The Lindenberg Reference Site Data Set Metadata Information

Reference Site:	**BALTEX Lindenberg**
Station Identifiers:	**Falkenberg / Forest**
Time Period:	**CEOP-II (2007-2010)**
	This version: January 01, 2007 to December 31, 2007

Contacts

CEOP Reference Site Manager

Dr. Frank Beyrich
Meteorologisches Observatorium Lindenberg /
Richard-Aßmann Observatorium
Deutscher Wetterdienst (DWD)

Am Observatorium 12
D - 15848 Tauche - OT Lindenberg
Germany

Tel.: +49 33677 60228
Fax: +49 33677 60280
email: frank.beyrich@dwd.de
www: http://www.dwd.de/mol

CEOP Data Manager:

Wolfgang K. Adam
Meteorologisches Observatorium Lindenberg /
Richard-Aßmann Observatorium
Deutscher Wetterdienst (DWD)

Am Observatorium 12
D - 15848 Tauche - OT Lindenberg
Germany

Tel.: +49 33677 60223
Fax: +49 33677 60280
email: wolfgang-k.adam@dwd.de
www: http://www.dwd.de/mol

Abstract

This document includes the metadata and specific information the user should be aware of when using any of the BALTEX Lindenberg reference site data from the CEOP Central Data Archive (CDA) for CEOP, Phase II. This first issue refers to the measurement period January 01, 2007 to December 31, 2007. Regular updates will be provided for the forthcoming years with reference to this basic version. It contains 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 January 01, 2007 - 0030 UTC to December 31, 2007 - 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).

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 radiosonde release point at MOL-RAO 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.

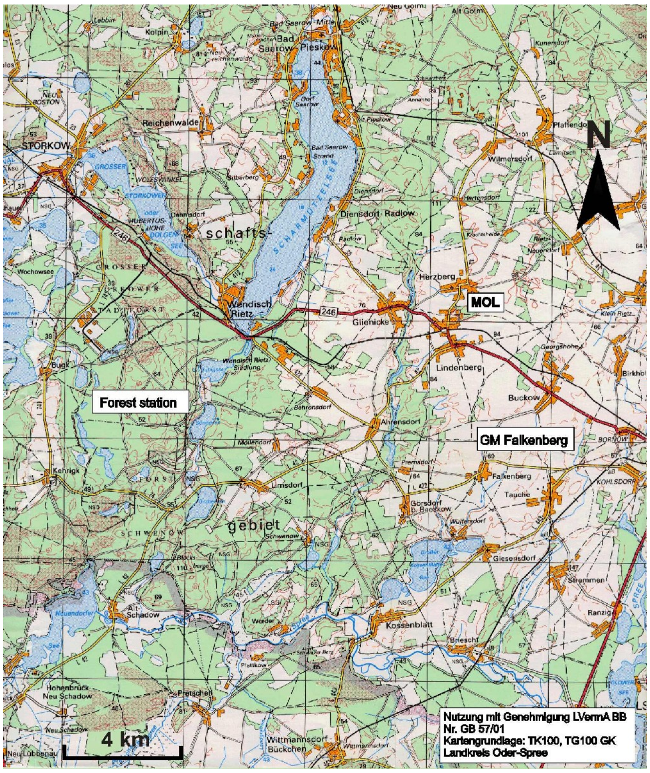

Figure 1 Map of the area around Lindenberg with the GM Falkenberg, Forest Station and MOL-RAO sites

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 other cereals, grass, rape, maize, and sun flowers. 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, and selected climate data are given in Table 3. The minimum / maximum temperatures recorded since 1906 in Lindenberg are – 28.0 °C (11 Feb 1929), and + 38.5 °C (11 Jul 1959, 9 Aug 1992), respectively.

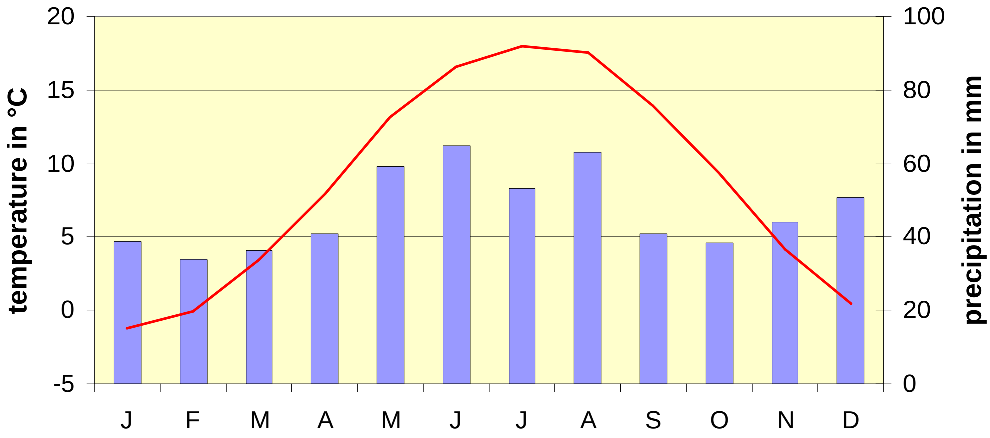

Figure 3 Climate Diagram for Lindenberg (1961-1990)

