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Density heterogeneity of the North American upper mantle from satellite gravity and a regional crustal model

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Density heterogeneity of the North American upper mantle

from satellite gravity and a regional crustal model

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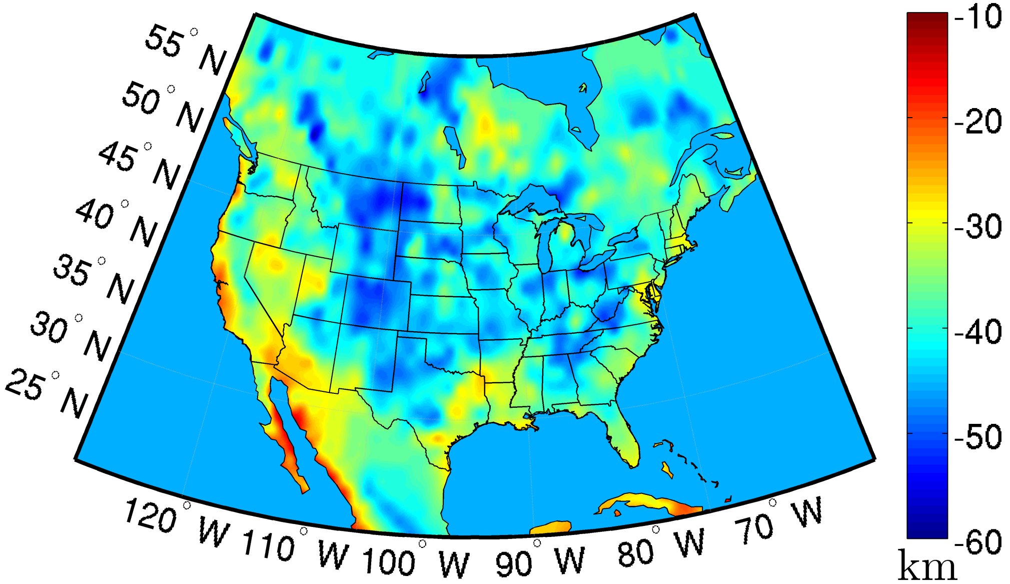
Motivation and objectives

- **Motivation**
  - **Determine density of the mantle in North America**
  - **Uncertainties in the velocity – density conversion**
- **Data**
  - **Crust 1.0 model**
  - **Gravity from GOCE satellite mission**
- **Method**
  - **Removing the effect of the deep mantle and crustal structure from gravity field**
- **Main uncertainties**
  - **Velocity – density conversion**
  - **Crustal structure (thickness and Vp)**

North America Moho (Crust 1.0)

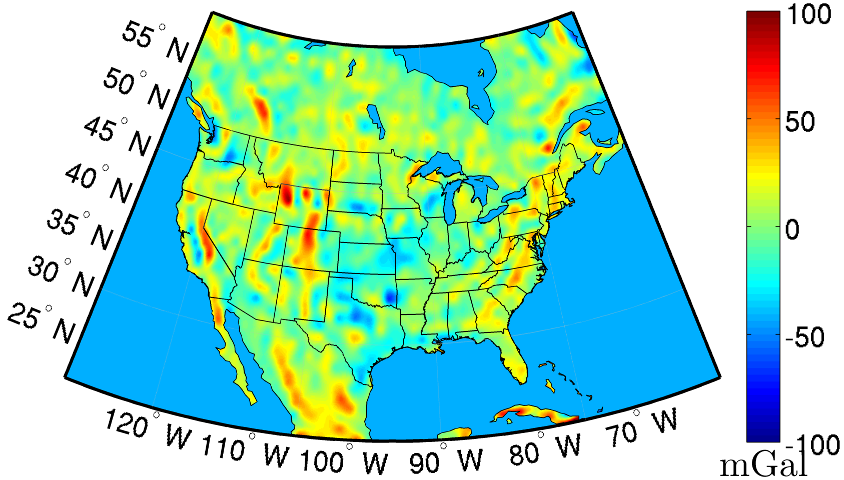


Crustal correction to gravity anomalies

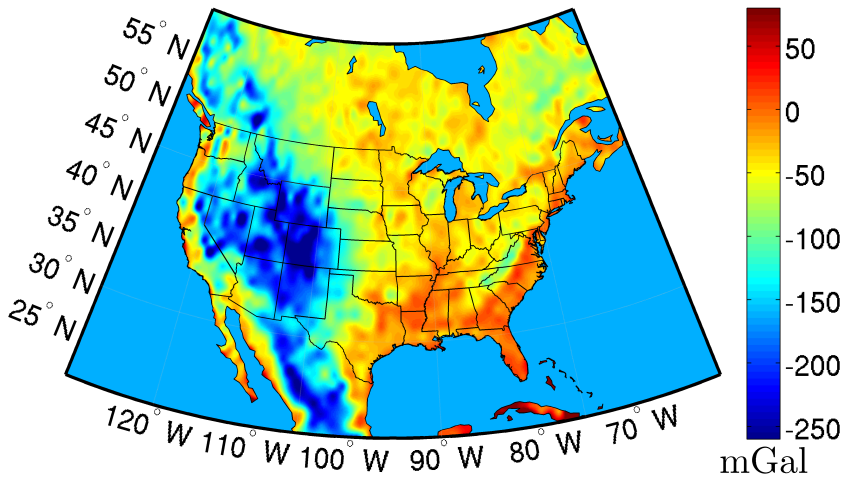
- Subtracting (stripping) gravity effect of the crust (including topography, 2.67 g/cm^3) from free-air gravity anomaly
- Gravity anomaly is based on GOCE Direct release 3 global geopotential model

