Short Course Large Scale Hydrology

Utrecht University

Niko Wanders

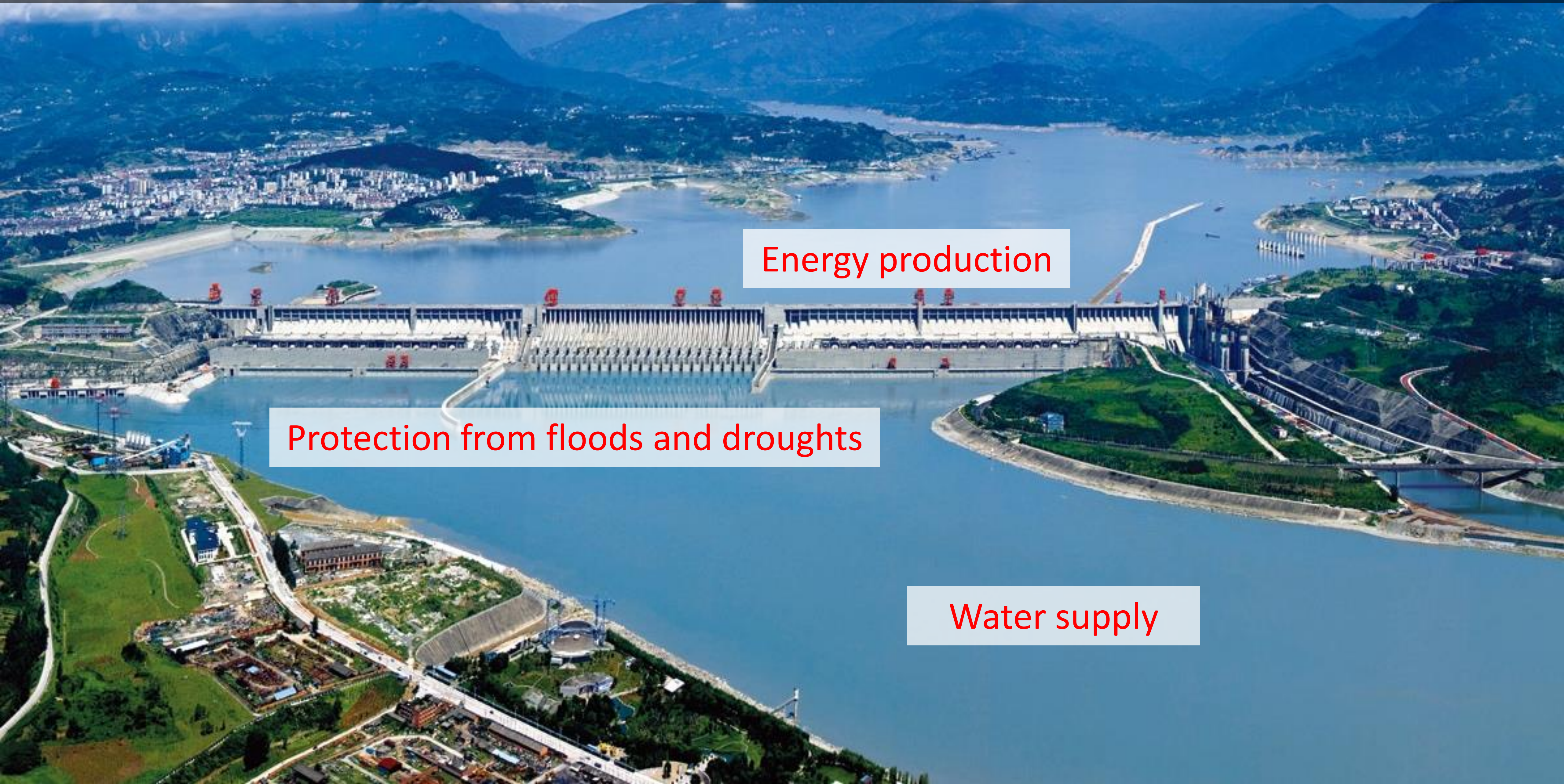
@niko_wanders

The natural water system

The human water system

Water as vital resource

Hydrology and humans



Hydrology and humans

2012-2015 California drought

$ 5.5 Billion damage

+40.000 jobs losses

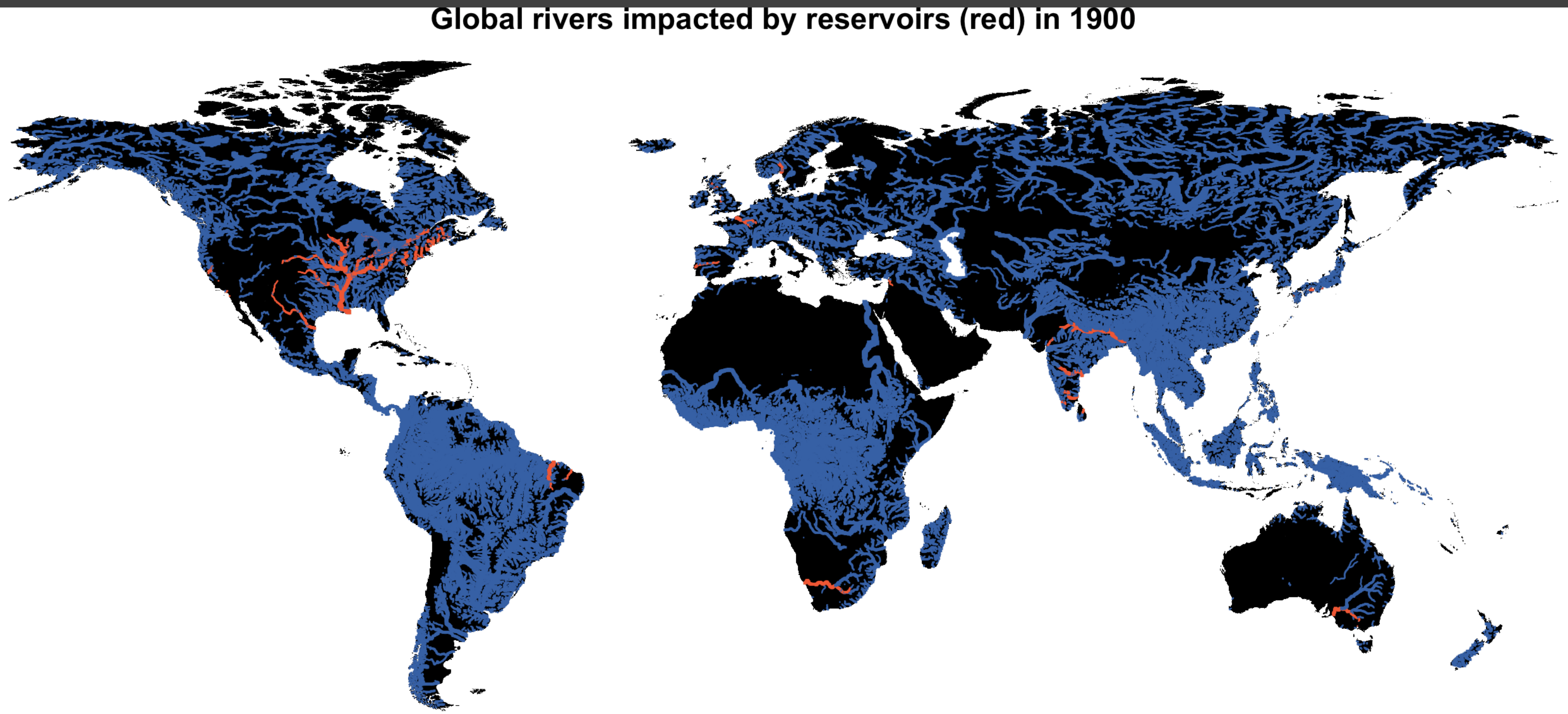
Hydrology and humans

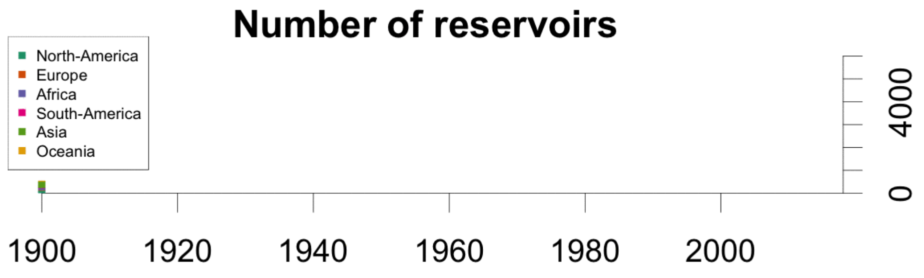
Millennium drought leading to
2010-2011 Queensland floods

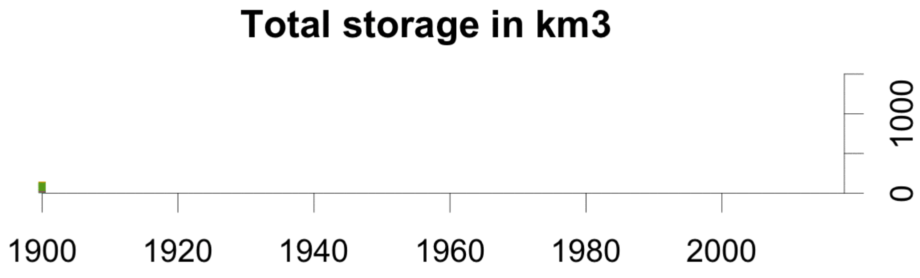
200.000 affected

$ 2.4 Billion damage

Reservoirs in the world







Kraaijenbrink, 2018

Improve understanding

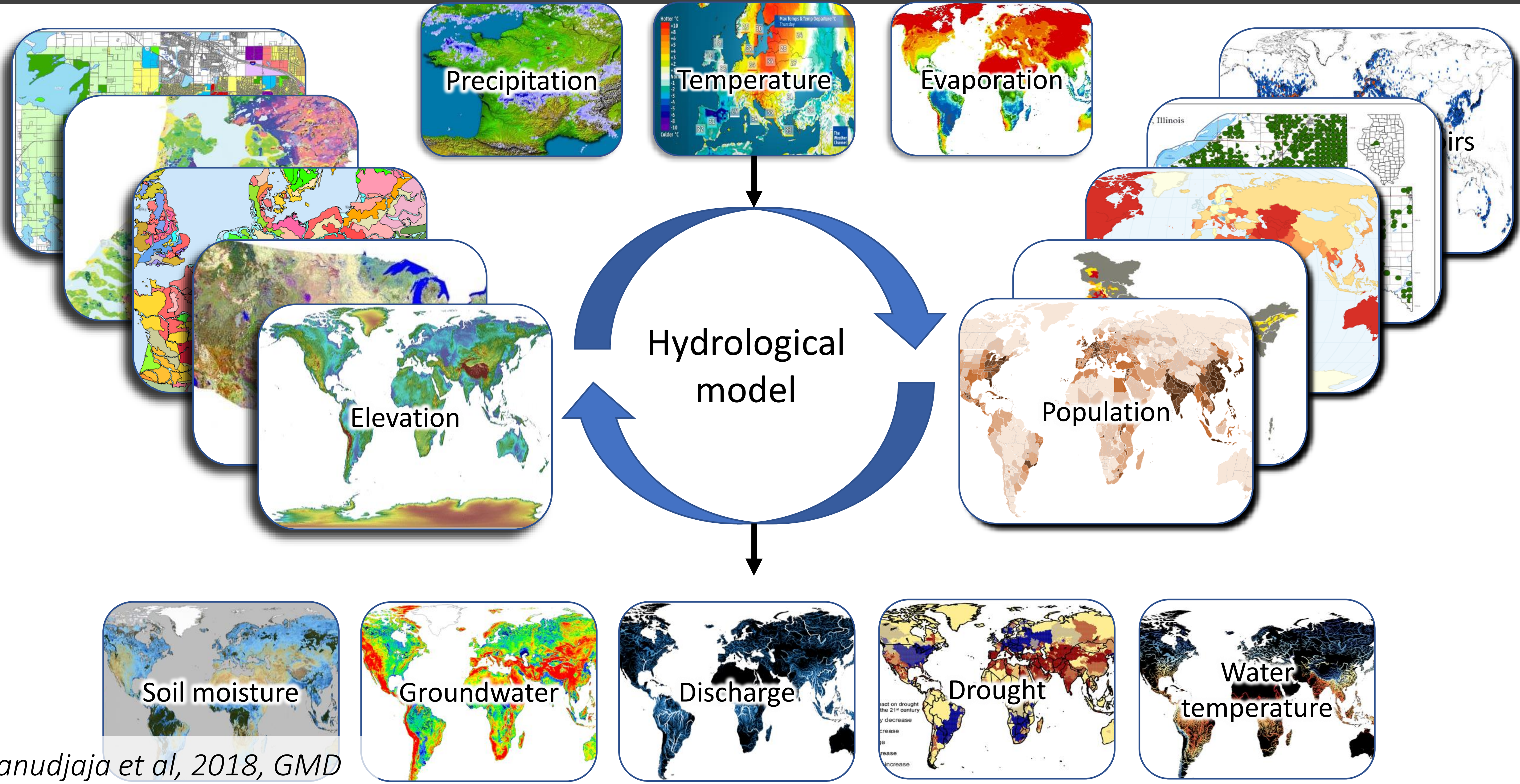
- Models that can mimic large scale water dynamics

