A Quantification of Climate Feedback from Permafrost Degradation and Thermokarst Methane Emission Under Climate Policy and Uncertainty

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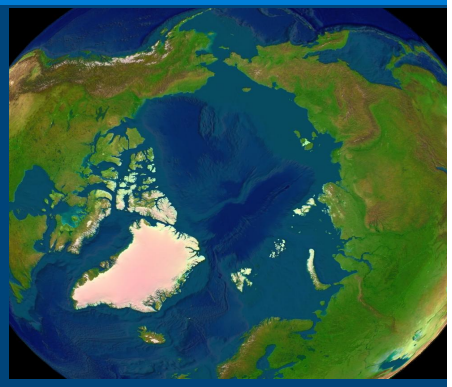
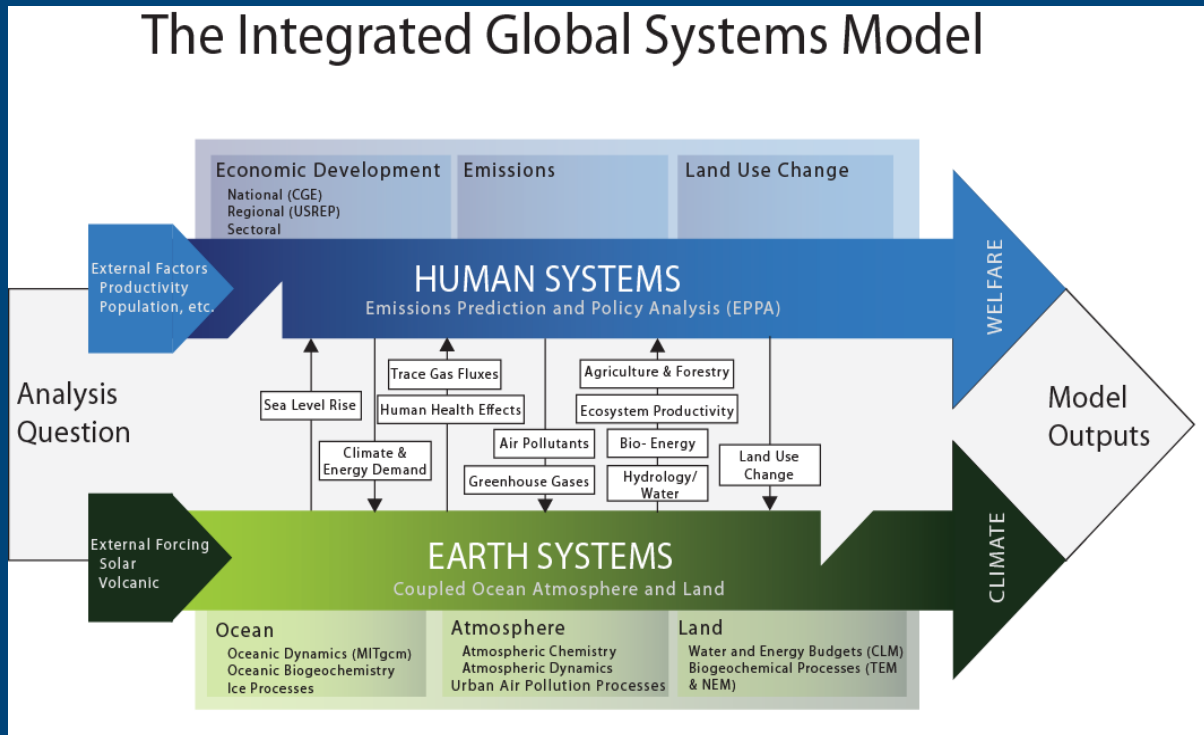


The Integrated Global Systems Model



Quasi-Linked Simulations with CLM3.5 @2°x2.5°, 1991-2100

Unconstrained Emission			
TCR	Emission	Notes	Abbreviation
High (95%)	Median (1330 ppm CO2)	+17 regional patterns	HTCR
Median (50%)		Baseline	MTCR
Low (5%)		+17 regional patterns	LTCR
Median (50%)	High(95%) (1660 ppm CO_2)		MTCR_HEM
	Low (5%) (970 ppm CO_2)		MTCR_LEM

