Gravimetric Survey in the VIDAL quadrangle, continued

Field Camp 2005

Vivian Leung, William McGehee, Shelsea Pedersen, Adele Schwab, Shaye Storm

Abstract
The primary objective of the study was to develop a subsurface map of the area being surveyed using gravity measurements taken at distinct points throughout the region. The location of the survey was the same as the previous year. Last years data was therefore taken into consideration when deciding where to take measurements this year. The gravity data was interpreted with the surface geology in mind. The region contained faults and various rock formations. Gravity measurements were taken every 200-300 meters to cover all the area needed for a better understanding of the region and its subsurface formations. In order to determine the density of the alluvium which covered a substantial portion of the geology of the region, gravity measurements were taken at the edge of a wash at two distinct elevations. The gravity measurements were also used with the purpose of improving last year's geology map. Once all of the field work was completed the MATLAB scripts from previous years were cleaned up and organized for a more logical flow of corrections. Due to new restrictions on airplane cargo, the gravimeter had less than ideal time to warm up before being taken out for measurements. A warm up test was performed back at MIT to get a preliminary understanding of the effect of temperature on the gravimeter readings.

I. Introduction

Method

The main objective of the field study was to develop a subsurface map of the region being studied. The means by which this was accomplished were analyzing slight changes in gravity across the region using the highly sensitive LaCoste and Romberg gravimeter. In the effort to understand the subsurface structures of an area based on surface gravity measurements, one would wish to take all their measurements in exactly the same manner and at exactly the same time so that any trends found in data would be due to actual subsurface structures, not one of the many predictable aberrations in local gravity that exist. Since this is not possible, one must be concerned about the effects these aberrations have on data including the natural drift in the precision of our mechanical gravimeter, tidal influences, elevation changes, effects of varied terrain, and the effects of the earth's latitude dependent oblateness as they are described in following sections.

Location at Base Camp and Local Geology

Latitude - 34.062513490 °N
Longitude - 245.455947957 °W

Ellipsoidal Height - 234.5261 (m)
Geoidal Height - -31.5 (m)

The Riverside Mountains are composed of four main groups of rocks. The oldest are Precambrian rocks at the north of the mountains. These contain a metaigneous unit including augengneiss, leucogranite, and granite with quartz veins as well as a metasedimentary unit including biotite schist, quartzite, and gneiss. Much of the Precambrian is mylonitic and contains folds ranging from the centimeter to meter scale. Outcrops usually have a dark orange-brown desert varnish tinged with maroon. The next oldest are Paleozoic rocks from part of the Grand Canyon sequence, including the Permian Supai formation, Mississippian Redwall, Devonian Temple Butte, Cambrian Upper Muav and Cambrian Lower Muav. These are limestones and dolomites which have been partially metamorphosed into marbles. At the south of the range, and partially at the east, there are rocks of Mesozoic age. These include metagranite, calcareous schist, a magmatic suite containing porphyry and a weathered granite and the Jurassic Planet Volcanics. Finally to the west of the mountains are Tertiary rocks. These include various sandstones, and conglomerates as well as scattered sections of lake sediments. Many of these rocks are characterized by a dull clay red color that is visible from a distance.

The Tertiary section is mostly defined by two faults. The eastern side is bound by a shallow detachment fault dipping ~10° to the west. The western side is bound by another detachment fault dipping to the east. To the south, the eastern detachment begins to curl northwards. The Tertiary is surrounded by Precambrian rocks at the north and west, Mesozoic rocks at the south, and Paleozoic and Mesozoic at the east. The Paleozoic and Mesozoic are connected through a complex series of faults and overturned faults. That section is separated from the Precambrian by a northeast-southwest thrust fault dipping ~30-40° north. This fault is cut off by the eastern detachment and reappears with metagranite in the hanging wall.

Regional Geology

To the north of the Riverside Mountains are the Basin and Range provinces of Nevada. This is a series of north-south longitudinal mountain ranges separated by expansive basins. They are created by continuing widespread extension causing tilted fault blocks and forming large scale horses and grabens. Closer to the Riverside Mountains, the Colorado River Extensional Corridor carries extensional activity to the south.

The west coast of the United States has been and is an active continental margin due to the complete subduction of the Kula *plate, continuing subduction of the Fallon plate and the northward strike-slip motion of the Pacific's plate relative to the North American plate. The western margin of the North American plate has been growing due to island arcs accreting to the continent.*

II. Procedures

Gravimeter

A LaCoste and Romberg gravimeter was used to take the gravity measurements in the field. The design of the gravimeter enables it to detect very slight changes in gravity. A mass is held on the end of a horizontal bar. A spring is attached to the bar at approximately a 45 degree angle. The spring is used to restore the mass to its designated "initial" position. The amount of force needed for the spring to bring the mass back into this position is converted into a gravity reading taken from the dial using a series of levers. The gravimeter is composed of metal parts. This requires that its internal temperature be maintained to prevent thermal contraction or expansion. The gravimeter is therefore completely sealed and its temperature is maintained using a battery powered heater. Mechanical drift due to creep in the metal spring will occur in the gravimeter. This required base camp gravity measurements at the start and finish of each day to be able to account for the drift.

Figure 1: *Using the gravimeter in the field*

GPS

GPS, Global Positioning System is a satellite-based navigation system put into orbit by the U.S. Department of Defense. Composed of a network of 27 Earth-orbiting satellites in geostationary orbit 12,000 miles above earth, of the 27 satellites, 24 are in use with the other 3 being spares; just in case one fails. Circling the earth twice a day, they transmit signal information to earth, and the GPS receivers take this information and use triangulation to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. This time differential tells the GPS receiver how far away the satellite is. Compiling the distance measurements from a few more satellites, the receiver can then determine the user's position and present it on the unit's electronic map.

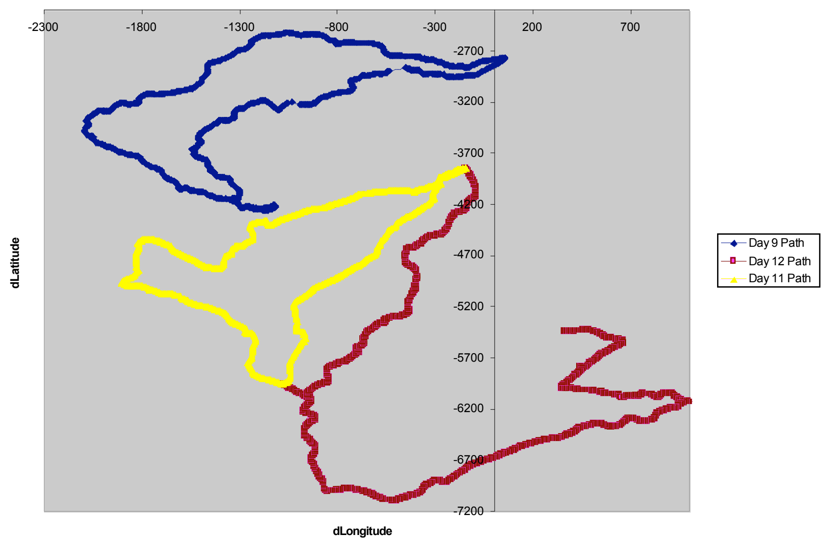
The fieldwork was executed with several different GPS setups. Throughout the roving fieldwork, both a mobile and static GPS were used; one that was carried throughout the area mounted on a tripod and one at base camp. Through these, the latitude, longitude and elevation of the gravity measurements were recorded; a GPS receiver must be locked on to the signal of at least three satellites to calculate a two-dimensional position (latitude and longitude) and track the movement. However, with four or more satellites in view, the receiver is able to determine the user's three dimensional position (latitude, longitude and altitude). At every location, the antenna would be reasonably leveled to increase precision, and then the height of the tripod antenna would be recorded using a height stick. While the measurements were not exact, that was alright, as it was only necessary to place the gravimeter within a meter or so of the GPS antenna. At each site, the GPS would be put into static mode so that it could take several minutes of measurements. These measurements, averaged over the time it took to make the measurement resulted in an accuracy that compensated for the small uncertainty relating to the displacement of the gravimeter. The two other GPS setups were used less frequently, and were related to seismographic research and to figuring out the location of the team at any given time. The first of these two setups resulted in the most precise measurements taken *throughout the course and were measured over the course of eight hours between two GPS tripod antennas no more than a half-mile apart. The GPS antennas were aligned with geodetic markers in the ground through an attached telescope with crosshairs. The height was then measured with the height stick and the antenna was aligned relative to true north. The second of these setups was simply a hand-held GPS receiver that relayed the team's position at all times and allowed for them to locate themselves during the fieldwork. This gave them the ability to record their latitude and longitude at each position and measurement which was an essential part of the later data analysis.*

