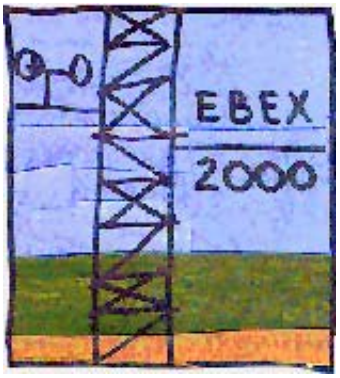


ENERGY BALANCE EXPERIMENT EBEX 2000

CONTRIBUTIONS OF THE UNIVERSITY OF BASEL DATA REPORT

including measurements of the TU Dresden and of the University of Padova

UNI
BASEL

R. Vogt, A. Christen, I. Lehner, E. van Gorsel

March 2001

1. Overview

All measurements of the University of Basel were carried out at Site 9 except the SODAR, which was operated near the trailers. Site 9 is in the SE corner of the whole EBEX-Array (30° 5.767' N, 119° 55.999' W WGS-84) and consisted of 5 towers. Three 6m-towers 9A, 9B and 9C were set up in a line aligned into mean wind (320°) and equipped with ultrasonic anemometers at two levels at 2.4 and 6.0 m. A 9 m profile tower with a temperature/humidity profile and cup anemometers at 6 levels was operated East of this line. NCAR operated another tower with one sonic (see Fig. 1):

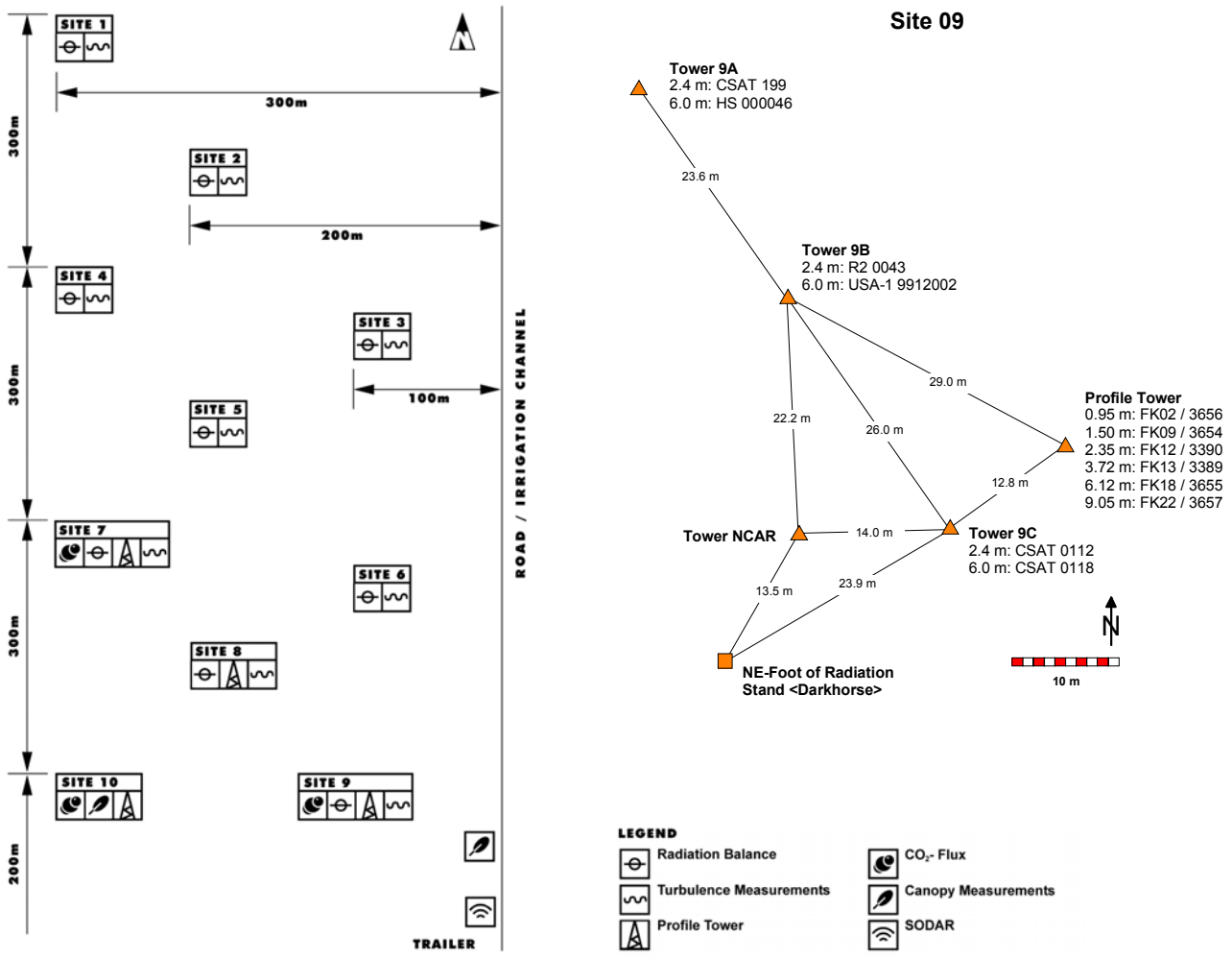


Fig. 1: Plan of the whole EBEX-Array (left) and a subset of Site 9 where the measurements of the University of Basel were carried out (right).

