Greenhouse gas emissions and climate impacts of a large-scale biofuels expansion

Collaborative work between MIT, MBL, Lehigh U. and others

NCAR Societal Dimensions Working Group
February 27, 2014

Land-use scenarios

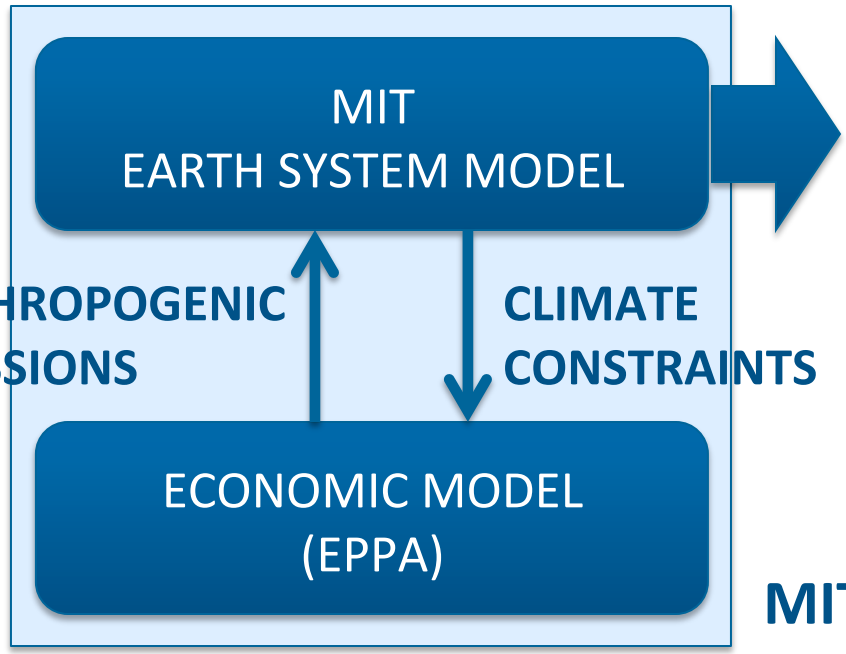
Under a climate stabilization policy (~650 ppm CO_2-eq stabilization by 2100, similar to RCP4.5), we investigate 2 land-use trajectories:

- CASE 1: "Extensification" that allows conversion of natural lands to meet demand as long as it's profitable – less constraint in land use, price is only factor.
- CASE 2: "Intensification" that is driven by more intense use of existing managed land – involves more constraints (legal, environmental) to convert to agricultural land.

Both land-use trajectories consider two energy-policies: with and without inclusion of first-generation biofuel penetration into the global energy resource portfolio.

=> 4 land-use scenarios.

