Metadata for ‘Profile measurements of snow transport and micrometeorology at Mizuho Station in Antarctica’

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1. Abstract

This data was collected at Mizuho Station (44.315°E, 70.71°S, 2230 m a.s.l.), East Antarctica, from **30 September to 22 November 2000** during the 41st Japanese Antarctic research expedition. Vertical profiles of the horizontal mass flux and particle number size distribution of drifting and blowing snow were measured in the lowest 10 m of the atmosphere using four **snow particle counters** (SPCs). Three 3-dimensional **ultrasonic anemometers** were deployed in the lowest 25 m of the atmosphere to record the wind velocity components and sonic temperature at a high frequency of 100 Hz. Additionally, an **automatic weather station** provided air temperature, relative humidity, air pressure, shortwave and longwave downward and upward radiation fluxes, surface temperature, snow temperatures at depths of 0.1 and 0.4 m below the surface, wind speed, and wind direction. The data is complemented by **weather observations** performed twice to eleven times per day by the Japanese Meteorological Agency.

Most of the time, the lowest SPC was situated at a height of 0.05 or 0.1 m above the snow surface. During certain periods called profile runs, the height of the lowest SPC was systematically varied between 0.02 and 0.2 m to increase the vertical resolution of the measured profiles. The other SPC's were installed at fixed heights of 1.1, 3.1, and 9.6 m. During each profile run, the lowest SPC was kept at a specific height for approximately 10 min before changing the height. If the wind speed remained approximately constant throughout a profile run, the data was used to compute the average snow-transport profile in that period. In total, 24 of such average profiles were obtained. A part of these SPC measurements are discussed in Nishimura and Nemoto (2005).

The ultrasonic anemometers were placed at heights of 0.3, 1, and 25 m. However, the height of the lowest ultrasonic anemometer was changed several times in the measurement period and ranged from 0.05 to 0.32 m. On top of that, 19 short periods (each lasting 15 to 160 min) were used to systematically vary the height of the lowest ultrasonic anemometer and thus increase the vertical resolution of the measured wind speed profile. Occasionally, drifting and blowing snow particles perturbed the ultrasonic measurement signal and electrically-charged particles caused an electric charge of the anemometers, leading to artifacts such as spikes and dropouts in the measured time series. These artifacts were largely removed and replaced by NaN, using the statistical spike removal algorithm of Mauder et al. (2013). However, the artifact removal was sometimes incomplete for the lowest anemometer because of very intense snow transport close to the surface. While temporal averages are barely affected by the artifacts, the high-frequency data of the lowest anemometer should be used carefully when computing turbulent fluxes using the eddy-covariance method.

2. Data set overview

(a) Metadata

The present file containing general metadata and three other files with specific metadata for the SPC’s and ultrasonic anemometers.

(b) SPC time series

Data from the SPC’s with 1-s intervals.

(c) SPC average profiles

Average vertical profiles of the horizontal snow mass flux, particle number size distribution, and mean and standard deviation of the particle diameter. In addition: average vertical profiles of the contribution of each diameter class to the horizontal snow mass flux for selected profile runs.

(d) – (i) Sonic data <n>

High-frequency time series from the ultrasonic anemometers, which are divided into 6 periods denoted by the index n.

(j) Spike percentage

Percentage of spikes removed from the ultrasonic anemometer data per 5-min interval.

(k) Wind speed profiles

Average vertical profiles of horizontal wind speed based on the ultrasonic anemometer data in 19 short periods, in which the height of the lowest anemometer was varied systematically.

(l) AWS data

Automatic weather station data with 10-min intervals.

(m) Weather observations

Observations of weather elements and phenomena by the Japanese Meteorological Agency.

3. Instrumentation and measurement site

The SPC sensors (SPC-S7, Niigata Denki) measure the number of snow particles and classify their diameters into 32 classes spanning the range from approximately 50 to 500 µm. These sensors were calibrated for the expected temperature conditions; therefore it is not necessary to perform a temperature correction in the postprocessing. The SPC’s were attached to a 30-m tall tower.

The ultrasonic anemometers (DA-600, Kaijo Denki) were installed on the same tower, apart from the lowest ultrasonic anemometer, which was installed on a tripod at a horizontal distance of approximately 2 m from the tower (Figure 2 in Nishimura and Nemoto, 2005). The automatic weather station was set up at a distance of 20 m from the tower.

Mizuho Station is located at a horizontal distance of approximately 250 km from the Antarctic coast and surrounded by a nearly flat, fairly uniform, snow-covered surface. The site often experiences easterly winds and wind-driven snow transport.

4. Data post-processing

The SPC data were converted from a binary format to the csv format. For the SPC at a height of 3.1 m, the smallest diameter class (44.82 µm) exhibited implausible, very high particle numbers due to noise; therefore, the particle numbers of the smallest diameter class were replaced by zero for this sensor. In a few rare situations, other diameter classes and other SPC sensors also showed obvious artifacts with particle numbers per size class and second ranging temporarily up to approximately 65000. The most extreme particle numbers were replaced by zero if they exceeded a threshold of 10000. However, this problem did not happen during the profile runs. The SPC’s regularly correct the time of their clock through GPS synchronization. Therefore, there is occasionally a time stamp, which is duplicated or skipped; please note that the recorded time stamps have not been modified. The horizontal particle mass flux F (g cm^{-2} s^{-1}) was computed as

$$F = \frac{\rho_p}{A \ \Delta t} \sum N_d \frac{4}{3} \pi \left(\frac{d}{2}\right)^3$$

where $\rho_p = 0.91\ g\ cm^{-3}$ is the assumed density of each snow particle, $A = 0.5\ cm^2$ is the area of the laser beam crossed by the particles, $\Delta t = 1\ s$ is the time interval, and N_d is the number of snow particles in the diameter class d (cm).

The lowest ultrasonic anemometer provided horizontal (X, Y) and vertical (W) wind velocity components and sonic temperature (T), while the other ultrasonic anemometers provided horizontal wind speed (U1, U25) and direction (D1, D25), vertical wind velocity component (W1, W25), and sonic temperature (T1, T25); here, 1 and 25 refer to the measurement heights of 1 m and 25 m, respectively. These data were converted from raw units to physical units. Artifacts were identified as follows and replaced by NaN:

- Values beyond constant plausibility limits were discarded (Table 1).
- The spike detection algorithm of Mauder et al. (2013) was applied to each wind velocity component and sonic temperature, considering the deviation of each data point from the 5-min block median. For the upper two anemometers, this algorithm was applied after computing the horizontal wind velocity components from horizontal wind speed and direction. The percentage of spikes/outliers removed by this algorithm is provided with the dataset for each 5-min interval. However, the lowest sonic anemometer was sometimes affected by so many spikes/artifacts that the algorithm only removed a part of them.
- Some (short) periods with remaining, obvious artifacts were identified and discarded by inspecting the time series.

Moreover, 19 short periods were removed from the time series of the lowest ultrasonic anemometer because the height of this anemometer was varied systematically in these periods, which may introduce discontinuities in the time series and would affect the computation of turbulent fluxes. These periods were only used to calculate average vertical profiles of wind speed.

Table 1: Plausibility limits for horizontal (X, Y) and vertical (W, W1, W25) wind velocity components, horizontal wind speed (U1, U25), and sonic temperature (T, T1, T25).

Type of limit	X, Y (m s^{-1})	W, W1, W25 (m s^{-1})	U1, U25 (m s^{-1})	T, T1, T25 (°C)
Lower	–24	–10	0	–55
Upper	24	10	40	–5

5. Description of the files and folders

In all files, the time is specified as local time (UTC+3).

