Geophysical Methods using Gravity Reduction on La Jolla Region

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Introduction

The Rose Canyon Fault within La Jolla can be found using geophysical techniques, one which was used in this experiment was a gravitational approach. The instruments used was a gravimeter which gives the difference between two gravity points using the known absolute gravity measurement at one point, our reference gravity measurement was taken at Zumberg's Lab. By collecting gravimeter readings around the studied region, La Jolla, we are able to use the raw gravity measurements to make several corrections such as latitude, free air, and Bouguer to process the raw data into useful measurements this process is called Gravity Reduction. By using Matlab to model the processed data it allows us to observe the current condition of the fault such as the depth, throw, and the fault's effect on the surrounding region.

Methodology

Equipment

Gravity measurements taken in the field were done using a relative gravimeter which requires a base station reading where the absolute gravitational acceleration is known, in this case Zumberg's Lab was used having a gravity reading of 3208.030 this year. A relative gravimeter measures variations in gravity from one location to another it does this by using a weight attached to a spring the amount the spring stretches allows us to measure the gravity within the area. The tension of the spring can be adjusted using the adjusting screw, also as the weight changes positions the mirror attached to the arm with the weight reflects light to the eye piece where the precise position of the arm is monitored. As a result of being such a sensitive instrument the mechanism is vulnerable to environmental factors such as temperature and air pressure so the parts must be thermostatically heated and sealed to maintain consistent spring length along with consistent buoyancy of the weight. Since this is a mechanical system using a spring, a base station is needed to calibrate the gravimeter. A tripod dish is used to easily place the gravimeter on top of any terrain where the measurement would be taken allowing the

Measuring Process

Once a location has been chosen the gravimeter must be placed on a tripod dish and adjusted roughly till the spirit levels are close to being balanced. Then fine adjustments can be made to the levels using the leveling screws, once the instrument is balanced the light is turned on and the arm is unlocked. Looking into the eye piece the mark is adjusted coming from the right till the reading line says 2.70 once this has been accomplished the beam is locked and the reading is read from the counter. Once finished the meter is turned off and placed within the case.

Survey Area

The area surveyed was between highway 805 and 5, specific locations were determined by the professor and at locations that had brass plugs which were placed by the city for mapping of elevations within La Jolla. By taking gravity measurements at each of these brass plugs we were able to collect 9 measurements, the first and the last being at Zumberg's Lab since it was our base station. Knowing the gravity readings along with the heights at the brass plugs, longitude/ latitude of positions, and time of when the readings were collected we are able to use all of the information to process the data through Gravity Reduction.

Problems

Some problems were encountered during the collection of data where it was difficult to adjust the reading to 2.70 on the gravimeter. This was because the reading was being taken near an intersection where there were constantly cars moving around shaking the ground shaking the sensitive gravimeter.

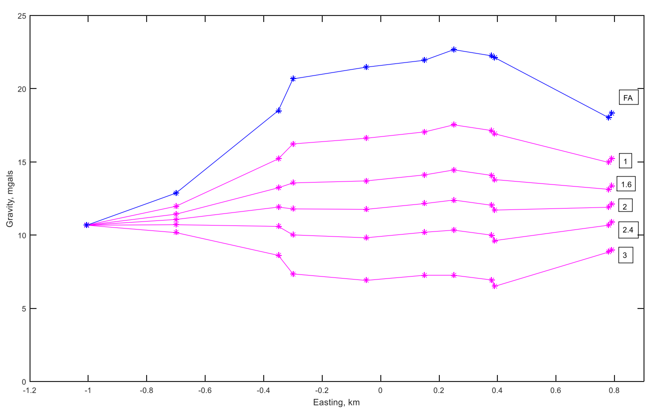
Description and Modeling of Data

The raw data collected from surveying the La Jolla region contains the latitude longitude, height, gravity reading, and time of measurements taken. These measurements must go through processing to become useful data so gravity reduction is applied to the data. The data must first be meter calibrated and the drift must be removed, this is done by converting the readings from the gravimeter into milligals using the calibration sheet. Next the drift must be removed from the observed data, since we are using a relative gravimeter we must make the initial base station reading 0.00 milligals giving us readings in respect to the base station. However, this gives us a different end reading for the same position this is due to small changes in gravity due to drift which must be removed through liner interpolation. Once the data has been interpolated it gives 0.00 milligals for the two base station readings.