Stabilization			
TCR	Emission	Notes	Abbreviation
High (95%)	550 ppm CO_2 Equivalent	+17 regional patterns	H450
Low (5%)		+17 regional patterns	L450

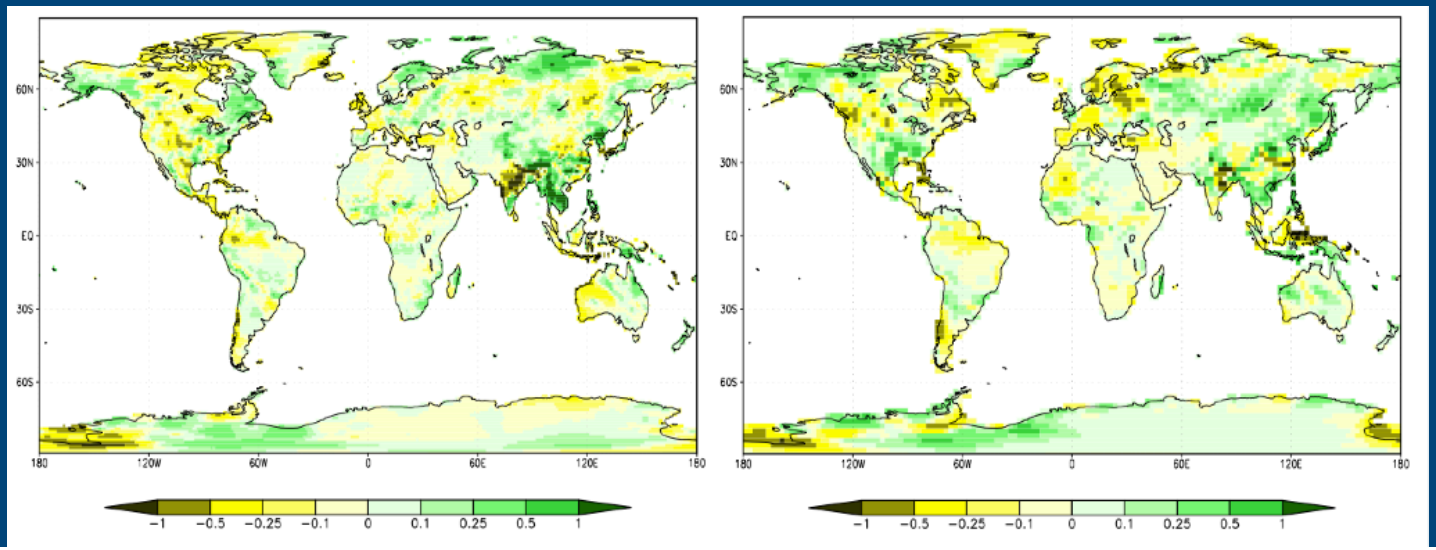
Total number of simulations: 17*4 + 7 = 75

Characterizing Regional Climate-Change Uncertainty in the IGSM: A Hybrid Approach

