

Dangerous Anthropogenic Climate Change from the Perspective of Adaptation

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Abstract

The stated “ultimate objective” of the United Nations Framework Convention on Climate Change is “stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”. In the more than 20 years since the Convention was negotiated, understanding has increased of the risks posed to human and natural systems by climate change. The social construction underlying the negotiations is that greenhouse gases (GHGs) are pollutants whose control could prevent serious (and future) impacts. However, research on climate change impacts has led to an enlarged framework: the magnitude and extent of possible risks of climate change depend not only on changes in global average temperature (e.g. global warming), but also the human and natural systems exposed to those changes and their underlying vulnerability. Climate change interacts with other drivers to increase (or decrease) risks, and affects risk through multiple pathways. Adaptation then focuses not just on climate change, but also on addressing underlying exposure and vulnerability.

The determination of what atmospheric concentration of GHGs constitutes dangerous anthropogenic interference with the climate system is a value judgment, which means that science alone cannot provide an answer. To help inform the policy process, the Intergovernmental Panel on Climate Change issued reports in 2001 and 2007, synthesising the literature on climate change impacts and identified reasons of concern to enable readers to evaluate the relationships between increases in global mean temperature and associated impacts. Each concern is consistent with a paradigm that could be used independently or in combination with other reasons to help determine dangerous atmospheric concentrations. The reasons for concern are the relationship between global mean temperature increase and damage to or irreparable loss of unique and threatened systems; distribution of impacts

among people and across regions; global aggregate damages; and probability of extreme weather events and of large-scale singular events. Assessments in 2001 and 2007 showed increasing risk with increasing temperatures, with the temperature at which risks become apparent varying across the reasons for concern, and with greater risks in 2007 than in 2001. The assessments addressed only how risks change as global mean temperature increases, and not how risks might change at different levels of warming. The assessments also identified impacts, vulnerabilities, and risks that would merit policy-makers' attention, including food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets, and modes of oceanic and atmospheric circulation.

Reasons for concern about the ability to adapt to projected impacts and the likelihood of sustainable adaptation include contractions and uncertainties in the window of opportunity for adaptation; the difference between adaptive capacity and adaptive action; the risk of maladaptation; and the misguided measures of loss.

Effective and efficient adaptation will be critical to increase the resilience of human and natural systems over the next few decades, although it will not be possible to prevent all impacts. Over the longer term, the magnitude and extent of climate change impacts will depend on the mix of adaptation and mitigation, with rapid and successful reductions in GHG emissions reducing how much adaptation will be needed later this century. Slower and less comprehensive mitigation will increase the likelihood of crossing thresholds that will result in dangerous impacts to human and natural systems.

A. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) lays out its objective in Article 2:¹

The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a

1 United Nations Framework Convention on Climate Change, Document FCCC/INFORMAL/84, GE.05-62220 (E) 200705 (1992), available at http://unfccc.int/essential_background/convention/items, last accessed 15 January 2013.

time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Scientific understanding at the time this paragraph was negotiated in 1991–1992 was insufficient for government negotiators to identify an atmospheric concentration of greenhouse gases (GHGs) that would meet the criteria for preventing dangerous anthropogenic interference with the climate system. Science alone will never be able to provide an answer because the determination of “dangerous” is a value judgment. In addition, the science and policy contexts continue to change with further socio-economic development, a growing knowledge base, and increased climate change. Greater understanding of the breadth and depth of multiple stresses associated with climate change means that climate change has moved from being simply a pollution problem to issues of global development, equity, and ethics (because those who have contributed the least to GHG emissions will experience the most severe consequences).

As detailed later, few impacts of climate change had been observed at the time the UNFCCC was negotiated, so the negotiations assumed impacts were unlikely to occur until later in the 21st Century. However, observations since then show that climate change is altering the mean and variability of temperature, precipitation, and other weather variables, and that the rise in sea level is increasing risk of storm surges, saltwater intrusion into fresh water, and inundation. Impacts are already evident in many sectors and regions with some species extinction, childhood mortality, and changing landscapes at least partially attributed to climate change. This raises the question of whether dangerous interference has already started. Nevertheless, the international policy process adopted a definition of *dangerous* as an increase in global mean surface temperature of +2°C above pre-industrial temperatures, based on interpretation of the scientific evidence and literature.

This article provides text on adaptation from, and offers a historic perspective on, the UNFCCC. The discussion includes a brief review of scientific perspectives on how to estimate dangerous climate change, particularly key vulnerabilities and reasons for concern, as well as issues of relevance to the question of what is “dangerous” anthropogenic climate change from the perspective of adaptation.

B. Adaptation in the UNFCCC

Article 2 is not the only place in the UNFCCC text that mentions adaptation. Article 3 lays out the principles underlying the Convention. As paragraph 3.3 states, the states parties “should take precautionary measures to anticipate, prevent, or minimise the causes of climate change and mitigate its adverse effects.”

To achieve this where there are threats of serious or irreversible damage, states parties should implement policies and measures that take into account different socio-economic contexts; are comprehensive; cover all relevant sources, sinks, and reservoirs of GHGs; cover adaptation; and comprise all economic sectors.

Article 4 then lays out the commitments of the states parties and mentions *adaptation* in several paragraphs that have guided negotiations for the UNFCCC’s implementation. Article 4 states the following:

All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall:

...

