[S4-P01] Global Geomagnetic Secular Variation on Millennial to Million Year Time Scales

Catherine Constable*[1]

[1]University of California, San Diego (UCSD) – 9500 Gilman Drive La Jolla, CA 92093-0225, United States

Abstract

Recent progress in paleomagnetic field modeling has led to the development of global time varying field models on centennial to million year time scales. Such models are used to assess the power spectrum of geomagnetic variations as a function of frequency. Simple power law models for the spectrum can be tied into Giant Gaussian Process Models (GGP) for paleosecular variation (PSV). The GGP models predict expected probability distributions for random temporal samples of geomagnetic elements, such as orthogonal vector field components or paleomagnetic observables such as declination, inclination, and intensity. This work re-visits existing GGP models to incorporate temporal correlations and provide a more realistic statistical description of PSV that can be used as the basis for comparisons with outputs from numerical dynamo simulations.

*Speaker

[S4-P02] Core stratification following a giant impact

Maylis Landeau*[1], Peter Olson[2], Renaud Deguen[3], and Benjamin Hirsh

[1]Department of Applied Mathematics and Theoretical Physics, University of Cambridge (DAMTP) – Wilberforce Road, Cambridge, CB3 0WA, United Kingdom

[2]The University of New Mexico [Albuquerque] – Albuquerque, Nouveau-Mexique 87131, United States

[3]Laboratoire de Géologie de Lyon - Terre, Planètes, Environnement [Lyon] (LGL-TPE) – Université Claude Bernard Lyon 1 – 2, rue Raphaël Dubois, 69622 Villeurbanne Cedex, France

Abstract

A stratified layer below the core-mantle boundary has long been suspected on the basis of geomagnetic and seismic observations. It has been suggested that the outermost core has a stratified layer about 100 km thick that could be due to the diffusion of light elements. Recent seismological evidence, however, supports a layer exceeding 300 km in thickness, which remains of enigmatic origin. We use analog experiments to show that the thick stratified layer at the top of Earth's core could be a vestige of the giant impact that formed the Moon during Earth accretion. We use experiments where a liquid blob, representing the core of the impactor, is released into another liquid consisting of two immiscible layers, representing the magma ocean and the protocore, respectively. We obtain scaling laws for the stratification of the post-impact core as a function of the density and size of the projectile core. These scalings predict that merging between Earth's protocore and a projectile core that is enriched in light elements and 20 times less massive can produce the thick stratification inferred from seismic data. Our experiments therefore favour moon-forming impact scenarios involving a Mars-sized or smaller projectile. Our results also suggest that the Earth's core was stratified in composition after its formation. By implication, the early geodynamo had to overcome this stratification to initiate.

*Speaker

[S4-P03] Geomagnetic jerks – is the secular variation continuous?

Richard Holme*[1], Grace Cox[2,3], and Yan Feng[4]

[1]Department of Earth Ocean and Ecological Sciences [Liverpool] – School of Environmental Sciences, University of Liverpool, 4 Brownlow Street, Liverpool L69 3GP, United Kingdom
[2]Department of Earth Ocean and Ecological Sciences [Liverpool] – School of Environmental Sciences, University of Liverpool, 4 Brownlow Street, Liverpool L69 3GP, United Kingdom
[3]Dublin Institute of Advanced Sciences – Ireland
[4]Nanjing University of Information Science Technology – China

Abstract

Geomagnetic jerks, jumps in the geomagnetic secular acceleration, are widely recognised as the most rapid variation in the field originating from the core. Events of matched timing also occur in variations in length of day (ΔLOD); however, the record suggests that these jumps are discontinuous, which would match not only a jump in the secular acceleration, but also a similar discontinuity in the secular variation (SV). This additional degree of freedom would bring into question the timing patterns of jerks; allowing a jump in SV would allow a jerk to be defined without a spatially dependent lag. It would also change the nature of possible causal processes. We have examined detailed records of the 2003.5 jerk, this being the jerk most clearly in evidence in ΔLOD. We focus on data from China as being an area in which satellite data suggest that the jerk will be seen more clearly. The usual SV time series is derived from annual differences in monthly means; using such data, the jerk is seen clearly in the Chinese data, but forward modelling shows that it is not possible to distinguish whether the jerk also includes a discontinuity in SV. Careful cleaning of external field signals from observatory time series in other locations is unfortunately also not able to distinguish whether a jump in the SV occurs. As a result, we do not have evidence that a jerk includes a jump in SV, but neither can we rule this out.

