Gravimetry

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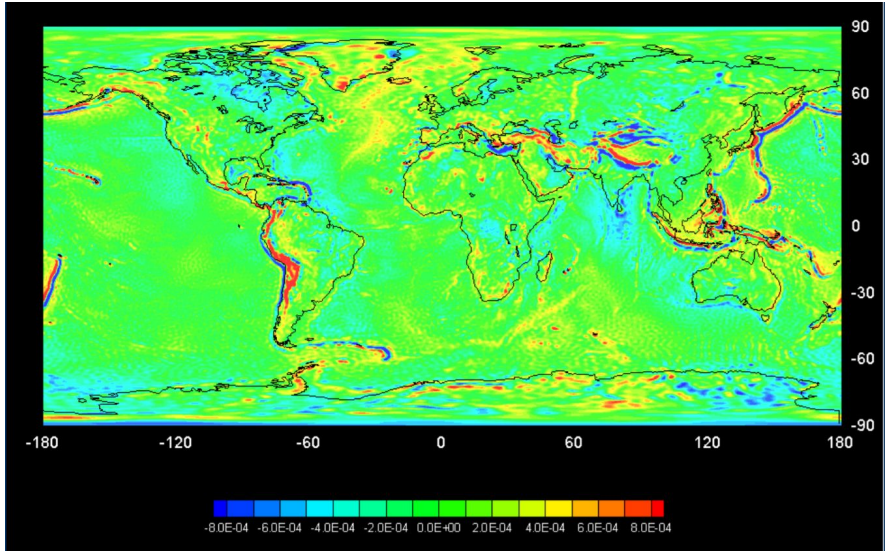
Outline

- What is gravimetry?
- Why do we care?
- How do we measure gravity?
- Gravity Corrections
- Program

What is Gravimetry?

- Study of Earth's gravity and how it varies
- The Earth is not a sphere!
  - It has a non-uniform density and due to its rotation, has a bulge around the equator
- Leads to the variation of gravity across the surface
  - Gravity variations are measured in mGal (cm/s^2)



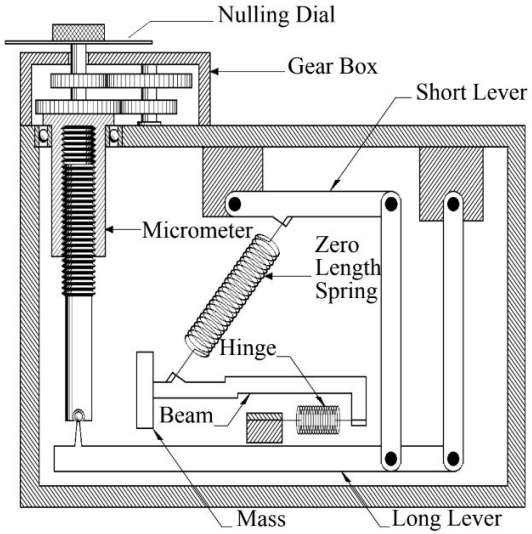
Gravity Anomalies based on GOCE Data

Why do we care?

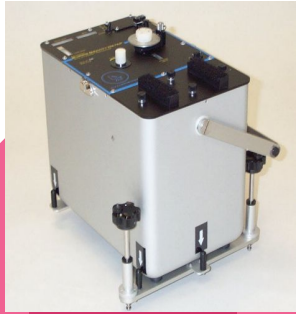
- There are many applications for gravity measurements
  - Petroleum, Mineral, Geotechnical and Archaeological Exploration
  - Geological Mapping - make a model of the shape of the Earth
  - Civil Engineering and Environmental Studies
  - Tectonic, Volcanic, and Geothermal Research
- Better understand Earth or any other extraterrestrial body

How to Measure Gravity

- A gravimeter!
- Uses Hooke's Law to calculate the change in gravity from one location to another
- Hooke's Law: $F = -kx$
  - k - spring constant
  - x - displacement of spring from equilibrium
- By calculating the force on the zero length spring based on the position of the mass, we can measure relative gravity



