

Addition to the Poster 2737

“Deep Structure of Hypocenters for the Vrancea Zone and the Black Sea using Satellite Data and the Gravity Tomography”

The main Theme: Ecologically tensional areas of Ukraine

Object: Identify displacements of the earth surface under the exposure of natural and man-made factors, using SAR images and the Gravity Tomography method.

Gravity Tomography Method

The algorithm for calculation of anomalous harmonic densities

This is the solution of the inverse gravity problem to determine density anomalies by the geopotential anomalies using the Professor H. Moritz's algorithm [1]. Anomalous harmonic densities can be calculated using spherical harmonics of the disturbing potential from the geoid gravity model, such as EGM96 or EGM 2008. The following final algorithm was used from [1]:

$$\rho_h = \sum_{n=2}^Z \sum_{m=0}^n \frac{M(2n+1)(2n+3)}{4\pi R^{n+3}} \times r^n (c_{nm} \cos m\lambda + s_{nm} \sin m\lambda) P_{nm}(\cos\theta),$$

where, ρ_h – anomalous harmonic density;

M – mass of the Earth;

R – radius of the Earth (in a point, to which the value of a geopotential is referred);

r – radius-vector of an internal point, in which a density disturbing the geopotential is determined,

$P_{nm}(\cos\theta)$ - Legendre polynomial of n^{th} degree and m^{th} order;

θ - central angle or spherical distance between R and r ;

c_{nm} and s_{nm} – coefficients of the surface geopotential spherical harmonics.

Estimation of the depth of disturbing layer by a number of harmonics

The obtained above density anomalies are obviously situated in different depths.

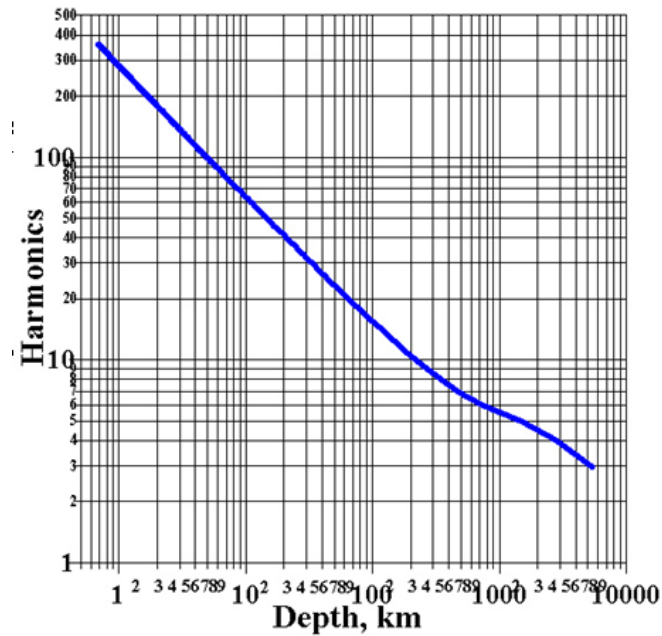
An assessment of the disturbing layer depth is computed by a known harmonic function in the geoid theory [1] for the case when the external potential of the internal masses confined by a sphere is determined

$$\frac{1}{\ell} = \sum_{n=0}^{\infty} \frac{r^n}{R^{n+1}} P_n(\cos \theta),$$

where ℓ - distance between the point, to which the value of a geopotential is referred and the point, to which the density disturbing the geopotential is referred.

Calculation was carried out with $n_{\min}=2$. At the right part of the expression the normalizing coefficient of spherical functions $(2n+1)^{1/2}$ was used [2]. If $\theta = 0$, then $P_n(\cos\theta) = 1$ for any n , and $\ell = R-r$. Under these conditions and for given values of ℓ , r and R the corresponding values of n were calculated.

Relationship between harmonic degrees n and depths ℓ of disturbing layers is shown in the bilogarithmic diagram.



Relationship between harmonic degrees n and depths r of the disturbing layers of the Earth. Value n is the sum of harmonicas in a range from degree 2 up to n .

