Human processes in global hydrological models

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GLASS and GHP Workshop
Including Water Management
in Large Scale Models

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Center for Environmental
Systems Research

UNIKASSEL
VERSITÄT

Overview

1. Selection of human processes
2. Model outcomes and analysis
3. Conclusions and next steps

Why do we need to consider human processes?

- Link: human activities and earth system changes

- Impacts: human and ecosystem health, food security

- Flow alteration: reservoir operation, water abstraction and consumption

Global Water Use: A Link Between Human Activities and Earth System Changes

Human activities

- Household activities
- Electricity use
- Manufacturing products
- Crop production

Water use

- Water consumption in households
- Power plant cooling water intake
- Manufacturing water intake
- Irrigation abstraction

Water fluxes

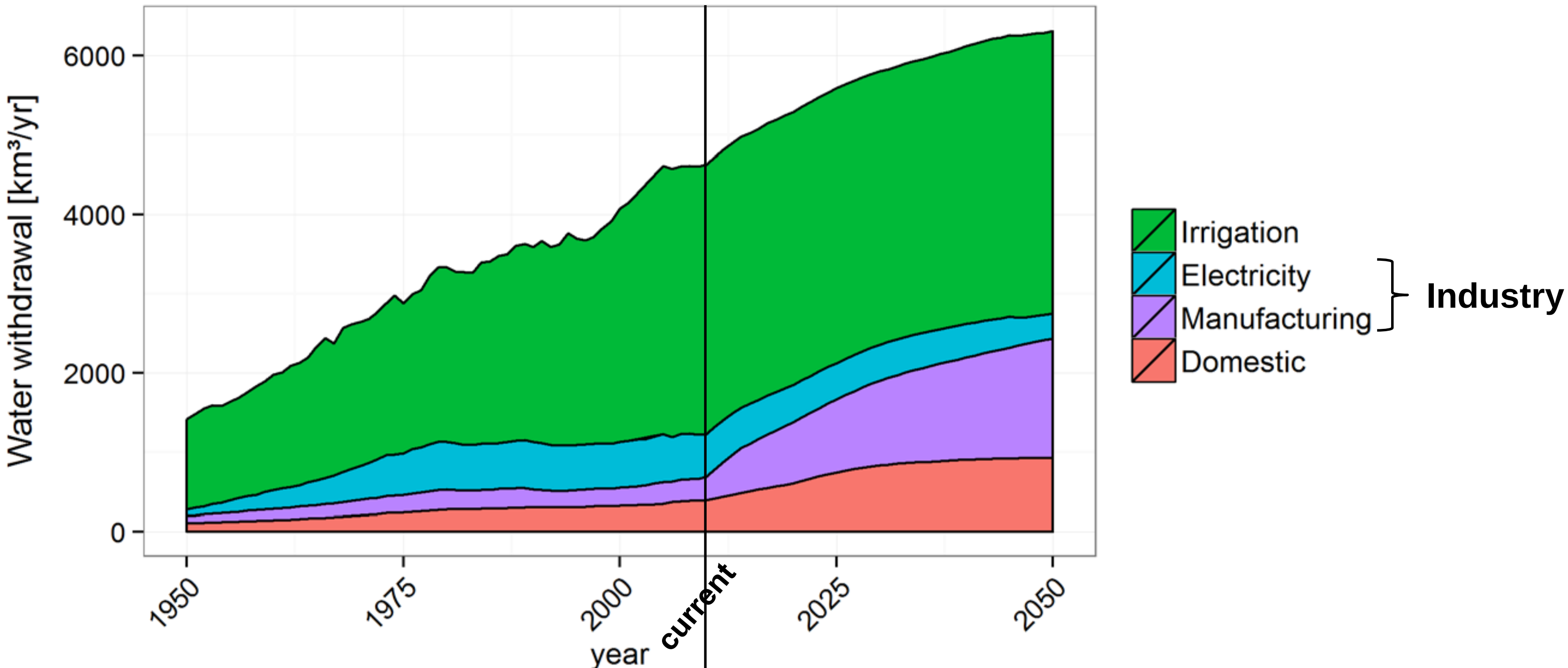
- Evaporation & transpiration
- Water abstraction
- Return flows

Earth system changes

- Change in moisture flux to atmosphere → Change in regional climate
- Changing water stress
- Depletion of river flow
- Water quality degradation
- Degradation of aquatic ecosystems & biodiversity Risk to human health & food security

Global Water Use: *Where we are*

Climate
Socio-economic
drivers → Water use model → Sectoral water uses



hindcast ← → forecast

Main drivers

- Population
- GDP, GVA
- Thermal electricity production
- Irrigated land
- Technological change rate

Flörke et al. (2013)
Wada et al. (2016)

