ClimateBasis Disko

Project no.: B67

Asiaq Report 2023-14

Arno C. Hammann

This edition of the ClimateBasis Manual

Please note that GeoBasis procedures are subject to ongoing changes and improvements and therefore, the manual is per definition always under construction/preliminary. If you have questions or comments to this edition, please contact:

Arno C. Hammann
Asiaq – Greenland Survey
Qatserisut 8
3900 Nuuk
E-mail: ach@asiaq.gl

Introduction

The DiskoBasis research area was established as a full level 1 site under the Greenland Ecosystem Monitoring (GEM) programme in 2016, succeeding a GEM pilot project which ran from 2013 to 2016. The current terrestrial research activities on Qeqertarsuaq (Disko) Island build upon a long history of investigations in the region dating back to the establishment of Arctic Station, on the outskirts of the town of Qeqertarsuaq, in 1906 and even before. The historic and continuing interest in this area is related to its large diversity of landscape types and habitats (Humlum, 1982; Citterio *et al.*, 2009). Within Greenland, Qeqertarsuup Tunua (Disko Bay) is the region with the largest abundance of animal and plant species (Fredskilds, 1996).

The ClimateBasis monitoring programme collects, processes and studies climate data by means of a automated weather station (AWS) on Teleø peninsula, and a microwave radiometer (atmospheric profiler) and a hemispherical camera located at Arctic Station.

Content

1 Site and instrumentation description

The island of Qeqertarsuaq (Disko Island) consists mainly of steep-sided table mountains of flood basalts which erupted during the rifting between Labrador and Greenland around 60 million years ago. The town of Qeqertarsuaq is located on a flat peninsula of Precambrian bedrock at the southernmost point of the island, at the foot of c. 500 m high basaltic cliffs oriented in the east-west direction. The predominant wind directions are therefore easterly or westerly; southerly winds are blocked by the topography, but northerly Foehn winds from the mountains are common. To the east of the town, the wide glacial Blæsedalen valley with the river Røde Elv interrupts the basaltic plateau in north-south direction. Arctic Station, which was founded in 1906, lies on the outskirts of town towards Blæsedalen.

ClimateBasis Disko operates an automated weather station (AWS, Climate Station Teleø), a microwave radiometer which reconstructs vertical profiles of atmospheric temperature and humidity (therefore also referred to as an atmospheric profiler, Microwave Radiometer / Atmospheric Profiler), and a hemispherical optical camera to detect the cloud-covered fraction of the sky based on visible-spectrum images (Hemispheric Camera). In the spring, a snow survey is carried out in Blæsedalen.

station	Asiaq station no.	longitude	latitude	elevation (m)
climate station Teleø	523	53° 31' 43.9" W	69° 14' 39" N	11.7
profiler / skycam	664 / 663	53° 31' 16" W	69° 15' 9.7" N	28

Table 1: Locations of ClimateBasis Disko installations.

