Hydrology

Marc Simard

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- Water resources
  - Lake and reservoir
    - Water surface height and bathymetry
  - Wetlands
    - Extent, depth, variability
  - River flows
    - Ground slopes
    - Water surface slopes
  - Snow packs and melt
    - Snow depth, SWE and changes
  - Ground water (e.g. Recharge and discharge,, Permafrost melt)
    - Subsidence
- Flooding and inundation modeling
- Wetland processes and management

Challenges in Hydrologic Sciences

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

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Modelling Freshwater Resources at the Global Scale: Challenges and Prospects

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Abstract Quantification of spatially and temporally resolved water flows and water storage variations for all land areas of the globe is required to assess water resources, water scarcity and flood hazards, and to understand the Earth system. This quantification is done with the help of global hydrological models (GHMs). What are the challenges and prospects in the development and application of GHMs? Seven important challenges are presented. (1) Data scarcity makes quantification of human water use difficult even though significant progress has been achieved in the last decade. (2) Uncertainty of meteorological input data strongly affects model outputs. (3) The reaction of vegetation to changing climate and CO_2 concentrations is uncertain and not taken into account in most GHMs that serve to estimate climate change impacts. (4) Reasons for discrepant responses of GHMs to changing climate have yet to be identified. (5) More accurate estimates of monthly time

1464 © 2019 The Author Hydrology R

A global hydrology research agenda fit for the 2030s

Robert L. Wilby

ABSTRACT

Global assessments show profound impacts of human activities on freshwater systems that, without action, are expected to reach crisis point in the 2030s. By then, the capacity of natural systems to meet rising demands for water, food, and energy could be hampered by emerging signals of anthropogenic climate change. The hydrological community has always been solution-orientated, but our generation faces perhaps the greatest array of water challenges in human history. Ambitious programmes of research are needed to fill critical data, knowledge, and skills gaps. Priorities include filling data sparse places, predicting peak water, understanding the physical drivers of mega

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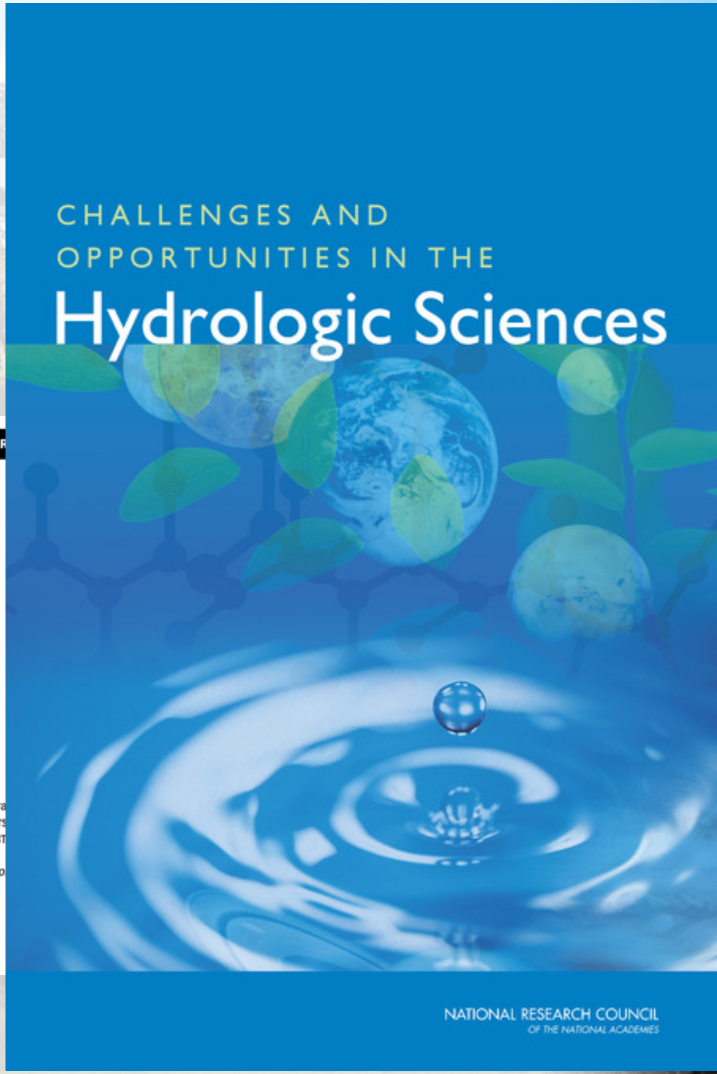

The Decadal Survey

What is recommended for hydrology?

