Detection of historical summertime monsoon precipitation variations and trends over the southwestern United States

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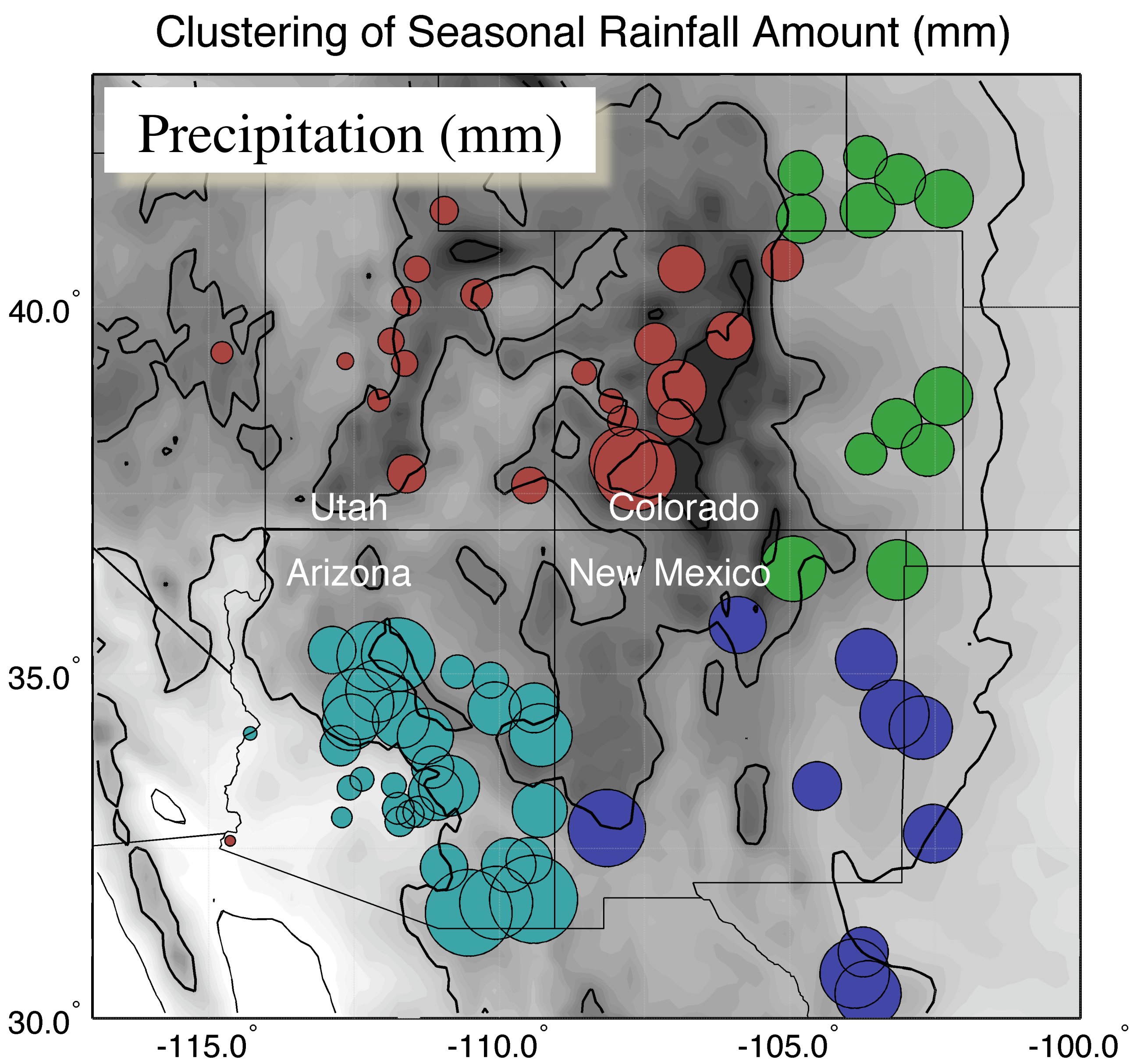
Introduction

