Arctic/Boreal Ecosystems and Climate: What changes can we expect in this century?

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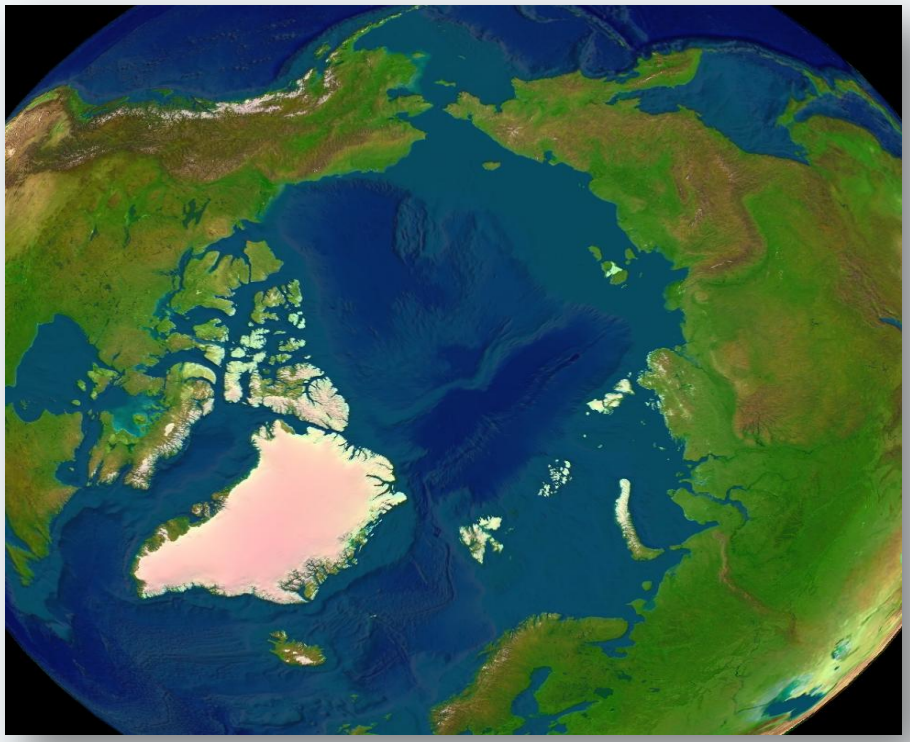


MIT Joint Program on the

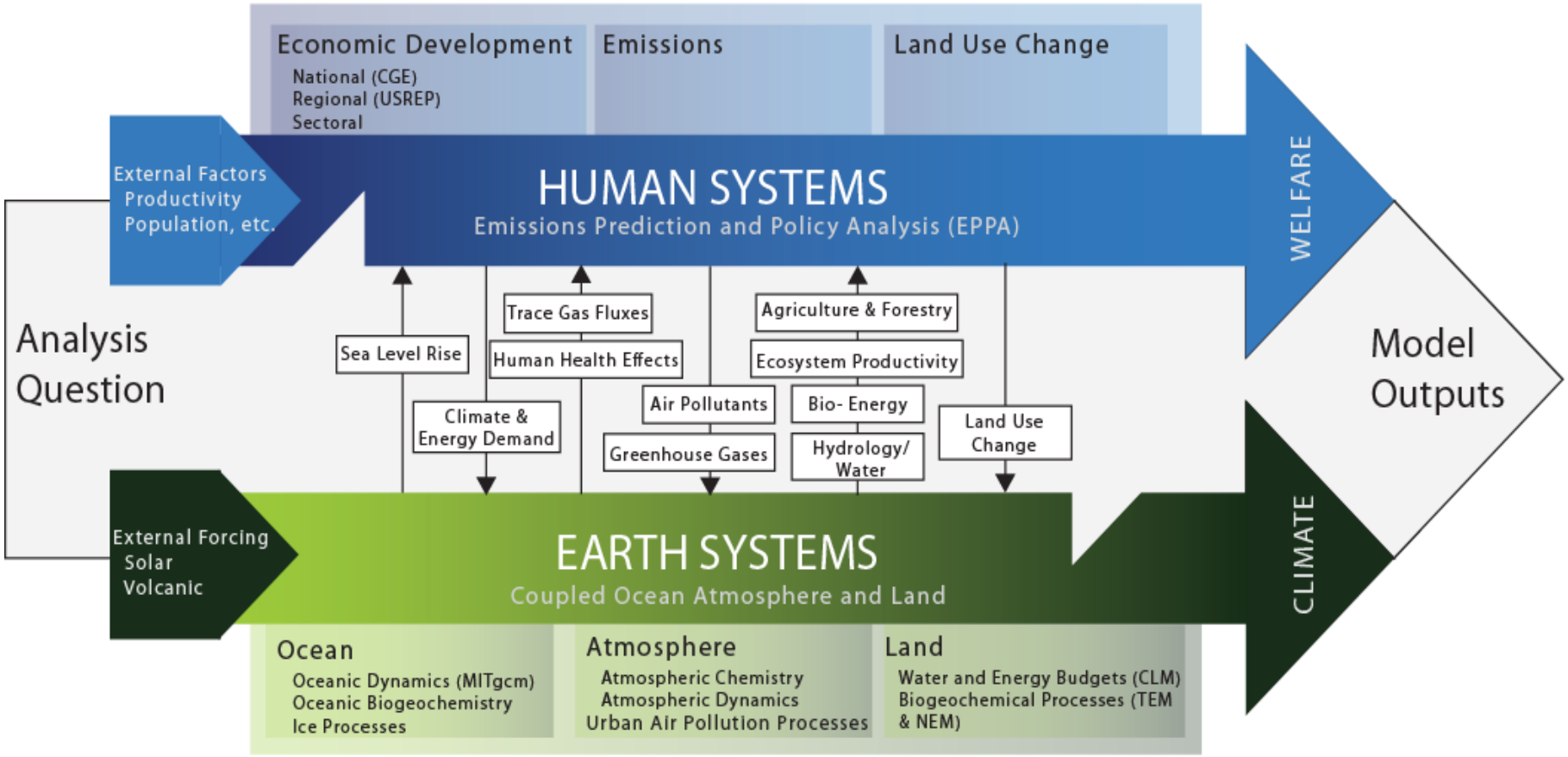
Science and Policy of Global Change

Arctic and Boreal Landscapes and Ecosystems:

- Amplified climate warming
- Permafrost
- Wetlands and lakes
- Carbon stores
- Land use and plant migration
- Biogeochemistry and natural emissions
- Potential feedbacks to climate warming?

MIT JOINT PROGRAM SCIENCE POLICY GLOBAL CHANGE

MIT Integrated Global Systems Model



MIT JOINT PROGRAM
SCIENCE POLICY
GLOBAL CHANGE

High-latitude amplification to climate warming

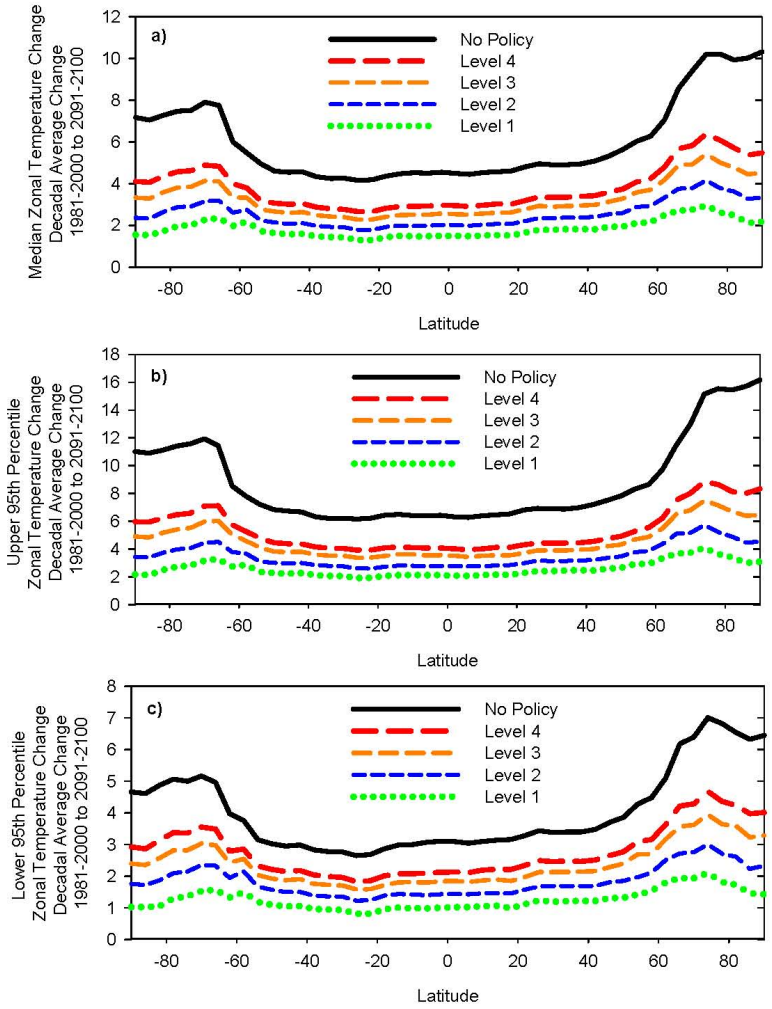
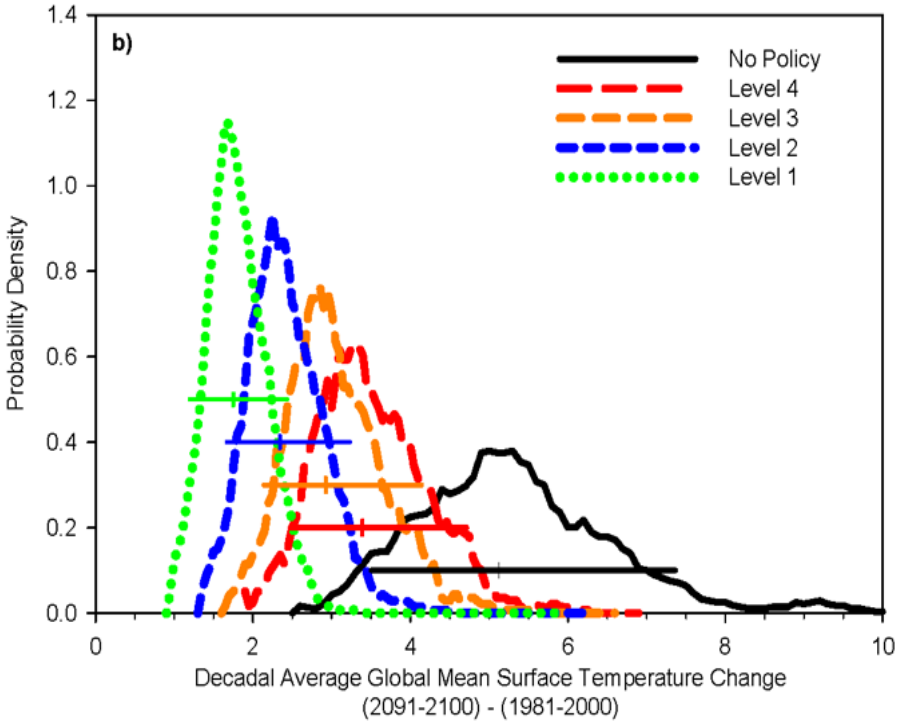


