Interstate liability for climate change-related damage
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1 Physics of Climate Change

1.1 Introduction

Climate change is arguably the greatest environmental challenge of our time. It has been the focus of scientific and academic research for several decades. Scientific findings on the link between human activities and the warming of the Earth’s climate brought the issue to the top of the international political agenda. The international political response to the problem began in 1992 with the adoption of the UNFCCC, and its 1997 Kyoto Protocol committing industrialized nations and EITs to achieve quantified emissions reduction targets carried it to a new level. Yet, negotiations towards a comprehensive global mitigation framework are still continuing today.10

While the UNFCCC remains the primary forum to develop an international response to climate change, concerns about the changing climate have permeated many other international processes. Impacts on civil aviation and maritime sectors are being addressed by the International Civil Aviation Organization (ICAO) and International Maritime Organization (IMO) respectively.11 Interlinkages between climate change and other environmental issues can be traced through the three Rio Conventions contributing to the same sustainable development goals, operating in the same ecosystems, and addressing interdependent issues.12 The UN Conference on Sustainable Development (UNCSD) recognizes climate change as ‘one of the greatest challenges of our time.’13 Much of the work undertaken by the International Bank for Reconstruction and Development (IBRD) in developing countries, too, focuses on sustainable development and climate change14 and the growing relevance of climate change-related issues to a number of other political processes cannot be underestimated.15

10 See Chapter 2 for a discussion of the international legal regime governing climate change.
11 E.g. for the ICAO’s and IMO’s respective climate change initiatives, see: <www.icao.int/environmental-protection/Pages/climate-change.aspx> and <www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/GHG-Emissions.aspx> (last visited on 26 March 2012).
14 The World Bank climate change initiatives can be found at: <http://climatechange.worldbank.org/climatechange/> (last visited on 26 March 2012).
15 E.g. 1971 Ramsar Convention on Wetlands, UN Forum on Forests (UNFF), Food and Agriculture Organization (FAO), International Organization for Migration (IOM), etc.
Already in the late 1980s, the UN General Assembly expressed concern that ‘certain human activities could change global climate patterns, threatening present and future generations with potentially severe economic and social consequences’ and requested immediate action leading to a comprehensive review and recommendations with respect to, *inter alia*, ‘the state of knowledge and the science of climate and climatic change.’\(^{16}\) The Intergovernmental Panel on Climate Change (IPCC), the leading intergovernmental body for the climate change science, was established in 1988 by the United Nations Environmental Programme (UNEP) and the World Meteorological Organization (WMO) to provide the international community with a clear scientific assessment of climate change and its environmental and socio-economic impacts.\(^{17}\) Later that year, the UN General Assembly endorsed the action by the UNEP and WMO in a resolution on the protection of the global climate for present and future generations of mankind.\(^{18}\) The role of the Panel, as defined by Principles Governing IPCC Work, is ‘to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation.’\(^{19}\) To date, the IPCC has released four climate change assessment reports and numerous special reports, methodology reports, technical papers, and other supporting material. The most recent Fourth Assessment Report (AR4) was published in 2007 and the Fifth Assessment Report is scheduled for release in 2013-2014. The data contained in AR4 provides the most current scientific assessment of climate change and serves as the basis for this chapter.

Following its release, AR4 attracted some public criticism due to inaccuracies contained in the report. Since then, the IPCC was independently reviewed by the InterAcademy Council.\(^{20}\) Following the InterAcademy Council recommendations, the IPCC undertook a complete review of its processes and procedures. Decisions on governance and management, conflict of interest, and procedures were adopted in June 2012.\(^{21}\) Since the AR4 controversy, many scientists have reaffirmed the

\(^{16}\) *Protection of global climate for present and future generations of mankind*, GA Res. 43/53 (6 December 1988).


\(^{18}\) GA Res. 43/53 (6 December 1988).


\(^{21}\) The relevant decisions are available from: <www.ipcc.ch/organization/organization_review.shtml#U0v--GdaHD4> (last visited on 8 January 2013).
validity of its key findings concluding that the failings in certain aspects of the report do not affect the overall scientific basis.22

The chapter briefly considers the science behind the legal issues examined in the present research. It begins its review of the causes and consequences of climate change by examining the role of anthropogenic (i.e. human) factors first. Second, the chapter describes the main consequences of the changing climate, e.g. global warming, and sea level rise and ocean acidification; and the ways those phenomena affect life on Earth. Third, it deals with climate change impacts across systems, regions, and sectors. Finally, the chapter shifts its focus to ways to address climate change, namely mitigation and adaptation, and closes with some concluding remarks.

