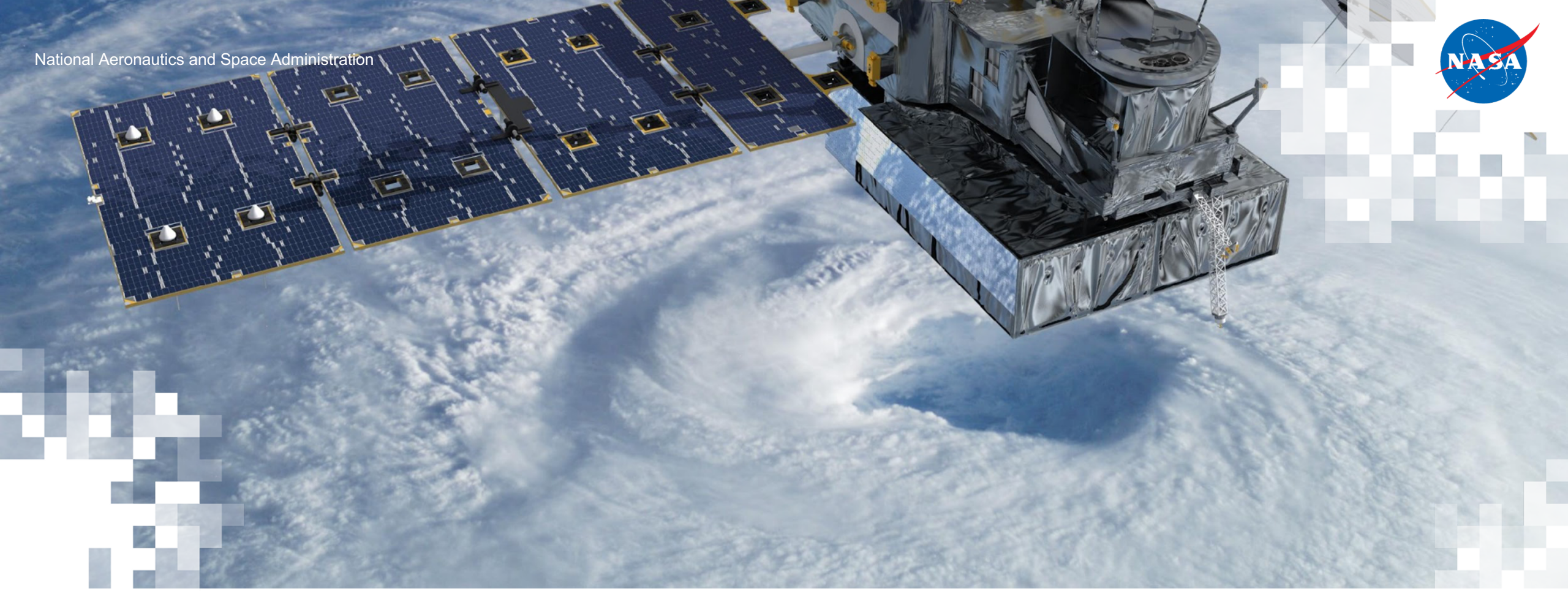


Exercise: Calculation of Precipitation Statistics
Case Study: Maputo & Mozambique

Amita Mehta and Sean McCartney

January 28, 2020

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

Objectives

- Learn to use Giovanni to access and analyze IMERG precipitation
- Learn to find precipitation statistics for Mozambique and for the Maputo region to identify dry and wet events

Requirements

- QGIS installed on your computer
- Microsoft Excel or Apache Open Office installed on your computer
- Shapefiles of Mozambique and Maputo saved on your computer
  - https://arset.gsfc.nasa.gov/water/webinars/IMERG-2020

Note

This is a three-part exercise:

- Part 1: Analyze and download IMERG precipitation data using Giovanni
- Part 2: Calculate seasonal standard deviation and precipitation anomaly maps for Mozambique in QGIS from the IMERG data
- Part 3: Calculate statistics of long-term IMERG time series over Maputo region using Microsoft Excel or Open Office Spreadsheet

Questions based on this exercise will be included in Homework 1

Part 1: Outline

- Analyze and download IMERG data for Mozambique using Giovanni
  - Create and download long-term mean seasonal precipitation maps
  - Examine and download seasonal mean time series of precipitation
  - Generate and download seasonal mean precipitation maps for individual years

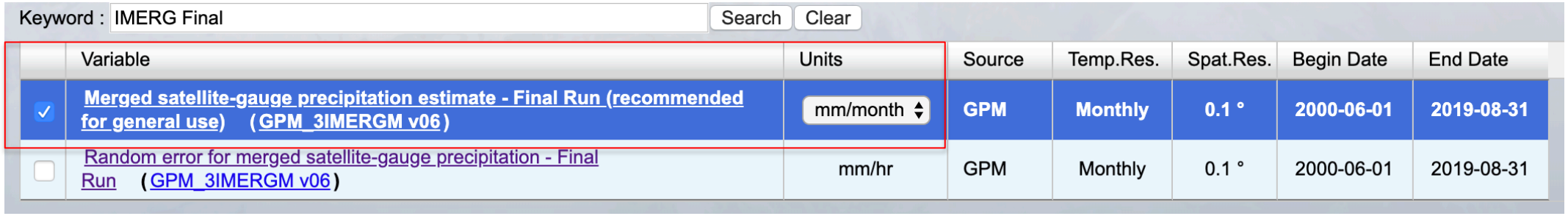
Part 1: Analyze and Download IMERG Precipitation using Giovanni

1. Go to Giovanni: http://giovanni.gsfc.nasa.gov/giovanni

2. On the Giovanni page you will see the following options:
   - **Select Plot:** allows selection of analysis options
   - **Select Date Range (UTC):** allows selection of a time period
   - **Select Region (Bounding Box or Shape):** allows selection of a geographic region by latitude-longitude, map, or shapefile
   - **Keyword:** allows search of data parameters by keyword
   - **Plot Data:** (bottom right) executes the action to make a desired plot

Part 1: Search for IMERG Precipitation Data

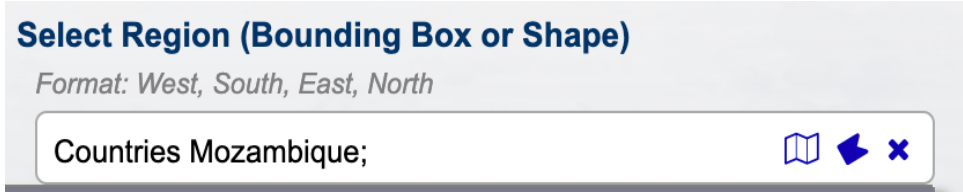
- Search for IMERG precipitation in **Keyword: IMERG**
- From the drop-down list select **IMERG Final**
- Select **Temp. Res. Monthly**
- Select **Merged satellite-gauge precipitation estimate – Final Run (recommended for general use)**
- Select **Units** to be **mm/month**

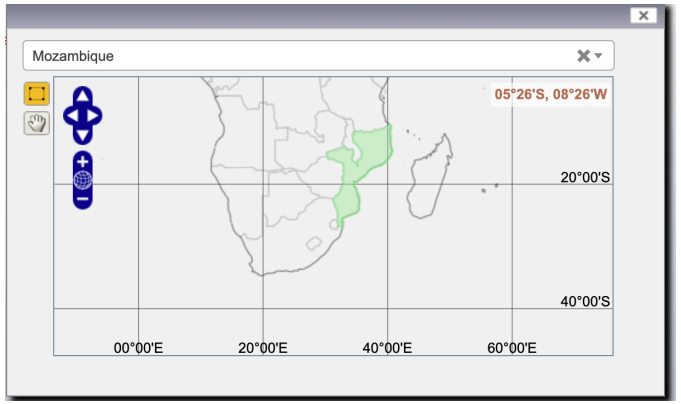


Part 1: Subset IMERG Precipitation for Mozambique

– Under Select Plot (top of screen), select **Maps: Monthly and Seasonal Averages**

– Under Select Region (Bounding Box or Shape)
  - Select a Shape…
  - Enter **Mozambique** in the **Select a Shape…** search window
  - You will see the map with Mozambique highlighted



