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Climate Change
and its
Humanitarian Impacts

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> "There is now sufficient scientific data to conclude, with a high degree of certainty, that the likely speed and magnitude of climate change in the 21st century will be unprecedented in human experience, posing daunting challenges of adaptation and mitigation for all life forms on the planet." [19]

> "Securitization and climate change, among other global forces, may trigger events of a magnitude that could sweep away the humanitarian system as we know it. Serious reform is not yet in the air, but it is unavoidable." [106]

> "Confronting climate change will be this generation's Cold War, only much more difficult because it could literally undermine the very notion of societal stability." [24]

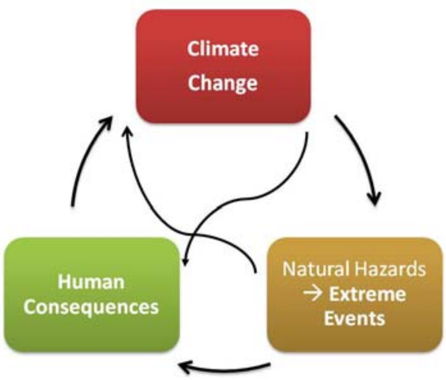
> "Our response to climate change will have "to be something of a Marshall Plan". [28]

> "If we stick to former paradigms we are bound to be defeated in every battle. The point is not to prepare plans and tools to avoid surprise, but to be prepared to be surprised." [29]

The globe's climate is varying and changing unequivocally. Nothing we do today will curb many significant transformations heralded by 2050. There is no uncertainty about this or the fact that there will be human consequences. Communities must be prepared to face the challenges of these consequences. Humanitarian and international development leaders must be equipped to assist the most vulnerable communities. Climate science generators must be aware of the crucial role they play in helping humanitarian decision makers process the most urgent information. In this report, we refer to *climate science* as any field that produces primary data reflecting dimensions of the physical climate, and the *humanitarian community* as actors whose mandate it is to save lives from physical events or processes (commonly referred to as disasters) as well as from complex (political) crises.

This report aims to synthesize the wealth of climate information specifically linked to **consequences across the globe that require the attention of the humanitarian community**. To do so, Stockholm Environment Institute (SEI) employs two main methods. First, an electronic survey was organized to capture the main differences in understanding and requirements between two sectors: those generating climate information and those using it to humanitarian ends. Secondly, over 200 peer-reviewed documents and gray literature were carefully canvassed and their findings mapped in a manner that may be useful to humanitarian actors, while highlighting ways the climate communities may put science to the service of society.

Figure 1: **Analytical Framework**



The analysis framework for this report is drawn from theoretical relationships between changing climate, natural hazards and human consequences (See Figure 1). There is growing scientific consensus that as our climate changes some natural hazards may increase in frequency and/or intensity. With either frequency or intensity increasing, processes and events become more 'extreme' and thresholds may be crossed that trigger positive feedback loops ('tipping elements', or abrupt changes in the physical world as we know it today [30]) and humanitarian crises. Human consequences are also likely as a direct result of climate change, without passing through extreme physical events, such as climate-driven economic crisis. There is wavering albeit growing certainty about which hazards may occur where and when, and what may be the most likely human and physical consequences. **Certainty is even greater, however, that there will be surprises.**

The paper begins with a description of the state of climate information, an inventory of some of the main actors engaged and the products they produce, and an exploration of the main challenges constraining use of climate information by humanitarian actors. Results of the e-survey will mainly support this section. Next, scientific evidence and consensuses are used to chart the physical and human consequences of our changing climate, including forcings, feedbacks and tipping points. This is not meant to be a comprehensive analysis, but rather a time saving triangulation of the wealth of scientific research and gray literature. The paper concludes with three specific climate consequence scenarios: sea level rise (applying the case of Small Island Developing States), drought (Ethiopia) and flooding and storms (Bangladesh). These narratives will provide a qualitative assessment of the confidence currently held in climate change science while escorting climate science to the doorstep of vulnerable households.

"Climate change is a problem area with its **own scientific language** and dominant wisdoms that have in the past acted as a barrier to understanding and involvement of the public, development and disaster communities." *[31]*

"The **language** spoken by climate change negotiators is little understood by the DRR (authors note: humanitarian) community." *[32]*

"With continuing population growth and increasing demands on environmental resources, the need to more effectively **identify, develop, and provide climate information useful for society** will become ever more vital." *[33]*

"As biologist E.O. Wilson once observed, "we are **drowning in information** while starving for wisdom," this might as well have had global climate change in mind." *[34]*

"An important bottleneck to understanding the implications of climate change remains **collection of and access to meteorological data** of sufficiently high resolution and continuity." *[35]*

"**With very little information available, and even less of it verified,** the [humanitarian] leader must have the conviction and the vision to lead the community out of its initial disorientation." *[29]* (Author's addition in brackets)

"Who can eat **information**?" *[36]*

"The truth is, we can change, and change fast, **even in the absence of perfect knowledge**." [37]

Climate information abounds, yet its uncertainty and potential for great surprise act as a barrier to effective application by the humanitarian community. Information users outnumber information "repackagers" who, in turn, exceed the number of generators of climate information. Each group has its own set of needs, processes for quality control, and constraints – the majority of which align poorly across the groups. Before briefly describing the main actors and products, cross-sector terminology to be used in this document merits clarification. Finally, major information challenges to using or soliciting climate information will be discussed.

A portion of this chapter is derived from a qualitative e-survey targeted to a mixed group of 66 actors who were known to generate, repackage or use climate information. A total of 22 respondents (representing at least 10 different agencies) completed the survey (33%[1] response rate) in April 2009. This set is in no way considered statistically representative of any particular group, but merely sets the stage to explore climate science information. Among the 22 respondents, only four were self-reported generators or near-generators of climate science information (i.e. classified themselves as 1 or 2 on a scale from 1: generators to 7: end users to 10: beneficiaries), leaving the remaining two-

[1] In the invitation letter members of the group were encouraged to forward the letter to additional colleagues or associates who might have been interested to respond to the survey. The response rate does not account for such additional invitations.

thirds to represent various user positions on the continuum between the two extremes. No one considered themselves to be end-users or beneficiaries of climate science information. For the remainder of this analysis, the four respondents identifying as *generators or near generators* are grouped together. The other group we refer to as the non-generators or users. Although the level of response does not allow us to do this with confidence, the results shed light on inter- and intra- group synergies. None of the generators and only one-third of the non-generators had a professional focus below the global level. One of the main objectives of the survey was to compare responses from the two main communities, generators and users, in order to better understand how to capitalize on the strengths and needs of both in monitoring climate consequences.

Climate science and disaster risk reduction alike are fraught with large and distracting discrepancies in use of key terms. The differences are important enough to create widespread confusion, and short of harmonizing the two sectors, definitions need to be explained and re-explained at each use. Eight key terms were assessed within the e-survey: hazards, vulnerability, risk, disaster, climate change, mitigation, adaptation and resilience by listing the various definitions published by the most authoritative sources (IPCC, UNFCC, ISDR, etc). For each, respondents were asked to choose which definition (no sources were cited) came closest to the one they regularly employed. The preferred definitions and any striking differences between the groups of respondents are noted in Annex B. They serve to highlight both the nuances and fundamental discrepancies in understanding and needs between generators and users of climate science information.

ACTORS

> "Most of our international, and many of our national, institutional arrangements for addressing climate change, disasters, and development act **in glorious isolation** from each other, politically, financially, and administratively." *[27]*

Despite improved links in recent years between climate scientists and humanitarian decision makers, the marriage is yet plagued by a poor understanding of risk, large areas of uncertainty and fragile trust. Some of the main actors involved, under the headings of generators, repackagers and promoters, users and humanitarian actors, and communities are tallied below.

GENERATORS OF CLIMATE SCIENCE INFORMATION

The **Intergovernmental Panel on Climate Change (IPCC)** was established in 1988 by the World Meteorology Office (WMO) and the United Nations Environment Program (UNEP) with a mandate to compile evidence and build and publish consensus on climate science. Reports produced include the 2007 IPCC Fourth Assessment Report, the 2001 IPCC Third Assessment Report and the 1995 IPCC Second Assessment Report.

World Meteorology Office (WMO) and its 188 constituent National Meteorological (and/or Hydrological) **Offices** (NMOs) throughout the world have the mandate and the capacity to develop and deliver climate and multi-hazard products and services. Given the weak meteorological network in Africa, a new effort has been launched entitled 'Weather Info for All' to install 5000 networks throughout the continent drawing on mobile telecommunications common to the majority of the population.

Research Institutions and entities producing Global Climate Models (GCMs, or General Circulation Models)**:** at least 16 entities produce climate science model projections reported by the IPCC: 7 are European, 4 Asian, 4 North American and one is Australian:

- Bjerknes Centre for Climate Research (BCCR), Norway
- Institut Pierre Simon Laplace (IPSL), France
- Centre National de Recherches Meteorologiques, Météo France
- Meteorological Institute of the University of Bonn (Germany) (w/Institute of KMA, Korea)
- Max Planck Institute for Meteorology, Germany
- Hadley Centre for Climate Prediction and Research, Met Office, UK
- Institute of Numerical Mathematics, Russian Academy of Science, Russia.
- CSIRO, Australia
- Beijing Climate Centre, China
- LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences, China
- Meteorological Research Institute, Japan Meteorological Agency, Japan
- CCSR/NIES/FRCGC, Japan
- Canadian Centre for Climate Modeling and Analysis (CCCma), Canada
- Geophysical Fluid Dynamics Laboratory, NOAA, USA
- NASA Goddard Institute for Space Studies (NASA/GISS),USA
- National Centre for Atmospheric Research (NCAR), USA.

REPACKAGERS AND PROMOTERS

The United Nations Framework Convention on Climate Change (UNFCCC) was created at the first Global Earth Summit in 1992. It outlines principles, commitments and mechanisms involved in monitoring climate change. The UNFCC is a legally binding agreement signed by 192 countries that obligate international communities to develop climate research and observation systems.

The **Conference of the Parties** (COP) is the "supreme body" of the UNFCCC – its highest decision-making authority. The COP is responsible for tracking international efforts to address climate change. It reviews the implementation of the Convention and examines the commitments of Parties in light of the Convention's objective, new scientific findings and experience gained in implementing climate change policies. A key task for the COP is to review the national communications and emission inventories submitted by Parties. Based on this information, the COP assesses the measures taken by Parties and the progress made in achieving objectives. The COP meets every year (Bali, Dec. 2007; Poznan, Aug. 2008; Copenhagen, Dec. 2009).

The International Strategy for Disaster Reduction (ISDR) is orchestrated through the Inter-Agency Secretariat of the ISDR (UN/ISDR). The UN/ISDR is the focal point in the United Nations system to promote links and synergies between, and the coordination of, disaster reduction activities in the socio-economic, humanitarian and development fields, as well as to support policy integration. The ISDR serves as an international information clearinghouse on disaster reduction, developing awareness campaigns and producing articles and other publications and promotional materials related to disaster reduction. The UN/ISDR conducts outreach and programming through its Geneva headquarters and regional units in Costa Rica and Kenya.

United Nations Development Program (UNDP), mandated with Disaster Risk Reduction since 1997, created the Bureau for Crisis Prevention and Recovery (BCPR) in 2001 to meet the ever-growing demands of escalating crises and recurring hazards. A main contributor to ISDR, BCPR's climate risk management is featured as a main global initiative. BCPR also produces the Disaster Risk Index (DRI).

Tyndall Centre for Climate Change Research is an entity that brings together scientists, economists, engineers and social scientists, who work together to develop sustainable responses to climate change through trans-disciplinary research and dialogue on both a national and international level - not just within the research community, but also with private sector, policy, the media and the public in general.

Stockholm Environment Institute (SEI), responsible for preparing this report, is an independent, international research institute with headquarters in Sweden, specializing in sustainable development and environment issues at multiple levels (local, national, regional and global policy). Their mission is to support decision-making and induce change towards sustainable development around the world by providing integrative knowledge that bridges science and policy in the field of environment and development. Climate enters into the SEI radar through climate governance, climate economics and climate adaptation. Climate & Energy and Risk, Livelihoods and Vulnerability are two main SEI Programmes; the latter managed in Oxford by Prof. Thomas Downing.

Feinstein International Centre (FIC, housed in Tufts University, USA) spearheads the 'Humanitarian Horizons' project with the main objective of helping the humanitarian community prepare for the complexities and uncertainties of the future by enhancing its anticipatory and adaptive capacities. The present report commissioned by FIC focuses on one of four drivers of change considered under the auspices of this project. FIC research — on the politics and policy of aiding the vulnerable, on protection and rights in crisis situations, and on the restoration of lives and livelihoods — feeds into teaching and long-term partnerships with humanitarian and human rights agencies.

The Tufts/FIC Humanitarian Horizons research is carried out jointly with the **Humanitarian Futures Programme** (HFP) at King's College, London. HFP aims to help humanitarian organizations involved in prevention, preparedness and response efforts to deal with future challenges, including climate change.

Early warning plays a key role in reducing the risks of climate change. The **Famine Early Warning Systems Network** (FEWS NET), a major longstanding entity in monitoring climatic and hazardous conditions, is a USAID-funded activity that collaborates with international, regional and national partners to provide timely and rigorous early warning and vulnerability information on emerging and evolving food security issues. FEWS NET professionals in Africa, Central America, Haiti, Afghanistan and the United States monitor and analyze relevant data and information in terms of its impacts on livelihoods and markets to identify potential threats to food security. Climate Outlooks are one of many FEWSNET products.

Entities that archive data on the impact of climate-related data are few; they include CRED/EM-DAT and reinsurance companies (e.g., Munich Re and Swiss Re). Since 1988 the WHO Collaborating **Centre for Research on the Epidemiology of Disasters** (CRED) has been maintaining an Emergency Events Database (EM-DAT), created with the initial support of the WHO and the Belgian Government. The main objective of EM-DAT is to support humanitarian action at national and international levels. It is an initiative aimed at rationalizing decision making for disaster preparedness, as well as providing an objective base for vulnerability assessment and the setting of priorities, climate included.

USERS, HUMANITARIAN ACTORS

> "Those who operate outside academia must be convinced that spatially diffuse and long-term impacts are relevant" [17].

> "Humanitarian organizations are able to act as disseminators, translators and gatherers of climate information" [38].

Humanitarian Futures Group (HFG) reports that many humanitarian agencies make use of little more than IPCC reports. Yet, six out of 16 NGOs interviewed claim climate change as a top priority and have been working on the issue since as early as 2002; none reported that it was of no concern to them [39]. A majority expect the issue to gain importance with time. In fact, a majority of the NGOs responding have staff working on the issue and almost one-third have delegated climate change teams or committees. Although will and interest is mounting, capacity remains insufficient to meet the challenges of scaling up and integrating adaptation.

A Centre for Climate & Development (CCD) is currently being developed under the auspices of DFID with an aim to address the shortcomings in the current climate knowledge base among those groups repackaging climate science for development, poverty reduction and humanitarian communities [40].

COMMUNITIES

Across the globe, most societies are aware of "critical thresholds of climatic stresses" and describe them with local color [41]. Furthermore, building climate change knowledge requires harmonizing science and community understanding [42]. Strengthening capacity at the national and local levels to deal with climate risks that are already perceived is a strong strategy to guide adaptation to future climate change [43]. There is mounting concern, however, that the utility of **local knowledge will be rapidly compromised as climate evolves beyond thresholds known by the eldest oral historians** [44].

PRODUCTS

> "There remains a notable gap between the supply and demand of climate change information" [45]

With time, NGOs and humanitarian organizations will require improved information about evolving extremes, changing risk and uncertainty. Climate information, although more and more frequently tailored to the needs of humanitarian agencies [35], is yet insufficient. Here is a very cursory list of general products available and employed that link climate to humanitarian efforts:

- **Global climate models** (also known as general circulation models, GCMs): The models produced are rarely used directly by humanitarian actors, but are more often downloaded and analyzed by repackagers, such as universities. The majority of the IPCC projections compare climate trends from 1980-1999 to 2080-2099, making estimates of the frequency of events during the shorter time frame difficult [27]. See list of GCM producers above.

- **Atmospheric and oceanic conditions**: These include general monitoring of observed trends via direct measurement of remote sensing proxies.

- **Climate outlooks or (extended) seasonal forecasts:** Regional and/or national meteorological offices provide increasingly reliable forecasts of temperature, rainfall, and risk of extremes [15]. Lag times range from three months to one year. These are the most useful products for food security and agriculture [46]. One example is the Regional Climate Outlook organized by WMO for the Horn of Africa [46].

- **Climate change country profiles and or indices:** A growing number of entities use GCM output and other climate science information to produce global analyses or profiles for a select number of countries. Maplecroft has sophisticated country profiles available worldwide at a high cost online. Germanwatch prepares an annual climate risk index (CRI) based on Munich Re damage data for the combined hazards of storms, floods, heatwaves and mass movement. Organized by UNDP, Tyndall and the University of Oxford, climate change profiles for 52 developing countries are available online. CARE/OCHA and World Bank[2] have independently produced global maps portraying the evolving geography of risk.

- **Weather forecasts:** These include local forecasts with lag times of several hours to one week.

- **Vulnerability analyses:** Humanitarian actors are turning more and more to broad, regularly updated poverty sensitive analyses that apply climate change, as a singular driver, to an assessment of general livelihoods and community conditions. UNFCCC claims that socio-economic data in developing countries is as important as climate information [46].

- **WeADAPT:** This collaboration between leading organizations on climate adaptation includes new and innovative tools and methods, datasets, experience and guidance aimed to enhance the knowledge base of the climate adaptation community. The wiki is a collaborative project for a community of contributors.

- **Damage and loss data:** Entities such as CRED EM-DAT and general reinsurance companies (Munich Re or Swiss Re) archive the impacts of registered disaster events worldwide since 1900, to varying degrees of resolution and accuracy. Recently the drought data has been improved using a methodology that now characterizes drought events consistently with other natural hazards [48].

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[2] The World Bank Hotspots analysis relied on CRED/EMDAT and other sources to map the economic and social consequences of volcanoes, landslides, floods and drought. [47]

For those humanitarian actors desiring a global geography of climate change risk and all its faces, the following efforts may be a useful starting point. Before delving into them, however, it is important to note that all maps listed below (except the UNU Human Mobility set) are global country level databases or maps based on past occurrence, not projections, and that former risk is no longer likely to be an adequate indication of future risk under a warming climate. Furthermore, readers are invited to review and employ them with caution; although the best information available is used, some efforts go beyond the scientific comfort zone to prematurely link climate change and mortality.

- WB Hotspots, 2005 (using CRED data): features volcanoes, landslides, floods, drought and cyclones

- UNDP Disaster Risk Index (DRI): features earthquakes, cyclones, flooding

- UK Met Office: series of four maps featuring water stress and drought risk, flooding risk, crop yield production risk and human health risk

- Germanwatch, 2007 (using Munich Re data): Climate Risk Index (CRI) covering storms, floods, heatwaves and mass movements

- CARE/OCHA Humanitarian Implications of Climate Change, 2008 (uses CRED data): features flood, cyclone and drought maps with conflict and population density overlays

- Global Humanitarian Forum, 2009 (using Maplecroft, Munich Re and CRED data) features the following maps:

    - Physical vulnerability to weather-related disasters and sea level rise
    - Mortality related to climate change
    - Areas vulnerable to climate-related water challenges

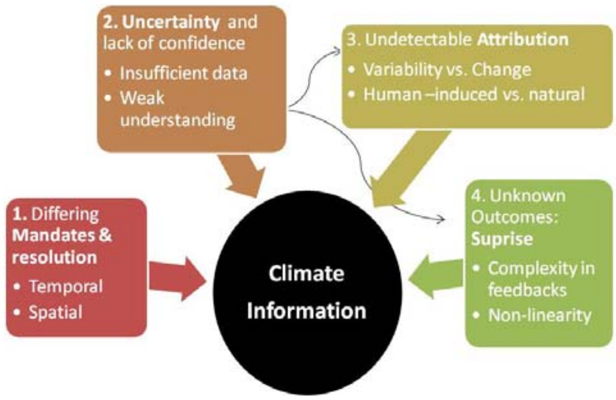
- Socio-economic vulnerability to climate change

- UNU/CARE/CIESEN: In Search of Shelter, Mapping the Effects of Climate Change on Human Migration and Displacement, 2009 (uses IPCC and other data): features eight regional maps portraying climate-driven human mobility.

CHALLENGES

There are a number of challenges that constrain access to, availability of, user-friendliness of, and desire to use climate information by humanitarian practitioners. Only four main constraints are summarized here, addressed in order of simplicity: differing mandates of the two groups, uncertainty/confidence,

Figure 2:
Factors Challenging Humanitarian Use of Climate Information



attribution and finally, the surprise factor, linked to complexity and non-linearity. Many of these constraints are inter-related and Figure 2 attempts to map their potential links.

DIVERSE MANDATES

> "Irreversible climate changes due to carbon dioxide emissions have **already taken place**, and future carbon dioxide emissions would imply further irreversible effects on the planet, with **attendant long legacies for choices made by contemporary society**" *[10]*.
>
> "Practitioners want clear statements about causal relationships and local near-term impacts on which to base their intervention decisions, while scientists…use new and emerging climate science to determine the implications of change on biophysical, social, economic, political and cultural systems, processes and entities at a variety of temporal and spatial scales, but often in the longer term" [45].

There is a fundamental challenge in aligning the temporal and spatial mandates of climate scientists with those of the humanitarian community. While humanitarian actors focus above all on the short term and the local (saving lives now), climate scientists invest huge effort and significant funding to predict climate for Year 2100 at a global level. It is easy to understand the rift between the two groups. Researchers have described the cleavage between science and decision makers as "*a paradigm lock*" [49, 50], while very few have the ability to identify a key [50].