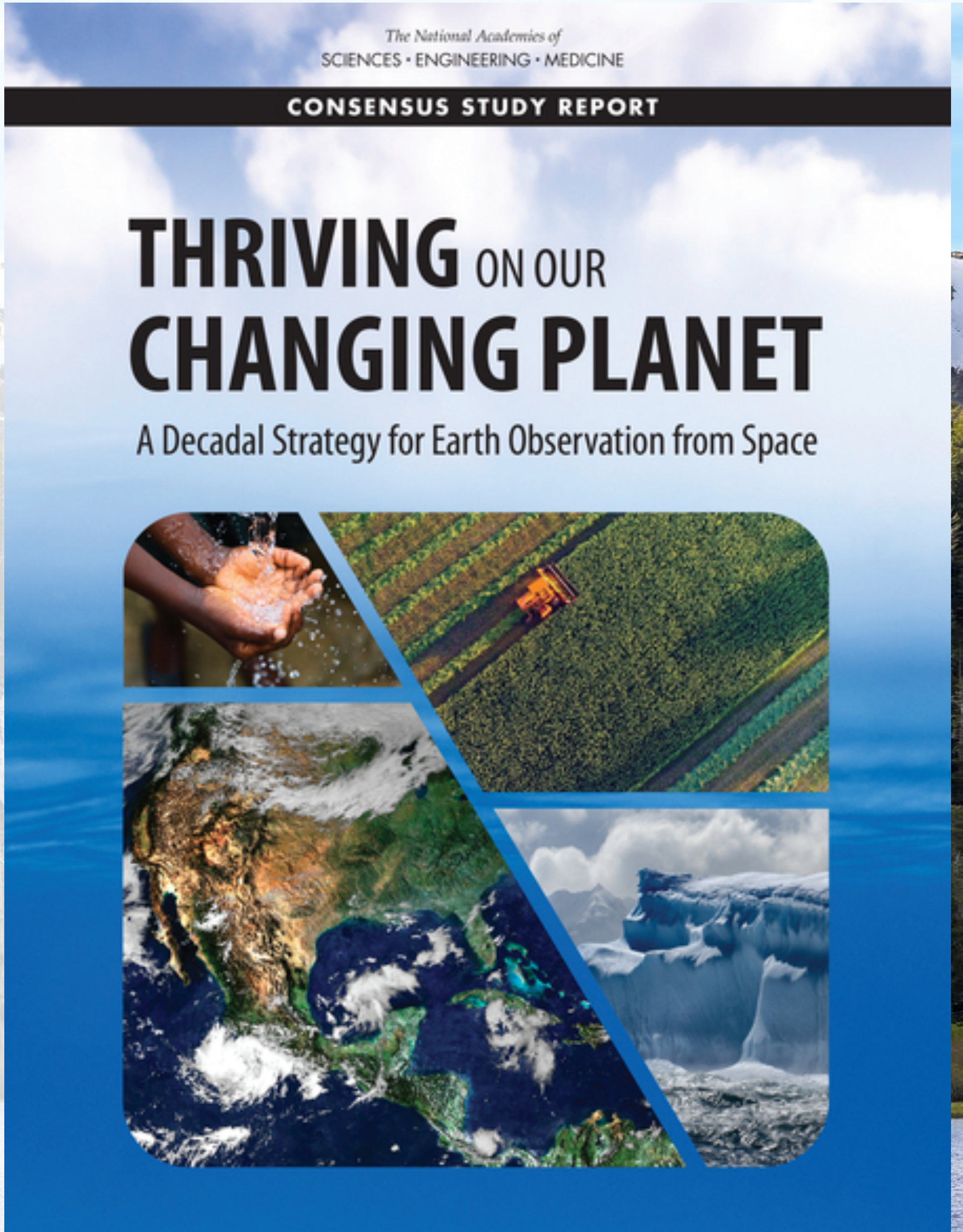

TABLE 3.2 Science and Applications Priorities for the Decade 2017-2027—The Science and Applications Portion of the Full Science and Applications Traceability Matrix (SATM) in Appendix B

