Does half a degree of global warming matter? Results from the BRACE 1.5 study

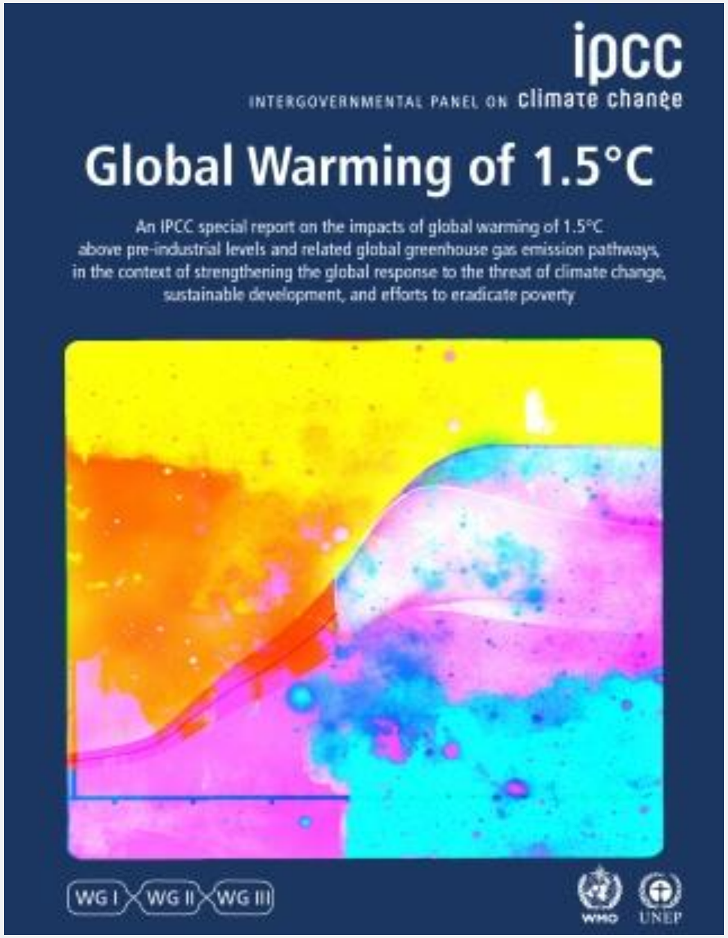
Brian O’Neill, University of Denver

Special thanks: Travis Aerenson, Flavio Lehner, Angie Pendergrass, Xiaolin Ren, Ben Sanderson, Gary Strand, Claudia Tebaldi, Yangyang Xu, Yaqiong Lu

Additional thanks: Ed Byers, Shinichiro Fujimori, Reto Knutti, Jean-Francois Lamarque, David Lobell, Matthias Weitzel, …

Payne Institute, Colorado School of Mines

29 October 2018



The Washington Post

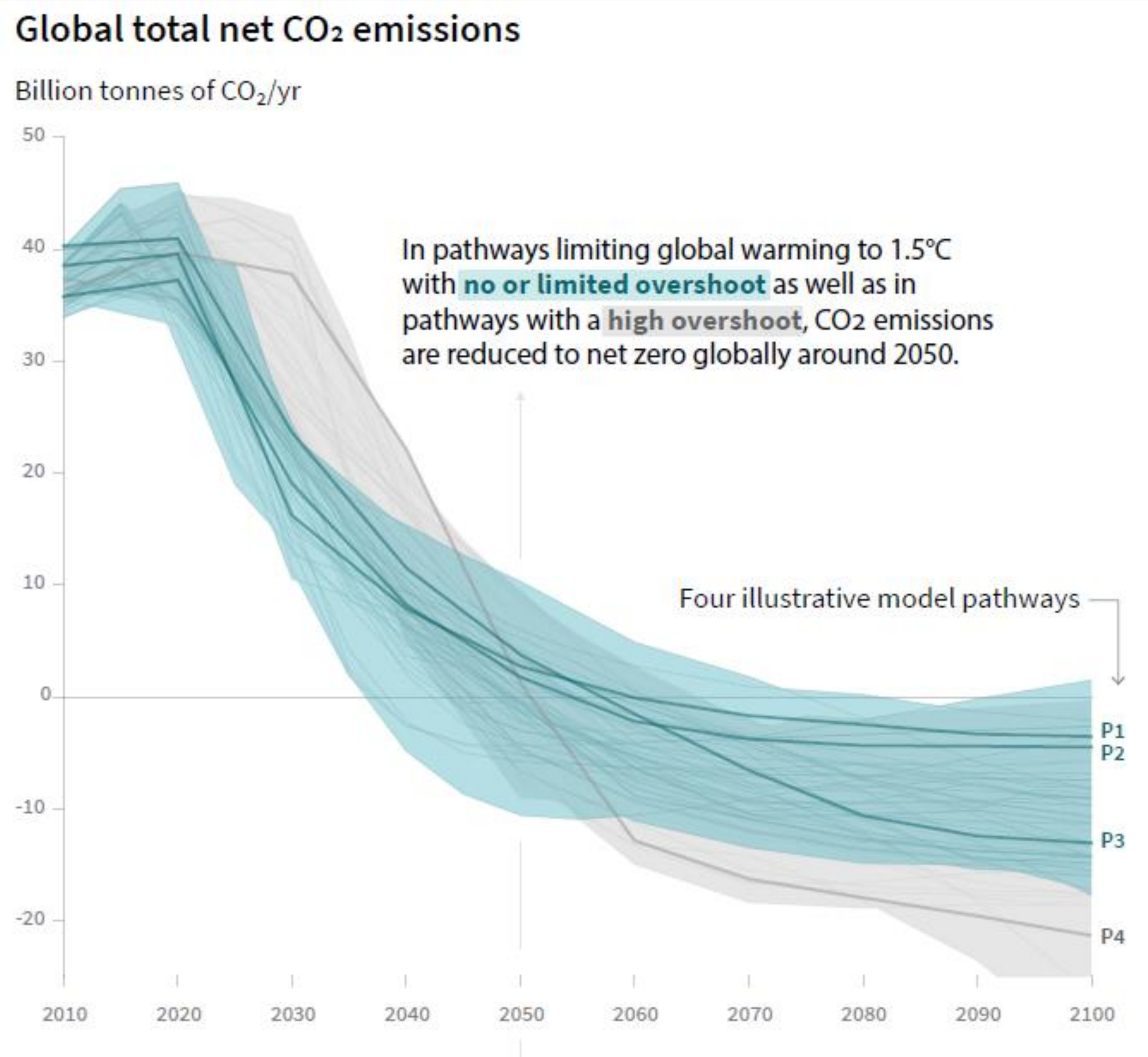
The world has just over a decade to get climate change under control, U.N. scientists say

The New York Times

Major Climate Report Describes a Strong Risk of Crisis as Early as 2040

FP

The Hope at the Heart of the Apocalyptic Climate Change Report



Global total net CO_2 emissions
Billion tonnes of CO_2/yr
50
40
30
20
10
0
-10
-20
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
In pathways limiting global warming to 1.5°C with no or limited overshoot as well as in pathways with a high overshoot, CO_2 emissions are reduced to net zero globally around 2050.
Four illustrative model pathways
P1
P2
P3
P4

BRACE1.5

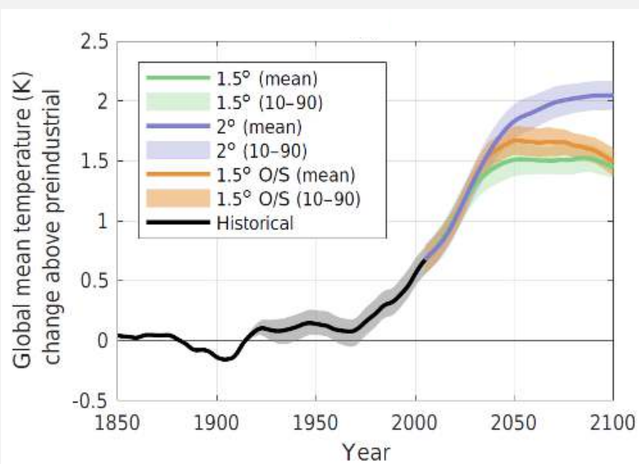
Benefits of Reduced Anthropogenic Climate Change

Do impacts differ substantially between 1.5 and 2 C of warming?

