Available online at www.sciencedirect.com
ScienceDirect
Current Opinion in Environmental Sustainability

Climate change, related hazards and human settlements

Gordon McBean and Idowu Ajibade

The assessments of the Intergovernmental Panel on Climate Change (IPCC, 2007) have demonstrated that the climate is changing and the future will see higher sea levels, more heat waves, intense storms and heavy precipitation events and extension of drought areas. These climate hazards are having impacts on human settlements causing major loss of life, social disruption and economic hardship. Recent literature has demonstrated that the problem is more rather than less critical. Linking of climate change adaptation with disaster risk reduction is important and starting to happen although there are significant barriers. Less developed countries and the poorest people in all countries are those most at risk and usually with the least capacity to adapt and reduce risk. A new international research initiative, Integrated Research on Disaster Risk: addressing the challenge of natural and human-induced environmental hazards (including climate change) has been established to meet the needs of providing an enhanced research base on which to develop and implement public policies.

Address
Department of Geography, The University of Western Ontario, London, ON N6A 5C2, Canada

Corresponding author: McBean, Gordon (gmcbean@uwo.ca)

Current Opinion in Environmental Sustainability 2009, **1**:179–186

This review comes from the inaugural issues
Edited by Rik Leemans and Anand Patwardhan

Available online 4th November 2009

1877-3435/$ – see front matter

DOI 10.1016/j.cosust.2009.10.006

Introduction

The harsh impacts of climate variability and change and related hazards are increasingly being felt across the world. Populations in low-elevation coastal zones, port cities [1] and river deltas, which are estimated to include about 10% of the world's population [2], have been found to be exceptionally vulnerable [3]. Already, urban populations in Asian river deltas such as Dhaka, Kolkata, Yangoon and Hai Phong are faced with increase flooding, while coastal cities in Africa such as Abidjan, Accra, Alexandria, Lagos, Freetown, Maputo and Cape Town are projected to be severely affected by rising sea level [3]. The colossal damage associated with climate-related hazards are extremely daunting—massive loss of human life, displacement, property damage and total disruption of daily activities, as witnessed in the Tropical Cyclone Nargis and Hurricane Katrina. Poor and low income communities are particularly vulnerable as many people driven by poverty and unemployment settle in hazardous physical environments at risk from ecological disturbances, diseases, storms, floods, firestorm and landslides [4•]. Their physical exposure and vulnerability is often accompanied by a deficit of adaptive capacity to cope with the changing climate.

While economic, political and environmental factors are dominant drivers of displacement and migration today, climate change and extreme weather events are also having detectable effects [5,6,7•] as is demonstrated by cases in Alaska and small island states like Tuvalu and Kiribati where sea-level rise is forcing thousands of inhabitants to emigrate to Australia and New Zealand [8]. In spite of these examples, the relationships between climate change and migration are highly complex and unpredictable [5,9] as there are difficulties in separating other pull–push factors including volatile conflicts, famine, and poverty. With increasing climate change, disasters of all kind will continue to be a major driver of short-term displacement and migration [5].

Despite the strong forces of nature, measures can be taken to prevent climate-related hazards from becoming major human catastrophes [10••,11,12]. This paper thus addresses questions on how climate-related hazards affect human settlements with an emphasis on coastal areas and examines proactive measures that governments can take to reduce vulnerability and increase communities' capacity to prevent, absorb and recover from disturbances. The paper also draws attention to the added value of an integrated approach to climate change adaptation and disaster risk reduction.

Natural hazards and vulnerable communities

A natural disaster can be defined as a 'serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources' [13]. Disasters occur when there is a hazard impacting on a vulnerable community or population. The challenge for human settlements is not simply about the occurrence of natural hazards but the intensity and frequency with which they are happening and also their increasing vulnerability. The number of reported disasters has increased, from about 65 per year in the 1960s, 200 per year in the 1980s, almost 280 per year in the 1990s to about 470 per year for the first part of this decade; floods

(33%), storms (23%, including hurricanes, typhoons, tornadoes, mid-latitude winter storms) and droughts (15%) are the most frequent triggers for disasters (CRED 2009; URL http://www.cred.be/). For the period January 1975 and October 2008, 8866 events killed over 2 million people with economic losses over US$ 1.5 trillion (CRED, 2009). As noted in the 2009 Global Assessment Report on Disaster Risk Reduction [14••], with the very meaningful subtitle 'Risk and poverty in a changing climate, invest today for a safer tomorrow', only 0.26% of the events accounted for 78.2% of the mortality, mostly in developing countries while 0.28% of the events accounted for 40% of economic loss, mainly in developed countries. These statistics point out the crucial importance of mega-disasters and how they impact developing and developed countries differently and how disaster risk threatens human development [14••]. In 2008 alone, 354 natural disasters with a death toll three times higher than the annual average for the period 2000–2007 were recorded [15]. Tropical Cyclone Nargis resulted in an estimated 140,000 mortalities in Myanmar, primarily due to a storm surge in the low-lying densely populated Irrawaddy River delta [16] while the flooding of the Kosi River in India affected 3.3 million people [17]. The Sichuan earthquake in China, a reminder that not all hazards are climate related, recorded more than 87,000 deaths with more than 60 million people severely affected. Overall economic losses in 2008 were more than twice the annual average for 2000–2007 [15].