- 4.1 e: Cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture, and for the protection and rehabilitation of areas, particularly in Africa, affected by drought and desertification, as well as floods.
- 4.1 f: Take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions, and employ appropriate methods, for example impact assessments, formulated and determined nationally, with a view to minimising adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change. ...
- 4.4: The developed country Parties and other developed Parties included in Annex II shall also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects. ...
- 4.8: In the implementation of the commitments in this Article, the Parties shall give full consideration to what actions are necessary under the Convention, including actions related to funding, insurance and the transfer of technology, to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures.

- 4.9: The Parties shall take full account of the specific needs and special situations of the least developed countries in their actions with regard to funding and transfer of technology.

C. *Historical Perspective*

National and international organisations began serious consideration of the possible consequences for human and natural systems of increasing GHG emissions in the 1970s. For example, in 1970, the Massachusetts Institute of Technology convened a one-month study of critical environmental problems, focusing on environmental issues whose cumulative effects on ecological systems would be so large and prevalent that they would have worldwide significance.² The 50 participants in the study were primarily concerned with the effects of pollution on humans through changes in climate, ocean ecology, and large terrestrial ecosystems. The subjects investigated for climatic effects included the increasing carbon dioxide content of the atmosphere, the particle load of the atmosphere, and contamination of the troposphere and stratosphere by subsonic and supersonic aircraft. This list of topics highlights an important historical perspective: that climate change is an environmental pollutant and reducing GHG emissions through mitigation will solve any negative consequences of exposure.

This perspective is understandable in context of other environmental concerns starting in the 1960s, with the publication in 1962 of *Silent Spring* by Rachel Carson on the environmental hazards of pesticides, particularly on birds.³ The book is widely credited with helping launch the contemporary environmental movement. Other environmental issues of importance in the 1970s and 1980s included stratospheric ozone depletion and acid rain. Stratospheric ozone depletion went from an unknown issue in early 1970 to a multilateral environmental agreement in 1985 and an international treaty⁴ in 1987 that successfully reduced the emissions of ozone-depleting chemicals.⁵ Throughout the 1970s and 1980s, there was ongoing scientific and policy debate about the effects of sulphur deposition (*acid rain*) on ecosystem resources in the United States, resulting in the US Congress pass-

2 SCEPT (1970).

3 Carson (1962).

4 The Montreal Protocol on Substances that Deplete the Ozone Layer.

5 United Nations Framework Convention on Climate Change, Copenhagen Accord, Document FCCC/CP/2009/L.7 (2009).

ing the Acid Deposition Act 1980, establishing an 18-year assessment and research programme that also was successful in reducing the relevant emissions.⁶

A common thread running through these and similar environmental problems is that they are caused by an agent (pesticides, chemicals that deplete ozone, sulphur compounds) whose release or emission was relatively easily and successfully controlled after overcoming initial resistance. These agents are typically short-lived compared with carbon dioxide, so reducing emissions relatively quickly led to improvements in the impacts of concern. Furthermore, alternatives or substitutes could be made fairly readily available in most cases. A key first step in understanding these issues was risk identification (showing the agents of concern which led to adverse impacts), followed by the scientific determination of a level of exposure that would lead to ‘acceptable’ risk (where *acceptable* was defined by regulators), usually in terms of risk to human health. This approach – and its success – informed efforts to understand the impacts of and strategies to control climate change. In essence, under this approach, impacts are directly related to emissions. Equally important, the way to manage impacts is to reduce GHG emissions; thus, mitigation is the primary policy task. That perspective is reflected in the language in the UNFCCC and in activities since its negotiation, underscoring the original intention that the treaty should focus on reducing the source of climate change, rather than on adapting to the changes.⁷ Adaptive capacity was not regarded as a policy objective but as an indicator of the extent to which societies could tolerate changes in climate. The tension between mitigation and adaptation has strongly characterised the discourse on climate change policy.

Table 1 summarises the historic framing of the climate change debate and adaptation thinking.

6 Lackey & Blair (1997:9–13); Likens & Bormann (1974:1176–1179).

7 Schipper (2006:82–92).

Table 1: Historic Framing of Climate Change and Adaptation Thinking⁸

Time Frame	Forum	Main Questions
CLIMATE CHANGE DEBATE		
1960s–1970s	World Meteorological Organization (WMO) Climate scientists	Is climate change an issue of concern? How will climate change affect the weather?
Mid-1980s–early 1990s	UNFCCC Intergovernmental Panel on Climate Change (IPCC)	Is climate change occurring? How will climate change affect global human and natural systems? Who should be responsible for reducing emissions?
Late 1990s–early 2000s	UNFCCC Regional decision-makers	What are the relative costs of mitigation and adaptation? How vulnerable are communities to climate variability and its consequences?
ADAPTATION THINKING		
1970s–early 1980s	Club of Rome Academics	What are the ecological limits to human development and growth? What are the options to respond to climate change? What sort of impacts can systems sustain? Will systems adapt automatically?
Late 1980s	IPCC WMO, International Council of Scientific Unions and UN Environment Programme Advisory Group on Greenhouse Gases (AGGG)	What will the impacts be? How much adaptation are society and ecosystems capable of? How much can adaptation offset the need to mitigate?
Early 1990s	IPCC	Is mitigation more important than adaptation for responding to climate change? What is the optimal balance between mitigation and adaptation in responding to climate change?
Late 1990s	UNFCCC Research bodies	How can policy support adaptation? Who is vulnerable to climate change and why? How much adaptation will be needed? What are the links between adaptation and development?
Early 2000s	IPCC United Nations Development Programme Global Environment Facility The World Bank Donors Research bodies	What constitutes <i>adaptive capacity</i> ? How can adaptation be integrated into existing sustainable development plans? What is needed to mainstream adaptation? How can adaptation policy be designed?

