Drought Severity Assessment Tool DSAT 1.0

USER MANUAL

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I. Introduction

The **Drought Severity Assessment Tool 1.0 (DSAT)** is a decision support tool created for the Navajo Nation to allow water managers to generate Standardized Precipitation Index (SPI) values specific to chosen boundaries within the Nation. The tool was created by the NASA DEVELOP Climate Team in 20 weeks during the Spring and Summer of 2015 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.

$$\mathbf{SPI} = \frac{\underline{(X_i - X)}}{\sigma}$$

X*i* = 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.

IV. Installation

A. Software Requirements

The DSAT requires the following programs to run:

- **R version 3.2.4**
- **Rstudio**
- **Necessary R packages**

***Note: tested operating systems:** Windows 8

R 3.2.4

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 3.2.4. It is available for download through:

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


R-3.2.4 for Windows (32/64 bit)

Download R 3.2.4 for Windows (62 megabytes, 32/64 bit)
Installation and other instructions
New features in this version

If you want to double-check that the package you have downloaded exactly matches the package distributed by R, you can compare the md5sum of the .exe to the true fingerprint. You will need a version of md5sum for windows: both graphical

Frequently asked questions

- How do I install R when using Windows Vista?
- How do I update packages in my previous version of R?
- Should I run 32-bit or 64-bit R?

Please see the R FAQ for general information about R and the R Windows FAQ for Windows-specific information.

Other builds

- Patches to this release are incorporated in the r-patched snapshot build.
- A build of the development version (which will eventually become the next major release of R) is available in the r-devel snapshot build.
- Previous releases

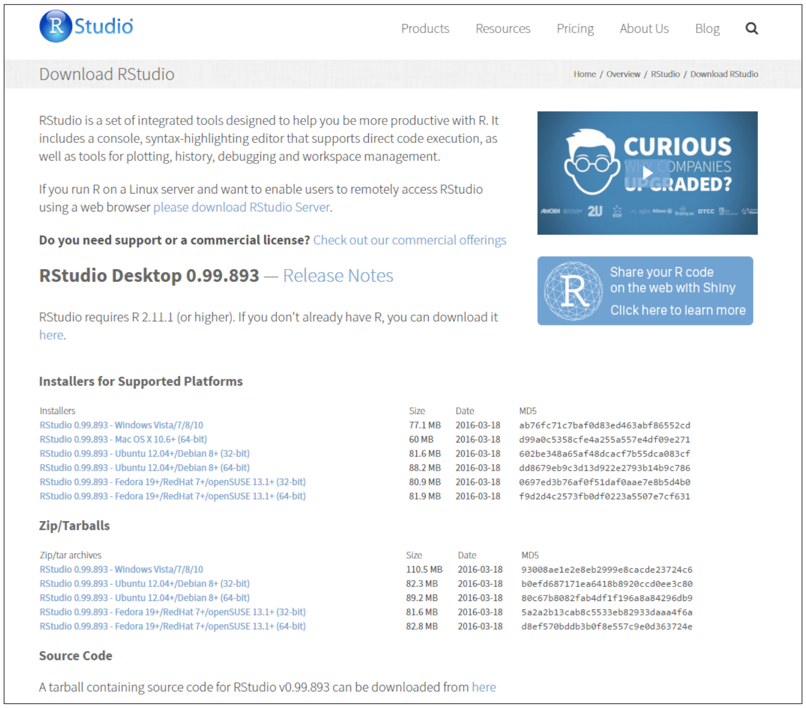
Note to webmasters: A stable link which will redirect to the current Windows binary release is
<CRAN MIRROR>/bin/windows/base/release.htm.

Last change: 2016-03-17, by Duncan Murdoch

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.

B. Opening the DSAT

DSAT Package

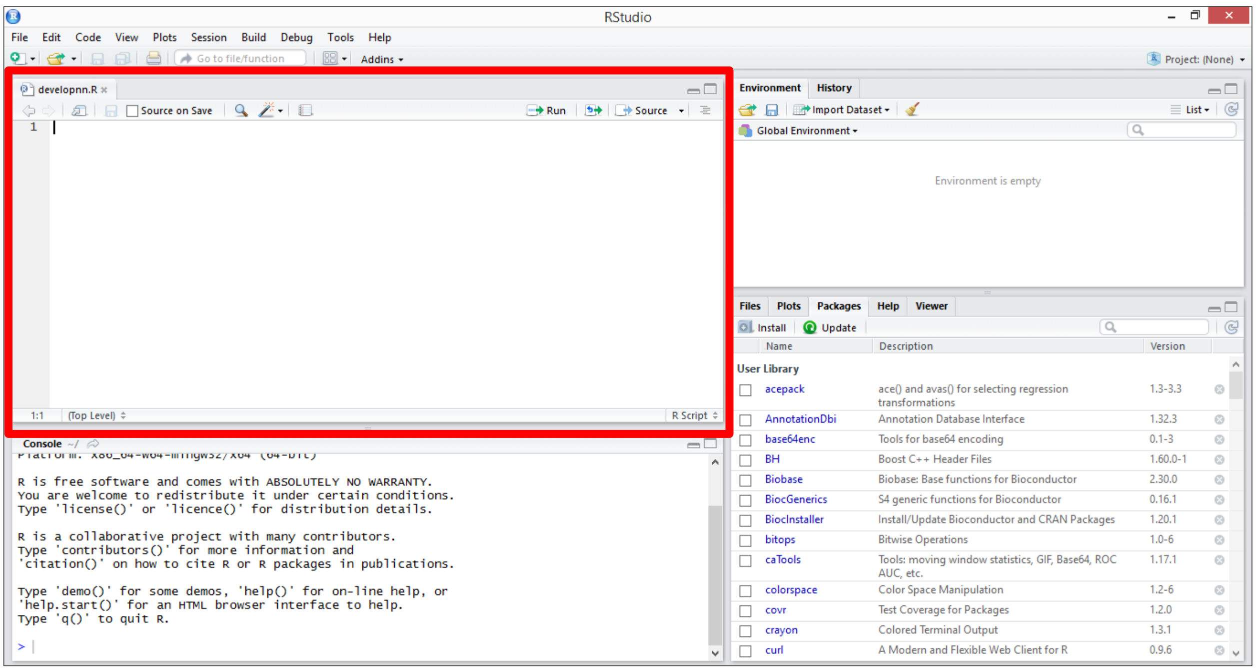
To use the DSAT (after R and R Studio have been installed) complete the following steps:

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

2. **Open the README text file** and make sure that you understand all of the points. ***This is very important to running and operating DSAT 1.0.***

3. **Open** the Rstudio console.

