ClimateBasis Monitoring Program

Nuuk Basic
2013

Project no.: B53-05

Asiaq Report 2014-15 May 2014

Introduction

The ClimateBasis monitoring program in Nuuk is part of the Nuuk Ecological Research Operations (NERO). The aim of NERO is to improve the understanding of the composition, function, dynamics and changes of the ecosystem in the low Arctic. NERO is part of Greenland Ecosystem Monitoring (GEM).

The ClimateBasis monitoring program includes collection, quality control and communication of data, which describes the climate and hydrology in Kobbefjord.

In 2013 the ClimateBasis monitoring program included two climate stations (Climate Station 1 (No. 652) and 2 (No. 653)) one hydrometric station (Hydrometric Station 1 (650) and three diver stations, diver station (H3 (No. 654), H4 (No. 655) and H5 (No. 656)). For a detailed description see Iversen and Thorsøe (2009).
This report contains information about Climate Station 1, Climate Station 2 and Hydrometric Station 1.

Asiaq, Greenland Survey, is responsible for the operation of ClimateBasis. The Danish Energy Agency finances the ClimateBasis monitoring program.

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Content

1 Measuring Program 2013, Climate Stations

An overview of the measuring program for station 652 and station 653 during 2013 can be seen in Table 1.1 and Table 1.2.

Table 1.1 Overview of measuring program for st. 652, 2013.

Parameter	Sensor Type	Sensor Height (m.a.t.)	Measuring Range	Sensitivity (resolution)	Accuracy	Data Stored in the Data logger[1]	
						Average/sum	Sample/max/min
Air Temperature	Rotronic, HC2	2 m	-50 - +100 °C	0.1 °C	+/- 0.1 °C	$[0;30]^{30min}_{10sec}$ Average	$[-]^{30min}_{10sec}$ max/min
Relative Humidity	Rotronic, HC2	2 m	0 - 100 %RH	0.1 %	+/- 1 %	$[0;30]^{30min}_{10sec}$ Average	
Air Pressure at Station	Vaisala, PTB101 B	1.5 m	600 - 1060 hPa	0.1 hPa	+/- 4 hPa	$[0;30]^{30min}_{10sec}$ Average	
Wind Speed	Theodor Friedrichs & Co 4034.0000	10 m	0.5 - 60 m/s	0.1 m/s	+/- 0.3 m/s	$[0;10]^{10min}_{10sec}$ Average	$[-]^{30min}_{10sec}$ max/min
Wind Speed	Theodor Friedrichs & Co 4034.0000	2 m	0.5 - 60 m/s	0.1 m/s	+/- 0.3 m/s	$[0;10]^{10min}_{10sec}$ Average	$[-]^{30min}_{10sec}$ max/min
Wind Direction	Theodor Friedrichs & Co 4444.0001	10 m	1-359°			$[0;10]^{10min}_{10sec}$ Average	$[-]^{30min}_{10sec}$ at max wind
Short Wave Radiation, Incoming and Outgoing	Kipp & Zonen, CNR1	2 m	0 - 1000 W/m^2	0.6 – 2.7 W/m^2	+/- 10 % for daily sums	$[0;5]^{5min}_{10sec}$ Average	
Long Wave Radiation, Incoming and Outgoing	Kipp & Zonen, CNR1	2 m	+/-250 W/m^2	0.3 – 1.1 W/m^2	+/- 10 % for daily sums	$[0;5]^{5min}_{10sec}$ Average	
UV-B	Solar Light 501A	2 m	0 - 583 mW/m^2	< 0.583 mW/m^2	+/- 5 % for daily total	$[0;5]^{5min}_{10sec}$ Average	
PAR	Kipp & Zonen PAR Lite	2 m	0 - 3700 µmol/(S*m^2)	1.2 – 1.8 µmol/(S*m^2)	+/- 10 %	$[0;5]^{5min}_{10sec}$ Average	
Relative Vegetation Index, Incoming	Skye Inst. SKR110	2 m	<500 µmol/m^2/s	100 µmol/m^2/s	+/- 3 - 5 %	$[0;5]^{5min}_{10sec}$ Average	
Relative Vegetation Index, Outgoing	Skye Inst. SKR110	2 m	<500 µmol/m^2/s	100 µmol/m^2/s	+/- 3 - 5 %	$[0;5]^{5min}_{10sec}$ Average	
Precipitation	Ott Pluvio	-	0 - 99.99 mm	0.05 mm/h	+/- 1%	$[0;60]^{60min}_{10sec}$ sum	$[-]^{x min}_{10sec}$ Sample
Snow Depth	Campbell Scientific SR50A	-	0.5 - 10 m	0.1 mm	+/- 1 cm or 0.4 %		$[178;180]^{180min}_{10sec}$ Average

[1)] Data stored in the data logger is given as $[a;b]^{d}_{c}$, where 'd' is the interval between outputs written to the data logger, 'c' is the interval between scans of the sensor, 'a' and 'b' are minutes into the interval between output. Average values are found by averaging data values measured with interval c between 'a' and 'b'. Sample values are measured 'a' minutes into the interval between output.

Table 1.2 Overview of measuring program for st. 653, 2013.

Parameter	Sensor Type	Sensor Height (m.a.t.)	Measuring Range	Sensitivity (resolution)	Accuracy	Data Stored in the Data logger[1]	
						Average/sum	Sample/max/ min
Air Temperature	Rotronic, HC2	2 m	-50 - +100 °C	0.1 °C	+/- 0.1 °C	$[0;30]^{30min}_{10sec}$ Average	$[-]^{30min}_{10sec}$ max/min
Relative Humidity	Rotronic, HC2	2 m	0 - 100 %RH	0.1 %	+/- 1 %	$[0;30]^{30min}_{10sec}$ Average	
Air Pressure at Station	Vaisala, PTB101 B	1.5 m	600 - 1060 hPa	0.1 hPa	+/- 4 hPa	$[0;30]^{30min}_{10sec}$ Average	
Wind Speed	Met One 034B	10 m	0.4 - 49 m/s	0.1 m/s	+/- 0.12 m/s (>10.1 m/s 1.1%)	$[0;10]^{10min}_{10sec}$ Average	$[-]^{30min}_{10sec}$ max/min
Wind Speed	Theodor Friedrichs & Co 4444.0003	2 m	0.5 - 60 m/s	0.1 m/s	+/- 0.3 m/s	$[0;10]^{10min}_{10sec}$ Average	$[-]^{30min}_{10sec}$ max/min
Wind Direction	Met One 034B	10 m	0 - 360°	0.5°	+/- 4°	$[0;10]^{10min}_{10sec}$ Average	$[-]^{30min}_{10sec}$ at max wind
Short Wave Radiation, Incoming and Outgoing	Kipp & Zonen, CNR1	2 m	0 - 1000 W/m^2	0.6 – 2.7 W/m^2	+/- 10 % for daily sums	$[0;5]^{5min}_{10sec}$ Average	
Long Wave Radiation, Incoming and Outgoing	Kipp & Zonen, CNR1	2 m	+/-250 W/m^2	0.3 – 1.1 W/m^2	+/- 10 % for daily sums	$[0;5]^{5min}_{10sec}$ Average	
UV-A	Kipp & Zonen UVS-AB-T	2m	0 - 9000 mW/m^2	< 90 mW/m^2	+/- 5 % for daily total	$[0;5]^{5min}_{10sec}$ Average	
UV-B	Kipp & Zonen UVS-AB-T	2 m	0 - 600 mW/m^2	< 6 mW/m^2	+/- 5 % for daily total	$[0;5]^{5min}_{10sec}$ Average	
PAR	Kipp & Zonen PAR Lite	2 m	0 - 3700 µmol/(S*m^2)	1.2 – 1.8 µmol/(S*m^2)	+/- 10 %	$[0;5]^{5min}_{10sec}$ Average	
Relative Vegetation Index, Incoming	Skye Inst. SKR110	2 m	<500 µmol/m^2/s	100 µmol/m^2/s	+/- 3 - 5 %	$[0;5]^{5min}_{10sec}$ Average	
Relative Vegetation Index, Outgoing	Skye Inst. SKR110	2 m	<500 µmol/m^2/s	100 µmol/m^2/s	+/- 3 - 5 %	$[0;5]^{5min}_{10sec}$ Average	
Precipitation	Ott Pluvio2	-	0 - 99.99 mm	0.05 mm/h	+/- 1%	$[0;60]^{60min}_{10sec}$ sum	
Snow Depth	Campbell Scientific SR50	-	0.5 - 10 m	0.1 mm	+/- 1 cm or 0.4 %		$[178;180]^{180min}_{10sec}$ Average

[1)] Data stored in the data logger is given as $[a;b]^{d}_{c}$, where 'd' is the interval between outputs written to the data logger, 'c' is the interval between scans of the sensor, 'a' and 'b' are minutes into the interval between output. Average values are found by averaging data values measured with interval c between 'a' and 'b'. Sample values are measured 'a' minutes into the interval between output.

2 Inspections of the Stations during 2013

Asiaq technicians visited the Nuuk Basic climate stations four times in 2013. Three additional visits to the stations were carried out by other Asiaq personnel. A summary of the work done on each station is given below.

2.1 Time Line and Summary of Events for st. 652

2013-01-01	Start of quality check period
2013-01-10	Technicians visit: Download data.
2013-01-29	Technicians visit: Replaced fuse on data logger from 50 mA to200 mA. RF link turned on.
2013-03-21	Precipitation reference record. Power supply checked.
2013-06-26 – 2013-06-29	Technicians visit: Download data, upload new program, reference tests at both arrival and departure. AT/RH sensor was replaced from a Vaisala to a Rotronic and the cabling was changed from 3 wire bridge to 4 wire bridge. WS 10 m was replaced. RVI sensors got new brackets, RVI-lower was relocated on a new 1 m crossbeam. Precipitation gauge was emptied and filled with new antifreeze and oil, precipitation reference record. CNR1 temperature sensor was changed from 3 wire bridge to 4 wire bridge. Because of that the connector box at the 2 m mast was changed and all CNR1 plugs were changed on the logger. SD sensor membrane was replaced. Iridium modem was mounted. RF link was mounted. Guy wires were tightened.
2013-09-13	Technicians visit: Download data. Guy wire on 2 m mast was moved because it interfered with the CNR1sensor.
2013-10-30	Download data.
2013-12-05	Download data. SD reference record.
2013-12-31	End of the quality check period

2.2 Time Line and Summary of Events for st. 653

2013-01-01	Start of quality check period
2013-01-10	Technicians visit: Download data.
2013-01-29	Technicians visit: Replaced fuse on data logger from 50 mA to200 mA. Changed two batteries. RF link turned on.
2013-03-21	Precipitation reference record. Power supply checked.
2013-06-26 – 2013-06-29	Technicians visit: Download data, upload new program, reference tests at both arrival and departure. AT/RH sensor was replaced from a Vaisala to a Rotronic and the cabling

	was changed from 3 wire bridge to 4 wire bridge. RVI sensors got new brackets. Precipitation gauge was emptied and filled with new antifreeze and oil, precipitation reference record. CNR1 temperature sensor was changed from 3 wire bridge to 4 wire bridge. Because of that the connector box at the 2 m mast was changed and all CNR1 plugs were changed on the logger. RF link was mounted. Guy wires were tightened. All 6 batteries were replaced. Regulator to wind generator was replaced.
2013-09-13	Technicians visit: Download data. CNR1 mounting a resistor. Power system controlled.
2013-10-30	Download data.
2013-12-05	Download data. SD reference record.
2013-12-31	End of the quality check period

2.3 The Results of the Reference Tests at st. 652

Table 2.1 Arrival and departure reference tests 2013-06-26 and 2013-06-27 at st. 652.

		2013-06-26 Arrival			2013-06-27 Departure		
Parameter	**Unit**	**Logger**	**Reference**	**Time**	**Logger**	**Reference**	**Time**
Wind speed 10 m	m/s	-	8.3	19:36	7.7	6.9	20:08
Wind direction 10 m	Degree	27.27	ca. 27	19:49	27.74	27.00	20:08
Wind speed 2 m	m/s	7.45	6.90	19:06	3.47	3.30	19:31
Air temperature 2 m	°C	4.53	5.16	18:54	9.28	9.11	19:40
Relative Humidity 2 m	%	78.83	77.10	19:55	53.88	55.68	19:40
Air pressure	hPa	995.64	995.71	19:02	1006.13	1006.50	19:22
Snow Depth	m	0.44	0.41	20:00	0.44	0.41	20:18
Distance to snow	m	1.85	1.86	19:58	1.86	1.84	20:17
Precipitation	mm	101.8	100.2	19:03	-	8.9 cm	-
CNR1 Short Wave in	W/m^2	147.80	149.85	18:10	92.61	94.71	19:48
CNR1 Short Wave out	W/m^2	13.54	15.34	19:53	17.43	18.58	19:35
Battery	V	14.15	12.39	19:00	13.86	13.93	19:24

2.4 The Results of the Reference Tests at st. 653

Table 2.2 Arrival and departure reference tests 2013-06-27 and 2013-06-28 at st. 653.

