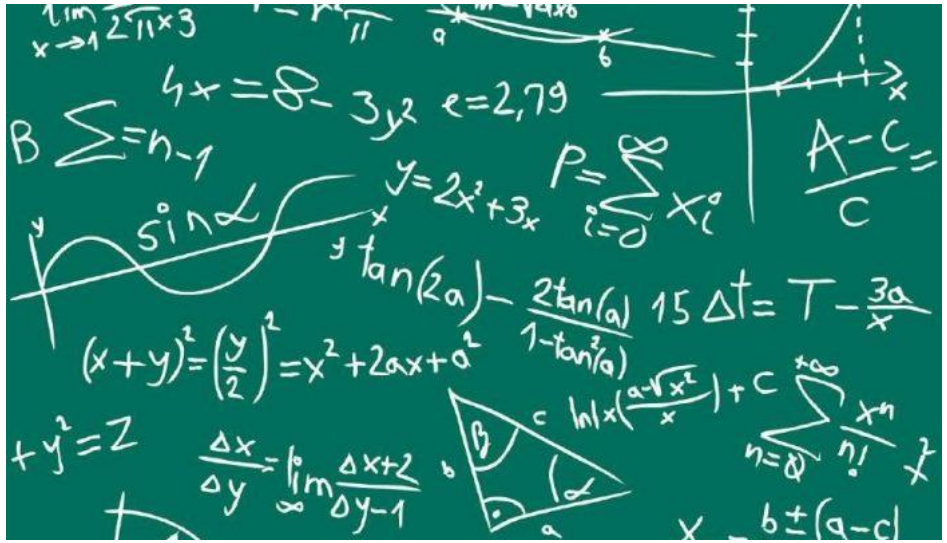
Twenty-three unsolved problems in hydrology (UPH) – a community perspective



Article in Hydrological Sciences Journal/Journal des Sciences Hydrologiques · June 2019

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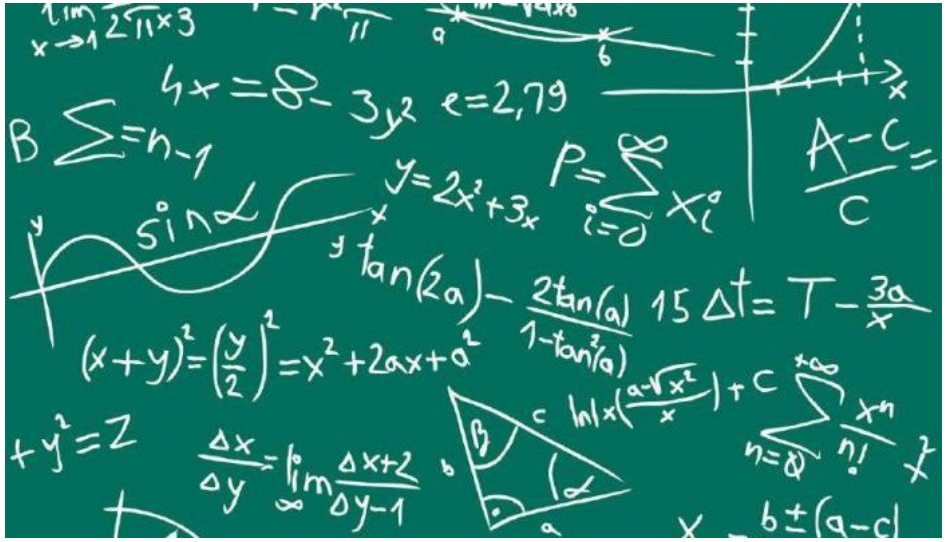

Günter Blöschl

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https://youtu.be/C3nADj-NI_Y

Mathematische Probleme.

Vortrag, gehalten auf dem internationalen Mathematiker-Kongreß zu Paris 1900.

Von

D. Hilbert.

Wer von uns würde nicht gern den Schleier lüften, unter dem die Zukunft verborgen liegt, um einen Blick zu werfen auf die bevorstehenden Fortschritte unsrer Wissenschaft und in die Geheimnisse ihrer Entwickelung während der künftigen Jahrhunderte! Welche besonderen Ziele werden es sein, denen die führenden mathematischen Geister der kommenden Geschlechter nachstreben? welche neuen Methoden und neuen Thatsachen werden die neuen Jahrhunderte entdecken — auf dem weiten und reichen Felde mathematischen Denkens?

Die Geschichte lehrt die Stetigkeit der Entwickelung der Wissenschaft. Wir wissen, daß jedes Zeitalter eigene Probleme hat, die das kommende Zeitalter löst oder als unfruchtbar zur Seite schiebt und durch neue Probleme ersetzt. Wollen wir eine

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https://youtu.be/jyObwmNr7Ko

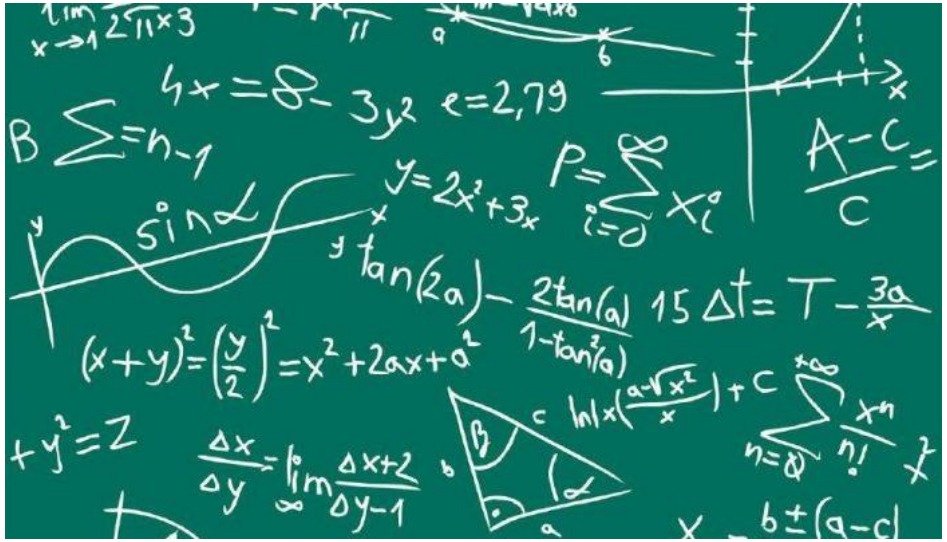
To all hydrologists of the world: A Call to Arms!

What are the 23 unsolved problems in Hydrology that would revolutionise research in the 21st century?

To make tangible progress, the problems should

- relate to observed **phenomena** (Why do they happen?)
- should be **universal** (not only apply to one region)
- should be **specific** (so they can be solved)

Twenty-three unsolved problems in hydrology

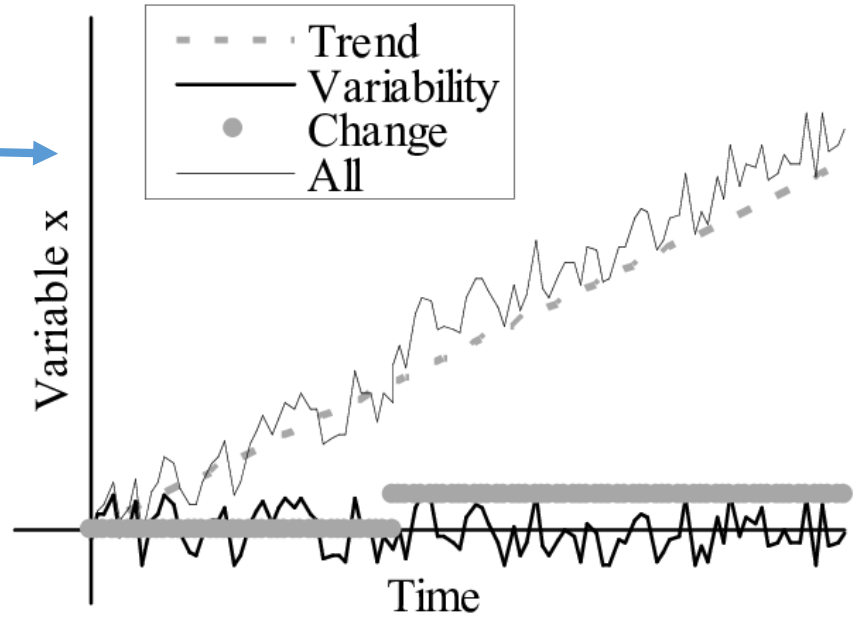


Who cares and why?

