



DROUGHTVIEW : SATELLITE-BASED DROUGHT MONITORING AND ASSESSMENT

Jeremy Weiss and Michael Crimmins

Remotely sensed data are valuable for monitoring, assessing, and managing impacts to arid and semi-arid lands caused by drought or other changes in the natural environment. With this in mind, we collaborated with scientists and technologists to redevelop [DroughtView](#), a web-based decision-support tool that combines satellite-derived measures of surface greenness with additional geospatial data so that users can visualize and evaluate vegetation dynamics across space and over time. To date, users of DroughtView have been local drought impact groups, ranchers, federal and state land management staff, environmental scientists, and plant geographers. Potential new applications may include helping to track wildland fire danger. Here, we present the functionality of DroughtView, including new capabilities to report drought impacts and share map information, as well as the data behind it.

How to Use DroughtView

The redeveloped DroughtView is designed for both computers and mobile devices, and now allows a user – whether in the office or the field – several ways in which to utilize remotely sensed and several other geospatial datasets for monitoring and assessing the response of vegetation to weather events like drought. For example, periods of time with below-average precipitation can cause ecological drought, when a lack of rain or snow leads to reduced growth or death of vegetation in natural systems. Remotely sensed data can depict such events that reduce forage in rangelands and subsequently impact ranching activities. Aspects of navigating the map-based interface of DroughtView and working with its new suite of tools are described below.

Navigation

When DroughtView initially loads, two map windows appear side by side showing ‘Actual’ (left window) and ‘Difference from Average’ (right window) surface greenness data along with an overlay of national and state boundaries and places (Figure 1; these and other data layers are further described in the following subsection, ‘Functionality’). Both map windows are centered on the state of Arizona. To change the zoom level, use the ‘plus’ and ‘minus’ buttons in the upper left of the screen, the scroll wheel on or a double-click of a mouse (desktop computer), or a two-finger pinch motion (mobile device) in either of the two map windows. To move the image in a cardinal direction, click and drag with a mouse or swipe with a finger. Below the ‘plus’ and ‘minus’ zoom buttons is a location button that pinpoints your

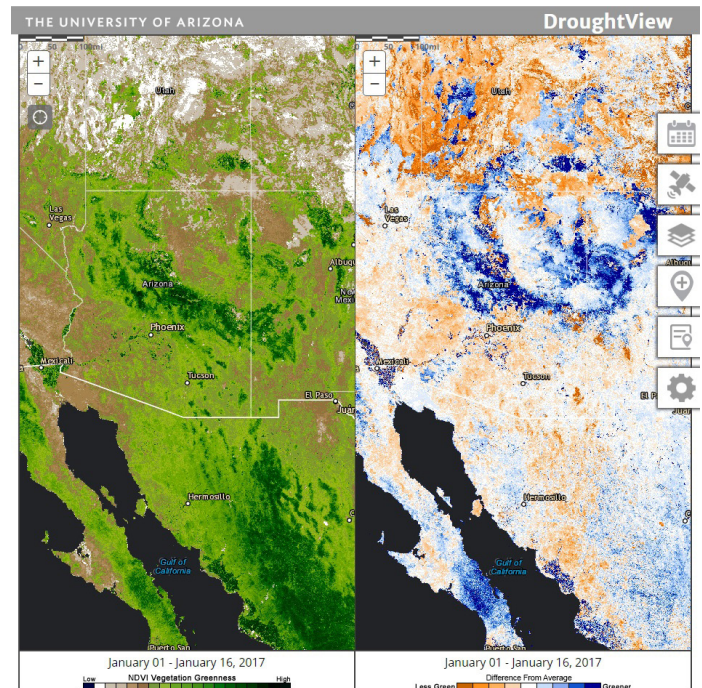


Figure 1. To facilitate comparison, DroughtView displays remotely sensed and other geospatial data in two adjacent map windows. Map navigation tools are located in the upper left of each window, whereas tools for functionality are along the right side of the web-based interface.

location on the map (for GPS-enabled devices). A scale bar is located at the top left of each map window.

Functionality

There are six different icons along the right side of the DroughtView interface (Figure 1). Clicking on these icons accesses the following tools, in order from top to bottom.

