IAHS 2022

XIth SCIENTIFIC ASSEMBLY

29 May to 3 June 2022 - Montpellier (France)

Scientific programme

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The scientific programme of the assembly has been shaped by IAHS and its commissions and working groups, and the Montpellier Local Organizing Committee has been mobilized for some specific sessions. IAHS' partners within the UN System will join as co-conveners of some of the sessions. Specific workshops will be further proposed.

S1. Unsolved Problems in Hydrology: Overarching session

Convener: Günter Blöschl
Co-Conveners: Berit Arheimer, Christophe Cudennec

Unsolved Problems in Hydrology have been identified through a community consultation and prioritization process, and formalised by Blöschl *et al.*, 2019. *Twenty-three Unsolved Problems in Hydrology (UPH) – a community perspective.* Hydrological Sciences Journal, 64, 10, 1141-1158, https://doi.org/10.1080/02626667.2019.1620507. Several thematic sessions of the 2022 Assembly will articulate with some of these UPHs. This overarching session will welcome communications about the overall epistemic challenges and progress.

S2. Floods: Processes, Forecasts, Probabilities, Impact Assessments and Management

Convener: Svenja Fischer
Co-Conveners: Andreas Schumann, Günter Blöschl, Elena Volpi, Chris White, Alberto Viglione, Marcelo Uriburu

One main aspect of the direct socio-economic relevance of hydrology consists in its ability to predict or to forecast extreme flood events. Prediction refers here to the assessment of the probability of a value related to the flood (e.g., the maximum peak discharge during one event) to be exceeded, without specifying the time of occurrence. Forecast refers instead to a statement of the future development of a variable related to the flood with a specification of the time of occurrence. With regard to their impacts, floods play a very important role for the society in general and human beings living in flood prone areas in particular. Because of missing information and a short memory of harmful events in the past, the public awareness of floods is often insufficient and flood prevention and protection are insufficient in many parts of the world. Existing tools and methods for flood prediction and forecast may be outdated, as new problems have to be considered, e.g. such as:

- increased uncertainties, caused by climate change and human impacts;
- first indicators for changing flood regimes, caused by climate variabilities;
- relevance of interlinks between atmosphere and river basins in the formation of extreme floods;
- risks as a result of the concentration of people and goods in river valleys;
- demand for more reliable hydrological data for flood design;
- complexity of flood protection at the river basin scale, where one human intervention may affect the impacts of existing or planned measures in not foreseeable ways several others, and so on.

It is explicitly encouraged to link to the Unsolved Problems in Hydrology (UPH) Initiative (https://iahs.info/IAHS-UPH.do), which includes (but is not exclusive)

1. Is the hydrological cycle regionally accelerating/decelerating under climate and environmental change, and are there tipping points (irreversible changes)?
9. How do flood-rich and drought-rich periods arise, are they changing, and if so why?
10. Why are runoff extremes in some catchments more sensitive to land-use/cover and geomorphic change than in others?
11. Why, how and when do rain-on-snow events produce exceptional runoff?
19. How can hydrological models be adapted to be able to extrapolate changing conditions, including changing vegetation dynamics?
20. How can we disentangle and reduce model structural/parameter/input uncertainty in hydrological prediction?
The large variety of flood problems demand collaborative actions of experts from different branches of hydrology. Therefore, this call covers many aspects related to floods, including processes of flood generation, the assessments of flood probabilities, regionalization issues, flood forecasting and the need for impact forecasts and other economic aspects of risk management.

S3. Change in extreme droughts in the future

Convener: Gil Mahé
Co-Conveners: David Hannah, Yonca Cavus, Ebru Eris, Mohamed Meddi

Drought is an extreme which has always drawn attention of the hydrological science community. It has been so more these days as too little water is not an avoidable case anymore with the change in hydrology, which can be either natural or because of human activities. Regardless of the nature of the change, we now face more frequent and more severe droughts for which actions are needed to be taken in advance for the sustainability of water-dependent sectors; irrigation, energy, industry, tourism, ecology, etc. Consequently, the economy is affected by the drought. An awareness is clearly needed to cope with the consequences of drought, and to be able to anticipate major drought spells. For this aim, people could be encouraged to include the concepts of water scarcity, water conservation and drought prevention in their everyday life. Also, it is expected that these concepts are considered in water resources management and planning. Legislative background is needed for the future water scarcity and drought management. Innovative and novel tools, methods and techniques are expected for the future to understand the drought process, make research and practice. They are also needed for promoting water savings, using alternative resources, encouraging the use of renewable sources; and discussing the environmental, economic and social impacts of water scarcity and drought. Studies touching upon all above concepts and issues are welcome to this session. Particularly welcome are studies showing experiences of how research directions can be driven from users and professional needs and requirements.

S4. Water resource management in a changing world: economic, environmental and societal trade-offs and synergies

Convener: Barry Croke
Co-Conveners: Jennifer Adam, Jean-Marie Kileshye Onema, Suxia Liu, Marloes Mul, Hwirin Kim, Elpida Kolokytha, Charalampos Skoulikaris

The aim of this symposium is to bring together experts from different countries to advance water resource management across the globe, particularly in light of changes affecting water resources. This includes the impacts of climate change, population growth, land use/cover change, changing social perceptions and interests, as well as changes in the policy setting. This will consider both water quantity and quality, and focus on the hydrological aspects, as well as the connections between hydrology and other disciplines (e.g. ecology, agronomy, social science, policy research).

The conference will focus on a range of water resource management methodologies and issues, including:

1. Integrated Water Resource Management: best practices in planning and management
2. Adapting of water resources systems by balancing economic, social and environmental needs and desires (UPH22):

- managing environmental flows to maintain the ecological worth of rivers and receiving bodies (e.g. lakes, wetlands, estuaries, reefs;
- impact assessments of water resources management on public health (incl COVID-19);
- new approaches to assess and control the spatio-temporal distribution of water resources, including advanced sensors and data-driven systems;
- decision making to ensure improved water resource allocation, taking into consideration the breadth of potential users in terms of equity, economy and ecology.

3. Risk-based management of water resources: droughts and the handling of uncertainties in demand and supply model outputs.

