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The high relevance of the biogeophysical impacts of land use change in low emission scenarios

GEWEX Conference – May 2018

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Annette L. Hirsch, Sonia I. Seneviratne, Jonathan Doelman, Lena Boysen, Victor Brovkin, Detlef van Vuuren, Elke Stehfest, Urs Beyerle, Edouard L. Davin, H. J. Kim, D. Mitchell, T. Nitta, G. Shiogama, S. Sparrow, S. Wilson

1.5 vs 2 degrees and land-use change

- Paris agreement: Limiting global warming to well below 2 degrees & pursue efforts towards 1.5 degrees
- Require substantial mitigation efforts, including land-use change, e.g.,
  - Increasing terrestrial carbon sequestration through reforestation or changes in agricultural management
  - Transitioning away from fossil fuels towards bioenergy/CCS
- Additionally, increasing demand for food also imply LUC (food crops, grazing of livestock, …)

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Land-use scenarios for 1.5 / 2 degrees?

IMAGE land-use scenarios

SSP1
'Sustainability'

SSP2
'Middle of the Road'

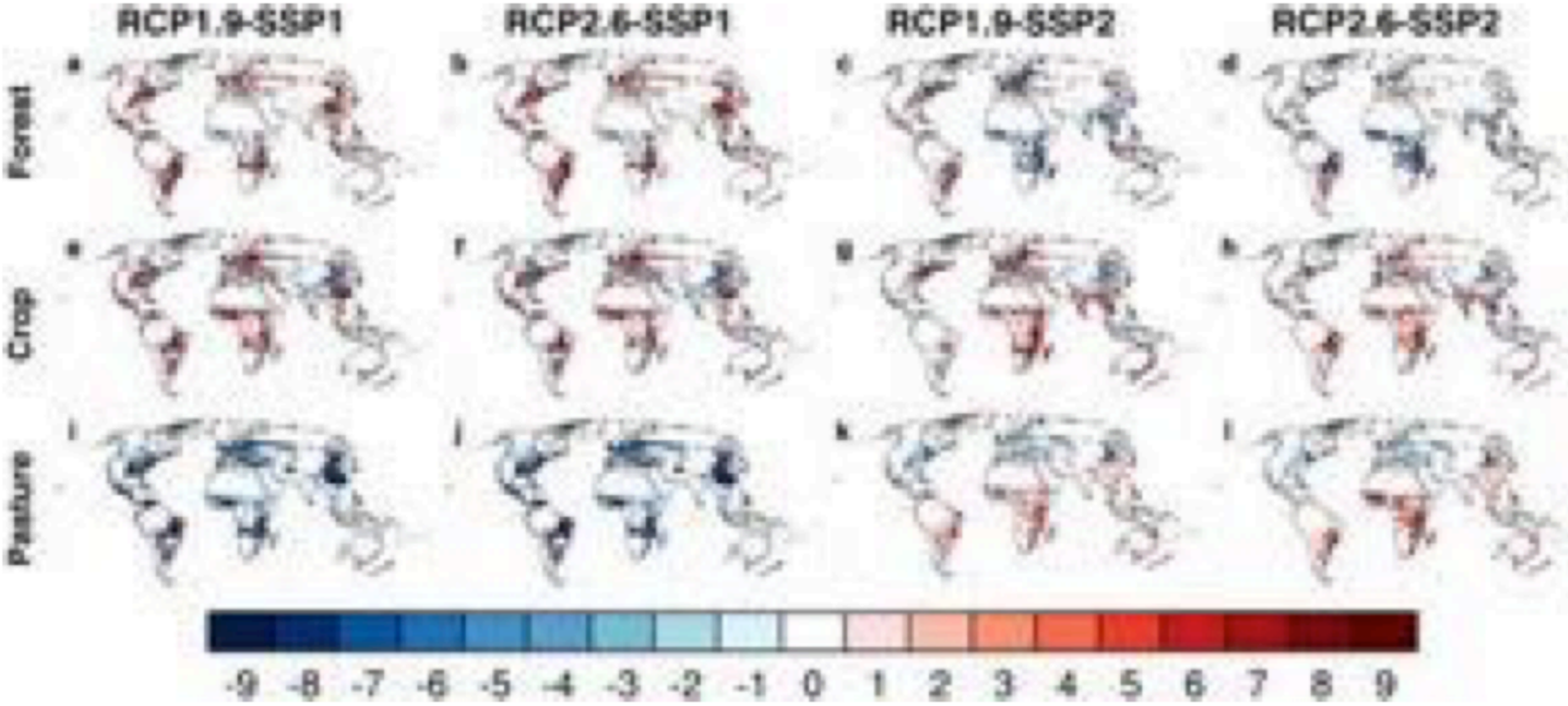

IMAGE land-use scenarios

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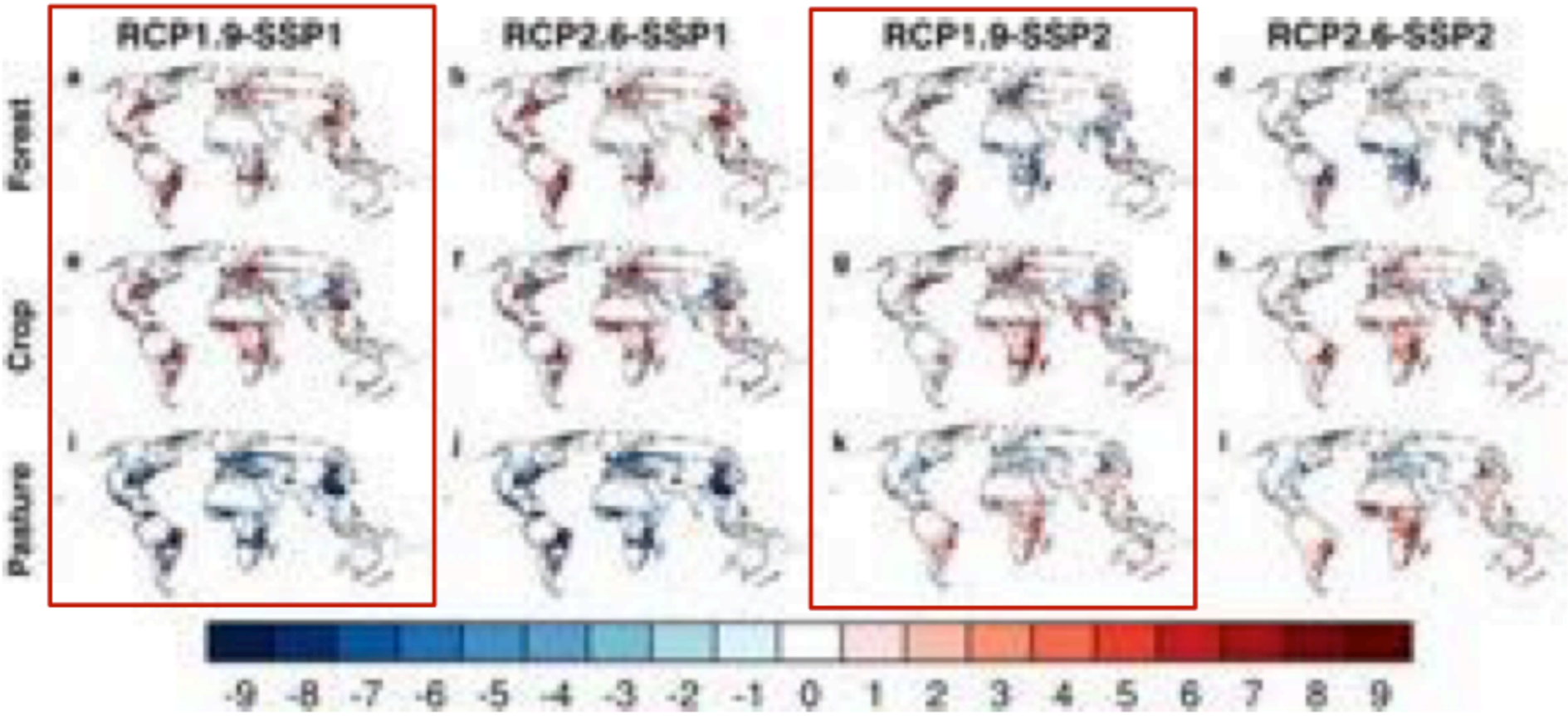
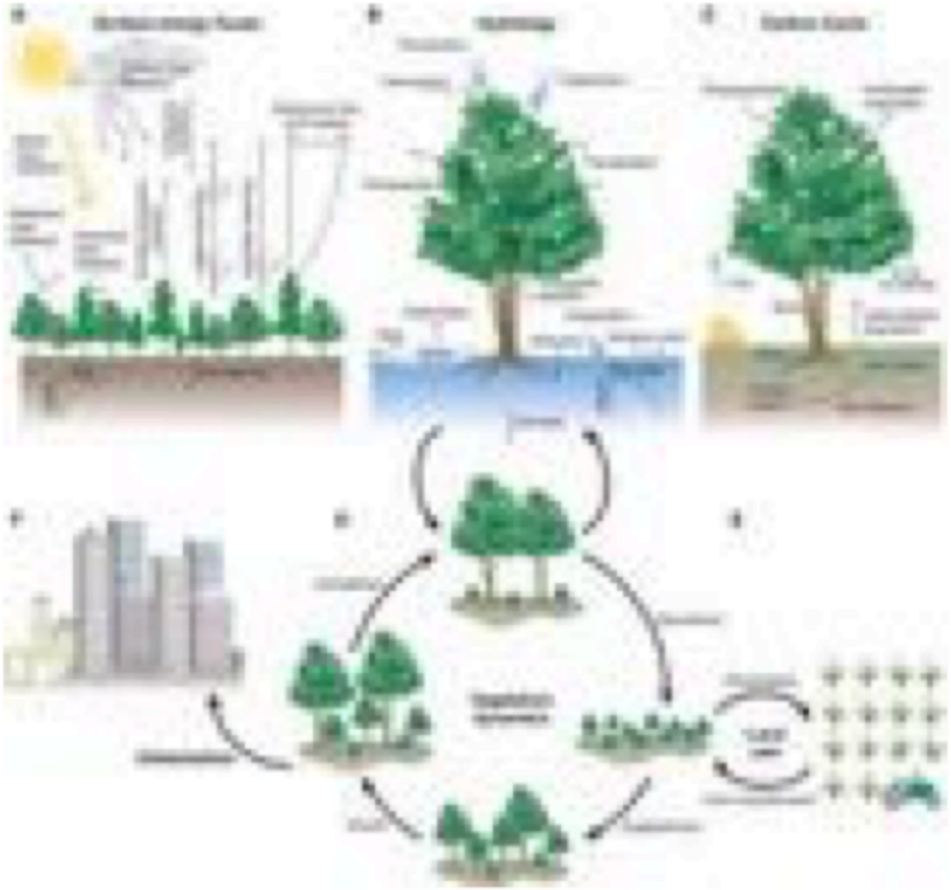
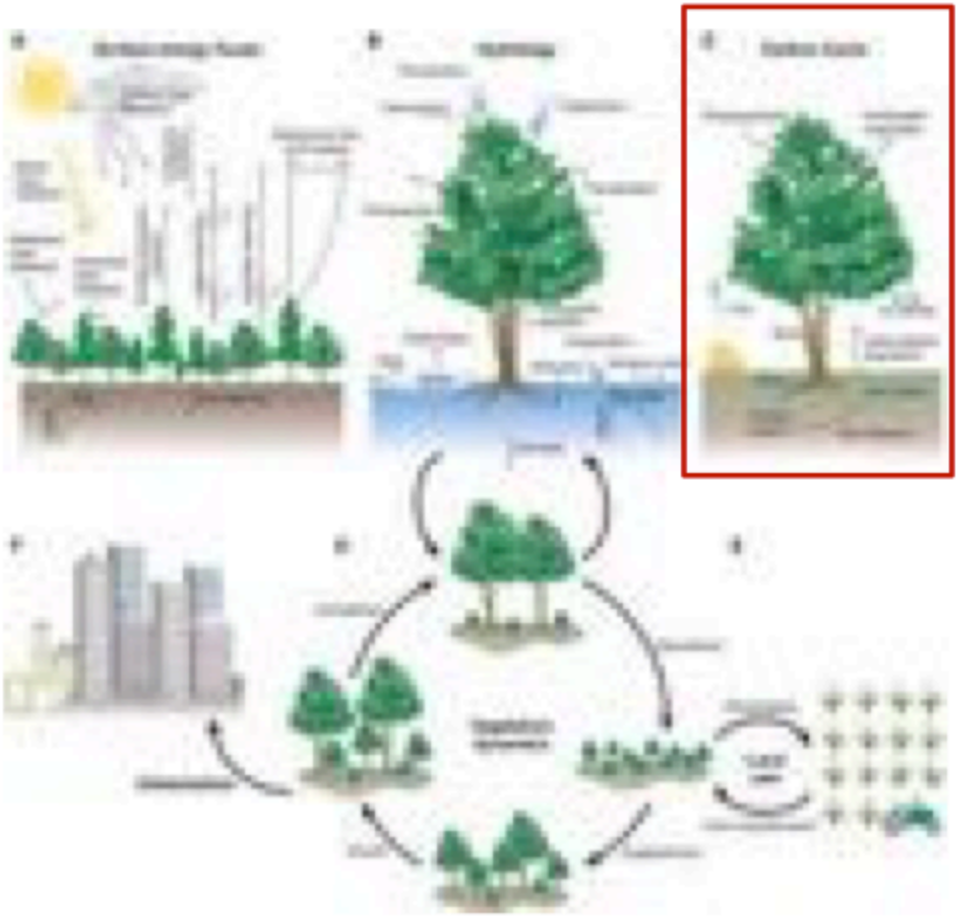


LUC: biogeochemical vs biogeophysical effects



Bonan, 2008

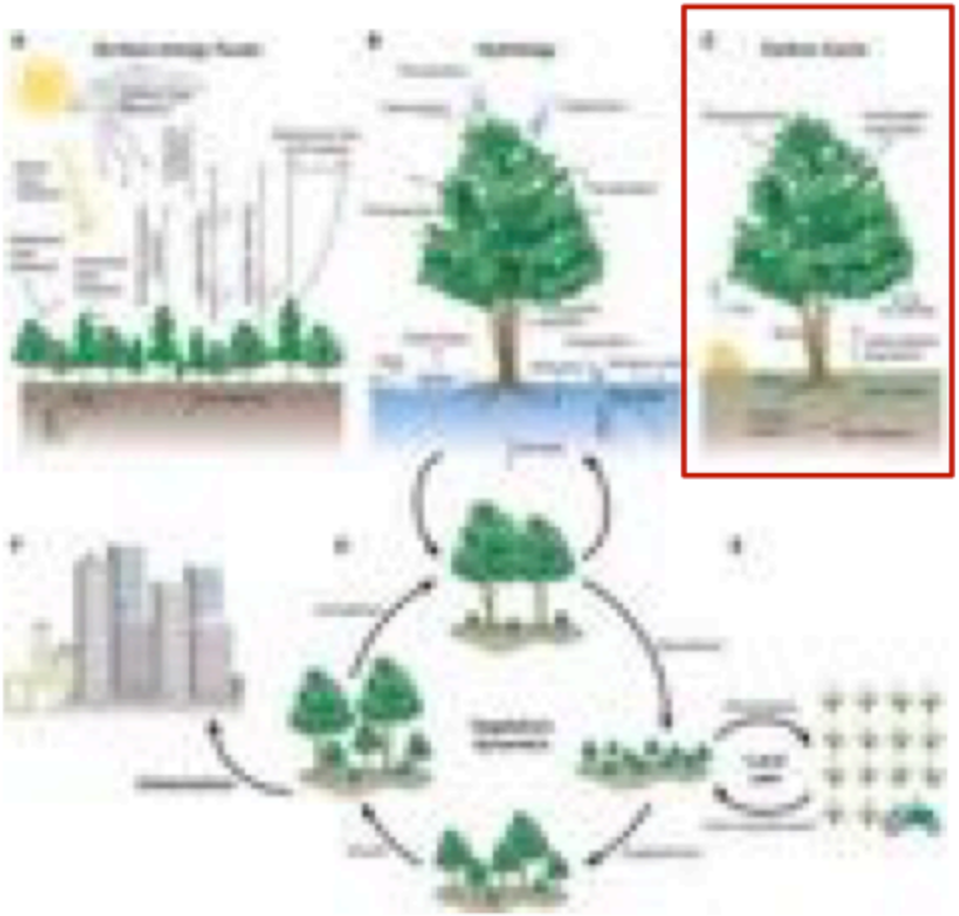
LUC: biogeochemical vs biogeophysical effects



Bonan, 2008

- Biogeochemical effects:
  - Carbon cycle

LUC: biogeochemical vs biogeophysical effects



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- Biogeochemical effects:
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  - ➢ Accounted for in IAMs

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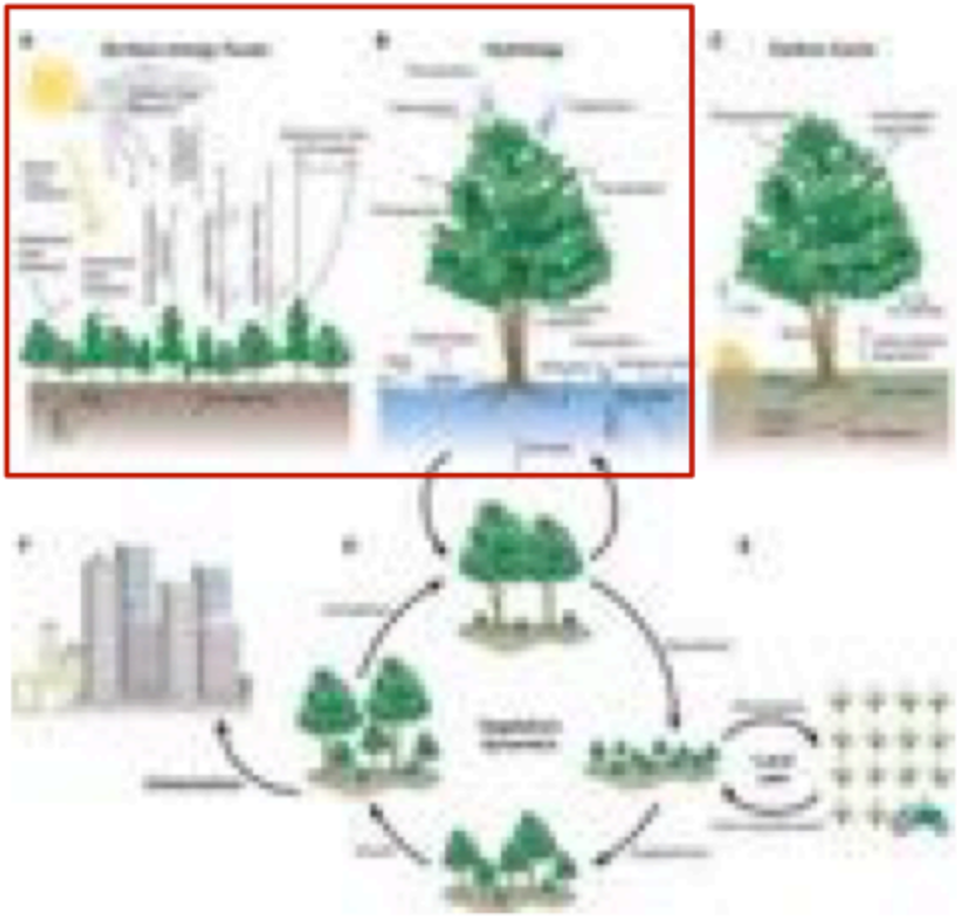

Bonan, 2008

- Biogeochemical effects:
  - Carbon cycle
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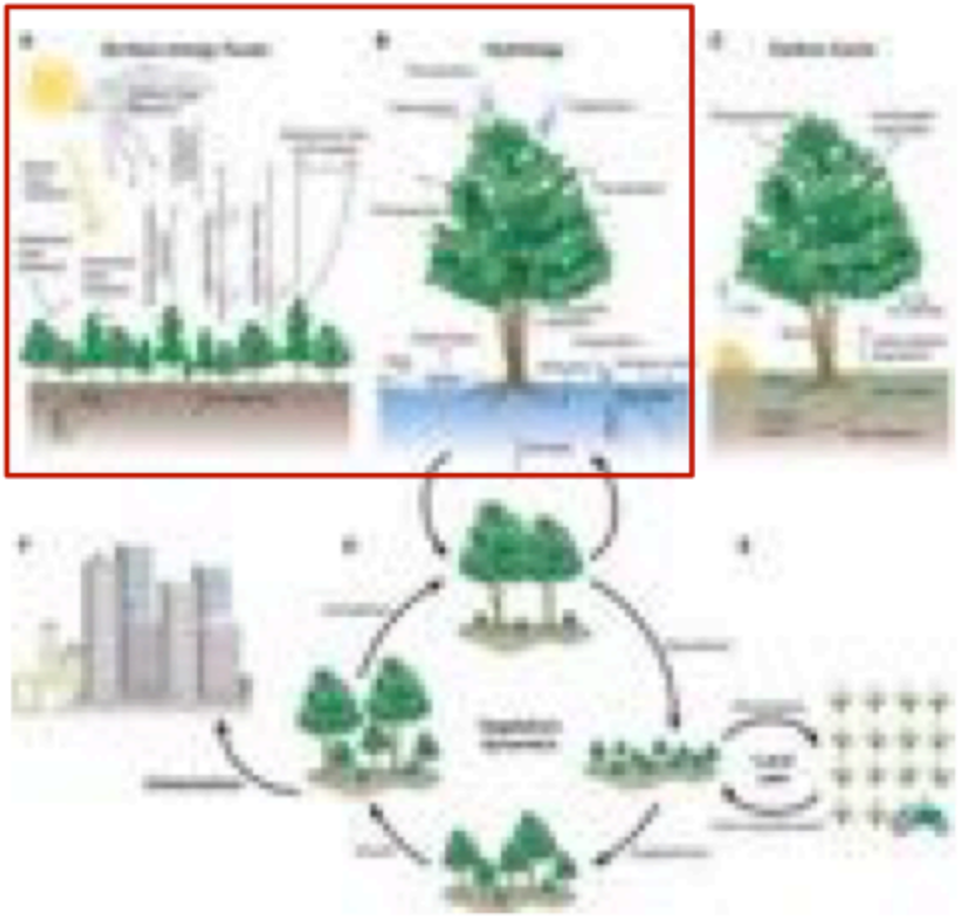
- Biogeophysical effects:
  - Albedo
  - Evapotranspiration/latent heat flux
  - Surface roughness

LUC: biogeochemical vs biogeophysical effects



Bonan, 2008

- ❑ Biogeochemical effects:
  - Carbon cycle
  - ➢ Accounted for in IAMs
- ❑ Biogeophysical effects:
  - Albedo
  - Evapotranspiration/latent heat flux
  - Surface roughness
  - ➢ Unaccounted for in IAMs

Main research question

How important are biogeophysical effects of land-use change for low emission scenarios?

Focus on hot extremes (TXx)

HAPPI

- HAPPI = Half a degree Additional warming, Prognosis and Projected Impacts (www.happimip.org)
- Aim: To evaluate the difference in impacts between 1.5˚C and 2˚C end of the century climates
- AMIP simulations
- 50-100 ensemble members per experiment
- 3 Experiments:
  - Present Decade ('Hist', 2006-2015)
  - 1.5˚C ('Plus15')
  - 2˚C ('Plus20')
- Land use set to 2095 values from RCP2.6 for 1.5˚C and 2˚C experiments
- Natural forcings set to Hist values in all experiments

HAPPI-LAND

Additional 1.5˚C and 2˚C simulations with altered land-use:

- Present-day Land Use
- SSP1 Land Use (IMAGE IAM, RCP 1.9)
- SSP2 Land Use (IMAGE IAM, RCP 1.9)

