UNIVERSITY OF BAYREUTH

Micrometeorology

CADEX
Cold Air Drainage Experiment 2015
in the Ecological Botanical Gardens of the University of Bayreuth
Field Report

Lena Pfister
Armin Sigmund
Christoph Thomas

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1.1 Overview of Ecological Botanical Gardens

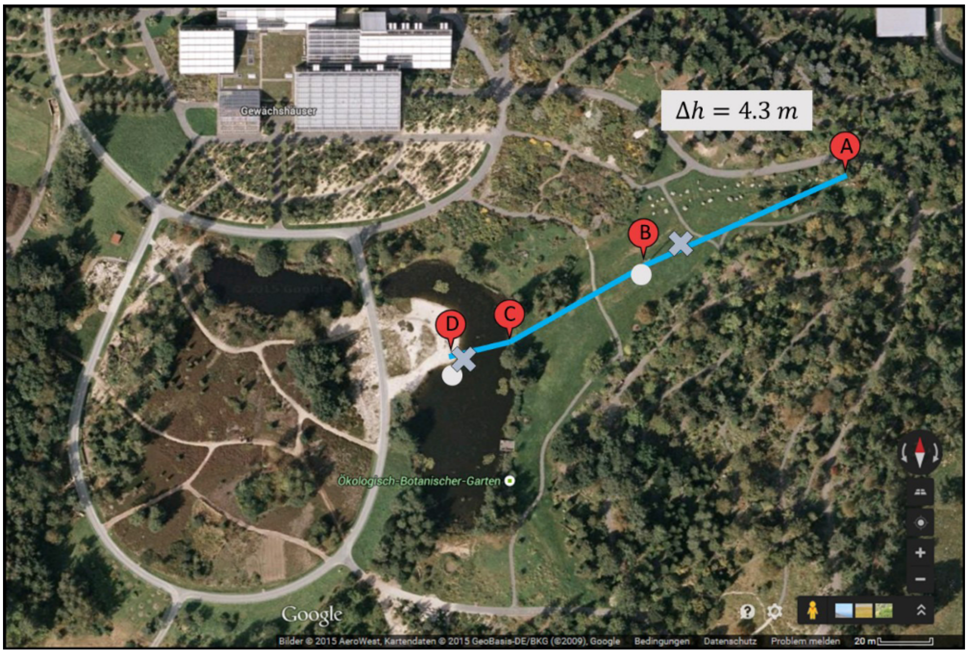


Figure 1.1 Overwiev of the field site in the Ecological Botanical Gardens of the University of Bayreuth. Δh : difference in height between both ends of the transect (A and D). B: Meteorological Measurement Station (tower). C and D: Borders of the lake in the depression. Near B and D profile measurements (◯) and ultrasonic anemometers (**X**) were installed.

The measurements of CADEX were taken in the Ecological Botanical Gardens (EBG) of the University of Bayreuth, which was founded in 1978 as a central institution of the university. The gardens accommodate over 10 000 plant species from all over the world. Our field site were located on a small hill with an gentle inclination of about 1.3 ° resulting from the 170 m long transect (point A until point D, see Figure 1.1) with an height difference (Δh) of 4.3 m. Our main objectives were to capture cold air drainage along the hill above the different sites and cold air pooling above the lake via the DTS-technique, ultrasonic anemometers and an open-path hygrometer above the lake.

1.2 Deployment of CADEX

The DTS Installation consisted of one coherent optical fiber with a length of $\approx$ 2000 m, which was hung up along a transect and afterwards wound around two columns.
The transect can be disposed in four sections:

- an open stock with different tree species and some bushes at point A at the start of the transect (0 m - 30.5 m of the transect) and a small stream (3.2 m - 3.8 m of the transect)

- a meadow until point C (30.5 m - 135.7 m of the transect)
- a lake between point C and point D (135.7 m - 166.9 m of the transect)
- a sandy ground until point D (166.9 m - 170 m of the transect)

At each end of the transect we put up a tower where we could attach and strengthen the fiber and leave $\approx$ 10 m additional fiber to be able to fix the fiber in case of damage. At point B there was the permanently installed meteorologic measurement tower of the EBG for recording of radiation, moisture and temperature of air and of soil, air pressure, precipitation and wind velocity and direction. Additionally to the transect two columns were installed at point B (in the following "column at the tower") and point D (in the following "column at the lake"), which had a higher physical spatial resolution than the transect. An ultrasonic anemometer was installed $\approx$ 14 m upside the hill from point B in a height of 10 cm above ground to measure the advection and another ultrasonic anemometer with an open-path hygrometer was set up at the tower at point D for turbulent flux measurements above the lake.
During the installation of CADEX a single-ended measurement of channel 1 was started at the 7th of March at 18:28:53. The full setup was completed at the 13th of March at 13:20:59.

2 DTS

2.1 Introduction

Both ends of the fiber were connected to the measuring device (Model ORYX DTS, Sensornet Ltd, Elstree, HERTS, United Kingdom). We had two single-ended measurements of the fiber at a 30-second interval (channel 1 and channel 2 of the Oryx), while channel 2 was the reverse measurement of channel 1. Accordingly we could average the both measurements to increase the accuracy of them.

2.2 Deployment

2.2.1 Setup Transect

The Sensornet Oryx base station was setup rectangular to the transect at point B at the edge of the meadow. The different elements were either protected by a lock-up or were screened from view under a small pine. The acquired data of the Oryx was written to an external mini-computer for subsequent retrieval.
Along the transect the fiber was tightened at six heights, which were 5 cm, 10 cm, 20 cm, 50 cm and 100 cm above ground and 2 cm below ground. The fiber was inserted into the ground through a self constructed plow (Figure AA.1). To hold the fiber at the different heights all along the transect we used 1 m-long poles every $\approx$ 12 m of the transect with special blocks attached (Figure A.2). Every block had a wave like groove in which the fiber lay and was additionally hold by a plastic tube in this groove. Every pole was anchored with 2 nails in the ground and three anchoring cables (Figure AA.3). Self designed pulleys and pulley-holder were designed to strengthen the fiber. Three of them were attached at the start of the transect at the tower in the open stand near the stream at point A of Figure 1.1 and four of them were attached at the big tower at the lake at point D. The pulleys had a diameter of 15 cm, so as to wrap the fiber 3-4 times around without signal loss. In addition to this wrapping the fiber was fixed to the pulley with electrical tape. The holder of the pulley had a 20 cm long groove where the pulley could be moved in order to strengthen the fiber (Figure AA.4).
The fiber started at the base station and ran into an ice water bath (0° C) where about 50 m of it was coiled up on a self-constructed tube with a diameter of $\approx$ 12.5 cm and submerged into the water and then with the same setup went directly into a warm water bath ($\approx$ 17° C), which can be seen in Figure AA.5. After the fiber ran through the transect and was coiled up the two columns, it went through the ice water bath and warm water bath again and ended at the Oryx (Figure 2.1).

2.2.2 Setup Columns

One column was located at the lower end of the transect (at the lake), the other one at the meteorological measurement station in the middle-section of the slope (Figure 2.2). They were constructed of white reinforcement fabric which was stuck on transparent rings in distances of about 1 m (Figure 2.3a and Figure 2.3b). The column at the tower had

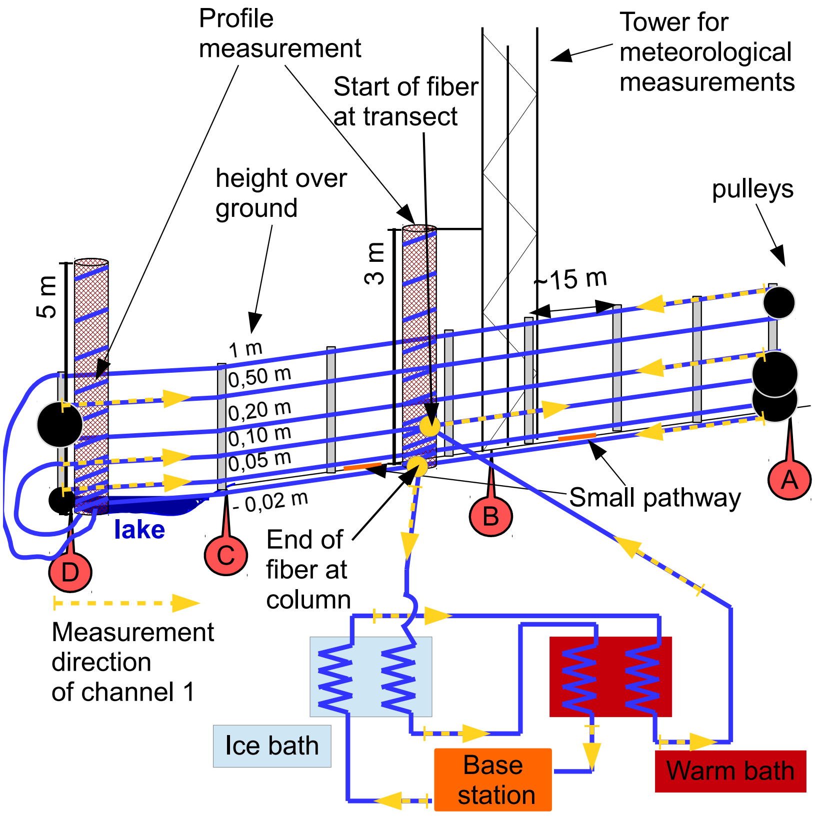
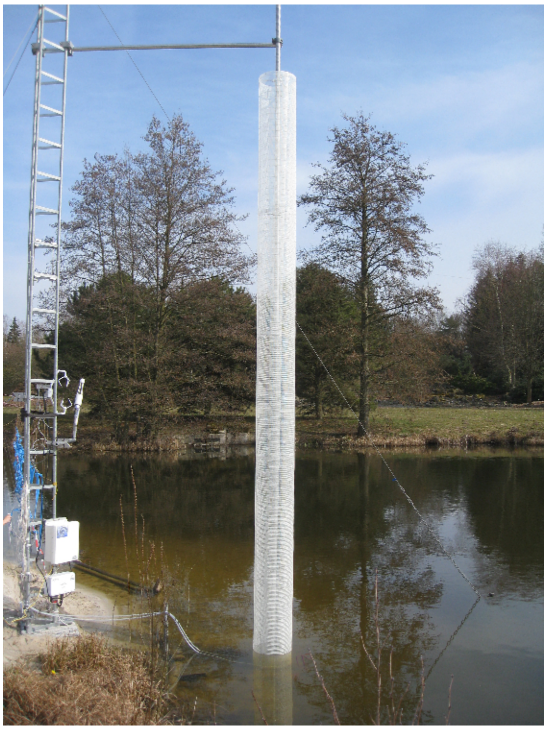


