

Preface

The book *MATLAB Recipes for Earth Sciences* is designed to help undergraduates, and PhD students, post-doctoral researchers, and professionals find quick solutions for common problems in data analysis in earth sciences. It provides a minimum amount of theoretical background, and demonstrates the application of all described methods through the use of examples. The MATLAB software is used since it not only provides numerous ready-to-use algorithms for most methods of data analysis but also allows the existing routines to be modified and expanded, or new software to be developed. The book contains MATLAB scripts, or *M-files*, to solve typical problems in earth sciences, such as simple statistics, time-series analysis, geostatistics, and image processing, and also demonstrates the application of selected advanced techniques of data analysis such as nonlinear time-series analysis, adaptive filtering, bootstrapping, and terrain analysis. It comes with a compact disk that contains all MATLAB recipes and example data files as well as presentation files for instructors. The MATLAB codes can be easily modified for application to the reader's data and projects.

This revised and updated Third Edition includes new sections on software-related issues (Sections 2.4, 2.5, 2.8 and 2.9). Chapter 2 was difficult to update since MATLAB has expanded so much over the years, and I have deliberately tried to restrict this chapter to demonstrating of those tools actually used in the book. A second difficulty arose from the current move by *The MathWorks Inc.* to use and incorporate objects and classes in some areas of their MATLAB routines, although there does not seem to be any intention of abandoning the existing procedural code. Again, I have restricted the introduction and use of objects and classes to the absolute minimum, even at the expense of omitting one of the new features of MATLAB. Some functions, however, such as those for distribution fitting use this new concept of object-oriented programming, and I hope that the reader will forgive me for not explaining all the details of the MATLAB code when using it. The other new sections are on distribution fitting (Section 3.9), and on nonlinear and weighted regression (Section 4.10), as these techniques are widely used in, for instance, isotope geochemistry and geochronology. Sections 8.7

to 8.9 introduce some advanced methods in image analysis such the extraction of color-intensity transects from laminated sediments, automatic grain size analysis, and the quantification of charcoal in microscope images. These techniques are frequently used in my research projects and are always in demand during the short courses that I teach.

In order to derive the maximum benefit from this book the reader will need to have access to the MATLAB software and be able to execute the recipes while reading the book. The MATLAB recipes display various graphs on the screen that are not shown in the printed book. The tutorial-style book does, however, contain numerous figures making it possible to go through the text without actually running MATLAB on a computer. I have developed the recipes using MATLAB 7 Release R2010a, but most of them will also work with earlier software releases. While undergraduates participating in a course on data analysis might go through the entire book, the more experienced reader may use only one particular method to solve a specific problem. The concept of the book and the contents of its chapters are therefore outlined below, in order to make it easier to use for readers with a variety of different requirements.

- *Chapter 1* – This chapter introduces some fundamental concepts of samples and populations. It also links the various types of data, and questions to be answered from the data, to the methods described in the succeeding chapters.
- *Chapter 2* – A tutorial-style introduction to MATLAB designed for earth scientists. Readers already familiar with the software are advised to proceed directly to the succeeding chapters. The Third Edition now includes new sections on data structures and classes of objects, on generating M-files to regenerate graphs and on publishing M-files.
- *Chapters 3 and 4* – Fundamentals in univariate and bivariate statistics. These two chapters contain basic concepts in statistics, and also introduces advanced topics such as resampling schemes and cross validation. The reader already familiar with basic statistics might skip these two chapters. The Third Edition now includes new sections on fitting normal distributions to observations and on nonlinear and weighted regression analysis.
- *Chapters 5 and 6* – Readers who wish to work with time series are recommended to read both of these chapters. Time-series analysis and signal processing are closely linked. A good knowledge of statistics is required

to work successfully with these methods. These two chapters are independent of the preceding chapters.