Gravimeter Schematic



Gravity Corrections/ Anomalies

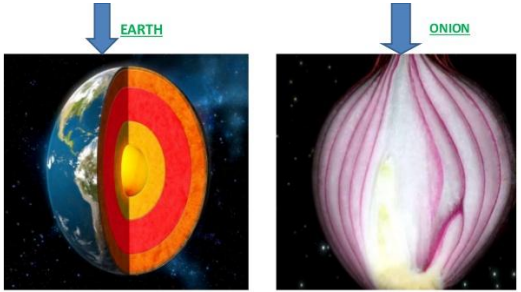
- Tides
- Instrumental Drift
- Free Air
- Bouguer (or Topographic)

Instrumental Drift

- Gravimeter uses a spring
- Springs are subject to deformation over time
- The gravimeter holds the spring to a constant temperature to minimize the deformation and give more accurate readings
- A measurement must be taken in the same location before and after the survey

Free Air Correction

- Gravity is an inverse square law $$F_g = G\frac{m_1 m_2}{r^2}$$
- The farther from a source of mass, the lower the force of gravity
- The free air correction accounts for a rise in elevation
- But, more mass is enclosed at a higher elevation (if you are still on the surface of the Earth)

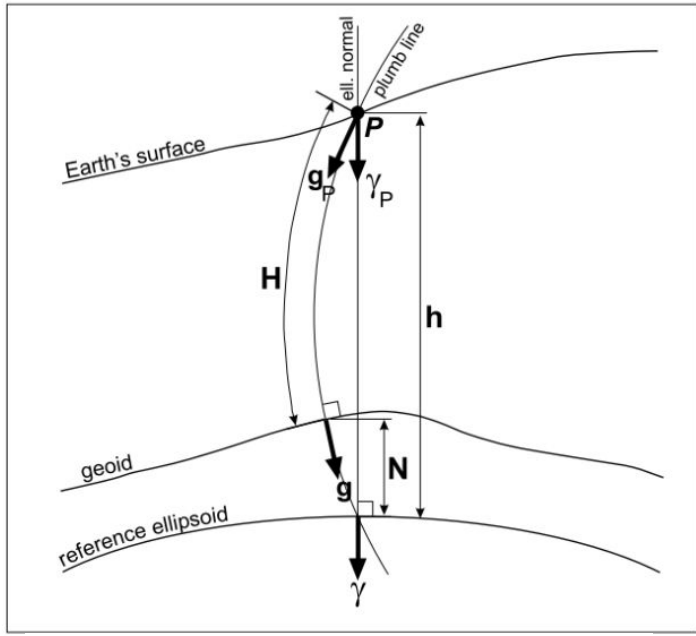


INTERIOR OF THE EARTH

Just like an onion, the Earth is made up of several concentric layers with one inside another.