Table 3 – Selected climate data for Lindenberg (1961-1990)

	J	F	M	A	M	J	J	A	S	O	N	D	Year
T mean (deg C)	-1.2	-0.1	3.4	7.9	13.1	16.5	17.9	17.6	13.9	9.3	4.1	0.4	8.6
RR sum (mm)	38.6	34.0	35.9	40.7	59.1	64.8	53.2	63.0	40.8	38.5	44.1	50.4	562.8
Sunshine (hrs)	46.2	70.1	123.2	165.1	225.3	228.2	228.9	217.1	157.2	115.3	50.9	37.4	1664.9
No. of days with													
Tmin < 0 °C	23	19	16	5	-	-	-	-	-	1	8	17	89
Tmax < 0 °C	10	6	2	-	-	-	-	-	-	-	2	7	27
Tmax > 25 °C	-	-	-	0	3	9	11	10	3	0	-	-	36
Tmax > 30 °C	-	-	-	-	0	1	3	2	0	-	-	-	6
precip. ≥ 0.1 mm	17	15	14	13	14	13	13	12	13	13	16	19	172
snow cover	17	12	6	0	0	-	-	-	-	0	2	10	47
Thunderstorm	0	0	1	1	5	7	7	6	3	0	0	0	30
Fog	9	7	5	3	3	2	2	3	5	9	9	9	66

1.5 Site Details

Falkenberg

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, this area is surrounded by grassland and agricultural fields in the immediate vicinity, a small village is situated about 600 m to the SE, and a small, but heterogeneous forest area lies to the W and NW at about 1 to 1.5 km distance (see Figure 2).

The Falkenberg site was used for agricultural farming activities until around 1990 when it was transformed to a grassland area. Main vegetation species are perennial ryegrass (*Lolium perenne*), red fescue (*Festuca rubra*), dandelion (*Leontodon autumnalis*, *Taraxacum officinale*), bromegrass (*Bromus hordeaceus*), and clover (*Trifolium pratense*, *Trifolium repens*). Management of the site includes fertilisation with about 35 kg / ha of urea pellets (46% of nitrogen) once per year. The meadow is mowed regularly (up to six times per year) in order to keep the mean vegetation height below 20 cm. This leads to a typical roughness length for momentum (z_0) at around or below 0.01 m. A time series of vegetation height and roughness length (determined from the momentum flux measurements during near-neutral stratification) over the 2007 annual cycle is shown in Figure 4. The leaf-area index (LAI) at the Falkenberg field site may vary in dependence on the vegetation growth stage between values of < 1 m^2 m^{-2} up to values around 3 .. 4 m^2 m^{-2} (e.g., Falge et al., 2005).

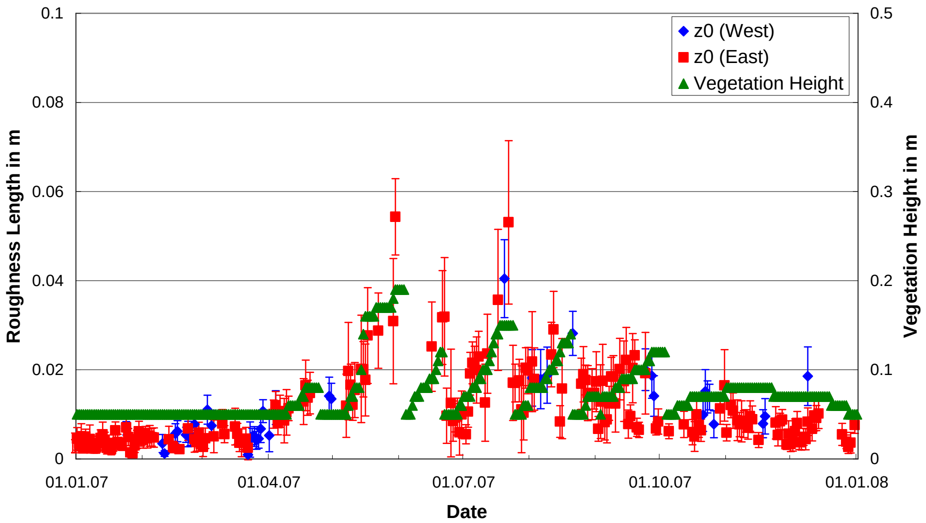

Figure 4 Time evolution of the estimated values of mean vegetation height (right y-axis) and roughness length for momentum (left y-axis) at the Falkenberg boundary layer field site for the 2007 annual cycle (red and blue symbols indicate estimates based on measurements at the two flux stations in the eastern and western part of the field site – see section 2)

A soil profile from the GM Falkenberg is shown in Figure 5. The depth of the upper layer of sand (pale soil - *Eutric Podzoluvisol*) is around 60 cm at the place where the operational soil temperature and moisture measurements are performed. Within this layer, the plough horizon (resulting from the former farming activities) at a depth of about 30 cm can be clearly seen. The content of organic matter in this upper soil horizon is about 1-2 % of mass. Below the sand there is a layer of loamy sand or loam, the transition depth varies between about 50 cm and 1m.

