REGIONAL ORTHOGONAL MODEL (ROM) OF THE GEOMAGNETIC SECULAR VARIATION IN THE EUROPE FOR 1980-2009 YEARS

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ABSTRACT

The regional orthogonal spatial-temporal model of the secular variation of the main geomagnetic field in Europe has been constructed. The model covers the years from 1980.0 to 2009.0. As the basic set of experimental data the annual mean from the magnetic observatories in Europe have been used. The regions without experimental data have been filled by the synthetic data calculated from IGRF-11's model. Temporary changes are presented by the decomposition via natural orthogonal components. Spatial behavior is described by Legendre polynomials. The model allows estimating the secular variation of the geomagnetic field at the beginning of each year from the given time interval for any point of the considered region. The algorithm of model construction does not imply any smoothing of the data. However, as well as in the models presented earlier for other regions of the planet, the presented (regional) model of Europe is substantially more accurate compared with the global models of the secular variations.

1. INTRODUCTION

Primary we planned to present the completed model as it was declared in the title of the paper. However, during the progress of the work, we understood that we should be more experienced in processing the data from the geomagnetic repeat stations (RS). RS are the points where the geomagnetic field is measured every 2 or 3 years.

Thus, so far we present a concept of the model and the model's basic components that do not provide all spatial details.

2. METHOD

An idea of the method of Regional Orthogonal Modeling (ROM) of geomagnetic field $H(\varphi,\lambda,t)$ was proposed by Vadim Golovkov *et al.* [1].

<u>What we have?</u> We have two types of the data observations of the geomagnetic field (***H)*** made in specified areas of the Earth surface in specified periods. In other words, we have continuous and discontinuous time series.

<u>What we need?</u> We need a model to know the realistic ***H*** for any location and for any time in the specified spatial area and time period. Moreover the model should contain the most details of the non-smoothed observational data.

2.1 Essence of the method

Spatial-temporal modeling of the changes of the geomagnetic field on the Earth's surface can be described as follows:

$$H(\varphi,\lambda,t)=\sum_{i=0}^{I}\sum_{j=0}^{J}\sum_{t=0}^{T}a_{ijt}F(\varphi)\cdot G(\lambda)\cdot D(t),$$

where φ and λ are the geographical coordinates, t is the time (years or other units); F, G and D are the some functions being usually analytical ones.

It has been proved theoretically and practically that the model shows the best results, when the sets of F, G and D functions are orthogonal. Therefore we can convert the first formula in other kind:

$$H(\varphi,\lambda,t)=\sum_{m=1}^{M}b_m E_m(\varphi,\lambda,t),$$

where $b_m = a_{ijk}$, $E_m(\varphi, \lambda, t) = F_i(\varphi)\, G_j(\lambda)\, D_k(t)$, and m is number of the some combination from i, j and k. We describe the orthogonal condition as:

$$\int E_m(x)\cdot E_l(x)dx \begin{cases} =0 & l\neq m \\ \neq 0 & l=m \end{cases}$$

2.2 Method realization

The requirement of function orthogonality can be met if we take the Natural Orthogonal Components (NOC) as the time $D_k(t)$ functions and the Legandre polynomials as the spatial $F_i(\varphi)$ and $G_j(\lambda)$ functions. The algorithm of modeling consists of the two steps. <u>First step</u> is the construction of the time $D_k(t)$ functions. Here the continuous time series of the most stable observatories, located in the specified territory and nearby, can be used.

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Second step is spatial modeling. Here all available data (from observatories, repeat stations, etc.) can be utilized. The time functions obtained in the first step are used in the conditional equations. All data should be referred to the same epoch, for example, to the beginning or to the middle of year.

2.3 Usage of the method

The method named by the authors as ROM ("Regional Orthogonal Modeling") has been applied earlier to create the regional models for the USA ("ROM-USA"), Canada ("ROM-Canada"), the Far East and Japan ("ROM-FAR EAST", "ROM-Japan"), Arctic regions ("ROM-Arctic").

