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POLISH MAGNETIC MEASUREMENTS IN THE BALTIC — HISTORY AND PROSPECTS

ABSTRACT

The progress in observation technology and navigation systems, as well as improvements in appliances used for carrying out magnetic measurements require a knowledge of the Earth's magnetic field distribution, not only on land but also in water regions. In order to update the results of marine magnetic measurements the knowledge of specific variations in a water region is required. It is connected with establishing a network of repeat stations taking regular measurements of three independent components of the Earth's magnetic field. Charts contained in the *Atlas of the Baltic Magnetic Charts* in which the discovered anomalies in a geomagnetic field are marked can be useful in designing such a network.

Key words:

Earth's magnetic field, magnetic measurements at sea, secular variations of a geomagnetic field, repeat stations, isopods.

INTRODUCTION

Because of its instability, i.e. changes in time and difficult to predict character of these changes, measurements of the Earth's magnetic field should be carried out systematically, especially at the so called magnetic repeat stations. They are specially stabilized points of the magnetic network of a country. In Poland it is called the Basic Magnetic Warp. Magnetic measurements at such stations should be carried out every 2-3 years and it should include determining three independent elements of the geomagnetic field [12].

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At present it is a measurement of the module of absolute geomagnetic field magnitude F , measurement of magnetic inclination I (the angle between the horizontal plane running through the point of measurement and vector \mathbf{F}) and the measurement of magnetic declination D (the angle between true north and magnetic north). The measurement of the element F , carried out with a proton magnetometer, directly gives the total value of F at the moment of measurement. At present the non-magnetic theodolite with Flux-Gate D/I head is used to measure magnetic declination and inclination. The absolute values of magnetic inclination are computed as the mean of four readings from the vertical circle of the theodolite — the north-south directions at various positions of the probe.

The measurement of magnetic declination is carried out through setting a leveled telescope in the direction east-west and taking four readings on the horizontal circle of the theodolite at various positions of the probe. Each measurement series finishes with aiming the telescope at the azimuth mark and the horizontal circle reading. The azimuth mark is a constant land-based point (church spire, mast, chimney, etc.), whose geographic azimuth is known as a result of prior measurements, mostly astronomic measurements with regard to the sun. The final result of the series is determining the magnetic north direction, as the direction corresponding to the mean of the readings on the line west-east on the horizontal circle of the theodolite. The actual value of declination is the difference between the magnetic north and the true north of the azimuth mark [12].

The results of the magnetic measurements carried out at repeat stations are necessary to determine long-term changes in the Earth's magnetic field called secular variations [12]. They are used to make charts of isopors, lines connecting points having the same secular variations for any selected area. Having such a chart it is possible to convert values of elements of the geomagnetic field obtained through magnetic measurements from one epoch (measurement epoch) to the other epoch (elaboration epoch).

In order to elaborate magnetic charts for any region magnetic measurements need to be carried out at measurement points arrayed with regard to the magnetic field image. It must be remembered that the points should be located at places of calm magnetic conditions far from local sources disturbing the Earth's magnetic field. The results of the measurements carried out at a magnetic point, on different occasions and different epochs are reduced to one elaboration epoch on the basis of isopor maps. The uniform material is used for further elaboration, e.g. for elaborating isolines (lines having the same the same values of the Earth's magnetic field element), elaborating distribution of changes in the element on any profile, elaborating

a model of local magnetic anomalies, etc. Magnetic anomalies are the areas where differences between the values of the Earth's magnetic field element obtained from the direct measurement (local model) and computed from the normal magnetic field are substantial, i.e. exceed a few times the values of the secular variations of this element [10, 11]. The values of the normal field are calculated from coefficients elaborated every five years (formula for potential) for the global model of the Earth's magnetic field. At present the most often used model is IGRF (International Geomagnetic Reference Field) which is based on all the available world magnetic data from land, marine and satellite measurements [12].

HISTORY OF MAGNETIC MEASUREMENTS IN THE BALTIC

Until the mid 1800s only measurements of magnetic declination and magnetic dip (inclination) were carried out. This limitation stemmed from the capabilities of the instruments available at the time. It was Gauss who was the first to observe the differences within the distribution of the Earth's magnetic field in time and space.

The first measurements of magnetic declination used in navigation in the Baltic were carried out as early as the first half of the 16th century. The results of the systematic measurements carried out in the 17th century at the magnetic points arrayed in the vicinity of Gdańsk allowed for elaborating secular variations and their interpretations (Johannes Hevelius) [3, 4].

Irregularities in compass indications in the western part of the Gulf of Finland were observed in the first half of the 18th century. The declination measurements based on a chosen number of points in this area made it possible to determine the places of the magnetic declination anomaly.