- Global numerical climate models, and even high-resolution regional models, are equivocal on the projected response of the North American monsoon to future human-induced increases in global mean temperatures (*IPCC, 2007; CCSP, 2008*)
- However paleo records suggest that during periods of relatively warm temperatures—including the climatic optimum of A.D. 900-1300 and the mid-Holocene—there was a northward expansion of the summertime North American monsoon (*Petersen, 1994; Mock and Brunell, 1999; Harrison et al., 2003*)
- Research objective: ***Determine whether the historical record of summertime monsoon precipitation over the southwestern United States contains any detectable trends***
  - Such detection efforts serve as the first step in future attribution studies designed to understand the external drivers—either natural or anthropogenic—that produce these trends

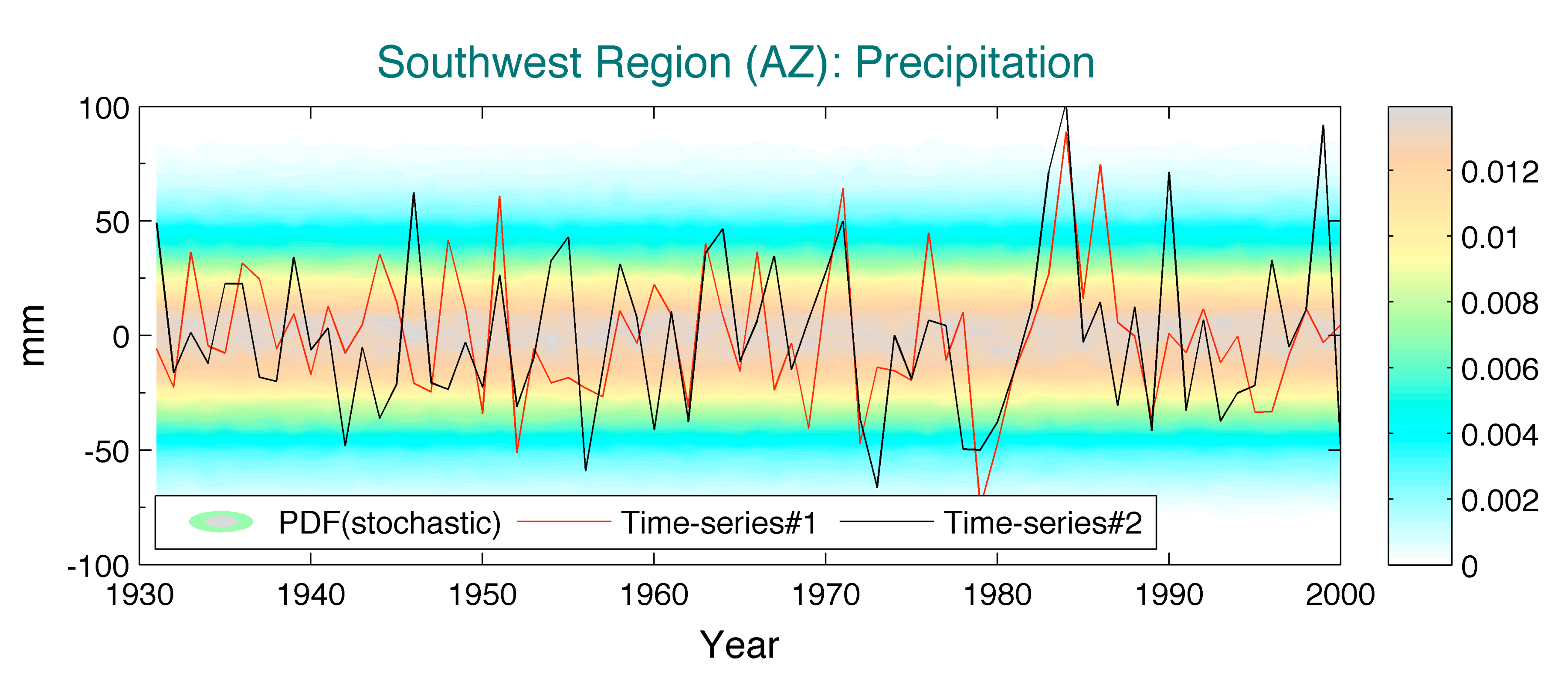
Clustering of Station Precipitation: July-Sept.



