Geomagnetic research from Space

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GeoMagnetic Research from Space

The Decade of Geopotential Field Research, inaugurated in 1999 with the launch of CHAMP (Challenging Minisatellite Payload), was designed as an international effort to promote and coordinate continuous monitoring of geopotential field variations and usher in a new era in the study of geomagnetism through separating the multitude of sources contributing to the Earth’s magnetic field and gravity fields.

Interpretation of the new magnetic data from the Decade has led to improvements in scientists’ knowledge of the changing small scales of the Earth’s magnetic field, providing details of magnetic field generation within the Earth’s core. The new magnetic data have also been used in the World Digital Magnetic Anomaly Map (WDMAM) project, which ‘images’ the lithosphere’s igneous and metamorphic rocks. Such data, associated theory, and modelling work also led to the discovery of previously unidentified processes with magnetic signatures that can be observed by satellites, including oceanic tides, ionospheric field current systems, and widespread mantle upwelling subduction zones. Knowledge of the magnetic properties of these processes provides scientists with a new perspective of the physics involved in the phenomenon.

CHAMP, one of the main data collectors for the Decade, can receive the atmosphere by the end of 2009, depending on solar activity. CHAMP enabled the in-situ measurement of the East Antarctic Oceanic magnetic anomaly south of the McMurdo Sound, which is a fundamental shift from the past, which provided ancient oceanic magnetization, 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 usher in a new era of geomagnetism through separating the multitude of sources contributing to the Earth’s magnetic field.

Looking to the Future: AGU Council Takes Important Action

At the Joint Assembly in Toronto, the AGU Council approved three major initiatives in response 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.

While our scientific values and principles remain the same, our science is evolving against a dynamic background 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 premier scientific community we have come to rely on, we must build a rock-solid foundation of (1) an effective governance structure, (2) strategic executive leadership, and (3) a strategic planning culture that is transparent and inclusive and builds long-term continuity.

The Council believes the changes will:

- Facilitate sections, focus groups, and committees working together to deliver the science needs of our community.
- 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 nonprofit law and best practices for a scientific society. The task force 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 take effect in July 2010.

These are important decisions for the future of the Union, and we have a plan in place to provide you with full details. Full details will appear in upcoming issues of Eos and on the AGU 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 Hool as interim executive director following the retirement of Fred Spilhaus in January 2009. Interim appointments are a common usage of the term “interim” in modern governance, which includes empowering AGU staff with authority and autonomy; building a strategic plan that is inclusive and builds long-term continuity; providing you with the preeminent scientific society. The Statutes and Bylaws Committee will require an affirmative mail vote of the membership.

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.

Geomagnetic Research

Understanding the Effects of Internal Magnetic Fields

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 other terrestrial planet besides the Earth with a planetwide intrinsic magnetic field. Two recent flybys of the Sun’s innermost planet by NASA’s Mercury Surface, Space Environment, Geodesy, Imaging, and Ranging (MESSENGER) spacecraft 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 nondipole moments, manifested as polar and equatorial “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 dawn of space exploration and is closely tied to the overall decrease of the strength of Earth’s dipole (5% per century) since that time [Jackson and Fink, 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 cause significant displacements of the pole [Mendes and Drummond, 2003].

What causes such changes in the field? Changes of internal origin can now be witnessed with unprecedented space and time precision through geophysical monitoring of geopotential field vari-ations and usher in a new era in the study of geomagnetism through separating the multitude of sources contributing to the Earth’s magnetic field.

--By E. Fred Christiansen, H. Lier, G. Hult, R. Haggmark, and M. Pekeris

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resolution, providing detailed pictures of fast changing small-scale structures in the field produced within the core [Malavieille et al., 2002, 2007]. The dynamics of these features have been shown to affect the length-of-day variation and may testify to unexpect-

A new approach to the analysis of satellite magnetic signatures are expected to continue apace with Swarm. However, the spatial scale of these signals overlaps with those from the core and crust, and they have not yet been isolated.

Complications to Measurements

Satellites' ability to isolate the Earth's internal magnetic fields are a variety of magnetic fields from sources above the neutral atmosphere, in the region called geospace, several of which have been recognized for the first time as a consequence of high-resolution magnetometers and planimetric CHAMP data. Some of these fields are associated with regions of dense plasmas [Lühr et al., 2003] or irregularities within the equa-

Electron density anomalies are prominent north and south of the magnetic equator, especially after sunset. These lead to magnetic field depletions of only one part in 10^8 [Figure 1e], whereas they were not previously recognized. The magnitudes and scale size of these features fall within the range of crustal anomalies, and earlier models of the crustal magnetic field were generally not able to account for these features. Some authors [Blakely et al., 2007] have commented on the effects of solar activity on the magnetic field in the magnetotail, as observed by the CHAMP satellite, [2003]. The characteristics of the magnetic field in the magnetotail are likely to be recognized and isolated. Extensive simulation studies have shown how different characteristics of multiple local times can be optimized to do the best job of separating internal, external, and induced fields.

Looking to the Future

New discoveries of processes through geophysical research may be used to predict the future behavior of the Earth's magnetic field. Work on prediction already began, with promising results [Fournier et al., 2007, 2008]. This approach suggests that the coverage of the Swarm satellites will significantly advance studies of the 3-D electric conductivity of the Earth's crust. Conductivity variations often correspond to large-scale variations in water content, and this approach could complement seismic techniques for imaging subsalted rocks within the mantle. Finally, the magnetic signature of subduction and serpentinitization will allow for detailed study of the possible connection between intraslab earthquakes and the hydrated fore-arc mantle [Blakely et al., 2007].

Expected results from Swarm and new results from CHAMP and Ørsted will be presented at the Second Swarm International Science Meeting, held at the Ger-

References

This paper focuses on the Earth's internal magnetic fields and is based on a number of recent advances. Recent advances in satellite magnetic research have included the development of new algorithms for data assimilation, which have been applied to a variety of data sets, including GRACE, CHAMP, and Swarm. These algorithms have been developed in collaboration with a number of research groups, including the University of California at Los Angeles, the University of Texas at Austin, and the University of British Columbia. The results of these studies have been published in a number of scientific journals, including Geophysical Research Letters, Geophysical Journal International, and Earth and Planetary Science Letters. The authors would like to acknowledge support from the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF).