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Article

Micrometeorological measurements during the total solar eclipse of August 11, 1999

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Abstract

Micrometeorological measurements of radiation, atmospheric and soil parameters, and turbulent energy and momentum fluxes, ozone and carbon dioxide fluxes have been conducted over a maize field at Freising-Weihenstephan in Southern Germany during the total solar eclipse on August 11, 1999. For the period 30 minutes before and after the totality the weather conditions at the location where the micrometeorological measurements were made was satisfactory. Several connections between the irradiation and other meteorological parameters over a maize field have been found. The time response between irradiation and the long-wave upward radiation was only a few minutes, whereas almost all parameters caused by the turbulent transport had a time shift of up to 30 minutes. A period of nearly 30 minutes with reduced turbulence regime after the totality was found. Using a wavelet transformation for the time series, a change of time scales from longer to shorter ones was observed before the totality, and after the turbulence increased in the short time scales. The investigation of the residuum of the closure of the energy balance showed that with a time shift for the latent heat flux (unlike the net radiation) after the totality, a better energy budget closure was obtained.

Zusammenfassung

Mikrometeorologische Messungen der Strahlung, atmosphärischer und Bodenparameter und der turbulenten Energieflüsse, des Impulsflusses und der Flüsse von Ozon und Kohlendioxid erfolgten über einem Maisfeld in Süddeutschland während der totalen Sonnenfinsternis am 11. August 1999. Am Messstandort Freising-Weihenstephan herrschten in einem Zeitraum von 30 Minuten vor und nach der Totalität befriedigende Bedingungen für mikrometeorologische Untersuchungen. Somit konnten verschiedene Wechselwirkungsbeziehungen zwischen der Einstrahlung und anderen meteorologischen Parametern über einem Maisfeld gefunden werden. Während die Zeitverschiebung zwischen der Einstrahlung und der langwelligen Ausstrahlung nur wenige Minuten betrug, war für alle Parameter, die durch ein turbulentes Regime beeinflusst wurden, eine zeitliche Verzögerung der Reaktion auf die Totalität um ca. 30 Minuten zu verzeichnen. Es konnte eine Periode von ca. 30 Minuten Dauer nach der Totalität mit reduziertem turbulenten Regime festgestellt werden. Mittels Wavelet-Transformation der Zeitreihen konnten die Veränderung der Zeitskalen der Turbulenz vor der Totalität von längeren zu kürzeren Skalen und die Turbulenzzunahme nach der Totalität beginnend mit kürzeren Zeitskalen gezeigt werden. Untersuchungen zum Residuum der Schließung der Energiebilanz am Erdboden zeigten eine bessere Schließung bei einem gegenüber der Strahlungsbilanz zeitversetzten latenten Wärmestrom.

1 Introduction

Solar eclipses are astronomical phenomena which inspire meteorologists to conduct special investigations. Themes for such experimental investigations were mostly radiation measurements (HINZPETER and WÖRNER, 1955) and related studies in atmospheric chemistry. Recently these studies were combined with special experiments in the atmospheric boundary layer and the surface layer (KAPOOR et al., 1982) including measurements of turbulent fluxes (EATON et al., 1997). Unfortunately, in all the previous micrometeorological studies made were during partial solar eclipses. Of course, significant changes of the radiation and turbulent fluxes were found, but 'night time' conditions with a negative net radiation could not be investigated. Therefore, the total solar eclipse observed on August 11, 1999 over Southern Germany was of special micrometeorological interest. The measuring programme of the Uni-

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Table 1: Micrometeorological devices used (data sampling: *20 Hz; **10 Hz; other parameters: mean values over 20 s), canopy height: 2.3 m.

