Confronting the Prediction Challenge of Global Change

To What Extent Can Mitigation and Adaptive Actions Benefit Risk, Reward, and Resiliency?

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AWMA Workshop on Climate Risks, Rewards, and Resiliency
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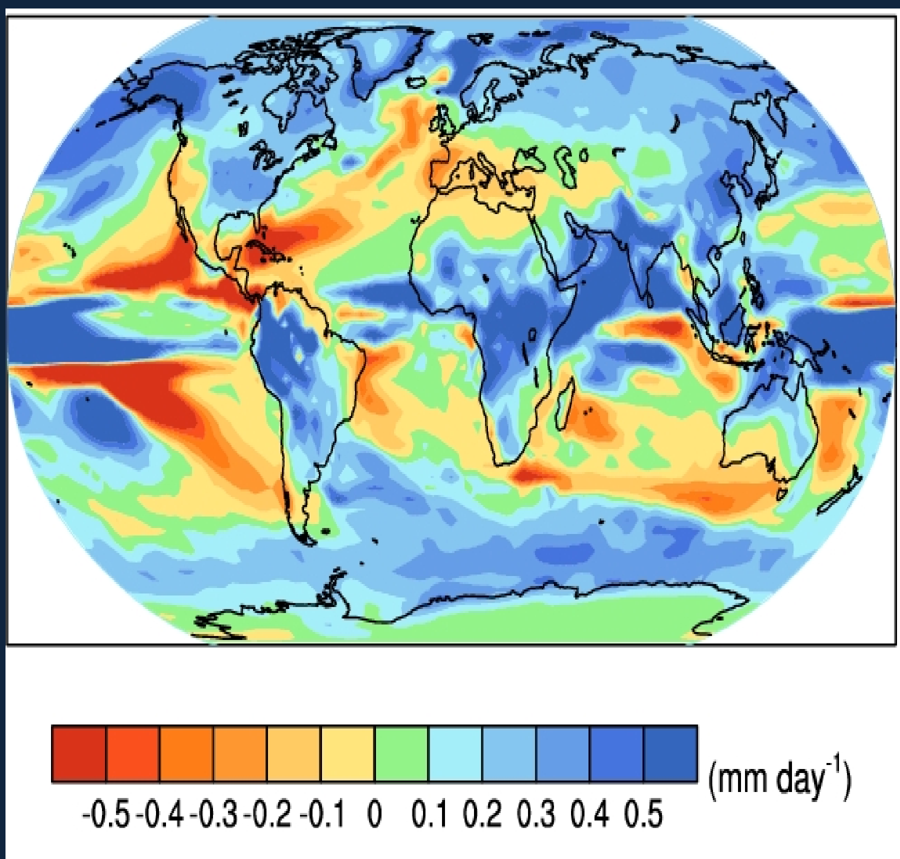
MIT Joint Program — Science — Policy — Global Change

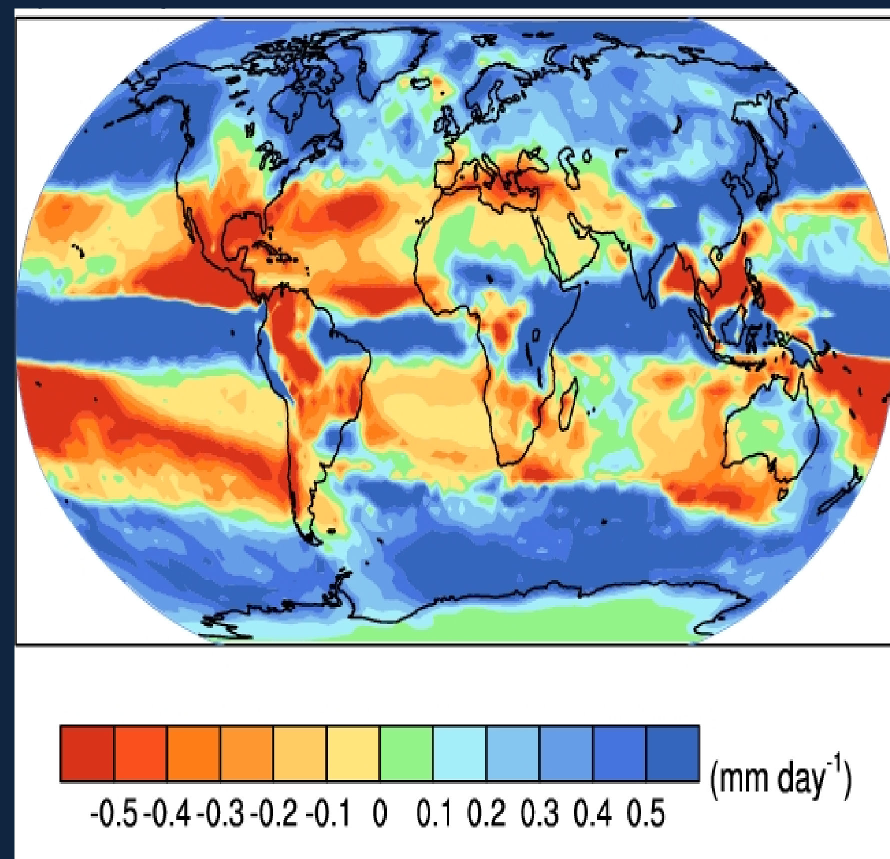
"Prediction is very difficult, especially about the future." N. Bohr

"…all models are wrong; the practical question is how wrong do they have to be to not be useful?" Box and Draper

Uncertainty in Global/Regional Change
Respond and Adapt to What Exactly?

Simulated Precipitation Change in 21st Century: A1B Scenario
Opposing Climate Model Results at the Regional Scale

