Surface Climate Variability of the United States and Relationships to Generalized Flow Patterns

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1. Introduction

Extensive research of El Nino-Southern Oscillations (ENSO) in the past decades has made seasonal to interannual predication an attainable effort. Many recent studies focus on interdecadal climate variability. The most dramatic effects of global climate variability is mostly likely felt at the regional level. Therefore it is important to fully understand climate fluctuations at the regional scale and determine their relationships with broader-scale climate variations. In the first attempt of this climate project, we focus on the analysis of surface climate variability of the United States, and its relationship with generalized flow regimes. An empirical approach is adopted for this study.

2. Method and data

The first part of this study attempted to derive surface climate regions based on monthly precipitation and temperature data within the 344 climate divisions of the conterminous United States for the time period 1895-1991. Monthly precipitation and temperature anomalies within each division are formed by removing their corresponding mean values. They are then normalized with respect to standard deviations, and merged into annual and seasonal arrays (DJF, MAM, JJA, SON). Rotated Principal Components Analysis (RPCA) is applied to the annual and seasonal anomaly data to effectively group climate divisions into statistically homogeneous climate regions for both surface variables.

3. Results

Based on annual data, a total of nine precipitation regions and five temperature regions were created (Fig. 1). The derived regions are more spatially and temporally complete than typically seen in recent literature. Results and comparisons with relevant literature indicate that the regions are climatologically plausible for both surface variables. Significant trends were identified in the associated regional time-series anomalies. Long-term increases in precipitation are evident in all regions east of the Mississippi River and the Northwest (PCs 1-6). Of the regions displaying long-term precipitation change, four shows significant shifts in interannual variability through time (PC 1, 2, 3, 6). For temperature, fewer long-term changes were noted as a significant increase in temperature occurred only in the Southwest region (PC 5). Significant reductions in temperature variability were confirmed in three regions.

To determine the influence of the global forcing on the regional climatologies, a simplest approach is to seek correlations between surface precipitation/temperature and various generalized flow patterns like the Pacific/North American (PNA), the Southern Oscillation (SOI), and North Atlantic Oscillation (NAO). These so-called teleconnection patterns are well documented in many studies of interannual oscillations, and recent studies have indicated all three atmospheric flow patterns are also good indicators of interdecadal scale climate variability. Currently, interdecadal climate variability is still not well understood, partly due to a lack of sufficient data. Here low-pass filtered PNA, SOI, and NAO indices are used as different measures of interdecadal variability. They are correlated with similarly low-pass filtered time series of averaged annual precipitation and temperature in each climate regions. Significant relationships are shown in Fig. 1.