Shapes of the Earth

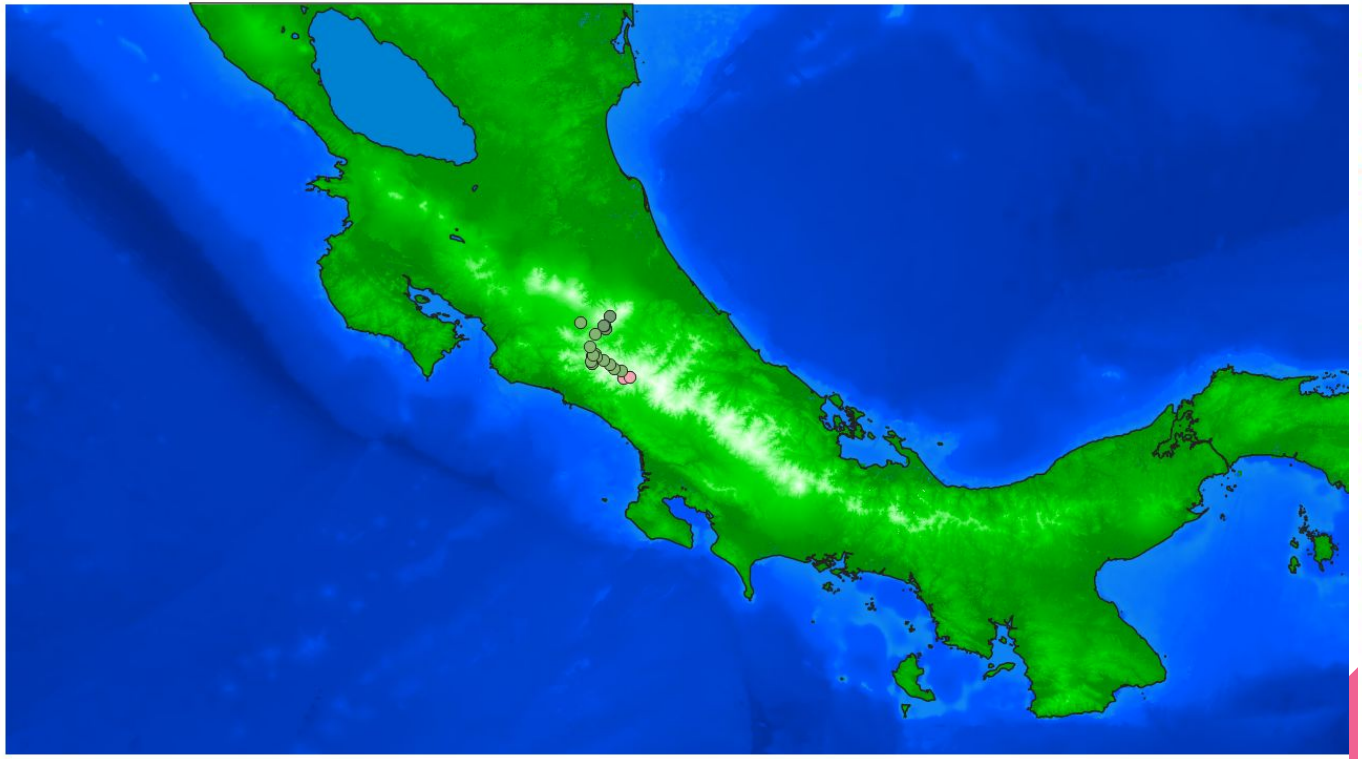
- Ellipsoid
  - The shape of the Earth can be modeled as an ellipsoid
  - Gravitational measurements help make the model better
- Geoid
  - Where the gravitational potential energy is the same
    - This is an equipotential surface
- Orthometric Height - height above the geoid (H)
- Ellipsoid Height - height above the ellipse (h)
- Geoid Height - difference between geoid and ellipse (N)