Figure 5 Soil profile at the Falkenberg boundary layer field site

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 6 and Figure 7, respectively.

Figure 6 View towards NW across the pine forest with the Forest Station tower in the upper left quadrant

Figure 7 Birds view at the forest plantations around the Forest Station tower

The terrain at the Forest Station site is slightly slanted from East and South 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 7) of pine plantations (*pinus sylvestris*). The mean tree height around the tower is 15 m, but it reaches up to 20 m in other (older) parts of the plantations in the vicinity of the forest tower. The mean stem diameter is about 15 cm, and the number of stems is roughly 1800 per hectar. The roughness length for momentum (z_0) and the displacement height (d) at the forest site have been estimated based on wind profile and turbulence measurements, the mean values are z_0 = 2.0 .. 2.5 m, and d ≈ 9 .. 10 m.

1.6 Site References

WWW: http://www.dwd.de/mol
Literature: Neisser et al. (2002), Beyrich et al. (2002), Stiller et al. (2005), Beyrich and Mengelkamp (2006)

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 8. 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.

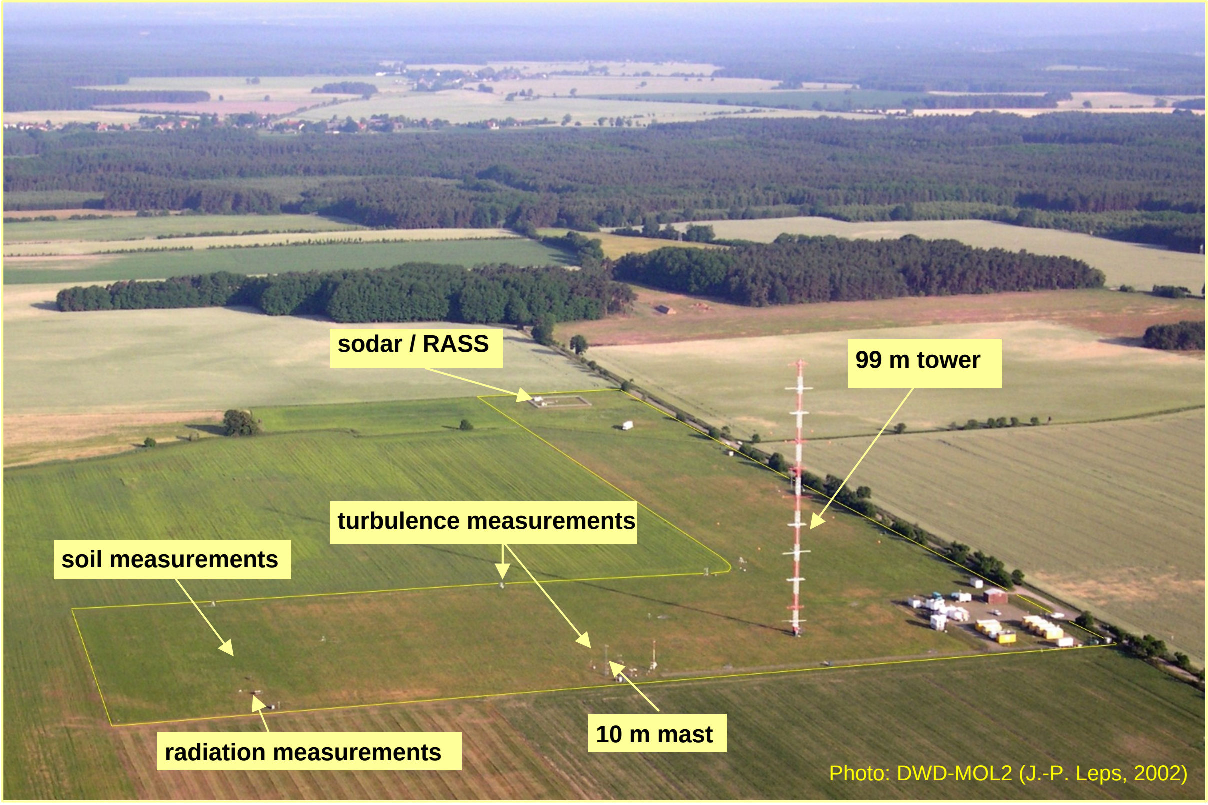

Figure 8 The DWD-MOL boundary layer field site (GM) Falkenberg towards WNW

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 9). 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 8). Soil measurements are performed west of the radiation measurements.

