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Editorial

Editorial: Bridging Scales and Embracing New Technology to Address Challenges in Modern Hydrology

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1. Hydrology and Water Resource Are at an Inflection Point

It is with both pride and urgency that we present the inaugural issue of *Hydrology and Water Resources* (*HWR*) that aims to advance the integration of hydrological science with innovative solutions for global and regional water security. Water, often called our "liquid gold", lies at the centre of climate stability, ecosystem resilience, economic security, and societal wellbeing. Yet global freshwater systems are undergoing profound transformations driven by climate warming, land use change, groundwater depletion, coastal salinisation, and accelerating hydroclimatic extremes.

Hydrology as a discipline now stands at a pivotal moment. We are witnessing:

- Intensification of the global water cycle under warming,
- Increasing subannual variability and compound extremes,
- Expanding drylands and groundwater stress,
- Rapid advances in satellite observation and artificial intelligence (AI)-based modelling, and
- A pressing need to translate scientific insight into adaptive water governance.

The six papers in this inaugural issue collectively capture this transition. They move beyond fragmented problem solving and instead illuminate a unifying theme: hydrology must integrate physical principles, storage dynamics, ecological processes, and intelligent modelling across scales.

2. Highlights from the Inaugural Issue

The six papers featured here represent the breadth of our scope, touching on the pillars of modern water science:

1. Fundamental Theory and Scaling: Hunt et al. [1] revisit the foundational work of Klemes and Eagleson, discussing the structure of hydrologic sciences through the lens of ecological optimality and spatio-temporal scaling. Their work addresses how the hydrology curriculum can be improved to better solve the water balance equation.
2. The Critical Role of Groundwater: Zhang et al. [2] challenge the traditional dominance of precipitation in streamflow modeling. Using data from over 1600 global catchments, they demonstrate that groundwater storage is a primary buffer for streamflow variability at subannual scales, particularly in water-limited regions.
3. Mechanisms of Evapotranspiration (ET): Zhou and Yu [3] provide a critical physical interpretation of the complementary relationship (CR) for evapotranspiration. By linking CR to the surface energy balance and the "wet Bowen ratio", they offer a physically grounded framework that enhances ET estimation across diverse environments.
4. Ecohydrology in Drylands: In a comprehensive review, Xie et al. [4] utilize multi-source remote sensing to analyze the spatiotemporal dynamics of drylands. Their findings reveal a significant decline in groundwater and terrestrial water storage between 2001 and 2022, highlighting the sensitivity of these regions to global warming and human intervention.

5. AI and Aquifer Vulnerability: Nourani et al. [5] demonstrate the operational transition of AI in monitoring by applying machine learning to saltwater intrusion vulnerability. Their AI-based models significantly outperformed traditional expert-based methods (like GALDIT) in capturing the complex salinity patterns of the Urmia and Salmas aquifers.
6. Predicting Ungauged Basins: Zheng et al. [6] tackle the persistent challenge of predicting streamflow in ungauged catchments. By proposing a “process-informed” machine learning framework that integrates multivariate adaptive regression splines with the Budyko theory, they improve both the interpretability and robustness of hydrological predictions.

Taken together, the contributions in this issue suggest four foundational pillars for next-generation hydrology: (1) Physical grounding across scales: from percolation theory to energy balance constraints; (2) recognition of storage and buffering processes: particularly groundwater as a regulator of variability and resilience; (3) Integration of intelligent modelling with theory for process-informed machine learning rather than black-box prediction; (4) Prediction in ungauged catchments, a challenging topic that can be addressed using large samples of hydrological data. Hydrology must now operate simultaneously at pore scale, catchment scale, continental scale, and planetary scale.

3. Moving Forward

The inaugural issue of *HWR* signals our commitment to bridging theory and application, observation and modelling, physics and artificial intelligence, local water challenges and global resilience. As Editor-in-Chief, I invite researchers, engineers, policymakers, and students worldwide to contribute to this collective effort. The complexity of modern water challenges demands not isolated advances, but integrated insight. The future of hydrology lies in uniting scales, systems, and intelligence to safeguard water security for generations to come.

Conflicts of Interest

The author declares no conflict of interest.

Use of AI and AI-Assisted Technologies

During the preparation of this work, the author used Gemini to proofread the manuscript. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

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