Dialogue:
Developing a Hydrology Research Strategy to Enhance Water Security in South Africa

Towards a Hydrology research strategy

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26 August 2021

IWR

50 Years | WATER RESEARCH COMMISSION

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AIMS

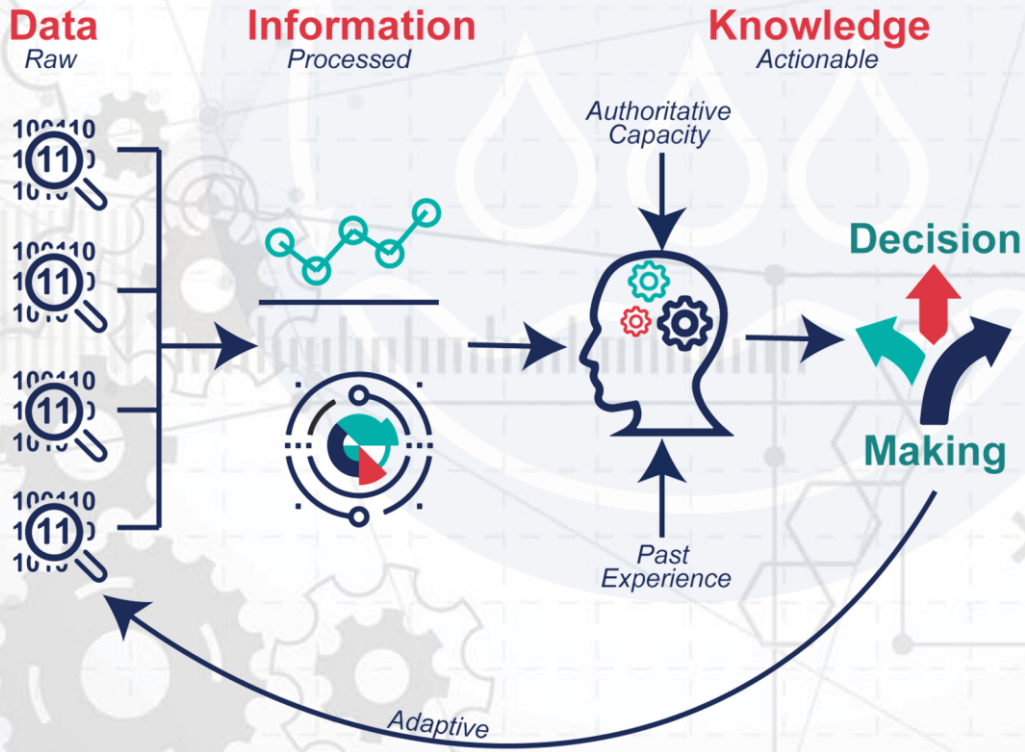
A review of and scoping for water scarcity/security research in South Africa: towards a research strategy

The aim of this study is to **review, consolidate and scope** hydrological and water resources research considering the projected socio-economic trajectories, demand and needs patterns and changes in weather patterns and climate.

INTERNATIONAL ALIGNMENT / NATIONAL RELEVANCE

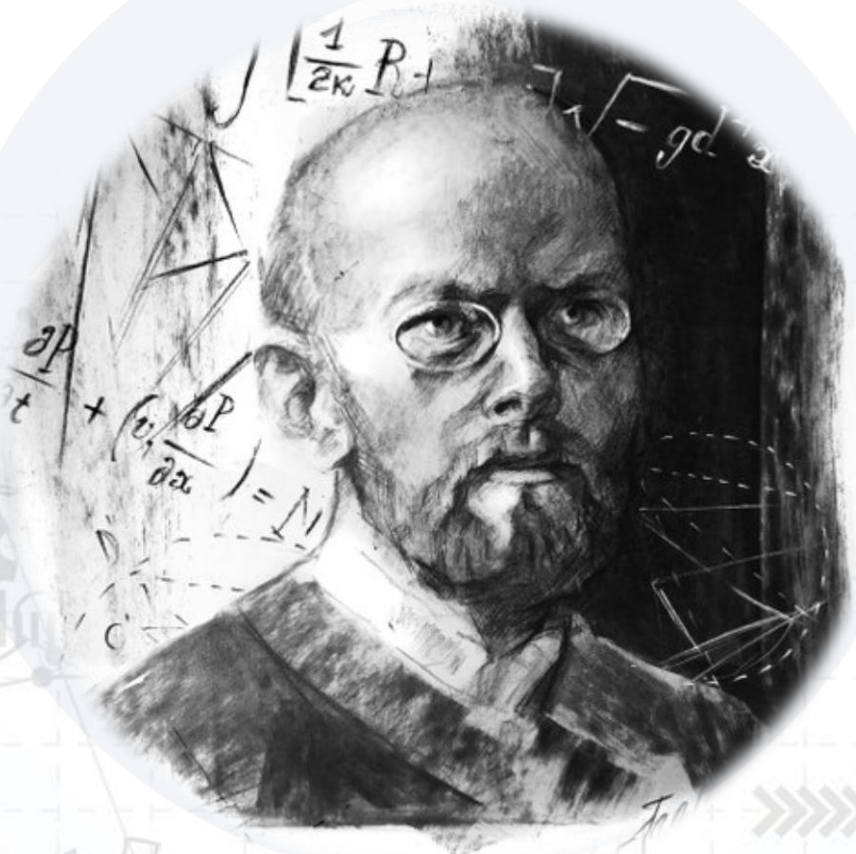
2003-2012, IAHS Decade - Predictions in Ungauged Basins (PUB)