The software was developed within the gravimetric tomography method and allows to compute values of heights of both the full geoid (all harmonics of a model used) and differential geoid, values of the anomalous harmonic densities in units of g/cm^3 and values of upper cover depths of disturbing layers of the Earth. The spherical coefficients of the EGM96 global geopotential geoid model were used. Dense anomalies are computed relating to the PREM density model [3].

The spatial-scale of harmonics (half wavelength) or lateral resolutions of the EGM96 model is 0.5° [4]. Maximum degree of the model is 360. Computing was carried out with an interval of 0.25° . Blue color indicates regions of less dense structures and yellow color indicates more dense structures in all figures below. Depths on the vertical cross-sections are shown from the terrestrial surface and the ocean bottom.

These tomographic models provide clear images of different layers, bodies and geospheres of the Earth (The Atlas of Antarctica, for example, www.uac.gov.au/SitePages/Home/atlas.aspx). Tomographic data were compared many times with different seismic models. There are similarities and distinctive features also, which can supplement each other.

1. Moritz H. 1990. The Figure of the Earth. Theoretical Geodesy and the Earth's Interior. Wichmann, Karlsruhe.
2. Shimbirev B.P., Theory of the Earth's Figure, Moscow, Nedra, p. 431, 1975 (in Russian).
3. Dziewonski A.M., Anderson D.L., 1981. Preliminary Reference Earth Model. Phys. Earth Planet. Inter., 25, 297-356.
4. H. Rapp, Y. M. Wang, and N. K. Pavlis, The Ohio State 1991 Geopotential and Sea Surface Harmonic Coefficient Models, 410, Dept. of Geodetic Sci. and Surv., Ohio State Univ., 1991.

1. Structure of the Vrancea's seismogenic body (Fig. 1.1)

The gravity tomography models show a mechanism of formation (delamination) and structure of Vrancea and Dinarides seismogenic bodies which are the most intensive sources of the earthquakes in Europe. The process of detachment and sinking of the lower parts of the continental lithosphere causes an earthquake until it reaches thermal equilibrium with the surrounding asthenosphere (Ducea M.N. Fingerprinting orogenic delamination. GEOLOGY, v. 39; no. 2; February 2011 p. 191–192).

2. Opposite displacements in Crimea! (Fig. 2.1)

Displacement of the Crimean Mountains in the north-west direction with a maximum intensity of 4 cm in the area of the Roman-Kosh Mount is caused by the earthquakes in the Black Sea, 40 km from the Peninsula. Tomographic model (Fig. 2.4) shows that there is a mechanism of delamination and detachment at a depth of 8 km and 13 km also.