The Report of the Workshop on '*Climate Change and Disaster Losses: Understanding and Attributing Trends and Projections*' [18•] concluded that direct economic losses due to disasters had increased, with particularly large increases since the 1980s. Changing patterns of extreme weather-related events and the changing vulnerability of communities were seen as having central roles. With a changing climate, more intense hazards are expected and better preparation to respond adequately is necessary such that losses in human and economic terms can be curtailed.

Information on global disaster statistics is prepared by several organizations including the Centre for Research on the Epidemiology of Disasters (CRED, 2009), the Munich Reinsurance-supported Natural Hazards Assessment Network (NATHAN) and the United Nations International Strategy for Disaster Reduction (UNISDR). Gall *et al.* [19] have commented on the difficulties and relative accuracies of these data sources but it is clear that overall trends are valid. Major events gather worldwide attention but there are many lower impact events that do not while still causing great harm. These lower impact events are often not included in the data bases; for example, the CRED data base does not register reports of small-scale disasters below its threshold of 10 deaths, 100 affected people, or a call for international assistance. As the Global Assessment Report [14••] notes, many regions are exposed to more frequently occurring low-intensity losses affecting large numbers of people with damage to housing and local infrastructure.

Natural hazards by themselves do not cause disasters; instead it is the combination of exposure, vulnerability and ill preparedness of populations that results in disaster [20]. Vulnerability is a function of physical exposure to hazards, sensitivity to the stresses they impose, capacity to adapt to these stresses, susceptibility, fragility and lack of resilience in socio-economic and physical infrastructures [10••,21]. Vulnerability also depends on many other factors including [12,22•]: magnitude of hazard; timing, persistence and reversibility of impact; and estimation and perception of risk. Vulnerability thus becomes a key distinguishing factor between those who suffer loss and those who escape it [23] and their resilience is a key determinant of how well they are able to absorb, adjust and recover from external shocks like typhoons, floods and earthquakes.

Geographic disparity and socio-economic inequalities between and within countries can also have implications on vulnerability. While developed societies like Germany, Norway and Japan have built infrastructure and technological strength that reduces vulnerability and allow for immediate rapid emergency response to natural hazards, developing countries, with fewer economic resources and technology are generally unable to cope with or manage natural hazards. Geographic disparity can mean more or less hazards in particular zones; for example people living along the coast of Florida may find themselves exposed to storms and flooding while people inland and away from rivers are less vulnerable. The overwhelming damage caused by hurricane Katrina in New Orleans has been partly blamed on both the technical issues of poor emergency and evacuation planning as well as on socio-economic inequalities between those who had the resources to leave early and resettle temporarily in hotels and those who had to depend on the State to aid their evacuation [24]. Climate-related hazards when ill-managed or inadequately prepared for can easily become human disasters on a grand scale [25•] deeply affecting physical, mental and emotional health of people. Even those who escape death or injury can be left traumatized by the loss of relatives, friends and belongings, particularly if they are already marginalized by poverty.

A reoccurring question is whether people contribute to their own predicament by making uninformed or unwise choices to live in hazard prone areas? This presupposes that choice is available. But reality shows that this not always the case [23]. Millions of communities living in rapidly urbanized countries in Asia, Latin America and Africa are often driven by poverty and economic considerations to settle in life-threatening areas. For many, the choice to relocate or remove themselves from this

situation simply does not exist, leading to a position where potentially disastrous situations, are created [23]. Overriding issue in an era of climate change are these equity concerns, since climate change will have strongly differential effects on people and societies within and between countries, regions and generations, and on ecological systems.

As the climate changes, a major concern is how to address the vulnerability of populations in the so-called 'climate hotspots' such as heavily populated deltas (especially Asian mega-deltas), low-lying coastal urban areas and the atolls [26]. In many countries the lack of political will and incapacity of local governments to address environmental risks currently facing large sections of the population within their jurisdiction further complicate response to hazards and perpetuates deficits in protective infrastructure and services. Climate risks then become an additional level of risk on already high levels of vulnerability and deficit adaptive capacity. The Global Assessment Report [14••] reflects this concern in its conclusion that: ''*Global disaster risk is highly concentrated in poorer countries with weaker governance*'' and that ''*governance arrangements for disaster risk reduction in many countries do not facilitate the integration of risk considerations in development.*'' In the end, critical issues will be the implementation of good governance and the generation of the political will to act.