Figure 9 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 8), 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 10). Fast-response infrared hygrometers are added to the sonics for the direct measurement of the latent heat flux using the eddy-covariance method.

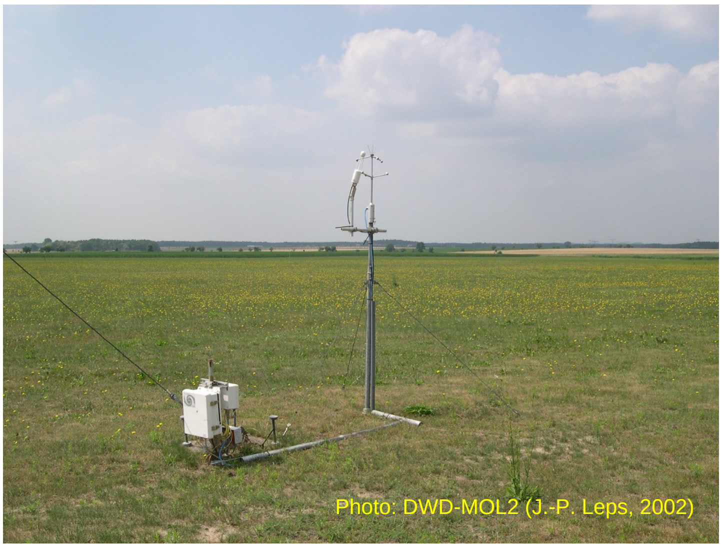

Figure 10 Turbulence measurement system S1 (USA-1 + LI7500 hygrometer)

2.2 The Forest Station

The Forest Station in its present configuration has been set up in autumn, 2002. The central measurement facility is a lattice tower construction of triangular shape with a side length of 40 cm (see Figure 11). 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 close to the top of the crown region, level 6 is situated in the roughness sublayer, and the upper three 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 11 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 4.

Sensor replacements (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 at 00, 06, 12, and 18 UTC using Vaisala RS-92-AGP radiosondes in connection with Vaisala Digi-Cora III ground equipment and GPS wind finding. Release times are between XX-60 and XX-45.

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

Table 4

Parameter	Measurement Height	Sensor	Measurement principle	Manufacturer	Reference	Remarks
basic meteorology						
• Temperature / Humidity	2 m (Forest: 2.25 m)	HMP-45D / Frankenberger Psychrometer	Pt-100 / capacitive Pt-100 / psychrometer	Vaisala Th. Friedrichs	http://www.vaisala.com http://www.th-friedrichs.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	Thies	http://www.thiesclima.com	
• pressure	1 m (Forest: 28 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	1.65 m (Forest none)	SR50A	sonic ranging sensor	Campbell Sci.	http://www.campbellsci.com	with reflection plate
Radiation						
• shortwave	2 m (Forest 29 m)	CM24	thermopile	Kipp & Zonen	http://www.kippzonen.com	ventilated
• longwave	2 m (Forest 29 m)	DDPIR	thermopile	Eppley	http://www.eppleylab.com	ventilated
• surface temp.	2 m (Forest 26 m)	KT15.82D	pyro-electric	Heitronics	http://www.heitronics.com	
• PAR	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 cm	HP3	flux plate	RIMCO		
tower						
• temperature / humidity	40 m, 98 m (Forest: 17.5 m, 28.3 m)	HMP-45D / Frankenberger Psychrometer	Pt-100 / capacitive Pt-100 / psychrometer	Vaisala Th. Friedrichs	http://www.vaisala.com http://www.th-friedrichs.com	ventilated, radiation shielded
• wind speed	40 m, 98 m (Forest: 17.5 m, 28.3 m)	wind transmitter F460	cup cup	Thies Climatronics	http://www.thiesclima.com http://www.climatronics.com	
• wind direction	40 m, 98 m (Forest: 30.6 m)	wind dir. transm. USA-1	vane sonic	Thies METEK	 http://www.metek.de	
turbulent fluxes						
• momentum	2.4 m (Forest: 30.6 m)	USA-1	sonic	METEK	http://www.metek.de	
• sensible heat	2.4 m (Forest: 30.6 m)	USA-1	sonic	METEK		
• latent heat	2.4 m (Forest: 30.6 m)	LI-7500	infrared hygrometer	LiCor	http://www.licor.com	

3. Data Collection and Processing

3.1 Data Collection

Sampling and averaging times for the data are given in Table 5.