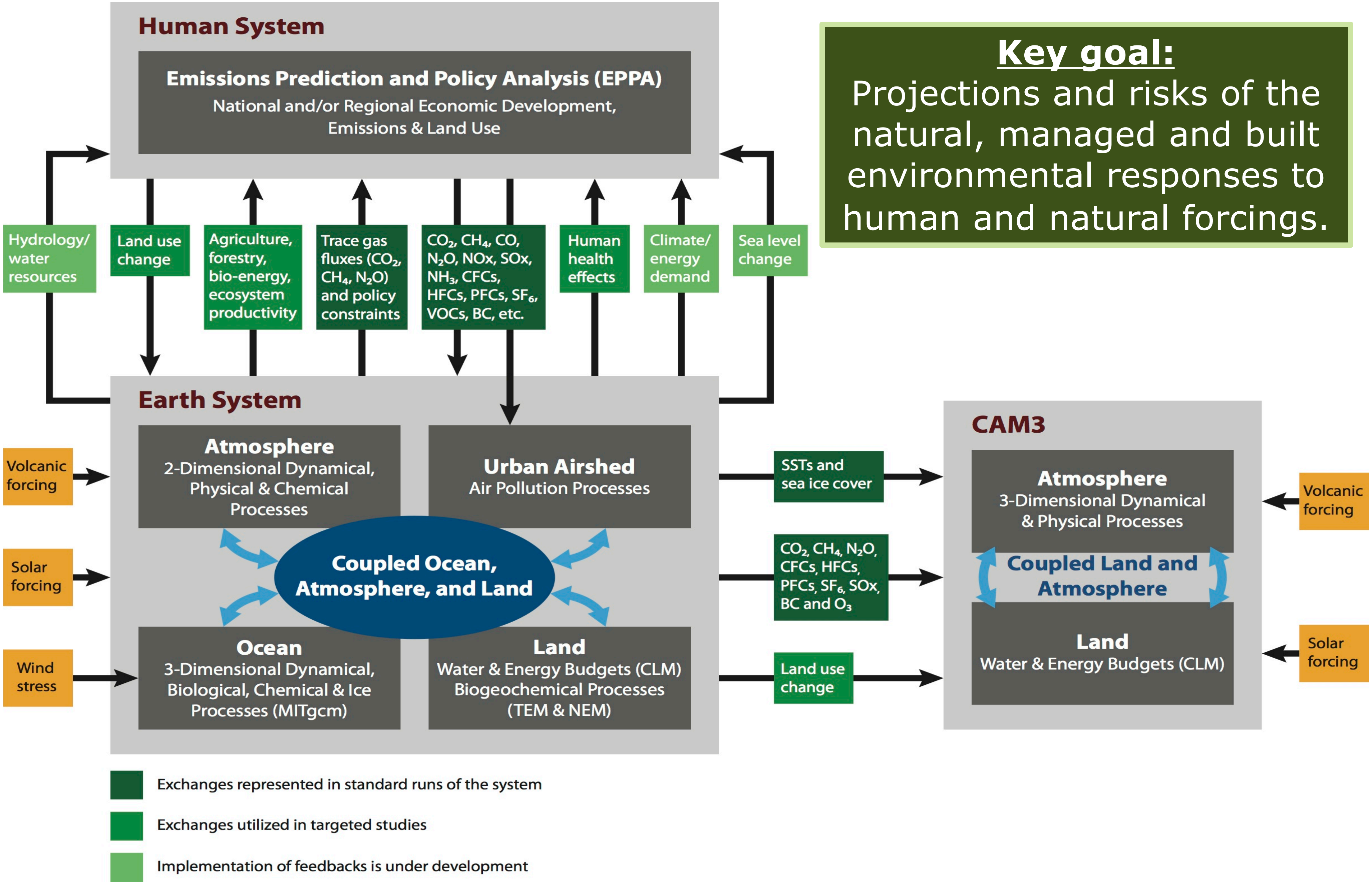




How to prepare when regional changes differ in sign?

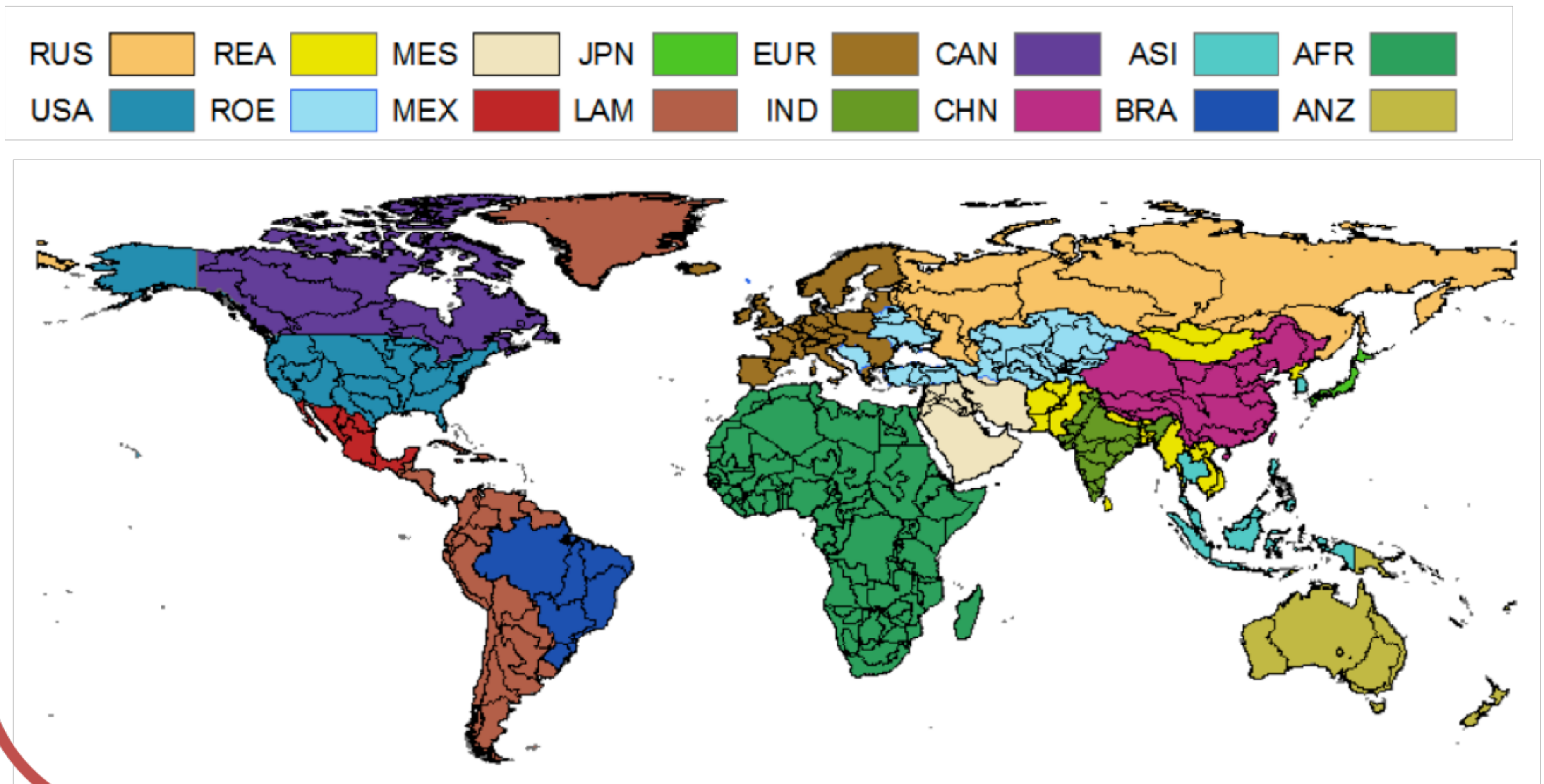
MIT Integrated Global System Model (IGSM)

Key goal:
Projections and risks of the natural, managed and built environmental responses to human and natural forcings.