Summary of All Experiments Performed for HAPPI-Land

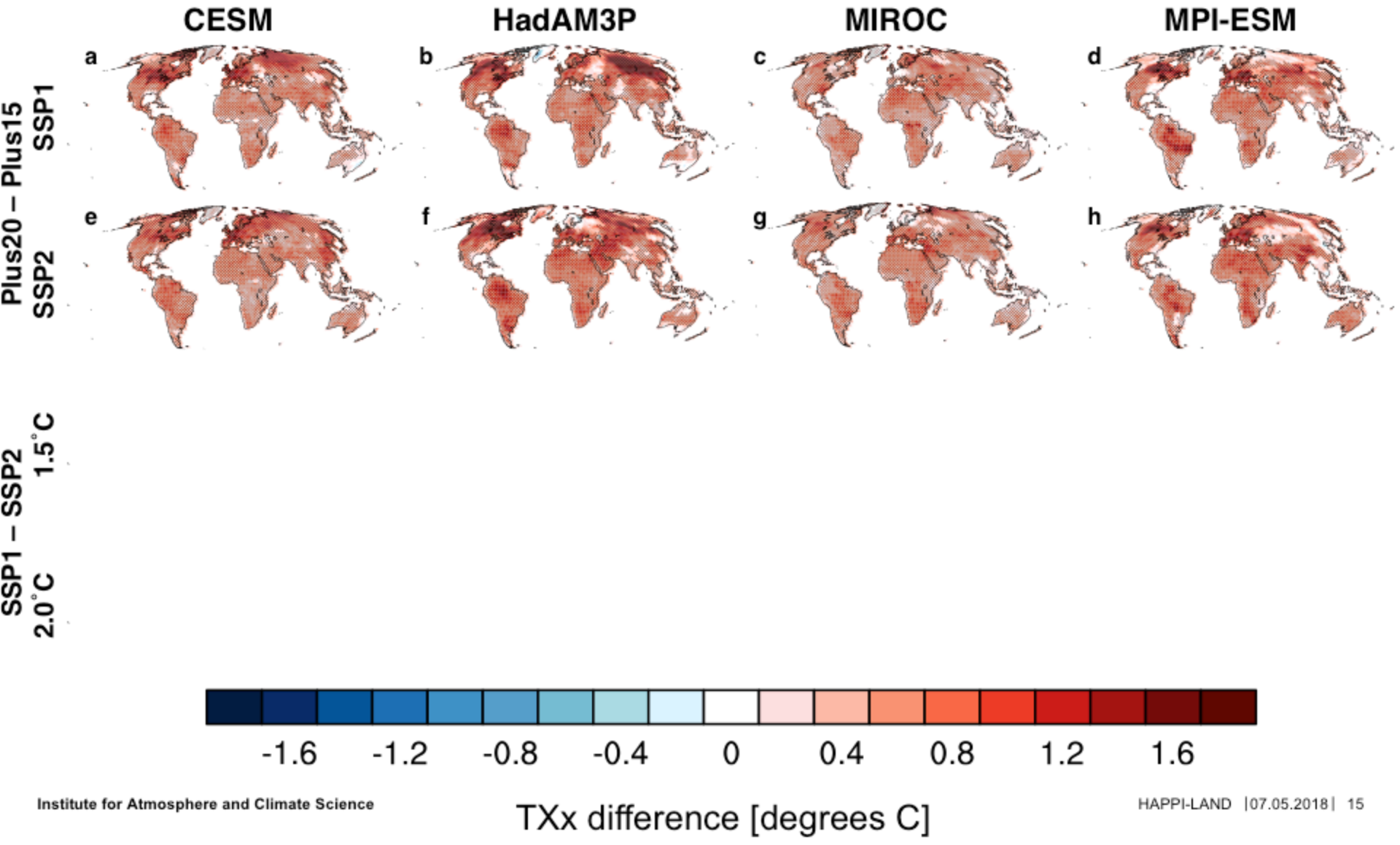
Project	Ensemble name	Climate forcing[a]	Land use
HAPPI[b]	Hist	Hist	Hist
HAPPI-LAND	$Plus15_{Hist}$	Plus15	Hist
	$Plus20_{Hist}$	Plus20	Hist
	$Plus15_{SSP1}$	Plus15	SSP1[c]
	$Plus20_{SSP1}$	Plus20	SSP1[c]
	$Plus15_{SSP2}$	Plus15	SSP2[c]
	$Plus20_{SSP2}$	Plus20	SSP2[c]

GCMs

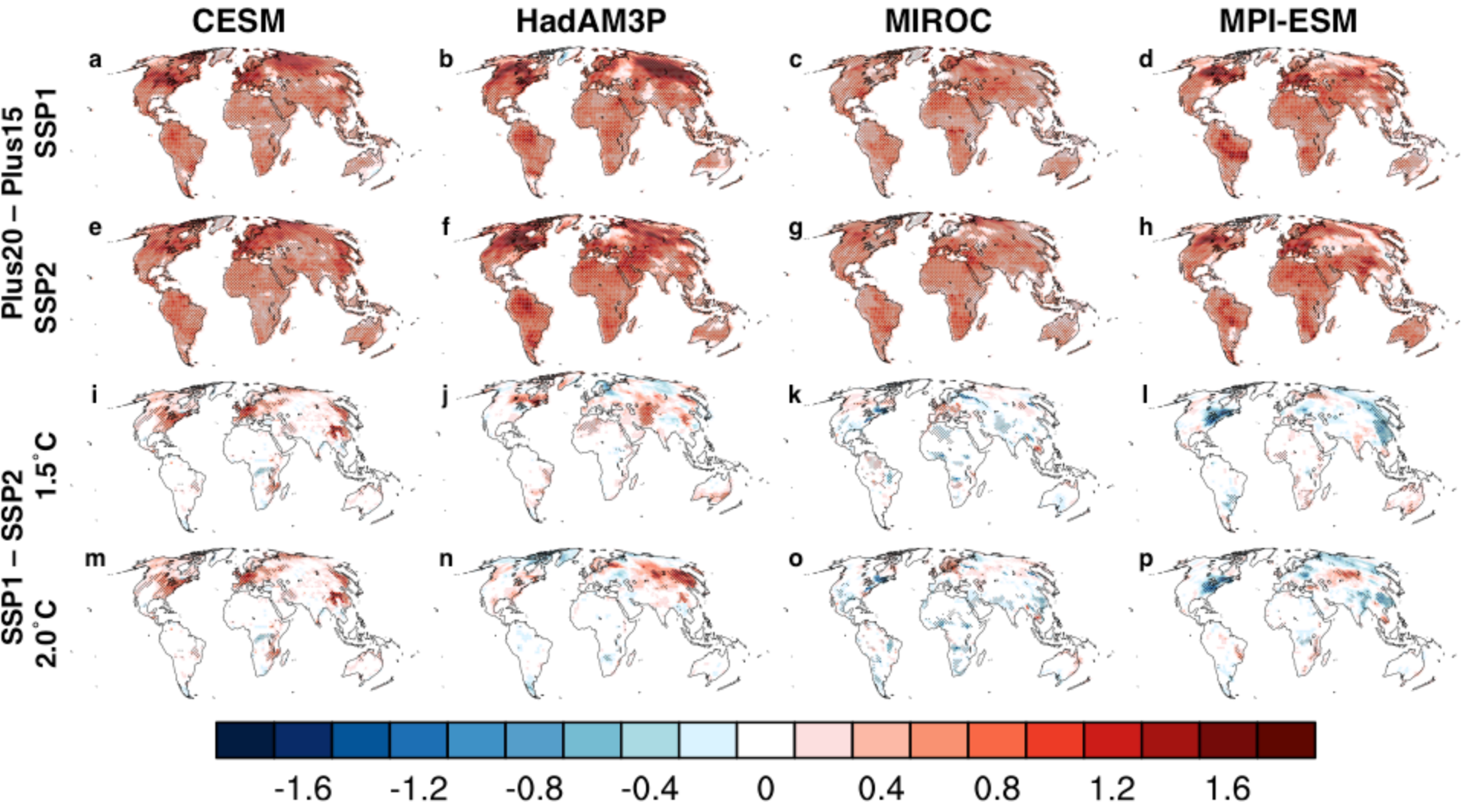
Climate Models Contributing to HAPPI-Land

Model	Version	Resolution (longitute × latitude)	Model years per experiment	References
CESM	CAM4 CLM4CN	2° × 2°	200	Neale et al. (2013)
HadAM3P	2 MOSES2	1.88° × 1.25°	300	Guillod et al. (2017)
MIROC	5	150 × 150 km	200	Shiogama et al. (2014)
MPI-ESM	ECHAM6.3	1.9° × 1.9° (T63)	100	Giorgetta et al. (2013)

