Zinta Zommers · Ashbindu Singh
Editors

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Foreword

This summer I made a "Wall of Logs" for my kids in the garden behind my house in Guelph, Canada. I used cut wood from fallen trees around our city home. I also repaired our flooded basement, roofing damaged by wind and flood, and drainage systems around our house. On July 19, 2013, a 119-km/h wind and rain storm – the equivalent of a Level 1 Hurricane – swept through Southwestern Ontario, leaving some 150,000 households without power and leading to a record number of insurance claims. Like the effects of "extreme weather events" anywhere, most of the cost – including my sore back – was not covered by insurance, and whether covered or not, the work had to be done.

In May 2013, some 20 years after the 1992 Earth Summit first put climate change on the international political agenda, the daily mean concentration of atmospheric carbon dioxide passed the 400-ppm mark. Earlier 2007 UN IPCC predictions on temperature rise have proven accurate, and a 2013 World Bank study warns that we are well on the way to a 4-degree warmer world – well beyond the 2-degree marker, beyond which dangerous climatic changes are likely to occur. If we get there – and all indications are that we will – we will be in a period of what some scientists have called "very dangerous warming."

As human beings, we have created our own geological epoch, the *Anthropocene*, where human pressures on the planet risk triggering abrupt and irreversible changes with potentially catastrophic outcomes for human societies and for other life-forms (Rockstrom 2009). We have already crossed three of nine planetary boundaries – or tipping points – and risk triggering nonlinear, abrupt environmental change within continental and planetary biospheric systems. While Bangladesh and many other developing countries are working to quantify current and future loss and damage, climate change poses an existential threat to Small Island Developing States (UNFCCC 2013). Already some islands of New Guinea have been evacuated, and Pacific Island States are negotiating with other states on relocations and land purchases.

Globally, drought, flooding, fire, and all manner of adverse weather events abound. Even the most stalwart of conservative thinking recognizes that something is seriously wrong. The July 2, 2012, editorial of *The Financial Times* drily noted that "simply letting climate change rip and tidying up the damage as it occurs is not an enviable strategy… in poor countries, higher temperatures will mean an increased risk of hardship and societal collapse, and rich countries will be forced to respond."

In the last 25 years, I have done other work that I thought had to be done. I have worked in global health as a researcher and as a humanitarian practitioner and leader with Médecins Sans Frontières (Doctors Without Borders), the Drugs for Neglected Diseases Initiative, and Dignitas International. Much of this has meant practical medical humanitarian efforts aimed at the relief of suffering while supporting people's right to be agents in their own destiny. Equity as a principle is key to humanitarian work. It assumes that all people are equal in worth and dignity, approaches the pursuit of justice through fairness, and essentially argues that people in similar situations should be treated similarly. Humanitarianism requires that we care for the other and that we act both for and with each other. It is not always a given.

My work has also involved a deep engagement with the process of knowledge creation and its influence on practical humanitarian action. In situations of crisis – be it war, genocide, famine, epidemic disease, natural disaster, or social crisis – this means adapting to the reality of changing real-time events and needs with the best available evidence and engaging in practical actions now. As experience and objective knowledge grow or change, so too can the effectiveness of one's future actions. In delivering humanitarian assistance, developing medicines for neglected tropical diseases, or in working to improve clinical outcomes or health systems in the developing world, a commitment to the best science for the most neglected people has been paramount.

We need the best science to help us understand climate change as clearly as possible and to help us choose and shape the best adaptive strategies. This necessarily means a multidisciplinary approach to designing and testing disaster preparedness and early warning (DPEW) systems that can accommodate complex scientific, technical, social, and governance challenges.

Designing early warning systems for climate change (EW-CC) with equity as a guiding principle can contribute to building genuine community resilience. EW-CC systems are at a nascent stage in terms of predicting exactly when, where, how big, and who will be affected by extreme weather events. While these will improve as data reliability and modeling improves, there is enough knowledge now to both credibly imagine a seamless integrated warning system and to guide development so that these capacities can be developed in a timely manner.

Effective early warning systems are not simply technical networks that deliver warnings in the "last mile" before disaster but are also cultural and political processes that engage traditional knowledge and community in the "first mile" of system design and use. Such systems could also include ongoing crowd-sourced data and analysis and be broadened or at least aligned with broader public health prevention and treatment and health surveillance strategies.