Pete Loucks
Cornell University, USA

23 Hydrologic Problems:

- **Time variability and change**
- Space variability and scaling
- Variability of extremes
- Interfaces in hydrology
- Measurements and data
- Modelling methods
- Interfaces with society



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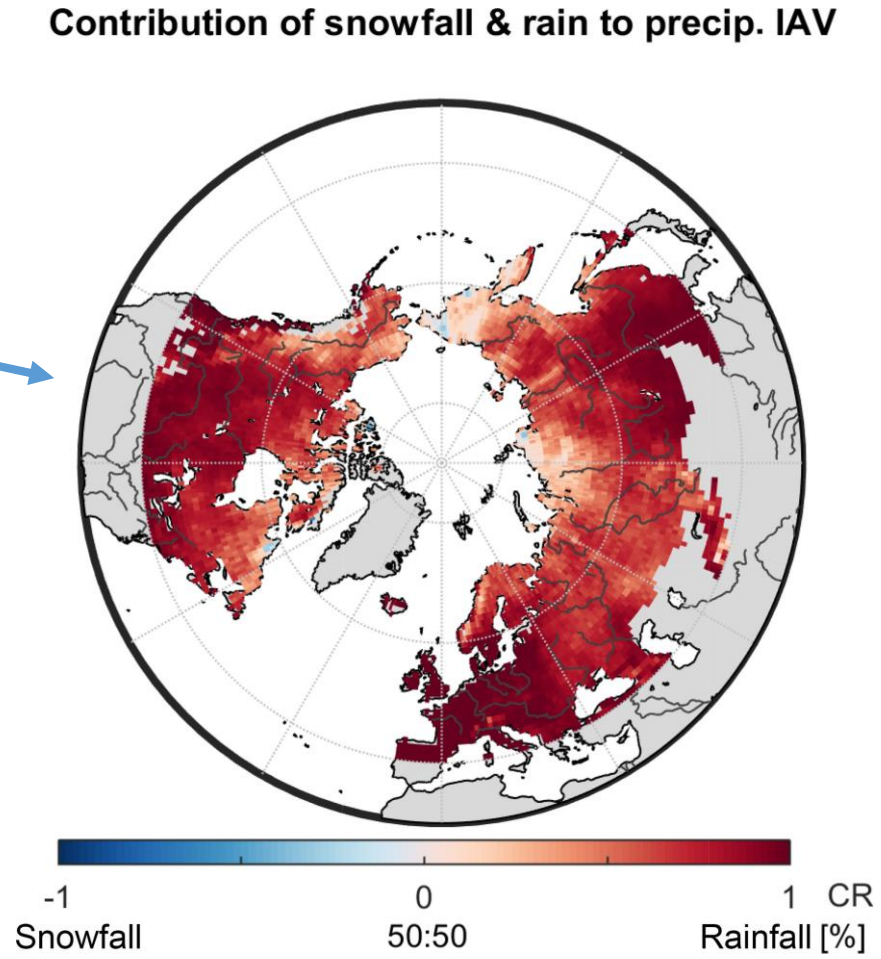

Understanding terrestrial water storage variations … across scales. Tina Trautmann et al.

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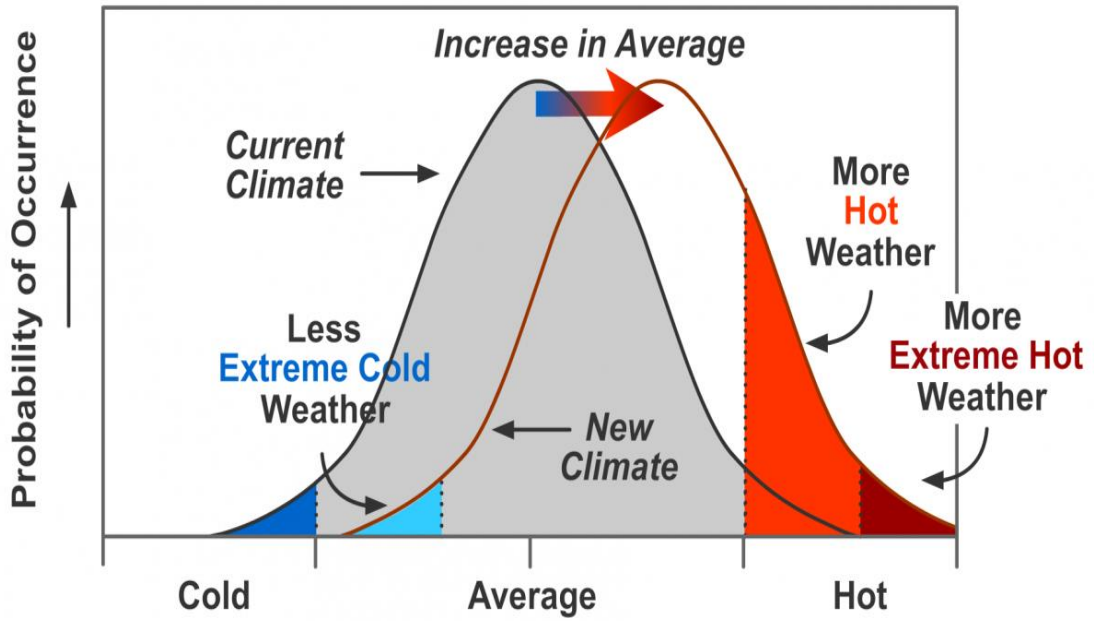

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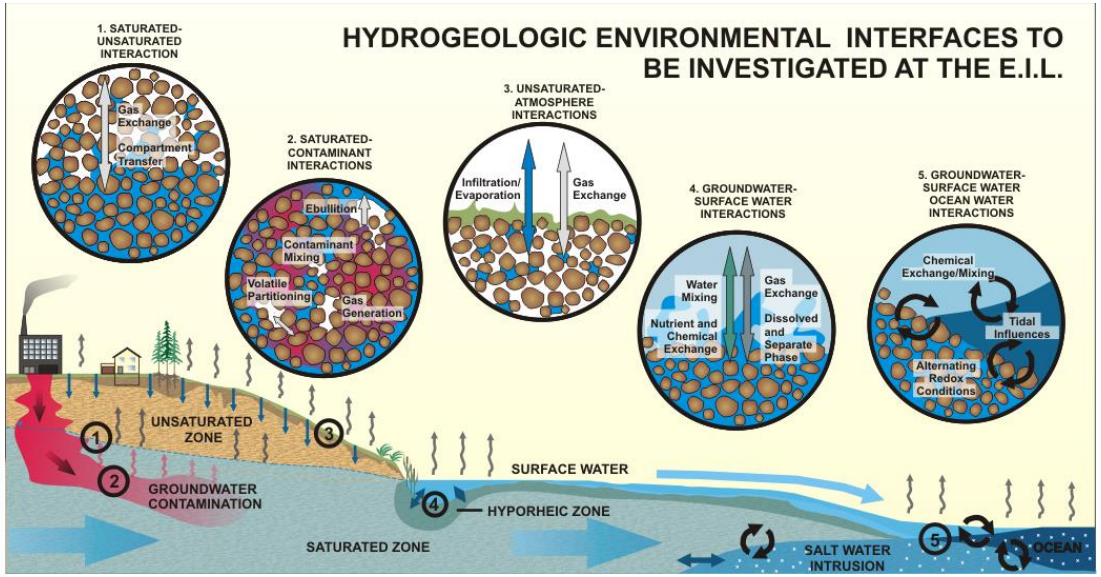