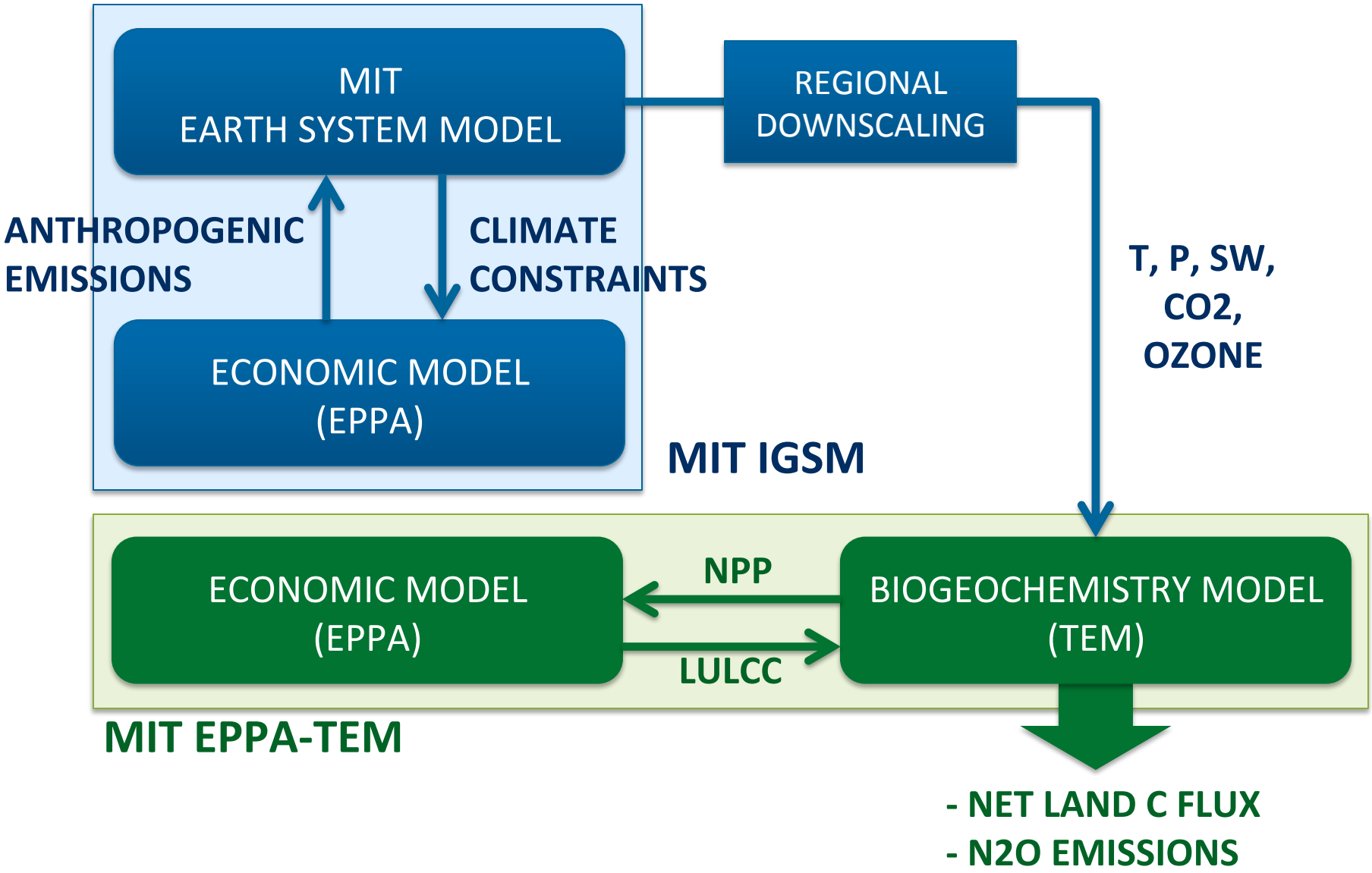
MODELING FRAMEWORK #1



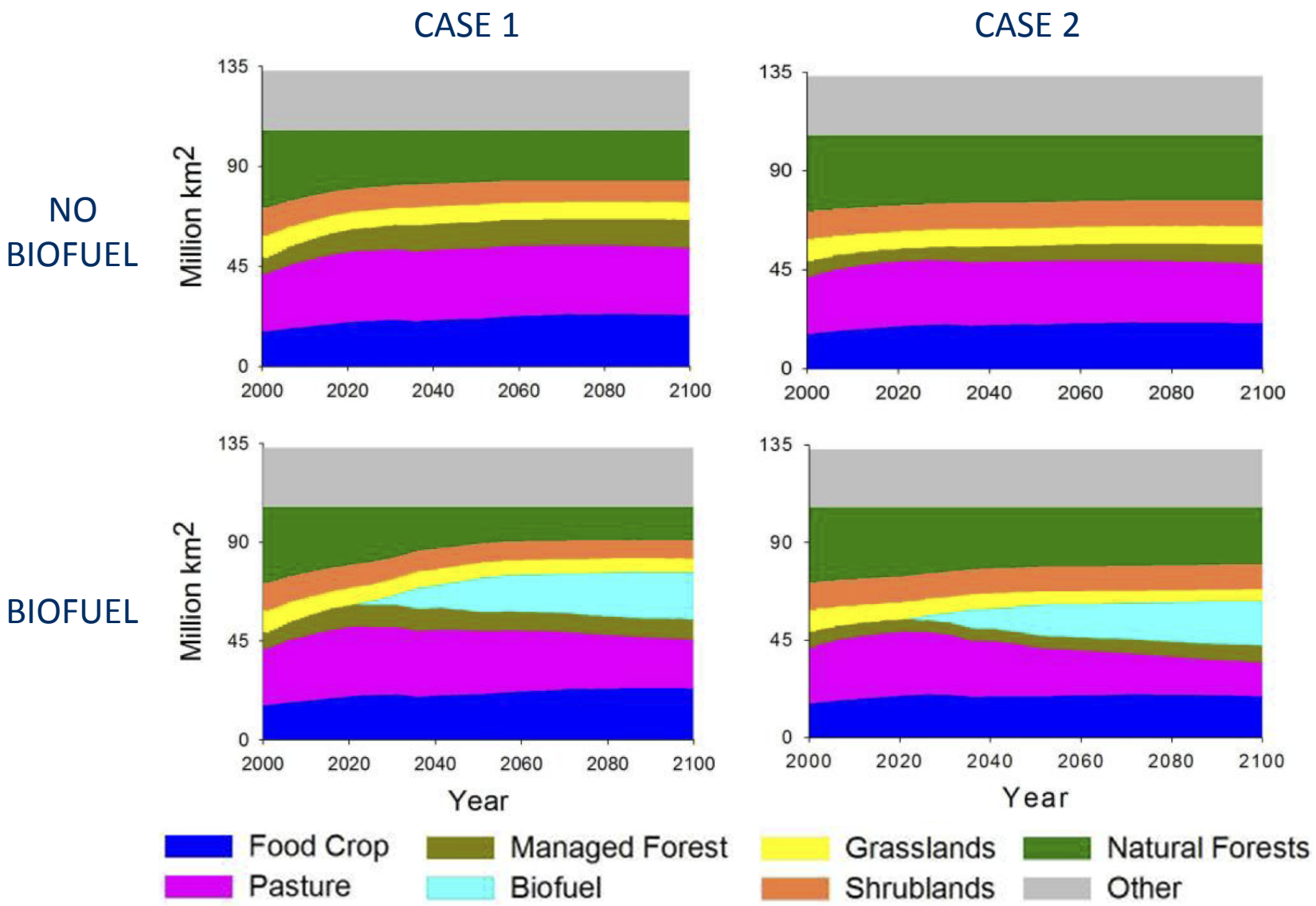
2D ZONAL-MEAN
- CLIMATE
- GHG CONC.