SELECT DATE(S) With this calendar-based panel, select a biweekly composite time period (defined in the following section, ‘Understand the Data behind DroughtView’) using either the ‘previous’ or ‘next’ buttons, or by selecting an individual date (Figure 2). Click on the single ‘greater than’ or ‘less than’ sign buttons to move to previous or subsequent months, and the double ‘greater than’ or ‘less than’ sign buttons to move to previous or subsequent years. The play button slowly animates surface greenness and precipitation data when they are selected to appear in the map windows, chronologically showing

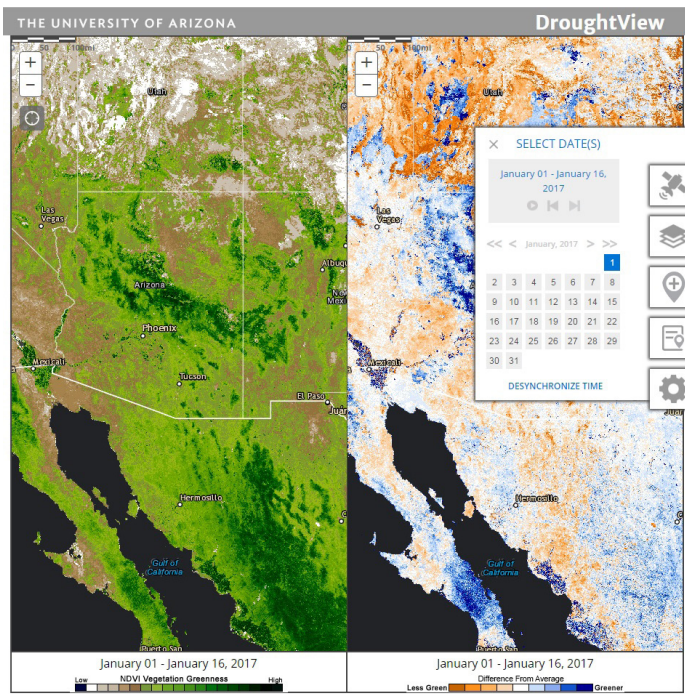


Figure 2. The SELECT DATE(S) tool panel allows users to choose the time period of surface greenness and precipitation data that date back to 2001. Buttons for animating data based on biweekly composite periods, moving back to a previous period, and moving forward to a subsequent period are located below the text that denotes the period set for the map windows, which is 'January 01 - January 16, 2017' in this figure.

data from different biweekly composite periods. At the bottom of this panel is a time synchronization option. The default setting is for both map windows to display time-varying data for the same biweekly composite period. Click on 'DESYNCHRONIZE TIME' to select different biweekly composite periods for the 'LEFT' and 'RIGHT' map windows using the options previously described.

BASE LAYERS Options in this panel determine the base layer data shown in the 'LEFT' and 'RIGHT' map windows (Figure 3). Choose from multiple datasets including remotely sensed measures of surface greenness based on the Normalized Difference Vegetation Index (Greenness - NDVI) and Enhanced Vegetation Index (Greenness - EVI), cloud and snow masks for these remotely sensed data (Data Quality), precipitation totals for corresponding biweekly composite periods (Precipitation), high-resolution aerial imagery (Aerial Map), a topographic map (Topo Map), and a general base map (None). Details regarding NDVI, EVI, data quality, and precipitation base layers are in the following section, 'Understand the Data behind DroughtView'. Map keys that explain symbology for NDVI, EVI, data quality, and precipitation base layers appear at the bottom of the map windows when these data are displayed. There are four different products for the NDVI and EVI base layers available in the corresponding drop-down menus. Select 'Actual' to display surface greenness values, 'Difference from Average' to show how surface greenness data compare to 2001-2012 average values of the same biweekly composite period, 'Difference from Period' to display how surface greenness data compare to values of the previous biweekly composite period, or 'Difference from Year' to show how surface greenness data compare to values of the same biweekly composite period from the previous year. At the bottom