*Speaker

[S4-P04] The Geomagnetic Field is (probably) not reversing

Maxwell Brown[1,2], Monika Korte[1], Richard Holme*[3], Ingo Wardinski[4], and Sydney Gunnerson[5]

[1]German Research Centre for Geosciences (GFZ) – Telegrafenberg, 14473 Potsdam, Germany
[2]University of Iceland – Institute of Earth Sciences, Sturlugata 7, 101 Reykjavík, Iceland
[3]Department of Earth Ocean and Ecological Sciences [Liverpool] – School of Environmental Sciences, University of Liverpool, 4 Brownlow Street, Liverpool L69 3GP, United Kingdom
[4]Laboratoire de Planétologie et Géodynamique (LPG) – Université de Nantes, Centre National de la Recherche Scientifique : UMR6112 – Bât. 6, 8 et 9Faculté des Sciences et Techniques2 rue de la Houssinière - BP 9220844322 Nantes Cedex 3 (FRANCE), France
[5]University of Iceland – Institute of Earth Sciences, Sturlugata 7, 101 Reykjavík, Iceland

Abstract

It is well known that the geomagnetic field has been decreasing steadily in its intensity since the first direct measurements due to Gauss in 1833. This often leads to suggestions that the field may be entering a reversal. The decline in the field is dominated by the growing South Atlantic Anomaly (SAA); is this evidence that the field is likely to reverse? To examine this, we compare current behaviour with a new model of two magnetic excursions, the Laschamp (at 41 kyr) and Mono Lake (at 36 kyr). Our model spans from 50 kyr to 30 kyr BP, with many new data series compiled as part of a project based at Potsdam, Germany. We find that the development of the excursions is unlike current field behaviour; in particular, before the excursion, the field weakens in both the northern and southern hemispheres. Before the excursions, the field enters a new state during which the power in the dipole at the CMB is similar to the power in other components while still being dipole dominant at Earth's surface. Fluctuations in the field then allow the dipole field to weaken severely, observed at the surface as an excursion. The current field does not display this structure. However, prior to the excursion, there are several periods during which strong SAA-like features appear. For example, such a feature is seen at around 46 kyr, but the field recovers without a full excursion developing. The appearance of the SAA in our model relies not only on intensity records, but is particularly constrained by declination measurements. However, we have confidence in our model structure because features are also reported in isotopic records, both beryllium and chlorine, which also shows a strong feature at the same time. The implication is that the deep SAA allows atmospheric penetration of cosmic radiation, leading to peaks in their isotopic records. As a result, we argue that the current secular variation and development of the SAA is not consistent with past excursions, but instead forms a separate feature of the secular variation, with past SAAs developing and recovering without an excursion. Crucially, however, while have shown that current behaviour does not match past excursions, we have not directly ruled out a reversal. While it seems reasonable that a reversal is an extension of an excursion, it could be that the reversal is a separate

*Speaker

process. However, our model encourages us to develop a similar model from observations for a reversal (perhaps the Bruhnes-Matayama). Only then can we be (more) certain that today's field is not entering a reversal.

[S4-P05] Core field modeling using the ASM experimental vector mode on board the ESA Swarm satellites, recent advances and prospect for future satellite missions

Gauthier Hulot*[1], Pierre Vigneron[2], Jean-Michel Léger[3], and Thomas Jager[3]

[1]Institut de Physique du Globe de Paris (IPGP) – IPG PARIS, Université Sorbonne Paris Cité (USPC), Universite Paris VII - Paris Diderot, CNRS : UMR7154 – IPGP, 1 rue Jussieu, 75005 Paris, France
[2]Institut de Physique du Globe de Paris (IPGP) – IPG PARIS, Université Sorbonne Paris Cité (USPC), Universite Paris VII - Paris Diderot, CNRS : UMR7154 – IPGP, 1 rue Jussieu, 75005 Paris, France
[3]CEA-LETI – CEA-LETI, CEA LETI – France