Table 5 - 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 min.	10 min.	arithm. average
radiation			
• shortwave	1 sec.	10 min.	arithm. average
• longwave	1 sec.	10 min.	arithm. average
• surface temp.	1 sec.	10 min.	arithm. average
• PAR	1 sec.	10 min.	arithm. average
soil			
• soil tempera-ture	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.	10 min.	average acc. to eq. (6)
• sensible heat	0.05 sec.	10 min.	
• latent heat	0.05 sec	10 min.	
radiosonde			
• pressure	5 sec.	none	does not apply
• temperature	5 sec.	none	does not apply
• humidity	5 sec.	none	does not apply
• wind speed	5 sec.	none	does not apply
• wind direction	5 sec.	none	does not apply

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) is derived directly from Pt-100 resistance measurements (4-wire connection) using standard linearised Pt-100 characteristics. An offset correction is applied to the HMP temperature data based on a regular intercomparison of the HMP temperature measurements against the psychrometer temperature measurements during nighttime. This offset correction typically is in the range 0.05 .. 0.20 K, it has been found to be quite constant in time (variations of less than 0.05 K).

Relative humidity (both in the surface and tower data sets) is measured simultaneously by HMP-45D capacitive humidity sensor and by aspirated psychrometer during the warm season. A correction equation for the HMP is derived based on these parallel measurements by minimising the rmsd when compared to the psychrometer data. The coefficients of the non-linear regression model are controlled and (if necessary) updated twice a year. This correction equation is then applied regularly to the HMP measurements. Relative humidity values > 100 % are set equal to 100 %.

According to the "CEOP Reference Site Data Set Procedures report" (see at http://www.eol.ucar.edu/projects/ceop/dm/index_new.html), the following equations are 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) $$e[hPa] = E_{Sat}[hPa] - 0.00066 * \left(1 + 0.00115 * t_{wet}[°C] * p[hPa] * \left(t[°C] - t_{wet}[°C]\right)\right)$$

(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*** are taken from the measurements at the 10m mast (see Figure 9). Due to the mast construction there are flow distortion effects on the wind speed measurements for winds from the sector between 035 and 085 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*** are 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 near-surface wind direction and selection of the closest tower wind direction value - if no data available from near surface → vector averaging of all three wind direction values.
2. Selection of representative wind speed measurement in dependence on wind direction.

Wind speed values smaller than 0.13 ms^{-1} (Falkenberg SFC, Forest) and 0.3 ms^{-1} (Falkenberg TWR), respectively, are interpreted as calm and set to zero in the original 10-minutes data set. In this case corresponding 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 17.45 m and 28.3 m levels, respectively (note that for CEOP Phase I, the lower measurement height reported was 14.55 m). Wind direction data are available for the top of the tower only, u- and v- wind components are therefore 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 values < 3 Wm^{-2} are set equal to zero.

Longwave radiation (Rlw) is 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) $$Rlw = \frac{U_{emf}}{c}(1 + k_1 \sigma T_B{}^3) + k_2 \sigma T_B{}^4 - k_3 \sigma \left(T_D{}^4 - T_B{}^4\right)$$

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

Precipitation is measured for quality control by a tipping bucket sensor NG7051 (Th. Friedrichs GmbH, http://www.th-friedrichs.com/) in parallel to the measurement with the Pluvio weighing range gauge.

Snow depth information is derived from the travel time of an ultrasonic signal reflected at the snow surface (snow plate). Transformation of the time signal to distance considers the mean temperature and humidity measured at the 1m level of the small lattice mast (see section 2.1). Averaging of the original 1min data to 10min intervals takes into account internal sensor quality code information.

Soil moisture (qsoil) at the ***GM Falkenberg*** is measured at the upper two levels by 4 (at − 8 cm) and 2 (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 is measured by 6 flux plates (GM Falkenberg, −5 cm), 4 flux plates (GM Falkenberg, −10 cm) and 3 flux plates (Forest Station), respectively. Reported values are averages over all available sensors.

Turbulent momentum and sensible heat fluxes are 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) is applied to the <u'w'> and <v'w'> covariances, both covariances are 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 is 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 is determined by computing the mean eddy-covariances between the vertical velocity and humidity fluctuations. The fluxes are 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) is applied with different values for stable / unstable stratification.

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

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

A composite flux data set is 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 are applied:

wind direction from sector > 000...010 deg: data are taken from S1
wind direction from sector > 010...030 deg: fluxes from S1 and S2 are averaged
wind direction from sector > 030...150 deg: data are taken from S2
wind direction from sector > 150...190 deg: fluxes from S1 and S2 are averaged
wind direction from sector > 190...360 deg: data are taken from S1.

Bad data are 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 are 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 6.

