Technical comments on the data records from the Vernagtbach station for the period 2002 to 2012

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1. Introduction

This document gives some comments on the time series of meteorological and hydrological quantities, recorded at the Vernagtbach station since 2002. Compared to the period 1970 to 2001, the logging devices were changed, i.e. instead of the digital Modas device and the analogue paper charts used up to the year 2002, two Campbell loggers (type CR23X) were installed; they are called 'Meteologger' and 'Hydrologger'. In summer 2012, the CR23X of the 'Hydrologger' was replaced by a 'CR1000'. The electrical power to run these loggers is supplied by solar panels which feed the accumulators. With these loggers, temporally higher resolved data series are now provided, i.e. 10 minute centred averages for the meteorological data and 5 minute centred averages for the hydrological ones. Table 1 shows the list of parameters from the Vernagtbach site now published in the PANGAEA data base. The first and second columns give the parameter names as used in PANGAEA. In the third column, 'Scan interval' indicates how often a single value is measured by the logger and 'Averaging interval' indicates the published averaging period of the data. The 'supplier' of the tool is given in the fourth and the 'sensor' in the fifth column. 'Period of record' indicates whether the time series is delivered for the complete calendar year or only for parts of it.

The meteorological parameters are recorded on the 'Meteologger' which is mounted directly on the stakes of the devices (c.f. Fig. 1). Hydrological parameters are recorded on the 'Hydrologger', which is positioned within the station. The placement of each logger close to its devices prevents electric disturbances due to long cables.

The following text gives some remarks regarding calibration and error correction of the recorded parameters - in addition to the more general comments provided for the first period (doi:10.1594/PANGAEA.775113, 'Further details' of the data set 1970 to 2001). As a matter of principle, the original data were left unchanged, if we were not sure about the reason of a possible error.

Table 1: List of parameters, recorded at the Vernagtbach site, for the years 2002 to 2012.

Parameter	**Short name**	**Scan/averaging interval**	**Supplier**	**Sensor**	**Period of records**
Temperature, air, ventilated	TTT_v	5 sec/10 min	Thies	Pt-100, ventilated	All year
Temperature, air, unventilated	TTT_u	5 sec/10 min	--	Pt-100, unventilated	All year
Station pressure	PoPoPoPo	20 sec/10 min	Druck	RPT 410 Barometric sensor	All year
Humidity, relative	RH	20 sec/10 min	Thies	Hair Hygrometer	All year
Precipitation sum	Precip	5 sec/10 min	Belfort	Weighing gauge	All year
Precipitation difference	Precip	5 sec/10 min	Belfort	Weighing gauge	Only in summer
	Precip	sum of pulses within10 min	Gertsch	Tipping bucket, unheated	c.f. Table 2
Wind direction[1]	dd	5 sec/10 min	Thies	Wind vane	All year
	dd	5 sec/1 hour	Thies	Wind vane	All year
Wind speed	ff	5 sec/10 min	Thies	cup anemometer	All year
	ff	5 sec/1 hour	Thies	cup anemometer	All year
Short-wave downward	SWD	5 sec/10 min	Kipp&Zonen	CM7B, unventilated	All year
Short-wave upward radiation	SWU	5 sec/10 min	Kipp&Zonen	CM7B, unventilated	All year
Long-wave downward radiation [2]	LWD	5 sec/10 min	Schenk	Pyrradiometer Type 8111, unventilated	Only in summer
Long-wave upward radiation	LWU	5 sec/10 min	Schenk	Pyrradiometer Type 8111, unventilated	Only in summer
Snow thickness	S	120 sec/10 min	Campbell	SR50 Sonic Ranging Sensor (temperature compensated)	All year
Water stage	H	10 sec/5 min	Various manufacturers	C.f. Paragraph 9, Table 4	Only in summer
River discharge	Q	10 sec/5 min	Derived from Water stage	C.f. Paragraph 9	Only in summer
Conductivity, electrolytic[3]	Cond elect	10 sec/5 min	WTW	LF 323	All year
Temperature, water	Temp	10 sec/5 min		Pt-100	All year

[1] For details see Table 3.
[2] For long-wave radiation determination see § 7.2
[3] For 2002 and 2003, only 10 minute averages are available for electrolytic conductivity and water temperature in summer.