Figure 2.1 Draft of the setup of CADEX with all six heights, both columns, calibration baths and the base station. The measurement direction of channel 1 is illustrated by yellow arrows.

transparent rings in 0.01 m, 1.00 m, 2.01 m and 3.02 m height above ground. The column at the lake had transparent rings in -0.28 m, 0.60 m, 1.60 m, 2.60 m, 3.60 m and 4.79 m above water level. A blue lettering on the reinforcement fabric was mostly removed with alcohol. In the direction of channel 1 the optical fiber first ran directly from the bottom to the top of the columns. Then it was wound from the top to the bottom around the columns. It was stuck by 4 points of hot glue per winding (Figure 2.3c). The metal cone end of the hot-melt gun damaged the PVC-coating of the optical fiber at some points when having contact too long (Figure 2.3d). The optical fiber sections which ran to and away from the columns were enveloped by transparent silicone tubes for stabilization and protection.
The distance between the windings was 5 cm in the upper part and 1.02 cm in the lower part of the columns (Figure 2.4 and Figure 2.5). Both columns had a circumference of 1.01 m. With the column at the lake also water temperatures were measured until a depth of 29.6 cm.



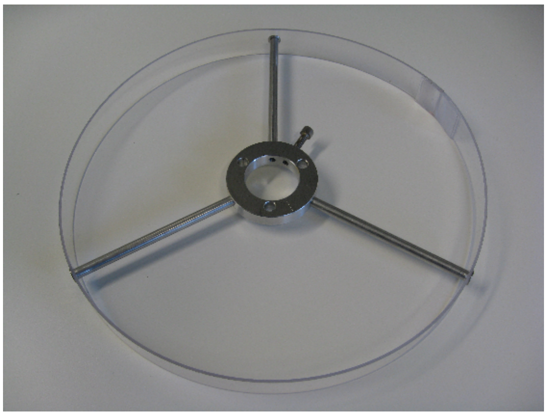
(a) Column at the lake

(b) Column at the tower

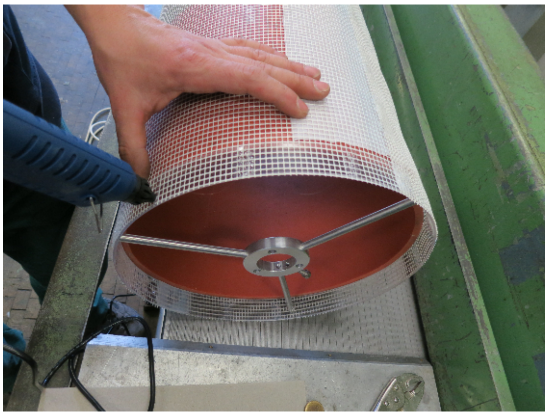
Figure 2.2 Columns in the field

2.2.3 Mapping

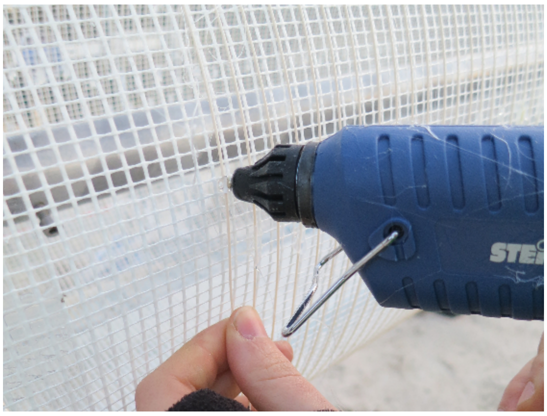
The optical fiber was mapped by cooling it at specified locations like the beginning and end of one height of the fiber. Additionally the distances between the poles were determined with a measuring tape. Ice packs or ice enveloped in a towel were used to



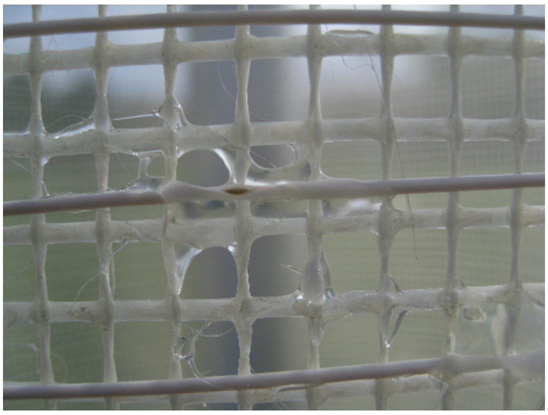
(a) Transparent ring



(b) Gluing reinforcement fabric



(c) Gluing fiber optic winding



(d) Melted PVC-coating at a glue dot

Figure 2.3 Columns in the field

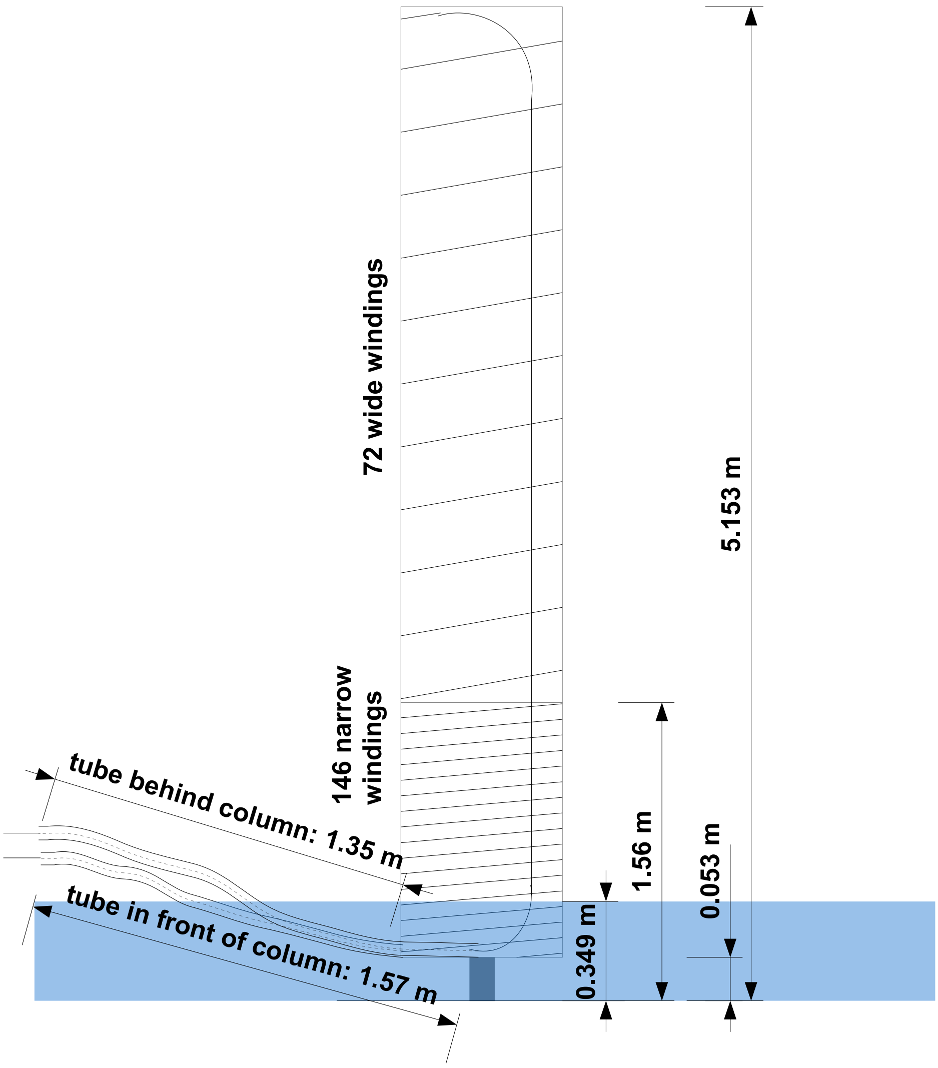


Figure 2.4 Proportions of the column at the lake. "In front of/behind column" refers to the direction of channel 1.

create a low temperature anomaly in the measured signal. Each position was recorded as length along the fiber (LAF) in meters for channel 1 before the first brake on 25th of March (Table 2.1). The positions on the columns could not all be reached. Therefore we used positions in front of and behind the columns to calculate the wanted positions with the help of the proportions and counts in windings (Table 2.2). We assumed to measure the point in the middle of the ice packs or towel. In addition the windings of the columns were counted in order to compare it with the result of the mapping (Table 2.3). The mapping was done on 18th march 2015. Before there had been only one break of the optical fiber during setup.