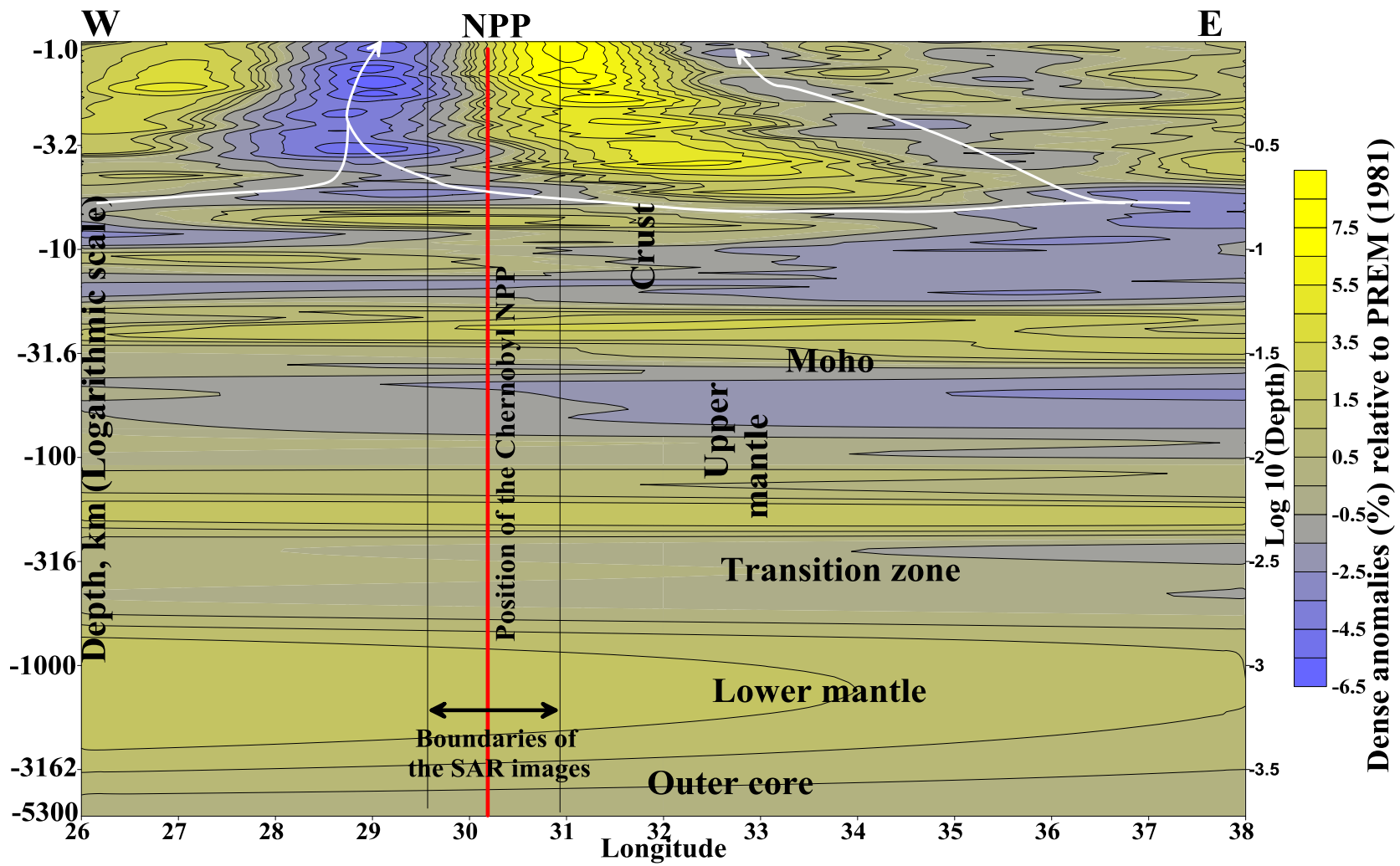
New information of the D-InSAR technology is displacement to the southeast in the western part of the Crimean Peninsula. Tomographic models (Fig. 2.2 and 2.3) clearly show a trend of density anomalies movement in the direction of to the east in the depth range up to 4 km. Obviously, this is due to the geodynamic influence of Dinarides and Balkanides.

3. Technogenic disasters, Kryvyy Rih mining town

Krivoy Rog town historically developed as a mining town. Open pits and mines directly abut to the city. Maximum technogenic subsidences of about 10 mm/day identified in the areas of mining and large-block constructions of the steel plant.

4. Chernobyl, 30 years later

The Chernobyl NPP was constructed around active movements of a terrestrial surface by intensity of 7,4 cm in 16 months, as in horizontal and vertical situation. These days are the 30 years after the Chernobyl Hazard. Once again, we return to this area on the basis of the D-InSAR technology and the Gravity Tomography modelling. Significant displacements near the NPP are confirmed by the stress thrust of the blue and yellow structures on the model below. The region of the contour lines compression is related, apparently, by means of refilling of thinned masses from the depth of 6 km. Such intense contact areas in Europe are observed only in the mountainous regions of the Carpathians. This can be seen in Figure 1 of our Poster.



Structure of the Earth up to the 5300 km by the Gravity Tomography modeling. White lines show a dynamics of thinning masses from the West and East to the Chernobyl NPP.