Physical Geodesy

Calculation of Bouger Gravity Anomalies

In this exercise, I would like to show you topography, bouger correction and bouger gravity anomalies plots from some spesific points in United States.

11.06.2020

Doğu İlmak

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Definitions

What is free-air anomaly?

In geophysics, the free-air gravity anomaly, often simply called the free-air anomaly, is the measured gravity anomaly after a free-air correction is applied to correct for the elevation at which a measurement is made. The free-air correction does so by adjusting these measurements of gravity to what would have been measured at a reference level. For Earth, this reference level is commonly taken as the mean sea level.

What is topography?

Topography is the study of the shape and features of land surfaces. The topography of an area could refer to the surface shapes and features themselves, or a description (especially their depiction in maps).

Topography is a field of geoscience and planetary science and is concerned with local detail in general, including not only relief but also natural and artificial features, and even local history and culture. This meaning is less common in the United States, where topographic maps with elevation contours have made "topography" synonymous with relief.

Topography in a narrow sense involves the recording of relief or terrain, the three-dimensional quality of the surface, and the identification of specific landforms. This is also known as geomorphometry. In modern usage, this involves generation of elevation data in digital form (DEM). It is often considered to include the graphic representation of the landform on a map by a variety of techniques, including contour lines, hypsometric tints, and relief shading.

What is bouger anomaly?

In geodesy and geophysics, the Bouguer anomaly (named after Pierre Bouguer) is a gravity anomaly, corrected for the height at which it is measured and the attraction of terrain. The height correction alone gives a free-air gravity anomaly.

Simple reduction:

The gravitational acceleration outside a Bouguer plate is perpendicular to the plate and towards t, with magnitude $2\pi G$ times the mass per unit area, where is the gravitational constant. It is independent of the distance to the plate (as can be proven most simply with Gauss's law for gravity, but can also be proven directly with Newton's law of gravity). The value of is 6.67×10^{-11} N m^{2} kg^{-2}, so is 4.191×10^{-10} N m^{2} kg^{-2} times the mass per unit area. Using 1 Gal = 0.01 m s^{-2} (1 cm s^{-2}) we get 4.191×10^{-5} mGal m^{2} kg^{-1} times the mass per unit area. For mean rock density (2.67 g cm^{-3}) this gives 0.1119 mGal m^{-1}.

Plotting Datas in Octave

Plotting Map and Topography of the Area

First of all we need to import free-air gravity anomalies data from our file which is file ' dogu.txt' to workspace by dragging to workspace or 'load' function*(load('dogu.txt')*. Check if the coverage of sampled data is sufficiently regular and with no gaps over selected area. The height differences should be at least 100 meters (to obtain visible effect of Bouguer correction). Select and plot data using the code:

(Fig.1 Code of the Map and Topograhy of the Area)

```
1  clear
2
3  bfid = fopen('counties.bln');
4
5  while feof(bfid)==0;
6
7      n = fscanf(bfid,'%i,%i',2);
8      if isempty(n)==1;
9          break
10     end
11     fila = fscanf(bfid,'%g,%g',[2 n(1)]);
12     if n(1)~=length(fila(1,:));
13         fila = fscanf(bfid,'%g %g',[2 n(1)]);
14     end
15     la=fila(1,:);
16     fi=fila(2,:);
17     plot(la,fi,'Color',[.4 .4 .4],'LineWidth',1);
18     title('Calculation of Bouguer Gravity Anomalies')
19     ylabel('Latitude')
20     xlabel('Longitude')
21     hold on
22
23 end
24
25 data = load('dogu.txt');
26 latnad83 = data(:,3);
27 lonnad83 = data(:,4);
28 elevngvd88m = data(:,5);
29 faanom =  data(:,2);
30 figure(1)
31 plot(lonnad83,latnad83,'k+','Color','r');
32 hold on
33 figure(2)
34 plot3(lonnad83,latnad83,elevngvd88m,'k+');
```

In this code, firstly we need to import the USA map for see much more clear. We import is with the bfid function. You can see it on the Fig.1.

We need to drag our latitude and longitude in our .bln file. In the 15th and 16th row you can see how we drag into our code.

We add some features like xlabel, ylabel and title in our plots.