		2013-06-27 Arrival			2013-06-28 Departure		
Parameter	**Unit**	**Logger**	**Reference**	**Time**	**Logger**	**Reference**	**Time**
Wind speed 10 m	m/s	4.28	4.00	21:15	2.76	2.80	20:25
Wind direction 10 m	Degree	211.16	212.00	21:18	211,79	212	20:28
Wind speed 2 m	m/s	5.50	5.00	21:30	2.80	3.00	20:36
Air temperature 2 m	°C	8.00	9.01	21:24	6.81	6.58	20:15
Relative Humidity 2 m	%	55.49	53.10	21:25	64.79	64.95	20:15
Air pressure	hPa	1006.89	1006.52	21:28	1003.96	1003.60	19:54
Snow Depth	m	0.53	0.41	21:37	0.52	0.45	19:58

Distance to snow	m	1.67	1.69	21:36	1.68	1.73	20:00
Precipitation	mm	Accuracy	test ok	18:55	-	8.4 cm	-
CNR1 Short Wave in	W/m^2	13.40	14.23	21:40	338.62	364.26	20:09
CNR1 Short Wave out	W/m^2	2.44	1.99	20:50	67.05	72.43	20:02
Battery	V	14.50	14.49	21:27	13.96	13.93	19:55

2.5 Time Line and Summary of Events for st. 650

2013-01-01	Start of quality check period
2013-01-10	Technicians visit: Download data.
2013-03-22	Water level reference record.
2013-06-29	Technicians visit: Download data. Reference test at both arrival and departure.
2013-07-11	Water level reference record. Replacement of dives in the lake.
2013-08-02	Replacement of baro-diver.
2013-10-30	Download data.
2013-12-04	Download data. Replacement of silica gel.
2013-12-31	End of the quality check period

2.6 The Results of the Reference Tests at st. 650

Table 2.3 Arrival and departure reference tests 2013-06-29 at st. 650.

		2013-06-29 Arrival			2013-06-29 Departure		
Parameter	**Unit**	**Logger**	**Reference**	**Time**	**Logger**	**Reference**	**Time**
Air temperature 2 m	°C	4.37	4.29	00:01	4.40	4.39	00:08
Water level 1	m	3.37	-	00:02	3.37	-	00:07
Water level 2	m	3.69	-	00:02	3.69	-	00:07
Water temperature 1	°C	-	-	-	-	-	-
Water temperature 2	°C	-	-	-	-	-	-
Logger temperature	°C	5.20	-	23:59	5.94	-	00:07
Battery	V	9.80	9.70	00:00	10.94	10.91	00:07

3 Data Processing

The aim of the data processing is to establish one data series of high quality for each measured parameter.
The data processing includes the following steps:

1. Any necessary corrections of the data are performed.
2. Data exceeding the physical limits for the given parameter are removed.
3. Comparison of data from sensors measuring the same parameter (when available) and/or from sensors measuring related parameters is used to identify outlying records. Also the reference tests are included in the data evaluation.
4. If possible the data series from each station are adjusted or corrected using regression or interpolation. Gaps created due to editing are filled in step five.
5. Data from each station are normally combined by averaging data from each station. In case of missing data correlated values are included in the average:

Data on both stations	Only data on St.652	Only data on St.653	No data
½(St.652+St.653)	½(St.652+ St.653=αSt.652+β)	½ (St.653+ St.652=αSt.653+β)	No data

Correlations used in case of missing data on one of the stations can be seen in Table 3.1, Table 3.2, Table 3.3 and Table 3.

The data processing includes data from the period 2013-01-01 to 2013-12-31.

Table 3.1 Station 652=coefficient*(Station 653)+offset. These sensors have the same correlations before and after the station visit due to no changes on the sensors.

	2013-01-01 to 2013-12-31	
	Coefficient	**Offset**
QFE	1.00056	-0.698682
PAR	0.97404	-0.142394
UVB	0.95663	0.000120743
WS 2 m	0.984884	0.0778889
WS 10 m	0.977994	-0.155913

Table 3.2 Station 652=coefficient*(Station 653)+offset. These sensors have different correlations before and after the station visit due to change of sensor or leveling.

	2013-01-01 0:00 to 2013-06-27 19:35		2013-06-27 19:40 to 2013-12-31 23:55	
	Coefficient	**Offset**	**Coefficient**	**Offset**
ATA	1.01475	0.119489	0.996434	-0.0371425
RH	0.986508	0.159938	0.99034	-0.289083
LRI	1.04076	-14.2232	1.0432	-15.2703
SRI	1.00662	0.320651	1.00722	-0.079556

Table 3.3 Station 652=coefficient*(Station 653)+offset. These parameters have different correlations depending on snow cover conditions.

	Snow Cover	No Snow Cover	Snow Cover
	2013-01-01 0:00 to 2013-03-15 23:55	**2013-05-23 0:00 to 2013-10-30 23:55**	**2013-11-01 0:00 to 2013-12-31 23:55**

	Coefficient	Offset	Coefficient	Offset	Coefficient	Offset
SRO	0.991414	-0.0020423	0.90785	0.29408	-	-
LRO	1.0024	-1.44305	0.944876	18.2638	0.998413	-0.936684

Table 3.5 Station 652=coefficient*(Station 653)+offset. Different correlations between snow depth sensors dependent upon different snow cover conditions.

	2013-01-10 to 2013-12-31	
	Coefficient	**Offset**
SD	0.832451	0.00018059

A short description of the data processing for each parameter is given below. The figures with regression lines display edited data. The production time series are stored in the Greenland Ecosystem Monitoring Database.

3.1 Air Pressure

The air pressure is measured at station 652 and station 653 inside the data logger cabinet. The logged air pressure data reflect the air pressure at the position of the sensor (no altitude correction).

Station 652, air pressure, 1.5m, 30 min.:
- 100 records are missing (0.6% of all data records in the quality check period).
- No measurements lie outside the interval [900 hPa; 1100 hPa].
- 1 record was deleted due to error from datalogger.

Station 653, air pressure, 1.5m, 30 min.:
- 25 records are missing (0.1% of all data records in the quality check period).
- No measurements lie outside the interval [900 hPa; 1100 hPa].
- No records were deleted.

KOB, air pressure, 1.5m, 30 min.:
- No records are missing
- The time series is 100% complete.

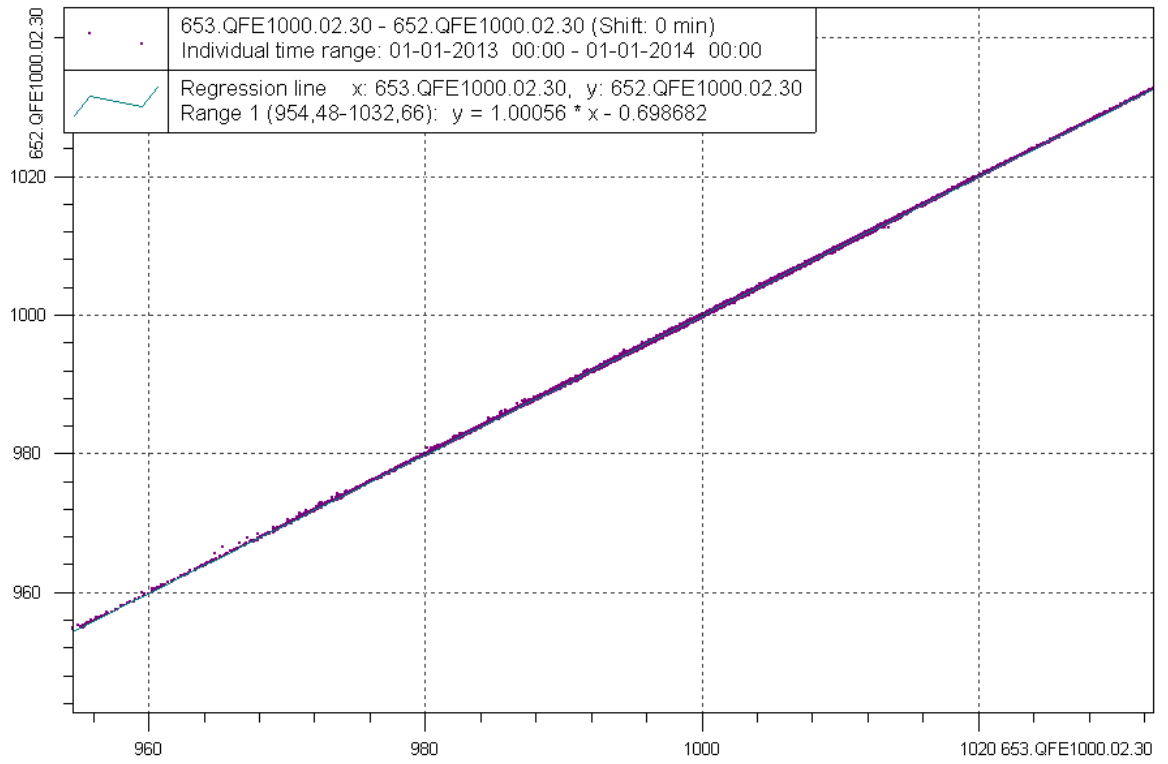


Figure 3.1 Air pressure measured at station 652, y, as a function of air pressure measured at station 653, x. The regression line is given in Table 3.1.

3.2 Air Temperature

The air temperature is measured 2 meters above terrain at station 652 and station 653.

The air temperature is measured using temperature probes housed in radiation shields. The radiation shields are not artificially ventilated due to the limited power supply at the stations. Studies show that this may give too high temperature measurements in case of calm winds and clear sky, Andersson & Mattisson (1991), Arck & Scherer (2001). Corrections for this possible error have not been performed.

Reference tests from 2013 and comparison with station 650 show that data from 1/1 to 26/6 2013 has to be adjusted by +0.83 °C for Station 652 and +1.0 °C for Station 653. 26/6 – 28/6 2013 the air temperature sensors is replaced with new sensors and the wiring is changed from 3 to 4 wire bridge. After the replacement adjustment is not necessary anymore.

Station 652, air temperature, 2m, 30 min.:

- 100 records are missing (0.6% of all data records in the quality check period).
- No measurements lie outside the interval [-40°C; 25°C].
- No records were deleted.
- Data has been adjusted by +0.83 °C (1/1-26/6 2013).

Station 653, air temperature, 2m, 30 min.:

- 25 records are missing (0.1% of all data records in the quality check period).

- No measurements lie outside the interval [-40°C; 25°C].
- No records were deleted.
- Data has been adjusted by +1.0 °C (1/1-28-6 2013).

KOB, air temperature, 2m, 30 min.:

- No records are missing.
- The time series is 100% complete.

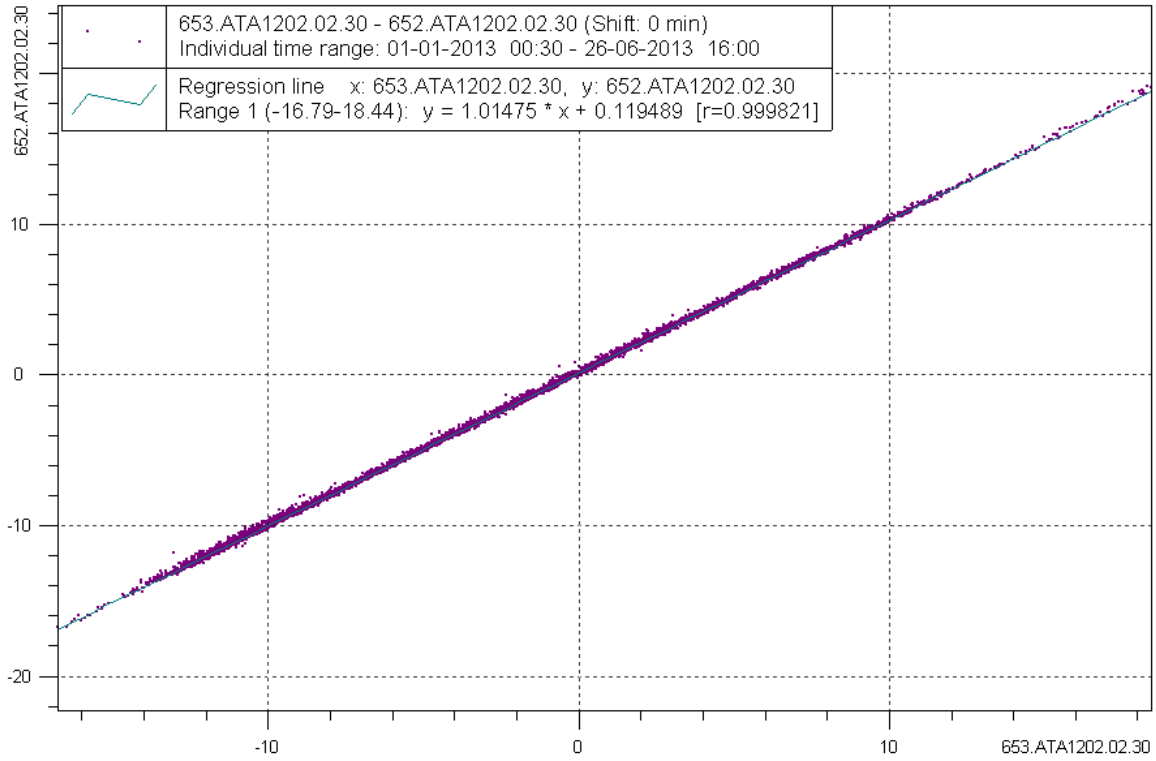


Figure 3.2 Average air temperature measured at station 652, y, as a function of air temperature measured at station 653, x. The regression line is given in Table 3.1.

