Introduction to Natural Hazards

CHAPTER 1

RATIONALE

The field of environmental studies is usually intro- events that appear over a short time period. They include phenomena such as earthquakes, tsunami, volcanic eruptions and flash *floods*. This book deals should realize that death and property loss from these latter perils can be just as severe as, if not worse than, those generated by geological and climatic hazards. A final section examines the social impact of hazards.

HISTORICAL BACKGROUND

The world of myths and legends

(Holmes, 1965; Day, 1984; Myles, 1985; Milne, 1986; Bryant, 2001)

Myths are traditional stories focusing on the deeds of gods or heroes, often to explain some natural phenomenon, while legends refer to some historical event handed down – usually by word of mouth in traditional societies. Both incorporate natural hazard events. Prehistoric peoples viewed many natural disasters with shock and as a threat to existence. Hazards had to be explained and were often set within a world of animistic gods. Such myths remain a feature of belief systems for many peoples across the world – from Aborigines in Australia and Melanesians in the South Pacific, to the indigenous inhabitants of the Americas and the Arctic Circle. With the development of written language, many of these oral myths and legends were incorporated into the writings of the great religions of the world. Nowhere is this more evident than with stories about the great flood. Along with stories of Creation, the Deluge is an almost ubiquitous theme. The biblical account has remarkable similarities to the Babylonian Epic of Gilgamesh. In this epic, Utnapishtim, who actually existed as the tenth king of Babylon, replaces Noah, who was the tenth descendant of Adam. The biblical account parallels the epic, which tells of the building of an ark, the loading of it with different animal species, and the landing of the ark upon a remote mountaintop. Babylonian civilization was founded in what was called Mesopotamia, situated in the basin of the Euphrates and Tigris Rivers, which historically have been subject to cataclysmic flooding. Clay deposits in excess of 2 m have been found at Ur, suggesting a torrential rain event in the headwaters of the valley that caused rivers to carry enormous *suspension loads* at high concentrations.

Such an event was not unique. The epic and biblical accounts are undoubtedly contemporaneous and, in fact, a similar major flood appears in the written accounts of all civilized societies throughout Middle Eastern countries. For example, broken tablets found in the library of Ashurbanipal I (668–626 BC) of Assyria, at Nippur in the lower Euphrates Valley, also recount the Babylonian legend. The Deluge also appears worldwide in verbal and written myths. The Spanish conquistadores were startled by flood legends in Mexico that bore a remarkable similarity to the biblical account. Because these staunchly Catholic invaders saw the legends as blasphemous, they ordered the destruction of all written native references to the Deluge. The similarities were most remarkable with the Zapotecs of Mexico. The hero of their legend was Tezpi, who built a raft and loaded it with his family and animals. When the god Tezxatlipoca ordered the floodwaters to subside, Tezpi released firstly a vulture and then other fowl, which failed to return. When a hummingbird brought back a leafy twig, Tezpi abandoned his raft on Mt Colhuacan. A Hawaiian legend even has a rainbow appearing, which signals a request for forgiveness by their god Kane for his destructiveness. Almost all legends ascribe the flood to the wrath of a god. The Australian Aborigines have a story about a frog named Tiddalik drinking all the water in the world. To get the water back, all the animals try unsuccessfully to get the frog to laugh. Finally, a cavorting eel manages the task. However, the frog disgorges more water than expected and the whole Earth is flooded. In some myths, floods are attributed to animals urinating after being picked up. Many myths are concerned with human taboo violations, women's menstruation, or human carelessness. Almost all stories have a forewarning of the disaster, the survival of a chosen few, and a sudden onset of rain. However, the Bible has water issuing from the ground, as do Chinese, Egyptian, and Malaysian accounts. The latter aspect may refer to earthquakes breaking *reservoirs* or impounded lakes. Many Pacific island and Chilean legends recount a swelling of the ocean, in obvious reference to *tsunami*. Despite the similarities of legends globally amongst unconnected cultures, there is no geological evidence for contemporaneous flooding of the entire world, or over continents. It would appear that most of the flood myths recount localized deluges, and are an attempt by human beings to rationalize the flood hazard.

