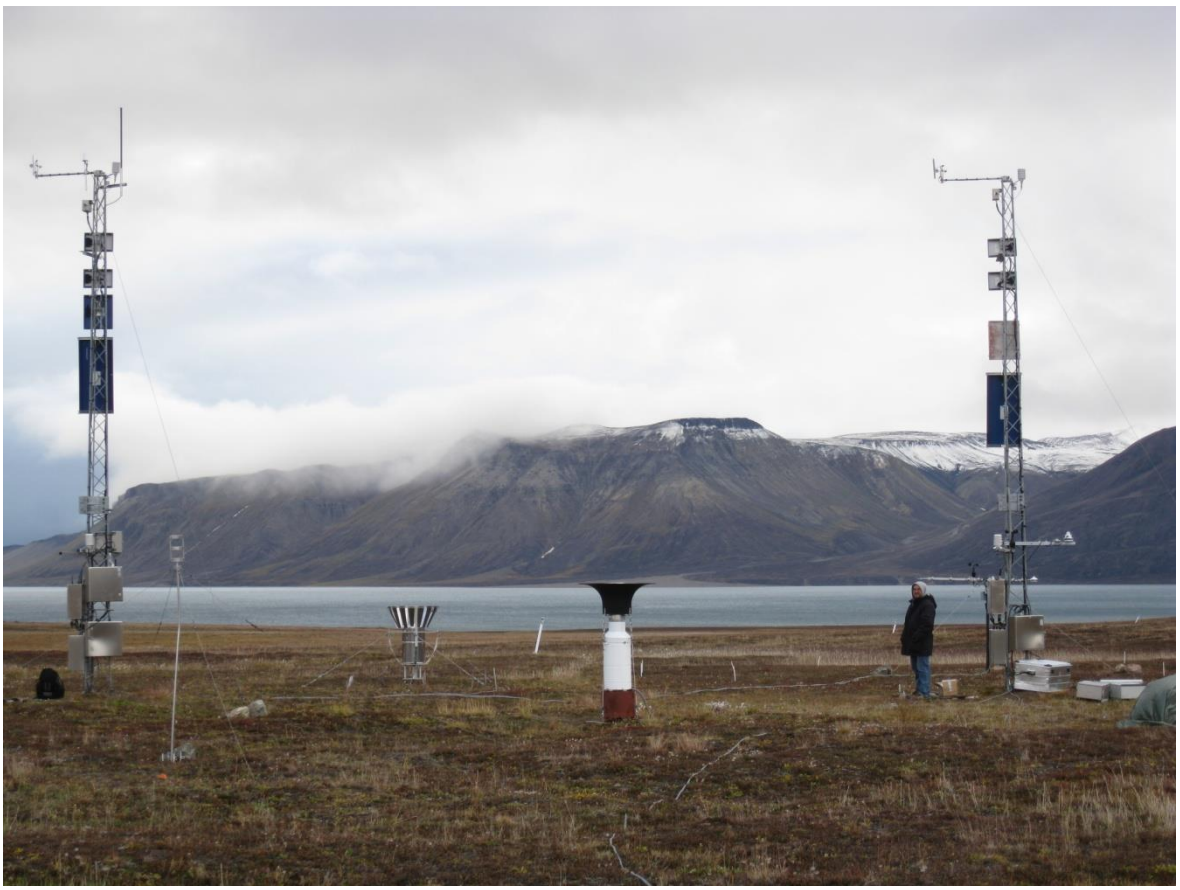
ClimateBasis Monitoring Program Zackenberg 2013



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Introduction

The ClimateBasis monitoring program in Zackenberg is part of the Zackenberg Ecological Research Operations (ZERO). The aim of ZERO is to monitor changes in the Arctic environment and to improve the understanding of the composition, function and dynamics of the ecosystem in the high Arctic.
ZERO is part of Greenland Ecosystem Monitoring (GEM) which is a leading integrated monitoring and long term research program on ecosystem and climate change effects and feedbacks in the Arctic.

The ClimateBasis program includes collection, quality control and communication of data, which describes the climate in the area near the research station in Zackenberg.

The ClimateBasis monitoring program included in 2013 three measuring stations; climate station east (Asiaq no. 640) and west (Asiaq no. 641) and a hydrometric station at Zackenbergelven.

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

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Content

1 Measuring Program 2013-2014

This section gives an overview of the sensors and the measuring program for the period January 1st 2013 00:00 to December 31st 2013 24:00.

1.1 Climate Station East, Station 640

Station 640 is placed app. 3 km east of Zackenberg Research Station. The station consists of a 7.5 m mast, a 2 m mast for radiation sensors and a precipitation gauge. An overview of the sensors, their accuracies, the scanning frequency and the logging interval is given in Table 1.1.

Measured Parameter	Sensor Type	Sensor Placement	Unit	Sensitivity (resolution)	Accuracy	Data Stored in the Data Logger[2)]	
		Meter [1)]				Average	Sample
Air Temperature	Vaisala, HMP 45D	+2	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{30min}_{-}$
Air Temperature	Vaisala, HMP 45D	+7.5	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$
Relative Humidity	Vaisala, HMP 45D	+2	%	0.1 %	+/- 3 %	-	$[0]^{60min}_{-}$
Relative Humidity	Vaisala, HMP 45D	+7.5	%	0.1 %	+/- 3 %	-	$[0]^{60min}_{-}$
Air Pressure at Station	Vaisala, PTB110	+1.66	hPa	0.1 hPa	+/- 4 hPa	-	$[0]^{60min}_{-}$
Wind Speed, mean and max	Theodor Friedrichs & Co. 4034.0000X	+2	m/s	0.1 m/s	+/- 0.3 m/s	$[0;10]^{10min}_{10sec}$	$[0]^{30min}_{-}$
Wind Speed, mean and max	Met One, C034B	+7.5	m/s	0.1 m/s	+/- 0.12 m/s	$[0;10]^{10min}_{10sec}$	-
Wind Direction, mean and at max wind	Met One, C034B	+7.5	degrees	+/- 0.5 °	+/- 4 °	$[0;10]^{10min}_{10sec}$	-
Snow Depth, sonic range sensor	Campbell, SR50A	+1.94	M	0.1 mm	+/- 1 cm or 0.4 %	-	$[0]^{180min}_{-}$
Acc. Precipitation	Ott Pluvio	+1	mm	0.1 mm/h	+/- 1 %	-	$[60]^{60min}_{-}$
Shortwave Radiation, incoming and outgoing	Kipp&Zonen, CM7B Kipp&Zonen, CNR1	+2 +2	W/m^2 W/m^2	0.6 – 2.7 W/m^2	+/- 10 % for daily sums	- $[0]^{5min}_{-}$	$[0]^{30min}_{-}$ -
Longwave Radiation, incoming and outgoing	Kipp&Zonen, CNR1	+2	W/m^2	0.3 – 1.1 W/m^2	+/- 10 % for daily sums	$[0]^{5min}_{-}$	-
Net Radiation	Kipp&Zonen, NR. Lite Kipp&Zonen, CNR1	+2 +2	W/m^2 W/m^2		+/- 5 %	- $[0]^{5min}_{-}$	$[0]^{30min}_{-}$ -
PAR	PAR Lite, Quantum	+2	µmol/(m^{2}s)	0.005 µmol/(s*m^2)	+/- 5 %	-	$[0]^{30min}_{-}$
Soil Temperature	Campbell, 107-L	-0.025	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$
Soil Temperature	Campbell, 107-L	-0.10	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$
Soil Temperature	Campbell, 107-L	-0.40	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$
Soil Temperature	Campbell, 107-L	-0.80	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$
Soil Temperature	Campbell, 107-L	-1.30	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$

Table 1.1 Sensors and measuring program at climate station east, station 640.

[1)]Meter above terrain, [2)]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.

Climate Station West, Station 641
Station 641 is placed app. 10 m west of station 640. The station consists of a 7.5 m mast, a 2 m mast for radiation sensors, a precipitation gauge and a separate mast for measuring the snow depth (formerly st. 644). An overview of the sensors and the program is given in Table 1.2.

Table 1.2 Sensors and measuring program at climate station west, station 641.

Measured Parameter	Sensor Type	Sensor Placement	Unit	Sensitivity (resolution)	Accuracy	Data Stored in the Data Logger[2)]	
		Meter [1)]				Average	Sample
Air Temperature	Vaisala, HMP 45D	+2	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{30min}_{-}$
Air Temperature	Vaisala, HMP 45D	+7.5	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$
Relative Humidity	Vaisala, HMP 45D	+2	%	0.1 %	+/- 3 %	-	$[0]^{60min}_{-}$
Relative Humidity	Vaisala, HMP 45D	+7.5	%	0.1 %	+/- 3 %	-	$[0]^{60min}_{-}$
Air Pressure at Station	Vaisala, PTB110	+1.6	hPa	0.1 hPa	+/- 4 hPa	-	$[0]^{60min}_{-}$
Wind Speed, mean and max	Theodor Friedrichs & Co. 4034.0000X	+2	m/s	0.1 m/s	+/- 0.3 m/s	$[0;10]^{10min}_{10sec}$	-
Wind Speed, mean and max	Met One, C034B	+7.5	m/s	0.1 m/s	+/- 0.12 m/s	$[0;10]^{10min}_{10sec}$	-
Wind Direction, mean and at max wind	Met One, C034B	+7.5	degrees	0.5 °	+/- 4 °	$[0;10]^{10min}_{10sec}$	-
Snow Depth, sonic range sensor[4)]	Campbell, SR50A	+1.805	m	0.1 mm	+/- 1 cm or 0.4 %	-	$[0]^{180min}_{-}$
Acc. Precipitation	Belfort, 5915 x	+1.5	mm	1 mm		-	$[0]^{60min}_{-}$
Short Wave Radiation, incoming and outgoing	Kipp&Zonen, CM6A	+2	W/m^2	0.6 – 2.7 W/m^2	+/- 10 % for daily sums	-	$[0]^{30min}_{-}$
UV-B Radiation	Solar Light, 501A	+2	W/m^2	< 0.583 mW/m^2	+/- 5 % for daily total	-	$[0]^{30min}_{-}$
Soil Temperature	Campbell, 107-L	-0.00	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$
Soil Temperature	Campbell, 107-L	-0.05	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$
Soil Temperature	Campbell, 107-L	-0.20	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$
Soil Temperature	Campbell, 107-L	-0.60	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$
Soil Temperature	Campbell, 107-L	-1.00	°C	0.1 °C	+/- 0.4 °C	-	$[0]^{60min}_{-}$

[1)]Meter above terrain, [2)]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 Inspection of the Stations, summer 2013

Two technicians from Asiaq visited Zackenberg Research Station in the period May 30st to June 12st 2013. A summary of the work done on each station is given below.

2.1 Technical Services at Station 640, Climate Station East

Visual inspection of the station revealed no obvious damages. Upon arrival to the station the data and the program were downloaded. Reference tests were then made. All reference tests except air temperature and relative humidity at 7.5 m gave acceptable results.
The air temperature and relative humidity sensor in both 2 and 7.5 m were changed due to new wiring and the NR Lite was changed due to the scheduled 2 years change.

The results of the reference tests carried out upon arrival are summarized in Table 2.1 and Table 2.2.

Table 2.1 Test of the Pluvio precipitation gauge May 31st at station 640.

Pluvio Precipitation Gauge [mm]		
Weight	**Reading**	**Reference**
0.982 kg	49.3	49.1
1.966 kg	98.3	98.3

Table 2.2 Arrival reference test May 31st at station 640.

Parameter	Unit	Logger	Reference	Time
Wind Speed 7.5 m	m/s	4.2	4.3	17:32
		4.0	4.7	17:33
Wind Direction 7.5 m	degree	116	118	17:35
Air Temperature 7.5 m	°C	-2.5	-1.7	17:37
		-2.4	-1.6	17:38
Relative Humidity 7.5 m	%	94.7	91.0	17:38
		94.7	90.5	17:39
Wind Speed 2 m	m/s	4.2	4.1	17:48
		2.7	2.7	17:48
Air Temperature 2 m	°C	-1.3	-0.8	18:24
		-1.4	-0.9	18:25
Relative Humidity 2 m	%	89.8	87.8	18:25
		90.4	88.4	18:26
Air Pressure	hPa	1018.5	1018.2	17:40
Battery	V	14.06	14.16	18:17
Albedometer, upper (SRI)	W/m^2	337	318	17:52
		465	473	17:55
Albedometer, lower (SRO)	W/m^2	58.4	62.1	18:12
		61.4	60.1	18:13
Albedometer, upper (CNR1)	W/m^2	324	318	17:52
		452	473	17:55
Albedometer, lower (CNR1)	W/m^2	58.6	62.1	18:12
		56.8	60.1	18:13
Distance to Snow	m	-1.952	-1.962	18:06
Snow Depth	m	0.3*	0.32*	18:10

* - the distance is tested on a box

Before departure reference tests were made once more. The reference tests approved that the overall quality of the tested parameters are acceptable.