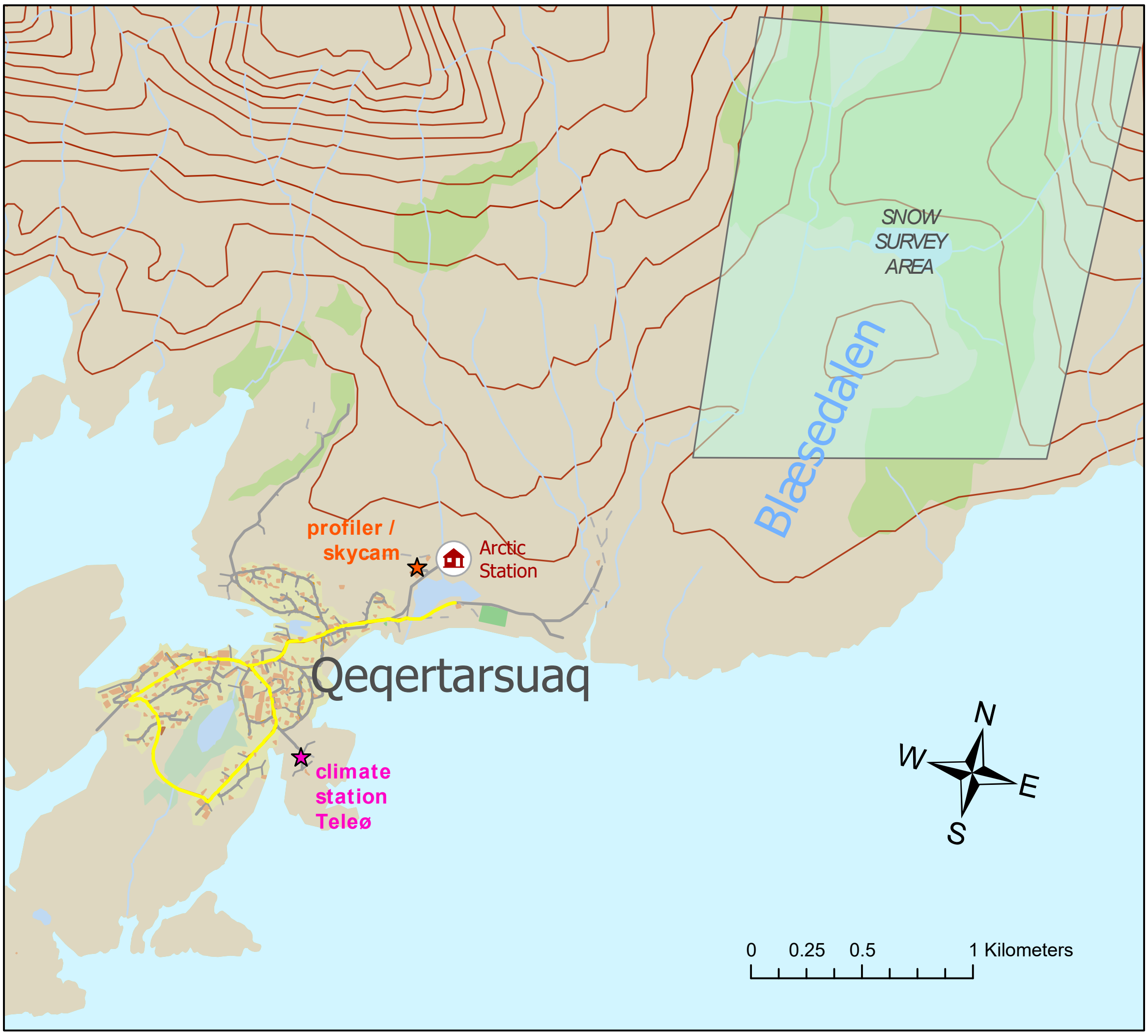

Figure 1: ClimateBasis Disko operations in and around the town of Qeqertarsuaq.

1.1 Climate Station Teleø

The climate station is located on a peninsula within the town of Qeqertarsuaq known as Teleø; this is due to the fact that a weather station has operated at this location since September 1993, and the existing timeseries from this weather station have been continued under the GEM programme. While the location has remained the same in order to safeguard the homogeneity of the timeseries, many sensors have been added in 2016 when ClimateBasis Disko became a full GEM subprogramme. Table 1 lists all parameters that are currently measured together with the sensor makes currently used and their respective measurement characteristics.
Data from the station is transmitted hourly via cell phone modem to Asiaq and certain parameters are displayed on Asiaq's weather website.
The currently used datalogger is the model CR3000 by Campbell Scientific.

