CEOP Reference Site Data Set Metadata Information

Reference Site:	**BALTEX Lindenberg**
Station Identifiers:	**Falkenberg / Forest**
Time Period:	**EOP3 / EOP4**
	October 01, 2002 to December 31, 2004
	(for Forest January 01, 2003 to December 31, 2004)

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Abstract

This document includes the metadata and information the user should be aware of when using any of the BALTEX Lindenberg reference site data from the CEOP Central Data Archive (CDA) submitted for the measurement period October 01, 2002 to December 31, 2004. It includes a description of the measurement sites, the instrumentation, the data collection and quality control procedures and some remarks pointing at peculiarities of specific data.

1. Data Set Overview

1.1 Site and Time Period

This description refers to the data from the BALTEX Lindenberg reference site for the period October 01, 2002 - 0030 UTC to December 31, 2004 - 2400 UTC. The BALTEX Lindenberg reference site comprises two independent stations named Falkenberg and Forest. These represent the two major land use types in the Lindenberg area (grassland / farmland, forest). Data from the Forest Station are available for the period January 01, 2003 - 0030 UTC to December 31, 2004 - 2400 UTC, only.

1.2 Site Co-ordinates

All surface ~, soil ~, tower ~ and flux measurements of the Falkenberg station have been performed at the Falkenberg Boundary Layer Field Site (in German: Grenzschichtmessfeld <GM> Falkenberg) of the Meteorological Observatory Lindenberg - Richard-Aßmann Observatory (MOL-RAO).
The co-ordinates of the GM Falkenberg are given by:

52° 10' 01" N	14° 07' 27" E	73 m NN
52.17° N	14.12° E	

The radiosondes are released at the site of the Meteorological Observatory Lindenberg – Richard-Aßmann Observatory (MOL-RAO) which is about 5 km to the North of the Falkenberg site.
The co-ordinates of the MOL are given by:

52° 12' 36" N	14° 07' 12" E	112 m NN
52.21° N	14.12° E	

The Forest Station is situated in a pine forest about 10 km to the West of the Falkenberg site. The co-ordinates of the Forest Station are given by:

52° 10' 56" N	13° 57' 14" E	49 m NN
52.18° N	13.95° E	

1.3 Site Operator

The Meteorological Observatory Lindenberg – Richard-Aßmann Observatory (MOL-RAO) is part of the business area Research and Development of the Deutscher Wetterdienst (DWD), the national meteorological service of Germany.

1.4 General Site Description

Landscape

Lindenberg is a small village situated in a rural landscape in the East of Germany about 65 km to the South-East of the centre of Berlin, the capital of Germany. A map of the area around Lindenberg is presented in Figure 1, and a view from a birds perspective across the area with the GM Falkenberg in the centre is shown in Figure 2.

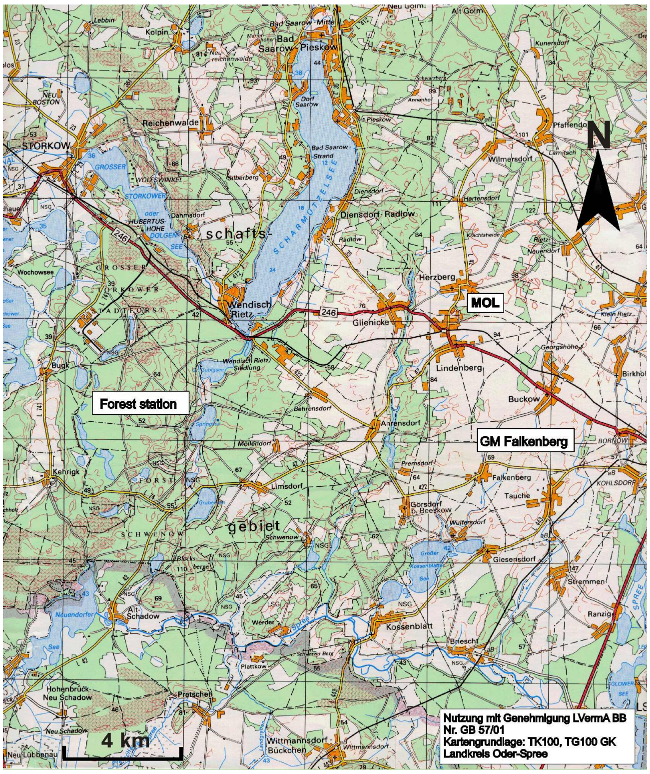

Figure 1 Map of the area around Lindenberg with the Falkenberg, Forest Station and observatory sites

Figure 2 Aerial view towards NW at the landscape around the boundary layer field site GM Falkenberg (the L-shaped area in the centre of the photo)

The landscape in the region around Lindenberg was formed by the inland glaciers during the last ice age exhibiting a slightly undulating surface with height differences of less than 100 m over distances of about 10 km. The lowest areas in the Spree river valley (which forms a wide bend around Lindenberg in the South, East and North at distances of between 10 and 20 km) are at about 40 m above sea level and a few hills north-east of Lindenberg reach 130 m above sea level. A number of small and medium-sized lakes are embedded in this landscape. Both, the orography and the mixture of surface types are rather typical for large parts of northern Central Europe south of the Baltic Sea.

Land Use

The land use in the area is dominated by forest and agricultural fields (40 - 45 % each), lakes cover 5-7 %, villages and traffic about 5 %. For the agricultural fields, triticale (a hybrid between wheat = *triticum* and rye = *secale*) is the dominating vegetation, significant parts of the farmland are also covered by grass, rape and maize. The land use classification in the vicinity of the two stations depends on the scale considered, a characterisation at different scales is given in Table 1.

Table 1 – Land use around the Lindenberg reference stations depending on scale

Land cover within	Falkenberg	Forest Station
100 m	Grassland	pine forest
500 m	grassland / cropland	pine forest
10 km	grassland / cropland – 60 % pine forest – 30 % open water – 5 % settlements – 5 %	grassland / cropland – 28 % pine forest – 60 % open water – 7 % settlements – 5 %

Soil

The soil type distribution in the area around Lindenberg is dominated by sandy soils. In the forested parts west of Lindenberg (see Figure 1), the sand reaches a depth of several meters. Dominating soil reference groups are brown soil - *Cambic Arenosol*, and *Ferric Podzol*. At the GM Falkenberg, sandy soils (pale soil - *Eutric Podzoluvisol*, brown soil - *Cambic Arenosol*) cover a layer of loam, which can be typically found at a depth of between 50 cm and 80 cm, locally even below.

Typical physical parameters of the soil are listed in Table 2

Table 2 - Physical parameters of the soil at the Lindenberg reference stations

layer no.	horizon	upper boundary [cm]	lower boundary [cm]	clay / poor clay [M%]	sand [M%]	dry density [g/cm^3]	pore volume [%]	field capacity *) [V%]	wilting point [V%]	hydraulic conductivity [cm/d]	soil heat capacity [*10^6 J/(K*m^3)]
Lindenberg – Falkenberg station											
1	Ap	0	30	26	74	1.6	37	16	4	110	1.32
2	Al	30	60	26	74	1.7	36	18	3	80	
3	Bt	60	120	40	60	1.7	34	24	11	20	
Lindenberg – Forest Station											
1	Ap	0	30	12	88	1.5	37	16	4	550	
2	Bs	30	60	8	92	1.6	37	16	4	550	
3	IIC	60	>150	8	92	1.6	37	16	4	550	

*) Soil physical parameters given in Table 2 are partly based on standard soil data tables, winter measurements at GM Falkenberg indicate a field capacity of about 23 ± 2 % for the upper two soil layers and of about 30 ± 3 % below.

Climate

Lindenberg represents moderate mid-latitude climate conditions at the transition between marine and continental influences. Monthly mean temperatures (1961-1990) vary between –1.2 deg C (January) and 17.9 deg C (July), and the mean annual precipitation sum is 563 mm. The annual precipitation pattern shows a main maximum during summertime and a secondary maximum in December with minima in February and October. The climate diagram is shown in Figure 3. During winter, the average number of days with minimum / maximum temperatures below 0 °C is 89 and 27, respectively.

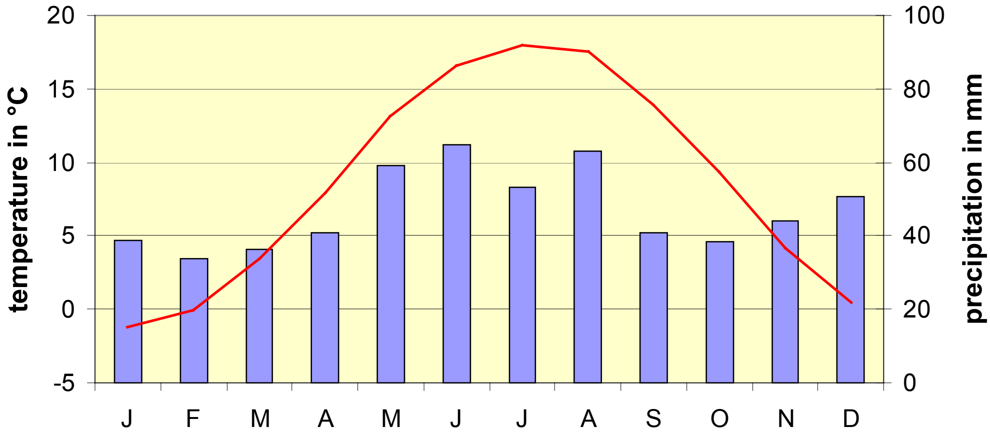

Figure 3 Climate Diagram for Lindenberg (1961-1990)

1.5 Site References

WWW: http://www.dwd.de/en/FundE/Observator/MOL/
Literature: Neisser et al. (2002), Beyrich et al. (2002)

2. Instrumentation Description

2.1 The Falkenberg Field Site

A photograph of the Falkenberg boundary layer field site and its infrastructure and measurement installations is shown in Figure 4. The terrain around the GM Falkenberg is slightly slanted from NNE towards SSW with height differences of less than 5 m over a distance of about 1 km. The central part of the field site is a flat meadow of 150 * 250 m^2 covered by short grass (managed regularly so that the vegetation height is always less then 20 cm), this area is surrounded by grassland and agricultural fields in the immediate vicinity, a small village is situated about 600 m to the SE (see also Figure 2), and a small, but heterogeneous forest area lies to the W and NW at about 1 to 1.5 km distance. The basic installation of the GM Falkenberg was performed in 1998, and the number of sensors and measurement systems has gradually been complemented over the following years.

