**ReadMe file for “Global groundwater available is significantly lower: Exponential decline of specific yield with water table depth” to run python scripts to obtain specific yield Sy**

We are providing this script to retrieve the specific yield values for mascon number 27 in the United States. This script can be used for any region, provided that the mascon shapefiles and corresponding datasets are prepared according to the steps provided below.

**Download all essential data and scripts into a folder and name it as “example\_data\_for\_sy”.**

1. **The United State shapefile**

Create a folder titled "1\_US\_Outline" and place the downloaded US outline shapefile, named "1\_US\_Outline.shp," along with its associated auxiliary files, into this folder.

1. **Mascon shapefiles**

Create a folder titled "2\_mascon\_shp" and place the downloaded US mascon shapefile, named "2\_GRACE\_US\_mascon\_27.shp," along with its associated auxiliary files, into this folder.

Note: Prepare your own mascon shapefiles for the specific study region as needed.

1. **JPL mascon data**

Download the JPL mascon data (.nc file) from

<https://podaac.jpl.nasa.gov/dataset/TELLUS_GRAC-GRFO_MASCON_CRI_GRID_RL06.3_V4>

Specification: Grid size: 0.5°x 0.5°, Temporal resolution: monthly,

Required variables: lwe\_thickness, uncertainty (default unit is centimeter, converted to meter). Main program will take care of the unit conversion mentioned.

Create a folder titled "3\_GRACE\_JPL" and place the downloaded GRACE JPL .nc file into this folder.

1. **Soil moisture and uncertainty**

Download the soil moisture data (.nc files) from the following link:

<https://cds.climate.copernicus.eu>

Specifications: Grid size: 0.25° x 0.25°, Temporal resolution: Daily

Required variables: Soil moisture (sm), soil moisture uncertainty (sm\_uncertainty)  
Note: The default unit of soil moisture is m³/m³. To convert to meters, multiply by a factor of 0.05 as the soil moisture data is available upto 5 centimeter depth.

After downloading, clip the .nc files according to the required mascon shapefile. Compute the monthly soil moisture anomaly and corresponding uncertainty (using the error propagation law) from the daily soil moisture data. Finally, save the output in CSV format.

An example CSV file titled “ts\_sma\_smau\_uncer\_mascon\_27.csv” for Mascon 27 of the United States is made available. Create a folder titled "4\_soil\_moisture" and place the downloaded CSV file into this folder.

1. **Groundwater level and uncertainty**

Download the monthly groundwater level data from the following sources and apply filtering criteria mentioned in the manuscript:

For the United States: https://waterdata.usgs.gov/nwis/gw

For European countries and Australia: http://ggmn.un-igrac.org/

For China: https://doi.org/10.6084/m9.figshare.27004054.v2

Specifications:

Data type: Point/punctual data

Temporal resolution: Monthly

Required variable: Groundwater depth (unit: meters below ground level (m bgl))

After downloading, clip the CSV file according to the required mascon shapefile. Compute the monthly median value of the groundwater level and the median absolute deviation (representing uncertainty). Finally, save the output in CSV format.

An example CSV file titled “ts\_gwl\_m\_per\_month\_Jan2004\_Dec2022\_mascon\_27.csv” for Mascon 27 of the United States is made available. Create a folder titled "5\_groundwater\_level" and place the downloaded CSV file into this folder.

**All input files required to run the main script are ready now.**

1. **Mascon wise specific yield**

To run the main script titled “compute\_specific\_yield.ipynb,” you need to provide the paths for the inputs obtained from the previous steps.

## Add path at six places

* **US:** add path of the United States shape file

US=gpd.read\_file(r'/add\_your\_path/example\_data\_for\_sy/1\_US\_outline/1\_US\_Outline.shp')

* **shapefile\_directory**: add path of the folder containing Mascon shape file

shapefile\_directory ='/add\_your\_path/example\_data\_for\_sy/2\_mascon\_shp/'

* **GRACE\_JPL\_file:** add path of the GRACE JPL .nc file

GRACE\_JPL\_file=glob.glob('/add\_your\_path/example\_data\_for\_sy/3\_GRACE\_JPL/\*.nc')

* **sm\_directory:** add path of the soil moisture anomaly and uncertainty CSV file

sm\_directory = '/add\_your\_path/example\_data\_for\_sy/4\_soil\_moisture/'

* **gwl\_directory:** add path of the groundwater level and uncertainty CSV file gwl\_directory ='/add\_your\_path/example\_data\_for\_sy/5\_groundwater\_level/'
* **filtered\_df.to\_csv:** add path of the output folder to save final .csv file containing yearly mascon wise specific yield with corresponding uncertainty reported.

filtered\_df.to\_csv(f'/add\_your\_path/example\_data\_for\_sy/output/{shapefile\_name}\_after\_IQR.csv', index=False)