parameter	sensor	range	sensitivity	accuracy	valid at
air temperature	Rotronic, HC2A-S3	-50–100 °C	0.1 °C	± 0.1 °C	23 °C
		0.5 m	10 - sample; 60 - sample, ave, min, max		
		2 m	10 - sample; 60 - sample, ave, min, max		
		4 m	10 - sample; 60 - sample, ave, min, max		
		7.5 m	10 - sample; 60 - sample, ave, min, max		
relative humidity		0–100 %	0.1 %	± 0.8 %	23 °C
		0.5 m	10 - sample; 60 - ave, min, max		
		2 m	10 - sample; 60 - sample, ave, min, max		
		4 m	10 - sample; 60 - ave, min, max		
		7.5 m	10 - sample; 60 - ave, min, max		
air pressure	Vaisala, PTB101B	600–1060 hPa	0.1 hPa	± 0.5 hPa	20 °C
		1.6 m	60 – sample		
wind speed	Vector Instruments, A100R	0.2–75 ms^{-1}	0.1 ms^{-1}	0.1 ms^{-1}	0.3–10 ms^{-1}
				± 1 %	10–55 ms^{-1}
				± 2 %	>55 ms^{-1}
		0.5 m	10 – ave, max		
		2 m	10 – ave, max		
		4 m	10 – ave, max		
	Gill Instruments, Wind Observer 70	0.01–70 ms^{-1}	0.01 ms^{-1}	± 2%	12 ms^{-1}
		7.5 m	10 – ave, max		
wind direction		0, 359°	1°	± 2°	12 ms^{-1}
		7.5 m	10 – ave		
shortwave*	Kipp & Zonen, CM6B	0–1400 Wm^{-2}	9–15 µV/Wm^{-2}	± 8 %	hourly
				± 5 %	daily
		2 m	5 – ave, std		
longwave*	Kipp & Zonen, CGR4	0–250 Wm^{-2}	5–10 µV/Wm^{-2}	± 3 %	daily
		2 m	5 – ave, std		
UV-B	Solar Light, 501V3	0–10 MEDh^{-1}		± 5 %	daily
		2 m	5 – ave, std		
PAR	Kipp & Zonen, PQS1	0–10000 µmol/m^{2}s	4–10 µV/µmol/m^{2}s	± 3 %	
		2 m	5 – ave		
precipitation	Ott, Pluvio^2	6–1800 mmh^{-1}	6 mmh^{-1}	6 mmh^{-1}	
			60 – sample		
snow depth	Campbell Scientific, SR50A	0.5–10 m	0.25 mm	± 1 cm or 0.4 %	
			ave over last 2 of every 60 minutes		

Table 2: Parameters measured at the climate station. For each parameter, the parts of the table underlain in blue give the sampling scheme currently in use. For several sensor types, more than one sensor is

mounted at different heights, which are given in the first column, whereas the second column gives the sampling type for a given sampling frequency. For example, | 2 m | 10 - sample; 60 - sample, ave, min, max | means that for the sensor mounted at 2 m above ground, point samples are archived every 10 minutes, whereas samples, averages over the whole sampling period, minimum and maximum values over the sampling period are archived every 60 minutes. (*) Only incoming short- and longwave radiation are measured.

1.2 Microwave Radiometer / Atmospheric Profiler

The microwave radiometer installed near the library building at Arctic Station is the model HATPRO ("Humidity and Temperature Profiler") G5 of the company Radiometer Physics GmbH (RPG). It measures microwave emissions of water vapour (in the 22-32 GHz band) and oxygen (51-59 GHz) molecules and uses 7 bandpass-filtered channels for each of the two bands (14 in total) to construct vertical profiles of water vapor and temperature by means of a statistical model. The statistical model is developed on the basis of radiosonde profiles of atmospheric variables and corresponding radiative transfer calculations (Instrument Operation and Software Guide, 2021).

The instrument has two measurement modes: a full tropospheric profile mode in which the receiver points to the zenith, and a boundary layer scan mode in which the receiver is incrementally moved from an elevation angle of 5˚to zenith. The boundary layer scan mode provides many more degrees of freedom for a statistical model and a correspondingly higher vertical resolution of the resulting profile, but is only available for the temperature band. In addition to vertical profiles, the instrument also provides column-integrated timeseries of water vapor and liquid water. Note, however, that the used frequency bands do not correspond to emission lines from ice, such that ice present in the atmosphere cannot be detected. Similarly, during rainfall, no useful profiles can be acquired.