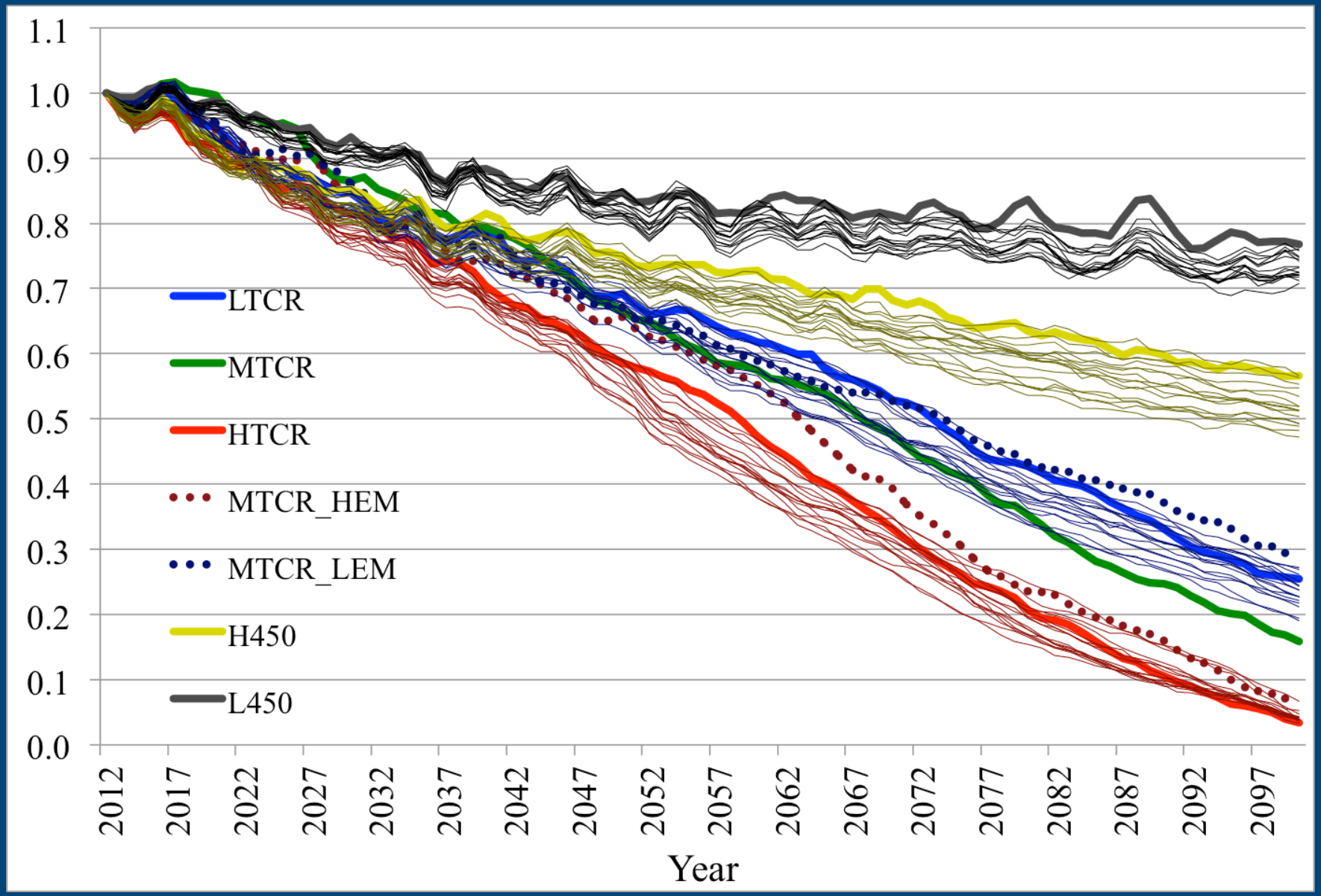
Schlosser et al., 2011 (JP Report #205)

$$V_{x,y}^{IGSM} = \left(C_{x,y} + \frac{dC_{x,y}}{dT_{Global}} * \Delta T_{Global}^{IGSM}\right) * \overline{V}_{y}^{IGSM}$$

