Projected impacts of climate change on large-scale water resources at 1.5°C, 2°C and 4°C global warming

Richard Betts, Lamprini Papadamitriou, Aris Koutroulis, Pierre Friedlingstein, Catherine Morfopoulos, Klaus Wyser

Met Office

UNIVERSITY OF EXETER

helix
www.helixclimate.eu

JULES Annual Meeting, Harper Adams University, 5th September 2018

Context: the United Nations Paris Agreement aims to limit global warming to "well below" 2°C relative to pre-industrial – "pursuing efforts" to limit to 1.5°C

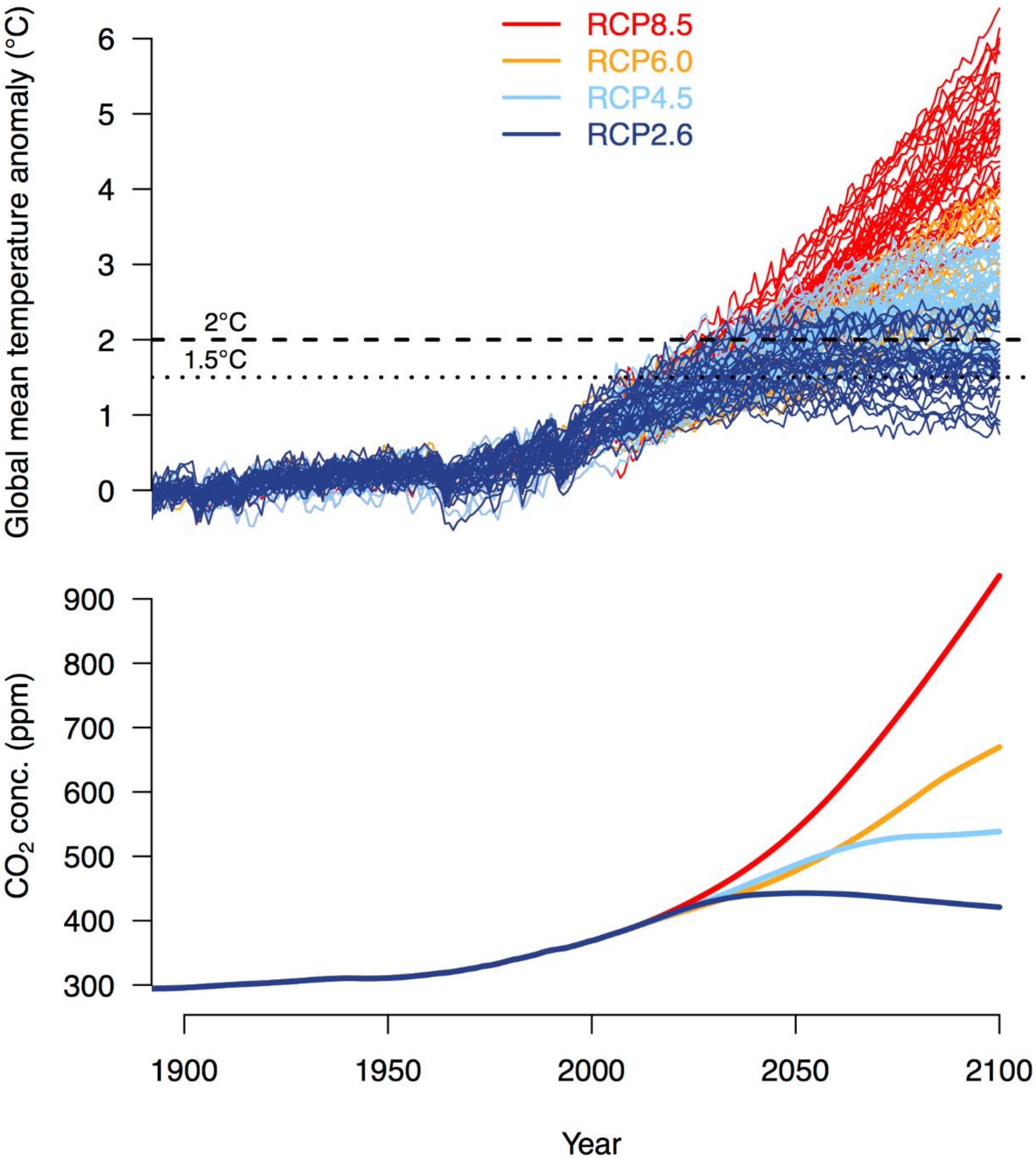
Key questions:

1. What will be the impacts at 2°C?
2. How much of these can we avoid if we achieve 1.5°C?
3. What will be the consequences of missing these targets? Eg. what happens at 4°C?

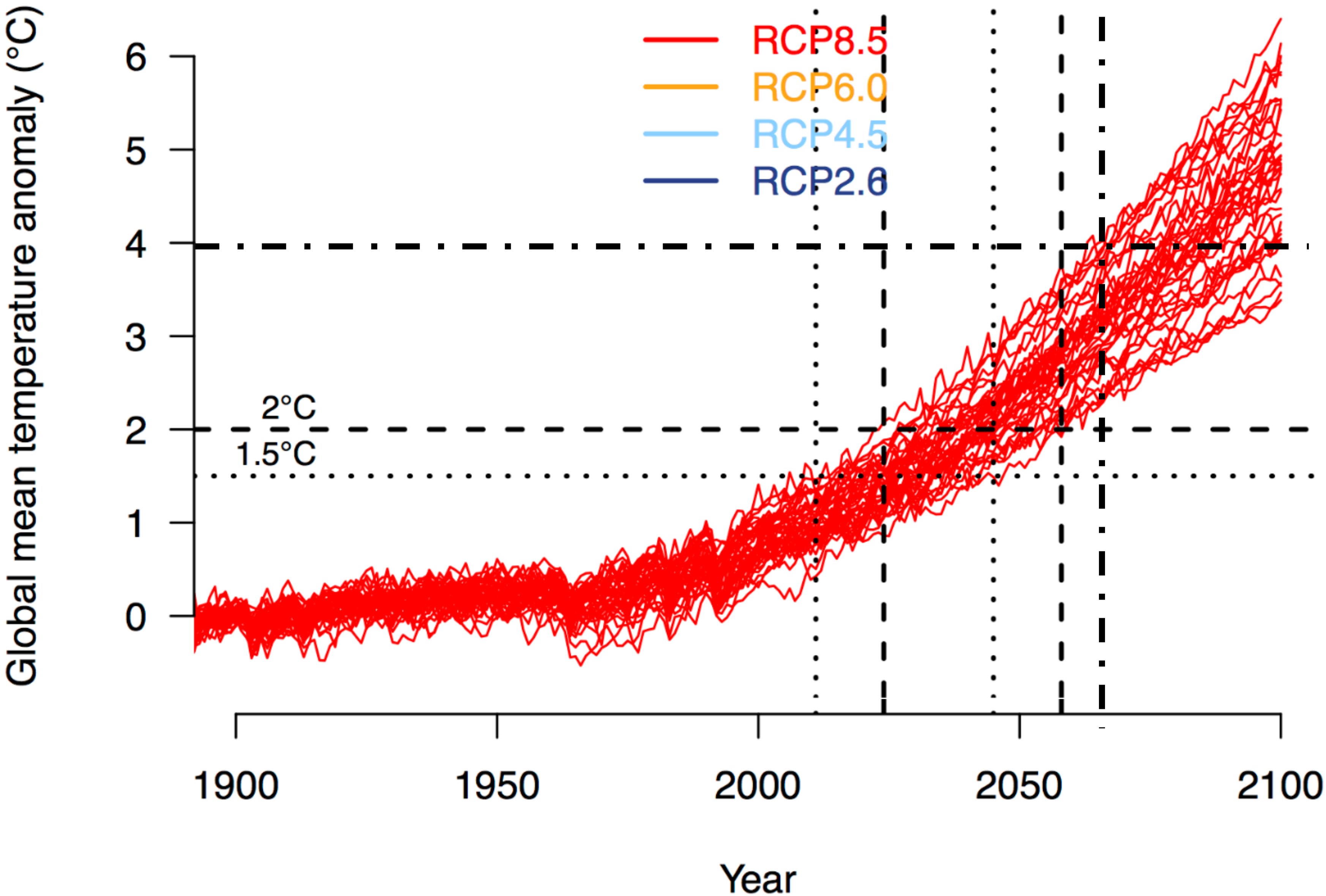
Address this here for **freshwater resources**, using climate projections to drive **JULES** to simulate changes in **runoff**