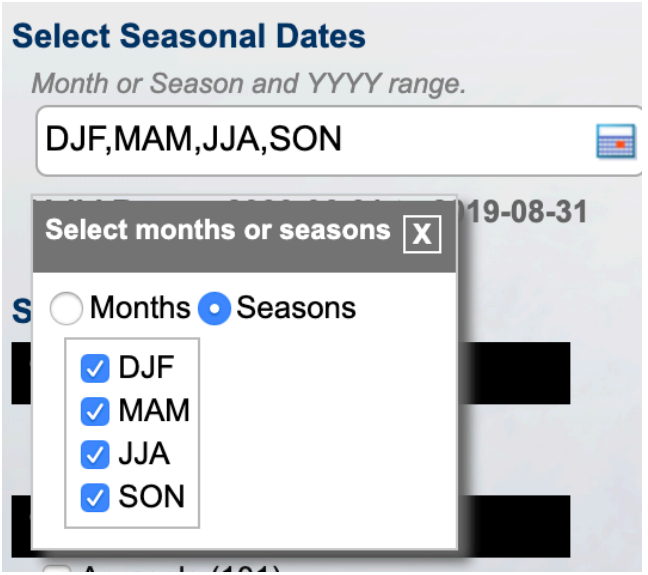


Part 1: Plot Long-Term Mean Seasonal Precipitation Maps

– Under Select Seasonal Dates:
  - In the ***Month or Season and YYYY range*** select **Seasons: DJF, MAM, JJA, SON**

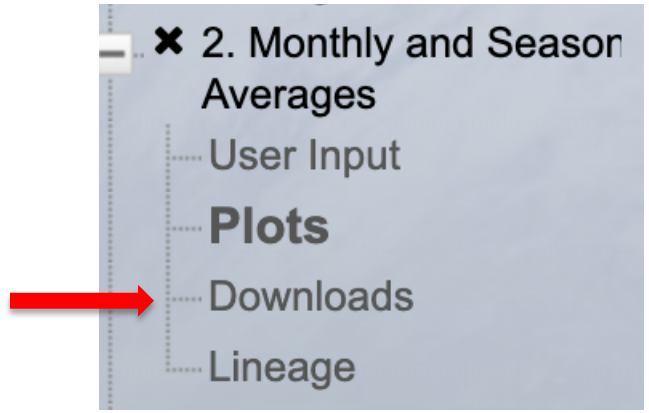
[Note: DJF is December-January-February
MAM is March-April-May
JJA is June-July-August
SON is September-October-November]

  - Select Beginning and end years to be **2000** and **2019**
  - Click on **Plot Data** (on the bottom right of the screen)
  - You will get four seasonal precipitation maps averaged from 2000 to 2019
  - We will analyze these maps in QGIS



Part 1: Download Seasonal Mean IMERG Data

3. Click on **Download** (in the left menu bar) to save the seasonal mean data in **GEOTIFF** format (note that you will have to login to NASA Earthdata to download the data)
   - Rename the files to shorter names for convenience
   - Recommended names:
     'IMERG-Mean-DJF.tif', 'IMERG-Mean-MAM.tif', etc.

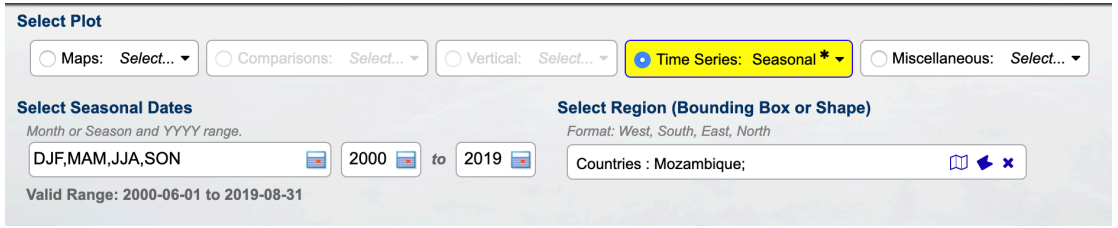


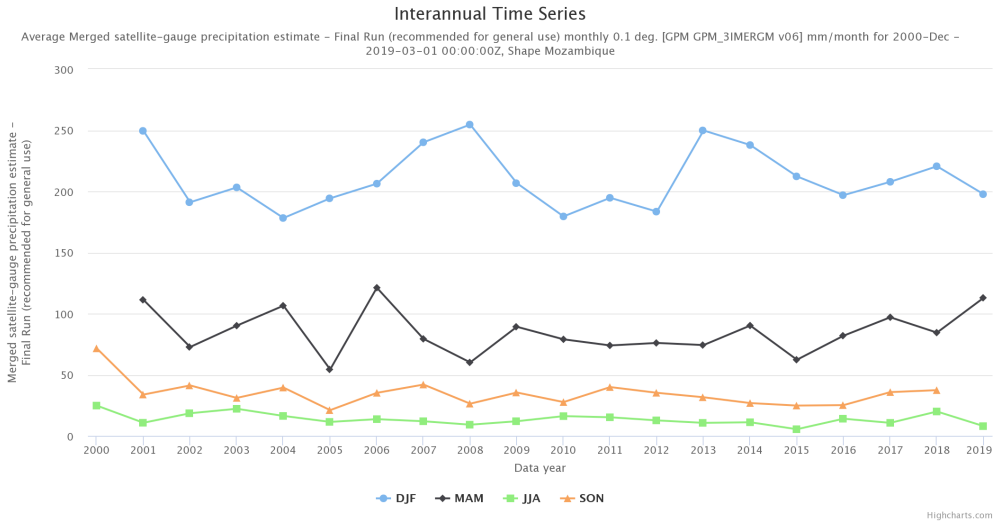
GEOTIFF:

GPM_3IMERGM_06_precipitation.20000101-20191231.SEASON_DJF.180W_90S_180E_90N.tif
GPM_3IMERGM_06_precipitation.20000101-20191231.SEASON_MAM.180W_90S_180E_90N.tif
GPM_3IMERGM_06_precipitation.20000101-20191231.SEASON_JJA.180W_90S_180E_90N.tif
GPM_3IMERGM_06_precipitation.20000101-20191231.SEASON_SON.180W_90S_180E_90N.tif

Part 1: Plot Seasonal Precipitation Time Series for Mozambique

4. Click on **Back to Data Selection** (bottom right corner of screen)
   - Under "Select Plot" Select **Time Series: Seasonal**
   - Keep all other options the same
   - Click on **Plot Data** (bottom right)
   - You will get a plot with four time series' showing precipitation averaged over Mozambique for each of the four seasons
   - Study the plot and note the season with the maximum amount of rain
   - Click on **Download** (in the left menu bar) to save the time series as a .csv file on your computer. Once downloaded, rename the file: **IMERG-TS.csv**

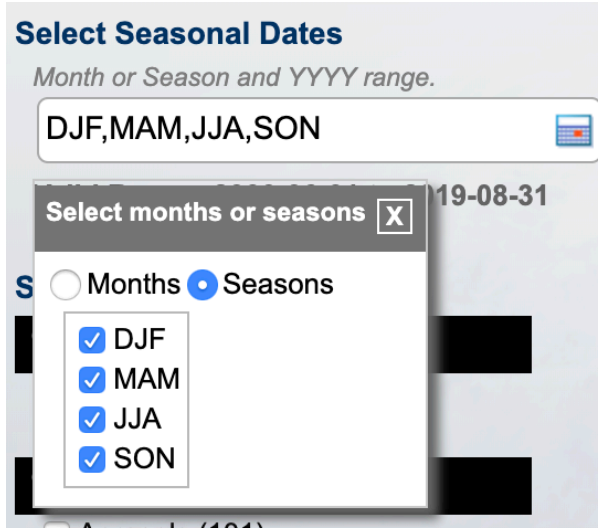




Combined ASCII:
g4.ints.GPM_3IMERGM_06_precipitation.20000101-20191231.180W_90S_180E_90N.csv

