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Editorial

Scientific debate of Panta Rhei research – how to advance our knowledge of changes in hydrology and society?

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The Scientific Decade 2013–2022 of the International Association of Hydrological Sciences (IAHS) “Panta Rhei—Everything Flows” is dedicated to increasing our knowledge of interactions and feedbacks between hydrology and society. Research is focused on processes and drivers of change in the water cycle with a strong consideration of the interactions with the changing human system. The general objective is to improve our descriptions and predictions of water resources dynamics to support sustainable societal development under global change conditions (Montanari *et al.* 2013, McMillan *et al.* 2016).

With this issue of the Hydrological Sciences Journal we start the Panta Rhei opinion paper series. The purpose of the series is to enrich and improve the Panta Rhei approach via diverse, critical and constructive opinions from different disciplines, “schools”, and experiences. For this, we have identified key questions and debatable topics, which will be covered by invited opinion papers over the course of the next two years. Besides the two papers published in this issue, it is anticipated that two Panta Rhei opinion papers will be published in the next few volumes of Hydrological Sciences Journal at roughly four to six months intervals. The opinion papers are identifiable via the Panta Rhei logo and the sub-heading 'Opinion paper' on the front page and will be electronically linked to the online collection of Panta Rhei opinion papers. Additionally, we want to motivate a scientific discussion in response to the contributions and topics presented.

The Panta Rhei approach

Panta Rhei is driven by an active research community of currently about 400 researchers within 31 diverse working groups. The core of the working group activities is network building and exchange of scientific ideas and results, possibly fostering integration and synergies between different philosophies, approaches and methodologies (Mount *et al.* 2016). More and more, the working groups are also used for sharing data and models, such as in “virtual laboratories” (Ceola *et al.* 2015). Working

groups have initialised common research projects (either with or without external funding) and are organising workshops (mentioned as a successful community approach by Thompson *et al.* 2011), conferences, sessions and special issues in scientific journals. Panta Rhei also encourages active exchange and collaboration between working groups. Among the initiatives currently under way is a web-based, interactive world map showing information on: (i) people associated with Panta Rhei, and (ii) Panta Rhei case studies of change in hydrology and society. Additionally, a Panta Rhei day is organised every year, providing an opportunity for Panta Rhei colleagues to meet and discuss. This has resulted in working groups actively working together, for example on hydrological extremes, which is covered by working groups focussing on either floods or droughts. Panta Rhei is an open community that welcomes scientists in the field of hydrology and the broader interdisciplinary community to join a working group or to start a new working group.

Achievements of the working groups during the first Panta Rhei biennium 2013–2015 are summarised and discussed by McMillan *et al.* (2016). Among the identified challenges are understanding and predicting coupled human-water systems and their changes, and supporting society at large as well as specific communities in policy and decision making towards sustainable development. These challenges are exacerbated by uncertainties in data and knowledge, which are partly associated with the difficulty of generalizing results from case studies (Ostrom 2007). We contend that we can only tackle these challenges with research that is interdisciplinary, both within hydrology and beyond, that mixes quantitative and qualitative methods, and that is transdisciplinary in its inclusion of water resources practitioners, policy makers and the public.

Hydrology has always been an interdisciplinary science, with roots in physical geography, geoscience and engineering. Hydrologists frequently collaborate with biogeochemists, ecologists, economists and political scientists, among others, and this is evident in Panta Rhei (McMillan *et al.* 2016) – perhaps increasingly so. Hydrologists have embraced that the hydrological cycle borders and links multiple other natural science domains and they often strive to integrate these in collaboration with experts from the respective domains for a more complete understanding of hydrological processes. Hydrology is also frequently an applied science; many hydrologists are used to working with water resources practitioners, industry and at the interface with policy. For example, efficient and sustainable risk management of hydrological extremes requires continuous and integrated cost assessment (Kreibich *et al.* 2014), which is best undertaken jointly by natural scientists, engineers, economists, social scientists and risk management practitioners. Urban water sustainability is another example with growing importance (Hering *et al.* 2013). Solving key problems related to water scarcity needs to engage urban ecologists, geoscientists, engineers from diverse disciplines, stakeholders from public and private organizations, urban planners, public health researchers and urban economists, among others (Paterson *et al.* 2015). Yet another example of interdisciplinary research efforts is the water-energy-food nexus (Conway *et al.* 2015).