Coordinate Systems

While spherical in nature, the Earth is constantly distorted due to the centrifugal force of daily rotation, resulting in a shape more akin to an oblate ellipsoid. The distance between the Earth's poles and its equator varies by about 20 kilometers at any given time due to this force. It is because of this that spherical coordinates, while seemingly obvious at first, would not be as helpful as one may initially believe, and as a result there have been several ellipsoidal coordinate systems devised. The three most common coordinate systems still in use today include NAD27, NAD83 and WGS84; the final two digits of each system represent the year in which they were first established. WGS84 was found to be particularly well fit for GPS, and was what the team used as their coordinate system this year. The only other relevant coordinate system used was NAD27, which is quite useful when using digital or flat two dimensional maps of the Earth.

Planning of Measurement Point

Two types of gravity measurements were taken in the field. The first day was devoted to taking readings along the road at permanent geodetic markers. The succeeding days of field work were mainly devoted to trekking new terrain to gain a more detailed subsurface map than achieved the previous year. The distance between data points were aimed to be 200 meters. After the first day of hiking and a meeting with the geology field camp, it was decided to spend the next two days exploring the area to the south and southeast to locate the pattern of a fault and determine the presence of a basin.



III. Corrections

Drift

The drift of the gravimeter is hardly perceptible over the time span of a year, so its influence on our gravity measurements is insignificant. Thus there is no reason to calculate it for our degree of precision. If the drift correction were significant, however, it would be performed after the tidal correction as follows.

$$g_{driftcorrected} = g_{dial} + ((g_{morning} - g_{evening})/(t_{morning} - t_{evening})) \times (t - t_{morning})$$

Conversion

The gravimeter was calibrated after manufacture. The table accompanying the gravimeter was used to determine the conversion factor between the dial reading, and its value in milligals.

Day-to-Day Base Camp Correction

After drift and tidal corrections have been taken into account, the base camp measurements at the start and finish of each day should be the same. A day-to-day correction was therefore needed.

$$g_{daycorrected} = g_{driftcorrected} + g_{1stmorning} - g_{nthmorning}$$

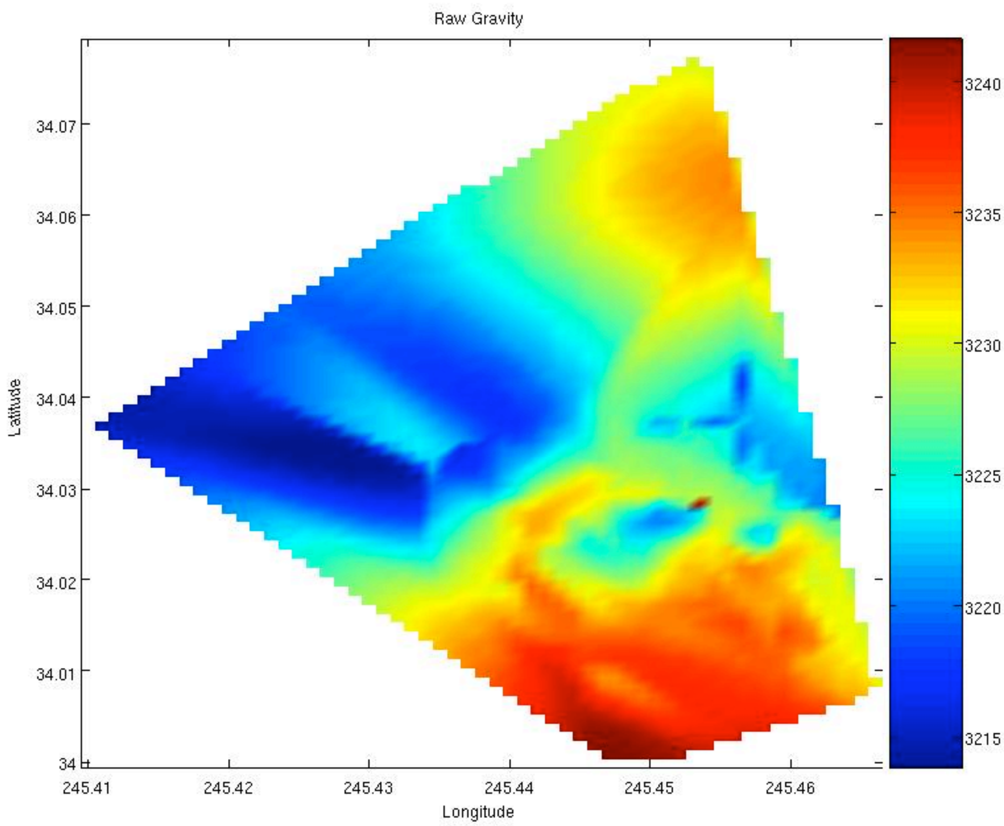


Figure 3: Raw gravity

Tidal

The tidal correction is small, but it is much larger than the drift so therefore must be accounted for first. The tidal forces on earth due to the moon and the sun vary throughout the day and influence the gravimeter readings. The orbits of the sun and the moon cause the surface of the Earth to reshape slightly. This alteration in the position of the Earth's mass causes an increase in gravity at high tide and a decrease in gravity at low tide. Because the effect is most significant in large bodies of water, the effect of tides on gravity measurements is much more pronounced near the oceans. The Riverside Mountains are sufficiently far inland that the tides alter gravity measurements by less than .5 milligals. The forces for each time of measurement were determined using ETGTAB and subtracted out.

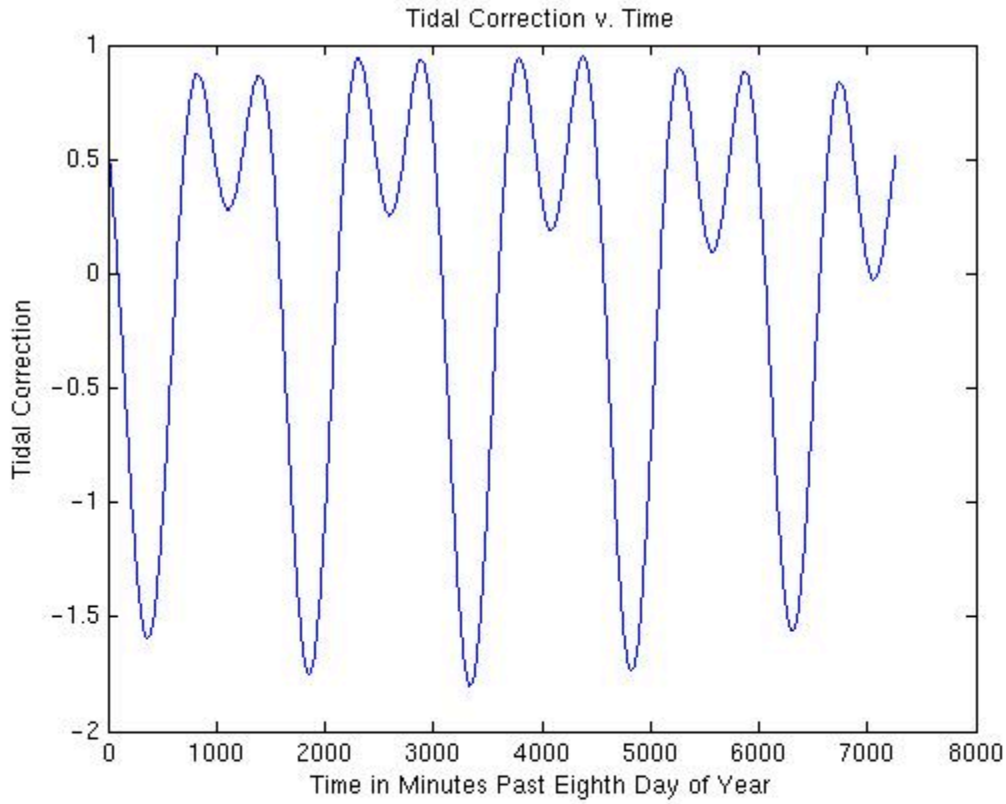


Figure 4: Tidal Correction
Extreme peaks are the effect of the moon, whose gravity is less than that of the sun but whose orbit is closer; middle peaks are the effect of the sun. The effect of the sun is about 50% that of the moon.

