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A global slowdown of tropical-cyclone translation speed and implications for flooding

Thomas Mortlock, Risk Frontiers

As the Earth's atmosphere warms, the atmospheric circulation changes. These changes vary by region and time of year, but there is evidence to suggest that anthropogenic warming causes a general weakening of summertime tropical circulation. Because tropical cyclones are carried along within the ambient environmental wind, there is an expectation that the translation speed of tropical cyclones has or will slow with warming.

Severe Tropical Cyclone *Debbie*, which made landfall near Mackay in March 2017, was an unusually slow event, crossing the coast at only seven kilometers per hour. Likewise, the "stalling" of Hurricane Harvey over Texas in August 2017 is another example of a recent, slow-moving event. While two events by no means constitute a trend, slow-moving cyclones can be especially damaging in terms of the rainfall volumes that are precipitated out over a single catchment or town (Fig. 1). A slow translation speed means strong wind speeds are sustained for longer periods of time and it can also increase the surge-producing potential of a tropical cyclone.

Figure 1. Flooding during TC Debbie; left – flood gauge in the Fitzroy River; centre – flooded runway at Rockhampton Airport; right – the flooded Logan River and Pacific Motorway. Source: Office of the Inspector-General Emergency Management (2017).

But have changes in the translation speeds of tropical cyclones been observed in the Australian region and can we draw any conclusions about any impact of these changes on related flooding?

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A recent article published in the journal *Nature* by James Kossin of NOAA looks at tropical cyclone translation speeds from 1949 through to 2016, using data from the US National Hurricane Center (NHC) and Joint Typhoon Warning Center (JTWC), and finds a 10 percent global decrease. For western North Pacific and North Atlantic tropical cyclones, he reports a slowdown over land areas of 30 percent and 20 percent respectively, and a slowdown of 19 percent over land areas in Australia.

The following is an extract from Kossin's article, followed by some comments on the significance of his work for the Australian region. The full article and associated references are available here.

Kossin's article – in short

Anthropogenic warming, both past and projected, is expected to affect the strength and patterns of global atmospheric circulation. Tropical cyclones are generally carried along within these circulation patterns, so their past translation speeds may be indicative of past circulation changes. In particular, warming is linked to a weakening of tropical summertime circulation and there is a plausible a priori expectation that tropical-cyclone translation speed may be decreasing. In addition to changing circulation, anthropogenic warming is expected to increase lower-tropospheric water-vapour capacity by about 7 percent per degree (Celsius) of warming. Expectations of increased mean precipitation under global warming are well documented. Increases in global precipitation are constrained by the atmospheric energy budget but precipitation extremes can vary more broadly and are less constrained by energy considerations.

Because the amount of local tropical-cyclone-related rainfall depends on both rain rate and translation speed (with a decrease in translation speed having about the same local effect, proportionally, as an increase in rain rate), each of these two independent effects of anthropogenic warming is expected to increase local rainfall.

Time series of annual-mean global and hemispheric translation speed are shown in Fig. 2, based on global tropical-cyclone 'best-track' data. A highly significant global slowdown of tropical-cyclone translation speed is evident, of –10 percent over the 68-yr period 1949–2016. During this period, global-mean surface temperature has increased by about 0.5 °C. The global distribution of translation speed exhibits a clear shift towards slower speeds in the second half of the 68-yr period, and the differences are highly significant throughout most of the distribution.