A special collection in Environmental Research Letters

K. Ebi & S. Gourdji, Guest Editors

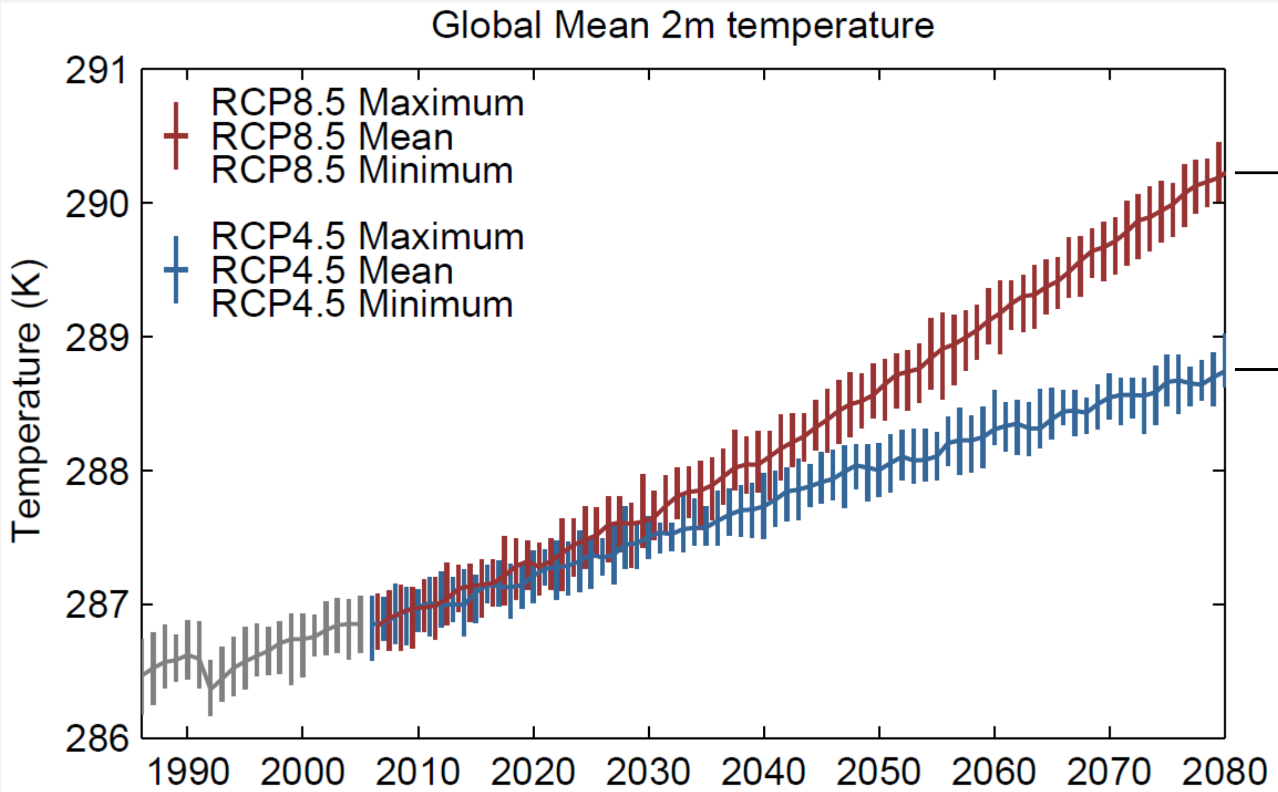
CESM/CMIP5 Ensembles



Biophysical & Societal Impact Models

Impacts
Extreme events
Health
Agriculture
Energy
Multi-sector

Conceptual framework: Avoided impacts



Sanderson et al., 2015.

Higher emissions
Larger impacts

More mitigation
Lower emissions
Lower impacts

Cost: Mitigation, adaptation

Benefit: Avoided impacts

BRACE: RCP8.5, ~3.7 C warming 2060-80 vs.
RCP4.5, ~2.5 C warming

BRACE 1.5: 2 C stabilization vs. 1.5 C stabilization

The Paris Agreement (2015)

Aims to limit global warming…

> “to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels”

2°C target previously agreed in Copenhagen Accord (2009)

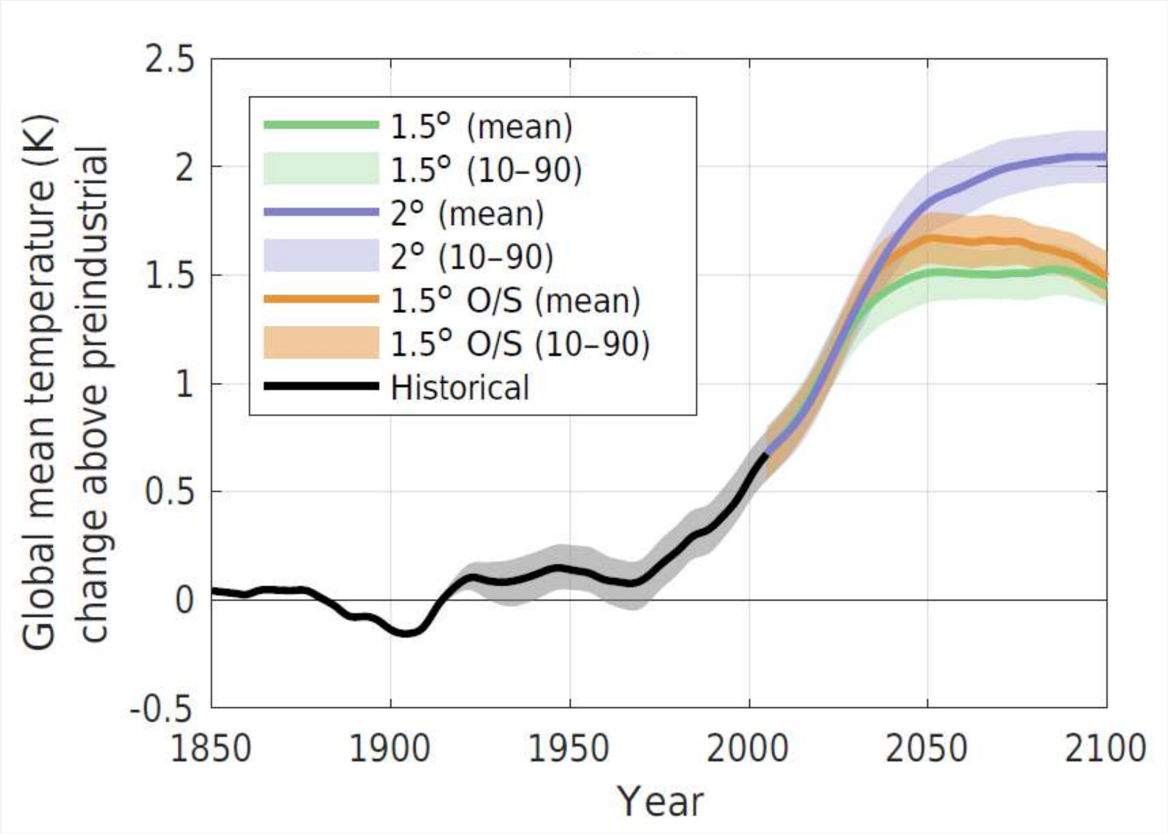
Just released: IPCC Special Report on 1.5 Degrees

Climate model simulations

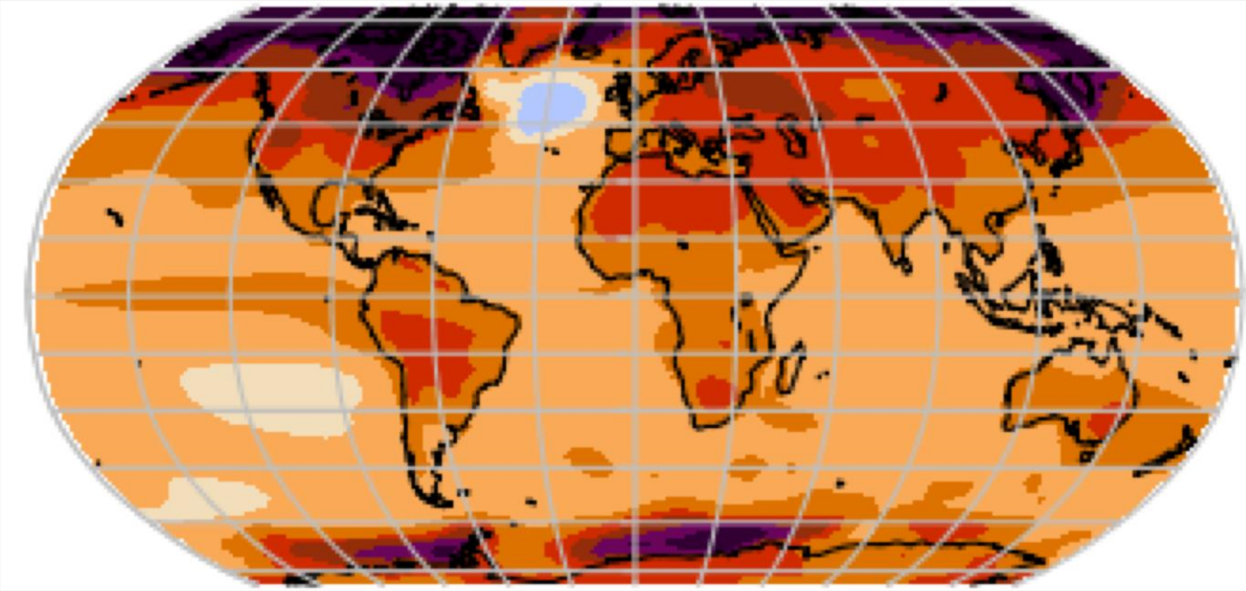
CESM 1.0 simulations (Large Ensemble version)

