ECONOMICS

The rising costs of hurricanes

The impact of climate change on economic losses from tropical cyclones is a major concern. New research shows that — like changes in population and assets — climate change may double global losses from hurricanes.

Stéphane Hallegatte

Major hurricane landfalls such as Hurricane Katrina in New Orleans and Cyclone Nargis in Myanmar have caused terrible human and economic damages. These losses explain the widespread concern that climate change may increase the intensity of such events and therefore exacerbate the human and economic impacts. Even though at present anthropogenic climate change cannot be detected in disaster loss data[1], this could change in the future. Indeed, hurricane intensity — if not frequency — is likely to increase in the future, at least in some ocean basins, and the impact on losses could then become significant[1]. This possible outcome has been mentioned by many as a major motive for implementing international climate policies. But it would also have consequences on other national policies, such as coastal management and urban planning. Now in *Nature Climate Change*, Mendelsohn *et al.*[2] provide new insights on the future patterns of hurricane losses by investigating at the global scale the full causal chain from greenhouse-gas emissions to economic losses, combining the effects of climate change and socio-economic drivers. They identify the influence of these drivers on losses and find that the effect of climate change may be as strong as that of socio-economic changes.

There has been a long debate on climate change and hurricanes. Some scholars have linked recent increases in hurricane intensity with climate change, and anticipate a large increase in hurricane losses in the future[3]. Others have suggested that the current variability is linked with natural factors, and indicate that the impact of climate change on hurricanes is likely to remain undetectable in this century[4]. It has also been claimed that, regardless of how hurricane intensity changes in response to global warming, the influence of climate change on hurricane losses will be dominated by socio-economic changes, on which risk-mitigation national policies should focus[5]. Mendelsohn and colleagues[2] suggest otherwise.

The researchers used four global climate models to assess how large-scale climate conditions may change in response to increasing greenhouse-gas concentrations. Because these low-resolution models can hardly reproduce the physics of hurricanes, they use a hurricane model to estimate the consequences of climate change on hurricane frequency, intensity and location. Finally, to analyse how these changes in hurricane activity would affect economic losses, they conduct a statistical analysis on both past hurricane landfalls in the United States to estimate how economic losses depend on hurricane intensity, and at the global scale to estimate the dependency of damages on income. Combining these statistical relationships with projected changes in hurricane activity and a scenario for future population and income, they produce scenarios of future hurricane losses.

At the global level, climate change is found to increase hurricane losses in each of the climate models used. On average, socio-economic trends and climate change are each responsible for a doubling of hurricane losses, resulting in a fourfold increase in total losses, from US$26 billion per year at present to US$109 billion in 2100. These results suggest that climate change may become a major determinant of trends in disaster losses in the future. They also highlight that additional hurricane losses due to climate change would be more than $50 billion per year in 2100 and so represent quite a significant channel through which global warming negatively affects the world economy and global welfare. Relative to income, however, hurricane losses are projected to decrease, from 0.04% of world gross domestic product per year at present to 0.01% in 2100.

Although interesting, the analysis has limitations. Mendelsohn *et al.*[2] find — consistent with previous research[6] — that the growth in hurricane losses is slower than wealth growth: a 1% increase in income leads to a 0.4% increase in average economic losses from hurricanes. They argue that as countries get richer, they implement risk-reduction measures and become less vulnerable. But in many countries, income growth also led to increased migrations and investments in areas at-risk, and this trend may dominate

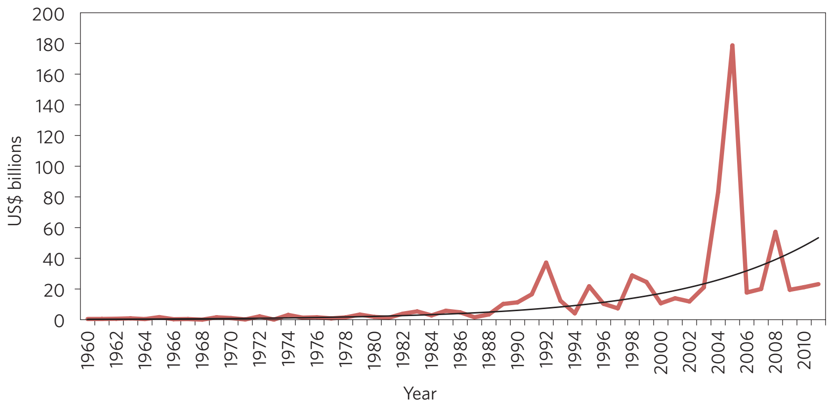

Figure 1 | Global economic losses from storms in regions affected by tropical cyclones (in US$ billions). Mendelsohn and colleagues[2] estimate the impact of climate change on economic losses from tropical cyclones in combination with changes in socio-economic drivers. They found that changes in population and income, and climate change could each double the economic costs of hurricanes. Data taken from EM-DAT — The Office of US Foreign Disaster Assistance/Centre pour la Recherche sur l'Epidemiologie des Désastres International Disaster Database (www.emdat.be).

