



Natural Catastrophe Risk Management and Modelling

A Practitioner's Guide

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WILEY Blackwell

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Management and Modelling**

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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.

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



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

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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.

Contributors

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

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Contributor*	Section(s)	Biography
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Radovan Drinka	4.3	<p>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.</p>
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Contributor*	Section(s)	Biography
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Joanna Faure Walker	3.7	Joanna P. Faure Walker received BA (MA Cantab) and MSci. degrees in Natural Sciences, specializing in Geology, from the University of Cambridge, and a DPhil degree in Earth Sciences from University College London. Following her PhD, Faure Walker became an analyst for the catastrophe modelling firm, RMS. She is currently a Senior Lecturer at UCL IRDR (Institute for Risk and Disaster Reduction) with research interests that include earthquake geology, rates of fault deformation and interaction, seismic hazard, and the transitional phase of recovery. She lectures on natural hazards, vulnerability, risk and their integration into decision-making.
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Peter Geissbuehler	3.4	Peter Geissbühler has worked at Tokio Millennium Re AG as the Head of the Actuarial and NatCat Department in Europe since 2011. Before he joined Tokio Millennium, Peter worked at RMS as a Director for European and International Product, mainly responsible for managing the European Winterstorm Model in 2011. Peter started his career at Converium as a cat modeller and pricing actuary where he built models for typhoons in South Korea. In addition, he was senior pricing actuary for cat business for many European countries. Peter holds a PhD in Climatology.
Alexandros Georgiadis	4.3	Alexandros Georgiadis joined Impact Forecasting (Aon Benfield) in 2009. His focus is the development of a probabilistic windstorm risk model for Europe, addressing the climate research-related aspects of the project in collaboration with the University of Cologne. His

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Contributor*	Section(s)	Biography
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Rashmin Gunasekera†	2.14, 3.10, 4.3, 6.2.4	Rashmin Gunasekera is a disaster risk management specialist at the World Bank, focusing on disaster risk assessment and risk financing within the Latin American & Caribbean region. He has over 15 years experience extending to the public sector, re/insurance industry and academia. Prior to joining the World Bank in 2012, he was a Divisional Director of a global reinsurance intermediary and a coordinator of the Willis Research Network, the world's largest collaboration between public science and the financial sector. He has also been a research scientist for an EU project on volcanic risk, and holds an honorary lectureship at UCL. His PhD is in earthquake seismology.
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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Barbara Page	4.3-4.6	Barbara Page is a Senior Director in the model product management group at Risk Management Solutions Ltd (RMS). She obtained an MA in Natural Sciences from Cambridge University and a PhD in volcanology from Edinburgh University. Over the past 20 years, Dr Page has fulfilled a variety of roles at RMS in developing and managing catastrophe risk modelling products for the global private insurance market.
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.
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Contributor*	Section(s)	Biography
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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.
Junaid Seria	2.10, 2.11	Junaid Seria works as a Solvency II Nat Cat Actuary at SCOR and is responsible for embedding Solvency II in the business activities of the Nat Cat team. This includes SII training, independent validation of cat model methods and results, and developing governance structures. Previously he worked as an Actuarial Executive at KPMG in London where he specialized in cat risk consulting. This included managing authorization engagements for two UK reinsurer start-ups, managing cat risk validation engagements for UK primaries. He was also the cat risk expert reviewer for internal model submissions to the Bermudian Monetary Authority.
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	<p>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.</p>
Jane Toothill	3.5	<p>Jane Toothill has over 20 years' experience in the modelling of natural catastrophes. Jane worked for the modelling company EQECAT and reinsurance broker Guy Carpenter, prior to joining JBA Group in 2008. She became one of the founding directors of JBA Risk Management in 2011, where she heads operations and catastrophe modelling. During her career Jane has also worked for the British Geological Survey and acted as an advisor on Zurich Financial Services' Natural Catastrophe</p>

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Contributor*	Section(s)	Biography
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Dickie Whitaker	6.3.3	<p>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.</p>

*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.

†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 World Bank, its Board of Executive Directors, or the governments they represent.

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

1

Fundamentals

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

1.1 Overview

- 1.2 Catastrophes, Risk Management and Insurance
- 1.3 What Are Catastrophe Models?
- 1.4 Why Do We Need Catastrophe Models?
- 1.5 History of Catastrophe Models
- 1.6 Who Provides and Uses Catastrophe Models?
- 1.7 What Are Catastrophe Models Used For?
- 1.8 Anatomy of a Catastrophe Model
- 1.9 Model Input
- 1.10 Model Output: Metrics and Risk Measures
- 1.11 Statistical Basics for Catastrophe Modelling

Notes

References

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

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.