- Are computationally efficient

- Can improve insight into the hydrological cycle at large scales

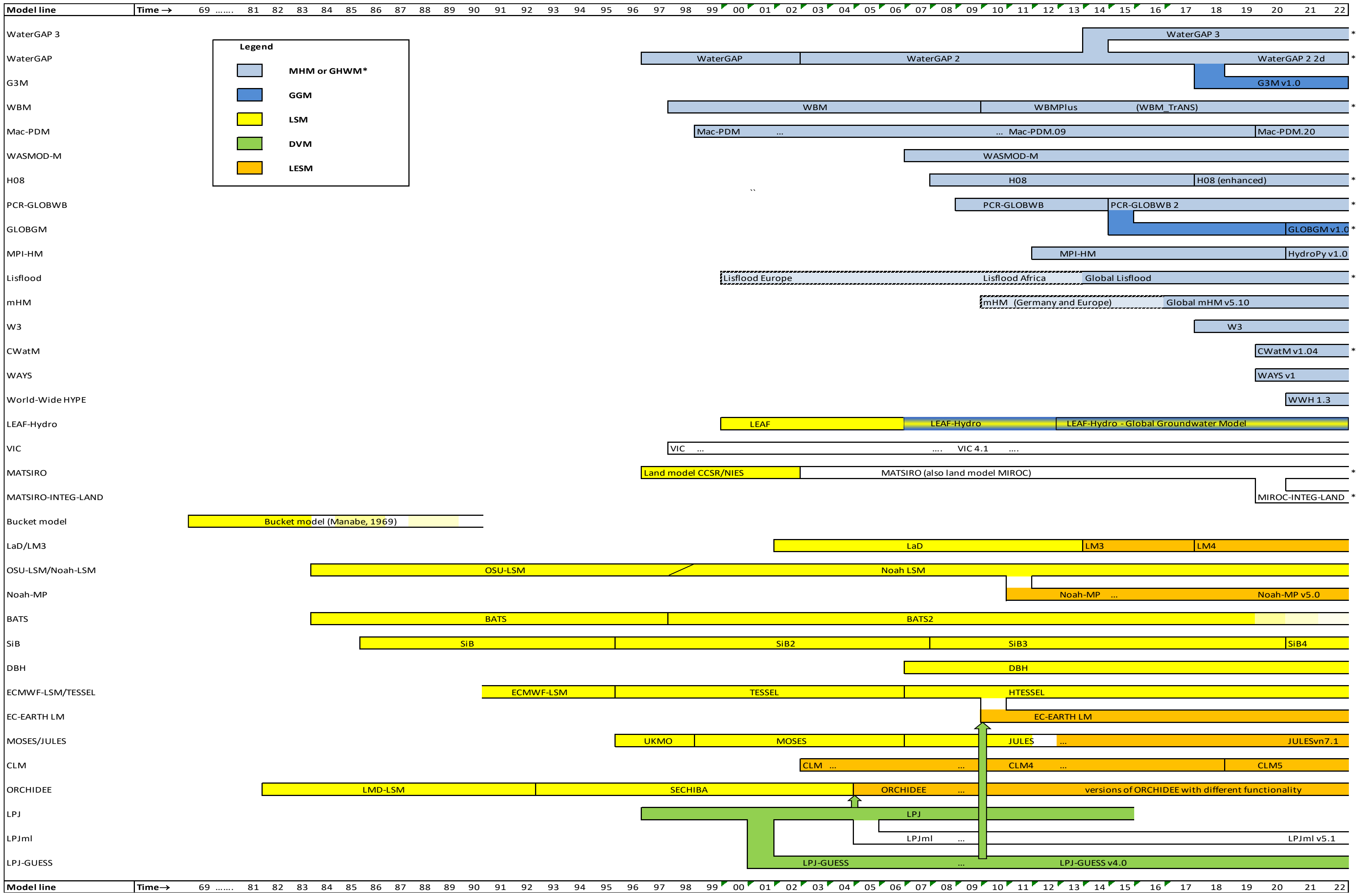
- Physically constrained

What we need to model the global hydrology



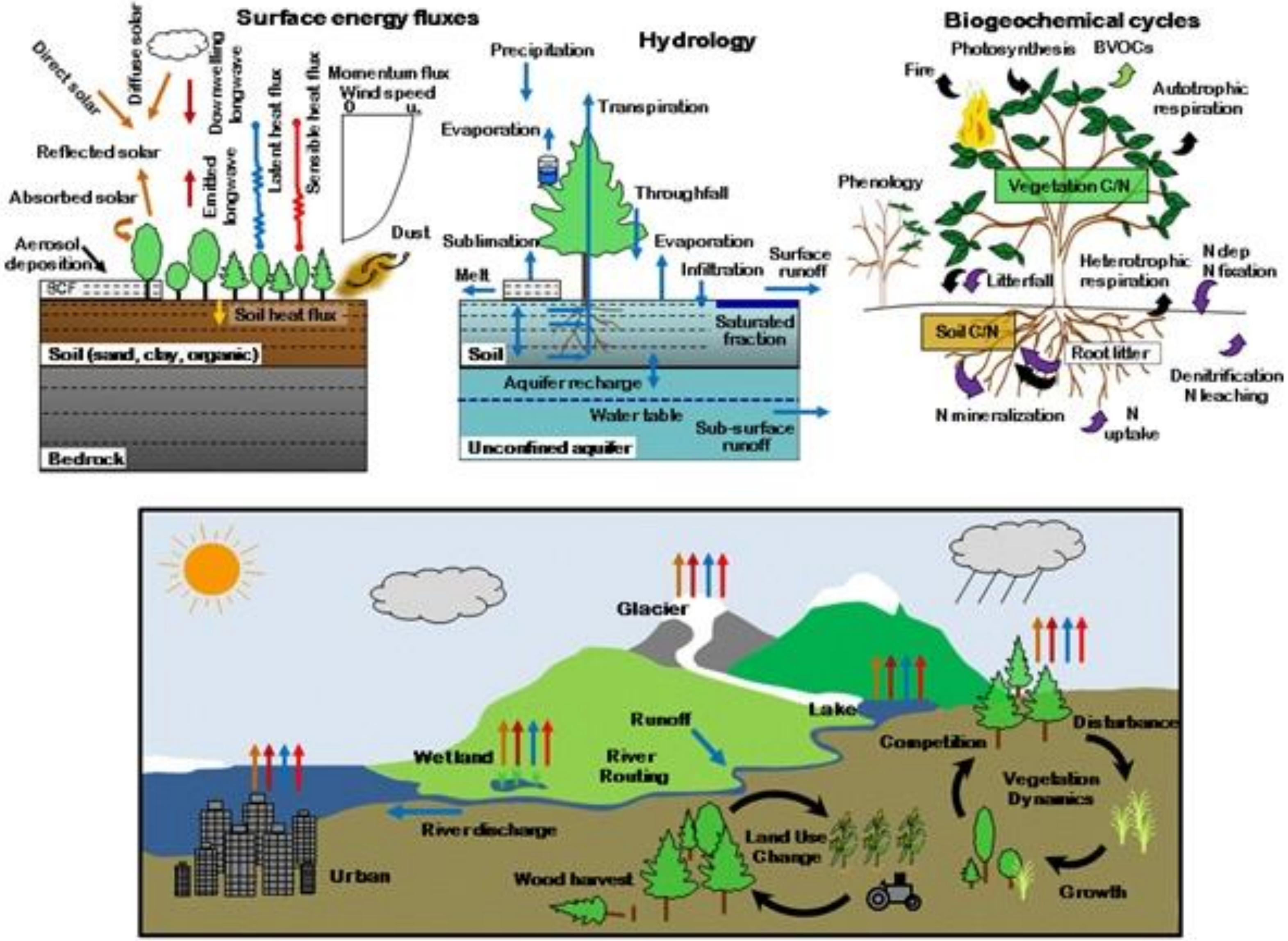
Sutanudjaja et al, 2018, GMD

The history of global hydrological modelling

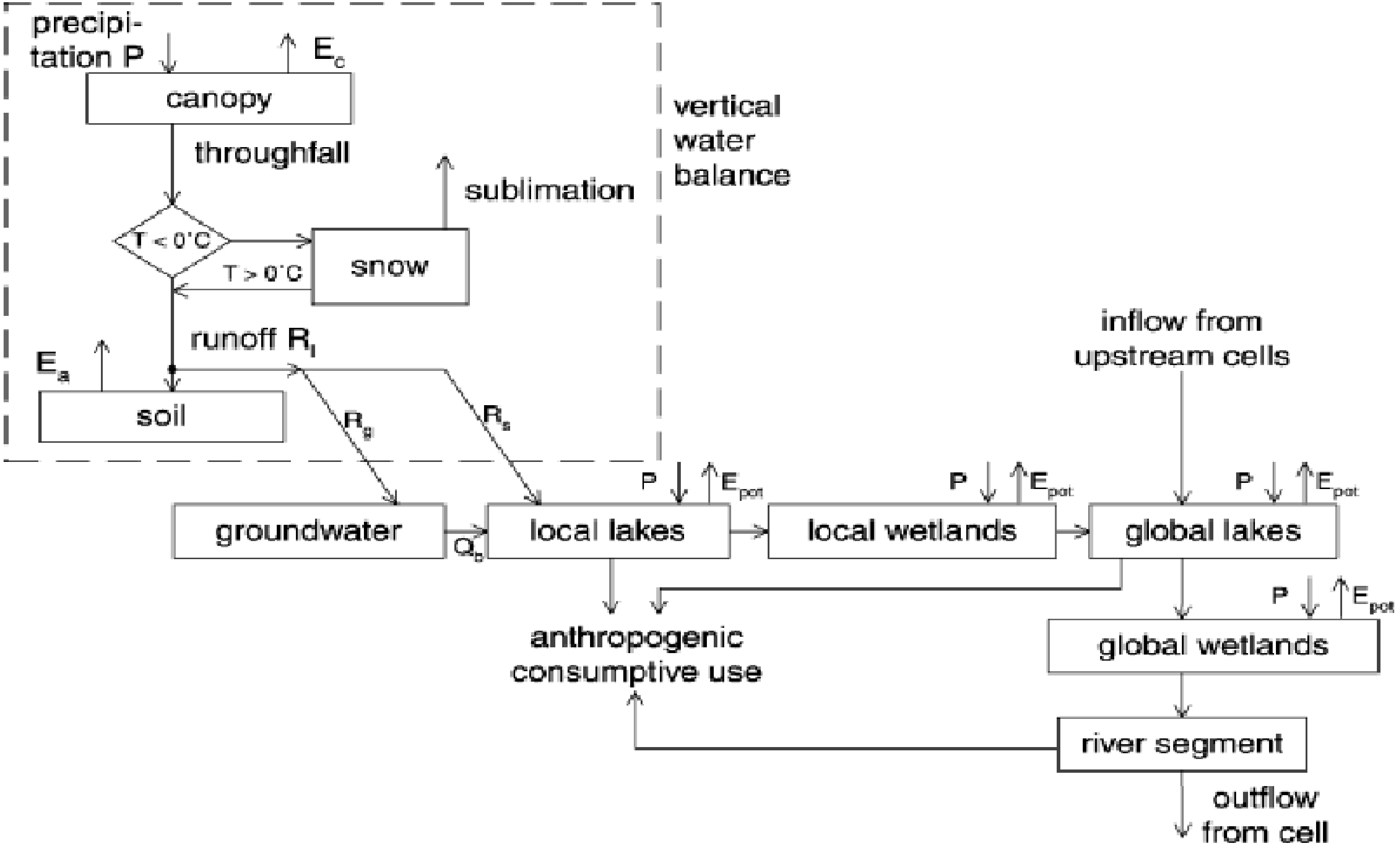


Bierkens, WRR, 2015

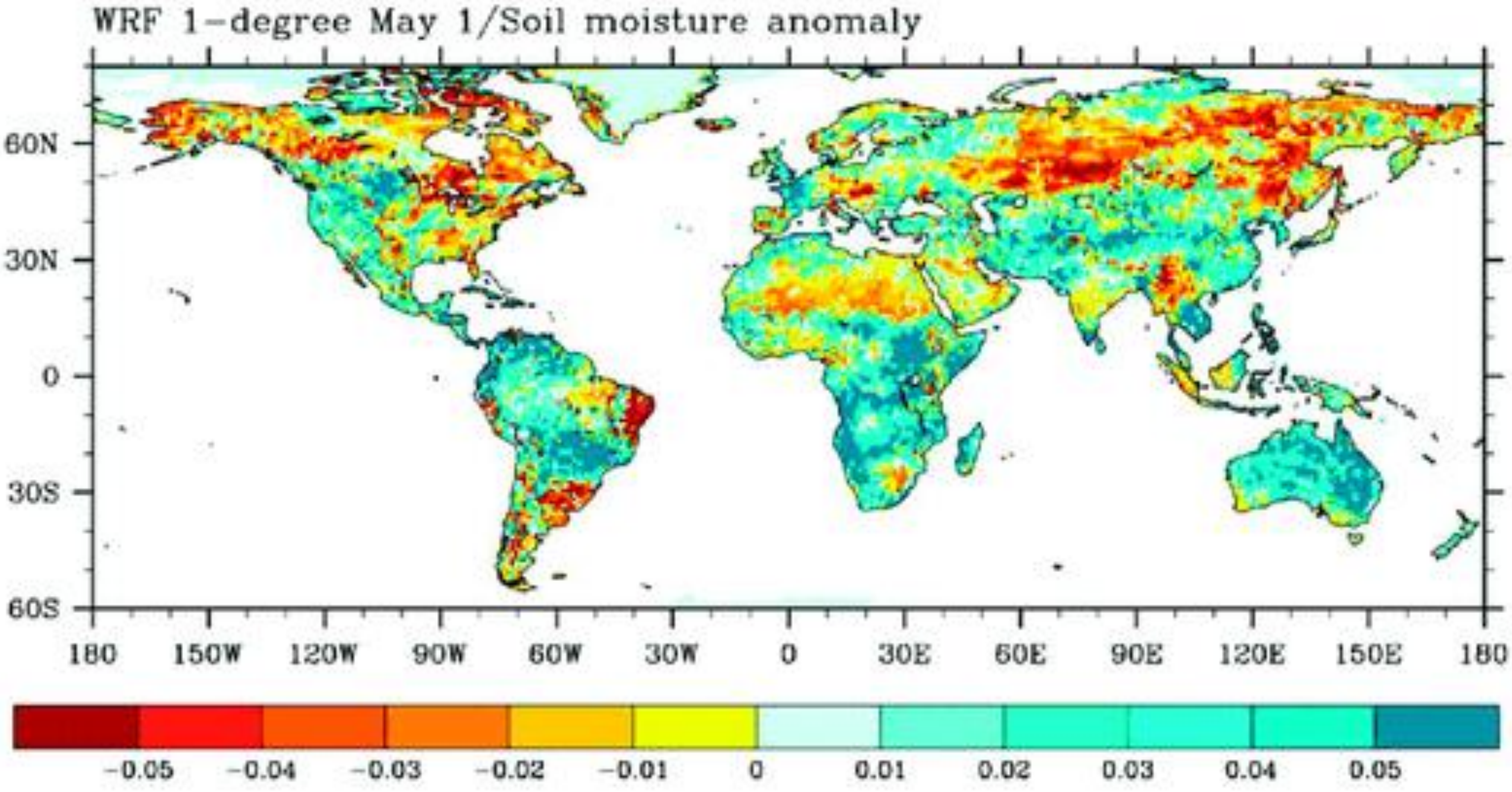
The history of global hydrological modelling



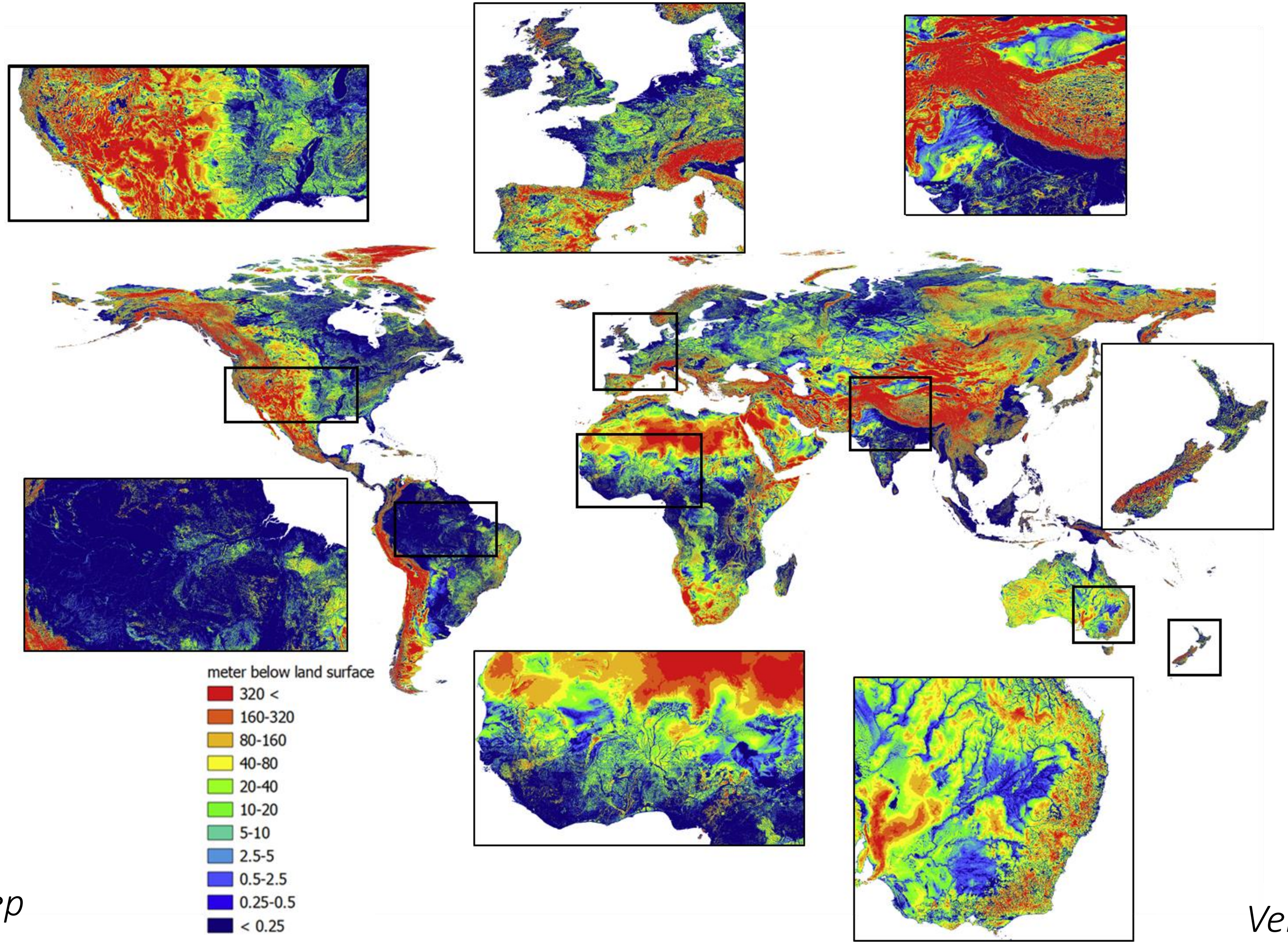
The history of global hydrological modelling



Pushing the boundaries



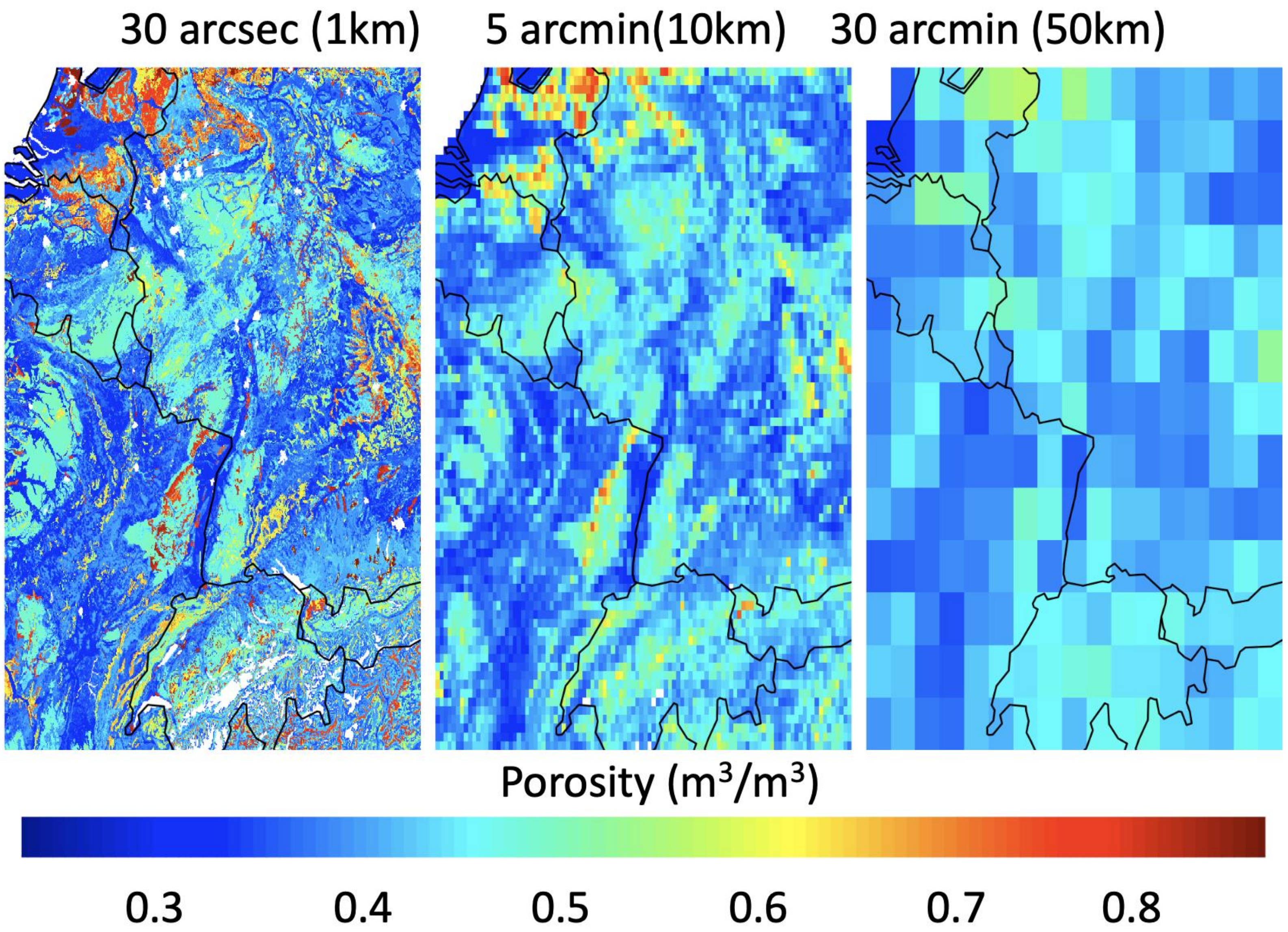
Pushing the boundaries



Verkaik et al, in prep

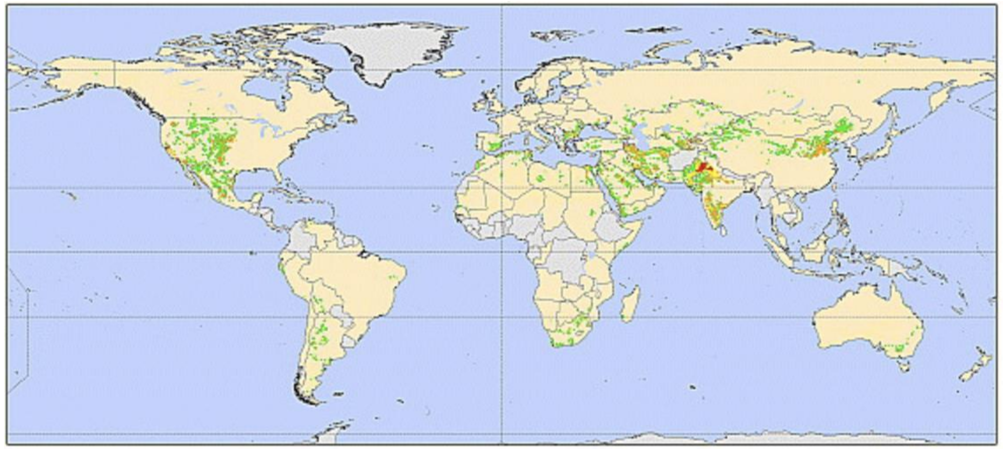
Verkaik et al, in prep

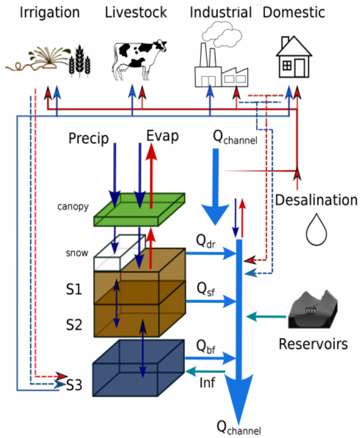
Pushing the boundaries

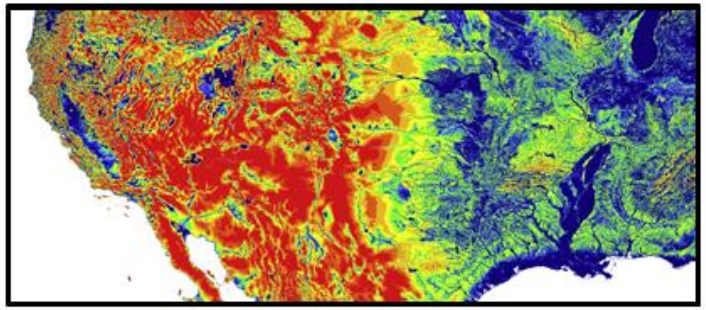


Samaniego et al, 2017

Vision and progress

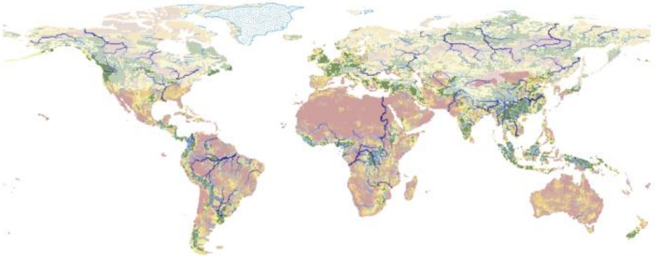


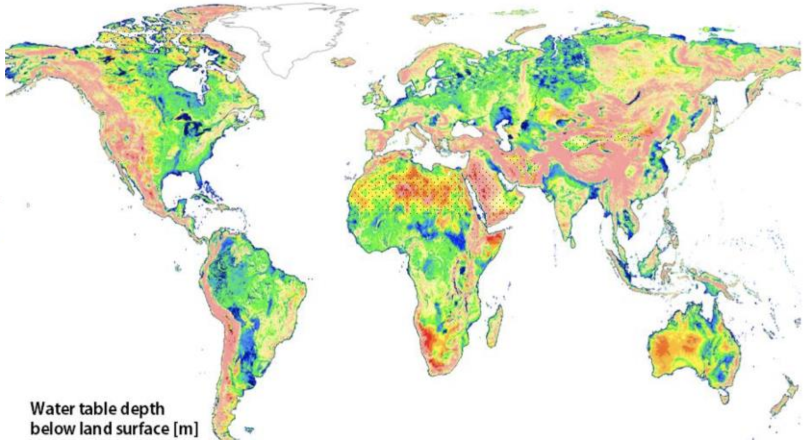


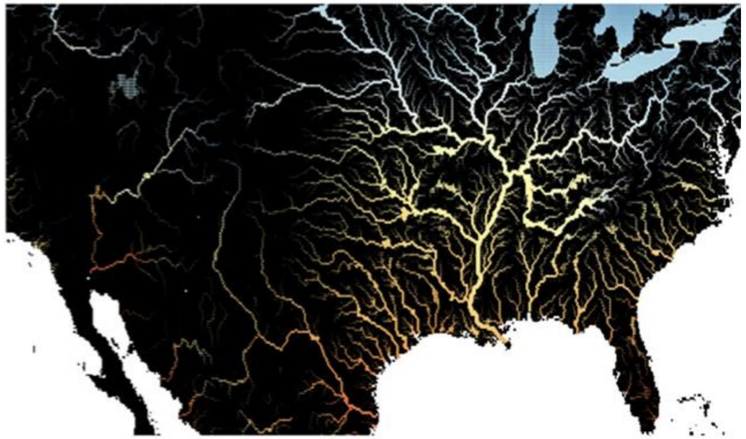


2011 2018 2022

2007 2015 2019 2027







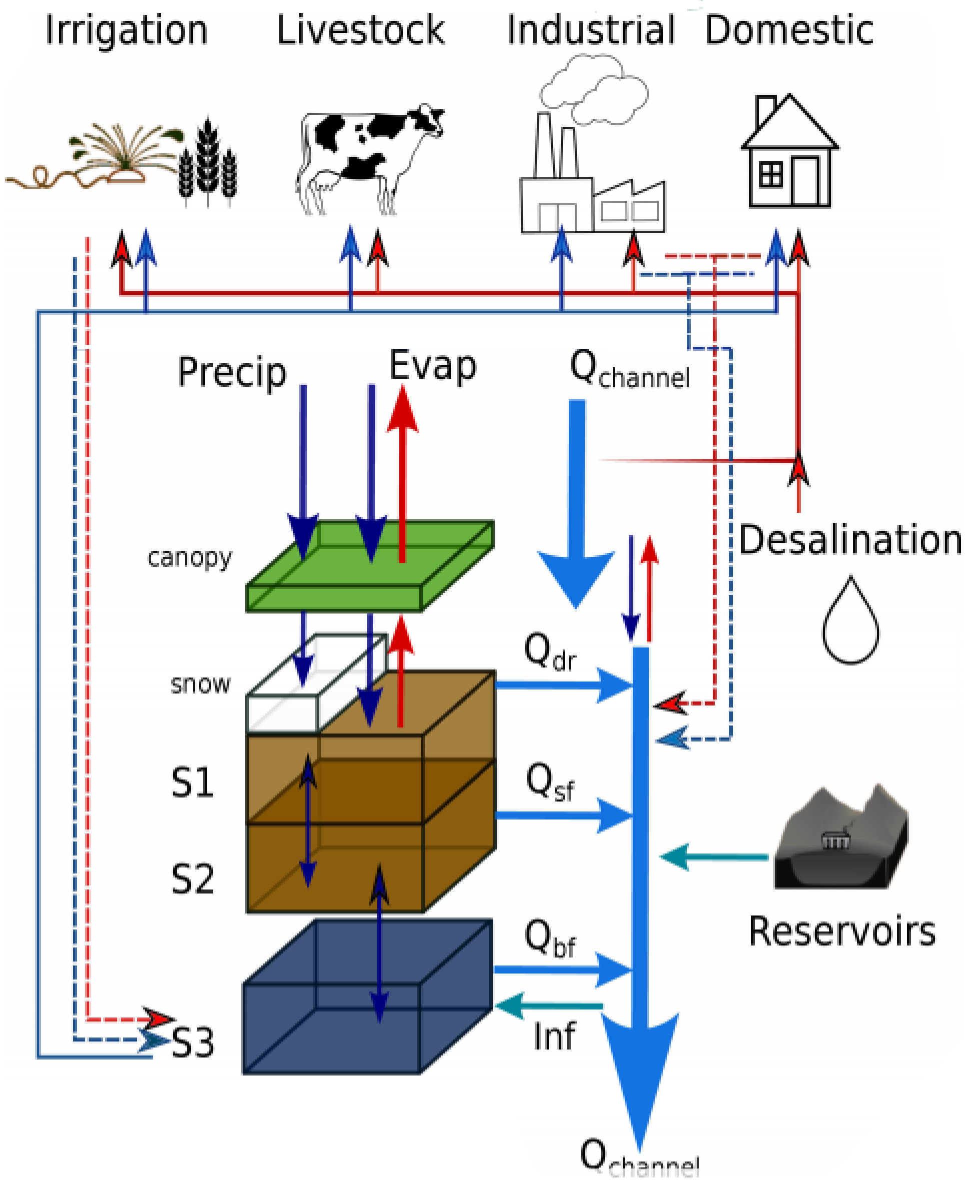
Global hydrological modelling with PCR-GLOBWB