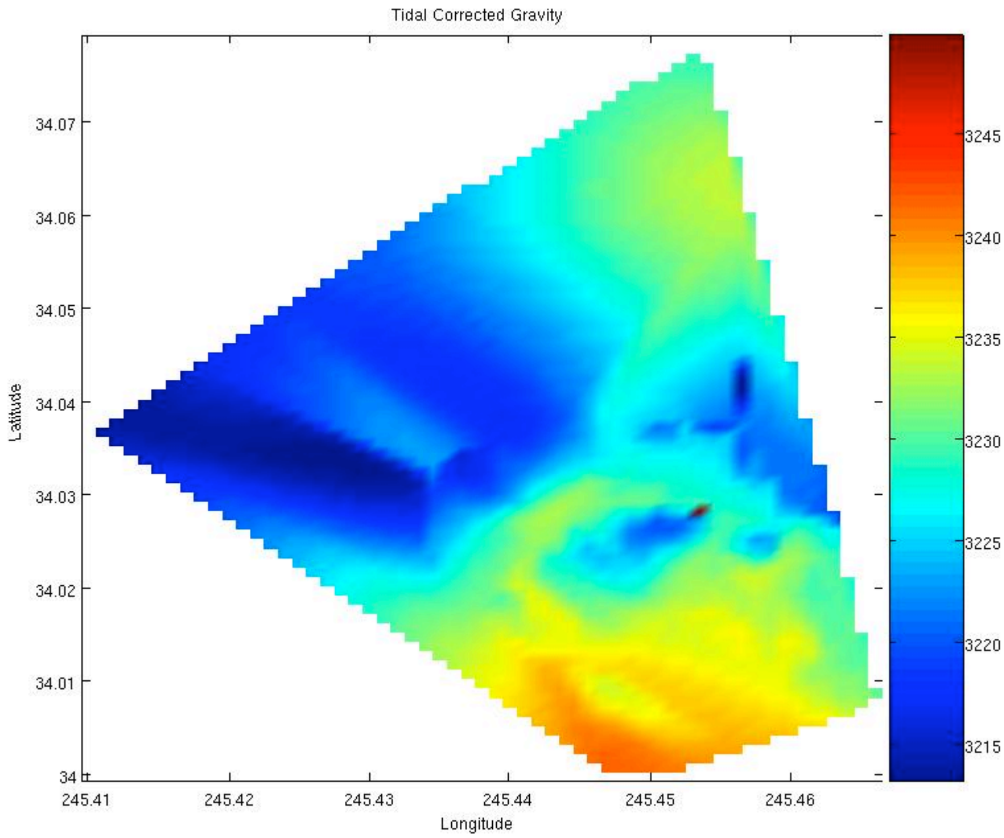


Figure 5: Tidal corrected gravity

Latitude

As the Earth is an oblate spheroid with more mass centered about the equator than the poles, local gravity varies as a function of latitude. One would think that gravity would be greater near the equator since there is more mass directly below the point of measurement. But as gravity is an inverse square relation from the center of mass, the density of the earth is not enough to make up for the greater distance (squared) at the equator from the centroid as compared that of the poles. Hence local gravity increases as latitude increases, and is governed by the below equation:

$$g_{raw} = 978032 \times (1 + 5.2789 \cdot 10^\wedge{-3} \sin(\gamma)^\wedge 2 - 2.35 \cdot 10^\wedge{-6} \sin(\gamma)^\wedge 4)$$