The results of the reference tests carried out before departure are summarized in Table 2.3.

Table 2.3 Departure reference test June 1st at station 640.

Parameter	Unit	Logger	Reference	Time
Wind Speed 7.5 m	m/s	5.5	5.6	16:28
		6.0	5.7	16:29
Wind Direction 7.5 m	Degree	114	118	16:31
		116	118	16:31
Air Temperature 7.5 m	°C	1.2	1.2	16:32
		1.2	1.2	16:33
Relative Humidity 7.5 m	%	70.3	68.2	16:33
		70.7	68.9	16:34
Wind Speed 2 m	m/s	3.1	3.1	16:16
		3.0	3.2	16:16
Air Temperature 2 m	°C	1.8	1.7	15:55
		1.8	1.8	15:58
Relative Humidity 2 m	%	66.8	64.5	15:56
		64.0	63.4	15:57
Air Pressure	hPa	1015	1015	15:58
Battery	V	13.91	13.95	16:00
Albedometer, upper (SRI)	W/m^2	149	151	16:12
		147	149	16:14
Albedometer, lower (SRO)	W/m^2	14.9	15.8	16:07
		13.9	15.2	16:09
Albedometer, upper (CNR1)	W/m^2	146	151	16:12
		144	149	16:14
Albedometer, lower (CNR1)	W/m^2	14.5	15.8	16:07
		14.1	15.2	16:09
Distance to Snow	m	-1.962	-1.964	16:10
Snow Depth	m	0.319*	0.324*	16:20

* - the distance is tested on a box

2.2 Technical Service at Station 641, Climate Station West

Visual inspection of the station revealed no obvious damages, but the incoming and outgoing solar radiation sensor was out of level. Reference tests were made upon arrival. All reference tests gave acceptable results except relative humidity at 2 m that was slightly outside the tolerance and the incoming solar radiation (SRI) that was out of level.
No sensors were changed but the wiring of the air temperature sensor at both 2 and 7.5 m was changed from 3 to 4-wire half bridge.

Before departure reference tests were made once more. The reference tests approve that the overall quality of the tested parameters are acceptable, except for the incoming solar radiation.

The results of the reference tests carried out upon arrival and before departure are

summarized in Table 2.5, Table 2.6 and Table 2.6

Table 2.4 Test of the Belfort precipitation gauge May 30st at station 641.

	Reference test at arrival			Reference test at departure		
Belfort [mm]	**Station**	**Reference**	**Difference**	**Station**	**Reference**	**Difference**
	156.2	153 ± 4.5	3.2	154.9	153 ± 4.5	1.9

Table 2.5 Arrival reference test May 30st at station 641.

Parameter	Unit	Logger	Reference	Time
Wind Speed 7.5 m	m/s	4.0	3.3	12:17
		4.3	4.4	12:18
Wind Direction 7.5 m	degree	115	114	12:21
Air Temperature 7.5 m	°C	5.3	5.5	15:35
		5.6	5.6	15:35
Relative Humidity 7.5 m	%	46.7	42.8	15:35
		43.5	40.5	15:35
Wind Speed 2 m	m/s	3.6	3.3	12:29
Air Temperature 2 m	°C	4.6	4.2	12:30
		4.5	4.4	12:30
Relative Humidity 2 m	%	61.1	58.6	12:31
		57.7	55.6	12:31
Air Pressure	hPa	1010.3	1010.3	12:17
Battery	V	14.29	14.34	12:33
Albedometer, upper (SRI)	W/m^2	645	624	12:36
		660	641	12:38
Albedometer, lower (SRO)	W/m^2	95.4	95.9	15:30
		93.1	95.1	15:30

Table 2.6 Departure reference test June 1st and 22nd at station 641.

Parameter	Unit	Logger	Reference	Time
Wind Speed 7.5 m	m/s	2.4	2.2	11:52
		2.8	2.5	11:53
Wind Direction 7.5 m	degree	114	114	11:35
Air Temperature 7.5 m	°C	0.5	0.5	12:05
		0.5	0.4	12:06
Relative Humidity 7.5 m	%	77.7	77.9	12:07
		77.9	76.9	12:07
Wind Speed 2 m	m/s	3.7	3.7	12:30
		5.1	4.8	12:31
Air Temperature 2 m	°C	0.5	0.4	12:32
		0.5	0.3	12:32
Relative Humidity 2 m	%	83.0	82.0	12:33
		85.3	83.3	13:33
Air Pressure	hPa	1017.3	1017.1	11:48
Battery	V	14.58	14.66	12:17
Albedometer, upper (SRI)	W/m^2	667	641	12:25
		678	651	12:26
Albedometer, lower (SRO)	W/m^2	96.3	103	12:19
		96.6	100	12:20
Distance to Snow	m	-1.769	-1.795	11:29
Snow Depth	m	No test		

3 Data Processing

The aim of the data processing is to establish one data series of high quality for each measured parameter, called ZAC.
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, interpolation or arithmetic. Gaps created due to editing are filled in step five.
5. Data from each station are combined by averaging data from each station. In case of missing data on one of the stations an orthogonal regression, st.640= α*st.641+β, is included in the average:

Data on both stations	Only data on St.640	Only data on St.641	No data
½(St.640+St.641)	½(St.640+ (1/α)St.640+(-β/α))	½ (St.641+ (αSt.641+β))	No data

   Regression values (α or coefficient and β or offset) used in case of missing data can be seen in **Fejl! Henvisningskilde ikke fundet.**, Table 3.2 **These parameters show difference in correlations before and after the station visit (e.g. due to sensor changed, program altered, sensor out of level, rewiring, etc.). The period is split up into two, January 1st 2013 to May 30th and June 1st to December 31st 2013. Exact time stamps depend on the sensor in question and can be found in the corresponding figures.**
   Station 640= coefficient*(Station 641)+offset., Table 3.3.
6. If a parameter on one of the stations is considered suspect, the other station is used as the main contributor to the final ZAC time series. Gaps in the main data series for the given parameter are filled with data from the other data source (if available) after transformation using orthogonal regression between the sensors.

A short description of the data processing for each parameter is given below. The figures with regression lines do not show data, which have been removed in the course of the data processing (see point 2 and 3 above). The production time series are stored in the Zackenberg Climate Database.

The data processing includes data from the period January 1st 2013 00:00 to December 31st 2013 24:00.

Table 3.1 These parameters show no significant difference in correlations before and after the station visit. This is for the full period, January 1st 2013 to December 31st 2013
Station 640= coefficient*(Station 641)+offset.

	2013-01-01 to 2013-12-31		
	Coefficient	**Offset**	**Remark**
WS 2m	0.783956	-0.100356	The regression is between st.641 WS in 2m and ZAC WS in 7.5m
WS 7.5m	0.962508	0.14107	
PAR	2.11238	-0.671223	The regression is between PAR at st. 640 and ZAC.SRI.5
WSM 7.5m	0.96559	0.142837	

SRI	0.9622	0.827416	The regression is between 5 and 30 min both at st. 640

Table 3.2 These parameters show difference in correlations before and after the station visit (e.g. due to sensor changed, program altered, sensor out of level, rewiring, etc.). The period is split up into two, January 1st 2013 to May 30th and June 1st to December 31st 2013. Exact time stamps depend on the sensor in question and can be found in the corresponding figures.
Station 640= coefficient*(Station 641)+offset.

	2013-01-01 to 2013-05-30		**2013-06-01 to 2013-12-31**		
	Coefficient	**offset**	**Coefficient**	**Offset**	**Remark**
AT 2m	0.999921	-0.278864	1.0019	0.07553	Change to 4WireHalfbridge
AT 7.5m	1.00234	-0. 120363	1.00162	0.340794	Change to 4WireHalfbridge
QFE	0.999623	0.175325	0.999477	0.461726	Change to 50Hz
RH 2m	0.991421	0.919201	1.03591	-3.41815	Sensor changed at st. 640

Table 3.3 Station 640.30min=coefficient*(Station 640.5min)+offset. This parameter has a pronounced different winter and summer correlation.

	Snow cover		**No snow cover**		**Snow cover**	
	2013-01-01 0:00 to 2013-05-23 0:00		**2013-06-05 0:00 to 2013-08-28 0:00**		**2013-10-05 0:00 to 2013-12-31 23:55**	
	Coefficient	**Offset**	**Coefficient**	**Offset**	**Coefficient**	**Offset**
SRO	0.978196	1.51793	0.970193	1.57898	0.997659	0.593477

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 640 and 641 inside the data logger cabinet. The logged air pressure data values reflect the air pressure at the position of the sensor (no altitude correction).

Data from January 1st 2013 00:00 to December 31st 2013 23:00 is included in the data processing. The sensors on st. 640 and 641 were not changed at the visit in 2013.The data are a mean of the data from the two sensors (fluctuations are seen on both sensors). The results of the data checks are summarized below.

Station 640, air pressure, 60min.:

- 27 records are missing, corresponding to 0.3% of the period.
- No measurements lie outside the interval [900 hPa, 1100 hPa].
- No records were deleted.

Station 641, air pressure, 60min.:

- 23 records are missing, corresponding to 0.3% of the period.
- No measurements lie outside the interval [900 hPa, 1100 hPa].
- No records were deleted.

ZAC, air pressure

- 10 records are missing, corresponding to 0.1% of the period. This is due to the station visit in May/June.
- The time series is 99.9% complete.

The regression improves when the analysis is split up into two periods, one prior to the station visit (1/1-13 – 30/5-13) and one after the visit (1/6-13 –31/12-13). This is due to a change in the data logger program on all parameters, now logging at 50 Hz instead of 250Hz.

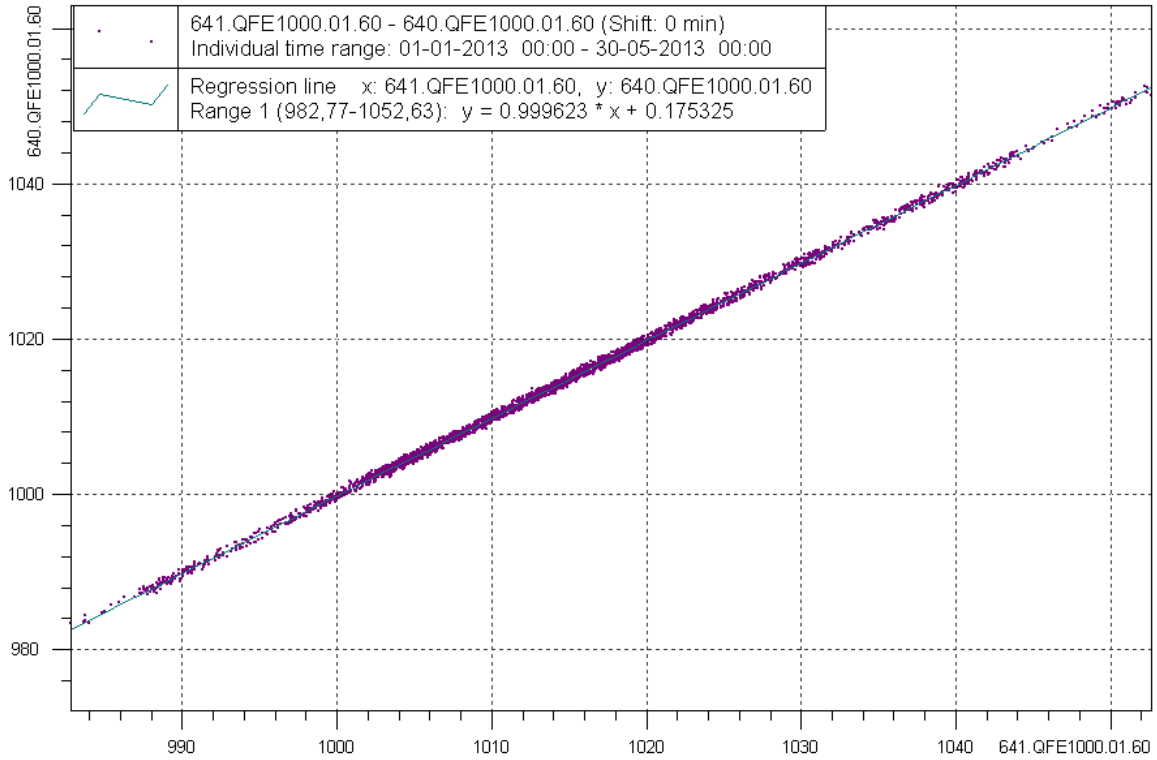

Figure 3.1 Air pressure measured at Zackenberg east (station 640), y, as a function of air pressure measured at Zackenberg west (station 641), x. The figure shows a regression based on data prior to the station visit (January 1st – May 30th). The regression lines are given in table 3.2

