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Evaporation over a Heterogeneous Land Surface: EVA_GRIPS and the LITFASS-2003 Experiment – an Overview

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Abstract

The EVA_GRIPS (Evaporation at Grid / Pixel Scale) project was realised as a part of the German Climate Research Program (DEKLIM) in order to determine the area-averaged evaporation over a heterogeneous land surface at the scale of a grid box of a regional numerical weather prediction or climate model and / or at the scale of a pixel of a satellite image. EVA_GRIPS combined surface based measurements, satellite data analysis and numerical modelling activities. A meso-scale field experiment, LITFASS-2003, was carried out in the heterogeneous landscape around the Meteorological Observatory Lindenberg

(MOL) of the German Meteorological Service in May and June, 2003. The experiment was embedded in the comprehensive, operational measurement program of the MOL. Experimental determination of surface fluxes on a variety of spatial scales was achieved by employing 14 flux stations over different types of land use, 10 scintillometers, a combination of ground-based remote sensing instruments (three lidars and a wind profiler / RASS system) and the Helipod, a turbulence probe operated by a helicopter. Surface energy fluxes were also derived from satellite data. Modelling work included the use of different SVAT schemes, a large-eddy simulation model and three meso-scale atmospheric models. LITFASS-2003 took place during a very dry late spring / early summer period resulting in significant heterogeneity concerning soil water availability and evaporation. A few precipitation events during the experiment added another strong heterogeneity pattern to the one prescribed by the land surface characteristics. The paper gives an overview on the background of EVA_GRIPS, and on the measurements and meteorological conditions during LITFASS-2003. A few general results are discussed.

Key Words

area-averaging, evaporation, heterogeneous land surface, LITFASS, turbulent fluxes

1. Introduction

Land surface - atmosphere interaction processes (i.a., reflectance, absorptance, and emittance of electromagnetic radiation, evapotranspiration and the transfer of heat, surface friction) play an important role in the energy and water cycle over a wide range of scales and exhibit a major influence on the diurnal cycle of near surface values of temperature, humidity, wind, and associated phenomena (e.g., dew or fog) as well as on the spatial distribution of clouds and precipitation. Among these processes, the turbulent fluxes of momentum, heat and water vapour represent the fundamental link between the soil-vegetation system and the overlying atmosphere. The turbulent transport of water vapour is of special interest since it connects the energy and water cycles. Water availability at the soil / vegetation - atmosphere interface determines the consumption and redistribution of energy at the surface and hence controls the evolution of the atmospheric boundary layer (ABL, see, e.g., Betts et al., 1996) with effects on the state of the atmosphere in general. An adequate description of the surface - atmosphere exchange processes in numerical weather prediction (NWP) and climate models is therefore fundamental for a reliable simulation of weather and climate conditions both at the surface and in the free atmosphere. However, considerable deficits have still to be noticed concerning our understanding and ability to properly describe these processes consistently over a variety of scales ranging from the local patch to the regional landscape scale. This does in particular hold for heterogeneous land surfaces which are typical for most regions in Central Europe. The effect of land-surface heterogeneity combined with the heterogeneity of incoming radiation and precipitation at the surface results in large spatial variations of the surface energy fluxes. Pielke and Avissar (1990) have summarised observations that demonstrate the significant impact of land-surface heterogeneity on the atmosphere.

Contemporary regional weather and climate prediction models have a typical grid resolution of the order of 10 km in the horizontal dimension and consist of 30 to 50 atmospheric layers resulting in a vertical resolution of a few decametres close to the ground. The tendency is towards even finer grids. Grid size reduction makes the grid point model output more sensitive to a proper description of the surface characteristics and of the surface - atmosphere interaction processes. However, many flux parameterisation schemes currently used in climate and NWP models have been derived for models with a much coarser grid resolution assuming homogeneous surface cover within one grid cell. Over the last fifteen years increasing efforts have been therefore devoted to the problem of taking into account the sub-grid scale land-surface heterogeneity by an appropriate averaging concept. Strategies suggested include, e.g., the use of effective parameters, the mosaic and tile approaches, or explicit subgrid schemes (e.g. Avissar and Pielke, 1989; Avissar, 1991; Lhomme et al., 1994; Mahrt, 1996; Mölders et al., 1996; Giorgi and Avissar, 1997; Schlünzen and Katzfey, 2003).

In 1995, the German Meteorological Service (Deutscher Wetterdienst, DWD) initiated the LITFASS project (LITFASS = '**L**indenberg **I**nhomogeneous **T**errain - **F**luxes between **A**tmosphere and **S**urface: a Long-term **S**tudy') in order to develop and to test a strategy for the operational determination of the area-averaged turbulent fluxes of heat, momentum, and water vapour over a heterogeneous landscape at the meso-γ scale (2-20 km). LITFASS combined measurements in the heterogeneous landscape around the Meteorological Observatory Lindenberg (MOL) with numerical model simulations using a large-eddy-simulation (LES) type high-resolution model (Beyrich et al., 2002a, Herzog et al., 2002). A first field campaign, LITFASS-98, was carried out in the region around the MOL in May and June, 1998. LITFASS-98 added to a sequence of field experiments performed in the 1980ies and 1990ies over heterogeneous land surfaces in different geographical and climate regions and devoted to the question of flux-averaging (e.g., HAPEX-MOBILHY – André et al., 1988, FIFE - Sellers and Hall, 1992, EFEDA - Bolle et al., 1993, BOREAS – Sellers et al., 1997, NOPEX - Halldin et al., 1998). Determination of area-averaged fluxes during these field experiments was mainly based on aircraft measurements (e.g. Mahrt and Ek, 1993; Crawford et al., 1996;

Frech et al., 1998; Mahrt et al., 2001), a methodology not suited to provide long-term data sets for a great variety of weather situations.

In general, field experiments of limited duration can provide valuable and comprehensive datasets for process studies but usually represent a limited spectrum of meteorological situations. This resulted in a general need for reliable, high-quality long-term data sets on land-surface atmosphere interaction processes for model development and testing (e.g. ECMWF, 1999; Gustafsson, 2000). The LITFASS measurement facilities established at MOL have therefore been set into continuous operation since summer 2001. These include

- a boundary layer field site (in German: **G**renzschicht-**M**essfeld, GM) close to the village of Falkenberg equipped with a 99m meteorological tower, a 10m profile mast, a sodar / RASS, and measurement systems for the determination of soil, radiation and turbulence parameters (e.g., Neisser et al., 2002),
- a network of micrometeorological (flux) stations operated over different land use classes in the LITFASS area (grassland, farmland, forest, water, e.g., Weisensee et al., 2001),
- networks of automatically recording rain gauges and global radiation sensors to characterise the spatial variability of the main meteorological forcing parameters (insolation, and precipitation), and
- a large-aperture scintillometer (LAS) over a path length of 4.7 km for the estimation of area-representative sensible heat fluxes (Beyrich et al., 2002c).

The synthesis of local measurements with modelling work and satellite data analysis (e.g. Hasager and Jensen, 1999; Braun et al., 2001) seems to have the highest potential of successfully solving the area-averaging problem (from local in-situ measurements to path- and area-integrated information) and appears to be suited to generate the long-term data sets, requested by the NWP and climate modelling communities. This strategy is in line with the conclusion formulated by Parlange et al. (1995): 'The combination of field measurements, ABL similarity modelling, and numerical simulations is providing a timely advancement of our understanding of land surface fluxes and the ABL'.

2. The EVA_GRIPS Project

Previous work on the area-averaging of fluxes left some gaps still to be filled:

- Model studies to characterise the influence of a heterogeneous land surface on the turbulent structure of the atmospheric boundary layer have been mostly performed for synthetic land use patterns; real surface structures have rarely been considered (e.g. Mölders and Raabe, 1996; Avissar and Schmidt, 1998; Liu et al., 1999, Friedrich et al., 2000).
- Both, experimental and model studies to determine the regional evaporation have often considered well defined drainage / run-off areas with a rather homogeneous land surface structure, so that the area-integrated evaporation could be estimated from a closure of the water budget based on measurements of precipitation and run-off. Direct measurement of the latent heat flux was, however, often limited to one reference site.
- The influence of surface heterogeneity at the meso-γ-scale on regional evaporation has not been investigated sufficiently for a mixture of land use types typical for Central Europe (forest, agriculture, meadows, and water in close vicinity to each other). Past European programs did either consider a different spatial scale or were performed under different climate conditions.
- Exchange processes at the surface and atmospheric boundary layer processes are strongly coupled to each other; this coupling has often not found proper attention in previous field programs by either concentrating on the ABL or the surface processes.

Moreover, new techniques are available now even for long-term continuous operation allowing for more comprehensive measurement programs of surface and boundary layer processes (sodar / wind profiler / RASS, MWR profiler, reliable fast response humidity sensors, scintillometers). Taking advantage of the new developments and taking into account the research gaps mentioned above, the EVA_GRIPS (Evaporation at Grid / Pixel Scale) project was realised as a part of the German Climate Research Program (DEKLIM). The primary goal of EVA_GRIPS was the determination of the area-averaged evaporation over a heterogeneous land surface at the scale of a grid box of a regional atmospheric circulation model and / or at the scale of a pixel of a satellite picture. Because evaporation is determined through the availability of energy and water at the land surface all remaining components of the surface energy and water balance had to be considered as well. Through the combination of surface based observations, satellite data analysis, and numerical simulations, EVA_GRIPS aimed for

- an assessment of the consistency of area-averaged surface flux values derived from experimental data using a suite of measurement systems from the local to the regional scale and from the surface layer up to the boundary layer,
- a study of the relevance of mesoscale circulations / advective transports for the exchange of energy and water vapour over a heterogeneous land surface,
- a study of the link between surface layer water vapour transport and ABL processes and structure,
- the development, improvement, and testing of aggregation rules for the determination of grid averaged surface parameters and methodologies to calculate grid averaged fluxes,
- an investigation of the impact of various averaging strategies on the simulation of the atmospheric boundary layer,
- an assessment of the sensitivity of modelled fluxes on grid resolution, surface heterogeneity and on the representation of turbulence, clouds and precipitation, and of the model uncertainty in determining area-averaged evaporation fluxes by controlled inter-comparison experiments between different models.

Two research programs based on comparable arguments and ideas have been established in Scandinavia and in the USA over the last decade, namely the NOPEX and ABLE / CASES activities (see, e.g., Halldin et al., 1999; LeMone et al., 2000, Poulos et al., 2002). When compared to these programs, EVA_GRIPS differs in scale (meso-γ vs. meso-β), areal coverage (grid-cell or satellite pixel vs. watershed), degree of land-surface heterogeneity, and regional climate.

