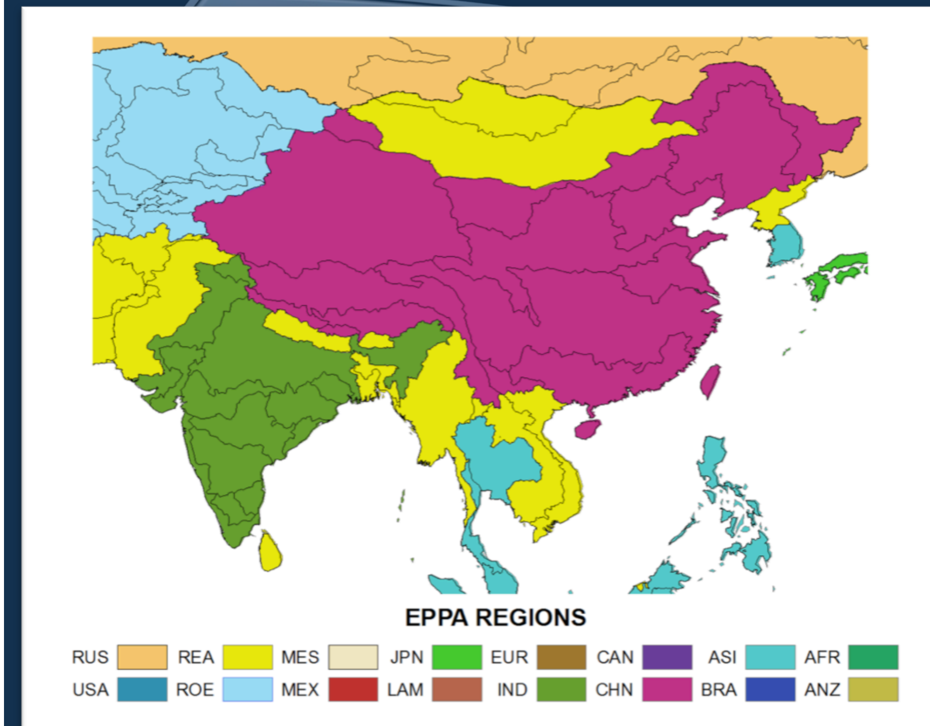
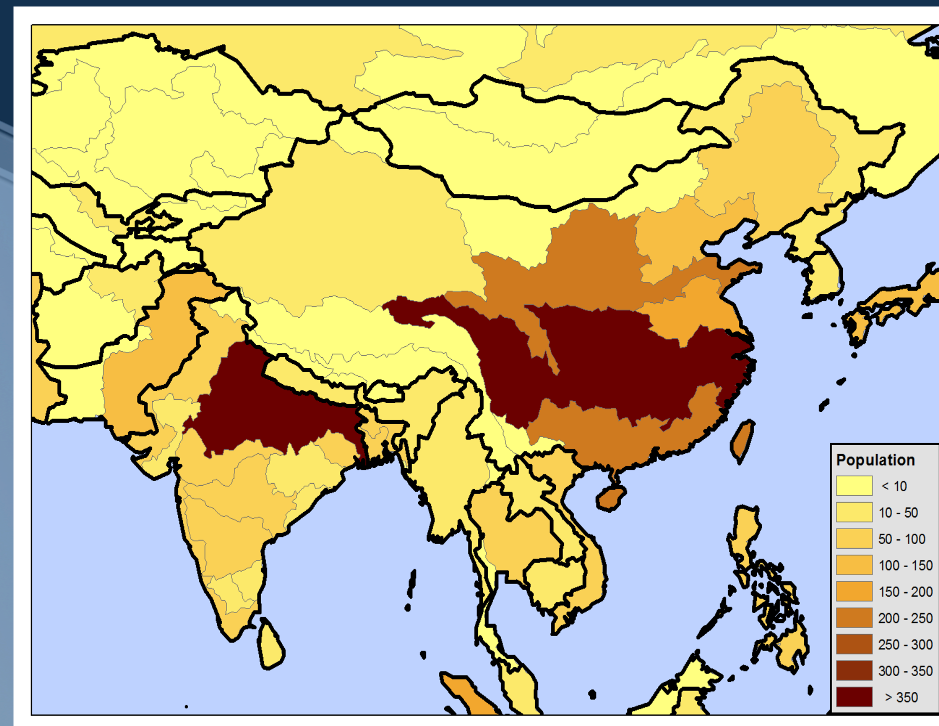
Assessing the Roles of Regional Climate Uncertainty, Policy, and Socio-Economics on Risks to Water Stress: A Large-Ensemble Pilot Case for Southeast Asia





C. Adam Schlosser, Chas Fant, Xiang Gao, Ken Strzepek, Henry Jacoby, Elodie Blanc, Andrei Sokolov, Erwan Monier, Channing Arndt, Sherman Robinson, Sergey Paltsev, and John Reilly

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We gratefully acknowledge support from the Joint Program's industrial and federal agency sponsors

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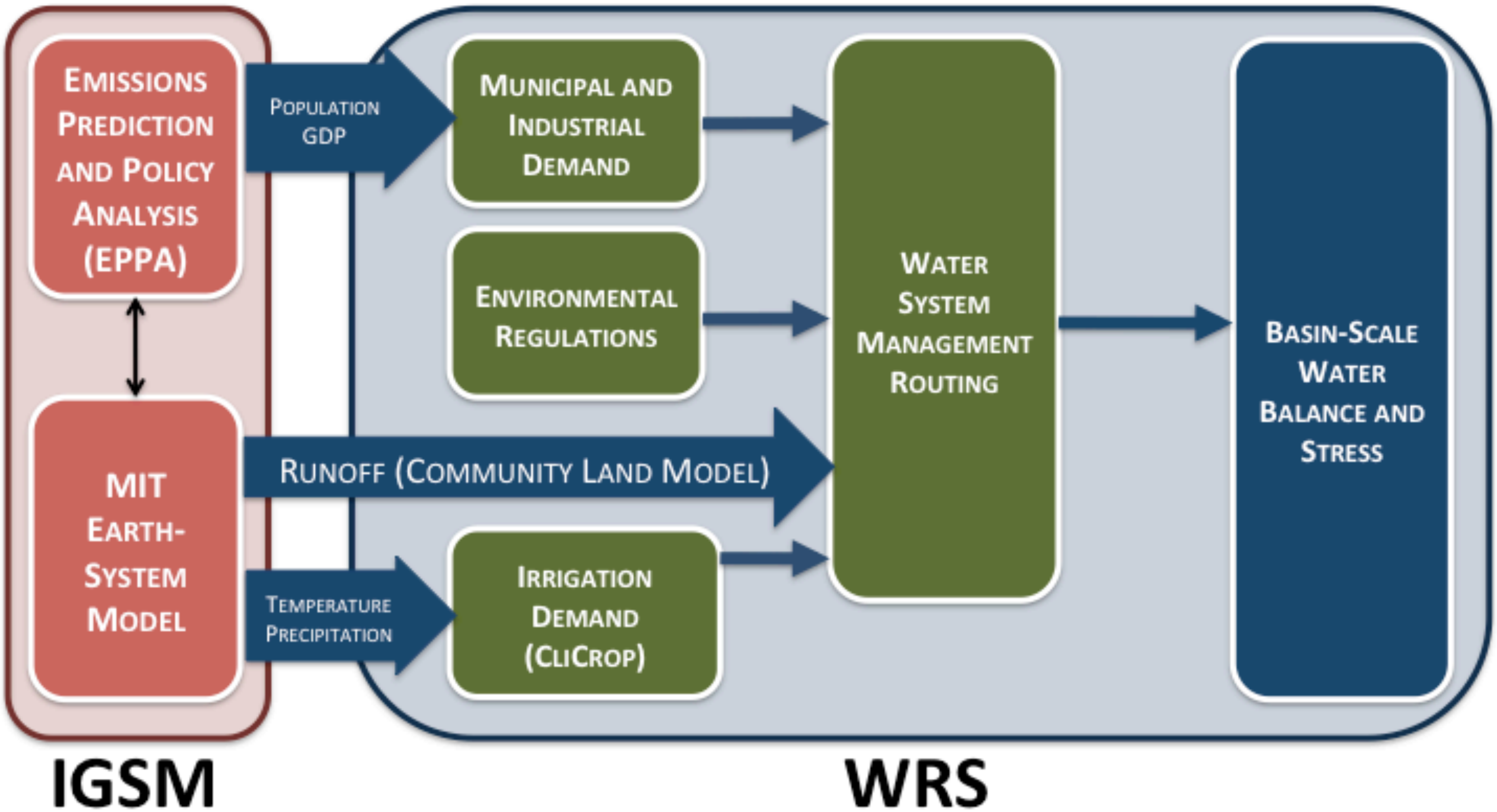
The Integrated Global System Model (IGSM) Water Resource System (WRS) Framework



