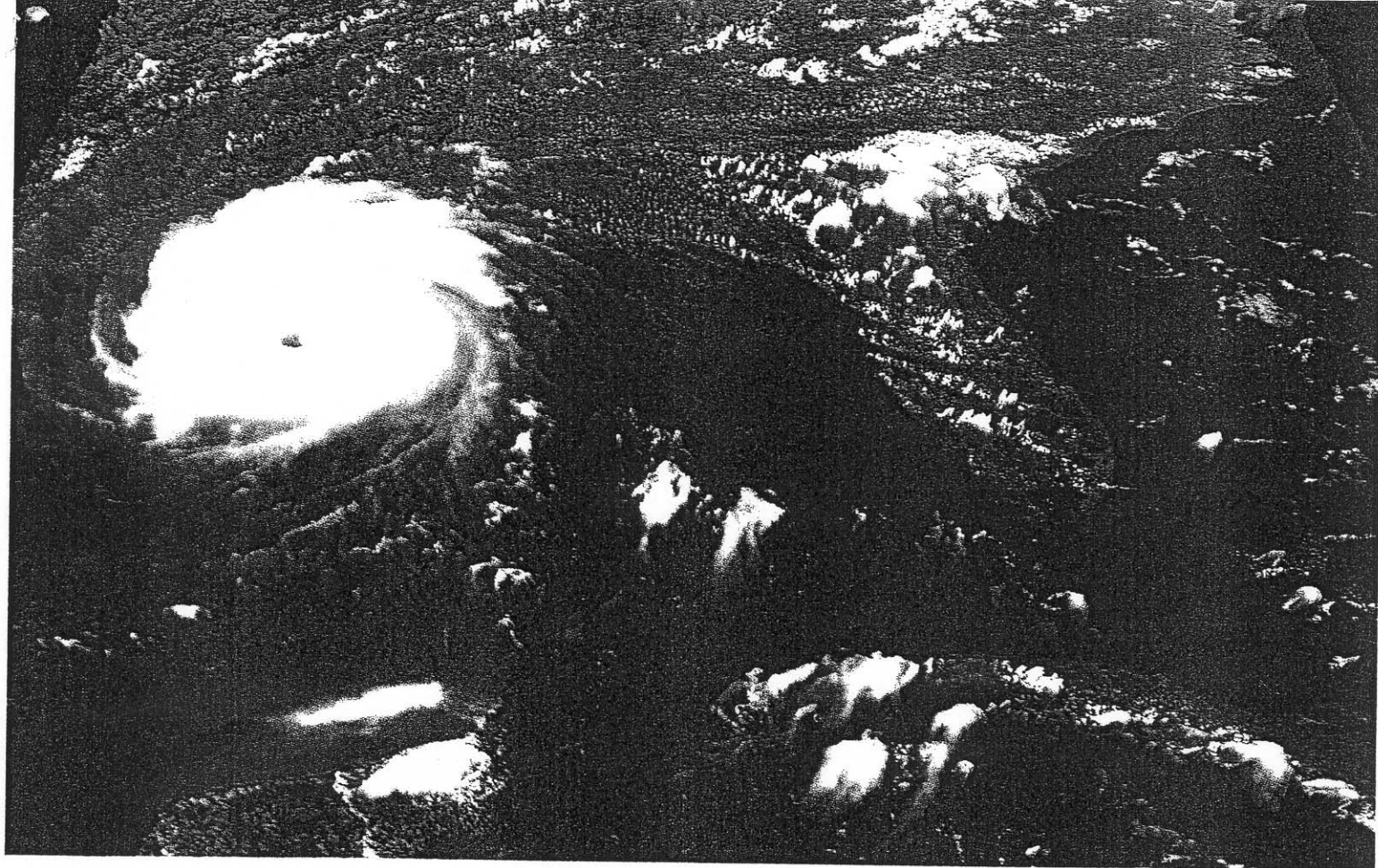




METEOROLOGY

TAMING THE WIND

In the middle of what is likely to be the most active hurricane season on record, Roger Pielke Jr explains how hurricane prediction in the US is storming ahead

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 ►

Above: a computer-generated perspective of Hurricane Andrew with its central 'eye' and a swirl of clouds. The hurricane, which struck in August 1992, is seen over the Gulf of Mexico with the Yucatán Peninsula at bottom left of picture. Andrew reached speeds in excess of 230 kilometres per hour

◀ 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 (5.7 hurricanes a year between 1950 to 1994): from 1930 to 1959, 25 major hurricanes struck the US; from 1960 to 1989, only 15 made landfall; while the last four years have been among the quietest this century. But recent major 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

