Climate and drought over the past 1000 years in the Last Millennium Reanalysis

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Introduction

Large drought variability has occurred over the past 2000 years. To study the climate relationships that influenced drought, a data assimilation approach is employed. Better understanding past drought variability may help us prepare for potential changes over the coming century.

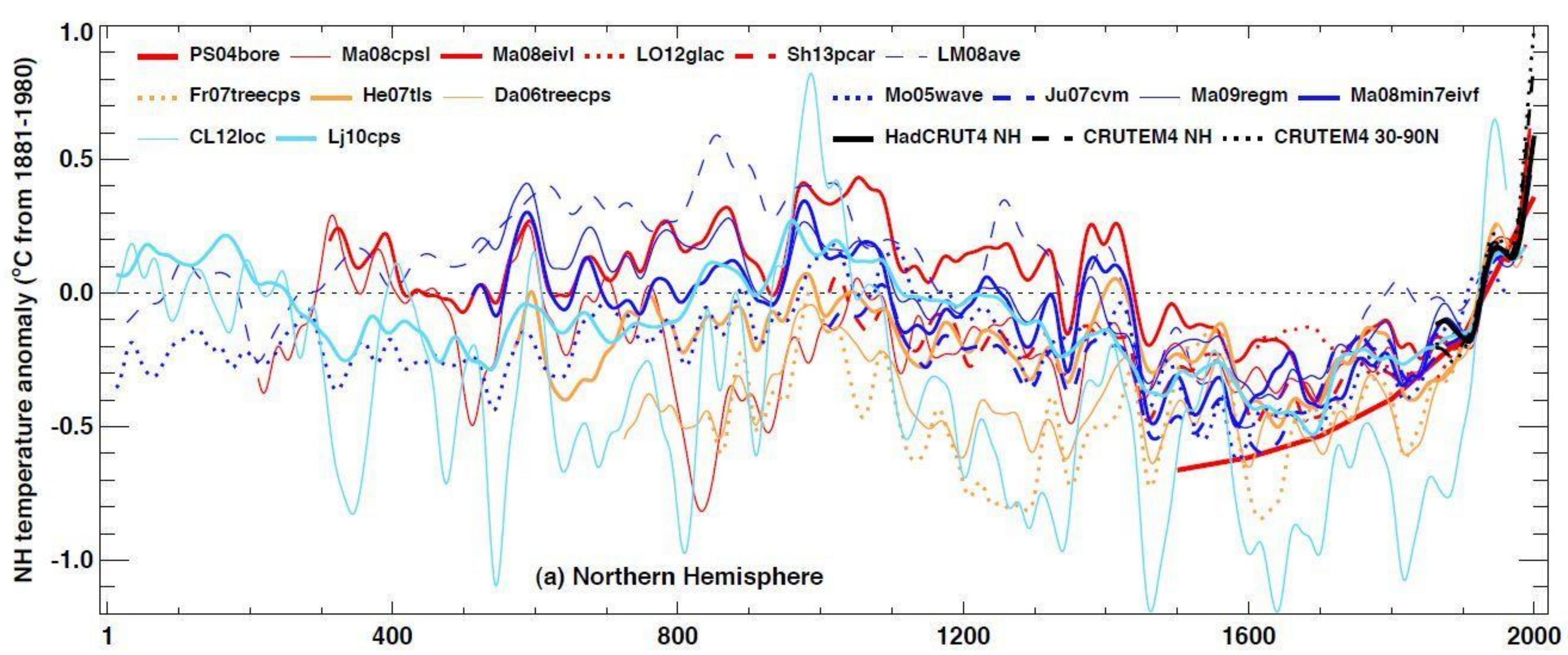

Fig. 1. Important climate variability has occurring over the past 2000 years, as seen in Northern Hemisphere temperature reconstructions (from IPCC AR5).

1. Data Assimilation

The Last Millennium Reanalysis (LMR) project is a data assimilation approach which uses information from proxy records and climate models to reconstruct past climate.

