

# Exercise 1: Using Earth Observations to Monitor Water Budgets for River Basin Management II

Amita Mehta and Sean McCartney

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# Exercise 1

- This exercise focuses on acquiring the data we will use for water budget estimation in sessions 2 & 3.

# Objectives

- After participating in this exercise, attendees should be able to replicate the steps for acquiring Earth science data provided from NASA's Earth Observing System Data and Information System ([EOSDIS](#)), accessed from:
  - Giovanni for **IMERG\*** precipitation data
  - AppEEARS\* for **MODIS Evapotranspiration (ET)** data
  - PO.DAAC\* for **GRACE-FO Terrestrial Water Storage (TWS)** anomaly data
  - NASA GES DISC\* for **GLDAS 2.1** data

\*IMERG: Integrated Multi-satellite Retrievals for GPM

\*AppEEARS: Application for Extracting and Exploring Analysis Ready Samples

\*PO.DAAC: Physical Oceanography Distributed Active Archive Center

\*GES DISC: Goddard Earth Sciences Data and Information Services Center



# Requirements

- Account registered with NASA EarthData
- QGIS installed on your computer
- Folder with a shapefile of the Limpopo River Basin saved on your computer (link to access the shapefile is found at the link below).
  - <https://arset.gsfc.nasa.gov/water/webinars/water-budgets-river-basin>





# Note

This is a four-part exercise to save NASA Earth science data to a directory on your computer for analysis in sessions 2 & 3 of the webinar series:

Part 1: Download IMERG precipitation data

Part 2: Download MODIS ET data

Part 3: Download GRACE-FO Terrestrial Water Storage (TWS) anomaly data

Part 4: Download GLDAS 2.1 precipitation, ET, TWS, and runoff data

– Questions based on this exercise will be included in Homework 1



# Part 1

Download monthly IMERG precipitation data for the selected months:

1. December (2018), January, February (2019)
2. June, July, August (2019)








# Part 1: Download Monthly IMERG Precipitation Data

1. Go to: <https://giovanni.gsfc.nasa.gov/giovanni/>
2. Login using your EarthData username and password
3. Select Plot → Map, Accumulated
4. Select Date Range (UTC) → Dec 1, 2018 to Feb 28, 2019

**Select Plot**

Map, Accumulated 

**Select Date Range (UTC)**

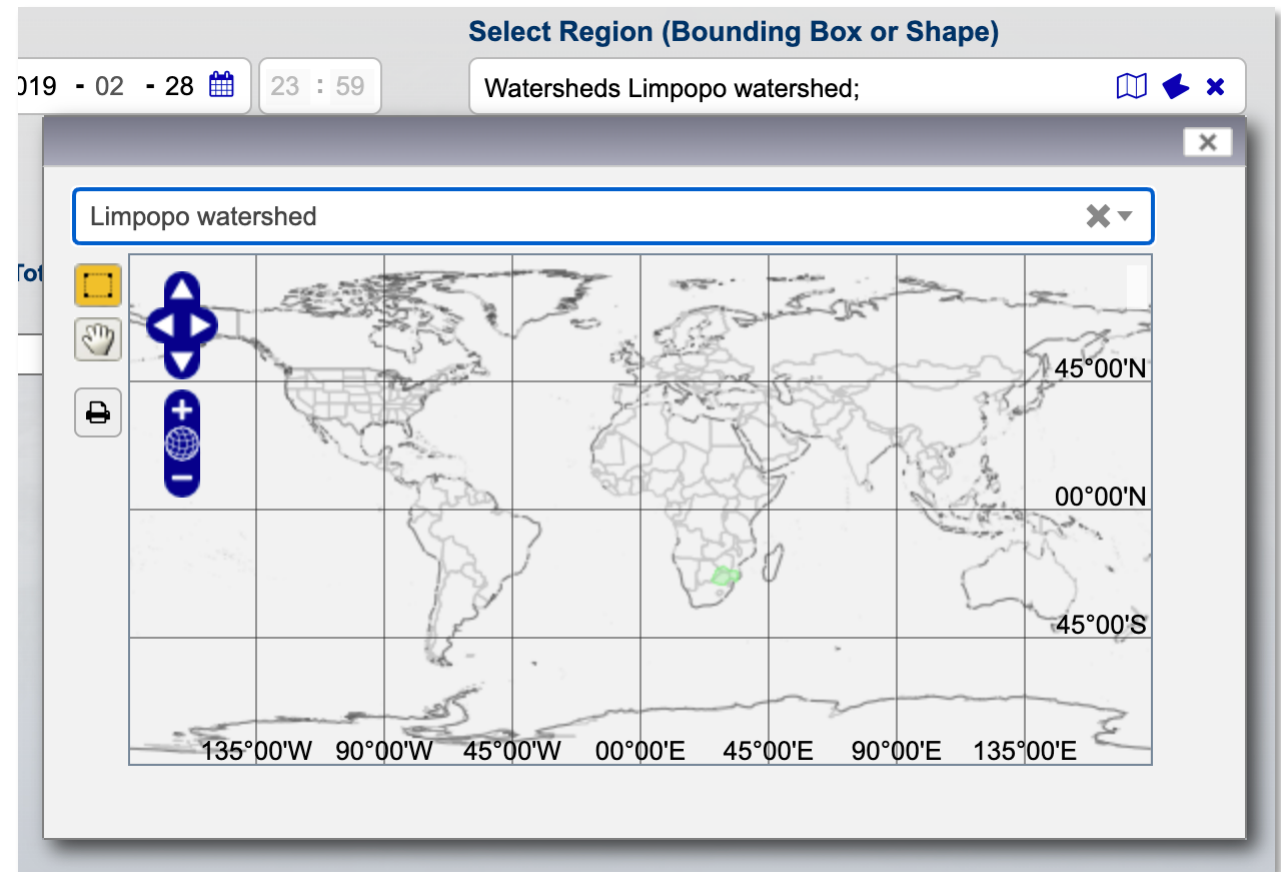
2018 - 12 - 01  00 : 00 to 2019 - 02 - 28  23 : 59

Valid Range: 1948-01-01 to 2020-07-10



# Part 1: Download Monthly IMERG Precipitation Data

5. Select Region (Bounding Box or Shape)
  - Click on the blue icon (Select a shape...).
  - Type “Limpopo watershed” and click on the highlighted text.
  - Once selected, the watershed polygon will be delineated in green on the map.