$$OBJ = \frac{\sum_{mth} SRR_{mth}}{12} + \min(SRR) - \frac{\sum_{mth} SPILL_{mth}}{STC} + \frac{ST_{end\_yr}}{STC} - 100(\min(ST - EVAP, 0))$$

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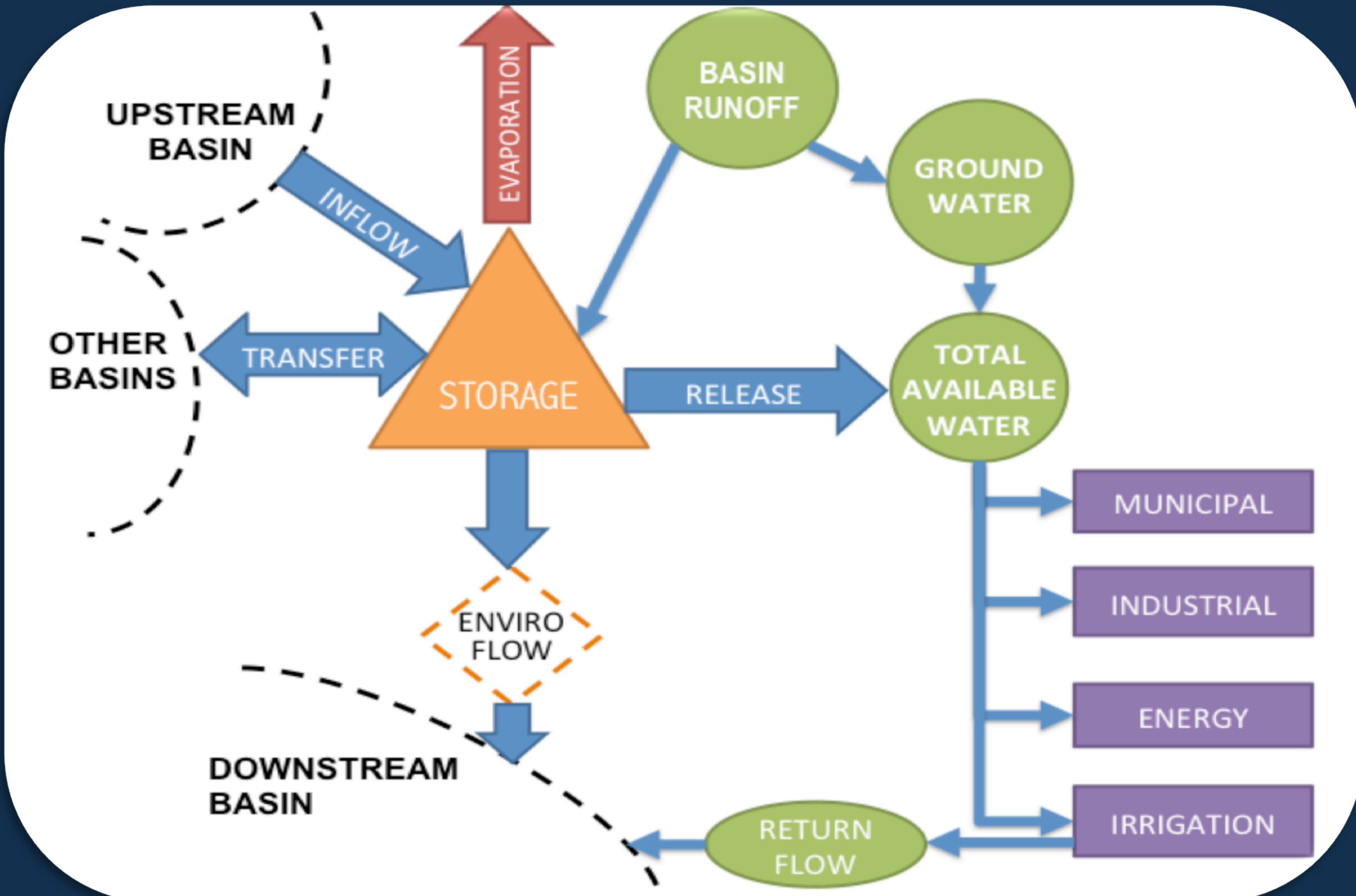
Modeling Water Resource Systems under Climate Change: IGSM-WRS, Strzepek, K., C. A. Schlosser, A. Gueneau, X. Gao, C. Fant, E. Blanc, and, B. Rasheed, and H. Jacoby (JAMES, 2013).

Assessment Sub-Region (ASR) Analysis for Water Resources



"Water Stress" Index

$$WSI = \frac{\text{Total Demand}}{\text{Runoff + Inflow}}$$

IGSM Scenarios

(Sokolov et al., 2009, and Webster et al., 2009)

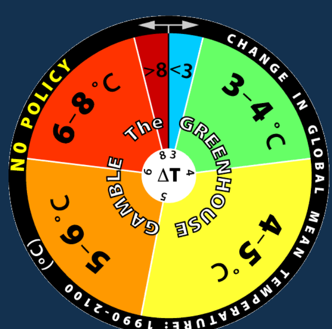
No Policy (Reference):

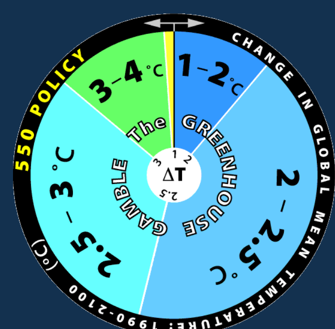
- "Unconstrained Emissions"

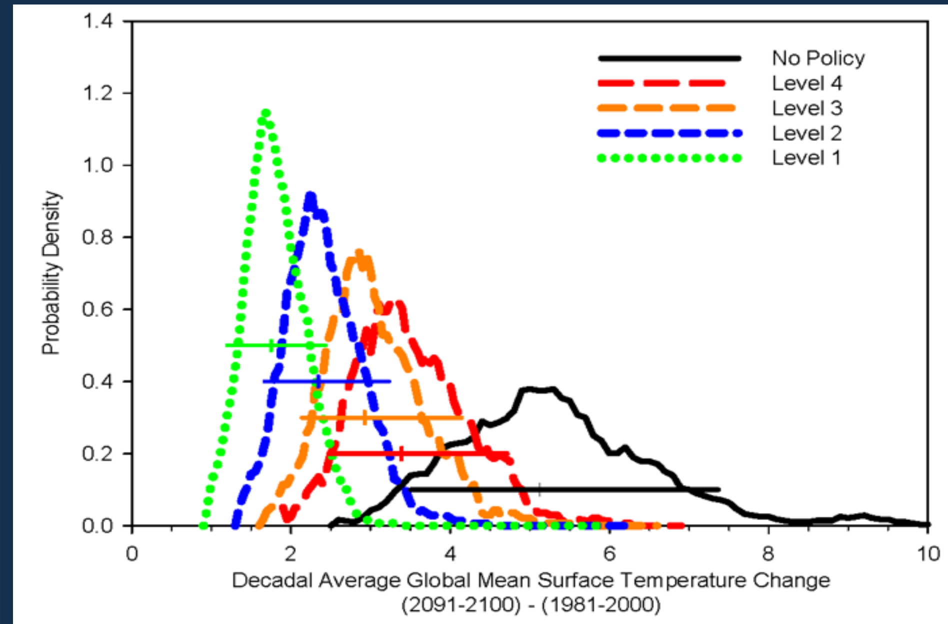
Stabilization Scenarios: U.S. CCSP

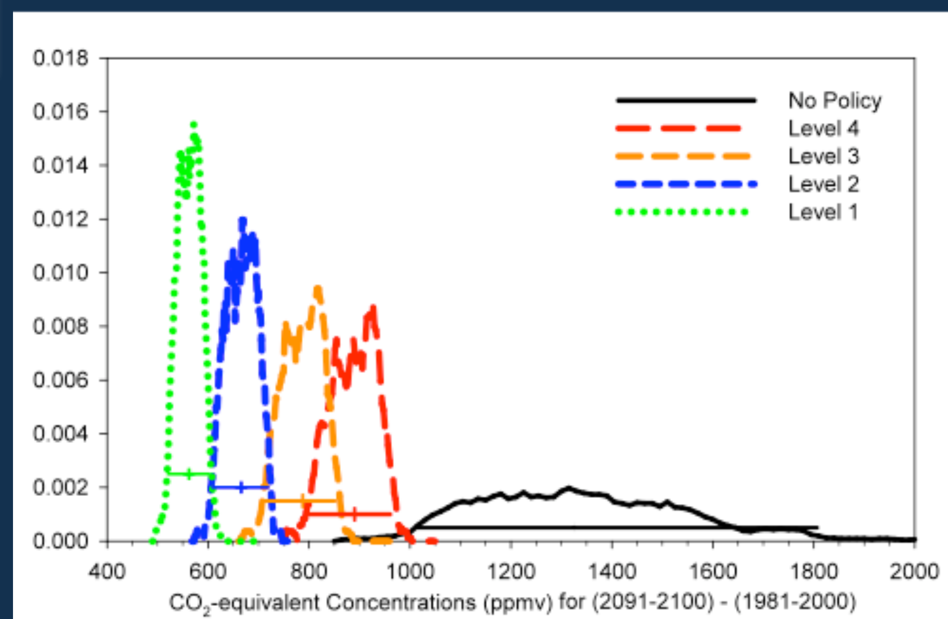
- Level 4 (750 CO_2, 890 CO_2-eq)
- Level 3 (650 CO_2, 780 CO_2-eq)
- Level 2 (550 CO_2, 660 CO_2-eq)
- Level 1 (450 CO_2, 560 CO_2-eq)

Temperature-change distributions conveyed as "The Greenhouse Gamble" wheels









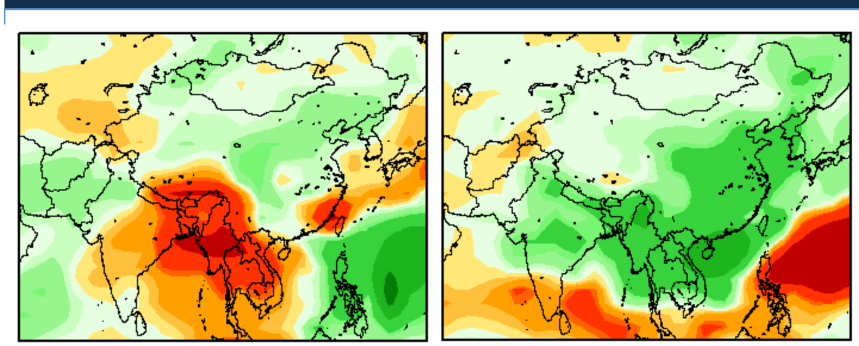
CHARACTERIZING REGIONAL CLIMATE-CHANGE UNCERTAINTY IN THE IGSM: A HYBRID APPROACH

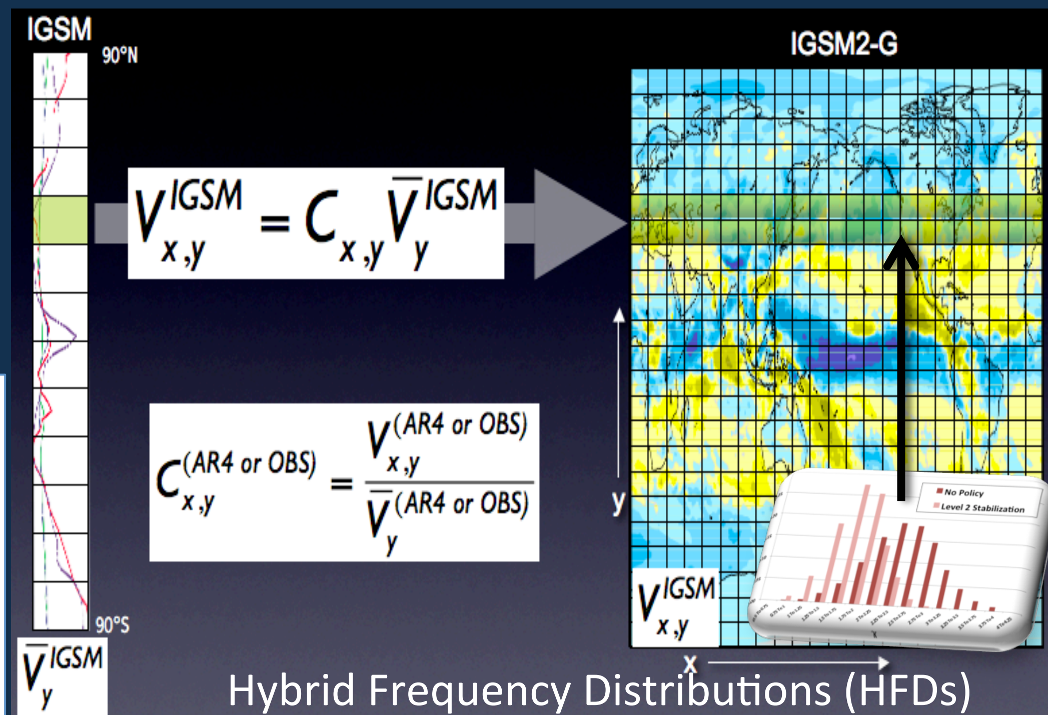
Schlosser et al. (J. Climate, 2012)

$$V_{x,y}^{IGSM} = \left(C_{x,y} + \frac{dC_{x,y}}{dT_{Global}} * \Delta T_{Global} + 0.5\frac{d^2C_{x,y}}{dT_{Global}^2}\Delta T_{Global}^2\right) * \overline{V}_y^{IGSM}$$

$\frac{dC_{x,y}}{dT_{Global}}$: Climate-change kernel describing the change of $C_{x,y}$ with global temperature from CMIP3 climate models.

Precipitation



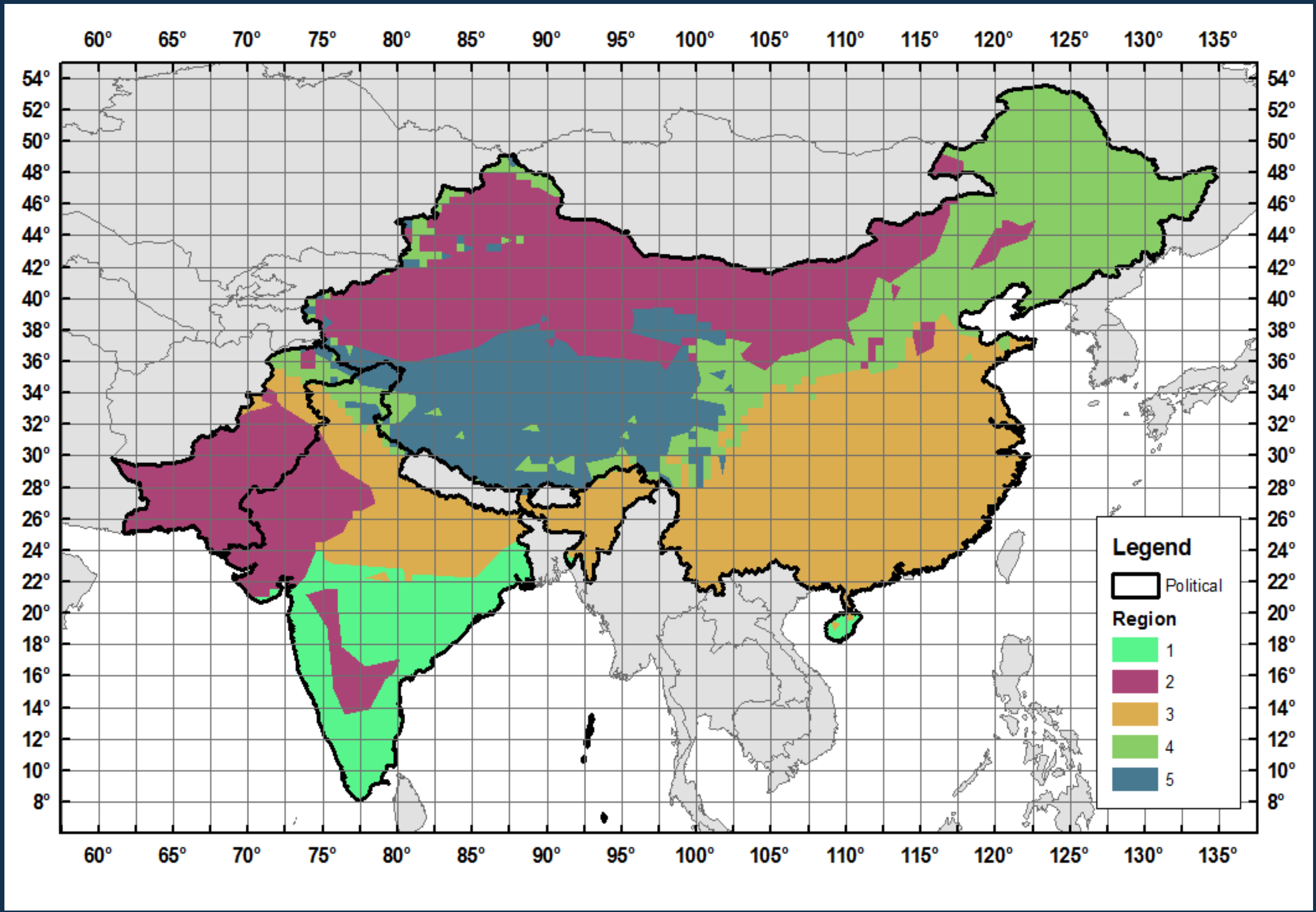


Hybrid Frequency Distributions (HFDs)

Numerical Experiments

- Using the IGSM uncertainty framework and HFD procedure produces 6,800 plausible socio-economic-climate future pathways in combination.
  - Computationally expensive and redundant(?) to run all through IGSM-WRS.
- Thinning procedure based on Gaussian Quadrature approach (Arndt et al., 2006). Select variables that are deemed “important” to preserve distributional effects on impact scheme.
- Simulations are run out to 2050 for the “Unconstrained Emissions” (UCE) ensemble scenario from the IGSM. The IGSM-WRS framework is run via a “delta method” approach – wherein historical climate is augmented by simulated trends in climate.
- Climate and Socio-economics are considered separately and jointly:
  - ***Just Growth***: Baseline climate with future GDP and population
  - ***Just Climate***: Subset of future climates with GDP and population at 2000
  - ***Climate and Growth***: Subset of future climates, GDP and population

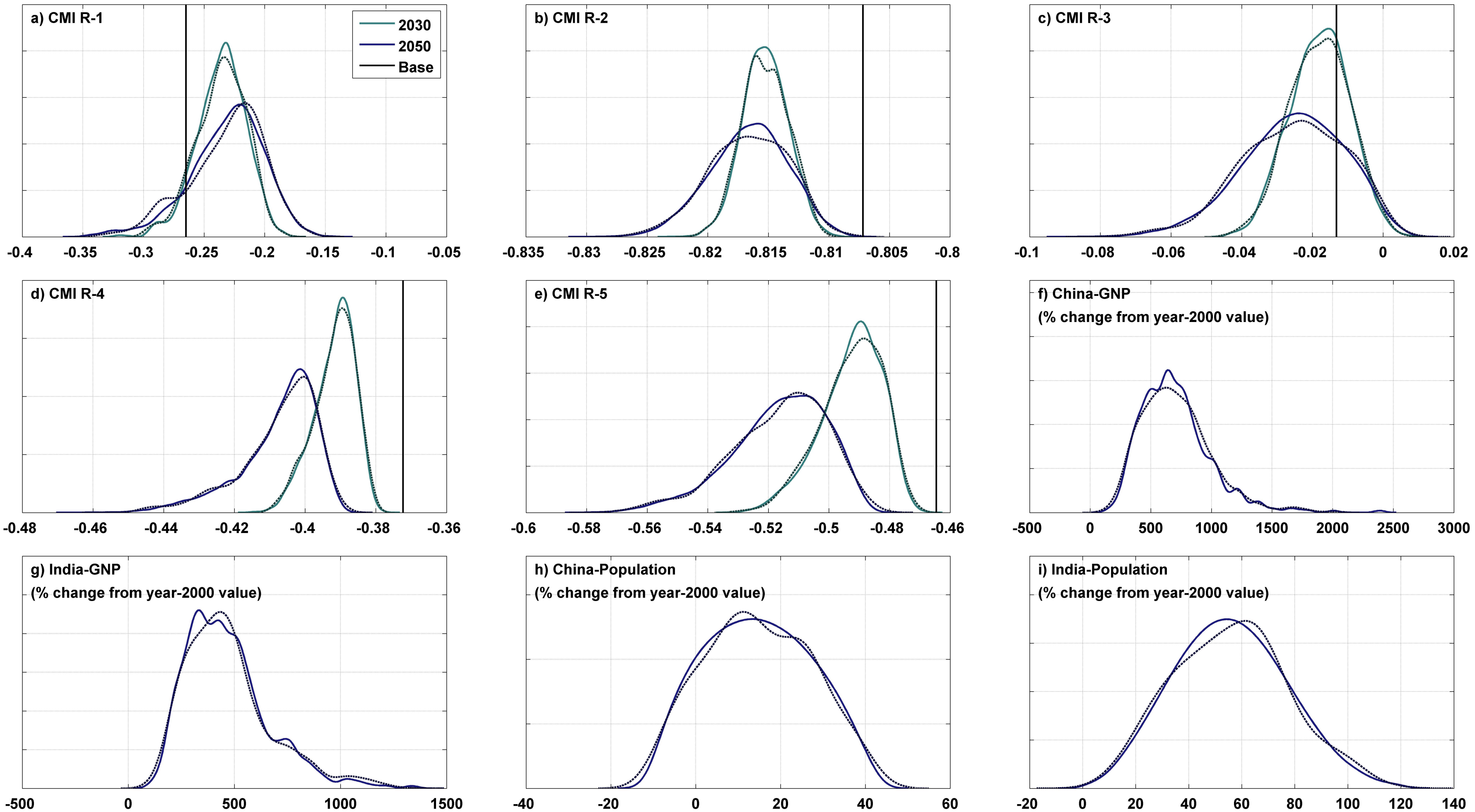
Regions for Gaussian Quadrature Thinning of Meta-Ensemble



- Climate-Moisture Index (CMI), both at 2030 and 2050, for five climatic zones.
- Gross National Product (GNP) at 2050 for China and India.
- Population at 2050 for China and India.

Using 14 variables, the procedure reduces 6,800 members to ~650.

Gaussian Quadrature Reduction of IGSM Meta Ensembles: UCE Scenario

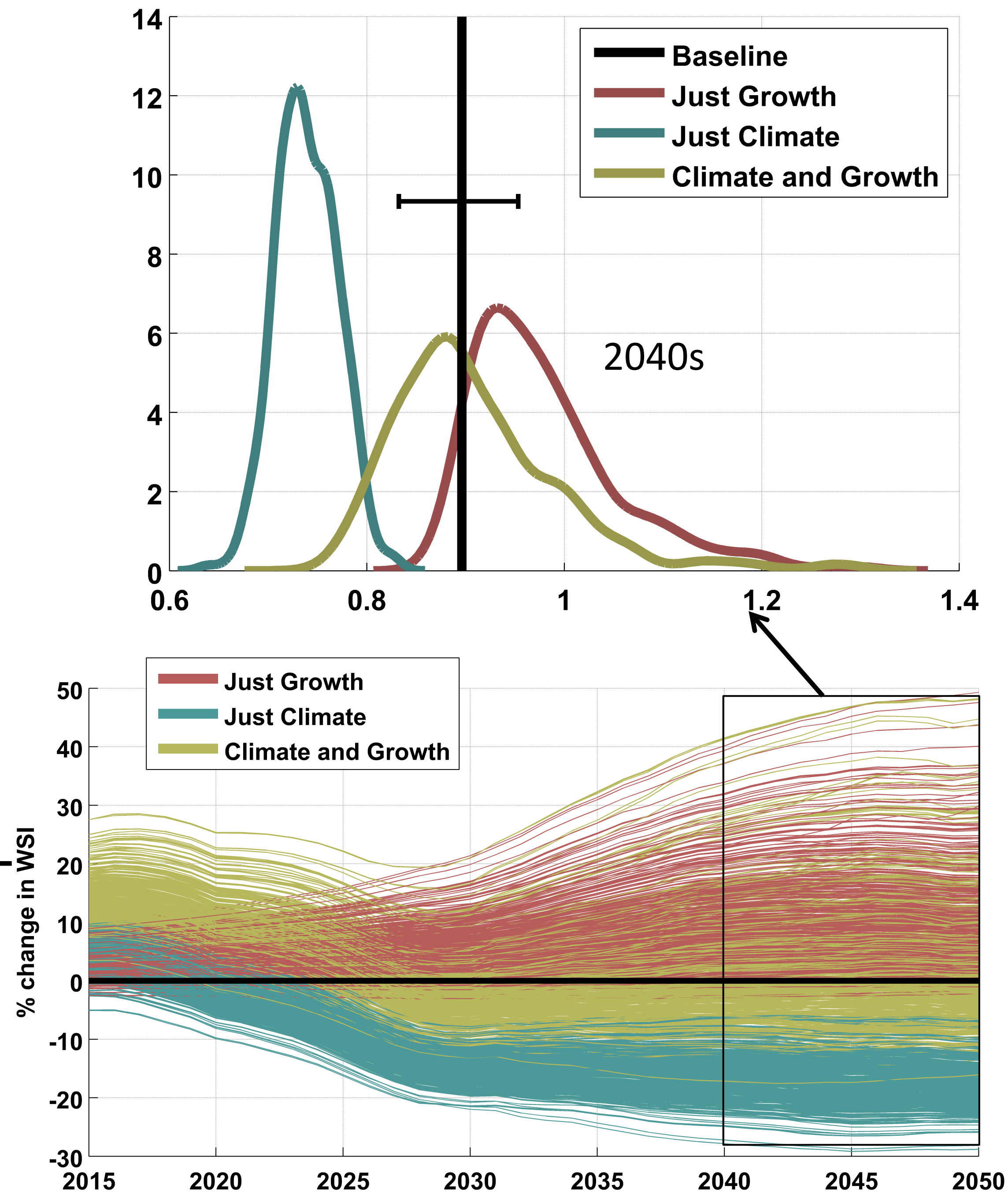


Study Regions

Water Stress in India

ASR average weighted by population

$$WSI = \frac{\text{Withdrawal (Dom, Ind, Lvstk, Irr)}}{\text{Supply (Runoff, Inflow)}}$$