Almost as ubiquitous as the legends about flood are ones describing volcanism or the disappearance of continents. North American natives refer to sunken land to the east; the Aztecs of Mexico believed they were descended from a people called Az, from the lost land of Aztlán. The Mayas of Central America referred to a lost island of Mu in the Pacific, which broke apart and sank with the loss of millions of inhabitants. Chinese and Hindu legends also recount lost continents. Perhaps the most famous lost continent legend is the story of Atlantis, written by Plato in his *Critias*. He recounts an Egyptian story that has similarities with Carthaginian and Phoenician legends. Indeed, if the Aztecs did migrate from North Africa, the Aztec legend of a lost island to the east may simply be the Mediterranean legend transposed and reoriented to Central America. The disappearance of Atlantis probably had its origins in the catastrophic eruption of Santorini around 1470 BC. Greek flood myths refer to this or similar events that generated tsunami in the Aegean. It is quite possible that this event entered other tales in Greek mythology involving fire from the sky, floating islands and darkening of the sky by Zeus. The Krakatau eruption of 1883 also spawned many legends on surrounding islands. Blong (1982) describes modern legends in Papua New Guinea that can be related to actual volcanic eruptions in the seventeenth century. The Pacific region, because of its volcanic activity, abounds in eruption mythology. For example, Pele, the fire goddess of Hawaii, is chased by her sister from island to island eastward across the Pacific. Each time she takes refuge in a volcano, she is found by her sister, killed, and then resurrected. Finally, Pele implants herself triumphantly in the easternmost island of Hawaii. Remarkably, this legend parallels the temporal sequence of volcanism in the Hawaiian Islands.

Earthquakes also get recounted in many myths. They are attributed by animistic societies in India to animals trying to get out of the Earth. Sometimes the whole Earth is viewed as an animal. Ancient Mexicans viewed the Earth as a gigantic frog that twitched its skin once in a while. Timorese thought that a giant supported the Earth on his shoulder and shifted it to the other side whenever it got too heavy. Greeks did not ascribe earthquakes to Atlas, but to Poseidon disturbing the waters of the sea and setting off earth tremors. The oscillating water levels around the Greek islands during earthquakes were evidence of this god's actions. In the Bible, earthquakes were used by God to punish humans for their sins. Sodom and Gomorrah were destroyed because they refused to give up sins of the flesh. The fire and brimstone from heaven, mentioned with these cities' destruction, were most likely associated with the lightning that is often generated above earthquakes by the upward movement of dust. Alternatively, it may have come from meteorite debris. The Bible also viewed earthquakes as divine visitation. An earthquake preceded the arrival of the angel sent to roll back Christ's tombstone (Matthew 28: 2).

Myths, legends, and the Bible pose a dilemma because they do not always stand up to scientific scrutiny as established in the last three centuries. Today an incident is not credible unless it can be measured, verified by numerous witnesses, viewed as repeatable, and certainly published in peer-reviewed literature. Media accounts, which may be cobbled together and subject to sensationalism because of the underlying aim to sell a product, are regarded with suspicion. There is distrust of events that go unpublished, that occur in isolated regions, or that are witnessed by societies with only an oral tradition occurring in isolated regions. Legends, however, can become credible. Hence, the Kwenaitchechat legend of a tsunami on the west coast of the United States suddenly took on scientific acceptability when it received front-page coverage in *Nature*. It was shown – using sophisticated computer modelling – that the source of a tsunami that struck the east coast of Japan on 26 January 1700 could have originated only from the Cascadian subduction zone off the west coast of the United States. The fact that the legend mentions water overrunning hilltops has still not been explained. Sometime in the future, we will find it just as hard to believe that published statements were accepted as articles of faith when they were scrutinized by only two referees who often came from an entrenched inner circle of associates. Certainly, the rise of information on the Internet is challenging twentieth century perceptions of scientific scrutiny.

Catastrophism *vs.* uniformitarianism

(Huggett, 1997)

Until the middle of the eighteenth century, western civilization regarded hazards as 'acts of God' in the strict biblical sense, as punishment for people's sins. On 1 November 1755, an earthquake, with a possible surface magnitude of 9.0 on the Richter scale, destroyed Lisbon, then a major center of European civilization. Shortly after the earthquake, a tsunami swept into the city and, over the next few days, fire consumed what was left. The event sent shock waves through the salons of Europe at the beginning of The Enlightenment. The earthquake struck on All Saints' Day, when many Christian believers were praying in church. John Wesley viewed the earthquake as God's punishment for the licentious behavior of believers in Lisbon, and retribution for the severity of the Portuguese Inquisition. Immanuel Kant and Jean-Jacques Rousseau viewed the disaster as a natural event, and emphasized the need to avoid building in hazardous places.

The Lisbon earthquake also initiated scientific study of geological events. In 1760, John Mitchell, Geology Professor at Cambridge University, documented the spatial effects of the earthquake on lake levels throughout Europe. He found that no seiching was reported closer to the city than 700 km, nor further away than 2500 km. The seiching affected the open coastline of the North Sea and shorelines in Norwegian fjords, Scottish lochs, Swiss alpine lakes, and rivers and canals in western Germany and the Netherlands. He deduced that there must have been a progressive, wave-like tilting movement of the Earth outward from the center of the earthquake, different to the type of wave produced by a volcanic explosion.

