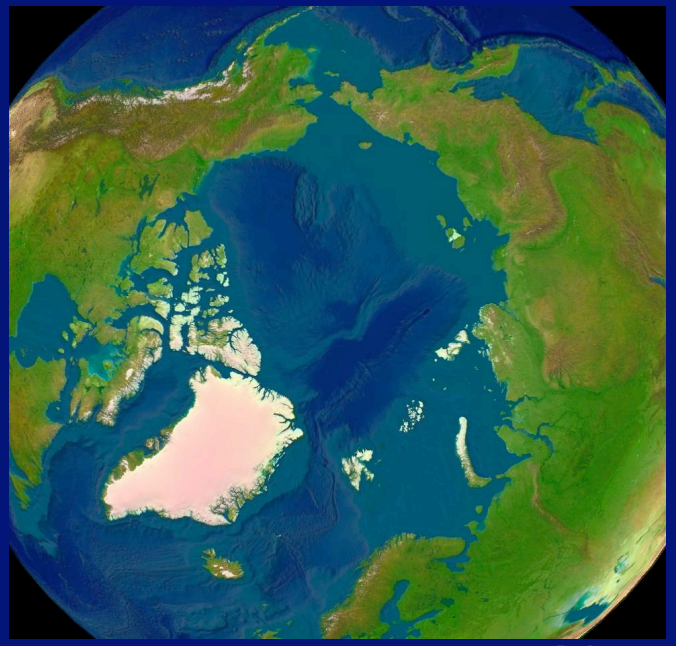
Quantifying Climate Feedbacks from Abrupt Changes in High-Latitude Trace-Gas Emissions

Project Objective:

Quantify the potential for threshold changes in natural emission rates of trace gases, particularly methane and carbon dioxide, from pan-arctic terrestrial systems under the spectrum of anthropogenically forced climate warming, and the extent to which these emissions provide a strong feedback.

Tested Hypothesis:

There exists a climate warming threshold beyond which permafrost degradation becomes widespread and thus instigates strong and/or sharp increases in methane emissions (via thermokarst lakes and/or wetland expansion). These would outweigh any increased uptake of carbon (e.g. from peatlands) and would result in a strong, positive feedback to global climate warming.



Project Investigators:

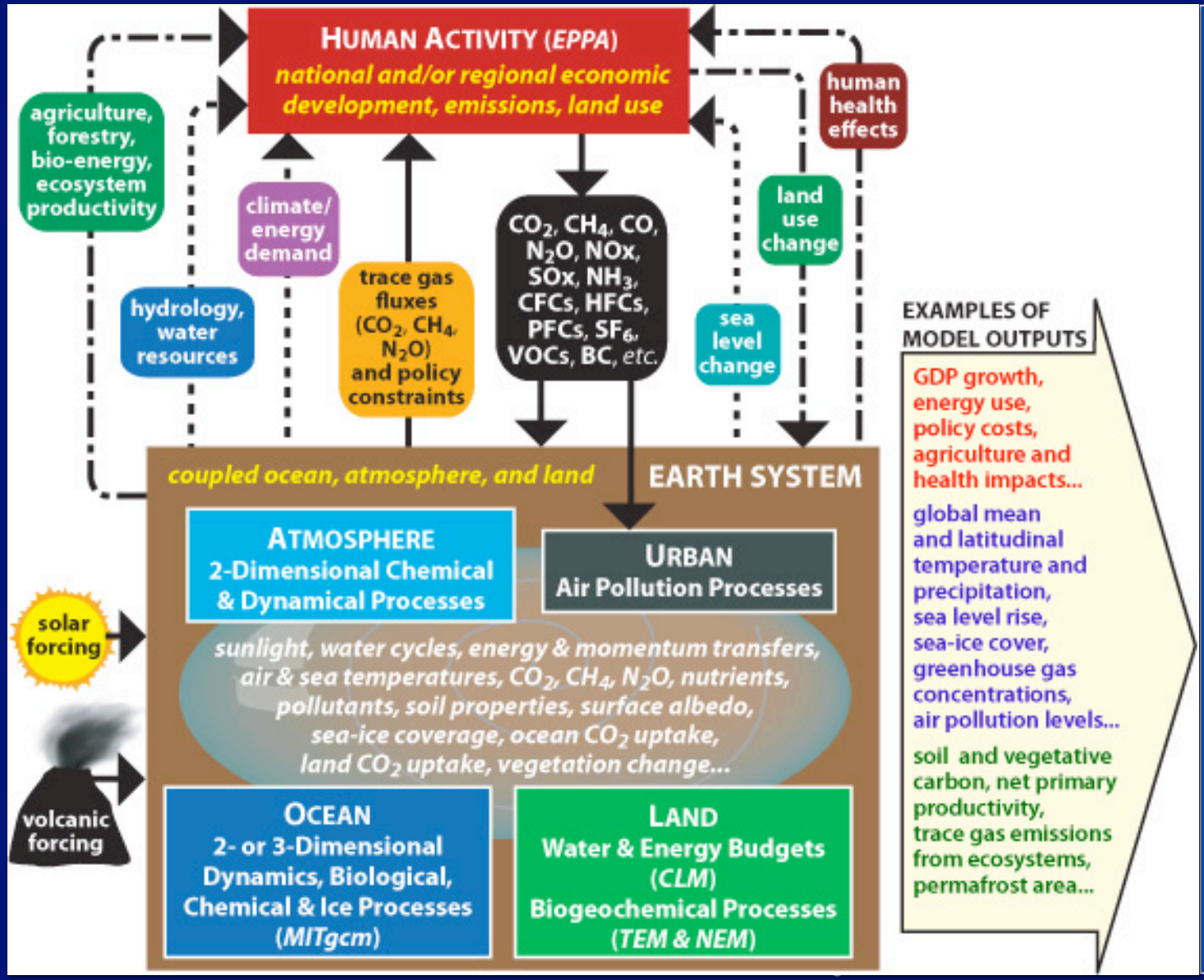
MIT: C. Adam Schlosser, Xiang Gao, and Ron Prinn
Penn State: Chris E. Forest
Marine Biological Laboratory: Jerry Melillo and David Kicklighter
Purdue: Qianlai Zhuang
University of Alaska: Katey Walter

Support:

DOE Abrupt Climate Change Program

The MIT Integrated Global System Model Version 2

(IGSM2: Sokolov et al., 2005, JP Tech. Report #124 EPPA: Paltsev et al. 2005, JP Tech. Report #125
Land: Schlosser et al., 2007 JP Tech Report #147 Ocean: Dutkiewicz et al., 2005, JP Tech. Report #122)



IGSM2 Integrated Assessment model

Designed for analyzing the global environmental changes that may result from anthropogenic causes, quantifying the uncertainties associated with the projected changes and assessing the costs and environmental effectiveness of proposed policies to mitigate risk.

