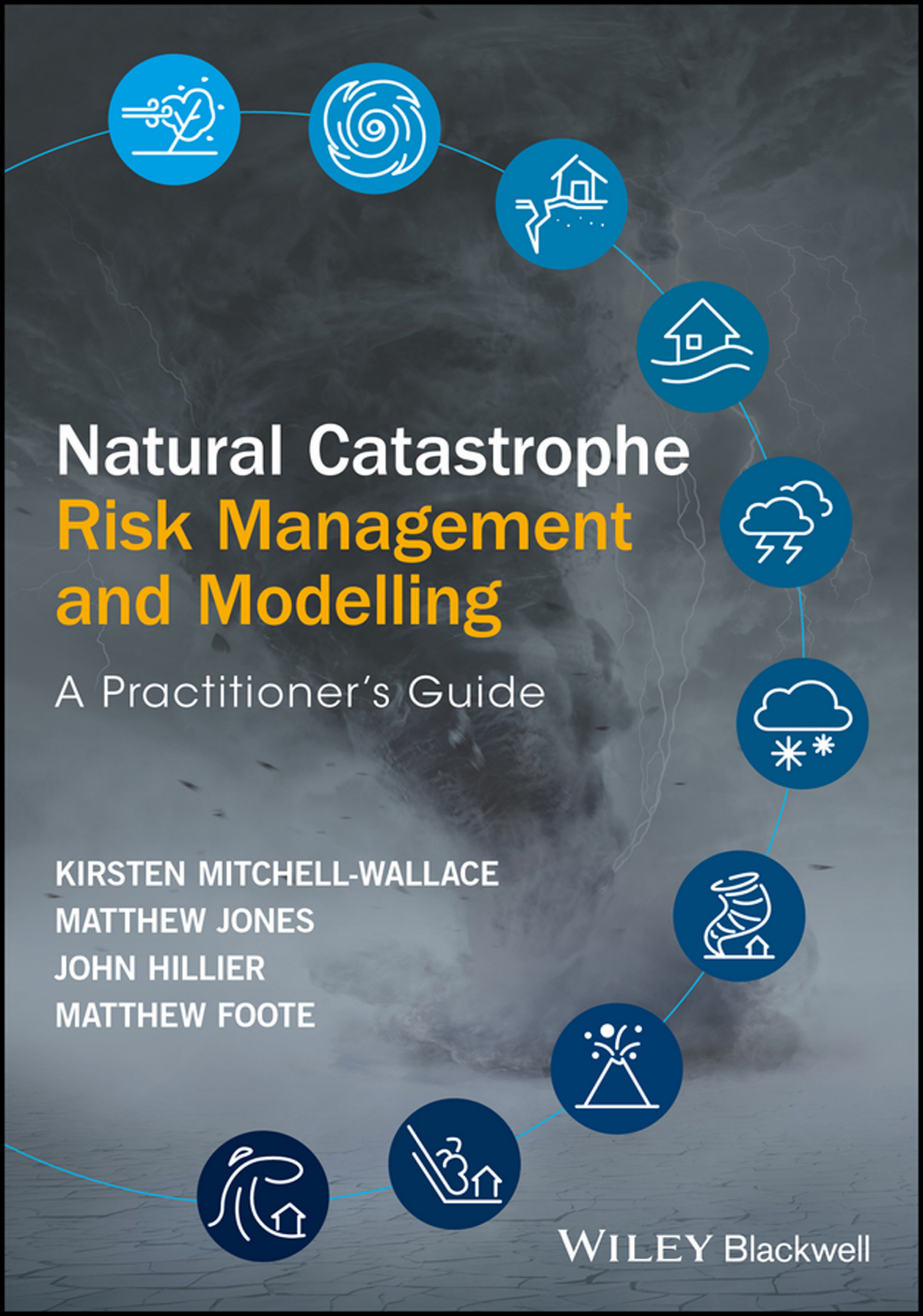

Natural Catastrophe Risk Management and Modelling

A Practitioner's Guide

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WILEY Blackwell

Natural Catastrophe Risk
Management and Modelling

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A Practitioner's Guide

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Contents

List of Contributors and Acknowledgements

We, the main authors, wish to expressly thank the other authors and reviewers who have contributed to this book and made it possible. Catastrophe risk management and modelling is a discipline that draws upon a wide range of knowledge and expertise, so we could not have created a credible practitioner's guide without the widespread support that we have received from the catastrophe modelling community.

