

## Editorial: Hydrogeomorphology – a long-term scientific interface

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### ABSTRACT

Hydrogeomorphology is reframed as an old inter-discipline, which is still highly relevant to both hydrology and geomorphology, renewed by new techniques and new questions in line with challenges of ungauged basins; anthropogenic changes in driving forces, landscape structures, and dynamic functions; translation of science into practice; and retrospective and prospective analyses. The corpus and experience of hydrogeomorphology are also highlighted regarding new emerging sub- or inter-disciplines, in terms of epistemic bridging and dealing with complexity.

**Key words** | change, coevolution, inter-discipline, organized complexity, structure–function

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Hydrological and water management issues are more and more related with connex compartments, structures, processes, dynamics, and hazards. Such connections and interfaces obviously follow the water flows between ‘spheres’: atmosphere, cryosphere, terrestrial/marine hydro-spheres, and biosphere. Some others emerge in terms of nature–society interactions, through both water uses and land uses, and do not always display explicit, causal, and upstream–downstream relationships.

These issues are actually exacerbated by the question of changes, from global to local ones, and from external driving ones to internal ones within hydrosystems (Rockström & Karlberg 2010; Koutsoyiannis 2013; Montanari *et al.* 2013; Jimenez Cisneros *et al.* 2014; Savenije *et al.* 2014); with strong flow forward, feedforward, threshold, and tipping points effects. The hydrological complexity is thus more and more identified and tackled, but still not fully understood.

The scientific study of these connections and interfaces is classically based on the coupling of respective approaches, with strong challenges of making disciplinary semantics, variables, models, and other concepts converge. This is especially the case with soil–plant–atmosphere, surface–ground waters, and land–sea interactions (Hallett *et al.* 2010; Krause *et al.* 2011; Ubertini & Miralles-Wilhelm 2013; Cudennec *et al.* 2014). Some recent focuses on the water–food–energy nexus and on water security (UNEP 2009; Turrall *et al.* 2011; UNESCO 2012; UN Water 2013;

Cudennec *et al.* 2015) do reinforce such coupling challenges, with scientific questions arising from increasing practical and societal interconnected problems.

Beyond these coupling approaches, new systemic visions are emerging in order to bridge over these interfaces toward more integrated approaches. Some dedicated water-related focuses of wider disciplines are becoming explicit fields, such as hydroinformatics (Abbott 1999), hydro-politics, hydro-diplomacy, and hydro-psychology (Sivakumar 2011, 2014; Asah 2015; Eliason 2015). Some converging (sub)disciplines are now being identified such as hydrometeorology and hydroclimatology (Peck 1978; Bengtsson 2013; Wilson *et al.* 2013), hydro-pedology (Lin 2003), biohydrology (Hallett *et al.* 2010), ecohydrology (Smettem 2008; Porporato & Rodriguez-Iturbe 2013), and ecohydraulics (Blanckaert *et al.* 2013) for a more comprehensive naturalism. And actually some holistic frames to address the nature–society interactions are being proposed, especially socio-hydrology (Sivapalan *et al.* 2012), renovated hydrological engineering (Koutsoyiannis 2014; Snelder *et al.* 2014) and knowledge dissemination (Koutsoyiannis & Kundzewicz 2007; Cudennec & Hubert 2008; Blöschl *et al.* 2014; Hughes *et al.* 2014).

Similarly to hydrogeology, hydrogeomorphology is an old inter-discipline whose history goes back to the late 1800s and has provided seminal papers with strong relevance for both hydrology and geomorphology (see Kirkby (2011) and Wohl (2014) for epistemic retrospectives), which

remains explicitly actual and active (Sidle & Onda 2004), and which is still very promising.

Many aspects make hydrogeomorphology very rich in itself, several of them being addressed in this issue. Indeed, it is an inter-discipline studying complex interfaces, which refer to structure–function relationships, coevolutions, and multi-scale coupling and nesting. It is also a science, which faces strong challenges of identifying genericity and generalizing knowledge from a wide variability of specific settings.

The latter is obviously made necessary by the large hydro-geomorpho-climatic variability of the world, which requests comparisons, typologies, similarity approaches (Chalov & Alexeevsky 2015; Fraedrich 2015; Rajendra Prasad *et al.* 2015), then synoptic views (Cudennec *et al.* 2007), and ultimately syntheses toward improved understanding and predictions in data-scarce or -heterogeneous contexts (Blöschl *et al.* 2013; de Lavenne *et al.* 2015; Hannaford *et al.* 2013; Hrachowitz *et al.* 2013).

