Further details to

Bettlachstock, Switzerland: Long-term forest meteorological data from the Long-term Forest Ecosystem Research Programme (LWF), from 1997-2016

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Summary

High quality meteorological data are needed for long-term forest ecosystem research, particularly in the light of global change. The long-term data series published here comprises almost 20 years of measurements for two meteorological stations in Bettlachstock in Switzerland where one station is located within a natural mixed forest stand (BTB) with European beech (*Fagus sylvatica*; 170-190 yrs), European silver fir (*Abies alba*; 190 yrs) and Norway spruce (*Picea abies*; 200 yrs) as dominant tree species. A second station is situated in the very vicinity outside of the forest (field station, BTF). The meteorological time series are presented in hourly time resolution of air temperature, relative humidity, precipitation, photosynthetically active radiation (PAR) and wind speed. Bettlachstock is part of the Long-term Forest Ecosystem Research Programme (LWF) established and maintained by the Swiss Federal Research Institute WSL.

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1 Introduction

High quality meteorological data often found the basis for numerous scientific analyses in the light of global change. The Long-term Forest Ecosystem Research programme (LWF) at the Swiss Federal Research Institute WSL investigates anthropogenic and natural forces on the long-term health and functioning of forests and the potential effects on ecosystem services. For that purpose, a profound understanding of the relationship between processes, causes and effects in forest ecosystem is necessary (Schaub et al., 2011) and weather data usually provide the background information to infer such interrelations.
Within the LWF, measurements have been started in 1995 on 16 forest stations within the level 2 plots of ICP Forests (ICP Forests, 2016; http://icp-forests.net/). This data repository here comprises the most important meteorological time series of one of those stations: Bettlachstock, located in the canton of Solothurn in Switzerland.

2 Materials and Methods

2.1 Site

The measurements were carried out at Bettlachstock in the Swiss Canton of Solothurn, on the southern hillside of the Jura mountain chain within the community of Bettlach (Fig. 1). Time series of two plots have been recorded, one within the forest (Fig. 2a) and a second one outside of the forest (field station, Fig. 2b). Tab. 1 shows further details on the research station characteristics.