Whether interdisciplinarity is able to achieve a more comprehensive understanding of human-water systems and an improved water management depends on how well the philosophical and methodological differences of the disciplines as well as their data and language disparities can be accommodated (Krueger *et al.* 2016). Most of the aforementioned disciplines are philosophically close in that they share the goal of generalizing from observed phenomena, often via models and certainly quantitatively. In contrast, hydrologists have collaborated much less with the often qualitative social sciences, such as human geography, anthropology and sociology – but such collaborations are at least envisaged to increase in Panta Rhei (McMillan *et al.* 2016). The summary paper of the first Panta Rhei biennium (McMillan *et al.* 2016) already showcases different philosophical positions side by side. We find different views on the positionality of the researcher; the researcher as a neutral observer, as an inseparable component of the system under study, and as an active agent of change. We find

contrasting views on predictability and the fundamental nature of uncertainty; some sections problematize the limits of hydrological predictability, before people are even considered, while others are optimistic about predicting coupled social-hydrological systems. Even researchers that are philosophically close may differ methodologically, which is again evident from the first biennium paper. For instance, the scales of analysis, in space and in time, are very different, ranging from global coupled models to local field experiments, and may not easily be integrated. This relates to the setting of system boundaries, with some focusing on hydrology, others on eco-hydrology or on socio-hydrology. These differences beg the question of quality standards: How well do we need to test a model? What are reliable data? McMillan *et al.* (2016) showcase different valuations of quantitative versus qualitative data and different valuations of stakeholder or citizen science data, and we should expect more of these issues to come up when trying to integrate different research strands. Underlying all interdisciplinary efforts is the issue of language. For instance, McMillan *et al.* (2016) pinpoint two different uses of the phrase ‘water and energy’; in terms of drivers of the physical system and in terms of the related footprints of water and energy.

How should *Panta Rhei* accommodate these philosophical, methodological, data and language differences that are only just beginning to emerge? The literature on interdisciplinarity in a water research context recommends: familiarization with the literature of the respective other discipline (Baveye 2013), articulation of terminology and development of shared language (Bracken and Oughton 2006) and elaboration of common research quality criteria (Connelly and Anderson 2007). All this will require time, continuity and trust on the basis of respectful contestation of research positions (Krueger *et al.* 2016). The *Panta Rhei* opinion paper series seeks to provide the space for such a productive clash of perspectives.

The *Panta Rhei* opinion paper series

In this issue of the *Hydrological Sciences Journal*, we start the *Panta Rhei* opinion paper series with two contributions, namely “Prediction in a socio-hydrological world” by Veena Srinivasan *et al.* (2016) and “The role of experimental work in hydrological science – insights from a community survey” by Theresa Blume *et al.* (2016). We initiated this opinion paper series to chart how the scientific community has been framing research under *Panta Rhei* as well as the specific scientific challenges that *Panta Rhei* has brought, e.g. the challenge of inter- and transdisciplinarity, the challenge of characterising a system under change. We hope to enrich and improve the *Panta Rhei* approach via diverse, critical and constructive opinions. We therefore invite discussions and further opinions in response to the contributions and topics presented in the opinion paper series.

Since each of the many disciplines working on hydrology and society has its own philosophy, methodology, data and terminology, we expect and indeed hope that the opinion papers will motivate lively debates and contradictory opinions. Because the *Panta Rhei* topics extend beyond the existing expertise of hydrologists, there is much to be gained from exchanging ideas and opinions with an interdisciplinary community as a precursor for productive collaboration. We want to use the *Panta Rhei* opinion paper series to further elaborate and discuss the above mentioned contradictions and emerging debates and develop with time new interdisciplinary cooperation and lines of research.

We have identified key questions and debatable topics, which will be covered by invited opinion papers over the course of the next two years. Besides the two papers published in this issue, the following topics will be discussed in due course: water-energy-food nexus; societal consensus about flood risk management strategies; attribution of change in hazard and risk of hydrological extremes; integrated

hydrology joining different systems, e.g. mountain, rural and urban areas; inter- and transdisciplinary research on floods and water availability; etc.

We sincerely hope for your engagement in this scientific debate by formal scientific discussion. Please contribute your ideas or critique on the accepted opinion papers by writing and submitting your commentary within six months from their online publication. Commentaries may be discussions, comments on the opinion papers or further opinions on the addressed topic. Once the commentary is deemed suitable for publication, the authors of the original opinion paper will be invited to submit a 'Reply to commentary' so that the two (or more) contributions to the formal scientific discussion can be published together in a later issue of the Hydrological Sciences Journal. These contributions will be electronically linked to the collection of Panta Rhei opinion papers for future reference.

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