Drought and Non-Stationarity: Information Gathering Session 2

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Motivation

….drought risks continue to escalate rapidly in many regions around the world due to an observed increase in the frequency of high-magnitude droughts driven by climate change, water scarcity, increasing water use, poorly implemented water resources management, unsustainable and inadequate land management, increasing structural vulnerabilities in many societies, and the growing exposure of both expanding and aging populations in many regions. (Drought Resilience +10 Conference Conclusions and Recommendations)

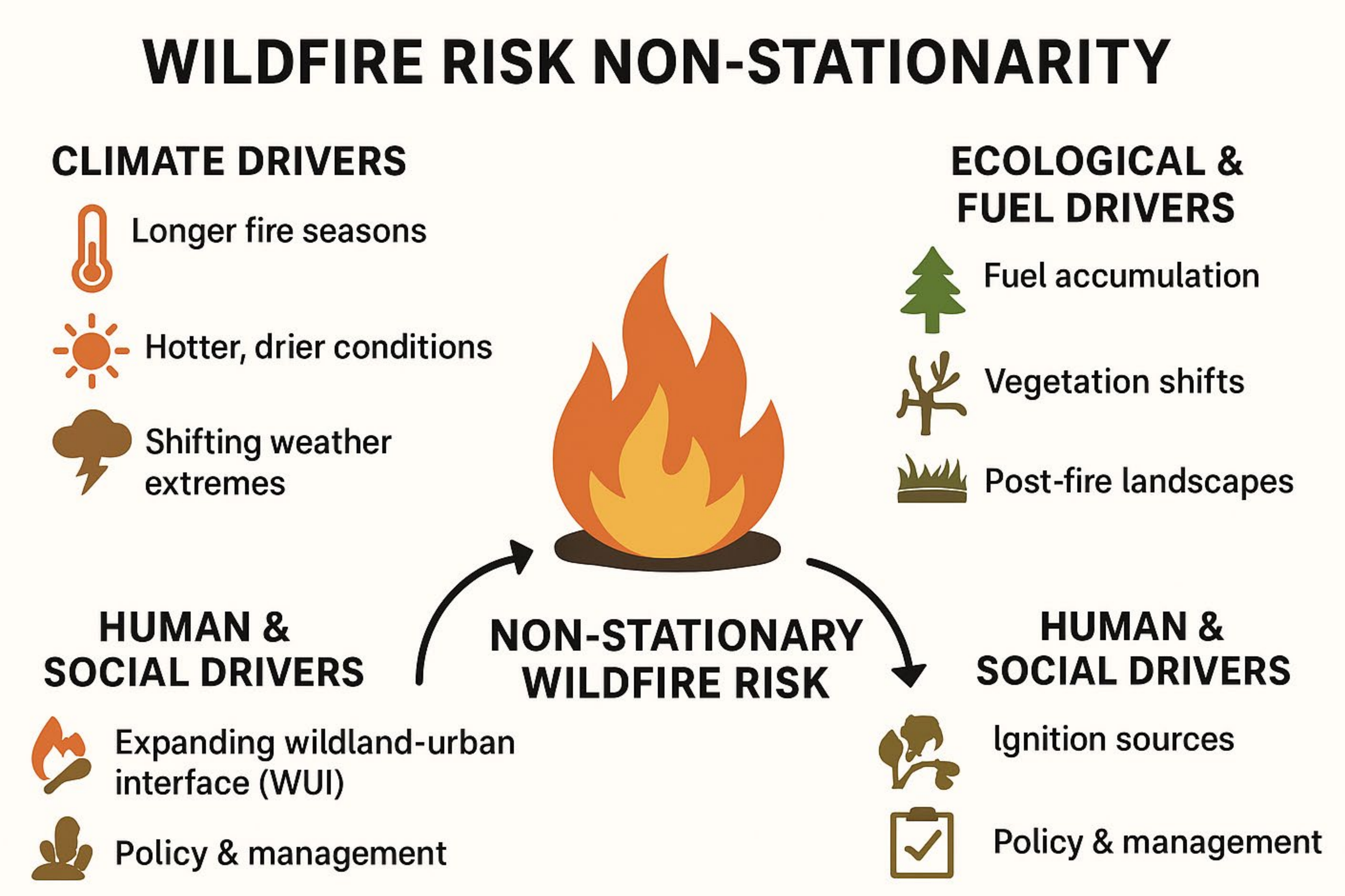
The enhanced earlier warning and improved preparedness from improved drought monitoring in a rapidly warming climate will help shift from a crisis-orientated response to a proactive management of drought risk impacts