The 2011 drought and famine in East Africa meant 13 million people needed food assistance. It also left 500,000 people dead, and the drought has been directly attributed to the effects of climate change (Lott et al. 2013). An early warning system was in place, and appropriate early warnings were released, but with little effect until the famine was well advanced and in the global public space. Besides understanding the technical, political, governance, and moral challenges of early warning systems, we need to more fully understand the phenomenon of if and how human beings respond to emergency, crisis, disaster, or catastrophe in their own or in distant communities. Do human beings always respond? Under what circumstances and with what constraints? Is, for example, empathy central to a positive response? If so, then how can it be both cultivated and incorporated into the design of early warning systems? These are crucial questions to the effective design of EW-CC systems.

My own global health work has also engaged the influence of humanitarian action and new knowledge on broader political processes and choices. Politics is an imperfect process, and yet it can and does move. The twentieth-century political theorist Hannah Arendt defined politics as “action” (d’Entreves 2008). Hers is a kind of Newtonian operational definition, devoid of ideology, and a simple description of the phenomenon itself. She also views action as a form of human togetherness. I think both conceptions are entirely accurate and helpful in thinking through how we engage future action on early warning systems for climate change. As scientists, citizens, and most importantly as human beings, we each and in our associations with each other must continue to take appropriate action. Our common destiny depends on how we do this, how quickly, and how effectively.

The October 2013 UN IPCC Assessment concluded that global warming is unequivocal and that human influence has been its dominant cause since the mid-twentieth century (IPCC 2013). Temperatures are likely to increase by up to 4.8° C if emissions remain high, and sea levels will possibly rise by 1 m by 2100. Heat waves are likely to occur more frequently and last longer, while wet regions will get wetter and dry regions will get dyer. Much of the global warming is irreversible and temperatures will remain “at elevated levels for many centuries.” It also warns that limiting climate change will require “substantial and sustained” reductions of green house gas emissions, which are reaching a tipping point.

While some may merely have to build “Log Walls,” others are faring and will fare far worse. There is no escape from our biosphere. It is the only place we live. And yet, we are changing it so that it is unlivable for many, especially those who are poorest and already most marginalized.

Equity-oriented, flexible, adaptive DPEW systems are a hallmark of community resilience. Whether integrated with effective mitigation strategies or not, the work has to be done, and done well. This book is an outstanding step in that direction.

Waterloo, Canada James Orbinski, OC, MSC, MA, MD

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Acronyms and Abbreviations

AMO	Atlantic Multi-decadal Oscillation
AMOC	Atlantic Meridional Overturning Circulation
AMV	Atlantic Multi-decadal Variability
AOD	Aerosol Optical Depth
CCAA	Climate Change Adaptation in Africa
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CERES	Clouds and the Earth's Radiant Energy System
CEWS	Community Early Warning System
CHAP	Common Humanitarian Action Plan
CHF	Common Humanitarian Fund
CIDA	Canadian International Development Agency
CIDCM	Center for International Development and Conflict Management
DAC	Development Assistance Committee
DCM	Drought Cycle Management
DEC	Disasters Emergency Committee
DFID	Department for International Development
DMB	Disaster Management Bureau
DRR	Disaster Risk Reduction
ECMWF	European Centre for Medium-Range Weather Forecasting
ENAC	Emergency Notification and Assistance Convention Website
ENS	Earthquake Notification Service
ENSO	El Niño Southern Oscillation
EO	Earth Observation
ERF	Emergency Response Fund
EWS	Early Warning System
FAO	Food and Agriculture Organization of the United Nations
FEWSNET	Famine Early Warning System Network
FFWP	Flood Forecasting and Warning Process
FSNWG	Food Security and Nutrition Working Group