Today we suggest create the same secular variation model for Europe ("ROM-Europe"). This model, if to be linked to the model of the main geomagnetic field of one of the epoch (for example, 2006.0), can provide us the way to creation of the regional model of the geomagnetic field of the Europe for all examined interval, in particular, for an interval of 1980-2009.

3. DATA SELECTION

In our case, the continuous data come from dataset of geomagnetic Observatories (OBS, blue points, Fig. 1) and discontinues data are – dataset of geomagnetic Repeat Stations (RS, red points, Fig. 1). The data are numerous, but their quality varies very much. So, firstly, it is necessary to choose an optimal dataset for correct modeling.

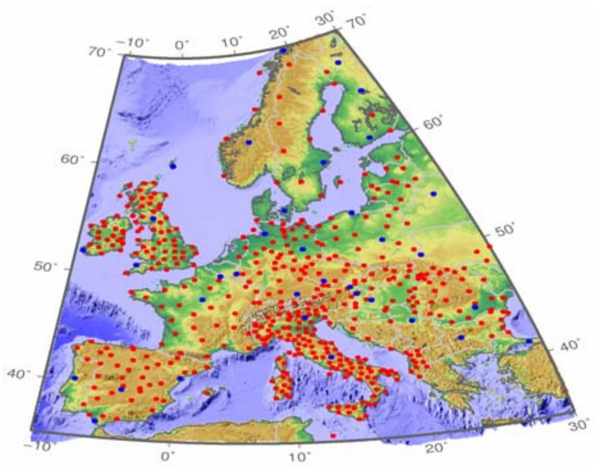


Figure 1. Map of geomagnetic European Observatories (blue points) and Repeat Stations (red points)

3.1 RS data selection

What RS dataset we should choose? RS are shown by red points in Fig. 1. This difficult question is opened yet for us. So, the results presented below have been received without RS dataset.

3.2 OBS data selection

We have selected 28 magnetic European observatories (Fig. 3) from the total number about 50 (Fig. 2) for current investigation. They have a continuous series of observations for the period of 1979-2009. This choice is not final. List of used observatories are shown in Tab. 1.

Figure 2. Map of geomagnetic European Observatories

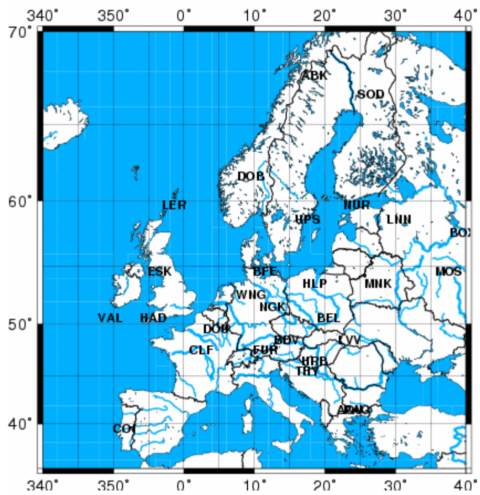


Figure 3. Map of selected geomagnetic European observatories (28), which have a continuous series of observations during 1979-2009 years

3.3 Artificial (IGRF) RS data selection

It is well known that the part of the European territory (mainly, the sea areas) are not covered by dataset. The one way for solving this problem - to add the dataset with the artificial RS calculated by IGRF-11 model. Such points are marked by symbols “ig” in Fig. 4. (IGRF-11 is International Geomagnetic Reference Field Model.)

Table 1. List of used observatories

1	ABISKO	15	KRASNAYA PAHRA
2	BELSK	16	L AQUILA
3	BOROK	17	LEIRVOGUR
4	BRORFELDE	18	LERWICK
5	BUDKOV	19	MINSK
6	CHAMBON	20	NAGYCENK
7	COIMBRA	21	NIEMEGK
8	DOMBAS 2	22	NURMIJARVI
9	DOURBES	23	PANAGYURIS
10	ESKDALEMUI	24	SODANKYLA
11	FURSTENFEL	25	STEPANOVKA
12	HARTLAND	26	SURLARI
13	HEL	27	VALENTIA
14	HURBANOVO	28	WINGST