2013–2022, IAHS Decade - Panta Rhei—Everything Flows



TWENTY-THREE UNSOLVED PROBLEMS IN HYDROLOGY

David Hilbert in 1900



Influenced 20th-century mathematics

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

Günter Blöschl, Marc F.P. Bierkens, Antonio Chambel, Christophe Cudennec, Georgia Destouni, Aldo Fiori, James W. Kirchner, Jeffrey J. McDonnell, Hubert H.G. Savenije, Murugesu Sivapalan, Christine Stumpp, Elena Toth, Elena Volpi, Gemma Carr, Claire Lupton, José Salinas, Borbála Széles, Alberto Viglione, Hafzullah Aksoy, Scott T. Allen, Anam Amin, Vazken Andréassian, Berit Arheimer, Santosh K. Aryal, Victor Baker, Earl Bardsley, Marlies H. Barendrecht, Alena Bartosova, Okke Batelaan, Wouter R. Berghuijs, Keith Beven, Theresa Blume, Thom Bogaard, Pablo Borges de Amorim, Michael E. Böttcher, Gilles Boulet, Korbinian Breinl, Mitja Brilly, Luca Brocca, Wouter Buytaert, Attilio Castellarin, Andrea Castelletti, Xiaohong Chen, Yangbo Chen, Yuanfang Chen, Peter Chifflard, Pierluigi Claps, Martyn P. Clark, Adrian L. Collins, Barry Croke, Annette Dathe, Paula C. David, Felipe P. J. de Barros, Gerrit de Rooij, Giuliano Di Baldassarre, Jessica M. Driscoll, Doris Duethmann, Ravindra Dwivedi, Ebru Eris, William H. Farmer, James Feiccabrino, Grant Ferguson, Ennio Ferrari, Stefano Ferraris, Benjamin Fersch, David Finger, Laura Foglia, Keirnan Fowler, Boris Gartsman, Simon Gascoin, Eric Gaume, Alexander Gelfan, Josie Geris, Shervan Gharari, Tom Gleeson, Miriam Glendell, Alena Gonzalez Bevacqua, María P. González-Dugo, Salvatore Grimaldi, A. B. Gupta, Björn Guse, Dawei Han, David Hannah, Adrian Harpold, Stefan Haun, Kate Heal, Kay Helfricht, Mathew Herrnegger, Matthew Hipsey, Hana Hlaváčiková, Clara Hohmann, Ladislav Holko, Christopher Hopkinson, Markus Hrachowitz, Tissa H. Illangasekare, Azhar Inam, Camyla Innocente, Erkan Istanbulluoglu, Ben Jarihani, Zahra Kalantari, Andis Kalvans, Sonu Khanal, Sina Khatami, Jens Kiesel, Mike Kirkby, Wouter Knoben, Krzysztof Kochanek, Silvia Kohnová, Alla Kolechkina, Stefan Krause, David Kreamer, Heidi Kreibich, Harald Kunstmann, Holger Lange, Margarida L. R. Liberato, Eric Lindquist, Timothy Link, Junguo Liu, Daniel Peter Loucks, Charles Luce, Gil Mahé, Olga Makarieva, Julien Malard, Shamshagul Mashtayeva, Shreedhar Maskey, Josep Mas-Pla, Maria Mavrova-Guirguinova, Maurizio Mazzoleni, Sebastian Mernild, Bruce Dudley Misstear, Alberto Montanari, Hannes Müller-Thomy, Alireza Nabizadeh, Fernando Nardi, Christopher Neale, Nataliia Nesterova, Bakhram Nurtaev, Vincent O. Odongo, Subhabrata Panda, Saket Pande, Zhonghe Pang, Georgia Papacharalampous, Charles Perrin, Laurent Pfister, Rafael Pimentel, María J. Polo, David Post, Cristina Prieto Sierra, Maria-Helena Ramos, Maik Renner, José Eduardo Reynolds, Elena Ridolfi, Riccardo Rigon, Monica Riva, David E. Robertson, Renzo Rosso, Tirthankar Roy, João H.M. Sá, Gianfausto Salvadori, Mel Sandells, Bettina Schaefli, Andreas Schumann, Anna Scolobig, Jan Seibert, Eric Servat, Mojtaba Shafiei, Ashish Sharma, Moussa Sidibe, Roy C. Sidle, Thomas Skaugen, Hugh Smith, Sabine M. Spiessl, Lina Stein, Ingelin Steinsland, Ulrich Strasser, Bob Su, Jan Szolgay, David Tarboton, Flavia