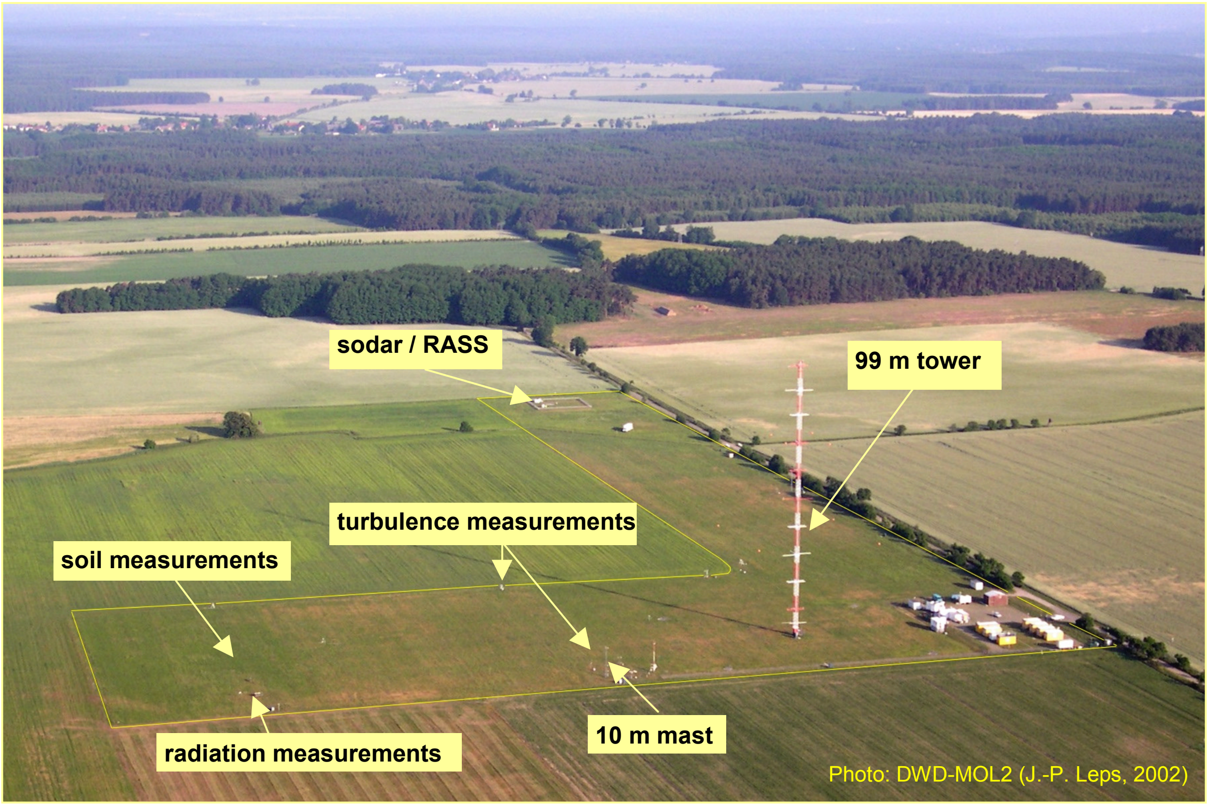

Figure 4 The DWD-MOL boundary layer field site (GM) Falkenberg towards WNW

The central measurement facility at GM Falkenberg is a 99m tower, a lattice construction of rectangular cross section with a side length of 1.2 m. It is equipped with booms to carry sensors at every 10 m, three booms are mounted at each level pointing approximately towards S, W, and N (with a shift of 11 deg). Standard meteorological profile measurements (wind speed, temperature, humidity) are performed at levels 10 m, 20 m, 40 m, 60 m, 80 m, and 98 m. Wind sensors are mounted on each of the three booms at these height levels in order to ensure that there is always at least one sensor not influenced from the structure of the tower. The measurement levels at 30 m, 50 m, 70 m, and 90 m are planned to be instrumented with turbulence sensors in the future, up to now turbulence measurements were realised during field experiments of several weeks duration in 1998, 2000, 2002, and 2003, respectively.

The basic meteorological data are measured at a 10 m lattice mast (Figure 5). This mast is of triangular shape with a side length of 40 cm, the wind sensors are mounted at booms of 1.5 m length oriented towards SW. The rain gauge and the pressure sensor are operated in the vicinity of this mast. The radiation measurements are performed at a bar construction erected about 120 m to the South of the 10 m mast (see Figure 4). Soil measurements are performed west of the radiation measurements.

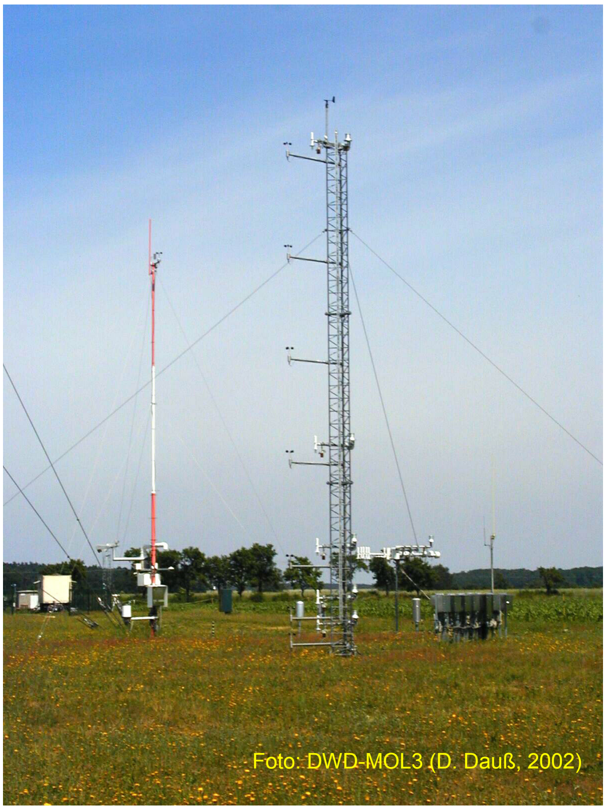

Figure 5 The 10 m mast for standard meteorological measurements from SSW

Flux measurements are performed using omni-directional sonic anemometer-thermometers. Two of these instruments are operated at the western wiring of the 10 m mast (S1) and at the western edge of the field site (S2, see Figure 4), respectively, providing flux data representative for the grassland area both for westerly and easterly wind directions. The sonics are mounted on top of tall tube masts (see Figure 6). Fast-response infrared hygrometers have been added to the sonics in spring 2003 for the direct measurement of the latent heat flux using the eddy-covariance method.

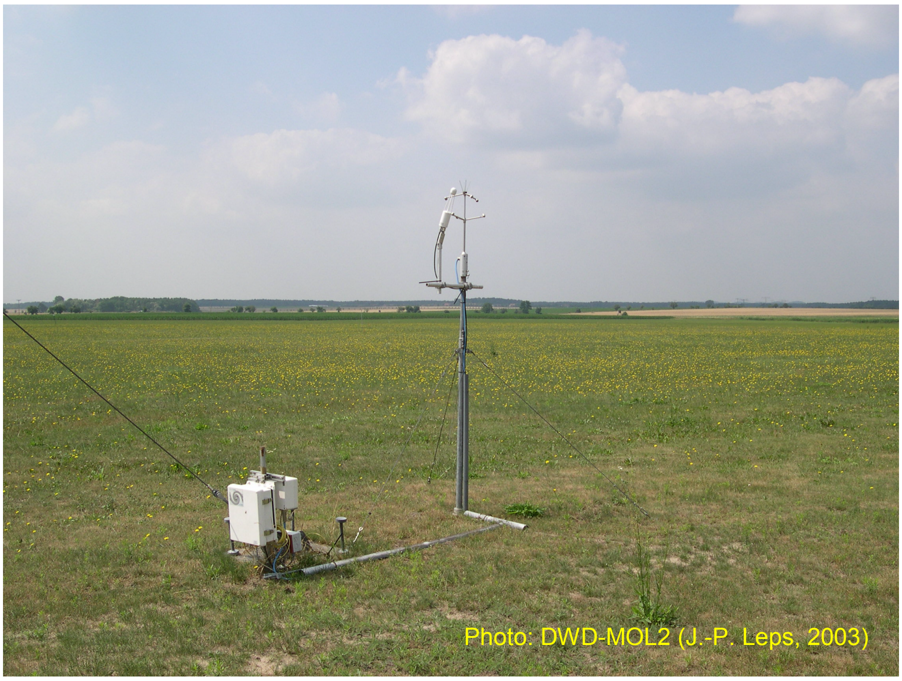

Figure 6 Turbulence measurement system S1 (USA-1 + LI7500 hygrometer)

2.2 The Forest Station

The Forest Station is situated about 10 km to the West of the GM Falkenberg (see Figure 1). A photograph across the forest with the forest tower and a birds view from directly above the tower site are presented in Figure 7 and Figure 8, respectively.

Figure 7 View towards NW across the pine forest with the Forest Station tower in the upper left quadrant

Figure 8 Birds view at the forest plantations around the Forest Station tower

The terrain at the Forest Station site is slightly slanted from East towards West with a height difference of about 10 m over a distance of 1 km. A small lake and a clearing of a few hectars in size are situated about half a kilometer to the West of the forest tower. The forest consists of regular sectors (see Figure 8) of pine plantations (*pinus sylvestris*). The mean tree height around the tower is 14 m, but it reaches up to 18 m in other (older) parts of the plantations in the vicinity of the forest tower. The mean stem diameter is about 14 cm and the number of stems is roughly 1800 per hectar.

