Lehr- und Forschungszentrum für Landwirtschaft
Raumberg-Gumpenstein

15. Gumpensteiner Lysimetertagung 2013, 199 – 202
ISBN: 978-3-902559-90-6

Simultaneous estimation of actual evapotranspiration and precipitation by weighable lysimeters and comparison with eddy covariance and rain gauge measurements

Sebastian Gebler[1*], H.-J. Hendricks-Franssen[1], Thomas Pütz[1], H. Post[1], M. Schmidt[1] and Harry Vereecken[1]

Zusammenfassung

Im Rahmen dieser Arbeit wird die aktuelle Evapotranspiration (ETa) einer Eddy Kovarianz- (EC) und einer benachbarten Lysimeterstation mit sechs hexagonal angeordneten wägbaren Lysimetern für das Untersuchungsgebiet Rollesbroich (Eifel, Deutschland) verglichen. Die Gegenüberstellung von ETa aus Lysimeter- und energiebilanzkorrigierten EC- und Messungen ist in der Literatur relativ selten beschrieben, erlaubt jedoch weitere Erkenntnisse über die Aussagefähigkeit beider Methoden. Ein Vergleich von Mai 2012 ergab eine ETa-Differenz von 29 % in der Monatssumme basierend auf den Messungen der beiden unterschiedlichen Methoden. Während das Monatsende eine relativ gute Übereinstimmung aufweist, finden sich Unterschiede hauptsächlich in den trockenen Perioden in der Mitte des Monats. Darüber hinaus konnte mit Hilfe eines automatischen Filter- und Glättungsalgorithmus der Niederschlag aus den Wägedaten der Lysimeter abgeleitet werden. Diese zeigen konsistent und eindeutig höhere Summen als die benachbarte Kippwagenstation an. Aus unserer Sicht ist es daher möglich, zuverlässig Niederschlag und Verdunstung mittels Lysimeter zu bestimmen.

Schlagwörter: Eddy Kovarianz Methode, Evapotranspiration, Niederschlag, Lysimeter

Summary

This study compares actual evapotranspiration (ETa) measurements obtained with the Eddy-Covariance (EC) method and ETa measured by a set of six weighable lysimeters, for the Rollesbroich site in the Eifel (Germany). The comparison of ETa measured by EC (including correction of the energy balance gap) and by lysimeters is rarely reported in literature and allows more insight into the performance of both methods. A comparison of ETa for the two measurement set-ups (EC and lysimeters) for May 2012 shows a monthly difference of 29 %. While at the end of the month both methods produce very similar results, in the dryer periods in the middle of the month high deviations arise. The lysimeter data were also used in combination with a filter algorithm to indirectly estimate the precipitation amounts from the lysimeter measurements. The estimated precipitation amounts of the lysimeter data were clearly and consistently larger than the precipitation amounts recorded with a standard rain gauge at the Rollesbroich test site. Our main conclusion is that weighable lysimeter data can be used to simultaneously estimate precipitation and actual evapotranspiration in a reliable manner.

Keywords: eddy covariance method, evapotranspiration, lysimeter, precipitation

Introduction

Although precipitation and actual evapotranspiration measurements have a quite long tradition, the estimation of precipitation and actual evapotranspiration (ETa) is still a challenge in regional scale hydrological modeling. Common precipitation measurement methods still exhibit uncertainties of more than 10 % depending on the device location and climatic conditions (i. e. wind exposition, snow deposition) (e.g., SEVRUK 1996, BRUTSAERT 2010). Moreover rime and dew, which contribute up to 5 % of annual precipitation, are not taken into account (e.g. MEISSNER et al. 2007). Our study compares the precipitation and evapotranspiration water balance components calculated with a set of six weighable lysimeters with nearby eddy covariance (EC) and precipitation measurements. This allows more insight into the performance and uncertainties of these methods. In addition, it allows a better interpretation of these data which are also used for model verification purposes.

