





The Future of Drought in the United States Consensus Study

National Academies of Science, Engineering, and Medicine

27 May 2025

Agenda





Introduction - Veva Deheza (NIDIS Executive Director



The Cost of Drought - Joel Lisonbee (NIDIS Drought Information Coordinator)



The Physical Science Context - Andrew Hoell (NOAA Physical Science Laboratory)



The Foundation for the Study and Statement of Task - Britt Parker (NIDIS Senior Program Manager)

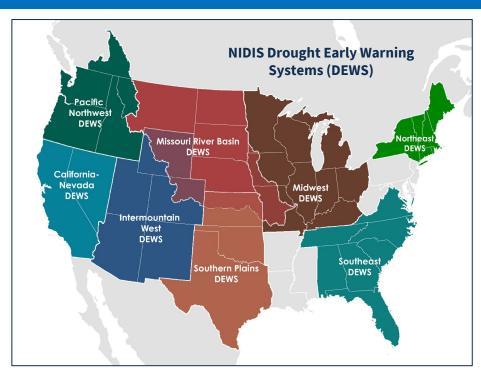
What is the National Integrated Drought Information System (NIDIS)?



NIDIS is a multi-agency partnership with a mission to mitigate the impacts and costs of drought by improving the nation's capacity to proactively manage drought-related risks.

How do we do this work?

- The U.S. Drought Portal: www.drought.gov
- Regional Drought Early Warning Systems
- Improving drought prediction and forecasting
- Collaborate with partners and build state & local drought capacity
 - Supporting drought planning and preparedness
 - Supporting drought impact assessments



NIDIS Public law

NIDIS

"DROUGHT...causes or may cause— (i) substantial economic or social impacts; or (ii) substantial physical damage or injury to individuals, property, or the environment."

Established the National Integrated Drought Information System

To:

"engender better informed and more timely decisions thereby leading to reduced [drought] impacts and costs"

NIDIS is authorized to engage in partnerships with:
 Governments

• Federal. and Agencies

- o State,
- o Tribal,
- o Local,
- o Private sector,
- Academic institutions.
- o Citizen scientists



The Ask of this Committee





- The drought assessment challenge is already upon us, given that droughts differ greatly from one to the next and thus our responses must differ as well.
- We would like specific guidance on how to adjust and improve drought assessments
 - Outcomes from this project must be applied for the benefit of those most impacted by drought, such as farmers, ranchers, water managers, and electricity producers.
- WHY: If we can get drought assessment right, then we can be confident that drought preparations and response actions will be more effective.
- This is a complex ask -
 - Blend physical science, social science and economic science
 - Provide recommendations for improving the mechanics of drought assessment



Thank you to the NASEM,

Thank you to the Committee for tackling this issue.

The Economic and Human Costs of Drought



\$372 Billion

Total Cost of Drought from 1980-2025
3rd highest for all billion dollar disasters

\$11.6 Billion

Average Cost Per Drought Event in the U.S. 2nd highest per event for all billion dollar disasters



Average Fatalities from Drought and Heat Waves Each Year 2nd highest per year for all billion dollar disasters