Designed to stabilize at 1.5 or 2 C, or to overshoot 1.5 C

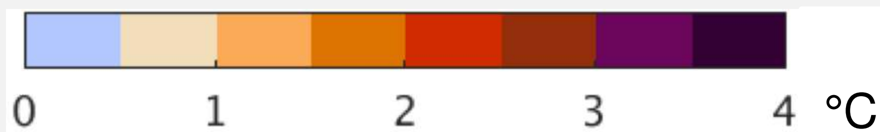
10+ initial condition ensemble members per scenario



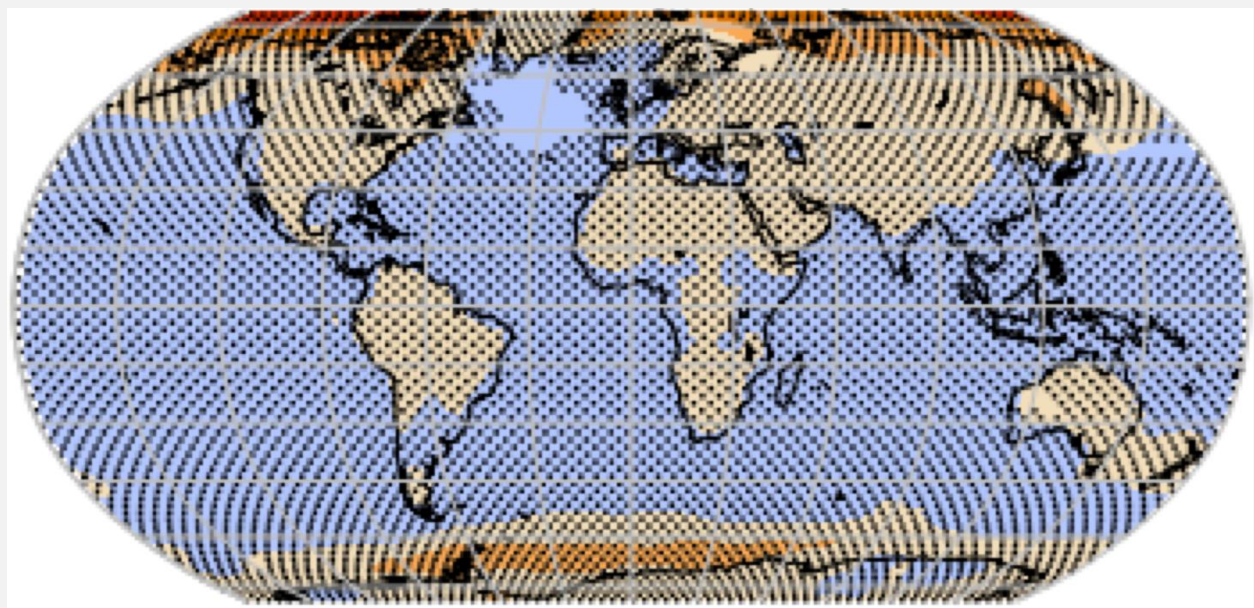
Sanderson et al., 2017



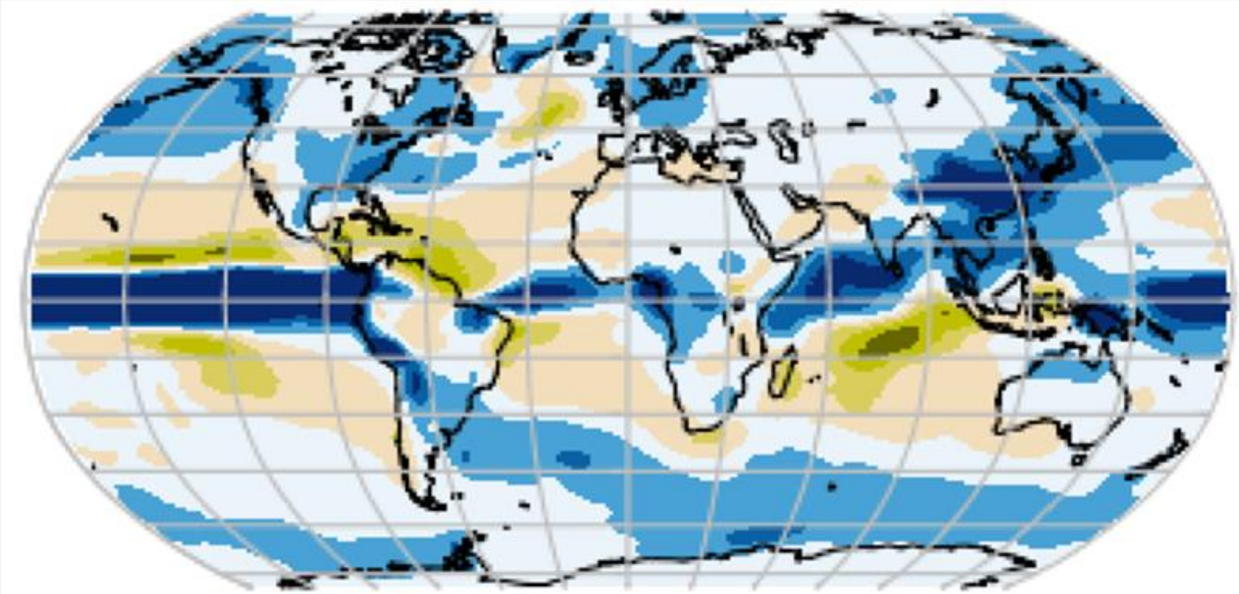
Mean temperature change, 2 C scenario, (2071-2100) – (1976-2005)



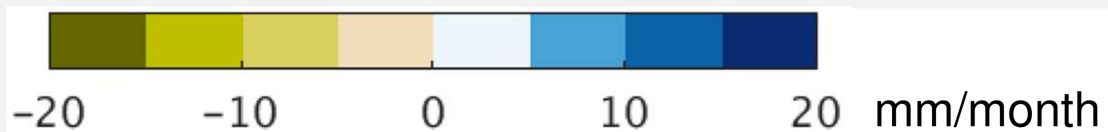
Mean temperature differences, 2 C vs 1.5 C, (2080-2100)



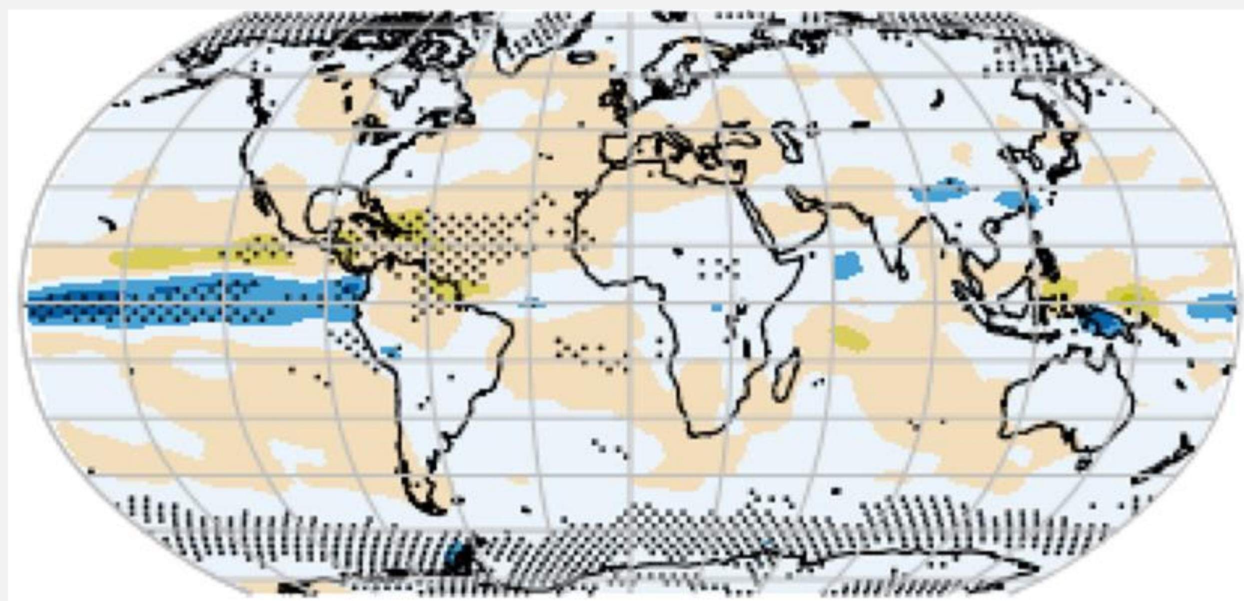
Sanderson et al., 2017



Mean preciptation change, 2 C scenario, (2071-2100) – (1976-2005)



