Drought **S**everity **A**ssessment **T**ool

DSAT 2.0

USER MANUAL

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Acknowledgements

We would like to thank Carl McClellan, Teresa Showa, Robert Kirk, Jason John, Maurice Upshaw, and Crystal Lynn Tulley-Cordova of the Navajo Nation Department of Water Resources: Water Management Branch for providing project guidance, feedback, and in-situ data. Thank you to Ramsey Seweingyawma of the Navajo Technical University for his communication and providing ancillary GIS data.

Thank you to Andrew Nguyen, Chippie Kislik, Juan Torres-Perez, Venkat Lakshmi, Cindy Schmidt, Michael Bender, and the DEVELOP National Program for their guidance, encouragement, and help throughout the process.

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I. Introduction

The **Drought Severity Assessment Tool 2.0 (DSAT)** is a decision support tool created for the Navajo Nation to allow water managers to use satellite data to calculate and visualize Standardized Precipitation Index (SPI) values specific to chosen boundaries within the Nation. The tool was created by the NASA DEVELOP Climate Team at the Ames Research Center in Mountain View, CA. The team focused on creating an SPI tool using the open source statistical program R for the data processing, and the R package Shiny for the user interface.

II. Tool Overview

Capabilities

The DSAT uses monthly precipitation rasters to calculate 1-, 6-, or 12- month SPI values cell by cell. These SPI rasters can then be used to calculate summary statistics based on user specified boundary layers. For example, the water managers can use summary statistics to calculate average SPI values for agencies within the Navajo Nation to create drought severity maps, supporting resource allocation decisions. This provides a way to create a customized regional drought assessment that was not available before.

Interface

This tool uses the open source statistical program R for data processing, and the R package Shiny for the user interface. The end user will install and run the R software and necessary packages on their desktop.

III. Drought Index Background

Standardized Precipitation Index Background

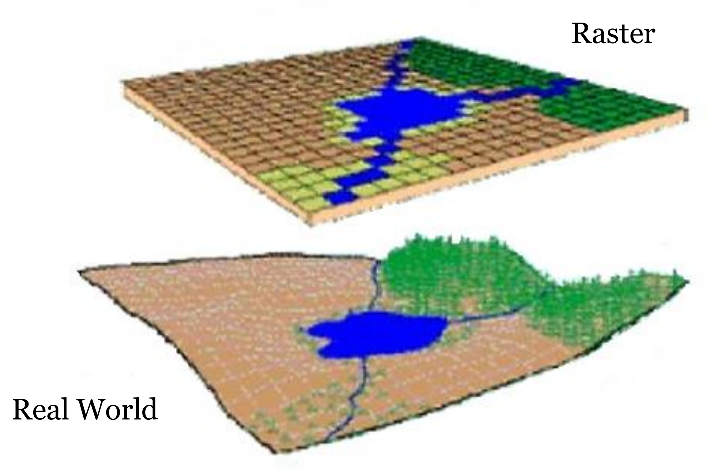
The SPI is an index that compares accumulated rainfall during a specific period of time to accumulated rainfall during that specific time period throughout history. The SPI equation requires at least 30 years of historical data to compare against the selected specific period. In this way, SPI is able to determine how far off from the "normal" precipitation level an area is. SPI is calculated as either a 1-month, 3-month, 6-month, or 12 month SPI, where each time period indicates a different kind of drought.

$$\textbf{SPI} = \frac{(Xi-X)}{\sigma}$$

Xi = accumulated precipitation over months of interest
X = historical avg. accumulated precipitation over months of interest
σ = standard deviation

For example, a 3-month SPI might be used for measuring a climatological drought, a 6-month SPI to measure an agricultural drought and a 12-month SPI for a hydrological drought. Definitions of different time periods of SPI can differ among sources and geographic areas, and the user is encouraged to explore their specific needs in order to determine which type of SPI will best suit their purposes.

SPI is calculated for each pixel (cell) in that month's raster. Commonly used in Geographic Information Systems (GIS) applications, a raster is a spatial data model that is made of equally-sized cells. These cells are arranged in rows and columns, with each cell containing an attribute value – in this case, the SPI calculation – and location coordinates.



IV. Installation

A. Software Requirements

The DSAT requires the following programs to run:

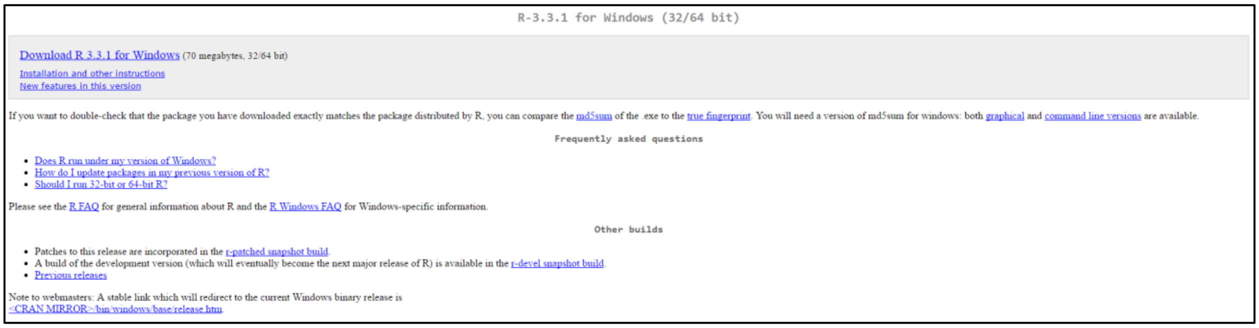
- **R version 3.3.0**
- **Rstudio**
- **Necessary R packages**

***Note: tested operating systems:** Windows 7

R 3.3.0

R is a free statistical language and computing environment created by an international collaboration of developers. To run the tool, the user will need to download R 3.3.0. It is available for download through:

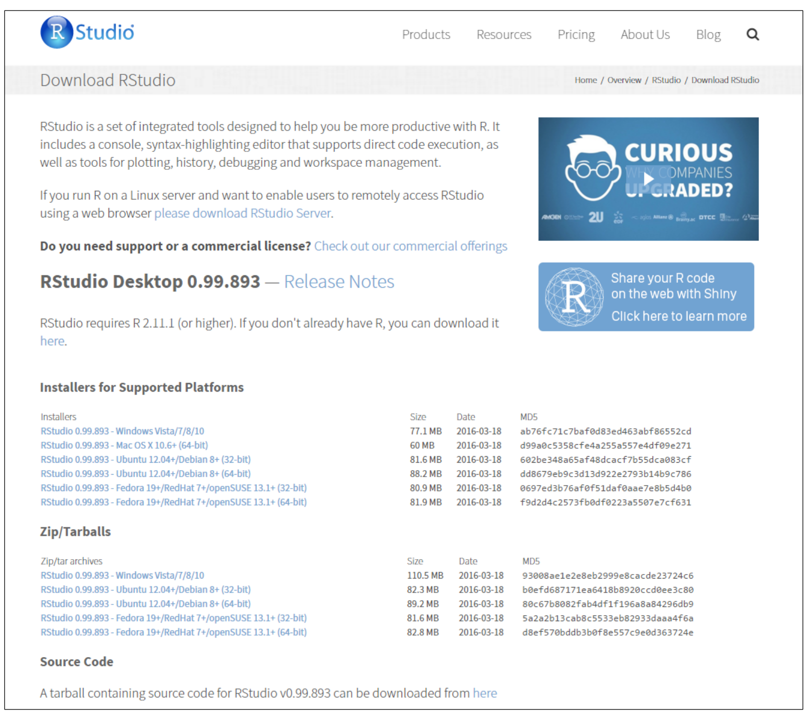
https://cran.r-project.org/bin/windows/base/



Rstudio

R studio is an integrated development environment (IDE) designed to operate with the R programming language and R packages. To run the tool, the user will need to download RStudio, available at from this website:

https://www.rstudio.com/products/rstudio/download/



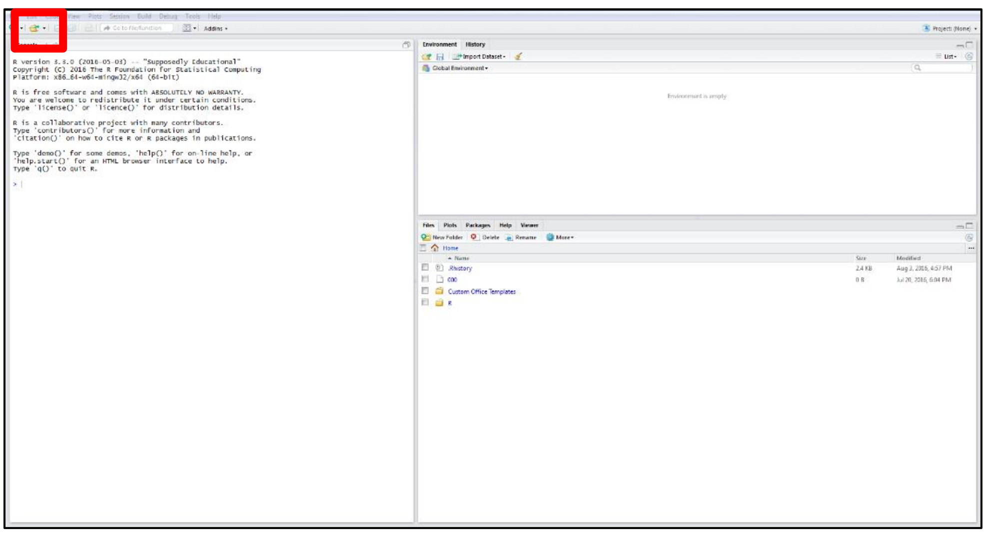
Necessary R Packages
R packages are created by developers as subset languages and functions designed to operate together and run coding. The DSAT uses multiple R packages in order to run. An install script is provided in the manual, and individual packages and their download locations are listed in Appendix D. ***Please note that the manual installation of these packages was necessary to pass NASA Software Release Authority and provide public access to DSAT.***

B. Opening the DSAT

DSAT Package
To use the DSAT (after R and R Studio have been installed) complete the following steps:

1. **Download** and unzip the DSAT.zip file. Save the DSAT folder directly into the C drive (e.g. `C:/DSAT 2.0`).

2. **Open** the Rstudio console. Open the '**Open.r**' file (`C:/DSAT 2.0/Open.r`) in Rstudio.

