THE CALCULATION OF THE TOPOLOGY OF DEEP MAGNETIC INHOMOGENEOUS OF THE EARTH'S MANTLE FROM MAGSAT, CHAMP GEOMAGNETIC SATELLITE DEEP-SOUNDING METHODS

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ABSTRACT

The MAGSAT, OERSTED, CHAMP satellite data are still extensively used in the study of magnetic anomaly fields. The average altitude of the MAGSAT and CHAMP satellites is approximately 400 km. Altitudes of the new system SWARM from 3 satellites are about 450 and 530 km, which makes it considerably more effective to extract anomaly (constant) magnetic field and magnetic variation field from measured field. However, it seems likely that anomaly magnetic field of the lithosphere at such altitudes (530 km) can be identified only in these cases when they are very intense, like, for example, in the case of the Kursk magnetic anomaly. It is desirable, that the satellite altitude was low than 400 km. SWARM system allows reality to extract of different component geomagnetic field and to calculate deep inhomogeneous in the mantle of the Earth. Practically all the methods for the solution of forward and inverse problems of the anomaly magnetic field are based on the results of integral methods. In the present project numerous calculations will be performed of integral method analysis of the anomaly magnetic field and deep transformation from the SWARM measurements.

INTRODUCTION

The published MAGSAT, OERSTED, CHAMP satellite maps of anomaly magnetic field, which have been obtained by a number of investigators [1, 2, 3], were presented but, they are significantly smoothed out, local anomalies are practically missing on the maps. Such satellite magnetic maps cannot be used for performing a geophysical interpretation of the local ionosphere heterogeneity. The goal of the present paper is the identification of long-wavelength magnetic anomalies of the lithosphere, the Earth's mantle for the Atlantic region. The second goal is the show of results of the calculation and analysis of the space-deep structure of magnetic heterogeneity in the depth of the Earth's mantle, their correlation with anomaly seismic heterogeneity, as well as with other geophysical parameters.

EXPERIMENTAL DATA AND TECHNIQUE PROCESSING

The data from the satellite MAGSAT, CHAMP were used in constructing digital maps of space structure of the magnetic anomaly field for the Atlantic region. For these regions with coordinates within latitudes from 55^0 S to 55^0 N and within longitudes from 90^0 W to 90^0E, the 1007 morning (6 LT) and 970 evening (18 LT) MAGSAT passes and 100 CHAMP passes within longitudes from 0^0E to ± 60^0E were chosen, for which the geomagnetic activity index $K_p < 2$. The passes were chosen for the scalar field B and for three components X, Y, Z. So, 18700 MAGSAT measurement points of the magnetic field were used for each component of the field within the limits of these regions under consideration. The magnetic field measured at the altitude of the satellite is a complex function of space and time and is caused by various physical sources, among which are the following: processes within fluid parts of the Earth's core, responsible for more than 90% of value of the measured magnetic field, that has been termed the main magnetic field; current systems near the Earth generating the magnetosphere and ionosphere fields; induction fields of the Earth's mantle; and, finally, anomaly fields related to magnetization of the Earth's lithosphere. A rather complex problem arises of extraction the fields measured at the satellite. With the aid of analytical models for each of the mentioned components the main geomagnetic field and magnetosphere field were calculated, which were removed from the MAGSAT, CHAMP measured values [3, 4, 5, 6]. The residual fields obtained in this way were used in construction of the maps of the magnetic anomaly field. For this purpose, for example, for MAGSAT data, the entire territory Atlantic region was divided into $1^0 \times 1^0$ blocks, and the mean values were calculated within each block, which were taken as the values of the anomaly magnetic field. One can find a comprehensive description of this technique for obtaining anomaly fields [6, 7, 3]. We have constructed MAGSAT numerical maps of the space structure of the magnetic anomaly field for the Atlantic region from evening and morning passes separately, as well as from the total information for the scalar field and components. Additionally, the East-European region map (the part of the Atlantic region) was constructed of differences of the *Xa, Ya, Za* component value of the anomaly magnetic field from the CHAMP passes reflecting an error, which amounted, on the average, to 5 nT. The spatial structure of the magnetic anomaly field within the Atlantic region for the scalar field map ΔB_a is shown in Figure 1.

