

Curbing Catastrophe

What does Japan's 2011 nuclear accident have in common with the 2005 flooding of New Orleans from Hurricane Katrina? What does global warming have to do with "Black Hawk Down" Mark Bowden's classic account of a military disaster in Somalia? What is the relation between coal and tuna? This thought-provoking book presents a compelling account of recent and historical disasters, both natural and human-caused, drawing out common themes and providing a holistic understanding of hazards, disasters, and mitigation for anyone interested in this important and topical subject. Based on his on-the-ground experience with several recent major disasters, Timothy Dixon explores the complex science, politics, and economics behind a variety of disasters and environmental issues, and argues that many of the worst effects are avoidable. He describes examples of planning and safety failures, provides forecasts of future disasters, and proposes specific solutions for hazard mitigation. This book shows how billions of dollars and countless lives could be saved by adopting longer-term thinking for infrastructure planning and building, and argues that better communication is vital in reducing global risks and preventing future catastrophes.

TIMOTHY H. DIXON is a professor in the School of Geosciences and Director of the Natural Hazards Network at the University of South Florida in Tampa. In his research, he uses satellite geodesy and remote sensing data to study earthquakes and volcano deformation, coastal subsidence, ground water extraction, and glacier motion. He has worked as a commercial pilot and scientific diver; has conducted research at NASA's Jet Propulsion Laboratory in Pasadena, California; and was a professor at the University of Miami, where he co-founded the Center for Southeastern Tropical Advanced Remote Sensing (CSTARS). Dixon was a Distinguished Lecturer for the American Association of Petroleum Geologists (AAPG) in 2006–2007. He is also a Fellow of the American Geophysical Union (AGU), the Geological Society of America (GSA), and the American Association for the Advancement of Science (AAAS). He received a GSA Best Paper Award in 2006, and received GSA's George P. Woollard Award in 2010 for excellence in geophysics.

Cambridge University Press
978-1-107-03518-8 — Curbing Catastrophe
Timothy H. Dixon
Frontmatter
[More Information](#)

Curbing Catastrophe

Natural Hazards and Risk Reduction in the Modern World

TIMOTHY H. DIXON

University of South Florida



CAMBRIDGE
UNIVERSITY PRESS

Cambridge University Press
978-1-107-03518-8 — Curbing Catastrophe
Timothy H. Dixon
Frontmatter
[More Information](#)

CAMBRIDGE UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom
One Liberty Plaza, 20th Floor, New York, NY 10006, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
4843/24, 2nd Floor, Ansari Road, Daryaganj, Delhi – 110002, India
79 Anson Road, #06–04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org

Information on this title: www.cambridge.org/9781107035188
10.1017/9781139547345

© Timothy H. Dixon 2017

This publication is in copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of Cambridge University Press.

First published 2017

Printed in the United Kingdom by TJ International Ltd. Padstow Cornwall

A catalogue record for this publication is available from the British Library.

ISBN 978-1-107-03518-8 Hardback

Additional resources for this publication at www.cambridge.org/dixon

Cambridge University Press has no responsibility for the persistence or accuracy of URLs for external or third-party Internet websites referred to in this publication and does not guarantee that any content on such websites is, or will remain, accurate or appropriate.

Cambridge University Press
978-1-107-03518-8 — Curbing Catastrophe
Timothy H. Dixon
Frontmatter
[More Information](#)

For my grandchildren and their grandchildren

Contents

Preface	<i>page</i> xiii
Acknowledgments	xx
1 Black and White Swans, Communication, Evolution, and Markets	1
Long-Term Risk, Listening Skills, and Evolution	4
Cost of Disasters and the Role of Markets	7
2 What Is a Natural Disaster? Where Do They Occur and Why? Are They Different from Human-Made Disasters?	14
Earth’s Natural Cycles: Volcanoes, Climate, and Earthquakes	23
How Does the Motion of Plates Lead to Earthquakes and Tsunamis?	28
Volcanoes and Climate	33
Hurricanes, Flooding, and Sea-Level Rise	36
3 If We Know So Much about Natural Disasters, Why Do We Remain Vulnerable?	40
Scientific Uncertainty	40
Time Lag, Sticky Infrastructure, and the Challenge of Relocation	45
The Importance of Building Codes	50
Cost versus Benefit	59