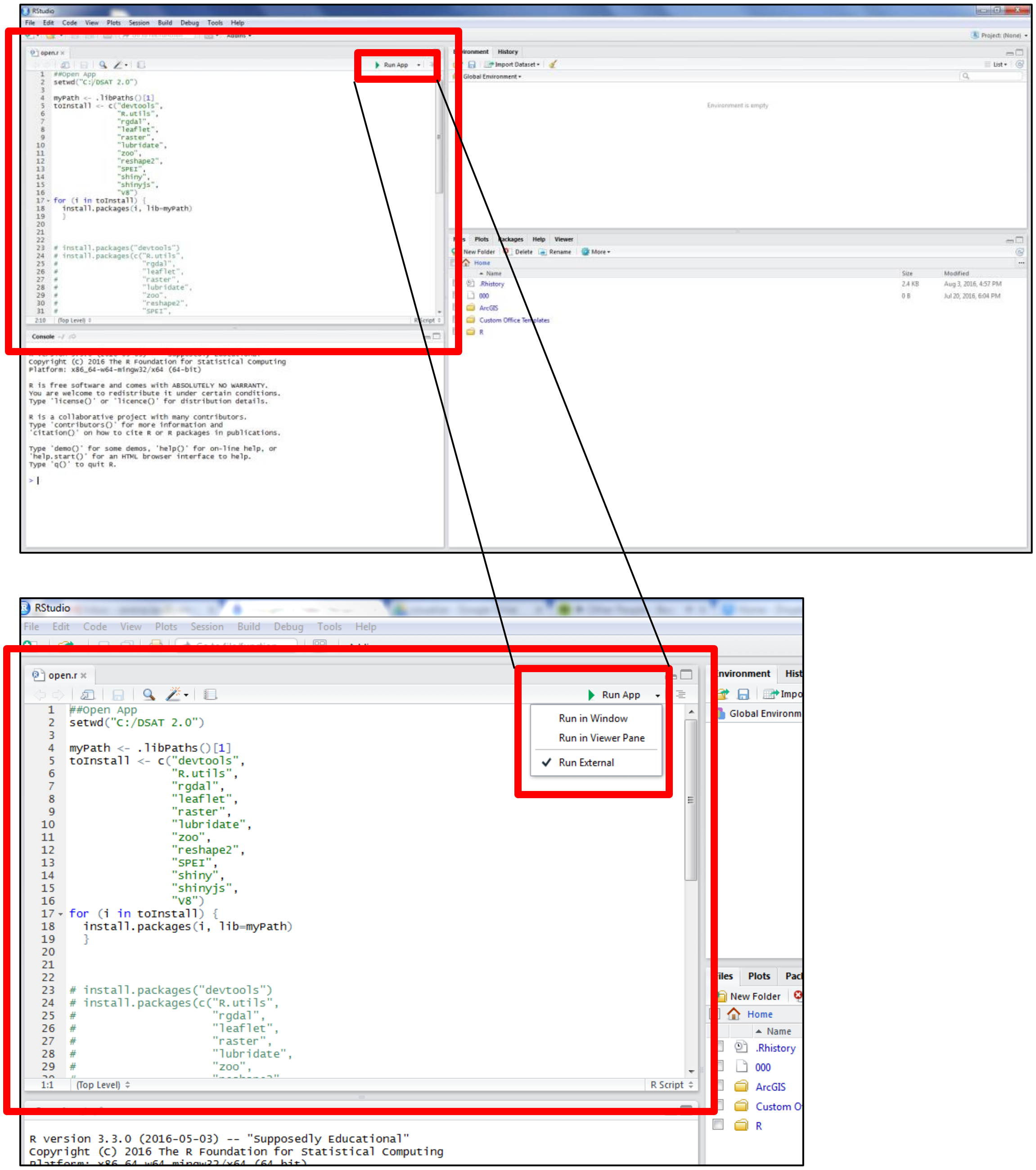


   This file should appear in the Rstudio source editor window in the upper left-hand quadrant of the screen.

3. **Install necessary packages.**

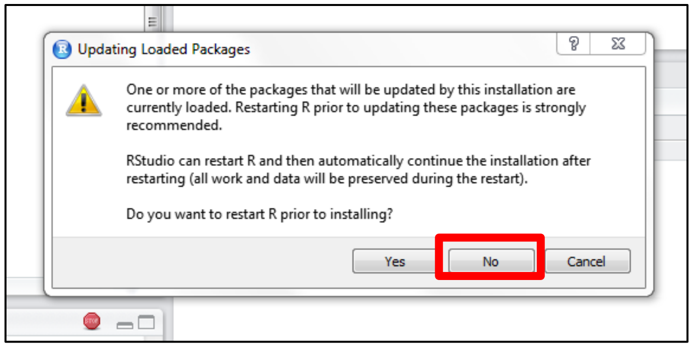
   3.1 Click and hold down the 'Run App' button in the top-right corner of the source editor. Select "Run External" in the dropdown that appears.

Please note: in order to satisfy the NASA Software Release Authority, the packages could not be automatically installed.



3.2 Rstudio will go through and install the necessary packages. The user can follow this progress in the Console window in the bottom left quadrant.

Rstudio may prompt to restart R prior to installing in a separate window. Click "**No**." If the message persists, continue to click "**No.**"

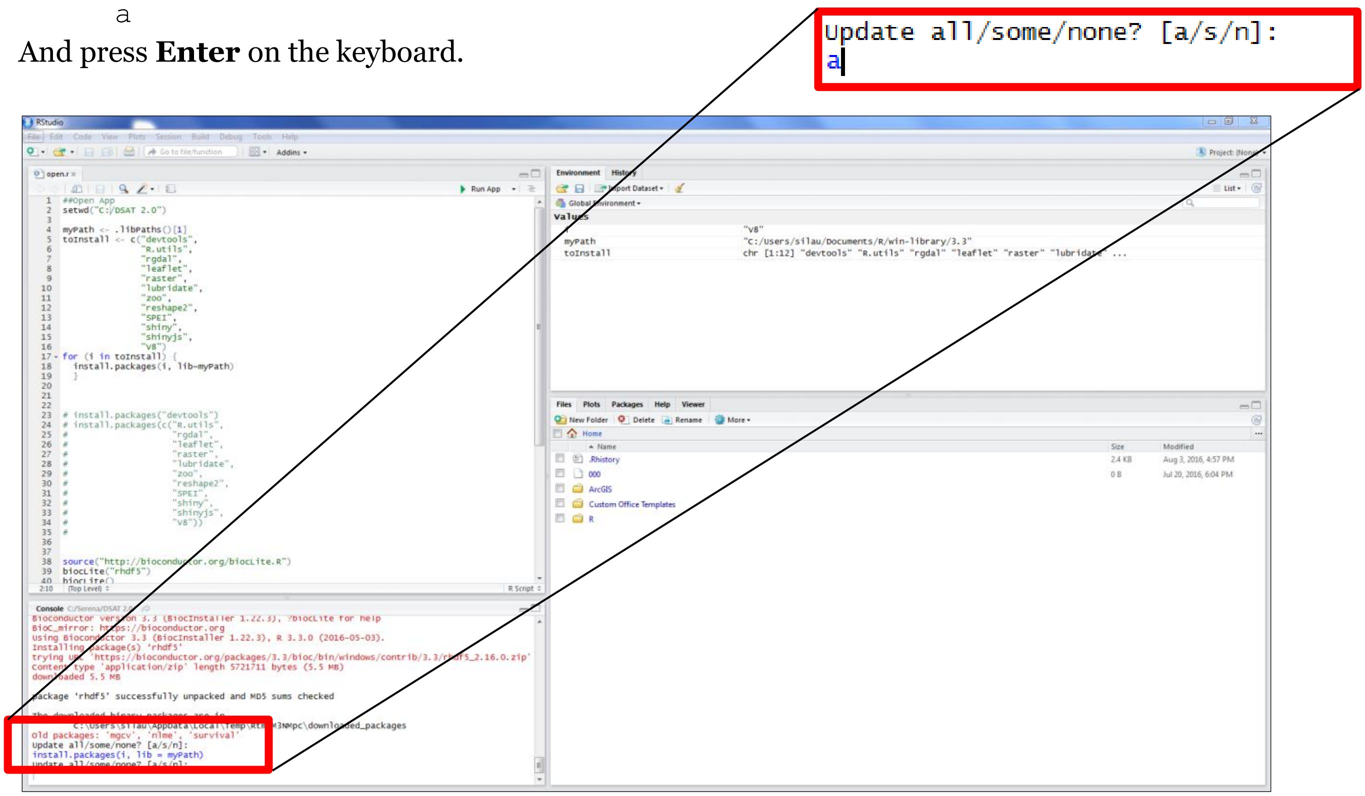


As the packages are being installed, a message in the Console may appear:
“`Update all/some/none? [a/s/n]:`”

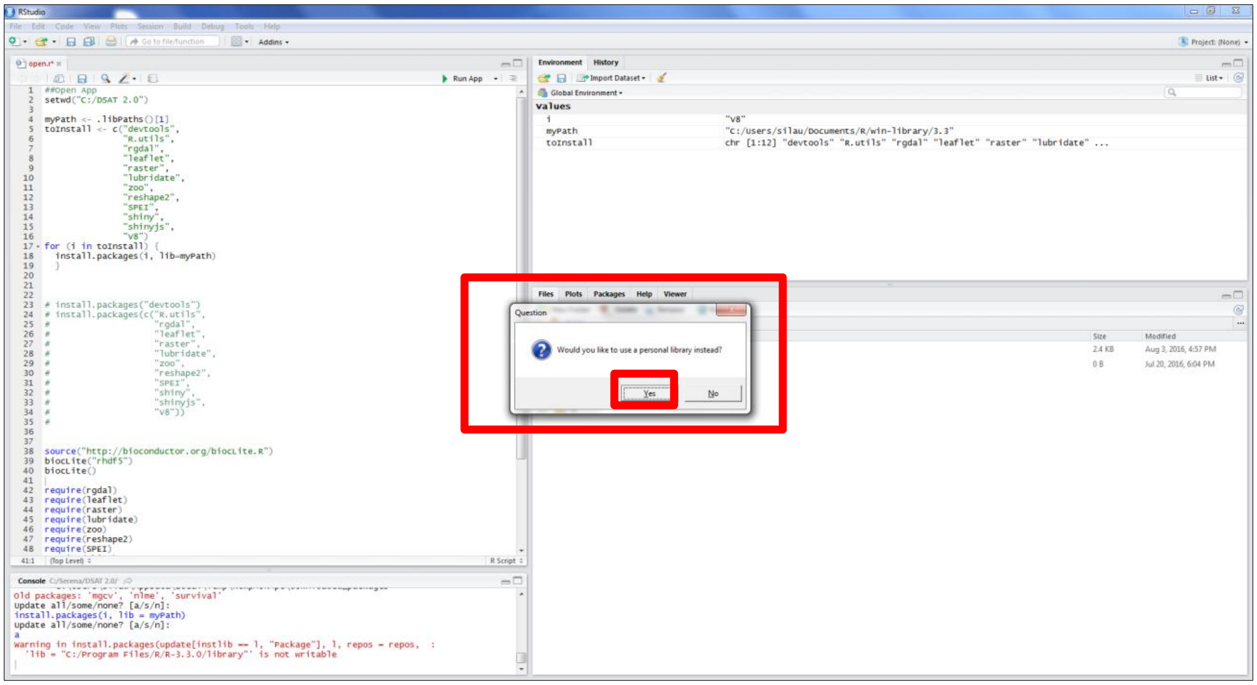
In the Console, type:

    a

And press **Enter** on the keyboard.