Each main author had oversight of one of the main chapters (i.e. 2–5), and sculpted it as appropriate; the structure of each topic and nature of the material required different approaches by chapter. This said, we have all re-written, polished and homogenized all the chapters of the book to produce what we hope is a coherent journey through the topic of catastrophe risk management and modelling.

We have chosen to accredit ourselves in reverse alphabetical order, selected with a degree of randomness befitting the subject matter of this guide.

As well as the four main authors, many contributors provided material for chapters, or sub-chapters, of the book; sometimes an author contributed in more than one place. These contributions are summarized in the table below, and, as appropriate, authors are listed at the start of sections that they co-wrote.

The contributions of the many external reviewers drawn from outside the editorial team were also invaluable; in particular, we are indebted to Alan Calder, George Cooper, Jeff Gall, Claire Crerar, Paul Nunn and Claire Souch who reviewed the entire book or a large part of it.

We thank Wiley's editors and team for giving us the opportunity to produce this guide and assisting us along the way.

Main Authors

This guide has four main authors who also acted as editors. Here, we introduce ourselves in reverse alphabetical order.

Kirsten Mitchell-Wallace is the Regional Cat Manager for Europe, Middle East and Africa at SCOR, leading cat teams based in Zurich and Paris in support of property treaty business written from this region, including US Cat. Before this, she was Head of Cat Pricing and Methodology and responsible for coordinating the development of SCOR's own view of risk, as well as managing the Zurich-based cat team. Prior to joining SCOR in 2009, she was a Senior Catastrophe Risk Analyst at Willis, London, for 5 years, working first on European, then Japanese business. She started her career with two years at Risk Management Solutions in London and two years at risk management consultancy, Risk Solutions, from 2001. Kirsten has a PhD in Atmospheric Physics from Imperial College, London, and a Masters in Meteorology from Reading University, as well as a degree in Chemistry from the University of Bristol. She also has an International Diploma in Risk Management from the Institute of Risk Management. Kirsten is passionate about catastrophe modelling.

Acknowledgments: I would first like to thank my husband, Richard, for keeping our family fed and Arthur clothed throughout this project. Without his incredible support, my contribution could never have been possible.

I would then also like to thank the many people outside the editorial team who reviewed my chapter and made valuable suggestions: Sibylle Steimen, Claire Crerar, Alan Calder, Paul Nunn, Claire Souch, Iakovos Barmpadimos, Roger Bordoy, George Cooper, Thomas Premier and Thomas Linford. Thanks to Parvez Chowdury and Tobias Hoffmann for their review of the actuarial matter. Special thanks to Tom for associated discussions and to Paul for his support of this endeavour.

I would like to thank my many co-authors for their contributions and for being, without exception, a pleasure to work with. I have learned a lot! Thank you also to my fellow editors for a real team effort. In loving memory of my father, Derrick G. Mitchell.

Matthew Jones is the founding Director of Cat Risk Intelligence, a UK-based company providing catastrophe risk management consultancy to the (re)insurance industry.

In his previous role as Global Head of Catastrophe Management for Zurich Insurance Group, Matthew led the organizational change required to establish a global catastrophe management team with consistent processes to provide catastrophe knowledge, systems, models and services across Zurich's general insurance lines of business. He worked for Zurich for fourteen years, including various roles in the actuarial pricing and catastrophe risk management fields. Prior to this Matthew was a reinsurance pricing actuary for St Paul Re in London.

