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Predicting global runoff and hydrological drought in 1991-2024 using the HBV-PML model

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Abstract: Accurate estimates of actual evapotranspiration (ET) are essential for simulating hydrological processes, particularly for predicting streamflow and hydrological drought in ungauged catchments. Traditional hydrological models, which typically use only precipitation and potential evaporation as inputs, often produce unreliable ET estimates. This limits their performance in regions with sparse observational data.

To address this, we incorporated ET constraints from a biophysically based remote-sensing model, the Penman-Monteith-Leuning version 2 (PML-V2), calibrated with flux tower data into an enhanced HBV hydrological model (HBV-PML) (Huang et al. 2022). This coupling allows PML-V2 ET estimates (Zhang et al. 2019) to replace the original ET estimates from HBV, ensuring consistent outputs between the two models.

We applied HBV-PML to 4,641 small catchments globally, using a basin-attribute similarity approach to transfer parameters from 10 hydrologically similar catchments to each target basin. Ensemble simulations from these 10 parameter sets showed that HBV-PML runoff estimates were slightly lower than those from the original HBV model. Nevertheless, both models achieved a median Kling-Gupta Efficiency (KGE) exceeding 0.50 for monthly runoff and 0.45 for daily runoff remarkable for HBV-PML given that its ET matched PML-V2 exactly.

Using this parameterization, we predicted daily runoff at 0.05-degree resolution for global land areas during 1991-2024, then aggregated results into ~1,000 HydroSHEDS Level 4 basins. The predictions reveal intensified hydrological drought over the past 34 years, with record severity in 2023-2024. This study highlights the potential of integrating accurate ET estimates into hydrological models to achieve reliable runoff and drought predictions while greatly improving ET accuracy.

Keywords: *Hydrological prediction, streamflow, evapotranspiration, drought, model, HBV, PML*

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