Hurricanes, Typhoons and Tropical Cyclones

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The name Hurricane originates from the word "Hurakan", a Mayan god, one of their creator gods, who it's said blew his breath across the Chaotic water and brought forth dry land, later destroying the men of wood with a great storm and flood. It's also said that a 17th-century Hurricane likely inspired Shakespeare's The Tempest and led to the British colonisation of Bermuda.

The recent Category 5 Hurricanes Katrina and Rita that hit the Gulf coast of the US in August and September last year reminded the world how powerful and destructive they can be. Fatalities as a result of Katrina have been estimated to be around 1,300. This is less than Hurricane Okeechobee in 1928 that reportedly killed over 2,500 people in the US, although Katrina is undoubtedly the most costly (in terms of loss of life and an estimated $200 billion financial damage) natural disaster in US history.

The naming convention began in the 1940s originally with women's names only. Since 1978, the United Nation's World Meteorological Organization (WMO) has used a pre-determined list of names for each ocean basin of the world, that for obvious reasons does not use the letters Q, U, X, Y or Z. When a storm like Hurricane Katrina strikes, that causes loss of life and/or widespread damage, the country most affected by the storm may ask the WMO to "retire" the name from the list as an act of respect – some fifty names have been retired since 1978 in the Atlantic basin alone.

So what makes a Hurricane?

To be precise it's actually a Tropical Cyclone. These are deep low pressure systems that occur in tropical or sub-tropical waters. They are tropical depressions at a sustained surface wind speed below 39 mph and become tropical storms when winds exceed this. When these winds exceed 74 mph, then they become severe tropical cyclones which, in the North Atlantic, we call Hurricanes (a name I will use generically hereafter).

For Hurricanes to form there need to be several favourable conditions, which include:

- the presence of warm ocean waters, that is temperatures at least as high as 26.5ºC and through a sufficient depth of at least 50 m;
- an atmosphere which is humid at mid levels (around 5km) and that promotes thunderstorm activity;
- a minimum distance of at least 500 km from the equator to maintain the rotation and the existence of an organised pressure system near the surface;
- low values (less than about 23 mph) of vertical wind shear between the surface and the upper atmosphere, so as not to disrupt the organisation of cyclone.

Of course, these conditions in themselves do not mean that a Hurricane will form, but they are necessary for development to occur.

Table 1: Regional terminology for Tropical Cyclones (after Newman, 1993)

Hurricane	the North Atlantic Ocean, the Northeast Pacific Ocean east of the dateline, or the South Pacific Ocean east of 160E
Typhoon	the Northwest Pacific Ocean west of the dateline
Severe tropical cyclone	the Southwest Pacific Ocean west of 160E or Southeast Indian Ocean east of 90E
Severe cyclonic storm	the North Indian Ocean
Tropical cyclone	the Southwest Indian Ocean

The destructive power of Hurricanes is typically measured in Categories 1 to 5, from the Saffir - Simpson Hurricane Scale.

Hurricane forecasting across the globe

The advent of satellite observations from the 1960s has meant that the global meteorological community is able to monitor and track Hurricanes as they move and develop across the oceans. However it is still a difficult process to predict their tracks with sufficient notice in order to provide useful warnings.

The WMO has a number of Regional Specialist Meteorological Centres (RSMC) that have the responsibility for issuing Hurricane warnings in their specific areas of responsibility. As the Met Office is one of the few National Meteorological Services in the world that runs a global weather forecast model it is able to provide Hurricane forecasts that support the work of the RSMCs.

Met Office forecasts are issued twice a day as "forecast guidance" to the relevant RSMC in the form of a 6-day forecast of the Hurricane track. Explicit forecasts of maximum wind speed are not given as the Met Office's model at present cannot resolve the wind field with sufficient detail. However, a qualitative indication of forecast wind strength is given based on relative vorticity (at the 850 mb pressure level in the atmosphere).

The Met Office's forecasts for Katrina were some of the most accurate forecasts available, and were the first to predict the correct location of landfall over the Gulf coast, some 3 days before it struck New Orleans.

The forecasts for Katrina were sent to the National Hurricane Centre in Miami (as the responsible RSMC for the Atlantic) who used these, along with those from other modelling centres in order to issue warnings. Like other RSMCs, the National Hurricane Centre looks at all available information and makes a judgement as to the most likely evolution of the Hurricane system. This type of "ensemble" approach uses the spread of forecasts to create probabilistic warnings, which over recent years have become more common place. The European Centre for Medium Range Weather Forecasting (ECMWF) creates itself an ensemble forecast of Hurricane tracks by using the same model run