Societal or Science Question/Goal	Earth Science/Applications Objective	Importance
QUESTION H-1. Water Cycle Acceleration. How is the water cycle changing? Are changes in evapotranspiration and precipitation accelerating, with greater rates of evapotranspiration and thereby precipitation, and how are these changes expressed in the space-time distribution of rainfall, snowfall, evapotranspiration, and the frequency and magnitude of extremes such as droughts and floods?	**H-1a.** Develop and evaluate an integrated Earth system analysis with sufficient observational input to accurately quantify the components of the water and energy cycles and their interactions, and to close the water balance from headwater catchments to continental-scale river basins.	Most Important
	H-1b. Quantify rates of precipitation and its phase (rain and snow/ice) worldwide at convective and orographic scales suitable to capture flash floods and beyond.	Most Important
	H-1c. Quantify rates of snow accumulation, snowmelt, ice melt, and sublimation from snow and ice worldwide at scales driven by topographic variability.	Most Important
QUESTION H-2. Impact of Land Use Changes on Water and Energy Cycles. How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally, and globally, and what are the short- and long-term consequences?	**H-2a.** Quantify how changes in land use, water use, and water storage affect evapotranspiration rates, and how these in turn affect local and regional precipitation systems, groundwater recharge, temperature extremes, and carbon cycling.	Very important
	[STV] H-2b. Quantify the magnitude of anthropogenic processes that cause changes in radiative forcing, temperature, snowmelt, and ice melt, as they alter downstream water quantity and quality.	important
	[TO=STV] H-2c. Quantify how changes in land use, land cover, and water use related to agricultural activities, food production, and forest management affect water quality and especially groundwater recharge, threatening sustainability of future water supplies.	Most important
QUESTION H-3. How do changes in the water cycle impact local and regional freshwater availability, alter the biotic life of streams, and affect ecosystems and the services these provide?	**H-3a.** Develop methods and systems for monitoring water quality for human health and ecosystem services.	Important
	H-3b. Monitor and understand the coupled natural and anthropogenic processes that change water quality, fluxes, and storages in and between all reservoirs (atmosphere, rivers, lakes, groundwater, and glaciers) and the response to extreme events.	Important
	[STV] H-3c. Determine structure, productivity, and health of plants to constrain estimates of evapotranspiration.	Important
QUESTION H-4. How does the water cycle interact with other Earth system processes to change the predictability and impacts of hazardous events and hazard chains (e.g., floods, wildfires, landslides, coastal loss, subsidence, droughts, human health, and ecosystem health), and how do we improve preparedness and mitigation of water-related extreme events?	**H-4a.** Monitor and understand hazard response in rugged terrain and land margins to heavy rainfall, temperature, and evaporation extremes, and strong winds at multiple temporal and spatial scales.	Very Important
	[STV] H-4b. Quantify key meteorological, glaciological, and solid Earth dynamical and state variables and processes controlling flash floods and rapid hazard chains to improve detection, prediction, and preparedness. (This is a critical socioeconomic priority that depends on success of addressing H-1c and H-4a.)	Important
	H-4c. Improve drought monitoring to forecast short-term impacts more accurately and to assess potential mitigations.	Important
	[STV] H-4d. Understand linkages between anthropogenic modification of the land, including fire suppression, land use, and urbanization on frequency of, and response to, hazards. (This is tightly linked to H-2a, H-2b, H-4a, H-4b, and H-4c.)	important

Goals

- ***H-1. Water Cycle Acceleration.*** How is the water cycle changing? Are changes in evapotranspiration and precipitation accelerating, with greater rates of evapotranspiration and thereby precipitation, and how are these changes expressed in the space-time distribution of rainfall, snowfall, evapotranspiration, and the frequency and magnitude of extremes such as droughts and floods?
- ***H-2. Impact of Land Use Changes on Water and Energy Cycles.*** How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally, and globally, and what are
- ***H-3.*** How do changes in the water cycle impact local and regional freshwater availability, alter the biotic life of streams, and affect ecosystems and the services these provide?
- ***H-4.*** How does the water cycle interact with other Earth system processes to change the predictability and impacts of hazardous events and hazard chains (e.g., floods, wildfires, landslides, coastal loss, subsidence, droughts, human health, and ecosystem health), and how do we improve preparedness and mitigation of water- related extreme events?

Most Important Objectives

H-1a. Develop and evaluate an integrated Earth system analysis with sufficient observational input to accurately quantify the components of the water and energy cycles and their interactions, and to close the water balance from headwater catchments to continental-scale river basins.
H-1b. Quantify rates of precipitation and its phase (rain and snow/ice) worldwide at convective and orographic scales suitable to capture flash floods and beyond.
H-1c. Quantify rates of snow accumulation, snowmelt, ice melt, and sublimation from snow and ice worldwide at scales driven by topographic variability.
[TO=STV] H-2c. Quantify how changes in land use, land cover, and water use related to agricultural activities, food production, and forest management affect water quality and especially groundwater recharge, threatening sustainability of future water supplies.

