

# Global Water Resources: Human and Climate Impacts over the 21st Century

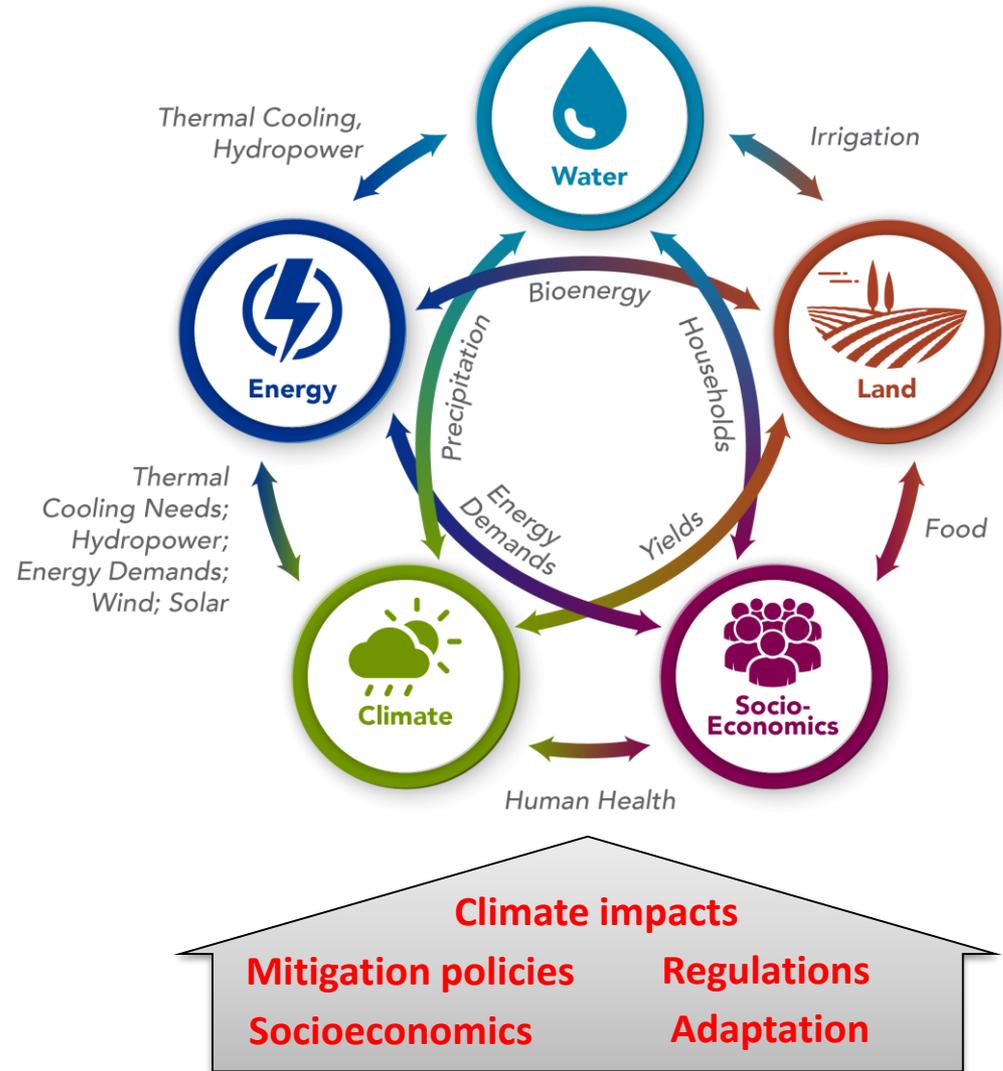
MOHAMAD HEJAZI ON BEHALF OF PNNL TEAM

THE JOINT GLOBAL CHANGE RESEARCH INSTITUTE  
PACIFIC NORTHWEST NATIONAL LABORATORY  
COLLEGE PARK, MARYLAND

September 27, 2018

# Research questions

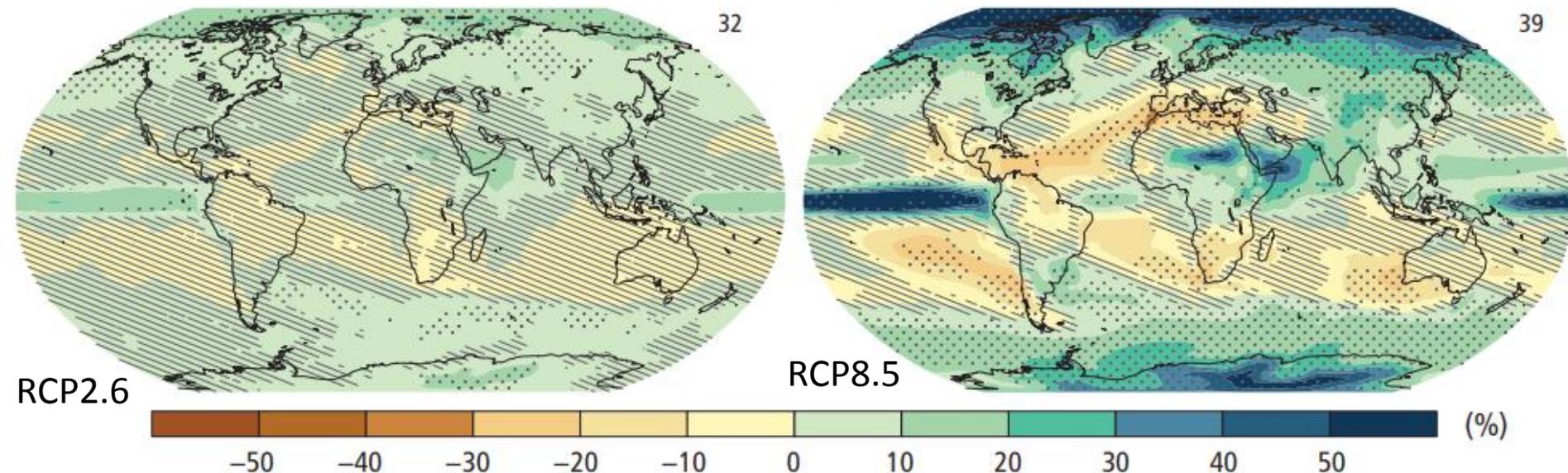
- ▶ How will climate change impact water availability and scarcity in the future?
- ▶ How will the coevolution of water-energy-land-climate-economy systems affect water scarcity and groundwater depletion rates across the globe?
- ▶ What are the relative contributions of climate and human systems on water scarcity regionally and globally?



