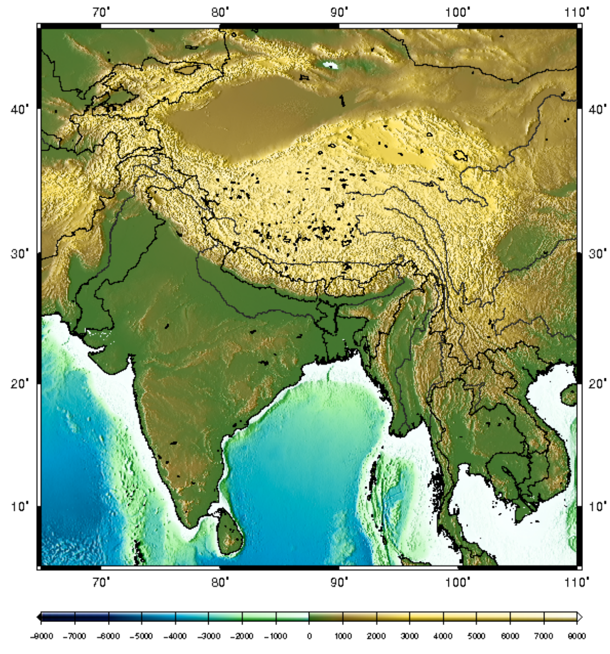
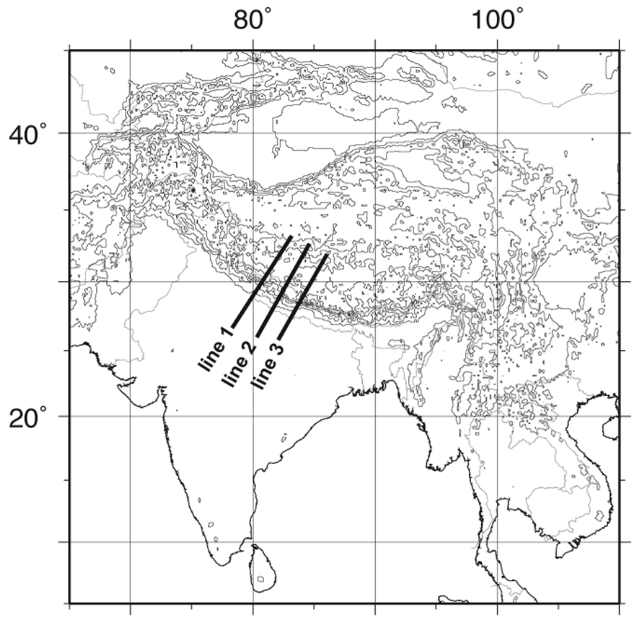
Gravity Modelling–Testing Hypotheses Using Gravity Data

How is the high topography of the Himalaya and Tibetan Plateau supported at depth?

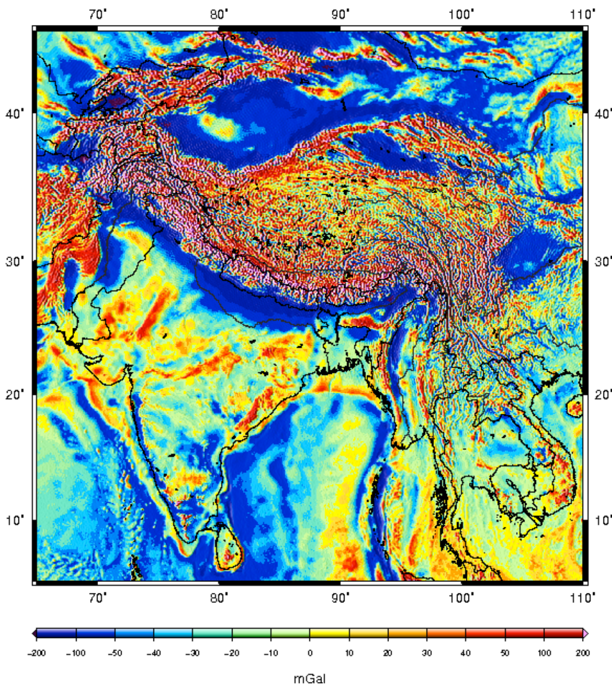
The aim of this practical is to use a forward modelling approach (using the semi-infinite slab approximation) to assist in the interpretation of the gravity anomalies observed along three transects (lines 1, 2 and 3) for the Himalaya-Tibetan Plateau region (see maps below).