When it prompts to install on your personal library in the “Question” window, click “**Yes**.” This will download the last packages.



3.3 Once all of the packages are installed, the Console will show no more activity. The tool is ready for use, and a new window should open displaying the DSAT user interface. This window will open in your computer's default web browser.

If there are any issues relating to the installation process, see Appendix F for work arounds.

VI. Data

The DSAT utilizes precipitation data from the Climate Hazards InfraRed Precipitation with Station Data (CHIRPS) dataset to provide a temporally-continuous set of precipitation data from 1981 to the present. The final CHIRPS product takes advantage of stations' sources and is complete during the third week of the following month. Final products for all times, domains, and formats are calculated at that time (see Appendix B for more details).

Spatial Resolution: 0.05 degree (5 km)	Units: mm/month

VII. The Drought Severity Assessment Tool

An overview of the three main functions of the DSAT:

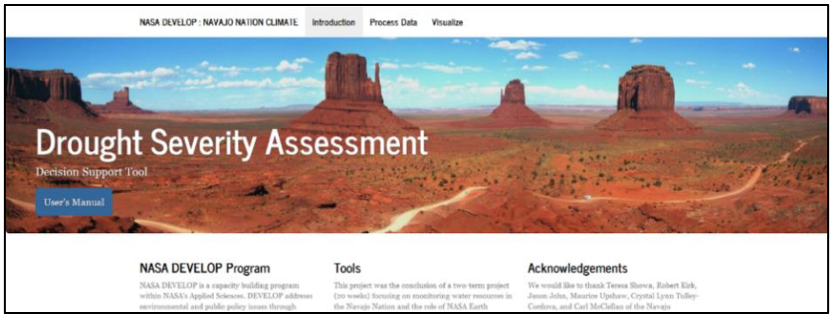
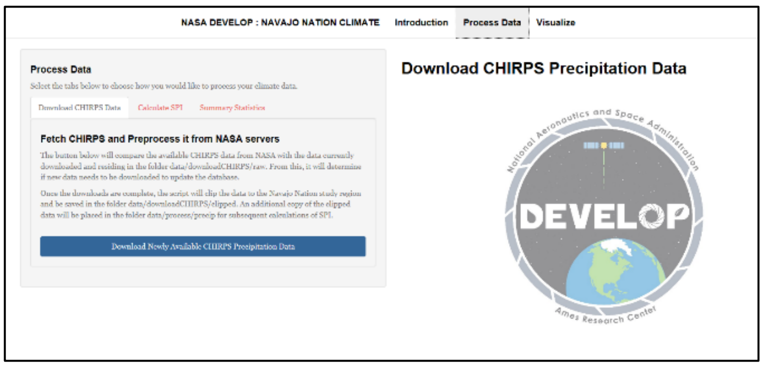
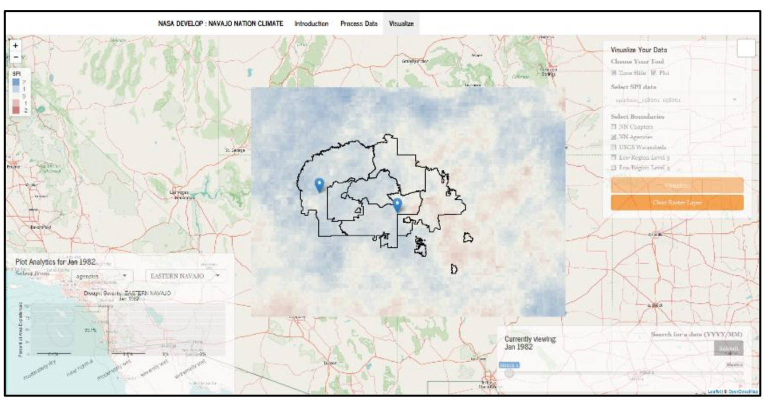
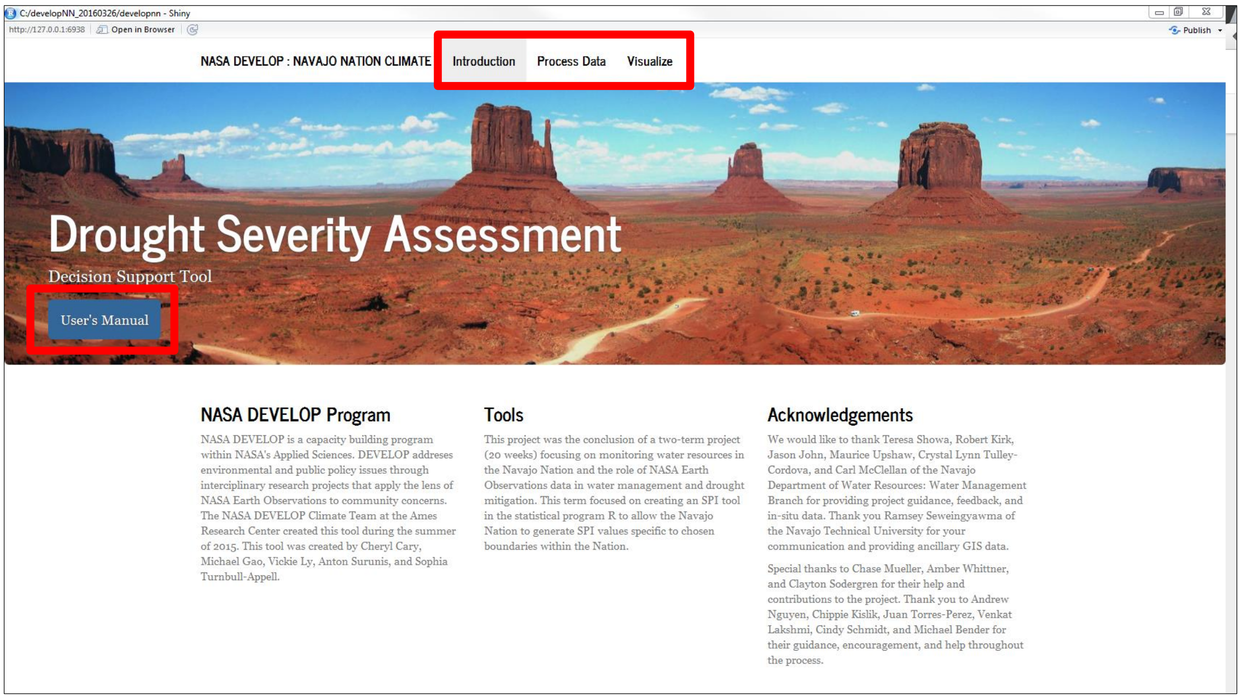
User Interface	Functions
	**<u>Introduction</u>** This is the opening page that links to a 'User Manual.'
	**<u>Process Data</u>** In this section, the user can do three things: • Download CHIRPS Data • Calculate SPI • Summary Statistics
	**<u>Visualize</u>** The user can visualize the SPI rasters on a web map. Additionally, the user can use the 'Time Scale' to specify a specific month and year, as well as 'Plot Analytics' to examine a particular area of choice.

Table 1. An outline summarizing the 3 general uses of DSAT.

A. Introduction

The introduction page is the first thing the user will see when they run the application. **Click on the button 'User Manual'** for the user manual to pop up in a separate window.

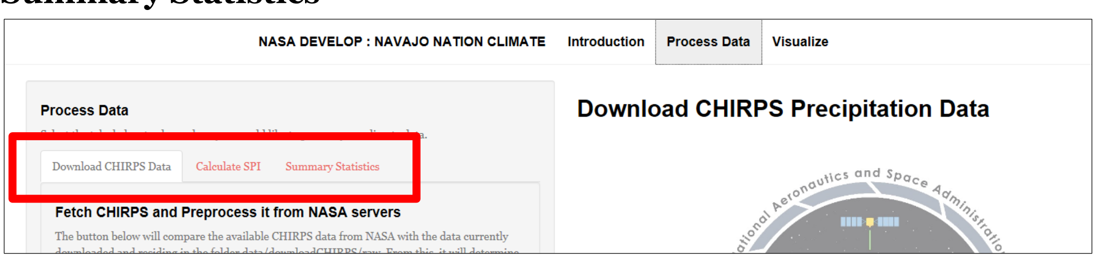
At the top of the page, there are 3 tabs outlining the pages**: Introduction, Process Data,** and **Visualize.**



B. Process Data

The '**Process Data'** tab contains three different functionalities for processing the data:

1) **Download CHIRPS Data**
2) **Calculate SPI**
3) **Summary Statistics**



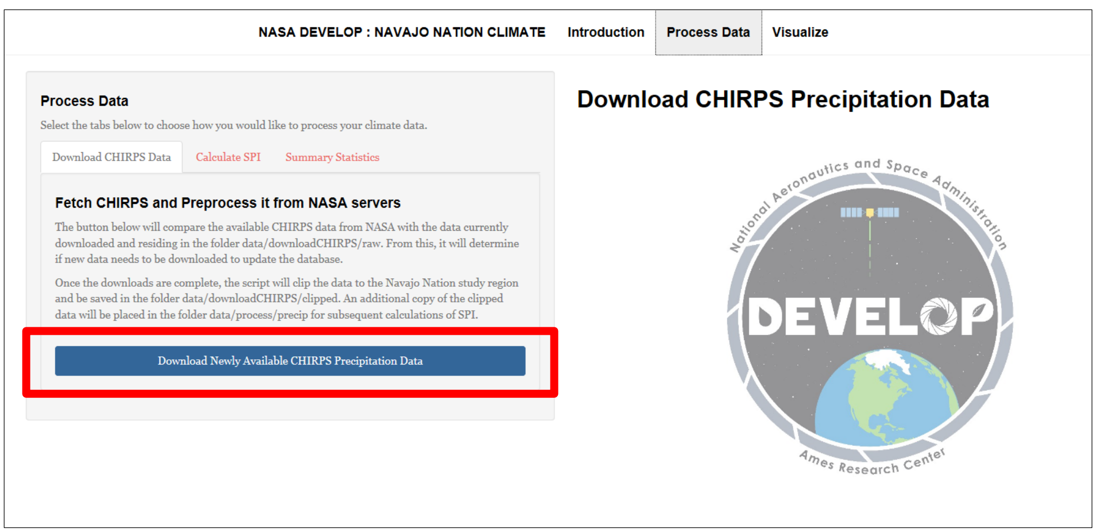
1. *Download CHIRPS Data*

The Download CHIRPS Data function allows the user to automatically download new CHIRPS data as it becomes available. It connects to the CHIRPS ftp, downloads files that do not currently exist in the file structure, and clips them to the minimum bounding rectangle for the HUC-8 watersheds that encompass the Navajo Nation. The coordinates for this bounding rectangle are (-113.149°, -104.349°, 33.299°, 38.499°).

