Global Warming Science: A Quantitative Introduction to Climate Change and its Consequences. Eli Tziperman. Princeton University Press, Princeton, New Jersey 08540, USA and Woodstock, Oxfordshire OX20 1TR, UK. 2022. xvi + 315 pages. Price: US$ 150.00.

Global warming is one of the great challenges human beings will face in the 21st century. Hence young people are concerned about their future in this changing world. Many popular books have been published on this topic, written not for students but the general public. Such books lack academic rigour and do not provide a quantitative understanding of this complex issue. The faculty who teach an introductory course on climate change do not have many good books to recommend to their students. Topics that should be covered in an introductory course on climate change are vast. There is a need to cover the science of climate change, its impact and issues related to the policy and prediction of the future. The book under review fills this void. The author Eli Tziperman is a Professor at Harvard, USA, well-known for his work in climate science. The book focuses on the science of climate change and its impact. The most important part of an undergraduate textbook is the exercise at the end of each chapter that enables a student to test his understanding of the concepts. One of the best examples of excellent exercises is in the book entitled *Atmospheric Science: An Introductory Survey* (Second edition, Elsevier) by J. M. Wallace and P. V. Hobbs. Tziperman has adopted a different approach. At the end of each chapter, he has given problems that can be solved using the Jupiter Python notebook. This is a novel approach dealing with a large amount of data available in this field. I would have liked a few problems at the end of each chapter that have analytical solutions which can be used to understand the role of various parameters. Chapter 1 provides a guided tour of the topics covered in the book. Chapter 2 discusses the greenhouse effect. The simple model that the author uses does not consider the absorption of solar radiation by the atmosphere. Hence he does not discuss Kirchoff's law, which is the cornerstone of the physics of radiation transfer. Students must understand that the earth's atmosphere absorbs 20% of the incoming solar radiation, but emissivity of the atmosphere is more than 90%. This large difference occurs because the incident solar radiation is in the wavelength range 0.4 to 4 μm, while the radiation emitted by the earth's surface and the atmosphere is in the range 4–100 μm. In this chapter, the author should have provided a quantitative definition of the greenhouse effect. The questions at the end of this chapter are thought-provoking. Chapter 3 discusses the impact of an increase in carbon dioxide on the global mean temperature and the concept of feedback. Chapter 4 deals with the impact of ocean warming, glacier melting and ice-sheet melting on sea-level rise, while chapter 5 discusses ocean acidification. In chapter 6, the changes in ocean circulation are covered. The well-known simple model of Henry Stommel is used to introduce the concept of a tipping point. The role of cloud feedback on the earth's climate is a complex topic. The author has introduced a simple model to explain cloud feedback, but I am not sure if students will find this approach convincing. Chapter 8 discusses the impact of global warming on cyclones (called hurricanes in America). In chapters 9 and 10, the author deals with the changes in ice in the Arctic, Antarctic and Greenland. He considers the retreat of mountain glaciers in chapter 11 and shows that this is mainly on account of human-induced causes and not due to the end of the Little Ice Age. In chapter 12, there is a nice discussion on the impact of climate change on droughts and extreme rainfall events. The impact of global warming on heat waves and forest fires is covered in the last two chapters. This book should have considered past climate change and compared it with future climate change. Any topics missing in the book can be supplemented by the information available in the Intergovernmental Panel on Climate Change reports. I strongly recommend this book to anyone who plans to teach an introductory course on climate change.

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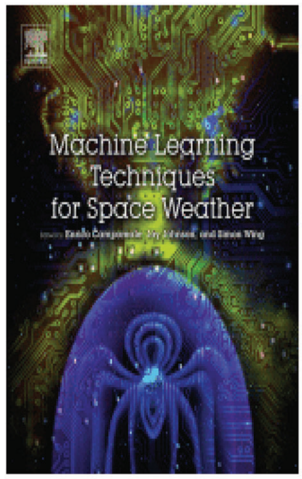

Machine Learning Techniques for Space Weather (1st Edition). Enrico Camporeale, Simon Wing and Jay Johnson. Elsevier, Radarweg 29, PO Box 211, 1000 AE, Amsterdam, The Netherlands. 2018. 454 pages. Price: US$ 140. Paperback ISBN: 9780128-117880.

This book written in a specialized learning style and employing machine learning is designed to provide a brief understanding of space weather information. It attempts to bridge the gap between the applicability of machine learning to broad applications and agreement and mutual understanding by presenting a persuasive machine learning approach to space weather studies. Due to the wide availability of data and primarily open-source datasets, the rising trend and demand in machine learning offer new avenues to comprehend the scientific phenomena of early space weather occurrences. This book is an excellent resource for machine learning applications and has considerable information about space weather. It begins with an understanding of space physics and is complemented by specific applications in regression, classification, and supervised and unsupervised learning.

