SURVEY DESIGN AND INTERPRETATION
PROJECT OUTLINE

- Overview of study area
  - Geologic background
  - Questions about area that need to be evaluated
- Evaluation of suitability of a gravity survey for answering questions
- Determining survey parameters
  - Data requirements
  - Constraints
- Acquire data
- Evaluate data
Housing development in Golden, CO

- Nearby abandon mine sites and one known mine in area
- Regionally mine subsidence is an issue

http://mining.state.co.us/Programs/Abandoned/MineSubsidence/PublishingImages/rapson.jpg
GEOLOGIC BACKGROUND

- Paleozoic sediments and basement
- Golden fault (thrust)
- Cretaceous marine sediments
- Tertiary volcanics and intrusives
COAL SEAMS AND MINES

- Mines located in NS striking, nearly vertical beds in Laramie Fm.

- Shaft encountered coal at 173, 245 and 317 ft depths
MINE TUNNELS

- Are expected to run north-south
- Between 3-5 m in diameter
- Between 5 - 100m deep (biggest concern <15m)
CLIENT’S COORDINATE SYSTEM

- (-250, 250)
  - 39.7667 degrees N, 105.237 degrees W
- (250, 250)
  - 39.7667 degrees N, 105.222 degrees W
- (-250, -250)
  - 39.7621 degrees N, 105.237 degrees W
- (250, -250)
  - 39.7621 degrees N, 105.222 degrees W
OUR STUDY AREA TODAY
CAN WE USE GRAVITY TO FIND THESE TUNNELS?

- What sort of signal will a tunnel produce?
  - Amplitude
  - Width
  - Position and orientation
- Can we see that signal through the measurement uncertainty?
  - *How do we know what the uncertainty is?*
SURVEY PLANNING

- Use applets to:
  - Create forward models of anticipated tunnels and shafts
  - Look at how results change when varying:
    - Measurement spacing
    - Number of measurements (using reasonable standard deviation)
  - Decide on parameters for survey taking into account:
    - Cost of survey
    - Need for data quality
GETTING GRAVITY APPS TO WORK

Download

GravitySurvey.zip ~369 kilobytes

*For instructions on how to install and use the survey java applet click here.

- Download
- Extract
- Follow directions on website
- Run BlueJ
TEAM WORK

Three teams
- Jason, Patrika, Cameron, Joseph
- Lindsey, Greg, Emily, Elise
- Shaimaa, Mikhail, John
GRAVITY DATA ANALYSIS

- Obtain data
- Correct for tides and drift
- Latitude & elevation and slab corrections
- Remove regional background
- Use apps to model structures in subsurface


Steps

- Correct for tides and instrument drift
  - Locate base station measurements
  - Linear interpolation between each base station measurement
  - Subtract correction from each data point

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Δg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1230</td>
<td>3.816</td>
</tr>
<tr>
<td>1382</td>
<td>3.8831</td>
</tr>
<tr>
<td>1470</td>
<td>3.9755</td>
</tr>
<tr>
<td>1524</td>
<td>4.0035</td>
</tr>
<tr>
<td>1676</td>
<td>4.0362</td>
</tr>
<tr>
<td>1716</td>
<td>4.0061</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>grav</th>
<th>correction value</th>
<th>corrected daily offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.816</td>
<td>-0.0000</td>
<td>3.816</td>
</tr>
<tr>
<td>-145</td>
<td>3.9229</td>
<td>0.000163</td>
<td>3.922737</td>
</tr>
<tr>
<td>-142.5</td>
<td>3.9555</td>
<td>0.001522</td>
<td>3.953978</td>
</tr>
<tr>
<td>-140</td>
<td>3.9415</td>
<td>0.003411</td>
<td>3.938089</td>
</tr>
<tr>
<td>-137.5</td>
<td>3.9124</td>
<td>0.005805</td>
<td>3.906595</td>
</tr>
<tr>
<td>-135</td>
<td>3.9224</td>
<td>0.00868</td>
<td>3.91372</td>
</tr>
<tr>
<td>-132.5</td>
<td>3.9001</td>
<td>0.012009</td>
<td>3.888091</td>
</tr>
</tbody>
</table>
Correction needs to account for shift in starting point from each day

<table>
<thead>
<tr>
<th>time</th>
<th>grav</th>
<th>correction value</th>
<th>daily offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1230</td>
<td>3.816</td>
<td>3.757285</td>
</tr>
<tr>
<td>-145</td>
<td>1254</td>
<td>3.9229</td>
<td>3.863537</td>
</tr>
<tr>
<td>-142.5</td>
<td>1262</td>
<td>3.9555</td>
<td>3.894778</td>
</tr>
<tr>
<td>-140</td>
<td>1270</td>
<td>3.9415</td>
<td>3.878889</td>
</tr>
<tr>
<td>-137.5</td>
<td>1278</td>
<td>3.9124</td>
<td>3.847395</td>
</tr>
<tr>
<td>-135</td>
<td>1286</td>
<td>3.9224</td>
<td>3.85452</td>
</tr>
<tr>
<td>-132.5</td>
<td>1294</td>
<td>3.9001</td>
<td>3.828891</td>
</tr>
</tbody>
</table>

Check that corrected base station gives you the same reading every time
LATITUDE, ELEVATION, SLAB AND TERRAIN CORRECTIONS

- Do we need to correct for latitude?
- He tells us that we don’t need to correct for elevation changes
- What about slab and terrain corrections?
Regional background is provided in the module

Use a ruler or a digitizing program to extract values from the plot
### Regional Background

The data presented in the table is used to fit a polynomial function to the observed values. The function is given by:

\[
y = -0.0000000000021931x^4 + 0.0000000036522937x^3 - 0.000016211698922x^2 + 0.000130624926790x + 3.7936428412918200
\]

with an \( R^2 \) value of 0.9994416335871890.