EVA_GRIPS was part of the international Baltic Sea Experiment BALTEX (see, e.g., Raschke et al., 2001), the European contribution to the Continental Scale Experiments within the Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research Programme (WCRP) of WMO. Within BALTEX the area around Lindenberg was selected as a reference site for land - air interaction studies (together with Sodankylä - Northern Finland, Marsta / Norunda - Central Sweden, and Cabauw - The Netherlands). Equally, Lindenberg is one of the European reference sites for the CEOP (Co-ordinated Enhanced Observation Period) project in GEWEX (e.g., Lawford et al., 2004).

3. The LITFASS-2003 Experiment: Goals and Study Region

Based on the central goal of the EVA_GRIPS project, the LITFASS-2003 field experiment focused on the experimental investigation of the exchange of water vapour and energy between a heterogeneous land surface and the atmosphere and on the interaction of the exchange processes with the atmospheric boundary layer (ABL) structure. The basic goal of the field experiment was the collection of a comprehensive data set suited for the validation of different types of numerical simulation models and of strategies to derive land surface parameters from satellite data taking into account area-averaging and scale-aggregation issues. To achieve this general objective, the following specific aims were formulated:

- Direct measurement of the local water vapour and energy fluxes using eddy-covariance techniques at a number of sites in the measurement area considering the surface properties (representation of all major land use and soil classes) and the spatial variation of precipitation, cloudiness, and radiation (i.e., the water and energy input) across the study area,
- experimental determination of the area-averaged turbulent fluxes at the surface and inside the ABL using spatially integrating measurement and analysis techniques (scintillometry, airborne measurements),
- performance of profile measurements of the latent heat flux inside the ABL using ground based remote sensing systems in order to link the near-surface observations to the area-averaging measurements,
- identification and quantitative description of small- and meso-scale processes and structures determining the exchange of water and energy over a heterogeneous land surface,
- characterisation of the vertical structure of the ABL and its spatial and temporal variability, and experimental determination of characteristic scaling parameters over inhomogeneous terrain,
- analysis of satellite data with respect to the derivation of two-dimensional fields of soil and vegetation parameters (NDVI, LAI etc.), surface radiation and energy fluxes for the study area.

Although the focus of the project was on evaporation, other processes and parameters like precipitation, soil moisture, radiation ~, ground ~ and sensible heat fluxes had to be considered as well taking into account the central role of evaporation as a link between the energy and water cycle at various scales.

The study region of the EVA_GRIPS project was a 20*20 km^2 area (the so-called LITFASS area, Beyrich et al., 2002a) around the Meteorological Observatory Lindenberg

(MOL) of the DWD. The boundaries of the LITFASS area are given by the following co-ordinates:

52°05’30” N	13°54’00” E
52°16’30” N	14°12’00” E

The MOL is situated in a rural environment in the North-Eastern part of Germany, about 65 km to the South-East of Berlin. The landscape in this area has been formed by the inland glaciers during the last ice age exhibiting a slightly undulated surface with height differences of between 80 m an 100 m over distances of between 10 km and 15 km. The land use is dominated by forest and agricultural fields (more than 40 % each), lakes represent 6-7 % while villages and traffic roads cover less than 5 % (compare Figures 1-4). This mixture of surface types is typical for the region and also for larger parts of northern Central Europe south of the Baltic Sea.

The forest is mainly situated in the western part of the area, while agriculture is dominant in the eastern part (see Figure 2). For the farmland, cereals (triticale, rye, and to a smaller extent barley and wheat) are the main type of crops; significant parts of the agricultural fields are also covered by grass, rape, and maize. The overall percentages of the basic land use types in the area are indicated in Figure 3. The fractions of the different types of agricultural crops may change slightly from year to year. During the last five years, however, they differed by not more than 2 % from the numbers given in Figure 3. The soil type distribution is dominated by sandy soils. In the forested western part of the area, the sand reaches a depth of several meters. 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 50 cm to 80 cm, locally even below.

Figure 1

Figure 2

Figure 3

The LITFASS-2003 field experiment was performed in the LITFASS area from 19 May to 17 June 2003, i.e., during the main growing season. Scientists, technicians and students from 13 research institutes and universities participated in the field campaign. A list of the participating institutions is given in the Appendix.

4. Measurement Systems and Experimental Setup

At MOL a comprehensive operational measurement program is performed in order to characterise the vertical structure of the atmosphere. Measurements include, i.a., the operation of the LITFASS boundary layer measurement facilities (see section 1), a radiation station of the global BSRN network (e.g., Ohmura et al., 1998), a complex of ground-based remote sensing systems (two wind profiler radar / RASS, a sodar / RASS, a microwave radiometer profiler (MWRP), a cloud radar – e.g., Engelbart and Steinhagen, 2001), and the execution of four regular PTU radiosoundings per day (e.g., Leiterer et al., 2000). These operational measurements along with the available infrastructure and logistics represent an ideal basis to carry out a meso-scale field experiment embedded into a long-term background measurement program.

Linked to the operational measurements of the MOL, additional systems and instruments were set up for the LITFASS-2003 experiment. The experiment measurement program comprised:

- 14 micrometeorological and flux stations operated over different surfaces representing the major land use types in the area (forest, water, and different types of agricultural farmland: grass, cereals, rape, maize), and laser scintillometers at five of the sites (see also Beyrich et al., this issue),

- three large aperture optical scintillometers (LAS) and a microwave scintillometer (MWS) set up along three different paths over distances of 3 to 10 km (see also Meijninger et al.; Kohsiek et al., this issue),
- synchronised high-resolution (10 seconds sampling rate) measurements of water vapour and vertical velocity profiles by a DIAL-/RASS-combination and by a DIAL / Doppler lidar combination (see also Hennemuth et al., this issue),
- more than 60 flight hours with the Helipod, a turbulence probe operated on a rope below a helicopter (see also Bange et al., this issue).

During four days, a mapping of the surface temperature distribution in the LITFASS area with an infrared camera on board of a Tornado aircraft of the Deutsche Bundeswehr (German Air Force) was performed. Moreover, monitoring activities included the collection of information on soil and vegetation parameters and on the spatial distribution of precipitation and radiation across the study region. A detailed list of the different measurement systems is given in Table I, and the set-up of the instrumentation during LITFASS-2003 is shown in Figure 4.

Table 1

Figure 4

The MOL site and the GM Falkenberg, which is situated about 5 km south of the MOL, formed the two central measurement sites of the experiment (see Figure 4). An additional remote sensing site, equipped with a sodar and a ceilometer, was set up in the western (forested) part of the area. The micrometeorological measurements were concentrated in the eastern part of the study region. They covered all major agricultural crops (triticale, rye, barley, rape, maize and grassland), forest and water. The long-distance scintillometer paths represented three different distributions of major land use classes with forest-to-farmland ratios of about 20, 2, and 0.1, respectively, in the footprint area of the paths.

Different flight patterns were designed for the Helipod flights. Patterns used for flux measurements included (for details, see Bange et al., this issue):

- the "grid" pattern - a sequence of five to seven horizontal flight legs of 10-15 km length separated by about 2 km and oriented in North-South- and East-West-direction respectively flown at low altitude (about 100 m agl),
- the "vertical grid" pattern - a sequence of straight legs of 15-20 km length flown along the mean wind direction at five to six altitudes between about 100 m and 1 km agl (corresponding to scaled altitudes of between less than 0.1 up to 0.7 times the boundary layer height).
- the "box" pattern - a sequence of four flight legs roughly forming a square with about 10 km side length flown at different altitudes (typically at about 100 m, 400 m, and 700 m agl),
- the "catalogue" pattern - a sequence of legs of 10-15 km length arranged over fairly homogeneous sub-regions of the study area (farmland, forest, water) and over a mixed land surface flown at 2-3 altitudes between about 100 m and 700 m agl.

With respect to the experimental determination of the turbulent fluxes, several orders of scales in the magnitudes of sampling domains and footprint area sizes were covered by this combination of the measurement systems (see Table 2).

Table 2

5. QA / QC Activities

Special attention within the EVA_GRIPS project and, in particular, in connection with the LITFASS-2003 experiment, was given to quality assurance and quality control issues of the measurements (see also Mauder et al., this issue). This included the performance of a pre-experiment in May and June 2002 at the GM Falkenberg in order to perform an inter-comparison of the different types of turbulence measurement systems as well as of radiation and soil sensors operated by the different groups. In addition, the different Helipod flight patterns were tested during this pre-experiment in order to define and to adopt the data analysis and interpretation strategy to the goals of the project, and to get a first insight into the representation of the heterogeneous landscape in the measured data. During a second campaign in September 2002, the synergy of systems for the flux profile measurements was realised for the first time. Eddy-covariance measurements at the surface and at the 90 m level of the Falkenberg tower were performed along with water vapour DIAL and wind profiler / RASS soundings over a period of two weeks, and the Helipod was flown on four days to assess the suitability of the vertical grid ~, catalogue ~ and box flight patterns in comparison with the lidar / RASS profile measurements.

In order to minimise differences in the estimates of the turbulent surface fluxes from the eddy-covariance measurements caused by different sensor and systems characteristics, only two types of ultrasonic anemometer-thermometers and fast response hygrometers were used during the LITFASS-2003 experiment, namely sonics CSAT-3 (Campbell Sci. Ltd.) and USA-1 (METEK GmbH), and hygrometers KH-20 (Campbell Sci. Ltd.) and LI7500 (LiCor Inc.), respectively. A laboratory calibration procedure for the fast response hygrometers was set up and tested at MOL during the pre-experiment in 2002 (Weisensee et al., 2003). Prior to and after LITFASS-2003, all KH-20 and LI7500 instruments from the different groups were calibrated with this unified procedure. The calculation and quality assessment of the turbulent surface fluxes for LITFASS-2003 was realised with one unique program module applied to the eddy-covariance measurements of the different groups (see Mauder et al., 2005, this issue). This ensured comparability of the computed fluxes with respect to data treatment and correction algorithms.

In addition, post-field consistency checks were performed between the data from the different sites and / or instruments collected during LITFASS-2003. This included a thorough comparison of the downward radiation flux measurements under clear-sky conditions, a plausibility control for the temperature, humidity, wind and soil data, and the inter-comparison of the humidity profile data from the DIAL, radiosonde, and microwave radiometer profiler (MWRP) systems. The measurements performed within the ABL with the ground-based remote sensing systems and with the Helipod underwent a thorough statistical analysis and error estimate to ensure the reliability, comparability, and representativeness of the derived fluxes (see also Hennemuth et al., this issue).

6. Meteorological Conditions

The first half of the year 2003 was characterised in the experimental region by a rather cold and long winter with little snow, followed by a very warm and dry late spring and early summer period. With the exception of January 2003, all the other months were too dry and had an excess of sunshine compared to the long-term (30 years) mean. Some selected climate data for this period are summarised in Table 3.

