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Stormy weather Storms in America and the Pacific are evidence of climate change

Governments are getting a bit better at dealing with threats like Hurricane Florence and Typhoon Mangkhut

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PEOPLE living on opposite sides of the planet have in recent days felt the disastrous consequences of distant rumblings in the deep ocean. In America, they are still suffering the devastation left by Hurricane Florence, which made landfall in North Carolina on September 14th. Less than 12 hours later super-Typhoon Mangkhut tore into the Philippines, subsequently to hit Hong Kong and southern China. Mangkhut packed a bigger punch: a category 5 storm when it first hit land, to Florence's category 1. But the impact of both was linked to rising levels of greenhouse gases in the atmosphere, which are changing the climate and warming the sea.

For that reason, future storms are also likely to be more severe than in the past.

Florence and Mangkhut have shown the progress that has been made in preparing for them and mitigating the damage—but also highlighted how vulnerable many communities remain, especially in Asia.

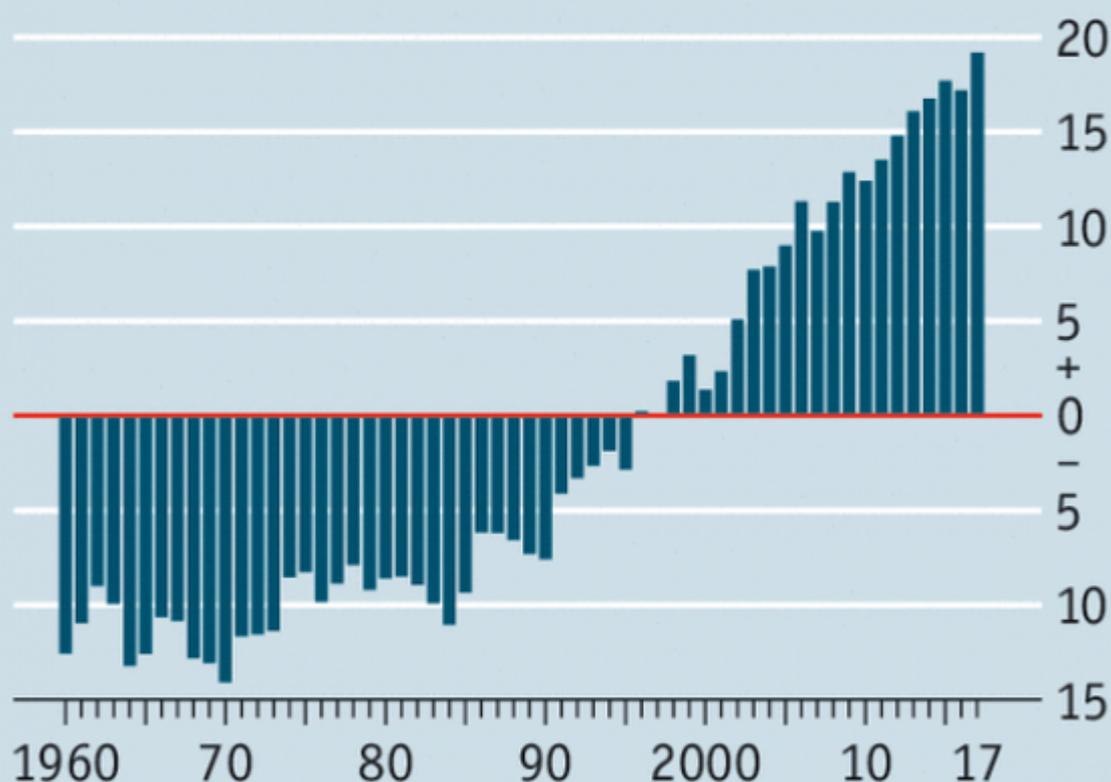
The link with climate change comes from the accumulation in the atmosphere of greenhouse gases produced by the industrial burning of fossil fuels and by deforestation. They create an imbalance in the energy flowing in and out of the planet, driving temperatures up. About 90% of that additional energy ends up stored in the oceans. Researchers who monitor sea temperatures down to 2,000 metres have plotted a steady rise since the 1950s, reaching a record high last year (see chart). So far, 2018 is on course to set a new record.