2. Radiation Stand

Nine radiation sensors with a total of 13 measurements were operated at the radiation stand at Site 9, three instruments by NCAR and six by the University of Basel. Table 1 gives an overview of the radiation sensors of the University of Basel. The measurements started at July 27 and were stopped August 26 2000. Data were logged with a sampling rate of 2 s by a Campbell Scientific 23X datalogger. Averages and standard deviations were written into memory every minute.

Tab. 1: Radiation measurements operated by the University of Basel during EBEX at Site 9. Symbols: ↓ = downward radiation, ↑ = upward radiation. AVG = Average Values, STD = Standard Deviation.

Position	Serial No.	Sensor	Measurement	Sampling Interval	Storage Interval	Calibration
R1	980098	Kipp & Zonen CNR1	↓ ↑ Shortwave Radiation ↓ ↑ Longwave Radiation	2 s	1 min AVG / STD	Manufacturer Calibration (1999)
R2	910004	Kipp & Zonen CM 21	↓ Shortwave Radiation	2 s	1 min AVG / STD	Recalibration at Kipp (8.4.1997)
R3	30323F2	Eppley PIR / WRC	↓ Longwave Radiation	2 s	1 min AVG / STD	WRC
R4	950239	Kipp & Zonen CM 21	↓ Shortwave Radiation	2 s	1 min AVG / STD	Calibration at WRC (3.12.1996)
R6	31207F3	Eppley PIR / WRC	↑ Longwave Radiation	2 s	1 min AVG / STD	WRC
R7	923939	Kipp & Zonen CM 11	↑ Shortwave Radiation	2 s	1 min AVG / STD	Manufacturer Calibration

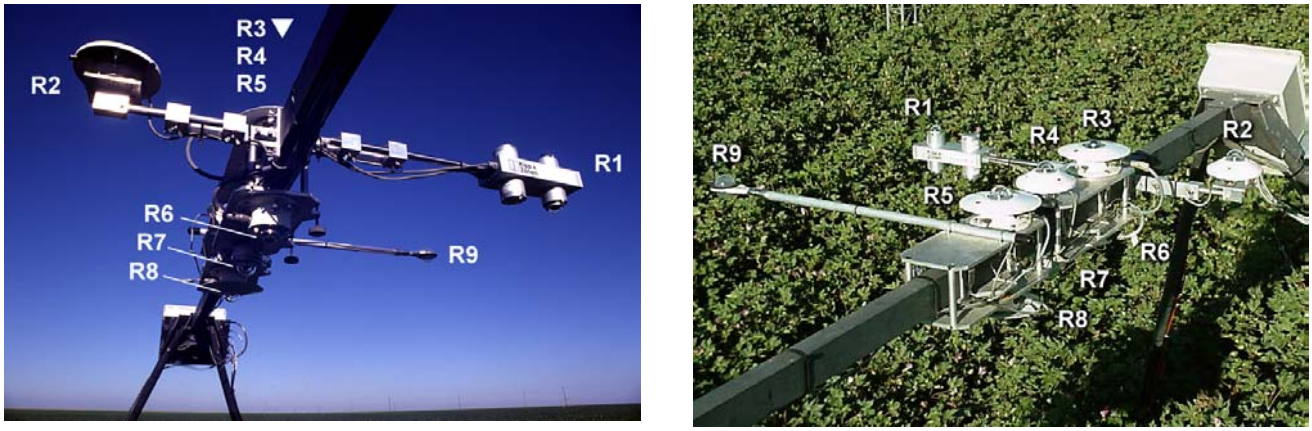


Fig. 2 and 3: Instrumentation of the radiation stand at Site 9 including the instruments operated by NCAR (R5, R8, R9). Left photo viewed towards E, right one towards WSW, the dark horse was aligned W-E.