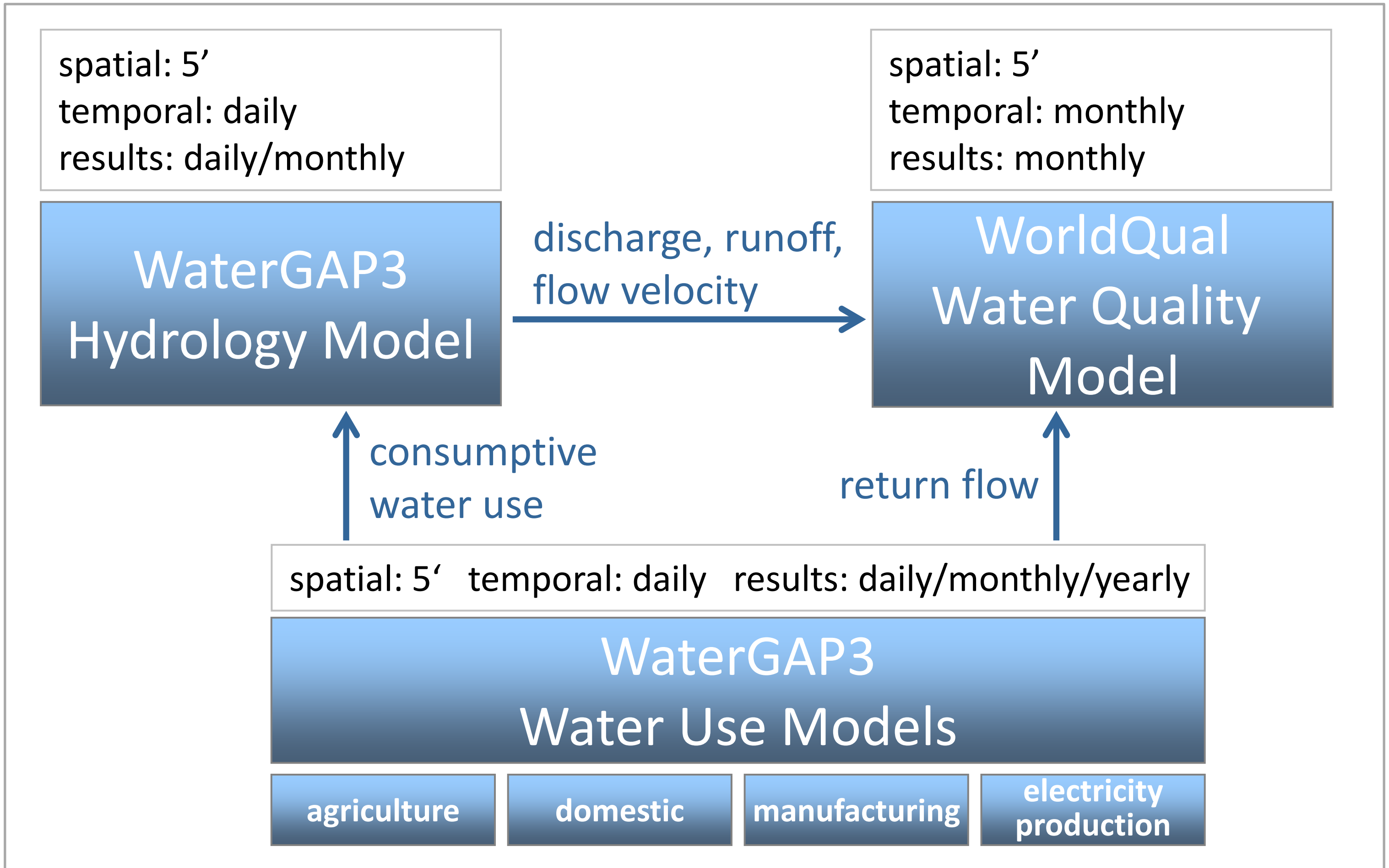
Global Water Use: *Where we are*

Climate
Socio-economic
drivers → Water use model → Sectoral water uses

Climate change → Global hydrology model → Geographic distribution water availability

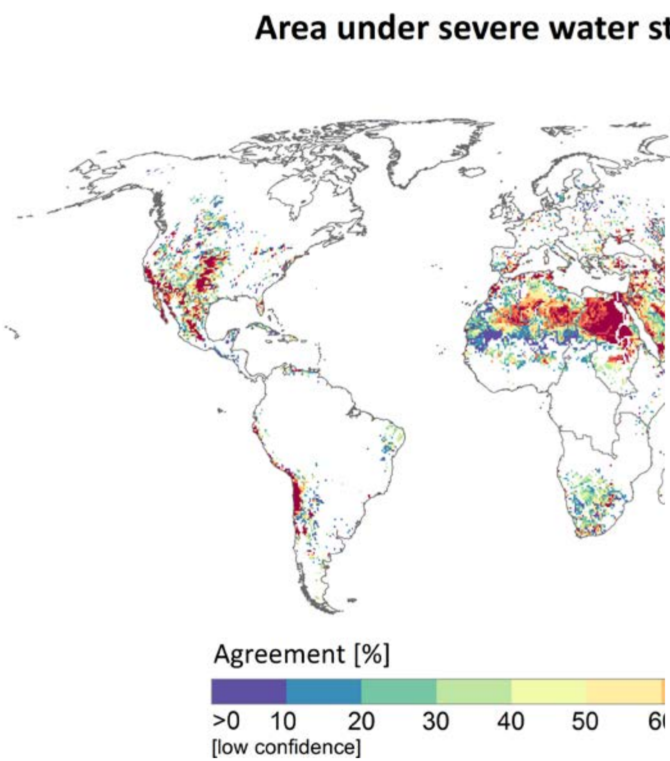
Climate
Socio-economic
drivers → Global water quality model → Geographic distribution loadings in-stream concentrations