Mean precipitation differences, 2 C vs 1.5 C, (2080-2100)



Sanderson et al., 2017

Indices of impact-relevant extremes

Temperature

- Annual max/min of daily temperature
- Warm spell duration

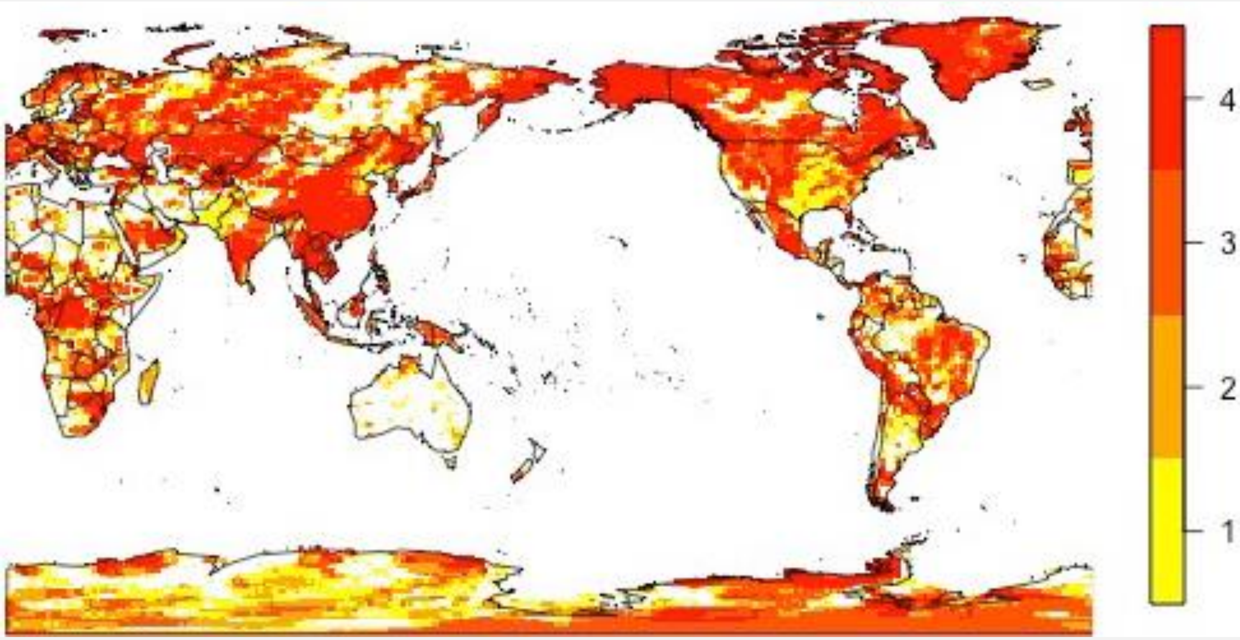
Precipitation

- Days >10mm
- Precip intensity
- Max 5-day precip
- Total precip, days >95th percentile

Agriculture-related

- Dry spell duration
- Annual frost days
- Growing season length

Aerenson et al., 2018.

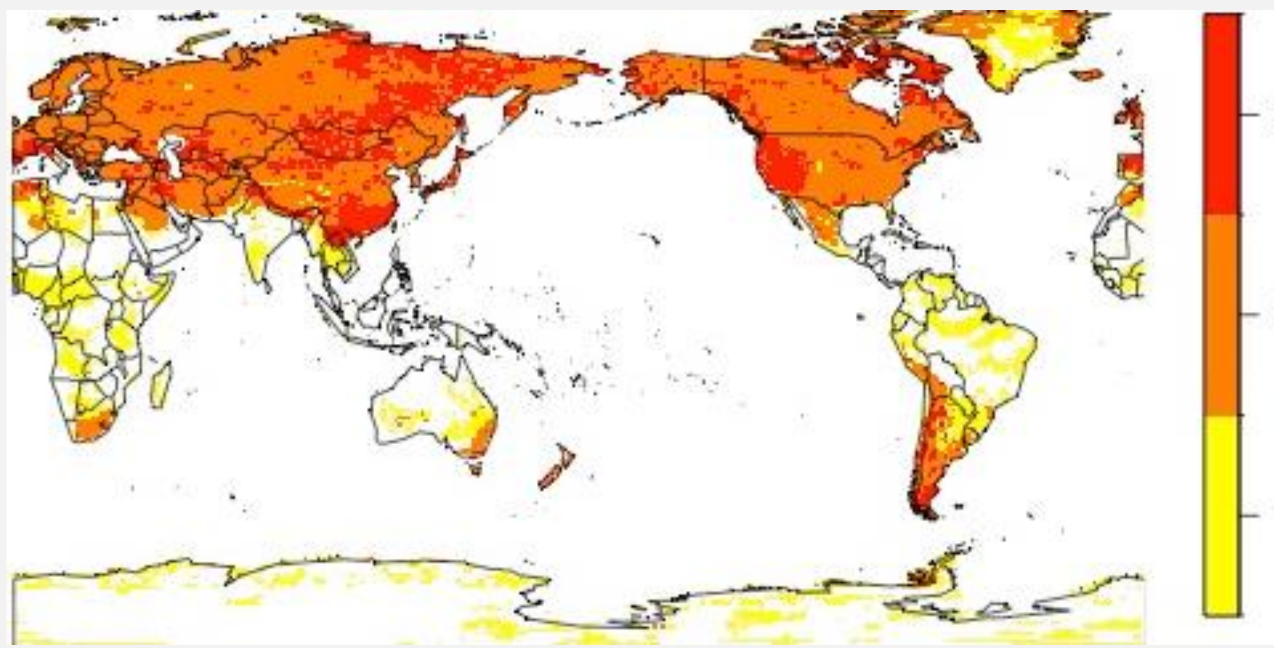


<u>Precip. Indices</u>

# of indices with stat. signif. differences in 1.5 vs 2 C scenario

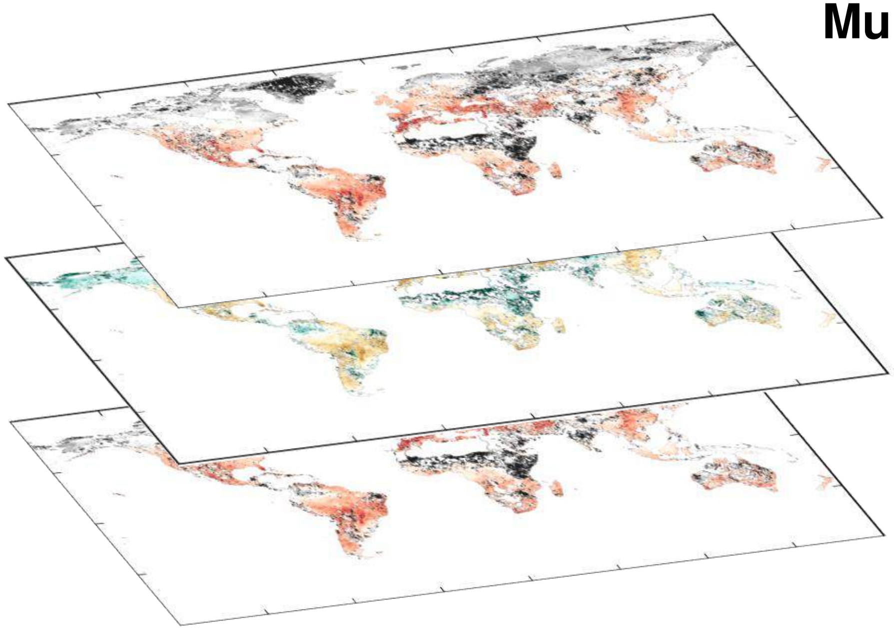
<u>Agric. Indices</u>

# of indices with stat. signif. differences in 1.5 vs 2 C scenario



Aerenson et al., 2018.