Figure 7. Zonal mean surface temperature change from the 1981-2000 average to the 2091-2100 average by policy case (a) median zonal temperature change, (b) upper 95th percentile zonal temperature change, and (c) lower 95th percentile zonal mean temperature change.



Largest increases in temperature occur at higher latitudes. Slightly more pronounced difference with larger climate warming.

Surface-air temperature changes

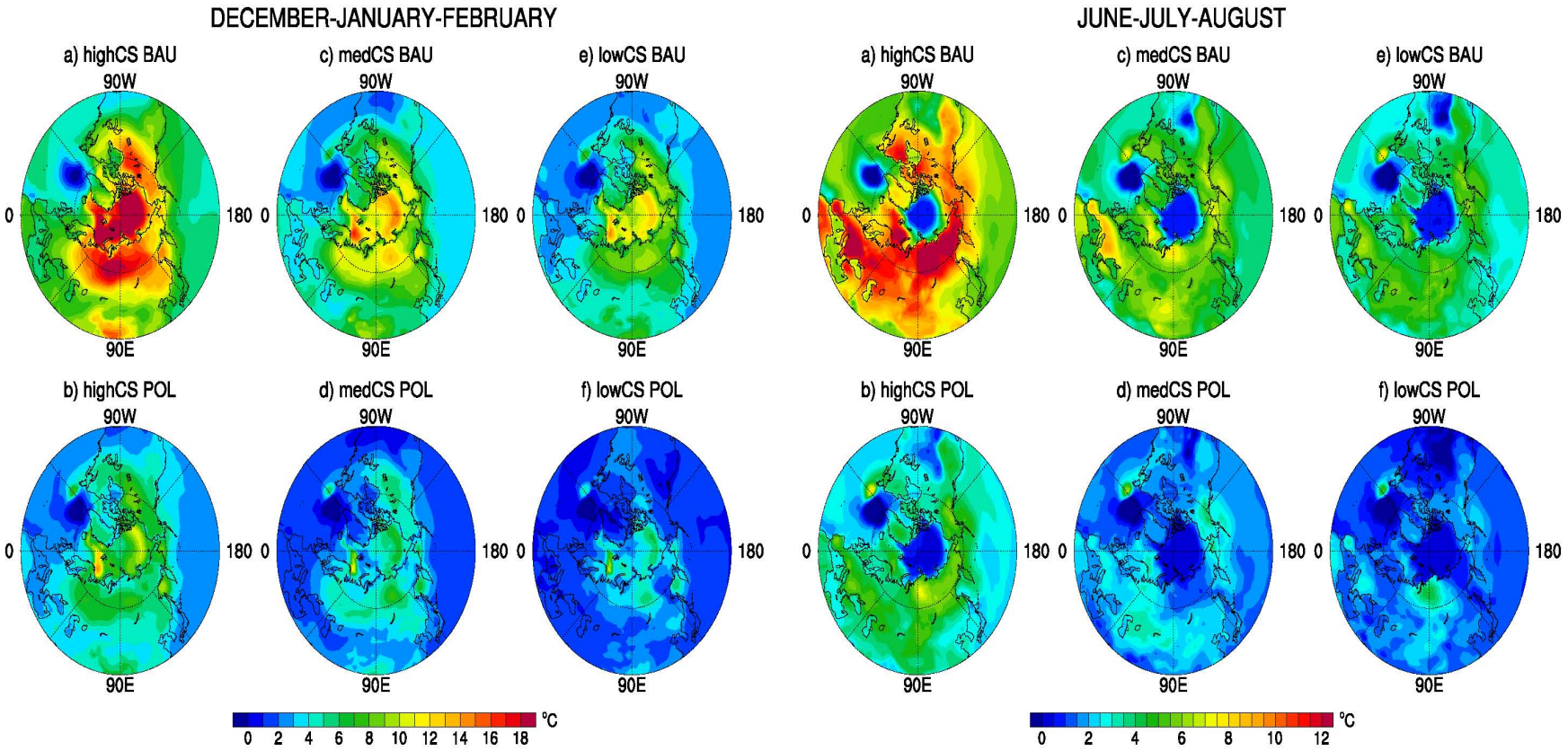


Figure 4: Changes in surface air temperature between the 2001-2010 mean and the 2091-2100 mean for winter and summer for the six simulations.

