Hands on LithoFlex

Supplement

Oceanic area: South China Sea

LithoFlex course

Work book

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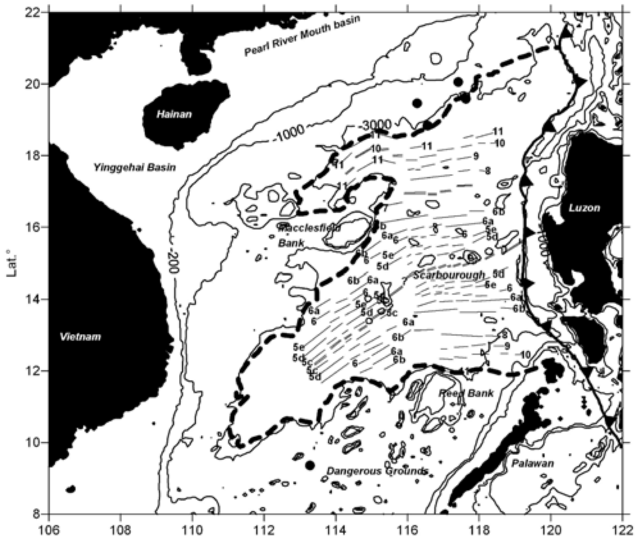
Carla Braitenberg, Patrizia Mariani
Department of Earth Sciences, Trieste University

Overview

- Familiarize with
  - the Flexure response of the crust to loads
  - the Gravity field.
  - Load: Oceanic basin, seamounts, sediments

Working area: South China Sea (SCS)



Geological sketch

Working files for SCS

Bouguer field	→	**boug.grd**
Topography	→	**topo.grd**
Sediment thickness	→	**sedithick.grd**
Bouguer field	→	**boug.grd**
NS Section	→	**AA'.bln**
Seamounts Section	→	**BB'.bln**

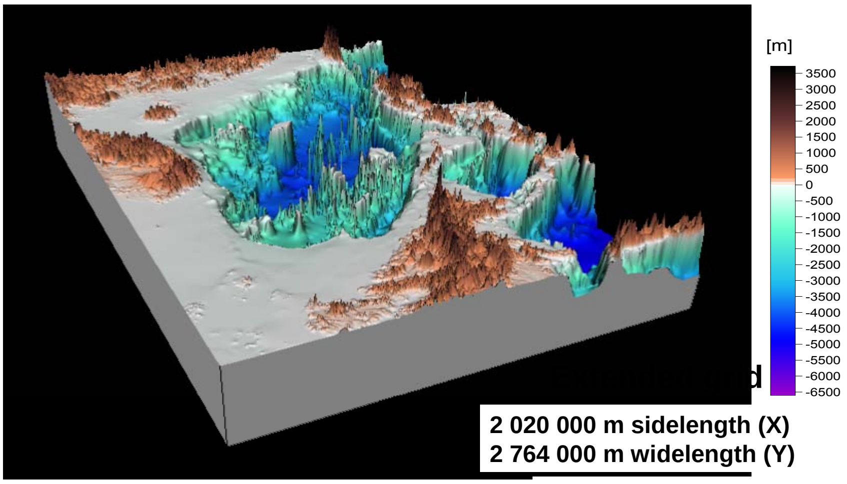
Grids in folder ..\Wb_supp_grids

1st Step
Describe given fields and maps:

- Use Surfer or Geosoft
- Create maps and simple profiles
- give short description of field properties