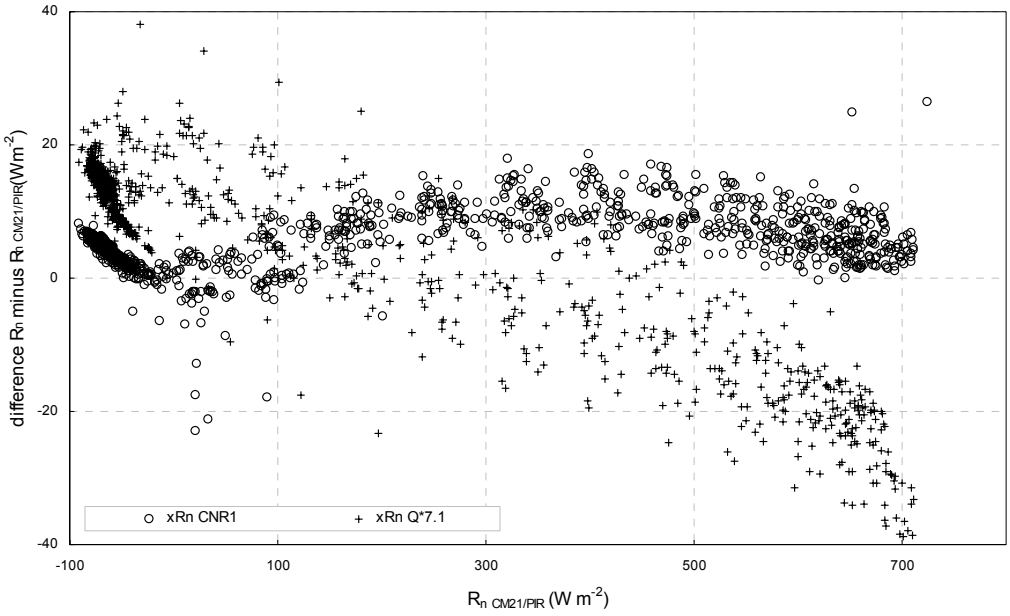


Fig. 4: Comparison of net radiation at Site 9. The system CM21(R4)/CM11(R7)/PIR(R3,R6) is compared to CNR1 (R7) and Q* (R9, NCAR) over the whole measurement period (30 min mean values).

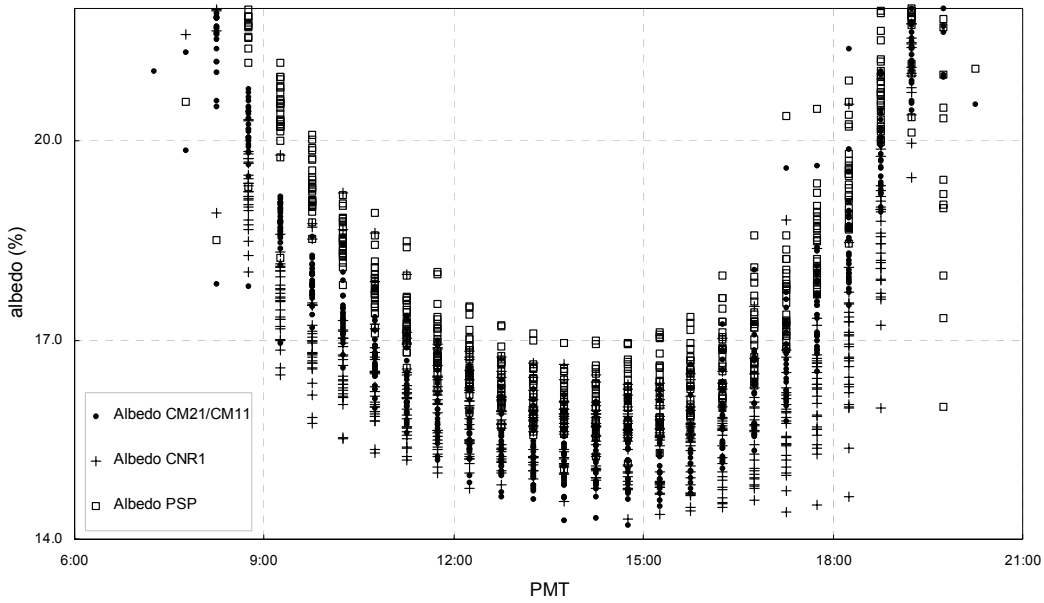


Fig. 5: Albedo in function of daytime at Site 9. Albedo calculated from the system CM21(R4)/CM11(R7), CNR1 (R7) and PSP (R5, R8, NCAR) are shown over the whole measurement period (30 min mean values).

3. Soil Measurements

Tab. 2: Soil heat flux and soil temperature measurements operated by the University of Basel during EBEX at Site 9 from July 27 to August 26. Symbols: AVG = Average Values, STD = Standard Deviation.

