Understand and Predict the Severe Drought Event In the Western United States and Their Influence On Water Resources and Human Health

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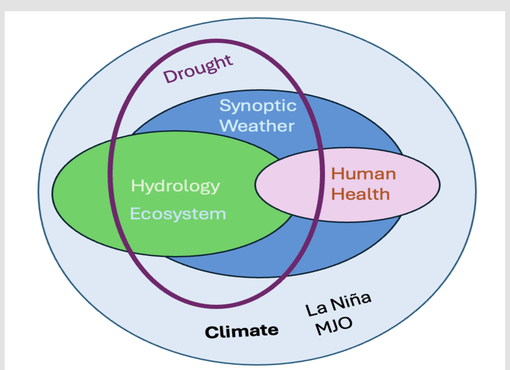
ABSTRACT

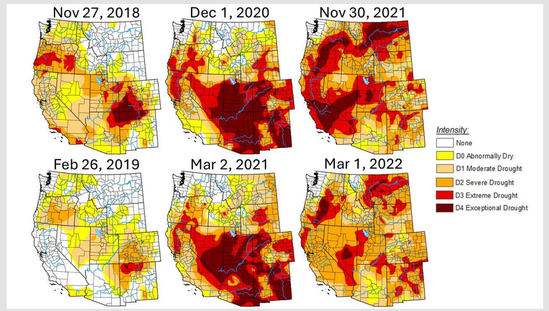
The western U.S., including California, Oregon, Nevada, Utah, and New Mexico, has faced severe droughts in recent years. In 2022, over 32% of the region experienced extreme drought, impacting water availability, daily life, and public health. This project focuses on Northern Utah, collaborating with experts in climate, hydrology, and health to: 1) Improve drought prediction using historical and current data, and 2) Examine the hydrological and health impacts of drought. Our goal is to enhance forecasting and provide useful insights for policymakers.

Research indicates that La Niña and the Madden–Julian Oscillation (MJO) influenced droughts in the western U.S. from 2020 to 2022, while the North American Monsoon affected summer drought severity. These findings underscore the significance of ENSO, MJO, and monsoon patterns in drought forecasting. The team also evaluated satellite data for drought monitoring and found that groundwater in headwater catchments serves as a strong predictor of stream/runoff efficiency. Groundwater storage variability reflects approximately four years of climate conditions, with Great Salt Lake levels trailing by 1–2 years. This insight aids in predicting water supply and dust exposure risks. Using hospital and meteorological data, researchers are investigating the health effects of drought. Overall, the study establishes a link between regional droughts, groundwater storage, and declining lake levels, which contribute to increased dust exposure and associated health risks.

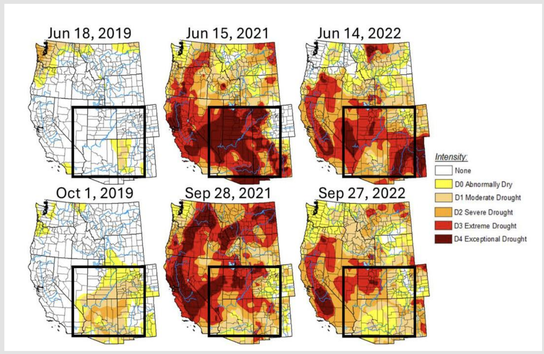
Interaction Among Drought, Climate, Hydrology, and Human Health



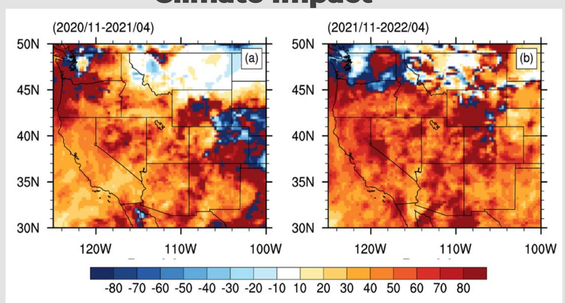
Drought in the Western U.S. (2020–2022), Winter