- Results in near term avoidance of losses by mitigating drought impacts
- Frees up economic resources that would have been invested to address the avoided drought impacts
- Allows for the investment of the saved economic resources to be invested in more resilient infrastructure to reduce future drought impact risk

(See Sendai Framework for Disaster Risk Reduction 2015-2030)

Drought Monitoring Priorities

- Easily explainable, understood and readily available.
- Objective, quantitative and readily reproducible when new data, model analyses and hindcasts become available.
- Period of record that allows comparisons with experienced drought and known droughts of record.
- At temporal and spatial scales with an accuracy to support decision making.
- Meaningful characterization drought conditions in:
  - Regions with significant wet and dry seasons
  - Well-plumbed systems
  - Irrigated, non-irrigated and natural environments
  - Drought versus trajectory of aridification.
- Represent extreme droughts and their impacts within a background of aridification.
  - Aquifer and groundwater conditions
- Coherent nowcasts of onset, intensity and duration
  - Detection of sudden onset and rapid intensification of flash droughts



Because the probability distribution of fire events (size, severity, or frequency) is changing with climate change, land use and fire suppression effects, landscape and vegetation changes, parameter reference points from historical analyses are unlikely to serve reliably for future predictions. Fire in the 21st century is, and will continue to be, nonstationary.

Littell, J. S., McKenzie, D., Wan, H. Y., & Cushman, S. A. (2018). Climate change and future wildfire in the Western United States: An ecological approach to nonstationarity. Earth's Future, 6(8), 1097–1111. https://doi.org/10.1029/2018EF000878

Non-stationarity of wildfire risk relevant for ten-year forest plans and species succession management. Observed trend in severity and acreage of most extreme fires but as much a confluence of management practices and climate. Big destructive natural fires in 1800s and early 20th century prior to implementation of USFS '10 AM' fire suppression policy from 1935 to 1978.

Tim Brown, Western Regional Climate Center | Desert Research Institute

NOAA Atlas 15

National Precipitation Frequency Update

NOAA's Atlas 15 estimates …

- NOAA Atlas 15 Pilot data was released in 2024 to provide stakeholders with an early first look at the Intensity-Duration-Frequency (IDF) data to collect feedback.
- Pilot methods, data, and website will be refined through 2026 and 2027, when NOAA Atlas 15 will be fully published.
- Information will be developed using seamless spatial analysis with a non-stationarity assumption.
- Information will be presented as two national volumes.

Atlas 15 to be delivered with robust web visualizations and data services.

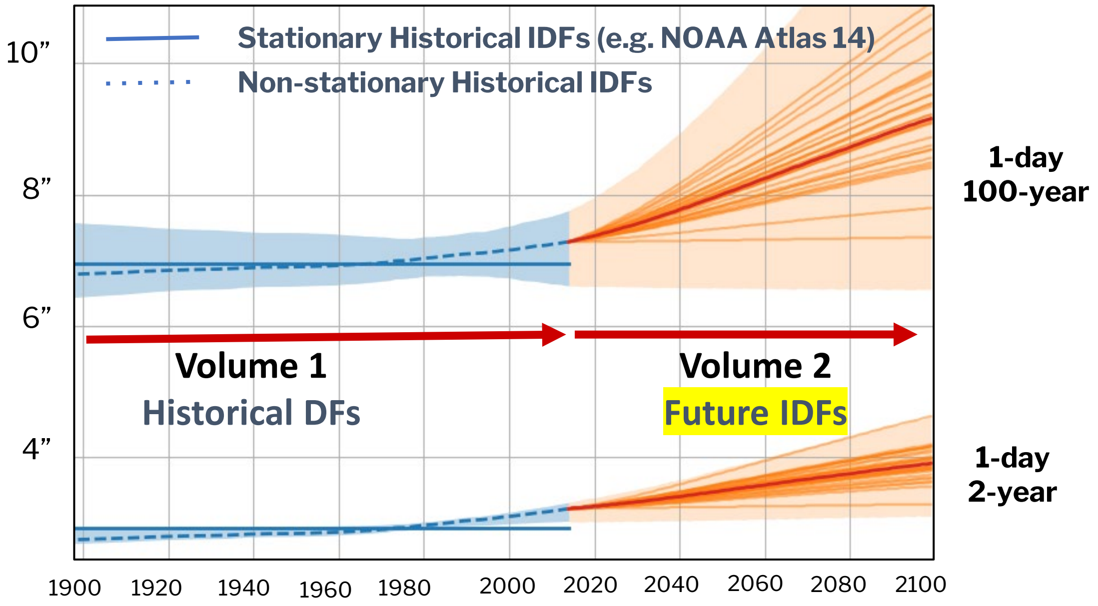
Volume 1: Based on historical gages and observed trends