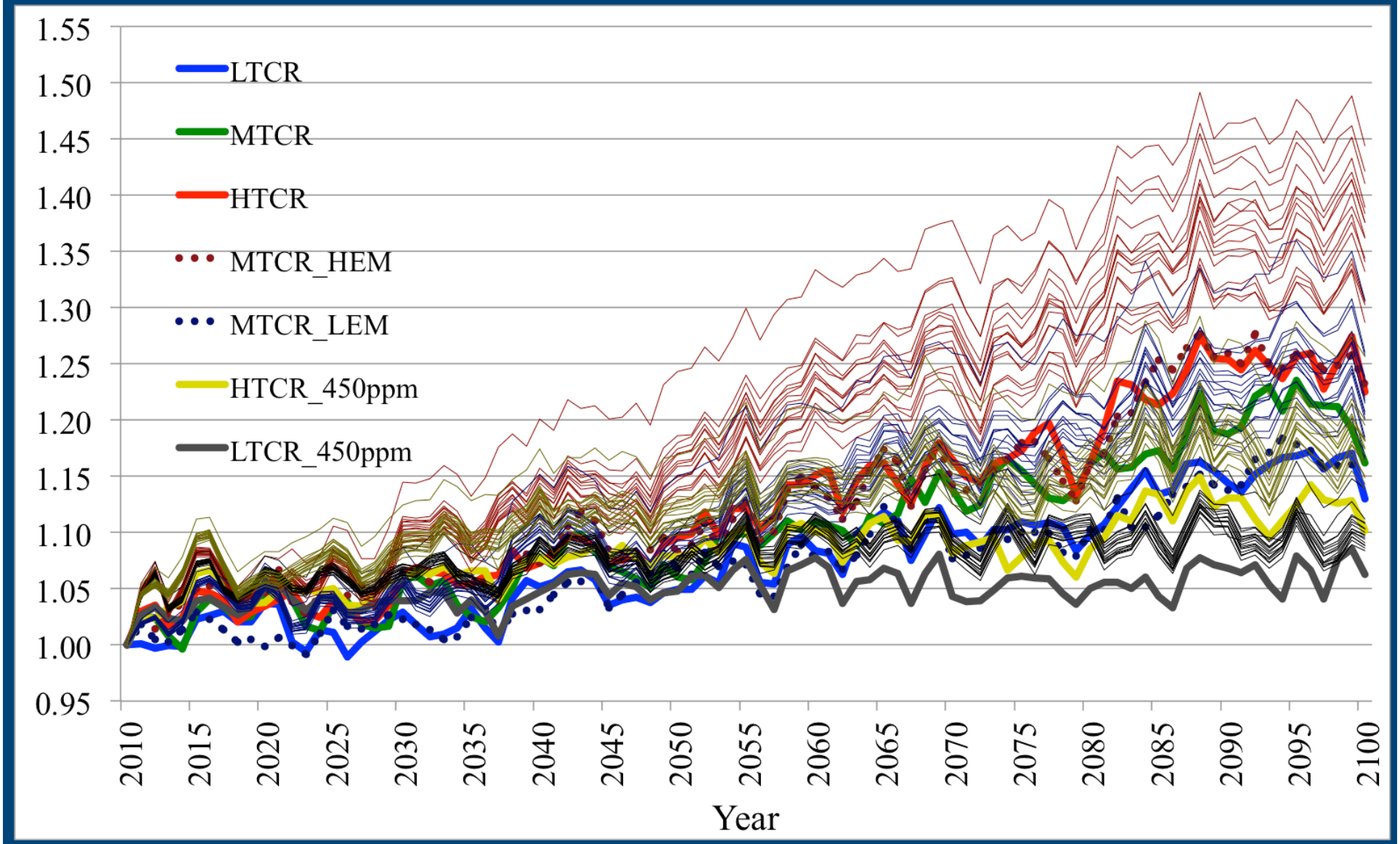
$\frac{dC_{x,y}}{dT_{Global}}$: The change of transformation coefficient at CO_2 doubling normalized by global temperature difference between the doubled CO_2 and the 20th century, based on the IPCC AR4 archive (~17 GCMs).



Trend in 45 ~ 90N Near-Surface Permafrost Extent (Fractional Change with Respect to 2012, Excluding Glacier)