Model resolution:

- Regular grid of 0.5° (50 km), 0.1 ° (10 km), 0.01 ° (1 km)
- Daily time step

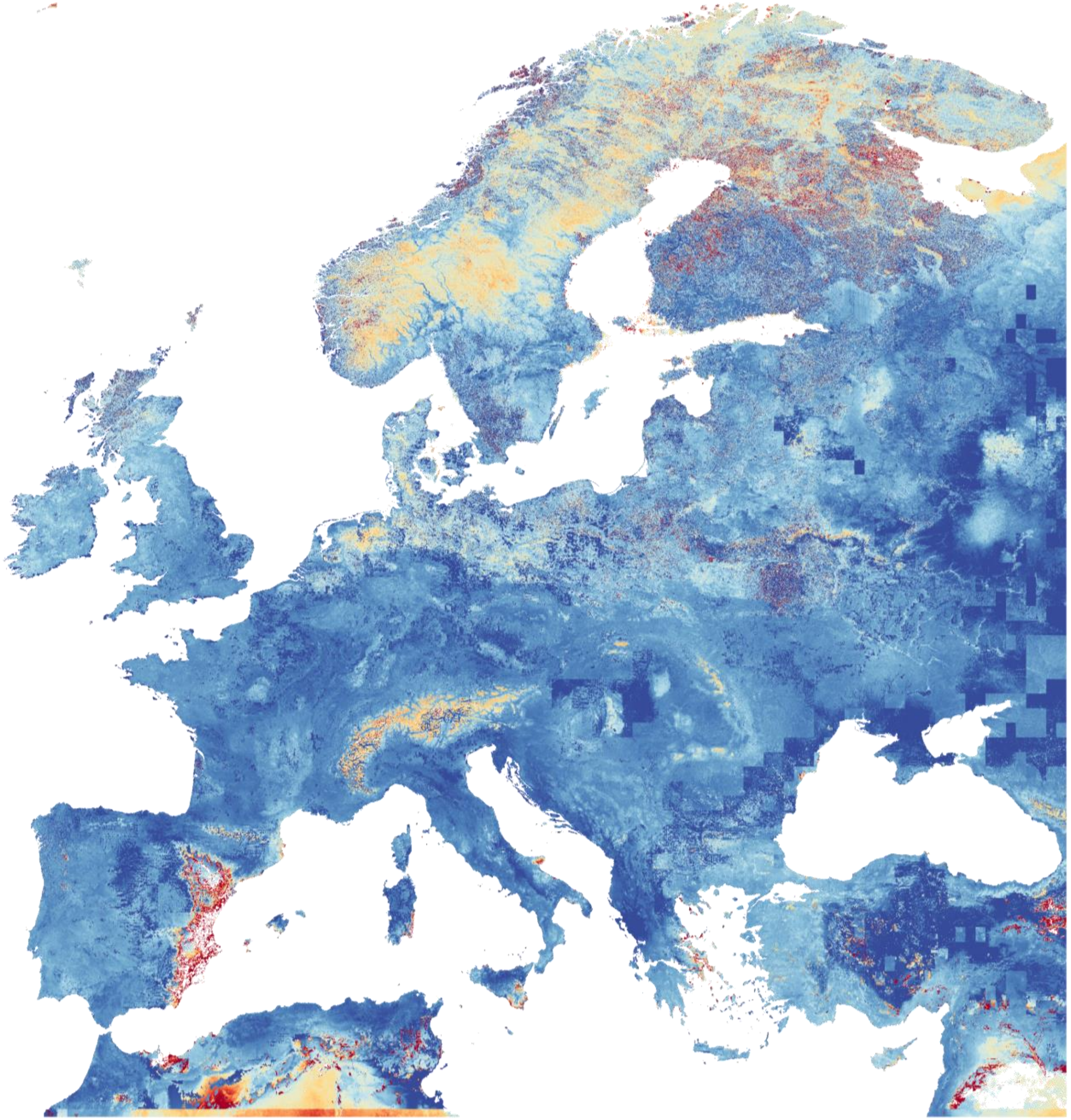
Model includes:

- Human water interactions
  - Groundwater pumping
  - Irrigation
  - Surface water abstraction
  - Lakes and reservoirs
- Flood plains
- 2D groundwater flow
- Coupling with hydrodynamic models
- Water temperature

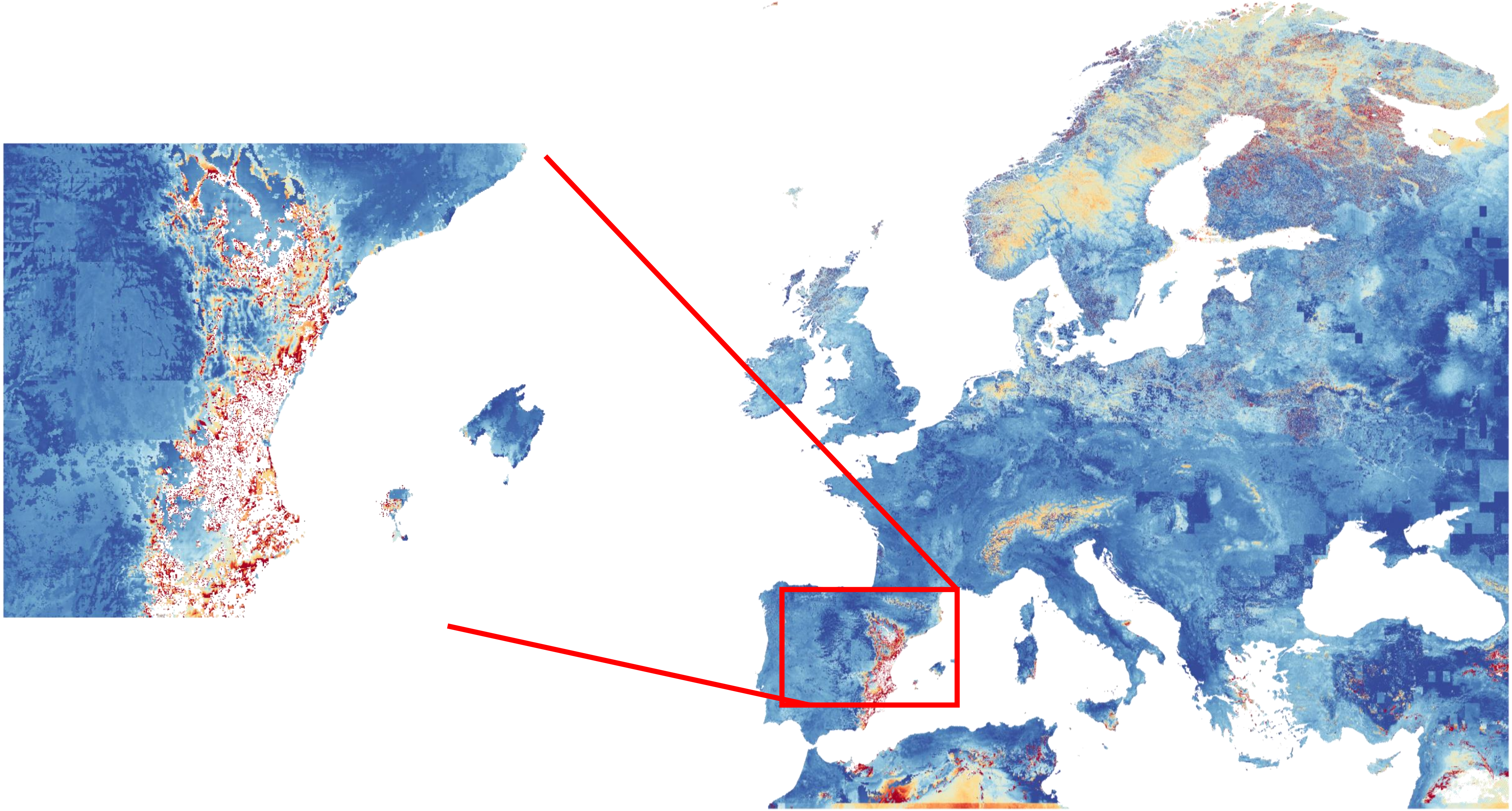


Sutanudjaja et al, 2018, GMD

How does it work?

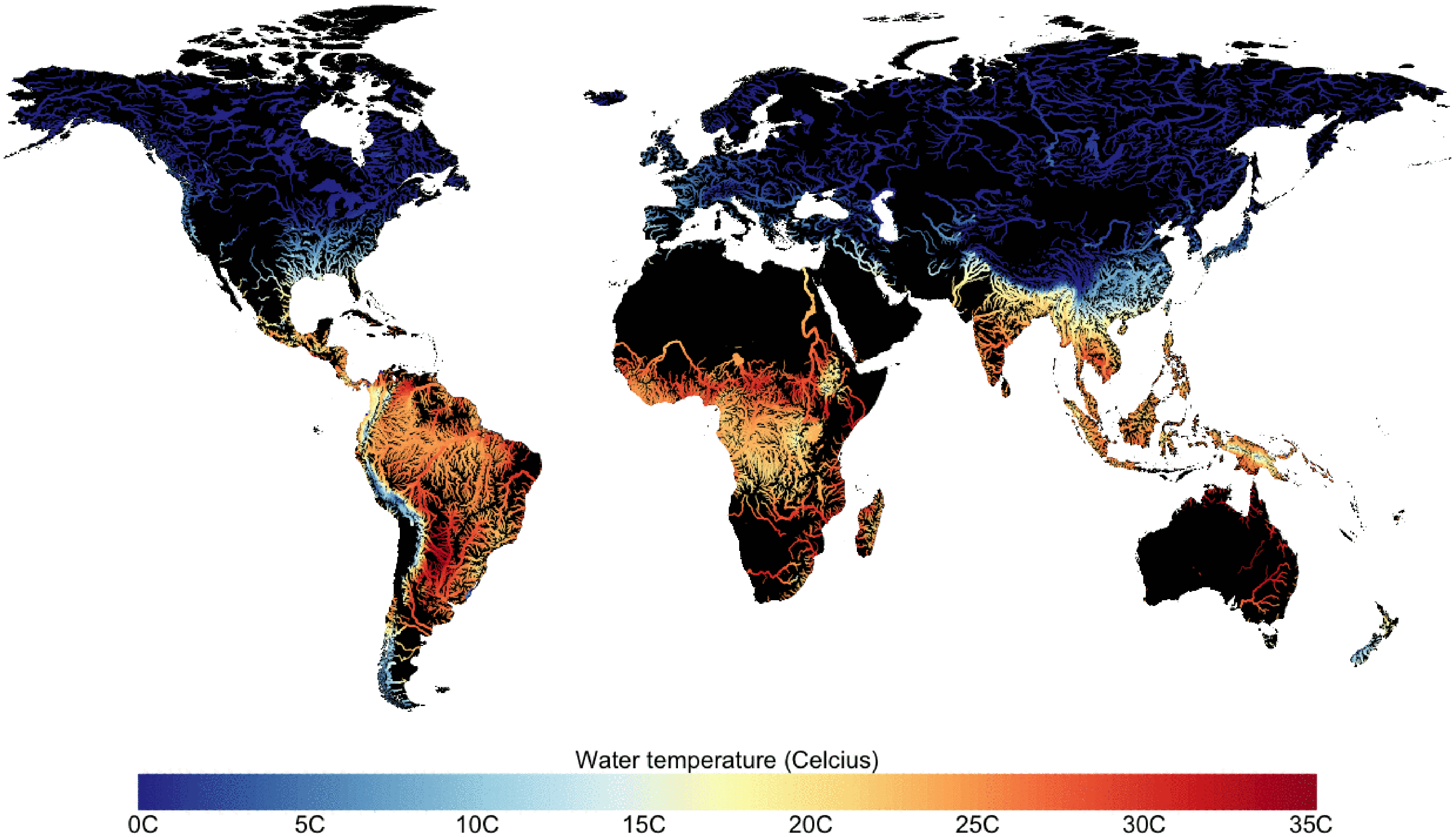


How does it work?



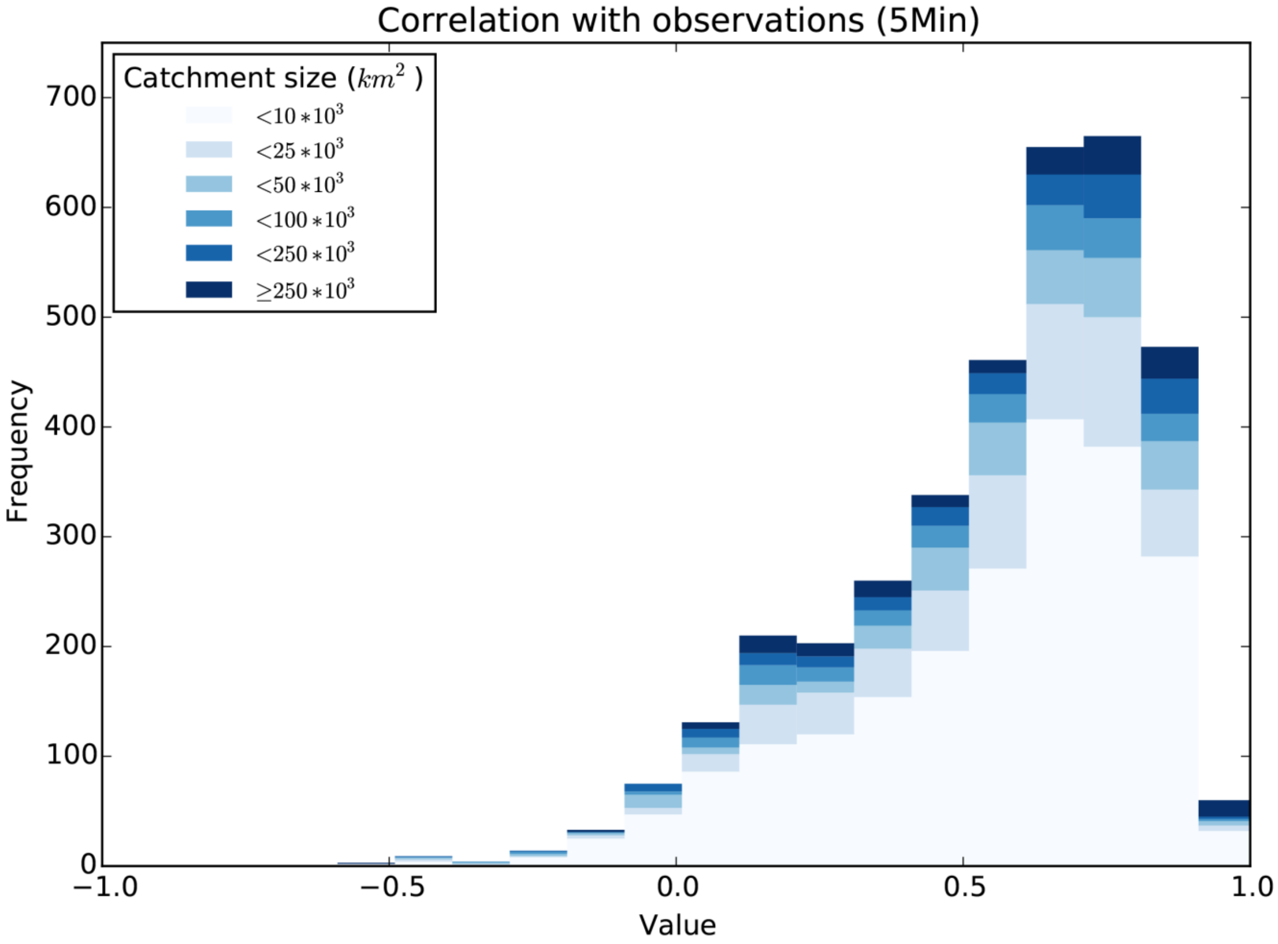
How does it work?