Table 3

The first half of the year 2003 was one of the driest since the beginning of the Lindenberg record in 1905: From January to June 2003, 165.4 mm were recorded comrisong only 60 % of the normal rainfall amount. These atypical observations resulted from an unusual circulation pattern during most of the time with dominating easterly wind directions: The most frequent wind direction was ESE, while during “normal” years winds from the SW are dominant. The extreme precipitation deficit between February and May 2003 resulted in a rapid and early consumption of the soil water storage already at the beginning of the vegetation period. This is illustrated in Figure 5 showing the time series of soil moisture and daily precipitation sum from March 2003 till the end of June 2003. Continuous TDR measurements of soil moisture were supported by regular probing with the gravimetric method and by mesurements with the Lumbricus sonde (profile measurements of the di-electric constant of the soil). Although differences up to 3-5 Vol-% may be noticed for single measurements, the general evolution of estimated soil moisture is in good agreement between the different measurements. At the beginning of the LITFASS-2003 experiment, soil moisture was already quite low (between 5 and 8 Vol-% typically), and it further decreased close to the wilting point during LITFASS-2003 in some parts of the region.

Figure 5

At the beginning of the experiment, the region was influenced by a cyclonic south-westerly to westerly flow with several frontal passages and embedded high pressure ridges. After the first week, the meteorological situation was dominated by anticyclonic influence of an upper level ridge extending from Central Europe to Scandinavia. At the surface this caused high-pressure influence as well, which was only temporarily interrupted by the passage of shallow low-pressure zones with embedded showers or thunderstorms. During the last week, the study region came again under the influence of the frontal zone, however, it remained on its warm side.

The weather was thus characterised by high insolation and a few days only with significant precipitation. Nighttime temperatures were mostly above 10 deg C except for two nights during the first week. Daytime maximum temperatures exceeded 30 deg C during several days, in particular during the first decade of June. Winds were generally weak to moderate and frequently blew from easterly directions; the 10m wind speed was mostly less than 6 ms^{-1}. Single gusts up to 25 ms^{-1} occurred during thunderstorms on 5 and 8 June. Time series of basic meteorological parameters for the period of the LITFASS-2003 experiment are shown in Figure 6.

Figure 6

Measurable precipitation was recorded during the one-month period of the experiment on eight days only. Significant amounts of rain occurred in connection with two frontal systems at the beginning of the experiment (18-19 May, 4-13 mm) and during the passage of low-pressure zones with embedded showers and thunderstorms on 5 June (1-45 mm), 8 June (8-20 mm), and 12 June (2-9 mm). In particular the precipitation event on 5 June produced an extremely heterogeneous distribution of rain across the study region which caused a rather complex spatial pattern of evaporation during the following days. The second thunderstorm situation three days later resulted in a more smooth precipitation distribution. The spatial pattern of rain during these two events compiled from the measurements of the Berlin weather radar (precipitation scan mode) and the regional LITFASS rain gauge network is illustrated in Figure 7.

Figure 7

Figure 8 depicts the moisture content of the atmospheric boundary layer (ABL) during daytime for the individual days of the experiment as derived from measurements with the water vapour DIAL, with the MWRP, and from the data of the 12 UTC radiosonde. Data from all three systems were averaged over the height range between 500 m and 1000 m above ground representing the central part of the ABL in most cases, and the upper half of the ABL for a few days when the ABL growth was slow. Error bars indicate the variability of humidity within this height range. The humidity values derived from the three different systems are in reasonable agreement taking into account the site separation and the different principles of measurement. While the DIAL was operated at GM Falkenberg, both the MWRP and the radiosonde release point are situated at the MOL site. The radiosonde profile represents a snapshot of the instantaneous structure of the ABL during the time of the ascent, the height range of interest is passed by the radiosonde along a slanted path within less than two minutes. The DIAL and MWRP data reflect the characteristics of the ABL directly above the instrument; while the DIAL measurements were performed with a vertical resolution of 60 m averaged over ten minutes, a smoothing of the vertical profile is inherent to the MWRP analysis scheme and is typical for passive remote sensing instruments. From Figure 8 it is obvious, that the ABL humidity was rather low between 20 May and 22 May, it then increased for four days in connection with a frontal system that brought moist subtropical air from the South. North-easterly winds advected rather dry air between 27 May and 31 May. At the beginning of June, continental air masses were advected from South-East and South resulting in maximum humidity values of more than 10 gm^{-3} on 5 June. Minor variations of ABL moisture at an intermediate level occurred for the rest of the experimental period except for 11 June when some moist air was present after the passage of a weak front.

Figure 8

A central parameter to characterise the ABL structure is the ABL height which also serves as a scaling parameter for the vertical profiles of fluxes, variances and structure parameters for a well-mixed convective boundary layer. Knowledge of the ABL height was of interest for the interpretation of the flux profiles derived from the DIAL/RASS, DIAL/Doppler lidar and Helipod measurements. An estimation of the ABL height can be obtained from vertical profile measurements with in-situ and ground based remote sensing systems. Corresponding estimates for the daytime convective ABL have been derived from the radiosonde, lidar and wind profiler data. The ABL height during the noontime radiosonde ascent for the period of the experiment is shown in Figure 9. The wind profiler radar (WPR) data have been analysed for a local maximum of the backscattered signal that can be expected at the top of a fairly mixed convective ABL (e.g., Beyrich and Görsdorf, 1995). Height values displayed are an average of the position of this maximum in the mean reflectivity profiles of the five WPR beams in its standard operation mode. Error bars of ±150 m are given corresponding to the height resolution of the system. The DIAL data were analysed for the occurrence of sharp gradients and local variance maxima both in the backscatter intensity and water vapour profiles averaged over ten minutes (for details, see Lammert, 2004). ABL height values shown in Figure 9 are averages over six 10-minute intervals with the maxima and minima indicated by the error bars. Radiosonde profiles have been analysed according to three different criteria: (i) the height of an elevated inversion base, (ii) the height above which a sudden drop in moisture occurs, and (iii) the height at which a parcel rising with the temperature measured at the surface becomes neutrally buoyant. The mean, maximum and minimum from the three estimates are presented in Figure 9. In general, good agreement between the different ABL height estimates from the three systems can be noticed. Deviations are within the uncertainty range during most of the days. A few exceptions correspond to situations with disturbed ABL structure or a not well-defined ABL top (e.g. 31 May). Early afternoon mixing heights typically were between 1200 m and 2000 m. However, there were also a few days with 11UTC ABL heights below or around 1000 m. Maximum values between 2500 m and 3000 m occurred on 31 May and 02 June.

Figure 9

7. Selected Results

It is beyond the scope of this overview paper to present the major results of the LITFASS-2003 measurements and EVA_GRIPS project achievements here in detail. Instead, a few exemplary results shall be discussed which illustrate the complexity of the ABL structure and processes over the study area. For details and for the different aspects of the measurements, data analysis and modelling activities, the reader is referred to the papers comprised in this special issue.

The heterogeneity in land use, soil and vegetation characteristics causes a complex heterogeneous pattern of basic aerodynamic, thermal and hydrological characteristics of the land surface across the LITFASS area. As an illustration, the surface temperature distribution on 17 June 2003, around noon both measured from the Helipod during a grid flight and derived from NOAA-16 satellite imagery using the SESAT algorithm (Berger, 2001), is shown in Figure 10. Differences of more than 10 K can be found over rather short distances. The coldest surfaces are the lakes while the highest temperatures were measured over the farmland areas. In the satellite picture, a few cold spots at the lateral boundaries of the LITFASS area are due to clouds. The general surface temperature distribution between the forested and farmland areas, and the water surfaces is quite comparable, but the detailed structure of the surface temperature pattern can be much better resolved from the Helipod measurements. Note that the whole Helipod flight took about two hours, starting with the N-S flight legs in the eastern part of the area and ending with the E-W legs at the southern edge. Hence, effects of different surfaces partly match with non-stationarity effects in Figure 10a. However, this non-stationarity is considered to be of secondary importance during the hours after local noon on a day with dominant clear sky. The changes in local surface temperature during the time of the flight as measured with infrared thermometers at GM Falkenberg, and at the forest and lake sites, respectively, did not exceed 5 K for Falkenberg and 2 K for the other two sites. The SESAT algorithm was also used to infer land surface parameters (e.g., the leaf-area index) and energy fluxes over the LITFASS area from the satellite data. The land-surface parameters were then taken as external parameters at the lower boundary for mesoscale model simulations (see Heret et al., this issue)

Figure 10

As a consequence of the variability of surface characteristics and meteorological forcing conditions, significant differences were found for the surface energy fluxes between the three major land use classes (forest, farmland, water), but also between the different types of agricultural farmland (see Beyrich et al., this issue). The combined effect of the forcing conditions on the turbulent energy and water vapour fluxes can be illustrated by the Bowen ratio ($Bo = H / \lambda E$) characterising the partitioning of available energy between the sensible and latent heat fluxes. The variability of Bo over the period of the LITFASS-2003 experiment for some of the micrometeorological sites is shown in Figure 11. Highest Bo-values were always found over the forest. Over the lake, Bo was less than one all the time indicating the dominance of evaporation over the free water surface. For most of the other sites, Bo was less than one at the beginning of the experiment after some rain occurred on 18-19 May. During the dry period between 27 May and 5 June a gradual increase of Bo can be noticed over all land surfaces. This increase was only weak over rape and rye fields which were still at the end of their bloom and represented a dense green vegetation mass. In contrast, dominance of the sensible heat flux could be noticed over dry grass at GM Falkenberg and especially over the maize fields being more or less bare soil surfaces at this time. The Bowen ratio sharply dropped down to values around 0.5 after the rain event of 5 June in the southern part of the study region. For the sites in the North (represented by the barley site in Figure 11), where only a small amount of precipitation was measured (see Figure 7), the sensible heat flux still remained dominant and the decrease of Bo only occurred after the second rain event on 8 June. During the last ten days of the experiment, a gradual increase of Bo was noticed again at all of the sites (except for the lake), interrupted only on 13 June due to some rain during the night before. Towards the end of the experiment, Bo was lowest over the maize fields which now had developed green plants of about 60 cm height while the rape and cereals had become senescent and more dry. As it is obvious from Figure 11 the highest differences in Bo occurred at the end of the dry periods on 4 June and 17 June. The reduced increase in Bo between 1 June and 5 June can be attributed to the warm and more humid air masses prevailing in the area during these days (compare Figure 8) thus reducing the surface – air temperature differences and also the water stress for the plants. This also illustrates the interrelations between the ABL structure and processes and the surface fluxes.

