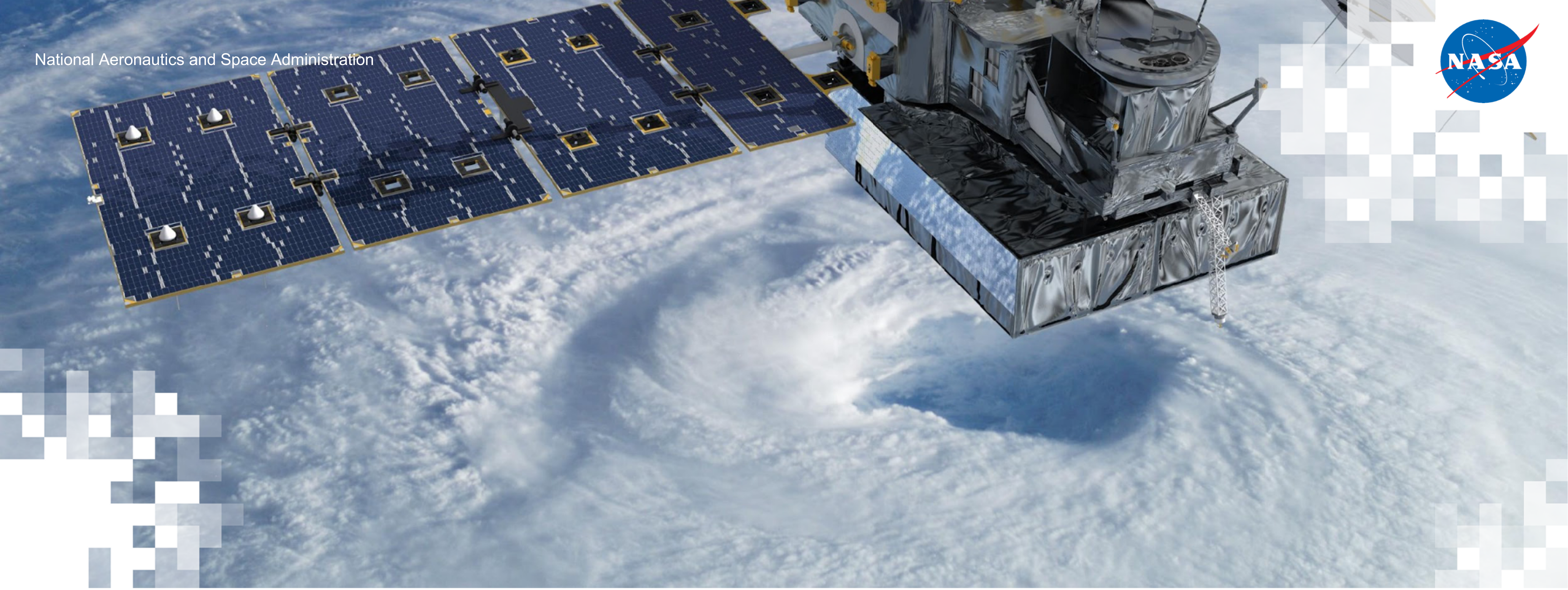


Applications of GPM IMERG[1] Reanalysis for Assessing Extreme Dry and Wet Periods

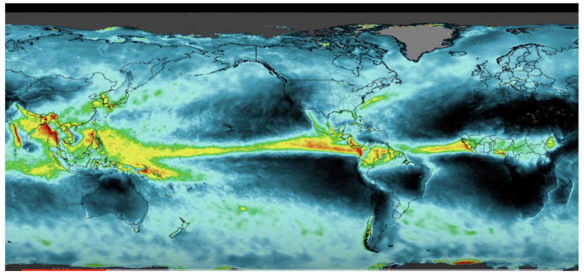
Amita Mehta and Sean McCartney

January 30, 2020

[1]IMERG: Integrated Multi-satellitE Retrievals for Global Precipitation Measurements (GPM)

Training Outline

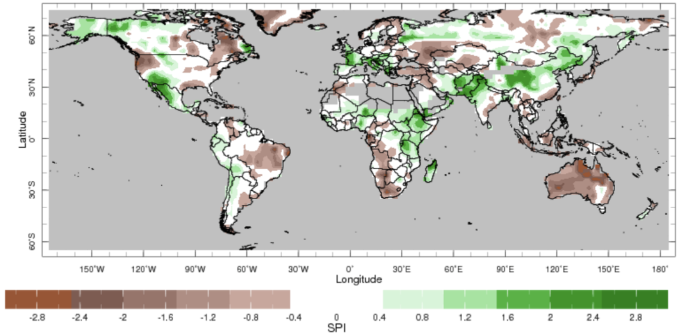
January 28, 2020



Calculation of Precipitation Statistics Using IMERG

https://www.youtube.com/watch?time_continue=9&v=qNlRQgACTFg&feature=emb_title

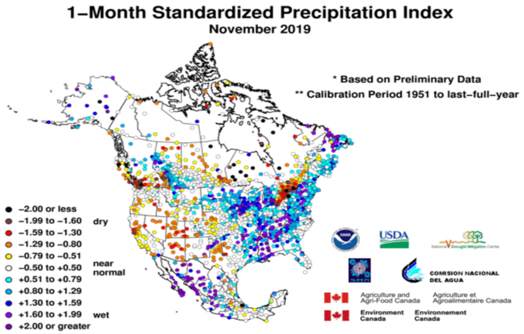
January 30, 2020



Calculation of SPI based on IMERG to Monitor Wet and Dry Conditions

https://iridl.ldeo.columbia.edu/maproom/Global/Precipitation/SPI.html

February 4, 2020



Flood and Drought Risk Assessment Based on IMERG Statistics and SPI

https://www.ncdc.noaa.gov/monitoring-content/temp-and-precip/drought/nadm/indices/spi/maps/ghcnd-na-1mon-spi-dot-pg.gif

Training Format and Certification

- Three 2-hour sessions:
  - Part-1: Presentations and demonstrations of data access and analysis
  - Part-2: Lab time with hands-on, computer-based exercises
- Homework Assignments will be available after all three sessions from: https://arset.gsfc.nasa.gov/water/webinars/IMERG-2020
  - Answers must be submitted via Google Form
  - Due dates: February 11, 18, and 25
- Certificate of Completion will be awarded to those who:
  - Attend all webinars
  - Complete all homework assignments
- You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com

Prerequisites

Attendees that do not complete the required prerequisites may not be adequately prepared for the pace of the training.