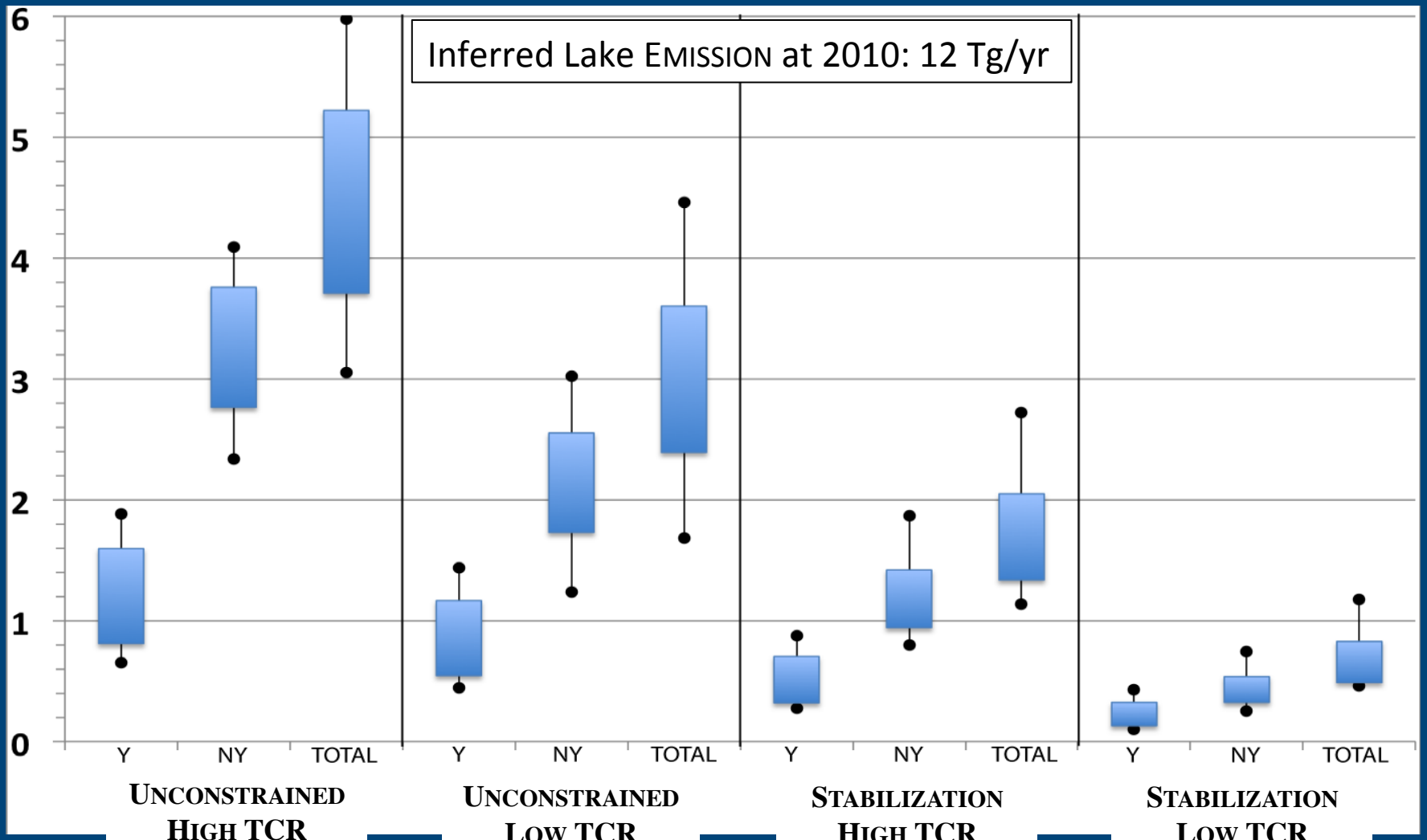
Trend in 45 ~ 90N Inferred Thermokarst Lake Extent (Fractional Change with Respect to 2010)