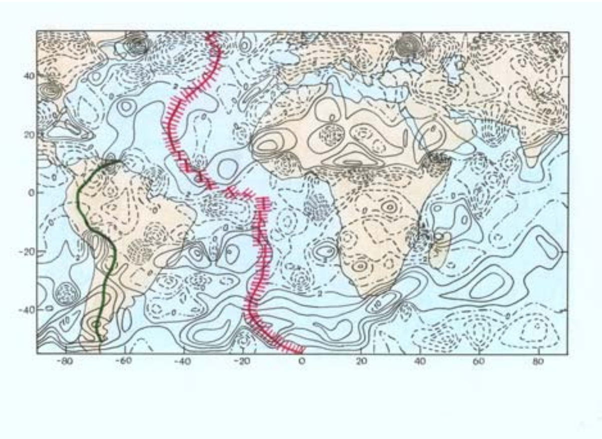

Figure 1.

INTEGRAL AND DIFFERENTIAL ANALYSIS METHODS FOR THE ANOMALY MAGNETIC FIELD OF THE ATLANTIC REGION

In order to interpret magnetic anomaly fields they should be represented not only in the spatial, but also in the frequency domain. Practically all the methods for the solution of forward and inverse problems of the anomaly magnetic field are based on the results of integral methods. In the present work numerous calculations were performed of spectral analysis of the anomaly magnetic field isolated out of the MAGSAT, CHAMP measurements for the Atlantic region. Results of numerical calculations for the chosen series of MAGSAT, CHAMP profiles are presented in Figure 2. As one can see from the figure, the main peaks in the spectra of anomaly fields at the satellite altitudes fall within periods approximately from 400 to 4000 km [8]. The periods of large regional anomalies with L_1 = 400-500 km, L_2 = 1000-1200 km, L_3 = 2000 km and L_4 = 3000-3500 km are the most significant ones. As to the peaks within the periods from 6000 km to 8000 km, they require special investigation. As illustrated by [8], the latter are not manifested in all the passes. Therefore, most likely, these peaks are related to residual fields from the main magnetic field and from the fields of the magnetospheric-ionospheric origin.

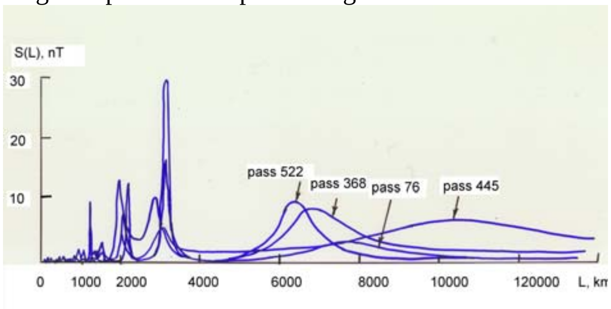

Figure 2.

If we used the differential method of CHAMP satellite geomagnetic data analysis, that we extracted Kursk magnetic anomaly in very nice (Fig. 3) [9].

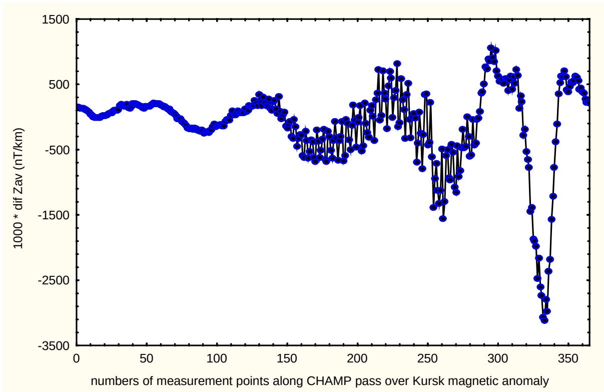

Figure 3.

The dynamic integral transform permits not only to identify characteristic features, but, also, to observe their changes in time or in space. In other words, the dynamic integral transform provides a two-dimensional distribution of the series under investigation with independent values of its integral parameters and coordinate. For example, the MAGSAT anomaly magnetic field substantially supplements the near-earth data in determining the structure of the magnetically telluric inhomogeneous of the lithosphere and Earth's mantle (Fig. 4) [3, 4, 5, 6]. In many cases, especially when ground measurements are absent, the MAGSAT magnetic anomaly field permitted to reveal magnetic inhomogeneities, to establish the contribution of deep-seated sources, to take into account the relationship between ground and satellite anomalies, and, finally, to construct a magnetic model of the lithosphere for a number of regions.