The Forest Station in its present configuration has been set up in autumn, 2002. After a test phase the operational measurements started on December 01, 2002, data were delivered to the CEOP archive starting on January 01, 2003. The central measurement facility is a lattice tower construction of triangular shape with a side length of 40 cm (see Figure 9). Standard measurements of mean meteorological parameters (wind speed, temperature, humidity) are performed at nine levels: 2.25 m, 4.05 m, 9.50 m, 12.05 m, 14.55 m, 17.45 m, 21.00 m, 24.15 m, and 28.30 m, respectively. The first two levels represent the stem region, the next three levels are immediately below, inside and slightly above the crown region, and the upper four levels represent the above-canopy part of the atmospheric surface layer. Wind sensors are mounted on booms pointing towards SSE at 1.15 m distance to the tower. Radiation measurements are performed above the canopy, sensors are mounted at the tower. The turbulence measurements using eddy covariance instrumentation are carried out at the top of the tower. Soil measurements are performed along two different profiles close to the tower down to a depth of 1.5 m, the distance between the two profiles is about 1.5 m. The rain gauge for precipitation measurements is situated at the forest clearing about 500 m to the West of the tower.

Figure 9	The 30m tower at the Lindenberg Forest Station

2.3 Sensor List

A list of sensors used at the GM Falkenberg and at the Forest Station is given in Table 3.

Note that a replacement of the combined temperature-humidity sensor HMP-35D by the more recent model type HMP-45D was realised both at the 10m mast and at the 99m tower on March 23, 2004, and on April 14-15, 2004, respectively. At the forest tower, HMP-45D has been operated during complete CEOP – EOP3 and EOP4.

A few other sensor replacements (e.g., of the turbulence sensors and of the cup anemometers in connection with configuration updates or regular maintenance and calibration activities, respectively) were performed without changing the sensor type.

Operational radiosonde measurements at MOL are performed four times daily. Before July 01, 2004, release time was around 0445 UTC, 1045 UTC, 1645 UTC, and 2245 UTC, respectively and the soundings were performed using Vaisala RS-80-30 (RS-80-30E) radiosondes (Vaisala Oy, Finland - http://www.vaisala.com) and Vaisala PC-Cora ground equipment. Wind finding was done by radar tracking of the balloon using Gematronik 300WF radar. Since July 01, 2004, Vaisala RS-92-AGP radiosondes have been used in connection with Vaisala Digi-Cora III ground equipment and GPS wind finding. Release times have been slightly shifted to around 0515 UTC, 1115 UTC, 1715 UTC, and 2315 UTC, respectively.

For details on sensor specifications, see the web sites of the different manufacturers.

Table 3

Parameter	Measurement Height	Sensor	Measurement principle	Manufacturer	Reference	Remarks
basic meteorology						
• Temperature / Humidity	2 m (Forest: 2.55 m)	Frankenberger Psychrometer / HMP-35D/45D	Pt-100 / psychrometer Pt-100 / capacitive	Th. Friedrichs Vaisala	http://www.th-friedrichs.com http://www.vaisala.com	ventilated, radiation shielded
• wind speed	10 m (Forest none)	F460	cup	Climatronics	http://www.climatronics.com	
• wind direction	10 m (Forest none)	wind dir. transm.	vane	Thiess	http://www.thiesclima.com	
• pressure	1 m (Forest: 26.00 m)	PTB220A RPT410V	piezo-resistance piezo-resistance	Vaisala Lambrecht	http://www.vaisala.com http://www.lambrecht.net	
• precipitation	1 m	Pluvio	weighing	Ott Hydrometrie	http://www.ott-hydrometrie.de	
• snow depth	- (Forest none)	snow stick	manual reading			
Radiation						
• shortwave	2 m (Forest 28.95 m)	CM24	thermopile	Kipp & Zonen	http://www.kippzonen.com	ventilated
• longwave	2 m (Forest 28.95 m)	DDPIR	thermopile	Eppley	http://www.eppleylab.com	ventilated
• surface temp.	2 m (Forest 26.10 m)	KT 15.82D	pyro-electric	Heitronics	http://www.heitronics.com	
• Phar	2 m (Forest none)	LI190SZ	photo diode	LiCor	http://www.licor.com	
Soil						
• soil temperature	-5, **-10**, -15, **-20**, **-30**, -45, -50, **-60**, **-90**, -100, -120, **-150** cm	Pt-100	Pt-100	TMG		bold: measurement levels Forest
• soil moisture	-8, -15, **-30**, -45, **-60**, **-90** cm	TRIME EZ	TDR	IMKO	http://www.imko.de	bold: measurement levels Forest, also -10, -20, -150 cm
• soil heat flux	- 5, -10 cm	HP3	flux plate	RIMCO		
tower						
• temperature / humidity	40 m, 98 m (Forest: 14.55 m, 28.3 m)	Frankenberger Psychrometer / HMP-35D/45D	Pt-100 / psychrometer Pt-100 / capacitive	Th. Friedrichs Vaisala	http://www.th-friedrichs.com http://www.vaisala.com	ventilated, radiation shielded
• wind speed	40 m, 98 m (Forest: 14.55 m, 28.3 m)	wind transmitter F460	cup cup	Thiess Climatronics	http://www.thiesclima.com http://www.climatronics.com	
• wind direction	40 m, 98 m (Forest: 30.55 m)	wind dir. transm. USA-1	vane sonic	Thiess	 http://www.metek.de	
turbulent fluxes						
• momentum	2.4 m (Forest: 30.55 m)	USA-1	sonic	METEK	http://www.metek.de	
• sensible heat	2.4 m (Forest: 30.55 m)	USA-1	sonic	METEK		
• latent heat	2.4 m (Forest: 30.55 m)	LI-7500	infrared hygrometer	LiCor	http://www.licor.com	after April 01, 2003

3. Data Collection and Processing

3.1 Data Collection

Sampling and averaging times for the data are given in Table 4.