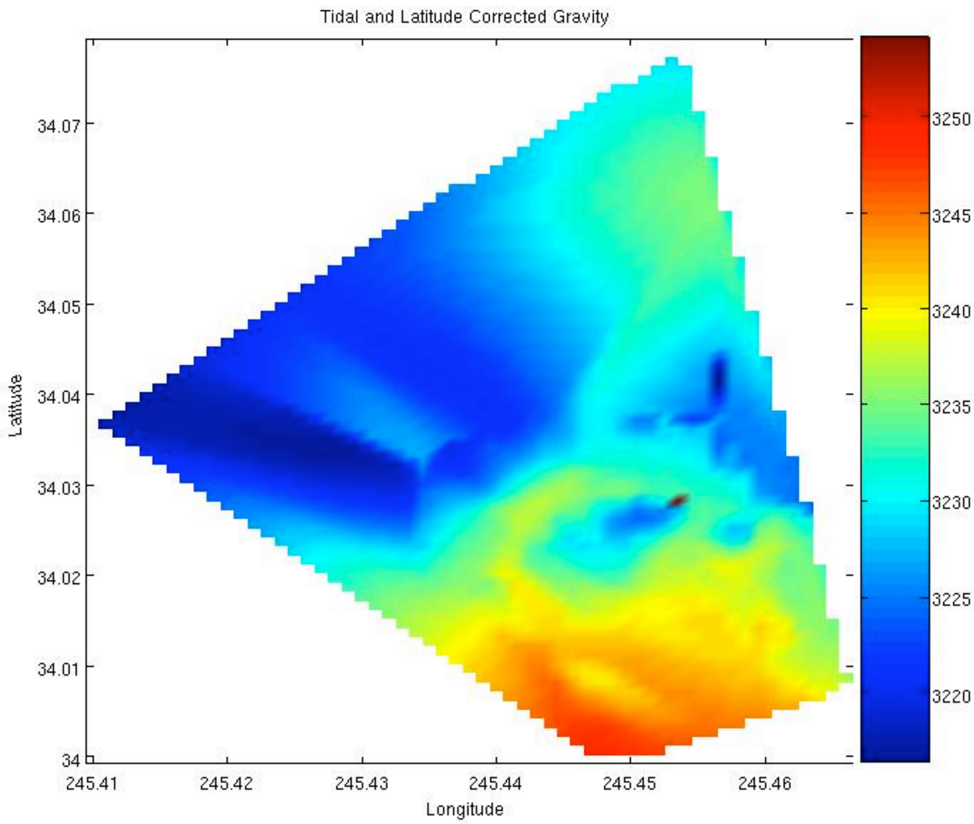


Figure 6: Latitude corrected gravity

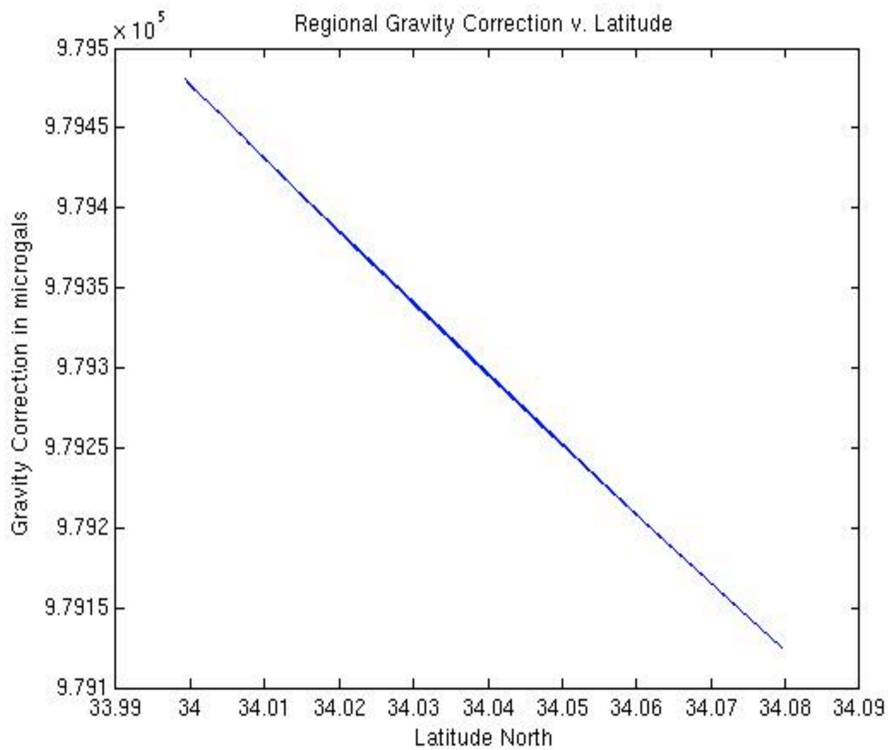


Figure 7: Local latitude correction

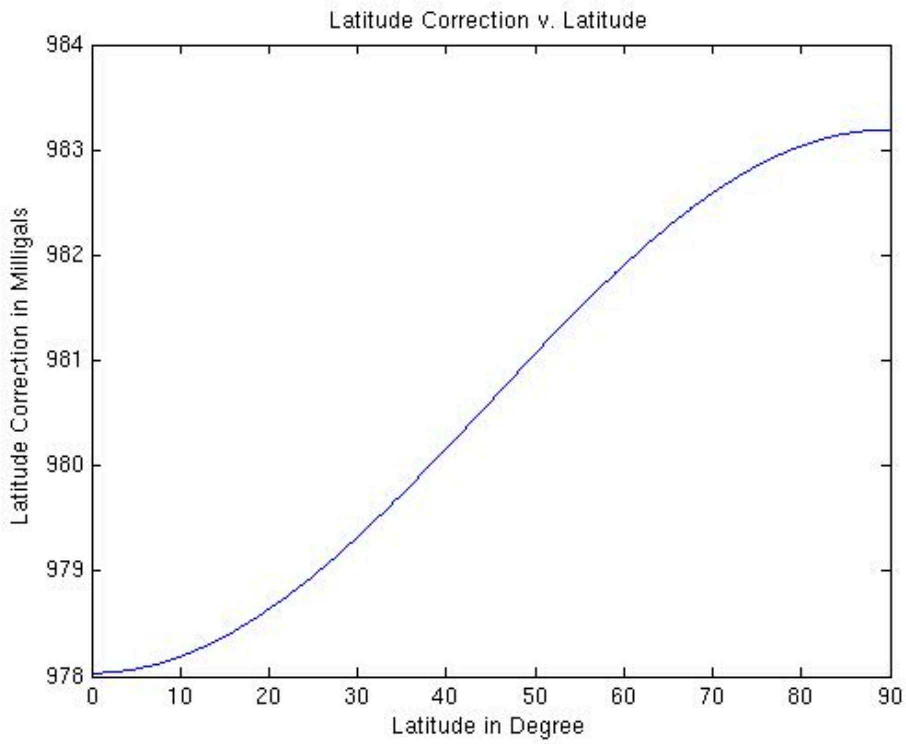


Figure 8: Global Latitude Correction

The Bouguer and Free Air Corrections

The effect of the mountains and canyons on the gravity measurements must be subtracted out in order to determine the underlying surface features. This is accomplished in part by the application of the Free Air and Bouguer corrections.

Free-Air Correction:

The Free Air correction accounts for differences in elevation. The height of the gravimeter was calculated using GPS for each gravity measurement in the field. This was to eliminate elevation as a factor affecting the gravity recorded. Increase in elevation brings the gravimeter further from the earth's center of mass, and thus produces a decrease in recorded gravity. The same idea holds for decreasing elevation. Since gravity is inversely proportional to the square of the distance from the center of mass of an object, higher elevations have lower gravity.

$$g_{free-air} = g_{raw} - 0.307 mgal/m \times h$$

NOTE: elevation=height as measured by GPS with respect to base camp

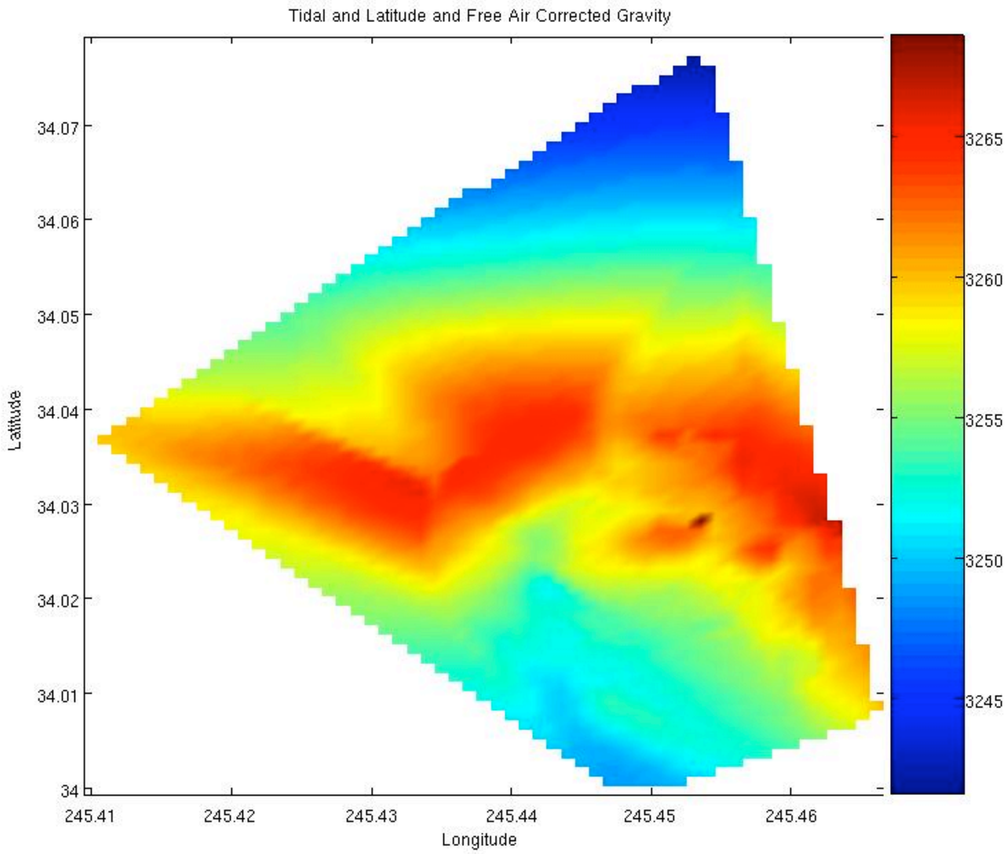


Figure 9: Free-air corrected gravity

Bouguer Correction:
The Bouguer correction allows us to remove the effect of the mass contained in the mountains on our gravity measurements.

$$g_{bouger} = g_{free-air} + 2\pi\rho G h$$

The derivation is as follows:

$$dm = 2\pi r dr \sigma$$

$$Ghdm/(r^2 + h^2)^{3/2}$$

$$\int_0^\infty \sigma G h 2\pi r dr/(r^2 + h^2)^{3/2}$$

$$\Rightarrow 2\pi\sigma G$$

$$(\sigma = \rho h)$$

$$\therefore 2\pi G \rho h$$

Once the terrain effects are removed with the Free Air and Bouguer corrections, the resulting gravity measurements provide us with the relative rock densities. When these densities are *combined with geologic maps containing information on the type and density of rock at the site, we are finally able to determine the thickness of the underlying rock.*