Especially invited are contributions with topics related to the "Unsolved Problems in Hydrology" Initiative. Particular questions of interest are here question 22: "What are the synergies and tradeoffs between societal goals related to water management (e.g. water-environment-energy-food-health)?" and question 23: "What is the role of water in migration, urbanisation and the dynamics of human civilisations, and what are the implications for contemporary water management?" During the symposium, a session will be held to specify potential sub-questions of UPH 22 and 23.

Other UPH questions are relevant too, and the authors are encouraged to present their view from the water management perspective:

- UPH 1. Is the hydrological cycle regionally accelerating/decelerating under climate and environmental change, and are there tipping points (irreversible changes)?
- UPH 3. What are the mechanisms by which climate change and water use alter ephemeral rivers and groundwater in (semi-) arid regions?
- UPH 4. What are the impacts of land cover change and soil disturbances on water and energy fluxes at the land surface, and on the resulting groundwater recharge?
- UPH 9. How do flood-rich and drought-rich periods arise, are they changing, and if so why?
- UPH 10. Why are runoff extremes in some catchments more sensitive to land-use/cover and geomorphic change than in others?
- UPH 18. How can we extract information from available data on human and water systems in order to inform the building process of socio-hydrological models and conceptualisations?

S5. A Synthesis of Change in Hydrology and Society: Coevolution and prediction of coupled human-water systems

Convener: Fuqiang Tian
Co-Conveners: Giuliano Di Baldassarre, Heidi Kreibich, Jing Wei

As 2nd decadal initiative of IAHS "Panta Rhei - Everything Flows" aims to achieve an improved understanding of water cycle processes by focusing on their changing dynamics in respect of interactions and feedbacks with human systems. Approaching the end of this Panta Rhei decade (2013-2022), it is time to synthesize the achievements of this decade. The main focus of this grand

synthesis, which will be published in an IAHS book, is on coevolution and prediction of coupled human-water systems, including understanding of emergent phenomena, mechanisms, and implications for predictions and practices. This session welcomes contributions that contribute to and critically reflect the following synthesis topics: 1) Theoretical/conceptual framework for understanding changes in hydrology and society; 2) Coevolution and emergent phenomena; 3) dynamic models; 4) Data needs and acquisition; 5)Benchmark datasets in various context and scales, including human-flood, human-drought, agricultural, transboundary and global systems; 6) Case studies from Panta Rhei working groups, IAHS Commissions and beyond.

S6. Understanding the human footprint on the hydrological cycle/processes in a changing world

Convener: David Hannah
Co-Conveners: Gil Mahé, Honeyeh Iravani, Guillaume Thirel, Anil Mishra

Human impacts on the water cycle are ever increasing. Some of our actions affect purposefully water stores and fluxes, while other human activities have unintended impacts on catchment. In the Anthropocene, humans have reshaped the water cycle and altered hydrological processes in three connected ways: (1) every agricultural, industrial, and domestic activity uses water directly and indirectly, (2) humans have directly modified 77% of the Earth's land surface, excluding Antarctica, through activities such as agriculture, deforestation, and wetland destruction, and (3) climate change is altering nearly every water store and flux (shrinking glaciers, permafrost melting, depleted groundwater, precipitation timing and intensity, drought, flooding, evapotranspiration etc.). These human modifications are creating a 'water crisis' not only by modifying water quantity (i.e. availability) dynamics but also water quality (i.e. pollution). In response to this crisis, we call on researchers to more explicitly conceptualise, quantify and understand the human footprint on the hydrological cycle/ processes, and implications for the sustainable management of freshwaters. In addition, nine years after the 'Testing simulation and forecasting models in non-stationary conditions' workshop at the 2013 IAHS general assembly, we urge researchers to present their most recent advances on preparing hydrological models to face a changing future. Recent advances on model robustness, associated testing, multi-modelling, understanding and reducing uncertainties are welcome. All spatial and temporal scales are concerned, as well as highly modified to pristine catchment (engineered, urban, rural and near-natural).

S7. Grounded socio-hydrology

Convener: Olivier Barreteau,
Co-Conveners: Andrew Ogilvie, Margreet Zwarteveen

Socio-hydrology has made significant progress throughout during the Panta Rhei scientific decade. This provides a welcome opening of hydrological viewpoints to understand water flows, water uses and water management. However, most of these new approaches, despite their diversity, come from hydrology and seek to integrate information from other disciplines within their existing frameworks. Our proposition is to ground socio-hydrology in case-studies, gathering information related to water flows, uses and management, analysing interdependencies among them, and challenging outcomes of these analyses according to local stakeholders' knowledge. Several conceptual frameworks have recently emerged to facilitate a balanced analysis of these interdependencies and their consequences in socio-ecological systems. These point out the role of soft and hard infrastructures in these

interdependencies. The key point is that (1) there is no a priori pre-eminence of a category of processes to explain water flows, uses and management, and (2) existence of multiple interactions across disciplinary domains and investigation methods may generate unexpected feedback loops. This leads towards a revised understanding of several related cycles (water, information, norms…), all involving intertwined physical and social interventions on flows and transformations within these cycles.

S8. Hydrometeorological predictability on subseasonal to seasonal scale: Potential for hydrological decision making

Convener: Harald Kunstmann
Co-Conveners: Fuqiang Tian, Christopher White, Yuri Simonov

Increasing frequencies of droughts and hot extremes, as well as increasing precipitation variabilities worldwide, can trigger conflicts of water use. Proactive and sustainable water management is required, that can benefit from basing decisions on longer-range weather forecasts such as the subseasonal- to seasonal (S2S) timescale that aim to predict hydrometeorological development of events in the coming weeks and months. This ICCLAS-led session aims at consolidating the current state of opportunities for hydrological decision making on S2S predictability, particularly in reservoir operation for hydroelectric power generation, irrigation and water resources. We invite for both disciplinary and cross-disciplinary abstracts from climate, hydrology and engineering sciences. We ask particularly for contributions addressing 1) skill analyses of S2S predictions, 2) statistical postprocessing and skill improvement approaches, 3) community efforts to provide operational products, and 4) efforts bridging from science to practice. Interdisciplinary case studies for different climate regions worldwide are particularly encouraged.