Table 4 - Sampling and averaging times of data for Lindenberg CEOP site

Parameter	Sampling Interval	Basic averaging Interval	30-minute data creation
basic meteorology			
• temperature	1 sec.	10 min.	arithm. average
• humidity	1 sec.	10 min.	arithm. average
• wind speed	1 sec.	10 min.	arithm. average
• wind direction	1 sec.	10 min.	vector average
• pressure	1 sec.	10 min.	arithm. average
• precipitation	1 min.	10 min.	sum
• snow depth	1 reading / day	none	none
radiation			
• shortwave	1 sec.	10 min.	arithm. average
• longwave	1 sec.	10 min.	arithm. average
• surface temp.	1 sec.	10 min.	arithm. average
• phar	1 sec.	10 min.	arithm. average
soil			
• soil temperature	1 sec.	10 min.	arithm. average
• soil moisture	1 sec. 10 min. (Forest)	10 min.	arithm. average
• soil heat flux	1 sec.	10 min.	arithm. average
tower			
• temperature	1 sec.	10 min.	arithm. average
• humidity	1 sec.	10 min.	arithm. average
• wind speed	1 sec.	10 min	arithm. average
• wind direction	1 sec.	10 min.	vector average
turbulent fluxes			
• momentum	0.05 sec. [1)]	10 min.	average acc. to eq. (6)
• sensible heat	0.05 sec. [1)]	10 min	
• latent heat	0.05 sec	10 min	
Radiosonde			
• pressure	10 sec.	none	does not apply
• temperature	10 sec.	none	does not apply
• humidity	10 sec	none	does not apply
• wind speed	30 sec.	none	does not apply
• wind direction	30 sec.	none	does not apply

[1)] Sampling interval of the turbulence measurements was 0.1 sec until January 22, 2003 at S1 and until April 15, 2003 at S2

3.2 Data Processing

In this section, a few remarks are given on specific steps in the data processing. Parameters for which no comments are given, were directly derived from the sensor output.

Temperature (in the meteo ~, soil ~ and tower data sets) was derived directly from Pt-100 resistance measurements (4-wire connection) using standard linearised Pt-100 characteristics.

Relative humidity (both in the surface and tower data sets) was measured simultaneously by HMP-35D / HMP-45D capacitive humidity sensor and by aspirated psychrometer during the warm season. A correction equation for the HMP was derived based on these parallel measurements by minimising the rmsd when compared to the psychrometer data. This

correction equation has then been regularly applied to the HMP measurements over the winter period. Relative humidity values > 100 % were set equal to 100 %.
According to the "CEOP Reference Site Data Set Procedures report" (see at http://www.joss.ucar.edu/ghp/ceopdm/), the following equations have been used to determine relative humidity from the psychrometer measurements:

(1) $$E_{Sat}[hPa] = 6.1078 * \exp\left\{\frac{17.08085 * t[°C]}{234.175 + t[°C]}\right\}$$

(2) $$e[hPa] = E_{Sat}[hPa] - 0.00066 * (1 + 0.00115 * t_{wet}[°C] * p[hPa] * (t[°C] - t_{wet}[°C]))$$

(3) $$RH[\%] = \frac{e[hPa]}{E_{Sat}[hPa]} * 100\%$$

Note that the coefficients in (1) are valid over water only, the use of (1) therefore implies small inaccuracies when calculating specific humidity and dew point temperature for winter measurements at temperatures below 0 deg C from the HMP measurements.

The ***surface wind*** data (10 m) at ***GM Falkenberg*** were taken from the measurements at the 10m mast (see Figure 5). Due to the mast construction there are flow distortion effects on the wind speed measurements for winds from the sector between 045 and 075 deg, these data are flagged correspondingly (see section 4). The ***tower wind*** data (measurements are available from three anemometers at the three booms of each level) at ***GM Falkenberg*** were processed as follows:

1. Determination of wind direction from the measurements at three booms by vector averaging of those measurements which differ by less than 10 deg - if all three measurements differ by > 10 deg, comparison with the wind at the neighbouring level and selection of the closest wind direction - if no data available from neighbouring level vector averaging of all three wind direction values.
2. Selection of representative wind speed measurement in dependence on wind direction.

For both, the surface and tower wind data, wind speed values less than 0.3 ms^{-1} were interpreted as calm and set to zero in the original 10-minutes data set, in this case wind direction is set equal to zero as well. Note that wind direction equal to zero marks calm conditions, while wind from North is indicated by a wind direction of 360 deg.
No ***surface wind*** data are reported for the ***Forest Station*** since the lower measurement levels are within the canopy. The ***tower wind*** data for the ***Forest Station*** include the measurements from the 14.55 m and 28.3 m levels, respectively. Wind direction data are available for the top of the tower only, u- and v- wind components have therefore been calculated for the upper level only. Due to the mast construction there are flow distortion effects on the wind speed measurements for winds from the sector between 290 and 350 deg, these data are flagged correspondingly (see section 4).

Shortwave radiation measurements were corrected for a mean zero-offset of the nighttime measurements (usually 1-3 Wm^{-2}, this correction is applied for the Falkenberg data only), radiation values < 2 Wm^{-2} were set equal to zero.

Longwave radiation (Rlw) was computed from the voltage measured at the thermopile (U_{emf}) using both measured body (T_B) and averaged dome temperatures (T_D) for correction (see Philipona et al., 1995):

(4) $$Rlw = \frac{U_{emf}}{c} + \sigma_B{}^4 - k\sigma\left(T_D{}^4 - T_B{}^4\right)$$

Net radiation was calculated considering the downward / upward components of the measured shortwave and longwave radiative fluxes.

Soil moisture (qsoil) at the ***GM Falkenberg*** was measured at the upper two levels by 4 (at – 8 cm) and 3 (at – 15 cm) sensors, respectively. Reported soil moisture values are an average of all measurements at a given depth which differ by not more than Max (5 Vol-%, 0.5 qsoil). ***Soil moisture*** data at the ***Forest Station*** are from profile 1 at –10 cm, –30 cm, and – 60 cm, data at –20 cm, –90 cm, and – 150 cm is from profile 2. ***Soil temperature*** data at the ***Forest Station*** down to 90 cm come from profile 1, the 150 cm data are from profile 2.

Soil heat flux at all levels was measured by 6 flux plates (GM Falkenberg) and 3 flux plates (Forest Station). Reported values are averages over all available sensors. During summer 2003, the number of flux plates available for the averaging decreased from six to four at the –10cm level at GM Falkenberg.

Turbulent momentum and sensible heat fluxes were determined from the high resolution measurements of the three wind components and of the sonic temperature by computing mean eddy covariances. Double rotation (see, e.g., Kaimal and Finnigan, 1994) has been applied to the <u'w'> and <v'w'> covariances, both covariances were used to compute friction velocity:

(5) $$u_* = \left(\langle u'w' \rangle^2 + \langle v'w' \rangle^2 \right)^{1/4}$$

The sensible heat flux has been corrected for buoyancy and cross-wind effects according to Schotanus et al. (1983) using the modified equations from Liu et al. (2001).