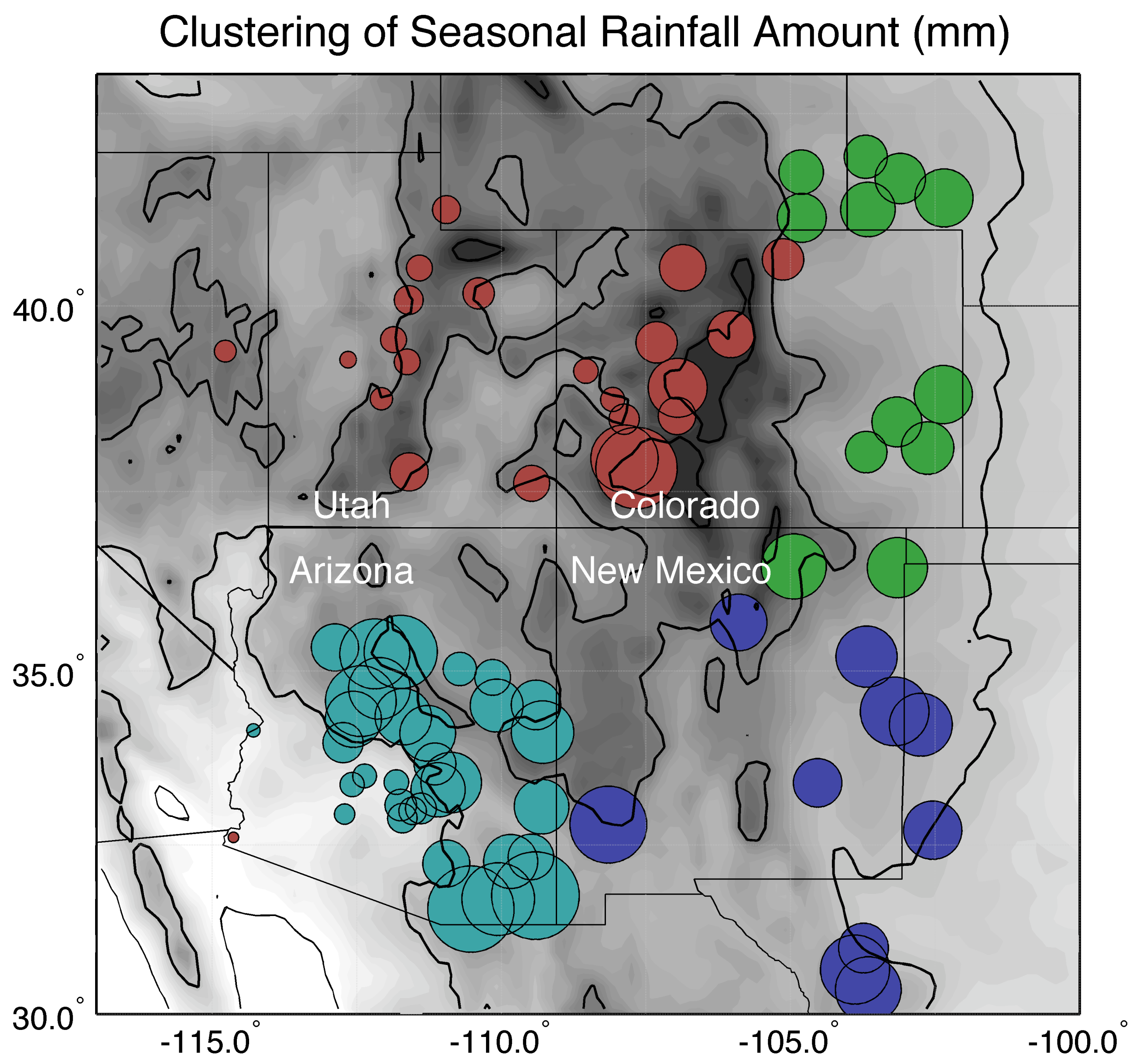
Method of Detection

- Detection: "Demonstrating that the climate has changed in some defined statistical sense" (*Stocker et al., 2010*)
  - Requires a method to estimate the range of internal variability absent any external drivers
  - Here we use stochastic daily-precipitation models, in which the statistical characteristics of daily precipitation (i.e. frequency, size, and intensity) are determined by that found in the observed system:
    - Generate 15,000 separate 70-year sequences of 92-day summertime precipitation time-series using a stochastic daily-rainfall model derived for each cluster
    - Estimate the internal variability of various precipitation means and extremes that can occur simply as a result of the stochastic evolution of daily weather events with fixed characteristics, e.g. that can occur even in a stationary climate
  - A detectable change in the *observed* climate is then defined relative to this internal variability, ***i.e. as those changes/trends in the means and extremes that could only have resulted from a change in the underlying climate characteristics of the region***

