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GPGN 303
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Lab 1 Report

Introduction

The purpose of gravity lab 1 is to practice taking relative gravity measurements in with relative gravimeters in the field and learn how to compute from data the Earth's radius and the free-air gradient of its gravity field. These values are significant because they enable geophysicists to use gravimetry to model the Earth based on density and volume. Attempting to accurately measure the well known values of the free-air gradient and radius will test our ability to properly use relative gravimeters to measure and calculate some quantitative geophysical properties of the Earth.

Objectives

The main objectives of this lab were to become familiar with tools and methods used in gravitational data collection, and what we could do with that data. LaCoste & Romberg Model G and Scintrex CG-5 gravimeters were used, and we were to become comfortable with the use and care of these machines. Another objective of this lab was to calculate the free-air gradient of the earth's gravity field. This calculation would then be used to to solve for the earth's radius.

Procedure

This lab began with our groups using the CG-5 meter at the Absolute Gravity Station DA (S0, the pad by lot at 15th and Arapahoe). The control parts of the CG-5 include the battery and charger, leveling base platform, leveling adjustment screws and digital display, keypad, and digital graphics display. We placed the meter on the pad, and turned it on, secured it to the base, then used the leveling adjustment screws to level the meter, according to the digital display. When the meter was at +/- 1 arc seconds from level, a smiley face would appear. We navigated to the start menu and pressed record. Everyone quickly walked 3 meters away and stood still, so that the meter did not pick up any unnecessary movement. When the blue light on the side of the meter turned off, the relative gravity measurements, standard deviation, and time were recorded. These meters were powered down, placed in the storage case, and at the end of the lab were connected to the charger. Image 1 shows what the top of the CG-5 meter looks like.

Image 1

We then set up the LNR meter at the Absolute Gravity Station XA (S0, the steps by the north-east corner of the Green Center). The control parts of the LNR include the battery and charger, leveling screws and bubbles, the eyepiece, locking knob, adjustment dial, and reading with a decimal read out. The meter was placed on a level step, locked into place, connected to the battery, and leveled. Then it was unlocked by turning the locking knob counterclockwise all the way. The light was then turned on. The dial was adjusted until the cross-hairs read 2.4 in the eye piece. This number is just used as a base for the measurement, and is different for most LNR meters. It compensates the change in gravity. The reading was taken from the counter and dial (integer off the counter and two decimals off the dial). Time was also recorded. The meter was then locked and the light was turned off, and the meter was secured in the carrying case. Image 2 shows what the top of an LNR meter looks like.