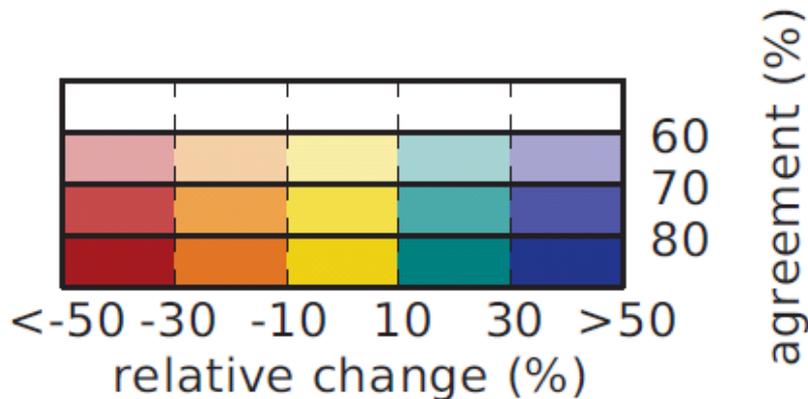
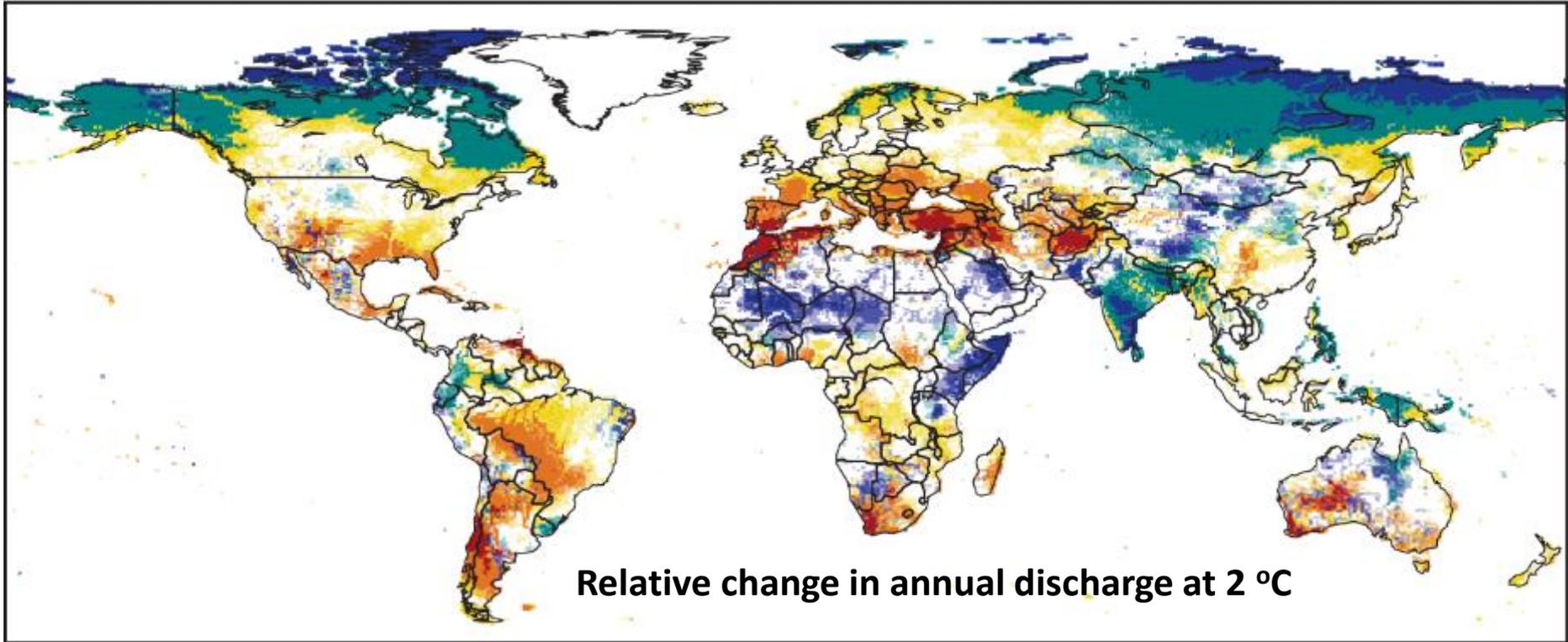
# Future Changes in Mean Precipitation

- ▶ Changes in precipitation in a warming world will not be uniform.
- ▶ High latitudes and the equatorial Pacific are likely to experience an increase in annual mean precipitation by the end of this century under the RCP8.5 scenario.
- ▶ Many mid-latitude and subtropical dry regions, mean precipitation will likely decrease, while in many mid-latitude wet regions, mean precipitation will likely increase under the RCP8.5 scenario

Change in average precipitation (1986–2005 to 2081–2100)



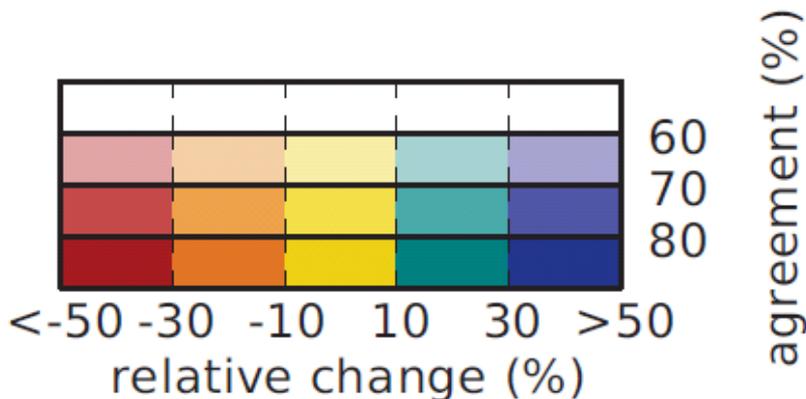
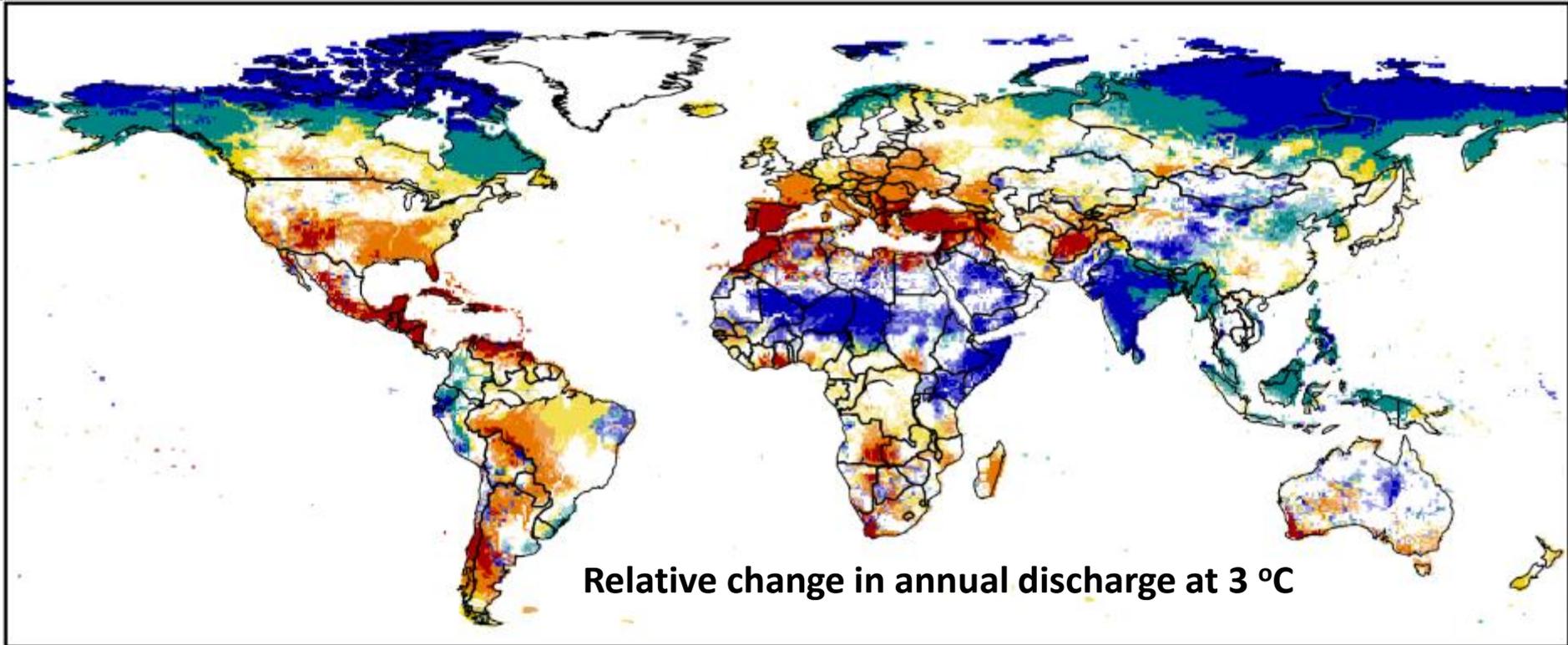
# Climate impact on water supplies



Ensemble model simulation with  
11 global hydrological models (GHMs),  
5 global climate models (GCMs) under RCP 8.5  
emission scenarios

Schewe et al. (2014; PNAS)