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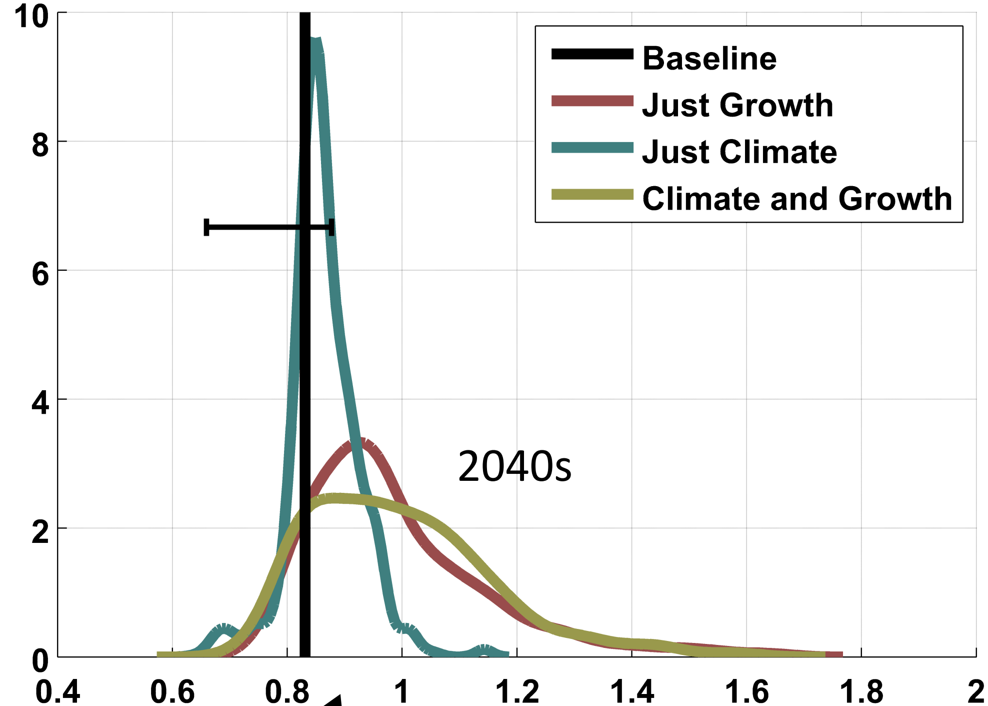
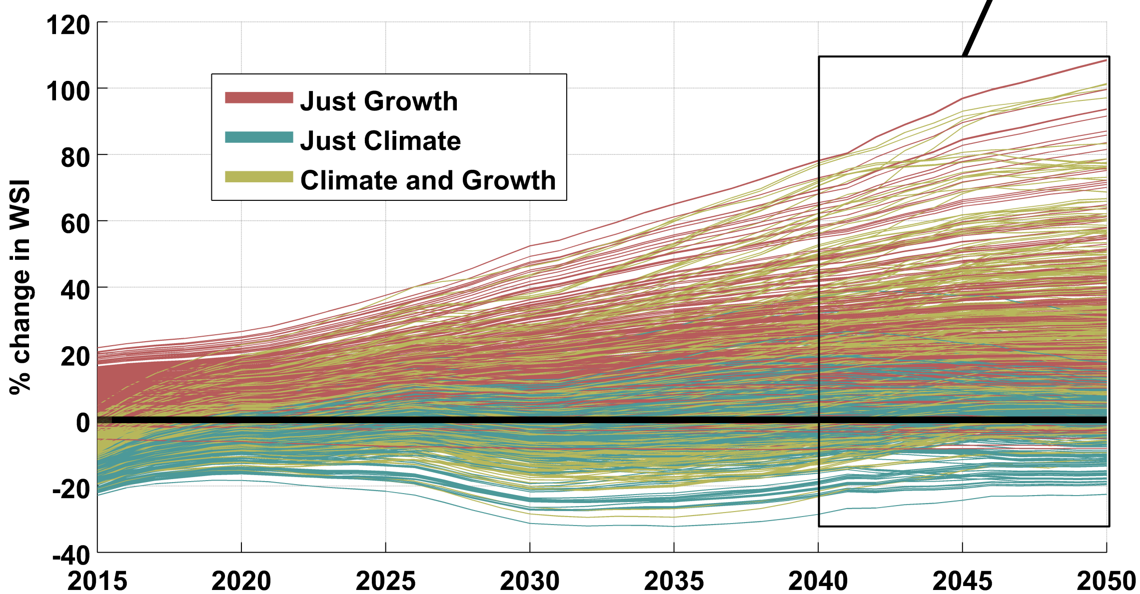
Water Stress in China

ASR average weighted by population





$$WSI = \frac{\text{Withdrawal (Dom, Ind, Lvstk, Irr)}}{\text{Supply (Runoff, Inflow)}}$$