Table 6 - Acceptance range limits for automatic data quality control

Parameter	lower limit	upper limit
basic meteorology		
• temperature	- 30 deg C	+ 50 deg C
• humidity	10 %	106 %
• wind speed	0 ms^{-1}	30 ms^{-1}
• wind direction	0 deg	360 deg
• pressure	950 hPa	1040 hPa
• precipitation	0 mm	40 mm
radiation		
• shortwave down	- 10 Wm^{-2}	1250 Wm^{-2}
• shortwave up	- 10 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
• PAR down	- 10 $\mu mol*m^{-2}*s^{-1}$	2500 $\mu mol*m^{-2}*s^{-1}$
• PAR up	- 10 $\mu mol*m^{-2}*s^{-1}$	1600 $\mu mol*m^{-2}*s^{-1}$
soil		
• soil temperature	- 30 deg C	+ 50 deg C
• soil moisture	1 Vol-%	40 Vol-%
• soil heat flux	- 100 Wm^{-2}	+ 200 Wm^{-2}
tower		
• temperature	- 30 deg C	+ 50 deg C
• humidity	10 %	106 %
• wind speed	0 ms^{-1}	30 ms^{-1}
• wind direction	0 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 6 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 7.

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 7 - Physically based tests of measured parameters

parameter	test description
basic meteorology	
• temperature	comparison HMP vs. psychrometer, Flag = G if $\Delta T < 0.5$ K
• humidity	comparison HMP vs. psychrometer, Flag = G if $\Delta RH < 5$ % (April to October only)
• wind speed	Flag = G if V (8 m) / V (10 m) = 0.87 .. 1.10
• wind direction	-
• pressure	Flag = G if $\vert p(t) - p(t\text{-}1) \vert < 1$ hPa
• precipitation	Flag = G if ΔRR (Pluvio – tipping bucket) < 0.5 mm
radiation	
• shortwave down / shortwave 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 (0.07 ... 1.00 in case of snow) These limits apply if shortwave_down ≥ 50 Wm^{-2}
• longwave down	Flag = G if $0.7 * \sigma T_{2m}^4$ < downward longwave radiation < $1.0 * \sigma T_{2m}^4$
• longwave up	Flag = G if $\sigma (T_{2m} - 5 K)^4$ < upward longwave radiation < $\sigma (T_{2m} + 5 K)^4$
• surface temp.	Flag = G if $\sigma (T_{surf} - 3 K)^4$ < upward longwave radiation < $\sigma (T_{surf} + 3 K)^4$
• PAR down / PAR up	Flag = G if PAR_down / Rsw_down = 1.65 … 2.1 (for sw_down > 100 Wm^{-2}) Flag = G if PAR albedo: 0.05 ... 0.20 (0.05 ... 1.00 in case of snow)
soil	
• soil temperature	Flag = G 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
• soil moisture	Flag = G if difference between sensors < 5 Vol-% or 50 % of the mean value (upper levels at GM Falkenberg only), and if Tsoil > 0 deg C at neighbouring levels
• soil heat flux	Flag = G if difference between sensors < Max (30 %, 10 Wm^{-2}) of mean value
tower	
• temperature	Comparison HMP vs. psychrometer, Flag = G if $\Delta T < 0.5$ K
• humidity	Comparison HMP vs. psychrometer, Flag = G if $\Delta RH < 5$ % (April to October only)
• wind speed	GM Falkenberg: Flag = G if $-1\ ms^{-1} < \Delta V < +3\ ms^{-1}$ per 20 m height difference Forest / 17.45 m: Flag = G if V (17.45 m) = 0.65 .. 0.80 V (21.00m) Forest / 28.3 m: Flag = G if V (24.15 m) = 0.85 .. 1.00 V (28.3 m)
• wind direction	GM Falkenberg: Flag = G if wind direction difference of at least 2 booms < 10 deg
turbulent fluxes	
• friction velocity	Flag = G if $u_* < 0.15 * V$ (if V > 3 ms^{-1}) and if σ_w / u_* is within certain limits
• sensible heat	Flag = G if sign (H) matches sign ($\Delta T/\Delta z$) and if (H + LE) < (net radiation - soil heat flux)
• latent heat	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 035 deg to 085 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 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 8.

Table 8 - 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

Redundant sensors are in operation for most of the measured parameters at GM Falkenberg. In case of missing or technically disturbed values of the primary sensor system, these measurements have been considered to fill potential data gaps.

No gap filling procedures using model assumptions have been applied for the data period January 01, 2007 to December 31, 2007.

6. Data Remarks

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

General

January 2007 was a very windy month with the highest monthly mean values of wind speed since the beginning of the measurements at GM Falkenberg. On January 18, winter storm "Kyrill" passed over Lindenberg with maximum half-hourly averaged wind speed of about 23 ms^{-1} at the 98 m tower level. Power failure in connection with this storm event caused some data losses. Power failures at Falkenberg also occurred during thunder-storms on May 29, May 31, and August 21. Data losses due to high voltages at the data loggers because of lightning occurred on May 29-30, 2007 (SFC data), and again on July, 22-23, 2007 (STM data), at the forest site. Due to data transmission problems a series of data gaps appear in the forest station data set between September 27, and October 01, 2007. Extensive maintenance activities (e.g. cleaning, check of bearings, replacement of desiccants and wearing material etc.) are performed regularly twice a year (in spring and autumn) at all stations. This may cause short operation interrupts for a number of sensors. In 2007, these maintenance activities were performed on March 26-27, and on November 05 at Falkenberg, and on March 28 and November 08 at the Forest site, respectively.