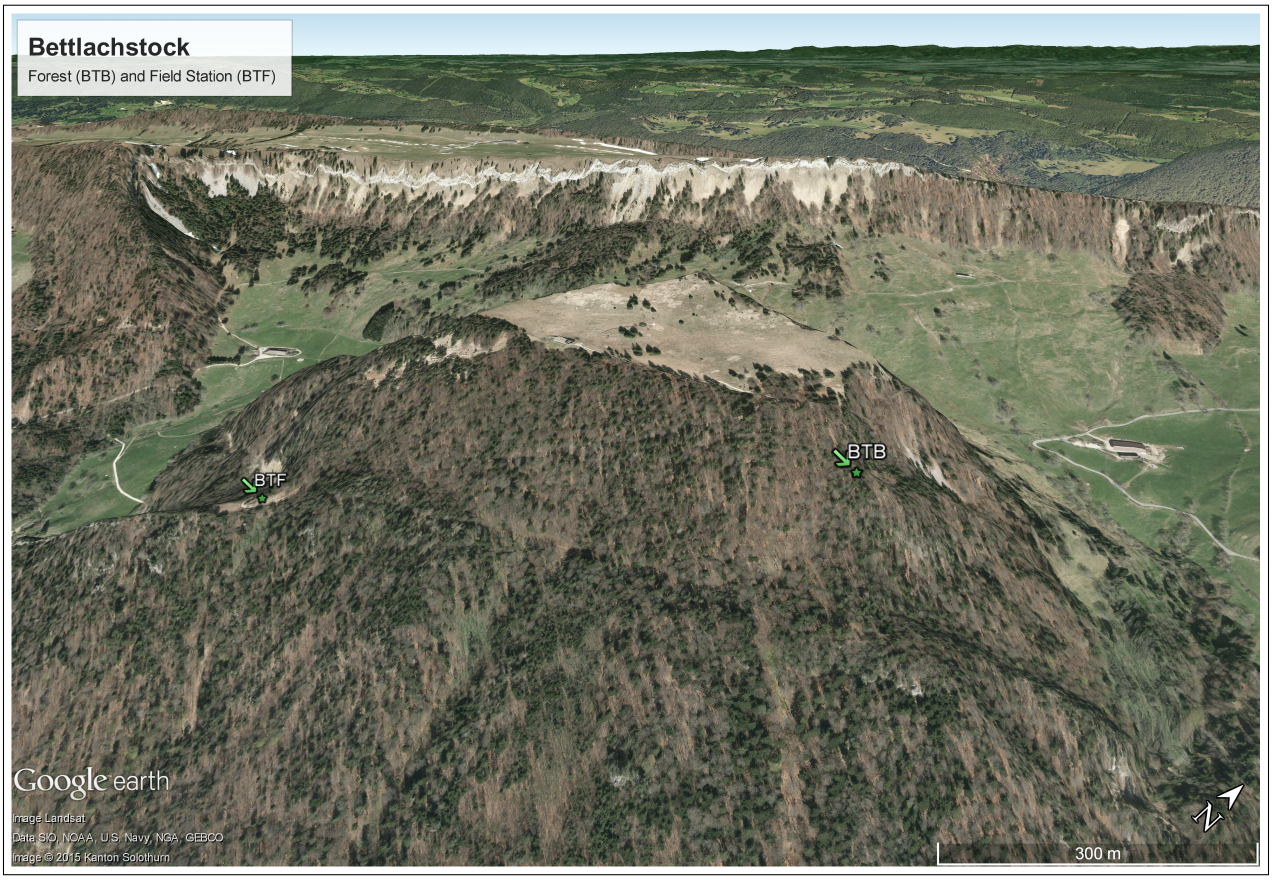


Figure 1: Site aerial photo from both Bettlachstock stations. Source: Google. 2016. Site aerial photo from both Bettlachstock stations. Retrieved November 11, 2016, from https://www.google.ch/maps.

Table 1: Meteorological station setting.

Community / canton	Bettlachstock / SO	
Commissioning date	6 June 1996	
	BTB (forest)	**BTF (field)**
Coordinates (Lat / Lon)	47.224404 ° / 7.417322 °	47.222273 ° / 7.413282 °
Altitude	1096 m a.s.l.	1075 m a.s.l.
Orientation	SE	S
Mean slope	64.5 %	37.5 %

(a) BTB: Forest station

(b) BTF: Field station

Figure 2: Images of the meteo stations in Bettlachstock.

Table 2: Forest characteristics.

Woodland association*	Nr. 13h; Cardamino-Fagetum tilietosum
Main tree species (lat.)	*Fagus sylvatica*
Management system	High forest
Silvicultural system	Group selection
Top-height diameter	49.5 cm
Plot size	1.28 ha
Number of trees DBH $\geq$ 12 cm (2011)	N = 632
Maximum tree age	
Fagus sylvatica	170-190 yrs
Picea abies	210 yrs
Fraxinus excelsior	170 yrs
Ulmus glabra	160 yrs
Abies alba	190 yrs
Geology (German)	Kettenjura, Jura; Dogger, oberer Hauptrogenstein
Soil types (WSL)	Rendzina, verbraunte Rendzina

*after Ellenberg and Klötzli (1972)

2.2 Sensors

Sensor and measurement specifications

Each station within the LWF acquires data continuously over ten minute periods. Here with this data set, hourly data is provided. All measurements are post-measurement values (e.g., values from 15:10 o'clock compromise data averaged (temperature, humidity, photosynthetic active radiation and wind speed) or summed up (precipitation) over the period of 15:00:01 to 15:10:00). The sensor types are listed in Tab. 3.

Table 3: Sensor specifications.