- Integrated terrain information
- Models trend in historical observations (when it exists) to account for short-term non-stationary temporal changes *(i.e., Present-day risk of extreme rainfall)*

Volume 2: Incorporates long-range projections as adjustment factors

- Future precipitation informed by model outputs, modeled non-stationary temporal changes
- Provides adjustment factors to Volume 1 to calculate future estimates *(i.e., Future risk of extreme rainfall)*

NOAA Atlas 15 Pilot Documentation and Website:
Perica, S., J. Hanrahan, M. Lago, K. Kunkel, and D. Martin, 2024: Atlas 15 Pilot Technical Report. NOAA. National Weather Service, Office of Water Prediction, Silver Spring, MD.
Available at: https://water.noaa.gov/about/atlas15

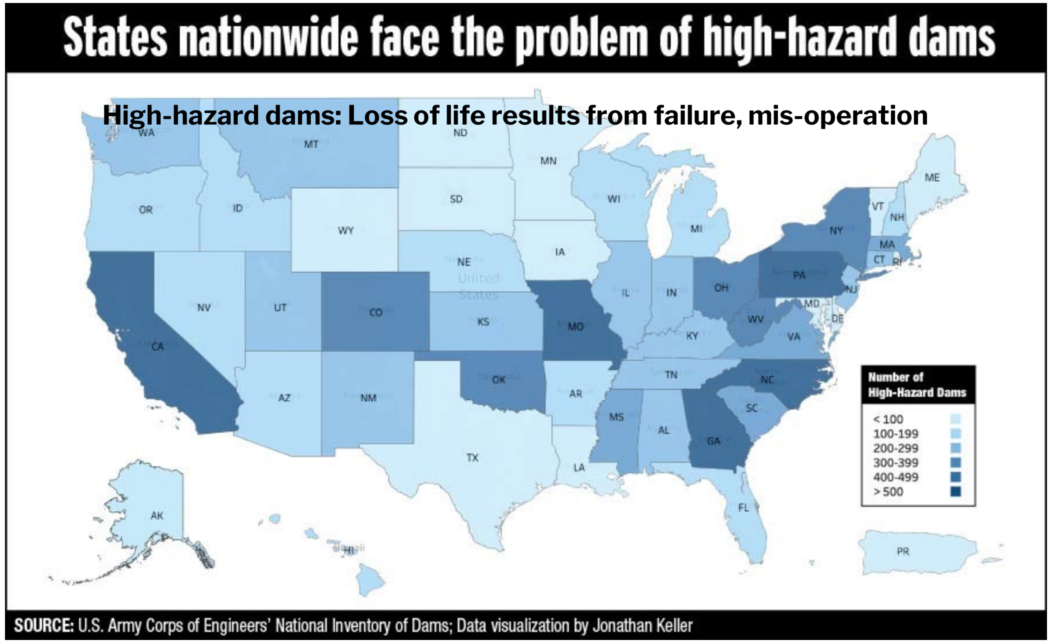


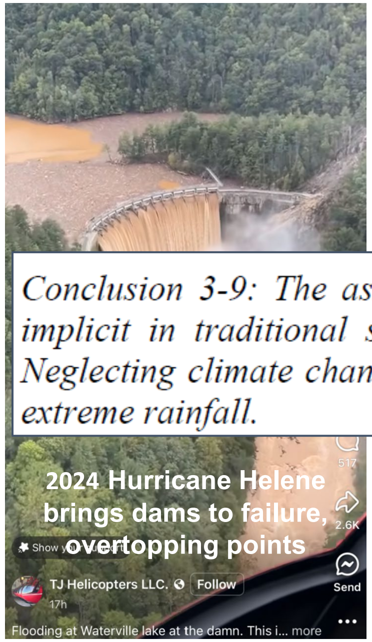
[NOAA Atlas 15 Pilot Technical Report](https://water.noaa.gov/about/atlas15)

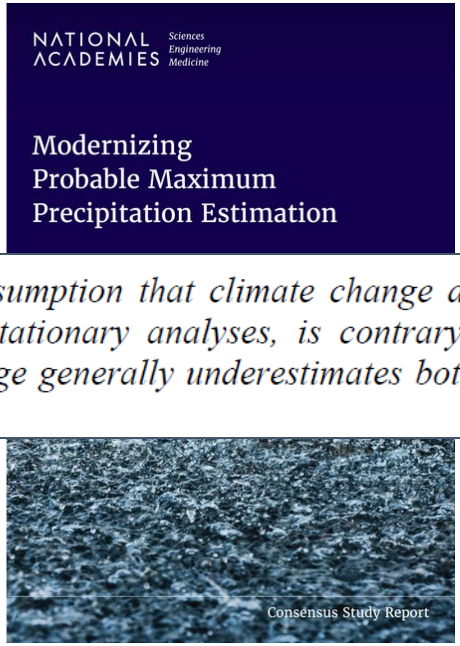
Sandra Pavlovic, NOAA Office of Water Prediction | National Water Center

