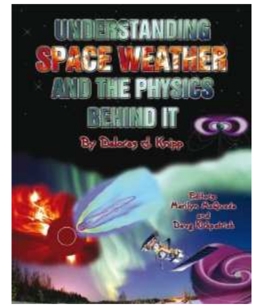

Title: ***Understanding Space Weather and the Physics Behind It***
Author: D. Knipp
Publisher: McGraw-Hill
ISBN: 978-0-07-340890-3
Published: 2011
Length: 727 pages including 14 chapters, 4 appendices and 28 page index
Status: In print
Availability: Online or regular book sellers for about 110 USD, used slightly less

This encyclopedic, softbound book is part of the *Space Technology Series* sponsored by the United States Department of Defense and NASA. ***Understanding Space Weather*** is the fourth and last (at least for now) in a series of space weather books I have reviewed: ***Solar Storms ~ 2000 Years of Human Calamity!*** by S. Odenwald; ***The Sun, The Earth and Near Earth Space ~ A Guide to the Sun-Earth System*** by J. Eddy; and ***An Introduction to SpaceWeather*** by M. Moldwin. I also reviewed a fifth book directly related to space weather: ***From the Sun: Auroras, Magnetic Storms, Solar Flares and Cosmic Rays*** by S. Suess. These reviews may be found at {Reeve}.

The current book is the best and most technical of all those reviewed and, although the most expensive, is well worth the money. The price is about the same for new and used and the price has increased since I purchased the book for 70 USD in late 2012. At that time the book could be rented from Amazon.com for about 35 USD but that option appears to be gone (September 2018). If you do not shop around you could pay over 200 USD. What is real nice about this book is that you do not have to be a physicist to read it but, if you are and want to see the math, you will find enough of it to make you happy.

As we should know by now from the previous books in this review series, space weather encompasses the natural processes that affect Earth and the near-Earth environment, spacecraft and space travel. The Sun and the ever-present solar wind produced by it are in complete control of space weather. The solar wind is moving plasma (charged particles) that carries with it portions of the Sun's magnetic field. The wind interacts in various ways with Earth's atmosphere and magnetosphere. The Sun also produces many types of transient events that affect radio propagation in and through the ionosphere, electric and telecommunications infrastructure, all types of spacecraft, astronauts, airline flight crews and passengers and global navigation satellite systems.

Understanding Space Weather is split into three *units*. Over one-half the book, about 440 pages, is in Unit 1. Unit 1 covers **Space Weather and Its Physics** with nine chapters (1 through 9), four with a name beginning with "Space is a Place ... " and then "... with Weather", "... with Energy", "... with Fields and Currents", "... with Plasma". Other chapters in this unit cover sources of space weather and how the Sun acts on Earth's atmosphere. Chapter 8 in this unit covers Earth's neutral and ionized atmosphere and radio propagation in the ionosphere. The discussion on the detrimental effects of space weather on propagation focuses on high frequency propagation that depends on the ionosphere. Its detrimental effects on UHF propagation and global navigation satellite systems (GNSS) are not covered here (they are briefly mentioned in Unit 3) but there is a good discussion on how Global Positioning System (GPS) signals are used to measure the total electron content (TEC) in the ionosphere.

Other stars besides the Sun contribute to space weather and their effects are discussed in chapter 9. In particular are the cosmic rays from outside our solar system. These usually are noticeable only during solar cycle minimum when their effects are not swamped by the Sun. There is a lot of very interesting information in this detailed but easy-to-read chapter including transient luminous events (TLE), characterization of the ionosphere by latitude and layer and how the ionosphere interacts with the geomagnetosphere. I found my understanding of these complex processes much improved by the many illustrations and examples.

Unit 2 is called **Active Space Weather and Its Physics** and consists of three chapters (10, 11 and 12) in about 150 pages. If readers paid attention in Unit 1, they already know about high-speed streams in the solar wind and high energy particles, heliospheric currents and other phenomena. Unit 2 is where readers learn about the interplanetary medium (IPM) as a *conduit for space weather*, how Earth's magnetosphere is linked to the IPM and disturbances in Earth's atmosphere. The very interesting discussions cover transient disturbances such as coronal mass ejections (CME) and how they are detected and, if geoeffective, tracked on their way to Earth, where their embedded magnetic field can connect with Earth's magnetic field. This reconnection can lead to strong geomagnetic storms. CMEs are not the only perils that travel through the IPM. There also are solar energetic particles (SEP). These consist of heavy charged particles such as protons that are a direct radiation danger to humans in space or in flight at high altitudes. SEPs are accelerated by solar events such as flares and other strong transient events on the Sun

Unit 3, **Impacts and Effects of Space Weather and Space Environment**, has two chapters (13 and 14) and they contain a total of about 100 pages. This is where someone sat down and made a list of all the bad things that can happen as a result of space weather. However, there is very little that informs the reader about severity in relation to event frequency. For example, an unanswered question is: Is a severe event that occurs once every million years worse than a mild event that occurs a million times in one year? And, how should the ill effects of space weather be handled by interested parties in terms of mitigation or severity reduction?