Multi-sector climate and vulnerability hotspots



Multiple indicators (14) across 3 sectors

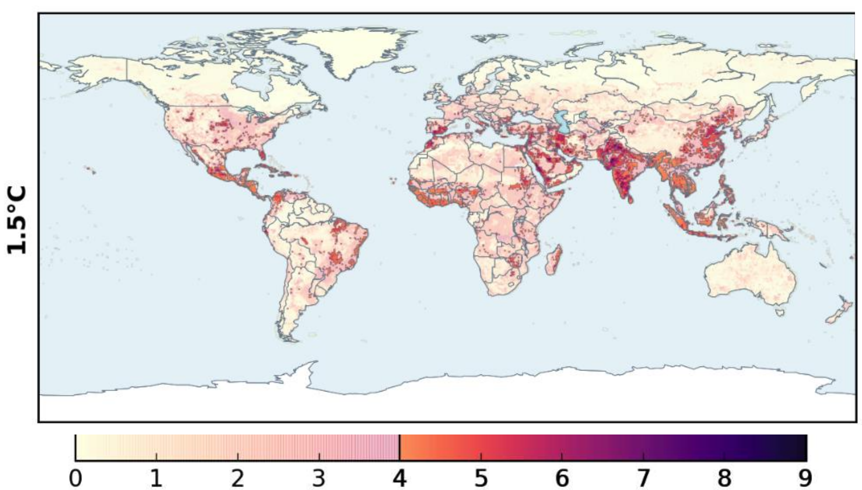
Water
- **Water scarcity**
- **Flood risk**

Energy
- **Cooling degree days**
- **Clean cooking access**

Land
- **Crop yields**
- **Habitat degradation**

1.5 °C

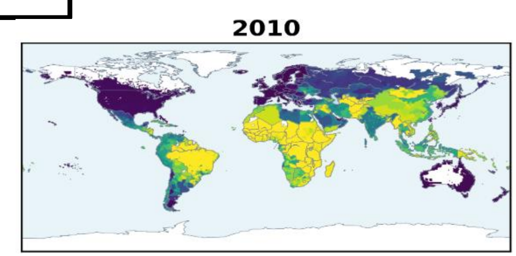
combined indicators



Hotspots of vulnerabilities and impacts

SSP1-3

Byers et al. (2017, in review)



Multi-sector climate and vulnerability hotspots

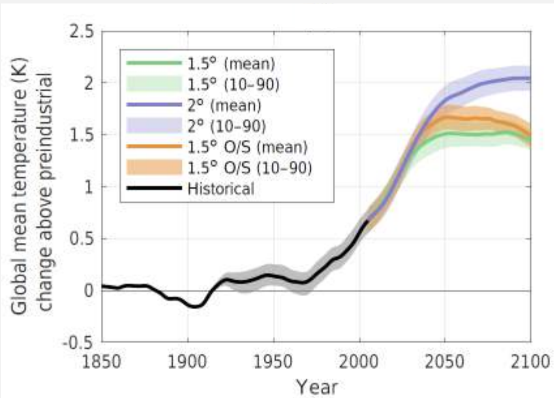
Global population exposure to substantial multi-sector risk

	1.5 C	2 C
Exposed	20%	35%
Exposed & vulnerable	3%	6%

Results more sensitive to socio-economic development pathway

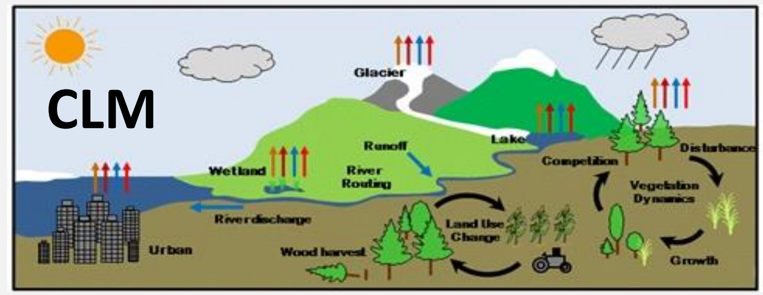
Ag & Land Use

1.5/2 C Ensembles

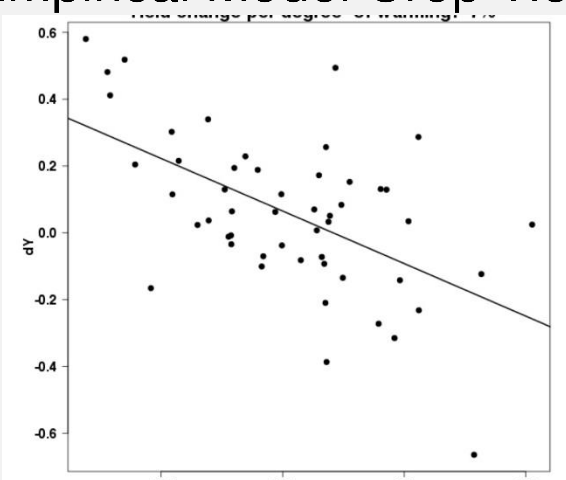


Sanderson et al., 2017

CLM Crop Yields

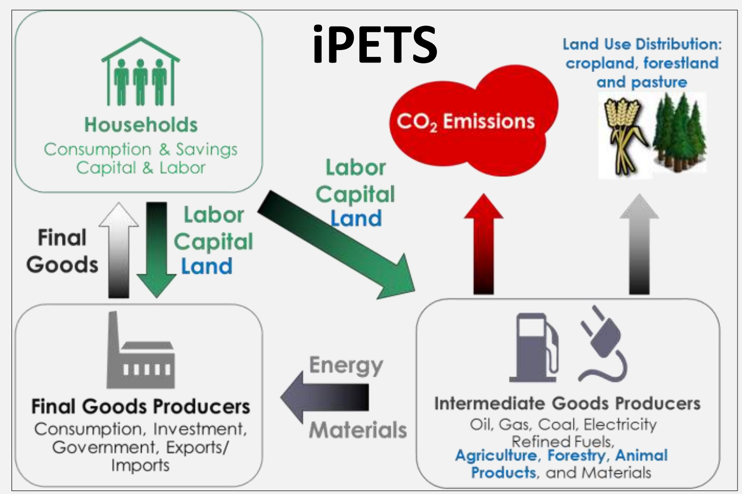


Empirical Model Crop Yields



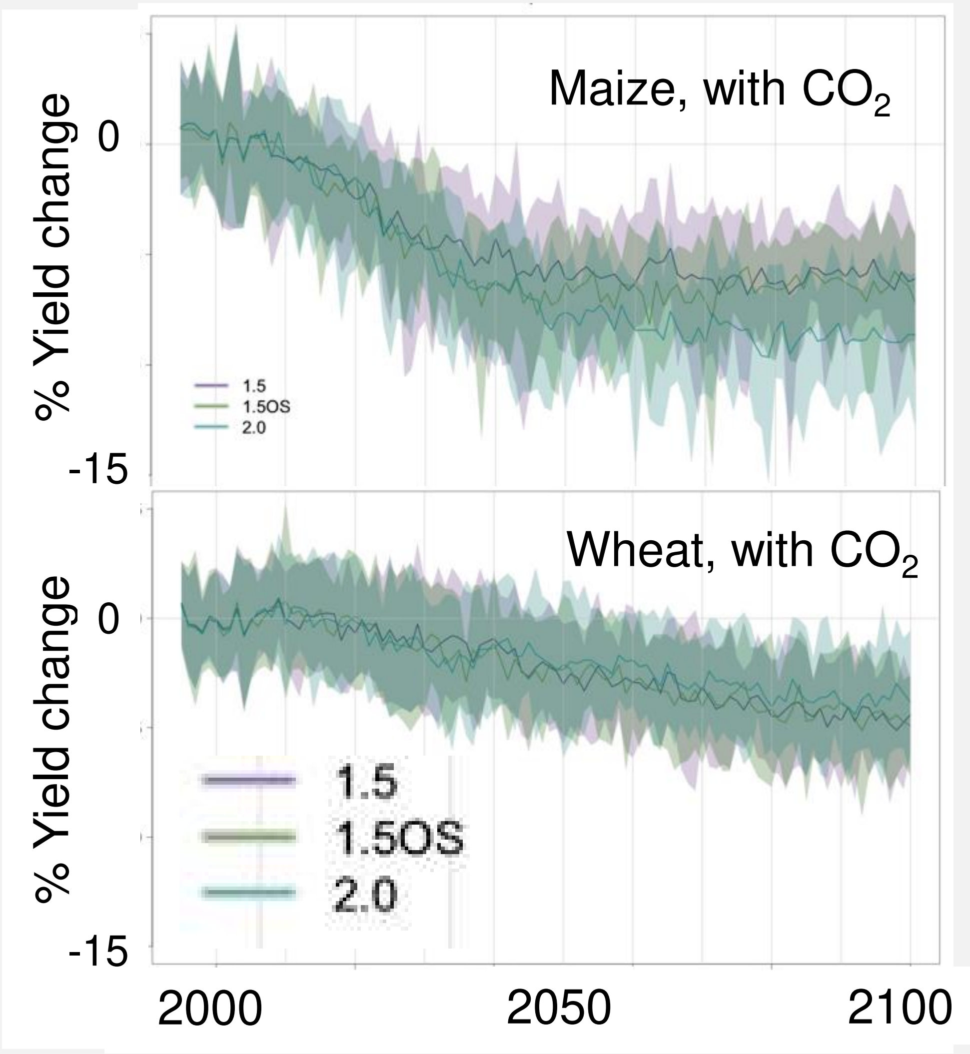
Tebaldi & Lobell, 2018.

iPETS Economic Impacts



Ren et al., subm.

