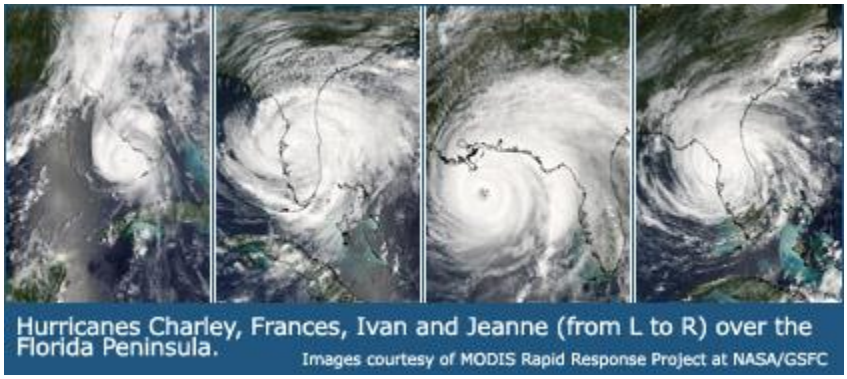
Three hurricanes and a storm

29 Sep 2004



Hurricanes Charley, Frances, Ivan and Jeanne (from L to R) over the Florida Peninsula.
Images courtesy of MODIS Rapid Response Project at NASA/GSFC

This year's hurricane season brought unusually high costs to the Caribbean and the southern states of the US. Four major hurricanes – Charley, Frances, Ivan and Jeanne - brought around two thousand deaths to the region, as well as property damage amounting to many billions of dollars. However, these impacts have been unevenly spread between richer and poorer nations. The accuracy and effectiveness of disaster prediction and hazard management have also varied quite noticeably between each of the different storm events and across the nations that have been touched by them.

Curriculum links

KS2
Geography 1a-e, 2a-g

KS3
Citizenship 1a, 1f, 1h, 1i, 2a-c, 3a-c
Geography 1a-f, 2a-e, 3a-e, 4a, 5a-b, 6d, 6f, 6i
IT 1a-c, 2a, 3a-c, 4a-d

KS4
Citizenship 1a, 1f, 1h, 1i, 2a-c, 3a-c
Geography Climate; population and development issues
IT 1a-c, 2a, 3a-c, 4a-d

Scottish Curriculum 5-14
Geography levels D-E

Written by Dr Simon Oakes who teaches geography at Mander Portman Woodward (London) and is a senior A-level examiner for Edexcel.

What were the impacts of Charley?

29 Sep 2004

Hurricane Charley south of Cuba on 12th August 2004 ©NOAA

Twenty people died in Florida in the wake of Hurricane Charley, as wind speeds reached 145 mph across the state during 14-15th August, causing widespread destruction. Additionally, one person died in Jamaica and several in Cuba, bringing the death toll to 27. Two million Floridians were told to flee, in an act of peacetime disaster planning that was unprecedented in its scale for the US.

However, on this occasion, the hazard management process was only a partial success. Not enough is known about the mechanisms that drive hurricanes to accurately forecast the *exact* course that they will take. Charley landed much further south on Florida's Gulf Coast than meteorologists predicted, catching by surprise the many residents that had not been evacuated (*The Independent*, 15 August 2004). In the worst storm to hit the state for twelve years, this Category-4 hurricane proceeded to leave a trail of devastation that stretched from Punta Gorda on the Gulf Coast, all the way to Daytona Beach on the Atlantic coast.

- In Lee County alone, 250,000 structures were damaged, including multimillion-dollar waterfront homes (high-value assets that are more readily associated with an MEDC such as the US than with LEDC neighbours such as Haiti). State Governor Jeb Bush put preliminary damage estimates at US$15 billion (£8.1 billion).
- 80% of buildings in Charlotte County were damaged or destroyed.
- As Charley pushed northeast through the state, it stripped the orange groves in central Florida, leaving farmers with long-term financial worries.
- 1.1 million people in the state were left without power and three Florida cities – Arcadia, Port Charlotte and Punta Gorda – were left entirely without water.
- Closed airports disrupted holiday travel at the peak of the season, which resulted in heavy losses for tourist businesses; loss-of-earnings insurance claims will be high. Even Orlando Disney World was forced to close for a day.
- A major change to the physical environment occurred when Charley breached a spit, severing North Captiva island (the hooked end of the landform) from the mainland. The right eyewall of the hurricane passed directly over North Captiva island, resulting in a breach that is 450 metres wide. From the Gulf of Mexico, storm waves and currents flowed across the island, forcing sand back towards the coastline, further changing the morphology of the landform. In the southeast United States, most of the inlets cut through the barrier islands have been formed in a similar way, during previous hurricanes. See: http://coastal.er.usgs.gov/hurricanes/charley/