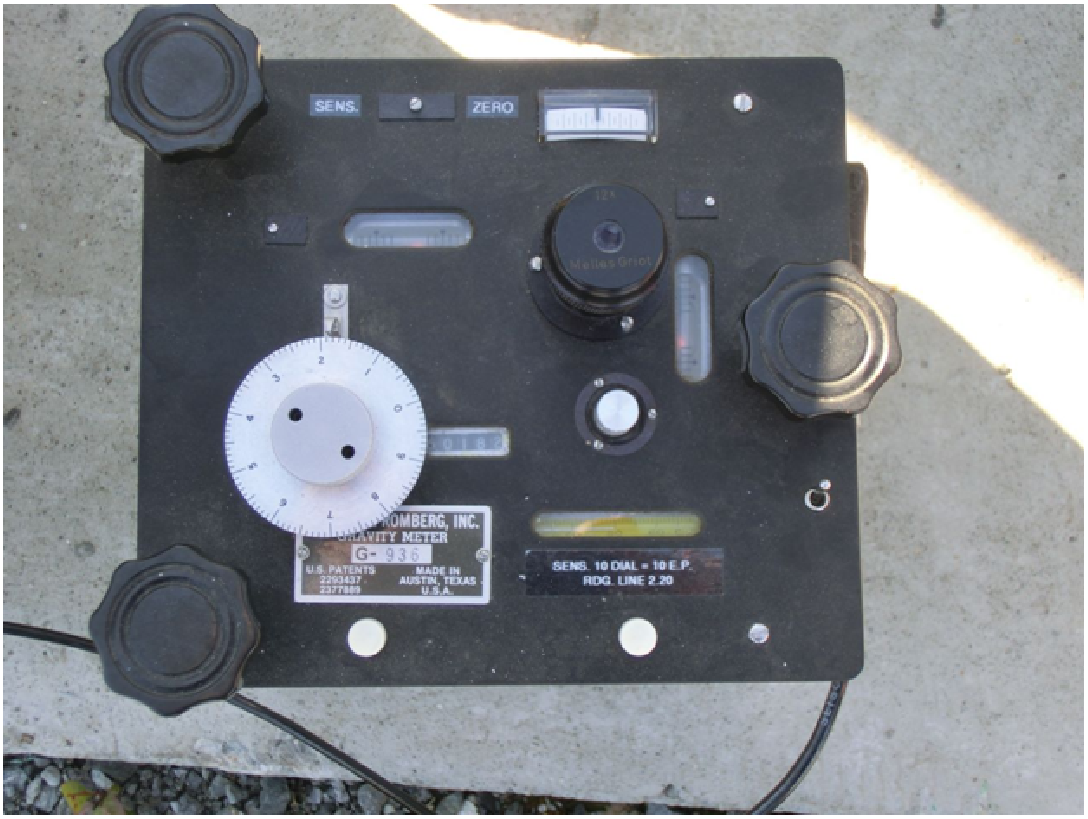

Image 2

These steps for the CG-5 and LNR were repeated at the 1st floor of Alderson Hall, near the elevator by the main entrance, and on the 4th floor near the elevator (S1 and S2, respectively). The difference in these floors was 12.34 meters. The CG-5 was then used again at DA, and the LNR at XA, in order to measure the drift of the gravity field since the first measurements.

Two readings were recorded with each device at each station. The readings from the LNR gave a gravity value that was in counter units. These units were then converted into mGal, the same units that the CG-5 readings were in. The average differences in the gravity field between S0 (from the initial recording) and S1 were then calculated, and then between S1 and S2. Then values were used to find the absolute gravity readings for stations S1 and S2.

The gradient value between S1 and S2 was then calculated, and was compared to the theoretical value of the gradient value. This step showed that several sources of error were present during our recordings. Using the two observed gravity values converted into absolute gravity values, the radius of the earth was then calculated, assuming that the earth is a perfect sphere and that the value of the gravitational constant and mass of the earth was unknown. This value was compared to the true radius of the earth, again showing that there were multiple sources of error.

Data Processing

The first calculation performed in this lab was a conversion from counter units on the LNR to mGals. The initial units were only useful when dealing with LNR meters, and they had to be converted in order to perform any further calculations. This equation is listed below:

Counter Reading (mGal from Table)	Factor for Interval
3169.7	1.02481
Conversion Example (Counter to mGal):	
g=C+F*(A-B)	C=mGal Value (from Table)
	F=Factor for Interval (from Table)
	A=Reading from Gravimeter
	B=Counter Reading (from Table)

(1)

The Counter Reading and Factor for Interval were found on a provided conversion table. The counter reading was 3169.7 for every LNR measurement taken, and the factor for interval was 1.02481 for every LNR measurement taken.

After this conversion was performed, the average differences in S0 and S1, and S1 and S2 had to be calculated for both meters. This was done by subtracting the larger value from the smaller one, resulting in a negative number that was used in determining absolute gravity values.

The conversion from relative to absolute gravity was the next necessary calculation, and the equation for this process is listed below:

AG (S1) = S0 + Avg Difference in Grav Field (S0 and S1)
AG (S2) = S1 + Avg Difference in Grav Field (S1 and S2)

(2)

In equation 2, the provided absolute gravity measurement for S0 is added to average difference in the gravity field from S1. This gives a lower absolute gravity measurement (since the average differences were negative). This value was then added to the average difference in the gravity field from S2, in order to solve for the absolute gravity of S2. This is done for both the CG-5 and LNR readings.

