

EFFECT OF HETEROGENEITIES IN THE LOWER MANTLE STRUCTURE ON THE FORMATION OF SOME SECULAR VARIATION FOCI

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Abstract. In this paper we consider a region which is at different times characterized by well-known foci of the main magnetic field of the Earth (MGMF) secular variation: Europe and the Caspian. Previously, on the basis of a macro model of MGMT sources the impact of the parameters changes for the different scale sources on the secular variation spatial structure was studied. The formation and decay of the considered secular variation foci proved to be due to the parameters change of two particular sources of the third order of smallness, located at the core-mantle boundary. This effect was also observed in the records of all nearby magnetic observatories. The reasons underlying this change of the sources parameters however remained unclear. In this work we compare visible trajectories of these sources to different models of the lower mantle structure, based on seismic tomography data. As a result, we obtain that density and temperature heterogeneities of the lower mantle have the decisive influence on the change of sources parameters. This result coincides with that obtained earlier for the Caribbean region.

Introduction

The local foci in spatial distribution of the secular variation (SV) components of the main geomagnetic field (MGMF) are primarily generated by changes in the core-mantle boundary flow structure. Previously, we investigated the degree of influence of different scale sources on SV using a macro model of MGMT sources developed by us [Demina et al., 2008b]. Results of this study as well as an analysis of the spatial structure of SV forecast error [Demina and Bricheva, 2014] show that SV anomalies can be considered as an integral result of change of several sources, including those with a magnetic moment three orders of magnitude less than the magnetic moment of the main dipole. However, in some cases, the influence of sources of such scale can be identified in the SV spatial structure. The question about the reasons of these changes is still open. Previously we considered as possible influencing factors the heterogeneity of the lower mantle structure and the topography of the core-mantle boundary [Demina and Soldatov, 2012, Demina, 2014].

Formulation of the problem and the data used

In this work we consider the area including the well-known SV foci: Europe and the Caspian. Demina et al. [2008a] have shown how the change of parameters of two sources of the third order of smallness located at the core-mantle boundary can be traced in the records of all surrounding magnetic observatories. Since the size of SV anomalies created by sources of the third order of smallness is significantly less than the size of anomalies created by large-scale sources, to estimate the influence of the former it is necessary to detect their contribution to SV. For this purpose we calculated the SV components depending on the large-scale sources and subtracted the obtained result from the SV components calculated from the IGRF model. The residuals can then be compared with SV depending on the selected sources of the third order. So one can estimate an influence of each of them on the SV structure in different epochs and compare with changes of corresponding magnetic parameters. Then, using a 3D model of the lower mantle structure, one can estimate the extent of its influence on these changes, as it has been done for the Caribbean region [Demina and Soldatov, 2012, Demina, 2014].

Results

For the comparison, we have selected two sources with the magnetic moment of the 3rd order of smallness with respect to the main dipole. For the sake of definiteness, we have arbitrarily numbered them 17th and 18th for eastern and western one, respectively. SV anomalies generated by these sources are located in the area of well-known SV foci. For the selected area we calculate SV components for the period 1900-2010 from the coefficients of IGRF. Then we calculate the total contribution to SV from large-scale sources,

for which the size of the anomalies produced by them is much larger than area considered. The difference between SV-IGRF and SV of large-scale sources represents a total contribution of small-scale sources, including the two that we explore and compare. The spatial structure of Z - components of SV in these three variants for a number of epochs is shown in Fig. 1. A contribution from the changing parameters of the two selected sources is superimposed on the spatial structure of SV differences.