- [Fundamentals of Remote Sensing]
- [Overview and Applications of Integrated Multi-Satellite Retrievals for GPM (IMERG) Long-term Precipitation Data Products]

Register on NASA Earthdata

- https://earthdata.nasa.gov/

Install QGIS version 3.x

- https://qgis.org/en/site/

Install Panoply

- https://www.giss.nasa.gov/tools/panoply/

Install Anaconda Python version 3.7

- https://www.anaconda.com/

Windows users only, install Git Bash (or another Bash shell) on your PC

- https://gitforwindows.org/

Objectives

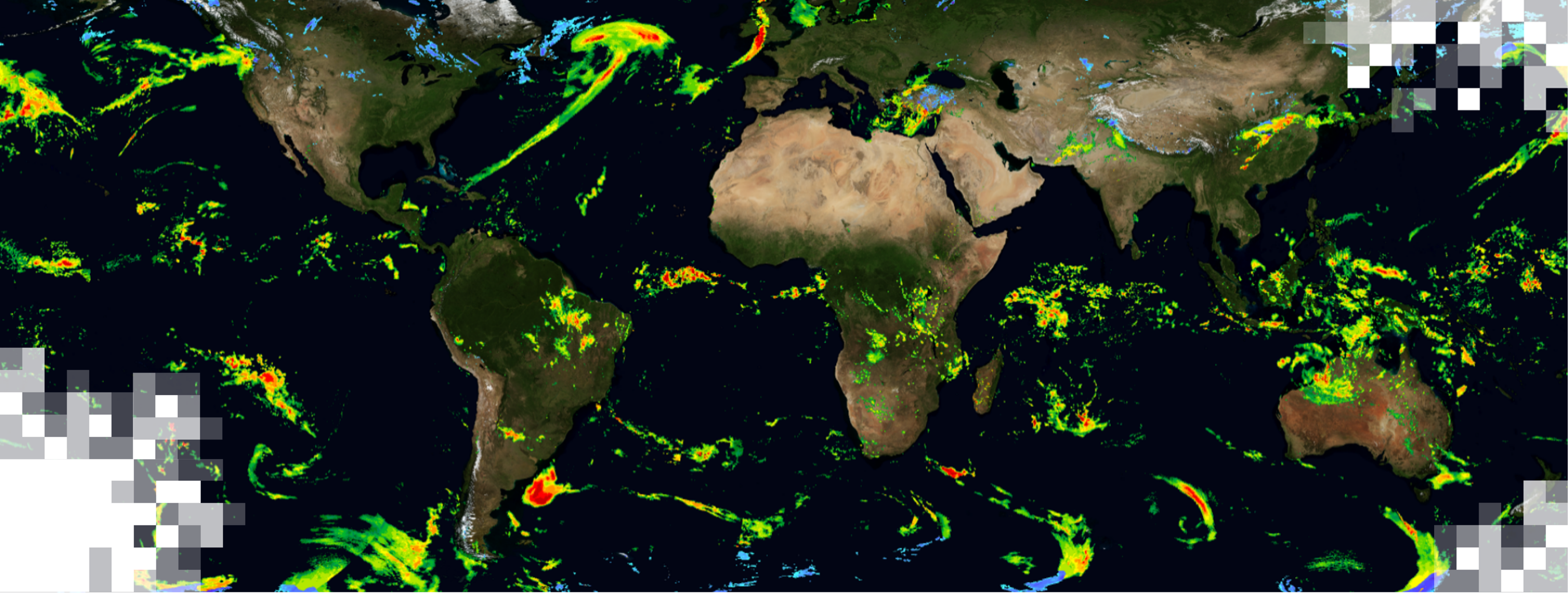
- Learn how to bulk download IMERG data from NASA GES DISC

- Determine how to calculate the Standardized Precipitation Index (SPI) for assessing extreme dry and wet periods

- Interpret the results using Panoply and QGIS

Part-2 Outline

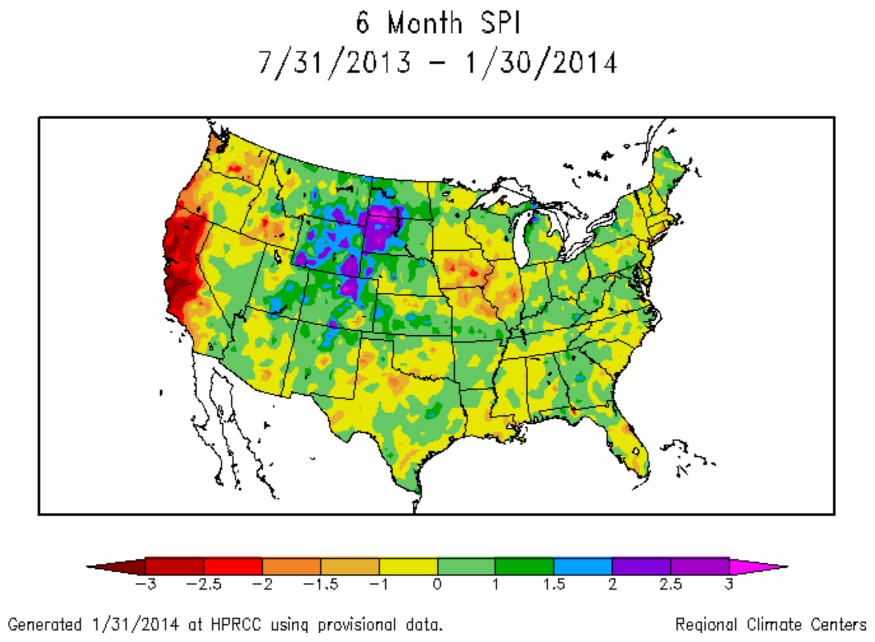
- Background on the Standardized Precipitation Index (SPI)
- Demonstration: Calculation of SPI
  - Case Study: Texas (USA)
  - Bulk download IMERG from NASA GES DISC
  - Preprocess data using NetCDF Operator (NCO)
  - Calculate SPI using Python
  - Interpret the results using Panoply and QGIS
- Exercise: Calculation of SPI as above
  - Case Study: Mozambique



Background on the Standardized Precipitation Index (SPI)

Standardized Precipitation Index (SPI)

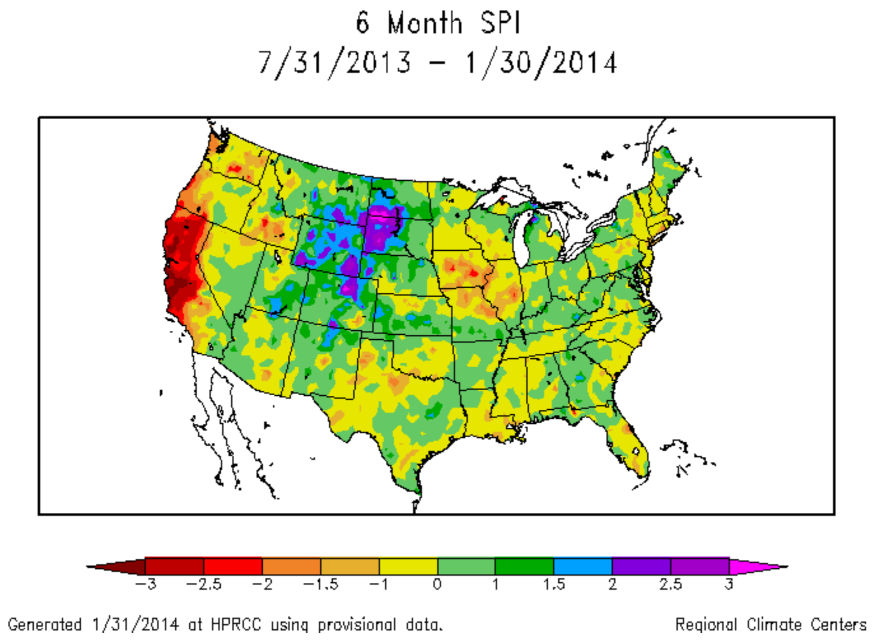
- First developed by T.B. McKee et al. (1993) and used by Guttman (1999)
- Used for estimating meteorological conditions based on precipitation alone
- Wet or dry conditions can be monitored on a variety of time scales from sub seasonal to interannual
- Can be compared across regions with markedly difference climates
- Does not consider the intensity of precipitation and its potential impacts on runoff, streamflow, and water availability



6-month SPI through January 2014 capturing drought in California and extreme wet conditions in Colorado and the Dakotas. Credit: High Plains Regional Climate Center

Standardized Precipitation Index (SPI)

- Expressed as the number of standard deviations from the long-term mean, for a normally distributed random variable, and fitted probability distribution for the actual precipitation record
- SPI values < -1 indicate a condition of drought, the more negative the value the more severe the drought condition. SPI values > +1 indicate wetter conditions compared to a climatology



6-month SPI through January 2014 capturing drought in California and extreme wet conditions in Colorado and the Dakotas. Credit: High Plains Regional Climate Center

SPI Interpretation

https://drought.unl.edu/droughtmonitoring/SPI.aspx

- **1-month:** Similar to a map displaying the percent of normal precipitation for a month. Reflects relatively short-term conditions. Its application can be related closely with short-term soil moisture and crop stress.