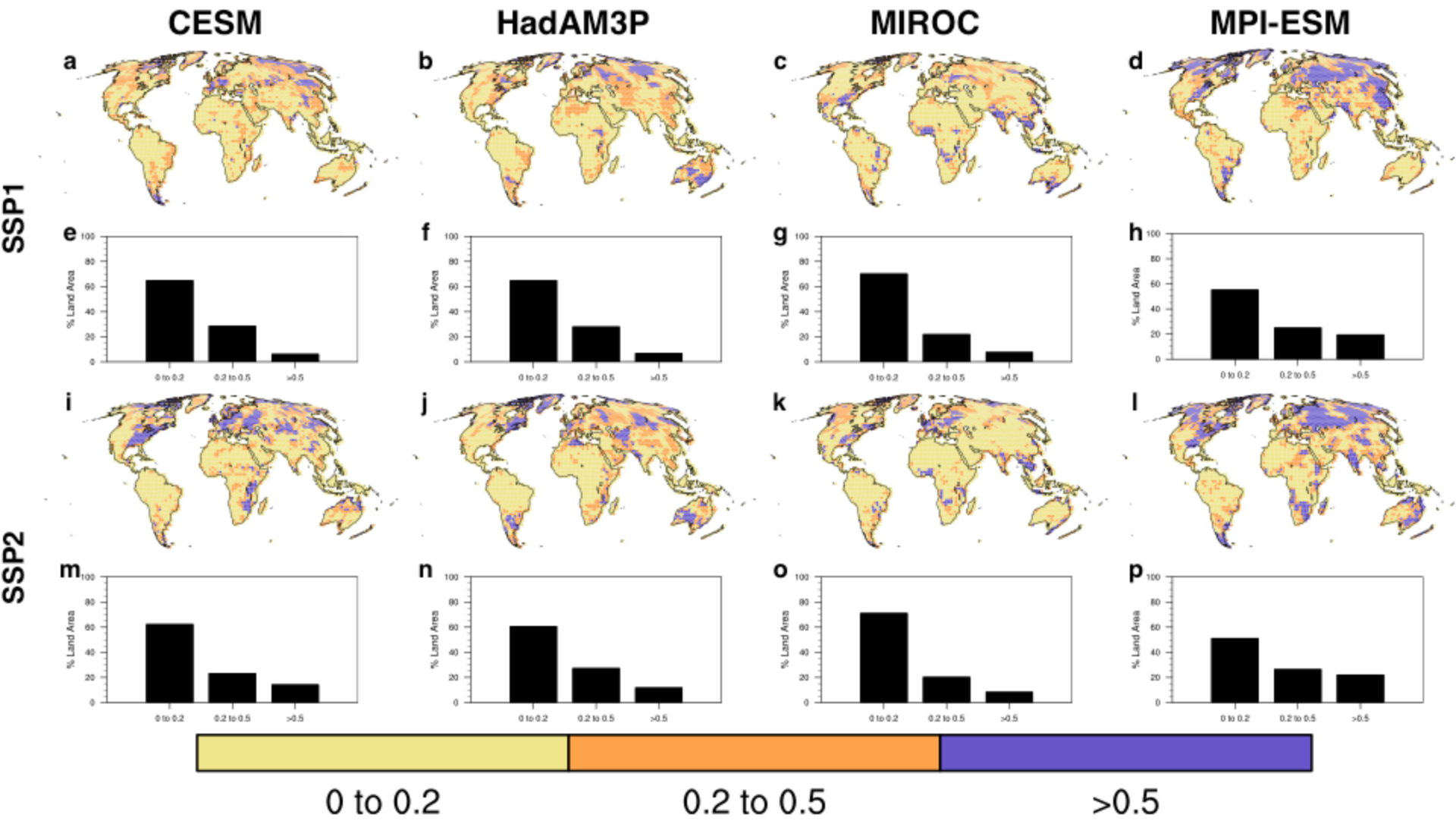
1.5 vs 2 degrees / SSP1 vs SSP2



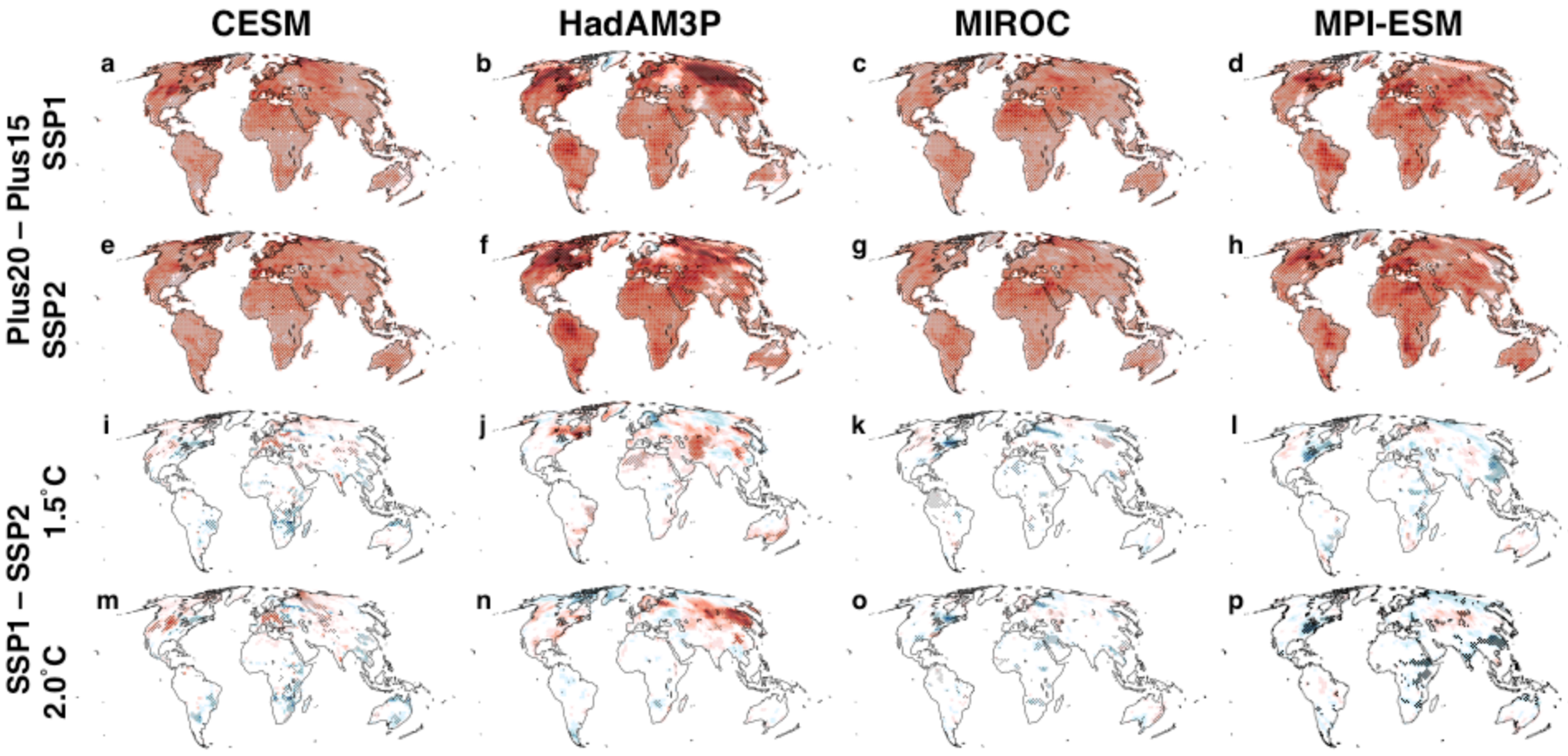
1.5 vs 2 degrees / SSP1 vs SSP2



Ratio of LUC effect to total effect (Plus15)

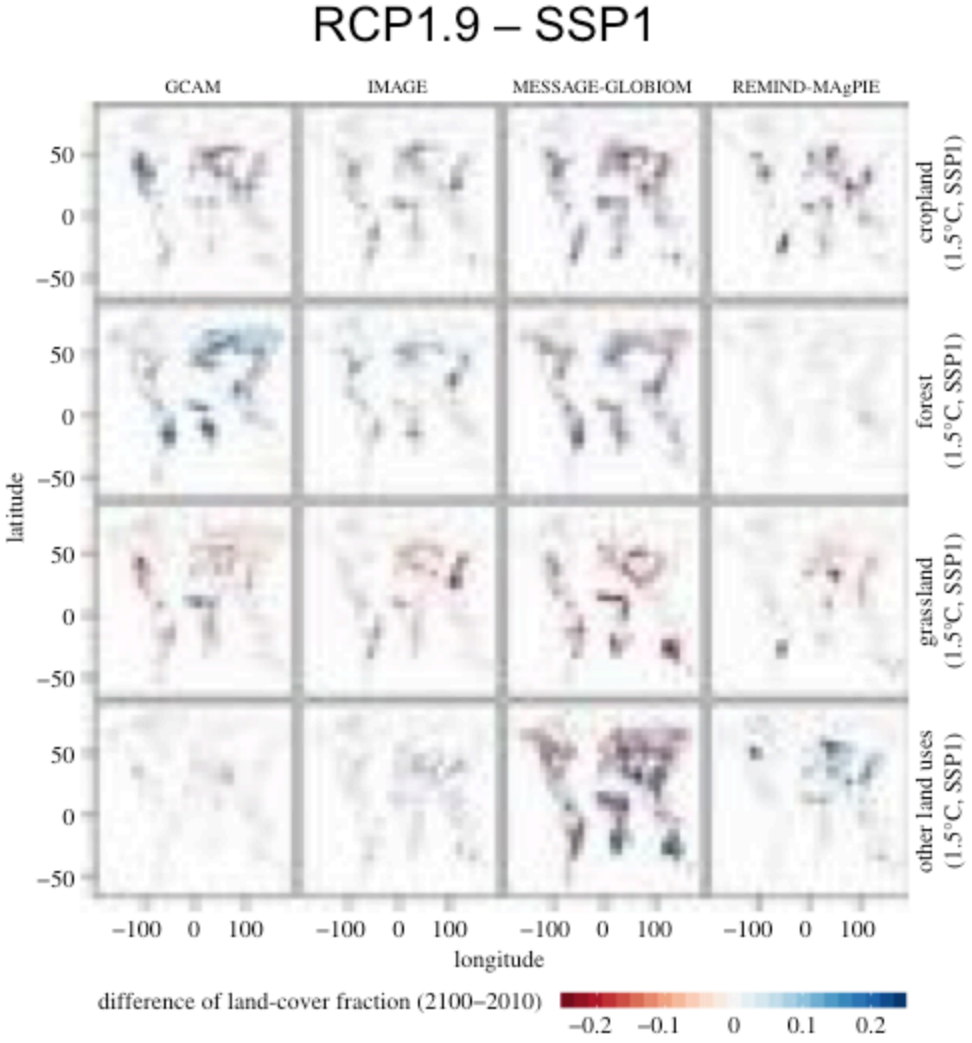


Cold extremes (TNn)



