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Climate Impacts on Global and Regional Water across the Shared Socioeconomic Pathways

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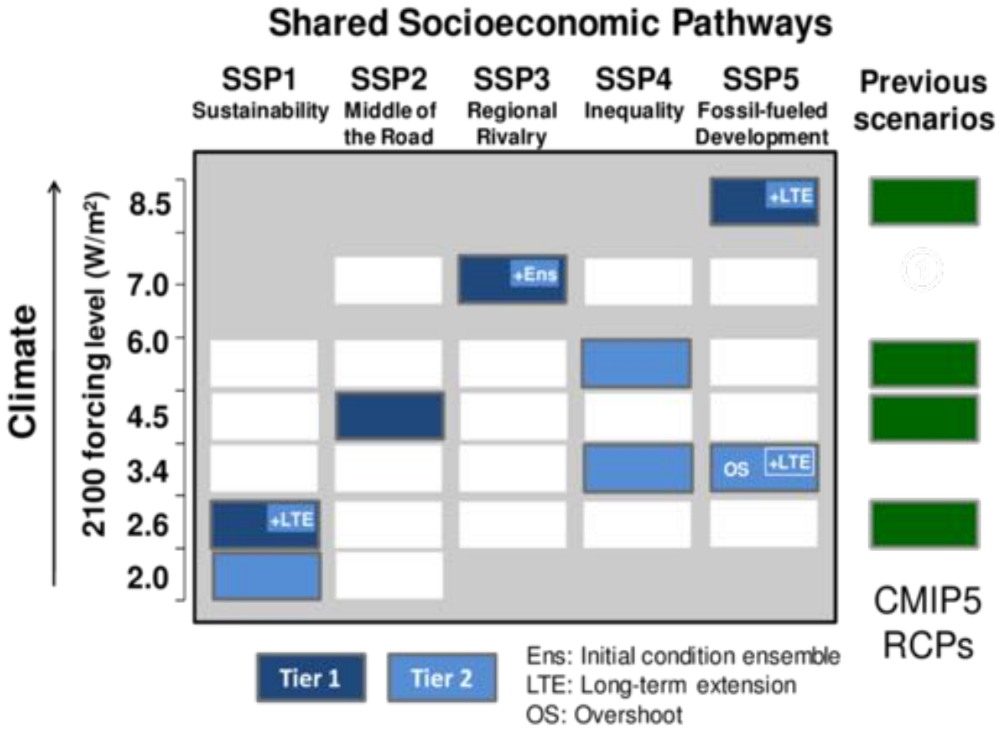
Motivation & Research Question

- A combination of scenarios, the SSPs and RCPs, will make up the basis for the IPCC Assessment Report 6
- Future global water demands are highly variable and dependent upon both human and climate influences.
- The impact of water is largely absent from future climate and socioeconomic scenario analyses

- *What are the climate and socioeconomic driven impacts on global, regional, and basin level water demands across the SSP-RCP scenario matrix?*



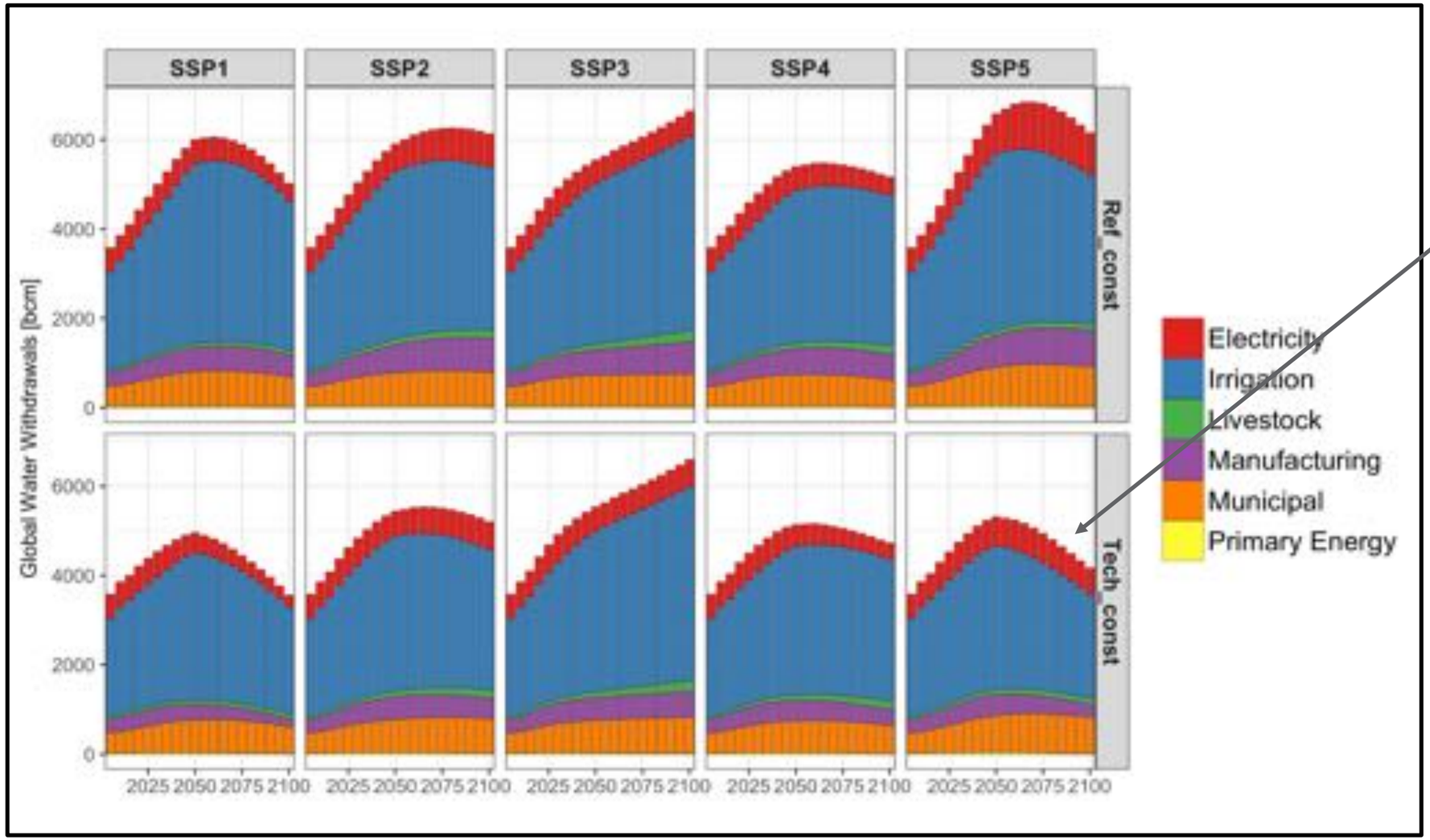
O'Neill et al. (2016) Geosci. Model Dev.

