The Pan-American Precipitation Pattern and its tropical connections

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Summary

When the southern U. S. and Mexico are wetter than normal, northern and south-central South America are drier and wetter than normal, respectively. This Pan-American Precipitation Pattern (PAPP) recurs on interannual to interdecadal time scales. Its variability is shown to be strongly influenced by the tropical Pacific SST anomalies. The polarity of PAPP is connected to the mean condition of the tropical Pacific SST. A warm tropical Pacific corresponds generally to a (wet, dry, wet) pattern in precipitation for (southern U. S., northern South America, south-central South America). A cold tropical Pacific corresponds to the opposite phase that is related to prolonged droughts in the southwest U. S.

Presipitation anomalies over the Americas

Observation and GCM simulations have shown that when the southern United States and Mexico is wet, north and south-central South America are dry and wet, respectively. The positive (wet south U.S.) and negative phases of this "Pan-American Precipitation Pattern" (PAPP) recur on interannual to interdecadal time scales. A collection of the observed and simulated precipitation anomalies for the Americas on these time scales are shown in Figs. 1-3. The simulations are based on 64 GOGA (AGCM forced with global SST),16 POGA-ML (AGCM forced with Pacific SST and coupled to a mixed layer ocean elsewhere), and several repeated-seasonal-cycle (SCYC) runs performed at LDEO based on NCAR CCM3 (see Huang et al. 2005)

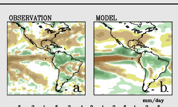

Fig. 1 The observed and simulated January-May precipitation anomalies for the 1998-2002 North American drought event. Model result is the mean of GOGA runs.

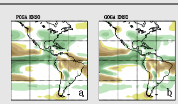

Fig. 2 The warm-minus-cold ENSO composites of Jan-May precipitation anomalies for 1960-1999 from the ensemble mean of (a) POGA-ML, and (b) GOGA runs.

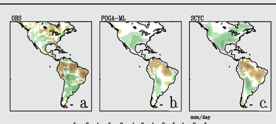

Fig. 3 The interdecadal shift in Jan-May precipitation, defined as the difference between the 1976-1998 and 1961-1976 epoch means. (a) Observation. (b) Ensemble mean of POGA-ML runs. (c) Time mean of an SCYC run.

Despite some differences in detail, the precipitaton patterns in Figs. 1-3 share the common structure of a wet south U. S. and Mexico accompanied by a dry north South America and a wet south-central South America, or the opposite polarity with a dry-wet-dry structure. This first-order pattern is our PAPP. As a notable variation of PAPP, the precipitation anomaly in the southern U. S. is shifted eastward for ENSO (locally projecting on the "canonical ENSO response"), and westward on decadal and longer time scales.

SST and tropical connections

The PAPP structure on interannual to interdecadal time scales are found to be reproducible by forcing an atmospheric GCM with observed tropical Pacific SST anomalies, suggesting a tropical control of PAPP. The detail of the tropical SST anomaly is not critical in producing PAPP. This can be appreciated by comparing the SST anomalies (warm, cold, and warm-minus-cold composites) for ENSO in Fig. 4 and those for the interdecadal shift in Fig. 5. They are substantially different in detail, even though a PAPP-like structure is observed and simulated for both time scales. The warm-minus-cold SST anomalies in Figs. 4c and 5c do share a common structure of a warm tropical eastern/central Pacific and a pair of cold side bands in the western Pacific. In observation and simulations, this type of Pacific SST anomaly is shown to force the "positive" phase of PAPP with a wet southern U. S. The opposite of that SST anomaly is shown to produce the "negative" phase of PAPP that is related to prolonged droughts in the southwest U. S. and Mexico, a recent example being the 1998-2002 North American drought.

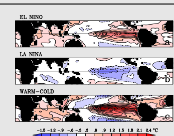

Fig. 4 The composites of observed January-May SST anomalies for ENSO. (a) Warm events. (b) Cold events. (c) Warm-minus-cold composite.

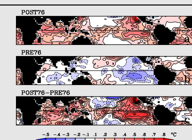

Fig. 5 The observed Jan-May SST anomalies associated with the interdecadal climate shift. (a) The epoch mean for 1976-1998 (a warm phase) . (b) The epoch mean of 1961-1976 (a cold phase). (c) Difference between warm and cold phases.

Moisture budget and large-scale circulation

The moisture budget associated with PAPP is illustrated in Fig. 6 for the simulated interdecadal shift (post-1976 minus pre-1976). Over most of the Americas, the precipitation anomaly is balanced by moisture convergence. Evaporation, related to memory in soil moisture, is important in the southwest U. S., consistent with Schubert et al. (2004). The simulated shift in large-scale circulation has a strongly zonally and hemispherically symmetric component, shown in Fig. 7, that is found to be tropically forced. This structure is also found to be associated with PAPP on shorter time scales of ENSO and multi-year droughts (Seager et al. 2003, Schubert et al. 2004). It co-exists with the classical tropically-forced Rossby wave train that emphasizes the zonally asymmetric component of the circulation anomaly. Both have an impact on the precipitation over the Americas (Huang et al. 2005).

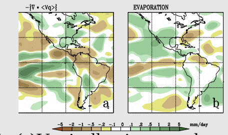

Fig.6 (a)Vertically integrated moisture convergence, and (b) Evaporation, for the interdecadal shift from GCM simulation.

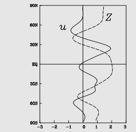

Fig. 7 The 200 hPa zonal mean zonal wind and height associated with the interdecadal shift.

Statistical significance

The statistical significance of the PAPP structure can be determined from the ensemble mean and intra-ensemble variance of the GCM simulations. Figure 8 shows an example for the interdecadal shift in precipitation from the GOGA runs. The ensemble mean (left) shows the three major centers of PAPP indicated by boxes 1-3. An analysis of the signal-to-noise ratio based on the probability distribution of all ensemble members (right) indicates that all three centers are highly significant. The precipitation anomalies there can be confidently attributed to the SST forcing. In contrast, the precipitation over box 4 (northwest U. S.) has a small S/N ratio. The observed wetness in the post-1976 era in this region (Fig. 3a) is likely due to internal variability unrelated to SST forcing.

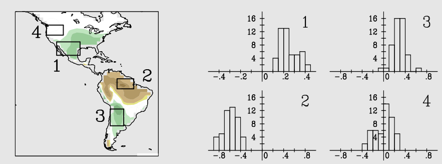

Fig.8 Left panel: The ensemble-mean precipitation for the interdecadal shift from GOGA runs. Right 4 panels: The probability distribution function of precipitation anomalies for all ensemble members for boxes 1-4.

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