Global water modeling framework WaterGAP

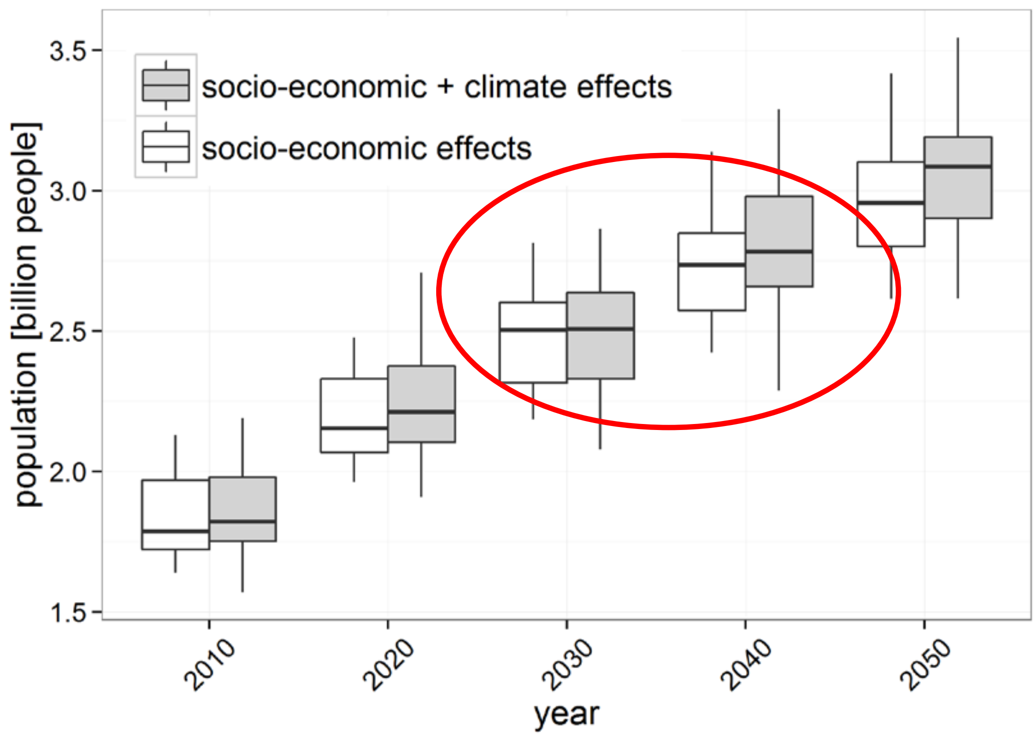


Impact: Water stress

Uncertainty of climate scenarios ♦ ensemble GHM calculations



2050



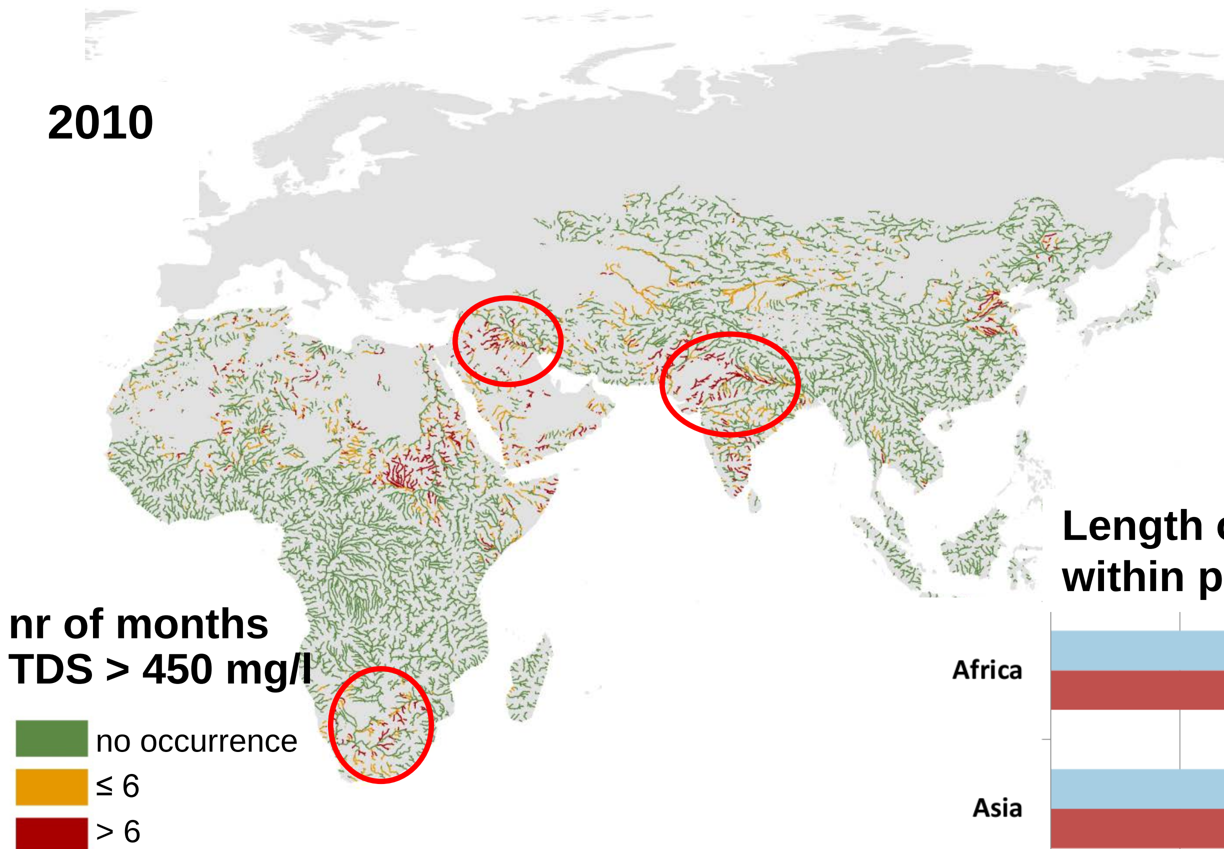
WTA = withdrawals-to-availabil

severe water stress: WTA > 0.4

Flörke et al. (in review)

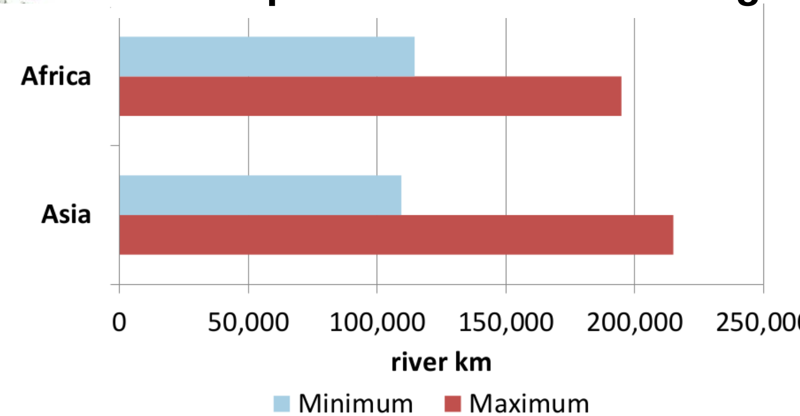
Impact: Water quality degradation

What is the level of salinity pollution and how does it impair water use?