- Topography
- Sediment thickness
- Bouguer anomaly
- Free air anomaly

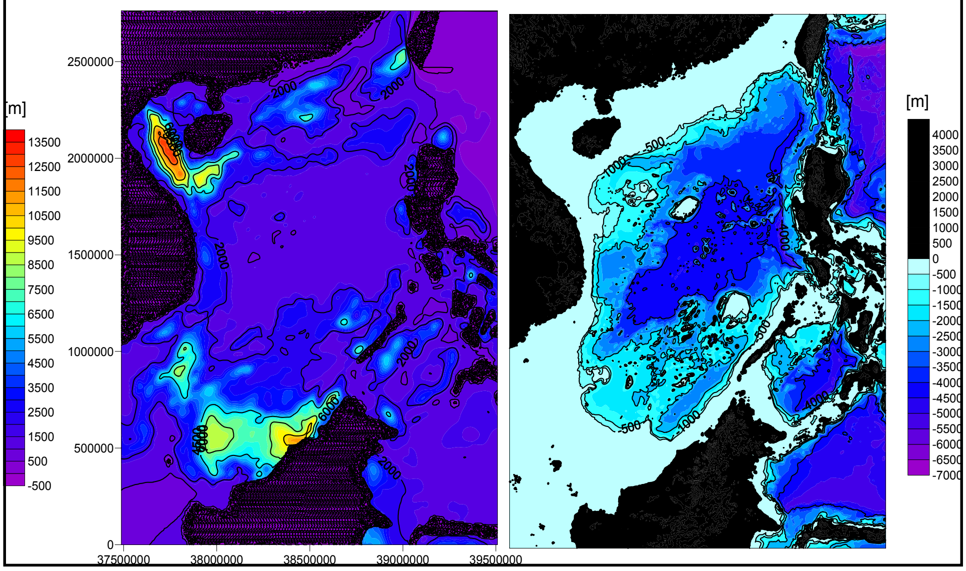
Topography



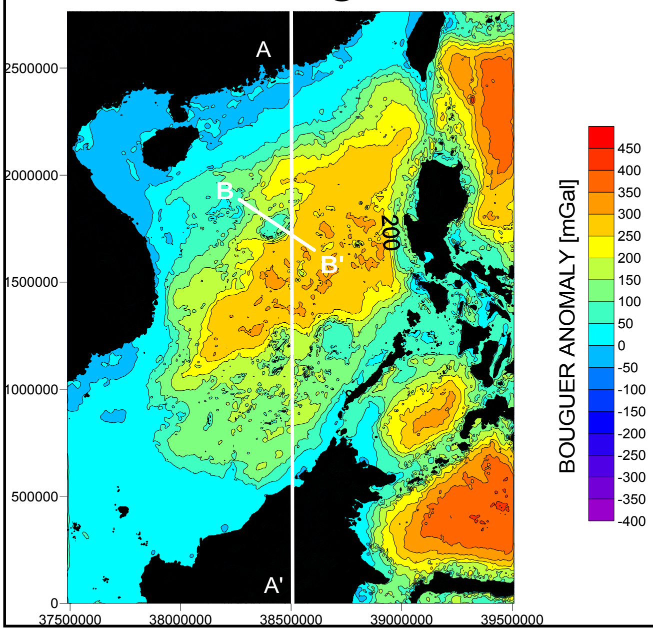
2 020 000 m sidelength (X)
2 764 000 m widelength (Y)