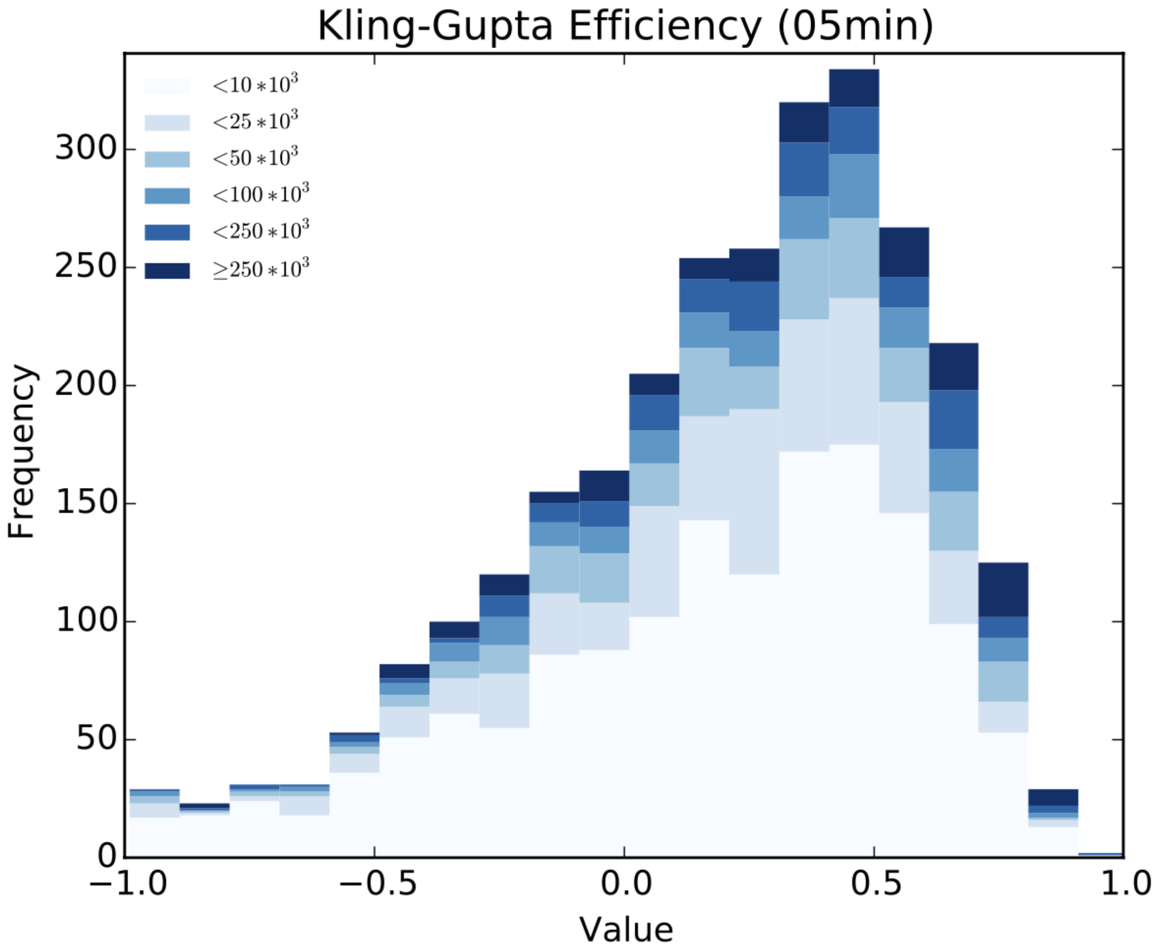
Simulating global water temperatures



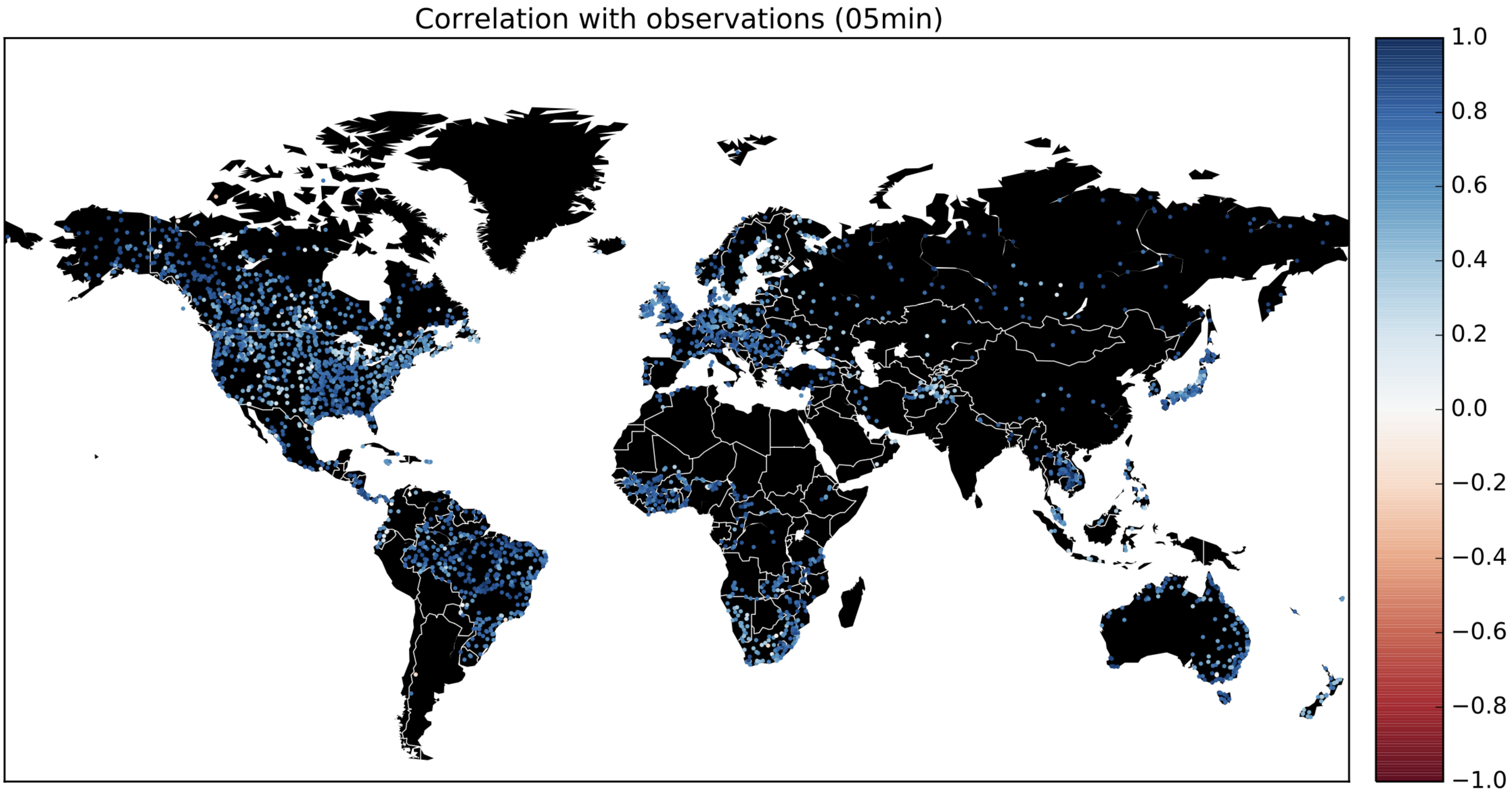
Wanders et al (2019), WRR

Validation is key

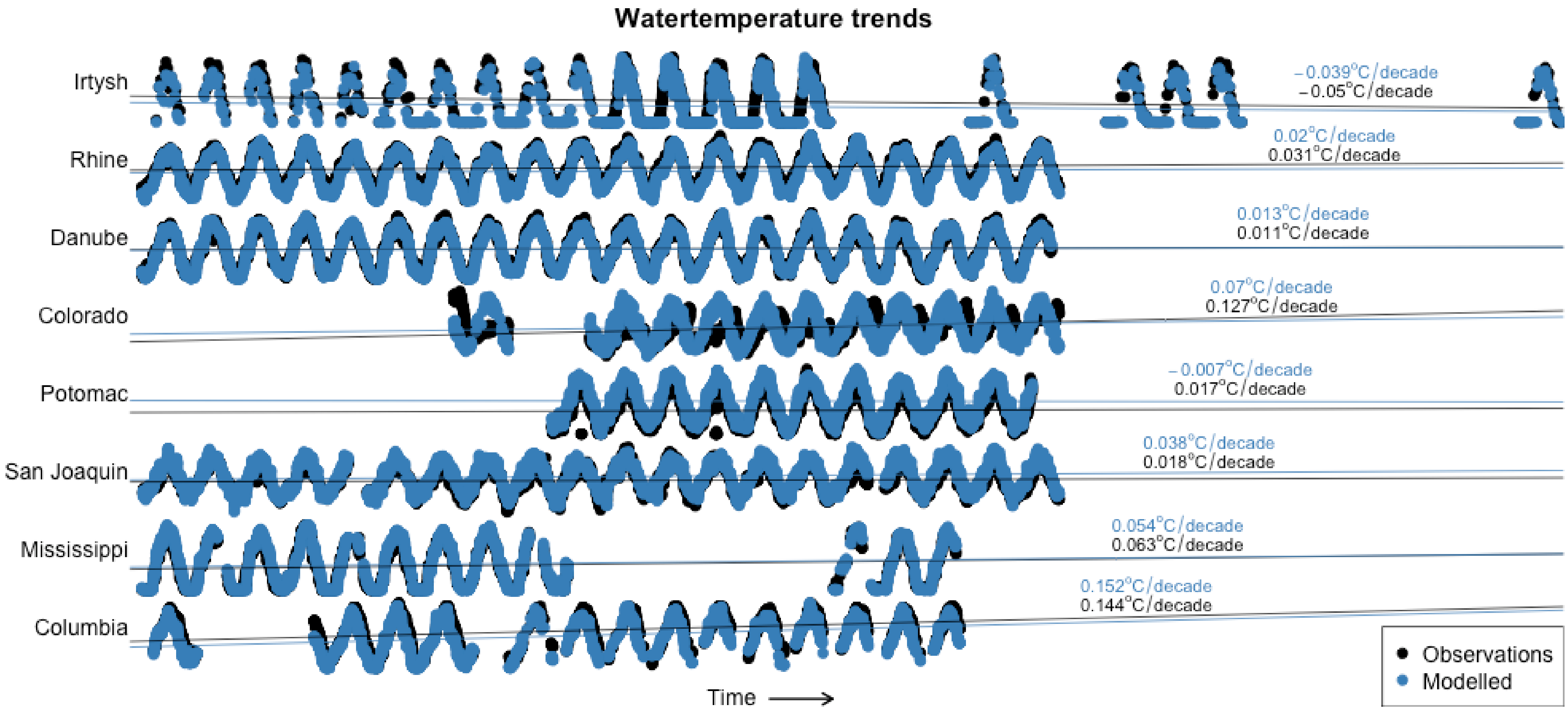




Validation is key

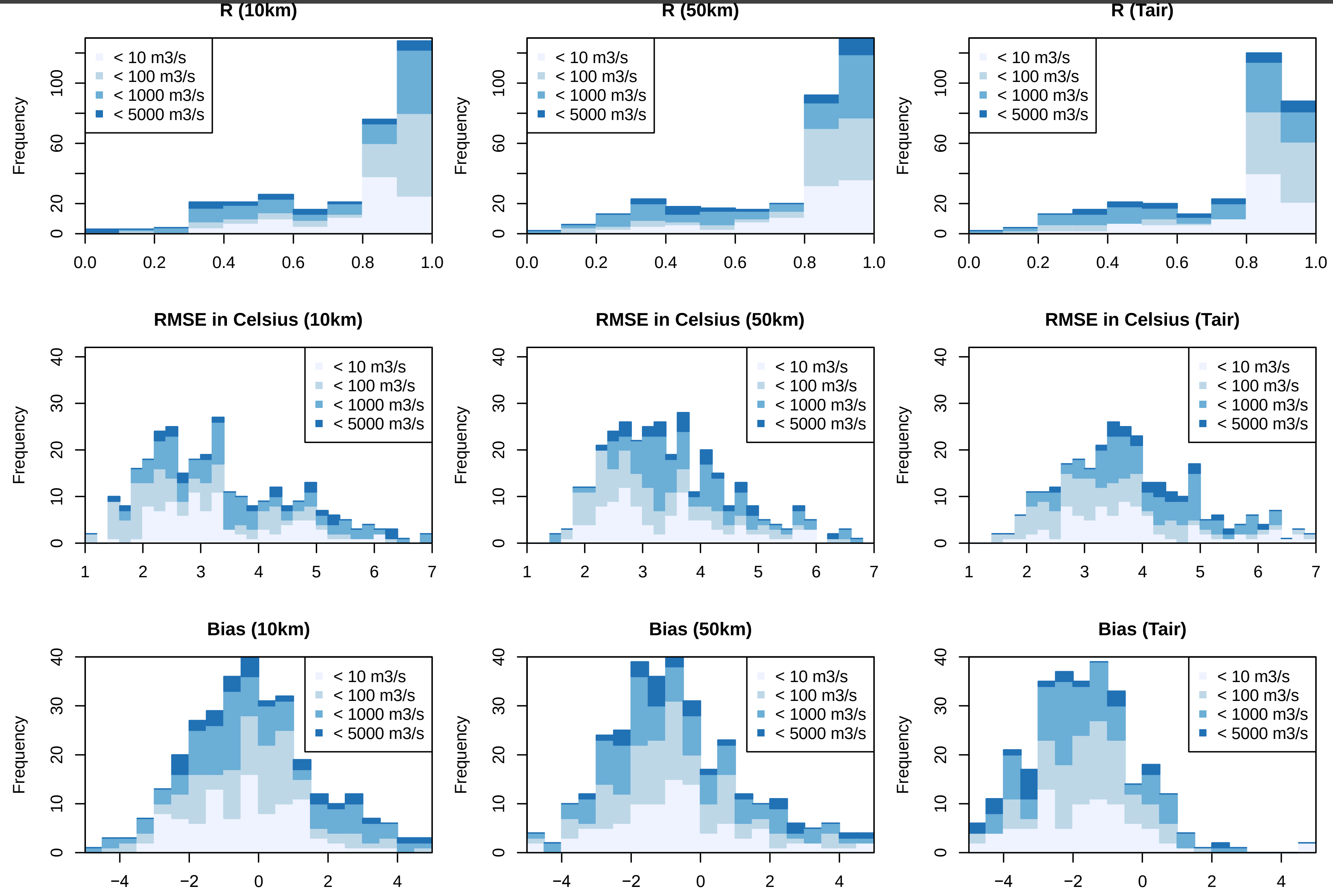


Global water temperature trends



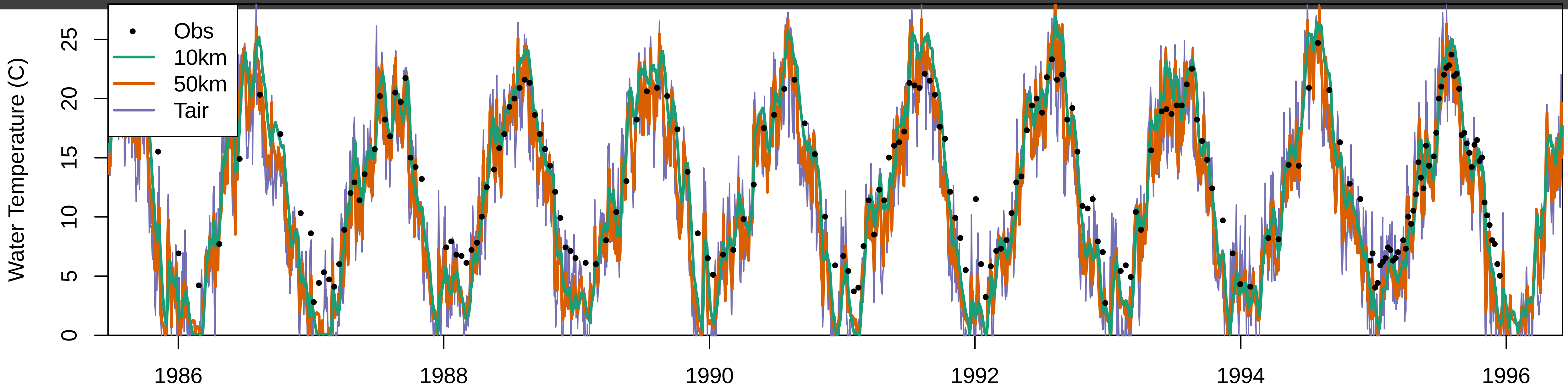
Wanders *et al.* (2019), WRR

Validation

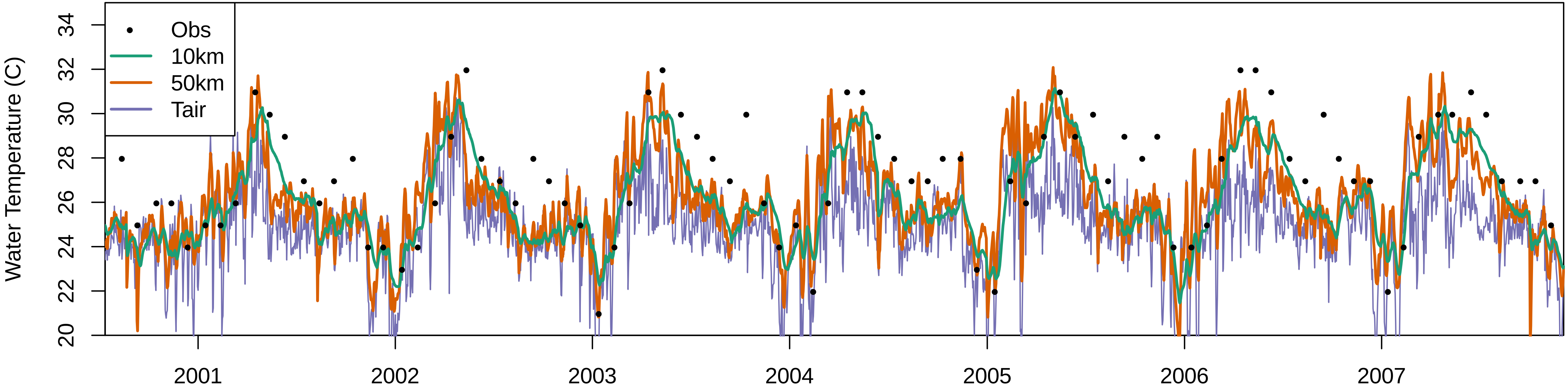


R (10km)
R (50km)
R (Tair)
RMSE in Celsius (10km)
RMSE in Celsius (50km)
RMSE in Celsius (Tair)
Bias (10km)
Bias (50km)
Bias (Tair)
Frequency
< 10 m3/s
< 100 m3/s
< 1000 m3/s
< 5000 m3/s

Validation

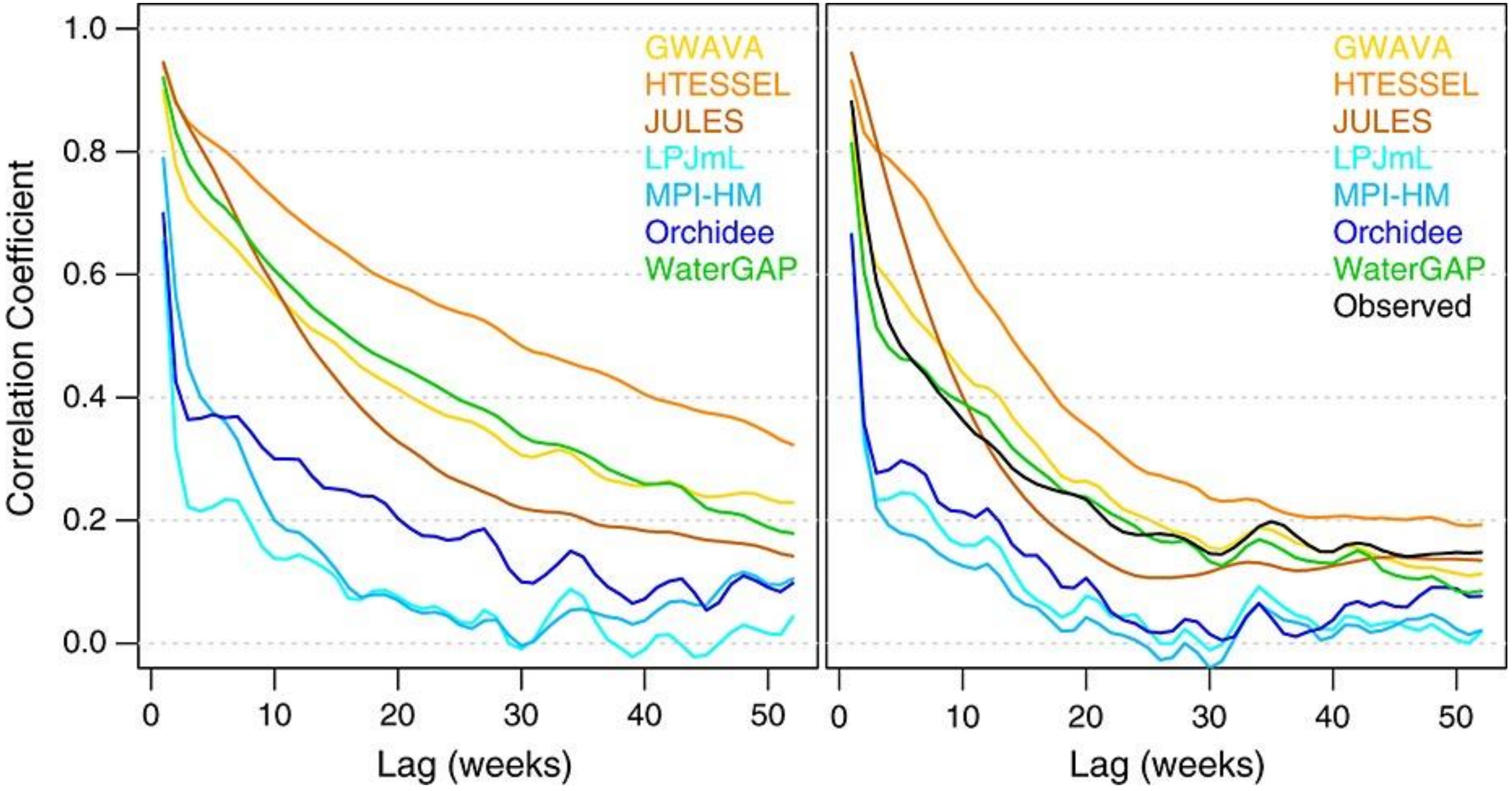


Obs
10km
50km
Tair
Water Temperature (C)
0
5
10
15
20
25
1986
1988
1990
1992
1994
1996



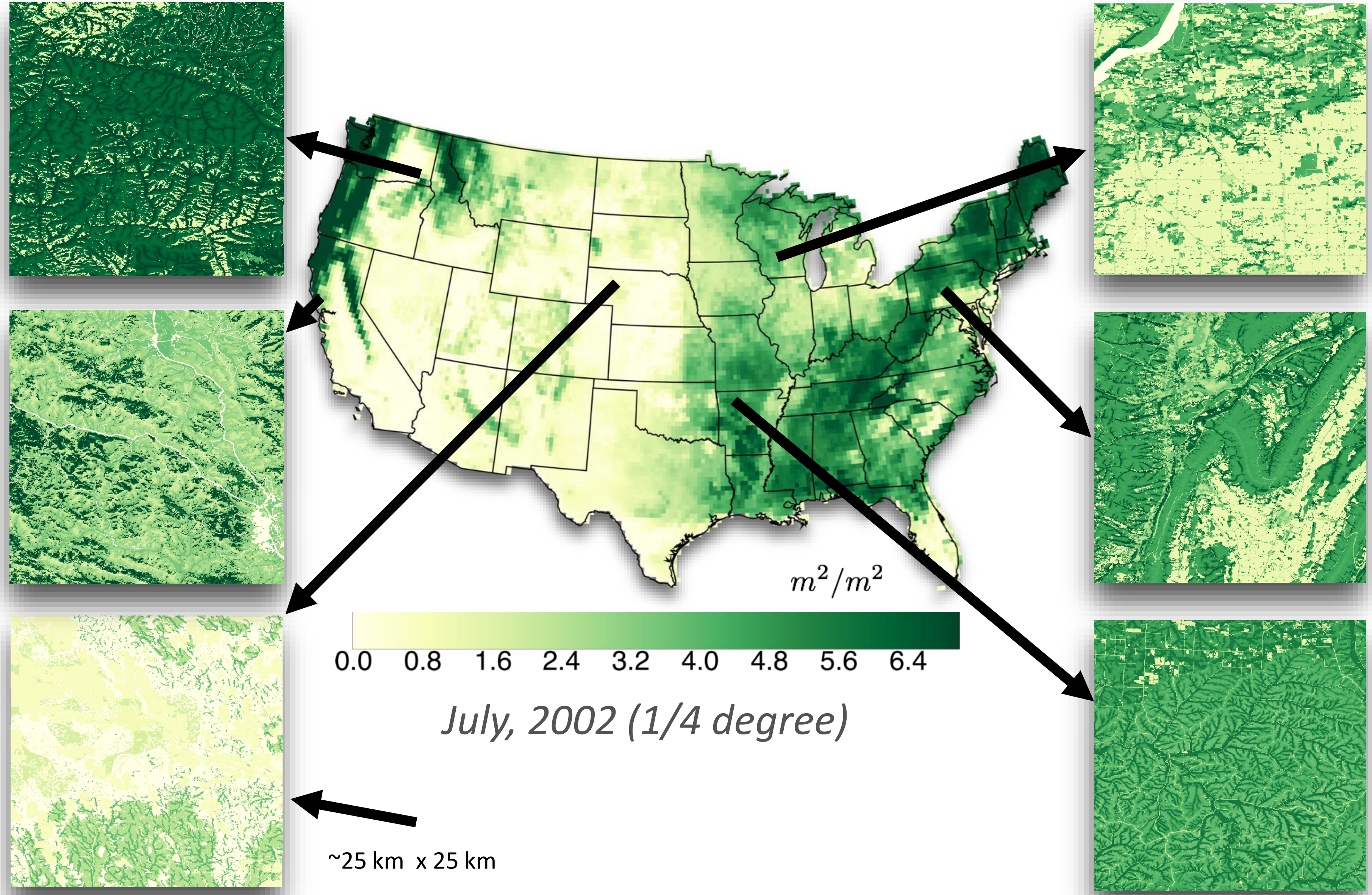
Obs
10km
50km
Tair
Water Temperature (C)
20
22
24
26
28
30
32
34
2001
2002
2003
2004
2005
2006
2007