Temperature / Humidity

Temperature and relative humidity (both in the surface and tower data sets) was measured simultaneously by HMP-45 capacitive humidity sensor and by aspirated psychrometer during the warm season. For consistency reasons, the HMP data were selected for the CEOP data set. Moreover, tests have revealed that the HMP temperature measurements are less influenced by radiation errors on hot summer days than the psychrometer measurements. Both, HMP temperature and humidity data are corrected as described in section 3.2. Failure of the ventilation caused questionable temperature and humidity data from the HMP sensor during the period June 21, 2007 to July 06, 2007 at the forest station. HMP data were replaced by psychrometer data for this period. Failure of the data logger caused missing temperature and humidity data over the period May 26, 2007, to May 29, 2007, at the Falkenberg 98m tower level.

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 35° ... 85°, 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 Falkenberg SFC data set and in the Forest Station TWR data set, especially during the period 20070208-20070211.

Wind Direction

Wind direction data at the Forest Station are taken from the eddy-covariance system at the top of the tower. Due to the mounting of the infrared gas analyser close to the sonic anemometer, there are flow distortion effects on the sonic measurement for a wind direction sector 330° .. 030°, the wind direction data are therefore flagged with Flag = D in this case.

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. Due to a configuration error of the Pluvio data logger, data sampling and averaging were not performed properly during the period January 09, to July 02, 2007 at both sites. As a consequence, additional internal smoothing of the precipitation time series occurred which could not be corrected *a posteriori*. This means that the dynamics of single precipitation events is not correctly represented in the data set, but the precipitation sum is finally correct for each single event.

Snow depth
The snow depth sensor at Falkenberg was not in operation between April 21, 2007, and November 13, 2007, no snow occurred during this period.

Radiation
Frequent gaps in the data set of upward photosynthetically active radiation (PAR) at the Falkenberg site are due to sensor problems.

Surface Temperature
During summer days with high insolation, measured surface temperature values at GM Falkenberg occasionally 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). Most of these flags were corrected manually since we are convinced that the surface temperature measurements are basically correct. They are generally supported by the data from a backup sensor. Differences to a surface temperature estimate from the upward longwave radiation are mainly attributed to the different field of view of the sensors. Flags were kept for those values influenced from the shadow of the bar construction. This shadow crosses the small footprint of the KT15 instrument during the morning hours causing a significant signal reduction under clear sky conditions from March till September. 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 (see Beyrich, 2006). 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 % if interpreted as soil heat flux at the surface.

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 following disturbed sectors are valid

Falkenberg, S1 system	030-120 deg
Falkenberg, S2 system	300-010 deg

Forest Station 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 ensure that no flow distortion and limited fetch effects occur for the flux composite (see section 3.2) at GM Falkenberg.

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., 2006).

Icing during winter conditions caused a number of sensor faults of the sonic anemometer. No latent heat flux can be determined in case of water droplets / ice crystals on the windows of the infrared hygrometers due to precipitation or in case of liquid water in the path during fog. This causes missing latent heat flux data during 15-20 % of the time.

The footprint conditions for the flux measurements have been analysed in detail based on data from the LITFASS-2003 experiment (Beyrich et al., 2006). An estimate of the footprint area that is covered by the surface of interest (the grassland surface of the boundary layer field site, the pine crowns at the forest station) in dependence on wind direction and stability is given in Table 9. For the Falkenberg flux composite, the minimum values are given for the wind direction sectors where both S1 and S2 data were used to determine the surface flux.

Table 9 – Estimated percentage of flux footprints originating from the study surface for the Lindenberg – Falkenberg and Lindenberg Forest sites

wind direction in °	030	060	090	120	150	180	210	240	270	300	330	360
Stratification	Falkenberg											
Stable	90	95	85	95	95	90	95	90	85	90	95	90
Neutral	95	95	90	95	95	95	95	95	90	90	95	95
Unstable	> 95	> 95	95	> 95	> 95	>95	> 95	> 95	95	95	>95	95
	Forest											
Stable	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95
Neutral	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95
Unstable	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95

These footprint estimates are base on calculations with a stochastic footprint model that were performed by M. Göckede (Department of Micrometeorology, University of Bayreuth), see, e.g., Göckede et al. (2005)

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).