FWI	Fire Weather Index
GAR	Global Assessment Report on Disaster Risk Reduction
GDP	Gross Domestic Product
GEOFON	GEO-Forschungs Netz
GFDRR	Global Facility for Disaster Reduction and Recovery
GFMC	Global Fire Monitoring Center
GIEWS	Global Information and Early Warning System (Food and Agriculture Organization)
GFIMS	Global Fire Information Management System
Global EWS Fire	Global Early Warning System for Wildland Fires
GSN	Global Seismic Networks
HDI	Human Development Index
HERR	Humanitarian Emergency Response Review
HEWS	Humanitarian Early Warning Service
HFA	Hyogo Framework of Action
IACRNA	Inter-Agency Committee on the Response to Nuclear Accidents
IAEA	International Atomic Energy Agency
ICL	International Consortium on Landslides
ICPAC	IGAD Climate Prediction and Applications Center
ICT	Information and Communications Technology
IEC	Incident and Emergency Centre
IFRC	International Federation of Red Cross and Red Crescent Societies
IGAD	Intergovernmental Authority on Development
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
IPO	Inter-decadal Pacific Oscillation
KMD	Kenyan Meteorological Department
LIC	Low-Income Country
MODIS	Moderate Imaging Spectroradiometer
NAO	North Atlantic Oscillation
NASA	National Aeronautics and Space Administration
NDMA	National Drought Management Authority
NGO	Non-governmental organization
NMHS	National Meteorological and Hydrological Services
NOAA	National Oceanic and Atmospheric Administration
OCHA	Office for the Coordination of Humanitarian Affairs (United Nations)
OECD	Organisation for Economic Co-operation and Development
PDO	Pacific Decadal Oscillation
PDV	Pacific Decadal Variability
PMD	Pakistan Meteorological Department
RANET	Radio and Internet for the Communication of Hydro-Meteorological and Climate Related Information
RH	Relative Humidity

RSMC	Regional Specialized Meteorological Centres
SIDS	Small Island Developing States
SREX	Special Report on Extreme Events and Disasters by the Intergovernmental Panel on Climate Change
SST	Sea Surface Temperatures
TRP	Turkana Rehabilitation Project
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFPA	United Nations Population Fund
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USGS	United States Geological Survey
WFP	World Food Programme
WOVO	World Organization of Volcanic Observatories
WWW	World Weather Watch

Chapter 1
Introduction

Zinta Zommers and Ashbindu Singh

"Normal has changed… The normal is extreme."
(Attributed to U.S. National Weather Service acting director Laura Furgione)

Abstract This chapter provides an introduction to this book, briefly outlining each chapter. It discusses the challenges posed by climate-related hazards, highlights critical components or early warning systems, mentions examples of current early warning systems, and describes emerging areas of development. Suggestions on ways to improve warning communication, and encourage early action, are provided. The potential utility of broader risk management approaches and flexible and forward decision-making are also mentioned. This chapter concludes that great progress has been made in early warning systems. But sustained efforts are needed to refine the political, social, and financial mechanisms that support warning systems. Continued improvement is all the more urgent given an ethical responsibility to issue warnings that prevent loss of life and property and help build adaptive capacity.

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The year 2013 began in the water for the Holmes family. Early in January, grandparents and grandchildren spent hours clinging to a jetty in Tasmania – immersing themselves in the Ocean to escape bushfires.[1] Such fires destroyed at least 109 ha and more than 200 buildings (NOAA 2013a). Elsewhere in Australia, temperatures were so high that the Bureau of Meteorology had to extend its weather map temperature scale by adding a new color – purple – for extreme heat. In February, Tropical Storm Haruna hit Mozambique and continued toward Madagascar, affecting food security and agriculture in the region. In March, flash floods damaged 220 homes, destroyed crops, and displaced 1,200 people in Uganda (Levin 2013). New Zealand saw the worst drought in 30 years resulting in a revenue loss of $820 million USD and contributing to extreme food shortages (Levin 2013). In May, Tropical Cyclone Mahasen created landfall in Bangladesh, affecting 1.3 million people and destroying almost 50,000 homes (Levin 2013). In this same month, the widest tornado ever recorded in US history hit Oklahoma, causing numerous deaths and damaging homes. June brought extreme flash floods and landslides to Northern India, killing over 1,000 people and leaving an equal number missing (Levin 2013). Throughout July, drought continued in large parts of central and southern United States, as well as in part of interior Alaska. Some areas have only received 35–65 % of normal precipitation for the past two years (NOAA 2013b). Yet more devastation occurred on August 14, when flash floods hit Khartoum, Sudan, damaging 15,399 households, affecting 84,000 people (IFRC 2013a).

These statistics reflect merely a small sample of disasters over the past year. Around the world, extreme weather events are becoming increasingly "normal." Indeed, observations since 1950 indicate increases in extreme weather events (IPCC 2011), and further increases are expected in the twenty-first century as a result of climate change. The 2011 IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (IPCC SREX) predicts rising wind speed of tropical cyclones, increasing intensity of droughts, and a growing frequency of heat waves. A one-in-20 year "hottest day" event is likely to occur every other year by the end of the twenty-first century. Heavy precipitation events are also on the rise, potentially impacting the frequency of floods and almost certainly affecting landslides (IPCC 2011).

Hazards have significant impacts on both human lives and national economies. Between 1991 and 2005, 3,470 million people were affected by disasters globally, and over 960,000 people died. During this time, economic losses from disasters totaled US$ 1,193 billion (UNISDR 2008). Without significant action, losses from extreme weather are expected to continue to increase in future (IPCC 2012; Shepherd et al. 2013). The Overseas Development Institute (Shepherd et al. 2013) estimates that up to 325 million extremely poor will be living in the 49 hazard-prone countries in 2030. In areas with limited social safety nets, lack of access to markets, capital, assets, or insurance mechanisms, natural disasters have the potential to reverse development progress and entrench poverty (Shepherd et al. 2013). Hsiang et al. (2013) even claim that

[1] http://www.theguardian.com/world/interactive/2013/may/26/firestorm-bushfire-dunalley-holmes-family

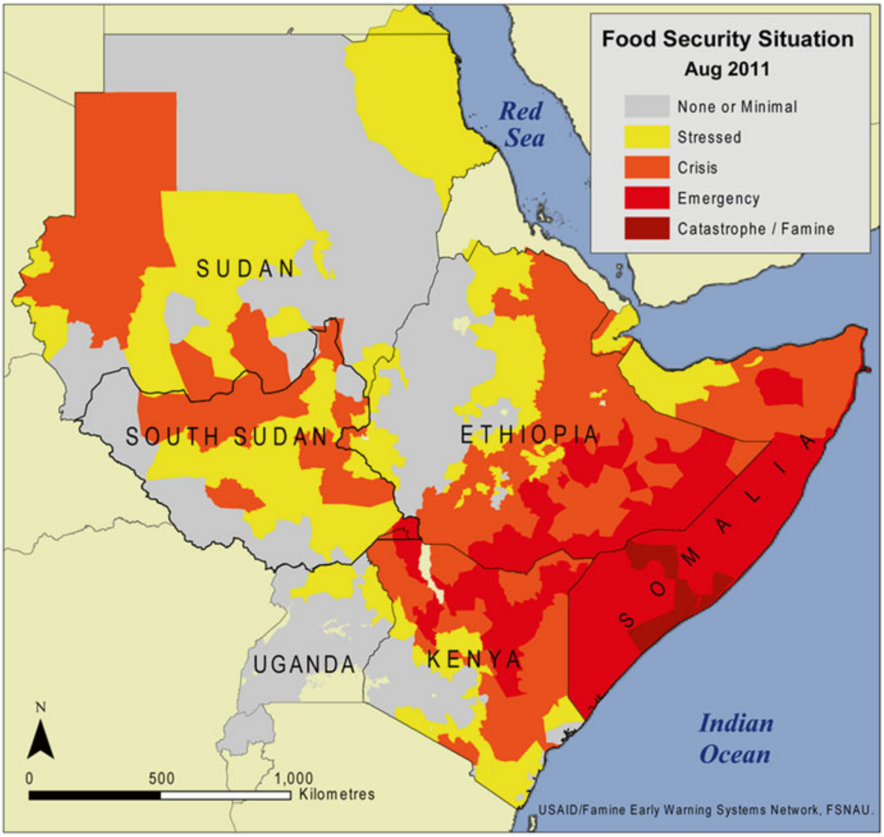

Fig. 1.1 Map demonstrating areas of food shortage in East Africa during the 2011 drought crisis. Reduced rainfall periods in East Africa have been attributed to climate change (Lott et al. 2013) (Source: Modified from UNHCR/USAID)

warmer temperatures and rainfall extremes can lead to substantial increases in conflict (with a 4 % median increase in interpersonal violence and 14 % median increase in intergroup violence for each standard deviation change in climate toward warmer temperatures or extreme rainfall). While these findings may be debated, it is clear that climate change is already causing loss and damage (Warner et al. 2012). Lott et al. (2013) conclude that the failure of the 2011 spring rains in East Africa, which resulted in widespread famine, was caused by a rise in sea surface temperature due to anthropogenic climate change (Fig. 1.1). Climate change impacts will be felt around the world. As President Barack Obama told the United Nations (New York Times 2009):

> No nation, however large or small, wealthy or poor, can escape the impact of climate change. Rising sea levels threaten every coastline. More powerful storms and floods threaten every continent. More frequent drought and crop failures breed hunger and conflict in places where hunger and conflict already thrive. The security and stability of each nation and all peoples…are in jeopardy.

1.1 Early Warning Systems for Climate Change

Despite well-acknowledged dangers posed by climate change, the world continues to take insufficient action to curb emissions of greenhouse gases. On May 9, 2013, the daily mean concentration of atmospheric carbon dioxide (CO_2) surpassed 400 parts per million (ppm) – the highest recorded level since measurements began in 1958 at Mauna Loa Observatory in Hawaii. As greenhouse gases continue to increase, the goal of staying within 2 degrees of warming is increasingly implausible. To constrain global warming to within 2 degrees, developed countries need to cut emissions 25–40 % below 1990 levels by 2020. However, global emission levels, and promises of emissions reductions, remain far off track (UNEP 2012). According to the United Nations Environment Programme's 2012 Emissions Gap Report, "Global greenhouse gas emissions.... are estimated at 50.1 $GtCO_2$ (with a 95 % uncertainty range of 45.6–54.6). This is already 14 percent higher than the median estimate (44 $GtCO_2$) of the emission level in 2020 with a likely chance of meeting the 2 degree target."

Attention is therefore increasingly turning from climate change mitigation to climate change adaption. According to the Intergovernmental Panel on Climate Change (Schneider et al. 2007), "Adaptation can significantly reduce many potentially dangerous impacts of climate change and reduce the risk of many key vulnerabilities." However, lack of technical, financial, and institutional capacity hinders effective adaptation and is resulting in an adaptation gap (Schneider et al. 2007).

Adaptation to extreme events has been particularly limited, despite improvements in forecasts and understanding of risks. The IPCC explains:

> One reason is the decline in local concern and thus a reduced propensity to adopt proactive adaptation measures, as the memory of specific disaster events fades.... communities can still be taken by surprise when extreme events occur, even though scientific evidence of their potential occurrence is widely available. Economic damage and loss of life from Hurricane Katrina 2005, the European heat wave 2003, and many other similar events are due in large measure to a lack of sufficient anticipatory adaptation, or even maladaption in some cases (Schneider et al. 2007).

Indeed studies show that our judgments about uncertain events, such as the probability of a hazard striking, are skewed by availability biases ("the ease with which the relevant mental operations of retrieval, construction, or association can be performed"). Because likely events are easier to imagine than unlikely events, it is difficult for us to accurately estimate risk (Tversky and Kahneman 1974). As climate change increases hazard occurrence, our risk assessments may suffer from yet further errors, because we often fail to adequately update our decision-making with new information (Kahneman 2011). Even if households try to take preparatory action, many are only partially successful in adapting, as coping mechanisms have costs associated with them or have negative effects in the long term (Warner et al. 2012).

Early warning systems can help improve "anticipatory adaptation" and reduce the loss of lives and damage to property. In fact, they were identified by the IPCC SREX report (2011), "as key to reducing impacts from extreme events." Already in 2005, United Nations Secretary-General Kofi Annan called for the establishment of a worldwide early warning system for all natural hazards. The 2010 UNFCC Cancun Agreements invite "all Parties to enhance…climate change related disaster risk reduction strategies (such as) early warning systems." In 2012, the outcome document of the United Nations Conference on Sustainable Development (Rio +20) called for countries to "build resilience to disasters with a renewed sense of urgency" and "ensure early warning systems (EWS) and disaster risk assessments are a key part of disaster resilience efforts at all levels." The United Nations High Level Panel on Post 2015 Development Goals has even encouraged the incorporation of disaster risk reduction into the post-2015 development agenda (UN 2013).

1.2 Book Summary

This book explores the feasibility of using early warning systems to prevent losses from climate change associated hazards – such as hurricanes, fog, floods, droughts, and fires. Chapters in this book highlight specific components of the early warning process – including ways to identify vulnerable communities, predict hazards, and deliver information. Satellite images illustrate the transnational impact of disasters. Case studies provide detailed examples of current early warning systems, and highlight gaps in knowledge and coverage.

This book is unique in bringing together contributions from authors in different fields and from different parts of the world – Africa, Asia, Europe, and North America. Despite widespread calls for early warning systems, there has long been a lack of dialogue between fields. Discourse often occurs within the boundaries of specific disciplines – meteorology, anthropology, and political science for example. There is limited coherence in activities and policy frameworks related to climate change adaptation and disaster risk reduction (Mitchell and Van Aals 2008). To encourage cross-disciplinary learning, this book brings together authors with different areas of expertise. Each discipline brings a unique approach, along with field-specific terminology or biases. But the different perspectives also offer unique tools, which can be used to better early warning systems.

1.3 The Challenge

The first three chapters of this book focus on the challenge before us – hazards and human vulnerability to hazards. In Chap. 2, Sandra Banholzer, James Kossin, and Simon Donner review the links between climate change and extreme events. Generalizations are hard to make and predictions are limited by uncertainties in science. Formal detection of trends, for example, is constrained by the length and quality of the historical data records and uncertain understanding of natural variability. However, the latest review of scientific data makes clear that climate change is linked to increasing intensity of droughts and precipitation, and increasing frequency of heat waves. Mean tropical cyclone intensity and rainfall rates are also projected to increase with continued warming. As science progresses, it is critical to further tease out natural variations in climate from human-caused changes. There is mounting evidence that humans may influence hazards such as cyclones through a variety of activities, through particulate pollution as well as greenhouse gases.

In Chap. 3, Ritesh Gautam describes a hazard that has links both to changes in climate and human activities – fog. Each year during December and January, dense fog engulfs the Indo-Gangetic Plains in Southern Asia, extending over a stretch of 1,500 km disrupting airline traffic and causing massive delays in trains resulting in significant financial losses and inconveniences. Gautam shows that the fog results from increasing atmospheric pollution combined with moisture from north-westerlies. Trends in poor visibility suggest a significant decrease in air quality and an increase in foggy days. Such results highlight the fact that we face a range of both old and new hazards, and that the hazards – and the challenges they pose – change and evolve.

Not all extreme events however lead to disasters. Disaster risk is not only a function of exposure or severity of hazard, but also reflects the concentration of people or assets in the area and their vulnerability (UNISDR 2011b). In Chap. 4, Ryan Hogarth, Donovan Campbell, and Johanna Wandel discuss the topic of vulnerability and its relevance to early warning systems. Vulnerability depends on a range of physical, social, political, economic, cultural, and institutional characteristics (UNISDR 2009). Vulnerability assessments can help identify which particular stakeholder groups are most in need of early warning, and which groups are able to respond to warnings. According to the "behavioral paradigm," individuals may misinterpret hazard risks due to inadequate information or a tendency to be short sighted, as already mentioned. However, a comparison of the impacts of earthquakes in Haiti and Chile indicates that even if individuals receive warnings, socio-economic factors may constrain early action. Structural paradigms and the Pressure Action Response model provide a framework with which to understand disparities in vulnerability. The authors review strengths and weaknesses of different methods used in vulnerability assessments and provide a case study from an ongoing assessment in the Caribbean.

1.4 Critical Components of Early Warning Systems

In Chap. 5, Ilan Kelman and Michael Glantz define "early warning systems" and outline questions that need to be considered in early warning system design. An early warning system should be viewed as a social process, rather than a combination of technical equipment designed to detect hazards and send details to authorities. In the past, a "Last Mile" approach was applied to early warning system design. People and communities were only considered toward the end of system design. Kelman and Glantz argue that a "First Mile" approach should be used to involve communities from the outset.

Further, early warning systems should be considered a continuous process – embedded in day-to-day functioning of the society rather than springing to life before hazard events. In addition to continuity, early warning systems must be: (1) timely, with lead times that give sufficient opportunity for action; (2) transparent, open for scrutiny and feedback; (3) flexible to expand to different hazards and vulnerabilities; and (4) have defined catalysts or triggering mechanisms.

Box 1.1 Improved early warning systems have ten common characteristics, which have contributed to their success, irrespective of the political, social, institutional, and economic factors (WMO 2011):

1. **Political recognition.** There is a strong political recognition of the benefits of early warning systems, reflected in harmonized national and local disaster risk management policies, planning, legislation.
2. **Common operational components.** Each effective system is built upon four components–hazard detection, monitoring, and forecasting; risk analysis and incorporation of risk information in emergency planning and warnings; dissemination of timely and authoritative warnings; and community planning and preparedness with the ability to activate emergency plans.
3. **Role clarification**. Stakeholders are identified, their roles and responsibilities and coordination mechanisms are clearly defined, and then they are documented within national and local plans and legislation.
4. **Resource allocation.** Early warning system capacities are supported by adequate resources (human, financial, equipment, etc.) across national and local levels, with long-term sustainability in mind.
5. **Risk assessment**. Hazard, exposure, and vulnerability information are used to carry out risk assessments and the development of warning messages.
6. **Appropriate warnings.** Warning messages are clear, consistent and include risk information; designed to link threat levels to emergency preparedness and response actions (using colors, flags, etc.); understood by authorities and the population; and issued from a single (or unified), recognized, and authoritative source.
7. **Timely dissemination.** Warning dissemination mechanisms are able to reach the authorities, other stakeholders, and the population at risk in a timely and reliable fashion.
8. **Integration into response planning.** Emergency response plans are developed with consideration for hazard/risk levels, characteristics of the exposed communities (urban, rural, ethnic populations; tourists and particularly vulnerable groups such as children, the elderly, and the hospitalized), coordination mechanisms, and various stakeholders.
9. **Integration in relevant educational programs.** Training in risk awareness, hazard recognition, and related emergency response actions is integrated in various formal and informal educational programs and linked to regularly conducted drills and tests across the system to ensure operational readiness at any time.
10. **Feedback**. Effective feedback and improvement mechanisms are in place at all levels to provide systematic evaluation and ensure system improvement over time.

Unfortunately, as Veronica Francesca Grasso illustrates in Chap. 6, current early warning systems lack many of these components. Grasso reviews the state of early warning systems for both rapid-onset hazards and slow-onset hazards, focusing on the technical needs and agencies involved in monitoring. Even though many early warning systems are operational worldwide, numerous high-risk countries remain "uncovered." Furthermore, out of 86 countries that reported recent progress in early warning system development, the majority indicated that, "achievements were neither comprehensive nor substantial" or "recognized limitations in key aspects, such as financial resources and/or operational capacities." Frequently reported impediments to early warning system development include lack of funding; inadequate coordination between local, national, and regional levels; and lack of human resources or infrastructure. Most countries report warning systems for single hazards, particularly floods and cyclone or hurricanes. Only few countries have early warning systems for droughts, fires, famines, or heat waves.

Nevertheless, great strides have been made in developing, or improving, early warning systems in countries such as Bangladesh, Cuba, and France (Golnaraghi 2012). Aspects that have contributed to success are described below.

Chapters 7, 8, 9, 10, and 11 provide detailed examples of early warning systems for wildfires, dust storms, and floods, while aspects of early warning systems that need greater consideration – including communication, the role of gender and ethics – form the focus of Chaps. 12, 13, 14, and 15.

1.5 Examples of Early Warning Systems

Fires currently burn 330–431 million ha of global vegetation each year, mainly in tropical grasslands and savannahs. Climate change is expected to increase both fire occurrence and area burned, particularly in boreal forests, due to warmer conditions and longer fire seasons. Fire early warning systems are based on fire danger ratings. They can be used to provide both short-term and longer-term warnings, and can help identify levels of resources that should be mobilized in emergencies. Currently less than half the countries in the world have national fire danger rating systems. Yet clear examples of best practice exist, such as the Canadian Forest Fire Weather Index. In Chap. 7, William de Groot and Michael Flannigan describe progress toward developing a global early warning system for wildland fires. Both the science and institutional structures necessary for fire early warning are well developed, indicating that this should be a hazard against which the world is well protected.

By contrast, scientific understanding of dust storms, and early warning systems to protect against these, are less well developed. Dust storms emit an estimated 2,000 teragrams of dust per year (Tg/year). In parts of Japan, dust storms can occur on more than 300 days a year (MoE 2008). As Lindsey Harriman describes in Chap. 8, efforts have been made to increase the accuracy and length of dust storm forecasts. But the impacts of dust storms may occur far from the cause. This creates challenges for both dust storm mitigation and early warning systems. Coordinating early warning efforts or communicating early warning alerts across national boundaries remains a challenge.