# Part 1: Download monthly IMERG Precipitation Data

- Next to **Keyword** type “IMERG Final monthly” and click **Search**.
- Select the Variable “Merged satellite-gauge precipitation estimate - Final Run (recommended for general use) (GPM\_3IMERGM v06).”
- Change units to **mm/month**.
- Click on Plot Data.

Keyword :

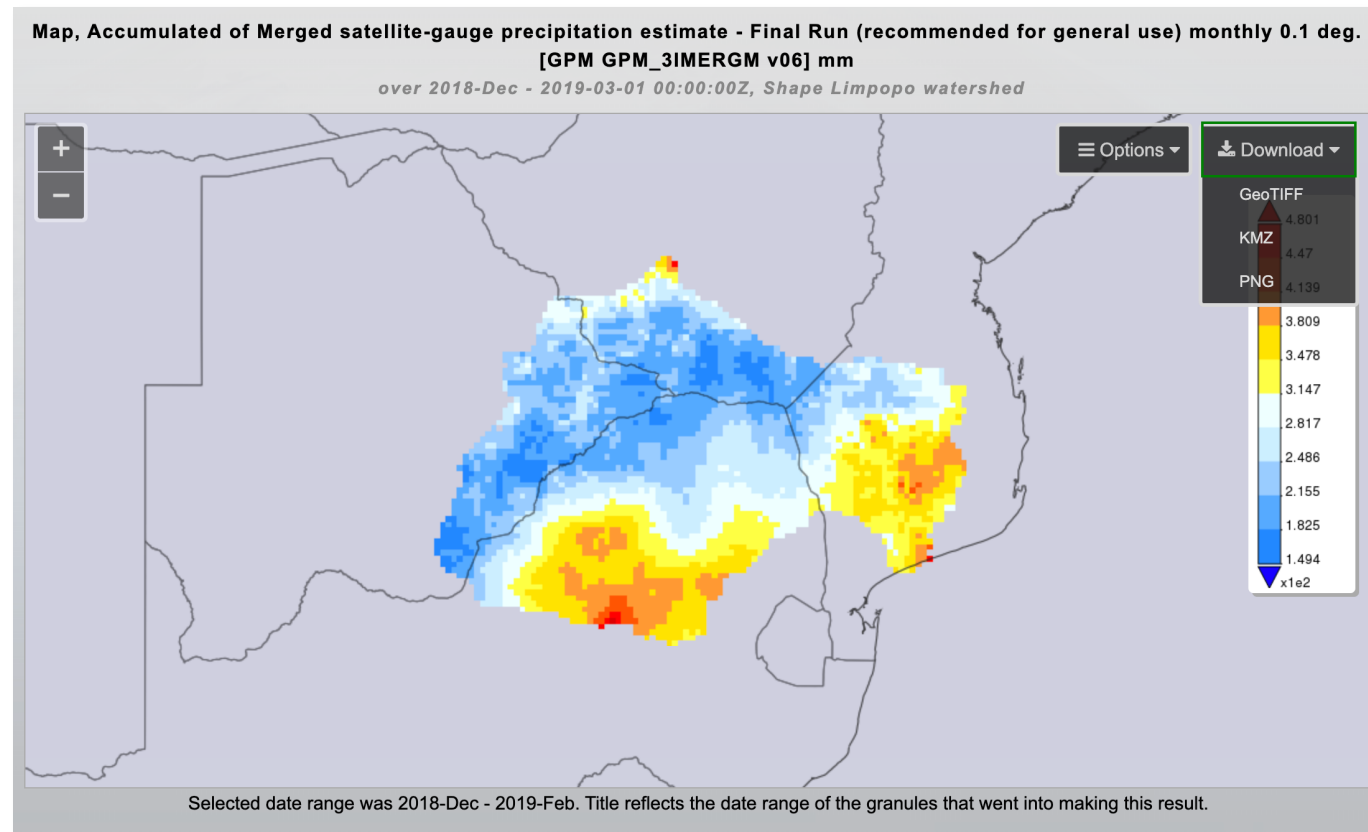
	Variable	Units	Source	Temp.Res.	Spat.Res.	Begin Date	End Date
<input checked="" type="checkbox"/>	<a href="#">Merged satellite-gauge precipitation estimate - Final Run (recommended for general use) (GPM_3IMERGM v06)</a>	<input type="text" value="mm/month"/>	GPM	Monthly	0.1 °	2000-06-01	2020-03-31



