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CABOT INSTITUTE

IAHS AISH

Panta Rhei
Water and Society: Science and Education

Thorsten Wagener

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In this talk I will discuss how I see hydrology education evolve

1. Water and society
2. Shifting baseline for hydrology education
3. Current hydrology education
4. Future hydrology education
5. Some examples of connecting across disciplines

Change in Hydrology and Society

Montanari, Young, Savenije, Hughes, Wagener, Ren, Koutsoyiannis, et al. 2013. “Panta Rhei – Everything Flows”, Change in Hydrology and Society – The IAHS Scientific Decade 2013-2022, *Hydrological Sciences Journal.*

WATER AND SOCIETY

Water problems are all around us: Floods, droughts, water scarcity, pollution …

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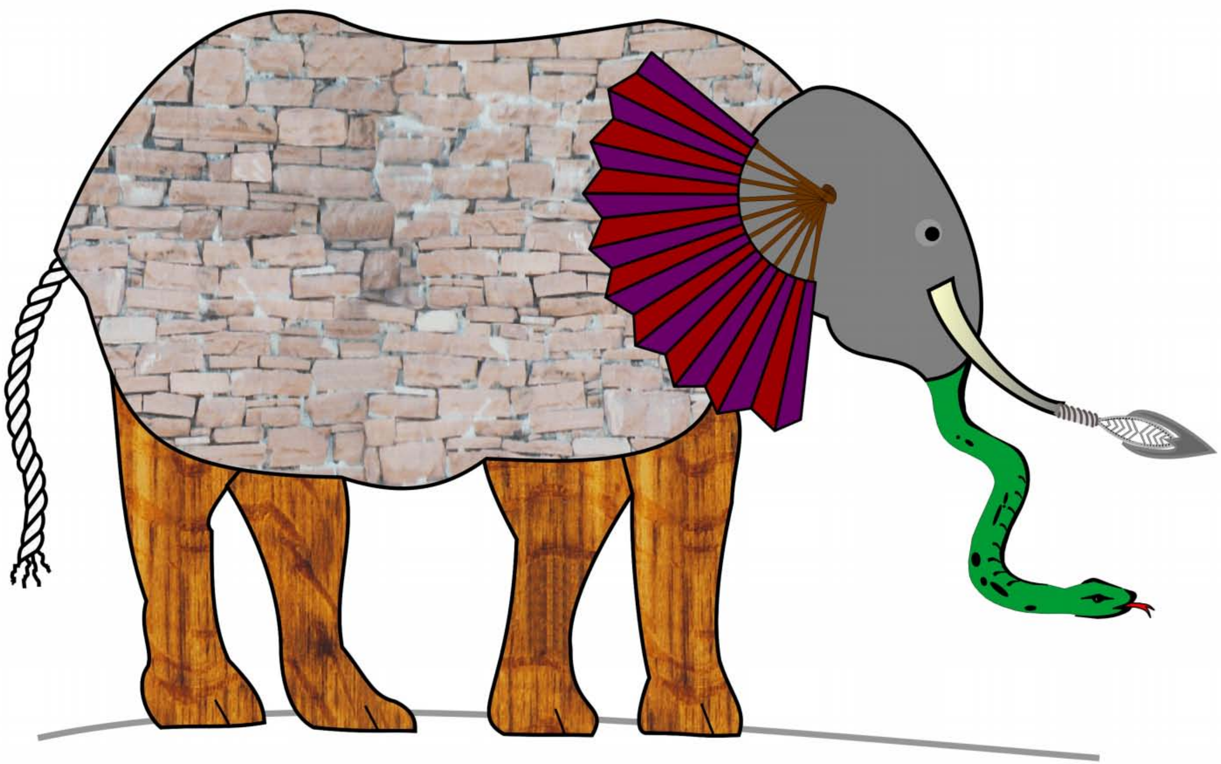
In the International Association of Hydrological Sciences we recently finished a first scientific decade to focus our science



For synthesis discussion see:

- Bloeschl et al., 2013, Cambridge University Press
- Hrachowitz et al., 2013, Hydrology and Earth System Sciences

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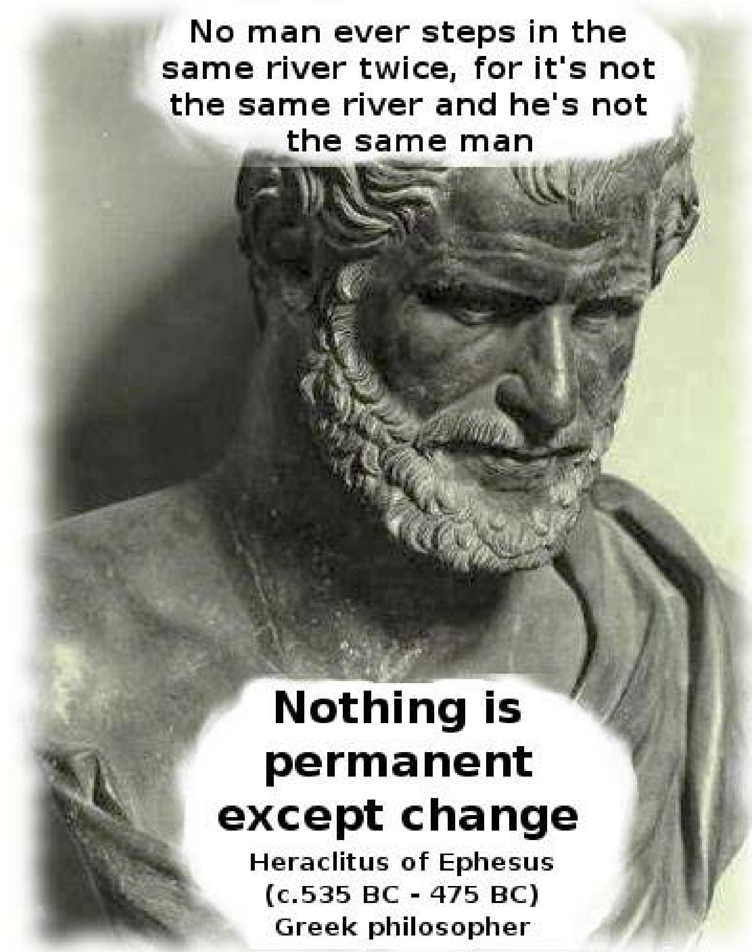
Panta Rhei: The new IAHS Scientific Decade 2013-2022

Launched in July 2013 at the IAHS General Assembly



Panta Rhei is organized in working groups

1. Hydro-meteorological extremes: Decision making in an uncertain environment - Chair: Pedrozo-Acuña
2. Large dams, society, and environment - Chair: Bellie Sivakumar
3. Thirsty future: energy and food impacts on water - Chair: Ana Mijic
4. Changing biogeochemistry of aquatic systems in the Anthropocene – Chair: Hong-Yi Li
5. Transdisciplinarity - Chair: Tobias Krueger
6. Natural and man-made control systems in water resources - Chair: Ronald van Nooijen
7. Water and energy fluxes in a changing environment - Chair: Maria J. Polo
8. Epistemic uncertainties - Chair: Paul Smith
9. Comparative water footprint studies - Chair: Arjen Y. Hoekstra
10. Hydrologic services and hazards in multiple ungauged basins - Chair: Hilary McMillan, NIWA
11. Understanding flod changes - Chair: Alberto Viglione
12. Physics of hydrological predictability - Chair: Alexander Gelfan
13. Mountain hydrology - Chair: Shreedhar Maskey
14. Large sample hydrology - Chair: Vazkén Andreassian
15. Socio-hydrologic modeling and synthesis - Chair: Veena Srinivasan
16. Sustainable water supply in a urban change - Chair: Tatiana Bibikova
17. Water footprint of cities - Chair: Alfonso Mejia
18. Evolving urban water systems - Chair: Alfonso Mejia
19. Changes in flood risk - Chair: Heidi Kreibich
20. Anthropogenic and climatic controls on water availability (ACCuRAcY)
21. Floods in historical cities - Chair: Alberto Montanari
22. Prediction under Change (PUC) - Chair: Hafzullah Aksoy

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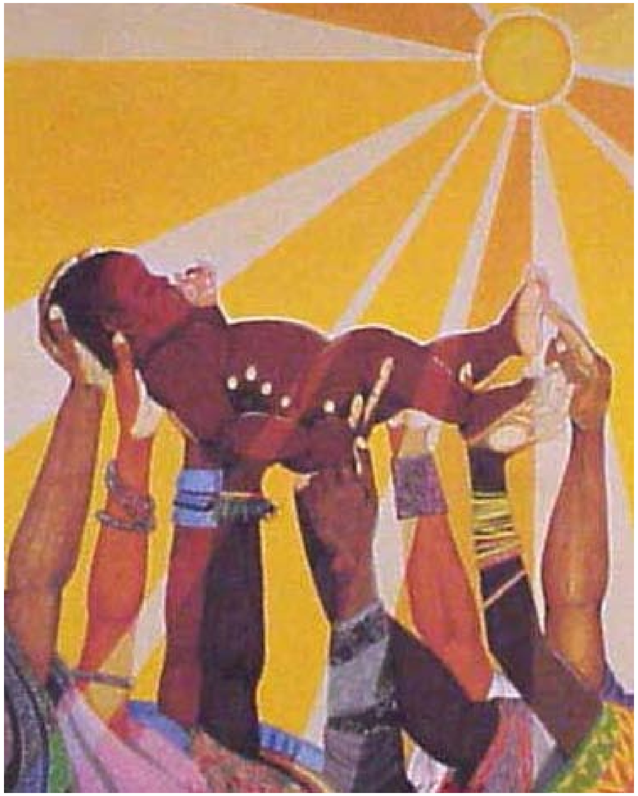

Wagener, Sivapalan, Troch, McGlynn, Harman, Gupta, Kumar, Rao, Basu and Wilson. 2010. The future of hydrology – An evolving science for a changing world. *Water Resources Research*.