Xmin=37 488 000 m
Xmax=39 508 000 m
Ymin=0 m
Ymax=2 764 000 m

Sediment thickness and Topography



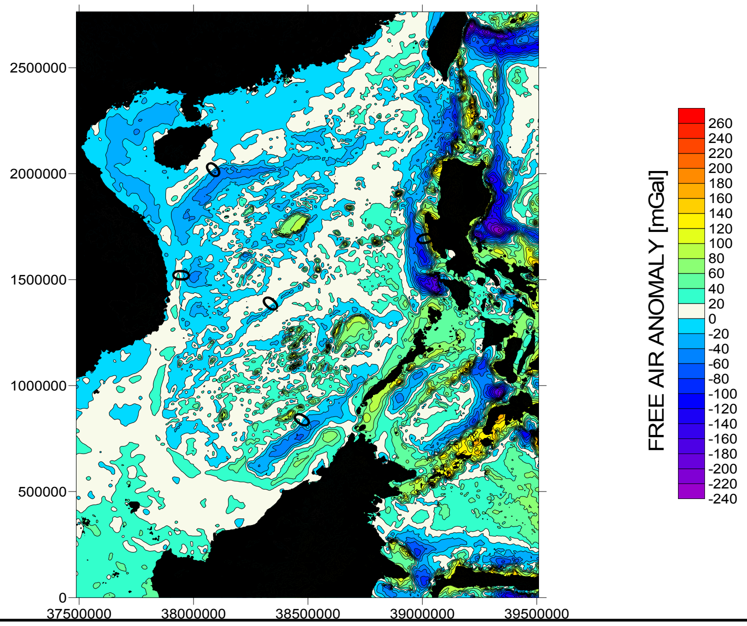
Bouguer-anomalies



Section NS→AA'.bln

Section along the seamounts→BB'.bln

Free Air Anomaly



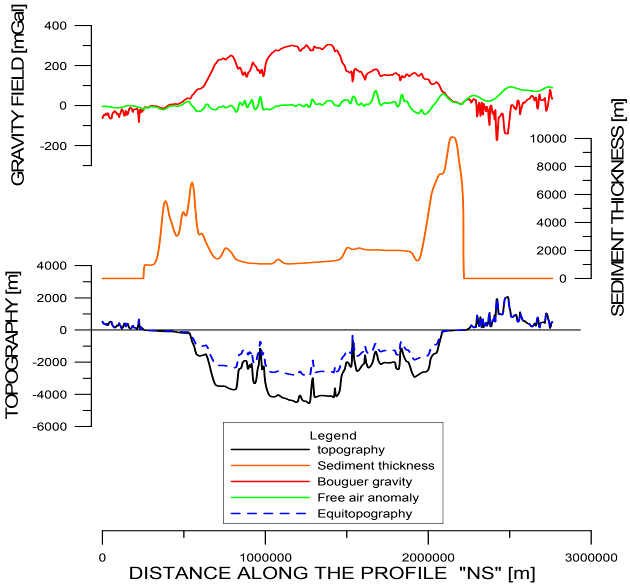
2^{nd} Step
Comparison of fields and structure:

- **Goal**: Compare fields and structure along profiles for better understanding.

- **Method**: Tracing profiles using: AA' and BB' (in next figure an example).
  - For Surfer: GRID/Slice, open a grid and select a boundary file (e.g. AA'.bln and BB'.bln), and save a dat-file.
  - For Grapher: GRAPH/2dGraphs/Line-Scatter, and open the file (dat format). selecting columns D (as *x*) and C (as *y*).

Gravity, topo, load etc.

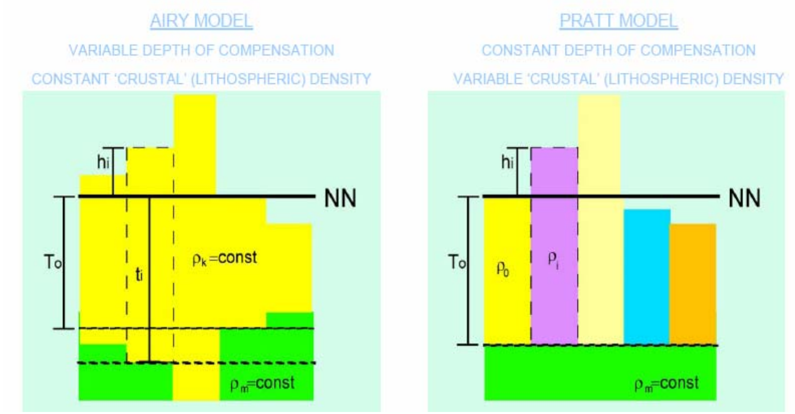
Example: profile N-S (AA'.bln)



3rd Step
Introduction to the flexure modeling

- **Goal**: Analysis of the Isostatic models:
- **Method**: application of the
- Local compensation: Airy and Pratt models (a);
- Regional compensation: lithospheric flexure model (b).