# Part 1: Download Monthly IMERG Precipitation Data

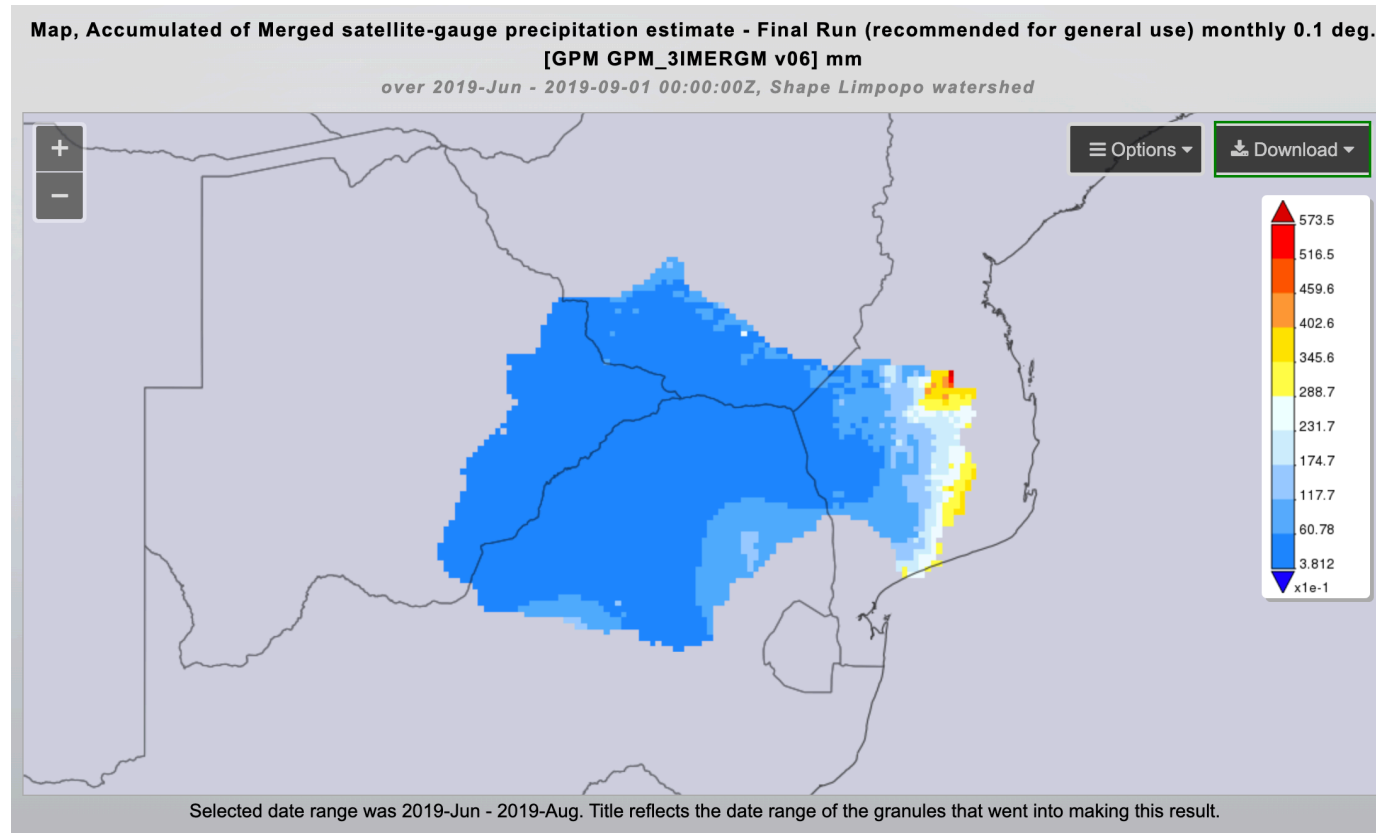
10. Click on Download → GeoTIFF.

11. Save the file to a working directory on your computer with a short, descriptive filename (e.g. IMERG\_Dec18-Feb19.tif).



# Part 1: Download Monthly IMERG Precipitation Data

12. Click on “Back to Data Selection” (lower right button).
13. Repeat steps 4 - 11 for June – August (2019) and save to your working directory with short, descriptive filename (e.g. IMERG\_Jun-Aug19.tif).





# Part 2

Download 8-day MODIS ET data products (MOD16) for the selected months:

1. December (2018), January, February (2019)
2. June, July, August (2019)

## Note:

- The start and end dates are in Julian days.
- The Julian day for each MODIS image represents the first day of the 8-day composite.
- The MOD16 file name has the following naming convention:

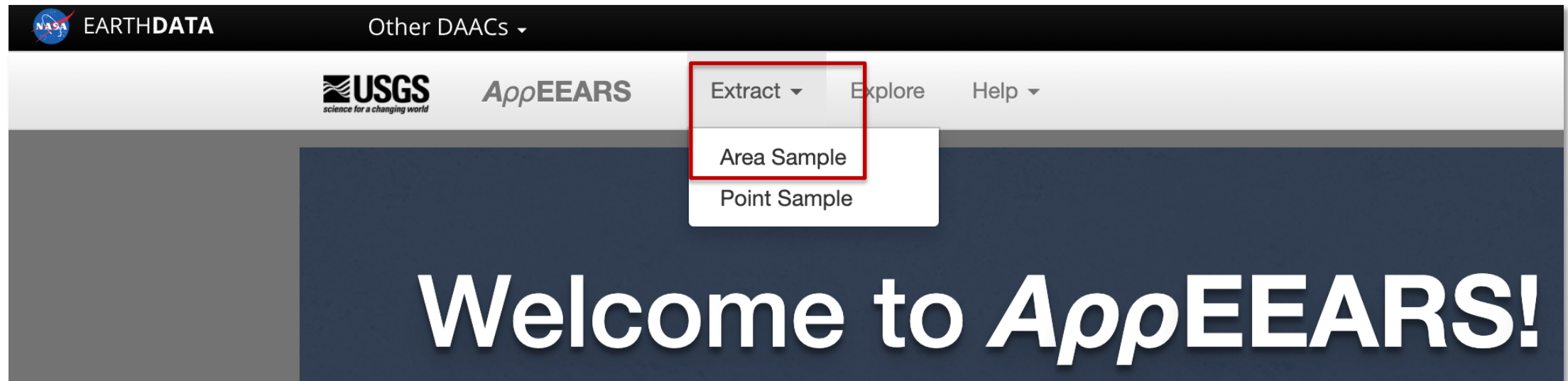
**MOD16A2.A2002081.h02v06.105.2010355155223.hdf**

- MOD16A2 - Product Short Name
- .A2002081 - Julian Date of Data Acquisition (A-YYYYDDD)
- .h02v06 - Tile Identifier (horizontalXXverticalYY)
- .105 - Collection Version
- .2010355155223 - Julian Date and time of being generated (YYYYDDDDHHMMSS)
- .hdf - Data Format (HDF-EOS)



## Part 2: Download 8-day MODIS ET Data

1. Go to <https://lpdaacsvc.cr.usgs.gov/appears/>.
2. Sign In using your EarthData username and password.
3. From the menu bar select Extract → Area Sample.
4. Click on “Start a new request.”



## Part 2: Download 8-day MODIS ET Data

5. Enter a name to identify your sample = **MODIS ET Dec18 – Feb 19**
6. Upload a file... → click on the blue **click here** and select the zipped shapefile of the Limpopo River Basin provided from the ARSET website:  
<https://arset.gsfc.nasa.gov/water/webinars/water-budgets-river-basin>
  - The basin extent will appear in the window on the right.
7. Start Date 12-01-2018                      End Date 02-28-2019

Enter a name to identify your sample

MODIS ET Dec18 – Feb 19

Upload a file or draw a polygon using the or icon

Drop a vector polygon file containing the area feature(s) to extract or [click here](#) to select the file.

Supported file formats:

- ESRI Shapefile (*zip including .shp, .dbf, .prj, and .shx files*)
- GeoJSON (*.json or .geojson*)

Start Date: 12-01-2018      End Date: 02-28-2019

Is Date Recurring?

