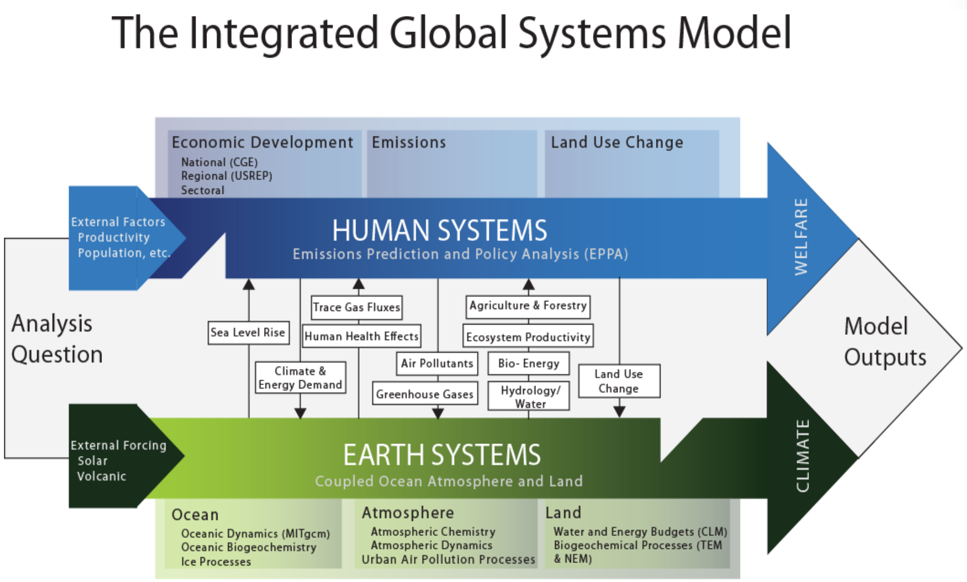
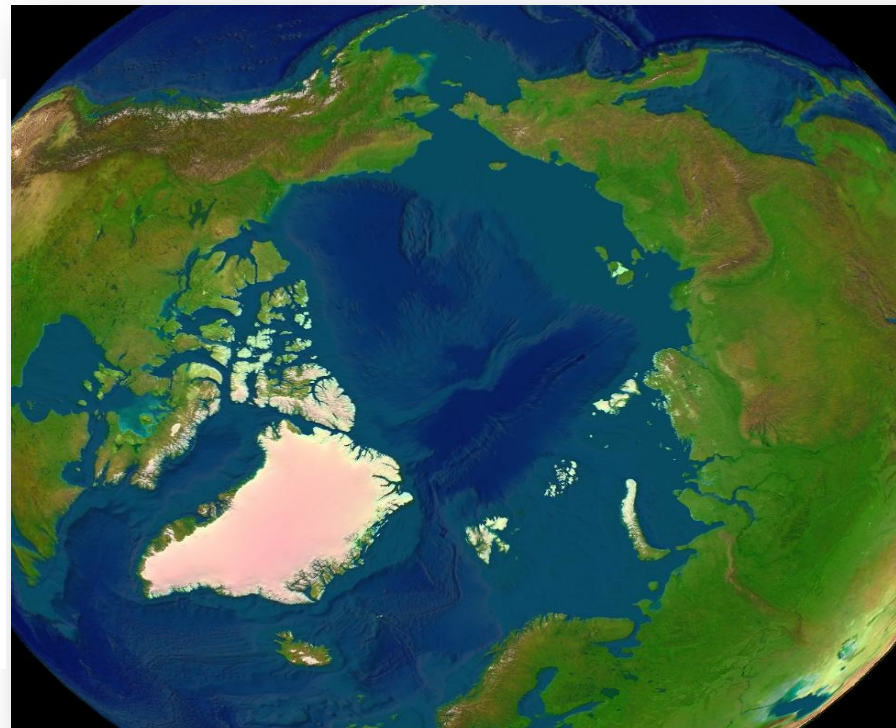
21ST CENTURY PROJECTIONS OF CH4 AND N2O SOIL-ECOSYSTEM EMISSIONS AND CLIMATE-POLICY EFFECTS

C. Adam Schlosser, Xiang Gao, Eri Saikawa, Andrei Sokolov, Katey Walter, Qianlai Zhuang, Jerry Melillo, and David Kicklighter





