Report of the Workshop on

"Climate Change and Disaster Losses:
Understanding and Attributing Trends and Projections"

25-26 May 2006
Hohenkammer, Germany

WORKSHOP SUMMARY REPORT

Introduction

In summer 2005 Roger Pielke, Jr. of the Center of Science and Technology Policy Research at the University of Colorado and Peter Höppe of the Geo Risks Research Department of Munich Re learned from each other that each planned to organize a workshop on the assessment of factors leading to increasing loss trends due to natural disasters. Both agreed that such a workshop was timely, especially given the apparent lack of consensus on the role of climate change in disaster loss trends. Roger Pielke, Jr. and Peter Höppe decided to have a common workshop in 2006 in Germany to bring together a diverse group of international experts in the fields of climatology and disaster research. The general questions to be answered at this workshop were:

- What factors account for increasing costs of weather related disasters in recent decades?
- What are the implications of these understandings, for both research and policy?

The participants were selected by a workshop organizing team that met in December, 2005. Participants were selected for their high level of competence and to represent a wide range of different attitudes to the subject. All participants came into the workshop agreeing that anthropogenic climate change is a concern.

In total 32 participants from 13 countries attended the two day workshop (list of participants attached). "White papers" from 25 participants were submitted in advance and formed the basis of the discussions. The workshop was organized in 4 sessions:

1. Trends in extreme weather events
2. Trends in Damages
3. Data issues – extreme weather events and damages
4. Syntheses discussion

In the syntheses session the discussion was focused on finding consensus positions among the participants on statements about the attribution of disaster losses and the policy implications. These 20 statements are listed in the preceding executive summary and are described in more detail below. Following the Workshop Summary Report are the white papers which provide the views of individual participants. Participants were provided the opportunity to revise their white papers following the workshop. The report concludes with participant biographies and the Workshop agenda.[3]

The workshop was sponsored by Munich Re, the U.S. National Science Foundation, the Tyndall Center for Climate Change Research, and the GKSS Research Center.

1. Climate change is real, and has a significant human component related to greenhouse gases.

We adopted the IPCC definition of climate change. According to the IPCC (2001) *climate change* is

> "Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use."[4]

[3] The views expressed in this report are those of the participating individuals. Institutional affiliations are only provided for identification purposes.

[4] http://www.grida.no/climate/ipcc_tar/wg1/518.htm

The IPCC also defines *climate variability* to be

> "Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability)."

We use the phrase *anthropogenic climate change* to refer to human-caused effects on climate.

2. Direct economic losses of global disasters have increased in recent decades with particularly large increases since the 1980s.

A wide range of datasets and analyses from around the world paint a consistent picture: Direct economic losses (adjusted for inflation, but not otherwise adjusted) have been increasing rapidly in recent decades around the world (Crompton et al. Dlugolecki, Faust et al., Muir-Wood et al., Pielke, and Zapata-Marti white papers). Global data on disasters collected by Munich Re is illustrative of the more general conclusions. Similar data has been collected by Swiss Re and CRED at the Leuven Universty (EM-DAT).