(a) Metadata

A zip file containing the following files:

File	Description
Readme.pdf	The present file explaining the content, variables, and units of the dataset.
Sensor_height_SPC_L.csv	This file specifies the height of the lowest SPC at the beginning of each day. If the height was changed the new height is indicated by the variable ‘Modified height’ with the respective time or time period in parentheses. Periods with a systematic variation of the sensor height between 0.02 and 0.2 m are specified in the column ‘Profile runs’ (for further details, see FluxProfile.csv in data resource (c)).
period_per_file_SPC_L.csv	Overview of the first and last time stamps of time series files from the lowest SPC (folder SPC_L in data resource (b)). The files from the other SPC’s cover approximately the same periods.
mizuho_met_data_info.csv	Overview of the first and last time stamps of the time series files from the ultrasonic anemometers and changes of the sensor height

	of the lowest ultrasonic anemometer. The variable ‘met data’ specifies the beginning of the filenames in data resources (d) – (i), ‘data count’ is the number of records in the file, and ‘height_Sonic_L’ is the height (m) of the lowest ultrasonic anemometer above the snow surface at the beginning of the file. If this height was changed in the period covered by the same file the new height (m) is indicated in the variable ‘modified_height’ with the respective time or time period in parentheses. The ‘comments’ are field notes, specifying for example the 19 short periods in which the height of the lowest ultrasonic anemometer was varied systematically to measure a high-resolution vertical wind speed profile.

(b) SPC time series

The zip file contains folders named SPC_<label>, where label specifies one of the four SPC sensors according to Table 2:

Table 2: Labels of the SPC sensors.

Label	Height above surface (m)	Comment
H	9.6	
M	3.1	
A	1.1	
L	0.02 to 0.2	The height of the lowest SPC was varied with time, see Sensor_height_SPC_L.csv in data resource (a) and FluxProfile.csv in data resource (c).

Each folder contains files named mzh<digits><label><index>_conv_<yyyymmdd>.csv, where digits are four digits usually representing the month and day, label is explained in Table 2, index is a digit that differs between files recorded on the same day, and yyyymmdd specifies the date of the first time stamp in the file.
In each file, the second line represents the header line with the following variables:

Variable	Units	Description
DATE	-	Time stamp in the format yyyymmddHHMMSS
TEMP	°C	Temperature from the built-in temperature sensor with low accuracy
<value>	-	Particle number for the diameter class specified by the variable name (value), which is the particle diameter in µm (center of interval)

(c) SPC average profiles

The zip file contains the following data files (in csv or xlsx format) and plots (in pdf format) visualizing average vertical profiles for the SPC profile runs:

File	Description
FluxProfile.csv	Mean and standard deviation of the horizontal particle mass flux (g cm^{-2} s^{-1}) for each profile run. The first line contains metadata (name of the profile run, friction velocity u*, date) while the second and third lines specify the variables and units, where ‘SD’ is the standard deviation of the mass flux and ‘Period’ is the time period used to compute the statistics.