S9. Stochastic Hydrology with contributions on methodologies and applications, for modeling, forecasting, change assessment, and uncertainty quantification

Convener: Elena Volpi
Co-Conveners: Simon Michael Papalexiou, Antonio Zarlenga, Marco Marani, Alberto Viglione

Stochastic hydrology offers efficient tools for characterizing processes in hydroclimatic systems, e.g., for hydrologic design, hydroclimatic systems modeling and forecasting, and water resources management. Theory and application of stochastic processes enables a faithful and consistent representation of natural processes that in many cases outperforms outcomes of physically based models. Stochastic modelling offers the means to mimic the variability of processes in space and time, and to characterize the inherent uncertainty in probabilistic terms. For example, this allows to simulate synthetic space-time fields reproducing the characteristics of the process – the main statistical properties across multiple spatial and temporal scales – for assessing the hydrological impact in a complex and changing environment.
This session calls for papers developing and discussing stochastics tools to systematically deal with uncertainty, constant or sudden change, and space-time variability, for characterization or simulation (including disaggregation) purposes of hydroclimatic variables such as precipitation, temperature, streamflow, or soil properties. Contributions are invited, for instance, on the improvement of stochastic modeling in hydrology, innovative techniques for identifying model structure, calibrating

parameters, assessing uncertainties, etc. (see also the Unsolved Problems in Hydrology UPHs 1-4 and 5-8 identified by Blöschl et al., 2019, which are related to time-variability and change and space-variability and scaling, respectively).

S10. Forecasting and making decisions under uncertainty: ensemble approaches, evaluation methods and lessons learnt from post-event analyses

Convener: Shaun Harrigan
Co-Conveners: James Bennett, Marie-Amélie Boucher, Celine Cattoën-Gilbert, Fernando Mainardi Fan, Ilias Pechlivanidis, Maria-Helena Ramos, Paolo Reggiani

Forecasting plays a key role in decision making. This may concern users dealing with both risk assessment of extremes (floods, droughts) and water resources management, and involves several scales in time (hours to weeks or months ahead) and space (global to local forecasts). A large number of operational applications may benefit from hydrological forecasting systems that include uncertainty quantification and issue reliable and accurate forecasts.
This session explores the interconnections between ensemble hydro-meteorological forecast techniques and decision making under uncertainty, with applications such as (but not limited to) communication of flood warning, drought risk assessment, reservoir control and operation planning, water use planning among multiple users, hydropower production, fluvial transportation, agricultural and food production management.
Contributions are particularly welcome on:

- understanding and quantifying sources of uncertainty and predictability for decision-making;
- real-time (or near real-time) approaches for ensemble data assimilation, NWP preprocessing, seamless forecasting, multi-model combinations, sub-selection of ensemble sets and hydrological post-processing;
- the challenges of effective communication of hydrometeorological forecasts and the visualisation of their uncertainty and skill;
- the challenges of transferring science into operational practices;
- improving the engagement of users in the definition and development of novel operational forecasts products and services;
- verification of ensemble forecasts, in particular methods tailored to decision makers.

The session is organized under the auspices of the HEPEX (www.hepex.org) initiative, which brings together a community of practice in hydrological ensemble predictions to foster scientific developments necessary to improve the skill of probabilistic hydrological predictions and their use in operational contexts.

S11. Extremes in hydroclimatic systems

Convener: Krzysztof Kochanek
Co-Conveners: Ilaria Prosdocimi, Salvatore Grimaldi, Ernest Amoussou, Alberto Viglione

The occurrence of extreme hydroclimatic events has a tremendous impact on society and environment. Hence, there is an urgency in understanding and modeling the extreme events , since they are still (despite rapid development of the methodology and techniques) not fully captured by space and time variability (see also the Unsolved Problems in Hydrology UPHs 9-11 identified by Blöschl et al., 2019). More specifically, it is of fundamental importance to understand which mechanisms rule the occurrence of extreme events, how they emerge from the parent processes and

how thy change in time or space due to external environmental factors. This session calls for contribution on advances in statistical theory and applications dealing with extremes in hydroclimatic systems, including multivariate statistical tools, Bayesian techniques, processing and analysis of global data, etc.

S12. Quantifying uncertainty in hydrological systems: A Bayesian point of view

Convener: Ashish Sharma
Co-Conveners: Ilaria Prosdocimi, Dmitri Kavetski, Lucy Marshall, Mojtaba Sadegh, Alberto Viglione

Past decades have seen a flurry of activity in Bayesian applications in hydrology. These applications include those to quantify model and parameter uncertainty, develop alternatives to reduce structural uncertainty through sensible averaging procedures, to new alternatives of defining uncertainty by relaxing the framework for specifying model likelihoods. Additionally, hydrologists are starting to adopt data assimilation as a new way to both reduce predictive uncertainty, and also to assess where assumed model structures may not be fully adequate. This session invites contributions involving new and innovative ways of using Bayesian methods for the type of hydrological problems mentioned above, as well as other emerging problems that such techniques have been put for use in.

S13. Recent and future satellite missions for observation of the continental water cycle

Convener: Gilles Boulet
Co-Conveners: Yangbo Chen, Amir AghaKouchak, Yaning Chen, Chris Hopkinson, Maria José Polo

Recently launched Earth observation satellite missions, as well as missions scheduled for launch in the next decade or so, open a new era in Space Hydrology. Those sensors enable us to observe new variables of the continental water cycle, or improve the observation capacity of existing platforms. Amongst the former, SWOT will help monitor the surface water levels at fine resolution, while TRISHNA and LSTM will provide surface temperature data at plot scale every few days with potential retrieval of both evapotranspiration and surface water stress. Amongst the latter, are operational missions, such as the Copernicus system, offering free access to high resolution data with an enhanced revisit frequency in the order of a few days, consistent with the typical time scale of a drydown period. They also provide a series of downstream services and products ready for use as constraints in hydrological models: Sentinel 2 for vegetation cover monitoring, and Sentinel 1 for soil moisture applications, amongst others.
This session thus focuses on both potential applications and the challenges associated with using the upcoming large datasets optimally. In this session, we welcome contributions on the following subjects:

- sensors and systems: this subtopic will cover technologies, platforms and remote sensing products, used – or with potential future applications – in hydrological remote sensing. Presentations on the latest international cal/val campaigns, impact assessment, initiatives and data products are welcome. This includes GPM, SMOS_HR/SMAP, Sentinels, SWOT, TRISHNA/LSTM, ECOSTRESS, etc.
- theories and methods: this subtopic focuses on the latest progress in theories and methods relevant to designing Hydrological Observing Systems based on recent or planned satellite missions, i.e. i) inversion of hydrological variables (observation models) such as

precipitation, snowpack, evapotranspiration, soil moisture, groundwater, water bodies, river discharge etc, and ii) assimilation of remote sensing products and their associated uncertainty, with special attention to scaling (aggregation, disaggregation) and footprint analysis.

