

## Editorial

# Hydrometeorology and Hydroclimate

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*Meteorology* is the main driving force of *hydrology* along time, from the instantaneous states and processes until the monthly, seasonal, yearly, and sometimes multiyear sequences. Meteorology drives and impacts much of the hydrological flows and storages, thus water balance terms as well as hazards, across a geometric and functional interface. This interface develops within a certain thickness, yet thin regarding the planetary radius and critical for water and other dynamics. This heterogeneous *Critical Zone* ranges from the bottom of groundwater reservoirs to the top of the tree canopy [1], including surface water liquid and frozen and gaseous flows and storages. Complex space-time effects develop in this critical zone such as orographic and oceanic influences on moisture-precipitation dynamics, hydrogeomorphological structure-function relationships, upstream-downstream integration, subsystems connectivities, variability interdependences, and scaling issues [2–6]. In some geographic settings, this critical zone is further complexified by extreme conditions of some of the properties, such as dryness or wetness, groundwater geometries and dynamics, cryospheric developments (snow, ice, and permafrost), soil and land covers, water uses, and concentration of water-driven chemicals.

The *hydrometeorological interface* is further subject to complex feedback and feedforward effects, from local fluid mechanic and thermodynamic processes themselves to major interactions within the macroscopic oceanic, lacustrine, cryospheric, deep ground, and biospheric and atmospheric interdependences [7–9]. Ongoing reorganizations of these interdependences actually change the general distribution of

water across the different compartments and the corresponding geographies, with impacts on physical properties and corresponding potential resources and hazards. These include but are not limited to interaction with greenhouse gases concentration trends underlying climate change, cryospheric shrinkage, changes of the land-ocean interface, individual and cumulative effects of anthropogenic infrastructures, massive groundwater pumping which locally reduces the resilience to drought and globally increases the atmospheric and hydrological circulating water, and accompanying geodetic and subsidence adjustments [10–15]. These are all intertwined, as elementary socioecological crises are symptoms which now appear to be imbedded in the general macroscopic accelerating transformations of the *Anthropocene* syndrome [16–19]. Intertwining is also emerging across a general nesting, eventually self-organizing, from global and hemispheric dynamics (from the natural oceano-hydrometeorological ones to new globalization ones) to regional and local niches and settings which can be called *AnthropoScenes*.

In statistical terms, meteorology can be characterized by climate, and statistical hydrology can be jointly analyzed, which distinguishes *hydrometeorology* and *hydroclimate*. Changes in climate, in terms of magnitude, statistical distribution, spatial distribution, timing and (a-)synchronicity, and range of variables, can have impacts on hydrological processes and statistics, as well as on associated dynamics such as erosion, pollution, snow and ice, ecohydrology, and water uses. These impacts are also often mixed with the ones of geographic changes [4, 6, 8, 15, 20].

In such a complex setting, enhanced by nonlinearities, retroactions, and coevolutions, *identifying change from variability* and eventual *nonstationarity* is a major issue [20–23]. Further, deciphering, fingerprinting, and attributing causes and impacts are complex in the frame of the Anthropocene and thus ultimately of the Water Security issue and Sustainable Development Goals [8, 24–29].

This special issue is aimed as an additional *bridge* over the interfacing boundaries and call for deeper *cooperation* from the hydrological community towards the meteorological one. Specific challenges can indeed be identified from the hydrological perspective, all the more thanks to the recently launched agenda setting *Panta Rhei* initiative on change in hydrology and society of the IAHS—International Association of Hydrological Sciences of the IUGG—International Union of Geodesy and Geophysics of the ICSU [15, 20] and thanks to the actual conceptualization of the Anthropocene from the strictly stratigraphic definition [30] to the wider epistemic understanding of ongoing and future socioecological relationships [17–19].