Global crop yield, empirical model



Estimated from global aggregated yield and climate data, 1962-2014

<u>Projection results, 1.5 C vs 2 C</u>
<u>With CO_2 fertilization:</u>

No significant difference in wheat yields

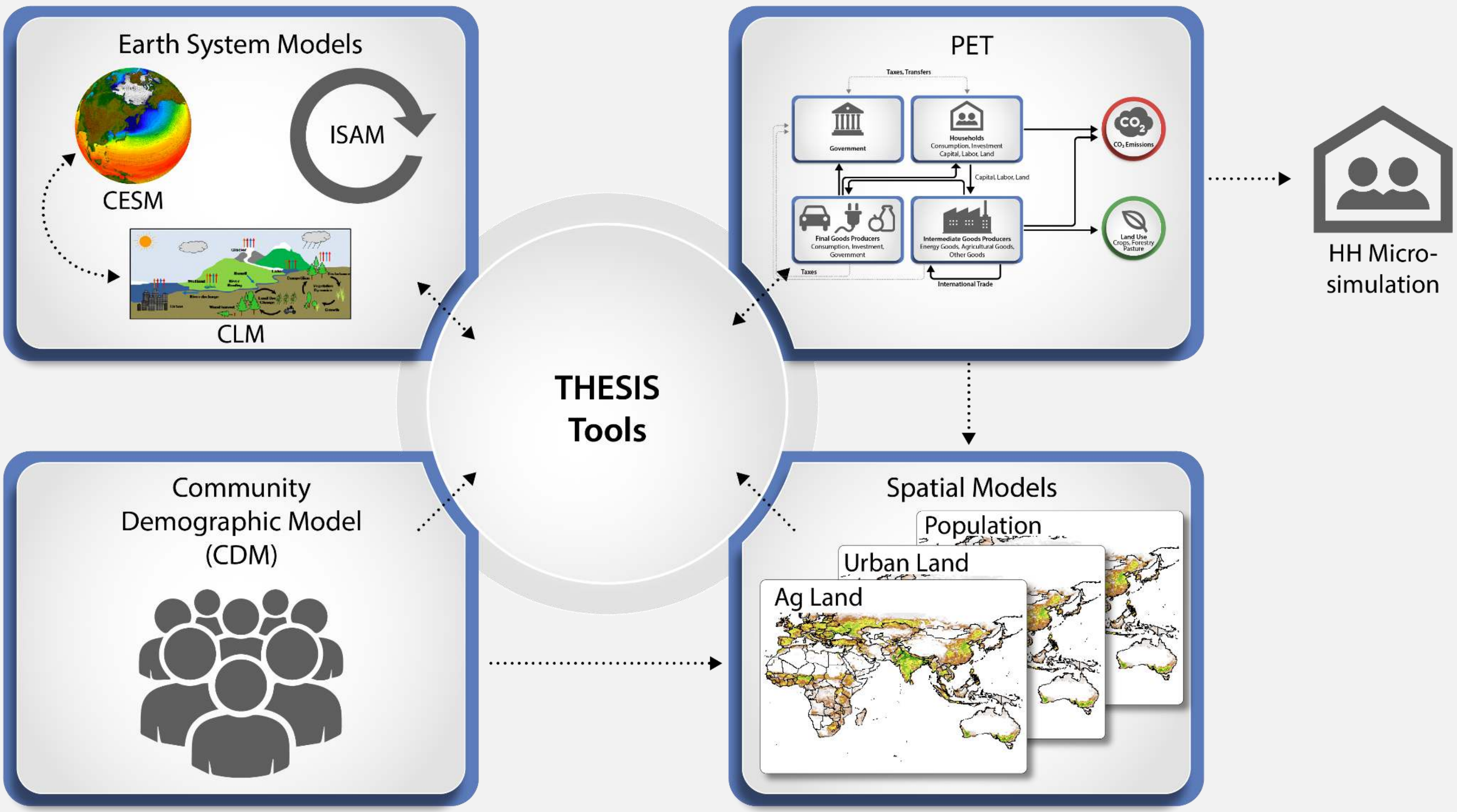
A few percent lower yields in maize

<u>Without CO_2 fertilization:</u>

A few percent lower yields for both wheat and maize

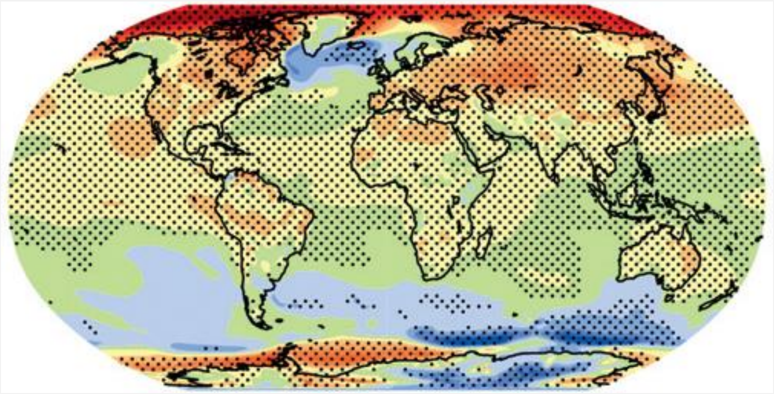
Tebaldi & Lobell, 2018.

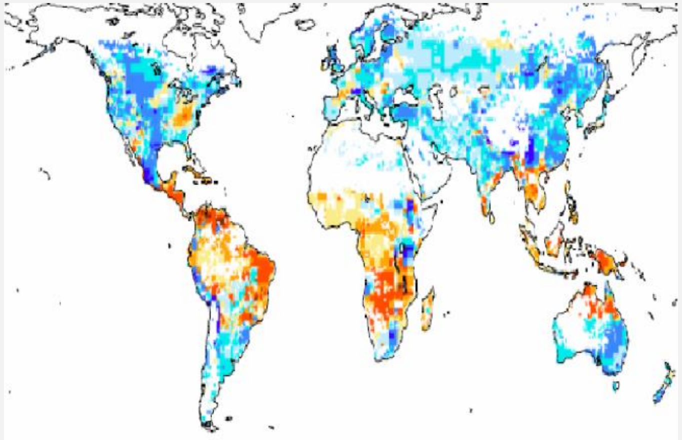
Integrated assessment framework



Community Land Model (CLM)