MIT IGSM

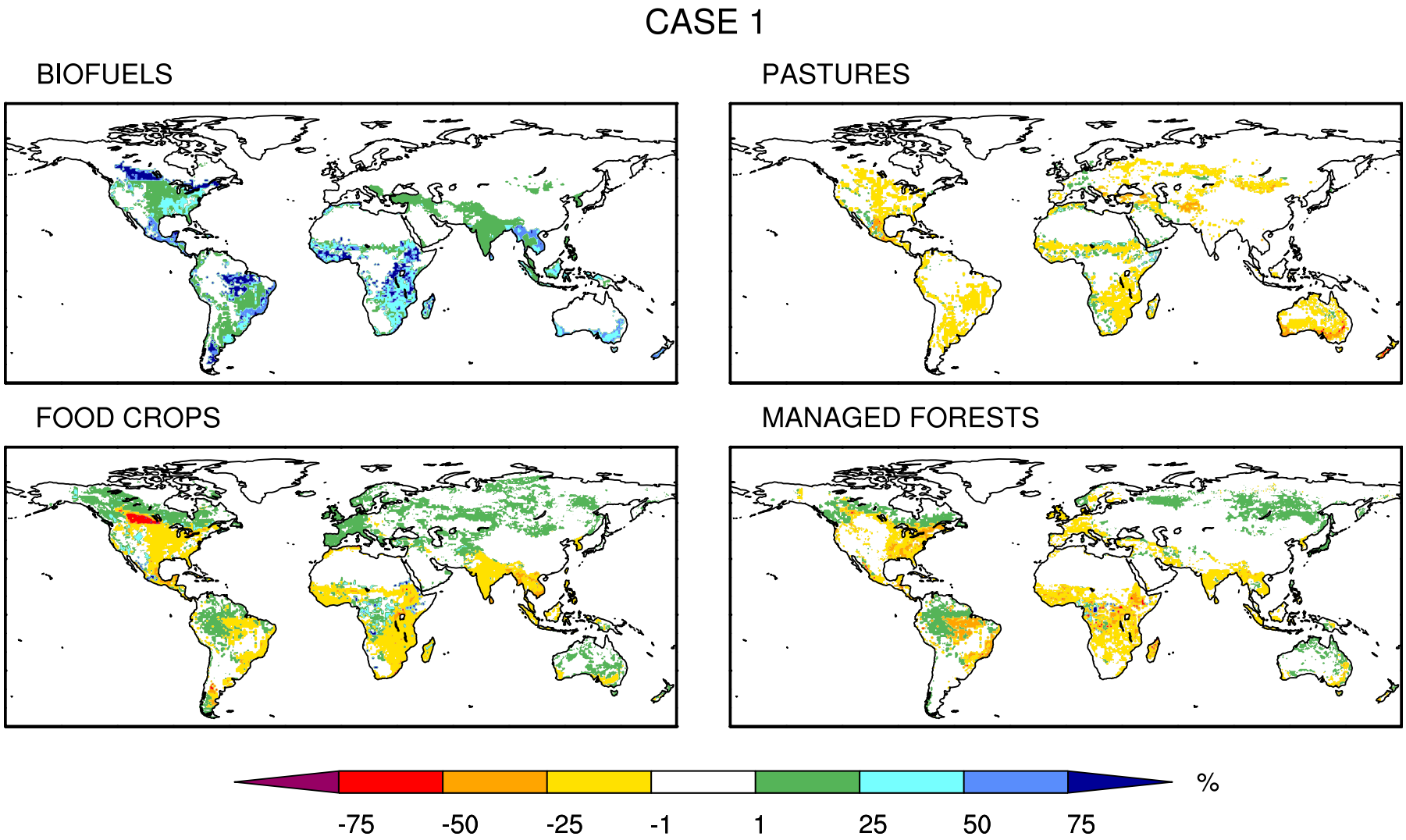
MODELING FRAMEWORK #1



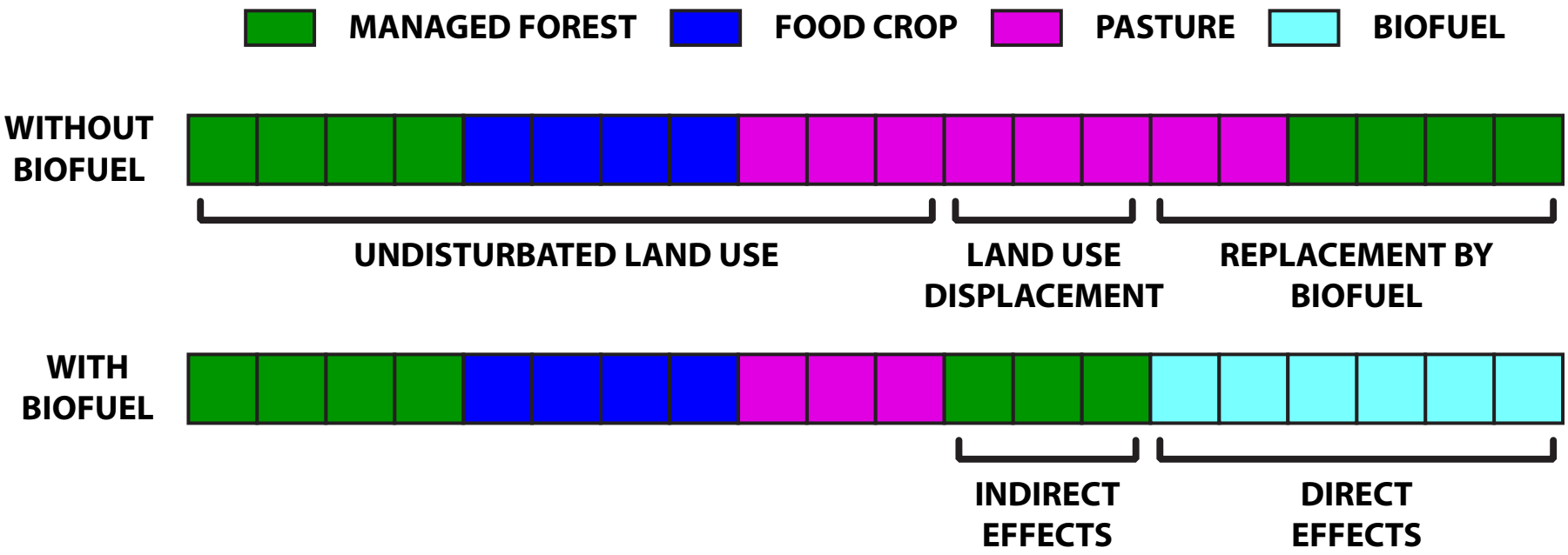
GLOBAL LAND USE CHANGE



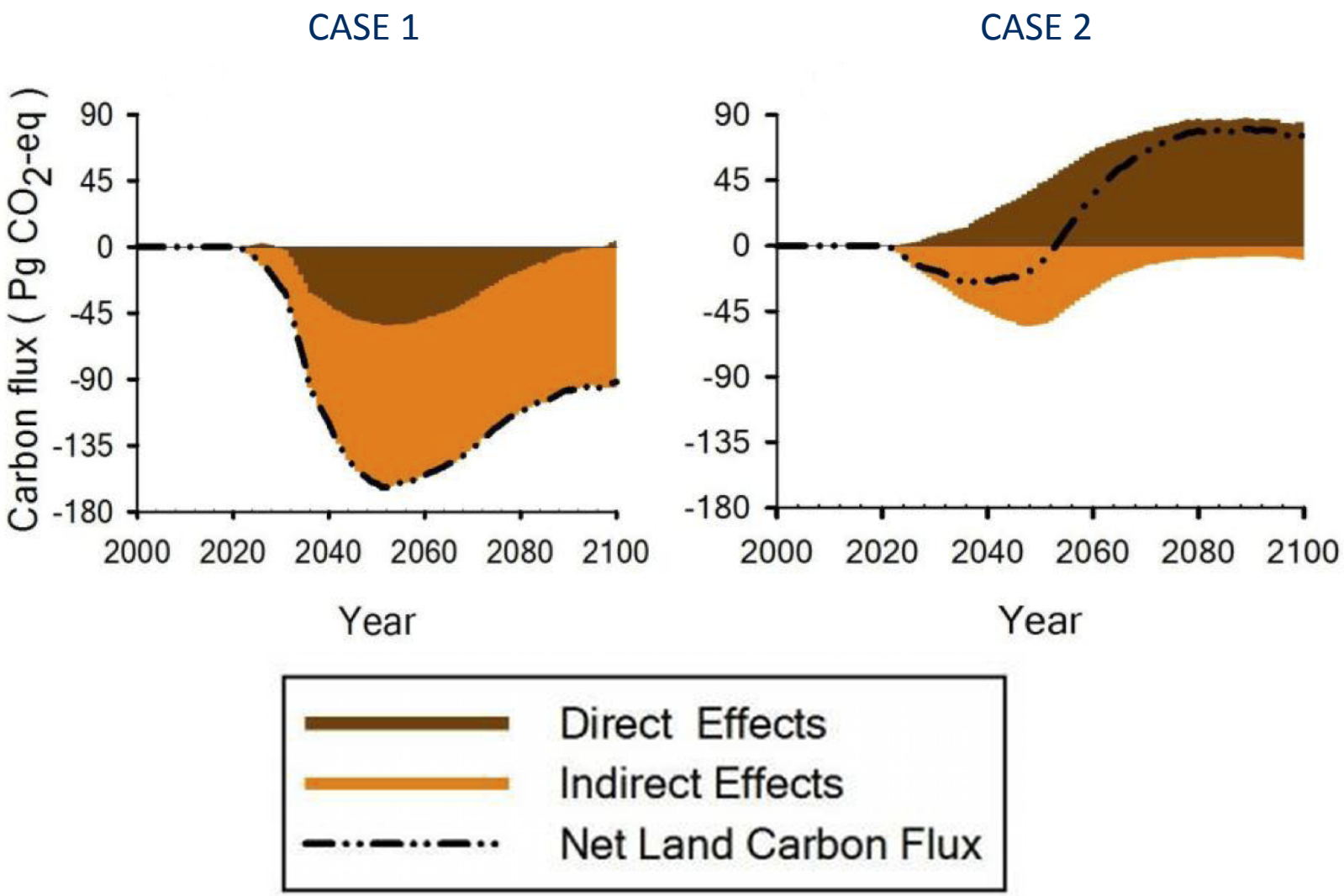
IMPACT OF BIOFUEL ON LAND USE CHANGE



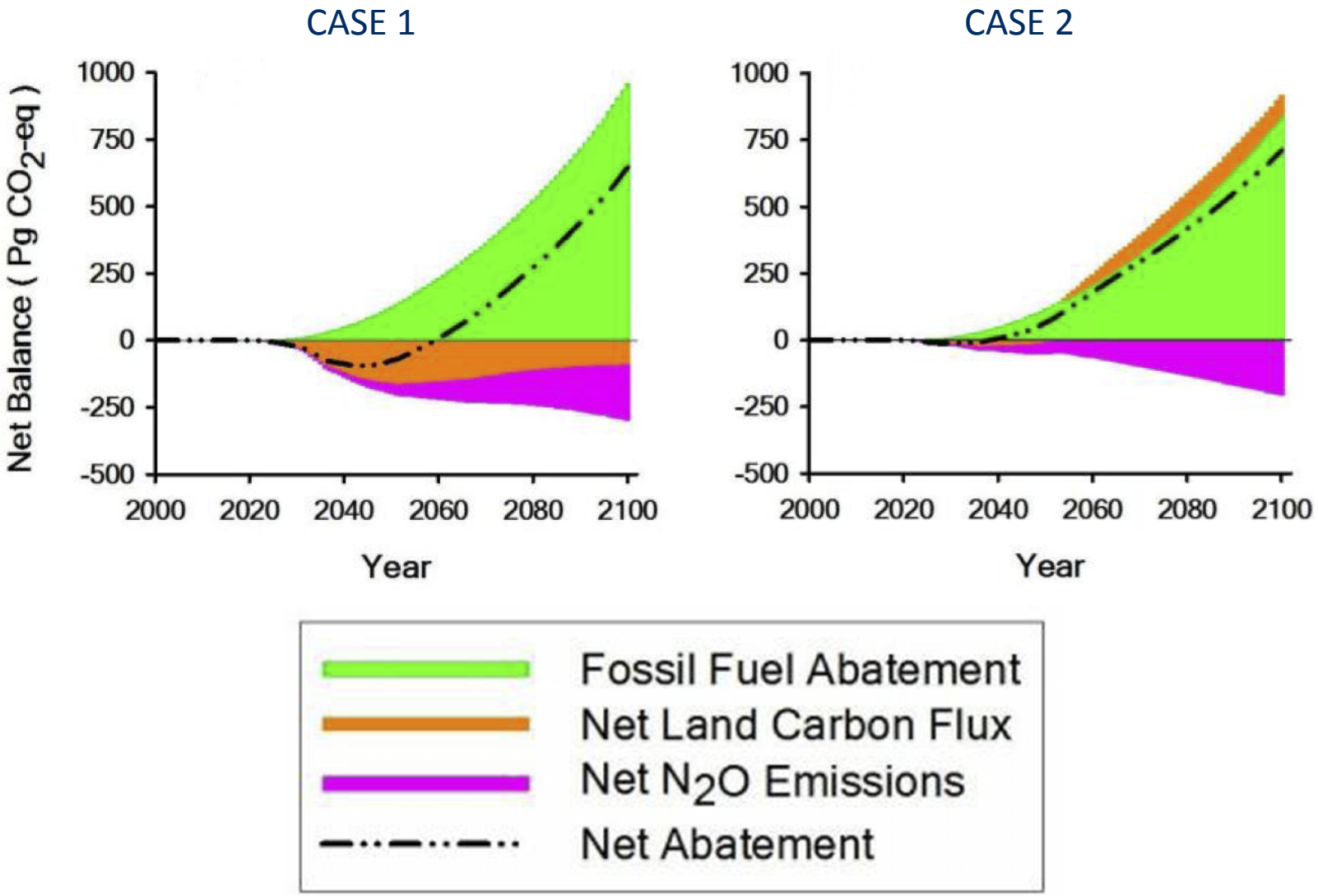