Humanitarian planners debate the temporal focus of their work but futures outlooks within this community generally range from 18 months to ten years

> "All of these timeframes exceed verifiable seasonal forecasting systems (i.e. climate variability) and fall ahead of existing climate projections (climate change). This 'gap' in climate information requires that humanitarian organizations source climate change information from both the climate variability community and climate change community" [26].

Climate futures typically take a much longer view. The UNFCCC, for example, specifically emphasizes "*threats of serious or irreversible damage*" with strong hints at a long-term horizon [10]. This applies to environmental science in general.

> "As with the problem of climate change, ecosystem change involves processes that operate **over very different time-scales**, small fast processes generally being embedded in large slow processes. This has a number of implications both for the way that processes are modeled, and for the way that decision-makers seek to learn from experience [51].

This is where the paradigm lock develops: How does one translate 100-year predictions for Northern Europe into something a humanitarian decision maker can use today within his metropolitan focus [14]?

Climate science generators responding to the e-survey consider the greatest impact of climate change most likely to occur between 2031 and 2050 for land degradation, desertification and sea level rise. They consider pollution, heat waves, and drought to be manifesting impacts now and the other phenomena to be more likely to occur beginning around 2015. Humanitarian users, on the other hand, see drought and flooding to be incurring impacts at the present time, followed by storms and pollution. In fact, only two of the 18 non-generators chose '2031-50' (one of four choices provided) as the timeframe of concern.

Overall, climate science users see climate change as significantly more immediate than the science generators. This is particularly interesting given the above analysis of the same respondents in which science generators found many phenomena more important than the humanitarian users. There seems to be a key distinction between immediacy and importance in the community of practice.

More and more studies highlight creeping hazards or synchronous small events leading to more disastrous ones [53]. The immediacy of many disaster events (i.e. tsunamis, earthquakes) is such that it easily triggers the United Nations and humanitarian players into action, while more gradual environmental issues such as climate change do not induce the United Nations to rush to prepare a response [54]. **Humanitarian planners either need to extend their horizons or climate scientists must find appropriate products that guide current practice in more meaningful ways, or both.** A growing number of humanitarian organizations, nonetheless, are encouraged to recognize that attempting to understand and anticipate climate realities in 2020 or beyond today may make for more sound practice and better returns on costly humanitarian investments [38].

UNCERTAINTY AND CONFIDENCE

> "We now often find ourselves moving from **uncertainty**, a dimension to which we are well accustomed, to **ignorance**" [29].,
>
> "The climate system is changing, so uncertainty about extremes is rising" [15].
>
> "...the necessity to live with profound uncertainties is a quintessential condition of our species" [55].
>
> Agencies have to "be more concerned with the rigorous and systematic gathering of data"...."once better data is available, more research into the relationship between hazards, vulnerability, climate change and humanitarian response will be needed" [56].
>
> "We are inevitably inferring the probability distribution of extreme events from a limited set of empirical information, resulting in an estimated fat-tailed distribution which is **itself uncertain**" (Ackerman and Stanton 2006).

Another fundamental constraint is the length and robustness of observed records since the instrumental era began. Data for climate impacts and especially for the more rare extreme events are simply insufficient. More frightening, however, is that climate change has forced scientists and humanitarian decision makers alike to admit what little we really understand about synchronicity and the positive feedback loops between one impact and another, at both physical and socio-economic scales. Much of our lack of understanding is linked to the fourth constraint, that of complexity and non-linearity, described in more detail below.

Despite the fact that scientists hold the strongest confidence in projections of temperature [15], all temperature estimates have uncertainties that arise from gaps in data coverage [57]. IPCC strives to regularly report on the level of uncertainty and proposes three different approaches to describing it: 1) qualitative assessments described by the quality of evidence or degree of agreement, 2) quantitative assessments using expert judgment on a scale of 1-10, and 3) for specific outcomes such as extreme events, the "virtually certain" to "unlikely" scale of percentage thresholds [9]. The latter was applied in the e-survey.

Many researchers speculate about which areas manifest the greatest scientific uncertainty. Here are some of their proposals:

- How temperature and precipitation may eventually translate into weather hazards [58].

- Spatial distribution in climate changes (global being more certain than local), how temperature/precipitation will provoke hazards, and choice of factors that will determine vulnerability [59].

- Cloud feedbacks [60].

- The magnitude and speed of warming, as well as by how much and in which timeframe emissions must be reduced to achieve stable concentration [61].

- Climate system feedbacks, such as from clouds, water vapor, atmospheric convection, ocean circulation, ice albedo, and vegetation, solar variability, critical ocean phenomena, including ocean mixing and large-scale circulation features [33].

- Despite the fact that one of the major recent advances in climate science has been the recognition that the variability of climate is associated with a small number of climate modes, there is only limited understanding of the physical mechanisms that produce and maintain these teleconnections and the extent to which they interact [33].

- Projections for relatively small-scale atmospheric phenomena: thunderstorms, tornadoes, hailstorms and lightning [15].

- Although historical, existing sources may still be the most reliable information over the next decade [26], "*past performance of the climate is becoming a less reliable predictor of future performance, thus future climate will be less familiar and more uncertain under climate change*". [62, 63].

- Estimating the social cost of carbon in the Stern Report has introduced uncertainty in the results [64].

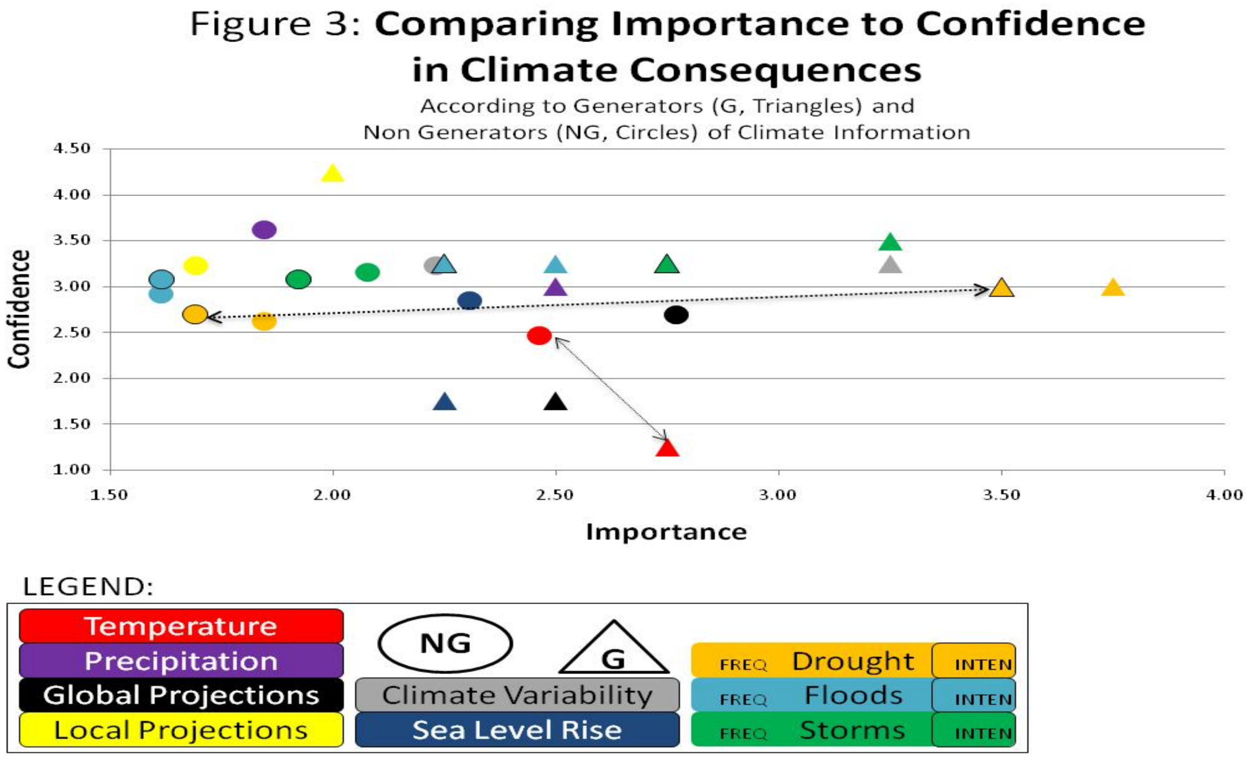
Humanitarian practitioners are inherently tied to cost-effectiveness in their programs and emerging responses – a reality made many times more complicated by uncertainty in available information. NGOs concerned about climate change report misinformation, poor understanding, doubt and suspicion ("the latest aid fad") as major factors limiting their solicitation or use of climate information [39]. An element that humanitarian agencies may need to alter is the degree of risk that they willing to take in planning for future crises. E-survey respondents for this report were asked to complete the sentence:

My work requires knowing that a climate outcome or result is...

with one of the standard IPCC categories of *virtually certain* (> 99% probability of occurrence), *extremely likely* (> 95%), *very likely* (> 90%), *likely* (> 66%) or *more likely than not* (> 50%). Surprisingly, although it represented the top survey response overall, ***none of the climate information generators*** **required a minimum of 90% confidence.** The second most common answer was '*likely*' (greater than 66% confidence), provided by one-third of non-generators and generators. This odd result may reflect non-representative profiles of the respondents or a trend towards a growing tolerance for large uncertainty, among both groups.

In the subject e-survey, respondents were asked to rank a list of 12 phenomena by both a) how important each was to the respondent's professional mandate and b) the level of confidence they place in projections of their evolution. Results are plotted in Figure 3, below. Choices ranged from 1, Most Important or Most Confident to 5, Least Important or Least Confident. The answers were averaged across both groups, generators (G, triangles) and non-generators (NG, circles) producing pairs of same-colored shapes. The colors portray the 12 different phenomena, remaining the same for both groups, G triangles and NG circles. The black-outlined shapes compare intensity to frequency of the same physical phenomenon. Taking the example of drought intensity (orange outlined shapes) follow the arrow from one of the leftmost circles (for which non-generators attributed low importance) to one of the right-most triangles (to which generators gave very high importance at only a slightly higher confidence level, as compared to the non-generators).

Bearing in mind the small sample size, striking relationships surface. The most important phenomena for non-generators include **global projections, temperature and sea level rise**. To generators, **drought frequency and intensity, storm frequency and climate variability** are the most important. Many of these conclusions appear counter-intuitive, given, for example, the understood focus of scientists on climate change. The least important phenomena are floods (light blue on left for non-generators) and local projections (yellow, for generators). Greatest confidence is held in precipitation (purple, by non generators) and local projections (yellow, by generators). The least confidence is held in temperature, global projections and sea level rise (all by generators). This last relationship is peculiar, given other reports of scientists' confidence in temperature projections.



In addition, **generators give greater importance than non-generators to most of the 12 phenomena** (e.g., triangles are systematically to the right of similar colored circles). The most striking example is drought intensity (outlined orange, see dotted line). The only exceptions are for global projections (black) and sea level rise (dark blue), which are perceived by non-generators as being more important.

Non-generators are slightly more likely than generators to hold higher confidence in phenomena, such as in temperature (red, see arrow). An exception is local projections (yellow) for which generators hold greater confidence than do the non-generators / users.

The **frequency** of the three events (non-outlined shapes for drought, floods and storms) **is systematically more important and benefits only marginally from more confidence** than the intensity (outlined) of the same events.

This analysis, although entirely qualitative and non-representative, underscores the colossal discrepancy between the generators and users of climate science information.

ATTRIBUTION

Climate Change vs. Climate Variability

A major challenge in the marriage of climate science and the humanitarian sector concerns the fundamental difference between climate variability and climate change and the perceived need of many to attribute observed phenomena to one or the other. Another related issue of attribution is to determine the relative weight of anthropogenic causes of climate change, as compared to natural processes. The planet's climate has varied and changed naturally across all time scales. Since instrumental observations have been recorded, however, there has been an unprecedented increase in both global average temperatures and carbon dioxide emissions. These two changes, heralding what has been named 'global climate change' and an anthropogenically-driven 'greenhouse effect' mark the difference between normal *climate variability* and current *climate change*.

The IPCC distinguishes the two terms mainly through their temporal aspects. They define climate variability as *"…variations in the mean state and other statistics of the climate on* ***all spatial and temporal scales*** *beyond that of individual weather events…*" [65] and climate change as *"a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an* ***extended period, typically decades or longer****" (IPCC, 2007).*

Other agencies, such as the United Nations Framework Convention on Climate Change (UNFCCC) make a distinction between the two terms entirely related to their supposed attribution, with *"climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes"* (IPCC, 2007).

The problems of climate variability and climate change are "intrinsically connected" [33] and cannot be clearly separated [67-69], and there are many arguments that both challenge and encourage distinctions between climate variability and climate change. While the mandate of the UNFCCC, for instance, stipulates strictly climate change, and not variability [66], and in certain cases, **climate variability has been proven to have more impact** on resources than even human-induced climate change [68]. Responses to climate variability are foundational for future adaptation to climate change [36]. In contradiction to most research, however, the media regularly portray new hazards as directly linked to climate change [31]. Short-term and long-term climate variability have different effects: while the former is linked to adaptation the latter is more directly associated with fundamental changes in the productive base of a society [31].

In the end, direct attribution is impossible: "*every weather event is the product of random forces and systemic factors*" [70], and distinguishing between the two is difficult [71-73].

Anthropogenic vs. Natural Causes

Attribution is a double-barreled weapon within the global climate change debate. Most climate change skeptics expend substantial effort arguing whether the observed phenomena are a result of natural or anthropogenic climate change. Because droughts, fires, downpours, epidemics and floral/faunal range shifts, coral bleaching and other phenomena are not readily resolved in Global Climate Models, or agreed upon by an official consensus of scholars, there is less confidence in their attribution.

The IPCC employs the terms *detection* and *attribution* and lists them in the Glossaries of Working Group 1, Physical Science Basics and Working Group 2, Impacts, Adaptation and Vulnerability. In the Working Group 1 Glossary, while **detection** of climate change is *"the process of demonstrating that climate has changed in some defined statistical sense, without providing a reason for that change",* the **attribution** of causes of climate change takes detection a step further and is considered to be *"the process of establishing the most likely causes for the detected change with some defined level of confidence*" (Intergovernmental Panel on Climate Change (IPCC) 2007). An explanation of anthropogenic climate change may be one of its "*most likely causes*".

There is not a scientifically validated method at present to attribute visible or measured impacts to anthropogenic climate change except in some regions of the earth where the signal is both very strong and has a direct link to the outcome. For this reason, few studies to date have convincingly teased the climate change signal or footprint from the host of confounding factors that contribute to changing patterns. Scientists combine biology and economics to show that between 74 and 91% of species that have evolved (temporally or spatially) over the past twenty years have done so in a manner directly aligned with climate change predictions [74].

The Global Humanitarian Forum compares 25 years of trends in geophysical disasters (e.g., volcanoes and earthquakes) to that of climate-linked disasters. The increase in climate-linked disasters beyond the geophysical trend is attributed entirely to climate change, reportedly with enough confidence to link absolute mortality (an annual average of 325,000 lives lost) to climate change [44]. This precocious assertion crosses the comfort threshold of most climate scientists and academics, but the provocative warning may succeed to trigger a more rapid compromise in Copenhagen 2009 between skeptics and firm climate change believers.

To evaluate the importance of attribution among the subjects of our report, over two-thirds of responding generators in the e-survey and over 40% of non-generators feel strongly (e.g. "have no doubt") that attribution of an event between climate variability or climate change makes a difference to their work. The second most common answer, "not at all", was employed strictly by non-generators. **There is a clear trend that the closer you place your efforts to end-users, the more likely you are to see attribution as irrelevant.**

SURPRISE FACTORS LINKED TO NON-LINEARITY, COMPLEXITY

> "The relationship between the magnitude of an event and the nature of its impact can be very **complex.**" [41]

> "In the world of planning and politics **anything that is unprecedented, exceptional or non linear is instinctively rejected.** The problem is that we are all sons/daughters of Descartes doing all we can as (risk) managers and even academia to stay away from, and to deny the mere existence of anything outside normality. We must be ready to cross those defensive stands and strive to acquire the intellectual and psychological ability to move about creatively in a highly unstable and opaque world." *[29]*

> "…the widespread occurrence of **time lags, inertia and hysteresis** in both ecological and social systems means that **feedback loops do not automatically lead to optimal control**—by the time impact signals are received, avoidance of the problem may no longer be possible. These complexities should be considered the norm rather than the exception." *[51]*

> "Most people think of climate change as a slow process that occurs in a predominantly **linear** manner. In the scientific community, however, there has been a paradigm shift ...processes of a changing climate within the Earth's system are largely **non-linear and often involve positive feedback and threshold effects**." *[75]*

Key related terms that depict complexity:

Non-linearity
Tipping Points
Thresholds
Abrupt Climate Change
Rapid Climate Change
Severe Climate Change
Paradigm Regime Shifts
Singularities
Climate Surprises

Many humanitarian users report confusing messages related to climate science [45]. Given the complexity of the issue this is easy to understand, but some actors blame lack of government leadership and sufficient attention by the climate science community. All of the constraints discussed above lead to the most unwieldy one, that of complexity and inevitable surprise resulting from nonlinear, and therefore hard to pin down relationships [13].

We have learned that although every disaster may feel "local", the interaction between ecosystem services and human well-being, or "teleconnections" (e.g., ENSO) occurring at huge spatial scales (global trade or the mixing of carbon dioxide) mean that **even those local phenomena have far-reaching consequences**. Assuming a linear relationship between extreme events and disasters, for example, if the number of extreme events doubles, the number of disasters would also double. Many scientists believe that this relationship between intensity and impact is cubed, at the very least, in the case of cyclones [27], and is likely to be non-linear for most hazards [76].

Some important ecosystem services subject to nonlinear changes include dryland agriculture, fisheries, and freshwater quality. Social systems are also subject to nonlinearities (Repetto 2006) and the interactions of social and ecological thresholds have scarcely been explored (Walker and Meyers 2004; Walker and Salt 2006) [77].

Non-linearity and complexity require the introduction of other related terms. Major non-linear complexities are often described as, or are closely linked to, *abrupt climate change*. Although this relates to the suddenness of a change, the speed is captured in the non-linear power relationships that may occur after a critical *threshold* is crossed. We also speak of *tipping points* – temporal thresholds beyond which major surprises are expected. Other terms used include *rapid climate change*, *severe climate change*, *paradigm regime shifts*, *singularities* or *climate surprises* – each with its own package of nuances. Seminal tipping points and abrupt climate changes are described in Annex A: Technical Note.

In summary, the following points may be useful to guide humanitarian action in regards to climate information:

- The panoply of climate information products is on the rise, growing more and more tailored to humanitarian needs.

- There remains a wide gap between generators and users of climate information that must be explored and filled with appropriate products that capitalize on what science can yield while meeting life-saving needs.

- Although local and indigenous knowledge is valued in regard to evolving climates, concern is mounting that the future holds surprises that may exceed thresholds remembered by the eldest oral historian.

- A major challenge lies in discordant temporal and spatial mandates of generators and users of climate science information. Although humanitarians typically operate locally on 18-month planning horizons, climate science generators focus globally on a 30-50 year timeframe. According to the e-survey, climate science users see climate change as significantly more immediate than the science generators. Humanitarian planners either need to extend their horizons or climate scientists must find appropriate products that guide current practice in more meaningful ways, or both.

- The smaller the scale of a phenomenon (i.e., storms as opposed to widespread drought), the lower the confidence of their predictions, and the more likely humanitarian actors will need to accept and act under greater uncertainty. Among e-survey respondents, frequency of hazards is more important than intensity as priorities governing their work.

- It can be concluded that the elements in which climate scientists (generators) have the greatest confidence are rarely those that are most important to the humanitarian agencies (non generators), and conversely, elements most important to humanitarian agencies (non generators) are routinely subject to the greatest lack of confidence by the climate scientists (generators).

- The closer an actor places his/her efforts to end-users of climate science information, the more likely he/she is to see attribution (climate change versus variability) as trivial. The effects of climate variability may be as disquieting and far-reaching as those of climate change and should remain humanitarian priorities.

- Local phenomena have important consequences and the relationship between intensity and impact of hazards is more likely to be cubed, non-linear and entirely unpredictable. This complexity and lack of confidence deters humanitarians from more actively soliciting or using climate science information.

- Humanitarians and development actors alike should beware of packaged projections such as "deaths due to climate change". Although there may be value in provocation, the current stage of understanding does not permit mapping future climate risk with any level of confidence. Painting the future with the colours and media of today will be nothing more than impressionistic.

> "We now have a choice between a future with a **damaged** world or a **severely damaged** world." [9]

> "Despite general agreement that global climate change is taking place, there is **less consensus about the consequences and impacts that may arise**." *[17]*

Evidence is growing on the consequences of climate change. These consequences may manifest themselves through an increasing frequency or intensity of natural phenomena (hazards) and/or through human impacts. Forcings and feedbacks between natural and human consequences will play an additional role in defining the outcomes of climate change.

'NATURAL' OR PHYSICAL CONSEQUENCES: CLIMATE EXTREMES AND HAZARDS

> "One of the highest priorities for decision-makers is to determine how climate variations, whether natural or human-induced, alter the **frequencies, intensities, and locations of extreme events**" *[33]*

> "It is now more likely than not that human activity has contributed to observed increases in heat waves, intense precipitation events, and the intensity of tropical cyclones" [78].

Although IPCC reports provide strong 'hints' at changes in the frequency and intensity of hazards, they clearly avoid making statements that could be construed as *disaster predictions* [27] – the exact element that humanitarian agencies could most benefit from. Instead, each actor is obliged to sift through the scientific literature and anecdotal evidence to produce some defensible indication of where, when and how future hazards may occur and how likely it is that they will become disasters.