1. Press the "Download newly available CHIRPS Precipitation Data" button
2. The new, clipped CHIRPS data will be found in `C:/DSAT 2.0/data/downloadCHIRPS/clipped` as well as `C:/DSAT 2.0/data/process/precip`

Note that the raw (unclipped) global CHIRPS data is downloaded and stored in the folder `C:/DSAT 2.0/data/downloadCHIRPS/raw`. These data are approximately 56,267 KB each. The function looks to the "clipped" folder in `C:/DSAT 2.0/data/downloadCHIRPS` to assess what new files it needs to download, so it is suggested that the user leave these files in the folder after download.

Refer to Appendix E for further information on file structure and how to access data products.



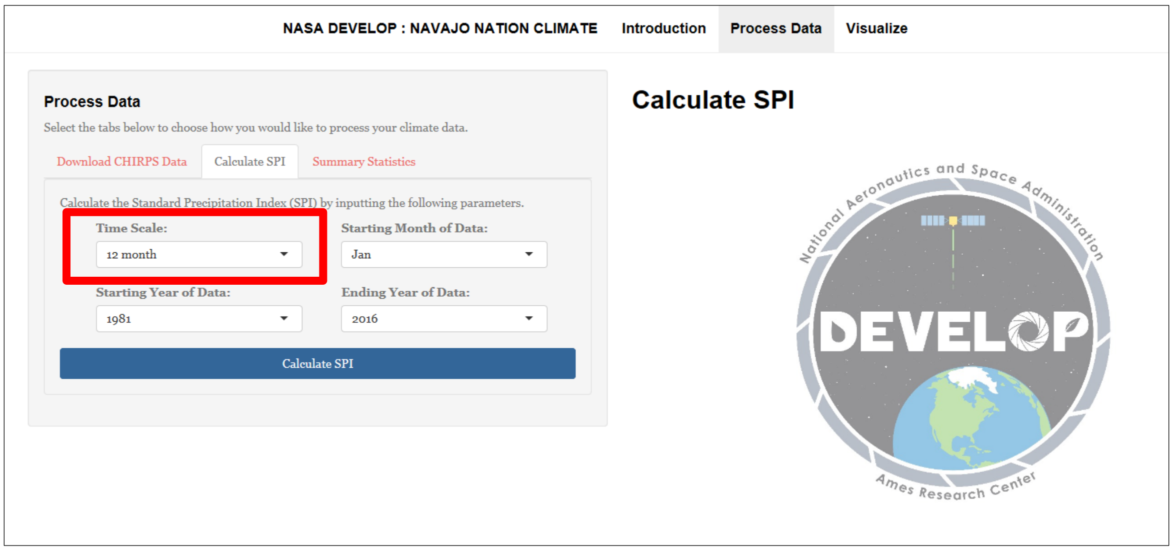
2. *Calculate SPI*

The calculate SPI function allows the user to calculate SPI values for each pixel of the CHIRPS data, and can be run successively. To start, the user is provided with options to tailor their calculation.

1. Time Scale – Type of SPI

The user first selects which type of SPI they would like to calculate under 'Time Scale.'

NOTE: The folder with precipitation data (`C:/DSAT 2.0/data/process/precip`) requires at least 30 years of data.

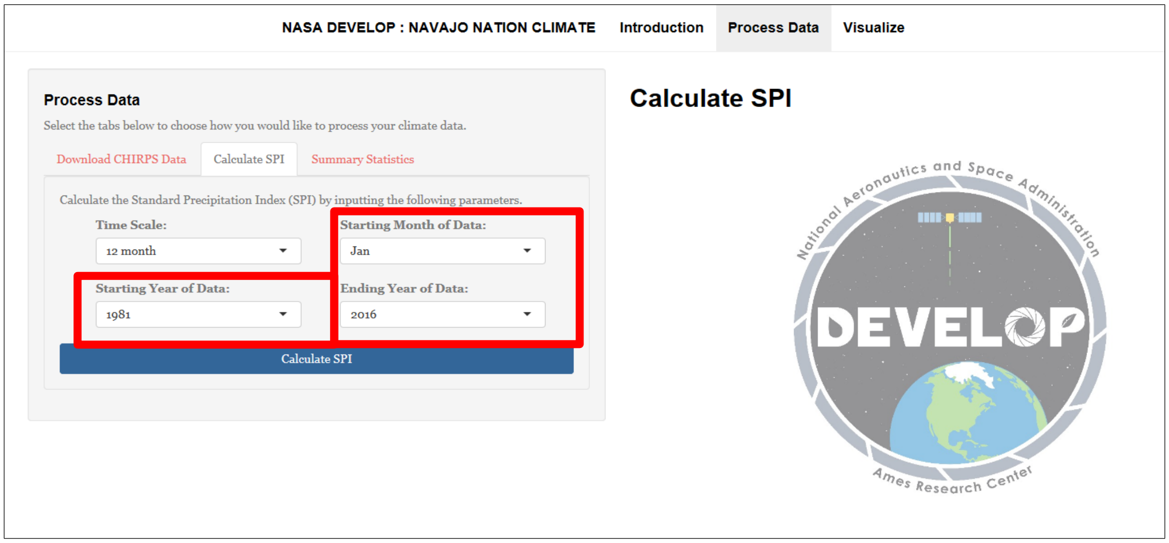


2. Time Range

Next, the user selects a starting month, starting year, and ending year of data. The ending month is not selectable, as, by definition, SPI ends on the same month it begins.

NOTE: The SPI Calculation depends on the time scale selected and the availability of the data.

For example, if the selected starting month and year is January 1981, and the selected time scale is 6 months, the first SPI raster outputted will be June 1981. This is because there is no CHIRPS data prior to January 1981. (The SPI calculation for any given month requires that data is available for *x* number of months before that month, where *x* is the selected time scale.)



Output:
The SPI rasters are created by the tool, and output into:
`C:/DSAT 2.0/data/process/spi` and `C:/DSAT 2.0/data/visualize/spi`

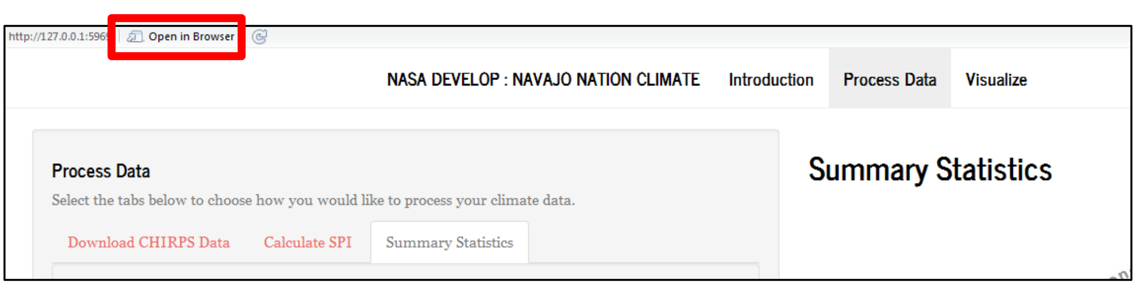
Within these directories, the SPI rasters are contained within a folder with the following naming convention:
`spi/spi`[time scale]`mo_`[start YYYYMM]-[end YYYYMM]

Refer to Appendix E for further information on file structure and how to access data products.

3. Summary Statistics

The Summary Statistics tab uses the calculated SPI rasters to generate and view summary statistics by month for a specified boundary, such as Navajo Nation political boundaries, USGS watersheds, and EPA Level III and IV ecoregions.

The summary statistics will appear in a panel to the right. To download this information as a .csv file, **the user must open DSAT in the browser** before continuing the next steps.



1. **SPI data**

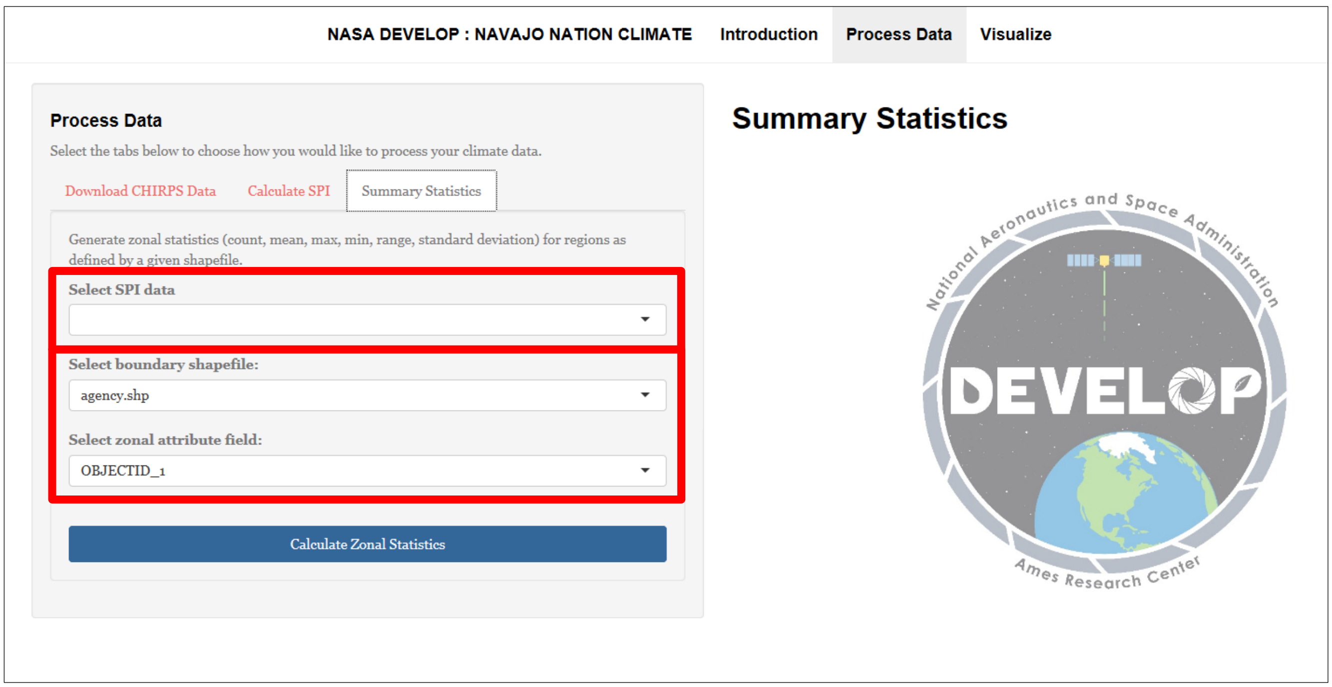
The user first selects the specific folder containing the SPI data.