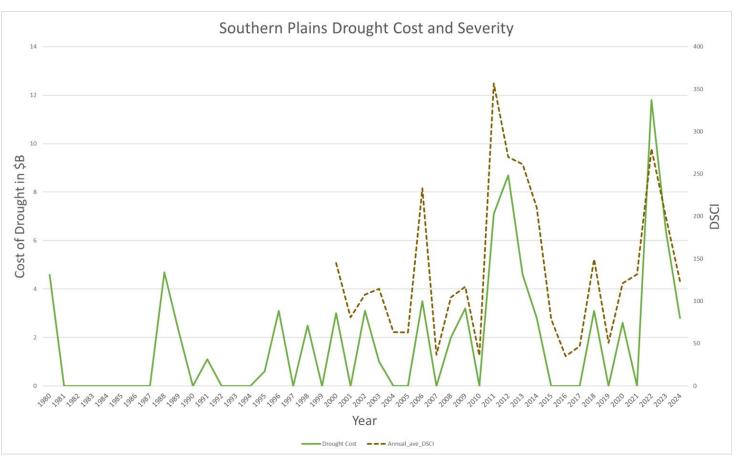






Example: Great Plains—less drought can be more costly

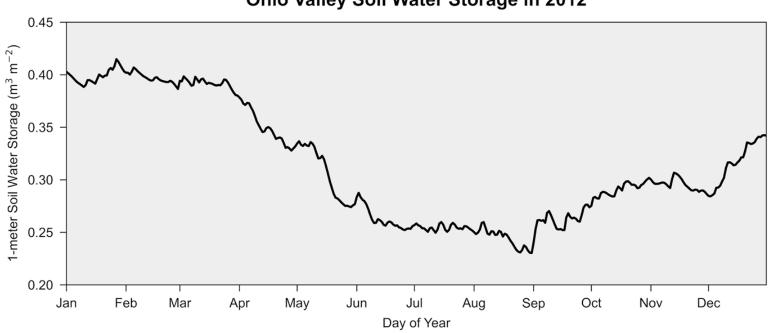




Drought Assessment Requires Context



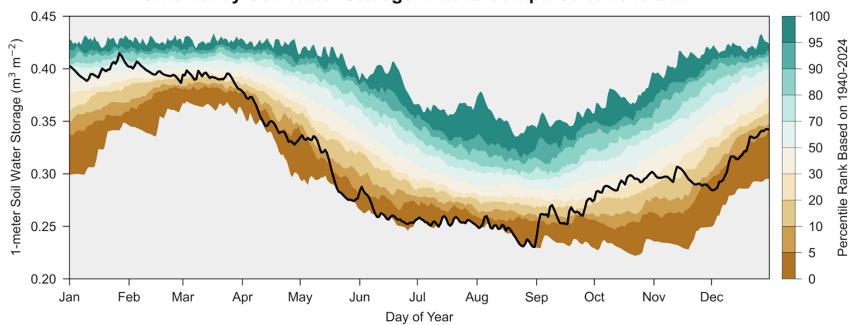
Ohio Valley Soil Water Storage in 2012



Establish Context Using Like Events Composed of Past Years



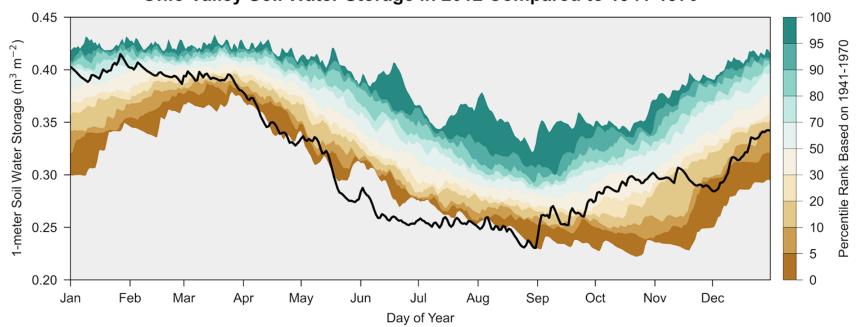




Context Differs Based on the Years Included

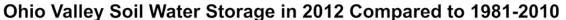


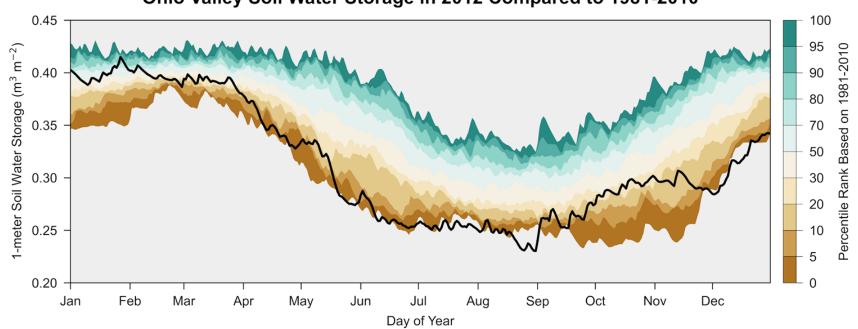




Context Differs Based on the Years Included



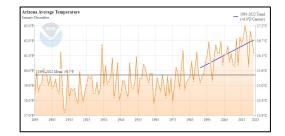




OUESTION

How should drought be assessed?

Should drought be defined using *all available data*, knowing that there are strong trends in the data and the past is not representative of the present?



Should drought be defined using a **shorter modern reference period**, knowing that there have been extreme events in the past that should not be ignored (e.g., the dust bowl)?



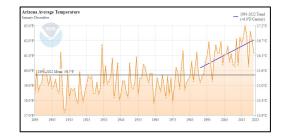
Should drought in the *paleoclimate record* be considered?



QUESTION

How should drought be assessed?