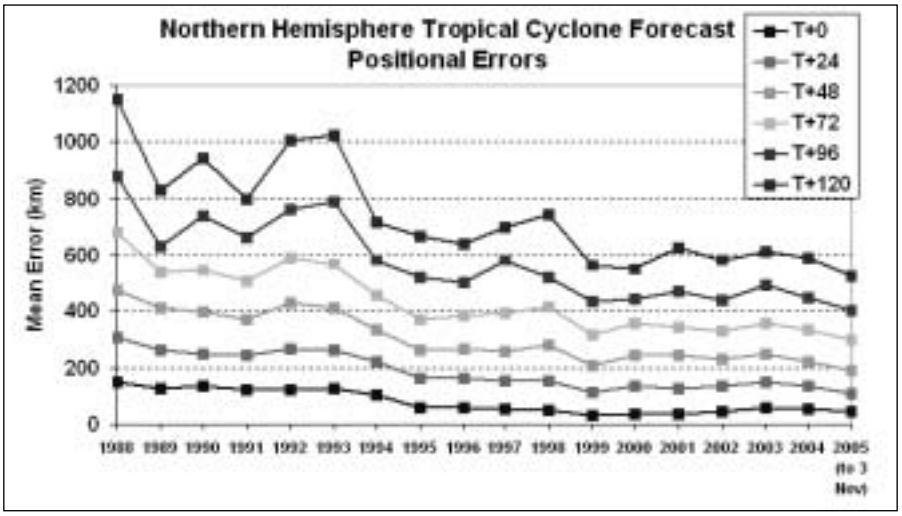

Figure 1. A plot showing the improvements over recent years in the tropical cyclone track forecast errors from the Met Office's Global Weather Prediction Model. The error is measured in km and each line in the plot represents a forecast lead time in hours, where T is an analysis field at the time of the forecast and T+24 is, for example, a forecast for 24 hours ahead."

many times with small changes to the initial representation of the developing system.

The Met Office's forecasts of Hurricanes are some of the best in the world. It regularly verifies the quality of these forecasts, in particular in terms of the positional error of the predicted Hurricane over time. Figure 1 shows the decrease in positional error in the forecasts from 1988 to present day, at 1 (T+24) to 5 (T+120) days ahead. Notice in particular the significant improvement in 1994, which resulted from introducing a new initialisation scheme, developed as part of a collaboration with the City University of Hong Kong.

What are the climate models telling us about how Hurricanes are changing?

Hurricane Katrina is the sixth most intense Hurricane in our observations history in the North Atlantic and was overtaken by Wilma and Rita – all occurring in 2005. Many people suggested that in the active Atlantic season in 2005 we were seeing the effects of climate change first hand.

Following Hurricane Katrina, Kerry Emanuel at MIT, one of the world's leading authorities on Hurricanes, hit the headlines with his paper in Nature on "Increasing destructiveness of tropical cyclones over the past 30 years" (2005). The press made big news of these new findings suggesting that Kerry had shown Climate Change was indeed causing Hurricanes to increase. Of course, that is not what he had shown.

We know that under a changing climate sea surface temperatures will increase, which is favourable for the formation of more intense Hurricanes. But we also know that this is not the only condition needed to encourage Hurricane development. Simulations with the climate models show that other criteria, like low vertical wind shear, are not necessarily favourable in a warmed climate.

In fact, attributing the increase of events like Hurricanes to human-induced climate change is almost impossible with current climate models. The current global models are too coarse a resolution to resolve features like Hurricanes. Some studies have looked at embedding higher resolution regional climate models within the global predictions, but can only give broad indications of trends that have a large degree of uncertainty. What the climate models can do is to look at larger scale tropical storm systems as a surrogate for Hurricane development, but as yet these studies are inconclusive and an active area of research.

What Kerry Emanuel has done is use historical observations of Hurricanes to look for trends in the data. His studies suggest that globally the annual frequency of Hurricanes has remained relatively constant at around 90. Although frequency varies from year to year across the different ocean basins there are no observed long-term increase trends. However what he has also suggested from his studies is that:

"Records of Hurricane activity worldwide show an upswing of both the maximum wind speed in and the duration of Hurricanes. The energy released by the average Hurricane (again considering all Hurricanes worldwide) seems to have increased by around 70% in the past 30 years or so, corresponding to about a 15% increase in the maximum wind speed and a 60% increase in storm lifetime."

Drawing conclusions from time series of Hurricane data is fraught with difficulties. Methods of observing Hurricanes have changed over time. Before the 1950s observations of wind speed are only available over land or from ships. After that reconnaissance aircraft brought back additional measurements. Then from around 1980 we began to have reliable estimates of wind speeds from satellites.

What has remained relatively constant though through time is the way in which pressure observations have been made, which can be related to Hurricane intensity. At present Kerry Emanuel's observations remain some of the closest indications we have that not the frequency but the intensity of Hurricanes has increased over the last 30 years – watch this space!

Table 2. The most intense recorded Hurricanes in the North Atlantic as measured by central pressure levels.

Rank	Hurricane	Year	Pressure (in millibars)
1	Wilma	2005	882 mb
2	Gilbert	1988	888 mb
3	Labor Day	1935	892 mb
4	Rita	2005	897 mb
5	Allen	1980	899 mb
6	Katrina	2005	902 mb

References

Emanuel , K. A., 2005: Increasing destructiveness of tropical cyclones over the past 30 years. Nature, 436, 686-688.

Neumann, C.J., 1993: Global Overview - Chapter 1. Global Guide to Tropical Cyclone Forecasting, WMO/TC-No. 560, Report No. TCP-31, World Meteorological Organization; Geneva, Switzerland.

Further information about the Met Office and its Hurricane forecasts can be found at 'www.metoffice.gov.uk' and 'www.metoffice.gov.uk/weather/tropicalcyclone/index.html'.http://www.britishembassy.de/S&I