Figure 11

Different methods were used to determine the area-averaged fluxes of heat and water vapour over the study region. A flux composite was derived from the local micrometeorological measurements at 13 sites by a suitable averaging and aggregation scheme taking into account the data quality of the single flux measurements and the relative occurrence frequency of the different land use types across the area (see Beyrich et al., this issue). Area-averaged fluxes both over the mainly farmland and forest parts of the area were derived from the long-distance scintillometer measurements (see Meijninger et al., this issue). Profile extrapolation and inverse modelling methods were applied to determine the area-averaged surface fluxes from the Helipod measurements during the "box" and "grid" flights (see Bange et al., this issue) and from the DIAL / wind lidar measurements (see Hennemuth et al., this issue), respectively. In general, the different estimates of the regionally representative surface fluxes supported each other quite well. The area-averaged fluxes were then used for comparison and validation studies with different mesoscale numerical models (see Ament and Simmer, this issue; Heinemann and Kerschgens, this issue, Heret et al., this issue). In particular, different flux aggregation strategies and different methods to derive the land surface parameters (including the use of satellite data) were tested with these models. As an example, the mean diurnal cycle of the area-averaged sensible and latent heat fluxes during the LITFASS-2003 period as derived from the eddy-covariance measurements and compared to the output of the DWD NWP model is presented in Figure 12. The results of three types of model runs are shown. The first was the operational run at the time of the experiment, the second one was a modified LM version with improved soil moisture initialisation (based on precipitation measurements prior to the experiment period) and a subgrid-scale land surface parameterisation scheme (mosaic approach, for details see Ament and Simmer, this issue), and the third version made use of adapted land-surface parameters (partly derived from NOAA-16 satellite data) and also used measurement-based soil moisture data for initialisation.

Figure 12

As can be seen from the Figure, the operational LM simulation underestimated the sensible heat flux and considerably overestimated the latent heat flux. Moreover, the model simulation yielded a mean Bo ratio smaller than one ($H < \lambda E$) while in the measurements the sensible heat flux exceeded the latent heat flux. These model deficits could be significantly reduced by introducing the above-mentioned modifications to the LM. In particular, the simulated Bo ratio obtained with the modified model version was above one during daytime in agreement with the measurements. A remaining difference is the decrease of evaporation in the afternoon that is obvious in the measurements but not properly simulated with LM. This decrease is attributed to the limited water availability during the mostly dry experimental period.

Large-eddy simulations for a number of days from the LITFASS-2003 experiment were performed with the LES model PALM (Raasch and Schröter, 2001) at 100 m horizontal resolution. These simulations were used, i.a., to study the possible contribution of mesoscale circulations to the area-averaged fluxes within the ABL. Simulations were performed for the daytime hours between 0500 and 1500 UTC. They were initialised with the 0600 UTC radiosonde profiles (time of the sonde ascent at MOL is 0445 UTC) and driven by the composite sensible and latent heat fluxes for the major land use classes (forest, water, grass, cereals, maize, rape) as derived from measurements at the ground. The composite flux values were distributed over the study area according to the detailed land use pattern.

The different days investigated represent cases of different forcing with respect to wind speed and net radiation. The contribution of the mesoscale vertical sensible and latent heat flux to the respective total fluxes is illustrated for four days in Figure 13

Figure 13

For the sensible heat flux, a significant contribution of the mesoscale to the total flux was found for a case with very week winds only, it is in the range between 10 to 20 %. For wind speeds of 4 ms^{-1} or higher, the mesoscale flux typically amounts to about 5 % of the total flux. Results are different for the latent heat flux. Here, mesoscale circulations contribute to the total area-averaged flux with 10 to 20 % typically. There is a week dependence on wind speed only. These differences are attributed to the structure of the ABL and of the overlying free troposphere. Due to entrainment, warm and dry air is usually transported downward in the ABL. The scalar transport due to mesoscale downward vertical motion thus causes a negative temperature flux but a large positive moisture flux. Consequently, positive fluxes dominate in the horizontally averaged mesoscale latent heat fluxes, while for the averaged temperature flux positive and negative contributions partly cancel and the resulting (mesoscale) flux is small only. Figure 13 also reveals a slightly increasing contribution of the mesoscale latent heat fluxes during the course of the day, which is due to the fact that the non-organised convection tends to weaken in the afternoon. Additional "homogeneous" simulations were carried out using the area averaged surface fluxes calculated from the measurements as boundary conditions. The results show almost no differences in the vertical profiles of the total fluxes to those from the corresponding runs with inhomogeneous surface heating. Compared to a homogeneous surface, the mesoscale circulations thus do not amplify the total vertical transport but only decrease the contribution of the non-organised convection. This relative effect may not have to be regarded in boundary layer flux parameterisations of larger scale models.

8. Summary and Final Remarks

The LITFASS-2003 experiment was conducted over a 20*20 km^2 area of heterogeneous landscape around the Meteorological Observatory Lindenberg (MOL) of the German Meteorological Service (Deutscher Wetterdienst, DWD). LITFASS-2003 was the central part of the experimental activities of the EVA_GRIPS project which was focused on the determination and parameterisation of the area-averaged evaporation over a heterogeneous land surface. Measurements were performed during a one-month period (19 May to 17 June 2003) and covered the main vegetation growth phase in late spring, and early summer. The design of LITFASS-2003 was based on experiences from the LITFASS-98 experiment performed five years ago in the same area (Beyrich et al., 2002a). However, the measurement programme was considerably extended when compared to the earlier field campaign, this is illustrated by the summary given in Table 4.

A hierarchy of instruments and methods was used to derive the fluxes of energy and water vapour from the local to the regional scale including eddy-covariance measurements both at the surface (over all relevant land use classes) and on a 99m meteorological tower, scintillometry, ground-based remote sensing systems and airborne measurements using the Helipod, a turbulence probe carried by a helicopter. All these measurements were embedded in the routine measurement program of the MOL. In addition, the areal distribution of land surface parameters and energy fluxes was derived from satellite data. This strategy appeared to be very well suited with respect to the goals of EVA_GRIPS and can thus be recommended for future experiments with similar objectives. It met the demand formulated by Parlange et al. (1995): 'To understand transport at the scales of interest in hydrology, it is important to measure evaporative processes at (all) those scales'.

LITFASS-2003 took place at the end of a warm and dry spring period with low values of the soil water content already at the beginning of the experiment. Under these conditions, heterogeneity of the land surface characteristics was quite pronounced. The synoptic situation during LITFASS-2003 was - except for the first week and for the last week - dominated by anticyclonic influence causing conditions of mostly dry weather with high insolation and weak winds, often from easterly directions. Two precipitation events at the end of the third week reduced the water stress to the vegetation. The first of these two rain events with a very uneven distribution of precipitation added significant heterogeneity to the meteorological forcing in addition to the heterogeneity caused by the land surface characteristics. This resulted in a quite complex evaporation pattern the following days.

The LITFASS-2003 experiment provided a comprehensive and unique data set on land surface / atmosphere interaction processes over a heterogeneous land surface at the meso-γ scale. A complete quality-controlled time series of area-averaged surface fluxes from the four-weeks period of the LITFASS-2003 experiment (with a data coverage of more than 80 %) has been created. This data set could be used - for the first time - to validate mesoscale atmospheric models at grid scale against measurements over a time period of several weeks.

Analysis of the measured data revealed a significant variability of the surface layer fluxes across the area in dependence on both the land use and the meteorological forcing conditions. Area-averaged surface fluxes calculated from the local measurements by using the tile approach were in good agreement with area-representative values directly obtained from the scintillometer and Helipod measurements.

The data collected during LITFASS-2003 were used either as boundary conditions and forcing data for different kinds of numerical models or as a verification data set within the EVA_GRIPS project. The modelling activities in EVA_GRIPS comprised 1-dimensional models for off-line simulations of the soil-vegetation-atmosphere exchange processes (see Mengelkamp et al., this issue), 3-dimensional non-hydrostatic mesoscale models (see Ament and Simmer; Heinemann and Kerschgens, Heret et al., this issue), a hydrostatic mesoscale climate model and a large-eddy simulation model. Moreover, the data were used to validate retrieval algorithms for the determination of land surface parameters and energy fluxes from satellite data (see Heret et al., this issue, Tittebrand et al., 2005). First comparisons with output data from the operational NWP model runs at DWD showed a systematic overestimation of the latent heat flux in the model data. By changing the soil moisture model initialisation and by introducing a sub-grid scale flux parameterisation the LM performance could be improved.

LES were performed for a number of case studies with heterogeneous forcing at the surface according the measured heat fluxes over the different surface types. They revealed the existence of mesoscale circulations in the study region, preferably under weak wind conditions. These may significantly contribute to the total flux especially for the transport of latent heat. This leads to the conclusion that local flux profile measurements (as performed with the ground based remote sensing systems in LITFASS-2003) might not necessarily be representative for the mean ABL flux profiles in the study area. It is therefore advisable, to perform a model study on mesoscale circulations during the design phase of the measurement strategy in future field experiments.

The results obtained from the flux measurements at different scales, from the modelling activities and from the satellite data analysis will be discussed in detail in a series of papers following the present overview in this issue of Boundary-Layer Meteorology.