Climate change and related hazards

''Over the last two decades (1988–2007), 76% of all disaster events were hydrological, meteorological or climatological in nature; these accounted for 45% of the deaths and 79% of the economic losses caused by natural hazards. The real tragedy is that many of these deaths can be avoided.'' [27]

With climate-related hazards being the triggers for the majority of disasters, there is an obvious concern about how a changing climate will make the situation worse in the future. The events that have already occurred cannot, of course, be attributed solely to climate change as other important factors are population growth, settlement patterns and land-use changes as cities expand. The impacts on people are related to the relative poverty of many new city dwellers and poor urban planning, while the growing economic losses are related to, partly, the growing wealth, However, the increase in the number of climate-related events due to heavy precipitation events and related flooding is consistent with the conclusions of the scientific studies regarding the increase in the frequency of heavy precipitation events [28–31] and the summaries of the Intergovernmental Panel on Climate Change (IPCC) [32••]. Typhoons are also a major cause of disasters and some studies have identified trends in numbers of intense typhoons and some have found no evidence of trends [33–40]. The IPCC concluded that it was likely that a trend occurred in late 20th century (post-1970) in some regions [41•]. Höppe and Pielke [18] while noting the importance of increasing vulnerability concluded that climate change and variability are factors that influence trends in disasters. It was clear that adaptation to extreme weather events should play a central role in reducing societal vulnerabilities to climate and climate change.

The IPCC [41•] projects as the climate warms further, there will be varying impacts in different regions and likely increases in the frequency of heavy precipitation events, intense tropical cyclone activity with risks of floods, drought and risk of water shortage, and incidences of extreme high sea level [32,42•]. They further [43••] adduced sea-level rise would exacerbate inundation, storm surge, erosion and other coastal hazards, increasingly stressing coastal communities and habitats. These stresses would interact with development, pollution, population growth and the rising value of coastal infrastructure, thus increasing the vulnerability of communities to climate variability and change.

International concern over climate change has been growing in response to climate events, the growing movements in civil society and findings from recent research studies [44••,45,46]. Stern [47•] and others have demonstrated that although the costs of emission reductions are large, the costs of no action are much higher. These concerns are reflected in the 2009 Declaration of the Leaders of the Major Economies Forum (MEF) on Energy and Climate that states: ''*Climate change is one of the greatest challenges of our time. . . . climate change poses a clear danger requiring an extraordinary global response, . . .*'' [48]. The German Advisory Council on Global Change [49••] concluded that sea-level rise and storm and flood disasters have already contributed to conflict, especially during phases of domestic political tension and in the future could threaten cities and industrial regions along the coasts of China, India and the USA. Water-related hazards, such as tropical cyclones, storm surges, flooding, landslides and mudflows are of great threat to coastal and riparian communities whose economies are often closely linked to climate-sensitive resources [26]. Rapid urbanizing settlements are especially vulnerable as incoming people, usually with lower economic capacity often live along river banks, in coastal zones or on unstable hill slopes [50•] With sea level now rising faster than earlier projected [51], there is greater concern about the submerging of low-lying lands, eroding of beaches, increasing salinity of fresh water aquifers and intense coastal flooding [52].

Addressing vulnerabilities through climate change adaptation and disaster risk reduction

Vulnerability to climate-related hazards can be addressed through a combination of two broad approaches: disaster risk reduction (DRR) and climate change adaptation

(CCA) [53••]. The two approaches are different, with origins in different communities of practice, but they intersect with investments in one enhancing the other. The two communities share common nomenclatures and conceptual notion of risk, hazard, vulnerability, and resilience. There are also practical overlaps in the execution of their activities and long-term planning strategies. However, some DRR specialists are skeptical of the sudden popular interest of the adaptation community in their work. One major criticism against the adaptation community (CCA) is the extensive focus on climate as the main driver of hazards and perceived focus on a long-term agenda that only encompasses part of the entire array of hazard (excluding, earthquakes, for instance) [54]. Another major barrier is the mismatch of scales—temporal, spatial and functional [53]. Disaster risk reduction, particularly the response and recovery aspects are usually related to events of short-term duration while climate change community is mostly focused on longer term perspectives, which go far beyond immediate disasters. Also, while the disaster risk community is habitually dealing with local issues, the climate community has mostly worked on the global scale and the prediction of events down to the local scale is still problematic. Despite the differences in both fields, a growing understanding among practitioners is that a holistic approach that tackles the proximate and root causes of vulnerability and hazards will require shared knowledge, tools, method and information from both communities.

Disaster risk reduction refers to the development and application of policies, strategies, and practices that minimize vulnerabilities [55]. It includes measures taken to protect livelihoods and assets of communities and individuals from the adverse impact of hazards [20]. Efforts taken to reduce disasters under this framework may include: disaster education, information and strengthening early warning systems; the development of standardized methods for communities: building codes, emergency management plans; the development of strategies and technologies to reduce the impact of extreme events on the built environment; promotion of risk wise behaviour; and, finally, identification of vulnerable sectors of society including groups and infrastructure and produce plans that address their special needs [56].