2. **Boundary shapefile**

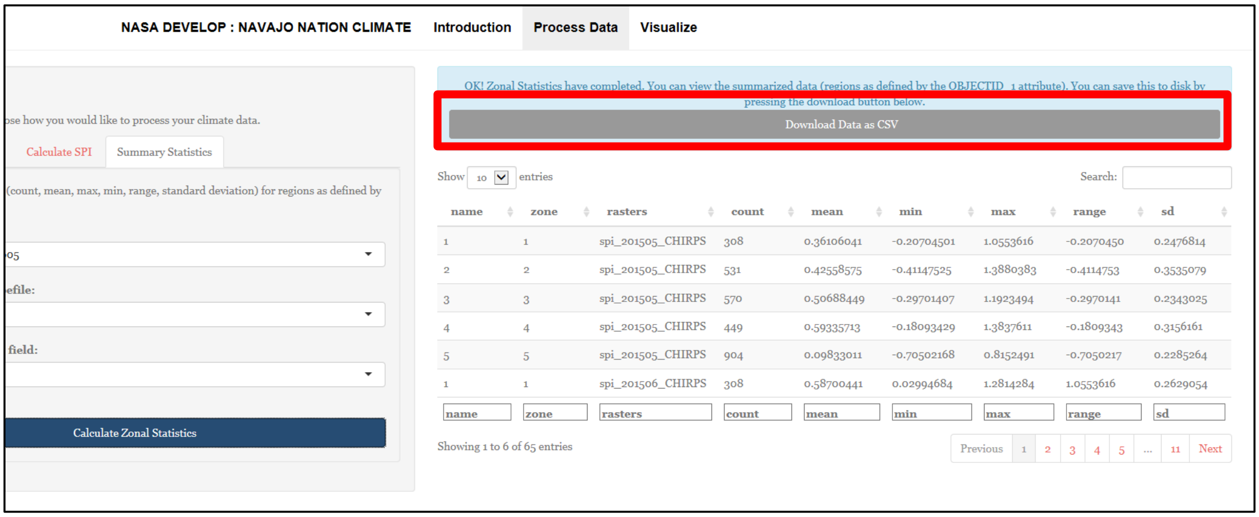
The user then selects a boundary; Navajo Nation agencies are the default. Other boundary options include Navajo Nation chapters, USGS watersheds, and EPA Level III and IV ecoregions.

3. **Attribute field**

The user must then choose a summary area for the statistics to be calculated; these attribute choices change according to the boundary shapefile selected.



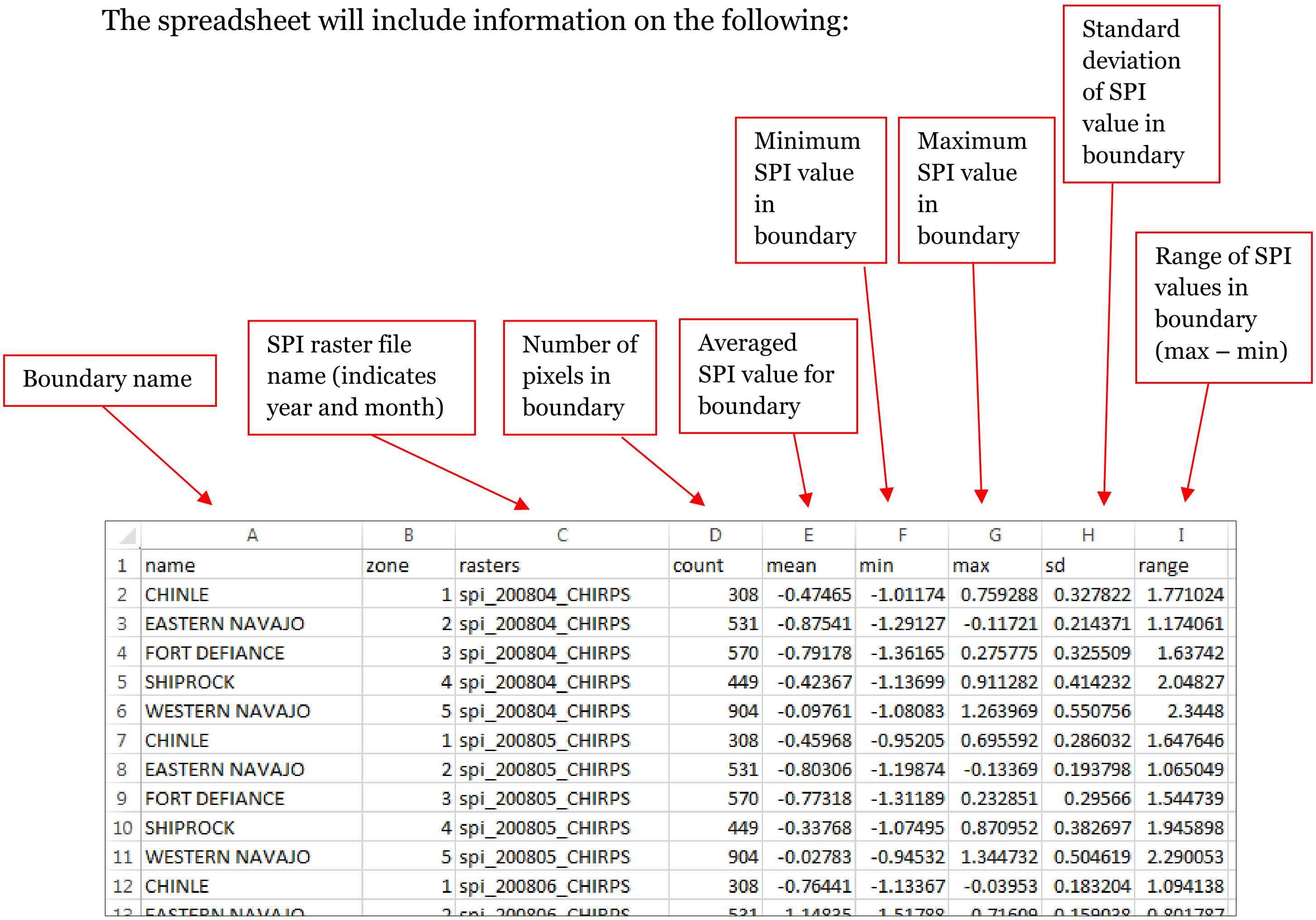
The summary statistics will appear in a panel to the right. The user can download this as a `.csv` file by clicking on the “Download Data as CSV” button at the top of the screen. Note again, the user must be in the browser to download the csv file.



Interpreting Summary Statistics

A spreadsheet will be downloaded into your computer's "Downloads" folder, entitled `summarystats_zonalTable.csv`

The spreadsheet will include information on the following:



	A	B	C	D	E	F	G	H	I
1	name	zone	rasters	count	mean	min	max	sd	range
2	CHINLE	1	spi_200804_CHIRPS	308	-0.47465	-1.01174	0.759288	0.327822	1.771024
3	EASTERN NAVAJO	2	spi_200804_CHIRPS	531	-0.87541	-1.29127	-0.11721	0.214371	1.174061
4	FORT DEFIANCE	3	spi_200804_CHIRPS	570	-0.79178	-1.36165	0.275775	0.325509	1.63742
5	SHIPROCK	4	spi_200804_CHIRPS	449	-0.42367	-1.13699	0.911282	0.414232	2.04827
6	WESTERN NAVAJO	5	spi_200804_CHIRPS	904	-0.09761	-1.08083	1.263969	0.550756	2.3448
7	CHINLE	1	spi_200805_CHIRPS	308	-0.45968	-0.95205	0.695592	0.286032	1.647646
8	EASTERN NAVAJO	2	spi_200805_CHIRPS	531	-0.80306	-1.19874	-0.13369	0.193798	1.065049
9	FORT DEFIANCE	3	spi_200805_CHIRPS	570	-0.77318	-1.31189	0.232851	0.29566	1.544739
10	SHIPROCK	4	spi_200805_CHIRPS	449	-0.33768	-1.07495	0.870952	0.382697	1.945898
11	WESTERN NAVAJO	5	spi_200805_CHIRPS	904	-0.02783	-0.94532	1.344732	0.504619	2.290053
12	CHINLE	1	spi_200806_CHIRPS	308	-0.76441	-1.13367	-0.03953	0.183204	1.094138
13	EASTERN NAVAJO	2	spi_200806_CHIRPS	531	-1.14825	-1.51788	-0.71609	0.159038	0.801787

Example 1: Pixel Math

The user can do a number of things using the information from the Summary Statistics and the Plot Analytics tool (pg. 24). For example, the user can also perform pixel math to determine how much of a chapter's area (km²) is experiencing rainfall corresponding to a specific SPI range.

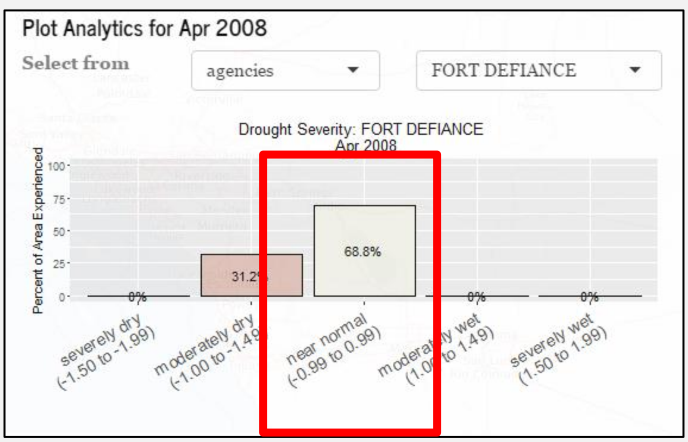
For example, taking the first line: There are 308 pixels that make up Chinle's area in April 2008.

	A	B	C	D	E	F	G	H	I
1	name	zone	rasters	count	mean	min	max	sd	range
2	CHINLE	1	spi_200804_CHIRPS	308	-0.47465	-1.01174	0.759288	0.327822	1.771024
3	EASTERN NAVAJO	2	spi_200804_CHIRPS	531	-0.87541	-1.29127	-0.11721	0.214371	1.174061

Knowing this, the user can calculate the total area of Chinle:

1 pixel = 5 km² Total Area of Chinle: 308 pixels x 5 km² = **1540 km²**

Now, in conjunction with the Plot Analytics tool, the user can define more specifically the total area *within* Chinle that is experiencing rainfall corresponding to a specific SPI range. With the selected boundary as chapters, and the selected summary area as Chinle, the user can multiply the **pixel percentage** corresponding to the desired SPI range by the total area of Chinle to calculate the **area of Chinle experiencing that level of rainfall.**



Where, the area of Chinle experiencing rainfall levels corresponding to the SPI range [range] is *the percentage of pixels for that SPI range from bar plot* x *total area of Chinle* = [ ] km²

So, the area of Chinle experiencing rainfall levels from the SPI range [-0.99 to 0.99]:
68.8% x 1540 km² = 105,952 km²

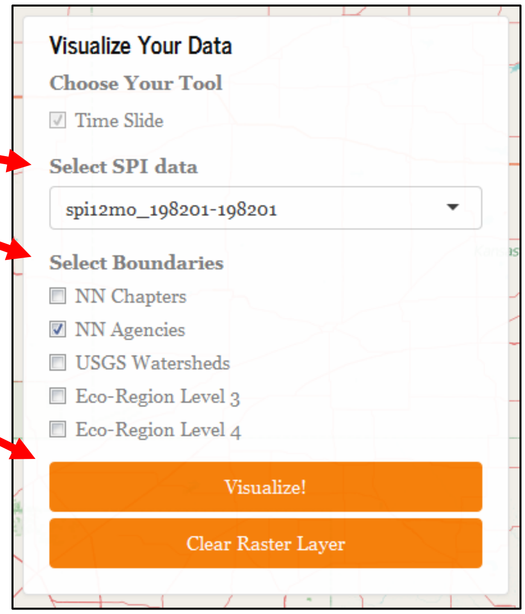
Thus, we can conclude that **105,952 km²** of Chinle was experiencing a nearly normal precipitation (SPI value = -0.99 to 0.99).