Summary & Outlook

- Biophysical effect of land-use change is critical for hot extremes in low emission scenarios
- Large model uncertainties in the sign and strength of the effect (e.g., LUCID)
- Additional uncertainty from IAM land-use change scenario



Seneviratne et al. (2018), Phil. Trans. A

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AGU PUBLICATIONS

Earth's Future

RESEARCH ARTICLE

10.1002/2017EF000744

Biogeophysical Impacts of Land-Use Change on Climate Extremes in Low-Emission Scenarios: Results From HAPPI-Land

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Key Points:
- Land-use change (LUC) accounts for 20% change in temperature extremes for low-emission scenarios
- Multimodel results show projected temperature extremes depend on where and what land-based mitigation activities are pursued
- For some regions and models, LUC can affect temperature extremes as much as a half degree change in global mean temperature

Supporting Information:
- Supporting Information:
- Figure S1.

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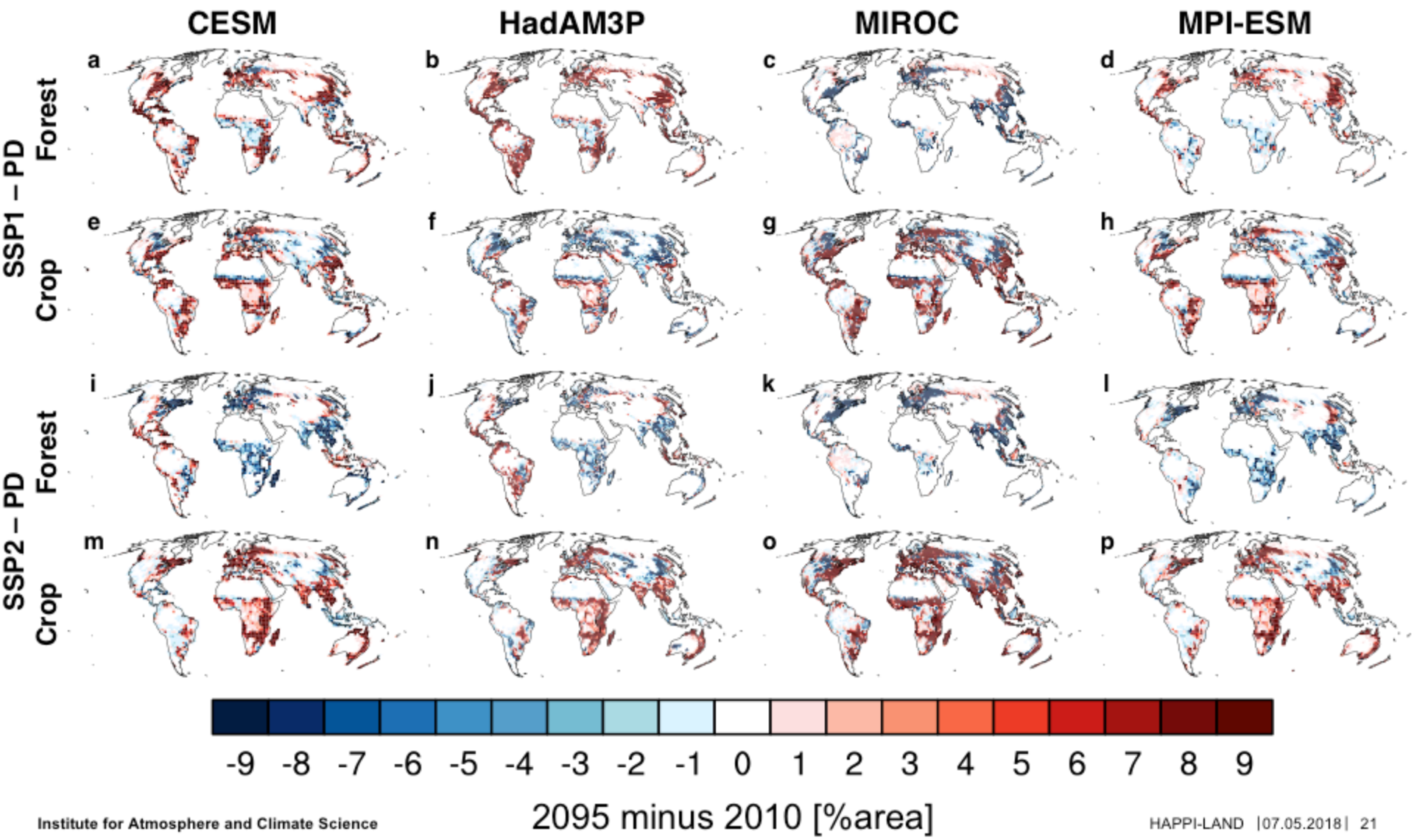
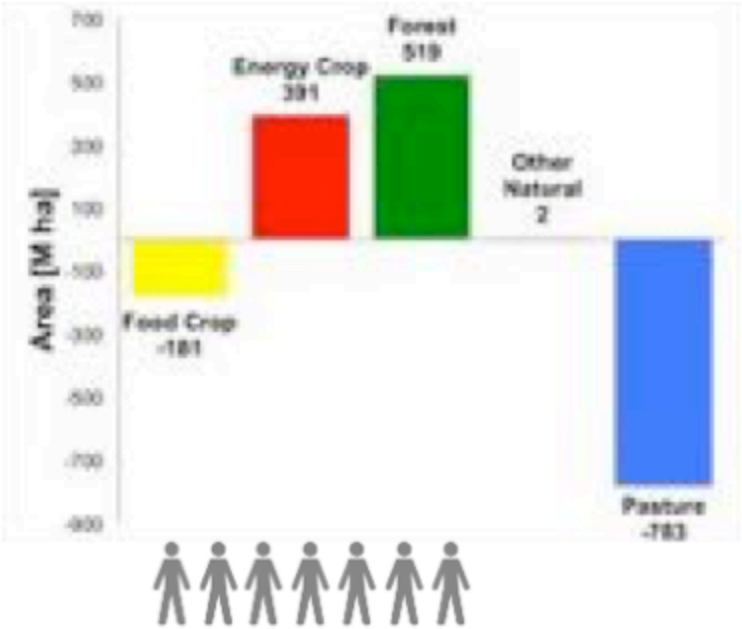
Multi-model imposed LUC

