MODELLING OF DECLINATION'S SECULAR VARIATION FOR THE PURPOSES OF REGIONAL TOPOGRAPHIC MAPPING

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Abstract. The most significant of the Earth's magnetic field elements is the geomagnetic declination, which is widely used in geodesy, cartography and their associated navigational systems. The geomagnetic declination is incorporated in the naval navigation maps and is used in the navigation process. It is also a very important factor for aviation where declination data have major importance for every airport (civil or military).

As the geomagnetic field changes with time but maps of the geomagnetic declination are not published annually and are reduced to an epoch in the past (Buchvarov and Cholakov, 1985), it is necessary to define two additional parameters in the maps, needed to determine the value of the geomagnetic declination for a particular moment in the future: 1) estimated value of the annual declination variation and 2) a table with the average diurnal variation of the declination for a given month and hour.

Key words: PAG observatory, geomagnetic declination, geomagnetic secular variations, prediction models..

Introduction

The goal of this research is to analyze the annual mean values of geomagnetic declination on the territory of the Balkan Peninsula for obtaining a best fitting model of that parameter which can be used for prediction of the declination value for the next 10 years (Mandea, 2001).

The latest version of the GFZ Reference Internal Magnetic Model (GRIMM-3.0) was used to compare the magnetic field evolution predicted by that model between 2001 and 2010 to the data collected in five operating geomagnetic observatories in the Balkan region (PAG, SUA, PEG, IZN, GCK) over the same time interval.

In this study are tested different time-scale periods and different order polynomials to create the most appropriate prediction model and to estimate the obtained results. It is perceived that linear models which are used to determine the annual declination variation in cartography provide enough accurate information for the declination map’s users.

Datasets used in the research

1. Model derived from satellite data: The GFZ Reference Internal Magnetic Model (GRIMM) has been derived from nearly eight years of CHAMP satellite data and seven years of observatory hourly means. At high latitudes, full vector satellite data are used at all local times. By doing so, a separation is possible between, on one hand, the fields generated by the ionosphere and field aligned currents, and, on the other hand, the fields generated in the Earth's core and lithosphere. This selection technique leads to a data set where gaps are avoided during the polar summers allowing the modeling of the core field with an unprecedented time resolution.
2. Secular data from several INTERMAGNET observatories near to PAG observatory: The observatories used (Fig.1) for the second dataset are located on the Balkan Peninsula or in near vicinity (Iznik). Annual mean values of the declination are used from:

Grocka, Serbia and Montenegro (GCK) -	Latitude = 44° 38'	Longitude = 20° 46'
Surlari, Romania (SUA) -	Latitude = 44° 41'	Longitude = 26° 15'
Pedeli, Nea Makri, Greece (PEG) -	Latitude = 38° 5'	Longitude = 23° 56'
Iznik, Turkey (IZN) -	Latitude = 40° 30'	Longitude = 29° 44'
Panagyurishte, Bulgaria (PAG) -	Latitude = 42° 31'	Longitude = 24° 11'

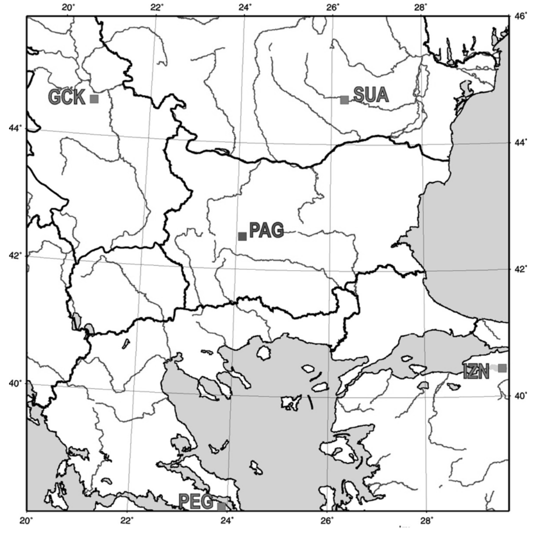

Fig.1. Locations of the observatories which data are used for modelling

3. Bulgarian repeat stations network data: The repeat stations measurements in Bulgaria started in 1934. The eight points selected then were supplemented with seven more in 1964.

