AT the beginning of August, Hurricane Erin, the fifth of the season, hit Florida. But its impact was negligible compared to its predecessor, Andrew, which in the same month three years ago killed 35 people, left 250,000 homeless, and caused $30 billion (£20 billion) worth of damage. The devastation and disruption it created has given rise to the question – and much criticism – of whether the US is adequately prepared for hurricanes, to which its eastern and southeastern coastal states are especially vulnerable. Policymakers are now looking at ways in which their communities can be given better warning and protection. In this respect, the geographical science of hurricane prediction has much to offer.

Hurricanes are classified by their damage potential according to a scale developed in the 1970s by Robert Simpson, director of the National Hurricane Center, and Herbert Saffir, an engineer. The Saffir/Simpson scale is used by the US National Weather Service to give public officials information about a storm’s intensity. Category 3, 4, and 5 storms are ‘major’ hurricanes and are responsible for about 80 per cent of the damages associated with US hurricanes.

Hurricanes pose a number of threats to coastal communities, including storm surges, high winds (sometimes tornadoes) and excessive rainfall. A storm surge is a dome of water at the centre of a storm, caused by low surface pressure, which can 'pile up' water at the coast and inundate low-lying coastal areas. In 1900, more than 6,000 deaths occurred in Galveston, Texas, primarily because of a hurricane storm surge. Winds have also been responsible for significant loss of life, and the damage caused by Hurricane Andrew has focused attention on their impact. In September 1928, hurricane wind caused the waters of Lake Okeechobee, Florida to overflow, leading to the deaths of almost 2,000 people. Deaths caused by excessive rainfall have primarily occurred...
inland: in 1969, more than 100 people died after Hurricane Camille caused flooding with heavy rains.

Research led by Dr. William Gray, a scientist at Colorado State University, shows that hurricane impact in the US over recent years has been below the historical average. Since 1980, only 15 hurricanes have struck the US, compared to the average of 25 from 1950 to 1984. Of these, fewer than half have made landfall in the last four years have been among the quietest this century. But recent hurricanes, including Andrew in 1992 and Hugo in 1989, have led many scientists and disaster experts to conclude that this good fortune may be coming to an end. And if hurricanes become more frequent, will the US be adequately prepared?

When hurricanes strike, they cost lives and dollars, and disrupt communities. And while there has been fewer hurricanes in recent years, their economic and social costs have been rising, largely because of increasing coastal population and development. A rough calculation shows that the US has suffered about $100 billion ($67 billion) in hurricane-related damages over the last 45 years, or well over $2 billion ($1.3 billion) a year (after compensating for inflation).

However, this average figure underestimates the magnitude of potential hurricane damage today owing to the increased level of coastal development. A more realistic indication, perhaps, is the amount of insured property: in 1993, the coastal counties represented about 15 per cent of the total insured property in the US, amounting to some $21.4 trillion.

Concurrent with this trend has

**Forecasting a hurricane**

A forecast involves analyzing data from satellites, radar, and other devices to determine the storm’s direction, speed of movement, intensity, and location, with respect to time. This data is then converted into computer models of storm development and intensity. The US National Hurricane Center uses several computer models to track an Atlantic hurricane. They are based on various mathematical relationships and physical understanding of hurricanes. A number of models are used because experience has shown that each one has its own strengths and weaknesses. A new model designed by the Geophysical Fluid Dynamics Laboratory in Princeton, New Jersey, may dramatically improve the accuracy of forecast tracks because of its higher resolution and better understanding of the physical processes of hurricanes. However, such improvements will not remove the importance of the forecaster’s subjective judgement. The forecaster’s subjective judgement about a hurricane is necessary because the various models often provide conflicting information that needs interpretation. The result of the forecaster’s judgement and output from the various models is an official forecast that the public will see or hear.