Calculating the gradient value between the two observation locations was required, and the equation for this is listed below:

$$\text{Gradient} = ((\text{S2 Absolute Grav})-(\text{S1 Absolute Grav}))/12.34 \quad (3)$$

Equation 3 subtracts the first solved for absolute gravity from the second, and divides by the difference between S1 and S2 (in meters). This is done for both the CG-5 and LNR readings.

The final calculation performed was solving for the earth's radius. The Taylor Series is performed upon an existing equation to end in one which does not use the gravitational constant or the mass of the earth. This equation is listed below:

$$\text{Radius} = (2*12.34*(\text{S1 Absolute Grav})/((\text{S1 Absolute Grav})-(\text{S2 Absolute Grav})))/1000 \quad (4)$$

Equation 4 allowed us to plug our values for absolute gravity from S1 and S2 and the difference in height of S1 and S2 into the equation, and easily solve for the radius. This value was then divided by 1000 in order to convert from meters to kilometers.

Results

CG5					
Station	Reading (mGal)	Stnd Dv	Recorder	Time	Average for Stations (mGal)
S0-DA	4213.834	0.025	Stuart	9:23am	
S0-DA	4213.831	0.04	Rowdy	9:32am	4213.8325
S1	4212.267	0.063	James	10:48am	
S1	4212.271	0.069	Nick	10:51am	4212.269
S2	4208.836	0.063	James	10:21am	
S2	4208.805	0.124	Garrett	10:23am	4208.8205
S0-DA	4213.762	0.025	Samara	11:14am	
S0-DA	4213.765	0.023	Stuart	11:15am	4213.7635

Table 1

Table 1 shows the measurements, standard deviation, recorder, time, and average station values for the CG-5 meter that we gathered.

LNR					
Station	Reading (Counter)	Conversion (mGal)	Recorder	Time	Average for Stations (mGal)
S0-XA	3144.905	3144.289836	James	9:56am	
S0-XA	3144.715	3144.095122	Zack	9:59am	3144.192479
S1	3143.805	3143.162545	Austin	10:28am	
S1	3143.040	3142.378565	Dallas	10:31am	3142.770555
S2	3140.553	3139.829863	Ginevra	10:53am	
S2	3140.610	3139.888277	Dallas	10:51am	3139.85907
S0-XA	3144.909	3144.293935	Sam	11:17am	
S0-XA	3144.888	3144.272414	Victor	11:25am	3144.283175

Table 2

Table 2 shows the measurements, converted measurements, recorder, time, and average station values for the LNR meter that we gathered.

CG5	Average Differences in Gravity Field
S0(1) and S1	-1.5635
S0(2) and S1	-1.4945
S1 and S2	-3.4485
LNR	Average Differences in Gravity Field
S0(1) and S1	-1.421923875
S0(2) and S1	-1.51261956
S1 and S2	-2.91148521

Table 3

Table 3 shows the average differences in the gravity field for S0 and S1, and S1 and S2 for both of the meters.

	Absolute Gravity Measurements (mGal)
XA	979570.598
DA	979571.122
S1 (CG5)	979569.5585
S2 (CG5)	979566.11
S1 (LNR)	979569.1761
S2 (LNR)	979566.2646

Table 4

Table 4 shows the absolute gravity measurements that we calculated for each station, from the provided absolute values from XA and DA.

	Gradient Value between S1 and S2 (mGal/m)
CG5	-0.27945705
LNR	-0.235938834
	Theoretical Gradient Value = -0.3086 mGal/m

Table 5

Table 5 shows our calculated gradient values for both meters, and lists the theoretical gradient value. Possible causes for error or discrepancy in this measurement are listed below, in the Discussion.

	Radius of Earth (km)
CG5	7010.51956
LNR	8303.585807
	True Radius of Earth = 6378 km

Table 6

Table 6 shows what our calculated values were for the radius of the earth for the CG-5 and LNR meters, and gives the true radius of the earth. Possible causes for error or discrepancy in this measurement are listed below, in the Discussion.