MIT Joint Program on the
SCIENCE AND POLICY OF GLOBAL CHANGE

QUASI-LINKED SIMULATIONS WITH CLM3.5 @2°X2.5°, 1991-2100

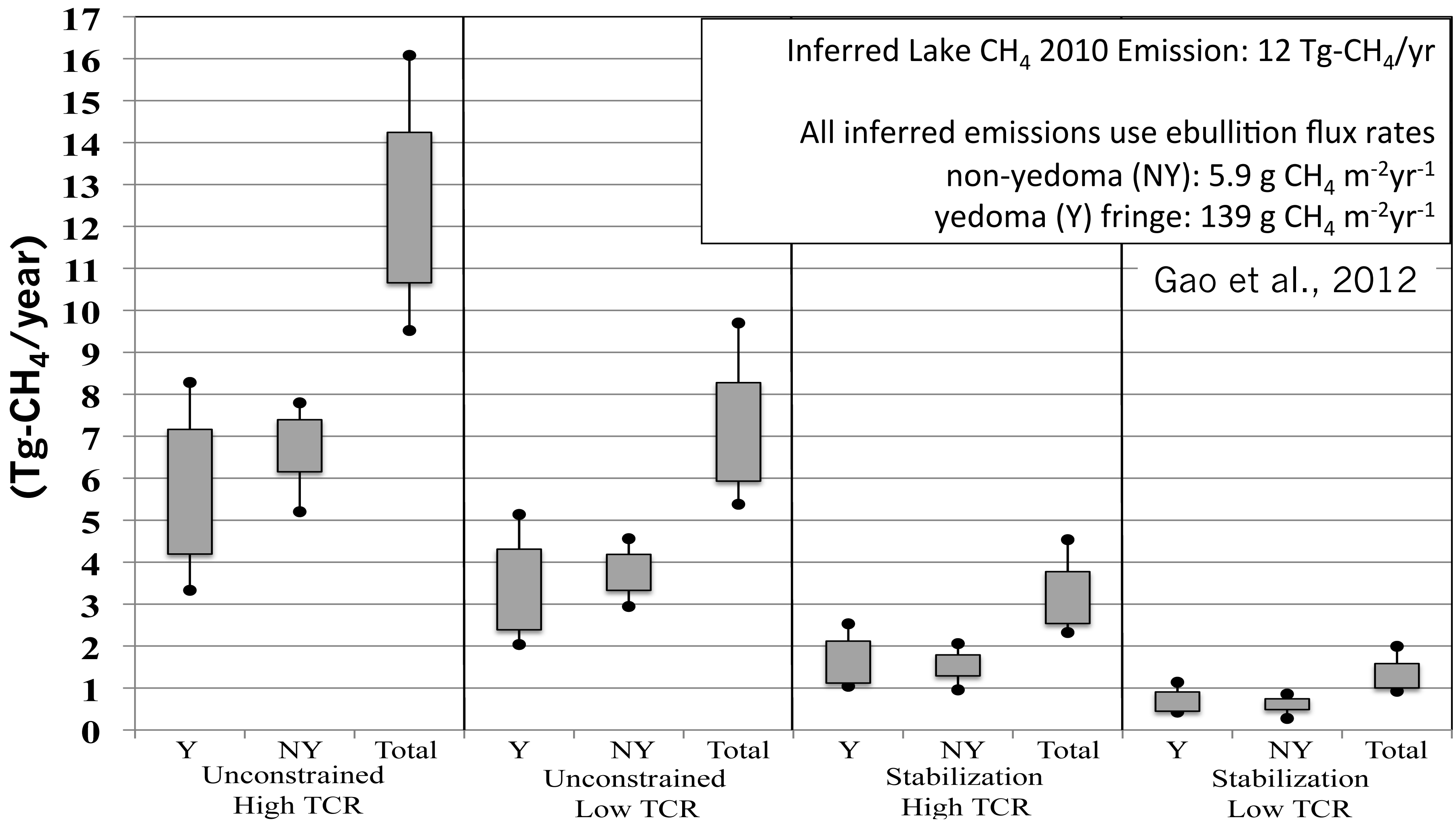
UNCONSTRAINED EMISSION			
TCR	Emission	Notes	Abbreviation
High (95%)	Median (1330 ppm CO2)	+17 regional patterns	HTCR
Median (50%)		Baseline	MTCR
Low (5%)		+17 regional patterns	LTCR
Median (50%)	High(95%) (1660 ppm CO_2)		MTCR_HEM
	Low (5%) (970 ppm CO_2)		MTCR_LEM