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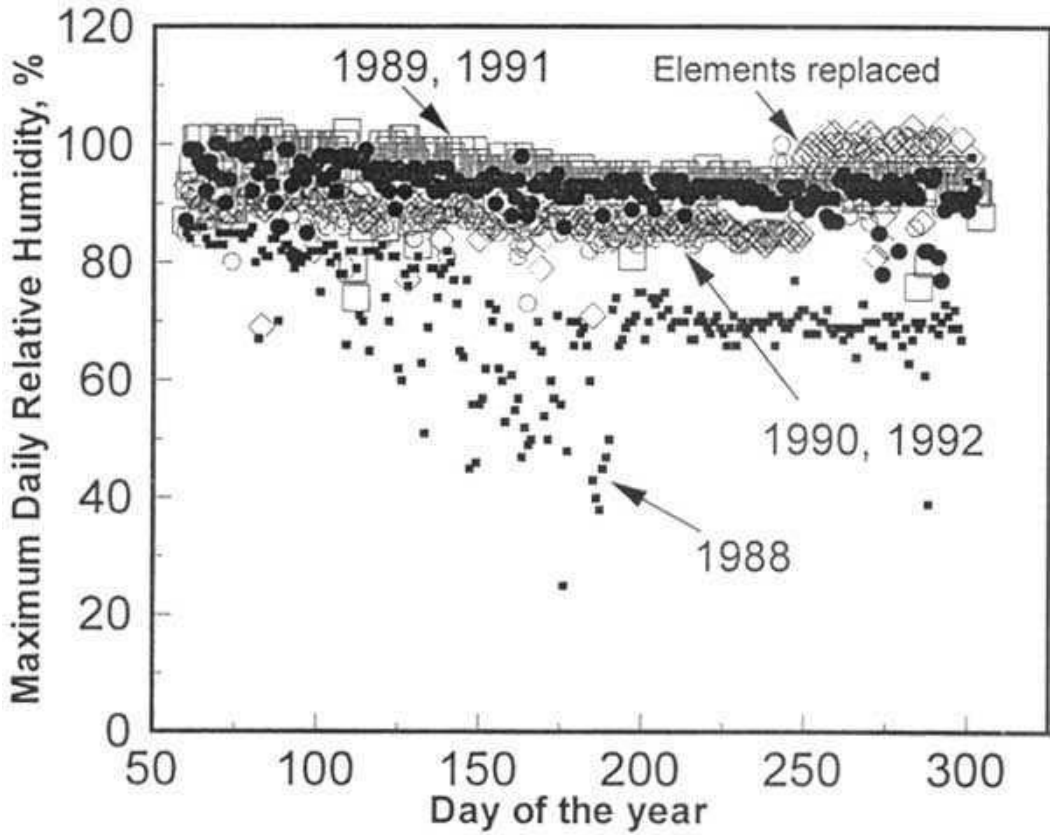

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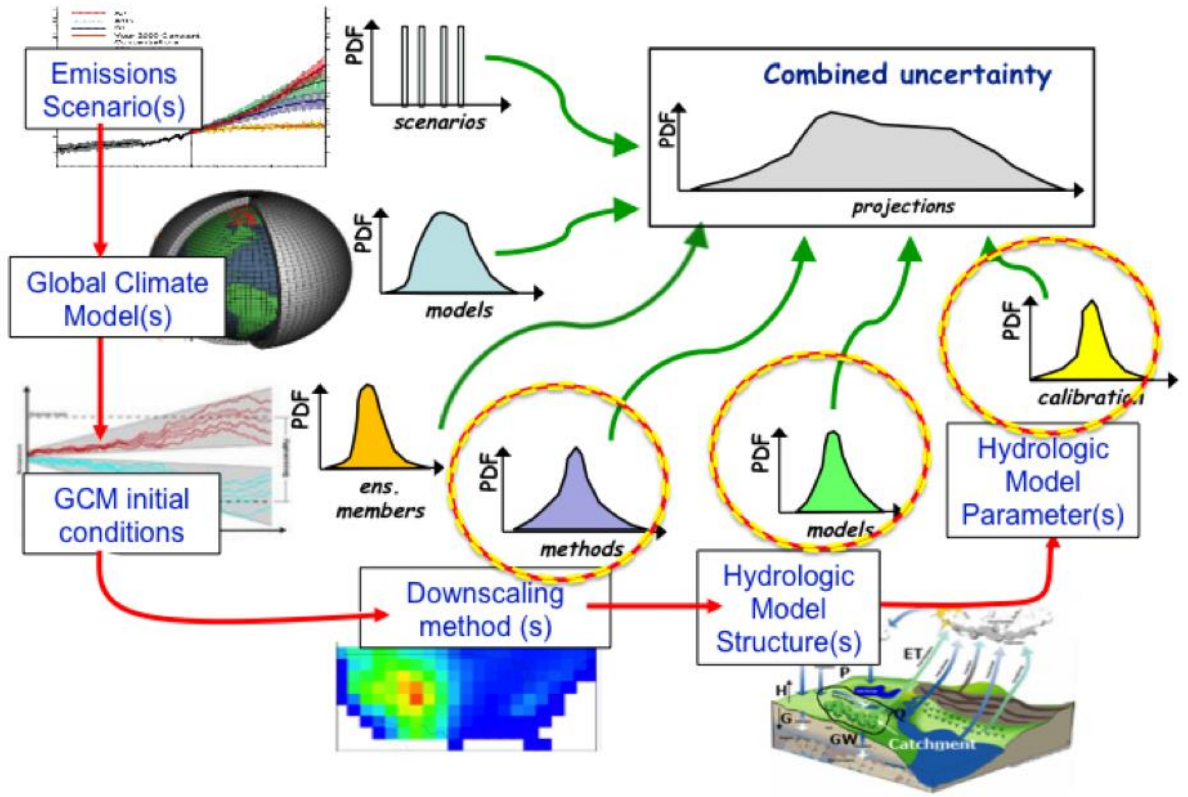

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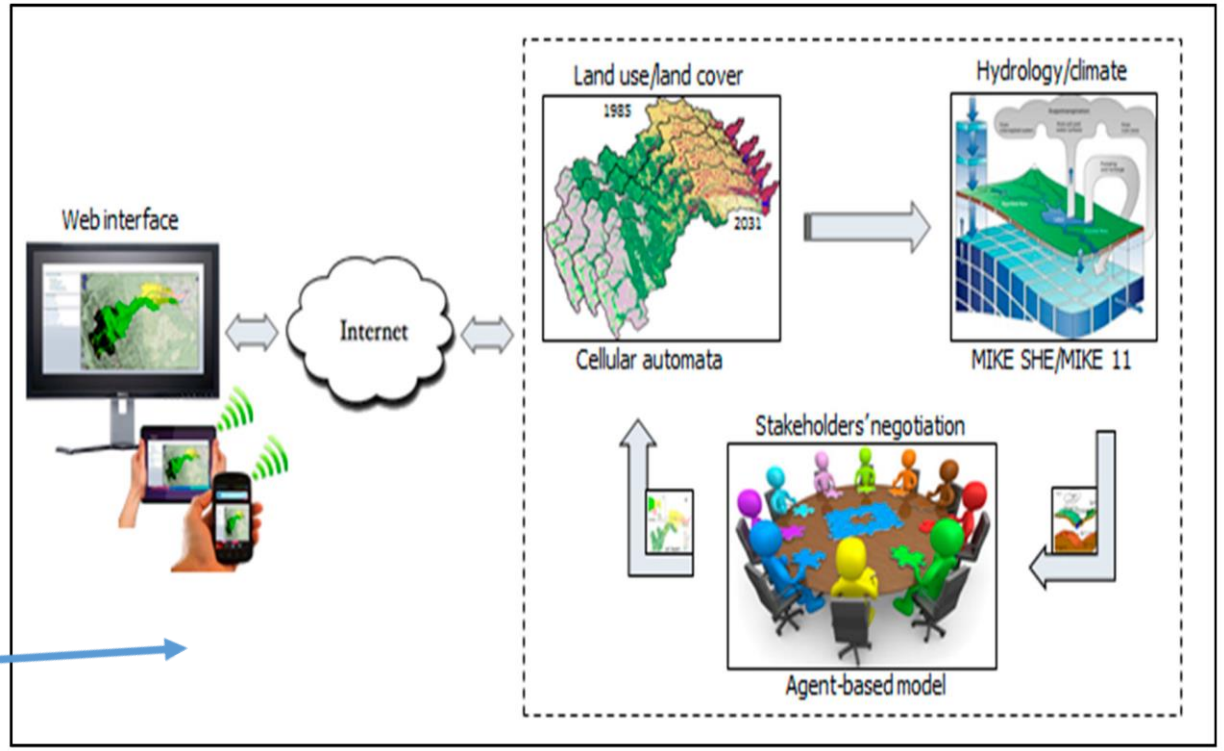