Prior:
Output from CCSM4 last millennium simulation.

Proxies:
- PAGES2k v2[1]
- Trees compiled by P. Breitenmoser[2].
- Additional NCDC proxies.

Method:
The Kalman filter updates the prior climate state to better match proxies. The proxies inform temporal variability and model covariances help fill in spatial information.

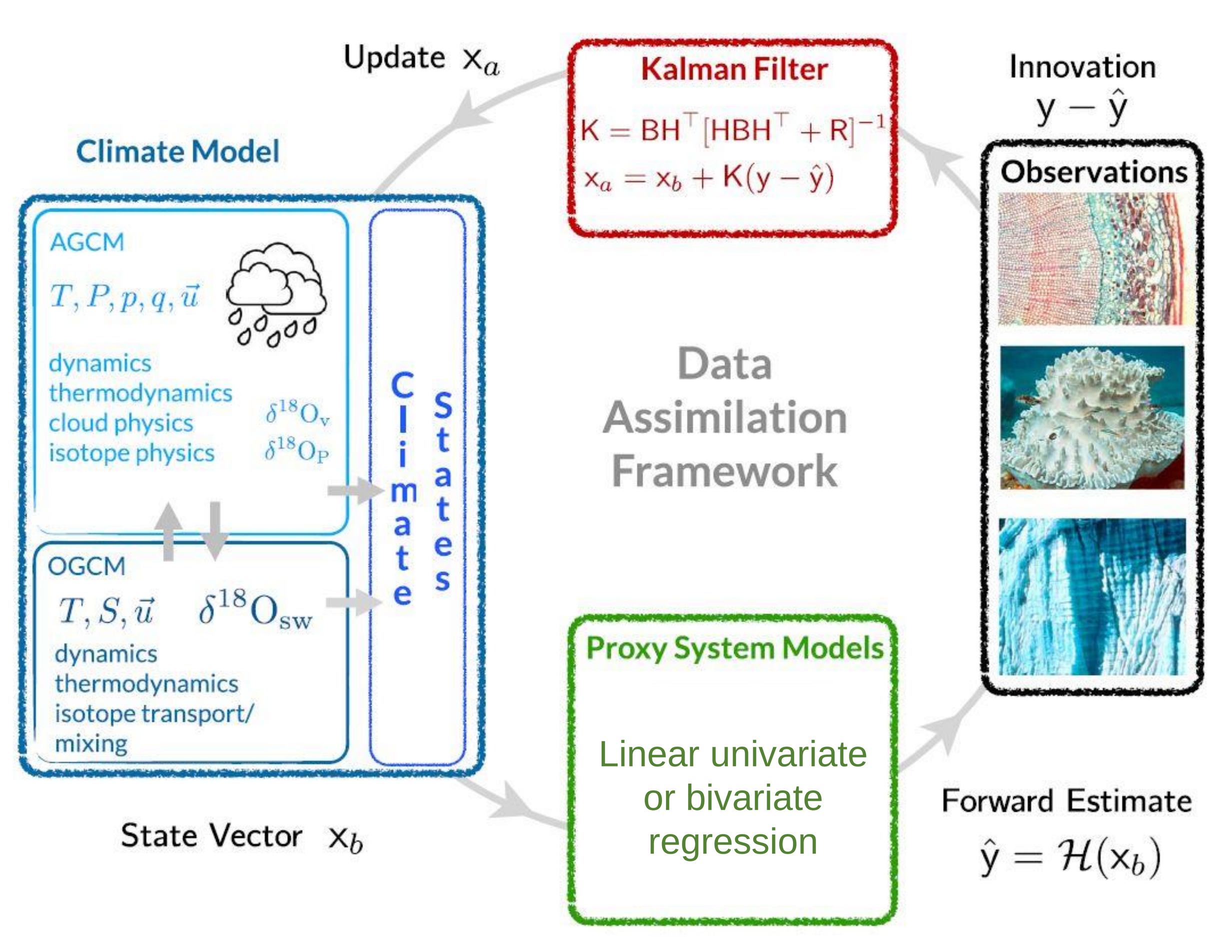

Fig. 2. Schematic of data assimilation.