the effect of risk-reduction measures[7]. The statistical analysis at the global scale pools together observations in different countries and at different points in time. The underlying assumption — which has been used repeatedly in the literature[6] — is that as developing countries' income approaches that of present-day rich countries, their vulnerability characteristics will also be the same. In other words, when, for example, Bangladesh has an income similar to Sweden's present income, it will also have the same vulnerability. This is a strong assumption especially because there are factors — such as geography[8] — affecting the relationship between losses and income, which are left out of the analysis. Therefore, it sounds overly optimistic to claim that as countries get richer hurricane losses will automatically decrease relative to income and thus be more easily manageable.

Other limitations make these results preliminary. Sea-level rise is not taken into account, because of the difficulty in accounting for local topography and coastal protections. Other analyses[9] have shown that the exposure of coastal populations may increase rapidly because of sea-level rise and increased urbanization. This effect may be responsible for most of the increase in hurricane losses in the future. Also, the analysis takes only the direct impact of hurricanes into account, even though indirect losses can represent a large share of welfare impacts[10]. This is especially important because, according to this study, most of the increase in hurricane losses is likely to materialize through the most intense hurricanes, and these large-scale shocks are those for which indirect losses are the largest[11]. Given all these limitations, it is likely that the results underestimate future hurricane losses as a consequence of climate change, and accordingly the researchers identify the aspects in need of further work.

However, Mendelsohn *et al.*[2] show that even under conservative assumptions, changes in the global climate may translate into a large increase in hurricane losses. This is an important insight to inform the decision-making process on world climate policies. At the local scale, it also means that risk management will become even more important in the future than it is at present, and that it will increasingly face events of a rising intensity. Considering the irreversibility in coastal development and urban planning, the researchers call for a more energetic stance in the design and implementation of risk-management practice in coastal areas. ❒

Stéphane Hallegatte is at the Centre International de Recherche sur l'Environnement et le Développement (CIRED), 45bis, Avenue de la Belle Gabrielle, F-94736 Nogent-sur-Marne, France, and Météo-France.
e-mail: hallegatte@centre-cired.fr.

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OCEANOGRAPHY

Centennial warming of ocean jets

Identification of an enhanced centennial warming trend in ocean subtropical boundary currents has important implications for our understanding of how climate change is happening.

Richard G. Williams

A central question in climate science is how the ocean is responding to the slight increase in radiative warming from increasing concentrations of greenhouse gases. Although there is a clear signal of more heat being stored in the global ocean since 1955 (refs 1,2), the associated pattern of ocean warming is less clear. Drawing on previous reconstructions of sea surface temperature trends over the twentieth century[3], Lixin Wu and colleagues present a new view of ocean warming in *Nature Climate Change*[4]. They identify enhanced subtropical warming of the western boundary currents, namely the Kuroshio Current, the Gulf Stream, the Brazil Current, the East Australian Current and the Agulhas Current. The centennial warming trend over these boundary currents is twice as large as the global average. This localized warming is important for the climate system, because the boundary currents redistribute heat within the ocean (Fig. 1), and provide heat and moisture to the overlying atmospheric storm tracks.

It is necessary to consider the difficulties in constructing reliable and representative centennial trends before interpreting this result. Historical ocean data are sparse and restricted to seafaring and trade routes at the start of the twentieth century[5]. Although there is this inherent difficulty, Wu and colleagues analyse the sea-surface-temperature trends based on six different reconstructions from 1900 onwards: two sets based solely on the available historical data and four sets based on different optimal interpolations. There are similar enhanced warming signals in the subtropical boundary currents in all of these reconstructions, implying that their result is independent of the analysis method. As an independent check, they also compare their result with two reconstructions of marine air temperature and again find enhanced warming trends over the western boundary currents.

Assuming that these centennial warming trends are reliable, there is still a concern as to how representative they are compared with shorter-term variability, particularly decadal changes[5]. This aspect is not fully addressed, but the authors do split their post-1900 record into two separate parts. Although the trends differ slightly over each separate period, they find a broadly similar response — enhanced warming of the subtropical western boundary currents.

How might these enhanced subtropical warming trends for western boundary currents be achieved? Local warming from the atmosphere is perhaps unlikely to provide this spatial imprint and might instead possibly dampen sea-surface-temperature anomalies over many decades. Changes in basin-scale overturning are also unlikely to be the