Matthew graduated from the University of Nottingham in 1993 with a degree in Physics. He then completed a PhD in Oceanography and Remote Sensing from University College London, while being based at the UK's National Oceanography Centre in Southampton. He is a Fellow of the Institute and Faculty of Actuaries.

Acknowledgments: I would like to thank my wife Zoe, and my children, Adam, Lauren and Becky, for their love, support and patience. I am extremely grateful to Jane Hayes for allowing me a sabbatical from Zurich to help write some of this book. I am also very thankful to Alan

Calder, Jeff Gall and Claire Souch for the time they put into reviewing and making improvements to Chapter 5; to Fortunat Kind for his input and improvements (including the 'Christmas tree' diagram!); to Gary Hemming for his review of some actuarial pricing aspects; to Federico Waisman for allowing many of his model comparison exhibits to be included; and to Ye Liu for some very helpful statistical discussions.

John Hillier is currently a Senior Lecturer at Loughborough University, with research interests that include various geo-hazards (e.g. earthquake, landslide, flooding, extra-tropical cyclones), multi-hazard risk to property and infrastructure, use of impacts (e.g. loss data) to gain insights into physical processes, and inter-dependencies (i.e. 'links' or interactions) between perils.

He received B.A. (M.A. Cantab) and M.Sci. degrees in Natural Sciences specializing in Geology from the University of Cambridge, and a D.Phil degree in Marine Geophysics from the University of Oxford.

After studying he was awarded a research fellowship at St Catharine's College, Cambridge, and then worked for Zurich Insurance as a catastrophe modeller.

Acknowledgments: I am extremely grateful as ever for the love, tolerance and support of my wife, Katie; I do not say this enough, so I would like to say it explicitly here. My love and thanks also to Ben and Charlotte for putting up with Daddy working when you could clearly think of better things I should be doing.

Academically, I appreciate the stoic perseverance and professionalism of all 16 contributors on the perils in Chapter 3 in the face of requests for more detail in fewer words, or for correcting errors I inadvertently introduced when re-writing an initial submission to half its original length. The following reviewers did a great job of making sure we did a robust and thorough job, with numbers in brackets indicating sections: Rebecca Bell (Imperial College) [3.7], Thierry Corti (Swiss Re) [3.6], Mark Dixon (RMS) [3.3], Juergen Grieser (RMS) [3.4], Joanna Faure-Walker (UCL) [3.8], Greg Holland (NCAR) [3.2], Edmund Penning Rowsell [3.5], Tiziana Rossetto [3.9], Robin Spence [3.10]. This said, any remaining errors should be considered mine and mine alone.

Matthew Foote is an exposure management specialist with over twenty years of experience in the (re)insurance industry, including roles with Willis and Guy Carpenter reinsurance brokers, Risk Management Solutions, Mitsui Sumitomo and most recently Argo Group. For seven years Matthew was the Research Director of the Willis Research Network, responsible for the coordination and development of industrial-academic collaborations involving over fifty research organisations and universities.

Matthew began his career as a cartographer and geographic information specialist, working primarily with earth observation (EO) data and other imagery-based data. He has a First Class degree in Geography from Birkbeck, University of London, is a Fellow of the Royal Geographical Society/IBG and a Chartered Geographer.

Acknowledgments: My thanks are short and simple, first, to Paula, my wife, for all she has done, and to my children Ciara and Michael for inspiring me. I would also like to particularly acknowledge the efforts of Barbara Page, Adam Podlaha, Shane Latchman, Rashmin Gunasekera and Claire Souch, and to express my gratitude to Stuart Lane for his advice in the very early stages of developing this book.

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The following practitioners and academics contributed to this guide. For volunteering your time and expertise, we thank you.