Climate extremes: Although climate science has mainly focused on monitoring mean conditions [79], this slow and steady evolution of averages may become little more than a backdrop for ever-intensifying and ever-increasing climatic extremes. There has been a critical need to improve scientific knowledge of climate extremes. In the IPCC's first supplementary assessment report (1992), *extreme events* were not addressed per se. By 1995, the IPCC's Second Assessment Report claimed that data were inadequate to provide any evidence of heightened extremes [80].

This lack of understanding triggered a series of workshops and research efforts whose results allowed the Third Assessment Report (TAR) in 2001 to be much more conclusive. The TAR was able to draw initial conclusions on extreme precipitation and extreme temperatures. Although droughts were seen to have become more common in certain areas, other extreme events such as tropical storms and tornados revealed no convincing trends. In 2003, there was strong evidence that human-induced forcings could account for recent extreme temperatures [81]. The most recent IPCC report, the Fourth or AR4, has clearly driven home the climate change/extreme event link for all humanity [82].

There have been many attempts to define or describe "extreme events," but a lack of historical data makes a fixed definition nearly impossible. A flexible dynamic definition of the term must be relative to the society in which the event occurs [76]. Additional descriptions and definitions have included the following:

- Extreme events are short term perturbations outside the magnitudes of the normal range of an averaging period...may be measured in minutes or years with return periods of at least ten years [41].

- "Occurrences relative to some class are notable, rare, unique, profound or otherwise significant in terms of its impacts, effects or outcomes...They are inherently contextual determined by interaction". New information and the media may heighten our understanding of the complexity surrounding extreme events [83].

- "[Global climate model] projections of extreme events are sparse; they are not designed to explore the effects of extremes, yet damage varies strongly in a nonlinear way as the intensity of a climate variable rises", as cited in [27].

- Evidence is compelling that natural climate variations, or teleconnections, (i.e., ENSO, PDV, and the NAO/NAM), can significantly alter the behaviour of extreme events, including floods, droughts, hurricanes, and cold waves (IPCC, 2001a,b)[33].

- IPCC's own "projections concerning extreme events in the tropics remain uncertain" [76].

- The type, frequency and intensity of extreme events are expected to change as the earth's climate changes, and these changes could occur even with relatively little mean climate change [63].

- Extreme events do not obey statistical distributions and may follow power laws [84].

Physical or natural consequences of climate change

Extreme events *(examples):*
Temperature Changes
Floods
Storms
Landslides/mass movement
Extreme processes *(examples):*
Drought
Sea Level Rise
(Land) Degradation
Deforestation
Desertification

Excluding 'mega-disasters', contrary to current thought, mortality from climate-related disasters is on the rise "…*at a faster rate than world population growth*" [85].

Other extremes are less physical events than processes. Based on the above definitions, communities may experience extreme land degradation, deforestation or desertification. According to the IPCC, degradation of soil is likely to be intensified by adverse changes in temperature and precipitation. These slower-moving phenomena, for which it is much more difficult to establish start and end dates and which are equally if not more complex than other events, are more commonly referred to as processes. Slow onset processes may offer a larger window of opportunity for humanitarian or other action, but there is little proof that they pose smaller risks [10]. Drought is a hazard that could be considered either an event or a process. Extreme processes may be more easily characterized by their intensity than by their frequency. Extreme processes, in the context of climate change, are even less well understood than extreme events.

In summary, extreme events and processes are increasing in frequency and/or intensity and they, their projected geographies and exact human consequences are among the poorly understood consequences of climate change. They merit a concise targeted research program. The state of knowledge about four natural consequences (extreme events or processes) will be described in greater detail within the next chapter. Although not intended to be a comprehensive review, the sections on sea level rise, drought, and flooding and storms lay out the evidence systematically.

Below, human consequences are explored. The chapter ends with a general discussion of forcings and feedbacks within and between 'natural' and human consequences or subsystems.

HUMAN CONSEQUENCES, HUMAN SECURITY

> "Climate change will reconfigure patterns of risk and vulnerability across many regions. The combination of increasing climate hazards and declining resilience is likely to prove a lethal mix for human development" *[13]*.

> "The climate models predict the extreme climate events. We then have to project how you get from a drought to a famine, from a hurricane to a hurricane that causes damage, from a flood to flooded homes; there are huge areas of uncertainty here" [56].

Human consequences of climate change

- *Reduced access to natural resources*
- *Conflict and inequality*
- *Impoverishment*
- *Food Insecurity*
- *Heightened Mobility*
- *Impaired Health*

Human consequences of climate change are plentiful and range from slight changes in the way most of the planet's inhabitants live their lives to the end of an entire civilization. It is urgent to recognize that human security is not simply about freedom from conflict or prevention of population displacement. It is intimately linked to the development of human capabilities in the face of change and great uncertainty. Individuals and communities exposed to both rapid change and increasing uncertainty are challenged to respond in new ways that protect their social, environmental, and human rights. "*Considering human security as a rationale for disaster risk reduction and climate change adaptation emphasizes both equity issues and the growing connections among people and places*" within coupled natural human systems [63].

The e-survey respondents for this report were asked to prioritize, based on knowledge they have generated, transmitted and/or received, the two most important human consequences of current climatic change (beyond the hazards discussed above) that make populations vulnerable. They were given the choice of reduced access to resources, conflict & equality, mobility, food insecurity, impaired health and heightened poverty or were asked to supply an alternative option for their choice.

Out of the three generators and 14 non-generators who completed this question, the most common response overall was *reduced access to resources* (see Table 1). This consequence was largely a greater priority for the non-generators (8/14) than for the generators (1/3). The second most common priorities overall included *conflict*, tied with *poverty* among the generators, and tied with *poverty and food security* among the non-generators. No respondent in either group prioritized *health* as an outcome of climate change. These consequences will be explored in the order of priority attributed by respondents.

Table 1: Prioritizing Human Consequences of climate Change

Which consequence of an evolving climate contributes most to vulnerability?	Generators (n=3)	Non-Generators (n=14)
Reduced access to natural resources	1	8
Conflict & inequality	2	5
Impoverishment	2	5
Food insecurity	0	5
Heightened mobility	1	3
Impaired health	0	0

The section below sketches the major human consequences. For each consequence, the current level of understanding will be synthesized by answering the following questions:

1.) What do experts and recognized authorities have to say about the hazard/consequence?

2.) Is there a documented impact today (or in the recent past)?

3.) What are projections for the future?

4.) Where do the greatest uncertainties lie? and finally,

5.) What are potential feedbacks and/or links to other phenomena?

HUMAN CONSEQUENCE 1: ACCESS TO RESOURCES

Description of access: The human impacts of climate change are expected to manifest primarily through impacts on natural resources, on which the poor depend heavily, and on human health [31]. Natural resources include water, land, biodiversity, forests and energy; the most vulnerable depend directly on these services. Water, a source of life and livelihoods, is a main focus in this section. Large areas of the developing world face the imminent prospect of increased water stress. Changes in precipitation and temperature lead to changes in runoff and water availability. Water flows for human settlements and agriculture will likely decrease, exacerbating acute pressures in water-stressed areas. Over the course of the 21st century water supply stored in glaciers and snow cover will decline, posing immense risks for agriculture, the environment and human settlements. Water stress will figure prominently in low human development traps, eroding the ecological resources on which the poor depend, and restricting options for employment and production. Safe and sustainable access to water — water security in a broad sense — is a sine qua non condition for human development [13].

1.) What do authorities have to say about access to resources?

Climate change is expected to exacerbate current stresses on water resources from population growth, economic and land-use change, urbanization included. More than one sixth of the world's population is currently dependent on melt water from mountain ranges, which by mid-century will likely decrease water availability in mid-latitudes, in the dry tropics and in other regions [85].

There is a high confidence that the resilience of many ecosystems will be undermined by climate change, with rising CO2 levels damaging ecosystems, reducing biodiversity, and compromising services provided (IPCC). The world is heading towards the unprecedented loss of biodiversity and the collapse of ecological systems during the 21st century. At temperature increases in excess of 2°C, rates of extinction will increase exponentially [13].

2.) Is there a documented impact on resources today (or in the recent past)?

- Around 25 million 'water refugees' have departed areas where the resource has become too scarce to survive [86].

- Environmental degradation is gathering pace with coral, wetland and forest systems suffering rapid losses [13]. Nearly 30% of coral reefs have already been lost to climate change [74].

- Climate change has already contributed to a loss of species. Nearly one in four mammal species is in serious decline [13]. Nearly half of species studies worldwide demonstrate measureable responses (range shifts, spring earlier/fall later) to evolving climates [74].

3.) What are projections for the future regarding access to resources?

- Populations affected: By 2080, climate change could add up to 1.8 billion people to those currently living in water-scarce environments (under a threshold of 1000 cubic metres per capita per year) [13]. Between 350 million and 600 million Africans would suffer increased water scarcity if global temperature were to rise by 2°C over pre-industrial levels [11].

- There is high confidence that many semi-arid areas (e.g. the Mediterranean Basin, western United States, southern Africa and north-eastern Brazil) will suffer a decrease in water resources due to climate change.

- Widespread mass losses from glaciers and reductions in snow cover over recent decades are projected to accelerate throughout the 21st century, reducing water availability, hydropower potential, and changing seasonality. Regions dependent on meltwater from major mountain ranges concern one-sixth of the world's current population (IPCC WGI 4.1, 4.5; WGII 3.3, 3.4, 3.5).

- Water runoff is projected with high confidence to increase by 10 to 40% by mid-century at higher latitudes and in some wet tropical areas, including populous areas in East and Southeast Asia, and to decrease by 10 to 30% over some dry regions at mid-latitudes and dry tropics, due to decreases in rainfall and higher rates of evapotranspiration.

- The negative impacts of climate change on freshwater systems outweigh its benefits (high confidence). Areas in which runoff is projected to decline face a reduction in the value of the services provided by water resources (very high confidence). The beneficial impacts of increased annual runoff in some areas are likely to be tempered by negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risk (IPCC WGII 3.4, 3.5, TS.4.1).

- Increased temperatures will further affect the physical, chemical and biological properties of freshwater lakes and rivers, with predominantly adverse impacts on many individual freshwater species, community composition and water quality. In coastal areas, sea level rise will exacerbate water resource constraints due to increased salinisation of groundwater supplies (IPCC WGI 11.2-11.9; WGII 3.2, 3.3, 3.4, 4.4).

- ECOSYSTEM / BIODIVERSITY: Approximately 20 to 30% of plant and animal species assessed to date are likely to be at increased risk of extinction if temperatures exceed 1.5 to 2.5°C (medium confidence) (IPCC WGII 4.ES, Figure 4.2, SPM). Under these conditions and in concomitant atmospheric CO2 concentrations, major changes in ecosystem structure and function, ecological interactions and shifts in geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services, e.g. water and food supply are projected (IPCC WGII 4.4, Box TS.6, SPM).

4.) What are the greatest uncertainties regarding access to resources?

There is no certainty as to how exactly these projections will be geographically distributed.

5.) What are potential feedbacks and/or relations between resource access and other phenomena?

Water is related to almost every other sector:

- Within the natural subsystem: especially precipitation, flooding and drought

- Within the human subsystem: conflict, impoverishment, mobility, food security and health

HUMAN CONSEQUENCE 2: CONFLICT & EQUALITY

Description of conflict: A discussion about conflict and equality inevitably addresses vulnerability. Vulnerability to climate change is the degree to which systems are susceptible to, and unable to cope with, adverse impacts. There are many vulnerable populations in the context of climate change – the poor, the elderly, children (who make up at least 50% of those affected by disasters [7]), pregnant women and those in particularly high-risk locations [87]. Where climate change coincides with other transnational challenges to security, such as terrorism or pandemic disease or pre-existing ethnic and social tension, the impact will be magnified [19]. Women's historic disadvantages—their limited access to resources, restricted rights, differentiated exposure to risk and a muted voice in shaping decisions—make them highly vulnerable to climate change which is likely to accentuate existing inequalities [13]. All of these tensions, edged on by climate change can become drivers for conflict.

1.) What do experts have to say about climate-driven conflict?

Environmental factors are rarely, if ever, the sole cause of violent conflict [88]. The wider security implications of climate change have been largely ignored and seriously underestimated in public policy, academia and the media [19]. Direct links between climate and conflict, however, are difficult to confirm [32]. High profile security advisors from many western countries are now exploring links between climate and security and there is fear that the most climate-vulnerable may become the next 'public enemy' [89].

2.) Is there a documented conflict-driven impact today (or in the recent past)?

- Archaeological records often associate resource scarcity with unequal society and tension, for example the relationship between social stratification and desiccation [52].

- Out of 38 cases of migration directly attributable to climate change during the twentieth century, half led to conflict [28, 90, 91].

- Since 1990 at least eighteen violent conflicts have been fuelled by the exploitation of natural resources [88]. Research suggests that over the last sixty years 40% of all intrastate conflicts have had links to natural resources. While in Liberia, Angola and the Democratic Republic of Congo civil strife has centred on "high-value" resources (timber, diamonds, gold, minerals or oil), those in Darfur and the Middle East have involved control of fertile land and water [88].

3.) What are projections for future climate-driven conflict?

- As the global population continues to rise, and the demand for resources continues to grow, there is significant potential for conflicts to intensify in the coming decades. Potential consequences of climate change on water availability, food security, disease prevalence, coastal boundaries, and population distribution may exacerbate existing or create new tensions [88].

- Even where conflicts do not occur, those with the most financial and human capital are likely to gain, exacerbating inequality [92].

4.) What are the greatest uncertainties regarding climate-driven conflict?

- Causal chains: "*Human-induced climate change is one of the most drastic neo-Malthusian scenarios*". Causal chains linking climate change to conflict are fraught with uncertainties [92-94].

- Ability of governments and institutions to respond to rising climate-linked tension.

5.) What are potential feedbacks and /or relations between conflict and other phenomena?

- Conflict may be directly related to reduced access to resources

- Heightened mobility: conflict may be both a cause and a consequence of migration

- Sea level rise, land degradation and drought are known to trigger conflict

HUMAN CONSEQUENCE 3: GENERAL IMPOVERISHMENT

Description of impoverishment: The human impacts of climate change will be strongly influenced by poverty [82]. Across much of the developing world (including countries in the medium human development category) there is a complex interaction between climate-related vulnerability, poverty and human development. Climate shocks affect livelihoods in many different ways [13]. "*As the twenty-first century unfolds, humanity faces two defining challenges*": lifting the lives of the global poor and stabilizing the Earth's climate [42].

1.) What do authorities have to say about climate-driven impoverishment?

Poor communities can be especially vulnerable, in particular those concentrated in high-risk areas {IPCC WGII 7.2, 7.4, 5.4, SPM}.

2.) Is there a documented impact today (or in the recent past)?

- Emerging risk scenarios are documented threats to many dimensions of human development.

- Extreme and unpredictable weather events are already a major source of poverty [13].

3.) What are projections for future climate-driven impoverishment?

> "The impacts of climate change will fall disproportionately upon developing countries and the poor persons within all countries, and thereby exacerbate inequities in health status and access to adequate food, clean water, and other resources" (IPCC 2001, 12).

4.) What are the greatest uncertainties regarding this impoverishment?

Precisely how changes in ecosystem services may impact absolute and relative poverty is an area of work which is still largely uncharted [77].

5.) What are potential feedbacks and/or relations between impoverishment and other phenomena?

- With a temperature increase of between 1.5C and 2.0C, (already poor) farmers' income declines significantly in LDCs (Hare, 03).

- Migration: In South Africa, poverty is a crucial factor in children's decisions to leave their families and look for work [95].

HUMAN CONSEQUENCE 4: FOOD SECURITY AND AGRICULTURAL PRODUCTIVITY

Description of food insecurity: Climate change influences all aspects of food security: food availability, access and utilization (nutrient access) [46]. Climate variables also affect biophysical factors, such as plant and animal growth, water cycles, biodiversity and nutrient cycling, as well as the ways these are managed (land use and agricultural practices) for food production. Climate also influences physical / human capital – such as transport, storage and marketing infrastructure, houses, productive assets, electricity, and human health – which indirectly alters socio-economic factors that govern access to and utilization of food, thereby threatening food system stability [96].

1.) What do experts have to say about climate-induced food insecurity?

As climate change gathers pace, agricultural production in many developing countries will become riskier and less profitable. At a global level, aggregate agricultural output potential may be only slightly affected by climate change. While agricultural potential could increase by the 2080s by 8% in developed countries (as a result of longer growing seasons), potential in the developing world could fall by 9% due to expansion of drought-prone areas [13].

2.) Is there a documented climate-induced food insecurity impact today?

- Today is a situation "*where food production no longer meets demand, and the reserves for major crops have been declining rapidly*". The situation is further exacerbated by an annual loss of arable land [96].

- In world markets, the prices for many key agricultural products have gone up to unprecedented levels over the last three decades, triggering a rising demand for meat and milk products in developing economies, a parallel demand for liquid agro-fuels for transportation in industrialized countries and the high volatility in harvests at the global level [96].

3.) What are projections for future climate-related food security?

- By 2080, the number of additional people at risk of hunger could reach 600 million—twice the number of people living in poverty in sub-Saharan Africa today [13].

- Globally, crop productivity is projected to *increase* slightly at mid- to high latitudes for local mean temperature increases of up to 1 to 3°C, depending on the crop, and then decrease beyond that level in some regions (medium confidence) (IPCC WGII 5.4, SPM). "*..in some areas, global warming will initially boost agricultural productivity*"[15].

- At lower latitudes, especially in seasonally dry and tropical regions, crop productivity is projected to *decrease* for even small local temperature increases (1 to 2°C), which would accentuate risk of hunger (medium confidence) (IPCC WGII 5.4, SPM). "*In some countries, yield from rain-fed agriculture could be reduced by up to 50% by 2020*" (IPCC).

- Potential gains in a warmer world are smaller, particularly for agricultural production in temperate climates. The fertilizer effect of CO2 has been overestimated and parallel climate stress on crops limits

its effects. The effects on food production of increasing disaster frequency and intensity is becoming clearer [96].

4.) What are the greatest uncertainties linked to food insecurity?

- The precise causal chains between poor production (drought) and famine are unclear.

- How able will populations be to adapt their livelihoods and find creative solutions?

5.) What are potential feedbacks and /or relations between food insecurity and other consequences?

- Major losses in agricultural production will lead to increased malnutrition and reduced opportunities for poverty reduction. Overall, climate change will lower the incomes and reduce the opportunities of vulnerable populations.

- Impoverishment and health represent a 'double exposure', those most exposed to market fluctuations will be double losers [31]. Three-quarters of the world's poor are dependent on agriculture with obvious implications for global poverty reduction efforts [13].

- Mobility and human displacement: The increases in temperature and the frequency of droughts and floods are reported to affect crop production negatively, thereby triggering increases in the number of people at risk from hunger and rising levels of displacement and migration [85].

- Conflict: hungry people may have less to lose.

HUMAN CONSEQUENCE 5: HEIGHTENED MOBILITY

Description of heightened mobility: Flight is a standard human response to extreme events and processes, and over time it may result in the permanent relocation of populations. Flight from environmental or climate stress has many faces. Three of them are captured by UNU's recent research under the EACH-FOR Project [97]:

- Environmental Emergency Migrants/Displacees who flee the worst of an environmental impact on a permanent or temporary basis. These are people who have to flee because of the swiftness of an environmental event and who must take refuge to save their lives. Examples include people who flee natural events such as hurricanes, tsunamis or earthquakes.

- Environmentally Forced Migrants who "have to leave" in order to avoid the worst of environmental deterioration. For this category of people, the urgency for flight is less than for those people fleeing sudden and rapid-onset environmental events (defined as Environmental Emergency Migrants/Displacees) since the pace with which the environment is changing and/or deteriorating is slower. In this category, people may not have a choice to return due to the physical loss of their land. An example would be a person who has to move because their place of residence disappears due to sea-level rise.

- Environmentally Motivated Migrants describes those who 'may leave' a steadily deteriorating environment in order to pre-empt the worst. In such cases there is no emergency nor is it a last resort action to move, instead, it is a situation in which individuals who foresee a deteriorating environment may decide to move in order to avoid further deterioration of their livelihoods. Examples would include people who face desertification or repeated flood events that continuously threaten livelihoods.

Urbanization, a hidden face of climate-driven migration, has become the dominant feature of human settlement patterns over the past century. More than half of the world's current population lives in cities. Over the next several decades, the largest urban population changes are expected to occur in coastal areas, particularly in Asia and Africa [63]. "*As cities absorb ever growing populations, they will lock in their climate vulnerabilities for the next 50 years*" [42]. Movement to urban settings will put increasing strain on already overburdened infrastructure, but it may also fail to deliver people from the impact of climate change – many of the places to which they will naturally gravitate, such as large coastal cities, are increasingly exposed to risk [11]. The linkages between rapid urbanization and disasters have often been described as reflexive: cities create their own risks by causing degradation of the local, regional, and global environments. High concentrations of resources and people within cities also highlight high economic, social, and environmental costs. In return, these costs are likely to escalate as a result of growing populations in coastal cities, many of which are already highly vulnerable to sea-level rise, tsunamis, and other hazards. By the year 2015, there are expected to be 60 megacities in the world, each with a population of 10 million or more people [63].

1.) What do experts have to say about climate-induced mobility?

> "As temperatures rise and conditions deteriorate significantly, climate change will test the resilience of many societies around the world. Large numbers of people will be compelled to leave their homes when resources drop below a critical threshold" [98].

Already anticipated migration may be accelerated or spurred on by climate change: the impact of an extreme climatic event is to accelerate an existing process, not necessarily to initiate a new one [41].

2.) Is there documented impact of climate-induced mobility today?

- There is evidence of the impact of climatic change and extreme climatic events on human population movements [41].