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Appendix

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List of Tables

Table 1 Measurement systems operated during the LITFASS-2003 experiment

Measurement Complex	Operator [1)]	Number of Systems	Site(s)	Status of Operation [2)]	References
Basic Measurements					
• synoptic weather station	DWD	1	MOL	op	
• routine radiosoundings	DWD	1	MOL	op	Leiterer et al. (2005)
• additional radiosoundings	DWD	1	MOL	sel	Leiterer et al. (2005)
• BSRN station	DWD	1	MOL	op	Ohmura et al. (1998), http://www.bsrn.ethz.ch
• GM Falkenberg	DWD	1	GM	op	Neisser et al. (2002)
Ground-Based Remote Sensing					
• sodar / RASS	DWD	1	GM	op	Engelbart and Steinhagen (2001)
• 1290 MHz WPR / RASS	DWD	1	MOL	op	Engelbart and Steinhagen (2001)
• 492 MHz WPR / RASS	DWD	1	MOL	op	Engelbart and Steinhagen (2001)
• MWRP	DWD	1	MOL	op	Engelbart and Steinhagen (2001)
• cloud radar	METEK	1	MOL	cont	http://www.metek.de
• micro rain radar	DWD	1	MOL	op	Peters et al. (2002)
• wind / temperature radar	MPI	1	GM	cont	Hirsch (2000)
• DIAL	MPI	2	GM	sel	Wulfmeyer and Bösenberg (1998)
• wind lidar	MPI	1			Bösenberg and Linné (2002)
• Raman lidar	AWI	1			Schäfer et al. (1995)
• sodar	ALUF	1	Bw	cont	http://www.scintec.com
• laser ceilometer	DWD / MPI	3	MOL / GM / Bw	op / cont	Münkel et al. (2001)
Micrometeorological Measurements					
• micrometeorological stations over all relevant land use classes	DWD, GKSS, TUDD, UBT, WUR, MPI	14 (13 sites)	see Figure 4	op / cont	Weisensee, et al. (2001) Beyrich et al. (2002b) Beyrich et al., this issue
• turbulence measurements at the 99 m tower	DWD	2	GM	cont	

Table 1 (Continued)

Scintillometer Measurements					
• laser scintillometer SLS-20/40	DWD, GKSS WUR, LIM	7	see Figure 4	op / cont	de Bruin et al. (2002), Hartogensis et al. (2002) http://www.scintec.com
• LAS	DWD, WUR	2	see Figure 4	op / cont	Beyrich et al. (2002c)
• XLAS	KNMI / WUR	1	see Figure 4	cont	Kohsiek et al. (2002)
• Microwave scintillometer	DWD / Ubern	1	GM → MOL	cont	Lüdi et al. (2005), Martin et al. (2002)
Airborne Measurements					
• Helipod sonde	TUBS	1	-	sel	Bange and Roth (1999), Bange et al. (2002)
• Tornado	Bundeswehr	1	-	sel	
Monitoring in the LITFASS area					
• registr. precipitation gauges	DWD	14	see Figure 4	op	Beyrich et al. (2002a)
• global radiation	DWD	5	see Figure 4	op	
• soil moisture monitoring	DWD	2	GM / HV	sel	
• LAI - measurements	DWD	9	see Figure 4 (A1-A9)	sel	for details regarding the A1-A9, FS, and SS sites see
• water temperature	DWD / BTU	8	see Figure 4 (FS,SS)	op / sel	Beyrich et al. (this issue)
[1] short names of the operators are explained in the Appendix, [2] op - operational at MOL, cont - continuously during LITFASS-2003, sel - selected days only					

Table 2 Sampling characteristics of the flux measurement systems operated during the LITFASS-2003 experiment

Table 2			
measurement system	sampling scale	sampling domain	footprint scale
sonic / hygrometer	10^{-1} m	10^{-1} m	$10^{1}..10^{2}$ m
(~ at tower)	10^{-1} m	10^{-1} m	$10^{2}..10^{3}$ m
laser scintillometer	10^{2} m	10^{2} m	$10^{2}..10^{3}$ m
remote sensing	10^{2} m	10^{1} m	$10^{3}..10^{4}$ m
LAS / MWS	10^{3} m	10^{3} m	$10^{3}..10^{4}$ m
XLAS	10^{4} m	10^{4} m	$10^{3}..10^{4}$ m
Helipod	10^{0} m	10^{4} m	$10^{3}..10^{4}$ m

Table 3 Selected climatological data of the synoptic weather station at the MOL during the period December, 2002 till June, 2003 in comparison with the long-term climatological mean (1961-1990).

Table 3										
month	air temperature		precipitation		sunshine duration		days with frost ($T_{min} < 0$ °C)		summer days ($T_{max} > 25$ °C)	
	mean (°C)	vs. climate (K)	sum (mm)	vs. climate (%)	sum (h)	vs. climate (%)	number	vs. climate	number	vs. climate
Dec 02	-2.5	-2.9	14.6	29	64.9	173	27	+ 8	-	-
Jan 03	-1.0	+0.2	49.4	128	44.3	96	18	- 5	-	-
Feb 03	-1.9	-1.8	4.7	14	121.7	174	28	+ 9	-	-
Mar 03	4.1	+0.7	25.8	72	167.8	136	20	+ 4	-	-
Apr 03	8.7	+0.8	31.5	77	212.8	129	10	+ 5	-	-
May 03	15.7	+2.6	14.1	24	254.4	113	-	-	8	+ 5
Jun 03	19.4	+2.9	39.9	62	294.6	129	-	-	14	+ 5

Table 4 Selected elements of the measurement programme of LITFASS-2003 compared to LITFASS-98

Component of the measurement programme	LITFASS-98	LITFASS-2003
surface flux measurements		
• eddy covariance	6 sites	13 sites
• laser scintillometer	1 site	5 sites
tower flux measurements	4 levels	2 levels
long-distance scintillometers	1 path	3 paths
humidity flux profiling	none	DIAL + RASS / Doppler lidar + RASS
airborne flux measurements	1 flight Helipod + DO128	24 flights Helipod
radiosoundings	4 daily	4 daily + 20 extra soundings
surface temperature mapping	none	6 Tornado flights

Figure Captions

Note for the publication:

Figures 1, 2, 3, 4, and 10 should be published as colour prints on four pages, Figures 2 and 3, and also Figures 10a and 10b should be published on the same page.

Figure 1

Photo of the landscape around Lindenberg (the LITFASS area) with the GM Falkenberg in the centre, marked by the arrow (photo: F. Beyrich, DWD-MOL, 2002)

Figure 2

Land use map of the LITFASS area during the period of the LITFASS-2003 experiment (this Figure was prepared by C. Heret, TU Dresden, and J. Uhlenbrock, University of Hannover)

Figure 3

Relative occurrence frequency of the major land use classes in the LITFASS area

Figure 4

The experimental set-up and measuring strategy of the LITFASS-2003 experiment

red circle	micrometeorological station
yellow circle	remote sensing site
blue circle	rain gauge
blue circle with red ring	rain gauge with global radiation sensor
blue triangle	water table measurement
red solid / dashed line	long-distance scintillometer path

This figure is based on a topographic map TK100 issued by the Landesvermessungsamt Brandenburg, reproduction has been kindly permitted under Ref.-No. GB 57/01

Figure 5

Daily precipitation sum and soil moisture (measured with three independent techniques at a depth of 15 cm) at the GM Falkenberg during the period March to June 2003

Figure 6

Time series of basic meteorological parameters measured at the Meteorological Observatory Lindenberg for the period of the LITFASS-2003 experiment: daily maximum / minimum temperatures and wind direction (upper panel), daily precipitation sum and sunshine duration (lower panel)

Figure 7

Spatial distribution of rain in the LITFASS area on 05 June (left) and 08 June (right) based on measurements with the Berlin weather radar and with a regional rain gauge network
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Figure 8

Mean absolute humidity values in the middle of the ABL (500-1000 m agl) at 11 UTC for the period of the LITFASS-2003 experiment as derived from radiosoundings, water vapour DIAL and MWRP measurements.
(MWRP and DIAL data were provided by J. Güldner, DWD-MOL, and B. Hennemuth, MPI Hamburg)

Figure 9

Daily ABL heights at noontime during the LITFASS-2003 experiment
(DIAL data were provided by A. Lammert, MPI Hamburg)

Figure 10

Areal distribution of surface radiative temperature across the LITFASS area as measured with the Helipod during a grid flight on 17 June 2003, 1132-1333 UTC (upper panel) and as derived from a NOAA-16 satellite image taken at 12:02 UTC (lower panel)

(these Figures were prepared by P. Zittel , TU Braunschweig, and A. Tittebrand, TU Dresden)

Figure 11

Mean Bowen ratio during daytime (0800-1400 UTC) over different surface types over the period of the LITFASS-2003 experiment.

(data were provided by S. Huneke, GKSS, M. Mauder, University of Bayreuth, W.M.L. Meijninger, Wageningen University, and J.-P. Leps, DWD-MOL)

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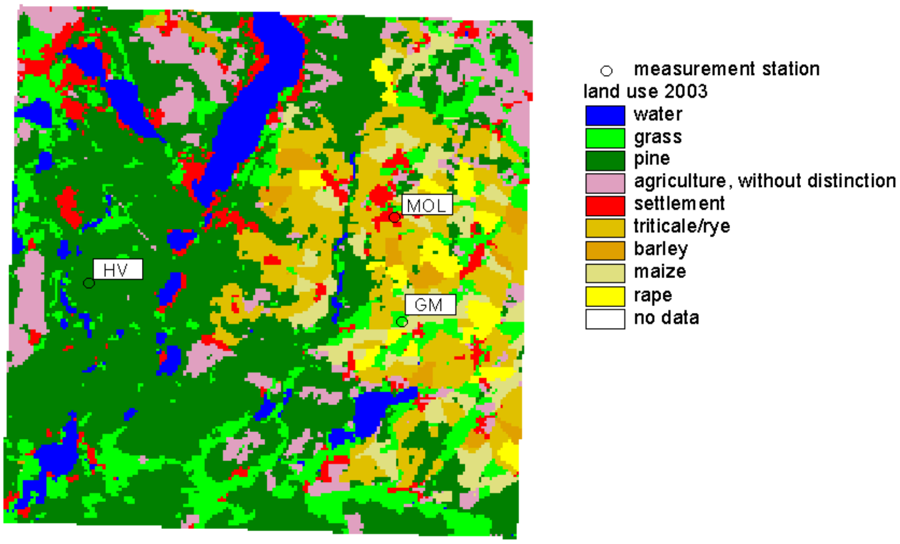

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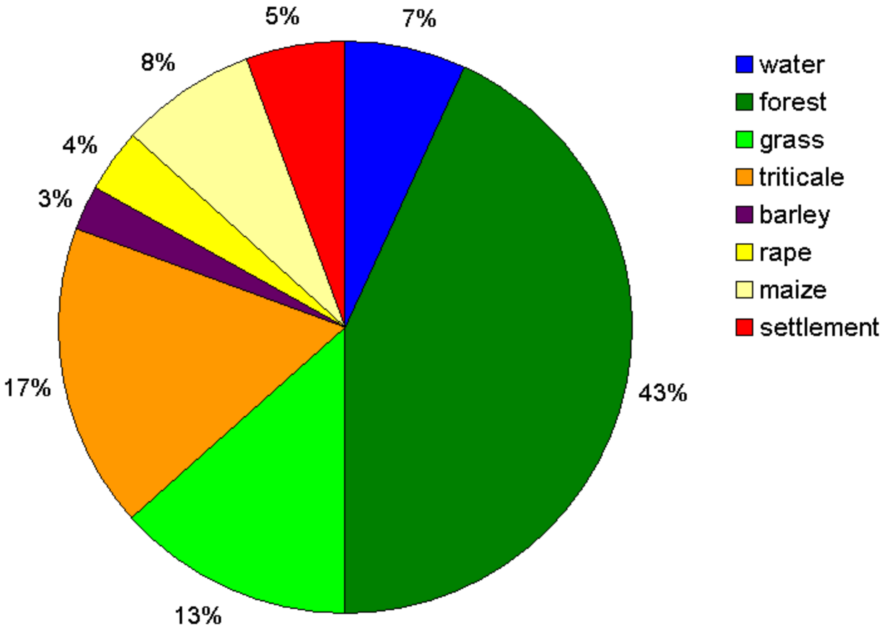

