Reply

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Nicholls (2011) questions the validity of the main conclusion of my work, that is, that anthropogenic climate change thus far did not have a significant impact on economic losses from natural disasters (Bouwer 2011). His argument is that changes in building techniques and monitoring and forecasting may have reduced the vulnerability to economic damages, thereby balancing a possible increase in either the frequency or intensity of weather hazards. While such effects may certainly play a role, he provides no support that these factors have actually contributed to a substantial reduction in losses over the period of the last decades. Here I will give some reflections on these arguments.

We need not, as Nicholls (2011) argues, dismiss a decrease in vulnerability before we can conclude that anthropogenic climate change has not had an impact on losses from weather disasters. Losses can only have increased due to climate change if there is also an anthropogenic trend of increasing occurrence of the related weather extremes. A human contribution to trends in most large-scale weather-related hazards that were addressed by the studies that I presented, such as extratropical storms and river floods, has, however, not been found (Solomon et al. 2007; Rosenzweig et al. 2007), and for tropical storms it remains uncertain if activity has exceeded natural variability (Knutson et al. 2010). My statement that anthropogenic climate change thus far did not have a significant impact on economic losses from these extremes is therefore robust in my view. I did provide the caveat that for smaller-scale weather extremes for which anthropogenic changes have been established (such as heat waves, droughts, and heavy precipitation events), such impacts may be found, but studies of long time series of damages are rarely available for these extremes.

I agree with Nicholls that it is unlikely that weather forecasts and changes in building regulations have not had any effect on economic vulnerability to natural disasters. The challenge, however, is to find out *how large* the effect on actual economic losses actually has been over longer periods of time. Such quantification would certainly help to support evidence-based policy for vulnerability reduction. However, few quantifications of the avoided losses resulting from vulnerability reduction are available (Benson and Twigg 2004), and economists have resorted to risk modeling or impact-based historic analyses to estimate such benefits (Mechler 2005). Measures for protecting buildings and home content are most often taken after large and rare events, and certainly are not taken everywhere around the world. Government-initiated programs, such as improved building codes in Florida, for instance, have lead to actual reductions in vulnerability to hurricanes only recently (Hallegatte 2008; Pielke et al. 2008). Moreover, direct economic losses from large weather disasters have increased at a rate of about 125% per decade since the 1970s, which is much larger than the average rate of global gross domestic product (GDP) growth (Bouwer et al. 2007). This indicates that a rapid trend of increasing exposure is the main cause for rising losses with urbanization, and an increasing concentration of people and assets along the coasts are the main drivers. Clearly, before vulnerability reduction can turn this trend around, substantial efforts over longer periods of time are needed.

Monitoring and forecasting weather hazards may certainly help to reduce the loss of life. While the number of deaths resulting from floods has apparently increased at a lower rate than economic losses (UN ISDR 2009), it is unsure to what extent forecasting may have reduced economic losses, especially in the largest and most extreme damaging events.

As I have suggested in my article, the match between the loss record normalized for nonclimatic drivers of risk (i.e., changes in exposure and wealth) and the geophysical record of observed weather extremes, such as tropical cyclone landfalls and flood occurrence, provides a good test for the validity of the analysis. Some studies have tested such matches (e.g., Pielke et al. 2008), but more can be done in order to find out the exact causes of variations and trends in disaster losses. Importantly, and as I have pointed out earlier, loss data are far from accurate, which complicates the detection of the relatively subtle signals of anthropogenic climate change and risk reduction. Even if economic losses from certain weather extremes increased, it is unlikely that they would be observed in the loss data, because natural variability and other drivers dominate this loss record, which has high uncertainty ranges. For example, a recent study using climate model results shows that anthropogenic changes in U.S. hurricane losses can be detected only

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after some 260 yr from now, or at the earliest after some 120 yr (Crompton et al. 2011). The first signals of changing weather disaster risks will therefore likely come from geophysical data, not from loss data.

REFERENCES

Benson, C., and J. Twigg, 2004: Measuring mitigation: Methodologies for assessing natural hazard risks and the net benefits of mitigation. ProVention Publ., 149 pp.

Bouwer, L. M., 2011: Have disaster losses increased due to anthropogenic climate change? *Bull. Amer. Meteor. Soc.*, **92,** 39–46.

——, R. P. Crompton, E. Faust, P. Höppe, and R. A. Pielke Jr., 2007: Confronting disaster losses. *Science,* **318,** 753.

Crompton, R. P., R. A. Pielke Jr., and K. J. McAneney, 2011: Emergence time scales for detection of anthropogenic climate change in US tropical cyclone loss data. *Environ. Res. Lett.,* **6,** 014003, doi:10.1088/1748-9326/6/1/014003.

Hallegatte, S., 2008: A roadmap to assess the economic cost of climate change with an application to hurricanes in the United States. *Hurricanes and Climate Change,* J. B. Elsner and T. H. Jagger, Eds., Springer, 361–386.

Knutson, T. R., and Coauthors, 2010: Tropical cyclones and climate change. *Nat. Geosci.,* **3,** 157–163.

Mechler, R., 2005: Cost-benefit analysis of natural disaster risk management in developing and emerging countries. German Society for Technical Cooperation Manual, 84 pp.

Nicholls, N., 2011: Comments on "Have disaster losses increased due to anthropogenic climate change?" *Bull. Amer. Meteor. Soc.,* **92,** 791.

Pielke, R. A., Jr., J. Gratz, C. W. Landsea, D. Collins, M. Saunders, and R. Musulin, 2008: Normalized hurricane damages in the United States: 1900-2005. *Nat. Hazards Rev.,* **9,** 29–42.

Rosenzweig, C., and Coauthors 2007: Assessment of observed changes and responses in natural and managed systems. *Climate Change 2007: Impacts, Adaptation and Vulnerability.* M. L. Parry et al., Eds., Cambridge University Press, 79–131.

Solomon, S., D. Qin, M. Manning, M. Marquis, K. Averyt, M. M. B. Tignor, H. L. Miller Jr., and Z. Chen, Eds., 2007: *Climate Change 2007: The Physical Science Basis.* Cambridge University Press, 996 pp.

UN ISDR, 2009: Risk and poverty in a changing climate: Invest today for a safer tomorrow. UN International Strategy for Natural Disaster Reduction Global Assessment Rep. on Disaster Risk Reduction, 207 pp.