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

Gao et al., 2012

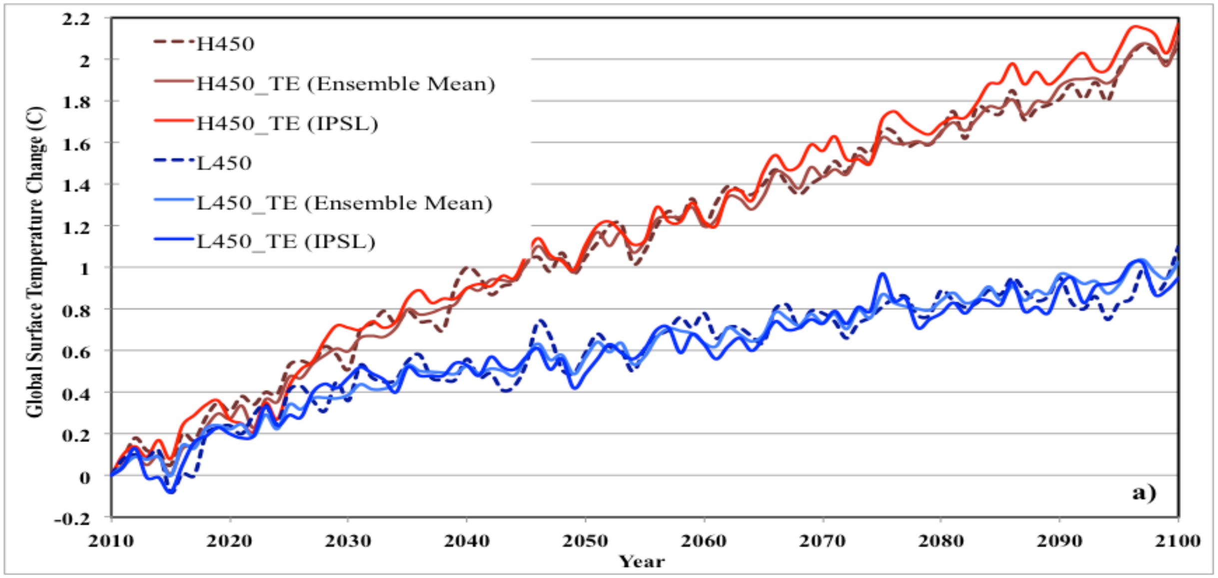
Changes in Methane Emission from Lake Expansion by end of 21st century



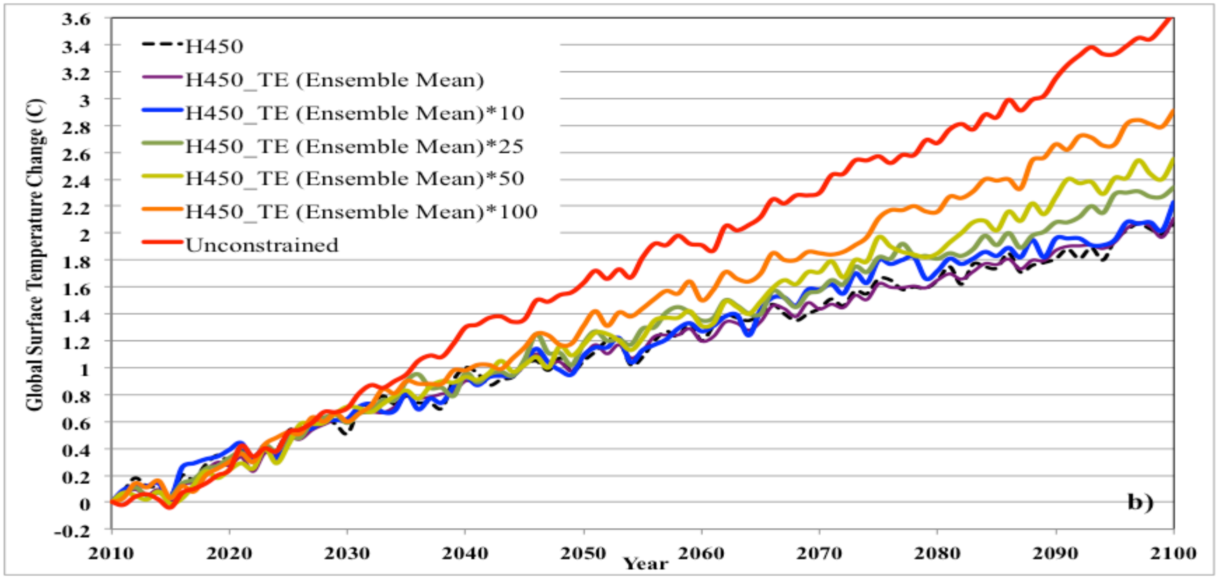
EPPA GLOBAL HUMAN CH_4 UCONSTRAINED EMISSION CHANGE: 349 TG/YR