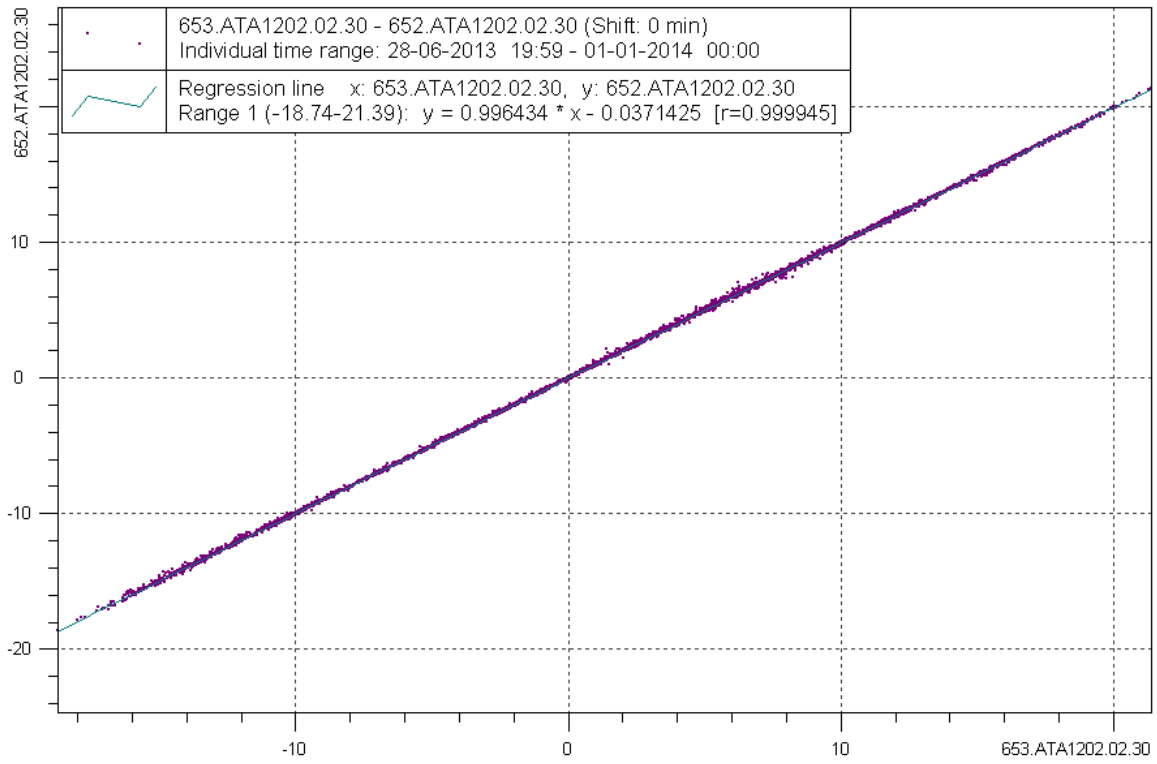


Figure 3.3 Average air temperature measured at station 652, y, as a function of air temperature measured at station 653, x. The regression line is given in Table 3.1.

3.3 Relative Humidity

The relative humidity is measured by the same sensor as air temperature.

Station 652, relative humidity, 2m, 30 min.:

- 100 records are missing (0.6% of all data records in the quality check period).
- 20 records lie outside the interval [15%; 104%], but the records are reliable.
- No records were deleted.

Station 653, relative humidity, 2m, 30 min.:

- 25 records are missing (0.1% of all data records in the quality check period).
- 20 records lie outside the interval [15%; 104%], but the records are reliable.
- No records were deleted.

KOB, relative humidity, 2m, 30 min.:

- No records are missing.
- The time series is 100% complete.

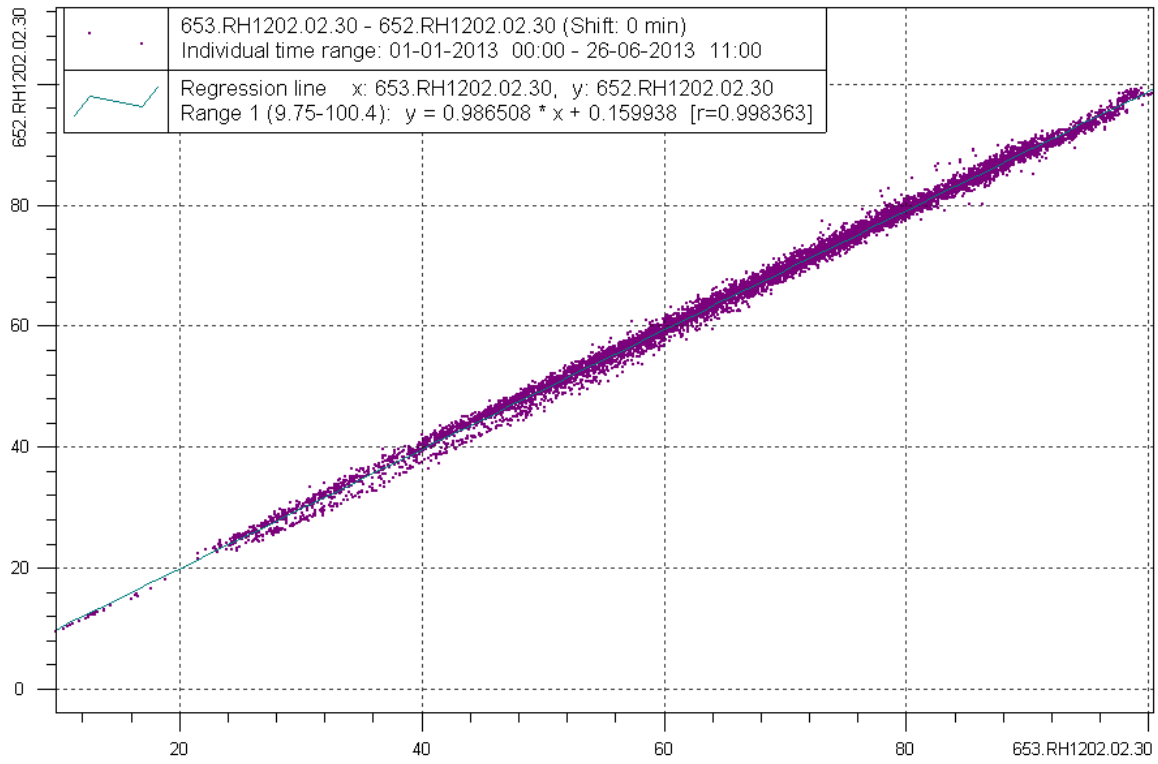


Figure 3.4 Average relative humidity measured at station 652, y, as a function of relative humidity measured at station 653, x. The regression line is given in Table 3.1.

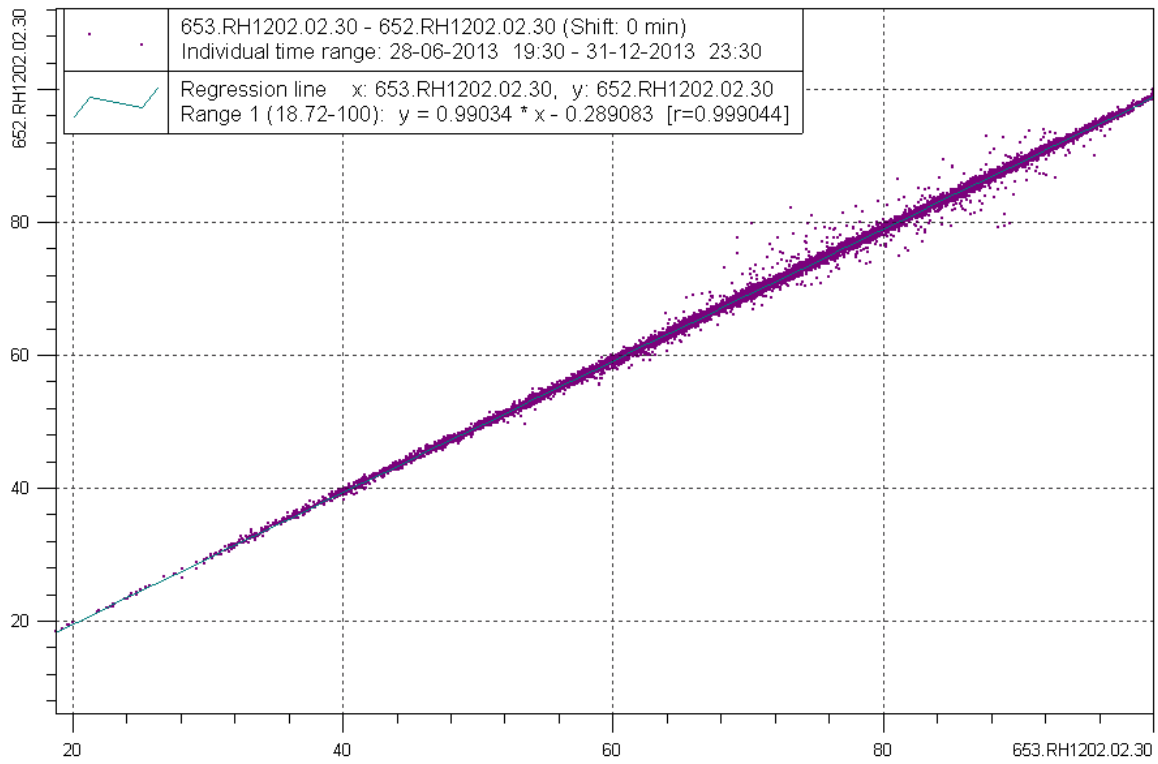


Figure 3.5 Average relative humidity measured at station 652, y, as a function of relative humidity measured at station 653, x. The regression line is given in Table 3.1.

3.4 Wind Speed, 2m

26/6 2013 the wind speed sensor in 2m at station 652 was replaced with new sensor.

Station 652, wind speed, 2m, 10 min.:

- 163 records are missing (0.3% of all data records in the quality check period).
- 14508 records were deleted. 14340 were deleted due to a defect fuse and 168 due to frozen sensor, long period with zero or unrealistic low wind speed.
- No records were deleted due to suspect values.

Station 653, wind speed, 2m, 10 min.:

- 68 records are missing (0.1% of all data records in the quality check period).
- 1835 records were deleted due to frozen sensor or long period with zero speed.
- No records were deleted due to suspect values.

KOB, wind speed, 2m, 10 min.:

- 782 records are missing (1.5% of the data).
- The time series is 98.5% complete.

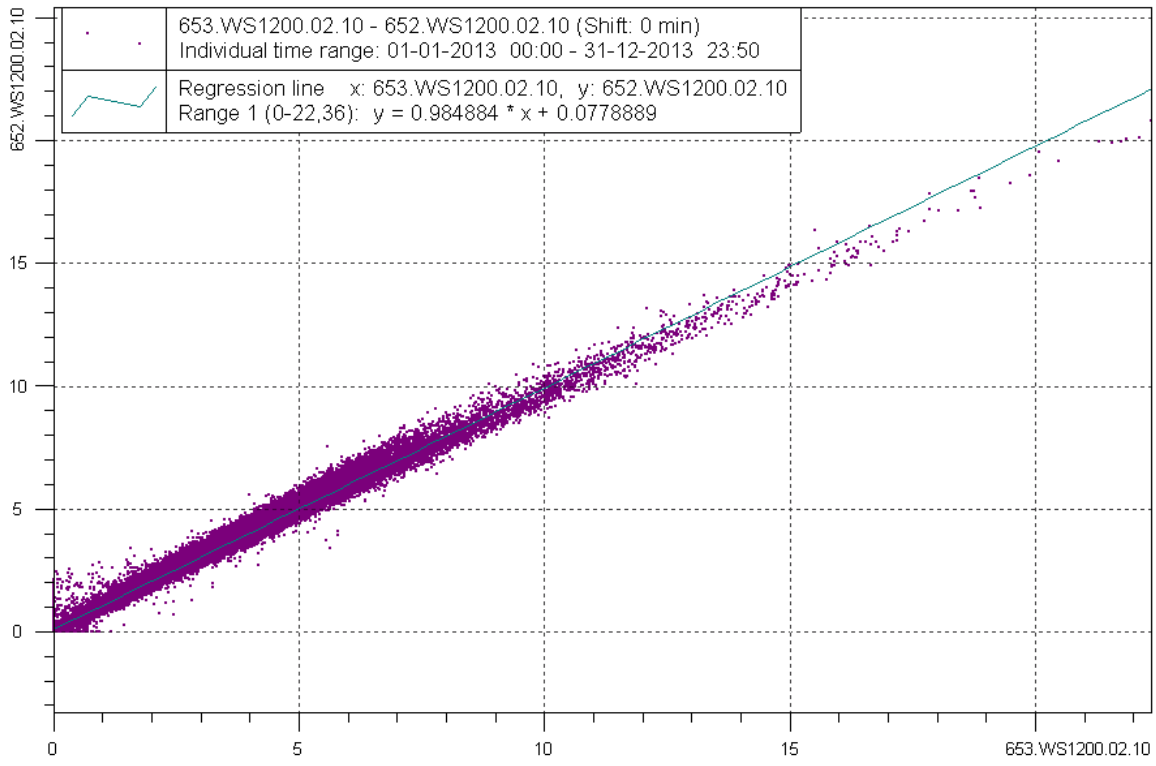


Figure 3.6 Wind speed measured 2 m above ground at Kobbefjord station 652, y, as a function of wind speed measured 2 m above ground level at Kobbefjord station 653, x. The regression line is given in Table 3.2.

3.5 Wind Speed, 10m

Station 652, wind speed, 10m, 10 min.:

- 163 records are missing (0.3% of all data records in the quality check period)
- 28164 records were deleted. 18164 were deleted due to a defect fuse and 10000 due to frozen sensor, long period with zero or unrealistic low wind speed.
- No records were deleted due to suspect values.

Station 653, wind speed, 10m, 10 min.:

- 68 records are missing (0.1% of all data records in the quality check period).
- 221 records were deleted due to frozen sensor, long period with zero or unrealistic low wind speed.
- No records were deleted due to suspect values.

KOB, wind speed, 10m, 10 min.:

- 146 records are missing (0.3% of the data).
- The time series is 99.7% complete.