When Should drought be defined using all available data, knowing that there are strong trends in the data and the past is not representative of the present?



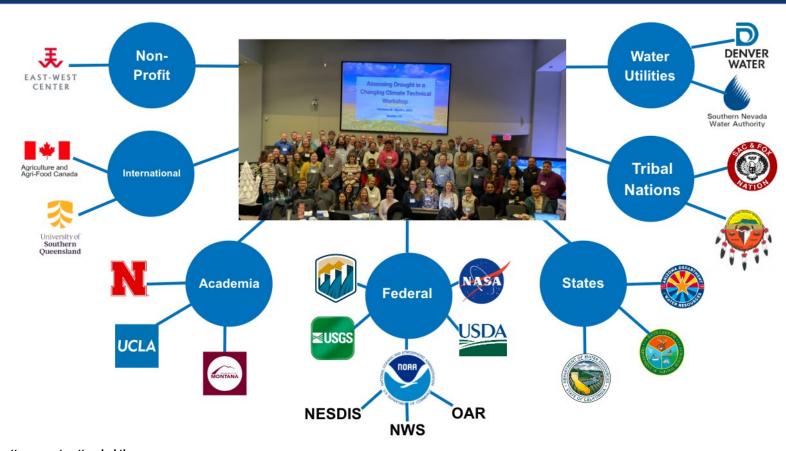
When Should drought be defined using a shorter modern reference period, knowing that there have been extreme events in the past that should not be ignored (e.g., the dust bowl)?



When Should drought in the **paleoclimate record** be considered?

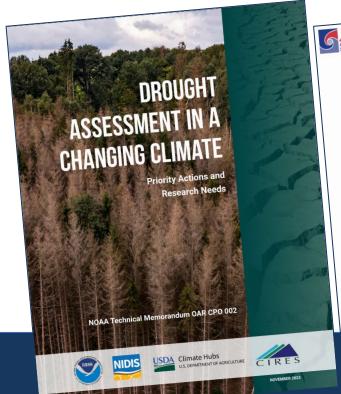


Assessing Drought—Accounting for Non-Stationarity



102 subject matter experts attended the workshop representing 44 institutions.

Foundation for this Study





JOURNAL OF APPLIED AND SERVICE CLIMATOLOGY

Published Online May 30, 2024

Drought Assessment in a Changing Climate: A Review of Climate Normals for Drought Indices

Joel Lisonbee¹, John Nielsen-Gammon², Blair Trewin³, Gretel Follingstad¹, Britt Parker⁴

NOAA/National Integrated Drought Information System, and Cooperative Institute for Research in the Environmental Sciences (CIRES), University of Colorado Boulder, Boulder, Colorado, USA onveronmental sciences (Circos), University of Cotorado Bouloer, Bounder, Colorado, USA.

² Department of Atmospheric Sciences, Texas A&M University, College Station, TX, USA. ³ Australian Bureau of Meteorology, Melbourne, Victoria, Australia 4 NOAA/National Integrated Drought Information System

Corresponding Author: Joel Lisonbee, joel.lisonbee@noaa.gov

Should drought be considered an extreme dry period based on the entire record of available data? Or, should drought be considered a low in precipitation variability within the context of a present, contemnorware surveignt we commerced a sow in preceptation variationly within the context of a present, contemporary climate? The two most common reference periods are the full period of record (all observed data porary cumate; 1 or you mans common reservable persons and one more person of the pers on as more as punsioner and a 242-year renetrance cumumongy, movever, cuman non-stationarmy may render the "all-data" approach an inaccurate or obsolete comparison unless a trend is factored in. The nature the "annuaria" approach an maccurate of october comparison amess a create is aim of this review is to explore the literature for approaches to addressing these issues.

attiti on titus neview is so explore use sineatimete for appressurates to autoressing tituse cassies.

The World Meteorological Organization (WMO) has recommended a 30-year reference period for The World Meteorological Organization (WMO) has recommended a 20-year selection of the most climatological applications since 1935, but for drought assessments and drought indices the modus most cumanotognat apparations since 1772, but for drought assessments and drought instices are mounts operandi has been to use as much data as possible. However, in the literature, the "all data" approach has been challenged by evident impacts from climate change-induced non-stationarity. Over the past nas occis catalengos oy crustent impacts nom cintare crange-massecu non-nanountry. Over the past several years, as potential errors in drought assessments became more apparent due to a stationarily severa years, as potential errors in urought assessments became more opparent use to a nanomatry assumption when applying drought indices, several studies have adopted shorter reference periods, with моживариом можи проугия можеры шанасто, месчая анализы пого внортом нализе техническием реализм, оны 30-years being the most common. Furthermore, several recent papers have recommended using short 20-years term use most common, rutuactioner, several recent papers have recommended using anot reference periods with more frequent data updates for drought assessments to be representative of a conreservace persons with more strengent state updates for groupin assessments to be representative or a con-temporary climate. Additionally, at least 18 non-stationary drought indices have been proposed in efforts to retain long datasets and account for non-stationarity in the climate system.