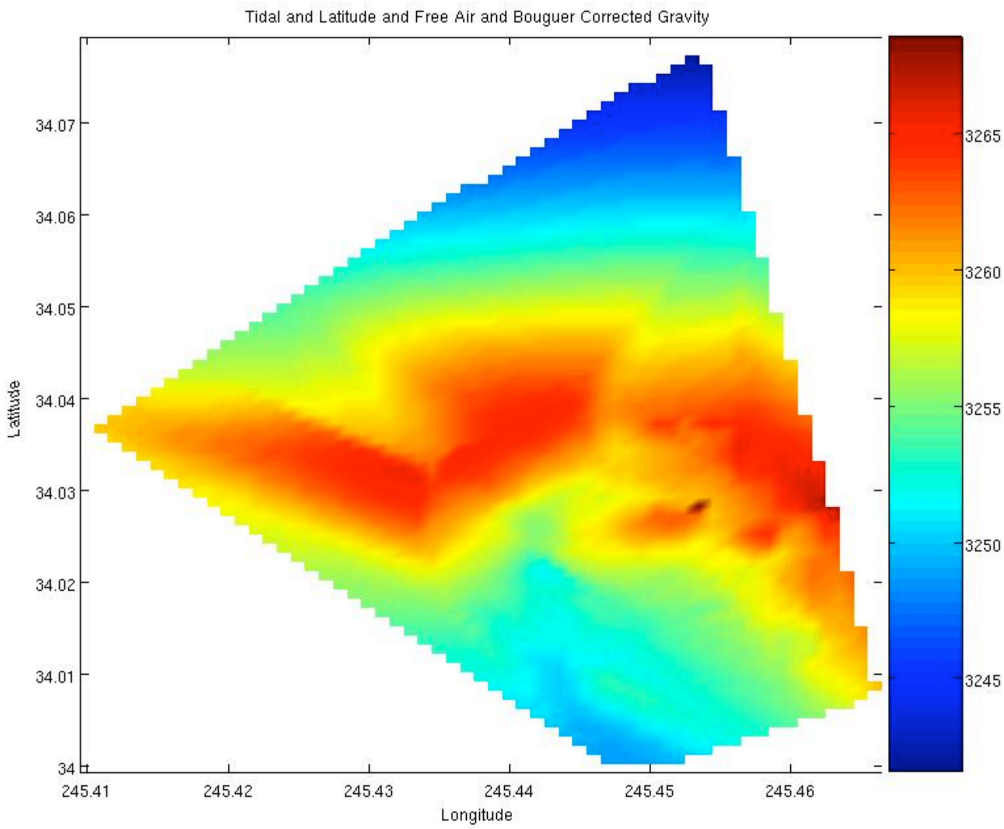


Figure 10: Bouguer corrected gravity

Terrain Correction

The terrain correction accounts for two aspects of the topography on which gravity measurements are taken. When in a valley, the elevated mass to the side of the gravimeter has an upward attraction. This upward attraction decreases the observed gravity. When on the top of a hill or mountain, the sloping mass below the gravimeter has a slight downward attraction, also decreasing the observed gravity.

IV. Analysis

The higher gravity band in the center of the graph corresponds to the higher density preCambrian rocks. The eastern part of the graph also has a higher density region that corresponds to the Paleozoic and Mesozoic to the east of the Eastern detachment fault. The Tertiary has lower gravity which shows less density of rock. Tertiary rocks are mostly sandstones, conglomerates and lake sediments, which are lower densities than the reworked and partially metamorphosed preCambrian rocks. If this area is in isostatic balance, the Tertiary would also be in a thicker layer underground. From geological mapping, the Eastern detachment fault looks very shallow, therefore probably not having a deep basin associated with the Tertiary.

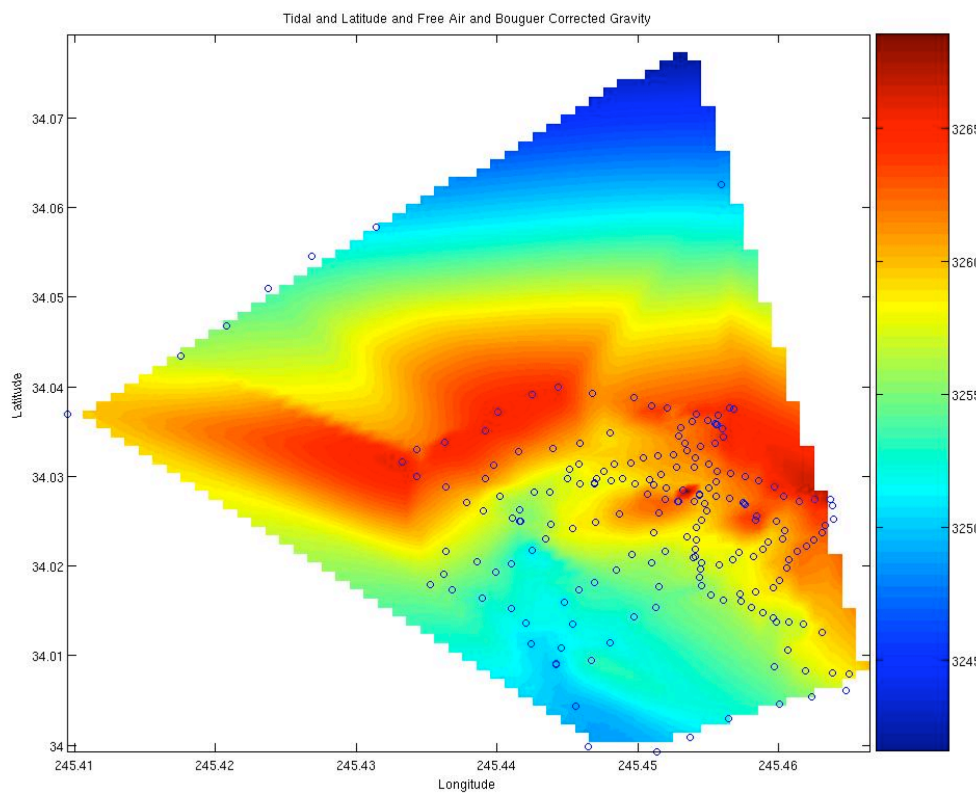


Figure 11: Combined 2004 & 2005 Data Points

Calculating densities of various rock types

Two measurements at the edge of a wash were taken on the first day of hiking. The edge of the wash was composed of alluvium. Taking two measurements of distinct elevation at the edge of *the wash enabled the calculation of the density of the alluvium:*

$$g_B = k - 2\pi G(\Delta h)\rho / 2$$

$$g_A = k + 2\pi G(\Delta h)\rho / 2 - \Delta h(0.307) mgal / m$$

$$\Delta g = 3233.55 - 3232.16 = 1.39 mgal = g_B - g_A$$

$$1.39 = 2\pi G(\Delta h)\rho - \Delta h(0.307)$$

$$\Delta h = 6.96m$$

$$1.39 = 2\pi G(6.96)\rho - 6.96(0.307)$$

$$G = 6.673 \times 10^{-11} \times (100000000)$$

$$\rho = 2.56 g / cm^3$$

Gravimeter Warm-Up Test

Due to the new inability to transport the gravimeter batteries on airplanes, the gravimeter had to be warmed up starting in the field. Instead of the ideal warm up time of a week, the gravimeter had only 12 hours to reach operational temperature of 47.6°C. The time allotted for battery re-charging was also only 12 hours. This created problems on the last day in the field when the battery voltage dropped below the ideal voltage of 12V. Although the day was completed with the gravimeter maintaining its ideal temperature, a test was done back at MIT to observe the temperature dependence of the dial reading on the gravimeter.

