

Hans von Storch • Götz Flöser (Eds.)

Models in Environmental Research

With 103 Figures



Springer

Contents

Chapter 1 Models as Focusing Tools: Linking Nature and the Social World1

by Nico Stehr

<i>Abstract</i>	1
<i>1.1 Models as Focusing Tools: Linking Nature and the Social World</i>	1
<i>1.2 The Practice of Modeling</i>	3
<i>1.3 The Methodology of Modeling</i>	4
<i>1.4 Isomorphism</i>	5
<i>1.5 Quantification</i>	5
<i>1.6 Modeling Societal Sensitivity</i>	6
<i>1.7 Examples of Models</i>	7
<i>1.8 The Poverty of Economics</i>	7
<i>1.9 Hybrid Forms or the Linkage between Social and Physical Processes</i>	9
<i>Appendix: Additional Comments of Modeling Climate and Societal Sensitivity</i>	12

Chapter 2 Models between Academia and Applications.....17

by Hans von Storch

<i>Abstract</i>	17
<i>2.1 Introduction</i>	17
2.1.1 Laboratory Model	18
2.1.2 Miniaturisation.....	18
2.1.3 Numerical Models	21
2.1.4 Specifics of Environmental Research	25
<i>2.2 General Properties of Models</i>	27
<i>2.3 Purpose of Models</i>	30
2.3.1 Quasi-realistic Models Surrogate Reality	30
2.3.2 Cognitive Models: Reduction of Complex Systems	32
<i>2.4 Conclusions</i>	32
<i>Acknowledgments</i>	33

Chapter 3 Basic Concepts in Dynamical Modeling35

by Peter Müller

<i>Abstract</i>	35
<i>3.1 Introduction</i>	35
<i>3.2 Classical Mechanics</i>	36
3.2.1 Equations of Motion	36
3.2.2 Hamiltonian Dynamics.....	37
3.2.3 Integrable Systems.....	38

3.2.4	Flow in Phase Space.....	39
3.3	<i>Ideal Fluids</i>	40
3.3.1	Lagrangian Description	41
3.3.2	Eulerian Description.....	42
3.4	<i>Thermodynamics</i>	43
3.4.1	The Second Law of Thermodynamics.....	43
3.4.2	Diffusion	44
3.5	<i>Dynamical Systems</i>	45
3.6	<i>Statistical Mechanics</i>	47
3.6.1	Combinatorics.....	47
3.6.2	H-theorem.....	49
3.7	<i>Stochastic Processes</i>	52
3.7.1	Random Walk.....	52
3.7.2	Autoregressive Process	53
3.7.3	Langevin Equation.....	54
3.7.4	Stochastic Differential Equations	55
3.8	<i>Discussion</i>	56
	<i>Acknowledgments</i>	57
 Chapter 4 Process-oriented Models in Physical Oceanography.....		59
by Aike Beckmann		
	<i>Abstract</i>	59
4.1	<i>Introduction</i>	59
4.1.1	Philosophy of Process Models	60
4.1.2	Process Model Strategies	61
4.1.3	Parameter Space	62
4.2	<i>Examples</i>	63
4.2.1	Linear and Linearised Models.....	63
4.2.2	Nonlinear Models	70
4.2.3	Interdisciplinary Process Models.....	81
4.2.4	Sea Ice Models.....	83
4.3	<i>Concluding Remarks</i>	84
4.3.1	Outlook	84
4.3.2	Comments on Numerical Process Models.....	85
	<i>Acknowledgments</i>	86
	<i>Appendix</i>	86
A	HPE	86
B	QG	87
C	SWE	88
D	RG	88
 Chapter 5 Mathematical Models in Environmental Research.....		89
by H. Langenberg		
5.1	<i>Introduction</i>	89
5.2	<i>Mathematical Models – an Overview</i>	89

5.2.1	Box Models.....	90
5.2.2	Cellular Automata.....	92
5.2.3	Differential Equations.....	94
5.2.4	Other Techniques.....	94
5.3	<i>From Nature to Navier-Stokes' Equations</i>	94
5.3.1	The Ocean Currents.....	95
5.3.2	Wind and Sea Bottom.....	96
5.3.3	The Coriolis Force.....	96
5.3.4	River Runoff, Solar Heating, Surface Cooling.....	97
5.3.5	Sea Surface Elevation.....	97
5.3.6	Continuity.....	99
5.3.7	The Resulting Equations.....	99
5.3.8	Difficulties.....	100
5.3.9	Boundary Conditions.....	101
5.3.10	Simplifications.....	101
5.4	<i>From Differential Equations to a Numerical Representation</i>	102
5.4.1	Discretisation.....	103
5.4.2	Simulation.....	104
5.4.3	Simplifications.....	106
5.5	<i>Summary</i>	106
	<i>Acknowledgments</i>	107