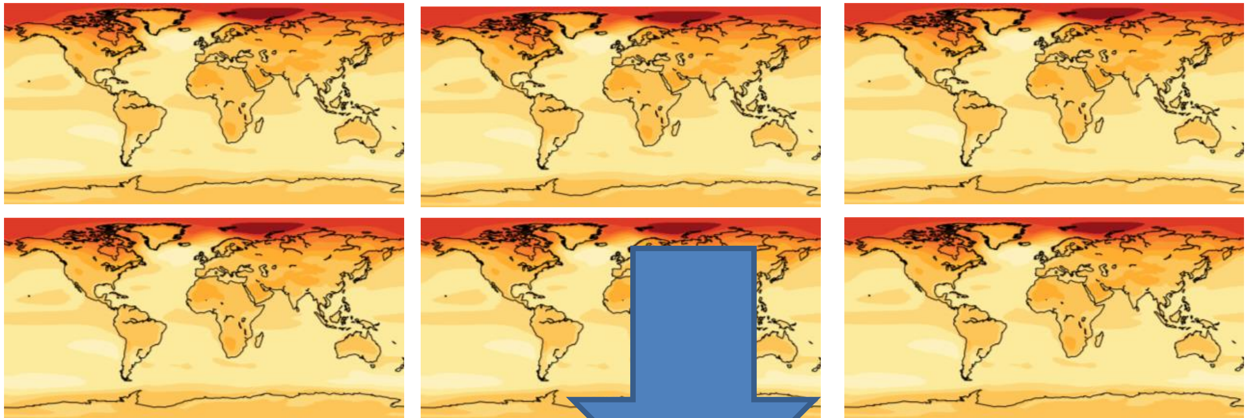
Global mean temperature projected by CMIP5 multi-model ensemble

CO_2 concentrations in RCPs (Representative Concentration Pathways)

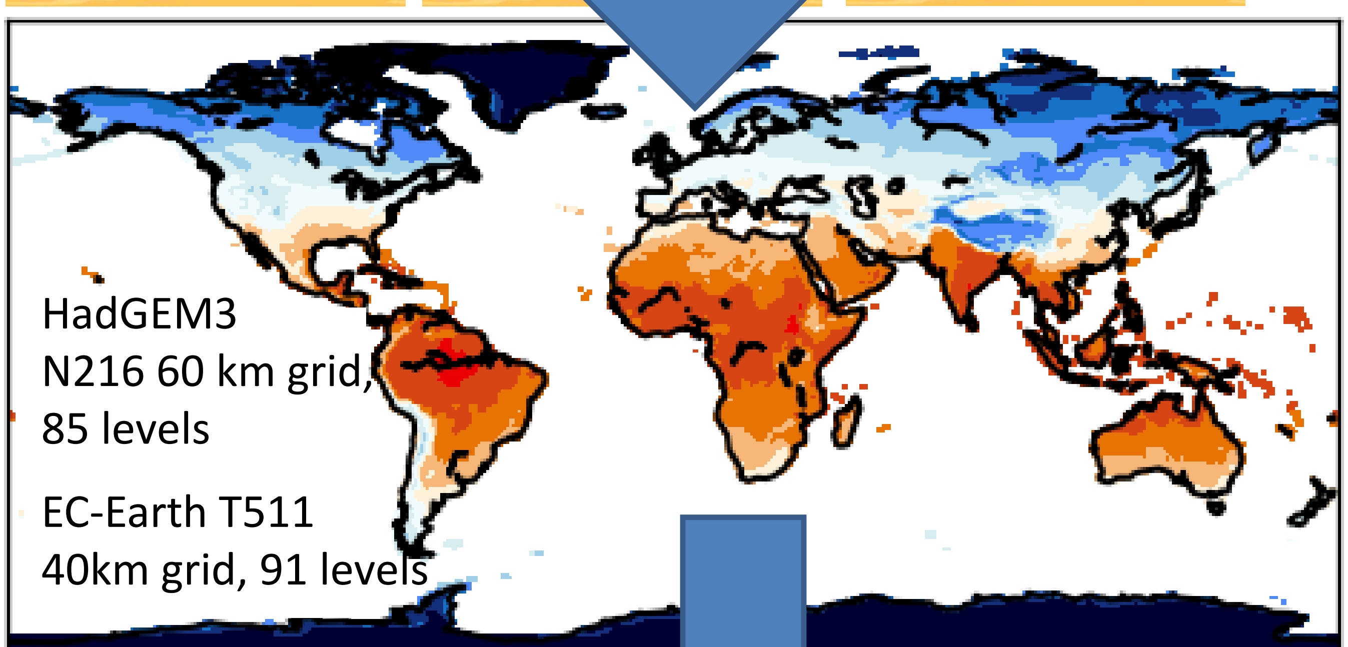


Here focus on RCP8.5 scenario

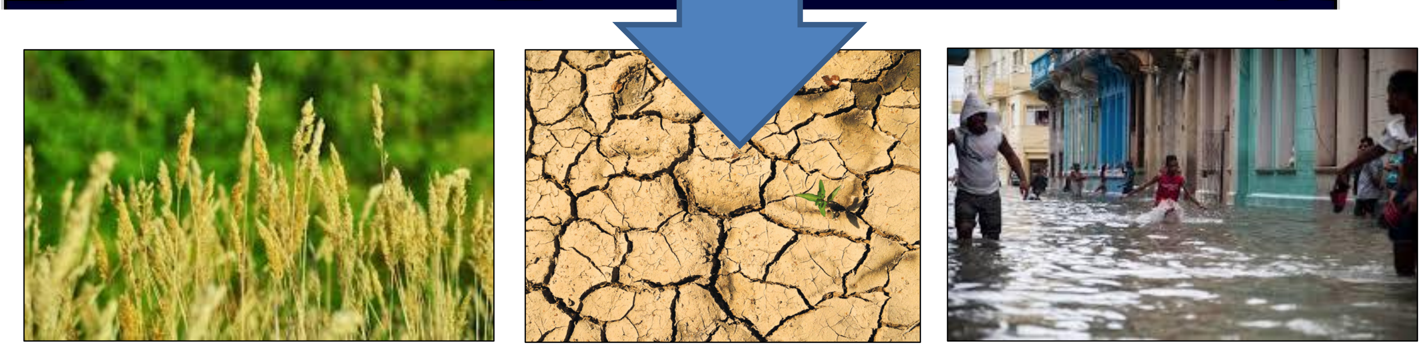




Existing CMIP5 projections with RCP8.5: GHGS, sea surface temperatures, sea ice



New higher-resolution models than in CMIP5 (atmosphere only)



Various impacts sectors: use JULES for water resources

JULES setup

"JULES-W1" configuration – as used in Water sector of ISIMIP (Inter-Sectoral Impacts Model Intercomparison Project) Phase 2 (Papadimitriou *et al.*, 2016; 2017)

Global domain, 0.5° resolution

Vegetation: 5PFTs prescribed at present-day state
Plant physiology responds to changing CO_2 concentrations (ie: stomatal closure affects transpiration, but no change in leaf area index or vegetation distribution)