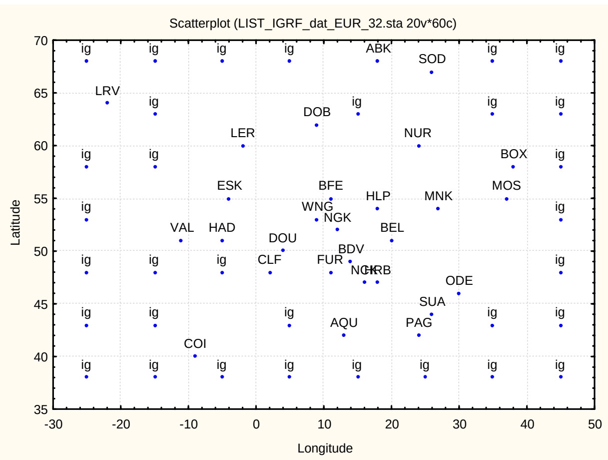


Figure 4. Map of artificial RS (“ig”) calculated by IGRF-11 model

3.4 Preliminary summary of data selection

Our data selection by present moment is shown in the Table 2.

4. RESULTS

We believe that it is reasonable to build not the only single “ROM-Europe”, but the following set of models based on the in-name indicated data sources:
“ROM-Europe-OBS”;
“ROM-Europe-OBS+IGRF”;
“ROM-Europe-OBS+RS”;
“ROM-Europe-OBS+RS+IGRF”.
Each version has its “pros” and “cons” so that any user may choose ones fitting for his needs. The preliminary versions “OBS” and “OBS+IGRF” are available in present time.

Table 2. Data selection by today

Name of points	**Space points**	**Time points**	**Total**
Geomagnetic Observatories (OBS)	28	28	784 (28x28=784)
Magnetic Repeat Stations (RS)	0	0	0
Artificial RS (IGRF)	32	6	192 (32x6=192)
Total	60	60	976

4.1 Time functions

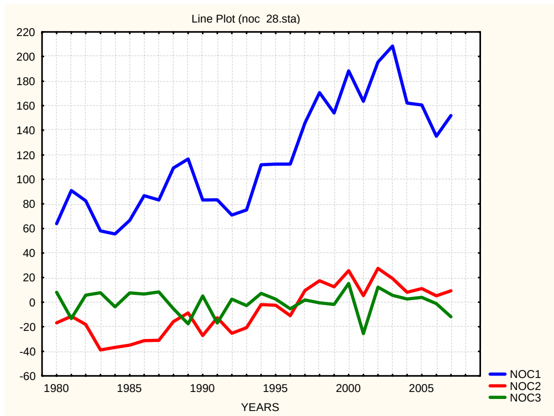


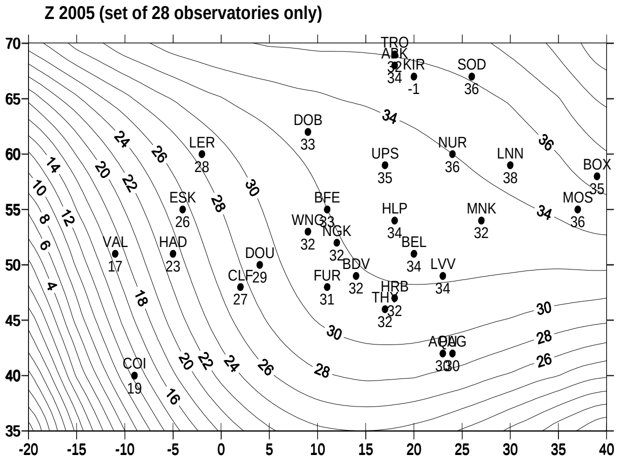
Figure 5. Time $D_k(t)$ functions are the first three natural orthogonal components (NOC) of Z-component of secular variation (SV), based on the data of 28 observatories

4.2 Models ”ROM-Europe-OBS” and "ROM-Europe-OBS+IGRF"

Z-component of SV (nT/year) of created models for the epoch of 2005.0 is shown as the contour lines (Fig. 6). The under-point numbers indicate the variations measured in the observatories.

