CLIMATE SCIENCE

Shifting storms

An analysis of historical storm data reveals that the average latitude at which tropical cyclones attain their maximum intensity has undergone a pronounced shift towards the poles over the past three decades. SEE LETTER P.349

HAMISH RAMSAY

Considerable attention has been devoted to the regional and global effects of climate variability and climate change on the behaviour of tropical cyclones over the past decade or so. Catastrophic events such as Hurricane Katrina (2005), Cyclone Nargis (2008), Hurricane Sandy (2012) and Typhoon Haiyan (2013) have led scientists and non-scientists alike to ask how climate change is affecting the intensity, frequency and location of tropical cyclones around the globe. There is a general consensus among experts that anthropogenic warming will lead to fewer, but more intense, tropical cyclones[1]. However, little attention has been paid to understanding long-term shifts in the geographical location of these cyclones, particularly when at their peak intensities (Fig. 1).

On page 349 of this issue, Kossin and co-authors[2] shed light on this aspect by examining trends in the latitude at which the maximum intensities of storms occur, a metric referred to in their study as the lifetime-maximum intensity (LMI). Their findings reveal a pronounced migration of the annual-mean LMI towards the poles over the past 30 years, at a rate of about 1° of latitude per decade, although this metric varies considerably on regional scales. If this poleward migration of tropical-cyclone LMI continues, it will probably have major impacts, including increased threats to coastal communities that have historically not been susceptible to hazards posed by tropical cyclones.

The observed poleward trends in the annual-mean LMI are consistent with, and within the range of, the observed expansion of the tropics since about 1979 (refs 3, 4). Several climate-related features have been used to diagnose this expansion, which is thought to be due to increased concentrations of anthropogenic greenhouse gases. These features include ozone depletion in the stratosphere, which lies just above the lowest portion of the atmosphere (the troposphere); the height of the boundary between the stratosphere and the troposphere (the tropopause); and the width of the Hadley circulation, the main meridional overturning circulation in the troposphere, which is characterized by rising air and thunderstorms near the Equator and dry, sinking air at around 30° north and 30° south, where many of the world's deserts are found.

Kossin *et al.* suggest that two factors known to modulate tropical-cyclone development and intensity may have contributed to the observed poleward migration of annual-mean LMI: deep-layer vertical wind shear, that is, the absolute difference between wind speeds in the upper and lower troposphere; and potential intensity, a thermodynamically based theoretical upper limit of tropical-cyclone intensity that depends on local sea surface temperature and atmospheric temperature and humidity. Many storms never achieve their potential intensity because of competing influences, such as strong vertical wind shear and intrusions of dry air. However, in principle, increased potential intensity and decreased vertical wind shear should promote more-intense storms, all other factors being equal. That such trends moving away from the Equator have been observed over the past 30 years (see Fig. 2 of the paper[2])

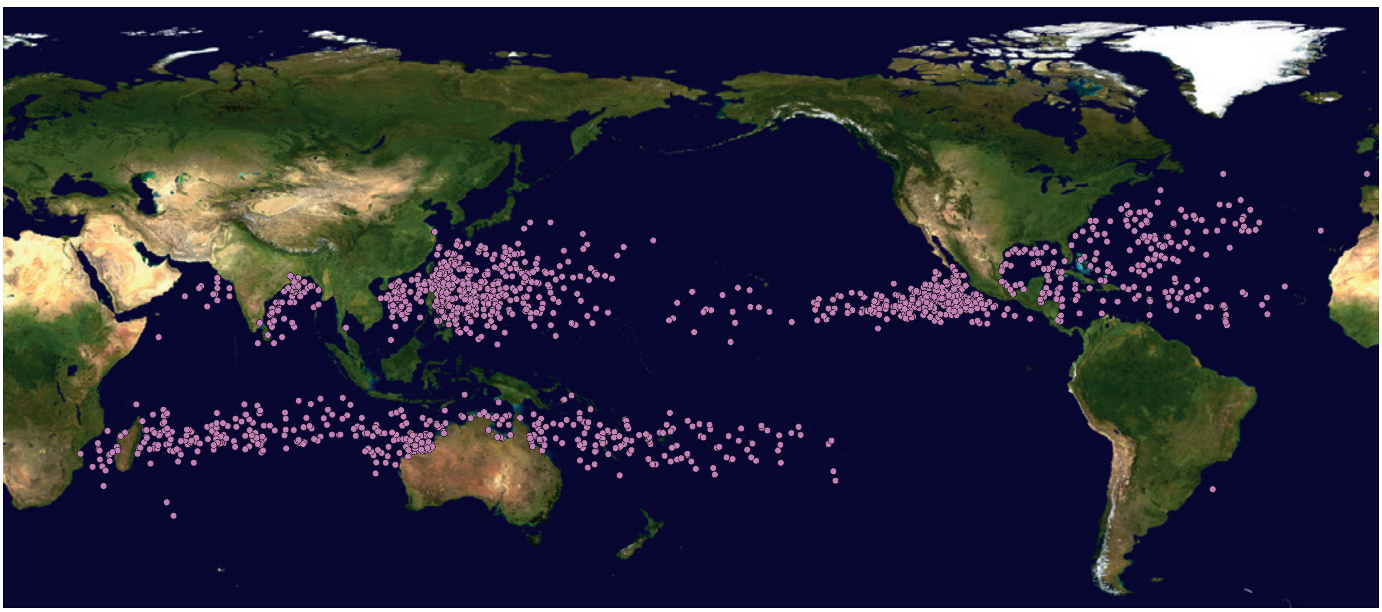
BACKGROUND IMAGE: NASA GODDARD SPACE FLIGHT CENTER

Figure 1 | Global distribution of tropical cyclones at their peak intensities. The background image is from NASA's Visible Earth catalogue, and the tropical-cyclone data come from the National Climatic Data Center's IBTrACS archive[10,11] for the period 1982–2012. Only the locations of storms that achieved an intensity of at least a category 1 hurricane (that is, a wind speed of at least 119 kilometres per hour) are shown. The locations represent a subset of the 'best-track' data used by Kossin and colleagues[2] to construct global and regional trends in the mean latitude at which storms reached their maximum intensities.

therefore seems at least qualitatively consistent with the observed poleward migration of annual-mean LMI.