No irrigation, crops or glaciers

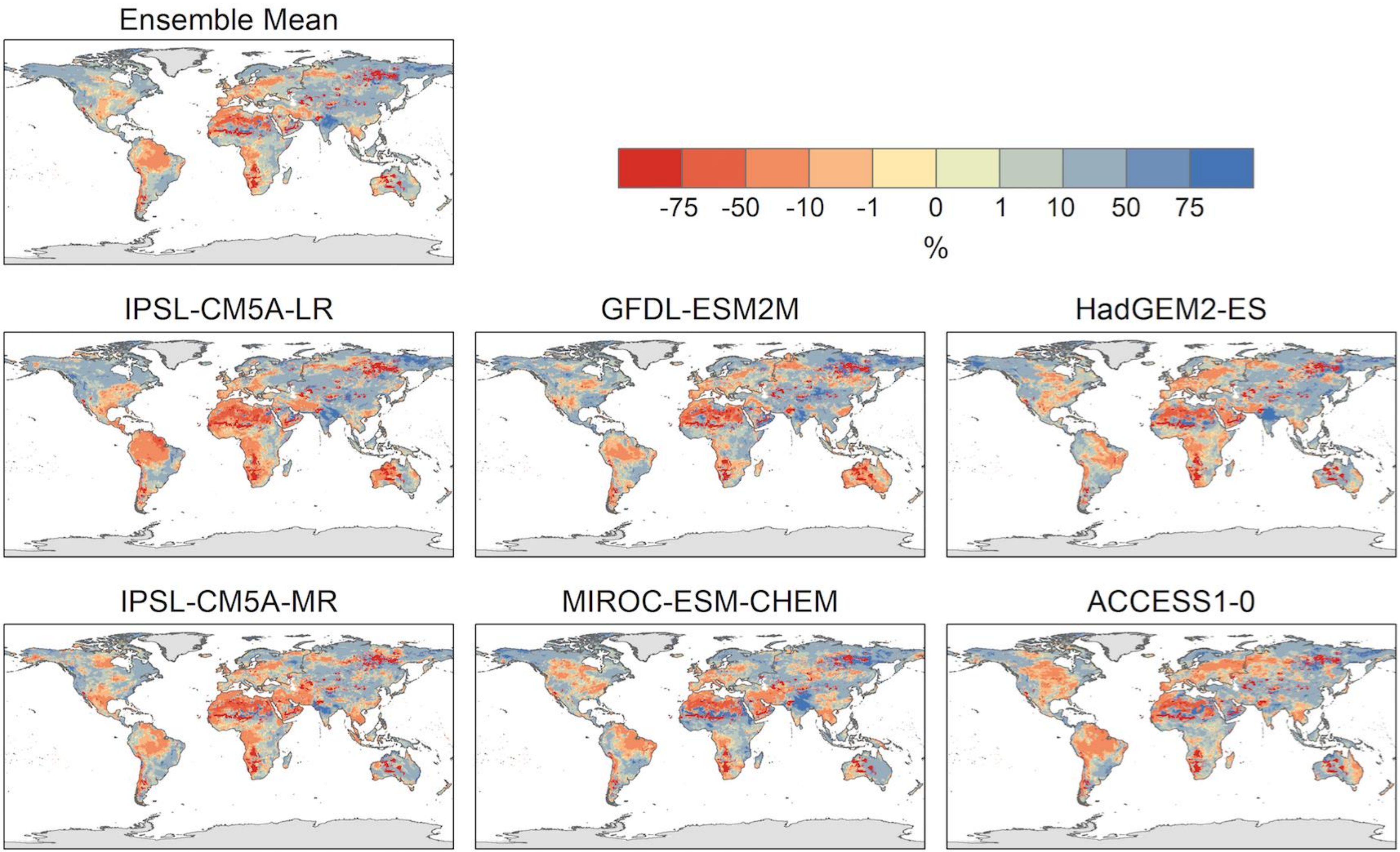
Driving data from HELIX climate projections bias-corrected with observations (Watch Forcing Data Era-Interim) – as in ISIMIP2

Key questions arising from the experimental design:

What is the role of the different SST and sea ice change patterns for regional climate changes?

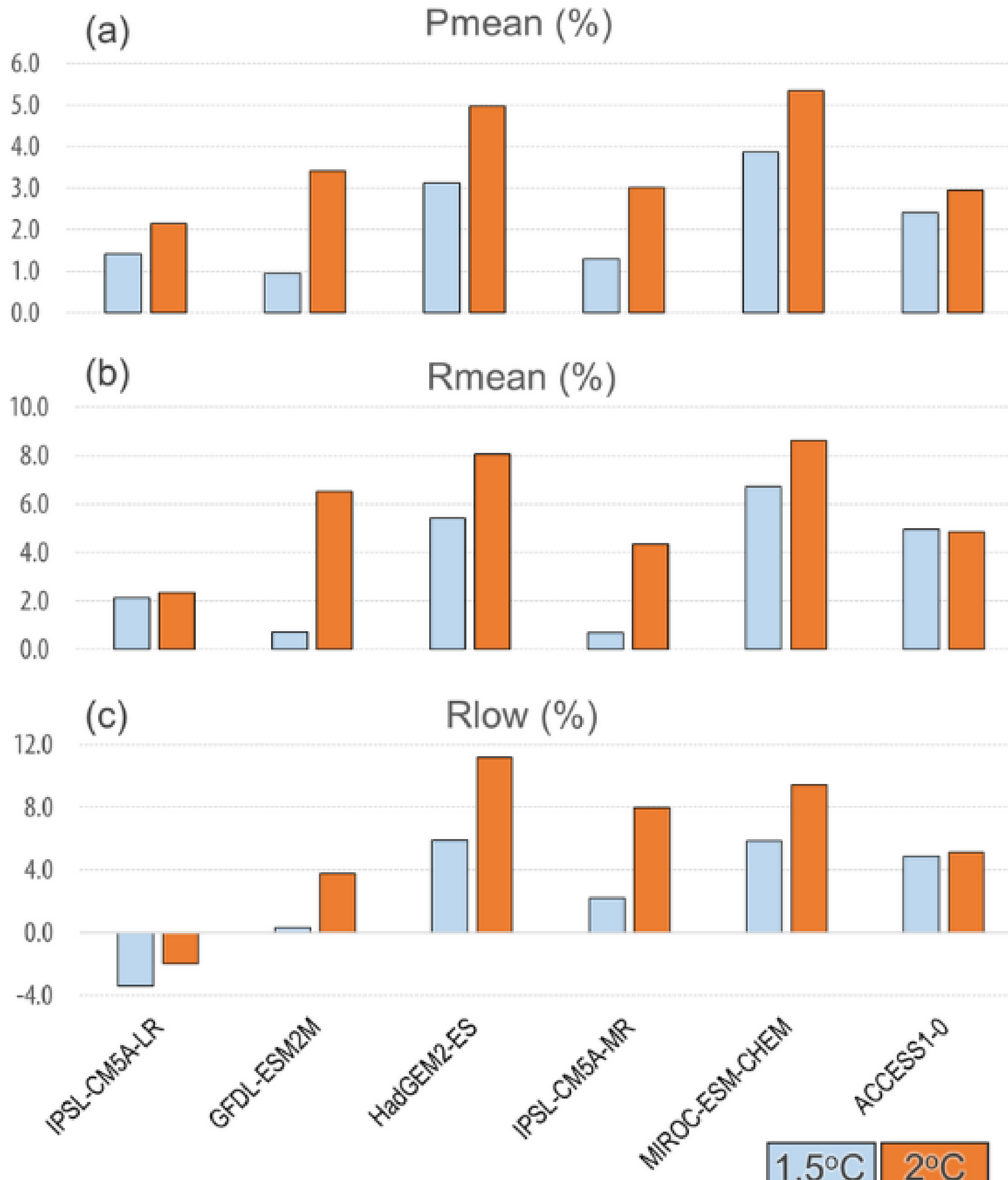
Do the two atmosphere models respond differently?

Projected changes in annual mean runoff at 2°C global warming: JULES driven by HadGEM3 atmosphere with patterns of SST and sea ice change from 6 CMIP5 models



