Uncertainty quantification of regional climate change based on structural uncertainty in atmospheric GCMs

Chris E. Forest[1], Wei Li[1], Chii-Yun Tsai[1], Alexis Hoffman[1], Joseph Barsugli[2], Thorsten Wagener[3], Erwan Monier[4]

[1]Pennsylvania State University; [2]CIRES, University of Colorado at Boulder; [3]University of Bristol, UK; [4]MIT

INTRODUCTION

Overview

We examine the uncertainty in teleconnection response of multiple versions of the NCAR/DOE Community Atmospheric Model (CAM) and the GFDLAM2. We analyze the sensitivity of local changes in climate by estimating the linear operator that relates regional climate change to SST anomaly patterns in the tropics and extra-tropics. This linear method provides Global Teleconnection Operators (GTOs) for each model that can be used to diagnose different model behaviors. By using historical SST anomaly patterns, we can test the method by estimating the impact of SST changes on regional climates when compared to the response simulated by the full non-linear model (Li et al., 2012).

Goals

- Understand the impacts of structural differences in climate models on the atmospheric teleconnection processes that contribute to regional climate change.
- Understand the component of regional climate variability driven by patterns of SST variability using the GTO.

Research Highlights: Application to dust sources, rivers, and NAO/PNA

- We estimate the sensitivity of dust emissions to SST anomaly patterns and identify the seasonal climate change on the dust cycle (Hoffman et al., 2014).
- We estimate the GTO for river basins to examine the teleconnection response impacting regional water resources (Tsai et al., 2014).
- We apply the GTO method to study variability in the North Atlantic Oscillation (NAO) and Pacific-North America (PNA) patterns (Li and Forest, 2014).

Key Points

- The GTO approach can capture the decadal variability for multiple climate variables and identify the relative importance of ocean sectors.

LINEAR RECONSTRUCTION EXAMPLES

Linear Reconstruction Tests

- The expected response to time varying SST patterns is estimated by:

$$\widetilde{R}_j(t) = \sum_{k=1}^{N} (\Delta SST(x_i, t) \cdot K_{ij} \cdot W(x_i)) + \varepsilon, \qquad (2)$$

- This linear reconstruction is then compared to the ensemble mean of AMIP simulations driven by observed SSTs for 1950–2000.

Applications to Dust Sources and Precipitation over River Basin

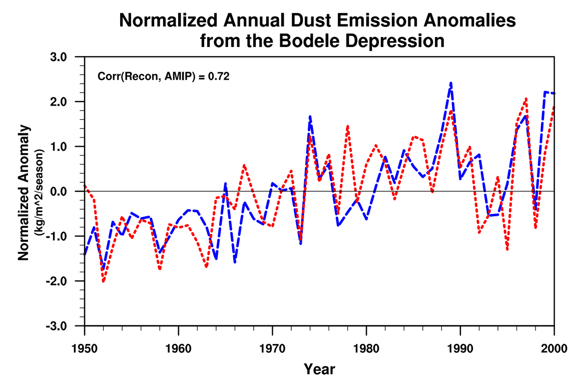

Figure 4 : Historical record of normalized annual dust emission anomalies from the Bodélé Depression for the linear reconstructions (blue dash) and AMIP ensemble (red dot).

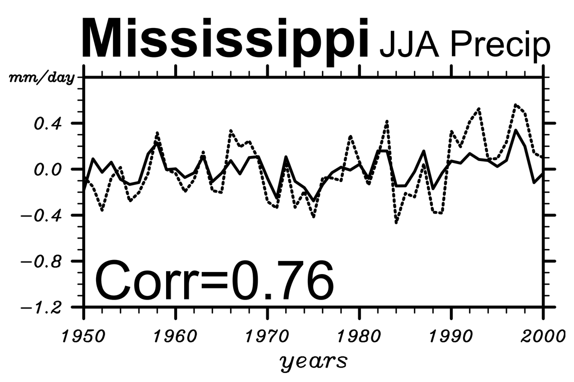

Figure 5 : Time series plots of reconstruction (solid line) and AMIP ensemble mean (dash line) for Mississippi River Basin during JJA

- The linear method estimates the positive trend in dust emissions from 1960–1985 (Hoffman et al., 2014).
- The linear method identifies potential predictability for precipitation over the Mississippi River Basin during JJA (Tsai et al., 2014).