Height in m	*Parameter*	*Device*	*Producer/Reference*
4.70	friction velocity*	CSAT3	Campbell Sci.
4.70	sensible heat flux*	CSAT3, Pt150, 12 μm	Campbell, Sci. AIR
4.70 4.65	latent heat flux*	CSAT3 KH20	Campbell Sci. Campbell Sci.
4.60	carbon dioxide flux**	USA1 LiCor 6262	METEK LiCor
3.60 for O_3 tube	ozone flux**	USA1 fast response O_3-sensor OS-G-2	METEK GEFAS, (GÜSTEN and HEINRICH, 1996)
0.5	ozone concentration	Modell 8810 M	Monitor Labs
3.95	short-wave radiation (up and down)	CM 14	Kipp & Zonen
3.95	long-wave radiation (up and down)	PIR/WRC	Eppley, (PHILIPONA et al., 1995)
3.95	IR surface temperature	KT 15	Heitronics
–0.02, –0.05, –0.1, –0.2	soil temperature below maize	Pt 100	Geratherm
–0.02, –0.05, –0.1, –0.2	soil temperature below grass	Pt 100	Geratherm
–0.02	soil heat flux	Rimco	Thies
$-0.0 \ldots -0.2$	soil moisture	gravimetric	
6.3, 3.9, 3.1, 2.5	wind velocity profile	F160	Climatronics
6.3	wind direction	F 160	Climatronics
6.0, 3.9, 3.2, 2.3, 1.0	temperature and moisture profile	Frankenberger-Psychrometer	Friedrichs & Co.

versity of Bayreuth was integrated within the Bavarian solar eclipse experiment (BAYSOFI) that took place in Freising-Weihenstephan, which is about 30 km NE of Munich (FABIAN et al., 2001). The main topic of this study was focused on time response functions dependent on the forcing of the Sun's radiation. Such responses are of special interest for the energy transformation to turbulent and for plant physiological processes (FOKEN et al., 2000). The research in this paper are of a more general character and describe meteorological parameters in the time interval of ± 1.5 hours from the time of the totality. The parameters investigated are the radiation fluxes, wind velocity, temperature and moisture, turbulent energy fluxes as well as the fluxes of carbon dioxide and ozone. Special investigations were made about the time shift between the forcing by the net radiation and meteorological parameters and turbulent fluxes. Furthermore spectral properties of these parameters were investigated and finally the differences in the response times of the turbulent fluxes have been discussed concerning the problem of the residuum of the closure of the surface energy balance (FOKEN, 1998).

2 Measuring sites, instrumentation and observation conditions

To obtain the plant physiological measurements, a maize field (Zea mays) was selected with a high transpiration rate (even when not irrigated) in mid August (FOKEN et al., 2000). The measuring place was situated near Freising-Weihenstephan in Bavaria/Germany (48°24'N, 11°43'E, 450 m a.s.l.) in a flat part of the valley of the Isar river. The canopy height was about 2.3–2.5 m (zero-plane displacement approximately 1.5 m). The fetch at the upwind side of the measuring place was more than 150 m. For details of the instrumentation see Table 1. In the immediate vicinity of the total phase of the eclipse the sky was only partly covered with thin clouds (Sc translucidus). At 9 a.m. (UTC) a rain shower occurred and a thunderstorm passed at 1 p.m.

Additionally, two flat grass land sites acquired by the Technical University of Munich at Scheyern (48°29'N, 11°26'E, 451 m and 492 m a.s.l.), with a typical agricultural meteorological instrumentation were investigated. Also, data from the 32-m meteorological tower at the

'Kranzberger' forest station of the Technical University of Munich (48°25'N, 11°39'E, 485 m a.s.l.) were collected. Unfortunately during the total eclipse, the sky at these sites were cloud-covered and showers occurred.

For comparison, the data from the University of Budapest which was measured over flat terrain at Fülöpháza/Hungary in the Puszta region (46°52.5'N, 19°24'E, 115 m a.s.l.) were also used. This is because this site was not affected by clouds.

3 Courses of the mean parameters and the turbulent fluxes

3.1 Mean meteorological parameters

The total solar eclipse on August 11, 1999 was ideal with respect to the nearly constant extra terrestrial irradiation conditions observed during the eclipse. The values of extra terrestrial incoming short-wave radiation at the beginning (09:17 UTC) was 1070 W/m^2 and at the end of the period (12:01 UTC) it was 1135 W/m^2 (RENDTEL, 1999). For a comparison, some results of the partial (94%) solar eclipse recorded on May 10, 1994 in New Mexico (EATON et al., 1997) was used. For this eclipse the short-wave radiation at the end was twice of the value at the beginning.