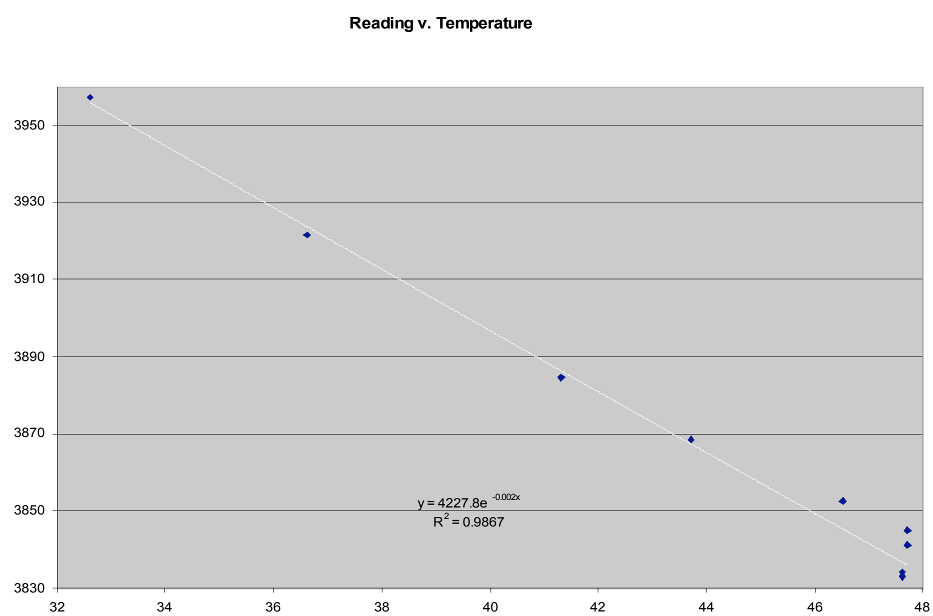


Figure 12: Gravimeter Test

MATLAB Codes

```
%Data Sets for pure_data.m-Columns
% 1 point name
% 2 year
% 3 day of year
% 4 hour California time
% 5 minute
% 6 minutes past Jan 8, 2005 00:08:00 UT
% 7 gravity dial reading
% 8 height correction (cm)
% 9 latitude degrees North
% 10 longitude degrees East
% 11 absolute height elliptical (m)
%%%%%%%%%%%%%

load pure_data.m;
load crude_data.m;
name=pure_data(:,1);
minutes=pure_data(:,6);
dial=pure_data(:,7);
hcorr=[crude_data(:,8);pure_data(:,8)];
lat=[crude_data(:,9);pure_data(:,9)];
long=[crude_data(:,10);pure_data(:,10)];
height=[crude_data(:,11);pure_data(:,11)];

cname=crude_data(:,1);
cminutes=crude_data(:,6);
cdial=crude_data(:,7);

%Gravity Conversion
%formula derived elsewhere
%%%%%%%%%%%%%%%%%%%
g_dial=dial.*1.0576-6.6959;
cg_dial=cdial.*1.0576-6.6959;
ga_dial=[cg_dial;g_dial];


%Tidal Correction
%%%%%%%%%%%%%%%%%%
load tides.m
Atides=[(tides(:,3)-8).*1440+60.*(-8+tides(:,4))+tides(:,5)
tides(:,7)./1000];
plot(Atides(:,1),Atides(:,2))
R=floor((minutes)./5+.5)+1;
g_tide=g_dial-Atides(R,2);

load ctides.m
Btides=[(ctides(:,3)-11).*1440+60.*(-8+ctides(:,4))+ctides(:,5)
ctides(:,7)./1000];
plot(Btides(:,1),Btides(:,2))
S=floor((cminutes)./5+.5)+1;
cg_tide=cg_dial-Btides(S,2);
aname=[cname;name];
ga_tide=[cg_tide;g_tide];

%Drift Correction
%%%%%%%%%%%%%%%%%
```

```
%extract Base Camp Values from Tidal correction
%fit linear function
%correct ga_tide according to linear function

%Latitude Correction
%%%%%%%%%%%%%%%%%%%%
lat_corr=978032*(1 + 5.2789e-3*(sin(lat*pi/180)).^2 - 2.35e-
6*(sin(lat*pi/180)).^4)-978032*(1 + 5.2789e-3*(sin(max(lat)*pi/180)).^2
- 2.35e-6*(sin(max(lat)*pi/180)).^4);
g_lat=[aname ga_tide-lat_corr];

%Free Air Correction
%%%%%%%%%%%%%%%%%%%%
aheight=height-hcorr./100;
g_freeair=[g_lat(:,2)+.307.*(height-min(height))]

%Bouguer Correction
%%%%%%%%%%%%%%%%%%%
b_corr=2*pi*2.57*6.673e-6.*height;
g_boug=[g_freeair(:,2)-b_corr];

%Terrain Correction
%%%%%%%%%%%%%%%%%%%
%get function

%GRAPHING
%%%%%%%%%
[x,y]=meshgrid(min(long):.0001:max(long), min(lat):.0001:max(lat));
z=griddata(long,lat,g_ABC(:,3),x,y,'cubic');
shading interp
pcolor(x,y,z);
```

Complete Gravity Data [2004/2005]

398	2005	9	8	9	2409	3064.24	155	34.062513490	245.455947957	234.5261
300	2005	9	9	8	2468	3052.21	154	34.037689998	245.456536568	318.5864
301	2005	9	9	25	2485	3049.52	161	34.036960010	245.454166844	329.1656
302	2005	9	9	48	2508	3057.03	157	34.037582271	245.452102272	293.4955
303	2005	9	10	4	2524	3052.19	157	34.037867776	245.450992315	318.0387
304	2005	9	10	15	2535	3056.49	163	34.038769919	245.449708245	296.6910
305	2005	9	10	29	2549	3057.58	158	34.039261417	245.446812833	290.2621
306	2005	9	10	40	2560	3052.48	161	34.039953330	245.444377440	317.7218
307	2005	9	10	54	2574	3050.23	167	34.039181237	245.442492588	326.2248
308	2005	9	11	5	2585	3048.37	163	34.037190879	245.440097307	333.5737
309	2005	9	11	20	2600	3050.06	158	34.035033897	245.439205357	326.0381
310	2005	9	11	34	2614	3047.30	157	34.033812280	245.436265521	336.6247
311	2005	9	11	41	2621	3053.99	157	34.033043138	245.434303289	302.9273
312	2005	9	12	0	2640	3045.46	151	34.031606533	245.433257161	344.1159
313	2005	9	12	15	2655	3050.36	161	34.030001590	245.434331011	320.3288
314	2005	9	12	48	2688	3053.25	157	34.028817933	245.436359403	304.0886
315	2005	9	12	59	2699	3057.27	163	34.027099473	245.437879373	282.2406
316	2005	9	13	12	2712	3059.63	164	34.026192575	245.438996469	268.9596
317	2005	9	13	24	2724	3062.10	163	34.025327465	245.441120398	254.4667
318	2005	9	13	36	2736	3062.46	155	34.025021036	245.441642901	251.7352
319	2005	9	13	47	2747	3063.77	174	34.025043313	245.441709377	244.9804
320	2005	9	14	1	2761	3061.06	151	34.024620406	245.443818658	258.2936
321	2005	9	14	20	2780	3063.58	158	34.026323390	245.441630141	247.3861
322	2005	9	14	34	2794	3061.00	154	34.027805185	245.440214121	262.7658
323	2005	9	14	52	2812	3053.03	169	34.029710822	245.439193763	305.3905
324	2005	9	15	6	2826	3052.95	163	34.031249467	245.439803878	308.4703
325	2005	9	15	25	2845	3053.86	154	34.032810584	245.441537482	305.1351
326	2005	9	15	37	2857	3056.49	166	34.033151226	245.444004577	292.7974
327	2005	9	15	50	2870	3057.08	162	34.033700595	245.445873803	288.7447
328	2005	9	16	1	2881	3058.42	159	34.034884416	245.448021805	281.1332
329	2005	9	16	26	2906	3052.33	163	34.037690600	245.456527915	318.5505
399	2005	9	16	57	2937	3064.51	155	34.062513490	245.455947957	234.5261
602	2005	8	14	25	1345	3059.10	175	34.079484906	245.454115018	230.4597
603	2005	8	14	44	1364	3052.59	115	34.057754673	245.431457058	279.5927
603.1	2005	8	14	57	1377	3051.47	158	34.054523211	245.426856156	287.5884
603.2	2005	8	15	7	1387	3050.32	160	34.050995468	245.423718915	294.3972
603.3	2005	8	15	16	1396	3049.26	162	34.046798783	245.420783209	302.2302
603.4	2005	8	15	31	1411	3048.19	164	34.043462833	245.417518742	308.9389
604	2005	8	15	43	1423	3046.15	140	34.036963884	245.409534260	324.0786
498	2005	11	8	36	5316	3064.67	107	34.062513490	245.455947957	234.5261
400	2005	11	9	19	5359	3059.53	158	34.028025667	245.454354486	276.6360
401	2005	11	9	42	5382	3052.36	153	34.027191569	245.452879778	309.7561
402	2005	11	9	52	5392	3052.12	162	34.025979444	245.451520729	308.6683
403	2005	11	10	4	5404	3052.90	148	34.025783851	245.448702489	301.6027
404	2005	11	10	15	5415	3057.29	144	34.024861308	245.446985537	279.5474
405	2005	11	10	28	5428	3055.66	134	34.024230526	245.445397916	283.3190