Includes an economic model for analysis of greenhouse gas and aerosol emissions and mitigation proposals, a coupled atmosphere-ocean-land surface models with interactive chemistry and of natural ecosystems.

IGSM Scenarios

(Sokolov et al., 2009, and Webster et al., 2010)

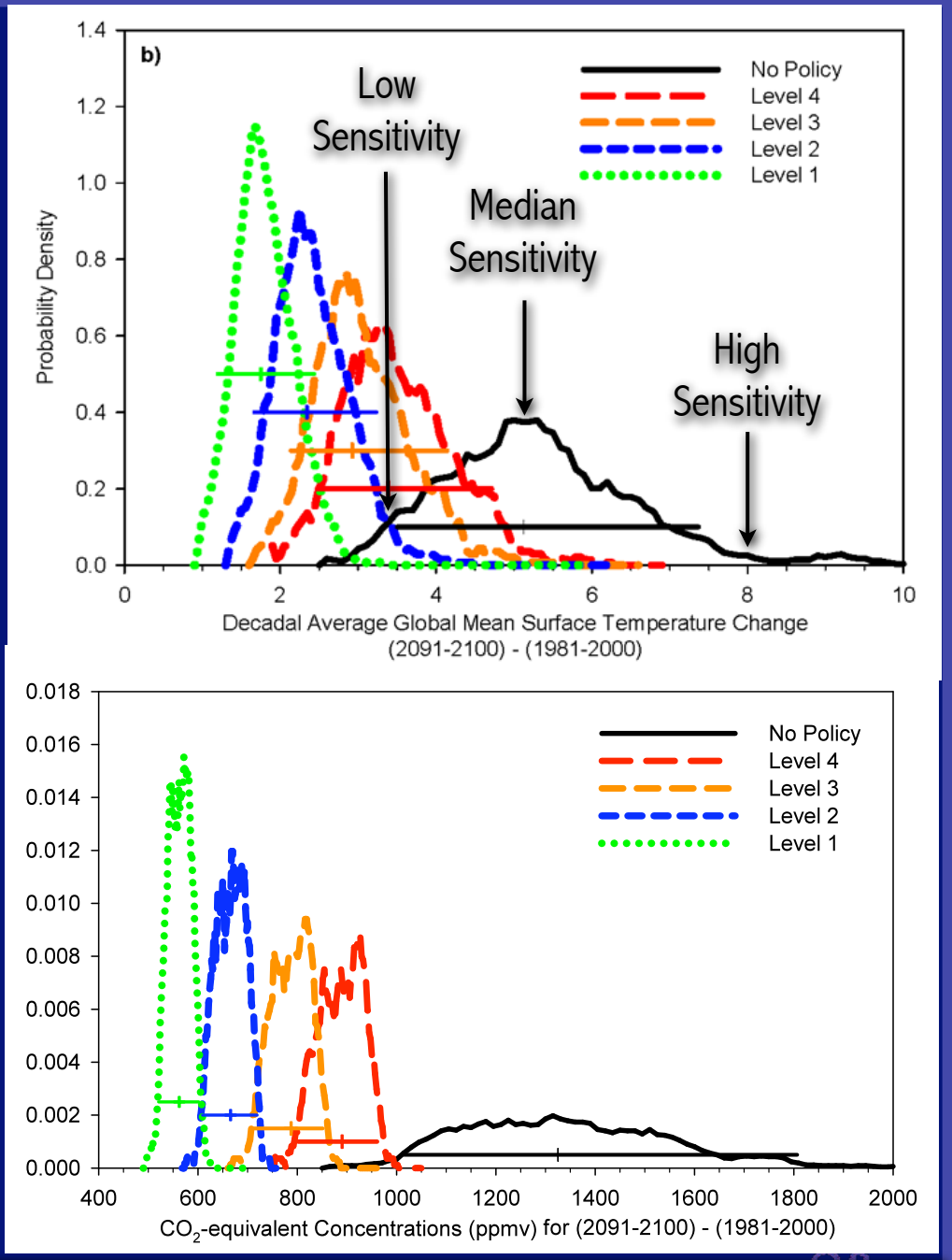
No Policy (Reference):

- Climate & EPPA samples

Policy Scenarios:

Representative Concentration Pathways (RCPs)