Serial No.	Sensor	Measurement	Position	Sampling Interval	Storage Interval
65638	Rimco HFP	Soil Heat Flux	4th furrow S of darkhorse feet	2 s	1 min AVG / STD
65640	Rimco HFP	Soil Heat Flux	1st furrow S of darkhorse feet	2 s	1 min AVG / STD
G0057	Rimco HFP	Soil Heat Flux	2nd ridge S of darkhorse feet, S-slope	2 s	1 min AVG / STD
65628	Rimco HFP	Soil Heat Flux	3rd ridge S of darkhorse feet, N-slope	2 s	1 min AVG / STD
CBT16 (15)	CS 107	Soil Temperature	4th furrow S of darkhorse feet	2 s	1 min AVG / STD
CBT19 (10)	CS 107	Soil Temperature	1st furrow S of darkhorse feet	2 s	1 min AVG / STD
CBT18 (8)	CS 107	Soil Temperature	2nd ridge S of darkhorse feet, S-slope	2 s	1 min AVG / STD
CBT17 (5)	CS 107	Soil Temperature	3rd ridge S of darkhorse feet, N-slope	2 s	1 min AVG / STD

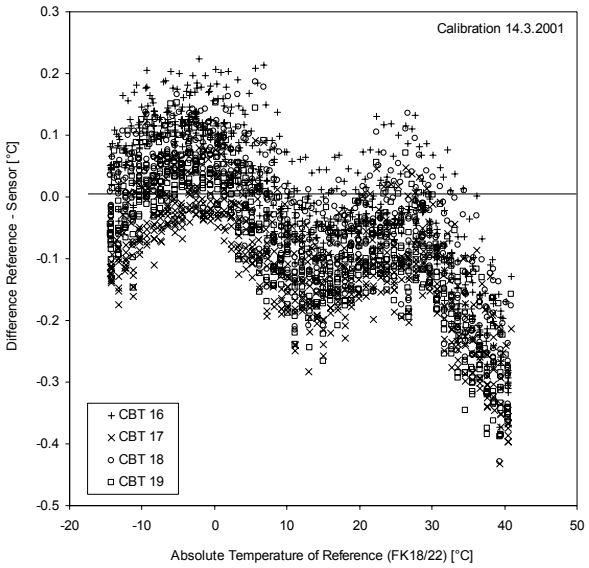


Fig. 6: The four soil thermistors which were operated during EBEX in the calibration bath of the University of Basel. The plot shows the temperature dependence of the measurements.

4. Temperature and Humidity Profile

The 9 m tower was equipped with ventilated psychrometers at six levels and operated from July 31 3:30 to August 23 18:00 UTC with some gaps due to power failures from July 31 to August 4. Before the operational period, a field intercomparison was carried out over 4 days with all six psychrometers mounted at same height (July 27 to July 30). Data were logged with a sampling rate of 2 s by a Campbell Scientific CR10 datalogger equipped with a multiplexer AM 416. Averages and standard deviations were stored every minute.

Tab. 3: Psychrometer profile measurements operated by the University of Basel during EBEX at Site 9. Symbols: AVG = Average Values, STD = Standard Deviation.

Height of booms	Serial No.	Sensor	Measurement	Sampling Interval	Storage Interval	Calibration
0.95 m	FK02	Psychrometer	Temperature / humidity	2 s	1 min AVG / STD	DRT: 22.2.2001 (22/23) WBT: 22.2.2001 (22/23)
1.50 m	FK09	Psychrometer	Temperature / humidity	2 s	1 min AVG / STD	DRT: 22.2.2001 (22/23) WBT: 22.2.2001 (22/23)
2.35 m	FK12	Psychrometer	Temperature / humidity	2 s	1 min AVG / STD	DRT: 2.2.1999 (KV98) WBT: 2.2.1999 (KV98)
3.72 m	FK13	Psychrometer	Temperature / humidity	2 s	1 min AVG / STD	DRT: 22.2.2001 (22/23) WBT: 2.2.1999 (KV98)
6.12 m	FK18	Psychrometer	Temperature / humidity	2 s	1 min AVG / STD	DRT: 29.11.1996 (9/18) WBT: 29.11.1996 (9/18)
9.05 m	FK22	Psychrometer	Temperature / humidity	2 s	1 min AVG / STD	DRT: 5.12.1996 (5/19) WBT: 22.2.2001 (22/23)