SHIFTING BASELINE FOR HYDROLOGY EDUCATION

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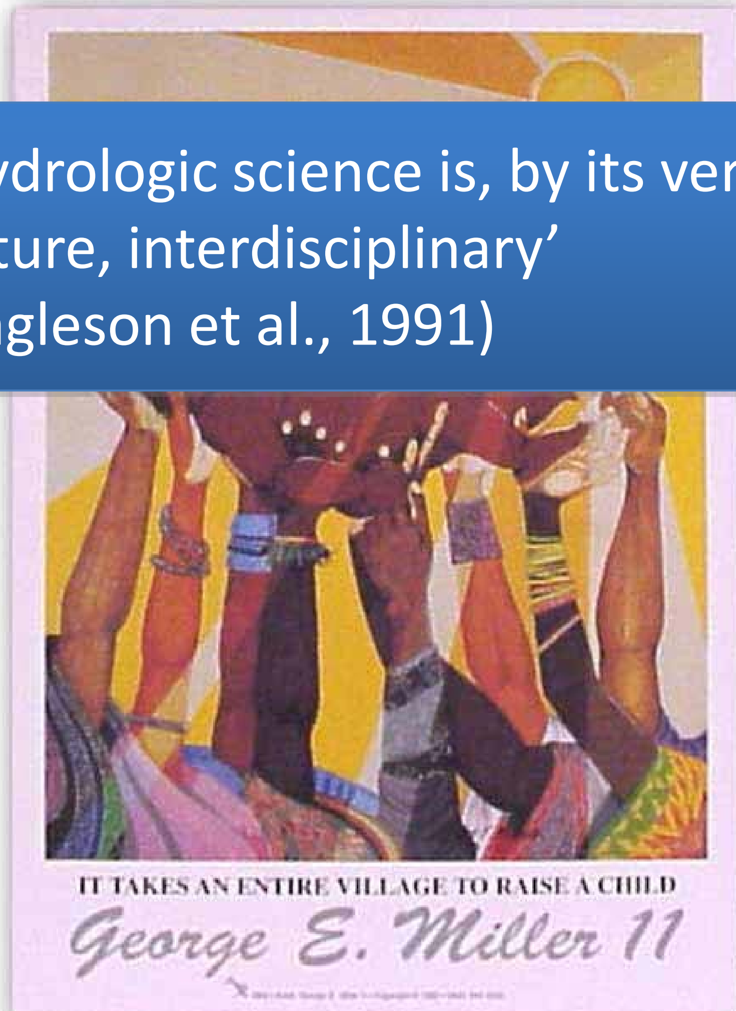
It takes a village to raise a child …



‘Hydrologic science is, by its very nature, interdisciplinary’ (Eagleson et al., 1991)

… who (what) does it take to educate a hydrologist who can solve today’s and tomorrow’s problems?

Eagleson et al. 1991. **Opportunities in the Hydrologic Sciences**. *National Academy Press: Washington, DC.*

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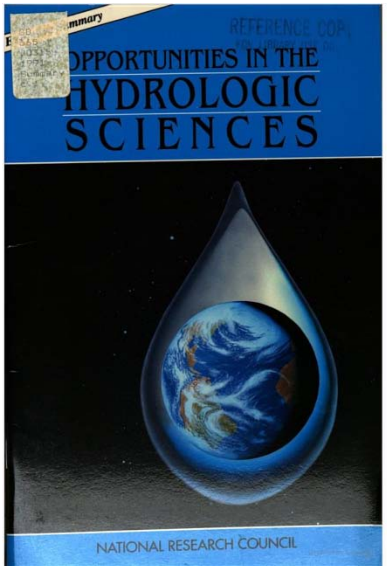
http://www.chesilhurstschoolprek6.com/It%20takes%20a%20whole%20village%20to%20raise%20a%20child.jpg

Eagleson et al. discussed opportunities in hydrology, including those regarding education



"Hydrology moved from engineering to science departments as well."

"Research topics come from societal needs as much as they come from the flow of scientific ideas and technological breakthroughs."

"Faculty with strong interest in hydrology are found in a diverse array of departments."

"Because of the multidisciplinary nature of the hydrologic sciences, students from widely different backgrounds are likely to be attracted to the discipline."

Hydrological Sciences - Journal - des Sciences Hydrologiques, **35**, 6, 12/1990

The education of hydrologists

(Report of an IAHS/UNESCO Panel on hydrological education)

J. E. NASH
Department of Engineering Hydrology, University College, Galway, Ireland

P. S. EAGLESON
Ralph M. Parsons Laboratory, Department of Civil Engineering, Building 48-335, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

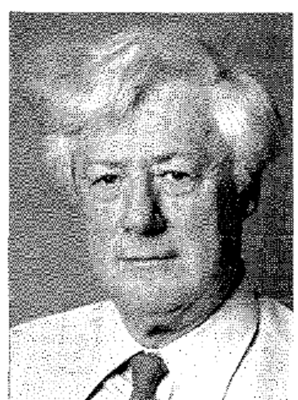
J. R. PHILIP
Commonwealth Scientific and Industrial Research Organization, PO Box 821, Canberra, ACT, Australia

W. H. VAN DER MOLEN
Lindelaan 8, 6871 DX Renkum, The Netherlands

"The present structure of hydrological education, generally tailored to the needs of specialized non-hydrological disciplines, is ill-fitted to cope with present and future requirements."

