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Fusion of all-weather and high-resolution satellite soil moisture data for better simulating evapotranspiration over China

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Abstract: Evapotranspiration (ET) is a key hydrologic variable linking the Earth's water, carbon and energy cycles. Remote sensing (RS) datasets are usually identified as essential inputs for driving ET processes at large spatial scales. Since ET is an earth-surface process mainly controlled by integrated effect from the amount of water available in soils, the demand of water vapor in the atmospheric column, and the incoming long-wave and short-wave radiation from the sun and the cloud, a large number of RS ET models have employed surface energy models for calculating ET from continental to global domains, few have included soil moisture as their model input. Instead, most of them exploited atmospheric vapor pressure deficit or soil temperature as the proxy for quantifying water availability in the soil. The 9-km resolution SMAP L4 soil moisture product has been dedicated to improvement of the conventional MODIS ET product (MOD16) in recent research. Such effort has expectedly obtained superior validation performance on daily ET estimates, compared to the conventional MOD 16 product. However, the research also admitted that the coarse resolution (9-km) of SMAP soil moisture estimates may contribute to extra modelling errors on ET at the target resolution of 500-1000 m. This hints that RS soil moisture data at higher spatial resolutions are in particular need for modelling of large-scale ET process with higher accuracy.

Based on an improved downscaling methodological framework on AMSR-E/AMSR-2 passive microwave surface soil moisture product in our previous study (Song et al. 2021, https://doi.org/10.1029/2020GL091459), we have developed a 1-km resolution daily all-weather surface soil moisture data product all over China (Song et al. 2022, https://doi.org/10.5194/essd-14-2613-2022). In this study, we investigated the potential capability of this product on improving the ET estimation accuracy of a recently developed diagnostic water-carbon coupled biophysical model based on the Penman-Monteith equation, i.e. the PML-V2 model (Zhang et al. 2019, https://doi.org/10.1016/j.rse.2018.12.031). In this model, the total evapotranspiration is conceptually divided into three components including soil evaporation, vegetation transpiration, and evaporation of precipitation intercepted by the vegetation. To calculate the soil evaporation, an input parameter f is required and is originally represented as a function of accumulated precipitation and soil equilibrium evaporation in the recent month or half, based on meteorological features from the GLDAS V2.1 reanalysis datasets. As this parameter is actually defined to quantify the soil wetness degree, we have used our downscaled RS soil moisture datasets to recalculate it, as $f=\frac{SM_0-SM_{min}}{SM_{max}-SM_{min}}$. SM_0 herein denotes soil moisture content of a 1-km pixel at one certain time, whilst SM_{min} and SM_{max} respectively denote the theoretical minimum and maximum thresholds on evaporative efficiency of local soils and are related to soil texture properties. Both the original PML-V2 and the SM-constrained new model were applied for calculating 8-day averaged ET at all 1-km pixels in China throughout the years of 2010-2019. The estimated ET based on the original PML-V2 and the SM-constrained PML were respectively validated using corresponding in situ observations from 8 national-level ET flux sites which are all characterized by crop land covers.

The validation results show that ET outcomes generated by the SM-constrained PML model is in better correspondence with the in-situ observations (RMSE≈0.752 mm/day) compared with the original PML-V2 outcomes (RMSE≈1.178 mm/day). This has preliminarily confirmed the feasibility of using high-resolution RS soil moisture data for improving ET simulation performances.

Keywords: *Evapotranspiration, all-weather, soil moisture, land surface temperature, high-resolution*