- U.S. CCSP Level 4
- U.S. CCSP Level 3
- U.S. CCSP Level 2
- U.S. CCSP Level 1

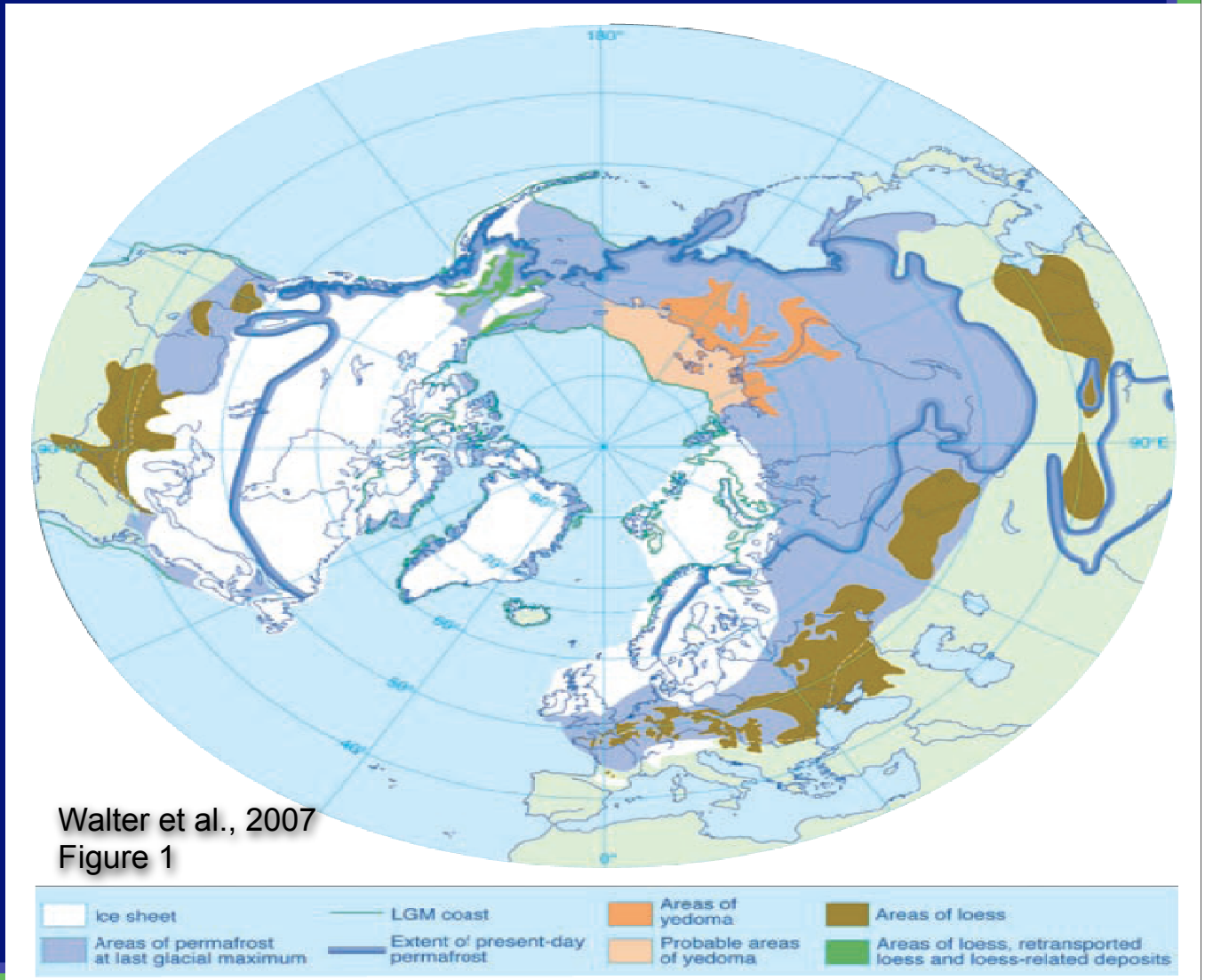


Run 400 member ensembles using Latin hypercube sampling for each policy

Research Tasks

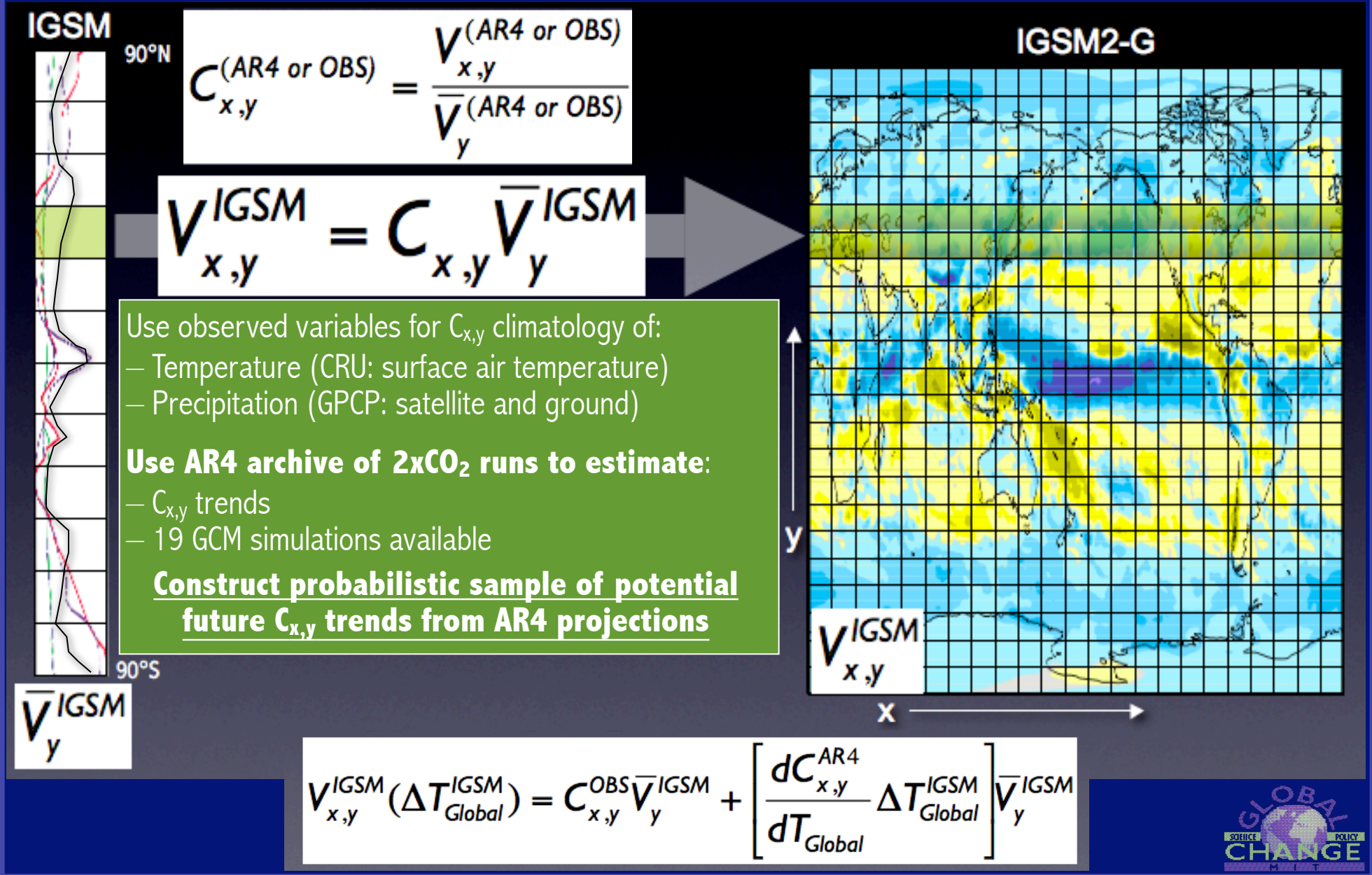
- **Task 1**: Implement Methane Dynamics Model (MDM) and Terrestrial Ecosystems Model (TEM) associated with changing wetland conditions (as calculated from CLM).
- **Task 2: Formulate thermokarst-lake effect into the IGSM2.**
- **Task 3: Numerical Experiments within Integrated Global Systems Model (IGSM) framework.**

KNOWING THERE'S UNCERTAINTY IN REGIONAL CLIMATE CHANGE... PROJECT ZONAL PATTERNS OF THE IGSM2 ATMOSPHERE ONTO THE LONGITUDINAL GRIDS OF A LAND MODEL SYSTEM.