8 (ibid.).

D. Framework for Impacts and Adaptation

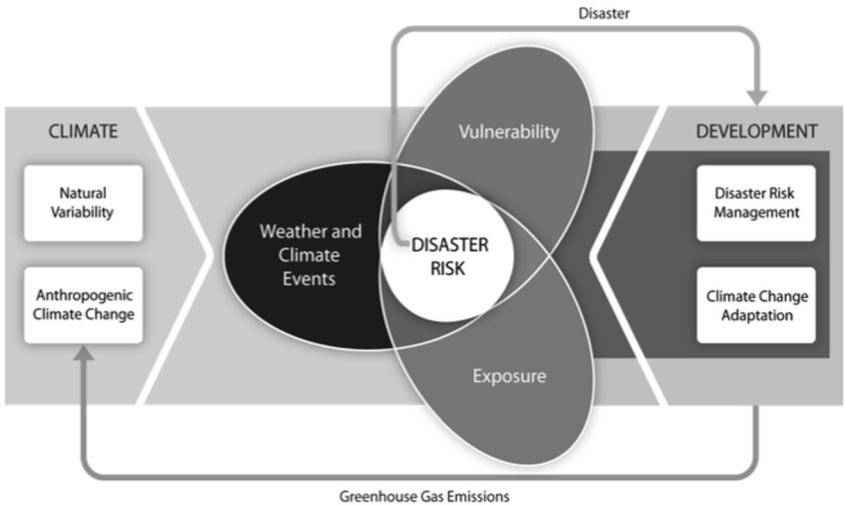
Research over the past 30 years on the impacts of climate change has led to a more nuanced framework of how climate change could affect human and natural systems. The magnitude and extent of possible risks of climate change depend on —⁹

- changes in temperature, precipitation, and other weather variables
- human and natural systems exposed to these changes, including people and their livelihoods; infrastructure; economic, social, or cultural assets; environmental services and resources, and
- vulnerability of these systems, where vulnerability is defined as the propensity or predisposition to be affected.

Figure 1 illustrates this framework, focusing on extreme weather and climate events. The figure shows the three components of risk, highlighting that realised risk in terms of disasters can influence subsequent development, including through disaster risk management and climate change adaptation, and that development is a driver of the anthropogenic climate change that influences the frequency and intensity of extreme weather and climate events.

9 IPCC (2012:3–21).

Figure 1: Components of Disaster Risk from Weather and Climate Events¹⁰



Using this framework, adaptation is understood to increase resilience by decreasing exposure or increasing vulnerability. Climate change could be considered to be dangerous when levels of exposure or vulnerability are deemed unacceptable.

Irrespective of whether climate change is considered primarily as a pollution problem (as at the outset) or as a more complex and nuanced challenge involving questions about, among other things, the costs of strategies, policies, and measures to control, prepare for, respond to, and recover from impacts, it is also about sustainable development, equity, and social justice. Whatever the framing, there has always been an underlying question about the locus of responsibility. Under the UNFCCC, the states parties agreed that climate change was a common responsibility. Article 3.1 states the following:

The Parties should protect the climate system for the benefit of present and future generations of humankind. On the basis of equity and in accordance with their common but differentiated responsibility and respective capabilities. ... Accordingly the developed countries should take the lead in combatting climate change and the effects thereof.

10 (ibid.:2).

The question of liability was addressed in the 17th UNFCCC Conference of the Parties (COP17) held in Durban in December 2011. At COP17, the developing countries, increasingly dissatisfied with the lack of progress by developed countries in controlling emissions and by the poor results from the Kyoto Protocol, introduced the concept of *loss and damage* that refers to liability and compensation for losses and damages that could not be avoided by adaptation, including loss of land to sea level rise and loss of species. At COP18 in Doha in December 2012, proposals were made to establish a mechanism under the UNFCCC to manage and provide oversight for funds provided by developed countries to cover loss and damage. There are substantial difficulties in establishing and implementing such a mechanism, including on what basis it would be decided how much each developed country should contribute, and on what basis it would be decided how much each developing country could receive. Because of the contentious issues involved, the only solution may be to refer them to the international judicial process. However, before this could happen, there would have to be a substantial expansion and evolution in the international law of the environment.

E. Determining Dangerous

The determination of what atmospheric concentration of GHGs constitutes “dangerous anthropogenic interference with the climate system” is a policy decision, although increasing legal actions suggest that national and international courts may play a role in providing an answer. *Dangerous* is a function of the degree to which impacts are negative and are considered unacceptable. The latter component is a value judgment. There is growing research on impacts to help answer the first component. As indicated previously, scientific understanding of climate change, current and future impacts, and range of policy instruments has increased significantly since 1992, including through assessments prepared by the Intergovernmental Panel on Climate Change (IPCC). The IPCC was established in 1988 by the World Meteorological Organization and the United Nations Environment Programme to provide national governments with a clear scientific view on the current state of knowledge in climate change, its potential environmental and socio-economic impacts, and options to manage the attendant risks. The three working group reports contributing to the IPCC’s Fifth Assessment Report will be completed in late 2013 and early 2014.