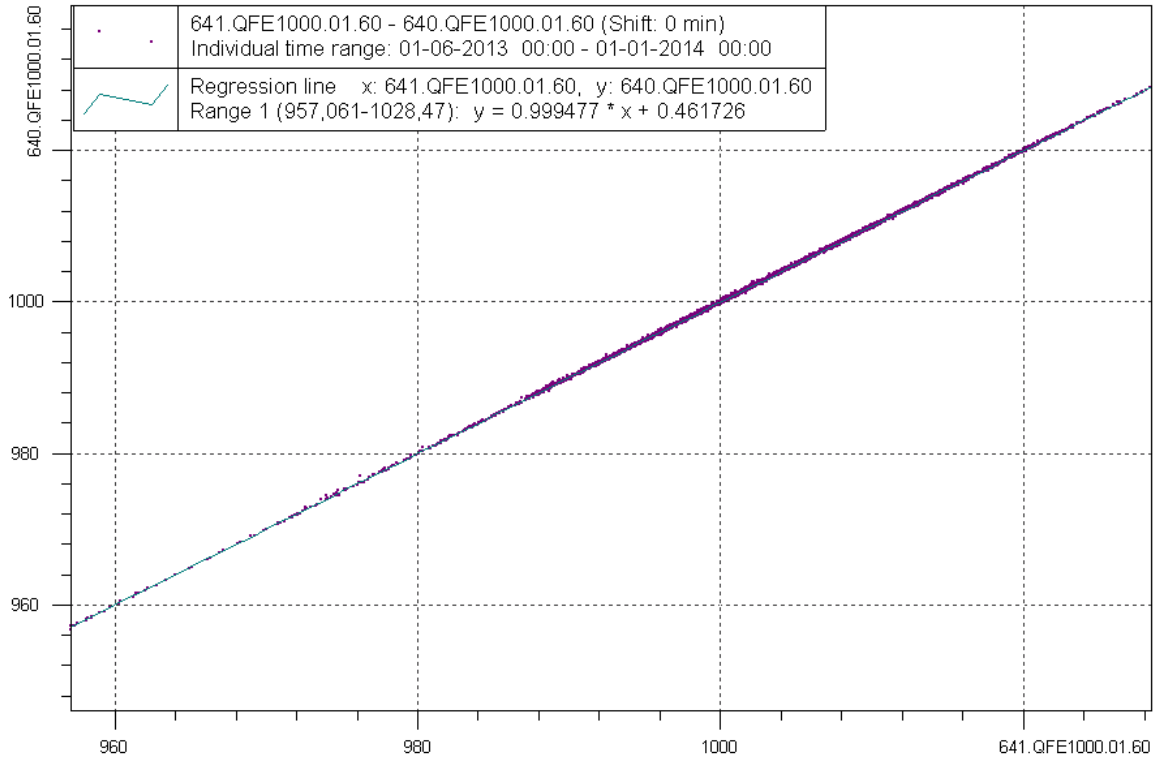

Figure 3.2 Air pressure measured at Zackenberg east (station 640), y, as a function of air pressure measured at Zackenberg west (station 641), x. The figure shows a regression based on data collected after the station visit (June 1st – December 31th). The regression lines are given in table 3.2.

3.2 Air Temperature

The air temperature is measured 2 m and 7.5 m above terrain level at station 640 and station 641.

The air temperature is measured using temperature sensors 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). A correction of these data has not been performed.

Sensors in 2 m

Data from January 1st 2013 00:00 to December 31st 2013 23:30 is included in the data processing. Both sensors were changed at the visit in May/June 2013. In earlier years data from one of the stations was chosen as the main data source, but now the data is a mean of the available data from the two stations. For st. 640 the reference tests at departure in August 2012 and the reference test at arrival in May/June 2013 showed deviations larger than tolerated. The data has therefore been corrected by +0.75 °C from January 1st 2013 00:00 to June 1st 2013 16:00. The departure tests showed very low deviations (+/- 0.07 at the largest), mainly due to the shift from 3WireBridge to 4WireBridge connections from sensor to logger box. No corrections were therefore necessary from June to December 2013.

Station 640, air temperature, 2m, 30 min.:

- 54 records are missing, corresponding to 0.3% of the period.
- No measurements lie outside the interval [-40°C, 25°C].
- No records have been deleted
- Data have been adjusted by +0.75°C (January 1st 2013 00:00 - June 1st 2013 16:00)

Station 641, air temperature, 2m, 30 min.:

- 69 records are missing, corresponding to 0.4% of the period.
- No measurements lie outside the interval [-40°C, 25°C].
- No records have been deleted

ZAC, air temperature, 2 m, 30 min:

- 44 records are missing, corresponding to 0.3% of the full period. This is due to the station visit in May/June.
- The time series is 99.7% complete.

The regression improves when the analysis is split up into two periods, one prior to the station visit (1/1-13 – 30/5-13) and one after the visit (1/6-13 – 31/12-13). This is due to a change in the data logger program on all parameters, now logging at 50Hz instead of 250Hz, but more importantly for the temperature parameter, a shift from using 3Wire halfbridge to using 4Wire halfbridge connection to data logger.

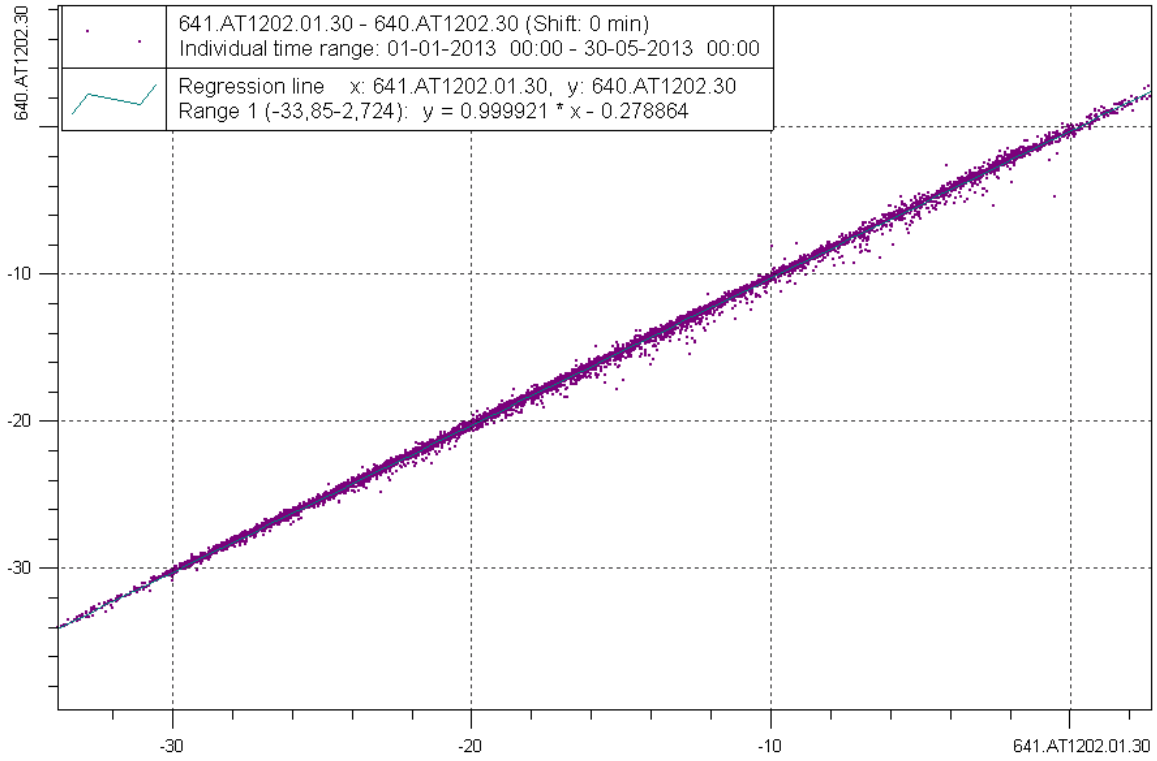

Figure 3.3 Air temperature measured 2 m above terrain at Zackenberg west (station 641), y, as a function of air temperature measured 2 m above terrain at Zackenberg east (station 640), x. The

figure shows a regression based on data prior to the station visit (January 1st – May 30th). All regression lines are given in table 3.2..

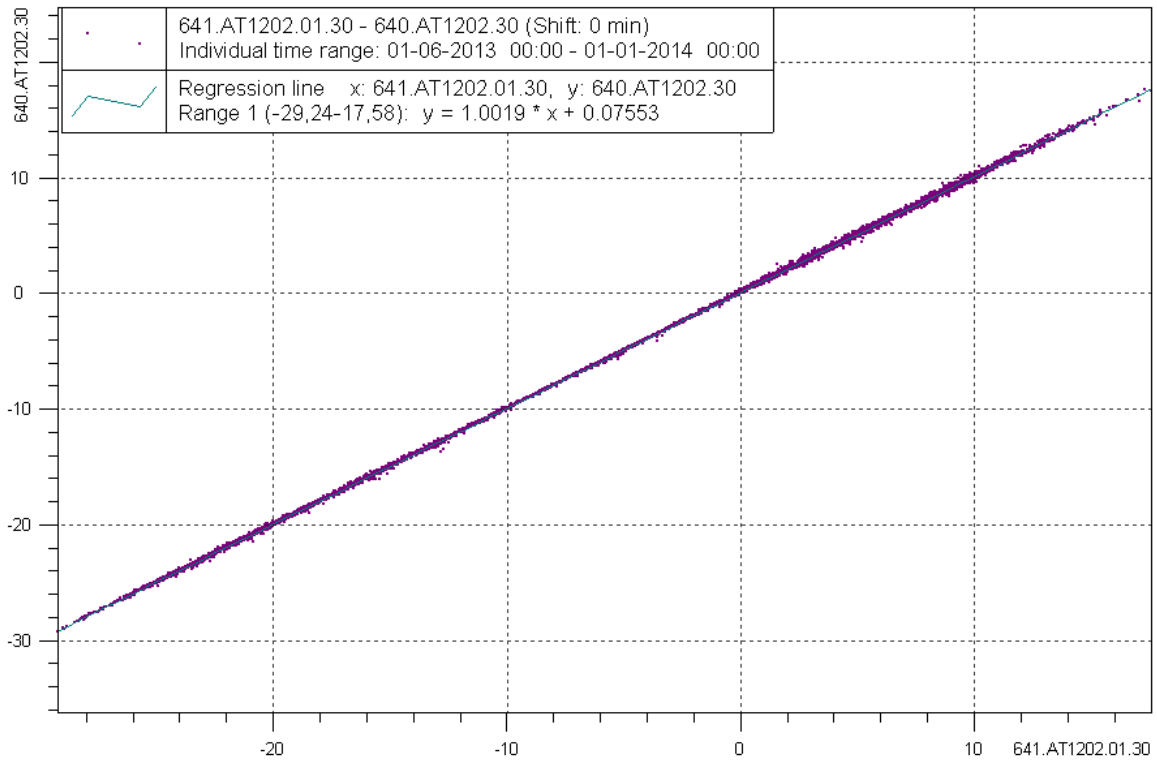

Figure 3.4 Air temperature measured 2 m above terrain at Zackenberg west (station 641), y, as a function of air temperature measured 2 m above terrain at Zackenberg east (station 640), x. The figure shows a regression based on data collected after the station visit (June 1st – December 31th). All regression lines are given in table 3.2.

Sensors in 7.5 m

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

Both sensors were changed at the visit in May/June 2013. In earlier years data from one of the stations was chosen as the main data source, but now the data is a mean of the available data from the two stations. For st. 640 the reference tests at departure in August 2012 and the reference test at arrival in May/June 2013 showed deviations larger than tolerated. The data has therefore been corrected by +0.8725 °C from January 1st 2013 00:00 to June 1st 2013 16:00. The departure tests showed very low deviations (+/- 0.09 at the largest), mainly due to the shift from 3WireBridge to 4WireBridge connections from sensor to logger box. No corrections were therefore necessary from June to December 2013.

Station 640, air temperature, 7.5m, 60min:

- 27 records are missing, corresponding to 0.3% of the period.
- No measurements lie outside the interval [-40°C, 25°C].
- No records have been deleted.
- Data have been adjusted by +0.8725°C (January 1st 2013 00:00 - June 1st 2013 16:00)

Station 641, air temperature, 7.5 m above terrain, 60min.:

- 23 records are missing, corresponding to 0.3% of the period.
- No measurements lie outside the interval [-40°C, 25°C].
- 6 records with unrealistic values have been deleted, corresponding to 0.1% of the period.