2. LMR compares well with existing data sets

Temperature and drought in LMR match well with existing data sets. An advantage of LMR: A unified approach to reconstruct a variety of climate variables simultaneously.

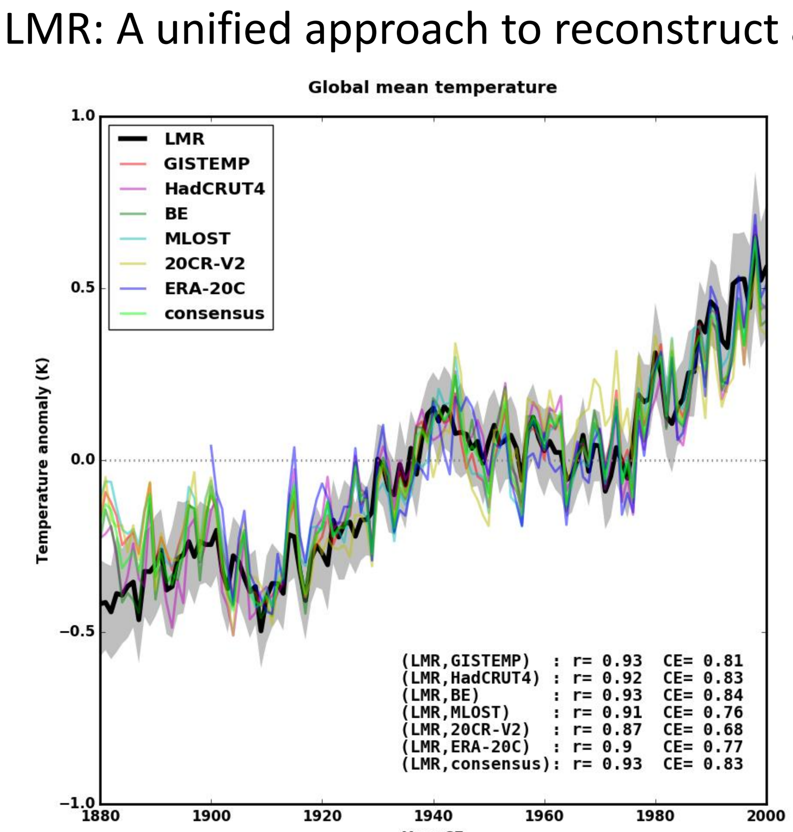

Fig. 3. Global-mean temperature in the LMR compared to reference data sets.