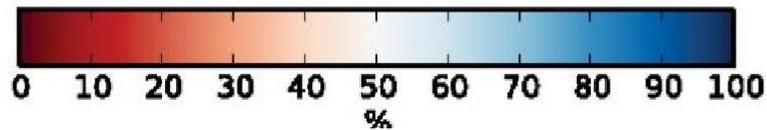
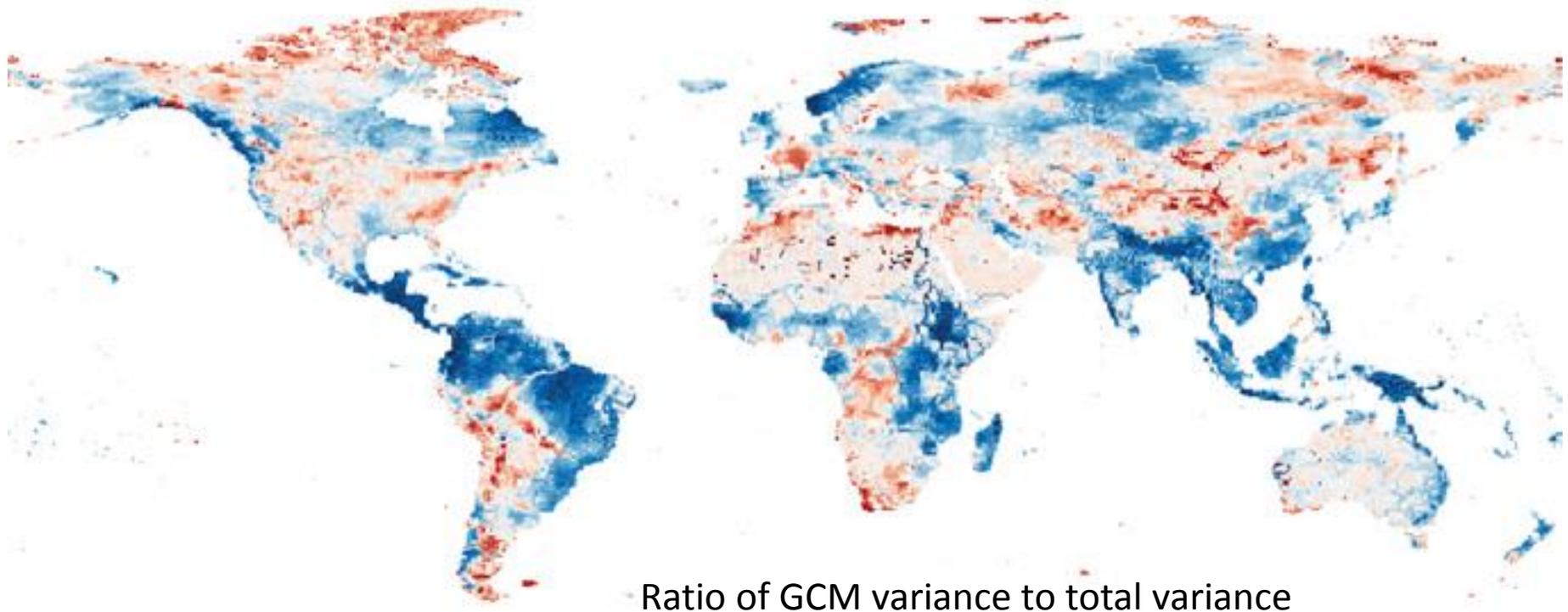
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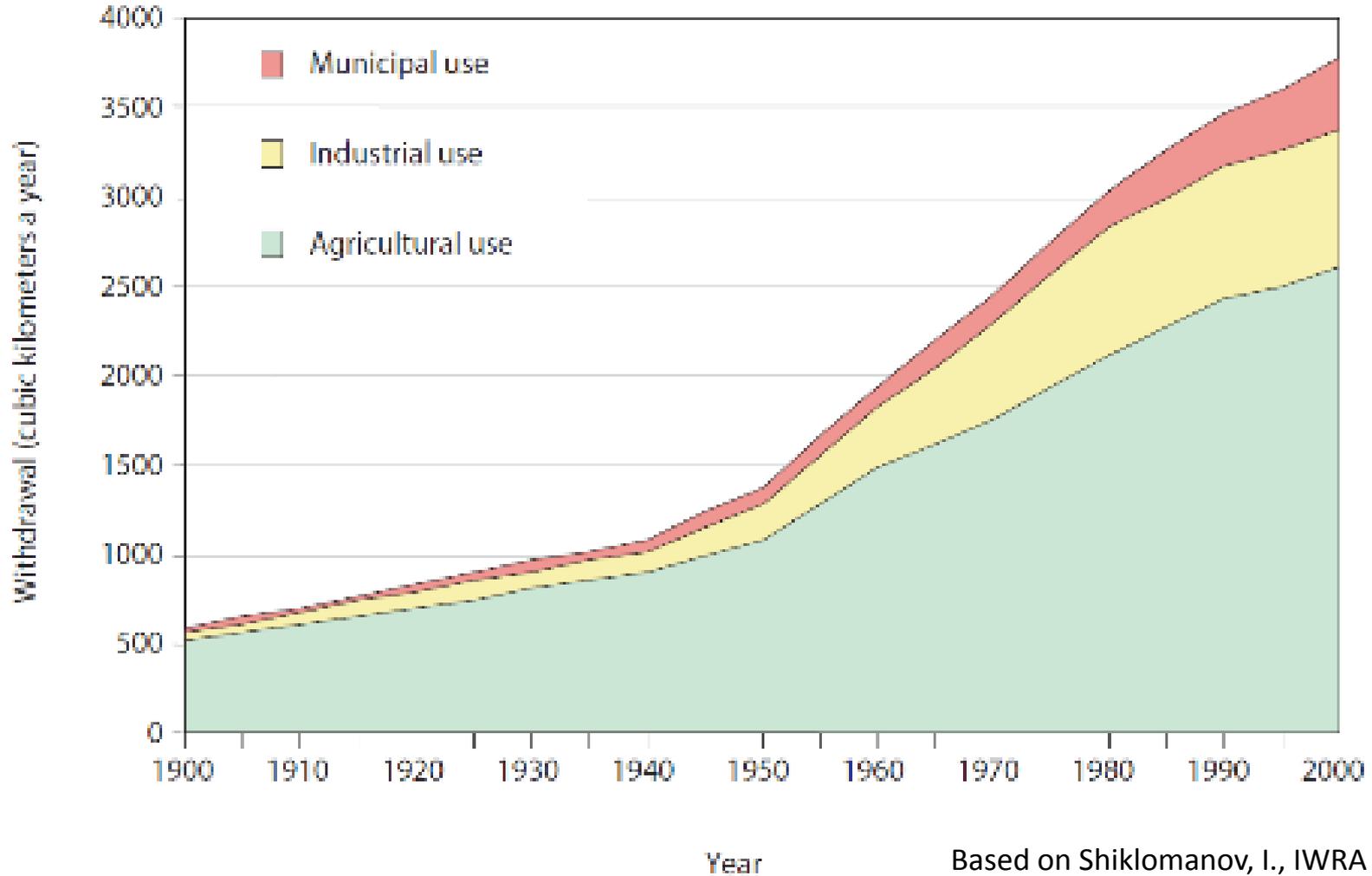
# Uncertainty is comparable between hydrologic and climate models