Part 1: Plot IMERG Precipitation for Individual Seasons

5. Click on **Back to Data Selection** (bottom right)
   - Under "Select Plot", select **Maps: Monthly and Seasonal Averages**
   - Under "Select Seasonal Dates", for ***Month or Season and YYYY range***, select **Seasons: DJF, MAM, JJA, SON**
   - Select the beginning and end years to be **2001**
   - Click on **Plot Data** (on the bottom right of screen)
   - You will get four seasonal precipitation maps for the year 2001
   - Repeat Step 3 to download the seasonal GEOTIFF data for 2001 as 'IMERG-2001-DJF.tif' etc.
   - Repeat the above steps (in Step 5) for years 2002 to 2019 individually
   - You will have four files per year for 2001 to 2019: 'IMERG-YYYY-SSS.tif' where YYYY is 2001 to 2019 and SSS represents all four seasons



Note: The data for DJF for each year are available from ARSET for use in part 2 https://arset.gsfc.nasa.gov/water/webinars/IMERG-2020

Part 2: Outline

- Calculate seasonal standard deviation and precipitation anomaly maps for Mozambique in QGIS from IMERG data
  - Import long-term seasonal mean precipitation maps and seasonal mean annual maps in QGIS
  - Calculate standard deviation
  - Calculate anomalies (departure from mean) for each year
- Save your QGIS project. Homework-1 will have questions based on this exercise.

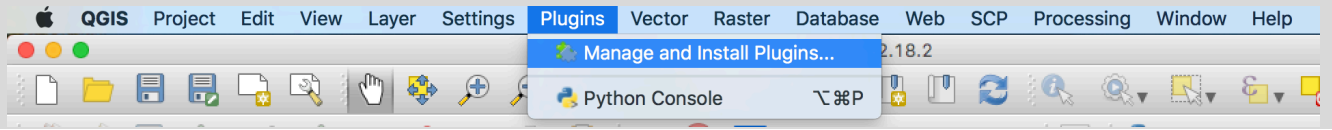
Part 2: Precipitation Analysis in QGIS

1. Open QGIS and start a new project

2. On the top menu bar, click on **Web** to check if you have the **QuickMapServices Plugin**

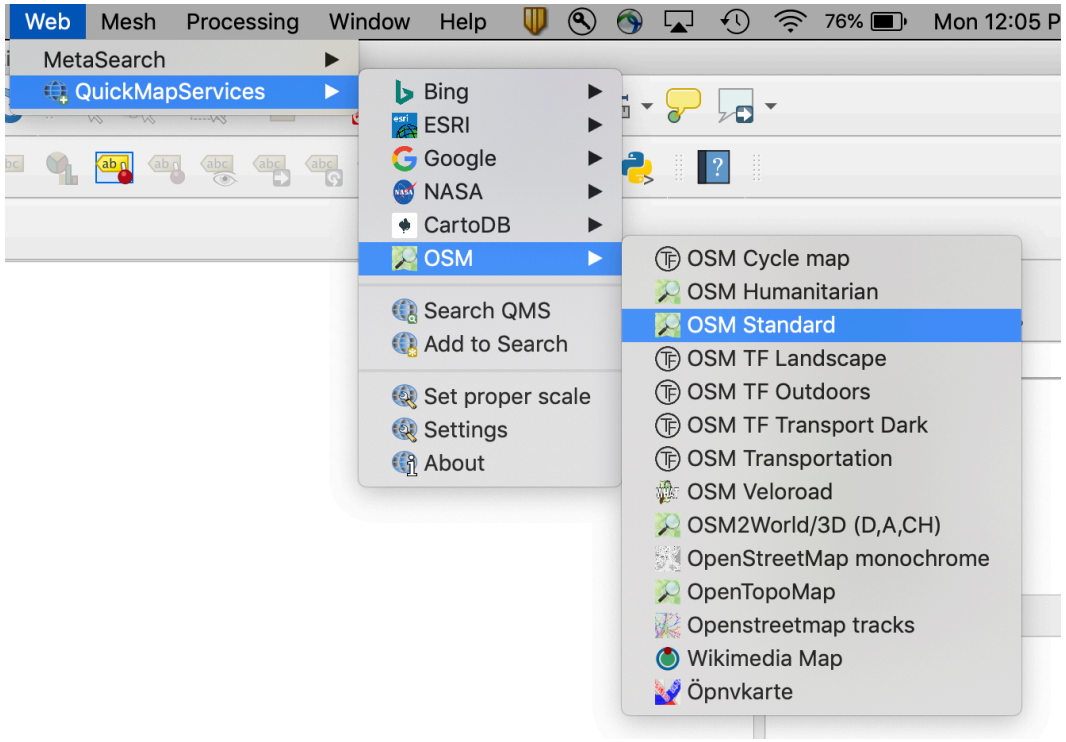
If you do not have the QuickMapServices Plugin:

- Select **Plugins** from the top menu and choose **Manage and Install Plugins**
- You will get a window with options for Plugins
- Enter QuickMapServices in the search window
- Click on the **QuickMapServices Plugin** and click **Install** in the bottom right



Part 2: Precipitation Analysis in QGIS

3. From the top menu bar, click on **Web**, select **QuickMapServices → OSM → OSM Standard** as the background map



This exercise uses the plugin **OSM Standard**, but you may use any other map option available in QuickMapServices

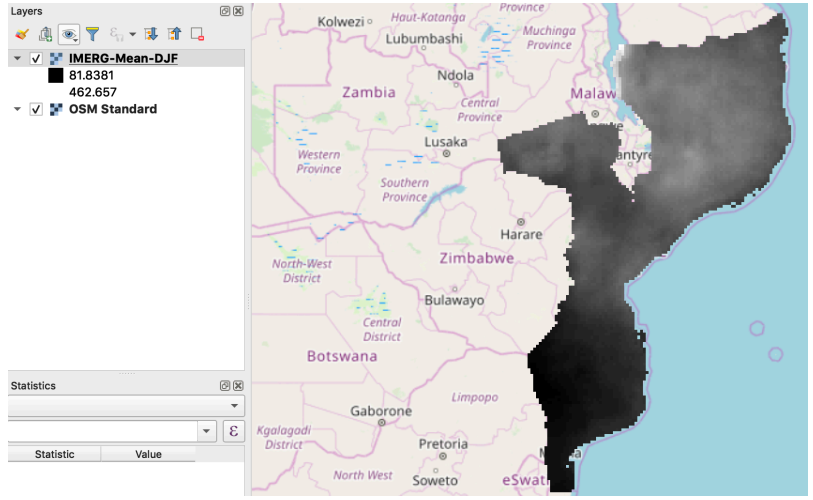
Part 2: Add Mozambique and Maputo Shapefiles

4. Click on the menu on the left bar and click **Add Vector** to add the Mozambique sub-region shapefile (MOZ-Level_1.shp)
5. To make the shapefile transparent, right-click on the layer file → **Properties** → **Symbology** → **Simple Fill**
   - For "Fill Color", select **Transparent Fill**
   - Click on the down arrow in the **Stroke color** window and choose a color for the shapefile boundary (This example uses black)
   - Set the **Stroke Width** to be 1.0
   - Click **OK** to get the following result in QGIS
6. Repeat steps 4 and 5 but use the shapefile for Maputo (Maputo.shp) and choose a different color in **Stroke color** (this example uses dark blue)

Part 2: Add Seasonal Mean DJF Precipitation to QGIS

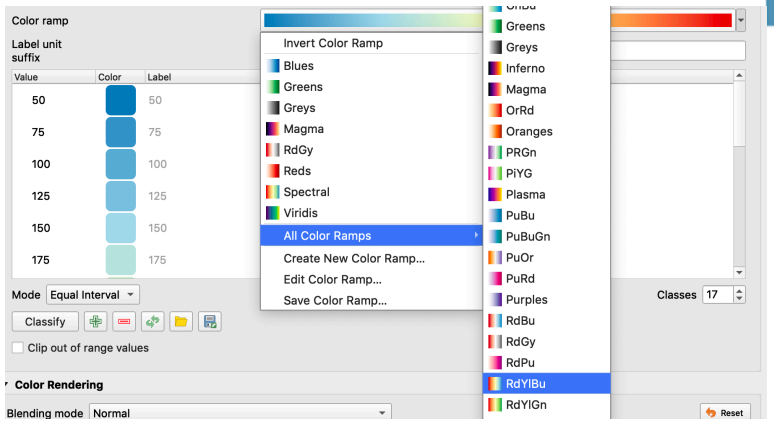
7. In QGIS, click on the **Add Raster** icon in the Manage Layers Toolbar