Abstract

ESA's Swarm constellation, launched in November 2013, is currently the only satellite mission measuring the Earth's magnetic field with enough accuracy to allow detailed reconstruction of the dynamics of the core. It is currently planned to operate until at least 2021 (possibly up to 2024 or even beyond, if the health of the satellites allows for it). Core dynamics, however, involves widely different time scales and full understanding of the many processes involved will likely need many more years of similarly accurate observations from space. Thinking beyond Swarm is thus crucial. In this poster, we will demonstrate the possibility of monitoring the core field by relying on much cheaper satellite missions by relying on a miniaturized version of the ASM magnetometers used on the Swarm satellites. The nominal role of these instruments on the Swarm mission is to provide the 1 Hz absolute scalar needed for calibration of the VFM fluxgate magnetometers, which complement the magnetometry payload. This magnetometry payload strategy is similar to the one that has been used in all previous similar missions (MAGSAT, Oersted, CHAMP). It has been very successful. Indeed, Swarm nominal magnetic data derived from ASM scalar data and VFM vector data have proven to be of excellent quality. But because it relies on two different instruments that need to be placed some distance apart to avoid interference, such a strategy makes it difficult to design satellites much smaller and cheaper than the Swarm satellites. Such issues, however, could be avoided by using the full capacity of the ASM instruments to simultaneously provide collocated 1 Hz scalar and vector data. This capacity has now been demonstrated on Swarm. ASM instruments on Swarm have indeed been run in this experimental mode, providing more than four years of both nominal scalar data needed for the mission and experimental self-calibrated ASM-V vector data. As will be shown, time-varying core field models built using only these ASM-V data compare extremely well with core field models built in exactly the same way using nominal data of the Swarm mission, demonstrating the capacity of this instrument to provide data that would allow monitoring the time-varying core field. Combining this capacity with the fact that such instruments can now be miniaturized and used to design equally accurate nanosatellite missions opens the possibility to monitor the field on a permanent basis for field dynamics investigations, at a much lower cost than previously possible.

*Speaker

[S4-P06] Assimilation of ground and satellite magnetic measurements: inference of core surface magnetic and velocity field changes

Olivier Barrois* , Nicolas Gillet[1], Chris Finlay[2], Magnus Hammer[3], and Yannick Martin

[1]Institut des Sciences de la Terre – Institut des Sciences de la Terre Grenoble-Alpes – France
[2]Technical University of Denmark (DTU) – DTU Space, Diplomvej 371, DK-2800 Kgs. Lyngby, Denmark
[3]Technical University of Denmark (DTU Space) – 2800 Kgs. Lyngby, Denmark

Abstract

We jointly invert for magnetic and velocity fields at the core surface over the period 2000–2017, directly using ground-based observatory time series and measurements from the CHAMP and Swarm satellites. Satellite data are reduced to the form of virtual observatory time series distributed on a regular grid in space. Such a sequential storage helps incorporate voluminous modern magnetic data into a stochastic Kalman filter, whereby spatial constraints are incorporated based on a norm derived from statistics of a numerical geodynamo model. Our algorithm produces consistent solutions both in terms of the misfit to the data and the estimated posterior model uncertainties. We retrieve core flow features previously documented from the analysis of spherical harmonic field models, such as the eccentric anti-cyclonic gyre, and enhanced diffusion patterns under Indonesia. In contrast to the steady flow which is strong under the Atlantic hemisphere but very weak below the Pacific, interannual motions appear evenly distributed over the two hemispheres. Recovered interannual to decadal flow changes are predominantly symmetrical with respect to the equator outside the tangent cylinder. In contrast, under the Northern Pacific we find an intensification of a high latitude jet, but see no evidence for a corresponding feature in the Southern hemisphere. The largest flow accelerations that we isolate over the studied era are associated with an eastward shift of the equatorward, meridional branch of the planetary gyre around 90○ E that is linked to the appearance of a strong eastward equatorial jet below the Western Pacific.