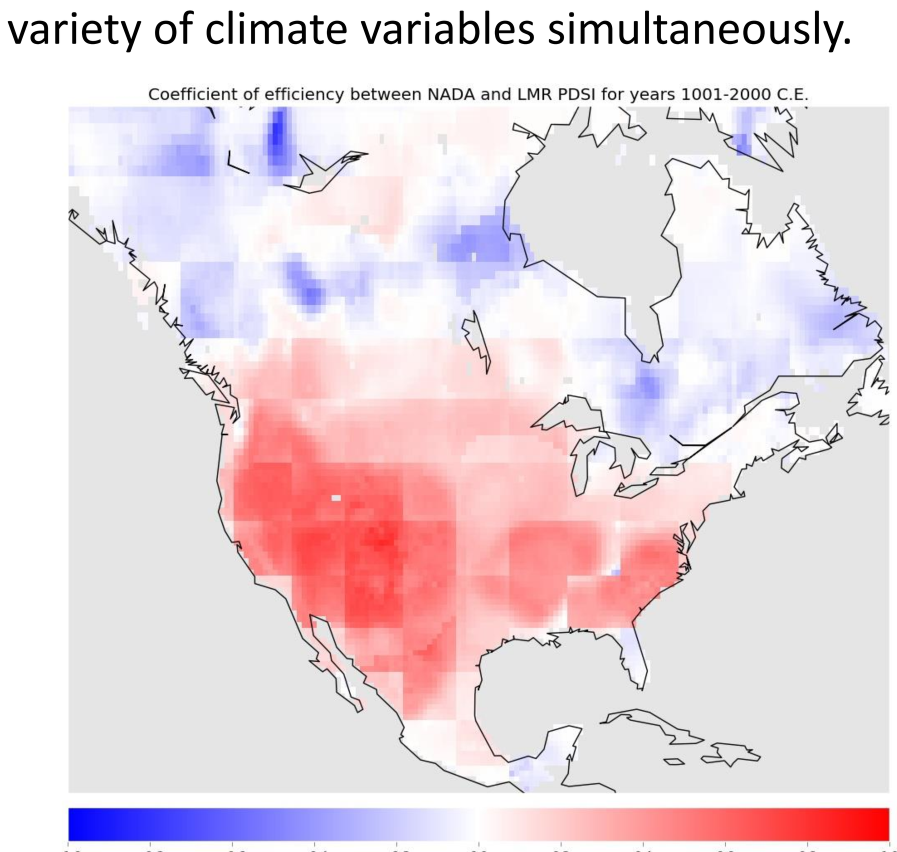

Fig. 4. Coefficient of efficiency between drought (PDSI) in the LMR and the North American Drought Atlas at every location.

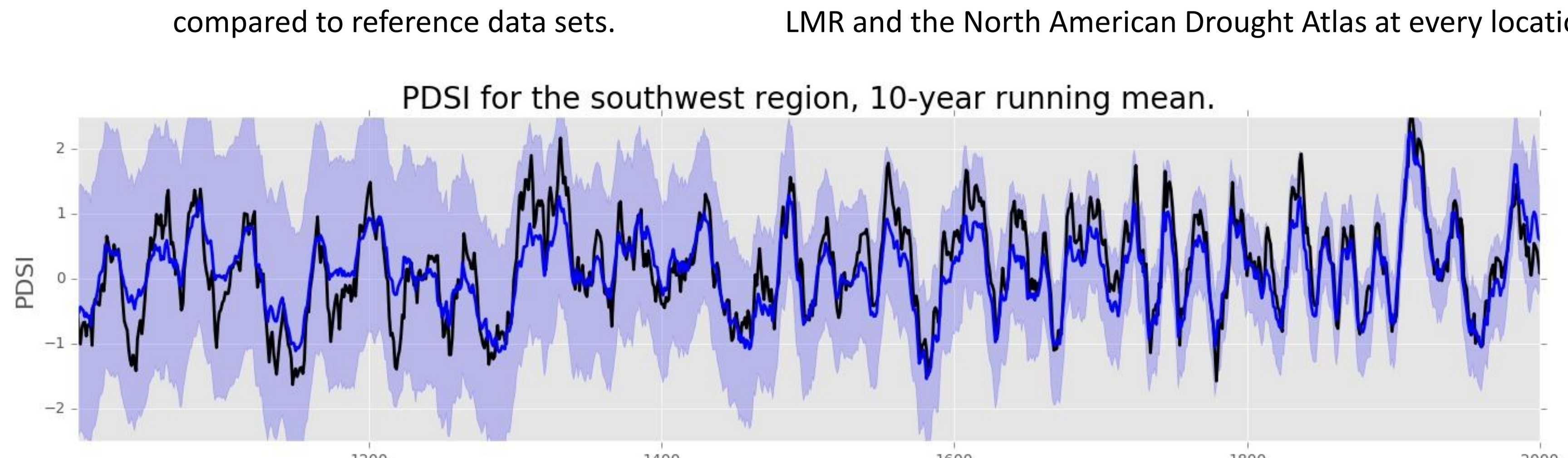

Fig. 5. Drought (PDSI) in the southwestern U.S. in the LMR (blue) and North American Drought Atlas (black).