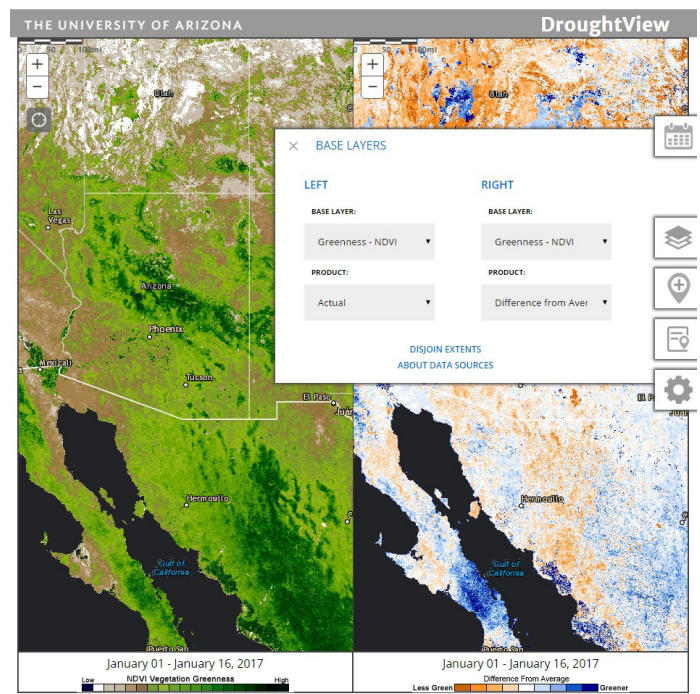


Figure 3. With the BASE LAYERS tool panel, users select information to display in both map windows. Options include remotely sensed data, precipitation data, aerial imagery, a topographic map, and a general base map. Details regarding these base layers are in the following section, 'Understand the Data behind DroughtView'.

of this panel is a spatial extent, or area, join option. The default setting is for both map windows to show the same spatial extent. Click on 'DISJOIN EXTENTS' to be able to display different areas in the map windows. Similarly, click on 'ABOUT DATA SOURCES' at the bottom of this panel to see details regarding NDVI, EVI, data quality, and precipitation base layers.

OVERLAYS Using the options in this panel, add data layers to both of the map windows to provide spatial reference and context (Figure 4). Select from 'BOUNDARIES AND PLACES', which is shown by default, 'ROADS', 'GRAZING ALLOTMENTS', 'FEDERAL/TRIBAL LANDS', 'CURRENT USDM', 'CURRENT YEAR FIRES', 'HISTORICAL FIRES', and 'WATERSHEDS'. Details regarding these overlays are in the following section, 'Understand the Data behind DroughtView'. Multiple overlay layers can be displayed at the same time. Click on 'ABOUT DATA SOURCES' at the bottom of this panel to see details regarding the overlay layers.

ADD POINT TO MAP With this panel, there are three different ways to place a point on a map window and facilitate the reporting of drought impacts (Figure 5). Enter latitude and longitude (format example: 32.5, -110.9) or an address in the corresponding text box, or click on 'MANUALLY PLACE POINT', which allows a cursor click (desktop computer) or finger tap (mobile device) at a desired location on a map window to add a point. Subsequently clicking on the added point displays a dialogue box that shows the latitude and longitude of the point along with a link that brings up a Drought Impact Survey. In this survey, select an impact category (described in REPORTED IMPACTS below), enter an email address for contacting, add a brief impact description, set an observation date, and add attachments such as