Local Equilibrium (a): Airy and Pratt models



$$r_i = \frac{h_i \rho_c}{\rho_m - \rho_c}$$

$$r_i = \frac{h_i(\rho_c - \rho_w)}{\rho_m - \rho_c}$$

$$\rho_i = \frac{\rho_0 T_0}{T_0 + h_i}$$

Regional Isostasy (b) (Vening-Meinesz)

$$W(\vec{k}) = F(\vec{k})H(\vec{k}) = \frac{\rho_l}{\rho_m - \rho_{in} + \frac{D}{g}\left|\vec{k}\right|^4} H(\vec{k})$$

Flexural rigidity

$$D = \frac{E T_e^3}{12(1-\sigma^2)}$$

T_e = elastic thickness

E = Young Modulus

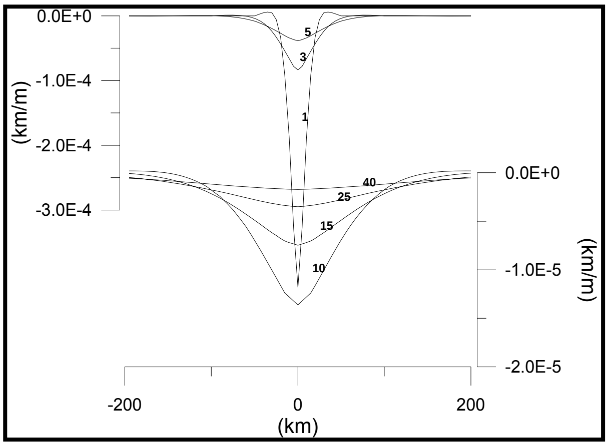
σ = Ratio Poisson

Typical values:

E= 10^{11} N/m^2

σ = 0.25

Flexure rensponse to topographic pointload
Te=1,3,5,10,15,25,40 km



Prepare for flexure modeling :

- Calculate the Equivalent Topographic load.

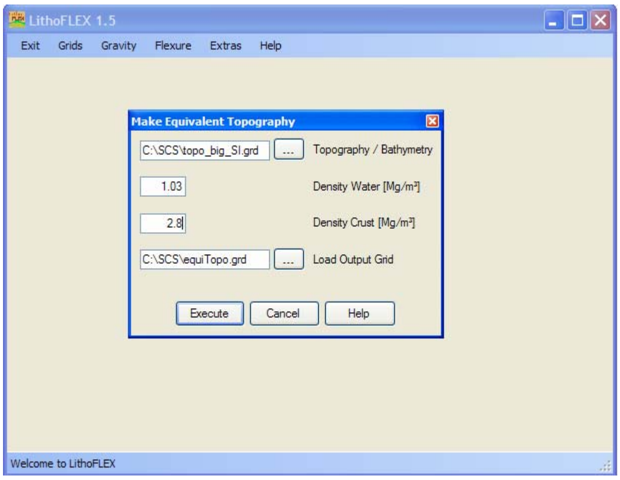
- <u>Equivalent Topography</u>: takes into account all masses of the crustal column, that deviate from the crustal reference model.
- E.g. water, sediments, basalts
- Total load: proportional to the sum of topography and the equivalent topography

4th Step
Create the Equi-Topography:

- **Goal**: It is the input file to the Flexure.