For example, here are some of the computations performed in this lab using the equations listed above.

Equation **(1)** was used to calculate the relative gravity measurements on the LNR gravimeter . Those calculations were computed as follows for location S0-XA:

$$[3169.700 + 1.02481 * (3144.905 - 3169.700)]\ \text{mGal} = 3.144.28984\ \text{mGal}$$

Equation **(2)** was used to calculate the average relative gravimeter measurement from two readings at the the same location. Here is an example of one of these calculations at location S0-XA.

$$[(3144.28984 + 3144.09512) / 2]\ \text{mGal} = 3144.19248\ \text{mGal}$$

Equation **(3)** was used to calculate a value for the gradient of the gravity between two measurement locations. In this example the gradient was calculated with measurements obtained on the CG-5 at locations S1 and S2.

$$[(979569.559 - 979566.110)\ \text{mGal} / 12.34\ \text{m}] = -0.27945705\ \text{mGal} / \text{m}$$

Equation **(4)** was used to calculate the radius of the Earth using a Taylor series estimation. This example calculation was performed using data from the CG-5 and was computed as follows:

$$(2 * 12.34\ \text{m} * [979569.559\ \text{mGal} / (979569.559 - 979566.110)\ \text{mGal}]) / 1000)\ \text{Km} = 7010.52\ \text{Km}$$

Discussion

The two main focuses of this discussion are evaluating the calculated free-air gradient and radius and explaining any discrepancies that may exist with the known values for the free-air gradient and radius. The measured free-air gradient of the Earth's gravity field was 90.55% of the known free-air gradient with the CG-5, and 76.44% of the known free-air gradient with the LNR. This error was likely caused by physical disruptions in the vicinity of the meter during measurement, imperfect calibration or measurement, local air currents, possible regional microseismicity, the significant elevation above sea level, possible non-uniform subsurface rock densities, and tidal effects from the Moon and Sun [1]. Both values of the free-air gradient were less than the known values meaning the most significant sources of error diluted the gravity field.

Consequently, these sources of error also affected the calculations for the radius of the Earth because the absolute gravity measurements in combination with a Taylor Series approximation yield the radius measurement. The calculated measurements for the radius of the Earth, 7010.51 Km with the CG-5 and 8303.58 Km with LNR, and known measurement for the Earth's radius, 6378 Km, are consistent with a diluted gravity field. Since the free-air gradient calculations are less than the known values, and gravity changes as a function of inverse radius squared, we would expect the free-air gradient to be a function of negative radius cubed. This means as radius increases the free air gradient changes less. That result is consistent with both, the calculated free air gradient and radius. A larger radius warrants a free-air gradient closer to zero than the known value of the free-air gradient.

Error plays a significant problem in this lab because there were no corrections for known sources of error, like tidal effects and elevation and it is impossible to accurately correct for any and all miscellaneous sources error. Error also plays a significant role because all the calculations in this lab are dependent on the error prone relative gravimeter readings.

Conclusion

This lab presents multiple conclusions concerning relative gravimetry in the field, using gravimetry measurements in calculations, and sources of error in gravimetry data processing. Although the values calculated in this lab are not accurate enough to justify a credential as an experimental geophysicist, the field results were not obtained in an environment of error reduction and were not corrected for known sources of error. Additionally, each person participating in this lab learned about relative gravimeters and their associated procedures of storage, handling, and data collection.

Work Distribution

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- Measurements
- Calculations
- Objectives
- Procedure
- Data Processing
- Results

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- Measurements
- Calculations
- Introduction
- Discussion
- Conclusion

Citations

[1] H.O. Siegel. (1995, August). A Guide to High Precision Gravimeter Surveys. Scintrex Limited. Concord, Ontario. [Online]. Available: http://scintrexltd.com/downloads/GRAVGUID.pdf