As expected, readers are told in Unit 3 about a transformer failure and major electrical outage that occurred in USA and Canada during a geomagnetic storm in 1989. This is the poster-transformer used in every book on space weather to illustrate what can happen. It turns out that transformers in auroral and sub-auroral regions have shorter lifetimes than at lower latitudes. The cause is thought to be geomagnetically induced currents (GIC) that lead to heating and transformer insulation breakdown. Readers are not given the actual statistics, which I believe is an oversight. The point is that electric utility infrastructure, and telecommunications infrastructure, too, can fail due to space weather.

Most books about space weather tell readers such failures will lead to economic ruin. What this and all the other space weather books fail to appreciate or even mention is that electrical and telecommunication engineers have not been sitting with their feet up on the desk thinking only about payday for the last few decades. The infrastructures in question most likely were much less robust in 1989 than when ***Understanding Space Weather*** was written 20+ years later and they are presumably even more robust now.

What about space weather effects on military systems? These seldom are mentioned in any space weather book and ***Understanding Space Weather*** is no exception. I think the reasons are obvious. However, an incident recently came to light that concerned unintentional detonation of a large number of naval magnetic-influence mines off the cost of Vietnam in August 1972. In this case there had been a series of X-class solar flares produced by a gigantic sunspot, complete with coronal mass ejections and other extreme transient phenomena. It was concluded that the resulting geomagnetic disturbances set off the mines. This led to redesign of the mine detonators. The events are described in a paper written, coincidentally, by the author of ***Understanding Space Weather*** and others {Mines}.

Some readers of this review are terrified by math (at least that is what I have been told). They should know this book uses some algebra to explain concepts, but the book far from being mathematically opaque or dense. It is easy to skip the math and just read on and look at the many illustrations and associated captions. Math often appears only in examples and "focus boxes" but some concepts cannot be adequately explained without it. On the other hand, for readers who cannot get through the day without hauling out Maxwell's equations at least once, Appendix B shows how they may be used to derive the speed of light in a vacuum, and Appendix C has several vector identities that will serve to keep physicists out of trouble. ***Understanding Space Weather*** includes two additional appendices, A and D. Appendix A shows the space weather scales used by NOAA – the geomagnetic storm scale, solar radiation storm scale and radio blackout scale. These also may be found online at {NOAA}. Appendix D tabulates many physical constants and heliophysical and geophysical values such as Planck's constant, Sun's mass and Earth's mass.

Pause for Inquiry challenges appear throughout the text. These questions help the reader test their understanding, and the author thoughtfully provided answers at the end of each chapter. A reader can go through the book at their best speed of comprehension and look to an example, focus box or question for additional detail only if desired.

I do not think this is the kind of book that will be read from beginning to end, but I did find myself reading a particular topic and then moving to the next one and the next one after that, and so on. The book is easy to browse or flip through but most readers will not go far without stopping to read. ***Understanding Space Weather*** is heavily illustrated – there are very few pages that do not have any illustrations. Examples and focus boxes have a colored background so they stand out from the regular text. At the end of each chapter are lists of *Key Words*, answers to the *Pause for Inquiry* questions, references used in the development of the chapter, and lists for *Further Reading and Historical References*. Thankfully, this book does not rely on internet links for references, which become obsolete. The author made no assumptions about the reader's level of knowledge. There is something for everyone even if all you want to do is look at the pictures and drawings.

Understanding Space Weather makes it quite clear that space weather, like terrestrial weather, is driven by the Sun. The details and level of this drive have steadily emerged from initial studies of the Sun at visible wavelengths and later at radio wavelengths with terrestrial radio telescopes and over much wider frequency ranges from satellites and other spacecraft. There is much about the Sun we do not understand and perhaps never will. On the other hand, our understanding advances every day, and this book provides a good benchmark for our knowledge to its date of publication. That raises the question about the book's currency. It was published in 2011, seven years before this review. Sure, investigators have learned a lot since then but I do not think that additional knowledge has made this book obsolete. Far from it. If nothing else, the book provides a solid background for how the Sun works and how it affects Earth. Any serious student of space weather will benefit from ***Understanding Space Weather***.

Citations:
{Mines} https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2018SW002024
{NOAA} https://www.swpc.noaa.gov/noaa-scales-explanation

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

Reviewer - Whitham Reeve is a contributing editor for the SARA journal, Radio Astronomy. He obtained B.S. and M.S. degrees in Electrical Engineering at University of Alaska Fairbanks, USA. He worked as a professional engineer and engineering firm owner/operator in the airline and telecommunications industries for more than 40 years and now manufactures electronic equipment for use in radio astronomy. He has lived in Anchorage, Alaska his entire life. Email contact: whitreeve@gmail.com

Physicists have now provided the first major results of NASA's Magnetospheric Multiscale (MMS) mission, including an unprecedented look at the interaction between the magnetic fields of Earth and the sun. The article describes the first direct and detailed observation of a phenomenon known as magnetic reconnection, which occurs when two opposing magnetic field lines break and reconnect with each other, releasing massive amounts of energy.Â How magnetic reconnection takes place, a critical step in understanding space weather. Date: May 12, 2016.

A new textbook on space weather, Understanding Space Weather and the Physics Behind It, aimed at upper-level undergraduates and beginning graduate students, contains numerous examples of basic physics applications in space weather. We will highlight a few of the examples from the text.Â It is now well understood that space weather represents a significant threat to infrastructure resilience, and is a source of risk that is wide-ranging in its impact and the pathways by which this impact may occur. Although space weather is growing rapidly as a field, work rigorously assessing the overall economic cost of space weather appears to be in its infancy.