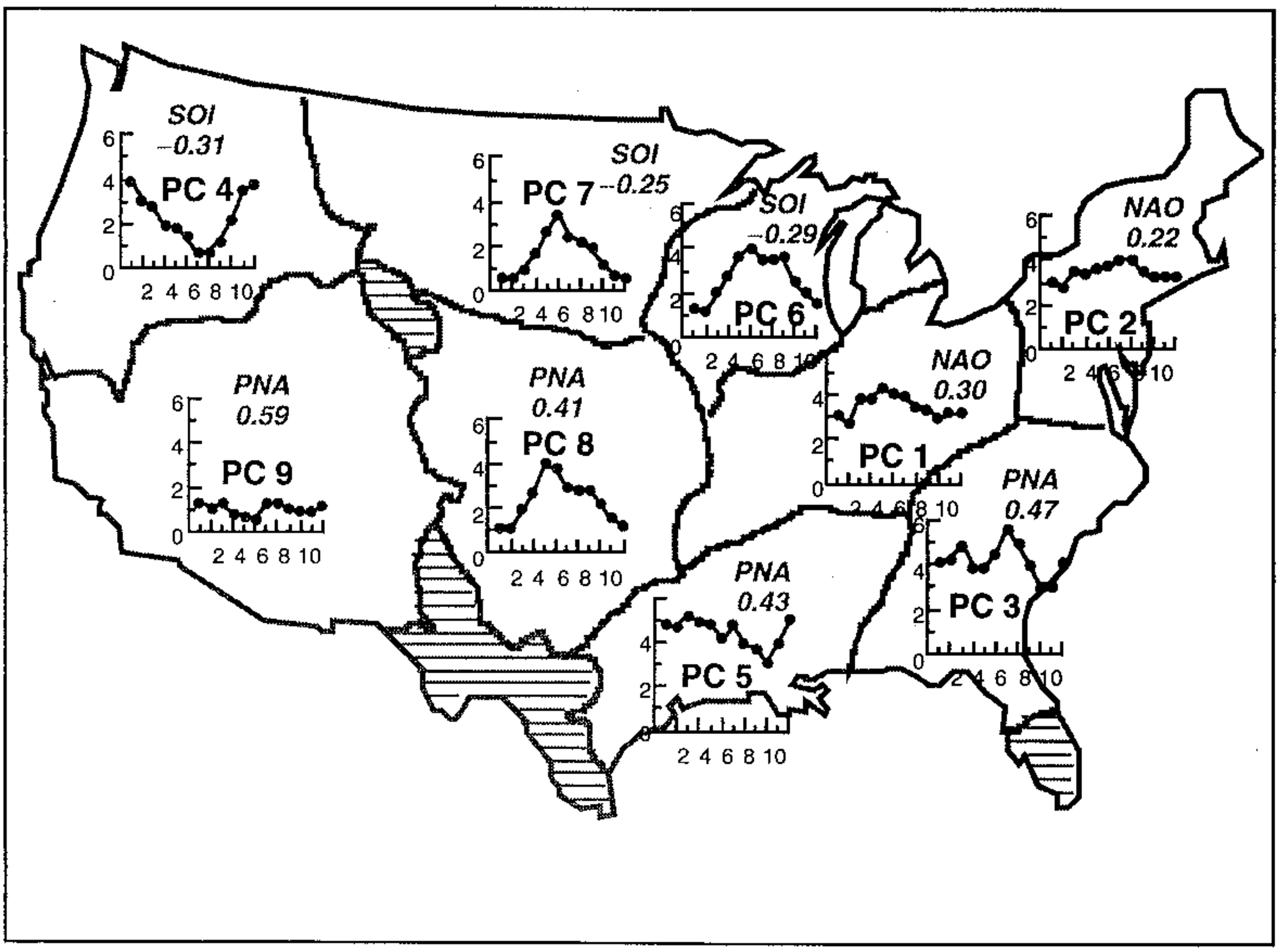
PCs 3, 5, 8, and 9 in Fig. 1a all relate most strongly to variations in the PNA. All of the PNA correlated regions show positive correlations indicating that meridional (zonal) wave flow across North American relates to positive (negative) precipitation departures in the associated regions. The SOI relates well to interdecadal precipitation variations in regions 4, 6, and 7. The negative SOI periods are associated with wetter than normal years in the associated regions. The NAO relates well to precipitation variations in regions 1 and 2, indicating that strong zonal (weak meridional) flow across the North Atlantic relates well to positive (negative) precipitation departures in these regions.

Interdecadal-scale surface temperature variations relate strongly to the PNA pattern (Fig. 1b). The negative correlations indicate zonal flow induces positive temperatures in regions 1, 2 and 3. This is confirmed by slightly weaker positive correlations to the NAO (not shown). The significant negative correlation between temperature and PNA in region 4 is consistent with a weaker negative correlation to the SOI (not shown). Temperature in region 5 relates most strongly to interdecadal variations present in the phase of the SOI, i.e. ENSO events relate to positive temperature departure in the region. Typically the negative phase of the SOI correlates well with the positive PNA.

The interannual variability in surface precipitation and temperature is analyzed based on seasonal data. The results will be reported in the meeting.

