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Discussion

Comment on “A hybrid approach combining the FAO-56 method and the complementary principle for predicting daily evapotranspiration on a rainfed crop field’ by D. Kim et al.

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ABSTRACT

Kim et al. (2019) proposed to scale the generalized complementary-relationship-obtained daily evapotranspiration (ET_{GCR}) rate by the wet-environment ET value (ET_w) as an index (K_s) of soil water stress but they did not tie their index-values to any soil moisture data. With daily measurements from the same study area (Mead, Nebraska) and period (2002–2012) it is demonstrated that there indeed exists a statistically significant near-linear relationship between K_s ($=ET_{GCR}/ET_w$) and the volumetric soil water content (*VWC*) when scaled by its maximum observed value, a proxy for field capacity (*FC*). The soil moisture data therefore support, with increasing reliability as the length of the averaging period grows, the employment of ET_{GCR}/ET_w as a practical indicator of soil water stress, the latter here defined as *VWC/FC*.

In the FAO-56 method (Allen et al., 1998) of crop ET estimation the so-called water stress coefficient (K_s) scales back the ET rate of a well-watered field of crop to account for the limiting moisture status of the soil under drying conditions. Its application requires soil moisture measurements which may not always be available or may not be representative for large fields of heterogeneous soils. Any attempt that replaces local, point-wise measurements of the soil moisture status with more readily available standard meteorological data that are innately representative of a larger area (due to turbulent mixing of the atmospheric boundary-layer air flow) to derive K_s, maybe welcome by hydrologists, hydrologic modellers, agronomists, irrigation engineers, developers and/or managers.

Kim et al. (2019) proposed the application of the actual ET estimate (ET_{GCR}) – obtained by the generalized complementary relationship (GCR) of Szilagyi et al. (2017)—when further scaled by the wet-environment ET rate (ET_w) – the latter derived by the Priestley-Taylor equation (1972)—as a practical indicator of soil water stress but they failed to link their empirical coefficient to any soil moisture data to verify their claim that such a choice is indeed adequate and representative of the moisture status of the soil. With recent publicly available soil moisture (i.e., volumetric water content) data from four depths (10, 25, 50, and 100 cm) averaged among three locations within the same site [65.4 ha of maize (odd years) and soybean (even years) near Mead, Nebraska, USA] and period (May 1 – Ocober 31 of 2002 – 2012) Kim et al. (2019) studied, it is now possible to investigate such a desired link.

Hourly air- and dew-point temperature, as well as wind velocity data for the Mead site [plus incoming solar radiation, eddy-covariance (EC) measured ET rates, volumetric soil moisture, among many other variables] are available from AMERIFLUX (https://ameriflux.lbl.gov) and were averaged into daily values to be used in the calibration-free generalized complementary relationship (Szilagyi et al., 2017) model together with the daily net surface radiation, R_n [derived from daily-aggregated hourly incoming solar radiation by the algorithm of Morton (1983)]. The resulting daily ET_w-scaled ET_{GCR} values were then regressed against the eddy-covariance measurements in Fig. 1. The sole parameter value of the GCR, the Priestley-Taylor α, was set to 1.18, the same as Kim et al. (2019) applied. Note that in principle the GCR model of Szilagyi et al. (2017) is calibration-free and an α value of 1.15 was derived (Szilagyi, 2018) as representative of the conterminous US on a monthly scale, but the derivation depends on the temporal and spatial resolution of the data and the quality of R_n, all different now from that of Szilagyi et al. (2017) and Szilagyi (2018).

The ET_{GCR} values form a practically unbiased (relative bias is 1%) estimate of the daily EC-derived ET rates and explain 67% of the variance (i.e., the linear correlation coefficient, R, is 0.82) found in the latter, similar to what Kim et al. (2019) published separately for the maize ($R = 0.86$) and soybean ($R = 0.7$) field, employing a different algorithm to estimate R_n from solar radiation. The Nash-Sutcliffe efficiency value, *NSE*, is 0.63, again within the values (i.e., 0.71 and 0.45, respectively) of Kim et al. (2019).

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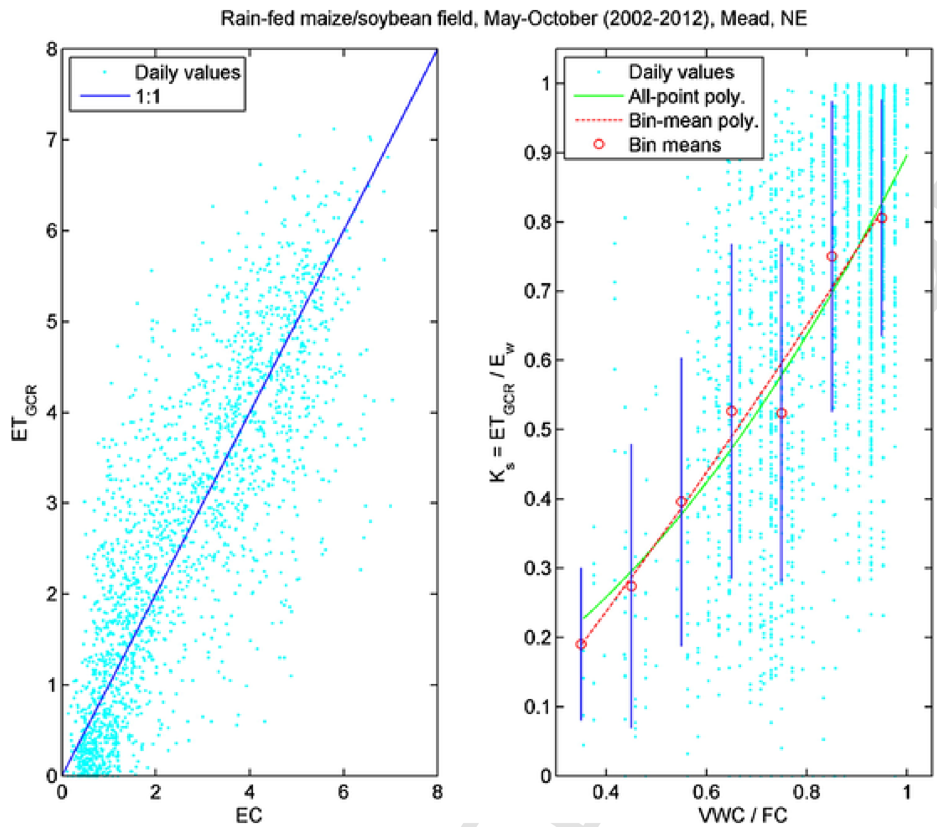

