METEOROLOGY

Are there trends in hurricane destruction?

Arising from: K. Emanuel *Nature* 436, 686–688 (2005)

Since the record impact of Hurricane Katrina, attention has focused on understanding trends in hurricanes and their destructive potential. Emanuel¹ reports a marked increase in the potential destructiveness of hurricanes based on identification of a trend in an accumulated annual index of power dissipation in the North Atlantic and western North Pacific since the 1970s. If hurricanes are indeed becoming more destructive over time, then this trend should manifest itself in more destruction. However, my analysis of a long-term data set of hurricane losses in the United States shows no upward trend once the data are normalized to remove the effects of societal changes.

Historical hurricane losses can be adjusted to a base year's values through adjustments related to inflation, population and wealth². For at least three reasons, this data set is appropriate for identifying long-term climate signals. First, a long-term record of flood damage (collected in a similar way to and by the same agency as the hurricane data) is of sufficient quality to identify long-term trends³. Second, a methodology² developed in 1998 produces results that are consistent with the results of catastrophe models used by the insurance industry to assess hurricane losses⁴. Third, and most crucially, the data set contains climate signals, such as that of the El Niño–Southern Oscillation, which has a well established climatological relationship with interannual hurricane behaviour (see refs 5, 6, for example).

Specifically, an index of sea-surface-temperature anomalies of the Niño 3.4 region of the central Pacific in August, September and October is highly correlated with observed normalized damages in the same year⁵. The observed intensity change⁷ in Atlantic basin hurricanes between El Niño and La Niña events is of similar magnitude to the changes in annual accumulated power-dissipation index identified by Emanuel¹; the ability to identify the signal of the former suggests therefore that the normalized damage database is of sufficient size and quality to identify climate signals of the magnitude discussed by Emanuel.

A data set of hurricane losses (focusing on direct damages related to wind, and generally excluding rain-caused flood damage) for individual storms⁸ extended to 2004, which includes only those storms causing damage, shows no upward trend. For example, take the 86 storms causing at least US\$1 billion in normalized damages, which removes a bias caused by small storms resulting in no damage in the early twentieth century (that is, not subjected to normalization). There is an average per-storm loss in 1900–50 for 40 storms (0.78

events per year) of \$9.3 billion, and an average per-storm loss in 1951–2004 for 46 storms (0.85 events per year) of \$7.0 billion; this difference is not statistically significant. Adding Hurricane Katrina to this data set, even at the largest loss figures currently suggested, would not change the interpretation of these results.

These loss data indicate two possibilities with respect to Emanuel's analysis¹: if the power-dissipation index metric is an accurate indicator of hurricane destructiveness, then the trend identified by Emanuel could be an artefact of the data and/or methods; alternatively, the trend he identifies is an accurate reflection of trends in the real-world characteristics of storms, but the power-dissipation index is a weak indicator of hurricane destructiveness — which would call for the identification of climate metrics more directly associated with societal outcomes. In any case, it is misleading to characterize Emanuel's results as indicating an increase in "destructiveness" or as an indication of future increases in destruction resulting from changes in the power-dissipation index.

The bottom line is that, with no long-term trend identified in normalized hurricane damage over the twentieth century (in the United

States or elsewhere; see ref. 8, for example), it is exceedingly unlikely that scientists will identify large changes in historical storm behaviour that have significant societal implications. Looking to the future, Emanuel¹ provides no evidence to alter the conclusion that changes in society will continue to have a much larger effect than changes in climate on the escalating damage resulting from tropical cyclones⁹.

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METEOROLOGY

Hurricanes and global warming

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Anthropogenic climate change has the potential for slightly increasing the intensity of tropical cyclones through warming of sea surface temperatures¹. Emanuel² has shown a striking and surprising association between sea surface temperatures and destructiveness by tropical cyclones in the Atlantic and western North Pacific basins. However, I question his analysis on the following grounds: it does not properly represent the observations described; the use of his Atlantic bias-removal scheme may not be warranted; and further investigation of a substantially longer time series for tropical cyclones affecting the continental United States does not show a tendency for increasing destructiveness. These factors indicate that instead of "unprecedented" tropical cyclone activity having occurred in recent years, hurricane intensity was equal or even greater during the last active period in the mid-twentieth century.

My first concern is that Emanuel's figures²

do not match their description: his Figs 1–3 aim to present smoothed power-dissipation index (PDI) time series with two passes of a 1–2–1 filter, but the end-points — which are crucial to his conclusions — instead retain data unaltered by the smoothing; this is important because the last data point plotted in Emanuel's Fig. 1 is far larger than any other portion of the time series. Even after adding last year's busy hurricane season into the analysis and then properly using the filter, as described, the crucial end-point of the smoothed time series no longer jumps up dramatically in the last couple of years (Fig. 1a). About one-third of the increase in Atlantic PDI in Emanuel's graph for the past ten years is incorrect owing to inappropriate plotting of the data, even if the active 2004 season is incorporated.

A second concern is the bias-removal scheme used to alter the data for the Atlantic for 1949–69. Emanuel can demonstrate