3. U.S. drought vs. ENSO

Drought in the southwest U.S. covaries with La Nina sea surface temperatures and a cold Pacific Decadal Oscillation, as seen in mode 1 of a maximum covariance analysis. Possible connections with the Atlantic Multidecadal Oscillation are not as clear.

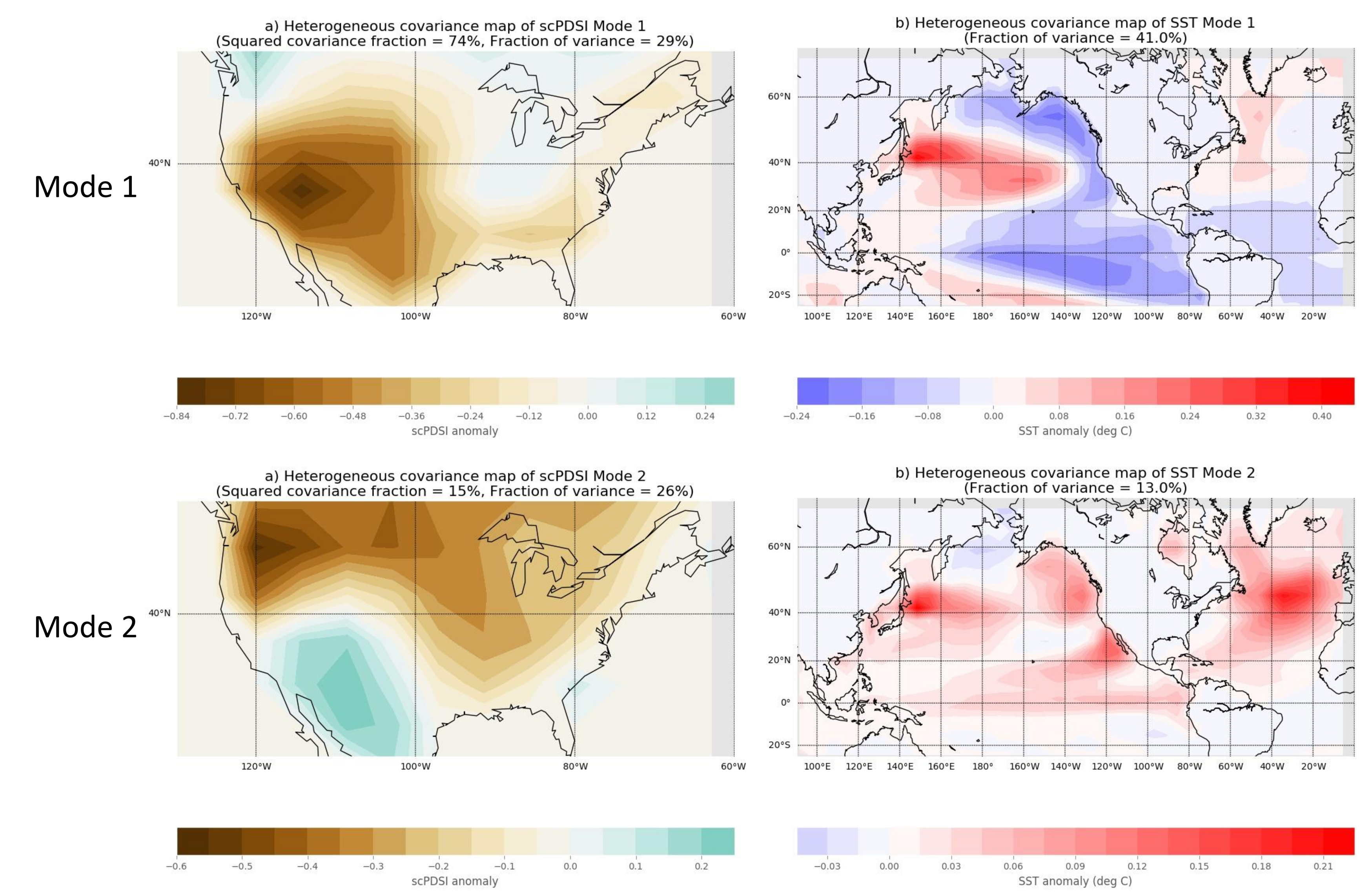

Fig. 6. (top) Mode 1 and (bottom) mode 2 of a maximum covariance analysis between U.S. drought and SSTs.