406	2005	11	10	41	5441	3058.90	148	34.022986470	245.443442485	265.2391
407	2005	11	11	1	5461	3059.93	152	34.021737686	245.442519597	244.9981
408	2005	11	11	16	5476	3065.20	167	34.020290628	245.441019863	231.3924
409	2005	11	11	26	5486	3060.90	150	34.019361741	245.439948701	250.2138
410	2005	11	11	38	5498	3061.25	137	34.020463535	245.438558455	252.5530
411	2005	11	11	49	5509	3059.36	143	34.021648969	245.436371885	265.4465
412	2005	11	12	7	5527	3060.68	153	34.019033452	245.436216157	254.6845
413	2005	11	12	15	5535	3060.94	160	34.017927541	245.435291823	252.8601
414	2005	11	12	26	5546	3061.87	138	34.017387335	245.436835179	246.2310
415	2005	11	12	36	5556	3063.70	141	34.016406282	245.438927875	234.9377
416	2005	11	13	8	5588	3064.04	157	34.015304977	245.441004469	231.8523
417	2005	11	13	17	5597	3065.70	139	34.013602235	245.442073286	223.4664
418	2005	11	13	30	5610	3068.52	152	34.011365115	245.442457585	209.0050
419	2005	11	13	41	5621	3069.24	136	34.009068122	245.444164815	204.3236
420	2005	11	13	54	5634	3066.94	149	34.010794078	245.444590043	216.9023
421	2005	11	14	5	5645	3065.89	143	34.013525013	245.445409747	223.3297
422	2005	11	14	18	5658	3065.61	157	34.015973087	245.444826352	224.6310
423	2005	11	14	48	5688	3061.76	142	34.017354029	245.445855360	244.5750
424	2005	11	15	0	5700	3062.29	152	34.018175013	245.446916812	243.3730
425	2005	11	15	16	5716	3059.41	133	34.019492308	245.448476222	259.3967
426	2005	11	15	31	5731	3058.08	145	34.021334771	245.449590297	268.4018
427	2005	11	15	45	5745	3057.87	142	34.023773275	245.451142459	277.4771
428	2005	11	16	4	5764	3059.39	151	34.028035824	245.454354379	276.6907
499	2005	11	16	43	5803	3064.59	107	34.062513490	245.455947957	234.5261
500	2005	12	10	7	6847	3065.80	151	34.013717014	245.459849542	239.1750
501	2005	12	10	34	6874	3061.88	167	34.012644704	245.463065761	261.6974
502	2005	12	10	44	6884	3063.71	163	34.010600441	245.460681410	248.5407
503	2005	12	10	53	6893	3066.18	154	34.008714769	245.459700774	232.4108
504	2005	12	11	6	6906	3064.49	165	34.008352420	245.461886690	243.8718
505	2005	12	11	17	6917	3063.17	156	34.008069931	245.463819567	251.7638
506	2005	12	11	30	6930	3062.99	161	34.007956519	245.465035981	253.6762
507	2005	12	11	49	6949	3060.37	165	34.007557678	245.466848294	267.0543
508	2005	12	12	5	6965	3064.22	151	34.006068625	245.464827438	243.3768
509	2005	12	12	17	6977	3066.65	165	34.005354790	245.462393400	229.4760
510	2005	12	12	29	6989	3067.72	151	34.004618793	245.460098812	220.7347
511	2005	12	12	40	7000	3068.90	147	34.002930916	245.456463530	210.4649
512	2005	12	13	16	7036	3069.88	155	34.000880842	245.453711046	200.9776
513	2005	12	13	28	7048	3070.84	147	33.999315299	245.451391902	192.3673
514	2005	12	13	42	7062	3071.70	156	33.999839397	245.446506697	187.9929
515	2005	12	13	58	7078	3070.64	158	34.004301470	245.445617705	195.1619
516	2005	12	14	12	7092	3069.39	158	34.009053130	245.444168900	204.4690
517	2005	12	14	34	7114	3064.28	159	34.009495365	245.446739245	231.5974
518	2005	12	14	44	7124	3067.25	166	34.011413065	245.448038558	217.0085
519	2005	12	14	55	7135	3065.44	147	34.014362668	245.449738240	227.4041
520	2005	12	15	9	7149	3064.61	153	34.015397087	245.451253212	234.7622
521	2005	12	15	21	7161	3064.31	160	34.017693978	245.451534929	239.6058
522	2005	12	15	34	7174	3061.83	153	34.020307302	245.450988209	251.5167
523	2005	12	15	44	7184	3062.45	164	34.021589261	245.451958357	252.5995
524	2005	12	15	55	7195	3062.14	148	34.023258296	245.453468592	259.5484
599	2005	12	16	45	7245	3064.74	107	34.062513490	245.455947957	234.5261
1	2004	11	10	56	1136	3052.72	144	34.037488333	114.543196667	315.8989
2	2004	11	11	7	1147	3054.86	147	34.036860000	114.544300000	304.7219
3	2004	11	11	17	1157	3054.99	148	34.036273333	114.545011667	304.1429
4	2004	11	11	28	1168	3056.03	152	34.036090000	114.546111667	297.3579
5	2004	11	11	38	1178	3056.73	153	34.035425000	114.546941667	294.2749
6	2004	11	11	49	1189	3057.13	149	34.034541667	114.547118333	291.4649
7	2004	11	11	55	1195	3057.08	147	34.033703333	114.546645000	291.9019
8	2004	11	12	1	1201	3057.76	152	34.032876667	114.546508333	287.9879
9	2004	11	12	15	1215	3058.25	153	34.032426667	114.547460000	284.6499
10	2004	11	12	22	1222	3058.24	154	34.032331667	114.548530000	283.1669
11	2004	11	12	30	1230	3058.67	154	34.032045000	114.549611667	280.7309
12	2004	11	12	43	1243	3059.15	156	34.031535000	114.550496667	277.0839
13	2004	11	12	52	1252	3059.52	148	34.031325000	114.551636667	273.5529
14	2004	11	12	59	1259	3059.77	150	34.030616667	114.552418333	270.9359
15	2004	11	13	7	1267	3060.26	151	34.029765000	114.552928333	267.8089
16	2004	11	13	24	1284	3061.27	151	34.029135000	114.553055000	260.3779