In addition to these basic retrieved properties, several derived quantities are also calculated. Cloud-base height, in particular, is derived by additionally measuring, with a separate infrared radiometer, longwave radiation in the 9.2-10.6 µm band, which responds to emissions from the cloud base. The derived temperature is then compared to the temperature profile to locate the height at which the atmospheric temperature is equal to that calculated for the cloud base. Boundary layer height and several meteorological stability indexes are derived through secondary calculations.

parameter	**frequency band used**	**scan mode**	**nominal vertical resolution***	**nominal accuracy (RMS)***	**temporal resolution archived**
humidity	22-32 GHz	zenith	100 m (0–2 km) 250 m (2–5 km) 400 m (5–10 km)	0.4 g m^{-3}	1 min
temperature	51-59 GHz			0.25 K (0–1 km) 0.35 K (1–2 km) 0.5 K (>2 km)	1 min
		boundary layer	30–50 m		20 min
integrated water vapor				± 0.2 kg m^{-2}	1 sec
integrated liquid water				± 20 g m^{-2}	1 sec
cloud base height					1 sec
boundary layer height					20 min
stability indexes					1 min

Table 3: Parameters derived through microwave emission measurements. (*) The values given for vertical resolution and accuracy of the derived profiles corresponding to the heights within the atmospheric column given in brackets. Note, however, that the nominal resolution is not necessarily equivalent to actual information content of the profiles, which is strongly constrained by the number of degrees of freedom (e.g. the number of frequency channels used) available for the statistical models. Compared to radiosonde profiles, radiometer-derived profiles will appear as if smoothed with filter and may, for example, not capture all temperature inversions (Löhnert & Maier, 2012).

1.3 Hemispheric Camera

In order to derive fractional cloud cover with the algorithm by Wacker et al. (2015), a hemispherical camera is installed next to the microwave radiometer at Arctic Station. The camera used is a security camera from the manufacturer Mobotix. Purpose-made cameras for scientific purposes exist and have certain advantages over the type used here (e.g. a shading device to block out direct sunlight similar to what is used to measure diffuse solar radiation; also, a known mathematical model for the lens distortion – in the case of security cameras this is inaccessible proprietary information). However, besides cost, the primary advantage of the camera used here is its sturdiness with respect to weather influences.
The original algorithm is being improved and adapted to arctic conditions.

2 Procedures

2.1 Station maintenance

Once per year, the climate station is visited by Asiaq personnel to perform maintenance and reference testing. This includes a check of the installation's hardware and a change of sensors where necessary. Sensors are replaced in regular intervals by freshly calibrated ones (1-2 years for temperature and humidity sensors, 2-4 years for radiation sensors; wind sensors have their ball bearings replaced every 2-4 years and the acoustic snow depth sensor has its membrane changed every 1-2 years). Malfunctioning sensors are replaced as soon as possible.
Reference tests are conducted with calibrated sensors upon arrival at the station and at the end of the visit, after sensors have been replaced. Table 3 shows the reference tests conducted and the respective permitted tolerances for the tests.
The sensor measuring UV-B radiation is always left in place, but a calibrated reference sensor is installed and collects data during each station visit. The measurements collected by the fixed sensor are then corrected with the help of the temporary / calibrated sensor.

sensor	**tolerance**
air temperature	± 0.5 K
relative humidity	± 3 %
wind speed	± 1 m s^{-1}
wind direction	± 10°
atmospheric pressure	± 0.5 hPa
shortwave radiation	± 15 W m^{-2}
snow depth	± 1 cm

Table 4: Conducted reference tests and allowable deviations between installed and reference sensors.

The maintenance procedures for the microwave radiometer are currently still evolving and consist mainly of troubleshooting its operation, software updates and regular replacement of the foam cover which protects the movable parabolic mirror.
Field reports, detailed log sheets and photos are filled out and collected during each visit, including the serial numbers of installed sensors.