ZAC, air temperature, 7.5m, 60min.:

- 10 records are missing, corresponding to 0.1% of the full period. This is due to the station visit in May/June.
- The time series is 99.9% complete.

The regression improves when the analysis is split up into two periods, one prior to the station visit (1/1-13 – 30/5-13) and one after the visit (1/6-13 – 31/12-13). This is due to a change in the data logger program on all parameters, now logging at 50Hz instead of 250Hz, but more importantly for the temperature parameter, a shift from using 3Wire halfbridge to using 4Wire halfbridge connection to data logger.

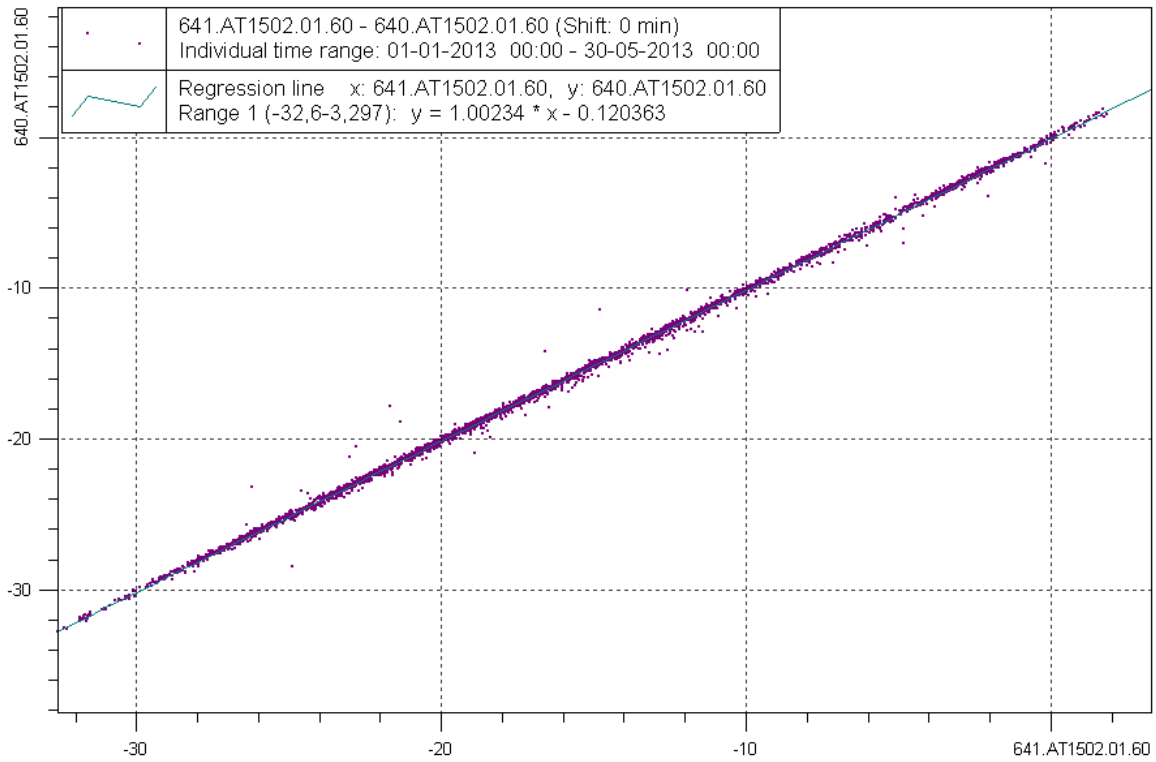

Figure 3.5 Air temperature measured 7.5 m above the terrain at Zackenberg east (station 640), y, as a function of the air temperature measured 7.5 m above the terrain at Zackenberg west (station 641), x. The figure shows a regression based on data prior to the station visit (January 1st – May 30th). All regression lines are given in table 3.2.

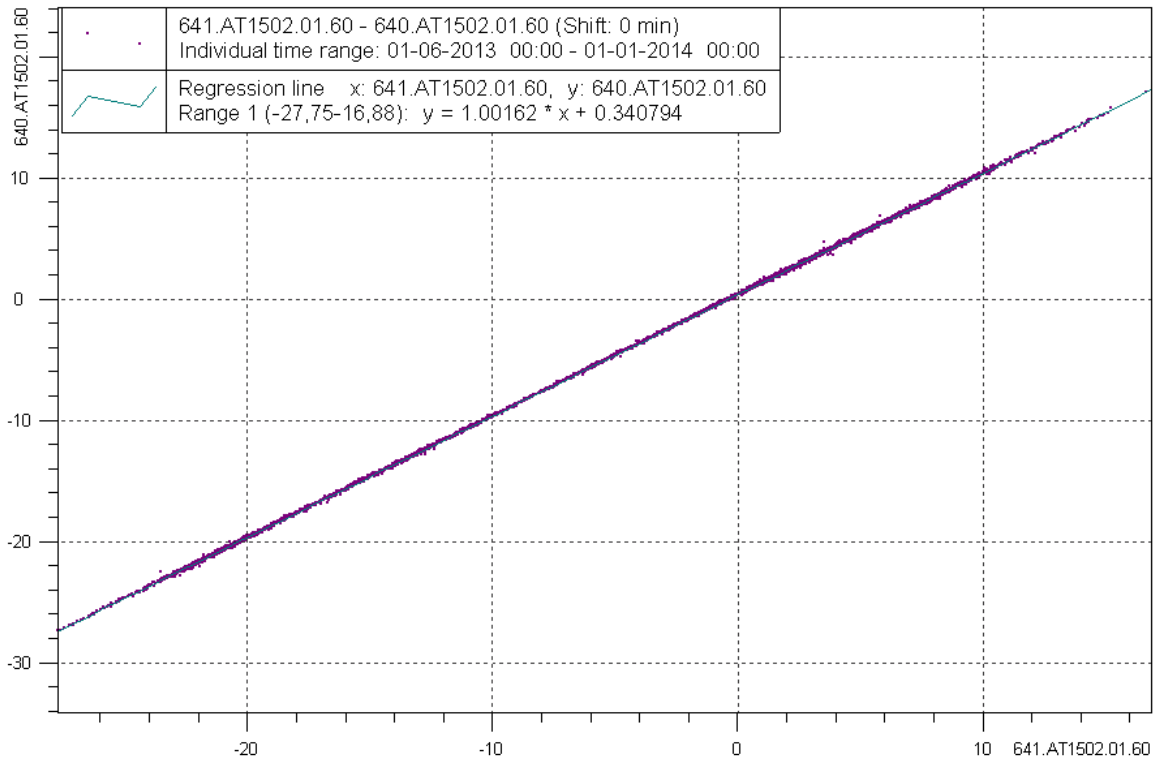

Figure 3.6 Air temperature measured 7.5 m above the terrain at Zackenberg east (station 640), y, as a function of the air temperature measured 7.5 m above the terrain at Zackenberg west (station 641), x. The figure shows a regression based on data collected after the station visit (June 1st – December 31th). All regression lines are given in table 3.2.

3.3 Relative Humidity

The relative humidity is measured by the same sensor unit as the air temperature, both in 2 and 7.5 m. The data from 7.5 m above terrain are not included in the quality check and are therefore not processed.

Data from January 1st 2013 00:00 to December 31st 2013 23:00 is included in the data processing. The sensor at station 640 (Zackenberg east) was changed at the visit in June 2013 along with the new wiring of the air temperature sensor. The results of the data checks are summarized below.

Station 640, relative humidity, 2m, 60min:

- 27 records are missing, corresponding to 0.3% of the period. All of those are missing due to maintenance of the station.
- No records lie outside the normal span in relative humidity [20%, 104%]
- No records were deleted.

Station 641, relative humidity, 2m, 60min.:

- 23 records are missing due to upgrade of the station; this corresponds to 0.3% of the period. All of those are missing due to maintenance of the station.
- No records lie outside the normal span in relative humidity [20%, 104%]
- No records were deleted.

ZAC, relative humidity, 2m, 60min.:

- 10 records are missing, corresponding to 0.1% of the period.
- The time series is 99.9% complete.

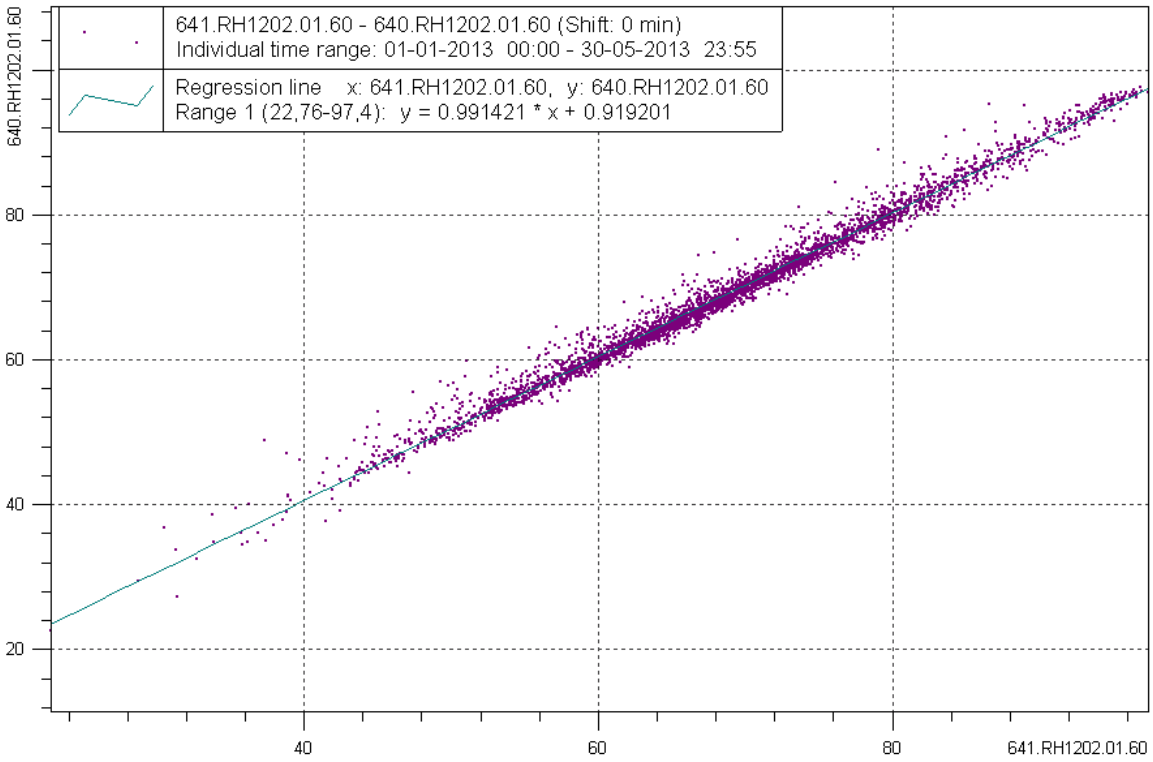

Figure 3.7 Relative air humidity measured 2 m above the terrain at Zackenberg east (station 640), y, as a function of the relative air humidity measured 2 m above terrain at Zackenberg west (station 641), x, for the period before station visit.

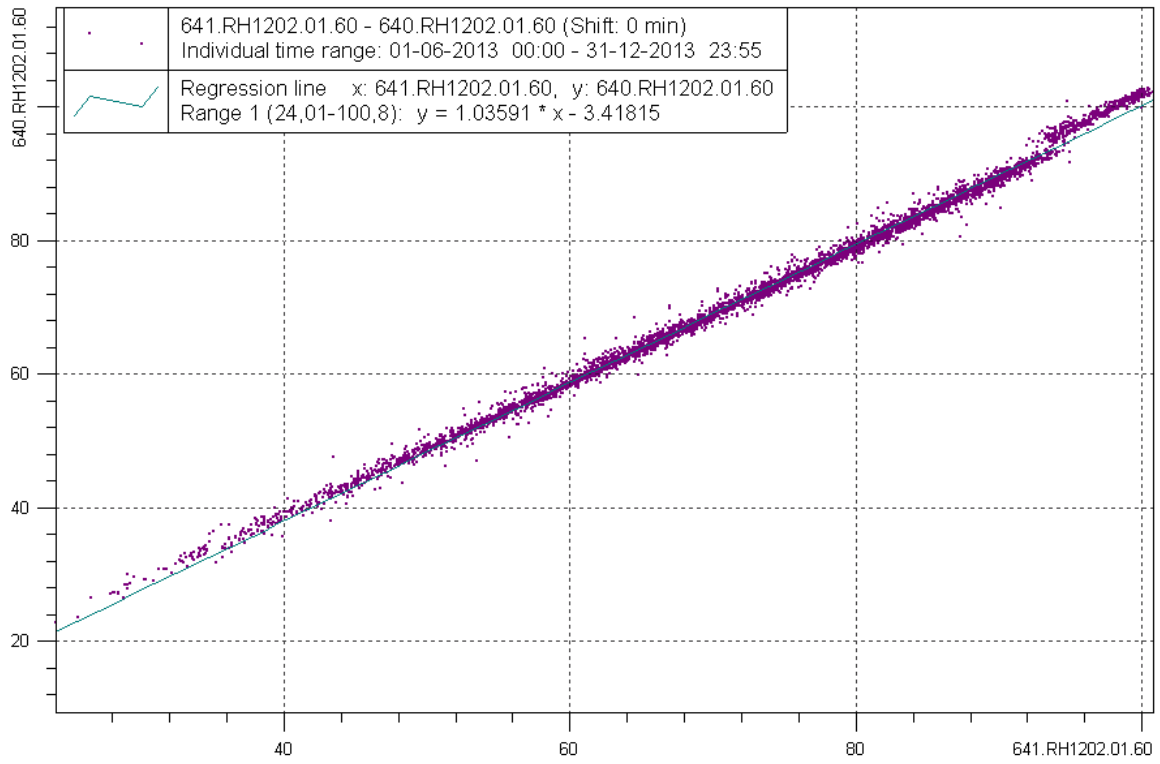

Figure 3.8 Relative air humidity measured 2 m above the terrain at Zackenberg east (station 640), y, as a function of the relative air humidity measured 2 m above terrain at Zackenberg west (station 641), x, for the period after station visit where sensor at st.640 was changed.