Hackney and Featherstone 2003

Elevation Map of Costa Rica

Elevation is above the ellipsoid

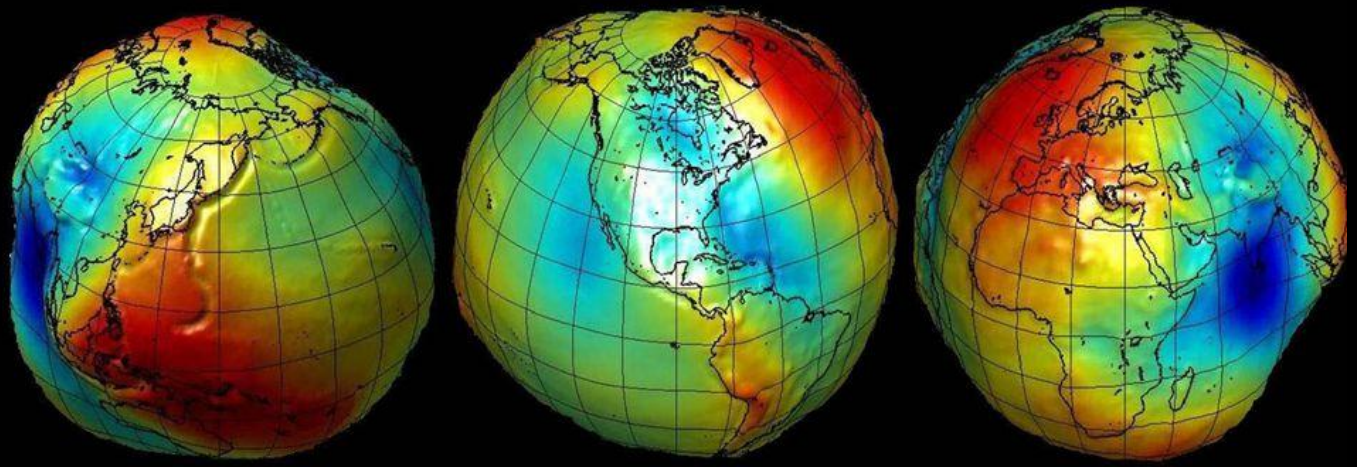


Elevation
-5514
-4000
-3500
-3201
-2000
-1000
-500
-100
-50
-10
0
5
10
50
75
100
200
300
500
1000
1200
1424
2000
2500
3000
3500
3555
3600
3736

Mission Goals

The Earth Gravity Field (Equipotential Surface)

seen on Ground

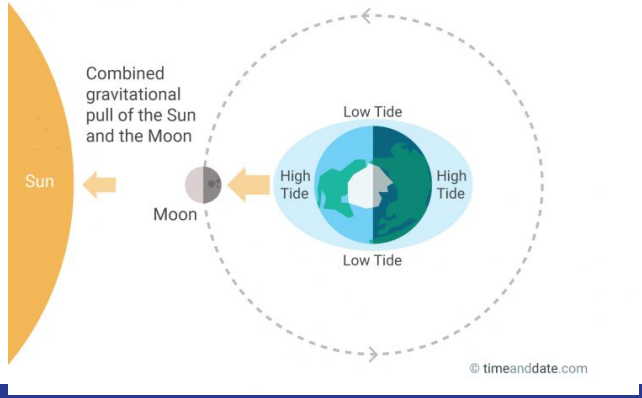


Free Air Anomaly Calculation

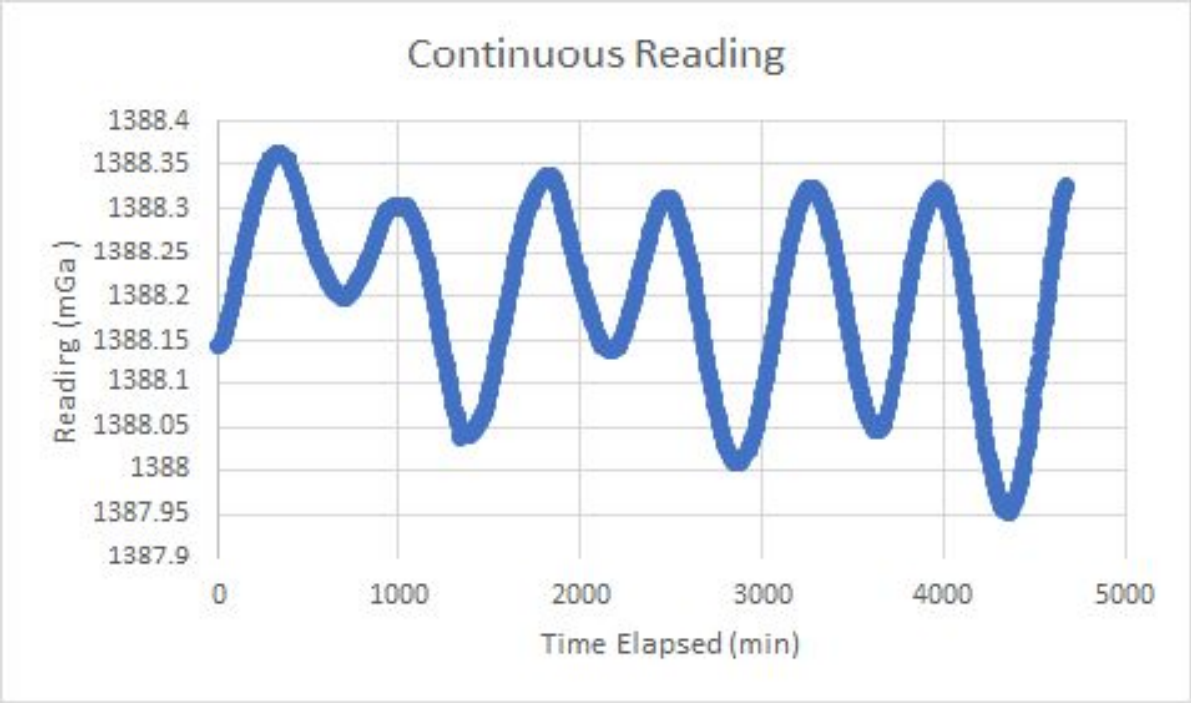
- $\delta g_F = 2\frac{g}{R}h$
- g = measured gravity
- h = height above the ellipsoid (elevation)
- $\frac{2g}{R} = 0.3086$ mGal m^{-1}