Water Sector Assumptions for the SSPs

- Qualitative assumptions for the water sector were derived from the storylines of the SSPs
- Assumptions are made for 4 water sectors.
- Quantitative values applied to assumptions based upon previous literature and current technological advancement rates

		SSP1	SSP2	SSP3	SSP4			SSP5
					High-income	Medium-income	Low-income	
SSP Prescribed Challenges	Challenges to Mitigation	Low	Medium	High	Low			High
	Challenges to Adaptation	Low	Medium	High	High			Low
Socioeconomics	Population in 2100	6.9 billion	9 billion	12.7 billion	0.9 billion	2.0 billion	6.4 billion	7.4 billion
	GDP per capita in 2100	$46,306	$33,307	$12092	$123,244	$30,937	$7,388	$83,496
Fossil Resources (Technological Change/Acceptance)	Coal	Med/Low	Med/Med	High/High	Med/Low	Med/Med	Med/High	High/High
	Conventional Gas & Oil	Med/Med	Med/Med	Med/Med	High/Low	High/Low	High/Low	High/High
	Unconventional Oil	Low/Med	Med/Med	Med/Med	Med/Low	Med/Low	Med/Low	High/High
Electricity (Technology Cost)	Nuclear	High	Med	High	Low	Low	Low	Med
	Renewables	Low	Med	High	Low	Low	Low	Med
	CCS	High	Med	Med	Low	Low	Low	Low
Fuel Preference	Renewables	High	Med	Med	High	High	High	Med
	Traditional Biomass	Low	Low	High	Low	Low	High	Low
Energy Demand	Buildings	Low	Med	Low	High	Med	Low	High
Water Use (Efficiency Improvements)	Irrigation	High	Med	Low	High	High	Low	High
	Manufacturing	High	Med	Low	High	Med	Low	High
	Energy	High	Med	Low	Med	Med	Med	High
Water (Technological Change)	Shift to Recirculating and Dry Cooling	High	Med	Low	High	Med	Low	High
	Municipal	High	Med	Low	High	Med	Low	High
	Municipal Water Price	Med.	Med	High	Low	Med	High	Low

Water sector SSP assumptions provide a *more comprehensive* water demand projection and *reduce demands by up to 32%*

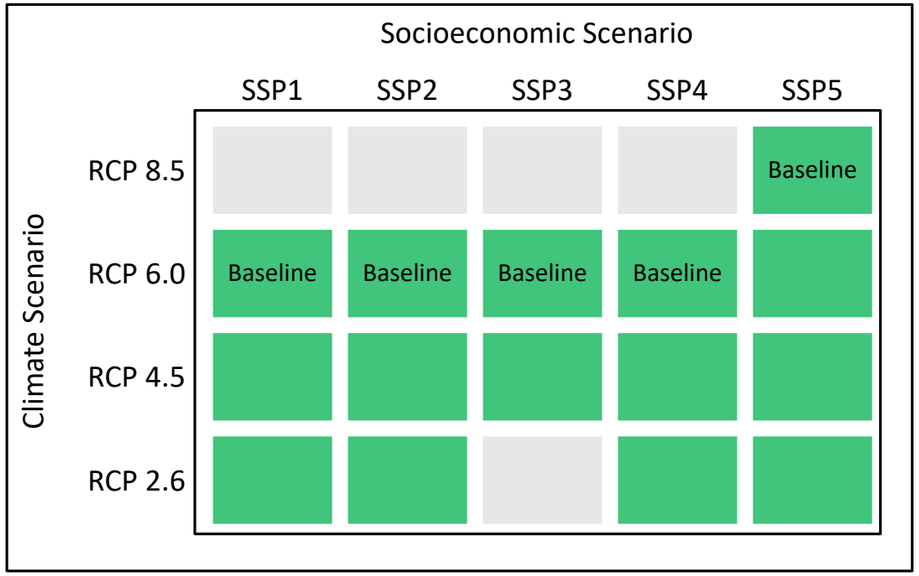


Reductions brought upon by the addition of water sector assumptions

Adding Climate to the SSPs

- Improve future multiscale water demand projections by including:

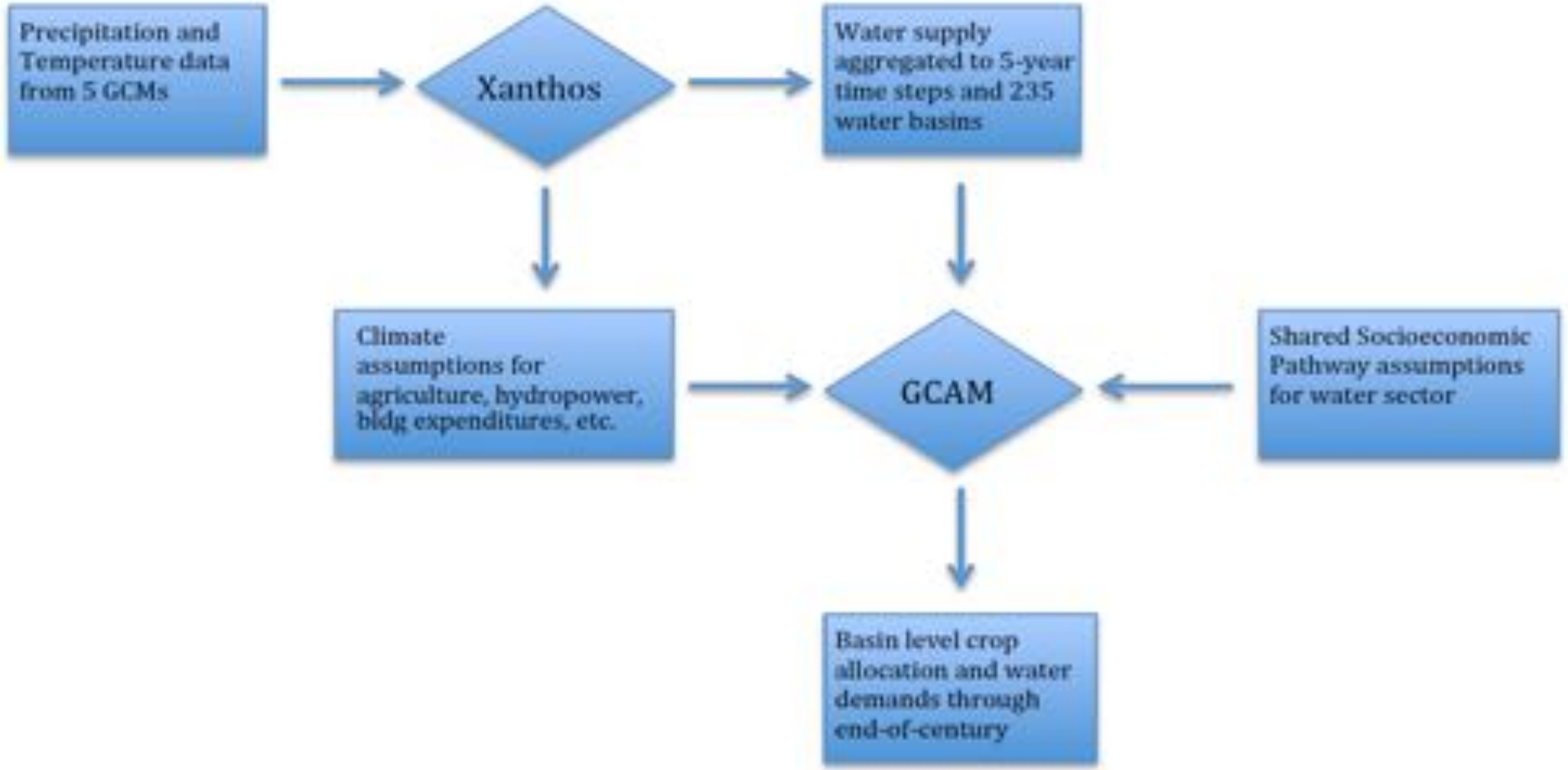
1. Climate derived cross-sectoral impacts
   - *Xanthos* derived future water supply*
   - Hydropower expansion**
   - Ag Productivity changes^
   - Building Energy expenditures^^
2. Global surface and groundwater constraints
3. Five distinct socioeconomic driven sectoral responses



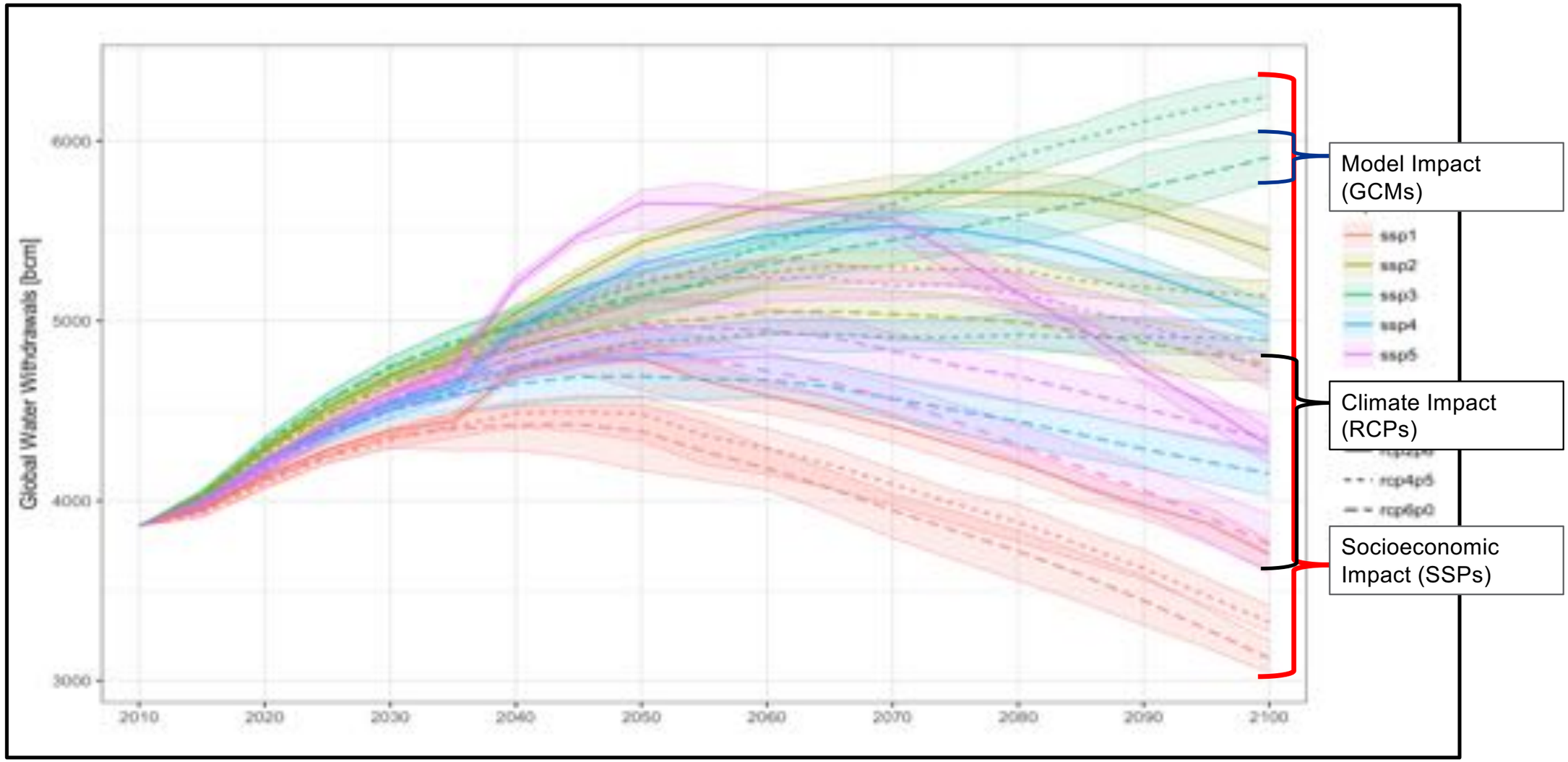
15 SSP-RCP combinations x (5 GCMs + 1 no climate) = 90 total scenarios