DIRECT VS. INDIRECT EFFECTS



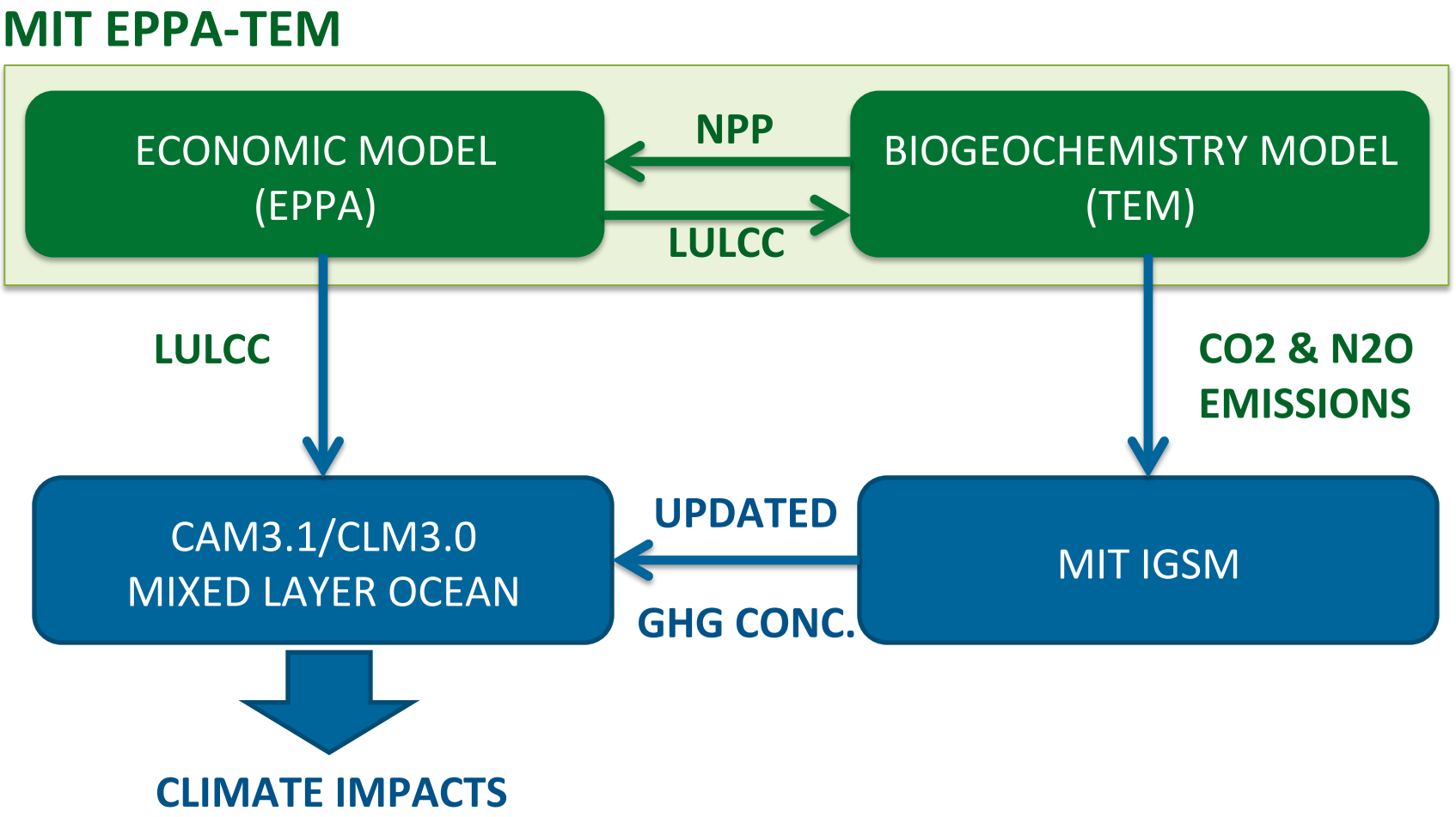
LAND CARBON FLUX



GHG CARBON FLUX



MODELING FRAMEWORK #2



CLIMATE SIMULATIONS

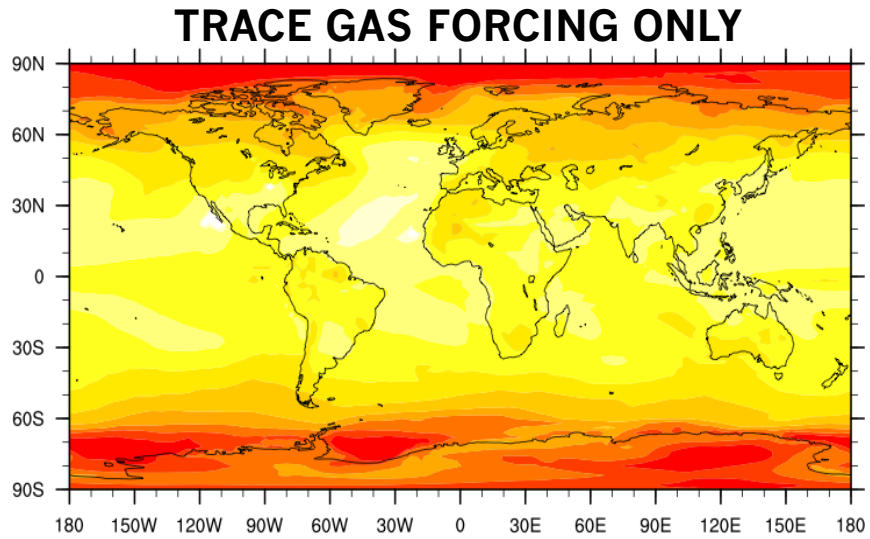
CAM3.1 at 2x2.5 resolution with mixed layer ocean

80-year equilibrium simulations (considering only last 50 years)

- For present-day (1990 conditions)
- For each of the 4 land-use scenarios, 2050 conditions:
    - Land-use change only (biogeophysical impacts)
    - GHG only (biogeochemical impacts)
    - LUC + GHG (total impacts)