4.3 Approximation quality of model

Z-component of SV (nT/yr) of Nimegk observatory (**sv Z_0**), model “ROM-Europe-OBS” (**sv Z_M**) and the difference (**sv Z_0 - sv Z_M**) are shown in the Table 3.



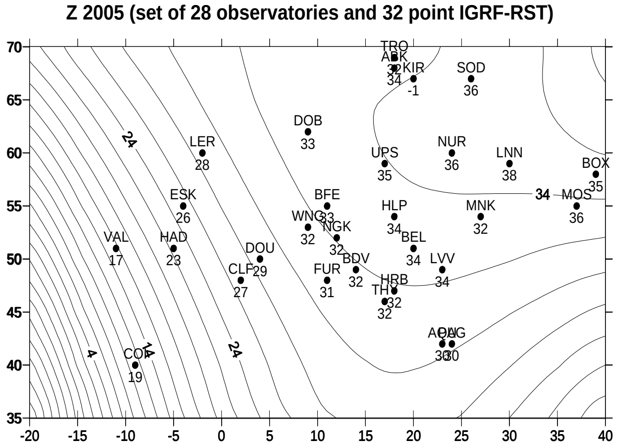


Figure 6. "ROM-Europe-OBS“ (left), "ROM-Europe-OBS+IGRF“ (right)

Table 3. Approximation quality of model

Epoch	**sv Z_0**	**sv Z_M**	**sv Z_0 - sv Z_M**	**Epoch**	**sv Z_0**	**sv Z_M**	**sv Z_0 - sv Z_M**
1980.0	14.000	14.560	.560	1994.0	27.000	26.132	-.868
1981.0	28.000	27.152	-.848	1995.0	22.000	22.437	.437
1982.0	27.000	26.139	-.861	1996.0	22.000	22.945	.945
1983.0	14.000	17.345	**3.345**	1997.0	33.000	32.816	-.184
1984.0	20.000	19.868	-.132	1998.0	40.000	39.601	-.399
1985.0	21.000	20.827	-.173	1999.0	33.000	32.581	-.419
1986.0	27.000	27.417	.417	2000.0	40.000	39.832	-.168
1987.0	23.000	22.734	-.266	2001.0	34.000	33.062	-.938
1988.0	35.000	33.130	-1.870	2002.0	37.000	37.452	.452
1989.0	35.000	34.374	-.626	2003.0	46.000	45.250	-.750
1990.0	22.000	23.059	1.059	2004.0	30.000	31.521	1.521
1991.0	26.000	25.471	-.529	2005.0	32.000	32.036	.036
1992.0	17.000	16.439	-.561	2006.0	23.000	22.539	-.461
1993.0	17.000	17.542	.542	2007.0	28.000	28.954	.954

CONCLUSIONS

- Our previously developed algorithm for modeling the geomagnetic secular variations [1-3] is capable to provide a high-precision spatial-temporal model for Europe;
- Accuracy achieved in our model may be as high as twice in comparing with the global models;
- Our algorithm does not need smoothing of the data, which allows one to retain the high-frequency details of the spectrum of the secular variation;
- With absolute accuracy of 10-15 nT, the model may occur specifically useful for reducing of geomagnetic survey of one epoch to another;
- The model can be used for verification of the experimental geomagnetic data and other tasks.

REFERENCES

1. Golovkov V.P., Burdelnaya I.A., Filippov S.V., Kogoeva G.A. Regional spatial-temporal modeling by using method of natural orthogonal components. *Geomagnetism and aeronomy*, Vol. 34, N. 4, 130-137, 1994.
2. Golovkov V.P. and Newitt L.R. An Evaluation of a Regional Ortogonal Field Model for Canada with Respect to the Canadian Geomagnetic Reference Field. *J. Geomagn. Geoelectr.*, Vol. 49, 337-346, 1997.
3. Burdelnaya I.A., Filippov S.V., Golovkov V.P., Fujiwara S., Tanabe T., Nishi S., Kaidzu M., Natsuzaka S. Regional ortogonal models of the geomagnetic field changes over the Far East. *Earth Planets Space,* Vol. 51, 287-296, 1999.

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