The book is organized into 16 independent chapters, divided into 3 main sections, presenting the central theme in a well-organized and clear manner. The three primary machine learning applications covered in this book are as follows: (1) automatic event detection, (2) knowledge discovery and (3) modelling. These topics are the most important chapters of this book because they contain essential knowledge and analytical methodologies. The first chapter provides an excellent overview of the entire book. Each chapter includes relevant references that provide extensive and comprehensive coverage of the published literature and electronic sources, and the authors' own works. It strives to provide a technical understanding of how machine learning is convincingly implemented in space weather. The book discusses the processes, choice of the appropriate method and interpretation of the model. The collection of topics is unique and authoritative, and no similar work has been previously published in the specified area.

The first of the two chapters in Part I provides a foundation for readers new to space weather research. Furthermore, there is a well-established context on the significance of the influence on societal and economic implications, and the disclosure of data availability and forecast products.

A brief, high-level review of the three primary subjects in machine learning applications is provided in Part II, which includes information theory, regression and classification, discussed in chapters 3, 4 and 5 respectively. For instance, Johnson *et al.* provide an example of a magnetosphere dynamics study for determining the nonlinear dynamics characteristics, dependencies among variables, and predictability of the system dynamics using information-theoretical tools. The usefulness of the proposed method can also be used to investigate the solar cycle, substorms, and magnetospheric indices which complement other modelling efforts in the space weather studies.

Chapters 6–16 in Part III are devoted to applications using several machine learning algorithms for space weather parameters, including a broad range of categories in solar wind, magnetospheric dynamics, radiation belt electrons, magnetospheric conditions and electron fluxes. Some practical examples are provided to highlight the utility of machine learning. There has been significant development in radiation belt study regarding information-theoretical methods, regression-based forecasting and modelling. Wing *et al.* analyse the outer radiation belt electron to determine which solar wind variables are causally associated using numerous information theory methodologies such as mutual information, conditional mutual information and transfer entropy. The proposed methodologies helped improve model development by selecting input parameters such as solar wind velocity and density, nonstationary dynamics detection and the effect of different factors on the prediction horizon. Kellerman predicts the mega electron-volts (MeV) of electron fluxes in the radiation belts and has devised an autoregressive forecasting verification. Bortnik *et al*. present a feed-forward neural network for magnetospheric conditions, which uses neural networks to estimate electron density in the radiation belt, and specify wave and flux parameters. Boynton *et al*. suggest a method for applying NARMAX to radiation belt electrons and geomagnetic indices. Zhelavskaya *et al*. use neural networks to recreate the plasma density electrons from satellite measurements, which also affect the radiation belt electrons. Several studies have been conducted on geomagnetic indices. Chandorkar *et al*. present a probabilistic forecasting paradigm with Bayesian inference for geomagnetic indices. Consolini studied the time series of geomagnetic activity indicators such as scale-invariance and self-similarity over a wide range of timescales and revealed the complex nature of the Earth's magnetospheric dynamics. More categorization work has been done in magnetospheric particle dispersion, solar flare, coronal hole and solar wind. For example, Souza recommends employing a neural network to classify magnetospheric particle dispersion. Massone *et al*. compare various machine learning algorithms for solar flare forecasting. Delouille *et al*. propose utilizing support vector machines and decision trees to classify the coronal hole. Heidrich-Meisner *et al*. have demonstrated the benefits of the unsupervised machine learning method for solar wind categorization by clustering solar wind with *k*-means, which aids in distinguishing solar wind varieties based on their properties for a better understanding of the physics behind solar winds.

The emphasis of the space weather studies in machine learning applications in this book includes fundamental aspects, followed by applications that are well categorized in sequence. Clear highlights from contributing authors provide comprehensive discussions regarding space physics and space weather principles, machine learning and related applications, which are discussed in detail. Majority of the topics are competently covered. The book identifies the essential technological systems that are at risk of being influenced by the space weather effect and it establishes a plan for future actions in all possible areas covered in many chapters. It also provides an excellent update on space and satellite-related issues such as awareness, traffic management, debris, risk management and new potential technology.

Those interested in the early research in space weather using machine learning should read this book. Although it covers a wide range of topics, each chapter of the book is essentially entirely self-contained, with necessary illustrations aiding in the communication of ideas, and with references provided alongside the text. The reference list is extensive, and one of the most useful features is that each item is hyperlinked to the reference (in an electronic form), which opens in a new window. Accordingly, the author can deliver the material well, even without referencing the equations and figures by their numbers. Other works, such as those listed in this book, may be referred to by the readers requiring a more systematic and comprehensive approach to content explanation. Hence, book is highly recommended.

Overall, the book is outstanding. The discussion presented is pervasive and delivers essential information on the subject matter. Anyone interested in learning from this book will find it to be an engaging read with valuable references that will aid professional engineers, data scientists and researchers. It is also a must-have for readers and scholars who want to learn more about machine learning applications in space weather.

I anticipate additional enhancements in the next edition. For example, inclusion of a glossary list to develop standard terminology in space weather, easing the process of understanding scientific concepts and serving as a valuable reference for novices. It would be good to have more sample programing codes for a practical hands-on experience, thus adding value in continuously communicating the context. Furthermore, a final conclusion that connects all of the presented chapters would have provided more added value in terms of expressing a clear connection for all chapters.

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