Walter et al., 2007
Figure 1

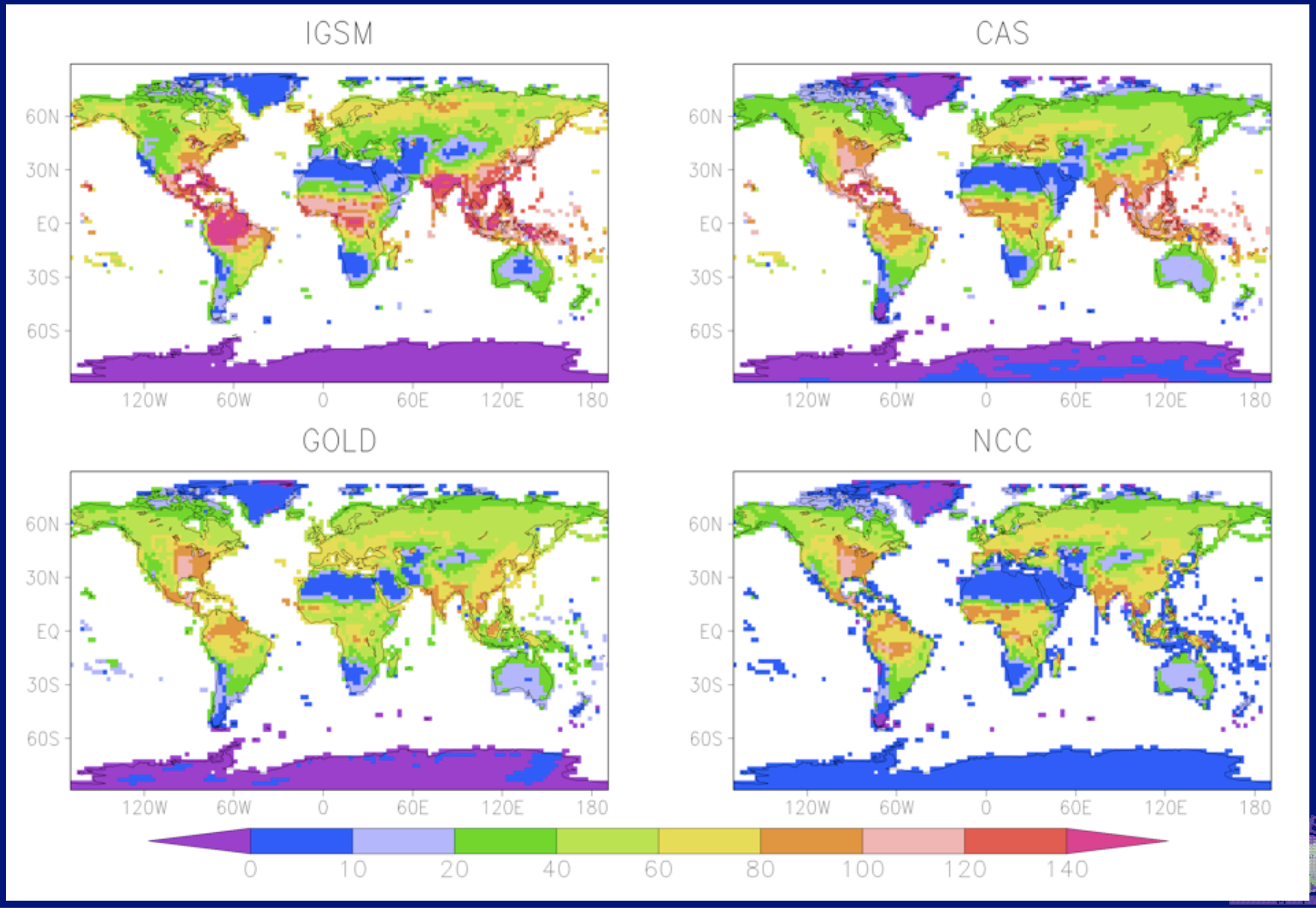
Merging Regional Climate Uncertainty in the IGSM Framework