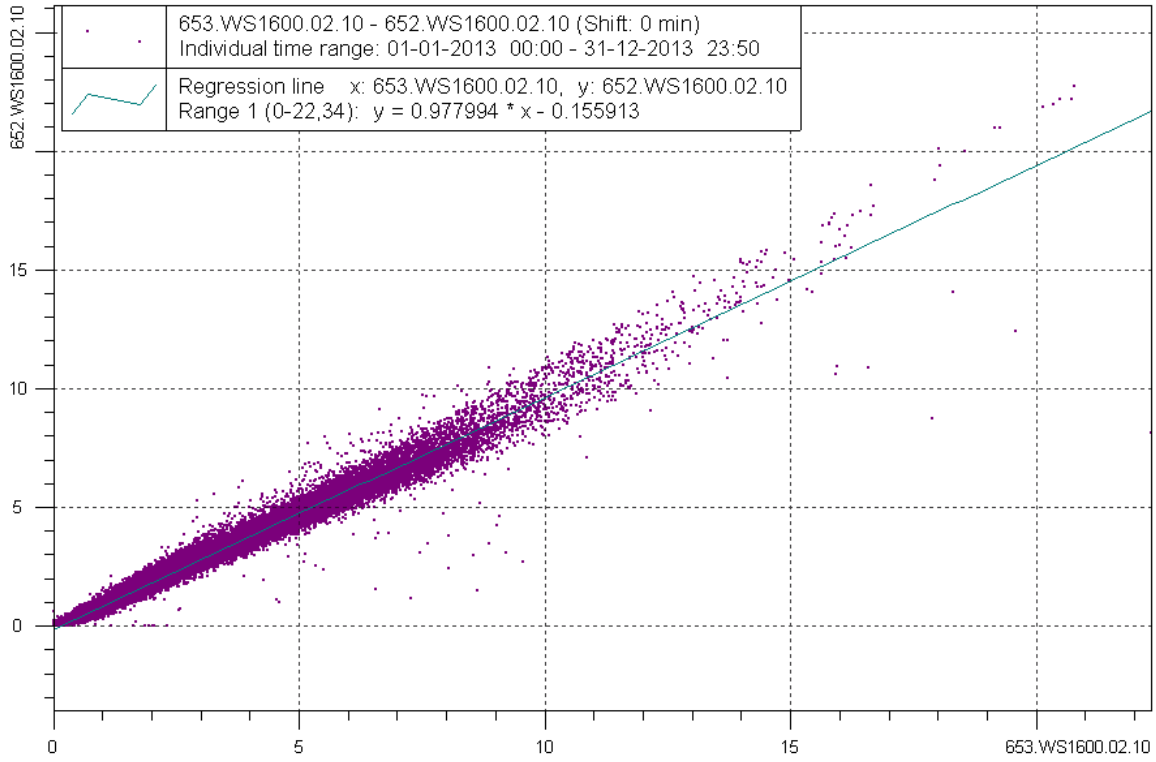


Figure 3.7 Wind speed measured 10 m above ground at Kobbefjord station 652, y, as a function of wind speed measured 10 m above ground level at Kobbefjord station 653, x. The regression line is given in Table 3.2.

3.6 Wind Direction, 10m

Wind direction is measured 10 meters above terrain at station 652 and 653. The wind direction is relative to geographic north. The combined time series is calculated as the interior bisector of the two measured wind directions. When only one station produces valid data these wind direction records are copied directly to the final time series.

Station 652, wind direction, 10m, 10 min.:

- 298 records are missing (0.6% of all data records in the quality check period).
- 21402 records are deleted due to defect fuse or zero wind speed
- No measurements lie outside the interval [0^o; 360^o].
- No records were deleted due to suspect values.

Station 653, wind direction, 10m, 10 min.:

- 68 records are missing (0.1% of all data records in the quality check period).
- 474 records are deleted due to zero wind speed
- 10 records are deleted due to long period with constant data value.
- No measurements lie outside the interval [0^o; 360^o].
- No records were deleted due to suspect values.

KOB, wind direction, 10, 10 min.:

- 383 records are missing (0.7% of the data).
- The time series is 99.3% complete.

3.7 Incoming Shortwave Radiation

The incoming shortwave radiation is measured 2 meters above terrain at both station 652 and station 653 with a four component Kipp & Zonen net radiometer (CNR1), which measures shortwave radiation with wavelengths 300 to 2800 nm. The sensor has approx. the same sensitivity (spectral response) to all wavelengths in the interval.

1/1-26/6 data on the two sensors is shifted a bit. Data from st. 652 is shifted about 10 min later and data from st. 653 is shifted about 10 min earlier. The problem is probably because the sensors are a bit out of level. Both sensors are within the range of data from 2007-2012 and are both brought into calculation of KOB. At station visit 26/6-29/6 the problem was solved and data from the two stations are very much alike the rest of the year.

When this report refers to *the maximum direct incoming radiation* it is calculated according to Gray and Male (1981), with a transmissivity of the atmosphere of 1, i.e. no absorption or reflection of radiation through the atmosphere.

Station 652, incoming shortwave radiation, 2m, 5 min

- 330 records are missing (0.3% of all data records in the quality check period).
- 1176 records (1.1% of the data) were deleted as the sensor was covered with snow.
- 36346 records (34.6% of the data) showed negative incoming radiation in cases where the sun was more than one degree below the horizon. These records were set to zero.
- 10823 records (10.3% of the data) were positive in cases where the sun was more than one degree below the horizon. These records were set to zero.
- 23 records had higher values than the maximum theoretical direct incoming radiation. In cases where a data record exceeded the theoretical value and the theoretical value is higher than 25 W/m^2, these records were replaced by linear regression with values from station 653. In case station 653 should also have recorded a value higher than the theoretical maximum then the record was set to equal the theoretical maximum.

Station 653, incoming shortwave radiation, 2m, 5 min

- 140 records are missing (0.1% of all data records in the quality check period).
- 1015 records (1.0% of the data) were deleted as the sensor was covered with snow or gave erroneous values.
- 37100 records (35.3% of the data) showed negative incoming radiation and 10343 records (9.8% of the data) were positive in cases where the sun was more than one degree below the horizon. These records were set to zero.
- 27 records had higher values than the maximum theoretical direct incoming radiation. In cases where a data record exceeded the theoretical value and the theoretical value is higher than 25 W/m^2, these records were replaced by linear regression with values from station 652. In case station 652 should also have recorded a value higher than the theoretical maximum then the record was set to equal the theoretical maximum.

KOB, incoming shortwave radiation, 2m, 5 min

- 1005 records are missing (1.0% of the data).
- The time series is 99.0% complete.

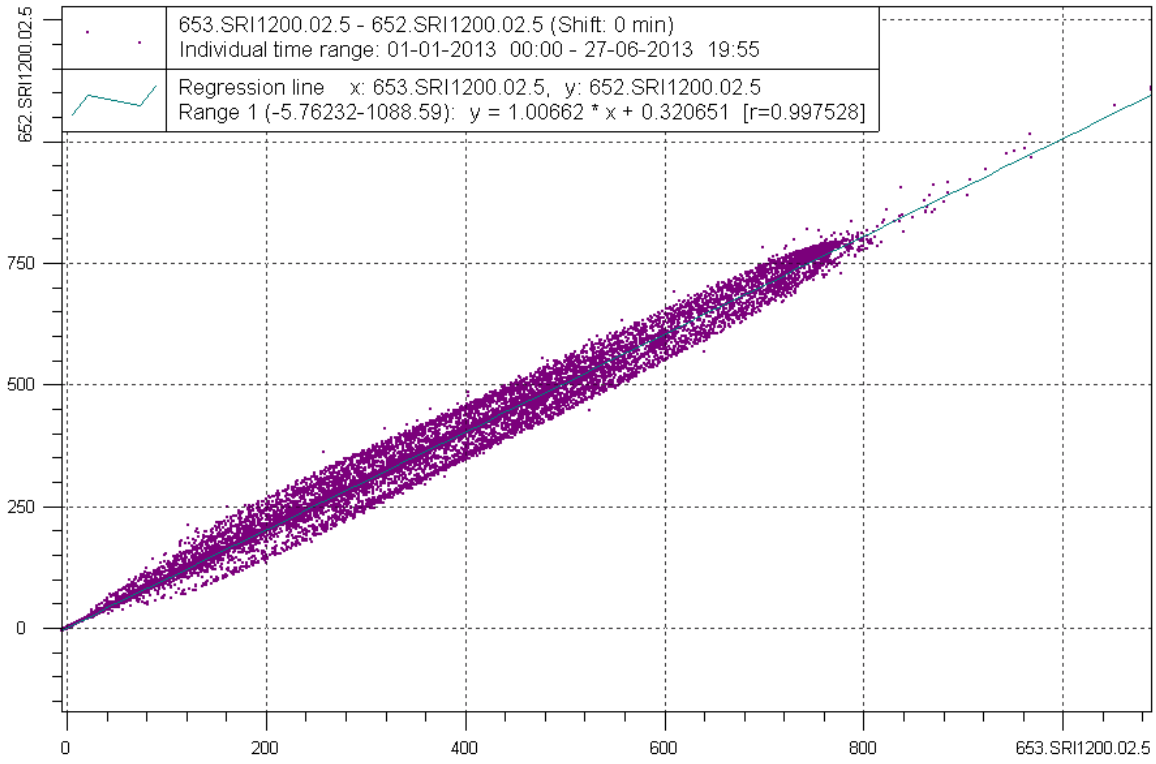
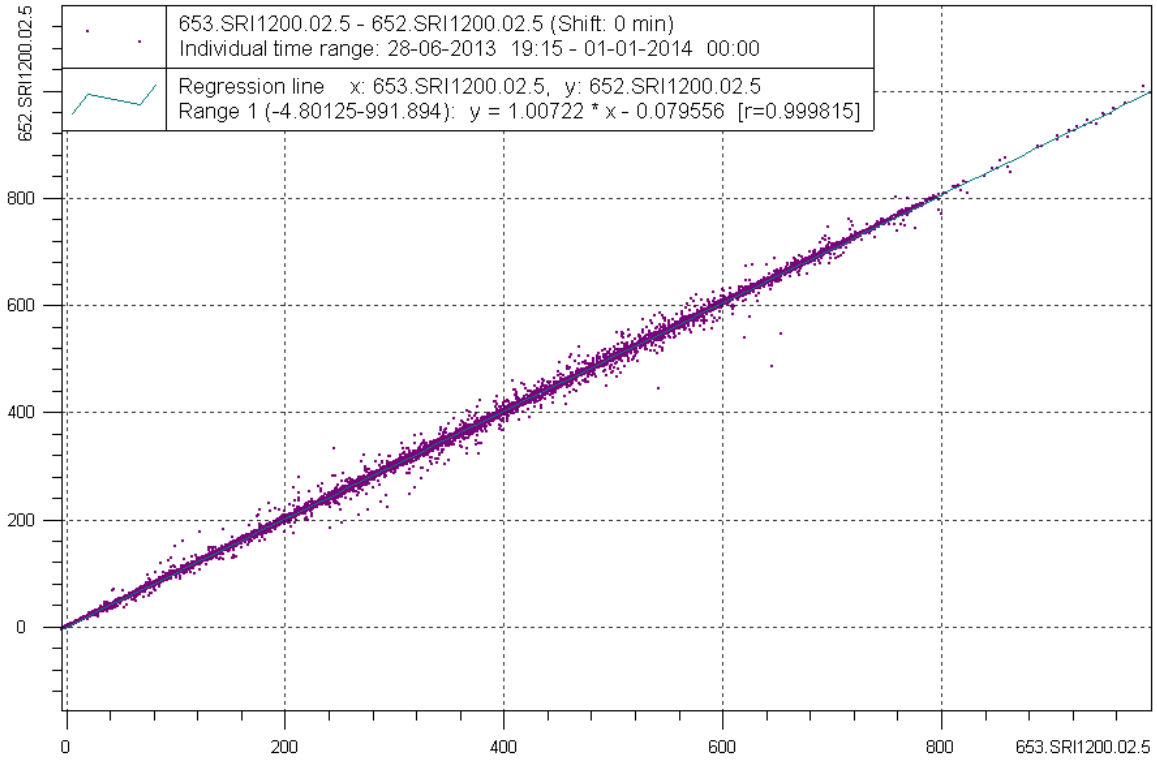


Figure 3.8 Incoming shortwave radiation (W/m^2) measured at station 652, y, as a function of incoming shortwave radiation measured at station 653, x. The regression line is given in Table 3.2.



Figur 3.9 Incoming shortwave radiation (W/m^2) measured at station 652, y, as a function of incoming shortwave radiation measured at station 653, x. The regression line is given in Table 3.2.

3.8 Outgoing Shortwave Radiation

The outgoing shortwave radiation is measured 2 meters above terrain at both station 652 and station 653. The outgoing shortwave radiation is measured with a Kipp & Zonen four component net radiometer (CNR1), which measures shortwave radiation with wavelengths 300 to 2800 nm. The sensor has apparently the same sensitivity (spectral response) to all wavelengths in the interval. In the spring 2013 there were several periods of first snow cover and then melt. One regression was used for the period before first melting and a summer regression (no snow cover conditions) was used for the remaining period where the correction was needed.

Station 652, outgoing shortwave radiation, 2m, 5 min

- 330 records are missing (0.3% of all data records in the quality check period).
- 3137 records (3.0% of the data) showed negative outgoing radiation and 45246 records (43.0% of the data) were positive in cases where the sun was more than one degree below the horizon. These records were set to zero.
- 77 records (0.1% of the data) were deleted due to erroneous values.

Station 653, outgoing shortwave radiation, 2m, 5 min

- 188 records are missing (0.2% of all data records in the quality check period).
- 3129 records (3.0% of the data) showed negative outgoing radiation and 45071 records (42.9% of the data) were positive in cases where the sun was more than one degree below the horizon. These records were set to zero.
- 48 records (0.0% of the data) were deleted due to erroneous values.

KOB, outgoing shortwave radiation, 2 meters above terrain, 5 min

- 1 record is missing.
- The time series is 100% complete.