Fig. 1: Meteorological devices at the Vernagtbach station (Photograph from 28 April 2011 by Matthias Siebers, KEG)

2. Air temperature

In addition to the unventilated thermometer within the Stevenson screen, a ventilated one was installed outside. Both data sets are reported in the PANGAEA data set. Both thermometers are frequently calibrated by putting them into snowmelt water; they are also compared to the well calibrated maximum and minimum thermometers within the hut.

Since 22 July 2012, maximum and minimum values are also published for both parameters.

3. Station pressure

The device is mounted within the containment of the data logger. The calibration was performed by the manufacturer.

4. Relative humidity of the air

As in the previous decades, the relative humidity of the air is measured with a hair hygrometer, positioned within the Stevenson screen. Calibration is performed with an Assmann psychrometer at least once per year. Frequent comparisons of the analogue display of the device with the digital values confirm the validity of the records.

5. Precipitation

In November 2001, a digital weighing gauge was installed at the Vernagtbach station. In the data set published here, records of this digital gauge as well as of the tipping bucket are given. The distance between the two devices is 10 meters. In Table 2, the periods with records of the two instruments is given.

Table 2: Series of precipitation data (Vernagtbach station) and photographs (Vernagtferner)

	Belfort – digital gauge	**Gertsch – tipping bucket**	**Photographs**
2002	01.01.– 31.12.	02.05. – 30.11.	01.05. - 01.10.
2003	01.01.– 31.12.	30.04. – 20.10.	01.06. - 01.10.
2004	01.01.– 31.12.	27.04. – 24.10.	28.04. – 01.10.
2005	01.01.– 31.12.	29.04. – 24.10.	01.05. – 03.06. 08.06. – 28.09.
2006	01.01.– 31.12.	27.04. – 22.11.	27.04. – 01.11.
2007	01.01.– 31.12.	29.04. – 16.12.	29.04. – 04.06. 11.06. – 01.07. 25.07. - 29.09.
2008	01.01.– 31.12.	30.04. – 05.11.	18.06. – 30.09.
2009	01.01.– 31.12.	04.06. – 16.11.	25.06. – 04.11.
2010	01.01.– 31.12.	09.04. – 23.10.	29.04. – 04.06. 17.06. – 31.12.[4]
2011	01.01.– 31.12.	29.04. – 28.09.	01.01.– 31.12.
2012	01.01.– 31.12.	02.05. – 25.10.	01.01.– 31.12.

Two data sets are given from the records of the digital weighing gauge, i.e. (I) original weighing gauge data for the whole year, (II) 10 minute precipitation values, derived from these records for the summer period, i.e. 1 May to 31 October. A threshold of 0.021 mm per 10 minutes is used in the determination of (II), which replaces to some extent the implicit filtering by the manual evaluation of the paper charts in the data sets until 2001. Series (I) includes evaporation from the bucket and events like the emptying of the gauge or putting salt into the bucket to prevent freezing in winter. In the determination of series II, these events were removed.

As in the years before, data from the unheated tipping bucket are only available during summer.

Most of the precautions and caveats regarding precipitation from the first period remain valid for these two instruments (c.f. doi:10.1594/PANGAEA.775113, ‘Further details’). The most important ones are (I) Covering of the weighing gauge by snow in winter, (II) retardation of the precipitation signal of the tipping bucket when snow has to melt before it runs through the see-saw and (III) wind disturbances by blowing snow into or out of the devices.

[4] Since 18 August 2010, up to three photographs per day are digitally available on www.glaziologie.de

The availability of photographs of the glacier region is given in the last column of Table 2. This information helps to distinguish rainfall from snowfall events, c.f. the files called 'Availability of Photographs from the Vernagtferner Basin' in the PANGAEA data base.

6. Wind speed and wind direction

Wind speed and wind direction of each year are published for two averaging intervals, i.e. 10-minute data and hourly data. Table 3 gives the kind of wind variables provided for PANGAEA.

Table 3: Wind variables recorded and published in the PANGAEA data base

Time step	**Speed**	**Short Name**		**Direction**	**Short Name**
10 minute	Arithmetic Average	ff_AVG		Vectorial Average	dd_WVT
				Standard Deviation	dd_STD
1 hour	Arithmetic Average	ff_AVG		Vectorial Average	dd_WVT
	Minimum[5]	ff_MIN		Standard Deviation	dd_STD
	Maximum	ff_MAX		Histogram	dd_B01 to dd_B12

For wind speed, average values are published for both time steps. Minima and maxima of wind speed (ff_MIN and ff_MAX) in the hourly records are based on 5-sec single values. Periods where the minimum wind speed of 0.3 m/s indicates that the cups could be frozen were not removed from the data set.