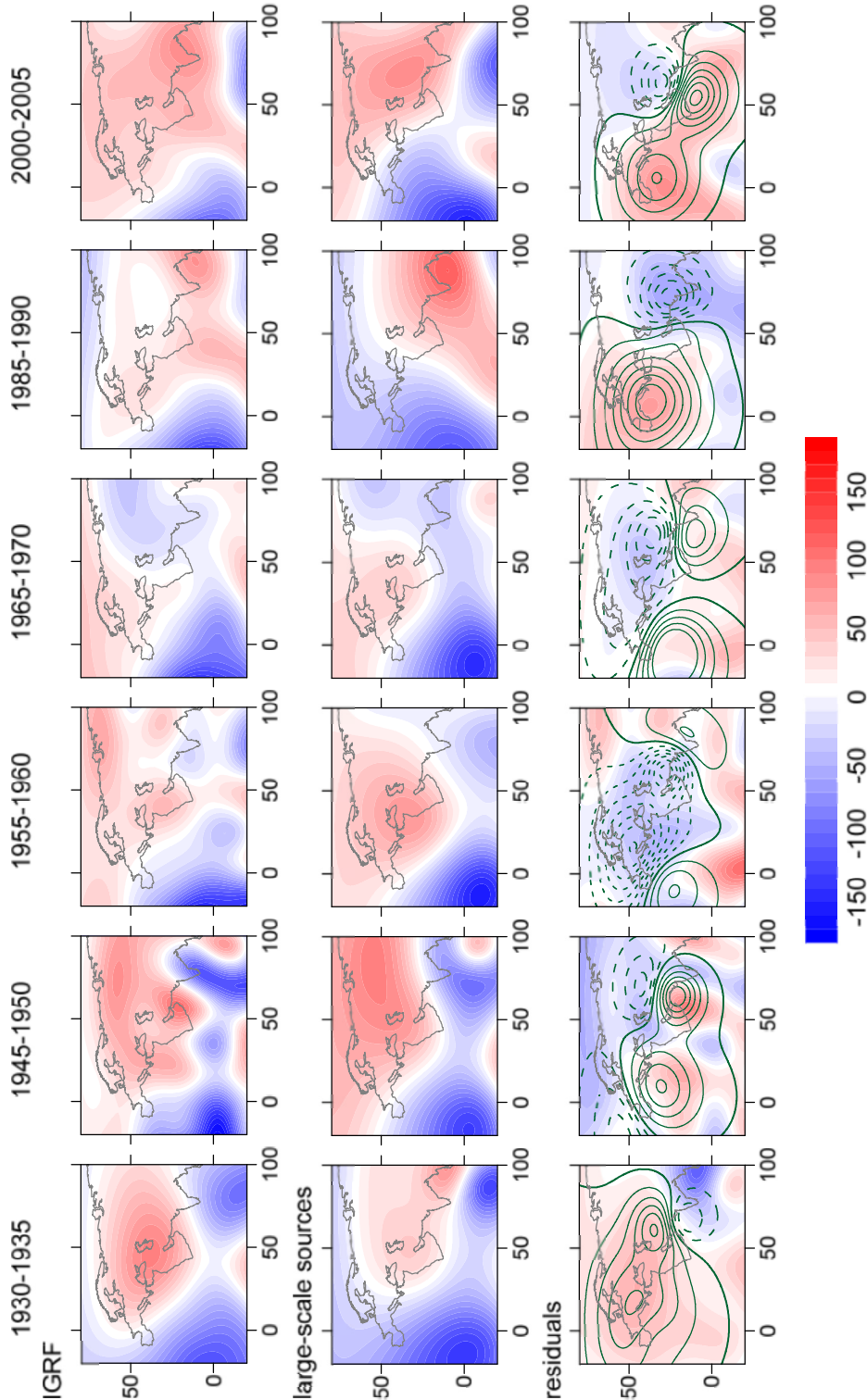


Fig. 1 A comparison of the difference between SV-IGRF and SV of large-scale sources with the SV of 17 and 18 sources. Isolines on the residual charts are traced with 5 nT spacing, the positive values are shown by solid lines, the negative values are shown by dashed lines, the bold solid line denotes zero value.