4. Climate patterns of the driest and wettest years

The driest years in the southwest U.S. have a clear La Nina pattern and a blocking high in the north Pacific. The opposite is true for the wettest years.

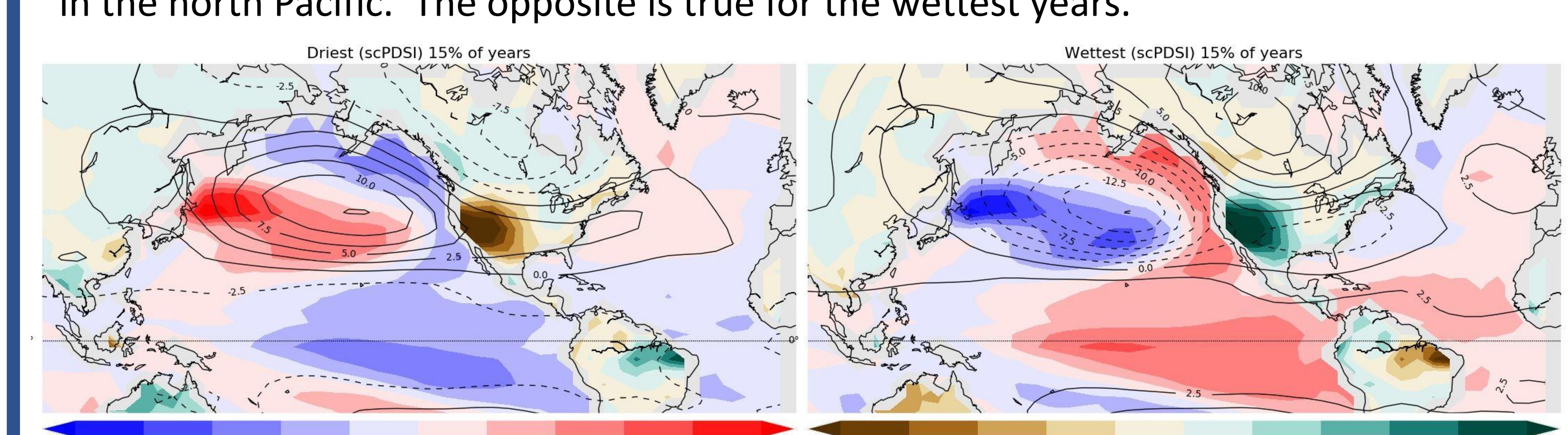

Fig. 7. PDSI, SST, and 500 hPa heights during the (left) driest and (right) wettest 15% of years in the southwest U.S.

5. Other things affect drought too

For the southwest U.S., El Nino years can be dry and La Nina years can be wet, defying expectations.