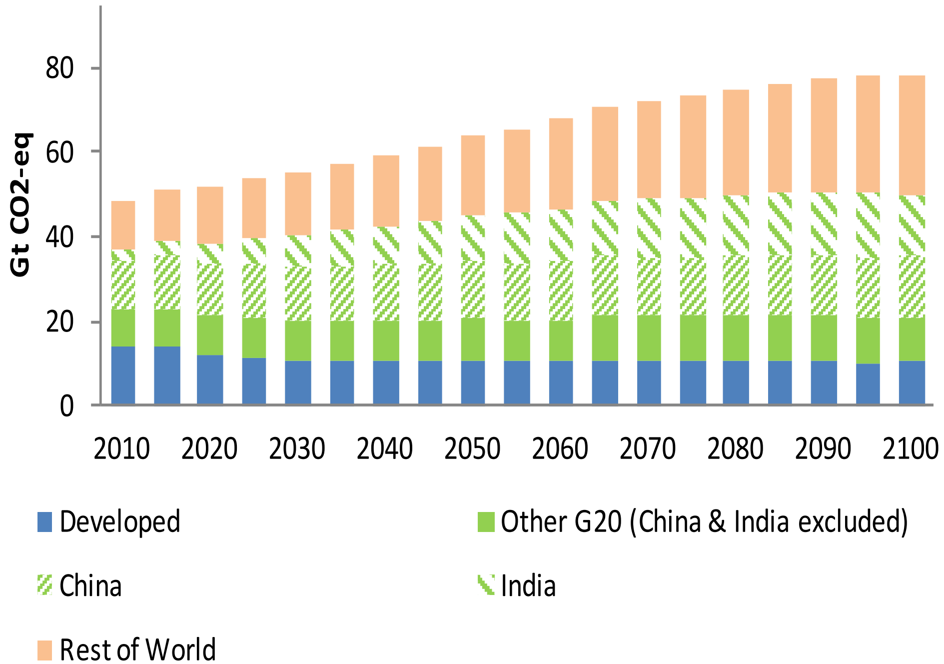


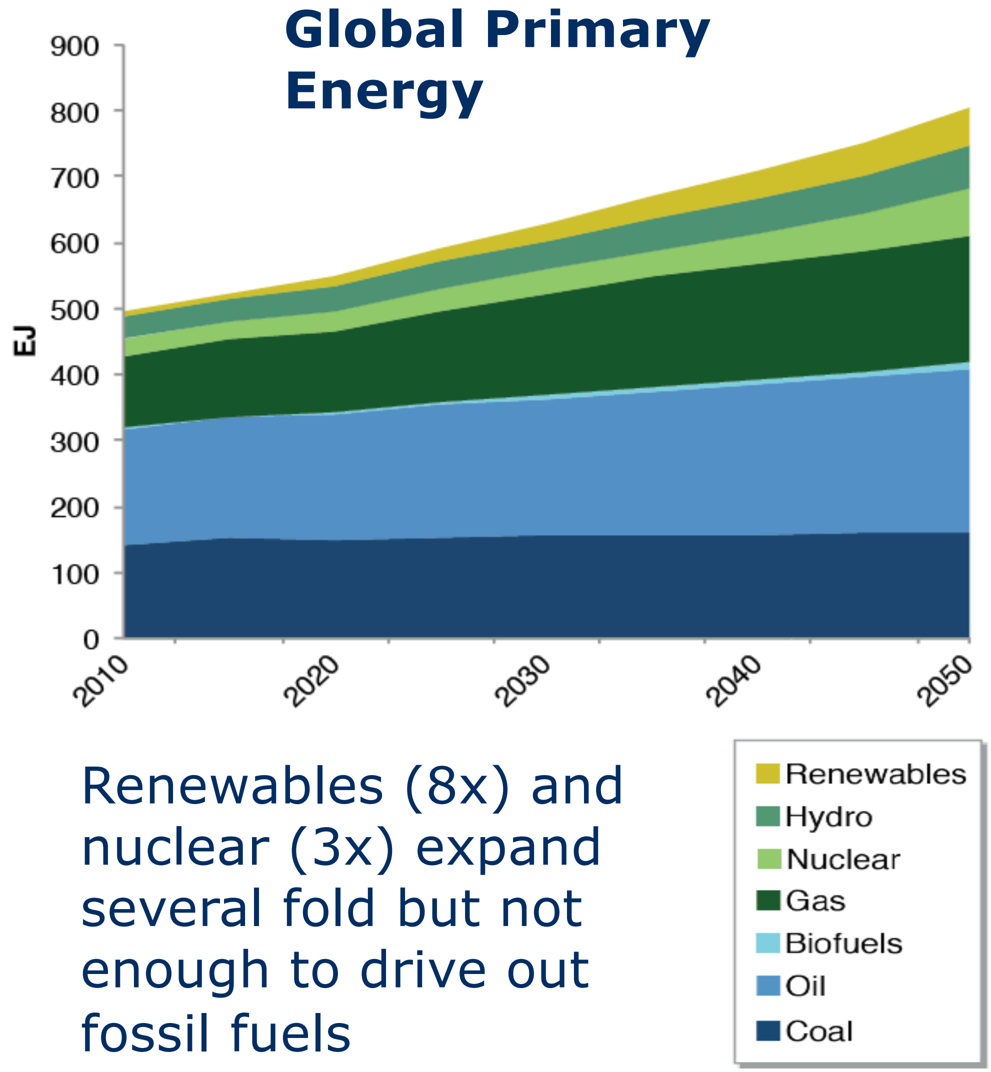
Any Prediction Model Must Represent the Earth's Systems – Whether Natural, Managed, or Built – In Discrete Pieces in Space and Time. Below is an Example for the IGSM.

EPPA Regions and Assessment Sub-Regions



Expected Global GHG Emissions if Paris Pledges are Implemented, but No Further Action



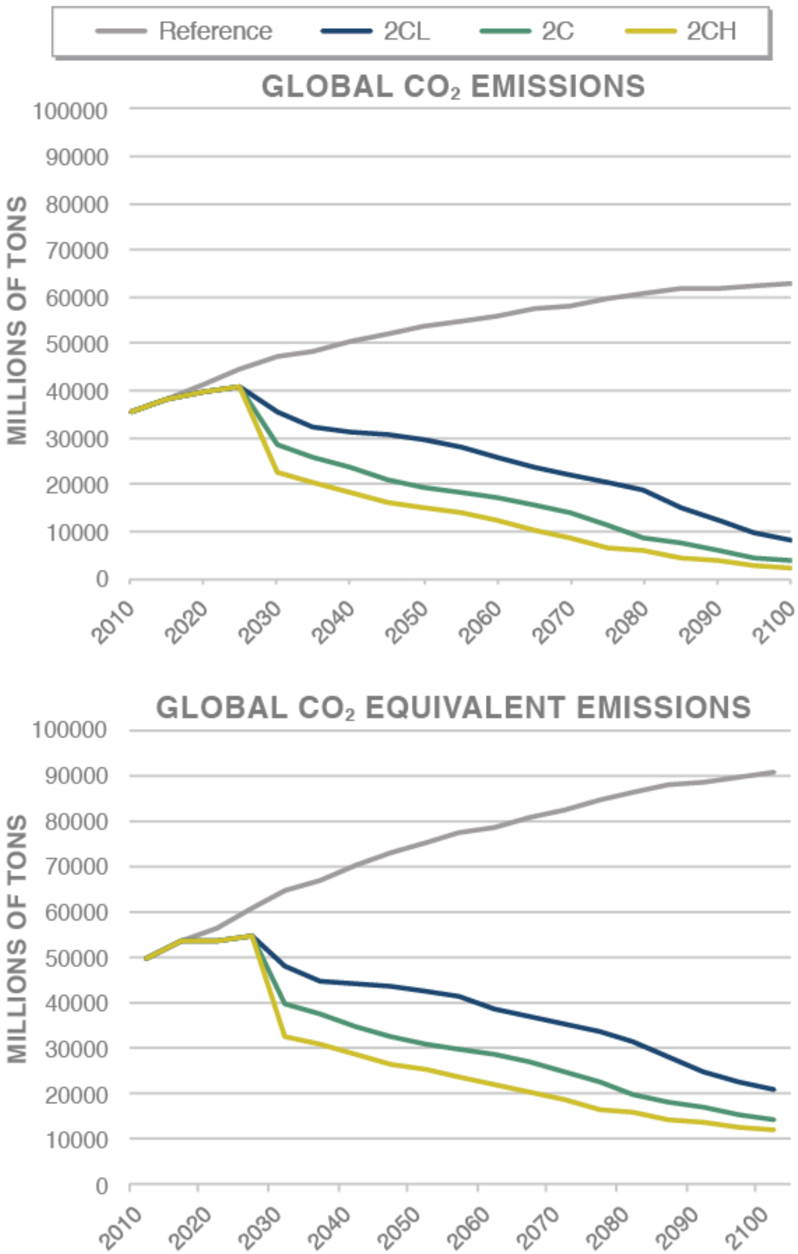


Emissions are flat and declining for most of the G20 (including China) and Developed countries but emissions in India and the Rest of the World would continue to grow.

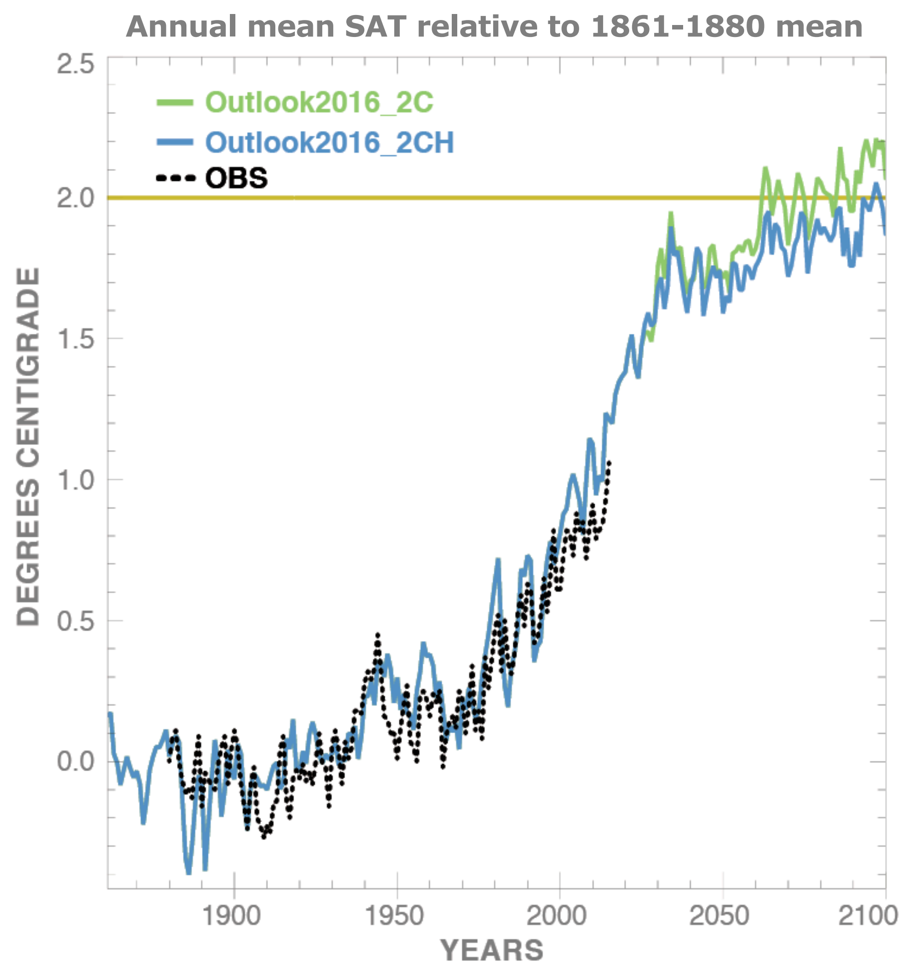
Renewables (8x) and nuclear (3x) expand several fold but not enough to drive out fossil fuels