Models matter



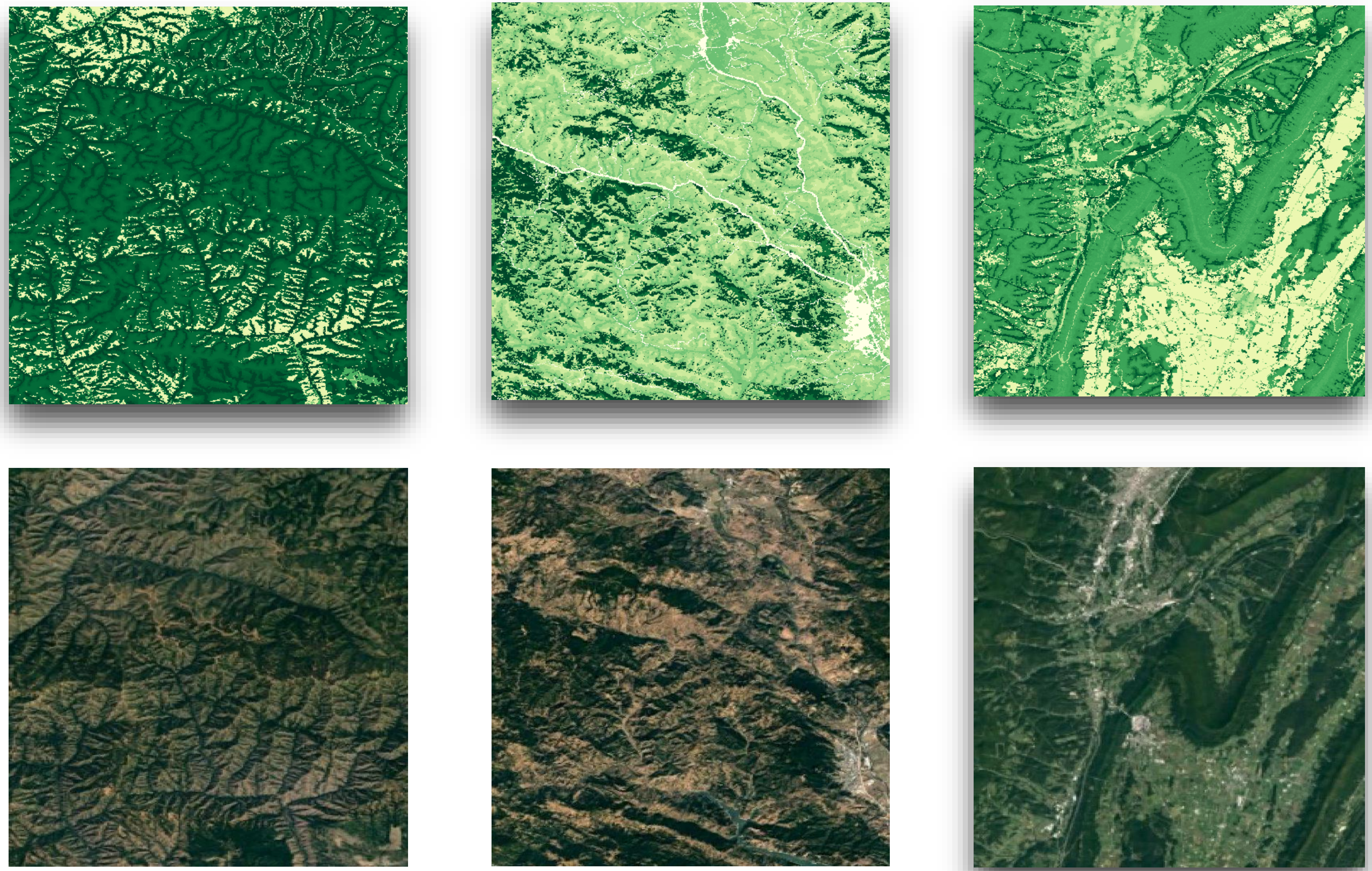
Tallaksen and Stahl GRL, 2014

Hyper-resolution modelling



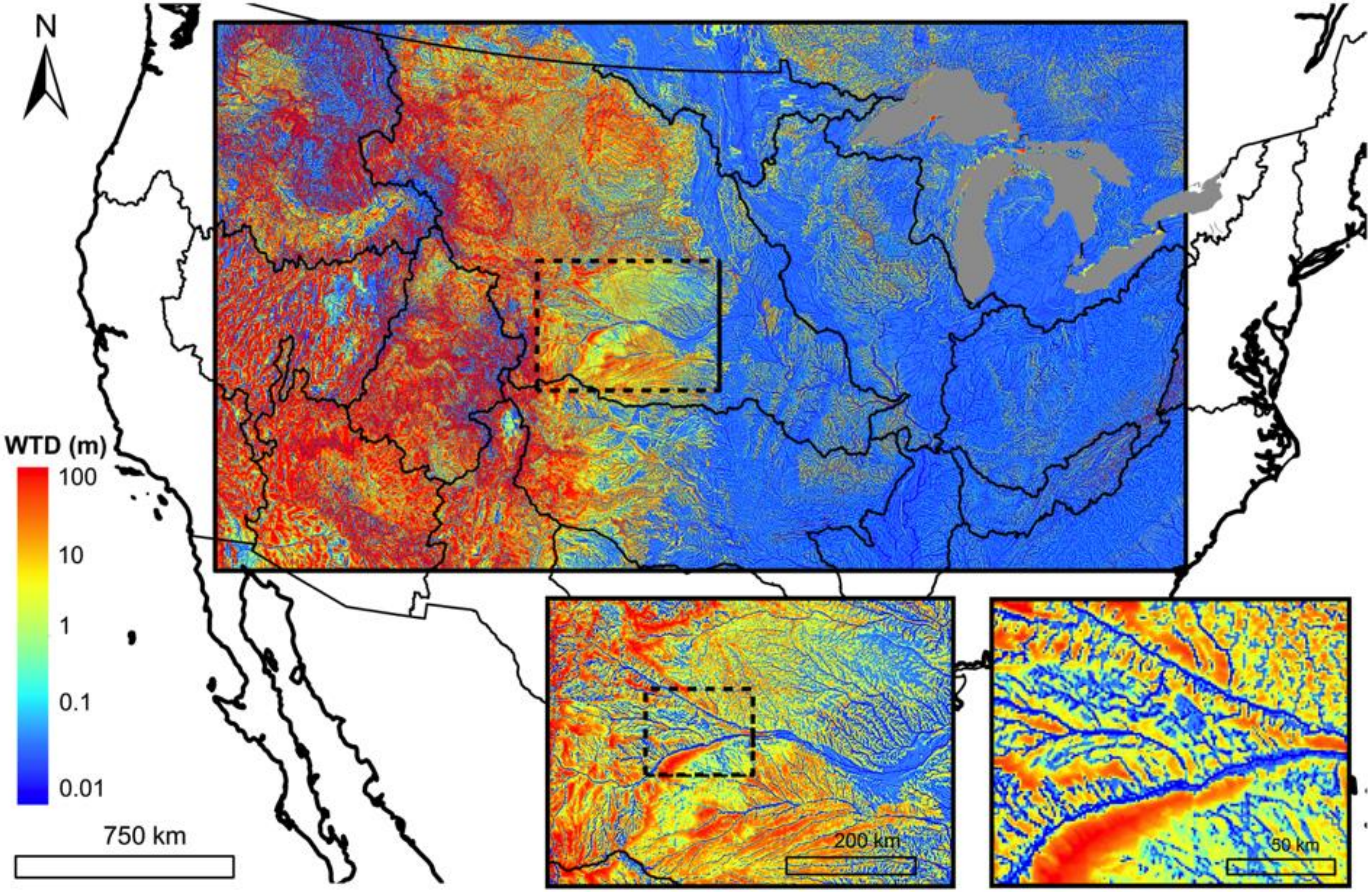
Chaney et al., HESS, 2018

Hyper-resolution modelling



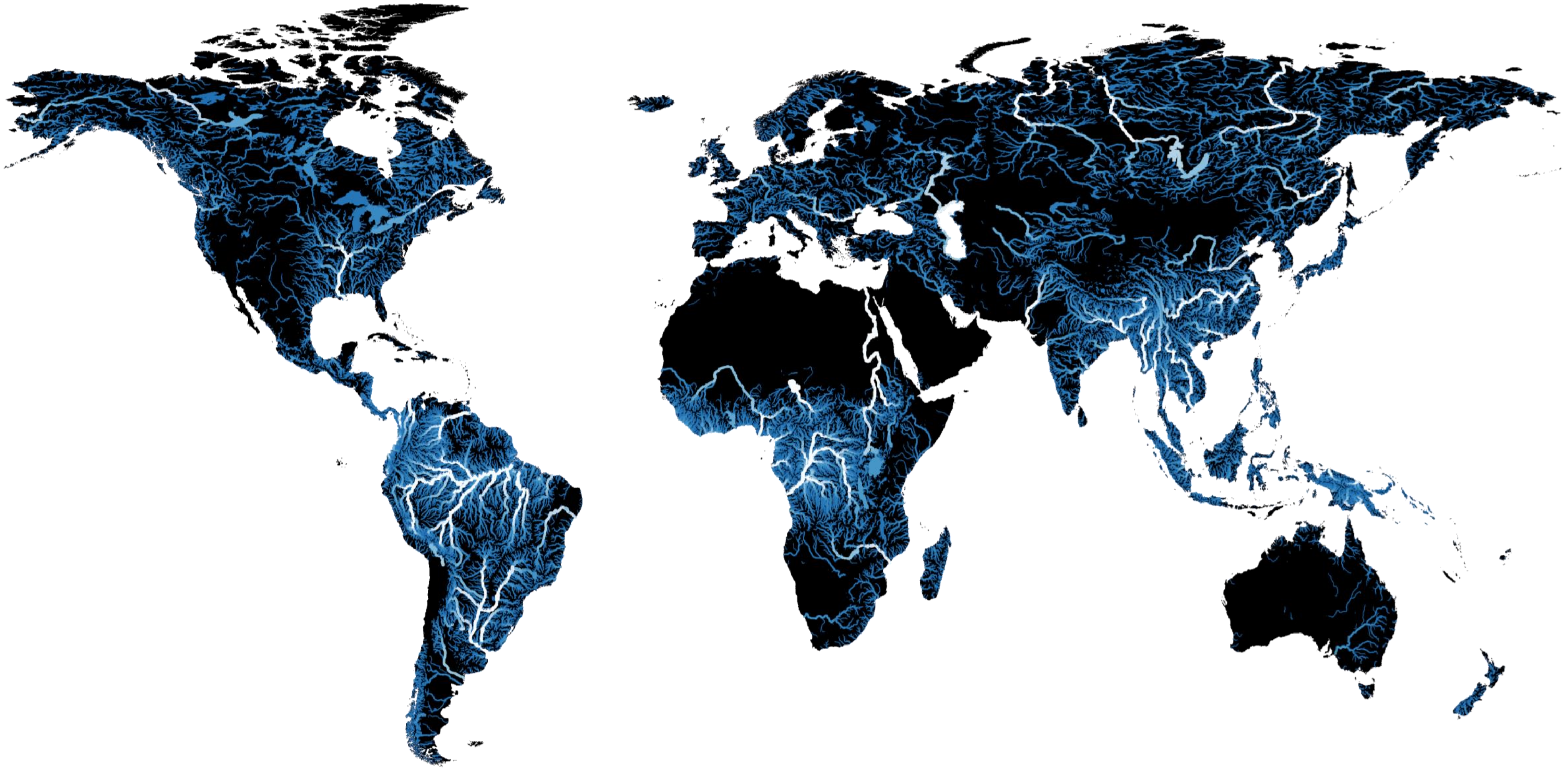
Chaney et al., HESS, 2018

Resolution matters

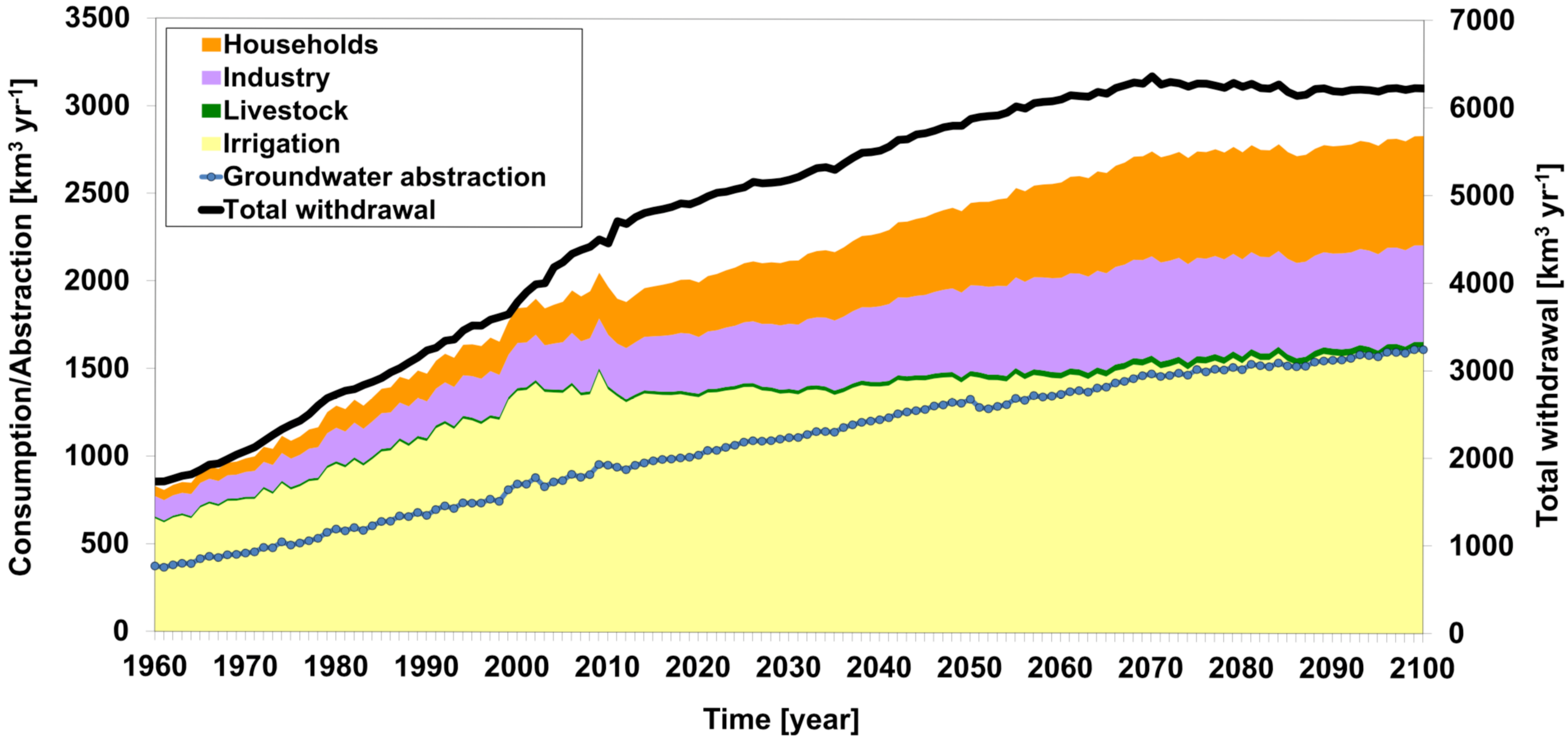


Maxwell et al, GMD, 2015

Making invisible water flow visible

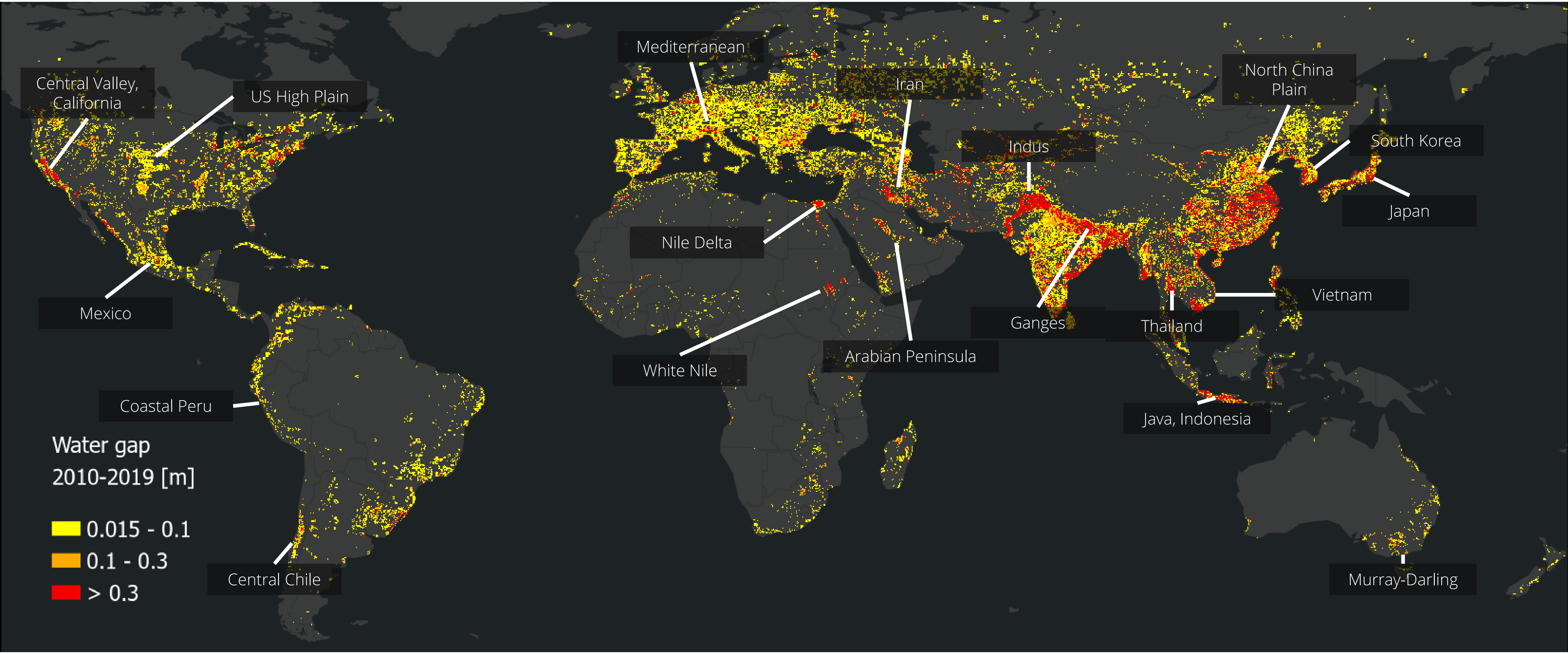


Making invisible water consumption visible

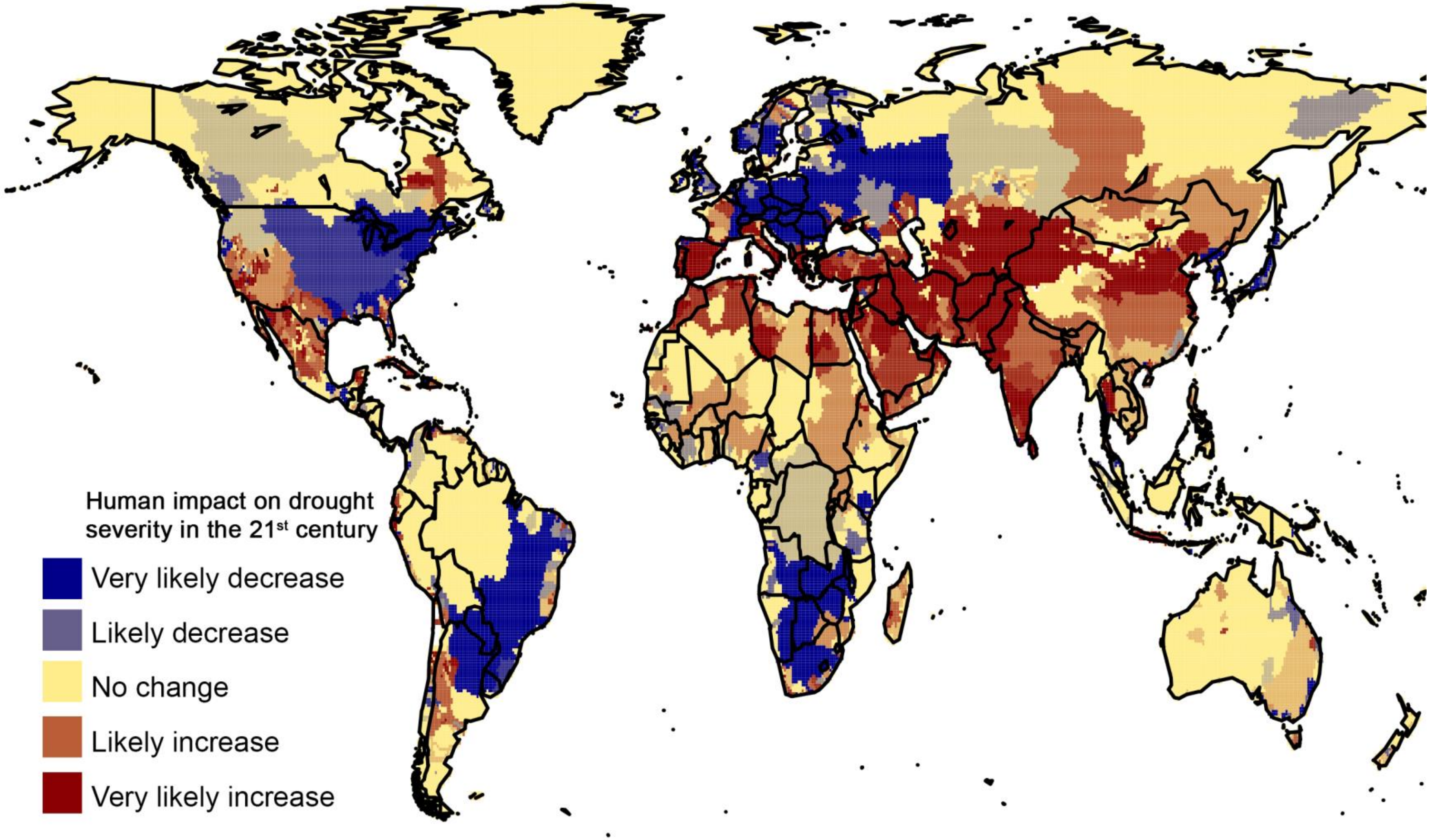


Wada and Bierkens, 2014, ERL

Making invisible water consumption visible

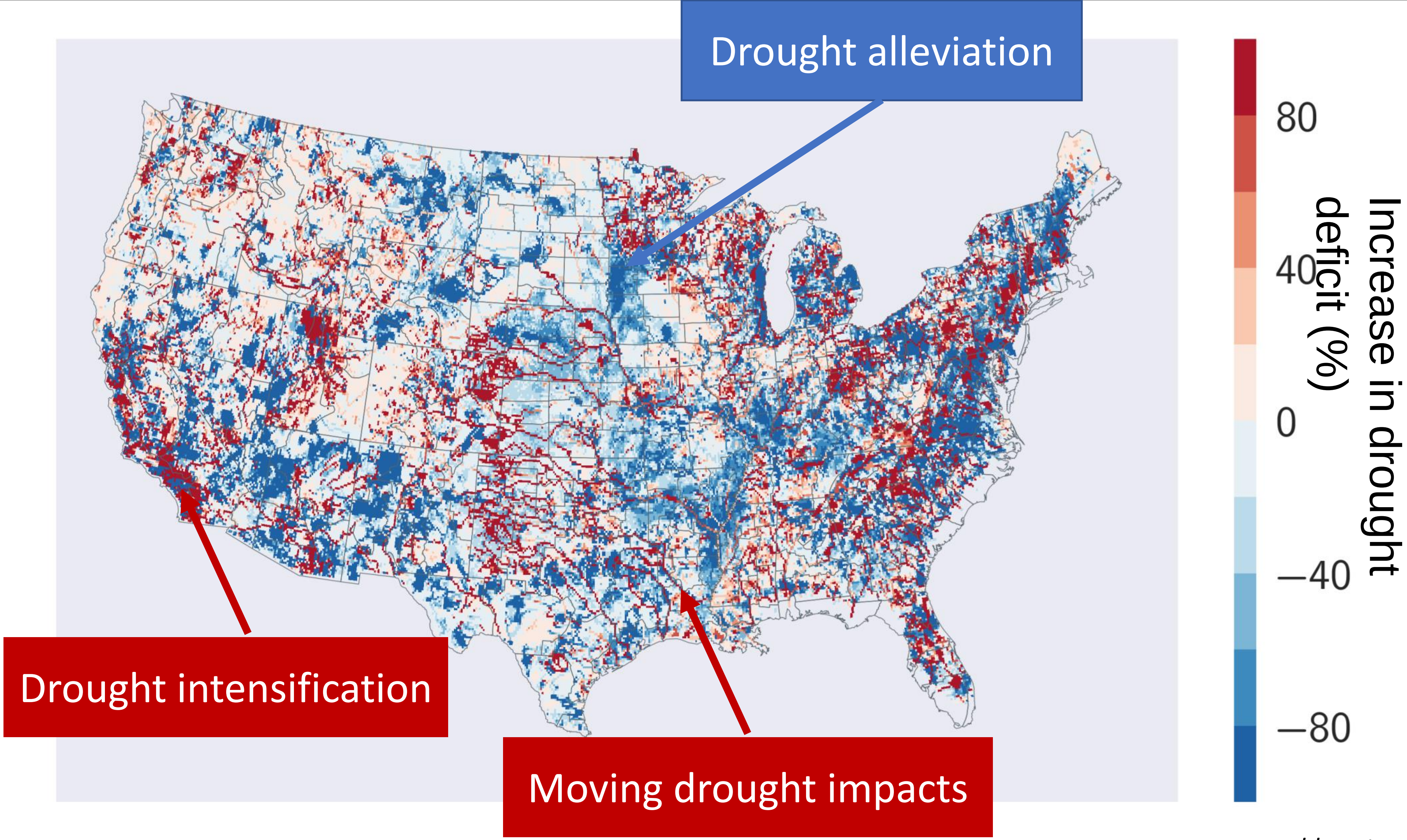