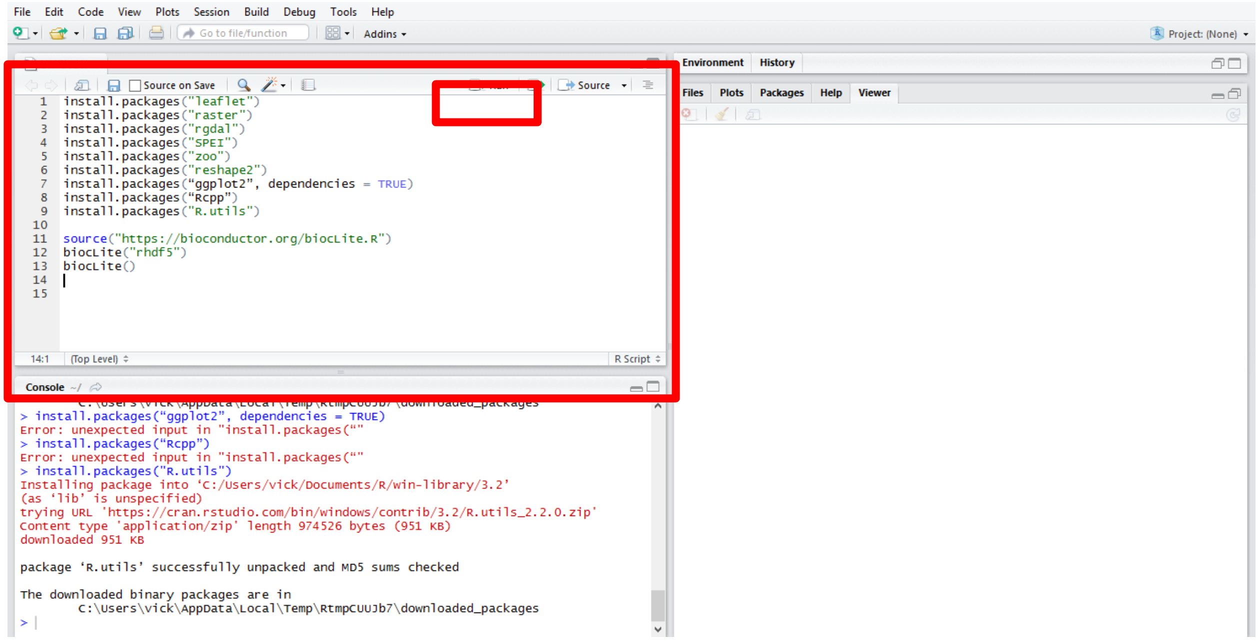
4. **Rstudio source editor.** Locate the Rstudio source editor in the **<u>top left hand corner</u>**. This is where the user will write (copy and paste) commands.



5. **Install necessary packages.**

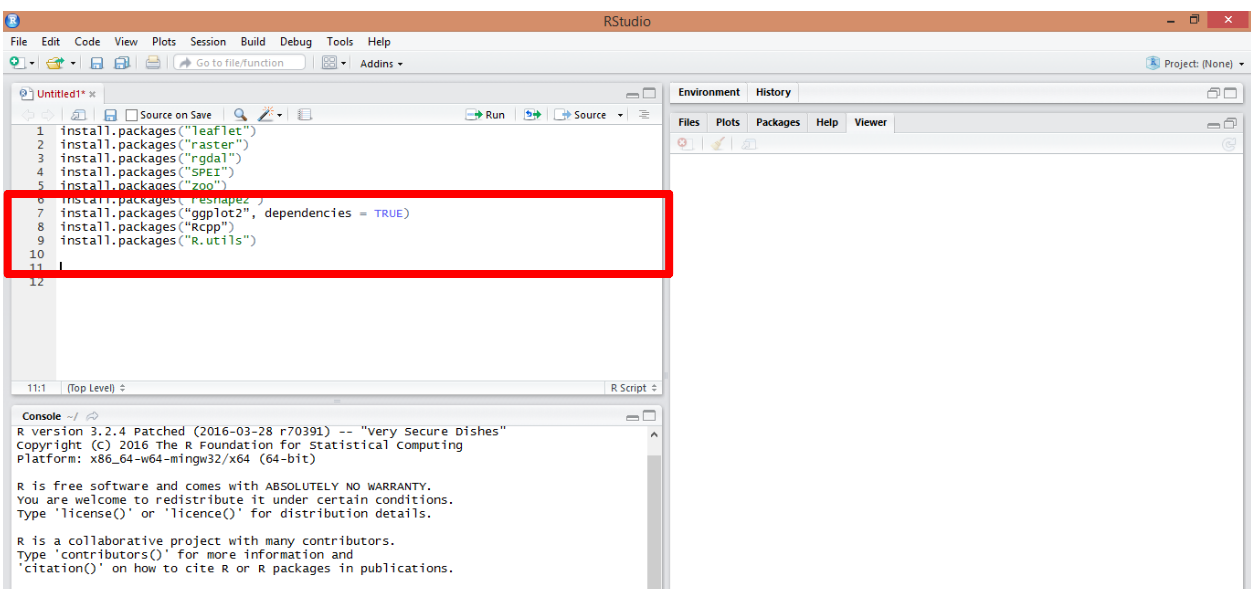
   4.1 Open the '**OpenDSAT.r**' file (C:/DSAT/OpenDSAT.r) in Rstudio. This file should appear in the source editor. Highlight the list of packages to install and hit 'Run' in the top-right corner of the source editor. *Please note: in order to satisfy the NASA Software Release Authority, the packages could not be automatically installed.*

```
install.packages("leaflet")
install.packages("raster")
install.packages("rgdal")
install.packages("SPEI")
install.packages("zoo")
install.packages("reshape2")
install.packages(“ggplot2”, dependencies = TRUE)
install.packages(“Rcpp”)
install.packages("R.utils")
```



4.2 Following the instructions in the '**OpenDSAT.r**' file, highlight the following and press 'Run':

```
source("https://bioconductor.org/biocLite.R")
biocLite("rhdf5")
biocLite()
```



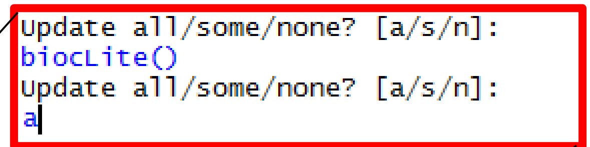
4.3 Rstudio will go through each line and installs the necessary packages. The user can now progress in the Console window in the bottom left.

The user will see a progress bar progress until it has finished installing the necessary packages.