RELEVANT UNSOLVED PROBLEMS 1 OF 2

THEME	#	Subject
Time variability and change	1	Irreversible hydrological changes under climate change
	2	Cold region runoff and groundwater change in a warmer climate
	3	CC and Water use impact on ephemeral rivers and groundwater
	4	Impact of land cover and soil disturbance on water fluxes
Space variability and scaling	5	Spatial heterogeneity and homogeneity
	6	Catchment scale hydrological laws
	7	Preferential flows across multiple scales
	8	Streamflow response to precipitation
Variability of extremes	9	Changes in flood and drought rich periods
	10	Sensitivity of runoff extremes to land use/cover changes, etc
	11	Runoff from rain-on snow event

RELEVANT UNSOLVED PROBLEMS 2 OF 2

THEME	#	Subject
Interfaces in hydrology	12	Hillslope–riparian–stream–groundwater interactions
	13	Groundwater fluxes across boundaries
	14	Long-term persistence of sources responsible for the degradation of water quality
	15	Extent, fate and impact of contaminants of emerging concern
Measurements and data	16	Innovative techn. to measure variables at different spatial and temporal scales
	17	Traditional hydrological observations vs soft data
	18	Data for socio-hydrological models and conceptualisations
Modelling methods	19	Adapt hydrological models to changing conditions
	20	Reduce hydrological model uncertainty (structure/parameter/input)
Interfaces with society	21	Communicate uncertainty results
	22	Society and water management
	23	Water and migration, urbanisation, civilisation dynamic

ADDITIONAL QUESTIONS

THEME	#	Subject
Additional	1	Water use data
	2	Model improvement for better process representation.
	3	Structured hydrological society
	4	National database of hydrological information
	5	Soil data

THE APPROACH

Searches conducted per (questions) themes on the major databases

Snowball technique applied to identify other relevant work

Systematic literature review to identify:

- relevant studies
- Research and knowledge gap

A focus of surface hydrology

Not enough work done is published – Too many reports hard to access.

TIME VARIABILITY AND CHANGE

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

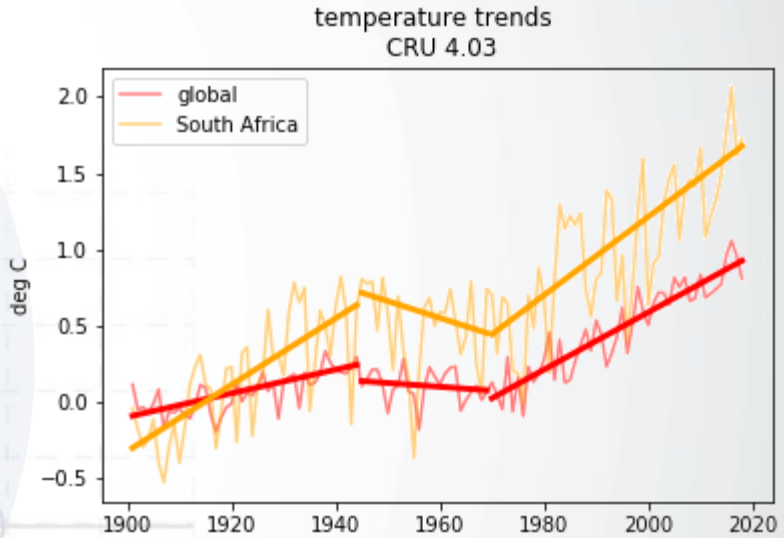
Projected changes in climate in South Africa? (meteorologist).

Impact of CC on water resources (surface and groundwater)

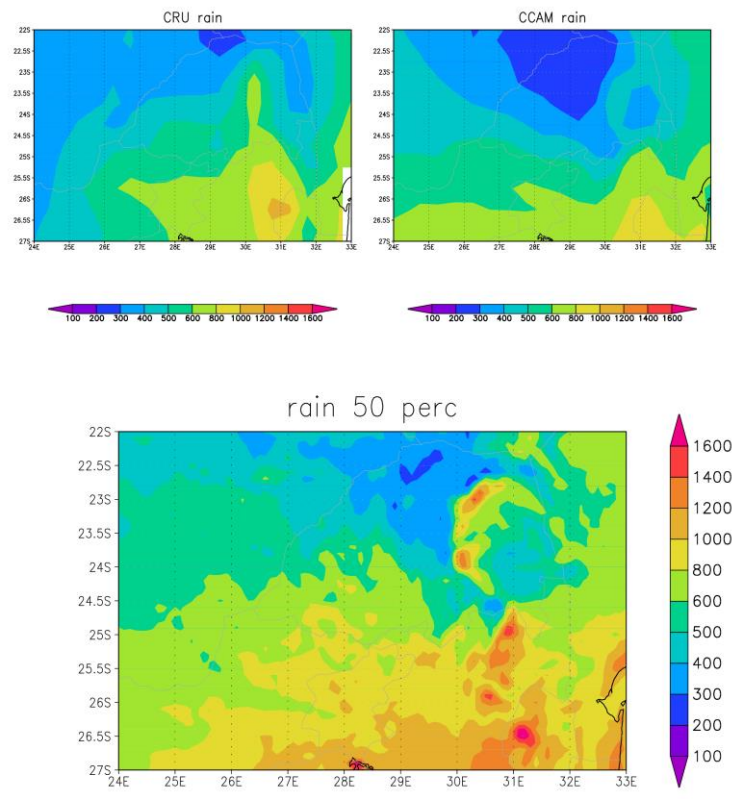
Areas (i.e. main water sources areas) that require more detail assessment of the impact of CC on the hydrology and WR

Impact of climate change on water resources and water supply

Impact of climate change on water services.