Kevin Trenberth of the US National Centre for Atmospheric Research says this explains storms like Florence and Mangkhut. Tropical storms in the Atlantic (known as “hurricanes”) and Pacific (“typhoons”) draw their energy from this abyssal heat store. Warmer oceans mean more intense and longer-lasting storms. Climate models have long forecast this. Moreover, sea levels are rising at a rate of 3mm per year. Two factors explain this: water expands as it warms; and glaciers are melting at both poles. Higher seas mean storm surges reach farther inland. And, as

Getting into hot water

Global ocean heat content, 0-2,000m

Deviation from 1981-2010 average, 10^{22} joules



Source: Lijing Cheng and Jiang Zhu

the atmosphere warms, it can hold more moisture that eventually falls as precipitation.

Recent studies have explored these effects in detail, using real events. Earlier this year, for instance, Mr Trenberth showed that deep-ocean temperatures just before Hurricane Harvey, which led to disastrous flooding in Houston in August 2017, were at a peak globally and in the Gulf of Mexico.

Data recorded just after the storm revealed a drop in the heat content of the Gulf that closely matched the amount of rain unleashed by the hurricane. Mr Trenberth and his colleagues concluded that Harvey “could not have produced so much rain without human-induced climate change.” Kerry Emanuel, of the Massachusetts Institute of Technology, estimates that a hurricane like Harvey in 2017 was made six times more likely by human greenhouse-gas emissions, and that by 2100 the risk will be 18 times higher than it was in the late 20th century.

A man who knows his stormy

Florence received an awestruck presidential reception. “One of the wettest we’ve ever seen from the standpoint of water”, noted President Donald Trump. In fact, America has endured far wetter and more damaging. Moody’s estimates that Florence caused between \$17bn and \$22bn in damage. Katrina, which devastated New Orleans in 2005, cost \$160bn in current dollars; Harvey cost \$125bn; Maria, which affected Puerto Rico in 2017, cost \$90bn.

The death toll of Florence, estimated at 37, is well behind those seen by Katrina, which killed 1,833, and Harvey (88). A recent study calculated that Maria killed 2,975, over a longer period, though Mr Trump, sensitive to criticism of his administration’s flat-footed response to that disaster, has disputed those figures. In contrast, a sensible government reaction to Florence probably helped limit damage and loss of life. Mandatory evacuation orders were issued three days before landfall. New Orleans only got such an order on the eve of Katrina’s arrival.

That Florence was not a chart-topping storm is small comfort to the North Carolinians whose homes and businesses were destroyed. Local economies could take years to recover. Some homeowners will be compensated by the national flood-insurance programme, which is subsidised by the government, in effect paying people to live in areas at high risk of flooding. Even so, the Federal Emergency Management Agency estimates that 40% of small businesses never reopen after a natural disaster. The state’s livestock industry has already taken a beating. The state agriculture department said that Florence had killed 3.4m chickens and drowned 5,500 pigs. Such casualties are expected to rise.

There’s no sun up in the sky

If storms can wreak such havoc in the world’s richest country, their impact in poor Asia-Pacific countries is even more far-reaching. Every year, the Asia-Pacific region is battered by more and bigger storms than reach America. There, the approach has been to move people away from the coast where possible. After Bangladesh found itself in 1970 in the path of cyclone Bhola, which killed between 300,000 and 500,000

people, making it the deadliest tropical cyclone on record, it began building a large network of raised shelters. Still, some people would refuse to use them. So now they accommodate livestock as well as people; have separate facilities for women; and are accessible to the disabled. But, according to Saleemul Huq, who directs the International Centre for Climate Change and Development, a research institute in Dhaka, the Bangladeshi system's biggest success has been its education programme, which has taught children how to respond to early warnings and take shelter.

The Philippines, too, has grim experience of storms. Haiyan, one of the strongest tropical cyclones yet recorded, which struck in 2013, remains a fresh memory. It pummelled the central part of the Philippines and crossed the country, killing 6,300 people and leaving 1,062 missing, by the official count. In comparison, the government's handling of Typhoon Mangkhut is counted a success. After it passed, Harry Roque, a spokesman for President Rodrigo Duterte, said his boss was "very, very satisfied" with the effort.