Floods also require regional approaches to early warning system design, as rainfall in one part of a river basin can lead to flooding downstream. Chapters 9 and 10 provide two different examples of flood early warning systems, from different parts of the world. Both offer similar lessons. In Chap. 9, S.H.M. Fakhruddin describes progress toward 1–10-day flood forecasting in Bangladesh. Due to Bangladesh's flat topography, one-fifth to one-third of the country is often flooded during the monsoon. England also faces flood risks and damage, with losses from flooding approaching US$1.2 billion in 2012. In Chap. 10, Janak Pathak and Richard Eastaff describe the flood forecasting system developed by the UK Environment Agency. Both chapters illustrate that improvements in flood forecasting can help save lives and property, but they also highlight the complex institutional collaboration needed to develop effective warning systems. Detailed assessments of community needs – including forecast lead time and methods of warning dissemination – are critical. "The community wants accurate and timely messages which must address public concerns, contain what people want to know, give guidance on how to respond, and use examples, stories and analogies to make the point," Fakhruddin writes.

Chapter 11 provides insight into institutional process of developing early warning systems. James Oduor, Jeremy Swift, and Izzy Birch describe the steps through which Kenya developed an early warning system for drought, run today by the National Drought Management Authority (NDMA). Drought response has evolved over time, with input from a range of experts. Institutional memory is critical to ensure learning from past early warning successes and failures. Long-term commitment from funders is also vital, along with some degree of institutional autonomy. This can be achieved from having specialized, permanent agencies dedicated to early warning. The authors note that, "Before the early warning system was in place, there was considerable political intervention in the allocation of emergency aid…. A strong and credible early warning system can reduce political influence and ensure that decisions are taken on the basis of objective evidence." They also emphasize that it is critical for early warnings to result in rapid response – without the latter, the former has little purpose. The NDMA thus tries to run a "Drought Management System" not just an "Early Warning System," which includes activities to support livelihoods and reduce poverty, enabling household response.

1.6 Gaps and Weaknesses

Methods of communicating warnings and consequent public response are weak components in many warning systems (Penning-Rowsell and Green 2000). Information dissemination varies from country to country and between warning systems themselves. It is clear that multiple methods of communication are often needed to ensure warnings reach communities, but the public may not trust all sources equally. Chapters 12 and 13 highlight some challenges in warning delivery and household response.

In Chapter 12, Laurence Créton-Cazanave discusses the processes used to filter different sources of information. In France's Vidourle watershed, the number of "entities," or actors, in early warning systems has grown rapidly over the last 30 years. Government monitoring services and private contractors are all actively involved in early warning systems. Yet, the proliferation of "entities" can impact the capacity for action, as the process of interpreting different spatial and temporal information impedes decision-making.

Créton-Cazanave argues that to avoid being overwhelmed by information, people have developed coping strategies – prioritizing certain sources of information, while ignoring others. Alternatively, individuals may also apply a "detour" strategy, using an intermediary to mediate or decode information and eliminate competition in courses of action. For both these strategies, trust is critical. Trust must therefore be a focus of early warning system design. Trust needs to be fostered, and processes that permit the distinction between what is "less" and "more" important must be developed and constantly reassessed. Again, this reminds us that early warning systems are not simply technical networks but cultural and political processes. Créton-Cazanave writes:

> All this means moving away from a system of government by instrument which, under the cover of technical efficiency, tends to deny the political dimension of the choices made and therefore removes them from the democratic debate.

Moving from information source to response strategy, Ginger Turner and coauthors review actions taken before severe floods in Punjab, Pakistan. In the summer of 2010, unusually heavy monsoon rains left approximately 20 % of Pakistan underwater and caused US$10 billion in damages. At least 20 million people were affected by the flood, with an estimated 1.6 million houses destroyed. Survey data from 640 households reveal that face-to-face warning, from neighbors or government officials, significantly increased the probability of households taking pre-flood mitigation action. Remote warnings such as television and radio announcements did not have a significant effect on taking any mitigation. Timing of warning was also important, as sufficient preparation time significantly increased the likelihood of moving household possessions. Previous experience with floods also increased the likelihood of pre-flood action. Such action yielded benefits. Turner et al. find that receiving a warning and taking mitigation action reduced the actual loss of household structure value, and taking pre-flood mitigation action also significantly increased the likelihood of having recovered household possessions.

Chapter 14 highlights the gendered impact of warning delivery. Verbal warnings or notices in public spaces may not reach women, as they are often excluded from the public sphere and have greater rates of illiteracy. Warnings distributed by mobile phones are also problematic because women may not have access to the household phone. While the need for gender awareness in early warning systems is officially stated, implementation is lagging. Partly as a result, extreme weather events continue to have a disproportionate impact on women. As Joni Seager writes in Chapter 14, "The primary takeaway conclusion from the literally hundreds of studies and reports