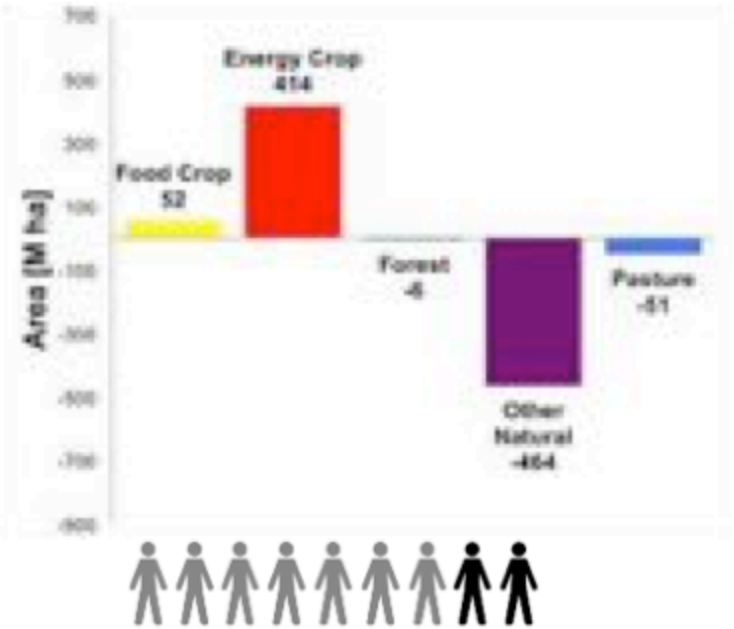


SSPs

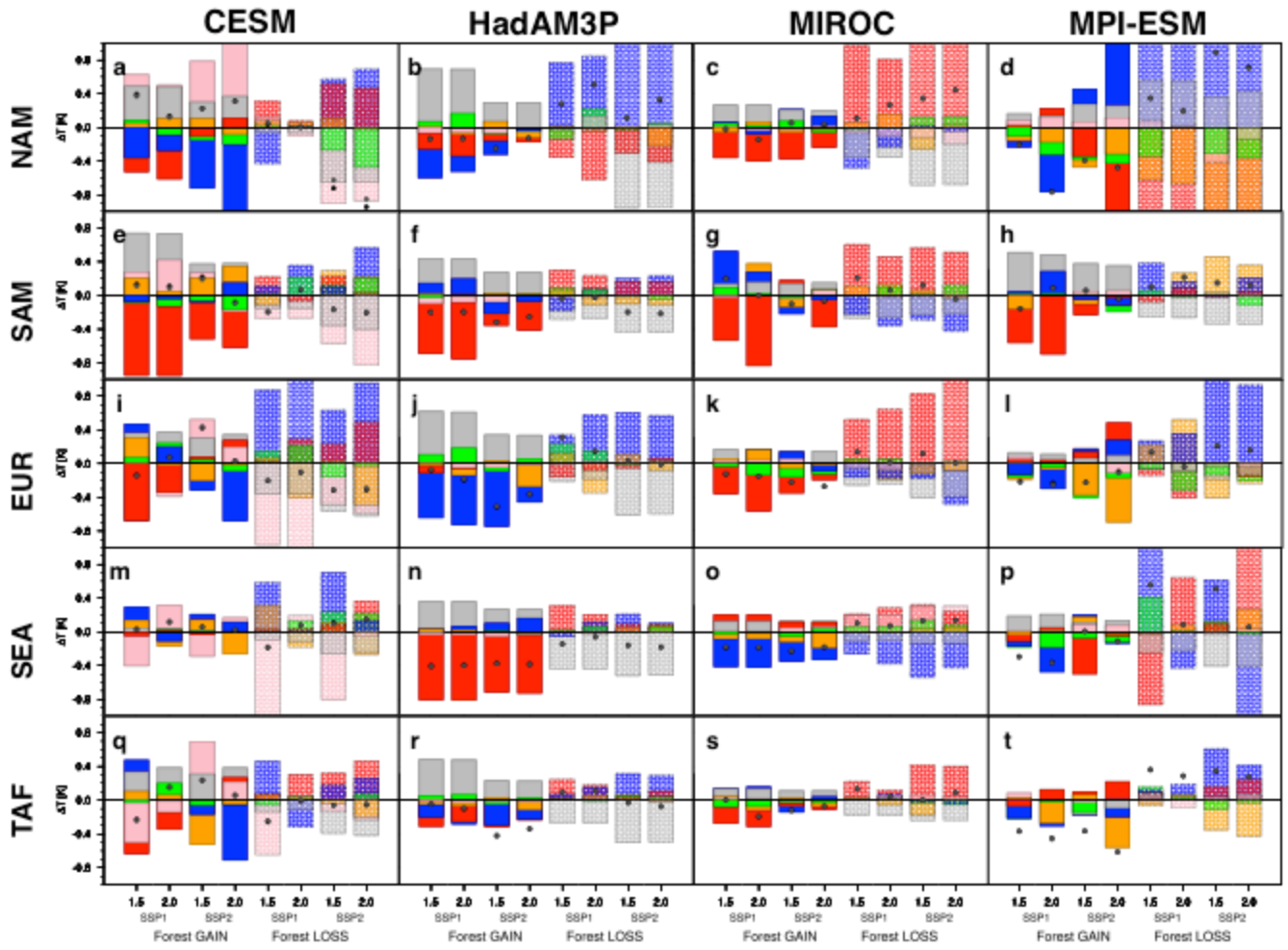
SSP1



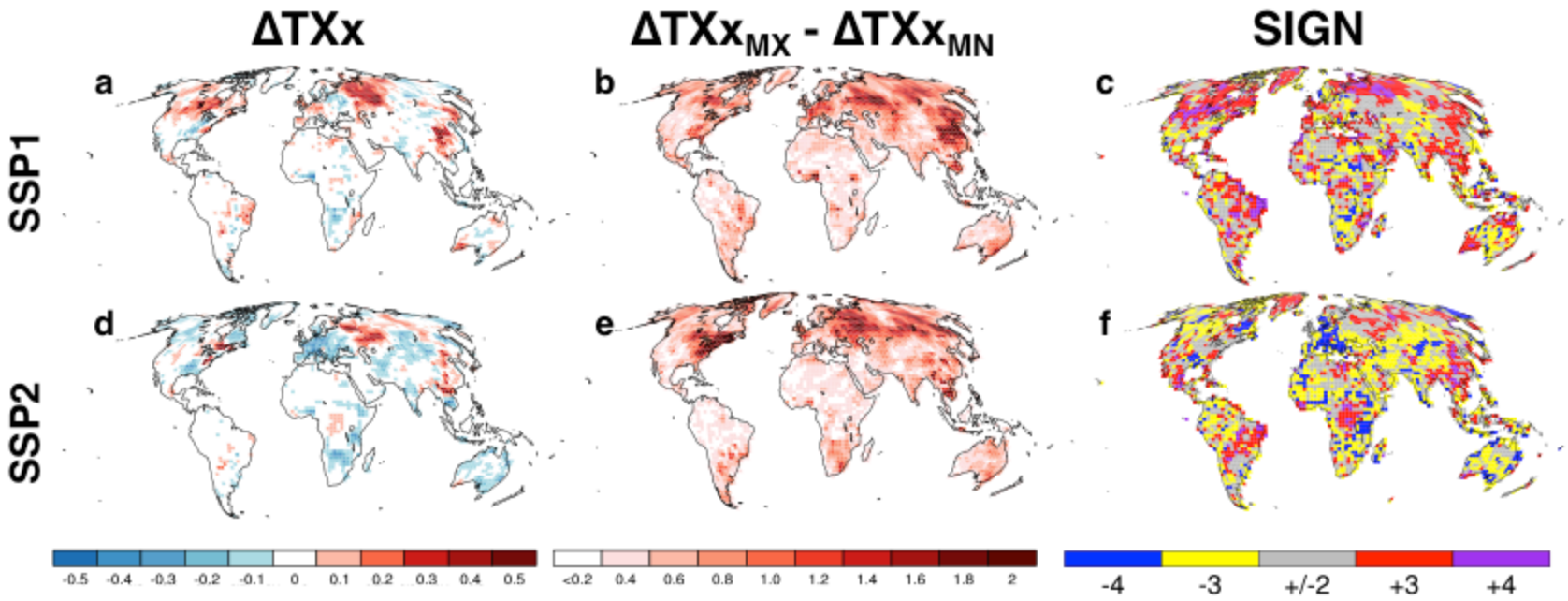
SSP2



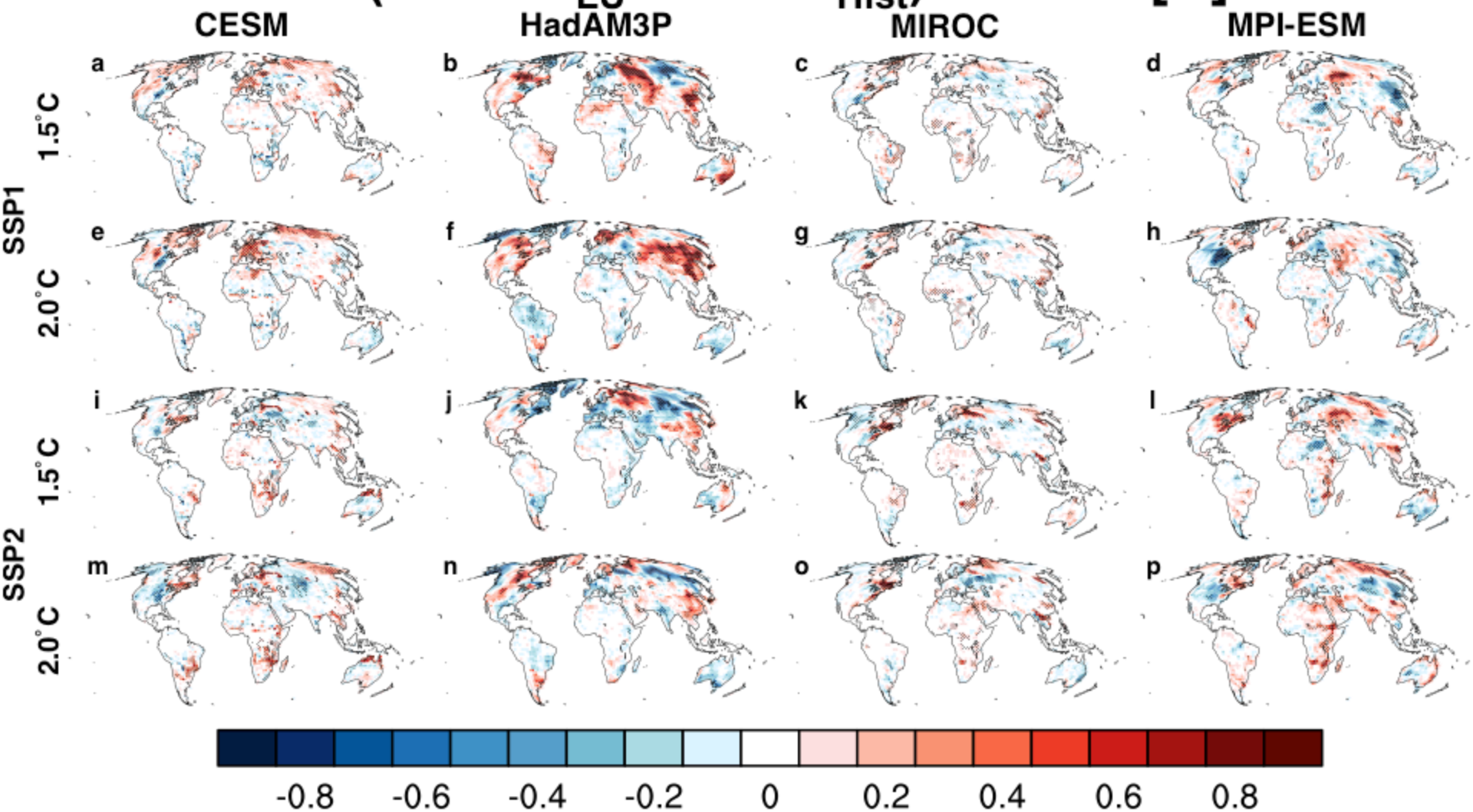
Surface energy balance decomposition



Model uncertainty



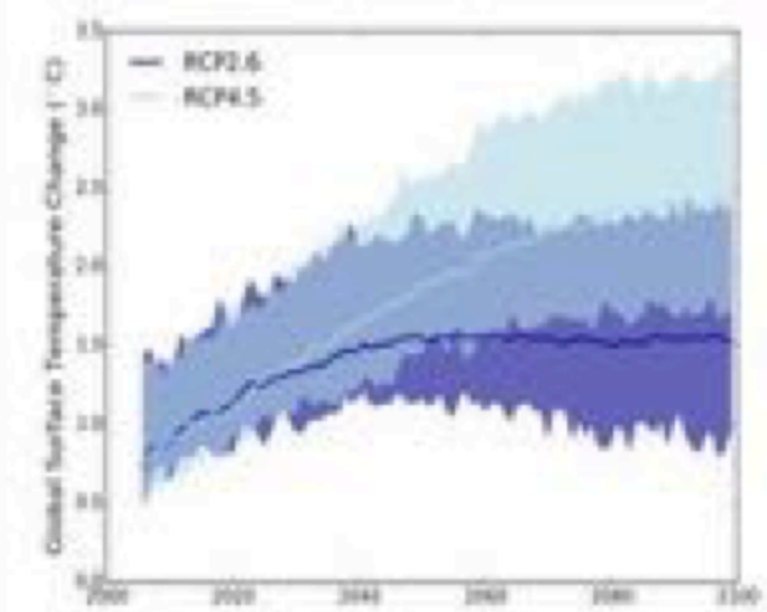
LUC effect ($PlusZZ_{LU}$-$PlusZZ_{Hist}$) on TXx [K]



- Large uncertainties, but model agree on the magnitude of LUC effect

Experimental Design

- AMIP simulations
- 50-100 ensemble members per experiment
- 3 Experiments:
  - Present Decade ('Hist', 2006-2015) observed SSTs
  - 1.5˚C (Plus15): SST/sea ice/GHG = obs+RCP2.6 using 2091-2100 mean changes
  - 2˚C (Plus20): SST/sea ice/GHG = obs+(0.41*RCP2.6+0.59*RCP4.5) using 2091-2100 mean changes
- Aerosols/ozone and **land use** set to 2095 values from RCP2.6 for 1.5˚C and 2˚C experiments
- Natural forcings set to Hist values in all experiments



Source: Mitchell et al., GMD 2016

Climate mitigation scenarios and LUC

- Emission scenarios (e.g., RCP2.6) are derived from Integrated Assessment Models (IAMs) based on socio-economic and policy assumptions.