The comparison of the extra terrestrial radiation with the global radiation is given in Fig. 1a. Around the period of totality there were about ± 25 minutes with a partly covered sky with thin clouds (Sc tr). The short periods with observed global radiation higher than the extra terrestrial radiation were caused by reflection from high parts of clouds (Cu con, Cb) at some distance away from the measuring site. In contrast to the experiments during partial solar eclipses (EATON et al., 1997), for the total eclipse a negative net radiation (nearly 'night time' conditions) was observed from 10:31 to 10:49 UTC (totality 10:37 to 10:40) and is illustrated in Fig. 1a. The minimum of net radiation was found shortly after the totality (10:40:30 UTC). In general, the influence of the net long-wave radiation on the net radiation was small, therefore global and net radiation have a nearly similar course. The reflected short-wave radiation was found to be exactly equal to the global radiation reduced by the albedo of maize (18%). According to Fig. 1b both components of the long wave radiation reached low values at the beginning of the totality which corresponds with the almost cloudless sky at this time. The long-wave upward radiation (corresponding to surface temperature) was a minimum at the end of the totality (10:40:30 UTC). The surface temperature was at a minima for about 10 minutes and then started to increase with a positive net radiation at 10:50 UTC.

During the partial solar eclipse in 1994 in New Mexico (EATON et al., 1997) no effect on the wind velocity, except of the daily course, was found. But measurements made in Weihenstephan showed significant effects. The mean wind velocity was about 3 m/s before and 4 m/s after the eclipse. The time shift between the minimum of irradiation and the minimum of the wind velocity was about half an hour (Fig. 1c). No time shift was found between the wind speeds above and inside the canopy. The same effect was also found at the Hungarian station Fülöpháza (cloudiness: 1/8), which was not affected by a partially cloudy sky.

The explanation for the large time shift observed can only be a phenomenological one. Unfortunately no measurements for the whole boundary layer were made at Freising-Weihenstephan. One reason may be a decoupling of the lower part of the surface layer on a local scale due to stabilisation, which is typically for stable stratification (HANDORF et al., 1999). An other reason could be a change of the pressure gradients in a meso-scale due to a reduced heating of the surface. Meso-scale and boundary layer experiments or numerical studies would be necessary for further explanation.

The cooling of the air (Fig. 1d) continued up to 20 minutes after the totality. Then with increasing turbulence (see also Section 3.2) heating of the whole surface layer resumed. Significant differences were not found between the temperature above and inside the canopy. These conditions are more similar to the conditions during sunrise and cannot be compared with the results during a partial solar eclipse, where only a small time shift between the irradiation and the air temperature of about 7 minutes was found (EATON et al., 1997). The observed temperature decrease at the upper measuring level at 6.0 m was about 1.5 K, but it is approximately 2.5 K at the Hungarian station Fülöpháza. In the literature values of approximately 2–3 K at 1.5 m above the ground are reported (ANDERSON, 1999).

The water vapour pressure had its minimum at the end of the totality (Fig. 1d) and increased with the turbulence about 20 minutes later. But this change is much smaller than the temperature change. Inside the canopy the effect of a time shift can not be separated from high moisture fluctuations.

Soil parameters were measured under the maize and at a grassland site nearby at depths of –2 and –5 cm. At a depth of about –2 cm below the grass the soil heat flux was also observed. The soil moisture was mainly influenced by the rain showers in the morning. The decrease of the temperature at –2 cm depth was about 0.2 K while at –5 cm only the increase of the temperature according to the daily cycle was interrupted. The time shift from the totality was about 35 and 40 minutes, respectively. At –10 cm and –20 cm the influences of the solar eclipse was not detectable in the temperature measurements. Under the maize the results for –2 cm were similar to that at –5 cm depth under the grass. At depths deeper than –2 cm the effect of the eclipse was not noticed in the temperature measurement. The changes in the soil heat flux (Fig. 2b) with a reduction of nearly 10 W m—2 at –2 cm below the grass were more significant. The course was in phase with the corresponding soil temperature (FABIAN et al., 2001). Because of the