Selected file (\_MACOSX/.Aqueduct\_river\_basins\_LIMPOPO)

Map showing the Limpopo River Basin highlighted in green, covering parts of Zimbabwe, Mozambique, Botswana, and South Africa. Coordinates: Lat: 55.125 Lon: -74.461. Map source: Leaflet | NASA EOSDIS GIBS.

To clear a polygon, draw a new polygon or upload a vector polygon file.



## Part 2: Download 8-day MODIS ET Data

8. Select the layers to be included in the sample →
  - Type “mod16” and 3 options will be presented.
  - Click on Terra MODIS Net Evapotranspiration Gap-Filled (ET & LE) **MOD16A2GF.006**.
9. Select ET\_500m.

The screenshot displays a user interface for selecting data layers. It is divided into two main sections: 'Select the layers to include in the sample' and 'Selected layers'.

**Select the layers to include in the sample**

- Terra MODIS Net Evapotranspiration Gap-Filled (ET & LE)**  
*MOD16A2GF.006, 500m, 8 day, (2000-01-01 to Present)*
- ET\_QC\_500m
- LE\_500m
- PET\_500m
- PLE\_500m

**Selected layers**

- ET\_500m (500m, 8 day)



## Part 2: Download 8-day MODIS ET Data

10. Output Options → File Format → GeoTiff

11. Projection → Geographic

12. Click Submit.

13. You will receive a link to download the data in an email.

### Output Options

**File Format:** GeoTiff ▼

**Projection:** **Geographic** ✕

Datum: WGS84

EPSG: 4326

PROJ.4: `+proj=longlat +datum=WGS84 +no_defs`



# Part 2: Download 8-day MODIS ET Data

10. Repeat steps 7 – 13 for the months June, July, August (2019).

The screenshot shows the NASA Earth Data Downloader interface for MODIS ET data. The interface is divided into several sections:

- Enter a name to identify your sample:** A text input field containing "MODIS ET Jun 19 – Aug 19".
- Upload a file or draw a polygon using the or icon:** A dashed blue box containing instructions: "Drop a vector polygon file containing the area feature(s) to extract or [click here](#) to select the file." Below this, it lists supported file formats: ESRI Shapefile (.zip including .shp, .dbf, .prj, and .shx files) and GeoJSON (.json or .geojson).
- Start Date:** A date picker set to "06-01-2019".
- End Date:** A date picker set to "08-31-2019".
- Is Date Recurring?:** A checkbox that is currently unchecked.
- Select the layers to include in the sample:** A list of layers with expand/collapse icons. The top layer is "Terra MODIS Net Evapotranspiration Gap-Filled (ET & LE) MOD16A2GF006, 500m, 8 day, (2000-01-01 to Present)". Below it are "ET\_QC\_500m", "LE\_500m", "PET\_500m", and "PLE\_500m".
- Selected layers:** A list showing "ET\_500m" with a resolution of "500m, 8 day".
- Output Options:** A section for "File Format" (set to "GeoTiff") and "Projection" (set to "Geographic" with details: Datum: WGS84, EPSG: 4326, PROJ.4: +proj=longlat +datum=WGS84 +no\_defs).
- Map:** A satellite map of southern Africa showing a green polygon over the Limpopo river basin. The map includes labels for Zimbabwe, Mozambique, Botswana, Johannesburg, and Maputo. Coordinates are shown as "Lat: -26.437 Lon: 23.783".



# Part 3

Download monthly GRACE-FO TWS data for the selected months:

1. December (2018), January, February, March (2019)
2. June, July, August, September (2019)





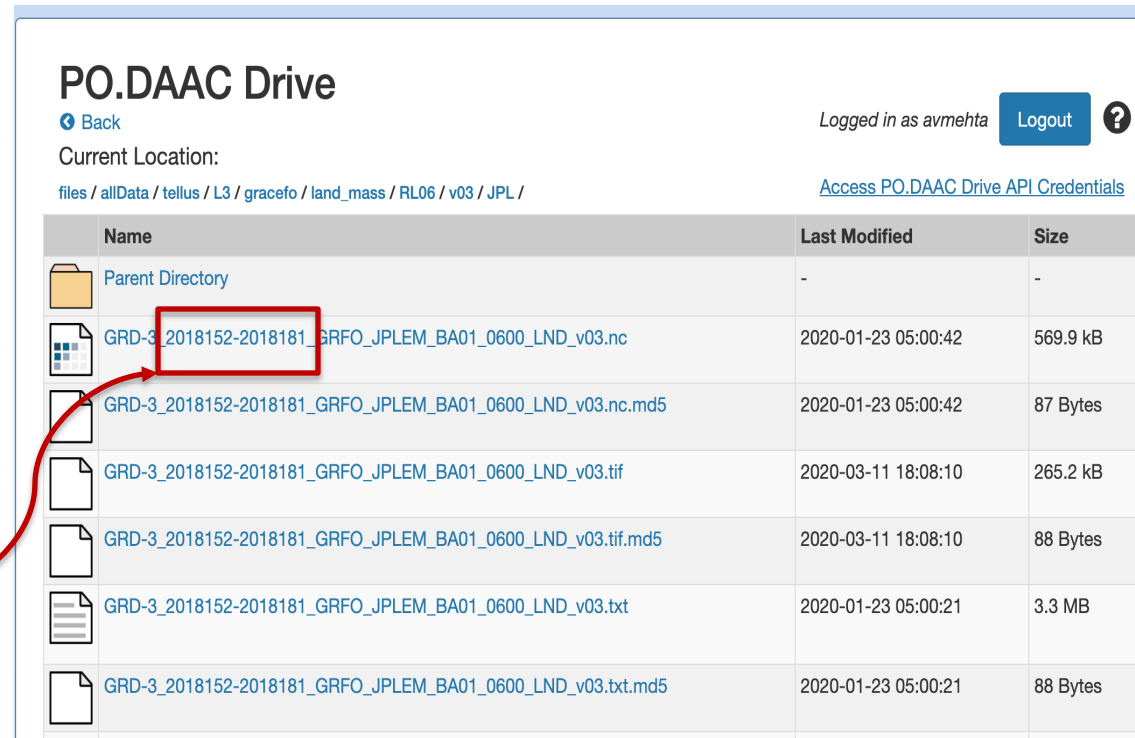
# Part 3: Download Monthly GRACE-FO TWS Data

1. Go to [https://podaac-tools.jpl.nasa.gov/drive/files/allData/tellus/L3/gracefo/land mass/RL06/v03/JPL](https://podaac-tools.jpl.nasa.gov/drive/files/allData/tellus/L3/gracefo/land_mass/RL06/v03/JPL).