Tidal Corrections

- A more apt name is the gravity anomalies from celestial bodies (lunisolar corrections)
  - Tidal corrections can be misleading because most of the corrections come from the sun and moon
- Longman Tide Model -- 1959
  - Calculates north-south and east-west components of the tidal accelerations due to the moon and sun at any point on the earth's surface at any given time



Tidal Corrections



Observed Diurnal Tidal Periods of Costa Rica

Bouguer Anomaly

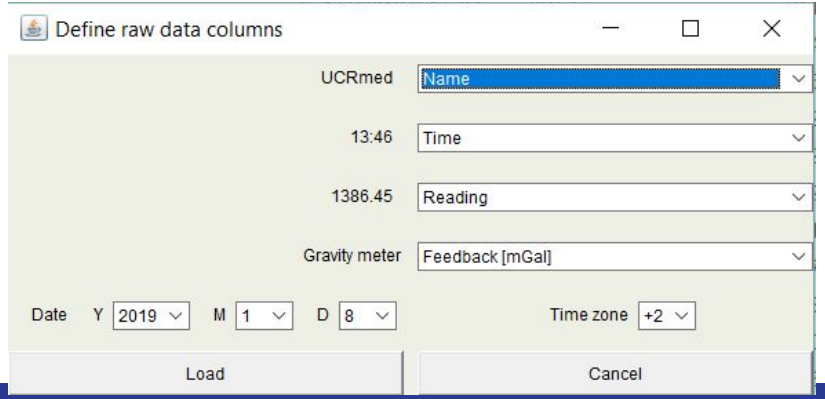
- Approximates the ground to be a long, infinite slab of thickness H and density ρ
  - This is the roughest correction
- Allows to correct for rock of different densities (mean density of rock is 2.67 g cm^{-3})
- $\delta g_b = 2\pi\rho G H$
- Using the mean density, the anomaly is 0.1119 mGal m^{-1}
- More accurate corrections come from mathematically calculating the mass of the rocks from the local topography

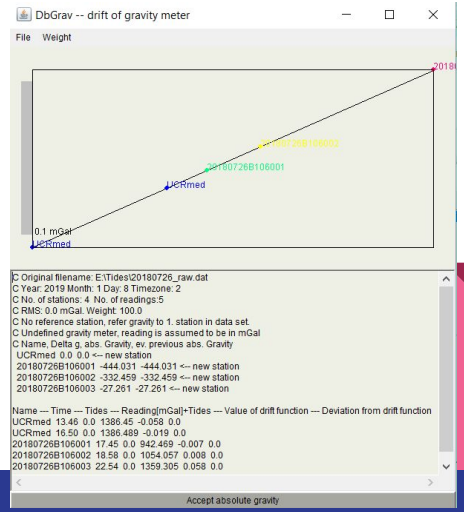
The Program

DbGrav

- There exists other programs that can perform corrections
  - Pros: Rapidly calculates corrections based off of the tides and topography
  - Cons: There is a high uncertainty with these numbers, lack of customizability, user must submit multiple files, and each file must be from the same day
- We are trying to create an open source program to control every step and maintain accuracy

