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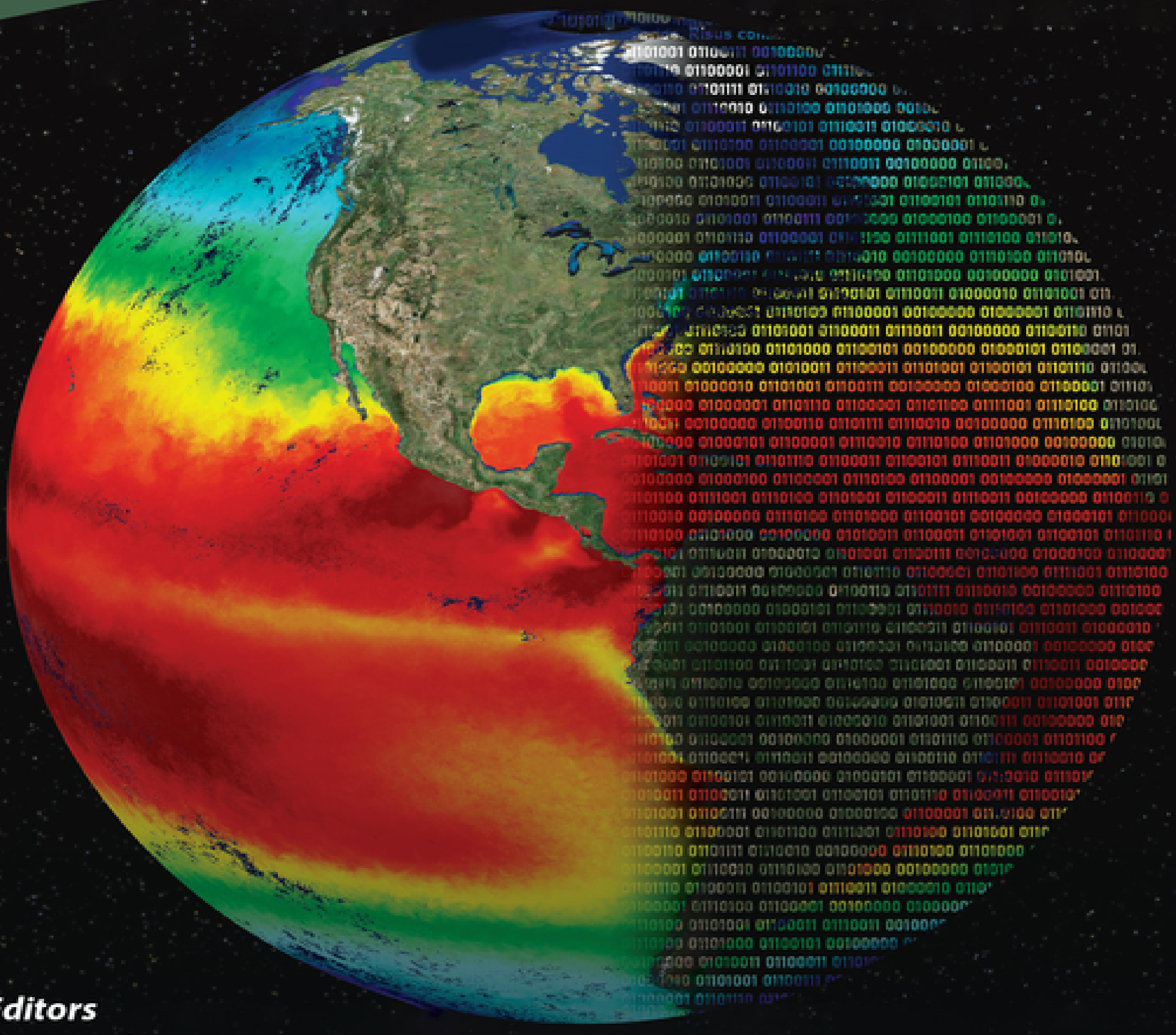

Editors
Thomas Huang
Tiffany C. Vance
Christopher Lynnes

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Table of Contents

List of Tables

List of Illustrations

Chapter 14

Chapter 15

Special Publications 77

BIG DATA ANALYTICS IN EARTH, ATMOSPHERIC, AND OCEAN SCIENCES

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Preface

The seeds for this book were sown in sessions on Big Data Analytics, held at the 2016 Fall Meeting of the American Geophysical Union. At the time, Earth Science data were projected to rise by orders of magnitude in the coming decade, and the community was investigating a variety of emergent technologies and techniques to make the best use of the coming deluge. The chapters of this book are a representative, but by no means exhaustive, collection of those and similar investigations.