*Speaker

[S4-P07] COV-ARCH/COV-LAKE: ensemble models from archeomagnetic and sediment records for the past 3 millennia

Gabrielle Hellio[1] and Nicolas Gillet*[2]

[1]Laboratoire de Planétologie et Géodynamique de Nantes (LPGN) – Université de Nantes, Institut national des sciences de lÚnivers, Centre National de la Recherche Scientifique : UMR6112, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers – 2 Rue de la Houssinière - BP 92208 44322 NANTES CEDEX 3, France

[2]Institut des Sciences de la Terre (ISTerre) – Université Joseph Fourier - Grenoble 1, Institut français des sciences et technologies des transports, de l'aménagement et des réseaux, Institut national des sciences de lÚnivers, Institut de recherche pour le développement [IRD] : UR219, PRES Université de Grenoble, Université Savoie Mont Blanc, Centre National de la Recherche Scientifique : UMR5275, Université Grenoble Alpes, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers, Institut national des sciences de lÚnivers – BP 53 - 38041 Grenoble cedex 9, France

Abstract

We present two ensembles of geomagnetic field models spanning the last three millennia: COV-ARCH is calculated using all available archeological artefacts and volcanic lava flows; sediment records are added to this dataset to build COV-LAKE. Given the sparse distribution of archeomagnetic observations and their associated large uncertainties, the recovery of magnetic field changes from such data is an ill-posed inverse problem that requires assuming some prior information. This is usually performed by imposing arbitrary regularizations in space and time. Instead, we construct the prior knowledge entering the objective function to be minimized from spatial and temporal statistics of the geomagnetic field, as available from satellites, ground-based observatories and paleomagnetic measurements, and validated by numerical dynamo simulations. Our approach relies on the projection of model coefficients onto temporal cross-covariance functions.

Our results advocate for an almost constant axial dipole decay from 1700 onward, preceded by an era where the dipole trend is weak, possibly slightly positive. We observe in both hemispheres persistent low to high latitude patches over the past 3000 yrs. We also confirm a westward drift of flux patches at the core mantle boundary at a speed of about 0.20○/yr to 0.25○/yr. Despite the sparse data distribution in the Southern hemisphere, the South Atlantic Anomaly appears in both ensembles of models around 1800 AD. A similar low intensity event seems to have appeared below the Indian Ocean over 600 – 1400 AD. Both global models are in general good agreement with regional master curves, though filtering out some of the centennial oscillations. Such models and their associated uncertainties are suited to be used as observations in geomagnetic data assimilation studies.

*Speaker

[S4-P08] Thermal stratification beneath the core mantle boundary

Sam Greenwood*[1], Jon Mound[2], and Chris Davies

[1]University of Leeds (Leeds) – School of Earth Sciences, LS2 9JT Leeds, United Kingdom
[2]University of Leeds – School of Earth Environment, University of Leeds, Leeds, LS2 9JT, United Kingdom

Abstract

A stably stratified region at the top of the Earth's outer core has been suspected for some time based on seismic and geomagnetic observations. This _˜200km thick region is characterised by a lack of vertical motion of the liquid, confining convection to deeper in the core. If such a layer exists, this will affect the production of the magnetic field and has implications for the thermal evolution of the entire planet, yet the nature of the stable layer is currently unknown. As such we aim to investigate the formation and evolution of the layer by developing a 1-D chemical and thermal evolution model for the Earth's core. Our model will account for a stably stratified region and evolve its thickness over time, producing a thermal/chemical profile of the core for the present day. We vary the Core-Mantle-Boundary heat flux and the density jump at the ICB to produce a variety of thicknesses of layers. Comparisons to observations can then place constraints on these variables for the case of purely thermal stratification. Future work will combine thermal stratification with chemical stratification and attempt to match the observational evidence of the layer, providing a 1D profile of its internal structure. This will provide appropriate buoyancy profiles for geodynamo simulations to explore the impacts a stably stratified region has on the spatial and temporal structure of the magnetic field.

*Speaker

[S4-P09] A purely diffusive model for geomagnetic secular variation

Maurits Metman*†[1], Phil Livermore[1], Jon Mound[1], and Ciaran Beggan[2]

[1]Institute of Geophysics and Tectonics, School of Earth and Environment, University of Leeds – School of Earth and Environment Building, Leeds LS2 9JT, United Kingdom

[2]Geomagnetism Team, British Geological Survey – British Geological Survey, The Lyell Centre, Research Avenue South, Edinburgh EH14 4AP, United Kingdom