The world remains largely fossil fuel dominated: ~75% but down from ~83% w/o the Paris agreement

If Paris locks us in through 2025, how fast must emissions turn down after?



Three emissions paths for high, median, and low climate sensitivity—how certain do we want to be about avoiding 2° C?



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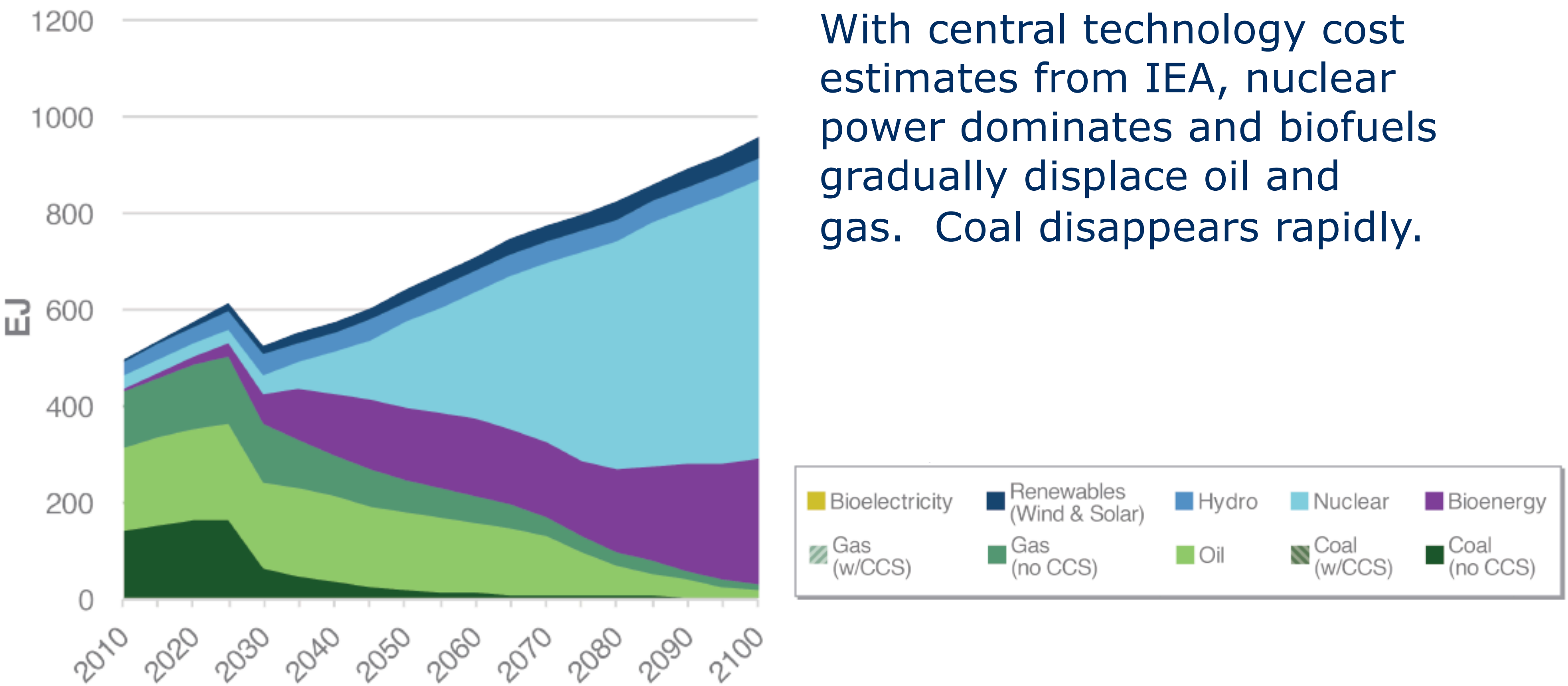
Implications for Energy Use and How It is Supplied Depends on Technology Advances

We simulate different possible scenarios using IEA estimates of technology costs, and ranges. Here for median climate sensitivity.



With central technology cost estimates from IEA, nuclear power dominates and biofuels gradually displace oil and gas. Coal disappears rapidly.