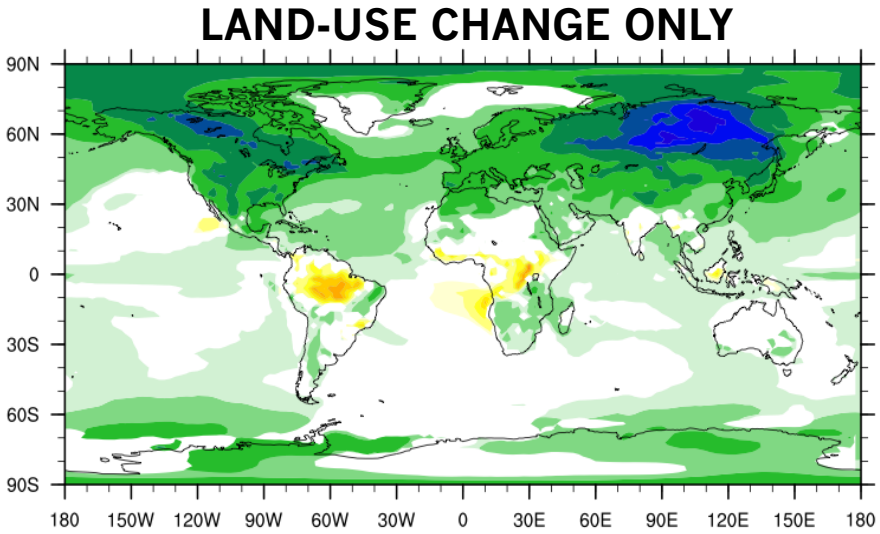
First-generation biofuels are represented in CLM by corn