North Captiva island. Pre-Hurricane Charley aerial photo on the left was taken a few days following the passage of 2001's Tropical Storm Gabrielle. Note the two small breaches in the central part of the island compared to the 450-m -wide breach carved by Charley in 2004 that is shown in the right photo.

How effective was the management of Charley?

29 Sep 2004

Trailer homes are seen after being destroyed in the wake of Hurricane Charley in Punta Gorda, August 15, 2004. Thousands left homeless in southwest Florida faced picking up their lives. © Reuters

In some respects, the US disaster response was very good – for instance, some 4,000 National Guard troops ferried supplies, erected tents for temporary shelter and patrolled against looting.

However, the overall impact of the hazard was far greater than originally expected due to a range of factors, both physical and human:

- The hurricane was the strongest to hit Florida in a dozen years – insulation against an event of this magnitude will always be difficult.
- Half of the deaths were in Punta Gorda, a settlement of 15,000 people, where there was talk of lack of preparedness due to inaccurate predictions. Forecasts originally said that the hurricane would strike 110 miles north, in Tampa. The two million people evacuated from the Tampa region represented the "largest peacetime evacuation in US history" (*The Independent*, 15 August 2004). However, because the level of risk associated with Punta Gorda was thought to be lower, not everyone evacuated the area, hence the high death toll.
- Such errors occur because the mechanisms that drive hurricanes are still not fully known. Hurricanes behave erratically, especially when the winds that drive them weaken. Imperfect understanding of these processes makes entirely accurate prediction of hurricane movement hard to achieve.
- Emergency workers opened care stations to dispense water, ice and food and give residents a chance to take showers, for many their first in three days. But the lack of phone service and power made it difficult to co-ordinate relief efforts.

Charley was the most devastating storm to hit Florida since Hurricane Andrew ripped up parts of the Miami area in 1992 and may have caused as much as $25 billion in damage. It had been responsible for the biggest peacetime evacuation in US history. However, Charley did not retain this distinction for long, as it was immediately followed by a larger storm system: Hurricane Frances!

Hurricane Frances on 7th Sept 2004, as the still large storm moves very slowly through eastern Alabama and western Georgia, USA ©NOAA

How did the impacts and management of Frances compare?

29 Sep 2004

Initial reports suggested that Frances was a greater threat than Charley. Twice the size of Charley, Frances was at first predicted to be the worst storm to hit Florida for nearly fifty years.

1,000 miles wide and bringing winds of more than 120mph, 15 million people looked to be in its path (*The Guardian*, 04 September 2004). With inaccurate predictions of Charley's course still fresh in their minds, emergency planners decided to take no chances and evacuated 2.5 million people this time. A 300-mile stretch of coastline around Miami was cleared – breaking records once again for the biggest evacuation in Florida's history. Even

the Kennedy Space Centre at Cape Canaveral –home of the space shuttle – was evacuated for the first time in its history, with all 14,000 workers sent home. By widening the evacuation area, forecasters could be more confident this time that there would not be a repeat of the loss of life caused by Charley. They were right to do so and the reduced impacts were as follows:

People waiting with shopping trolleys for ice and water after Hurricane Frances. A Florida National Guard soldier is with them in a car park in Stuart, Florida September 6, 2004. The supplies were to arrive at 8 a.m. but still hadn't shown up four hours later. © Reuters