3.4 Wind Speed

The wind speed is measured in 2 and 7.5 m above terrain at both stations. The configuration from the manufacturer of the sensor at 7.5 m above terrain level means that an offset of 0.281 m/s corresponds to values between 0 - 0.281 m/s. Values of 0.281 m/s is hence regarded as ~ 0 m/s. Before the annual technical inspection in June the data logger was programmed so that values of 0.281 m/s was shown as 0.0 m/s but on 1st June the program was changed so 0.281 is shown as 0.281 m/s.

Data from January 1st 2013 00:00 to December 31st 2013 23:50 is included in the data processing. Two single wind speed time series for 2 and 7.5 m have been created for the period using the method described in section 3.

Wind speed data in 2 meter from station 640 are considered as suspect and are therefore not used in the combined time series. Missing wind speed data in 2 meter are filled out with data from 7.5 meter using a regression as described in section 3, Table 3.2.

The results of the data checks are summarized below.

Station 640, wind speed 2m, 10min.:

- All 52560 records are considered as suspect and are not used in the combined time series.

Station 641, wind speed 2m, 10min.:

- 210 records are missing corresponding to 0.4% of the period. 208 of those are missing due to maintenance of the station.
- 236 records have been deleted due to frozen sensor, corresponding to 0.5% of the full period.

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

- Some missing records are replaced by data from ZAC, 7.5 m, using the regression line shown in Figure 3.. If no data at station 641, 2 m, exists, data are replaced by data from station ZAC, 7.5 m, using linear regression.
- 159 records are missing, corresponding to 0.3%.
- The time series is 99.7% complete

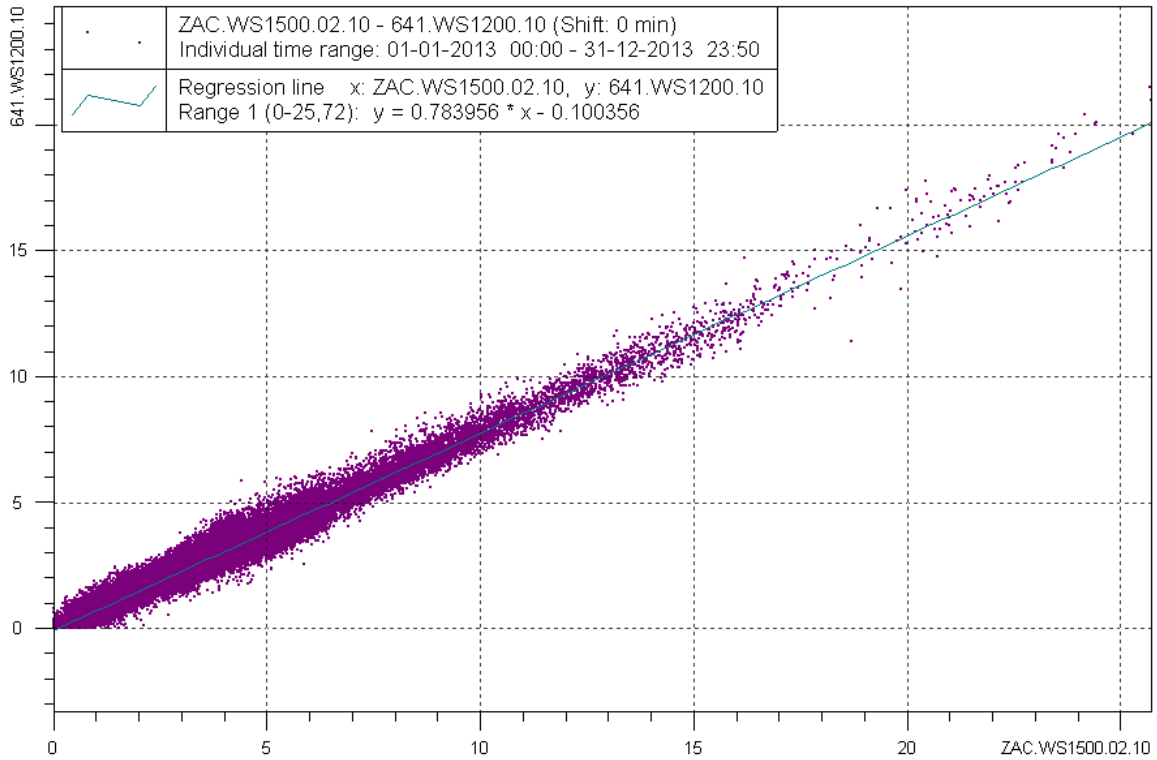

Figure 3.9 Mean wind speed 2 m above the terrain measured at Zackenberg west (station 641), y, as a function of mean wind speed 7.5 m above terrain at Zackenberg (station ZAC), x (checked data). Regression line and formula can be found in table 3.1.

Station 640, wind speed 7.5m, 10min.:

- 163 records are missing corresponding to 0.31% of the period. All of those are missing due to maintenance of the station.
- 104 records have been deleted due to frozen sensor, corresponding to 0.2% of the period.

Station 641, wind speed 7.5m, 10min.:

- 210 records are missing corresponding to 0.4% of the period. 208 of those are missing due to maintenance of the station.
- 111 records have been deleted due to frozen sensor, corresponding to 0.2% of the period.

- 1 record has been deleted due to unrealistic values.

ZAC, wind speed 7.5m, 10min.:

- 159 records are missing in the final time series, corresponding to 0.3% of the full period.
- The time series is 99.7% complete

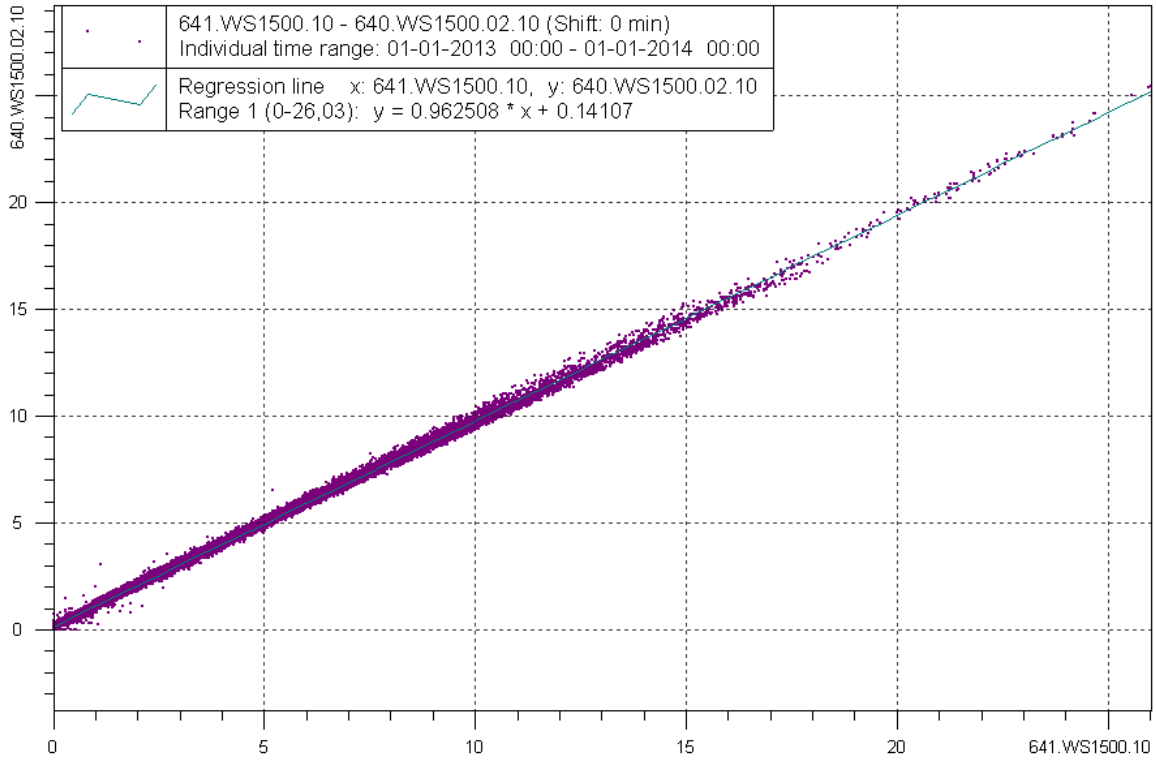

Figure 3.10 Wind speed measured 7.5 m above terrain at Zackenberg west (station 640), y, as a function of wind speed measured 7.5 m above terrain level at Zackenberg east (station 641), x. Regression line and formula are shown and can be found in table 3.1..

3.5 Maximum Wind Speed

The maximum wind speed is measured by the wind speed sensors 2 and 7.5 m above terrain level at both station 640 and station 641.
The configuration from the manufacturer of the sensor at 7.5 m above terrain level means that an offset of 0.281 m/s corresponds to values between 0 - 0.281 m/s. Values of 0.281 m/s is hence regarded as ~ 0 m/s. Before the annual technical inspection in June the data logger program was programmed so values of 0.281 m/s was shown as 0.0 m/s but 1st June the program was chanced so 0.281 is showed as 0.281 m/s.

Data from January 1st 2013 00:00 to December 31st 2013 23:50 is included in the data processing. Two single wind speed time series for 2 and 7.5 m have been created for the period using the method described in section 3.

Wind speed data in 2 meter from station 640 are considered as suspect and therefore not used in the combined time series. From February 19th 2013 to October 11th 2013 wind

speed data in 2 meter from station 641 are also considered as suspect so no wind speed maximum are available for this period.

The results of the data checks are summarized below.

Station 640, maximum wind speed, 2m, 10min.:

- All 52560 records are considered as suspect and are not used in the combined time series.

Station 641, maximum wind speed, 2m, 10min.:

- 211 records are missing corresponding to 0.4% of the period. 209 of those are missing due to maintenance of the station.
- 231 records have been deleted due to frozen sensor, corresponding to 0.6% of the period.
- 4 records have been deleted due to unrealistic wind speed values.
- Data from the period February 19th 2013 00:00 to October 10th 2013 23:50 are made suspect due to periods with some unrealistic high wind speed when compared with the other wind speed measurements and are not used in the final time series. This corresponds to 64.1% of the period.

ZAC, maximum wind speed, 2m, 10min.:

- 33906 records are missing, corresponding to 64.5% of the full period.
- The time series is 35.5% complete

Station 640, maximum wind speed, 7.5m, 10min.:

- 163 records are missing corresponding to 0.3% of the period. All 163 records are missing due to maintenance of the station.
- 99 records have been deleted due to frozen sensor, corresponding to 0.2% of the period. The rest of the data is regarded as valid.

Station 641, maximum wind speed, 7.5m, 10min.:

- 210 records are missing corresponding to 0.4% of the period. 208 of those are missing due to maintenance of the station.
- 109 records have been deleted due to frozen sensor, corresponding to 0.2%.