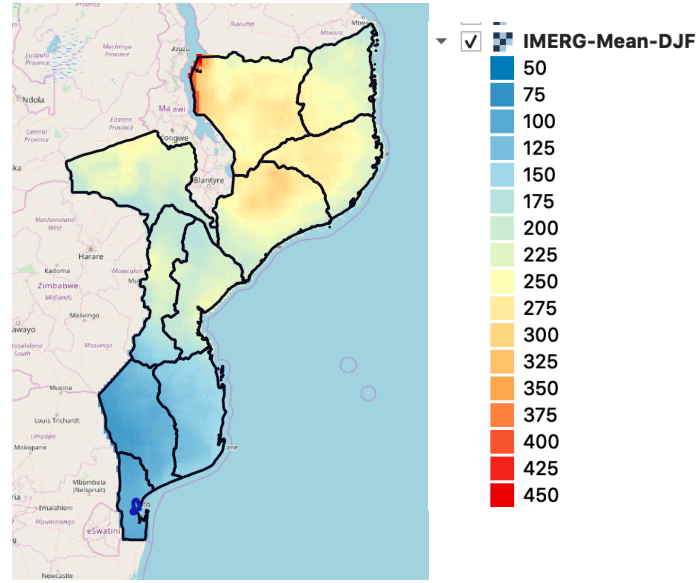
8. Navigate to the seasonal mean data file for DJF (**IMERG-Mean-DJF)** saved on your computer from Giovanni analysis and click on **Open** and **Add**
   - A **Coordinate Reference System Selector** box may pop up. Select WGS84, EPSG 4326
   - From the top Menu Bar you can zoom in and out on the layer
   - Note the minimum and maximum precipitation values below the raster name from the **Layers** panel on the left



Part 2: Add Color to the Precipitation Layer

9. Right click on the layer IMERG-Mean-DJF and go to **Properties → Symbology**
   - Select the **Render Type** as **Singleband pseudocolor**
   - Next to the **Color ramp** drop-down arrow, select **All Color Ramps → (RdYlBu)** Red-Yellow-Blue color palette.
   - Change the **Min** and **Max** values to **50** and **450** respectively
   - Below the color display, change the **Mode** to **Equal Interval** and **Classes** to **17** and Click **OK**





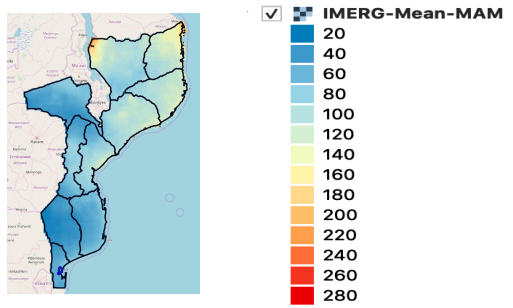
Part 2: Add All Seasonal Mean Precipitation Layers to QGIS

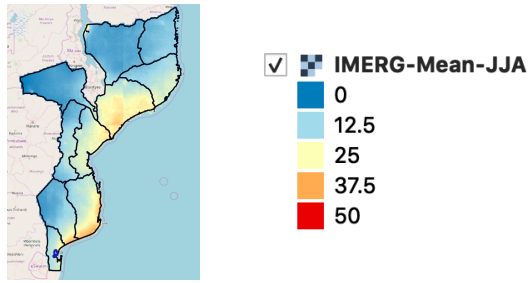
10. In your QGIS map, click on the **Add Raster** icon in the Manage Layers Toolbar

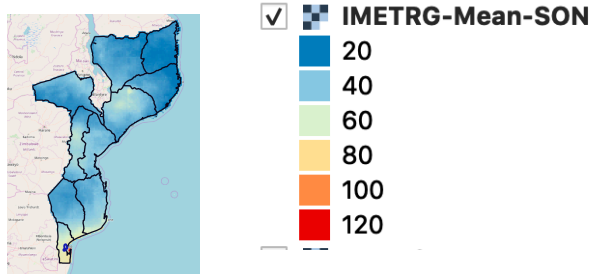
11. Navigate to the seasonal mean data files for MAM, JJA, SON saved on your computer and follow Step 8 and note min and max values

12. Add color to the MAM, JJA, SON following Step 9, but choose appropriate **Min, Max,** and **Equal Interval Classes** in **Symbology**

13. Study the maps for each season

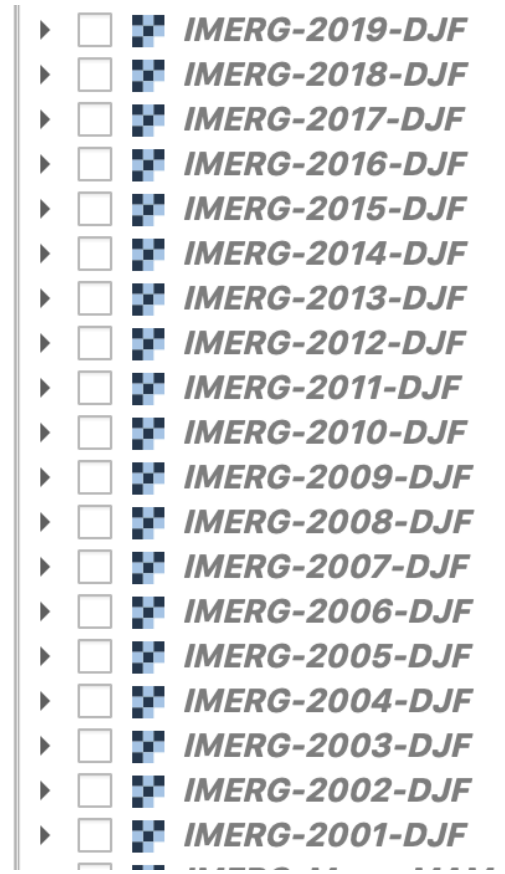






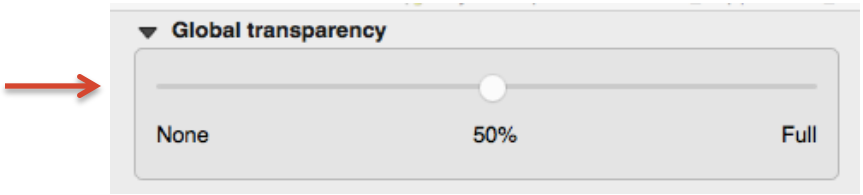
Part 2: Add DJF Precipitation for Individual Years

14. In your QGIS map, click on the **Add Raster** icon the Manage Layers Toolbar
15. Navigate to the seasonal mean data files for DJF saved on your computer for the years 2001 to 2019
16. Select and add the same color scheme to each precipitation layer from 2001 to 2019
    - Follow Step 9 to get the color scheme for (IMERG-2001-DJF) but set **min** and **max** to be **50** and **750** respectively, also set **Equal Interval → Classes** to **21**and click **OK**
    - Right-click on the (IMERG-2001-DJF) raster and go to **Styles → Copy Style**
    - Right-click on all subsequent layers (e.g. IMERG-2002-DJF to IMERG-2019-DJF) and go to **Styles → Paste Style** to use the same color scheme for each seasonal mean data layer for DJF



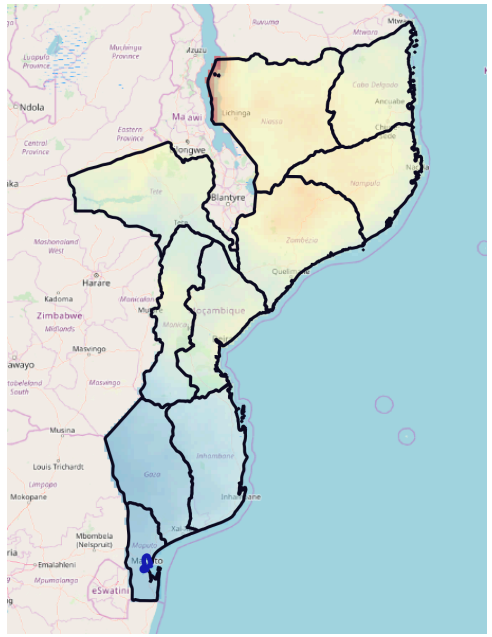
Part 2: Make the Layers Partially Transparent (Optional)