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

Temperature Feedback from Future Lake-Emission of Methane



TEMPERATURE FEEDBACK IS SMALL FOR EITHER UNCONSTRAINED OR STABILIZATION CASE



ADDITIONAL ~10-FOLD INCREASE IN CH_4 EMISSION TREND NEEDED TO PROVIDE SALIENT TEMPERATURE RESPONSE

Gao et al., 2012

Development of CLM-CN-N2O

- Saikawa et al. (2011, *GBC* under revision) and JP Report #206 (http://globalchange.mit.edu/pubs/abstract.php?publication_id=2213).
- N_2O emissions flux module within CLM-CN v3.5 includes the DeNitrification-DeComposition (DNDC) Model (Li *et al*., 1992).
- CLM-CN-N_2O includes pools of N_2O, NO_3^-, NH_3 and NH4$^+$, and treats N inputs from atmospheric deposition, biological N fixation, N losses to NH_4^+ and NO_3^- leaching.
- N_2O emissions via nitrification & denitrification at each timestep.
  - NH_4^+ is produced via biomass decomposition.
  - Nitrification is temperature and moisture takes place under aerobic conditions. NO_3 is produced from NH_4^+, and in between, N_2O is also released.
  - Denitrification, a process converting NO_3 into N_2, is also temperature and soil moisture dependent and takes place under anaerobic conditions. The growth rate of denitrifiers, NO_3^-, nitrite (NO_2^-), and N_2O, is controlled by the ratio of the soluble C in saturated soil layer to the total soil C as well as the ratio of each denitrifier to the total soil N. The dynamics of the soil C pool are calculated in CLM-CN.