23 Hydrologic Problems: ⟷ Water Management Decisions

Design and Operation of Infrastructure for:

- **Time variability and change** 1-4
- **Space variability and scaling** 5-8
- **Variability of extremes** 9-11
- **Interfaces in hydrology** 12-15
- **Measurements and data** 16-18
- **Modelling methods** 19-20
- **Interfaces with society** 21-23

- Surface and Groundwater Storage
- Allocations to meet demands
  - Agriculture, Cooling, Domestic, Industrial
- Flood Protection
- Drought Mitigation
- Water Quality Management
- Recreation
- Ecosystem Habitat
- Hydropower Production
- Stormwater Drainage

Time variability and change

1. Is the hydrological cycle regionally accelerating/decelerating under climate and environmental change, and are there tipping points (irreversible changes)?

   - **Durations and frequencies of droughts, floods impact infrastructure design/operation.**

Time variability and change

1. Is the hydrological cycle regionally accelerating/decelerating under climate and environmental change, and are there tipping points (irreversible changes)?

   - **Increasing runoff impacts management of water quality.**

Time variability and change

2. How will cold region runoff and groundwater change in a warmer climate (e.g. with glacier melt and permafrost thaw)?

- **Changes in runoff and infiltration impacting land and water management.**

Time variability and change

2. How will cold region runoff and groundwater change in a warmer climate (e.g. with glacier melt and permafrost thaw)?

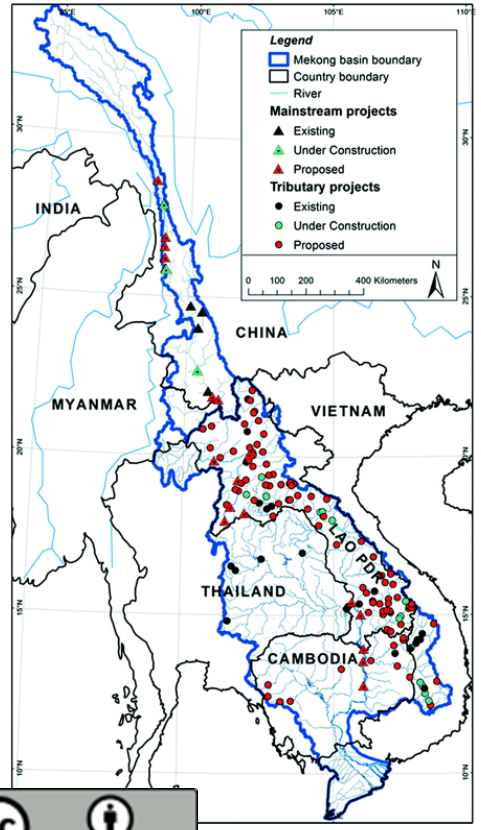
- **Glacier melt impacting distribution and amount of river flow.**

Figure 1: Map of Tibetan Plateau.
Source: www.yowangdu.com

Time variability and change

2. How will cold region runoff and groundwater change in a warmer climate (e.g. with glacier melt and permafrost thaw)?

- **Glacier melt impacting demand for water supply reservoirs.**



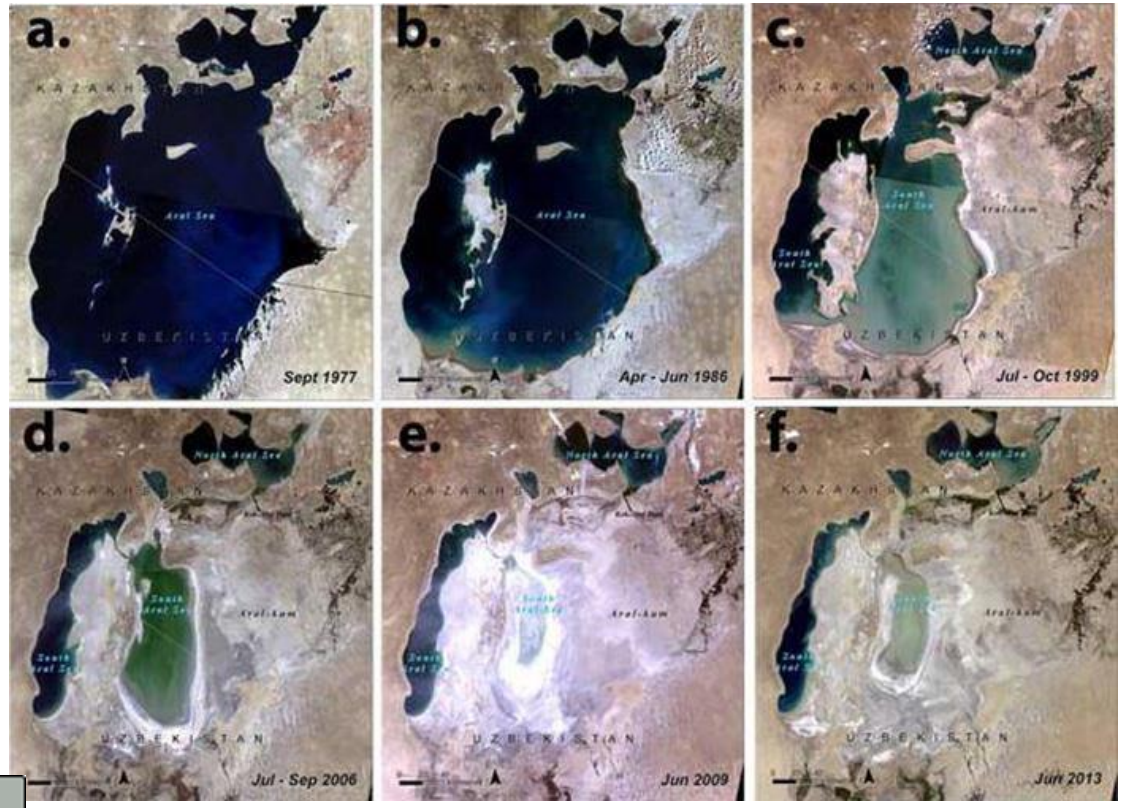
Time variability and change

2. How will cold region runoff and groundwater change in a warmer climate (e.g. with glacier melt and permafrost thaw)?

Time variability and change

3. What are the mechanisms by which climate change and water use alter ephemeral rivers and groundwater in (semi-) arid regions?

- **Water use decisions impact lake hydrology.**



Time variability and change

3. What are the mechanisms by which climate change and water use alter ephemeral rivers and groundwater in (semi-) arid regions?