- There were already 25 million ecomigrants in the world a little more than a decade ago (Source: Norman Myers, a respected British environmental researcher at Oxford University) [99].

- In Brazil, rural/urban migration (1960-70) in the worst drought-affected state involved 36% of the population compared with neighbouring states less exposed to drought (14 and 22%) (Hall 1978).

- In several Sahelian countries, roughly 10 million people have been driven to move by prolonged drought and famine [99].

- About 2.5 million Americans became ecomigrants after drought and land degradation during the Dust Bowl years of the 1930s [99].

3.) What are projections for climate-induced mobility?

- The most vulnerable industries, settlements and societies to projected climate change are those in coastal and river flood plains, those whose economies are closely linked with climate-sensitive resources and those in areas prone to extreme weather events, especially where rapid urbanisation is occurring (IPCC WGII 7.1, 7.3, 7.4, 7.5, SPM).

- "An additional 1 billion people will be forced from their homes between now and 2050. "*Forced migration is the most urgent threat facing poor people in developing countries*" [11].

4.) What are the greatest uncertainties regarding climate-driven mobility?

- It is impossible to isolate single drivers in the causal change connecting climate and mobility.

- There are challenges in measuring the scale and geography of the historical phenomenon worldwide, as well as anticipating projections for the future.

5.) What are potential feedbacks and /or relations between mobility and other phenomena?

- Degradation: In the Philippines, upwards of 4 million people have moved from lowlands to highlands as a result of degraded environments (deforestation) [99].

- Poverty: the latest IPCC impact report warns that the regions most vulnerable to the effects of climate change are those already struggling with other problems that force people from their homes: '*Vulnerable regions face multiple stresses that affect their exposure and sensitivity [to climate change] as well as their capacity to adapt. These stresses arise from, for example, current climate hazards, poverty and unequal access to resources, food insecurity, trends in economic globalisation, conflict and incidence of diseases such as HIV/AIDS.*'

- Conflict: Regions where climate change holds the greatest risk of creating population displacement include countries that are already wracked by conflict and are hosts to groups that pose security concerns internally and internationally" [11]. The main impact of environment factors on migration from SSA countries occur through their impact on conflict and economic growth [100].

HUMAN CONSEQUENCE 6: IMPAIRED HEALTH

Description of impaired health: Climate change is likely to have major implications for human health in the 21st century. Changes in climate are likely to alter the health status of millions of people, manifested through increased deaths, disease and injury due to heat waves, floods, storms, fires and droughts. Increased malnutrition, diarrhoeal disease and malaria in some areas will heighten vulnerability and development goals will be threatened by longer term damage to health systems from disasters [101]. Extreme weather events and climate-related disasters will not only trigger short-term disease spikes but also have more enduring consequences, such as on a nation's economy [19]. Droughts and floods are often catalysts for wide-ranging health problems, including an increase in diarrhoea among children, cholera, skin problems and acute under-nutrition [64].

1.) What do experts say about climate-driven health impairment?

Climate change will affect human health through complex systems involving changes in temperature, exposure to extreme events, access to nutrition, air quality and other vectors. Some infectious diseases such as malaria, waterborne disease (diarrhoea and cholera), and cardio-respiratory disease will become more widespread as the planet heats up [19]. Currently small health effects can be expected with very high confidence to progressively increase in all countries and regions, with the most adverse effects in low-income countries (IPCC). Critically important will be factors that directly shape the health of populations such as education, health care, public health initiatives, and infrastructure and economic development {IPCC WGII 8.3, SPM}.

2.) Is there a documented climate-driven health impact today?

- New contemporary diseases have been linked to warming climates, such as chikungunya (Indian Ocean), swine flu and bird flu [102].

- The Anopheles mosquito can only breed at temperatures warmer than 16°C, thereby creating a new geography of malaria prevalence with global warming [103]. Evidence is mounting on the influence of climate change on malaria in warming areas and topographies [104].

- In Central Mexico (1998 to 2000), children under five had greater chances of falling sick when they suffered a weather shock: the probability of illness increased by 16% with droughts and by 41% with floods [13].

- Cholera in Bangladesh is linked to rising sea surface temperatures (SST) [105].

3.) What are projections for future climate-induced health impacts?

- The health status of millions of people is projected to be affected through increases in malnutrition; increased deaths, disease and injury due to extreme weather events; increased burden of diarrhoeal diseases; increased frequency of cardio-respiratory diseases due to higher concentrations of ground-level ozone in urban areas; and the altered spatial distribution of some infectious diseases (IPCC WGI 7.4, Box 7.4; WGII 8.ES, 8.2, 8.4, SPM).

- Infectious diseases such as malaria and Ross River fever will become more widespread as the planet warms: temperature is a key factor in their prevalence [19]. One estimate for Africa suggests that malaria exposure will increase by between 16 – 28% under a range of climate change scenarios [63].

- Climate change is projected to bring some benefits in temperate areas, such as fewer deaths from cold exposure, and some mixed effects such as changes in range and transmission potential of malaria in Africa. Overall, however, it is expected that benefits will be outweighed by the negative health effects of rising temperatures, especially in developing countries (IPCC WGII 8.4, 8.7, 8ES, SPM).

- Except in the very hottest parts of the world, it is reasonable to expect that humans will adapt to gradual increases in average temperature. It is likely that gradual warming will lead to gradual change in the minimum-mortality temperature as well. In this case, there will be little or no mortality change based on the first degree of warming [64].

4.) What are the greatest uncertainties regarding climate-induced health impairment?

- Interactions between disease, environment and people are complex.

- Health activists claim that the "*recognition of uncertainty is not a case for inaction*"[13].

5.) What are potential feedbacks and /or relations between health and other phenomena?

- Drought: A link has been drawn between drought in Kenya and the appearance of the Indian Ocean chikungunya virus [102]. Also linked to drought is a likely rise in malnutrition [104].

- Poverty: Deteriorating nutrition and falling incomes generate a twin threat: increased vulnerability to illness and fewer resources for medical treatment [64].

- Inequality: Where there is a heavy burden of disease and disability, the effects of climate change are likely to be more severe than otherwise [13]. Indian women born during a drought or a flood in the 1970s were 19% less likely to ever attend primary school, when compared with women the same age who were not affected by disasters [13]. No less than 88% of the "disease burden attributable to climate change afflicts children" under 5 years [105].

FORCINGS & FEEDBACKS BETWEEN CLIMATE CHANGE CONSEQUENCES IN A COUPLED SYSTEM

"Our knowledge …about the linkages between climate change, extreme events, disasters, and disaster response…is rudimentary [27]."

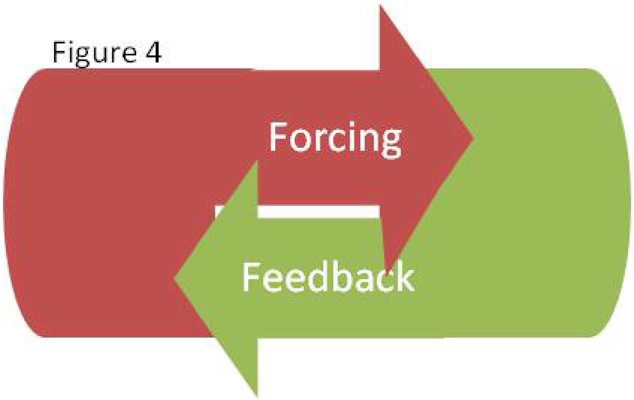
> "In an increasingly complex world, the propensity for extreme weather events to interact with political and economic processes to cause much larger and more complex emergencies than expected needs to be spelled out [106]."

The IPCC reports that there is "*no simple link*" between a global rise in temperature and damage caused by climate change [11]. The spread of disasters is often described using interconnected causality chains [84], and feedback loops spanning coupled natural and human systems (CNH). There may be a series of trends that accumulate and reach a tipping point [107]. Even if a singular event or process is not in itself catastrophic (conveying that elements have *adapted*), the cumulative impact of repeated or synchronous hazards may push a system past a threshold that undermines the capacity or legitimacy of governments, or jeopardizes human security of citizens [19]. Feinstein International Centre differentiates between sequential or 'cascading' impacts from crisis agents and synchronous 'multi-hazard' impacts [106]. **It must not be forgotten that potential increases in extreme events come "*on top of alarming rises in vulnerability*"** [15].

DEFINITION OF FORCINGS & FEEDBACKS

Forcings are agents causing a change in a given system. Volcanic eruptions, solar variations and anthropogenic changes in the composition of the atmosphere or land use are external forcings to the climate system. In the same grain, sea level rise, an agent in the natural system, is an external forcing to human mobility, an agent in the human system.

Figure 4



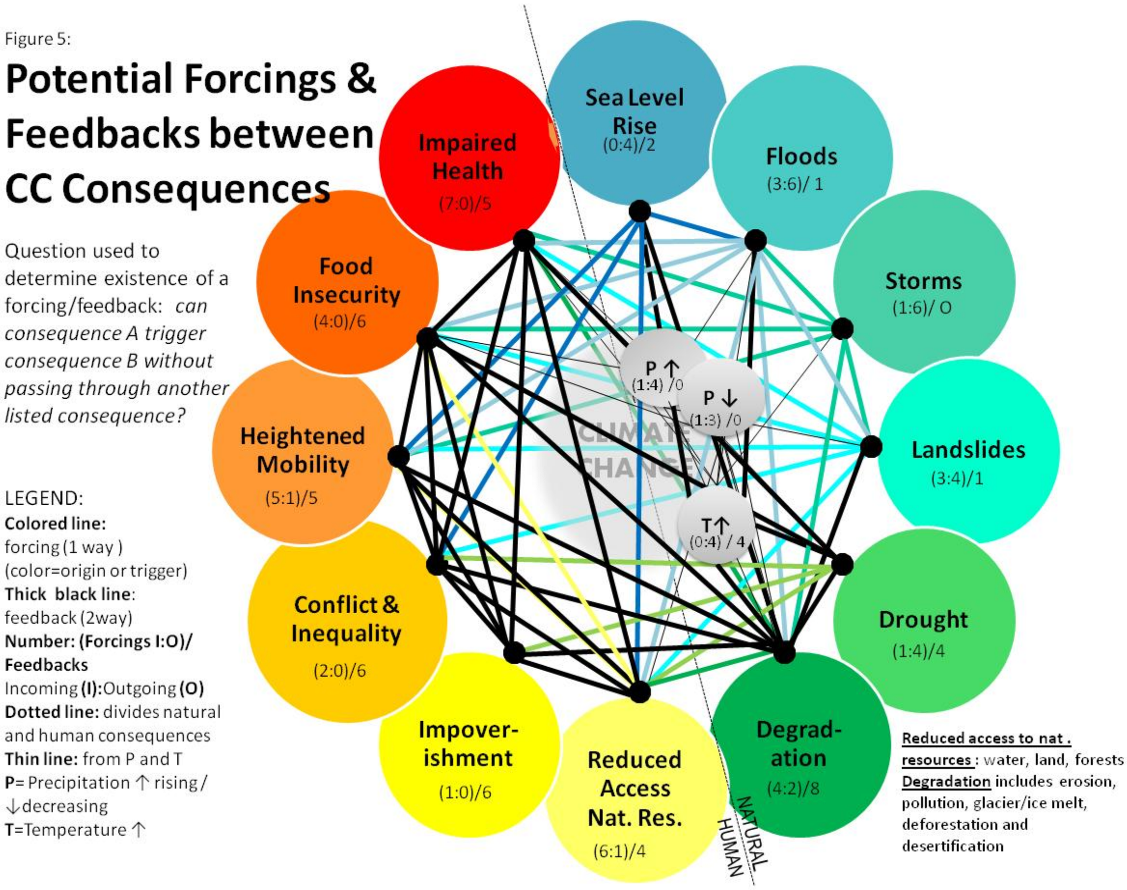
A climate feedback, according to the IPCC Glossary, is "an interaction mechanism between processes in the climate system that results when an initial process triggers changes in a second process that in turn influences the initial one", thus closing the loop (See Figure 4). A positive feedback (e.g., decreasing albedo) intensifies the original process (here, of global warming), and a negative feedback reduces it. An example of a positive feedback within the social system is reduced access to water (or forests) that triggers human migration which in turn depletes water or forest resources in a previously pristine location. In a coupled natural human (CNH) system, forcings and feedbacks can stay within one subsystem or cross the line between the two.

Based on the description above, a set of consequences were studied to assess the potential forcings and feedbacks between and within the climate, natural and human subsystems. It is not possible to assess every climate, physical or human factor in this analysis (i.e. albedo, evapotranspiration or population growth). Elements (or consequences) in the climate system that were assessed are three (3): rising temperatures, precipitation increasing and precipitation decreasing. Within the natural/physical system, we assess the previously described six (6) extreme events and processes: degradation (including erosion, glacier/ice melt, deforestation and desertification), drought, landslides, storms, floods and sea level rise. The human system contains the aforementioned six (6) elements: reduced access to natural resources (for the purposes of this study, water, land, forests), impoverishment, conflict and inequality, heightened mobility, food insecurity, impaired health.

For each element, the question that was asked to determine existence of a forcing or feedback was: *can consequence A trigger consequence B without passing through another consequence (studied here)?* The relationships have been greatly simplified to explore trends and potential associations. The term *trigger* is used to avoid causality; inevitably one consequence may have causal characteristics but may not assert a forcing or feedback *in isolation of other elements*. If there is evidence that consequence A requires another listed consequence to trigger consequence B, however, it is not hereby considered a forcing or feedback per se.

Viewing all the forcings and feedbacks together (Figure 5) enables us to grasp the complexity of a coupled system, but more importantly to understand how, **even without a direct or causal relationship**, spin-offs and triggers can ignite non-linear and possibly sudden consequences simultaneously –with the potential to abruptly tip the coupled system into chaos, or a new state.

In the figure, the natural/physical consequences are shown in green to blue shaded circles on the right side of the dotted line and the human consequences in yellow to red circles on the left. Forcings are represented by coloured lines in the colour of the trigger. Feedbacks are represented by thick black lines (no colour because they represent two-way relationship). The thin black lines are used for relationships with the climate variables: Precipitation (P, rising or decreasing) and Temperature (T, only rising assessed here). The number under each consequence name represents the number of forcings Incoming (I): Outgoing (O)/ Number of feedbacks.



At first glance, the forcings and feedbacks appear chaotic; even the words 'climate change' in the light gray circle are almost invisible beneath the numerous links. There is a predominance of feedbacks (thick black lines) in the human subsystem (left side), although significantly fewer outbound forcings. Out of the six feedbacks crossing the threshold between the human and natural subsystems, four are linked to degradation, the consequence with the greatest number of feedbacks (n=8). Rising temperatures are implicated in four feedback loops: sea level rise, floods, drought and degradation. Each of these can change, at least temporarily, land cover thereby altering albedo and further exacerbating temperatures.

Consequences the most responsible for triggering others (with or without feedbacks) are degradation, drought and rising temperatures, all within the natural/physical subsystem. Those consequences that are least responsible include rising and falling precipitation. This is deceiving, though, because increased precipitation can trigger floods, which is only one step away from degradation, the most complex phenomenon. Degradation is linked in some way to every other consequence of climate change.

The next three most complex phenomena are found within the human subsystem: impaired health (12 interactions, of which 5 are feedbacks), heightened mobility (11 interactions with six feedback loops) and reduced access to natural resources (11 interactions of which five are feedbacks). For impaired health, all five outbound forcings are also feedbacks; therefore, they not listed as an outbound forcing. This is common to four consequences in the human subsystem but to none of the elements in the natural system. Impaired health also has the greatest number of inbound forcings (n=7). See Table 2. The only elements that have no direct relationship with impaired health are lowered precipitation and sea level rise, both of which can certainly contribute to impaired health, but specifically via another consequence, such as reduced access to natural resources (potable water, for example).

Among the hazard events/processes (natural consequences), degradation is the most complex and sea level rise the most simple. Sea level rise has two feedbacks – rising temperatures

Table 2: Forcings & Feedbacks between climate change consequences in CNH System	forcing IN	forcing OUT	FEEDBACK (FB)	Total Triggers (Out + FB)	Total Number of Relationships
A. Temperature ↑	0	4	4	**8**	**8**
B. Precipitation ↑	**1**	**4**	**0**	**4**	**5**
C. Precipitation ↓	1	3	0	**3**	**4**
D. Storms	**1**	**6**	**0**	**6**	**7**
E. Floods	3	6	1	**7**	**10**
F. Sea Level Rise	**0**	**4**	**2**	**6**	**6**
G. Landslides	3	4	1	**5**	**8**
H. Drought	**1**	**4**	**4**	**8**	**9**
I. Degradation	4	2	8	**10**	**14**
J. Red. Access to Nat. Res.	**6**	**1**	**4**	**5**	**11**
K. Impoverishment	1	0	6	**6**	**7**
L. Conflict & Inequality	**2**	**0**	**6**	**6**	**8**
M. Heightened Mobility	5	1	5	**6**	**11**
N. Food Insecurity	**4**	**0**	**6**	**6**	**10**
O. Impaired health	7	0	5	**5**	**12**
CLIMATE (A-C)	**0.7**	**3.7**	**1.3**	**5.0**	**5.7**
HAZARDS (D-I)	2.0	**4.3**	2.7	**7.0**	9.0
HUMAN (J-O)	**4.2**	**0.3**	**5.3**	**5.7**	**9.8**

and degradation. Higher temperatures are known to contribute to thermal expansion of sea water and as glaciers melt (here a form of degradation) more water will reach the seas. It likewise exerts a direct forcing on floods and three human consequences: reduced access to natural resources (land), conflict (as more and more people will dwell in smaller and smaller spaces) and heightened mobility (flight from the land claimed by rising waters).

The robustness of these conclusions and the particular selection of consequences merit investigation; the triggers are clearly sensitive to the choice of consequence included in the analysis. It is important to note that these are *potential* forcings and feedbacks. They will not occur in every situation and they depend on a host of confounding factors. There are certainly more links than those identified in this table and the list will grow as science expands to understand the complexities of climate change consequences in a coupled system.

In summary based on this preliminary analysis alone, here below are the elements important to conclude for the humanitarian community:

- No climate consequence, natural or human, occurs in a vacuum.

- Across both systems, **degradation** (in the physical system, here including erosion, pollution, glacier/ice melt, deforestation and desertification) is the most complex of all climate change consequences. Degradation is a highly packed consequence that meets with almost complete silence in humanitarian literature (and is only marginally addressed in climate change literature). This suggests that a greater focus on this phenomenon by humanitarians and development workers alike will reap profound benefits upon the entire linked system.

- The second most complex consequence is **impaired health** in the human subsystem. A deepening understanding of human health impacts benefits from a growing body of activists and scientists publishing on links to climate change. A continued and expanded focus is necessary to help reduce current and emerging health risks throughout the coupled system.

- **Sea level rise** (SLR), in the physical subsystem and **impoverishment** in the human subsystem appear to be the least complex due to the lowest number of direct forcings and feedbacks with other consequences. This simplicity, however, is misleading, as a closer look demonstrates that all of the relationships for SLR and 6 out of 7 of those for impoverishment are outbound triggers, signifying that nearly every link with these 'simple consequences' can escape control and trigger another consequence, sending off destructive reverberations throughout the system. Drought and storms have similar but slightly weaker characteristics.

- The human system is **more complex** than the natural / physical system. This is characterized by an average of 9.8 relationships with other consequences, versus an average of 9.0 relationships for consequences in the physical subsystem; twice as many feedbacks on average (5.2 versus 2.7 for the physical subsystem) and a greater proportion of total outbound triggers that are also feedbacks.

- This indicates **higher levels of non-linearity in the human subsystem** meriting further research. High non-linearity suggests easily-ignited, hard to predict and difficult-to-control consequences of climate change.

- The complexity of the coupled system is such that **all actors must be clearly cognizant** of potential for sudden ignition between subsystems and/or consequences and must be **poised and ready to rapidly intervene**.

- There is no shortage of climate change consequences to be managed by both humanitarians and development workers. The lessons above underscore the urgency of an **integrated multi-hazard package** of interventions and a **close partnership between humanitarian and development efforts** towards the common aim of reducing risk and saving lives, keeping households at the centre of resilience.

For a Technical Note on Coupled Systems, tipping points, and abrupt climate changes, please see Annex A.

CLIMATE APPLICATIONS

In this chapter, three scenarios of climate change consequence are applied. Case study narratives include:

- Sea Level Rise in Small Island Development States (SIDS),
- Drought and ENSO in Ethiopia, and
- Flooding and storms in Bangladesh.

Each scenario illustrates the non-linearity, complexity and reality of forcings and feedbacks. Answers can be found in Annex C to questions on expert opinions, impact in the recent past, projections, uncertainties and feedbacks.

SCENARIO 1: SEA LEVEL RISE (SLR) AND SMALL ISLAND DEVELOPING STATES (SIDS)

> Migration as an adaptation option is "missing the point" says Jon Barnett (Political Geographer, University of Melbourne, Australia). "Adaptation should aim to protect the rights of people to live in their homes" *[24]*.

Recall that sea level rise is considered by the forcing and feedback analysis above to be the most simple of the natural consequences of climate change. Starting with this phenomenon, we demonstrate the extent to which the most simple consequence can spark the most complex and tightly coupled series of triggers and whirlwind impacts.

SEA LEVEL RISE: DESCRIPTION OF THE PHENOMENON

We have more information on sea level rise today than ever before, thanks to satellite (radar) altimetry from the past decade and global tide gauge data going back 100 years [21]. There are three processes that are known to contribute to SLR:

1. **Thermal expansion:** Higher temperatures directly cause ocean water to expand, forcing sea levels to rise: this has been the dominant source of sea level rise in at least the past decade.

2. **Loss of land ice:** Continental glacial retreat leads to an influx of fresh water mass from mountains.