2. There will be a list of GRACE-FO monthly TWS files.

## Note:

- The start and end dates are in Julian days, available from [https://podaac-tools.jpl.nasa.gov/drive/files/allData/tellus/L3/docs/GRACE GRACE-FO Months RL06.pdf](https://podaac-tools.jpl.nasa.gov/drive/files/allData/tellus/L3/docs/GRACE_GRACE-FO_Months_RL06.pdf), for each year and month
- The files are available in NetCDF (nc), tif, and text formats.



PO.DAAC Drive

Back

Logged in as avmehta Logout

Current Location:  
files / allData / tellus / L3 / gracefo / land\_mass / RL06 / v03 / JPL /

Access PO.DAAC Drive API Credentials

Name	Last Modified	Size
Parent Directory	-	-
GRD-3_2018152-2018181_GRFO_JPLEM_BA01_0600_LND_v03.nc	2020-01-23 05:00:42	569.9 kB
GRD-3_2018152-2018181_GRFO_JPLEM_BA01_0600_LND_v03.nc.md5	2020-01-23 05:00:42	87 Bytes
GRD-3_2018152-2018181_GRFO_JPLEM_BA01_0600_LND_v03.tif	2020-03-11 18:08:10	265.2 kB
GRD-3_2018152-2018181_GRFO_JPLEM_BA01_0600_LND_v03.tif.md5	2020-03-11 18:08:10	88 Bytes
GRD-3_2018152-2018181_GRFO_JPLEM_BA01_0600_LND_v03.txt	2020-01-23 05:00:21	3.3 MB
GRD-3_2018152-2018181_GRFO_JPLEM_BA01_0600_LND_v03.txt.md5	2020-01-23 05:00:21	88 Bytes

For data search use the following link and type GRACE or GRACE FO in the search window:  
<https://podaac.jpl.nasa.gov/>



## Part 3: Download Monthly GRACE-FO TWS data

3. Select tif file for December 2018 (Julian day 335-365): **GRD-3\_2018335-2018365\_GRFO\_JPLEM\_BA01\_0600\_LND\_v03**.
4. Click on the filename and download to save on your computer.  
Recommendation: Save the file with a short, descriptive filename. For example, in this exercise we will use: **GRFO\_TWS\_Dec18.tif**.
5. Repeat steps 3 and 4 for January, February, March (2019), & June, July, August, September (2019) and save to a working directory on your computer with short, descriptive filenames (see example above).

Month Sr No	GRACE/GRA	MONTH	YEAR	START DAY	YEAR	END DAY
195	164	JUN	2018	152	2018	181
196	165	JUL	2018	182	2018	212
197	NA	AUG	2018	213	2018	243
198	NA	SEP	2018	244	2018	273
199	166	OCT	2018	274	2018	313
200	167	NOV	2018	305	2018	334
201	168	DEC	2018	335	2018	365
202	169	JAN	2019	1	2019	31
203	170	FEB	2019	26	2019	63
204	171	MAR	2019	60	2019	90
205	172	APR	2019	91	2019	120
206	173	MAY	2019	121	2019	151
207	174	JUN	2019	152	2019	181
208	175	JUL	2019	182	2019	212
209	176	AUG	2019	213	2019	243
210	177	SEP	2019	244	2019	273
211	178	OCT	2019	274	2019	304
212	179	NOV	2019	305	2019	334
213	180	DEC	2019	335	2019	365

From: [https://podaac-tools.jpl.nasa.gov/drive/files/allData/tellus/L3/docs/GRACE\\_GRACE-FO\\_Months\\_RL06.pdf](https://podaac-tools.jpl.nasa.gov/drive/files/allData/tellus/L3/docs/GRACE_GRACE-FO_Months_RL06.pdf)




# Part 4

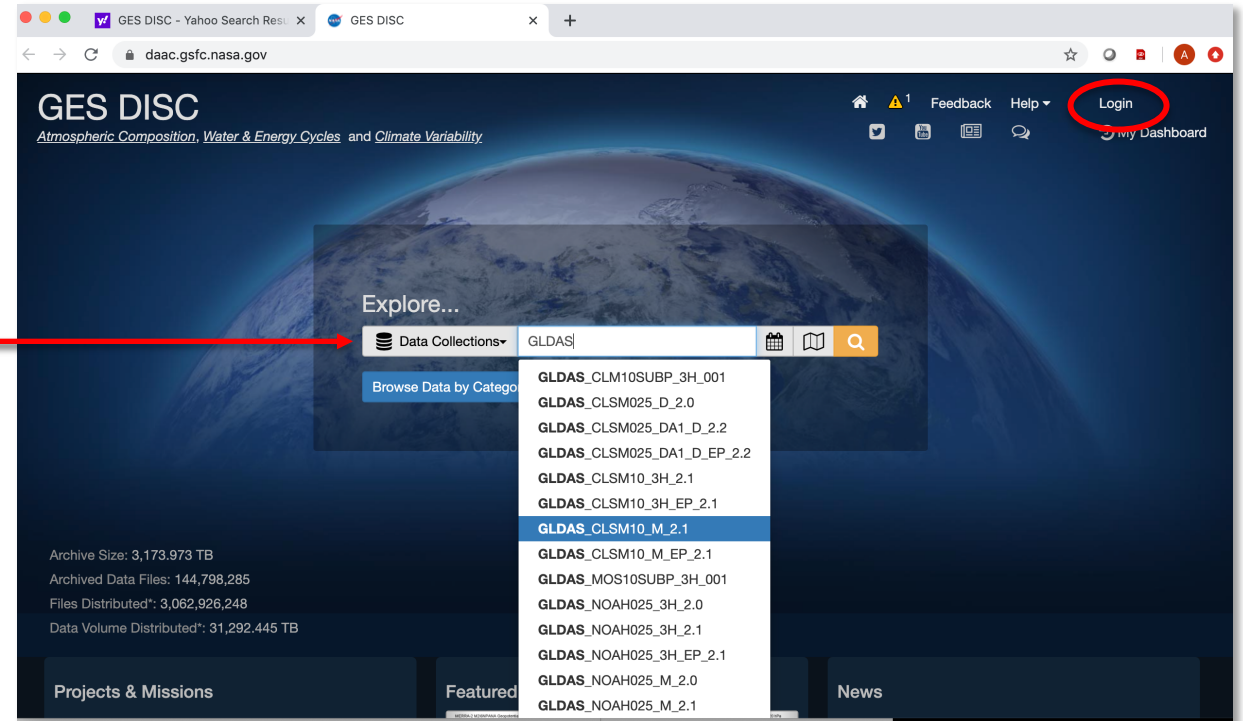
Download monthly precipitation, ET, TWS, Runoff, and Baseflow Runoff data from GLDAS 2.1 for the same selected months:

1. December (2018), January, February, March (2019)
2. June, July, August, September (2019)



# Part 4: Download Monthly GLDAS 2.1 Data

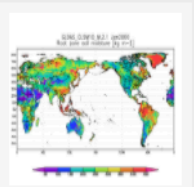
1. Go to GES DISC  
<https://daac.gsfc.nasa.gov/>.
2. Login (top right) using your NASA EarthData username and password.
3. In the **Explore...Data Collection** window type GLDAS.
4. Select **GLDAS\_CLSM10\_M2.1** and click on search. 



# Part 4: Download Monthly GLDAS 2.1 Data



5. You will see the following information along with the link for the dataset:

Image	Dataset	Source	Version	Time Res.	Spatial Res.	Process Level	Begin Date	End Date
 Hover	<a href="#">GLDAS Catchment Land Surface Model L4 monthly 1.0 x 1.0 degree V2.1 (GLDAS_CLSM10_M 2.1)</a> <a href="#">Subset / Get Data</a>	Models/Analyses Catchment-LSM	2.1	1 month	1.0 ° x 1.0 °	4	2000-01-01	<a href="#">2020-03-31</a>

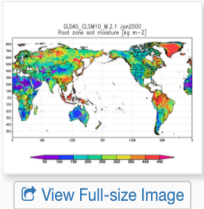
6. Click on the dataset link.



# Part 4: Download Monthly GLDAS 2.1 Data

7. You will see description of the dataset and a link to documentation.
8. Click on the **Subset/Get Data** link.

**GLDAS\_CLSM10\_M: GLDAS Catchment Land Surface Model L4 monthly 1.0 x 1.0 degree V2.1**



NASA Global Land Data Assimilation System Version 2 (GLDAS-2) has three components: GLDAS-2.0, GLDAS-2.1, and GLDAS-2.2. GLDAS-2.0 is forced entirely with the Princeton meteorological forcing input data and provides a temporally consistent series from 1948 through 2014. GLDAS-2.1 is forced with a combination of model and observation data from 2000 to present. GLDAS-2.2 product suites use data assimilation (DA), whereas the GLDAS-2.0 and GLDAS-2.1 products are "open-loop" (i.e., no data assimilation). The choice of forcing data, as well as DA observation source, variable, and scheme, vary for different GLDAS-2.2 products.

GLDAS-2.1 data products are now available in two production streams: one stream is forced with combined forcing data including GPCP version 1.3 (the main production stream), and the other stream is processed without ...[more](#)

[View Full-size Image](#)

**Data Access**

- [Online Archive](#)
- [Earthdata Search](#)
- [OPENDAP](#)
- [Subset / Get Data](#)

[Product Summary](#) [Data Citation](#) [Documentation](#)

**Shortname:** GLDAS\_CLSM10\_M  
**Longname:** GLDAS Catchment Land Surface Model L4 monthly 1.0 x 1.0 degree V2.1  
**DOI:** 10.5067/FOUXNLXFAZNY  
**Version:** 2.1  
**Format:** netCDF  
**Spatial Coverage:** -180.0,-60.0,180.0,90.0  
**Temporal Coverage:** 2000-01-01 to 2020-03-31  
**File Size:** 2 MB per file  
**Data Resolution**  
**Spatial:** 1.0 ° x 1.0 °  
**Temporal:** 1 month



# Part 4: Download Monthly GLDAS 2.1 Data

9. Select **Download Method** → **Get File Subsets using the GES DISC Subsetter**

10. Under **Method Options**:

- **Refine Date Range** - Choose dates using the drop-down arrow.
- **From: December 1, 2018**
- **To: September 30, 2019**
- **Refine Region** - Use drop-down arrow and enter coordinates encompassing the Limpopo River Basin:

West longitude = 25.0  
South latitude = -27.0  
East longitude = 35.0  
North latitude = -19.0

Download Method ?

Download Method: ✓ Get File Subsets using the GES DISC Subsetter Reset

Method Options ?

Refine Date Range: ✓ 2018-12-01 to 2019-09-30 Reset

NOTE: All dates and times are in UTC.

From: 2018-12-01 To: 2019-09-30

Available Range: 2000-01-01 to 2020-03-31

December 2018

Sun	Mon	Tue	Wed	Thu	Fri	Sat
25	26	27	28	29	30	01
02	03	04	05	06	07	08
09	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31	01	02	03	04	05

September 2019

Sun	Mon	Tue	Wed	Thu	Fri	Sat
01	02	03	04	05	06	07
08	09	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	01	02	03	04	05
06	07	08	09	10	11	12

Refine Region: ✓ 25.0, -27.0, 35.0, -19.0 Reset

25.0,-27.0,35.0,-19.0

Map showing the region defined by the coordinates. Available Range: -180, -60, 180, 90. Cursor Coordinates:





# Part 4: Download Monthly GLDAS 2.1 Data

11. Using the drop-down arrow for **Variables**, first choose only **Evap\_tavg = Evapotranspiration (kg m<sup>-2</sup> s<sup>-1</sup>)**