Climate change → Change in potential yield



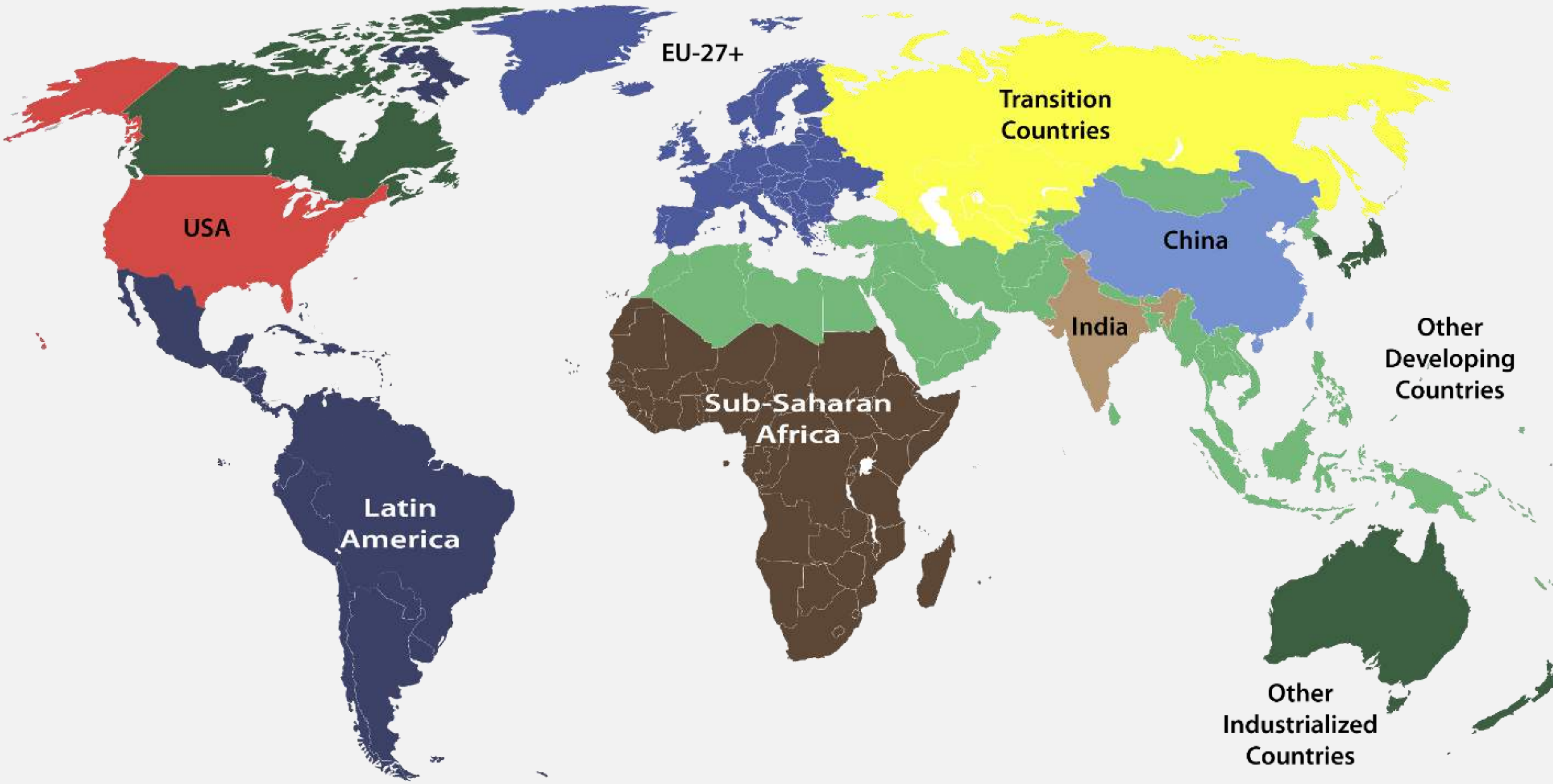


Eight crop types

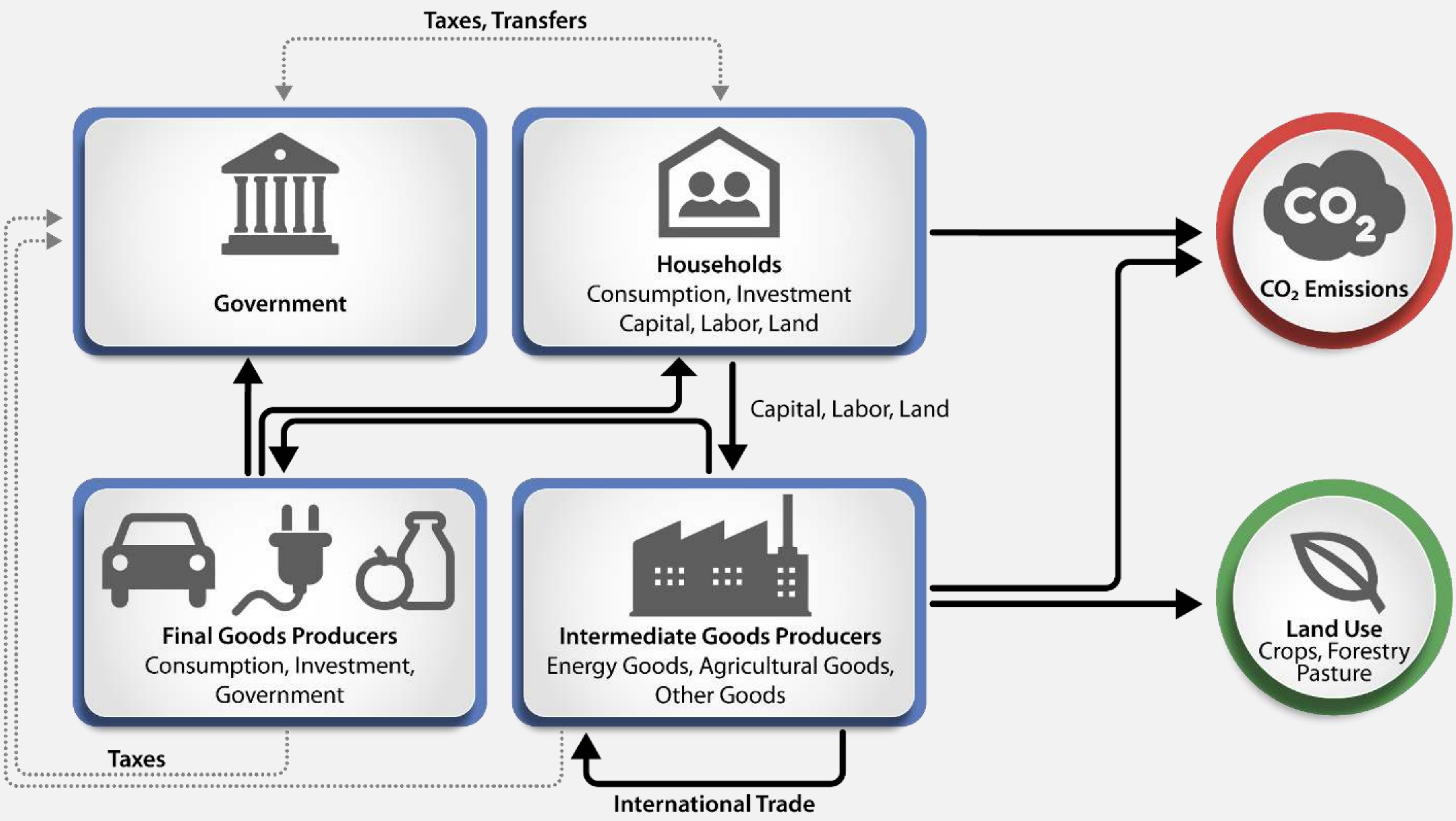
- Wheat, temperate/tropical maize, temperate/tropical soybean, rice, cotton, sugarcane

N fertilizer, irrigation

Integrated Population-Economy-Technology-Science (iPETS) Model: 9 Regions, with Trade



iPETS model structure and components



Inputs (SSP-based) → iPETS Model → Outputs

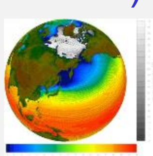
Economic **initial conditions** (region, sector)

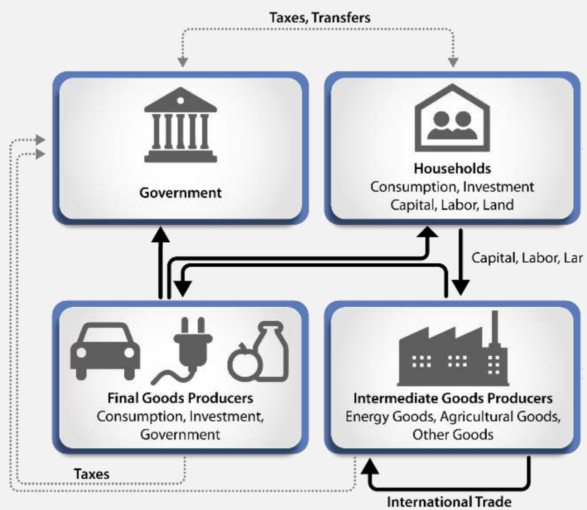
Projected **population**

Technological progress: projected productivity of land, energy, labor

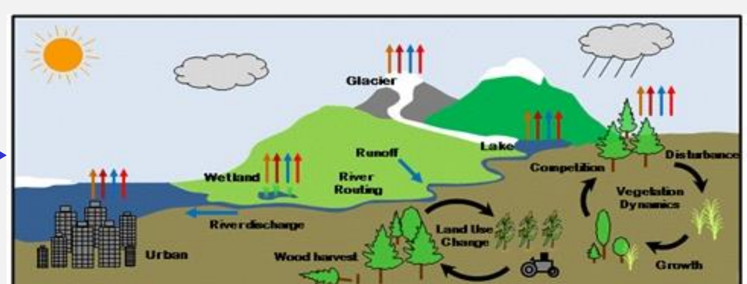
Policies (carbon tax, emissions permits, non-climate, etc.)