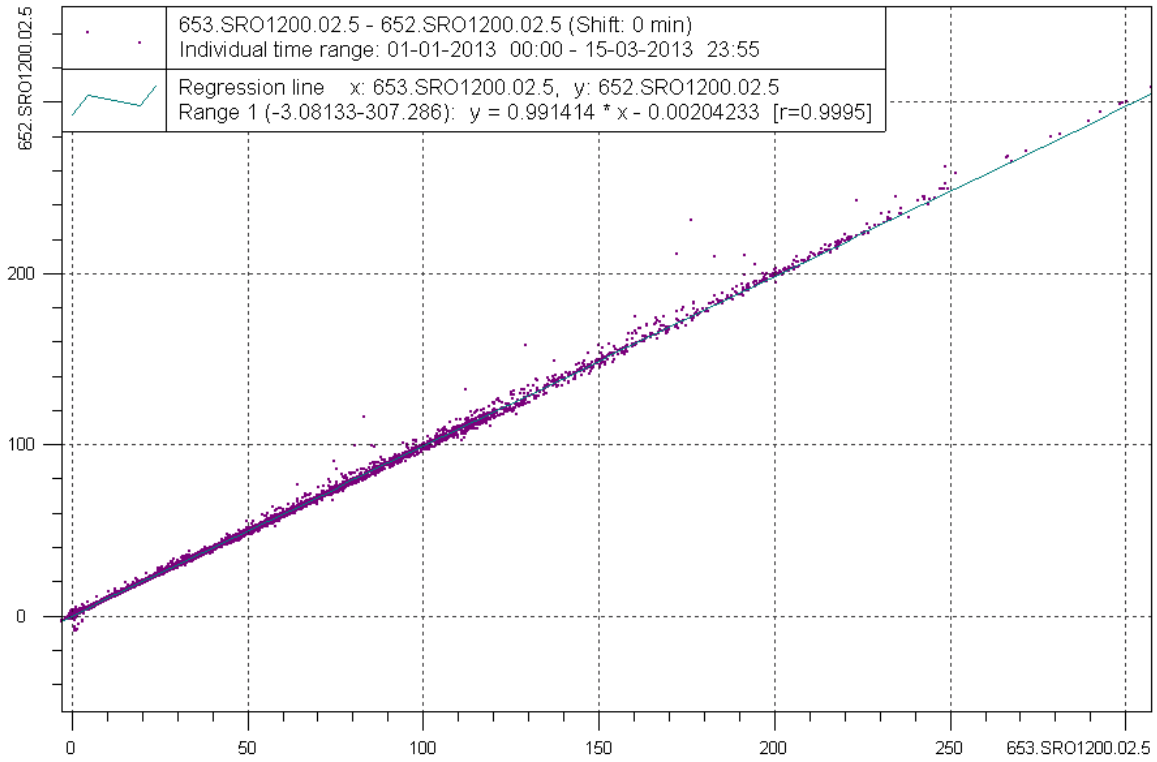
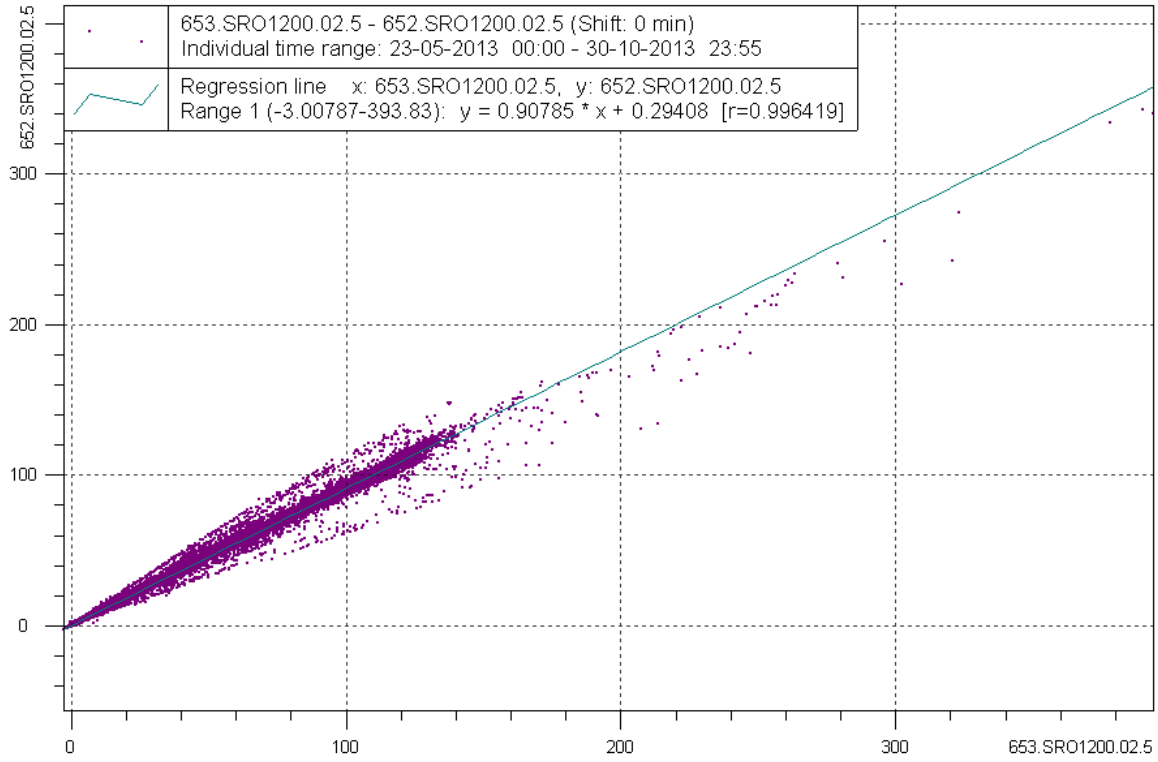


Figure 3.10 Outgoing shortwave radiation measured at station 652, y, as a function of outgoing shortwave radiation measured at station 653, x. The regression line is given in Table 3.3.



Figur 3.11 Outgoing shortwave radiation measured at station 652, y, as a function of outgoing shortwave radiation measured at station 653, x. The regression line is given in Table 3.3.

3.9 Incoming Longwave Radiation

The incoming longwave radiation is measured 2 meters above terrain at both station 652 and station 653 with a Kipp & Zonen four component net radiometer (CNR1), which measures longwave radiation with wavelengths 5 to 50 μm. The sensor has approx. the same sensitivity (spectral response) to all wavelengths in the interval.

The measured longwave radiation (LRI) is a combination of the voltage signal from the sensor (LRIM) and the temperature of the sensor (LRT) in the following way:

LRI=LRIM+(5.67*10^-8)*LRT^4

Therefore the quality control of LRI is mainly done on LRT and LRIM.

Station 652, incoming longwave radiation, 2m, 5min.:

- 330 records are missing (0.3% of the data in the quality check period) due to station visit or wrong LRT.
- 2577 records were deleted (2.8% of the data) as they were affected by either snow or water on the surface of the sensor.
- 1041 records were denoted suspect (1.0% of the data) since there was large differences in LRIM, but not large enough to exceed 30W/m^2 in LRI. It was not possible to determine which station was correct.

Station 653, incoming longwave radiation, 2m, 5 min.:

- 329 records are missing (0.3% of the data in the quality check period) due to station visit or wrong LRT.
- 2336 records were deleted (2.8% of the data) as they were affected by either snow or water on the surface of the sensor.
- 1041 records were denoted suspect (1.0% of the data) since there was large differences in LRIM, but not large enough to exceed 30W/m^2 in LRI. It was not possible to determine which station was correct.

KOB, incoming long wave radiation, 2m, 5min.:

- 2491 records are missing (2.4% of the data).
- The time series is 97.6% complete.

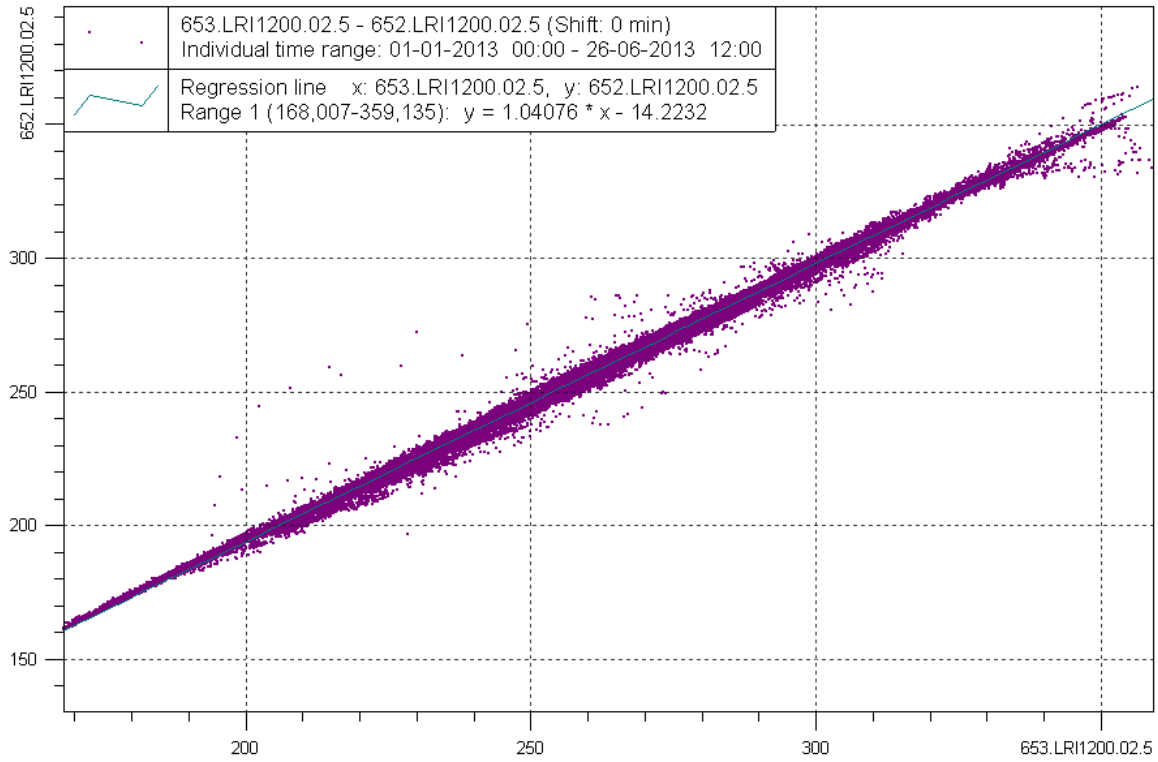


Figure 3.12 Incoming longwave radiation (W/m^2) measured at station 652, y, as a function of incoming longwave radiation measured at station 653, x. The regression line is given in Table 3.2.

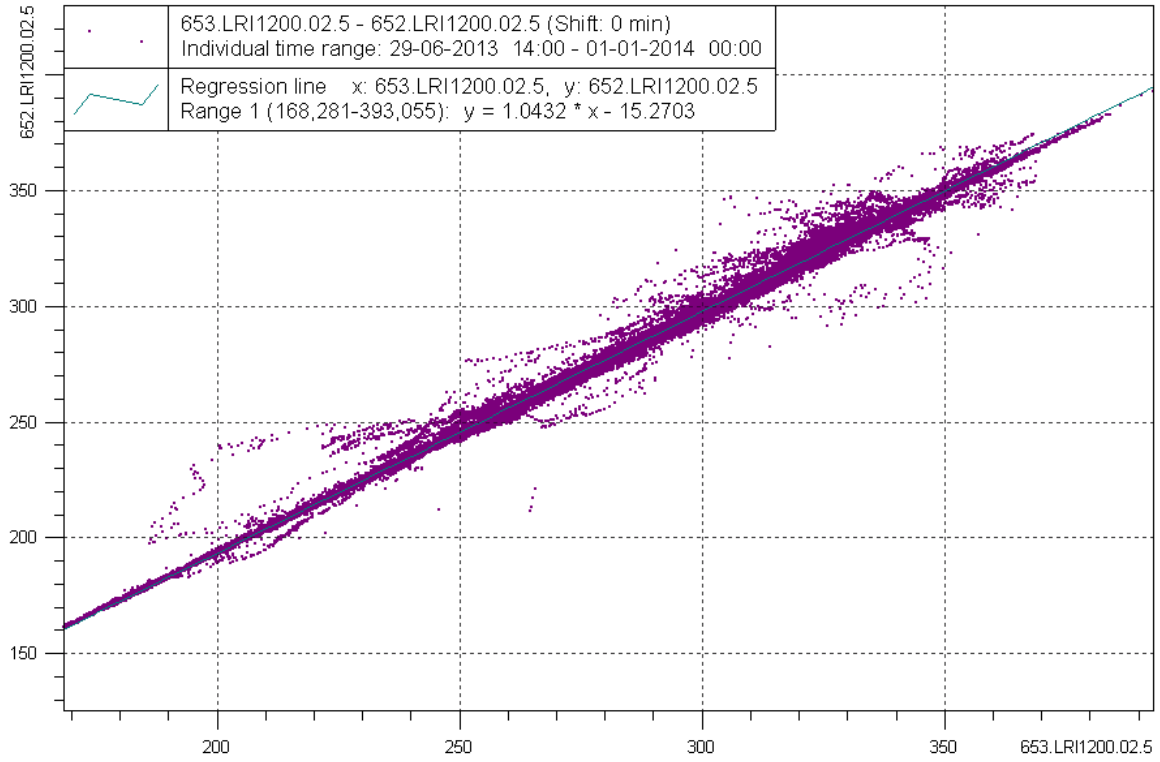


Figure 3.13 Incoming longwave radiation (W/m^2) measured at station 652, y, as a function of incoming longwave radiation measured at station 653, x. The regression line is given in Table 3.2.

3.10 Outgoing Longwave Radiation

The outgoing longwave radiation is measured 2 meters above terrain at both station 652 and station 653. The outgoing longwave radiation is measured with a Kipp & Zonen four component net radiometer (CNR1), which measures long wave radiation with wavelengths 5 to 50 µm. The sensor has approx. the same sensitivity (spectral response) to all wavelengths in the interval.