  - Oceanic water replaces crust: the water effect is decreasing the total load
- **Method:**
  - *LithoFlex*/GRIDS/Make Equivalent Topography
  - INPUT FILE: **topo.grd** [m]
  - Density Water: **1.03** [Mg/m^3]
  - Density Crust: **2.8** [Mg/m^3]
  - Save the Output file: **Equi_Topo.grd** [m]

Tool: Make Equivalent Topography



Apply load to flexure model:

- **Goal**: calculate the Flexure Moho
- **Method**: *LithoFlex*/FLEXURE/Forward Flexure
- Procedure: test different flexure parameters (e.g. effective elastic thickness Te)

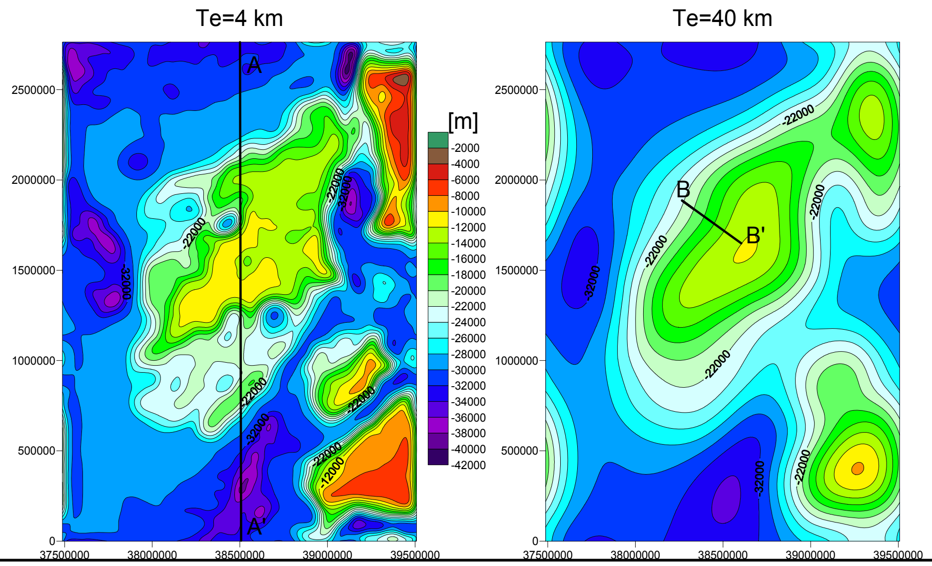
Crust Mantle Interface (Moho) creation

- *LithoFlex*/ Flexure/Forward Flexure/Fast
- INPUT FILE: **Equi_Topo.grd** [m]
- Other parameters:

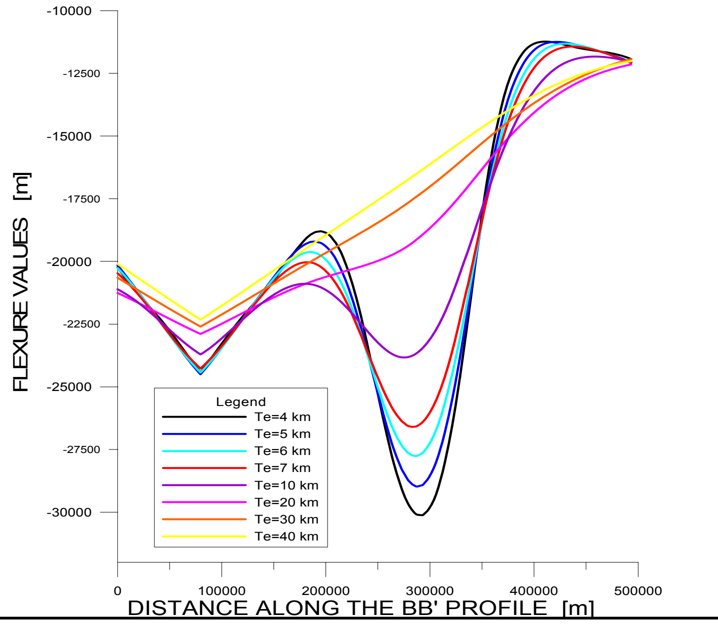
- Te Max: **7** [km], Te min=**4** [km], ΔTe=**1** [km];
- Reference depth: **-30000** [m];
- Crust density: **2.8** [Mg/m^{3}],
- Mantle density **3.2** [Mg/m^3]
- Save the output files: **flexure.grd** [m]

- Describe output files and make the slices for two sections (choose a profile, example: AA' and BB')
- Run again the tool withTe=**10**, **20**, **30**, **40** km
- Create a Te variation plot for section BB'.