17. Right-click on any raster layer you want to make transparent and go to:
    Properties → Transparency



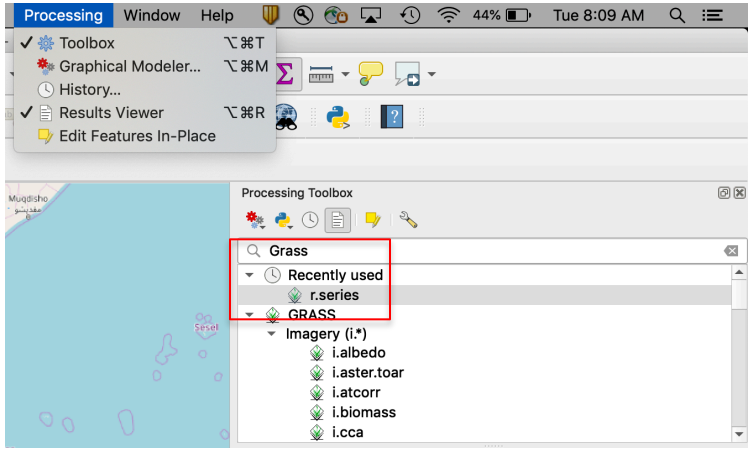
18. Change the **Global Opacity** level and click **OK** and you will see the precipitation layer that is partially transparent and the map below the data layer

    Note: You may need to unselect other layers in your Manage Layers Toolbar to view the basemap

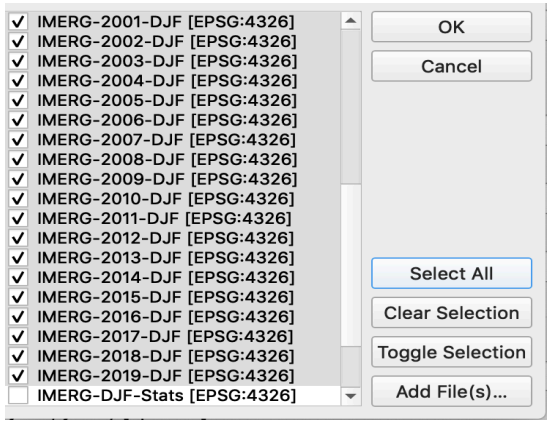


Part 2: Calculate Standard Deviation of Seasonal Precipitation

19. Open **Processing → Toolbox** (menu bar) in QGIS
    - Search for **Grass** routines in the Toolbox
    - Scroll down and find **r.series** from the list of Grass routines in the Toolbox window

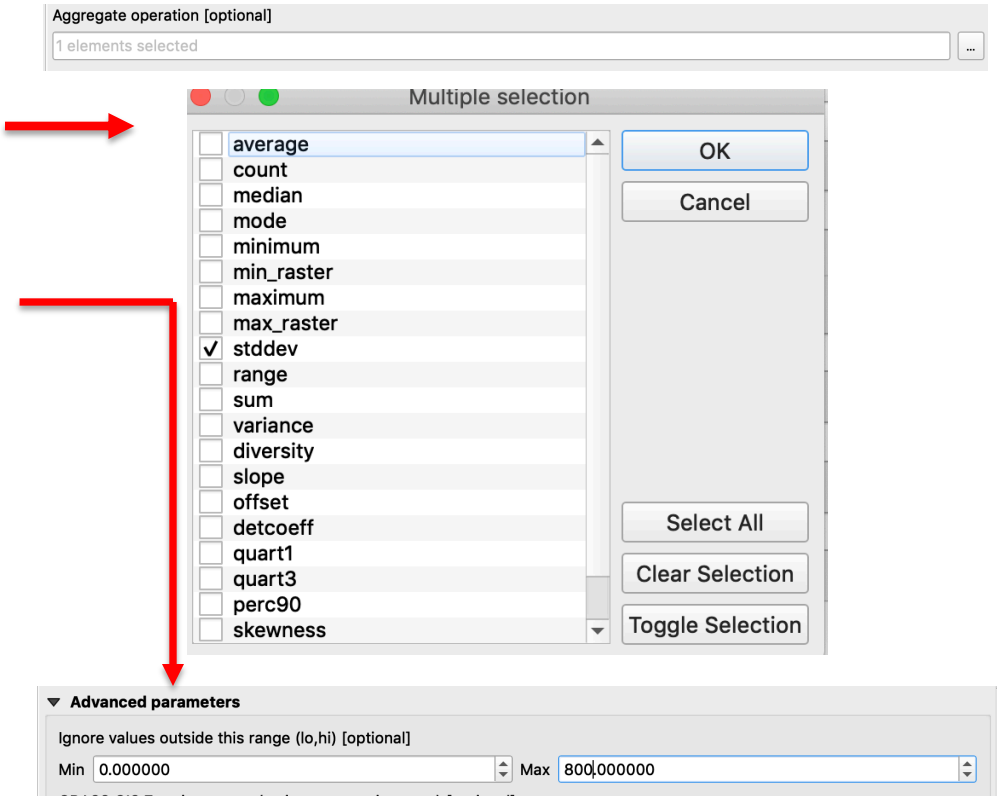


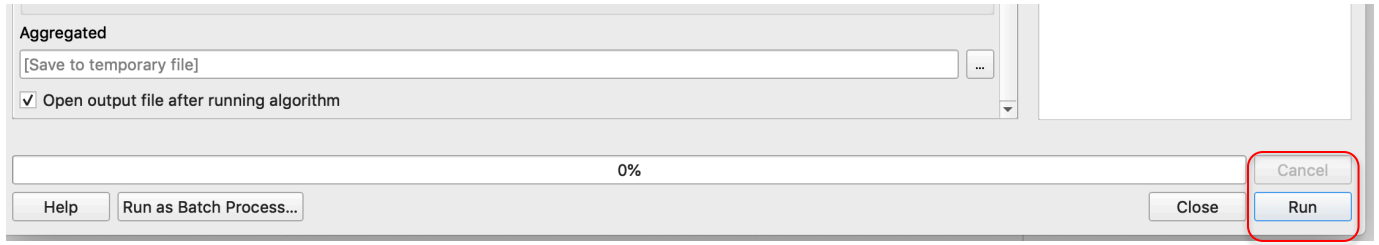
20. Click on **r.series** to open a window to select parameters
    - Go to **Input Raster Layer(s)**, from the drop-down option select IMERG precipitation layers for 2001 to 2019 **(IMERG-2001-DJF to IMERG-2019-DJF)**, and click **OK**
    - Select **Propagate Nulls**