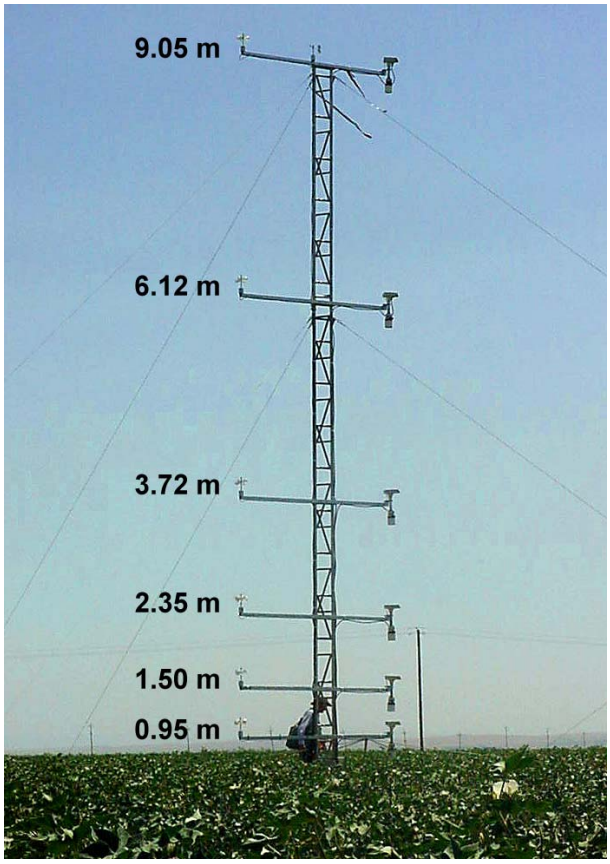


Fig. 7: Profile tower during field operation viewed towards S

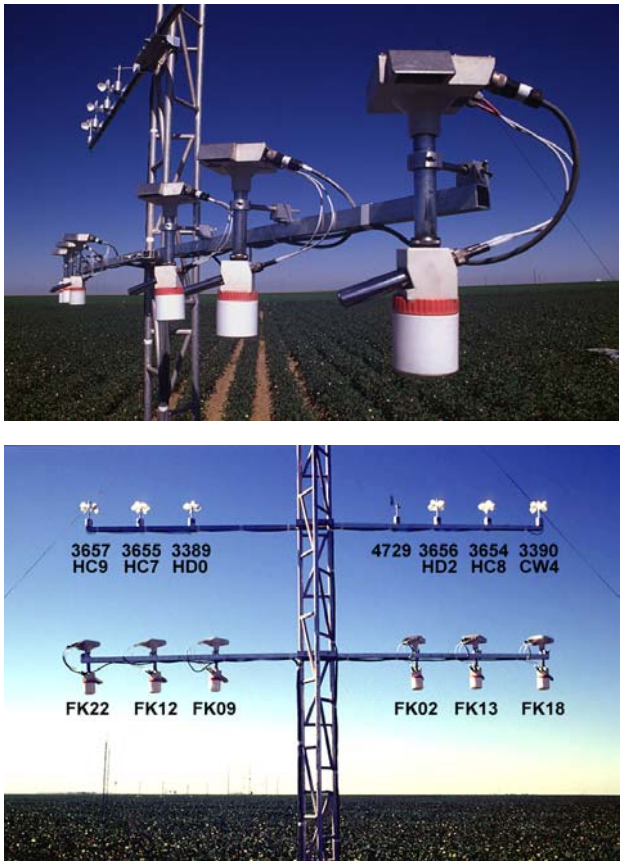


Fig 8 and 9: Setup of the intercomparison of psychrometers and cup anemometers. Upper photo viewed towards E, lower photo towards NNW.

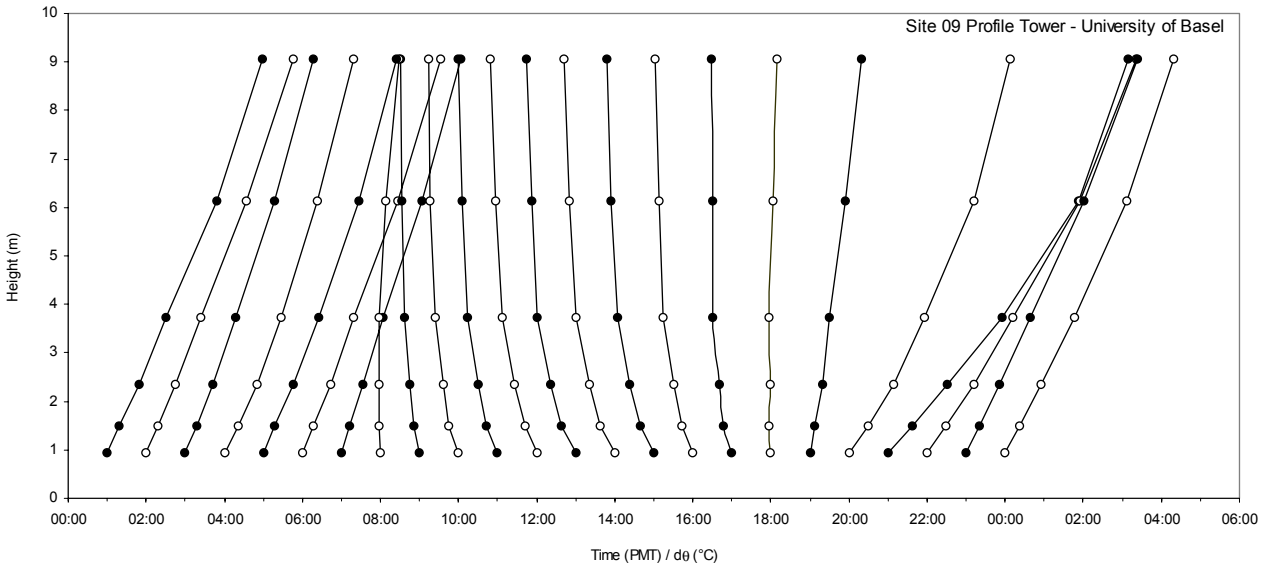


Fig. 10: Mean potential temperature θ gradients in function of daytime. Mean values over 14 days are shown (August 4 2000 00:00 to August 23 00:00 PMT). 1 hour corresponds to 1 K potential temperature difference. Positive lapse rates are drawn to the right, negative to the left.