S14. Groundwater sustainability in a changing climate: modeling and experimental analyses from urban, agricultural and ecological contexts.

Convener: Daniele Pedretti
Co-Conveners: Michelle Newcomer, Barry Croke, Amir Aghakouchak

Groundwater is arguably the most strategic freshwater resource for humans and the biosphere. If properly managed, groundwater can be resilient to climate change, making it a valuable resource to protect and optimize for climate change mitigation plans. Yet, groundwater can be also vulnerable to antropic contamination and naturally a poorly renewable resource, requiring our efforts to ensure its long-term sustainability. This session gathers theoretical and applied studies focusing on groundwater sustainability. The session welcomes experimental and modeling tools and analyses performed from the shallow soils and vadose zone to deeper environmental studies, including fossil aquifers. Among the topics, the session addresses:

- the development and use of modern techniques, such as managed aquifer recharge (MAR);
- the optimization of pumping wells and draining systems;
- the optimization of groundwater-driver irrigation and other agricultural applications;
- the sustainable use of groundwater to save groundwater-dependent ecosystems; including rivers and streams endangered by aquifer overexploitation, and;
- the disturbance of external factors, such as wildfires.

The results and discussions emerging from this session will help disentangling some of the “23 Unsolved Problems in Hydrology”, in particular climate-change-driven time variability (questions 1-4), the role of different interfaces in hydrology to control the management of groundwater (questions 12-15) and the impact of groundwater sustainability on the society (questions 21-23).

S15. Advancements on understanding and modeling of the fluxes of groundwater across boundaries.

Convener: Alraune Zech
Co-Conveners: Antonio Zarlenga, Gil Mahé, Flavia Tauro

While groundwater and surface waters have been historically treated as separate entities, they represent a continuum in the hydrological cycle. Of particular importance are the water and mass transport processes across aquatic-terrestrial interfaces, including their physical-chemical-biological interactions that take place in a range of different marine and freshwater systems. Such interactions have important implications for water quantity, water quality, and ecological health. Water and mass flows through the interfaces between groundwater and surface waters are crucial as they actively regulate the transfer of nutrients, contaminants, and water between groundwater and surface environments. The importance of the topic is reflected by questions #13 of the 23 unsolved problems in hydrology (UPH): “What are the processes controlling the fluxes of groundwater across boundaries (e.g. groundwater recharge, inter-catchment fluxes and discharge to oceans)?”. Unfortunately, there

is still a substantial lack of understanding of the main physical mechanisms ruling water and mass transport along interfaces as well as standardized methods to measure the processes involved along the interfaces. This is because such processes typically integrate a large variety of scientific disciplines such as hydrology, biogeochemistry, biology, physics, and chemistry, and partly because research is often organized by close compartments, lacking a truly holistic and interdisciplinary approach. This session welcomes novel contributions from interdisciplinary research on groundwater–surface water interactions, along a variety of thematic areas, scales, and experimental and modelling-based methodologies and approaches, possibly revealing knowledge gaps and future research needs. Contributions are sought related to the following relevant interfaces :

- groundwater–river Interactions ;
- groundwater - vadose zone studies ;
- hyporheic zone studies ;
- groundwater–lake interactions ;
- groundwater–ocean interactions ;
- interactions of groundwater with wetlands.

S16. Dealing with subsurface contamination and risks: technical solutions and practical applications, from shallow to deep geological environments

Convener: Felipe de Barros
Co-Conveners: Wouter Buytaert, Christine Stumpp, Elena Volpi

Subsurface resources, such as aquifers and the vadose zone, are subject to multiple sources of contamination that may pose risk to human health and the functioning of ecosystems. Sources of pollution include waste disposal facilities, accidental spills of toxic substances, landfill leachate, agricultural activities, industrial water discharge, deep nuclear waste repositories, mining waste management (e.g. acid mine drainage) and seawater intrusion. Improved understanding of the mechanisms controlling plume dispersion and dilution is critical to better manage the subsurface environment in an effective manner. However, *predicting* the fate and transport of these substances in the subsurface environment and *estimating* the associated risks are challenging tasks given the presence of hydrogeological heterogeneity at a broad range of scales and multiple sources of uncertainty stemming from the incomplete characterisation of the subsurface. This session aims to attract contributions that focus on developing tools that 1) address fundamental problems in contaminant transport in the subsurface environment at different scales, 2) quantify uncertainty in model predictions, 3) identification of pollution sources using tracer techniques, and 4) provide practical solutions to site management. The topics covered in this session are well aligned with the "23 Unsolved Problems in Hydrology" presented in Blöschl *et al.* (2019). This session will bring together experts from hydrogeology, uncertainty quantification and risk analysis and invites contributions ranging from analytical and numerical modelling of contaminant transport in the subsurface environment and data analysis of contaminant sites.

S17. Tracer methods in catchment and critical zone hydrology

Convener: Christine Stumpp
Co-Conveners: Przemyslaw Wachniew, Maki Tsujimura, Giovanny Mosquera, Zhonghe Pang, David Hannah

Stable and radioactive isotopes as well as other natural and artificial tracers are useful tools to study water flow, solute transport and transformation processes in hydrology. They are of particular importance for identifying sources of water, contaminants and nutrients, flow paths, transport properties and geochemical processes, and for quantifying important hydrological variables, such as water transit times. We invite contributions that demonstrate the application and recent developments of isotope and other tracer techniques in catchment hydrology and the critical zone. This includes field and modelling studies in the areas of surface-groundwater interactions, unsaturated and saturated zone, rainfall-runoff processes, ecohydrology, nutrient or contaminant export, or other relevant processes in catchments and the critical zone.