*Li et al. (2017) & Vernon et al. (2018)
**Turner et al. (2017)
^Snyder et al. (*in review)*
^^Clarke et al. (2018)

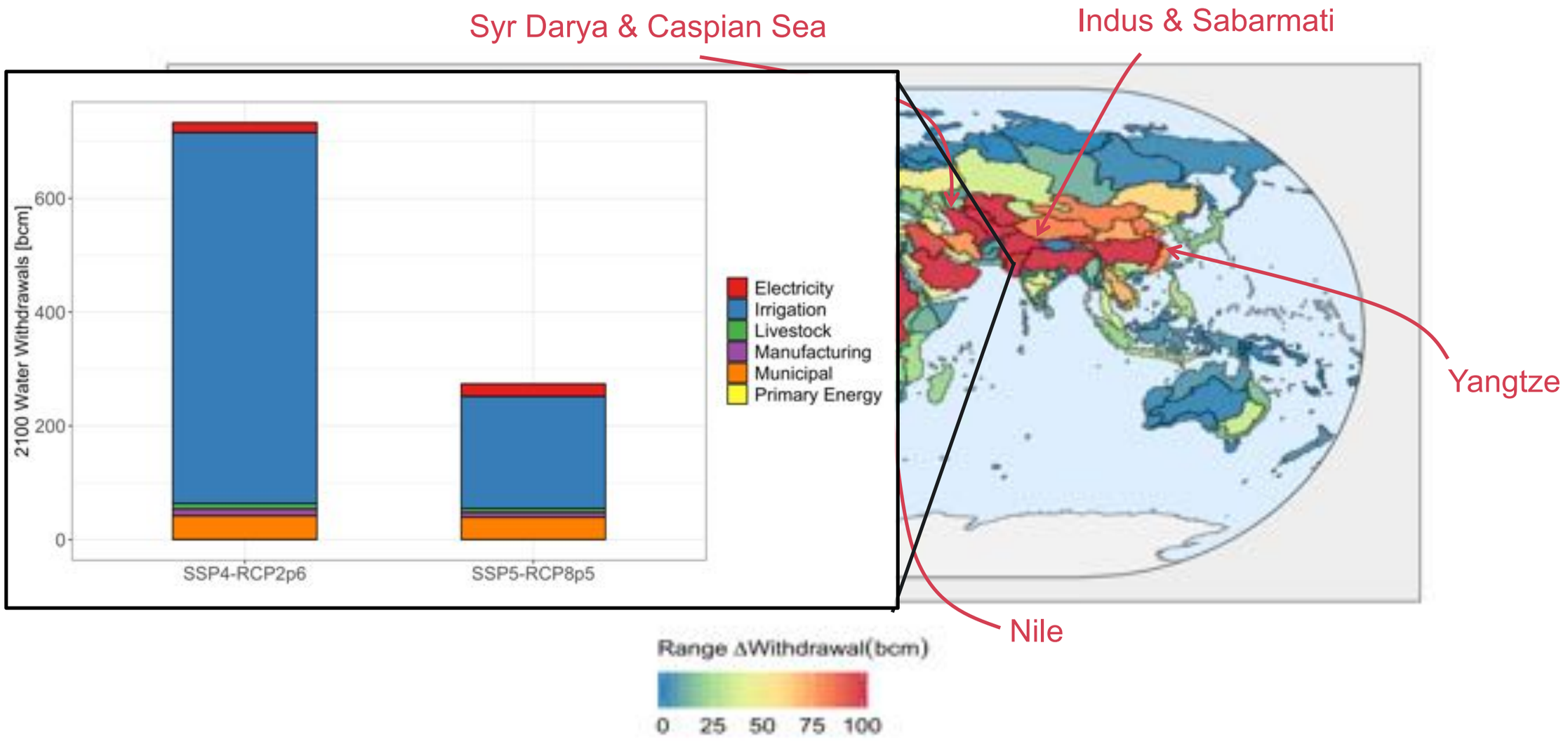
From GCM to GCAM – Assumptions and Additions



