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## Continental-scale assessment of hydrological cycle across Europe under anthropogenic warming

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Climate change is fundamentally altering the spatial and temporal dynamics of the hydrological cycle, with profound implications for water security, ecosystem stability, and regional climate resilience. Building on the framework of Thakur et al. (2025), which evaluated how PET-method choices influence historical hydrological trends, we extend the framework to future conditions using CMIP6-based ISIMIP3b projections. We assess changes in precipitation (P), runoff (Q), total water storage (TWS), and actual evapotranspiration (AET) at 1°C, 2°C, and 3°C global warming levels across 553 European catchments. Using 165 mesoscale Hydrologic Model (mHM) simulations per catchment (five GCMs, three SSPs, 11 PET methods, we introduce a framework to detect emerging hydrological cycle patterns based on trend combinations. quantify projection agreement using the Data Concurrency Index (DCI) and characterize uncertainty with two complementary metrics that capture variability ( $\psi$ ) and temporal inconsistency ( $\chi$ ) for each warming level and hydrological variable.

Our findings show a marked expansion in the spatial extent of negative trends in P, Q, and TWS with increasing warming, while AET trends are positive in over 96% of catchments. More than two-thirds of catchments follow clear wetting (W1) or drying (D1) hydrological cycle patterns, with D1 becoming increasingly dominant at higher warming levels. PET methods offer consistent directional agreement, but GCMs contribute the most disagreement, particularly for Q and TWS. Even with these coherent signals, uncertainty ( $\psi$  and  $\chi$ ) remains substantial and increases with warming. Although the PET contribution increases, it consistently remains below that from GCMs and SSPs.

Reference:

Thakur, V., Markonis, Y., Kumar, R., Thomson, J. R., Vargas Godoy, M. R., Hanel, M., and Rakovec, O.: Unveiling the impact of potential evapotranspiration method selection on trends in hydrological cycle components across Europe, *Hydrol. Earth Syst. Sci.*, 29, 4395–4416, <https://doi.org/10.5194/hess-29-4395-2025>, 2025