Drought in the Western U.S. (2020–2022), Monsoon Season



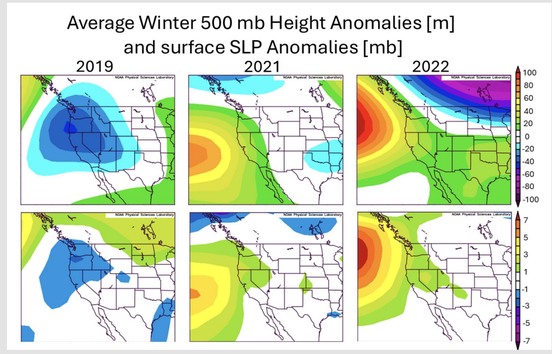
Climate Impact

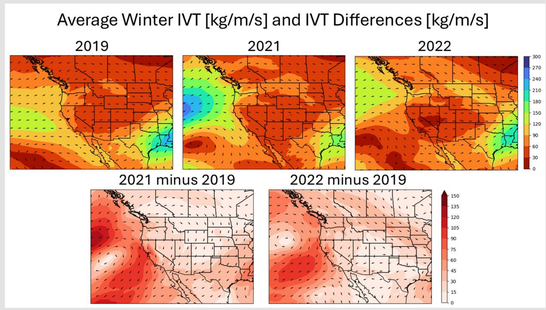


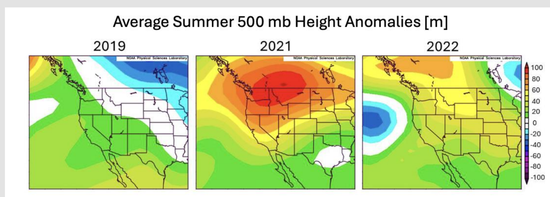
The percentage (%) of seasonal precipitation anomalies explained by La Niña is approximately 40% on average during the cold seasons of 2020–2022.

In addition, the MJO can account for about 10-20% of precipitation anomalies.

Synoptic Weather Conditions



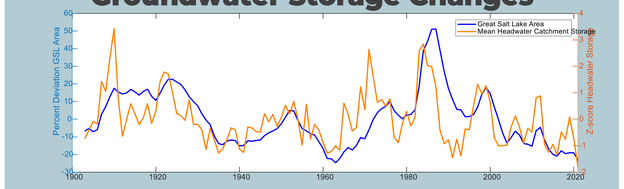




Comparing the drought conditions during 2021 and 2022 to climatology, as well as to the non-drought conditions during 2019. It is found that:

- During the winter of the drought years, stronger upper-level ridging and a more expansive high-pressure system over the Pacific were observed, compared to normal and to 2019. This established a stronger blocking pattern than usual, preventing synoptic-scale precipitation from reaching the western U.S. leading to a precipitation deficit.
- In the summer of the drought years, the North American Monsoon helped alleviate drought conditions in the southwest U.S., while the rest of the West experienced more intense drought conditions.

Groundwater Storage Changes



Time series of groundwater storage in headwater catchments and the Great Salt Lake (GSL) area since 1902. Mountain groundwater storage and GSL area follow a similar temporal pattern with the GSL area slightly muted and lagging headwater catchment groundwater by 1-2 years.

This result offers a novel method to predict the potential water supply to the lake, as well as the extent of its exposed area. The groundwater storage index developed is a novel, wholistic, watershed wide index of regional drought that integrates multiple seasons and allows prediction of water resources and GSL dust.

Using hospital records, meteorological data, and information on the conditions of the Great Salt Lake. Research is ongoing to study the impacts of droughts on air quality, and subsequently on human health, particularly on respiratory diseases.

Outcomes and Impacts

Publications

- Pye, M. and Z. Pu, 2024: Synoptic-scale Circulation of the Western United States Drought of 2021 and 2022. *Journal of Applied Meteorology and Climatology*. Under revision.
- Hou, Z., and Pu, Z. (2023) Assessing CYGNSS Satellite Soil Moisture Data for Drought Monitoring with Multiple Datasets and Indicators. *Remote Sensing*, 2024, 16(1), 116; https://doi.org/10.3390/rs16010116
- Wolf, M., Jamison, L.R., Solomon, D.K., Strong, S., Brooks, P.D. (2023) Multi-year Climatic Controls on Groundwater Storage in Seasonally Snow-Covered Headwater Catchments, *Water Resources Researc*h 59 (6), e2022WR033394

Report

This 1U4U project contributed to the 2023, 2024, and 2025 report of ***"great salt lake strike team annual report to the legislature"***.

Successful Grants

1U4U Research contributed to the two new grants:

- The award for "Options and Cost for Great Salt Lake Dust Control" funded by UDWR from 2024-2026, $400,000. (Brooks)
- The award for Earth System Modeling and Data Assimilation project, funded by DOE from 2024-2027, $600,000. (Pu)

Acknowledgements

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