Mitchell's 1760 work on the Lisbon earthquake effectively represents the separation of two completely different philosophies for viewing the physical behavior of the natural world. Beforehand, the *Catastrophists* dominated geological methodology. These were the people who believed that the shape of the Earth's surface, the stratigraphic breaks appearing in rock columns, and the large events associated with observable processes were cataclysmic. Catastrophists believed events had to be cataclysmic to allow the geological record to fit with the date for the Earth's creation of 4004 BC, as determined by Biblical genealogy. Charles Lyell, one of the fathers of geology, sought to replace this 'catastrophe theory' with gradualism – the idea that geological and geomorphic features were the result of cumulative slow change by natural processes operating at relatively constant rates. This idea implied that processes shaping the Earth's surface followed laws of nature as defined by physicists and mathematicians as far back as Bacon. William Whewell, in a review of Lyell's work, coined the term *uniformitarianism*, and subsequently a protracted debate broke out about whether or not the slow processes we observe at present apply to past unobservable events. The phrase 'The present is the key to the past' also arose at this time and added to the debate.

In fact, the idea of uniformitarianism involves two concepts. The first implies that geological processes follow natural laws applicable to science. There are no 'acts of God'. This type of uniformitarianism was established to counter the arguments raised by the Catastrophists. The second concept implies constancy of rates of change or material condition through time. This concept is nothing more than inductive reasoning. The type and rate of processes operating today characterize those that have operated over geological time. For example, waves break upon a beach today in the same manner that they would have one hundred million years ago, and prehistoric tsunami behave the same as modern ones described in our written records. If one wants to understand the sedimentary deposits of an ancient tidal estuary, one has to do no more than go to a modern estuary and study the processes at work. Included in this concept is the belief that physical landscapes such as modern floodplains and coastlines evolve slowly.

Few geomorphologists or geologists who study earth surface processes and the evolution of modern landscapes would initially object to the above concept of constancy. However, it does not withstand scrutiny. For example, there is no modern analogy to the nappe mountain building processes that formed the European Alps or to the *mass extinctions* and sudden discontinuities that have dominated the geological record. Additionally, no one who has witnessed a *fault* line being upthrusted during an earthquake, or Mt St Helens wrenching itself apart in a cataclysmic eruption, would agree that all landscapes develop slowly. As Thomas Huxley so aptly worded it, gradualists had saddled themselves with the tenet of *Natura non facit saltum* – Nature does not make sudden jumps. J. Harlen Bretz from the University of Chicago challenged this tenet in the 1920s. Bretz attributed the formation of the scablands of eastern Washington to catastrophic floods. For the next forty years, he bore the ridicule and invectiveness of the geological establishment for proposing this radical idea. It was not until the 1960s that Bretz was proved correct when Vic Baker of the University of Arizona interpreted space probe images of enormous channels on Mars as features similar to the Washington scablands. At the age of 83, Bretz finally received the recognition of his peers for his seminal work.

Convulsive events are important climatic and geological processes, but are they likely to occur today? This is a major question cropping up throughout this book. The climatic and geological processes responsible for most hazards can be described succinctly. However, do these processes necessarily account for events occurring outside the historical record (in some places this is a very short record indeed)? In some cases, the evidence for catastrophic events cannot be explained. For example, there is ongoing debate whether or not mega-tsunami or super storms can move boulders to the top of cliffs 30 or more meters high. The mega-tsunami theory has been attacked – mainly because no historical tsunami generating similar deposits has been witnessed. However, the same argument can be applied to the alternative hypothesis of mega-storms. The dilemma of changing hazard regimes will be discussed at the end of this book.

The relationship between humans and natural hazards (Susman et al., 1983; Watts, 1983)

The above concepts emphasize the natural aspect of natural hazards. Disasters can also be viewed from a sociological or humanistic viewpoint. An extensive chapter at the end of this book deals with the human response to natural hazards at the personal or group level. While there are great similarities in natural hazard response amongst various cultures, societies and political systems, it will be shown that fundamental differences also occur. This is particularly evident in the ways that countries of contrasting political ideology, or of differing levels of economic development, cope with drought. Both Australia and Ethiopia were afflicted by droughts of similar severity at the beginning of the 1980s. In Ethiopia, drought resulted in starvation followed by massive international appeals for relief. However, in Australia no one starved and drought relief was managed internally.