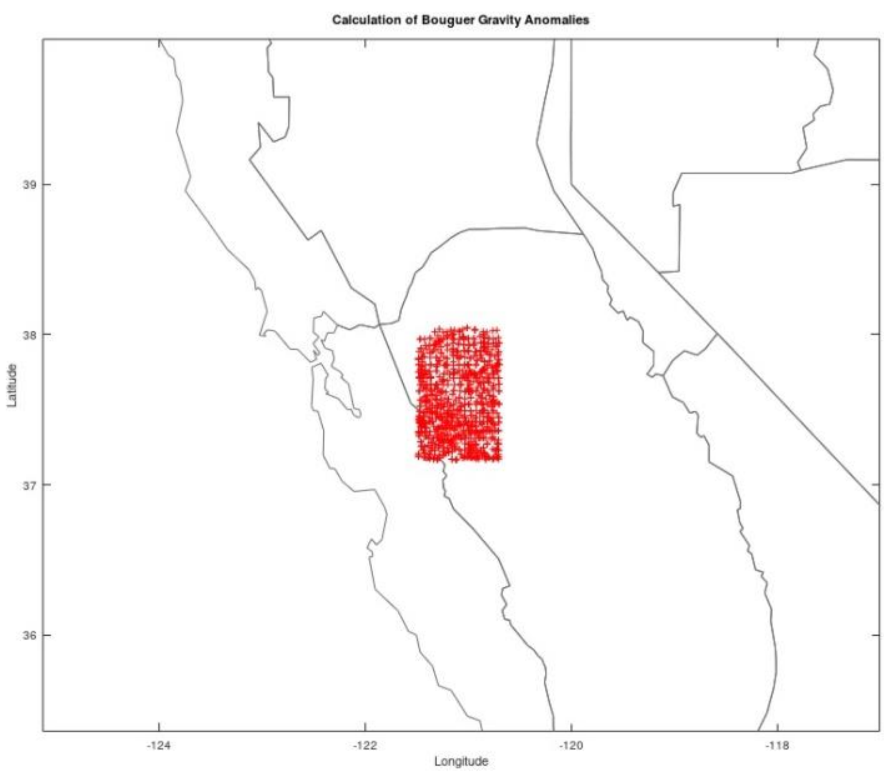
We imported my data as I mentioned. From the 26th row to 29th row we dragged our datas into our code. After that we are tried to plot them in two figures.

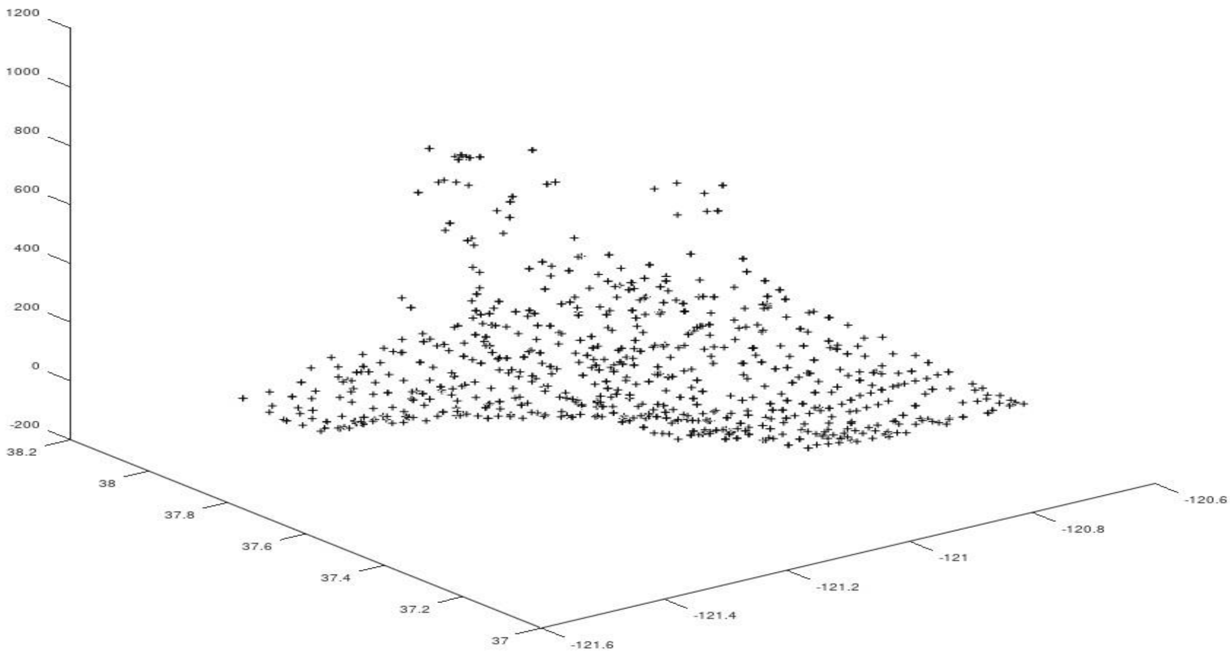
(Fig.2 Plot of the Map)

