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Validation of an improved energy balance model to estimate actual evapotranspiration in irrigated cotton ecosystems of Central Asia

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The understanding of the hydrological and the energy cycles are essential in order to describe the complex interactions within the climate system of the earth. Being recognized as an essential component of both the water and the energy cycle, reliable estimation of actual evapotranspiration and its spatial distribution is one outstanding challenge in this context. For instance, in irrigation systems of arid regions, artificial locations of evapotranspiration have been created. An in-depth process understanding is of paramount importance, as irrigated agriculture consumes about 70 % of the available freshwater resources worldwide, with a significant but unsatisfyingly quantified impact on the water cycle, especially on regional scale. Moreover, an exact quantification of ET inside these artificial ecosystems enables assessments of crop water consumptions and hence about water use efficiency (WUE). The withdrawal of water for agricultural use in the countries of Central Asia is more than 90%. Khorezm region in Uzbekistan is a case study region for the problems of irrigated agriculture in CA.

For Khorezm the seasonal actual ET was calculated for the years 2003 – 2010 using the partly modified surface energy balance algorithm for land (SEBAL). SEBAL was implemented based on MODIS time series to calculate the energy balance components like net radiation (Rn), sensible heat (H), latent heat (LE), and soil heat flux (G). Whilst SEBAL is using an empirical equation for estimating G, a more physically based method was introduced in this study. This method uses microwave soil moisture products (ASAR-SSM and ASCAT-SSM) as additional input information. The modelled energy balance components were intensively validated by field measurements with an eddy covariance system and soil sensors. For turbulent heat fluxes the RMSE is about 40 W/m^2 for H and 80 W/m^2 for LE with a coefficient of determination (r^2) of 0.64 for H and 0.52 for LE. Soil heat flux estimation could be improved using the physically based method. While the empirical equation leads to RMSEs of 80 W/m^2 and r^2 of 0.09, the improved approach for G shows RMSE of about 35 W/m^2 and r^2 of 0.46. Whereat, the impact of the improvement in G estimation on the ET modelling is low due the relatively small proportion of G in the total energy balance, compared to the components Rn, H, and LE. For cotton, the seasonal actual ET varies between 500 mm in dry years and 750 mm in years with higher water availability. Hence, WUE is small compared to other irrigated cotton ecosystems with seasonal ET of about 400 mm. Considering the required amount of irrigation water for the entire area of the irrigation system of 10 mio. ha with a proportion of cotton of about 30%, illustrates the dimension of water diversion in CA. Thus, in the studied case only cotton disturbs the natural cycles by ET in the desert ecosystem. However, for an exact quantification transfer of this method into other irrigated systems of CA, regional meteorological observations are necessary.