Truncated gravity data from GOCE

- GOCE DIR release 3 geopotential model (Pail et al., 2011)
- Truncation of free air gravity anomaly (spherical harmonic degree 10)
  - to eliminate those components that presumably are of deep mantle origin

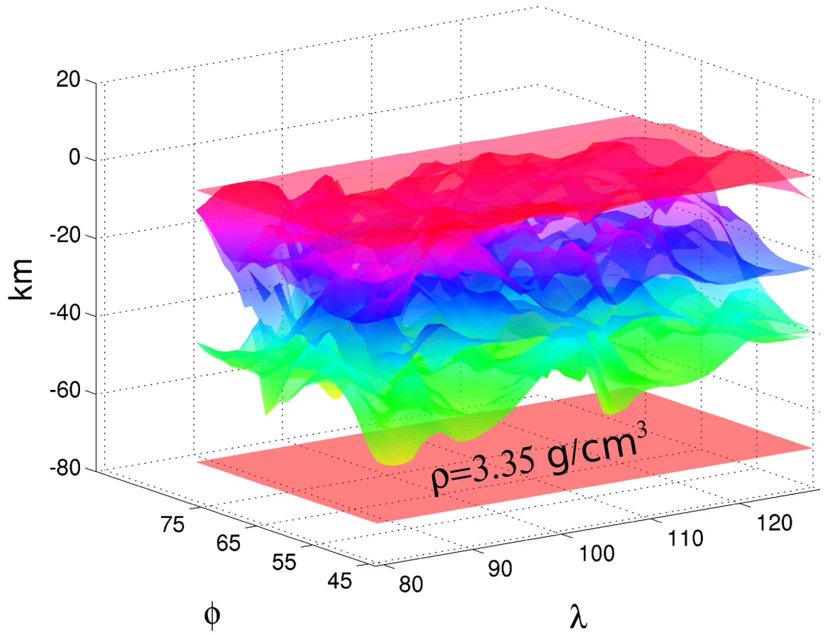


North America - Free air gravity anomaly [mGal]

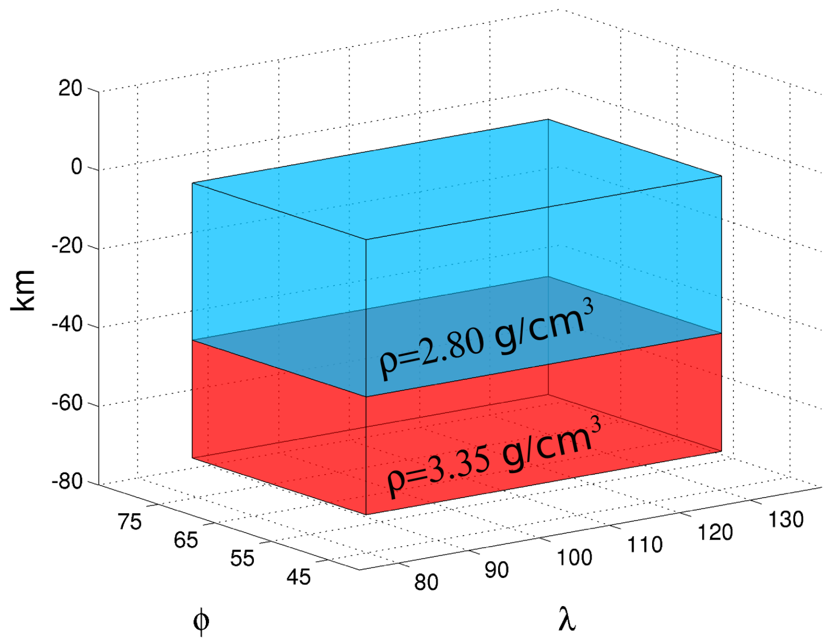


North America - Bouguer gravity anomaly [mGal]