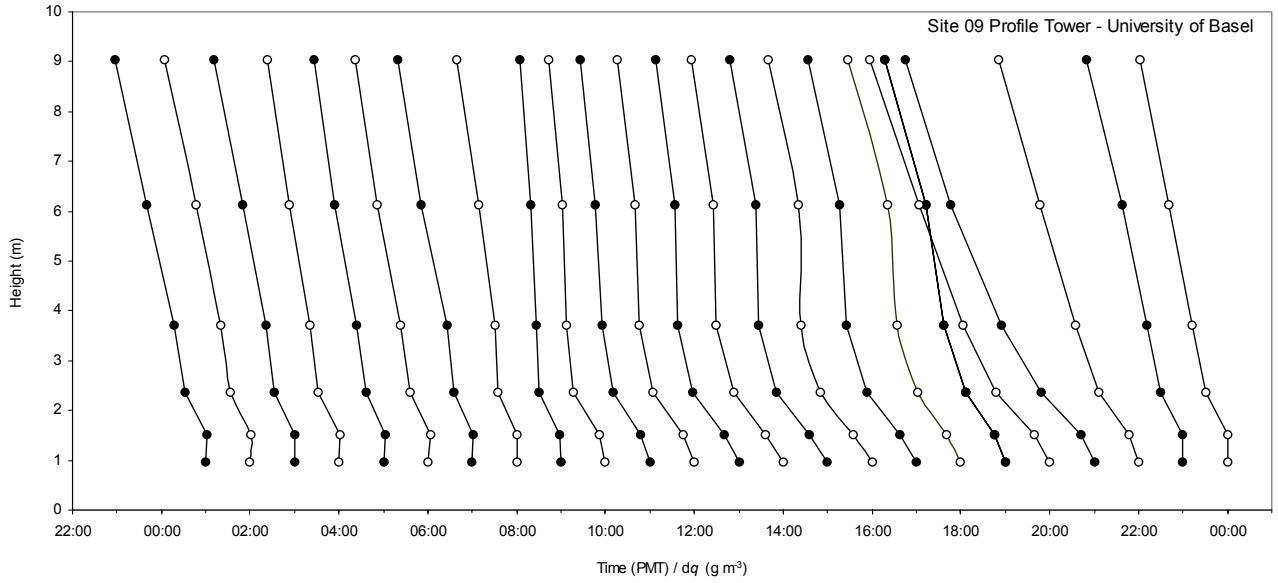


Fig. 11: Mean absolute humidity gradients in function of daytime. Mean values over 17 days are shown (August 4 2000 00:00 to August 23 00:00 PMT, without August 11 and 12). 1 hour corresponds to 1 g m^{-3} absolute humidity difference . Positive gradients are drawn to the right, negative to the left.

5. Cup Anemometer Profile

At the same tower and in same heights as the temperature/humidity profile also a cup anemometer wind profile with light cups (Vector Instruments A101L) was operated. On top at 9m a wind vane (W200P) was installed (See Fig. 7).

Tab. 4: Wind profile measurements operated by the University of Basel during EBEX at Site 9. Symbols: AVG = Average Values, STD = Standard Deviation.

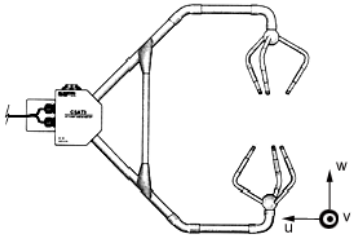
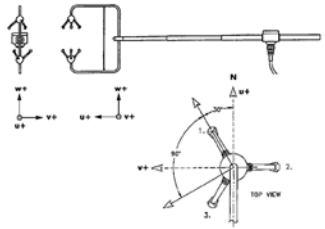
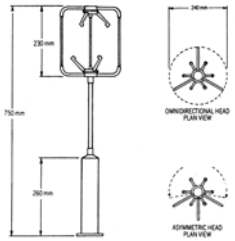
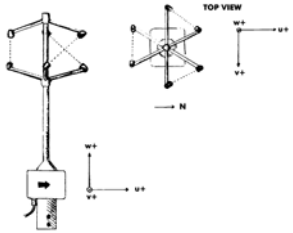
Height of booms	Animuth from N	Serial No.	ID Cup	Sensor	Measurement	Sampling Interval	Storage Interval
0.95 m	-	3656	HD2	Vector Instruments A101L	Wind velocity	2 s	1 min AVG / STD
1.50 m	-	3654	HC8	Vector Instruments A101L	Wind velocity	2 s	1 min AVG / STD
2.35 m	-	3390	CW4	Vector Instruments A101L	Wind velocity	2 s	1 min AVG / STD
3.72 m	-	3389	HD0	Vector Instruments A101L	Wind velocity	2 s	1 min AVG / STD
6.12 m	-	3655	HC7	Vector Instruments A101L	Wind velocity	2 s	1 min AVG / STD
9.05 m	-	3657	HC9 / 3X0 [2]	Vector Instruments A101L	Wind velocity	2 s	1 min AVG / STD
9.05 m	142°	4729	-	Vector Instruments W200P	Wind direction	2 s	1 min AVG / STD

