P9.3 PROCESSING AND QUALITY CONTROL OF EDDY COVARIANCE DATA DURING LITFASS-2003

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1. INTRODUCTION

During the experiment LITFASS-2003, which took place in a 20x20 km^2 area near the Meteorological Observatory Lindenberg, Germany, turbulent fluxes of momentum, sensible, and latent heat were measured at nine agricultural sites, two grassland sites, one forest site, two lake sites, and at two levels of a 100 m tower. For more information, see presentations 9.1 by Beyrich et al. as well as 9.2 through 9.5, all from this conference.

For this presentation, only the six stations operated by the University of Bayreuth (UBT) and the German Meteorological Service, Meteorological Observatory Lindenberg (MOL), were included in the study, because both groups were responsible for all data processing and quality control issues. Other stations were operated by the GKSS Research Centre Geesthacht, the Meteorology Group of Wageningen University, the University of Hamburg, and the University of Technology Dresden.

2. EXPERIMENTAL SETUP

At each site, all components of the energy balance (Q_s^*: net radiation, Q_H: sensible heat flux, Q_E: latent heat flux, Q_G: ground heat flux) were measured:

$$-Q_s^* = Q_H + Q_E + Q_G \,. \qquad (1)$$

The instrumentation of the six measuring sites that were used, comprising over crop (A5), maize (A6), grassland (NV2, NV4), pine forest (HV, canopy height 14 m), and a lake (FS) is given in Table 1.

3. INTERCOMPARISON PRE-EXPERIMENTS

The intercomparison of the sensors had already started one year before the experiment. All radiation sensors and the sonic anemometers of the participating institutes were compared, most of them during a pre-experiment in May/June 2002 at the Boundary-layer field site Falkenberg of the German Meteorological Service.

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Table 1: Instrumentation of the used measuring sites

Site	radiation	Sonic anemometer	analyser	Soil heat flux plate
A5	CNR-1	USA-1	KH20	HP3
A6	CM24 DD-PIR	CSAT	LI-7500	HFP01SC
NV2	CM24 DD-PIR	USA-1	LI-7500	HP3
NV4	CM24 DD-PIR	USA-1	LI-7500	HP3
HV	CM24 DD-PIR	USA-1	LI-7500	HP3
FS	CM24 DD-PIR	USA-1	LI-7500	-

Of specific interest was the comparison made between intercomparison of the gas analyzers done in the field and those done in the laboratory. The results of the comparison between the variance of the absolute humidity and the latent heat flux, measured at about 3.25 meters above grasslands, are given in Tables 2 and 3. The reference measuring was the Campbell CSAT3 combined with the LI 7500 (LiCor Inc.) of the University of Bayreuth (UBT). Furthermore, the METEK USA-1 and the Campbell KH20 operated by UBT and the Meteorological Observatory Lindenberg (MOL) were used in the comparison experiment, together with the instruments of the other groups (see. Chapter 1).

Table 2: Comparison of the variance of the humidity fluctuations during the comparison experiment 2002, reference UBT#1, LI 7500

sensor	Abs. value (offset) [g^2m^{-6}]	Regression coefficient	R^2
MOL#1 KH20	0.0139	1.25	0.87
MOL#2 LI 7500	0.0323	1.02	0.92
UBT#2 KH20	0.0022	1.10	0.97

All Krypton (KH-20) and infrared (LI7500) hygrometers used at the different micrometeorological stations during LITFASS-2003 were calibrated both before and after the field campaign in the laboratory using a dew point generator (LI-610, LiCor Inc.) to generate a sequence of five pre-defined dew point values from 5 deg C to 21 deg C, first in an increasing and then in a decreasing order. The adjustment time was at least seven minutes for each calibration point, and a precision dew point mirror (EdgeTech Dew-Prime II) was used for control (Weisensee et al., 2003). The difference in the slope of the calibration line between the two calibrations was typically less than 2 %.

Table 3: Comparison of the latent heat flux during the comparison experiment 2002, reference UBT#1, CSAT3 / LI 7500

sensor	Abs. value (offset) [Wm^{-2}]	Regression coefficient	R^2
MOL#1 USA-1/ KH20	28.8	1.07	0.77
MOL#2 USA-1/ LI 7500	18.5	0.87	0.74

4. EDDY COVARIANCE DATA ANALYSIS

4.1 Data calculation and correction

The eddy covariance data of all LITFASS-2003 sites were post-processed in a uniform way. Therefore, we used the comprehensive turbulence software package TK2 (http://www.bayceer.uni-bayreuth.de) , which was developed at the University of Bayreuth. It includes quality tests of the raw data and necessary corrections of the covariances, as well as quality tests for the resulting turbulent fluxes. The major components of this quality control system are:

- Identification of spikes after Vickers and Mahrt (1997).
- Determination of the time delay of all additional sensors (e.g. LI-7500 gas analyser) through the calculation of cross correlations.
- Cross wind correction of the sonic temperature after Liu et al. (2001), if not already implemented in sensor software (necessary for METEK USA-1)
- Planar Fit method for coordinate transformation (Wilczak et al., 2001).
- Correction of oxygen cross sensitivity of Krypton-hygrometers (Tanner et al., 1993; van Dijk et al., 2003).
- Spectral corrections after Moore (1986) using the spectral models by Kaimal et al. (1972) and Højstrup (1981).
- Conversion of fluctuations of the sonic temperature into fluctuations of the actual temperature after Schotanus et al. (1983).
- Density correction of scalar fluxes of H_2O and CO_2 after Webb et al. (1980) and Liebethal and Foken (2003).
- Iteration of the correction steps because of their interacting dependence

