IMPROVING DROUGHT INDICATOR PERFORMANCE

Recent research has shown drought metrics are sensitive to climate change and non-stationarity (e.g., Hoylman et al., 2022; Stevenson et al., 2022; Sofia et al., 2023). More specifically, drought metrics and models are very sensitive to the reference period chosen to assess current conditions. Non-stationary drought metrics and models are available and often characterize non-linear trends in meteorological time-series (e.g., Generalized Additive Model in Location, Scale and Shape modeling; Wang et al., 2015; Rashid & Beecham, 2019). These methods attempt to capture changes to the central tendency and variance in the meteorological time series and account for these changes over time. Methods such as these might be preferable, as they can consider past extreme events (e.g., the Dust Bowl) in the characterization of current events, while also leveraging information about more recent climatological conditions. However, there might be some drawbacks to these methods in that some are complex and might not be easily applied to operational drought monitoring systems or might need to be accompanied by effective communications (Cammalleri et al., 2021). In addition to drought metrics that use the full period of record while statistically accounting for non-stationarity, recent research has proposed maintaining the raw dataset but truncating it to only include the most recent past. This framework follows the notion of climate normals as established by the World Meteorological Organization. However, depending on the rate of change at a location, shorter or longer reference periods with annual updates are preferable.

There are other challenges that also impact drought indicator performance to include changes in extreme events, changes to snowpack and melt, as well as understanding drought recovery. This section provides priority actions to work toward more sophisticated approaches to incorporate non-stationarity statistics in drought metrics and assessments. This could include exploring new approaches or modifying existing ones. As more sophisticated approaches are validated and incorporated into drought assessment, the community can consider retiring older methods or metrics that are no longer useful.

Priority Actions:

1. Conduct a Drought Indicator Intercomparison Project to include the creation of a centralized function (e.g., OpenET, World Climate Research Programme Coupled Model Intercomparison Project, Agricultural Model Intercomparison and Improvement Project) for comparing drought metric efficacy in terms of decision-making (e.g., for versions of SPEI calculated differently, such as Thornwaithe or Penman-Monteith or Penman PET equations, or with different periods of reference). Provide guidance on when they should be used, and at what time, location, or in an ensemble. Results could be used to update the WMO Handbook of Drought Indicators and Indices.

2. Develop guidance as to which climate reference periods are most appropriate for various applications, including the drought assessment process. Specific considerations include: across drought indices, for datasets with short periods of record, regional differences, and when comparing multiple indices of various record lengths.
3. Evaluate current monitoring infrastructure to ensure data are available to improve performance of existing and future indicators given non-stationarity.
4. Conduct a literature review and summarize with practitioners the existing knowledge on drought assessment metrics and tools that are sensitive to changing climates and non-stationarity.
5. Distinguish between drought and aridification and develop and operationally adopt distinct environmental indices for these two conditions.
6. Evaluate the performance of current drought indices to account for runoff and infiltration during high intensity precipitation events and consider these findings in drought assessments.
7. Develop or improve drought indicators that realistically handle variability of precipitation at a shorter temporal resolution (e.g., sub-monthly or sub-daily) to account for sporadic, intermittent, or extreme rainfall.
8. Deliberately account for changes in seasonality, intensity, and interannual variability of precipitation in drought assessments.
9. Evaluate methods for improving indicator performance in locations where indicators are complicated by climate change. For example, in Alaska, where drought is not well understood, the warming climate is leading to increases in streamflow and soil moisture due to thawing permafrost and melting glaciers, even during periods of below-normal precipitation.
10. Develop or improve existing drought recovery products that include temperature and other atmospheric measurements, snowpack, shallow groundwater, and other drought metrics, and evaluate their efficacy. Ensure products capture “drought buster” events, the role of non-stationarity, and nuances such as reservoirs or groundwater.

Research Questions:

1. How can observations and models be used and combined to define and quantify non-stationarity?
2. How accurately do current drought metrics capture changes in variability?
3. How can non-stationarity be addressed while adequately sampling the full range of drought variability? What existing or new methods can address non-stationarity?
4. How sensitive are drought metric percentiles to period of record and approach (e.g., moving window, quantile regression approach, general additive model with time, general additive models with time and climate teleconnections) and drought type (i.e., as was done for flooding in Jain & Lall, 2001)?

5. Drought is defined by not only lack of precipitation, but also other indicators (e.g., evaporative demand, vegetation changes), (1) how are these changing over time, and (2) are they reliable indicators for drought? In evaluating the reliability of current indicators or future indicators, consider using impact data in the evaluation methodology.
6. What are the right indicators to track intense precipitation events through time? Would a weighted SPI work? What are other variables (beyond SPI) that would be more informative, whether on their own or in combination with SPI?
7. What methods have been used, and what new methods could be considered to determine the utility and relevance of particular drought indices (e.g., snowpack) in a changing climate?
8. Determine how changing variability affects the indicator-impact relationship in each region through an evaluation of the indicators and how future conditions will impact their uses.
9. What reference frame (e.g., reference period, experience) is most appropriate for describing drought within aridifying and humidifying climates? Does the choice of framing vary with definition of drought, sector, or decision served?
10. Which indicators are useful/valuable to each sector or community in areas experiencing aridification? Are the indicators effective in informing management decisions and adaptation?
11. How are low-frequency, high-intensity precipitation events reflected in variables and drought indices, and how do they impact drought assessment temporally and spatially?
12. How can drought indices better reflect how intensity of an event affects drought conditions? Are there times (and if so, when) current drought indices should be forgone in the event of high-intensity precipitation events because they will not represent the condition on the ground well?
13. What constitutes drought recovery? What are the most appropriate drought metrics and spatial and temporal scales to look at for drought recovery? How do high precipitation events, or series of events (e.g., atmospheric rivers), contribute to recovery?
14. How have drought intensification rates (and recoveries) changed during the past few decades? How could they change in the future based on model projections?
15. Can sector and region-specific user-defined drought indicators be developed, and if efficacious, be incorporated into national drought assessment products?
16. How are drought metrics related to primary productivity in different ecological or agricultural systems? Are there benchmarks that can be associated with suggested actions?

HIGHLIGHT: FLASH DROUGHT

Flash droughts are droughts characterized by unusually rapid intensification (Otkin et al., 2022). There has been a transition toward more flash droughts over 74% of global regions during the past 64 years (Yuan et al., 2023; Christian et al., 2023). Further, this transition is associated with greater evapotranspiration and precipitation deficits caused by anthropogenic climate change and is projected to expand to all land areas in the future. Flash drought increases the complexity of drought monitoring and forecasting, making the priority actions and research questions associated with this phenomenon even more important in our quest to improve drought assessment in a changing climate.

Pictures showing the diverse impacts of flash drought during 2021, including (a) spring wheat in central Montana that did not have enough rain to germinate by 9 Aug, (b) heavily grazed pasture in central Montana on 7 Sep, (c) poor winter wheat heading in southeastern Washington on 21 May, and (d) a grassfire in central South Dakota on 2 Aug. All pictures were obtained from the Condition Monitoring Observer Report for Drought (CMOR-Drought) tool maintained by the National Drought Mitigation Center. Citation: Bulletin of the American Meteorological Society 103, 10; 10.1175/BAMS-D-21-0288.1