viii CONTENTS

4	Japanese Earthquakes and Nuclear Power Plant Failures	66
	Hydrogen: Why Is It Produced in Nuclear Power Plant Accidents? Why Is It Dangerous? What's It Got to Do with the Hindenburg?	72
	How Bad Was Fukushima?	73
	What Went Wrong?	81
	A Disturbing Precursor	89
	Regulation and Transparency	92
5	Future Earthquake and Tsunami Disasters	94
	Sleepless in Seattle	95
	Tsunamis in Switzerland	108
	The Orient Express	110
6	Nuclear Power, Coal, and Tuna: The Concept of Relative Risk	117
	The Toxic Legacy of Lead	122
	Mercury and Coal	128
	Deaths from Coal versus Deaths from Nuclear Power	136
	Carbon Capture and Storage	143
	What about Solar?	144
7	Past and Future Coastal Flooding: Galveston, New Orleans, Bangladesh, and the Specter of Sea-Level Rise	151
	The Great Galveston Hurricane of 1900	155
	New Orleans and Hurricane Katrina	158
	River Deltas, Subsidence, and Levees	158
	Could It Happen Again?	162
	Sea-Level Rise: A Slow Disaster in the Making	167
	Slow Sea-Level Rise and Rapid Flooding	170
	What Other Regions Are at Risk?	178
	Summary	182

8	What’s All the Fuss about Global Warming?	186
	Communication: The Need for Long-Term Data and the Challenge of Explaining Them	191
	The Time Lag Problem: Why We Need to Think Long Term	212
	Economic Consequences	216
	Some Lessons from Greenland	220
9	Solutions	229
	Communication	230
	Transparency	239
	Let Markets Work Their Magic	244
	The Magic of New Technology: Blue LEDs, the Tesla, and Photosynthesis	251
	R&D and Taxes	254
	Avoiding the “Coal Trap”	255
	Independent Boards	257
	Lessons Learned	259
	The Challenge of Large Infrastructure Projects	260
	Summary	261
	Summary of Recommendations by Chapter	263
	References and Further Reading	270
	Index	287

Online Appendix

Available at www.cambridge.org/dixon

Appendix: Additional Background Material and Exercises for Students

Chapter 2

What Is a Fault?

Stick-Slip, Strain Accumulation, Elastic Rebound, and Earthquakes

Question 2-1 (Earthquake slip rates – long term)

Question 2-2 (Earthquake slip rates – short term)

Earthquake Size, Rupture Area, and Fault Type

Question 2-3 (Earthquake energy and rupture area)

Chapter 3

Earthquake Recurrence Intervals and Aliasing

Question 3-1 (Earthquake recurrence and sampling)

Question 3-2 (Earthquake recurrence and clustering)

Chapter 4

Question 4-1 (Radioactive decay and nuclear fission)

Question 4-2 (Instrument design)

Chapter 5

Chapter 6

Question 6-1 (Lead in cities)

Boom-and-Bust Cycles, the Price of Oil, and Population Growth:

The Magic of Differential Equations

Question 6-2 (Predator-prey and exponential growth)

Question 6-3 (Graphing exponential growth)

Question 6-4 (Exponential growth and human population)

Question 6-5 (Predator-prey, boom and bust, and the price of oil)

Question 6-6 (Boom and bust cycles in commodities)

Chapter 7

Subsidence, Flooding, and Failure of the MRGO Levee during Hurricane Katrina.

Question 7-1 (Exponential subsidence)

Question 7-2 (Subsidence and flooding from Glacial Isostatic Adjustment)

Question 7-3 (The importance of considering multiple factors)

Chapter 8

Question 8-1 (Wien's Law)

Question 8-2 (Solar irradiance at the top of Earth's atmosphere)

Question 8-3 (Solar irradiance at Earth's surface)

Question 8-4 (Earth's average temperature, without greenhouse)

Question 8-5 (Earth's average temperature, with greenhouse)

Question 8-6 (Earth's average temperature, with extra CO₂)

Question 8-7 (Heat content of the uppermost solid Earth)

Impacts on Human Health

Question 8-8 (Chronic kidney disease, multiple factors)

The Long-Long Term

Question 8-9 (Correlation of temperature and CO₂)

Question 8-10 (Role of feedbacks)

References and Further Reading

Preface

“Civilization exists by geological consent, subject to change without notice.”