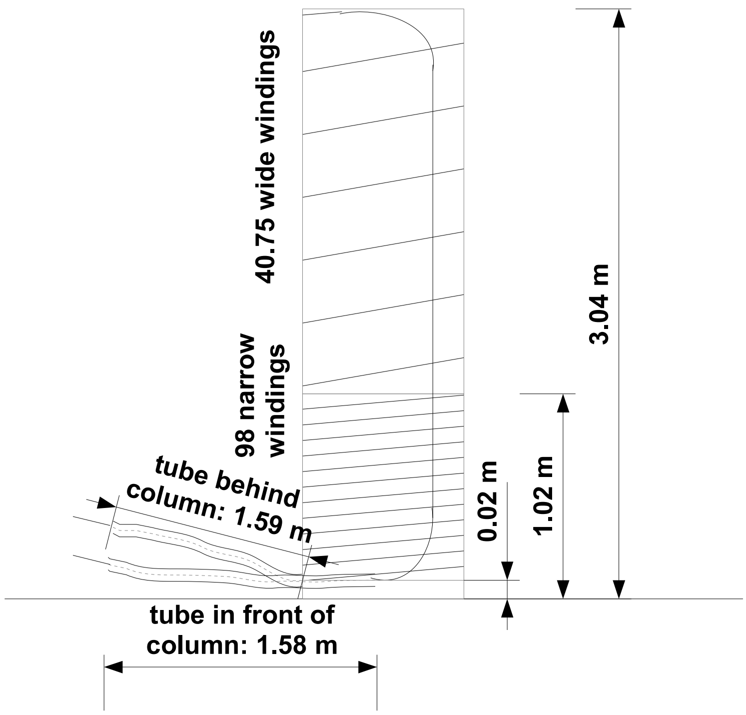


Figure 2.5 Proportions of the column at the tower. "In front of/behind column" refers to the direction of channel 1.

Table 2.1 Mapping the columns: LAF for channel 1. "In front of"/"behind" refers to the direction of channel 1 before the first brake on 25^{th} of March.

Column at the lake		**Column at the tower**	
Position	**LAF [m]**	**Position**	**LAF [m]**
30 cm in front of the tube in front of the column	1221	30 cm in front of the tube in front of the column	1607
		30 cm in front of the end of the wide windings	1655
30 cm behind the tube behind the column	1448	30 cm in front of the end of the wound optical fiber	1752

Table 2.2 Calculated positions of the columns: length along the fiber (LAF) for channel 1 before the first brake on 25^{th} of March.

Position	**Column at the lake**		**Column at the tower**	
	z [m]	**LAF [m]**	**z [m]**	**LAF [m]**
top	4.80	1228	3.04	1612
end of wide windings	1.19	not measured	1.02	1655
bottom	- 0.30	1446	0.02	1752

Table 2.3 Number of windings (counted) and measurements (result of mapping) on the columns

section	Column at the lake		Column at the tower	
	windings	**measurements**	**windings**	**measurements**
wide windings	72	-	40.75	43
narrow windings	146	-	98	96
total	218	216	138.75	139

Note: Because of a circumference of 1.01 m and a sample length of 1.0146 m the number of windings and measurements should be nearly identical.

2.2.4 Transfer Matrix

The mapping was used to create a transfer matrix to get every height of the transect and the columns and their sections from the raw data (Table 2.4).

Table 2.4 Transfer Matrix of CADEX dependent on the LAF of channel 1 before the first brake on 25^{th} of March

Position	**Height**	**LAF [m]**	**Comment**
transect	- 2 cm	273	start at point A
		410	end at point C
	5 cm	458	start at point D
		627	end at point A
	10 cm	183	start of first half at point B
		263	end of first half at point A
		1491	start second half at point D
		1578	end second half at point B
	20 cm	645	start at point A
		815	end at point D
	50 cm	824	start at point D
		995	end at point A
	100 cm	1012	start at point A
		1183	end at point D
column at the meteorologic tower	-	1227	start at point B
	-	1446	end at point B
	-	1300	transition from 1 cm to 5 cm winding
colum at the lake	-	1613	start at point D
	-	1753	end at point D
	-	1654	transition from 1 cm to 5 cm winding

2.2.5 Calibration

The two ice water baths or so called zero baths are used for slope calibration as the returned intensity of the laser pulse exponentially declines with the length along the fiber. After the slope of the temperature signal was calibrated, it needed an additional offset calibration which was done by the warm water baths or so called span baths.

2.3 Data Availability

Before the setup was complete, measurements were taken only with channel 1 of the ORYX. The actual measurement campaign was performed with channel 1 and 2 with an acquisition time of 30 s for each channel and a sample length of 1.046 m (Table 2.5). Actually we entered 1 m for spatial averaging. Apparently this parameter cannot be set more exactly than 1.046 m. We tried to change it to 1.000 m on 18th March 2015 17:36:31. But it was overwritten automatically by 1.046 m before continuing. This resulted in a spatial averaging of 1.000 m in the configuration file. But sample length remained 1.046 m. We assume that spatial averaging of 1.000 m means effectively 1.046 m. The measurement campaign was interrupted several times because of breaks (Table 2.6). Some of these breaks were caused by animals, maybe rabbits, biting into the optical fiber. Besides there were further interruptions of the measurements during the mapping of the optical fiber and during a power cut-off on the site (Table 2.7). After the power cut-off two data files with the same time stamp were acquired as sometimes else:

1) channel 1 20150423 091611 00001.ddf

2) channel 1 20150423 091611 00002.ddf

But these files seem to be identical.

Table 2.5 Measurement periods

period	**configuration**	**active channels**	**start**	**end**
during setup	first_run_obg	1	2015-03-07 18:28:53	2015-03-13 10:45:18
measurement campaign	cadex_first	1 and 2	2015-03-13 13:20:59	2015-04-29 10:14:40

Table 2.6 Fiber modifications

Number	Date of change (CET)	Date of fix* (CET)	Position as LAF [m]	Height [m]	Change (removed fiber) [m]
1**	2015-03-12 13:11:18	2015-03-13 10:36:18	351	-0.02	0.08
2	2015-03-25 06:45:19	2015-03-25 19:20:17	772	0.20	4.07
3	2015-03-27 17:15:17	2015-03-27 18:54:17	769 (Splicing point of Nr. 2)	0.20	0.23
4	2015-03-30 22:11:17	2015-04-02*** 15:22:05	699	0.20	0.68
5	2015-04-04 00:40:05	2015-04-04 10:27:10	689	0.20	0.05
6	2015-04-07 12:16:10	2015-04-07 17:10:50	1004	1.00	3.20
7	2015-04-09 04:53:50	2015-04-09 15:08:37	767	0.20	1.34
8	2015-04-14 12:13:37	2015-04-14 19:08:08	1000	1.00	0.20
9	2015-04-15 11:51:08	2015-04-15 14:37:56	768 (Splicing point of Nr. 7)	0.20	0.19
10	2015-04-15 20:28:56	2015-04-16 14:49:51	643	0.20	0.08
11	2015-04-20 15:37:51	2015-04-20 18:59:04	1001	1.00	0.22
12	2015-04-21 05:18:04	2015-04-21 16:01:43	687	0.20	0.12
13	2015-04-21 18:11:43	2015-04-21 18:31:49	687	0.20	2.00

∗ Date of fix is the time when splicing was done, but the fiber was hung up in the correct height some minutes later.

∗∗ during setup, before complete start of the measurement.

∗ ∗ ∗there were stromy conditions these days and we waited until the conditions for cold air formation got better

Table 2.7 Further interruptions

Start of interruption (CET)	**End of interruption (CET)**	**Reason**
2015-03-18 11:32:59	2015-03-18 17:39:19	Mapping the optical fiber with configuration "CADEX_transfermatrix"
2015-04-23 08:59:49	2015-04-23 09:05:11	power cut-off on the site
2015-04-23 09:10:11	2015-04-23 09:14:11	power cut-off on the site

2.4 Data archiving

2.4.1 Raw data

DTS data for both fibers is organized by channel and by date in CADEX/Oryx/CADEX_first/channel_#{date}. You can find this data on the server of our meteorologic department with the path:
btgmm6.geo.uni-bayreuth.de/volumes/mmraid/mm_archive/Data_2015/OeBG/CADEX/Oryx/CADEX_first
The raw data includes four values, each in a column of the .ddf-file:

- LAF: length along the fiber
- Temperature
- Stokes
- Anti-Stokes

Additionally in the head of the .ddf-file the time stamp and reference temperature of both PT100 temperature measurements are included.