- Only four deaths were reported in the US, although at least two died in the Bahamas, which Frances also passed over.
- The 75-mile wide eye passed directly over the town of Stuart, destroying many buildings. Four neighbouring counties were declared a disaster zone, with 4 million people left temporarily without power.
- Although Frances was a larger system than Charley, the wind-speeds were actually lower. Much of the damage associated with Frances therefore resulted from wide-scale flooding, rather than wind damage, as over 30cm of rain fell across much of the state.
- The disaster relief operation, involving 6,000 National Guardsmen and the erection of 233 emergency shelters, cost over $160 million.
- Some interesting positive impacts of the hurricane were reported by *The Guardian* (04 September 2004): mobile home manufacturers saw their share prices rise by 5% on Wall Street, with sales expected to rocket due to the anticipated need to re-house evacuees. DIY chains also experienced a bonanza, as Floridians sought out wood and metal sheeting to protect their homes.

Despite these losses, as Frances passed, Floridians breathed a collective sigh of relief. Fewer lives had been lost to the second hurricane. The management of Frances had therefore been a greater success than Charley (although the poorer Caribbean islands had still suffered some deaths). But then, right behind Frances, came Hurricane Ivan.

Was Ivan terrible?

29 Sep 2004

Above the Eye of Hurricane Ivan
Credit: Expedition 9 Crew, International Space Station NASA

Hurricane Ivan hit the Caribbean island of Tobago on 7th September, killing one person, before pounding Grenada, where it left at least 37 dead. Most of the poorly-constructed buildings in the capital, St George's, were completely destroyed. Dozens more lost their lives as Ivan struck Barbados, Venezuela, the Dominican Republic, Jamaica, Cuba, the Cayman Islands and the US states of Florida and Alabama. The final death toll appears to be around 122.

Once again, the general unpredictability of hurricanes figures strongly in the story of Hurricane Ivan. For instance, on the 12th September Ivan was expected to make a direct hit on Jamaica. By now a Category-5 hurricane generating winds of 165mph, initial predictions forecast utter disaster. However, at the last minute the hurricane veered towards the south of Jamaica, rather than passing across the middle of the island. This lowered the final death toll to between 20 and 56 (estimates vary), as the hurricane missed some of the most densely populated areas where large numbers of people had resisted attempts to evacuate them.

In fact, a total of 500,000 people in the predicted danger zone had refused to leave their homes for fear of looting and burglary (*Sunday Times*, 12 September 2004). Mostly lacking insurance, they knew that they would be unable to replace their possessions should they be stolen. In a cost-benefit analysis, many decided to risk staying in their homes, despite the approaching hurricane. Some of them were sadly still caught by the hurricane, even with its changed path – deaths that could easily have been avoided. This can be compared this with the US response to Frances, where millions of well-insured Americans were mostly compliant with the evacuation plans, trusting the National Guardsmen to maintain law and order and to prevent looting.

Damage caused to the Caribbbean island of Grenada by Hurricane Ivan as it passed through on September 7 2004. The hurricane, was a rare category five storm with 160 mile per hour (260kph) winds. © Reuters

What about the impacts and management of Ivan?

29 Sep 2004

Cuban President Fidel Castro points to a satellite image of the Hurricane Ivan approaching Cuba, as the Cuban chief weather forecaster talks during a live TV broadcast in Havana, September 11, 2004. © Reuters

As the island of Cuba's population of 11.2 million braced themselves for impact, about 1.3 million were ordered to evacuate their homes along the southern coast of the island.

Cuba is a Communist state with a highly authoritarian government. President Fidel Castro has the power to arrest people who fail to obey an evacuation order (*The Guardian*, 13 September 2004). For this reason, the evacuation was far more successful than in Jamaica, where half a million had stayed in their homes. This point demonstrates just how important social and political differences between neighbouring states can be in determining the impact of a natural hazard. In the event, Cuba experienced no loss of life but saw serious damage to its tobacco crops (the island is famous for its cigars). Previous hurricanes in 2002 caused $40m losses to this valuable export industry.