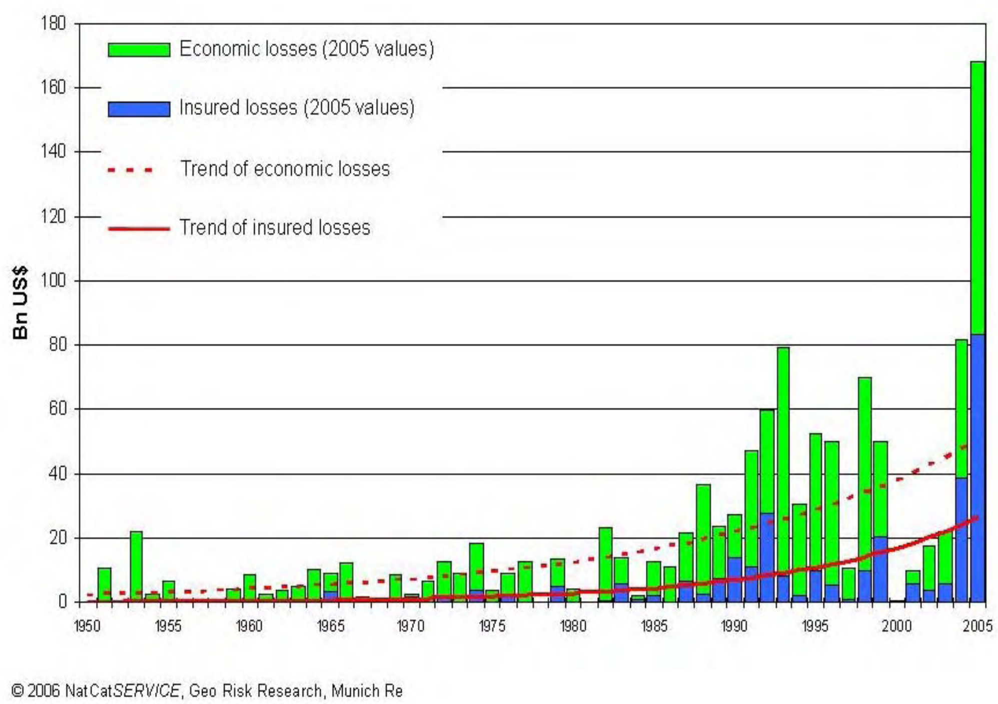

Fig. 1 Global trend in losses due to great weather disasters.

It is important to recognize that disaster losses do not increase in every region at a constant rate (Muir-Wood et al. white paper). Some regions may see decreasing trends (Muir-Wood et al. white paper). Disaster losses typically come in discrete, large values and the trend record is driven by the increase in the costs of the largest disasters, such as hurricanes in the United States (Faust et al. white paper). Since the 1980s there has been a particularly large increase in the frequency and magnitude of disasters.

3. The increases in disaster losses primarily result from weather related events, in particular storms and floods.

According to the data of the Munich Re NatCat*SERVICE*® database of great natural disasters, since 1950 the contribution of weather related events like windstorms and floods amounts to 69% of all economic (38% windstorm, 25% floods, 6% other weather related events) and even 89% (79% windstorm, 5% floods, 5% other weather related events) of insured losses. The trend of the global numbers of great natural catastrophes since 1950 shows a steep increase in weather related disasters from about one event in the 1950s to about 5 in recent decades while geophysically-caused disasters (earthquakes, tsunamis, volcano eruptions) have increased from one to less than 2 in the same time. Weather related disasters therefore are the major contributor to increasing losses due to natural disasters (more details in Faust et al. white paper).

4. **Climate change and variability are factors which influence trends in disasters.**

   Climate change and variability are important factors which shape patterns and magnitudes of disaster losses.

   For example, even after adjusting for changes in inflation, wealth, and population in the 1970s and 1980s the United States experienced approximately $41 billion and $36 billion in hurricane losses, respectively (Data from Pielke white paper). By contrast, the 1990s and 2000s (through 2005) saw $87 billion and $167 billion. The 1970s and 1980s were characterized by below average hurricane activity and storm landfalls, whereas the period since 1995 has seen very active seasons and correspondingly more landfalls, particularly in 2004 and 2005 (Knutson white paper; Faust et al. white paper).

   Similarly, in Australia 13 tropical cyclones made landfall along its east coast from 1966-1975 whereas 7 made landfall from 1996 to 2005 (and 1976-1985 had 7 landfalls and 1986-1995 had 6, Crompton et al. white paper). Loss data adjusted for changes in inflation, wealth, and population show a corresponding decrease in losses between the two periods. Similar results have been found for floods (Pielke white paper) and other weather events in different regions around the world (Muir-Wood et al. white paper). Thus, climate change and variability are factors which influence trends in disasters.

5. **Although there are peer reviewed papers indicating trends in storms and floods there is still scientific debate over the attribution to anthropogenic climate change or natural climate variability. There is also concern over geophysical data quality.**

   According to the methodology of the IPCC, detection and attribution of trends in the frequency and/or intensity of storms and floods to anthropogenic climate change depends on the rejection of the null hypothesis that trends which have been detected as statistically significant are within the range of natural climate variability. When this null hypothesis is rejected, "detection" is achieved and in a second step, the most probable mix of eternal drivers for this change is determined - a step called "attribution". In its 2001 report the IPCC found no overall pattern of increasing extreme events, though it did identify changes in some regions. Attribution of a trend to a specified driver (e. g. anthropogenic climate change) is not easy to achieve. With respect to storms and floods in some cases there are insufficient record lengths, which consequently do not allow the exclusion of long-term internal variability as causes of observed trends or to assess how well real internal climate variability is reflected in climate model simulation runs.