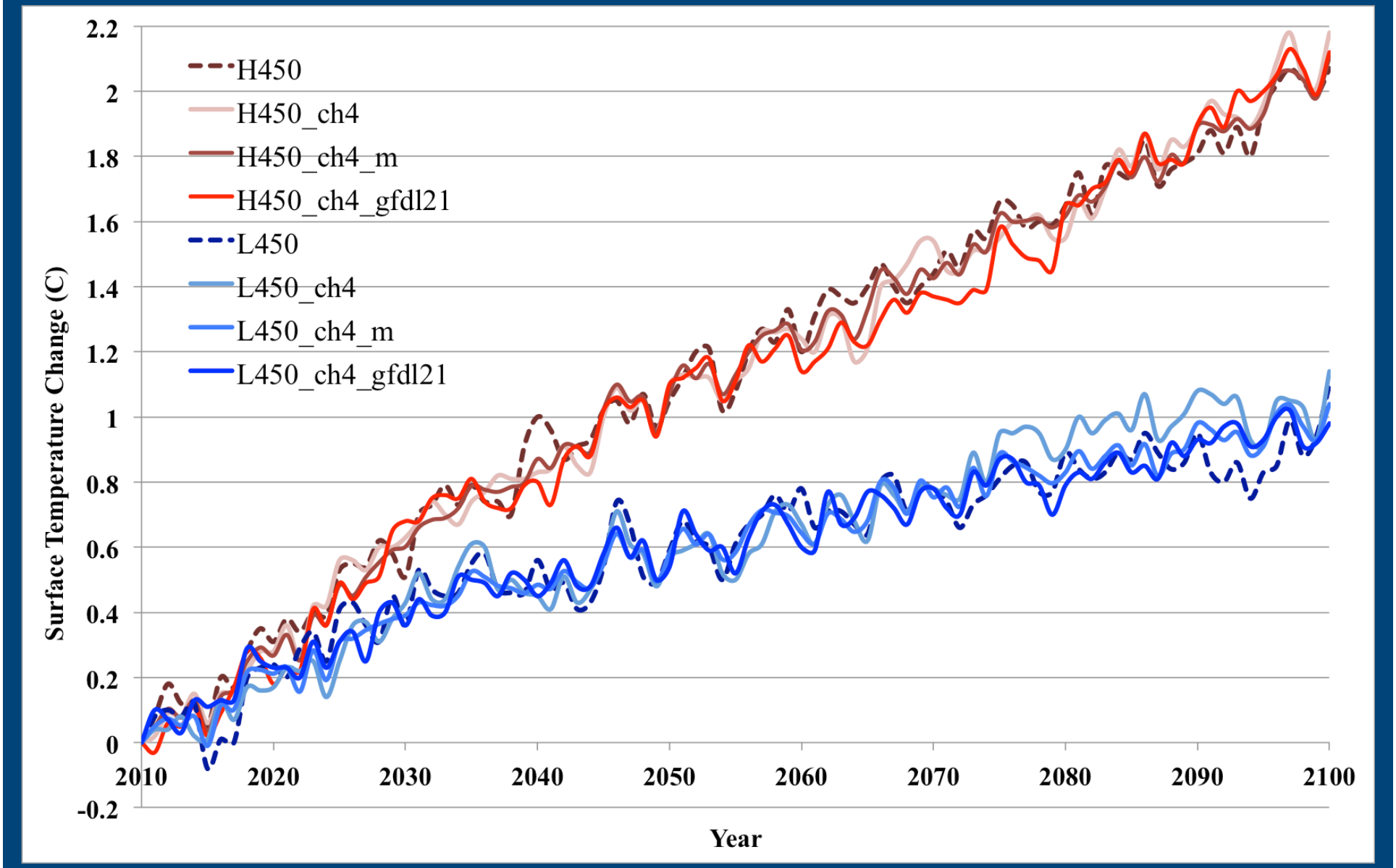
Inferred End of 21st Century Change in Methane Emission from Thermokarst Lake Expansion