- CMIP5: 1 IAM developed 1 scenario…
- For CMIP6, new framework as follows [Riahi et al., 2017]:
  - Design of five narratives: 'Shared Socio-economic Pathways' (SSP)
  - Translation into quantitative projections for main socioeconomic drivers (population growth, economic activity, urbanization)
  - Use of IAMs to derive quantitative projections of energy, land use and emissions associated with the SSPs.

SSP-RCP matrix

- Different SSPs can be compatible with a given RCP

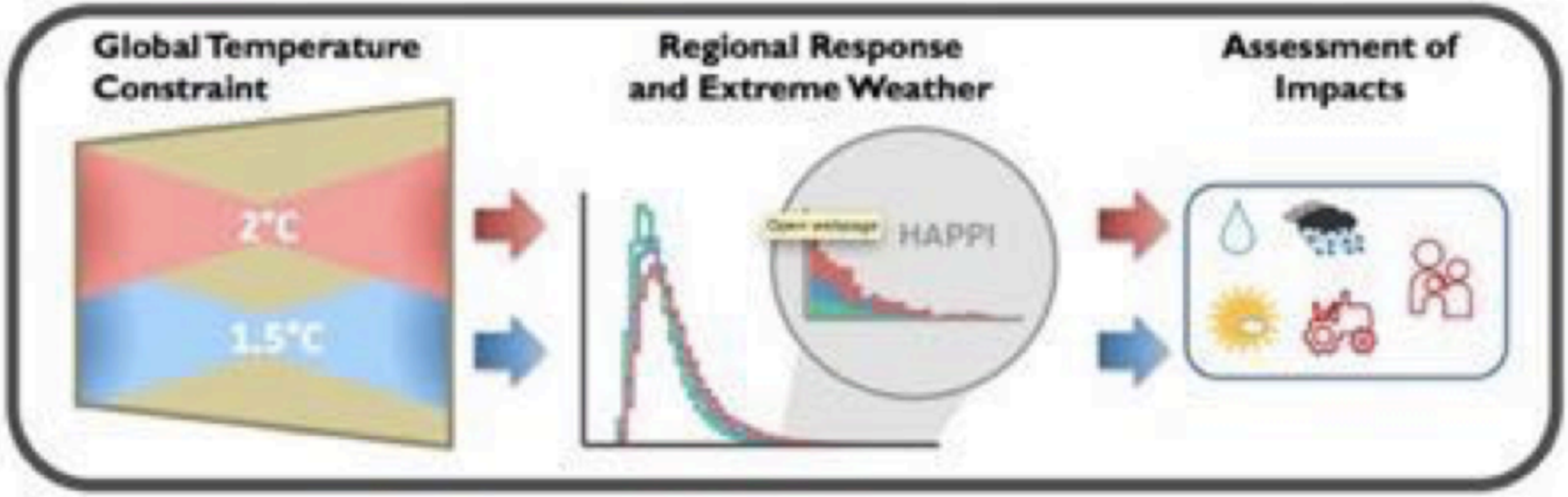
	SSP1	SSP2	SSP3	…
RCP1.9	yes	yes		
RCP2.6	yes	yes		
RCP3.7	yes	yes	yes	
…				

- Range of possible land-use change compatible with a RCP (e.g. SSP-IAM combinations)
- New RCP1.9 compatible with 1.5 degree

➢ LUC from IMAGE IAM

HAPPI

- HAPPI = Half a degree Additional warming, Prognosis and Projected Impacts
  www.happimip.org
- Aim: To evaluate difference in impacts between 1.5˚C and 2˚C end of the century climates
- Contribution to the IPCC SR1.5



Mitchell et al., GMD 2016