ON THE WEB

The Tree-Ring Drought Atlas Portal

Gridded Drought Reconstructions for the Past 500–2,000 Years

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Various web portals exist for monitoring droughts and prolonged wet periods (pluvials) in the modern instrumental record such as the National Integrated Drought Information System (<https://drought.gov/>), the U.S. Drought Monitor (<https://droughtmonitor.unl.edu/>), the Drought Risk Atlas (<https://droughtatlas.unl.edu/>), the West Wide Drought Tracker (<https://wrcc.dri.edu/wwdt/>), and the KNMI Climate Explorer (<http://climexp.knmi.nl>). Placing these dry and wet periods into a longer-term context can be a challenge and paleoclimate datasets, such as gridded drought reconstructions from tree rings, could help fill this gap. However, while some of these reconstructions can be found on the web (e.g., KNMI Climate Explorer), there is not a single, user-friendly web tool for all of them. Recently, web tools were developed as part of a research project that created two gridded tree-ring reconstructions—1) the Mexican Drought Atlas (Stahle et al. 2016), a gridded reconstruction of the summer (June–August) Palmer drought severity index (PDSI) centered over Mexico, and 2) the North American Seasonal Precipitation Atlas (NASPA; Stahle et al. 2020), gridded reconstructions of cool (December–April) and warm (May–July) season total precipitation and standardized precipitation indices (SPI) over North America. The suite of web tools has been expanded to include other gridded tree-ring reconstructions of PDSI including the Eastern Australia and New Zealand (Palmer et al. 2015), European Russia (Cook et al. 2020), Monsoon Asia (Cook et al. 2010a), North American (NADA; Cook et al. 2010b), Old World (Cook et al. 2015), and South American Drought Atlases (Morales et al. 2020). This “Tree-Ring Drought Atlas Portal” is located at <http://drought.memphis.edu/> and facilitates analysis of all these gridded reconstructions. These web applications

allow students and scientists across multiple disciplines to assess the long-term history of droughts and pluvials over their regions of interest.

Drought atlas development

Development of these drought atlases has evolved over time, and each drought atlas web application includes a link to the associated article in the literature that describes the development of the selected drought atlas and a direct link to the complete dataset provided by NOAA Paleoclimatology (<https://www.ncsl.noaa.gov/products/paleoclimatology>). All articles are presented in the “For further reading” section below. Succinctly, each gridded drought atlas was developed via a method known as point-by-point principal components regression, where tree-ring chronologies with 1) a significant correlation and 2) within a specific radius of each grid point were selected and calibrated or trained on the instrumental data. A portion of the instrumental record was withheld from this training process and used to verify the reconstruction. Calibration and verification statistics were produced and assessed for evidence of statistical skill. In the case of the NASPA, weak calibration and verification statistics over certain regions were observed due to the paucity of tree-ring chronologies with a significant signal. Therefore, the NASPA web tools mask reconstructed grid points by default if the leave-one-out cross-validation reduction of error statistic (CVRE) is less than 0.2 (Stahle et al. 2020). Users of the NASPA web tools can adjust the CVRE value or even turn the feature off, which could be helpful to examine the sensitivity of drought and pluvial events to any reconstructed grid points of poorer quality.

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Investigating instrumental and reconstructed data using the map tools

Each drought atlas includes instrumental data, so users can assess the instrumental and reconstructed data during the periods of overlap. This allows the reconstructions to be visually examined to evaluate how well they reproduce known extremes in the instrumental record. An example from the 1930s Dust Bowl is presented in Figs. 1a and 1b, which show composite maps of the instrumental and reconstructed data, respectively, and suggest the NADA does have skill in reproducing the spatial footprint of the Dust Bowl. Calibration and verification statistics vary across North America, which impacts the ability of the tree rings to capture some of the finer-scale details. Nonetheless, broad spatial patterns are reproduced well. Another map tool available is correlation, which can be used to assess the response of an instrumental or reconstructed variable to forcing such as El Niño–Southern Oscillation (ENSO). Figures 1c and 1d map significant correlations ($p < 0.05$) between the extended multivariate ENSO index (MEI; Wolter and Timlin 2011) and the instrumental and reconstructed cool season SPI and suggest the NASPA has skill in reproducing the cool season moisture

response from ENSO over North America. Thus, it is not only quantitative measures of statistical skill but also the examination of spatial patterns between the instrumental and reconstructed data that lends credibility to the reconstructions in each drought atlas. Note also that the NADA and NASPA maps in Fig. 1 were forced to the same latitude and longitude region. This can be done in all mapping tools by either specifying latitude and longitude coordinates or by using the included interactive map to select a specific region to map (see the next section). All map tools allow the user to download the generated map as an image file (.png), an encapsulated postscript file (.eps) that can be used to further edit the map in other vector graphics programs like Adobe Illustrator, and a GeoTIFF file (.tif) that can be imported into Geographic Information System software. Complete details on each map tool, available options, and output can be found within the help system.

