**Electronic supplement**

Table S1: Mapping of questions resulting from the voting process to the questions consolidated by the working group (Table 1).

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| **Questions as an outcome of the voting process**  Gold  Silver  Moved up from raw list  New | **Consolidated questions** |
| **Time variability and change** | **Time variability and change** |
| Is the hydrological cycle regionally accelerating/decelerating under global warming?  Can we identify tipping points of hydrological systems due to changes in climate and/or human impacts. .. regime changes | 1. Is the hydrological cycle regionally accelerating/decelerating under climate and environmental change and are there tipping points (irreversible changes)? |
| When will we run out of glacier augmentation (to runoff and groundwater) and what will happen to those catchments? (until and after) What is the hydrologic effect of thawing permafrost | 2. How will cold region runoff and groundwater change in a warmer climate (e.g. with glacier melt and permafrost thaw)? |
| Understanding the dynamics of temporary rivers / Why, when and how do rivers dry up? | 3. What are the mechanisms by which climate change and water use alter ephemeral rivers and groundwater in (semi-) arid regions? |
| What are the effects of natural and anthropogenic soil disturbances on heat and mass fluxes at the land-atmosphere interface?  What are the impacts of climate and environmental change on aquifer recharge? | 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? |
| **Space variability and scaling** | **Space variability and scaling** |
| Why are evapotranspiration rates spatially homogeneous despite differences in controlling mechanisms?  Why is soil-water content so variable in space and time?  Why do changes in the snow fall regime have a very different impact on stream flow in different catchments?  Why is aridity (according to the Budyko Curve) the main controlling factor in the partitioning between runoff and evapotranspiration?  How can we identify the similarities between catchments?  Why are reaction coefficients for the same process heterogeneous in time and in space across different soils, streams, lakes, catchments, groundwater bodies…? | 5. What causes spatial heterogeneity and homogeneity in runoff, evaporation, subsurface water and material fluxes (carbon and other nutrients, sediments), and in their sensitivity to their controls (e.g. snow fall regime, aridity, reaction coefficients)? |
| Why do dominant hydrological processes emerge and disappear across scales? Why is hydrology simple at the catchment scale despite being complex at smaller scales?  What are the emergent hydrological laws at catchment scale?  How do constitutive relationships and their parameters change with scale? | 6. What are the hydrologic laws at the catchment scale and how do they change with scale? |
| Why is most flow preferential and what are the consequences? | 7. Why is most flow preferential across multiple scales and how does such behaviour co-evolve with the critical zone? |
| Why is stream water so young when ground water is so old?  Why do streams respond so quickly to rainfall, with storm flow that is so old?  What is the fate and lifetime of evaporated water from land surfaces? | 8. Why do streams respond so quickly to precipitation inputs when storm flow is so old, and what is the transit time distribution of water in the terrestrial water cycle? |
| **Variability of extremes** | **Variability of extremes** |
| Why do drought and flood rich/poor periods exist? Why do we see long term cycles and correlations in hydroclimatological variables? What is the cause of the Hurst phenomenon? Are the characteristics of extreme events changing and if so why? Floods and droughts  How to reconstruct paleohydrological phenomena during the Holocene and why did they happen?  How do extreme floods and droughts around the world teleconnect with each other and with other factors? | 9. How do flood-rich and drought-rich periods arise, are they changing, and if so why? |
| How do geomorphic processes interact with floods and droughts?  Why are some catchments more sensitive to land-use/cover change than others?  What is the role of changing land use/land cover change patterns on in-situ and downwind droughts and floods? | 10. Why are runoff extremes in some catchments more sensitive to land-use/cover and geomorphic change than in others? |
| What are the controls on and consequences of (e.g. streamflow, groundwater recharge, evaporation, soil moisture etc.) the spatial and temporal patterns of snow and ice in catchments?  Why and when do rain-on-snow events produce exceptional runoff? | 11. Why, how and when do rain-on-snow events produce exceptional runoff? |
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| **Interfaces in hydrology** | **Interfaces in hydrology** |
| Groundwater-surface water interactions / regional  What are the processes of groundwater-surface water interactions, including the role of the hyporheic zone (e.g. in contaminant fate and transport), and the dependencies of different ecosystems?  Why is the connectivity between hillslopes and streams so heterogeneous and dynamic? | 12. What are the processes that control hillslope-riparian-stream-groundwater interactions and when do the compartments connect? |
| What are the processes in the unsaturated zone, which have significant impacts on groundwater recharge and composition?  What are the storages and fluxes of groundwater across boundaries (oceans, atmosphere and inter-catchment fluxes) at different scales? | 13. What are the processes controlling the fluxes of groundwater across boundaries (e.g. groundwater recharge, inter-catchment fluxes and discharge to oceans)? |
| What controls long-term spatio-temporal evolution of catchment water quality? What factors contribute to the persistence of sources contributing to the degradation of water-quality?  What are the dominant processes controlling the fate of material fluxes in catchments over different spatial and temporal scales? | 14. What factors contribute to the long-term persistence of sources responsible for the degradation of water-quality? |
| What is the extent, fate and impacts of contaminants of concern (EOCs) in groundwater?  How are microbial pathogens removed in the subsurface? | 15. What are the extent, fate and impact of contaminants of emerging concern and how are microbial pathogens removed or inactivated in the subsurface? |
| **Measurements and data** | **Measurements and data** |
| How to reduce uncertainty in large-scale hydrological fluxes using novel technologies/remote sensing?  How can we accurately measure subsurface properties, states and fluxes at a range of scales in space and time? | 16. How can we use innovative technologies to measure surface and subsurface properties, states and fluxes, at a range of spatial and temporal scales? |
| How can we convincingly put a value to hydrological observation systems with open data to reverse the current trend of decline of observation systems?  What are the consequences of choosing between a large number of less accurate observations vs a few more accurate measurements?  Working with different data sources / big data  Under what conditions can we substitute space for time in hydrology? | 17. What is the relative value of traditional hydrological observations vs soft data (qualitative observations from lay-persons, from data mining etc.), and under what conditions can we substitute space for time? |
| How to extract information from available data on human and water systems in order to inform the building process of socio-hydrological models? | 18. How can we extract information from available data on human and water systems in order to inform the building process of socio-hydrological conceptualisations and models? |
| **Modelling methods** | **Modelling methods** |
| How do we adapt hydrological models to be able to extrapolate to changed conditions. What is the sensitivity of hydrologic models to vegetation dynamics? | 19. How can hydrological models be adapted to be able to extrapolate to changing conditions, including changing vegetation dynamics? |
| How to disentangle and reduce model structural/parameter/input uncertainty in hydrological prediction? | 20. How can we disentangle and reduce model structural/parameter/input uncertainty in hydrological prediction? |
| Interfaces with society | Interfaces with society |
| How to communicate (un)certainty to decision makers and general public  How can we improve flood and drought forecasting on different lead times?  Why are drought and flood risk assessments ineffective? (social) | 21. How can the (un)certainty in hydrological predictions be communicated to decision makers and the general public? |
| Water-energy-food nexus  Water quality – ecosystem health – human health nexus  Water sustainability of large cities | 22. What are the synergies and tradeoffs between societal goals related to water management (e.g. water-environment-energy-food-health)? |
| How strong is the impact of hydrological change on the migration of people worldwide and what is the effect of migration on hydrologic change? What is the role of water in the collapse of ancient civilizations and the implications for contemporary water management? | 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? |