J. E. Nash

P. S. Eagleson



J. R. Philip

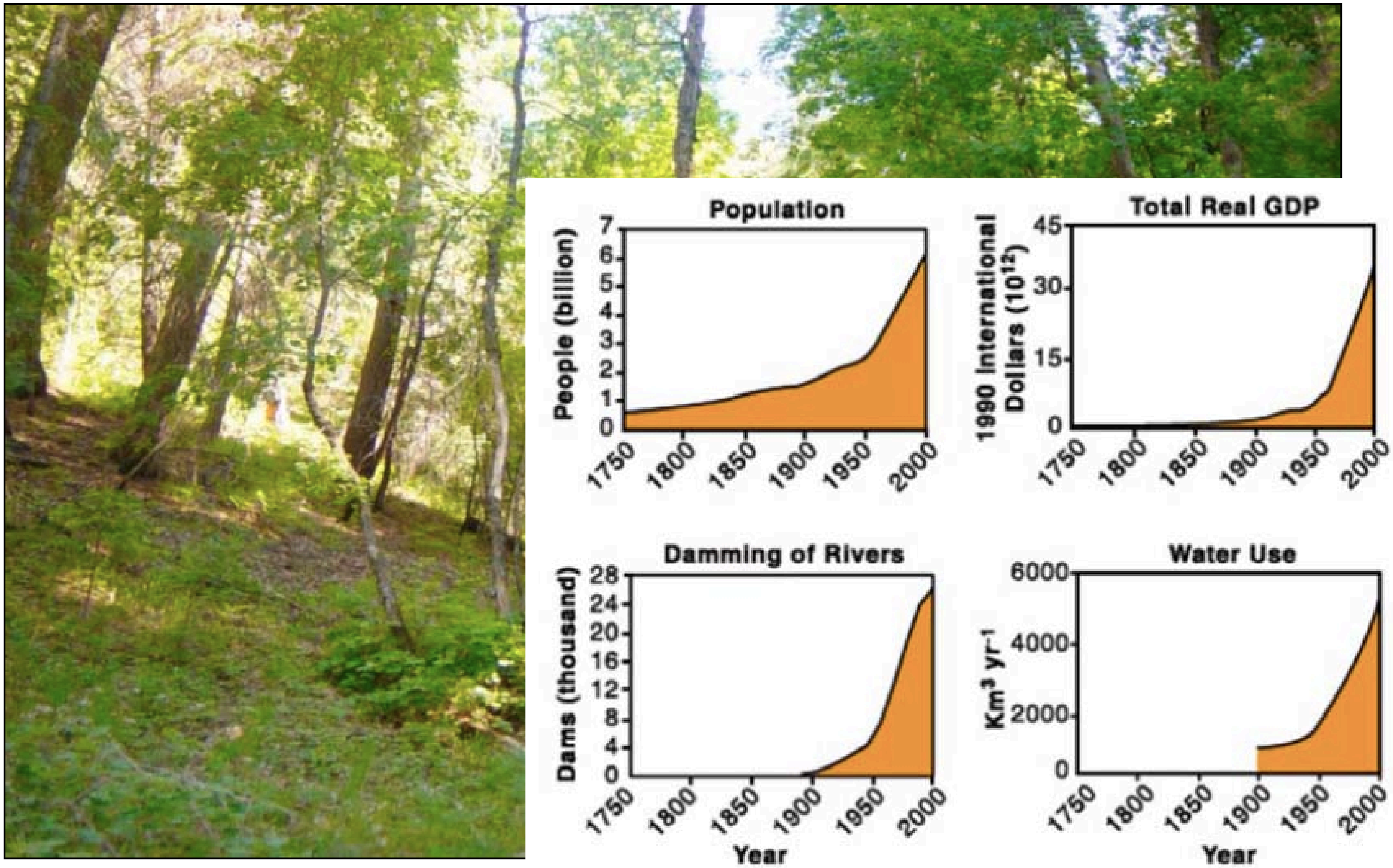
W. H. van der Molen

Activities to advance undergraduate education in hydrology as proposed 20 years ago included:

The education of hydrologists
(Report of an IAHS/UNESCO Panel on hydrological education)

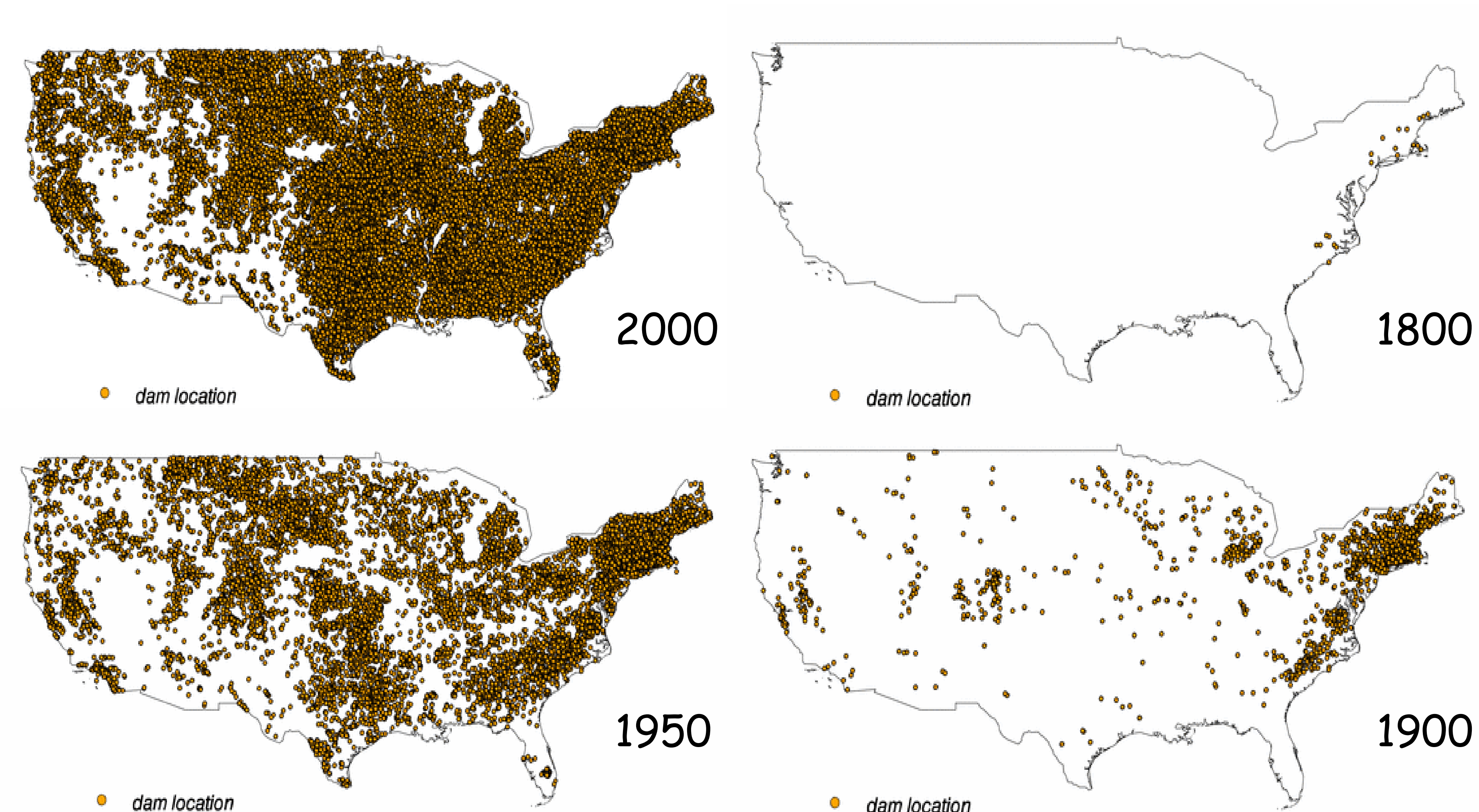
- Organization of a solid (perhaps senior-level) *undergraduate* course in scientific hydrology
- More field and laboratory experience
- Define hydrology education of a unified field of natural sciences
- The need for a coherent and comprehensive science in its educational image
- The inclusion of human activity into hydrology

This is the kind of environment we love to study hydrology in, but…



Steffen et al., 2004

Societal problems related to water do not lie in headwater catchments!



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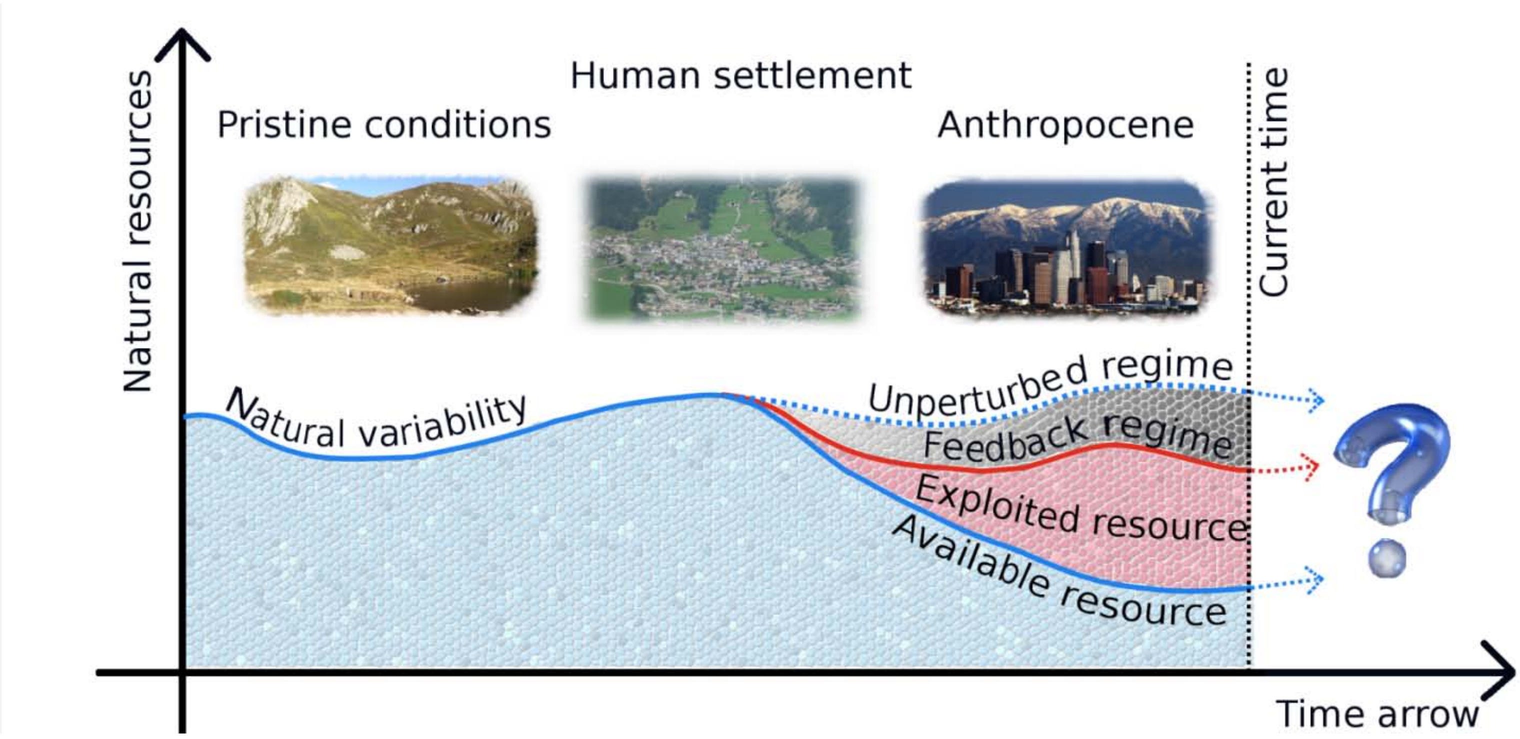
Credit: Charles Vorosmarty