Parameter	**Unit**	**Height**	**Interval**	**Mode**	**Producer / Model**	**Fig.**
Temperature	°C	2 m	10 min	Mean	Retronic / MP100A	3
Rel. humidity	%	2 m	10 min	Mean	Retronic / MP100A	3
Precipitation	$mm\ m^{-2}$	1.5 m	10 min	Sum	Campbell Sc. / ARG100	4
PAR*	$W\ m^{-2}$	3 m	10 min	Mean	Skye Instr. / Quantum	5
Wind speed	$m\ s^{-1}$	4.6 m	10 min	Mean	Vector Instr. / A100R	6

Annotations

Temperature / relative humidity For both temperature and relative humidity a combined sensor is used. The thermometer is a commonly used DIN Class B sensor (accuracy ±0.3 K) whereas the hygrometer has an accuracy of ±1.5 % rH (both at 23 ±5°C).

Precipitation Precipitation is collected by a raingauge with a funnel width of 254 mm and a tipping bucket registering 0.2 mm of precipitation.

PAR The PAR sensor measures solar radiation with wavelength between 400 nm and 700 nm.

Wind speed Wind speed is measured by an anemometer with an accuracy of ±0.1 m s^{-1} at wind speed up to 10 m s^{-1} (±1 % of reading between 10-55 m s^{-1}).

*Photosynthetically active radiation

3 Results

3.1 Air temperature (temp)

The recorded data from 10 minute intervals have been averaged to the full hour (minutes 30, 40, 50, 00, 10, 20 averaged). First, minor manual data exclusions have been made where data values were in irrecoverably bad shape. Then an absolute filter (-42°C < x < +47°C) and a relative filter have been applied (0.001 % quantile). A differential filter removed data entries with jumps larger than 6°C from one hour to the other. Then a relative moving window filter has been applied, where data points have been excluded if they exceeded the 0.1 % quantiles on both ends (0.1 %, > 99.9 %) in a fourteen day moving window for every single hour. After filling small gaps linearly (two hours), we compared the data from the individual station with the partner station (i.e. field vs. forest stations). Large differences between the two time series (> 20°C) were removed. Furthermore, in a density plot between field and forest station, data outside of the 99.9 % contour (not including the extreme edges) were removed (for details please contact Matthias Haeni, matthias.haeni@wsl.ch). If the station data correlated in a linear manner with a $R^2 > 0.95$, data gaps were filled with the calculated data from the partner station.

3.2 Relative humidity (rH)

The recorded data from 10 minute intervals have been averaged to the full hour (minutes 30, 40, 50, 00, 10, 20 averaged). First, minor manual data exclusions have been made where data values were in irrecoverably bad shape. Then an absolute filter (0 % < x < 110 %) and a relative filter have been applied (0.001 % quantile). A differential filter removed data entries with larger jumps than 30 % from one hour to the other. The data have then been compared to Meteonorm computed data (Meteonorm, 2016; http://www.meteonorm.com/en/), and the time series have been scaled conservatively for each individual year to counteract large sensor drifts. Then, a relative moving window filter has been applied, where data points have been excluded if they exceeded the 0.1 % quantiles on both ends (< 0.1 %, > 99.9 %) in a fourteen day moving window for every single hour. After filling small gaps linearly (two hours), we compared the data from the individual station with the partner stations (field to forest stations and vice versa). Large differences between the two time series (> 60 %) were removed. Furthermore, in a density plot between field and forest station, data outside of the 99.9 % contour (not including the extreme edges) were removed (for details please contact Matthias Haeni, matthias.haeni@wsl.ch). If the station data correlated in a linear manner with an $R^2 > 0.95$, data gaps were filled with the calculated data from the partner station.

3.3 Precipitation (precip)

The recorded data from 10 minute intervals have been summed up to the full hour (minutes 10, 20, 30, 40, 50, 00 to the hour). First, minor manual data exclusions have been made where data values were in irrecoverably bad shape. Then an absolute filter (0 mm < x < 100 mm) has been applied. Long periods with no precipitation(> 120 days of zero values) have been excluded, because in this case a clogged rain gauge system must be assumed. Then we compared the data from the individual station with the partner station (field to forest stations and vice versa). Large differences between the two time series (> 50 mm) were removed. Furthermore, in a density plot between field and forest station, data outside of the 99.9 % contour not including the extreme edges were removed (for details please contact Matthias Haeni, matthias.haeni@wsl.ch). If the station data correlated in a linear manner with an $R^2 > 0.8$, data gaps were filled with the calculated data from the partner station.