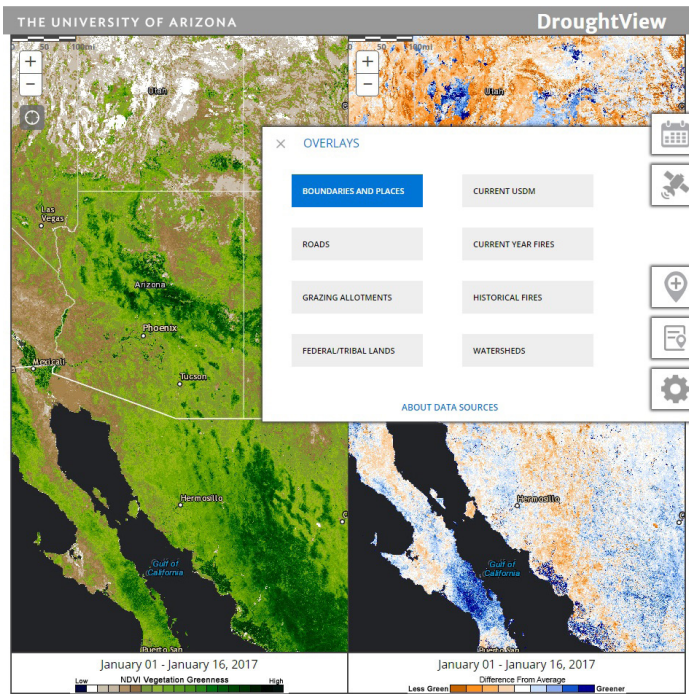


Figure 4. Users can display additional geospatial information in both map windows by choosing from several options in the OVERLAYS tool panel that range from land management boundaries to designated drought areas. Details regarding these datasets are in the following section, 'Understand the Data behind DroughtView'.

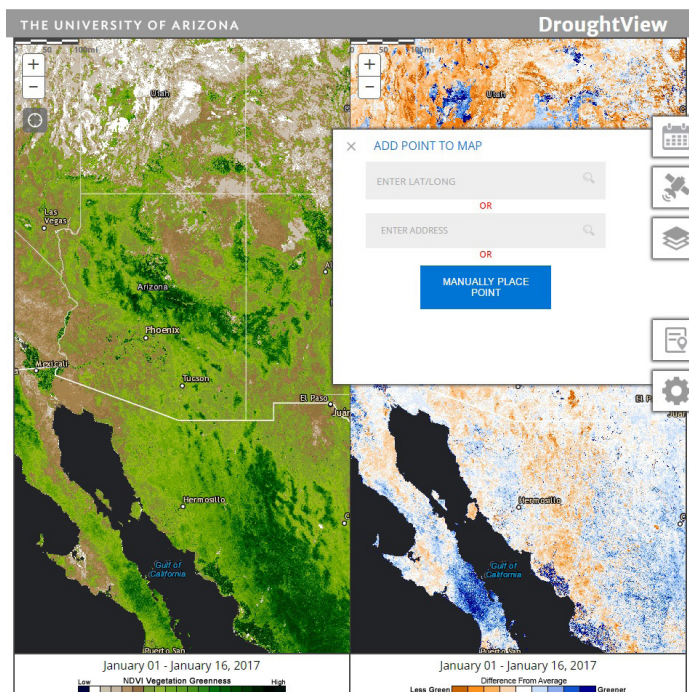


Figure 5. The ADD POINT TO MAP tool panel is the starting point for users to report site-specific drought conditions and submit related information such as photographs of corresponding impacts.

a photograph of the impact, a report document with additional impact details, or other related resources such as website URLs. Saving input to the Drought Impact Survey adds the information to a DroughtView impacts database and makes it available for display through options in the REPORTED IMPACTS panel. Options for sharing drought impact survey information are described in HELP AND TOOLS below.

REPORTED IMPACTS Use the options in this panel to display reported drought impacts in the map windows (Figure 6). Select from several impact categories including 'WILDFIRE', 'TOURISM AND RECREATION', 'AGRICULTURE', 'PLANTS AND WILDLIFE', 'WATER', 'HEALTH', and 'OTHER'. Depending on the area displayed within the map windows, it may be necessary to zoom out in order to view reported drought impacts. Clicking on individual impact reports will display related survey information. Reports from multiple impact categories can be displayed at the same time.

HELP AND TOOLS Print and generate share links for customized maps with features in this panel (Figure 7). Click on the 'CREATE SHARE LINK' button to produce a unique URL that can be used to automatically recreate a customized DroughtView display in other browser windows such as those of colleagues. Simply copy and paste the URL to share information like locations of and corresponding changes in surface greenness related to drought impacts. Click on 'PRINT MAP' to generate a report page that can be printed or saved as a document. Turning off the web browser blocker for pop-up windows may be necessary for the 'PRINT MAP' feature to work properly. There also is a button on this panel that leads to more information regarding DroughtView.