Big Earth Data Analytics can be defined as the application of increasingly sophisticated tools for data analysis and display to the rapidly increasing volume of Earth science data to obtain information, and eventually insight. This combines two concepts: Big Earth Data and Data Analytics. Big Earth Data refers both to the volume of data sets and the combination of data from a variety of sources, in a variety of formats, and from a variety of disciplines. To get a sense of the volume, NOAA generates tens of terabytes of data a day from satellites, radars, ships, weather models, and other sources. The National Aeronautics and Space Administration (NASA) Earth Observation archives were growing by more than 30 TB per day in 2020 with daily growth expected to increase to 130 TB/day by 2024 as new satellites launch; and the European Centre for Medium-Range Weather Forecasts (ECMWF) meteorological data archive adds 200 terabytes of new data daily. However, the data are "big" not only in their volume but in their varied formats, disciplines, structures, and formats. As such, they are disruptors to traditional analysis methods, and to the kinds of questions that can be asked by researchers. Data analytics are increasingly driven by the availability of high-volume and heterogeneous data sets. Data size and complexity affect all aspects of data management and usage, requiring new approaches and tools. Despite the challenges to acquire, use, and analyze Big Earth Data, they are already being utilized extensively in climate, oceanographic, and biology related works. Easily available data lead to the ability to analyze longer scale records and patterns over large spatial domains.

Analyses of these data borrow both from traditional scientific analyses and from tools developed for business applications. These types of data analytics are developed by university and other research teams. They are increasingly becoming an area of interest to cloud providers and analytics companies. From Google's Earth Engine for analyzing Earth science data at scale, to the National Oceanic and Atmospheric Administration's (NOAA's) Big Data Program, big data about the Earth and their analysis are increasingly common. Amazon's Elastic MapReduce and SageMaker are common building blocks for cloud-based analysis and Galileo (a.k.a. Service Workbench) is Amazon's latest Web application for interactive analysis. Microsoft Azure ML Studio is another popular cloud-based data analysis solution. Big Earth Data analyses increasingly rely on cloud-based storage and processing capabilities as the volume of the data and the computing resources needed go beyond local resources.

This book is organized into three parts. It starts with the big picture, covering Big Data Analytics Architecture. This part begins with a chapter addressing the geospatial aspect of Big Earth Data from a variety of perspectives. This is followed by a chapter discussing the data management challenges posed by data at scale, particularly in the context of making them available for analysis. This is complemented by a chapter discussing the challenges of scaling up the analysis itself. The following chapters cover large-scale projects such as NASA's Earth Exchange, which enables large scale data analysis in a supercomputing environment and the NOAA Big Data Project, which makes data sets available to end users via several cloud providers. Part I also includes chapters on architectures and fully realized systems, such as Data Cube, NEXUS and the Apache Science Data Analytics Platform, and a NoSQL based platform for exploring and analyzing in situ data.

The second part of the book, Analysis Methods for Big Earth Data, addresses some specific techniques to derive information and/or insight from big data, emphasizing the unique aspects of Earth Observations. Part II begins with two chapters on the use of geospatial statistics for analysis, followed by a chapter melding machine learning with geophysical constraints, and finally a chapter benchmarking different analytical methods for spatiotemporal analysis.

The third part of the book, Big Earth Data Applications, describes a few specific applications of big analysis techniques and platforms: weather and climate model analysis, atmospheric river patterns, Antarctic land surface temperatures extremes, satellite in situ match-ups of oceanographic data, and vessel tracking. This is clearly a small sample of existing applications; rather, the sample shows how some very different analysis methods can find diverse applications in the Earth sciences.

While the application of big Earth data analytics covers a range of applications, a number of common themes in the chapters of this book include (1) the role of the cloud, especially with ever increasing data sizes; (2) limitations and costs of using the cloud, including the unpredictability of costs and the high cost of data egress from the cloud; (3) techniques to maintain data integrity during file transfers; (4) efficiencies via partial reads from Web object storage;