In this plot, we can see our points in United States. This area is next to the San Francisco.

We can define the coordinates in plot.

If you want to see the area in Google Earth, please click the arrow.





(Fig.3 Plot of the Topograhy of the Area)

In Fig.3 we can clearly see the topography of the area with the dots.

Plotting Topography, Bouger Correction, Bouger Gravity Anomalies and Bouger Anomalies

```
clear
clc

data = load('dogu.txt');
latnad83 = data(:,3);
lonnad83 = data(:,4);
elevngvd88m = data(:,5);
faanom = data(:,2);

plot(lonnad83,latnad83,'k+');
plot3(lonnad83,latnad83,elevngvd88m,'k+');

for i = 1 : length(elevngvd88m)
  if elevngvd88m(i) < 0
    BO(i,1) = -0.0687 * elevngvd88m(i); %if depths are negative numbers
  else
    BO(i,1) = -0.1119 * elevngvd88m(i);
  end
end

x = -121.48:0.013:-120.70;
y = 37.167:0.01463333333:38.045;
[X,Y] = meshgrid(x,y);
Z = griddata(lonnad83,latnad83,faanom,X,Y);
surf(X,Y,Z)
subplot(2,2,3)
view(35,45)
zlabel('mGal/m')#bouger correction
ylabel('Latitude')
colorbar
xlabel('Longitude')
hold on

Z1 = griddata(lonnad83,latnad83,BO,X,Y);
title('c) Bouger Anomalies')
surf(X,Y,Z1)
subplot(2,2,1)
view(35,45)
```

For plotting these values, we need to add dogu.txt again. We are going to drag necessery datas again.

In this part we are going to calculate bouger anomalies according to the rule:

BO = -0.0419 ρ H, ΔgB = ΔgFA + BO

Bouguer correction for average crust density inland

ρ = 2.67 g/cm3 (BO = - 0.1119 · H)

Bouguer correction for sea water ρ = 1.04 g/cm3 (-1.63 g/cm3 relatively to land, BO = + 0.0687 · depth)

(Fig.4 Code fort he topography, bouger correction, bouger gravity anomalies and bouger anomalies.)

