

Panta Rhei: an evolving scientific decade with a focus on water systems

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Abstract The paper presents an overview of the activity of Panta Rhei, the research decade launched in 2013 by the International Association of Hydrological Sciences. After one year of activity Panta Rhei has already stimulated several initiatives and a worldwide involvement of researchers in hydrology and sister disciplines. Providing an overview of the status of Panta Rhei is essential to further promote the participation of scientists and the completion of its structure, which is currently being shaped by receiving Research Theme and Working Group proposals from the community.

Key words Panta Rhei; hydrology; society; change

INTRODUCTION

Panta Rhei, the new scientific initiative of the International Association of Hydrological Sciences (IAHS) for the decade 2013–2022, was launched in Gothenburg, Sweden, in July 2013, during the IAHS General Assembly (Montanari *et al.* 2013). Since then, the governance of Panta Rhei has been defined by nominating the Target Leaders, and a scientific session at the Fall Meeting of the American Geophysical Union officially started the scientific activity.

Panta Rhei is a grassroots, bottom-up research endeavour and therefore IAHS decided to stimulate the scientific community to take the lead in defining its structure. An open call for the definition of Research Themes (RTs), to address the Panta Rhei Science Questions, and for the creation of the first Working Groups (WGs) was issued in November 2013. Open and bottom-up research initiatives are exciting opportunities for researchers, but effective involvement of the community is needed to make them fully operational and inclusive. Panta Rhei met this challenge as the first call for RTs and WGs was a success. A total of 22 WG and 11 RT proposals were received by IAHS, involving nearly 250 scientists from several countries. This first and positive result is a confirmation of the popularity of IAHS and its scientific decades, which effectively promote the involvement of young scientists and stimulate educational and research initiatives in hydrology. This paper presents a preliminary summary of the activity of Panta Rhei, and also highlights its first research results.

HYDROLOGY, CHANGE AND SOCIETY – A RESEARCH CHALLENGE

The interaction among hydrological systems, change and society has been recently studied by an increasing number of contributions stimulated by several initiatives and developments, including Panta Rhei. In particular, Panta Rhei is committed to broadening the focus of hydrological change by including climate modelling, which often is the main research goal of papers dealing with change and the connections between hydrology and society (see, for instance, recent papers by AghaKouchak and Mehran 2013, Carey *et al.* 2013, Crosbie *et al.* 2013, Ficklin *et al.* 2013, Hagemann *et al.* 2013, Henley *et al.* 2013, Konar *et al.* 2013, Mengistu *et al.* 2013, Miller *et al.* 2013, Moody and Brown, 2013, Mutibwa and Irmak, 2013, Null and Viers, 2013, Teegavarapu, 2013). A relevant stimulus to such a way forward was also the introduction of the concept of socio-hydrology (Sivapalan *et al.* 2012, Lane 2014), which is based on the recognition that hydrology co-evolves with society as a result of the human impact on hydrological dynamics. While classical hydrology traditionally focused on pristine catchments to gain deep understanding of water cycle features and relationships, socio-hydrology aims to achieve an improved comprehension of the impacts of anthropogenic development on the environment (see, for instance, Brath *et al.* 2002, 2006) and water systems in particular.

Socio-hydrology was the subject of numerous recent contributions. A special issue on “Predictions under change: water, earth, and biota in the Anthropocene”, edited by M. Sivapalan, T. J. Troy, V. Srinivasan, A. Kleidon, D. Gerten and A. Montanari, is being produced by *Hydrology and Earth System Sciences*, and already has more than 30 accepted papers. Among them, some articles explicitly recognize the contribution, in terms of ideas, of Panta Rhei (e.g. Thompson *et al.* 2013, Gupta *et al.* 2014, Savenije *et al.* 2014). Additional recent contributions focusing on the interaction between hydrology and society include Awange *et al.* (2013), Brown *et al.* (2013), Devineni *et al.* (2013), Nazemi *et al.* (2013), Paton *et al.* (2013) and Patterson *et al.* (2013).

Moreover, the concept of environmental change was discussed in several recent papers (see, for instance, Gebrehiwot *et al.* 2013, Koutsoyiannis 2013, Liu *et al.* 2013, Rootzén and Katz 2013, Steinschneider *et al.* 2013, Mejia *et al.* 2014). Some contributions have already presented attempts to provide socio-hydrological models (Di Baldassarre *et al.* 2013, Konar and Caylor 2013, O’Bannon *et al.* 2014, O’Connell and O’Donnell 2014, Viglione *et al.* 2014), that allow the derivation of meaningful projections of possible future environmental and societal developments.