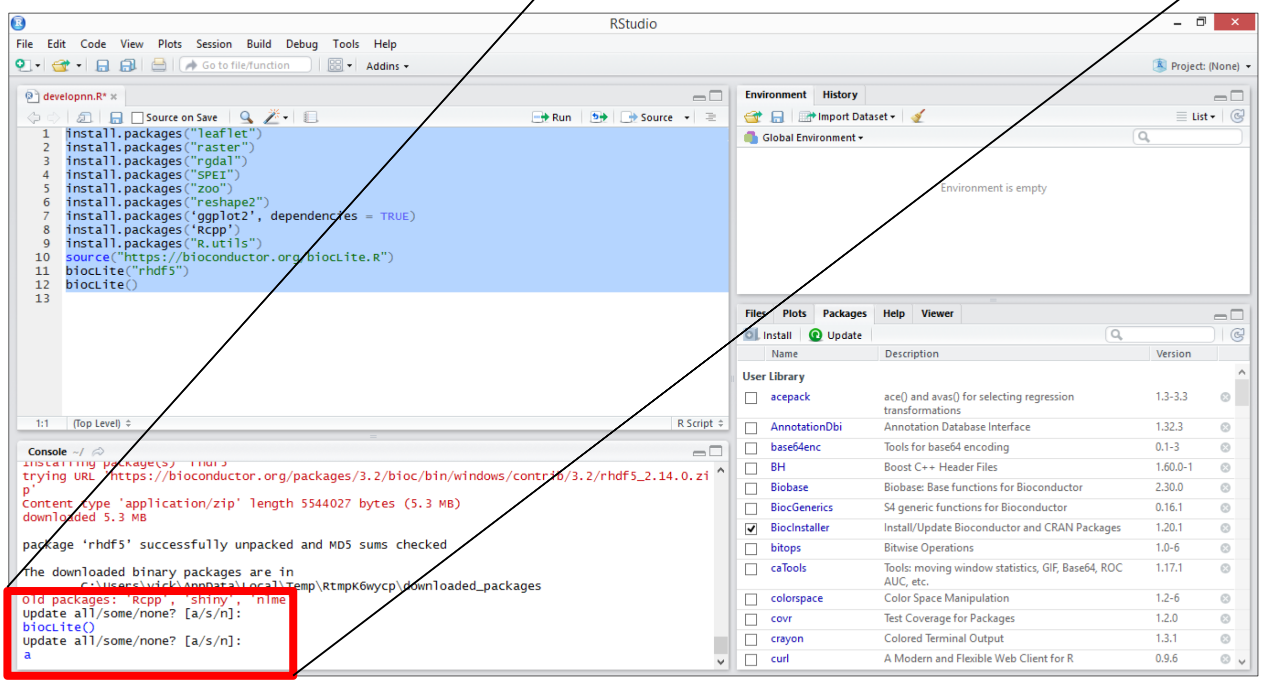
Once the packages are installed, a message in the Console will appear:
"Update all/some/none? [a/s/n]:

In the console, type:

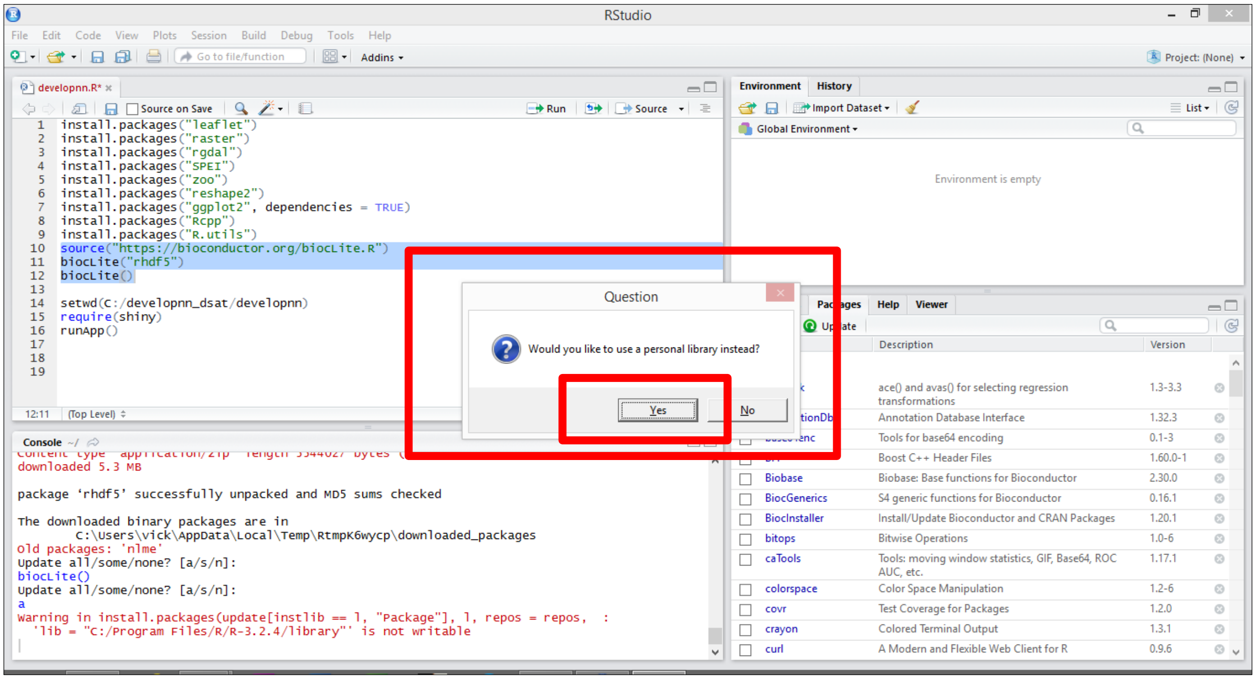
a



And press **Enter** on the keyboard.



When it prompts to install on your personal library, click "**Yes**." This will download the last packages.



4.4 Once all of the packages are installed, the Console will show no more activity. The tool is ready to run.

Following the instructions in the '**OpenDSAT.r**' file, highlight the following and click 'Run'. (Note that in R what would normally be a backslash in the filepath is changed to a forward slash):

```
setwd("C:/file_name")
require(shiny)
runApp()
```

After a couple minutes, a new window should open displaying the DSAT user interface.

There are common errors that have been encountered. See Appendix F for work arounds.