4.2. Quality control

The application of the quality control procedure, after Foken and Wichura (1996), on the data from the micrometeorological stations during the LITFASS-2003 campaign allows us to asses the quality of turbulent fluxes. Figure 1 shows the proportion of half hour values of latent heat flux between 06:00 and 20:00 UTC, which were classified as the highest quality, indicating data which can be used for fundamental research. These are the quality classes 1-3 according to Foken et al. (2004)

Furthermore, all sites where investigated for their footprint characteristics and the existence of internal boundary layers. Measurements were excluded if the sensor was not located within the new equilibrium layer of an internal boundary layer δ after a sudden change of the surface characteristics. This is the case after Raabe (1983) and Jegede and Foken (1999) for heights

$$z \leq \delta = 0.3 \cdot \sqrt{x} \, . \qquad (2)$$

with x: fetch (see Table 4).

To determine the land use composition within the source area of each measurement position, the three dimensional Lagrangian stochastic trajectory model of Langevin type (Thomson, 1987) was used. The parameterization of the flow statistics and the effect of stability on the profiles were in line with those used in (Rannik et al., 2000; Rannik et al., 2003). In the models, particles are dispersed by turbulent diffusion in vertical direction, along mean wind and cross mean wind directions. They are then carried downwind by horizontal advection. Particles tending downwards are perfectly reflected at the height z_0. In the course of this study, the simulations were performed releasing $5 \cdot 10^4$ particles from a height close to the ground. The particles were then tracked until the upwind distance accounted for approximately 90 percent of the total flux. The principle aim of the footprint study was to determine the flux contribution of the target land use area for different sets of wind direction and stability classes in order to check whether the measurements are representative for the specified land use type under different conditions (see Table 4).

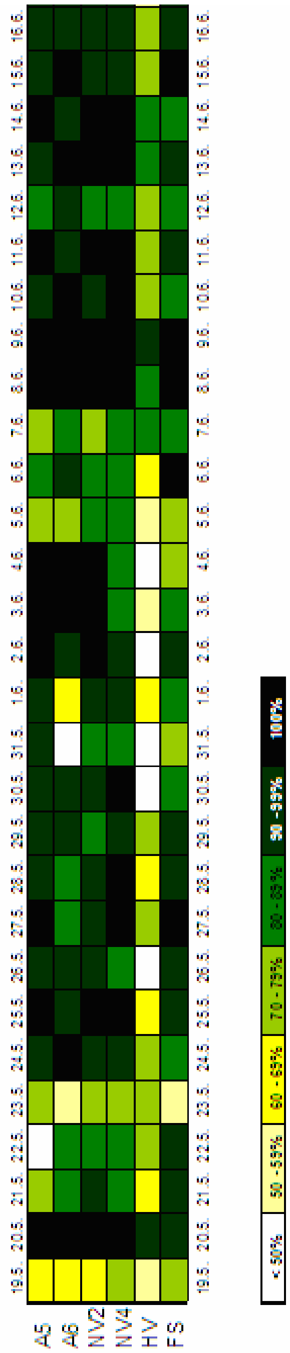

Table 4: Fetch x, height of the new equilibrium layer δ and percentage of the flux from the target land use area (AOI) dependent on the wind direction and stability for site A6

	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	360°
x in m	29	41	125	360	265	203	211	159	122	81	36	28
δ in m	1.6	1.9	3.4	5.7	4.9	4.3	4.4	3.8	3.3	2.7	1.8	1.6
	AOI in %											
stable	36	49	81	99	96	92	93	88	81	70	44	35
neutral	51	63	90	100	100	98	98	95	90	82	59	50
unstable	62	74	98	100	100	100	100	100	98	91	70	61

Figure 1 (left): Availability of high quality flux data between 06 and 20 UTC (white: also missing data)

5. SOIL HEAT FLUX

Regarding the soil heat flux, we tested different approaches to determine this component of the energy balance from in-situ measurements such as soil temperature, soil moisture, and heat flux plate records. We concentrated on two methods: first, a combination of the gradient approach and calorimetry and second, a combination of heat flux plate measurements and calorimetry. For each approach, we tested several reference depths (depths where the temperature gradient or the heat flux plate measurement is conducted). To get an idea about the correctness of the results, we conducted a sensitivity analysis, testing the sensitivity of the two approaches and of different reference depths to variations in the input data file. From these analyses, we draw the following conclusions:

- It is safer to use the gradient approach rather than heat flux plates.
- The deeper the reference depth, the better.
- Measurements in shallow depths should receive the most attention and effort.
- It is critical to measure temperatures correctly.

We decided to use the soil heat flux calculated from the gradient/calorimetry approach with a reference depth of 0.20 m as the "correct" soil heat flux.

6. CONCLUSIONS

The processing of the eddy covariance data of all these sites with one software tool, including transformations and corrections like planar-fit rotation, Schotanous-correction, Moore-correction, and WPL-correction, was very beneficial in comparing all data produced by different groups. Furthermore, all fluxes were quality checked on the basis of the tools proposed by Foken and Wichura (1996) and flagged as high quality data, moderate quality data, and low quality data, combined with the height of possible internal boundary layers and the footprint sector.

Using the calculated 'surface' soil heat flux, we also get a much better closure of the energy balance than using pure plates measurements.

Considering these findings for flux calculations, corrections, and data quality, it was possible to determine composite time series for different surface types to provide validation data for models and to determine area-averaged fluxes.

7. ACKNOWLEDGMENT

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