FLUX_ParticleSize.xlsx	Contribution of each diameter class to the horizontal snow mass flux for selected profile runs covering a wide range of friction velocities. Each tab of the spreadsheet file refers to a different run specified by the name of the tab (the order follows the decreasing friction velocity). The values in the header line represent the particle diameter (µm) of each size class while the data in the remaining lines represent the mass flux contribution (g cm^{-2} s^{-1}). If a measurement height appears twice, the lowest SPC was placed at this height in both an initial phase and final phase of the profile run to check whether the conditions changed with time during the run.
MeanDiameter.csv	Mean particle diameter (µm) as a function of height for each profile run. The first line contains the names of the profile runs, where the suffix 'a' indicates a control measurement at one or more heights. For example, Run1a is identical to Run1 at all heights apart from the height of 0.1 m, where the lowest SPC was located in both an initial phase and final phase of the run. The second and third lines specify the variables and units.
SIZE_distribution.xlsx	Average particle number size distribution as a function of height for each profile run. Each tab of the spreadsheet file refers to a different run. The first two lines contain metadata (name of the run and friction velocity u*). The third line is the header line, where DIAMETER is the particle diameter (µm) of each size class and the remaining variable names specify the heights; the suffix '_2' indicates that the measurements at this height were repeated in the final phase of the profile run. The remaining lines contain the percentage of particles (%) per size class.
Flux.pdf	Plots of the horizontal particle mass flux (horizontal axis) as a function of height (vertical axis). The error bar indicates two times the temporal standard deviation, which appears assymetric because of the logarithmic axis. Pages 1 to 7 show all profile runs ordered chronologically while pages 8 to 14 show the same runs ordered according to friction velocity u_*. The weather description above each plot (e.g., Cloudy& Drifting snow) is a visual observation made by the Japanese Meteorological Agency (see data resource (m)). The description 'Snow precipitation' inside the plots of Run 3 and Run 5 is based on field notes.
ParticleSize_new.pdf	Plots of the mean particle diameter and particle number size distribution as a function of height. The size distributions on the right side are shown with a logarithmic diameter axis.
FluxPerSizeClass_selected.pdf	Plots of the contribution of each diameter class to the horizontal snow mass flux for selected profile runs. Additionally, plots of the mass flux profiles, mean particle diameter profiles, and particle size distributions are included for the selected runs.

(d) – (i) Sonic data <n>

Zip archives containing 100-Hz time series from the sonic anemometers. Each zip archive covers a part of the measurement period denoted by index n and contains csv files named MZH<fileID>_<yyyymmdd>_<HHMMSS>_<msec>.csv, where fileID is a unique label for each file and yyyymmdd, HHMMSS, and msec are the date, time, and milliseconds of the first time stamp of the file. The frequency of the measurement records is 100 Hz. The header line of each csv file contains the following variables:

Variables	Units	Sensor height (m)	Description
X, Y	m s^{-1}	0.05 to 0.32[b]	Horizontal wind velocity components aligned with a wind direction of 160° and 70°, respectively. Wind direction can be computed as $D = atan(X/Y) * \frac{180}{\pi} + 70 \quad if\ Y \geq 0,$ $D = atan(X/Y) * \frac{180}{\pi} + 250 \quad if\ Y < 0.$
W	m s^{-1}	0.05 to 0.32[b]	Vertical wind velocity component
T	°C	0.05 to 0.32[b]	Sonic temperature
X1[a], Y1[a]	m s^{-1}	1	Horizontal wind velocity components aligned with westerly and southerly wind directions, respectively. Wind direction can be computed as $D = atan(X/Y) * \frac{180}{\pi} + 180 \quad if\ Y \geq 0,$ $D = atan(X/Y) * \frac{180}{\pi} \quad if\ Y < 0.$
W1[a]	m s^{-1}	1	Vertical wind velocity component
T1[a]	°C	1	Sonic temperature
X25, Y25	m s^{-1}	25	Horizontal wind velocity components aligned with westerly and southerly wind directions, respectively. Wind direction can be computed as for the anemometer at a height of 1 m (see above).
W25	m s^{-1}	25	Vertical wind velocity component
T25	°C	25	Sonic temperature

[a] not contained in the first file (MZH0003_20000930_132854_00.csv) because the respective sensor was not installed yet
[b] The height was varied with time, see mizuho_met_data_info.csv in data resource (a).

(j) Spike percentage

A csv file containing the percentage (%) of spikes/outliers in the total number of records in each 5-min interval of the ultrasonic anemometer data, as detected and removed by the algorithm of Mauder et al (2013). The header line specifies the respective variable, to which the algorithm was applied (X, Y, etc., see table above). The time stamp (Time_centered) in the format yyyy-mm-dd HH:MM:SS refers to the center of each interval.