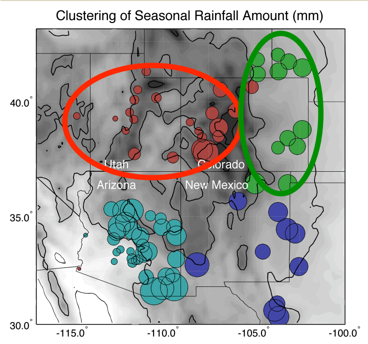
Stochastic Precipitation Estimates

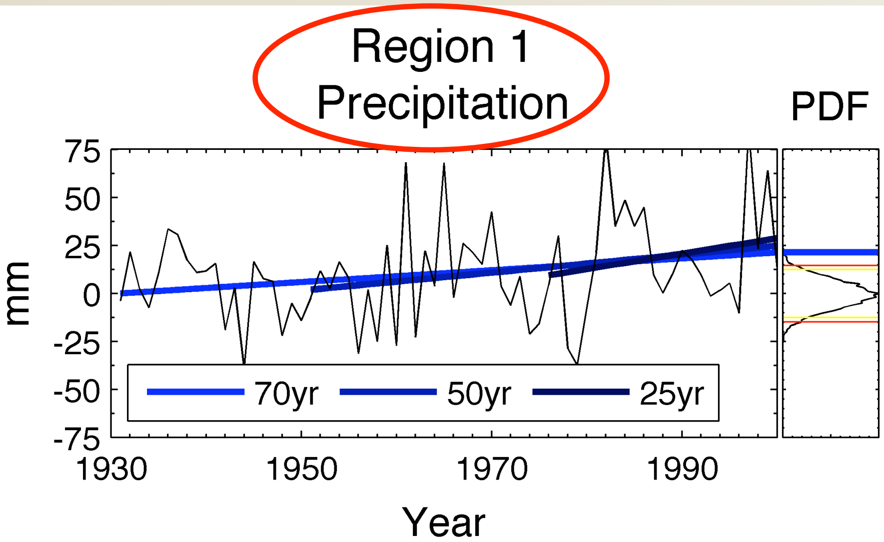


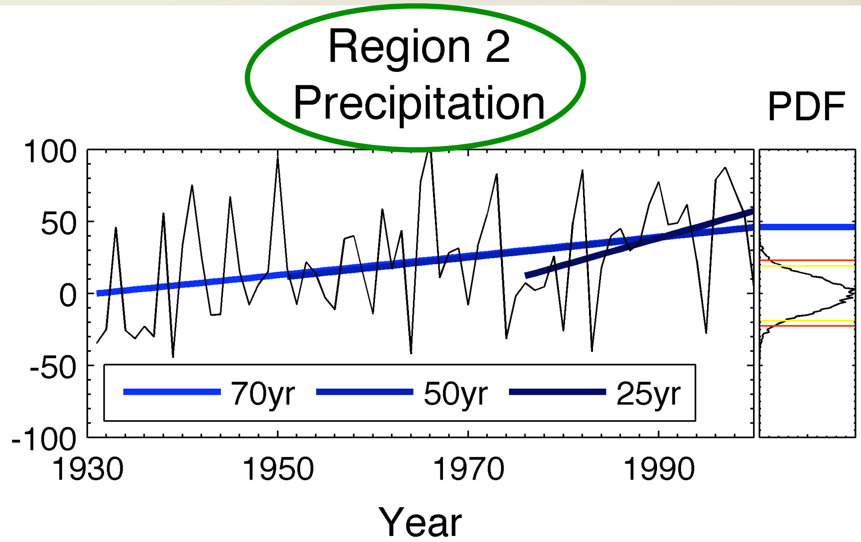