Will Durant, American philosopher and writer (1885–1981)

We have a troubled relationship with our home planet. While we depend on it for the air we breathe, the water we drink, the soil that grows our crops, and the minerals and energy we consume, we also exploit and despoil its resources with little thought for the future. We’re rapidly depleting freshwater aquifers and mineral deposits that took the Earth thousands to millions of years to develop. Too often, we build our homes, factories, and power plants in vulnerable areas, next to earthquake faults, volcanoes, and low-lying areas prone to flooding. We use energy in ways and amounts that have harmful consequences. Rather than choosing to fit ourselves into the planet’s ecosystem and use its resources sparingly, we have chosen a more confrontational approach.

Astronomical observations suggest that numerous planets in our galaxy have the conditions necessary for life. Given the immense size and age of our galaxy, we might expect that at least a few of these planets have developed advanced civilizations, but there is no evidence of this. The conundrum is known as Fermi’s Paradox, after atomic scientist Enrico Fermi, who famously said, “Where is everybody?” Astronomer Carl Sagan speculated that any planet that developed an advanced civilization would soon destroy itself, either through war or environmental degradation.

Politicians and diplomats have the job of preventing war. Scientists have the job of educating the public and government

xiv PREFACE

officials about the planet and its ecosystems, and how we can do a better job of “fitting in” to our environment. Designing, locating, and building our infrastructure so that it’s tough enough to meet nature’s demands, but is also kind to the planet’s ecosystems, are important aspects of fitting in. This book describes some of our most important successes and failures in these areas.

In the last decade, three major disasters unfolded in areas where I have some professional background: the 2005 flooding of New Orleans associated with Hurricane Katrina; the 2010 earthquake in Haiti; and the 2011 earthquake and tsunami in Japan. I had worked in New Orleans and Haiti prior to those two events, doing research on the geological processes that ultimately contributed to the disasters (subsidence and sea level rise in New Orleans; plate motion and earthquake strain accumulation in Haiti). In the two cases I worked on directly, I was struck by the fact that scientists “in the know” knew these disasters were inevitable, but felt powerless to do anything about them. The public was largely ignorant, and government officials, policy makers, and in Haiti’s case, aid agencies, were focused on issues deemed more immediate. Many businesses were uninterested or even hostile to the warnings of scientists. Similar problems appear to apply to Japan’s recent nuclear disaster and to many environmental issues. A big part of the problem is communication, or more specifically, its lack. Many scientists are not very good at communicating their knowledge of risk to the public, including the long-term consequences of building things in harm’s way or designing them to inadequate standards. Equally culpable, some politicians, some members of the media, and some members of the public are not especially good at listening to scientists who discuss these issues. Scientific literacy seems to be on the decline in modern society, which is odd given our increasing use of and dependence on technology that ultimately comes from science. Aspects of the current debate about energy use and global warming similarly reflect poor communication among scientists, policy makers, the media, and the public, and failure of the last three groups to adequately consider long-term trends.

This book attempts to address these problems. It discusses issues on the boundary between science, business, and government, including costs, risks, and mitigation strategies for natural and human-made hazards. I describe examples where scientists have been called on to give policy advice on these hazards, why this advice is sometimes taken and sometimes ignored, and the economic and human consequences of following or ignoring that advice. I describe examples where scientists got things right and where they got things wrong. I suggest some reasons why humans tend to ignore obvious, long-term problems; suggest how scientists might overcome this tendency; and make specific suggestions on how to improve information flow, decision making, and transparency. In addition to hind-casts (in-depth forensic analysis of past disasters, known to my critics as Monday morning quarterbacking), I also make some forecasts. Some of these forecasts will be controversial, but hopefully will spur debate, additional research, and much-needed public and private action.

This book has three main themes, all related to natural or human-made disasters: the importance of communication, the importance of understanding long-term processes and time scales, and the economic consequence of failure. I'll wrestle with what long-term means in later chapters, but for now let's define it as anything longer than a typical human life span. The concept of time lag is another recurring theme. It's used to explain why cities are often located in areas now considered unsafe (Chapter 3), why the price of oil goes through such large swings (Chapter 6), and why it's so difficult for scientists to explain the dangers of global warming (Chapter 8).