1.2 Climate Change, Its Causes, and Consequences

Natural changes of the Earth’s climate have played a fundamental role in the development of life as we know it. Basalt eruption events, sea-level falls, and asteroid impacts are among the possible causes of several major and lesser extinction events due to drastic environmental changes associated with those occurrences. Such changes include global cooling by enhanced cloud formation; global warming through the emission of carbon dioxide; and the production of acid rain and the destruction of the ozone layer attributed to nitrogen and sulphur compounds release into the atmosphere.23 Solar variation, too, is hypothesized to have contributed to the Earth’s surface temperature changes.24 Natural factors have caused the climate to change in the past and will continue to do so in the future. Today, warming of the climate system is unequivocal.25 Yet, natural environmental changes are not the sole cause of climate change. It has generally been accepted that human activities also contribute to it.26

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22 Climate Change Assessments, review of the processes and procedures of the IPCC, InterAcademy Council (October 2010), p. vii.
1.2.1 Anthropogenic Factors

In 2007, the IPCC stated with ‘very high confidence’ that ‘the global average net effect of human activities since 1750 [i.e. the beginning of the Industrial Revolution] has been one of warming.’27 The Panel observed that global greenhouse gas (GHG) emissions due to human activities have increased by 70 per cent between 1970 and 2004 and further concluded that ‘[m]ost of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase’ in GHG concentrations of anthropogenic origin.28 With respect to the past 50 years, the IPCC stated that the observed widespread warming of the atmosphere and ocean, together with ice mass loss, support the conclusion that it is ‘very likely’ that climate change ‘is not due to known natural causes alone.’29 It is ‘very likely’ that most of the global warming over the past 50 years is due to anthropogenic GHG increases and it is ‘likely’ that there is discernible anthropogenic warming ‘averaged over each continent.’30 The IPCC also detected ‘discernible human influences [that] extend beyond average temperature to other aspects of climate, including temperature extremes and wind patterns,’ and concluded that ‘[a]nthropogenic warming over the last three decades has likely had a discernible influence on observed changes in many physical and biological systems.’31

1.2.2 Global Warming

One of the main observed changes in the Earth’s climate is the warming of the atmosphere. With the increase in GHG concentrations, more heat generated by the ultraviolet rays from the Sun is trapped in the upper layers of the atmosphere and prevented from going back into space. This causes the global temperatures to rise. The warming, in turn, entails other environmental shifts, such as the rise of the global average sea level due to thermal expansion of sea water and the melting of land ice in the mountains and Polar Regions, ocean acidification, changing weather patterns, and extreme weather events.32 If business-as-usual behavioural strategies are maintained and the rates of GHG emissions are kept at current, or above current, levels, further warming of the atmosphere will ‘induce many changes in the global climate system

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during [...] [this] century that would very likely be larger than those observed during the [...] [last] century." In the best-case scenario, the global temperatures will rise by 1.8°C with a likely range of 1.1-2.9°C by the end of this century; the worst-case scenario envisions a rise of 4°C with a likely range of 2.4-6.4°C.  

The IPCC has indicated with ‘very high confidence’ that physical and biological systems in terrestrial and marine ecosystems are already being affected by recent regional temperature increases. There is ‘high agreement’ and ‘much evidence’ that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades. And even if GHG concentrations are stabilized, anthropogenic warming and sea level rise will continue beyond the 21st century due to the time scale associated with climate processes.

1.2.3 Sea Level Rise and Ocean Acidification

The global average sea level rise is driven by the rising temperatures and it is ‘very likely’ that anthropogenic emissions contributed to this process during the second half of the 20th century. In combination with geological land changes, it is principally expected to affect coastal regions and small low-lying islands, some of which could disappear underwater because of an average sea level rise of merely several centimetres. Vast coastal territories could become uninhabitable due to the damaging effects of tidal surges, coastal erosion, and destruction of food crops. In 2009, the UN General Assembly expressed ‘deep concern’ that the ‘adverse impacts of climate change, including sea level rise, could have possible security implications’ and jeopardize the very existence of some small low-lying countries.