Using the time series tools to place the Dust Bowl drought into perspective

Each drought atlas contains a time series tool that allows users to extract a single grid point or an average of multiple grid points. Like the map tools, specific latitude and

FIG. 1. Comparison between (left) instrumental and (right) reconstructed data can give confidence in the skill of the tree-ring reconstructions. (a) instrumental and (b) NADA-reconstructed summer (June–August) PDSI data are composited during the Dust Bowl from 1930 to 1939. Significant correlations ($p < 0.05$) between the extended MEI and (c) the instrumental and (d) the NASPA-reconstructed cool season (December–April) SPI are mapped from 1892 to 2005. Note that the reconstructions capture broad spatial patterns shown in the instrumental data.

longitude coordinates can be specified or the interactive map can be used. In this example, the interactive map was used to select and average all reconstructed NASPA grid points for the state of Kansas into a time series to place the 1930s Dust Bowl into a paleoclimate perspective (Fig. 2). The extracted cool and warm season SPI from AD 1500 to 2016 are shown in Fig. 3. One of the most severe droughts in the past 500 years occurred in the middle nineteenth century (Herweijer et al. 2006), and an assessment of the numerical .txt file that can be downloaded after any time series is generated, reveals most individual years from

Latitude Region: °N
 Top = Northernmost (Max = 54.75)
 Bottom = Southernmost (Min = 15.25)

Longitude Region: °W °W
 Left = Westernmost (Max = 132.75)
 Right = Easternmost (Min = 58.25)

Use Google Map to Select the Region?

If yes, move and resize the box to select a specific latitude/longitude region. Latitude/longitude coordinates in the boxes above will change automatically.

FIG. 2. Screenshot of the latitude and longitude options available to users of the web applications. Note that latitude and longitude regions may be either manually entered or interactively selected using a map. The online help system details the different options available to the user.

FIG. 3. Extracted NASPA (a) cool and (b) warm season reconstructed SPI for the Kansas region from AD 1500–2016. Annual SPI values are in red and are smoothed with a 10-yr cubic smoothing spline in black to highlight decadal-scale variation. The cubic smoothing spline is customizable. See the help system for further details.

1845 to 1865 have SPI values of less than zero, especially during the cool season. Moreover, the smoothed data are less than zero for the entire 21-yr period in both cool and warm seasons (i.e., over Kansas, this drought was about twice as long as the Dust Bowl). However, note that lower SPI values are reconstructed for the mid-nineteenth century drought during the cool season than the warm season (Fig. 3a vs Fig. 3b, respectively). This is opposite of the Dust Bowl, which seems to have been more intense during the warmer months. A similar result was found in Burnette and Stahle (2013) using early instrumental data from the area. Figure 3 also shows other droughts in both the cool and warm seasons with individual years exceeding the worst years of the Dust Bowl, especially during the cool season, while the Dust Bowl ranks as one of the most persistently dry anomalies during the warm season. Drought similarity can also be assessed spatially by using the extraction tools to compute a drought area index (e.g., Cook et al. 2004) or by using the congruence and correlation time series tools, which compute an index of similarity between a composite map of a multiyear event and maps of the same area for a selected range of years (not shown). Complete details on each time series tool, available options, and output can be found within the help system.

What is next?

Development of these web tools continues. A hardware upgrade is forthcoming as are code improvements that will allow the web tools to render well on a variety of devices. There is also interest in making these drought atlases more “living,” so droughts in real time can be placed into a longer-term paleoclimate perspective. However, differences between the version of the instrumental dataset used for reconstruction and the most recent version of that dataset complicate this process requiring careful implementation of such capabilities. Additional drought atlases are also being developed and will be added to the portal as they are published. Moreover, there are other valuable tree-ring reconstructions such as streamflow that are candidates for future additions (e.g., Fleming and Sauchyn 2013; Ho et al. 2017).

Tree-ring reconstructed drought atlases have been available for some time from NOAA Paleoclimatology. However, the format of these data made them difficult to use by a wider group of students and researchers in the atmospheric, environmental, and social sciences. This “Tree-Ring Drought Atlas Portal” allows easier access to these reconstructions that provide an important paleoclimate context on drought and pluvials over the past 500 to 2,000 years.

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