All points were investigated, stabilized and later duplicated with spare ones and secured with lasting miras. Up to 1980 they were measured every three years and then because of the small secular variations – every five years. Isoporic maps for different periods are elaborated. The repeat stations are shown on the map in Fig.2. Last series of geomagnetic field measurements were performed during 2007 and 2012 using Di-Flux (theodolite Zeiss 020B and Mag-01H) and GSM-19 proton magnetometer.

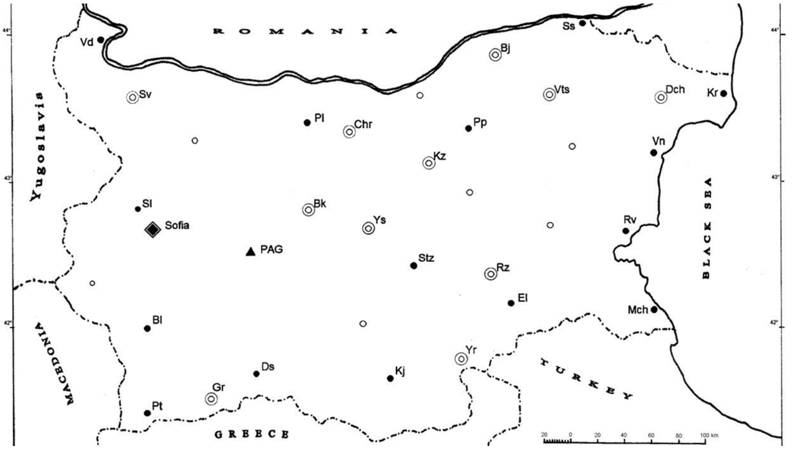

Fig.2. Location of the repeat stations in Bulgaria

▲ - Panagyurishte observatory; ● - repeat stations; ◎ - first class points ; ○ - new points.

Model Derived From Satellite Data

The latest version of the GFZ Reference Internal Magnetic Model (GRIMM-3.0) is used to extract the magnetic field secular variations predicted by that model between 2007 and 2012 and to compare them to the data registered in the Balkan Peninsula observatories and the repeat station measurements on the Bulgarian territory.

GRIMM-3.0 model is to provide a highly accurate description of the core field and its temporal evolution, the model contains some external field estimates as a by-product from the necessary separation of sources in the modeling approach (Korte and Lesur, 2012).

Using linear interpolation we created model of the annual variation of the Declination in a window from Lat. 41,2°N to Lat. 44.2°N and form Long. 22°E to Long 28°E (Fig. 3)

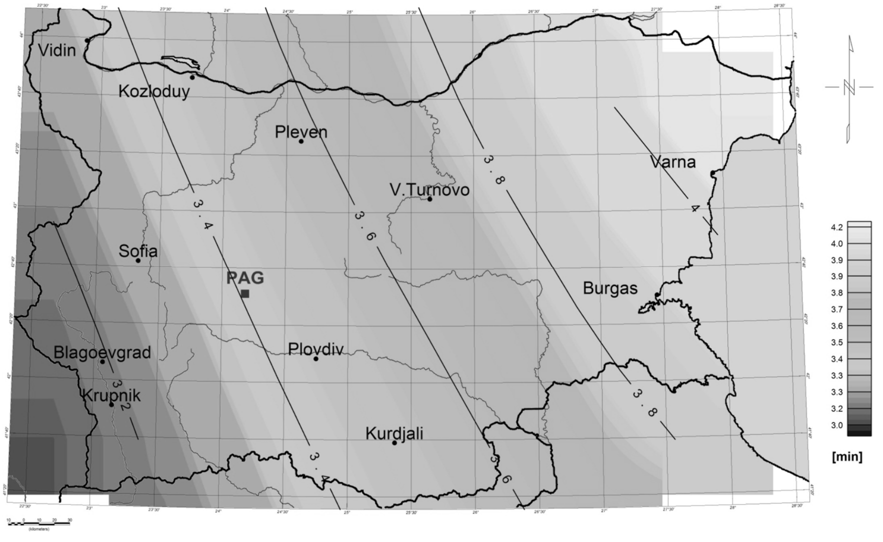

Fig.3. Model of the Declination annual variation for the territory of Bulgaria obtained from GRIMM-3.0 model for the period 2007-2012

Model Derived From Observatory Data

Published annual mean values of the Declination obtained in Panagyurishte observatory (PAG) (Butchvarov and Cholakov, 2006; Cholakov and Mihovski, 2010) and the four neighboring geomagnetic observatories (SUA, IZN, PEG and GCK) were used for the periods as follows:

PAG – 2000-2012	SUA – 2000-2010
IZN – 2007-2012	PEG – 2000-2012
	GCK – 2000-2011

Model of the Declination annual variation is obtained by linear fit using least squares method. Obtained values are in the range 4.9 to 5.8 min per year (Fig. 4).
Due to the fact that the observatories used for modeling are far away from Bulgarian territory, after the interpolation there are some features that cannot be explained with the expected main field characteristics presented in isoporic maps of previous researches.