Human impact on global water resources



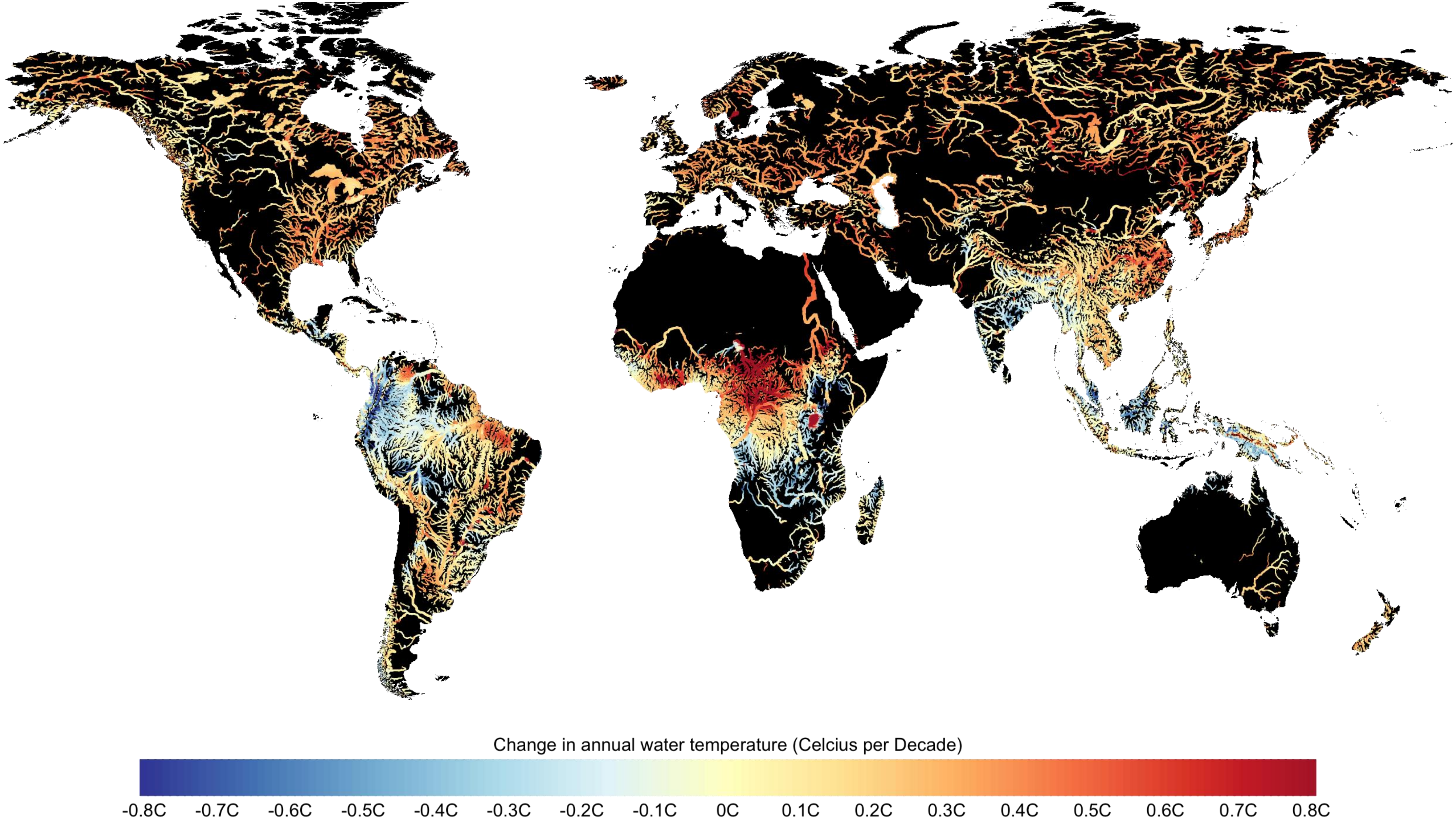
Wanders and Wada, JOH, 2015

Making invisible impacts visible



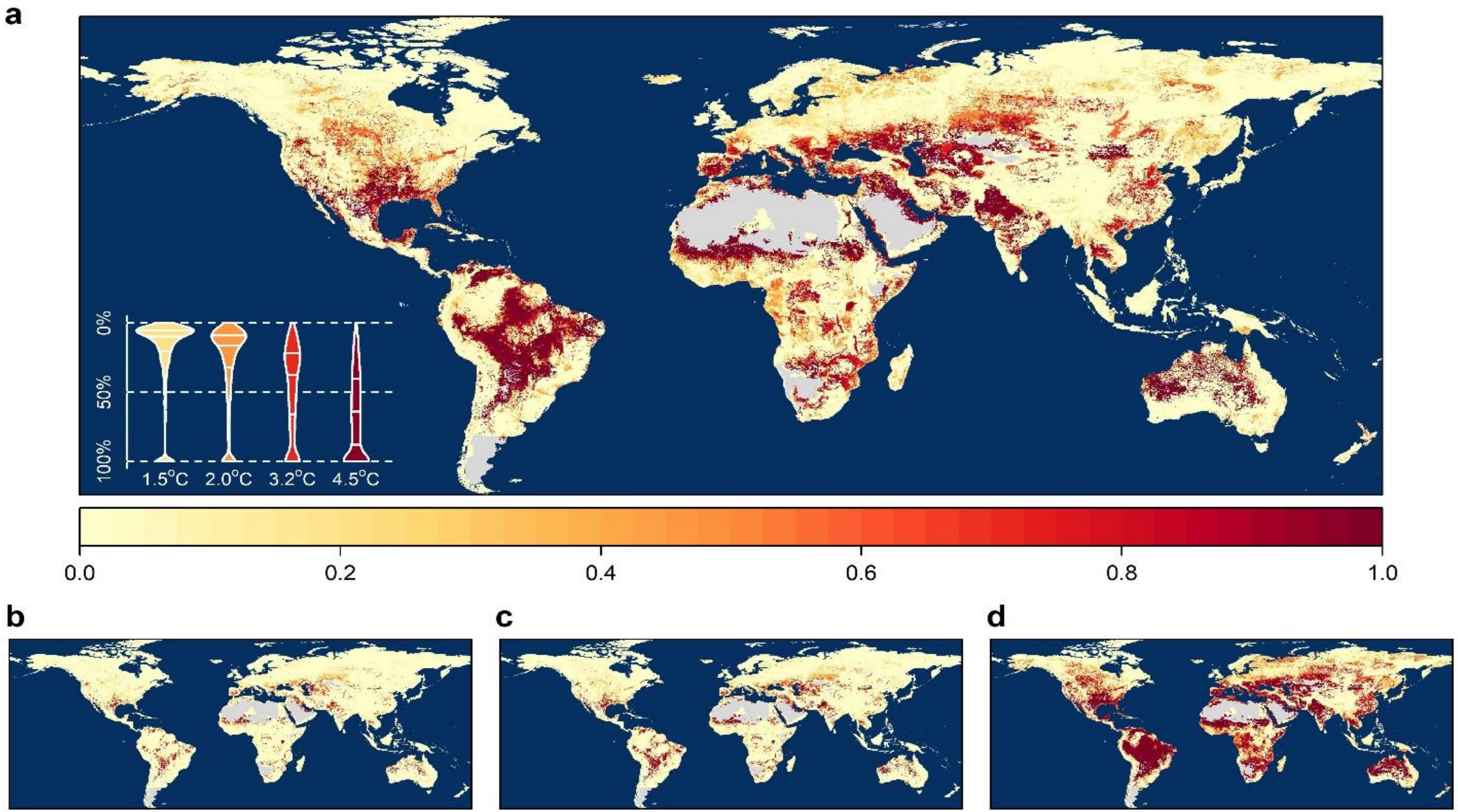
He et al., 2017, GRL

Trends in global water temperatures



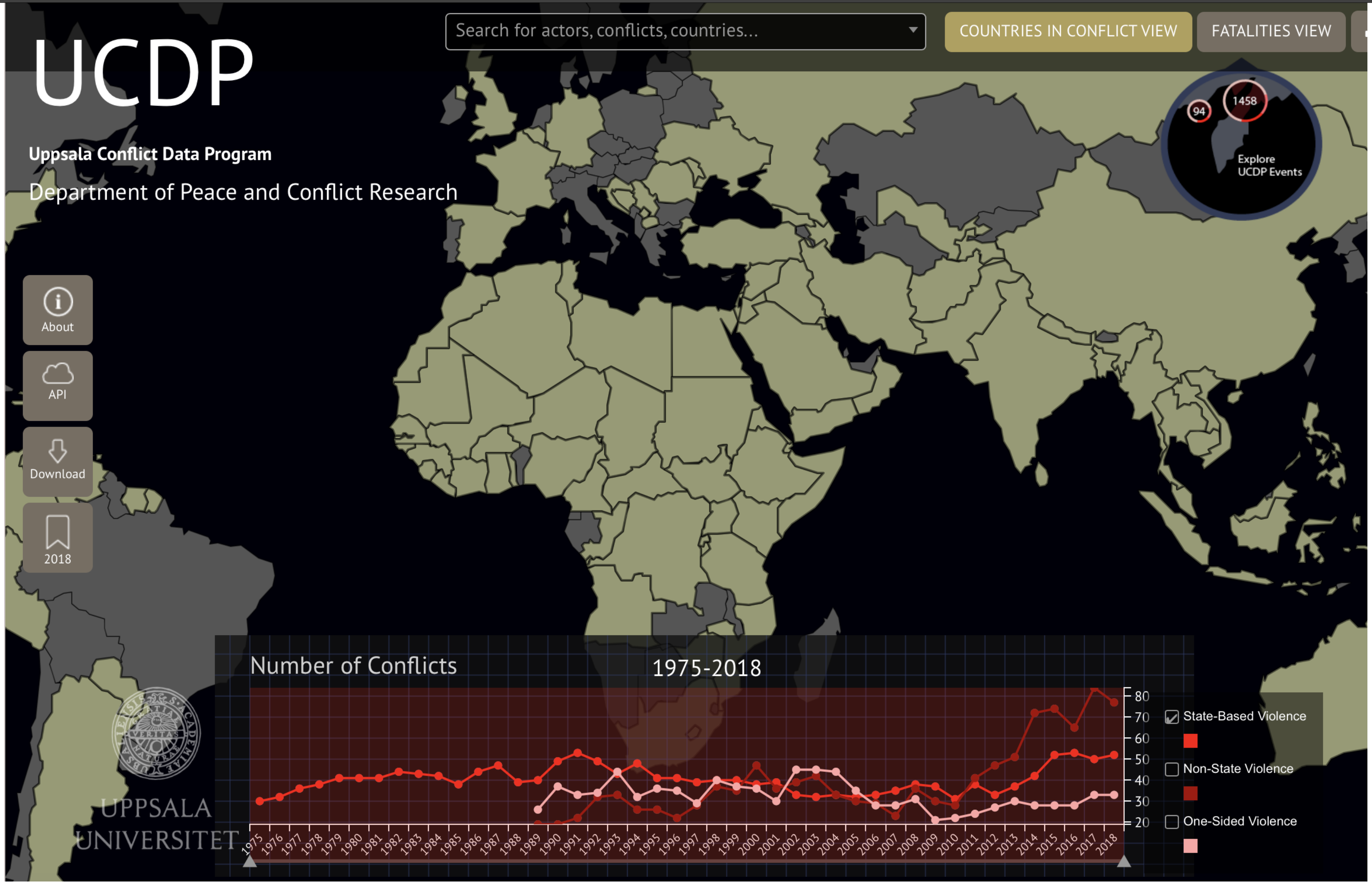
Wanders et al (2019), WRR

Visible impacts on fish species



Barbarossa et al. (2021), Nature com

Visible impacts on global security

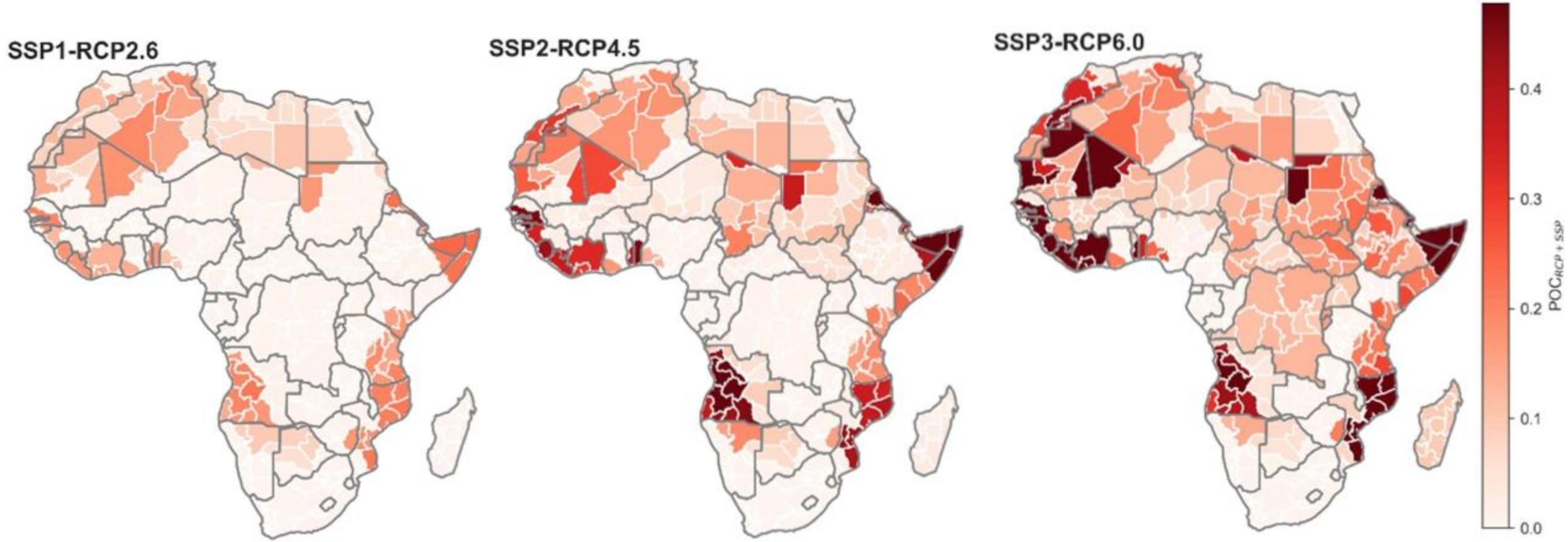


UPPSALA UNIVERSITET

CNDS

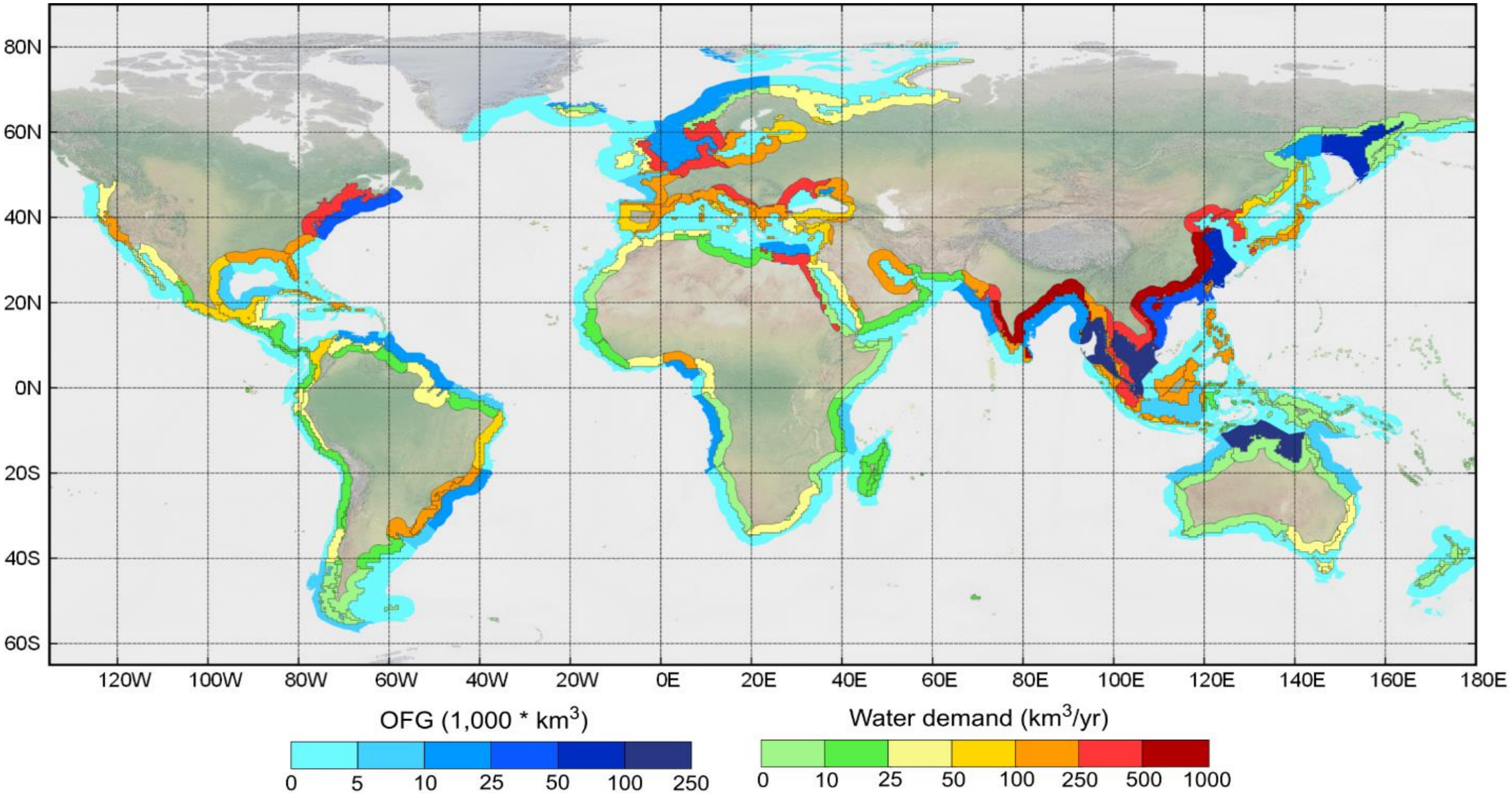
PRIO Peace Research Institute Oslo

Bridging to new communities, drought and conflict