- *Chapters 7 and 8* – I recommend reading through both of these chapters since the processing methods used for spatial data and for images have much in common. Moreover, spatial data and images are often combined in earth sciences, for instance when projecting satellite images onto digital elevation models. The Third Edition now includes new sections on color-intensity transects of laminated sediments, automated grain size analysis from photos and quantifying charcoal in microscope images.
- *Chapter 9* – Data sets in earth sciences often have many variables and many data points. Multivariate methods are applied to a great variety of large data sets, including satellite imagery. Any reader particularly interested in multivariate methods is advised to read Chapters 3 and 4 before proceeding to this chapter.
- *Chapter 10* – Methods to analyze circular and spherical data are widely used in earth sciences. Structural geologists measure and analyze the orientation of slickensides (or striae) on a fault plane. The statistical analysis of circular data is also used in paleomagnetic applications. Microstructural investigations include the analysis of the grain shapes and quartz c-axis orientations in thin sections.

While the book *MATLAB Recipes for Earth Sciences* is about data analysis it does not attempt to cover modeling. For this subject, I recommend the excellent book *Environmental Modeling Using MATLAB* by Ekkehard Holzbecher (Springer 2007), which first introduces basic concepts of modeling and then provides a great overview of modeling examples using MATLAB. Holzbecher's book uses a very similar concept to *MATLAB Recipes for Earth Sciences* as it gives a brief introduction to the theory, and then explains MATLAB examples. Neither book provides a complete introduction to all available techniques, but they both provide a quick overview of basic concepts for data analysis and modeling in earth sciences. One of the few critical reviewers of the First Edition of *MATLAB Recipes for Earth Sciences* raised the question of why I had not included a chapter on finite-element and finite-difference modeling, and on solving differential equations – in his opinion a major omission in the book. However, this is far beyond of the scope of the book and my own expertise. Students and colleagues interested in this topic are directed to the book

MATLAB Guide to Finite Elements: An Interactive Approach by Peter I. Kattan (Springer 2007). While my book may be considered by some to be a little light on image processing, I have included in Chapter 8 three new sections on the analysis of sediment images. I would also strongly recommend to anyone interested in this topic the very successful book *Digital Image Processing Using MATLAB* by Gonzales, Woods and Eddins (Gatesmark Publishing 2009), for which a 2nd edition has just been published.

I have taken all other critiques quite seriously and invite all readers to also comment on the Third Edition: the book is constantly changing and evolving. As the Third Edition appears on the bookshelves I will create a new folder on the hard disk of my computer named *Fourth Edition*, where new ideas will be collected. The book has benefited from the comments of many people, in particular my contributing authors Robin Gebbers and Norbert Marwan, my colleagues Ira Ojala, Lydia Olaka, Jim Renwick, Jochen Rössler, Rolf Romer, Annette Witt, and the students Matthias Gerber, Mathis Hain, Martin Homann, Stefanie von Lonski, Oliver Rach, Marius Walter and Max Zitzmann. I very much appreciate the expertise and patience of Elisabeth Sillmann at *blaetterwaldDesign* who created the graphics and the complete page designs of the book. I am much obliged to Ed Manning for professional proofreading of the text. I also acknowledge Naomi Fernandez from the *Book Program* and Kate Fiore from *Academic Support* at *The MathWorks Inc.*, Claudia Ologge and Annegret Schumann at *The MathWorks GmbH Deutschland*, Christian Witschel, Chris Bendall and their team at *Springer*, and Andreas Bohlen, Brunhilde Schulz and their team at *UP Transfer GmbH*. I also thank the *NASA/GSFC/METI/ERSDAC/JAROS* and the *U. S./Japan ASTER Science Team* and the director Mike Abrams for allowing me to include the ASTER images in this book.

Potsdam, April 2010

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<http://www.springer.com/978-3-642-12761-8>

MATLAB® Recipes for Earth Sciences

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2010, XI, 336 p. With online files/update., Hardcover

ISBN: 978-3-642-12761-8