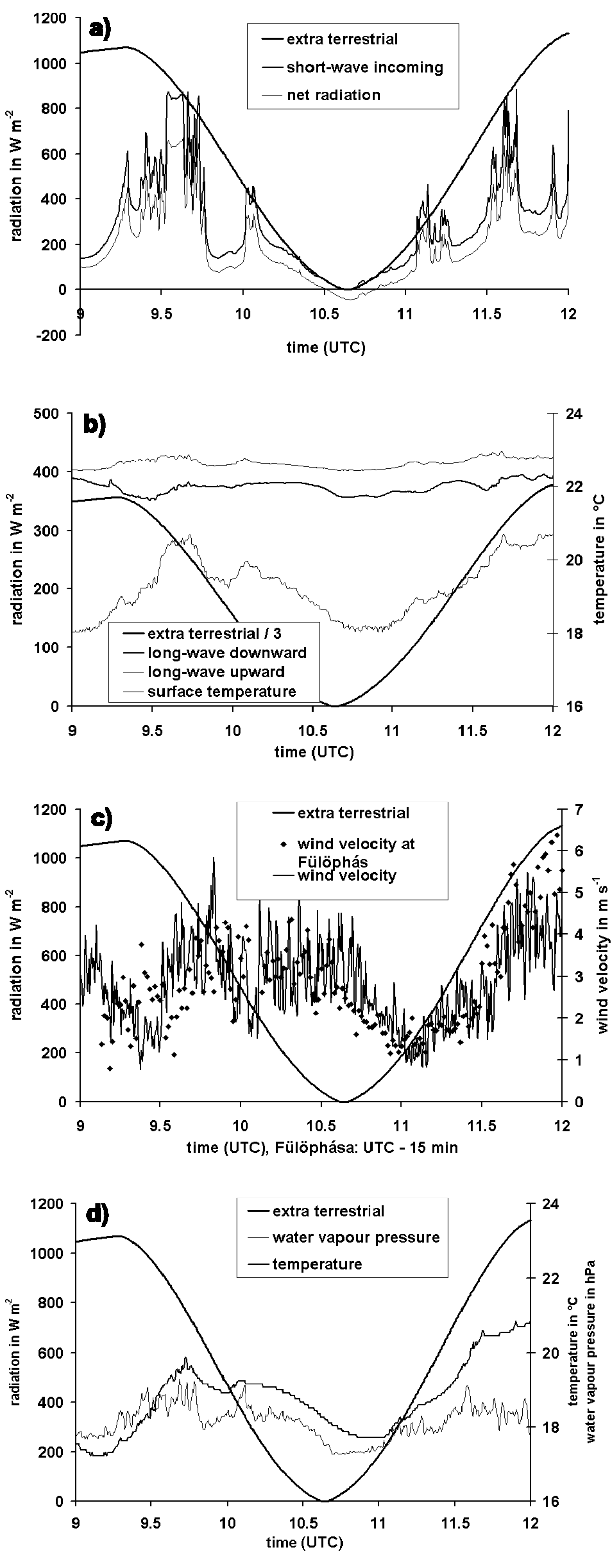

Figure 1: Meteorological parameters observed during the total solar eclipse on August 11, 1999. For comparison the extra terrestrial radiation is included (RENDTEL, 1999): a) Global and net radiation; b) Up- and downward long-wave radiation and surface radiation temperature; c) Wind velocity at a height of 6.3 m (with a time shift of –15 minutes the data of the Hungarian observations at Fülöpháza are included too); d) Air temperature and water vapour pressure at a height of 6.0 m.

large response times a superposition of the influence of the solar eclipse with that of the changing cloudiness can not be excluded (LEEDS-HARRISON et al., 2000).

3.2 Turbulent fluxes

Turbulent fluxes of momentum, sensible and latent heat, carbon dioxide and ozone were measured with the eddy covariance method (KAIMAL and FINNIGAN, 1994) and an averaging interval of 5 minutes. This short averaging time is adequate (FOKEN et al., 1995) when the high frequency part of the turbulence spectrum dominates the turbulent exchange. Due to the strong change in the radiation forcing during the eclipse, all measured turbulent fluxes, were expected to be in a non-steady state for longer averaging periods. Therefore, the quality of the turbulent fluxes would not have been acceptable (FOKEN and WICHURA, 1996) for time scales much longer than 5 minutes. Changing the averaging time we found that the 5-minute fluxes covers most of the energy. Consequently, we focused the analysis on this short averaging time. An interesting fact is that during the totality, the quality of the flux measurements were much better than during the periods with changing cloudiness and higher irradiation before 10 a.m. and after 11 a.m. The influence of non-steady state conditions on the results of flux measurements was tested by the variation of the averaging time in the carbon dioxide flux (FOKEN et al., 2000). During the totality the flux was similar for all integration times, while out of this time period the shorter integration times show a strong variability and different flux values compared to the fluxes determined for longer periods. This is typical for highly non steady state conditions.