DbGrav UI





Our Program

- Only 1 file is needed
- Data can be from a range of days

Input File

- File must be a .csv file (comma delimited)
- Data must in specific order and units:
  - Station name
  - Time in UTC
  - UTC date (mm/dd/yyyy) or (m/dd/yyyy)
  - Longitude (in degrees)
  - Latitude (in degrees)
  - Elevation (in meters)
  - Measurement (in mGal)

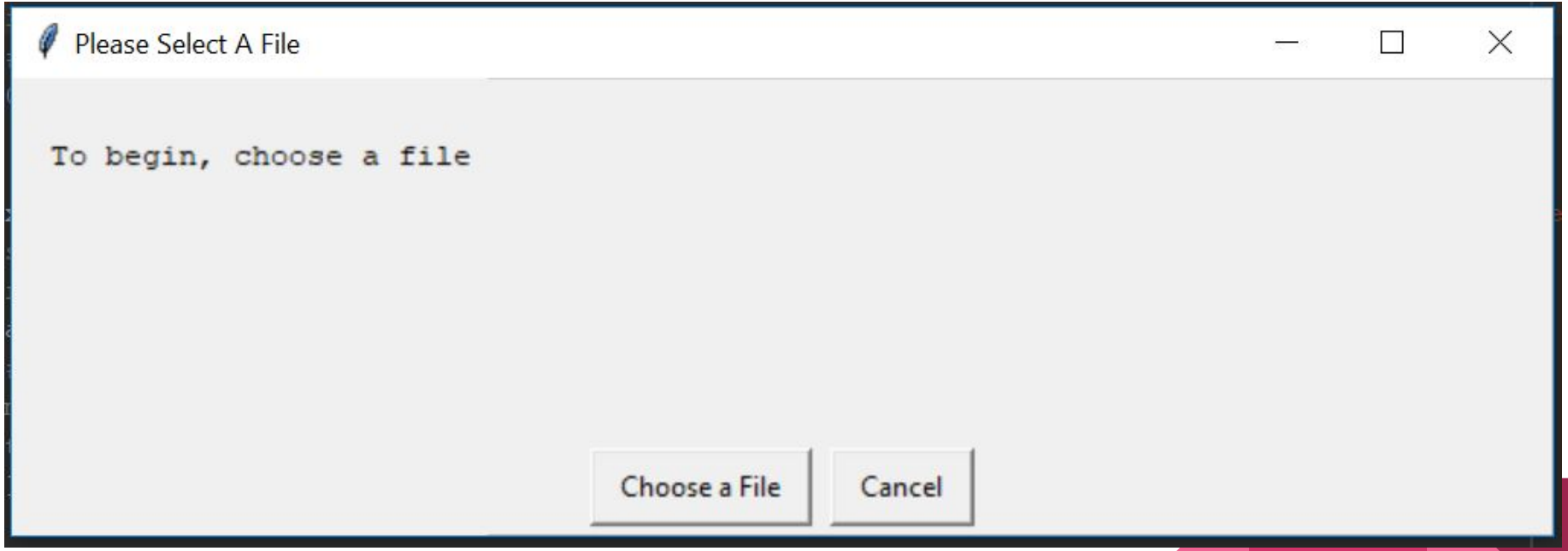
Input File From the Program’s Eyes

```
with open(file, 'r') as data_file:
    data = csv.reader(data_file, delimiter=',')
    station = [] #to be stored as a string
    time = [] #time utc format hh:mm
    date = [] #date must be in mm/dd/yyyy (utc date)
    longitude = [] #to be stored as a float
    latitude = [] #to be stored as a float
    elevation = [] #must be in meters, stored as a float
    measurement = [] #must be in mGal, stored as a float
```

