Mechanisms for Precipitation Variability of the Eastern Brazil/SACZ Convective Margin

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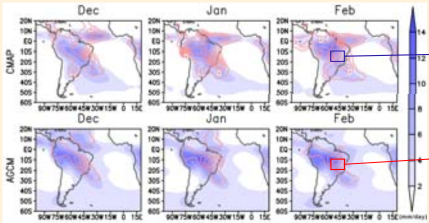
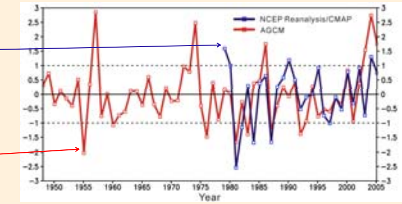
Motivation: Key features of the summertime precipitation in South America include strong monsoon convection in central Amazonia and the South Atlantic Convergence Zone (SACZ), which extends from eastern Brazil into the adjacent Atlantic Ocean. Along the eastern edge of the strong convection zones is a transition toward the low-precipitation region of the southern tropical Atlantic trades. On interannual time scales, the precipitation shows strong variability from the eastern Brazil to La Plata Basin. Such variability can result in drought and flood events, which have significant impact on human activity and economy. The better understanding of the mechanism that produces such variability is crucial to improve predictions of those important hydrological events. The present study focuses on the ability of climate models to represent the sensitivity of precipitation to the low-level anomalous flows and the associated moisture advection over the eastern Brazil/SACZ convective margin on interannual time scales. We use the UCLA AGCM to perform simulations and mechanism-testing experiments.

Monthly Mean Precipitation and Variance:



Mean precipitation (shaded) and its variance (contours) for December, January, and February from CMAP, and AGCM. The boxes (55˚W-40˚W, 20˚S-10˚S) in the plots for February mark the regions selected for calculation of 850 hPa wind indices.

850 hPa Wind Index (February):

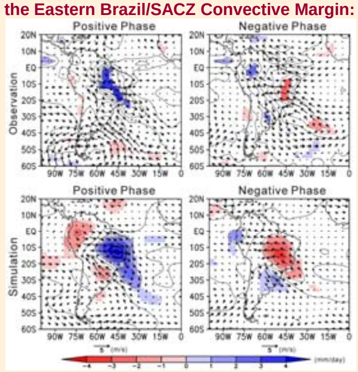


Time series of February 850 hPa wind index from NCEP/NCAR reanalysis (blue curve) and AGCM (red curve). The wind index is defined as the 850 hPa zonal mean wind averaged over the boxes marked in the Figure to the left, and normalized by the standard deviation of its time series for the entire period of study.

Composite Analysis:

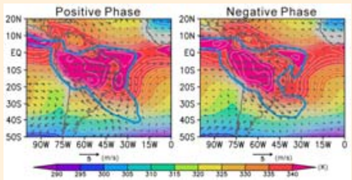
The inflow variability is associated with the leading mode of wind variability over sub-tropical South America (Robertson and Mechoso 2000), and the connection is established through the mechanism of an analytic prototype for convective margin shifts proposed in Lintner and Neelin (2007; 2010). Over the eastern Brazil/SACZ convective margin, the weaker (stronger) convection tends to occur together with stronger (weaker) low-level inflows in reference to the mean easterly trades. By changing the "ventilation" effect (Chou and Neelin 2001), stronger (weaker) inflows with low moist static energy from the Atlantic Ocean suppress (promote) convection.

Positive/Negative Phases of Precipitation Variability over the Eastern Brazil/SACZ Convective Margin:



Composites of February anomalies in precipitation and 850 hPa wind from observation and simulation during the positive and negative phases based on the 850 hPa wind index. The shaded regions correspond to values of precipitation anomalies that are significant at the 95% confidence level.