Regional Precipitation Patterns



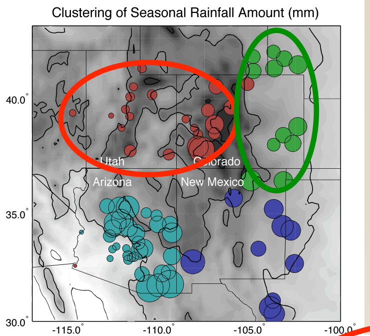
Seasonal-Mean Trends

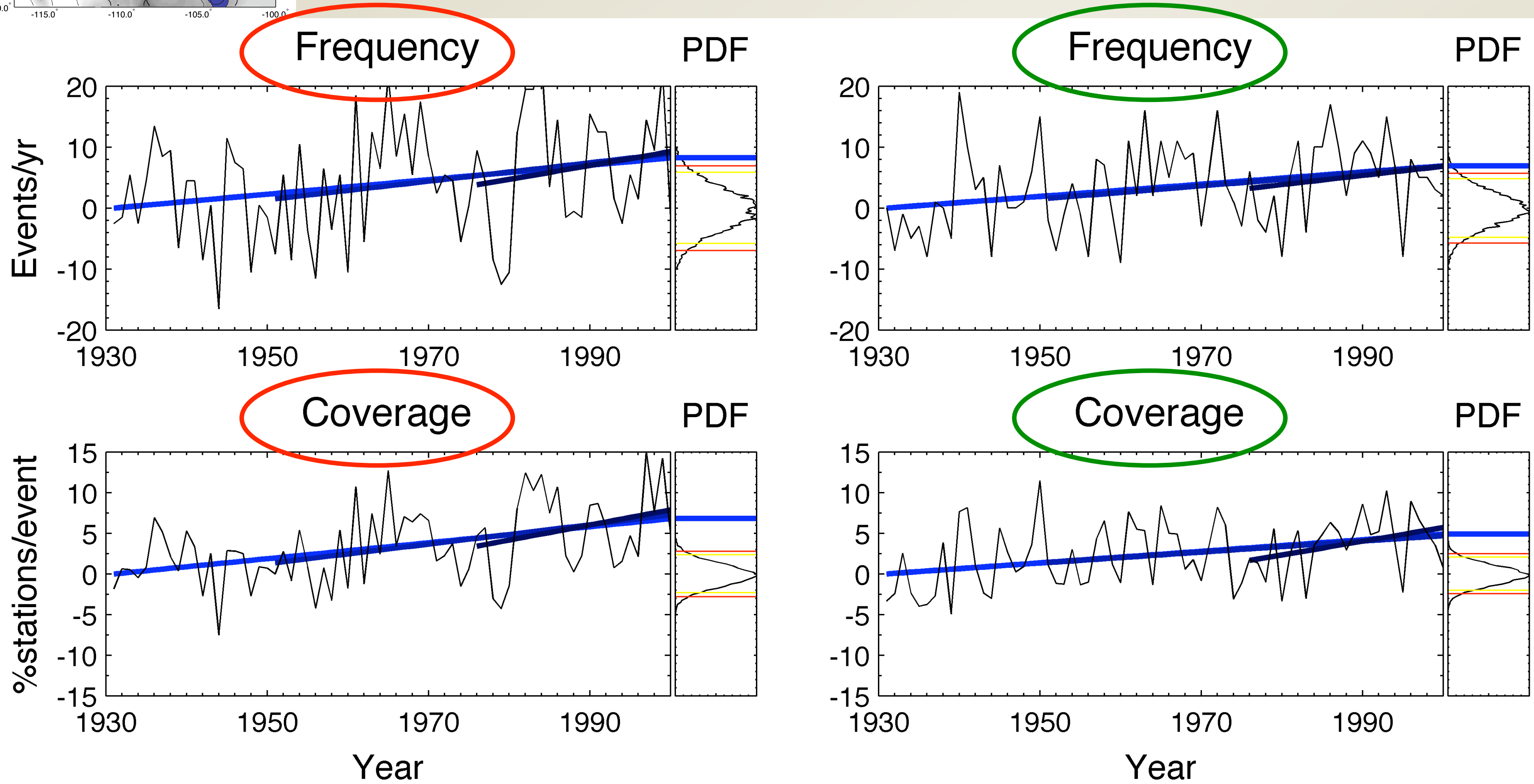