For wind direction, the vectorial average (dd_WVT) and the standard deviation (dd_STD) are provided for both time steps. The quantities "dd_B01" to "dd_B12" (Fig.2) of the hourly wind direction data represent the relative shares of the twelve direction sectors to the total hourly value. To give an example: dd_B01 = 0.297 indicates that 29.7 % of all wind directions within an hour lie in the north sector, i.e. between 345° and 15°.

[5] Only since 14 August 2003

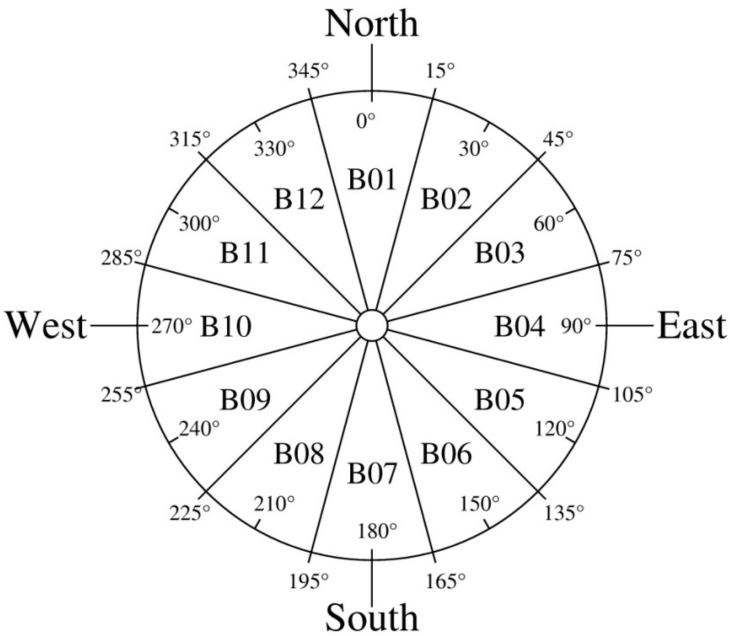

Fig. 2: Wind rose with sector names included, as they are used in the Vernagtbach data set

7. Radiation components

Due to power supply shortages, all radiation instruments at the Vernagtbach climate station are unventilated; for most of the time, the wind velocities of the glacier wind are supposed to be high enough to provide sufficient ventilation conditions.

7.1 Short-wave radiation

Short-wave downward and upward radiation, i.e. global and reflected radiation is recorded all year round. If fresh-fallen snow (mainly in winter, but not entirely) covers the upper cup of the device, global radiation is reduced to some extent. As the exact onset and the end of these periods are hard to detect, these data were not deleted; they can at least partly be detected by the calculation of the albedo. Small negative values during the night were also left unchanged, in order to allow the user of the data to apply his individual determination routine for nightly offsets.

Calibrations by comparison with standardized devices provided by the Meteorological Institute of the Ludwig-Maximilians-University, Munich were performed several times, lastly in 2010. They indicate a small and stable offset of the Vernagtbach tools to the well calibrated Munich ones. This offset was applied for all the years since 2002.

7.2 Long-wave radiation

Long-wave radiation (LWD, LWU) was determined by subtracting short-wave radiation (SWD, SWU) from the signals of the total radiation devices (Gos, Gus) both for the downward and the upward component.

As individual calibration factors were available for the long-wave and short-wave part of the total radiation device, they were used according to the formula (1a) published in the manual of the radiation balance meter after Prof. Schulze (Dr. Lange, Strahlungsbilanzmesser nach Prof. Dr. Ing. Rudolf Schulze, Bedienungsanleitung BDA 065).

$$LWD = Gos * 52.2 + ((Tgp + 273.16)^{4} * 5.670373 * 10^{-8}) – (SWD * 1.3249)$$

$$LWU = Gus * 54.6 + ((Tgp + 273.16)^{4} * 5.670373 * 10^{-8}) – (SWU * 1.3684)$$

LWD and LWU result in W/m² when Gos and Gus are provided in mV and Tgp, the temperature of the device in °C. The Stefan-Boltzmann constant amounts to $5.670373 * 10^{-8}$ W/(m² K^{-4}), and SWD and SWU are given in W/m². The calibration constants for long-wave radiation amount to 52.2 (W/m²)/mV (downward component) and 54.6 (W/m²)/mV (upward component). The calibration constants for short-wave radiation amount to 39.4 (W/m²)/mV (downward component) and 39.9 (W/m²)/mV (upward component). The factors 1.3249 (= 52.2/39.4) and 1.3684 (= 54.6/39.9) are calculated as the quotients of the respective calibration factors, they are used to correct the short-wave components.

When global and total downward radiation cups were covered with snow, one of the two can become snow-free earlier than the other. This behavior can result in large outliers in the long-wave downward radiation, which are at least partly visible in the data set.

8. Snow thickness

Snow thickness is measured with an accuracy of ±2 cm. Major peaks, which are most likely no real signals, were removed from the records; in case of doubt, they were left unchanged. For temperature compensation of the sonic ranger, the ventilated air temperature records were used.

9. Water stage and river discharge

Long-term records of discharge in a highly glacierized region as the Vernagtferner basin require several measures to provide data of sufficient quality. For the design of the measurement equipment, one has to consider the high diurnal and seasonal variability in the range of 20 l/s to 20000 l/s of the water stage between May and October (Escher-Vetter and Reinwarth, 1994; Ketzer, 2010). As the small, medium size and large sediment load of such a stream causes problems, a flushing box with two rinsing tubes was installed since 1974 to connect the channel floor to the standing pipes which house the float.

Besides, large boulders can change the geometry of the river bed upstream; they are mainly accounted for by the individual calibration for each year.

From November to the end of April, water stage is typically low and shows nearly no diurnal variation. Only single stage measurements were therefore made, mainly in the 1970ies and early 1980ies, they form the basis of the uniform monthly averages for these months over the years (c.f. Table 6).

Several sensors and methods have been combined since the start of the series in 1974. Until 2001, water stage was provided by floating gauges (Moser et al., 1986). Since 2002, the CR23X 'Hydrologger' - and even more the CR1000 installed in 2012 – allow the installation of additional instruments. These sensors are used to bridge gaps in the standard floating gauge records. Table 4 shows the sensors and methods used since 2002. Each device or method is marked with its 'Identification number'; these are also published in the PANGAEA data set.

Table 4: List of devices and methods used for continuous time series of the water stage

Identification number	Sensor/Method	Remarks
1	Standard floating gauge	Communicating tubes as connection from the channel floor to the stand pipes
2	Endress+Hauser Ultrasonic (with air temperature compensation)	Above the center line of the stream
3	SR 50 Sonic ranging sensor (with air temperature compensation)	Same height as No. 2, but on the orographically right side of the stream
4	Electrolytic conductivity	C.f. paragraph 11
8	Model / additional stage	Model in 2002 / Rofen stage in 2012
9	Manually supplemented	Based on paper charts

This approach of combining several tools to get an uninterrupted time series of a parameter is quite similar to the one applied for precipitation in the years 1970 to 2001 (c.f. doi:10.1594/PANGAEA.775113, 'Further details').

In order to get a uniform water stage series for the total recording period of each year, the records of the devices 2, 3 and 4 are adjusted to the standard water stage (Id.-No.1). Discharge Q is then calculated from water stage H – corrected for the different rinsing tube conditions - with a numerical value equation of the form

$$Q\,[m^3/s] = a * H\,[cm]^{\,b}$$

Since the late 1990ies, calibration is performed with the salt dilution method. Several series of calibrations are made each year to cover the highest possible range of water stages. From these calibrations, the polynomial coefficients a and b (Table 5) are determined. In 2002 and 2003, the same relation is used; it discerns between water stages below (first numbers) and above 250 mm (second numbers) for both coefficients. For the years 2004 to 2010, the results of calibrations of each year were used to determine the coefficients. In 2011 and 2012, average values of all the calibrations of the years 2008 to 2012 were used.