2.4.2 Processed data

Each measurement period of 30 s about 2000 temperature values were stored. These values are saved as .ddf-files in the path above. We have measurements every 30 s, which means a total of 2880 files for 24 hours. This have to be handled by a structure array. It consists of seven elements:

- dt: data time
- ch: channel number
- transect: values of the transect
- columns: values of both columns
- icebaths: values of the icebaths
- warmbaths: values of the warmbaths
- reftemp: reference temperatures from the measurement of temperature in the calibration bath by the PT100

The last five elements consist of several elements again. They are listed in the Table 2.8. The measurements were merged for each night, processed and saved as the mentioned structure array on the server of our meteorologic department with the path:
btgmm6.geo.uni-bayreuth.de/Volumes/mm_raid/mm_archive/Data_2015/OeBG/CADEX/Processed_data/only_nights

Table 2.8 Structure array of a night of processed data with number of rows and columns for each element it. After "data" in first column each subsequent column is a subdirectory of the previous column. "data length" refers to number of measurements taken during the measured period.

				rows	**columns**
data	.dt			1	data length
	.ch			1	data length
	.transect	.x		1	972
		.z		1	972
		.Tf		data length	972
		.St		data length	972
		.aSt		data length	972
	.column	.lake	.z	1	216
			.Tf	data length	216
			.St	data length	216
			.aSt	data length	216
		.tower	.z	1	138
			.Tf	data length	138
			.St	data length	138
			.aSt	data length	138
	.icebaths	.first		data length	59
		.last		data length	41
	.warmbaths	.first		data length	49
		.last		data length	39
	.reftemp	.zero		data length	1
		.gain		data length	1
		.internal		data length	1

2.5 Observations

During the measurement campaign an algae film developed on the column at the lake in the section which stood in water. Polliwogs stayed there in the last days of the measurement campaign (Figure 2.6a). Because of vegetation growth the optical fiber near the ground was more and more in the ground vegetation layer (Figure 2.6b).

(a) polliwogs in the lake

(b) ground vegetation layer, column at the tower

Figure 2.6 Columns in the final stage of the experiment (2015-04-27)

2.6 Setup of the glass fiber

We used a 50/125 Multimode glass fiber from AFL (FBR00259 DRAKA 50/125 BIF OM2, AFL, Mönchengladbach, Germany). We chose this fiber, because it has a low transmissibilty, has a very low attenuation after splicing and is easy to handle. The fiber is composed of an outer coating with a diameter of 900 μm, which protects the fiber against outer influence, a textile fiber for a higher degree of tension stability, a cladding with a diameter of 125 μm, which keeps the optical signal within the core, and the core with a diameter of 50 μm, which transmits light (Figure 2.7).

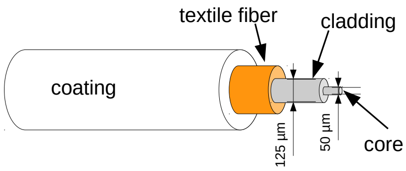


Figure 2.7 Setup of the fiber with diameter of the components

2.7 Splicing

We used a fusion splicer (Model S178 A/V2, Serial Nr. 32900, Fitel, Furukawa Electric Co. LTD., Laser Components, Germany). You need the following devices:

- 3 wire stripper; diameters: 2 mm, 0.5 mm, 125 μm (we used wire strippers from Ripley ®, Miller®, Cromwell, CT., USA)
- 1 scissors
- alcohol and tissues
- heat shrink tubing, diameters: 900 μm and 250 μm
- special heat shrink tubing for stabilization of the splice section (FAL PS-3A-40mm "Schrumpfspleissschutz", SN: LO132338, Laser Components GmbH, Olching, Germany)
- high precision optical fiber cleaver (Model S326, Furukawa Electric Co. LTD., Laser Components, Germany)
- fusion splicer

The wire stripper with the biggest diameter is needed for splicing of pigtails, because the outer coating of them are bigger. We used two different types of heat shrink tubing. One type was the "normal" heat shrink tubing as it is used for electronics, of which we had both diameters, and the other one was a special heat shrink tubing from Laser Components with a piece of metal and hot glue in it to protect the glass fiber from new damage. In order to get full protection we first stabilized the splice section with the special heat shrink tubing, then added the heat shrink tubing with the small diameter at each side of it and finally put the heat shrink tubing with the biggest diameter above all of them to protect the splice section from moisture.
The following instructions serve as a guideline to splice the fiber in case of break:

1. Put on needed heat shrink tubing in the order one big, one small, one special and one small heat shrink tubing on one fiber
2. Tighten each fiber in the corresponding fiber holder from inside the fusion splicer with space of $\approx$ 4 cm at each end for splicing
3. Use wire stripper with a diameter of 0.50 mm to remove outer coating. Strip about 1 cm of sheathing at a time.
4. Cut off fibrous sheathing
5. Take smallest wire stripper and remove second coating

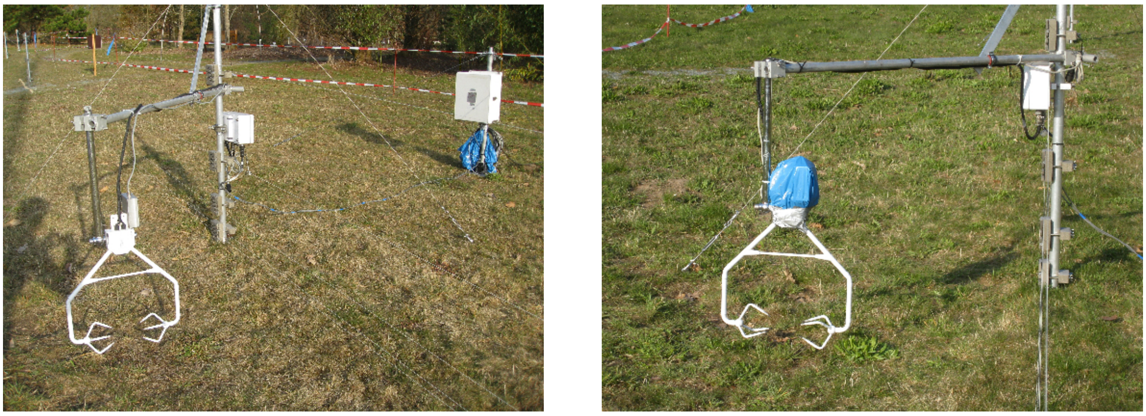
6. You now have 2 concentric cylinders of just glass. Clean them with alcohol.
7. Chop the fiber with the optical fiber cleaver and DO NOT CLEAN AGAIN
8. Until now NEVER TOUCH THE GLASS FIBER AGAIN!
9. Open fusion splicer, put both holder inside, close the fusion splicer and turn it on.
10. The fusion splicer works automatically, so just push the green button at bottom right.
11. At least you should now see both ends of the fiber in the screen where they will be spliced
12. You can see the quality of the splicing process in the screen. A picture of the splicing will be saved automatically.
13. Open fusion splicer, CAREFULLY release the fiber from holders, put the special heat shrink tubing over the splicing section and put the fiber with the heat shrink tubing into the heater.
14. When the heater is closed, the fusion splicer automatically starts and ends heating.
15. Repeat this process for every heat shrink tubing.

Best practice splicing in a laboratory, because it is quite challenging outside in the field when it is for example dark and cold. If it do not work well at these conditions, never mind, because the described fusion splicer does not work well at low temperatures although operating temperatures until -10 °C should be possible according to specifications.

3 Flow and Flux measurements

3.1 Setup

For the flow and flux measurements two Ultrasonic Anemometers (Model CSAT3, Campbell Sci., Logan, UT, USA) were installed on the site. The Ultrasonic Anemometer with Serial Number 0205 hung upside down near the tower in order to measure the wind velocity and direction in 10 cm above ground. The other one with Serial Number 1756 was installed above the lake in combination with an open-path hygrometer (Model LI 7500, Serial Nr. 75H-0270, LI-COR, Lincoln, NE, USA) for turbulent flux measurements. All data were taken by two data loggers (Model CR3000, Campbell Sci., Logan, UT, USA) at 20 Hz: "Turm-Logger" for the CSAT Sonic at the tower and "See-Logger" for CSAT Sonic and LICOR hygrometer at the lake. Both were installed on the 13^{th} March.



(a) first CSAT-installation before exchange **(b)** final CSAT-installation after exchange

Figure 3.1 CSAT at the tower

The CSAT at the tower had to be exchanged because of rain water which drained into the tubes of the CSAT and caused damage to the electronics. The rain water got into the CSAT because it hung-upside down and a sealing ring at the bottom of the measuring devise was broken. Therefore the CSAT at the meteorologic tower and its electronic box were exchanged on 9^{th} April 2015 (Figure 3.1).
Declination in March was 2° 44' and 2° 45' in April. All values given in this chapter are measured relative to magnetic North. Accordingly our values have to be shifted by ≈ 3 ° to West in order to get the geographic North.
The angle to magnetic north and height above ground before and after the installation of the new CSAT were checked, but they did not change. The height above ground h_m was 10 cm and the angle to magnetic north α_N was 328° (Figure 3.2).
This CSAT was hung upside down, thus the orientation completely changes and can be seen in Figure 3.2. The x-component for the CSAT at the meteorologic tower is now the upward directed wind-component, which would be the z-direction of a CSAT in a

”normal” setup. Accordingly the y-component of the upside-down-CSAT measures the winds downwards the slope or in other words the katabatic-component, which would be the -y-direction of a ”normal” CSAT. Finally the z-direction of the CSAT at the tower measures cross slope west-winds, which would be the x-component of a ”normal” setup CSAT like the CSAT at the lake. The x-, y-, and z-component of the CSAT at the tower should be shifted that the components can be compared with the data achieved at the lake and at the meteorologic tower at point B.
The initial distance between the tower at the lake and the CSAT and LICOR was quite

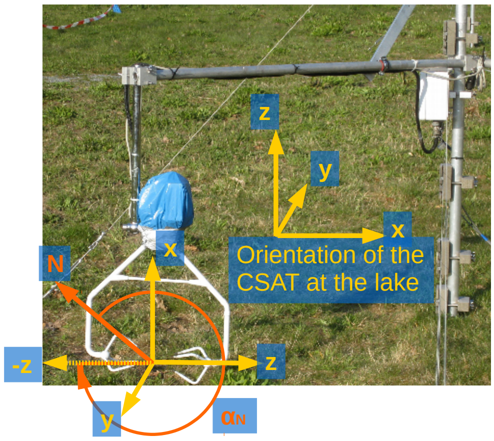


Figure 3.2 Orientation of the CSAT at the meteorologic tower. It was hung upside down, thus the orientation changes. This figure should clearify how the angle α_N to North was measured and what each directions measures.

small. Thus to get better measurements of the fluxes above the lake, the distance between tower and the two measuring devices were extended on the 17^{th} March (Figure 3.3). Accordingly we had a change in the angle to north, distance between the devices and in height above ground which can be seen in Table 3.1.The angle between CSAT and LICOR to north have been measured with a compass and the distance between CSAT and LICOR have been measured with a folding rule. The middle of measuring-distance of the measuring devices were the reference point for determination of angles, heights or distances between them (Figure 3.4).