3. **Losses of the Greenland and/or Antarctic ice sheets** have recently been observed. There is growing understanding that the risk of additional contributions to sea level rise from melting of both the Greenland and possibly Antarctic ice sheets may be larger than projected [108], although it may be more closely associated with wind than with temperatures [10].

Already highly vulnerable to climate disasters, small-island developing states form the front line of climate change. Forty-five island states are classified by the United Nations as 'Small Island Developing States' (SIDS) [109] and can be roughly partitioned into Pacific, Caribbean, Indian Ocean and West African island groups [110]. According to the IPCC, almost all island states will be adversely affected by accelerated sea-level rise (IPCC, 2001). The Pacific and Indian Ocean islands are the most low-lying and at the greatest risk of sea-level rise. The islands of the Maldives, with 100% of their land area less than 5m above sea level, are extremely vulnerable to even minor rises. In the Pacific Islands of Kiribati and Tuvalu, land has already been lost to rising sea-levels.

Setting aside the aforementioned startling projections, even modest rises in sea level are likely to result in significant consequences for SIDS. On the side of *natural consequences* these include:

- Degradation: coastal erosion, loss of mangrove forests, loss of protective coral reefs, sand beaches and agricultural land; salt water intrusion and salinisation of freshwater aquifers. Long before migration becomes the only option, erosion and rising tides will compromise infrastructure, settlements and the economic well-being of entire nations [44].

- Flooding: submersion of land and increased riverine flooding.

- New coastlines that increase exposure to hurricanes and storm surges.

- Biological diversity exposed to greater risk (Lewis, 1990; Maul, 1993).

Potential feedbacks: a change in land cover (from land to water) will alter albedo and further contribute to a changing climate.

In regards to *human consequences*, the following are likely to accompany or occur shortly after the natural consequences:

- Reduced access to natural resources: especially land and potable or irrigation water. General water resource availability is affected by decreased rainfall and saltwater intrusion. Freshwater supplies are compromised, forcing governments to undertake costly investments in desalination [64], water transfers, etc.

- Food insecurity: via a shortening of the growing season and/or drought [111].

- Heightened mobility, as settlements and arable land on the coast are compromised. Those living nearest the coast will lose their homes and capital assets; those whose livelihoods depend on coastal agriculture will lose their productive assets. Many will lose both.

- Impoverishment: Reduced agricultural yields may lead to economic losses. Extreme weather, environmental degradation and sea rises may also reduce tourism. With only a 50cm increase in sea levels, over one-third of the Caribbean's beaches would be lost, with damaging implications for the region's tourist industry [64].

- Social tension may mount, laying the ground for potential conflict and less equitable development.

- Loss of sovereignty: Kiribati, Tuvalu and the Maldives may become entirely uninhabitable, thereby losing national and cultural heritage.

The populations of these countries will be forced to relocate, and thus contend with international immigration policies.

Synchronicity: In case the consequences listed above are not sufficient to foster a paradigm regime shift in a coupled system, the following consequences (less directly linked to sea level rise per se) are also known to occur in SIDS, due to global warming. They will occur simultaneously with the natural and human consequences above:

- Extreme events which already regularly occur in SIDS: the most disaster prone island group is in the Caribbean. Cuba, Haiti and Jamaica suffered 20, 20, and 9 disaster events (only those with natural triggers included) respectively between 1987-97 [108].

- Rising sea surface temperatures (causing coral bleaching which affects artisanal fisheries and reduces storm surge protection) and acidification of the oceans.

- Changes in precipitation that cause drought (which in turn will further affect drinking water and food security through agriculture).

- Damage to terrestrial forests due to extreme events.

- Salt water flooding and coastal erosion render vegetable production a daily struggle [44].

SIDS CASE STUDY

Future evacuation due to sea-level rise and extreme weather is likely for many low-lying Pacific islands. Many SIDS have initiated discussions with neighbouring Australia and New Zealand about safe migration routes to nearby countries on higher ground.

- The government of Tuvalu, a Polynesian island nation with a population of some 12,000, has already negotiated an agreement with New Zealand to accept 75 Tuvaluan immigrants annually since 2002. Despite the potential exit strategies, some believe that the focus should be on securing the sovereignty and the rights of societies that will be impacted by climate change [24].

- President Tong of Kiribati pleads with the international community to help relocate entire nations to higher ground homelands. He calls for an international fund to purchase land for which citizens are prepared to pay. Many citizens of Kiribati are already building skills that would be valuable in other countries and are seeking status in New Zealand [99]. In Kiribati, one estimate of the combined annual damage bill from climate change and sea-level rises in the absence of adaptation puts the figure at a level equivalent to 17–34 percent of GDP [13].

- In the Maldives, 80% of the land area is less than 1 metre above sea level, and even the most benign climate change scenarios point to deep vulnerabilities [13].

- Although not a SIDS, a one metre rise in sea level would inundate 18% of Bangladesh's land area, threatening 11% of the population. The impact on river levels from sea rise alone could affect an additional 70 million people [13]. See Scenario 3 below.

Both climate change science and adaptation in SIDS are gaining momentum. Key issues for humanitarian agencies will include acquiring analyses downscaled to island nations and a focus on rising sea levels, without losing sight of the multitude of coupled consequences linked to sea level rise in the short-to-medium term.

SCENARIO 2: DROUGHT/ENSO AND ETHIOPIA

DROUGHT: DESCRIPTION OF THE PHENOMENON

Drought is commonly defined as deficit precipitation compared to a reference period. There are four types of drought: meteorological, hydrological, agricultural and socio-economic. There is no publicly available database that tracks global drought disasters; there is therefore little possibility to verify drought-related events and consequences [112]. Beyond the average trends, changes in the frequencies of extreme events such as drought may be one of the most significant consequences of climate change [20]. Because of the large-scale character of drought, it is often preferable to study the phenomenon within a regional context (Demuth and Stahl, 2001; Tallaksen, 2000, [20].

According to the World Bank Hotspots analysis, roughly 38% of the land area is exposed to some level of drought, representing 70% of the world's population and the same proportion of agricultural production.

Under pristine conditions the ecosystem can normally cope with drought and growth failure. When precipitation resumes, a system should be able to redress any damage incurred. Even with prolonged drought or desiccation, the system may eventually recuperate as the phenomenon subsides. When recurrent drought and excessive human pressure on land (over-cultivation, overgrazing, over-cutting, etc.) are combined, systems may be irrecoverably damaged [25].

Despite that droughts are often reported as short-term, single events, some important impacts may be obscured where multiple or recurrent droughts create repeated shocks over several years. If climate change scenarios predicting more frequent or more intense droughts hold true, consequences could be significant and reversals in human development rapid [13].

Drought has a well documented link to El Niño/Southern Oscillation (ENSO) – an ocean/atmosphere cycle that spans a third of the globe. El Niño generally increases the risk of drought across southern Africa and large areas of South and East Asia, while increasing storm activity in the Atlantic [13]. El Niño has been known to warm global temperatures by about 0.2 °C in a single year, affecting both the ocean surface and air temperatures over land [113]. ENSO occurs every three to seven years, at varying strengths as a result of a complex set of interactions between the atmosphere and the tropical Pacific Ocean. Both phases (La Niña and El Niño) influence weather patterns across the globe [15].

Rather than conceptualize drought as an unexpected phenomenon that systematically requires a humanitarian response, scientists prefer to perceive of drought as a frequent reality that societies must learn to accommodate [114]. Drought-related famine events are often multi-country or multi-year events. Famine, however, is not a hazard, but rather a particular outcome and most commonly a consequence of multiple complex natural or non-natural factors (e.g., drought, conflict, economic disruption). It may be difficult or even impossible to identify the dominant causes of famine; they may have little connection to documented natural hazard events [112].

Natural consequences: Drought manifests itself in a change of vegetative cover, which in turn reduces surface albedo, thereby nudging global temperatures even higher. Beyond this vicious feedback loop, drought also directly triggers land degradation, as desiccation sets in, nutrients are leached and fertility erodes. Land degradation entails a reduction (or loss) in the capacity of land to produce what society expects and reflects economic loss but not necessarily ecological deterioration; it is inherently linked to drought [114].

Human consequences: Drought has direct links with every possible human consequence of climate change. By definition, drought manifests in reduced access to water, and later to once-productive land that is no longer arable. When agricultural yields are reduced or lost, there is a direct impact on both food security (household consumption) and revenue (impoverishment). Although controversial, drought conditions have repeatedly been linked to situations of conflict, such as in Darfur. Heightened mobility, such as outmigration and urbanization, has been linked to drought in certain situations and contexts. The links between drought and food insecurity go without saying, as does the resulting malnutrition and impaired health that accompany lower consumption levels.

ETHIOPIA CASE STUDY

Ethiopia is considered one of the poorest and most drought-prone countries of the world. The World Bank Hotspots analysis estimates that 29.9% of the land area of Ethiopia and 69.3% of the country's population is at high mortality risk of two or more hazards [47]. At least 18 droughts were recorded in Ethiopia prior to the 21st century [115]. It is estimated that one half of all Ethiopian households experienced at least one major drought shock between 1999 and 2004 [13].

Projections for Ethiopia

Temperature: Mean annual temperatures between 1960 and 2006 have already risen by 1.3°C and are projected to rise an additional 1.1 to 3.1°C by 2060. From the past average of 23.08°C (1961-90) the annual average temperature for 2070-2099 is projected to be 26.92 °C (Cline 2007).

Precipitation: Precipitation in Ethiopia is largely the result of the migration of the Inter-Tropical Convergence Zone (ITCZ), highly sensitive to ENSO variations. Precipitation shows no significant trends, but many models concert to project an increase of between 10 and 70% by 2060 [116, 117]. Cline (2007) suggests that rainfall may reduce from the current average of 2.03 to 1.97mm/day and national submissions to UNFCCC suggest a decrease in the north and an increase in the south.

Extreme events: Ethiopia has experienced at least five major droughts since 1980, along with dozens of local episodes. Despite recurrent drought, flooding features more and more often among the set of recurrent and destructive hazards [118]. Projections for increased rainfall may attenuate drought while further accentuating floods in the country. The Dire Dawa Flood in 2006 killed hundreds [44]. No convincing predictions are to be found in the literature on extreme event frequency or intensity in Ethiopia.

Authorities, farmers and pastoralists have noted change in regional climate over the past ten years and are testing appropriate adaptive mechanisms. Their perceptions, however, do not align with recorded precipitation trends. The discrepancy must lie either with access to the water resources or to household needs that have evolved over time [119].

Given the strong influence ENSO has on East African seasonal rainfall, and the wide disagreement in projected changes, ENSO projections are highly uncertain, especially for inter-annual variability [116]. It is important to note that Ethiopia represents a very complex environment that is still poorly resolved in current climate models. Making future projections with greater clarity and confidence than what is provided above is not possible today. Projected phenomena climate scientists are most confident about such as rising temperatures and snow melt are not resolved down to the level of countries.

Consequences in Ethiopia

Specific climate change consequences on the *human side* in Ethiopia are numerous. They include:

- **Reduced access to resources:** Although Ethiopia has abundant water, it has one of the lowest reservoir storage capacities in the world. Ethiopia has twelve major river basins, and combined with eleven major lakes, is home to the "water tower" of Northeast Africa. Run-off to Nile tributaries (Abay and Awash Rivers) is projected to suffer a reduction of up to one-third due to climate change. Lake Tana area's basin runoff is highly susceptible to climate change [120]. In the Lake Ziway Watershed, runoff is projected to drop and will likely be unable to satisfy future water demands [121].

- Inter-ethnic rivalry in Ethiopia is largely linked to fierce competition for scarce resources, such as land and water [122]. Climate change in Ethiopia is also projected to trigger the drying of wetlands, thereby affecting bird species' breeding sites and biodiversity (World Bank, 2008). Some researchers argue that increased food security may go counter to the maintenance of genetic diversity in plant species [123].

- **Heightened mobility:** Most prevalent in the eastern regions of Ethiopia are recurrent waves of drought-related displacement such as in 2000 and 2003 [122]. Recurrent drought, alongside other variables, has been linked to distress migration but mass migration of this genre in the region should be proposed with caution [115].

- Other research attests that, although highly controversial, government organized resettlement of drought victims is frequent and many towns have been created to serve drought-stricken households. Urbanization typical of LDCs is not occurring in Ethiopia [124]. At times, drought has been little more than a pretext for the government to resettle less desired constituents to distant and/or marginal areas [125].

- **Conflict and inequality**: Desertification, salinisation and water scarcity have been known to trigger increased competition for natural resources, thereby creating situations where conflict can brew. This occurs more frequently in those areas where governments are unable to support parallel sources of income, one example being the conflict between farmers and pastoralists in the Oromia and Ogaden regions of Ethiopia[44].

- Drought has partially contributed to conflict and ethnic federalism in Ethiopia [122]. War accentuates household vulnerability to drought [115].

- **Impoverishment:** Drought shocks are a root cause of transient poverty and World Bank analyses demonstrate a strong relationship between precipitation and GDP trends [13]. The 1999-2000 drought saw the proportion of asset poor households rise from 60% in 1997 to 78% in 2003 (north-eastern Ethiopia). As a consequence, 95% of studied asset-destitute households remained poor 6 years later. After the 1984-1985 famine, an average of 10 years was needed for asset-poor households to recover their livestock holdings to pre-famine levels.

- Diversified income sources have made households more resilient to climate variability [115] although households with fewer than 45 head of cattle appear to have insufficient resources to promote income diversification [126]. The adoption and use of fertilizer was significantly lower for those with higher consumption risk due to drought [126].

- Extended drought impacts negatively on livestock herds. Ethiopian households get trapped in cycles of drought that spiral into poverty and discourage efforts to build up an asset bases or to reinforce income. Among Ethiopian pastoralists, having a large herd of 45-75 cattle at the beginning of a drought during 1980-1997 helped to smooth consumption and maintained herd size at a reasonable level thereafter [126].

- **Food Insecurity**: In the Ethiopian NAPA, yield reductions of wheat of up to 33% are predicted as a response to climate change. Although the impact of climate change on agricultural production and the economy may be only moderate [127], this hides large pockets of food insecure households. The number of Ethiopians assisted by relief operations has risen since 1997 with an all-time high in 2000 (triggered by the 1999/2000 drought) [128].

- Ethiopian farmers have already been reported to change agricultural practices and abandon farming as a response to climate change [119].

- In Ethiopia, 10% less rainfall translates almost instantaneously into reduced household consumption, with a smaller impact on the poorer with lower livestock holdings. At least one drought between 1999 and 2004 lowered per capita consumption by about 20% in 2004 [126].

- **Impaired health**: Childhood malnutrition in Ethiopia is characterized by the likelihood that those born in a drought year are 36% more malnourished and 41% more likely to be stunted than in a non-drought year. Compared to their counterparts in other villages, Ethiopian children (in utero or less than 36 months during the 1984 famine) living in a village where drought was prominent were significantly shorter (stunted) ten years after the shock [126].

- Malaria has charted a new geography in Ethiopian highlands and cholera is reportedly directly related to an increase in flooding.

Forcings and feedbacks in Ethiopia

Spiraling feedbacks have followed this pastoral narrative for the past century: failure of short rains triggers small scale farming adaptation, subsequent rain failure of long rains catalyzes distress sales of livestock; while the more wealthy households sell early and juggle the risk, more vulnerable households get only marginal returns leading to loss of capital for the poorest and terms of trade reduced (livestock prices falling sharply relative to cereal prices); urban centers serve as magnets to drought-stressed households whose ability to feed their members is endangered, resulting in malnutrition and impaired health.

What is novel in the 21st century in Ethiopia is uncharted albeit uncertain variability and change in the climate, the likelihood of more frequent droughts and the arrival of unprecedented floods, all built on a foundation of burgeoning population and swift urbanization. Whether the changes in store for Ethiopian pastoralists include floods or drought, both will require climate adaptations, with varying techniques in herd composition and land-use.

Every consequence in this new Ethiopian narrative is more closely interlinked with each of the others. At some unknown point, despite the well-documented resilience of Ethiopian livelihoods, one consequence may eventually tip the scale and with or without conflict, a paradigm shift into a new state may occur. Demands on humanitarian assistance require above all mental flexibility to anticipate rapidly implemented interventions on multiple fronts despite great uncertainty.

SCENARIO 3: STORMS, FLOODING AND BANGLADESH

STORMS: DESCRIPTION OF THE PHENOMENON

More intense tropical storm activity is one of the givens of climate change. Warming seas will fuel more powerful cyclones. At the same time, higher sea temperatures and wider climate change may also alter the course of cyclone tracks and the distribution of storm activity. Controversy on the cyclone-global warming link remains high.

Tropical cyclones are low-pressure weather systems that form over warm waters between the latitudes of 30N and 30S. Cyclogenesis occurs when six criteria are satisfied: warm ocean waters, an atmosphere that cools rapidly, mid-troposphere moisture, Coriolis forces for rotation, an organized, rotating system with spin (vorticity) and convergence and minimal vertical crosswinds at varying altitudes. Rising near-surface atmospheric temperatures can trigger a subsequent rise in sea surface temperatures (SST), aligning the conditions to spawn a cyclone. On average, 48 cyclones are spawned each year [129] and roughly 7% of the world's land area has been impacted by cyclonic activity during the 21-year period studied by World Bank's Hotspot Analysis. Predominantly on the coast, nearly 24% of the world's population lives in the affected areas [47].

FLOODING: DESCRIPTION OF THE PHENOMENON

Although the "*primary reservoir of floodwaters*" [130] – precipitation – is included in the IPCC table, there is yet no evidence (nor will there likely be in the near future) that directly associates a single driver with future flood events at any level of confidence. In IPCC's AR4, Table 3.2, flooding is mentioned frequently as an "*example of a major projected impact*" related to an extreme weather phenomenon, but not as a phenomenon itself. Drivers of flooding are numerous: precipitation, drainage basin factors, and sea level rise, to name only a few.

It is expected that climate change will strongly influence the hydrological characteristics of the atmosphere. Higher temperatures cause an increase in evaporation, and the moisture capacity of the atmosphere will also increase. This may lead to increases in precipitation with above all an influence on intensity [22].

In contrast, floods whose critical peak flows are determined by small to meso-scale processes, are typically analyzed in basin-specific approaches, focusing on single watersheds. Fluvial systems set in motion many complex interactions. *"Although climate may be the 'driving force' there is a considerable 'cultural blur'…which can make it difficult to distinguish between changes in flood frequency that are climatically induced and those that are due to human activity. Often the changes are a mixture of the two*" (Jones 1997, [20].

About one third of the world's land area is exposed to flooding. Flood prone areas are home to a large proportion of both the world's population (82%) and economic assets [47, 131].

Natural consequences: Storms can catalyse floods, and floods can further trigger temperature rises (in the case of reduced albedo). Both storms and floods can result in landslides and further degradation.

Human consequences: Both storms and floods can heighten mobility (homes destroyed or under water), food insecurity (produce and/or markets damaged) and impaired health (risk of injury as well as heightened exposure to disease). They can also have a direct effect on access to natural resources (e.g., by endangering potable water sources).

BANGLADESH CASE STUDY

Bangladesh is the quintessential country of extremes. It has been named the "*wettest land on earth*" [132] and therefore, is the perfect context in which to explore the impact of both storms and flooding, separately and as a synchronous hazard. It is also known as "*the most disaster prone country*" or the most "*climate-vulnerable country*" [133].

Included in Bangladesh's National Adaptation Plan of Action (NAPA) are three main physical consequences of climate change: sea-level rise, changing rainfall patterns, and increases in the frequency and intensity of extreme events [134]. Greater than 70 major disasters have occurred since 2000: cyclones, local storms, floods and droughts have killed 9,000 people and incurred damages of more than US$5 billion. One-fifth of the country is flooded every year, and in past extreme years, two-thirds of the country has been inundated. [44].

The World Bank Hotspots analysis estimates that 97.1% of the land area and 97.7% of the country's population is at high mortality risk of two or more hazards [47]. Its fragility is exacerbated by one of the highest population densities in the world and a high dependence on primary natural production (agriculture and fishing) and extreme poverty. Thirty and 26 percent of land and population, respectively, are exposed to three hazards.

Flooding in Bangladesh has been termed "*a normal part of the ecology*" [13], thereby strengthening the argument that hazards are best perceived as daily occurrences rather than surprising outcomes. Although over 20% of the county's land is flooded annually, major events have recorded flood coverage of up to 67% of the national surface area (linked to the 1998 flood) [132].

Despite the fact that the southwestern part of the country has been known more for drought than for floods [132], in 2007, a category five cyclone made landfall in southwestern Bangladesh and took another 3,500 lives [42]. The most recent flood prior to that date was registered in 1905.

Climate Projections for Bangladesh

Temperature: In concert, many models predict annual warming in Bangladesh by 2020 of approximately 1.2°C, and between 1.9 and 2.4°C by 2050. There is high confidence that this trend will be linked to temperature extremes [135].

Precipitation: Projections predict only modest changes in annual rainfall ranging from a 1% decrease to a 4% increase [135]. Changes in the seasons are expected to be larger, with drier winters and wetter summers through 2050.

Extreme events and processes

Floods: There is medium confidence that greater intensities of rainfall are likely to accompany wetter monsoon seasons and trigger flooding [135].

Although climate change appears to be heightening the frequency and intensity of floods in the region, the 1998 flood is still considered the '*flood of the century*' [136]. During that event, 1,000 individuals died and an additional 30 million became homeless. A considerably smaller proportion of the rice produced was left for the survivors, who resorted to divesting their capital (what little was not damaged by the rising tides) and incurring significant debt to rebuild their livelihoods. Most importantly, childhood malnutrition had reportedly doubled after the 1998 flood [13], leaving irreversible effects on many young lives.