In 1935 the World Meteorological Organization (WMO) instructed member nations to calculate climate normals using a 30-year period, from 1901 to 1930 (Guttman 1989). For most climatological applications, the 30-year reference period has been the standard. However, for drought, the modus operandi has typically been to include as much data as possible, usually the full period of record. The rationale for this is that a larger dataset reduces the sampling uncertainty and produces a more stable dataset. This is important because drought represents the extremes of climate variability at one tail of the statistical distribution. On the other hand, in regions that experience pronounced trends in the climate system, treating the distant past as "representative" means present or future drought assessments are compared to a very different climate of the past. This issue is especially significant when assessing

long-term drought (over periods of multiple years, sometimes referred to as "megadroughts"), as internal variability will generally be lower over longer periods, and hence long

-term trends will be larger relative to internal variability. Several recent publications have helped frame the issue of drought assessment in a non-stationary climate (Paulo et al. 2016; Wang et al. 2021; Mi et al. 2022; Hoyiman et al. 2022). For example, following their analysis of megadrought and pluvial events in climate projections over the 21st century, Stevenson et al. (2022) point out that "background trends are so large that if traditional stationary definitions are used to identify megadrought or pluvial, in those places where the trend emerges, the entire late 21st century is identified as a single large event" (Stevenson et

These findings shed light on the broader question of how to define drought. The Glossary of Meteorology defines



Earth's Future

RESEARCH ARTICLE 10.1029/2024EF005276

Climate change adds conceptual and

Climate change adds conceptual and quantitative challenges to fraditional drought assessments
 Robucing the tensitivity of drought indicators to non-stationarity is easen-

Gal for accurately assessing future

 Multiple drought definitions or correctly assess drought in a changing

Supporting Information may be found in the online version of this article.

J. Lisenbee.

Lisonbee, J., Parker, B., Fleishman, E., Ford, T. W., Bocinsky, R. K., Fortingsta G., et al. (2025). Prioritization of research O., et H. (2023). Protessional on some on drought assessment in a changing climate. Eursh's Future, 13. e2024EF005276. https://doi.org/10.1029/

wived 10 SEP 2024 Accepted 17 DEC 2024

Author Contributions: Conceptualization: Joet Lisonbee.

Britt Parker Formal analysis: Joet Lisonboe, Tren Methodology: Joet Lisonbee Project administration: Joet Lisonboo.

erm rutter Writing – original druft: Joet Lisonbee. inca Fleishman, Trent W. Ford, R. Kyle Bocinsky, Greet Follingslad, Abby G. Francet, Zachary H. Hoyiman, Amy R. Hudson, John W. Niedom-Gammon, Natalie A. Umphlett, Elliot Wickham

> @ 2025. The Author(s). This is an open access article under the terms of the Creative Commons Aurobation License, which permits use, distribution and reproduction in any medium, provided the original work is property cited.

LISONBEE ET AL







Prioritization of Research on Drought Assessment in a

Joel Liombes¹ ©, Briti Parker² ©, Frica Fleishmun², Trent W, Fred² ©, R. Kyle Rocinsky³ ©, Greta Fleishmun², Amy K. Hudson³, Greta Fellimental⁴, Alaby C, Friedre ⁶, Zachary H, Huyhmun² ©, Amy K. Hudson³, Greta Fleishmun², Greta Fleishmun², Greta Fleishmun², Greta Fleishmun³, Andrew Hoell: , Jacob Jones , f.rm Lane , Lacuary Leasor , Yongquat.

Jason A. Otkin , Amanda Sheffield , Dennis Todey , and Roger Pulwarty , and Roger Pulwarty .

