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Eye On The Storm

This year's meeting of the American Association for the Advancement of Science (AAAS), held in Washington, covered its usual eclectic range of topics. We report on three: the forecasting of hurricanes, how the world might end and a complete record of the genes in a fruit fly.

The environment Search archive Links FROM space, there are few more awe-inspiring sights on the earth's surface than a hurricane: a white Catherine-wheel swirl of cloud sailing over an ocean's perfect blue. From the surface, however, the awe takes on a more sinister tone. Mankind has come to take dominion over the natural world for granted. But the death and destruction that a hurricane can wreak are a reminder that nature is not always the benevolent mother that both ancient and modern myth-makers would have their audiences believe.

Over the past 30 years, hurricanes have been responsible for four of the five biggest natural disasters to hit America. Although better forecasting and evacuation have, over the past century, reduced the death toll from 7,000 to a few score each year, the amount of hurricane-induced damage to property has risen enormously. Hurricane Andrew, the worst to hit America in the 1990s, inflicted $37 billion-worth of destruction.

That is why the AAAS devoted a day-long session to the science of hurricanes and, in particular, to ways of improving the forecasting of their behaviour on time scales that stretch from hours to millennia. Such knowledge would be useful in many ways. It would help those in the path of a storm to decide their response. It would help those who govern storm-prone areas to plan and regulate their buildings more safely. And it would help those who pick up the bill—the world's insurance and reinsurance companies—to prepare and to stay profitable.

Some teacup

There are two obvious questions that people like to ask about hurricanes: "Is it coming my way?" and "How strong is it?" Existing models are quite good at answering the first question: they can look three days ahead, with an average error of roughly 250km (150 miles). Considering that it costs some $450,000 to prepare a kilometre of coastline for a coming storm, the greater the accuracy the better. But forecasters are much worse at answering the second question. Hurricanes frequently gain or lose strength in ways that catch meteorologists by surprise. Isaac Ginis of the University of Rhode Island thinks he has a solution.

Although hurricanes are aerial beasts, they draw their power from marine heat. It is a pity, therefore, that existing models of their behaviour have such a poor grasp of the details of the interaction between air and sea. Dr Ginis and his colleagues have put that right by looking at how a hurricane stirs cold water out of the ocean depths in a way that contributes to its own demise.

The top few metres of the sea are relatively warm. At the bottom of this warm layer is a narrow zone called the thermocline, below which things suddenly become much colder. Normally, there is not much mixing of the water above and below the thermocline. A hurricane, however, can change that. The amount of mixing depends partly on the strength of the hurricane and partly on the depth of the thermocline. But the result of the mixing is to reduce the temperature at the sea's surface—and thus to reduce the strength of a hurricane.

That explains, for example, why hurricanes that cross from the Caribbean into the Gulf of Mexico often lose strength. Although the normal surface temperature in both bodies of water is about the same, the thermocline is nearer to the surface in the Gulf of Mexico. That makes it easier for a hurricane to stir cold water up to the surface. Applying knowledge about the depth of the thermocline over the entire North Atlantic to hurricanes last season improved predictions of their strength by almost a third.

Reaping the whirlwind

Residents are primarily interested in knowing when and where to run. But insurance companies need a little more information. To begin with, they want to know how much damage a given strength of storm is likely to do to any given piece of coastline, in order to make financial provisions.

Auguste Boissonade works for Risk Management Solutions, a firm based in Menlo Park, California. His firm, and others like it, are starting to turn out computer models that can estimate for an insurance company the cost of a storm even before it happens. These models work by integrating vast amounts of information from sources as varied as census results and satellite images. They have data not only on the value, construction type and number of buildings in an area, and the likely value of their household goods, but also on the local topography and vegetation. That means they can work out roughly how much a storm's force will be broken by hills and trees before it has a chance to do significant damage. And that, in turn, enables insurance companies to set their premiums more precisely.

But insurers are equally interested in the frequency of damaging storms. Although strong hurricanes are rare, they do disproportionate amounts of damage. Around 85% of hurricane-related payouts are caused by a mere one-fifth of the hurricanes that reach land. Firms want to know three things: whether big storms are becoming more or less common, whether certain coasts are being hit more or less often, and just how frequent are the biggest of the big storms—the ones whose effects could break a careless insurance outfit. The strengths and tracks of hurricanes hitting America have been recorded with reasonable accuracy for over a century. A casual glance at the data suggests that the number of storms varies randomly from year to year. But if only those tempests strong enough to cause serious damage are studied, a disturbing picture emerges. The number and distribution of big hurricanes seems to flip-flop between two fairly stable patterns.