From this perspective, the following specific challenges are of particular interest:

- (i) Using historical information, palaeorecords, and forensics of severe events to elucidate *past changes* in climate and hydrology, including changes in hydrometeorological/climatic extremes.
- (ii) Deepening the *processes understanding* and physical foundation of models, enlarging the frontiers of modeled systems to encompass the critical interfaces and zone, and adapting models to assimilate new observation means and data sources.
- (iii) Assessing the *dynamic behaviour* of hydrometeorological systems in their links and feedback with *coevolving* natural/socioeconomic systems and exploring the *attribution* issue by inverting causal relationships.
- (iv) Analyzing *changes in patterns* of stable/unstable dynamical states of hydrometeorological/climatic systems, the contribution of these changes to *self-organization* of the systems, the *emergence* of nesting subsystems and coherent scenes, and the nature of *adaptation* to changing environmental complexity.
- (v) Advancing approaches for analyzing *predictability* of the water cycle processes including interdependences, separating predictable and unpredictable patterns, and dividing inherent epistemic and model-derived limits to predictability.
- (vi) Improving the *data chain* from in situ observation to open access dissemination, interoperability and *indicators* for accounting, and stewarding and progressing on related targets, especially in the frame of the new global societal project which is now shaping through the *Sustainable Development Goals* [29], the Paris Agreement related to *Climate Change* [31], the implementation of *Climate Services* in nexus with food, disasters, energy, health, and water resources [32], *extreme and disastrous events* and the Sendai

framework [28, 33, 34], and multiple *Water Security* challenges [26, 27].

- (vii) Developing interdisciplinary *foresight* methodologies and feeding comprehensive *prospective* explorations of the future hydrometeorological/climatic interface in the wider perspective of the critical zone in the Anthropocene and climate change trends [1, 18, 35–37].

The papers published in this special issue do all feed the hydrometeorological/climatic bridge, from the whole or continental-scale changing water cycle (X. Feng and P. Houser and J. Yin et al.) and some emblematic water-driven AnthroScenes (Y. T. Dile et al., G. Li et al., Y. Li et al., and Y. Tang et al.) to some focused studies of physical processes (T. A. McCorkle et al. and B. M. Shrestha et al.), while contributing to several of the specific challenges identified here above: change assessment (G. Li et al., Y. Li et al., and J. Yin et al.), nesting (J. Liu et al.), conjunction of causalities (Y. Tang et al.), and effects of anthropogenic actions (Y. T. Dile et al. and B. M. Shrestha et al.), as applied to a range of hydrometeorological/climatic variables, geographic contexts, and space-time-frequency scales. Several papers submitted, while not published here according to a timely scheduled peer review, were also framing in this rationale and do have the potential to later contribute to the debate and progress. There is no doubt that scientific progress and innovation will be very active in the coming years in the field of hydrology [3, 4, 15, 38, 39], not only in its core but also over its numerous complex and changing interfaces, from sociohydrology [20, 36, 37] and the eventually self-organizing processes of the socioecological Anthropocene [15, 18, 19] to the fragile critical zone, and the changing frontiers between the oceanic, ground, terrestrial flowing and stored cryospheric and atmospheric components of the hydrosphere, among which hydrometeorology and hydroclimate remain key challenges for scientific pluridisciplinarity and for putting new knowledge, methods, and skills into practice through observation, assessment, mitigation, and adaptation [39, 40].

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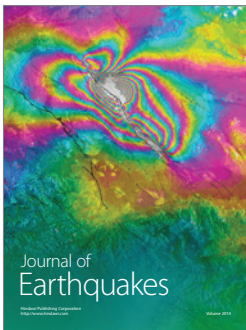
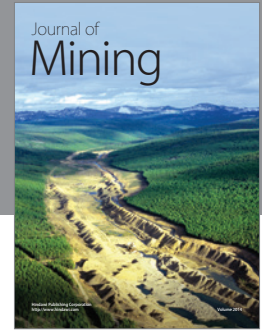
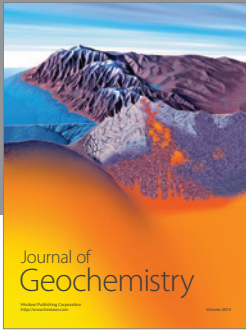
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