- **Water use decisions impact river hydrology.**

Time variability and change

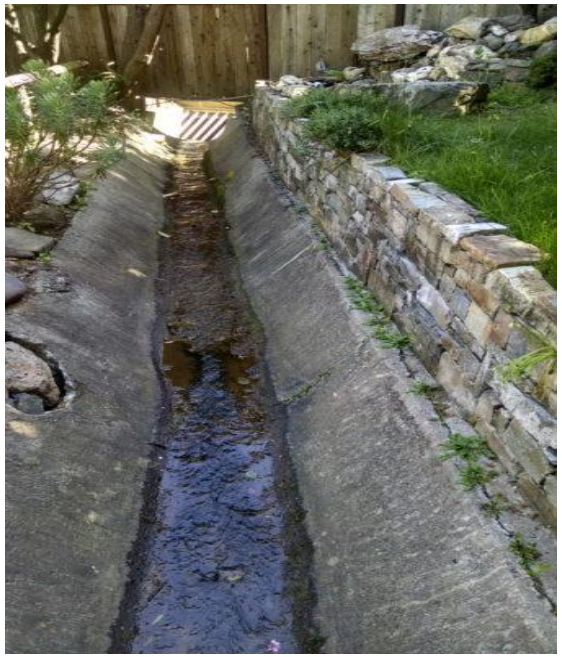
3. What are the mechanisms by which climate change and water use alter ephemeral rivers and groundwater in (semi-) arid regions?

- **Water use decisions impact groundwater hydrology.**

Time variability and change

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?

- **Impacts design of infrastructure for drainage and groundwater recharge**.



Space variability and scaling

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)?

- **Influences watershed management policies.**

Space variability and scaling

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)?

- **Influences watershed management policies in forests.**

Space variability and scaling

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)?

- **Influences watershed management policies on farms.**

Space variability and scaling

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)?

- **Influences watershed management policies in urban areas.**

Space variability and scaling

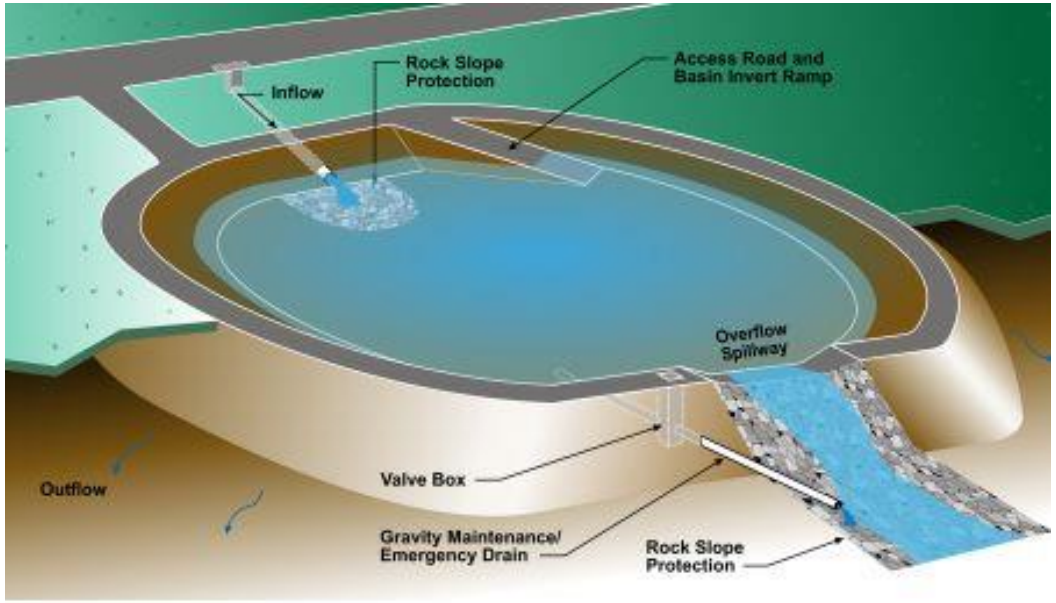
6. What are the hydrologic laws at the catchment scale and how do they change with scale?

- **Impacts effectiveness of upstream reservoirs vs larger downstream reservoirs.**

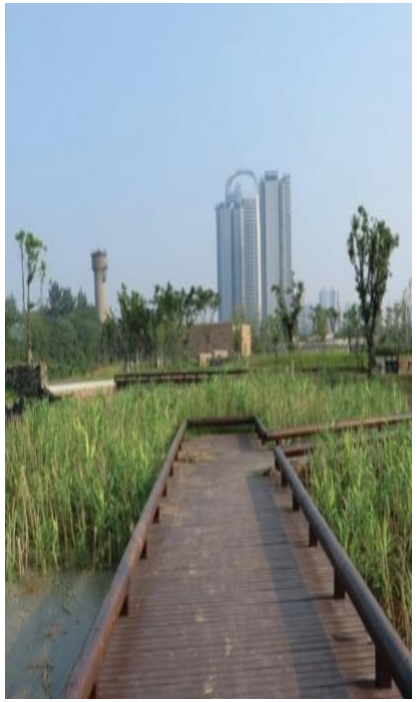
Space variability and scaling

7. Why is most flow preferential across multiple scales and how does such behaviour co-evolve with the critical zone?

- **Impacts land and channel erosion. Affects design and operation of infiltration basins and artificial wetlands.**



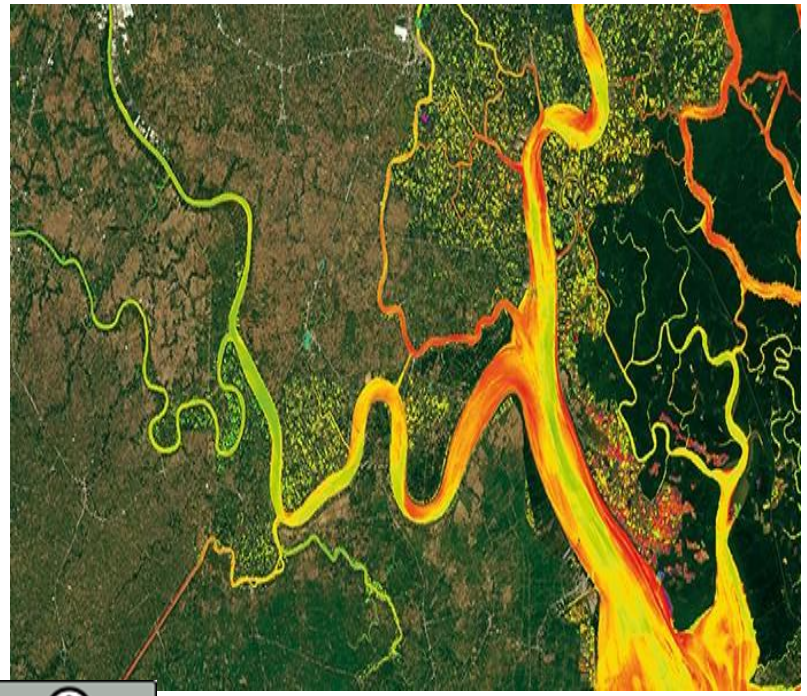
INFILTRATION BASIN



Space variability and scaling

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?

- **Flows and their velocities needed for design an operation of flood control reservoirs and river water quality estimation.**



Variability of extremes

9. How do flood-rich and drought-rich periods arise, are they changing, and if so why?

- **Critical for future capacity expansion planning and system design and operation.**

Variability of extremes

10. Why are runoff extremes in some catchments more sensitive to land-use/cover and geomorphic change than in others?

- **Impacts design of infrastructure for managing runoff.**

Variability of extremes

11. Why, how and when do rain-on-snow events produce exceptional runoff?

- **Impacts design of infrastructure for managing runoff.**

Interfaces in hydrology

12. What are the processes that control hillslope–riparian–stream–groundwater interactions and when do the compartments connect?

- **Helps predict inputs to groundwater aquifers and surface water storage sites and capacity requirements for reservoirs, pumps, etc.**

Interfaces in hydrology

13. What are the processes controlling the fluxes of groundwater across boundaries (e.g. groundwater recharge, intercatchment fluxes and discharge to oceans)?