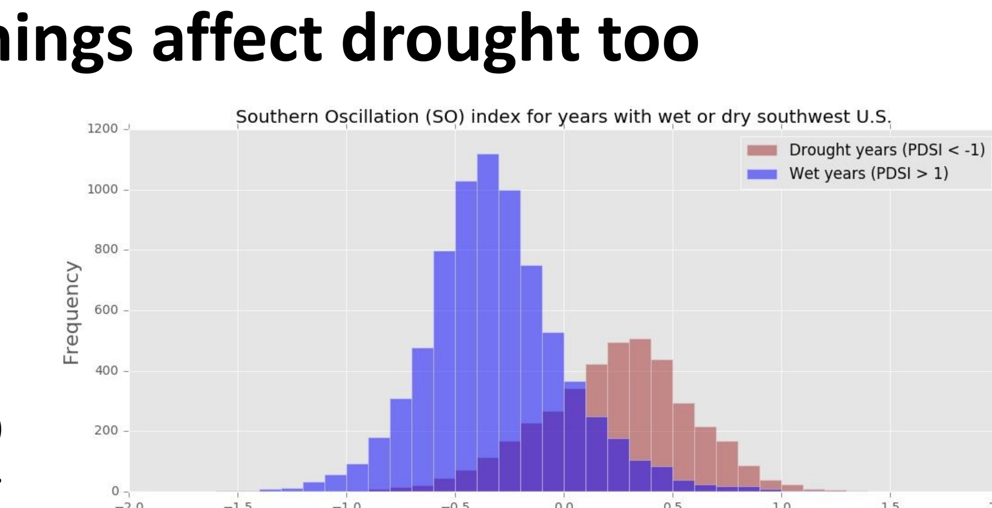

Fig. 8. The Southern Oscillation Index (SOI) for dry and wet years in the southwest U.S.

6. Possible effects of volcanic eruptions

Volcanic eruptions have a clear impact on temperature, but might have affected past droughts as well. The response may depend on the location of the eruption[3].

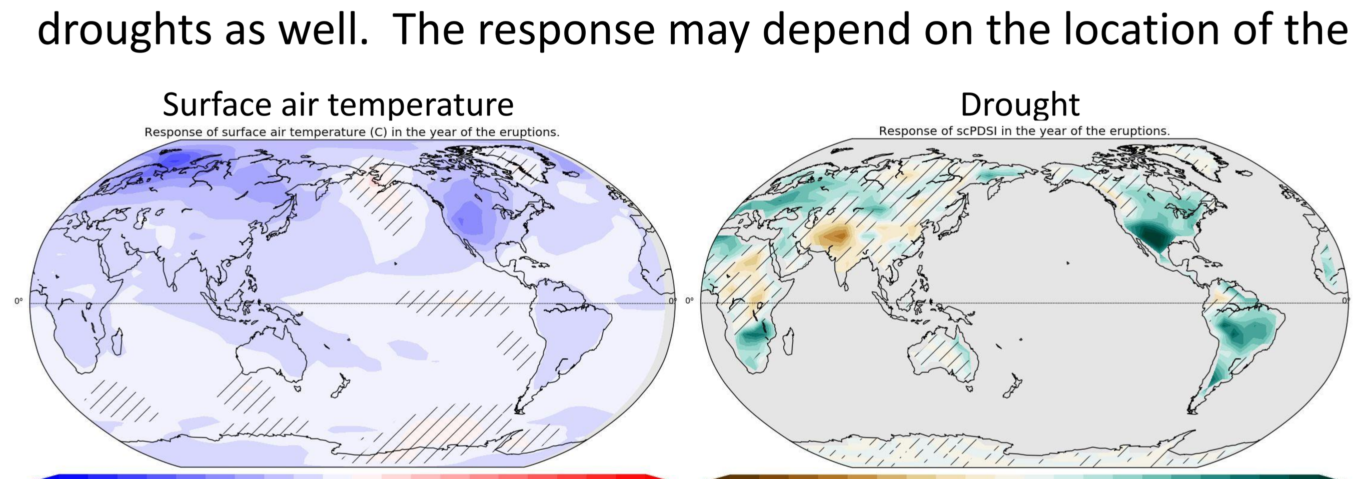

Fig. 9. Annual-mean (left) temperature and (right) drought responses for the years of the 22 largest volcanic eruptions. Hatching marks responses which are not significantly different from 0.

References

1. PAGES2k consortium: A global multiproxy database for temperature reconstructions of the Common Era. *Scientific Data*, in revision.
2. Breitenmoser, P., et al. 2014: Forward modelling of tree-ring width and comparison with a global network of tree-ring chronologies. *Clim Past.*
3. Stevenson, S., et al., 2016: "El Nino Like" Hydroclimate Responses to Last Millennium Volcanic Eruptions. *J. Climate.*

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