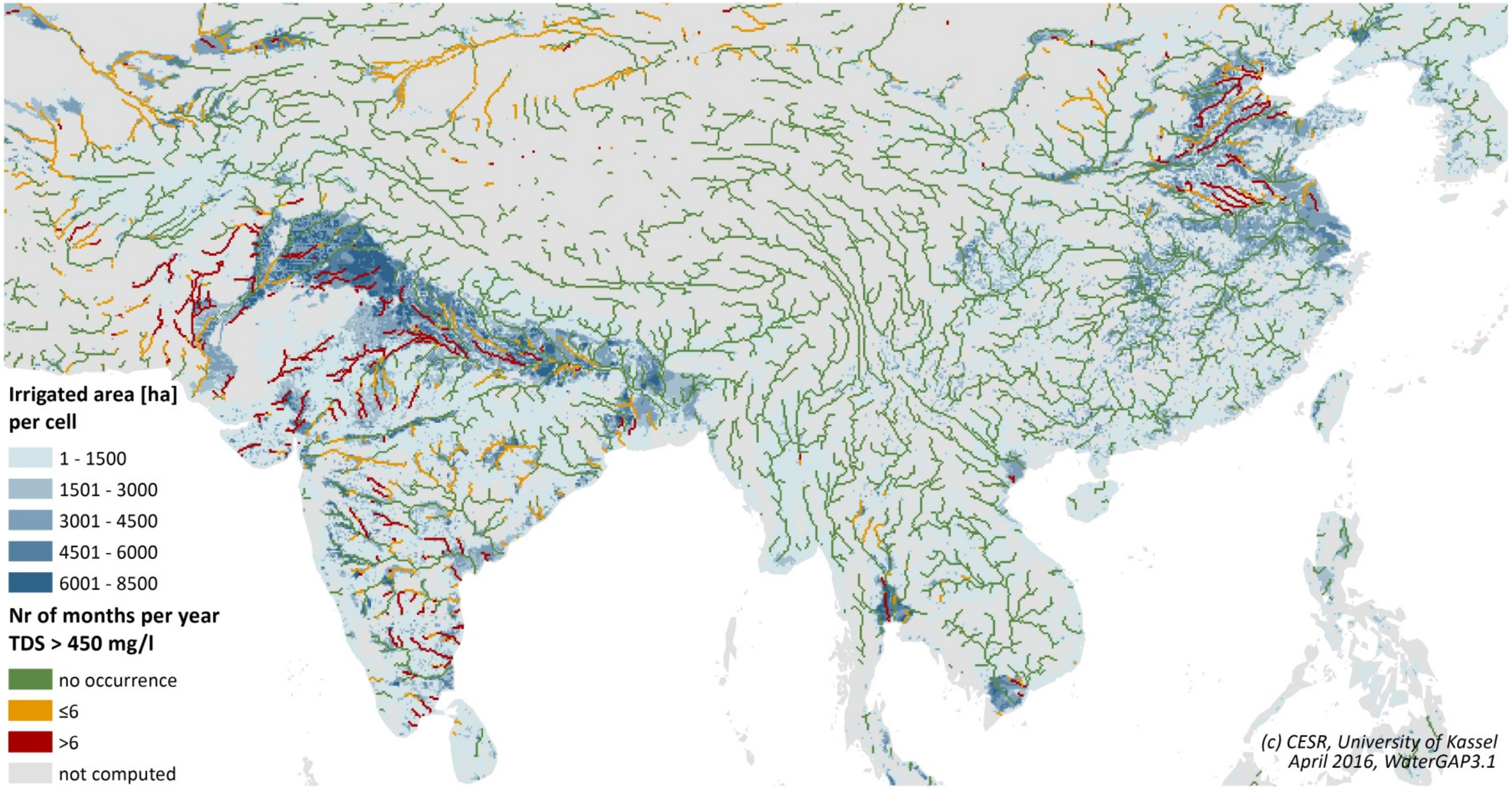
UNEP (2016)

Length of river stretches within pollution class > 450 mg/l



Impact: Water quality degradation

What are the implications for food security?