TIME VARIABILITY AND CHANGE



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

What are the hydrological thresholds (ecological flow, maximum allowable flood that society can cope with and minimum allowable flow that is required for livelihoods and navigation, etc.) and response to climate change forcing?

TIME VARIABILITY AND CHANGE

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

How will future climate interact with the land use changes, the water use changes and affect the country's hydrology and water resources?

What are the most suitable approaches to reduce the bias of climate models in order to improve the efficiency of climate change impact studies on hydrological regimes?

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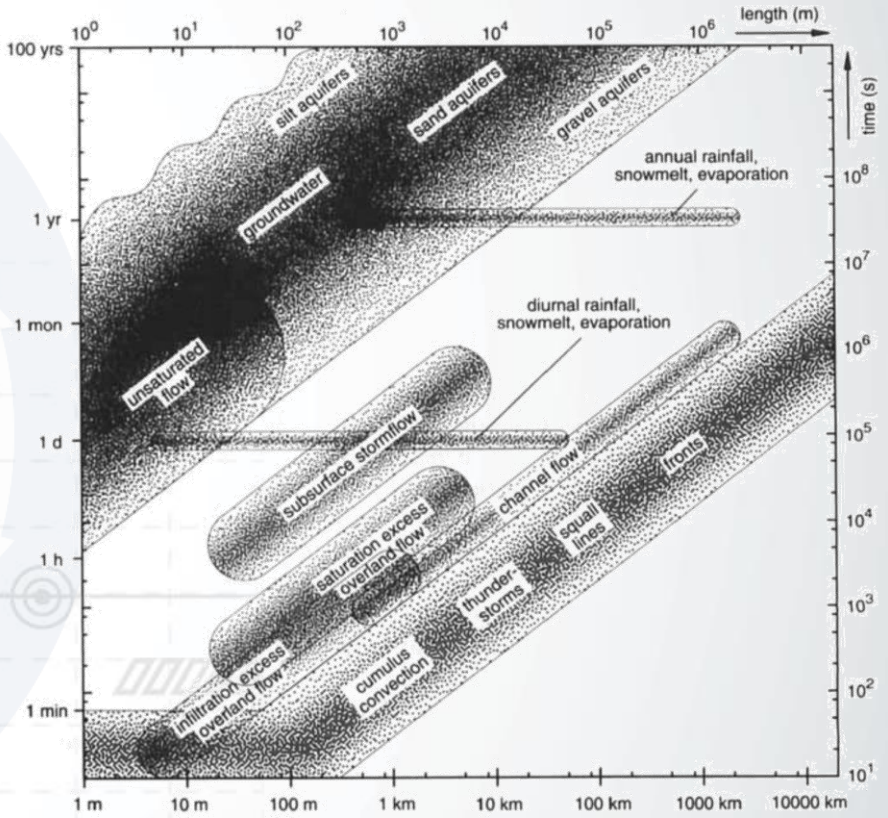
SPACE VARIABILITY AND SCALING

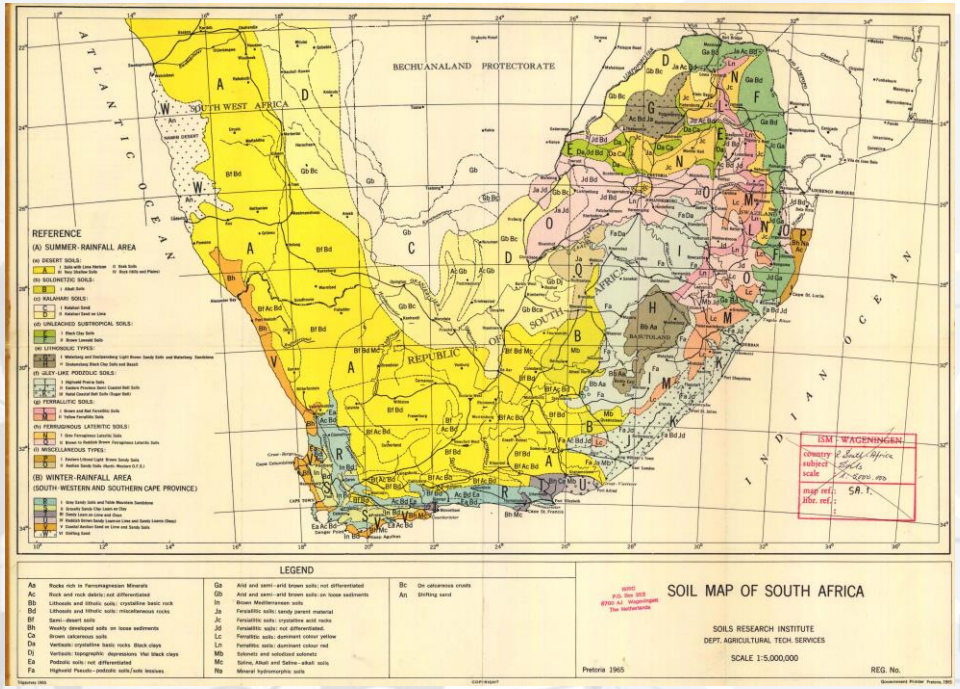
What causes spatial heterogeneity and homogeneity in runoff, evaporation, subsurface water and material fluxes (carbon and other nutrients, sediments), and in their sensitivity to their controls (e.g. snow fall regime, aridity, reaction coefficients)?