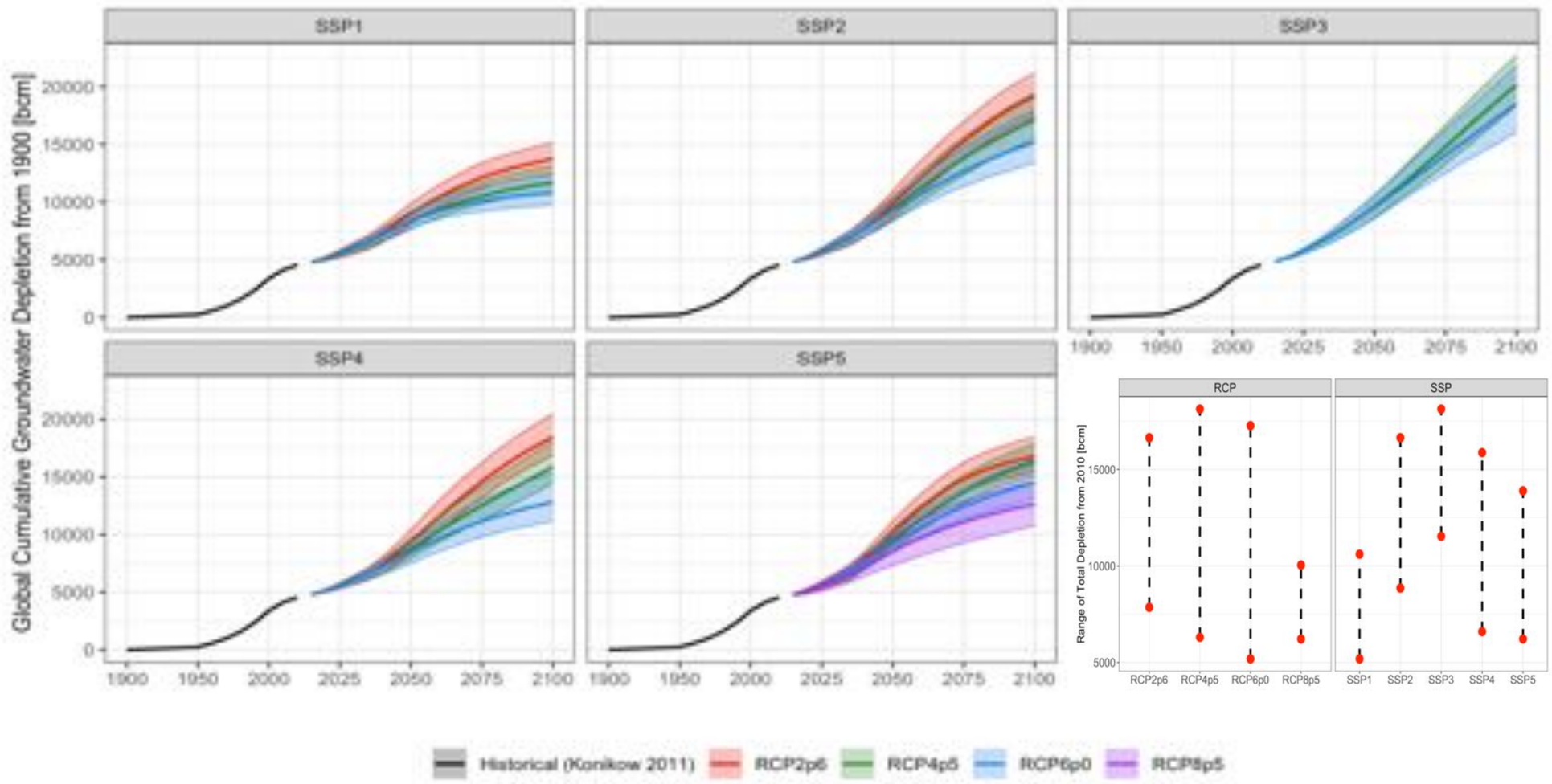
Water demand uncertainty *higher due to future socioeconomic changes* than climate or model variation



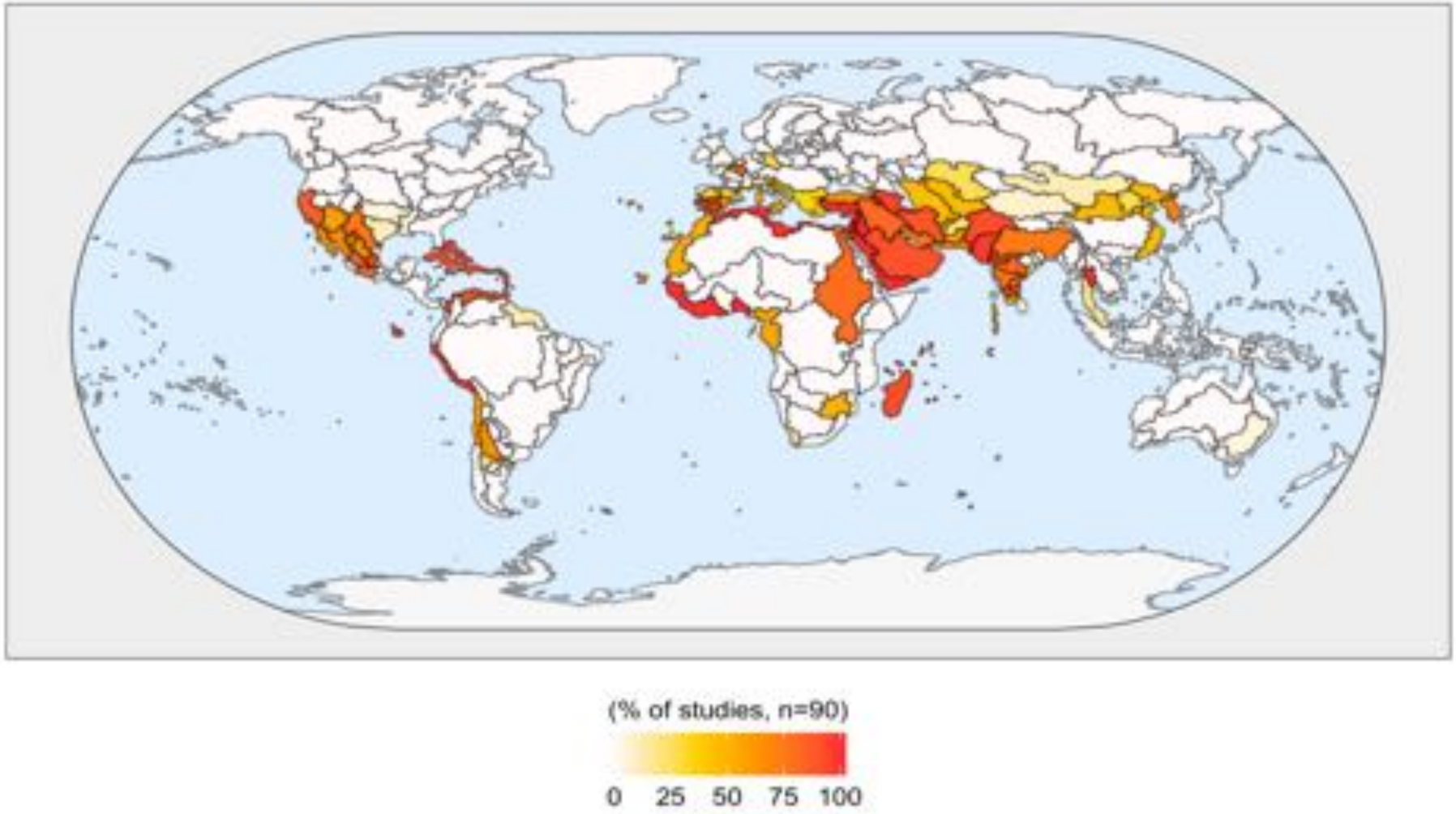
Future water withdrawal changes are *highly variable* in select basins



