Title: ***Geomagnetism, Aeronomy and Space Weather – A Journey from the Earth's Core to the Sun***
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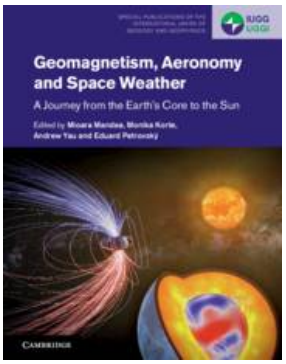

Geomagnetism, Aeronomy and Space Weather is a special publication of the *International Union of Geodesy and Geophysics* (IUGG). I purchased a new copy of the book on eBay at a substantial discount (something I never before thought possible). It is an edited volume of contributions by 64 individual researchers (including the editors) but has some unexplained rough spots. Most of the chapter sections are very well written while a couple are almost incomprehensible because of uncorrected poor grammar or the extreme use of undefined acronyms.

The book is not overly mathematical but it does assume a fairly high level of knowledge about the jargon and terminology used in discussing the technical aspects of the Sun, Earth and magnetic space in between. This book cannot be considered a tutorial; rather, it is a review of current research results put into the context of how prior theory and thinking has been shown in some cases to be wrong or incomplete or, more often, confirmed.

Considering the high pace of research in the subject fields, the book is a very good candidate for a *Living Reviews* format similar to that published by Springer for solar physics but, to my knowledge, no such almost continuous updating is available from Cambridge University Press. For me the book ties in very well with two others on my bookshelf, ***The Solar-Terrestrial Environment*** [Hargreaves] and ***The High-Latitude Ionosphere and Its Effects on Radio Propagation*** [Hunsucker], both of which I have scheduled for future reviews, as well as the several books on space weather that I already have reviewed.

Geomagnetism, Aeronomy and Space Weather consists of five parts: I. Introduction; II. Geomagnetic Field: Sources and Observations; III. Spatial and Temporal Variations of the Geomagnetic Field; IV. Space Weather; and V. Magnetic Fields Beyond the Earth and Beyond Today. As can be seen, the book starts with the Earth's magnetic field, which originates in its core, and moves progressively through Earth's lower and upper atmosphere and the study of aeronomy, and then through the space that is under the Sun's influence (the heliosphere). The focus is on the Sun's and Earth's magnetic fields and how they interact on small and large time and distance scales. Each of the five parts has several chapters for a total of nineteen chapters in all. Each chapter has numbered sections and subsections, which break down the many facets of the book and make it easy to stay oriented. The end of each chapter section contains a large list of references, making this book well cited and useful for further study.

Part I has three chapters that summarize the reasons and objectives of geomagnetic and aeronomy studies including understanding Earth's internal structure, determining Earth's tectonic history, paleomagnetic dating, surveying and exploration, state of Earth's magnetosphere and ionosphere, space weather hazards and the

effects of the geomagnetic field on life (the biosphere). Each one of these is discussed in more detail in later chapters.

One of the most important unanswered questions, which is discussed in Part II in five chapters, is the source of Earth's magnetic field. Many models have been developed and there seems to be some agreement on the basic makeup of the so-called *dynamo* in Earth's interior, but all the models do fail in some aspect. One of the major hinderances is that in-place measurements are impossible – even the deepest drill holes barely scratch Earth's surface. That means Earth's interior has to be inferred from ground level and geospace electromagnetic measurements. A review of the types and methods of measurements is given including the use of spacecraft to study the geomagnetosphere and the solar wind, the latter having a very strong external influence on the geomagnetosphere. It is interesting that seismic measurements are not mentioned in Part II, or anywhere else in this book for that matter, even though these have helped researchers infer the makeup of Earth's core.

I found the sections on magnetotellurics in Part II, chapter 6, Geomagnetic and Electromagnetic Observations at Ground Level, especially interesting. For reasons unknown to me, magnetotellurics are seldom mentioned in books on geomagnetism. Magnetotelluric measurements are used to infer Earth's subsurface electrical conductivity from measurements of the geomagnetic and geoelectric field variations at the surface. Besides a better understanding of Earth's subsurface from a scientific point-of-view, magnetotellurics find real applications in geothermal, mineral and gas and oil explorations and many other fields.