Yet by September 19th the death toll stood at 81 people and 70 were still missing. The number will probably rise. Rescue workers are still finding victims of the most deadly landslide, which buried a community of illegal miners digging for gold in a worked-out mine in the Cordillera mountains, in the north of Luzon, the main island. On September 15th, the day when Mangkhut hit Luzon, the National Disaster Risk Reduction and Management Council (NDRRMC) reported 194,368 people had taken refuge in shelters (mainly schools). It estimated the cost of the damage to agriculture at 14.3bn pesos (\$264m). Later the NDRRMC estimated that about 1.1m people had been affected by the storm.

Haiyan affected far more people, but in some respects Mangkhut, though it passed through only the north of Luzon, was bigger. Its bands of rain-bearing cloud swirled around an area 900km in diameter. As it approached Luzon, its winds sustained speeds of up to 205kph (127mph) near the centre, with gusts of up to 255kph.

One lesson learnt from earlier disasters was the need for earlier and more emphatic advice to people to seek refuge. The government's weather-forecasting service, called PAGASA, was tracking Mangkhut well before it reached Luzon. It warned of strong winds and heavy rain that would cause high waves at sea, storm surges up to six metres in height along the coast, and flooding and landslides inland.

PAGASA has been tracking roughly 20 storms a year since its founding in 1972, and this time its forecasts were accurate. They were translated into warnings spread on radio and television, by text message and over the internet. Radio is the most widely used mass medium, and only the poorest Filipinos are without mobile phones.

Mangkhut's winds blew down flimsy buildings, tore the roofs off sturdier ones and felled trees. But, like Florence, it wreaked most of its destruction through rain, which caused landslides and flash floods, inundating fields and ruining the crops in them, making roads impassable and cutting off electricity supplies. The storm halted all normal economic life. Schools were closed, to keep the pupils safe and to be used as public shelters; businesses were shuttered; ferry sailings and international and

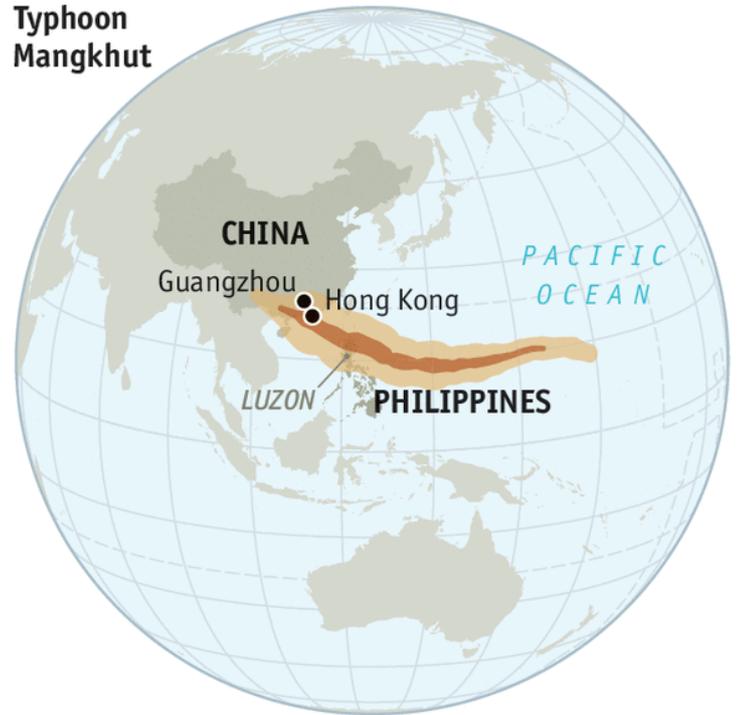
Trails of destruction

Wind speeds* ■ Tropical storm (63-118 km/h) ■ Hurricane/typhoon (>118 km/h)

Hurricane Florence



Typhoon Mangkhut



Sources: NOAA; Global Disaster Alert and Coordination System

*Sustained surface wind speeds

The Economist

domestic flights were cancelled. Mobile-phone networks were generally resilient, however.

The Philippines has a hierarchy of disaster-risk reduction, and management councils at every level of government. The system worked quite well this time. But it suffers from a malaise that afflicts the entire political structure. Politicians at the centre can say what they like, but local politicians do what they like. It also faces a more universal problem: that some disaster victims think they know best or, as in Bangladesh, are reluctant to abandon their property, such as livestock, to take shelter. The freelance miners in the Cordillera had that attitude. Most of those who died during Typhoon Haiyan were killed by storm surges in the eastern city of Tacloban, having been directed to take refuge in coastal shelters. Local lore had it that if a typhoon was coming, safety was in the high ground.