Climate change adaptation refers to any activity that reduces the negative impacts of climate change and/or takes advantage of new opportunities that may be presented [57] and can be either anticipatory or reactive. Anticipatory adaptations will usually incur lower long-term costs and are more effective. Designing adaptation policy for climate change requires careful assessments involving relevant stakeholders. Limited adaptation to climate-related hazards has already taken place but seldom taken within broader social and development context. [11,58••,59]. In many countries, climate change still remains a highly politicized issue and there are real concerns about investing in what is considered an abstract problem with low probability of occurrence, at the expense of other immediate and urgent needs. Information about climate change and local interpretation of risk assessments can be cultural and depend on values and ethics [22•,60••,61•]. Other barriers include technological, financial, cognitive and behavioural, as well as significant knowledge gaps. A key issue is the importance of clear communication of science to decision makers [62]. Because of these barriers, actions to reduce vulnerability do not necessarily happen even when there is high adaptive capacity. Fiscal capacity will be needed but limited by competing demands on scarce economic resources. Another limitation on climate change adaptation and related disaster risk reduction will be the ability to predict the detailed evolution of climate variability and change [63].

Mukheiber and Ziervogel [64••] have suggested specific principles required for adaptation planning at city/municipal level. The principles include: identify current trends and future projections of climate change risks on local vulnerability maps; assess the vulnerability at a sectoral level; review in this context current development plans and priorities; develop and prioritize adaptation options using consultative tools, including participatory assessment, social accounting matrices and cost benefit analyses; form a Municipal Adaptation Plan; and implement, monitor, and review the Plan. Durban, South Africa is an example of one of a few cities already taking such approach through the incorporation of climate change into long-term city planning by addressing the vulnerability of key sectors such as health, water and sanitation, coastal infrastructure, disaster management and biodiversity [65•]. Policy and planning processes for adaptation need to take these aspects into account in the design and implementation. Increasing the capacity of countries, regions, communities and social groups to adapt to climate change in ways that are synergistic with wider societal goals of sustainable development should be the objective. Adaptation for the coasts of developing countries will be more challenging than for coasts of developed countries, due to constraints on adaptive capacity [26]. Climate change adaptation needs to be seen as integral to enhancing socio-economic development and equity throughout the world [66•,67].

The Hyogo framework for Action supports such comprehensive approach [68••]. It calls on countries to reduce underlying risk by integrating disaster risk reduction with climate change adaptation and mainstreaming both into national development plans as a key strategy to realizing sustainable development [53,67,68••,69••]. Also many of the general principles and requirement for adaptation listed in the Bali Action Plan [70] are highly relevant to reducing disaster risk, particularly vulnerability assessments, capacity-building and response

strategies, as well as integration of actions into sectoral and national planning.

Not taking action now to incorporate disaster risk reduction and climate change adaptation into public policies may leave significant public liability later on, either because the risk may be too onerous for private sector insurance to carry or because of the sharply rising cost of disaster recovery and public safety [71] as climate change impacts become more fierce and urgent.

A research basis for actions

For many years there have been internationally coordinated research programmes on climate change, disaster risk reduction and related topics. For example, the World Climate Research Programme [URL http://wcrp.wmo.int] was originated in 1980 and the decade of the 1990s was declared to be the International Decade for Natural Disaster Reduction [URL: http://www.unisdr.org/eng/about_isdr/basic_docs/GA-resolution/a-res-54-219-eng.pdf] with a corresponding research programme. Yet, as have been noted above losses due to hazards (climate related and otherwise) are continuing to increase despite advances in the natural and social science of hazards and disasters. The International Council for Science (ICSU; URL: http://www.icsu.org) established first a scoping group and then, in 2005, a Planning Group on natural hazards research. It was the assessment of the ICSU Planning Group that, despite all the existing or already planned activities on natural hazards (which were summarized by their report [72••], an integrated research programme on disaster risk reduction, sustained for a decade or more and integrated across the hazards, disciplines and geographical regions, was an imperative. The value-added nature of such a programme would rest with the close coupling of the natural, socio-economic, health and engineering sciences. Subsequently, the International Council for Science (ICSU), the International Social Sciences Council (ISSC; URL: http://www.unesco.org/ngo/issc/) and the United Nations International Strategy for Disaster Reduction (ISDR) responded to these identified needs with a new international research initiative—Integrated Research on Disaster Risk (IRDR): Addressing the challenge of natural and human-induced environmental hazards [72••,73]. With the focus on disaster risk reduction the research will be aimed at integrated risk analysis, including consideration of relevant human behaviour and decision making processes in face of risk. The IRDR is guided by three-broad research objectives related to: the characterization of hazards, vulnerability and risk; understanding decision-making in complex and changing risk contexts; and reducing risk and curbing losses through knowledge-based actions.