Materials and Methods

The Rollesbroich study site is part of the TERENO-SoilCan network in Germany. The managed grassland study site is located in the Eifel low mountains range (Germany) and has an extension of 27 ha. The annual mean precipitation is 1200 mm with an annual mean temperature of 8°C (RUDI et al. 2010). In 2010 a set of six lysimeters was arranged in a hexagonal design around the centrally placed service unit hosting data recording devices. Each lysimeter has a surface of 1 m² and is equipped with a 60 l partial emptying weighted leachate tank. The lower boundary conditions are controlled by tensiometers. The weighable precision is

[1] Agrosphere Institute (IBG-3), Forschungszentrum Jülich GmbH, D-52428 JÜLICH
[*] Ansprechpartner: Sebastian Gebler, s.gebler@fz-juelich.de

100 g for the soil monolith and 10 g for the leachate tank. Measurement time interval is 1 min. Additional precipitation measurements are made by a standard tipping bucket rain gauge (0.1 mm resolution, measurement interval 10 min) at an altitude of 1 m above ground. The lysimeter data were processed in 4 steps:

- Automated threshold filter for outliers
- Calculation of hourly mean weights
- Separation of precipitation and evapotranspiration
- Comparison of lysimeter signals

Assuming that no evapotranspiration ET_a [LT^{-1}] occurs during a precipitation event, precipitation (*P*) [LT^{-1}] can be derived from the lysimeter water balance (1) as sum of leachate water (*L*) [LT^{-1}] and the change of soil water storage (ΔS_S) [LT^{-1}].

$$ET_a = P - L - \Delta S_S \quad (1)$$

$$P = L + \Delta S_S \quad (2)$$

It was assumed that increases of summed lysimeter and leachate weights are exclusively related to precipitation and negative differences are due to evapotranspiration.

After removing outliers from the data, the arithmetic hourly means of summed percolation and soil column weights were taken in order to remove the high noise in the measurement readings caused by wind and evapotranspiration dynamics. Moreover the additional information of the set of six lysimeters was used: It was found that hourly means of evapotranspiration and precipitation signals show high correlations in time. Only if all 6 lysimeters showed a parallel weight increase or decrease within the same direction their arithmetic mean was assigned to precipitation or actual evapotranspiration.

Latent and sensible heat fluxes were determined by an eddy covariance station at a distance of approx. 30 m from the lysimeters. Assuming that the energy balance gap is related to underestimation of turbulent fluxes (after taking into account the storage terms), the energy balance of the EC data was corrected related to KESSOMKIAT et al. (2013): The energy balance deficit was determined using a 3-h moving window around the measurements. In a second step the energy balance was closed based on a redistribution of the missing energy according to the evaporative fraction. The evaporative fraction was determined for a longer time window of one day. Hourly grass reference evapotranspiration (ET0) was calculated according to the FAO-method (Food and Agriculture Organization) including the Penman-Monteith equation for hourly values (ALLEN 2000). All required meteorological input parameters for the calculation of the potential evapotranspiration were taken from the EC station.

Results and Discussion

Figure 1 shows daily precipitation sums calculated from the lysimeter data and the tipping bucket gauge for May 2012. Compared to the lysimeter data the daily precipitation sums of the tipping bucket are consistently smaller. The monthly sums between both methods exhibit a difference of approx. 16 %. This lies within the expected wetting and wind loss error range for the tipping bucket. The precipitation sums measured by lysimeter and tipping bucket correlate well on an hourly basis (R^2 of 0.7). Furthermore small precipitation amounts in the lysimeter data (e.g. day 7) in the morning and evening hours are supposed to be dew. Further investigation is needed to verify this.

Figure 2 illustrates the evapotranspiration results of May 2012. The monthly sum of ETa calculated from hourly lysimeter data (ETa-LYS) was higher than the calculated grass reference evapotranspiration (ET0) values indicating that in this month evapotranspiration was not limited by soil moisture content, but energy. The difference between the monthly sum of ETa measured with EC and by the lysimeters was 29%. The differences in daily evapotranspiration between ETa-LYS and ET0 can be explained with the grass height. The grass length on the lysimeter surface at the study side was higher than the FAO reference grass (12 cm) until it was cut on May 21. Afterwards ETa-LYS were consistently lower than ET0. Moreover, it can be seen that all cumulated curves