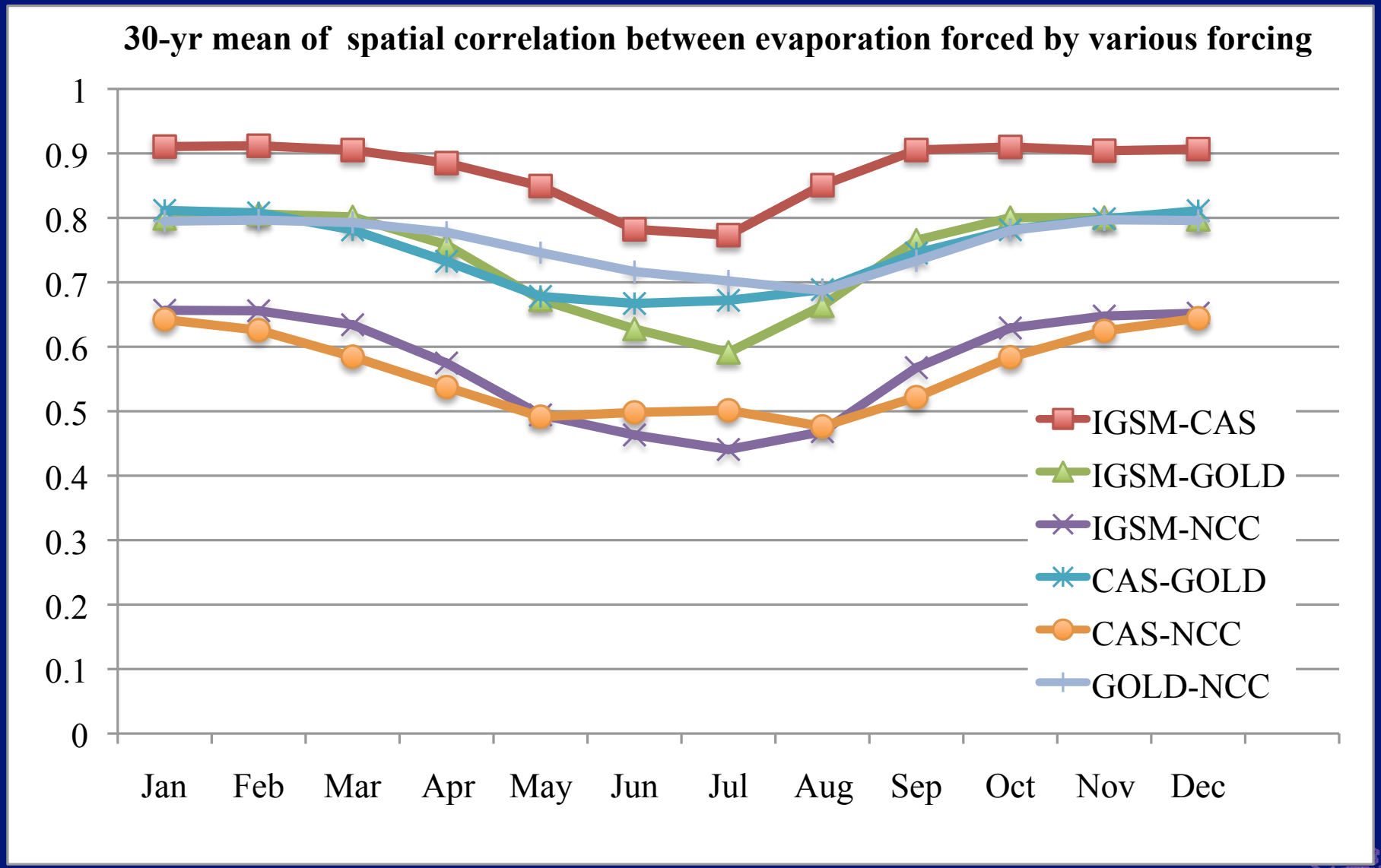
CLM Simulation Experiments

- Three "baseline" simulations with observationally-based bias-corrected forcing: CAS, GOLD, NCC
  - All runs span ~1950 to ~2000.
- Simulations with IGSM forcing:
  - IGSM atmosphere with low, median, & high climate sensitivity (C_S), and median emission scenarios (from EPPA).
  - Runs start in 2010 thru 2100, except for median climate sensitivity run - begins 1948.
  - Climatological projection of precipitation (GPCP) and temperature (CRU) across latitude band kept fixed.
- CLM Version 3.5 @ 2˚x2.5˚ spatial resolution.

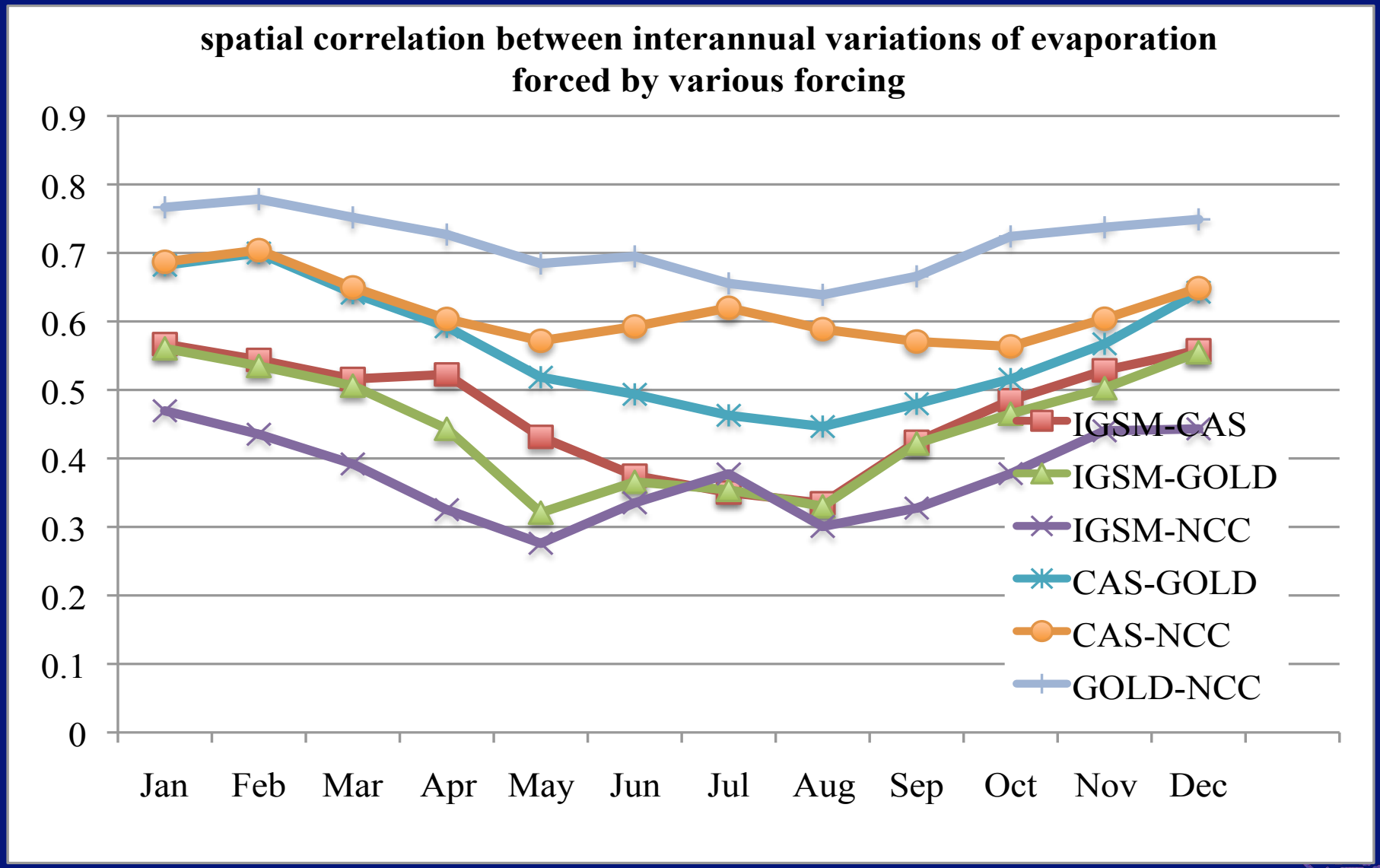
Consistency Between Forcings
JJA Latent Heat Flux (1971-2000)