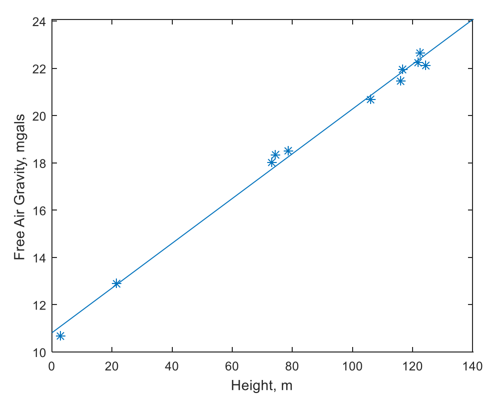
% 2016 Survey Gravimeter: G349, Date: 12 January 2016

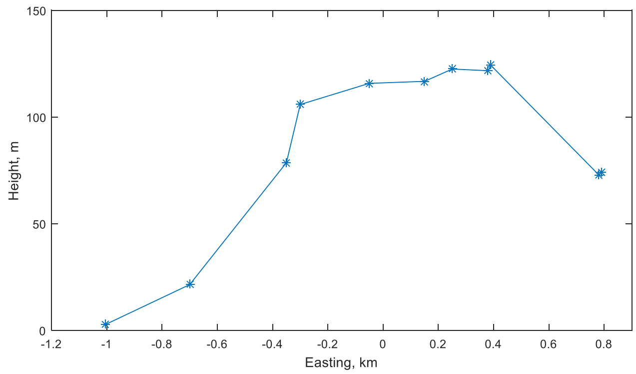
%	ID	lat	lon	height (m)	N/E (100')	Time	Reading	Raw	Station
156	- 3	32.86855	-117.25228	46.9392	NaN NaN	14 12	3208.930	0	% Zumberge lab (base)
157	11646	32.86509	-117.22534	90.1434	2558 17008	14 37	3200.395	-9.0908	% Charmant and Lebon
158	16348	32.87504	-117.21847	108.6450	2608 17030	15 00	3196.555	-13.1916	% Miramar and Regents
159	16334	32.87681	-117.21808	103.8627	2597 17030	15 07	3197.360	-12.3427	% Eastgate Mall and Regents
160	8534	32.87772	-117.21423	108.5993	2600 17043	15 19	3196.690	-13.0654	% Eastgate Mall and Genesee
161	16333	32.86865	-117.21869	105.4858	2567 17028	15 32	3196.950	-12.8010	% Regents and Crystal Dawn Ln
162	16332	32.86367	-117.22226	102.6832	2550 17017	15 42	3197.825	-11.8805	% Regents and Berino
163	-3	32.86855	-117.25228	46.9392	NaN NaN	16 03	3209.025	0	% Zumberge lab (base)

Above is the 2016 Gravity Data that has converted feet to meters and has the completed gravity measurements. Now that we have a complete data set from 1996 to 2016 we can continue and make the corrections to the gravity readings, the first correction to be made is the latitude correction which accounts for the Earth's elliptical shape and rotation. We use the latitude from the locations we collected the readings from and use the international gravity formula to correct the observed gravity. By using the free-air correction we are able to correct for gravity variations due to elevation differences in the location surveyed, for readings taken above the base station the correction is added if below the base station the correction is subtracted. These corrections were done to all of the data collected over the years around the La Jolla region. Now we must find the Bouguer density over the region so we can apply the Bouguer correction to all of the data collected, this is done by using Nettleton's method to a small region within La Jolla so that we can find the average density of the entire region in this case we use the data from 2002 and 2003. By guessing various



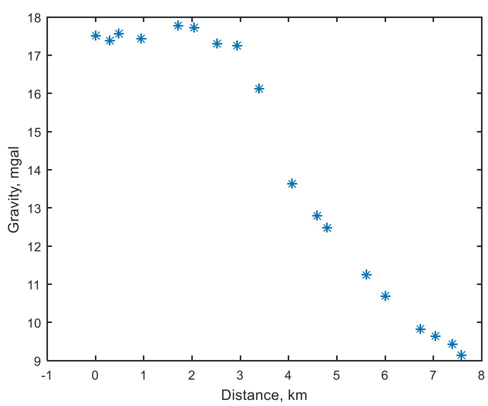
densities (I used 1.0g/cc, 1.6g/cc, 2g/cc, 2.4g/cc, and 3.0g/cc) and using them to apply Bouguer corrections to the free air corrected gravity we are able to see the best density for the region by plotting all the density corrections within Matlab. The graph shows the various densities and the free air gravity plotted against the easting, here we see that around 2.0 g/cc is the most sensible of the densities for the region. However since the graph only gives us a visual estimate on of what is the preferred density we must use a different method to give us a calculated density, in this case we plot the free air gravity plotted against the elevation. Then through Matlab we are able to find a trend using the PolyFit this gave me an intercept of