Application to NAO and PNA indices

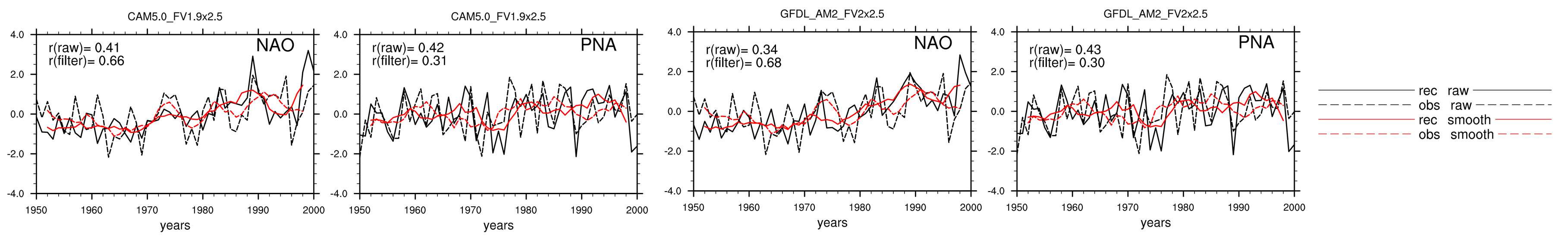

Figure 6 : Time series of NAO and PNA indices calculated from linear reconstruction and reanalysis data during 1950-2000. The reconstructed NAO index is obtained using the 2D SST anomaly fields over the tropical Indian Ocean and the Niño4 region, and the Caribbean sea. The time series of the PNA index is reconstructed by multiplying the sensitivity map with the 2D SST anomalies over the Niño4 region. Black and red lines denote the time-series of raw data and a 5-point running average.

- The variability of the NAO and PNA index from different model versions is estimated using the GTO-based reconstructions and compared with observations. Using the GTO approach, we identify key ocean regions that impact the two indices (Li and Forest, 2014).

GTO EXAMPLES

Basic Method: Estimate the ensemble-mean response, R_j, to an anomaly SST forcing, F_i

- Estimate Global Teleconnection Operator, K_{ij}, from

$$\overline{R_j} = K_{ij} \cdot F_i + \varepsilon, \qquad (1)$$

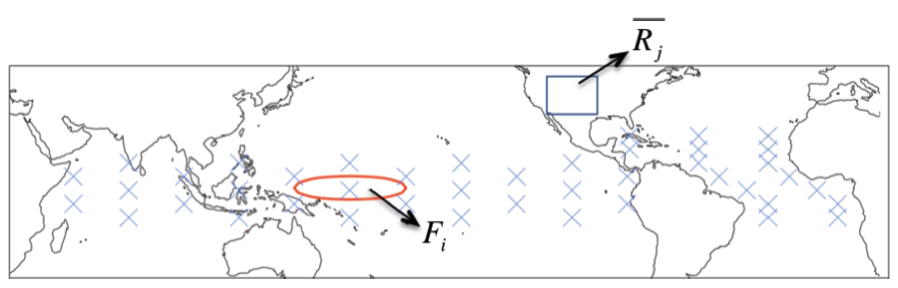

Figure 1 : Schematic figure showing how to relate ensemble-mean response, $\overline{R_j}$, to the ΔSST forcing, F_i

- Repeat this estimate for SST anomaly locations in tropics using either the Patch Method (Barsugli and Sardeshmukh, 2002) or the Random Patch Method (Li et al., 2012).

Global Teleconnection Operator (GTO) Maps

- Example: JJA precipitation over Central North America region
  Red (blue) ocean regions indicate that a positive SST anomaly will increase JJA precipitation.