Hitting the Cayman Islands next at 155mph, Ivan swamped the vulnerable British dependency (population: 45,000). Parts of the islands were covered with 2.5 metres of water and estimates suggest that 80% of homes were damaged. By now, Ivan had weakened to Category-4, yet still managed to claim a further fifteen lives. The Caymans also suffered from lawlessness in the wake of the hurricane, with local police shooting and killing two looters. A minor controversy later developed over whether reports of damages were under-played by the British government, fearful of disrupting tourism and flows of investment. Amazingly, this tiny British colony is home to 400 banks and is the world's fifth largest financial centre (*The Independent*, 22 September 2004).

After the Cayman Islands, Ivan finally headed for the US coast. Earlier during this particularly unpredictable hurricane's progress, both Mexico and the US had identified a major risk and had already staged evacuations. The Florida Keys were abandoned once more, while 12,000 Mexicans removed themselves from the Yucatan peninsula. Fears of disruption of oil pipelines in the Gulf of Mexico also led to the Transnational Corporation Shell taking the precaution of shutting down its oil ells and evacuating workers. World oil prices rose as a result – a "worldwide" hurricane impact that would not have occurred in past centuries but is now experienced by nations everywhere due to globalisation!

Pensacola, Florida, was one of the cities hardest hit by Hurricane Ivan. The Ikonos satellite captured this view of boats pushed against the shore in contrast to the neat lines harbor on January 4, 2003. Sections of roof appear to be missing from the white building in the bottom right corner. The buildings in the upper right corner also appear to be seriously damaged. What had been car parks in January 2003 now appear to be covered in mud, possibly a result of flooding.
Image: Space Imaging

On 16th September, Hurricane Ivan became the third major hurricane to make landfall in the US in six weeks, battering the Alabama coast and Florida, as well as three other states. Ivan is so far believed to have caused 52 deaths in the US, far more than hurricane Frances, despite the latter's enormous size (*USA Today*, 20 September 2004). A detailed account of Ivan's progress (although some of the figures may need updating) can be read here: http://news.bbc.co.uk/1/hi/world/americas/3655086.stm

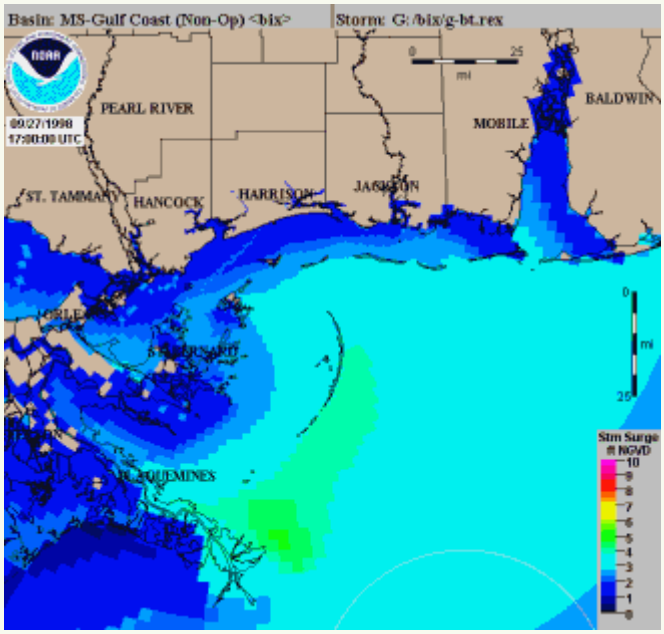
The impact of Ivan was ultimately far more deadly than either Frances of Charley on account of

(1) its greater wind strength, generating 35-feet-high waves in the Gulf of Mexico and

(2) a course that took it through densely populated urban areas in a number of Caribbean LEDCs with weaker building controls and regulations than the US and much fewer resources for emergency planning and relief.

Ivan has been registered as the sixth greatest hurricane ever recorded in the Atlantic Basin (judged by air pressure levels at the eye of the storm). At least 122 lives were lost to this hurricane and the figure would have been many more, had it passed directly over Jamaica. However, the next hurricane to arrive, although much weaker, was to claim more than ten times as many lives.

SLOSH (Sea, Lake and Overland Surges from Hurricanes) is a computerized model run by the National Hurricane Center (NHC) to estimate storm surge heights and winds resulting from historical, hypothetical, or predicted hurricanes.