Modernizing Extreme Precipitation Guidance for High-Risk Infrastructure

Probable Maximum Precipitation (PMP):
Design standard for high-hazard dams, nuclear sites where **failure is not an option**







Conclusion 3-9: The assumption that climate change does not affect extreme rainfall, implicit in traditional stationary analyses, is contrary to multiple lines of evidence. Neglecting climate change generally underestimates both present-day and future risk of extreme rainfall.

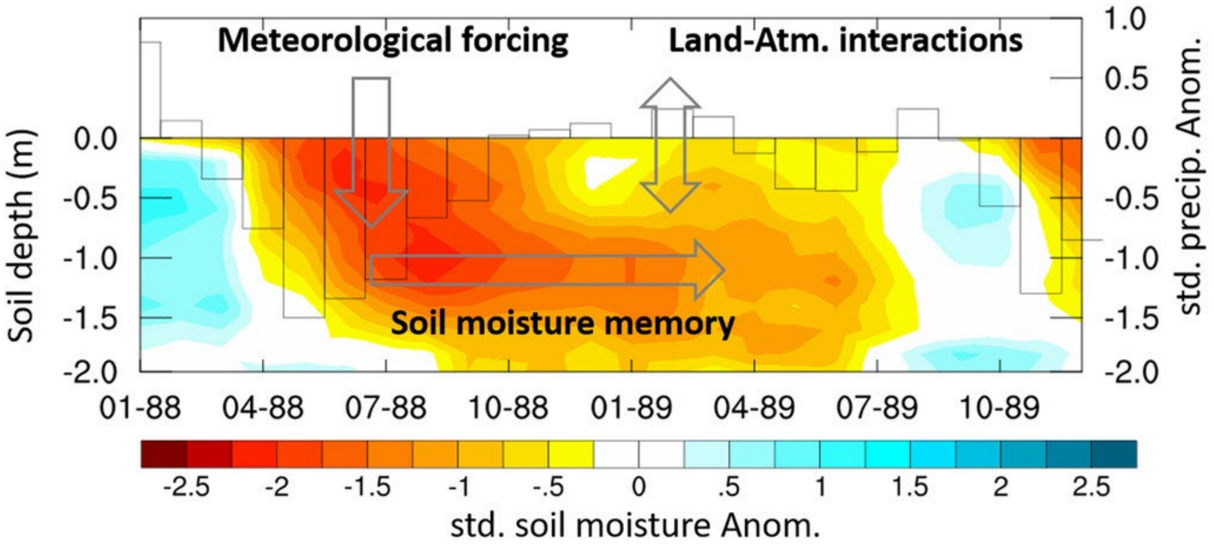
- **PMP is outdated**: 2024 National Academies Study → **community consensus on recommended approach for modernization**
- ***On non-stationarity:***
  - Long-term recommendation: Simulate effects of non-stationarity directly "through multi-model large ensemble kilometer-scale or finer-resolution modeling to construct the probability distribution of precipitation for PMP estimation under different climates"
  - Near-term potential: Historical reanalysis, Clausius-Clapeyron-based adjustment factors