   Other problems arise from inhomogeneous data sets suffering from changes in measurement techniques. For instance hurricane wind speeds were measured by empirical observation of wave characteristics from ships, by using pressure-wind relationships, by measuring velocities of airborne sondes dropped from aircrafts or by Doppler radar techniques. Equally the measurement intervals have changed over time. All these techniques need to be cross-evaluated and adjustments need to be done. Changing river discharges over time might depend on changing flow regimes accounted for by changing land use patterns or changing hydrodynamic characteristics of rivers brought about by hydro-engineering construction work over time.

6. **IPCC (2001) did not achieve detection and attribution of trends in extreme events at the global level.**

   Since IPCC 2001 additional research results have been published on the changing nature of extremes. Regarding 100-year floods on large river basins exceeding 200,000 km^2 Milly et al. (2002) found a statistically significant positive trend consistent with climate model results over the 20th century. A subsequent paper presented evidence that the global pattern of 20th century trends in mean annual streamflow was partially controlled by anthropogenic climate change though trends in single regions might be explained by internal variability (Milly et al. 2005). In addition evidence for increasing occurrences of intense extra-tropical precipitation events has been presented (Groisman et al. 2005).

   Regarding changing hurricane activity levels several studies document over the past decades a trend of more intense storms (in terms of peak intensity and portion of lifetime covered by very high wind speeds). These shifts are associated with positive trends in tropical sea surface temperatures – globally some 0.5 °C since 1970 - as the key parameter (Emanuel 2005a and 2005b; Webster et al. 2005; Hoyos et al. 2006). There are recently published studies attributing trends in sea surface temperatures since 1970 to anthropogenic climate change (e. g. Barnett et al. 2005). SST has been presented as the key parameter for tropical cyclone activity levels with evidence presented for storm intensity shifts driven by climate change due to anthropogenic GHG emissions forcing (Emanuel 2005a and 2005b; Hoyos et al. 2006). Emanuel (2006) stresses that a better parameter to use than SST is the potential intensity. However, the relative importance for TC activity rates of SST or potential intensity versus other factors such as vertical wind shear remains contested among scientists."

The sensitivity of hurricane intensity to sea surface warming implied in the Emanuel (2005a) results exceeds by a factor of 6 the sensitivity inferred from Knutson and Tueleya's (2004) idealized hurricane modeling study, which found a sensitivity of about 4% per degreee Celsius SST increase. In a recent examination of Atlantic potential intensity data since about 1980, the discrepancy with Knutson's modelling work appears to be a factor of 4, and the discrepancy might be partly attributable to a general reduction of surface wind speeds in the basin over time (Emanuel 2006; Knutson white paper). The Emanuel and Webster et al. studies have motivated a scientific debate, which focuses on the question of whether such strong observed tropical cyclone trends arise due to problems with observations—mainly data homogeneity issues (Landsea 2005; Chan 2006; Pielke et al. 2005; Anthes et al. 2006; Pielke et al. 2006). A 2006 statement by the World Meteorological Organization, drafted by scientists holding different views on the subject says:

> Given time the problem of causes and attribution of the events of 2004–2005 will be discussed and argued in the refereed scientific literature. Prior to this happening it is not possible to make any authoritative comment.

The IPCC will report again on this subject in 2007.

7. **High quality long-term disaster loss records exist, some of which are suitable for research purposes, such as to identify the effects of climate and/or climate change on the loss records.**

The longest and most complete global data sets of disaster losses have been compiled by the leading re-insurance companies Munich Re and Swiss Re. There is another global disaster data base by CRED, focusing on humanitarian aspects of natural disasters. Other (most of them regional) datasets exist in various organizations and government agencies around the world. For instance, flood and hurricane damage data has been kept by the U.S. government since the beginning of the past century. Some regions in Europe have archived records of disasters going back many hundreds of years, and the United Kingdom has been identified as having particularly long records. Such datasets are valuable resources for understanding disaster trends. Only a few however have been rigorously peer-reviewed.