ZAC, maximum wind speed, 7.5m, 10min.:

- If no data in 7.5 meter exists, data are replaced by data form station ZAC, 2 m, using linear regression
- 158 records are missing in the final time series corresponding to 0.3%.
- The time series is 99.7% complete

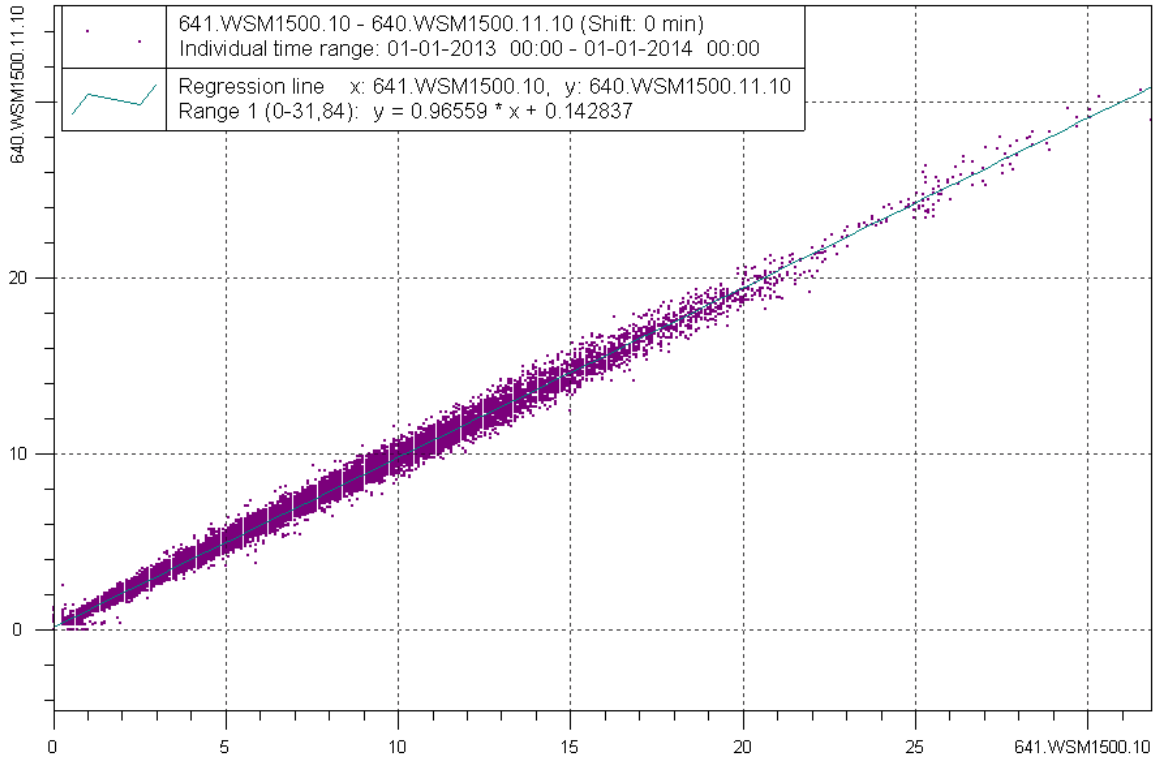

Figure 3.11 Maximum wind speed measured 7.5 m above terrain at Zackenberg west (station 640), y, as a function of maximum wind speed measured 7.5 m above terrain level at Zackenberg east (station 641), x. Regression line and formula are shown.

3.6 Wind Direction

Wind direction is measured 7.5 m above terrain at station 640 and 641. 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 feed directly into the final time series.

Data from January 1st 2013 00:00 to December 31st 2013 23:50 is included in the data processing. The results of the data checks are summarized below.

Station 640, wind direction, 7m, 10min.:

- 163 records are missing corresponding to 0.3% of the period. All of those are missing due to maintenance of the station.
- 13336 records are deleted due to defect sensor, corresponding to 25.4% of the period.
- 193 records are deleted due to wind speed = 0 m/s or the wind speed sensor is frozen, corresponding to 0.4% of the period.

Station 641, wind direction, 7.5m, 10min.:

- 210 records are missing corresponding to 0.4% of the period. 208 of those are missing due to maintenance of the station.
- 2317 records are deleted due to sensor error, corresponding to 4.4% of the period.
- 225 records are deleted due to wind speed = 0 m/s or the wind speed sensor is

frozen, corresponding to 0.4% of the period.

ZAC, the wind direction, 7.5m, 10min.:
- 298 records are missing, corresponding to 0.6% of the full period.
- The time series is 99.4% complete

No correlation between the two stations has been calculated.

3.7 Direction of Maximum Wind Speed

The direction of the maximum wind speed is also measured by the wind direction sensor 7.5 m above terrain level at both station 640 and station 641. 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 feed directly into the final time series.

Data from January 1st 2013 00:00 to December 31st 2013 23:50 is included in the data processing. The results of the data checks are summarized below.

Station 640, maximum wind direction, 7.5m, 10min.:
- 163 records are missing corresponding to 0.3% of the period. All 163 records are missing due to maintenance of the station.
- 13336 records are deleted due to defect sensor, corresponding to 24.5% of the period.
- 172 records are deleted due to wind speed = 0 m/s or the wind speed sensor is frozen, corresponding to 0.3% of the period.

Station 641, maximum wind direction, 7.5m, 10min.:
- 14837 records are missing corresponding to 28.2% of the period. 208 of those are missing due to maintenance of the station.
- 985 records are deleted due to defect sensor, corresponding to 1.9% of the period.
- 186 records are deleted due to wind speed = 0 m/s or the wind speed sensor is frozen, corresponding to 0.4% of the period.

ZAC, maximum wind direction, 7.5m, 10min.:
- 305 records are missing, corresponding to 0.6% of the period.
- The time series is 99.4% complete

No correlation between the two stations has been calculated.

3.8 Incoming Shortwave Radiation

The incoming shortwave radiation is measured 2 m above terrain at both station 640 and station 641. At both stations the incoming shortwave radiation is measured with Kipp & Zonen albedometers and at station 640 the incoming shortwave radiation is also measured with a Kipp & Zonen four component net radiometer (CNR1). Both sensors measure radiation with wavelengths from 305 to 2800 nm and have approx. the same sensitivity

(spectral response) to all wavelengths in the interval. The only difference between the two types of instruments is their physical size. The CNR1 has a diameter of 3.5cm whilst the albedometer is 5.5cm in diameter which makes snow more likely to accumulate on the albedometer.
The data was compared to the theoretical maximum direct incoming radiation (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). In cases where a data record exceeded the theoretical value and the theoretical value is higher than 25 W/m^2, the records were set to equal the theoretical maximum.

Data from the Kipp & Zonen albedometer at station 641 and station 640 from January 1st 2013 00:00 to December 31st 2013 23:30 is included in the data processing. The sensor at st. 641 was out of level upon arrival. Therefore this station's data are considered suspect prior to data analysis.

Data from The Kipp & Zonen four component net radiometer (CNR1) from January 1st 2013 00:00 to December 31st 2013 23:55 is included in the data processing. The sensor on station 640 was out of level upon arrival, but after the data analysis it is considered not to affect the measurements significantly.
For the final time series of ZAC the 5 min CNR1 data have been used. Gaps were filled by data from 640.SRI.30 corrected by a regression between the two. Data from st. 641 has not been used as they were considered suspect and there were no gaps in both 5 and 30 min. time series at st. 640 simultaneously. The 30 min. time series is an extract of the ZAC.SRI.5min, that is, every sixth measurement is put into a 30min time series, ZAC.SRI.30min.

Station 640, incoming shortwave radiation, 2m, 5 min.:

- 325 records are missing corresponding to 0.3 % of the period.
- 36 records were deleted due to unrealistic values, most likely since the sensor is in the shadow of either wind speed sensor or 7-meter mast, corresponding to 0.03% of the period. It is only late in fall and early in the spring the problem exists.
- 1407 records were denoted as suspect, either since SRI>SRM (most likely due to diffuse radiation) or since SRI<SRO (most likely due to snow covering the sensor or diffuse radiation only hitting the SRO sensor), corresponding to 1.3% of the period.
- 10744 records (10.2%) showed positive values, within the uncertainty range, in cases where the sun was more than one degree below the horizon. These records were set to zero in the final 5 min ZAC time series.
- 38892 records (37%) showed negative values, within the uncertainty range, in cases where the sun was more than one degree below the horizon and were set to zero in the final 5min ZAC time series.
- 85 records (0.1%) had higher values than the maximum theoretical direct incoming radiation and were set to equal the theoretical maximum in the final 5min ZAC time series.
- Remaining records denoted good, corresponding to 98.3% of the period. Data used as the final 5min ZAC time series.

Station 640, incoming shortwave radiation, 2m, 30 min.:

- 54 records are missing, corresponding to 0.3% of the period.
- 102 records were deleted due to unrealistic values, most likely rime (causing too high SRI) or snow (causing too low SRI, below SRO) on sensor, corresponding to 0.6% of the period.
- 293 records were denoted as suspect, since SRI>SRM (most likely due to diffuse radiation), corresponding to 1.7% of the period.
- 1118 records (6.4%) showed positive values, within the uncertainty range, in cases where the sun was more than one degree below the horizon.
- 6514 records (37%) showed negative values, within the uncertainty range, in cases where the sun was more than one degree below the horizon.
- 16 records (0.1%) had higher values than the maximum theoretical direct incoming radiation and were set to equal the theoretical maximum.
- Remaining records denoted good, corresponding to 97.4% of the period. Data used only to fill out gaps when CNR1 records are missing.

Station 641, incoming shortwave radiation, 2m, 30 min.:

- 69 records are missing, corresponding to 0.4% of the period.
- 123 records were deleted due to unrealistic values, most likely rime on sensor (causing too high SRI) or snow on sensor (causing too low SRI, below SRO), or a shadow from the mast at st. 640 (occurring every day at 7AM). This corresponds to 0.7% of the period.
- All values are too high (approx. 19W/m^2) compared to reference tests and are considered suspect. No correction has been made, since night/no-sun values are correct at zero. But at clear sky days the SRI is higher than at station 640.
- No data has been reported to the database.

ZAC, incoming shortwave radiation, 2m, 5 min.:

- 323 records are missing, corresponding to 0.3% of the full period. This is due to station visit.
- The time series is 99.7% complete.

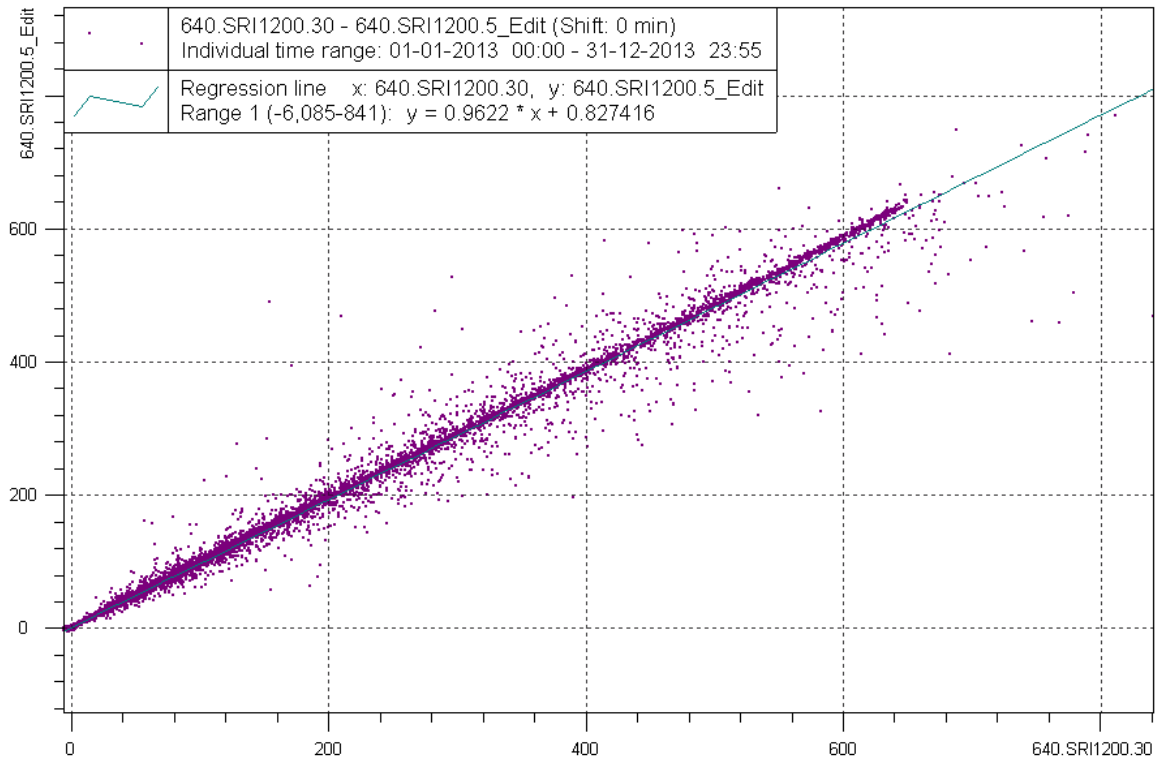

Figure 3.12 Incoming shortwave radiation (W/m^2) measured at Zackenberg east (station 640, 30 min), y, as a function of incoming shortwave radiation measured at Zackenberg east (station 640, 5 min), x. Regression line and formula are shown.