James Elsner of Florida State University has plotted the number of big storms in the North Atlantic since 1900. From 1900 to 1942 there was an average of 1.65 a year. From 1943 to 1964 this number rose to 3.57. From 1965 to 1994 it fell back to 1.67—almost identical with that in the first four decades of the century. But in 1995 it rose again, and is now once more running at around 31/2.

According to Dr Elsner, this change is related to sudden shifts in the position of the long-term area of high pressure that sits near the Azores. Ultimately, he believes these shifts are caused by changes in the behaviour of the "great ocean conveyor belt", a long-term circulation pattern that moves sea water from the Pacific ocean, via the Indian ocean, to the North Atlantic ocean, and back again.

When the conveyor is moving fast, it warms the North Atlantic, promoting the formation of strong hurricanes. Such shifts also seem to alter the balance of risk between America's Atlantic and Gulf of Mexico coasts. A high-pressure area that lies well to the south-west (and is associated with periods of fewer intense storms), diverts hurricanes to the Gulf coast; north-easterly high pressure tends to send them towards the Atlantic coast.

This pattern is also reflected in the amount of damage that big storms have done over the years. Superficially, the cost of storm damage has risen massively over the past century. However, Christopher Landsea of the National Oceanic and Atmospheric Administration applied a little common sense to the data by factoring out inflation, the rise in individual wealth over the period and, crucially, the increasing tendency of people to live by the seaside. Dr Landsea then asked, for each of the century's big storms, what would happen if an identical storm with an identical track were to strike today?

The pattern of damage was similar to the pattern of big-storm frequency uncovered by Dr Elsner. In particular, the 1970s and 1980s were relatively quiet. It is perhaps no coincidence that these decades saw the greatest ever boom in seaside building in America. At least part of the reason for this may be that the planning authorities were lulled into a false sense of security by the chance of being in a quiet part of the long-term hurricane cycle.

The current rise in the number of big storms seems, therefore, to be part of a natural pattern. But many people worry that global warming will bring a further increase in the number, and also the geographical distribution, of hurricanes. Kerry Emanuel of the Massachusetts Institute of Technology has reason to disagree.

On the face of it, a warmer world might be expected to create more storms, and some climate models predict it will. Others, however, suggest the number of hurricanes will fall. But Dr Emanuel's point is that even the worst predicted rise will be lost as noise in the variation in hurricane numbers from year to year.

On the issue of storms affecting more of the earth's surface, the worriers are, according to the models, just plain wrong. Their fear stems from the fact that a warmer world would have more ocean with a surface temperature above 26°C, the minimum needed to permit a hurricane to form, and thus more places in which hurricanes could prosper. But although a warm sea is a necessary condition for a hurricane, it is not a sufficient one. Current climate models do not suggest an expansion of hurricanes' natural habitat.

The biggest storms of all have, however, been so rare in recorded history that it is almost impossible to make meaningful statistical inferences from them. Instead, you have to turn to the geological record. This has been done by Kam-Biu Liu, of Louisiana State University, who has looked for traces of old hurricanes in the ponds that line much of America's Atlantic and Gulf coasts.

Coastal ponds are usually separated from the sea by a sand dune a few metres high. A strong enough hurricane can produce a surge of sea water over this dune. Normally, the bottom of a lake is muddy, but a hurricane-induced surge will bring sand into the pond. So by taking a core from the bottom and looking for sand layers, Dr Liu was able to record the passage of ancient hurricanes over the pond. Indeed, by taking several cores, progressively further from the coastal dune, and seeing how far a sand layer extends, he can make a good guess at how powerful a passing hurricane was.

His first discovery is one that is gratifying to the insurance companies: the record of the past 5,000 years from 22 different sites supports current guesses about the frequencies of really big storms. Any given bit of the coast seems likely to be hit by a hurricane of category four or five (the worst sort), on average, once every 300 years. But there is an interesting geographical variation: Gulf-coast sites are hit five times as often as those on the Atlantic coast.

There is also longer-term evidence to support Dr Elsner's theory of two stable hurricane patterns. Shifts in the position of the Azores "high" can be traced over the millennia by their effect on North America's rainfall. That pattern is well known from previous work on climate changes over the past few thousand years. And it turns out, according to Dr Liu's ponds, that shifts in the Azores high coincide with shifts in the hurricanes in exactly the way that Dr Elsner predicts.

Paleotempestology, as its practitioners call the subject, may sound esoteric. But all things connect in the end. If you live in a hurricane-prone area of the United States it is just possible that the size of your next insurance bill will be affected by what is found in some holes in the mud in Louisiana.

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