The average rate of the global average sea level rise over 1993 to 2003 was faster than that over 1961 to 2003 (about 3.1 millimetres per year as opposed to about 1.8), and the IPCC has stated with ‘high confidence’ that the rate of observed sea level rise increased from the 19th to the 20th century. It is estimated that in total over the last century the sea level rose by approximately 17 centimetres (12 to 22

39 Climate change and its possible security implications, GA Res. 63/281 (11 June 2009).
40 Climate change and its possible security implications, Report of the Secretary General, A/64/350 (11 September 2009), para. 71.
centimetres). \textsuperscript{41} According to the IPCC, the end of this century will see a global average sea level rise of 18 centimetres in the best and 59 centimetres in the worst case scenario. These projections include ‘increased ice flow from Greenland and Antarctica at the rates observed for 1993-2003,’ they do not account for a possible further increase or decrease of Polar ice flow rates as it is uncertain how those may change in the future. If the contribution due to increased ice flow from the Polar Regions were to grow further with the global average temperature, the sea level rise could increase by an additional 10 to 20 centimetres. \textsuperscript{42}

Another process associated with anthropogenic GHG emissions is that of ocean acidification by carbon dioxide. As the atmospheric concentrations of carbon dioxide grow, a greater amount of CO\textsubscript{2} is taken up by the ocean, which changes its chemical equilibrium. Once dissolved in ocean water, CO\textsubscript{2} forms a weak acid as pH levels decrease. \textsuperscript{43} Anthropogenic carbon emissions since the Industrial Revolution have led to the ocean’s acidification with an average decrease in pH of 0.1 units and a reduction in average global surface ocean pH of between 0.14 and 0.35 units is expected over the 21st century. \textsuperscript{44} Although the effects of observed ocean acidification on the marine biosphere are undocumented, more acidic waters are expected to have detrimental impacts on marine shell-forming organisms, such as corals, as well as their dependent species. \textsuperscript{45}

\subsection{1.2.4 Desertification}

On land, desertification is one of the greatest challenges to sustainable development linked to climate change. Desertification refers to ‘land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities’ \textsuperscript{46} and affects millions of people worldwide. Dryland ecosystems cover more than a third of the world’s land area. They are vulnerable to over-exploitation and inappropriate land use as well as to climatic changes. Although the relative importance of human and climatic factors in bringing about desertification is unclear, ‘climate change and desertification remain inextricably linked because of feedbacks between land degradation and

\textsuperscript{44} IPCC \textit{AR4, Synthesis Report} (2007), p. 72.
precipitation. This link is reflected in the close collaboration between the three Rio Conventions (see Section 1.1) and has also received ample recognition in the UN Convention to Combat Desertification (UNCCD) 10-Year Strategy. For instance, one of the outcomes under the policy operational objective reads: ‘[m]utually reinforcing measures among desertification/land degradation action programmes and biodiversity and climate change mitigation and adaptation are introduced or strengthened so as to enhance the impact of interventions.’

1.2.5 Extreme Weather Events

In its recent special report on managing the risks of extreme weather events and disasters, the IPCC stated that a changing climate leads to changes in the frequency, intensity, spatial extent, duration, timing of, and can result in unprecedented, extreme weather and climate events. There is ‘high confidence’ that exposure and vulnerability to extreme weather events will vary along spatial and temporal dimensions. It will also depend on various factors that determine the adaptive capacity of the affected area, e.g. economic, social, geographic, cultural, and environmental criteria. According to the IPCC projections, the injurious effects of climate change are ‘very likely’ to increase as frequencies and intensities of some extreme weather events increase. Significantly, there is evidence that ‘some extremes have changed as a result of anthropogenic influences, including increases in atmospheric concentrations of greenhouse gases’ albeit, admittedly, analysing and monitoring changes in extreme weather patterns is more difficult than calculating climatic averages.

1.2.6 Climate Change Effects Across Systems, Regions, and Sectors

The effects of climate change stretch far and wide and many negative consequences are expected to come from the growing global average temperatures and rising sea levels. Yet, while all parts of the world are expected to sustain some form of climate change depending also on their respective vulnerabilities, the timing and magnitude of impacts relating to differing amounts and rates of climate change will vary across