Precipitation Changes

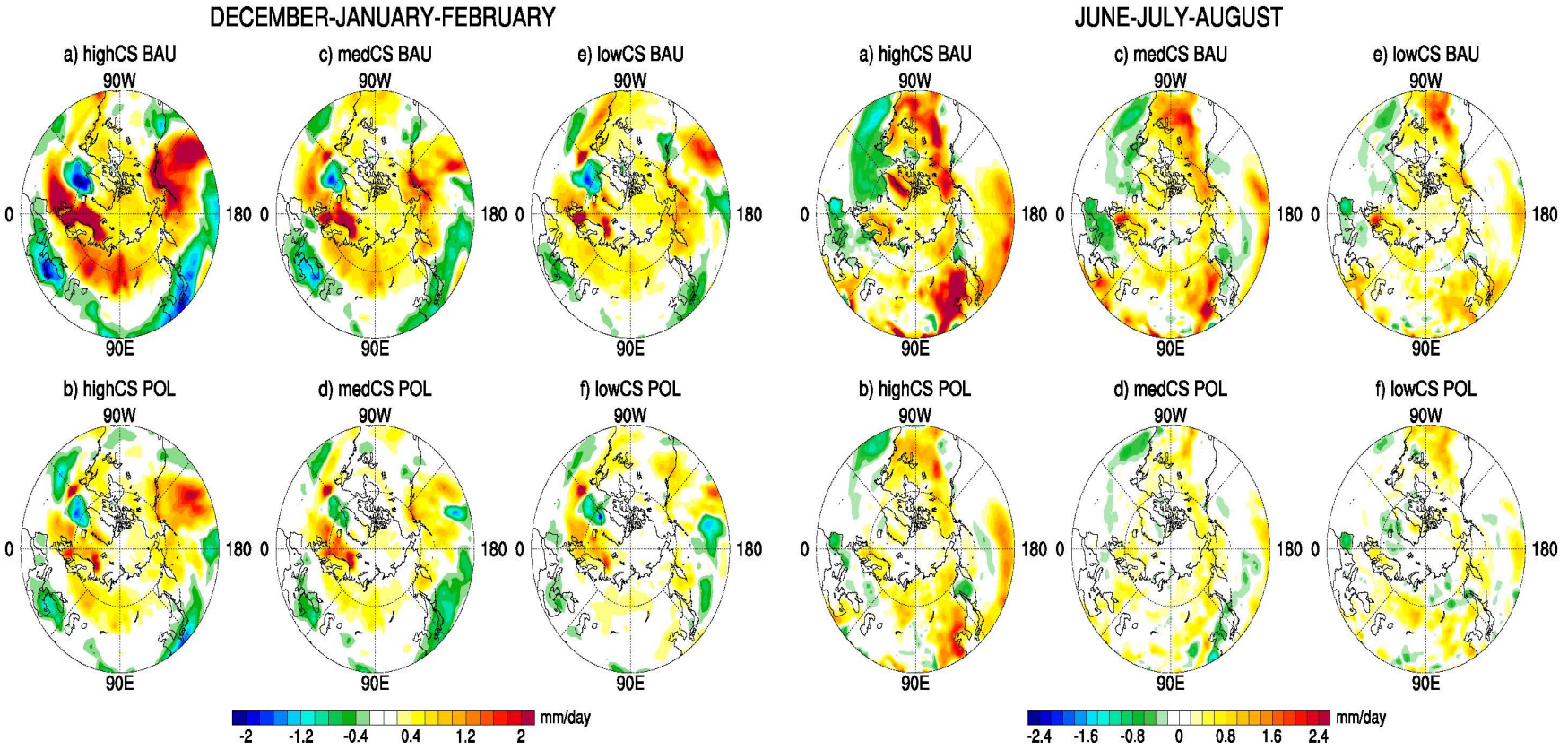
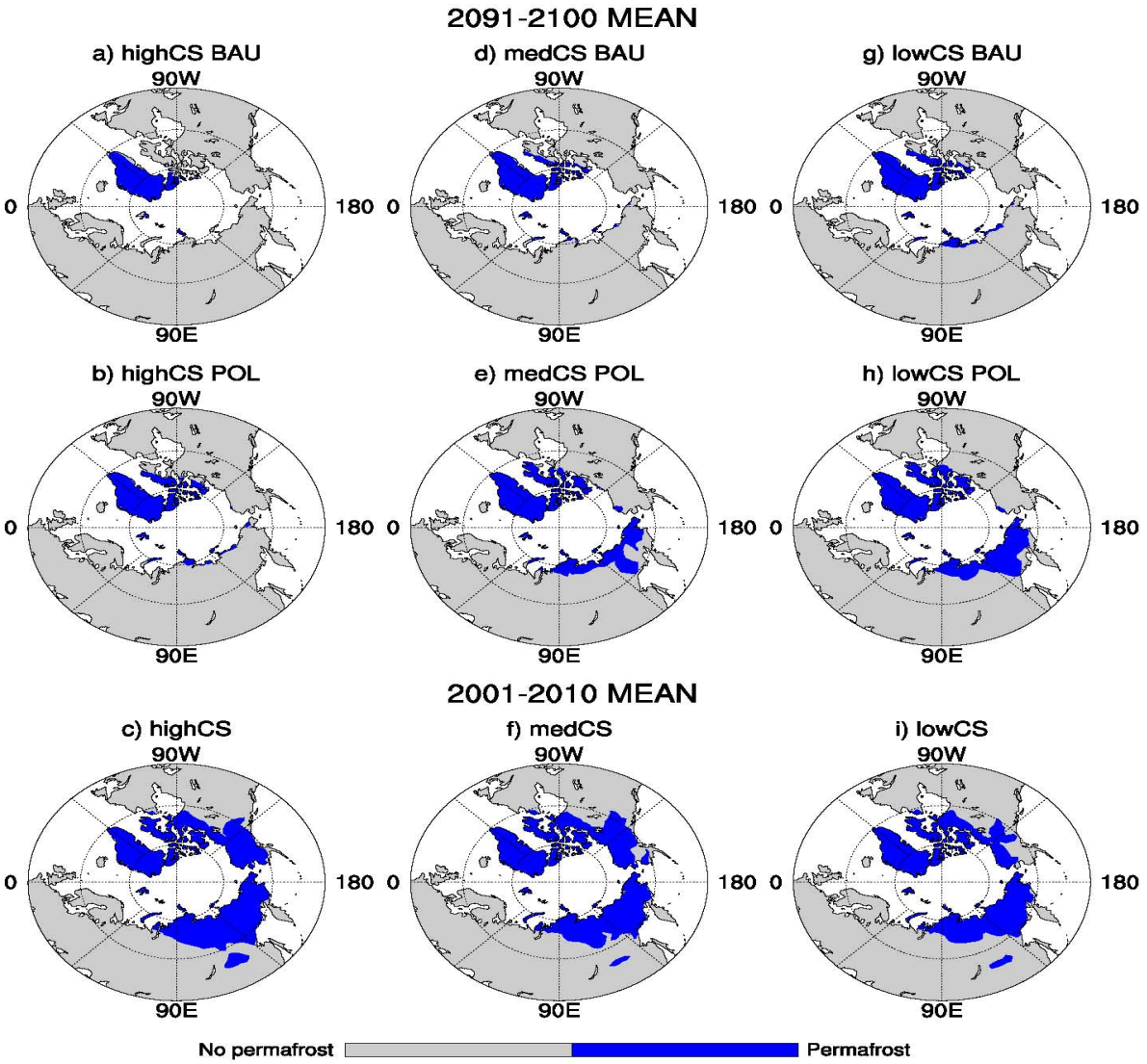


Figure 5: Changes in total precipitation between the 2001-2010 mean and the 2091-2100 mean for winter and summer for the six simulations.

Permafrost Degradation



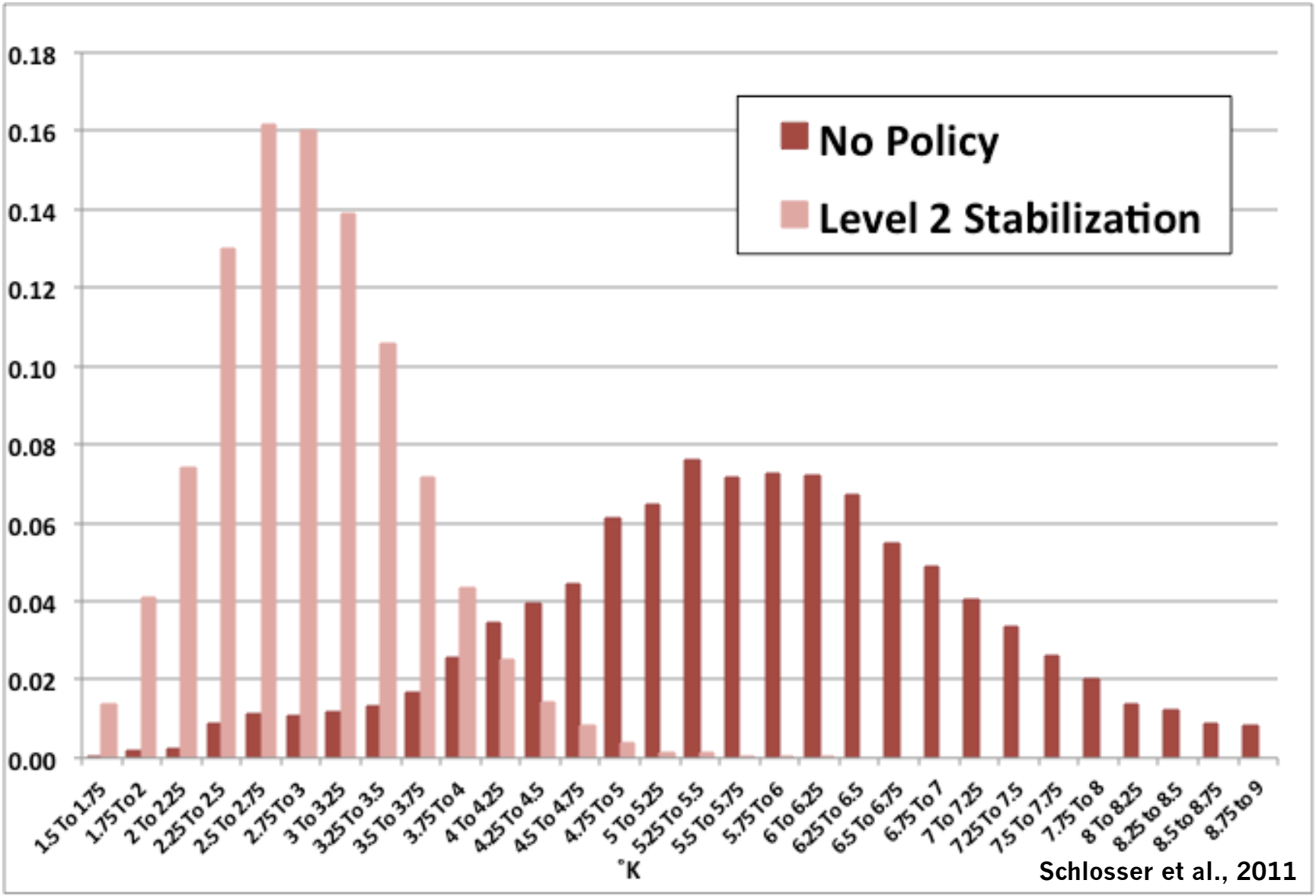
Permafrost and terrestrial carbon stores

Source: International Permafrost Association, 1998. Circumpolar Active-Layer Permafrost System (CAPS), version 1.0.