Station 652, outgoing longwave radiation, 2m, 5 min.:

- 332 records are missing (0.3% of the data in the quality check period) due to station visit or wrong LRT.
- No records were deleted.

Station 653, outgoing longwave radiation, 2m, 5 min.:

- 465 records are missing (0.4% of the data in the quality check period) due to station visit or wrong LRT.
- No records were deleted.

KOB, outgoing longwave radiation, 2m, 5 min.:

- 326 records are missing (0.3% of the data).
- 99.7% of the time series is complete

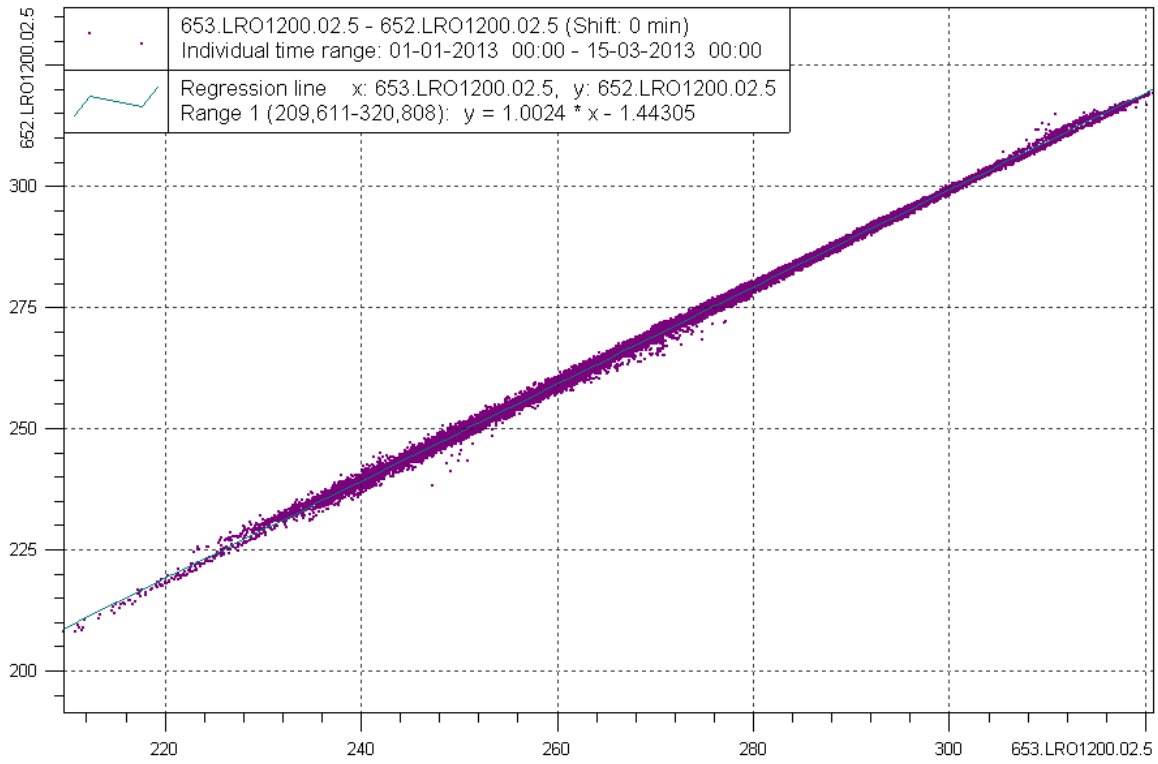
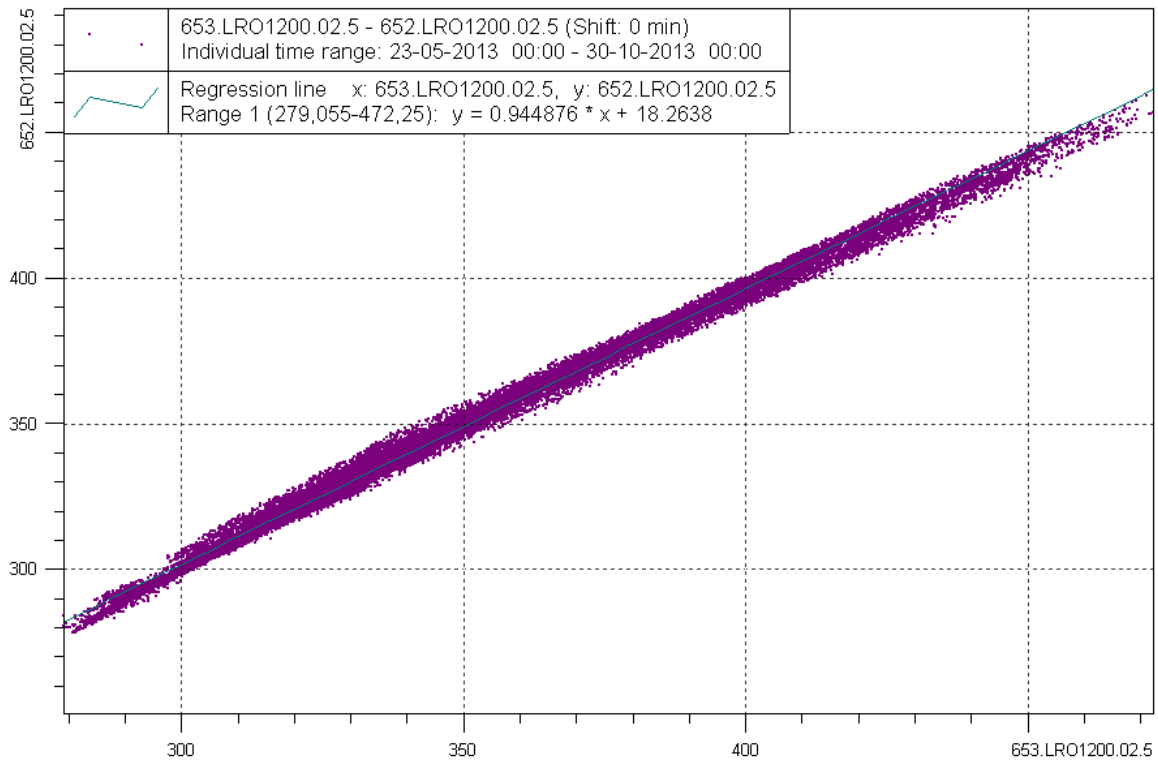
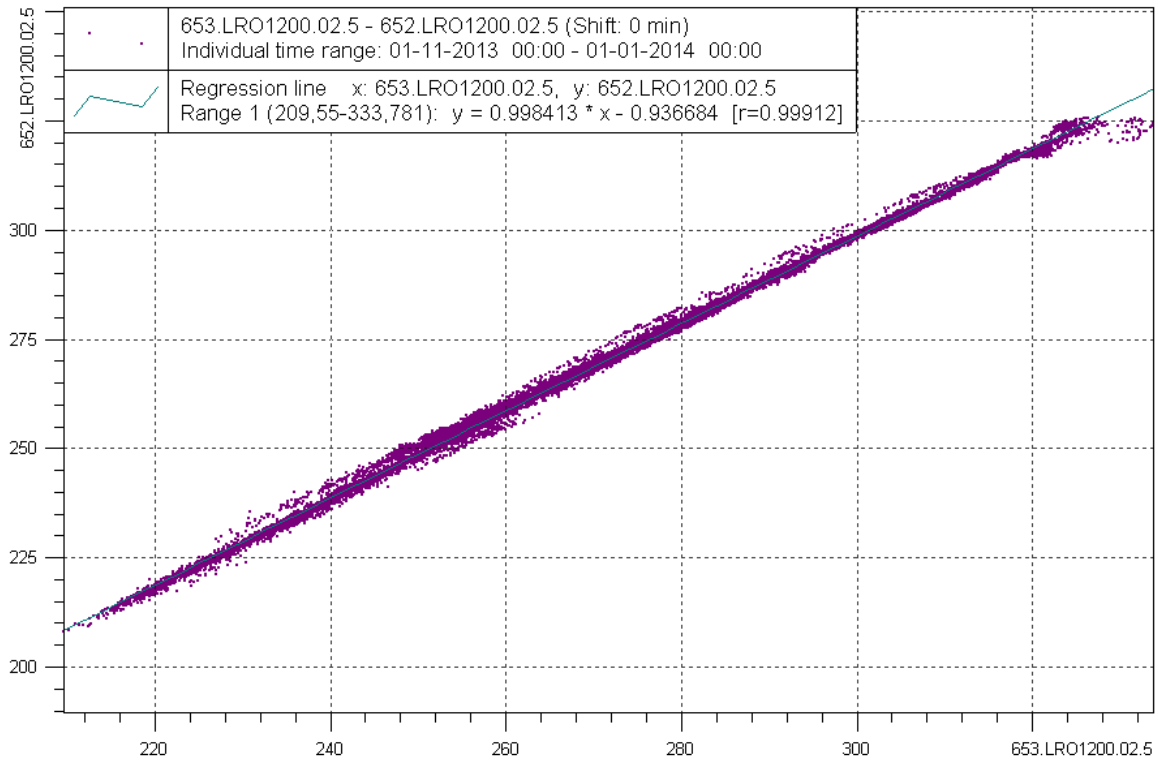


Figure 3.14 Outgoing longwave radiation (W/m^2) measured at station 652, y, as a function of outgoing longwave radiation measured at station 653, x. The regression line is given in Table 3.3.



Figur 3.1 Outgoing longwave radiation (W/m^2) measured at station 652, y, as a function of outgoing longwave radiation measured at station 653, x. The regression line is given in Table 3.3.



Figur 3. 16 Outgoing longwave radiation (W/m^2) measured at station 652, y, as a function of outgoing longwave radiation measured at station 653, x. The regression line is given in Table 3.3.

3.11 Photosynthetic Active Radiation (PAR)

The photosynthetic active radiation (PAR) is measured 2 meters above terrain at station 652 and station 653. PAR is measured with a Li-Cor quantum sensor, which measures the radiation with wavelengths between 400 and 700 nm. The sensor has app. the same sensitivity (spectral response) to all wavelengths in this interval.

Station 652, photosynthetic active radiation, 2m, 5 min

- 330 records are missing (0.3 % of the data).
- 1137 records (1.1% of the data) were negative, and 27548 records (26.2% of the data) were positive when the sun was more than 1 degree under the horizon. These values were set to zero.
- 1018 records were deleted (1.0 % of the data) as the sensor was covered with snow or because of error value.

Station 653, photosynthetic active radiation, 2m, 5 min

- 140 records are missing (0.1% of all data records in the quality check period).
- 425 records (0.4% of the data) were negative, and 8051 records (7.7% of the data) were positive when the sun was more than 1 degree under the horizon. These values were set to zero.
- 880 records were deleted (0.8 % of the data) as the sensor was covered with snow.

KOB, photosynthetic active radiation, 2m, 5 min

- 778 records are missing (0.7% of the data).

- The time series is 99.3% complete.

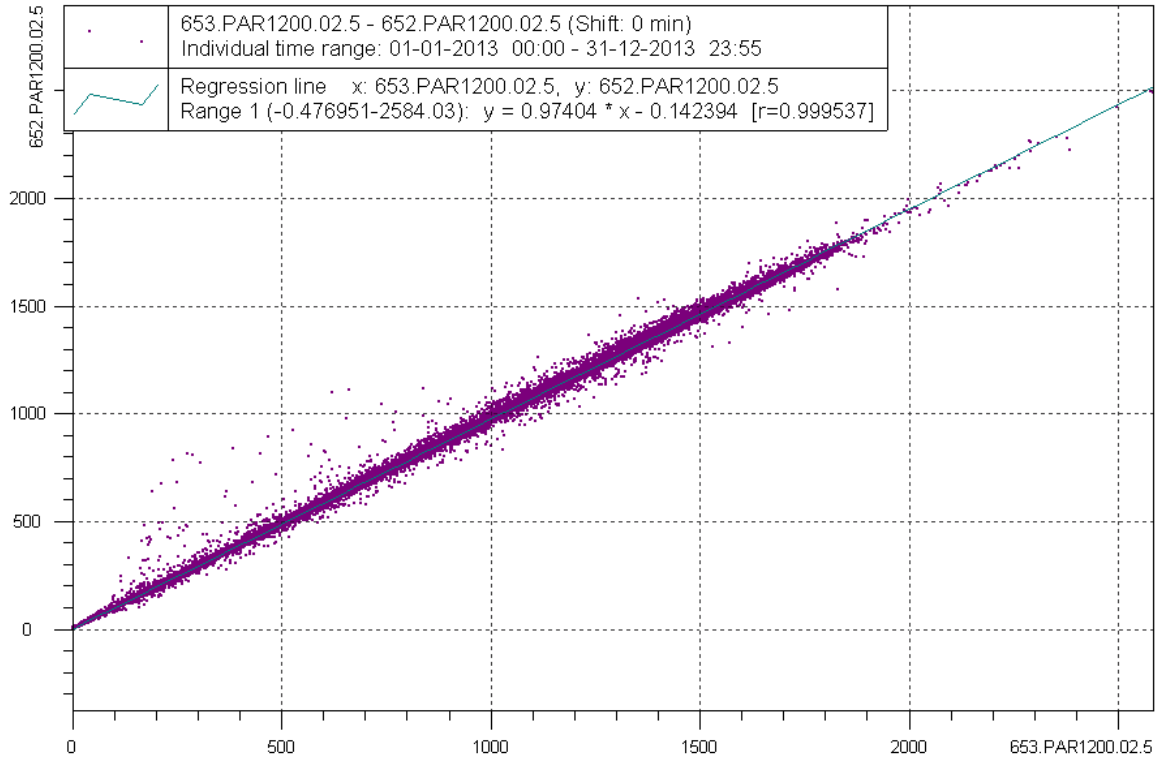


Figure 3.2 Photosynthetical active radiation (µmol/(s*m^2)) measured at station 652, y, as a function of Photosynthetical active radiation measured at station 653, x. The regression line is given in Table 3.2.