Abstract

Secular variation (SV) of Earth's core magnetic field is the sum of two contributions: one due to the interaction between core fluid flow and the magnetic field, and the other from magnetic diffusion. Assuming diffusion to be negligible on short time scales (i.e. the frozen-flux assumption), SV observations can constrain the fluid motion at the core's outer boundary, which can in turn be used for short-term forecasts of the magnetic field. However, when these forecasts are applied to periods of 5 years or longer, their cumulative error can be considerable. Ultimately, a model that includes both core flow and diffusion will best explain and forecast the geomagnetic field. As an intermediate step towards the construction of such a hybrid model, we investigate here the antithesis of a frozen-flux model, that of a purely-diffusive model, and its ability to explain the observed SV.
Over a defined time window, we optimise the initial spatial structure of the magnetic field within the outer core such that its subsequent diffusive-evolution best fits the observed geomagnetic observations (here the COV-OBS.x1 mean field model is used). We explore a range of time windows, and the option of including L2 regularisation, penalising large magnetic amplitudes within the core.

Our results show that a purely diffusive model can fit COV-OBS.x1 for 7 years within the error budget during that period, but constrains the magnetic structure only within the top few hundred km of the outer core. Error spectra of the regularised model show relatively large residuals for spherical harmonic degrees 5 and 7, while degrees 8 to 14 are captured particularly well.
We conclude that magnetic diffusion alone can explain SV on yearly to decadal timescales, and therefore offers an equally plausible explanation for the SV compared with the well-known frozen flux description. This suggests that a future hybrid model may fit the SV with much reduced error.

*Speaker
†Corresponding author: eemcm@leeds.ac.uk

[S4-P10] Time-dependent low latitude core flow and geomagnetic field acceleration pulses

Clemens Kloss*[1] and Christopher C. Finlay[1]

[1]Technical University of Denmark (DTU) – DTU Space, Diplomvej 371, DK-2800 Kgs. Lyngby, Denmark

Abstract

We present a new model of time-dependent flow at low latitudes in the Earth's core between 2000 and 2017, derived from magnetic field measurements made at mid and low latitudes onboard the *Swarm* and CHAMP satellites and at ground magnetic observatories. The model, called *CoreFlo-LL.1*, consists of a steady background flow plus a time-dependent flow, the latter being separated into geostrophic and quasi-geostrophic components. Core flow mode amplitudes are determined at 4 month intervals by a robust least squares fit to ground and satellite secular variation data. The *l1* norm of the mode enstrophies and the *l2* norm of the flow acceleration are minimised during the inversion. The resulting flows reproduce distinctive field acceleration pulses at Earth's surface through alternating bursts of converging/diverging non-zonal azimuthal flow acceleration that occur close to the core surface in the equatorial region. Such bursts are particularly prominent in the longitudinal sectors from 80-130○E and 60-100○W throughout the period studied, but are also evident in the equatorial Pacific from 130○E to 150○W after 2012. These bursts are characterised by a distinctive interannual alternation in time, changing sign between intervals of flow acceleration convergence and divergence. This sign change occurs rapidly, in a year or less, and when the structures involved are of large spatial scale they give rise to geomagnetic jerks at the Earth's surface. For example in 2014 *CoreFlo-LL.1* shows a sign change of the azimuthal flow acceleration in the equatorial Pacific, as a region of flow acceleration divergence near 130○E changes to a region of flow acceleration convergence. This is coincident with a divergence in the time-varying azimuthal flow under the equatorial Pacific reaching its maximum amplitude and a strong jerk event being observed in this region at the Earth's surface.

*Speaker

[S4-P11] Earth Deep Interior effects of magnetospheric ring current variations

Crisan Demetrescu*[1] and Venera Dobrica[1]

[1]Institute of Geodynamics, Romanian Academy – 19-21 J.L. Calderon st., Bucharest 37, 020032, Romania

Abstract

We compare oscillations seen in the geomagnetic field (dD/dt) at several timescales, namely sub-centennial (60-90 years), inter-decadal (20-35 years), decadal, and sub-decadal, to variations at the same timescales we show to be present in the Earth's rotation rate (LOD) and in the variations of the parameters describing heliosphere-magnetosphere environment, magnetospheric ring current included. The link between the first two processes has long been accepted in general as a manifestation of the Earth's angular momentum conservation (e.g. Le Mouel et al., 1981); we show it via cross-correlation analysis of the Hodrick-Prescot trend (Hodrick and Prescot, 1997) and of its sub-centennial and inter-decadal constituents (singled out by Butterworth filtering) that characterize the two processes. We advance the hypothesis of possible external drivers of variations observed in declination (dD/dt) and LOD at the two timescales as oscillations generated by long-term variations in the magnetospheric ring current. The intra-decadal (6-year) variation in LOD, considered of internal origin in the current literature, might be a response to intra-decadal variations in geomagnetic declination generated by a similar mechanism as above, thus having an external source.