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Šárka Černá	4.3	***Šárka Černá*** works in the business development team in Impact Forecasting doing product development and working with clients. She benefits from five years working as a catastrophe model developer, where she mainly focused on the mathematical and statistical aspects of flood models (e.g. Switzerland). She is involved in the development of the ELEMENTS platform, including testing and validation procedures for Solvency II. After joining Aon Benfield in 2010, Šárka was appointed their Chair of Research in 2014. Prior to 2010, she worked at the Institute of Thermomechanics of the Czech Academy of Sciences on statistical ultrasonic signal processing.
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Claire Crerar	2.7	***Claire Crerar*** has over 14 years experience working in catastrophe modelling, having started her career as a catastrophe risk analyst at Willis. After six years modelling for a wide range of global clients, Claire moved to Aspen where she led the London catastrophe modelling team, with responsibility for international treaty modelling and monitoring accumulations of catastrophe risk. After seven years in this role, Claire has recently shifted focus to concentrate on cat-related project work at Aspen. Claire has an MA in geography from Cambridge University and holds an Advanced Diploma in Insurance from the Chartered Insurance Institute.
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(*Continued*)

Contributor*	Section(s)	Biography
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Radovan Drinka	4.3	***Radovan Drinka*** is a catastrophe model developer at Impact Forecasting and a meteorologist involved in the European Windstorm project and atmospheric perils (e.g. hail, summer storm). He is also involved in an engineering approach to structure vulnerability to wind damage. He has two years experience as a catastrophe modeller after joining Aon Benfield in 2008. As a member of the Impact Forecasting team, Radovan has gained a wide knowledge of Impact Forecasting proprietary platform ELEMENTS, and has used it in his daily routine since 2010. Radovan earned a Masters degree in Physics, Meteorology and Climatology at the Comenius University, Bratislava, the Slovak Republic.
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Contributor*	Section(s)	Biography
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(*Continued*)

Contributor*	Section(s)	Biography
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Marc Hill	4.3	***Marc Hill*** is a principal modeller in the model development group at Risk Management Solutions Ltd (RMS). He studied for his MSc in Concrete Structures at Imperial College London and received a PhD in Engineering at University College London. He joined RMS in 2009 and has participated in a variety of vulnerability development projects, including the climate peril of wind, as well as post-catastrophe damage surveys.
Michael Kunz	3.4	***Michael Kunz*** studied Meteorology at the University of Karlsruhe (Dipl. Met.), where he also earned his PhD (Dr. rer. nat.) with his dissertation on orographic rain enhancement. In 2011, he completed his Habilitation at the Karlsruhe Institute of Technology (KIT) on the amplification of atmospheric processes over complex terrain. He is currently Senior Scientist and head of the working group 'Atmospheric Risks' at the Institute of Meteorology and Climate Research at KIT. His research focuses on extreme weather events (hail, heavy rainfall, and wind gusts), their probability, long-term variability, and related impacts. His working group has also developed various hazard and risk models in cooperation with insurance companies.
Rob Lamb	3.5	***Rob Lamb*** studied at the Universities of Cambridge and Lancaster, where his doctoral research was in numerical modelling of river catchment hydrology and uncertainty analysis. He was a research scientist at CEH Wallingford for six years, before moving to JBA Consulting in 2002. Since then, he has worked on academic and applied research in hydrology, river hydraulics, flood risk management, climate change adaptation and systems-based infrastructure risk analysis. Since 2012, he has held dual roles as a Professor in the Lancaster Environment Centre, and Director of the JBA Trust, a charitable research and knowledge exchange foundation sponsored by the JBA Group.
Shane Latchman	4.3, 4.5, 4.7	***Shane Latchman*** is Assistant Vice President in AIR's London office involved in some of AIR's Touchstone initiatives, such as the integration of third-party data and models, expanding AIR's capabilities in marine and energy, the Next Generation Financial Module, and the development of future multi-modelling/blending capabilities. He is a member of the catastrophe modelling and actuarial industry groups, and is heavily involved with rating agencies and regulators on topics,