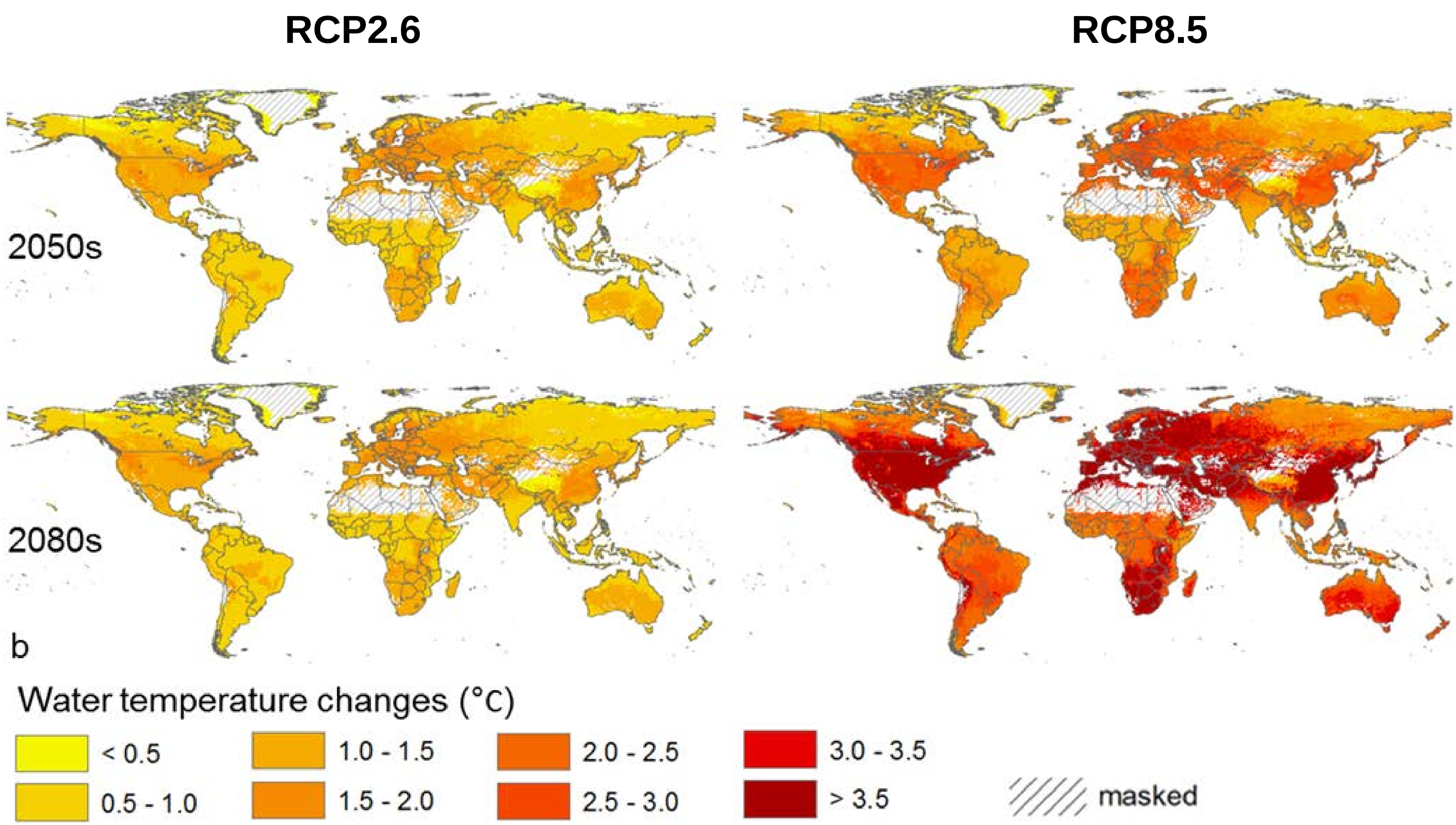


- 151 million ha under irrigation in Asia
- 49-77 million ha at risk

Flörke et al. (2016)

Impact: Water temperature

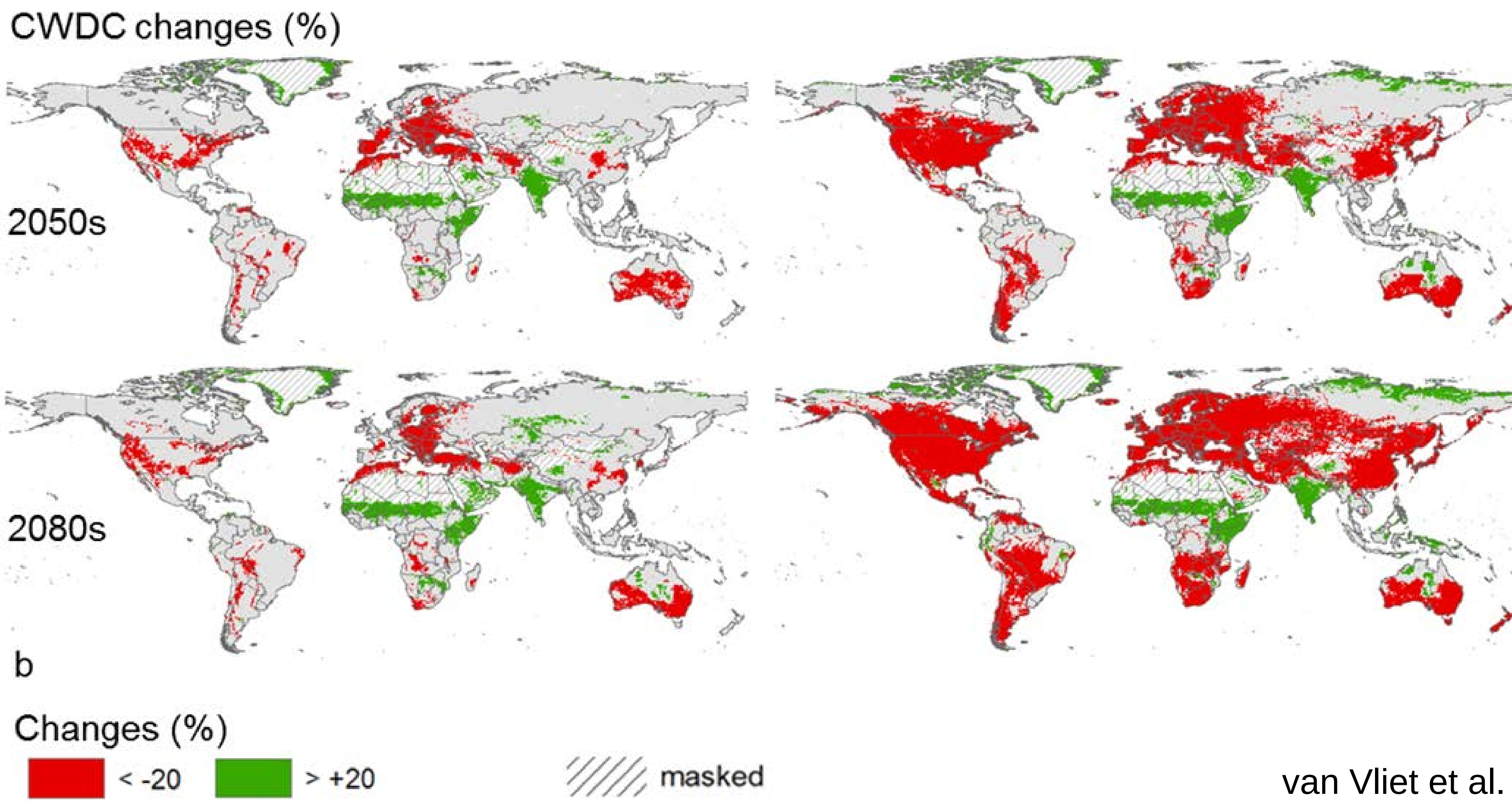
Uncertainty of climate scenarios ♦ ensemble GHM calculations