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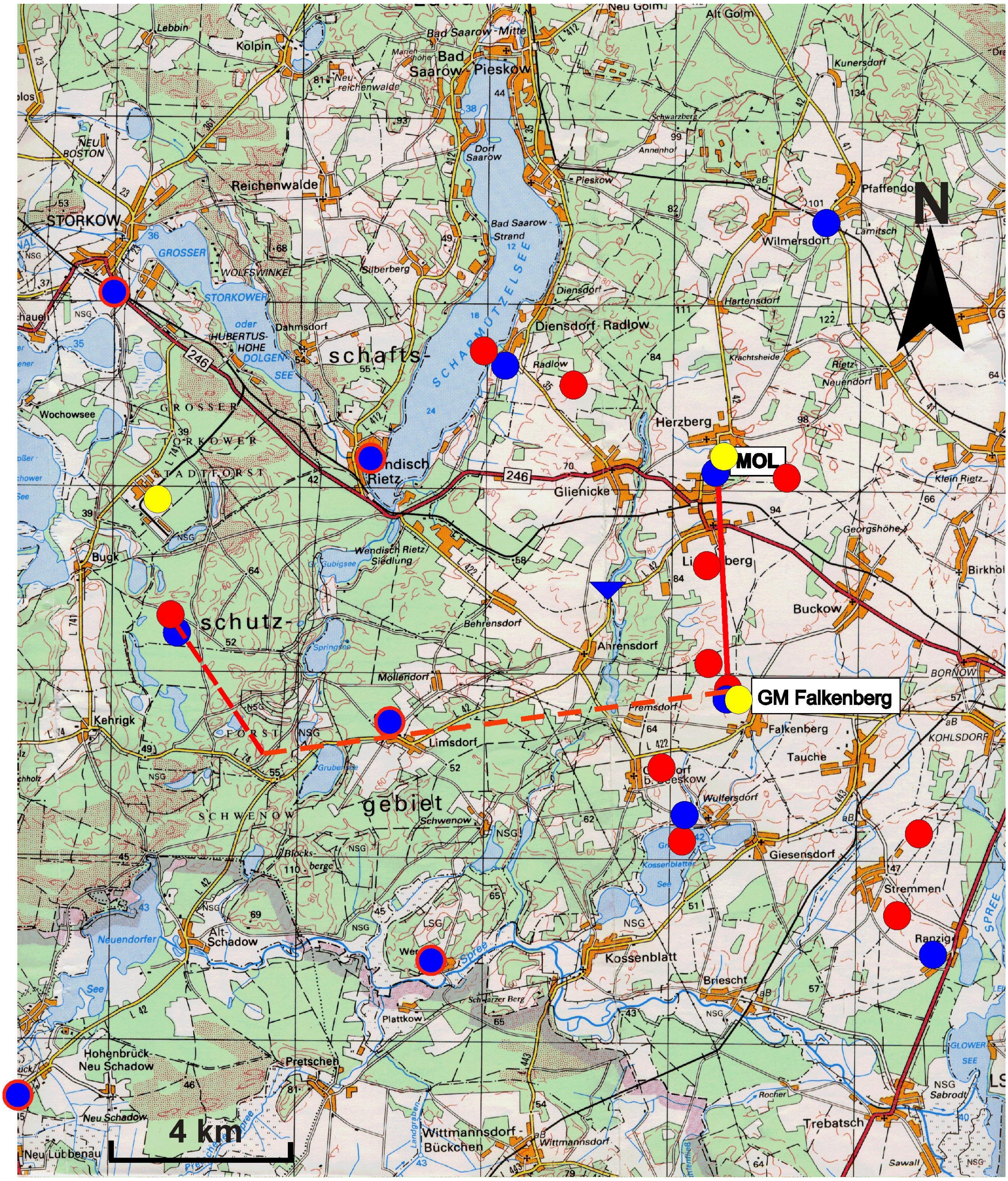

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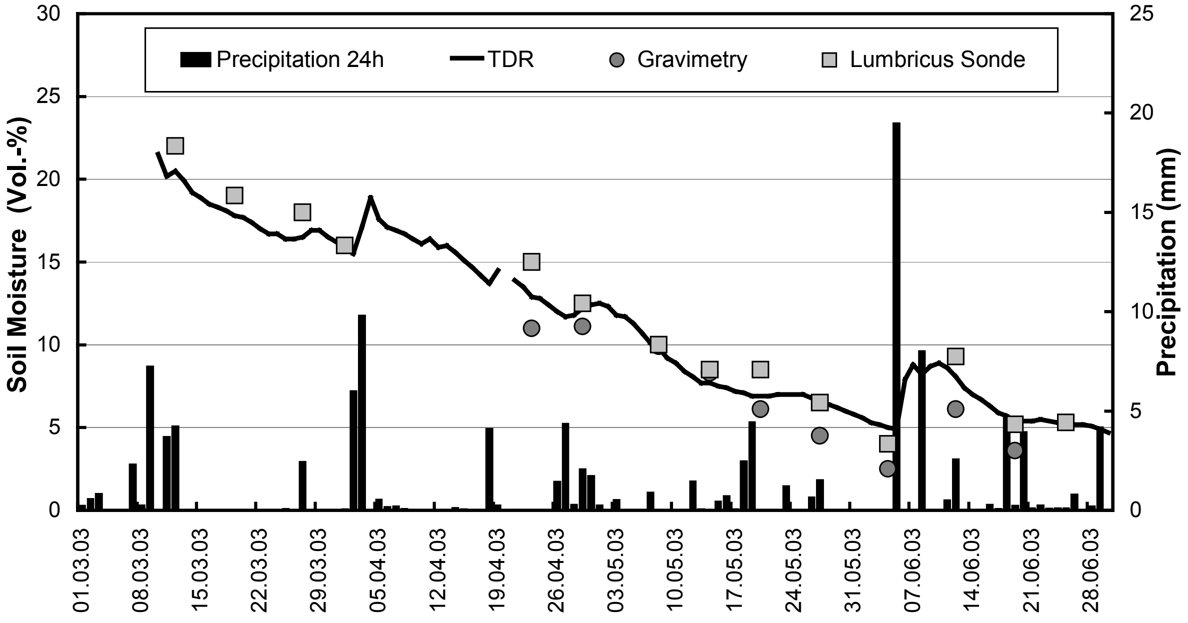

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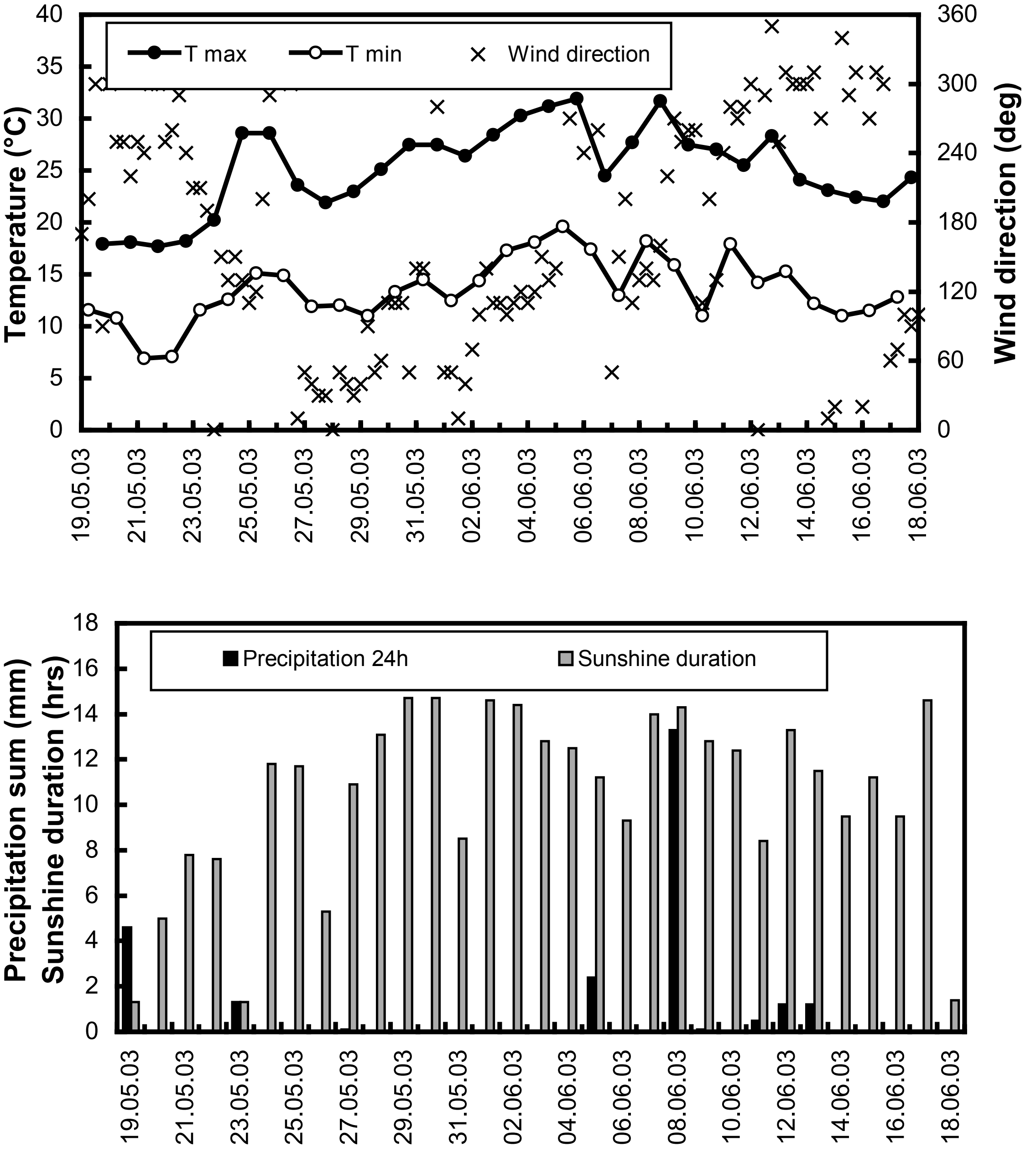