We have to ensure that hydrology (science and education) continues to be able to solve relevant problems



Montanari et al., 2013, HSJ

This changes where we do research and what we study, for example …

Current	Future
Humans are external to the hydrologic system	Humans are intrinsic to the hydrologic system, both as agents of change and as beneficiaries of ecosystem services
Assumption of stationarity: past is a guide to the future	Nonstationary world: past is no longer a sufficient guide to the future, expected variability could be outside the range of observed variability
Predicting response, assuming fixed system characteristics: boundary value problem with prescribed fixed topography, soils, vegetation, climate	Both system and response evolve: no longer a boundary value problem, boundary conditions and interfaces themselves evolve and are coupled. Becomes a complex adaptive system
Learning from studying individual places (often pristine experimental catchments) to extrapolate or upscale to other places	Comparative hydrology: learning from individual places embedded along gradients (e.g. changing climate, human imprint) and across spatial scales

…

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Wagener et al., 2010, *Water Resources Research*

The shifting baseline of a changing world needs to translate into differences in education

- *How will the hydrologic system respond to, and evolve under, natural and human induced changes in climate and the environment?*
- *How are natural, managed and engineered processes manifested in the various freshwater services that nature provides?*
- *How can hydrologic systems be managed towards sustainability?*

Answering these questions requires a strong scientific basis of engineering, and societal needs demand a science capable of making quantitative predictions.

Wagener, T., Weiler, M., McGlynn, M., Gooseff, M., Meixner, T., Marshall, L., McGuire, K. and McHale, M. 2007. Taking the pulse of hydrology education. *Hydrological Processes.*

CURRENT HYDROLOGY EDUCATION

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HYDROLOGICAL PROCESSES
Hydrol. Process. **21**, 1789–1792 (2007)

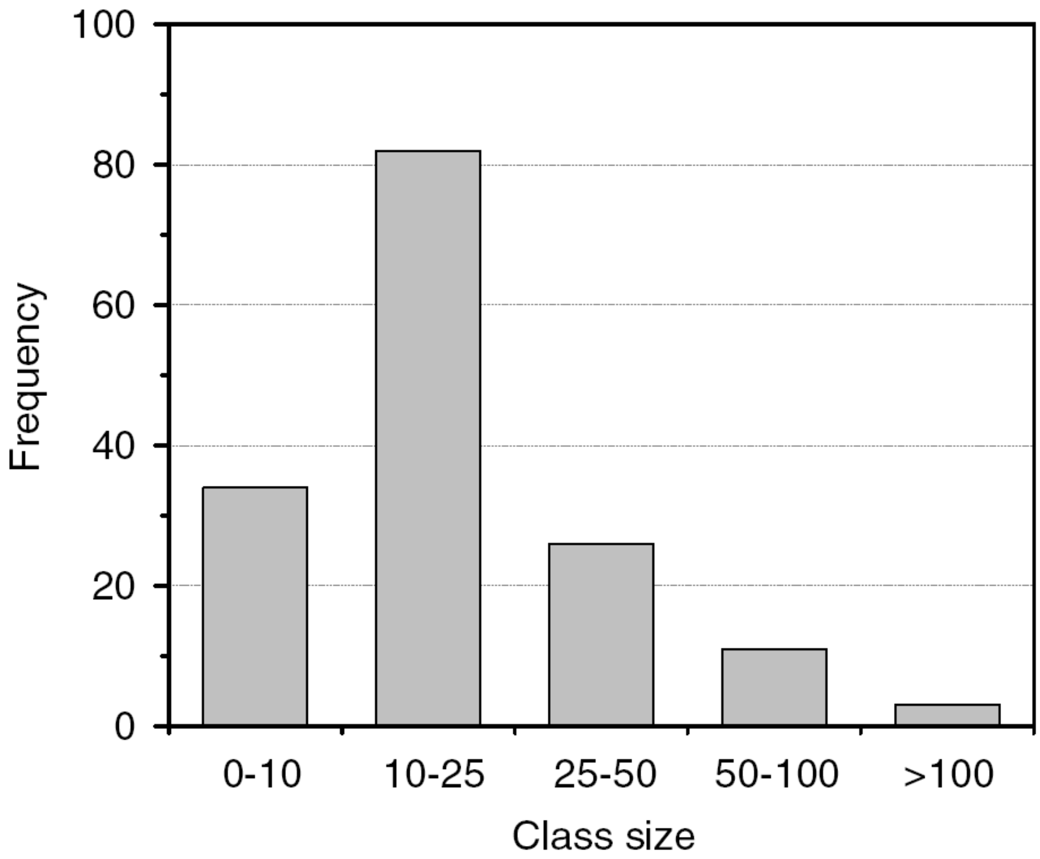
Taking the pulse of hydrology education

Thorsten Wagener
Markus Weiler
Brian McGlynn
Mike Gooseff
Tom Meixner
Lucy Marshall
Kevin McGuire
Mike McHale

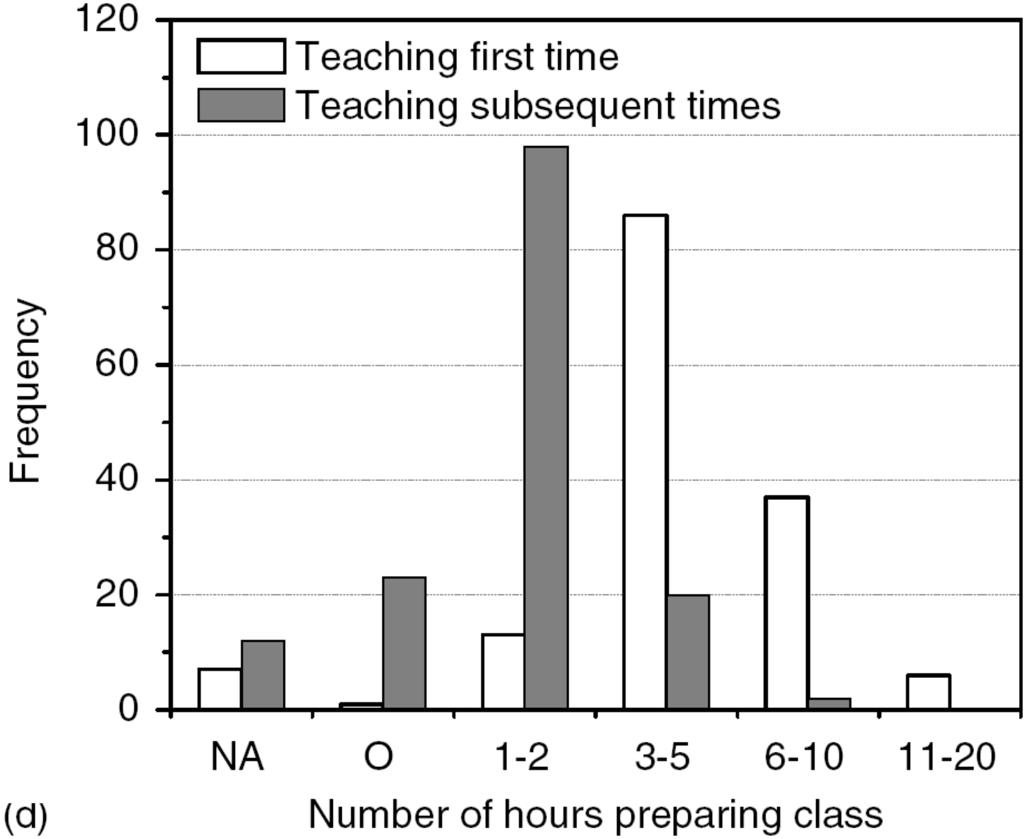
Conclusions

… while an education with a common basis is desirable, it is clearly not available at the moment. Hydrology educators are challenged to identify common principles, core knowledge, and approaches that should be included, in addition to areas where clear consensus is lacking.

Most of us teach small classes



Most of us spend many hours preparing lectures



(d)

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We use a wide range of textbooks

While ~40% used no textbook at all, all participants used a wide range of material to create their lectures, and 68% of the participants, who use a primary textbook, took 50% or less of their material from this primary text.

McMartin (1999) found that faculty have difficulty using internet resources in their teaching, specifically because of: lack of time to learn about the material, difficulties of finding usable material, and lack of training on how to use the material.