As the breadth and depth of scientific understanding has increased, so has the social construction of what impacts are unacceptable. The UNFCCC specifies three criteria for *dangerous*: time for ecosystems to adapt naturally; food production not to be threatened; and economic development enabled in a sustainable manner. However, these are not quantifiable criteria that can be measured and monitored, which makes them impractical to operationalise.¹¹ Also, while these three criteria are clearly important, they are not the only possible impacts of climate change that could have large-scale consequences. For example, there are growing concerns about a wide range of other consequences that could be considered dangerous, including the availability of sufficient quantities of safe water in some regions; the impacts of changing patterns of extreme weather and climate events; changes in the geographic range and incidence of climate-sensitive health outcomes; melting of large ice sheets in Greenland, the Arctic, and Antarctica; sea level rise; and the acidification of the oceans.

Furthermore, determining what concentration of GHGs causes unacceptable harm or injury varies by sector and geographic region. The UNFCCC recognises certain regions are more vulnerable to climate change, including least-developed countries, small island states, and areas with fragile ecosystems. At any particular concentration of atmospheric carbon dioxide, some vulnerable regions and sectors will experience significant impacts that they perceive to be unacceptable, while others will experience little to no impacts. In any one place there is likely to be a combination of adverse and beneficial impacts or opportunities, such as a longer growing season in some high-latitude countries. Scientific evidence overwhelmingly supports the conclusion that adverse effects will far outweigh the beneficial effects, especially as global mean surface temperature rises beyond +2°C above pre-industrial temperatures.

The time frame of impacts also is an important consideration, in both the short and longer term. The UNFCCC text has the implicit assumption that current atmospheric concentrations (or concentrations over the few decades following 1992) are not dangerous, so adaptation and mitigation are future issues. This is in contrast to the large number of scientific publications and empirical observations showing impacts are already being felt from climate change, particularly in developing countries and the high Arctic.¹² Further-

11 Burton et al. (forthcoming 2013).

12 Bernstein et al. (2007:52).

more, there was limited understanding of what is termed the *climate change commitment*: that current atmospheric concentrations of GHGs, particularly carbon dioxide, will take many decades to centuries to come to equilibrium – even without any further increase in concentrations. Sea level rise in particular is expected to continue for several centuries. Therefore, even if global emissions were immediately reduced, the climate would continue to change for several more decades. In other words, the planet is committed to additional warming in the short term no matter whether mitigation activities fail or succeed.

Human and natural systems need to adapt to these changes, which will include increases in the frequency, intensity, spatial extent, and duration of many extreme weather and climate events.¹³ Implementation of a wide range of adaptation policies and measures are critical in the short term if human and natural systems are going to cope successfully with the changes built into the climate system. Furthermore, it is not just the changing weather patterns themselves to which adaptation is required, but also to the consequences of those changing patterns, such as increases in the geographic range of insects and other disease vectors, leading to infectious diseases spreading to new regions.

Over the very long term, there is recognition that current atmospheric concentrations of carbon dioxide will continue to drive changes in climate for many hundreds of years.¹⁴ Furthermore, the climate change resulting from carbon dioxide emissions is largely irreversible for 1,000 years – even after emissions stop.¹⁵ Following the cessation of emissions, there will be a slow reduction in the atmospheric concentration of carbon dioxide with a compensating slow loss of heat to the ocean, resulting in global mean surface temperatures not changing significantly for at least 1,000 years. This could result in irreversible impacts such as dry-season rainfall reductions in several regions comparable to those of the ‘Dust Bowl’ era in North America in the 1930s and continuing sea level rise. Thermal expansion of the warming ocean provides a conservative lower limit for irreversible global average sea level rise of at least 0.4–1.0 m if 21st-Century carbon dioxide concentrations exceed 600 ppmv and 0.6–1.9 m for peak carbon dioxide concentrations exceeding about 1,000 ppmv. There will likely be additional contributions from melting glaciers and ice sheets. Thus, for coastal communities in low-

13 IPCC (2012).

14 Bernstein et al. (2007).

15 Solomon et al. (2009:1704–1709).

lying regions, atmospheric concentrations of carbon dioxide are already dangerous.

Finally, the UNFCCC alludes to – but does provide a framework for – addressing the fact that climate change is a stress multiplier. Changing weather patterns are often not the only driver of impacts, but can exacerbate other stresses to significantly increase risks. Therefore, a determination of *dangerous* will depend on the context. For example, a uniform amount of sea level rise will have very different impacts on coastal communities depending on their vulnerability.