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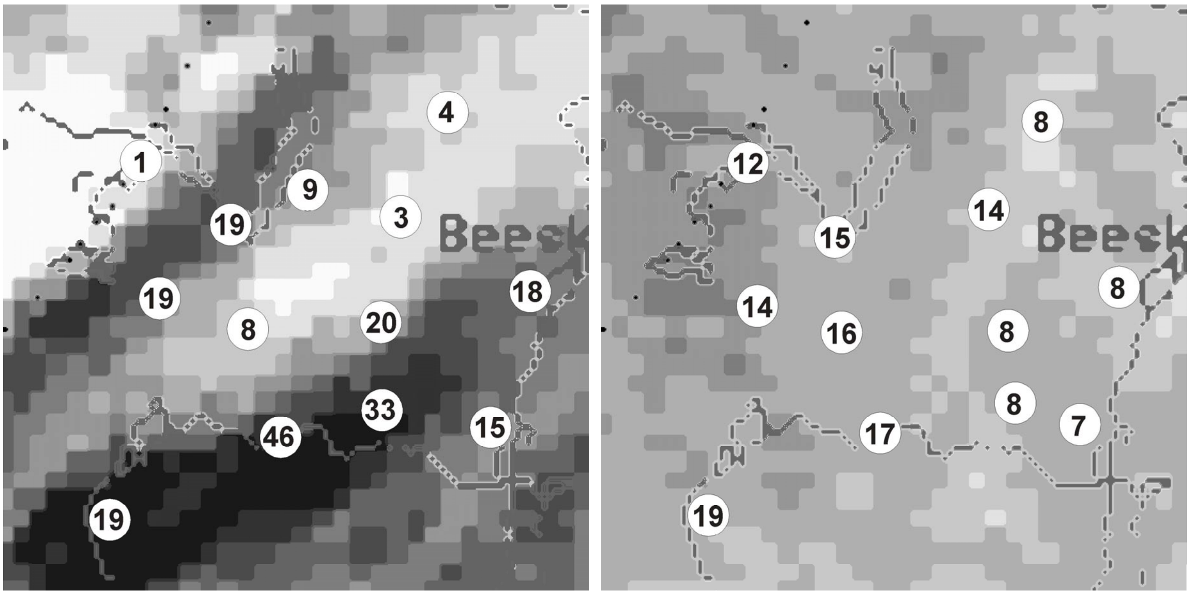

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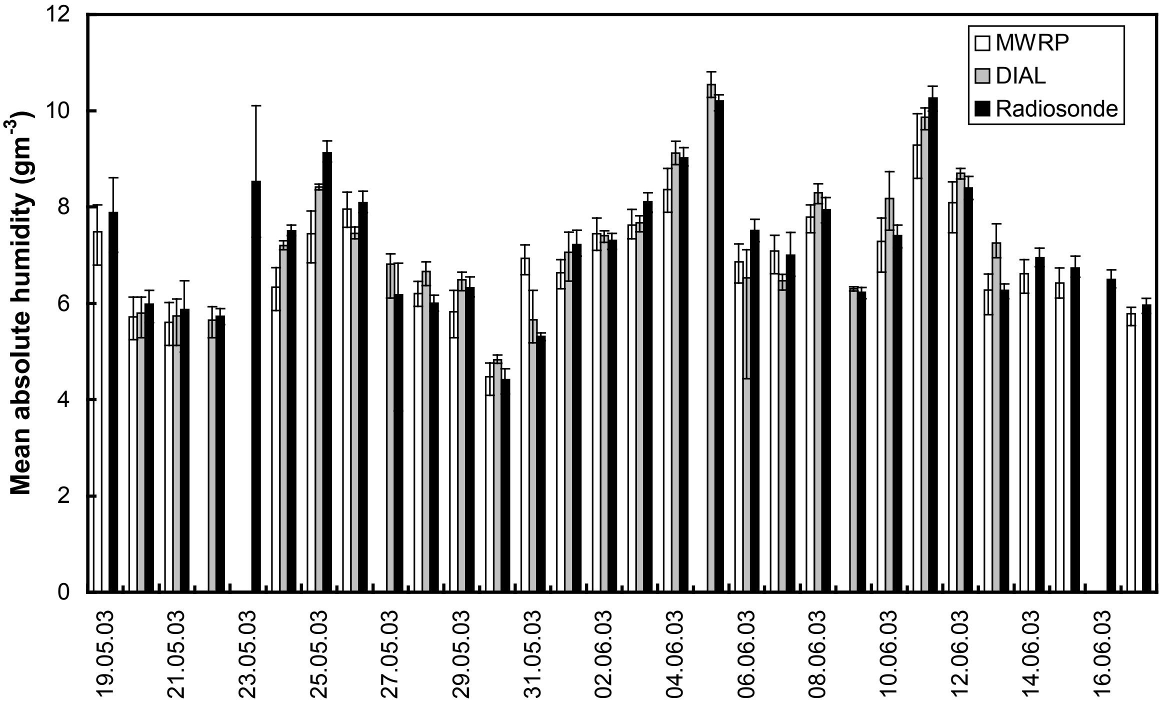

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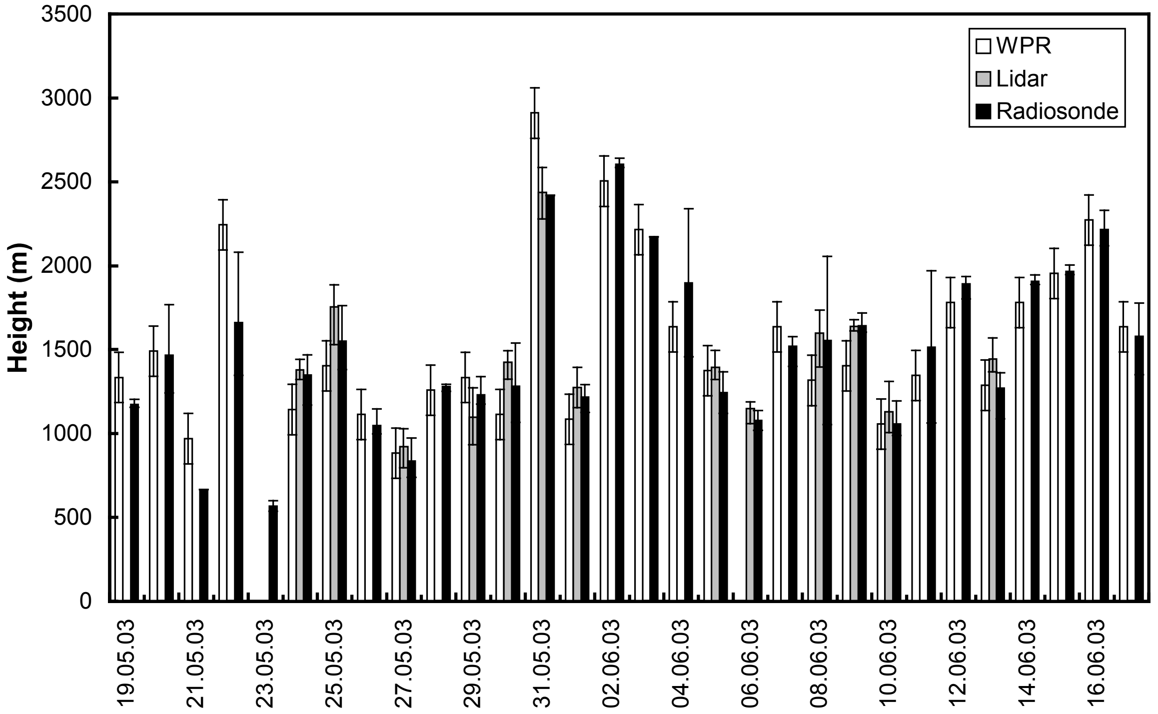

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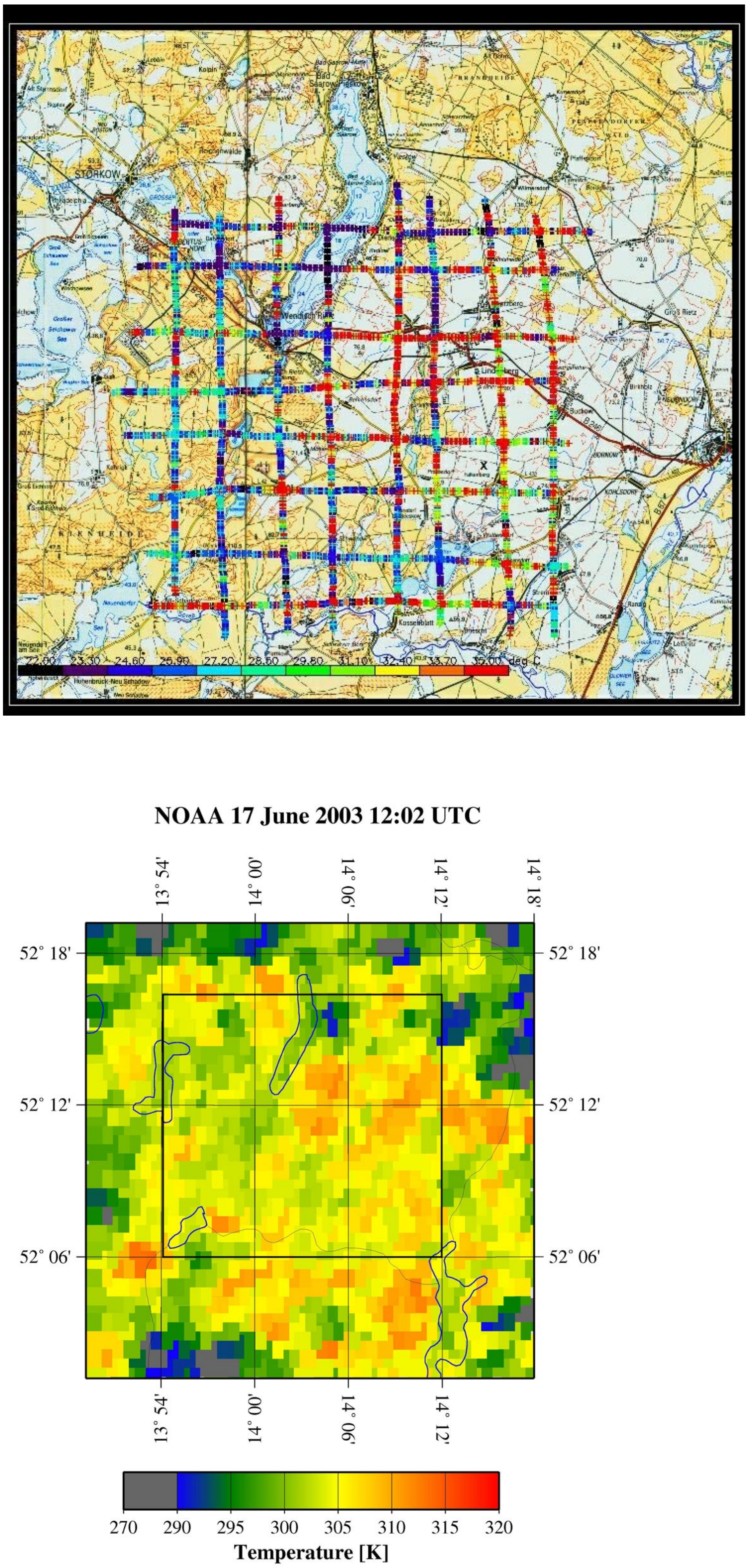