The examination of the friction velocity (Fig. 2a) confirms the results which were already described for the wind velocity (compare Fig. 1c). The near-zero value at 11:00 UTC indicated a response time of nearly 25 minutes. The course of the sensible heat flux (Fig. 2b) was very similar to the net radiation with a transition to stable conditions from 10:20 to 11:00 UTC. Similar results were also found during partial eclipses (EATON et al., 1997). The latent heat flux (Fig. 2b) decreased until 11.00 UTC, with positive values during this time. With the increase of the turbulence (increasing friction velocity and turbulent fluctuations) after 11:00, both heat fluxes increased and followed again the net radiation.

Reports on the variations of the ozone concentrations during an eclipse are not consistent (ANDERSON, 1999; BOJKOV, 1968). From the photochemical point of view, a decrease of O_3 during an eclipse should occur if the NO_x-concentrations are in the same order of magnitude as O_3. Rapid establishment of the photostationary equilibrium between NO, NO_2, and O_3 would lead to lower O_3 concentrations in a tropospheric air mass in this case. The results of the ozone concentration measurements and vertical ozone flux measurements are presented in Fig. 2c. Both the concentrations and the fluxes show small variations at a low absolute value. Therefore, the increase of the ozone concentration by about 2 ppb and of the fluxes to slightly positive values within about 5 minutes around the totality can not be considered as significant changes. Together with the absence of an apparent correlation between ozone and the fluxes of heat and carbon dioxide, we suppose from these findings that ozone (at 2 m height above the maize canopy) was primarily governed by advective processes rather than by local photochemical processes on short time scales or by turbulent exchange processes. At the Hungarian site (undisturbed irradiation conditions) a dramatically decrease of the ozone concentration of about 40% was found, however other Hungarian background monitoring stations showed different magnitude and direction (Jenki et al., 1999). Obviously, photochemical reactions and turbulent transport mechanisms as well as the local conditions and advections may be the reasons for different concentration changes and fluxes during solar eclipses.

The carbon dioxide flux (Fig. 2d) changes sign almost immediately at the beginning of totality due to the reduced photosynthetic activity of the maize plants. The reverse effect was observed promptly after the end of totality when photosynthesis restarted. Nevertheless, the magnitude of these fluxes did not increase immediately as it would have been expected with the in-crease in net radiation and plant activity, due to the breakdown of the turbulence regime. The magnitude did not reach the photosynthetic fluxes at leaf level (Foken et al., 2000) until the increase of turbulence.

The investigation of the stability parameter z/L (z: height over zero plane displacement, L: Obukhov length), completes the picture of the turbulence exchange mechanism during the solar eclipse. The parameter followed the sensible heat flux at the beginning of the eclipse (Fig. 2a), while after the totality the sensible heat flux increased (less negative), and the stratification becomes more stable due to the decreasing friction velocity. Extreme stability occurred around 11:00 UTC, because of the low friction velocities and the change of the sign of the sensible heat flux. With the increasing of turbulence the stratification was again in the range common for unstable stratification. Similar results were also found for partial solar eclipses (Eaton et al., 1997; Kapoor et al., 1982) by studying the refraction structure function in the atmospheric boundary layer. The stratification is only correlated with the net radiation, if the data around 11:00 UTC are excluded (Table 2).

The experiment was also designed to investigate residuum of the closure of the surface energy balance during a period of strong net radiation forcing. This is one of the most serious problems in the measurements and modelling of micrometeorological processes near the surface (Foken, 1998). According to Kukharets et al. (1998) non-steady state conditions are one of the reasons of a residuum of the surface energy balance.