Like most authors, I have some biases. I am a geologist, so I tend to view many issues through the prism of Earth science and the common sense approach inherent to my discipline. Although the book aims at a global focus, I live and work in the US, a country that – because of its size, location, and geologic setting – experiences many natural hazards, including hurricanes, tornadoes, earthquakes, tsunamis, and volcanic eruptions. This range of extreme natural

xvi PREFACE

phenomena makes the country a useful “natural laboratory” for some of our discussions.

This book doesn’t focus exclusively on natural hazards, nor does it provide a catalog of disasters. Rather, I focus on a few examples to illuminate common themes. Natural disasters, as well as the human-made kind, often share several features, including poorly designed infrastructure. Shining a spotlight on these common features can curb catastrophes for future generations. Otto von Bismarck, chancellor of Prussia and later Germany in the late 19th century, once said, “Only a fool learns from his own mistakes. The wise man learns from the mistakes of others.” My hope is that this book will help all of us learn from past mistakes.

The book is intended for a general audience. High school math – or better yet, simple common sense – is adequate preparation. Throughout the book, separate sections (“Boxes”) provide further detail for interested readers; consider it my attempt at a “Director’s Cut.” An online appendix entitled “Exercises for Students” is available as an electronic supplement from the publisher. It includes additional background material and example problems that are suitable for introductory undergraduate classes in natural hazards, geology, geography, climate change, and environmental science.

Chapter 1 gives an introduction and overview of major issues. Some of these are covered in more detail in later chapters, such as the cost of the earthquakes in Japan and Haiti, and the various missteps that contributed to these horrific disasters. Chapter 2 discusses what I mean by the term “natural hazard” and describes the underlying science. Readers with a background in Earth science will be familiar with most of this material. This chapter also makes the case that natural and human-made disasters are not so different. Both often have root causes in things like bad design, bad engineering, bad management, or failure to think long term. The solutions to preventing both types of disasters are also often similar (improved infrastructure). Chapter 3 looks at why our scientific understanding of hazards does not always translate into effective action. I emphasize the importance

of having a good long-term record when assessing a given hazard, and I provide an introduction to the measurement techniques that scientists use to obtain these records. Chapter 4 applies the lessons of Chapters 2 and 3 to the recent Japanese earthquake, tsunami, and nuclear plant failure, and describes an eerily similar event that took place years earlier that should have been a wake-up call for the nuclear industry. I argue that both nuclear disasters were preventable given knowledge available at the time, a position that remains controversial. Chapter 5 describes the possibility of future earthquake and tsunami disasters in several other areas, including the US Pacific Northwest; Geneva, Switzerland; and Istanbul, Turkey.

Chapter 6 considers the larger issue of nuclear power relative to other power sources, including coal, and uses this issue to introduce the concept of relative risk. I argue that nuclear power should remain on the energy table as an important carbon-free option, a stance that is not popular with many environmentalists. Chapter 7 discusses flood disasters, including examples from the US (Galveston, Texas and New Orleans, Louisiana) and Bangladesh, and considers how future flood risk will be exacerbated by sea-level rise. Chapter 8 reviews the cause of sea-level rise (global warming) and how this topic got to be so contentious. This chapter makes the case that global warming has similarities to some of the other more immediate disasters discussed in earlier chapters by focusing on the themes of scientific communication and the importance of considering long-term processes and economic consequences. Improved infrastructure (in this case for transportation and energy generation) is also relevant. The last chapter offers specific solutions, including a summary of recommendations.

Communication is a major theme of this book and is mentioned in almost every chapter. It is a two-way street: It is important for scientists and engineers to clarify complex subjects and crucial for the media, the public, and government officials to be active and engaged listeners. Communication also means different things to different people, and there are different levels of communication, from being informed to being strongly engaged. At the most basic

xviii PREFACE

level, it means transferring useful information. In several places, I assert that scientists need to do a better job of transferring information into the public domain. As an example of a deeper level of communication, a citizen activist could take information from this book, such as the scientific and engineering background related to the Japanese earthquake and nuclear disaster, or the environmental consequences associated with coal-fired power plants, and use it to influence public policy.