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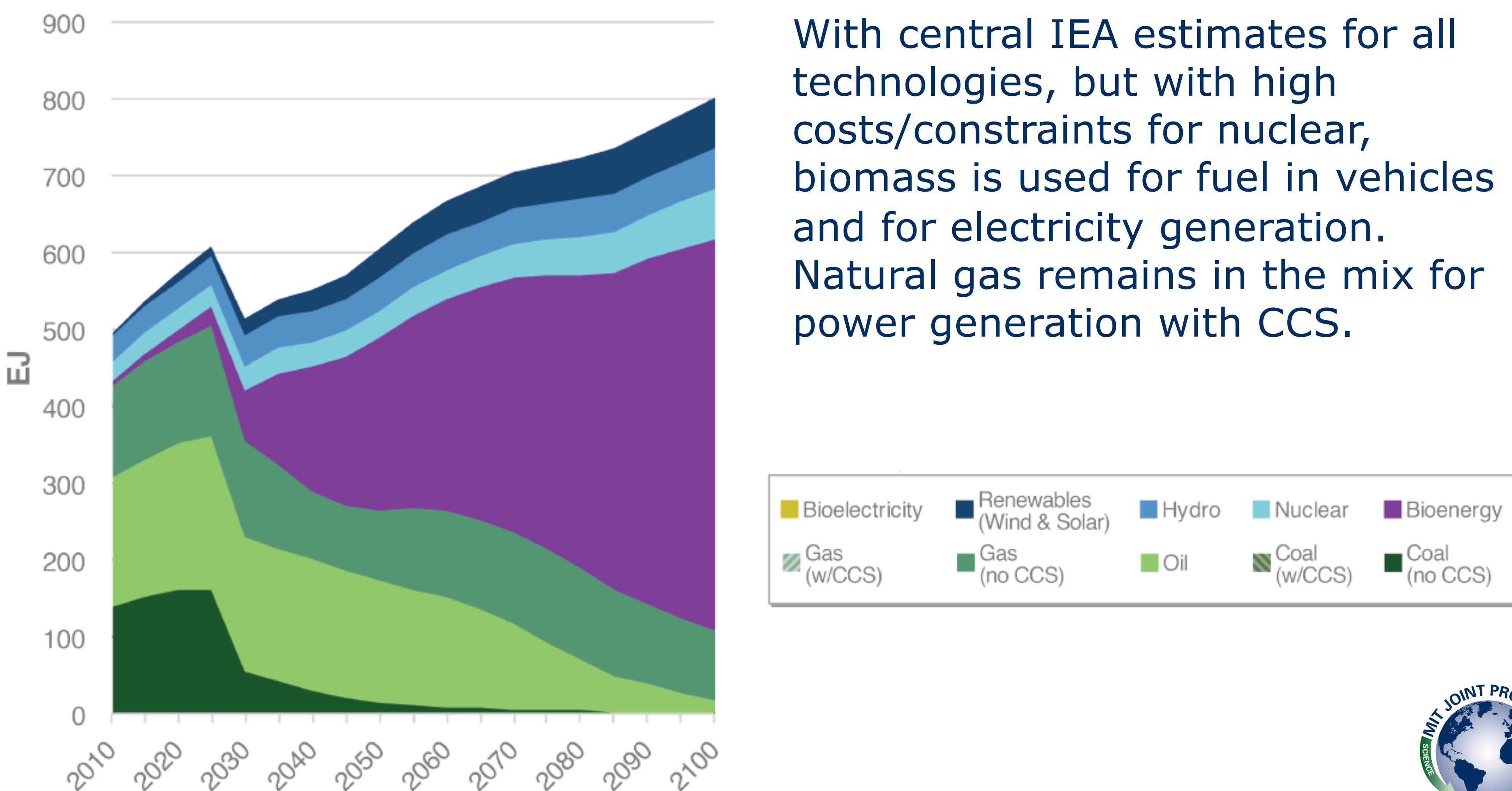
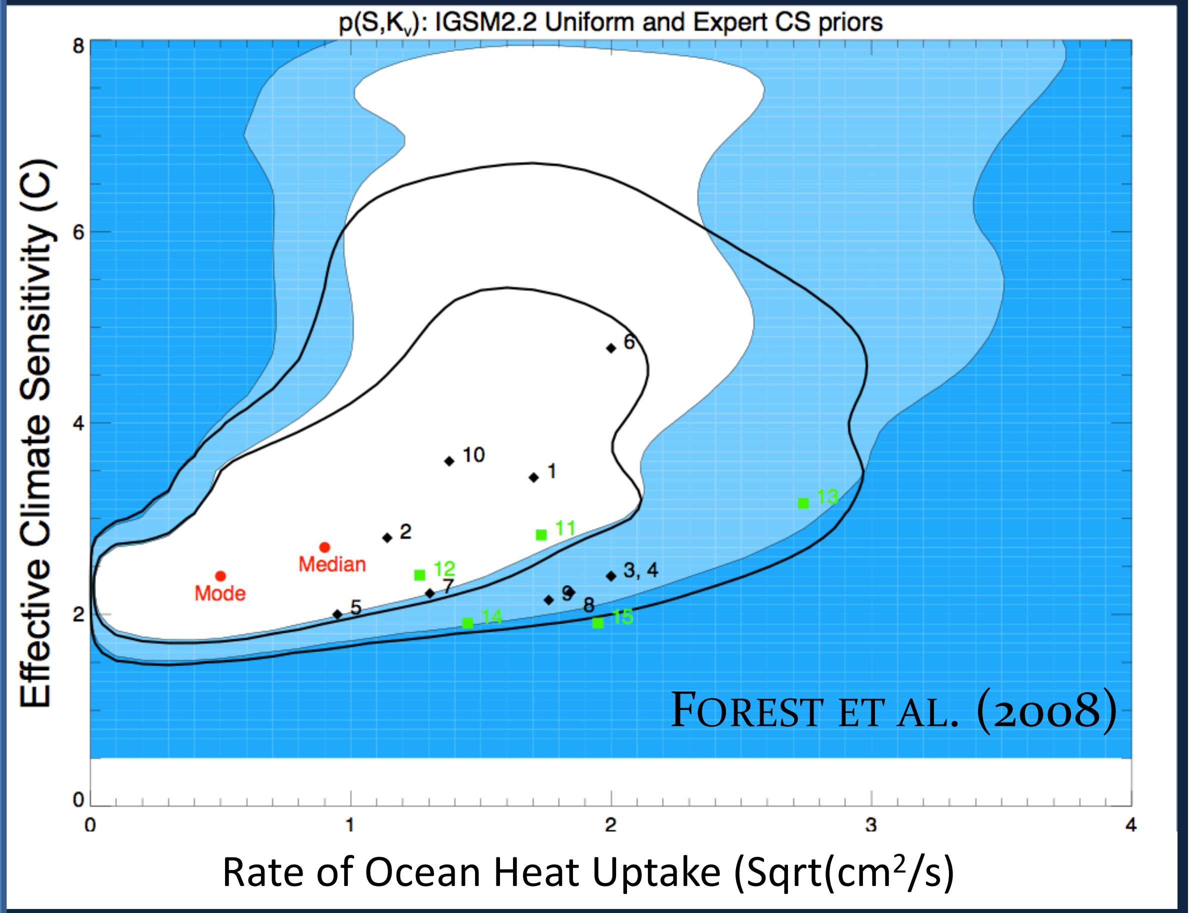


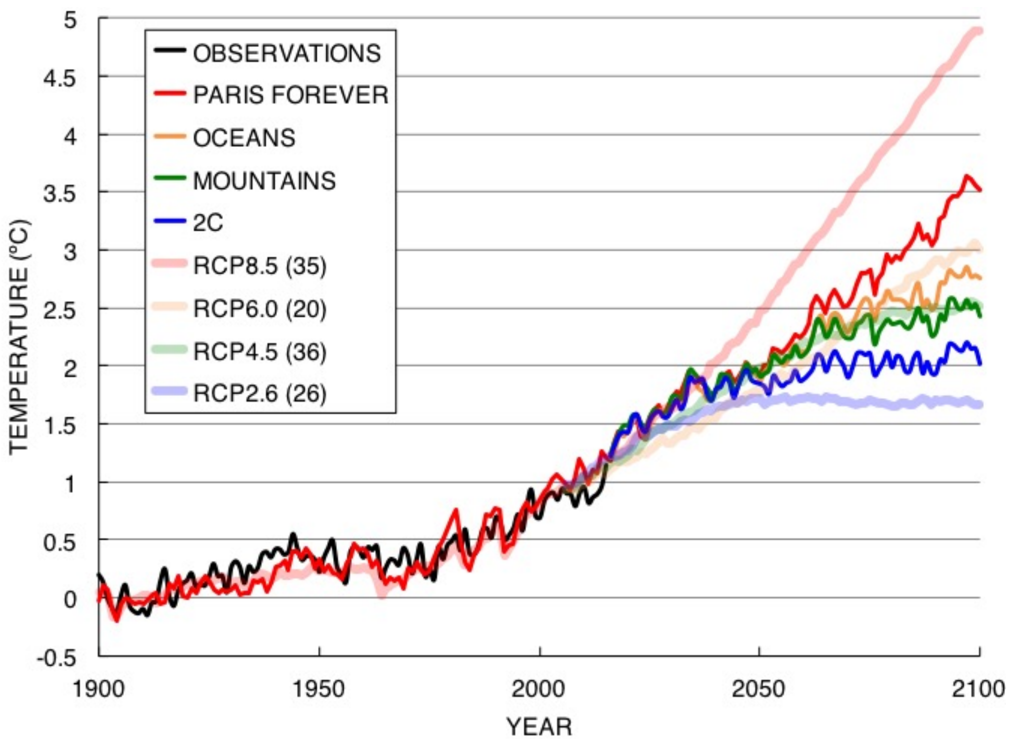
With central IEA estimates for all technologies, but with high costs/constraints for nuclear, biomass is used for fuel in vehicles and for electricity generation. Natural gas remains in the mix for power generation with CCS.