GHM variance  
predominates

GCM variance  
predominates

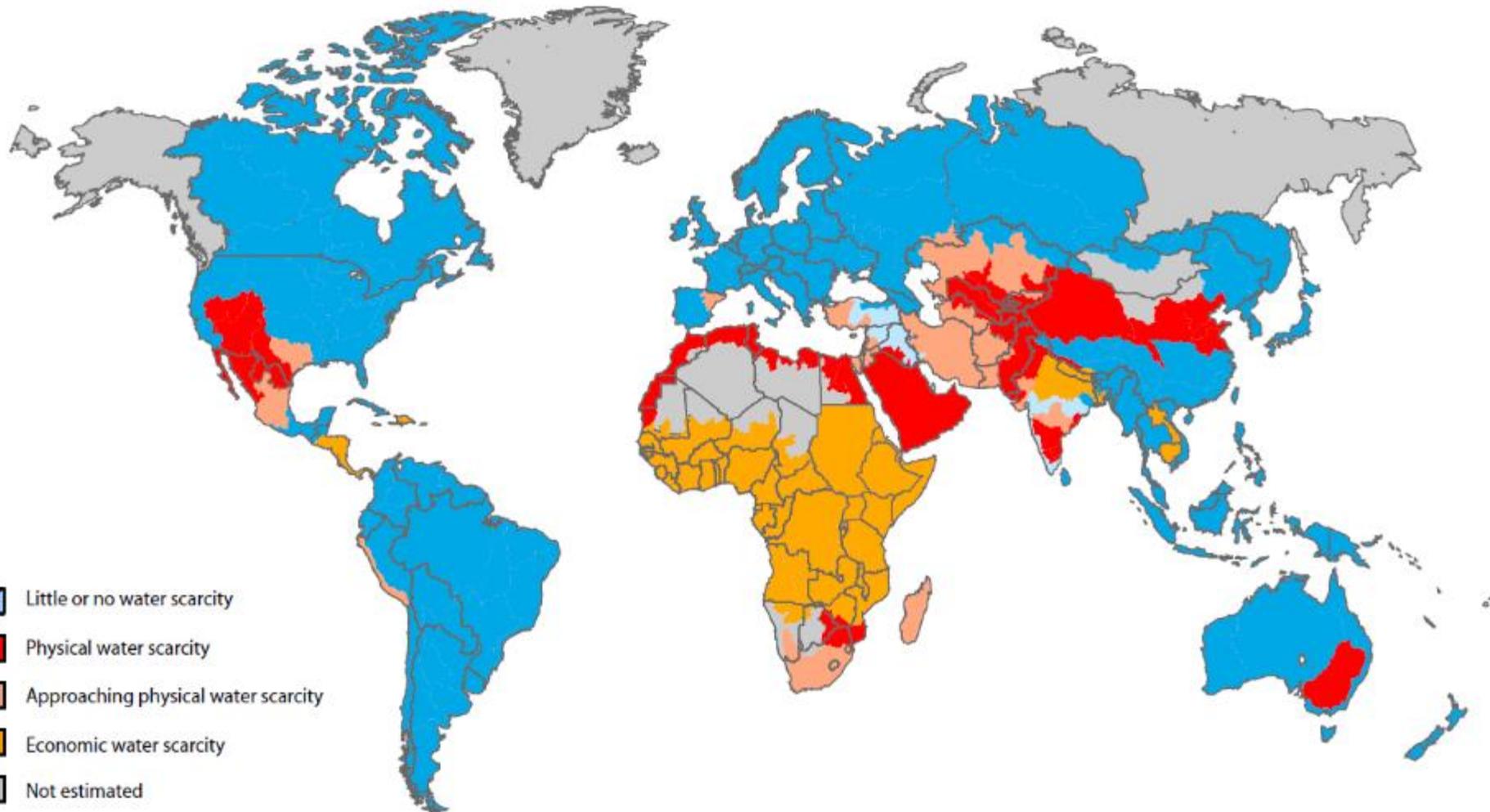
# But what about humans? How much water human expect to demand?



Based on Shiklomanov, I., IWRA Water International Vol 25 (1), March 2000

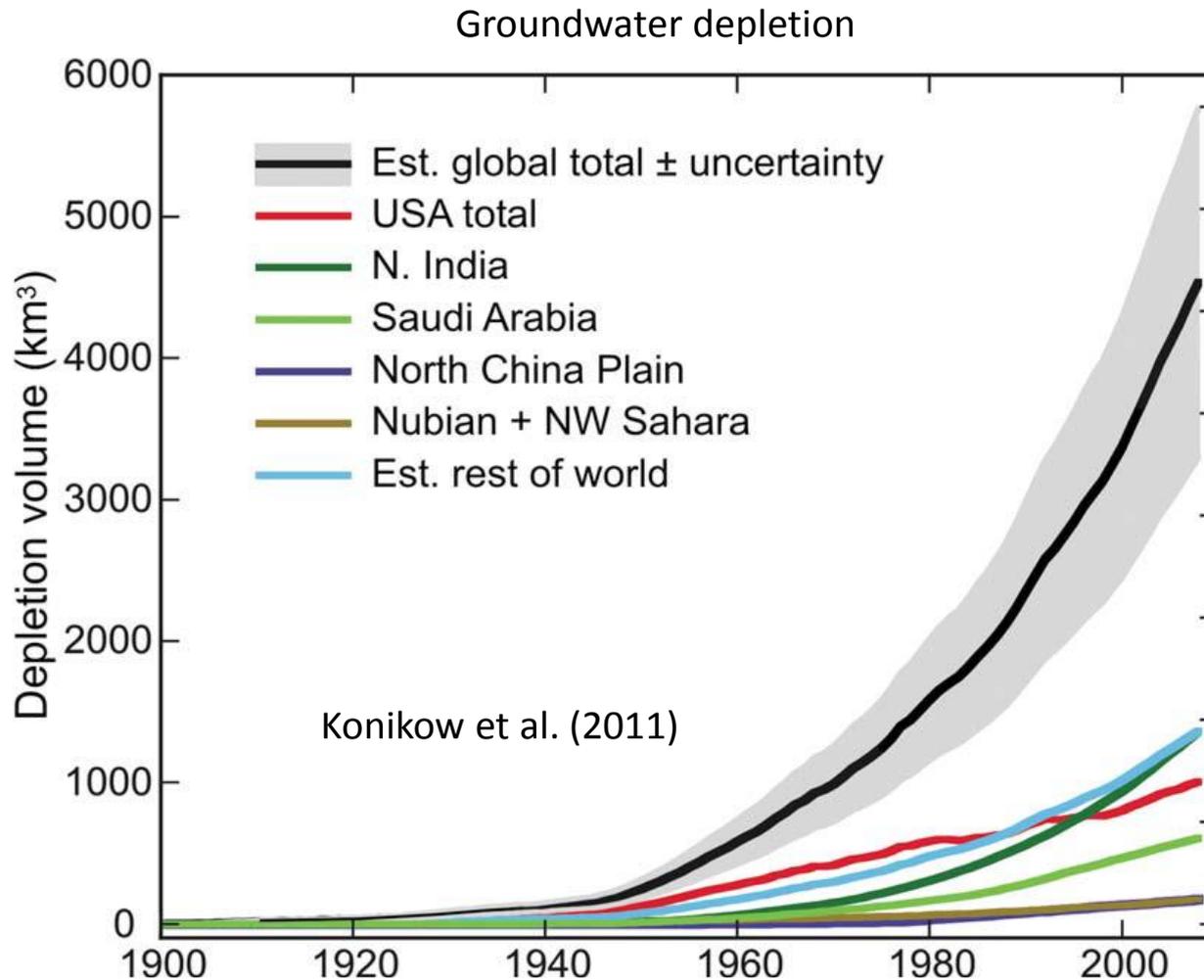
# Geography of water scarcity today

- ▶ A quarter of the world's people live in areas characterized by physical water scarcity. One billion live in basins that face economic scarcity.