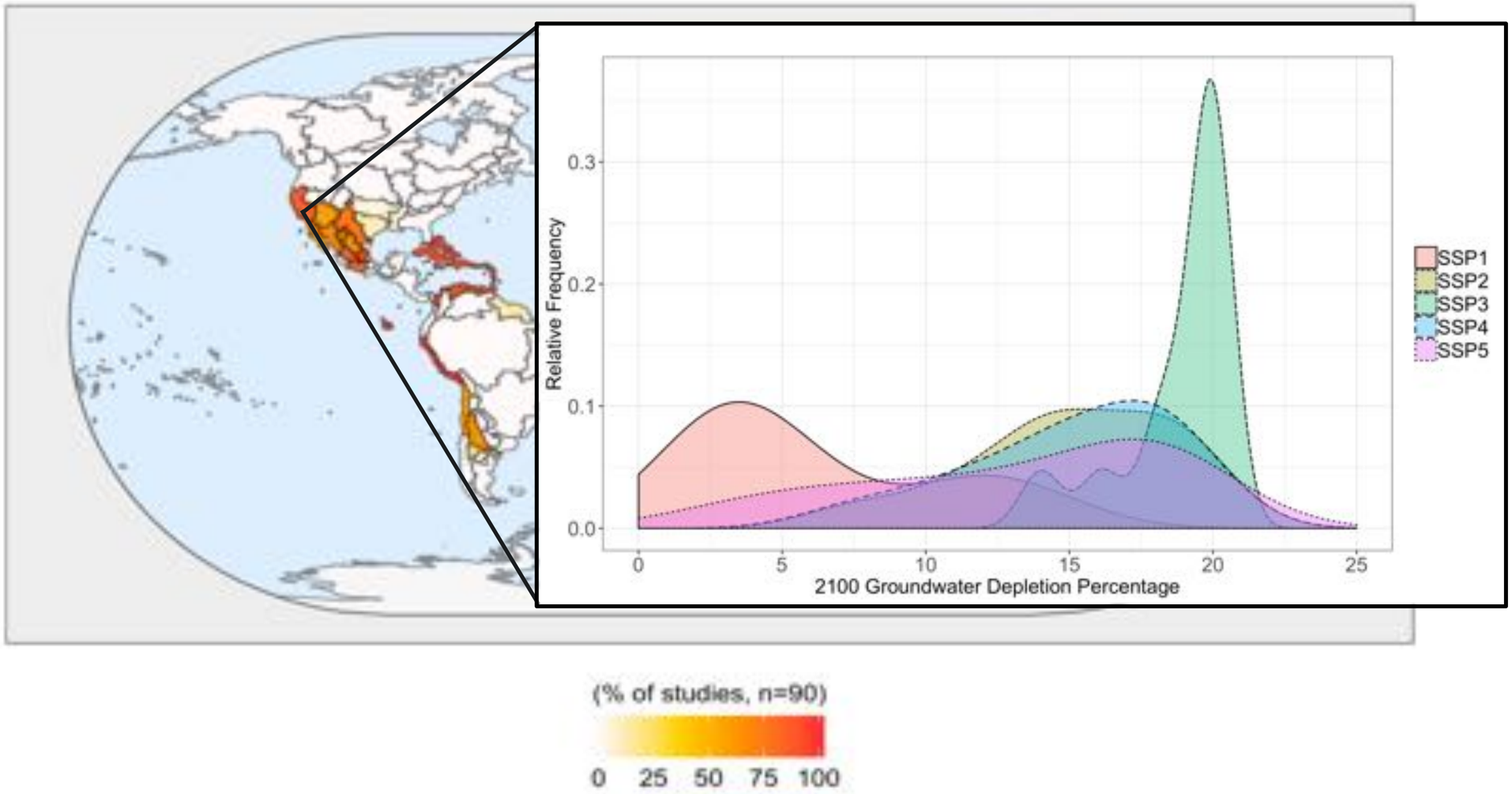
Groundwater extraction rate *doubles historical levels* and *show higher ranges across RCPs than SSPs*