3.9 Outgoing Shortwave Radiation

The outgoing shortwave radiation is measured 2 m above terrain at both station 640 and station 641 with the sensors described in 3.8.

Data from the Kipp & Zonen albedometer at station 641 and station 640 from January 1st 2013 00:00 to December 31st 2013 23:30 is included in the data processing. The sensor at st. 641 was out of level upon arrival. Therefore data from here are considered suspect prior to data analysis.

Data from The Kipp & Zonen four component net radiometer (CNR1) from January 1st 2013 00:00 to December 31st 2013 23:55 is included in the data processing. The sensor on station 640 was out of level upon arrival, but after data analysis it is considered not to affect the measurements. It has been decided only to report the 5 minutes data from the CNR1 sensor to the database.

Station 640, outgoing shortwave radiation, 2m, 5min.:

- 325 records are missing corresponding to 0.3 % of the period.
- 1 record was deleted due to unrealistic values.
- 40358 records (38.4%) showed positive values, within the uncertainty range, in cases where the sun was more than one degree below the horizon. These records were set to zero in the final 5min. ZAC time series.
- 9226 records (8.8%) showed negative values, within the uncertainty range, in cases where the sun was more than one degree below the horizon and were set to zero in the final 5min ZAC time series.

- 12 records (0.01%) had higher values than the maximum theoretical direct incoming radiation and were set to equal the theoretical maximum in the final 5min ZAC time series.
- Remaining records denoted good, corresponding to 99.7% of the period. Data used as the final 5 min ZAC time series.

Station 640, outgoing shortwave radiation, 2m, 30min.:

- 54 records are missing, corresponding to 0.3% of the period.
- 115 records were deleted due to unrealistic values (spikes +/- 20W/m^2 prior to station visit), corresponding to 0.7% of the period.
- 3747 records (21.4%) showed positive values, within the uncertainty range, in cases where the sun was more than one degree below the horizon.
- 3208 records (18.3%) showed negative values, within the uncertainty range, in cases where the sun was more than one degree below the.
- Remaining records denoted good, corresponding to 99% of the period. Data used only to fill out gaps when CNR1 records are missing.

Station 641, outgoing shortwave radiation, 2m, 30min.:

- 269 records are missing, corresponding to 1.5% of the period.
- 7200 records were denoted as suspect, since $SRO_{641}<SRO_{640}$ for the snow-covered part of the year prior to station visit. Also, the sensor was out of level prior to station visit. This corresponds to 41.1% of the period.
- Remaining records denoted good, corresponding to 57.4% of the period.
- No data has been reported to the database.

ZAC, outgoing shortwave radiation, 2m, 5min.:

- 323 records are missing, corresponding to 0.3% of the period. This is due to the station visit.
- The time series is 99.7% complete

The SRO is very dependent on the type of vegetation/snow that is below the sensor, therefore three regression lines between the 5min time series and the 30 min time series have been made and can been seen in table 3.3 and figures below.

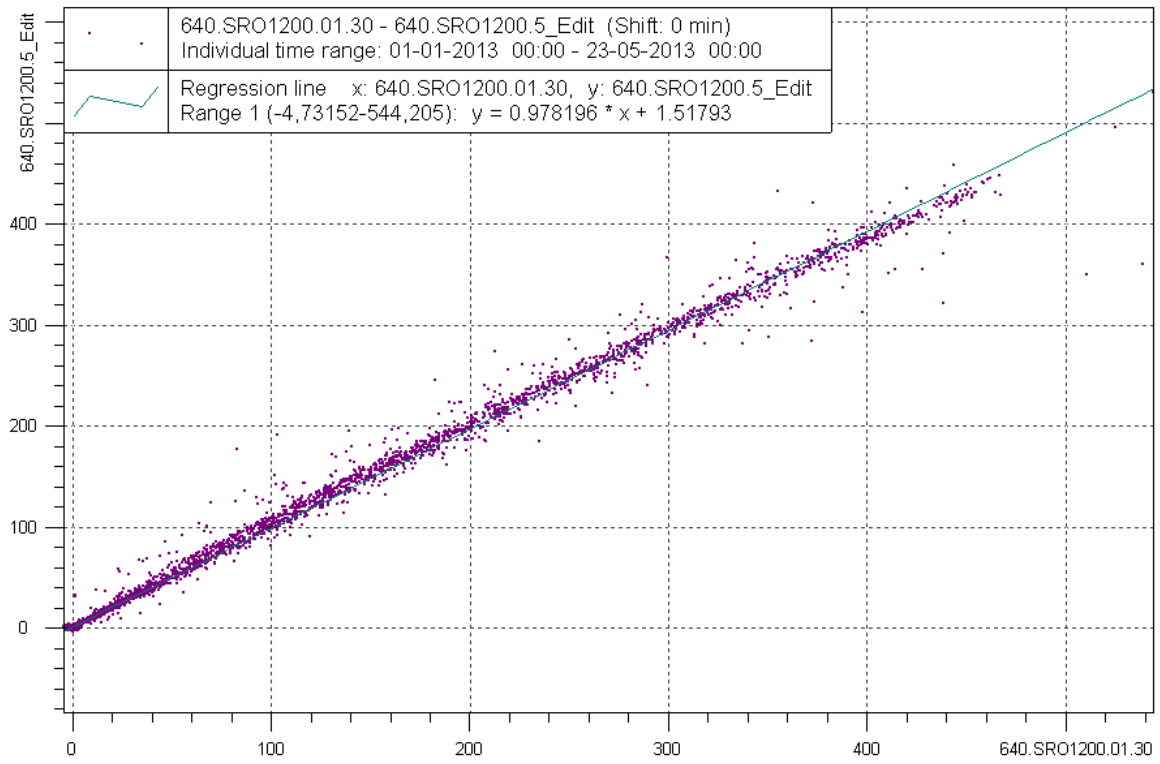

Figure 3.13 Outgoing shortwave radiation (W/m^2) measured at Zackenberg east (station 640, 5 min.), y, as a function of outgoing shortwave radiation measured at Zackenberg east (station 640, 30 min.), x. Regression line and formula are shown. During the period chosen there is snow beneath both sensors.

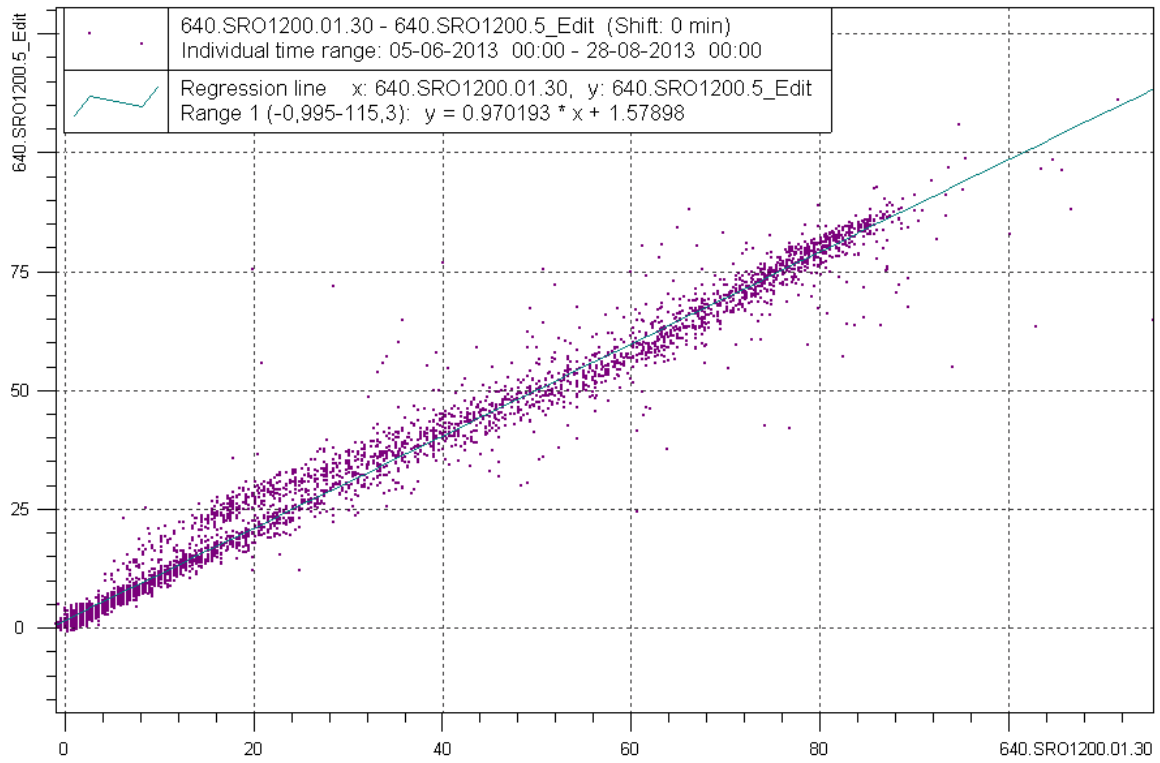

Figure 3.14 Outgoing shortwave radiation (W/m^2) measured at Zackenberg east (station 640, 5 min.), y, as a function of outgoing shortwave radiation measured at Zackenberg east (station 640, 30 min.), x. Regression line and formula are shown. During the period chosen there is bare soil/vegetation beneath both sensors.

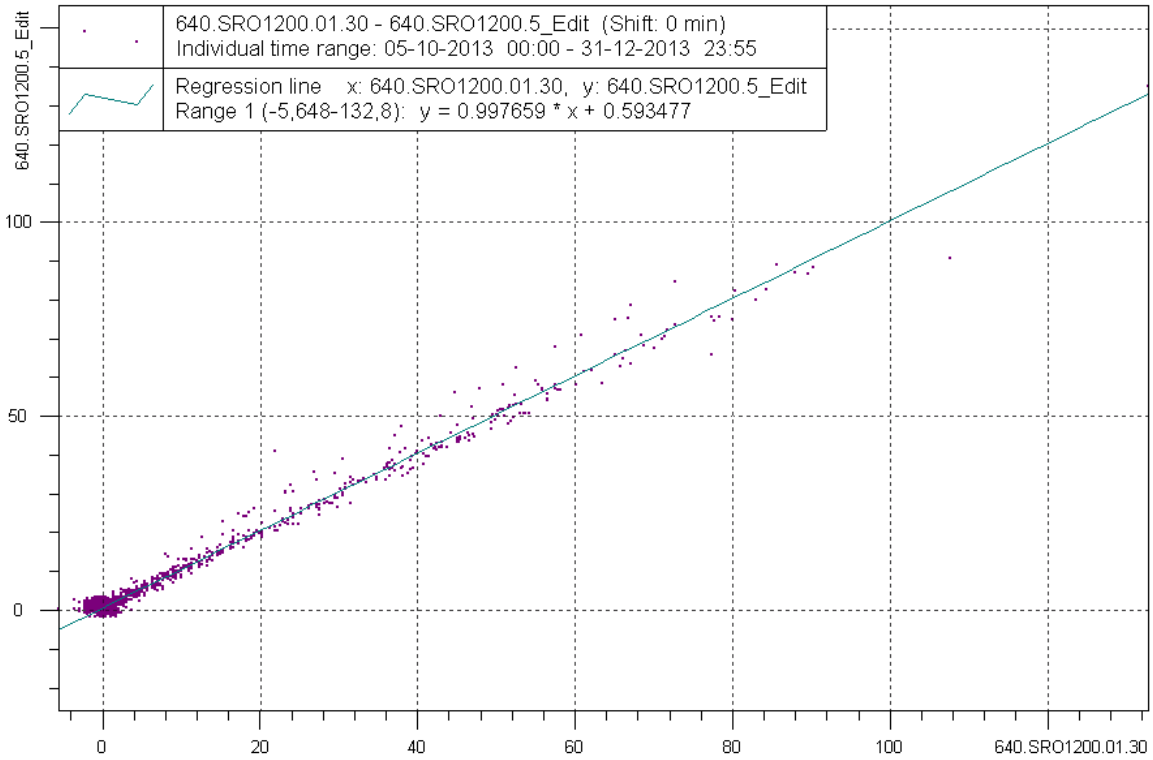

Figure 3.15 Outgoing shortwave radiation (W/m^2) measured at Zackenberg east (station 640, 5 min.), y, as a function of outgoing shortwave radiation measured at Zackenberg east (station 640, 30 min.), x. Regression line and formula are shown. During the period chosen there is snow beneath both sensors.