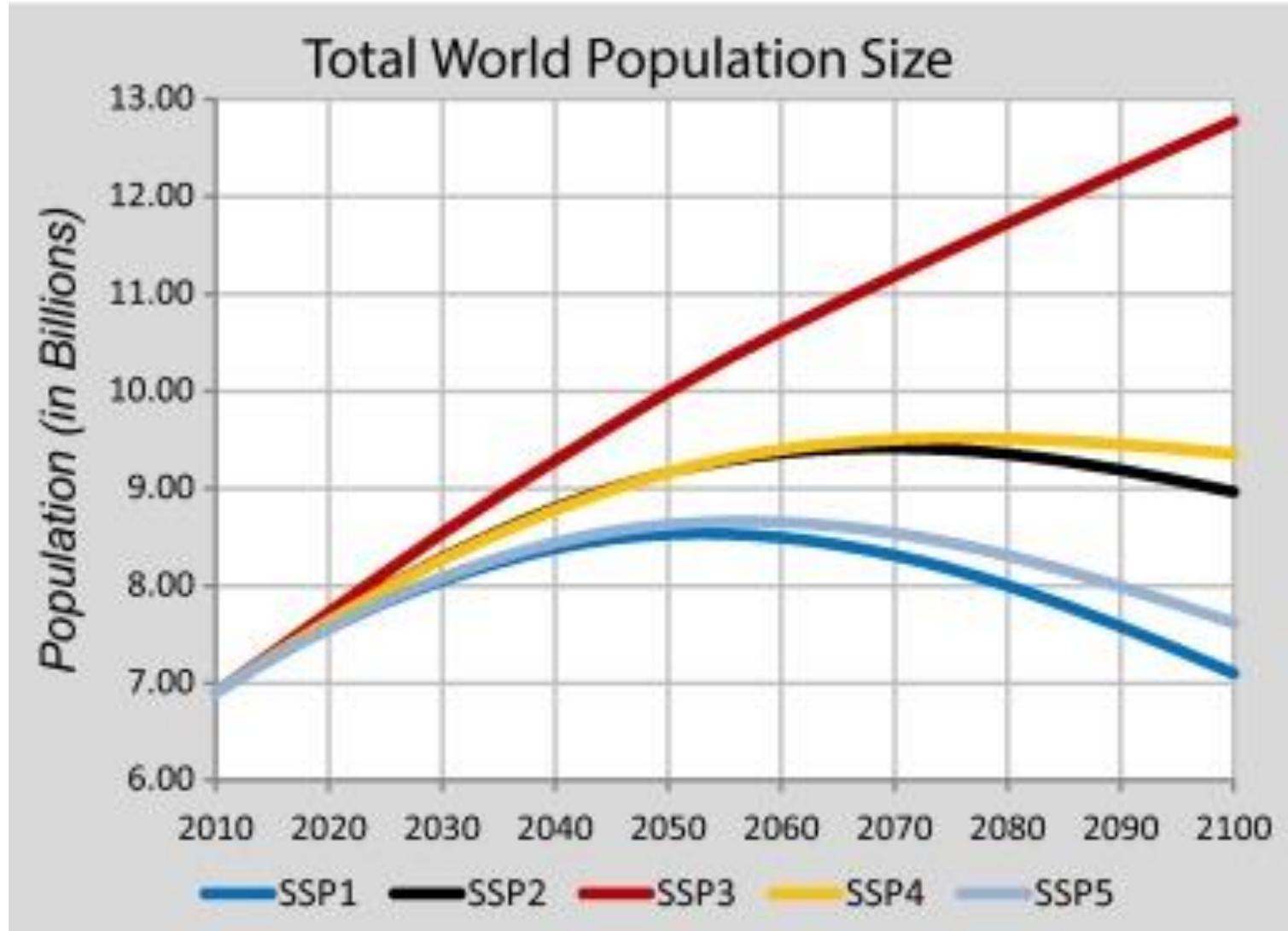
Source: Stockholm Environment Institute (SEI) and Stockholm International Water Institute (SIWI)

# And we are increasingly depleting our groundwater resources/reserves



- Water supplies and demands are variable in space & time and are generally out of phase
- Dependence on non-traditional water sources (depletable groundwater, desalinated water, water reuse, etc.)

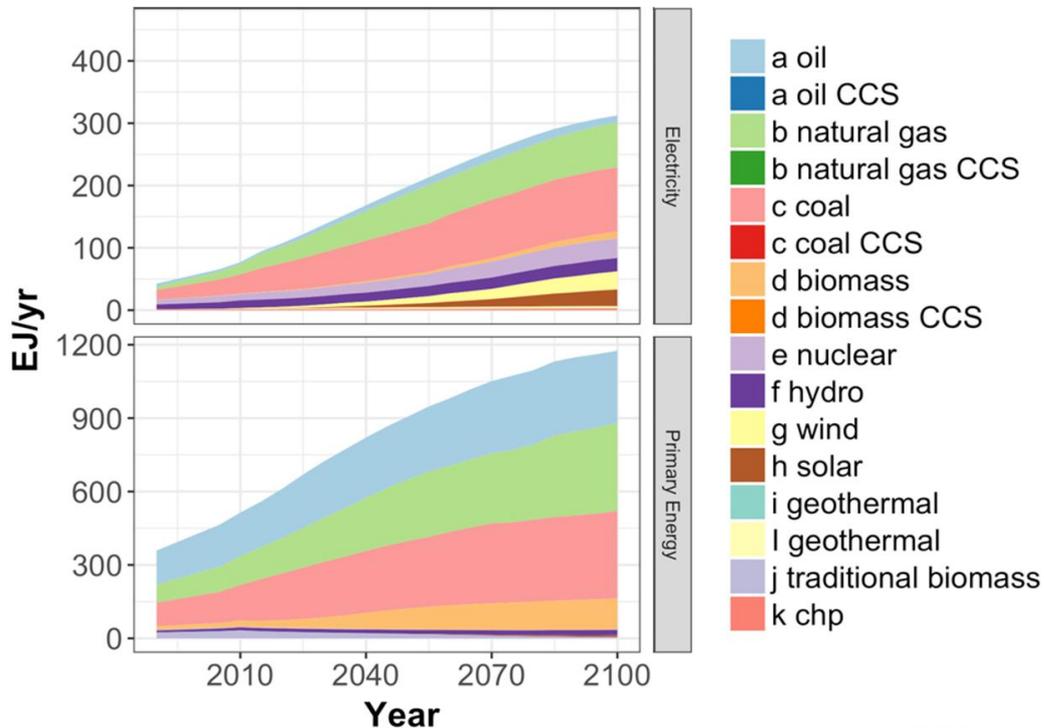
# Population projections over the 21<sup>st</sup> century under the Shared Socioeconomic Pathways (SSPs)