We started an effort to discuss the issue of hydrology education widely

Hydrol. Earth Syst. Sci., 17, 1393–1399, 2013
www.hydrol-earth-syst-sci.net/17/1393/2013/
doi:10.5194/hess-17-1393-2013

Preface

"Hydrology education in a changing world"

J. Seibert[1,2,3], S. Uhlenbrook[4,5], and T. Wagener[6]

We published over 25 papers on various educational issues

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Wagener, Kelleher, Weiler, McGlynn, Gooseff, Marshall, Meixner, McGuire, Gregg, Sharma and Zappe, 2012. It takes a community to raise a hydrologist: The Modular Curriculum for Hydrologic Advancement (MOCHA). *Hydrology and Earth System Sciences.*

FUTURE HYDROLOGY EDUCATION

The Modular Curriculum for Hydrologic Advancement (MOCHA) is

… establishing an online faculty learning community for hydrology education and a modular hydrology curriculum based on modern pedagogical standards. Hence attempting to answer the following questions:

How good could a watershed hydrology course be if all aspects of the course would be covered by 'topical' specialists?

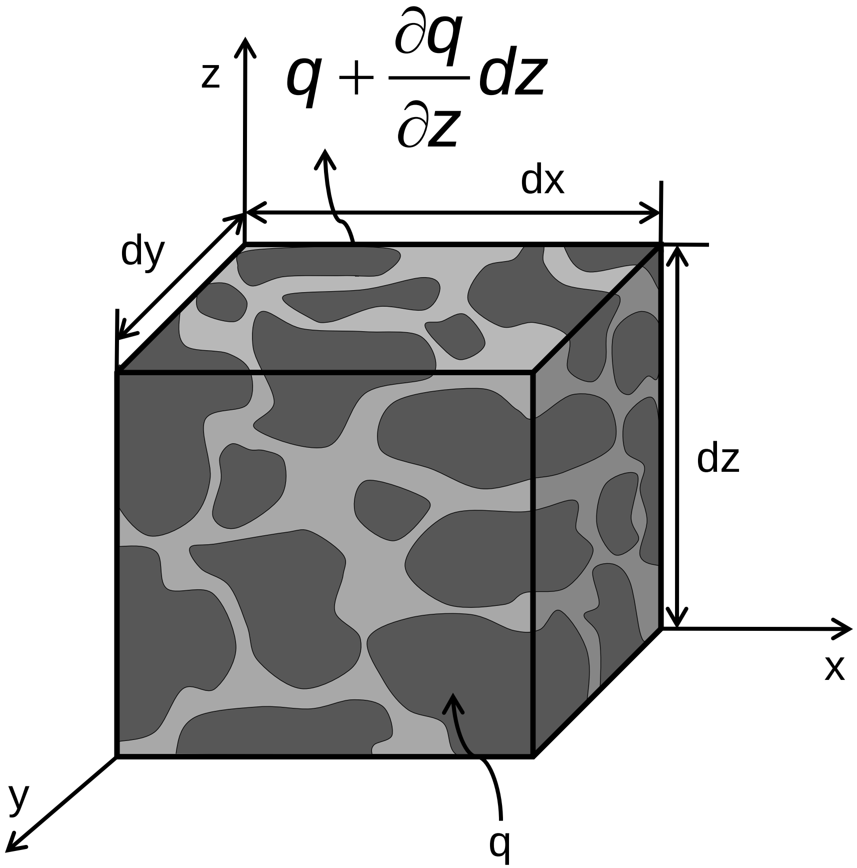
How holistic would the approach to hydrology education be if both scientists and engineers jointly develop the material?

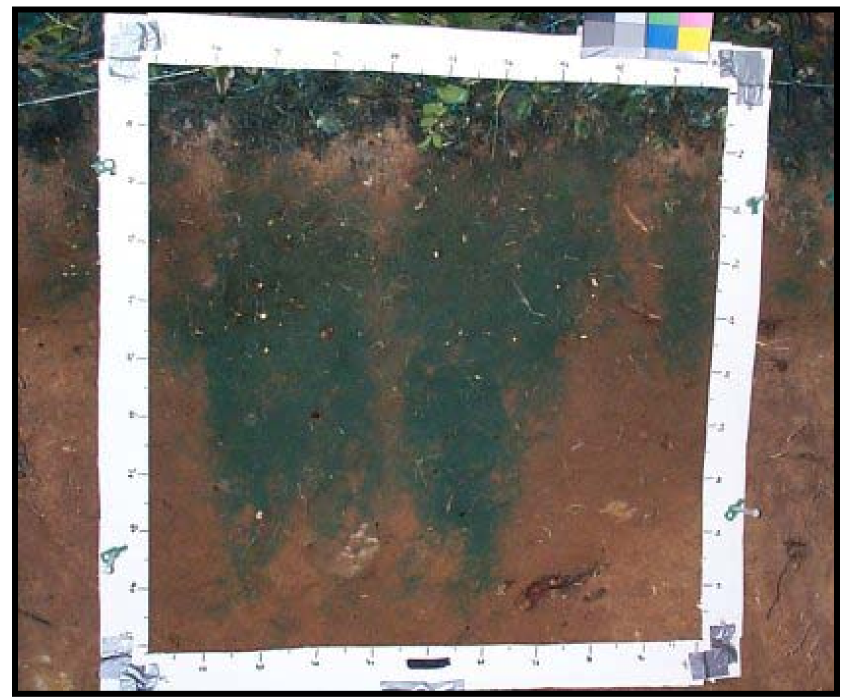
How much improvement would be possible if basic pedagogical guidelines would be followed throughout a course?

The science / engineering separation mentioned by Eagleson et al. has not gone away

Control Volume

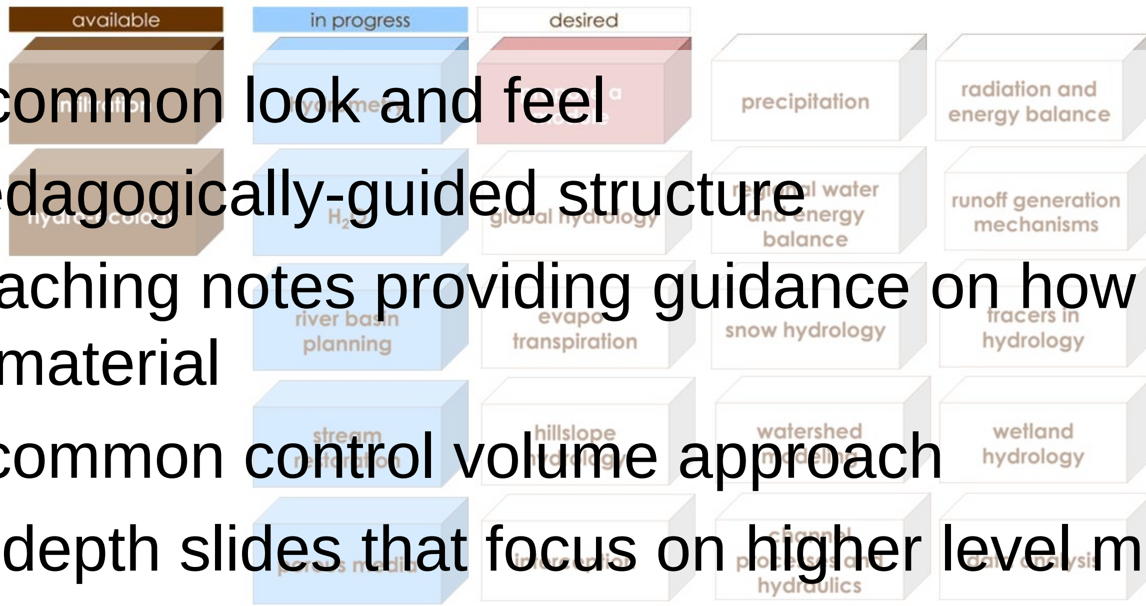
Real-World Process





[Picture by Markus Weiler]

MOCHA is based on modules, each covering ~3 hours of in-class teaching material



- A common look and feel
- Pedagogically-guided structure
- Teaching notes providing guidance on how to teach the material
- A common control volume approach
- In-depth slides that focus on higher level material
- Categorization of each slide with respect to spatial scale and topic addressed

… seamless connectivity through a common template!

Contribute a module in 3 easy steps

Register | **Create Module** | **Publish Module**

1 Register and log in to your account

2 Download module template and share your materials and expertise

3 Publish your module for others to use

… and become known as the leading educator in your hydrologic area of interest!