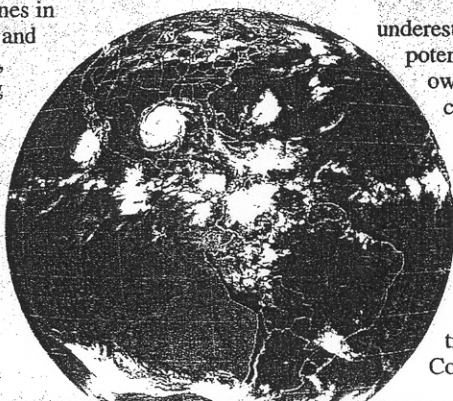


SYGMA

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

Above: the aftermath of Hurricane Andrew, which caused \$2 billion of damage in Florida and Louisiana. Left: a weather-satellite image showing Hurricane Allen on 8 August 1980 over the Gulf of Mexico. Another unidentified hurricane can be seen developing over the west coast of the US

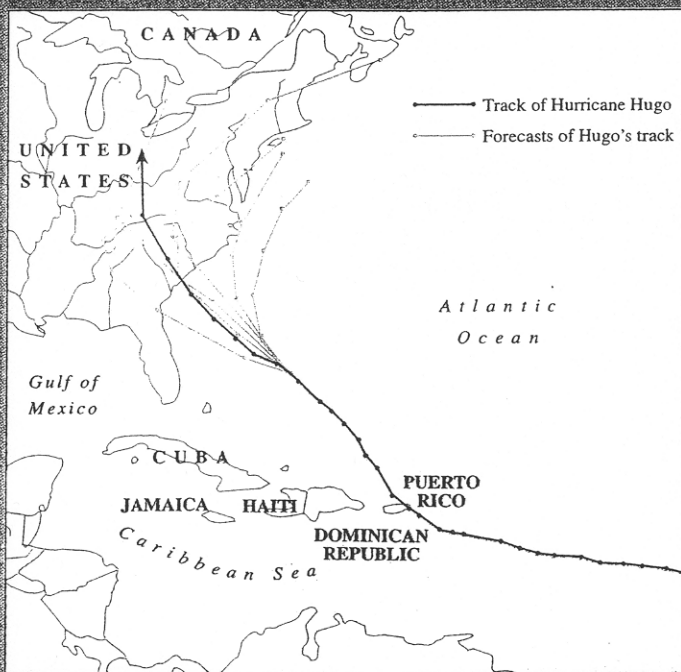


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Forecasting a hurricane

A forecast involves analysing data from satellite images, aircraft reconnaissance, ocean buoys, radar and ship observations, in order to determine the storm's direction, speed of movement (translation), intensity and location, with respect to time. This data is then converted into computer models of storm movement and intensity. The US National Hurricane Center uses several computer models to track an Atlantic hurricane. They are based on various statistical relationships and physical understandings of hurricanes. A number of models are used because experience has shown that each one has its own particular strengths and weaknesses. A new model designed by the Geophysical

Fluids 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 expertise. The forecaster's subjective judgement about a hurricane is necessary because the various models often provide conflicting information that needs interpreting. But the result of this marriage of forecaster judgement and output from the various models is an official forecast that the public will see or hear.



ALL MAPS AND CHARTS BY GARY HALEY

Above: forecasts for Hurricane Hugo according to six different hurricane track models over 72 hours. As the chart shows, the models indicated that Hugo might make landfall over Florida, Georgia, South Carolina, North Carolina, or miss land altogether. However, the judgement and expertise of hurricane forecasters made Hugo a well-predicted storm, with the official forecasts performing more accurately than any single computer model.

Category	Central Pressure (millibars)	Winds (knots)	Surge (metres)	Typical damage	Example location damage (1990 US\$)
1	≥980	64–82	1.2–1.6	minimal	Allison (1995) Florida (Gulf Coast) minimal
2	965–979	83–96	1.7–2.5	moderate	Bob (1991) New England \$1.5 billion
3	945–964	97–113	2.6–3.8	extensive	Alicia (1983) Texas \$2.4 billion
4	920–944	114–134	3.9–5.5	extreme	Andrew (1992) Florida >\$25 billion
5	<920	>134	>5.5	catastrophic	Camille (1969) Gulf Coast \$5.24 billion

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

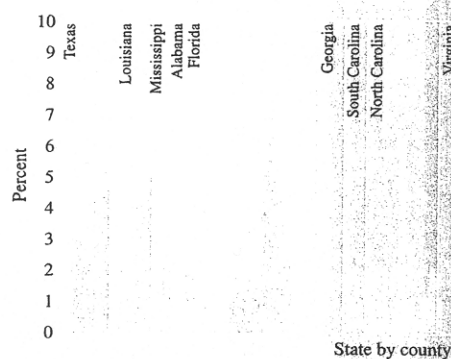
Below: the graph shows the annual probabilities (as a percentage) of a major hurricane landfall for each coastal country illustrated in the map, however all areas are at some risk

been 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 29 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.