The IRDR research programme fulfills the need for an international, multidisciplinary and an all-hazard research programme emphasized in the Hyogo Framework for Action. The added value of such a research programme lies in its coupling of natural sciences' examination of hazards with socio-economic analysis of vulnerability and mechanisms for engaging the policy decision-making process. The IRDR will draw upon the expertise and scientific outputs of many partners in research with the Earth System Science Partnership [ESSP; URL http://www.essp.org], the World Weather Research Programme [WWRP; URL http://www.wmo.int] and others and will collaborate with the capacity-building and regional research networks programme, Global Change System for Analysis Research and Training [START] project. START has, among other activities, identified cities at risk as a priority and in 2009 held a major workshop focusing on Asia's coastal mega-cities and the risk of climate change [74].

Conclusion

Integrating climate change adaptation and disaster risk reduction can prove useful in responding to current and future climate change. An integrated approach is becoming increasingly relevant and valuable to vulnerable cities and coastal communities seeking to enhance their adaptive capacity and build resilience against a rapidly changing climate. The UN ISDR Global Assessment Report makes three recommendations as key towards 'Investing today for a safer tomorrow'; these are: investment in risk-reducing development; incorporating risk reduction considerations; and a risk reduction governance framework. The report concludes with: ''*Without strengthening these arrangements and capacities, even large investments in development may have little tangible effect or be counter-productive. If the governance arrangements and capacities for risk reduction can be strengthened, small investments can produce huge benefits. Investing today to strengthen capacities is essential if future generations are to enjoy a safer tomorrow.*'' [14••] As countries move forward in addressing the issue of climate change, with much of the focus on emission reduction targets and their challenges, the relationship of climate change and its hazards and the implications for human settlements around the world must be kept in the forefront of thinking and action.

Acknowledgements

The authors acknowledge the Canadian Social Sciences and Humanities Research Council for their support of this research through a Knowledge Synthesis Grant on Climate Security.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Nicholls RJ, Hanson S, Herweijer C, Patmore N, Hallegatte S, Corfee-Morlot J, Château J, Muir-Wood R: **Ranking Port Cities with High Exposure and Vulnerability to Climate Change Extremes Exposure Estimates**. *Organization for Economic Co-operation and Development: environment working papers No. 1* 2008.

2. McGranahan G, Balk D, Anderson B: **The rising tide: assessing the risks of climate change and human settlements in low-elevation coastal zones**. *Environment and Urbanization* 2007, **19-1**:17-37.

3. UN-Habitat: *State of the World Cities Report 2008/2009: Harmonious Cities*, Nairobi, Kenya. http://www.unhabitat.org/downloads/docs/presskitsowc2008/PR%204.pdf (accessed July 14, 2009).

4. • Satterthwaite D, Huq S, Reid H, Pelling M,.Romero Lankao P: **Adapting to Climate Change in Urban Areas: The Possibilities and Constraints in Low- and Middle-income Nations**. *Human Settlements Discussion Paper Series*, 2007 Climate Change and Cities 1, London: International Institute for Environment and Development (IIED).

5. Brown, O: **Migration and Climate Change, IOM Migration**, *Research Series 31*, International Organization for Migration, Geneva, 2008.

6. International Organization on Migration, IOM Policy Briefing, Geneva, May 2009.

7. • Warner K, Ehrhart C, de Sherbinin A, Adamo S, Chai-Onn T: *In Search of Shelter. Mapping the Effects of Climate Change on Human Migration and Displacement*. Cooperative for Assistance and Relief Everywhere, Inc. (CARE); 2009.

8. Leighton M, Loster TR, Warner K: **The challenges of climate and migration**, *Development and Cooperation, No. 09 2009, Volume 50*, September 2009, 323–325.

9. Tacoli C: Crisis or adaptation? Migration and climate change in a context of high mobility. Prepared for Expert Group Meeting on Population Dynamics and Climate Change UNFPA and IIED In Collaboration with UN-HABITAT and the Population Division, UN/DESA, 24–25 June 2009.

10. •• Adger WN, Lorenzoni I, O'Brien KL (Eds): *Adapting to Climate Change: Thresholds, Values, Governance*. Cambridge University Press; 2009:514.

11. Adger WN, Agrawala S, Mirza MMQ, Conde C, O'Brien K, Pulhin J, Pulwarty R, Smit B, Takahashi K: **Assessment of adaptation practices, options, constraints and capacity. Climate Change 2007: Impacts, Adaptation and Vulnerability**. In *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Edited by Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE. Cambridge, UK: Cambridge University Press; 2007: 717-743.