³Cooperative Institute for Research in the Environmental Sciences (CIRES), University of Colorado Boulder, and NOAA Cooperative frasture for Research in the histocommental Sciences (CIMSS), University of Coorado founder, and VOAA/
National Integrated Drought Information System, Boulder, CO, USA, NOAA National Integrated Drought Information National Integrated Drought Internation System, Bondor, CO, USA, 'NOAA National Integrated Drought internation System, Bondor, CO, USA, 'College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, OR, System, Boulder, CO, USA, "College of Karth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, UUSA, "Itimois State Water Survey, Prairie Research Institute, University of Illinois, Champaign, IL, USA, "Montana. U2A, "Immus State Water Survey, Praine Research Institute, University of Immon, Champuge, it., U2A, "Shouland Climate Office, W.A. Franke College of Forestry and Conservation, University of Mediana, Miscoula, MT, USA, "Clark Commercement, W.A., Franke Cutego or recently and Conservation, University of Montana, Miscotha, MT, USA, "Claid University, Graduate School of Geography, Worcester, MA, USA," USENA-ARS, Creiter for Grain and Animal Health University, Catalante Schoul of Geography, Worcester, MA, USA, 'USDA-ARS, Center for Grain and Animal Health Research, Manhattan, KS, USA, 'Department of Atmospheric Sciences, Texas A&M University, College Station, TX, Research, Manhattan, K.S., USA, "Department of Atmospheric Sciences, Texas AdsM University, Codings Station, T.K.
USA, "Northeast Regional Climate Center, Certedl University, thirea, NY, USA, "South Carolina Department of Natural USA, Northeast Regional Climate Center, Cornell University, Ithics, NY, USA, "South Carolina Department of No. Resources. S.C. State Climatology Office, Columbia, SC, USA, "U.S. Geological Survey, North Central Climate. RESSURCES - S.C. SLAW Climatology Office, Columbia, N.C. USA, "U.S. Ceological Nervey, North Central Climate
Adaptation Science Center, Boulder, CO, USA, "NOAANWS National Water Center, Fascalossa, A.L. USA, "National
Action of Center, Control of Center, Contr Auspulson Science Center, noutour, C.J. (DA., NUAANWS Aussinst water Center, Inscansis, As., U.S., "Patient, Deought Miligation Center, University of Nebruska Lincoln, Lincoln, NE, USA, "U.S. Geological Survey, Maryland-Drough Miligition Center, University of Nederaka-Lincoln, Lincoln, NE, USA, "U.S. Geological Survey, Maryland-Delaware-D.C. Water Science Center, Cadamsville, MD, USA, "USDA-ARS Range Management Research Unit, Jornala Delaware-D.C. Water Science Center, Canonivine, M.D., UNA, "UNAN-ANA studge Management accurant units, sometime Experimental Range, Las Cruces, NM, USA, "Cooperative Institute for Research in the Environmental Sciences (CIRES). Experimental Mange, Las Cruces, Nah, Liba, "Cooperative transmate on Measures in the Instrumental Sciences (Linfo), University of Colorado Boolder, and NOAAPBysical Sciences Laboratory, Boulder, CQ, USA, "NOAA Physical Sciences Laboratory, Boulder, CQ, USA," University of Colorado Boulder, and NOAA/Physical Sciences Laboratory, Boulder, CO, USA, "NOAA Physical Sciences Laboratory, Boulder, CO, USA, "NUSDA Forest Service, Northern Laboratory, Boulder, CO, USA, "University of California, Lus Angeles, CA, USA, "USDA Forest Service, Northern LEDOTHIOTY, BUSINESS, C.U., U.S.A., "University of Latinerius, Los Anginos, L.A., U.S.A., "GALIA Ferent Service, Northern Research Station, Madison, W.I., U.S.A., "Missouri Climate Center, University of Missouri, Columbia, MO, U.S.A., "I Center Research Station, Madison, WI, USA, "Missouri Climate Center, University of Missouri, Columbia, MO, USA, "Center Ferrest Disturbance Science, USDA Forest Service, Washington, DC, USA, "Space Science and Engineering Cent for Ferest Distarbance Science, USDA Ferest Service, Washington, UK.; USA, "Space Science and Imagineering Compensive Institute for Meteorological Satellite Studies, University of Wiscomin-Madison, Madison, Wt, USA, ²²USDA. Cooperative Institute for Meteorological Saletitle Studies, University of Wascontin-Madison, Madison, Wi, USA, Midwest Climate Hub USDA-ARS National Laboratory for Agriculture and the Environment, Ames, Li, USA