S18. Tracers Solutions for the 23 Unsolved Problems in Hydrology

Convener: Przemyslaw Wachniew
Co-Conveners: Christine Stumpp, Maki Tsujimura, Giovanny Mosquera, Zhonghe Pang

Tracer methods in hydrology use spatial and temporal patterns of concentrations, abundances and physical properties of natural and man-made substances for a comprehensive understanding of the cycling of matter through the hydrosphere. As such, the inherently interdisciplinary tracer approach is applicable to all compartments of the hydrological cycle and gives insights into the processes that govern fluxes of water, solutes and solids. Changes in tracer signatures provide timescales for environmental processes and reflect environmental shifts and events. The potential of the tracer approach goes well beyond the technical applications such as groundwater or sediment dating and is potentially relevant to all thematic areas of the UPH, including the coupled human-water systems. For example, agricultural activities, at a catchment scale, affect fluxes of water and lead to the release of a variety of potential tracers, many of them being contaminants. These alterations are reflected in tracer signatures of soil water, groundwater, surface water bodies, soils and sediments. Furthermore, the isotopic signatures in precipitation and runoff provide another dimension for the identification of the patterns and functions in catchment behaviour. At the same time, many hydrological systems remain poorly characterized with respect to even basic tracer characteristics, such as stable isotope composition of water. The aim of this session is to develop tracer methods and to identify potential tracer applications in the context of the 23 UPH. Contributions should address any of the specific questions of the 23 UPH and demonstrate how tracers can add information on solving it.

S19. Innovation and citizen engagement to sense the Hydrological Cycle

Convener: Flavia Tauro
Co-Conveners: Fernando Nardi, Salvatore Grimaldi, David Hannah, Jérôme le Coz, Dominique Bérod

Traditional monitoring systems are a significant bottleneck to the comprehension of natural processes due to expensive equipment, limited spatial (and often temporal) coverage, and trained staff involved in measurement acquisition. To mitigate such criticalities, the MOXXI and CANDHY working groups welcome contributions that encompass:

- Innovative/do-it-yourself approaches to observe specific hydrological processes;
- Participatory initiatives aimed at improving our comprehension and management of water resources;
- Unintended instrumentation/methodologies for advanced hydrological measurements;
- Transdisciplinary approaches to observe Earth processes and;
- Success stories of projects involving innovative measurements and citizen science.

S20. Hydrology, new tools and innovative measurements and citizen science in Africa

Convener: Gil Mahé
Co-Conveners: Marloes Mul, Hubert H.G Savenije, Harald Kunstmann, Flavia Tauro, Fernando Nardi, Anil Mishra, Ernest Amoussou, Mohamed Meddi, Jean-Marie Kileshye Onema, Dominique Bérod

African scientists suffered for long from being far from hot spots of science and lacked from technical experts. This situation has changed a lot since some time. An increasing number of high schools and universities have trained numerous young students who stayed for many of them in their home countries. A lot of international cooperation programs have developed capacities of local agencies and research teams to use recent techniques, and the quality of communications and internet capacity have much increased too.
International UNESCO programs like FRIEND or G-WADI, or international programs like AMMA or WATERNET allowed since 20 years to build strong regional communities who are able to share and develop knowledge within Africa. Thus in many regions the most recent technologies and data management tools are frequently used, participative research and environmental surveys are increasing, and citizens are more frequently associated to development and research programs. In the context of climate change impact on water availability, Africa needs to improve its capacity of development of its own research programs based on well trained high level research community. This session aims at proposing African researchers, or colleagues working in/on Africa, to present results of researches using recent, innovative techniques, data, tools, in connection with society and development priorities, and report about research programs involving citizen participation. Among the main topics concerned, but not limitative, are spatial hydrology, innovative measurement and observation techniques, openand big data, participatory science experiment, science literacy and so on. This could provide some meaningful options to deal with challenges and uncertainties in the African context, and it is perfectly linked with specific aspects of the African Union Agenda 2063 where one of the priority areas for the next decade is to have well educated citizens and skills revolution underpinned by Science, technology and innovation. This falls under 'Inclusive growth and sustainable development' aspiration of the agenda.

S21. Hydrology of Mediterranean and semi-arid regions

Convener: Yves Tramblay
Co-Conveners: Hamouda Dakhlaoui, Christian Leduc, Hodson Makurira, Roger Moussa, Conrad Wasko, Elzbieta Wisniewski, Charalampos Skoulikaris

Water resources are an important issue in the Mediterranean and semi-arid regions due to water scarcity. The climate of Mediterranean areas (located in the Mediterranean basin but also in Australia, California, Chile and South Africa), and more broadly in semi-arid regions, is characterized by a strong spatio-temporal variability of precipitation. This implies a notable influence of extreme events, flash floods and drought periods which affect water resources management. While these regions record a significant population density, notably in developing countries in the South and East of the Mediterranean basin, they are particularly prone to and are sensitive to climate change, as revealed in several recent reports such as the IPCC or MedECC MAR1. in the past few decades, the expansion of urban areas, changes in land use and agricultural practice and the development of irrigation areas combined with climate change have strongly modified land and water resources. The objective of this session is to discuss the recent advances in Mediterranean and semi-arid hydrology, notably to address the following key challenges:

- the quantification and modelling of threshold effects on runoff genesis, in particular for intermittent and ephemeral streams with strong surface-subsurface interactions in drylands;
- the improvement of forecasting systems for water resources and extreme events, such as flash-floods and droughts;
- the improvement of measurements capabilities with novel approaches, data availability and sharing through regional or international cooperation;
- a better quantification of the impact of water-energy-food nexus on the hydrological cycle, through remote sensing and hydrological modelling;
- gaining a better understanding of the hydrological functioning through regional networking, to assess the potential impacts of climate and land use changes at the regional level.