*Speaker

[S4-P12] Core surface flows depending on electrical conductivity

Masaki Matsushima*†1

[1]Tokyo Institute of Technology – 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8551, Japan

Abstract

The Earth's magnetic field is generated and maintained by the dynamo action driven by fluid flow in the Earth's outer core. The flow pattern influences spatial and temporal variations of the geomagnetic field. Inversely, information of the fluid flow in the core can be provided by geomagnetic field data. Therefore, it is important to derive core flow near the core-mantle boundary (CMB) from geomagnetic field data to reveal core dynamics relevant to a realistic geodynamo model, core-mantle coupling with respect to the length-of-day, and other features in relation to the CMB.

So far, most of core surface flow models have been obtained on the basis of the frozen-flux approximation; the magnetic diffusion term in the induction equation is neglected, which implies that the magnitude of core electrical conductivity is equivalent to infinity. Therefore, it is impossible to investigate a possible effect of core electrical conductivity on the core flow. In reality, core electrical conductivity is finite, and the magnetic diffusion should contribute to temporal variation of magnetic field. In fact, the magnetic diffusion term in the induction equation can be larger than the motional induction and advection terms inside a viscous boundary layer, which should exist at a rigid boundary like the CMB. Hence, to estimate core surface flows, Matsushima (2015) has explicitly incorporated the effect of magnetic diffusion inside the viscous boundary layer, and presumed that the viscous force is influential in considering force balance inside the boundary layer. Below the boundary layer, he has assumed that the effect of magnetic diffusion is neglected, and imposed the tangentially geostrophic constraint or the tangentially magnetostrophic constraint.

In this method, core electrical conductivity can play an important role in estimating core surface flows. The temporal variations in the radial component of magnetic field, Br, at the CMB are caused by magnetic diffusion only because of the no-slip condition for core flows there. The second partial derivative of Br with respect to the radius has thus relation to core electrical conductivity. This means that core electrical conductivity can be important to infer Br inside the core. Furthermore, on the tangentially magnetostrophic constraint, the electrical current density, which is connected with the Lorentz force, has relation to core electrical conductivity. In this presentation, effects of core electrical conductivity on core surface flow models are investigated for various values of core electrical conductivity, which are still controversial. It turns out that mean toroidal flow and mean poloidal flow have different dependence on core electrical conductivity.

*Speaker

†Corresponding author: masaki.matsushima@eps.sci.titech.ac.jp

[S4-P13] Relating the South Atlantic Anomaly and geomagnetic flux patches

Filipe Terra-Nova*[1], Hagay Amit†[1], Gelvam Hartmann[2], Ricardo Trindade[3], and Katia Pinheiro[4]

[1]Laboratoire de Planétologie et Géodynamique de Nantes (LPGN) – CNRS : UMR6112, Laboratoire de Planétologie et Géodynamique de Nantes UMR-CNRS 6112 – 2 Rue de la Houssinière - BP 92208 44322 NANTES CEDEX 3, France

[2]Instituto de Geociências, Universidade Estadual de Campinas – Rua João Pandiá Calógeras, 51, 13083-870, Campinas, Brazil

[3]Departamento de Geofísica, Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo – Rua do Matão, 1226, Cidade Unive rsitária, 05508-090 São Paulo, Brazil

[4]Observatório Nacional – Rua General José Cristino, 77, 20921-400 Rio de Janeiro, Brazil