Part III covers in five chapters the changes in space and time (spatial and temporal) of the geomagnetic field. A problem common to most models of Earth's magnetic field is correctly producing the changes over long time periods. Short periods – up to about five years – are well modeled by, for example, the *International Geographic Reference Field model* (IGRF). But even that model stumbles as it has recently due to relatively sudden and unexpected changes in the position of the North Pole. The ionospheric field is briefly discussed in only 12 pages in Part III, chapter 11, in terms of coupling with the thermosphere and the many facets of equatorial, high latitude and polar cap characteristics and auroral processes. As is typical throughout the book, there are discussions in Part III about recent spacecraft missions that were launched to study the time and space aspects of the geomagnetic field. Chapter 13 in Part III, goes into the time aspect including magnetic field reversals and ultra-low and very low frequency magnetic waves.

The physical processes of space weather are covered in Part IV, and this includes the doomsday scenarios associated with the Sun's outbursts and how they affect Earth's magnetic field, us and our technologies. Many books have been written on the subject of space weather and its detrimental effects, including several that I reviewed as part of a space weather series (see {Reeve}), so Part IV held nothing new for me, but it still is a good overview.

Part V goes into how magnetic fields are thought to evolve in planetesimals and exoplanets. At first, I thought this out of place in a book on the Sun and Earth, but most of the discussion refers to planets, moons and smaller bodies in our solar system. The discussions are quite interesting. The discovery of paleo and remnant magnetism in a number of meteorites indicates that strong magnetic fields were present in early solar system bodies, something that, to me, seems unsurprising. The final chapters discuss our understanding of solar variability. Predicting and forecasting both short- and long-term changes in Earth's magnetic field and in the Sun's sunspot cycle are vexing problems far from resolution. One of the most visible problems is predicting the 11- and 22-year

sunspot cycles even though we have hundreds of years of observations. Some individual predictions have come *close but no cigar*. Of course, there are many other problems facing solar and geomagnetic science, not the least of which is the source of the Sun's coronal heating and the processes that produce eruptions such as flares and why sunspots form.

Geomagnetism, Aeronomy and Space Weather is heavily illustrated with charts and graphs. One annoyance is the use of shaded gray-black-white illustrations to replace the original colored illustrations in the references on which the book is based. Some but not all of the original colored plates are grouped in the middle of the book. This is a cost-savings measure used by publishers to give buyers less convenience for more money and something they never use to lower the book price. It is unfortunate that for the most part the inline illustrations are useless because the original references heavily used multi-colored graphs, colored *heat maps* and other color-coded illustrations. Some graphs do use dotted lines to delineate but those are relatively rare. Sure, readers can search out the original source to see the original colored chart but chances are it would be behind a paywall. Even if the original paper is free, why should they have to go to that trouble after paying 140 bucks for the book?

What is obvious from ***Geomagnetism, Aeronomy and Space Weather*** is how relatively little we knew about the Sun and heliosphere before the space age. For example, coronal holes, which are areas on the Sun whose magnetic field lines stretch out into the interplanetary space, were unknown until x-ray telescopes and detectors were launched far enough into space to eliminate the limiting effects of Earth's atmosphere. Specific space missions like the 19-year long Ulysses mission, the 23-year (and counting) long Advanced Composition Explorer (ACE) mission and, more recently, the Parker Solar Probe were launched specifically to study the Sun and solar environment. There have been and still are many other space missions to study Earth's magnetosphere and the Sun-Earth connection. Our increasing awareness of the importance of space weather effects on the safety of human interplanetary travel and spacecraft operation and reliability, and even on our own life on the ground, has really accelerated the number of new and planned space missions dedicated to space weather research. ***Geomagnetism, Aeronomy and Space Weather*** discusses and compares the results from many of them.

Citations:

[Hargreaves] Hargreaves, J., The Solar-Terrestrial Environment, Cambridge University Press, 1992

[Hunsucker] Hunsucker, R. and Hargreaves, J., The High-Latitude Ionosphere and Its Effects on Radio Propagation, Cambridge University Press, 2003

{Reeve} http://www.reeve.com/RadioScience/Radio%20Astronomy%20Publications/Radio_Astronomy_Book_Reviews.htm

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