Coupling the dynamics of hydrology and human development inevitably implies an increased complexity of models with involvement of a large number of parameters that are difficult to calibrate. The challenge for future research is to reach a compromise between the complexity of models and their applicability. This purpose has been explicitly recognized by Panta Rhei which elected “Science in practice” as one of its targets. Indeed, socio-hydrological models need to be developed with a pragmatic and interdisciplinary approach, by recognizing that the presence of uncertainty is unavoidable and therefore limits predicting capabilities. Increasing unknowns in models imply an increased complexity and a decreasing predictive ability (Fig. 1). However, achieving a better understanding of the functioning of hydrological processes under human impact, with the aid of new monitoring technologies and information, is planned. Gaining such improved insights is the real challenge for Panta Rhei, therefore providing a real practical benefit for planning adaptation measures to environmental change.

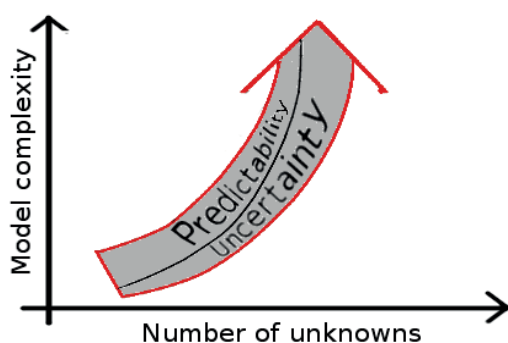


Fig. 1 Trade-off between model complexity, uncertainty and predictive capabilities.

PANTA RHEI – ACTIVITIES DURING THE FIRST YEAR

Panta Rhei was officially launched in July 2013 and the first months of work demonstrated its popularity throughout the hydrological community, clearly highlighting the effectiveness of IAHS research initiatives. Whereas, on the one hand, Panta Rhei is profiting from the success of the previous IAHS scientific decade on “Prediction in ungauged basins” (Sivapalan *et al.* 2003, Bloeschl *et al.* 2013, Hracowitz *et al.* 2013), on the other hand, it is clear that the worldwide consultation coordinated by IAHS to set up Panta Rhei was successful in identifying a unifying theme for the entire hydrological community (Montanari *et al.* 2013).

Research Themes and Working Groups

In November 2013 the Panta Rhei governance issued a call for Research Themes (RTs) and Working Groups (WGs). IAHS agreed to adopt a bottom-up philosophy to shape the structure of Panta Rhei and therefore the community was involved in the identification of the key research issues, thus

stimulating the active participation of scientists from all over the world. The call for RTs and WGs will be permanently open during the first biennium of Panta Rhei but an interim deadline of 31 January 2014 was set for stimulating the submission of start-up proposals. To date, 11 RT (see Table 1) and 22 WG (see Table 2) proposals have been received.

Table 1 Research Themes proposed by the community for Panta Rhei (up to March 10, 2014).

Research theme	Proposer
Transdisciplinarity	Tobias Krueger
Mountain hydrology	Shreedhar Maskey
Large-scale water projects and society	Bellie Sivakumar
Physics of changes	Alexander Gelfan
Water footprint assessment	Saket Pande
Water and energy fluxes in a changing environment	Maria J. Polo
Epistemic uncertainties	Paul Smith
Hydro-meteorological extremes: Decision making in an uncertain environment	Adrián Pedrozo Acuña
Global change in hydrology and society	Jos Timmermans
Reservoirs' impact	Aleksandr Tskhai

Table 2 Working Groups proposed by the community for Panta Rhei (up to 10 March 2014).

Working Group	Chair
Hydro-meteorological extremes: Decision making in an uncertain environment	Adrián Pedrozo Acuña
Large dams, society, and environment	Bellie Sivakumar
Thirsty future: energy and food impacts on water	Ana Mijic
Changing biogeochemistry of aquatic systems in the Anthropocene	Hong
Transdisciplinarity	Tobias Krueger
Natural and man-made control systems in water resources	Ronald van Nooijen
Water and energy fluxes in a changing environment	Maria J. Polo
Epistemic uncertainties	Paul Smith
Comparative water footprint studies	Arjen Y. Hoekstra
Hydrologic services and hazards in multiple ungauged basins	Hilary McMillan
Understanding flood changes	Alberto Viglione
Physics of hydrological predictability	Alexander Gelfan
Mountain hydrology	Shreedhar Maskey
Large sample hydrology	Vazkén Andreassian
Socio-hydrologic modelling and synthesis	Veena Srinivasan
Sustainable water supply in urban change	Tatiana Bibikova
Water footprint of cities	Alfonso Mejia
Evolving urban water systems	Alfonso Mejia
Changes in flood risk	Heidi Kreibich
Anthropogenic and climatic controls on water availability (ACCuRAcY)	Attilio Castellarin
Floods in historical cities	Alberto Montanari
Prediction under change (PUC)	Hafzullah Aksoy

The WG includes about 250 scientists from several different countries. Out of the entire list of WGs, five specifically focus on water systems. This is a promising picture for promoting the assessment, modelling and prediction of the status of water supply, irrigation and drainage systems in a changing environment.