Input File Example

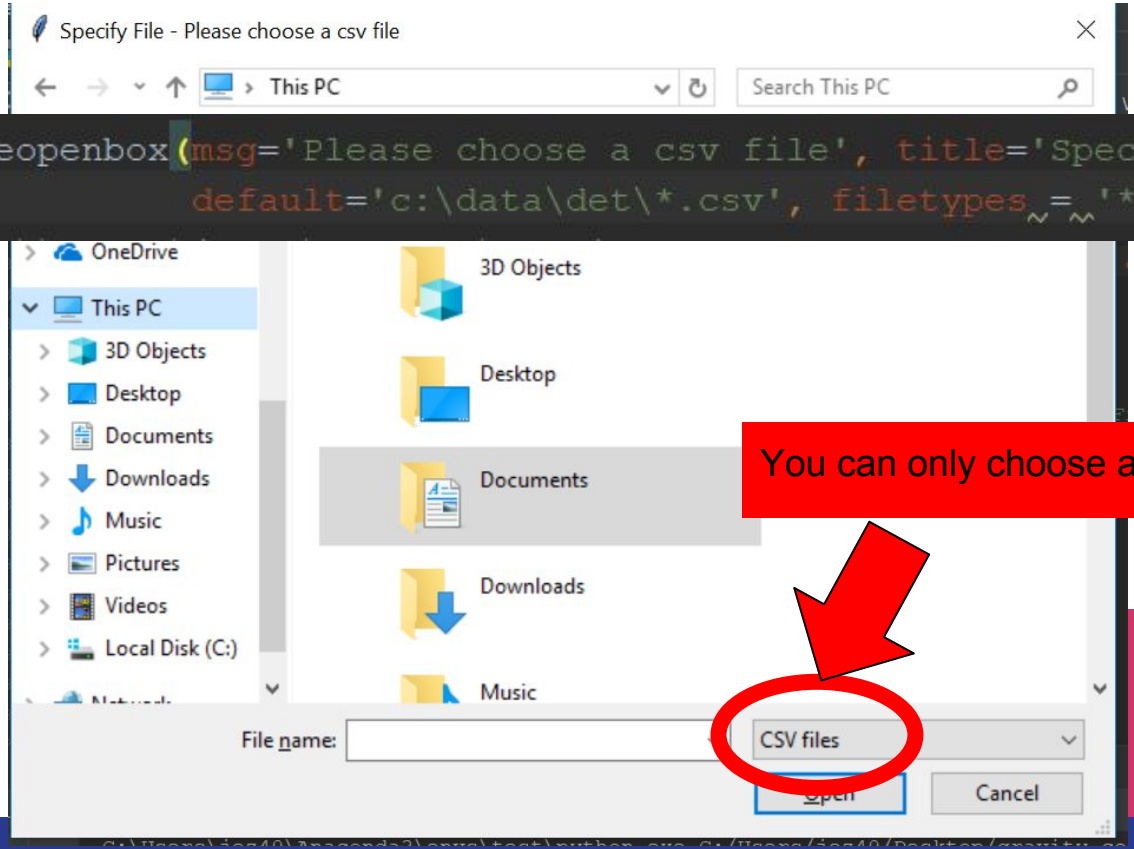
UCRmed	13:46	7/26/2018	-84.05111884	9.9389431	1195.302	1386.45
CDM	17:45	7/26/2018	-83.75546069	9.55473478	3478.99	942.475
Siberia	18:58	7/26/2018	-83.70626081	9.55661653	3014.188	1054.057
Santa Maria	22:54	7/26/2018	-83.96993644	9.65298736	1561.04	1359.318
UCRmed	16:50	7/27/2018	-84.05111884	9.9389431	1195.302	1386.489

Using The Program



Choosing A File

```
file = fileopenbox(msg='Please choose a csv file', title='Specify File',
                   default='c:\data\det\*.csv', filetypes = '*.csv')
```



You can only choose a .csv file

Output File

Station Name	Bouger Correction	Free Air Correction	Tide Correction	Drift Correction
UCRmed	0	0	0.026198843	0
CDM	255.5446872	704.7461168	0.145724589	0.023338841
Siberia	203.5333434	561.3082196	0.106802658	0.030467441
Santa Maria	40.9260822	112.8667468	-0.075241334	0.053513325
UCRmed	0	0	0.145785778	0.158586935