- **3-month:** Provides a comparison of the precipitation over a specific 3-month period with the precipitation totals from the same 3-month period for all the years included in the historical record. Reflects short- and medium-term moisture conditions and provides a seasonal estimation of precipitation.

- **6-month:** Compares the precipitation for that period with the same 6-month period over the historical record. A 6-month SPI can be very effective in showing the precipitation over distinct seasons and may be associated with anomalous streamflow and reservoir levels.

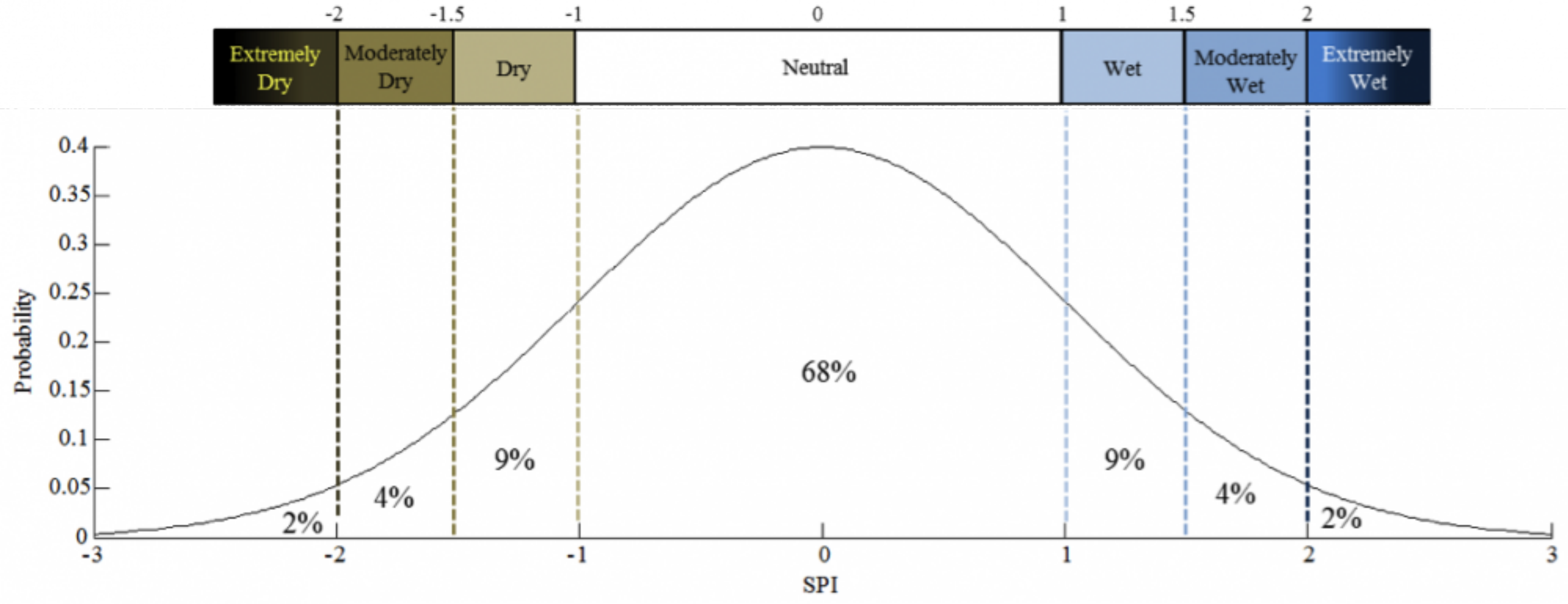
SPI Interpretation

https://drought.unl.edu/droughtmonitoring/SPI.aspx

- **9-month:** Provides an indication of precipitation patterns over a medium time scale. SPI values below -1.5 for these time scales are usually a good indication that significant impacts are occurring in agriculture and may be showing up in other sectors as well.

- **12-month:** Reflects long-term precipitation patterns. Longer SPIs tend toward zero unless a specific trend is taking place. SPIs of these time scales are probably tied to streamflow, reservoir levels, and even groundwater levels at the longer time scales. In some locations of the country, the 12-month SPI is most closely related with the Palmer Index, and the two indices should reflect similar conditions.

SPI Interpretation



SPI labels and their relationship to the normal curve. The intensity implied by each label corresponds to the degree of removal from mean conditions (i.e., SPI=0). The percentages printed within the regions bounded by the dashed lines indicate the probability for SPI values to fall within that region only.
Contributed by J. Keyantash.

References

Guttman, N. B., 1999: Accepting the Standardized Precipitation Index: A calculation algorithm. J. Amer. Water Resour. Assoc.., 35(2), 311-322

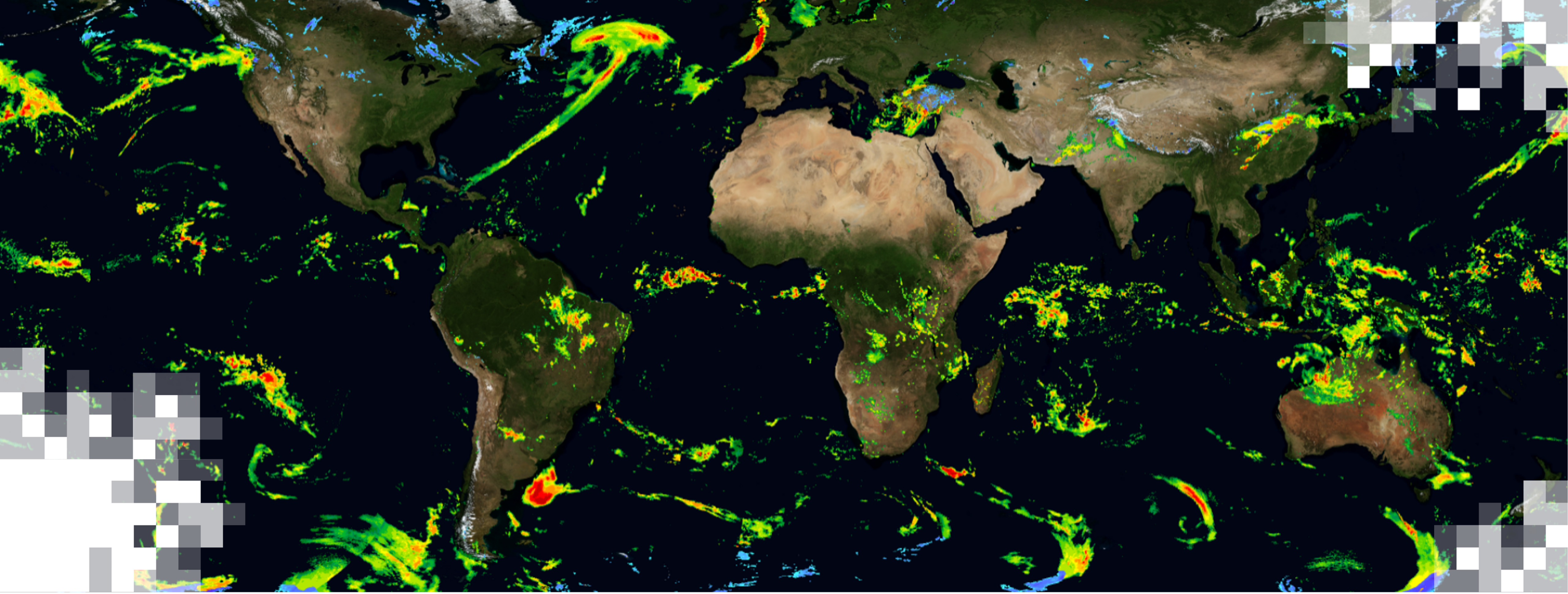
Keyantash, John & National Center for Atmospheric Research Staff (Eds). "The Climate Data Guide: Standardized Precipitation Index (SPI)." Retrieved from https://climatedataguide.ucar.edu/climate-data/standardized-precipitation-index-spi