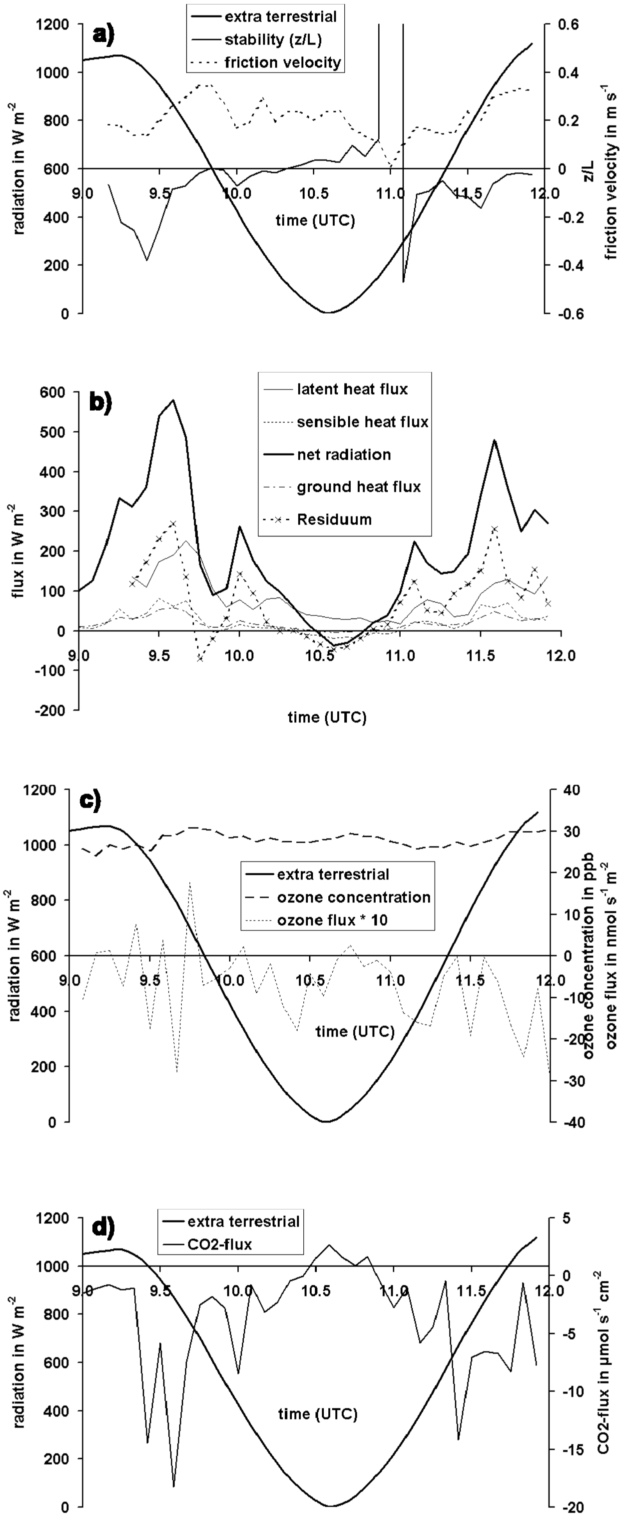

Figure 2: Turbulent fluxes measured during the total solar eclipse on August 11, 1999. For comparison the extra terrestrial radiation is included (Rendtel, 1999): a) Friction velocity and stratification (z/L); b) Sensible and latent heat flux in comparison with the net radiation and the soil heat flux (measured below grass), residuum of the energy balance closure; c) Ozone flux and ozone concentration; d) Carbon dioxide flux.

Table 2: Correlation of different fluxes with the net radiation in the period 10:00 to 11:15 (16 data points), bold: statistically significant.

Parameter	*Correlation coefficient*
Extra terrestrial radiation	**0.92**
Residuum of the energy balance closure	**0.92**
Sensible heat flux	**0.93**
Latent heat flux	**0.70**
Carbon dioxide flux	**–0.83**
Friction velocity	–0.25
Stratification (z/L)	0.02
Stratification (z/L) without data 10:55–11:05	**–0.77**

These conditions are typical for the solar eclipse. Of course, there are methodological problems for the quantitative investigation of the effect because of the non steady state conditions discussed above. The results are presented in Fig. 2b. The surface energy balance was not closed throughout the measuring time. The residuum of the closure was variable in magnitude and sign during the eclipse. It followed (after 10:30 UTC) the course of the net radiation (correlation coefficient r=0.92, Table 2) as well as the sensible heat flux (r=0.81). But no significant correlation was found between the residuum and the latent heat flux (r=0.36). Because the latent heat flux had after the totality a time shift of about 10 minutes towards the net radiation. This phase shift between both fluxes must be taken into account for the calculation of the energy balance. It was found that the latent flux corresponds with a net radiation about 10 minutes earlier. This is underlined by a correlation coefficient of the time shifted latent heat flux with the net radiation of r=0.83. With the shifted latent heat flux the residuum between 10:30 and 11:30 is about 50% smaller than is given in Fig. 2b. A general discussion of the residuum must be done together with the storage term of the soil (KUKHARETS et al., 1998) and the plants. Of course the complicated structure of the maize field needs some more investigation to determine the storage term, which probably reduces the residuum. Another possible reason for the residuum of the energy balance may be because of the time shift between fluxes at different measuring levels and the different times of increase of turbulence at these levels. The change in the soil heat flux was too small and hence it was not included in the discussion.