What about the impacts and management of Jeanne?

29 Sep 2004


The northern Haitian city of Gonaives is seen flooded on September 19, 2004 after Hurricane Jeanne passed through. More than 2,000 people died in Haiti from flooding and mudslides triggered by Tropical Storm Jeanne © Reuters

Jeanne was only at 'tropical storm' strength (there are two levels of tropical storm strength and five levels of hurricane strength in the Saffir-Simpson scale) when it hit Haiti on 15th September, killing nearly 2,000 people, thereby demonstrating that the strongest natural hazard events do not necessarily cause the greatest damage. Population density, building construction and hazard planning measures also determine the outcome of a hazard. In this instance, heavy rainfall and rising sea levels submerged poorly defended urban areas, causing massive loss of life through drowning (due to the low pressure, sea levels rise markedly during a tropical storm or hurricane). Another human factor - widespread deforestation of the island encouraging rapid surface run-off - made the situation even worse (*The Independent*, 22 September 2004). Mudslides claimed lives, as saturated soils flowed down-slope on the island's deforested hillsides.

Haiti has very poor levels of preparedness for natural hazards, which is unsurprising, given that it is the poorest country in the Western Hemisphere. 80% live below the absolute poverty threshold and malnutrition is widespread, with severe or moderate stunting of growth affecting 47% of under fives (*BBC news*). Under such circumstances, very little money is available for flood defences or to fund bodies such as the UK's Environment Agency that are dedicated to minimising flood risk. As the hurricane left Haiti, rioting broke out and UN peacekeepers

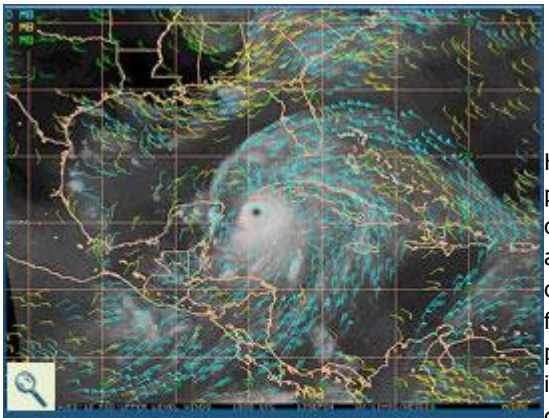
were called in to help distribute food aid in an increasingly lawless environment – quite a contrast with conditions in Castro's Cuba during Hurricane Ivan!

Man stands by his shop, prepared to defend it by force in Fort Pierce, Florida, September 2004, in the aftermath of Hurricane Jeanne. © Reuters

After strengthening to a hurricane, Jeanne came ashore along the coast of Florida, still recovering from the effects of the previous three hurricanes. This time, up to three million people in Florida had been told to evacuate the area, breaking evacuation records for the third time in a month. However, the regularity of hurricane warnings now meant that "hurricane fatigue" was beginning to set in amongst the population. Over time, repeated exposure to a hazard can result in people beginning to develop a fatalistic attitude, possibly through fatigue (tiredness) and exhaustion. As a result, many who evacuated in preparation for Hurricanes Charley, Frances and Ivan decided to stay put this time, despite warnings that Jeanne would be just as damaging (the phenomenon of "hurricane fatigue" is covered in some depth by *The Guardian,* 28 September 2004).

Reuters news agency (quoted on the *BBC news* website) reported emergency management spokeswoman Yvonne Martinez of Brevard County as saying that "people here are tired… a lot of them decided to ride out the storm at home and didn't evacuate. That's not really a good idea. This one is scary. We're concerned that there'll be a death toll in this one." As a result, several lives were needlessly lost to this, the weakest of the four hurricanes to hit Florida. For more details of Jeanne's impact on the US, especially Florida – now described by the Washington Post (28 September 2004) as "The Saturated Sponge State" rather than "The Sunshine State" - follow this link:

http://news.bbc.co.uk/1/hi/world/americas/3690736.stm


Hurricane Ivan's exhaust system. Blue arrows show wind speed at altitudes between 35,000 and 50,000 feet (arrows show wind direction) As cold, dry air departs toward the southwest and northeast, the storm pulls in warm,humid air at the bottom, sustaining its heat engine.
Image: CIMSS, University of Wisconsin-Madison