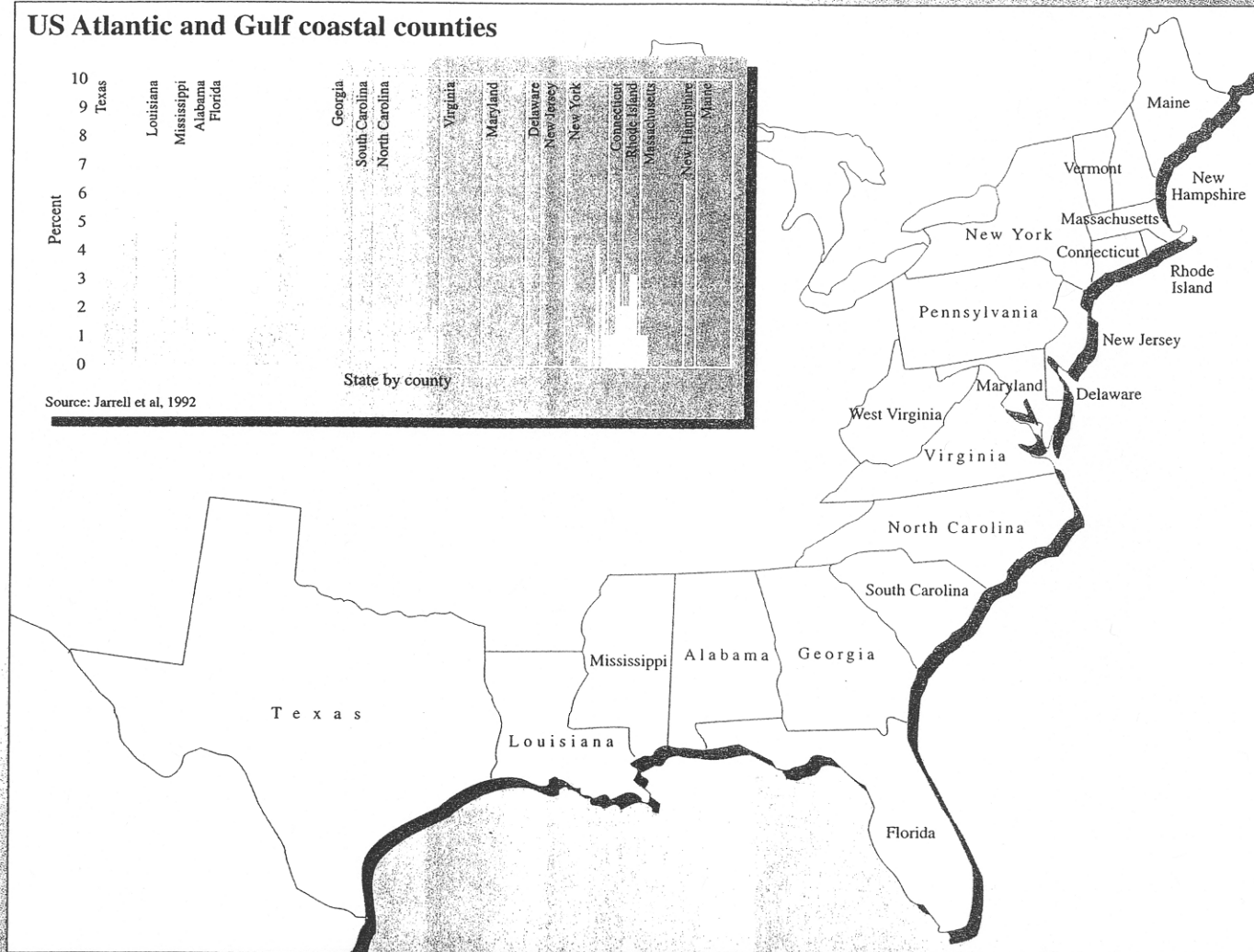
Preparedness for hurricanes has technical, practical, and political aspects which, are often determined by the idiosyncrasies of and resources available to each community. As a result, levels of preparation (and consequently, society's vulnerability to hurricanes) vary a great deal between communities along the US Gulf and Atlantic coasts. Long-term preparation includes the purchase of insurance, development of evacuation plans, enforcement of building codes, and planning for post-storm recovery. Short-term action includes establishing watches, issuing hurricane forecasts, warnings and evacuation orders, and the mobilisation of local, state, and federal disaster relief.