Observations and Models Allow Us to Place Boundaries to Our Confidence for Prediction

- Emissions Uncertainty
- Climate Sensitivity (change in Temperature due to change in radiative forcing).
- Heat uptake by Deep Ocean (& Carbon Uptake)
- Radiative Forcing of Aerosols
- CO_2 Fertilization Effect on Ecosystem (wide range)
- Precipitation Trends

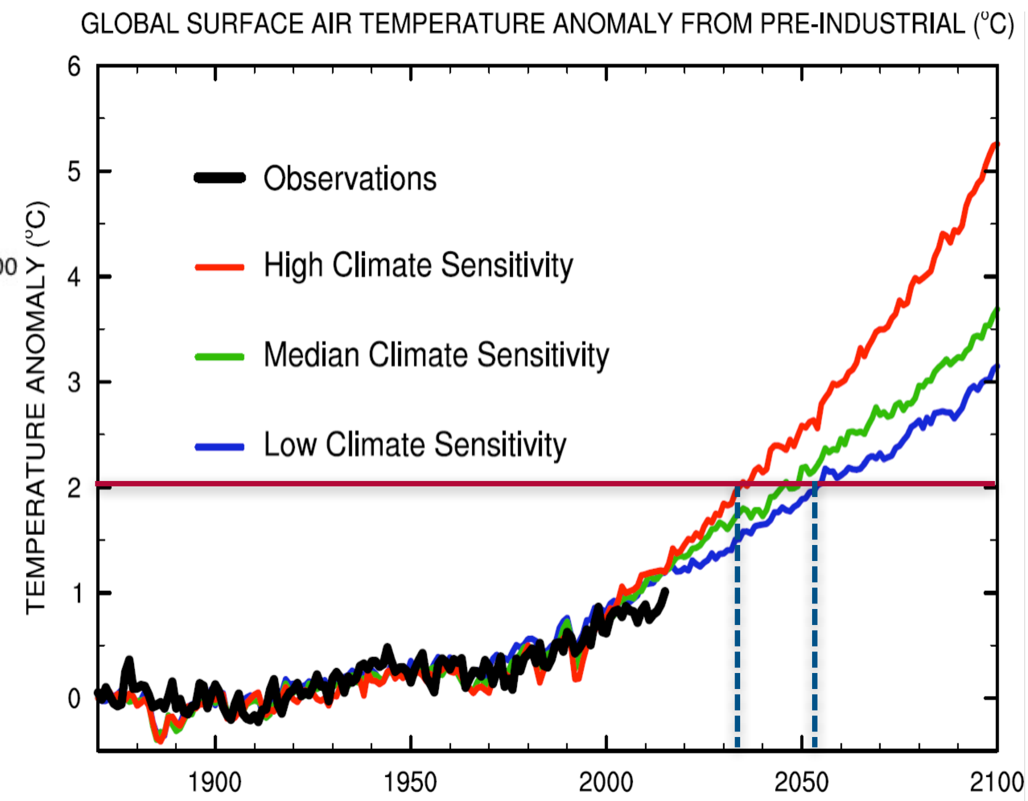


Not only Should We Account for the Range of Emission Scenarios – But Also "plausible" Global Responses



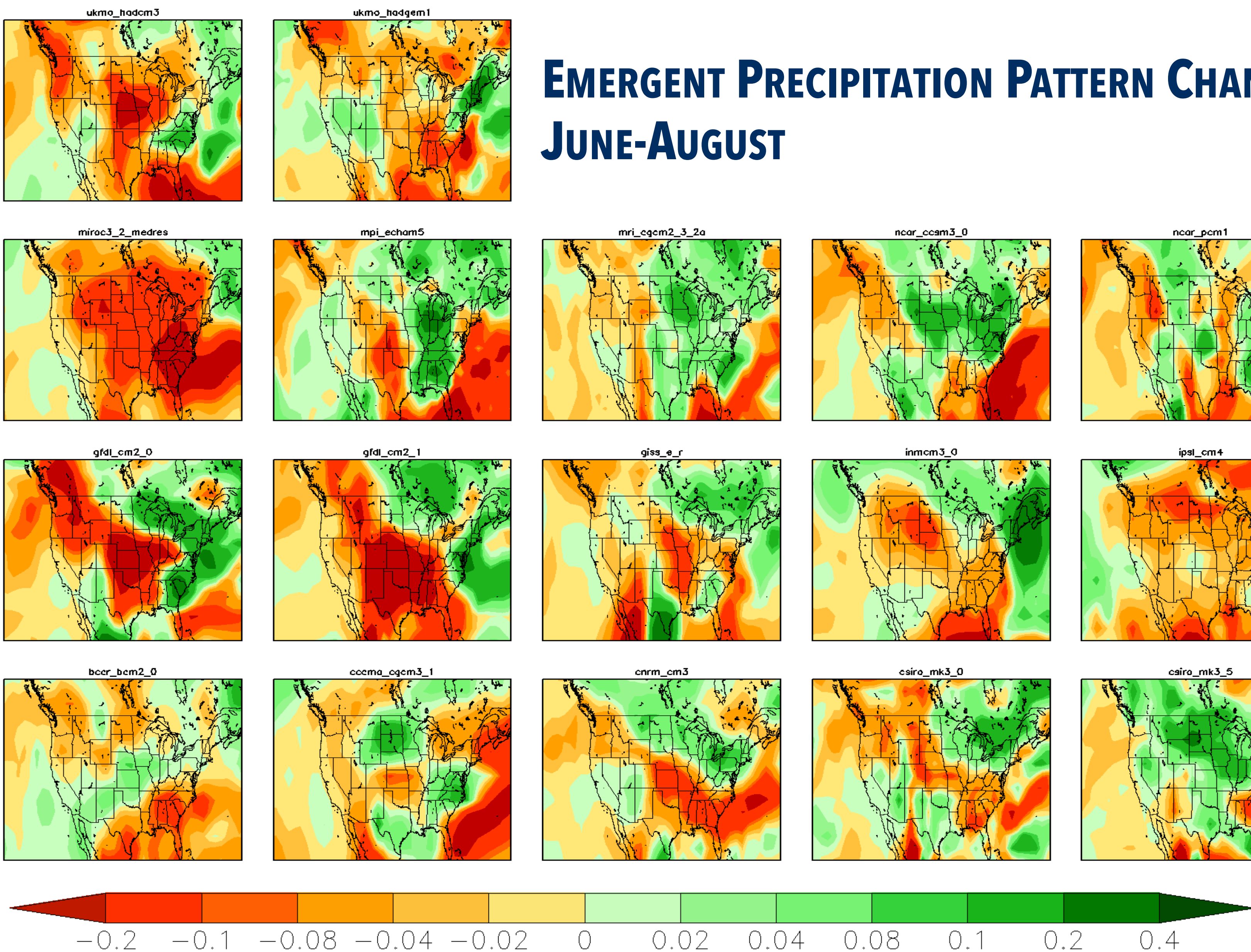
Shown above is a range of global temperature responses that result from a range of emission scenarios. Some convey little while others a strong degree of mitigating action.

Shown below each one of these emission scenarios should also cover the range of plausible responses – dictated by empirical knowledge



We Must also recognize and account for the wide Range of "plausible" patterns of change

Emergent Precipitation Pattern Changes June-August



IGSM Scenarios

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

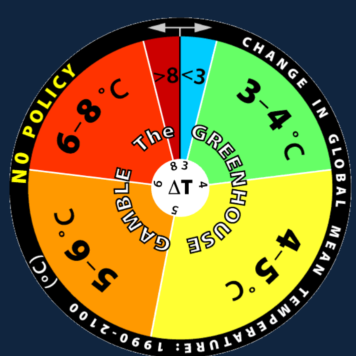
No Policy (Reference):