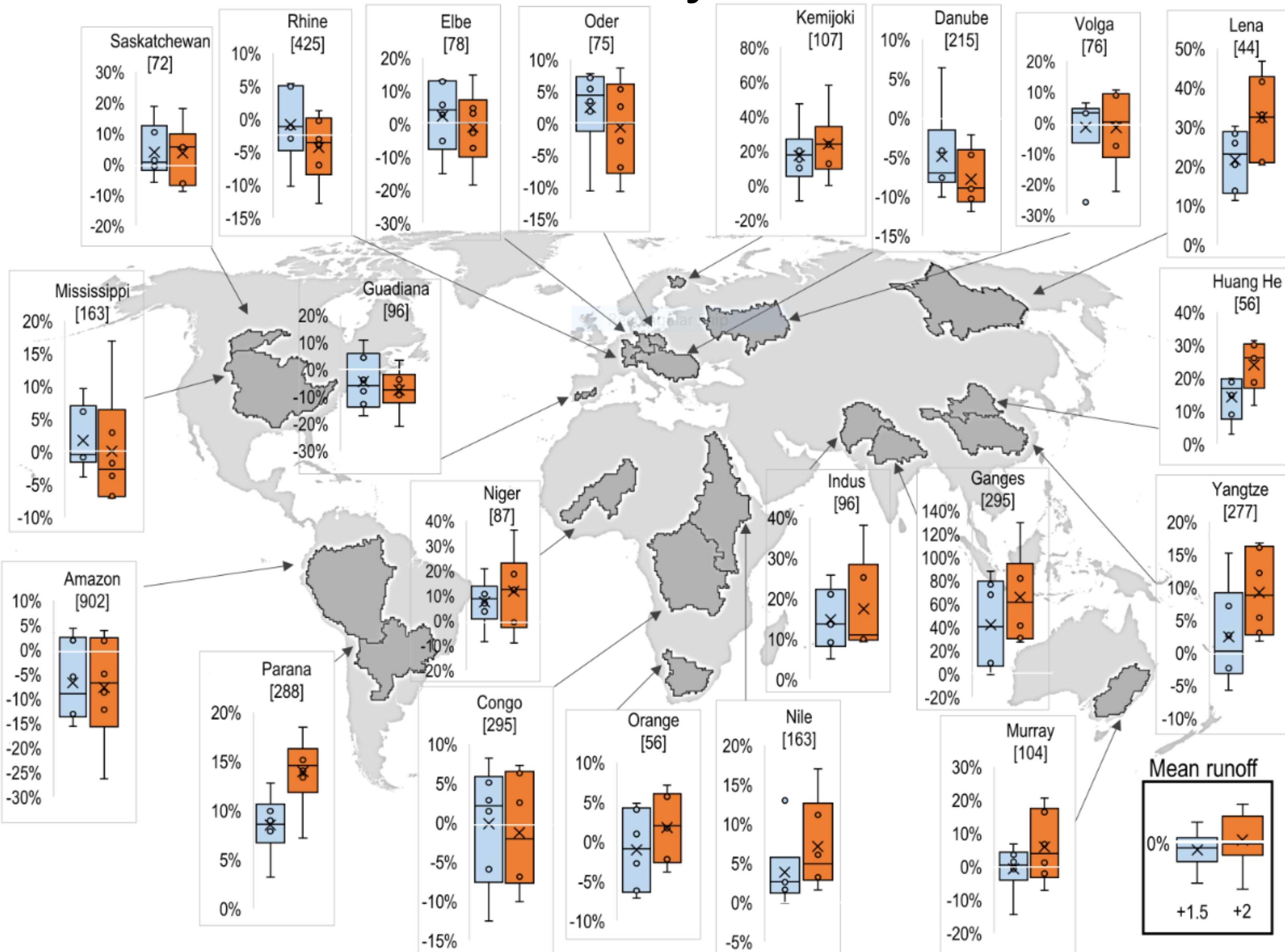
Global mean % changes in precipitation (P), annual mean runoff (Rmean) and 10th %ile runoff (Rlow) at 1.5°C and 2°C global warming

JULES driven by HadGEM3 atmosphere model with SSTs and sea ice from 6 CMIP5 climate models