What is the optimum level of discretisation (hydrologic response unit) to sufficiently address the catchment heterogeneity?

Explore hillslope-based catchment decomposition approach superior to hydrologic response unit (HRU)



SPACE VARIABILITY AND SCALING



Land type and soils data

Disaggregate the land types to provide the spatial distribution of various hillslopes and hydrological soil types within a land type

Produce a high-resolution soil map of South Africa for hydrological purposes

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VARIABILITY OF EXTREMES

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

Floods

Research priorities identified by Smithers and Schulze (2003) and Van Vureen et al., (2013).

Flood hazard mapping

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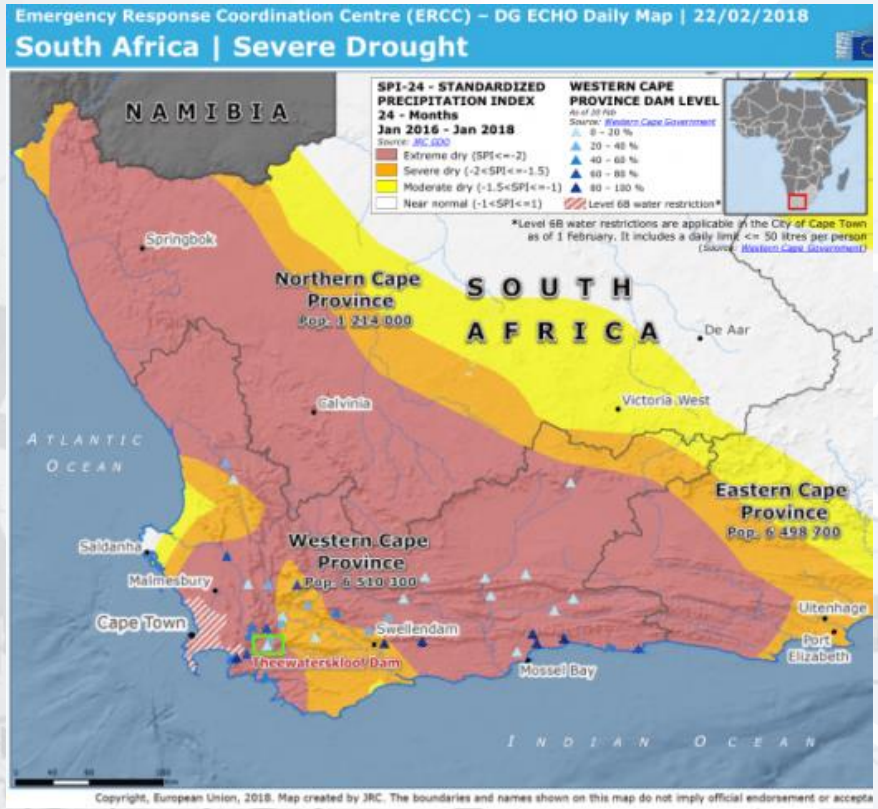
VARIABILITY OF EXTREMES

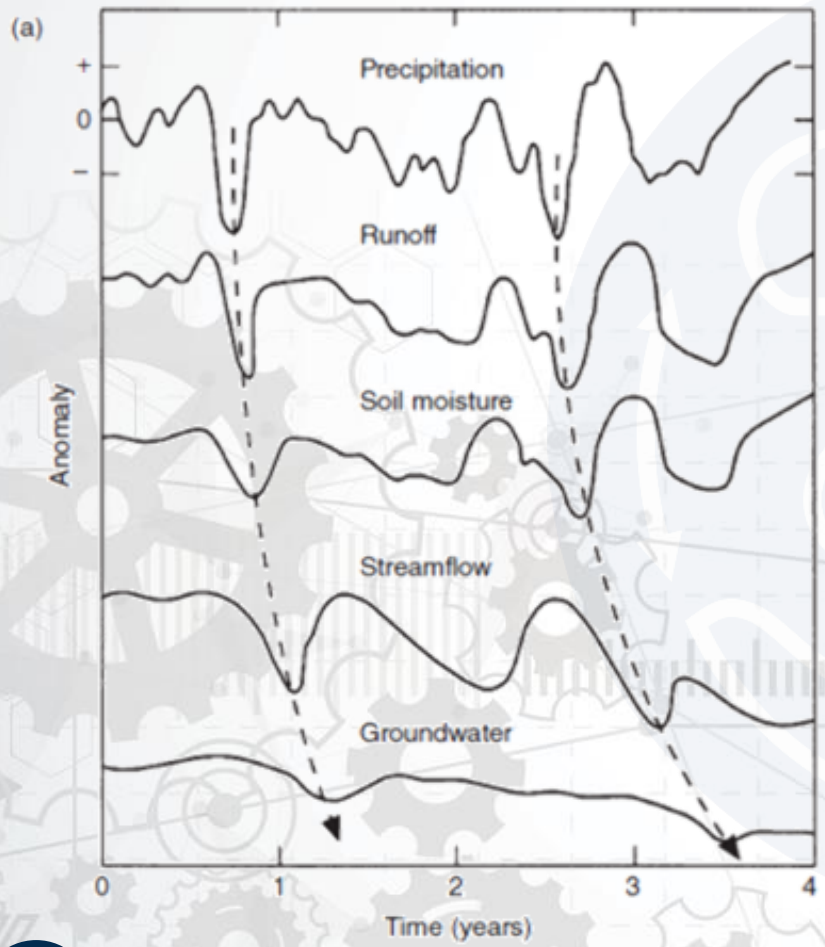


Droughts

Further our understanding of hydrological drought. Identify and address uncertainties and gaps in our knowledge about hydrological drought (Loon, 2015).