Crustal correction to gravity anomalies

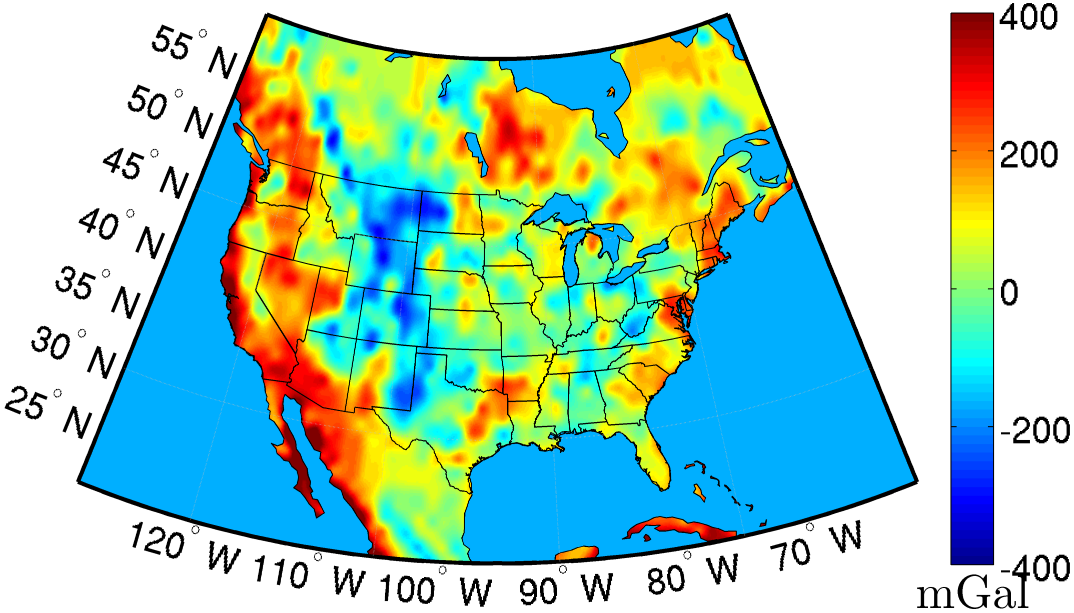


SibCrust model



Reference density model

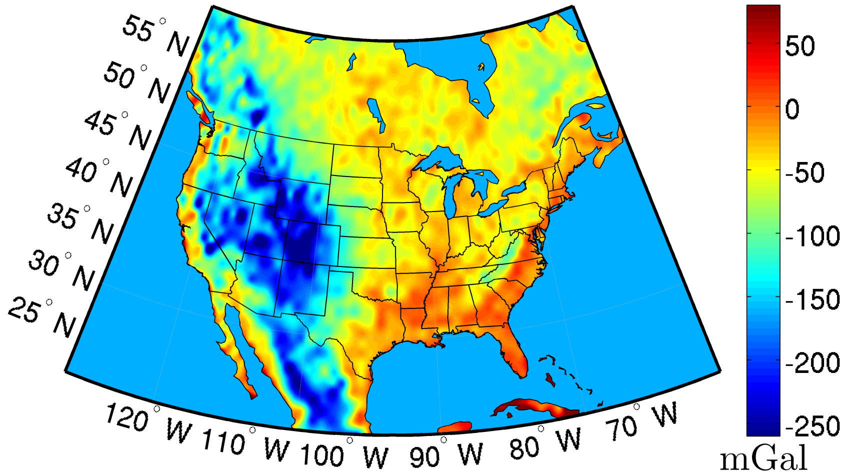
Crustal correction to gravity anomalies



- **Crustal contribution to gravity is large and spatially heterogeneous**

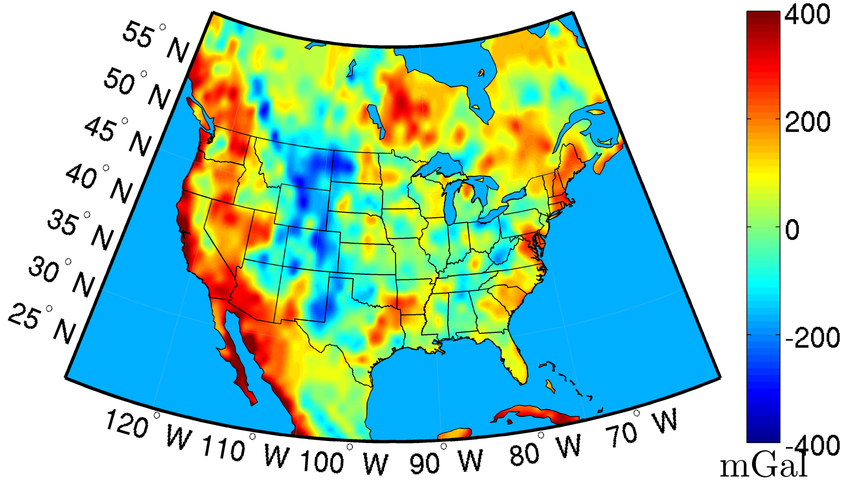
Mantle residual gravity =