Walter et al., 2007

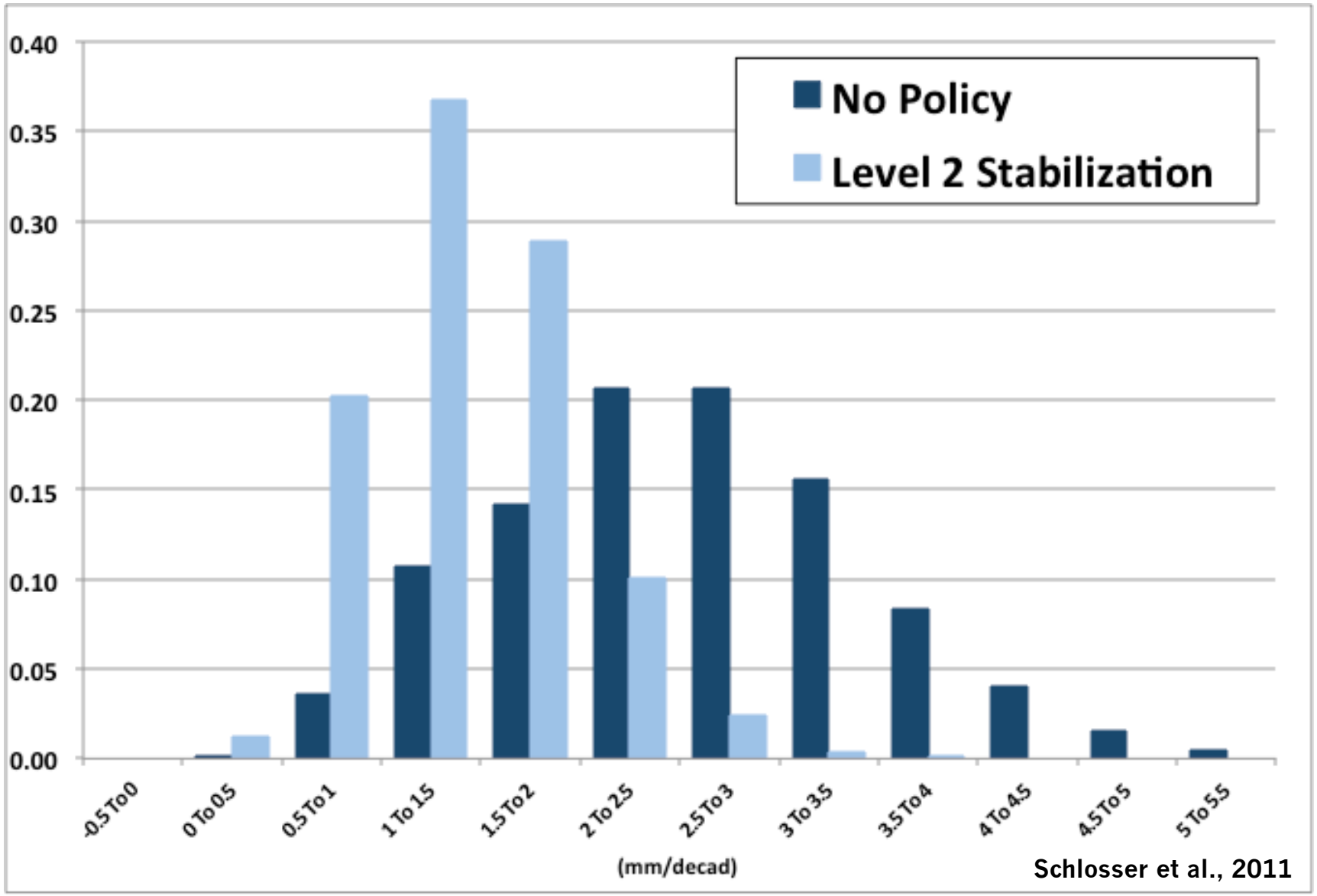
PERMAFROST THAW: DOES UNLOCKED CARBON IN THE SOIL SUPPORT STRONG METHANE FEEDBACK?

Yedoma Region Frequency Distributions
2075 Decadal Surface-Air Temperature Change