3.2 Measurements

The saved parameters at the two loggers can be seen in Table 3.3 and Table 3.2. The parameters were measured with a frequency of 20 Hz.

(a) first installation of CSAT and LICOR at the lake without extension of the mounting for flux measurements above the lake

(b) final installation of CSAT and LICOR at the lake after extension of the mounting for flux measurements above the lake

Figure 3.3 Installation of the CSAT and LICOR for flux measurements above the lake

Table 3.1 Angle from CSAT to magnetic north α_{CSAT}, angle from LICOR to magnetic north β_{LICOR}, height above ground (here: lake) of both devises (h_{CSAT} and h_{LICOR}) and distance between CSAT and LICOR $d_{CSAT\ to\ LICOR}$ of both installations at the lake

	α_{CSAT}	β_{LICOR}	h_{CSAT}	h_{LICOR}	$d_{CSAT\ to\ LICOR}$
until 17.03. 14:31	83°	222°	2.11 m	2.13 m	0.25 m
since 17.03. 15:50	92°	240°	2.13 m	2.15 m	0.26 m

Note: see draft of measuring devises and all parameter in Figure 3.4; all angles were measured relative to magnetic North: for geographic North rotate angles west by 2° 44' in March and 2° 45' in April

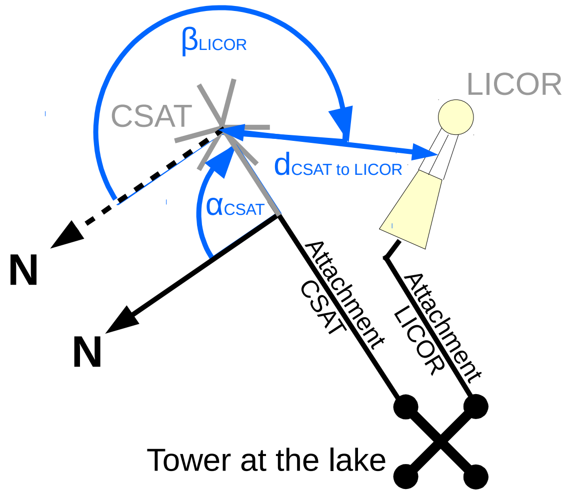


Figure 3.4 Determination of angles of CSAT and LICOR to north (α_{CSAT} and α_{LICOR}) and distance between them ($d_{CSAT\ to\ LICOR}$)

Table 3.2 Measurements of the logger at the lake

Measured parameters
Time stamp
Sonic Temperature
Wind velocity x-plane
Wind velocity y-plane
Wind velocity z-plane
Carbon dioxide concentration
Water vapor concentration
Air pressure

Table 3.3 Measurements of the logger at the tower and corresponding measured parameters on the slope

Measured parameters	Parameter on the slope
Time stamp	-
Sonic Temperature	-
Wind velocity x-plane	Wind velocity z-plane
Wind velocity y-plane	Wind velocity -y-plane
Wind velocity z-plane	Wind velocity x-plane

3.3 Data acquisition

3.3.1 Data availability (CSAT at the tower)

Because of the seal defect and the upside-down installation of the CSAT water got inside the tubing and caused damage. Therefore the CSAT at the tower and its electronic box were exchanged on 9th April 2015 (Figure 3.1, Table 3.4).

3.3.2 Data availability (CSAT at the lake)

Also at the lake we have some data missing for several reasons (Table 3.5). We also have to neglect data of the 17th of March from 14:31 until 15:50 o'clock. At this time we extended the installation of the CSAT and LICOR for a better position of the them above the lake.

Table 3.4 Stop reasons and time intervals of available data at the logger of the tower

start date (CET)	**stop date (CET)**	**reason of stop**
2015-03-13 18:13	2015-04-03 23:57	water damage and CSAT exchange
2015-04-09 14:18	2015-04-23 08:55	power cut-off on the site
2015-04-23 09:25	2015-04-29 14:21	end of experiment

Note: Until 2015-03-26 10:22:01 the time stamp of the Turm-Logger was 24 h 0 min 55 s too early. Therefore the data contains a period of overlapping time stamps

Table 3.5 Stop reasons and time intervals of available data at the logger of the lake

start date (CET)	**stop date (CET)**	**reason of stop**
2015-03-13 17:55	2015-03-23 08:55	power cut-off on the site
2015-04-23 09:13	2015-04-29 14:38	end of experiment

Note: Until 2015-03-26 12:01:09 the time stamp of the See-Logger was 24 h 0 min 54 s too early. Therefore the data contains a period of overlapping time stamps

3.3.3 Data archiving

Sonic data is also archived on the server of our meteorologic department:
btgmm6.geo.uni-bayreuth.de/volumes/mmraid/mm_archive/Data_2015/OeBG/...
...CADEX/Sonics/
The folder 'loggerfiles' contains raw data organized by the sites 'See' and 'Turm'. Both high resolution data ('ts_data') and averages ('avg') over one minute are included. The folder 'converted' contains converted data organized by the two sites and split up in two periods. In the first period the time stamp is 24 h 0 min 55 s too early. For the Tower-Logger it lasts until 26th March 10:22, for the Lake-Logger until 26th March 12:01. Afterwards in the second period the time stamp is corrected. Converted data is stored both as zipped csv-files and mat-files.

4 Time differences

Central European Time (CET) was used throughout the measurement campaign. On 25^{th} and 26^{th} March the times of the ORYX, the ORYX-PC and the two data loggers were compared and synchronized with the internet time (Table 4.1). The ORYX-PC had no difference, the ORYX proceeded 50 seconds, while the logger at the lake and the logger at the meteorologic tower were 24 h 0 min 54 s and 24 h 0 min 55 s too early. Even after comparison a difference of 4 s between the ORYX and the ORYX-PC remained, because the synchronization between ORYX-PC and ORYX took some time.
On 29^{th} of March the clock of the ORYX-PC unfortunately was changed to summer time and thus was proceeding 24 h. This was recognized on the 30^{th} of March and converted. Later on the time offset was only compared with the ORYX-PC (Table 4.1).

Table 4.1 Time offset in relation to ORYX-PC

Date	ORYX	Tower-Logger	Lake-Logger
2015-04-23	- 4 s	- 8 s	- 7 s
2015-04-29	- 4 s	- 5 s	- 4 s

Note: Positive value = too early. Negative value = too late.

5 Camera Traps

We used two camera traps called SnapShot Limited Black 5.0, Article Number 204472 from DÖRR GmbH, Messerschmittstrasse 1, 89231 Neu-Ulm. The two camera traps had different positions along the transect for different purposes:

- one camera trap at the lake
  ⇒ Observation of animals, fog above the lake and ice-formation in the lake

- one camera trap along the transect
  ⇒ Observation of animals

For the observations at the lake we chose continuous shooting with a frequency of one picture per 30 minutes and additionally we activated the trap sensor for animals walking by. In this case the camera took three photos with a frequency of one per second. At the transect we only used the trap sensor.
All pictures can be found on the server of the micro meteorology department with the path:
"/volumes/mm_raid/mm_archive/Data_2015/OeBG/CADEX/Pictures_Videos/camera_trap" with the sub-folders "lake" and "transect".

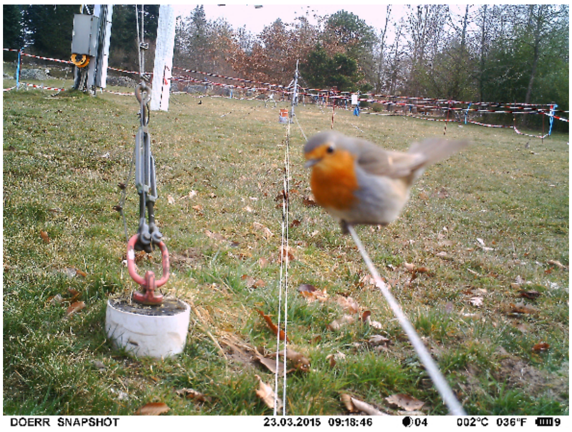
(a) Duck swimming through the transect at the lake

(b) Cat walking through the transect at the lake

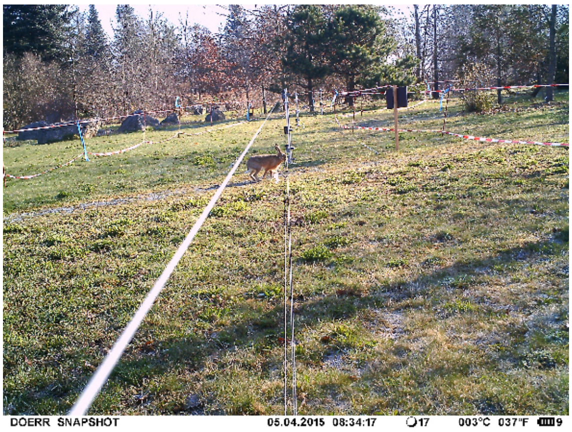
Figure 5.1 Observation of animals at the lake