3.3 Time shift between different parameters

The time shift between the middle of the totality and the minimum of several parameters was an issue in the investigations by several authors (ANDERSON, 1999; EATON et al., 1997). Following these investigations the time shift was determined as the time difference between the totality and the minimum of the corresponding parameter. Due to the different averaging periods used an investigation of the auto-covariance function was not made. These time shifts are given in Table 3 in comparison with the data given for a partial eclipse (EATON et al., 1997). While meteorological parameters and fluxes which are mainly forced by the radiation had a time shift of approximately 5 minutes, the friction velocity had a time shift of 25 minutes. This result is also underlined by the correlation coefficient between the net radiation and other fluxes (Table 2). All fluxes increased with the beginning of the developed turbulence after 11:00 UTC and again followed the course of available energy and plant activity in the right order of magnitude.

4 Scale analysis using the wavelet transformation

The scale analysis of highly non steady state processes during solar eclipses needs a time dependent investiga-

Table 3: Time shift between the middle of totality and the minimum of different parameters.

Parameter	*Time shift (min)* *Reference time:* 10:38.5 UTC	*Time shift (min)* (EATON *et al., 1997)* *)
net radiation	6.5**)	
long-wave upward radiation (surface temperature)	2	6
air temperature	20	6
water vapour pressure	2–20	
soil temperature (-2 cm), grass	35	30
soil temperature (-5 cm), grass	40	
soil heat flux (-2 cm), grass	35	
friction velocity	25	
sensible heat flux	5	∼5–10
latent heat flux	25	
carbon dioxide flux	< 5	
ozone flux	< 5	
stratification	25	∼ 5–15

*) data were selected from the figures (partial eclipse);