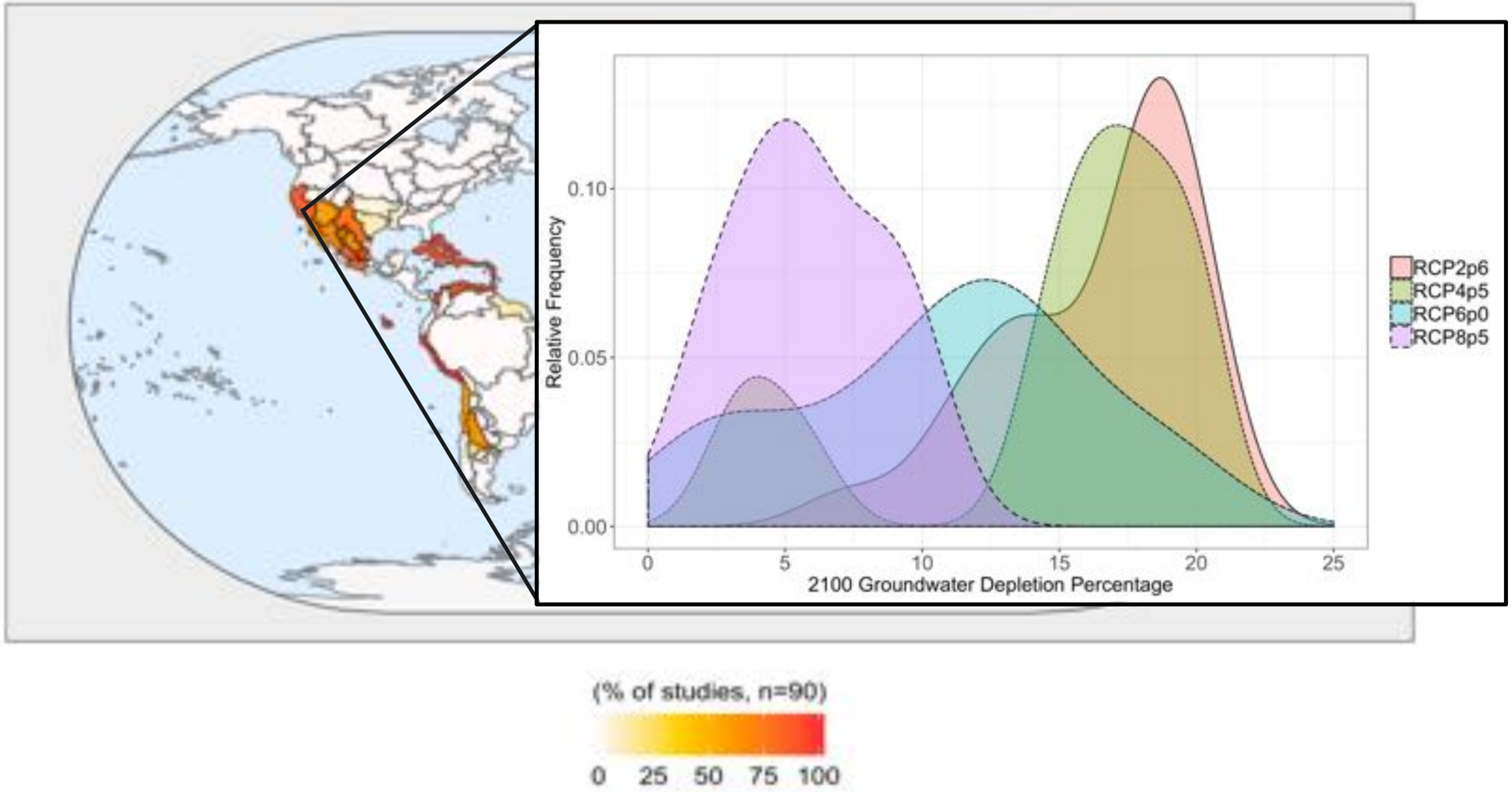
Basin level groundwater depletion of >5% occurs in >2/3 of scenarios across several NH mid-latitude basins



End of century groundwater depletion in California *increase* as future *technology assumptions decrease and population increase*



End of century groundwater depletion in California *increase* as *radiative forcing target decreases*



Conclusions & Future Directions

- Water sector assumptions for the SSP scenarios largely act to ***decrease future water demand by up to 32%*** from non-technology scenarios
- Future water demands across the SSP-RCP scenarios are ***highly variable*** in basins of North Africa, the Middle East, and China
- Groundwater extraction is likely to ***at least double*** from historical extraction values and basins such as California experience ***depletion increases as RF target decreases*** and ***technological improvements slow***

- Downscale water demands to grid resolution using *Demeter* – *Tethys* to provide scarcity and and sub-basin analysis
- Assess future trade impacts of water across the SSP-RCP scenarios