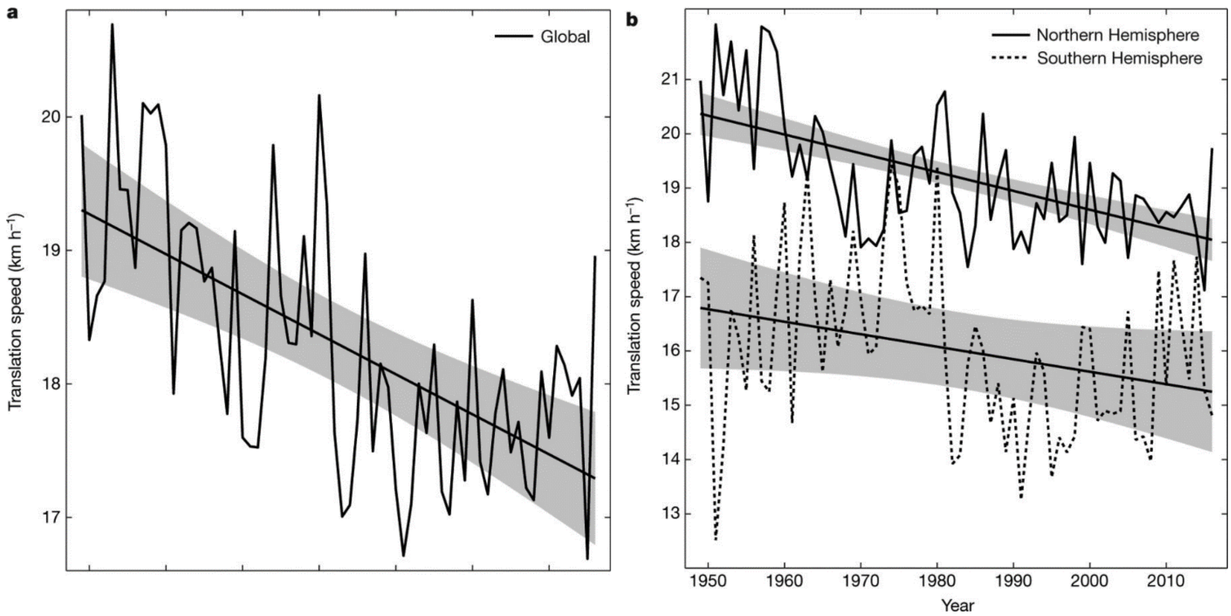

Figure 2. Global (a) and hemispheric (b) time series of annual-mean tropical-cyclone translation speed and their linear trends. Grey shading indicates 95 percent confidence bounds. Source: Kossin (2018).

This slowing is found in both the Northern and Southern Hemispheres (Fig. 2b) but is stronger and more significant in the Northern Hemisphere, where the annual number of tropical cyclones is generally greater. The times series for the Southern Hemisphere exhibits a change-point around 1980, but the reason for this is not clear.

The trends in tropical-cyclone translation speed and their signal-to-noise ratios vary considerably when the data are parsed by region but slowing over water is found in every basin except the northern Indian Ocean. Significant slowing of –20 percent in the western North Pacific Ocean and of –15 percent in the region around Australia (Southern Hemisphere, east of 100° E) are observed.

When the data are constrained within global latitude belts, significant slowing is observed at latitudes above 25° N and between 0° and 30° S. Slowing trends near the equator tend to be smaller and not significant, whereas there is a substantial (but insignificant) increasing trend in translation speed at higher latitudes in the Southern Hemisphere.