<table>
<thead>
<tr>
<th>mm on plot</th>
<th>grav</th>
<th>convert mm on plot to m on ground</th>
<th>shift origin</th>
<th>Polynomial fit</th>
<th>check difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>3.64</td>
<td>20.51282</td>
<td>-239.316</td>
<td>3.640243</td>
<td>-0.00024</td>
</tr>
<tr>
<td>0.5</td>
<td>3.66</td>
<td>34.18803</td>
<td>-225.641</td>
<td>3.660591</td>
<td>-0.00059</td>
</tr>
<tr>
<td>0.7</td>
<td>3.68</td>
<td>47.86325</td>
<td>-211.966</td>
<td>3.679073</td>
<td>0.000927</td>
</tr>
<tr>
<td>0.95</td>
<td>3.7</td>
<td>64.95726</td>
<td>-194.872</td>
<td>3.699704</td>
<td>0.000296</td>
</tr>
<tr>
<td>1.25</td>
<td>3.72</td>
<td>85.47009</td>
<td>-174.359</td>
<td>3.721082</td>
<td>-0.00108</td>
</tr>
<tr>
<td>1.56</td>
<td>3.74</td>
<td>106.6667</td>
<td>-153.162</td>
<td>3.739612</td>
<td>0.000388</td>
</tr>
<tr>
<td>2.06</td>
<td>3.76</td>
<td>140.8547</td>
<td>-118.974</td>
<td>3.762693</td>
<td>-0.00269</td>
</tr>
<tr>
<td>2.55</td>
<td>3.78</td>
<td>174.359</td>
<td>-85.4701</td>
<td>3.778233</td>
<td>0.001767</td>
</tr>
<tr>
<td>3.8</td>
<td>3.78</td>
<td>259.8291</td>
<td>0</td>
<td>3.793524</td>
<td>-0.00087</td>
</tr>
<tr>
<td>5.4</td>
<td>3.78</td>
<td>369.2308</td>
<td>109.4017</td>
<td>3.780873</td>
<td>-0.00087</td>
</tr>
<tr>
<td>6.57</td>
<td>3.76</td>
<td>449.2308</td>
<td>189.4017</td>
<td>3.760537</td>
<td>-0.00054</td>
</tr>
</tbody>
</table>

The plot on the right shows the trend of the data points along with the fitted polynomial curve. The values of grav are plotted against the distance.
CORRECT FOR REGIONAL BACKGROUND AND SMOOTH

- Subtract regional background from tide corrected signal
- Smooth data with a moving average
USE APPS TO MODEL DATA

- Download & run App

GravityReduction.zip ~381 kilobytes

*For instructions on how to install and use the app*
ENTER DATA INTO APP & INTERPRET

Applet Viewer: GravityVerticalShaft.class

Applet

Distance (m)

-250 -200 -150 -100 -50 0 50 100 150 200

Gravity (mgal)

-0.094 -0.090 -0.086 -0.082 -0.078 -0.074 -0.070 -0.066 -0.062 -0.058 -0.054 -0.050 -0.046 -0.042

Depth (m)

-0 5 10 15 20

Depth = 3.0 m
Radius = 7.5 m
Contrast = 0.56 g/cm³
X Location = 5.0 m
Y Location = 2.0 m
Bias = 0.00 mgal

Applet started.

Gravity Data Input

Use this form to submit your reduced gravity data for importation into the gravity modeling applet. The easiest way to get data into this form is to display your data set on your local machine in a text editor, select all of the data, copy all of the data to a paste buffer, and then paste the data into the text field shown in gray. Each line should contain one gravity observation and include the location of the observation and the value of the observation, in that order. After pasting your data into text field select the submit button to update the gravity data shown in the applet’s main window. You may resubmit new data sets at any time. Use the clear button to delete all of the data in the text field.

-247.5 0.037251927
-245 0.037178253
-242.5 0.038370045
-240 0.043211900
-237.5 0.045203032
-235 0.037024437
-232.5 0.025939629
-230 0.025185234
-227.5 0.031188300
-225 0.035533638
-222.5 0.035310494
-220 0.031599385
-217.5 0.024943741
-215 0.025289602
-212.5 0.017141335
-210 0.018607312
-207.5 0.021056451
-205 0.029543225
-202.5 0.02962445
-200 0.024062806
-197.5 0.02534471

Submit
Clear
Look for more than one way to fit your data with a model

- Try changing depth and diameter of tunnels and shafts
- Could more than one thing account for observations?
  - Big tunnel, little shaft etc.