Ensure good pedagogy by following the ABCD of creating a lesson

A	B	C	D
Planning the lesson	Beginning the lesson	During the lesson	Ending the lesson

In-class learning activity where students solve a small problem in teams

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Website currently offline

[1] Computer science & hydrology

[2] Process understanding across scales

[3] Water & health

SOME EXAMPLES OF CONNECTING ACROSS DISCIPLINES

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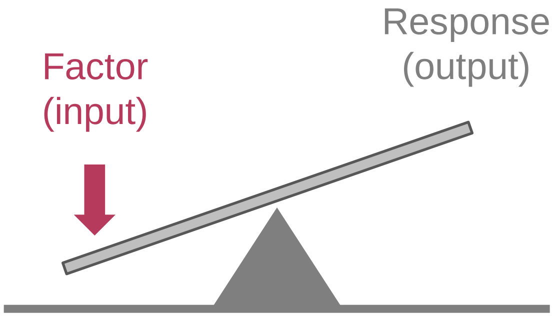
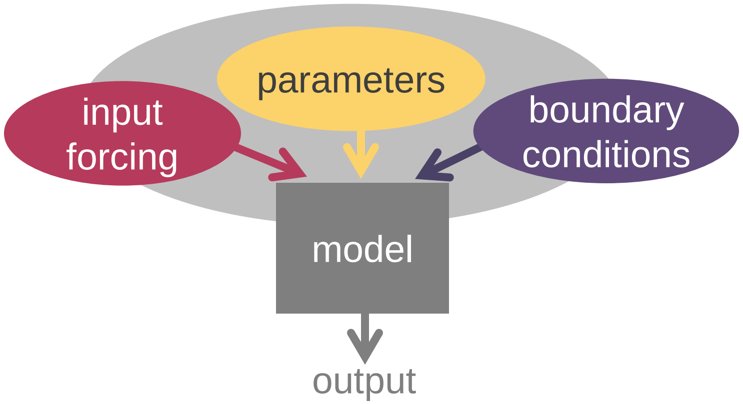
[1] Computer models are at the core of much of our science

For example, we regularly need to understand which uncertainties dominate in our predictions (i.e. sensitivity analysis).





Do we utilize computer science and mathematics sufficiently to effectively?

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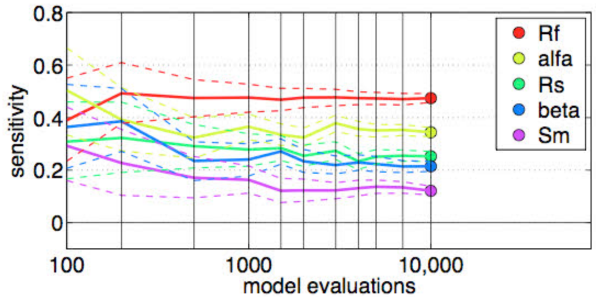
Pianosi et al., 2015, Env. Modeling & Software

Sensitivity Analysis Toolbox Features

modular structure → *facilitates multi-method approach*

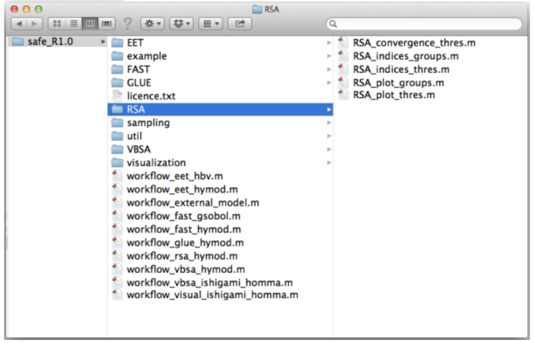
functions to assess robustness and convergence



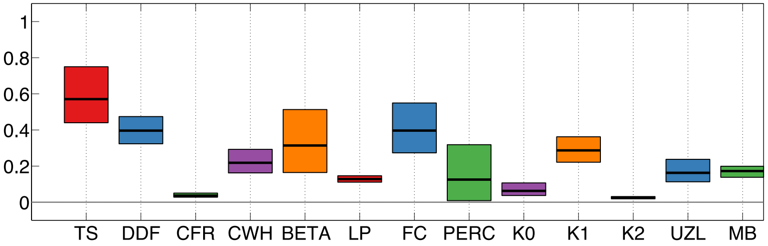

```
%% Step 3 (sample inputs space)
SampStrategy = 'lhs' ; % Latin Hypercube
N = 3000 ; % Number of samples
M = length(DistrPar) ; % Number of inputs
X = AAT_sampling(SampStrategy,M,DistrFun,DistrPar,N);

%% Step 4 (run the model)
Y = model_evaluation(myfun,X,rain,evap,flow) ;

%% Step 5a (Regional Sensitivity Analysis with threshold)

% Visualize input/output samples (this may help finding a reasonable value
% for the output threshold):
scatter_plots(X,Y(:,1),[],'rmse',x_labels) ;
scatter_plots(X,Y(:,2),[],'bias',x_labels) ;

% Set output threshold:
rmse_thres = 3    ; %  threshold for the first obj. fun.
bias_thres = 0.5 ; % behavioural threshold for the second obj. fun.

% RSA (find behavioural parameterizations):
threshold = [ rmse_thres bias_thres ] ;
[mvd,idxb] = RSA_indices_thres(X,Y,threshold) ;
```

more comments than commands

minimum dependency on Matlab version, etc. → *reduce obsolescence*



tutorial scripts (workflows) to get started → *learn by doing*



many visualization functions

http://bristol.ac.uk/cabot/resources/safe-toolbox/

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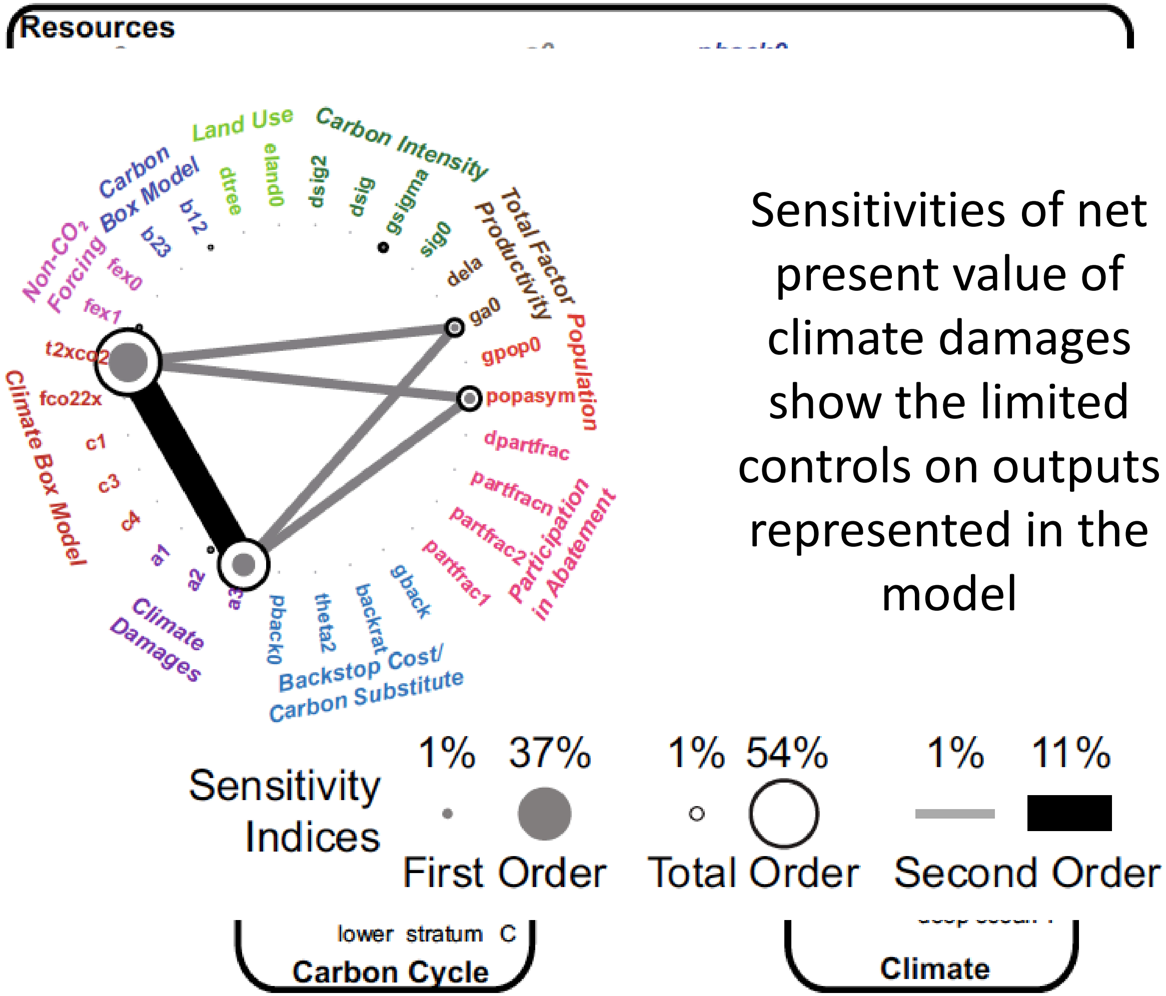
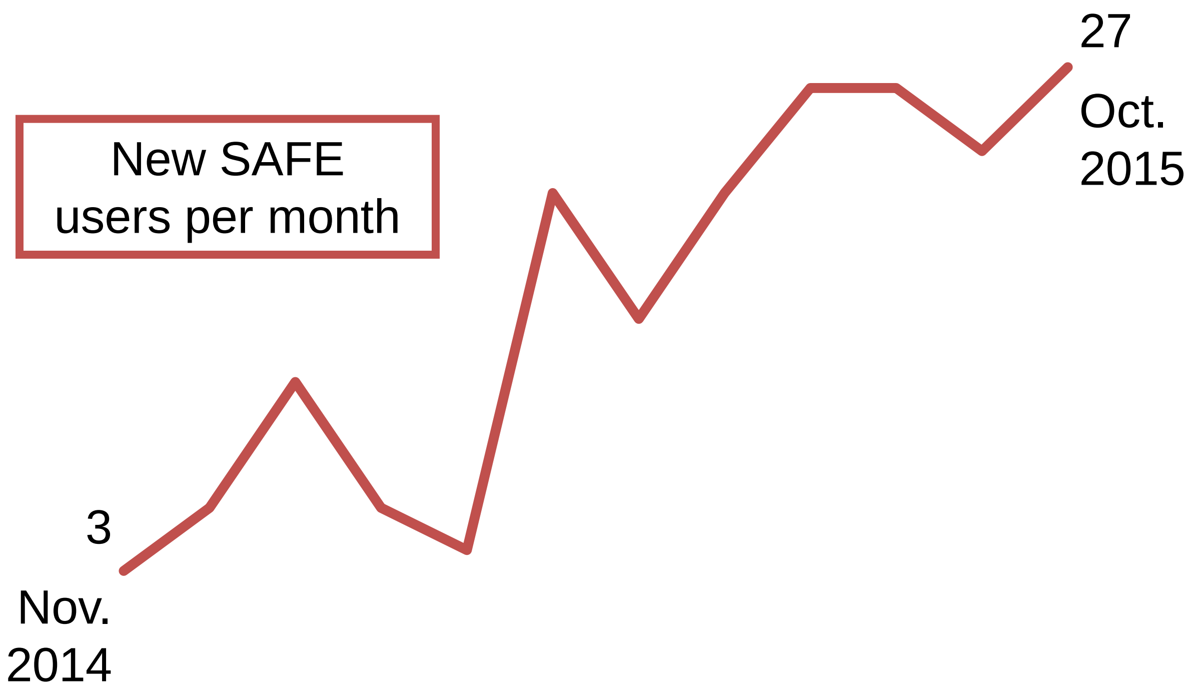
An example application to a global Integrated Assessment Model (DICE)