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Contributor*	Section(s)	Biography
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Paul Nunn	2.11	***Paul Nunn*** is Head of Catastrophe Risk Modelling at SCOR Global P&C, responsible for the management of natural hazard perils globally. A key aspect of the role is the provision of analytics and data for internal and external stakeholders, including SCOR's internal capital model, rating agencies, regulators and retrocessionaires. Before joining SCOR Global P&C, Paul was Head of Exposure Management at Lloyd's and previously worked for the cat modelling specialist firm, AIR Worldwide. He is also a Director of the non-profit Oasis Loss Modelling Framework company.
Brian Owens	3.2	***Brian Owens*** is a meteorologist and specialist in catastrophe risk management. As a Senior Director at Risk Management Solutions (RMS), he is responsible for their global models and data market and release strategy. He has more than 20 years experience in insurance, catastrophe financing, and catastrophe risk management, and has written numerous scientific articles and blogs. Mr Owens holds a BS in computer science from the National University of Ireland, an MBA from the University of Pennsylvania (Wharton), and an MS in meteorology from the University of Miami.
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Adam Podlaha	2.16, 4.3	***Adam Podlaha*** is the Head of Impact Forecasting at Aon Benfield, overseeing a team of 85+ catastrophe model developers responsible for over 100 models spanning 12 perils, plus the ELEMENTS loss calculation platform. In addition to managing the team, Adam collaborates with various governmental and non-governmental institutions to deliver the best quality models, finding ways to effectively quantify and visualise uncertainty and make catastrophe modelling platforms more open. He joined Aon Benfield in Prague as a flood model developer in 2003 and holds a PhD in Physical Geography from Charles University in Prague.
Petr Punčochář	4.3	***Petr Punčochář*** is responsible for the Impact Forecasting flood model development team in the EMEA and APAC regions, implementing new workflows and methodologies. Additionally, he provides insights on

(*Continued*)

Contributor*	Section(s)	Biography
		hydrology, hydraulics and geographical information systems. Prior to joining Aon Benfield in 2010, Petr was a research assistant at the Department of Hydraulics and Hydrology at the Czech Technical University. Petr is a member of the International Association of Headwater Control and Czech delegation of FAO committee for Mountain Watershed Management. Petr received his PhD in hydrology and open-channel hydraulics in 2011 from the Czech Technical University.
Gillaume Pousse	3.6	***Guillaume Pousse*** gained a PhD degree in Earthquake Engineering in 2005 from the French Institute for Nuclear Safety. He is working for Guy Carpenter and is dedicated to delivering analytics value to clients. He previously worked at a reinsurer, pricing/monitoring inward catastrophe business in earthquake-prone or traditionally non-modelled countries. He also contributed to documenting the view of the risk in a continuous and prospective way. Prior to this, he developed probabilistic earthquake loss models in London for insurers and reinsurers.
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Len Shaffrey	3.3	***Len Shaffrey*** is a Senior Scientist in the National Centre for Atmospheric Science and a Professor in the Department of Meteorology at the University of Reading, UK. His research interests include understanding how extremes such as European Windstorms and extra-tropical cyclones have varied in the past and how they might respond to climate change.
Milan Simic	4.3, 4.5, 4.7	***Milan Simic*** is Executive Vice President and Managing Director of International Operations for AIR Worldwide, and is responsible for business development, strategic growth initiatives, and client services. Milan has more than 25 years' experience in risk assessment, engineering consulting, teaching, and research. He is a Chartered Engineer of the UK Institution of Civil Engineers and has authored numerous papers. He is also a member of the OECD's High-Level Advisory Board on Financial Management of Large-Scale Catastrophes. He earned his MSc in Hydraulic Structures from the University of Belgrade and a PhD in Earthquake Engineering from the University of Bristol, UK.
Nilesh Shome	4.3	***Nilesh Shome*** earned his PhD in Structural Engineering from Stanford University, USA. He is a Vice President of Risk Management Solutions (RMS) Global Earthquake and Terrorism products, leading the research and development works. Dr Shome joined RMS in 2009 and has more than 15 years of professional experience in modelling risk from hurricanes, earthquakes and other natural and man-made hazards, for RMS and other agencies including the World Bank, the Federal Emergency Management Agency (FEMA) and the Applied