Ultimate deliverable: Federally-endorsed, state-of-the-science-informed design values, including uncertainty estimates and accounting for non-stationarity, for safe infrastructure engineering and operations

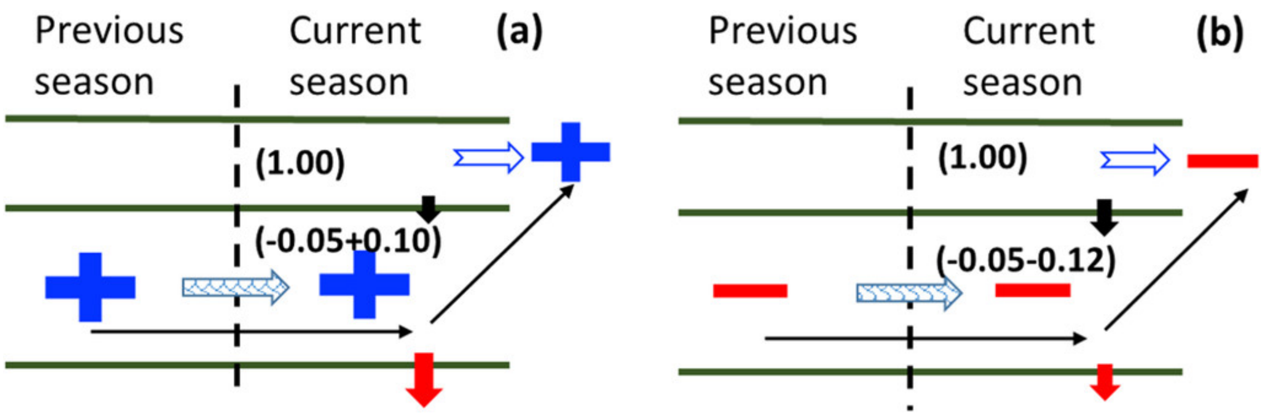
Kelly Mahoney, NOAA Physical Sciences Laboratory

Antecedent Aquifer and Groundwater Conditions

Soil moisture reemergence may enhance interannual-to-decadal variability of droughts



Evolution of Illinois soil moisture standardized anomalies during and after the 1988 drought, averaged over Illinois Climate Network (ICN) observations. Contour interval is 0.25 standard deviation. Also shown are the standardized precipitation anomalies (bars) for each month.



Physics of soil moisture reemergence. Panels depict with anomalous soil moisture conditions and the total soil water potential with anomalous soil moisture in the deep layer and (without loss of generality) climatological conditions in the root zone. (a) A deep layer wet anomaly would lead to a smaller potential gradient between the root zone and the deep layer with a reduced transfer water from root zone to the deep layer, resulting in a wet anomaly developing in the root zone. (b) A deep layer dry anomaly would lead to larger potential gradient between the root zone and the deep layer with an increased transfer water from root zone to the deep layer, resulting in a dry anomaly developing in the root zone.