3.10 Incoming Longwave Radiation

The incoming longwave radiation is measured 2 m above terrain at station 640. The incoming longwave radiation is measured 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.

Data from January 1st 2013 00:00 to December 31st 2013 23:55 is included in the data processing. The results of the data checks are summarized below.

ZAC, incoming longwave radiation, 2m, 5 min.:

- 325 records are deleted due to station visit, corresponding to 0.31% of the full period.
- 1317 records are deleted, corresponding to 1.25% of the period. This is due to sensor being covered with snow.
- The time series is 98.4% complete

Since the incoming longwave radiation is only measured at st. 640, the 1642 missing records could not be replaced.

3.11 Outgoing Longwave Radiation

The outgoing longwave radiation is measured 2 m above terrain at station 640 with the same sensors as described in 3.10

Data from January 1st 2013 00:00 to December 31st 2013 23:55 is included in the data processing. The results of the data checks are summarized below.

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

- 325 records are missing, corresponding to 0.3% of the period.
- The time series is 99.7% complete.

Since the outgoing longwave radiation is only measured at st. 640, the 325 missing records could not be replaced.

3.12 Photosynthetic Active Radiation (PAR)

The photosynthetic active radiation (PAR) is measured 2 m above terrain at station 640. The measurements were started in summer 2002. PAR is measured with a Li-Cor quantum sensor, which measures the radiation with wavelengths between 400 and 700 nm. The sensor has approx. the same sensitivity (spectral response) to all wavelengths in this interval.

The PAR measurement covers wavelengths that are a part of the shortwave incoming radiation, and as the spectrum of the solar radiation is approximately fixed, PAR depends linearly on the incoming shortwave radiation (Petersen, 2004). Regression between the photosynthetic active radiation data and the incoming shortwave radiation (from the quality controlled time series, as described above) are shown in Figure 3.

Data from January 1st 2013 00:00 to December 31st 2013 23:30 is included in the data processing. The results of the data checks are summarized below.

Station 640, PAR, 2m, 30 min.:

- 54 records are missing corresponding to 0.3% of the period.
- 40 records with unrealistic values have been deleted. The sensor most likely is covered with snow, since the sensors at st. 640 and 641 are covered with snow.
- 746 records corresponding to 4.3% of the period showed negative PAR radiation. These records were replaced by zero.
- 2762 records corresponding to 15.8 % of the period showed positive PAR radiation in cases where the sun was more than one degree below the horizon. These records were replaced by zero.

ZAC, PAR, 2m, 30min.:

- 54 records are missing, corresponding to 0.3% of the period.
- The time series is 99.7% complete.

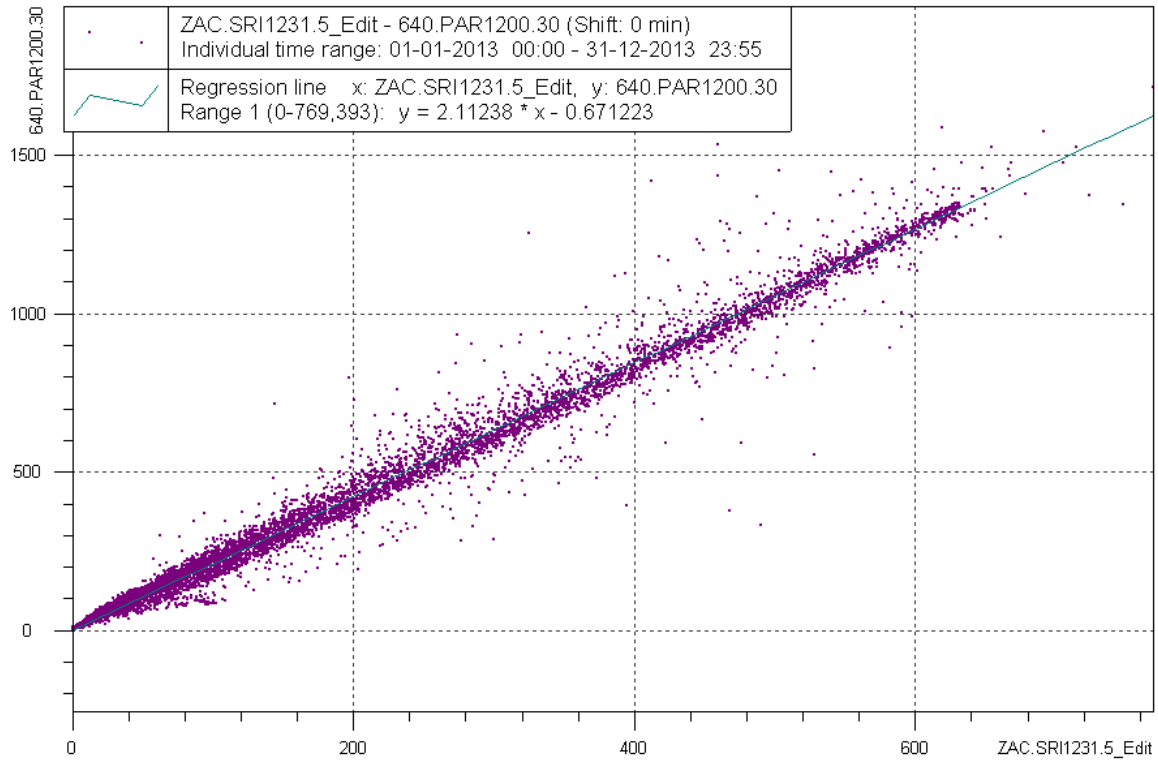

Figure 3.16 Photosynthetical active radiation (µmol/(s*m^2)), y, as a function of the incoming shortwave radiation (W/m^2), x. Regression line and formula are shown.

3.13 Ultraviolet B-radiation (UVB)

The UVB is measured 2m above terrain at station 641. The UVB has since July 1998 been measured with a Solar Light UV-Biometer.
The UVB measurement depends on the temperature of the sensor. Due to the limited power supply at the station the sensor's built-in thermostat has not been used. In the data processing the measurements are thus compensated for the deviation of the temperature of the sensor from 25 °C according to the formula given by the manufacturer, Solar Light Co Inc. (1991).
The UVB records were tested against a reference sensor mounted next to the UVB sensor in the period from 2013-05-31 to 2010-06-11, however the reference measurements were inappropriate due to malfunctioning data logger and the regression from 2012 was carried through to 2014 (RefUVB5 = 0.905902*641.UVB - 8.92448*10^-5).

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

ZAC, UVB, 2m, 30 min.:

- 69 records are missing, corresponding to 0.4% of the period.
- The time series is 99.6% complete.

Since UVB is only measured at st. 641, the 69 missing records could not be replaced.

3.14 Net Radiation

The net radiation is measured 2 m above terrain at station 640. The net radiation is measured with Kipp & Zonen NR-lite net radiometer, which measures the difference between incoming and outgoing radiation with wavelength 300 to 30000 nm, i.e. both short- and longwave radiation. The sensor has approx. the same sensitivity (spectral response) to all wavelengths in the interval.

Net radiation measurements are prone to errors under certain measurement conditions. Duchon and Brotzge (2000) describe different conditions that might compromise the measurements with the NR-lite, such as snow, rain, frost, dew, debris on the sensor, cosine response etc. A quality check has been used to evaluate whether or not the measurements were affected by rain. In these cases the measurements can be approx. 100-200 W too low. As the sensors measure the longwave radiation, it is to some degree sensitive to the wind speed, due to the turbulent fluxes. The measurements are compensated for the effect of the wind in accordance with the formula given by the manufacturer, Campbell Scientific (2002).

At st. 640 the short- and longwave in- and outgoing radiation is also measured with a Kipp & Zonen four component net radiometer (CNR1) 2 meters above terrain as explained above. The net radiation is also calculated from the four quality checked time series of short- and longwave in- and outgoing radiation (ZAC.SRI, ZAC.SRO, ZAC.LRI and ZAC.LRO).

Data from January 1st 2013 00:00 to December 31st 2013 23:30 (23:55 for 5min time series) is included in the data processing. The results of the data checks are summarized below.

Station 640, net radiation, 2m, 30min.:

- 54 records are missing corresponding to 0.3% of the period.
- 967 records have been deleted as the sensor was affected by precipitation or covered with snow (unrealistic compared to CNR1 calculations). This corresponds to 5.5% of the period.
- No records lie outside the interval [-200 W/m^2 – 1500 W/m^2].
- 431 records are denoted “suspect”, since sensor most likely was covered with snow or still affected by precipitation after rainfall, corresponding to 2.5% of the period.
- The time series is 94.2% complete.

ZAC, net radiation, 2m, 30min.:

- 1021 records are missing corresponding to 5.8 % of the period.
- The time series is 94.2% complete.

ZAC, net radiation, 2m, 5min.:

- 1643 records are missing corresponding to 1.6% of the period.
- The time series is 98.4% complete.

3.15 Albedo

The albedo is calculated from the quality checked incoming and outgoing short wave radiation and is calculated for 2013.

One time series is produced:

- A daily time series that gives the daily "accumulated" albedo. This is based upon the formula given by van den Broeke, et al. 2004, which calculates "accumulated" albedo as: $\alpha = \sum_{24h} SRO \ / \ \sum_{24h} SRI$. The reason for this formula is to reduce errors in SRI due to poor cosine response and to reduce errors based on instrument tilt. Due to the necessity to have complete coverage of both SRO and SRI, the accumulated albedo is only calculated when both time series have full coverage.
- When $\alpha > 1$, the albedo is set to errorvalue. This is primarily in wintertime where SRO and SRI are low and similar due to the snow covered surface.

ZAC, albedo, 2 m, calculated day values

- 110 records are missing (30.1% of the data).

3.16 Precipitation

At station 640 a Pluvio precipitation gauge is used and at station 641 there is a Belfort precipitation gauge. In these gauges antifreeze is added to ensure a proper performance during winter.

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

Station 641, precipitation, Belfort, 60min.:

- 23 records are missing in connection with the technical work on the station.
- 51 records in the period August 30th 09:00 to September 1th 11:00 are considered suspect and not used in the total time series. The gauge was emptied by Geobasis and they had problems to assemble it again.
- 788 data records were edited using filters and subsequently 202 records were edited manually. The signal from the Belfort rain gauge is unstable due to electronic noise which can be misinterpreted as precipitation events. The data has been filtered to eliminate the noise. The filter is removing noise smaller than 0.1 mm between precipitations events. Noise larger than 0.1 mm is afterwards edited manually by comparing the data with data from the Pluvio gauge, the tipping bucket, the snow depth sensor, the humidity, the incoming solar radiation and the daily log from GeoBasis (GeoBasis, 2013).

Station 641, precipitation, Pluvio, 60min.:

- Data are generally considered as suspect due to many periods with unrealistic amounts of precipitation. Only data in the period August 30th 09:00 to September 1th 11:00 where data from the Belfort on station 641 are considered suspect are quality controlled and used in the total time series for precipitation.

ZAC, precipitation, 60min.:

- 23 records are missing (0.01% of the data).

The data series represent the accumulated precipitation during the calendar year. Be aware that when longer periods with no data exist the value of the accumulated precipitation will be unchanged after the period with missing data, which could wrongly be interpreted as if no precipitation has occurred. The correct interpretation is that the amount of precipitation is unknown for that period.

Note that the data series has not been corrected for the efficiency of the precipitation gauge in catching precipitation, which is especially a problem during winter snow fall that occurs along with heavy winds.

3.17 Snow Depth

Point measurements of the snow depth are carried out with two snow depth sensors at st. 640 and 641.

Data from the period January 1st 2013 00:00 to December 31st 2013 21:00 is included in the data processing. Data from snow depth sensor at st. 641 is chosen as main data source, since snow depth sensor at st. 640 is influenced by the weather mast. The results of the data checks are summarized below.

Station 640, snow depth, 1.94m, 180min.:

- 9 records are missing due to station visit, corresponding to 0.3% of the period.
- 2074 records are left unchecked from 15/4-13 and onwards. This corresponds to 71.3% of the period.
- The time series is used only to fill holes in time series for st. 641.

Station 641, snow depth, 1.805m, 180min.:

- 11 records are missing due to station visit, corresponding to 0.4% of the period.
- 1 record has been deleted due to unrealistic value; it has been filled by linear interpolation.
- 170 records have been changed to zero either due to no snow conditions or negative values. This corresponds to 5.8% of the period.
- 993 records have been corrected by 0.011m from August 29th 2013 at 6PM and onwards, being the mean from June 1st to August 29th 2013 (no snow). This corresponds to 34.1% of the period.

ZAC, snow depth, 180min.:

- 11 records are missing corresponding to 0.4% of the period.
- The time series is 99.6% complete.

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