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Contributor*	Section(s)	Biography
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Rick Thomas	6.2.2	***Rick Thomas***. After studying Natural Sciences at Cambridge and doing a PhD and postdoc in modelling volcanic eruptions, Rick started work at CARtograph building catastrophe models in 1995. He moved from CARtograph to PartnerRe in 1997 where he led the creation of PartnerRe's in-house model suite, starting with US Hurricane models, but expanding to Japanese Typhoon, European Windstorm and global quake models. Rick moved from modelling to underwriting in the early 2000s and took over as Head of the international property CAT book at PartnerRe in 2004. Subsequent to Partner Re, Rick worked as an advisor to a fund investing in ILS, and as Head of Model Development and Evaluation at Willis Re, where he was also responsible for the Willis Research Network.
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Contributor*	Section(s)	Biography
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Craig Verdon	3.8	***Craig Verdon*** is currently the Head of Europe Catastrophe Modelling at Endurance Re in Zurich. He received BSc (Geology & Chemistry) and BSc (Hons) degrees from the University of Natal (Durban) and, after some time in industry, an MSc in Engineering Geology from Imperial College London. He worked in a variety of roles across the mining and engineering sectors before joining the catastrophe modelling industry as a product manager at RMS.
Renato Vitolo	4.3	***Renato Vitolo*** is Head of Risk Modelling, Operational and Reputational Risk at Banca Monte dei Paschi di Siena, Italy, building on being a quantitative risk analyst there since 2011. Previously, he was a Willis Re Research Fellow based at the University of Exeter, UK, specializing in the clustering of extreme events (windstorms, hurricanes, typhoons, floods) and building event sets for tropical cyclone risk assessment using global climate model output. Renato has a PhD in Meteorology.
Dickie Whitaker	6.3.3	**Dickie Whitaker** has 30 years' experience in the (re)insurance business and for the last 20 years has specialized in risk and innovation and linking academia, government and finance. Dickie has written and presented extensively on these subjects and has operated globally, having worked in both London and New York. He co-founded and works for the Lighthill Risk Network, FiNexus Ltd, Oasis Palm Tree Ltd, and is chief executive of Oasis Loss Modelling Framework Ltd.

*Disclaimer: The findings, interpretations, and conclusions expressed in this work are entirely those of the authors and should not be attributed in any manner to the organizations that they are currently or have been employed by.

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Foreword

This is a ground breaking and essential book. For the last quarter of a century, some of us have witnessed the birth and development of a new, profound and integrating professional and scientific discipline called catastrophe risk modelling. It has transformed the quality of insurance protection upon which more than a billion people depend for their security, and reformed an industry from relative ruin in the early 1990s to relative resilience just two decades later, in spite of a sharp increase in natural hazard risk over that time.

And yet, despite this significance, the discipline is barely known outside its own circles. It is difficult to estimate, but perhaps just 25,000 people worldwide are active members of the 'cat modeling' community among insurers, reinsurers, regulators, modeling providers, and related communities across academia, engineering and civil protection.

I entered this domain in 2005 and, like everyone, learnt about this field through professional courses, experience, the wisdom of colleagues and reports and articles dealing with specific issues. There was no consolidated text that brought this world together. Meanwhile sensing the wider significance of these methods, there was nowhere to point the curious non-insurer when asked to recommend a comprehensive guide to the field. I am grateful that we now have one, and delighted that many of those who shone a light for me ten years ago have come together with others to share their knowledge and experience for all.

The authors and contributors are to be congratulated, not just for producing the first detailed reference on catastrophe modeling, but also for creating the framing of a new discipline. It is path-breaking and one can only imagine the length of internal debates on so many defining points and fundamental issues. This breakthrough will, I hope, spur many other books and publications to support the expansion and further deepening of the field.