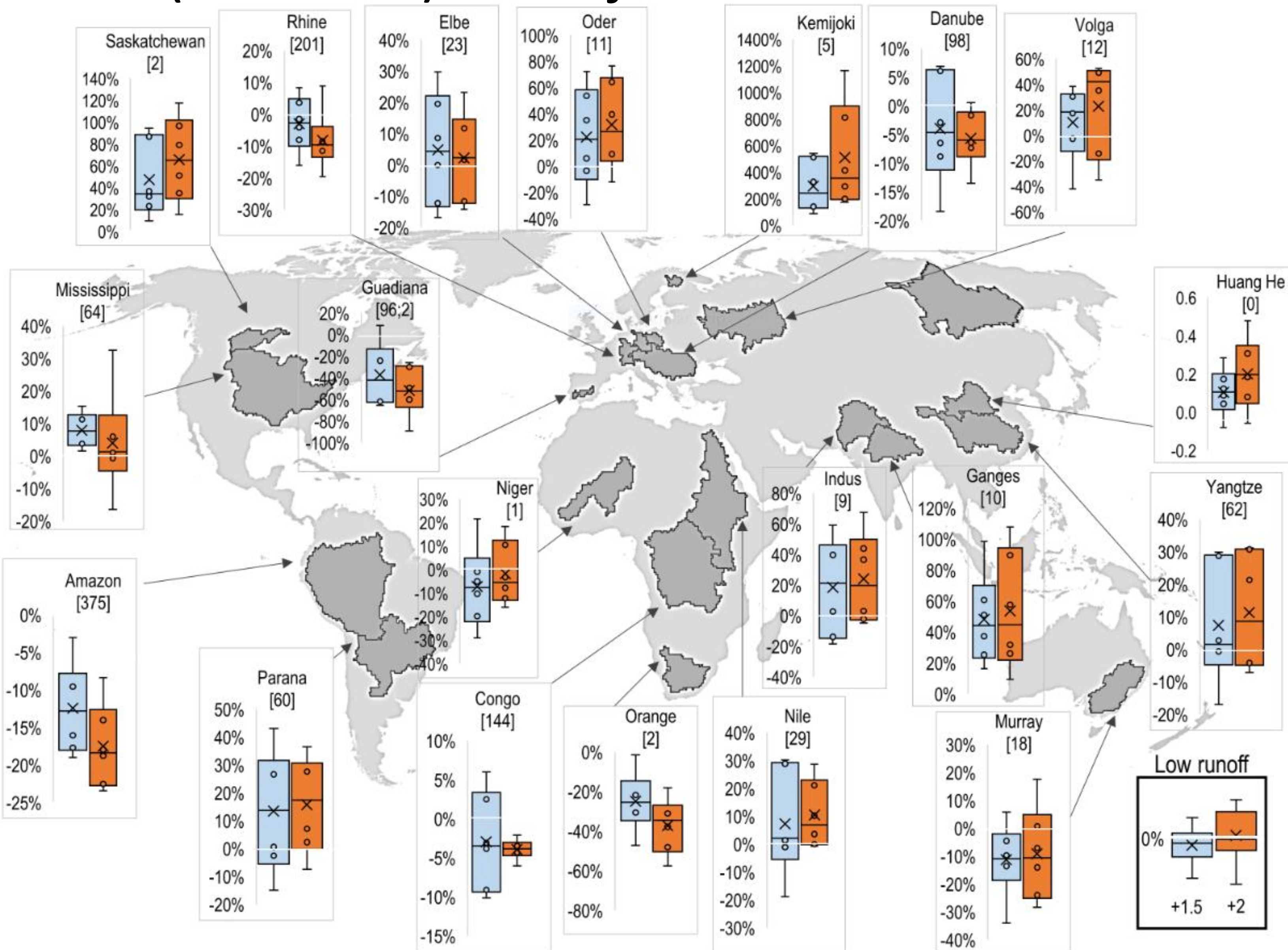


helix
www.helixclimate.eu

Ranges of projected changes in annual mean runoff in major river basins

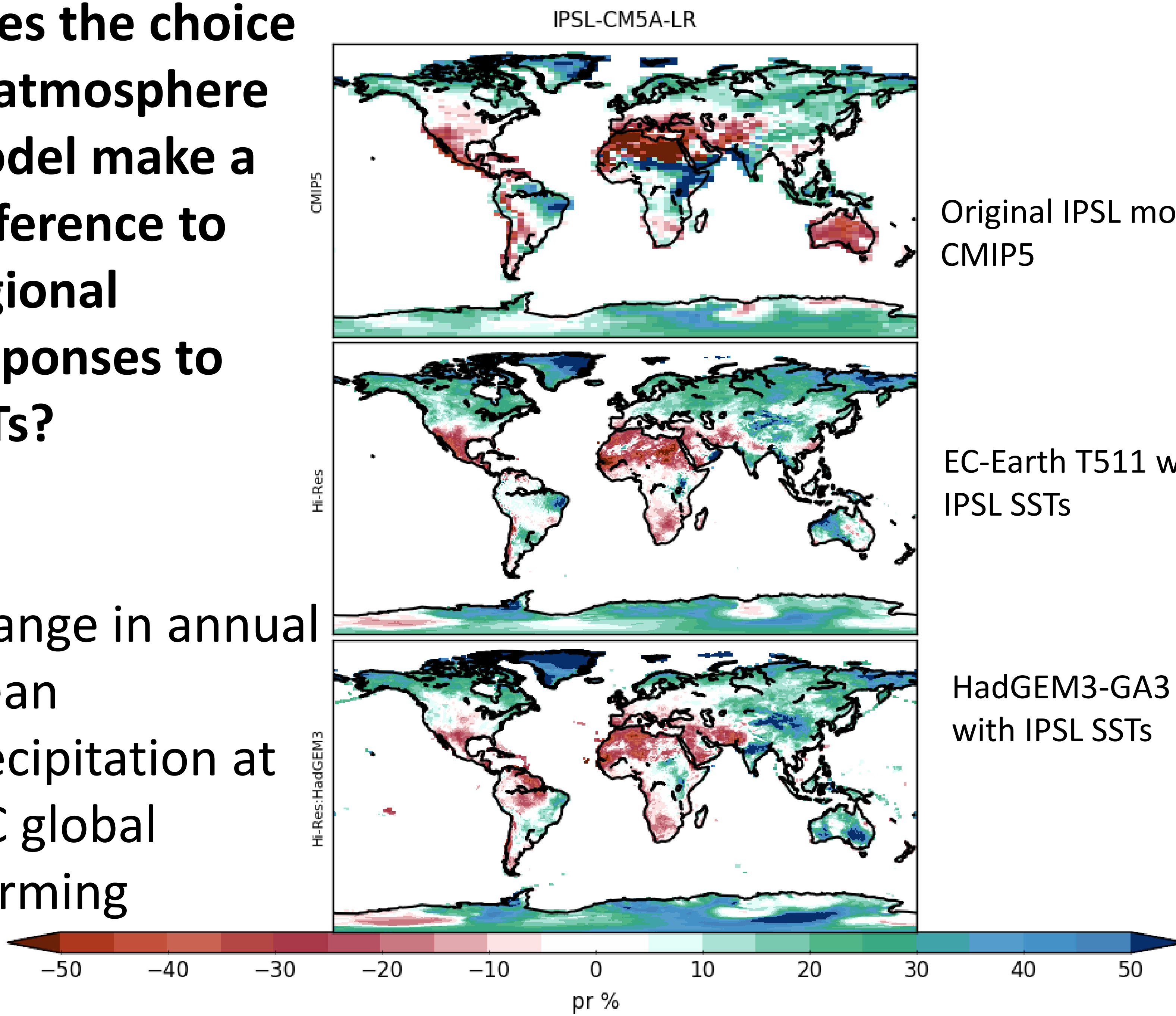


Ranges of projected changes in low runoff (10th %ile) in major river basins



Does the choice of atmosphere model make a difference to regional responses to SSTs?

Change in annual mean precipitation at 4°C global warming



Original IPSL model in CMIP5

EC-Earth T511 with IPSL SSTs

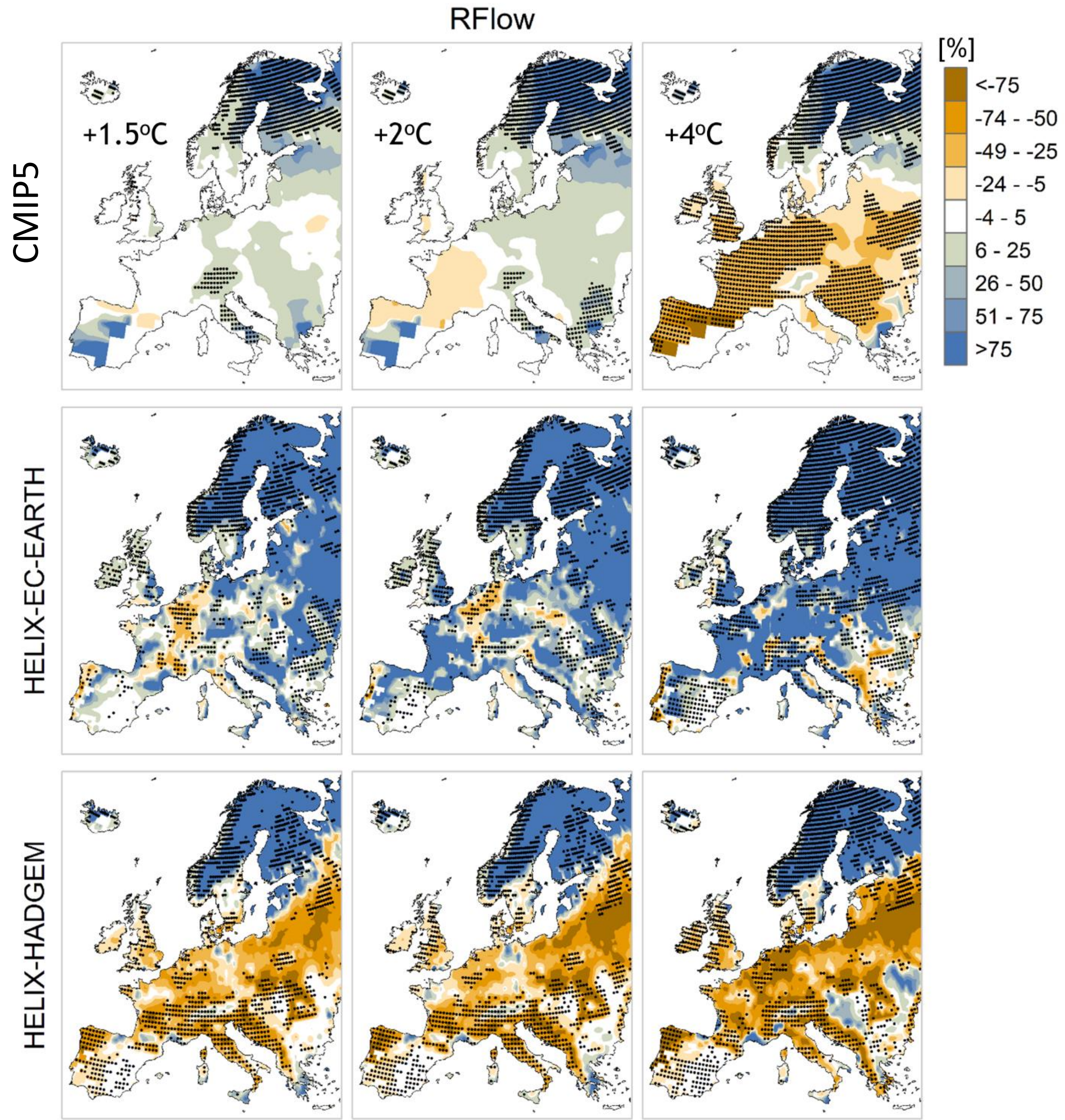
HadGEM3-GA3 N216 with IPSL SSTs

Effect of different atmosphere models with same SSTs

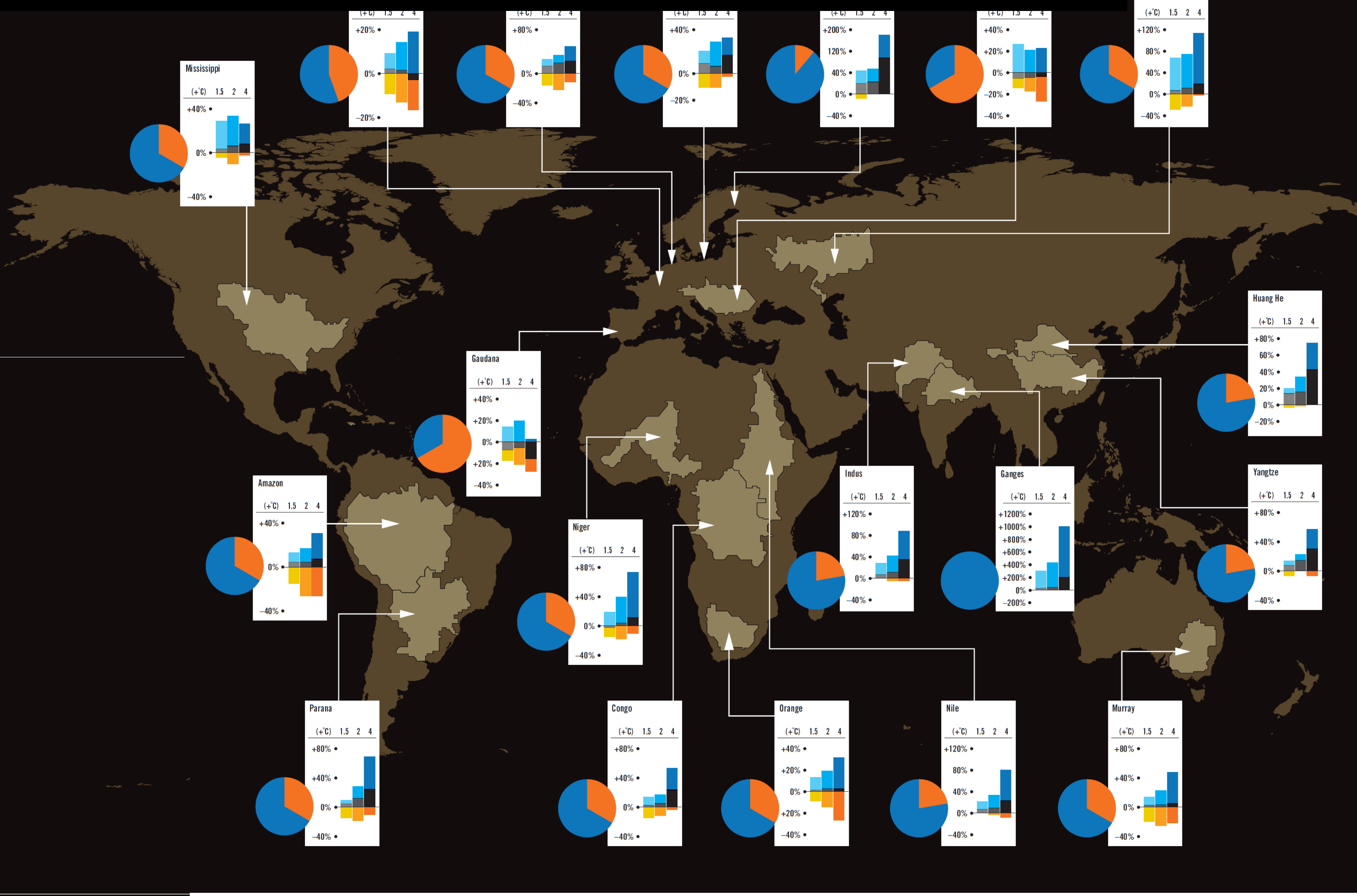
Hydrological drought (10^{th} %ile low flows) simulated by JULES