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48 The 10-year strategic plan and framework to enhance the implementation of the Convention (2008-2018), UNCCD Decision 3/COP.8, ICCD/COP(8)/16/Add.1 (2007), Ann., para. 11, Outcome 2.5.
50 IPCC SREX, Summary for Policymakers (2012), p. 5.
regions. It is also ‘likely’ that some systems, regions, and sectors will be especially affected because of uneven distribution of climate change impacts and varying adaptive capacity. Climate change is projected to have especially damaging effects on ecosystems such as the tundra and mountainous regions, Mediterranean-type ecosystems and tropical rainforests, mangroves and salt marshes, coral reefs and the sea ice biome. Water resources ‘in some dry regions at mid-latitudes […], in the dry tropics and in areas dependent on snow and ice melt’ will likely be put under serious strain by climate change.53 Agriculture in low latitudes, low-lying coastal systems, and human health in populations with low adaptive capacity are expected to be among the worst affected sectors. Regions, such as the Arctic, Africa, small islands, and Asian and African megadeltas are expected to bear the worst of climate change impacts.54

Yet, not all climate change impacts are negative. For example, some health-related benefits are projected in temperate areas, e.g. fewer deaths from cold exposure, as well as some mixed effects, such as changes in malaria range and transmission potential in Africa.55 Initial benefits are also projected for some regions in New Zealand by 2030.56 Aggregate yields of rain-fed agriculture are expected in some North American regions in the first decades of this century.57 Although in the Polar Regions specific ecosystems and habitats as well as indigenous ways of life are expected to be compromised, impacts on human communities resulting from the changing snow and ice conditions in the Arctic are projected to be of a mixed nature.58 Additional opportunities are expected to result from adaptation and mitigation activities.59 However, it is expected that initial benefits will be outweighed by the negative impacts of climate change.

1.2.6.1 Impacts on Systems and Sectors

Ecosystems: Overall, impacts of future climate changes on ecosystems are projected to place 20 to 30 per cent of plant and animal species at a ‘risk of extinction if increases in global average temperature exceed 1.5 to 2.5°C,’ and with a greater temperature increase, major changes in ecosystem structure and function, including negative consequences for biodiversity, are to be expected.60

**Food:** While mean temperature increases of between 1 and 3°C are expected to increase crop productivity slightly at mid- to high latitudes (e.g. in North America and parts of Russia), temperature increases above that will decrease food production. At lower latitudes crop productivity is projected to decrease even with a temperature rise of 1 to 2°C.\(^{61}\)

**Coasts:** Coasts are predicted to be exposed to increasing coastal erosion and sea level rise. By the end of the century, many millions more people than today are expected to experience annual floods due to the rising sea levels, with small island states and Asian and African megadeltas being affected the most.\(^{62}\)

**Societies:** Communities that stand to be particularly exposed to the damaging effects of the changing climate are those whose livelihoods are closely connected with climate-sensitive resources and localities. Poorer communities are expected to be particularly vulnerable.\(^{63}\)

**Health:** Climate change impacts on human health are expected to include: an increase in malnutrition due to reducing food availability; increased deaths and injuries associated with extreme weather events; increased frequency of cardio-respiratory diseases; and alteration in geographical distribution of infectious diseases. Benefits, such as reduced deaths from cold exposure, are expected to be outweighed by the negative impacts.\(^{64}\)

**Water:** The melting of glaciers, mountain snow pack, and small ice caps as well as changes in precipitation are expected to reduce water availability in a number of regions thus posing a threat to the sustainable development of the affected regions.\(^{65}\)

### 1.2.6.2 Impacts on Regions

Due to regional variability, climate change is expected to impact the world’s regions differently: some will be affected worse and sooner than others. According to IPCC predictions, the worst effects will be endured in developing countries, partially due to their low adaptive capacity.

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**Australia and New Zealand:** Some ecologically rich sites in Australia and New Zealand are predicted to suffer significant biodiversity loss. The region is expected to be affected by intensified water security problems and reduced agricultural production by 2030. Coastal development and population growth in coastal areas will increase risks associated with sea level rise and the growing frequency and severity of storms and flooding.66

**Europe:** Magnified regional differences; increased risks of flash floods; more frequent coastal flooding and increased coastal erosion; frequent wildfires and heat waves on land are projected for the European region. Mountainous areas are expected to be affected with glacier retreat, reduced snow cover, and significant loss of species. The southern portion of the European continent is projected to experience increased drought conditions, reduced water availability, and decreased crop productivity.67

**Latin America:** By mid-century, Latin America is projected to undergo gradual replacement of tropical forest by savannah in eastern Amazonia, with associated risks of significant biodiversity loss, reduced agricultural productivity, and water availability stresses.68

**North America:** In the early decades of the century, North America is projected to see an increase in aggregate yields of rain-fed agriculture (with important regional variability) alongside with negative impacts such as winter flooding and reduced summer flows, stresses on coastal communities and habitats, intensification of heat waves, and exacerbated competition for over-allocated water resources.69