Abstract Drought is a period of abnormally dry weather that leads to hydrological imbalance. Drought ADSITACE. Livought is a period of amormatly dry weather than means so nyurosogical amonance. Livought assessments determine the characteristics, severity, and impacts of a drought. Climate change adds conceptual assessments determine the characteristics, severity, and impacts or a drought. Climate craining asso conceptual and quantitative challenges to traditional drought assessments. This paper highlights the challenges of assessing. and quantitative challenges to traditional drought assessments. This paper reginingms are crassenges or assessing drought in a climate made non-stationary by human activities or natural variability. To address these challenges, erought in a cumate more non-stationary by numan activities or natural variations, 10 address those cuations, we then identify 10 key research priorities for advancing drought science and improving assessments in a we taken identify to key research priorities for survaining utwights science and amproving associations is changing climate. The priorities focus on improving drought indicators to account for non-stationarity, exanging cuttum. The priorities tocus on improving urough mucinors to account or non-stationarity, evaluating drought impacts and their trends, addressing regional differences in non-stationarity, determining the evaluating urough impaces and until trents, nearresting regional utrevence in non-mansorany, sententialing the physical drivers of drought and how they are changing, capturing precipitation variability, and understanding puysical drivers or orought and now takey are changing, capturing procipitation variationsy, and anticertainstit the drivers of aridification. Ultimately, improved drought assessments will inform better risk management, une curvers or ariuntection. Cummatery, amprovou drought assessments with attention better too management, adaptation strategies, and planning, especially in areas where climate change significantly afters drought. asapusation networks, and passiming, especially in areas where curious engine organization anech unsigns dynamics. This perspective offers a path toward more accurate and effective drought management in a non-

Plain Language Summary Drought is a period of abnormally dry weather that impacts water PIAMI LANGUAGE SUMMATY OROUGH is a period or annormally any weather that impacts water availability. Drought is commonly assented to determine how abnormal it is, how severe its impacts are, or availability. Drouget is commonly assessed to determine now annormal it is, how severe its impacts to both. Climate change complicates traditional drought assessments. For example, some climates are soon. Common country companions stransform through accomment, for example, some contains are becoming drier, making it more defficult to discern when a drought begins or ends. This paper highlights the challenges of assessing drought in a changing climate. It also identifies 10 key research priorities for use canadrogos un assessing acoupte no a coanging circume, it and medium to key research promise to advancing drought science and improving drought assessments in response to these challenges. These arvancing groups, science and improving groups, assessments in response to these chainings, none priorities include improving drought indicators to account for climate change, evaluating treads in drought. PERSTRUCTS increase improving arrought indicators to account for crimate cruning; evanuating crease in diverger, impacts; acknowledging that the climate isn't changing in the same way or at the same rate everywhere, so imputes, acanowrongous una une common une community in use some way of as use some rate years, as drought assessments must address regional differences; determining how the underlying causes of drought urungm assessments man anatron regional universities; determining now tre undersying causes or drough, are changing; exploring how changing precipitation characteristics, such as storm intensity and duration, are cassingue, exposuring new cassinging procephianou casacteristics, such as normal intensity and curration, impact drought; and better distinguishing drought in climates that are trending drive or wester. We hope this

Statement of Task



The study will:

- Discuss the drought-to-aridification continuum and differentiate among drought, multidecadal drought, and aridification. How do factors such as periods of record, drought type, regionality, and seasonality affect these classifications? How do current periods of record affect drought outlooks and predictions?

 Month
 Season
 Decade
 Drought
- Evaluate data sources currently used for drought assessment. What data will be needed to address non-stationarity? What methodologies can be used to improve future drought assessment, taking into account non-stationarity?
- Discuss metrics and indicators used in drought assessment and identify opportunities to inform decision making, including increasing integration of non-stationarity and incorporating uncertainty and/or confidence.
- Review existing and emerging approaches, both nationally and globally, for incorporating non-stationarity in drought
 assessment. Contrast these approaches with those of other natural hazard assessments. Are there best practices that can
 be applied to drought management? Are some approaches more appropriate for specific regions and/or time periods?

The committee will: Recommend a framework for incorporating non-stationarity considerations into drought assessment, for use across a range of geographic regions and of spatial and temporal scales.



Audience for this Work



The study will inform:

- public- and private-sector entities charged with assessing drought
- decision makers and policy makers who rely on accurate drought assessments for water and natural resources management and risk reduction ahead of and during times of low water availability
- information providers who may need to adjust products and tools based on recommendations. This would ensure that the necessary science, data, and metrics needed are available to inform sound decisions.
- NOAA/NIDIS and other federal agencies who are involved in drought assessment or make decisions based on drought assessment

