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A hybrid model of global land evaporation

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Transpiration (E_t) is a key variable in hydrology and climate, yet it remains poorly understood at global scales. In nature, several non-linearly interacting environmental variables, or 'stressors', limit the rates of Et below the demand by the atmosphere. In most process-based formulations of evaporation (E) – e.g., satellite-based algorithms and climate models – only a few of these stressors are considered, and their representation is usually based on limited empirical or experimental studies conducted at local scales. New hybrid approaches offer the opportunity to combine process-based knowledge on E_t and machine learning models in a synergistic manner, and to better characterise the influences of this myriad stressors on E_t.

Using a hybrid approach, we combine *in situ* and satellite observations of multiple stress variables using deep learning, aiming to construct a new formulation of transpiration stress (S_t) – the ratio by which potential transpiration is reduced to E_t. The data of S_t are assembled from 368 flux towers spread across the globe coming from multiple networks, as well as 90 sapflow-instrumented sites from a recently collected global archive. The covariates used as input features include: plant available water to represent water or drought stress, air temperature to represent heat stress, vapor pressure deficit to account for the effect of atmospheric demand on stomatal conductance, microwave vegetation optical depth to consider the phenological state of vegetation, incoming shortwave radiation as an indicator of light stress, and carbon dioxide which directly and indirectly affects ecosystem transpiration.

We show that our ground-up approach without any prior assumptions compares better than traditional formulations of S_t, both when compared to *in situ* observations as well as an independent satellite-based stress proxy (SIF/PAR). Embedding the new S_t function within a process-based model of E (the Global Land Evaporation Amsterdam Model, GLEAM) yields a hybrid model of evaporation (GLEAM-Hybrid) which is evaluated in its performance. In this hybrid model, the S_t formulation is bidirectionally coupled to the host model at daily timescales. An extensive validation shows that our hybrid approach (GLEAM-Hybrid) has the potential to outperform traditional process-based formulations (GLEAM) and pure machine learning-based estimates of E (FLUXCOM). Overall, the proposed approach provides a suitable framework to improve the estimation of E in satellite-based algorithms and climate models, and consequently increase our understanding of this crucial variable.