3.12 Ultraviolet B-radiation

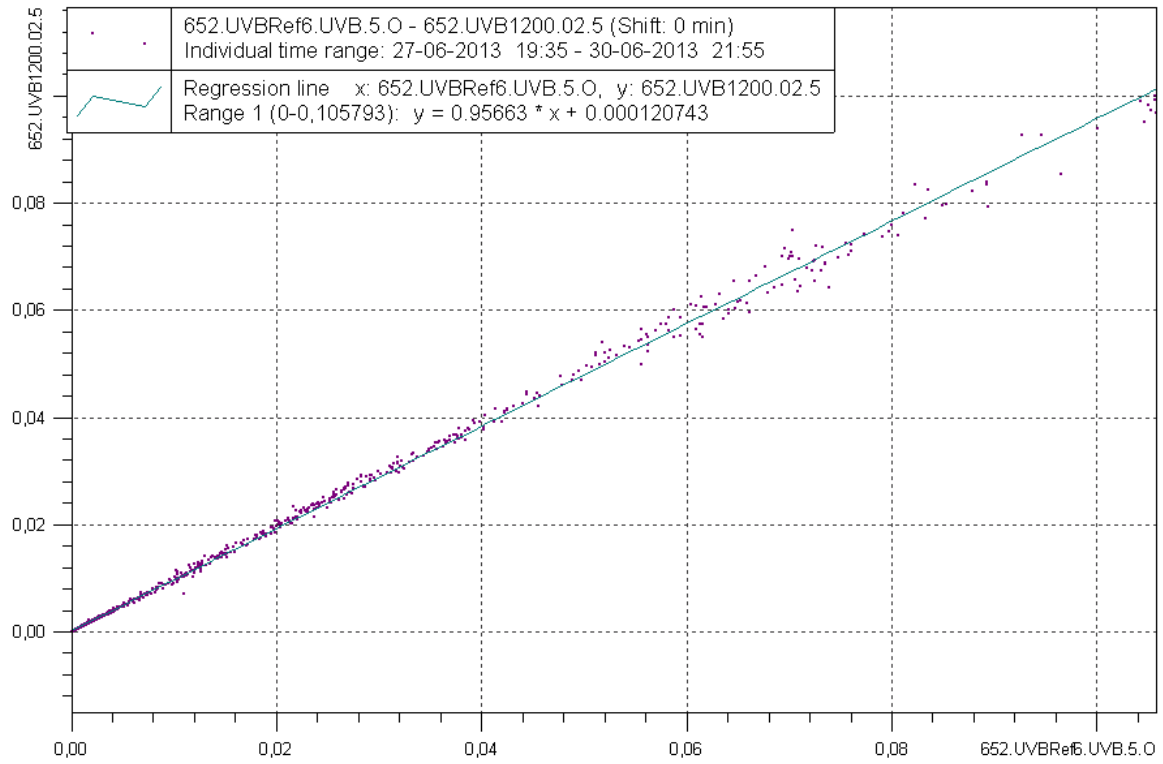
The ultraviolet radiation (UVB) is measured 2 meter above terrain at station 652. The UVB has since June 2008 been measured with a Solar Light UV-Biometer.
The UVB measurement depends on the temperature of the sensor; therefore the built-in thermostat has been used to ensure a constant temperature of 25°C of the sensor.

The UVB records were tested against a reference sensor mounted next to the UVB sensor in the period from 2013-06-27 to 2013-06-30. All UVB records at station 652 with the current sensor were adjusted according to the displayed regression line.

Data from January 1st 2013 00:00 to December 31st 2013 23:30 is included in the data processing.

KOB, UVB, 2m, 30 min:

- 330 records are missing (0.3% of all data records in the quality check period).
- 10648 records were set to zero when the sun was more than 1 degree below the horizon. This corresponds to 10.1% of all data in the quality check period.
- The time series is 99.7% complete



Figur 3.18 UVB radiation (W/m^2) measured at station 652, y, as a function of UVB radiation measured at the reference station, x. The regression line is given in Table 3.1.

3.13 Net Radiation (CNR1)

The net radiation (CNR1) is calculated from the four quality checked time series of short-, long-, in- and outgoing radiation. The CNR1 instrument (pyradio-/pyrgeometer) measures the difference between incoming and outgoing radiation with wavelengths in two spectral ranges; 300 to 2800 nm and 5 to 50 µm, i.e. both short- and longwave radiation. The sensor has app. the same sensitivity (spectral response) to all wavelengths in the interval.

KOB, net radiation (CNR1), 2m, 5 min.:

- 3351 records are missing (3.2% of the data).
- The time series is 96.8% complete.

3.14 Relative Vegetation Index

The RVI-sensor measures the reflection of near infra-red radiation (NIR, wavelengths 710nm to 750nm, centered at 730nm) and visible radiation (VIS, 630nm to 690nm, centered at 660nm). RVI is an acronym for Relative Vegetation Index and can be used to compute a Normalized Difference Vegetation Index (NDVI) that covers a numeric span from -1 to 1. Very dense rain forest has a NDVI value close to 1, while standing water (e.g. oceans and rivers), clouds and snow have NDVI values close to or below zero.

$$NDVI = \frac{NIR - VIS}{NIR + VIS}$$

According to Skye Instruments (2004) night readings of the RVI sensor should be at a constant of zero. If night readings regularly record a constant reading a night other than zero, this value should be used as an offset.

NDVI measurements are affected by both the solar zenith angle (SZA) and cloudiness. NDVI measurements on tall grass prairie in Africa show an increase in NDVI values with an increase in SZA (Middleton, 1991). Another study shows a decrease in NDVI values with increasing SZA over green-leaf vegetation (Singh, 1988). The dataset from Kobbefjord shows both characteristics, with NDVI values decreasing with increasing SZA early in the growing season and NDVI values increasing with increasing SZA later in the growing season and during snow cover.

During the annual station visit in 2012 an upwards facing RVI sensor was installed at both stations. This allows for a comparison of incoming and outgoing radiation in the specific wavelengths for near-infrared radiation and visible radiation. Therefore the following changes have been made to the NDVI formula from 2012-07-17 and onwards:

$$NIR = \mathrm{NIR_{refl}}/\mathrm{NIR_{in}}$$

$$VIS = \mathrm{VIS_{refl}}/\mathrm{VIS_{in}}$$

Before the installation of the upward facing sensor it was necessary to filter the data for cloudiness. After 2012-07-17 the data is not filtered for cloudiness any more.

Three time series are produced:

- A 5 minute time series with reflected radiation in the near infra-red spectrum (730 nm).
- A 5 minute time series with reflected radiation in the visual spectrum (660 nm).
- A daily NDVI time series.

When the upwards facing RVI sensors were installed there was a confusion of the plugs and the pins in the logger. Several attempts have been made to correct the error. To correct the data a period with correct connections is needed. In the summer 2014 the technicians will reconnect the RVI sensors and we assume to then be able to reconstruct the data back to 2012-07-17.

3.15 Precipitation

The precipitation is recorded with Ott Pluvio rain gauges; a Pluvio[1] at station 652 and a Pluvio[2] at station 653. At both stations, the gauges have a tendency to produce false pulses, especially in moderate to high wind conditions. These periods have been identified during the quality check by comparison to relative humidity, short wave incoming radiation, and daily recorded weather observations in Nuuk. During precipitation events both gauges were in good agreement and it was rare that false pulses would occur in both gauges at the

exact same time. Only data from station 653 are quality controlled and data from station 652 has only been used to identify false pulses/precipitation.

Antifreeze and oil is added to the gauges making them able to measure correctly in winter, too.

Station 652, precipitation, 60 min.:
- 49 records are missing (0.6% of all data records in the quality check period).
- All data are considered as suspect due to many periods with unrealistic amounts of precipitation.
- Data is not used in the combined KOB series

Station 653, precipitation, 60 min.:
- 11 records are missing (0.1% of all data records in the quality check period).
- 3308 data records were edited using filters and subsequently 97 records were manually edited. Filters have been used to eliminate noise in data and remove precipitation recorded at very low humidity.

KOB, precipitation, 60 min.:
- 11 records are missing (0.1% of the data).
- The time series is 99.9% complete

3.16 Snow Depth

Snow depth is measured at both station 652 and 653 using an ultrasonic sounding device (Campbell Scientific SR50) that measures the distance from the sensor to the ground/snow cover.
The data from both stations have been corrected by subtracting a constant value. This value is based on deviation from manual measurements as well as the mean deviation from zero during snow-free periods (prior to vegetation blooming).
The measurements are subsequently corrected to zero when no snow is present (seen from pictures and other parameters).

Station 652, snow depth, 180 min.:
- 19 records are missing (0.05% of all data records in the quality check period).
- 9 records were deleted as they were outside of the interval or erroneous.
- 327 records are automatically corrected to zero (1.1% of all data records in the quality check period, 3 of those are logger errors which have been corrected to zero for continuity reasons).
- 93 records are denoted suspect (data between 2013-01-10 00:00 and 2013-01-21 12:00), since there are no evidence of snowfall indicated by the sensor (0.3% of all data records in the quality check period).

Station 653, snow depth, 180 min.:
- 66 records are missing (2.3% of all data records in the quality check period).
- 7 records were deleted as they were outside of the interval or erroneous.
- 152 records are automatically corrected to zero (5.2% of all data records in the quality check period, 26 of those are logger errors which have been corrected to

zero for continuity reasons).

KOB, snow depth, 180 min.:

- No records are missing.
- The time series is 100% complete

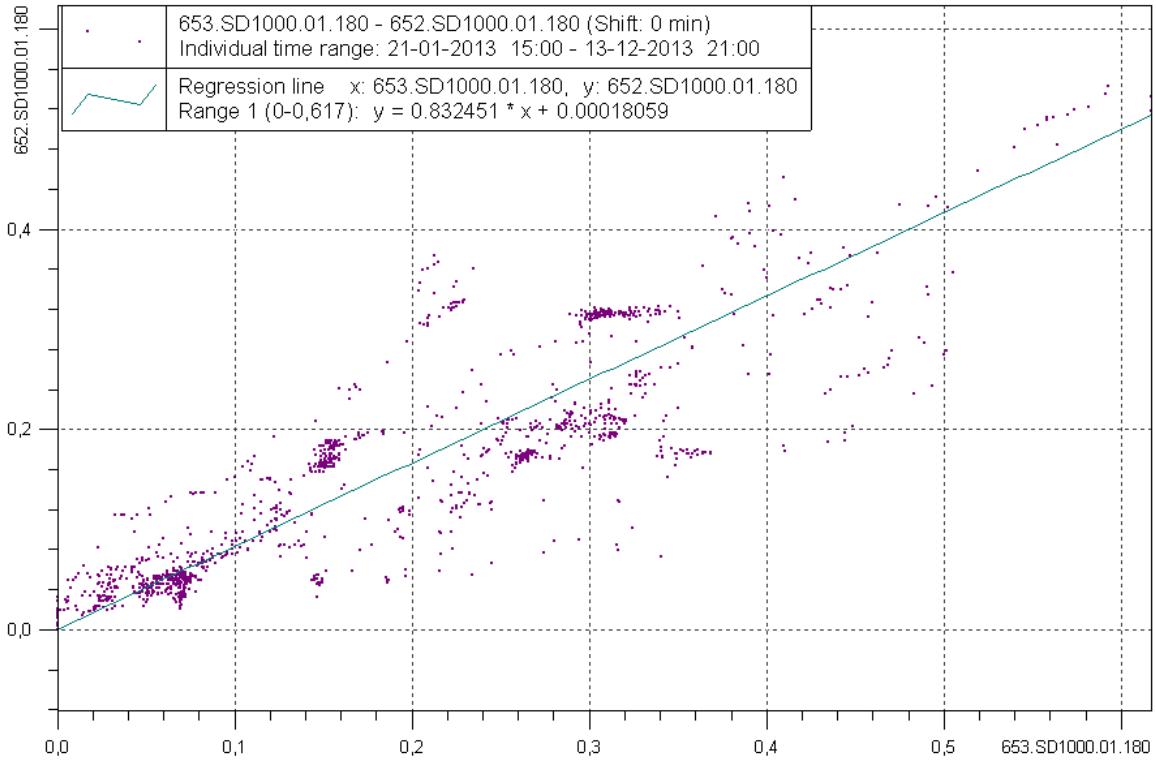


Figure 3.3 Snow depth measured at Kobbefjord station 652, y, as a function of snow depth measured at Kobbefjord station 653, x. The regression lines are given in Fejl! Henvisningskilde ikke fundet.**5.**

4 Measuring Program 2013, Hydrometric Station 650

The NuukBasic hydrology program includes five sites. For further description see Iversen and Thorsøe (2009).
This report describes data from the central drainage basin, st. 650, where a reliable open-water stage-discharge (Q/h) relation has been established after the 2009 season. For st. 651, st. 654, st. 655 and st. 656 not enough discharge measurements have yet been carried out to produce reliable Q/h-relations. Therefore data from these stations are not presented.
An overview of the hydrological data measuring program at st. 650 during 2013 is given in Table 4.1.

Table 4.1 Parameter, senor type, sensor height above terrain, sensor specifications and aggregations method for st. 650.