Part 2: Calculate Standard Deviation of Seasonal Precipitation

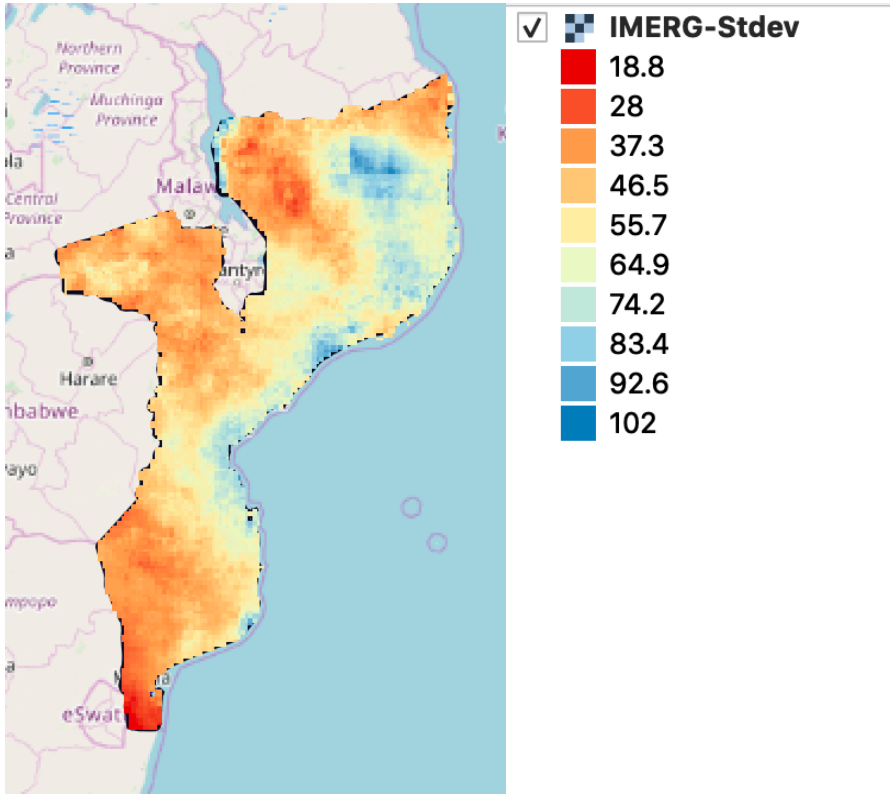
- Go to **Aggregate operations [optional]** and from the drop-down options select **stddev** for standard deviation and click OK
- Under **Advanced parameters → ignore values outside this range (lo, hi) [optional]**, enter **0.0** for low and **800.0** for high values
- Under **Aggregated** window you may enter a file name to save the results, or a temporary layer will be added to the QGIS project
- Select **Open output file after running algorithm**
- Click **Run**





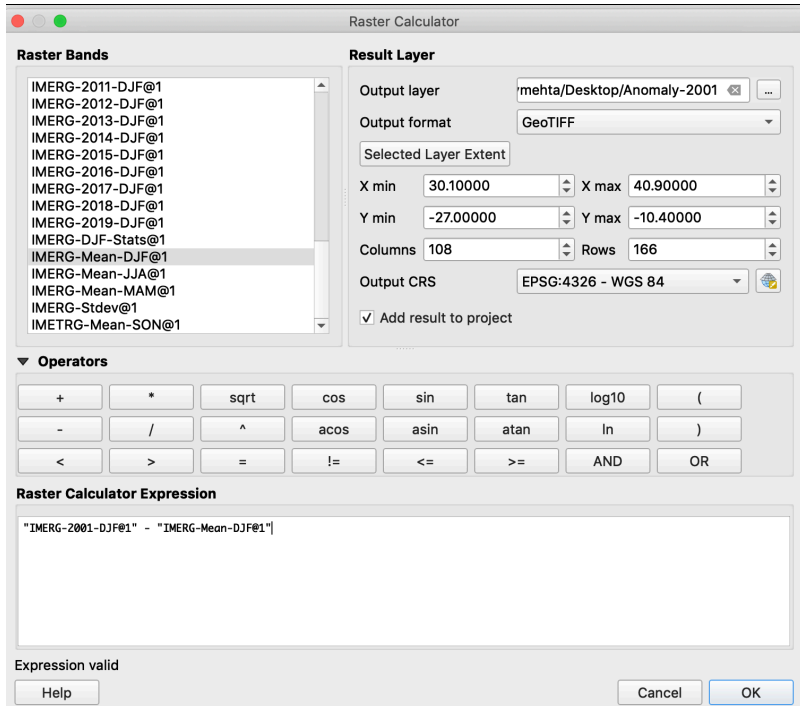
Part 2: Calculate Standard Deviation of Seasonal Precipitation

21. You will get a map of the standard deviation of precipitation over the 19-year period
    - Follow Step 9 to add color to the standard deviation layer (you may keep the actual **Min** and **Max** values from the data)
    - Note the minimum and maximum values



Part 2: Calculate Precipitation Anomalies

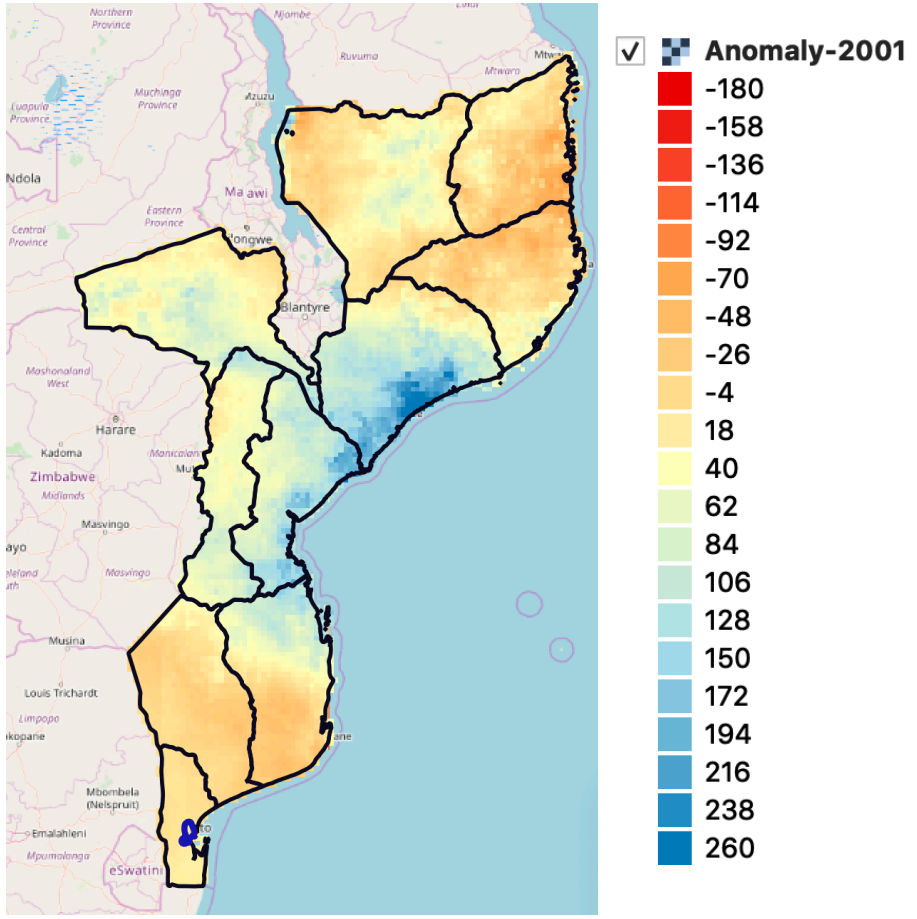
22. Open **Raster → Raster Calculator** (menu bar) in QGIS
    - In **Output layer**, save the data as **Anomaly-2001.tif**
    - Select **IMERG-2001-DJF** from the layers by double-clicking on the layer name, you will see the layer added in the **Raster Calculation Expression** window
    - Click on the minus (-) sign in the **Operations** window and then add **IMERG-Mean-DJF** by clicking twice and click **OK**
    - You will get a map of precipitation anomalies – departure from long-term mean precipitation for 2001
    - Repeat the above steps for years 2002 to 2019



Note: Precipitation anomaly maps for 2001-2019 are available from the ARSET website

Part 2: Add Color to the Anomaly Maps

23. Follow Step 9 to add the color scheme for (Anomaly-2001) but set **min** and **max** to be **-180** and **260** respectively. Also set **Equal Interval → Classes** to **21**and click **OK**.
    - Right-click on the (Anomaly-2001) raster and go to **Styles → Copy Style**
    - Right-click on all individual files (e.g. Anomaly-2002 to Anomaly-2019) and go to **Styles → Paste Style** to use the same color scheme
    - You will have 19 precipitation anomaly maps
    - Examine the anomaly maps to see which year/region had the maximum deficit and excess of precipitation