These and other issues make global determination of dangerous anthropogenic influence very challenging. Despite these challenges, the Copenhagen Accord states the “international scientific consensus” that a global mean surface temperature increase of 2°C above pre-industrial levels is the upper limit of what human societies could adapt to, and that anything above that concentration would be dangerous.¹⁶ However, this is more a political than a scientific consensus. Further research indicates the impacts associated with 2°C are greater than previous studies indicated, such that 2°C may now represent the threshold between dangerous and extremely dangerous.¹⁷ Pledges for GHG emission reductions put forward since the Copenhagen Accord could result in a 50:50 chance of a peak global temperature increase of at least 3°C above pre-industrial levels, with some estimates as high as 3.9°C.¹⁸

F. Reasons for Concern

Based on a growing literature base, the contribution of Working Group II to the IPCC’s Third Assessment Report, which addressed impacts, adaptation and vulnerability, included a chapter on vulnerability to climate change and what were termed *reasons for concern*.¹⁹ The chapter set out to synthesise the results of Working Group II’s report and assess the state of knowledge relevant to Article 2 of the UNFCCC. The authors specified that it was not their task to determine whether impacts were tolerable or dangerous. They

16 United Nations, United Nations Framework Convention on Climate Change, Copenhagen Accord, Document FCCC/CP/2009/L.7 (2009).

17 Anderson & Bows (2011:20–44).

18 Parry (2010:18–19); Sustainability Institute (2010).

19 Smith et al. (2009:915–967).

synthesised information on climate change impacts to enable readers to evaluate the relationships between increases in global mean temperature and such impacts, and created reasons for concern to aid readers in making their own determination of what constituted dangerous climate change. These reasons were taken from debates and literature about the risks of climate change. Each concern was consistent with a paradigm that could be used independently or in combination with other reasons to help determine what level of climate change was dangerous, and none was considered more important than another. The reasons for concern are the relationship between an increase in the global mean temperature and the –

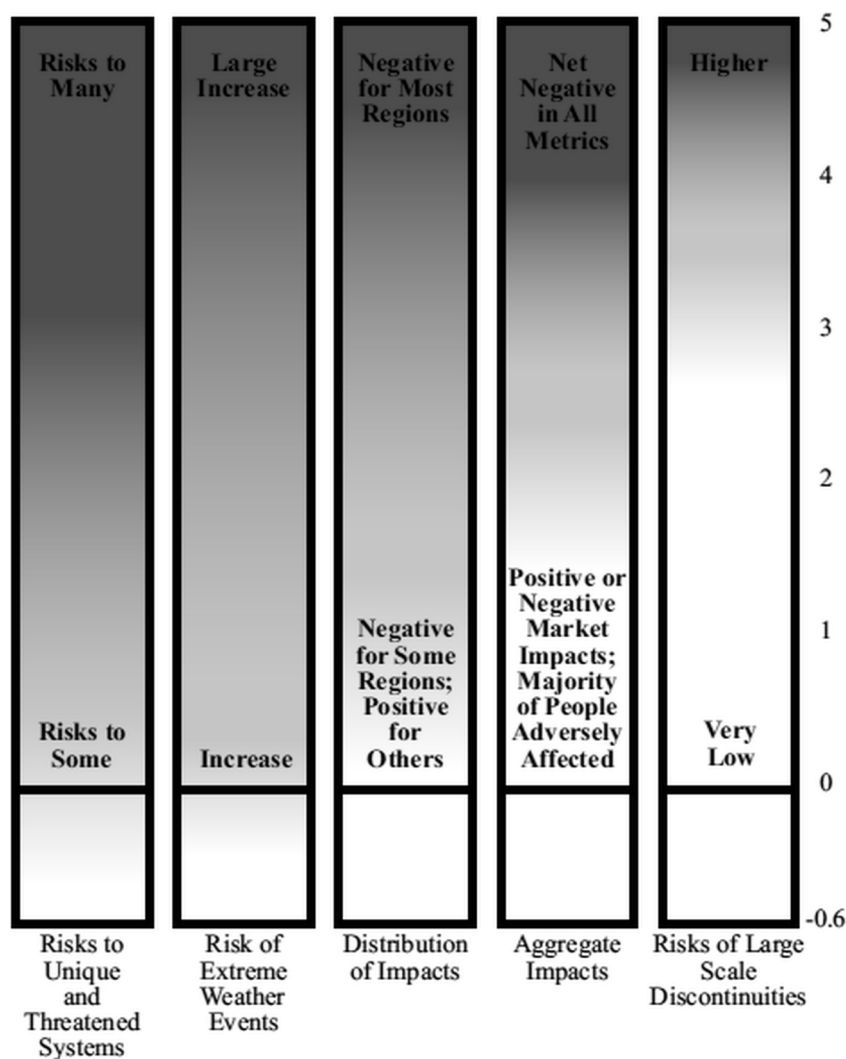
- **damage to or irreparable loss of unique and threatened systems:** This recognised that some systems restricted to a relatively narrow geographic range, but which could affect other entities, might be irreparably harmed by changes in climate beyond certain thresholds. Examples include melting of tropical glaciers, destruction and loss of coral reefs, loss of mangrove ecosystems, loss of biodiversity hotspots, and impacts on indigenous communities.
- **distribution of impacts among people and across regions:** Some regions, countries, islands, and cultures might be adversely affected by climate change, while others might or might not have net gains. Within countries, some regions or groups of people could be harmed more than others.
- **global aggregate damages:** The authors used a consistent method of measurement to aggregate impacts with global mean temperature increases, assessing whether change would be positive or negative, would occur smoothly or in more complex dynamic patterns, and whether aggregate impacts might mask unequal distribution of impacts.
- **probability of extreme weather events:** Increasing mean climate change alters the frequency, intensity, spatial extent, and duration of some extreme weather and climate events, such as heatwaves, extreme floods, droughts, and storms. This reason for concern considers whether the probability and consequences of such events might change as global mean temperature increased.
- **probability of large-scale singular events:** These include the breaking up of the West Antarctic Ice Sheet, the collapse of the North Atlantic thermohaline circulation, or destabilisation of international order by environmental refugees and the emergence of conflicts as a result of multiple climate change impacts.