Comparing Model Physics

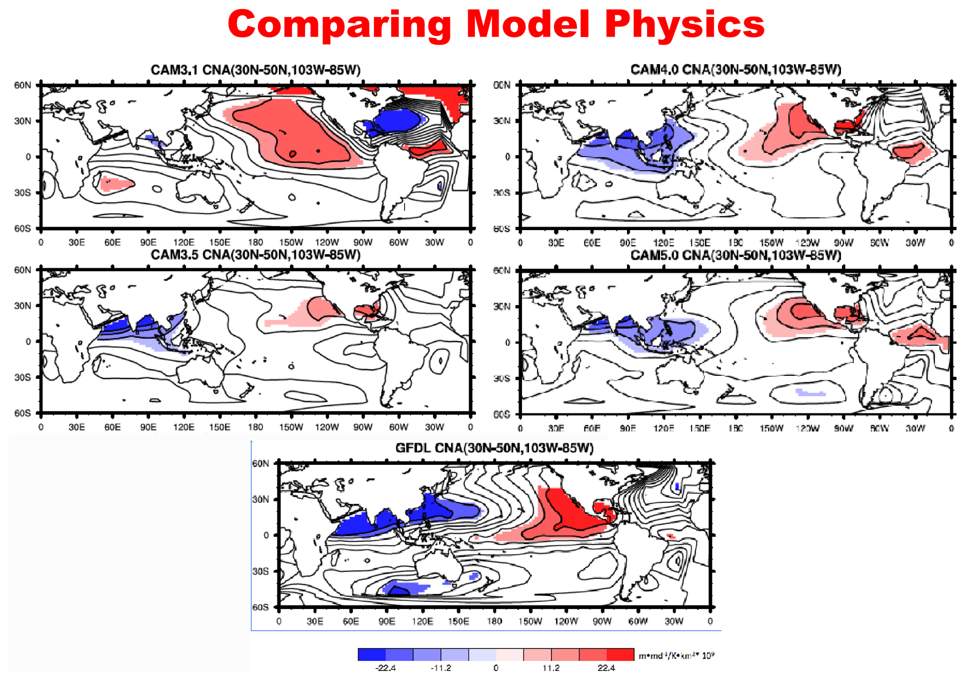

Figure 2 : Comparison of the GTO for summer (JJA) precipitation over the Central North America from different model versions. The models used for this result include NCAR CAM3.1, CAM3.5, CAM4.0, CAM5.0 (all at FV1.9° × 2.5° resolution) and GFDL (FV2° × 2.5° resolution).

Comparing Dynamical Cores

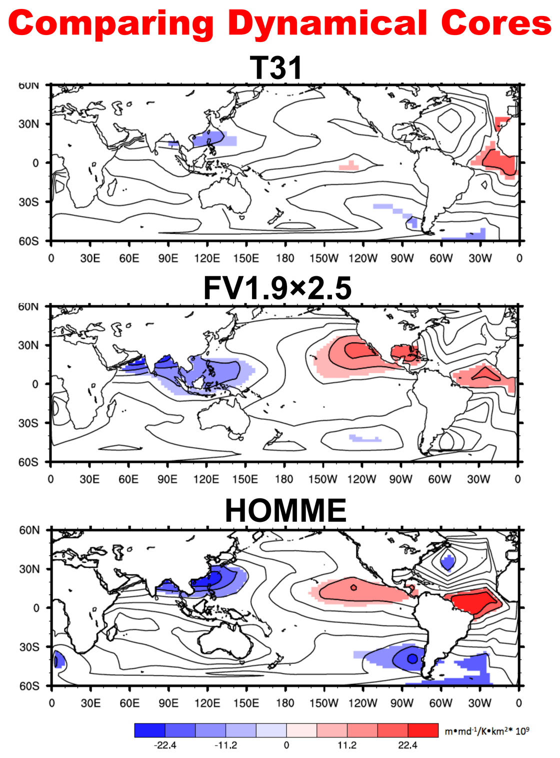

Figure 3 : Comparison of the GTO for summer (JJA) precipitation over the Central North America from different resolutions of CAM5.

SUMMARY/FUTURE WORK/REFERENCES

Summary

- Estimate GTO for multiple model configurations to explore sensitivity of teleconnection processes.

Resolution	Models					
	NCAR CAM				GFDL AM2	HadAM3 (CPDN)
	CAM3.1	CAM3.5	CAM4.0	CAM5.0		
T31				X		
T42	X					
T85	X					
FV0.9° × 1.25°				X		
FV1.9° × 2.5°	X	X	X	X	X	O
FV4° × 5°				X		
HOMME_N30				X		

Table 1 : GTO Experiments (**X**: complete, **O**: in progress)

- We applied to multiple regions and multiple variables:
  1. Dust emissions over 12 major sources
  2. Temperature and precipitation over 12 major river basins across the globe
  3. Temperature, precipitation, Z500 for all Giorgi regions
  4. Decadal-scale climate index patterns including NAO and PNA

Future Work

- We will examine the dependence of the GTO structure on equilibrium climate sensitivity (ECS) in CAM4/CAM5 using the cloud feedback adjustment approach (Sokolov and Monier, 2012).
- We will implement alternative surface anomalous forcings, F_i, over land and sea ice.

References

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