Geophysical Research Abstracts
Vol. 19, EGU2017-3356, 2017
EGU General Assembly 2017

Analysis and simulation of the water and energy balance of two cereal crops by using the Eddy Covariance Method and eco-hydrological modelling

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This study analyses the total water and energy balance for the growing seasons of two cereal varieties (spring barley and winter wheat) through hydro-meteorological experiments. The experiments were conducted in a highly productive agricultural environment close to Heidelberg, southwestern Germany. The Eddy-Covariance-Method was applied to measure the latent and sensible heat fluxes during the growing seasons of the years 2014 and 2015. Both years featured a number of exceptionally dry and hot weather conditions. Next to the measurement of standard meteorological parameters, soil moisture at different depths (in triple repetition), the individual radiation balance components as well as the phenological development of the studied crops was recorded.

Measurements of turbulent heat fluxes using the Eddy Covariance Method generally imply an unbalanced energy balance. This yields residuals of available energy which are neither sensitive nor associated to the latent heat flows. The energy balance ratio in this study was 69.7 % for spring barley (2014) and 76.5 % for winter wheat (2015). The energy balance gap was closed by two methods. One method divides the residuals in accordance with the ratio of sensible to latent heat (Bowen ratio). The other method allocates the entire residue of the sensible heat, so that the measured latent heat flows remain unchanged. The energy balance closure by the Bowen ratio method showed a significant increase in evapotranspiration. Based on the growing season from the start of the measurements in April to harvest in July, evapotranspiration increased in 2014 from 209.7 mm to 334.4 mm and in 2015 from 244.8 mm to 348.4 mm. The daily average evapotranspiration flux for the whole period was 3.6 mm d-1 and 3.4 mm d-1 for spring barley and winter wheat, respectively. The occurrence of secondary flow patterns, which lead to uncertainties in the energy balance closure, was evaluated by calculating the water balance from measured rainfall and soil moisture changes. The analysis suggests phases of overcorrection of the latent heat flux by the Bowen-ratio-method.

The experimental data were used to validate the eco-hydrological model TRAIN and to simulate the individual water and energy balance components on an hourly basis. At the core of the transpiration module within TRAIN is the Penman-Monteith equation. A crucial part of this equation is the requirement for a plant specific canopy resistance rc. This resistance was determined by rearranging the Penman-Monteith equation and using field data as input. The calculation procedure for rc showed for both cereals similar minimum values in the main growing season (33 sm-1 for spring barley and 47 sm-1 for winter wheat). Mean values of 89 sm-1 and 117 sm-1 and in particular the maximum values in the final stages of the growing season (634 sm-1 and 1889 sm-1) differed significantly. The derivation of canopy resistances allowed a landscape and crop specific calibration of the TRAIN model by multivariate linear regression analysis. The simulation results of the calibrated TRAIN showed high consistency with the measured evapotranspiration fluxes for both spring barley and winter wheat.