From 1861 Russian hydrographic expeditions included magnetic declination measurements in their exploration program together with bathymetric measurements. As a result the first chart of isogons was developed.

Between 1900 and 1905 the Danes carried out magnetic measurements on 80 marine points off the Island of Bornholm, also at the beginning of the 20th century similar work was undertaken by German scientists. They also included measurement of the horizontal component of the Earth's magnetic field, achieving the final accuracy in elaboration of the results of ± 100 nT.

From 1913 the magnetic declination was measured at approximately 300 points in the Swedish part of the Baltic, and in 1938 such measurement was carried

out at more than 140 points in the Gulf of Bothnia. In 1920 similar magnetic measurements were carried out by Estonian researchers on board the schooner 'Cecilia' [7].

In the 1930s Polish scientists joined in the measuring of marine magnetic measurements and they carried out the taking of magnetic measurements at 19 points arrayed along the Polish seacoast. The results of the magnetic measurements carried out by the Polish scientists were included in developing the magnetic declination chart for Poland and the southern part of the Baltic.

Because of the absence of appropriate instrumentation the measurement of all the elements of the geomagnetic field was not possible. It was not until after the WWII when proton magnetometers and Flux-Gate magnetometers were built that systematic magnetic measurements on land, in the air and at sea became possible.

POLISH MEASUREMENTS IN THE BALTIC IN THE SECOND HALF OF THE 20TH CENTURY

The first attempts of taking complex measurements in the southern Baltic were undertaken by the Institute of Geodesy and Cartography (IGC) at the beginning of the 1970s [13]. Such measurements were possible owing to the cooperation between IGC and the Soviet institute known as the Institute of the Earth's Magnetism and Radio Wave Propagation, by the Russian Academy of Science (IEMRWP) which had an amagnetic schooner 'Zarya'. Aboard the 'Zarya', in a midship compartment, an appliance was installed for measuring elements of the Earth's magnetic field — D , F , H and Z , where: D — magnetic declination, F — module of the Earth's magnetic field strength vector, H and Z are modules of horizontal and vertical components of this field respectively [7]. The impact of an external field on magnetometer probes did not exceed ± 1 nT, and the aggregate of all interference generated aboard the schooner did not exceed ± 10 – 20 nT.

In the 1980s the first repeat points were set up in the southern Baltic (fig. 1). In order to carry out measurements at the repeat points, which required higher accuracy, a special method, shown in figure 2 [6], was developed for selecting courses leading to a station. It allowed for the maximum increase in station localization accuracy and substantial reduction in deviation impact. Because of the 36-time passage of the ship through the measurement point it was possible to refrain from reduction taking into account daily (24-hour) changes. The measurements at the repeat stations were repeated 2–3 times between 1982 and 1988 and finally they

were used to elaborate secular variations for the southern Baltic with approximately ± 15 nT accuracy. So far it has been the first and the only network of marine repeat points [9].