12. Schneider SH, Semenov S, Patwardhan A, Burton I, Magadza CHD, Oppenheimer M, Pittock AB, Rahman A, Smith JB, Suarez A, Yamin F: **Assessing key vulnerabilities and the risk from climate change**. In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Edited by Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE. Cambridge, UK: Cambridge University Press; 2007:779-810.

13. UNISDR Terminology on Disaster Risk Reduction, 2009 http://www.unisdr.org/terminology.

14. •• United Nations International Strategy for Disaster Reduction (UN ISDR): **Global Assessment Report on Disaster Risk Reduction**. *United Nations, Geneva, Switzerland, 2009.* ISBN/ISSN: 9789211320282, 207 pp http://www.preventionweb.net/english/hyogo/gar/report/index.php?id=1130&pid:34&pih:2.

15. Rodriguez J, Vos F, Below R, Guha-Sapir D: **Annual Disaster Statistical Review 2008 – The numbers and trends**. *Centre for Research on the Epidemiology of Disasters*. 2009 http://www.emdat.be.

16. Office for the Coordination of Humanitarian Affairs, Myanmar *Cyclone Nargis*. OCHA Situation Report No. 48, 12 September 2008. http://myanmar.humanitarianinfo.org/coordination/Situation%20Reports/OCHA%20Myanmar%20SitRep%20No.%2048.pdf.

17. International federation of Red Cross and Red Crescent Societies, INDIA: FLOODS, *Information bulletin* no° 05 GLIDE FL-2008-000145-IND 3 September 2008.

18. • Höppe P, Pielke Jr R (Eds), Report of the Workshop on ''Climate Change and Disaster Losses: Understanding and Attributing Trends and Projections'' 25–26 May 2006 Hohenkammer, Germany, 270 pp http://sciencepolicy.colorado.edu/sparc/research/projects/extreme_events/munich_workshop/index.html.

19. Gall M, Borden KA, Cutter SL: **When do losses count? Six fallacies of natural hazards loss data**. *Bull Am Meteor Soc* 2009, **90**:799-809.

20. International Strategy for Disaster Reduction (ISDR), Climate Change and Disaster Risk Reduction, *Briefing No 01*, Geneva, September, 2008.

21. Cardona, OD, et al: *Disaster Risk and Risk Management Benchmarking*. *Information and Indicators Program for Disaster Risk Management.* Institute of Environmental Studies (IDEA) and Inter-American Development Bank (IDB), 2004, http://idea.manizales.unal.edu.co/ProyectosEspeciales/BID/desc_gta.asp?IdActividadAcademica=33.

22. • O'Brien K, Heyd T: **Culture, Values, & World Perspectives as factors in Responding to Climate Change**. In *Synthesis Report, Climate Change, Global Risk, Challenges & Decisions* – Copenhagen 2009; 10–21 March, http://climatecongress.ku.dk/pdf/synthesisreport (accessed, July 10, 2009).

23. Wisner B, O'Brien G, O'Keefe P, Rose J: **Climate change and disaster management**. *Disasters* 2006, **30(1)**:64-80 Overseas Development Institute, Blackwell Publishing, Oxford, UK.

24. Report by the Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina: **A Failure of Initiative**. Final Report. February 15, 2006. http://www.gpoacess.gov/congress/index.html.

25. • World Meteorological Organization: **Water and Disasters, Be informed and Be prepared**, Geneva, Switzerland, 2004, p 2–20.

26. Nicholls RJ, Wong PP, Burkett VR, Codignotto JO, Hay JE, McLean RF, Ragoonaden S, Woodroffe CD: **Coastal systems and low-lying areas**. *Climate Change 7: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (Eds), Cambridge University Press, Cambridge, UK, 2007, 315–356.

27. Wahlström M. (Assistant Secretary-General for Disaster Risk Reduction and Special Representative of the U.N. Secretary-General for the implementation of the Hyogo Framework for Action) – quoted in Birkmann J, Tetzlaff G, Zentel KO (Eds) Addressing the Challenge: Recommendations and Quality Criteria for Linking Disaster Risk Reduction and Adaptation to Climate Change. 2009 DKKV Publication Series 38, p 5.

28. Alexander LV *et al.*: **Global observed changes in daily climate extremes of temperature and precipitation**. *J Geophys Res* 2006, **111**:D05109 doi: 10.1029/2005JD006290.

29. Kharin VV, Zwiers FW, Zhang Z, Hegerl GC: **Changes in temperature and precipitation extremes in the IPCC ensemble of global coupled model simulations**. *J Climate* 2007, **2015**:1419-1444 doi: 10.1175/JCLI4066.1.

30. Tebaldi C, Hayhoe K, Arblaster JM, Meehl GA: **Going to extremes: an intercomparison of model-simulated historical and future changes in extreme events**. *Clim Change* 2006, **79**:185-211.

31. Hegerl GC, Zwiers FW, Kharin VV, Stott PA: **Detectability of anthropogenic changes in temperature and precipitation extremes**. *J Climate* 2004, **17**:3683-3700.