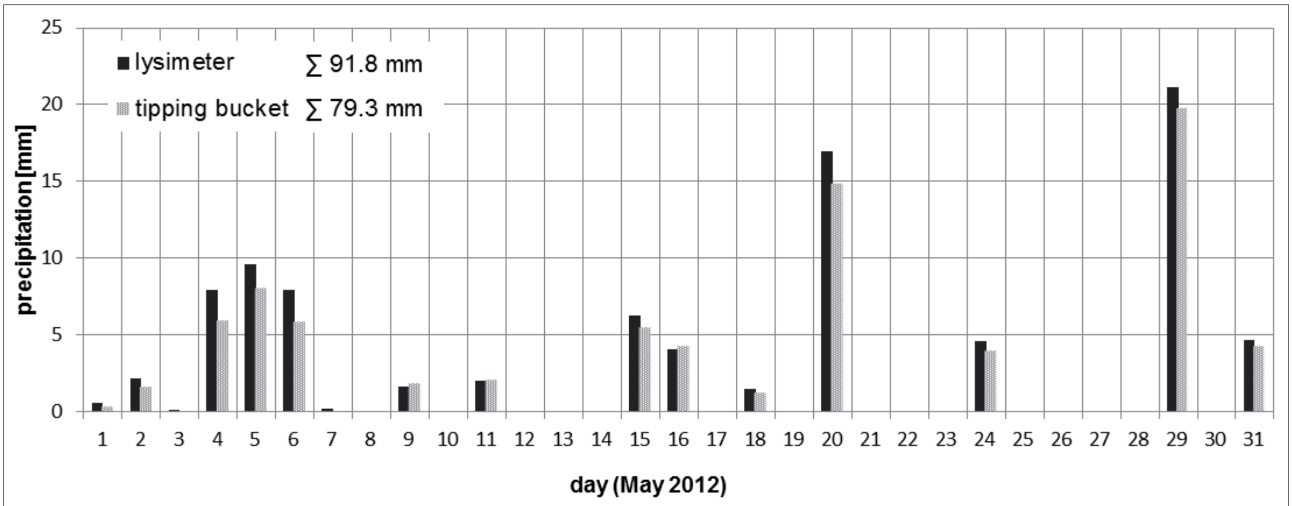

Figure 1: **Daily precipitation sums at the Rollesbroich study site in May 2012.**