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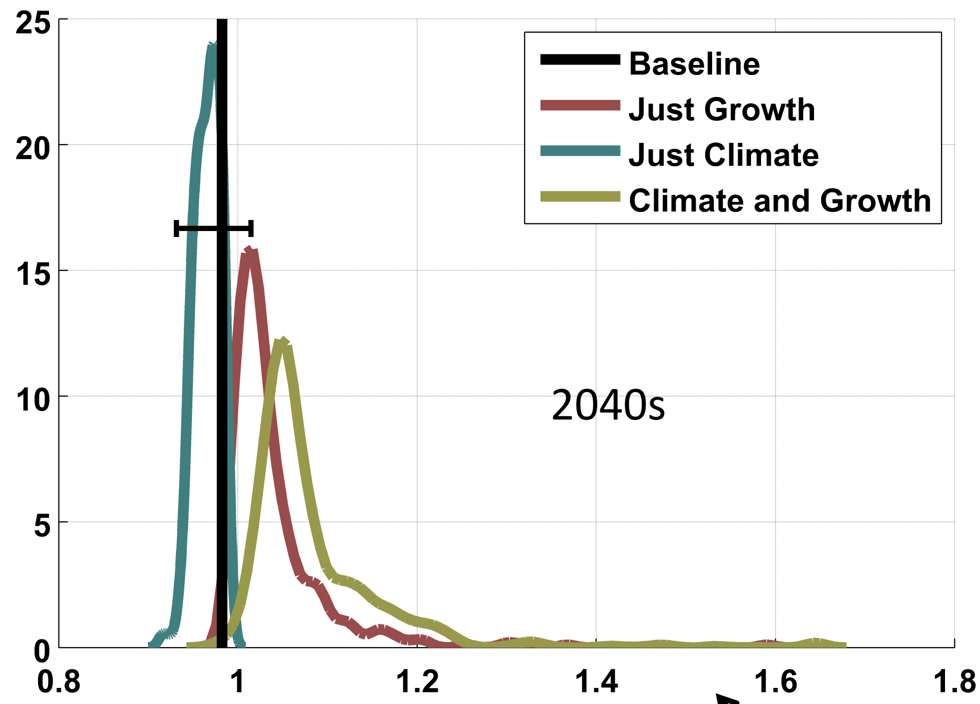
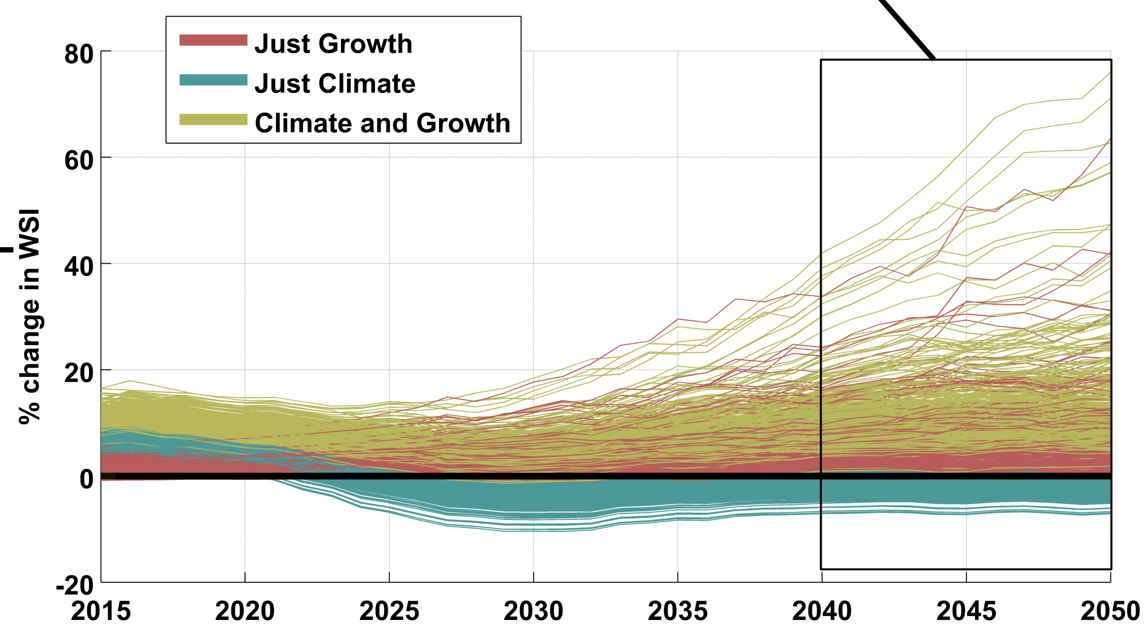
Water Stress in The Indus Basin

ASR average weighted by population

$$WSI = \frac{\text{Withdrawal (Dom, Ind, Lvstk, Irr)}}{\text{Supply (Runoff, Inflow)}}$$





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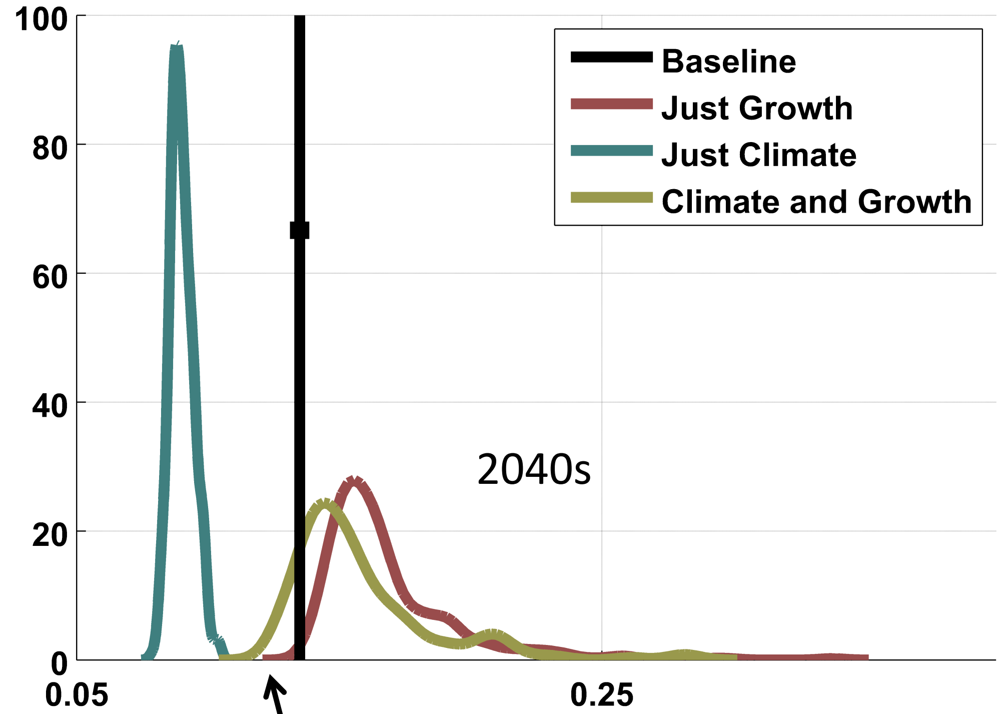
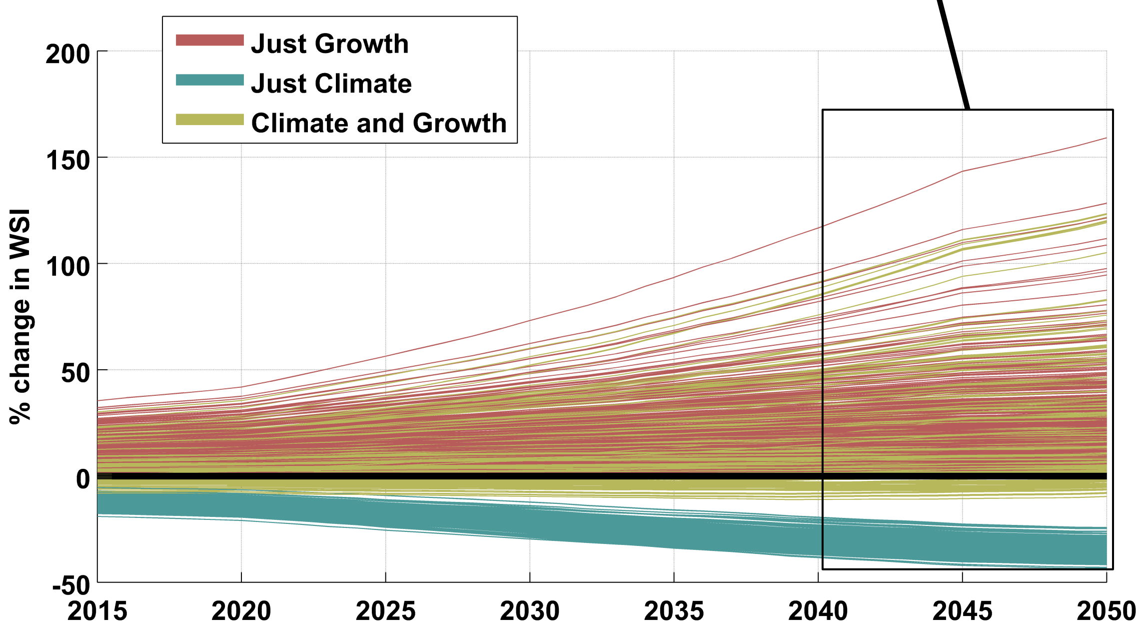
Water Stress in Mainland Southeast Asia