Sensitivities of net present value of climate damages show the limited controls on outputs represented in the model

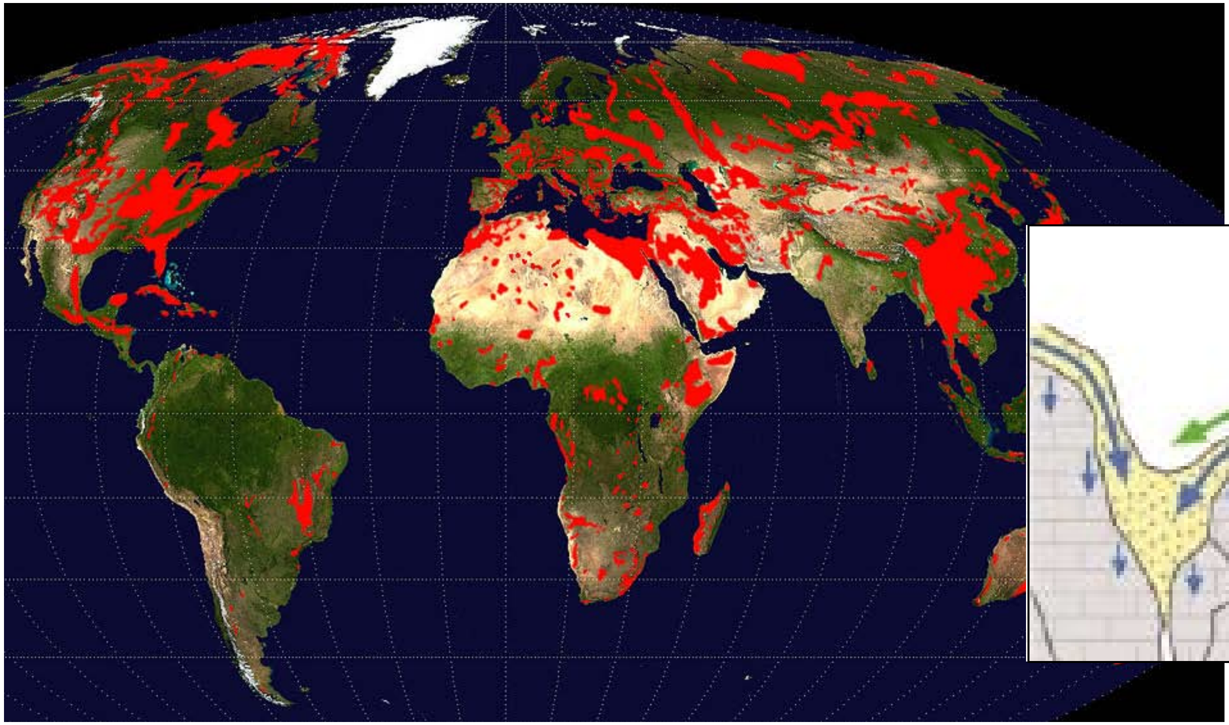
Butler et al., 2014, *Climatic Change*

If we can work with other fields than we can bring state of the are tools into our science

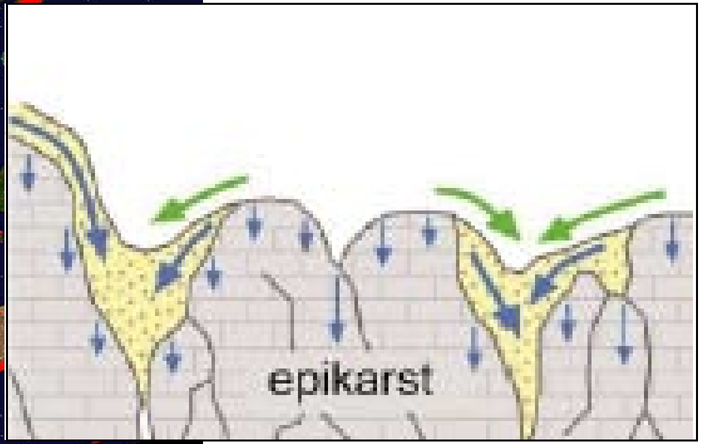


Pianosi et al., 2015, Env. Modeling & Software

[2] How to bring process realism into models at relevant scales (not headwaters)



Hartmann et al., 2014, *Reviews in Geophysics*



Karst regions cover about 10% of the Earth's continental area, and partially supply almost a quarter of the world's population with freshwater