TIP: How to stop and resume the tool

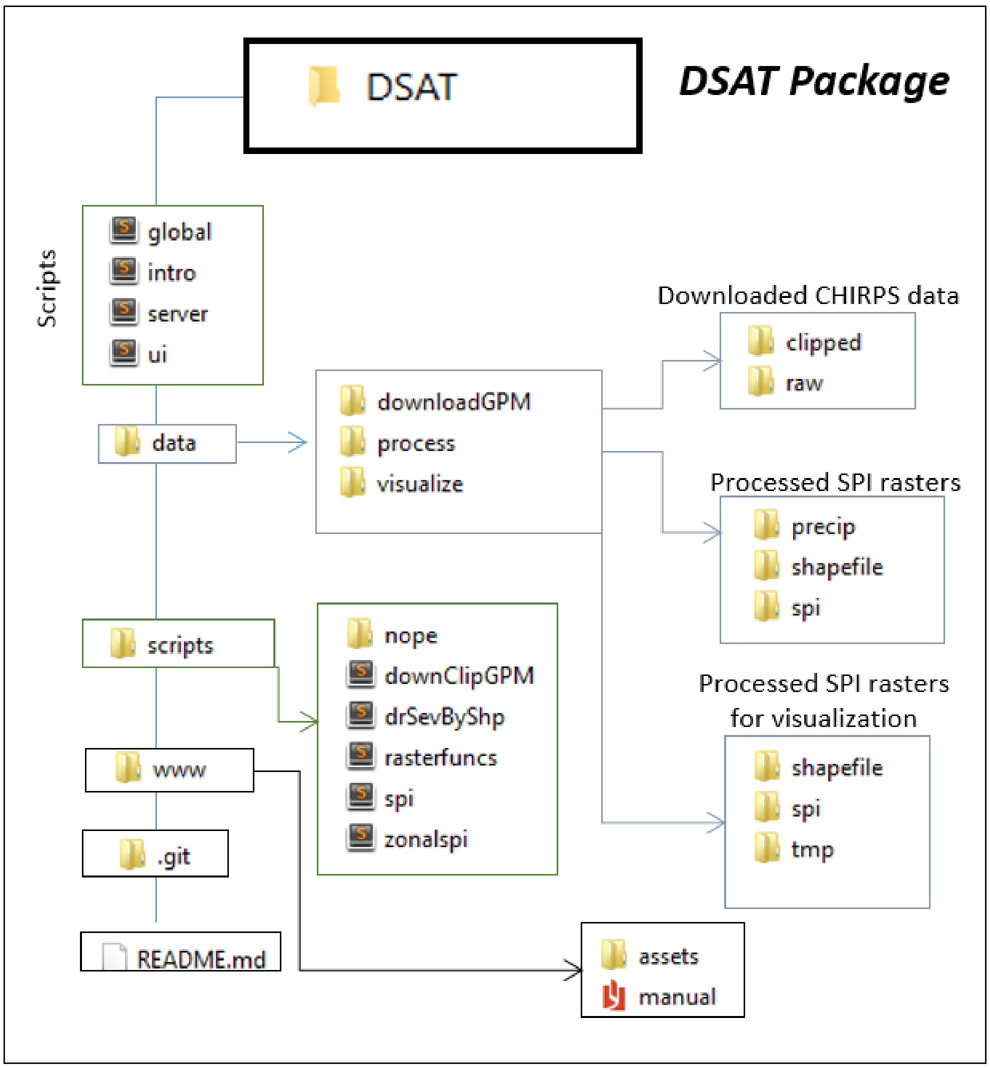
At any time, the DSAT session can be canceled. Either click the X button in the upper right corner, or go to the Rstudio Console and press the "esc" button on the keyboard. This will exit the viewer and stop the DSAT.

To resume, either **type "runApp()" in the console**, or highlight it in the source editor and press "Run."

V. DSAT File Structure

The DSAT folder contains a very specific file structure essential to its operation. Users will need to access specific folders to add/transfer different data for wanted results.

Please refer to Appendix E before proceeding and as a reference for necessary file manipulation.



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:	Units:
0.05 degree	mm/month

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.

VII. The Drought Severity Assessment Tool

An overview of the three main functions of the DSAT:

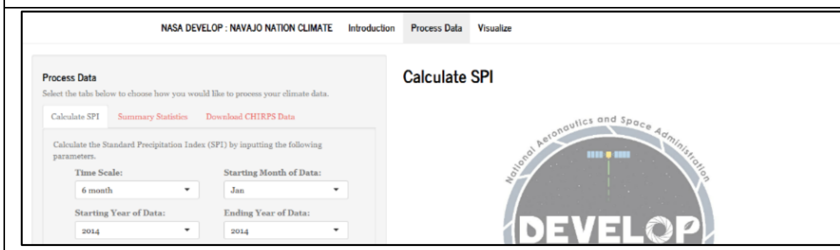
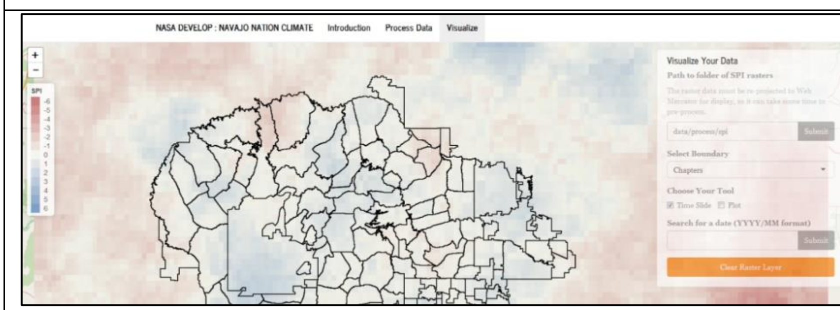
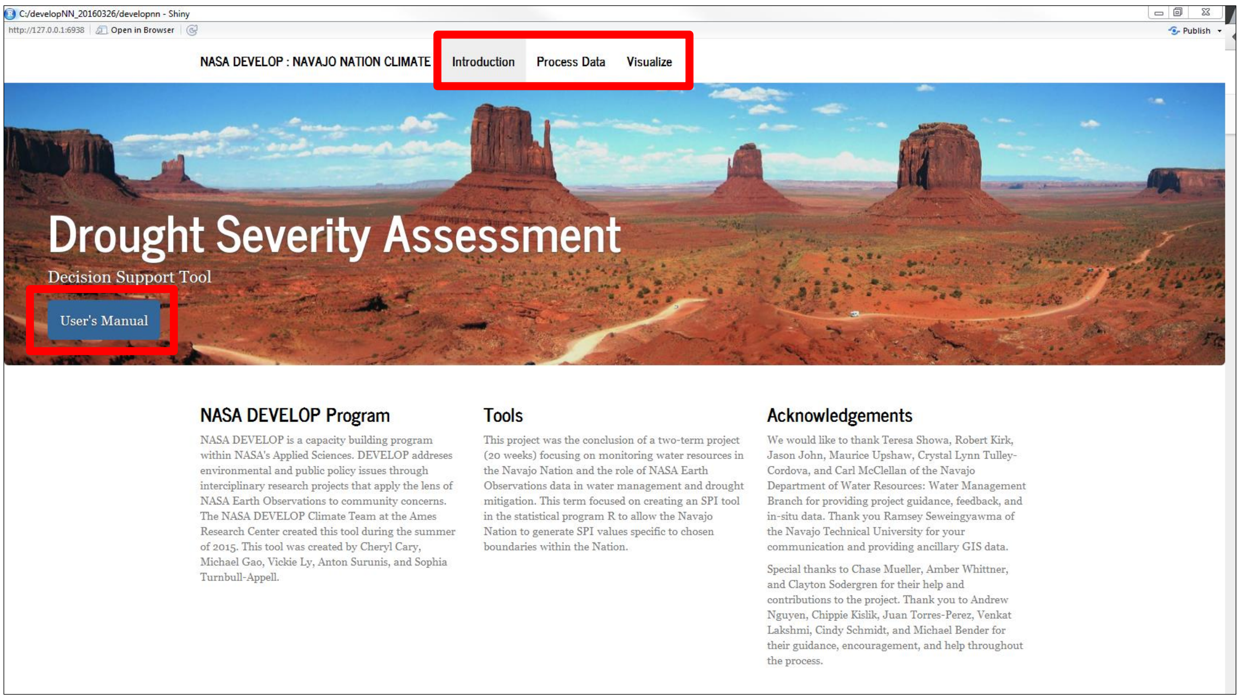
User Interface	Functions
	**Introduction** This is the opening page that links to a 'User Manual.'
	**Process Data** In this section, the user can do three things: • Calculate SPI • Summary Statistics • Download CHIRPS data
	**Visualize** The user can visualize the SPI rasters on a web map. Additionally, the user can use the 'Time Scale' to specify the time range and '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:

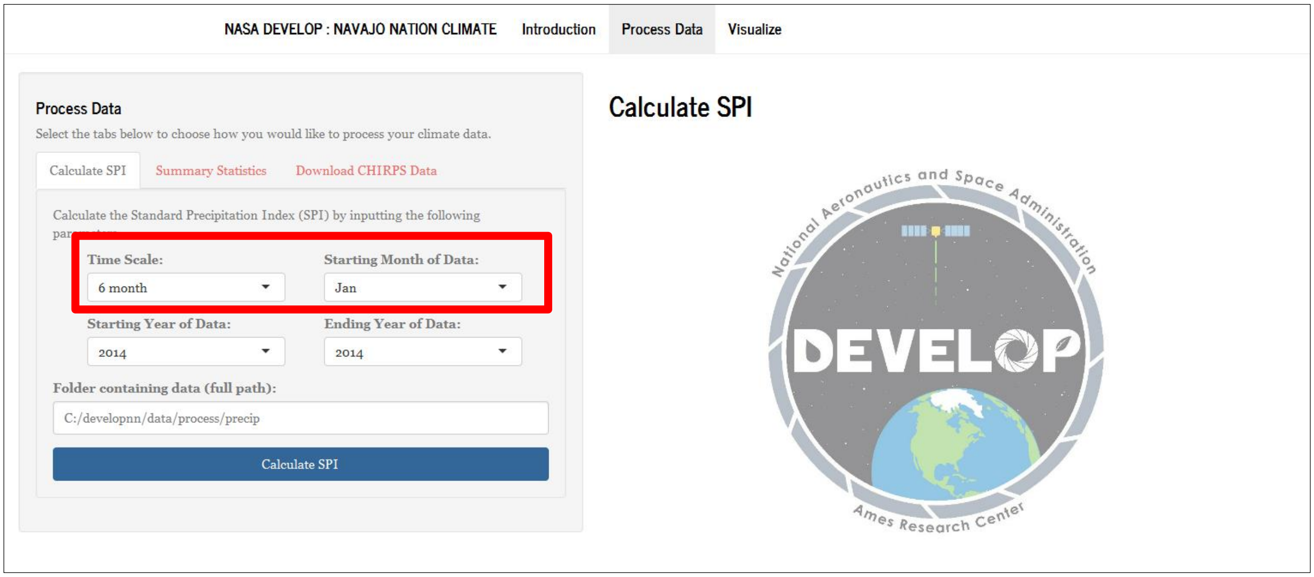
1) **Calculate SPI**
2) **Summary Statistics**
3) **Download CHIRPS**

1. Calculate SPI

The calculate SPI function allows the user to calculate SPI values for each pixel and raster. To start, the user is provided with options to tailor their calculation.

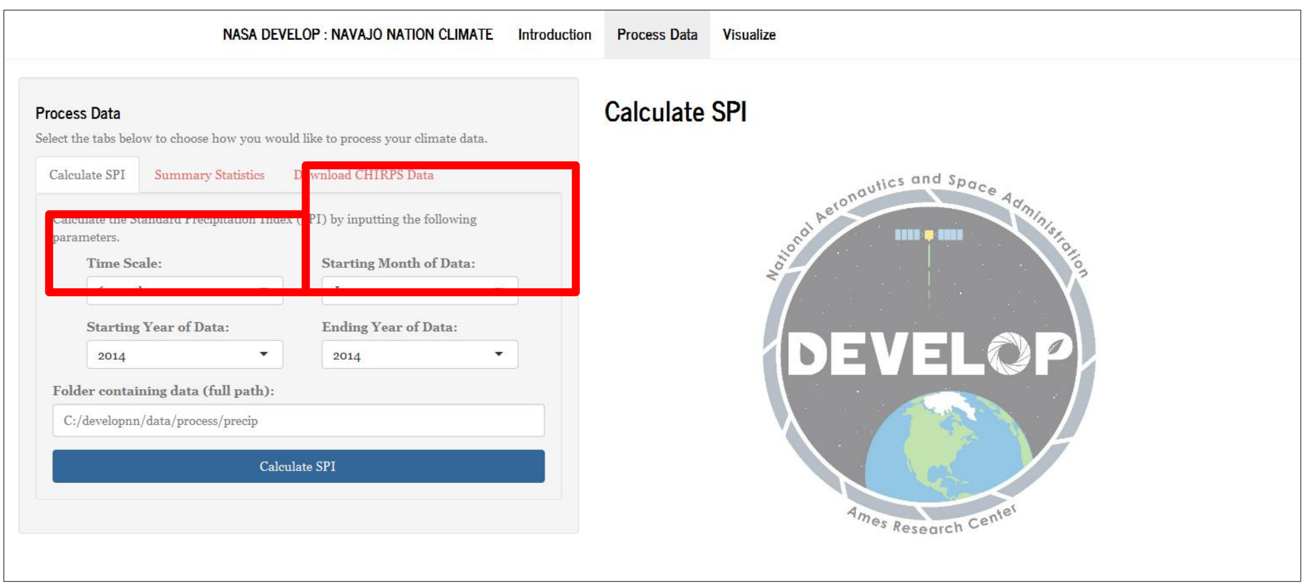
1. Time Scale – Type of SPI

The user first selects which type of SPI they would like to calculate under 'Time Scale.' NOTE: The folder with precipitation data requires at least 30 years of data.



