

Contents

Part I Fundamental Concepts

1	Introduction	3
1.1	Climate Archives, Variables and Dating	5
1.2	Noise and Statistical Distribution	5
1.3	Persistence	8
1.4	Spacing	10
1.5	Aim and Structure of this Book	14
1.6	Background Material	19
2	Persistence Models	31
2.1	First-Order Autoregressive Model	31
2.1.1	Even Spacing	32
2.1.2	Uneven Spacing	34
2.2	Second-Order Autoregressive Model	36
2.3	Mixed Autoregressive Moving Average Model	38
2.4	Other Models	39
2.4.1	Long-Memory Processes	39
2.4.2	Nonlinear and Non-Gaussian Models	40
2.5	Climate Theory	42
2.5.1	Stochastic Climate Models	42
2.5.2	Long Memory of Temperature Fluctuations?	44
2.5.3	Long Memory of River Runoff	48
2.6	Background Material	50
2.7	Technical Issues	58
3	Bootstrap Confidence Intervals	61
3.1	Error Bars and Confidence Intervals	62
3.1.1	Theoretical Example: Mean Estimation of Gaussian White Noise	64

3.1.2	Theoretical Example: Standard Deviation Estimation of Gaussian White Noise	66
3.1.3	Real World	67
3.2	Bootstrap Principle	71
3.3	Bootstrap Resampling	72
3.3.1	Nonparametric: Moving Block Bootstrap	73
3.3.2	Parametric: Autoregressive Bootstrap	77
3.3.3	Parametric: Surrogate Data	78
3.4	Bootstrap Confidence Intervals	78
3.4.1	Normal Confidence Interval	82
3.4.2	Student's t Confidence Interval	82
3.4.3	Percentile Confidence Interval	82
3.4.4	BCa Confidence Interval	83
3.5	Examples	84
3.6	Bootstrap Hypothesis Tests	85
3.7	Notation	88
3.8	Background Material	88
3.9	Technical Issues	100

Part II Univariate Time Series

4	Regression I	107
4.1	Linear Regression	108
4.1.1	Weighted Least-Squares and Ordinary Least-Squares Estimation	108
4.1.2	Generalized Least-Squares Estimation	110
4.1.3	Other Estimation Types	112
4.1.4	Classical Confidence Intervals	113
4.1.5	Bootstrap Confidence Intervals	117
4.1.6	Monte Carlo Experiments: Ordinary Least-Squares Estimation	117
4.1.7	Timescale Errors	122
4.2	Nonlinear Regression	132
4.2.1	Climate Transition Model: Ramp	133
4.2.2	Trend-Change Model: Break	139
4.3	Nonparametric Regression or Smoothing	144
4.3.1	Kernel Estimation	144
4.3.2	Bootstrap Confidence Intervals and Bands	146
4.3.3	Extremes or Outlier Detection	147
4.4	Background Material	151
4.5	Technical Issues	164
5	Spectral Analysis	169
5.1	Spectrum	170
5.1.1	Example: AR(1) Process, Discrete Time	172

5.1.2	Example: AR(2) Process, Discrete Time	172
5.1.3	Physical Meaning	172
5.2	Spectral Estimation	173
5.2.1	Periodogram.....	174
5.2.2	Welch's Overlapped Segment Averaging	178
5.2.3	Multitaper Estimation	179
5.2.4	Lomb–Scargle Estimation	187
5.2.5	Peak Detection: Red-Noise Hypothesis.....	192
5.2.6	Example: Peaks in Monsoon Spectrum.....	194
5.2.7	Aliasing	196
5.2.8	Timescale Errors	197
5.2.9	Example: Peaks in Monsoon Spectrum (Continued).....	198
5.3	Background Material.....	203
5.4	Technical Issues	213
6	Extreme Value Time Series	217
6.1	Data Types.....	218
6.1.1	Event Times	218
6.1.2	Peaks Over Threshold	218
6.1.3	Block Extremes	219
6.1.4	Remarks on Data Selection.....	220
6.2	Stationary Models.....	220
6.2.1	Generalized Extreme Value Distribution	220
6.2.2	Generalized Pareto Distribution.....	223
6.2.3	Bootstrap Confidence Intervals	228
6.2.4	Example: Elbe Summer Floods, 1852–2002	228
6.2.5	Persistence	230
6.2.6	Remark: Tail Estimation.....	232
6.2.7	Remark: Optimal Estimation	233
6.3	Nonstationary Models	233
6.3.1	Time-Dependent Generalized Extreme Value Distribution ...	234
6.3.2	Inhomogeneous Poisson Process.....	235
6.3.3	Hybrid: Poisson–Extreme Value Distribution	247
6.4	Sampling and Time Spacing	250
6.5	Background Material.....	255
6.6	Technical Issues	264

Part III Bivariate Time Series

7	Correlation.....	271
7.1	Pearson's Correlation Coefficient	272
7.1.1	Remark: Alternative Correlation Measures.....	273
7.1.2	Classical Confidence Intervals, Nonpersistent Processes	273
7.1.3	Bivariate Time Series Models	275

7.1.4	Classical Confidence Intervals, Persistent Processes.....	277
7.1.5	Bootstrap Confidence Intervals	277
7.2	Spearman's Rank Correlation Coefficient	283
7.2.1	Classical Confidence Intervals, Nonpersistent Processes	284
7.2.2	Classical Confidence Intervals, Persistent Processes.....	285
7.2.3	Bootstrap Confidence Intervals	285
7.3	Monte Carlo Experiments	287
7.4	Example: Elbe Runoff Variations	292
7.5	Unequal Timescales.....	294
7.5.1	Binned Correlation.....	295
7.5.2	Synchrony Correlation.....	298
7.5.3	Monte Carlo Experiments	299
7.5.4	Example: Vostok Ice Core Records	305
7.6	Background Material.....	306
7.7	Technical Issues	319
8	Regression II.....	321
8.1	Linear Regression	322
8.1.1	Ordinary Least-Squares Estimation	322
8.1.2	Weighted Least-Squares for Both Variables Estimation	325
8.1.3	Wald–Bartlett Procedure	327
8.2	Bootstrap Confidence Intervals.....	328
8.2.1	Simulating Incomplete Prior Knowledge	331
8.3	Monte Carlo Experiments	331
8.3.1	Easy Setting	332
8.3.2	Realistic Setting: Incomplete Prior Knowledge	335
8.3.3	Dependence on Accuracy of Prior Knowledge	335
8.3.4	Mis-Specified Prior Knowledge.....	339
8.4	Example: Climate Sensitivity.....	340
8.5	Prediction	341
8.5.1	Example: Calibration of a Proxy Variable	345
8.6	Lagged Regression	346
8.6.1	Example: CO ₂ and Temperature Variations in the Pleistocene	348
8.7	Background Material.....	352
8.8	Technical Issues	358
 Part IV Outlook		
9	Future Directions	363
9.1	Timescale Modelling.....	363
9.2	Novel Estimation Problems.....	364
9.3	Higher Dimensions.....	365

9.4	Climate Models	366
9.4.1	Fitting Climate Models to Observations	367
9.4.2	Forecasting with Climate Models	368
9.4.3	Design of the Cost Function.....	369
9.4.4	Climate Model Bias	370
9.5	Optimal Estimation	371
9.6	Background Material.....	374
References.....		377
Author Index.....		431
Subject Index		441

Climate Time Series Analysis

Classical Statistical and Bootstrap Methods

Mudelsee, M.

2014, XXXII, 454 p. 103 illus., Hardcover

ISBN: 978-3-319-04449-1