8. **Analyses of long-term records of disaster losses indicate that societal change and economic development are the principal factors responsible for the documented increasing losses to date.**

Societal change and economic development are the principal factors responsible for the documented increasing losses to date. Such results have been found looking at disasters globally (Burton white paper; Kemfert and Schumacher white paper; Muir-Wood et al. white paper) and in specific regions and for specific phenomena, such as with respect to US tornados (Brooks white paper), Australian weather-related hazards (Crompton et al. white paper), floods in the United Kingdom (Dlugolecki white paper), U.S. hurricane and floods (Pielke white paper), Indian tropical cyclones (Raghavan white paper), Chinese floods and storms (Ye white paper), Latin American floods and storms (Zapata-Marti white paper), and Caribbean hurricanes (Tompkins white paper).

Societal changes include population growth and migration to exposed locations, increasing wealth at risk to loss, policies which lead to increased (and in the case of risk mitigation, decreased) vulnerabilities, development characteristics (Gurjar et al. white paper; Burton white paper; Zapata-Marti white paper). Changes in various societal factors vary according to location. For instance, China has seen its GDP grow as fast as 8.5% per annum (Ye white paper) and regions such as Florida in the United States have seen population growth at a rate far greater than the national average. Europe has seen little population growth overall, but significant increases in wealth. Different patterns of societal change result in correspondingly different effects on trends in disaster losses. There is evidence that in some locations disaster mitigation policies have reduced vulnerabilities (Bouwer white paper), but the effect on losses and loss trends remains to be quantified.

9. **The vulnerability of communities to natural disasters is determined by their economic development and other social characteristics.**

The impact of extreme weather events therefore varies between the developing and the developed world. While the developed world sees the highest absolute direct economic (and insured) losses from weather extremes, the largest numbers of casualties and affected people occur in poor communities. For instance, the 2005 tsunami disaster that struck in different countries around the Andaman Sea revealed that there are large differences in impacts as well as speeds of recovery afterwards, depending on the economic and social development level of the coastal community (Adger et al. 2005). Disaster losses expressed as a percentage of GDP (e.g. Zapata-Marti white paper), or corrected for purchasing power parity (PPP) may give a better approximation of the economic impacts on developing countries.

Unsustainable exploitation of natural resources in many regions in the world may exacerbate the impacts of natural disasters, for instance by deforestation that may increase the frequency and intensity of floods (see Gurjar et al. white paper). The quantitative impacts of current and future economic development on vulnerability and loss trends are unknown (see Tompkins white paper). Some developments may reduce risks, as preparedness offsets risk. Others developments may increase risks. The relative role of disaster mitigation activities in addressing disaster losses remains poorly documented and understood. Recent studies comparing relevant cost-benefit analysis conclude, in spite of the methodological challenges, that the benefit to cost ratio of investments in disaster mitigation are about 2-4 (Mechler 2005).

10. **There is evidence that changing patterns of extreme events are drivers for recent increases in global losses.**

Statistics of loss events related to weather show both globally and for some regions substantial increases over the past decades. The major contributions are from storms and floods. For instance, in the North Atlantic there has been since the mid-1990s a higher basin-wide hurricane activity then on average. Before this period, since the beginning of the 1970s there was a lower-then-on-average activity level. Although there is concern about the quality of intensity data prior to the late 1960s on account of changes in observational techniques there is plenty of evidence that there was another period of high activity prior to 1970. Damage in the U.S. related to hurricanes since 1995 (11 years) already exceeds that which occurred from 1970-1994 (25 years), even after adjusting the data for societal factors.