**Asia:** Some of the worst climate change effects are expected to affect Asia, particularly its megadeltas. Reduced freshwater availability, increased flooding, and pressures on natural resources associated with industrialization and economic development are among the impacts projected for the region.70

**Africa:** The African continent stands to be especially affected by climate change. Its vulnerability is exacerbated by its low adaptive capacity. Already by 2020, 75 to 250 million people in Africa are projected to be exposed to increased water stresses and in some African states agricultural production, including access

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to food, is projected to be severely compromised. It is expected that by the end of the century, heavily populated low-lying coastal areas will be affected by sea level rise, while the cost of adaptation could amount to 5-10 per cent of gross domestic product (GDP). By 2080, arid and semi-arid land is projected to increase by 5 to 8 per cent.71

Polar Regions: The Polar Regions, too, are identified among the most vulnerable to the changing climate. Reductions in ‘thickness and extent of glaciers, ice sheets and sea ice […] [together with] changes in natural ecosystems’ are projected to have detrimental impacts on animal organisms and human populations.72 However, some impacts on human communities in the Arctic, especially those resulting from changes in snow and ice conditions, are expected to be mixed.

Small Islands: Climate change is expected to place small islands under particular strain from the rising sea levels. Increased inundation, storm surge, erosion, and ocean acidification will affect local resources and the livelihoods of island communities. By mid-century, the growing pressure on water resources is expected to render them insufficient to meet demand during low-rainfall periods.73

Effectively, the fact that the largest share of historical and current GHG emissions has originated in developed countries74 plays no part in the allocation of the injurious effects of climate change. It can be argued that countries that have contributed to climate change the least, i.e. developing states, particularly small island states and Africa, stand to suffer from it the most. The magnitude of regional impacts of climate change is exacerbated by developing states’ low adaptive capacity.

1.3 Responding to Climate Change: Mitigation and Adaptation

Climate change can be countered in a number of ways at the local level as well as globally. Consistent with the IPCC recommendations, societies could adjust to its impacts (adaptation), reduce its rate and magnitude by way of GHG emissions reduction and limitation (mitigation) or these responses could complement each other. The capacity to adapt to and mitigate climate change is contingent on socio-economic circumstances, environmental conditions, and the availability of

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74 See 1992 UNFCCC preamble.
information and technology.\textsuperscript{75} The IPCC has proffered a number of mitigation and adaptation options albeit far less information is available on the costs and effectiveness of the latter.

Adaptation strategies can reduce societies’ vulnerability to the injurious effects of climate change, both in the short and the long term. Adaptive capacity is intrinsically linked with social and economic development; however it is not evenly distributed across and within societies.\textsuperscript{76} It is subject to socio-political, economic, developmental, and cultural constraints. Even though developing countries are particularly susceptible to the injurious effects of climate change, societies with high adaptive capacity, too, can be vulnerable as evidenced by high mortality rates during the 2003 heat wave in Europe; the detrimental effects of Hurricane Katrina and Hurricane Sandy in the US in 2005 and 2012, respectively; and the destructive flash floods in Australia in 2012.

According to the IPCC, ‘[u]nmitigated climate change would, in the long term, be likely to exceed the capacity of natural […] and human systems to adapt’ to its injurious effects.\textsuperscript{77} Delayed GHG emissions reduction ‘significantly’ constrains lower stabilization levels opportunities, thereby increasing the risk of more serious climate change impacts. The IPCC has stated with ‘high confidence’ that although neither mitigation nor adaptation alone can avoid all climate change impacts, together they could significantly reduce the risks of climate change.\textsuperscript{78}

\subsection*{1.4 Concluding Remarks}

Scientific findings set out in the IPCC assessment reports have motivated the UNFCCC process since its conception. Stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system is the UNFCCC’s ultimate objective and Parties have interpreted it to mean that the global average temperature rise must not exceed 2°C above preindustrial levels.\textsuperscript{79} Compelling evidence of anthropogenic warming of the climate system presented in the IPCC AR4 can support informed decisions on the matter, including on increasing the level of ambition, in the context of the on-going negotiations, despite the absence of full scientific certainty. The following chapter describes the existing international legal framework for addressing climate change.

\textsuperscript{79} See 1992 UNFCCC, Art. 2; Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention, UNFCCC Decision 1/CP.16 (2010), para. 4.