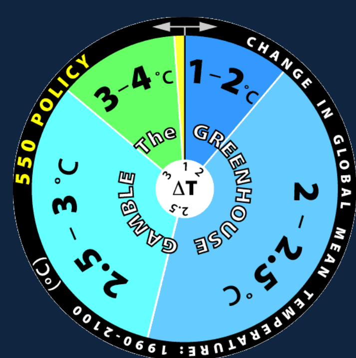
- **"Unconstrained Emissions"**

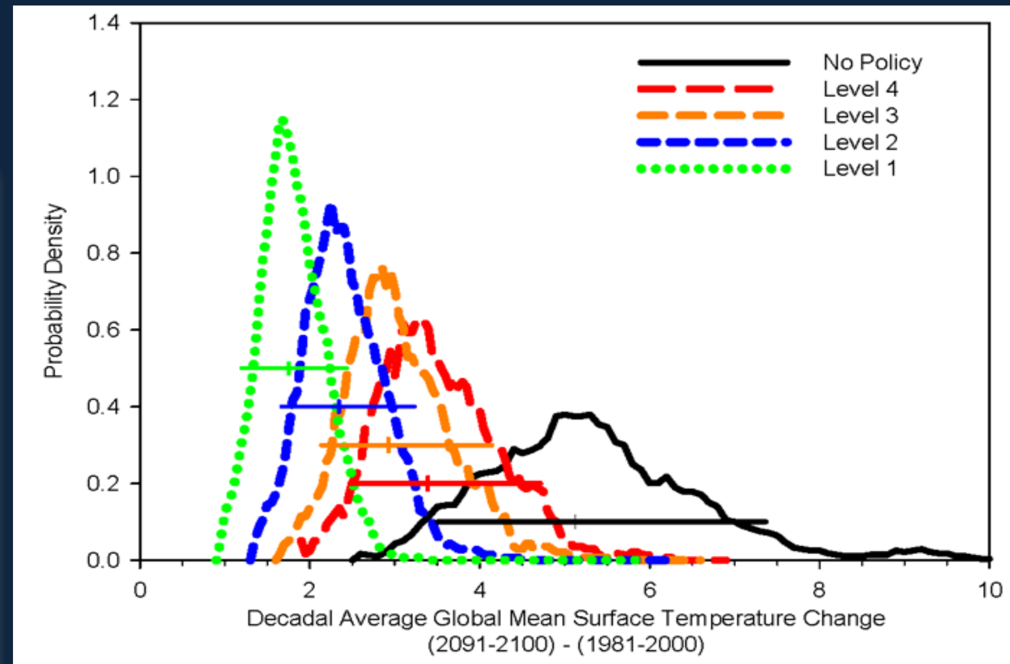
Stabilization Scenarios: U.S. CCSP

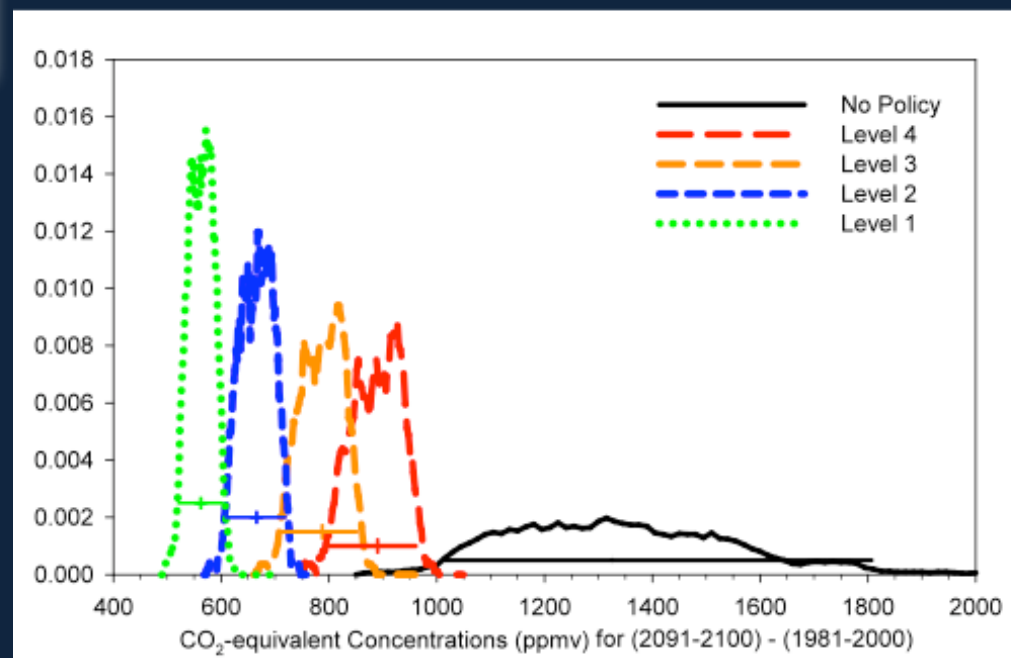
- **Level 4 (750 CO_2, 890 CO_2-eq)**
- **Level 3 (650 CO_2, 780 CO_2-eq)**
- **Level 2 (550 CO_2, 660 CO_2-eq)**
- **Level 1 (450 CO_2, 560 CO_2-eq)**

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

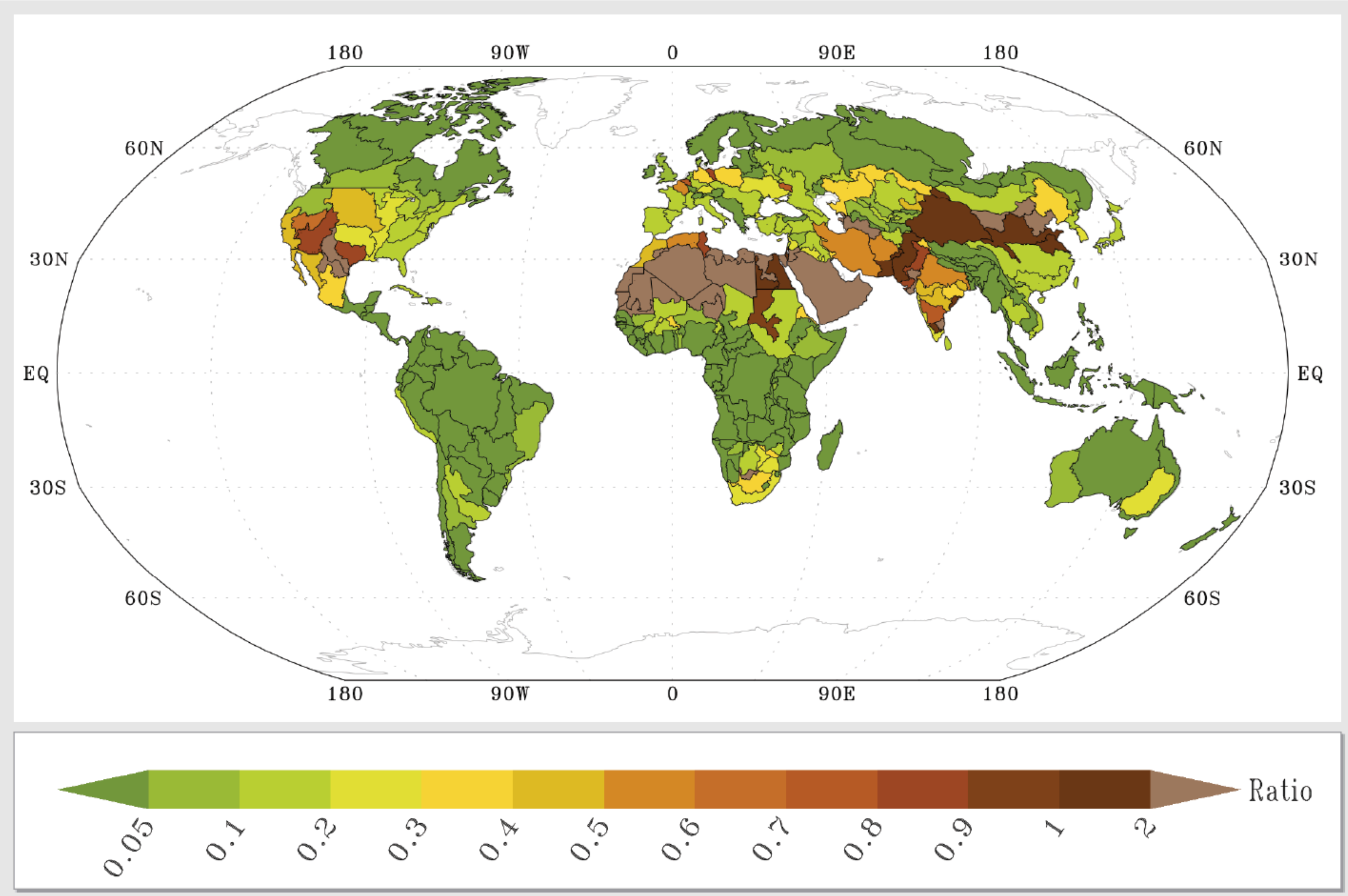




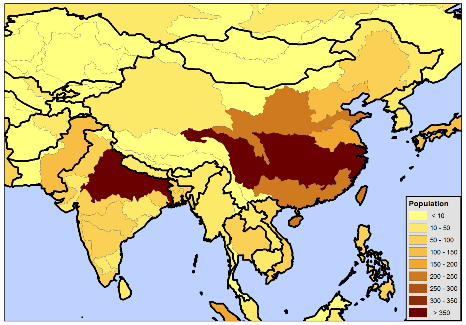




Implications: Current (2001-2020) "Water Stress"