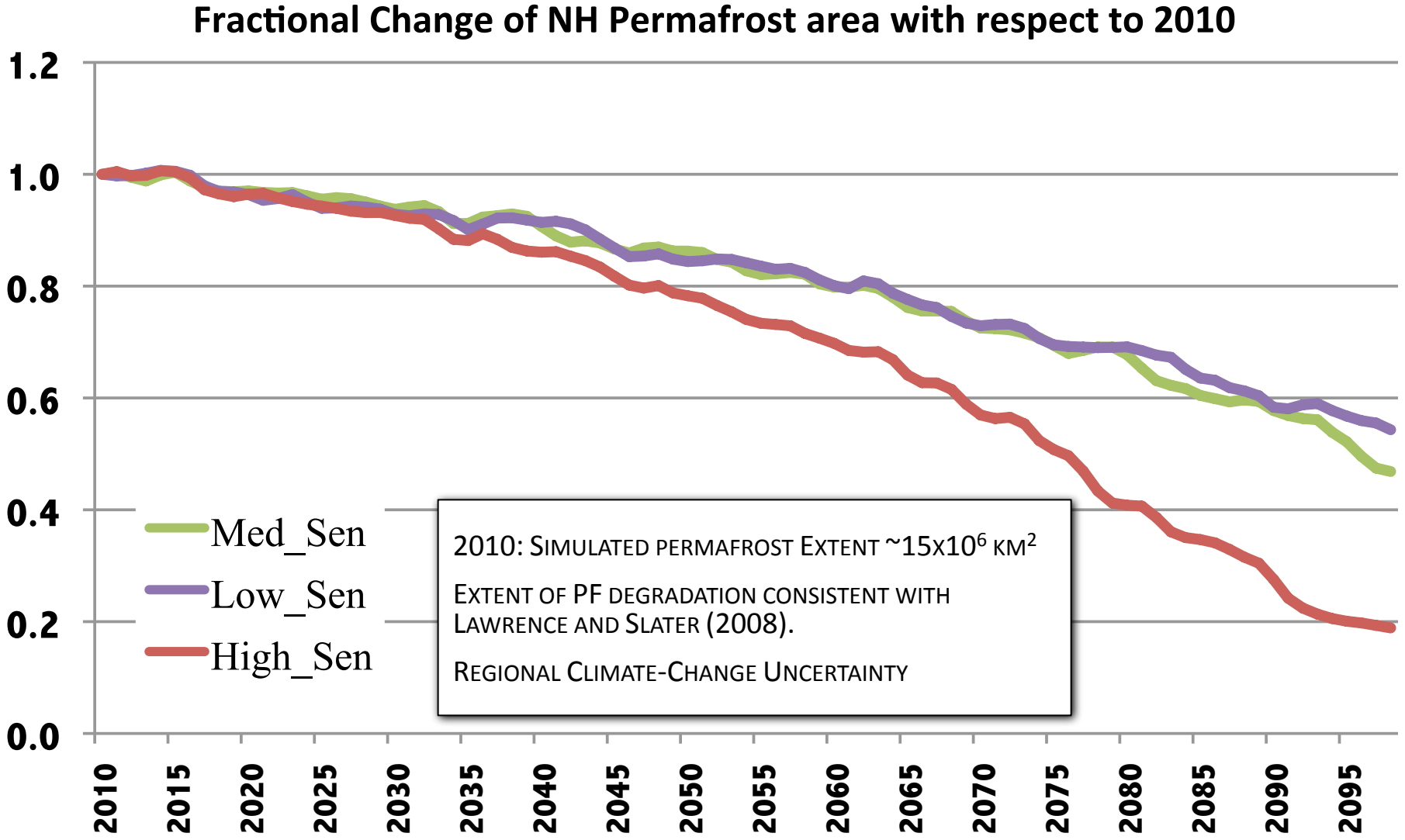
Consistency Between Forcings



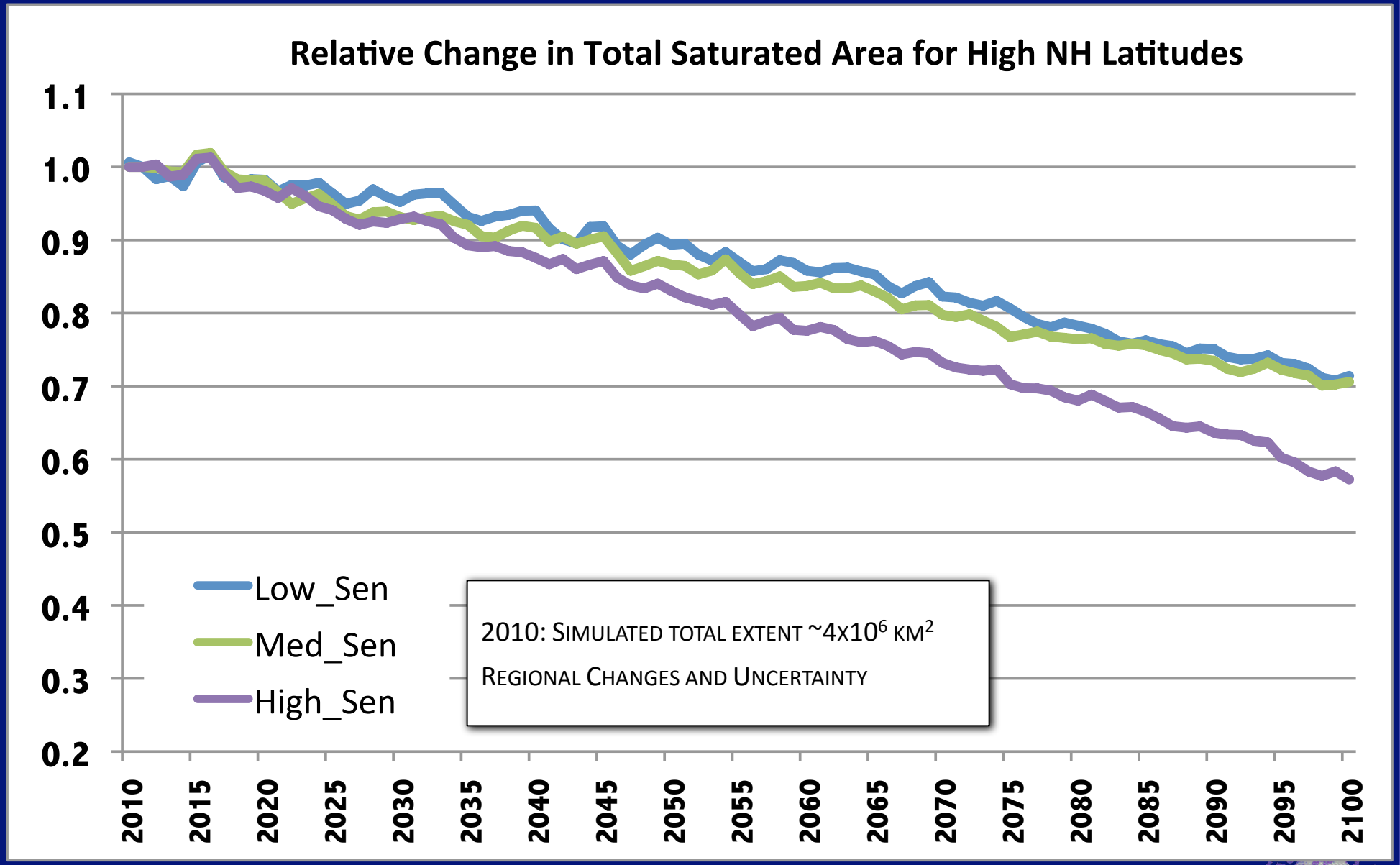
Consistency Between Forcings



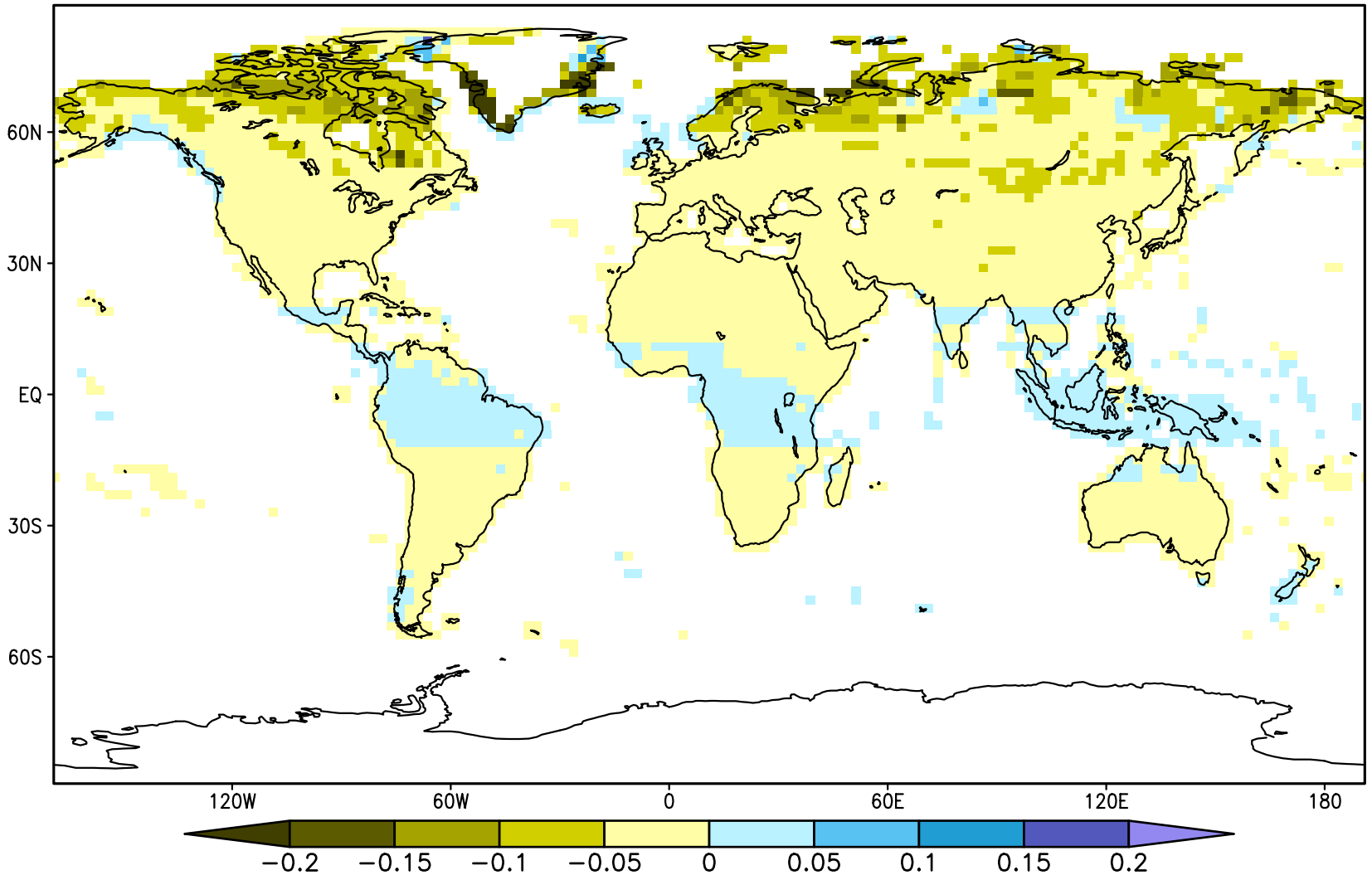
Trends in Near-Surface Permafrost



Trends in Saturated Area



Change in Saturated Area over 21st Century High Climate Sensitivity Run



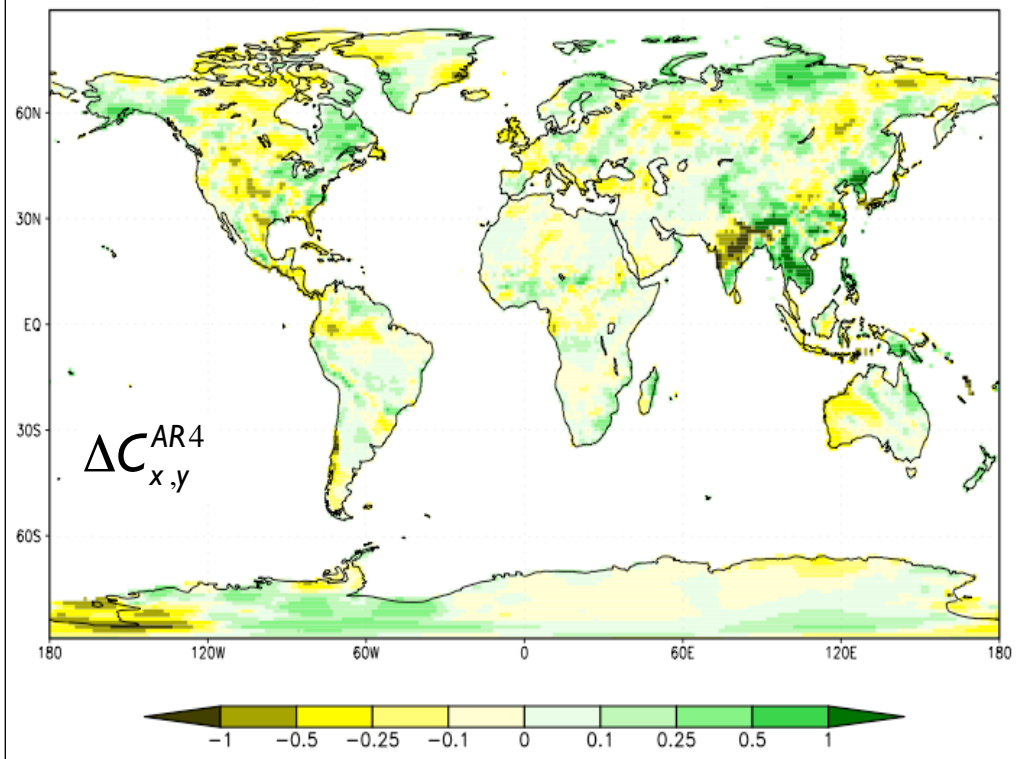
GrADS: COLA/IGES

LMWG/BGCWG Meeting, Feb. 9, 2010

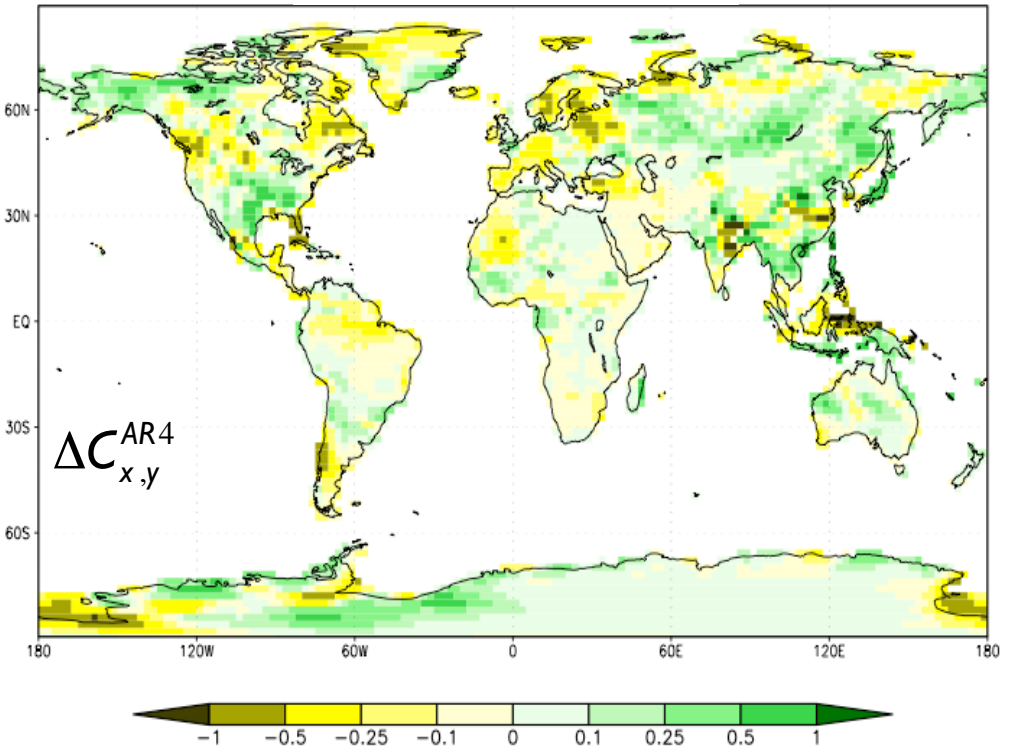
Regional Climate Change Uncertainty