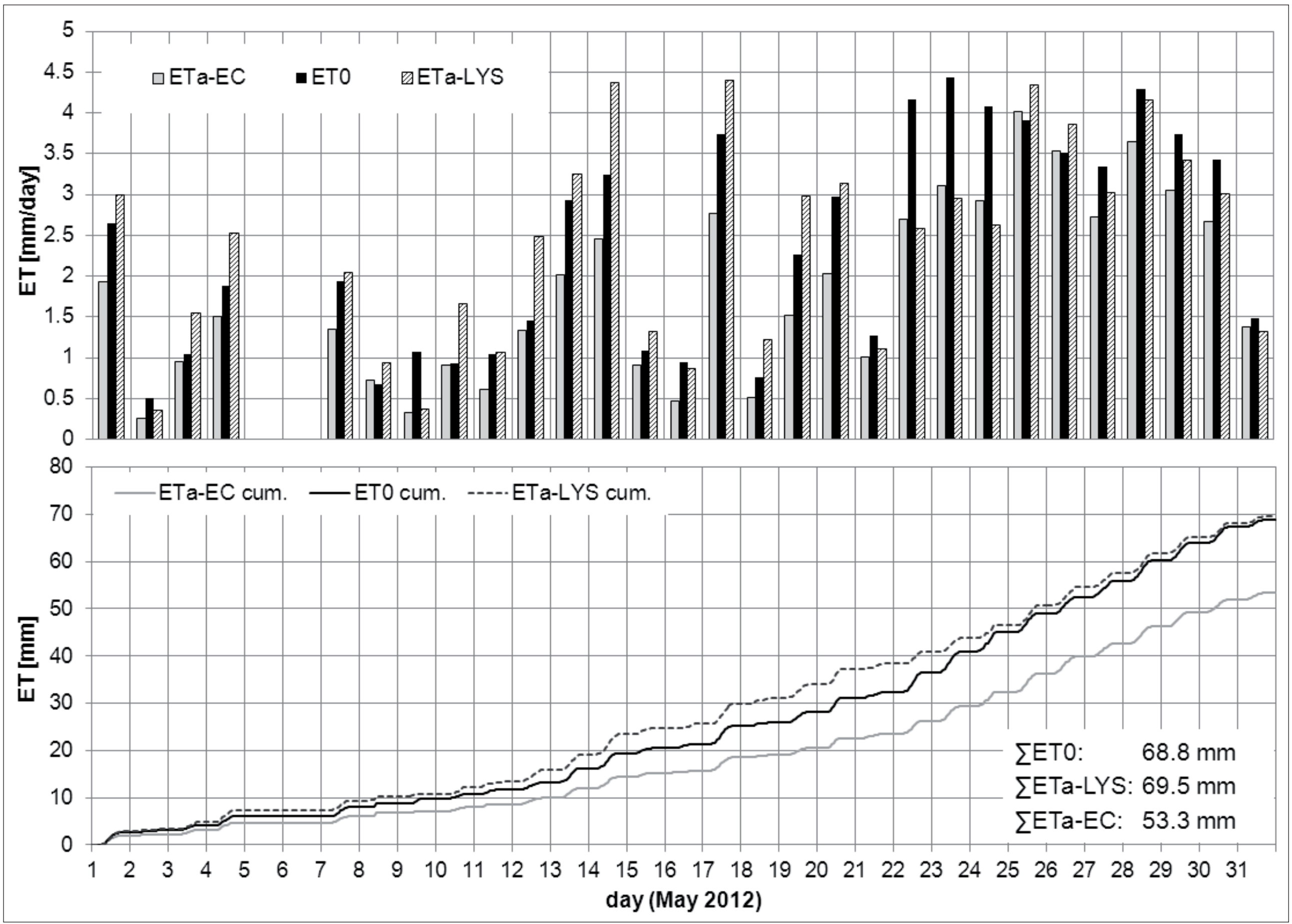

Figure 2: **Daily sums (upper) and hourly cumulated (lower) evapotranspiration of lysimeter and EC data compared to FAO grass reference.**

are close to each other until the relatively dry period from 7 – 14 May. Here the gap between ETa-LYS and ETa-EC increases until May 21. From May 21 onwards daily values for ETa-LYS, ETa-EC and ET0 are similar. It is supposed that differences in grass height are the reason for the gap between ETa-LYS and ETa-EC. For the detailed evaluation of the role of grass height more data are needed. Furthermore, FANK (2007) points out a dependency between precision of ET predictions and the measurement interval of the used data. In his study he concludes that a prediction on the basis of 10 minute data gives the best results.

Conclusions and Outlook

Weighable lysimeter data can be used to simultaneously estimate precipitation and actual evapotranspiration in a reliable manner. For the considered period of May 2012 the estimated hourly precipitation and evapotranspiration amounts derived by the filter algorithm of lysimeter data are consistent and plausible. A long term comparison for the year 2012 will show the influence of seasonal behavior of these results. For the investigation of small time intervals (10 – 30 min) filter and correction methods should be revised.

Acknowledgements

We want to acknowledge TERENO and SoilCan contributing data for this research.

Literature

ALLEN, R.G., 2000: Using the FAO-56 dual crop coefficient method over an irrigated region as part of an evapotranspiration intercomparison study. Journal of Hydrology, 229(1–2): 27-41.

BRUTSAERT, W., 2010: Hydrology: An Introduction / Wilfried Brutsaert. Univ. Press, Cambridge, XI, 605 S. pp.

FANK, J., 2007: Die Gras - Referenzverdunstung: Berechnungsergebnisse in Abhängigkeit von Messgeräten und Messintervall. 12. Gumpensteiner Lysimetertagung.

KESSOMKIAT, W., H.-J.H. FRANSSEN, A. GRAF and H. VEREECKEN, 2013: Estimating random errors of eddy covariance data: An extended two-tower approach. Agricultural and Forest Meteorology, 171–172(0): 203-219.

MEISSNER, R., J. SEEGER, H. RUPP, M. SEYFARTH and H. BORG, 2007: Measurement of dew, fog, and rime with a high-precision gravitation lysimeter. Journal of Plant Nutrition and Soil Science, 170(3): 335-344.

RUDI, J. et al., 2010: Multiscale Analysis of Hydrologic Time Series Data using the Hilbert–Huang Transform gsvadzone, 9(4): 925-942.

SEVRUK, B., 1996: Adjustment of tipping-bucket precipitation gauge measurements. Atmospheric Research, 42(1–4): 237-246.