- **Affects management of saltwater –freshwater exchanges along coastal aquifers.**

Interfaces in hydrology

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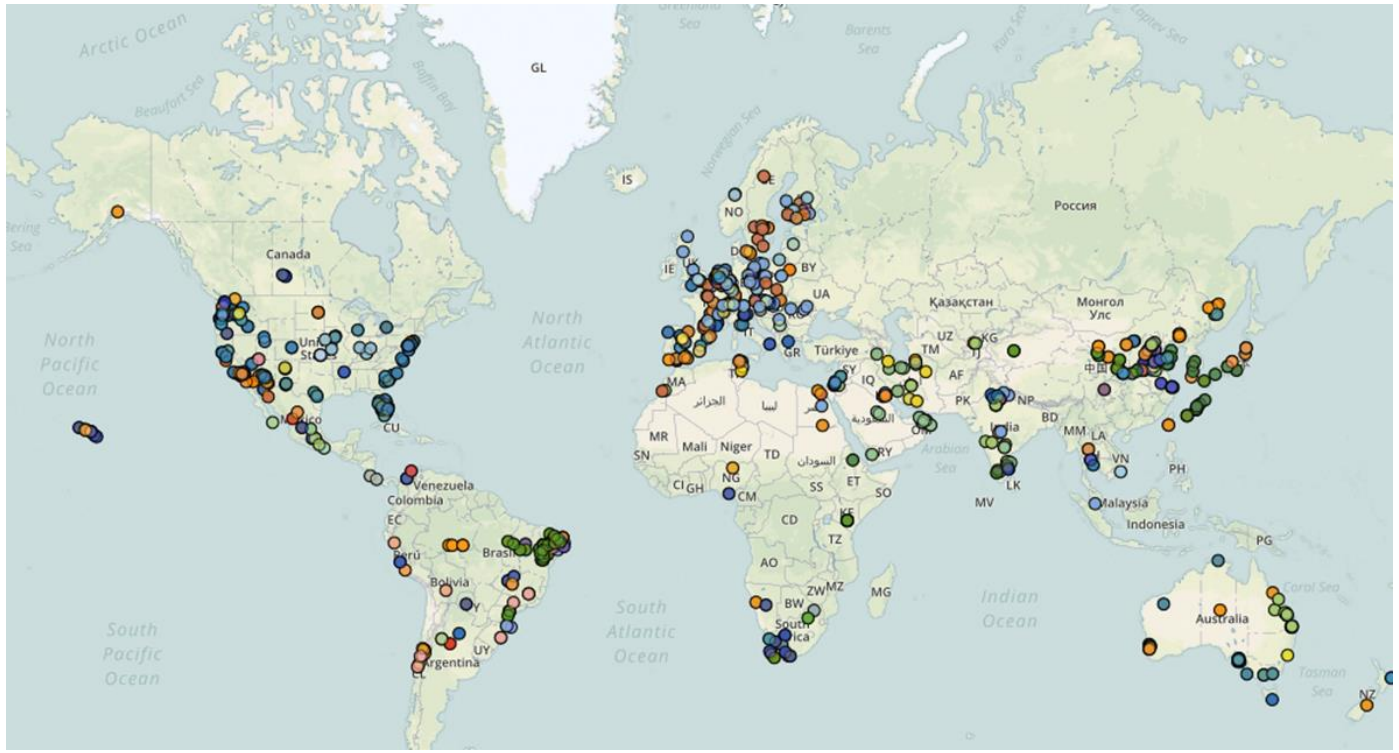

Interfaces in hydrology

14. What factors contribute to the long-term persistence of sources responsible for the degradation of water quality?

- **Affects measures taken to manage water quality.**

Interfaces in hydrology

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- **Affects measures taken to manage water quality.**

Interfaces in hydrology

15. What are the extent, fate and impact of contaminants of emerging concern and how are microbial pathogens removed or inactivated in the subsurface?

- **Affects cleanup of super fund sites, spills.**

Measurements and data

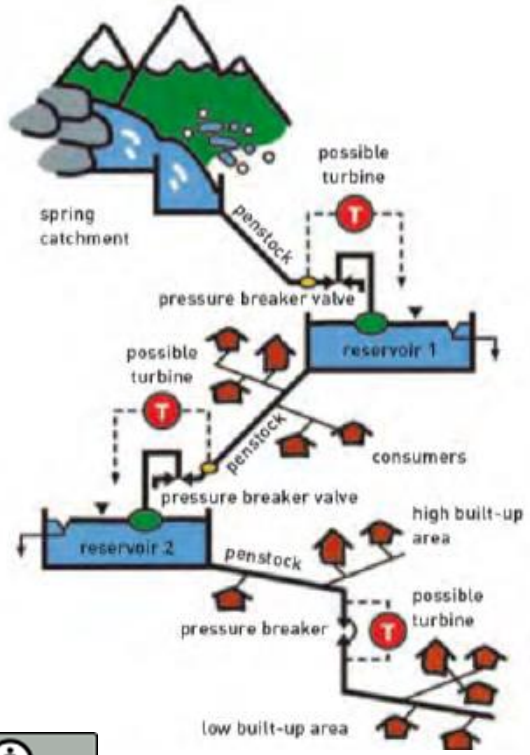
16. How can we use innovative technologies to measure surface and subsurface properties, states and fluxes at a range of spatial and temporal scales?

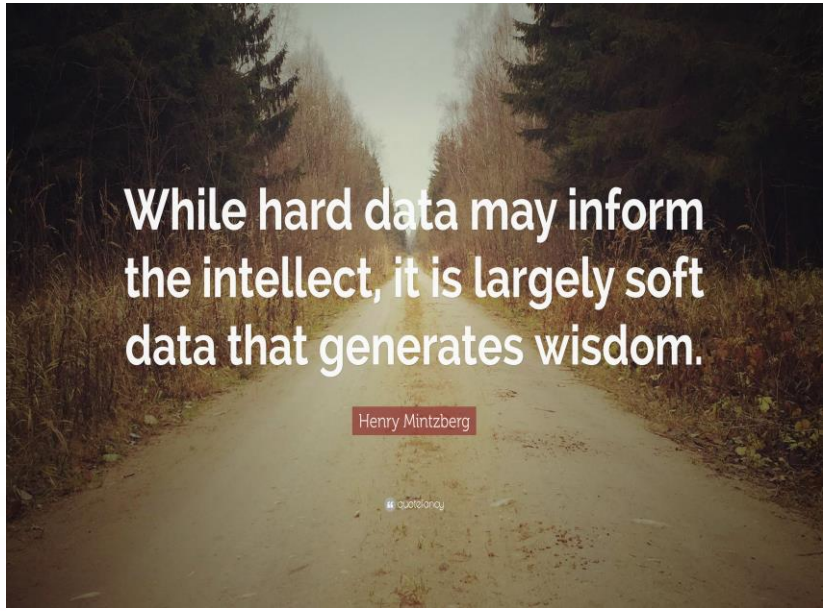
- **Data needed to assess geotechnical properties at potential dam, levee, treatment plant, canal, pipeline and wetland sites.**

Measurements and data

17. What is the relative value of traditional hydrological observations vs soft data (qualitative observations from laypersons, data mining etc.), and under what conditions can we substitute space for time?

- **Design of infrastructure requires data. Obtaining data costs money.**





Measurements and data

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?

- **Effectiveness of infrastructure determined by humans.**

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- **Effectiveness of water management decisions mainly determined by humans.**

Measurements and data

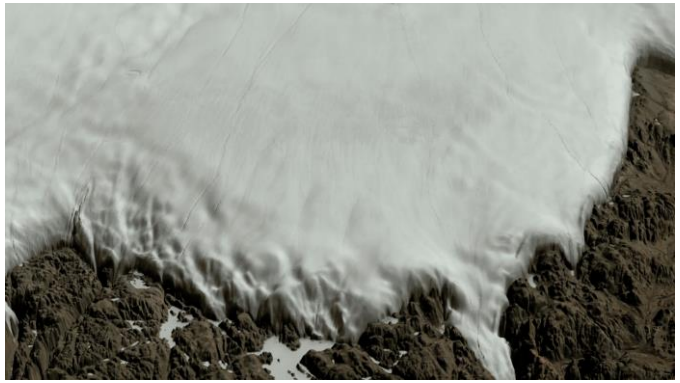
18. How can we extract information from available data on human and water systems in order to inform the building process of socio-hydrological models and conceptualisations?