32. •• Intergovernmental Panel on Climate Change: Summary for Policymakers. In: Climate Change 2007: **The Physical Science Basis**. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (Eds) 2007 Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

33. Webster PJ, Holland GJ, Curry JA, Chang HR: **Changes in tropical cyclone number duration, and intensity in a warming environment**. *Science* 2005, **309**:1844-1846.

34. Chan JCL: **Comment on ''changes in tropical cyclone number duration, and intensity in a warming environment''**. *Science* 2006, **311**:1713.

35. Pielke RA Jr, Landsea C, Mayfield M, Laver J, Pasch R: **Hurricanes and global warming**. *Bull Am Meteor Soc* 2005: 1571-1575. 86-11.

36. Anthes RA, Corell RW, Holland G, Hurrell JW, MacCracken MC, Trenberth KE: **Hurricanes and global warming–potential linkages and consequences**. *Bull Am Meteor Soc* 2006, **87**:623-628.

37. Pielke RA Jr, Landsea C, Mayfield M, Laver J, Pasch R: **Reply to hurricanes and global warming potential linkages and consequences**. *Bull Am Meteor Soc* 2006, **87**:628-631.

38. Emanuel K: **Increasing destructiveness of tropical cyclones over the past 30 years**. *Nature* 2005, **436**:686-688.

39. Landsea CW: **Hurricanes and global warming**. *Nature* 2005, **438**:E11-E12.

40. Emanuel K: **Emanuel replies**. *Nature* 2005, **438**:E13.

41. • Solomon S, Qin D, Manning M, Alley RB, Berntsen T, Bindoff NL, Chen Z, Chidthaisong A, Gregory JM, Hegerl GC, Heimann M, Hewitson B, Hoskins BJ, Joos F, Jouzel J, Kattsov V, Lohmann U, Matsuno T, Molina M, Nicholls N, Overpeck J, Raga G, Ramaswamy V, Ren J, Rusticucci M, Somerville R, Stocker TF, Whetton P, Wood RA and Wratt D: **Technical Summary**. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2007, p. 52.

42. • Domingues CM, Church JA, White NJ, Gleckler PJ, Wijffels SE, Barker PM, Dunn JR: **Improved estimates of upper-ocean warming and multi-decadal sea-level rise**. *Nature* 2008, **453**:1090-1094.

43. •• Intergovernmental Panel on Climate Change: Summary for Policymakers. In: Climate Change 2007: **Impacts, Adaptation and Vulnerability**. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (Eds), 2007 Cambridge University Press, Cambridge, UK, 7–22.

44. •• Parry M, Palutikof J, Hanson C, Lowe J: **Climate policy: squaring up to reality**. *Nature Reports: Climate Change* 2008, **2**:168-170.

45. Meinshausen M, Meinshausen N, Hare W, Raper SCB, Frieler K, Knutti R, Frame DJ, Allen MR: **Greenhouse-gas emission targets for limiting global warming to 2 degrees C**. *Nature* 2009, **458(7242)**:1158-1196.

46. Smith JB, Schneider SH, Oppenheimer M, Yohe GW, Hare W, Mastrandrea MD, Patwardhan A, Burton I, Corfee-Morlot J, Magadza CHD, Fussel H-M, Pittock AB, Rahman AF, Suarez A, van Ypersele J-P: **Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) ''reasons for concern''**. In *Proceedings of the National Academy of Sciences, USA* 2009, **106(11)**:4133-4137 doi/10.1073/pnas.0812355106.

47. • Stern NH: *The Economics of Climate Change: The Stern Review* Cambridge, UK: Cambridge University Press; 2007:. p. 149.

48. MEF - Major Economies Forum on Energy and Climate (2009) http://www.g7.utoronto.ca/summit/2009laquila/2009-mef.html (accessed July 20, 2009).

49. •• German Advisory Council on Global Change: **Climate Change as a Security Risk**. Earthscan Publications 2008, 271 pp.

50. • Huq S, Kovats S, Reid H, Satterthwaite D: **Editorial: reducing risks to cities from disasters and climate change**. *Environment and Urbanization* 2007, **19(1)**:3-15.

51. Rahmstorf S, Cazenave A, Church JA, Hansen JE, Keeling RF, Parker DE, Somerville RCJ: **Recent climate observations compared to projections**. *Science* 2007, **316(5825)**:709-1709.

52. Anderson K, Cahoon R, Gill S, Thieler E, William S, Titus J: **Coastal sensitivity to sea-level rise: a focus on the mid-atlantic region**. *A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*. U.S. Environmental Protection Agency, Washington DC, USA. 2009.

53. •• Birkmann J, Tetzlaff G, Zentel KO (Eds): *Addressing the Challenge: Recommendations and Quality Criteria for Linking Disaster Risk Reduction and Adaptation to Climate Change*. DKKV Publication Series; 2009:38.

