Spatial characteristics of the rainfall response to ENSO in CMIP5 model simulations

J.D Pérez and B.R. Lintner
Department of Environmental Sciences – Rutgers University

Abstract

Although many aspects of the tropical response to ENSO have been widely explored, the spatial characteristics of droughts and pluvials remain largely unexplored. In fact, current generation climate models exhibit uncertain spatial signatures of the ENSO tropical teleconnection compared to other aspects of ENSO variability, such as the amplitude of rainfall anomalies. Here, we analyze integrated measures of the spatial extent of drought and pluvial conditions in the tropics and their relationship to ENSO in observations as well as simulations of Phase 5 of the Coupled Model Intercomparison Project (CMIP5) with prescribed SST forcing.

Background

- During El Niño, synchronous droughts often occur over tropical continental regions, e.g., Nordeste Brazil.
- This has been studied in terms of intensity and duration but the spatial extent has received less attention.

$$S_{12} = \sum_{i=1}^{12} \left(\frac{\log P_i - \overline{\log P_i}}{\sigma_i} \right) \cdot \frac{\overline{P_i}}{\overline{P_A}}.$$

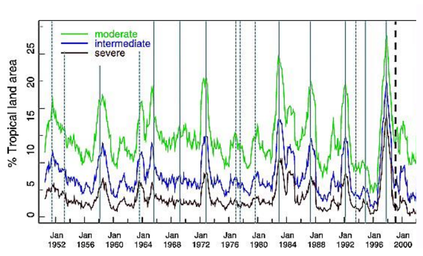
Drought (Pluvial) definition using a standardized precipitation index [SPI] Lyon (2004) and Lyon and Barnston (2005)

- Convective Margins (Neelin, 2006: Lintner and Neelin, 2007: Lintner and Neelin, 2009) as a framework to estimate where transitions between weak and intense precipitation conditions occur over Tropical South America (TSA)
- Multiple references to the CMIP5 models to describe ENSO's tropical teleconnections.

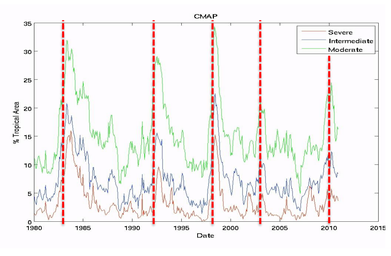
Methods and Data

- Compute the Lyon index on N = 24 CMIP5 models forced with prescribed sea surface temperature forcing.
- Compare simulation results to various observational or reanalysis products, including CMAP, CFSR and TRMM (In progress)
- Apply empirical orthogonal function (EOF) analysis to the drought index time series (In progress)

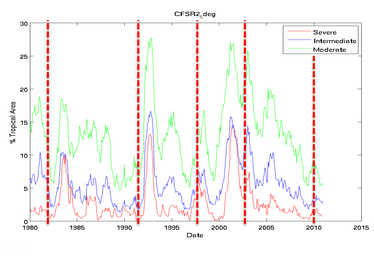
Results



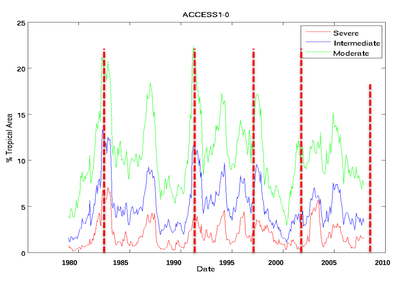
Lyon's Results



CMAP



CFSR Reanalysis



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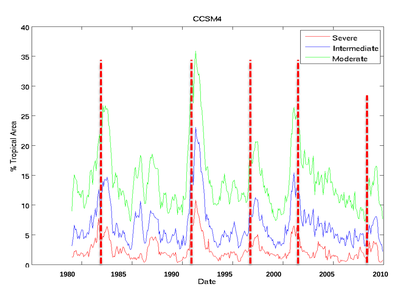
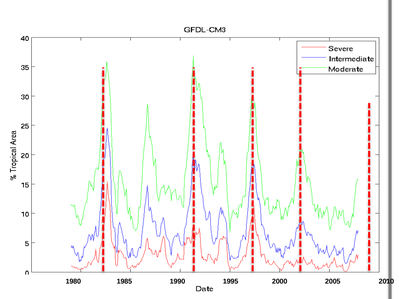
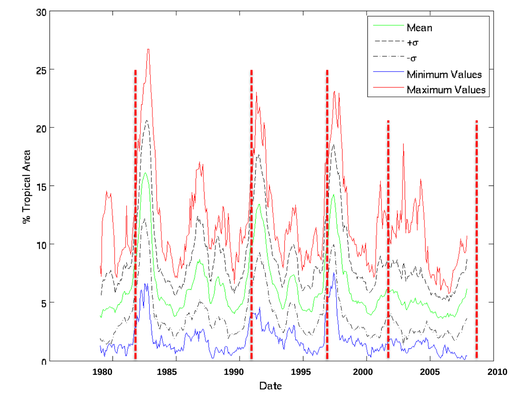