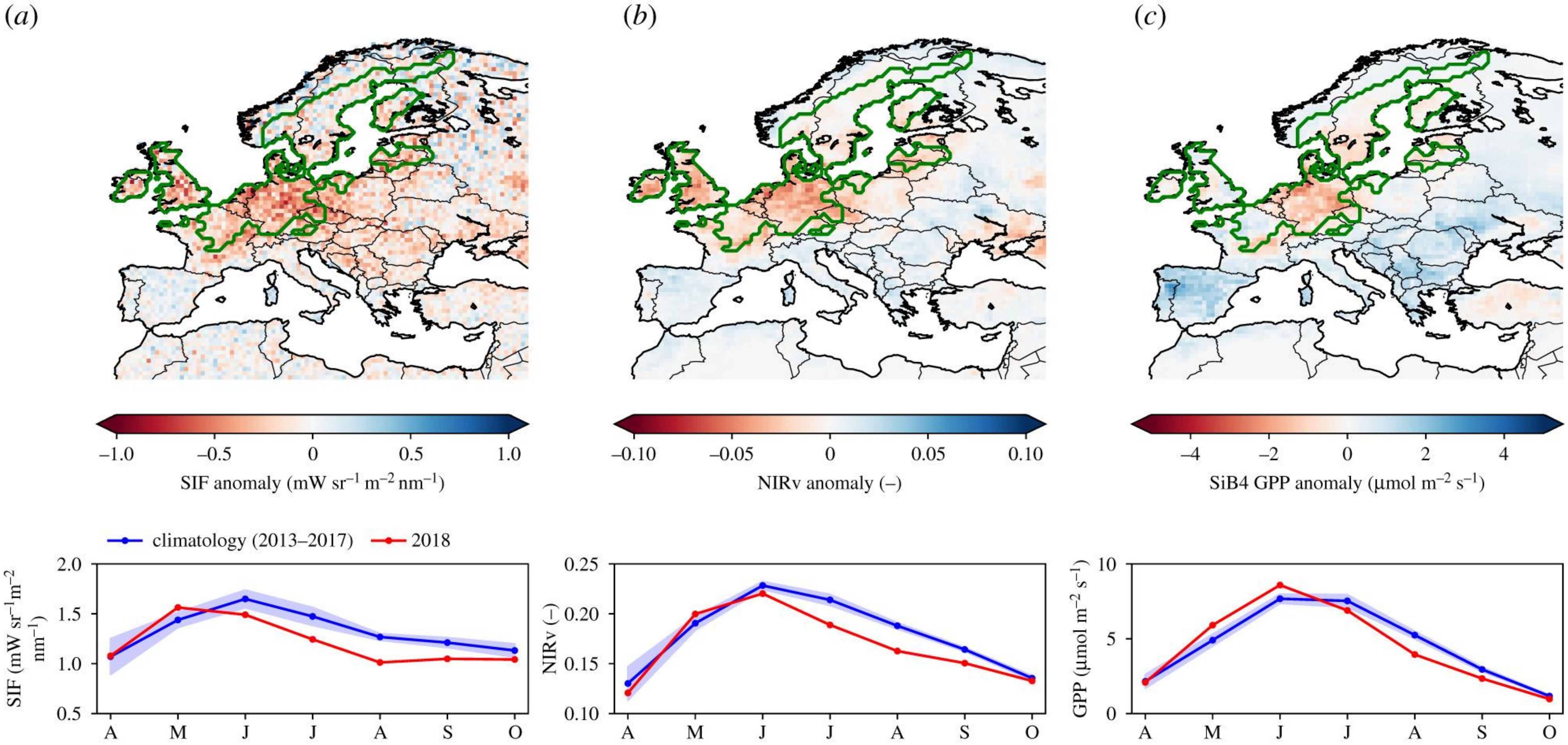
De Bruin et al 2022, GEC, Hoch et al 2021, ERL

Offshore fresh groundwater resources visible



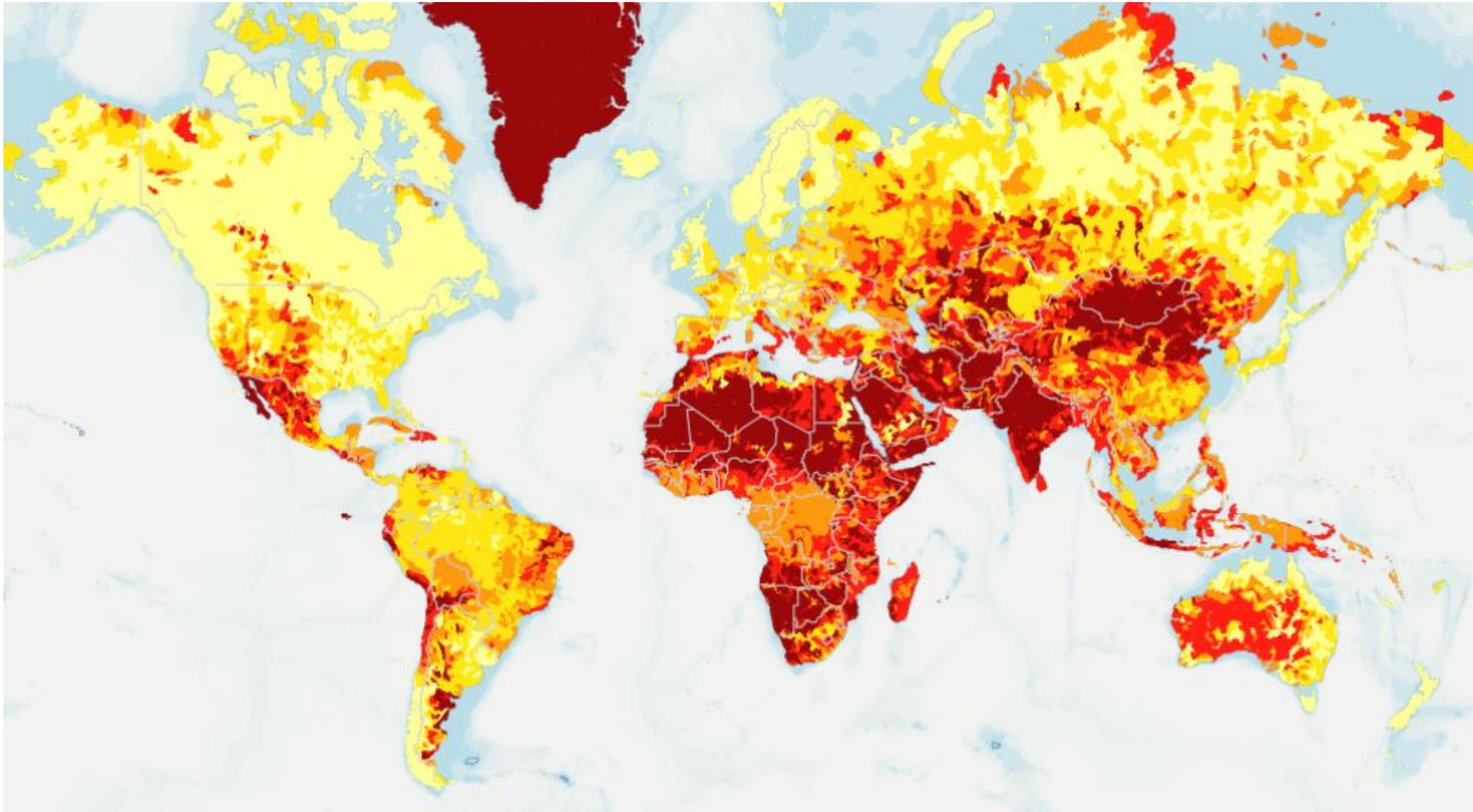
Zamrsky et al. (2021)

Linking hydrology to vegetation



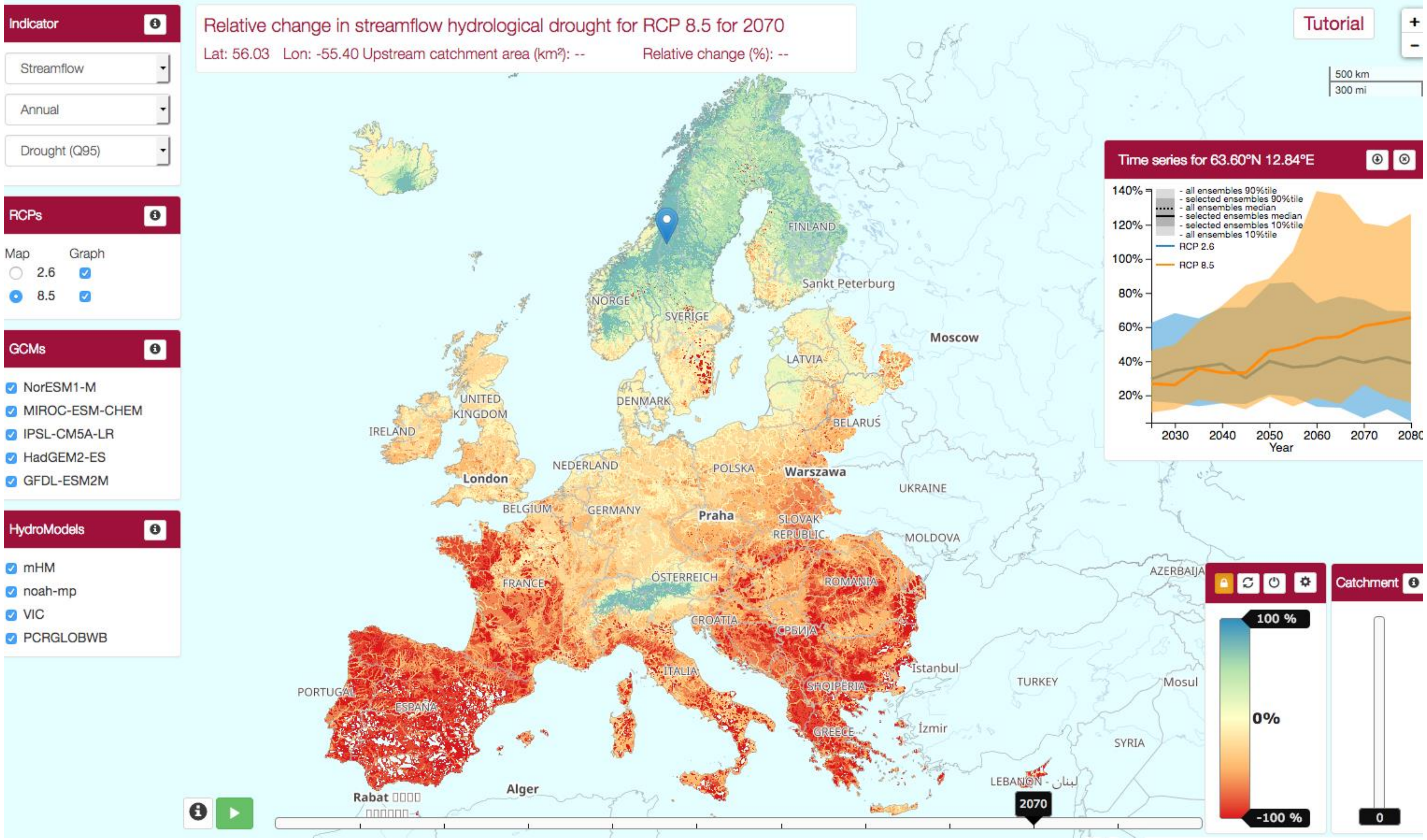
Smith et al., Philos. Trans. R. Soc. Lond., B, Biol. Sci., 2020

Making visible global hotspot of water scarcity



WRI Aqueduct water risk atlas

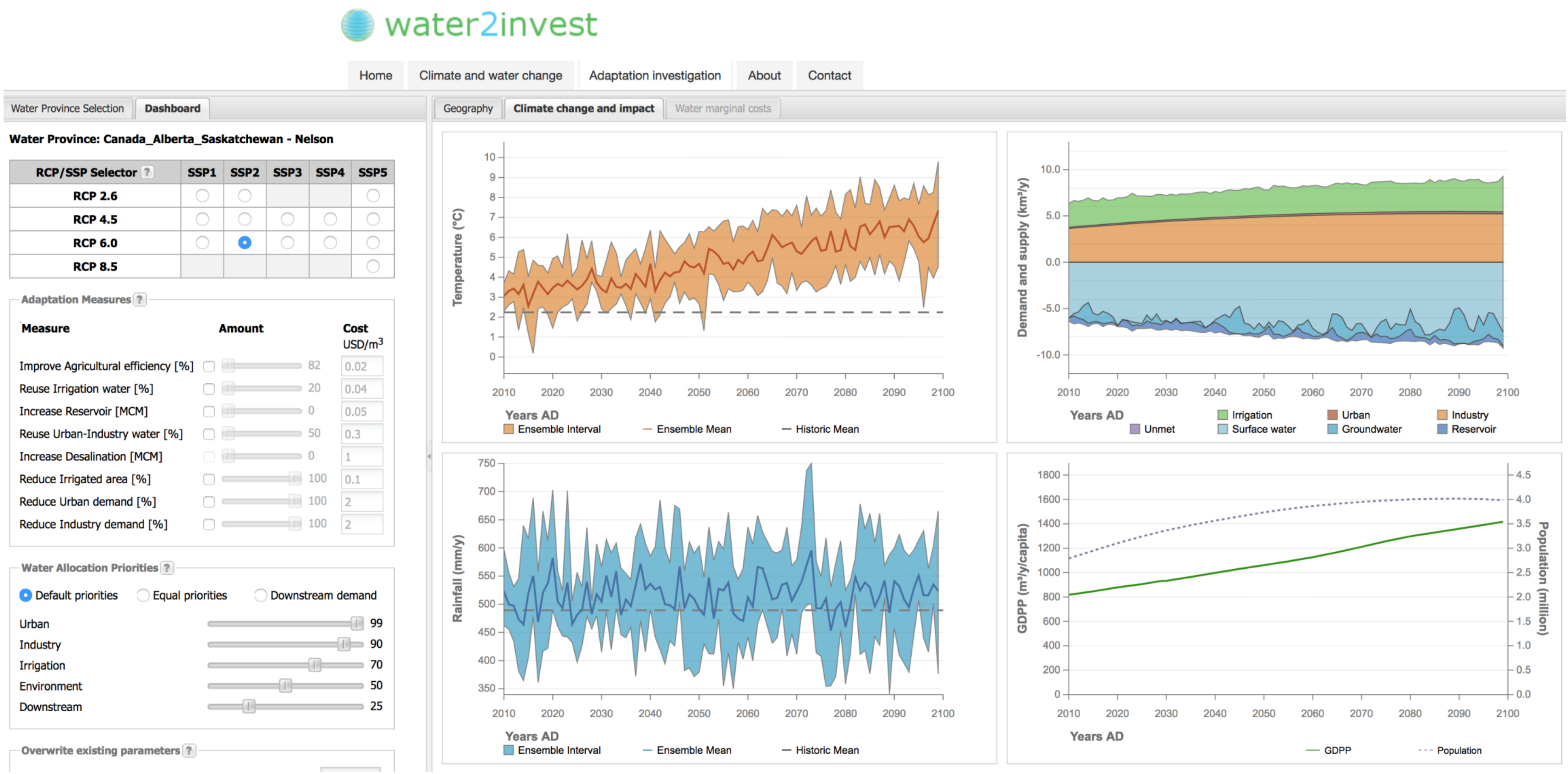
Providing information on climate projections



http://edge.climate.copernicus.eu/Apps/#climate-change

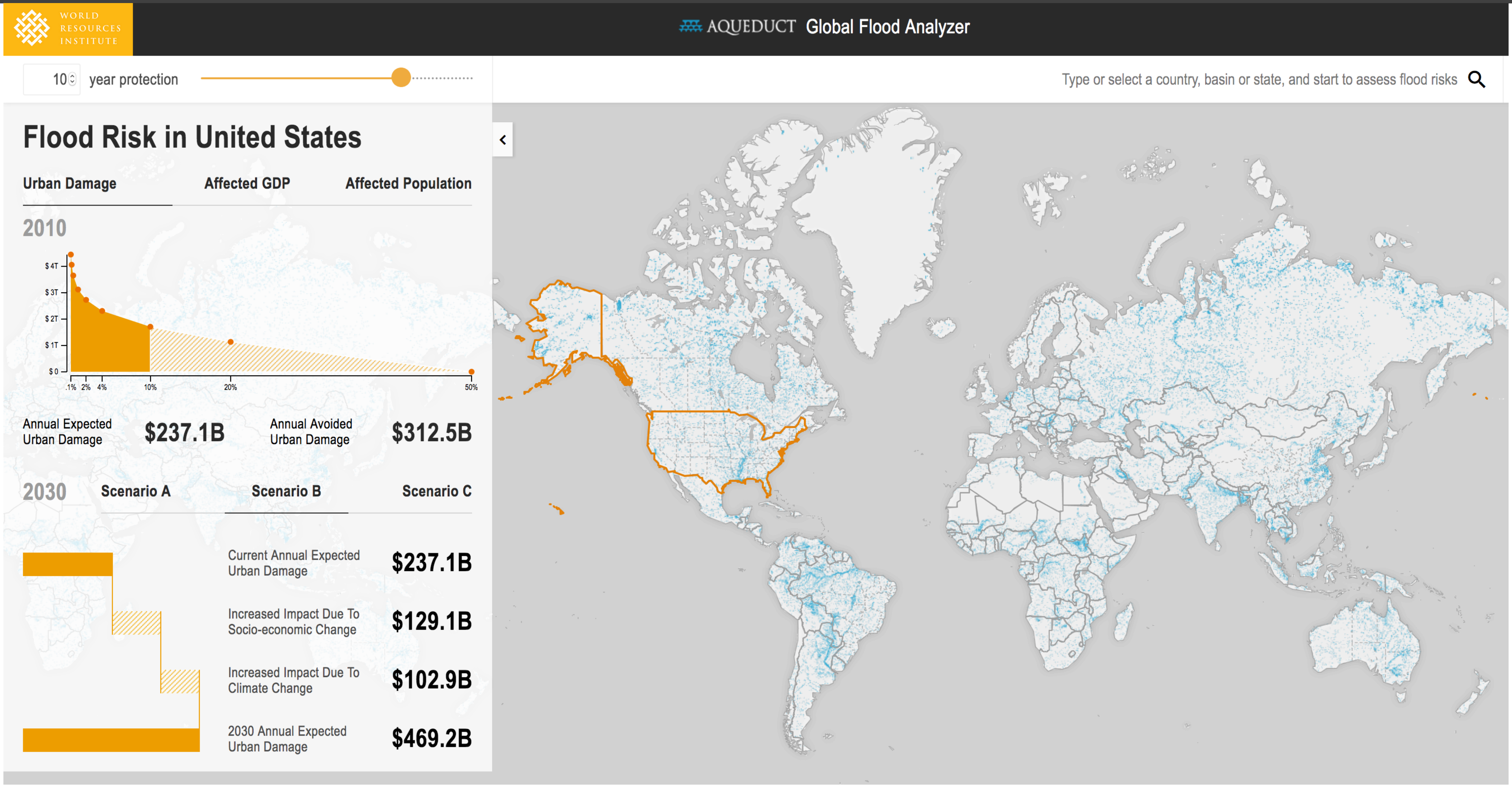
Marx et al., HESS, 2017 and Samaniego et al., 2018 NCC