Undulation Moho for Te=4, 40 km



Flexure for different Elastic thickness values (along the BB' section)



5^{th} Step
Calculate local isostatic response (Airy model)

- **Goal**: Calculate the expected crustal thickness variation for the Airy model.
- **Method**: LithoFlex/GRIDS/Combine Grids and the previous load for input file.

- The program must use the following formulas:

$$r = \frac{h\rho_c}{\rho_m - \rho_c}$$

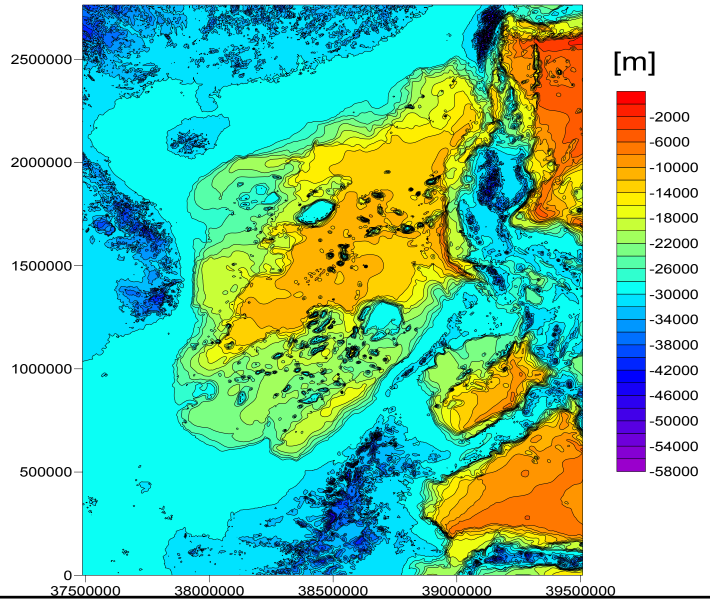
$$r = \frac{h(\rho_c - \rho_w)}{\rho_m - \rho_c}$$

Testing 5^{th} Step:
Calculation of Airy root

- *Lithoflex*/GRIDS/Combine Grids:
- INPUT FILE: **Equi_Topo.grd** [m]
- Click on: Scale
- a=**-7** [Mg/m^3]; b=**-30 000** [m]
- Save output grid: **Airy.grd**

- Create the slice along the AA' and BB' profiles.

Airy root



6th Step: Considering the gravity field

- **Goal**: calculate the gravity effect of crustal thickness variations due to the isostatic response
- **Method**: use the isostatic root and model it as the crust-mantle boundary → *LithoFlex*/GRAVITY/Gravity Discontiunity

Testing 6th Step

(a) Calculate the Moho gravity effect for the:

1) Regional flexural modelling

- Use Lithoflex: Gravity/Discontinuity;
- INPUT: flexure10.grd
- Reference depth: -30 000 [m];
- Density contrast: -0.4 [Mg/m^3];
- Save: grav04.grd

2) Airy model

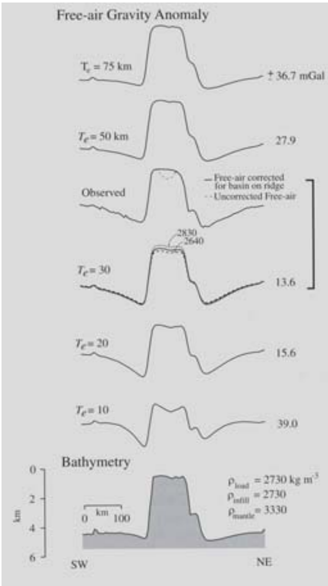
- Use Lithoflex: Gravity/Discontinuity;
- INPUT: airy_root.grd;
- Reference depth:
- -30 000 [m];
- Density contrast: -0.4 [Mg/m^3];
- Save:grav_airy04.grd

Test contrast density: -0.2, -0.3, -0.4 [Mg/m^3].
Test several Te, for the regional equilibrium.

