

Contents

Preface		xi
I	A Planet to Discover	1
1	Planet Earth	3
1.1	How Old Is the Earth? <i>Christiane Rousseau</i>	3
1.2	The Equation of Time <i>Christiane Rousseau</i>	4
1.3	How Inge Lehmann Discovered the Inner Core of the Earth <i>Christiane Rousseau</i>	5
1.4	Why Do Earthquakes Change the Speed of Rotation of the Earth? <i>Christiane Rousseau</i>	6
1.5	Mathematicians Listen as the Earth Rumbles <i>Christiane Rousseau</i> .	7
1.6	Flow through Heterogeneous Porous Rocks: What Average Is the Correct Average? <i>Todd Arbogast</i>	9
1.7	Imaging with Gaussian Beams <i>Nick Tanushev</i>	13
1.8	Thinking of Trees <i>Ilya Zaliapin</i>	15
2	Ocean and Atmosphere	19
2.1	Atmosphere and Ocean Dynamics through the Lens of Model Systems <i>Greg Lewis</i>	19
2.2	Atmospheric Waves and the Organization of Tropical Weather <i>Joseph Biello</i>	21
2.3	Nonlinear Waves and the Growth of a Tsunami <i>Estelle Basor</i>	23
2.4	Universality in Fractal Sea Coasts <i>Christiane Rousseau</i>	24
2.5	Ice Floes, Coriolis Acceleration, and the Viscosity of Air and Water <i>Robert Miller</i>	25
2.6	There Will Always Be a Gulf Stream — An Exercise in Singular Perturbation Technique <i>Robert Miller</i>	28
2.7	The Great Wave and Directional Focusing <i>John M. Dudley and Frédéric Dias</i>	31
2.8	Controlling Lightning? <i>Christiane Rousseau</i>	33
2.9	Mathematician Stepping on Thin Ice <i>Deborah Sullivan Brennan</i> . .	35
3	Weather and Climate	37
3.1	Numerical Weather Prediction <i>Wei Kang</i>	37
3.2	Lorenz's Discovery of Chaos <i>Chris Danforth</i>	39
3.3	Predicting the Atmosphere <i>Robert Miller</i>	40

3.4	Arctic Sea Ice and Cold Weather	<i>Hans Kaper</i>	41
3.5	Extreme Weather Event	<i>William J. Martin</i>	44
3.6	Wimpy Hurricane Season	<i>Brian McNoldy</i>	45
3.7	Extreme Events	<i>Hans Kaper</i>	46
3.8	The Need for a Theory of Climate	<i>Antonello Provenzale</i>	48
3.9	Mathematics and Climate	<i>Hans Kaper</i>	50
3.10	Climate Science without Climate Models	<i>Hans Kaper</i>	53
3.11	Supermodeling Climate	<i>James Crowley</i>	54
3.12	Reconstructing Past Climates	<i>Bala Rajaratnam</i>	55
3.13	(Big) Data Science Meets Climate Science	<i>Jesse Berwald, Thomas Bellsky, and Lewis Mitchell</i>	57
3.14	How Good Is the Milankovitch Theory?	<i>Hans Kaper</i>	58
3.15	Earth's Climate at the Age of the Dinosaurs	<i>Christiane Rousseau</i>	60
3.16	Two Books on Climate Modeling	<i>James Crowley</i>	61
4	Beyond Planet Earth		65
4.1	Chaos in the Solar System	<i>Christiane Rousseau</i>	65
4.2	KAM Theory and Celestial Mechanics	<i>Alessandra Celletti</i>	66
4.3	New Ways to the Moon, Origin of the Moon, and Origin of Life on Earth	<i>Edward Belbruno</i>	68
4.4	Low-Fuel Spacecraft Trajectories to the Moon	<i>Marian Gidea</i>	71
4.5	Where Did the Moon Come From?	<i>Christiane Rousseau</i>	73
4.6	Data Assimilation and Asteroids	<i>Robert Miller</i>	75
4.7	Understanding the Big Bang Singularity	<i>Edward Belbruno</i>	76
II	A Planet Supporting Life		79
5	Biosphere		81
5.1	The Mystery of Vegetation Patterns	<i>Karna Gowda</i>	81
5.2	How Vegetation Competes for Rainfall in Dry Regions	<i>Frank Kunkle and Karthika Muthukumaraswamy</i>	83
5.3	Biological Events in Our Water Systems	<i>Matthew J. Hoffman and Kara L. Maki</i>	85
5.4	Bird Watchers and Big Data	<i>Wesley Hochachka</i>	86
5.5	It's a Math-Eat-Math World	<i>Barry Cipra</i>	89
5.6	Ocean Acidification and Phytoplankton	<i>Arvind Gupta</i>	90
5.7	Ocean Plankton and Ordinary Differential Equations	<i>Hans Kaper</i>	91
5.8	Prospects for a Green Mathematics	<i>John Baez and David Tanzer</i>	93
6	Ecology and Evolution		97
6.1	Mathematics and Biological Diversity	<i>Frithjof Lutscher</i>	97
6.2	Why We Need Each Other to Succeed	<i>Christiane Rousseau</i>	98
6.3	The Unreasonable Effectiveness of Collective Behavior	<i>Pietro-Luciano Buono</i>	100
6.4	From Individual-Based Models to Continuum Models	<i>Hans Kaper</i>	102
6.5	Optimal Control and Marine Protected Areas	<i>Kent E. Morrison</i>	104
6.6	Linear Programming for Tree Harvesting	<i>Peter Lynch</i>	105