Parameter	Sensor Type	Sensor Height (m.a.t.)	Measuring Range	Sensitivity (resolution)	Accuracy	Data stored in the data logger [1]	
						Average/sum	Sample/max/min
Air Temperature 1	Campbell 107-L	2 m	-35 - +50 °C	0.1 °C	+/- 0.4 °C	$[0;30]^{30\,min}_{10\,sec}$ Average	$[-]^{30\,min}_{10\,sec}$ max/min/sample
Air Temperature 2	SWS MiniDiver (Baro)	2 m	-20 - +80 °C	0.01 °C	+/- 0.1 °C		$[-]^{60\,min}_{60\,min}$ sample
Atmospheric Pressure	SWS MiniDiver (Baro)	2 m	540 to 1150 hPa	0.3 hPa	+/- 0.5 hPa		$[-]^{60\,min}_{60\,min}$ sample
Water Level 1	Drück PTX1730		1.5 – 35 mH_2O	0.01 m	+/- 0.25%		$[-]^{60\,min}_{10\,sec}$ sample
Water Level 2	Drück PTX1730		1.5 – 35 mH_2O	0.01 m	+/- 0.25%		$[-]^{60\,min}_{10\,sec}$ sample
Water Level 3	SWS MiniDiver		0 – 10 mH_2O	0.003 m	+/- 0.005 m		$[-]^{60\,min}_{60\,min}$ sample
Water Level 4	SWS MiniDiver		0 – 10 mH_2O	0.003 m	+/- 0.005 m		$[-]^{60\,min}_{60\,min}$ sample
Water Temperature 1	Campbell 107-L		-35 - +50 °C	0.1 °C	+/- 0.4 °C		$[-]^{60\,min}_{10\,sec}$ sample
Water Temperature 2	Campbell 107-L		-35 - +50 °C	0.1 °C	+/- 0.4 °C		$[-]^{60\,min}_{10\,sec}$ sample
Water Temperature 3	SWS MiniDiver		-20 - +80 °C	0.01 °C	+/- 0.1 °C		$[-]^{60\,min}_{60\,min}$ sample
Water Temperature 4	SWS MiniDiver		-20 - +80 °C	0.01 °C	+/- 0.1 °C		$[-]^{60\,min}_{60\,min}$ sample

[1)] Data stored in the data logger is given as $[a;b]^{d}_{c}$, where 'd' is the interval between outputs written to the data logger, 'c' is the interval between scans of the sensor, 'a' and 'b' are minutes into the interval between output. Average values are found by averaging data values measured with interval c between 'a' and 'b'. Sample values are measured 'a' minutes into the interval between output.

5 Processing of Hydrological Data

As with climate data, the aim of data processing of the hydrological data is to establish one data series of high quality for each measured hydrological parameter.

The data processing for stage (water level) data includes the following steps:

1. Precise, manual measurements of the water level. For each measurement the position of the pressure transducers is calculated relative to a reference point at the station.
2. Necessary corrections of the data are performed. Erroneous data are deleted and sudden erroneous changes in water level caused by sudden shifts in the sensor position are corrected.
3. Additional changes in sensor position caused by either a slow physical or electronic signal drift of the sensor are corrected by linear interpolation between manual stage measurements.
4. The corrected water level is transformed to a relative height system where the reference point has a height of 100 meters.
5. Finally all valid water level data from the station are combined by averaging the measured water level from the different transducers.

The data processing and calculation of a Q/h-relation includes the following steps:

1. The discharge measurements are quality checked and assessed.
2. When enough discharge measurements have been carried out at different water levels spanning the range of natural variations, a Q/h-relation is established. Else, only preliminary Q/h-relations can be established. The Q/h-relations are established according to ISO 1100-2 (1998).

5.1 Discharge Measurements

In 2013 one manual discharge measurements has been carried out at st. 650 (22.3.2013). All manual discharge measurements span over values ranging from 0.07 to 10.16 $m^3 s^{-1}$ (under ice-free conditions range from 0.13 to 10.16 $m^3 s^{-1}$). This is unchanged in comparison with earlier reports. The total measured span in the water level under ice free conditions since 2006 is 1.015 m.

5.2 Q/h-relation

In 2009 a new Q/h-relation was calculated based upon a total of 17 discharge measurements (Iversen and Pernosky, 2010). The established Q/h-relation did not consider the periods where the outlet was affected by ice and /or snow and discharge measurements carried out in these periods were not included in the Q/h-relation.
The 2013 discharge measurement fits well into the Q/h-relation, which therefore has not been changed. The established Q/h-relation can be seen in Equation 1 and Figure 5.1. The threshold of 98.735 m is chosen as water levels beneath this value only occur during the winter.

Equation 1:

RC1: $Q = 8.77(h - 98.60)^{2.05781}$ when h<=98.735

RC2: $Q = 33.54(h - 98.68)^{1.8947}$ when h>98.735

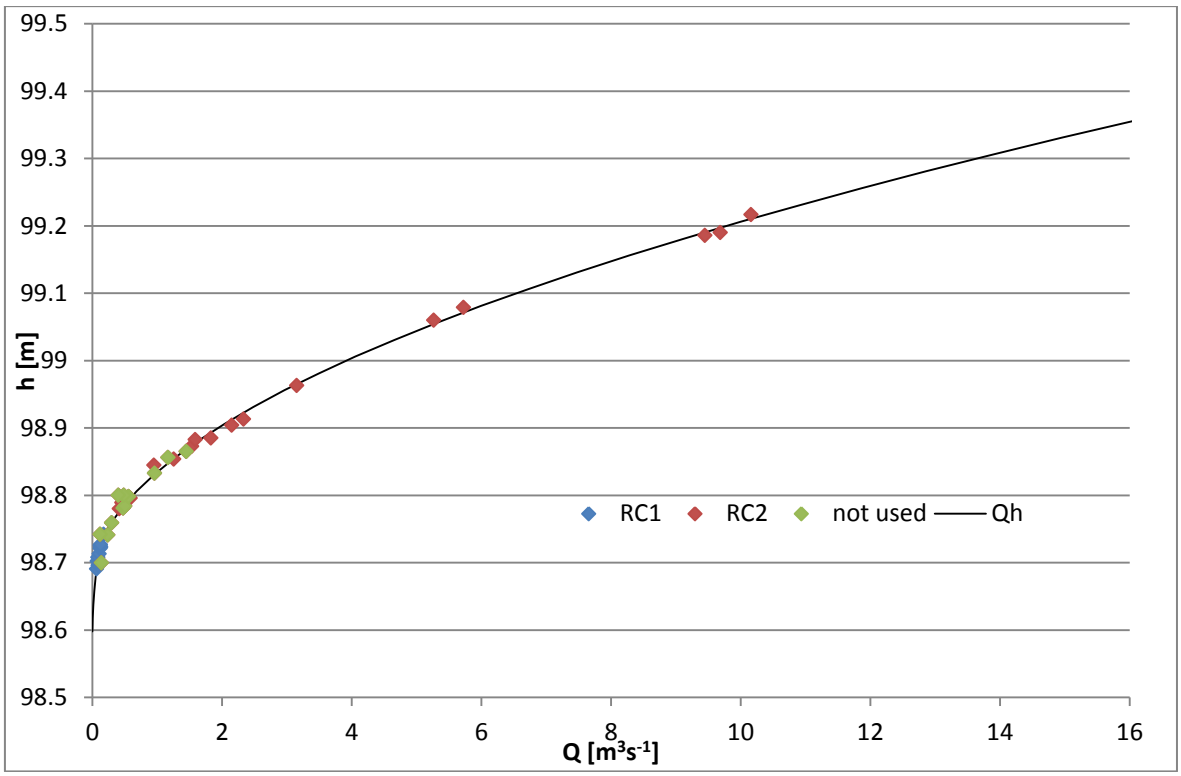


Figure 5.1 Q/h-relation for H1. All discharge measurements from 2006 to 2013 are shown. Green triangles – discharge measurements used in open water Q/h-relation with water levels above 98.735 m, purple triangles – discharge measurements used in winter Q/h-relation with water levels below or equal to 98.735 m, red squares – measurements not used in Q/h-relation.

5.3 River Water Discharge at st. 650

The total discharge from H1 during the hydrological year from 1 October 2012 to 30 September 2013 was $42.4*10^6$ m^3which is the second wettest on record. The total discharge corresponds to a runoff of 1368 mm when assuming that the drainage basin covers 31 km^2.

In 2013, the spring-discharge was comparably modest, which is a consequence of the shallow snow-cover and it took until early September and October until during two events the 10 m^3s^{-1} have been reached again. More than half of the total annual runoff occurred therefore from September onwards, with snow-melt being an unusually small contribution in 2013.

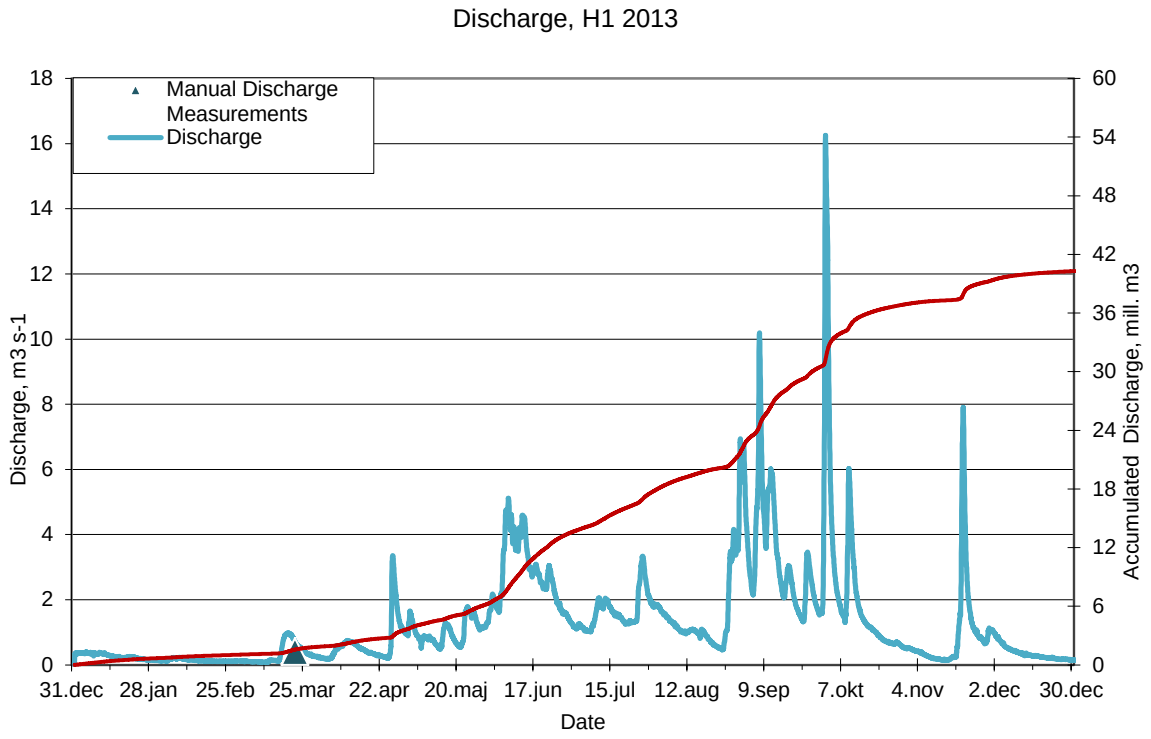


Figure 5.2 Discharge and accumulated discharge from st. 650 during 2013. Manual discharge measurements carried out during 2013 are shown with dark blue triangles.

References

Andersson, T. and Mattisson, I. 1991. *A field test of thermometer screens*. SMHI Reports Meteorology and Climatology, RMK 62, Swedish Meteorological and Hydrological Institute.

Arck, M. and Scherer, D. 2001. *A physically based method for correcting temperature data measured by naturally ventilated sensors over snow*. Journal of Glaciology, Vol.47, No.159, pp.665-670.

Brotzge, J. A. and Duchon, C. E. 2000. *A Field Comparison among a Domeless Net Radiometer, Two Four-Component Net Radiometers, and a Domed Net Radiometer*. J. Atmos. Oceanic Technol., 17, 1569–1582.

Campbell Scientific, Inc. 2002. *NR-Lite net radiometer instruction manual*. Campbell Scientific Inc., Logan, USA.

Gray, D.M. and Male, D.H., ed. 1981. *Handbook of snow. Principles, processes, management and use.* Pergamon Press, Canada.

ISO 1100-2. 1998. *Measurement of liquid flow in open channels – Part 2: Determination of the stage-discharge relation*. International standard. Second edition 1998-05-01.

Iversen, K.M. and Pernosky, M.A. 2010. Climate Basis Monitoring Program Nuuk Basic, 2009. Asiaq – Greenland Survey. 36 pp. Asiaq Report no. 2010-04.

Iversen, K. M. and Thorsøe, K. 2009. Nuuk Ecological Research Operations. ClimateBasis – Manual. 15 pp. Asiaq Report no. 2009-22.

Middleton, E. M. 1991. Solar zenith angle effects on vegetation indices in tallgrass prairie, *Remote Sensing of Environment*, 38, 1, 45-62.

Sicart, J. E., P. Ribsten, P. Wagnon, and D. Brunstein. 2001. Clear-sky albedo measurements on a sloping glacier surface: A case study in the Bolivian Andes, *J. Geophys. Res.*, 106 (D23), 31,729–31,737.

Singh, S. M. 1988. Simulation of solar zenith angle effect on global vegetation index (GVI) data, *Int. J. Remote Sensing*, 9, 2, 237-248.

Skye Instruments, Ltd. 2004. *Light: Non-zero reading from light sensors at night*. Skye Instruments Ltd., Llandrindod Wells, Powys, United Kingdom.

Solar Light Co Inc. 1991. *UV-Biometer Model 501A Version 3. User's Manual*. Solar Light Co., Philadelphia. USA.

van den Broeke, M., D. van As, C. Reijmer, R. van de Wal 2004. Assessing and Improving the Quality of Unattended Radiation Observations in Antarctica. *Journal of Atmospheric and Oceanic Technology*, 21, 1417–1431.