CLM-CN-N2O Model: Contemporary Assessment

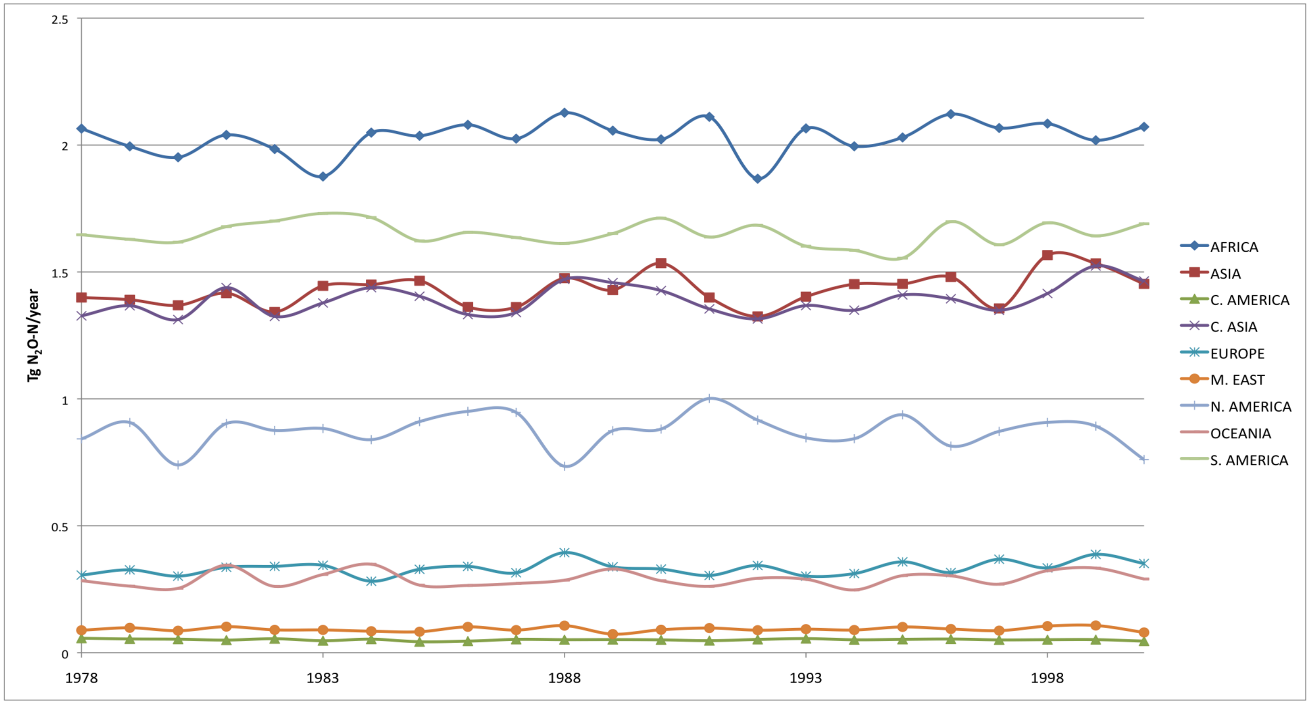


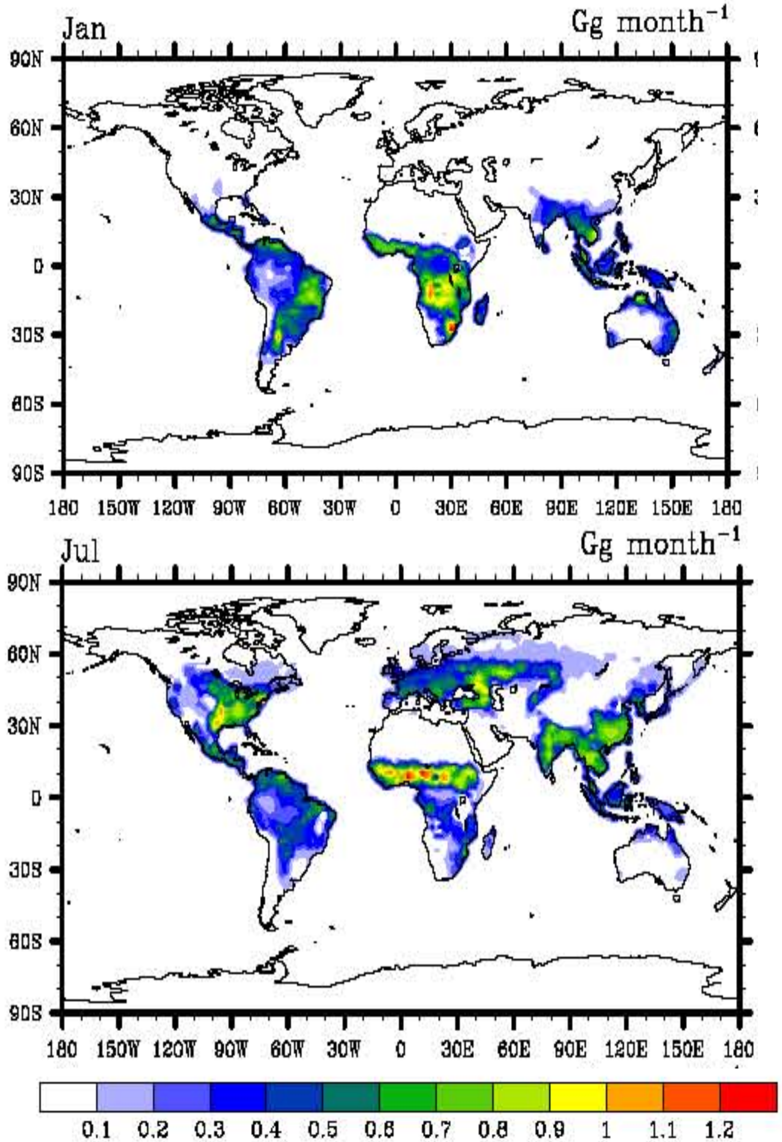
Table 1. Regional soil N_2O emissions for year 2000 (Tg N_2O-N/year)