Common SST driving models

IPSL-CM5A-LR
GFDL-ESM2M
HadGEM2-ES



River flow changes projected at 1.5°C, 2°C, 4°C: JULES driven by 2 atmosphere models, 9 SST and sea ice patterns



helix
www.helixclimate.eu

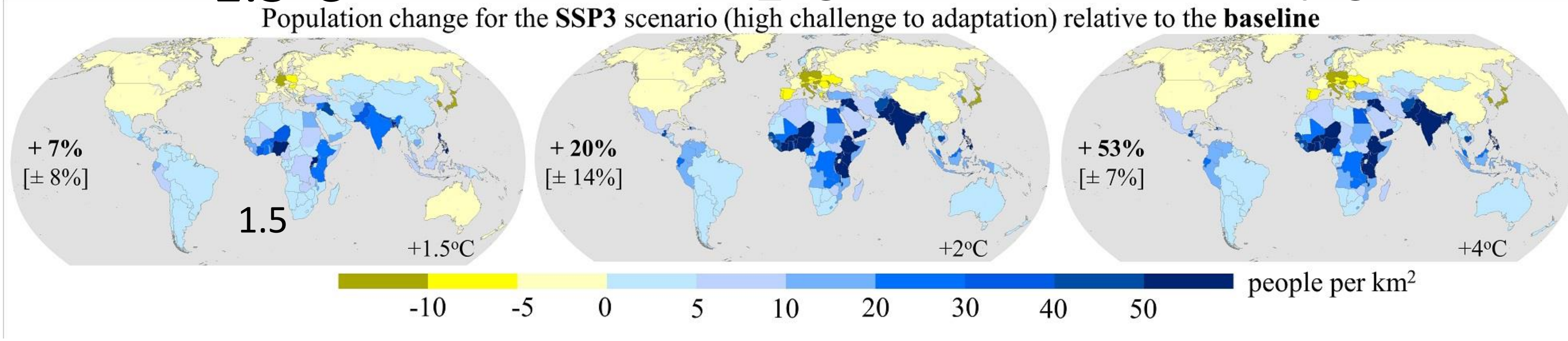
What does this mean for people?

Use 3 different scenarios of population and economic state from the Shared Socioeconomic Pathways (SSPs)

SSP3 “high challenge to adaptation”
SSP2 “medium challenge to adaptation”
SSP5 “high challenge to adaptation”

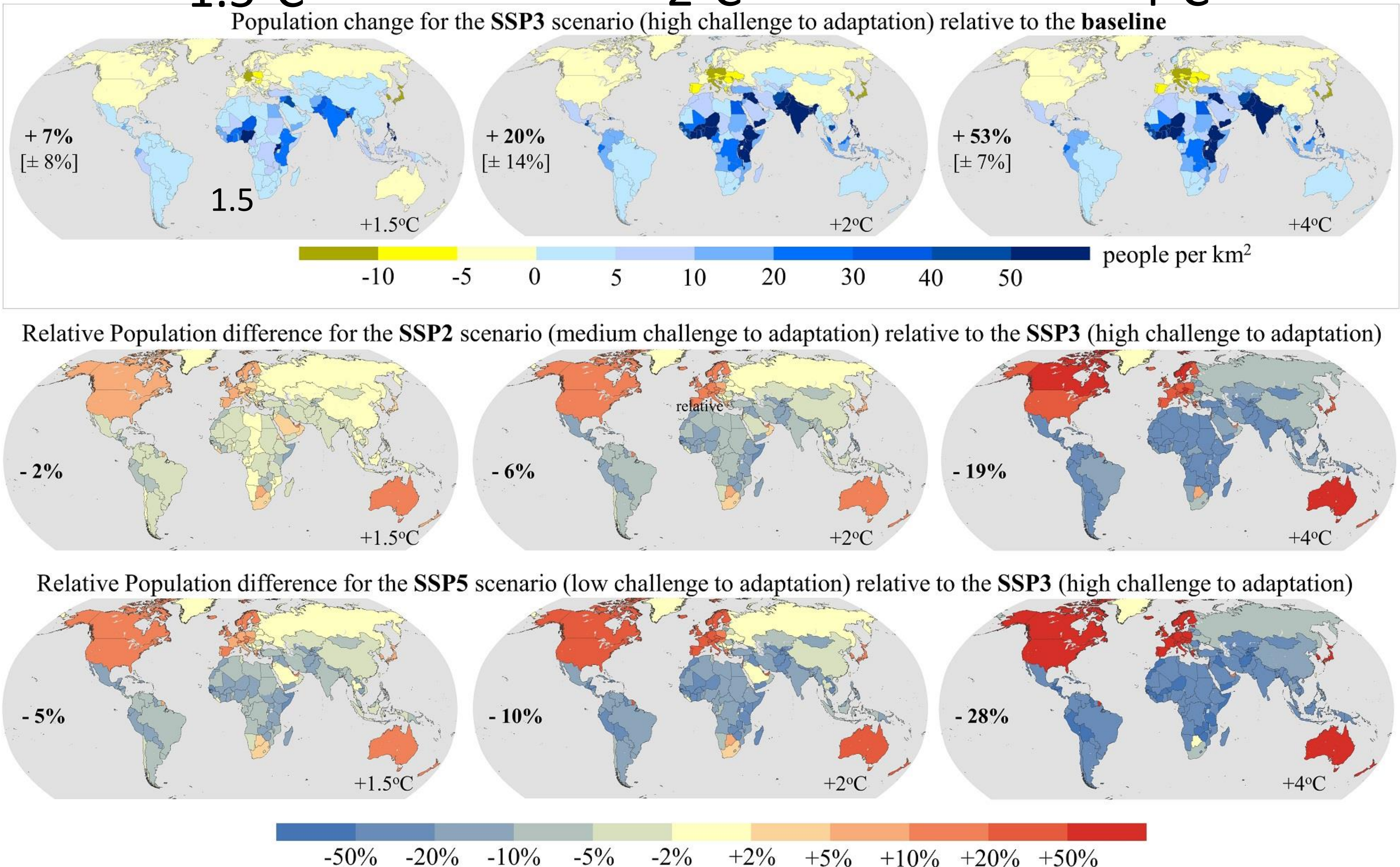
Population change projections at time of passing global warming levels (ensemble mean)

1.5°C 2°C 4°C



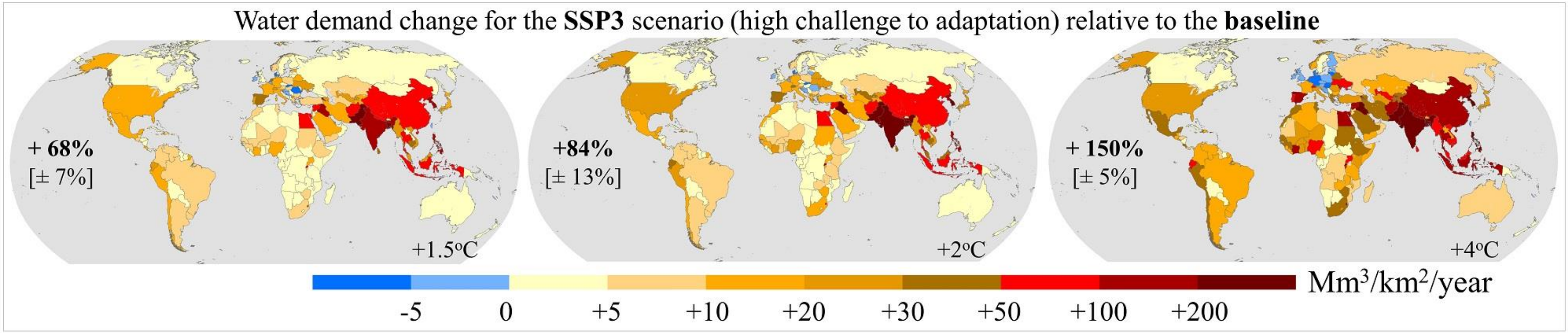
Population change projections at time of passing global warming levels (ensemble mean)