Turbulent latent heat flux for the period October 01, 2002 till March 31, 2003 was estimated with the modified Bowen ratio method after Liu and Foken (2001). This method uses the measured sensible heat flux (see above) and a Bowen ratio estimated from temperature and humidity measurements at two levels:

(7) $$l_v E = \frac{l_v \Delta T}{c_p \Delta q} H$$

Temperature and humidity measurements from the 0.5 m and 2 m levels at the 10m meteorological mast were used to determine the finite differences in (7). After April 01, 2003, fast-response humidity measurements were available from the operation of infrared hygrometers coupled to the sonic anemometer-thermometers at S1, S2, and at the Forest Station tower, respectively. The turbulent latent heat flux was then determined by computing the mean eddy-covariances between the vertical velocity and humidity fluctuations. The fluxes were corrected for density effects after Webb et al. (1980), and a mean correction for flux losses due to sensor separation and path averaging based on Moore (1986) was applied with different values for stable / unstable stratification.

Averaging of the ***turbulent fluxes*** from original 10-minute sampling intervals to half-hourly values was performed before applying rotations and corrections according to:

(6) $$\langle w'x' \rangle_{30} = \frac{1}{3}\sum_{i=1}^{3} \langle w'x' \rangle_{10,i} + \frac{1}{3}\sum_{i=1}^{3} \overline{w}_{10,i}\,\overline{x}_{10,i} - \frac{1}{9}\sum_{i=1}^{3} \overline{w}_{10,i} \sum_{i=1}^{3} \overline{x}_{10,i}$$

A composite flux data set has been created from the measurements with the two sonics (see section 2.2) at the ***GM Falkenberg*** taking into account the corresponding fetch conditions. The following rules have been applied:

wind direction from sector > 000...010 deg: data were taken from S1
wind direction from sector > 010...030 deg: fluxes from S1 and S2 were averaged

wind direction from sector > 030...170 deg: data were taken from S2
wind direction from sector > 170...190 deg: fluxes from S1 and S2 were averaged
wind direction from sector > 190...360 deg: data were taken from S1.

Bad data were replaced by the measurements from the other site if a lower quality flag was assigned to these data.

Radiosonde humidity measurements at MOL undergo an elaborated data processing procedure. This covers the following steps.

- ground preparation (100% RH test), ground check and correction
- temperature correction
- sensor response time correction
- detection of sensor icing and deletion of humidity values under icing conditions.

For details see Leiterer et al. (2004).

Other derived parameters were computed according to the equations given in the CEOP Reference Site Data Set Procedures Report.

4. Quality control procedures

The quality control algorithm of the field data covers several steps. For most of the data quick-look plots are created regularly. Obvious outliers identified in these plots are flagged manually.

As a second step, an automatic range test is performed for all measured parameters with the acceptance threshold values given in Table 5.

Table 5 - Acceptance range limits for automatic data quality control		
Parameter	lower limit	upper limit
basic meteorology		
• temperature	– 30 deg C	+ 50 deg C
• humidity	10 %	100 %
• wind speed	0.3 ms^{-1}	30 ms^{-1}
• wind direction	1 deg	360 deg
• pressure	950 hPa	1040 hPa
• precipitation	0 mm	40 mm
radiation		
• shortwave down	0 Wm^{-2}	1230 Wm^{-2}
• shortwave up	0 Wm^{-2}	800 Wm^{-2}
• longwave down	150 Wm^{-2}	500 Wm^{-2}
• longwave up	150 Wm^{-2}	700 Wm^{-2}
• surface temp.	– 40 deg C	+ 60 deg C
• phar down	0 $\mu mol*m^{-2}*s^{-1}$	2500 $\mu mol*m^{-2}*s^{-1}$
• phar up	0 $\mu mol*m^{-2}*s^{-1}$	1600 $\mu mol*m^{-2}*s^{-1}$
soil		
• soil temperature	– 30 deg C	+ 50 deg C
• soil moisture	3 Vol-%	50 Vol-%
• soil heat flux	– 100 Wm^{-2}	+ 200 Wm^{-2}
tower		
• temperature	– 30 deg C	+ 50 deg C
• humidity	10 %	100 %
• wind speed	0.3 ms^{-1}	30 ms^{-1}
• wind direction	1 deg	360 deg
turbulent fluxes		
• friction velocity	0.01 ms^{-1}	3 ms^{-1}
• sensible heat	– 250 Wm^{-2}	+ 750 Wm^{-2}
• latent heat	– 250 Wm^{-2}	+ 750 Wm^{-2}

Measured data exceeding the limits given in Table 5 are set to -9999.99 and get Flag = M.

The third step of the QC algorithm consists of a number of automatic tests, including sensor inter-comparison or physically based parameter check. An overview on these tests is given in Table 6.

Measured data that do not meet the physically based tests get Flag = D.

Finally, a manual control of those data which were automatically given Flag = D is performed. If auxiliary measurements and / or physical arguments give reason for acceptance of the data, Flag = D is transformed to Flag = G, otherwise Flag = D is kept or set to Flag = B.

Table 6 - Physically based tests	
Parameter	comparison / physically based data tests
basic meteorology • temperature • humidity • wind speed • wind direction • pressure • precipitation	 comparison psychrometer vs. HMP, Flag = G if $\Delta T < 1$ K comparison psychrometer vs. HMP, Flag = G if $\Delta RH < 5$ % Flag = G if V (10 m) > V (8 m) - - -
radiation • shortwave down / shortwave up • longwave down • longwave up • surface temp. • phar down / phar up	 Falkenberg: Flag = G if albedo: 0.15 ... 0.30 (0.15 ... 1.00 in case of snow) Forest: Flag = G if albedo: 0.07 ... 0.13 (0.00 ... 1.00 in case of snow) These limits apply if shortwave_down ≥ 50 Wm^{-2} Flag = G if $0.6 * \sigma T_{2m}^4$ < downward longwave radiation < $1.0 * \sigma T_{2m}^4$ Flag = G if $\sigma (T_{2m} - 5 K)^4$ < upward longwave radiation < $\sigma (T_{2m} + 5 K)^4$ Flag = G if $\sigma (T_{surf} - 3 K)^4$ < upward longwave radiation < $\sigma (T_{surf} + 3 K)^4$ Flag = G if phar albedo: 0.12 ... 0.30 (0.12 ... 1.00 in case of snow) (GM Falkenberg only)
soil • soil temperature • soil moisture • soil heat flux	 Flag = G if difference between neighbouring levels doesn't exceed height-dependent threshold (GM Falkenberg) or if difference between profile 1 and profile 2 is smaller than 2 K (at –5 cm) respectively 0.5 K (below –5 cm) at Forest Station Flag = G if difference between sensors < 5 Vol-% or 50 % of the measured value (upper levels at GM Falkenberg only) and if difference in time between two subsequent values < 5 Vol-% Flag = G if difference between sensors < 30 % (tested only if $\|G\| > 30$ Wm^{-2})
tower • temperature • humidity • wind speed • wind direction	 Comparison psychrometer vs. HMP, Flag = G if $\Delta T < 0.5$ K Comparison psychrometer vs. HMP, Flag = G if $\Delta RH < 5$ % GM Falkenberg: Flag = G if -1 $ms^{-1} < \Delta V < +2$ ms^{-1} per 20 m height difference Forest / 14.55 m: Flag = G if V (14.55 m) = 0.6 .. 0.85 V (17.45m) Forest / 28.3 m: Flag = G if V (24.15 m) = 0.85 .. 1.00 V (28.3 m) GM Falkenberg: Flag = G if wind direction difference of at least 2 booms < 10 deg
turbulent fluxes • friction velocity • sensible heat • latent heat	 Flag = G if $u_* < 0.15 * V$ (if V > 3 ms^{-1}) and if σ_w / u_* is within certain limits Flag = G if sign (H) matches sign ($\Delta T/\Delta z$) and if (H + LE) < (net radiation - soil heat flux) Flag = G if sign (LE) matches sign ($\Delta q/\Delta z$) and if (H + LE) < (net radiation - soil heat flux), for LE > 50 Wm^{-2}

