Western U.S. Precipitation During Pacific Decadal Oscillation Phase Changes

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Purpose



Fig. 1: Exposed rock due to dramatically declined water levels near Hoover Dam in Boulder City, Nevada on April 17, 2022 [8]

- Water scarcity in the western US, worsened by climate change, presents a growing challenge to residents who depend on runoff for drinking water and irrigation.
- Water management efforts can be enhanced by a well-rounded knowledge of precipitation variability.
- Our results will help water managers and city planners mitigate the effects of extreme drought in the western US.

Introduction

- The Pacific Decadal Oscillation (PDO) is a multidecadal climate variability pattern related to sea surface temperatures (SSTs) in the north Pacific Ocean.[6]
- Categorized into two phases – warm and cold (Figure 2).[6]
- The PDO affects temperature and precipitation across the globe,[6] including the western US.[3,4]
- Warm (cold) phase is associated with decreased (increased) annual precipitation in the Southwest US.[4]
- Pacific Northwest region has less pronounced teleconnections.[2,3]
- Length of historical record compared to timescale of PDO phases presents an obstacle to research.
- Limited research into the timing, duration, and precipitation impacts of PDO when neither PDO phase dominates
- No objective definition for PDO phase changes (PCs), the periods in between PDO phases.

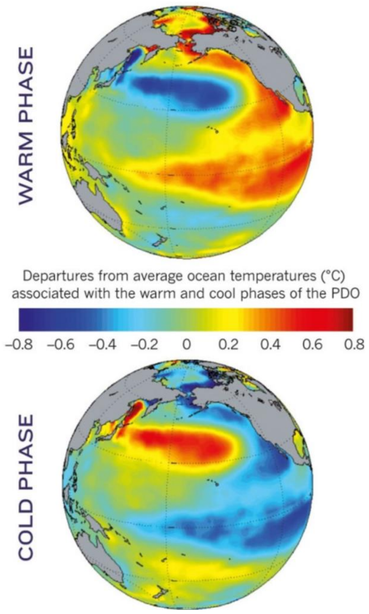


Fig. 2: Sea surface temperature patterns associated with the warm (top) and cold (bottom) phases of the PDO.[1]

Data

- We used the Community Earth System Model version 2 Large Ensemble (CESM2-LE) experiments to identify phase changes and determine the relationship with western US precipitation.
- CESM2 is among the most skillful global climate models.[5]
- The CESM2-LE experiment ran the CESM2 over a period from 1850 to 2100 with 100 members at a 1-degree spatial resolution.

Methods

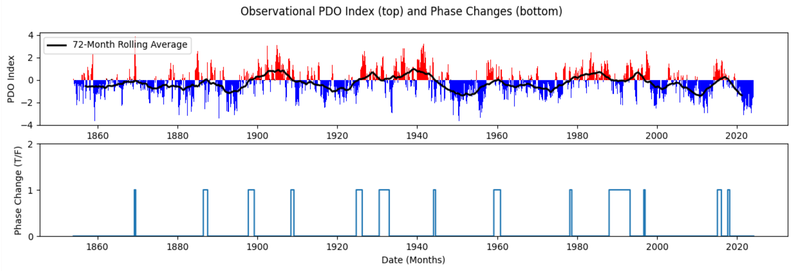


Fig. 3: Observational PDO index from NOAA between 1854 to 2024 (top).[7] Identified PDO phase changes based on our algorithm observing PDO index (bottom).

- Calculated the PDO index, the largest mode of North Pacific SST variability using an Empirical Orthogonal Function (EOF) analysis
- Developed an objective definition for PDO PCs using a rolling average and set index bounds which best reflected observations.