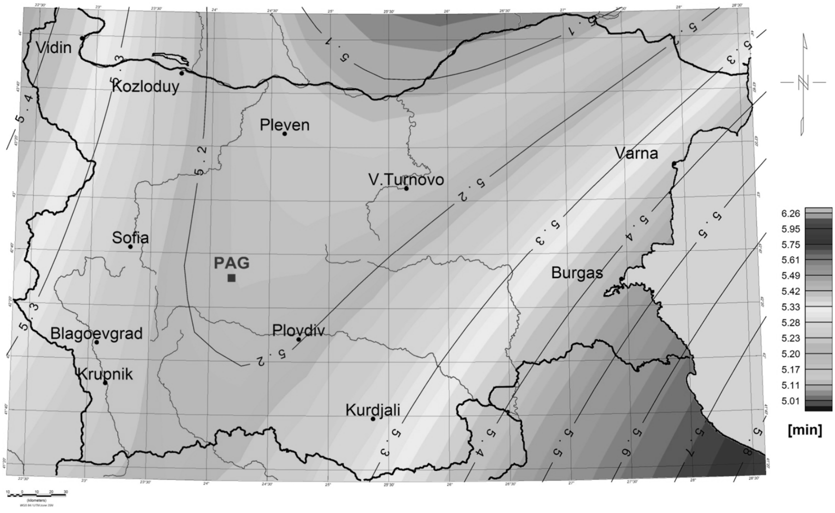

Fig.4. Model of the Declination annual variation for the territory of Bulgaria obtained from Declination annual mean values calculated in PAG, SUA, IZN, PEG and GCK observatories.

Model Derived from Repeat Station Measurement Data

The Geomagnetic Survey in the National Institute of Geophysics, Geodesy and Geography-BAS has reliable data for the declination registered in Geomagnetic Observatory Panagyurishte (PAG) since 1948 to now (Fig. 5). The existence of such a long row of data allows tests on secular variations of the magnetic field, to track dependencies related to various cycles of solar activity, as well as to make estimates of the annual change of declination for small periods in the future.

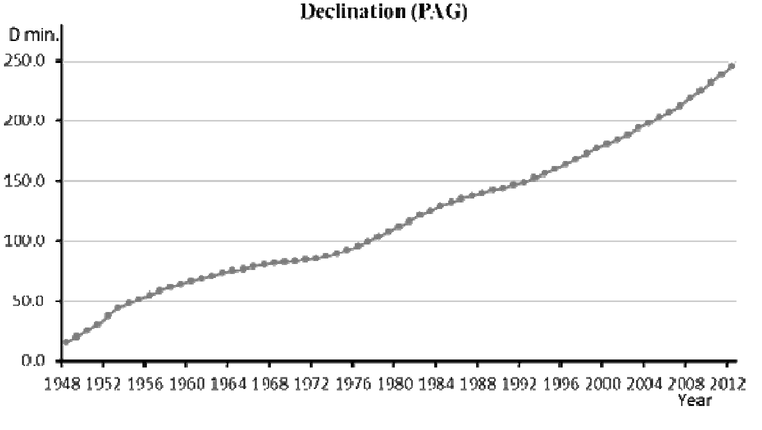

Fig.5. Annual Declination values obtained in PAG since 1948

Analysis of the Declination values, registered in the last 65 years in PAG indicates that the value of this element increases but with a different rate, thereby the annual variation is variable over time (Fig. 6). Several intervals of increase are observed, followed by a gradual decline in values, but in general from the plot of declination first derivative for the entire data a positive linear trend in the range of 1.5 min/year is calculated. Mathematical analysis of the behavior of geomagnetic declination and its first and second derivatives showed that for modeling the values of this parameter with extrapolation is appropriate to use data recorded after 2000.

