Editorial

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Hydrology in the era of global change: from scientific understanding to water security

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Water is the foundation of environmental sustainability, economic development, and human well-being. Yet, despite remarkable scientific and technological progress, the world is experiencing increasingly complex hydrological challenges driven by climate change, rapid urbanization, land-use transformation, groundwater depletion, water pollution, and growing societal demands. These interconnected pressures reinforce the need for hydrological research that not only advances scientific understanding but also supports effective decision-making for sustainable water management.

The *International Journal of Hydrology* seeks to provide a forum where innovative research contributes to addressing these global challenges. Hydrology has evolved considerably over recent decades, moving beyond the traditional study of rainfall–runoff relationships toward an integrated Earth-system perspective that considers the interactions among climate, ecosystems, groundwater, surface water, soils, and human activities. This broader vision has transformed Hydrology into one of the most interdisciplinary environmental sciences.

Recent advances in remote sensing, unmanned aerial systems, geographic information systems, high-performance computing, and artificial intelligence have significantly expanded our capacity to observe and model hydrological processes. Satellite missions now provide continuous monitoring of precipitation, evapotranspiration, soil moisture, groundwater storage, and surface water dynamics at unprecedented spatial and temporal resolutions. Meanwhile, machine learning algorithms complement physically based models by improving predictive capabilities in flood forecasting, drought assessment, groundwater recharge estimation, and water-quality monitoring.

Nevertheless, technological innovation alone cannot solve the world's water problems. Scientific uncertainty remains an inherent component of hydrological systems, particularly under changing climatic conditions. The increasing frequency of compound extreme events—including floods, droughts, heat waves, and water-quality crises—demands new modeling frameworks capable of integrating uncertainty analysis, risk assessment, and adaptive management. Future hydrological research must therefore balance predictive accuracy with transparency, interpretability, and practical applicability.

Climate change represents one of the defining challenges for contemporary Hydrology. Altered precipitation regimes, rising temperatures, glacier retreat, sea-level rise, and changes in evapotranspiration directly affect water availability across all climatic regions. Semi-arid and arid environments are particularly vulnerable, where limited freshwater resources, increasing population pressure, and fragile ecosystems amplify water insecurity. Likewise, highly urbanized watersheds face growing risks associated with flash floods, reduced infiltration, deteriorating water quality, and aging infrastructure.

Groundwater deserves particular attention within this context. As one of the world's most important freshwater reserves, groundwater supports drinking water supplies, irrigated agriculture, industrial production, and ecosystem functioning. However, excessive abstraction, contamination, saline intrusion, and declining recharge rates threaten aquifer sustainability in many regions. Strengthening hydrogeological monitoring, integrating surface water–groundwater interactions, and promoting managed aquifer recharge should remain priorities for both researchers and policymakers.

Water quality has become equally critical. Emerging contaminants—including pharmaceuticals, endocrine-disrupting compounds, antibiotics, pesticides, heavy metals, and microplastics—pose new challenges for environmental monitoring and public health protection. Hydrological investigations increasingly require multidisciplinary approaches that combine hydrodynamics, hydrochemistry, microbiology, environmental engineering, and ecological sciences to understand contaminant transport and develop effective mitigation strategies.

One of the most significant transformations in hydrological science is the growing recognition that water systems are socio-hydrological systems. Human decisions influence hydrological processes, while hydrological variability shapes economic activities, governance structures, and societal resilience. Consequently, future research must increasingly integrate physical sciences with economics, social sciences, public policy, and environmental governance. Such integration enables more comprehensive assessments of water security and supports the development of resilient adaptation strategies.

Open science also plays a central role in accelerating scientific progress. The availability of open datasets, reproducible computational workflows, transparent methodologies, and collaborative international research networks enhances scientific reliability while facilitating innovation. As environmental challenges transcend political boundaries, international cooperation remains indispensable for improving global hydrological knowledge and promoting equitable access to water resources.

The scientific community likewise bears an important responsibility in supporting the next generation of hydrologists. Capacity building, interdisciplinary education, gender equity, and international collaboration strengthen the diversity of perspectives required to address increasingly complex water challenges. Encouraging early-career researchers and expanding research partnerships between developed and developing countries will contribute to more inclusive and globally relevant scientific advances.

As we look toward the future, Hydrology will continue evolving alongside technological innovation and societal needs. Artificial intelligence, digital twins of watersheds, Internet of Things (IoT) sensor networks, cloud computing, and integrated Earth observation systems will undoubtedly reshape hydrological investigations. However, these technologies should complement—not replace—the physical principles that remain the foundation of hydrological science.

The mission of the *International Journal of Hydrology* is to encourage the dissemination of rigorous, innovative, and impactful research capable of advancing both scientific knowledge and practical water management. We welcome studies that bridge disciplinary boundaries, improve our understanding of hydrological processes, and contribute to achieving resilient, equitable, and sustainable water systems worldwide.

Ultimately, the future of Hydrology depends on our collective ability to translate scientific knowledge into effective action. Through interdisciplinary collaboration, methodological innovation, ethical scientific practice, and international partnerships, the hydrological community can provide the evidence needed to confront the water challenges of the twenty-first century. This journal remains committed to serving as a platform for scientific excellence and for promoting research that supports a more sustainable and water-secure future for all.

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Conflicts of interest

The author declares there is no conflict of interest.

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