Above forecasts for Hurricane Hugo according to six different hurricane track models over 72 hours. As the graph shows, the models disagreed and Hugo might have stayed out over Florida, Georgia, South Carolina, North Carolina or even New York. However, one of the forecasters, the National Hurricane Center, made a well-predicted storm, with the official forecasts performing more accurately than any single computer model.
<table>
<thead>
<tr>
<th>Category</th>
<th>Central Pressure (millibars)</th>
<th>Winds (knots)</th>
<th>Surge (metres)</th>
<th>Typical damage</th>
<th>Example location damage (1990 US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>≥980</td>
<td>64-82</td>
<td>1.2-1.6</td>
<td>minimal</td>
<td>Allison (1995) Florida (Gulf Coast) minimal</td>
</tr>
<tr>
<td>2</td>
<td>965-979</td>
<td>83-96</td>
<td>1.7-2.5</td>
<td>moderate</td>
<td>Bob (1991) New England $1.5 billion</td>
</tr>
<tr>
<td>3</td>
<td>945-964</td>
<td>97-113</td>
<td>2.6-3.8</td>
<td>extensive</td>
<td>Alicia (1983) Texas $2.4 billion</td>
</tr>
<tr>
<td>4</td>
<td>920-944</td>
<td>114-134</td>
<td>3.9-5.5</td>
<td>extreme</td>
<td>Andrew (1992) Florida $&gt;25 billion</td>
</tr>
<tr>
<td>5</td>
<td>&lt;920</td>
<td>&gt;134</td>
<td>&gt;5.5</td>
<td>catastrophic</td>
<td>Camille (1969) Gulf Coast $5.24 billion</td>
</tr>
</tbody>
</table>

While Andrew was not the most severe hurricane, according to the Saffir/Simpson scale (above) it caused the most damage.

Below, the graph shows the annual probabilities (as a percentage) of a major hurricane country landfall for each coastal county illustrated in the map; however, all areas are at some risk.

The rapid growth in population along the coasts of the Gulf of Mexico and southern Atlantic. According to the US Census Bureau, the combined population of Florida’s Dade, Broward and Palm Beach counties in 1990 was higher than 25 of the US states. Together, the 168 coastal counties of the Gulf and Atlantic seabords are home to approximately 40 million people, or about 16 per cent of the total US population.

Nonetheless, improved hurricane forecasts, complemented by better warning systems, have seen a dramatic drop in hurricane-related deaths this century. But a large loss of life is still possible in many areas, particularly if plans of action are not well formed and executed. Part of the challenge is that most US coastal communities have not experienced a severe hurricane in many years and may therefore have become complacent. This can undermine efforts to reduce the impact of hurricanes, as was revealed in southern Florida during Hurricane Andrew, where buildings...
codes had not been enforced, and in Louisiana where evacuation plans had not been updated.

Because society undertakes continuous change, efforts to reduce its vulnerability to hurricanes must keep pace with them. Hurricane track forecasts, for example, project the path of the hurricane and are released by the US National Hurricane Center in Miami in order to post hurricane watches and issue warnings. Local officials use the information to determine where to order evacuations out of the storm's path.

Although hurricane forecasters have made tremendous progress in improving their predictive skills in recent decades, hurricane track forecasting is still not totally reliable. This means that watches and warnings must cover a larger span of coastline than the hurricane will actually affect. For example, warnings are generally posted for a 200 kilometre-wide section of the coast, yet hurricane conditions generally affect only about an 80 kilometre-wide area. Such overwarning is problematic because of the costs of short-term preparation and a possible loss of faith by the public in the forecast process. To reduce these costs and retain credibility, forecasters are continuously striving to improve accuracy.

Yet, even the 'perfect forecast' is of limited use if, for example, evacuation plans are outdated or evacuation routes are blocked. To make sure this does not happen, 'user communities' such as the construction industry and emergency managers have to work together. This requires scientific research on hurricanes to be an on-going process of reducing society's vulnerability rather than simply providing information to people living in vulnerable locations. For example, research can help structural engineers and city planners to develop appropriate building codes and emergency managers to design and implement evacuation plans.

The collaboration between producers and users of scientific knowledge not only reduces people's vulnerability to hurricanes, it also reinforce public and political faith in the value of scientific research to societies across the globe.

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