Lloyd-Hughes, B., and M. A. Saunders, 2002: A drought climatology for Europe. Int. J. Climatol., DOI:10.1002/joc.846

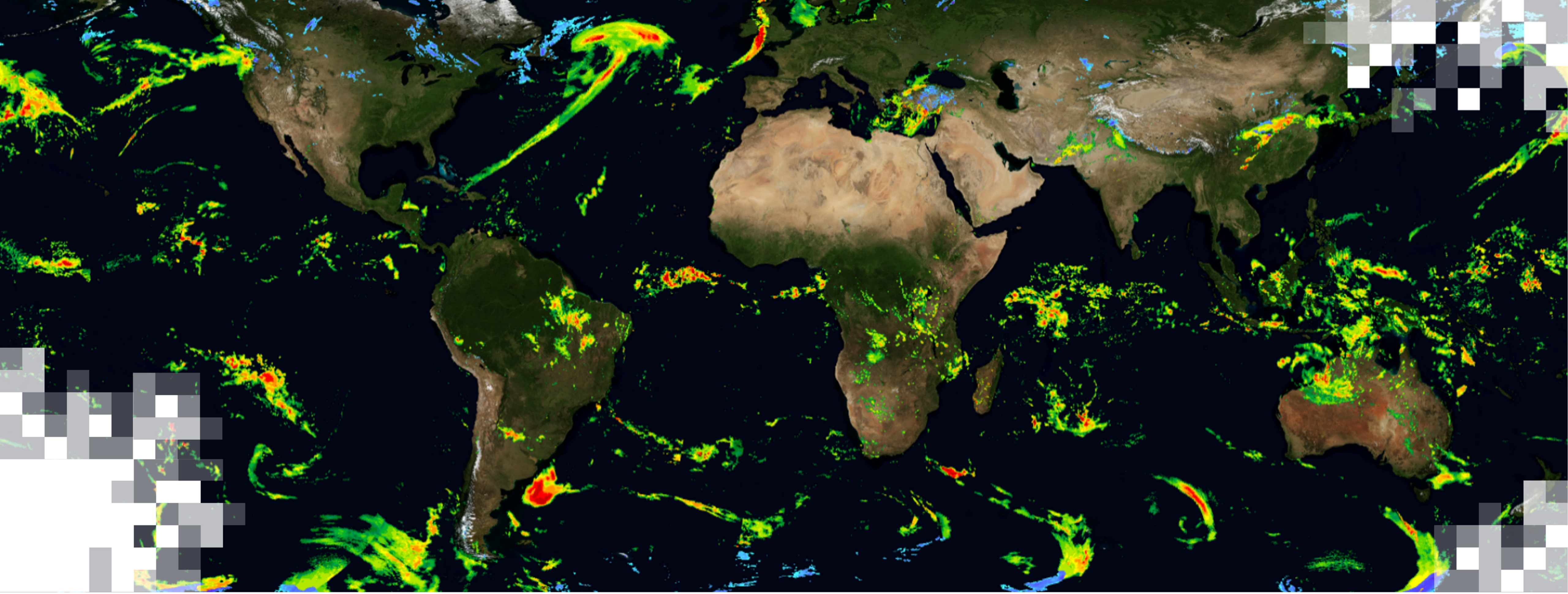
McKee, T.B., N. J. Doesken, and J. Kliest, 1993: The relationship of drought frequency and duration to time scales. In Proceedings of the 8th Conference of Applied Climatology, 17-22 January, Anaheim, CA. American Meterological Society, Boston, MA. 179-18

National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln

World Meteorological Organization (WMO), 2012: Standardized Precipitation Index User Guide



Demonstration: **Calculation of SPI**
Case Study: Texas



Exercise: **Calculation of SPI**
Case Study: Mozambique

Installing Software

If you encounter a problem, please look for a solution online or with your IT department. Due to limited resources, ARSET is not able to further assist you in the installation process.

1. Download and install Anaconda Python version 3.7 on your machine: https://www.anaconda.com/

   https://docs.anaconda.com/anaconda/install/windows/

2. For **Windows users**, download and install Git Bash for Windows: https://gitforwindows.org/

   a) If you have a Bash shell already installed on your Windows OS (e.g. Ubuntu Bash) you can use that for the exercise, but ***it must be*** a Bash shell

3. If you are new to using Bash refer to the following lessons with Software Carpentry: http://swcarpentry.github.io/shell-novice/

Installing Software

4. Using the Bash shell install the NetCDF library on your machine using the conda package manager:

   conda install -c anaconda netcdf4

5. (Bash) Install the NCO package on your machine using the conda package manager:

   conda install -c conda-forge nco

6. (Bash) Confirm where Anaconda and Python were installed:

   where conda

   where python

7. (Bash) Confirm your Python version:

   python --version

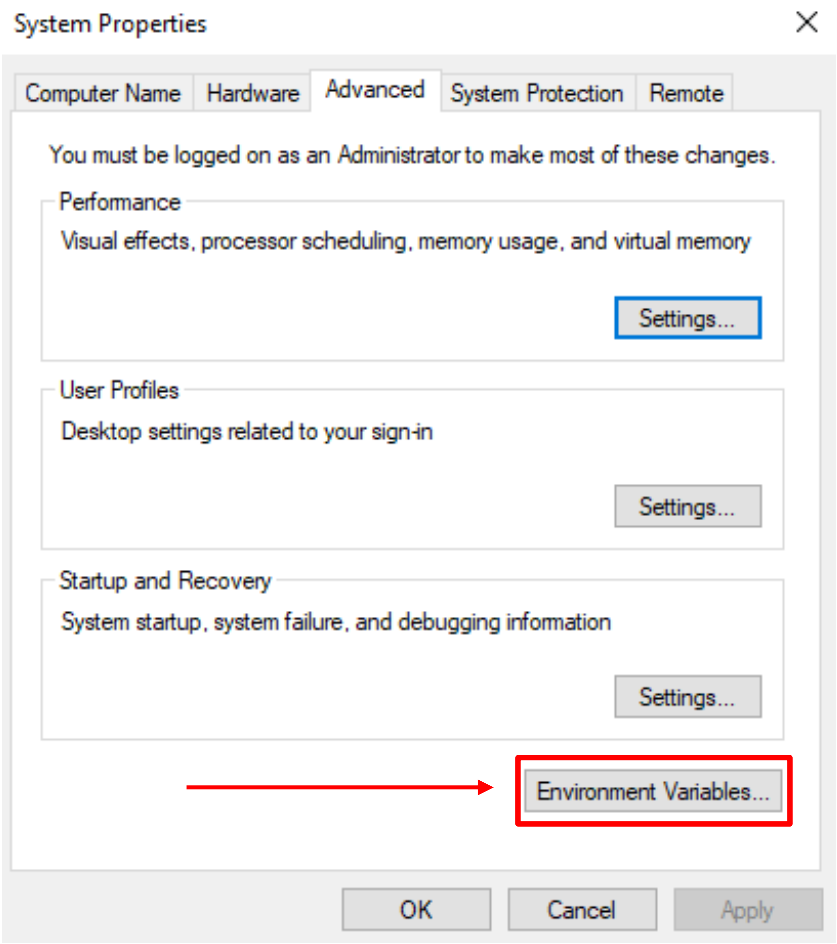
Installing Software

8. This step is for **Windows users only.** ***If you experience error messages running conda packages*** in the exercise, use Environmental Variables to establish a path to Anaconda