van Vliet et al. (2016)

Water temperature: Change in cooling water discharge capacity

RCP2.6 | **RCP8.5**



van Vliet et al. (2016)

- Global CWDC is expected to decrease by 4.5% to 15% in 2080
- Spatial patterns reflect changes in water temperature and river discharge

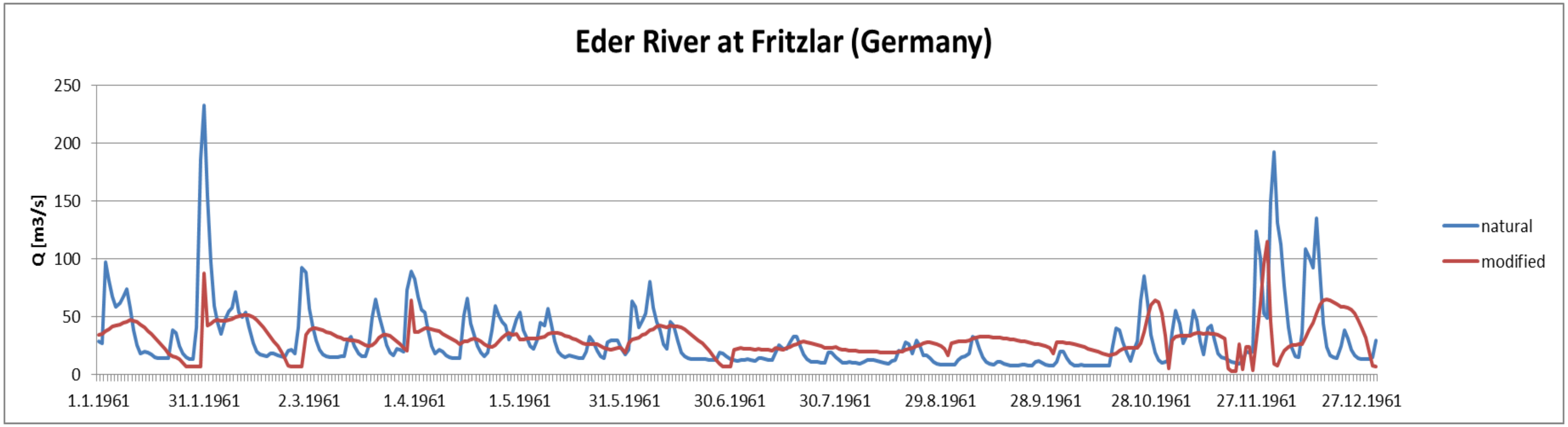
Closing the Loop
Water availability → Water use / Water quality degradation

Which feedbacks to include?

- Water scarcity → Rationing, restricting domestic water use
- Geographic shift in water availability → Inter-basin transfers → Change in water use
- Water scarcity → Shift in form of electricity production (link to energy scenarios) → Change in electricity water use
- Change in water availability → Change in patterns of crop production → Change in moisture fluxes
- Water quality degradation → Relocation of water use → Change in irrigated area
- Change in water temperature → Change in cooling water discharge capacity → Allocation of thermal power plants

Reservoir management: *Where we are*

How does dam operation affect river flow regimes?