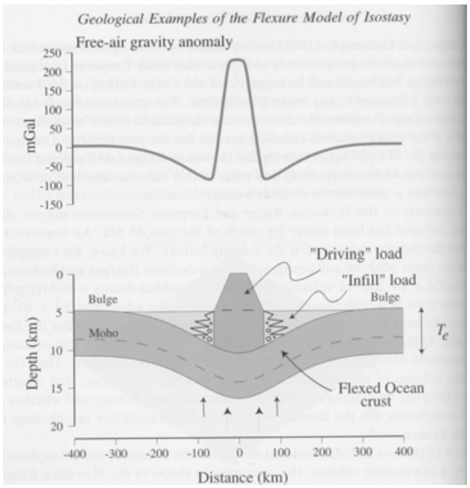
Expected response for a seamount

- A seamount has a characteristic signature in gravity due to the flexural crustal response.
- The gravity anomaly depends on the elastic thickness.
- See graphs in next slide.

Free air anomaly in Ocean



Watts A.B.



Watts A.B., (2002) Isostasy and Flexure of Lithosphere, (Cambridge University Press)

(b) Comparison of the results along profile BB'

Trace profiles and set them into a graph.

Notice: profile BB' cuts a seamount.

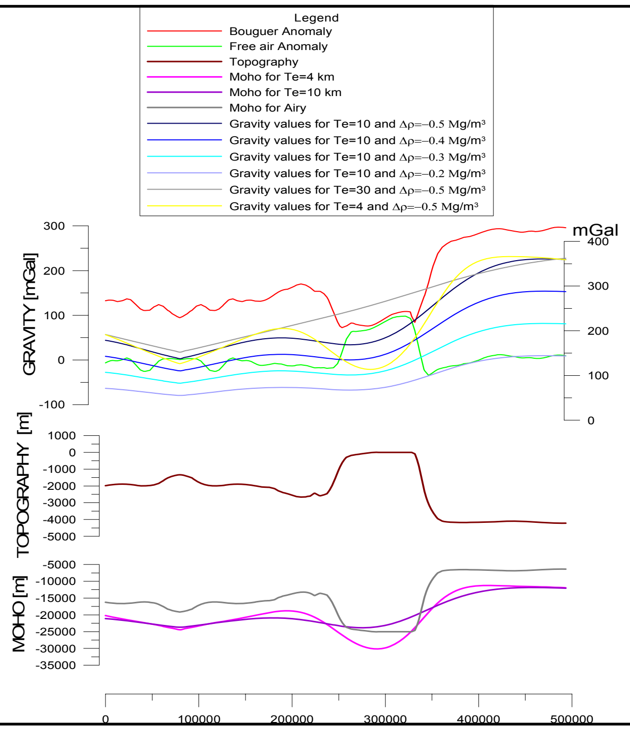
Create a new Grapher plot with for the BB' slice:

1) Airy Moho,
2) Topography
3) Bouguer anomaly and Free Air anomaly
4) Airy gravity effect

Continue comparison along profile BB’

Create a new plot centred on the sea-mount, with:

1) Flexural Moho for Te= 4 , 10 km,
2) Topography
3) Bouguer anomaly and Free air anomaly
4) Gravity effect for Te= 4 km,and 10 km for the different reference contrast.



Regional and Airy modelling

Analysis of Moho gravity effect

Describe:

- the difference between the regional and local compensation;
- the Moho gravity effect;

Why is the response for local and regional compensation?

(Because in the local compensation the rigidity is zero)

Conclusions on modeling the seamount

- Observation of the gravity field of the flexural response: it seems that for the tested parameters, the Bouguer field is best reproduced (apart from a shift) by the parameters Te= 4km and density contrast -0.5 [Mg/m3].