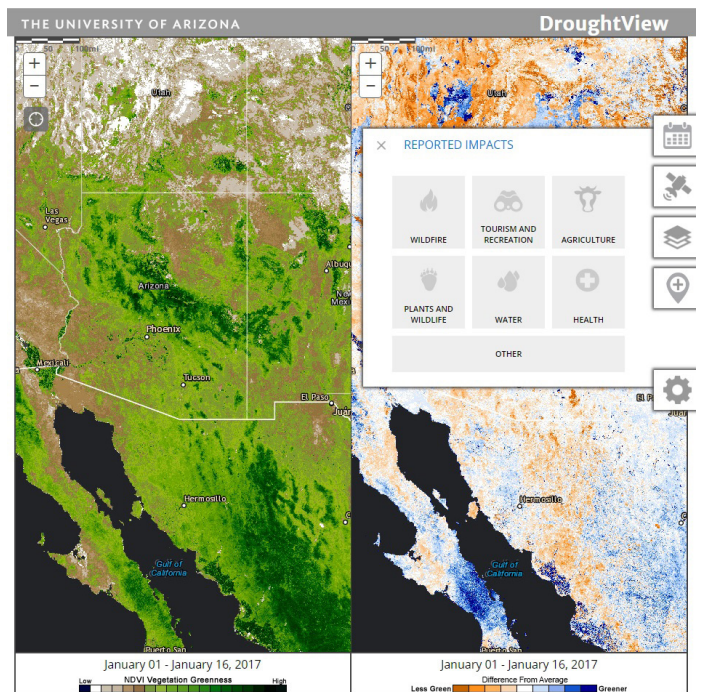


Figure 6. Users can display information from the DroughtView impacts database by selecting topical categories in the REPORTED IMPACTS tool panel.

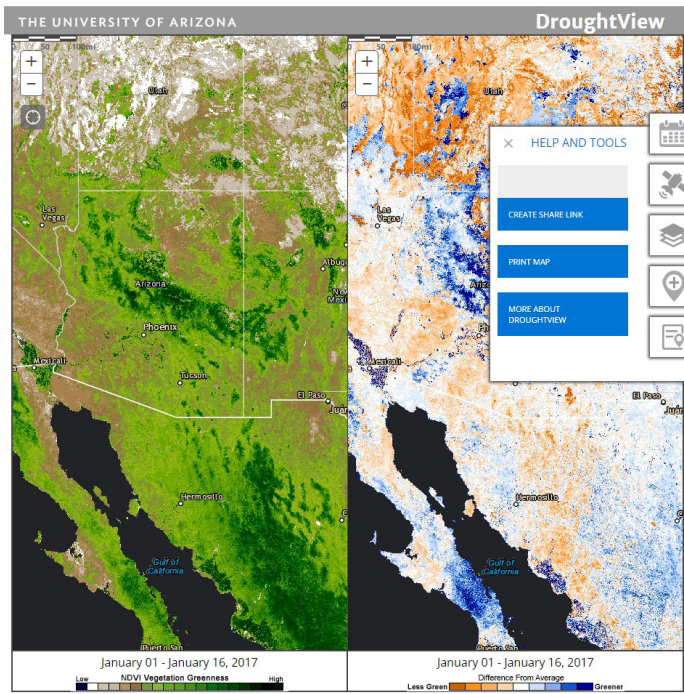


Figure 7. Along with printing or saving map information as a document and accessing the help menu, a new capability in DroughtView to share map information is within the HELP AND TOOLS panel.

Understand the Data behind DroughtView

The redeveloped DroughtView now provides a user with several measures of remotely sensed surface greenness, precipitation, and other geospatial data. Descriptions of these data, including their sources, are described below.