Seasonal-Mean Trends





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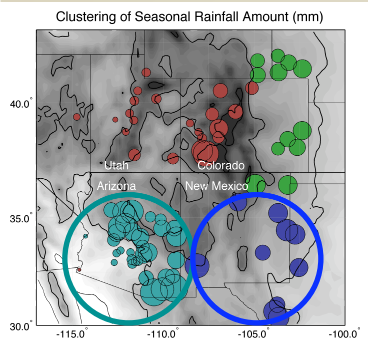
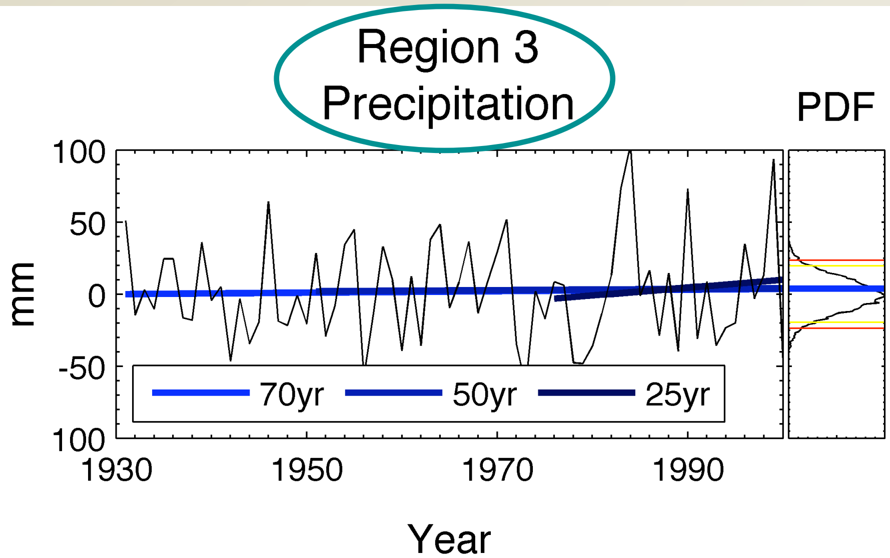
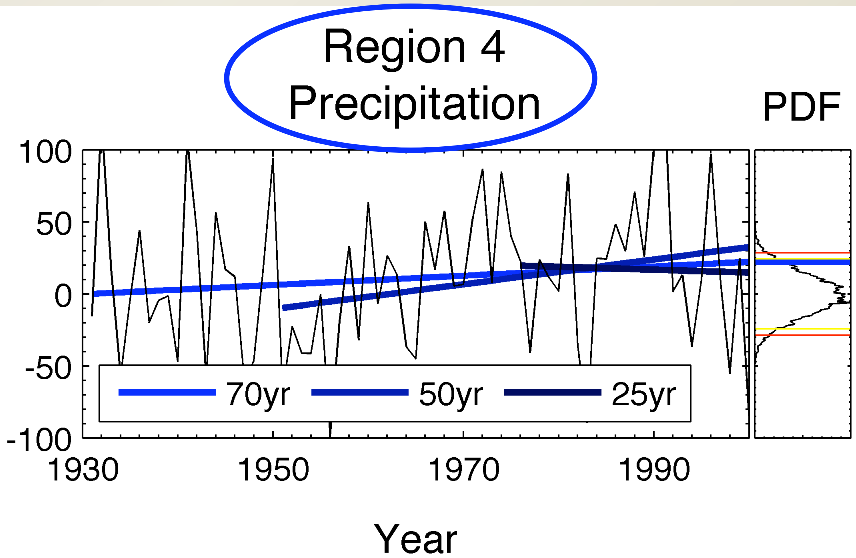
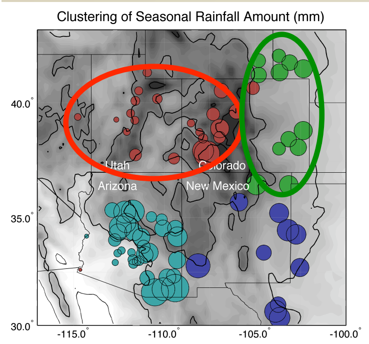
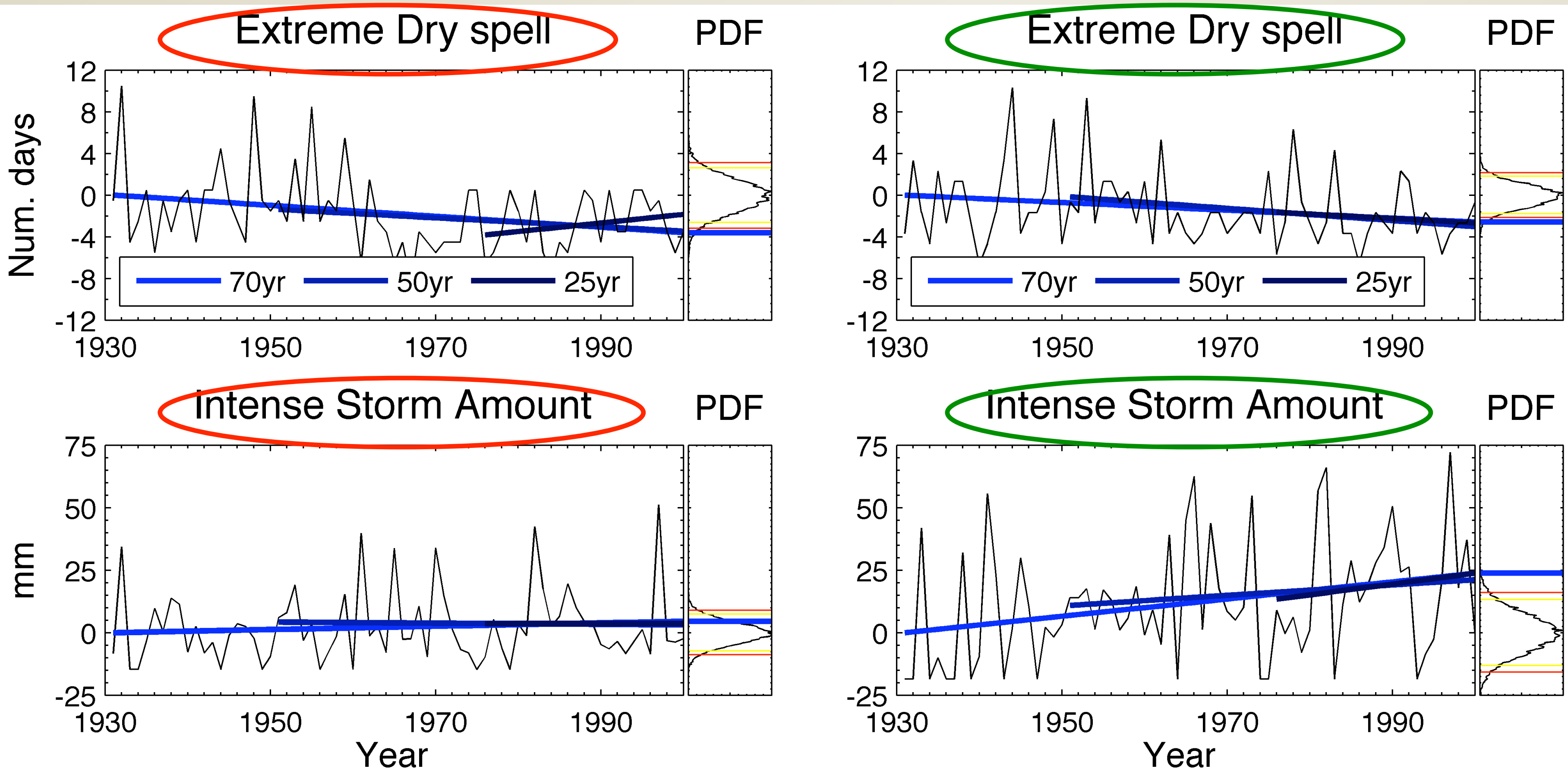