Figure 5.2 Fog in the morning at the lake

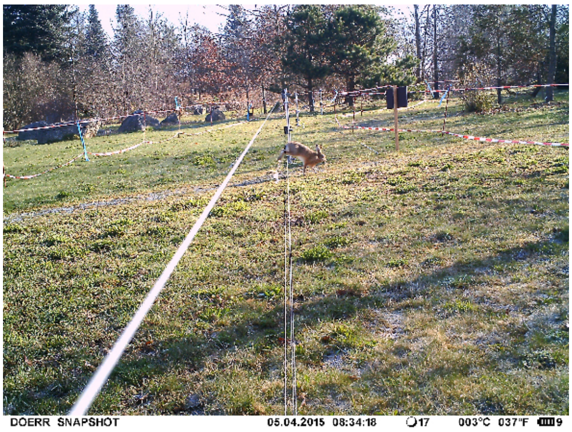
(a) Cat at the transect at night



(b) Robin redbreast sitting on the fiber



(c) Rabbit standing at the transect



(d) Rabbit jumping through the transect

Figure 5.3 Observation of animals at the lake

6 Fog Experiments

On 11^{th} and 20^{th} April 2015 fog releases were made on the site in order to visualize airflow and to observe cold air drainage and pooling. We released fog at several points along the transect and used a laser machine to make the airflow visible in one plane. Pictures and videos of these nights are archived on the server of the meteorologic department with the path "btgmm6.geo.uni-bayreuth.de/Volumes/mm_archive/Data_2015/OeBG/...
...CADEX/Pictures_Videos" in the folders:
2015_04_11_OeBG_Fog_release&laser
2015_04_20_OeBG_Fog_Release&Laser
In both nights the sky was nearly clear. On 11^{th} April we began at about 02:00. Dew formation took place and probably prevented cold air drainage. Instead we observed skin flow and convective mixture (Figure 6.1a). Over the lake surface evaporation was detected (Figure 6.1b and 6.1c).
On 20^{th} April the fog releases began a bit before sunset at about 19:30. In this night phases of cold air drainage were observed. A selection of the best pictures of 20^{th} April is given in Table 1 and Figures 6.2 - 6.15.

(a) Convective mixture at the lakeside **(b)** Evaporation above the lake **(c)** Evaporation above the lake

Figure 6.1 Observations of the fog at the lakeside on 11^{th} of April

Figure 6.2 Fog machine and conditions at sunset (IMG_3470.jpg)

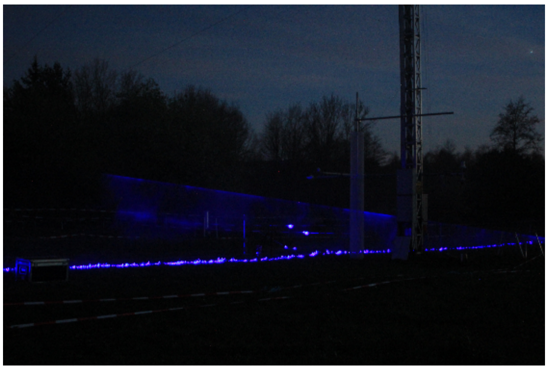


Figure 6.3 Overview with light wedge (IMG_3570.jpg)

Table 6.1 Selection of pictures of 20^{th} April at several events during this evening and night. For some events we choose continous shooting of ten pictures with a frequency of one picture per second. They are indicated with a (*) and the full series of pictures can be found on the meteorologic department server as mentioned above. Some pictures are included in this chapter and are listed in the third column of this table.

File names on the server	Description	Figure in this chapter
IMG_3468.JPG till IMG_3523.JPG	Fog machine without laser. Conditions at sunset	Figure 6.2
IMG_3570.JPG and IMG_3576.JPG till IMG_3578.JPG	Overview over the light wedge of the laser machine	Figure 6.3
IMG_3594.JPG*	Cold air creep	Figure 6.4
IMG_3604.JPG*	Cold air creep	Figure 6.5
IMG_3614.JPG*	Cold air creep, close-up view	Figure 6.6
IMG_3644.JPG*	Cold air flow on top of an existing cold air layer. Direction shear: Airflow is fastest at the bottom and rather turns back at the top.	Figure 6.7
IMG_3694.JPG*	Separating cold air flow over an existing col air layer. No direction shear.	Figure 6.8
IMG_3714.JPG*	Cold air flow near the ground and upper sheared flow. No direction shear.	Figure 6.9
IMG_3724.JPG*	Cold air flow near the ground and upper sheared flow which is rather stagnant.	Figure 6.10
IMG_3734.JPG*	Upslope flow near the ground and in the upper part. Shear vertices.	Figure 6.11
IMG_3784.JPG* and IMG_3794.JPG	Evolving shear vertex	Figure 6.12
IMG_3804.JPG*	Cold air flow with shear instabilities	Figure 6.13
IMG_3814.JPG*	Fog over the lake looks like an exploding fist	Figure 6.14
IMG_3824.JPG*	Convergence and blockage of flow over the lake and cold air flow.	Figure 6.15

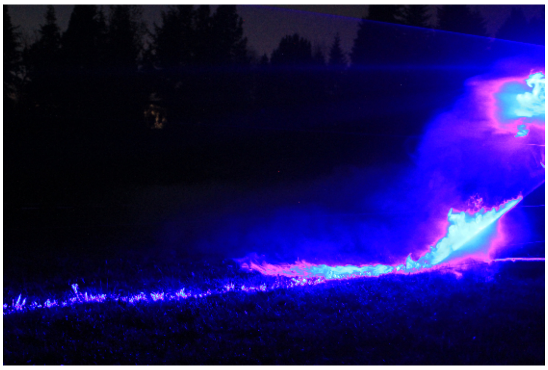


Figure 6.4 Cold air creep (IMG_3598.jpg)

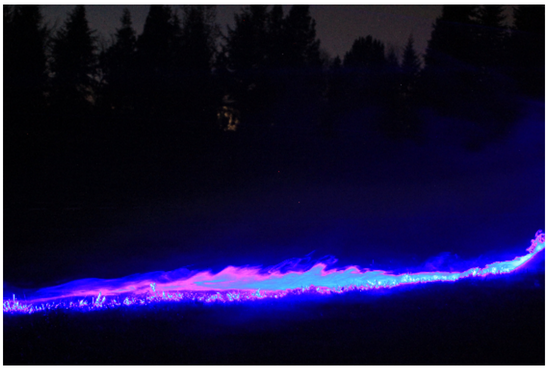


Figure 6.5 Cold air creep (IMG_3604.jpg)

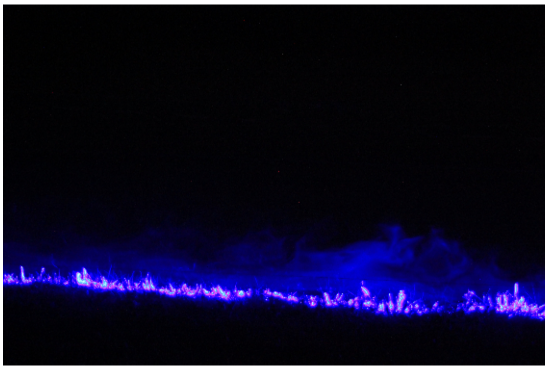


Figure 6.6 Cold air creep, close-up view (IMG_3614.jpg)

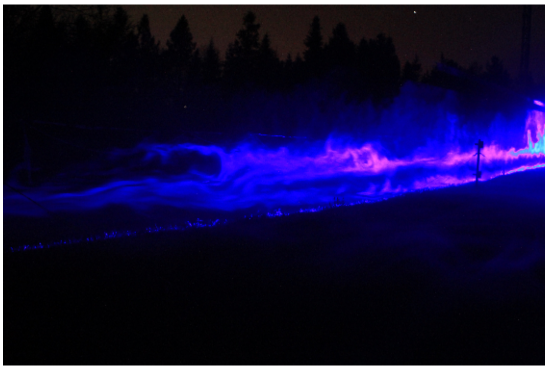


Figure 6.7 Flow over cold air layer with direction shear (IMG_3648.jpg)

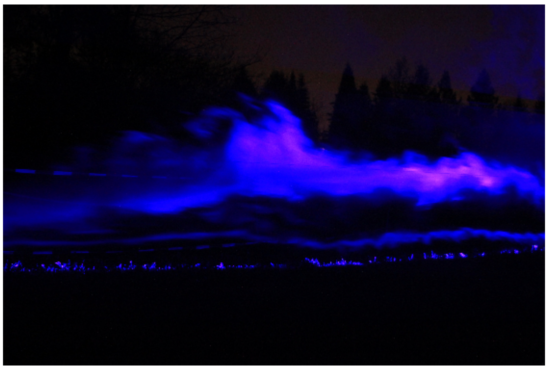


Figure 6.8 Separating flow over cold air layer without direction shear (IMG_3698.jpg)

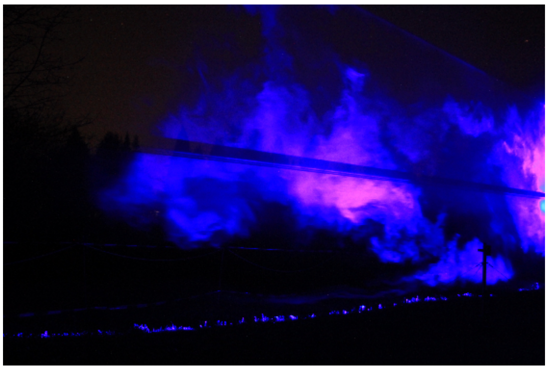


Figure 6.9 Cold air flow and upper sheared flow without direction shear (IMG_3722.jpg)