3.4 Photosynthetically active radiation (PAR)

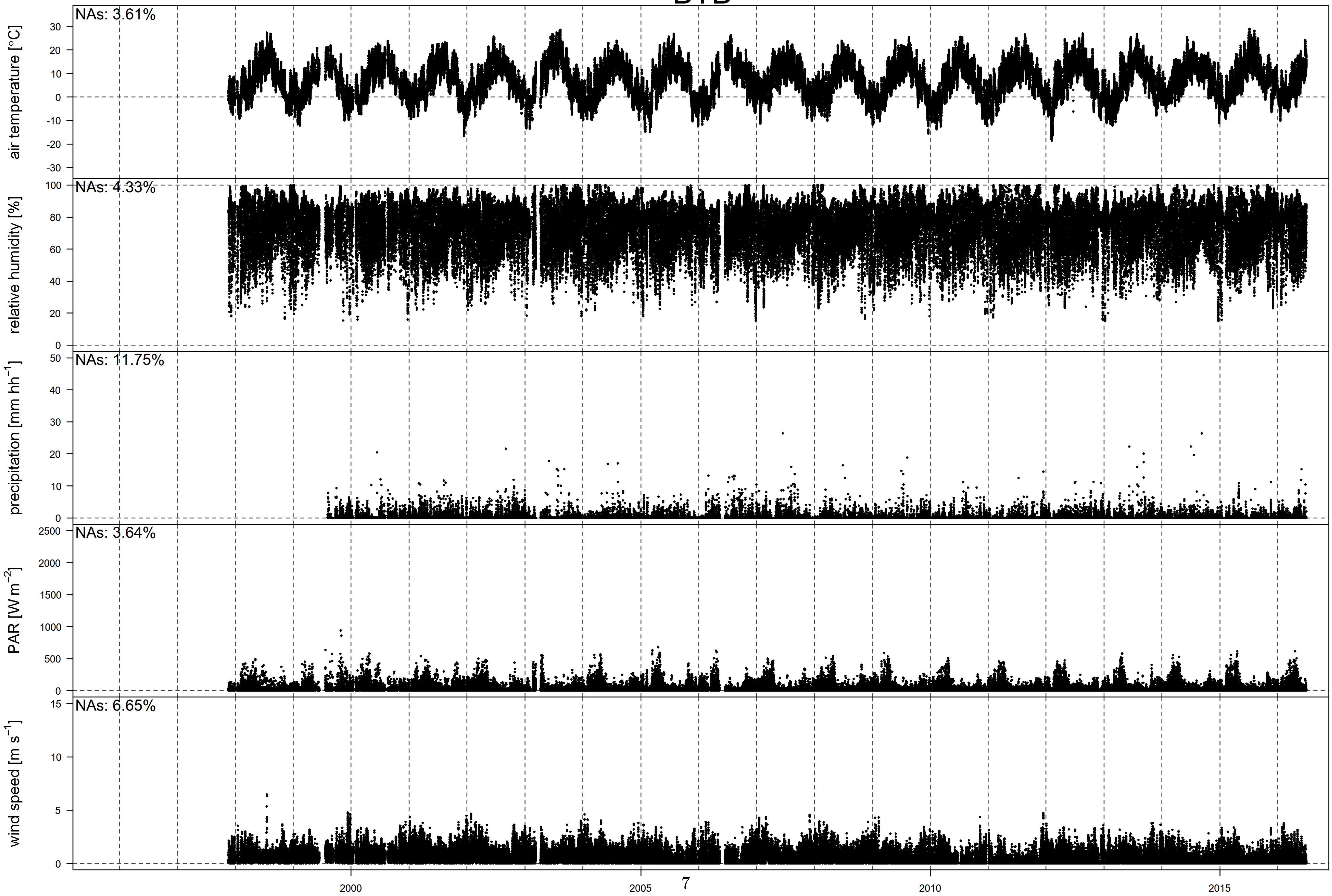
The recorded data from 10 minute intervals have been averaged to the full hour (minutes 30, 40, 50, 00, 10, 20 averaged). First, minor manual data exclusions have been made where data values were in irrecoverably bad shape. Then an absolute filter ($0\ W\ m^{-2} < \text{x} < 2500\ W\ m^{-2}$) has been applied. After filling small gaps linearly (two hours), we conducted a so-called night shift correction. Night time hours have been calculated in two ways: 1) From the data, where in the morning average PAR was first above $100\ W\ m^{-2}$ and in the evening first below $100\ W\ m^{-2}$. From the first so-called 'sunrise' time, half an hour was subtracted and to the latter so-called 'sunset' time, half an hour was added. 2) Sunset and sunrise times have been calculated from the google maps API (Google, 2016; https://developers.google.com/maps/). From both calculated methods, the more conservative 'sunrise' and 'sunset' times where chosen, i.e. the earlier one for 'sunrise' and the later one for 'sunset'. For the hours in-between the 'sunset' and 'sunrise' times (i.e. the night time hours) the absence of sunlight should lead to zero $W\ m^{-2}$ PAR. The average deviations of these night time hours from zero were then used to correct each individual day. Data were then scaled from year to year by comparing them to the average 99 % density contour of all years and scaling conservatively to counteract large sensor drift (for details please contact Matthias Haeni, matthias.haeni@wsl.ch).