Haiyan also shows the importance of official competence. The interior minister at the time, Mar Roxas (later one of the presidential candidates defeated by Mr Duterte), directed the response from Tacloban, but omitted to take a satellite phone. When the storm made mobile-phone networks inoperable and prevented him leaving Tacloban, he was unable to respond to looting. Before Mangkhut struck, Mr Duterte called for the wider use of satellite phones by the authorities.

Mangkhut was not through when it left the Philippines. It terrorised Hong Kong (see [article](#)) and Macau, where high winds and flooding left some 20,000 households without power—and, unprecedentedly, all 42 casinos shut for 33 hours. The city appeared better prepared than it was before Hato, last year's largest typhoon, in which ten people died. This time no lives were lost.

The same day Mangkhut made landfall in Guangdong, China's most populous

province, flooding coastal and riverside neighbourhoods, and toppling thousands of trees. China's state weather bureau said it was among the ten most powerful typhoons to hit the region since 1949. Mangkhut subsequently spun through the much-poorer provinces of Guangxi and Yunnan, though by then it had weakened from a typhoon to a tropical storm.

"Thank God it only lasted one day," said a shaken resident of Dongguan, a factory city not far from Hong Kong, who stayed indoors for 48 hours. In Guangzhou, the provincial capital, tower-block windows were blown out. So many trees fell in Shenzhen, bordering Hong Kong, that commuters who ventured out the next morning quipped that going to work meant clambering through "jungle". Several districts of Yangchun, a riverside city that had lain directly in Mangkhut's path, remained under water two days after the storm.

Near the seafront in Zhuhai, a mainland city of more than 1.5m people next to Macau, high winds whittled palm trees into sharp spindles. One resident recounts pushing his sofa against his windows, fearing that the rattling glass was about to shatter. But he says the city has cleared up more swiftly than after Hato, and that the Chinese government's preparations seemed more comprehensive, too. Days before Mangkhut arrived, the government began sending locals text messages warning them to stockpile food and water and prepare to stay in their homes. The instructions were widely obeyed.

Moving feat

Authorities in Guangdong estimated that the winds had directly caused more than 4bn yuan (\$580m) of losses and that four people had been killed (three were pinned beneath trees and one was struck by an advertising hoarding). Those figures may be incomplete, but on the whole southern China weathered the storm better than was feared. In advance, at least 2.5m of Guangdong's 105m residents were moved to safer places, said state media, though it gave few details of such a massive operation. Many of those who were moved appeared to be coastal-dwellers and construction workers, who often bed down in flimsy dormitories. They were sent to schools, stadiums and exhibition halls. Most flights and all high-speed trains were cancelled. Some 50,000 boats observed a halt to fishing.

The government bragged that its enormous new bridge across the Pearl River estuary survived unscathed, and reassured locals that two nuclear-power stations located on Guangdong's coast had also escaped damage. China's leaders have lately sought to improve the handling of natural disasters and other emergencies. In April a hopeful sign was the government's creation of a new Ministry of Emergency Management, drawing together staff who had previously laboured in a dozen different departments.

As well as cleaning up catastrophes, the new outfit is expected to accelerate efforts to make vulnerable settlements more resilient. China is the same size as America but has four times as many people; moreover, they are crammed into low-lying coastal megacities in the east of the country, such as those sprinkled across Guangdong.

Few countries have as much to lose as China from a world of rising seas and furious winds, but Bangladesh is even more vulnerable. For Mr Huq, the researcher, and representatives of the “least developed countries”, a negotiating body at the UN’s climate-change talks, the central question about storms in the Asia-Pacific is who pays for the damage. Although China is now the world’s biggest emitter of greenhouse gases, America and Europe are estimated to have emitted 37% of the global total between 1850 and 2012. The Philippines, by comparison, emitted 0.5%. That has triggered repeated calls for wealthy countries to help poorer ones pay for the cost of the effects of climate change, not least from tropical storms. Those calls are unlikely to grow softer. But, with the Carolinas still reeling from Florence, and Mr Trump in the White House, America, at least, is unlikely to offer an encouraging answer.

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