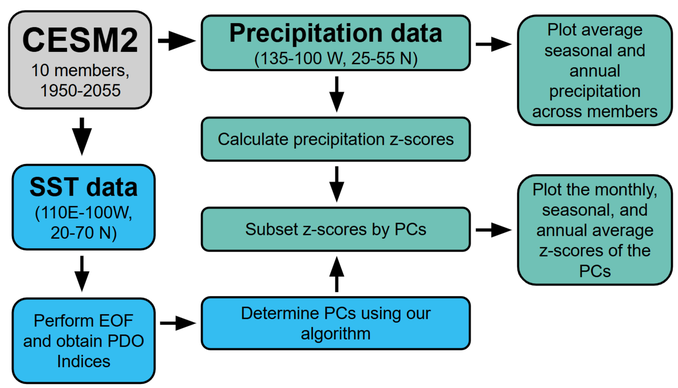


Fig. 4: A flowchart showing the data used from the CESM2, the steps taken to analyze the data, and the plots created for this research.

Results

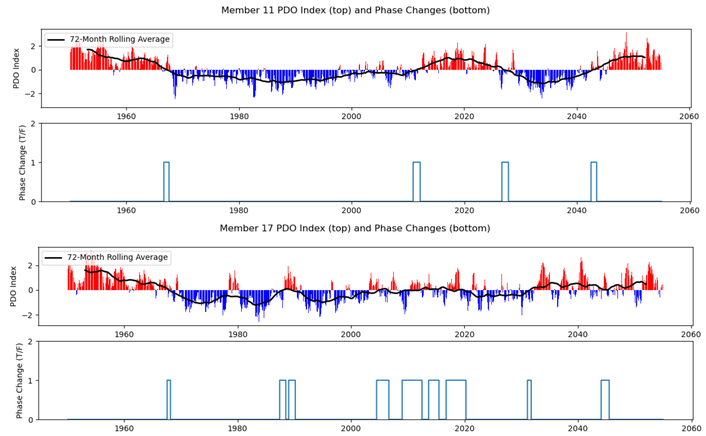


Fig. 5: Modeled PDO index from CESM2 members 11 (top) and 17 (bottom). Member 11 shows a clear pattern of PCs, while member 17 shows a less distinct pattern.

- Defined PCs as periods greater than 6 months apart where a 6-year rolling average of the PDO index falls within ±0.1.
- PC number and length varied across members (Figure 5).
- Ensemble mean precipitation during PCs showed a precipitation deficit in the Pacific Northwest and a surplus in the Southwest (Figure 6).

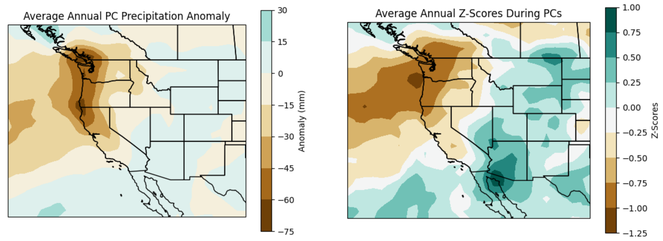


Fig. 6: Anomalies in ensemble mean annual precipitation during PCs, displayed as both raw values (left) and z-scores (right).

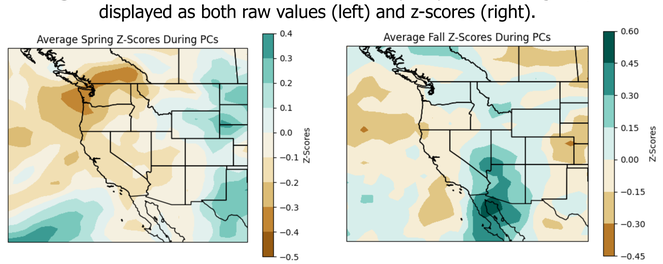


Fig. 7: Anomalies in ensemble mean seasonal precipitation during PCs for spring (left) and fall (right), displayed as z-scores.

Conclusions

- Precipitation during PCs on annual timescale resembles cold phase pattern but with more meaningful teleconnection in Pacific NW
- Long PCs potentially suggest the existence of a neutral PDO phase
- Future work could categorize PCs by concurrent ENSO phase or further explore the possibility of a three-phase paradigm

Science Questions

1. How is a PDO phase change defined?
2. How does precipitation amount and distribution in the western US vary during a PDO phase change?

References

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