Fig. 1. Regression plot of a) generalized complementary relationship (GCR) estimates against eddy-covariance (*EC*) measured daily ET rates (mm); b) water stress coefficient (K_s) versus ratio of volumetric soil water content (*VWC*) and its field capacity (*FC*). E_w is the wet-environment ET rate. The curves are the best-fit 2nd-order polynomials to all data points and to bin-means, respectively. The whisker denotes the standard deviation of the values within the respective bin. Sample size is 2024.

Planting was reported (Kim et al., 2019) to generally start between mid-April and mid-May, and the plants typically go to senescence by early October, therefore in May and October the soil moisture data were taken from a depth of 10 cm, while in the remaining time-period of the growing season, when the root system is developed, from a depth of 1 m. At both depths the daily mean volumetric water content (*VWC*) values were scaled by the maximum recorded daily average value, representing conditions close to field capacity (*FC*).

As seen in Fig. 1, the Kim et al. (2019) proposed soil water stress index, K_s, tends to have low values when the soil is indeed dry, and conversely, have large values when the soil is wet, even though variability is quite large (indicated by the length of the whiskers) for a given daily moisture value. The relationship between daily soil moisture and stress index is nearly linear, especially for the bin means. The linear correlation coefficient, *R*, is 0.58 (*NSE* = 0.34 for the curve fitted to all data points) which indicates a statistically significant, but only a moderately strong (linear) relationship between the variables for a sample size of 2024.

The relationship however strengthens with increasing length of the averaging period (Fig. 2), reflected in the growing *R* (i.e., 0.66, 0.72, 0.73, and 0.77) and *NSE* (i.e., 0.45, 0.52, 0.54, and 0.6) values as well as in the decreasing data scatter within the respective panels of Fig. 2. At the 20-day averaging period the K_s index proposed by Kim et al. (2019) explains 60% of the variability found in the corresponding soil moisture data.

In summary, the soil water stress index proposed by Kim et al. (2019) and obtained solely from atmospheric measurements as the ratio of the GCR-estimated daily ET and the corresponding wet-environment ET rate, was found to relate in a near-linear fashion to the actual water status of the soil at the study site. This finding lends further support to the practical applicability of their hybrid ET estimation method

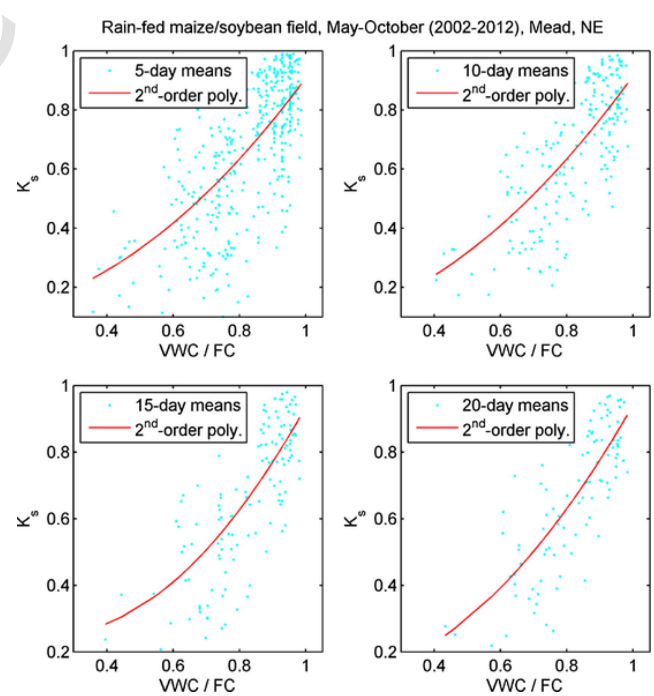

Fig. 2. Regression plots of different temporal averages of the water stress coefficient (K_s) versus ratio of volumetric soil water content (*VWC*) and its field capacity (*FC*). The curves are the best-fit 2nd-order polynomials. With averaging length the Nash-Sutcliffe model efficiency (*NSE*) value (%) increases as follows: 45, 52, 54, 60. Here model estimates are represented by the polynomial-curve values.

in rainfed crop fields provided the area that surrounds the field in question has similar (or at least not very different) land cover and moisture status in order to prevent any possible distorting energy and moisture transport onto the specific crop field. With the size of the crop field such limitations diminish (i.e., on a scale of one square-kilometer or larger) of course.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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