   Keep in mind that using this method might mean that you encourage certain applications to conflict with your Anaconda installation

   a) Click on the Start button and type in **environment variable** into the search box. Click on **Edit the system environment variables**

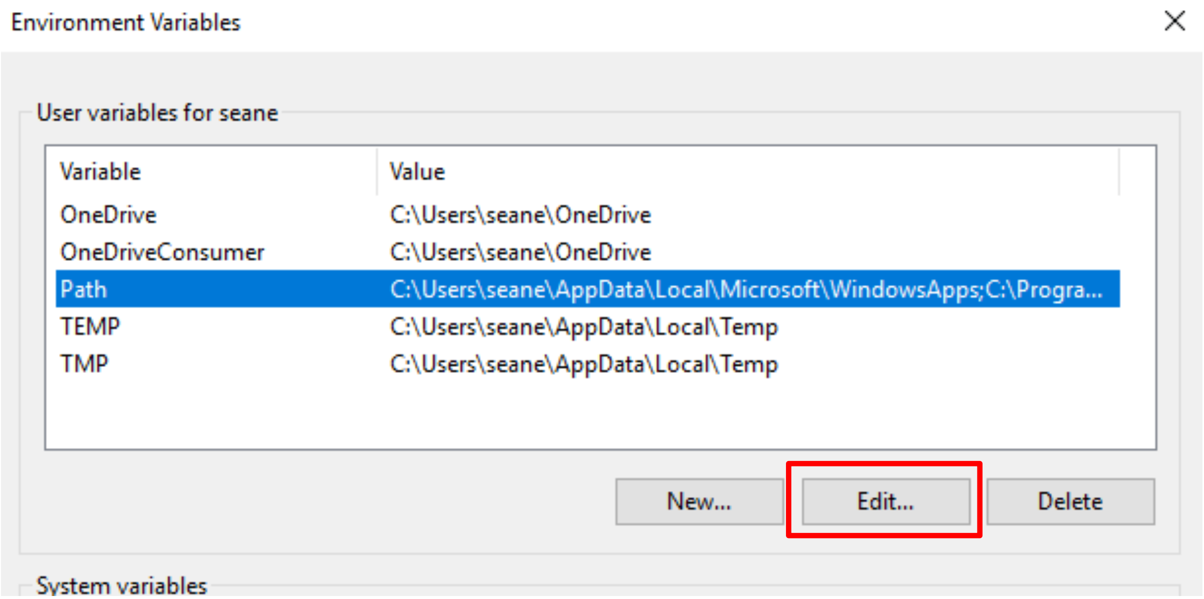
   b) This will open the **System Properties** dialog to the **Advanced** tab. Click on the **Environment Variables** button at the bottom



Installing Software

c) A window will appear with the Environment Variables dialog as shown below in Windows 10. It looks a bit different in Windows 7, but it works the same way. The dialog is split in two: the top for user variables and the bottom for system variables

d) Under "User variables" left-click on Path and select Edit…



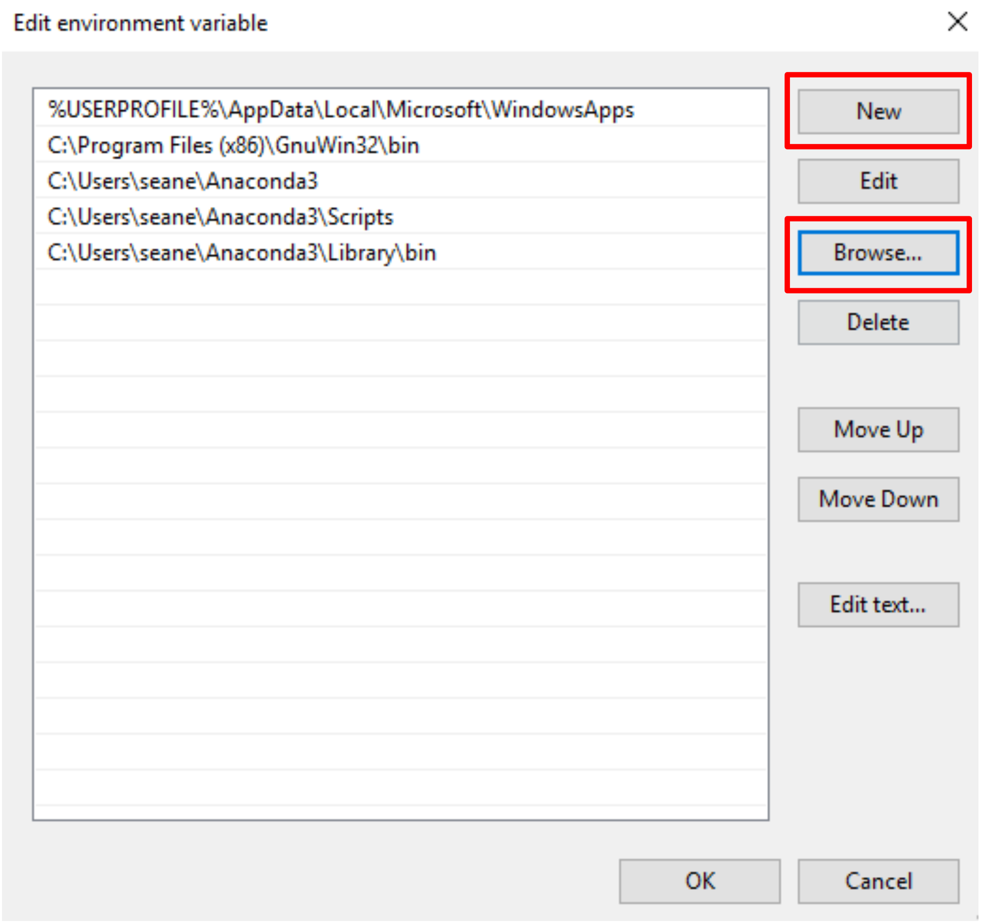
Installing Software

e) Knowing where Anaconda and Python were installed from Step 6, add these paths as environment variables.