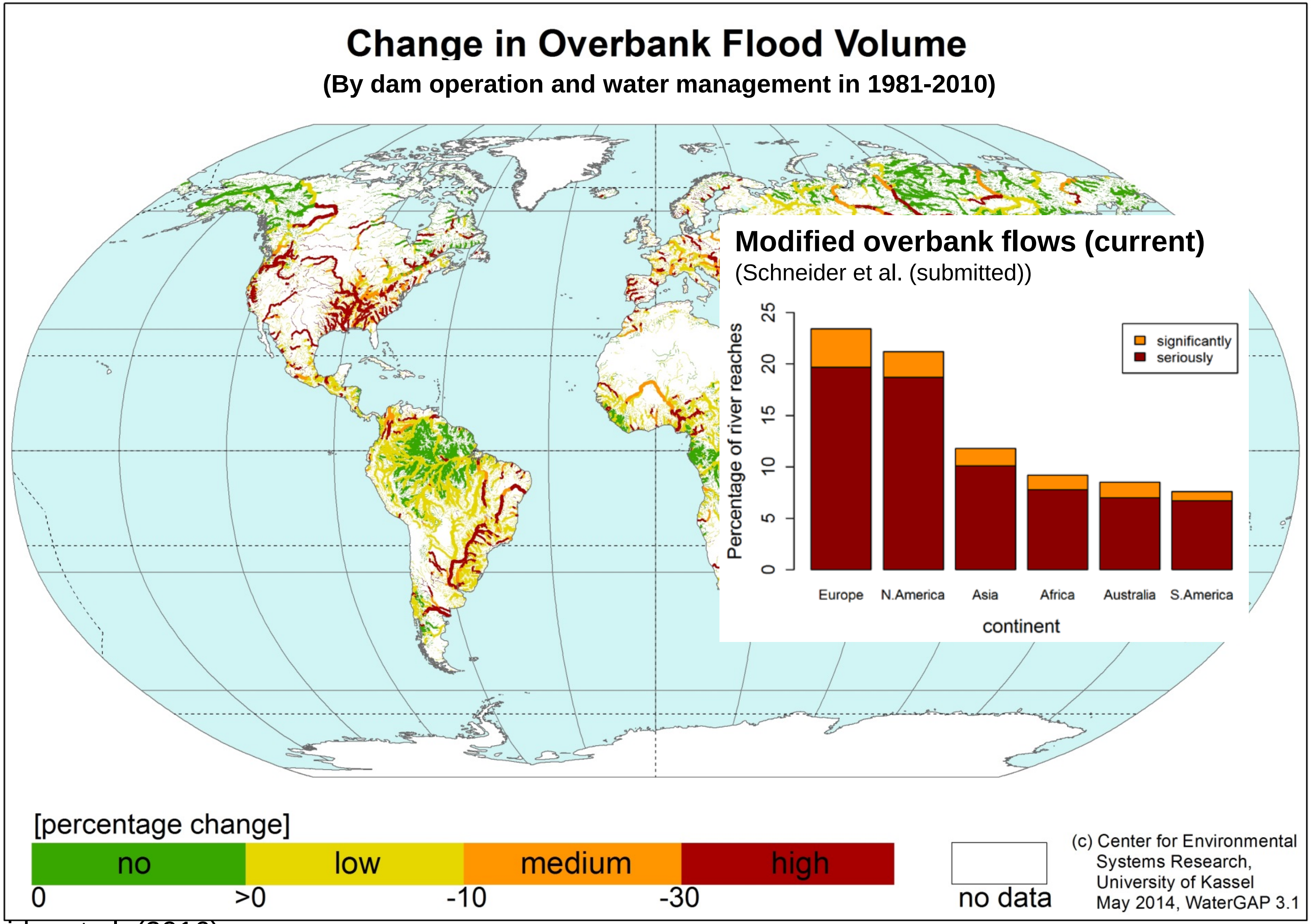
Flow alteration: Change in flood volume

Indicator of hydrological alteration: exceedance of bankfull flow

- Time series 1981-2010
- Thresholds for different levels of mean annual deviations
- Traffic light coding

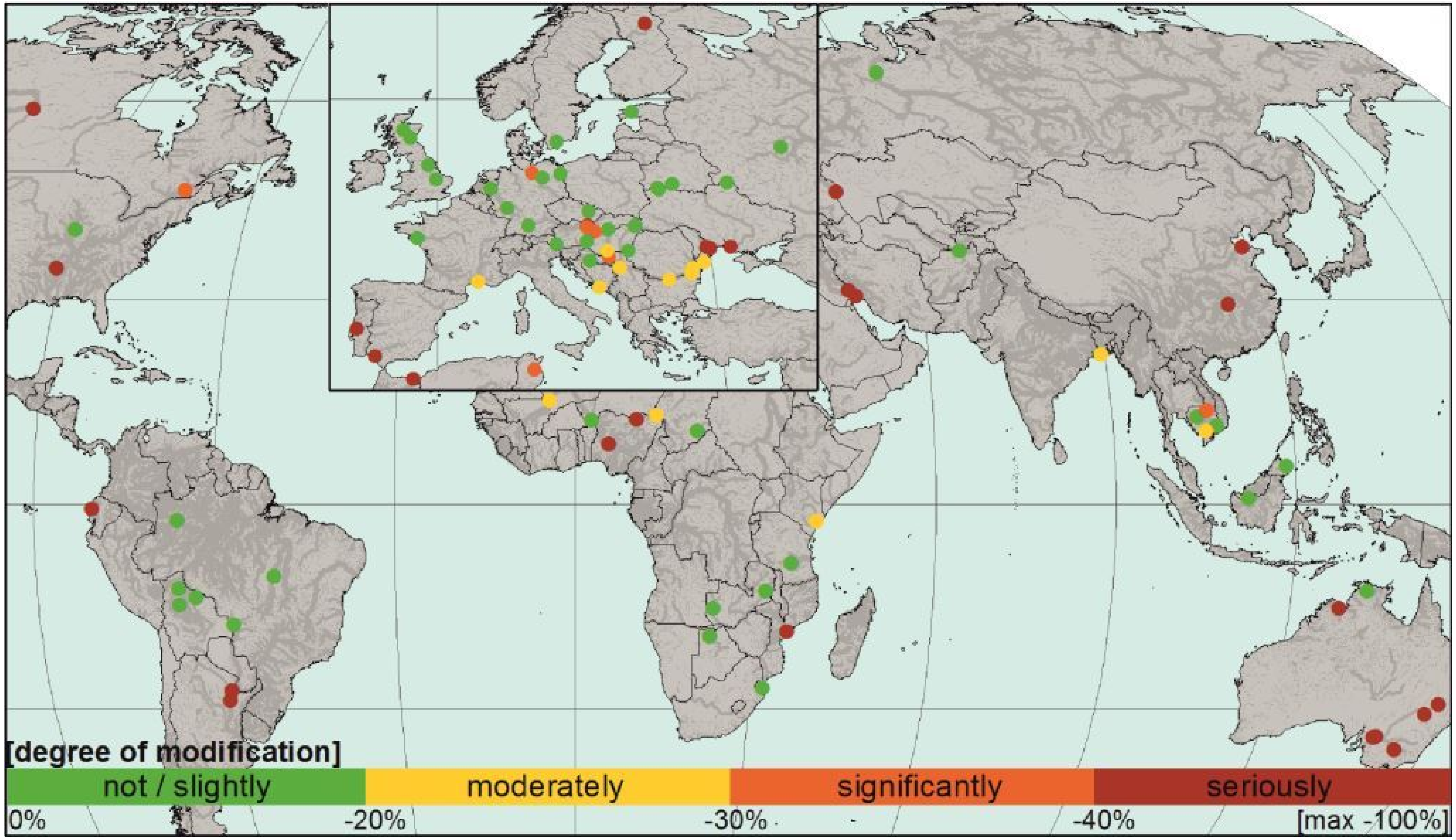
River status	Level of modification	Thresholds for reduction in flood volume
A	not/ slightly	$\Delta \leq 20\%$
B	Moderately	$20\% < \Delta \leq 30\%$
C	Significantly	$30\% < \Delta \leq 40\%$
D	Seriously	$\Delta > 40\%$

