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## Preface

The enormous progress over the last decades in our understanding of the mechanisms behind the complex system “Earth” is to a large extent based on the availability of enlarged data sets and sophisticated methods for their analysis. Univariate as well as multivariate time series are a particular class of such data which are of special importance for studying the dynamical processes in complex systems. Time series analysis theory and applications in geo- and astrophysics have always been mutually stimulating, starting with classical (linear) problems like the proper estimation of power spectra, which has been put forward by Udney Yule (studying the features of sunspot activity) and, later, by John Tukey.

In the second half of the 20th century, more and more evidence has been accumulated that most processes in nature are intrinsically non-linear and thus cannot be sufficiently studied by linear statistical methods. With mathematical developments in the fields of dynamic system’s theory, exemplified by Edward Lorenz’s pioneering work, and fractal theory, starting with the early fractal concepts inferred by Harold Edwin Hurst from the analysis of geophysical time series, nonlinear methods became available for time series analysis as well. Over the last decades, these methods have attracted an increasing interest in various branches of the earth sciences. The world’s leading associations of geoscientists, the American Geophysical Union (AGU) and the European Geosciences Union (EGU) have reacted to these trends with the formation of special nonlinear focus groups and topical sections, which are actively present at the corresponding annual assemblies.

Surprisingly, although nonlinear methods have meanwhile become an established, but still developing toolbox for the analysis of geoscientific time series, so far there has not been a book giving an overview over corresponding applications of these methods. The aim of this volume is therefore to close this apparent gap between the numerous excellent books on (i) geostatistics and the “traditional” (linear) analysis of geoscientific time series, (ii) the nonlinear modelling of geophysical processes, and (iii) the theory of nonlinear time series analysis.

This volume contains a collection of papers that were presented in a topical session on “Applications of Nonlinear Time Series Analysis in the Geosciences” at the General Assembly of the European Geosciences Union in Vienna from April 15–20, 2007. More than 30 colleagues from various countries used this opportunity to present and discuss their most recent results on the analysis of time series from problems originated in the fields of climatology, atmospheric sciences, hydrology, seismology, geodesy, and solar-terrestrial physics. Oral and poster sessions included a total of 38 presentations, which attracted the interest of many colleagues working both theoretically on and practically with nonlinear methods of time series analysis in the geosciences. The feedback from both presenters and audience has encouraged us to prepare this volume, which is dedicated to both experts in nonlinear time series analysis and practitioners in the various geoscientific disciplines who are in need of novel and advanced analysis tools for their time series. In this volume, presentations shown at the conference are complemented by invited contributions written by some of the most distinguished colleagues in the field.

In order to allow the interested reader to easily find methods that are suitable for his particular problems or questions, we have decided to arrange this book in three parts that comprise typical applications from the fields of climatology, geodynamics, and solar-terrestrial physics, respectively. However, especially in the latter case, the assignment of the different subjects has not always been unique, as there are obvious and rather strong links to the two other fields. Moreover, we would like to note that there are methods whose application has already become very common for studying problems from either of these fields.

The first 7 chapters deal with problems from climatology and the atmospheric sciences. A. Gluhovsky discusses the potential of subsampling for the analysis of atmospheric time series, which usually cannot be described by a simple linear stochastic model. In such cases, traditional estimates of already very simple statistics can be significantly biased, a problem that can be solved by using subsampling methods. J. Mikšovský, P. Pišoft, and A. Raidl report results on the spatial patterns of nonlinearity in simulations of global circulation models as well as reanalysis data. S. Hallerberg, J. Bröcker, and H. Kantz discuss different methods for the prediction of extreme events, a challenging problem of contemporary interest in various geoscientific disciplines. D.B. Percival presents an overview about the use of the discrete wavelet transform for the analysis of climatological time series, with a special consideration of ice thickness and oxygen isotope data. G.S. Duane and J.P. Hacker describe a framework for automatic parameter estimation in atmospheric models based on the theory of synchronisation. W.W. Hsieh and A.J. Cannon report on recent improvements on nonlinear generalisations of traditional multivariate methods like principal component analysis and canonical correlation analysis, which are based on the application of neural networks and allow the extraction of nonlinear, dynamically relevant components. R. Donner, T. Sakamoto, and N. Tanizuka discuss methods for quantifying the complexity of multivariate

time series, and how such concepts can be used to study variations and spatio-temporal dependences of climatological observables. As a particular example, the case of Japanese air temperature records is considered.

The next 5 chapters describe the analysis of time series in the fields of oceanography and seismology. S.M. Barbosa, M.E. Silva, and M.J. Fernandes discuss the issue of characterising the long-term variability of sea-level records in the presence of nonstationarities, trends, or long-term memory. A. Ardalan and H. Hashemi describe a framework for the empirical modelling of global ocean tide and sea level variability using time series from satellite altimetry. J.A. Hawkins, A. Warn-Varnas, and I. Christov use different linear as well as nonlinear Fourier-type techniques for the analysis of internal gravity waves from oceanographic time series. M.E. Ramirez, M. Berrocoso, M.J. González, and A. Fernández describe a time-frequency analysis of GPS data from the Deception Island Volcano (Southern Shetland Islands) for the estimation of local crustal deformation. A. Jiménez, A.M. Posadas, and K.F. Tiampo use a cellular automaton approach to derive a simple statistical model for the spatio-temporal variability of seismic activity in different tectonically active regions.

The final 4 chapters discuss problems related to dynamical processes on the Sun and their relationship to the complex system “Earth”. I.M. Moroz uses a topological method, the so-called template analysis, to study the internal structure of chaos in the Hide-Skeldon-Acheson dynamo, and compares her results with those for the well-known Lorenz model. N.G. Mazur, V.A. Pilipenko, and K.-H. Glassmeier describe a framework for the analysis of solitary wave signals in geophysical time series, particularly satellite observations of electromagnetic disturbances in the near-Earth environment. M. Paluš and D. Novotná introduce a nonlinear generalisation of singular spectrum analysis that can be used to derive dynamically meaningful oscillatory components from atmospheric, geomagnetic, and solar variability signals. Finally, R. Donner demonstrates the use of phase coherence analysis for understanding the long-term dynamics of the north-south asymmetry of sunspot activity.

We would like to express our sincerest thanks to those people who made the idea of this book becoming reality: the authors, who prepared their excellent results for publication in this book and the numerous referees, who helped us evaluating the scientific quality of all contributions and making them being ready for publication. We also acknowledge the support of Springer at all stages during the preparation of this book. We do very much hope that it will inspire many readers in their own scientific research.

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