C. Visualize

The Visualize tab allows the user to see the SPI rasters on a webmap, and use the **Time Slide** and **Plot Analytics** tools. Please note that the Time Slide and Plot Analytics windows are able to be moved around the screen for viewing ease, and are semi-transparent when the mouse is moved off the window.

To use these features, in the "Visualize Your Data" window:

1. Select the folder containing the SPI data
2. Select the boundary (or boundaries)
3. Click "Visualize!



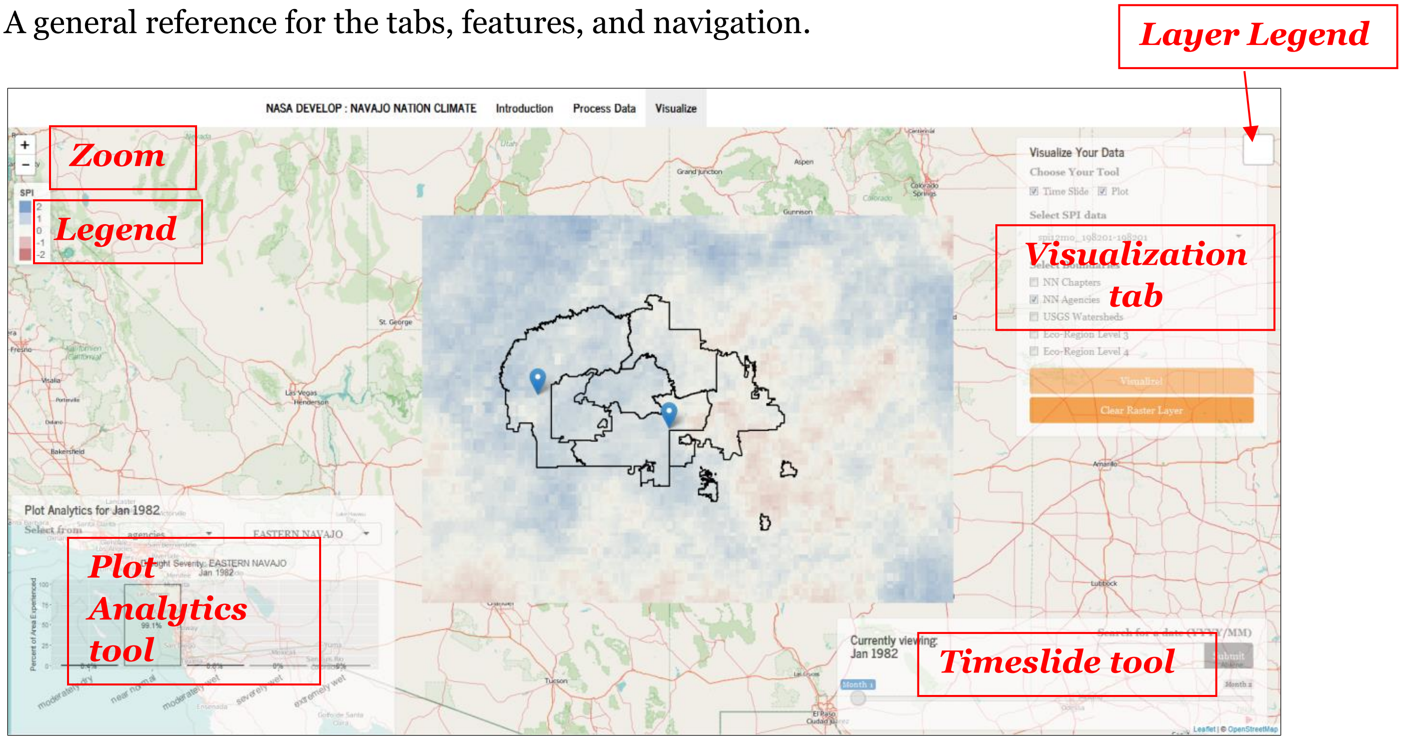
Optional:

- Select the "Plot" checkbox to use the Plot Analytics tool
- Change the layers displayed on the map within the Layer Legend

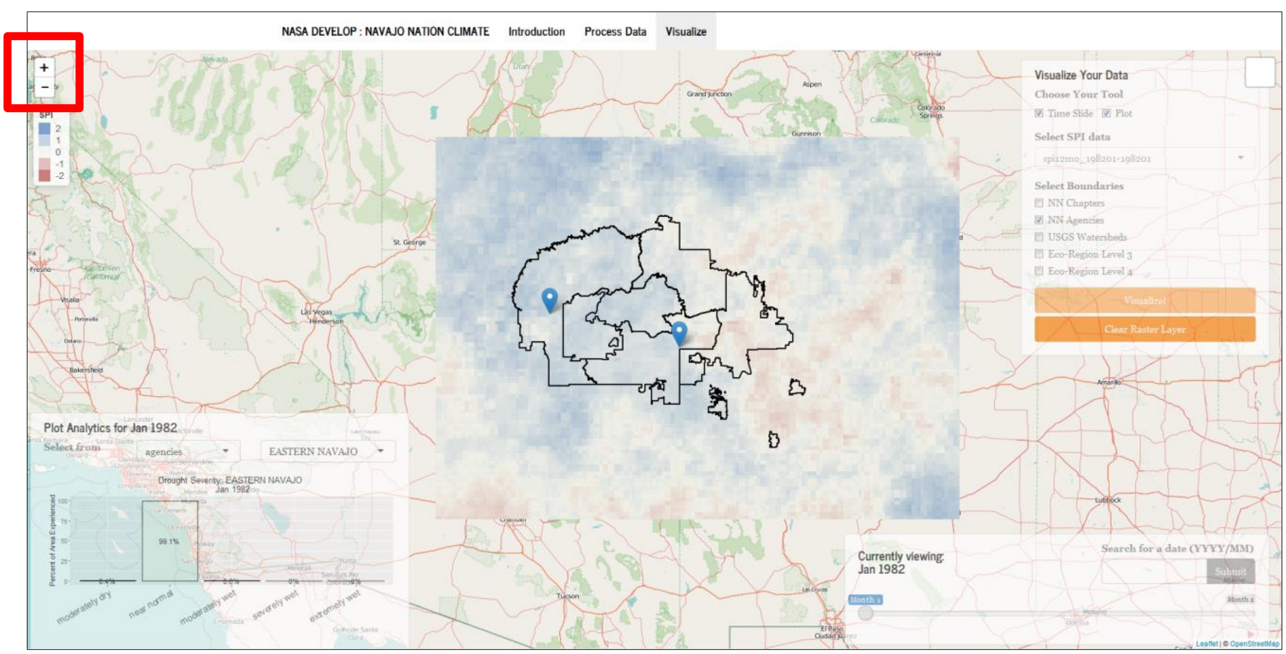
Nuts and Bolts

Navigating the Display

A general reference for the tabs, features, and navigation.



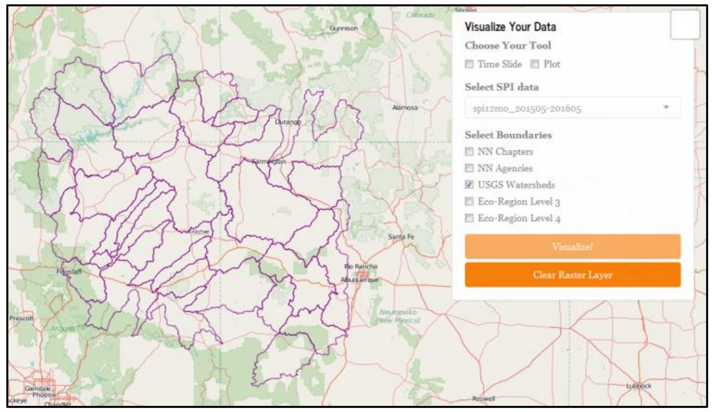
Click and drag anywhere on the map to pan to another location. Use the zoom in/zoom out tool on the left-hand side to get a closer look at what is displayed.

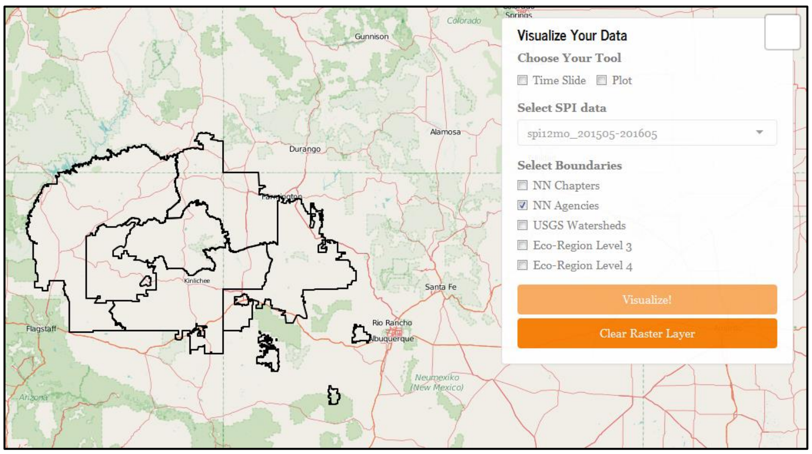


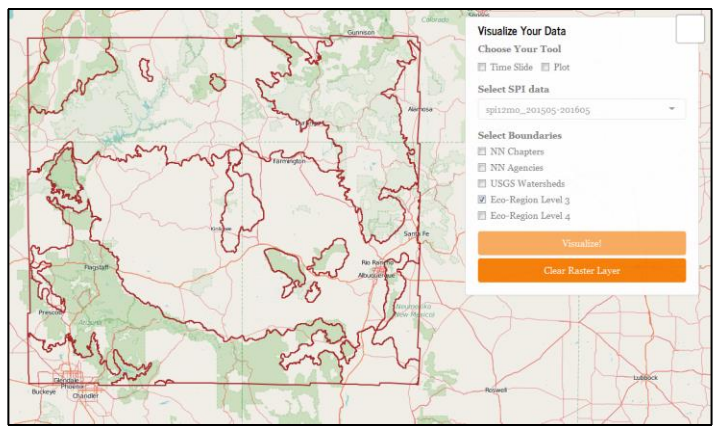
Select Boundaries

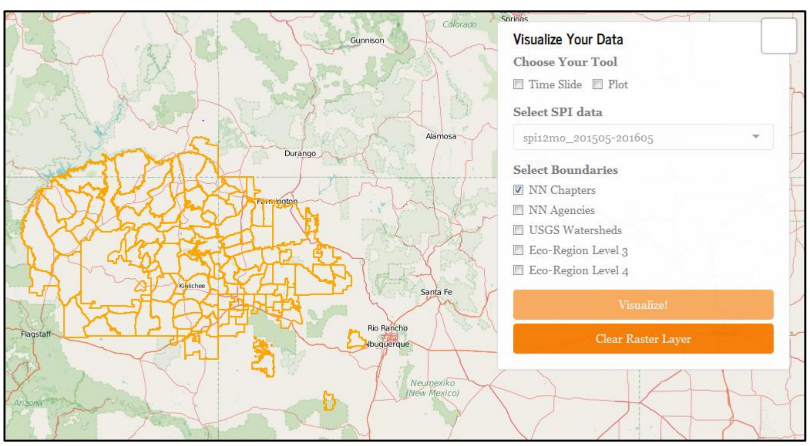
The SPI rasters are visible overlain by different boundaries, including **NN Agencies** (black)**, NN Chapters** (orange)**, USGS Watersheds** (purple)**, and EPA Ecoregions Levels III** (brown) and **IV** (green)**.**