It should be remarked that all tests are generally performed on the 10min averaged original data.

In addition to the tests described above, the wind speed measurements in the surface data set and the turbulent flux values are generally given Flag = D if distortion of the measurement from tower constructions or nearby obstacles has to be assumed. For the wind measurement at 10 m (GM Falkenberg) this holds for the wind direction sector 045 deg to 075 deg, tower wind data from the Forest Station suffer from flow distortion effects for the wind direction sector 290 deg to 350 deg. For the turbulent fluxes from GM Falkenberg flow distortion and poorly defined fetch conditions were considered for the wind direction sector 330 deg to 060 deg (over N) over the year 2003. In January 2004, the sensor mounting at S2 has been modified such that the flux composite does not contain any flow distortion sectors (see section 6). Turbulence measurements at the Forest Station tower experience flow distortion of the sonic measurements from the infrared hygrometer mounted nearby for a wind direction sector 330 deg to 030 deg.

The flagging rules applied when producing the 30min averages for the CEOP data set from the original 10min averages are summarised in Table 7.

Table 7 - Flagging rules for 30minute averaged data				
Flag i	Flag j	Flag k	Flag (ijk)	average covers
G	G	G	G	30 minutes
G	G	D, U	G	30 minutes
G	D, U	D, U	D, U	30 minutes
D, U	D, U	D, U	D, U	30 minutes
G	G	M	G	20 minutes
G	M	M	G	10 minutes
D, U	D, U	M	D, U	20 minutes
D, U	M	M	D, U	10 minutes
M	M	M	M	no data

5. Gap Filling Procedures

No gap filling procedures using model assumptions have been applied for the data period October 01, 2002 to December 31, 2004.

6. Data Remarks

This section gives specific additional information on different parameters the user should be aware of when using the data.

General
Due to a power failure at the Forest Station no data (except of the precipitation sensor) are available for the period Mar 28, 2003, 2300 UTC to March 31, 2003, 0830 UTC. Data logger problems caused general data losses at the Forest Station on December 08-09, 2003.

Humidity
Relative Humidity (both in the surface and tower data sets) was measured simultaneously by HMP-35/45 capacitive humidity sensor and by aspirated psychrometer during the warm season. If available, the psychrometer data were selected for the CEOP data set. The time intervals for which the humidity data are based on the psychrometer measurements are given in Table 8.

Table 8 - Availability of psychrometer humidity data

Year	GM Falkenberg		Forest Station	
	Surface data set	Tower data set	Surface data set	Tower data set
2002	Oct 01 till Oct 31	Oct 01 till Oct 31	-	-
2003	Mar 27 till Nov 04	Apr 01 till Nov 03	Apr 16 till Sep 02 Sep 19 till Nov 19	Apr 16 till Sep 02 Sep 24 till Nov 19
2004	Mar 29 till Oct 31	Jun 24 till Sep 05 Sep 24 till Oct 31	Apr 01 till Nov 14	Apr 01 till Nov 14

For the rest of the time, corrected HMP measurements (see section 3.2) were used.
HMP measurements had to be included in the data set as well during periods with (mainly nighttime) temperatures below freezing point when the psychrometer wet bulb temperature measurement becomes unreliable. This concerns periods in the second half of October and first half of November both in 2003 and 2004, during the first half of April, 2004, and also on May 14, 2004.
Periods of missing psychrometer measurements indicated in Table 8 during April to June 2004, and during September 2004 (at the GM Falkenberg tower) and also during September 2003 (at the Forest Station) were due to problems with the proper wetting of new charges of wicks applied for the wet-bulb temperature measurements with the Frankenberger psychrometers.

Wind Speed
No correction for overspeeding was performed on the cup anemometer measurements.
The wind speed measurement at 10 m (reported in the surface data set of the GM Falkenberg station) is influenced by the mast construction for wind directions from the sector 45° ... 75°, measurements are given Flag = D. Wind speed measurements at the Forest Station tower are influenced by the mast construction for wind directions from the sector 290° .. 350°, measurements are given Flag = D.
Icing during winter conditions caused a series of missing data values in the GM Falkenberg surface data set and in the Forest Station tower data set, especially during the periods 20021217-20021221, 20021230-20030106, 20030111-2030113, 20030129-20030206, 20031221-20031223, 20040102-20040105, 20040110-20040111, 20040118-20040122, 20041213-20041215, 20041219-20041222, and 20041228-20041229.
At the Forest Station tower, the cup anemometer at 14.55 m was damaged during a severe storm on April 05, 2003 causing missing data until April 16, 2003 when the broken cup was replaced.

Precipitation

The sensitivity threshold of the Pluvio sensor corresponds to a rain amount of 0.03 mm, smaller amounts can not be recorded. Continuous precipitation of weak intensity can therefore artificially appear as a series of single events. Each increase in mass of the gauge is detected by the sensor as precipitation (e.g., heavy insects). Isolated single values at the detection limit have therefore usually to be interpreted as questionable / corrupted data.
Strong frost caused a failure of the Pluvio sensor during the period Jan 01 to Jan 16, 2003, and again from Feb 01 to Feb 03, 2003. For these periods, measurements from a tipping bucket (manufactured by Friedrichs) operated side by side to the Pluvio were included in the GM Falkenberg data set. No replacement was possible for the Forest Station. Precipitation data for the Forest Station are also missing for the periods Aug 07 to Aug 18, 2003, (due to sensor malfunction), Feb 01 to Mar 10, 2004, (due to a sensor theft), and Nov 08 to Dec 06, 2004 (due to sensor failure).