Climate Change (CESM)





Climate Impact on Crop Growth (Community Land Model)



Total **economic output** (GDP)

Quantities of goods produced and consumed (energy, food)

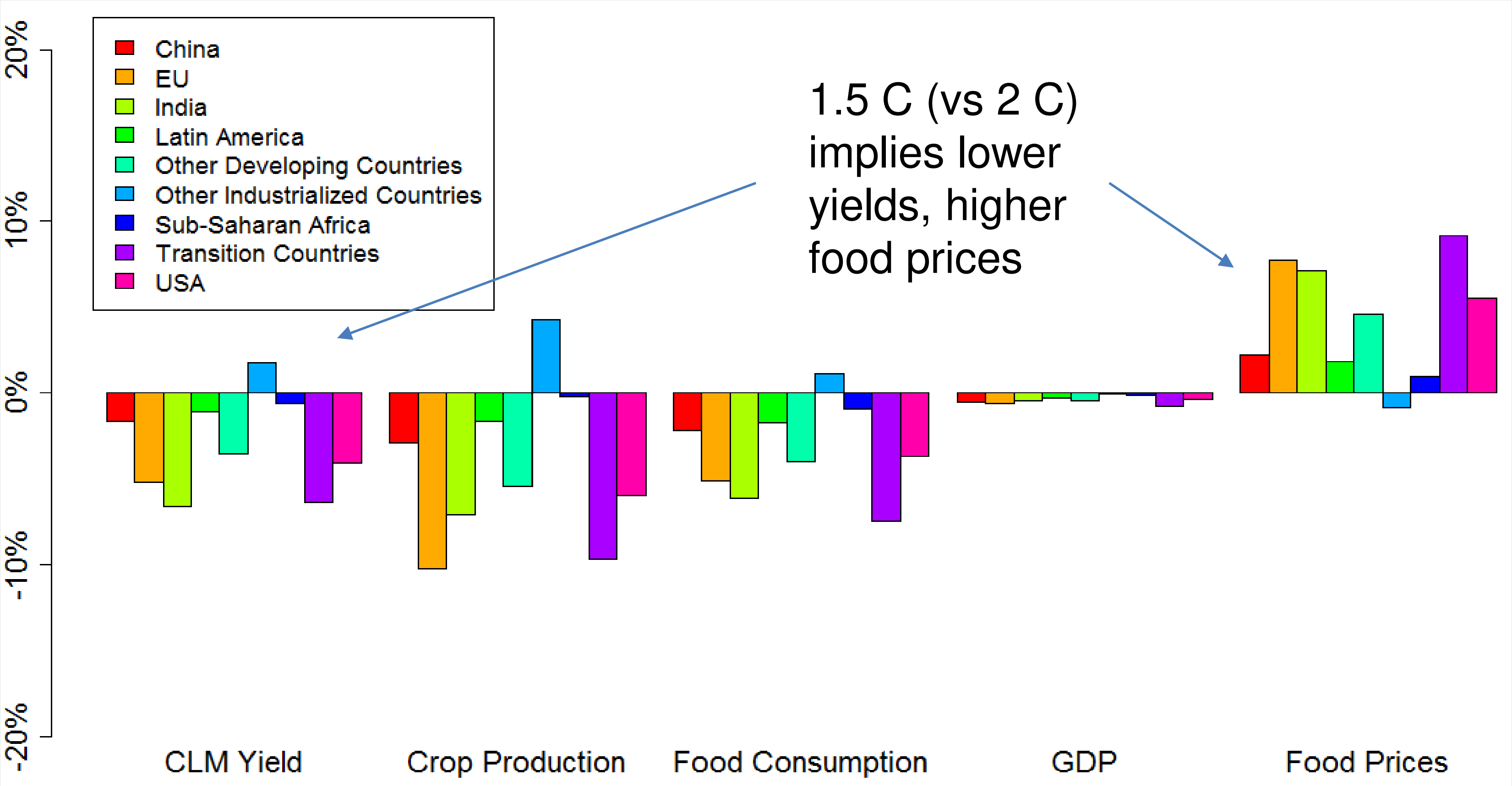
Prices of goods (energy, food)

Aggregate **land use** (cropland, pasture)

CO_2 emissions from energy use

Difference in impacts, 1.5 vs 2 C

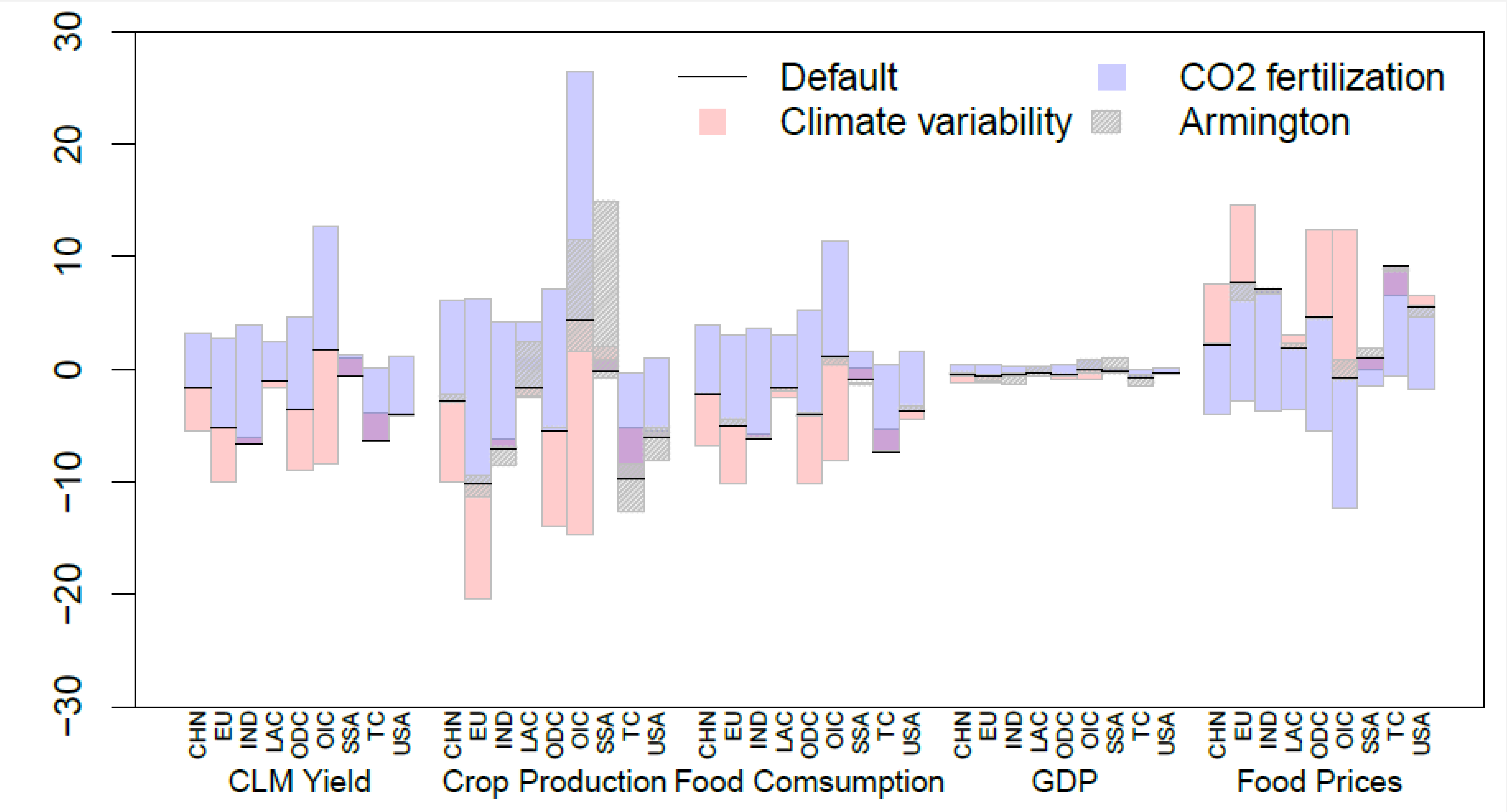
Default assumptions: With CO_2 fertilization (381 vs 443 ppm)
Armington elasticity = 2
Single CESM ensemble member



Uncertainty variants

Model	Variable	Value
Climate	CESM ensemble member	High regional temperatures
		Low regional temperatures
Crop	CO_2 fertilization	Included
		None
Economy	Trade elasticity	High (6.45)
		Medium (2.0)
		Low (0.45)

Difference in impacts, all uncertainties



iPETS agriculture conclusions

- Sign of change in regional agricultural impacts between 1.5 and 2 C scenario is uncertain
- Largest source of uncertainty is CO_2 fertilization
- Caveats:
  - Single climate model and crop model
  - Treatment of mitigation
  - Additional uncertainties in economic model

BRACE 1.5 Conclusions

Temperature & precipitation:

Means and many extremes differ significantly.
Implication for impacts?

Agriculture

Aggregate impact differences small or of uncertain sign

Building energy

Small differences in economic impacts

Exposure to multi-sector risks

Substantial differences in exposure

BRACE1.5

Benefits of Reduced
Anthropogenic Climate Change

Do impacts differ substantially between 1.5 and 2 C of warming?

A special collection in Environmental Research Letters

K. Ebi & S. Gourdji, Guest Editors

Climate:	Climate simulations to assess impacts (Sanderson et al.)
	Approximating low warming scenarios (Tebaldi & Knutti)
Extremes:	Changes in extreme temp/precip (Aerenson et al.)
Health:	US heat wave-related mortality (Anderson et al.)
Agric.:	Economic & biophysical impacts on agriculture (Ren et al.)
	Empirically modeled differences in yields (Tebaldi & Lobell)
Energy:	Economic impacts of energy demand changes (Chan et al.)
Multiple:	Exposure/vulnerability to climate hotspots (Byers et al.)