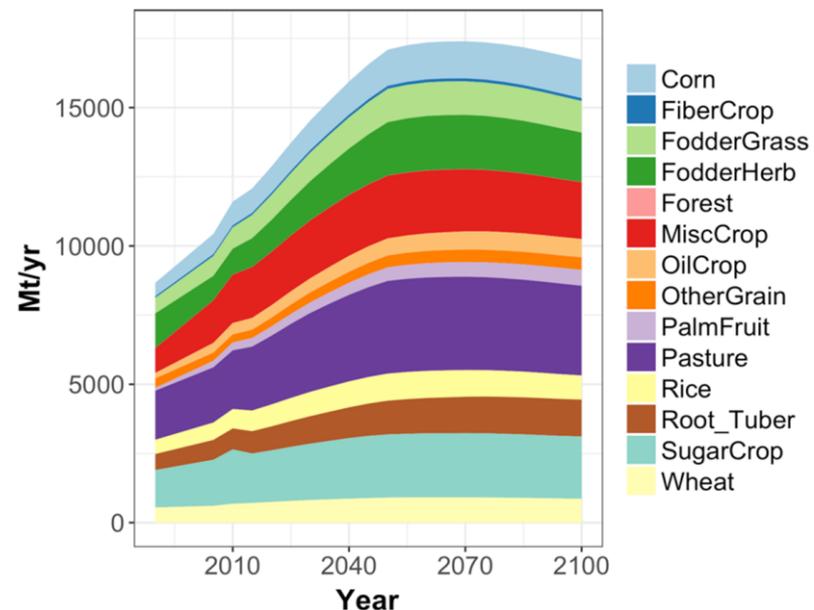
Source: KC and Lutz 2017

# Projections of Water-Energy-Land Systems over the 21<sup>st</sup> Century

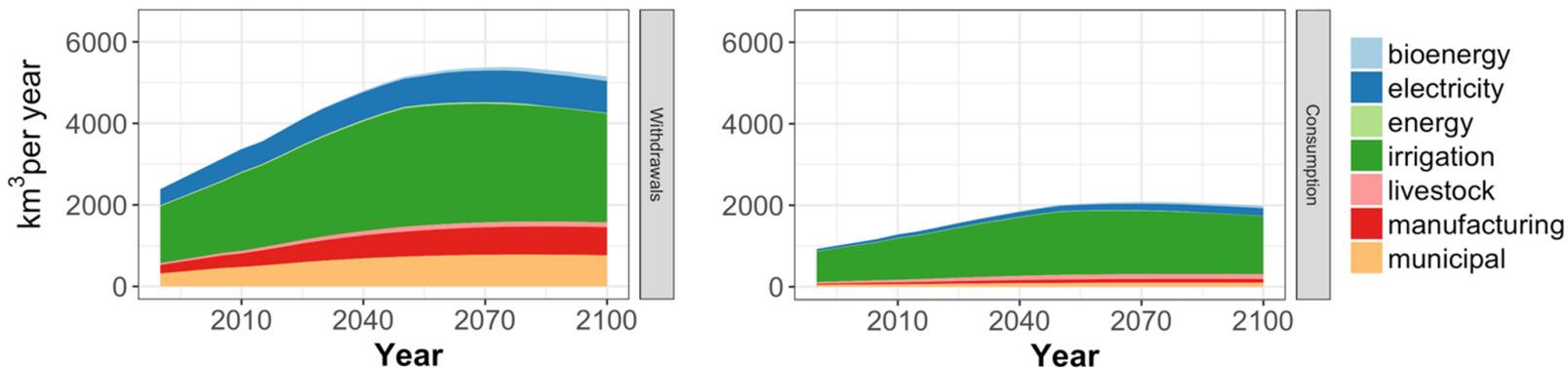
## ENERGY



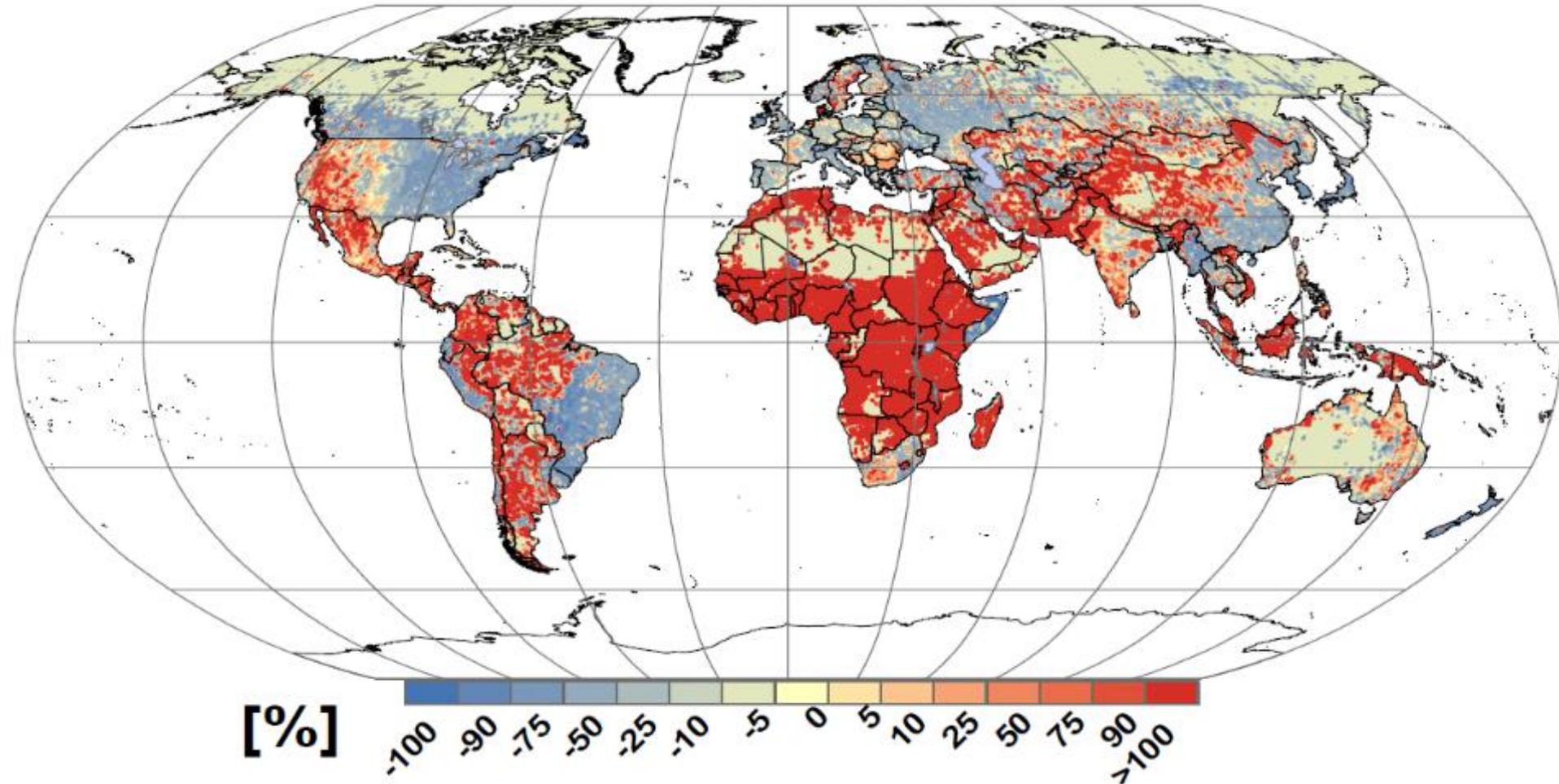
## AGRICULTURE



## WATER



# Relative change in human water consumption



**2100 – 2010; SSP2**

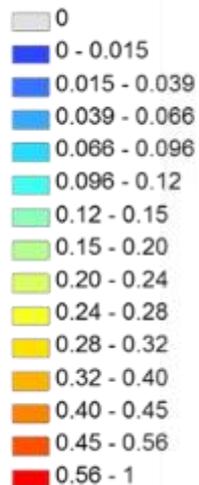
Wada and Bierkens (2014; ERL)



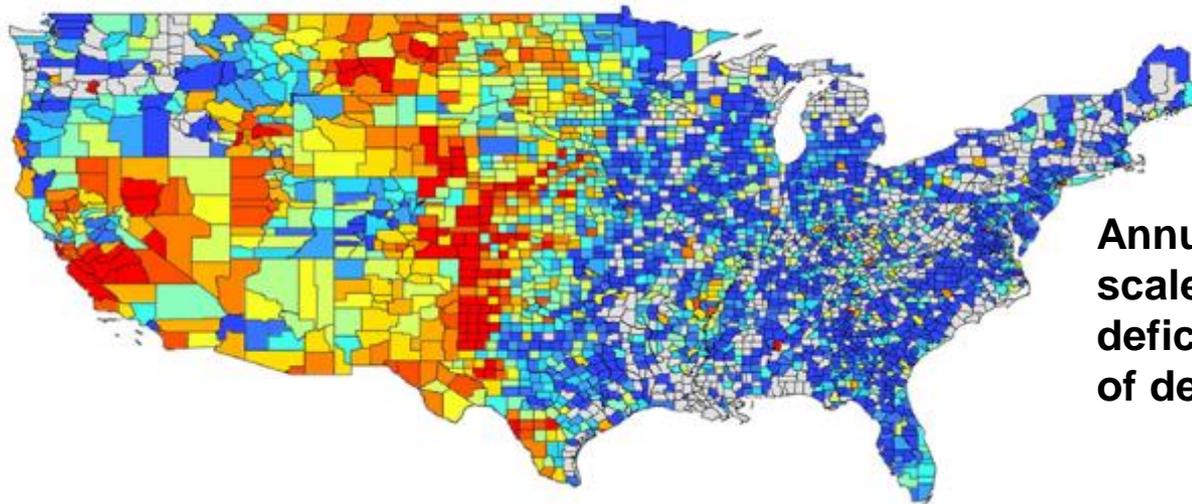
# Mitigating climate change might increase water scarcity: Avoiding unintended consequences!!!