(k) Wind speed profiles

A zip file containing a data file (WINDSPEED_profile.csv) and plots (MZH_WIND.pdf), describing 19 average vertical profiles of wind speed obtained by varying systematically the height of the lowest ultrasonic anemometer. In the data file, the first two lines contain metadata (name of the profile, e.g., ‘No. 1’; date; time period) while the third line represents the header line with variables and units, where U is the average horizontal wind speed. Additionally, the friction velocity u* based on the eddy-covariance method is specified for the period of each wind speed profile. A few of the wind speed profiles deviate clearly from a logarithmic profile in the lowest 20 cm of the atmosphere, which is likely due to the fact that the lowest anemometer was used to perform measurements at several heights but not at the exact same time.

(l) AWS data

The csv file contains 10-min averaged data from an automatic weather station. The first three lines describe the following variables, measurement heights, and units:

Variable	Units	Sensor height (m)	Description
DATE	-	-	Date in the format dd/mm/yyyy
TIME	-	-	Time in the format HH:MM. Although field notes suggest that the time refers to the end of the 10-min interval, the time series of wind speed, wind direction, and air temperature will correlate better with the ultrasonic anemometer data if we assume that the time represents the beginning of the 10-min interval.
WindSpeed	$m\ s^{-1}$	3	Average horizontal wind speed
WindDirection	°	3	Horizontal wind direction
MaxWS	$m\ s^{-1}$	3	Maximum horizontal wind speed
AirTemp	°C	1	Air temperature. During the coldest hours of some days, a constant value of –39.6 °C is recorded because the sensor cannot measure lower temperatures; these artifacts are still contained in the data.
Humidity	%	1	Relative humidity with respect to liquid water
Snow Surface Temp	°C	-	Snow surface temperature
Air Pressure	hPa	1	Air pressure
Short wave down	$W\ m^{-2}$	-	Downward shortwave irradiance
Long wave down	$W\ m^{-2}$	-	Downward longwave irradiance
Short wave up	$W\ m^{-2}$	-	Upward shortwave irradiance
Long wave up	$W\ m^{-2}$	-	Upward longwave irradiance
Snow Temp 10cm	°C	–0.1	Snow temperature at a height of 10 cm below the snow surface
Snow Temp 40cm	°C	–0.4	Snow temperature at a height of 40 cm below the snow surface

(m) Weather observations

A csv file with observations of weather conditions, visibility, cloud cover, cloud forms, and weather elements – twice or three times per day for most of the time and more often on certain days. The weather elements such as air temperature were obtained from a mini automatic weather station (MAWS) or manual measurements (if the MAWS was out of order). The first two lines specify the following variable names and units:

Variable	Units	Description
Date	-	Date in the format dd-<month>, where month is the abbreviation of the month in the year 2000.
Time_LT	-	Local time in the format HH:MM.
Atmospheric Pressure	hPa	Atmospheric pressure
Air Temp.	°C	Air temperature
Air Temp. 2	°C	Air temperature (repeated manual measurement)
Weather	-	Visual weather observation
Wind Direction	°	Wind direction
Wind Direction 2	°	Wind direction (repeated manual measurement)
Wind Speed	$m\ s^{-1}$	Horizontal wind speed
Visibility	km	Visibility
Cloud Amount	-	Cloud amount on a scale from 0 (no clouds) to 10 (overcast)
Cloud Forms	-	Cloud forms and their amount at low (CL), intermediate (CM), and great (CH) heights
Dew-point Temp.	°C	Dew-point temperature

Relative humidity	%	Relative humidity with respect to liquid water
Weather Phenomena	-	Visual observations of drifting snow, blowing snow, and mist
Remarks	-	Comments and explanations

References

Mauder, M., Cuntz, M., Drüe, C., Graf, A., Rebmann, C., Schmid, H.P., Schmidt, M., Steinbrecher, R. (2013). A strategy for quality and uncertainty assessment of long-term eddy-covariance measurements. Agric For Meteorol 169:122–135. https://doi.org/10.1016/j.agrformet.2012.09.006

Nishimura, K., Nemoto M. (2005). Blowing snow at Mizuho station, Antarctica. Phil. Trans. R. Soc. A. 363: 1647–1662. https://doi.org/10.1098/rsta.2005.1599