Abstract

The South Atlantic Anomaly (SAA) is a region of weak geomagnetic field intensity at the Earth's surface, which is commonly attributed to reversed flux patches (RFPs) on the core-mantle boundary (CMB). While the SAA is clearly affected by the reversed flux region below the South Atlantic, we show that the relation between the intensity minimum at Earth's surface and RFPs is not straightforward. We map a field-dependent intensity kernel (Constable, 2007a) to study the relation between the radial geomagnetic field at the CMB and the field intensity at Earth's surface. Synthetic tests highlight the role of specific patches (reversed and normal) in determining the location of the surface intensity minimum and demonstrate that the SAA can indeed be explained by a few intense patches. We show that the level of axial dipolarity of the field determines the stability of the relation between the SAA minimum and RFPs. The present position of the SAA minimum is determined by the interplay among several robust geomagnetic flux patches at the CMB. The longitude of the SAA minimum appears near the longitude of the Patagonia RFP due to the low-latitude normal flux patches (NFPs) near Africa and mid-Atlantic which diminish the effect of the Africa RFPs. The latitude of the SAA minimum is lower than the Patagonia RFP latitude due to the South Pacific high-latitude NFP and the axial dipole effect. The motion of the SAA minimum is explained by the motions and changes in intensity of these robust geomagnetic flux patches. Simple secular variation (SV) scenarios suggest that while the SAA path can be explained by advection, its intensity decrease requires magnetic diffusion. In addition these SV scenarios provide some speculative predictions for the SAA.

*Corresponding author:

†Speaker

[S4-P14] On equatorially symmetric and antisymmetric geomagnetic secular variation timescales

Hagay Amit*[1], Maélie Coutelier[1], and Ulrich R. Christensen[2]

[1]Laboratoire de Planétologie et Géodynamique de Nantes (LPGN) – CNRS : UMR6112, INSU, Université de Nantes – 2 Rue de la Houssinière - BP 92208 44322 NANTES CEDEX 3, France
[2]Max Planck Institute for Solar System Research – Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany

Abstract

It has been suggested that the secular variation (SV) timescales of the geomagnetic field vary as 1/n (where n is the spherical harmonic degree), except for the dipole. Here we propose that the same scaling law applies for SV timescales defined for different symmetry classes of the geomagnetic field and SV. We decompose the field and its SV into symmetric and antisymmetric parts and show in geomagnetic field models and numerical dynamo simulations that the corresponding SV timescales also vary as 1/n, again except for the dipole. The time-average antisymmetric/symmetric SV timescales are larger/smaller than the total, respectively. The difference in SV timescales between these two symmetry classes is probably due to different degrees of alignment of the core flow with different magnetic field structures at the core-mantle boundary. The symmetric dipole SV timescale in the recent geomagnetic field and in long-term time-averages from numerical dynamos is below the extrapolated 1/n curve, whereas before 1965 the geomagnetic dipole tilt was rather steady and the symmetric dipole SV timescale exceeded the extrapolated 1/n curve. We hypothesize that the period of nearly steady geomagnetic dipole tilt between 1810–1965 was anomalous for the geodynamo. Overall, the deviation of the dipole SV timescales from the 1/n curves may indicate that magnetic diffusion contributes to the dipole SV more than it does for higher degrees.

*Speaker

[S4-P15] Sub-Decadal Acceleration in Earth's Main Field

Regupathi Angappan[1], Brian Anderson*[2], Sarah Vines[2], and Sabine Stanley[1]

[1]Johns Hopkins University Department of Earth and Planetary Sciences (JHU EPS) – 301 Olin Hall 3400 N. Charles Street, Baltimore, MD 21218, United States

[2]Johns Hopkins University Applied Physics Laboratory [Laurel, MD] (APL) – 11100 Johns Hopkins Road, Laurel, Maryland, United States

Abstract

The geomagnetic field offers unique insights into the interior structure of Earth, its dynamics and evolution over time. The measured magnetic field is a superposition of magnetic fields derived from various sources; it consists of the field generated in Earth's core, fields derived from the Earth's inductive response, crustal magnetization, and external magnetic fields due to currents in the ionosphere and space environment. The different temporal and spatial scales that each of these sources exhibit can be used to distinguish and study the fields and their dynamics independently. To minimize contributions from other sources, studies of the core field require that data be carefully selected during geomagnetically quiet conditions and accumulated over all geographic longitudes. In this study, we use magnetic field observations from the constellation of Iridium satellites. This dataset offers unprecedented temporal and spatial coverage to probe variations in the Earth's field over sub-decadal time scales that have previously been inaccessible. The Iridium data allow us to derive Gauss coefficients and their amplitudes for individual quiet days using a direct convolution integral over the globe. Using a database of 261 quiet days for 2010 through 2015, we derive time series of the coefficients that allow discrimination between artifacts due to instrumental effects and natural signals indicating previously unobserved sub-decadal accelerations in the Earth's main field. Future work will focus on identifying the sources from which these accelerations arise by determining their locations, wavelengths, intensities, and time-scales.

