Geophysical Research Abstracts
Vol. 17, EGU2015-6526-2, 2015
EGU General Assembly 2015

Geophysical, petrological and mineral physics constraints on Earth's surface topography

Mattia Guerri (1), Fabio Cammarano (1), and Paul J. Tackley (2)

(1) University of Copenhagen, Department of Geosciences and Natural Resource Management, Copenhagen, Denmark (mattia.guerri@ign.ku.dk), (2) Institute of Geophysics, ETH Zurich, Zurich, Switzerland

Earth's surface topography is controlled by isostatically compensated density variations within the lithosphere, but dynamic topography - i.e. the topography due to adjustment of surface to mantle convection - is an important component, specially at a global scale. In order to separate these two components it is fundamental to estimate crustal and mantle density structure and rheological properties.

Usually, crustal density is constrained from interpretation of available seismic data (mostly VP profiles) based on empirical relationships such those in Brocher [2005]. Mantle density structure is inferred from seismic tomography models. Constant coefficients are used to interpret seismic velocity anomalies in density anomalies. These simplified methods are unable to model the effects that pressure and temperature variations have on mineralogical assemblage and physical properties.

Our approach is based on a multidisciplinary method that involves geophysical observables, mineral physics constraints, and petrological data. Mantle density is based on the thermal interpretation of global seismic tomography models assuming various compositional structures, as in Cammarano et al. [2011]. We further constrain the top 150 km by including heat-flow data and considering the thermal evolution of the oceanic lithosphere. Crustal density is calculated as in Guerri and Cammarano [2015] performing thermodynamic modeling of various average chemical compositions proposed for the crust. The modeling, performed with the code Perple_X [Connolly, 2005], relies on the thermodynamic dataset from Holland and Powell [1998]. Compressional waves velocity and crustal layers thickness from the model CRUST 1.0 [Laske et al., 2013] offer additional constrains. The resulting lithospheric density models are tested against gravity (GOCE) data.

Various crustal and mantle density models have been tested in order to ascertain the effects that uncertainties in the estimate of those features have on the modeled topography. We also test several viscosity models, either radially symmetric, the V1 profile from Mitrovica and Forte [2004], or more complex laterally varying structures.

All the property fields are expanded in spherical harmonics, until degree 24, and implemented in the code StagYY [Tackley, 2008] to perform mantle instantaneous flow modeling and compute surface topography and gravitational field.

Our results show the importance of constraining the crustal and mantle density structure relying on a multidisciplinary approach that involves experimentally robust thermodynamic datasets. Crustal density field has a strong effect on the isostatic component of topography. The models that we test, CRUST 1.0 and those in Guerri and Cammarano [2015], produce strong differences in the computed isostatic topography, in the range $\pm$600 m. For the lithospheric mantle, relying on experimentally robust material properties constraints is necessary to infer a reliable density model that takes into account chemical heterogeneities. This approach is also fundamental to correctly interpret seismic models in temperature, a crucial parameter, necessary to determine the lithosphere-asthenosphere boundary, where static effects on topography leave place to dynamic ones.

The comparison between results obtained with different viscosity fields, either radially symmetric or vertically and laterally varying, shows how lateral viscosity variations affect the results, in particular the modeled geoid, at different wavelengths.

References:

Brocher, T. M. (2005), Empirical Relations between Elastic Wavespeeds and Density in the Earth's Crust, Bulletin of the Seismological Society of America, 95(6), 2081-2092.

Cammarano, F., P. J. Tackley, and L. Boschi (2011), Seismic, petrological and geodynamical constraints on thermal and compositional structure of the upper mantle: global thermochemical models, Geophys. J. Int.

Connolly, J. A. D. (2005), Computation of phase equilibria by linear programming: A tool for geodynamic modeling and its application to subduction zone decarbonation, Earth and Planetary Science Letters (236),

524-541.
Guerri, M., and F. Cammarano (2015), On the effects of chemical composition, water and temperature on physical properties of the Earth's continental crust, submitted to Geochemistry, Geophysics, Geosystem.
Holland, T. J. B., and R. Powell (1998), An internally consistent thermodynamic data set for phases of petrological interest, J. metamorphic Geol., 16(309-343).
Laske, G., G. Masters, Z. Ma, and M. E. Pasyanos (2013), CRUST1.0: An updated global model of Earth's crust, in EGU General Assembly 2013, edited, Geophysical Research Abstracts, Vienna.
Mitrovica, J. X., and A. M. Forte (2004), A new inference of mantle viscosity based upon joint inversion of convection and glacial isostatic adjustment data, Earth and Planetary Science Letters, 225, 177-189.
Tackley, P. J. (2008), Modelling compressible mantle convection with large viscosity contrasts in a three-dimensional spherical shell using the yin-yang grid, Phys. Earth Planet. Int.