(Cambodia, Laos, Myanmar, Peninsular Malaysia, Thailand, and Vietnam)

ASR average weighted by population





$$WSI = \frac{\text{Withdrawal (Dom, Ind, Lvstk, Irr)}}{\text{Supply (Runoff, Inflow)}}$$

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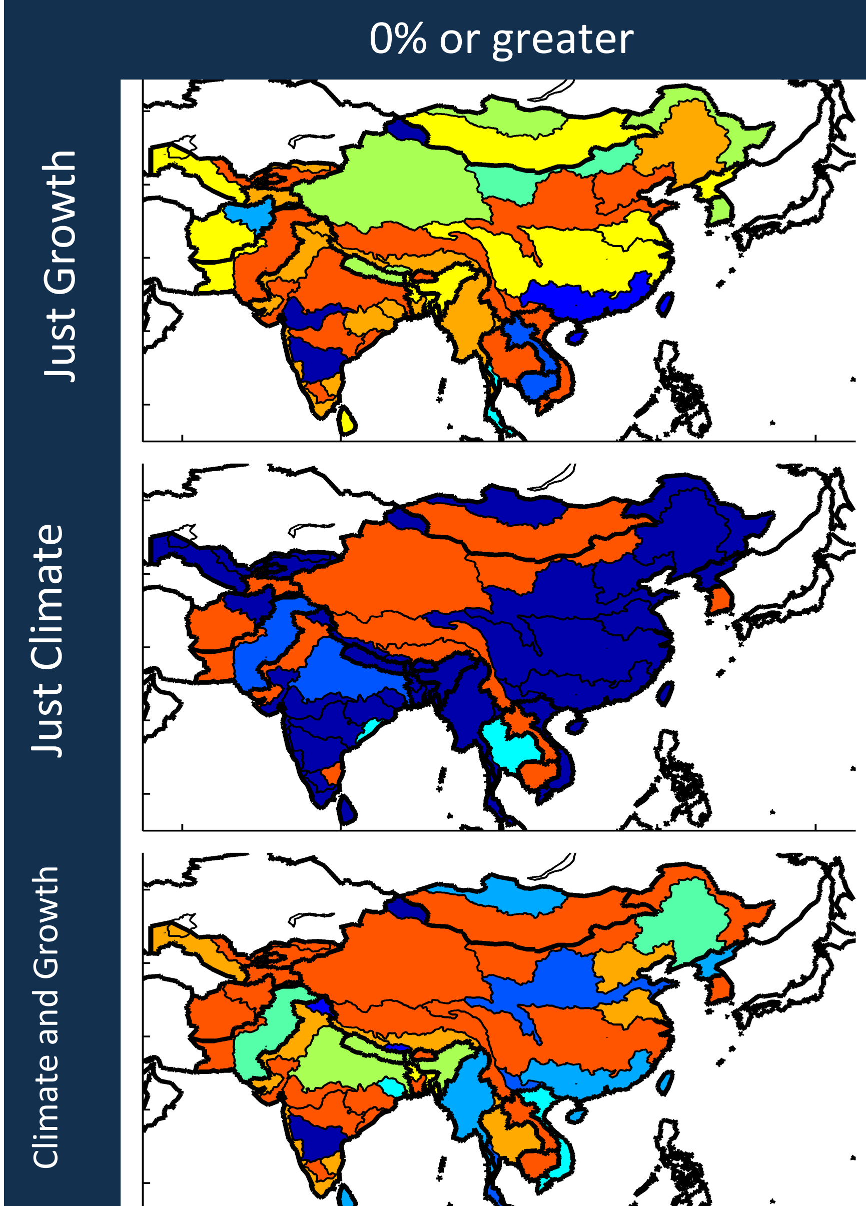
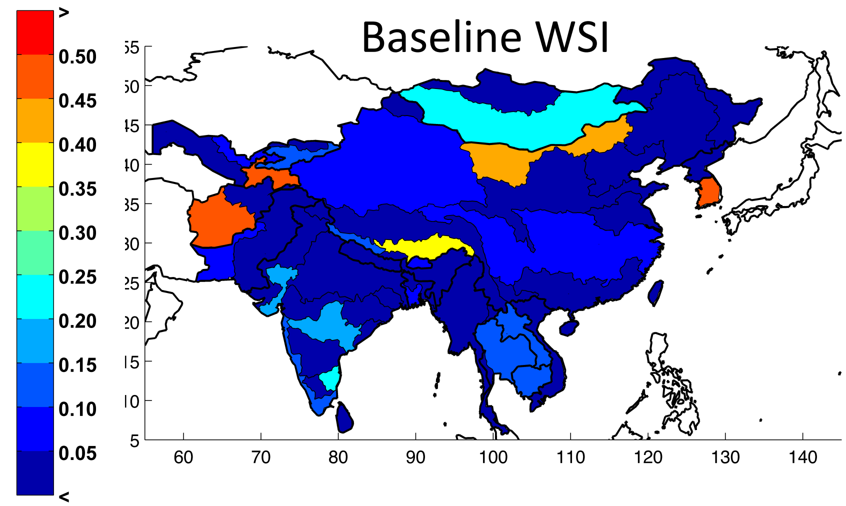
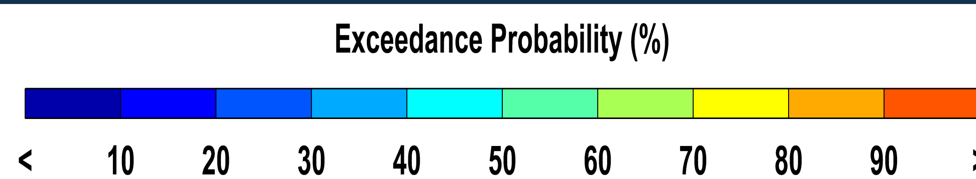




WSI Change at 2050: Exceedance Probability



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Closing Remarks

- Distributional trade-offs and amplifications from climate and socio-economics.
- Generally speaking, socio-economic changes contribute to WSI fat tail at 2050.
- Looking across ASRs - socio-economic growth and climate change offer differing roles to exceedance probability on absolute change of WSI distribution.
- Motivating issues to expand experimental design:
  - Effects of mitigation policy
  - Spatial and basin resolution
  - Interactive demand response
  - Changes to water-management infrastructure
  - Optimization and the "perfect" prediction for water calendar
  - Surface-water system stress only – assess groundwater resource sustainability
  - Changes in land use and irrigated areas
  - Explore adaptation/feedbacks of socio-economics (uncertainty in response)
  - Representation of glaciers and its downstream meltwater supply
  - Uncertainty in hydrologic response:
    - Promising methods (e.g. Koster and Milly, 1996) to capture structural variety in behavior.