1.5°C 2°C 4°C



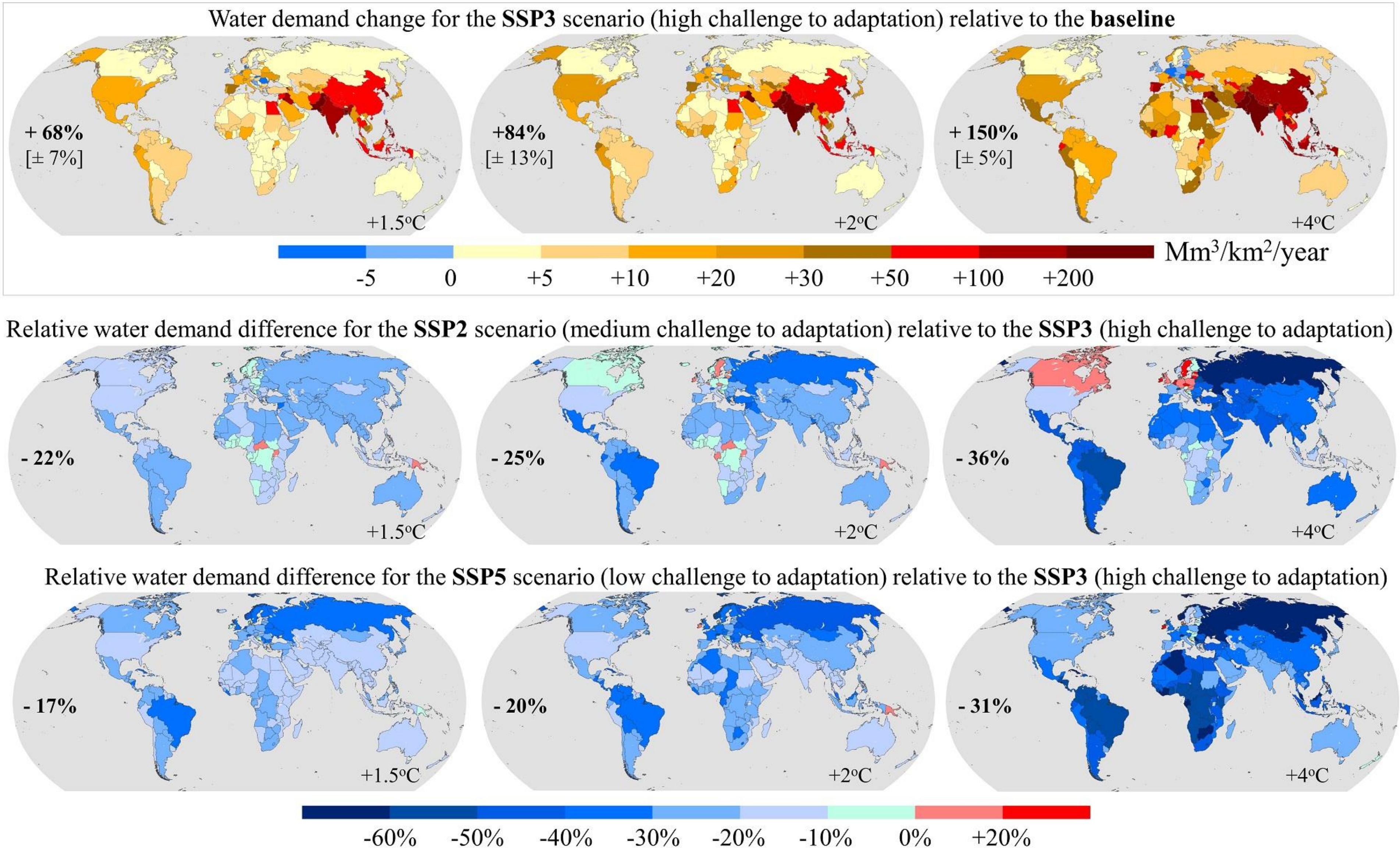
Water demand projections at time of passing global warming levels (ensemble mean)

1.5°C 2°C 4°C

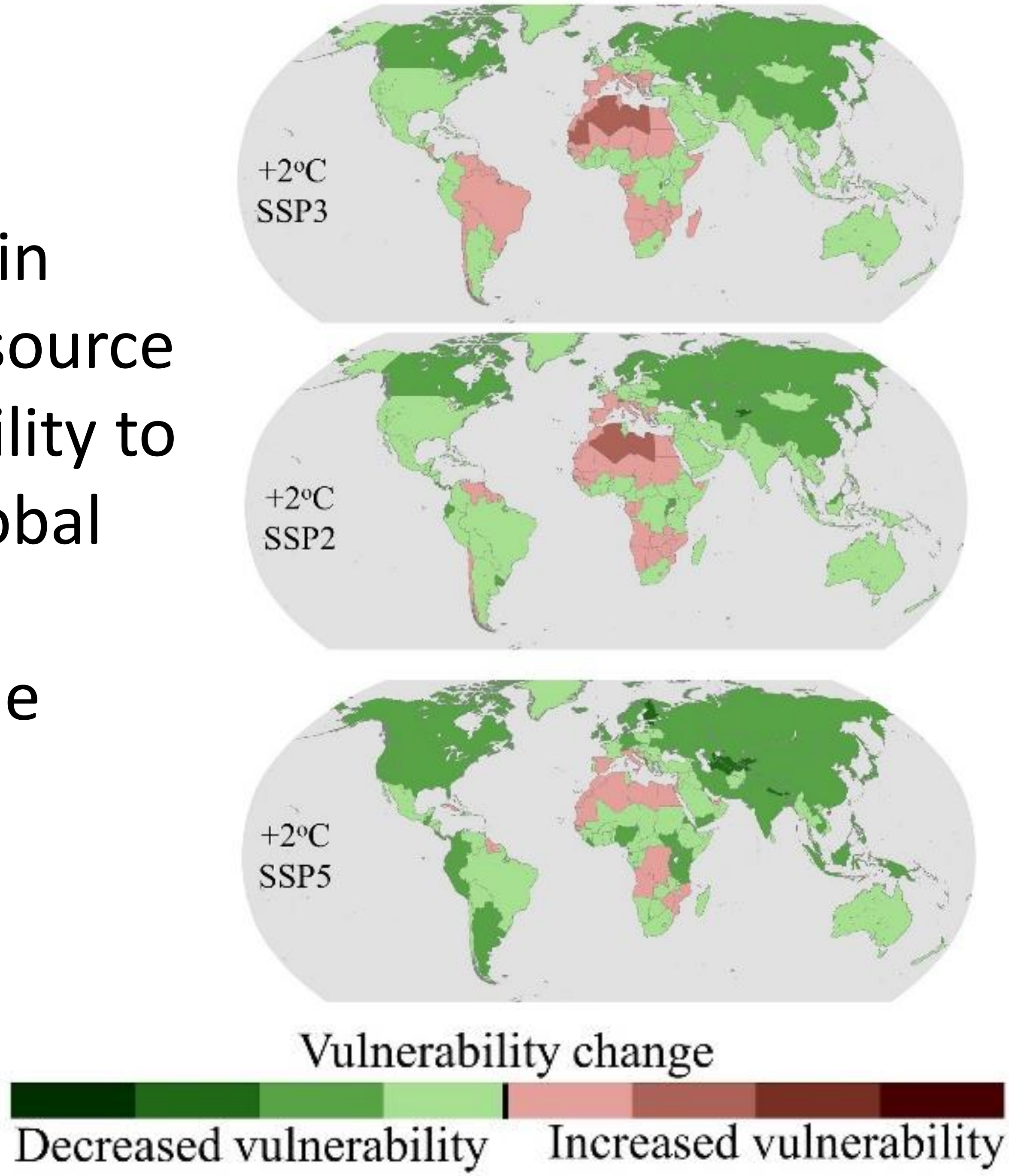


Water demand projections at time of passing global warming levels (ensemble mean)

1.5°C 2°C 4°C



Changes in water resource vulnerability to at 2°C global warming (ensemble mean)