Base Layers

Greenness - NDVI One of the satellite-derived measures of surface greenness used for DroughtView is NDVI, or the Normalized Different Vegetation Index. These data come from the [MODIS](#), or Moderate Resolution Imaging Spectroradiometer, instrument, which is aboard both the Terra and Aqua satellites. The MODIS instrument collects information about numerous atmospheric, land, and ocean phenomena through measurements over a wide range of the electromagnetic spectrum. MODIS measures surface greenness by comparing amounts of the visible-light and near-infrared parts of the electromagnetic spectrum reflected from the Earth's surface. Remotely sensed measures of surface greenness are linked to several characteristics of vegetation such as growth, density, and type (Figure 8). For example, NDVI values of broad forested areas typically are higher than those of grasslands. However, as a MODIS pixel, or area of measurement, is approximately 820 feet by 820 feet, individual plant types or species at a specific location are not discernible through surface greenness values. Although the coverage of the Terra and Aqua satellites allows for a complete electromagnetic view of the globe every two days, NDVI data in DroughtView represent a biweekly composite. This data product, calculated over predefined spans of 16 days, is an attempt to minimize contaminating effects

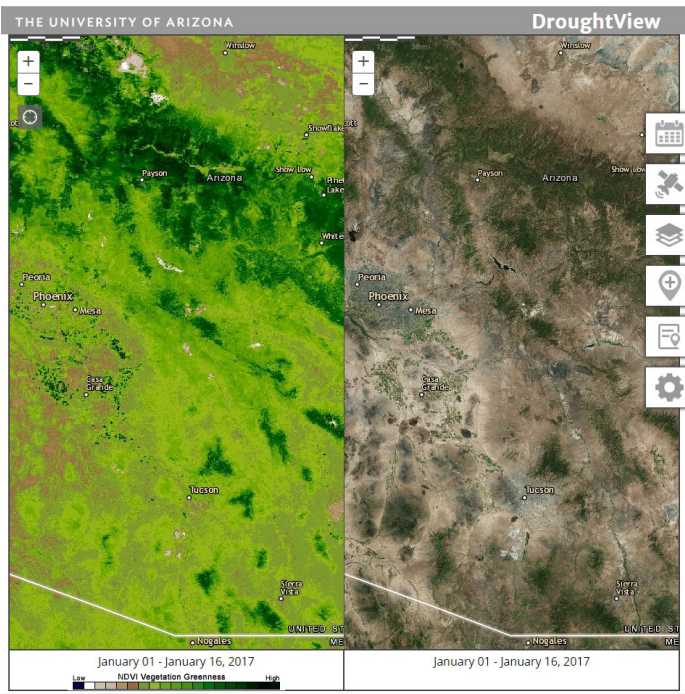


Figure 8. Over southcentral Arizona, dark green areas representing higher values of NDVI surface greenness (left map window) correspond to highly vegetated areas depicted in aerial imagery (right map window). Agricultural lands between Phoenix and Tucson are conspicuous in both maps, as are forested areas to the north and east of these major cities.

of things such as clouds on surface greenness measurements. Despite the compositing procedure, data quality issues can still arise due to factors like different scanning paths and viewing angles, as well as sensor degradation.

Greenness - EVI Another satellite-derived measure of surface greenness used for DroughtView is EVI, or the Enhanced Vegetation Index. These data also are MODIS based and presented as biweekly composites. The EVI differs slightly from NDVI in its calculation in order to better detect changes in surface greenness for areas with higher vegetative cover.

Data Quality The Cloud and Snow mask, or Data Quality base layer, also is based on MODIS data. This product identifies where satellite views of the Earth's surface are obstructed by clouds and where snow-covered land and snow-covered ice on inland water are located. The Cloud and Snow mask additionally shows where good data, marginal data (often near cloudy or snow-covered areas), and no data (due, for example, to instrument error) exist. The presence of clouds and snow lowers NDVI and EVI values.

Precipitation There are two different precipitation datasets used for DroughtView. For biweekly composite periods prior to 2005, precipitation totals are based on daily [PRISM, or Parameter-elevation Regression on Independent Slopes Model](#), data. For biweekly composite periods since 2005, precipitation totals are computed from daily [AHPS, or Advanced Hydrologic Prediction Service](#), data. More information on how both of these daily gridded precipitation datasets are developed is in [Arizona Cooperative Extension bulletin az1704](#) (Weiss and Crimmins 2016).