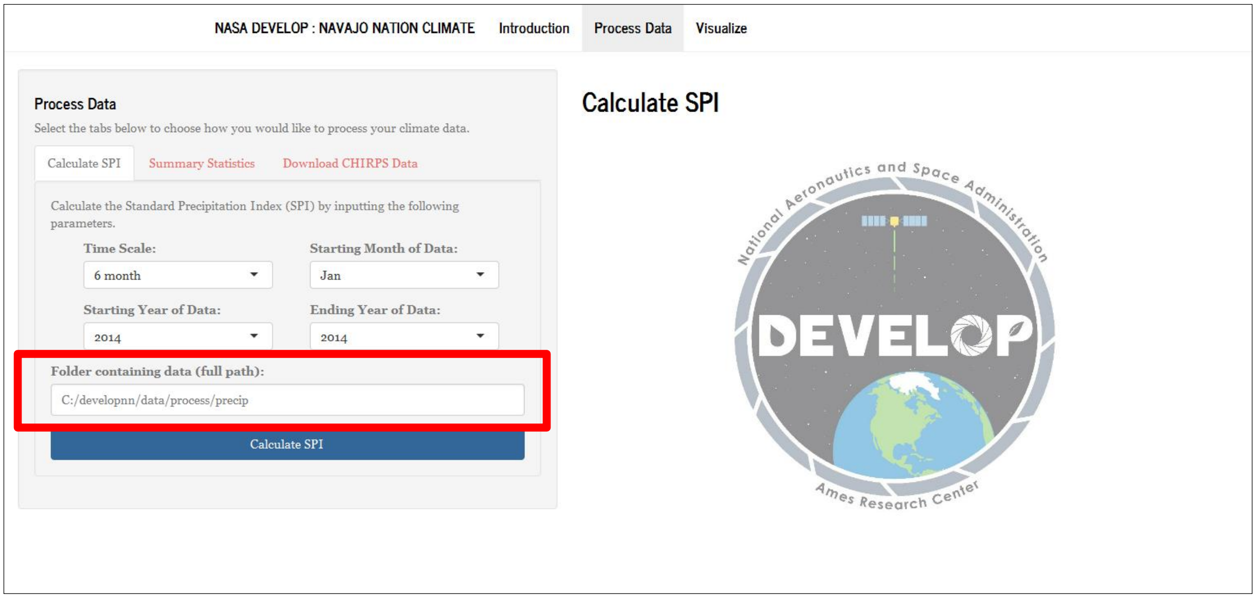
2. **Time Range**

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



3. **File Path to Precipitation Data, and Go!**

Finally, the user selects the folder containing all the precipitation data to be used in the SPI calculation. The clipped CHIRPS precipitation data must be copied and pasted into the appropriate file for this function to operate:
C:/file_name/**data/process/precip/**



Output:

The output calculated SPI rasters are created by the tool, and output into:
C:/file_name/**data/process/precip/spi**

* **Note:** the selection of date *will not* choose a subset of rasters from the available data within the selected folder. This date range is used purely in the SPI calculation to place the input data correctly in time. It is important the number of rasters within the selected folder match the number required for the selected date range. If this condition is not met, the program will generate an error.

2. Summary Statistics

The Summary Statistics tab uses calculated SPI rasters to generate and view summary statistics for each month's SPI raster within the time range of a specified boundary, such as Navajo Nation political boundaries, USGS watersheds, and EPA Level III and IV ecoregions.

The user must be sure the filepaths containing the precipitation data and the chosen shapefile are correct. When the shapefile is chosen, a dropdown menu will appear containing attribute choices, which will act as the summary area, the user must choose from in order for the calculation to operate.

Boundaries other than the above stated can be used by adding shapefiles to the *data/process/shapefile* folder. In order for the statistics to be calculated correctly the boundary projected coordinate system must be the same as the precipitation data.

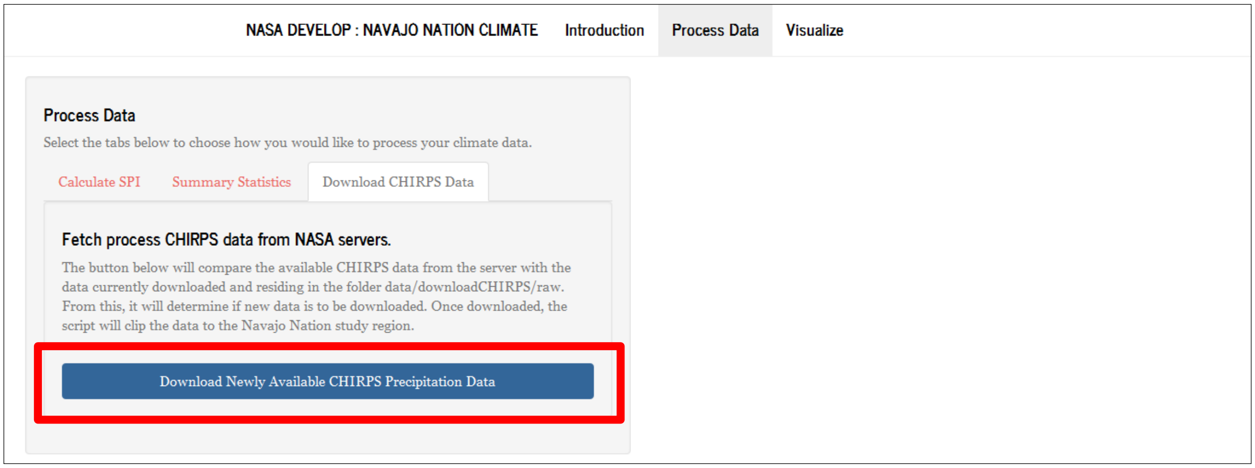
File Path containing Precipitation Data

3. Download CHIRPS

The Download CHIRPS 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 user specified study area.

1. Press the "Download newly available CHIRPS Precipitation Data"
2. The new, clipped CHIRPS data will be found in data/downlaodCHIRPS/clipped

Note that the raw global CHIRPS data is downloaded and stored in the folder data.downloadCHIRPS/raw . These data are approximately 14 MB each. The function looks to the raw folder to assess what new files it needs to download, so it is suggested that the user leave these files in the folder after download.



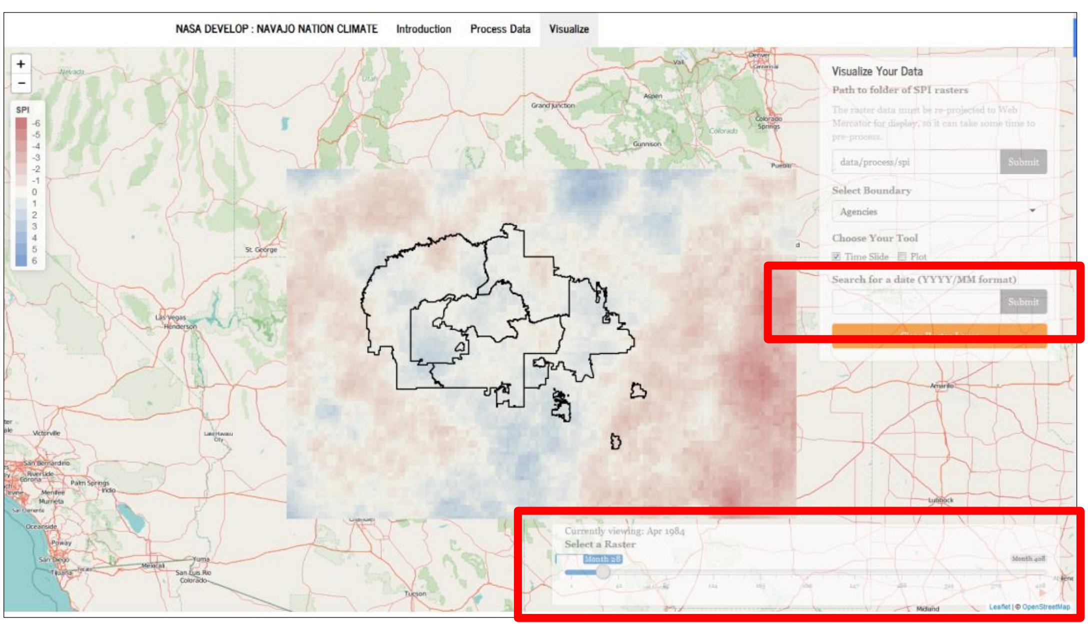
C. Visualize

The Visualize tab allows the user to see the SPI rasters on a webmap, and explore the **Time Plot,** and **Plot Analytics** functions. To use these features:

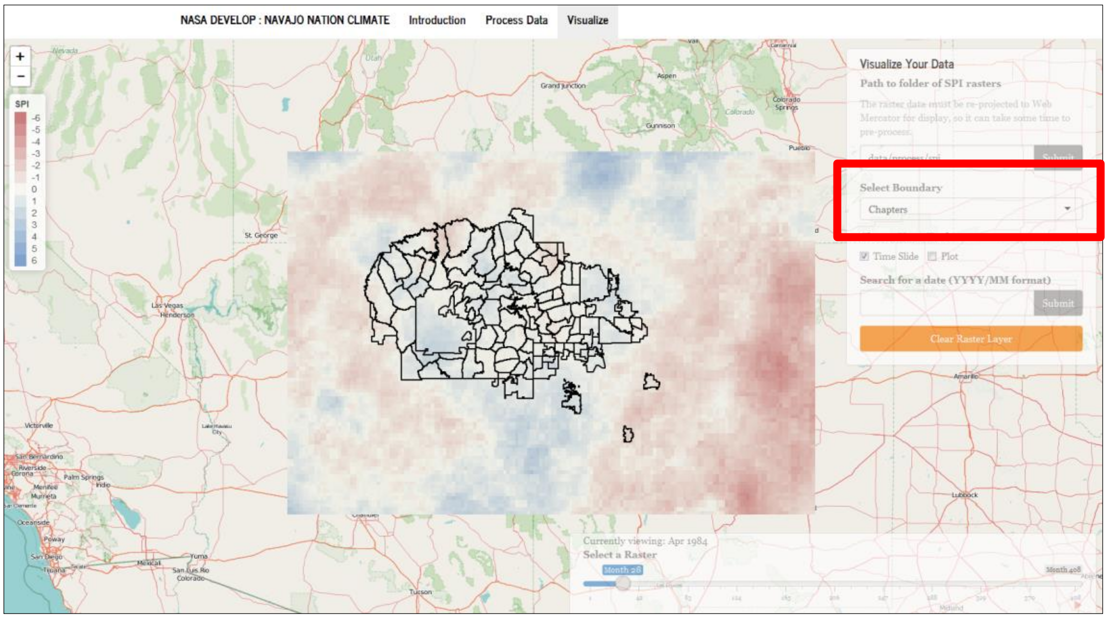
1. Ensure that the filepath seen in the "Visualize Your Data" box to the right of the window holds the calculated SPI Rasters
2. Select the appropriate boundary
3. Click "Submit"

Time Plot

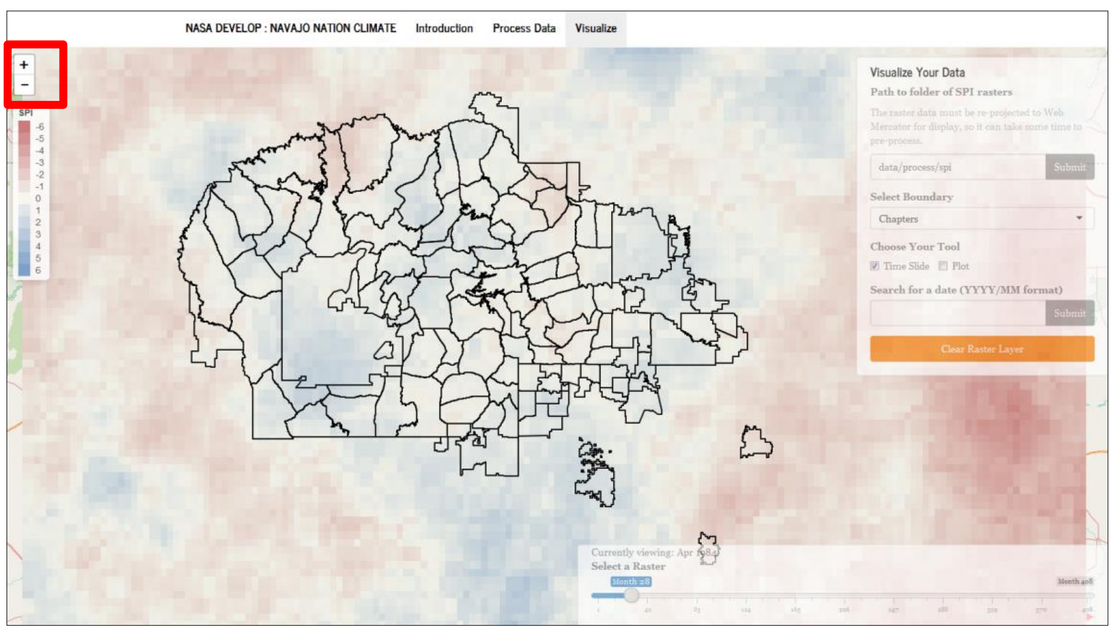
Under "Choose Your Tool," choose "Time Slide." Slide to the date (YYYY/MM) to the time of interest. A date of interest (YYYY/MM) can also be typed in the "Visualize Your Data" box. This will display the calculated SPI rasters on the map.



The SPI rasters are visible overlain by different boundaries, including **Agency, Chapter, Watershed, and EPA Ecoregions level III and IV.** New boundary shapfiles can be loaded into the file structure (C:/file_name/data/visualize/shapefile) and viewed overlaying the SPI rasters.

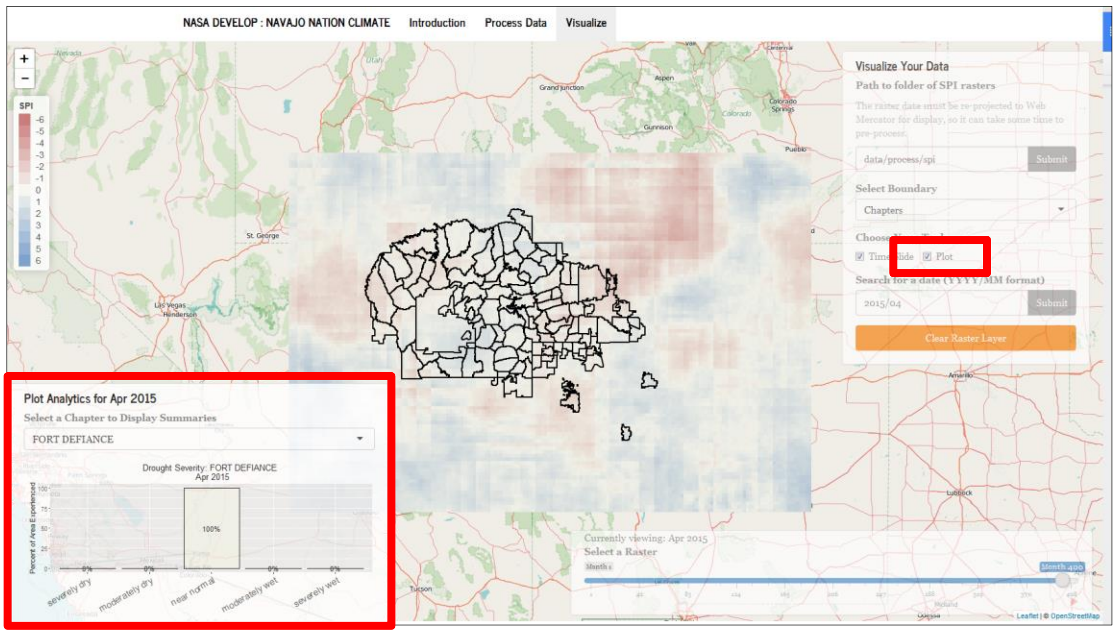


Use the zoom in/zoom out tool on the left-hand side to get a closer look.