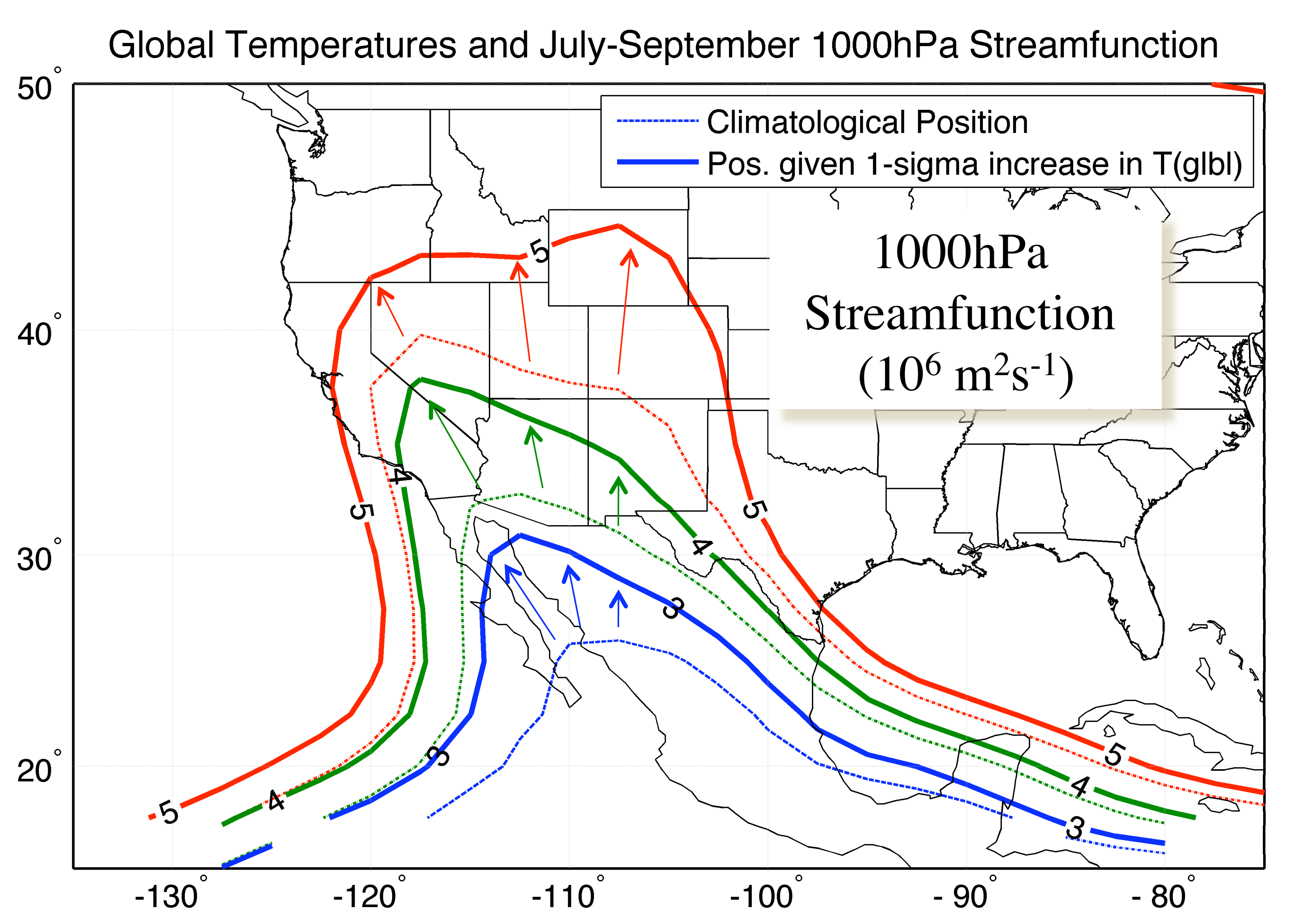


Trends in Extreme Event Occurrences





Trends in Dynamic Pressure Fields



Highlights

- Chain-dependent stochastic models derived from daily station data can be used to detect climate-change induced variations and trends in seasonal-mean precipitation and extreme events
- There has been a significant and systematic increase in summertime monsoon precipitation over a large portion of the southwestern United States during the last 70 years
  - The increases in summertime rainfall accompany a northward expansion of the summertime North American monsoon circulation into Colorado and Utah *coincident* with increasing global temperatures during the last half of the 20th century
  - These results are in agreement with the northward expansion of the summertime North American monsoon during periods of relatively warm temperatures, including the climatic optimum of A.D. 900-1300 and the mid-Holocene
  - They suggest that peripheral regions outside “core” monsoon areas may serve as “sentinel” regions in which detectable trends in precipitation characteristics are already emerging

Data Sets

- Daily precipitation data (*Eischeid et al., 2000*)
  - Based upon quality-controlled National Climatic Data Center (NCDC) Summary of the Day
  - Comprises 14,317 sites in the United States spanning at least 1948-2003
  - We analyze summertime (July-September) daily precipitation data at 78 stations over the southwestern United States that have complete data series spanning 70 years (1931-2000)
- NOAA/NCEP Reanalysis (*Kalnay et al., 1996*)
  - Monthly data at 2.5-degree resolution (approximately 250 km resolution)
  - ~65 years of data (1948-Current)
  - Observationally-constrained estimate of the state of the atmosphere based upon the assimilation of observed data within a numerical model system