11. **Because of issues related to data quality, the stochastic nature of extreme event impacts, length of time series, and various societal factors present in the disaster loss record, it is still not possible to determine the portion of the increase in damages that might be attributed to climate change due to GHG emissions.**

Long time series disaster loss data for some regions is either unavailable or of poor quality for various phenomena, particularly before the 1980s (e.g., for China) and the 1970s (Australia, Canada, Caribbean, Central America, China, Europe, India, Japan, Korea, United States) (Faust et al. white paper). The historical loss record is strongly influenced by a small number of very large events such as hurricane Katrina, which accounts for about 50% of global storm and flood losses in 2005 (Faust et al. white paper; Muir-Wood et al. white paper). Thus there is a strong element of chance in short-term records. Long-term, homogenous loss records of research quality are generally quite rare. Various societal factors such as changes in population and development, risk reduction measures, changing definitions and thresholds of disaster losses, land use and local environmental degradation, and so on, introduce many factors into changing patterns of losses over time.

12. **For future decades the IPCC (2001) expects increases in the occurrence and/or intensity of some extreme events as a result of anthropogenic climate change. Such increases will further increase losses in the absence of disaster reduction measures.**

It is a logical consequence that, if there will be more extreme events and/or these extreme events will increase in intensity losses will also increase. In general the increase in losses is associated linearly with the number of events (2 events mean 2-times the losses of one event) but nonlinearly with the intensity increase (e.g. for windstorms losses are a function of the exponent of the wind speed, which may range from 3-6). Only preventive measures like stricter building codes or movement of population out of high risk areas could compensate for such increasing trends.

13. In the near future the quantitative link (attribution) of trends in storm and flood losses to climate changes related to GHG emissions is unlikely to be answered unequivocally.

For the near future, issues related to data quality, the stochastic nature of extreme event impacts, length of time series, and various societal factors present in the disaster loss record, are expected to persist, making it unlikely that the quantitative link (attribution) of trends in storm and flood losses to climate changes related to GHG emissions will be answered unequivocally.

As a consequence we urge decision makers not to expect an unequivocal resolution of questions about the linkage of growing disaster losses and climate changes related to GHGs, as this area will remain an important area of study for years to come. Such uncertainty need not preclude proactive decision making. For instance, the insurance industry has already taken decisions to recognize the implications of increasing losses and loss potentials related to changing risk of hurricanes.

Policy Implications

14. Adaptation to extreme weather events should play a central role in reducing societal vulnerabilities to climate and climate change.

There are three main reasons for this conclusion.

1. Adaptation to climate variability and extremes has always been necessary and future adaptation can be most effectively designed if it continues and builds upon past experience. Declining global and U.S. trends over the long term in mortality and morbidity (or injury) rates due to various extreme weather events suggest that adaptation might successfully help contain losses (Goklany white paper).
2. Mitigation of greenhouse gas emissions will take substantial time to become effective and in the meantime adaptation will become increasingly necessary.
3. There is a current adaptation deficit, and practices of maladaptation and unsustainable development are serving to increase vulnerability in many places. In particular, the insufficient pricing of mitigation and adaptation in terms of goods and services preserved in the face of changes and extreme events' impacts leads to inappropriate valuation of risk reducing measures in investment and financial viability calculations both at the public and private sector level, particularly in developing countries.

In all socio-economic sectors impacts of climate variability and extremes occur now and adaptation policies and measures are used to help to reduce exposure and impacts. Climate changes, regardless of cause, may require a broader perspective in adaptive capacity than has been the case in the past. Generally these activities are in the domain of specialized professionals such as agronomists for agriculture, engineers and hydro-meteorologists for water management, irrigation, flood control etc., structural and design engineers for infrastructure , buildings etc., public health officials for infectious and vector borne diseases etc. The work of these professionals is not referred to as adaptation but may be described as plant breeding and selection, flood control or flood damage reduction, and so forth.

Current adaptation as now practiced is not sufficient to prevent the growth of losses from climate change, variability, and extremes. While adaptation cannot be expected to reduce present or future losses to zero it could be more effective.

Decision processes that are dependent upon unequivocal quantitative linkages of disaster losses to climate change might be reconsidered in the context of this expected continuing uncertainty. Decision makers might embrace more fully an alternative approach to decision making, e.g., based on vulnerability reduction or proactive risk management.