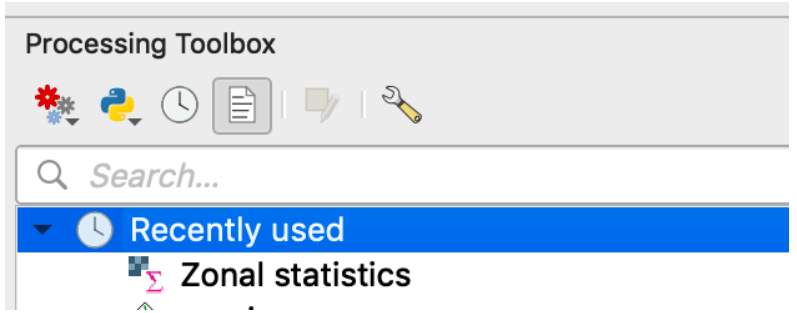


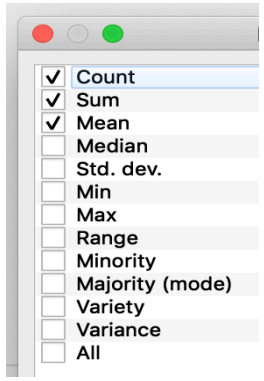
Part 3: Outline

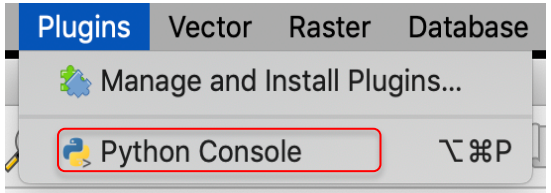
- Calculate statistics of IMERG time series over Maputo using Microsoft Excel or Open Office Spreadsheet
  - Extract time series of precipitation over the Maputo region using QGIS
  - Calculate mean, standard deviation, and percentile values of precipitation using Excel

Part 3: Extract Precipitation Time Series for Maputo Region

1. Download/copy the following Python scripts from: https://arset.gsfc.nasa.gov/water/webinars/IMERG-2020
   - **IMERG_ZonalStats.py** and **Anom_ZonalStats.py**
   - These scripts use the **Zonal Statistics** tool from the **Processing Toolbox** (View → Panels → Processing Toolbox) to find spatial precipitation statistics of precipitation for the area enclosed by the **Maputo** polygon. For example the script calculates mean precipitation **["STATS" : 2]**. Additional statistical parameters can also be calculated by selecting an appropriate index number (e.g. 0 for Count,1 for Sum , 3 for Standard Deviation etc.)
2. Click on **Plugin → Python Console** (Menu Bar) to open the **Python Console** below the QGIS Map View

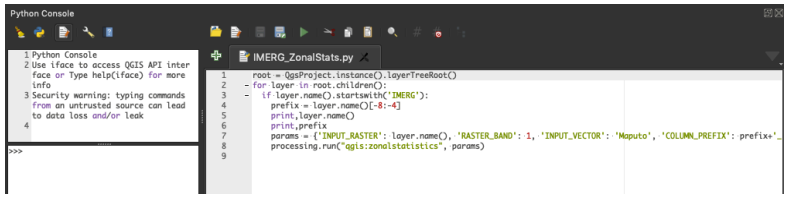




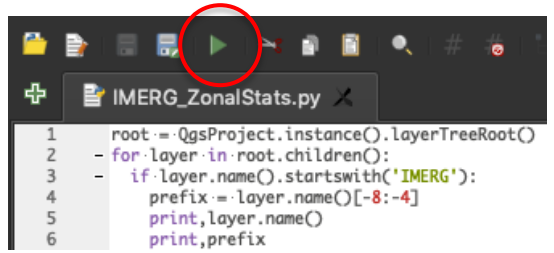


Part 3: Extract Precipitation Time Series for Maputo Region

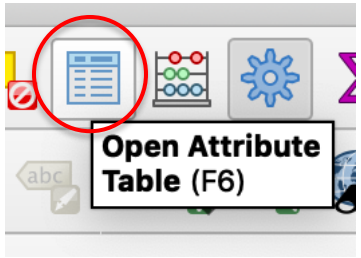
- In the Python Console click the Show Editor icon and open the **IMERG_ZonalStats.py** script in the editor window



- Click on the **Run Script** icon (green triangle in the Editor window) to execute the script



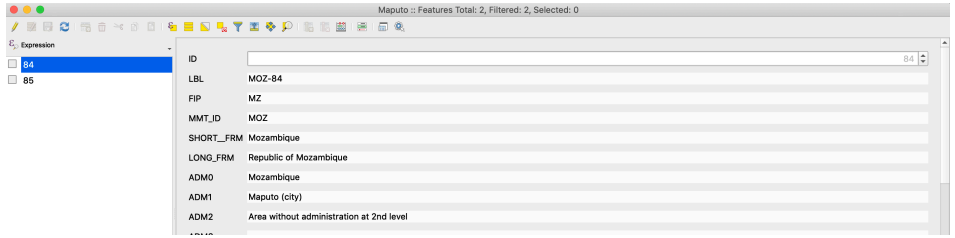
- The script will calculate the mean precipitation within the Maputo shapefile for all the rasters with 'IMERG' string in the name and save results in the **Attribute Table** of the shapefile

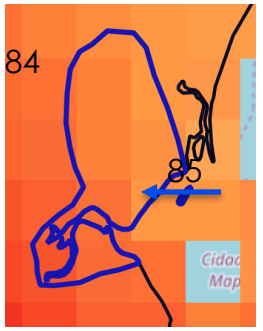


- Note that the 'prefix' in the script will be used to identify the raster for which the mean is calculated – in this example it will be 4-digit year extracted from the raster name (e.g. 2001_, 2002_ etc)

Part 3: Precipitation Mean Time Series for Maputo Region

3. Check and save the results:
   - Left-click on the Maputo layer and click on the **Open Attribute Table** (tool bar) or right-click on Maputo layer and click on **Open Attribute Table**
   - You will see two features (IDs 84 and 85) associated with Maputo polygons
   - You will see the list of mean precipitation for DJF for years 2001 to 2019
   - Following the steps from Part-2 for installing QGIS plugins, search and install the plugin **MMQGIS**
   - The next slide shows how to save the mean data in a csv file using MMQGIS

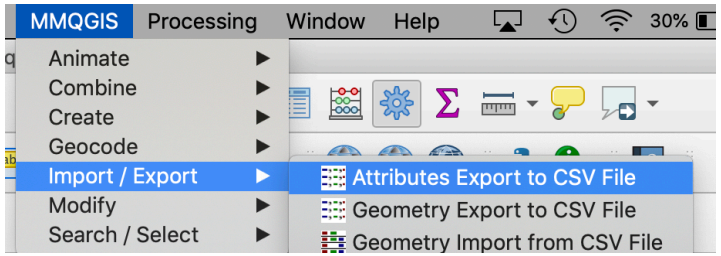


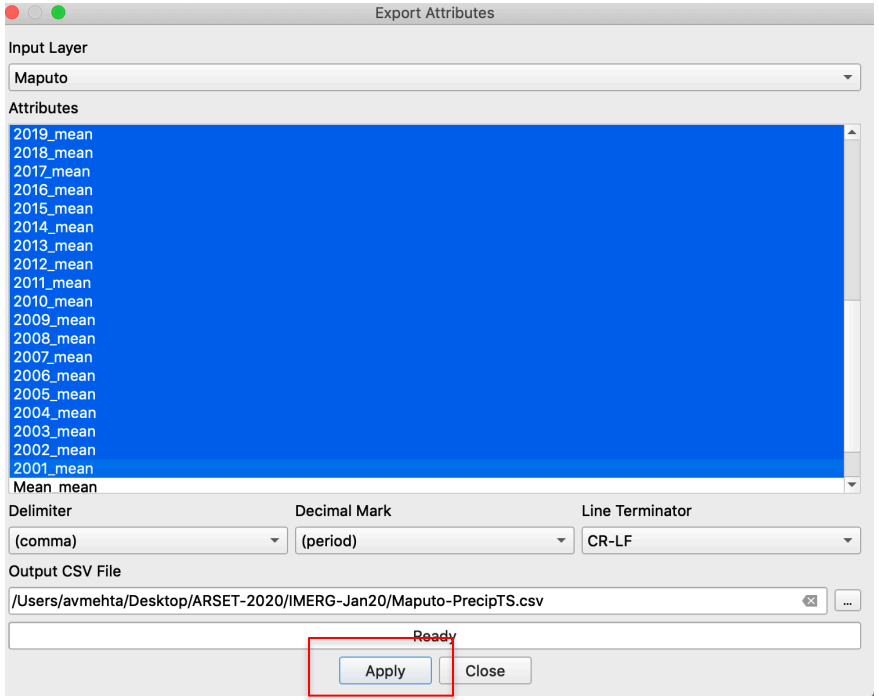


2019_mean	96.564775739397319
2018_mean	127.013371058872764
2017_mean	158.003849574497764
2016_mean	39.130940846034456
2015_mean	154.104703630719854
2014_mean	87.736631120954243
2013_mean	133.830122811453691
2012_mean	121.393145969935830
2011_mean	172.500037057059160
2010_mean	69.341823032924111
2009_mean	142.098044259207597
2008_mean	99.121473039899556
2007_mean	87.697238377162392
2006_mean	139.007158551897334
2005_mean	100.103166852678569
2004_mean	123.451486860002788
2003_mean	68.237694876534604
2002_mean	115.996332441057476
2001_mean	129.095409938267295

