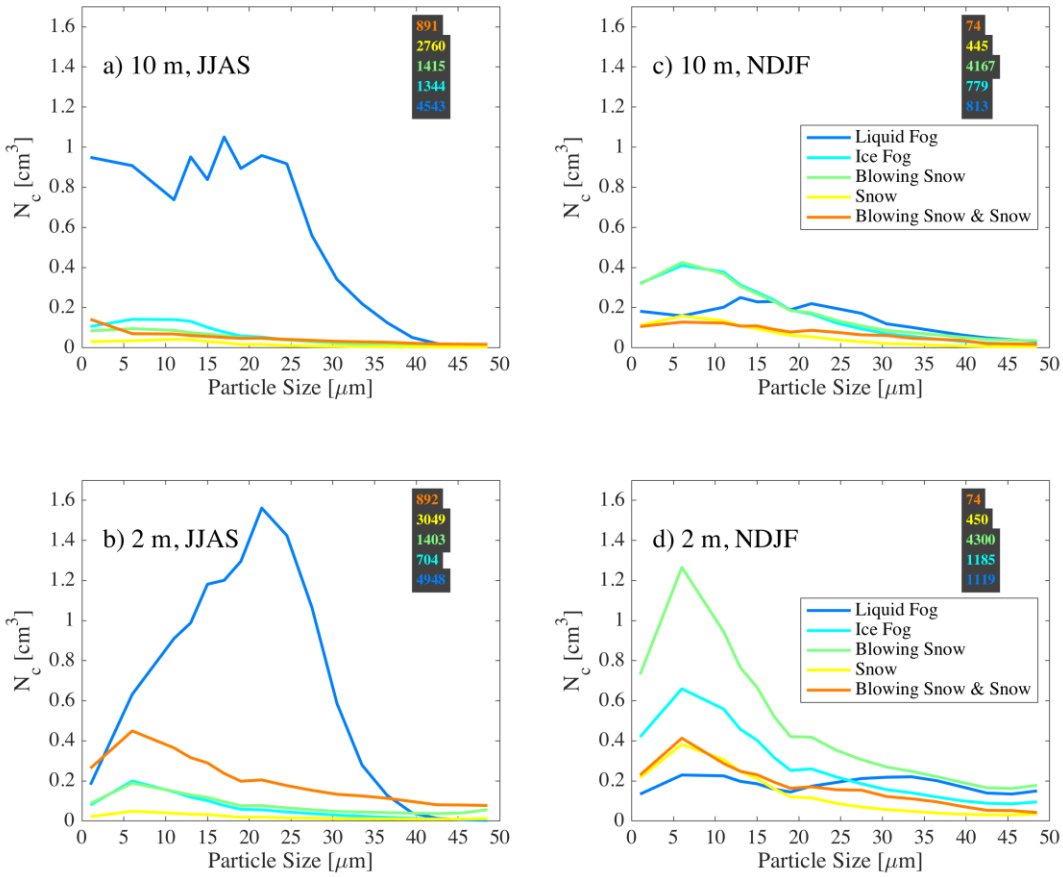

Figure 2. *Average number concentration (N_c) within the FM100 size bins for different classifications measured at 10 m (top row; a, c) and 2 m (bottom row; b, d). The left column (a,b) is for June-September (JJAS) and the right column (c,d) is for November-February (NDJF). The bin centres for the sizes are 1, 6, 11, 13, 15, 17, 19, 21.5, 24.5, 27.5, 30.5, 33.5, 36.5, 39.5, 42.5, 45.5 and 48.5 µm (refer also to the Supplement for additional information on FM100 sizing). Because the FM100 bin sizes are variable, the bin counts have been normalized such that the integral of the curves = average concentration for all bins. The values over the grey background are the number of 1-minute samples in each distribution. Figure from Cox et al. (2019). Refer to that publication for further details.*

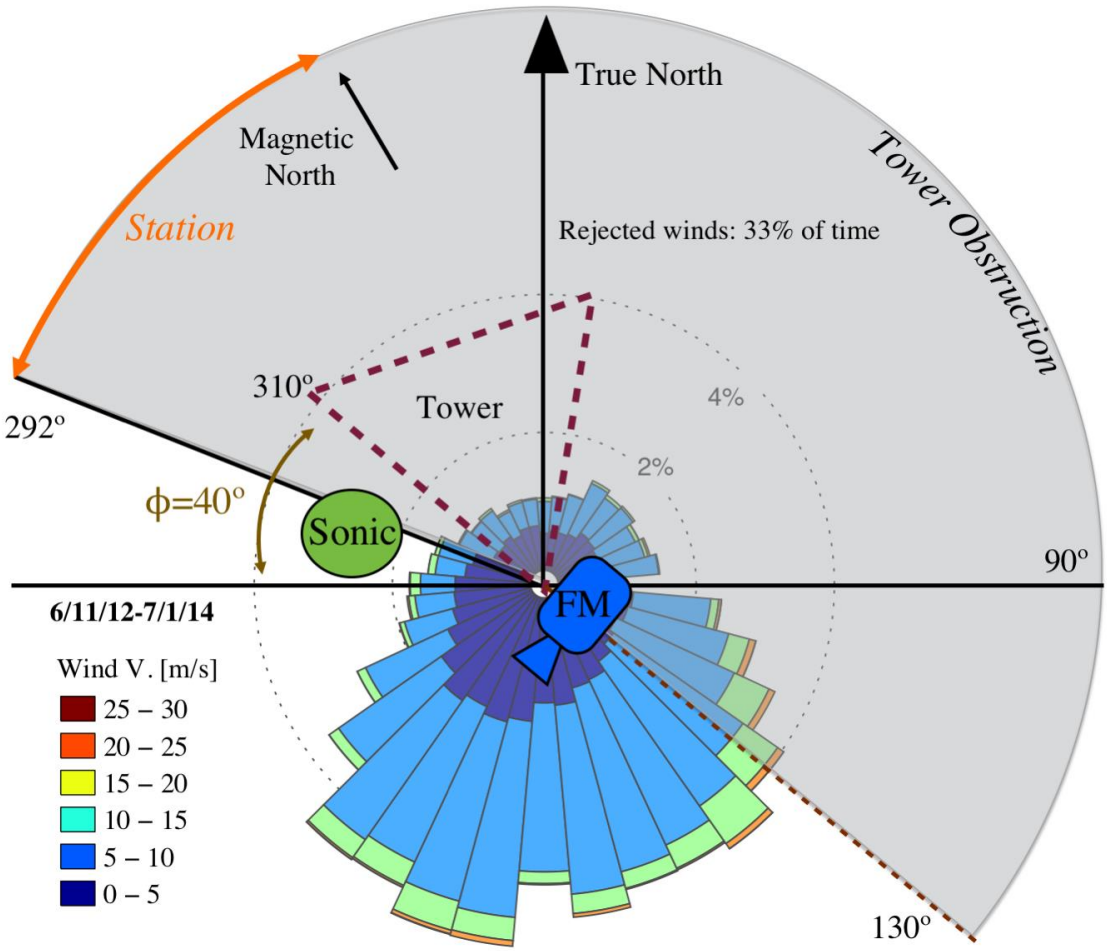

Figure 3. *Schematic plan view of the field setup of the FM100 (blue icon labelled "FM") on the tower (dashed triangle) at Summit Station. The green oval ("sonic") is the position of the Metek sonic anemometer. The grey shaded area are the wind directions that were rejected and the orange arrow denotes the sector facing the station. The wind rose is also shown cantered on the FM position.*