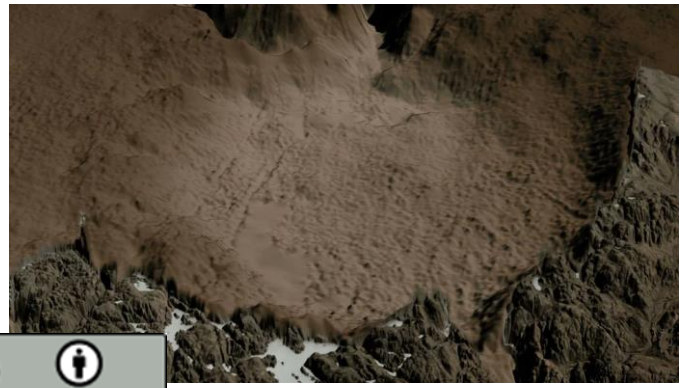
- **Effectiveness of water management decisions mainly determined by humans.**

Modelling methods

19. How can hydrological models be adapted to be able to extrapolate to changing conditions, including changing vegetation dynamics?

- **Needed to be able to evaluate the resilience of water management infrastructure to changing hydrologic and land cover/use conditions.**





Modelling methods

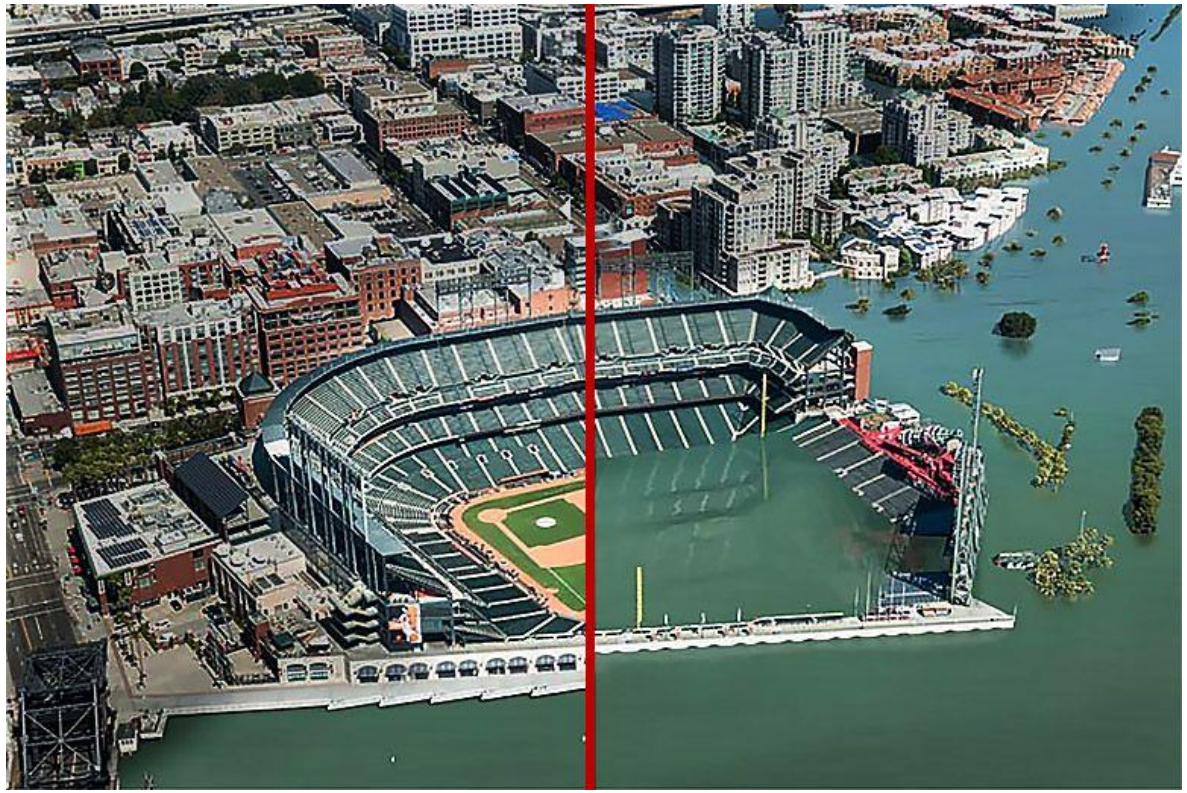
20. How can we disentangle and reduce model structural/parameter/input uncertainty in hydrological prediction?

- **Would generate efficiencies in design and operation of infrastructure**.

Interfaces with society

21. How can the (un)certainty in hydrological predictions be communicated to decision makers and the general public?

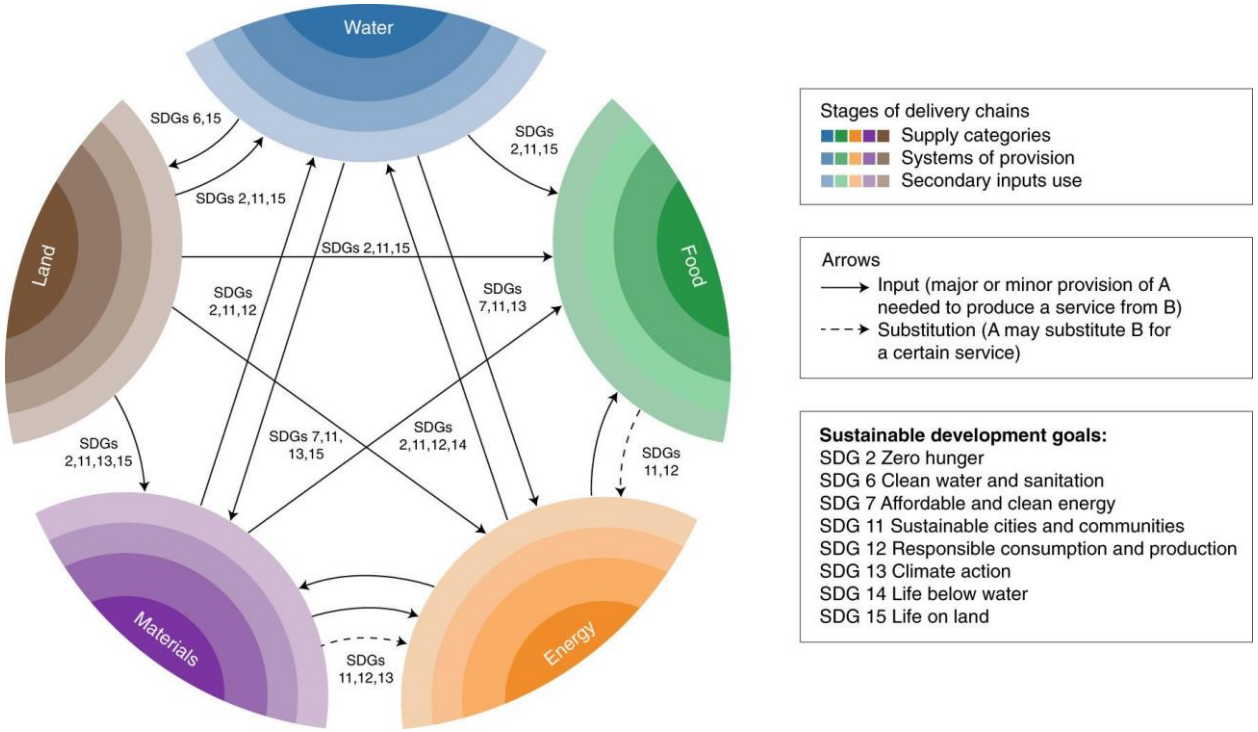
- **Should lead to more informed water management decision making**.



Interfaces with society

22. What are the synergies and tradeoffs between societal goals related to water management (e.g. water–environment–energy–food–health)?