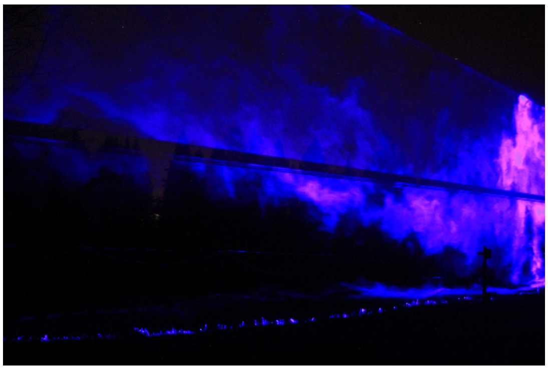


Figure 6.10 Cold air flow and upper sheared stagnant flow (IMG_3726.jpg)

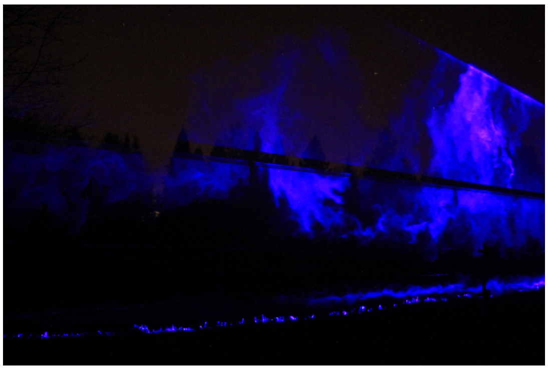


Figure 6.11 Upslope flow with shear vertice in the upper part (IMG_3734.jpg)

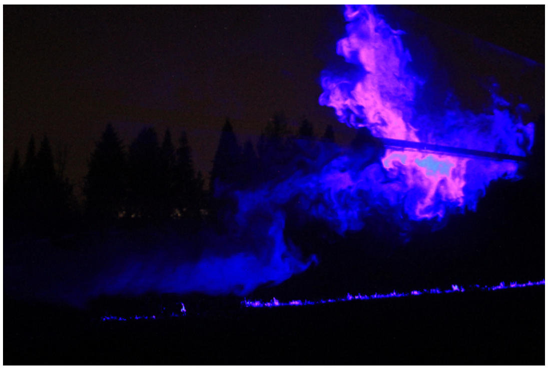


Figure 6.12 Evolving shear vertex (IMG_3744.jpg)

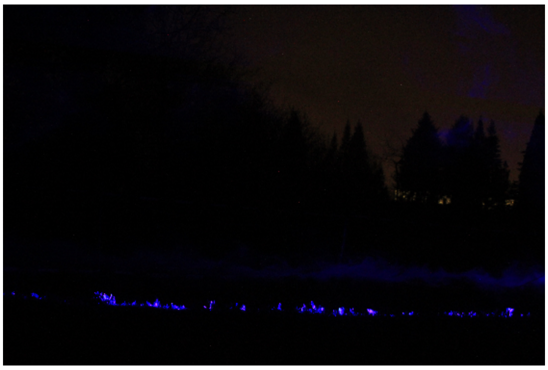


Figure 6.13 Cold air flow with shear instabilities (IMG_3804.jpg)

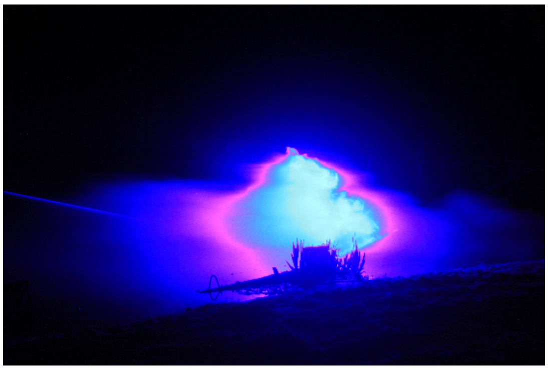


Figure 6.14 Fog over the lake looks like a mushroom cloud (IMG_3823.jpg)

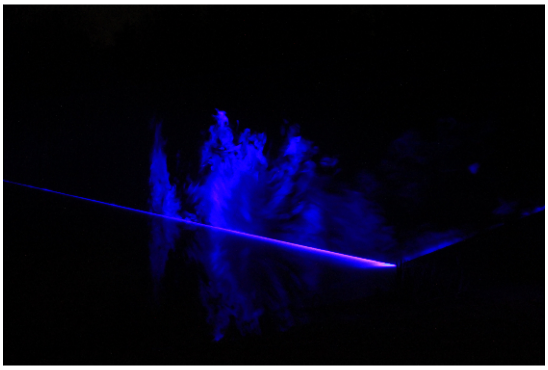


Figure 6.15 Convergence of flow over the lake and cold air flow (IMG_3829.jpg)

Table 6.2 Volumes in the series "University of Bayreuth, Micrometeorology, Arbeitsergebnisse"

Nr	Author(s)	Title	Year
1	Foken	Der Bayreuther Turbulenzknecht	01/1999
2	Foken	Methode zur Bestimmung der trockenen Deposition von Bor	02/1999
3	Liu	Error analysis of the modified Bowen ratio method	02/1999
4	Foken et al.	Nachfrostgefährdung des ÖBG	03/1999
5	Hierteis	Dokumentation des Experimentes Dlouhà Louka	03/1999
6	Mangold	Dokumentation des Experimentes am Standort Weidenbrunnen, Juli/August 1998	07/1999
7	Heinz et al.	Strukturanalyse der atmosphrischen Turbulenz mittels Wavelet-Verfahren zur Bestimmung von Austauschprozessen ber dem antarktischen Schelfeis	07/1999
8	Foken	Comparison of the sonic anemometer Young Model 81000 during VOITEX-99	10/1999
9	Foken et al.	Lufthygienisch-bioklimatische Kennzeichnung des oberen Egertales, Zwischenbericht 1999	11/1999
10	Sodemann	Stationsdatenbank zum BStMLU-Projekt Lufthygienisch-bioklimatische Kennzeichnung des oberen Egertales	03/2000
11	Neuner	Dokumentation zur Erstellung der meteorologischen Eingabedaten fr das Modell BEKLIMA	10/2000
12	Foken et al.	Dokumentation des Experimentes VOITEX-99	10/2000
13	Bruckmeier et al.	Documentation of the experiment EBEX-2000, July 20 to August 24, 2000	01/2001
14	Foken et al.	Lufthygienisch-bioklimatische Kennzeichnung des oberen Egertales	02/2001
15	Göckede	Die Verwendung des Footprint-Modells nach Schmid (1997) zur stabilitätsabhängigen Bestimmung der Rauhigkeitslänge	03/2001
16	Neuner	Berechnung der Evaporation im ÖBG (Universität Bayreuth) mit dem SVAT-Modell BEKLIMA	05/2001
17	Sodemann	Dokumentation der Software zur Bearbeitung der FINTUREX-Daten	08/2002
18	Göckede et al.	Dokumentation des Experiments STINHO-1	08/2002
19	Göckede et al.	Dokumentation des Experiments STINHO-2	12/2002
20	Göckede et al	Characterisation of a complex measuring site for flux measurements	12/2002
21	Liebethal	Strahlungsmessgerätevergleich während des Experiments STINHO-1	01/2003
22	Mauder et al.	Dokumentation des Experiments EVA_GRIPS	03/2003
23	Mauder et al.	Dokumentation des Experimentes LITFASS-2003, Dokumentation des Experimentes GRASATEM-2003	12/2003

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Nr	Author(s)	Title	Year
24	Thomas et al.	Documentation of the WALDATEM-2003 Experiment	05/2004
25	Göckede et al.	Qualitätsbegutachtung komplexer mikrometeorologischer Messstationen im Rahmen des VERTIKO-Projekts	11/2004
26	Mauder Foken	Documentation and instruction manual of the eddy covariance software package TK2	12/2004
27	Herold et al.	The OP-2 open path infrared gas analyser for CO2and H2O	01/2005
28	Ruppert	ATEM software for atmospheric turbulent exchange measurements using eddy covariance and relaxed eddy accumulation systems and Bayreuth whole-air REA system setup	04/2005
29	Foken (Ed.)	Klimatologische und mikrometeorologische Forschungen im Rahmen des Bayreuther Institutes fr Terrestrische Ökosystemforschung (BITÖK), 1989-2004	06/2005
30	Siebicke & Serafimovich	Ultraschallanemometer-berprfung im Windkanal der TU Dresden 2007	04/2007
31	Lüers & Bareiss	The Arctic Turbulence Experiment 2006 PART 1: Technical documentation of the ARCTEX 2006 campaign, May, 2nd to May, 20th 2006	07/2007
32	Lüers & Bareiss	The Arctic Turbulence Experiment 2006 PART 2: Visualization of near surface measurements during the ARCTEX 2006 campaign, May, 2nd to May, 20th 2006	07/2007
33	Bareiss & Lüers	The Arctic Turbulence Experiment 2006 PART 3: Aerological measurements during the ARCTEX 2006 campaign, May, 2nd to May, 20th 2006	07/2007
34	Metzger & Foken et al.	COPS experiment, Convective and orographically induced precipitation study, 01 June 2007 31 August 2007, Documentation	09/2007
35	Staudt & Foken	Documentation of reference data for the experimental areas of the Bayreuth Centre for Ecology and Environmental Research (BayCEER) at the Waldstein site	11/2007
36	Serafimovich et al.	ExchanGE processes in mountainous Regions (EGER): Documentation of the Intensive Observation Period (IOP1) September, 6^{th} to October, 7^{th} 2007	01/2008
37	Serafimovich et al.	ExchanGE processes in mountainous Regions (EGER): Documentation of the Intensive Observation Period (IOP2) June, 1^{st} to July, 15^{th} 2008	09/2008
38	Siebicke	Footprint synthesis for the FLUXNET site Waldstein/Weidenbrunnen (DE-Bay) during the EGER experiment	12/2008
39	Lüers & Foken	Jahresbericht 2008 zum Förderprojekt 01879- Untersuchung der Vernderung der Konzentration von Luftbeimengungen und Treibhausgasen im hohen Fichtelgebirge 2007 – 2013	01/2009