Without naming 'climate', many researchers have linked flooding to erosion [137-139] and migration [140-143]. As climate change gains credibility as a driver of flooding, it is easy to imagine how various human and physical forcings and feedbacks will be sparked.

Drought: There is medium confidence that the drier winters will exacerbate pre-existing drought conditions. Dry spells are likely to increase or lengthen and higher temperatures will encourage evapo-transpiration and soil moisture deficits [135].

Cyclones: Over one-half of the world's reported mortality due to tropical storms has occurred in Bangladesh [135]. There is only low confidence that tropical storms will increase in frequency or intensity in the region (IPCC). Storm surges are a well documented consequence of cyclones in the region.

Sea Level Rise (SLR): World Bank estimates project that if seas rise one meter, 56 million people in 84 developing countries will be forcibly displaced. Nearly half of these, 20 million, are found in Bangladesh [44]. For climate displaced migration, Bangladesh is on the most deadly list among island states, several African nations, China, India, Egypt and more isolated delta areas and coastal zones within other countries (Renner 2008).

Estimates of SLR in Bangladesh range from 4.5 to 23 cm by 2030 and 6.5 to 44 cm by 2050 (IPCC); NAPA estimates do not reach the highs reported here. An active delta, tectonic subsidence, tidal influence, and volatile morphology are all considered confounding factors of SLR in Bangladesh, making more precise projections impossible. The link between deforestation and SLR is debated and indirect at best via changes in terrestrial water storage. Immobile investments may be entirely lost, soil salinisation will inevitably affect crop production and national heritage sites such as the Sundarban forest/mangrove swamp ecosystems will be severely endangered under the moderate scenarios [144].

Specific climate change consequences within the *human subsystem* in Bangladesh include:

- **Access to natural resources**: Rapid population growth, environmental change and unequal access to resources have fostered a scarcity of land and water in rural Bangladesh. This, in turn, creates widespread "*landlessness, unemployment, declining wages and income, growing income disparities and degradation of human habitat*" in Bangladesh [142].

- **Food insecurity**: According to climate projections for Bangladesh, rice and wheat production could be reduced by 30 and 50, respectively, in the case of a 4°C temperature increase [13]. El Nino regularly influences fishing populations, thereby endangering the livelihoods of entire fishing communities [145]. Agricultural production losses due to flooding in 2007 alone are estimated at 1.3 million tons [44].

- **Impoverishment**: Households facing the highest risk of flooding in Bangladesh are the least well prepared and least economically resilient. The relationship between poverty and climate risk is reportedly complex and positive. Roughly one-third of households' annual income is lost due to flood events [146]. Climate irregularities are also known to contribute to increased debt patterns in Bangladesh [141]. Other studies focus on coping and indebtedness of char dwellers facing constant erosion linked to cyclone activity [147].

- **Conflict and inequality**: Given their inability to swim and limited mobility in Bangladesh, five times as many deaths were reported for women than for men during the cyclone/flood event in 1991 [13]. Indian-constructed dams on major regional rivers result in populations blaming certain flood rains on "Indian water" [132]. Such perceptions and dynamics can easily trigger cross border tension [148].

- **Heightened mobility**: Up to 35 million individuals risk losing their coastal land to rising sea levels [13]. Due to all of the above, a growing number of Bangladeshi are seeking more resilient livelihoods in neighbouring India, thereby contributing to rising cross-border tension [142, 143]. According to some researchers, migration is an option for those with resources [140], others have determined that it is an option of last resort, when no other possibility exists [137]. Urbanization and more generally, refugee flows, are often cited as a consequence of environmental stress in Bangladesh [148]. Common assumptions of poverty-induced immigration into high-risk areas and disaster-induced migration to urban areas have been refuted by others [149].

- **Impaired health**: The link between floods and psychological stress in Bangladesh underlines the importance of cultural perspectives of the environment [137]. Prevalence of Vibrio cholerae bacteria in Bangladesh is positively correlated with Sea Surface Temperatures (Colwell 1996, [44].

Forcings and feedbacks in Bangladesh

Inhabitants perceive increased precipitation to be the main cause of flooding, although the loss of between 40 – 60% of the nation's forest over the past 30 years [132], and temperature increases in that same period are also likely implicatd. The average temperature increase has been estimated at 0.6°C and precipitation at 5mm/year (Karmakar 2002). Those living on the flood embankments have both more to gain and more to lose in regards to climate-induced flooding [136]. There is plentiful evidence that aligns to maintain Bangladesh as the climate change laboratory of the 21st Century. Humanitarian and development workers need to join forces to lessen the impact and save lives.

CLIMATE CONCLUSIONS

Key points for humanitarian agencies in the age of climate change can be summarized as follows:

- Climate risk is a moving target. It is likely that the evidence compiled from the past 30-100 years is an insufficient baseline for future risk. All current geographies of climate risk are based on the best available historical evidence. This evidence, however, is insufficient to prepare humanitarian agencies for what is to come.

- Every variation in extreme events, environmental processes and disasters requiring humanitarian support this century cannot be attributed to climate change. Environments and climates have been evolving and/or degrading since the dawn of time and the hand of man.

  - By the time we can statistically attribute events to climate change they will have been socially significant for many years.

  - Attribution or lack thereof is not an excuse for inaction, as climate variability may trigger more damage than climate change. Humanitarian actors should leave attribution for the climate scientists and focus on preparing for an uncertain future.

- There is yet a large rift between climate scientists and the humanitarian community. While the science generators must align their products more carefully to humanitarian needs, humanitarian agencies must think beyond the standard short term horizons to understand the long term consequences of climate change.

- Few global mapping efforts present humanitarian targets based on projected climate change. Many nonetheless remain tools for the humanitarian sector.

  - Because current unknowns and uncertainty make it impossible today to identify idealized geographic targets on a global scale, humanitarian agencies are obliged to use acute field knowledge and regularly compare it to, and actively and constructively criticize, the evolving evidence base. It is important to carefully steer clear of premature causality, such as linking mortality and climate change.

- Given the level of uncertainty that plagues the field, it is crucial that the humanitarian machinery be greased and perfected. Systems such as recruitment, acquisition, communication, needs assessment, proposal preparation and evaluation need to be perfected now and systematically fine-tuned so that agencies are positioned to respond rapidly to any given surprise situation.

- In the absence of solid evidence, priority should be given to an integrated all-hazard humanitarian approach. The complex forcings and feedback loops between coupled consequences are such that a focus on one will be to the detriment of the coupled system as a whole. There is grave danger that tipping elements will spiral out of control starting with the most isolated of consequences. A few examples merit attention:

  - Humanitarian agencies must redefine the term disaster to include slow processes as well as rapid events. Degradation is the single most complex and interlinked of all physical climate consequences, but it rarely if ever figures in humanitarian discourse. In all of its many forms including erosion, ice melt, pollution, a humanitarian focus on degraded environments will be a huge contribution to risk reduction.

  - On the human side of climate consequences, impaired health, heightened mobility and access to resources are the most complex and inter-linked issues. Although access to resources does figure on the priority list, humanitarian agencies and science generators alike do not prioritize health as a key consequence of evolving climates. The debate should be reopened on priority intervention foci in a time of limited resources.

  - Sea level rise may be the simplest of all studied climate consequences, but it is only one step away from the most complex, degradation. It will be increasingly dangerous in a warming climate to ignore the forcings and feedbacks between numerous consequences.

- If humanitarian agencies are unable to master the multitude of consequences at the same time within an integrated approach, they must be held accountable for finding appropriate partners to complement their efforts at the level of their interventions.

  - Development agencies are ideal partners since climate spans both disaster and development and they have both the staying power and the local knowledge likely to ensure more sustainable impact.

REFERENCES

1. Klotzbach, P.J., *Trends in global tropical cyclone* activity *over the past twenty years (1986–2005).* Geophys. Res. Lett, 33(10): p. L10805,(2006).
2. Landsea, C.W., et al., *Can We Detect Trends in Extreme Tropical Cyclones?* Science, 313(5786): p. 452-454,(2006).
3. Anthes, R.A., et al., *Hurricanes and Global Warming—Potential Linkages and Consequences.* Bulletin of the American Meteorological Society, 87(5): p. 623-628,(2006).
4. Elsner, J.B., *Evidence in support of the climate change-Atlantic hurricane hypothesis.* Geophysical Research Letters, 33(16),(2006).
5. Pielke Jr, R., et al., *Reply to "hurricanes and Global Warming—Potential Linkages and Consequences".* Bulletin of the American Meteorological Society, 87(5): p. 628-631,(2006).
6. Pielke, R.A., et al., *Hurricanes and Global Warming.* Bulletin of the American Meterological Society, November 2005: p. 1571-1575,(2005).
7. Save the Children, *In the face of Disaster: Children and Climate Change*. 2008.
8. Practical Action, C.A., Oxfam and Tearfund., *Two degrees, one change.*
9. Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: Synthesis Report.* Fourth Assessment Report,,(2007).
10. Solomon, S., et al., *Irreversible climate change due to carbon dioxide emissions.* PNAS, 106(6): p. 1704–1709 (2009).
11. Christian Aid, *Human Tide: The Real Migration Crisis*. 2007.
12. Haile, M., *Weather patterns, food security and humanitarian response in sub-Saharan Africa.* Phil. Trans. R. Soc. B 360: p. 2169–2182,(2005).
13. UNDP, *Human Development Report: Fighting Climate Change*. 2008.
14. Helmer, M. and D. Hilhorst, *Natural disasters and climate change.* Disasters, 2006(30): p. 1,(2006).
15. van Aalst, M.K., *The impacts of climate change on the risk of natural disasters*. Disasters, 30(1): p. 5−18,(2006).
16. Crichton, D., *Climate and Catastrophe Risk*, M.I. Rendezvous, Editor. 2009
17. Gregory, K.J., et al., *Past hydrological events related to understanding global change: An ICSU research project.* Catena, 66(13): p. 2 – 13,(2006).
18. Cabanes, C., A. Cazenave, and C.L. Provost, *Sea Level Rise During Past 40 Years Determined from Satellite and in Situ Observations*. Science, 294: p. 840,(2001).
19. Dupont, A. and G. Pearman, *heating up the planet: Climate Change and Security*, in *Lowy Institute Paper 12*. 2006.
20. Lehner, B., et al., *Estimating the Impact of Global Change on Flood and Drought Risks in Europe: A Continental, Integrated Analysis.* Climatic Change, 75(3): p. 273-299,(2006).
21. Casenave, A. and R.S. Nerem, *Present-day Sea Level Change: Observation and Causes.* Reviews of Geophysics, 42(RG3001): p. 1-20,(2004).
22. Kleinen, T. and G. Petschel-Held, *Integrated assessment of changes in flooding probabilities due to climate change.* Climatic Change, 81(3): p. 283-312,(2007).
23. Holgate, S.J. and P.L. Woodworth, *Evidence for enhanced coastal sea level rise during the 1990s.* GEOPHYSICAL RESEARCH LETTERS, 31(L07305),(2004).
24. Haag, A.L. (2007) *Is this what the world's coming to?* Nature Reports Climate Change, 447, no. 7144, pp. 75-79.
25. Kassas, M., *Review Desertification: a general review.* Journal of Arid Environments, 30: p. 115-128,(1995).
26. Humanitarian Futures Group (HFG), *Planning for future climate change crises, a Briefing Note for Seminar at Kings College*. 2009.
27. OCHA, C., Maplecroft, *Humanitarian Implications of Climate Change: Mapping Emerging Trends and Risk Hotspots for Humanitarian Action*. 2008.
28. Reuveny, R., *Climate change-induced migration and violent conflict.* Political Geography, 26(6): p. 656-673,(2007).
29. Lagadec, P., *A New Cosmology of Risks and Crises: Time for a Radical Shift in Paradigm and Practice*. 2008.

30. Lenton, T.M., et al., *Tipping elements in the Earth's climate system.* PNAS, 105(6): p. 1786–1793,(2008).
31. Schipper, L. and M. Pelling, *Disaster risk, climate change and international development: scope for, and challenges to, integration.* Disasters, 30(1): p. 19−38,(2006).
32. Christoplos, I. *Changing the way we develop: dealing with disasters and climate change.* Oslo.
33. Randall Dole, N., et al., *Chapter 4: Climate Variability & Change in: Climate Change Science Programme (CCSP), Strategic Plan*, USCC, Editor. 2003.
34. Sugar, D.R.D., *From climate data to climate knowledge*, in *thehill.com*. 2008.
35. Few, R., et al., *Linking Climate Change Adaptation and Disaster Risk Management for Sustainable Poverty Reduction, Synthesis Report*, Vulnerability and Adaptation Resource Group (VARG), Editor. 2006, European Commission.
36. Vogel, C. and K. O Brien, *Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies.* Climate Research, 33(1): p. 111,(2006).
37. Whitty, J. (2006) *The Thirteenth Tipping Point: 12 global disasters and 1 powerful antidote.* Mother Jones, November/December 2006.
38. Humanitarian Fututres Programme (HFP). *PLANNING FOR FUTURE CLIMATE CHANGE CRISES: SUMMARY OF HUMANITARIAN FUTURES PROGRAMME WORKSHOP*. 2009. Kings College, London.
39. Rowling, M., *NGOs: running on empty?* Tiempo, www.tiempocyberclimate.org(Issue 69): p. 7,(2008).
40. DFID and NGOs, *Terms of Reference for the Center for Climate & Development, a DRAFT and a PPT Presentation*. 2009.
41. Heathcote, R.L., *Climate Impact Assessment: 15. Extreme Event Analysis*, in *http://www.icsu-scope.org/downloadpubs/scope27/chapter15.html*, SCOPE27, Editor. 200x.
42. LaFleur, V., N. Purvis, and A. Jones, *Double Jeopardy: What the Climate Crisis means for the Poor*, B.B. Roundtable, Editor. 2008.
43. UNDP, *A Climate Risk Management Approach to Disaster Reduction and Adaptation to Climate Change,*, UNDP Expert Group Meeting: Integrating Disaster Reduction with Adaptation to Climate Change, Editor. 2002: Havana, June 17-19.
44. Global Humanitarian Forum, *Human Impact Report, Climate Change: The Anatomy of a Crisis*. 2009.
45. SEI/Oxford, *Climate adaptation in southern Africa: Addressing the needs of vulnerable communities*, w. http://weadapt.org.uk/wikiadapt/index.php?title=Climate_adaptation_in_southafrica, Editor. 2008.
46. Bals, C., S. Harmeling, and M. Windfuhr, *Climate Change, Food Security and the Right to Adequate Food*, Germanwatch, Editor. 2008.
47. Dilley, M., et al., *Natural Disaster Hotspots: A Global Risk Analysis*, in *Disaster Risk Management Series*, H.M. Unit, Editor. 2005, World Bank: Washington D.C.
48. Below, R., E. Grover-Kopec, and M. Dilley, *Documenting Drought-Related Disasters: A Global Reassessment.* Environment and Development,(2007).
49. Endreny, T., et al., *Policy to coordinate watershed hydrological, social, and ecological needs: the HELP Initiative.* Water: Science, Policy, and Management: p. 395–411,(2003).
50. Gregory, P.J., J.S.I. Ingram, and M. Brklacich, *Climate change and food security.* Philosophical Transactions: Biological Sciences, 360(1463): p. 2139-2148,(2005).
51. ICSU-UNESCO-UNU Ad hoc Group, *Ecosystem Change and Human Well-being*, in *Research and Monitoring Priorities: Based on the Findings of the Millennium Ecosystem Assessment*. 2009.
52. Brooks, N. and N. Grist, *Development Futures in the light of climate change: creating new insights into the past, the present and global futures*, in *Policy Forum: International Development in the face of Climate Change: Beyond Mainstreaming?*, T.C.f.C.C. Research, Editor.
53. Auld, H., *Disaster Risk Reduction Under Changing Climate Conditions: Roles for the National Meteorological and Hydrological Services*. 200x.
54. McNamara, K.E., *PRAGMATIC DISCOURSES and ALTERNATIVE RESISTANCE: RESPONSES to CLIMATE CHANGE in the PACIFIC.* Graduate Journal of Asia-Pacific Studies, 6(2): p. 33-54,(2008).
55. Smil, V., *Energy at the crossroads: global perspectives and uncertainties*. 2003: MIT press.

56. IRIN (2009) *Humanitarian costs of climate change unpredictable*. IRIN: humanitarian news and analysis, 20 February 2009.
57. World Meteorological Organization (WMO), *WMO Statement on the Status of the World's Climate 2008*. 2009.
58. Thow, D.A. and M. de Blois, *Climate change and human vulnerability: mapping emerging trends and risk hotspots for humanitarian actors, Vol 2: Technical Annex*, O. CARE, Maplecroft, Editor. 2008, CARE, OCHA, Maplecroft.
59. Grainger, A., et al., *DESERTIFICATION AND CLIMATE CHANGE: THE CASE FOR GREATER CONVERGENCE.* Mitigation and Adaptation Strategies for Global Change, 5: p. 361–377,(2000).
60. Antilla, L., *Self-censorship and science: a geographical review of media coverage of climate tipping points.* Public Understand. Sci.: p. 1-17,(2008).
61. NOAA, M.G.M., *Best Practice Approaches for Characterizing, Communicating and Incorporating Scientific Uncertainty in Climate Decision Making* in *Synthesis and Assessment Product*, U.S.C.C.S.P.C. 5.2, Editor.
62. Leary, N.J., *Assessment of impacts and adaptation to climate change: final report of the AIACC project. How will the poor be affected by climate change?* , R.a.T. Global Change System for Analysis, Editor. 2007. p. 250 p.
63. O'Brien, K., et al., *Disaster Risk Reduction, Climate Change Adaptation and Security*, in *GECHS Report 2009: 3*, A.C.R.f.t.N.M.o.F. Affairs, Editor. 2008, University of Oslo.
64. Ackerman, F., *Hot, It's Not: Reflections on Cool It! by Bjorn Lomborg.*(2008).
65. Intergovernmental Panel on Climate Change (IPCC). *Glossary: Working Group 1: The Physical Science Basis, Fourth Assessment Report.* http://www.ipcc.ch/pdf/glossary/ar4-wg1.pdf 2007 [cited.
66. United Nations, *UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC),*, U. NATIONS, Editor. 1992.
67. Downing, T.E., A.A. Olsthoorn, and R.S.J. Tol, *Climate, change and risk*. 1999: Routledge.
68. Hulme, M., et al., *Relative impacts of human-induced climate change and natural climate variability.* Nature, 397(6721): p. 688-691,(1999).
69. Scheraga, J.D. and A.E. Grambsch, *Risks, opportunities and adaptation to climate change.* Climate Research, 11: p. 85-95,(1998).
70. UNDP, *Chapter 2: Climate Shocks: risk and vulnerability in an unequal world*, in *HUMAN DEVELOPMENT REPORT 2007/2008*, UNDP, Editor. 2008.
71. Burton, I. and M.K. van Aalst, *Come hell or high water: integrating climate change vulnerability and adaptation into bank work*. 1999: World Bank, Environment Dept.
72. Smithers, J. and B. Smit, *Human adaptation to climatic variability and change.* Global Environmental Change, 7(2): p. 129-146,(1997).
73. Ribot, J.C., A. Najam, and G. Watson, *Climate variation, vulnerability and sustainable development in the semi-arid tropics.* Climate Variability, Climate Change and Social Vulnerability in the Semi-Arid Tropics, Cambridge University Press, Cambridge, UK,(1996).
74. Parmesan, C. and G. Yohe, *A globally coherent fingerprint of climate change impacts across natural systems.* Nature, 421: p. 37-43,(2003).
75. Tänzler, D., B. Schinke, and C. Bals, *Is there "Climate Security" for India? "Tipping Points" as Drivers of Future Environmental Conflicts*. 2006, Germanwatch, Adelphi Research.
76. Dlugolecki, A., *The Cost of Extreme Events in 2030: A Report for United Nations Framework Convention on Climate Change.* 2007.
77. Metzger, M., R. Leemans, and D. Schroter, *A multidisciplinary multi-scale framework for assessing vulnerability to global change*, in *Millennium Ecosystem Assessment Conference: Bridging Scales and Epistemologies* 2004, Session 6.2: Multi-Scale Assessments: Advances, Insights, and Remaining Challenges: Alexandria, Egypt.
78. Smitha, J.B., et al., *Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern".* PNAS, 106(11): p. 4133–4137,(2009).
79. Katz, R. and B. Brown, *Extreme events in a changing climate: variability is more important than averages.* Climate Change, 21: p. 289-302,(1992).
80. Nicholls, N. and L. Alexander, *Has the climate become more variable or extreme? Progress 1992-2006.* Progress in Physical Geography, 31(1): p. 77 (2007).