Most of us work in specific areas and this text will be useful to experienced practitioners, to connect with wider aspects of the discipline, as well as essential reading for newer professionals. I am also excited that it will open up the field to many others across industry, science, NGOs and public policy, far beyond insurance, who can build on it, apply it and even criticize it as part of a wider, shared, endeavour to better understand, reduce and manage climate and natural hazard risks and protect the under-protected.

As we consider how to implement the UN Global Goals on climate risk and other natural hazards, catastrophe modelling will guide the changes needed to save millions of lives and livelihoods among exposed populations in the decades ahead. This book, and its future editions, will play a leading role in that journey.

Rowan Douglas CBE
CEO Capital Science & Policy Practice, Willis Towers Watson
Member, Prime Minister's Council for Science & Technology

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Fundamentals

Matthew Jones, Kirsten Mitchell-Wallace, Matthew Foote, and John Hillier

1.1 Overview

1.1.1 What Is Included

This chapter contains a broad overview of the topic of catastrophe modelling, including what catastrophe models are, why they are used, their overall structure and their output. Metrics used in catastrophe modelling are presented. Basic statistical concepts required for catastrophe modelling are also included for ease of reference.

1.1.2 What Is Not Included

Detailed information on every topic is not included. This is provided in the subsequent chapters.

1.1.3 Why Read This Chapter?

This chapter aims to give the reader an introductory background to catastrophe risk management and catastrophe modelling. It is targeted primarily at those new to the subject, but should also provide a refresher to those more familiar with the discipline. Reading this chapter together

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Edited by Kirsten Mitchell-Wallace, Matthew Jones, John Hillier and Matthew Foote.

with any subsequent chapters should provide depth on the topic covered – be that the main uses of models, a discussion of the major perils, how to build a model, or how to develop a view of risk. Alternatively, this chapter can be read in isolation to provide an introduction to catastrophe risk management and modelling, from the basics of insurance to the elementary statistics required when using these models. The statistical basics are provided for completeness and reference; less mathematically-minded readers can avoid this section without compromising understanding of following chapters.

1.2 Catastrophes, Risk Management and Insurance

In its broadest sense, a **catastrophe** is something that exceeds the capability of those affected to cope with, or absorb, its effects; in the context of natural hazards the driver is an extreme event causing widespread and, usually sudden, damage or suffering. In the insurance industry, definitions of catastrophe are commonly based on an event exceeding one of a number of thresholds for loss (e.g. total economic losses, insured losses, loss of life – for an example by Swiss Re, see Table 1.1). Organizations may choose to define an event as a catastrophe if that company or the whole industry has large or unexpected losses or if significant media attention is expected. For example, the US Property Claims Service definition of a catastrophe is 'an event that causes 25 m USD or more in direct insured losses to property and affects a significant number of policyholders and insurers'.

The terms risk, peril, and hazard are often used interchangeably in conversation. However, in the context of this book, we use the following definitions:

- A **peril** is a potential cause of loss or damage such as an earthquake or windstorm.
- **Risk** is uncertainty leading to potential adverse outcomes. It is also used as shorthand for an insured object.
- **Hazard** is the danger from the peril.

Catastrophes are a risk to organizations and society. Managing this risk (**catastrophe risk management**) is the ongoing process of: (1) identifying the risk given the context of the organization or community, (2) quantifying the risk, (3) deciding what to do, given the level of risk and the **risk appetite** (i.e. how much risk an entity is willing to take) of the organization or community, and (4) monitoring the level of risk.

Table 1.1 Criteria used by Swiss Re in 2014 to determine if events were categorized as catastrophes and entered into their *Sigma* database.

Threshold	Quantity
Insured loss, maritime disasters	US$19.6 m
Insured loss, aviation	US$39.3 m
Insured loss, other losses	US$48.8 m
Total economic loss	US$97.6 m
Casualties, dead or missing	20
Casualties, injured	50
Casualties, homeless	2000

Source: Swiss Re, 2015.