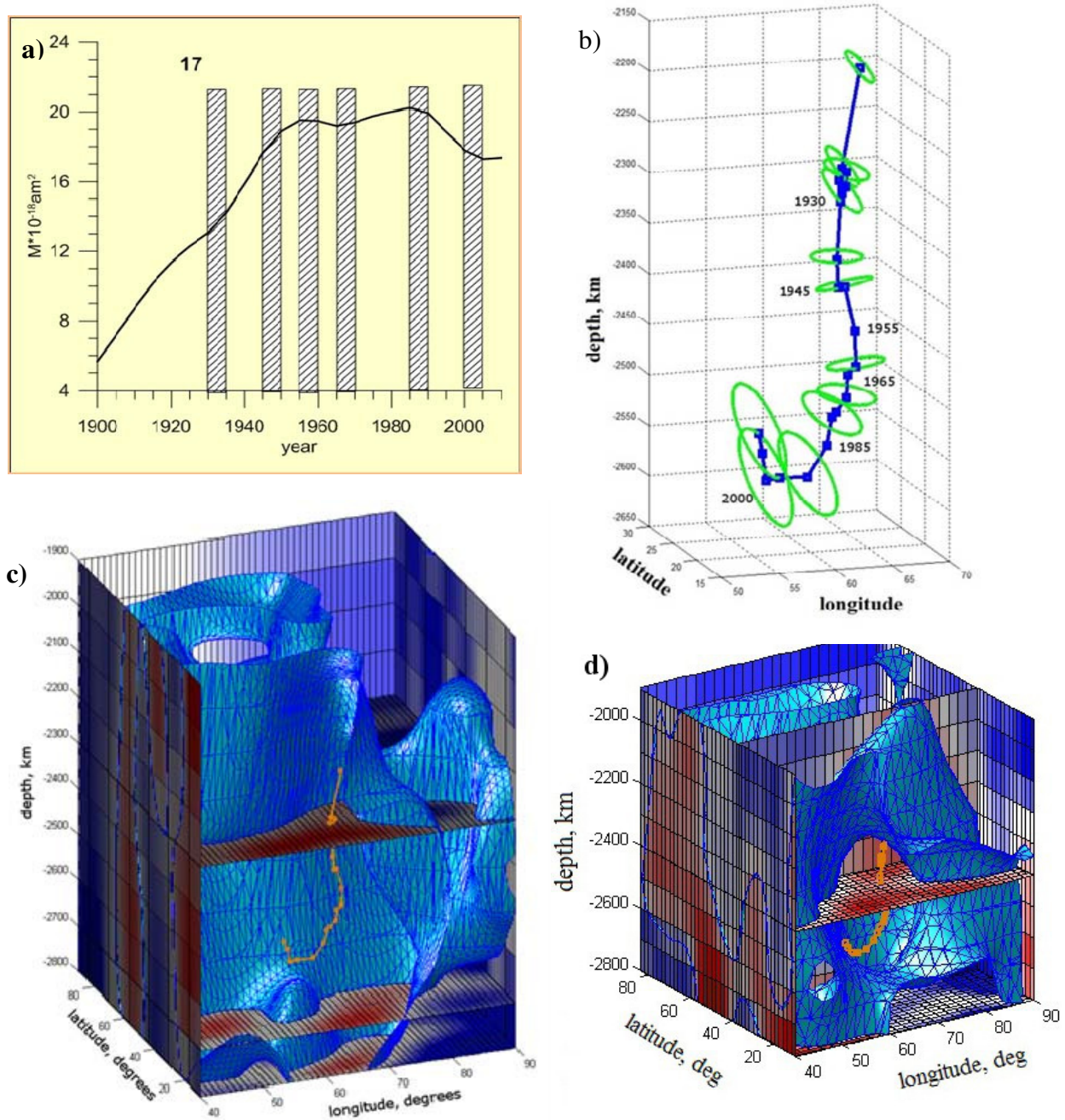


Fig. 2 Change of the 17th source parameters and a comparison with the lower mantle structure.

a) – change of the magnetic moment, time intervals presented in Fig. 1 are marked by hatching. b) – the 3-D trajectory of source, orientation of the magnetic moment vector is perpendicular to the circles plane. c) and d) – the 3-D presentation of velocity heterogeneities of the mantle and the trajectory of source. The areas of lower velocities are shown in red, the areas of higher velocities in blue, zero surfaces are shown by light blue color, the source trajectory is shown by light brown color. (c) is the S20 model of mantle structure [Ritsema et al., 2004] and (d) is the SAW24 model [Megnin and Romanowicz, 2000].

Changes in the magnetic moment magnitude for the 17th source and its trajectory are shown in Fig. 2 and for the 18th source in Fig. 3. Circles, modeling the source geometry are superimposed on the tracks; some points are omitted for the sake of clarity. Orientation of the circles reflects a direction of the magnetic moment vector. Two models, S20 [Ritsema et al., 2004] and SAW24 [Megnin and Romanowicz, 2000], were selected for comparison with the lower mantle structure. Figs. 2c, d and 3c, d, show the lower mantle structure for 17th and 18th sources, respectively, as a 3-D surface, separating the zone of higher and lower velocities. Trajectories of the sources are embedded in the respective volumes.