The authors concluded it was not possible to combine the different reasons for concern. They reviewed the associations between temperature and impacts for each reason and drew preliminary conclusions about the potential severity and risk of such impacts. Because of substantial uncertainty with respect to the temperature at which impacts occur, the temperatures are approximate indications of impacts, not absolute thresholds. Furthermore, the authors note that global mean temperature does not describe all relevant aspects of impacts, such as the rate and pattern of change, changes in precipitation and extreme weather and climate events, or latent effects such as rising sea levels. Also, the authors did not factor in the potential role of adaptation.

Figure 2 presents a summary of their findings.²⁰ Climate change consequences are plotted against increases in global mean temperature (°C) after 1900. Each column corresponds to a specific reason for concern and represents a range of associated outcomes with increasing global mean temperature. The colour scheme represents progressively increasing levels of risk. Global mean temperature increased approximately 0.6°C between 1900 and 2000, which led to some impacts. The figure shows increasing risk with increasing temperatures, and that the temperature at which risks become apparent varies across the reasons for concern. For example, risks were already becoming apparent to unique and threatened systems, but global average temperature would need to increase by about 3–4°C before risks of large-scale discontinuities might become apparent. The figure addresses only how risks change as global mean temperature increases, not how risks might change at different levels of warming. It also does not address when risks might be realised, nor does it account for the effects of different development pathways on vulnerability.

20 Smith et al. (2009:4134).

Figure 2: Reasons for Concern from the IPCC's Third Assessment Report²¹



21 (ibid.).

In 2007, the IPCC's Fourth Assessment Report²² revisited the reasons for concern assessed in the previous report. In addition to updating the assessment on these reasons, the authors also identified what they termed *key vulnerabilities*. Key vulnerabilities were impacts, vulnerabilities and risks that would merit policymakers' attention. Seven criteria were described to identify a key vulnerability: magnitude of impacts; timing of impacts; persistence and reversibility of impacts; likelihood of impacts and vulnerabilities, and confidence in those estimates; potential for adaptation; distributional aspects of impacts and vulnerabilities; and importance of the system(s) at risk. Key vulnerabilities were associated with many climate-sensitive systems, including food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets, and modes of oceanic and atmospheric circulation.

The chapter concluded that the following appeared robust across a diverse set of studies:

- A risk-management framework was a useful approach for addressing key vulnerabilities. However, the assignment of probabilities to specific key impacts was often very difficult, due to the large uncertainties involved. Uncertainties were due to factors such as climate sensitivity, regional climate change, vulnerability to climate change, and adaptive capacity and the likelihood of bringing that capacity to bear.
- Mitigating climate change and reducing GHG emissions would reduce the risk associated with most key vulnerabilities. Postponement of such actions generally increased risks.
- Current atmospheric GHG concentrations and the range of projections for future climate change meant that some key impacts (e.g. loss of species, partial deglaciation of major ice sheets) could not be avoided with high confidence. The probability of initiating some large-scale events was very likely to continue to increase as long as GHG concentrations and temperature continued to rise.

Figure 3 summarises the reasons for concern from the IPCC's Fourth Assessment Report,²³ using the same approach as that adopted in Figure 2 (although the figure only appeared in a subsequent publication).²⁴ In the six

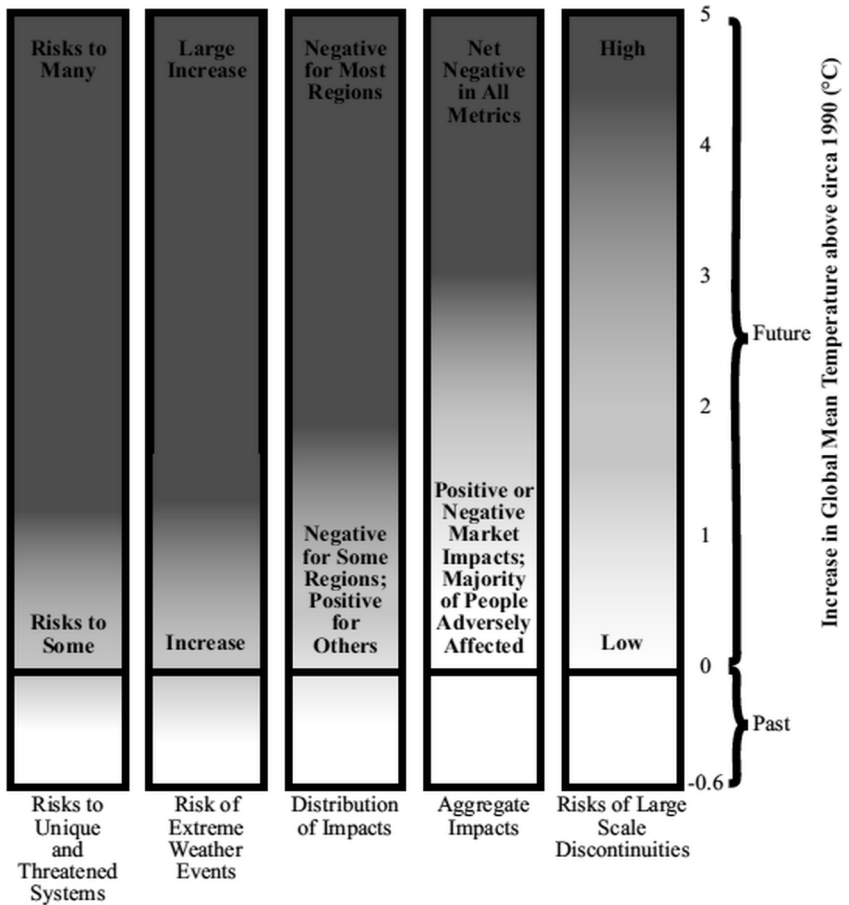
22 Schneider et al. (2007:779–810).