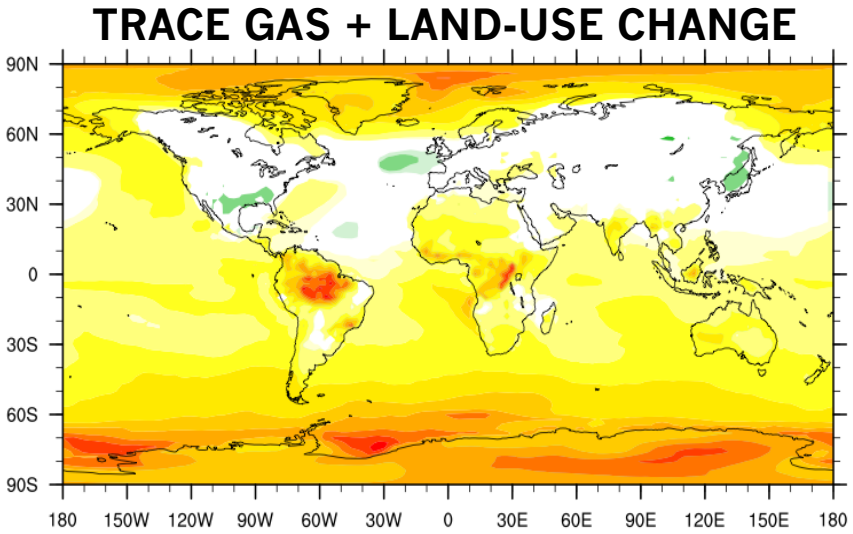
CLIMATE IMPACTS OF LAND-USE SCENARIO

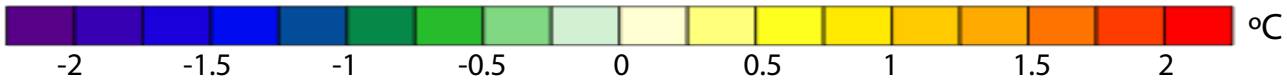


CASE 1 WITH BIOFUEL

2050 minus PRESENT-DAY

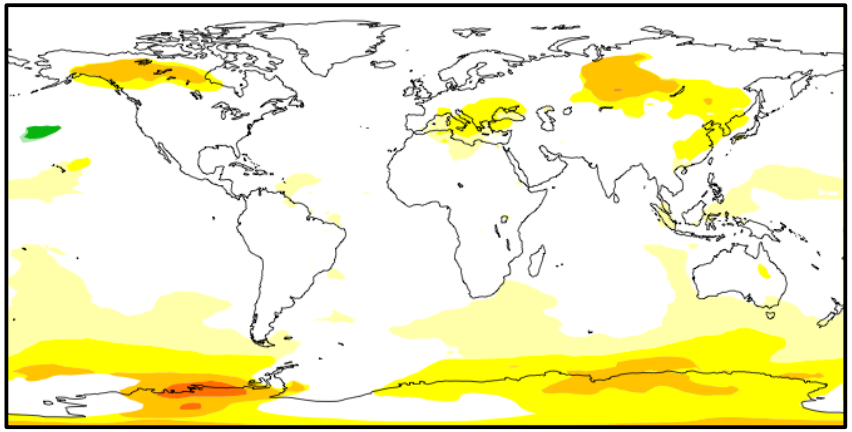






REGIONAL CLIMATE IMPACTS OF BIOFUELS

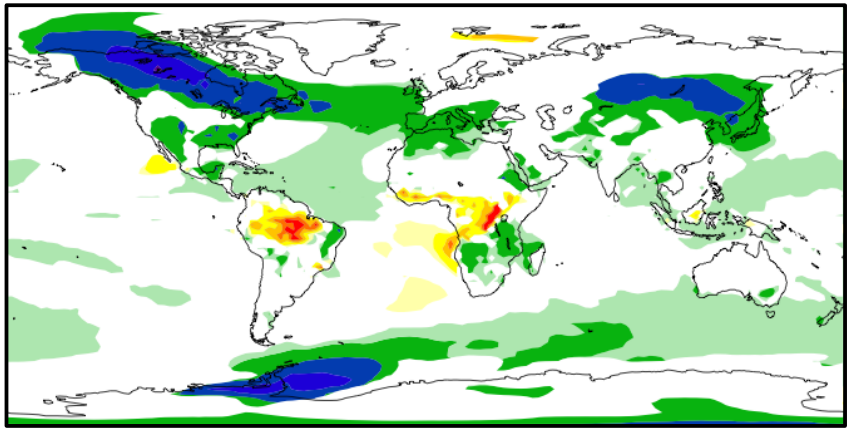
BIOGEOCHEMICAL IMPACTS



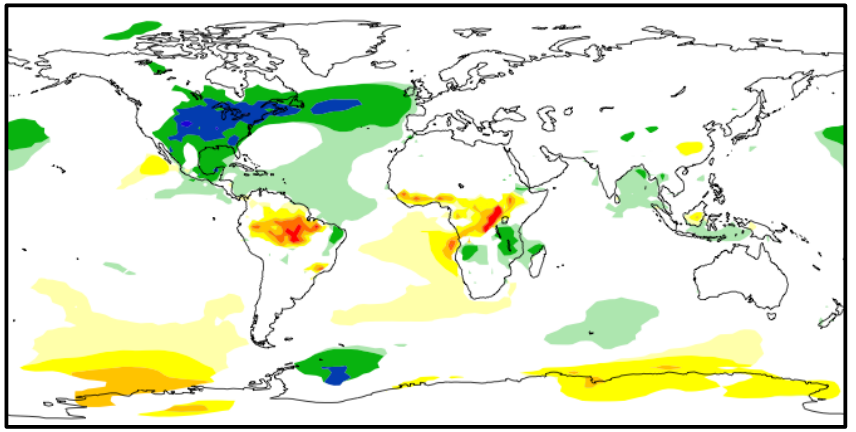
CASE 1

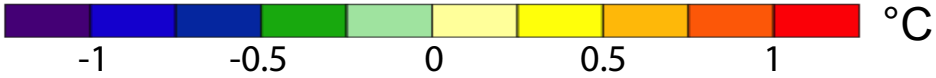
2050 minus PRESENT-DAY

BIOGEOPHYSICAL IMPACTS



TOTAL IMPACTS





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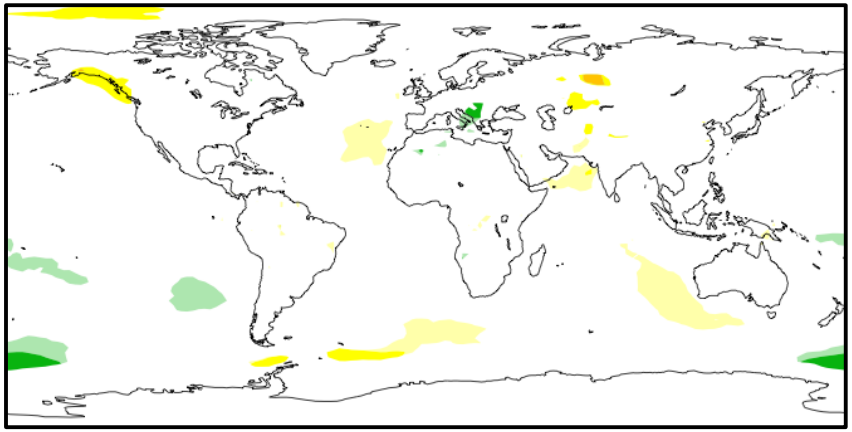
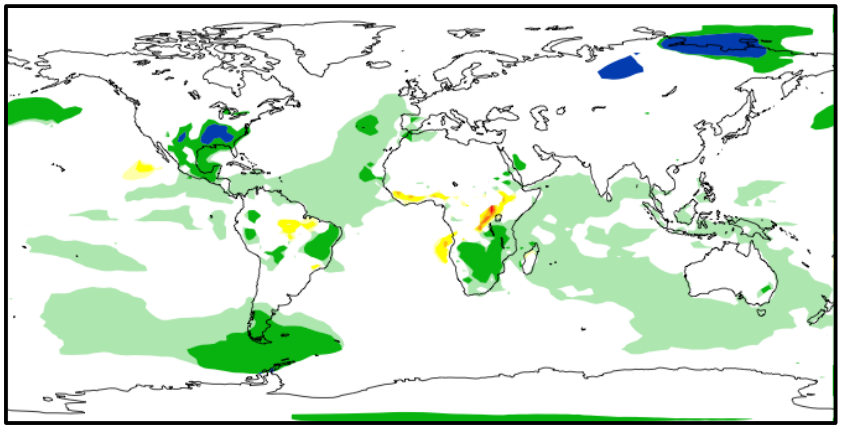