15. **Mitigation of GHG emissions should also play a central role in response to anthropogenic climate change, though it does not have an effect for several decades on the hazard risk.**

    Anthropogenic climate change results from the emission of greenhouse gases. CO_2 contributes most to the anthropogenic greenhouse effect and primarily is released when burning fossil fuels like coal, oil or natural gas. Other relevant green house gases are Methane, N_2O and CFCs and water vapor. Once released into the atmosphere CO_2 has an average residence time in the atmosphere of up to 200 years. This means that emission reductions of CO_2 cannot reduce its concentration on a short term and therefore cannot result in immediate changes to the climate system. Emission reductions, however, influence the future levels of CO_2 in the atmosphere and by this an even further increase in global temperatures and the potential for more and more intensive extreme events. Emission reductions are necessary to reduce the risk to reach levels of CO_2 concentrations which might lead to abrupt climate changes and/or processes in the atmosphere which could become irreversible (Kemfert and Schumacher white paper).

16. **We recommend further research on different combinations of adaptation and mitigation policies.**

    Adaptation and mitigation have been treated largely as separate and unrelated activities. The research and its application are in the hands of different types of professionals with different expertise and technical jargon often working in different domains. From an economic perspective mitigation and adaptation are often regarded as competing alternatives and some theoretical optimal mix of adaptation and mitigation is thus recommended. More recently the idea that there can be useful synergies and complementarities between adaptation and mitigation has been gaining in favor and currency. A chapter in the forthcoming IPCC 4th Assessment will be devoted to the benefits of adaptation and mitigation actions. For instance, this can take the form of seeking adaptation benefits in projects which are primarily motivated by mitigation objectives and vice versa.

17. **We recommend the creation of an open-source disaster database according to agreed upon standards.**

    Currently, only a few global databases exist, the most comprehensive being the NatCat*SERVICE*® database of Munich Re, the Sigma reports by Swiss Re and the EM-DAT database of CRED at Leuven University.

    The most comprehensive disaster databases are currently not publicly available. An open-source database would enable the scientific community to study worldwide disaster characteristics and trends as well as contribute to assessing and improving its quality.

    The databases mentioned above are expected to be reliable for data covering the period since the 1980s only for most areas in the world, however detailed and rigorous peer-reviewing of disaster datasets would provide greater understanding as to their accuracy. This is also the period for which the best quality data is available (see graphs presented in Faust et al. white paper). This period is too short for the purpose of climate-damage investigations. For the time before 1980 many smaller events are often not included, information is mostly available for large disasters, resulting in an incomplete overview of actual impacts from weather events. It has been estimated, however, that including all small events would probably increase the amount of losses recorded from "great natural disasters" in the NatCat*SERVICE*® Database by about 20% only.

    There is no single standard for collecting disaster information. Information is collected from various sources, including scientific reports, governmental and non-governmental organizations, weather services, insurance industry and news agencies (Faust et al. white paper). Linked to this, there is no single quality control standard of the disaster reports included in the different databases, though for some of the individual databases a high quality control standard is in place.

18. **In addition to fundamental research on climate, research priorities should consider needs of decision makers in areas related to both adaptation and mitigation.**

    Workshop participants agreed that in addition to fundamental research on climate, there exists considerable opportunity to focus research priorities on needs of decision makers taking decisions with short and long term implications related to climate adaptation and mitigation.

19. **For improved understanding of loss trends, there is a need to continue to collect and improve long-term and homogenous datasets related to both climate parameters and disaster losses.**

The collection of such data would consist of efforts to continue to record current climatological and weather observations and the collection of information on extreme weather events and their impacts, as well as extending current records back into the past.

For the latter, data on climate and extreme weather events dating up to 1000 years before present can be collected from paleo records contained in sediments and various other environmental records. For the more recent past, observational records and anecdotal information on weather and disasters in historical archives that are currently not accessible for research could be made publicly available. For instance, synthesis of document data and instrumental observations can help to extend flood records back to centuries before present (see for example Brázdil white paper). Also robust instrumental proxies for the frequency and/or intensity of weather events need to be compiled, as it has been done for NE Atlantic storminess using local air pressure and local water level readings (von Storch and Weisse white paper). Such proxies can often be compiled for the past two, or so, centuries.

The improvement of such records can aid to assess current investigations of risks and can help put current risks into a wider historical perspective. It will allow better understanding of loss trends by differentiating between long-term changes in the hazards themselves and changes in vulnerability.