8. Reference List

Beyrich, F., H.-J. Herzog, J. Neisser (2002): The LITFASS project of DWD and the LITFASS-98 experiment: The project strategy and the experimental setup. *Theor. Appl. Climatol.* **73**, 3-18

Beyrich, F. (Ed.), S.H. Richter, U. Rummel, and U. Weisensee, 2006: Ausgewählte Ergebnisse von Bodenfeuchte-Messungen am Meteorologischen Observatorium Lindenberg. Offenbach a.M.: *Deutscher Wetterdienst - Forschung und Entwicklung: Arbeitsergebnisse.* **Nr. 84**, 46 pp. (ISSN 1430-0281)

Beyrich, F., and H.-T. Mengelkamp, 2006: Evaporation over a Heterogeneous Land Surface: EVA_GRIPS and the LITFASS-2003 Experiment - an Overview. *Boundary-Layer Meteorol.* **121**, 5-32

Beyrich, F, J.-P. Leps, M. Mauder, J. Bange, T. Foken, S. Huneke, H. Lohse, A. Lüdi, W.M.L. Meijninger, D. Mironov, U. Weisensee, and P. Zittel, 2006: Area-Averaged Surface Fluxes over the LITFASS Region Based on Eddy-Covariance Measurements. *Boundary-Layer Meteorol.* **121**, 33-65

Culf, A.D., T. Foken, J.H.C. Gash (2004): The energy balance closure problem. *in P. Kabat and M. Claussen (Eds.): Vegetation, Water, Humans, and the Climate. A New Perspective on an Interactive System. Berlin – Heidelberg - New York: Springer*, pp. 159-166

Falge, E., S. Reth, N. Brüggemann, K. Butterbach-Bahl, V. Goldberg, A. Oltchev, S. Schaaf, G. Spindler, B. Stiller, R. Queck, B. Köstner, Ch. Bernhofer (2005): Comparison of surface energy exchange models with eddy flux data in forest and grassland ecosystems of Germany. *Ecological Modelling* **188**, 174-216

Göckede, M. T. Markkanen, M. Mauder, K. Arnold, J.-P. Leps, T. Foken (2005): Validation footprint models using natural tracer. *Agricult. Forest Meteorol.* **135**, 314-325

Kaimal, J.C., J.J. Finnigan (1994): Atmospheric boundary layer flows - their structure and measurement. *New York - Oxford: University Press*, 289 pp.

Leiterer, U., H. Dier, D. Nagel, T. Naebert, D. Althausen, K. Franke, A. Kats, F. Wagner (2005): Correction method for RS80A Humicap humidity profiles and their validation by lidar backscattering profiles in tropical cirrus clouds. *J. Atmos. Ocean. Technol*. **22**, 18-29

Liu, H., G. Peters, Th. Foken (2001): New equations for sonic temperature variance and buoyancy heat flux with an omnidirectional sonic anemometer. *Boundary-Layer Meteorol.* **100**, 459-468

Liu, H., Th. Foken (2001): A modified Bowen ratio method to determine sensible and latent heat fluxes. *Meteorol. Z. (N.F.)* **10**, 71-80

Mauder, M., C. Liebethal, M. Göckede, J.-P. Leps, F. Beyrich, Th. Foken (2005): Processing and quality control of flux data during LITFASS-2003. *Boundary-Layer Meteorol.* **121**, 67-88

Moore, C.J. (1986): Frequency-response corrections for eddy-correlation systems. *Boundary-Layer Meteorol.* **37**, 17-35

Neisser, J., W. Adam, F. Beyrich, U. Leiterer, H. Steinhagen (2002): Atmospheric boundary layer monitoring at the Meteorological Observatory Lindenberg as a part of the "Lindenberg Column": Facilities and selected results. *Meteorol. Z. (N.F.)* **11**, 241-253

Philipona, R., C. Fröhlich, Ch. Betz (1995): Characterisation of pyrgeometers and the accuracy of atmospheric longwave radiation measurements. *Appl. Optics* **34**, 1598-1605

Schotanus, P., F.T.M. Nieuwstadt, H.A.R de Bruin (1983): Temperature measurement with a sonic anomometer and its application to heat and moisture fluctuations. *Boundary-Layer Meteorol.* **26**, 81-93

Stiller, B., F. Beyrich, G. Hollaz, J.-P. Leps, S. H. Richter, U. Weisensee (2005): Continuous measurements of the energy budget components at a pine forest and at a grassland site. *Meteorol. Z.* **14**, 137-142

Webb, E.K., G.I. Pearman, R. Leuning (1980): Correction of the flux measurements for density effects due to heat and water vapour transfer. *Quart. J. Roy. Meteorol. Soc.* **106**, 85-100

Wilson, K., A. Goldstein, E. Falge, M. Aubinet, D. Baldocchi, P. Berbigier, C. Bernhofer, R. Ceulemans, H. Dolman, C. Field (2002): Energy balance closure at FLUXNET sites. *Agric. Forest Meteorol.* **113**, 223-243