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Nr	Author(s)	Title	Year
40	Lüers & Foken (Ed.)	Proceedings of the International Conference of "Atmospheric Transport and Chemistry in Forest Ecosystems" Castle of Thurnau, Germany, Oct 5 to Oct 8, 2009	10/2009
41	Biermann et al.	Mesoscale circulations and Energy and gaS exchange Over the Tibetan Plateau – Documentation of the Micrometeorological Experiment, Nam Tso, Tibet 25th of June – 08th of August 2009	11/2009
42	Foken & Falke	Documentation and Instruction Manual for the Krypton Hygrometer Calibration Instrument	01/2010 Update 12/2011
43	Lüers & Foken	Jahresbericht 2009 zum Förderprojekt 01879 – Untersuchung der Veränderung der Konzentration von Luftbeimengungen und Treibhausgasen im hohen Fichtelgebirge 2007 – 2013	07/2010
44	Biermann et al.	Tibet Plateau Atmosphere-Ecology-Glaciology Cluster Joint Kobresia Ecosystem Experiment: Documentation of the first Intensive Observation Period (IOP 1) summer 2010 in Kema, Tibet	01/2011
45	Zhao et al.	Complex TERRain and ECOlogical Heterogeneity (TERRECO);WP 1-02: Spatial assessment of atmosphere-ecosystem exchanges via micrometeorological measurements, footprint modeling and mesoscale simulations; Documentation of the Observation Period May 12th to Nov. 8th, 2010, Haean, South Korea	03/2011
46	Mauder & Foken	Documentation and Instruction Manual of the Eddy-Covariance Software Package TK3	05/2011
47	Serafimovich et al.	ExchanGE processes in mountainous Regions (EGER)-Documentation of the Intensive Observation Period (IOP3) June, 13th to July, 26th 2011	11/2011
48	Hübner et al.	Documentation and Instruction Manual for the Horizontal Mobile Measuring System (HMMS)	12/2011
49	Lüers et al.	The Arctic Turbulence Experiment 2009 - additional laser Scintillometer measurement campaign 2009 at the Bayelva catchment on Svalbard: Technical documentation and visualization of the near surface measurements during the ARCTEX-2009 campaign, August, 10th to August, 20th 2009	02/2012
50	Foken	Klimawanderweg auf der Landesgartenschau in Bamberg 2012	04/2012
51	Ruppert et al.	Whole-air relaxed eddy accumulation for the measurement of isotope and trace-gas fluxes	05/2012

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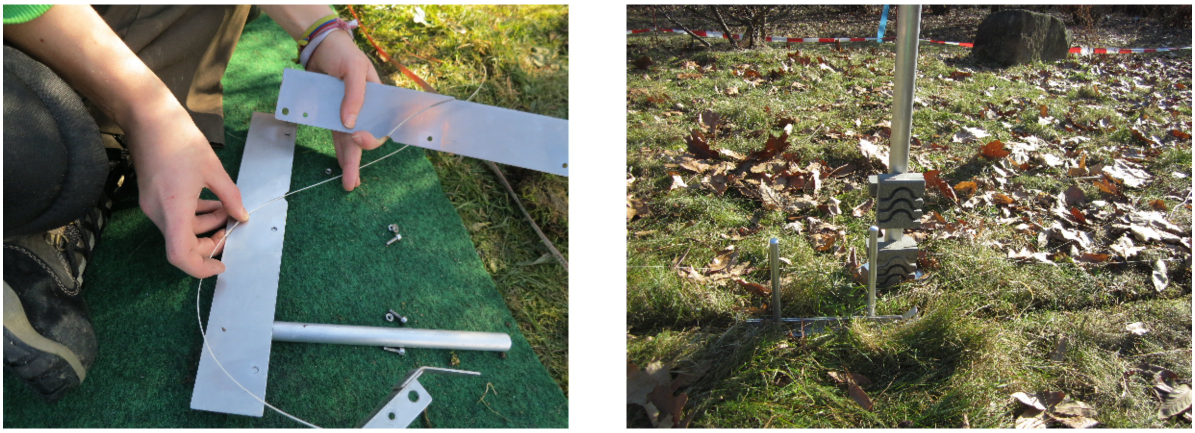
Nr	Author(s)	Title	Year
52	Foken	Jahresbericht 2010-11 zum Frderprojekt 01879 - Untersuchung der Veränderung der Konzentration von Luftbeimengungen und Treibhausgasen im hohen Fichtelgebirge 2007 – 2013	12/2012
53	Gerken et al.	Documentation of the Atmospheric Boundary Layer Experiment, Nam Tso, Tibet, 08^{th} of July – 08^{th} of August 2012	03/2013
54	Biermann (Ed.)	Tibet Plateau Atmosphere-Ecology-Glaciology Cluster Joint Kobresia Ecosystem Experiment: Documentation of the 2nd Intensive Observation Period (IOP 2) summer 2012 in KEMA, Tibet	05/2013
55	Babel et al.	Documentation of the EVENT-HMMS Experiment 2012 – Microclimatological effects of rain-out shelters within EVENT II	06/2013
56	Lüers et al.	160 Jahre Bayreuther Klimazeitreihe – Homogenisierung der Bayreuther Lufttemperatur- und Niederschlagsdaten	06/2014
57	Babel	An R routine for the simplified application of a footprint-based characterisation of a complex measuring site for flux measurements	06/2014
58	Lüers et al.	Application of a multi-step error filter for postprocessing of atmospheric flux and meteorological basic data	06/2014
59	Zhao et al.	GaFiR: a gap-filling package for ecosystem-atmosphere carbon dioxide flux and evapotranspiration data	06/2014
60	Foken et al.	Meteorologisches Instrumentenpraktikum an der Universität Bayreuth	08/2014
61	Foken & Lüers	Abschlussbericht zum Förderprojekt 01879 Untersuchung der Veränderung der Konzentration von Luftbeimengungen und Treibhausgasen im hohen Fichtelgebirge : 2007 2014	12/2014
62	Mauder & Foken	Documentation and Instruction Manual of the Eddy-Covariance Software Package TK3 (update)	07/2015

Appendix



(a) Inserting the fiber into the plow

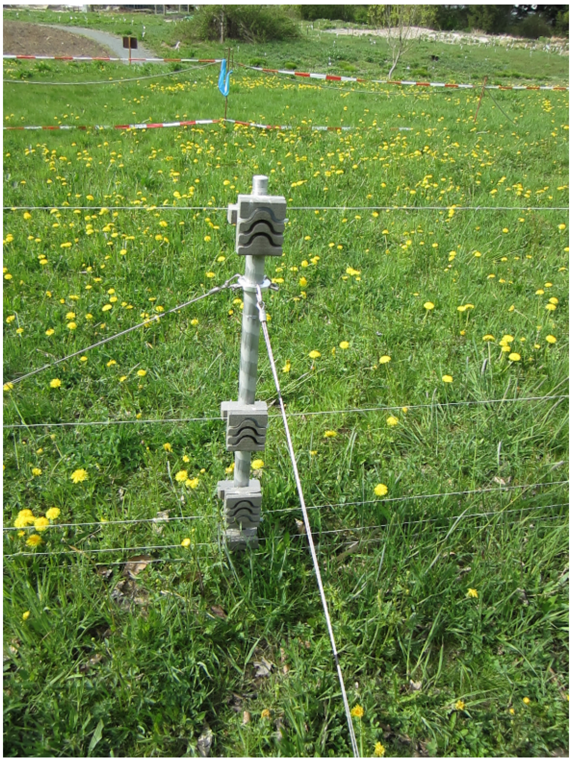
(b) Plow inserted into the ground

Figure A.1 self-designed plow for inserting the fiber into the ground

(a) Self-designed block with plastic tube

(b) Self-designed block without plastic tube, close-up view

Figure A.2 self-designed blocks to hold the fiber along the transect in the wanted height above ground and to facilitate strengthening of the fiber. The plastic tube additionally retains the fiber in the wanted position. The three grooves can be used to have three different fibers in one height without touching each other.



(a) self-designed poles with attached blocks and anchoring cables

(b) Earth nail to attach the anchoring cables

Figure A.3 self-designed poles with attached blocks and anchoring cables

(a) Pulley-holder attached to the small tower at point A of the transect

(b) Pulley-holder of 5 cm and 20 cm height at point A of the transect, close-up view

Figure A.4 self-designed pulley-holder at the tower at the lake

(a) Icebath for 'zero'-calibration

(b) Warmwaterbath with heater on the right side of the bath for 'span'-calibration

Figure A.5 Calibration baths at the transect