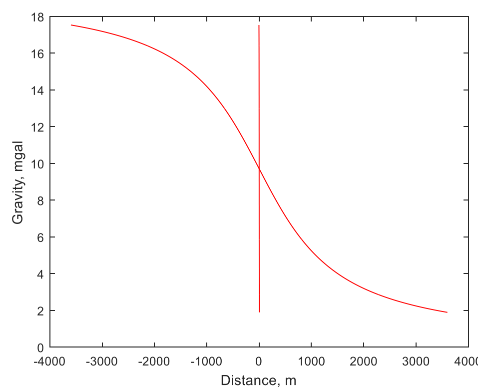




10.8 and a slope of 0.0946 mgal/m when divided by 0.04188 mgal g/cc/m gave me 2.1 g/cc. Since my density was off from the one the professor calculated which was 2.02g/cc I used his density for the Bouguer corrections for all the sites. The reason my correction is off could be due to my precision when making the free air gravity corrections along with the latitude corrections. Matlab's PolyFit proved to be a better estimate than the graphical Nettleton's method this is because it provides a calculated number by looking at the trend within the data, graphical method forced us to guess densities which can give us a range what the density could be but not a exact number. Below are the PolyFit Line to the left and to the right is the height plotted against the easting showing us the topography of the sites that were surveyed in 2002/2003.

By applying the Bouguer density from Nettleton's method to all of the sites surveyed throughout the years we are able to get the processed gravity readings and can proceed to plot them on a map. By using the script *plot. grav.m* which takes the longitude, latitude, and the corrected gravity readings to make a map of the area it then uses color to display the gravity within the region allowing us see the changes in gravity around the La Jolla region. The map

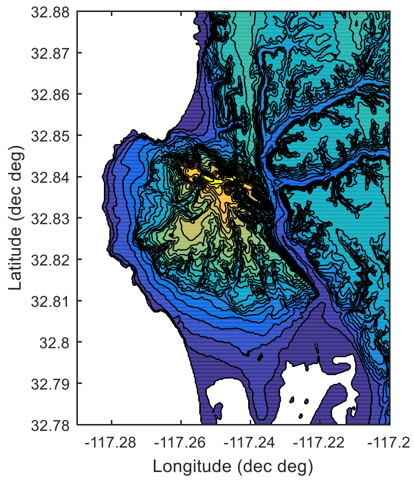


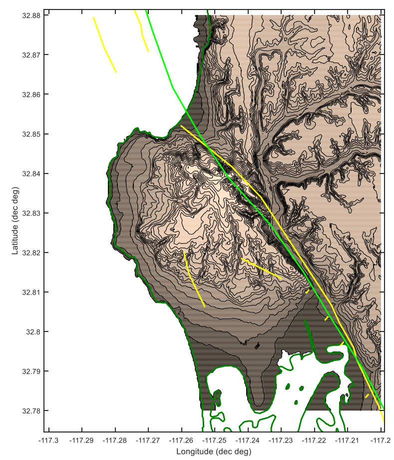


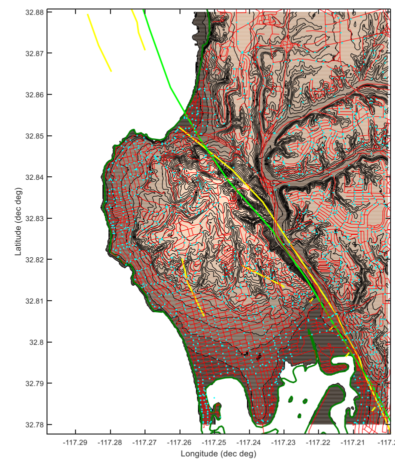
also shows all the sites that measurements have been taking from allowing us to determine which areas require further investigation for the future.

To model the buried fault within the region we are provided with data about the fault once which can be seen above to the left. When calculating the throw of the fault I calculated it to be 378.7 meters, when plugged into the fault modelling script, *fault.m*, it allows us to attempt to match the modeled fault to the actual fault data plot which can be seen above to the right.

Now that we have calculated the throw of the fault along with plotting the gravity data allowing us to interpret what is occurring gravity wise we can now use the *plot_mtsoledad_map.m* script to plot a topographic map, the survey sites, and the Rose Canyon Fault. The script first takes the longitude and latitude and lays it out according to known topographic information allowing us to see the features of the land. The plain topographic map makes it difficult visualize and interpret so reference features were added here we added contour lines allows us to see height differences within the region and the coastline was added to use give us more information of the area this later allows us to make correlations with the gravity reading plot. Now to apply features that associate our survey with the La Jolla region we added the Rose Canyon Fault allowing us to see how the fault has altered the region around it, in this case we see the large elevation change where the fault is bordering. Since our gravity readings were done by taking elevation changes at the city benchmarks we lay the location of all the benchmarks around the region along with the road map to let us see why there are areas that have not been surveyed yet.