23 (ibid.).

24 Smith et al. (2009:4133–4137).

years between the two assessments, risks increased considerably for all reasons for concern.

Figure 3: Updated Reasons for Concern from the IPCC’s Fourth Assessment Report²⁵



The chapter also concluded that adaptation could significantly reduce many potentially dangerous impacts of climate change and reduce the risk of many key vulnerabilities. However, the technical, financial, and institutional ca-

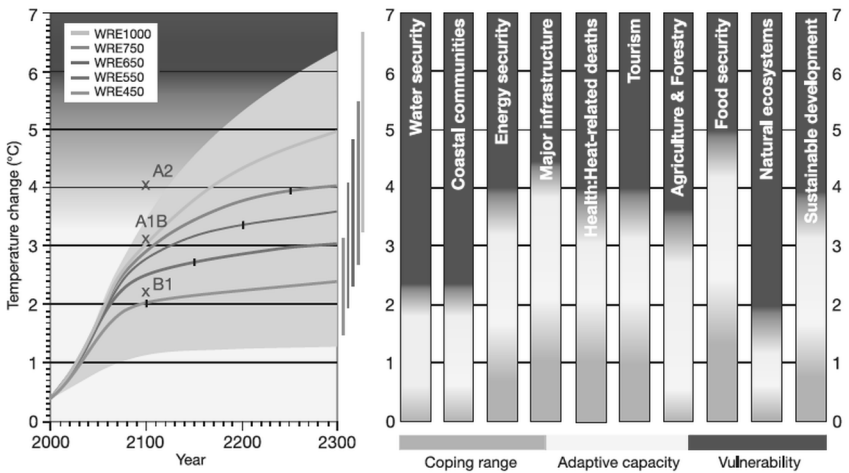
25 Schneider et al. (2007:779–810).

capacity, and the actual planning and implementation of effective adaptation, is quite limited in many regions. Furthermore, the risk-reducing potential of planned adaptation is either very limited or very costly for some key vulnerabilities, such as loss of biodiversity, melting of mountain glaciers, and disintegration of major ice sheets.

The Australia and New Zealand chapter of the IPCC's Fourth Assessment Report assessed the extent to which adaptation could reduce regional reasons for concern.²⁶ The left-hand panel shows global temperature change from the IPCC's Third Assessment Report, with the coloured curves representing temperature change associated with stabilisation at different carbon dioxide concentrations from 450 ppm to 1,000 ppm. The year of stabilisation is shown as black dots. The shaded area indicates the range of climate sensitivity across the stabilisation cases. The thin vertical lines next to the stabilisation curves show uncertainty in the year 2300. Crosses indicate warming in 2100. The right-hand panel summarises relative coping range, adaptive capacity, and vulnerability for critical sectors in this region, showing that, for example, the region has limited capacity to cope with further water insecurity, but would likely be able to cope with the impacts of an increase of 2°C on food security.

26 Hennessy et al. (2007:507–540).

Figure 4: Vulnerability to Climate Change Aggregated for Key Sectors in the Australia and New Zealand Region²⁷



G. Adaptation Reasons for Concern

Building on the ‘reasons for concern’ framework, Adger and Barnett²⁸ identified four reasons for concern regarding the ability to adapt to the identified impacts and the likelihood of sustainable adaptation:

- Contractions and uncertainties in the window of opportunity for adaptation
- The difference between adaptive capacity and adaptive action
- The risk of maladaptation, and
- The misguided measures of loss.

The first reason for concern is that the scale of projected changes and the interconnectedness of impacts mean that the window of opportunity for adaptation may be smaller than assumed. There will have to be major changes in policies and priorities if world governments commit to keeping the global mean temperature increase to less than 2°C above pre-industrial temperature; emissions reductions on the order of 80% or more by 2050

²⁷ (ibid.:529).

²⁸ Adger & Barnett (2009:2800–2805).

would be needed.²⁹ There is limited confidence that this is achievable, which means adaptation will be needed to ever larger changes in global mean temperature. It is hard to imagine the ability of societies to adapt to the significant impacts projected at temperature increases of 4°C or more, particularly on access to water and food security.³⁰ Ecosystems will transform into new states that may bear little resemblance to current functioning, and which would have potentially catastrophic consequences on the provision of ecosystem goods and services. Furthermore, these impacts are likely to interact – creating even more surprises.