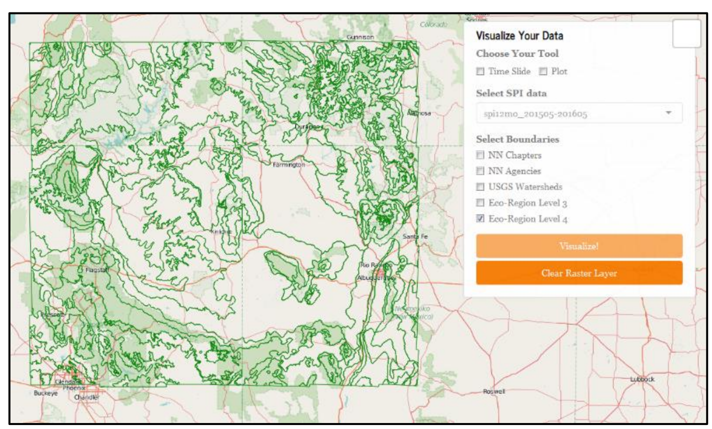
The user may select or unselect the checkboxes for different boundaries in the "Visualize Your Data" window. The map display and Plot Analytics tool will change accordingly.





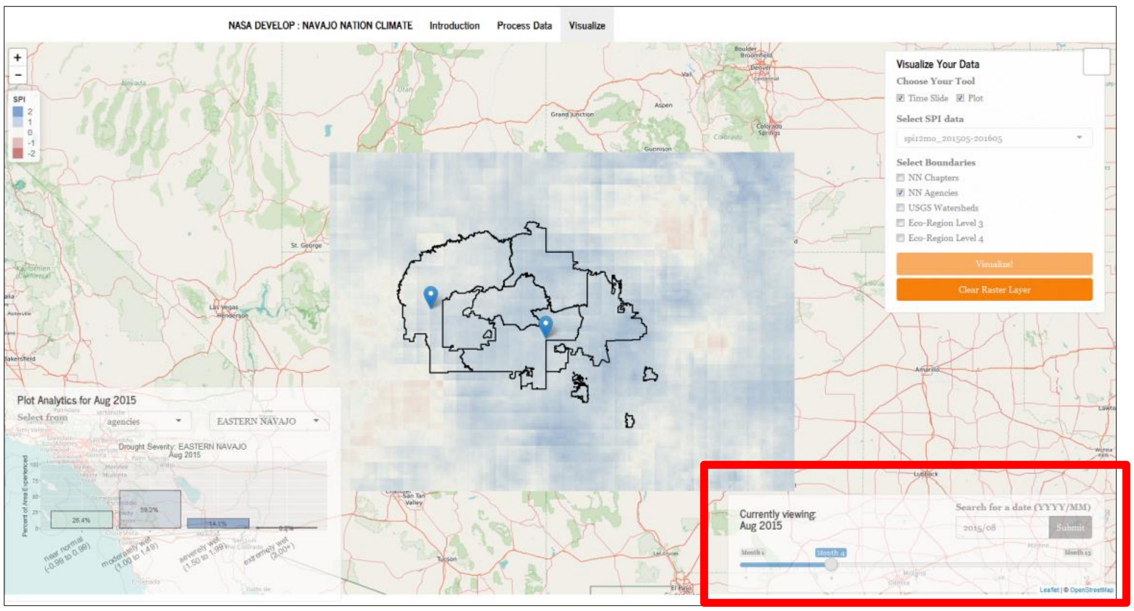




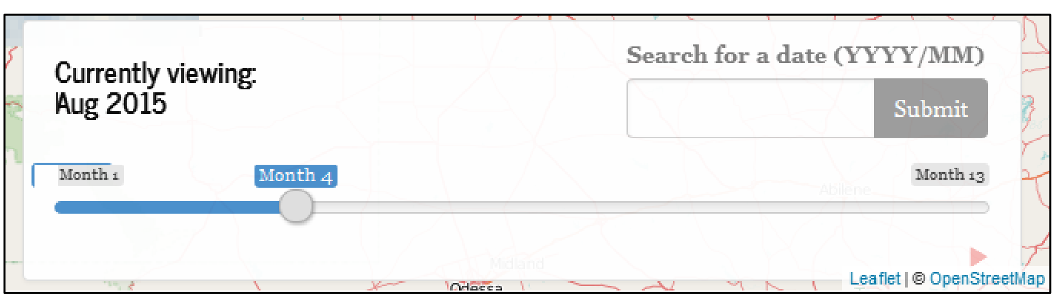


Time Slide Tool

The Time Slide window automatically displays in the lower right hand corner, as shown in red. After pressing the “Visualize!” button in the “Visualize Your Data” window, the user may slide to the month and year of interest. Clicking the triangular, red “play” button in the lower right hand corner of the Time Slide window allows the user to see a time series of the SPI rasters in the specified data folder’s time range.



A date of interest can also be directly “jumped” to by typing and submitting the date (in the format YYYY/MM) in the “Search for a date” box. This will display the corresponding SPI raster on the map. If the date searched for is in the incorrect format, an error will appear asking the user to verify the formatting so that it adheres to “YYYY/MM”. If the date is out of range, given the SPI data folder that has been selected by the user, an error will appear detailing that that SPI is unavailable.

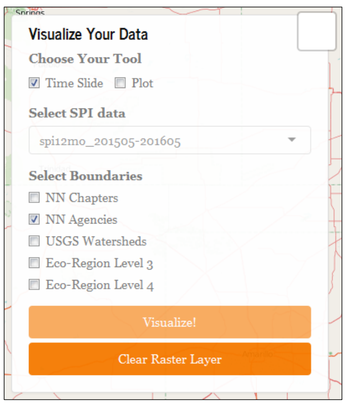


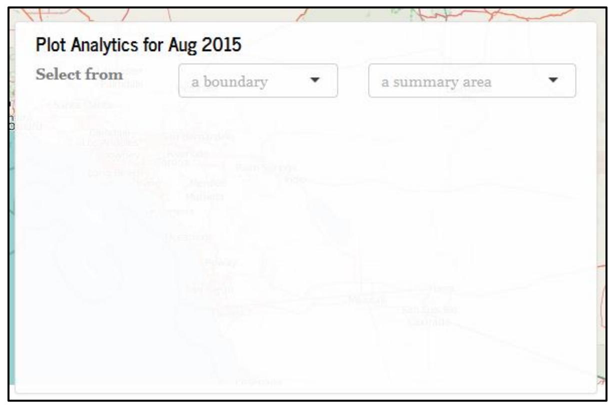
The Plot Analytics tool (described below) is responsive to the month and year indicated by the Time Slide tool, and will display the bar chart for that date.

The Time Slide window may be hidden by unchecking the Time Slide box under “Choose Your Tool” in the “Visualize Your Data” window.

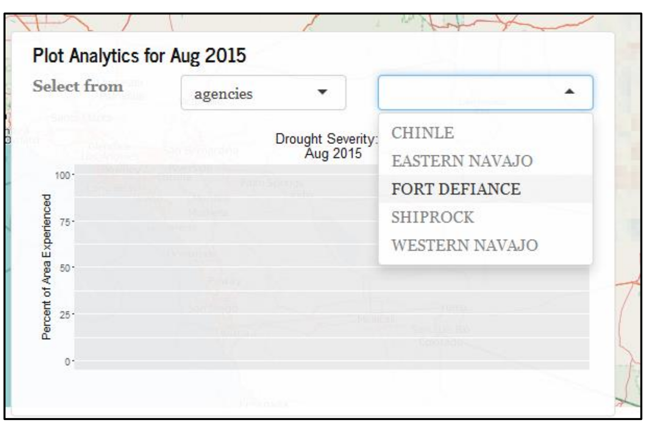
Plot Analytics Tool

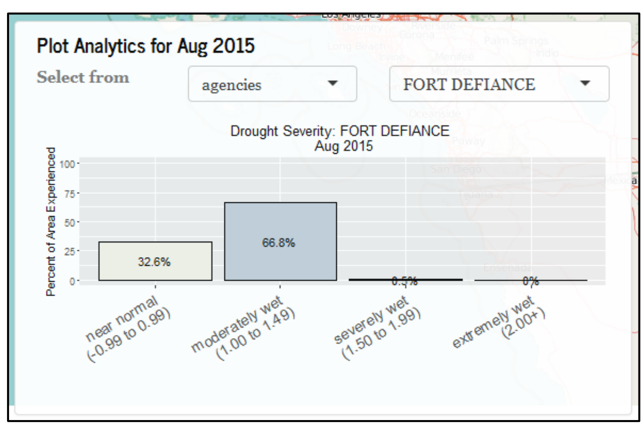
Upon pressing the “Visualize!” button, the user is given the option to display plot analytics for a summary area of a selected boundary. Under the “Choose Your Tool” section in the “Visualize Your Data” window, select the ‘Plot’ checkbox. Conversely, unselect it to hide the Plot Analytics window. A window with the Plot Analytics will load in the lower left hand corner.





Using the ‘Plot’ feature, the user can see the precipitation anomaly experienced by each summary area for the month selected. (Change the month selected using the Time Slide tool window. Different boundaries may also be (un)selected in the “Visualize Your Data” window, providing different summary area options for the plot to display.)