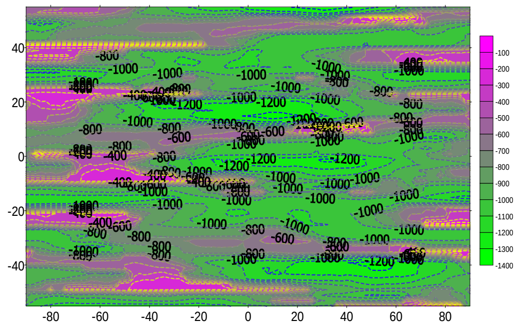

Figure 4.

MAGNETIC ANOMALIES OF THE ATLANTIC REGION FROM THE MAGSAT, CHAMP SATELLITE DATA AND THEIR RELATIONSHIP WITH THE DEEP STRUCTURE OF THE LITHOSPHERE AND THE EARTH'S MANTLE

The relationship between the magnetic anomaly field and tectonic structures within the Earth's lithosphere and the mantle is a matter of common knowledge [10]. In recent years certain progress based on satellite observations has been made in this direction. For instance, the data on scalar magnetic fields obtained from the CHAMP satellite measurements revealed that long-wavelength magnetic anomalies correlate well with large-scale tectonic structures [6, 7]. In this regard, magnetic anomaly field obtained at lower orbits of the MAGSAT satellite offer a great advantage. Making use of the global maps of the anomaly field obtained by [11, 12, 13, 4] revealed their good agreement with tectonic structures. The MAGSAT anomaly fields substantially supplement the near-earth data in determining the structure of the magnetically active layer of the lithosphere. In many cases, especially when ground measurements are absent, the MAGSAT magnetic anomaly field permitted to reveal magnetic inhomogeneities, to establish the contribution of deep-seated sources, to take into account the relationship between ground and satellite anomalies, and, finally, to construct a magnetic model of the lithosphere for a number of regions.

We have compared the spatial distribution of anomaly fields, with the tectonic structure of the Atlantic region, as well as with other geophysical fields. The total Atlantic region is divided into oceanic basins, submarine ridges, deep-sea grooves and continental margins. As one can see, island arcs and other uplifts of a greater part of the Atlantic Ocean are characterized by negative anomalies of the magnetic field. The central part of the Atlantic Ocean, especially the Sun Elena island uplift, is related to positive anomalies. At the same time, the satellite maps of the anomaly field also provide a clear confirmation for other tectonic structures. The Sen-Pol rift island, the Tristan-de-Kunia island uplifts in the southern part of the Atlantic Ocean and so on are examples.

The satellite anomaly gravity fields are of significant value for investigation of the structure of the Earth's lithosphere. For example, a comprehensive study of such fields was performed. The data on magnetic anomalies extracted from the MAGSAT satellite measurements, as well as the anomalies of gravity field, have revealed practically the same tectonic structures over of the Atlantic region (Figure 5, curve-1, 2).

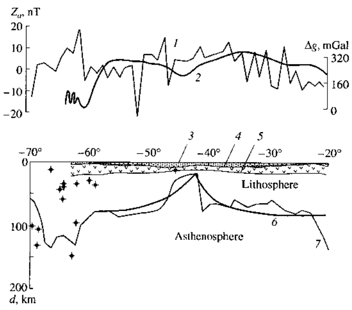

Figure 5.