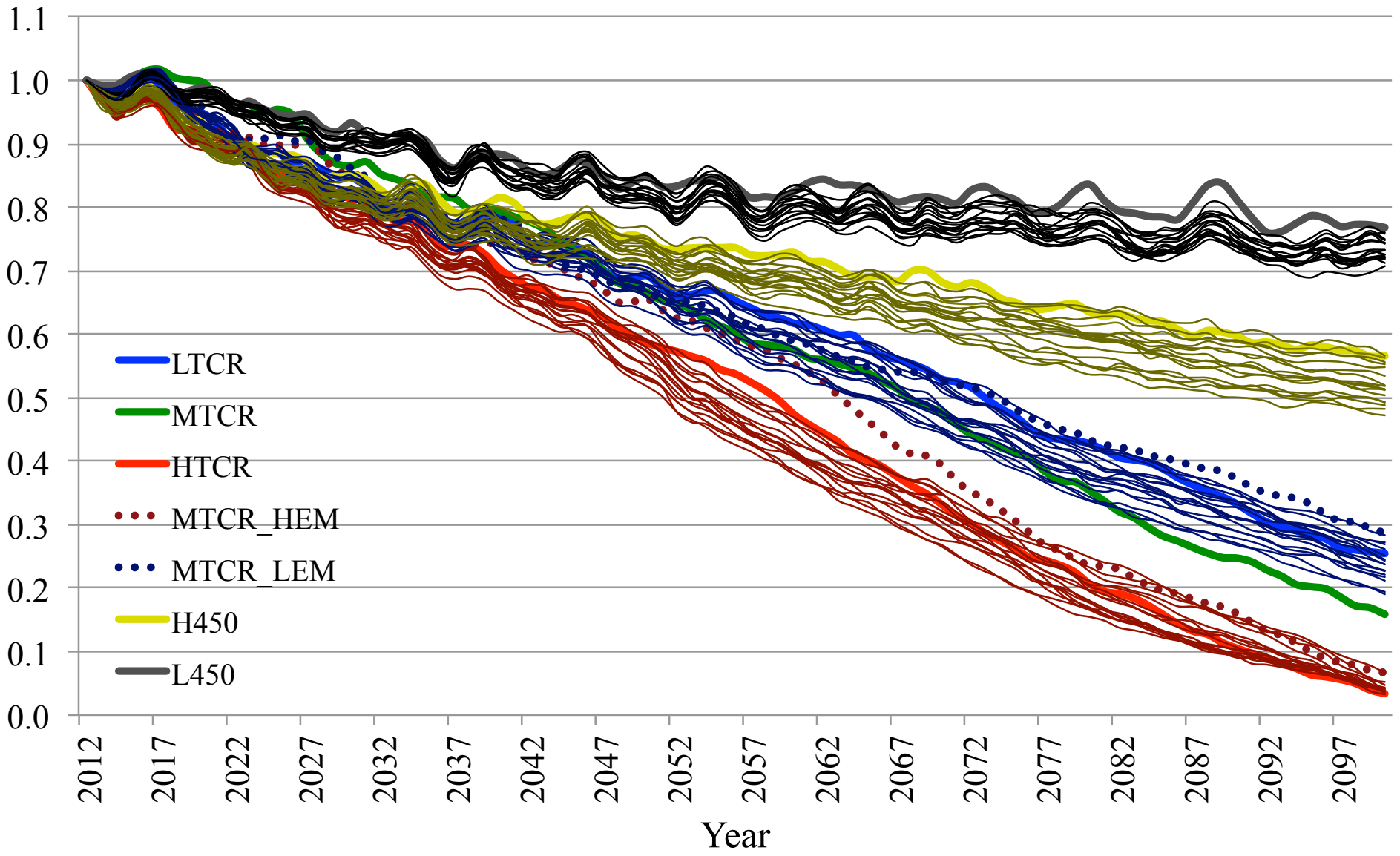
Schlosser et al., 2011

Yedoma Frequency Distributions
2075 Decadal Average Precipitation Change

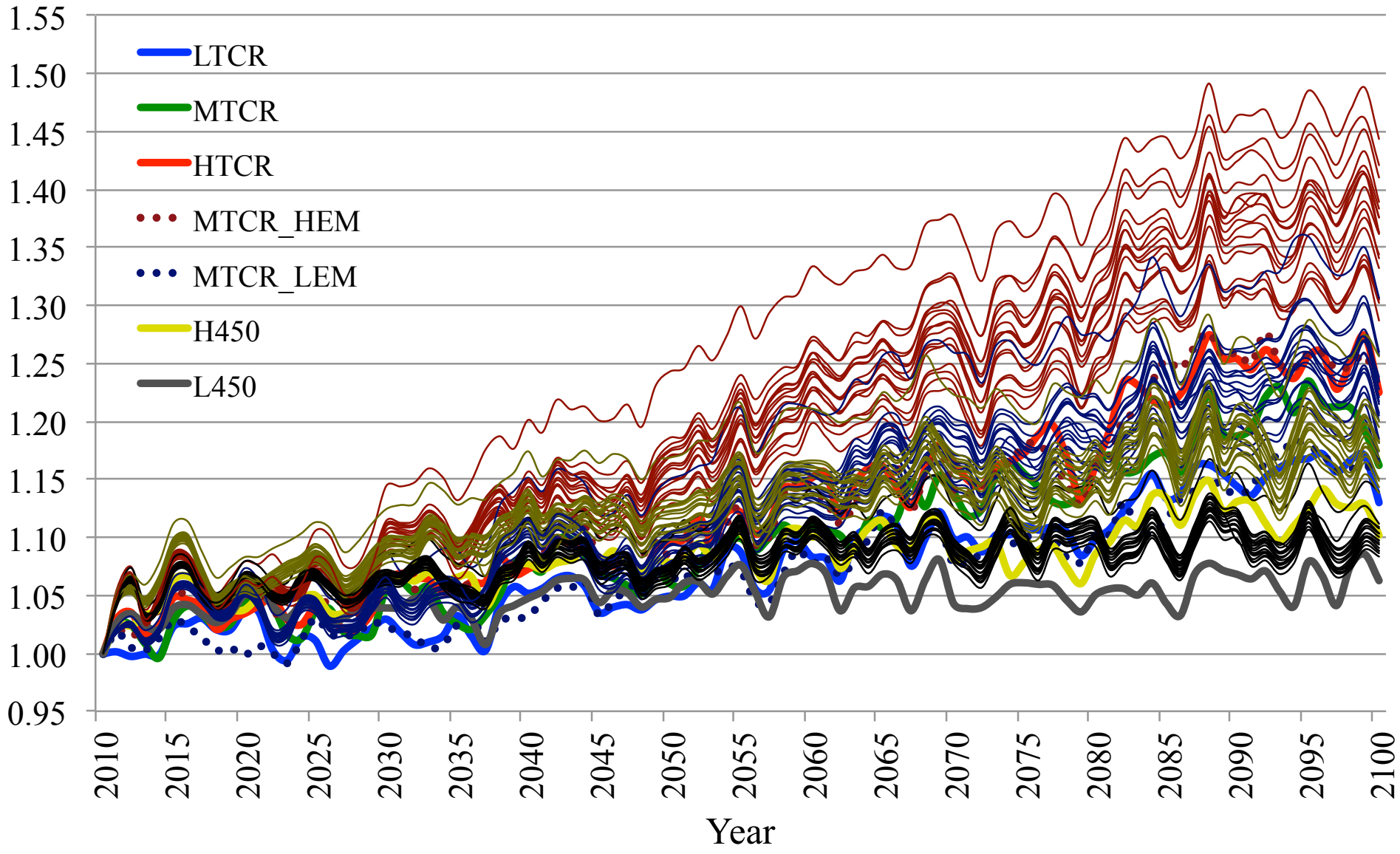


Schlosser et al., 2011

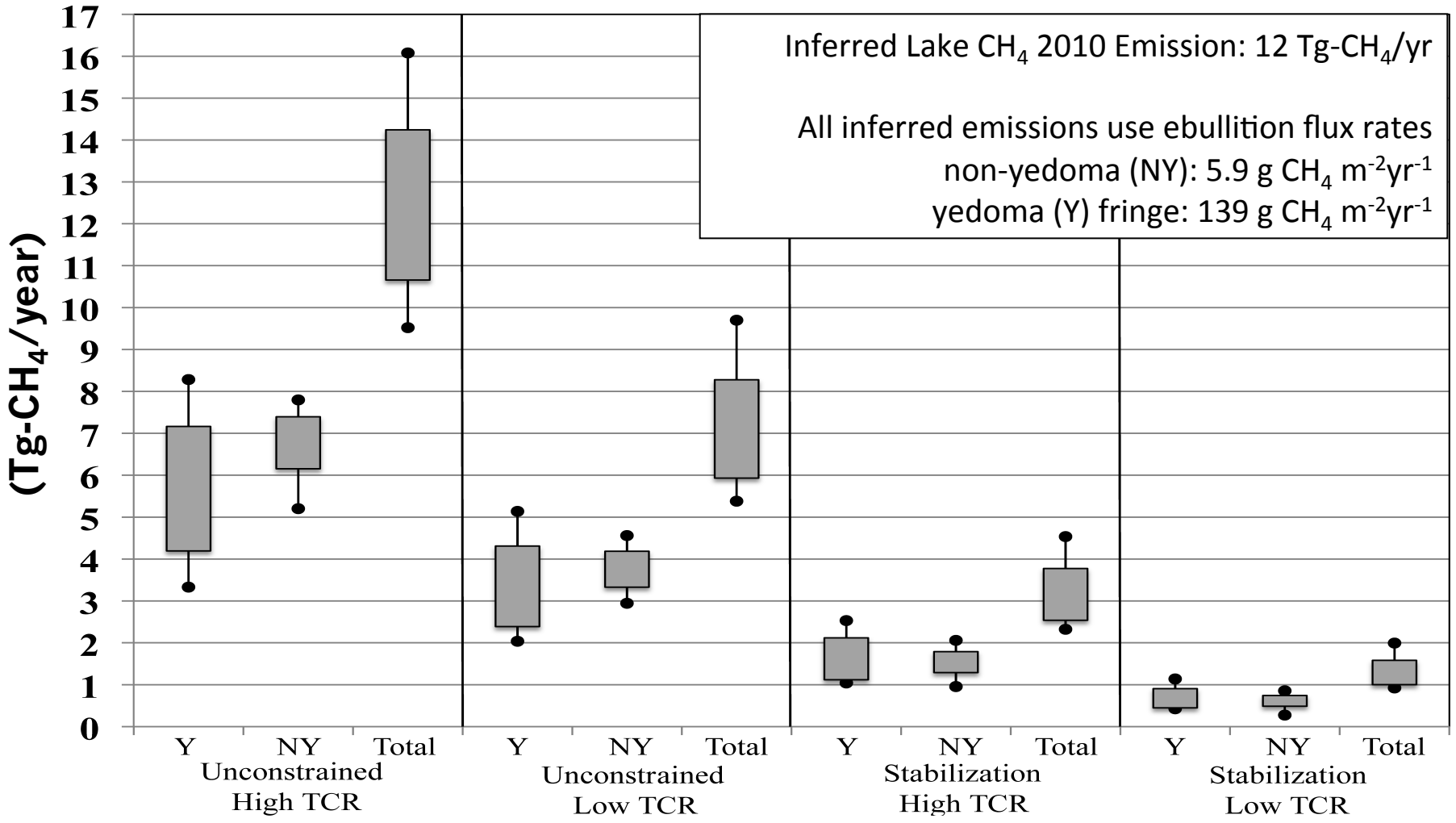
Relative change in near-surface permafrost extent



Relative change in saturated land extent



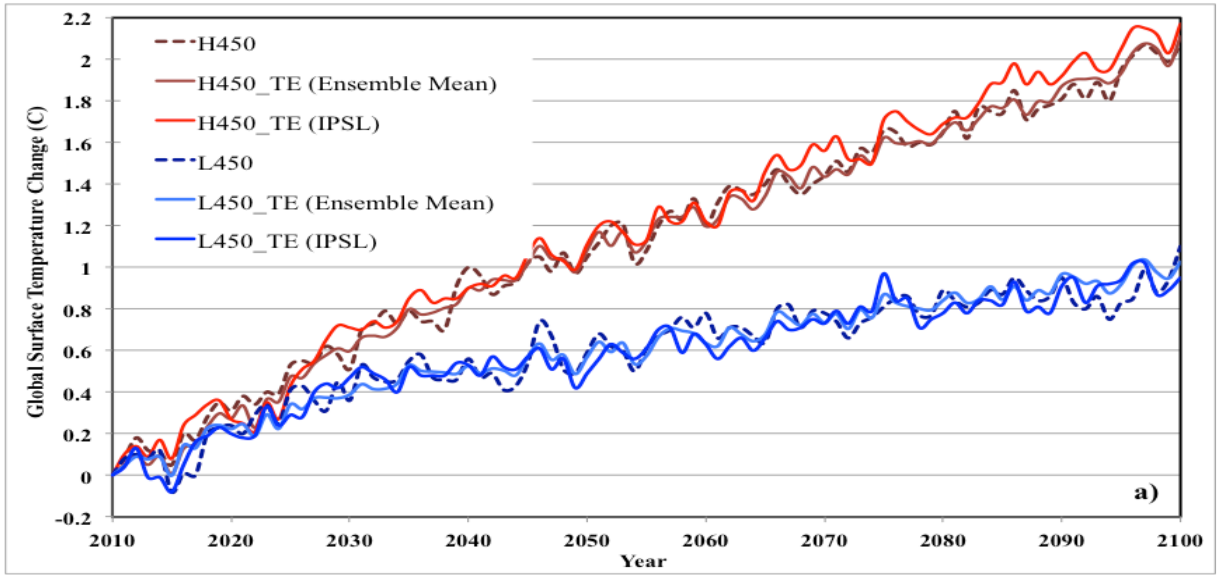
Changes in Methane Emission from Lake Expansion by end of 21st century

