

PCIC SCIENCE BRIEF: THE POLEWARD MIGRATION OF TROPICAL CYCLONE MAXIMUM INTENSITY

In a recent article published in the journal *Nature*, Kossin et al. (2014) use satellite data and reanalysis products to see if there has been a shift in the latitudes at which tropical storms reach their maximum intensity over the 1982-2012 period. The authors find that, globally, the latitudes of maximum intensity have shifted poleward, 53 kilometres per decade in the Northern Hemisphere and 62 kilometres per decade in the Southern Hemisphere. This trend of poleward migration is evident in all ocean basins, except the North Indian Ocean basin, in homogenized satellite and so-called “best track” data¹. Kossin and colleagues note that this migration is apparently linked to: (1) the absolute difference between wind speeds in the upper and lower troposphere and (2) potential intensity². These have both experienced changes that can be linked to the expansion of the tropics, which is thought to be due, in part, to anthropogenic causes.

Owing to the destructive power of tropical cyclones and their function in transporting warm, moist air poleward, there is a strong need to understand how climate change may affect their intensity, frequency and location. Examining the latter question, about shifts in tropical cyclone location, is difficult because measurements of cyclone intensity are uncertain. This makes storm duration hard to quantify, because a storm’s creation and demise are determined by measures of intensity. In a recent paper in *Nature*, Kossin et al. work around this problem by focusing on measurements of the position of the lifetime maximum intensity of storms, which is much less uncertain. Storms nearing their maximum intensity are more likely to already be under observation and measuring the position of a tropical cyclone’s peak intensity doesn’t depend on highly accurate measurements of the absolute value of its intensity.

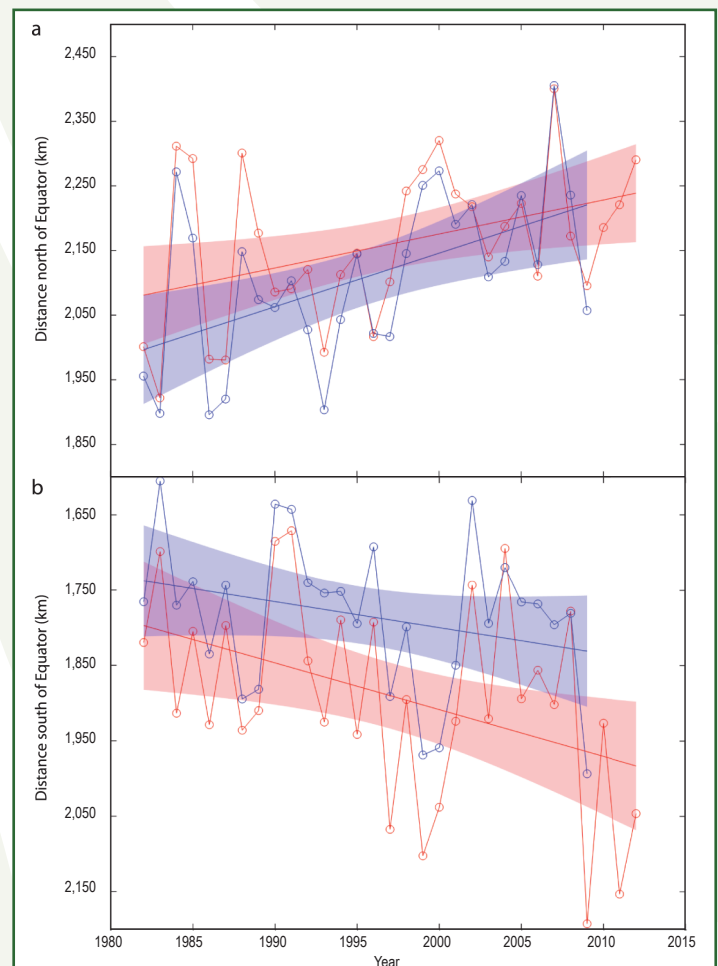


Figure: Measured distances of lifetime-maximum intensity of tropical cyclones, from Kossin et al. (2014).

This figure shows the annual-mean latitude of tropical cyclone lifetime maximum intensity in the Northern (a) and Southern (b) hemispheres, as calculated from the best-track historical data (red) and the ADT-HURSAT reanalysis (blue). Blue and pink shading indicate 95% confidence intervals.

