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Integrating soil moisture in SCOPE model for improving remote sensing of evapotranspiration and photosynthesis under water stress conditions

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A radiative transfer and process-based model, called Soil-Canopy-Observation of Photosynthesis and Energy fluxes (SCOPE), relates remote sensing signals with plant functioning (i.e., evapotranspiration and photosynthesis). Relying on optical remote sensing data, the SCOPE model estimates evapotranspiration and photosynthesis, but these ecosystem-level fluxes may be significantly overestimated if water availability is the primary limiting factor for vegetation. Remedying this shortcoming, additional information from extra sources is needed. In this study, we propose considering water stress in SCOPE by incorporating soil moisture data in the model, besides using satellite optical reflectance observations. A functional link between soil moisture, soil surface resistance, leaf water potential, and carboxylation capacity is introduced as an extra element in SCOPE, resulting in a soil moisture integrated version of the model, SCOPE-SM. The modified model simulates additional state variables: (i) vapor pressure (e_i), both in the soil pore space and leaf stomata in equilibrium with liquid water potential; (ii) the maximum carboxylation capacity (V_{cmax}) by a soil moisture dependent stress factor; and (iii) the soil surface resistance (r_{ss}) through approximation by a soil moisture dependent hydraulic conductivity. The new approach was evaluated at a Fluxnet site (US-Var) with dominant C3 grasses and covering a wet-to-dry episode from January to August 2004. By using the original SCOPE (version 1.61), we simulated half-hourly time steps of plant functioning via locally measured weather data and time series of Landsat (TM and ETM) imagery. Then, SCOPE-SM was similarly applied to simulate plant functioning for three cases using Landsat imagery: (i) with modeled e_i; (ii) with modeled e_i and $V_{cmax;}$ and (iii) with modeled e_i, $V_{cmax,}$ and r_{ss}. The outputs of all four simulations were compared to flux tower plant functioning measurements. The results indicate a significant improvement proceeding from the first to the fourth case in which we used both Landsat optical imagery and soil moisture data through SCOPE-SM. Our results show that the combined use of optical reflectance and soil moisture observations has great potential to capture variations of evapotranspiration and photosynthesis during drought episodes. Further, we found that the information contained in soil moisture observations can describe more variations of measured evapotranspiration compared to the information contained in thermal observations.