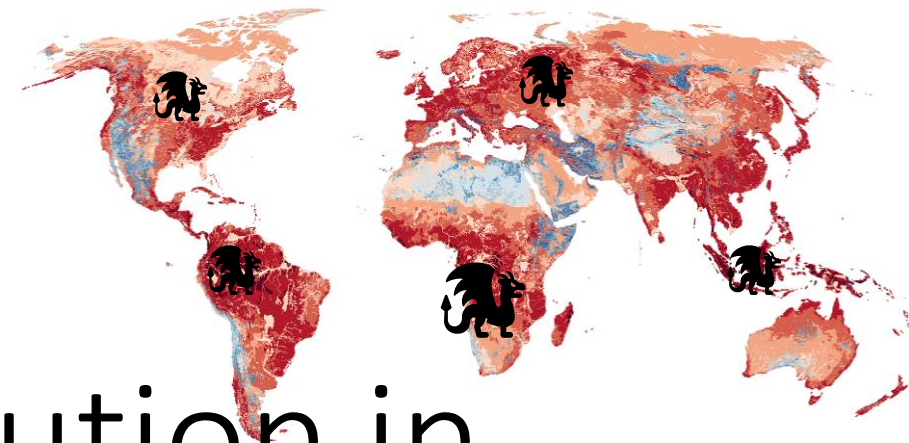




# Uncertainty attribution in global hydrologic models

Robert Reinecke, Francesca Pianosi, Thorsten Wagener

Where do the "dragons"<sup>1</sup>  
hide in global models? And  
how can we find them?

<sup>1</sup>Wagener et al. "On doing hydrology with dragons: Realizing the value of perceptual models and knowledge accumulation" WiresWater (in Review)

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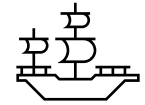
*Analysis of Hydrologic Systems Research Group*

# "Here be dragons!"

On medieval maps, knowledge gaps were hidden under images of dragons to mark dangerous or unexplored territory. The phrase "here be dragons" is still very much alive in our pop-culture today.



Later, they were acknowledged as white areas to encourage exploration.



[https://en.wikipedia.org/wiki/World\\_map](https://en.wikipedia.org/wiki/World_map)

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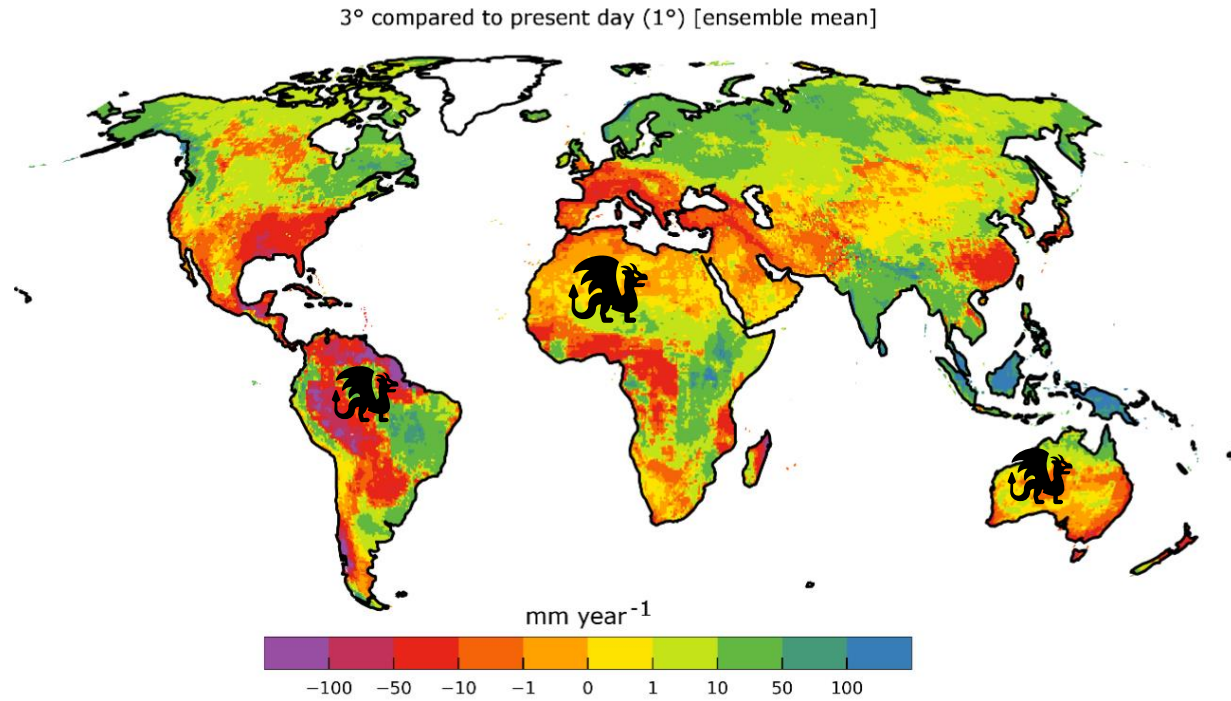