PCR-GLOBWB Applications – Water2Invest



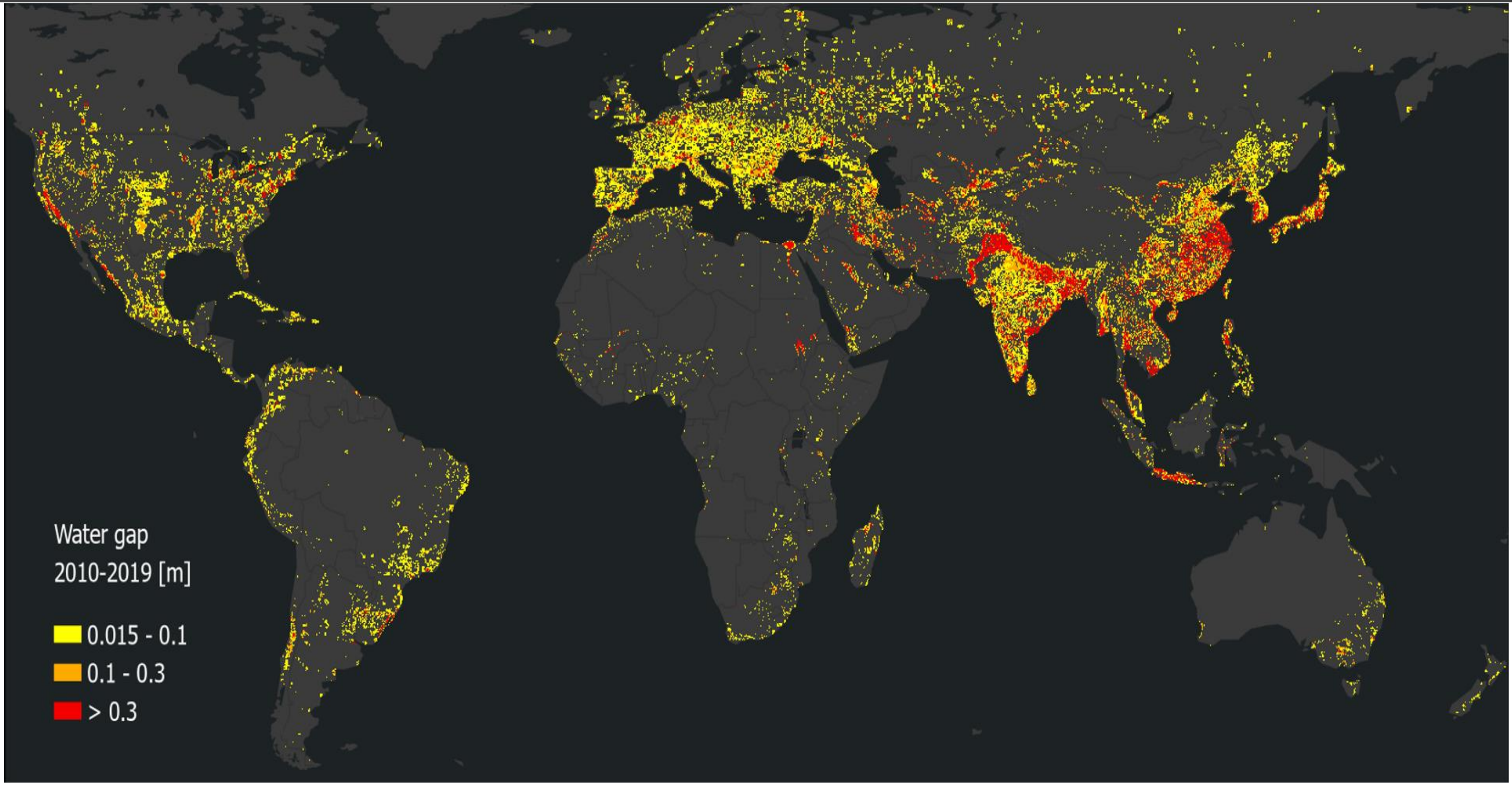
http://w2i.geo.uu.nl/

PCR-GLOBWB Application – flood analyzer



http://floods.wri.org/

PCR-GLOBWB Application – World Water Map



http://worldwatermap.nationalgeographic.org

The limits of large-scale simulations

- Validation
  - Often not validated against local observations

- Not as accurate as local simulations
  - Often no calibration
  - Often use global forcing data

- Processes not included
  - Often only include the main hydrological fluxes

The opportunities

- Available globally
  - Historic simulations
  - Future projections

- Suitable for large catchments

- Ability to compare regions
  - Models have similar configurations
  - Often no calibration

PCR-GLOBWB general properties and options

- Runs on all operating systems
- Core is Python2.x and 3.x
- Input and output are NetCDF formats
- Scripts available that allows for local setups
- Input data online (https://doi.org/10.4121/uuid:e3ead32c-0c7d-4762-a781-744dbdd9a94b)
- Output online (https://doi.org/10.4121/uuid:e3ead32c-0c7d-4762-a781-744dbdd9a94b)

- Documentation (https://doi.org/10.5194/gmd-11-2429-2018)
- Code(https://github.com/UU-Hydro/PCR-GLOBWB_model)

PCR-GLOBWB - Users around the world

PCR-GLOBWB open source

UU-Hydro / **PCR-GLOBWB_model**

Watch 10 | Star 17 | Fork 23

Code | Issues 0 | Pull requests 0 | Projects 0 | Insights

PCR-GLOBWB (PCRaster Global Water Balance) is a large-scale hydrological model intended for global to regional studies and developed at the Department of Physical Geography, Utrecht University (Netherlands). Contact: Edwin Sutanudjaja (E.H.Sutanudjaja@uu.nl).

3,987 commits | **1** branch | **2** releases | **3** contributors | GPL-3.0

Branch: **develop** | New pull request | Find file | **Clone or download**

edwinkost Merge pull request #3 from UU-Hydro/for_public_release_16_jan_2017 … Latest commit `ffd2b53` on Jan 16, 2017

config	Updating files.	a year ago
model	Updating files.	a year ago
.gitignore	Ignore cartesius output job files.	3 years ago
LICENSE	replaced user agreement with GPL-3 License	2 years ago
README.md	Updating README and add LICENSE	2 years ago
README.txt	Updating README and add LICENSE	2 years ago
known_issues.txt	Adding the files from the pcrglobwb git server (v2.0.2_beta).	4 years ago

README.md

PCR-GLOBWB

PCR-GLOBWB (PCRaster Global Water Balance) is a large-scale hydrological model intended for global to regional studies and developed at the Department of Physical Geography, Utrecht University (Netherlands).

https://github.com/UU-Hydro/PCR-GLOBWB_model

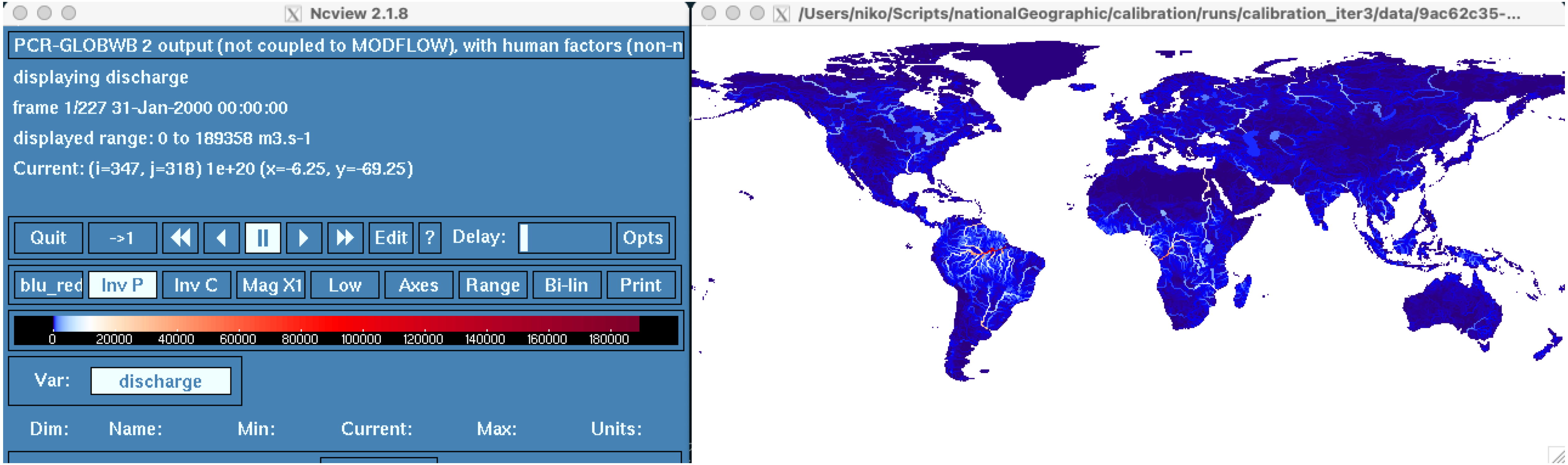
Useful tools for analyzing large scale data

- Python
  - Xarray
  - Pandas

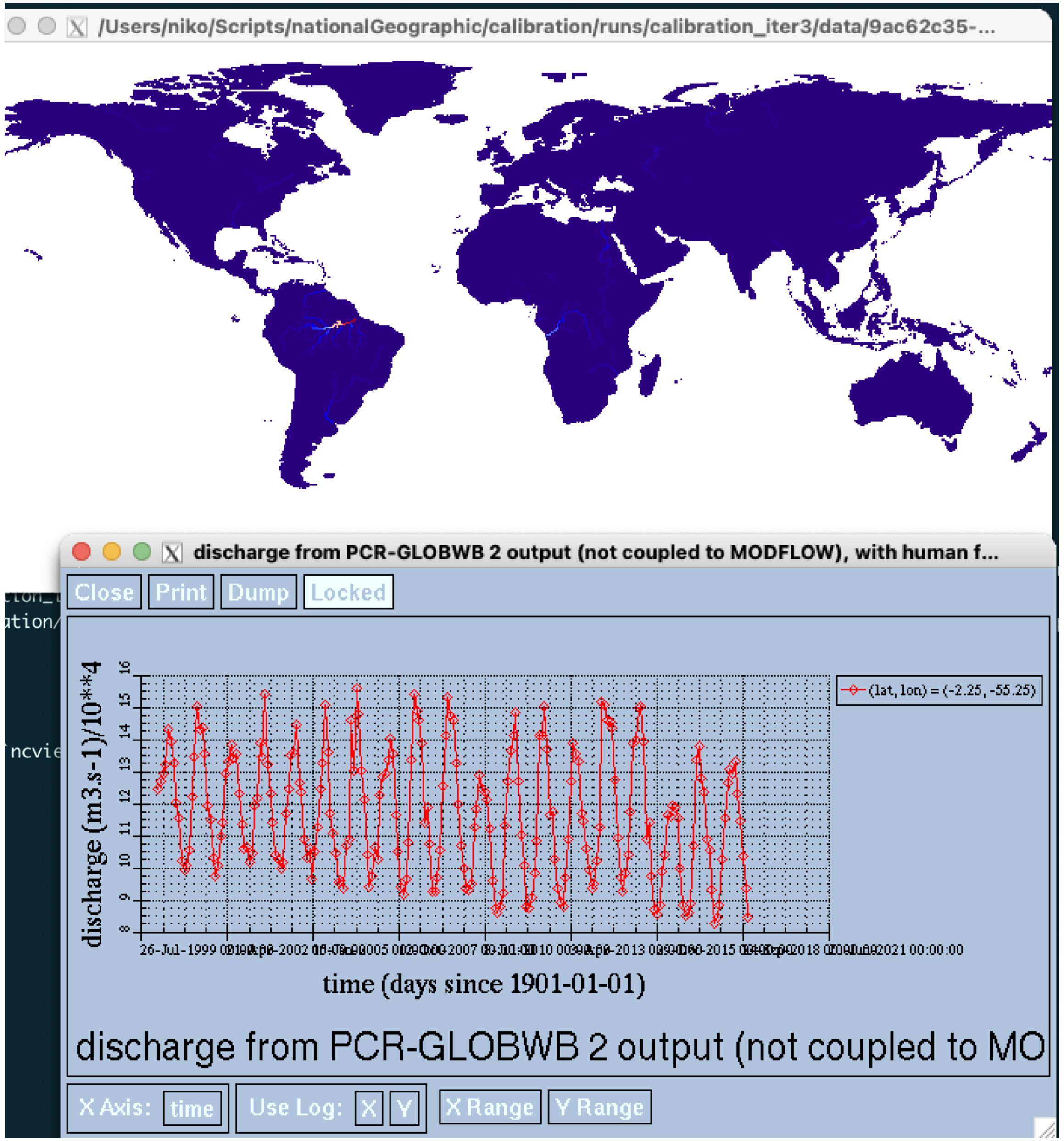
- Climate Data Operators (CDO)

- NetCDF viewer
  - Panoply
  - Ncview

Useful tools for analyzing large scale data



Useful tools for analyzing large scale data



Useful tools for analyzing large scale data

Home Projects Imprint + Privacy Policy Help

Max-Planck-Institut für Meteorologie **CDO**

Search:

Overview Activity News Wiki Forums Files Documentation

Overview

Climate Data Operators

CDO is a collection of command line Operators to manipulate and analyse Climate and NWP model Data. Supported data formats are GRIB 1/2, netCDF 3/4, SERVICE, EXTRA and IEG. There are more than 600 operators available.

- Documentation
- FAQ
- Downloads
- Community

Please register yourself for reporting bugs or postings

Latest news

Version 2.2.0 released
Added by Uwe Schulzweida 1 day ago

Version 2.1.1 released
Added by Uwe Schulzweida 4 months ago

Version 2.1.0 released
Added by Uwe Schulzweida 6 months ago

Version 2.0.6 released
Added by Uwe Schulzweida 9 months ago

Version 2.0.5 released
Added by Uwe Schulzweida about 1 year ago

View all news

Members

Manager: Luis Kornblueh, Ralf Mueller, Uwe Schulzweida

Developer: Dian Putrasahan, Fabian Wachsmann, Irina Fast, Joerg Wieners, Mathis Rosenhauer, Oliver Heidmann, Ralf Quast, Reinhar

Reporter: Aaron Spring, Brendan DeTracey, David Gobbett, Didier Sellmann, Jin-Song von Storch, Stefan Fronzek, William Sawyer

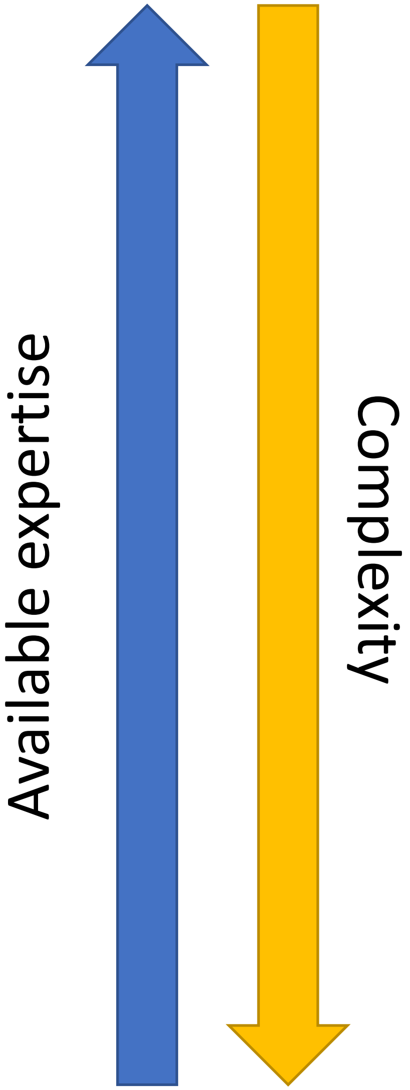
Moderator: Estanislao Gavilan, Karin Meier-Fleischer

Useful tools for analyzing large scale data

- Large scale computational resources
- Enough data storage
- Local expertise
- Remote expertise
- Tutorials

How to get started

- Use data from existing simulations
  - Model specific outputs
  - Output from large experiments (e.g. ISI-MIP)
- Run a Large Scale model
  - Regional or global
  - Historic or climate scenarios
- Adjusting existing large scale models
  - Add processes
  - Add outputs



How to get started

How to install

PCR-GLOBWB is developed in Python and uses various supporting packages (e.g. pcraster, numpy and netcdf4). Therefore, beside the PCR-GLOBWB model code, you will need a working Python package environment to install the PCR-GLOBWB model. Here we provide a short guide to installing PCR-GLOBWB. *Note that in this installation guide we assume you work on a Linux operating system*.

Python package environment

Please follow the following steps to setup a PCR-GLOBWB environment:

1. To create a Python package environment, we recommend to install Miniconda, particularly for Python 3. Follow the Miniconda install instructions given here. A user guide and short reference on the conda package manager can be found here.
2. Now that Miniconda is installed, you can use it to make a package environment. To install the correct packages and their versions, we have created an environment file on our GitHub repository. Use the environment file to install all required packages to a conda environment:

   ```
   conda env create --name pcrglobwb_python3 --file pcrglobwb_py3.yml
   ```

   This will create a environment named *pcrglobwb_python3*.
3. To activate the PCR-GLOBWB environment:

   ```
   conda activate pcrglobwb_python3
   ```

   This will set the current environment to the *pcrglobwb_python3* environment

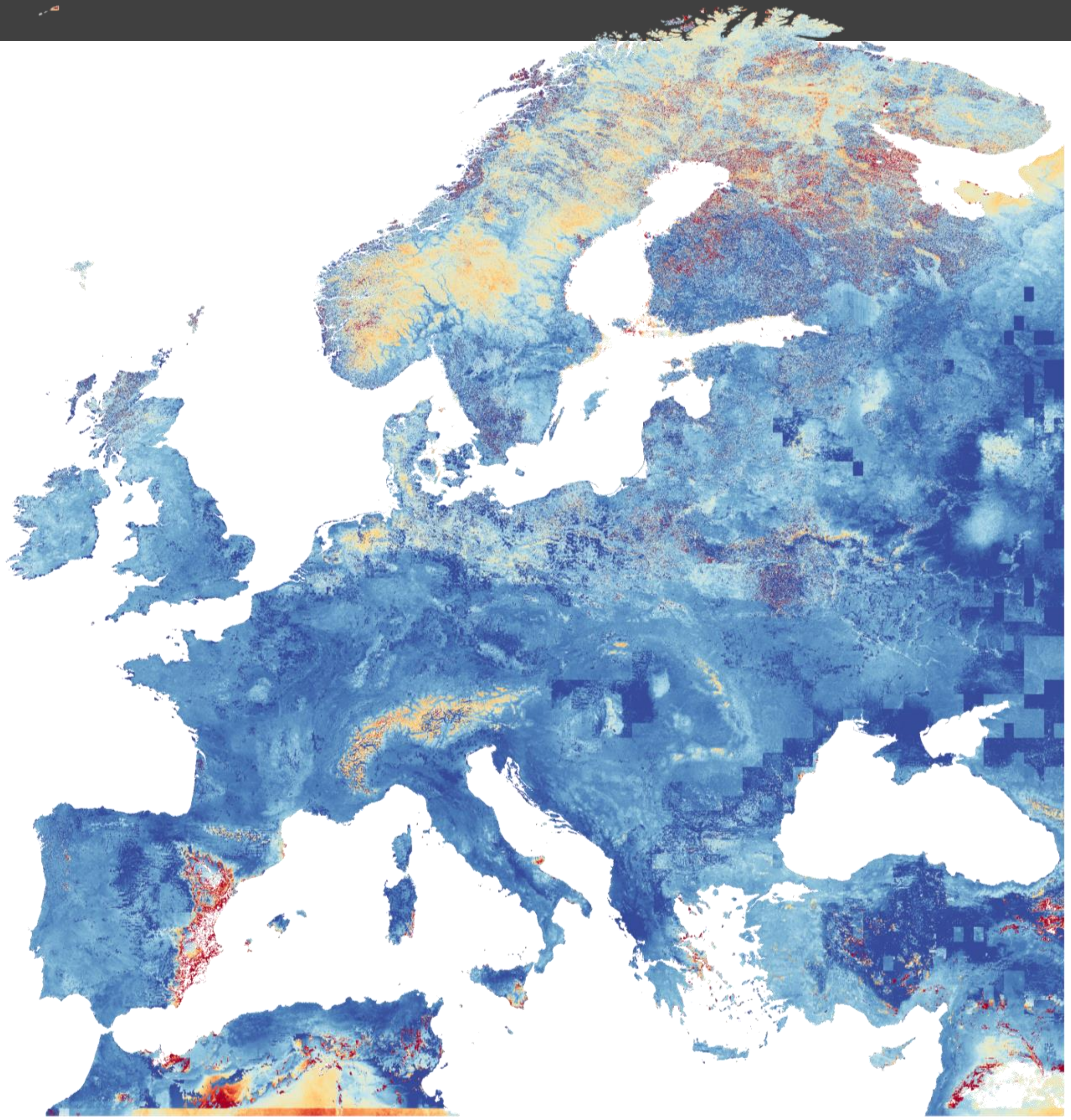
Storage

Variable	Units	Description
interceptStor	m	Canopy intercepted water storage
snowCoverSWE	m	Snow pack snow water equivalent storage
snowFreeWater	m	Snow pack free water storage
topWaterLayer	m	Top (ponding) water storage
storUppTotal	m	Upper (first) soil layer water storage
storLowTotal	m	Lower (second) soil layer water storage
storGroundwater	m	Non-fossil groundwater storage
storGroundwaterFossil	m	Fossil groundwater storage
surfaceWaterStorage	m	Surface (rivers, lakes and reservoirs) water storage
totalActiveStorageThickness	m	Total water storage (all of the above except for fossile groundwater storage)
totalWaterStorageThickness	m	Total water storage (all of the above)
satDegUpp	m_water.m_capacity-1	Upper (first) soil layer saturation degree
satDegLow	m_water.m_capacity-1	Lower (second) soil layer saturation degree
satDegTotal	m_water.m_capacity-1	Soil saturation degree (upper and lower layers)

- https://pcrglobwb.readthedocs.io/

How to get started - tips

- Start small
- Look at timeseries
- Double check that your data represents what you want



Best of both worlds

- **Do** use large scale hydrological models if:
  - You want to study a large region
  - Want to compare regions
  - Want direct access to data

- **Don't** use large scale hydrological models if:
  - You work on the <10km resolution
  - You want to calibrate
  - Work on one catchment

Short Course Large Scale Hydrology

Utrecht University

Niko Wanders
n.wanders@uu.nl

@niko_wanders