(Paths will be different depending on where you installed Anaconda on your machine)

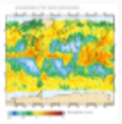
New → Browse… → Path to directory

f) You can delete these paths at any time by following the steps above, selecting the path, and clicking Delete



Data Acquisition

1. Download monthly IMERG data from GES DISC:
   a) Using a web browser, go to NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC): https://disc.gsfc.nasa.gov/
   b) Type "IMERG" in the search bar and click on the search icon
   c) Select IMERG Version 6 Level 3 data at "monthly" temporal resolution and click on the "Subset / Get Data" icon



GPM IMERG Final Precipitation L3 1 month 0.1 degree x 0.1 degree V06 (GPM_3IMERGM 06) 10.5067/GPM/**IMERG**/3B-MONTH/06 Subset / Get Data	Models/Analyses IMERG	06	1 month	0.1 ° x 0.1 °	3	2000-06-01	2019-09-30

   d) Leave the default date range since we want the entire time series

Data Acquisition

e) Under Spatial Subset enter 29, -28, 42, -9.5 (i.e. Mozambique)

f) Under Variables select only “precipitation”

g) Leave the default parameters under Grid

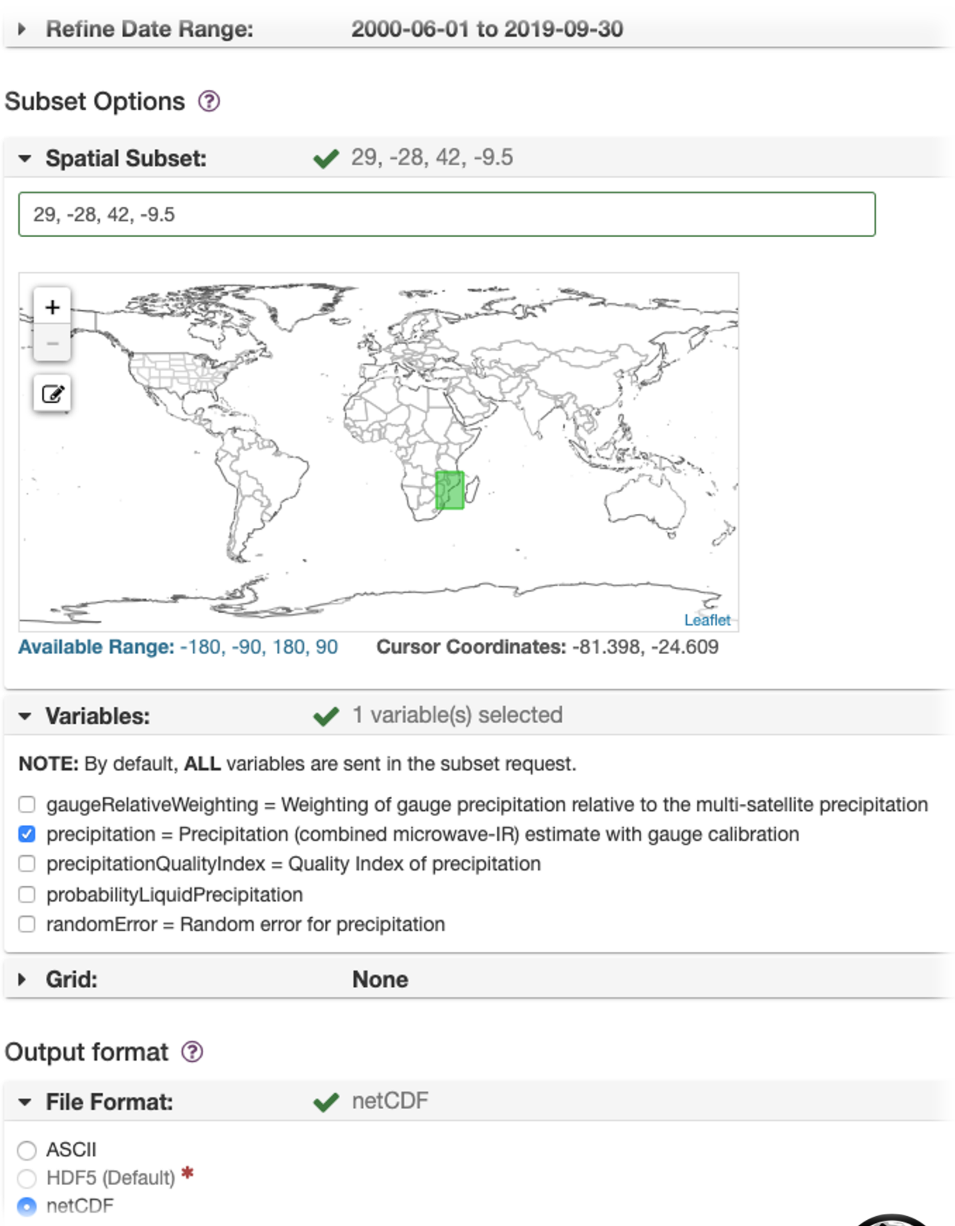
h) Under File Format select “netCDF”

i) Click Get Data

j) Follow the instructions for downloading data – **for convenience these data are made available on the training webpage:**

https://arset.gsfc.nasa.gov/water/webinars/IMERG-2020

e) Once downloaded, unzip the folder and rename it **IMERG**



Preprocess data using the NetCDF Operator (NCO)

1. Using the Bash shell, change directories to the IMERG folder and run the following lines of code
   a) If you are new to using Bash refer to the following lessons with Software Carpentry: http://swcarpentry.github.io/shell-novice/
   b) Information on NCO can be found at the link below: http://nco.sourceforge.net/nco.html
2. To read header contents of a netCDF file: **ncdump –h "file name"**
3. Ncks: this line of code loops through all IMERG files in the folder making "time" the record dimension/variable used for concatenating files:

   Mac: **for fl in *.nc4; do ncks -O --mk_rec_dmn time $fl $fl; done**

   Windows: **for fl in *.nc4; do ncks --mk_rec_dmn time $fl -o $fl.TMP; mv $fl.TMP $fl; done**

Preprocess data using the NetCDF Operator (NCO)

4. Ncrcat: this line of code concatenates all .nc4 files into one .nc4 file named IMERG_concat.nc4:

   Windows users *may first need to run the following command in Bash:*
   cp ~/Anaconda3/Library/bin/ncra.exe ~/Anaconda3/Library/bin/ncrcat.exe

   If the above command does not work*, try **renaming ncra.exe as **ncrcat.exe** in the **/Anaconda3/Library/bin/** folder

   ncrcat -h *.nc4 IMERG_concat.nc4

5. Ncpdq: this line of code changes the order of the variables for running the SPI code in Python

   ncpdq -a lat,lon,time IMERG_concat.nc4 IMERG_concat_ncpdq.nc4

6. You now have a preprocessed netCDF file which can be run using the Python code provided by the National Integrated Drought Information System (NIDIS)

Running SPI code

1. Go to the **Updated Climate and Drought Indices in Python** page from NOAA's National Integrated Drought Information System (NIDIS). https://www.drought.gov/drought/updated-climate-and-drought-indices-python
2. Follow the directions under the links provided. This is a developmental version of code that is originally developed at NCEI/NOAA, official release version available on drought.gov. This software is under BSD 3-Clause license, copyright **James Adams**, 2017.
   a) Climate Indices Project
   b) Documentation to Get Started
3. Move the IMERG folder with downloaded and preprocessed IMERG data into the climate_indices folder
4. Copy the **IMERG_concat_ncpdq.nc4** file from the IMERG folder and paste it into the **data** folder (inside the notebooks directory)

Running SPI code

5. Using the Bash shell change directories to the climate_indices (root) folder
6. From the Climate Indices in Python webpage follow the directions carefully to:
    a. Configure the Python environment
    b. NCO
    c. Indices Processing
7. Using the Bash shell change directories to the **climate_indices** folder
8. Using the Bash shell run the following code:

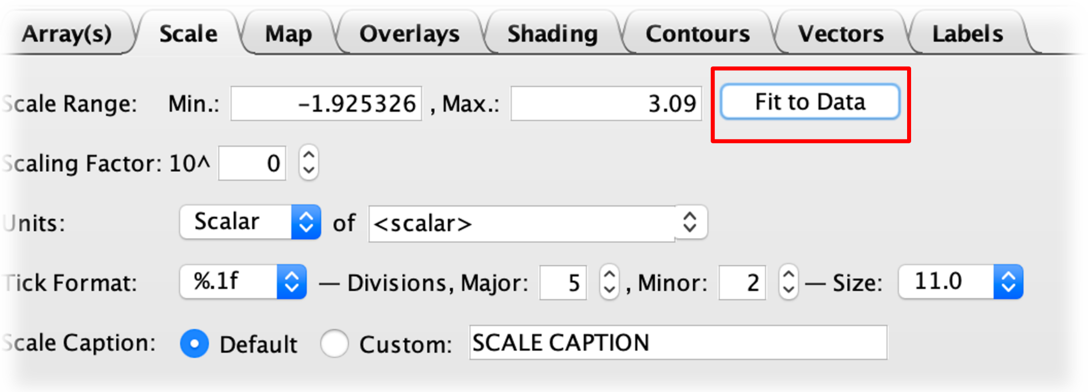
    process_climate_indices --index spi --periodicity monthly --netcdf_precip ../data/IMERG_concat_ncpdq.nc4 --var_name_precip precipitation --output_file_base ../data/IMERG --scales 3 --calibration_start_year 2000 --calibration_end_year 2019 --multiprocessing all

Running SPI code

9. The python code will compute SPI (standardized precipitation index – both gamma and Pearson Type III distributions) from an input precipitation dataset (in this case, the ***IMERG_concat_ncpdq.nc4*** dataset). The input dataset is monthly data and the calibration period used will be June 2000 through August 2019. SPI will be computed at a 3-month timestep. Output files are in the data directory: ***/data/IMERG_spi_gamma_03.nc*** and ***/data/IMERG_spi_pearson_03.nc***.

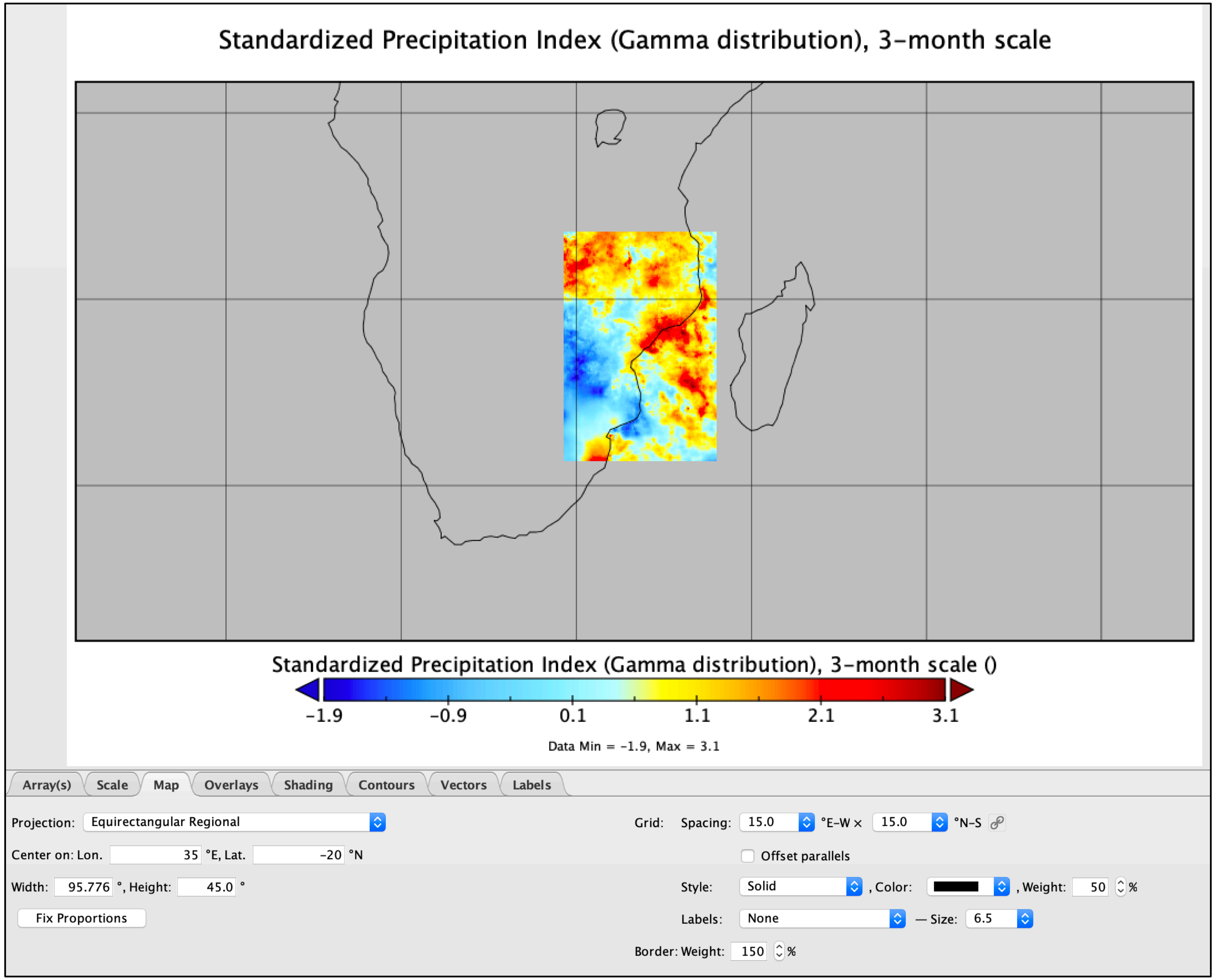
View the results in Panoply

1. Launch the Panoply desktop application
2. Open the SPI file IMERG_spi_gamma_03.nc in Panoply
3. From the Datasets tab select spi_gamma_03 and click Create Plot
4. In the Create Plot window select ‘Create a georeferenced <<Longitude-Latitude>> plot’ and click Create
5. When the Plot window opens, select any date from 2001
6. At the bottom of the window, click on the Scale tab → Fit to Data