ETOPO1 topography

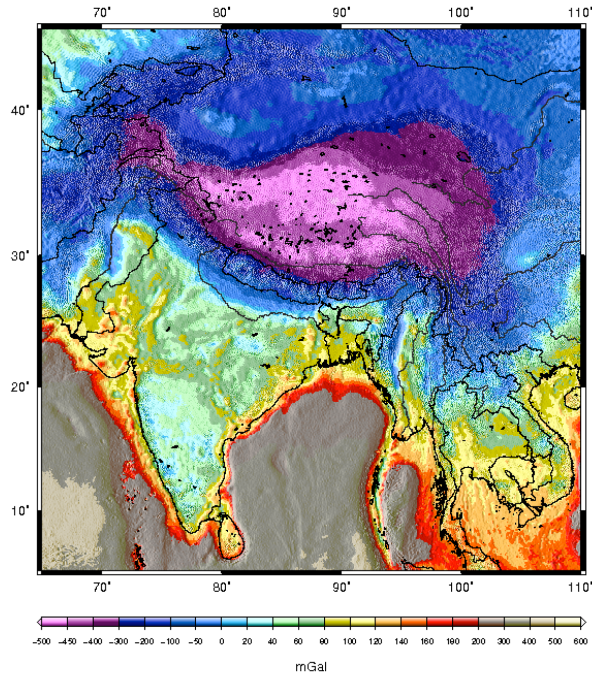




WGM2012 - Surface Free Air Anomaly (mGal)



WGM2012 - Complete Spherical Bouguer Anomaly (mGal)



Task 1.

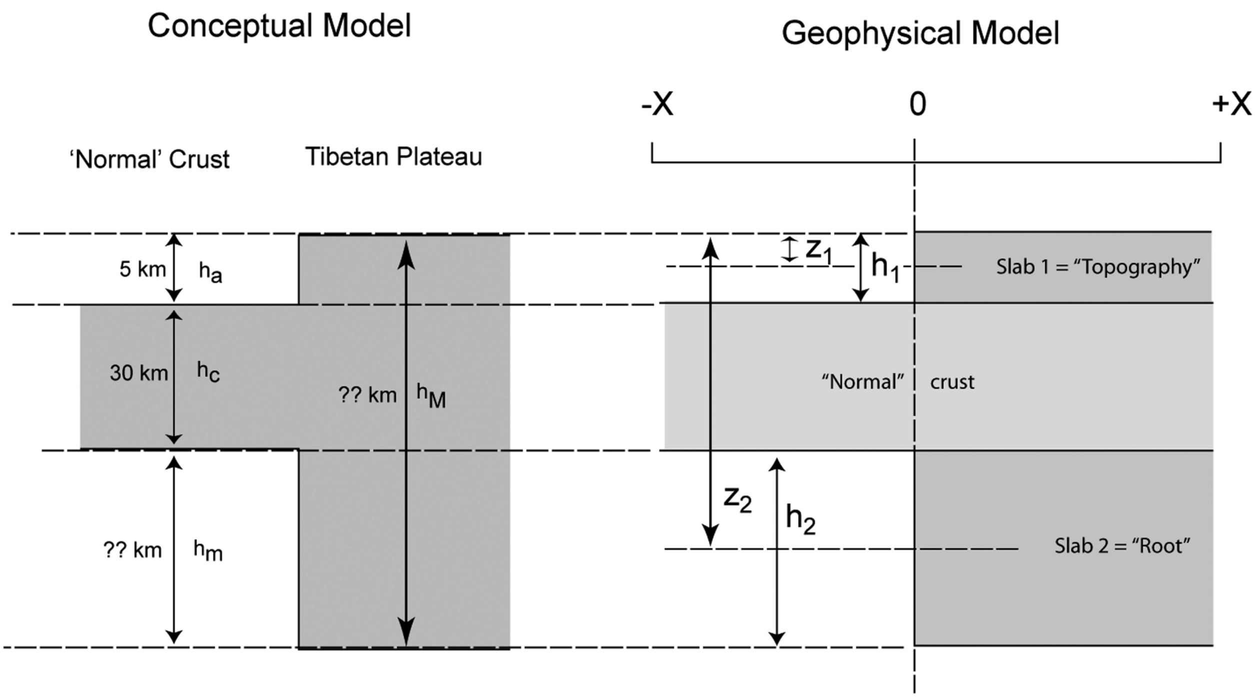
Down load the observed gravity data for the three transects (lines 1, 2 and 3) from the Moodle site. These are provided individually (one line per file) and also as a combined file (one file, each line on a separate workbook page). These data were extracted from the WGM2012 data set which a high resolution global dataset of Earth's gravity anomalies (Bouguer, isostatic and surface free-air), computed at global scale in spherical geometry. See the BGI website for further details; http://bgi.omp.obs-mip.fr/data-products/Grids-and-models/wgm2012