Chapter 6 Physical Modeling of Flow and Dispersion109

by Michael Schatzmann

6.1	<i>Introduction</i>	109
6.2	<i>Properties of Wind-Tunnel Boundary Layers</i>	109
6.3	<i>Dimensional Analysis</i>	113
6.4	<i>Matching of Similarity Requirements</i>	116
6.5	<i>Experiments</i>	117
6.6	<i>Variation of Similarity Parameters</i>	116
6.7	<i>Parameterisation of Thermodynamic Processes</i>	120
6.8	<i>Small-Scale/Full-Scale Comparisons</i>	122
6.9	<i>Investigation of Obstacle Effects</i>	124
6.10	<i>Conclusions</i>	126
	<i>Acknowledgements</i>	126

Chapter 7 Conceptual Models for Ecology-Related Decisions127

by Karl-Heinz van Bernem

	<i>Abstract</i>	127
7.1	<i>Introduction</i>	127
7.2	<i>The Wadden Sea – a Sensitive Environment</i>	129
7.3	<i>The Environmental Sensitivity Index (ESI) for Wadden Sea Areas</i>	130
7.3.1	The Evaluation.....	131
7.3.2	Evaluation of Individual Categories.....	132

7.3.3	General Evaluation	135
7.4	<i>Environmental (Ecological) Risk Assessment (ERA)</i>	137
7.4.1	Environmental (Ecological) Impact Assessment (EIA).....	139
7.4.2	The Construction Measures.....	140
7.4.3	The Integrated Ecological Monitoring-Investigations	142
7.5	<i>Ecological Monitoring of the Benthos</i>	142
7.6	<i>Conclusions</i>	145
Chapter 8	Models in the Mechanics of Materials	147
by Wolfgang Brocks		
	<i>Abstract</i>	147
8.1	<i>Introduction</i>	147
8.2	<i>Modeling in the Mechanics of Materials</i>	148
8.2.1	Testing.....	148
8.2.2	The Theory of Continuum Mechanics	153
8.2.3	Numerical Analysis	157
8.3	<i>Examples</i>	159
8.3.1	The Tensile Test	159
8.3.2	Micromechanical Modeling	161
8.4	<i>Conclusions</i>	164
Chapter 9	Mathematical Morphology	167
by Michel Schmitt		
	<i>Abstract</i>	167
9.1	<i>Introduction</i>	167
9.2	<i>An Introductory Example</i>	168
9.3	<i>The Morphological Tool Box</i>	169
9.3.1	The Four Operations.....	170
9.3.2	Characterisation of Openings and Filtering.....	172
9.3.3	Watersheds.....	174
9.3.4	The Construction Principle	176
9.3.5	Segmentation Programme	177
9.4	<i>Quantification and Morphological Measurements</i>	178
9.4.1	Granulometries, Spectral Function and Curve by Erosion	178
9.5	<i>Random Models</i>	180
Chapter 10	Statistical Interpolation Models	185
by Hans Wackernagel and Michel Schmitt		
	<i>Abstract</i>	185
10.1	<i>Introduction</i>	185
10.2	<i>The Random Function Model</i>	186
10.2.1	The Variogram.....	187
10.2.2	Kriging.....	189

10.3	<i>Multivariate Geostatistics</i>	191
10.3.1	Cokriging	191
10.3.2	Data Configurations.....	192
10.3.3	Isotopy: Intrinsic Correlation	193
10.3.4	Coregionalisation Models.....	193
10.3.5	Heterotopy: External Drift.....	194
10.3.6	Heterotopy: Collocated Cokriging	194
10.4	<i>Non-Stationary Model</i>	194
10.4.1	Intrinsic Random Functions of Order k	195
10.4.2	Kriging with Drift.....	197
10.4.3	Dual Kriging	199
10.4.4	Splines.....	200
10.5	<i>Conclusion</i>	201
 Chapter 11 Statistics – an Indispensable Tool in Dynamical Modeling		203
by Hans von Storch		
	<i>Abstract</i>	203
11.1	<i>Environmental Research</i>	203
11.2	<i>State Space Models</i>	204
11.3	<i>Statistics and Quasi-realistic Models</i>	205
11.3.1	Parameterisations.....	205
11.3.2	Analyzing Integrations of Quasi-Realistic Models	208
11.3.3	Merging Dynamical Knowledge and Observational Evidence.....	212
11.4	<i>Reduced “Cognitive” Models</i>	213
11.4.1	Principal Interaction Patterns	214
11.4.2	Principal Oscillation Pattern Analysis	215
	<i>Acknowledgments</i>	217
 References		219
 Subject Index		233