Table 5: Coefficients of the polynomials between water stage and discharge for the Vernagtbach gauge

Year	Coefficient a	Coefficient b
2002	0.7/2.25	2.13/1.767
2003	0.7/2.25	2.13/1.767
2004	2.259	1.792
2005	2.090	1.808
2006	2.770	1.729
2007	2.465	1.749
2008	5.835	1.596
2009	5.021	1.638
2010	3.162	1.692
2011	4.952	1.619
2012	4.952	1.619

On a whole, the standard floating gauge works quite reliably. A statistical analysis shows that only in the years 2002, 2003 and 2012 more than 25% of the recorded data were not provided by the standard floating gauge.

In 2002, no water stage records were available from 16 June to 13 July due to sediment blocking. As no other sensors were installed during this period, daily averages of discharge were implemented in the series, calculated with the HBV3-ETH9 model (Bergström and Forsmann, 1973; Braun et al., 2013). Therefore, the discharge data set (marked with Id.-No. 8) for this period shows no diurnal variation.

As water stage is available for November 2002, the actual data were included in Table 6, and the monthly averages of December and January were adapted accordingly. For all the other years, the standard winter mean values were left unchanged.

In 2003, the year with the highest discharge of the complete series, records of the newly installed SR 50 (Id.-No. 3) were used from 20 July to 3 September to fill the gap in the standard floating gauge, again caused by sediment blocking of the flushing box.

In 2012, the water stage record had to be assembled from all sensors.

Nevertheless, a short break had to be bridged for the period 25 August, 22:37 until 26 August 09:27. Id.-No. 8 in the discharge records indicates that values were estimated on the basis of the records of the Rofenache-gauge Q_Rofen (Müller et al., 2009) according to the numerical value equation

$$Q\ [m^3/s] = 0.277 * Q\_Rofen\ [m^3/s] - 1.09.$$

In this estimation, a temporal offset of 45 Minutes is applied to the Q_Rofen data to account for the time it takes the water to flow from the upper to the lower station.

Mean values for all the months are given in Table 6.

Table 6: Monthly averages of discharge in m^3/s as recorded at the Vernagtbach station for the period 2002 to 2012

Year	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2002	0.025	0.019	0.019	0.020	0.236	1.751	2.537	1.988	0.936	0.080	0.023	0.022
2003	0.020	0.019	0.019	0.020	0.496	3.802	3.800	5.093	0.965	0.248	0.050	0.035
2004	0.025	0.019	0.019	0.020	0.108	0.943	2.461	2.807	1.593	0.224	0.050	0.035
2005	0.025	0.019	0.019	0.020	0.388	1.872	2.556	1.446	1.469	0.161	0.050	0.035
2006	0.025	0.019	0.019	0.020	0.339	1.941	4.501	1.130	2.032	0.537	0.050	0.035
2007	0.025	0.019	0.019	0.020	0.512	1.992	2.861	2.610	0.525	0.274	0.050	0.035
2008	0.025	0.019	0.019	0.020	0.664	2.128	2.735	3.164	1.561	0.214	0.050	0.035
2009	0.025	0.019	0.019	0.020	0.851	1.492	2.898	3.982	1.690	0.665	0.050	0.035
2010	0.025	0.019	0.019	0.020	0.220	1.067	2.633	2.332	0.420	0.217	0.050	0.035
2011	0.025	0.019	0.019	0.020	0.638	1.550	1.992	3.513	2.505	0.582	0.050	0.035
2012	0.025	0.019	0.019	0.020	0.539	2.325	3.697	4.170	1.131	0.272	0.050	0.035

10. Electrolytic conductivity

The instrument is positioned in a small funnel connected to the flushing box, i.e. outside the main stream, but with glacier melt water running continuously through the funnel. This construction should shield it from the sediment in the glacier runoff. Nevertheless, there are periods without registration caused by a blocking of the flushing box with sediment or by grounding ice.

The records are published in PANGAEA as 5 minute averages (10 minutes for 2002 and 2003). During winter, hourly mean values were used to replenish the series.

11. Water temperature

The Pt-100 thermometer is located next to the conductivity sensor and therefore encounters the same problems of the flushing box being blocked.

The records are published in PANGAEA as 5 minute averages (10 minutes for 2002 and 2003). During winter, hourly mean values were used to replenish the series.

Data are missing from 22 July to 8 November 2012, caused by a programming error of the ’CR1000’.

12. Literature mentioned

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