Better quantification of hydrological drought. SPI and SPEI fall short in many regards. Investigate the use of a multitude of drought indices or even a composite index in hydrological drought monitoring.

VARIABILITY OF EXTREMES



Droughts

Moving to including the human aspects of hydrological drought (Loon, 2015). One of the questions is exploring the impacts of human intervention in drought propagation.

Application of drought research in water management and policy (Loon, 2015).

Changes in the drought signal due to propagation through the hydrological cycle, especially groundwater

VARIABILITY OF EXTREMES

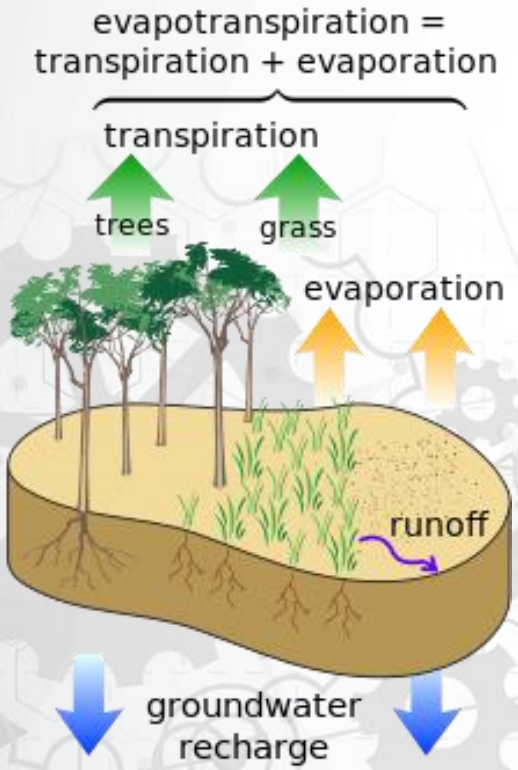
Why are runoff extremes in some catchments more sensitive to land-use/cover and geomorphic change than in others?

Incorporate non-stationary LULC in hydrological modelling

Apportion the impact of LULC changes on hydrological processes

Consider both anthropogenically induced biophysical changes and natural long-term growth in LUCC impact studies for large basins.

INTERFACES IN HYDROLOGY



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

Better quantify the interactions between surface and sub-surface systems

Further research on the complex interaction between human beings and the natural environment;

Better quantification of hydrological impacts of the invasion of alien vegetation in water source areas and along streamflow paths.

The need to monitor vegetation occurrences and their impacts on water resources availability

Back to basics - research catchment

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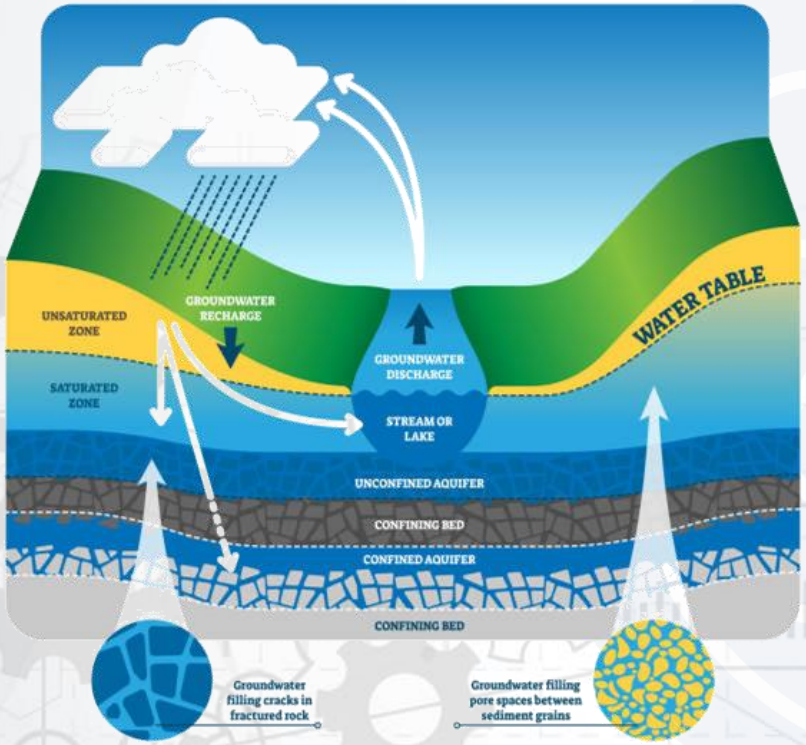
INTERFACES IN HYDROLOGY



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

Better quantification of groundwater hydrology to:

- *Bridge the gap between hydrology and hydrogeology;*
- *Improve modelling of the 'complete' hydrological cycle*

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MEASUREMENTS AND DATA

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

Evaluation and assimilation of various satellite-derived hydrological variable products over South Africa.