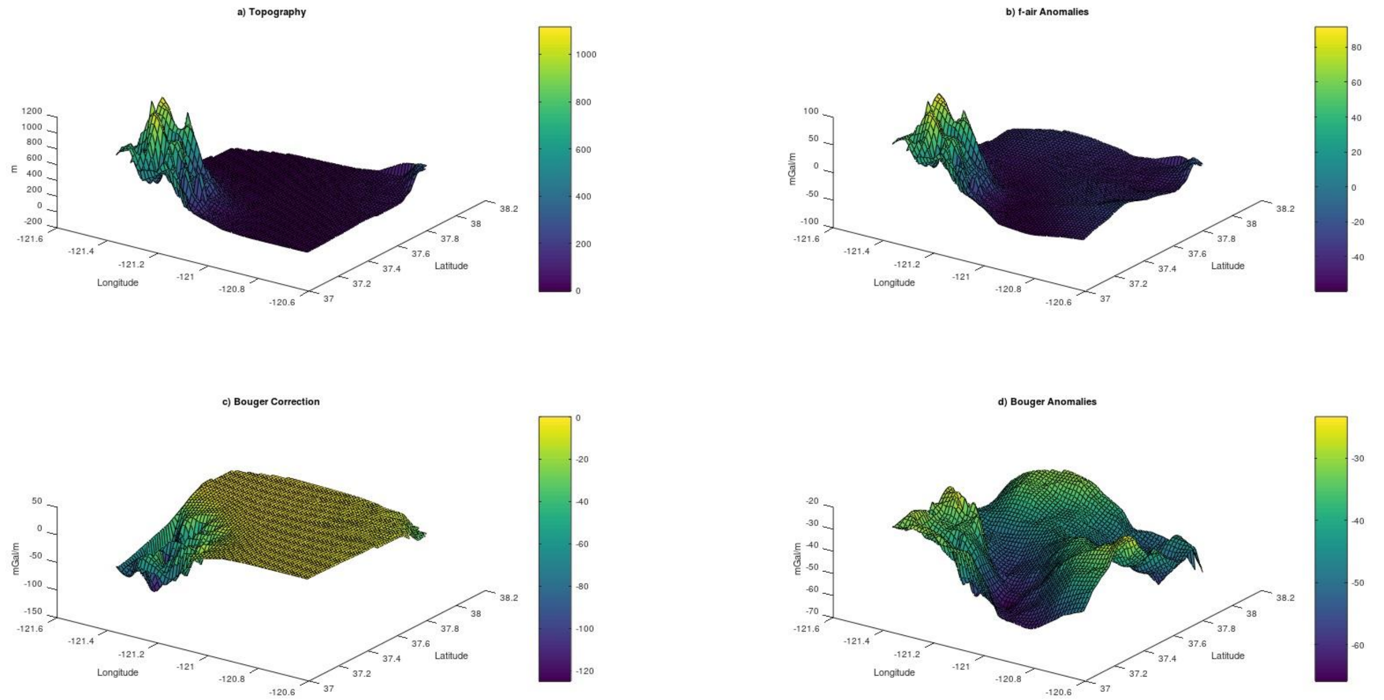
In this hyperlink you can look at it more: *https://www.mathworks.com/help/matlab/ref/subplot.html*

```
        BO(i,1) = -0.1119 * elevngvd88m(i);
    end
end

x = -121.48:0.013:-120.70;
y = 37.167:0.01463333333:38.045;
[X,Y] = meshgrid(x,y);
Z = griddata(lonnad83,latnad83,faanom,X,Y);
surf(X,Y,Z)
subplot(2,2,3)
view(35,45)
zlabel('mGal/m')#bouger correction
ylabel('Latitude')
colorbar
xlabel('Longitude')
hold on

Z1 = griddata(lonnad83,latnad83,BO,X,Y);
title('c) Bouger Correction')
surf(X,Y,Z1)
subplot(2,2,1)
view(35,45)
zlabel('m')# topography
ylabel('Latitude')
colorbar
xlabel('Longitude')
hold on
%
Z2 = griddata(lonnad83,latnad83,elevngvd88m,X,Y);
title('a) Topography')
surf(X,Y,Z2)
subplot(2,2,4)
view(35,45)
zlabel('mGal/m')#f-airanomalies-bouger anomalies
ylabel('Latitude')
colorbar
xlabel('Longitude')
hold on

Z3 = griddata(lonnad83,latnad83,faanom+BO,X,Y);
title('d) Bouger Anomalies')
surf(X,Y,Z3)
subplot(2,2,2)
view(35,45)
ylabel('Latitude')
colorbar
xlabel('Longitude')
hold on

Z4 = griddata(lonnad83,latnad83,faanom,X,Y);
title('b) f-air Anomalies')%f-air anomalies
zlabel('mGal/m')# f-airanomalies
surf(X,Y,Z4)
```

In Fig.5 we builded our plots. Firstly we need to show topography. After that we need to show bouger gravity anomalies then we need to show bouger anomalies and finally we need to show bouger correction. You can see it on fig.5 clearly.

We can show few plots in one window at the same time with subplot(a,b,c) function. In a, we can specify rows. In b, we can specify columns and in c we can specify the location of the plot where we want to put it.

(Fig.5 Code for the topography, bouger correction, bouger gravity anomalies and bouger anomalies.)



(Fig.6 Plots of free-air anomalies, topography, bouguer correction and bouguer anomalies)

At the end, in Fig.6 we draw 3D maps(surfaces) of free-air anomalies, topography, bouguer correction and bouguer anomalies using NAD83 coordinates.

END