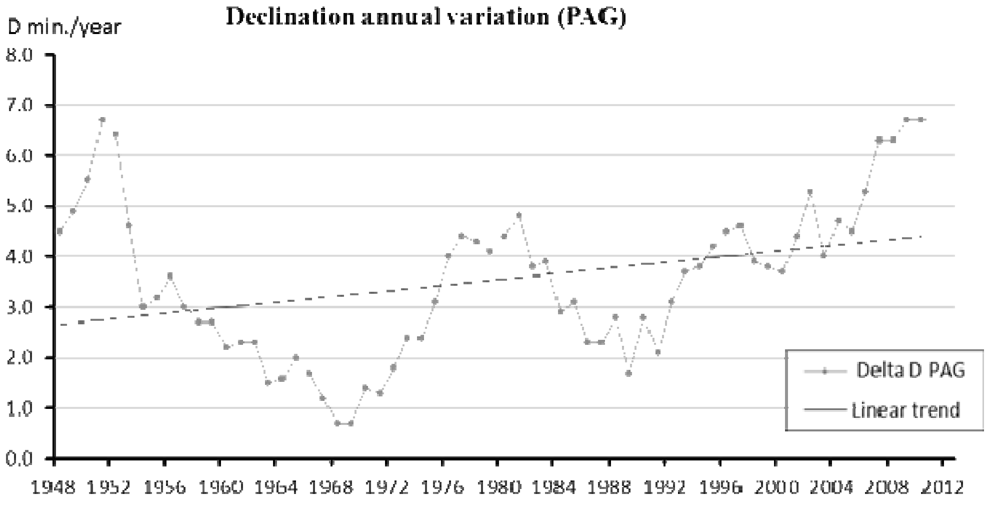

Fig.6. Declination Annual Variation in PAG observatory and calculated linear trend since 1948

For prediction of the Declination annual variation for the next 10 years data from PAG (Fig. 7), SUA, IZN, PEG, GCK and 6 repeat stations from Bulgarian territory are used. Regression analysis of each data series of the declination values is performed with a linear model using the least squares technique:

$$D(t)=D_0 + \Delta D.t$$

Where $D(t)$ is the Declination, D_0 is constant component of the equation, t is time in years and ΔD is the linear variation for the investigated period which is used as a prediction value of declination annual variation.

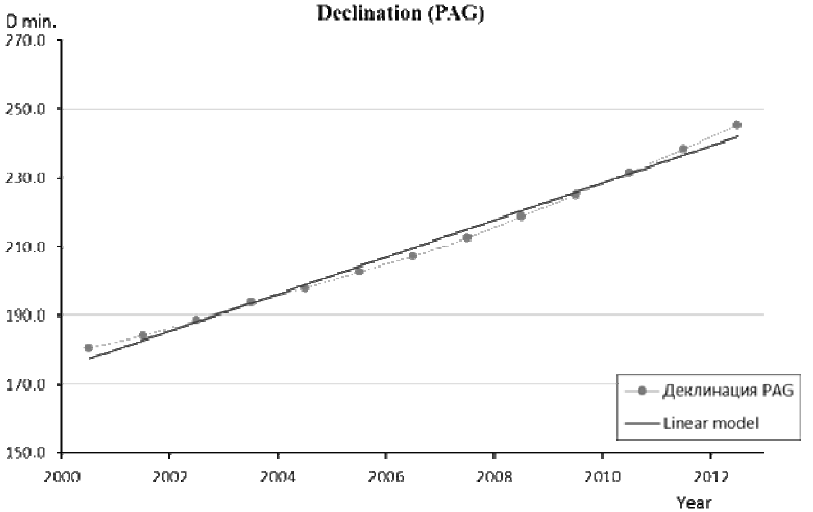

Fig.7. Linear model of the Annual Declination using least squares technique for the period 2000-2012

Calculated values are in the range between 5 and 5.5 min./year and a distinct W-E trend is observed on the map of Fig. 8.