Despite the large and statistically significant global trends in the annual-mean latitude of LMI, substantial region-to-region and year-to-year variability is evident. For instance, the North Atlantic region, which has received considerable media attention owing to events such as hurricanes Katrina and Sandy, shows almost no poleward trend on the basis of historical 'best-track' data over the past 30 years. Moreover, when the authors used a state-of-the-art data set of tropical-cyclone intensity (ADT-HURSAT; ref. 5), an opposite, equatorward, trend is found for the North Atlantic (see Table 1 of the paper[2]). Such regional differences in trends are probably due to climate modes that extend in time beyond the period for which accurate satellite-based data are available.

This is one of the limitations of trend studies based on satellite-derived estimates of tropical-cyclone intensity. Although the post-1970s geostationary satellite era is considered to be the most accurate part of the historical tropical-cyclone record, the relatively short observation period hampers the detection of trends influenced by modes of climate variability whose periodicity spans decades or longer, such as the Pacific Decadal Oscillation[6]. Any such variability implies that regions in which the poleward migration of annual-mean LMI has been more pronounced over the past 30 years might experience less-pronounced trends in the coming decades, and vice versa. Even on a global scale, a trend of 1° of latitude per decade of tropical expansion (that is, a 10° shift per century, assuming a constant rate of expansion) cannot be sustained without implausible changes to fundamental physical constraints on the global atmospheric circulation, such as Earth's rotation rate.

On year-to-year timescales, variability in tropical-cyclone formation and track is dominated by the phase of the El Niño–Southern Oscillation (ENSO) — the episodic warming (El Niño) and cooling (La Niña) of the surface temperature of the tropical Pacific Ocean. El Niño often promotes an equatorward migration of tropical-cyclone activity, whereas during La Niña a poleward displacement is observed[7], concomitant with changes in the width and intensity of the Hadley circulation[8]. It is therefore plausible that any trend in ENSO could project onto trends in tropical-cyclone activity. Kossin *et al.* attempt to remove this contribution by accounting for the effect of ENSO on the linear trend of annual-mean LMI latitude and then examining the residual data. The poleward migration remains pronounced and statistically significant, suggesting that ENSO plays only a minor part in the long-term hemispheric and global trends.

Kossin and colleagues' findings provide insight into the response of global tropical-cyclone activity to a changing climate. However, several questions remain unanswered. For instance, will future changes in wind patterns cause storms to move towards or away from coastlines[9]? What are the key mechanisms driving the observed tropical expansion, and how do these tie in with factors known to modulate tropical-cyclone intensity? Such questions remain the subject of future research. ■

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SYNTHETIC BIOLOGY

New letters for life's alphabet

The five bases found in nucleic acids define the 'alphabet' used to encode life on Earth. The construction of an organism that stably propagates an unnatural DNA base pair redefines this fundamental feature of life. **SEE LETTER P.385**

ROSS THYER & JARED ELLEFSON

All known life forms store and transmit information from generation to generation using the bases found in nucleic acids: adenine, cytosine, guanine, thymine and uracil. In nucleic-acid double helices, these form base pairs (guanine with cytosine, and either adenine with thymine in DNA, or adenine with uracil in RNA), which are mostly orthogonal — that is, little pairing occurs between other combinations of bases. However, this 'alphabet' seems to be an accident of history rather than a functional necessity, given that other orthogonal base pairs have been synthesized and shown to be processed by DNA-replication enzymes *in vitro*[1]. Because life on Earth is biochemically uniform, the formal possibility of alternative alphabets requires strong experimental proof. In this issue, Malyshev *et al.*[2] (page 385) provide just such a proof, by conclusively showing that an unnatural base pair can be stably propagated in the bacterium *Escherichia coli*.

Shortly after the discovery of DNA, it was proposed[3] that analogues of natural bases could form a third functional pair, but nearly 30 years passed before advances in organic synthesis and the development of methods for amplifying DNA gave scientists free reign to explore this hypothesis. In 1989, a base pair formed from isomers of guanine and cytosine was synthesized, and replication, transcription and even translation of DNA sequences incorporating this base pair were demonstrated *in vitro*[1,4]. Then in 1995 came the surprising finding[5] that hydrogen bonding between bases was not an absolute requirement for complementary binding, and could be replaced by steric compatibility (the fitting together of matching molecular shapes) and hydrophobic interactions. This culminated in the independent development of three highly orthogonal base pairs[6–8], each capable of *in vitro* replication fidelity exceeding 99%.

Malyshev *et al.* now describe the development of a bacterium capable of faithfully replicating a plasmid — a small, circular DNA molecule — containing the hydrophobic d5SICS:dNaM base pair (Fig. 1), thus creating the first organism to harbour an engineered and expanded genetic alphabet. This feat was far from simple: the authors first had to find a way of getting the bacterium to take up unnatural nucleotides, and then to work within the constraints of the billion-year-old habits of polymerases, the enzymes that synthesize polymeric nucleic acids.

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For more on the expanded genetic alphabet, visit:
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To solve the first problem, Malyshev and colleagues engineered an *E. coli* strain that expressed an algal nucleotide triphosphate transporter