III	A Planet Organized by Humans	107
7	Communication and Representation	109
7.1	The Challenge of Cartography <i>Christiane Rousseau</i>	109
7.2	What Does Altitude Mean? <i>Christiane Rousseau</i>	110
7.3	Drawing Conformal Maps of the Earth <i>Christiane Rousseau</i>	111
7.4	Changing Our Clocks <i>Hans Kaper</i>	113
7.5	High-Resolution Satellite Imaging <i>Paula Craciun and Josiane Zerubia</i>	115
7.6	Microlocal Analysis and Imaging <i>Gaik Ambartsoumian, Raluca Felea, Venky Krishnan, Cliff Nolan, and Todd Quinto</i>	116
7.7	How Does the GPS work? <i>Christiane Rousseau</i>	120
8	Energy	123
8.1	Integrating Renewable Energy Sources into the Power Grid <i>Wei Kang</i>	123
8.2	Mathematical Insights Yield Better Solar Cells <i>Arvind Gupta</i>	124
8.3	Mathematical Modeling of Hydrogen Fuel Cells <i>Brian Wetton</i>	126
8.4	Mathematical Models Help Energy-Efficient Technologies Take Hold in a Community <i>Karthika Muthukumaraswamy</i>	130
8.5	Geothermal Energy Harvesting <i>Burt S. Tilley</i>	132
8.6	Of Cats and Batteries <i>Russ Caflisch</i>	133
9	Economics and Finance	135
9.1	Dynamic Programming for Optimal Control Problems in Economics <i>Fausto Gozzi</i>	135
9.2	Solar Renewable Energy Certificates <i>Michael Coulon</i>	137
9.3	How Much for My Ton of CO ₂ ? <i>Mireille Bossy, Nadia Maïzi, and Odile Pourtallier</i>	140
9.4	The Social Cost of Carbon <i>Hans Engler</i>	141
9.5	Measuring Carbon Footprints <i>Hans Kaper</i>	142
9.6	Musings on Summer Travel <i>David Alexandre Ellwood</i>	143
9.7	The Carbon Footprint of Textbooks <i>Kent E. Morrison</i>	146
9.8	Sustainable Development and Utilization of Mineral Resources <i>Roussos Dimitrakopoulos</i>	147
9.9	Scientific Research on Sustainability and Its Impact on Policy and Management <i>Mark Lewis</i>	149
10	Human Behavior	151
10.1	Predicting the Unpredictable — Human Behaviors and Beyond <i>Andrea Tosin</i>	151
10.2	Budget Chicken <i>Kent E. Morrison</i>	152
10.3	Mathematics and Conflict Resolution <i>Estelle Basor</i>	154
10.4	Modeling and Understanding Social Segregation <i>Laetitia Gawvin and Jean-Pierre Nadal</i>	155
10.5	Modeling the Evolution of Ancient Societies <i>Estelle Basor</i>	157
10.6	Networks in the Study of Culture and Society <i>Elijah Meeks</i>	157
IV	A Planet at Risk	161
11	Climate Change	163
11.1	The Discovery of Global Warming <i>Hans Kaper</i>	163

11.2	Letter to My Imaginary Teenage Sister – 1	<i>Samantha Oestreicher</i>	. 164
11.3	Letter to My Imaginary Teenage Sister – 2	<i>Samantha Oestreicher</i>	. 166
11.4	Global Warming and Uncertainties	<i>Juan M. Restrepo</i>	. . . . . 167
11.5	How to Reconcile the Growing Extent of Antarctic Sea Ice with Global Warming	<i>Hans Kaper</i>	. . . . . 169
11.6	Rising Sea Levels and the Melting of Glaciers	<i>Christiane Rousseau</i>	. 170
11.7	Global Warming — Recommended Reading	<i>Hans Kaper</i>	. . . . . 170
12	Biological Threats		173
12.1	Mathematics behind Biological Invasions – 1	<i>Mark Lewis</i>	. . . . . 173
12.2	Mathematics behind Biological Invasions – 2	<i>James Crowley</i>	. . . . . 174
12.3	Surges in Latent Infections: Mathematical Analysis of Viral Blips	<i>Karthika Muthukumaraswamy</i>	. . . . . 175
12.4	Prevention of HIV Using Drug-Based Interventions	<i>Jessica M. Conway</i>	. . . . . 176
12.5	Random Networks and the Spread of HIV	<i>Estelle Basor</i>	. . . . . 179
12.6	Talking across Fields	<i>Persi Diaconis and Susan Holmes</i>	. . . . . 180
12.7	Using Mathematical Modeling to Eradicate Diseases	<i>Robert Smith?</i>	182
12.8	Neglected Tropical Diseases — How Mathematics Can Help	<i>Robert Smith?</i>	. . . . . 183
12.9	Contagious Behavior	<i>Estelle Basor</i>	. . . . . 185
13	Predicting Catastrophes and Managing Risk		187
13.1	Earthquake Modeling and Prediction	<i>Darko Volkov</i>	. . . . . 187
13.2	Seismic Risk Protection	<i>Alfio Quarteroni</i>	. . . . . 189
13.3	Fire Season	<i>James Crowley</i>	. . . . . 190
13.4	Plowing Fields of Data	<i>Kent E. Morrison</i>	. . . . . 191
13.5	Finding a Sensible Balance for Natural Hazard Mitigation with Math- ematical Models	<i>Karthika Muthukumaraswamy</i>	. . . . . 191
13.6	Modeling the Effects of Storm Surges on Coastal Vegetation	<i>Catherine Crawley</i>	. . . . . 193
13.7	Königsberg’s Bridges, Holland’s Dikes, and Wall Street’s Downfall	<i>Christian Genest and Johanna G. Nešlehová</i>	. . . . . 194
13.8	Systemic Risk in Complex Systems	<i>James Crowley</i>	. . . . . 196
	Contributor Index		199
	Name Index		201
	Subject Index		203