3.5 Wind speed (ws)

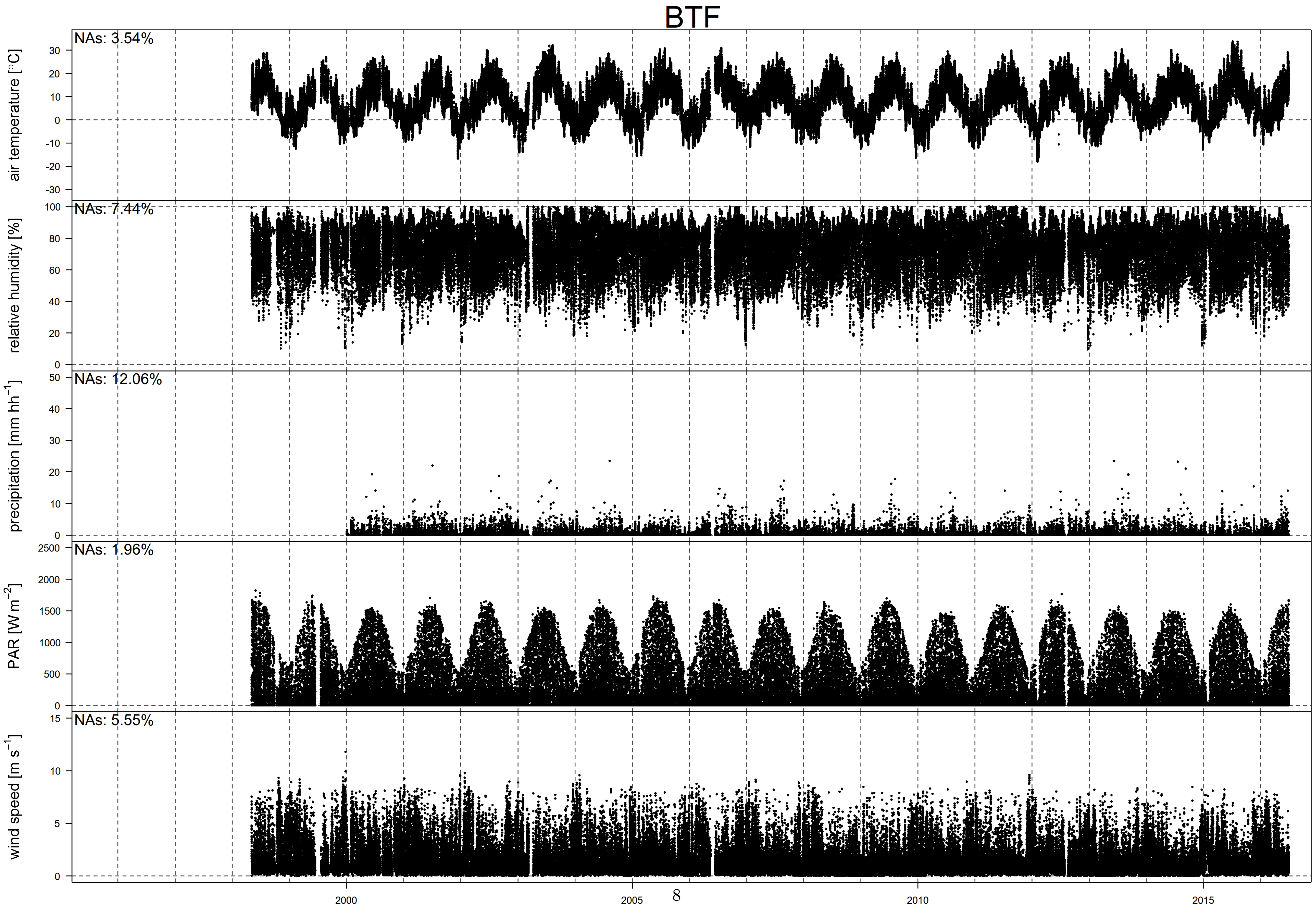
The recorded data from 10 minute intervals have been averaged to the full hour (minutes 30, 40, 50, 00, 10, 20 averaged). First, minor manual data exclusions have been made where data values were in irrecoverably bad shape. Then an absolute filter ($0\ m\ s^{-1} < \text{x} < 100\ m\ s^{-1}$) has been applied. Then, we compared the data from the individual station with the partner station (field to forest stations and vice versa). In a density plot between field and forest station, data outside of the 99.9 % contour (not including the extreme edges) were removed (for details please contact Matthias Haeni, matthias.haeni@wsl.ch). If the station data correlated in a linear manner with an $R^2 > 0.8$, data gaps were filled with the calculated data from the partner station.

