Geomagnetic research from Space

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Geomagnetic Research from Space

The sources of the Earth’s magnetic field fall into two categories: The field is generated either from electric currents or from magnetized material. Electric currents can be found throughout the Earth system: The largest of these current systems is found inside the metallic core, but smaller current systems exist within the ionosphere, magnetosphere, and oceans. The current systems within the Earth’s core are generated by a self-sustaining dynamo process and are closely tied to motions in the liquid metal outer core. Two main types of instruments are used to detect the geomagnetic field: fluxgate magnetometers, for measuring the direction of the field, and scalar magnetometers, for measuring its magnitude.

To learn more, scientists have recently looked to Mercury, the only other terrestrial planet besides the Earth with a planet-wide intrinsic magnetic field. Two recent flybys of the Sun’s innermost planet by NASA’s Mercury Surface, Space Environment, Geochronology, and Ranging (MESSENGER) spacecraft have revealed that the large-scale morphology of Mercury’s internal magnetic field [Anderson et al., 2008] is similar to that of Earth’s, although Mercury’s surface field is 2 orders of magnitude weaker. Dominantly dipolar and spin-aligned, the fields of both planets possess significant non-pole moments, manifested as polar and equatorial magnetic “lows.” In the case of Earth, the “low” is referred to as the South Atlantic anomaly, a region marked by a growing reverse flux patch on the top layer of the underlying core.

The South Atlantic anomaly is an oval-shaped geographic region in the southern Atlantic Ocean east of Brazil. Because of the relatively weak magnetic field here, particles from the Van Allen radiation belts have access to lower altitudes, and the associated increased radiation dose adversely affects satellites traveling through the region. This feature has existed since the early 1900s and is closely tied to the overall decrease of the strength of the Earth’s dipole (5% per century) since that time [Jackson and Flindt, 2007]. Another large-scale phenomenon is the rapid motion of the north magnetic dip pole (where the field direction is vertical). Because the horizontal component of the magnetic field in the region of this pole exhibits a very flat gradient, small changes in the field can result in significant displacements of the pole [Maanoo and Donn, 2008].

What causes such changes in the field?

Changes of internal origin can now be witnessed with unprecedented space and time coverage and resolution, providing details of magnetic field generation zones. Knowledge of the magnetic properties of these processes provides scientists with a new perspective on the physics involved in the phenomenon.

CHAMP, one of the main data collectors for the Decade, may reenter the atmosphere by the end of 2009, depending on solar activity. CHAMP was successfully retired by Swarm, the fifth Earth Explorer mission in the European Space Agency’s Living Planet Programme (Figure 1a). The new mission aims to measure the Earth’s magnetic field with unprecedented accuracy through a constellation of three polar-orbiting satellites, designed to maximize the scientific return in the areas of core dynamics, geomagnetization, and geomagnetic field variability, and three-dimensional (3-D) mantle conductivities. It will also investigate electric currents flowing in the magnetosphere and ionosphere, quantity satellite drag in the upper atmosphere, and search for the magnetic signature of ocean circulation.

The Decade has given geomagnetic research a strong foundation. Swarm will build on these past accomplishments and will be a crucial part of the future of geomagnetism through separating the multitudes of sources contributing to the Earth’s magnetic field.

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E. Friis-Christensen, H. Lühr, G. Hulot, and M. Puechey

Understanding the Effects of Internal Magnetic Fields

IN THIS ISSUE

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

Looking to the Future: AGU Council Takes Important Action

At the Joint Assembly in Toronto, the AGU Council discussed three major issues important to the Union’s future: (1) a recommendation for a change in governance structure, (2) the schedule for the search for a new executive director, and (3) the announcement of a new strategic planning initiative.

Why Now?

Last month, I updated you on important data gathering and deliberations completed by the Future Focus Task Force (FFTF), a 13-member committee established to advise the Council of changes needed for AGU’s future, and I promised to share the results with you soon.

While our scientific values and principles stand the test of time, our science is evolving against a dynamic backdrop of rapid economic, political, and technological change. Communicating science through meetings, publications, and public education and outreach needs to keep pace with these changes.

As the FFTF engaged with the membership and other worldwide partners over the last year, it became clear that to keep pace with AGU’s external environment and continue to provide you with the preeminent scientific community you have come to rely on, we must build a rock-solid foundation of (1) an effective governance structure, (2) exceptional executive leadership, and (3) a strategie planning culture that is transparent and inclusive and builds long-term continuity.

Council Gives Unanimous Approval to Governance Changes

For future success, we need a governance structure that works effectively, one that provides appropriate oversight to both the fiscal and legal business of AGU in a continuously evolving marketplace and one that has the structure to sustain the science through meetings, publications, and public education and outreach—the areas that you, our members, tell us are of greatest importance.

Therefore, the AGU Council voted unanimously to (1) create a 16-member AGU board of directors elected by the membership to oversee the business of the Union, and (2) expand the AGU Council to include sections, focus groups, and committee leaders to focus on matters related to the scientific activities of the Union.

The Council believes the changes will: 
 Ensure more efficient and accountable volunteer oversight; 
 Enable adaptation to a dynamic environment; 
 Foster a healthy balance of power between staff and volunteer leaders; 
 Protect inequities many perceive in the current system by including focus groups and committees charged with working together to deliver the science needs of our community.

