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Initial data for Atlas of Earth's main magnetic field

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Initial data, used for development of Atlas of Earth's Main Magnetic Field (EMMF) from 1500 to 2010, can be divided in five categories: 1. Coefficient values of EMMF expansion in spherical harmonics according to the Gauss method for the period of 1900–2005; 2. Coefficient values of EMMF expansion in spherical harmonics according to the Gauss method for the period of 1500–1900, obtained by modern computations; 3. Coefficient values of EMMF expansion in spherical harmonics according to the Gauss method for the period of 1500–1900, obtained in XIX century; 4. Data of geomagnetic observations, obtained in 1500–1900; 5. Historical world charts of geomagnetic field components, developed in 1500–1900. The first category is related to the International Geomagnetic Reference Field's (IGRF) data of the International Association of Geomagnetism and Aeronomy (IAGA). The second refers to coefficients, obtained in the framework of several modern approaches to modeling historical EMMF, adopted by the world scientific geomagnetic community. The third – to coefficients, calculated by the founder of the method of EMMF expansion in spherical harmonics K. F. Gauss and some of his contemporaries. The fourth deals with historical geomagnetic observations' data of 1500–1900, accumulated into a single data massif over 20 years by many researchers of the entire world, representing as of to date the most complete collection of such data. The fifth category relates to historical world charts of geomagnetic field components, elaborated by navigators and scientists during 1500–1900: isogonic, isoclinic, isodynamic lines. *KEYWORDS: Earth's magnetism, atlas, geomagnetic field models, historical data.*

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The Atlas of Earth's Main Magnetic Field (EMMF) (Atlas) compiles a unified set of physical, general geographic, thematic, including historical, charts of Earth's magnetic field, and also reference materials (texts and tables). Thus it provides a thorough and versatile study of the problem of Earth's magnetic field since 1500.

This Atlas is the first attempt to collect a vast variety of different sources starting from charts of direct instrumental observations to modern field models. The reason is that the data, accumulated over the total period of observations, is stored in different places and formats. There is a need of a unified scientific reference work, describing the field's alterations over hundreds of years.

The Atlas will present this information as world charts with isolines for various EMMF characteristics. The corresponding accuracy is determined by a method and time of its development. Nevertheless, even old charts dating from XVI–XVII centuries are of great interest especially together with comparative research from the modern viewpoint.

The design of the Atlas is based on the data that fall into the following categories:

1. Coefficient values of EMMF spherical harmonic expansion for the period of 1900–2005.

2. Coefficient values of EMMF spherical harmonic ex-

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pansion for the period of 1500–1900, obtained by modern computations.

3. Coefficient values of EMMF spherical harmonic expansion for the period of 1500–1900, obtained in XIX century.

4. Empirical models of Earth's magnetic field for the period of 1500–1800 created before XIX century.

5. Data of geomagnetic observations obtained in 1500–1900.

6. Historical world charts of geomagnetic field components, developed in 1500–1900.

The first category is comprised of International Geomagnetic Reference Field (IGRF) data of International Association of Geomagnetism and Aeronomy (IAGA). It represents a set of expansion coefficients up to degree 10 for the time period from 1900 to 2005 with 5-year time step (http://www.iugg.org/IAGA/).

The second category includes coefficients obtained in the framework of several modern approaches to historical EMMF modeling accepted by international society on geomagnetism. The main models used for creating maps of EMMF components for 1500–1900 are CALS3K.3 [*Korte et al.*, 2009] and GUFM1 [*Jackson et al.*, 2000]. The first one contains coefficients up to degree 10 and covers time interval 1000 B.C. to 1990 A.D. The second one comprises coefficient values up to degree 14 and allows to reconstruct EMMF for the time period from 1590 to 1990 with 1-year time step.

The third category contains coefficients calculated by the founder of EMMF spherical harmonic expansion method J. C. F. Gauss and several of his contemporaries, e.g., Hermann Peter Heinrich Fritsche [*Fritsche*, 1899]. The model of the last consists of coefficients up to degree 7 and refers to years 1600, 1650, 1700, 1780, 1842 and 1885.