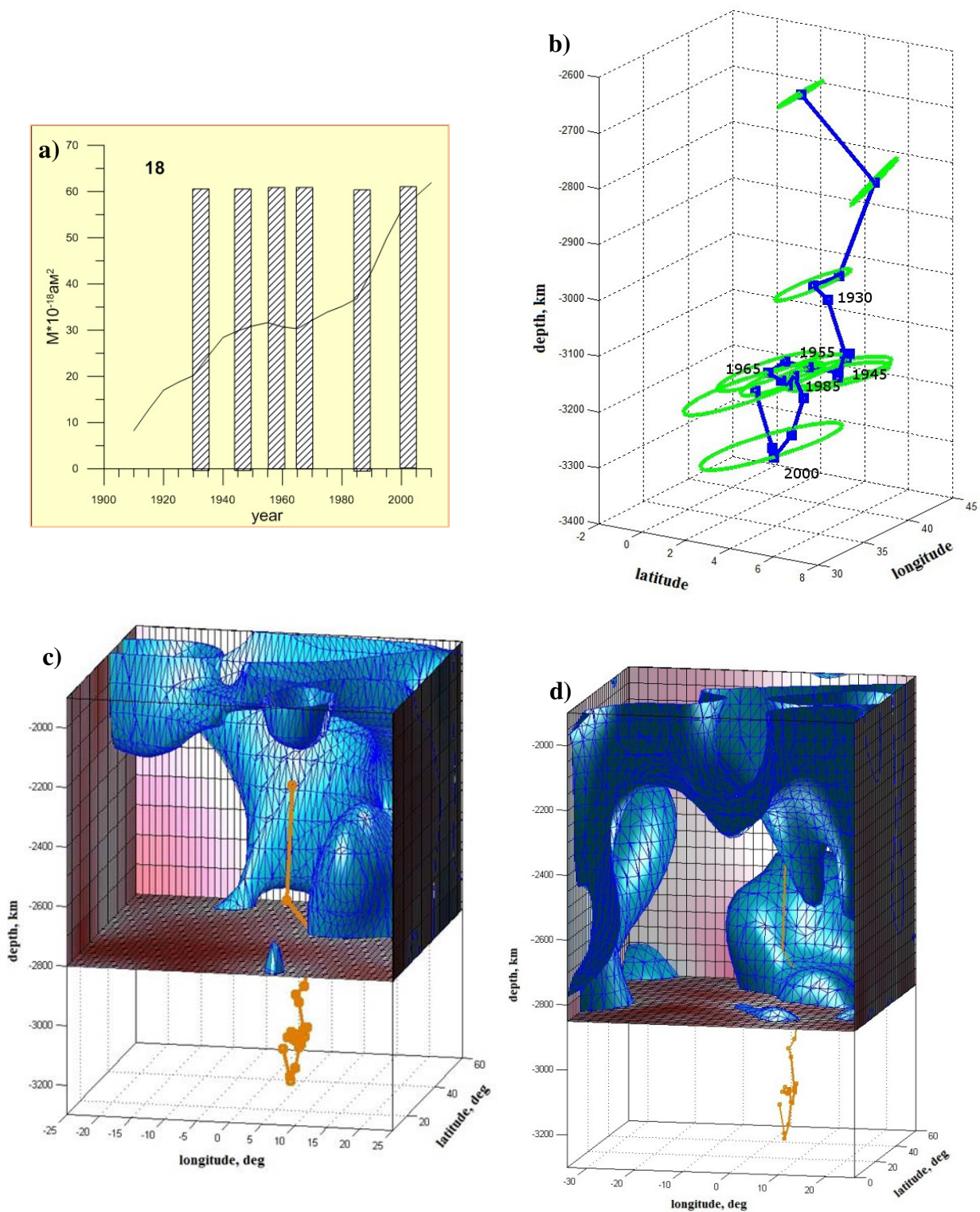


Fig. 3 Change of the 18th source parameters and a comparison with the lower mantle structure. The notation is as in Fig. 2.

Discussion

One can see that the contribution to SV from the two selected sources is determined either by change in the magnitude of the source magnetic moment, which is usually accompanied by a change in depth, or by changing the shape of its trajectory. The trajectory of the 17th source lies entirely in the lower mantle. Its

shape is in a good agreement with models of the lower mantle structure, based on seismic tomography. The trajectory of the 18th source already in the beginning of the considered period crosses the core-mantle boundary, but its most complex part lies just below the latter, as observed also for the Caribbean region [Demina, 2014]. However, it is clear that this trajectory connects the regions with higher velocities, as if they continue below the deepest level of seismic models. Since in the area traversed by the 18th source trajectory so-called cemeteries of lithospheric plates are believed to exist [Engebretson et al., 1992], it can be assumed that in these areas the topography of the core-mantle boundary is characterized by significant depth heterogeneities that may have a considerable effect on the structure of currents in the liquid core.

Conclusions

In this work, we examined the trajectories of the two possible secular variation sources in comparison with different models of the lower mantle structure, based on seismic tomography. As a result, we obtain that the velocity heterogeneities (heterogeneities of the density) in the lower mantle have a strong influence on the change of the parameters of the small-scale MGMTF sources located close to the core-mantle boundary. This result coincides with that obtained previously for the Caribbean.

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