Region	NCC	CAS	GOLD
AFRICA	2.07 (25.2%)	1.99 (22.5%)	1.79 (23.8%)
ASIA	1.45 (17.7%)	1.54 (17.5%)	1.27 (16.9%)
CENTRAL AMERICA	0.05 (0.6%)	0.05 (0.6%)	0.05 (0.6%)
CENTRAL ASIA	1.46 (17.8%)	1.85 (20.9%)	1.46 (19.5%)
EUROPE	0.35 (4.3%)	0.39 (4.4%)	0.35 (4.6%)
MIDDLE EAST	0.08 (1.0%)	0.10 (1.1%)	0.08 (1.1%)
NORTH AMERICA	0.76 (9.3%)	0.86 (9.7%)	0.75 (10.0%)
OCEANIA	0.30 (3.5%)	0.33 (3.7%)	0.29 (3.8%)
SOUTH AMERICA	1.69 (20.6%)	1.73 (19.6%)	1.47 (19.6%)
TOTAL	8.21	8.83	7.50

- Africa highest natural emission rate. Asia and S. America not far behind.
- Decreases seen to correspond with drought and El Nino years.

Saikawa et al., 2011/2012

Model Assessment: The good and not so good...



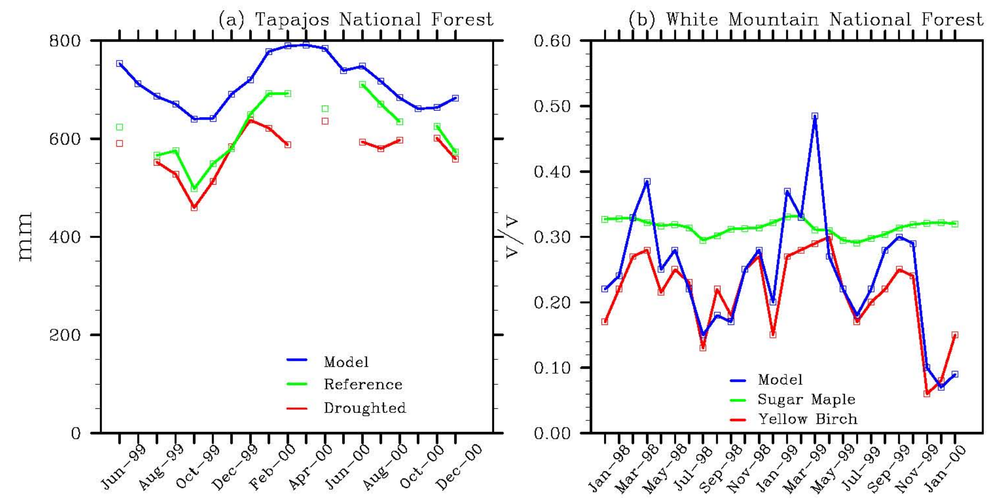


Figure 8. Comparison of volumetric water content of the (left) top 2m of soil between observations in the Tapajós National Forest and model and (right) top 10cm between observations in the White Mountain National Forest and model

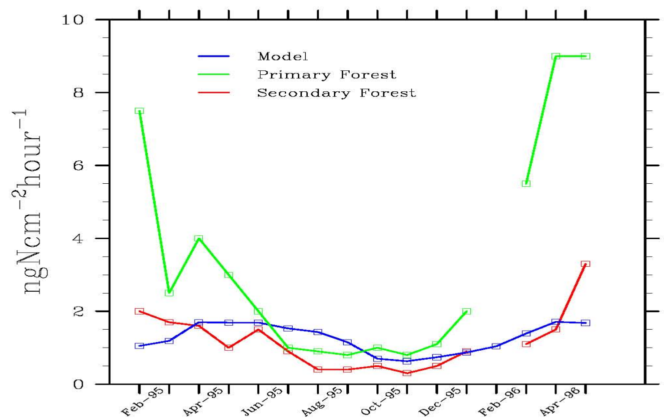
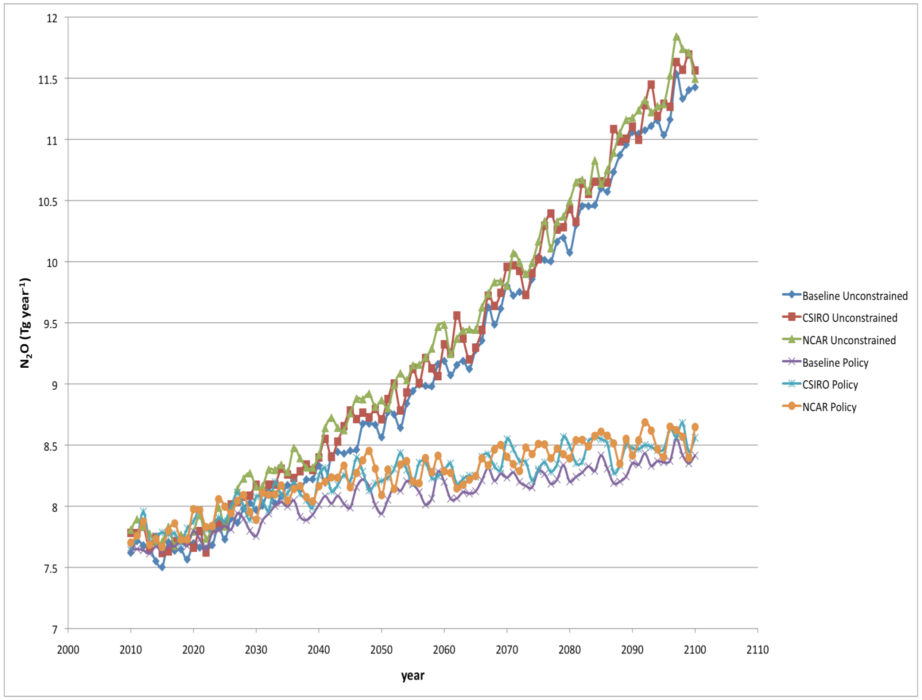