81. Christidis, N., et al., *Detection of changes in temperature extremes during the second half of the 20th century.* Geophysial Research Letters, 32(L20716),(2005).
82. Kerr, R.A., *Global Warming is Changing the World.* Science, 316: p. 188-190,(2007).
83. Sarewitz, D. and R. Pielke, *Extreme Events: A Research and Policy Framework for Disasters in Context.* International Geology Review).
84. Helbing, D., H. Ammoser, and C. Kauhnert, *Disasters as Extreme Events and the Importance of Networks for Disaster Response Management*, in *Disaster Management and Networks.* 200x.
85. International Strategy for Disaster Reduction (ISDR) Secretariat, *Global Risk Reduction,.* 2007.
86. Swiss Info (2009) *Water tensions remain in the pipeline.* www.swissinfo.ch/eng/
87. Bartlett, S., *Climate change and urban children: Impacts and implications for adaptation in low- and middle-income countries*, in *Human Settlements Discussion Paper Series Theme: Climate Change and Cities - 2*, International Institute for Environment and Development (IIED), Editor. 2008, IIED: London.
88. United Nations Environment Programme (UNEP), *From Conflict to Peacebuilding: The Role of Natural Resources and the Environment* 2009.
89. Morinière, L.C.E., R. Taylor, and M. Hamza (2009) *Global Footprint Mapping and Micro-SImulation: A tool for Risk Management* Earthzine, 20 April 2009.
90. Reuveny, R., *Ecomigration and Violent Conflict: Case Studies and Public Policy Implications.* Human Ecology: p. 1-13,(2008).
91. Reuveny, R., *Environmental Change, Migration and Conflict: Theory, Analysis and Empirical Explorations*, in *Human Security and Climate Change.* 2005, GECHS, UNEP, IHDP, CICERO: Oslo, Norway.
92. Nordas, R. and N.P. Gleditsch, *Climate Change and Conflict.* Political Geography, 26: p. 627-638,(2007).
93. Gleditsch, N.P., R. Nordas, and I. Salehyan, *Climate Change and Conflict: The Migration Link*, in *International Peace Academy (IPA) Working Paper Series.* 2007.
94. Nordas, R. and N.P. Gleditsch, *Climate Conflict: Common Sense or Nonsense?*, in *Human Security and Climate Change, An International Workshop.* 2005: Holmen Fjord Hotel, Asker, near Oslo, 21–23 June 2005.
95. Reale, D., *Away from Home: Protecting and supporting children on the move.* 2008, Save the Children UK,.
96. Food and Agriculture Organization (FAO) of the United Nations, *Climate Change and Food Security: A Framework Document.*(2008).
97. Dun, O., F. Gemenne, and R. Stojanov, *Environmentally Displaced Persons: Working Definitions for the EACH-FOR Project.* 2007.
98. Stern, *Stern Review: the Economics of Climate Change.*(2007).
99. Vedantam, S. (2009) *Climate fears are driving 'ecomigration' across globe.* Washington Post, 23 February 2009.
100. United Nations University (UNU). *Environmental Refugees: the Forgotten Migrants.* in *Environmental Refugees: the Forgotten Migrants.* 2007. UN Headquarters.
101. ISDR, *Briefing Note: Climate Change and Disaster Risk Reduction*, I.S.o.R. Reduction, Editor. 2008: Geneva.
102. Chretien, J.P., et al., *Drought-Associated Chikungunya Emergence along Coastal East Africa.* Am. J. Trop. Med. Hyg., 76(3): p. 405-507,(2007).
103. McMichael, A.J., *Global Environmental Change and Human Population Health: A Conceptual and Scientific Challenge for Epidemiology.* International Journal of Epidemiology, 22(1),(1993).
104. Ebi, K.L., M. Helmer, and J. Vainio (2008) *The Health Impacts of Climate Change: Getting Started on a New Theme.* Prehospital and Disaster Medicine, Jul-Aug 2008; 23(4): 60-64.
105. Patz, J.A., et al., *Climate Change and Global Health: Quantifying a Growing Ethical Crisis.* Eco-Health,(2007).
106. Webster, M., et al., *The Humanitarian Costs Of Climate Change*, T.U. Feinstein International Center, Editor. 2009.
107. Miller, F., R.K. Larsen, and F. Thomalla, *Hybrids, Bifocals, Tipping Points and Speed Dating: Report from the Resilience-vulnerability Colloquium - From Theory to Practice, From Disconnect to Synergy in Support of Sustainable Development*, S.E. Institute, Editor. 2008.

108. Smitha, J.B., et al., *Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern"*. PNAS, 106(11): p. 4133–4137,(2009).
109. United Nations, *World Statistics Pocketbook: Small Island Developing States* V.N. 24/SIDS, Editor. 2003, Department of Economic Series and Social Affairs Special Issue, Statistics Division Preliminary.
110. Pelling, M. and J.I. Uitto, *Small island developing states: natural disaster vulnerability and global change*. Environmental Hazards, 3: p. 49–62,(2001).
111. UNFCCC, *Vulnerability and Adaptation to Climate Change in Small Island Developing States (SIDS),*, in *Paper commissioned by the secretariat of the United Nations Framework Convention on Climate Change*, B.p.f.t.e.m.o.a.f. SIDS, Editor. 2007.
112. Grover-Kopec, E. and R. Below, *NEW METHODOLOGY FOR TRACKING DROUGHT DISASTER EVENTS*. 2007.
113. UK Met Office (2008) *Effects on the developing world*. (www.metoffice.gov.uk/climatechange/guide/effects/security/html)
114. Finan, T., *Drought and Demagoguery: A Political Ecology of Climate Variability in Northeast Brazil*, in *Public Philosophy, Environment, and Social Justice*. 1999, Bureau of Applied Research in Anthropology: Carnegie.
115. Meze-Hausken, E., *Migration caused by climate change: how vulnerable are people in dryland areas? Case Study: Ethiopia*. Mitigation and Adaptation Strategies for Global Change, 5(4): p. 379-406,(2000).
116. McSweeney, C., M. New, and G. Lizcano, *UNDP Climate Change Country Profiles: Ethiopia*, in *Profiles for 52 countries*, University of Oxford and Tyndall Centre for Climate Change, Editor. 2009: Oxford.
117. Seleshi, Y. and P. Camberlin, *Recent changes in dry spell and extreme rainfall events in Ethiopia*.(2005).
118. Federal Democratic Republic of Ethiopia, *Initial National Communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC)*, in *Climate Change Enabling Activities Project of Ethiopia,*, National Meteorological Services Agency, Editor. 2007, Global Environment Facility.
119. Meze-Hausken, E., *Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia*. Climate Research, 27: p. 19-31,(2004).
120. Hassan, R., *Assessing the impact of climate change on the water resources of the Lake Tana sub-basin using the Watbal model*, in *CEEPA Discussion Paper*, CEEPA, Editor. 2006, University of Pretoria: Pretoria.
121. Zeray, L., J. Roehrig, and D.A. Chekol, *Climate Change Impact on Lake Ziway Watershed Water Availability, Ethiopia*, in *Conference on International Agricultural Research for Development*. 2006, University of Bonn.
122. Internal Displacement Monitoring Centre, *Ethiopia: Addressing the rights and needs of people displaced by conflict*, Norwegian Refugee Council, Editor. 2007.
123. Unruh, J.D., *The Dilemma of African Agrobiodiversity: Ethiopia and the Role of Food Insecurity in Conservation*. 2000.
124. Kloos, H. and A. Adugna, *The Ethiopian Population: Growth and Distribution*. The Geographical Journal, 155(1): p. 33-51,(1989).
125. Cohen, C. and E. Werker, *Working Paper #25: Towards an Understanding of the Root Causes of Forced Migration: The Political Economy of "Natural" Disasters*. 2004.
126. ISDR, *Global Assessment Report (GAR) on Disaster Risk Reduction: Risk and poverty in a changing climate*, U. Nations, Editor. 2009.
127. Endeshaw Wolde, T., *Global Climate Change and Its economic impact on SubSaharan Africa: Simulation of a Computable General Equilibrium Model for Ethiopia*, in *Department Of Economics, Faculty of Social Science*. 2008, U. of Oslo.
128. Adams, L. and E. Kebede, *Breaking the poverty cycle: A case study of cash interventions in Ethiopia*, in *HPG Background Paper*, H.P. Group, Editor. 2005, ODI.
129. Shultz, J.M., *Epidemiology of Tropical Cyclones: The Dynamics of Disaster, Disease and Development*. Epidemiologic Reviews, 27,(2005).
130. Hayden, B.P., *Chapter 1: Flood Climates*, in *Flood Geomorphology*, P.C. Patton, Editor. 1988, John Wiley & Sons. p. 13-26.

131. Pelling, M., *The vulnerability of cities: natural disasters and social resilience*, ed. J. James. 2003: Earthscan.
132. Ali, A.M.S., *September 2004 Flood Event in Southwestern Bangladesh: A Study of its Nature, Causes, and Human Perception and Adjustments to a New Hazard.* Natural Hazards, 40: p. 89-111,(2007).
133. United Nations Development Programme Evaluation Office, *Country Evaluation: Assessment of Development Results, Bangladesh.* 2005.
134. Global Network of Civil Society Organizations for Disaster Reduction, *Clouds, but little rain...* in *A local perspective of progress towards implementation of the HFA*, Views from the Frontline, Editor. 2009.
135. Tanner, T., et al., *ORCHID: Piloting Climate Risk Screening in DFID Bangladesh. Summary.* 2007.
136. Chowdhury, M.R., *The Impact of 'Greater Dhaka Flood Protection Project' (GDFPP) on Local Living Environment – The Attitude of the Floodplain Residents.* Natural Hazards, 29: p. 309–324,(2003).
137. Hutton, D. and C.E. Haque, *Patterns of Coping and Adaptation Among Erosion-Induced Displacees in Bangladesh:Implications for Hazard Analysis and Mitigation.* Natural Hazards,(2003).
138. Haque, C.E. and M.Q. Zaman, *Coping with Riverbank Erosion Hazard and Displacement in Bangladesh: Survival Strategies and Adjustments.* Disasters, 13(4),(1989).
139. Mamun, M.Z., *Awareness, Preparedness and Adjustment Measures of River-bank Erosion-prone People: A Case Study.* Disasters, 20(1),(1996).
140. Kuhn, R.S., *The Determinants of Family and Individual Migration: A Case-Study of Rural Bangladesh*, I.R. Center, Editor. 2005.
141. Fisher, J.H., *Rural Development and Migration in Bangladesh.* 1993.
142. Alam, S., *Environmentally Induced Migration from Bangladesh to India.*(2003).
143. Datta, P., *Push-Pull Factors of Undocumented Migration from Bangladesh to West Bengal: A Perception Study.* The Qualitative Report, 9(2): p. 335-358,(2004).
144. Germanwatch, *Sea-Level Rise in Bangladesh and the Netherlands: One Phenomenon, Many Consequences.* 200x.
145. UNDP Evaluation Office, *Country Evaluation: Assessment of Development Results, Bangladesh*, UNDP, Editor. 2005.
146. Brouwer, R., et al., *Socioeconomic Vulnerability and Adaptation to Environmental Risk: A Case Study of Climate Change and Flooding in Bangladesh.* Risk Analysis, 27(2),(2007).
147. Howell, P., *Indigenous Early Warning Indicators of Cyclones: Potential Application in Coastal Bangladesh.* 2003.
148. Lee, S.-W., *Not a One-Time Event: Environmental Change, Ethnic Rivalry, and Violent Conflict in the Third World.* Journal of Environment Development, 6(365),(1997).
149. Lein, H., *Hazards and 'forced' migration in Bangladesh.* Norsk Geografisk Tidsskrift - Norwegian Journal of Geography, 54(3): p. 122 — 127,(2000).
150. Kerr, R.A., *Climate Tipping Points Come in from the Cold.* Science, 319: p. 153,(2008).
151. Kriegler, E., et al., *Imprecise probability assessment of tipping points in the climate system.* PNAS, 106(13): p. 5041-5046,(2009).
152. John Cairns, J., *Ecological Tipping Points : A Major Challenge for Experimental Sciences.* Asian J. Exp. Sci., 18(1&1): p. 1-16,(2004).
153. IGSD, *Tipping Points for Abrupt Climate Change: The Shadow that Haunts Climate Policy*, in *Climate Briefing Note.* 2008.
154. Hansen, J., *How can we avert dangerous climate change?* ,(200x).
155. Marten, G.G., *Environmental Tipping Points: A New Paradigm for Restoring Ecological Security.* Journal of Policy Studies (Japan), 20: p. 75-87,(2005).
156. Revkin, A. (2009) *Among Climate Scientists, a Dispute Over 'Tipping Points'.* New York Times, 28 March 2009.
157. Christian Aid, *The Climate of Poverty: Facts, Fears and Hope: a Christian Aid Report.* 2006: Christian Aid.
158. Wall, D.H., *Global change tipping points: above- and below-ground biotic interactions in a low diversity ecosystem.* Phil. Trans. R. Soc. B, 362: p. 2291–2306,(2007).
159. Schellnhuber, H., et al., *Introduction*, in *Avoiding Dangerous Climate Change.* 2006, Cambridge University Press: Cambridge: .

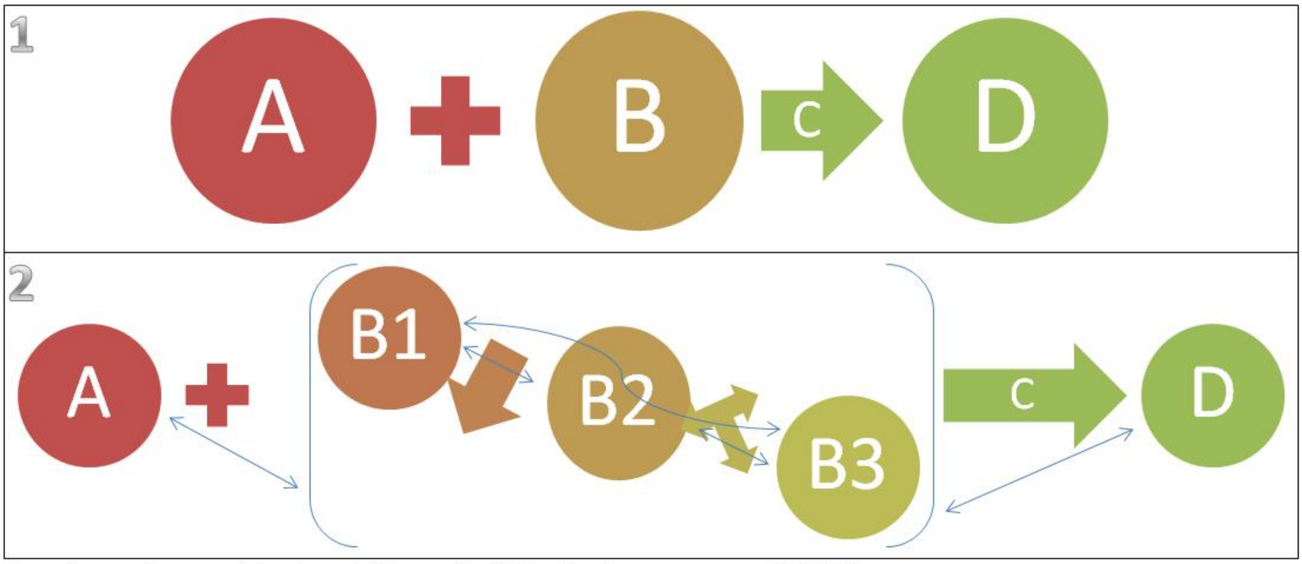
160. Schneider, S.H. and J. Lane, *An Overview of 'Dangerous' Climate Change.* Avoiding Dangerous Climate Change. Cambridge University Press, Cambridge, UK,(2006).
161. Blaikie, P.M., *At risk: natural hazards, people's vulnerability, and disasters.* 1994: Routledge.
162. Black, H., *Unnatural disaster: human factors in the Mississippi floods.* Environmental Health Perspectives, 116(9): p. A390,(2008).
163. Abramovitz, J.N., *Averting unnatural disasters.* State of the World: p. 123-142,(2001).
164. Cannon, T. *7. A hazard need not a disaster make: vulnerability and the causes of'natural'disasters.* 1993: Thomas Telford.
165. International Federation of the Red Cross (IFRC), *Defusing disaster, Reducing the risk: calamity is unnatural.* 2007.
166. Humanitarian Practice Network (HPN), *Disaster Risk Reduction*, in *Humanitarian Exchange*, ODI, Editor. 2007.
167. USAID, *ADAPTING TO CLIMATE VARIABILITY AND CHANGE A GUIDANCE MANUAL FOR DEVELOPMENT PLANNING*. 2007.
168. Adger, W.N., *Vulnerability.* Global Environmental Change-Human and Policy Dimensions, 16(3): p. 268-281,(2006).

ANNEX A: TECHNICAL NOTE ON CNH SYSTEMS, TIPPING POINTS AND ABRUPT CHANGES

This annex is a guide to clarify terms and concepts employed in climate science, disaster risk reduction and ecology literature on the topic of forcings and feedbacks, synchronicity and thresholds. The discussion is set in a CNH system in order to explore relationships between terms at the cusp of both settings. The goal of the exercise is to map the link between CNH systems and extreme events and processes to a potential threshold crossing, or regime shift, using all of the key terms found in contemporary literature.

Figure 4:

CNH Thresholds and Paradigm Shifts to New Regimes



Based on a given social vulnerability profile (A) in the human subsystem:

Scenario 1, Linear/direct: hazard (B) triggers a tipping point (C) shifting Coupled Natural Human (CNH) System into a new regime (D)

Scenario 2,Non-Linear/complex: multiple and possibly synchronous hazards (B1, 2, 3...) with feedbacks between Bs and B> A (arrows) . Tipping point (C) is reached shifting CNH System into a new regime (D), which may spin back and trigger additional hazards and greater vulnerability.

LEGEND

A: **Underlying Vulnerability** (Social System)

B: (Natural) **Hazard event and/or process**

C: **Threshold or Tipping Point**

B:C creates *rapid, abrupt or severe change, aka Climate Singularity or Climate Surprise, thereby triggering:*

D : **New State or Regime**

Tipping element: coupled natural human (CNH) subsystem

The backdrop for Figure 4 is the underlying vulnerability (A, in red) of the social system, a major factor of risk. B, in green, represents a natural or physical hazard event or process (either could be considered 'extreme', given the definition employed). The hazard B may be singular, linear and direct (as in Scenario 1) or multiple hazards may occur in combination, synchronously or not, with feedbacks or forcings (arrows) between them, or not (see Scenario 2, non-linear or complex). In either scenario, if and when a threshold or tipping point (C) is reached it may trigger abrupt, rapid or severe (climate) change (also referred to as a climate singularity or surprise) thereby catalyzing a regime shift, or new state (D). (Although most of these terms have been coined in the physical or ecological sciences they certainly have parallel names in the social sciences.)

Abrupt change results from some combination of the hazard (B) and the tipping point (C). The paradigm shift precipitated by the occurrence of a tipping point (C) may result in a qualitatively different set of processes and social vulnerabilities; for simplicity, we aggregate and represent these in a new regime (D). There remains the question about how a tipping point (C) may be reached; this is explored in greater detail below.

Current literature identifies between 8 and 13 potential abrupt changes or climate surprises, discussed briefly below. A newer term, tipping element [30], refers to a subsystem that can be switched into a qualitatively different state. These terms are often used interchangeably in the literature.

In the Third Assessment Report (TAR), the IPCC presented five reasons for concern (RFC) displayed graphically with a diagram known in the climate circles as the "burning embers":

1. Risk to unique and threatened species
2. **Risk of extreme weather events**
3. **Distribution of impacts, disparities**
4. Aggregate (monetary) damages
5. **Risk of Large Scale discontinuities.**

The emphasis in bold on three of these indicates the reasons for concern to the humanitarian community: extreme events, distribution/disparities and discontinuities, which are IPCC's way of avoiding use of the controversial term, "tipping point" (see below). The embers show how the RFC may change as temperatures rise. As non-linearity, complexity, hazards and extreme events have already been explored above, the remainder of this section will summarize forcings and feedbacks in the coupled natural human system and finish with a discussion of what the literature says about the tipping points, abrupt (rapid or severe) change, and tipping elements.

TIPPING POINTS OR THRESHOLDS

> "Society may be lulled into a false sense of security by smooth projections of global change. " [30, 60]
>
> "Tipping points, once considered too alarmist for proper scientific circles, have entered the climate change mainstream." [150]
>
> "Large uncertainties among experts about the prospects of triggering major changes in the climate system does not necessarily imply that such events are considered to be remote." [151]
>
> "It seems highly probable that at least one major tipping point will be reached in the 21st century, and exceeding one major tipping point will produce others." [152, 153]
>
> "Abrupt climate change could push the planet's fragile and already stretched ecosystem past an environmental tipping point from which there will be no winners. AR4 from exaggerating the impact of climate change it is possible that scientists may have underestimated the threat. " [19]

> "The nature of tipping points is that they happen dizzyingly fast." [37]

> "If we allow the planet to pass tipping points, to set in motion irreversible changes to the detriment of nature and humanity, it will be hard to explain our role to our children and grandchildren. " [154]

The number of scientific and other documents specifically exploring the notion of '*tipping points'* is growing exponentially. First used in the 1950s in social sciences to describe racial interactions in neighbourhoods and later, the point in time when a new idea takes flight and spread through society, it had clear links to the current 'feedback loop' or 'positive forcing' that engender change [155]. The term confers a sense of immediacy and menace that makes many scientists uncomfortable. On one side, there is little hard evidence and on the other "*admitting having reached a tipping point may be an excuse for inaction*" [156].

Tipping points for natural systems and those for social systems are likely to be very different: a very small increase in temperature may be a huge tipping point for social outcomes. Research to date on this relationship is very weak [26]. **Problem identification, solution finding, and decision making processes are likely to be lethargic when environmental 'tipping points' are reached** [42].

Proposed definitions for the term "tipping point" are numerous and are inventoried below:

- "A point of no return" [157];
- "Disturbances that will take a low-diversity region to a different state" [158];
- "Thresholds at which change suddenly becomes unstoppable" [156];
- "A situation in which the forces that create stability are overcome by those that create instability, resulting in disequilibrium" [152];
- "A part of the human-environment system that can lever far-reaching change" [155];
- "The threshold at which could abruptly and, perhaps almost irreversibly, switch the system to a different regime" [60, 159].
- "When radical change goes from a possibility to a certainty" [60];
- "The critical point at which a forcing will qualitatively alter the state of a system" [30].

Tipping points are very difficult to name and predict because they depend on fine-tuned measurements and phenomena "*too small or subtle to be captured in climate models*" [60], such as wind patterns on sea ice or the flow of water through ice sheet cracks. Schellenhuber is recognized for his list of 12 potential tipping points. Given the definitions used in this report, however, his Tipping Points are in fact Tipping Elements, or Abrupt Changes, discussed below.