Investigate the accuracy of relevant satellite data from different sources against reliable ground station data

Bias correction of remotely sensed hydrological variables – Digital Earth

Innovative techniques and instruments to measure rainfall, river discharge, soil moisture, etc. in South Africa.

MEASUREMENTS AND DATA

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

Citizen science-based network to record daily precipitation using low-cost tools across South Africa. Great potential to involved primary and secondary school kids.

Physical and virtual staff gauges for crowd-based stream level observations

MEASUREMENTS AND DATA

How can we improve our water use data?

Update WARMS using the V&V data and other existing databases.

Identify and collate all relevant datasets and update WARMS. Work in cooperation with all entities collecting water-use information and compile these data to produce water-use information aggregated at relevant hydrological and administrative boundaries. Every five years, compile and disseminate the nation's water use data for the main water use categories.

Develop a unified approach for collecting and organising water use information.

MEASUREMENTS AND DATA

A national water data repository?

Establish a national water data repository

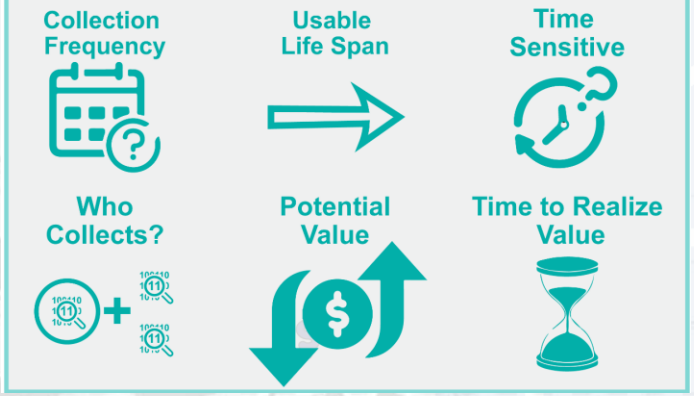
Data Valuation - Explore common costs associated with data collection and the impact of different data purposes on its attributes and value.

Quantify, document or communicate the value of open, shared and integrated water data.

MEASUREMENTS AND DATA

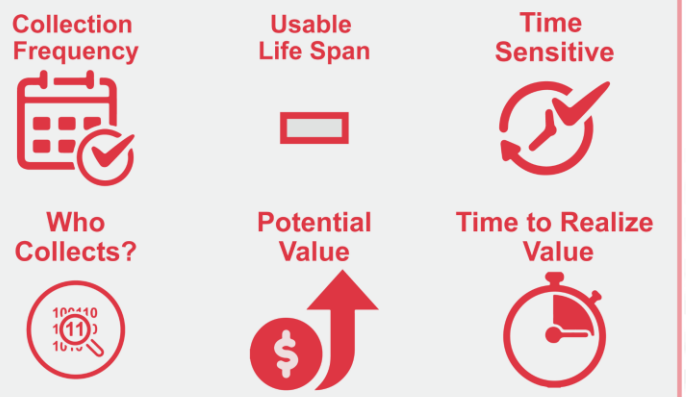
Research and Innovation Data

Used to innovate and create more efficient and higher impact decisions.



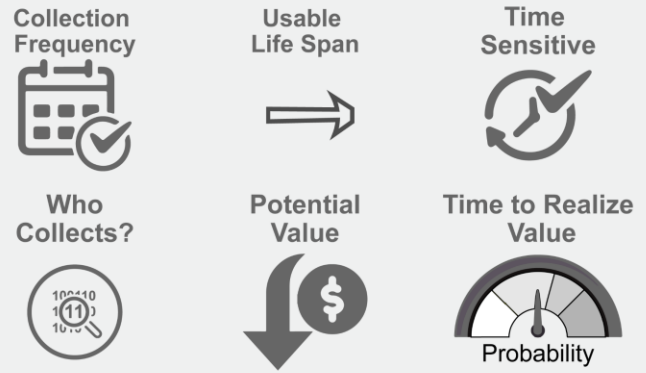
Operational Data

Used on a regular basis to inform day-to-day operations.



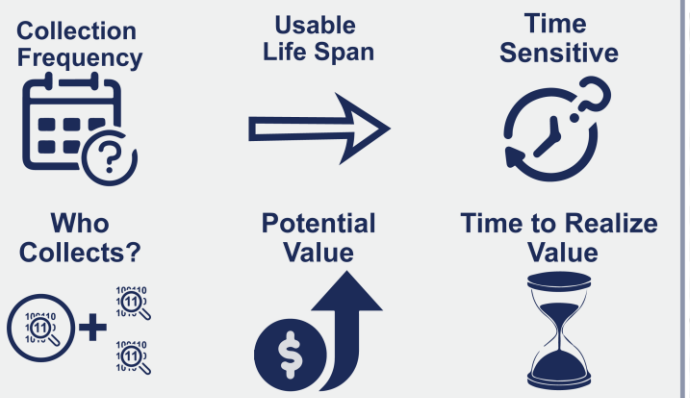
Regulatory Data

Used to determine if organizations are in compliance with regulations.