Intense tropical cyclones, known as typhoons, hurricanes or simply cyclones, depending on the ocean basin that they are in, can cause massive damage to human com-

- Best track data are estimates of storm intensity and position from a variety of observations which have been gathered into a global data set. For more information, see: Knapp, R.K., M.C. Kruk, D.H. Levinson, H.J. Diamond, and C.J. Neumann, 2010: The International Best Track Archive for Climate Stewardship (IBTrACS). *Bull. Amer. Meteor. Soc.*, **91**, 363–376. doi: <http://dx.doi.org/10.1175/2009BAMS2755.1>.
- Potential intensity is the theoretical limit on how strong a cyclone may become, determined using thermodynamic considerations of local environmental factors, such as sea surface temperatures, tropopause temperatures, local baroclinicity (the degree to which surfaces of constant pressure are at an angle to surfaces of constant density or temperature) and humidity.

munities through heavy rain, strong winds, large ocean waves and storm surge flooding. They also transport water and heat from lower latitude ocean regions high into the troposphere and poleward. The moisture from tropical cyclones over the Pacific Ocean can be drawn into and transported along storm tracks that reach British Columbia's (BC's) coast. On occasion, typhoon moisture will help form atmospheric rivers which are an important source of heavy rainfall on BC's coast. However, not all atmospheric rivers arise from typhoons. Tropical cyclones can also transition into extratropical cyclones and travel through midlatitude regions, as occurred recently on the Eastern seaboard with Hurricane Arthur and when the 2004 typhoon Tokage made an extratropical transition and travelled across the North Pacific, eventually making landfall in Alaska.

Tropical cyclones form³ when a disturbance—such as an elongated region of low pressure air moving westward through the tropical trade winds—generates upward convection over warm (roughly 26° Celsius or warmer) water. As this warm, moist air rises, it cools and some of the water vapour it holds condenses, which releases heat and causes the air to rise farther still. The resulting condensation forms storm clouds and air at the surface is drawn in to replace the rising air. Due to the rotation of the Earth, the system begins to rotate. To sustain all of this requires that a number of conditions are met; among them the absolute difference in wind speeds between the lower and upper troposphere, known as wind shear, must be relatively small or else the system will be tilted vertically, rendering it weaker, or tearing it apart entirely.

Working from the best-track record (a mix of ship, plane, surface and satellite observations) for the 1982-2012 period, Kossin and colleagues examine the latitudes at which tropical cyclones reached their maximum intensities over each ocean basin. They find that there is a pronounced poleward shift of roughly 1° of latitude per decade in the position at which the storms reach their maximum intensity: about 53 kilometres per decade in the Northern Hemisphere and about 62 in the Southern Hemisphere, for a total global trend of 115 kilometres per decade (see Figure). However, the authors also find that the trends vary regionally, with the strongest trend in the western North Pacific Ocean and the weakest trend in the North Indian Ocean.

The best-track record comes from a mix of different data sources and is not homogeneous, with different satellite instruments having different resolutions, inconsistencies

in aircraft reconnaissance using pressure-to-wind conversions and changes in the amount and quality of data available for a given period, among other issues. Because of this, the authors repeat their analysis with homogenized data, for which attempts were made to correct for such data issues. In this repeated analysis, in which they examine the 1982-2009 period, Kossin et al. again find a poleward shift, of about 118 kilometres per decade, in the locations of the maximum intensities of tropical storms. The findings for each basin are somewhat similar, with the western North Pacific basin, where storms are most frequent, contributing the most to the global trend and the North Indian Ocean contributing the least. However, in the homogenized data, the North Indian basin has no significant trend. The authors attribute this to the confined nature of the North Indian basin and nearby land to the north of the basin. While statistically significant poleward trends are evident in both the Northern and Southern Hemispheres in the best-track data, only the Northern Hemisphere trend is significant in the homogenized data.

In order to explain the poleward shift in the locations of the lifetime maximum intensities of these tropical cyclones, Kossin et al. examine three atmospheric data sets. They find that vertical wind shear has increased in the deep tropics and decreased in the subtropics, which makes the deep tropics less hospitable for cyclones and subtropics more hospitable. The authors also note that, while changes to potential intensity¹ are less consistent across the data sets, there is a general trend of greater increases to potential intensity in the subtropics, and also a reduction of potential intensity in the deep tropics in one data set, that could contribute to the poleward shift.

Finally, Kossin and colleagues examine the poleward migration in maximum intensity for evidence of connection to either El Niño or the expansion of the tropics. Using statistical regression analysis, they find that it is unlikely that variability in El Niño is responsible for the poleward shift. However, the authors find that the rate of poleward migration does fall within the estimates for the rate of the expansion of the tropics and that both undergo a step change in the 1990s, which further suggests that the two phenomena may be linked. The expansion of the tropics is thought to be at least partially due to anthropogenic influences⁴.

Kossin J.P., K.A. Emmanuel, and G.A. Vecchi, 2014: The poleward migration of the location of tropical cyclone maximum intensity. *Nature*, **509**, 349-352, doi:10.1038/nature13278.

3. The explanation presented here is a very simple picture compared to the reality of atmospheric dynamics on this scale. There are several competing theories regarding the development of tropical cyclones. For more information on these, see: Tory, K.J., and W.M. Frank, 2010: Tropical cyclone formation, Chapter 2 of *Global Perspectives on Tropical Cyclones: From science to mitigation* [J.C.L. Chan and J.D. Kepert, editors]. World Scientific, Singapore, 55-91.

4. For more information, see: Lucas, C., B. Timbal, and H. Nguyen, 2014: The expanding tropics: a critical assessment of the observational and modeling studies. *WIREs Climate Change*, **5**, 89-112, doi:10.1002/wcc.251.