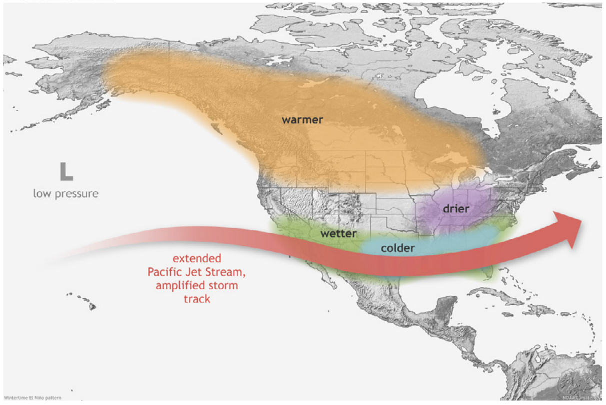
FOCUS AREA

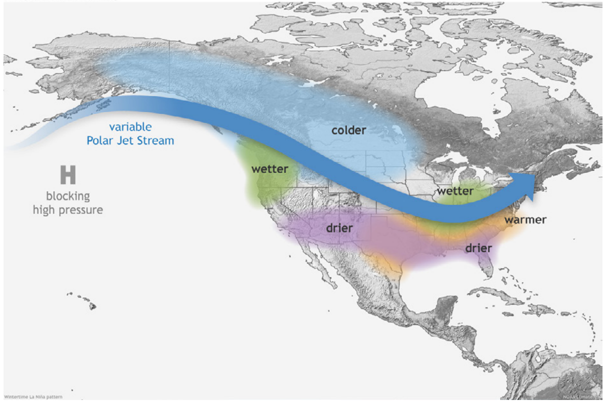
DETERMINING THE PHYSICAL DRIVERS OF DROUGHT AND HOW THEY ARE CHANGING

Drought drivers include climate dynamics that can create persistent weather patterns, which can cause droughts to form or end. The El Niño–Southern Oscillation (ENSO) is perhaps the most commonly used climate driver for drought prediction. Anthropogenic climate change might result in changes to the way ENSO impacts drought development and demise, although the details of those changes remain uncertain (Power & Smith, 2007; Cai et al., 2020). Other climate drivers, such as land-atmosphere feedbacks (Miralles et al., 2018), the Pacific Decadal Oscillation (PDO), the Atlantic Multi-decadal Oscillation (AMO), and the Indian Ocean Dipole (IOD), also influence drought progression across North America, but like ENSO, the influence of these drivers in a warmer world is uncertain (Pu et al., 2016). Despite the uncertainty, natural variability will continue to contribute to droughts and seasonal-to-decadal precipitation trends (sometimes wetter and sometimes drier).

TYPICAL EL NIÑO WINTERS



TYPICAL LA NIÑA WINTERS



El Niño and La Niña winter impacts on North American winters. Source: NOAA's Climate.gov

When multiple, slow-moving patterns are evident in the climate system, they can amplify or dampen alternate climate patterns, creating non-linear behavior in drought response. This climate variability, in tandem with underlying climate trends, can create unprecedented climate extremes. Novel drought conditions are emerging, creating droughts that look different today than they did a generation ago. Examples include "hotter" droughts and larger vapor pressure deficits (Mankin et al., 2021), human-induced and human-modified droughts (e.g., Crausbay et al., 2020), flash drought (Yuan et al., 2023; Christian et al., 2023), and increasing snow drought (Marshall et al., 2019) in a warmer climate. Drought forecasters can use seasonal forecasts to interpret and predict the influence of multiple climate drivers on temperature and precipitation patterns. However, seasonal precipitation forecasts over parts of the U.S. (especially the western U.S.) lack forecast skill (Pan et al., 2019; Kumar & Chen, 2020).

Improved modeling can increase understanding of drought's drivers. Modernization of models to better represent land surface processes (e.g., evapotranspiration, soil moisture) and ensuring the correct representation of global-scale drivers (e.g., the tropical Pacific) can improve our understanding of drought indicators and prediction at sub-seasonal to seasonal timescales. Deeper understanding of climate drivers can come from using machine learning techniques, improving representation of these processes and interactions in numerical models, and improving global observations/diagnostics to reliably attribute climate drivers.

Priority Actions:

1. Evaluate and enhance modeling to better represent processes at the land surface (e.g., evapotranspiration, infiltration) and other drivers (e.g., ENSO, localized land–atmosphere feedback) to improve drought indicators and prediction in areas where precipitation patterns are changing.
2. Improve understanding of how rising temperatures interact with other climatic factors to influence drought to include whether these relationships are stable in a changing climate, and if not, how they are projected to change.
3. Investigate the expectations of megadrought in the future being driven largely by persistent warming trends instead of low-frequency climate variability, taking into account the paleoclimate evidence for large-scale climate oscillations driving megadrought (Coats et al., 2015, 2016; Steiger et al., 2019)[2].
4. Evaluate and synthesize mechanisms leading to warmer droughts given that they are expected to have greater effects on soil moisture, water availability, plant mortality, and wildlife.
5. Continue to explore and evaluate the use of remote sensing as a viable path in hydro-climate applications and modeling, particularly as satellite records get longer and their integration with models becomes more commonplace.

Research Questions:

1. What are the effects of greenhouse gas emissions on low-frequency climate variability (e.g., ENSO, PDO, AMO) as it relates to drought (Rashid & Beecham, 2019; Geng et al., 2022; Fix et al., 2022)?
2. What physical drivers contribute to multi-year drought? How are those drivers changing? Is this a way that non-stationarity is impacting the characteristics of a drought event?
3. What is the role of temperature in a changing water cycle as it relates to drought? How does temperature affect drought during different seasons? Does a changing baseline mean that it is getting harder to get out of drought?
4. How accurately do climate-based drought indices (e.g., PDSI, SPI, SPEI) represent land- and water-based drought features and processes (e.g., streamflow, groundwater, soil moisture, vegetation)?

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[2] Some priority actions from the workshop were given with citations while most were not. Where a citation was provided, we are including those with the priority action.

5. How well do global and regional climate models simulate non-stationarity in drought, including the effects of global and local drivers of non-stationarity as distinguished from natural variability?
6. When considering climate drivers, how does monitoring and modeling uncertainty limit and/or impact our ability to disentangle drought from aridification?

(Top left) Albuquerque, New Mexico, Sept. 27, 2023. A distant thunderstorm. Photo by Joel Lisonbee; (Top right) Lake Granby, Colorado, June 16, 2023. Pinyon Pine after a rainstorm. Photo by Joel Lisonbee; (Bottom) Albuquerque, New Mexico, Sept 27, 2023. Prickly Pear. Photo by Joel Lisonbee