Broad Temporal/Spatial Decision-Making Data

Used to inform policy, investment, management, and decision support systems.



MODELLING METHODS

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

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

How can we improve SA hydrological model to better represent processes?

Which key hydrological processes are not properly represented in the Pitman and the ACRU models?

Update the Pitman model to better represent key identified hydrological processes.
Update the ACRU model to better represent key identified hydrological processes

INTERFACES WITH SOCIETY

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

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

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OBSERVATIONS

Hydrologic Sciences is extending into new territories

We must integrate with related sciences and embrace other (sub) disciplines

Systematic attention to the importance of hydrologic science in the public policy process

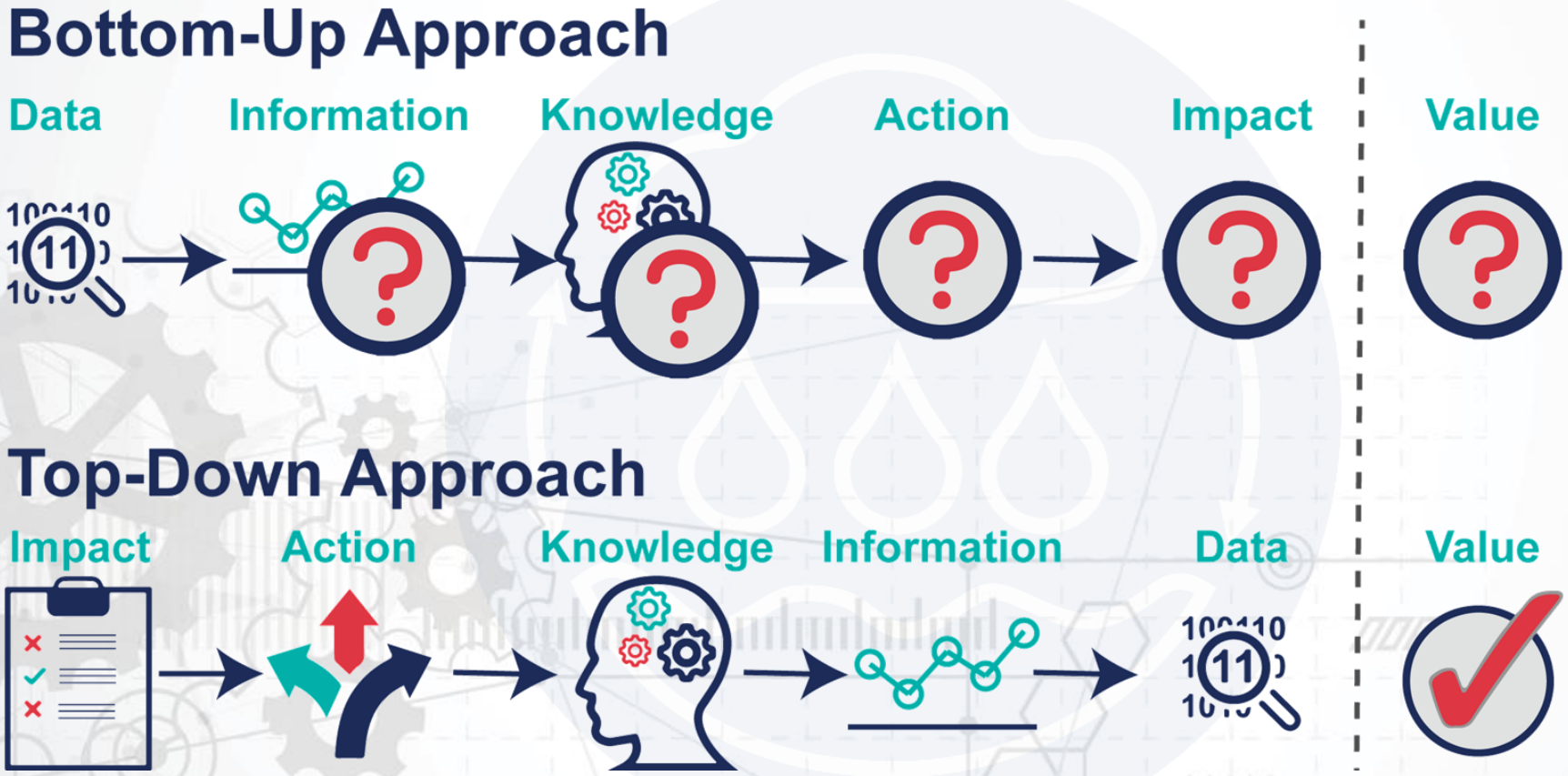
Need of deeper collaboration and communication with colleagues in the social sciences, including economics, political science, psychology, and sociology.

Deeper discipline knowledge – Research catchments

Enhance communication skills

SANCIAHS (Hydrology COP) to lead the next iteration of the research strategy?

OBSERVATION



RESOURCES

Money

- How big is the research slice?
- What are the needs of other disciplines?

People

- Where is the next generation of hydrologists?

Thank you

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