12. Scroll down to **Output format** and choose **File Format → GeoTiff (Please select ONLY ONE variable)**.

13. Click on **Get Data** (bottom right).

▼ **Variables:** ✓ 1 variable(s) selected

**NOTE:** By default, **ALL** variables are sent in the subset request.

- ACond\_tavg = Aerodynamic conductance (m s<sup>-1</sup>)
- Albedo\_inst = Albedo (%)
- AvgSurfT\_inst = Average surface skin temperature (K)
- CanopInt\_inst = Plant canopy surface water (kg m<sup>-2</sup>)
- ECanop\_tavg = Canopy water evaporation (W m<sup>-2</sup>)
- ESoil\_tavg = Direct evaporation from bare soil (W m<sup>-2</sup>)
- Evap\_tavg = Evapotranspiration (kg m<sup>-2</sup> s<sup>-1</sup>)**
- LWdown\_f\_tavg = Downward longwave radiation flux (W m<sup>-2</sup>)
- Lwnet\_tavg = Net longwave radiation flux (W m<sup>-2</sup>)
- Psurf\_f\_inst = Surface air pressure (Pa)
- Qair\_f\_inst = Specific humidity (kg kg<sup>-1</sup>)
- Qg\_tavg = Ground heat flux (W m<sup>-2</sup>)
- Qh\_tavg = Sensible heat net flux (W m<sup>-2</sup>)
- Qle\_tavg = Latent heat net flux (W m<sup>-2</sup>)
- Qs\_acc = Storm surface runoff (kg m<sup>-2</sup> per 3-hour)
- Qsb\_acc = Baseflow-groundwater runoff (kg m<sup>-2</sup> per 3-hour)
- Qsm\_acc = Snow melt (kg m<sup>-2</sup> per 3-hour)
- Rainf\_f\_tavg = Total precipitation rate (kg m<sup>-2</sup> s<sup>-1</sup>)
- Rainf\_tavg = Rain precipitation rate (kg m<sup>-2</sup> s<sup>-1</sup>)
- SnowDepth\_inst = Snow depth (m)
- Snowf\_tavg = Snow precipitation rate (kg m<sup>-2</sup> s<sup>-1</sup>)
- SnowT\_tavg = Snow surface temperature (K)
- SoilMoist\_P\_inst = Profile soil moisture (kg m<sup>-2</sup>)
- SoilMoist\_RZ\_inst = Root zone soil moisture (kg m<sup>-2</sup>)
- SoilMoist\_S\_inst = Surface soil moisture (kg m<sup>-2</sup>)
- SoilTMP0\_10cm\_inst = Soil temperature (0-10 cm underground) (K)
- SoilTMP10\_29cm\_inst = Soil temperature (10-29 cm underground) (K)
- SoilTMP29\_68cm\_inst = Soil temperature (29-68 cm underground) (K)
- SoilTMP68\_144cm\_inst = Soil temperature (68-144 cm underground) (K)
- SoilTMP144\_295cm\_inst = Soil temperature (144-295 cm underground) (K)
- SoilTMP295\_1295cm\_inst = Soil temperature (295-1295 cm underground) (K)
- SWdown\_f\_tavg = Downward shortwave radiation flux (W m<sup>-2</sup>)
- SWE\_inst = Snow depth water equivalent (kg m<sup>-2</sup>)
- Swnet\_tavg = Net shortwave radiation flux (W m<sup>-2</sup>)
- Tair\_f\_inst = Air temperature (K)
- TVeg\_tavg = Transpiration (W m<sup>-2</sup>)
- TWS\_inst = Terrestrial water storage (mm)
- Wind\_f\_inst = Wind speed (m s<sup>-1</sup>)

Output format ?

▼ **File Format:** ✓ GeoTIFF (please select ONLY ONE variable) Reset

- Cloud Optimized GeoTIFF (please select ONLY ONE variable)
- GeoTIFF (please select ONLY ONE variable)**
- netCDF

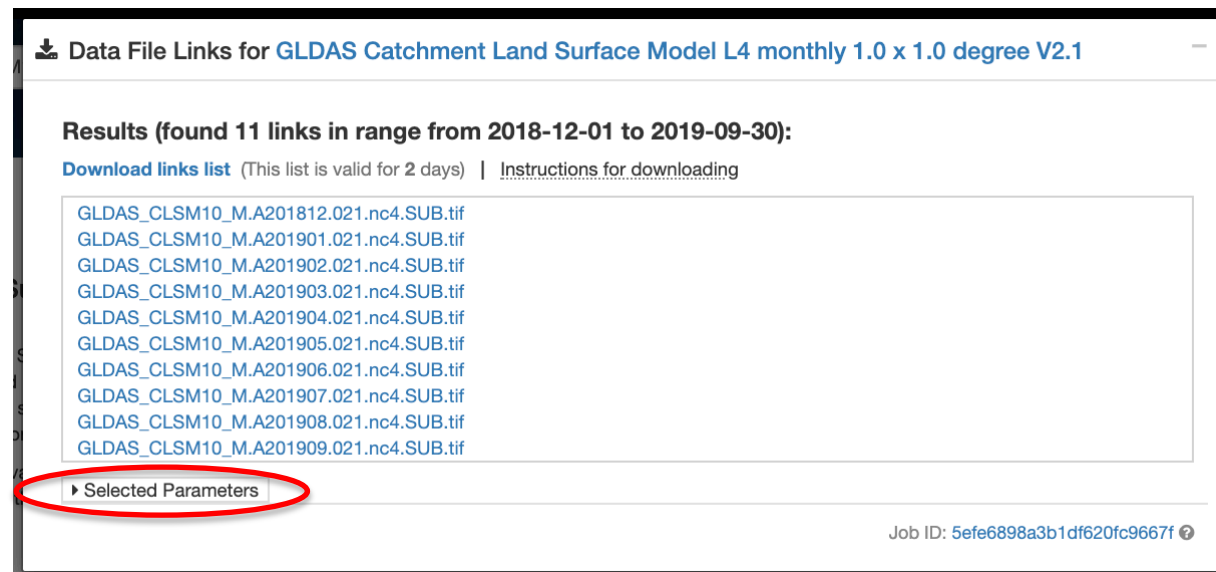
Reset All **Get Data**



# Part 4: Download Monthly GLDAS 2.1 Data

14. You will see the monthly data file list.
15. Click on the file name links for December (2018), January, February, March (2019) & June, July, August, September (2019).  
Recommendation: Save the files with short, descriptive file names.  
We will use **GLDAS2.1-ET-Dec18.tif** for December 2018, **GLDAS2.1-ET-Jan19** for January 2019, and so on for this exercise.