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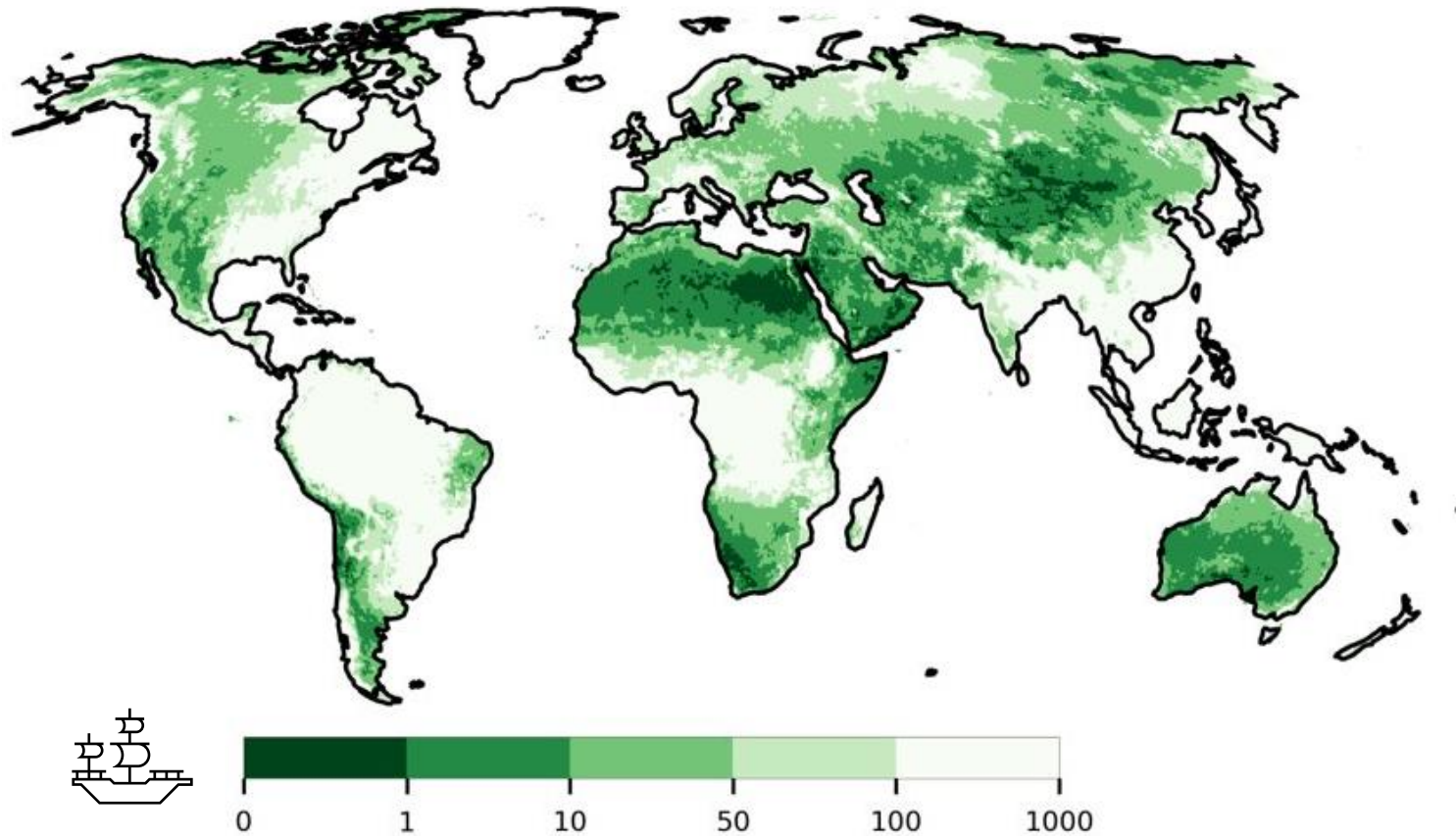
# Are we afraid of the dragons that hide in our global maps?