2.2 Data quality control

Quality control of the archived data is performed annually. Every timeseries is manually checked for unlikely values on the basis of expert knowledge. There is a certain availability of nearby measurements of the same parameter, for example from meteorological measurements performed by the GeoBasis program, which can be used for comparison to detect outlying values. The same parameter measured at different heights on the mast (as with air temperature, relative humidity and wind speed) is also used for comparisons.

Precipitation

The precipitation measurements at the climate station Teleø with the accumulating Ott Pluvio² rain gauge. In order to minimize evaporation and prevent freezing during the winter, a mixture of antifreeze, ethanol and oil (3 l / 3 l / 0.5 l, respectively) is added to the gauge after emptying it during a station visit. The sensitive pressure cell of the gauge registers a large amount of noise, whose sources are still under investigation. Wind, which is usually strong during rain or snow events, presumably leads to vibrations which may be reinforced / more easily transmitted in the presence of ice and snow in and around the gauge.

The data is therefore transformed into hourly rainfall increments by first applying the "neutral aggregating filter" (NAF) by Pan et al. (2016; Smith et al., 2019) and then differencing the accumulated timeseries.

No attempt is made to correct for wind-induced undercatch; however, it should be noted that we found that the amount of solid precipitation (snow) caught by the gauge typically exceeds water equivalent calculations based on other sources (e.g. snow depth sensor).

3 Annual snow survey

3.1 Drone-based snow volume mapping

The snow survey is carried out in Blæsedalen to the east of Arctic Station. A drone survey covering about 3.2 km^2 is carried out by photogrammetrically constructing a digital terrain model (DTM) of the snow-covered area and differencing it with a DTM constructed under snow-free conditions. Figure 1 shows the approximate extent of the surveyed area. Ground control points are measured in with RTK GPS with respect to a fix point located in the vicinity of the library building at Arctic Station.

3.2 Snow pits

Snow pits are dug at several locations within the area covered by the drone survey. While the locations are not very precisely adhered to, an attempt is made to visit approximately the same sites each year (table 4).

In a snow pit, the shadowed side of the pit is characterized in several ways. First, a stratigraphy is constructed by identifying layers of homogeneous snow/ice properties (hardness and grain size/type). Then, the density and temperature of the snowpack is measured in increments of 10 cm; the density is measured with a rip cutter and kitchen scale.

location	longitude	latitude	ground conditions
weather station	53° 28' 5.4" W	69° 15' 55.5" N	vegetation / dry
red hut	53° 28' 43.0" W	69° 15' 54.9" N	vegetation / dry
CENPERM site	53° 27' 44.8" W	69° 15' 55.7" N	wet soil
moraine	53° 28' 0.2" W	69° 16' 16.4" N	vegetation
moraine	53° 28' 1.0" W	69° 16' 16.4" N	vegetation
moraine	53° 28' 1.2" W	69° 16' 18.8" N	shrubs

Table 5: Approximate locations and characteristics of snow pits.

4 References

Citterio M., Paul F., Ahlstrøm A.P., Jepsen H.F. and Weidick, A. (2009) Remote sensing of glacier change in West Greenland: Accounting for the occurrence of surge-type glaciers. *Ann. Glaciol*. 50(53), 70–80 (doi:10.3189/172756410790595813)

Fredskild B. 1996 A phytogeographical study of the vascular plants of West Greenland. *Medd. Gronland, Biosci.* 45. 3-157

Humlum, O. (1982) Rock glacier types on Disko, central West Greenland. *Geogr. Tidsskr*. 82, 59–66

Instrument Operation and Software Guide (2021), Radiometer Physics GmbH

Löhnert, U., and O. Maier. "Operational Profiling of Temperature Using Ground-Based Microwave Radiometry at Payerne: Prospects and Challenges." *Atmospheric Measurement Techniques* 5, no. 5 (May 21, 2012): 1121–34. https://doi.org/10.5194/amt-5-1121-2012.