Plot Analytics
Under the “Choose Your Tool” tab, select ‘**Plot’**. A window with the Plot Analytics will load in the lower left hand corner, as shown highlighted below in red.

Using the ‘**Plot’** feature, the user can see the precipitation anomaly experienced by each boundary for the month selected.



Please note that the Time Slide and Plot analytics tool boxes are able to be moved around the screed for viewing ease

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, or self-drawn polygons) 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

Acknowledgements

We would like to thank Teresa Showa, Robert Kirk, Jason John, Maurice Upshaw, Crystal Lynn Tulley-Cordova, and Carl McClellan 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.

Special thanks to Chase Mueller for his immense help on the last leg of the project. Thank you to Amber Wittner and Clayton Sodergren for contributions to the project. 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.

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

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

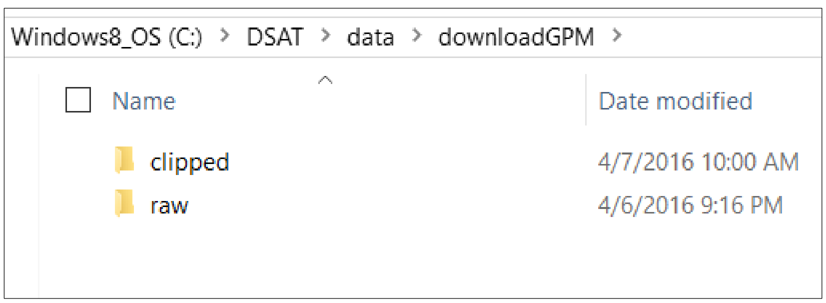
e. Manipulating the file structure

When the Download CHIRPS is completed, the global CHIRPS monthly precipitation data will be in the file:

DSAT/data/downloadGPM/raw

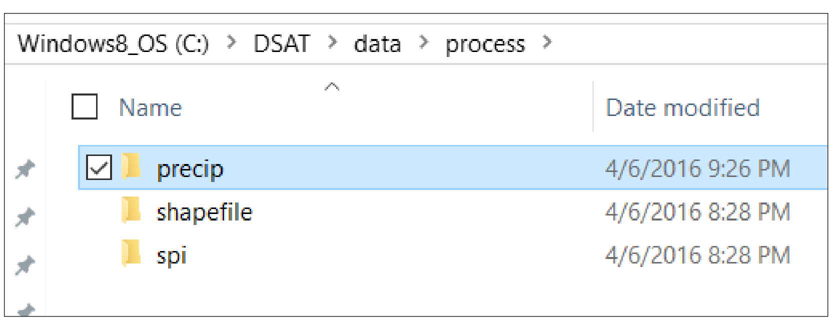
The clipped CHIRPS data will be in the file:

DSAT/data/downloadGPM/clipped



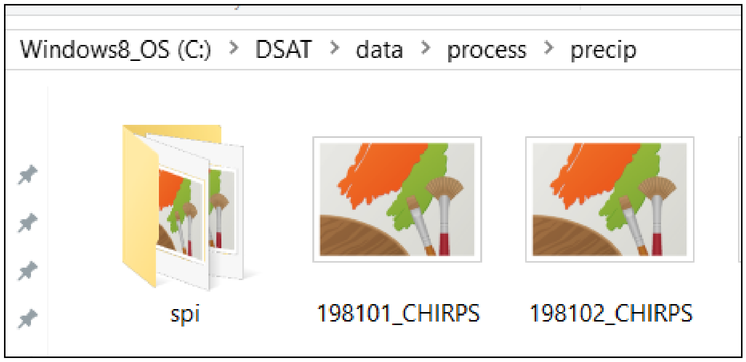
These clipped precipitation files will need to be transferred (either copy and pasted, or cut and pasted) into:

DSAT/data/process/precip



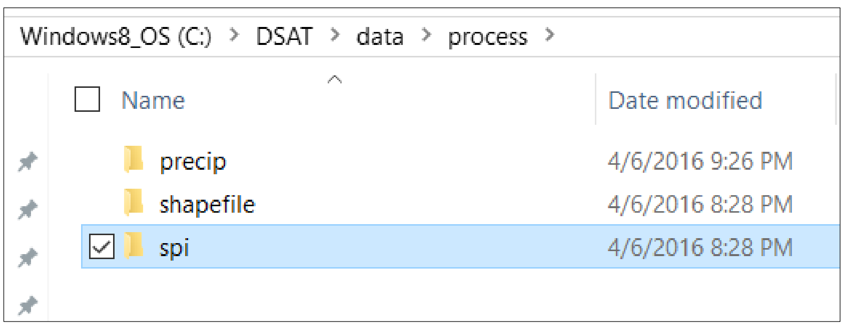
The Calculate SPI function of the tool will output into a folder in the precip folder it creates called spi:

DSAT/data/process/precip/spi



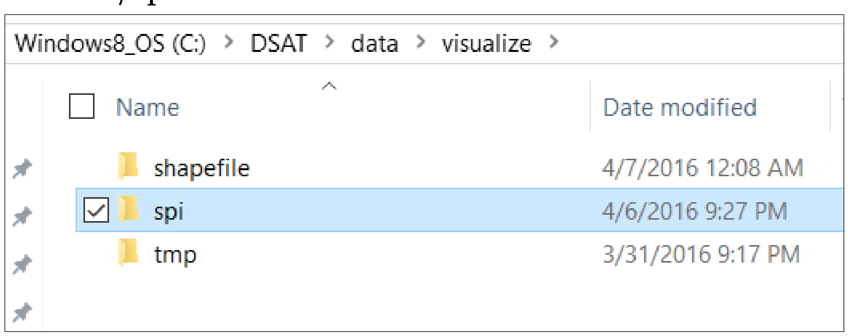
Once the function has run to completion the files in this folder will need to be copied and pasted into:

DSAT/process/spi



And

DSAT/process/visualize/spi



f. Common errors & work-arounds

Error: unexpected input in "setwd(C:/.."

To set the working directory, use the following script. Note the forward slashes:

setwd("C://file_name/file/file")

Error in x[[1]] : subscript out of bounds

A number of things can be going wrong. There can be a file missing from the file structure. An altered script.

Error in shinyAppDir(x) : App dir must contain either app.R or server.R.

Make sure that the working directory is connected to the DSAT package. The working directory can be checked with this function:

```
getwd()
```

and set the working director to a new location with:

```
setwd()
```