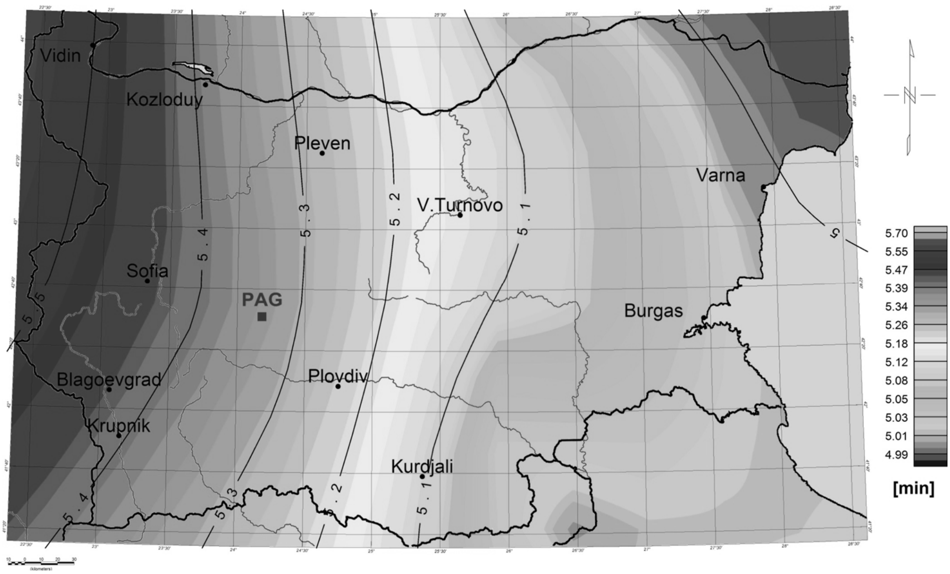

Fig. 8. Prediction model of the Annual Declination variation for the period 2013-2023 for the purposes of regional topographic mapping

The obtained results are comparable with the research done by Georgiev et.al where the annual declination model has a similar configuration but the obtained values for the period 1960-1980 are in the range 1.4-2.7 min./year. Calculated in this way prognostic values of the Annual Declination variation can be used in the topographic maps and for navigation.

Conclusions

Three different models are obtained aiming to predict the Annual Declination variation for the next ten years over the territory of Bulgaria. Satellite data from GRIMM 3.0 show only the long-wavelength components of the global geomagnetic changes which are not sufficient to present the local behaviour of the geomagnetic field secular variations with an accuracy which can be used for topographic mapping. Regional interpretations made by observatory data only provide more detailed representation of the investigated element. They have one main disadvantage which is the lack of data in long and equal time intervals. This was compensated by constraining the model using repeat station measurements in Bulgaria. As a result, a model of the Annual Declination variation is obtained having accuracy and resolution which is sufficient for the purposes of calculating the geomagnetic declination for a particular moment in the future and can be used in topography maps.

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References

Buchvarov, I., Cholakov, I., (1985): Reducing the absolute measurements of the components of Earth's magnetic field to a common epoch using a basic point and a field magnetic variation station. Bulgarian Geophysical Journal Vol XI No 1.

Butchvarov. I., Cholakov, I. (2006): Field and observatory geomagnetic measurements in Bulgaria, NATO, Geomagnetics for aeronautical safety, The Netherlands.

Cholakov, I., Mihovski, S. (2010): Magnetic repeat station survey of Bulgaria in 2007 and 2008. Bulgarian Geophysical Journal Vol 36.

Georgiev, Chr., Kostov, K., Cholakov, I. (1986): Isopors of Declination in Bulgaria for the Period 1940-1980, Bulgarian Geophysical Journal Vol XII No 3.

Korte, M., Lesur, V. (2012): Repeat station data compared to a global geomagnetic field model. Annals of Geophysics, 55, 6, p. 1101-1111.

Mandea, M. (2001): How well is the main-field secular variation known?, Contributions to geophysics and geodesy, Geophysical institute, Slovak Academy of Science, v. 31, № 1.

Моделиране на секуларната вариация на геомагнитната деклинация за целите на регионалното топографско картиране

М. Методиев

От елементите на земното магнитно поле, най-значимия е геомагнитната деклинация. Тя се използва в геодезията, картографията и свързаните с тях навигационни системи. Деклинацията е интегрирана в морските навигационни карти и се използва при процеса на навигация. Също така е много важен фактор за авиацията, където данните за деклинацията са от голямо значение за всяко летище.
Тъй като геомагнитното поле се променя във времето, но карти на геомагнитната деклинация не се публикуват ежегодно и биват редуцирани към епоха в миналото, е необходимо да се дефинират два допълнителни параметъра в картите, нужни за определянето на геомагнитната деклинация за даден момент в бъдещето: 1) изчислена стойност на годишната вариация на деклинацията и 2) таблица със средните денонощни вариации за даден месец и час.