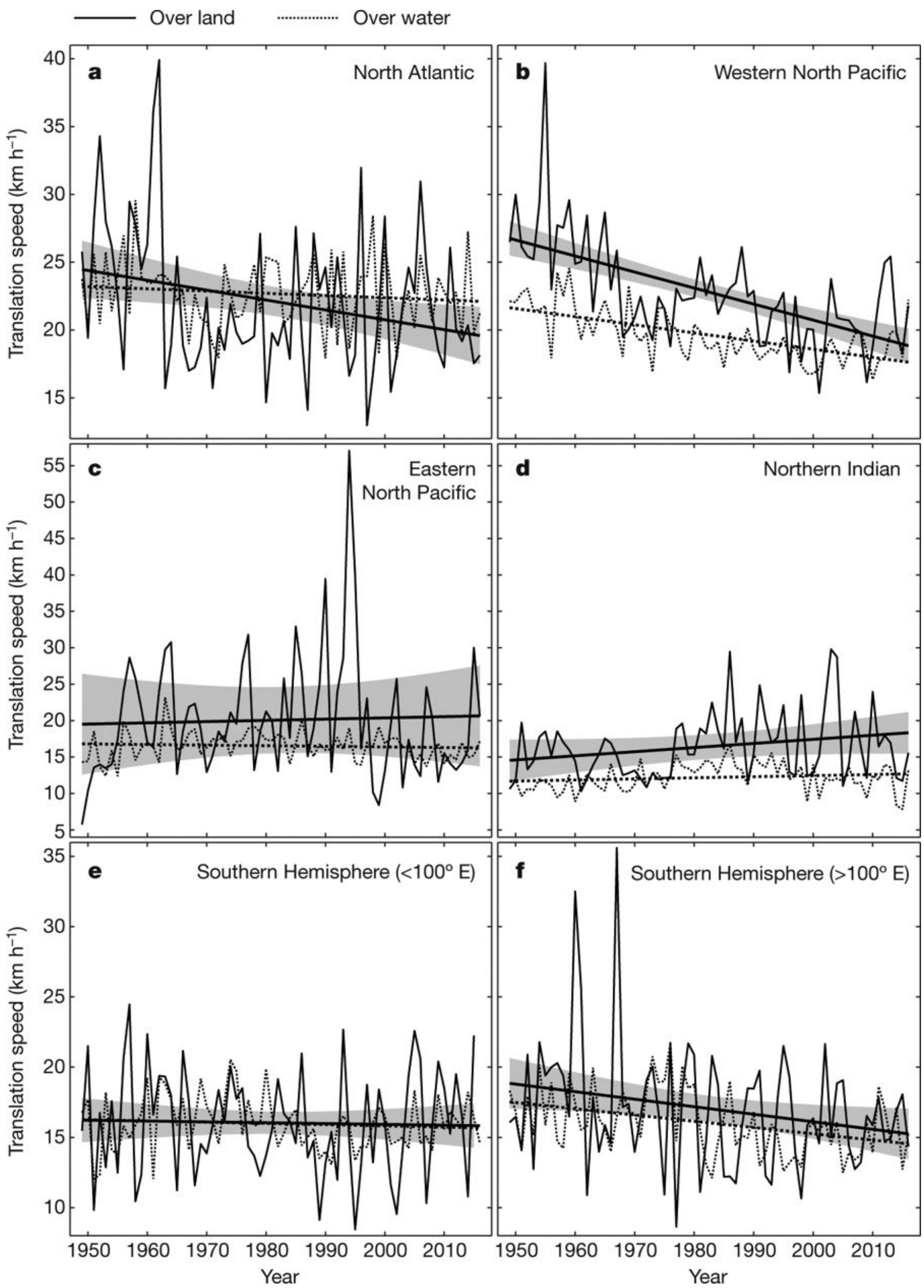

Figure 3. Time series of annual-mean tropical-cyclone translation speed and their linear trends over land and water for individual ocean basins. Source: Kossin (2018).

Changes in tropical-cyclone translation speed over land vary substantially by region (Fig. 3). There is a substantial and significant slowing trend over land areas affected by North Atlantic tropical cyclones (20 percent reduction over the 68-yr period), by western North Pacific tropical cyclones (30 percent reduction) and by tropical cyclones in the Australian region (19 percent reduction, but the significance is marginal).

Contrarily, the tropical-cyclone translation speeds over land areas affected by eastern North Pacific and northern Indian tropical cyclones, and of tropical cyclones that have affected Madagascar and the east coast of Africa, all exhibit positive trends, although none are significant.

In addition to the global slowing of tropical-cyclone translation speed identified here, there is evidence that tropical cyclones have migrated poleward in several regions. The rate of migration in the western North Pacific was found to be large, which has had a substantial effect on regional tropical-cyclone-related hazard exposure.

These recently identified trends in tropical-cyclone track behaviour emphasize that tropical-cyclone frequency and intensity should not be the only metrics considered when establishing connections between climate variability and change and the risks associated with tropical cyclones, both past and future.

These trends further support the idea that the behaviours of tropical cyclones are being altered in societally relevant ways by anthropogenic factors. Continued research into the connections between tropical cyclones and climate is essential to understanding and predicting the changes in risk that are occurring on a global scale.

Significance for the Australian region

While an interesting piece of work, the results for the Southern Hemisphere and the Australian region, are less clear than for the North Atlantic and North Pacific basins.

The trend shown in Fig. 2b for the whole of the Southern Hemisphere is not significant and is clearly composed of two separate trends, each spanning around 30 years. Assuming a homogenous dataset, the time series may be reflecting the strong influence of inter-decadal climate forcing.

In the Southern Hemisphere, the role of multi-decadal climate-ocean variability, like the Pacific Decadal Oscillation (PDO) or the Indian Ocean Dipole (IOD) has a large influence on decadal-scale climate variability (particularly in Australia) and can mask a linear, anthropogenically-forced trend.

The paper also mentions that global slowdown rates are only significant over-water (which makes up around 90 percent of the best track data used), whereas the trend for the 10 percent of global data that corresponds to cyclones over land (where rainfall effects become most societally relevant) is not significant. Therefore, it is unclear, at a global scale, whether tropical cyclones have slowed down over land or not. The trend for the Australian region (Fig. 3f, Southern Hemisphere > 100 °E), for both over land and over water slowdowns (approx. -19 percent), is only marginally significant. Further work could analyse translation speeds in the Australian region using our Bureau of Meteorology tropical cyclone database.

As with previous studies of changes to tropical cyclone behaviour in Australia, results are unclear. The relatively short time span of consistent records, combined with high year-to-year variability, makes it difficult to discern any clear trends in tropical cyclone frequency or intensity in this region (CSIRO, 2015).

For the period 1981 to 2007, no statistically significant trends in the total numbers of cyclones, or in the proportion of the most intense cyclones, have been found in the Australian region, South Indian Ocean or South Pacific Ocean (Kuleshov et al. 2010). However, observations of tropical cyclone numbers from 1981–82 to 2012–13 in the Australian region show a decreasing trend that is significant at the 93-98 percent confidence level when variability associated with ENSO is accounted for (Dowdy, 2014). Only limited conclusions can be drawn regarding tropical cyclone frequency and intensity in the Australian region prior to 1981, due to a lack of data. However, a long-term decline in numbers on the Queensland coast has been suggested (Callaghan and Power, 2010) and northeast Australia is also a region of projected decrease in tropical cyclone activity, including cat 4-5 storms, according to Knutson et al. (2015).

In summary, based on global and regional studies, tropical cyclones are in general projected to become less frequent with a greater proportion of high intensity storms (stronger winds and greater rainfall). This may be accompanied with a general slow-down in translation speed. A greater proportion of storms may reach south (CSIRO, 2015).

The take home message? ***The known-unknowns are still quite a bit greater than the known-knowns.***

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