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Thank you

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Additional Slides

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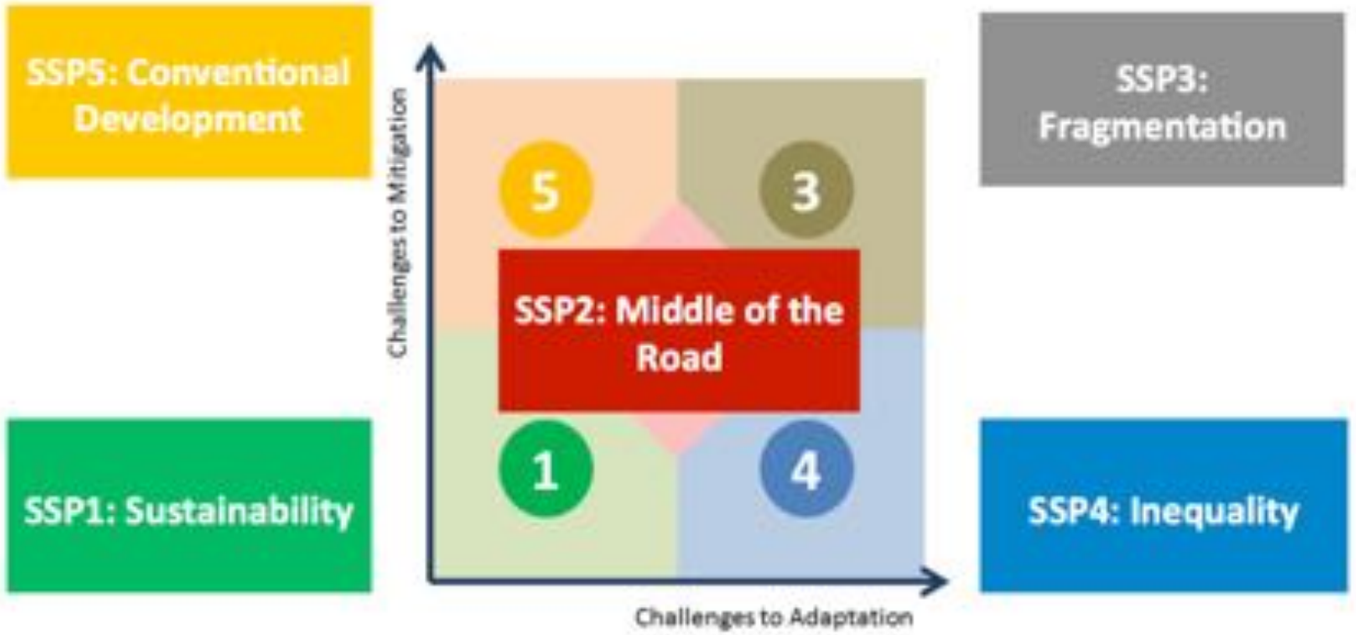
Definition of Shared Socioeconomic Pathways

- Five Shared Socio-economic Pathways were designed to explore a range of future societal circumstances that exhibit a wide range of
  - Challenges to adaptation, and
  - Challenges to mitigation.



Virtual Water within GCAM

- Imports and exports are calculated as the difference between production and demand at the GCAM regional scale.
- ***Virtual Water Export***
- $VWE_{[n_e,c,t]} = \sum_b \left(Exports_{[n_e,c,b,t]} * Water\ Intensity_{[n_e,c,b,t]} \right)$

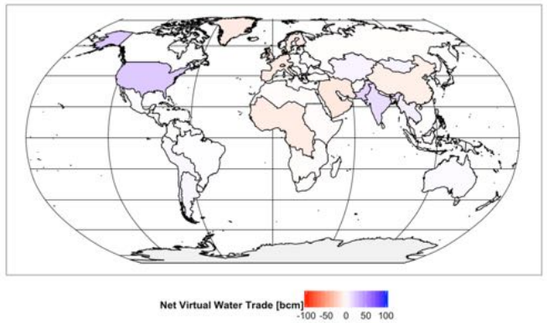
- ***Virtual Water Import***
- $VWI_{[n_i,c,t]} = Imports_{[n_i,c,t]} * \sum_{n_e} \left[\left(\frac{Exports_{[n_e,c,t]}}{\sum_{n_e} Exports_{[c,t]}} \right) * Weighted\ Avg\ W.I._{[n_e,c,t]} \right]$

- ***Net Virtual Water Trade****
- $VWT_{[n,t]} = \sum_c \left(VWE_{[c,n,t]} + VWI_{[c,n,t]} \right)$

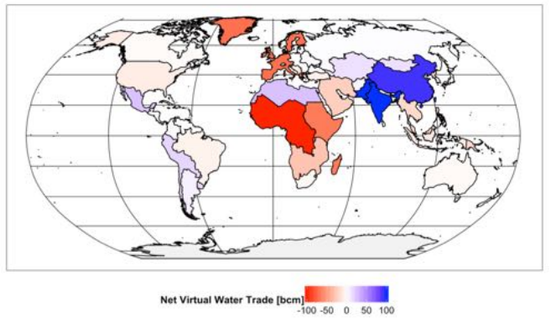
*as originating production basin for exports cannot be determined, VWT values will have small errors and should therefore be treated purely as model specific estimates

Virtual Water Trade changes sign and magnitude across regions in different socioeconomic scenarios

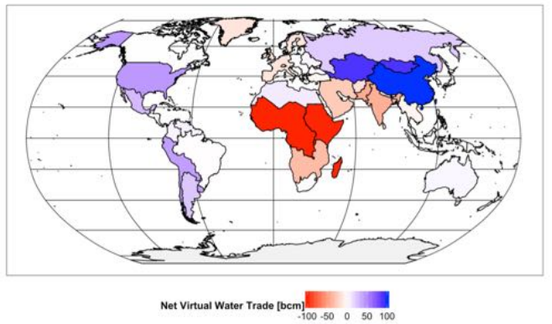
2010



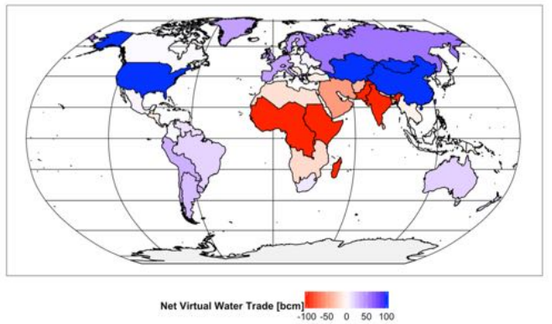
Climate Scenario: RCP 4.5



SSP1



SSP2



SSP3

2100

Virtual Water Trade differs across both regions and SSPs. Intensification of trade in the future results in global increases of VWT in all scenarios

Virtual Water Trade increases across all scenarios through end of century