The data are shown on the next two pages.

BTB



NAs: 3.61%
air temperature [°C]
30
20
10
0
-10
-20
-30
NAs: 4.33%
relative humidity [%]
100
80
60
40
20
0
NAs: 11.75%
precipitation [mm hh^{-1}]
50
40
30
20
10
0
NAs: 3.64%
PAR [W m^{-2}]
2500
2000
1500
1000
500
0
NAs: 6.65%
wind speed [m s^{-1}]
15
10
5
0
2000
2005
2010
2015


BTF
NAs: 3.54%
air temperature [°C]
30
20
10
0
-10
-20
-30
NAs: 7.44%
relative humidity [%]
100
80
60
40
20
0
NAs: 12.06%
precipitation [mm hh^{-1}]
50
40
30
20
10
0
NAs: 1.96%
PAR [W m^{-2}]
2500
2000
1500
1000
500
0
NAs: 5.55%
wind speed [m s^{-1}]
15
10
5
0
2000
2005
2010
2015

References

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Appendix

Pictures of sensors

Figure 3: Combined air temperature and humidity sensor

Figure 4: Precipitation sensor

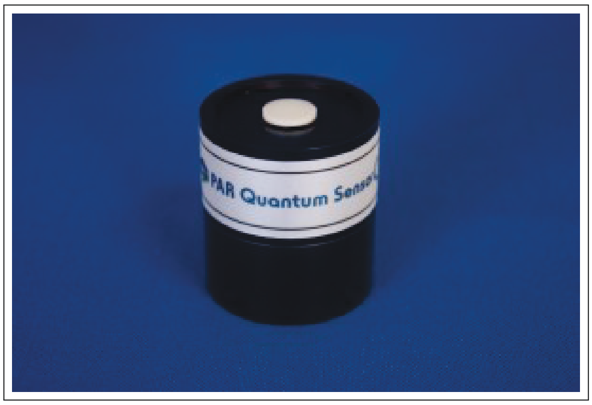

Figure 5: PAR sensor

Figure 6: Wind speed sensor