Bouguer gravity anomaly

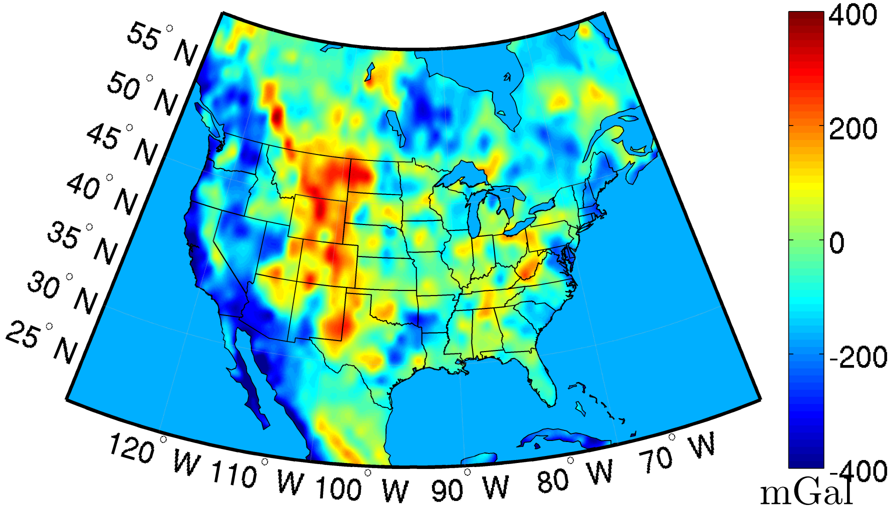


Free air gravity anomaly – Topography - Crust

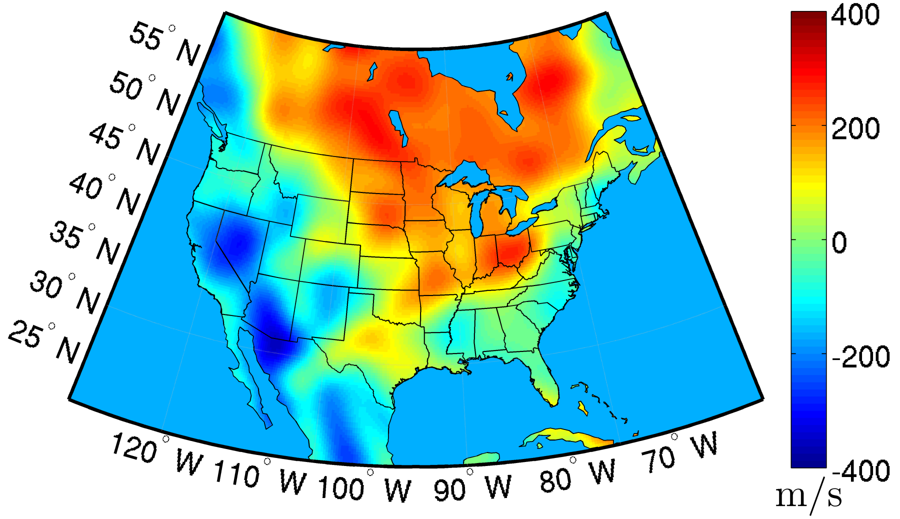
minus crustal correction



Residual mantle gravity for Crust 1.0 model



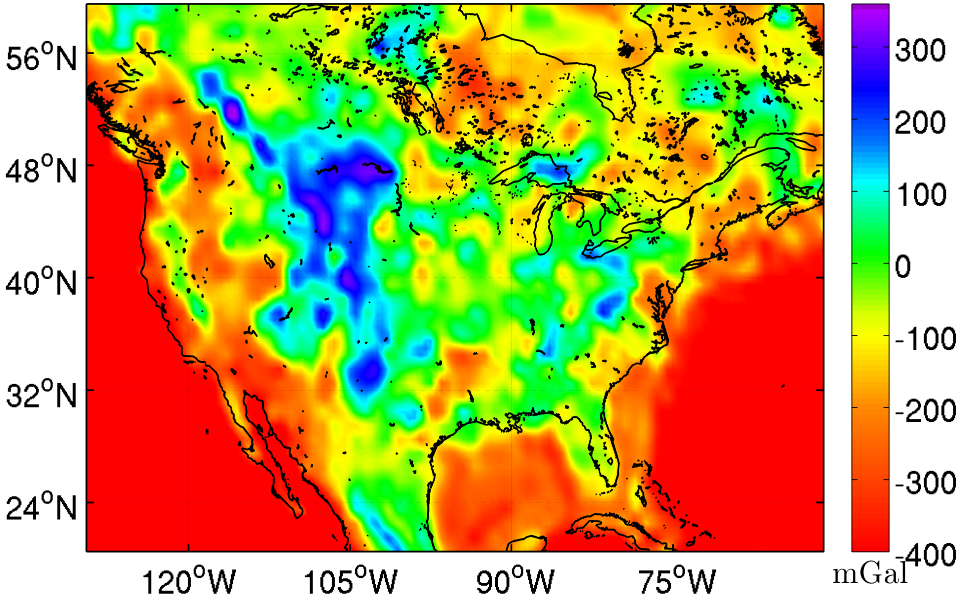
North American upper mantle surface wave tomography model



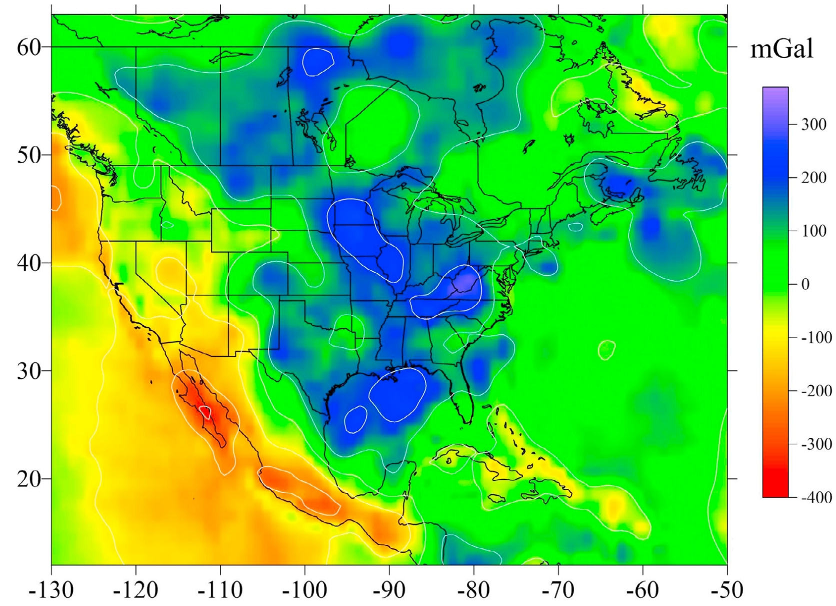
NA04, 150km

(van der Lee and Frederiksen, 2005)

Residual mantle gravity comparison



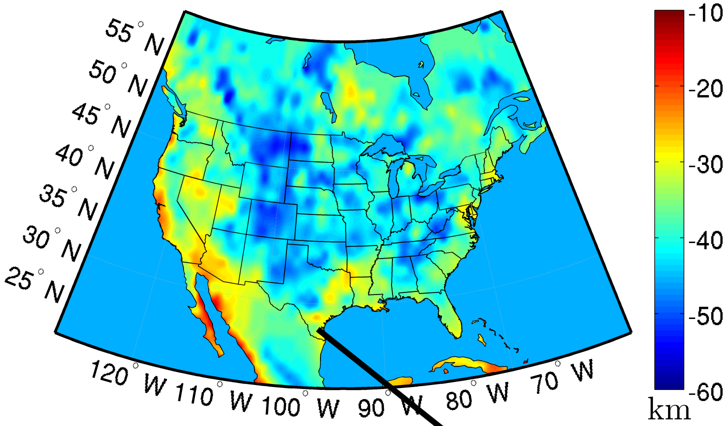
Mantle gravity (Crust 1.0)



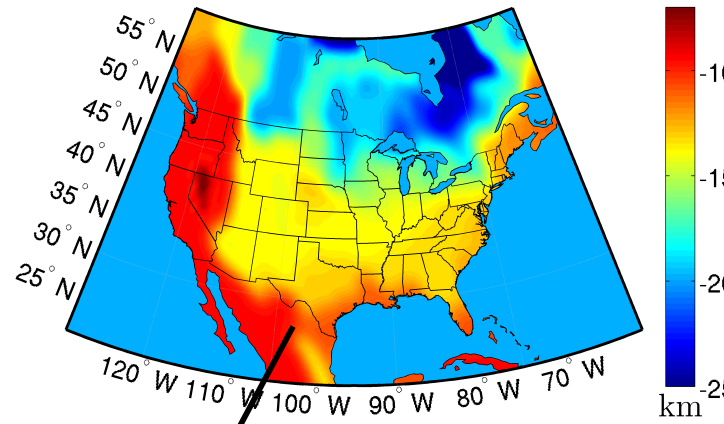
Mooney and Kaban, 2010

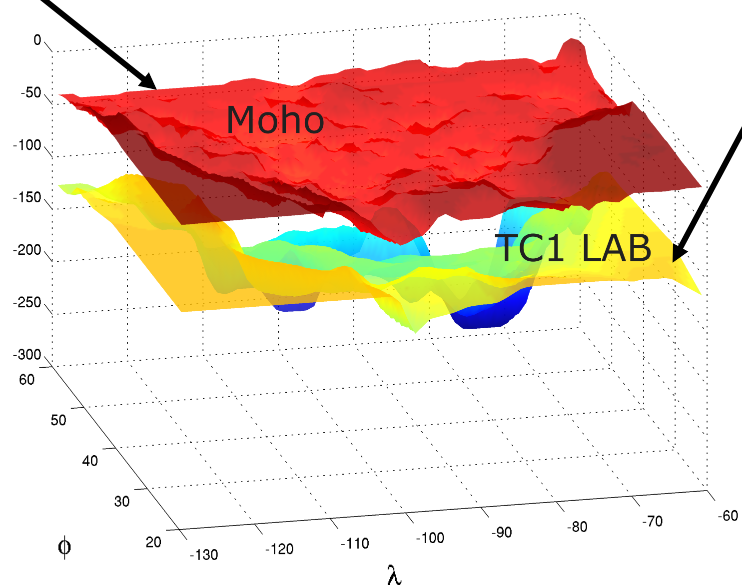
Defining lithospheric mantle

Moho (Crust 1.0)



TC1 LAB

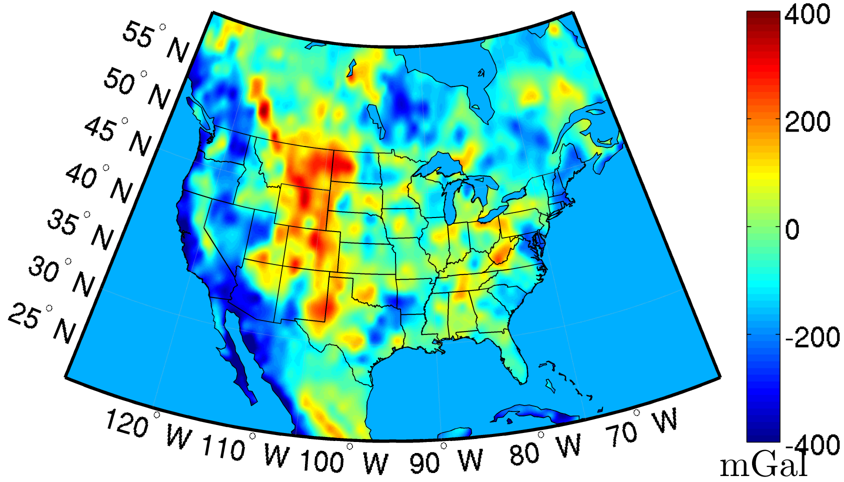




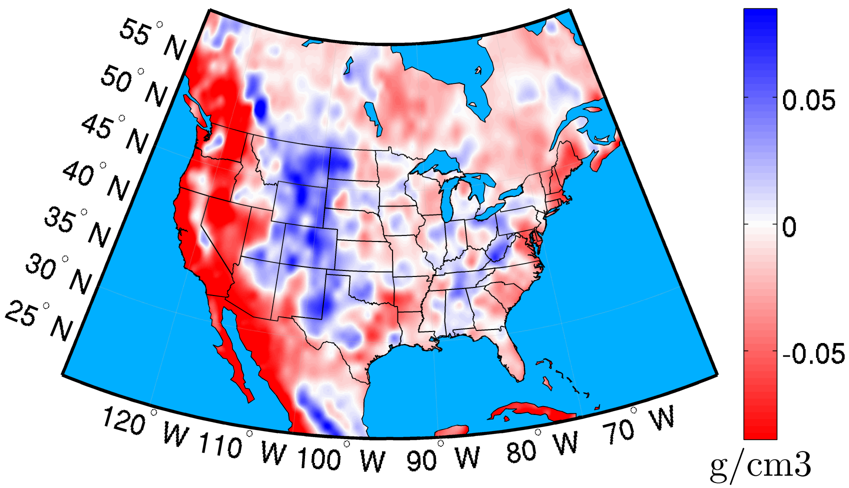
Mantle density anomaly

(Assumption - all density anomalies are in lithospheric mantle)