NOTES AND REFERENCES

Most nonfiction books and scientific articles make extensive use of footnotes and references that list relevant published work. While this allows interested readers to follow up on specific issues and gives proper credit to previous researchers, it can also make for cumbersome reading.

Here I've avoided footnotes and most references within the text wherever possible. Instead, relevant work for each chapter is compiled at the end of the book. In most cases, the link between specific points in the text and a given author's work should be clear from the title. In cases where this is not clear, I have either called out specific references in the text, with the author's last name and publication year in parentheses, or made a comment in the reference list itself.

Commented references are indicated by an asterisk (*).

COLOR FIGURES

In order to keep the book more affordable, figures are reproduced in black and white. The original versions of some of these figures are in color. The color versions are available on the author's web site (<http://labs.cas.usf.edu/geodesy/>)

CONFLICTS OF INTEREST

Throughout the book, and especially in the last chapter (Solutions), I make a case for transparency, particularly with regard to funding

sources. If people have access to more information and are aware of potential conflicts of interest when experts give their opinion, then better, more informed decisions can be made. So here goes for me: In the last two decades, I have received research funding from the US National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the Office of Naval Research (ONR), the Department of Energy (DOE), and British Petroleum (BP). I have also received an honorarium from the American Association of Petroleum Geologists (AAPG) for a series of public lectures. I have been involved in the governance of two scientific organizations, the American Geophysical Union (AGU) and the American Association for the Advancement of Science (AAAS), and am also a member and Fellow of the Geological Society of America. Where specific conflicts exist, I will call them out in the text, usually beginning with the phrase “full disclosure.”

Acknowledgments

Many people contributed ideas and time to this book, and I'd like to thank some of them here.

My wife, Dr. Jackie Dixon, a professional scientist with her own career and responsibilities, spent many hours reviewing early drafts and saved me from saying some really stupid things.

Dr. Robert Stern, a friend, colleague, and Professor of Geological Sciences at the University of Texas at Dallas, suggested I investigate Alaska's Nenana Ice Classic.

Dr. Grace Palladino had the misfortune of wading through an early draft, but nevertheless provided numerous suggestions and many encouraging words.

My friend and neighbor Rick Ker also reviewed an early draft and prevented a large number of typographical errors and mangled phrases.

Dr. Giovanni Sella re-drafted Figure 2.2 from its original color version to make it legible in black and white.

Dr. Louise Ander re-drafted Figure 6.2 from its original color version to make it legible in black and white.

John Hofmeister, former President of Shell Oil USA and author of *Why We Hate the Oil Companies*, provided a review and advice on how to avoid legal issues. Time will tell how well I followed his advice.

I am indebted to Dr. Charles Connor who brought to my attention the disturbing case of the Kashiwazaki Kariwa nuclear accident that occurred several years before the events at the Fukushima Daiichi nuclear plant.

Drs. John Adams and Chris Goldfinger provided critical background on the Cascadia Margin story and some great quotes.

Dr. Richard Somerville, a climate scientist at Scripps Institution of Oceanography, and Mark Bowden, author of *Black Hawk Down*, gave technical reviews of parts of the book, for which I am extremely grateful.

Dr. Amelia Shevenell gave me a number of important comments and an excellent figure illustrating long-term climate cycles.

I am indebted to Dr. David Chapman for suggesting one of the climate problems, and to Dr. Geoffrey Vallis for his delightful “primer” on oceans and climate, and for two other problems in the climate section (any errors are strictly my own).

Dr. Robert Yeats and two anonymous reviewers provided comprehensive reviews that greatly improved the book.

Dr. Emma Kiddle was my editor at Cambridge University Press and made a large number of useful suggestions, most of which I’ve followed.

Susan Santucci, founder of Ivy League Tutoring, kindly provided a final read and clean-up of my sometimes tortured prose.

Many figures in the book were prepared or improved by Theresa Maye, Design Magic Studio.

Parts of this book summarize my own research, which has been generously supported by the US National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), the Office of Naval Research (ONR), and internal funding from the University of South Florida (USF).

While parts of this book have been critical of the media, I recognize that there are some real heroes out there. Many journalists work hard to get the message out in the face of tight budgets, impossible deadlines, withering criticism, and even threats from special interests or thuggish governments.