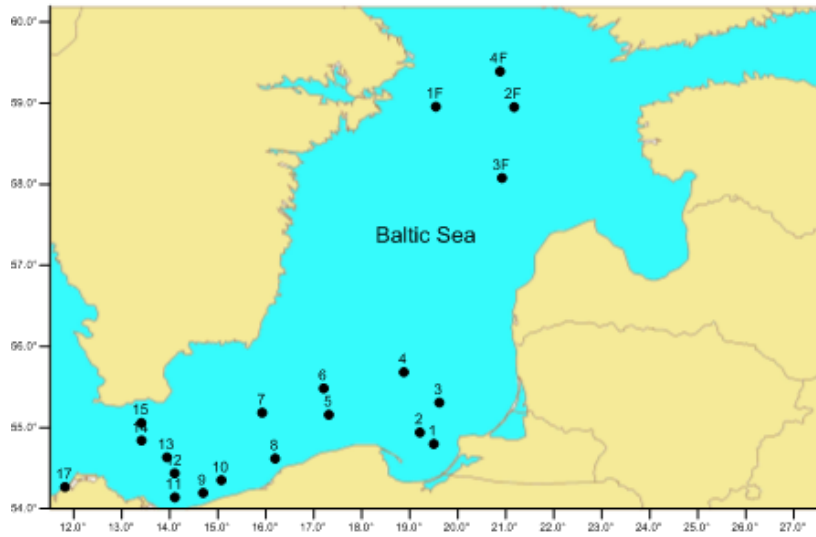


Fig. 1. Array of repeat stations in the Baltic measured between 1982 and 1988

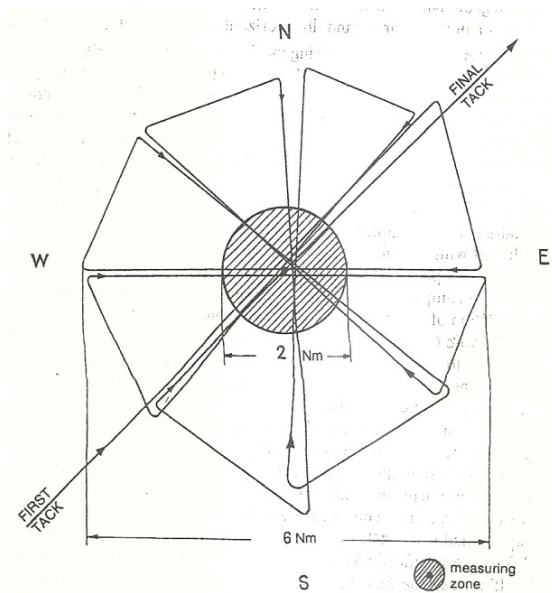


Fig. 2. A diagram of courses guiding to a marine repeat station

The measurements at survey points were carried out using the profile method, i.e. sailing the selected course on which the values of magnetic field elements and ship's position were recorded (fig. 3).



Fig. 3. Marine measurement profiles in the Baltic 1970–1990

The elaboration of the measurement results was very time consuming. First of all they had to be transformed from the analogue form into the digital one, external and internal interference had to be eliminated and all the values had to be reduced to one epoch. In the 1980s, owing to the modernization of measuring technologies, digital recording of data was implemented, which accelerated the process of data elaboration very much.

By 1990 the profile measurements had been finished and the all-encompassing elaboration process of the collected material had started. As a result 220 000 measurement points were obtained from which the values of the measured elements were reduced to one epoch 1990.5. The isopors used for this reduction were elaborated on the basis of distribution of changes in the Earth's magnetic field in the magnetic observatories located around the Baltic (fig. 4). The Magnetic Observatory IGF PAN at Hel was adopted as the base observatory.

Such measurements and on such a large scale, including almost the whole region of the Baltic (excluding territorial waters) were carried out for the first time. They were used to make the IGC atlas containing charts of all components of the

Earth's magnetic field, magnetic anomalies H and F and normal fields of these components as well as the isopor chart (fig. 5).

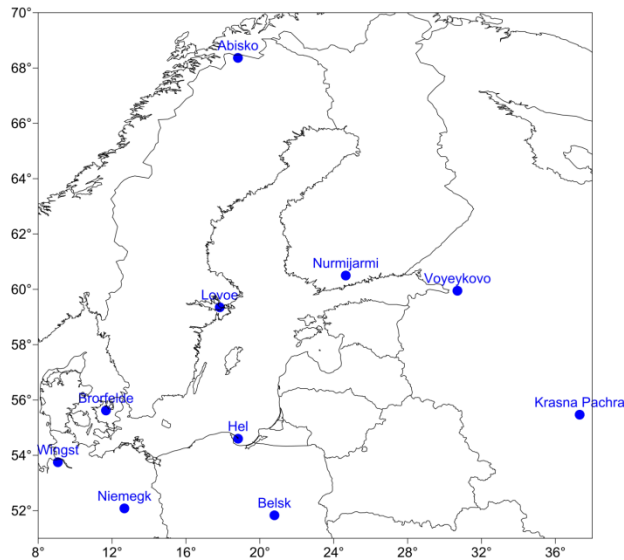


Fig. 4. The magnetic observatories located around the Baltic



Fig. 5. A folder of the atlas of Baltic magnetic charts

CURRENT PROBLEMS RELATING TO THE MARINE MEASUREMENTS

Since the 1990s Flux-Gate compasses (also called electronic compasses) have been more and more common in use onboard ships. Their construction and digital output signal allow for transmitting the precise course-related data to other appliances in the ship, for example to autopilots or ECDIS. This means, that at present the knowledge of declination is becoming more important than before [1].

Since 1990 there has been no single attempt to carry out marine measurements in the Baltic, or a proposal for initiating an alternative project for such measurements. At present, following the development of the new generation of measuring instruments designed both for localization and absolute magnetic measurements, the issue of networks of marine repeat points needs to be raised again.

Because of the increased precision requirements concerning navigation systems it appears indispensable to seek aid from potential fields or the gravitation field and the Earth's magnetic field. Using the knowledge relating to the distribution of these fields and their anomalies can enhance accuracy of navigation systems, especially in a situation where a satellite measurement is not possible.