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 building

US Atlantic and Gulf coastal counties



Source: Jarrell et al, 1992

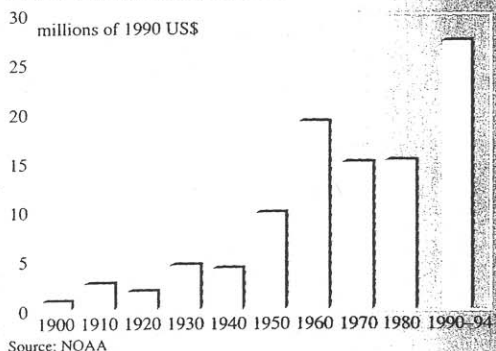


codes had not been enforced, and in Louisiana where evacuation plans had not been updated.

Because society undergoes 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

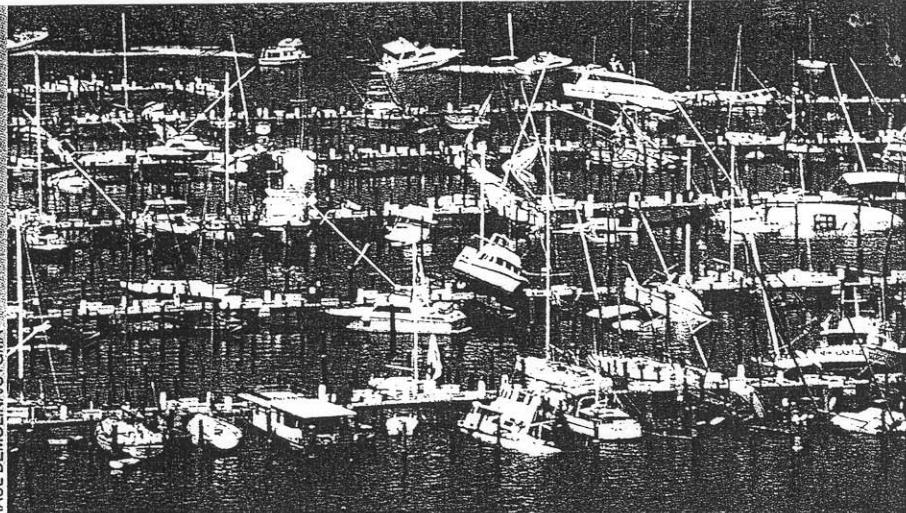
Hurricane losses by decade



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.

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

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RAUL DEMOLINA/SGMA

Hurricanes in the US

A hurricane forms as winds move towards an area of low pressure in the tropics. In the northern hemisphere, the winds begin to circulate in an anti-clockwise fashion due to the effect of the Earth's rotation. The eye of a hurricane – perhaps its most identifiable feature – is formed when the spiralling winds can no longer reach the centre of low pressure owing to the forces of rotation and wind speed. The eye is thus a region of extreme relative low pressure.

The oceanic location where conditions are favourable for hurricanes to develop changes over the Atlantic hurricane season (1 June to 30 November). In June, they tend to develop in the western Caribbean and Gulf of Mexico, while in July they usually develop further east. In August and September, the hurricane region extends to the coast of West Africa, shrinking back to the west in October and November.

A hurricane's motion, called its track, is a function of large-scale patterns of atmospheric circulation, which vary over the six-month hurricane season. Typically, hurricanes follow a parabolic track beginning over the tropical

Atlantic ocean. They move westward with the easterlies, or trade winds. The poleward motion of the atmosphere forces the typical hurricane north until it leaves the tropics and the trade winds, then it recurves to the east with the westerly winds further north, where it weakens over the cooler northern water.

But atmospheric disturbances, such as areas of high and low pressure, can cause a hurricane to divert from the 'typical' path. Also, changes in the seasons alter the basic structure of the atmospheric patterns which determine hurricane movement. Understanding these basic patterns, hours and days in advance, is the fundamental challenge facing hurricane track forecasters.

While every state from Texas through to Maine is subject to hurricane strikes, most storms make landfall over Florida and Texas. The low-lying sandy barrier islands, such as the exposed North Carolina Outer Banks, that essentially stretch from Texas to Maine are particularly vulnerable because they have often been developed and usually bear the brunt of an impact.