Residual mantle gravity



Mantle density anomaly

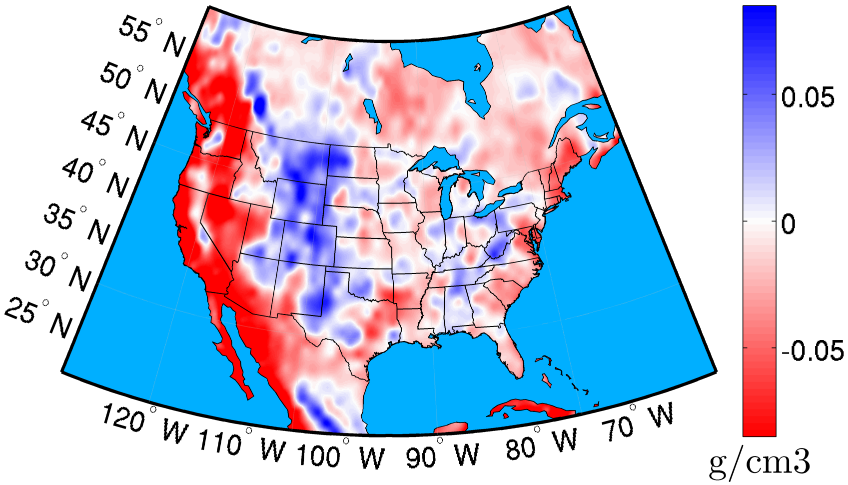


Free bord (mass balance) method

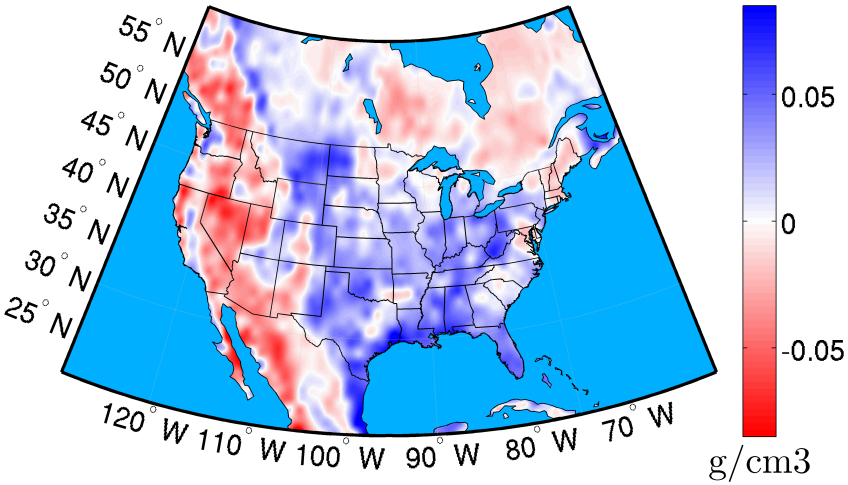
- Assuming astenosphere density (3.34 g/cm^3)
- Crustal contribution to the surface topography
  - Bc=Hc*(RhoA-AvgRhoC)/RhoA;
- Height of the sea level above the asthenosphere estimated at mid ocean ridge, D = 4.25km
- Lithospheric mantle contribution to the surface topography
  - Bm=Topo-Bc+D
- Thickness of lithospheric mantle (LAB)
- Lithospheric mantle

Mantle density anomaly

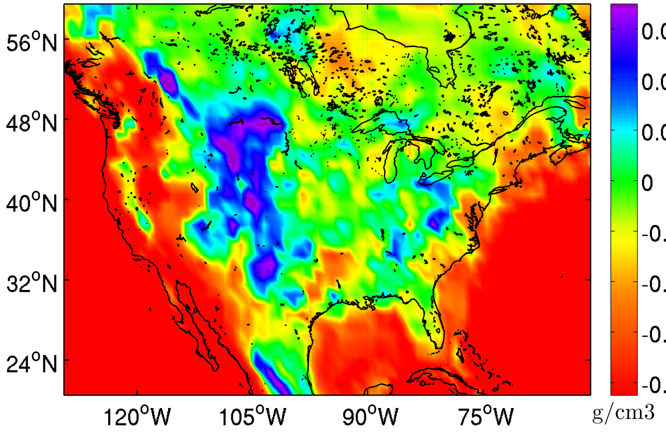
Layer stripping



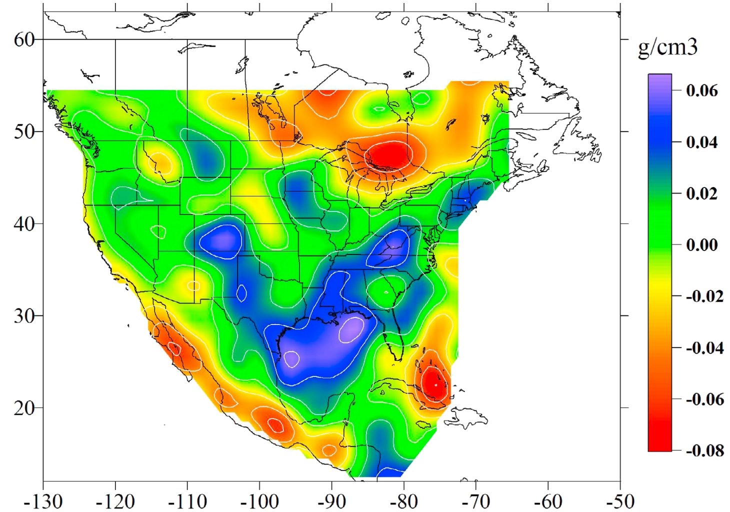
Free board (mass balance)