S22. Tropical Hydrology

Convener: Alain Dezetter
Co-Conveners: Ernest Amoussou, Pedro Luiz Borges Chaffe, Gil Mahé, Giovanny Mosquera

The purpose of this session is to review the state of scientific knowledge on tropical hydrology. The intertropical zone is the main energetic engine of climatic mechanics and can be characterized by the contrasting presence of tropical rainforest, tropical monsoon and tropical savanna climates. Convective phenomena are numerous and sometimes still poorly taken into account in climate models, making climate prediction more complex. However, the models agree on a trend towards global warming and an increase in extreme phenomena (excess rainfall and temperature, lack or scarcity of rainfall, etc.) whose consequences on hydrological regimes are sometimes unpredictable.
The impact of climate change on water resources depends not only on changes in the volume, timing, and quality of streamflow and recharge but also on system characteristics, changing pressures on the system, how the management of the system evolves, and what adaptations to climate change are implemented. Non-climatic changes may also have a greater impact on water resources than climate

change, as it is mentioned in the Panta Rhei scientific decade 2013–2022 of IAHS, about changes in hydrology and society.
For example, since the 1970s, most of tropical Africa has been experiencing a decline in rainfall, with high evaporation due to the increasing temperature that became more pronounced in the early 1980s, with the repercussion of a decrease in water resources. However, since the 1990s, there has been a slight recovery in rainfall, which is still lower than that recorded in the 1950s in this environment of high evaporative demand. All this, combined with the degradation of the vegetation cover and the reduction in the number of rainy days (concentration of rainfall over short periods), leads to a heavy surface runoff in Sahelian areas and thus to the degradation of ecosystems. Paradoxically also in some tropical humid areas, flood peaks increased while average rainfall and groundwater resources did not. Those changes in precipitation and temperature, as well as non-linear effects on moisture, evapotranspiration and soil, have consequences on the quantity and quality of water resources, agriculture, fisheries and livestock.
Research related to the assessment of past and future climate change, as well as observed changes in hydrological regimes and/or watershed uses, are welcome in this session, including studies about actual and future assessment of evaporation and land-use/cover change interactions with surface runoff conditions.

S23. Advances in snow and ice hydrology

Convener: Tobias Jonas
Co-Conveners: Melody Sandells, McKenzie Skiles, James McPhee, Timothy Link, Elzbieta Wisniewski, Vsevolod Moreydo

Storage and release of water from seasonal snowcovers and glaciers constitute critical components of the hydrological cycle in many parts of the world. Quantifying, understanding, and predicting the processes that control distribution and ablation dynamics of snow and ice provide ample research challenges, especially in complex mountainous terrain. Snowcover and glacier dynamics are influenced by surrounding topography, vegetation and other land surface characteristics that control accumulation and redistribution processes, as well as local micrometeorological conditions that control energetics and ablation. Accurate modelling of snow and ice melt dynamics requires methods to simulate a large range of physical processes that act and interact at a range of spatial and temporal scales. Advances in these areas are needed and relevant to develop improved tools for water managers concerned with floods, droughts, water supply, hydropower generation, and climate change impacts. This session will bring together experimental and modeling experts to address recent research in snow and ice hydrology.

S24. Cold region runoff and groundwater change

Convener: Melody Sandells
Co-Conveners: Felipe De Barros, Fuqiang Tian, Gökçen Uysal, María José Polo

Changes in the storage and delivery of water impact society. Cold regions are particularly susceptible to the effects of climate change so it is crucial to understand and plan for likely future hydrological changes in these regions. Changes in the timing and amount of meltwater release from snow and ice have implications for ecosystems and communities that depend on this water supply. Melting of permafrost can further lead to both ecosystem changes and infrastructure instabilities and damage. Due to the importance of this topic, ‘How will cold region runoff and groundwater change in a warmer climate?’ was selected as one of the key 23 unsolved problems in hydrology (UPH). This session will bring together experts in cold regions hydrology, climate change, biogeosciences, remote sensing, and

groundwater research to address this UPH. We welcome submission of presentations on all aspects of modelling and long-term monitoring of cold region hydrological components, particularly on:

- projected changes to the hydrological cycle in the cryosphere;
- assessment and monitoring frameworks for permafrost;
- long-term observations of snow and glacier melt;
- factors influencing longer-term water routing mechanisms;
- changing societal water needs in cold regions;
- implications for water systems operation and risk management;
- cold region ecosystem dependencies.

S25. Snow-melt driven erosion and sediment pathways in Polar regions

Convener: Sergey Chalov
Co-Conveners: Vsevolod Moreydo

Snow and ice melt in Polar regions are associated with dramatic changes in the hydrological regime and significantly enhance erosional processes. Such changes are the most important driver of the hydrological cycle of Polar rivers and dominate the fluxes of dissolved and particulate substances from land to the Arctic Ocean. This session aims to present studies which are devoted to mass transport phenomena in Polar regions that are associated with snow and ice melt such as continental erosion, sediment transport and water quality issues within the freshet period. The session will also include organic matter delivery to rivers due to permafrost thaw.

S26. Emerging contaminants and legacy pollutants in freshwater ecosystems

Convener: Stefan Krause
Co-Conveners: Alena Bartosova, Anne Jaffrézic, Françoise Elbaz-Poulichet

Human interaction with the water cycles is affecting surface water and groundwater quality across the globe. The widespread pollution of water resources is critically affecting human health and wellbeing, as well as negatively impacting ecosystem functioning and services, infringing on the achievement of several UN Sustainable Development Goals, most of all SDG6. Despite growing efforts internationally to regulate and reduce water pollution, including improved river basin management, advances in sustainable agricultural practice and implementation of polluter pays principles, water quality in surface water and groundwater bodies has failed to reach sustainable standards in most countries. One reason for this is that interventions in water quality management usually target one type of contaminants and pollution sources, despite increasing awareness and understanding of the complexity of water pollution challenges that see interacting diffuse and point source pollution with legacy and emerging contaminants interacting in their impact on affected ecosystems and people.
This session solicits presentations that focus on:

- emerging (e.g. pharmaceuticals, pathogens, microplastics) and legacy (e.g. nitrate, chlorinated solvents, heavy metals) pollutants in surface water and groundwater;
- interacting diffuse and point source pollutants;
- integrated management of co-existing / mixing contaminants;
- model-based and experimental analysis of multi-contaminant reactive transport and impacts;
- impacts of multi-stressor interactions between water pollution and other drivers such as climate change.