54. Mitchell T, van Aalst M: **Convergence of disaster risk reduction and adaptation to climate change**. *A review for UK DFID* **(October)**2008.

55. Pelling M, Schipper L: **Climate adaptation as risk management: limits and lessons from disaster risk reduction**. *IHDP Update* 2009, **2**:.

56. Applegate D: **Challenges to Building a Disaster Resilient Nation**. *Science News.* www.sciencenews.org 2008.

57. Lemmen DS, Warren FJ, Lacroix J: **Synthesis**. In *From Impacts to Adaptation: Canada in a Changing Climate 2007.* Edited by Lemmen DS, Warren FJ, Lacroix J, Bush E. Ottawa, ON: Government of Canada; 2008:1-20.

58. •• Dodman D, Satterwaite D: **Institutional capacity, climate change, adaptation and the urban poor**. *IDS Bull* 2008, **39(September (4))**.

59. Satterthwaite D, Huq S, Pelling M, Reid H, Romero Lankao P: **Adapting to Climate Change in Urban Areas: The possibilities and constraints in low- and middle-income nations**. Human Settlements Discussion Paper Series Theme: Climate Change and Cities – 1 International Institute for Environment and Development (IIED). http://www.iied.org/HS/topics/accc.html; www.iied.org/pubs/display.php?o=10549IIED, ISBN: 978-1-84369-669-8.

60. •• Hulme M: *Why We Disagree About Climate Change*. Cambridge University Press; 2009.

61. • O'Brien KL: In *Do values subjectively define the limits to climate change adaptation. In Adapting to Climate Change: Thresholds, Values Governance.* Edited by Adger WN, Lorenzoni I, O'Brien KL. Cambridge University Press. © Cambridge University Press; 2009: 164-180.

62. McBean GA: **Communicating to policy makers climate science with its inherent uncertainties**. In *Global Warming and Climate Change.* Edited by Grover V, Enfield. New Hampshire: Science Publishers; 2009:577-594.

63. Dessai S, Hulme M, Lempert R, Pielke R Jr: **Climate prediction: a limit to adaptation?** In *Adapting to Climate Change: Thresholds, Values Governance.* Edited by Adger WN, Lorenzoni I, O'Brien KL. Cambridge University Press; 2009:64-78.

64. •• Mukheibir P, Ziervogel G: **Developing a Municipal Action Plan (MAP) for climate change: the City of Cape Town**. *Environ Urban* 2007, **19.1**:143-158.

65. • Roberts D: **Thinking globally, acting locally: institutionalizing climate change at the local government level in Durban South Africa**. *Environ Urban* 2008. 20.2.

66. • Richardson K, Steffen W, Schellnhuber HJ, Alcamo J, Barker T, Kammen DM, Leemans R, Liverman D, Munasinghe M, Osman-Elasha B, Stern N., Wæver O: **Synthesis Report**. Climate Change, Global Risks, Challenges and Decisions, Copenhagen, 10-12 March 2009 www.climatecongress.ku.dk.

67. Hyogo Framework for Action http://www.unisdr.org/wcdr/intergover/official-doc/L-docs/Hyogo-framework-for-action-english.pdf.

68. •• McBean G: **Coping with global environmental change: need for an interdisciplinary and integrated approach**. In *Coping with Global Environmental Change, Disasters and Security Threats, Challenges Vulnerabilities and Risks. Hexagon Series on Human and Environmental Security and Peace*, vol. 5. Edited by Brauch HG, Oswald Spring U, Mesjasz C, Grin J, Kameri-Mbote P, Chourou B, Dunay P, Birkmann J. Berlin, Heidelberg, New York: Springer-Verlag; 2009.

69. •• Schipper L, Pelling M: **Disaster risk, climate change and international development: scope for, and challenges to, integration**. *Disasters* 2006, **30(1)**:19-38.

70. Bali Action Plan http://www.unfccc.int.

71. Mill E: **Synergisms between climate change mitigation and adaptation: an insurance perspective**. *Mitigation and Adaptive Strategies for Global Change,* 2007(12) 809–842, doi:10.1007/s11027-007-9101-x.

72. •• International Council for Science: **A Science Plan for Integrated Research on Disaster Risk: Addressing the challenge of natural and human-induced environmental hazards**. 2008 http://www.icsu.org/Gestion/img/ICSU_DOC_DOWNLOAD/2121_DD_FILE_Hazard_Report.pdf.

73. McBean G: **Introduction of a new International Research Program: Integrated Research on Disaster Risk - The challenge of natural and human-induced environmental hazards**. In *Geophysical Hazards: Minimizing Risk, Maximizing Awareness, International Year of Planet Earth series.* Edited by Beer T. Springer-Verlag; 2009.

74. START: Cities at Risk: Developing Adaptive Capacity for Climate Change in Asia's Coastal Megacities. 2009. http://www.start.org.