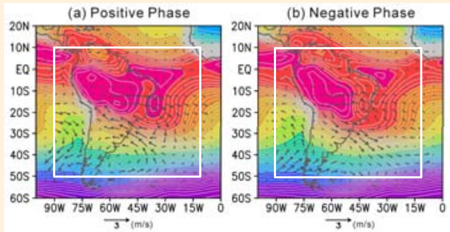
Low-level Flows and MSE Advection:



Composites of simulated February mean moist static energy (MSE, shaded) in the PBL and 850 hPa wind anomalies (arrows) during the positive/negative phases based on the wind index. Blue curves are the 4 mm day^{-1} contours composited of simulated February mean precipitation used to identify the convective margin.

Design of Mechanism-testing Experiments:

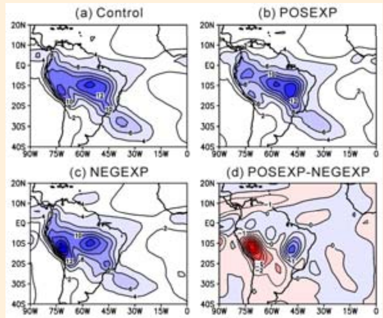
Three AGCM mechanism-testing experiments are performed in perpetual-February mode. A steady perturbation of the horizontal velocity field resembling the observed wind anomalies is artificially imposed in the moisture equation on the AGCM. The perturbation is required to be non-divergent in order not to generate vertical velocity that would directly lead to precipitation. In addition, the artificial perturbation is restricted to the low levels of the troposphere where moisture transports are important and to the region overlapping the eastern to southern Brazil and western Atlantic Ocean (90˚W-10˚W, 50˚S-10˚N). The following figure shows the wind perturbations in the PBL used in the imposed-wind experiments for both the positive and negative phases.



Composites of simulated February mean moist static energy (shaded) and non-divergent component of anomalous winds (arrows) in the PBL.

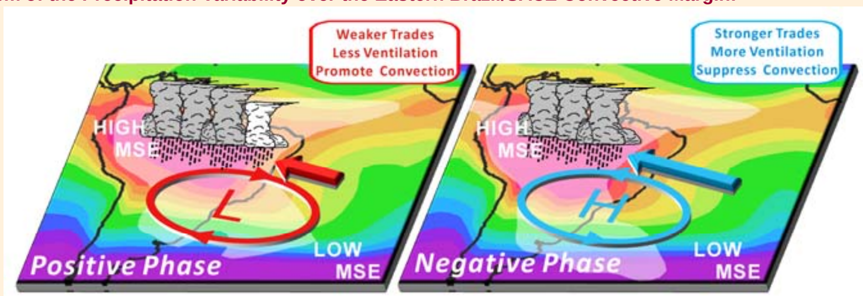
Precipitation Response to Inflow Changes:

Over the eastern Brazil/SACZ convective margin, the positive phase experiment (POSEXP) shows a precipitation maximum, while negative phase experiment (NEGEXP) shows weaker precipitation. Along the convective margins, weakened inflow in reference to the easterly trades from the Atlantic Ocean leads to strengthened precipitation, and strengthened inflow leads to lower precipitation.



Mean precipitation (mm day^{-1}) from (a) CONTROL, (b) POSEXP, and (c) NEGEXP experiments. Also plotted in (d) is the difference of precipitation between (b) and (c).

Mechanism of the Precipitation Variability over the Eastern Brazil/SACZ Convective Margin:



Schematic diagram of the mechanism for the precipitation variability of the eastern Brazil/SACZ convective margin during positive/negative phases as defined by the intensity of low-level easterly trades. Color shades represent the moist static energy (MSE) and white shades represent regions where deep convection occurs. Variability of the low-level easterly trades which are associated with the leading mode of wind variability on interannual time scales can modify the import of low MSE into the convective margin as represented by the red/blue arrow during positive/negative phases, and convection over the convective margin can be modified substantially through the "ventilation" effect.

References:

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