Overlays

BOUNDARIES AND PLACES Developed and provided by [ESRI ArcGIS Online](#), this data layer shows global place names and country, state/province, and county boundaries. The display of these administrative and cities data is scale dependent, with greater detail appearing as one zooms in to a location. This data layer is turned on by default.

ROADS Developed and provided by ESRI ArcGIS Online, this layer shows global transportation data including highways and roads. The display of these transportation data is scale dependent, with greater detail appearing as one zooms in to a location.

GRAZING ALLOTMENTS Made available by the [Arizona Game & Fish Department](#), this data layer includes Arizona State Land Department, Bureau of Land Management, and U.S. Forest Service allotments for the state of Arizona. Symbology of this data layer is available at the DroughtView website on the '[Understand the Data behind DroughtView](#)' webpage. These data are current through May 2011.

FEDERAL/TRIBAL LANDS Provided by ESRI ArcGIS Online, this data layer shows federal and tribal land areas of the United States symbolized by managing agency. Symbology of this data layer is available at the DroughtView website on the '[Understand the Data behind DroughtView](#)' webpage. The display of these management areas is scale dependent, with greater detail appearing as one zooms in to a location.

CURRENT USDM This data layer shows the current [U.S. Drought Monitor](#), a weekly mapping of drought conditions based on climatic, hydrologic, and soil moisture information along with related impacts. Symbology of this data layer is available at the DroughtView website on the '[Understand the Data behind DroughtView](#)' webpage. The U.S. Drought Monitor is jointly produced by the [National Drought Mitigation Center](#) at the University of Nebraska-Lincoln, the U.S. Department of Agriculture, and the National Oceanic and Atmospheric Administration.

CURRENT YEAR FIRES Made available by [GeoMAC, or the Geospatial Multi-Agency Coordination](#), this data layer shows perimeters of active and inactive fires of the current calendar year. Clicking on the boundary of a fire perimeter polygon will bring up a dialogue box with more information about fire year, name, and acres. Symbology of this data layer is available at the DroughtView website on the '[Understand the Data behind DroughtView](#)' webpage.

HISTORICAL FIRES Made available by GeoMAC, or the Geospatial Multi-Agency Coordination, this data layer shows perimeters of inactive fires from years prior to the current one since 2000. Clicking on the boundary of a fire perimeter polygon will bring up a dialogue box with more information about fire year, name, and acres. Symbology of this data layer is available at the DroughtView website on the '[Understand the Data behind DroughtView](#)' webpage.

WATERSHEDS Made available by the [USGS](#) through [The National Map](#), this layer shows the [Watershed Boundary Dataset](#) that defines perimeters of drainage areas formed by local and

regional terrain. The display of watershed boundaries is scale dependent, with greater detail appearing as one zooms in to a location. In this context, the Watershed Boundary Dataset has six levels of detail that include region, subregion, basin, subbasin, watershed, and subwatershed. Depending on the zoom level, individual watersheds are labeled by a 2-, 4-, 6-, 8-, 10-, or 12-digit HUC, or hydrologic unit code, respectively.

Additional Information on Drought and Remote Sensing of Vegetation

There are many online resources for more information about drought, including the [U.S. Drought Portal](#), [National Drought Mitigation Center](#), [U.S. Drought Monitor](#), [North American Drought Monitor](#), and [National Weather Service Climate Prediction Center](#). Similarly, one can find further descriptions of remotely sensed [measurements of vegetation](#) and corresponding [vegetation indices](#) on federal science agency websites.

References

Weiss J, Crimmins MA (2016) Better Coverage of Arizona's Weather and Climate: Gridded Datasets of Daily Surface Meteorological Variables. Arizona Cooperative Extension az1704, [cals.arizona.edu/research/climategem/resources/Weiss&Crimmins\(2016\)UACEgriddedWxclimdata.pdf](https://cals.arizona.edu/research/climategem/resources/Weiss&Crimmins(2016)UACEgriddedWxclimdata.pdf)



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THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
TUCSON, ARIZONA 85721

JEREMY WEISS

Climate and Geospatial Extension Scientist, School of Natural Resources and the Environment, University of Arizona

MICHAEL CRIMMINS

Climate Science Extension Specialist, Department of Soil, Water and Environmental Science, University of Arizona

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