[2] Change between HC9 and 3X0 on August 17 1:00 UTC.

6. Ultrasonic Anemometers

The three 6 m-towers 9A, 9B and 9C (see Fig. 1) were equipped with ultrasonic anemometers at 2.4 and 6.0m according to Tab. 5. The sonics at position A2 and B1 were both equipped with a fast hygrometer of type Campbell Scientific Krypton KH20. The system at B2 was run with a LICOR 7500 open path CO_2/H_2O analyzer.

All six sonics were collected via RS232 with PC (PIP6 / PIP5) using Labview 5.1. 20 Hz raw data of all sonics were written to disk and kept for further analysis. Raw data of the sonics at tower 9C (2 CSAT 3) were additionally streamed to the NCAR system, and mean values of the METEK USA-1 (TU Dresden) were collected in parallel by a 23X from TU Dresden.

Sensor	Head Geometry	Specification	North Definition	Data Coordinate System
Campbell CSAT 3 **A1, C1, C2** Campbell Scientific, Inc.		3-axis anemometer-thermometer 116 mm path length 60 Hz internal sampling rate 20 Hz data output rate No analog inputs RS 232 and analog output	Sonic North (0°) points from the fixing/spar in direction to the sensor head	right handed u+ axis points toward 180° (sonic S) v+ axis points toward 90° (sonic E) w+ axis points upward
Gill HS **A2** Gill Instruments, Ltd.		3-axis anemometer-thermometer 153 mm path length 100 Hz internal sampling rate 20 Hz data output rate 6 analog inputs (100 Hz) RS 232 and analog output	Sonic North (0°) points along the spar in direction to the sensor head	right handed *"spar alignment" (along spar)* u+ axis points toward 0° (sonic N) v+ axis points toward 270° (sonic W) w+ axis points upward *"axis alignment" (along transducer 1)* u+ axis points toward 330° v+ axis points toward 240°
Gill R2 **B1** Gill Instruments, Ltd.		3-axis anemometer-thermometer 147 mm path length 166.6 Hz internal sampling rate 20.8 Hz data output rate 5 analog inputs (10 Hz) RS 232 and analog output	Sonic North (0°) points in direction of the indicated North-arrow on the top of the instrument.	left handed u+ axis points toward 150° v+ axis points toward 240° w+ axis points upward
METEK USA-1 **B2** METEK Meteorologische Messtechnik GmbH		3-axis anemometer-thermometer 180 mm path length 100 Hz internal sampling rate 10/20 Hz data output rate 0/4 analog inputs RS 232 output	Sonic North (0°) points in direction of the indicated North-arrow on the side of the electronic box.	left handed *with no azimuth specified:* u+ axis points toward 0° (Sonic N) v+ axis points toward 90° (Sonic E) w+ axis points upward

Tab. 5: Ultrasonic anemometer types operated during EBEX at Site 9. Note that the METEK USA-1 involved had a slightly different design than shown in the figure.

All sonics (except METEK USA-1 9912002) were tested in a wind tunnel in March 1999 at ETH Zürich. There the sonics were exposed to 4 wind speeds (2, 4, 6, 8 m s^{-1}) by rotating them continuously around their vertical axis at eleven different tilt positions: (± 25°, ± 15°, ± 10°, ± 5°, ± 2.5°, 0°) using a tilting and rotation device. Two dimensional correction matrices were calculated from the wind tunnel data with a horizontal azimuth resolution of 4 degrees. These matrices are applied to the sonic data from EBEX.

Tab. 6: Ultrasonic anemometer measurements operated by the University of Basel, University of Padova and TU Dresden during EBEX at Site 9.