The most comprehensive information on the structure of the lithosphere is given using various geophysical observations. The results of such interpretation of anomalies of the magnetic field together with other geophysical fields along the cross Atlantic profile at latitude $\varphi = 16^0$N are presented in Figure 5. Here, curve 1 correspond to the measured vertical *(ΔZ_a)* component values of the anomaly magnetic field. Curve 2 represents the variation of the gravity field Δg. Under the geophysical fields mentioned, the complex geophysical cross-section of the lithosphere of the Atlantic region is shown, including the depth of the ocean bottom surface for this profile (curve 4), ocean surface (curve 3), the depth of Moho boundary (curve 5), the depth of the gravity active boundary of the lithosphere from the gravity field data (curve 6), and estimations of the depth of the magnetically active lithosphere boundary from the MAGSAT satellite measurements of the magnetic anomaly field (curve 7), the results of the our interpretation of seismic data in during the MAGSAT mission lifetime (stars). An analysis of the whole geophysical information presented in Fig. 5 testifies about the complicated lithosphere structure in this region. The MAGSAT, CHAMP satellite data mostly characterize long-wave length magnetic anomalies; therefore many local features of the structure of the lithosphere cannot be reflected in these anomalies. The extracted long-wavelength magnetic anomalies from the MAGSAT measurements together with gravity observations and with seismic data permits to suggest that their nature in a series of regions of the Atlantic Ocean is related to physical deep inhomogeneities within the upper mantle. From total information about the earthquakes during mission of the MAGSAT satellite we extracted the earthquakes related to a integrated cross-section (stars in Figure 5). Figure 5 shows that calculated values of depth of the lower boundary of the magnetically active layer (curve 8) from the anomaly magnetic field in separate zones apparently correlate with spatial and deep distribution of earthquake hypocenters. In particular the sharp boundaries between ledges and falls on the curve 8 over ~ -70^0 and ~ -60^0 are connected with the earthquakes hypocenters. Such boundaries of the lithosphere ledges are observed and in transformed detail gravitational fields. There are sharp changes of the boundary in a magnetic cross-section on the longitudes ~ -70^0 and -65^0 existence of which are confirmed by the seismological data (Figure 5, 6, 7). It is possible that the boundary edges of the lithosphere layer from the different geophysical data sets over the Atlantic Ocean region are connected with the mantle plums penetrating to Moho boundary in Atlantic rift zones.

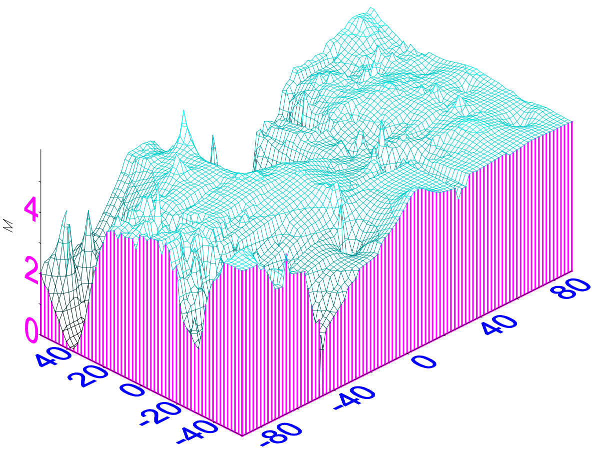

Figure 6

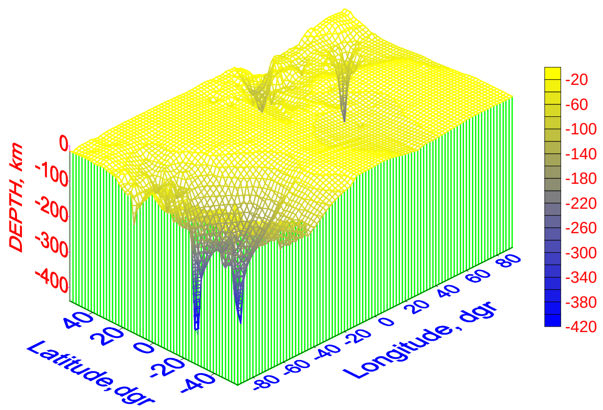

Figure 7

CONCLUSIONS

1. From the data of scalar and vector measurements of the magnetic field performed at the MAGSAT, CHAMP satellite, the anomaly maps in the Atlantic region have been constructed, which serve as the basis for investigation of the structure of the Earth's mantle.
2. The spectral analysis has been performed of the anomaly field for meridian passes over the Atlantic region. Characteristic scales are identified of large long-wave length anomalies with the following values at satellite altitudes (in km): $L_1 \cong 500$, $L_2 \cong 1000$, $L_3 \cong 2000$ and $L_4 \cong 3000$.
3. The integral transform of the profiles of the anomaly magnetic field for latitude $\varphi = 16^0$N has been performed, which permitted not only to find characteristic spatial inhomogeneities in the transformed magnetic fields, but also to show their localization on the profile.
4. The magnetic anomalies from the results of the MAGSAT satellite measurements over the Atlantic region have been extracted. A cross-section for this region using not only the anomaly magnetic field, but also of other geophysical fields has been constructed. It is shown that an integrated approach provides the most comprehensive and reliable information in order to understand and to investigate the structure of the Earth's mantle.

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