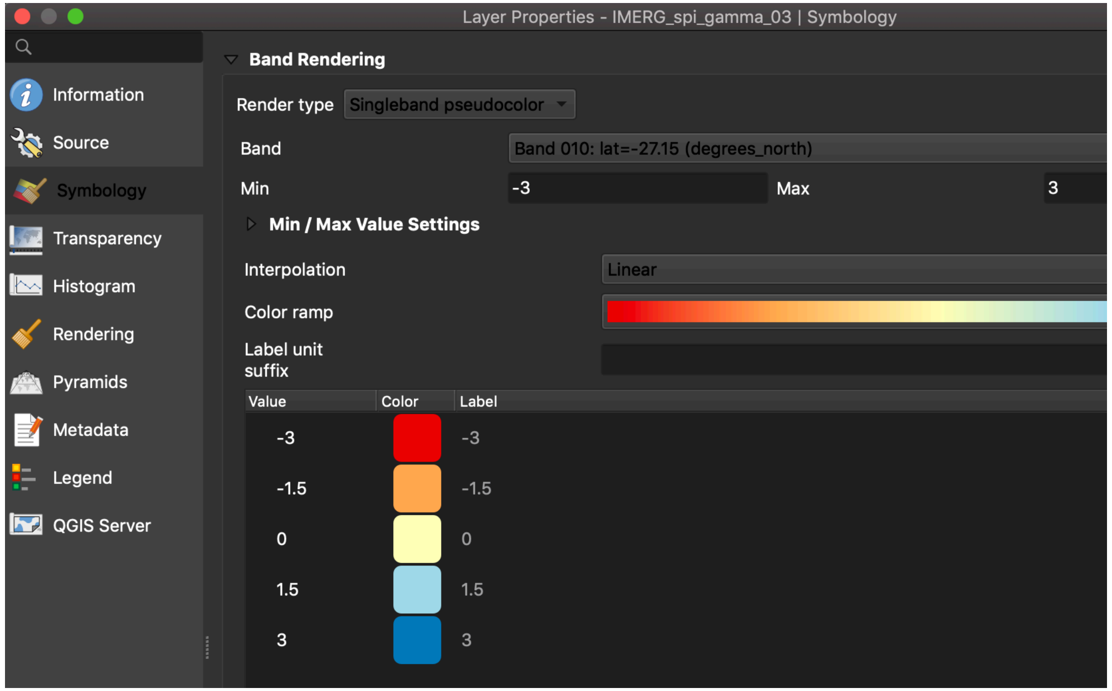
View the results in Panoply

7. Scale tab → Color Table: CB_RdYlBu.cpt
8. Map tab → Projection: Equirectangular Regional
9. Map tab → Center on Lon: 35 Lat: -20
10. Click on Fix Proportions
11. To explore the values in the array, click on on the Array 1 tab at the top of the window



View the results in QGIS

1. Launch the QGIS Desktop application
2. Add the raster file **IMERG_spi_gamma_03.nc** in QGIS
3. Right-click on the layer and select Properties
4. Click on Symbology and change the parameters to the following:
   a) Render type: Singleband pseudocolor
   b) Select a band
   c) Change the Min = -3 and Max = 3
   d) Change the color ramp to “RdYlBu” (if it’s not already selected)
   e) Click Apply and OK



View the results in QGIS

5. Right-click on the layer name in the Layers panel and select Zoom to Layer

6. We see the image is not displaying correctly. This is because longitude is being displayed as time ("seconds since 1970-01-01 00:00:00 UTC"). Confirm this by right-clicking on our layer in the Layers panel → Properties → Information. The Extent of longitudinal coordinates is much too large!

7. To correct this so we can display our data in QGIS, follow the steps below:
   a) Using the Bash shell, change directories to the “results” folder and run the following lines of code:

      ncpdq -a time,lat,lon IMERG_spi_gamma_03.nc spi_gamma_03_mozambique.nc

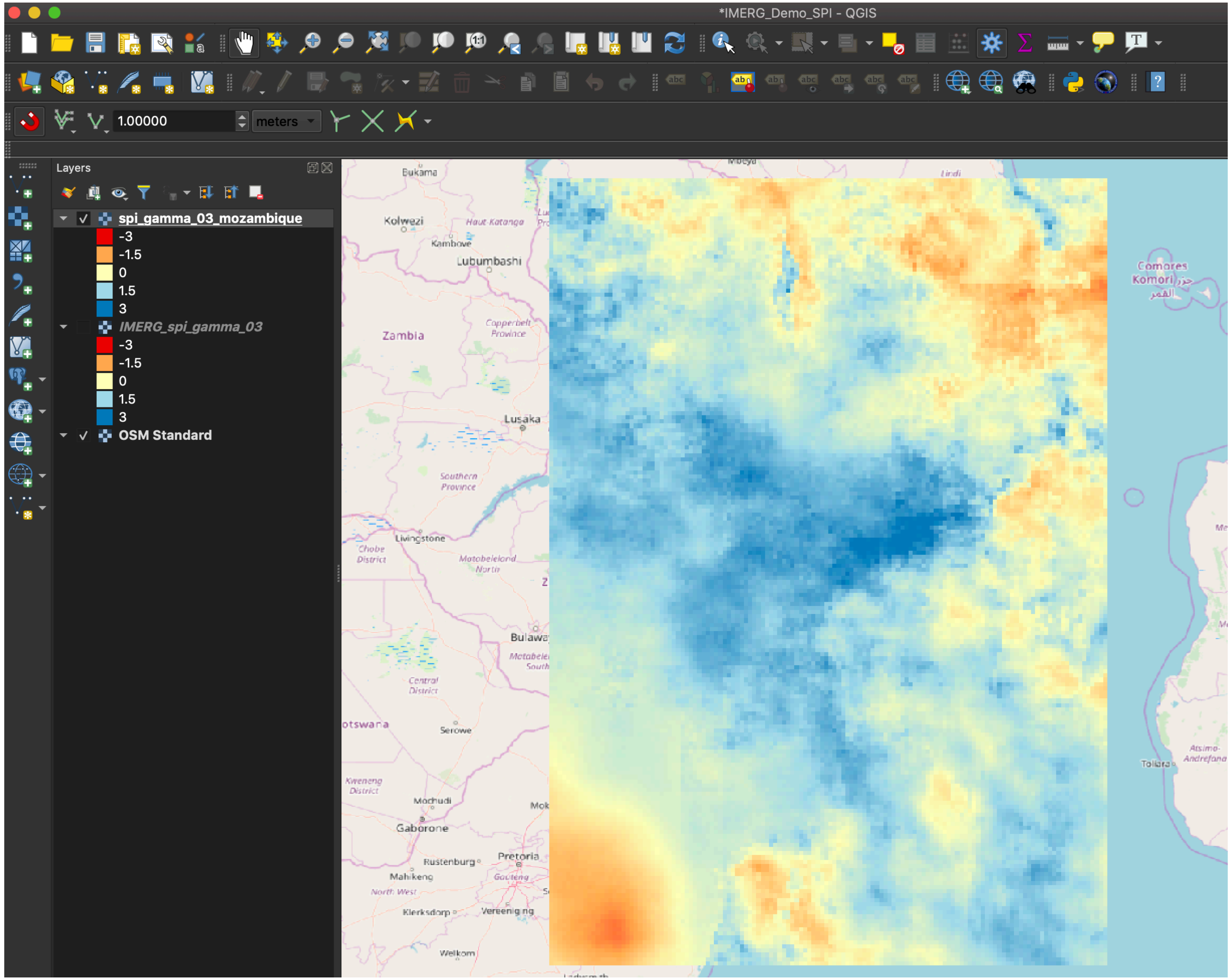
View the results in QGIS

8. Add the spi_gamma_03_mozambique.nc raster file to the Layers panel

9. Right-click on the spi_gamma_03_mozambique layer → Properties → Symbology:
   a) Render type: Singleband pseudocolor
   b) Select any band ***except*** the first 2 months (SPI needs a minimum of 3 months to create the index)
   c) Change the Min = -3 and Max = 3
   d) For color ramp select "RdYlBu" (if it's not already selected)
   e) Click Apply and OK
   f) Right-click on the layer name in the Layers panel and select Zoom to Layer

View the results in QGIS

10. For better visualization, add a Basemap to the Map View
    a) Menu Bar → Web → QuickMapServices → OSM → OSM Standard



Next Week

- Part 3 of the GPM IMERG training will be comprehensive. Participants will practice all the skills they learned in Parts 1 & 2 and apply them to a study area of their choice.
- Homework Assignments will be available after all three sessions from: https://arset.gsfc.nasa.gov/water/webinars/IMERG-2020
- Answers must be submitted via Google Form
- Due dates: February 11, 18, and 25

Contact information

Amita Mehta: amita.v.mehta@nasa.gov

Sean McCartney: sean.mccartney@nasa.gov

Thank You!