Pos	Height [1]	Azimuth from N	Serial No	Sensor	Measurements Calibration	Sampling / Storage	Analog Inputs
A1	2.4 m	323°	0199	CSI CSAT3	*u, v, w, θ* Wind tunnel matrix 1999	60 Hz / 20 Hz	-
A2	6.0 m	325°	000046	Gill HS	*u, v, w, θ, q, t_{s1}, t_{s2}* Wind tunnel matrix 1999	100 Hz / 20 Hz	Krypton KH20 # 1094 Heinmann #135 [1] Heinmann #134 [2]
B1	2.4 m	334°	0043	Gill R2	*u, v, w, θ, q* Wind tunnel matrix 1999	166.6 Hz / 20 Hz	Krypton KH20 # 1199
B2	6.0 m	356°	9912002	METEK USA-1	*u, v, w, θ, q, CO_2* Standard	20 Hz / 20 Hz	LICOR 7500
C1[3]	2.4 m	321°	0112	CSI CSAT3	*u, v, w, θ* Wind tunnel matrix 1999	60 Hz / 20 Hz	-
C2[3]	6.0 m	321°	0118	CSI CSAT3	*u, v, w, θ* Wind tunnel matrix 1999	60 Hz / 20 Hz	-

[1] Surface Temperature looking towards E.
[2] Surface Temperature looking towards W.
[3] Raw Data additionally collected by NCAR.
[4] Mean Data additionally collected by a Data Logger CSI of the TU Dresden (8 Hz).

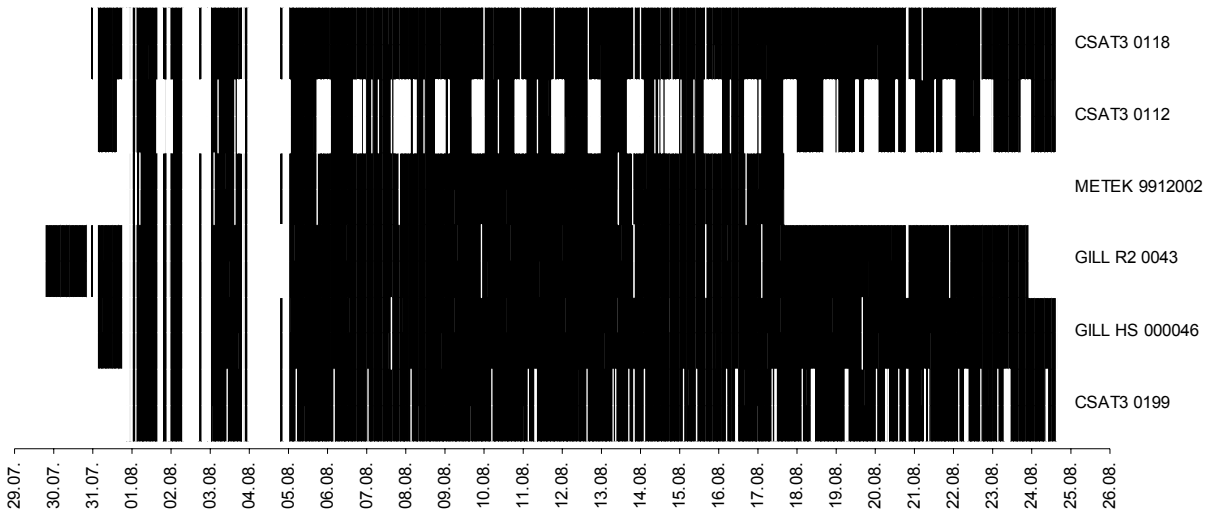


Fig. 12: Data availability of sonic data. Black areas indicate times where the sensor shows error free half hourly data blocks. White areas are data with acquisition errors or times where the sensors were not operated.

7. SODAR

From July 30 to August 23 a Flat Array SODAR (FAS64, Scintec) was operated by the University of Basel. The measurement and the analysis of the data was made by a specific software (FasRun 1.8).

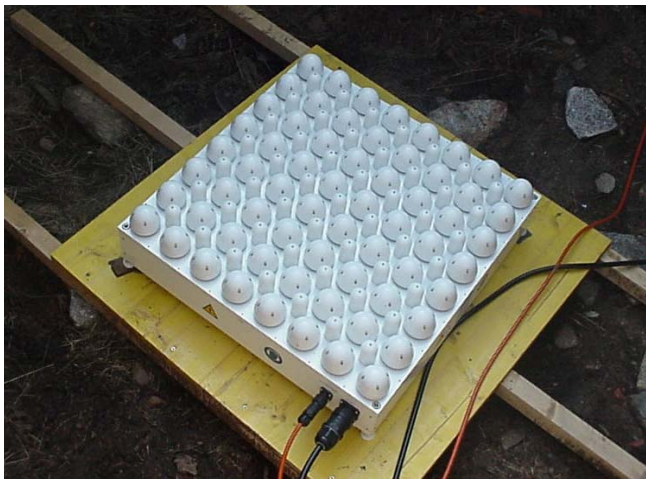


Fig. 13 and 14: Flat Array SODAR FAS64 and enclosure during operation in EBEX.