CCSM4

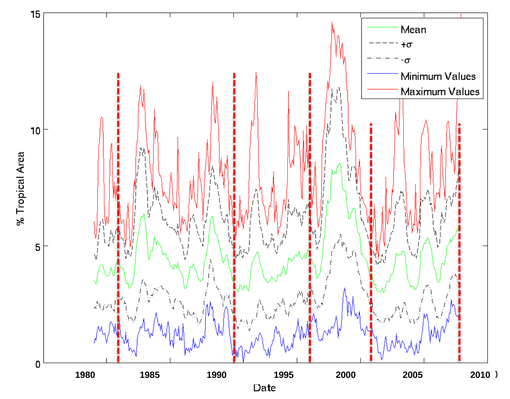


GFDL-CM3

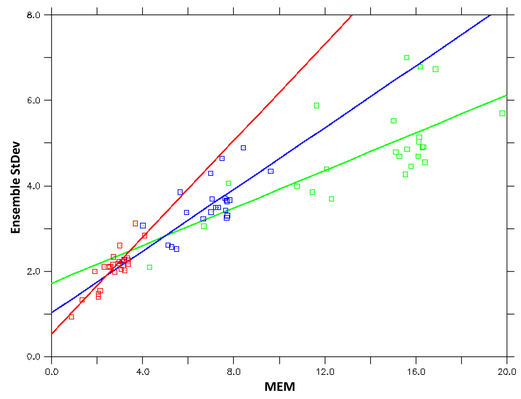
Results



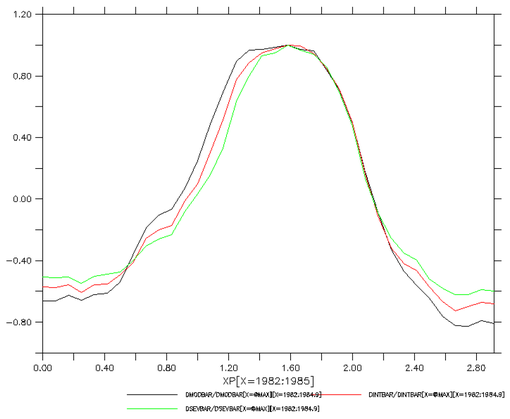
Intermediate Drought Ensemble Mean



Intermediate Wetness Ensemble Mean



Relationship between model ensemble mean (MEM) and standard deviation for the 3 drought categories



Moderate (black), intermediate (red), and severe (green) droughts, normalized by their maximum values, over the period Jan 82-Dec 84

Conclusions

- The Lyon tropical drought/pluvial index computed from the ensemble of prescribed SST CMIP5 model output compares favorably to observations.
- During El Niño events, the fraction of tropical land area experiencing drought increases; during La Niña events, the fraction of tropical land area experiencing pluvials increases.
- As drought intensity increases, the spread across the ensemble decreases, as more intense droughts are more tightly constrained by El Niño forcing.
- During the developing phase of El Niño conditions, severe drought development lags moderate droughts by ~2 months.

Future Work

- A more complete understanding of the ENSO teleconnection, such as its spatial heterogeneity, over tropical continents requires consideration of coupling to the land surface.
- We will analyze column and surface moisture and energy budgets over TSA to quantify the impact of various pathways of land-atmosphere coupling, such as the feedback between soil moisture and precipitation, on ENSO variability.
- We also aim to diagnose how changes in upstream moisture source regions and evapotranspiration affect downstream precipitation, especially along the margins of convection zones.

References

- Lyon, B. (2004), The strength of El Niño and the spatial extent of tropical drought, *Geophys. Res. Lett., 31*, L21204, doi:10.1029/2004GL020901.
- Lyon, B., and A. G. Barnston, 2005: ENSO and the spatial extent of interannual precipitation extremes in tropical land areas. *J. Climate, 18*, 5095–5109, doi:10.1175/JCLI3598.1.
- Lintner, B. R., and J. D. Neelin (2007), A prototype for convective margin shifts. *Geophys. Res. Lett., 34*, L05812, doi:10.1029/2006GL027305.
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