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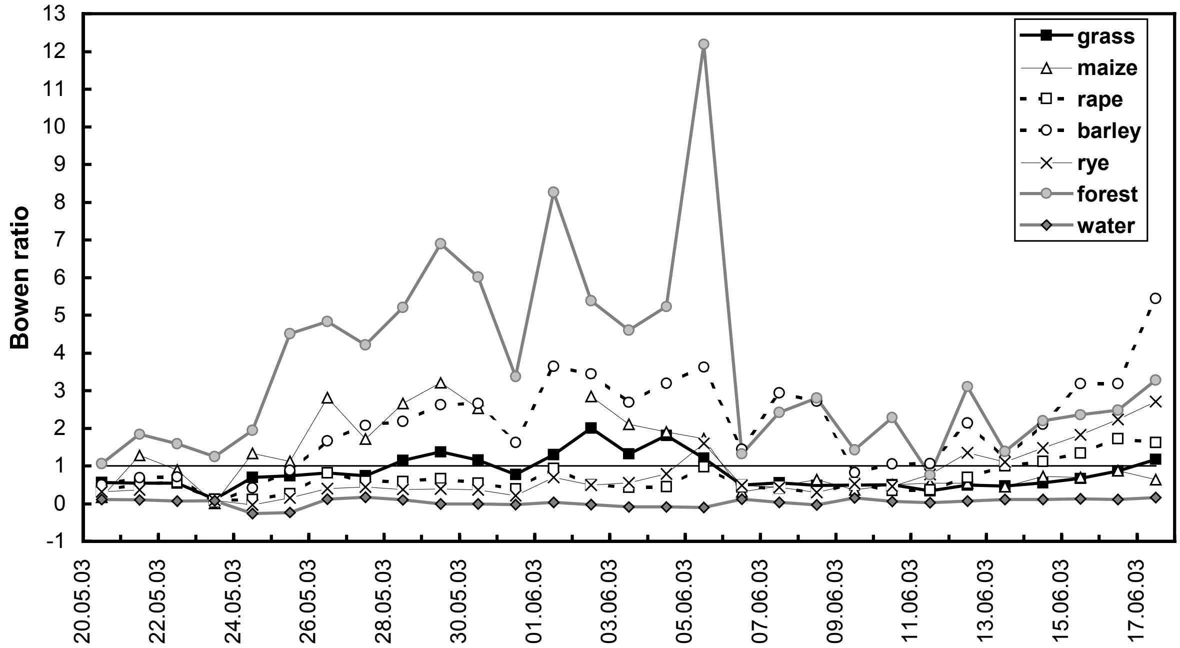

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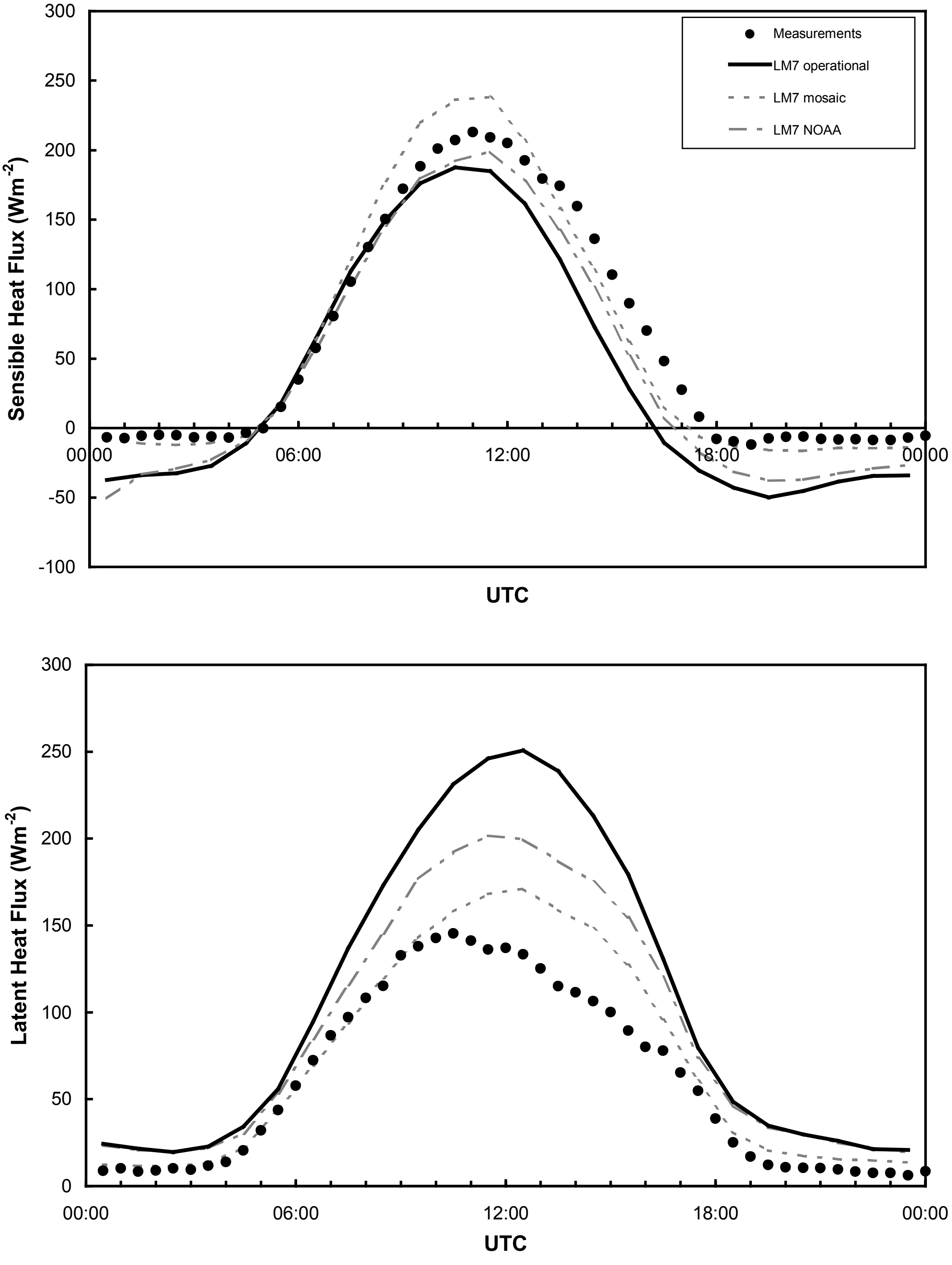

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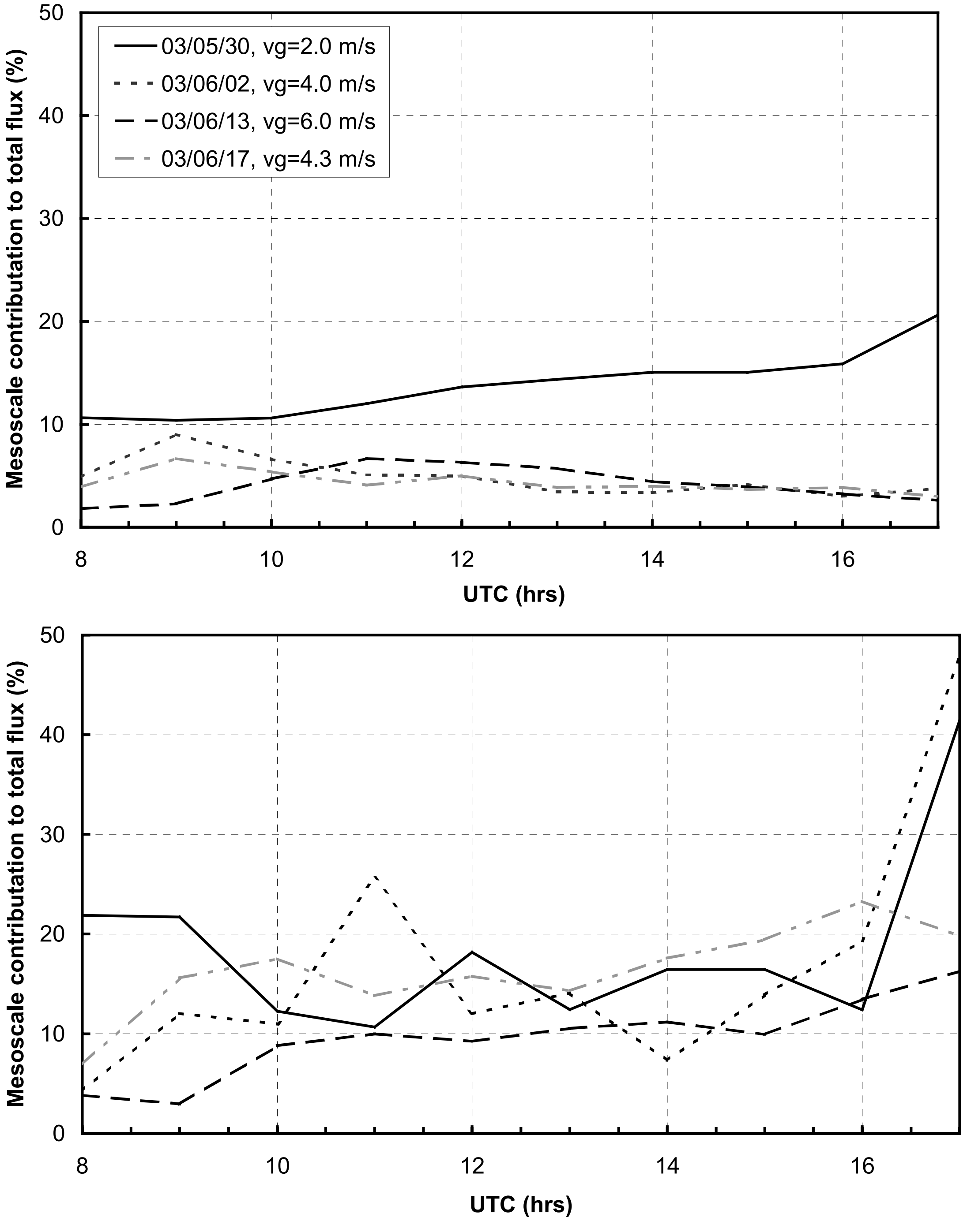

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