Snow depth

Snow depth at the GM Falkenberg is measured manually with a snow stick during working days only (not during weekends and public holidays). The measured data were assigned to the measurement time 0600 UTC. No snow measurements are performed at the Forest Station.

Radiation

Due to data logger failure, original radiation data at GM Falkenberg were missing over the period August 28 to September 01, 2003. Data have been replaced by back-up measurements with an independent second radiation complex (same sensor types as the standard system) operated West of the 99m tower (see Figure 4).
At the Forest Station there is a data gap for the longwave radiation components from June 24, 2004, till July 07, 2004, due to a sensor failure.

Surface Temperature

During summer days with high insolation, measured surface temperature values at GM Falkenberg frequently exceeded the threshold of + 3 K when compared to a (fictive) surface temperature calculated from the upward longwave radiation measurements. Flag = D has been assigned automatically to all these measurements (see section 4). These flags were not corrected manually although we believe that the high surface temperature measurements are generally correct which was confirmed by independent surface temperature measurements at the back-up radiation complex. Instead, we would like to give a warning to the data user that there may be a problem of representativeness when comparing the spot-like surface temperature measurement with the half-space field of view of the longwave radiation sensor. At the Forest Station, measured surface temperatures occasionally exceed the + 3 K threshold during the period with high solar elevation angles depending on the time of the day, radiation and wind conditions. This is attributed to the fact that the surface temperature sensor may see sun spots at the forest floor rather than the forest canopy under these conditions.

Soil Moisture

Soil moisture determination using the gravimetric method and the Lumbricus sonde (http://www.meteolabor.ch) is performed regularly during frost-free periods for comparison with the continuous TDR measurements. These control measurements gave systematically lower values of soil moisture than obtained from TDR. MOL is currently investigating the possible reason for this discrepancy. Soil moisture data should therefore be interpreted with some caution and may be subject to a correction or update at a later time.
If upper soil layers were frozen for longer time periods during the winter, this lead to unphysical soil moisture values which were given Flag = B.

Soil Heat Flux
Soil heat flux data reported in the data set were measured at - 5cm and - 10 cm depth, respectively. No correction for heat storage effects in the uppermost soil layers has been performed. Liebethal (personal communication, 2004) has found that a consideration of the heat storage may increase the measured soil heat flux below the short grass at GM Falkenberg by up to 100 %.

Turbulent Fluxes
Flux measurements of both eddy-covariance systems are affected from poorly defined fetch conditions and flow distortion effects for a certain wind direction sector. Flow distortion is unavoidable due to the mounting of the infrared hygrometer close to the sonic. Additional flow distortion arises from the vicinity of the 10m-mast in case of S1. The mounting of the infrared hygrometer relative to the sonic was changed twice during the data collection period in case of the S2 system. The following disturbed sectors are valid

S1 system	060-120 deg	during 20021001-20030331
	030-120 deg	during 20030401-20041231
S2 system	330-030 deg	during 20021001-20040415
	330-090 deg	during 20030416-20040121
	300-030 deg	during 20040122-20040329
	300-010 deg	during 20040330-20041231

The disturbed sector at the Forest Station is 330-030 deg.
Original flux data for the two systems at GM Falkenberg generally got Flag = D, if the wind direction was within these ranges. The final setup of the S1 and S2 systems (after 20040330) ensures, that no flow distortion and limited fetch effects occur for the flux composite (see section 3.2) at GM Falkenberg.
During summer 2004, a sensor failure occurred with the sonic at S2 following a thunderstorm event on June 09. This failure was not obvious in the pre-processed data and thus remained undetected for several weeks. The sensor was finally replaced on September 03, 2004. For the time period between June 09 and September 03, the momentum flux measured at S2 is not usable at all. For the scalar fluxes (of sensible and latent heat) several specific tests were performed and no obvious deviations from the typical behaviour were found. However, data were flagged with Flag = D for this time period as a warning to the user.
In order to assess the uncertainty of turbulent flux measurements using fast response sonic anemometer-thermometers, numerous inter-comparison experiments have been performed in the past. Three such experiments took place in Lindenberg in 1997, 1998 and 2002. The typical uncertainty of the turbulent flux measurements due to sensor specifications and sensor set-up has been found to be about 3-8 % for the sensible heat flux and about 10-15 % for friction velocity and latent heat flux. These uncertainties may increase by 5-10 % due to differences in the data processing algorithm applied by different research groups or being implemented in different types of sonic anemometers by the manufacturer (e.g., Mauder et al., 2005).
Icing during winter conditions caused a number of sensor faults of the sonic anemometer.
Latent heat fluxes for the period Oct 01, 2002 to March 31, 2003, at GM Falkenberg were estimated in an indirect way using vertical gradients of temperature and humidity (see section 3). Since the Bowen ratio is not well defined, if the gradients are very small, such situations were excluded from the computations. This caused a rather high number of missing values in the latent heat flux data set during the first half of EOP3.

Energy Budget Closure
A non-closure of the energy budget is typically found when determining all relevant flux parameters from independent measurements. The reason for this non-closure is not clear yet and is discussed controversially in the scientific literature (e.g., Wilson et al., 2002, Culf et al., 2004). Achieving closure of the local energy budget in micrometeorological field data therefore is still an issue of international research activities. In the present data set, the

majority of residual values is in the range of between 0 and 60 Wm^{-2}, but it amounts up to 100-150 Wm^{-2} (corresponding to about 20-25 % of the available energy) during summer days with high insolation.

Disclaimer

The data from the Lindenberg reference site have undergone the QA/QC procedure described in section 4 before being transferred to the CEOP Central Data Archive (CDA). The data supplier, however, can not guarantee the absence of any errors and can not take over any responsibility for results coming out of the use of the data. Data users who should discover problems, inconsistencies or any questionable effects when using the Lindenberg data are kindly invited to contact the Lindenberg site and / or data managers.

7. Reference Requirements

Use of the Lindenberg reference site data should be made according to the CEOP data policy rules outlined in the CEOP Reference Sites Data Release Guidelines. In particular every data user who should discover internal inconsistencies, questionable effects, missing data, or any other problems is encouraged to contact the responsible site and / or data managers.

The data source should be referred to as:
Deutscher Wetterdienst (DWD) - Meteorologisches Observatorium Lindenberg / Richard-Aßmann Observatorium.

Data users are requested to send a copy of any publication making use of Lindenberg data to MOL-RAO (see address above).

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