4. Discussion

The use of the generalized flow parameters as indices for global climate forcing clearly needs to be clarified. One particular important issue is the relationship between ENSO events and interdecadal-scale variability. Another issue is the intraseasonal oscillations in different phases of ENSO cycles. A significant portion of regional extreme weather events and short-term climate variations are related to these anomalous climate forcing



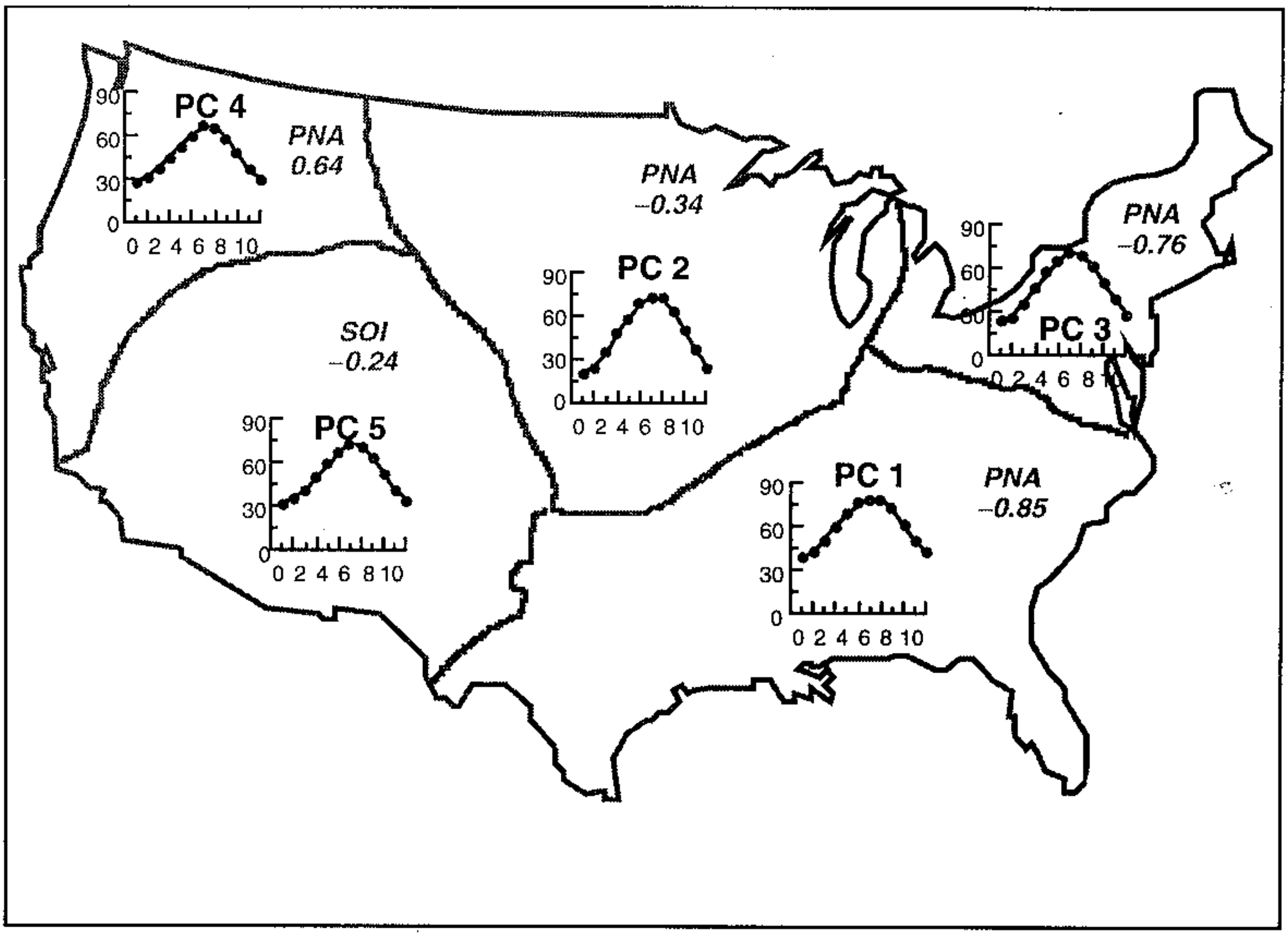


Fig. 1 Surface climate regions for the Conterminous United States and associated climagraphs. The regions are obtained by RPCA of annual precipitation and temperature anomalies in 344 US climate divisions. The nine principal components of precipitation (upper panel) and five principal components of temperature (lower panel) accounts for 60% and 87% of the total raw data variance, respectively. Also shown within each regions are the coefficients showing most strongly correlated atmospheric teleconnection indices to the precipitation and temperature at the interdecadal time scale.