Hydrology also serves other disciplines

TABLE 3.2 Science and Applications Priorities for the Decade 2017-2027—The Science and Applications Portion of the Full Science and Applications Traceability Matrix (SATM) in Appendix B

Societal or Science Question/Goal	**Earth Science/Applications Objective**	Importance
QUESTION S-4. What processes and interactions determine the rates of landscape change?	**S4b.** Quantify weather events, surface hydrology, and changes in ice/water content of near-surface materials that produce landscape	Important
QUESTION S-3. How will local sea level change along coastlines around the world in the next decade to century?	**[TO=STV] S-3b.** Determine vertical motion of land along coastlines, at uncertainty <1 mm/yr .	Most important
QUESTION S-6. How much water is traveling deep underground and how does it affect geological processes and water supplies?	**[TO=STV] S-6b.** Measure all significant fluxes in and out of the groundwater system across the recharge area.	Important
	S-6c. Determine the transport and storage properties in situ within a factor of 3 for shallow aquifers and an order of magnitude for deeper systems.	Important
	S-6d. Determine the impact of water-related human activities and natural water flow on earthquakes.	Important

Conclusion and observation from Global Hydrological Cycles and Water Resource Panel

- Although mentioned, the Decadal Survey does not provide requirements for topography.
- Water-related variables to address the most important hydrological science challenges and to water resource applications include: **soil moisture**, **stream flow**, **lake and reservoir levels**, **snow cover**, **glaciers and ice mas**s, **evaporation and transpiration**, **groundwater**, **water quality**, and **water use**.
  - However, high-resolution precipitation measurements emerged as a high priority with the Decadal Survey's Hydrology panel.
- While some objectives were not associated with STV, its potential ability to provide measurements of snow depth and topography could directly contribute, for example, to these objectives:
  - **H-1a.** Develop and evaluate an integrated Earth system analysis with sufficient observational input to accurately quantify the components of the water and energy cycles and their interactions, and to close the water balance from headwater catchments to continental-scale river basins.
  - **H-1c.** Quantify rates of snow accumulation, snowmelt, ice melt, and sublimation from snow and ice worldwide at scales driven by topographic variability.

Why not look into water-related variables to address most important hydrological science challenges?

Geophysical measurement	STV (i.e. height) addressing measurements?	Needed additional measurements	partially if
stream flow	Yes (discharge from slope)	River cross-section	
Lake and reservoir volume, and/or change	yes	Elevation/bathymetry	
snow depth	yes	Density/SWE	Partially with depth through modeling
glaciers and ice mass/change/melt	Yes	Depth/SWE	
water quality	No		Lidar may get wq, depth profile turbidity
LCLUC impact on water use/supplies	No	LCLUC and infrastructure monitoring	
Land topography and vegetation structure	yes		Into models for soil moisture (eg hill slopes), evaporation and transpiration (eg vegetation structure), and ground water (eg. Subsidence).

Scope of Study for STV

What the hydrological science questions that can benefits from large-scale (e.g. global) measurements of surface elevation?

What are the data product needs to achieve the related objectives?

Note that surface elevation may be that of the ground, water surface, snow surface and vertical structure of vegetation.

Example of SATM (science and applications traceability matrix)

Science and Applications		Physical Parameters		Level 3 or 4 Product	Spatial Needs			Temporal needs
Goals	**Objectives**	**Targeted Observable**	**Physical parameter needed**		**Observed Area**	**Coverage (%)**	**Sampling Distance (m)**	
H-3. How do changes in the water cycle impact local and regional freshwater availability, alter the biotic life of streams, and affect ecosystems and the services these provide?	H-3b. Monitor and understand the coupled natural and anthropogenic processes that change water quality, fluxes, and storages in and between all reservoirs (atmosphere, rivers, lakes, groundwater, and glaciers) and the response to extreme events	Surface Topography Vegetation Structure	Shallow bathymetry Vegetation Structure Water Surface elevation Snow Depth …and changes	Digital Terrain model Stem density Canopy volume SWE	Global Lands ~~Deserts of North Africa~~ All basins >1000 km^2	-- 100 66	50 m 25 m 10 m	Monthly Seasonally

Hydrology summary

- Charge to community
  - Identify science priorities
  - Evaluate state-of-the-art science, models and measurements
  - Identify product gaps
  - Identify priority products—related to elevation and vegetation structure—to significantly advance science toward goal
    - Note: elevation can be of ground (topography & bathymetry), water and snow surface, etc.
  - Where, when and how often should these products be generated?
  - Justify for measurement needs