The raw gravity data have been processed following the standard procedures you used in previous labs to calculate the Free Air and Bouguer anomalies. For each transect the mean gravity anomalies (and the calculated standard deviation) were extracted from 20km wide (measured at right angles to the transect line) and 5km long (measured along line of transect) windows along the line of the transect. This yields estimates of the gravity anomalies and the standard deviation at 5km intervals along each profile.

Inspect the gravity anomaly profiles for each line by plotting graphs of the anomaly values and the topography (adjust the scale of the topography as required so you can plot the curves on one graph) on the y-axis versus centre distance on the x-axis. Compare the shape and magnitude of the anomalies with respect to the topography (i.e. elevation) for each transect.

Compare the observed anomalies for the Himalaya-Tibet mountain range to those analysed in the previous lab session for a mountain in Airy isostatic equilibrium.

Task 2.



Use an Airy isostatic model and a simplified crustal structure such as illustrated in the sketch above to calculate the thickness of the crustal root (h_m) and the total crustal thickness (h_M) under the Tibetan Plateau assuming the surface topography is completely supported by the crustal root, i.e. it is in Airy isostatic equilibrium (ρ_c = 2.67, ρ_m =3.1, ρ_a = 0 all in g.cm^{-3}).

Task 3.

Use the **semi-infinite slab approximation** (see pages 250, 257 and 258, Chapter 8, Lillie) to model the Free Air gravity anomaly and the Bouguer gravity anomaly across the Himalaya-Tibet mountain front assuming a simple Airy isostatic model. It will be useful and convenient to set up your model so that the x-distance intervals match those in the observed datasets (i.e. -300 t0 400 km with intervals of 5km).

Test your model predictions of the BA and FAA by comparing the model anomalies with the observed anomalies along each of the three transects, lines 1, 2 and 3. You could do this by testing your model against each transect separately.

Given that our model design is very simple, you may also want to investigate whether an "average model", i.e. a model that attempts to fit the mean of the observations calculated across all three lines. That is calculate the mean Free Air anomaly and the mean Bouguer anomaly (based on the three transect values available) and fit a simple model to these mean values. Averaging the observations made along the three transects will "smooth" some of the variation arising from spatial differences in density, topography etc.

Ensure that you calculate the **Root Mean Square Deviation (RMSD)**, i.e. the average misfit between your model predictions and the observations, for each model you test and compare this with the mean standard deviation on the observations for the transect.

Also, make sure you plot a set of suitable graphs to illustrate the observed anomaly data, topography and your model results for each transect/line, ensuring that a plot of the residuals is also included to aid the evaluation and assessment of the model.

Task 4.

• Read the four papers discussing the gravity and structure of the Himalaya-Tibetan Plateau listed on Moodle (Braitenberg et al. 2000; Cattin et al. 2001, Jordan and Watts, 2005 and Jin and McNutt, 1996).

• Compile all the outputs from the tasks 1 to 3 (include a simple sketch for your model design (from Task 1), and you <u>must</u> show your workings for the calculation of h_m and h_M in Task 1) into a brief report (not more than 1500 words).

• Discuss how your model performed and how it enabled (or otherwise) the interpretation of the observed gravity data, and the implications of your model for the state of isostatic compensation of the Himalayan-Tibetan mountain front.

• Explicitly discuss, and quantify using the appropriate statistics, how well your model fitted the observed data and whether, and to what extent, a model of local (Airy type) versus regional (flexural) isostasy is applicable to explaining how the topography of this mountain chain is supported.

Comment/discuss your results/conclusions in light of those reported/discussed in the literature (i.e. the four papers indicated above).

You must submit this report for assessment by the appropriate deadline, 1000 Monday 3rd Dec 2014.