Water deficit is projected to increase more with climate change mitigation that favors biomass

Legend



Deficit over Demand for 2005



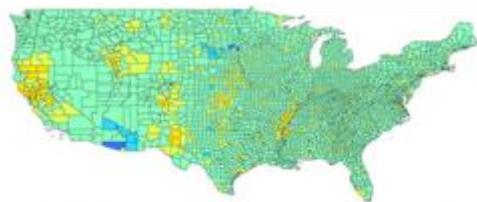
Annual county scale surface water deficit as a fraction of demand

2020s

2050s

2080s

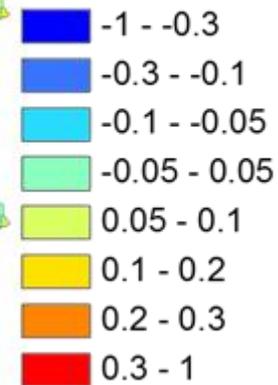
RCP4.5



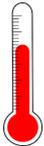
RCP8.5



Legend



# Climate change also impacts water demands in many ways



**Energy Demand**



Increases in electricity demand,  
decreases in natural gas demand



**Hydropower**



Changes in production of hydropower



**Thermal Power**



Decreases in thermal power production



**Agriculture**



Changes in productivity of land,  
bioenergy supply, crop production, carbon  
sequestration

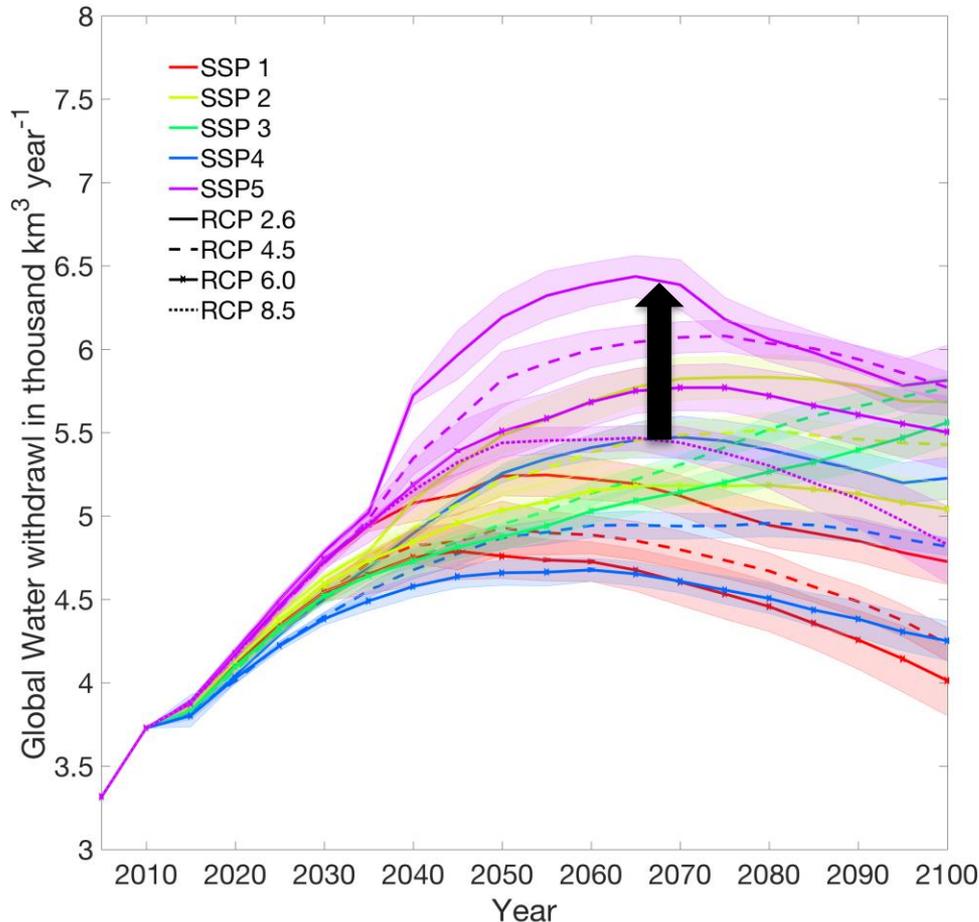


**Water Supply**



Changes in water availability (globally  
and regionally)

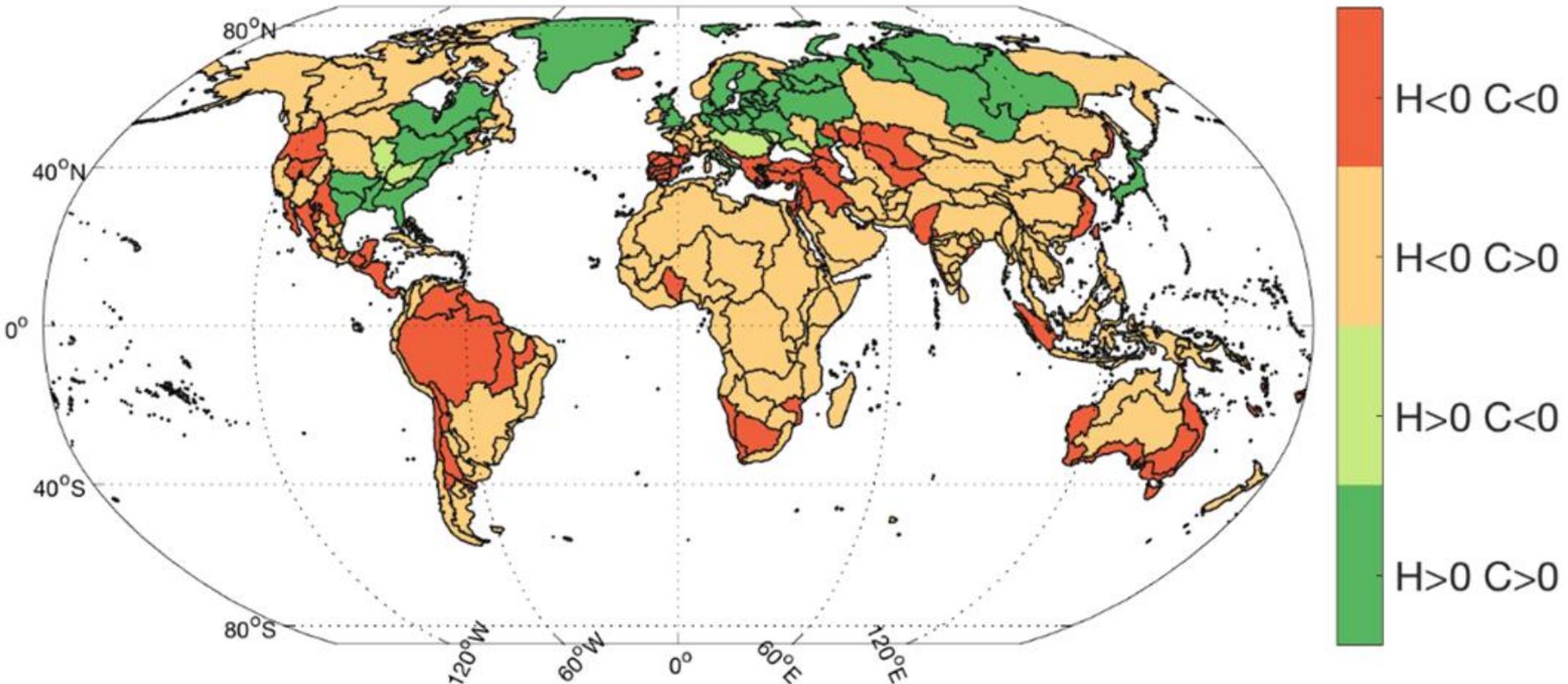
# Quantifying climate impact on water withdrawals



Global water withdrawals under different SSPs/RCPs with/without climate impacts

- A wide range of water withdrawals driven by the 5 SSPs
- Mitigation generally leads to higher water withdrawals
- Uncertainty in human system is far larger than in climate

# Humans play a larger role in affecting water scarcity conditions in the future



Distribution of positive (reducing water scarcity) and negative (worsening water scarcity) impacts by climate (C) and human (H) systems by basin