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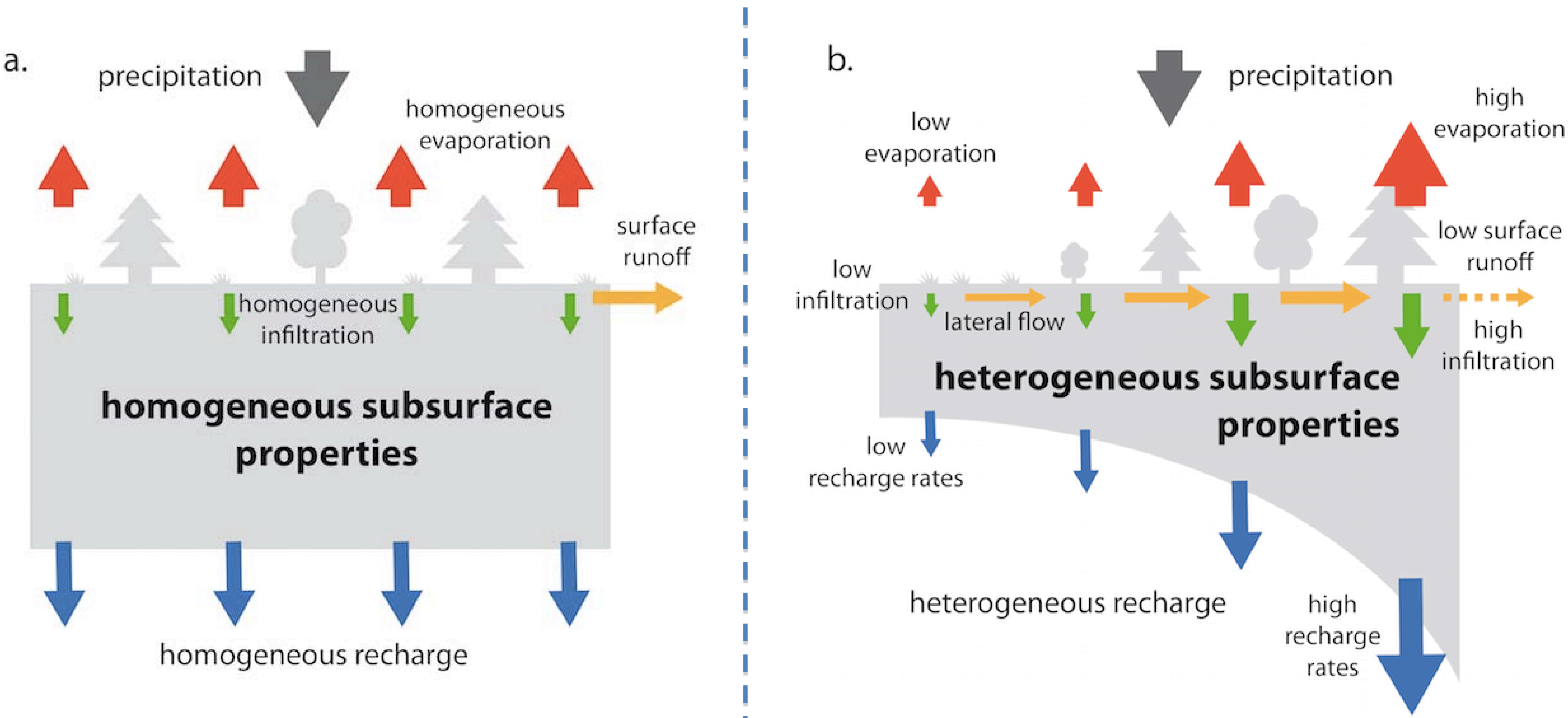
https://en.wikipedia.org/wiki/Karst#/media/File:Carbonate-outcrops_world.jpg

How can we scale up process understanding and bring it into earth system models?



e.g. PCR-GLOBWB

e.g. VarKarst-R

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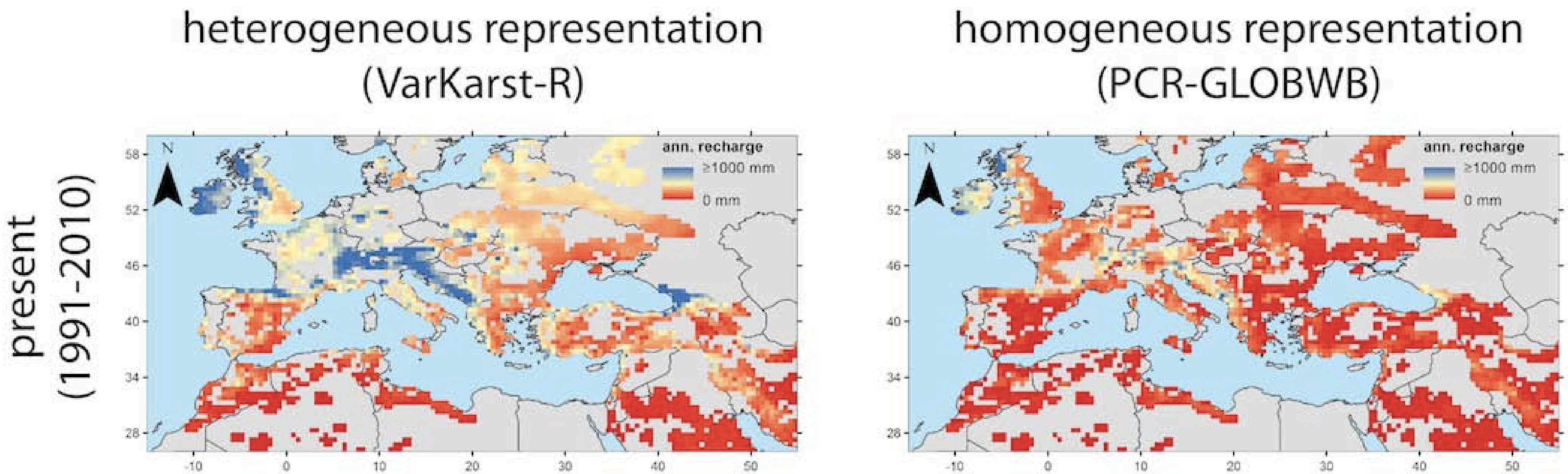
Hartmann et al., 2015, *Geoscientific Model Dev*.

We see significant difference in recharge estimates between the models

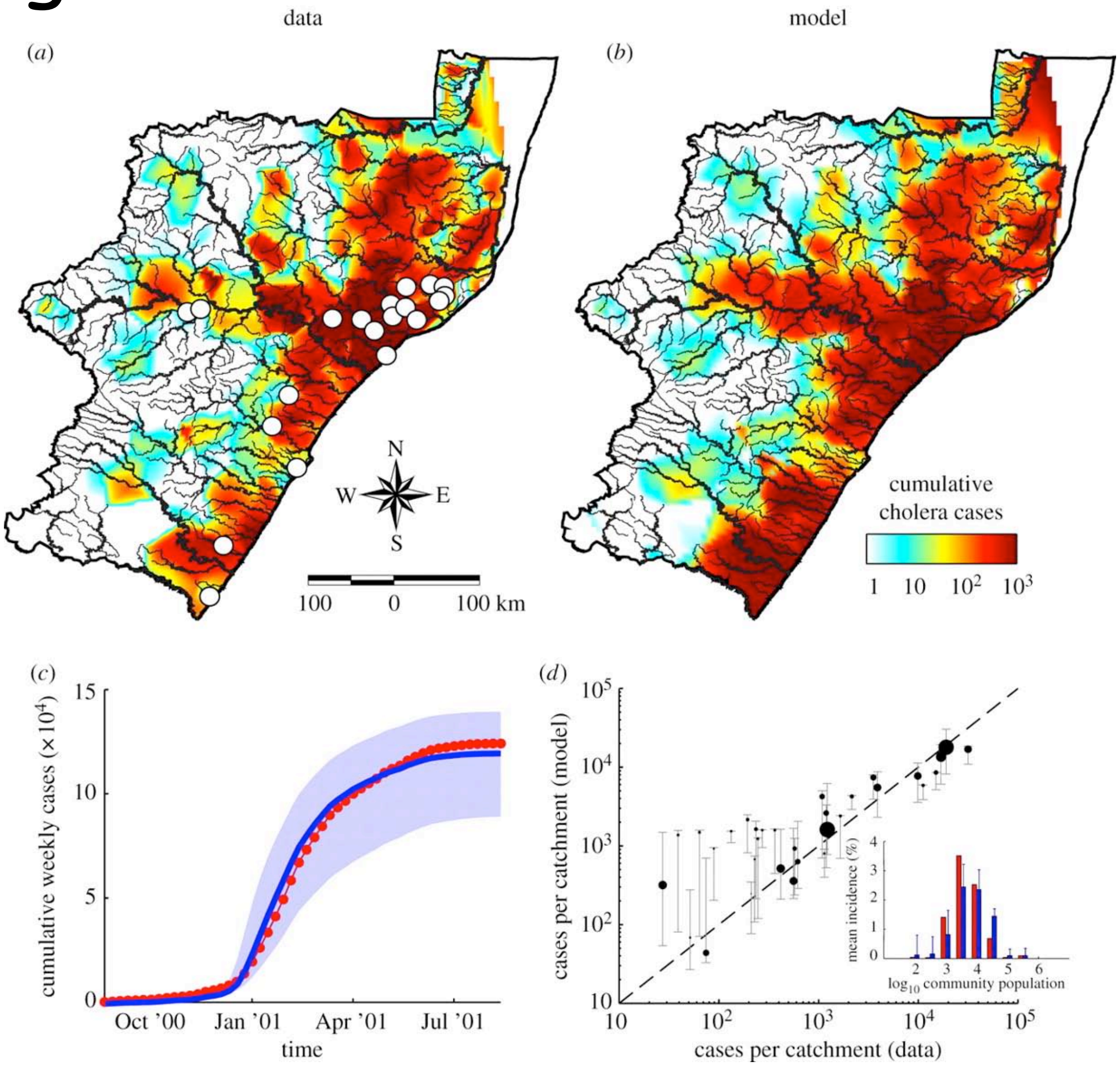


This leads to very significant differences in recharge projections under climate change

Hartmann et al., 2015, *Geoscientific Model Dev*.

[3] Water and Health – Mechanistic modelling of environmental drivers

E.g. cholera epidemic in the KwaZulu-Natal province of South Africa during 2000–2001



Mari et al., 2011, The RoyalSociety - Interface

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In conclusion, we have pushed hydrology education into a more prominent position in our science.
Including discussions on …

Change in Hydrology and Society

Undergraduate Curricula

Postgraduate Training incl. shared Tools

Continuing Mentoring for Developing Countries

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