Reservoir management: *Where we are*



Schneider et al. (2016)

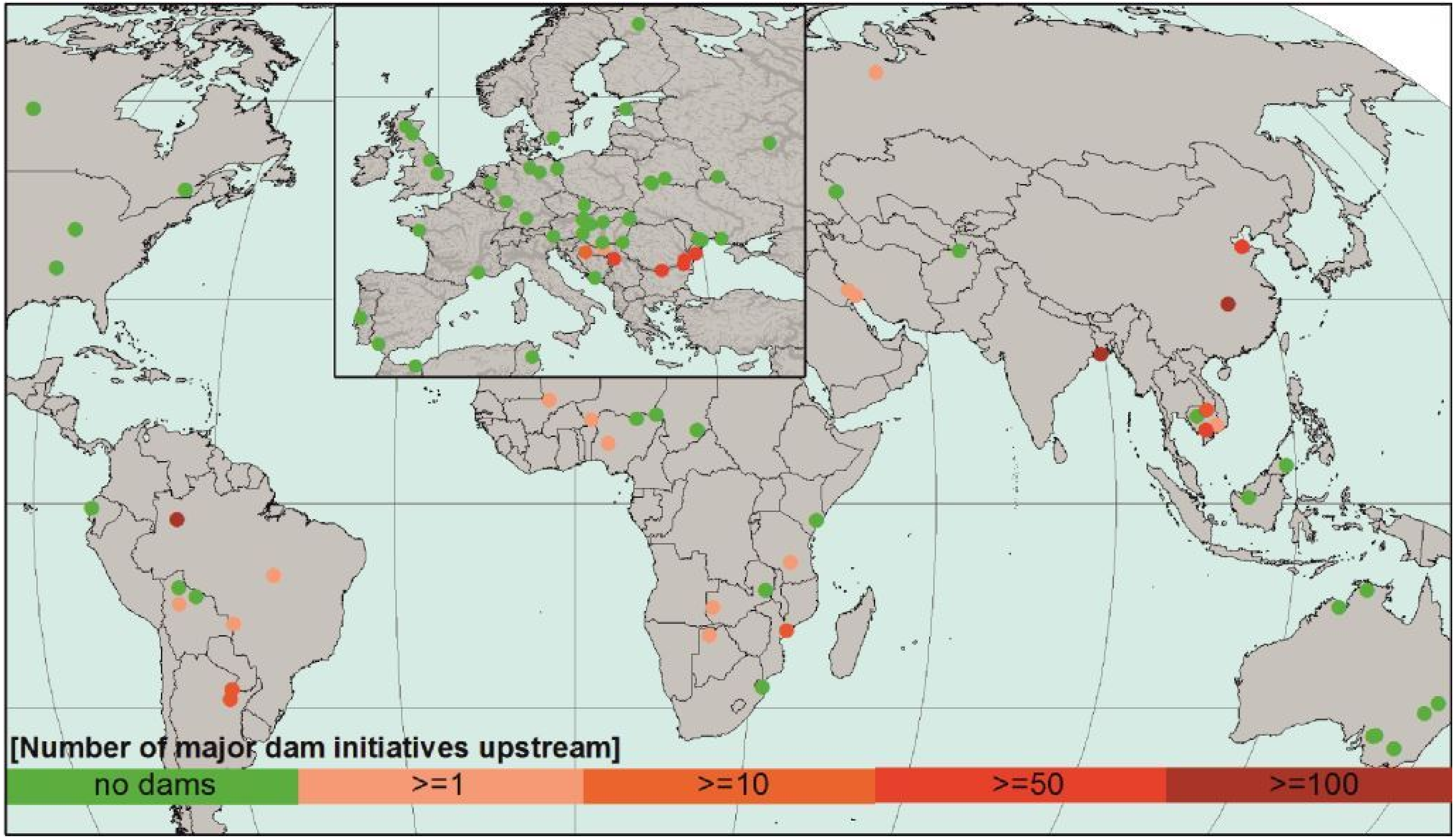
Water management: Riparian wetlands at risk



Schneider et al. (2016)

- >50% of selected Ramsar sites (total 93) impaired by reduced flood volumes
- 29% seriously affected by reduction in flood volume
- Hydropower generation most frequent dam type

Reservoir management: Planning of new initiatives



Schneider et al. (2016)

- New dams planned or under construction in 1/3 of upstream area
- 37% are not yet impaired by water management
- Hotspots in South America (67%), Asia (60%), Africa (47%)

Closing the Loop
Flow alteration → Water management

Which feedbacks to include?

- Reservoir operation → Reduction in flood volume
- Change in floodplain inundation → Change in evaporation patterns

Conclusions and next steps

Water use / Water management – Important link between human dimensions and biophysical aspects of earth system

Water availability / Water quality – Hotspots relevant for feedbacks within the water cycle and between systems

Next Steps

1. Validation of outcomes with observations and remote sensing
2. Improve concept of water stress. Not only long term availability of water but seasonality and water quality aspects.
3. Include feedbacks between changing water availability, water quality and water use / water management

Thank you!

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