*Speaker

[S4-P16] Satellite Constellation Data for Study of Earth's Magnetic Field

Brian Anderson*[1], Regupathi Angappan[2], Sarah Vines[1], and Sabine Stanley[2]

[1]Johns Hopkins University Applied Physics Laboratory [Laurel, MD] (APL) – 11100 Johns Hopkins Road, Laurel, Maryland, United States

[2]Johns Hopkins University Department of Earth and Planetary Sciences (JHU EPS) – 301 Olin Hall 3400 N. Charles Street, Baltimore, MD 21218, United States

Abstract

Characterization of the magnetic field generated deep in the Earth is key to understanding dynamics of core circulation and the dynamo. Space-flight measurement of the Earth's magnetic field has normally used highly precise magnetic field measurements from a few spacecraft to acquire data over the entire globe under quiescent conditions over periods of many months and years. The advent of commercial satellite constellations of many 10s of satellites may offer a new avenue for these observations, even with low-grade magnetic field observations, by trading high-precision individual measurement for extensive coverage and statistics. In this analysis, we assess whether the magnetic field data acquired from the Iridium Communications constellation of 70 low Earth orbiting satellites can be used to inform some aspects of our understanding of Earth's main field. The Iridium satellites are in near polar, 86-deg inclination, 780 km altitude, circular orbits, distributed with 11 satellites in each of six orbit planes evenly spaced in longitude. We use data from the first generation Iridium satellites, launched in the late 1990s, and acquired for scientific analysis beginning in January 2010. Although the magnetometers were only digitized with 30 nT resolution, we demonstrate that the uncertainties in the data are random errors so that the massive statistics, 300,000 samples/day over the Earth, allow determination of the average magnetic field in a given 9-deg latitude by 9-deg longitude bin to within about 2 nT. The data reduction, inter-calibration, coverage, quiet interval selection, and random error assessment are presented to motivate an initial assessment of the potentially new science that these data may enable.

*Speaker

[S4-P17] Evolution and probabilistic time analysis of Gauss multipoles originated at CMB and outer core

Sergey Starchenko*[1] and Svetlana Yakovleva[2]

[1]Pushkov Institute of Terrestrial Magnetism, the Ionosphere and Radio Waves Propagation (IZMIRAN) – Kaluzhskoe hwy 4, Troitsk, Moscow, 108840, Russia

[2]Pushkov Institute of Terrestrial Magnetism, the Ionosphere and Radio Wave Propagation (IZMIRAN) – Kaluzhskoe Hwy 4, Troitsk, Moscow, 108840, Russia

Abstract

We express logarithmic time derivatives of geomagnetic multipoles via the fluid velocity and magnetic field in the Earth's core. Those derivatives or exponential rates are estimated by averaged product of velocity gradient with sinus of the angle between velocity and magnetic field vectors. The typical or averaged rates are related to the geodynamo power flow and to other not-well known dynamo parameters allowing their observational estimations. Basing on IGRF and gufm1 models we present four-century evolutions of the rates. It shows no harmonic periodicities with longer flat 'quiet' and shorter pick-shaped 'disturbed' fields. Rates related to axissymetric harmonics are typically two orders of magnitude smaller than the corresponding tesseral rates. The exclusion is axisymmetric quadrupole with extremely large rate about 4/yr at 1650. This and similar picks ensure strongly non-linear geodynamo behavior. Developing our probabilistic time analysis we identify geomagnetic probabilities to grow/decay, expected values for grow/decay and median rates together with periodicity/aperiodicity estimates. The totals grow/decay variations defined as inverse rates are about 25 yrs and median variations are about 400 yrs since 1900. The typical disturbed fields' grow/decay variations about 10 yrs followed by abrupt (1950-1960) or stepwise (1985-2000) return to quiet field. During quiet and moderately disturbed intervals the field is slightly dominated with periodical (or more precisely – half-periodical) behavior. While it jumps from almost absolute periodicity to sufficient aperiodicity during the strongest disturbances with variation about 7 yrs in 1950-1960. From 1900 till 1995 the total probability for the geomagnetic field to grow was higher then to decay, while it preferably decayed since 2000.

*Speaker