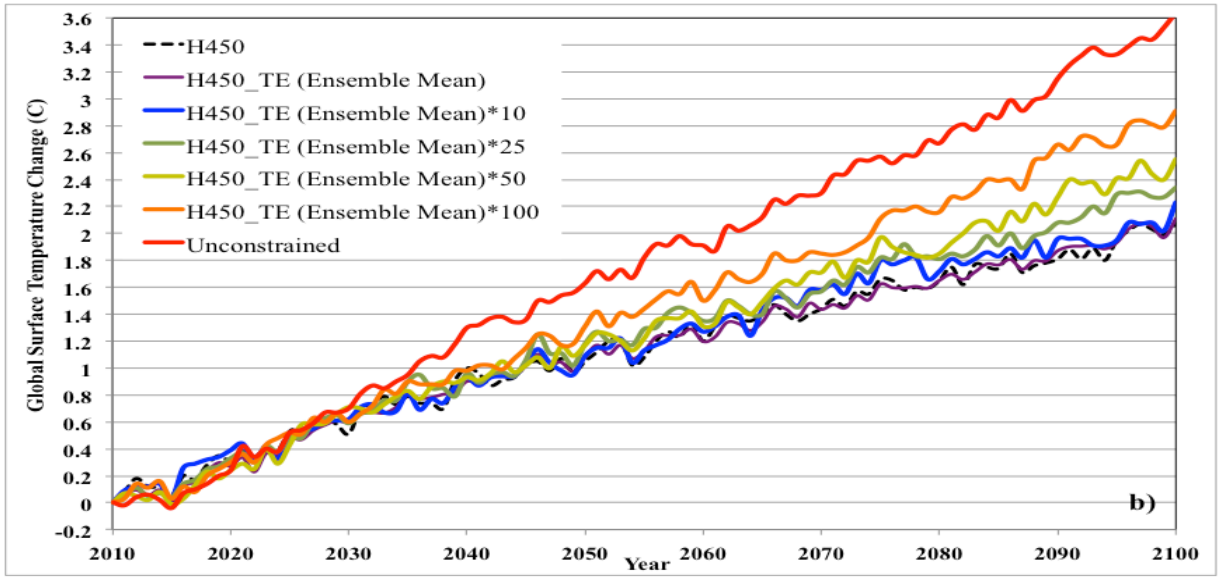


EPPA GLOBAL HUMAN CH_4 UCONSTRAINED EMISSION CHANGE: 349 TG/YR

EPPA GLOBAL HUMAN CH_4 STABILIZATION EMISSION CHANGE : 4TG/YR

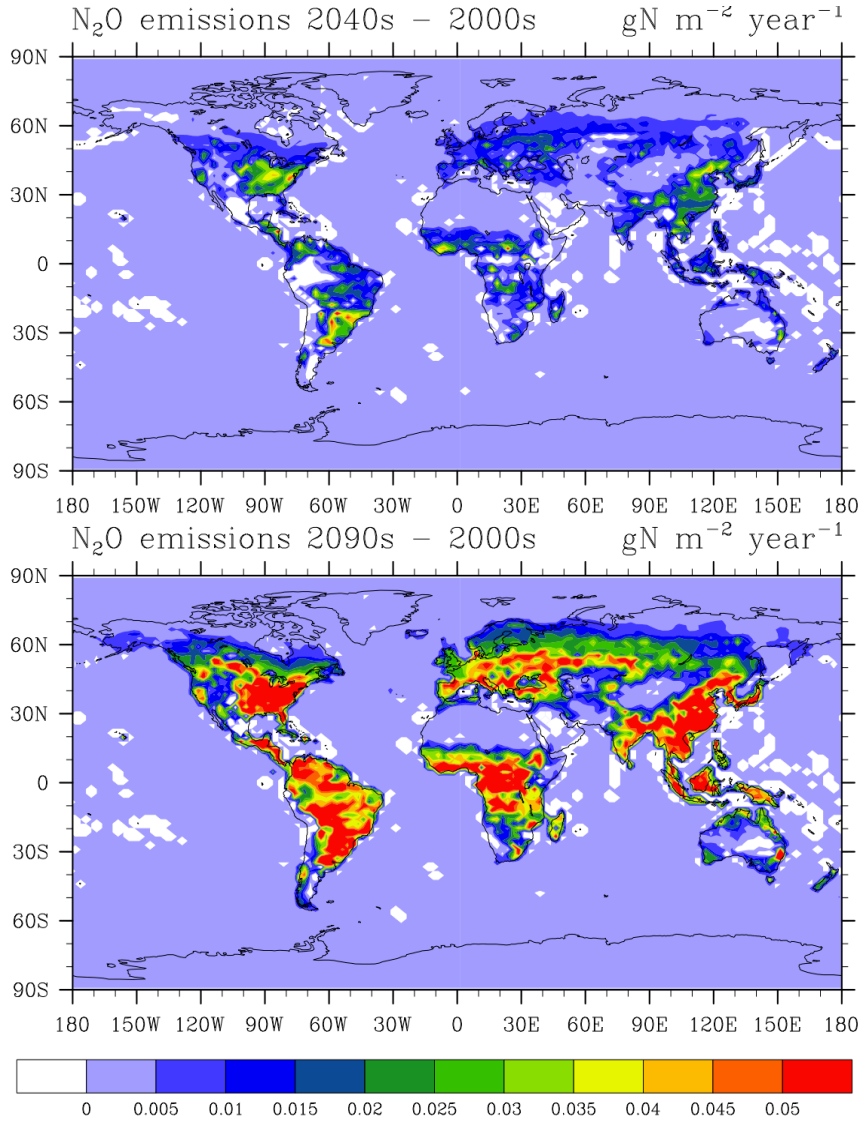
Temperature Feedback from Future Lake-Emission of Methane



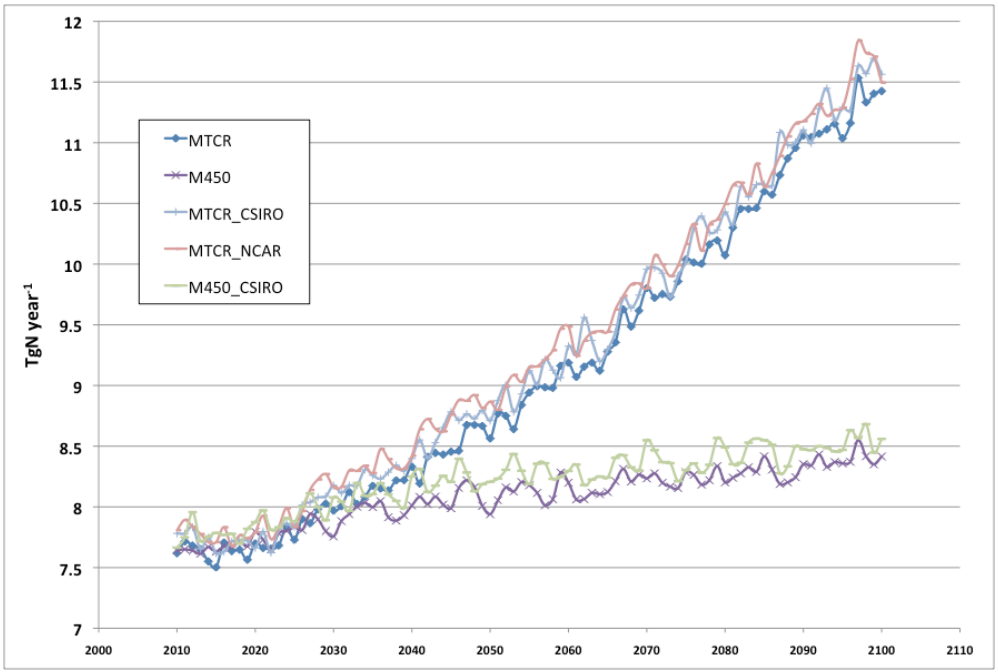


FEEDBACK IS SMALL

Changes in Soil N_2O Emission through 21st century

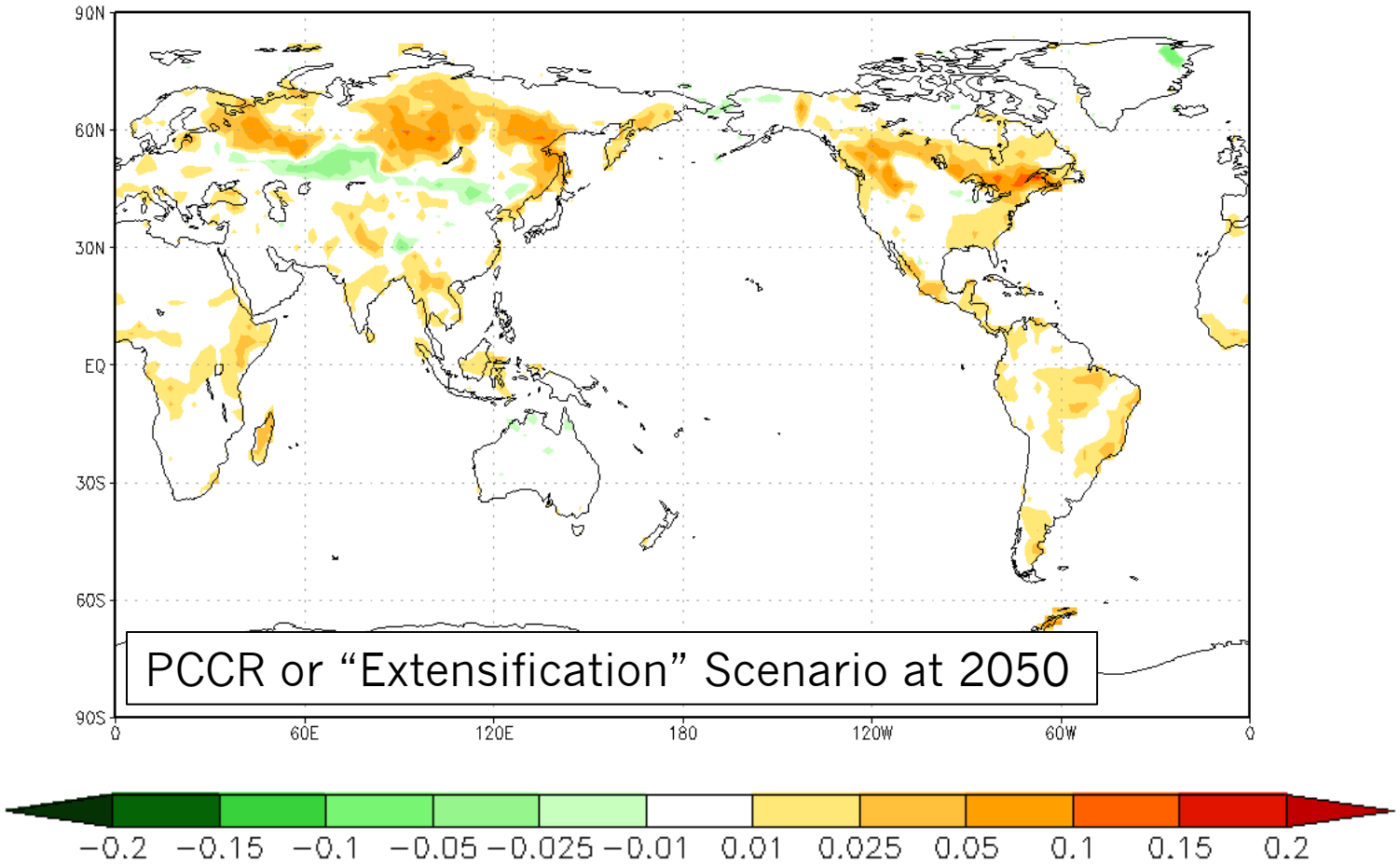


UNCONSTRAINED EMISSION SCENARIO



- In absence of human emission constraints, global soil emissions up by 50% at 2100.
- Notable boreal/Arctic increases at southern flank.
- Policy works!