ABRUPT CLIMATE CHANGE

(a.k.a. tipping elements, rapid or severe changes, singularities or surprises)

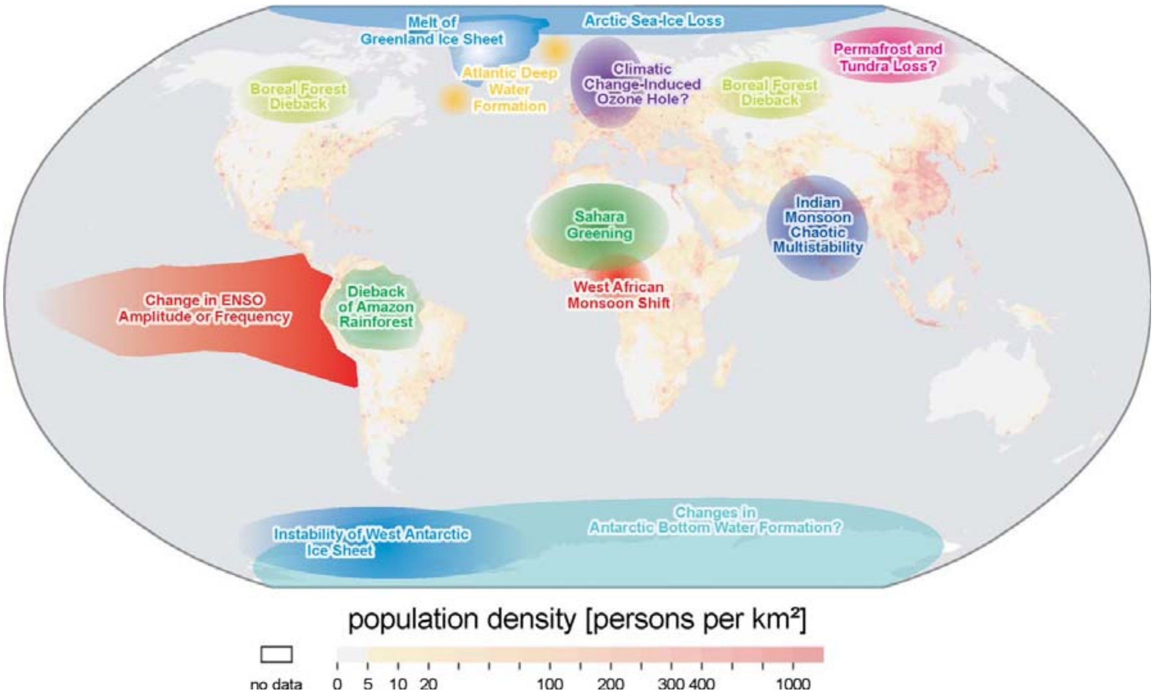
> "Anthropogenic warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change." (WGII 12.6, 19.3, 19.4, SPM) Abrupt climate change on decadal time scales is normally thought of as involving ocean circulation changes. In addition on

> longer time scales, ice sheet and ecosystem changes may also play a role. If a large-scale abrupt climate change were to occur, its impact could be quite high (see Topic 5.2). (IPCC WGI 8.7, 10.3, 10.7; WGII 4.4, 19.3)
>
> A growing number of scientists are raising concerns that the IPCC's projections are likely to be conservative and over-optimistic (Rahmstorf, 2007; Wheeler, 2007; Hansen et al., 2008, Palmer et al., 2008), and that large magnitude, abrupt, non-linear changes in the global climate system may occur during the 21st century (Schneider and Lane, 2006; Hansen et al., 2008) [52].
>
> While the risk of abrupt and catastrophic changes in the climate system is rising, such large changes are still highly unlikely to occur in the coming century. With respect to disaster risk reduction, the possibility of such events can generally be neglected. However, while currently small, the probability of abrupt climate change will increase along with the increasing rate, magnitude and duration of global warming. In that sense, the risk of such abrupt and catastrophic changes is yet another argument to take the risk of global climate change very seriously, particularly from the perspective of the 'precautionary principle' set out in the UNFCCC. [15]

Abrupt changes should be considered to be the **consequence of crossing a tipping point**. They are normally related to huge subsystem impacts. There is mounting evidence, however, that smaller disasters are increasing in frequency faster than the larger ones [27]. It is important to note that a small change can have large long-term consequences [30]. Some definitions of 'abrupt change' found in the literature may also be helpful in clarifying the term:

- Large scale components of the Earth system that may pass a tipping point [30].
- Mutually reinforcing feedback loops triggered by a tipping point propelling the system on a completely new course [155] .
- A large shift in climate that persists for years or longer over widespread areas that takes place so rapidly or unexpectedly that CNH systems may be unable to adapt [19].
- Large scale events of significant duration whose rate of change or variability is significantly greater than that observed in recent societal, economic or ecological systems [60].
- Imaginable or true un-envisioned climate surprises [160].

Figure 8: **Tipping Elements overlaid on population density** [30]



Lenton has written a seminal article on *tipping elements* that he defines broadly to include a.) both climatic and nonclimatic variables, b.) transitions that may be slower than the anthropogenic forcings causing it, c.) no necessary abrupt change, and d.) uncertain irreversibility [30]. Both Germanwatch and Lenton have made useful maps of the elements, Figure 8. Here follows is a quick list the tipping elements or abrupt changes most commonly explored in the literature:

- Going beyond a 2° C increase from the 1990 global temperature [13].
- Reorganization of the Atlantic Meridional Overturning Circulation [151].
- Dieback of the Amazon rainforest [151].
- Shift to a more permanent El Nino regime [151].
- Disintegration of Ice Sheets:
- Melt of the Greenland Ice Sheet [151]
- Loss of perennial Arctic sea ice: "*if not already passed...could occur well within this century*" [30] [150]
- Abrupt release of methane from thawing Arctic tundra [24]
- Disintegration of the West Antarctic Ice Sheet [151].

Common across all cited changes is that they all incur inevitable global consequences.

ANNEX B. TERMINOLOGY

Climate science and disaster risk reduction alike are fraught with large and distracting discrepancies in use of key terms. The differences are important enough to create wide-spread confusion, and short of harmonizing the two sectors, definitions need to be explained and re-explained at each use. Eight key terms were assessed within the e-survey: hazards, vulnerability, risk, disaster, climate change, mitigation, adaptation and resilience by listing the various definitions published by the most authoritative sources (IPCC, UNFCC, ISDR, etc). For each, respondents were asked to choose which definition (no sources were cited) came closest to the one they regularly employed. The preferred definitions and any striking differences between the groups of respondents are noted here below. They serve to highlight both the nuances and fundamental differences between understanding and needs of generators and users of climate science information.

- **Hazard**: *Potentially damaging physical events, phenomena or human activities that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation*. Seventy seven percent of respondents, including all the generators, preferred this to a Relief Web definition that mentioned "natural processes."

- **Vulnerability**: Although 10 out of 22 respondents preferred the seminal Blaikie definition [161]: "*the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard*", three out of the four generators preferred the ISDR definition of "*conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards*".

- **Risk**: Both users and generators were nearly perfectly divided between seeing risk as a formulaic function of hazards and vulnerability or as "*the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions* (ISDR)".

- **Disaster**: 95% of all respondents preferred the ISDR definition of "*a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources*" to IPCC's definition for extreme events as "*events that are rare at a particular place and time of year*". '*Natural disasters*' are a misnomer [31, 162-166] and much greater attention is required in permanently retiring this term from both climate science and humanitarian circles.

- **Climate change**: Interestingly, nearly half of all respondents (10/22) but only one of the four generators preferred the UNFCC definition: "*a change attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods*" to that of the IPCC: "*a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean* *and/or the variability of its properties, and that persists for an extended period, typically decades or longer*" which was chosen by half the generators and three other respondents.

- **Climate variability**: Generally refers to variations of the mean state of climate on all temporal and spatial scales [167]. For more discussion on the difference between this definition and the last, see Challenges / Attribution below.

- **Global change**: This term has come to reflect the combination of climatic and socio-economic changes that are both global and local as well as interrelated to physical and social drivers [50]. Its use is preferred when both physical and climatic causes and consequences are the subject. In this report, however, we are speaking distinctly about climate as a driver of change and so use the term climate change more often than global change.

- **Climate extremes:** Short-term perturbations of energy flows that provide magnitudes beyond the normal spectrum of an averaging period [41]. This term is often used interchangeably with *abrupt or complex events*, discussed in this report. In humanitarian circles, extreme events could be synonymous with disasters. This could be a 'useful' misnomer both to secure the supply of aid to the affected region and to deflect criticism from failure of governance.

- **Mitigation**: Four definitions were provided and the choice was spread evenly across three of them, that of IPCC, ISDR and UNDHA. Half of the generators chose the IPCC definition of "*an anthropogenic intervention to reduce the anthropogenic forcing of the climate system*". The meanings of the term differ significantly between the climate change and disaster management circles; in the former, use of the term 'mitigation' closely resembles prevention and the latter, adaptation [166].

- **Adaptation**: The majority of both groups chose the IPCC definition of "*initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects*". Scientists more and more frequently address the heightened confusion over the meaning of adaptation in the context of climate [35, 39]. Some of the confusion lies in the fact that humanitarian actors see little reason to disassociate climate change adaptation from disaster risk reduction (there is a wealth of literature on this comparison).

- **Resilience**: The majority of non-generators and all of the generators chose the IPCC's "*ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change*" over the ISDR definition. A similar definition is promoted by Adger [168] in his exposé on vulnerability.

ANNEX C. TECHNICAL NOTES ON CLIMATE CHANGE CONSEQUENCES

SEA LEVEL RISE

1.) What do authorities say about sea level rise (SLR)?

Anthropogenic carbon dioxide will cause irrevocable sea level rise [10]. Partial loss of ice sheets on polar land and/or the thermal expansion of seawater over very long time scales could imply sea level rise, major changes in coastlines and inundation of low-lying areas, with greatest effects in river deltas and low-lying islands (IPCC).

2.) Is there a documented impact today or in recent past of sea level rise?

Observed SLR is still hotly debated, perhaps less so than projected SLR. Here below are various estimates:

- Past 10 years: 3mm /yr (Leuliette, 2004)
- 1993-98: 3.2 ± 0.2 mm/yr [18] satellite altimetry alone
- 1993–2003: 2.8 ± 0.4 mm/yr [21]
- Last 55 years: 1.7 ± 0.2 mm/yr [23]
- 1900s: ice melting alone can account for 0.8 mm / yr [21]
- Past 100 years: 1-2 mm /yr [23].

3.) What are SLR projections?

IPCC: Current models project that sea level rise would occur over very long time scales (millennial) if a global temperature increase of 1.9 to 4.6°C (relative to pre-industrial) were to be sustained. Rapid sea level rise on century time scales cannot be excluded. (SYR 3.2.3; WGI 6.4, 10.7; WGII 19.3, SPM). Global average sea level is projected to rise by 2100:

- between nine and 88 centimetres [31]
- between 18–59 centimetres, but some estimates say as much as 1.4 m [2]
- 1–2 m [33] using only current ice discharge data.

4.) What are the greatest uncertainties regarding SLR?

- Poorly distributed global tide gauges, particularly in southern hemisphere [103, 105, 107].
- The date when temperature thresholds will be crossed, triggering more rapid SLR.
- The contribution of ice sheet melting [33].
- Impact of local tectonic movement [108]
- Non-uniformity in thermal expansion [105].

Sceptics say: “Seas have not risen in 50 years, laws of physics will not lend themselves to Armageddon” and “IPCC does not use SLR specialists.” [109]

5.) What are potential forcings and/or feedbacks between SLR and other phenomena?

There is a clear link between SLR and **other types of flooding**: By the 2080s, many millions more people than today are projected to experience riverine or other floods every year due to sea level rise. The numbers affected will be largest in the densely populated and low-lying mega – deltas of Asia and Africa while small islands are especially vulnerable (very high confidence) (IPCC WGII 6.4, 6.5, Table 6.11, SPM).

- Links with **coastal erosion**: Coasts are projected to be exposed to increasing risks due to climate change and sea level rise. The effect will be exacerbated by increasing human-induced pressures on coastal areas (very high confidence) (IPCC: WGII 6.3, 6.4, SPM).

- Excessive groundwater extraction which is lowering the land surface: a change in land water storage caused by anthropogenic activities could cancel out observed and projected SLR (hotly debated in the Philippines) [14].

- Climate-induced migration.

DROUGHT/ENSO

1.) What do authorities say about drought?

IPCC: Drought and floods will become more frequent and widespread across much of the world. Climate change will alter start dates of agricultural seasons as well as the length of growing periods --two key variables in food security [12]. A very large increase in both the spread and the severity of drought will leave almost a third of the planet scattered across the globe with extreme water shortages by the end of this century (Hadley Centre, 2006, [11].

2.) Is there a documented impact of drought today or in recent past?

- The percentage of the earth's land surface that suffers from severe drought has tripled in past ten years – from 1% to 3% [7].

- *"In parts of Africa and Asia, the frequency and intensity of droughts have increased over the past few decades...consistent with a general intensification of the hydrological cycle" [15].*

- In the last decades, the drought situation in many European regions has already become more severe (Arnell, 1994; DVWK, 1998; Demuth and Stahl, 2001; [20].

- Severe and protracted drought menaced the Sahel countries of Africa (1968-72) triggering world-wide concern [25].

3.) What are drought projections?

- *"There is not enough evidence to project intensity of future droughts…"[27].*

- Drought-affected areas are projected to increase in extent, with the potential for adverse impacts on multiple sectors, e.g. agriculture, water supply, energy production and health. Regionally, large increases in irrigation water demand as a result of climate changes are projected (WGI 10.3, 11.2-11.9; WGII 3.4, 3.5, Figure 3.5, TS.4.1, Box TS.5, SPM).

- Extreme drought conditions are expected to affect 8% of land areas by 2020, and no less than 30% by the end of the century [7].

- Longer droughts are expected in Mediterranean countries (Crichton 2009). Given future trends in Europe, increases in average precipitation and its variability are expected for northern regions, suggesting higher flood risks, while less rainfall, prolonged dry spells and increased evaporation may increase the frequency of droughts in southern areas (Jones, 1996; Watson et al., 1997; EEA, 1999; Arnell et al., 2000; Parry, 2000; IPCC, 2001a, Voss et al., 2002; Lehner, et al. 2006).

- By 2020, up to 250 million additional people in sub-Saharan Africa could have their livelihoods and prospects compromised by a combination of drought, rising temperatures and increased water stress [13].

- El Niño increases the probability of droughts across the rainforests of Indonesia. La Niña, meanwhile, may result in…warmer and dryer conditions in large parts of South America [15].

- Partly triggered by the severe 1997–98 El Niño, there has been substantial debate on the link between global warming and ENSO frequency or intensity. Despite great strides in modeling, only a few coupled ocean–atmosphere models are able to resolve contemporary ENSO patterns. Projecting what will happen to ENSO over the next one hundred years has produced limited results. Based on current climate models, however, global warming may "*have relatively little influence on the frequency or intensity of El Niño and La Niña episodes*" [15].

4.) What are the greatest uncertainties regarding drought?

- Large uncertainties surround teleconnections: especially the El Niño Southern Oscillation Index [64].

- Desertification impacts about 2.6 billion people or roughly 44% of the world's population [118, 119].

5.) What are potential forcings and/or feedbacks between drought and other phenomena?

- Water shortages

- Locust outbreaks

- Fires

- Links between El Niño and the timing of the monsoons, upon which entire agricultural systems depend. Changes in monsoon intensity and Society: during extreme low and high-flow events the threats to human societies and the environment are likely to be most critical, and the conflicts between competing requirements to be most intense [113].

STORMS

1.) What do the authorities have to say about storms?

"*No compelling evidence yet exists for significant trends in frequency of occurrence for tropical storms/ hurricanes*" (IPCC, 2001a,b). It is likely that tropical cyclones—typhoons and hurricanes—will become more intense as oceans warm, with higher peak speeds and heavier precipitation. All typhoons and hurricanes are driven by energy released from the sea—and energy levels will rise.

Despite great and unresolved controversy regarding the cyclone-global warming link [1-6], storms are featured in the IPCC table as a discrete stand alone singular phenomenon, with a projected "likelihood" of increasing intensity (but not frequency).

2.) Is there a documented impact of storms today?

- The first-ever hurricane in the South Atlantic struck Brazil in 2004; 2005 marked the first hurricane to hit the Iberian peninsula since the 1820s.

3.) What are storm projections?

- "The increase in cyclone intensity impacts the expected amount of contributions—the disaster impact— far more than does an increase in frequency….estimates are based on a cubed relationship between intensity and impact —a conservative assumption" compared with those discussed by Pielke [8].
- It is likely that tropical cyclones—typhoons and hurricanes—will become more intense as oceans warm, with higher peak speeds and heavier precipitation. All typhoons and hurricanes are driven by energy released from the sea—and energy levels will rise.
- One study found a doubling of power dissipation in tropical cyclones over the past three decades.
- Increased wind speeds between 450 and 550 [16].

4.) Where are the greatest uncertainties concerning storms?

- Sufficient longitudinal data
- Frequency versus intensity
- How global warming may change storm trajectories

5.) What are potential forcings and/or feedbacks between storms and other phenomena?

Scenarios for tropical storm activity demonstrate the importance of interactions with social factors. In particular, rapid urbanization is placing a growing population in harm's way.

FLOODING

1.) What do authorities say about climate-induced flooding?

- IPCC: There is now higher confidence: "in the projected increases in …floods, as well as their adverse impacts. Increases in …floods are projected in many regions and would have mostly adverse impacts, including …increased flood risk and extreme high sea level" {SYR 3.2, 3.3, Table 3.2; WGI 10.3, Table SPM.2; Table SPM.1}. **Floods will become more frequent and widespread across much of the world.** There is a significant risk that even a small increase in global mean temperature by less than 0.5°C will foster a significant increase in flooding probabilities affecting up to 20% of the world population (Kleinen and Petschel-Held 2007).

- The IPCC notes that the potential for climate change to intensify flood patterns may be particularly acute along the coast of East Africa. However, "*deriving quantitative estimates of the potential costs of the impacts of climate change (or those associated with climate variability, such as droughts and floods) and costs without adaptation is difficult*."

2.) Is there a documented impact today, or in recent past, of flooding?

- Mudelsee et al. (2003) showed that winter flooding has actually decreased, while summer flooding has remained essentially unchanged. The reduction in wintertime flooding may be linked to global warming as warmer and/or more polluted rivers result in a reduction in strong freezing events, eventually create water barriers and trigger enhanced flooding.

- In many areas, climate change is seen to influence riverine flooding and the general tendency is towards higher flood risk [15].

3.) What are flooding projections?

- Piecing together IPCC projections for most of the specific drivers of flooding, we can deduce a "*likely*" inexplicit increase of global flood risk. The main direct driver of flooding, **precipitation**, is "very likely" to increase in most areas of the globe, based on projections for the 21st Century using SRES scenarios. Available research suggests a significant future increase in heavy rainfall events in many regions…the resulting increased flood risk poses challenges to society, physical infrastructure and water quality. It is likely that up to 20% of the world population will live in areas where river flood potential could increase by the 2080s. Increases in the frequency and severity of floods are projected to adversely affect sustainable development. (WGI 11.2-11.9; WGII 3.2, 3.3, 3.4, 4.4).

- **Drainage basin** (indirect) **factors** are addressed by the following projection:
  The beneficial impacts of increased annual runoff in some areas are likely to be tempered by negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risk. (WGII 3.4, 3.5, TS.4.1)

- Increased incidence of extreme **high sea level** is "likely": By the 2080s, many millions more people than today are projected to experience floods every year due to sea level rise. The numbers affected will be largest in the densely populated and low-lying mega deltas of Asia and Africa while small islands are especially vulnerable (very high confidence) (WGII 6.4, 6.5, Table 6.11, SPM).

- Destructive changes in temperature, rainfall and agriculture are now forecast to occur several decades earlier than thought [9].

4.) What are the greatest uncertainties concerning flooding?

Uncertainty is partly due to modelling at global scale, whereas many effects occur at regional or local scales [17].

- Global warming is a relatively minor player in world water problems and land use change has been shown to represent a key component of global change (fluvial systems are highly sensitive) [17].

- Future behaviour of Indian monsoons [22].

- There is no generic answer in relation to the extent or even the direction of the change in flooding, other than that there is generally increasing uncertainty [15].

- There are large margins of uncertainty in projections for populations exposed to risk from flooding [13].

5.) What are potential forcings and/or feedbacks between flooding and other phenomena?

- Sea level rise

- Coastal flooding

- Tropical storms

- **Coastal flooding** is further captured in the following projections: With no greater rise in annual temperatures, increased damage from floods and storms will be present on coastlines 6.ES, 6.3.2, 6.4.1, 6.4.2. At only 2°C global average annual temperature increase (relative to 1980-1999) millions more people could experience coastal flooding each year. T6.6, F6.8, TS.B5. The IPCC highlights the vast numbers of people around the world who are at risk from flooding by the sea. 'In the absence of an improvement to protection, coastal flooding could grow tenfold or more by the 2080s to more than 100 million people a year, just due to sea-level rise alone.' [11]

- Flood levels now occurring in the UK once every 100 years could occur once every 3 years by 2080—according to the highest emission scenario (King, 2004) [17].

- What has been a 50-year event in the twentieth century becomes at least a 25-year event over the next 100 years [22].

- Fowler and Hennessy's analysis of global climate models suggested a 1.1 to 2.9% increase in global precipitation per degree (C) of warming, but, for this to be truly predictive, it would have to be downscaled to accommodate changes at the regional and sub regional level [26].

- One model using an IPCC scenario for high population growth estimates the number of additional people experiencing coastal flooding at 134–332 million for a 3–4°C rise in temperature [13].