Figure 11. Comparison of soil N_2O emissions flux between observations (primary forest and secondary forest) and model in Fazenda Fazenda Vitoriá

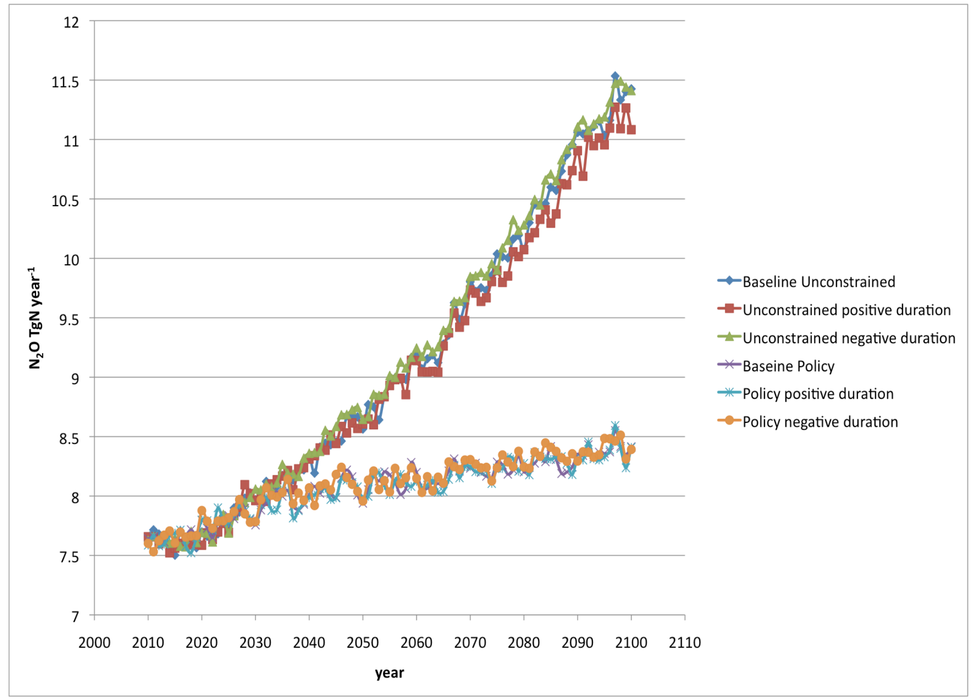
Saikawa et al., 2011/2012

Changes in Global Soil N_2O Emission through 21st century

Climate Policy vs. Regional Uncertainty

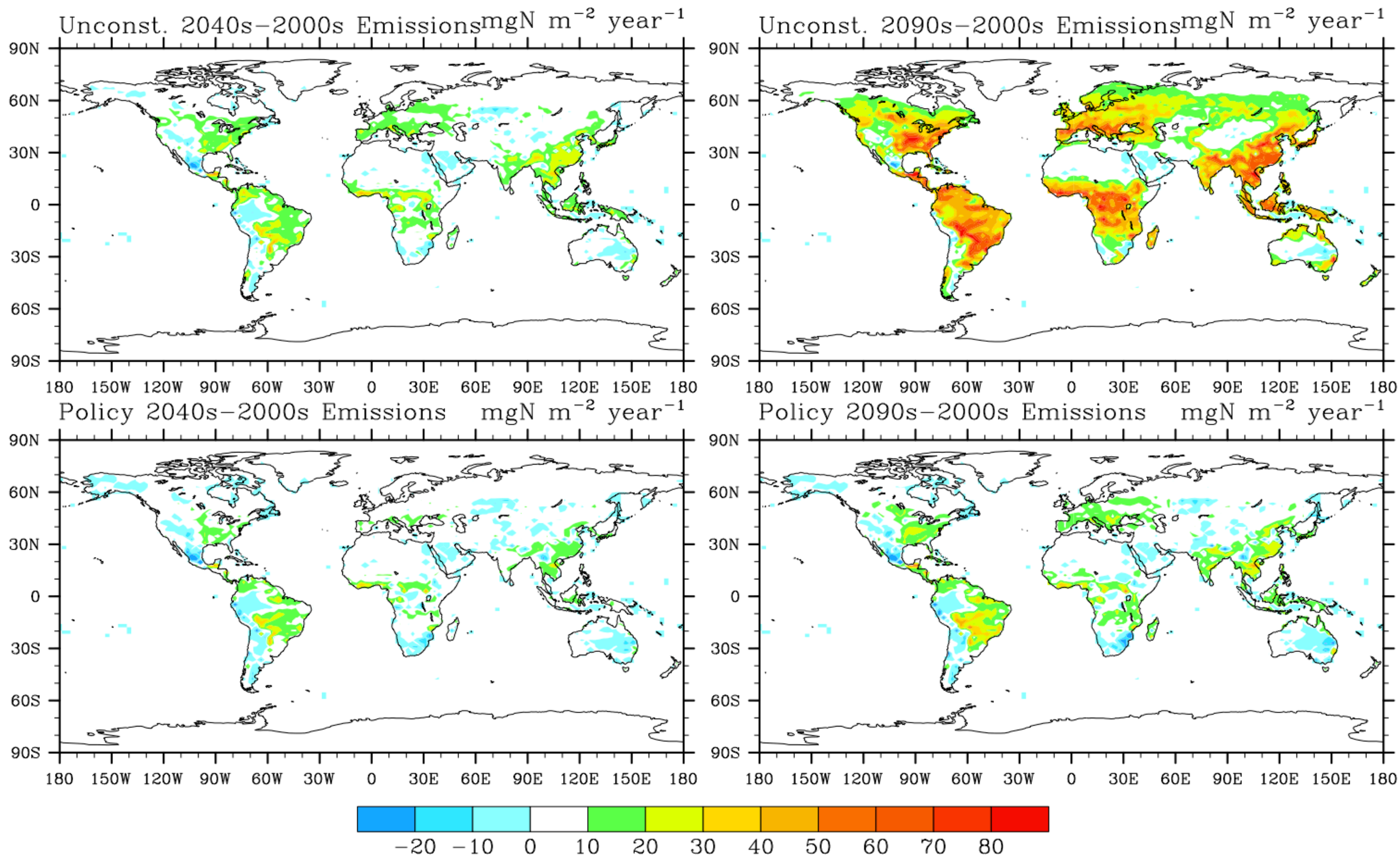


Climate Policy vs. Precipitation Frequency Uncertainty



- In absence of emission constraints, global soil emissions up 50% at 2100.
- Climate policy works!
- Uncertainty in regional climate patterns and precipitation frequency show low sensitivity in light of climate policy response.

Geographic Variations of N_2O emission change



Work continues to address such issues as…

- Adding Methane Dynamics Model (MDM, Zhuang et al., 2004) in CLM. Leveraging off work with CLM-CN-N2O development.
- Bulk/quasi-static geographic representation of saturated areas/wetlands/lakes and the importance of the biogeophysical response.
- Importance of agricultural expansion and fertilization… adding crop module in CLM-CN based on CliCrop (Fant et al., 2012) and CROPWAT formalisms.
- Just how important are the combined natural CH4 and N2O emissions responses?