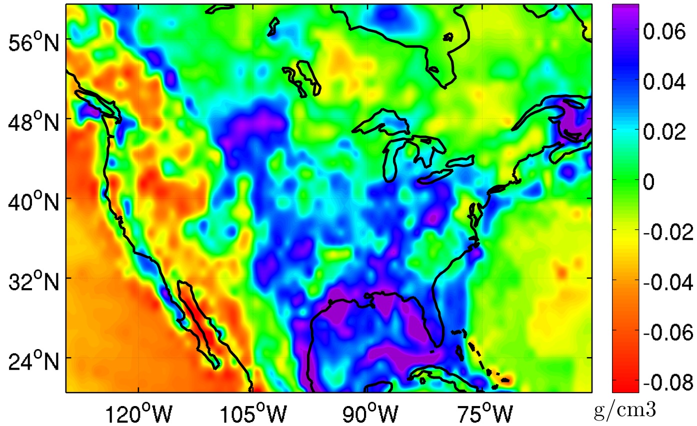
Mantle density anomaly comparison



Layer stripping

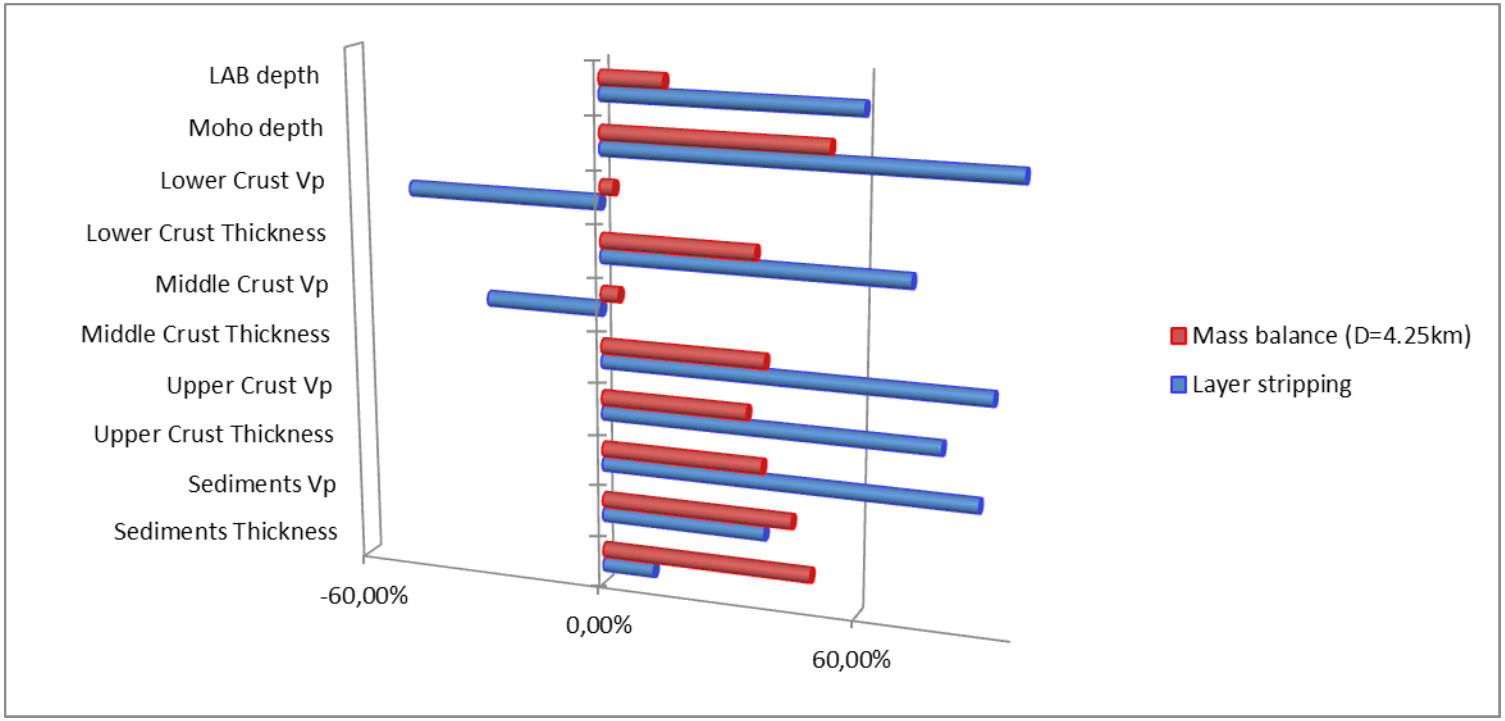


Mooney and Kaban, 2010



Free board (Mass balance)

Correlation coefficient between calculated mantle density and crustal and LAB structure



- Correlation coefficients are calculated for the final Mantle density anomaly grids, produced by two different methods
  - Gravity modelling (layer stripping)
  - Free-board (mass balance)

Conclusions

- Uncertainty in sediment thickness of 1km corresponds to an uncertainty of 0.05 g/cm^3 in average crustal density
- Uncertainty in sediment Vp velocity corresponds to the uncertainty of 0.01 g/cm^3 in average crustal density
- Moho thickness has strongest impact on both methods
  - Free-board (mass balance), 67%
  - Gravity method (Layer stripping), 94%
- Upper (86%) and middle crust (89%) thickness grids have also significant correlation with mantle density grid