In addition, as human and natural systems move into new territory with respect to weather patterns, there are increasing concerns about the possibility of crossing thresholds that result in disruptive regime shifts. For example, the Arctic is melting more rapidly than projected, which could lead to much larger increases in sea level over shorter time periods than many countries would be able to manage.³¹

The second reason for concern is that adaptive capacity will not necessarily translate into action. The assumption that it would is called the “adaptation myth”.³² For example, the US assumes the impacts of climate change will be within the limits of its ability to adapt. However, as one example illustrates, the number of annual natural catastrophes is rising faster in North America than anywhere else worldwide, with the increase entirely due to weather events.³³ The potential for weather-related losses in North America continues to rise due to socio-economic factors such as ongoing urbanisation and increasing property values. In addition, new technologies may create further risks.

The third reason for concern is the extent to which implemented adaptation policies and measures are not sustainable. Human choices have created path dependencies that may limit the range of future adaptation options in, for example, managing water resources because of the placement of dams and other infrastructure that may not be in optimal locations under future weather regimes, water rights agreements, etc.

The fourth reason for concern is that approaches to measure the success of adaptation often do not include social and cultural aspects. Adaptations

29 Meinshausen et al. (2009:1158–1162).

30 Parry et al. (2009:111).

31 Oppenheimer (2005:1399–1407).

32 Repetto (2009).

33 Munich (2012:12).

that do not take these perspectives into account may appear successful to policymakers, but may not be legitimate and equitable from the perspective of the communities involved.³⁴ An obvious example is the issue of managed retreat from small islands. Inhabitants of small islands such as Tuvalu have significant cultural, spiritual, familial, and historical ties with their land, which means that relocation would entail unbearable psychosocial losses.³⁵

In addition to the reasons for concern raised by Adger and Barnett, estimates of the costs of adaptation may be much larger than societies are willing to pay. For example, a global estimate of the adaptation costs of just treating diarrhoeal disease and malaria due to climate change in 2010 was US\$3–5 billion (in 2005 US\$), with the costs expected to decline over time with improvement in basic health services; the estimate also assumed UN population projections and strong economic growth.³⁶ Aggregating the potential adaptation costs over many sectors (but not over all possible impacts) for the year 2030 leads to upper-end estimates of more than US\$150 billion required in annual investment and financial flows to cover the costs of adaptation.²² It is highly unlikely that governments will be willing or able to pay this amount annually.

Another reason for concern is that adaptation measures seen to be beneficial in the short and medium term may prove to be maladaptive in the longer run. For example, measures to protect communities in the exposed coastal zones of Bangladesh, if successful, could improve living standards and make the region more attractive to additional settlement. However, in the longer run, it seems highly likely that these lands will be inundated with rising sea levels and will have to be permanently abandoned. Thus, good short-term adaptation may only be palliative.

H. Discussion

In the short term, the magnitude and extent of impacts of climate change – and, therefore, what societies may perceive to be dangerous anthropogenic interference with the climate system – will depend not only on the degree and rate of climate change, but also on the vulnerability of natural and social systems to these changes, and on the effectiveness of adaptation options to –

34 Barnett & Campbell (2010:211).

35 Montreux & Barnett (2009:105–112).

36 Pandey (2010).

- reduce exposures to a changing climate
- decrease the susceptibility of individuals, communities, nations, and regions to harm from these exposures, and
- increase their ability to prepare for, cope with, respond to, and recover from the exposures.

Although the UNFCCC indicates its ultimate objective as being to achieve stabilisation of GHG concentrations at a level that will allow time for ecosystems to adapt naturally; ensure that food production is not threatened; and economic development enabled in a sustainable manner, scientists, the general public, and policymakers are now considering a much wider range of impacts as indicating dangerous interference with the climate system, such as increases in the frequency and intensity of extreme weather events that disrupt societies and lead to security threats. Sectoral and regional assessments of the risks of climate change indicate a wide range of subglobal threats to human and natural systems.³⁷ Effectively anticipating and preparing for these risks requires a wide range of research – from obtaining a better understanding of approaching thresholds, to how to motivate appropriate behavioural change, to modifications of current and implementation of new strategies, policies, and measures addressing the risks of climate change. Adaptation research and practice can raise awareness of the impacts of climate change at local and regional levels, and of the financial and technical assistance required to avoid even more dangerous impacts than have been observed.

Over the longer term, the magnitude and extent of impacts will depend on the mix of adaptation and mitigation; rapid and successful reductions in GHG emissions will reduce how much adaptation will be needed. Slower and less comprehensive mitigation will increase the challenges to which human and natural systems will need to adapt. Effective and efficient adaptation may prevent dangerous impacts in some situations, although there are few studies estimating the trade-offs and associated costs.

Ultimately, the determination of what constitutes “dangerous” interference with the climate systems is a social choice that science can inform, highlighting the risks associated with various levels of climate change, the extent to which adaptation and mitigation can prevent or reduce those risks, and the associated costs and trade-offs that these actions will entail.

37 Bernstein et al. (2007).

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