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Spatial pattern evaluation of remote-sensing evapotranspiration products using surface water-balance approach: application of geostatistical functions for quantifying drivers and dependence structures of ET data

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Remote sensing-based RS observations can provide evapotranspiration ET estimations across temporal and spatial scales. In this study, two MODIS-based global ET, namely MODIS16 and two-source energy balance model TSEB are compared and evaluated using the surface water-balance WB ET method at monthly time-scale with 1 km spatial resolution for the entire land phase of Denmark (42,087 km^2). Then, the drivers and underlying dependence structures of ET datasets against land-atmosphere parameters are appropriately quantified using a linear-based multivariate principal component analysis PCA –and nonlinear-based bivariate empirical Copula analysis. For calculation of the surface WB ET method, in addition to the standard WB ET procedure (ET = precipitation P – discharge Q), we introduce a novel modification of standard WB method, which considers a groundwater exchange term. Here, modelled net intercatchment groundwater flow (GW_net) is also included in the ET calculation (ET = P – Q + GW_net); where the simulations are done by the national water resources model of Denmark (the DK-model) executed in the physically-based distributed MIKE-SHE hydrologic modelling code. The differences between the two WB methods are presented and discussed in detail to highlight the importance of considering GW data when investigating water-budget of small catchments. Our analysis will also be extended to compare ET datasets at different spatial scales (catchment size), aiming at further exploring the performance and ET uncertainties of remote sensing-based models. Our results indicate that the novel approach of adding GW-data in WB ET calculation results in a more trustworthy WB ET spatial pattern. This is especially relevant for smaller catchments where GW-exchange can be significant. Large discrepancy is observed in TSEB/MODIS16 ET compared to WB ET spatial pattern at the national scale; however, ΔET values are regionally small for most watersheds (~60% of all). Also, catchment-based analysis highlights that RS/WB ΔET decreases from <100km^2 to >200km^2 watersheds, and about 56% (67%) of all catchments have ΔET ±50 mm/year for TSEB (MODIS16). PCA-based analysis revealed that each ET dataset is largely driven by different parameters. However, land surface temperature LST and solar radiation Rs are found as most relevant driving variables. In addition, Copula-based analysis captures a nonlinear structure of the joint relationship with multiple densities amongst ET products and the parameters, showing a complex underlying dependence structure. Overall, both PCA and Copula analyses indicate that WB and MODIS16 ET products represent a closer spatial pattern compared

to TSEB. This study will help improve standard WB ET estimate method and contribute to deeper understanding the inter-correlations and real complex relationships between ET datasets and the nature of land-atmosphere parameters.