In dealing historically with the scientific and mathematical description of natural hazards, it is apt to discuss a sociological viewpoint formulated in the twentieth century. This sociological viewpoint states that the severity of a natural hazard depends upon who you are, and to what society you belong at the time of the disaster. It is exemplified and expressed most forcibly by Marxist theory. Droughts, earthquakes and other disasters do not kill or strike people in the same way. The poor and oppressed suffer the most, experience worst the long-term effects, with higher casualties more likely as a result. In Marxist philosophy, it is meaningless to separate nature from society: people rely upon nature for fulfillment of their basic needs. Throughout history, humans have met their needs by utilizing their natural environment through labor input. Humans do not enter into a set contract with nature. In order to produce, they interact with each other, and the intrinsic qualities of these interactions determine how individuals or groups relate to nature. Labor thus becomes the active and effective link between society and nature. If workers or peasants are able to control their own labor, they are better adapted to contend with the vagaries of the natural environment. The separation of workers from the means of production implies that others, namely those people (capitalists or bosses) who control the means of production, govern their relationship with nature. This state of affairs is self-perpetuating. Because capitalists control labor and production, they are better equipped to survive and recover from a natural disaster than are the workers.

The main point about the Marxist view of natural hazards is that hazard response is contingent upon the position people occupy in the production process. This social differentiation of reactions to natural hazards is a widespread phenomenon in the Third World, where it is typical for people at the margins of society to live in the most dangerous and unhealthy locations. A major slum in San Juan, Puerto Rico, is frequently inundated at high tide; the poor of Rio de Janeiro live on the precipitous slopes of Sugarloaf Mountain subject to *landslides*; the slum dwellers of Guatemala live on the steeper slopes affected by earthquakes; the Bangladeshi farmers of the Chars (low-lying islands at the mouth of the Ganges–Brahmaputra Delta in the Bay of Bengal) live on coastal land subject to storm surge flooding.

The contrast in hazard response between the Third World and westernized society can be illustrated by comparing the effects of Cyclone Tracy – which struck Darwin, Australia, in 1974 – to the effects of hurricane Fifi, which struck Honduras in September of the same year. Both areas lie in major tropical storm zones, and both possess adequate warning facilities. The tropical storms were of the same intensity, and destroyed totally about 80 per cent of the buildings in the main impact zones. Over 8000 people died in Honduras, while only 64 died in Darwin. A Marxist would reason that the destitute conditions of under-development in Honduras accounted for the difference in the loss of life between these two events. Society is differentiated into groups with different levels of vulnerability to hazards.

One might argue, on the other hand, that many people in Third World countries, presently affected by major disasters, simply are unfortunate to be living in areas experiencing large-scale climatic change or *tectonic* activity. After all, European populations were badly decimated by the climatic cooling that occurred after the middle of the fourteenth century – and everyone knows that the Los Angeles area is well overdue for a major earthquake. One might also argue that Third World countries bring much of the disaster upon themselves. In many countries afflicted by large death tolls due to drought or storms, the political systems are inefficient, corrupt, or in a state of civil war. If governments in Third World countries took national measures to change their social structure, they would not be so vulnerable to natural disasters. For example, Japan, which occupies a very hazardous earthquake zone, has performed this feat through industrialization in the twentieth century. One might further argue that Australians or Americans cannot be held responsible for the misery of the Third World. Apart from foreign aid, there is little we can do to alleviate their plight.

The Marxist view disagrees with all these views. Marxism stipulates that western, developed nations are partially responsible for, and perpetuate the effect of disasters upon, people in the Third World – because we exploit their resources and cash-cropping modes of production. The fact that we give foreign aid is irrelevant. If our foreign aid is being siphoned off by corrupt officials, or used to build highly technical projects that do not directly alleviate the impoverished, then it may only be keeping underprivileged people in a state of poverty or, it is suggested, further marginalizing the already oppressed and thus exacerbating their risk to natural hazards. Even disaster relief maintains the status quo and generally prohibits a change in the status of peasants regarding their mode of production or impoverishment.

The basis of Marxist theory on hazards can be summarized as follows:

- the forms of exploitation in Third World countries increase the frequency of natural disasters as socio-economic conditions and the physical environment deteriorate;
- the poorest classes suffer the most;
- disaster relief maintains the status quo, and works against the poor even if it is intentionally directed to them; and
- measures to prevent or minimize the effects of disasters, which rely upon high technology, reinforce the conditions of underdevelopment, exploitation and poverty.