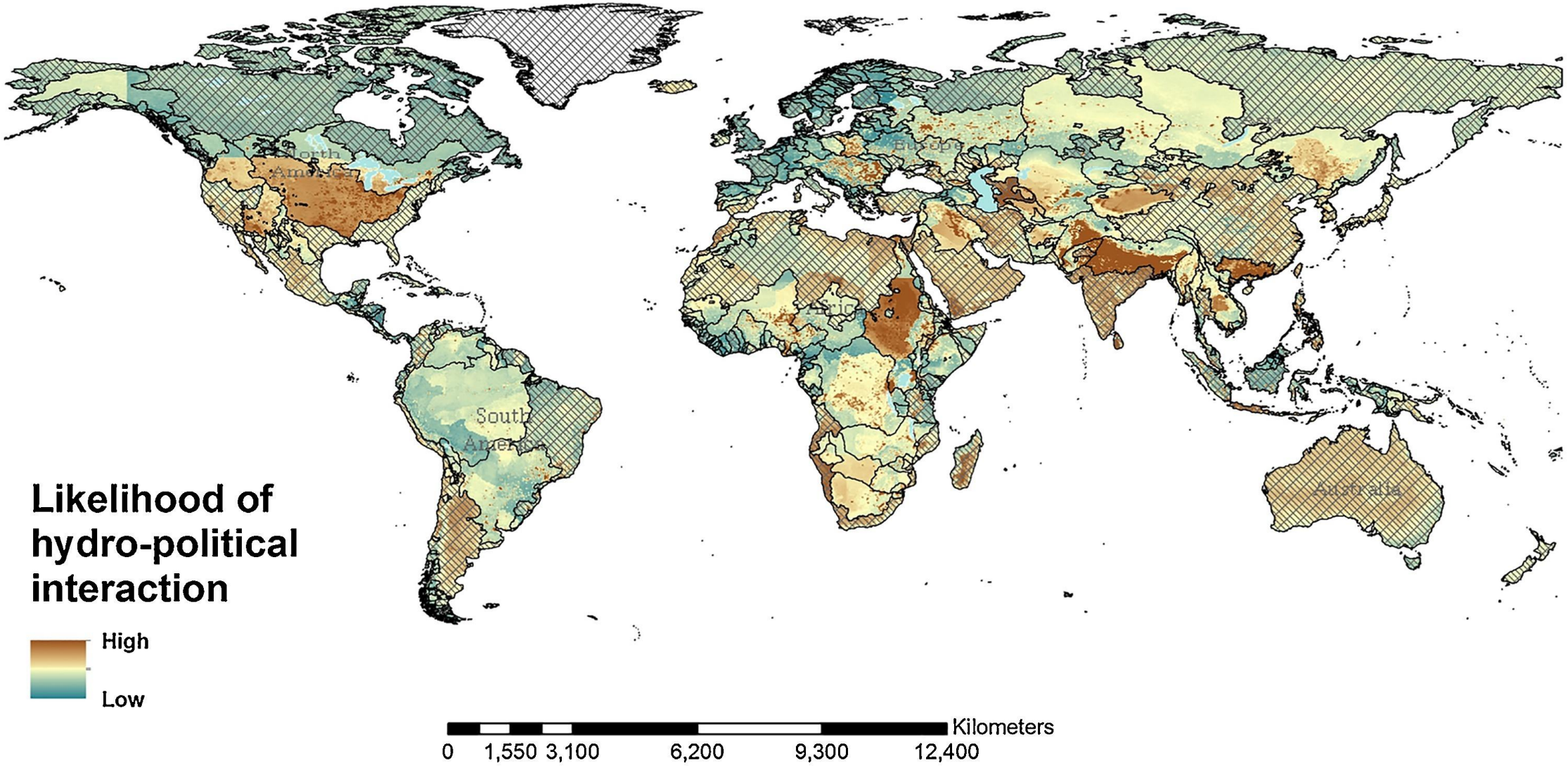
- **Estimated using water management models that include food, energy, environmental, and health components for specific basins or regions.**



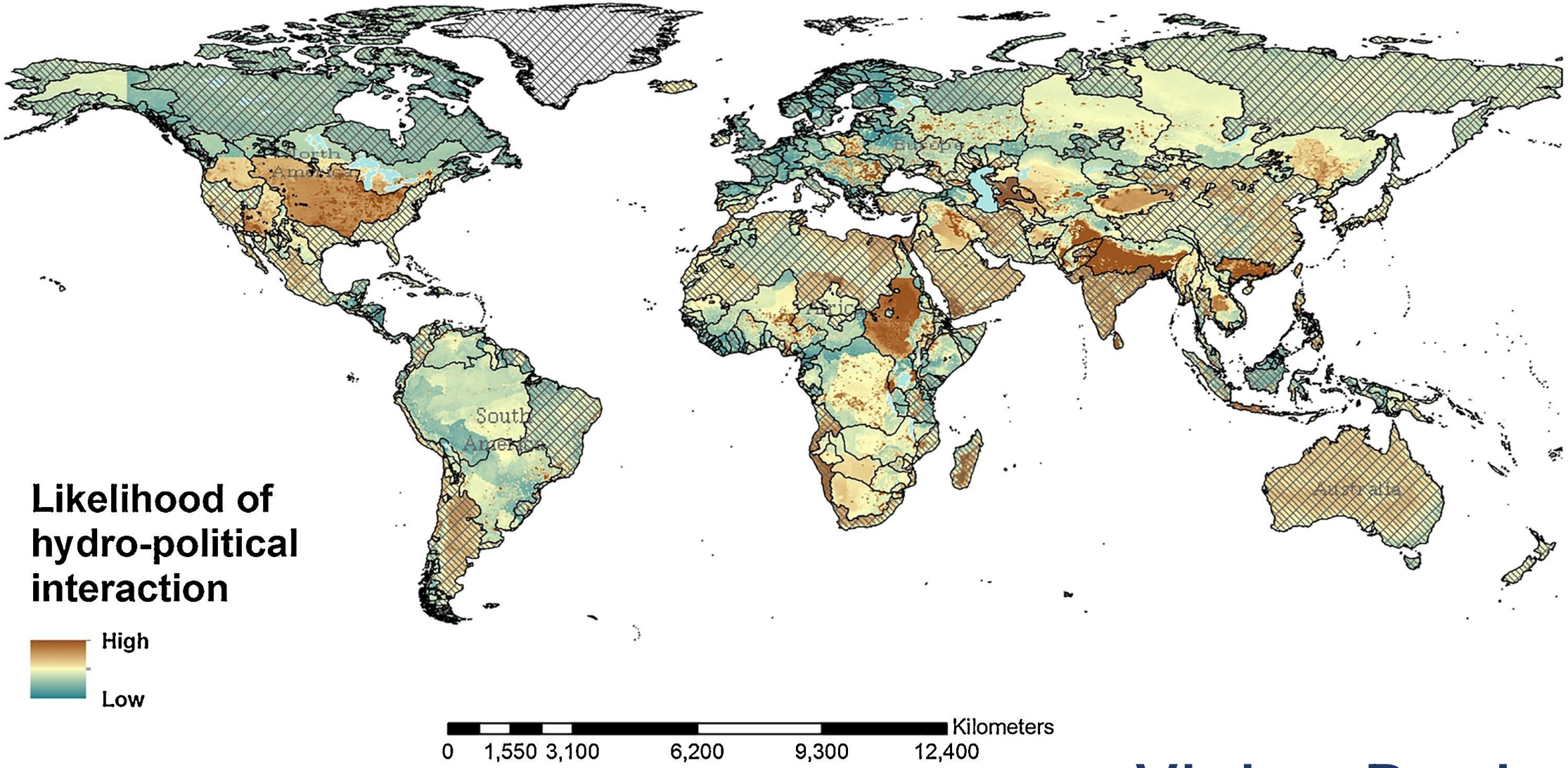
Interfaces with society

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?

- **Water management failures in areas of water stress and conflict contributes to migration.**



Likelihood of hydro-political issues in the main transboundary basins



Vielen Dank.

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