S27. Policies and mechanisms for water quality improvement and maintenance in a changing environment.

Convener: Xiaohong Chen
Co-Conveners: Elango Lakshmanan

Climate change and human activities are constantly changing the aquatic ecological environment, while human development raises higher requirements for the water environment ecology. Different countries and regions have different aquatic conditions of ecological environment with great diversities of water ecological culture and management system. In the process of water ecological environment control and restoration, how to effectively implement scientific management and decision-making to promote the improvement and maintenance of water environment ecology and to achieve the United Nations Sustainable Development Goals require policies and mechanisms that are adapted to regional differences in changing environments. The purpose of this session is to discuss and exchange research achievements in the following topics: (1) regional water ecological environment evolution accompanied by climate change and human activities; (2) methods and approaches of scientific management and decision-making in water ecological environment management and restoration; (3) experience of policies and mechanisms in water ecological environment control in different countries and regions; and (4) adaptive policies and mechanisms for the improvement and maintenance of water environment ecology.

S28. The added values of Ecohydrological approach for integrated large river basin management

Convener: Didier Orange
Co-Conveners: Honeyeh Iravani, Gil Mahé

The Large River Basin Management is still questioning the out-scaling to ensure the integrity of the whole watershed and to respond to the individual demand in terms of economics, water access and environmental protection. The human needs interact with quantities and qualities of the finite natural resource base. Without a comprehensive and cohesive approach of all these interactions, unprecedented pressures on land and water resources lead to highly decreasing agricultural productivity, loss of biodiversity, greater food insecurity, higher prevalence of diseases, and more water-driven issues as well as socio-economic and political instability. On top of that the current COVID-19 pandemic crisis accelerates the pressures on resources and societal stresses on the environment. In this context, ecohydrology is emerging as a compelling response to the challenges the World faces. The ecohydrology enhances solution-oriented approaches and nature-based solutions related to the dramatic spatial and temporal hotspots emerging more and more everywhere. Regional hydrology and flow regime characterization within the biogeochemical and biological processes in relationship with the land use change, land cover change and societal change can emphasize the comprehension and role of the hydrological template that regulates ecosystem functioning and societal development. Nowadays, ecological and social based approaches for watershed management including ecohydrology and socio-hydrology should be precised. Ecohydrology may be the most cost-efficient way, and perhaps the only way, for countries to meet the majority of the SDGs.
The topic of this session focuses on the scale issue: what are the most relevant and reliable variables to follow at the scale of a large basin to allow the characterization of the ecohydrological state of the basin and determine which are the main sources of stress on the ecohydrological balance? All kind of ecohydrological questions are welcome, showing diverse approaches from ground observations to satellite surveys.

S29. Sustainable water management in agricultural areas

Convener: Jérôme Molénat
Co-Conveners: Delphine Leenhardt, Rim Zitouna Chebbi, Fernando Nardi, Christophe Cudennec

Agriculture in the 21st century has been challenging the need of increasing production to supply food of a growing world population, in a context of climate change and increased pressure on resources, particularly water resources. Within a territory, the agricultural and hydrological systems are in strong interaction and co-evolve. On the one hand, agricultural production is dependent on water availability. On the other hand, agricultural activities can exert significant pressure on water resources through withdrawals, particularly for irrigation. The use of agricultural inputs (pesticides, fertilizers) or unconventional water (treated wastewater, brackish water, etc.) also poses health and environmental risks to aquatic ecosystems. Finally, the agricultural use of water comes into conflict with ecological, industrial or domestic uses in certain territories.
In this context, agroecology is promoted worldwide to contribute to food production and security, and also to preserve or restore natural resources, such as water, and ecosystems, including aquatic ecosystems. Agroecology takes advantage *inter alia* of diversities, plant or crop diversities and diversities of knowledge for example. It is based on a detailed knowledge of each context, and in particular of the hydrological processes and fluxes of catchment.
Along with agroecology, the emergence of the water-food-energy (WEF) nexus over the last ten years recognizes the strong interactions of these three components and the need to develop integrated approaches involving the agricultural, water management and energy sectors. The territory is then considered as a level of biophysical, social and economic organization to operate management strategy. The nexus is particularly used to reformulate and even rethink problems and solutions for the management of irrigated agriculture, which increases yields, withdrawals large volumes of water and consumes electrical energy to power the pumping and water distribution systems
In this session, we invite contributions on the following topics:

- understand, evaluate, and increase water use efficiency at the watershed scale in a context of climate change. The interest and role of agroecological solutions, such as the reasoning of the choice of crops, the spatial organization of cropping systems, or water conservation practices have to be considered, along with the added value of climate services;
- understanding the interactions between biogeochemical cycles, agriculture and water resources to identify agroecological solutions maintaining agricultural production and preserving water resource and aquatic environment;
- identifying and evaluating, particularly in relation to the wef nexus and climate, the interest of alternative water resources (treated wastewater, brackish water, etc.) or in terms of water storage or supply infrastructure (water reservoirs, small channels, etc.);
- how to accompany the agro-ecological transition, particularly in terms of decisions and changes impacting water resources (choice and spatial organization of cropping systems, choice of infrastructure and type of water for irrigation, landscaping, etc.)?
- studying the conflicts of uses, between agricultural water uses and other uses, within the territories and investigating the knowledge and cultural gaps that avoid the transitioning to fair and sustainable allocation of water resources among competing sectors following a WEF nexus approach. What are the origins of these conflicts? How can they be arbitrated? Which are the major barriers (technological, social, cultural, economic, etc.) that avoid the embracing of the multiple benefits of WEF nexus strategies;
- investigating the role of citizen and stakeholder engagement in support of agroecological sustainability and in promoting mutual trust among the multiple actors that govern water and natural resource management strategies in agricultural areas. Which are the value and

trade-offs characterizing the implementation of participatory approaches and citizen science for sustainable water management in agricultural areas?