The proposed changes include important oversight and collaboration between the board of directors and the new Council.

Membership Approval Sought

Changes to governance structure require amendments to our statutes and bylaws and will require an affirmative mail vote of the membership. I have appointed a small task force to draft the amendments needed, and at the same time to conduct an assessment of all of our governing documents to assure compliance with District of Columbia non-profit law and best practices for a scientific society. The Council will review these amendments prior to Council consideration this summer. After Council approval, the new governing documents will be submitted to you for a vote. Our goal is to complete the membership vote by November, so that if you approve them, the new structure can be in place for you to vote in July 2010.

These are important decisions for the future of the Union, and we have a plan in place to present you with full details. Full details will appear in upcoming issues of Eos and on AGU’s Web site.

Council Approves Schedule for Executive Director Search

The AGU Council also approved a schedule for the executive director search, which is part of a year-long succession planning process led by the Executive Review Committee. This search will officially begin in August 2009 and culminate in the selection of a new executive director by spring 2010. Applications will be sought in November–December 2009.

As part of the succession planning process, AGU appointed Robert Van Hook as interim executive director following the retirement of Fred Spilhaus in January 2009. Interim appointments were used as a transition approach for an executive director who is an effective advocate of all AGU members and the public as well as the groundbreaking work the next AGU executive director. In May, Bob provided the Council with an update about his progress. Some highlights include enhanced communications and tools, timely filtering of editorial positions, transfer of communications authorities to sections and focus group leaders, and perhaps most important, short- and long-term initiatives to improve AGU’s Web site and technology—all in response to previously expressed member input and interest.

New Strategic Planning Initiative

Finally, the AGU Council approved a new strategic planning process that represents a fundamental shift from the past, which involved a small group planning on a 2-year cycle and focusing on different terms. Our new strategic planning culture, in contrast, will have a 5-year time horizon and be continually adjusted across multiple leadership cycles, and actively engage AGU members, leaders, and external partners to help shape the future. It will be more transparent in how we plan, budget, and execute, and it will benefit from the latest AGU to undertake; and it will enable us to adopt new approaches needed, retain what is still relevant, and discard what no longer serves us. The centerpiece of this process will be a highly interactive conference for 64 partici- pants at AGU headquarters, 1–3 October 2009.

I hope you share my excitement about the progress we are making toward AGU’s future. Your opinion matters. I invite you to send me your comments at AGU@letters@agu.org. Stay tuned for more details over the summer!

Thom L. Croy, AGU President. Email tlcroy@mit.edu

VOLUME 90    NUMBER 25    23 JUNE 2009

213
Geomagnetic Research
fig. 1a). Schematic of the upcoming Swarm constellation, see within the geomagnetic environment of the Earth. Image courtesy of the European Space Agency (ESA)/Advanced Operations and Engineering Services (AOES) Medialab (B). Magnetic effect of the equatorial ionosphere anomaly after sunset at 400 kilometers in altitude from 23 to 27 October 2001 [Tulivu et al., 2003].

The color bar represents the change in magnetic field intensity, measured in nanoteslas. (c) Crust and upper mantle model of subduction zone and related serpentinite mantle wedge associated with magnetic and gravity anomalies, the latter measured in millihertz. Adapted from Blakely et al. (2005).

Magnetic Signatures of Oceanic Tides

Newly processed programs with satellite magnetic signatures also include the oceanic lunar semidiurnal (M2) tide [Tulivu et al., 2003]. The semidiurnal tide possesses a magnetic signature because seawater is an electrically conducting fluid. The flow of this fluid through the Earth’s main magnetic field in turn generates magnetic fields, but these do not affect the tidal flow to any significant degree.

Isolated features of the Earth’s internal magnetic field include large-scale patterns and fine-scale fluctuations that can be optimized to do the best job of separating internal, external, and induced fields. Extensive simulation studies have shown that these do not affect the tidal flow to any significant degree.

Complications to Measurements

Satellite missions have to be able to resolve the tidal field of the oceans, because the tidal field can be measured by satellites. This is particularly true for the tidal field of the oceans, because the tidal field can be measured by satellites. This is particularly true for the tidal field of the oceans, because the tidal field can be measured by satellites.

Looking to the Future

New discoveries of processes through analysis of satellite magnetic signatures are expected to complement space-based data from Earth’s magnetic core. The Swarm constellation will include two satellites for at least 2 years, measuring the west-east gradient of the magnetic field, and one at higher altitude in a different orbital plane. The new data set will carry investigations conducted during the Decade of Geophysical Field Research that reveal that subduction zone magnetic signatures may be an exception to this rule. Subducting oceanic slabs release water into overlying continental mantle, thereby reducing the density contrast between the slabs and the overlying mantle. Serpentinite often contains abundant magnetic minerals and the formal models suggest that cold, descending slabs cool the mantle to below the Curie temperature of magnetite. Therefore, a magnetic signature is expected to develop in the mantle above the subducting slab. Serpentinite also contains abundant iron and its metamorphism can lead to the formation of a magnetic signature. The thermal state of the mantle above the subducting slab is controlled by the temperature of the subduced slab, the rate of subduction, and the depth of the subduction zone. In addition, the depth of the subduction zone is controlled by the thermal structure of the Earth’s mantle and the temperature of the subducted slab.

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214

VOLUME 90 NUMBER 25 23 JUNE 2009