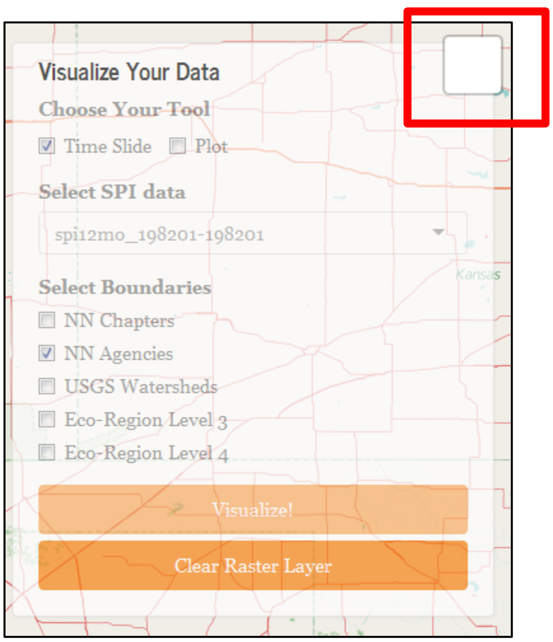


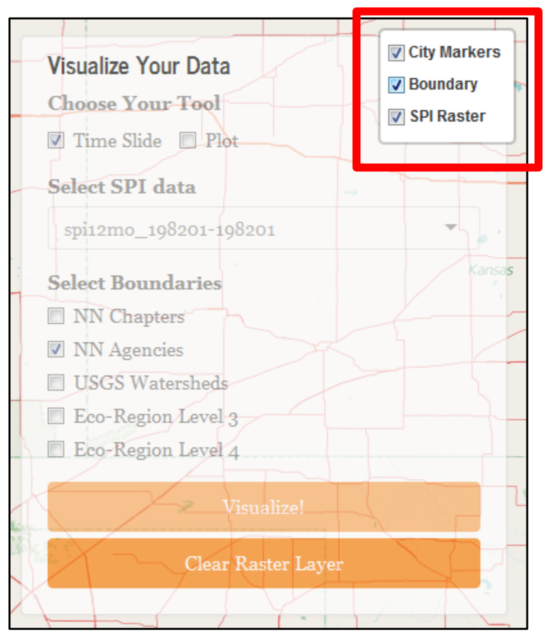
The precipitation anomaly is categorized according to the following x-axis labels on the plot, in accordance with the National Center for Environmental Information:

Category	*SPI Value*
Extremely Wet	2.00 and above
Very Wet	1.50 to 1.99
Moderately Wet	1.00 to 1.49
Near Normal	-0.99 to 0.99
Moderately Dry	-1.00 to -1.49
Severeley Dry	-1.50 to -1.99
Extremely Dry	-2.00 and less

Layer Legend

After clicking “Visualize!”, the Layer Legend will appear in the top right hand corner of the “Visualize Your Data” window. Hover over the Layer Legend to see the different layers displayed on the webmap: City Markers, Boundary, and SPI Raster. Click the checkbox to turn on or off the corresponding layer on the map.





City Markers

Selected reference cities appear on the map by default, and clicking on any blue marker will reveal the corresponding city name. The City Markers layer can be turned on or off by (un)selecting the “City Markers” checkbox using the Layer Legend described above.

The list of cities can be customized by editing the `citymarkers.csv` file in `C:/DSAT 2.0/data/visualize`. Latitude, longitude, and the city name are required.

Conclusions

The goal of the DSAT is to provide water resource managers in the Navajo Nation Department of Water Resources with the ability to create drought severity maps and monthly drought reports with finer spatial resolution and continuity than previously available. With the DSAT, we hope water resource managers will be able to determine which agencies and chapters are experiencing greater drought intensity and properly allocate drought mitigation resources. We also hope the tool will be able to be used with other boundaries (watershed, ecoregions, etc.) to better understand drought regimes in the area. By utilizing NASA Earth Observations, Navajo Nation resource managers and decision-makers will be able to monitor drought with a continuous feed.

The DSAT is now accessible through GitHub, a web-based Git repository hosting service. In making the DSAT public, users around the world will be able to make small adjustments to the DSAT to be used in other locations.

https://github.com/NASA-DEVELOP/DSAT

Appendix

a. Terms and Abbreviation

A list of terms and abbreviations used in this document:

Standard Precipitation Index (SPI)
Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)
Drought Severity Assessment Tool (DSAT)

b. CHIRPS precipitation data

CHIRPS Data
Climate Hazards Group InfraRed Precipitation with Station data
Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) is a 30+ year quasi-global rainfall dataset. Spanning 50°S-50°N (and all longitudes), starting in 1981 to near-present, CHIRPS incorporates 0.05° resolution satellite imagery with in-situ station data to create gridded rainfall time series for trend analysis and seasonal drought monitoring.

About: http://chg.geog.ucsb.edu/data/chirps/
All data: ftp://ftp.chg.ucsb.edu/pub/org/chg/products/CHIRPS-2.0/
Global monthly tifs:
ftp://ftp.chg.ucsb.edu/pub/org/chg/products/CHIRPS-2.0/global_monthly/tifs/

c. Other sources of precipitation data

Other types of precipitation data can be used within the DSAT to calculate and visualize SPI rasters (See Appendix C for other sources). In order for the DSAT to run properly all precipitation data must have the same extent, and spatial resolution, *this is essential for the DSAT to function*. Please also note that visualization on the web map in the tool requires the SPI rasters be projected in the WGS84 projected coordinate system; using only the data generated within the tool will ensure that this is the case, and requires no further action on the user's part.

The tool was designed so that other sources of precipitation data can be integrated. Here are other possible sources of precipitation data to be used in the tool. Ensure that all precipitation data used maintains the exact same extent and spatial resolution, and the processed SPI rasters are projected in WGS84 for the 'Visualize' component of the tool.

GPM

Sign up for user name password to be able to download GPM data. In the browser, navigate to

- http://registration.pps.eosdis.nasa.gov/registration/
- ftp://arthurhou.pps.eosdis.nasa.gov/

OpenDap

- http://gpm1.gesdisc.eosdis.nasa.gov/opendap/hyrax/GPM_L3/GPM_3IMERGHH.03/contents.html

TRMM - Old server for "Production" TRMM data. Does not contain GPM data, but may be maintained to preserve access to the popular 3B42RT algorithm.

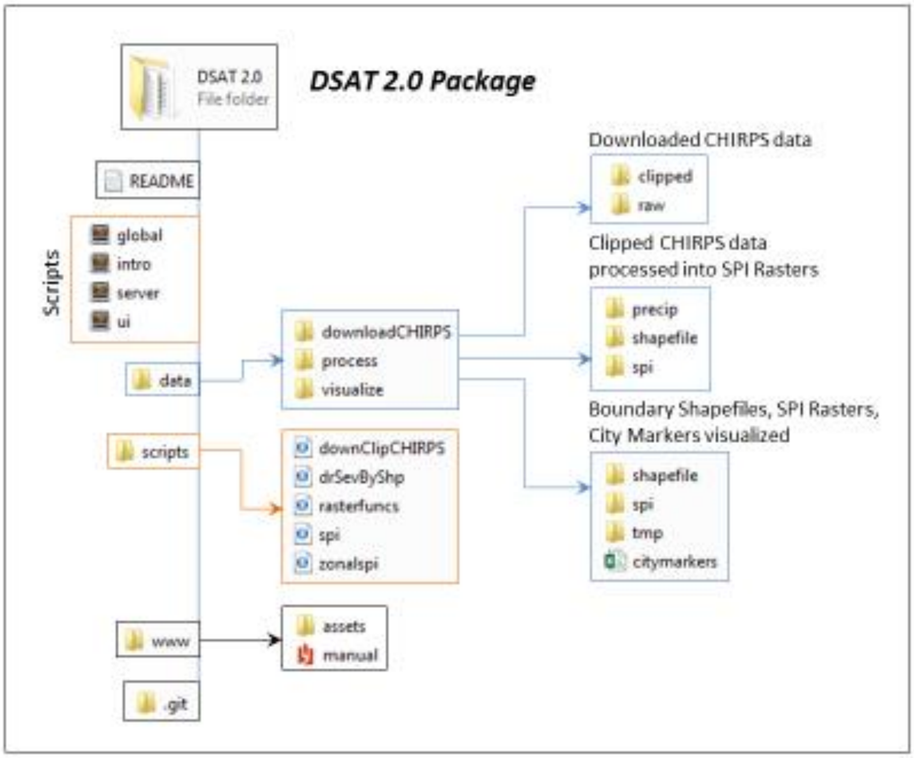
- ftp://trmmopen.pps.eosdis.nasa.gov

d. R libraries used by the tool

ggplot2: https://cran.r-project.org/web/packages/ggplot2/index.html
leaflet: https://cran.r-project.org/web/packages/leaflet/index.html
lubridate: https://cran.r-project.org/web/packages/lubridate/index.html
raster: https://cran.r-project.org/web/packages/raster/index.html
reshape2: https://cran.r-project.org/web/packages/reshape2/index.html
rgdal: https://cran.r-project.org/web/packages/rgdal/index.html
R.utils: https://cran.r-project.org/web/packages/R.utils/index.html
shiny: https://www.rstudio.com/products/shiny/download-server/
SPEI: https://cran.r-project.org/web/packages/SPEI/index.html
zoo: https://cran.r-project.org/web/packages/zoo/index.html
shinyjs: https://cran.r-project.org/web/packages/shinyjs/index.html
V8: https://cran.r-project.org/web/packages/V8/index.html
devtools: https://cran.r-project.org/web/packages/devtools/index.html

e. Manipulating the file structure

The DSAT folder contains a very specific file structure essential to its operation. Users will not need to access or manipulate any folders or files to use the tool itself.



When the Download CHIRPS is completed, the global CHIRPS monthly precipitation data will be in the folder:
`C:/DSAT 2.0/data/downloadCHIRPS/raw`

The clipped CHIRPS data will be in the folder:
`C:/DSAT 2.0/data/downloadCHIRPS/clipped`

An additional copy of the clipped CHIRPS data (to be used in the Calculate SPI part of the tool) will automatically be placed into:
`C:/DSAT 2.0/data/process/precip`

The Calculate SPI function will output the SPI rasters into the folder:
`C:/DSAT 2.0/data/process/spi`

An additional copy of the outputted SPI rasters (to be used in the Visualize part of the tool) will automatically be placed into:

```
C:/DSAT 2.0/data/visualize/spi
```

f. Installation troubleshooting

There may be two issues associated with the installation process.

First, ensure that the DSAT 2.0 folder has been dragged to the C:/ drive. If not, do so. Then close Rstudio, and restart.

If the problem is not resolved, type into the Console window in the bottom left hand corner of the Rstudio interface:
`.libPaths()[1]`

If the pathname (i.e., the location where the R packages are being installed) is
`C:/Program Files/R/…`
Follow the instructions below to change the package library location:

1. Type `.libPaths()` in the Console, and hit "Enter"

   ```
   >
   > .libPaths()
   ```

2. Copy the pathname beginning with (including the quotation marks)
   `"C:/Users/…"`

   ```
   > .libPaths()
   [1] "C:/Users/      /Documents/R/win-library/3.3" "C:/Program Files/R/R-3.3.0/library"
   >
   ```

3. Paste the pathname in line 4 of the open.R code so that it reads
   `myPath <- "C:/Users/…"`

   ```
   open.r*
   ##Open App
   setwd("C:/DSAT 2.0")

   myPath <- "C:/Users/      /Documents/R/win-library/3.3"
   toInstall <- c("devtools",
                  "R.utils",
                  "rgdal",
   ```

4. Press Ctrl+S on the keyboard to save these changes to the file
5. Click "Run App", and continue following the instructions detailed in "B. Opening the DSAT".