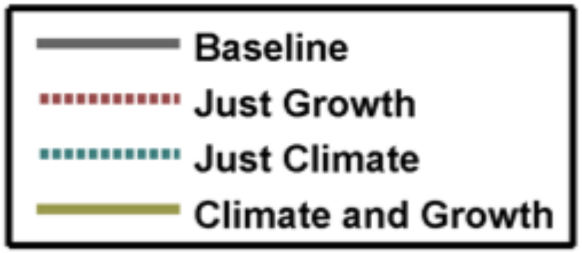


Current water Stress (unitless ratio of withdrawal versus availability) simulated average 2001-2020



Climate Mitigation Can Reduce - But not Eliminate - Heightened Risks to "Water Stress"

$$\text{Water Stress Index (WSI)} = \frac{\text{Total Demand}}{\text{Runoff + Upstream Inflow}}$$

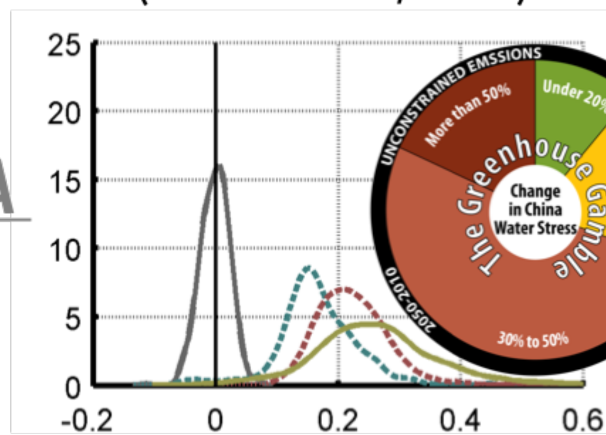


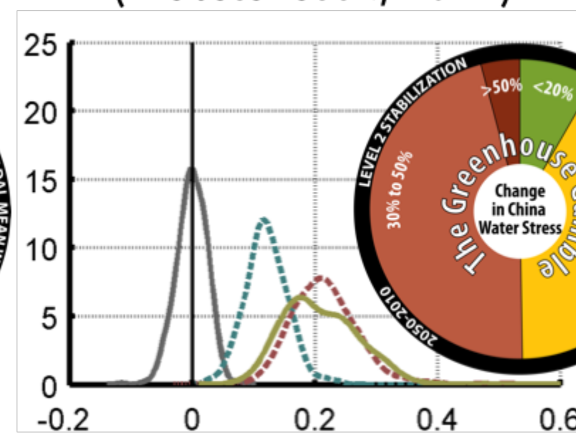
UNCONSTRAINED EMISSIONS
(Sokolov et al., 2009)

LEVEL 2 STABILIZATION
(Webster et al., 2011)

CHINA

Baseline WSI: 0.680

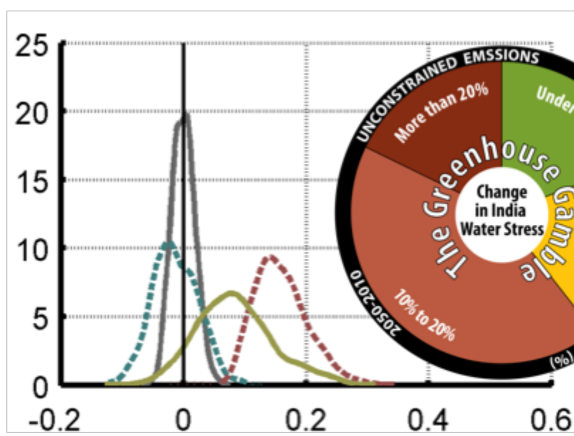


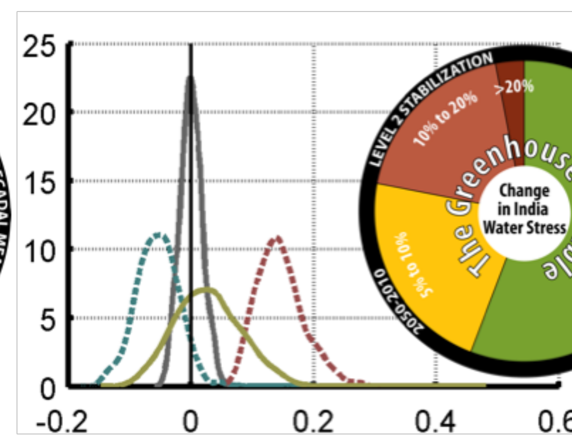


CHANGE IN DECADAL WATER STRESS (2041-2050)

INDIA

Baseline WSI: 0.700

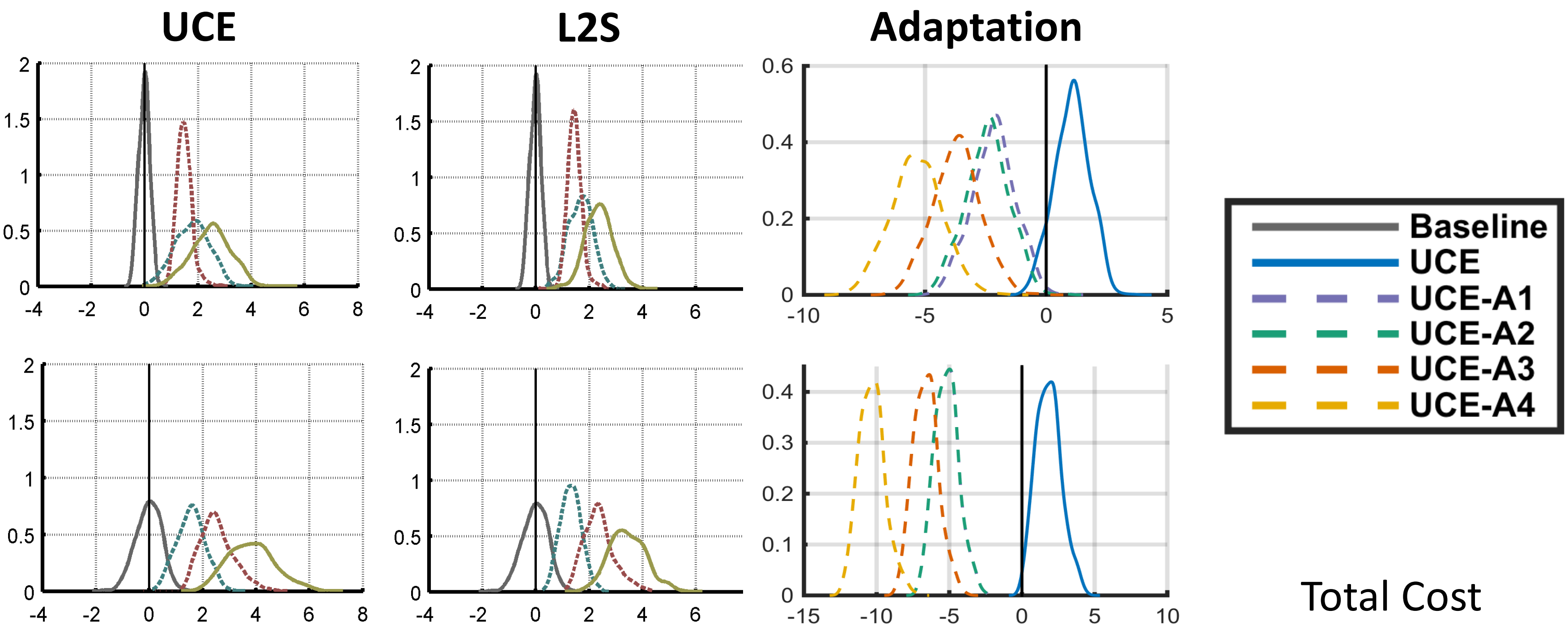




Change in decadal averaged Unmet Demand in 2040s Mitigation Vs. Adaptation

China
Baseline UD: 34%

India
Baseline UD: 23%



Adaptation Scenarios

- A1: UCE with lined canals
- A2: A1 with all irrigated lands at least furrow
- A3: A1 with all irrigated lands at least low efficiency sprinklers
- A4: A1 with all irrigated lands high efficiency sprinklers

Total Cost
(Billions 2000 US$)

	China	India
L2S	400	40
A1	35	23
A2	6	2
A3	81	73
A4	142	114

China 2050 population: 1.4 billion people
India 2050 population: 1.7 billion people

Thank You

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