It is also made necessary by the avenue to explore and increasingly understand structure–function relationships to: (i) better value geographic observable features in the assessment of functional processes (Chalov & Alexeevsky 2015; de Lavenne *et al.* 2015; Tananaev 2015); (ii) hierarchize and better understand strong feedbacks from functional processes on geographic structural features – often at longer cumulative time scales or through intense and rare events – (Fraedrich 2015; Steudel *et al.* 2015); and (iii) assess the relative influence of anthropogenic drivers and artifacts, compared to natural ones, in actual hydrogeomorphology (Sivapalan *et al.* 2012; Montanari *et al.* 2013; Bao *et al.* 2015; Rapinel *et al.* 2015; Steudel *et al.* 2015). Further, many extraterrestrial studies do deduce functional planetary histories from morphological observations and extrapolation or analogy of the Earth hydrogeomorphology (Baker 2006; Burr *et al.* 2013).

It is of utmost interest in order to better assess the way how natural and anthropogenic compartments (such as land units as erosion sources – Rosen & Xu 2015; Rajendra Prasad *et al.* 2015; Tananaev 2015; terraced hillslopes or lacustrine banks – Steudel *et al.* 2015; Bao *et al.* 2015; or rivers and lakes as functional geometries – Chalov & Alexeevsky 2015, Fraedrich 2015; Rapinel *et al.* 2015) are articulated in parallel, sequence and cascade, through

complex interfaces, scaling nets, anisotropies and convergences, and hysteresis effects, to better understand and quantify the overall picture and dominant dynamics which emerge from the hydrogeomorphological organized complexity (Blöschl & Sivapalan 1995; Rodriguez-Iturbe & Rinaldo 1997; Cudennec *et al.* 2004; Blöschl *et al.* 2013; Porporato & Rodriguez-Iturbe 2013; Singh *et al.* 2014).

Finally, this genericity seeking of the hydrogeomorphological inter-science from the worldwide hydrogeomorpho-climatic variability, of the structure–function relationships, and of emerging dynamics from the complexity of organized compartments has now to be put in an explicit temporal perspective. This perspective is multiple. The long-term perspective is needed to address the corresponding processes and structural evolutions. Long-term retrospectives are needed in this regard, including palaeo-studies (MacDonald & Herget 2013; Szafraniec 2013; Baker 2014), to understand hydrogeomorphological trajectories, to assess the influence of extreme events, and to decipher the influences of natural and anthropogenic drivers. The shorter-term analyses, from the event to the interannual scales, either in chronological, frequency, or spectral dimensions, are also needed to understand the corresponding dynamics, contingencies, non-linearities, and hazards, and to identify changes from variability. This strengthens approaches to explore and predict prospective dynamics, either through more explicit and geomorphology-based scenarios or through more comprehensive interdisciplinary approaches. Such explicit hydrogeomorphological approaches are very promising in order to reinforce the socio-hydrological understanding and stewardship of actual changes (Sivapalan *et al.* 2012; Koutsoyiannis 2013; Montanari *et al.* 2013; Jimenez *et al.* 2014; Savenije *et al.* 2014) as many ecological and human geographic dynamics are actually driven by relations to water and/or geomorphology (Porporato & Rodriguez-Iturbe 2013; Savenije *et al.* 2014; Manfreda *et al.* 2014; Viglione *et al.* 2014). This is now widely acknowledged, all the more thanks to new high-resolution observation techniques (Tarolli 2014; Rapinel *et al.* 2015), from local controls on elementary hydrogeomorphological compartments (Wohl 2014) such as hillslope terracing and best management practices (Nasri *et al.* 2004; Chen *et al.* 2014; Steudel *et al.* 2015), wetland conservation and engineering (Krause *et al.* 2011; Blanckaert *et al.* 2013; Rapinel *et al.*

2015), or (peri-)urban green design, to huge dams and water-related infrastructures setting up and management (Bao *et al.* 2015). And it leads to strongly tangible emerging hydrogeomorphological effects at upper levels, up to the continental and global ones, in the frame of the Anthropocene (Meybeck 2003; Rockström & Karlberg 2010; Steffen *et al.* 2011; Syvitski & Kettner 2011; Wilson *et al.* 2013). Yet, it conversely opens new (blue-)green integrated approaches to increase territorial resilience toward stronger water security.

Hydrogeomorphology is thus a long-term scientific interface as an old inter-discipline, which on the one hand deals with multi-temporal scale dynamics, trajectories, and changes; and on the other hand offers a strong background for long-term retrospective and prospective analyses. The corresponding strong interdisciplinary corpus and experience are also highly valuable to many emerging environmental inter-disciplines to address the related bridging epistemic challenges. The importance of hydrogeomorphological objects, dynamics, heritages, and perceptions – which universally underlie many human and ecosystemic land- and water-related dynamics and rationales – finally puts hydrogeomorphological science in a strong interface with societal challenges.

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