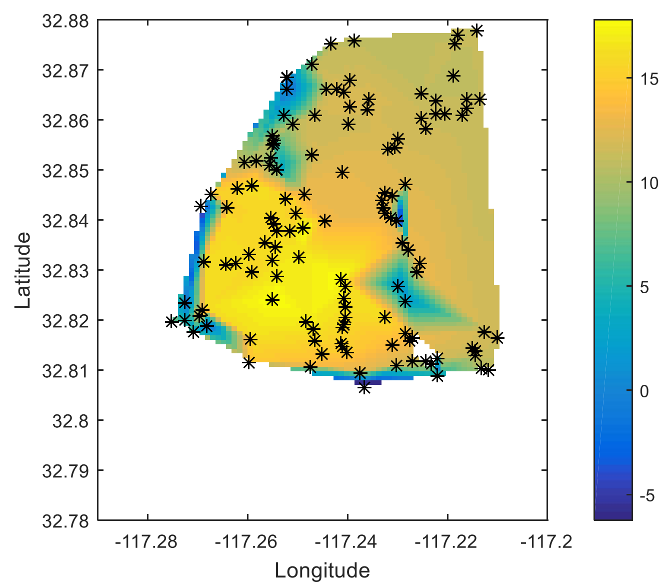


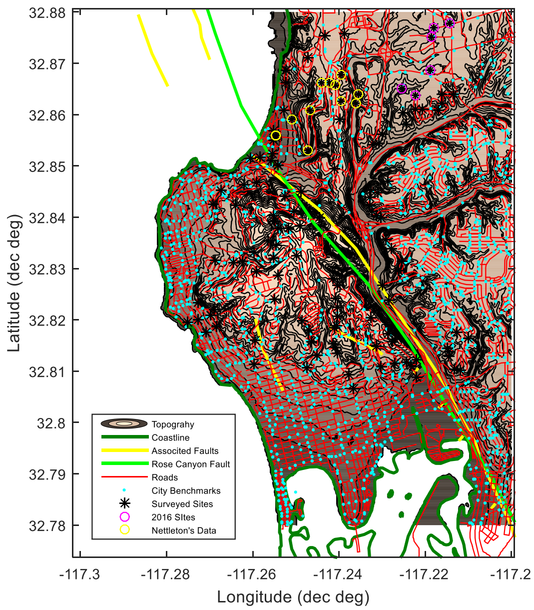




Interpretation

The reason behind doing all these corrections to the raw gravity readings taken is because between the base reading and all other location readings there is an attraction to an unknown anomalous masses and factors that contribute to it are latitude, elevation, and topography by correcting for these factors we can take our data from the geoidal surface which is the preferred equipotential surface. The reason the data from 2002-2003 was chosen to apply Nettleton's method is because the sites where the data was taken were from the shore to inland, this increase in elevation in the topography made this particular set of data useful to apply the method. When the gravitational effect of the feature is calculated at different densities the least apparent one on the gravity profile is the correct density. By applying Nettleton to the data conducted in 2002- 2003 we were able to find an average density of 2.02g/cc for the area sited this allowed us to assume that density for the La Jolla region letting us make the correction to all of the data. From the map we are able to see the elevated gravity readings around the Mount Soledad region along with the blue along the edge of the region indicating the shore line. The signs of Rose Canyon Fault can be observed by looking at the low gravity regions to the top right and left of Mt. Soledad this low to high gravity difference is the main indication of the fault. More evidence of the fault is given by the fault data plot showing around a max of 18 mgals and drop to lower than 10 mgals, the gravity map shows the this drop in gravity due to the fault clearly on the map at (-117.23, 32.825) longitude and latitude. Between these two low gravity regions there seems to be a region where gravity measurements have not been taken forcing the script we used to create a region where it was forced to average out the gravity. From the gravity plot alone however, we cannot determine why certain regions lack sites compared to





others this is the reason the map with the topography becomes important. From the topography map we can confirm that the Rose Canyon Fault is indeed bordering the large sudden difference in gravity, another feature is revealed at (-117.23, 32.84) which is the low gravity spike which when compared to the topography map is due to a low elevation. In the future if gravity measurements were conducted in (-117.24, 32.835) region there would be a clearer gravity model of the Rose Canyon Fault. From this data we can interpret that Mt. Soledad was created due to the Rose Canyon Fault uplifting that area.

Conclusion

By processing the gravity through gravity reduction we were able to see the gravity throughout the La Jolla region. The results gave us key information to help us interpret geological features within La Jolla, one of the most important was how Mt Soledad formed. The necessary corrections made to the readings collected from 1996 to 2016 have provided enough data to see the Rose Canyon Fault that borders Mt. Soledad also created Mt. Soledad. By using data about the fault and the density contrast we were able to determine the throw of the fault being around 378.7 meters. In the future to make the models clearer it would help to collect more data near the fault region where there seems to be a lack of sites, this would show the fault's path through the region.

Satellite Image of Region Surveyed