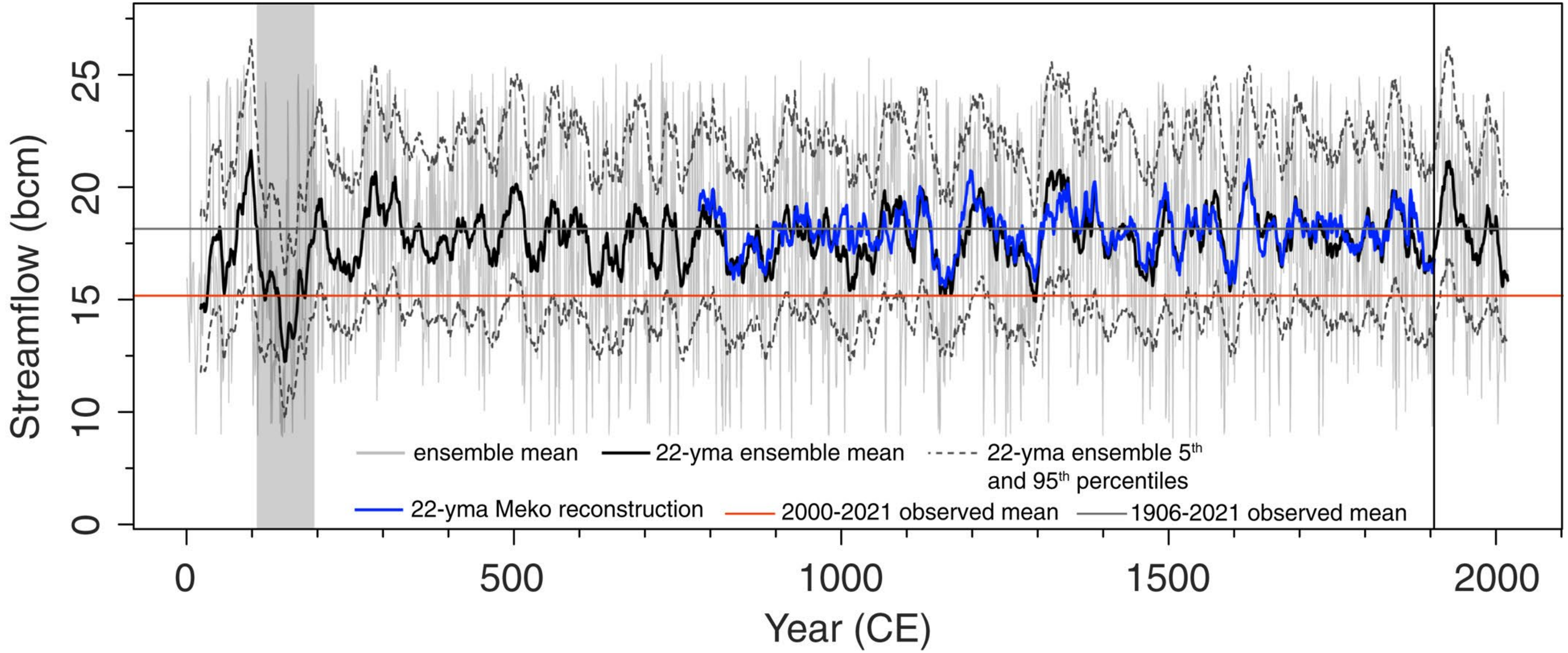
Kumar S, Newman M, Wang Y, Livneh B. Potential Reemergence of Seasonal Soil Moisture Anomalies in North America. ***J. Climate. 2019;32(10):2707-2734. doi:10.1175/JCLI-D-18-0540.1***

Drought Monitoring Opportunities

- Integrating homogeneous operational reanalyses and historic reanalyses.
- Blending of satellite, model and *in situ* observations.
- Leveraging of far-field sea surface and land surface conditions into the monitoring of drought risk.
- Incorporating antecedent aquifer and groundwater conditions to better represent the role of interannual-to-decadal variability and aridification trajectories in amplification of extreme conditions.
- Providing a mechanistic explanation of drying trends to differentiate between multiyear/decadal drought and aridification to support decision making.
- Pursuing a portfolio of approaches tailored for different applications (dryland farming, irrigated farming, water supply, streamflow, navigation, wildland fire risk, ...).
- Adopting impact-based tracking of drought and cascading effects.
- Developing innovative public-private-civil society partnerships.

Thank You

Tree Rings Reveal Unmatched 2nd Century Drought in the Colorado River Basin



Gangopadhyay, S., Woodhouse, C. A., McCabe, G. J., Routson, C. C., & Meko, D. M. (2022). Tree rings reveal unmatched 2nd century drought in the Colorado River Basin. Geophysical Research Letters, 49, e2022GL098781. https://doi.org/10.1029/2022GL098781