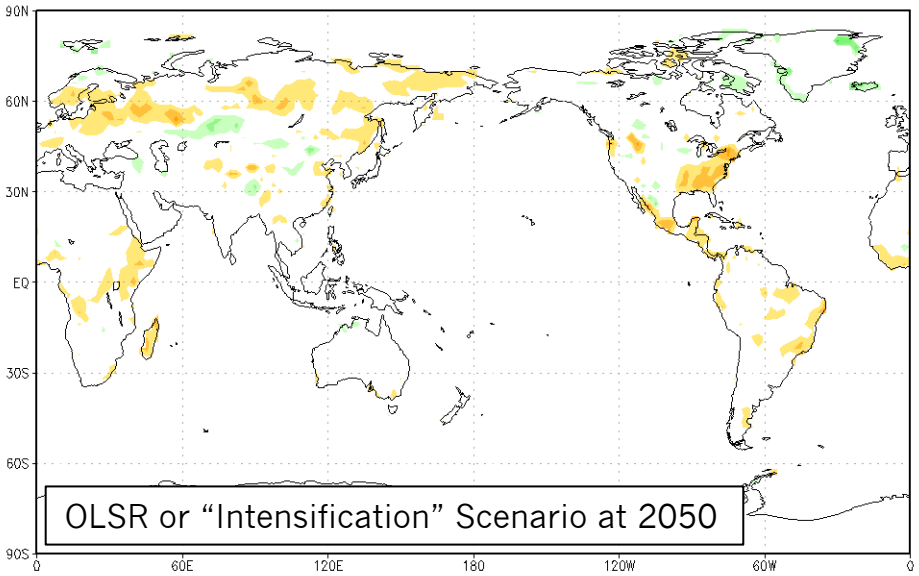
Land-use associated with climate/energy policy



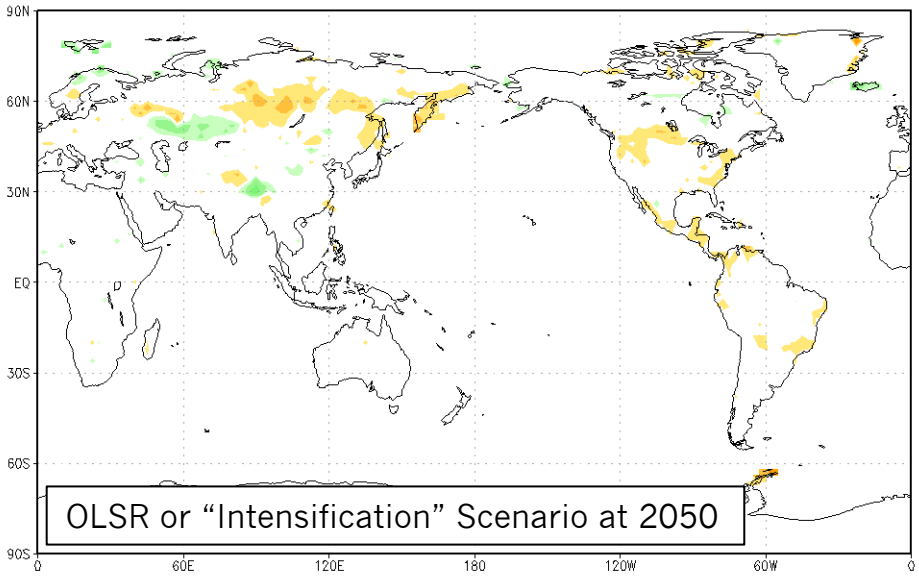
WIDESPREAD EXPANSE OF CLEARED (FORESTED) LAND FOR BIOFUELS SEEN AS INCREASES IN ALBEDO.

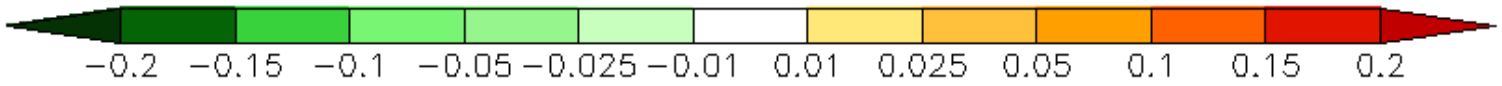
Land-use associated with climate/energy policy

With Biofuels



Without Biofuels

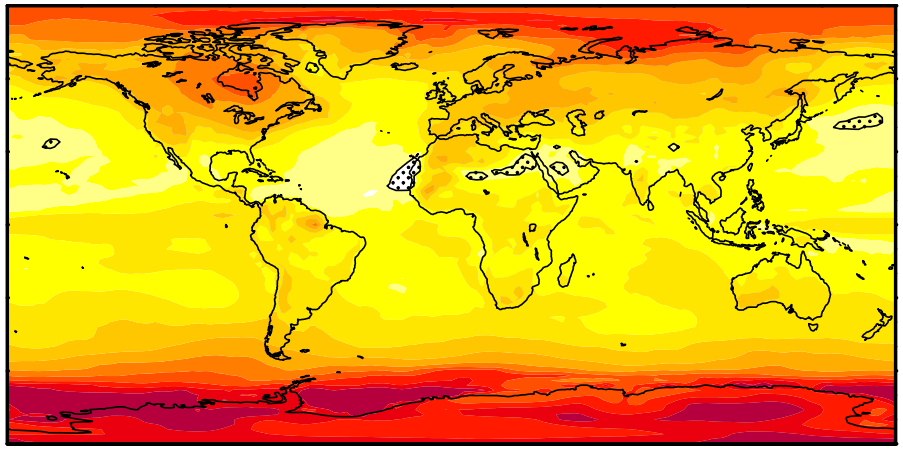




Notable areas of increased albedo are buffered or removed in the absence of biofuel penetration.

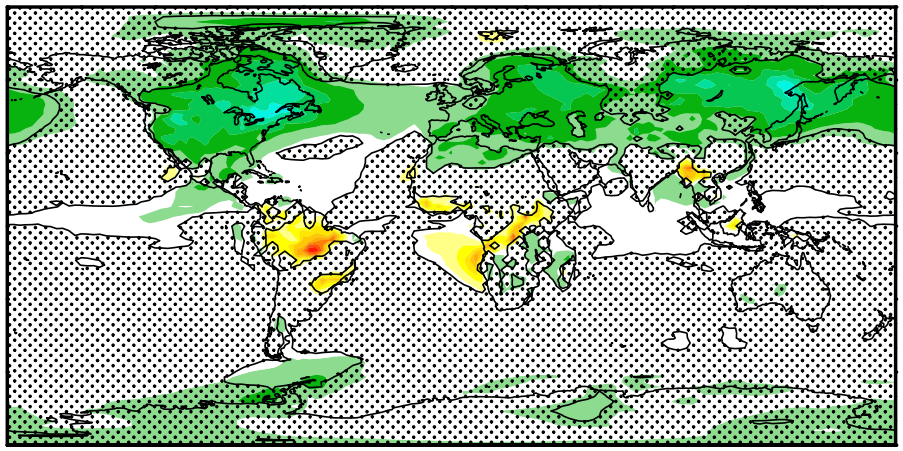
Surface-Air Temperature Changes: Land-Use Vs. GHG

Climate Change only

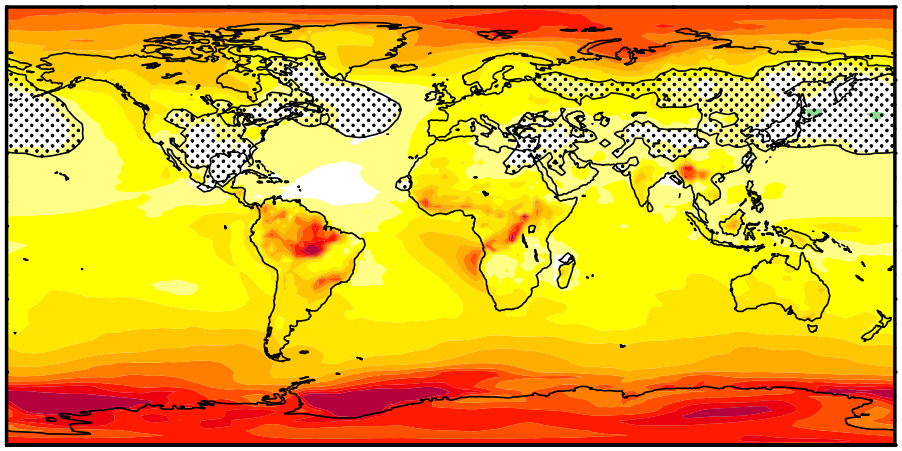


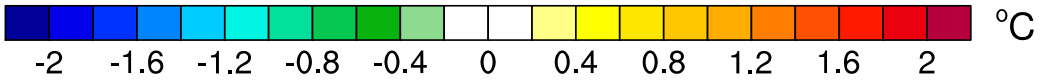
AT 2050 - BIOGEOPHYSICAL LAND-USE IMPACTS ON SURFACE TEMPERATURE CAN BE LARGER THAN THE BIOGEOCHEMICAL/CARBON IMPACT ON GLOBAL TEMPERATURE FROM BIOFUELS, *AND OF THE OPPOSITE SIGN*.