- Where do dragons hide in our global models?
- To which uncertainties can they be attributed?
- How can we ultimately defeat the dragons?
- Can we identify our dragons and replace them with white areas to encourage exploration?



Global groundwater recharge change based on an ensemble of 8 GHMs [Reinecke et al. 2021; HESS] + symbolic dragons

# Showing large variations between global models as white areas



- Where does that large variation originate?
- What parameters or other factors are driving the results?

Standard deviation of simulated groundwater recharge [mm/year] of 8 GHMs at preindustrial conditions (mean of 1981–2014) [based on data from Reinecke et al. 2021; HESS]

# It is time to analyze global models more rigorously

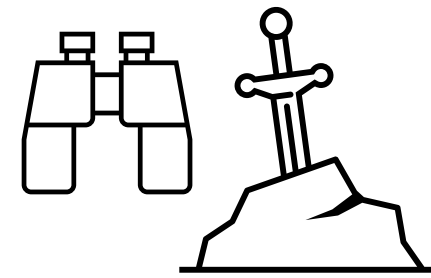
"Since many gHMs have matured recently, it is **perhaps time to pay more attention to** model performance, appropriate parameter ranges, **sensitivity analysis** and calibration of discharge at the monthly time scale." [Krysanova et al. 2020; Climate Change]

"Simulation of groundwater recharge in global models and the connected **uncertainties needs to be analyzed in greater detail by, e.g., the application of extensive sensitivity analysis.**" [Reinecke et al. 2021; HESS]

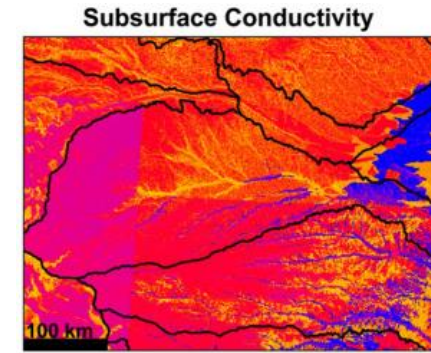
"ESM-SnowMIP results had to be re-submitted multiple times because **large errors were eventually traced to a poorly documented but highly sensitive parameter.**" [Menard et al. 2020; American Meteorological Society]



# Forging new weapons for global models



- It is **not** only a matter of more computation power to apply established catchment scale methods to global models ("bottom-up approach")
- Global models have unique challenges:
  - There is no consistent global data sets that adequately describe the system everywhere
    - For example, data on hydrogeology may contain artifacts due to state borders
  - General lack of global observations and data availability is restricted to specific areas/countries
    - Possible selected reasons
      - Data is not accessible to researchers outside of that specific country
      - Cumbersome work to collect data from multiple municipals
      - No local observations or knowledge due to missing funding
- Resulting issues for global models:
  - Determine appropriate parameters ranges in regions without any data
  - Model structure with generic assumptions to fit all regions
  - Observation availability with limited information on its uncertainty
  - Computational complexity



Condon, L. E., and Maxwell, R. M. (2015); WRR

## **Bottom-up:**

From catchment scale to the global scale

## **Top-Down:**

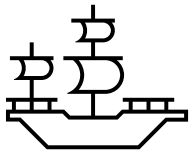
From the global scale to the catchment scale

How can we meet these challenges and mark and explore white areas?

# Top-down instead of bottom-up

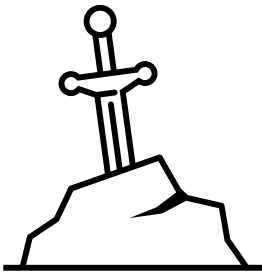


Find the dragons



Show white areas  
to encourage  
exploration!

Forge new  
tools/weapons  
to defeat the  
dragons



- Sensitivity analysis (SA) and specifically global methods offer the possibility to find dragons and explore white regions
- SA can help us to understand where additional information matters (what controls the outcome) and helps to disaggregate the problems ("Top-down approach")
- **We think that this top-down rather than bottom-up approach (see also box on slide 6) can advance our global models**
- **Challenges remain to "wield" the SA methods in a way that works for global models**
  - The application is challenging, and the methods need to consider the complexity of the models
  - Current examples: deGraaf et al. 2019, Nature; Reinecke et al. 2019, HESS