Based on the existing magnetic charts of the Baltic [8] a network of marine repeat points should be designed. Partly they can be land points located on islands or coasts, selected in such a way that it would be easy to sail to them and moor. Such points should be located far from the big Earth's magnetic field gradients and, if it were possible, their localization should be confronted with the bathymetric map of the Baltic. An example of the design of such a network, consisting of 18 points, was made using the chart of vector anomalies of the Earth's magnetic field absolute strength F (fig. 6).

The measurements of three independent components of the Earth's magnetic field at the repeat point of the marine network should be repeated no less frequently than every 2–3 years. They should be the base for developing a model of secular variations of the geomagnetic field in the Baltic region, which will ensure the possibility to systematically update the results of marine magnetic measurements and charts. At present such updates can be based only the field variations recorded in the magnetic observatories located around the Baltic (fig. 3).

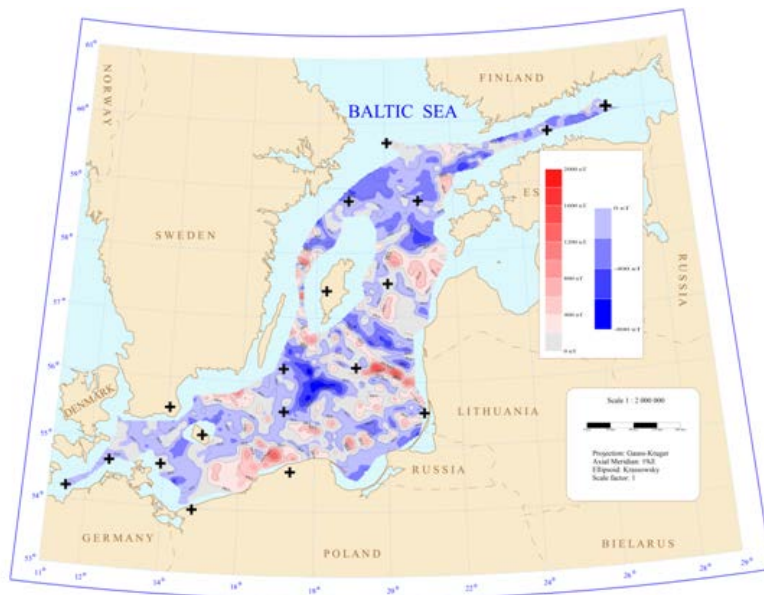


Fig. 6. A proposal of the network of marine repeat points set against the background of the chart of anomalies F

CONCLUSIONS

As it has already been mentioned above the progress in measuring instruments, relating to both navigation and geophysics, creates a need and offers possibilities of having more accurate geophysical data aiding navigation systems. Owing to the existing charts from the Atlas of Baltic Magnetic Charts it is possible to better design a network of marine repeat points and this way to obtain an accurate model of secular variations of the Earth's magnetic field in this region. In order to verify the charts from the atlas the magnetic measurements should be repeated on selected profiles or in places characteristic of changes in elements of the Earth's magnetic field.

Undoubtedly, to carry out this task would incur substantial financial expenses necessary to purchase equipment, an appropriate floating vessel, and to have a specialized project solving the problem of magnetic measurements at sea. Most of the work would be dedicated to proper array of the instruments used to measure components X , Y and Z of the magnetic field and correlation of the location of measuring probes with the magnetic north.

It is worth making an attempt to take on this challenge for the purpose of the development of science and learning the specificity of the geophysical fields in the Baltic region, all the more so that the results of the elaboration of the Earth's magnetic field generalize, to a large extent, the field image [5], neglecting all regional and local anomalies, and it is them that directly affect the accuracy of the navigation process.

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POLSKIE POMIARY MAGNETYCZNE NA BAŁTYKU — HISTORIA I PERSPEKTYWY

STRESZCZENIE

Rozwój technik obserwacyjnych i systemów nawigacyjnych oraz ulepszenie aparatury do pomiarów magnetycznych wymagają znajomości rozkładu pola magnetycznego Ziemi nie tylko na lądzie, ale i na akwenach. Do bieżących aktualizacji wyników morskich pomiarów magnetycznych potrzebna jest wiedza na temat zmian rocznych (wiekowych) na danym akwenu. Wiąże się to z założeniem morskiej sieci punktów wiekowych (*repeat stations*) i regularnymi na niej pomiarami trzech niezależnych składowych pola magnetycznego Ziemi. W zaprojektowaniu takiej sieci mogą być pomocne mapy z *Atlasu map magnetycznych Bałtyku*, na których uwidocznione są wykryte anomalie pola geomagnetycznego.

Słowa kluczowe:

pole magnetyczne Ziemi, pomiary magnetyczne na morzu, zmiany wiekowe pola geomagnetycznego, punkty wiekowe, izopody.