As previously mentioned, the call for RTs and WGs is permanently open during the first biennium of Panta Rhei. Instructions to submit proposals are provided at www.iahs.info/pantarhei. Scientists who are interested in affiliating to Panta Rhei may also consider the option of joining existing WGs. The WGs are open and researchers are invited to refer to the related WG chair.

Scientific symposia

A scientific session entitled “Hydrological change and water systems: feedbacks, prediction, and experimental management” was proposed under the auspices of *Panta Rhei* and held at the 2013 Fall Meeting of the American Geophysical Union (AGU). The session was convened by N. Basu (University of Waterloo, Canada), A. Montanari (University of Bologna, Italy), M.C. Bruno (Mach Foundation, Italy) and T. Melis (USGS, USA). Fifty-four oral and poster contributions were presented, evidence of a positive outcome. Six invited presentations were delivered by N. van de Giesen (Technical University Delft, Netherlands), C.T. Robinson (EAWAG, Switzerland), C.P. Konrad (USGS, USA), I. Creed (Western University, Canada), C. Lane (US EPA Office of Research and Development, Cincinnati, Ohio, USA), A. Viglione (Technical University Wien, Austria) and U. Lall (Columbia University, USA) on the three main themes of “Reservoir operation and control”, “Peatland and wetlands” and “Socio-hydrology and change”.

Three symposia dedicated to *Panta Rhei* were convened at the 2014 General Assembly of the European Geosciences Union (EGU). The first was a visionary session titled “*Panta Rhei*: a vision and an agenda for the next 10 years of hydrological research in support of society”, convened by G.H. de Rooij (Helmholtz Centre for Environmental Research – UFZ, Germany) and A. Montanari (University of Bologna, Italy). This session hosted the talks of six invited speakers: H. Savenjie (Technical University Delft, Netherlands), D. Koutsoyiannis (National Technical University of Athens, Greece), U. Lall (Columbia University, USA), B. Arheimer (SMHI, Sweden), E. Fofoula-Georgiou (Indiana University, USA) and S. Tamea (Politecnico di Torino, Italy). EGU 2014 also hosted the sessions “Stakeholders, public involvement and collaborative processes in hydrology research and water management”, convened by T. Krueger (University of East Anglia, UK) and G. Carr (Technical University Wien, Austria), and “Change in climate, hydrology and society”, convened by D. Koutsoyiannis (National Technical University of Athens, Greece), J. de Lima (University of Coimbra, Portugal), H. Lins (USGS, USA), X.L. Wang (Environment Canada, Canada), M. Mudelsee (Climate Risk Analysis, Germany), C. Cudennec (INRA, France) and C. Maftai (Ovidius University, Romania).

Finally, the conference “Evolving Water Resources Systems – Understanding, Predicting and Managing Water–Society Interactions”, held in Bologna (Italy) during 4–6 June 2014, is organized within the framework of *Panta Rhei*. A community paper will be produced after the conference to provide a vision for the future of water resources systems.

Promoting cooperation and visibility of scientific initiatives and publishing

One of the main missions of *Panta Rhei* is to promote the visibility of hydrological research and publishing. To this end, the *Panta Rhei* website (www.iahs.info/pantarhei) reports in the main page any *Panta Rhei* initiative. Researchers are invited to use the contact page of the website if they wish to communicate any related news.

Visibility of scientific publications will be achieved by hosting on the *Panta Rhei* website two lists of papers that are relevant to the subject of change in hydrology and society. One list will include papers that explicitly acknowledge *Panta Rhei* (the website provides instructions to this end) while a second list will include papers that are relevant to the *Panta Rhei* activity. Papers are included in the above lists on request of the authors, who are invited to use the contact page of the website to highlight their contributions. The community is invited to refer to the above lists of papers when working on *Panta Rhei*; they are meant to provide a coherent information source and to support the development of future research activities.

THE NEAR FUTURE OF PANTA RHEI

The activity of *Panta Rhei* will move forward in the first biennium with the objective of completing the structure of the RTs and WGs, while promoting educational and scientific initiatives. The latter will include scientific session at conferences, workshops and dedicated short courses. The most challenging commitments of *Panta Rhei* are those related to encouraging visibility and