S30. Nature-based Solutions as a global change adaptation strategy

Convener: Joris P C Eekhout
Co-Conveners: Federico Preti, Graham Jewitt, Jordi Morato

It is projected that hydrology will be strongly affected by global change, including climate change, catchment degradation, land use change, and other impacts. The hydrological impacts include prolonged periods of low flows, changing timing and magnitude of floods, and increasing plant water stress and soil erosion. Nature-based solutions (NBSs) are potentially cost-effective as an adaptation strategy to combat the projected negative impact of global change. NBSs encompass a broad range of actions that protect, restore, or sustainably manage ecosystems to provide benefits to people. They include established approaches such as ecosystem-based adaptation to disaster risk reduction, Soil and Water Bioengineering works (SWB), such as green and blue infrastructures, forest and landscape restoration, and natural climate solutions. We invite contributions that assess the effectiveness of NBS as a global change adaptation strategy on the water balance, hydrological extremes, soil erosion, hydrogeological risk, water quality, and more. We welcome studies based on modelling, and field and laboratory experiments at a range of spatial and temporal scales. We particularly encourage contributions that use multidisciplinary approaches to reach new conclusions.

S31. The Water & Health Nexus – Understanding water controls on human health and wellbeing in a drastically changing world

Convener: Stefan Krause
Co-Conveners: Christophe Cudennec, Laura Richards

The global pandemic of SARS-CoV-2 has once more highlighted in an agonising way how closely human health and well-being are connected to the global water cycle and safe access to clean and affordable water in order to sustain our needs for food, sanitation and hygiene, as well as energy production, cooling and transport. Unequal access to safe and clean water for hand hygiene has been identified by WHO as a major obstacle for safely handling the risk of the global health crisis unfolding across the world since 2020 and international efforts on interdisciplinary approaches to sustaining fair access to water for sanitation and hygiene are urgently needed to control the course of this, and potential future pandemics.

In addition to representing a precious commodity, water on the Earth's surface and in the subsurface acts as a transport vector for a wide range of water borne pollutants and pathogens causing diseases such as Cholera, Typhoid, Dysentery or Gardia. Public health concerns regarding these waterborne diseases are high in particular in areas with insufficient or failing water and sanitation infrastructure, with diarrhetic disease representing the second leading cause of death in infants under the age of five and causing higher numbers of infant deaths than malaria, measles and HIV/AIDS together. In addition, drinking water contaminated with critically high concentrations of pollutants such as arsenic, mercury or pesticides represents a global public health concern.

Advances to the mechanistic understanding of water as a transport vector for pathogens and disease are therefore urgently required in order to reduce the risk of pathogen dispersal and associated spread of spread waterborne disease. This involves detailed understanding of how the time dynamic evolution of hydrological connectivity and associated transport flow paths control the spread of waterborne diseases by potentially connecting pathogen sources across and within communities as well as how environmental conditions such as water levels, water temperature and chemistry status control the growth of pathogen concentrations or populations of vector-borne disease transmitting insects (e.g., mosquitos transmitting Dengue, Malaria or West-Nile virus). In addition, optimising the efficiency of water sanitation and hygiene measures and advancing the predictive capacity for epidemiological forecasting will require detailed understanding of hydrometeorological and water pollution pressures on water and sanitation infrastructure as well as adaptation and mitigation management.
The capacity of hydrological models and analysis tools to support predictions of both, pathogen source developments, contaminant activation and their spread is perhaps still underutilised when assessing public health risks associated with waterborne and vestor-borne diseases and pollutants. This session therefore calls for interdisciplinary contributions from the global water and health communities that demonstrate challenges, advances and solutions to:

- The risks posed by waterborne and vector-borne diseases under the influence of global environmental change and resulting pressures on water infrastructure, governance and management
- Water, sanitation and hygiene (WASH) practices, including in the context of conflicts, displacements and temporary settlements
- Wastewater-based epidemiology to provide predictive capacity and early warning of pathogen dispersal and associated public health risks
- Assessments of hydrological controls of health risks related to contaminant source activation and exposure
- Community-based approaches to water governance and safe access to clean water for all
- Economic, technological, behavioural and cultural approaches to educating high-risk communities about water sanitation and hygiene practices
- High-tech to off-grid solutions to providing water treatment opportunities

S32. Hydrology and Society: Gender as an essential dimension in solving societal hydrological challenges in learning and participatory processes

Convener: Valérie Borrell Estupina
Co-Conveners: Carolina Valenzuela, Raphaëlle Ducrot, Roger Moussa, Jean-Emmanuel Paturel, Andrew Ogilvie, Olivier Barreteau, Kouamé Auguste Kouassi, Aristide Douagui, Jean Messingué, Mònica Serrano

The central topic is the interaction between learning and the hybridization of knowledge and gender. It lies at the interaction between:

- Participatory and learning processes in hydrology and sustainable development, and
- Gender as an essential dimension in solving societal hydrological challenges.

This session concerns both the aspects of Education (learning or training process) and Research (participatory process). Papers attesting to an educational experience with learners, a participatory experience with managers and stakeholders, or a more conceptual research activity are welcome.

This session allows us to share questions such as:

- How is consideration of gender (power relationship, man-woman relationship, etc.) an essential and powerful dimension in the sustainable development of our territories in connection with the management of water resources throughout the world?
- How to make water and sustainable development stakeholders aware of the relevance of integrating the relational dynamics of gender in participatory and decision-making processes?
- How to ensure gender equity in a participation or learning system?
- What pedagogy should be implemented to make future and current hydrologists aware of the importance of the consideration of gender in the implementation of methodologies / solutions?
- What learning outcomes to achieve, or improve, by integrating the gender issue in hydrology training?
- How can gender-sensitive pricing improve learning processes? acquire general engineering and research skills? acquire transdisciplinary skills?

Thus, contributions could be focused on social learning, the participatory process, transdisciplinarity and their dimension relating to gender inclusion. They could also be more focused on formal education with a particular focus on gender inclusion.

S33. Open science and education, knowledge society, and inclusive progress towards Agenda 2030

Convener: Christophe Cudennec
Co-Converners: Berit Arheimer, Nilay Dogulu, UNESCO, WMO, UNU

This session will articulate inputs from the scientific community and ongoing intergovernmental developments, in particular at UNESCO (Open Science recommendation, IHP Strategy) and WMO (Resolution on data).