**) may be influenced by decreasing downward long-wave radiation.

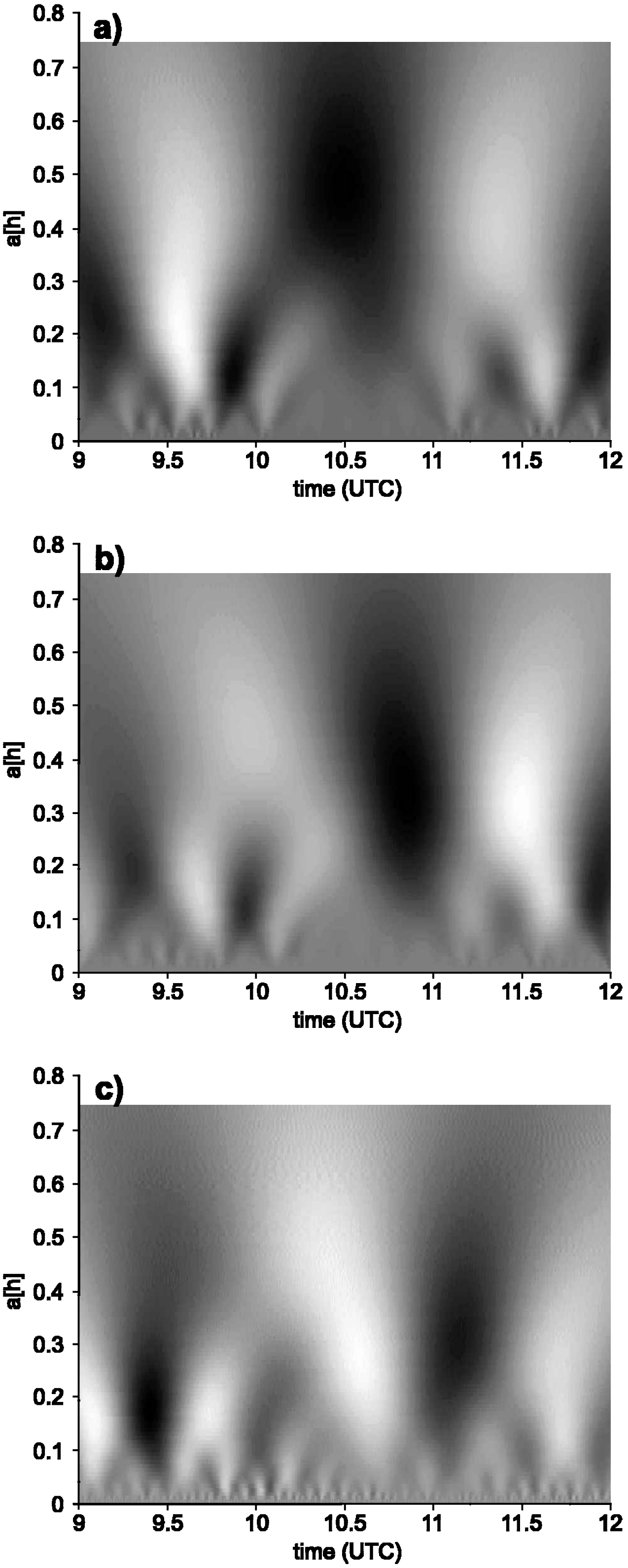

Figure 3: Wavelet analysis of meteorological parameters during the total eclipse on August 11, 1999. The ordinate gives the scale of the period of the fluctuations in hours and the abscissa the time. Black areas are of a low and white of a high wavelet coefficient. a) net radiation; b) air temperature at 6.0 m height; c) wind velocity at 6.3 m height.

tion of the spectral distributions. This can not be done by application of the classical Fourier analysis; therefore wavelet analysis (TORRENCE and COMPO, 1998) was chosen for this purpose. The wavelet analysis transforms a time series into a time-scale-space. (In contrast to the Fourier transformation, where the time series is transformed from time to spectral domain.) The advantage of this procedure is that it supplies information about the spectral distribution of the time series power as well as about the localisation of these information in the time domain itself. The time series are convoluted with special functions, the wavelet functions. The localisation of turbulent structures in time or in scale depends on the choice of the wavelet function. According to our experiences (HEINZ et al., 1999) the 'Mexican Hut' wavelet supports this problem. The time series of the meteorological parameters are based on 20 sec. mean values. The analysis was done with the 'Matlab' wavelet tool (MISITI et al., 1997).

In the following figures, a selection of parameters discussed in chapter 3 is presented using the wavelet analysis. All short-wave radiation fluxes are very similar to the picture given in Fig. 3a for the net radiation. The high wavelet coefficients (white areas) were found before and after the totality especially in the range of long time scales (periods larger than 0.3 h). For shorter time scales, high wavelet coefficients correspond to the nearly cloudless (some fluctuations by clouds) situations before and after the totality. No fluctuations in the range of short time scales (periods < 0.05 h) were found in the time period of ± 30 minutes about the totality. The analysis of the air temperature (Fig. 3b) looks similar to the results of the radiation with a time shift of the minima of the spectral density (black area) until about 15 minutes after the totality. In contrast, the wind velocity (Fig. 3c) showed minimum values up to about 30 minutes after the totality. The decrease for the wavelet coefficients of larger time scales from about 10:00 to 10:45 UTC was remarkable. From 10:45 to 11:10 UTC almost no fluctuations in time scales lower than 0.05 h were found. Then the turbulence increased with a generation of eddies in the high frequency range. At about 11:40 UTC the turbulence spectra seem to be fully developed. These results support the interpretation given in Section 3.1 for the wind velocity. The wavelet analysis of the turbulent fluxes was also done with the results of the eddy covariance flux measurements over an averaging time of 5 minutes. The sensible and the latent heat fluxes are very similar, and they are also similar to the course of the net radiation (Fig. 3a). The friction velocity is similar to the wind velocity (Fig. 3c). Minimum values for the wavelet coefficients were found not during the totality but about 20 minutes later. At about 11 a.m. the increasing of turbulence starts, beginning in the range of short time scales. This time is identical with the beginning of the increase in the other turbulent fluxes.

5 Conclusions

Despite the non-ideal weather conditions, the micrometeorological investigations conducted during the total solar eclipse on August 11, 1999 were an ideal 'laboratory' experiment because of the sudden change of the irradiation from mid-day conditions to nearly 'night time' conditions. Such conditions can not be found during sunrise and sunset and changing cloudiness. During and after the totality typical night-time conditions with stable stratification and a negative net radiation were found. An almost 30 minute period after the totality with extremely reduced turbulent fluxes was detected as a new result. Because of this, the friction velocity as well as the stability were not correlated with the net radiation. Other fluxes, which depended on the surface temperature or photosynthesis, such as the sensible heat, latent heat and carbon dioxide flux, responded to the change of the net radiation only with a small time shift, but with reduced magnitudes. The fluxes restored to their typical values after the increase of turbulence. Due to these circumstances the residuum of the closure of the surface energy balance was lower with a time shifted latent heat flux component rather than calculated with the fluxes, which were determined at the same time.

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