17	2004	11	13	54	1314	3061.87	158	34.029200000	114.554125000	259.5379
19	2004	11	14	7	1327	3062.94	177	34.028270000	114.556238333	252.8569
20	2004	11	14	12	1332	3062.85	153	34.028256667	114.557378333	251.1329
21	2004	11	14	24	1344	3062.54	152	34.029800000	114.555015000	257.0559
22	2004	11	14	29	1349	3061.75	145	34.030768333	114.554870000	260.3999
23	2004	11	14	38	1358	3061.51	149	34.031373333	114.554153333	263.7549
25	2004	11	15	5	1385	3061.33	149	34.029255000	114.553078333	260.1759
26	2004	11	15	12	1392	3061.1	156	34.029501667	114.551908333	262.9519
27	2004	11	15	18	1398	3060.95	149	34.029743333	114.551098333	265.5219
28	2004	11	15	23	1403	3060.61	156	34.029185000	114.550215000	267.1239
29	2004	11	15	32	1412	3060.65	150	34.029641667	114.549163333	268.9879
30	2004	11	15	39	1419	3059.05	157	34.030195000	114.548321667	278.3966
31	2004	11	15	46	1426	3058.84	156	34.030995000	114.547248333	280.1289
32	2004	11	15	51	1431	3058.48	151	34.031013333	114.546006667	282.7099
33	2004	11	15	59	1439	3057.89	146	34.031355000	114.544928333	287.2729
34	2004	11	16	7	1447	3057.74	154	34.032038333	114.545875000	287.4869
35	2004	11	16	32	1472	3052.77	144	34.037488333	114.543196667	315.8989
102	2004	13	9	33	3933	3052.9	155	34.037486667	114.543206667	315.7869
103	2004	13	9	55	3955	3058.04	121	34.031396667	114.544940000	287.1869
104	2004	13	10	5	3965	3058.18	113	34.030531667	114.544390000	285.7029
105	2004	13	10	11	3971	3058.79	118	34.029445000	114.544393333	282.4729
106	2004	13	10	21	3981	3059.49	119	34.028656667	114.544968333	277.8079
107	2004	13	10	31	3991	3059.77	123	34.027918333	114.545626667	274.6309
108	2004	13	10	41	4001	3060.87	121	34.027008333	114.545213333	269.2869
109	2004	13	10	48	4008	3060.45	124	34.026105000	114.545088333	272.2039
110	2004	13	10	56	4016	3061.22	122	34.025128333	114.545488333	266.8289
111	2004	13	11	2	4022	3061.74	121	34.024261667	114.545823333	263.0059
112	2004	13	11	12	4032	3061.52	121	34.022871667	114.545806667	263.9409
113	2004	13	11	19	4039	3062.11	131	34.021908333	114.545885000	259.2619
114	2004	13	11	26	4046	3063.06	116	34.020990000	114.546076667	251.9419
115	2004	13	11	32	4052	3063.11	119	34.020996667	114.545928333	252.1569
116	2004	13	11	40	4060	3063.88	125	34.020353333	114.545428333	248.7209
117	2004	13	11	48	4068	3063.22	117	34.020165000	114.544221667	254.3379
118	2004	13	11	58	4078	3064.67	125	34.020686667	114.543260000	248.3619
119	2004	13	12	8	4088	3064.59	121	34.021481667	114.542816667	249.7439
120	2004	13	12	16	4096	3064.28	123	34.021110000	114.541805000	253.1979
121	2004	13	12	22	4102	3063.97	121	34.021860000	114.541141667	255.9529
122	2004	13	13	5	4145	3063.44	128	34.022715000	114.540735000	256.1459
123	2004	13	13	12	4152	3063.1	117	34.022970000	114.539675000	262.5979
124	2004	13	13	19	4159	3062.44	129	34.023973333	114.539581667	265.4599
125	2004	13	13	26	4166	3061.33	123	34.025033333	114.540161667	270.2929
126	2004	13	13	41	4181	3052.9	118	34.025071667	114.541595000	311.5339
127	2004	13	13	51	4191	3055.77	124	34.025625000	114.541551667	299.2499
129	2004	13	14	11	4211	3058.25	124	34.026903333	114.542333333	285.4319
130	2004	13	14	18	4218	3058.82	118	34.027010000	114.542416667	281.9469
131	2004	13	14	24	4224	3059.76	108	34.027090000	114.542478333	276.0629
132	2004	13	14	30	4230	3059.15	112	34.027133333	114.542541667	280.3589
133	2004	13	14	36	4236	3059.06	113	34.027590000	114.543495000	280.2449
134	2004	13	14	43	4243	3059.72	119	34.027746667	114.544458333	275.5639
135	2004	13	14	52	4252	3059.64	115	34.027925000	114.545638333	274.5439
136	2004	13	15	8	4268	3057.77	118	34.032875000	114.546513333	287.5079
137	2004	13	15	14	4274	3056.74	110	34.033296667	114.545546667	293.2019
138	2004	13	15	21	4281	3055.69	119	34.033685000	114.544511667	300.1769
139	2004	13	15	28	4288	3050.99	118	34.034385000	114.543923333	322.7089
140	2004	13	15	38	4298	3054.66	107	34.035320000	114.543991667	304.8199
141	2004	13	15	44	4304	3056.1	117	34.035748333	114.544341667	297.6029
142	2004	13	15	51	4311	3055.24	116	34.035778333	114.544403333	302.2809
143	2004	13	15	58	4318	3055.34	109	34.035938333	114.544473333	302.0459
144	2004	13	16	9	4329	3052.87	167	34.037473333	114.543208333	315.9839
201	2004	14	8	53	5333	3052.9	143	34.037486667	114.543206667	315.7599
202	2004	14	9	10	5350	3059.84	177	34.027965000	114.545643333	275.2299
203	2004	14	9	22	5362	3059.37	147	34.028451667	114.546828333	277.3929
204	2004	14	9	29	5369	3059.2	149	34.028663333	114.547983333	277.5319
205	2004	14	9	35	5375	3059.62	129	34.029031667	114.548846667	274.5699
206	2004	14	9	42	5382	3052.87	140	34.027953333	114.549281667	306.5089
207	2004	14	10	9	5409	3053.89	133	34.027485000	114.548073333	303.6419
208	2004	14	10	12	5412	3052.59	149	34.027213333	114.547135000	308.5719
209	2004	14	10	20	5420	3056.26	156	34.027185000	114.546001667	292.9769
210	2004	14	10	27	5427	3059.8	178	34.027981667	114.545643333	275.3789
211	2004	14	10	40	5440	3064.62	175	34.019720000	114.545518333	246.3479
212	2004	14	10	47	5447	3064.33	166	34.018771667	114.545608333	245.2059
213	2004	14	10	53	5453	3065.73	175	34.017760000	114.545458333	236.1979
214	2004	14	11	0	5460	3065.41	171	34.016743333	114.544820000	240.0339
215	2004	14	11	6	5466	3066.23	178	34.016146667	114.543878333	237.1719
216	2004	14	11	12	5472	3064.46	165	34.016058333	114.542695000	246.6489
217	2004	14	11	19	5479	3064.26	157	34.015385000	114.541885000	248.0569
218	2004	14	11	25	5485	3064.42	118	34.014736667	114.541096667	248.1039
219	2004	14	11	32	5492	3066.74	176	34.014168333	114.540373333	236.4999
220	2004	14	11	39	5499	3065.63	157	34.013796667	114.539238333	241.8929
221	2004	14	11	46	5506	3064.85	150	34.013520000	114.538221667	244.8869
222	2004	14	11	57	5517	3064.13	174	34.016863333	114.542708333	249.4019
223	2004	14	12	4	5524	3063.73	163	34.017093333	114.541595000	253.5129
224	2004	14	12	9	5529	3063.82	177	34.017521667	114.540348333	255.8629
225	2004	14	12	13	5533	3063.04	157	34.018381667	114.539946667	260.1799
226	2004	14	12	18	5538	3061.1	159	34.019745000	114.539393333	273.4449
227	2004	14	12	23	5543	3061.79	150	34.020763333	114.539226667	269.9969
228	2004	14	12	27	5547	3061.11	156	34.021658333	114.538685000	274.9039
229	2004	14	12	34	5554	3060.4	157	34.022176667	114.538035000	278.7909
230	2004	14	12	41	5561	3061.06	170	34.022956667	114.537468333	276.4019
231	2004	14	13	18	5598	3060.39	177	34.023688333	114.536866667	279.4839
232	2004	14	13	29	5609	3058.08	143	34.024525000	114.536690000	293.2399
233	2004	14	13	36	5616	3056.31	144	34.025275000	114.536111667	299.0129
234	2004	14	13	47	5627	3048.02	136	34.026706667	114.536166667	339.6169
235	2004	14	13	53	5633	3050.09	137	34.027466667	114.536290000	331.2579
236	2004	14	14	7	5647	3054.61	143	34.027435000	114.537443333	309.0879
237	2004	14	14	12	5652	3057.91	141	34.027241667	114.538506667	290.5609
238	2004	14	14	23	5663	3056.88	135	34.027815000	114.539641667	295.1369
239	2004	14	14	31	5671	3053.54	126	34.028850000	114.540301667	311.3819
240	2004	14	14	42	5682	3056.98	130	34.029498333	114.541380000	294.0109
241	2004	14	14	50	5690	3056.84	157	34.029940000	114.542345000	293.6159

242	2004	14	14	56	5696	3057.8	148	34.030330000	114.543373333	288.9679
243	2004	14	15	4	5704	3058	138	34.030521667	114.544385000	286.1889
244	2004	14	15	21	5721	3052.83	143	34.037486667	114.543206667	315.7599