Preface

The Earth's climate is a complex, multidimensional multiscale system in which different physical processes act on different temporal and spatial scales. Due to the increasing atmospheric greenhouse gas concentrations, global average temperatures increase with time as a result of interactions among components of the climate system. These interactions and the resulting variations in various climate parameters occur on a variety of timescales ranging from seasonal cycles, yearly cycles to those with times measured in hundreds of years. Climatologists and environmentalists are striking to extract meaningful information from huge amount of observational record and simulation data for the climate system. Classic univariate time series analysis is not capable to handle well these complex multidimensional data. Recently, the techniques and methods of multivariate time series analysis have gained great important in revealing mechanisms of climate change, modeling tempo-spatial evolution of climate change and predicting the trend of future climate change.

This book covers the comprehensive range of theory, models, and algorithms of state-of-the-art multivariate time series analysis which have been widely used in monitoring, modeling, and prediction of climate and environmental change. Each chapter focuses on a specific issue of importance. Chapter 1 discusses artificial neural networks which can make full use of some unknown information hidden in high-dimensional climate data, although these information cannot be extracted directly; Chap. 2 discusses multivariate Harmonic analysis which can determine how the total variance of multivariate time series is distributed in frequency. Main techniques and methods include Fourier transform, fractional Fourier transform, space–frequency representation, sparse approximation, spherical harmonics, and harmonic analysis on graphs; Chap. 3 discusses wavelet representation for multivariate time series with time-dependent dominant cycles. Main techniques and methods include multiresolution analysis and wavelets, discrete wavelet transform, wavelet packet, wavelet variance, significant tests, wavelet shrinkage, and shearlets, bandelets, and curvelets. Chapter 4 focuses on stochastic representation and modeling, including stationarity and trend tests, principal component analysis, factor analysis, cluster analysis, discriminant analysis, canonical correlation analysis,

multidimensional scaling, vector ARMA models, Monte Carlo methods, Black–Scholes model, and stochastic optimization; Chap. 5 discusses multivariate spectral analysis and estimation, including periodogram method, Blackman–Tukey method, maximum entropy method, multitaper method, vector ARMA spectrum, and multichannel SSA; Chap. 6 focuses on the development of climate models and related experiments to understand the climate system and climate change; Chap. 7 gives some latest case studies on regional climate change to demonstrate how the methods and tools in Chaps. 1–6 are used; Chap. 8 discusses basic models and key indices on ecosystem and global carbon cycle; Chap. 9 discusses the methods used to reconstruct paleoclimates from proxy data. Chapter 10 introduces three methods to analyze multivariate time series in climate change economics and related latest researches.

Current climate and environmental research is facing the challenge of complex multidimensional data. This book on multivariate time series analysis starts from first principles, always explains various techniques and methods step by step, and shows clearly how to reveal physical meaning from the analysis of observed and stimulated multidimensional data. It has a comprehensive cover and also includes many of the author's unpublished researches. This book is accessible for researchers and advanced students who want to grasp state-of-the-art techniques and methods in multivariate time series analysis. This book builds a cross-disciplinary bridge between various analysis techniques and methods and latest published studies in the wide branches of climatology and environmental science.

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