Part 3: Precipitation Mean Time Series for Maputo Region

4. Click on **MMQGIS** (menu bar)
   - Go to **Import/Export → Attributes Export to CSV File**
   - In the **Attributes** section highlight 2001_mean to 2019_mean
   - In **Output CSV File** (bottom portion of the window) enter the following file name to save the attributes on your computer: **Maputo-PrecipTS.csv**
   - Select **Apply**
   - You will receive the message: **2 Records Exported** when the attributes are saved
   - Close the window





Part 3: Precipitation Time Series Statistics for Maputo Region

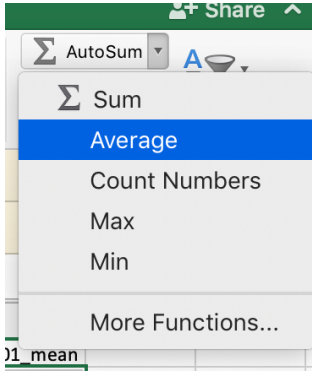
5. Click on **Maputo-PrecipTS.csv** on your computer to open in Excel (see below)
   - You will see 1) year row 2) mean precipitation over Maputo for the feature Id 84 (bigger region covering Maputo 3) mean precipitation for the feature ID 85 (small island close to the coast). We will focus on the bigger region (Id 84, row 2)
   - Based on the table, write down the year with the highest and lowest amount of precipitation

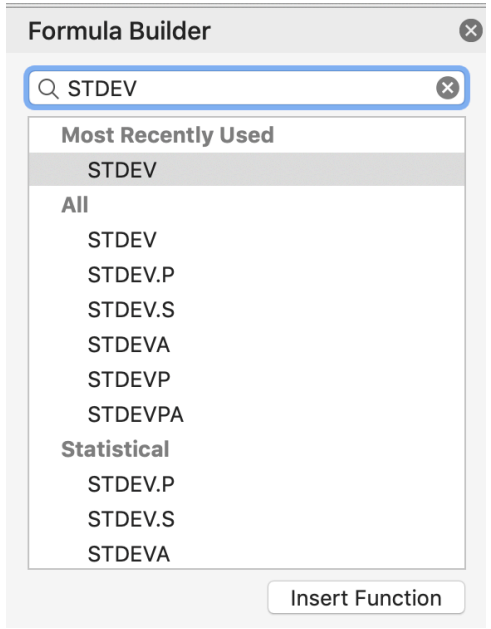
Maputo-PrecipTS.csv

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	2019_mean	2018_mean	2017_mean	2016_mean	2015_mean	2014_mean	2013_mean	2012_mean	2011_mean	2010_mean	2009_mean	2008_mean	2007_mean	2006_mean	2005_mean	2004_mean	2003_mean	2002_mean	2001_mean
2	96.5647757	127.013371	158.00385	39.1309409	154.104704	87.7366311	133.830123	121.393146	172.500037	69.341823	142.098044	99.121473	87.6972384	139.007159	100.103167	123.451487	68.2376949	115.996332	129.09541
3	101.456128	127.382299	167.321395	41.4259992	173.822122	87.6140215	145.10837	125.595412	194.583399	78.1594718	143.93512	100.313529	90.4808931	149.056039	102.790924	125.143174	72.0701436	116.966354	132.5794

Part 3: Find Mean, Standard Deviation, and Percentiles of Precipitation for Maputo Region

6. Select cell T2 from Maputo ID=84 (row 2 in the table). From the ribbon in the Home tab, use the drop-down arrow in **AutoSum** and select **Average**. Make sure cells **A2:S2** are highlighted and press Enter
   - You will get the mean precipitation value in the last column of the row
7. Select cell U2 for Maputo ID=84 (row 2 in the table)
   - In the **AutoSum** options click on **More Functions…** and search for **STDEV** for standard deviation
   - Click on **STDEV** and then **Insert Function** (bottom right) in the window
   - Make sure cells **A2:S2** are entered under Number1 and press Enter

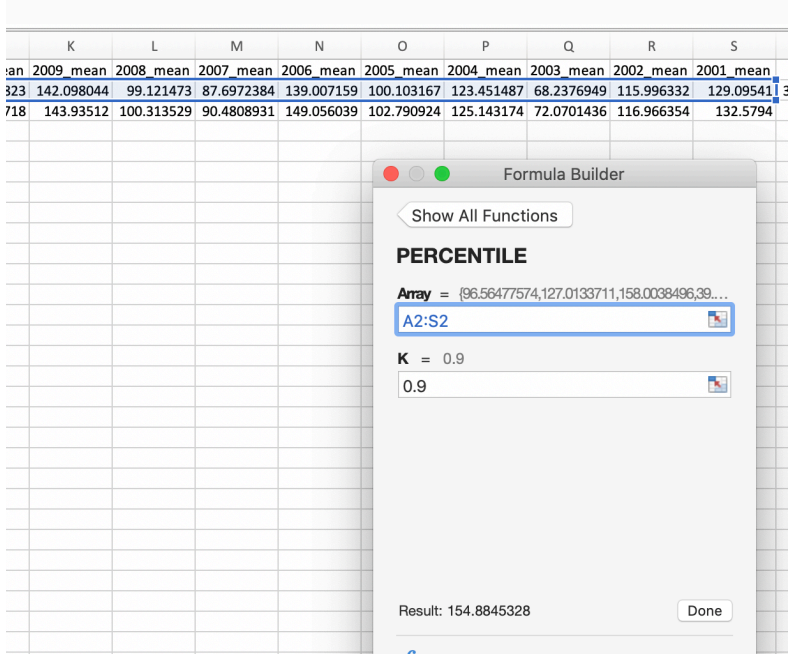




Part 3: Find Mean, Standard Deviation, and Percentiles of Precipitation for Maputo Region

8. Select cell V2 for Maputo ID=84 (row 2 in the table)

- In the **AutoSum** options go to **More Functions…** and search for **PERCENTILE**
- Click on **PERCENTILE** and then on **Insert Function** (bottom right) in the window
- You will see two options, **Array** and **K**
- Click in the **Array** box and enter the column range **A2:S2**
- Enter **0.9** in the **K** window for the 90th percentile value of the precipitation time series and click Enter
- Click in cell W2 and repeat the above steps for the 25th percentile, and cell X2 for the 95th percentile



Part 3: Precipitation Anomaly Time Series Statistics for Maputo Region

9. Download the file **Maputo-AnomTS.csv** from the webinar website:
   https://arset.gsfc.nasa.gov/water/webinars/IMERG-2020
   [This file can be created by going through steps 2-4 but using the the python script **Anom_ZonalStats.py** -- Optional]
10. Repeat step 8 to find 25th and 95th percentile values for **Maputo-AnomTS.csv**

Part 3: Questions

- What are the mean and standard deviation values in Steps 6 and 7?
- What are the 25th and 95th percentile values of precipitation in Step 8?
- Which years had the maximum and minimum anomalies?
- What are the 25th and 95th percentile values of precipitation anomalies in Step 9?
- Which year(s) had anomalies above the 95th percentile value?