Marxist philosophy does not form the basis of this book. It has been presented simply to make the reader aware that there are alternative viewpoints about the effects of natural hazards. The Marxist view is based upon the structure of societies or cultures, and how those societies or cultures are able to respond to changes in the natural environment. The framework of this book, on the other hand, is centered on the description and explanation of natural hazards that can be viewed mainly as uncontrollable events happening continually over time. The frequency and magnitude of these events may vary with time, and particular types of events may be restricted in their worldwide occurrence. However, natural hazards cannot be singled out in time and space and considered only when they affect a vulnerable society. An understanding of how, where and when hazards take place can be achieved only by studying all occurrences of that disaster. The arrival of a tropical cyclone at Darwin, with the loss of 64 lives, is just as important as the arrival of a similar-sized cyclone in Honduras, with the loss of 8000 lives. Studies of both events contribute to our knowledge of the effects of such disasters upon society and permit us to evaluate how societies respond subsequently.

Hazard statistics (Changnon & Hewings, 2001; CRED, 2002; Balling & Cerveny, 2003)

Figure 1.1 plots the number of hazards by region over the period 1975–2001. The map excludes epidemics or famine. Despite its large population, Africa is relatively devoid of natural hazards. This is due to the tectonic stability of the continent and the fact that tropical storms do not develop here, except in the extreme south-east. However the African population is affected disproportionately by drought. The frequency of events over the rest of the world reflects the dominance of climate as a control on the occurrence of natural hazards. This aspect is illustrated further for the twentieth century in Table 1.1. The most frequent hazards are *tornadoes*, the majority of which occur in the United States. Over the latter half of the twentieth century, their frequency – more than 250 events per year – exceeds any other natural hazard. Climatically induced floods and tropical cyclones follow this phenomenon in frequency. Tsunami, ranked fourth, is the most frequent geological hazard, followed by damaging earthquakes with nine significant events per year. All totalled, climatic hazards account for 86.2 per cent of the significant hazard events of the twentieth century.

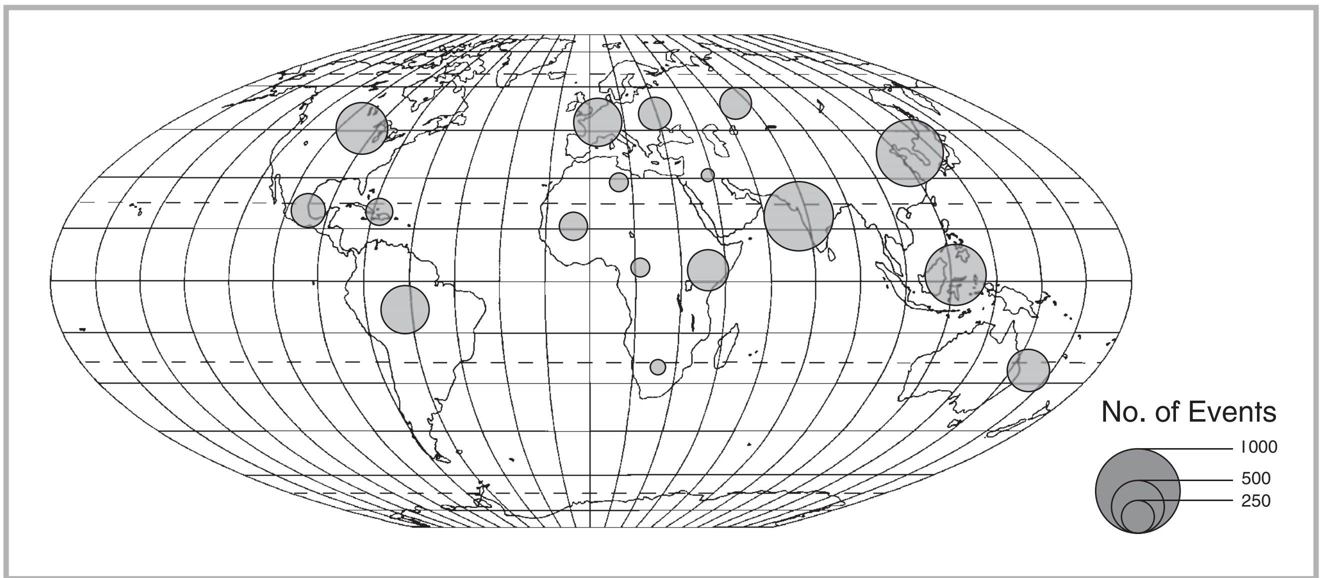

Fig. 1.1 Incidence of natural hazards by region 1975–2001 (based on CRED, 2002).

Table 1.1 Frequency of natural hazards during the twentieth century. Tsunami data comes from the Intergovernmental Oceanographic Commission (2003). Tornado statistics for the USA are for the 1990–1995 period only and derived from the High Plains Regional Climate Center (2003). All other data based on WHO (2002).

Type of Hazard	No of Events
Tornadoes (US)[1]	9476
Flood	2389
Tropical Cyclone	1337
Tsunami	986
Earthquake	899
Wind (other)	793
Drought	782
Landslide	448
Wild fire	269
Extreme temperature	259
Temperate winter storm	240
Volcano	168
Tornadoes (non-US)	84
Famine	77
Storm surge	18

[1] for F2–F5 tornadoes 1950–1995

The economic relevance of the biggest hundred of these hazard events is summarized over the same period in Table 1.2. Values are reported in US dollars and do not include inflation. Earthquakes, while ranking only fifth in occurrence, have been the costliest hazard ($US249 billion), followed by floods ($US207 billion), tropical storms ($US80 billion), and windstorms ($US44 billion). In total, the hundred most expensive natural disasters of the twentieth century caused $US631 billion damage. The single largest event was the Kobe earthquake of 20 January 1995, which cost $US131.5 billion. While this event is familiar, the second most expensive disaster of the twentieth century – floods in the European part of the former Soviet Union on 27 April 1991 costing $US60 billion – is virtually unknown.

Table 1.2 Cost of natural hazards, summarized by type of hazard for the 100 biggest events, 1900–2001 (based on WHO, 2002).

Type	Cost
Earthquake	$248,624,900,000
Flood	$206,639,800,000
Tropical storm	$80,077,700,000
Wind Storm	$43,890,000,000
Wild Fire	$20,212,800,000
Drought	$16,800,000,000
Cold wave	$9,555,000,000
Heat wave	$5,450,000,000
Total	$631,250,200,000

Figure 1.2 presents the number of hazards reported each year over the twentieth century. Apparently, natural hazards have increased in frequency over this

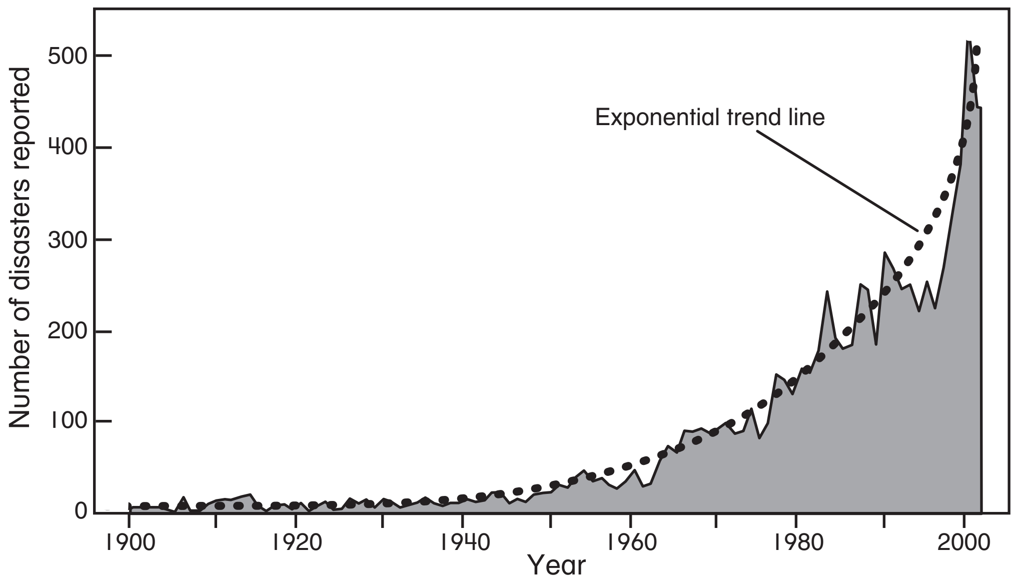

Fig. 1.2 Reporting incidence of natural hazards over time 1900–2001 (based on CRED, 2002).

time span from around ten events per year at the beginning of the century to over 450 events at the end. While increased vigilance and perception of natural hazards accounts for part of this increase, other data suggest that natural hazards are on the increase. The fact that these figures include both geological and climatic hazards rules out such a simple explanation as global warming as a major cause of this increased incidence. On the other hand, these figures should be treated with some caution because they do not always hold under scrutiny. For example, in the United States, the magnitude and frequency of thunderstorms, hailstorms, intense tornadoes, hurricanes and winter storms have not increased, but may have decreased. Over the same period, there is no increase in the cost of climatic hazards after the figures are adjusted for inflation. Instead, damaging events appear to recur at twenty-year intervals around 1950–1954, 1970–1974, and 1990–1994. This timing coincides with the peak of the 18.6 M_N *lunar cycle*, which will be described in Chapter 2.

Figure 1.3 presents the number of deaths due to natural hazards over the twentieth century. The time series does not include biological hazards such as epidemics or insect predation; however, it does include drought-induced famines. The number of deaths is plotted on a logarithmic scale because there have been isolated events where the death toll has exceeded the long-term trend by several million. On average 275 000 people have died each year because of natural hazards. If famine is removed from the data set, this number declines to 140 200 deaths per year. This reduction suggests that famine kills 134 800 people per year, roughly 50 per cent of the total number. Although the greatest number of deaths occurred in the 1930s – a figure that can be attributed to political upheaval and civil war – there is no significant variation over the twentieth century. This fact suggests that improved warning and prevention of natural hazards has balanced population increases resulting in a constant death toll. Many world organizations would consider several hundred thousand deaths per year due to natural hazards as unacceptable.

Table 1.3 presents the accumulated number of deaths, injuries and homeless for each type of hazard for the twentieth century. Also presented is the largest event in terms of death for each category. The greatest hazard during the twentieth century was flooding; however much of this was due to civil unrest. Half of the 6.9 million death toll occurred in China in the 1930s where neglect and deliberate sabotage augmented deaths. Earthquakes and tropical cyclones account for the other significant death tolls of the twentieth century. Interestingly, during the first three years of the twenty-first century 4242 deaths were caused by cold waves. This is 60 per cent of the total for the whole of the twentieth century despite the perception of global warming. In contrast, the death toll from a heat wave in France in 2003 resulted in 15 000

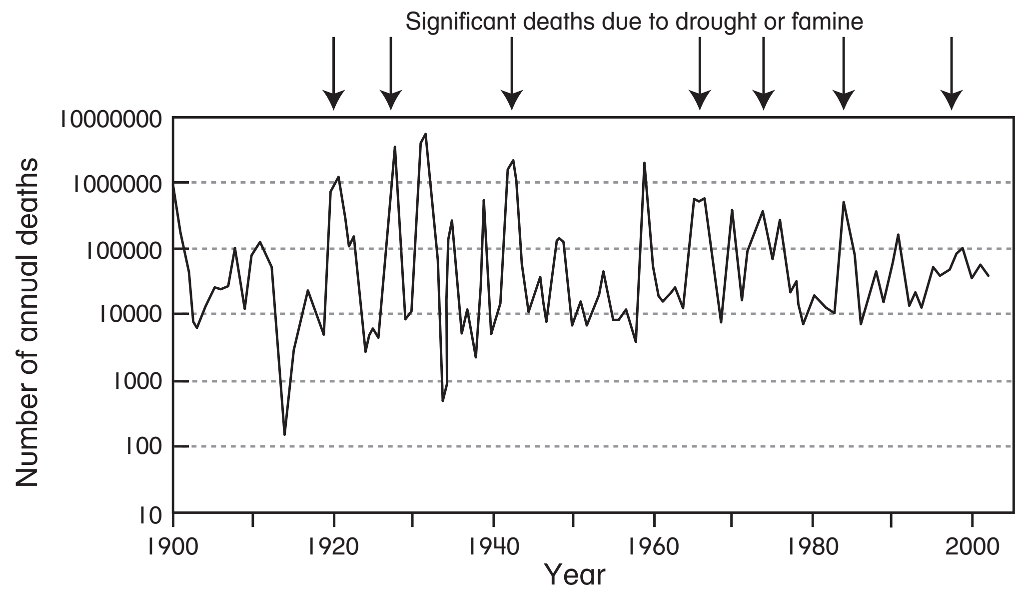

Fig. 1.3 Deaths from natural hazards over time 1900–2001 (based on CRED, 2002).

deaths, more than could be attributed to this cause during the whole of the twentieth century. Obviously, the statistics presented in Table 1.3 underestimate actual deaths, mainly because data were simply not collected for some hazards until recent times.

Table 1.3 also presents the number of injured and displaced people due to natural catastrophes in the twentieth century. Often hazard statistics concentrate upon death, not taking into account the walking wounded and the homeless who put a greater, more lasting burden, upon society. Eighteen times more people were made homeless by floods in the twentieth century than were killed. This ratio rises to 30 and 344 times respectively for tropical cyclones and extra-tropical storms. For example, the January 1998 ice storm that paralyzed Montreal killed twenty-five people. However up to 100 000 people were made homeless for up to a month afterwards because of the failure of electricity supplies as temperatures dipped to –40°C.

Table 1.3 Number of people killed, injured or displaced due to natural hazards during the twentieth century (based on WHO, 2002).

Type of Hazard	Deaths	Injuries	Homeless	Largest death toll event and date	Death toll
Floods	6 851 740	1 033 572	123 009 662	China, July 1931	3 700 000
Earthquakes	1 816 119	1 147 676	8 953 296	Tangshan, China, July 1976	242 000
Tropical cyclones	1 147 877	906 311	34 272 470	Bangladesh, Nov 1970	300 000
Volcano	96 770	11 154	197 790	Martinique, May 1902	30 000
Landslides, avalanches, mud flows	60 501	8 071	3 759 329	Soviet Union, 1949	12 000
Extra-tropical storms	36 681	117 925	12 606 891	Northern Europe, Feb 1953	4 000
Heat wave	14 732	1 364	0	India, May 1998	2 541
Tsunami	10 754	789	–	Sanriku Japan, Mar 1933	3 000
Cold wave	6 807	1 307	17 340	India, Dec 1982	400
Tornado	7 917	27 887	575 511	Bangladesh, Apr 1989	800
Fires	2 503	1 658	140 776	USA, Oct 1918	1 000
Total	10 052 401	3 257 714	183 533 065		

CHAPTER OUTLINES

While this book has been written assuming little prior knowledge in Earth science at the university level, there are occasions where basic terminology (jargon) has had to be used in explanations. More explicit definitions of some of these terms can be found in the glossary at the end of the book. You may have noticed already that some words in this book have been italicized. These terms are defined or explained further in the glossary. Note that book titles, names of ships and botanical names are also italicized, but they do not appear in the glossary.

Individual chapters are arranged around a specific concept or type of hazard. The mechanisms controlling and predicting this particular hazard's occurrence are outlined and some of the more disastrous occurrences worldwide are summarized. Where appropriate, some of humankind's responses to, or attempts at mitigating, the hazard are outlined.

The hazards covered in this book are summarized in Table 1.4, with a chapter reference for each hazard shown in the last column. The hazards, assessed subjectively, are listed in the order that reflects the emphasis given to each in the text. Table 1.4 also grades the hazards, on a scale of 1 to 5, as to degree of severity, time span of the event, spatial extent, total death toll, economic consequences, social disruption, long-term impact, lack of prior warning or suddenness of onset, and number of associated hazards. The overall socio-economic–physiological impact of the hazard is ranked using these criteria. The most important global hazard is drought, followed by tropical cyclones, regional floods, and earthquakes. Three of these four top hazards rank highest for cost (Table 1.2) and human impact (Table 1.3). These latter two tables do not evaluate drought because it develops so slowly and insidiously that it is often ignored when event statistics are collected. Of the top ten hazards, six are climatically induced. Table 1.4 has been constructed for world hazards. The ranking differs for individual countries and latitudes. For example, the ranking of hazards in the United States in terms of economic loss is tropical storms, floods, severe thunderstorms, tornadoes, extra-tropical storms, hail, and wind.

The hazards in the book are organized under two main parts: climatic hazards and geological hazards. Climatic hazards are introduced in Chapter 2, which outlines the mechanisms responsible for climatic variability. This chapter covers the basic processes of air movement across the surface of the globe, the concept of mobile polar highs, air–ocean temperature interactions resulting in the Southern, North Atlantic and North Pacific oscillations, and the effect of astronomical *cycles* (such as sunspots and the 18.6-year lunar tide) on the timing of climate hazard events.

A description of large-scale storms is then covered in Chapter 3. This chapter discusses the formation of large-scale tropical vortices known as tropical cyclones. Tropical cyclones are the second most important hazard, generating the greatest range of associated hazard phenomena. Familiar cyclone disaster events are described together with their development, magnitude and frequency, geological significance, and impact. The response to cyclone warnings in Australia is then compared to that in the United States and Bangladesh. Extra-tropical cyclones are subsequently described with reference to major storms in the northern hemisphere. These storms encompass rain, snow, and freezing rain as major hazards. Storm surges produced by the above phenomena are then described. Here, the concepts of probability of occurrence and exceedence are introduced. The chapter concludes with a description of dust storms as a significant factor in long-term land degradation.

Chapter 4 summarizes smaller hazards generated by wind. Attention is given to the description of thunderstorms and their associated hazards. These include tornadoes, described in detail together with some of the more significant events. The chapter concludes with a description of the measures used to avert tornado disasters in the United States.

These chapters set the scene for two chapters dealing with longer lasting climatic disasters, namely drought and floods. Chapter 5 deals with impact of human activity in exacerbating drought and people's subsequent responses to this calamitous hazard. Emphasis is placed on pre- and post-colonial influences in the Sahel region of Africa, followed by a discussion of modern impacts for countries representative of a range of technological development. The second half of the chapter deals with human response by a variety of societies, from those who expect drought as a natural part of life, to those who are surprised by its occurrence and make little effort to minimize its impact. These responses cover Third World African countries as well as developed westernized countries such as the United States, England, and Australia. The chapter concludes by describing the way