EPPA Global Global Human CH_4 Emission Change: 349 Tg/yr

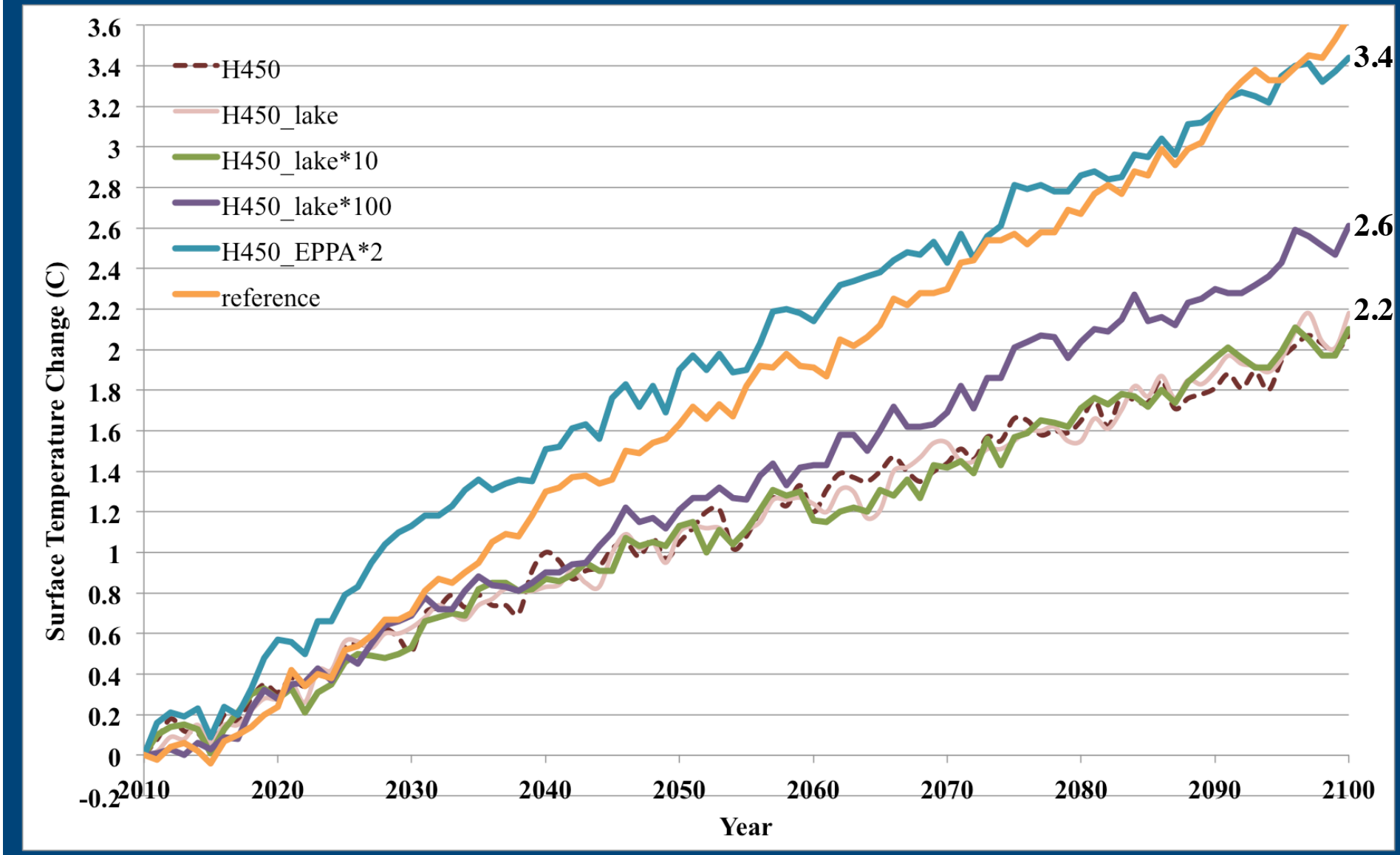
EPPA Global Human CH_4 Emission Change : 4Tg/yr



Climate Feedback (Stabilization)



Sensitivity of Climate Feedback



Summary

- Under range of uncertainty in TCR, permafrost degradation occurs linearly between 75% (Low TCR) to nearly 100% (high TCR) at 2100 for unconstrained emission case. Expansion in thermokarst lake occurs between 15% up to 25% for the low and high TCR, respectively.
- Stabilization policy could well prevent permafrost degradation (between 20% to 40%) and thermokarst lake expansion (between 5% and 15%).
- Incorporating regional climate change accelerates permafrost thawing and increases (inferred) lake expansion with the sensitivity of the latter much stronger.
- For unconstrained emission case, increase in lake methane emission is negligible compared with human global CH_4 emission increase (~ 345 Tg). However, the magnitude is comparable for stabilization case.
- Under the uncertainty of transient climate responses, emission, and regional climate changes, our modeled evidence indicates that the increase in CH_4 emission due solely to the expansion of the thermokarst CH_4-emitting lakes has little (if any) feedback to climate warming.
- Sensitivity experiments show that the increased CH_4 emission from thermokarst lake expansion has to be around 100-fold of current estimate to have any discernable temperature response.