Normalized Derivative of June Precipitation Coefficient Due to Doubling of CO_2

Model A

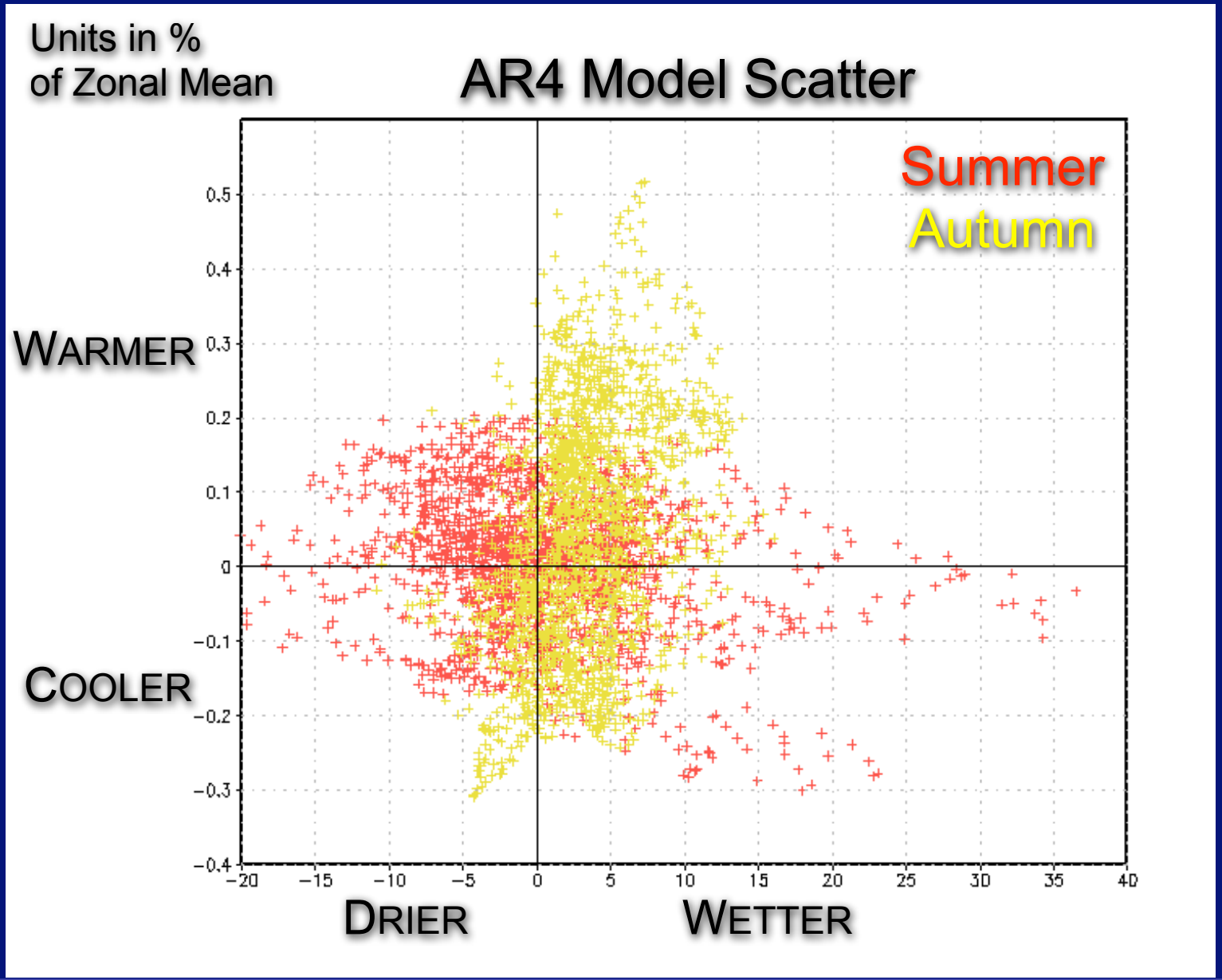


Model B



Implement these uncertain climate change patterns of the AR4 GCMs into the the IGSM2 framework.

Precipitation and Temperature 2xCO_2 Responses
Yedoma Region



Closing Remarks and Looking Ahead

- Under range of uncertainty in climate sensitivity, extent of permafrost degradation about a factor of 2.5.
- Widespread decreases in saturated area at high latitudes, with a range of 30% to ~45% reduction for the low and high climate sensitivity cases, respectively.
- Continue evaluation of CLM climatological simulations with IGSM and $C_{X,Y}$... Looking forward to CLM4 (for upgrades in soil carbon and permafrost treatment).
- Regional climate change uncertainty: simulations with $\Delta C_{X,Y}$ based on AR4 archive underway. Build ensembles that span the No-Policy and Policy IGSM runs.
- Upgrade methane dynamics module (Q. Zhuang). Total Lake emissions will be extrapoalted from latest field emission observations (K. Walter).