16. Click on **Selected Parameters** → **Refine Parameters**.
17. You will be navigated back to the data selection page.



Data File Links for **GLDAS Catchment Land Surface Model L4 monthly 1.0 x 1.0 degree V2.1**

Results (found 11 links in range from 2018-12-01 to 2019-09-30):

[Download links list](#) (This list is valid for 2 days) | [Instructions for downloading](#)

- [GLDAS\\_CLSM10\\_M.A201812.021.nc4.SUB.tif](#)
- [GLDAS\\_CLSM10\\_M.A201901.021.nc4.SUB.tif](#)
- [GLDAS\\_CLSM10\\_M.A201902.021.nc4.SUB.tif](#)
- [GLDAS\\_CLSM10\\_M.A201903.021.nc4.SUB.tif](#)
- [GLDAS\\_CLSM10\\_M.A201904.021.nc4.SUB.tif](#)
- [GLDAS\\_CLSM10\\_M.A201905.021.nc4.SUB.tif](#)
- [GLDAS\\_CLSM10\\_M.A201906.021.nc4.SUB.tif](#)
- [GLDAS\\_CLSM10\\_M.A201907.021.nc4.SUB.tif](#)
- [GLDAS\\_CLSM10\\_M.A201908.021.nc4.SUB.tif](#)
- [GLDAS\\_CLSM10\\_M.A201909.021.nc4.SUB.tif](#)

[Selected Parameters](#)

Job ID: 5efe6898a3b1df620fc9667f



# Part 4: Download Monthly GLDAS 2.1 Data

18. Repeat Steps 11-17 for the following variables one at a time:

- $Qs\_acc$  = Storm surface runoff ( $kg\ m^{-2}$  per 3-hour)
- $Qsb\_acc$  = Baseflow-groundwater runoff ( $kg\ m^{-2}$  per 3-hour)
- $Rainf\_f\_tavg$  = Total precipitation rate ( $kg\ m^{-2}\ s^{-1}$ )
- $TWS\_inst$  = Terrestrial water storage (mm)

Please refer to the next slide for recommended file names.

▼ Variables: ✓ 4 variable(s) selected

NOTE: By default, ALL variables are sent in the subset request.

- ACond\_tavg = Aerodynamic conductance ( $m\ s^{-1}$ )
- Albedo\_inst = Albedo (%)
- AvgSurfT\_inst = Average surface skin temperature (K)
- CanopInt\_inst = Plant canopy surface water ( $kg\ m^{-2}$ )
- ECanop\_tavg = Canopy water evaporation ( $W\ m^{-2}$ )
- ESoil\_tavg = Direct evaporation from bare soil ( $W\ m^{-2}$ )
- Evap\_tavg = Evapotranspiration ( $kg\ m^{-2}\ s^{-1}$ )
- LWdown\_f\_tavg = Downward longwave radiation flux ( $W\ m^{-2}$ )
- Lwnet\_tavg = Net longwave radiation flux ( $W\ m^{-2}$ )
- Psurf\_f\_inst = Surface air pressure (Pa)
- Qair\_f\_inst = Specific humidity ( $kg\ kg^{-1}$ )
- Qg\_tavg = Ground heat flux ( $W\ m^{-2}$ )
- Qh\_tavg = Sensible heat net flux ( $W\ m^{-2}$ )
- Qle\_tavg = Latent heat net flux ( $W\ m^{-2}$ )
- $Qs\_acc$  = Storm surface runoff ( $kg\ m^{-2}$  per 3-hour)
- $Qsb\_acc$  = Baseflow-groundwater runoff ( $kg\ m^{-2}$  per 3-hour)
- Qsm\_acc = Snow melt ( $kg\ m^{-2}$  per 3-hour)
- Rainf\_f\_tavg = Total precipitation rate ( $kg\ m^{-2}\ s^{-1}$ )
- Rainf\_tavg = Rain precipitation rate ( $kg\ m^{-2}\ s^{-1}$ )
- SnowDepth\_inst = Snow depth (m)
- Snowf\_tavg = Snow precipitation rate ( $kg\ m^{-2}\ s^{-1}$ )
- SnowT\_tavg = Snow surface temperature (K)
- SoilMoist\_P\_inst = Profile soil moisture ( $kg\ m^{-2}$ )
- SoilMoist\_RZ\_inst = Root zone soil moisture ( $kg\ m^{-2}$ )
- SoilMoist\_S\_inst = Surface soil moisture ( $kg\ m^{-2}$ )
- SoilTMP0\_10cm\_inst = Soil temperature (0-10 cm underground) (K)
- SoilTMP10\_29cm\_inst = Soil temperature (10-29 cm underground) (K)
- SoilTMP29\_68cm\_inst = Soil temperature (29-68 cm underground) (K)
- SoilTMP68\_144cm\_inst = Soil temperature (68-144 cm underground) (K)
- SoilTMP144\_295cm\_inst = Soil temperature (144-295 cm underground) (K)
- SoilTMP295\_1295cm\_inst = Soil temperature (295-1295 cm underground) (K)
- SWdown\_f\_tavg = Downward shortwave radiation flux ( $W\ m^{-2}$ )
- SWE\_inst = Snow depth water equivalent ( $kg\ m^{-2}$ )
- Swnet\_tavg = Net shortwave radiation flux ( $W\ m^{-2}$ )
- Tair\_f\_inst = Air temperature (K)
- TVeg\_tavg = Transpiration ( $W\ m^{-2}$ )
- $TWS\_inst$  = Terrestrial water storage (mm)
- Wind\_f\_inst = Wind speed ( $m\ s^{-1}$ )



## Part 4: GLDAS 2.1 Data Files

19. You will have the following files for each month – 40 files total at the end of Part 4:

GLDAS2.1-ET-monyy.tif	For Evapotranspiration
GLDAS2.1-PR-monyy.tif	For Precipitation
GLDAS2.1-RO-monyy.tif	For Storm Surface Runoff
GLDAS2.1-BRO-monyy.tif	For Baseflow Runoff
GLDAS2.1-TWS-monyy.tif	For Terrestrial Water Storage

Where mon = Dec (2018), Jan, Feb, Mar (2019), & Jun, Jul, Aug, Sep (2019)  
yy = '18 for Dec and '19 for all other months