20. **The community needs to agree upon peer reviewed procedures for normalizing economic loss data.**

Methods of normalizing economic loss data provide insight to trends in disaster losses. Various approaches to normalization have appeared in the peer reviewed literature (See, e.g., citations in Muir-Wood et al., Crompton et al., and Pielke white papers). A community consensus on approaches and their application in various contexts would provide a valuable resource to scholars and decision makers. In particular, understanding how to adjust data for significant economic changes over time, the integration of data from different countries and economic systems, and the role of risk reduction policies should be considered in such an effort.

References

Adger, W.N., T.P. Hughes, C. Folke, S.R. Carpenter, and J. Rockström, 2005. Social-Ecological Resilience to Coastal Disasters. Science, Vol. 309. no. 5737, pp. 1036 – 1039.

Anthes, R.A., R.W. Corell, G. Holland, J.W. Hurrell, M.C. MacCracken, K.E. Trenberth, 2006. Hurricanes and Global Warming—Potential Linkages and Consequences. Bulletin of the American Meteorological Society, Vol 87, pp. 623-628.

Barnett, T. P., D.W. Pierce, K.M. AchutaRao, P.J. Gleckler, B.D. Santer, J.M. Gregory, and W.M. Washington, 2005. A Warning from Warmer Oceans. Science, Vol. 309. no. 5732, pp. 284 – 287.

Chan, J. C.L., 2006. Comment on "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment." Science, Vol. 311: pp. 1713.

Emanuel, K., 2005a. Increasing destructiveness of tropical cyclones over the past 30 years. Nature, Vol. 436, pp. 686-688.

Emanuel, K., 2005b. Emanuel replies. Nature, Vol. 438, pp. E13.

Emanuel, K., 2006. Environmental influences on tropical cyclone variability and trends. Proceedings of 27th AMS Conference on Hurricanes and Tropical Meteorology, #4.2, http://ams.confex.com/ams/pdfpapers/107575.pdf.

Groisman, P.Y., R.W. Knight, D.R. Easterling, T.R. Karl, G.C. Hegerl, and V.N. Razuvaev, 2005. Trends in Intense Precipitation in the Climate Record. Journal of Climate, Vol. 18, No. 9, pp. 1326-1350.

Hoyos, C. D., P.A. Agudelo, P.J. Webster, and J.A. Curry, 2006. Deconvolution of the Factors Contributing to the Increase in Global Hurricane Intensity. Science, 16 March.

IPCC - Intergovernmental Panel on Climate Change, 2001.Climate Change 2001: The Scientific Basis. New York: Cambridge University Press.

Knutson, T. R. and R.E. Tuleya, 2004. Impact of CO2 –Induced Warming on Simulated Hurricane Intensity and Precipitation: Sensitivity to the Choice of Climate Model and Convective Parameterization. Journal of Climate, Vol. 17, pp. 3477–3495.

Landsea, C. W., 2005. Hurricanes and global warming. Nature, Vol. 438, pp. E11-E12.

Mechler, R., 2005. Cost-benefit Analysis of Natural Disaster Risk Management in Developing and Emerging Countries. Long Study. Interim report for GTZ.

Milly, P.C.D., R.T. Wetherald, K.A. Dunne, and T.L. Delworth, 2002. Increasing risk of great floods in a changing climate. Nature, Vol. 415, No. 6871, pp. 514-517.

Milly, P.C.D., K.A. Dunne, and A.V. Vecchia, 2005. Global pattern of trends in streamflow and water availability in a changing climate. Nature, Vol. 438, No. 7066, pp. 347-350.

Pielke Jr., R.A. C. Landsea, M. Mayfield, J. Laver, and R. Pasch, 2005. Hurricanes and Global Warming. Bulletin of the American Meteorological Society, Vol. 86, No. 11, pp. 1571-1575.

Pielke, Jr., R.A., C.W. Landsea, M. Mayfield, J. Laver, R. Pasch, 2006. Reply to Hurricanes and Global Warming Potential Linkages and Consequences. Bulletin of the American Meteorological Society, Vol. 87, pp. 628-631.

Webster, P.J., G. J. Holland, J. A. Curry, and H. R. Chang, 2005. Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment. Science, Vol. 309, pp. 1844–1846.