CASE 2

2050 minus PRESENT-DAY

BIOGEOPHYSICAL IMPACTS



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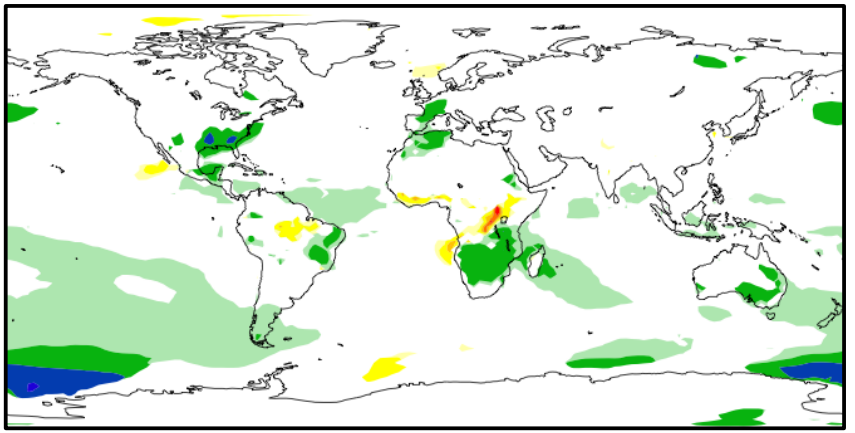
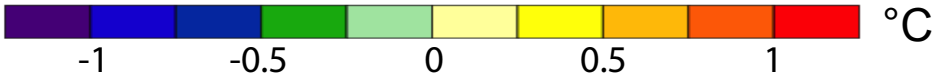
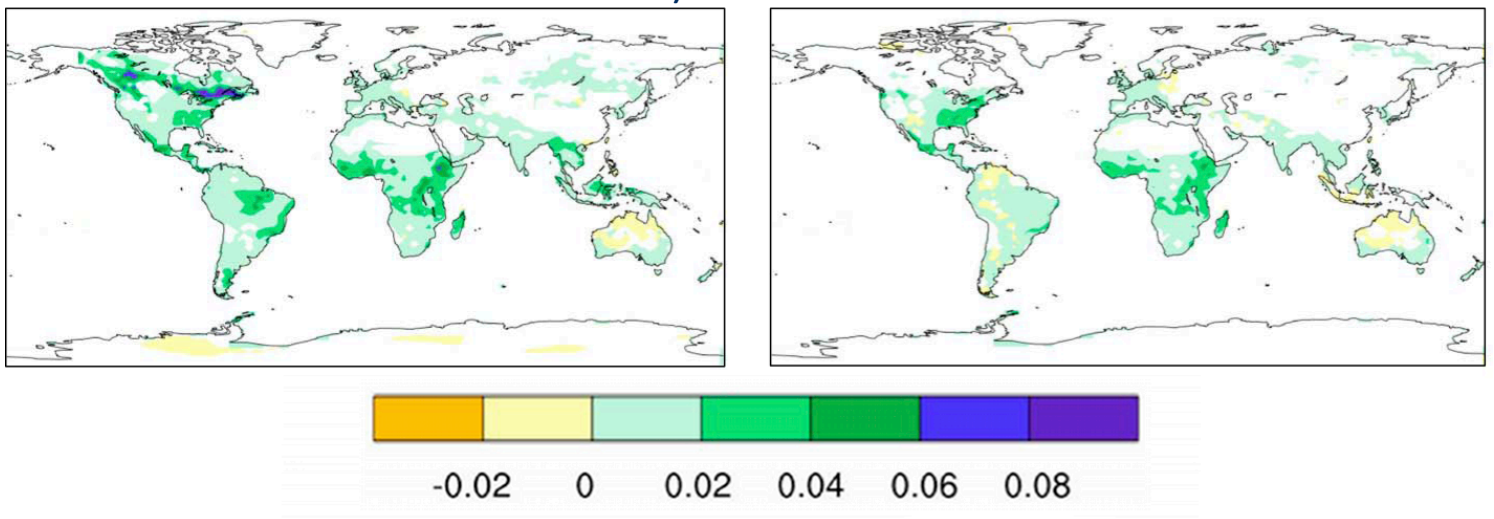




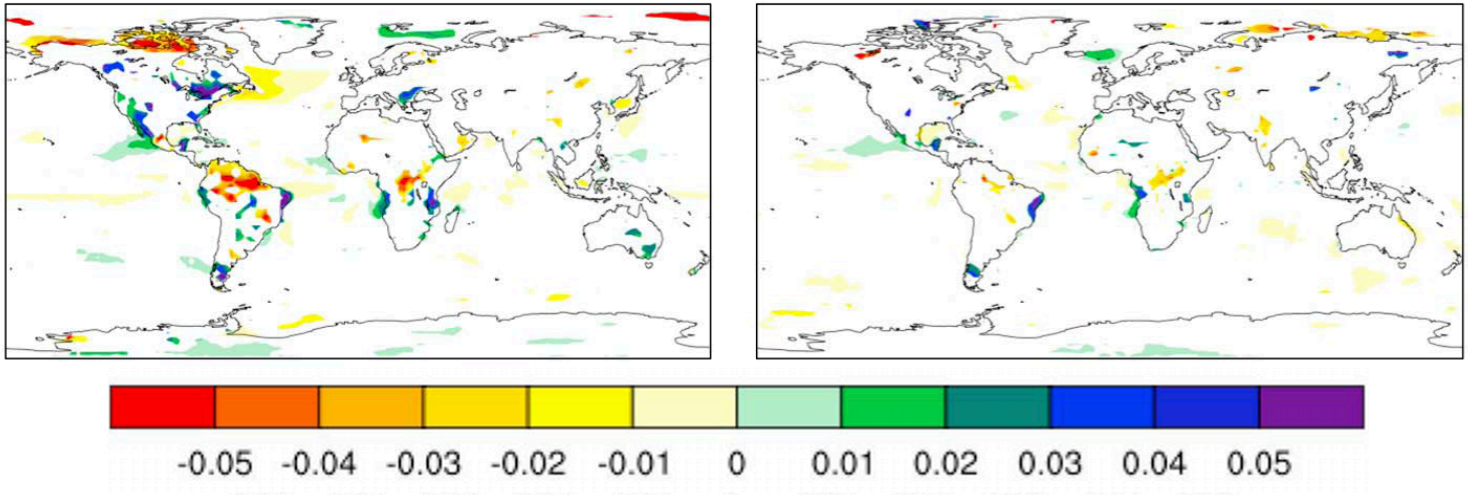
REGIONAL CLIMATE IMPACTS OF BIOFUELS

CASE 1 CASE 2

a) ALBEDO



b) EVAPORATIVE FRACTION



GLOBAL CLIMATE IMPACTS OF BIOFUELS

	CASE 1	CASE 2
BIOGEOPHYSICAL IMPACTS	-0.12	-0.10
BIOGEOCHEMICAL IMPACTS	+0.11	+0.04
GLOBAL IMPACTS	-0.01[d]	-0.06

[d] indicate statistically insignificant results

SUMMARY

Using linked economic, terrestrial biogeochemistry and climate models, we examined direct and indirect effects of possible land-use changes from a large-scale biofuel program and its impact on climate.

- Indirect land use will be responsible for substantially more carbon loss than direct land use
- Nitrous oxide emissions will be more important than carbon losses themselves in terms of warming potential (increases in fertilizer use)
- Biogeophysical and biogeochemical impacts compete resulting in regional heterogeneous climate impacts
    - Cooling at midlatitudes (albedo effect)
    - Warming in the tropics (evaporation effect)
- At the global level, climate impacts are small, especially the total (combined) impacts

REFERENCES

Melillo et al. (2009), Indirect emissions from biofuels: How important?, *Science*, 326, 1397–1399, doi:10.1126/science.1180251

Kicklighter et al. (2012), Potential Direct and Indirect Effects of Global Cellulosic Biofuel Production on Greenhouse Gas Fluxes From Future Land-Use Change. *MIT JPSPGC Report 210*, 118 pages. http://globalchange.mit.edu/files/document/MITJPSPGC_Rpt210.pdf.

Hallgren et al. (2013), Climate impacts of a large-scale biofuels expansion, *Geophys. Res. Lett.*, 40, 1624–1630, doi:10.1002/grl.50352