The fourth category contains several empirical models of Earth's magnetic field, which were developed by researchers in XVI–XVIII centuries basing on their geomagnetic observations. One of the main representatives of that time was Guillaume le Nautonier who published a book in 1603 with tables giving the value of declination and inclination as a function of latitude and longitude in the two hemispheres [*le Nautonier*, 1603].

The fifth category contains database on historical geomagnetic observations performed in 1510–1930, which were collected into one set during 20 years by many researches all over the world. This activity was headed by A. R. T. Jonkers, A. Jackson and A. Murray who succeeded to obtain the largest such compilation in the world [*Jonkers*, 2003]. It consists of 151,560 declinations, 19,525 inclinations, and 16,219 intensities. The GUFM1 model mentioned above was calculated basing on this dataset.

Finally, the sixth category consists of historical world maps of geomagnetic field components constructed by sailors and researchers in the time period from 1500 to 1900: isogons, isoclines and isodynams. The most significant charts included into this category are listed below:

1. The world chart of 1603 with the first appearance of the geomagnetic equator constructed by [*le Nautonier*, 1603].

2. The first world chart of isogons of magnetic declination constructed by [*Halley and Mortier*, 2002].

3. The first world chart of isoclines of magnetic inclination developed by Swedish physicist Johann Carl Wilcke in 1768 [*Wilcke*, 1978].

4. The first world chart of isodynams of vertical component created by Alexander von Humboldt in 1804 [*Krätz*, 1997].

5. World chart of isodynams of magnetic intensity of 1790–1830 built by Heinrich Berghaus in 1837 [*Rumsey*, 1837].

For global mapping of modeled EMMF components in the Atlas Miller cylindrical projection is used with scale 1:120,000,000.

References

Fritsche, Hermann Peter Heinrich (1899), *Die Elemente des Erdmagnetismus für die Epochen 1600, 1650, 1700, 1780, 1842 und 1885, und ihre saecularen Anderungen: berechnet mit Hülfe der aus allen brauchbaren beobachtungen abgeleiteten Coeffizienten der Gaussischen "Allgemeinen Theorie des Erdmagnetismus"* (in German), GFZ-Potsdam, Germany.

Halley, E., P. Mortier (2002), *Carte Generale De Toutes Les Costes Du Monde Avec Un Indice Des Variations Magnetiques Selon Les Observations Faites En L'Annee 1700 Par Edm. Halley,* Courtesy of Martayan Lan Fine Antique Maps, New York, USA.

Jackson, A., A. R. T. Jonkers, M. Walker (2000), Four centuries of geomagnetic secular variation from historical records, *Philos. Trans. R. Soc. London, Philos. Trans. Math. Phys. Eng. Sci., 358,* 957–990.

Jonkers, A. R. T., A. Jackson, A. Murray (2003), Four centuries of geomagnetic data from historical records, *Rev. Geophys., 41*(2), 1006.

Korte, M., F. Donadini, C. Constable (2009), Geomagnetic field for 0–3 ka, Part II: A new series of time-varying global models, *Geochem., Geophys. Geosys., 10,* Q06008. doi:10.1029/2008GC002297

Krätz, Otto (1997), *Alexander von Humboldt: Wissenschaftler, Weltburger, Revolutionar* (in German), Callwey, München, GFZ-Potsdam, Germany.

le Nautonier, G. (1603), *Mecometrie de l'Eyment: C'est a dire la maniere de mesurer les longitudes par le moyen de l'eyment (avec Priuilege du Roy, Fontaine Bleau, le quinziesme jour d'octobre 1601),* Sainte-Geneviéve Library, France.

Rumsey, David (1837), *Darstellung Der Isodynamischen Linien, nach den Beobachtungen der magnetischen Intensitat, die in den Jahren 1790 bis 1830 gemacht worden sind. 4te Abtheilung: Magnetismus No. 3,* Gestochen von Carl Poppey. Gotha, Justus Perthes, 1837, Gestochen von Edler, David Rumsey Map Collection (www.davidrumsey.com).

Wilcke, Johan Carl (1978), *Försök til en magnetisk inclinations charta (Kartografiskt material) af J. C. Wilcke, Skala 1:70,000,000,* National Library, Sweden.

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