Land Cover Change only



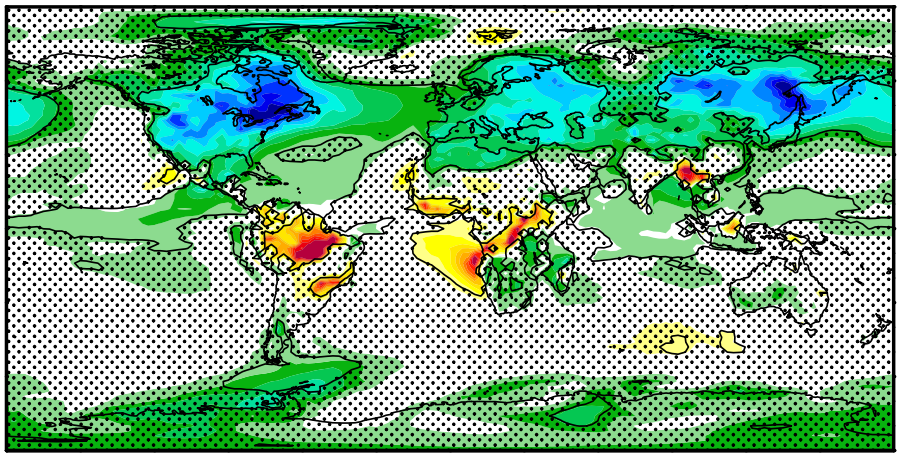
Climate Change + Land Cover Change



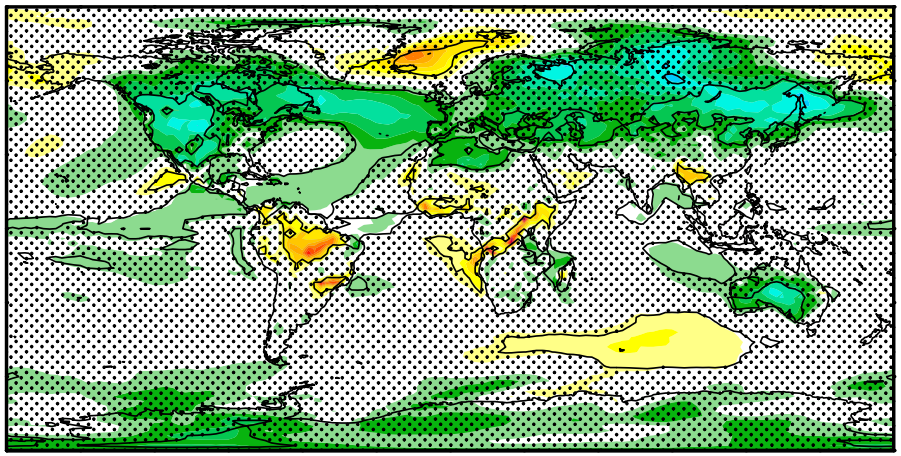


Surface-air temperature changes due to land use

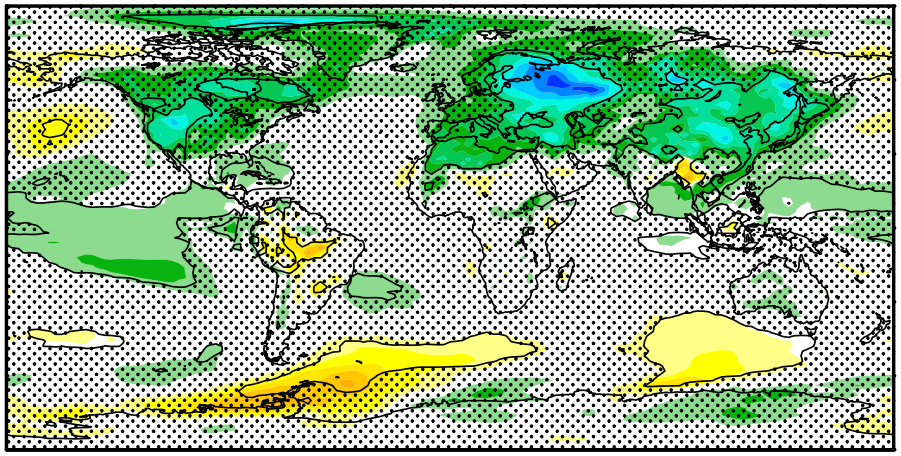
Land Cover Change only: PCCR scenario



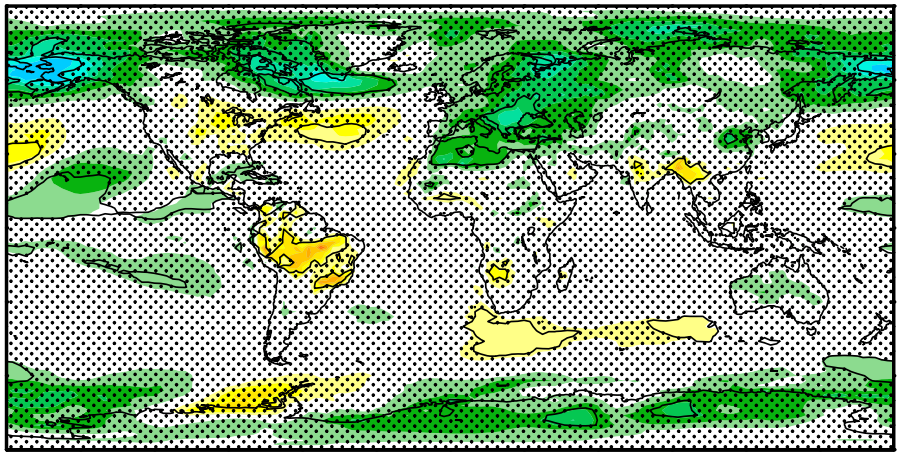
Land Cover Change only: OLSR scenario

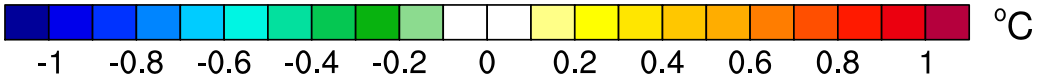


Land Cover Change only: PCCR-NoBiofuel scenario



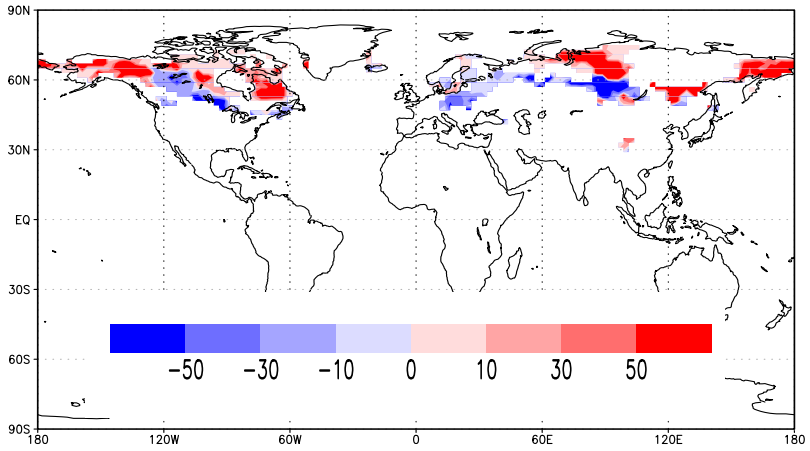
Land Cover Change only: OLSR-NoBiofuel scenario



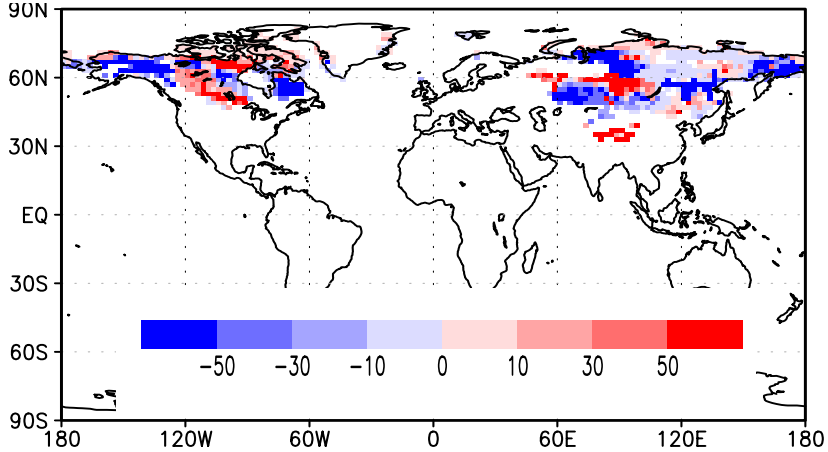


Plant Migration of Boreal/Arctic Vegetation

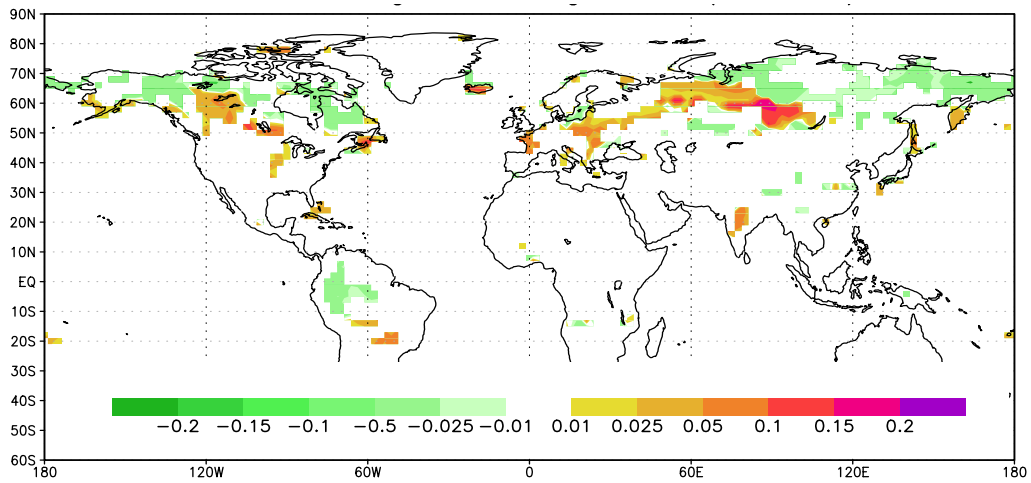
Change in boreal forest area (%)
early 21st century to the end of 21st century



Change in Arctic grass area (%)
early 21st century to the end of 21st century



Change in albedo
early 21st century to the end of 21st century



Closing Remarks

- Enhanced Arctic/boreal warming from increased concentration of radiatively-active trace gases.
- Most boreal/Arctic land areas will see increased precipitation.
- Near total degradation of near-surface permafrost from unconstrained emissions. Policy could help this substantially.
- Unlocked near-surface permafrost areas will emit more methane and (to a lesser extent) nitrous oxide. The good news: its temperature feedback within this century is small.
- Land-use and/or bioenergy: Locally, in coming decades – biogeophysics wins over biogeochemistry for climate "benefit".
- Natural migration by end of century potentially as "climate potent", biogeophysically speaking, as human land use (in 2050).