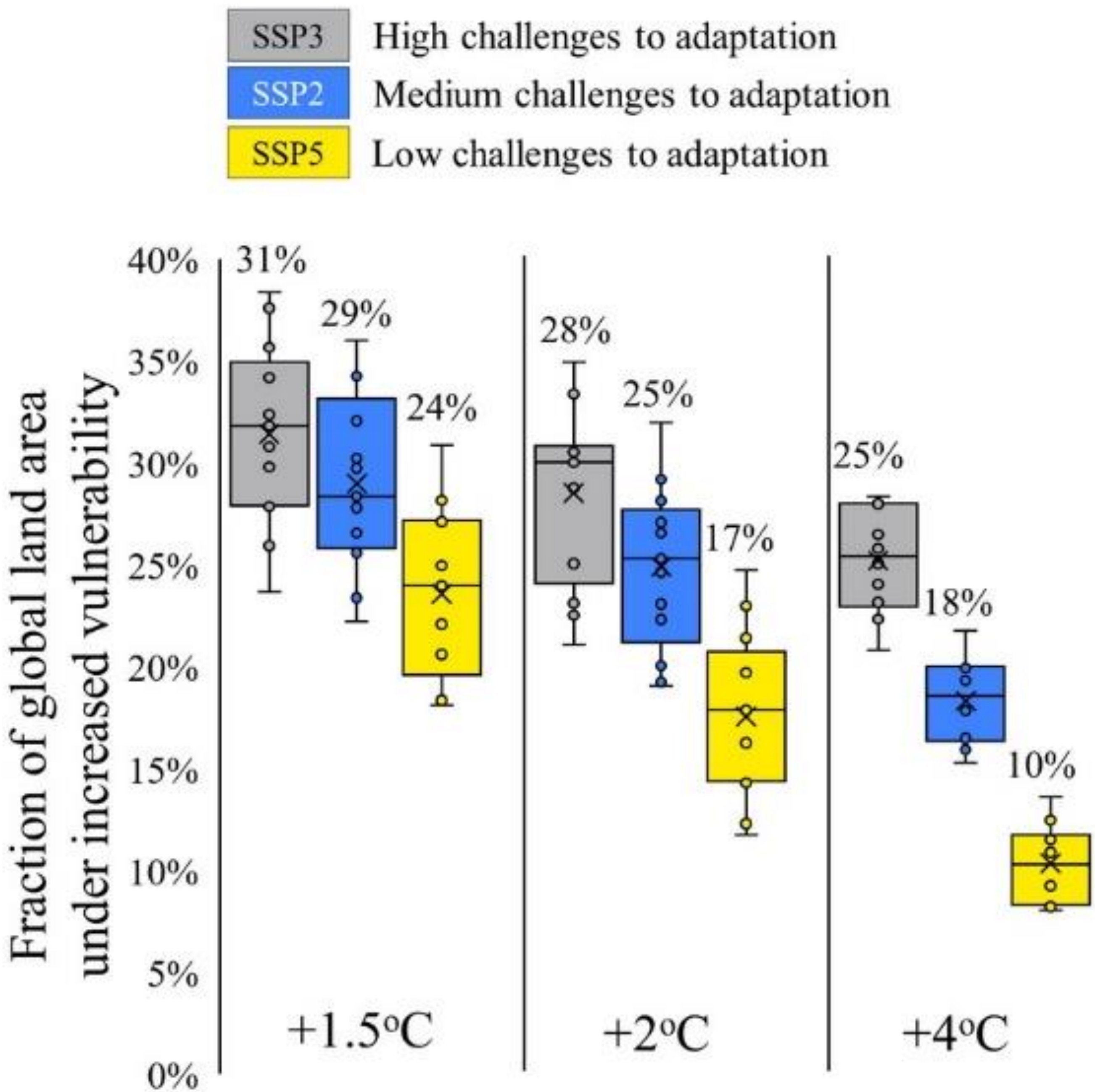


High challenge to adaptation

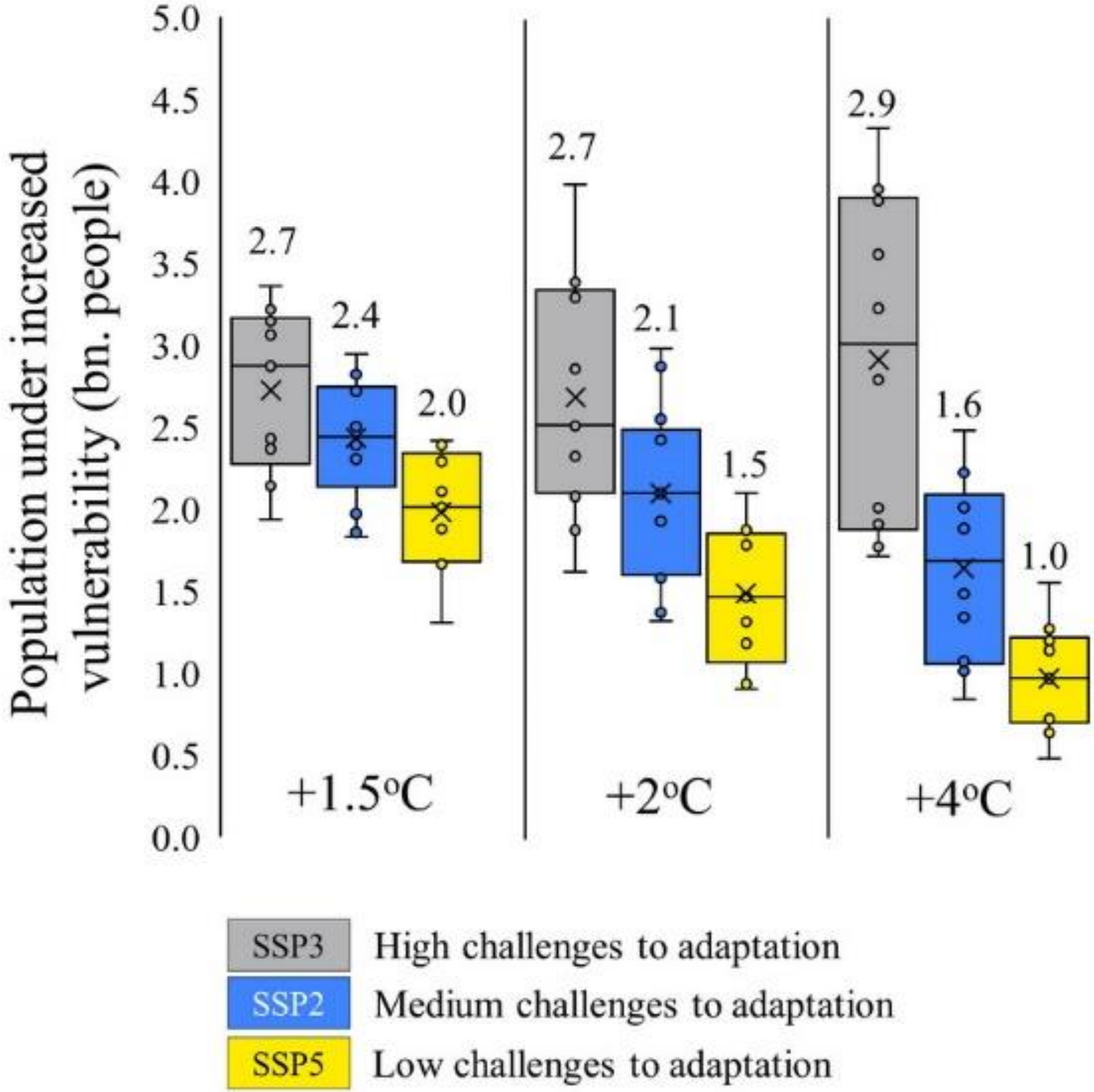
Medium challenge to adaptation

Low challenge to adaptation

Global vulnerability: fraction of land area



Global vulnerability: population



Conclusions

- At **2°C global warming**, complex geographical pattern of changes in freshwater resources. **Many areas get wetter but some get drier**
- Uncertainty in this depends on sea surface temperature and sea ice patterns, and also on which atmosphere model is used
- Generally **smaller changes at 1.5°C** but not in all basins (may be noise of variability)
- Generally **larger changes at 4°C**
- **Uncertainty increases with global warming**
- Socioeconomic scenario is a first-order effect on human impact
- For scenario with low challenge to adaptation, global water resource vulnerability projected to decrease
- For scenario with **high challenge to adaptation**, global water resource **vulnerability could either increase or decrease** with warming depending on patterns of climate change