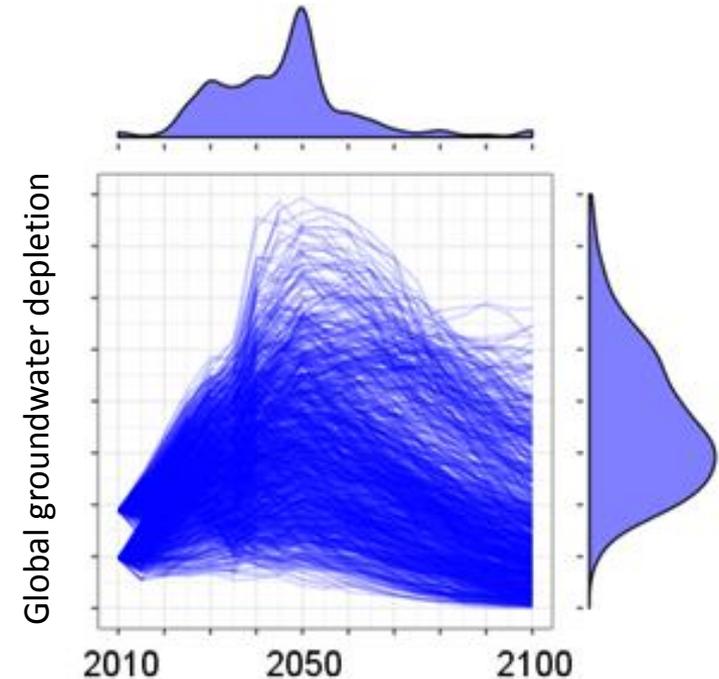
# Is groundwater no longer a viable backstop technology to solve the water scarcity problem in the 21st century?



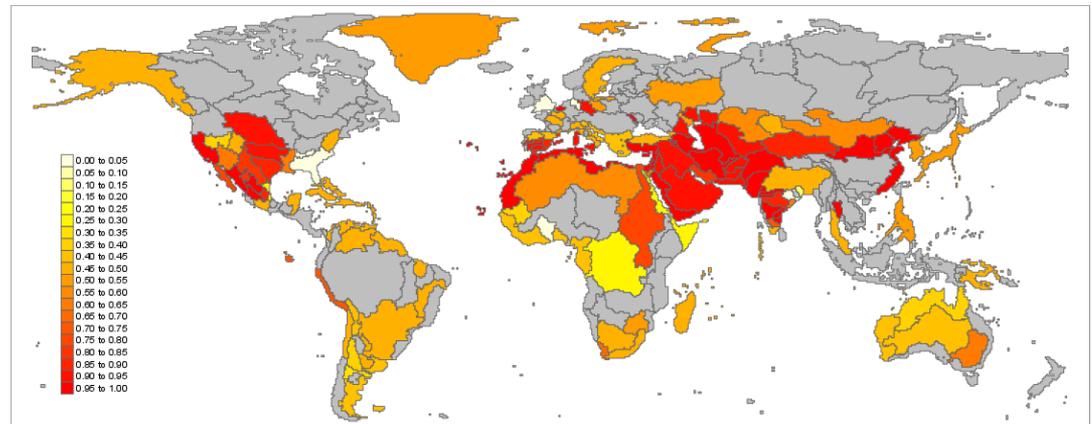
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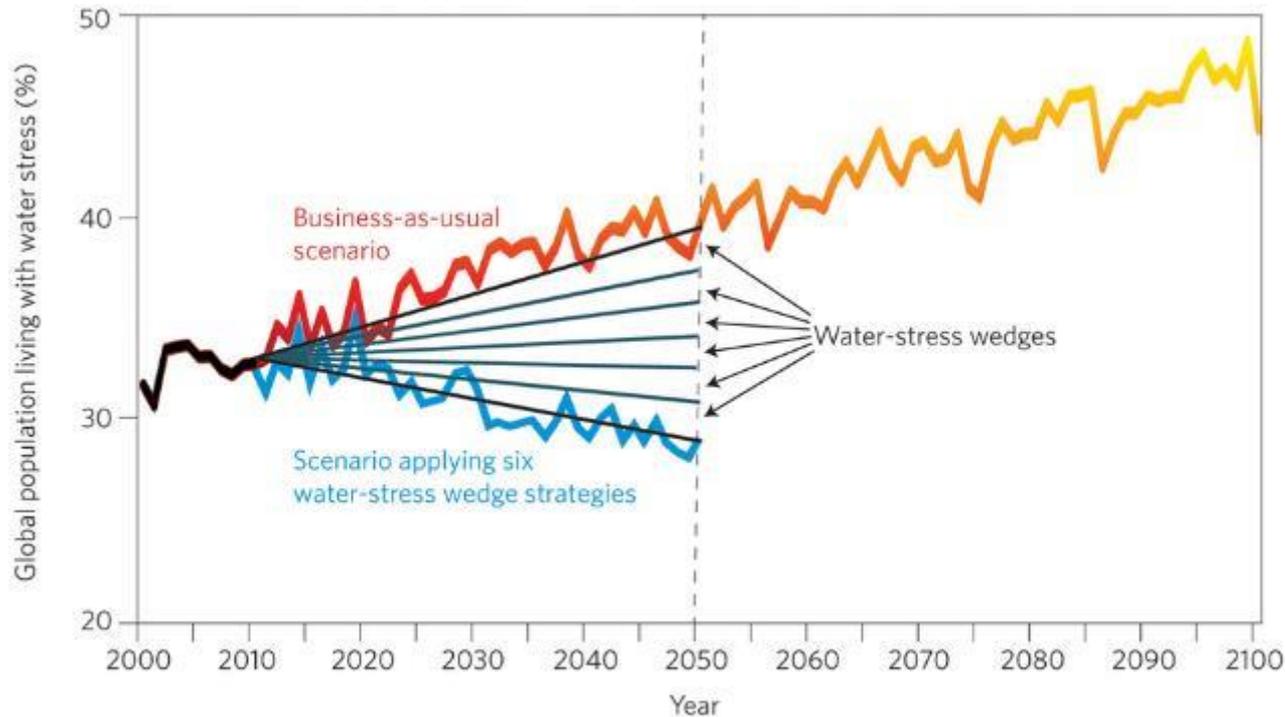
- ▶ Annual global groundwater depletion rate ( $\text{km}^3 \text{ year}^{-1}$ ) for 900 GCAM simulations, with the distributions of the time to peak, and the peak annual groundwater depletion rate during the 21<sup>st</sup> century.



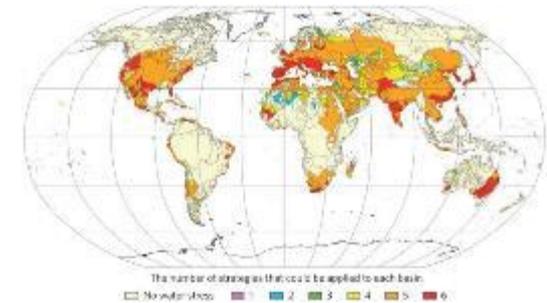
- ▶ Probability that groundwater annual rate of depletion peaks and declines in the 21<sup>st</sup> century at the basin level (based on 900 simulations).



# Reducing water scarcity possible by 2050



Different basins lend themselves to different measures for reducing water stress



We present six strategies, or water-stress wedges, that collectively lead to a reduction in the population affected by water stress by 2050, despite an increasing population.

- Water productivity – crop per drop
- Irrigation efficiency – decrease losses
- Water use intensity – industry and domestic
- Population
- Reservoir storage
- Desalination

**Soft path vs. Hard path**

*Wada et al. (2014), Nature Geoscience*

- ▶ Climate change will impact water availability and scarcity conditions in the future (overall wetter, but with winners and losers)
- ▶ Climate also impacts water demands both directly and indirectly
- ▶ Humans dominate the water scarcity signal in most regions
- ▶ Groundwater resources won't last forever – we are likely to see a peak and decline over the 21<sup>st</sup> century in groundwater depletion
- ▶ Importance of understanding the interlinkages between water and other systems (e.g., land, energy, economy) to understand the risks associated with future water scarcity conditions and to avoid unintended consequences when devising policies to achieve climate goals and SDGs.
- ▶ Some possible solutions to cope with the growing water scarcity problem (yield gap, technological change, irrigation efficiencies, trade, storage)



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# Thank you!

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