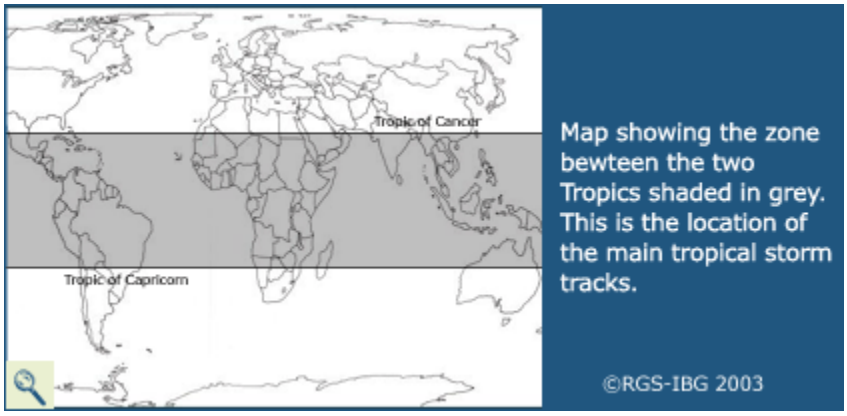
How does a hurricane work?

29 Sep 2004

Hurricanes are large rotating storms centred around low pressure areas. They develop between 5 and 30 degrees of latitude, starting life as a body of warm moist air over a tropical ocean that has reached the critical temperature of 26°C. Driven by the rotating earth's Coriolis Force, a flow of air develops around a central eye whenever prevailing winds near the ocean surface are able to form inward spirals of air. The ocean's heat drives the process, causing evaporation and sending moisture-laden clouds high up into the atmosphere. Hurricanes play an important role in transferring heat and energy between the equator and the poles. There are 5 levels of hurricane strength, according to the Saffir-Simpson scale, below which lie an additional two weaker levels, labelled "tropical storms".

What environmental conditions are needed for tropical cyclones to develop?

Crucial to tropical cyclone development is a sea surface temperature of 27ºC, the dominant wind direction must be east to west with some deflection due to the influence of the Coriolus* force producing rotation or spin. Given these conditions tropical disturbances or waves develop with about 100 or so detectable each year.



As the waves move westwards the wind speed increases to 38mph, once the circulation becomes closed a tropical depression develops. Then gradually shower and thunderstorm activity increases as the gusting winds stir up the warm ocean waters causing moisture to rise and condense as wind speeds increase up to 73 mph. It has now become a tropical storm. The accompanying heavy downpours release heat and energy and with increased wind speed to over 74mph a more definite eye (check out the satellite photo below) is formed. Gradually more and more air is forced to rise upwards and outwards with a significant barometric pressure drop at the ocean surface thus a tropical cyclone is born.

Annually about 10 tropical storms develop of which about 5 or 6 develop into full-blown hurricanes measured on the Saffir-Simpson (S-S) scale. The categories of 1 to 5 measures wind speed, barometric pressure and possible damage. So category 1 has wind speeds of 74-95mph, > 28.94 inches of mercury and minimal damage whereas category 5 has winds >155mph, <27.17 inches of mercury and catastrophic damage.

- View the BBC animation showing how a hurricane forms (scroll half-way down the page and click on 'open animation guide')
- For a full account of the origins of hurricanes visit the BBC

Summary: five important hazard themes

29 Sep 2004

(1) ***The unpredictability of hurricane paths makes the effective management of this category of natural hazard exceptionally difficult***. It was lucky for Jamaica that Ivan suddenly changed course away from the most densely populated parts of the island where it had been expected to hit. In contrast it was bad news for Florida's Punta Gorda, when Charley deviated away from its predicted path, hitting a settlement that had only been partially evacuated.

(2) ***The strongest storms do not always cause the greatest damage***. Only six lives were lost to Hurricane Frances, but 1,500 were taken by Jeanne when it was still categorised as just a "tropical storm" and had not yet reached full hurricane strength. Poor flood defences, weak planning regulations and poverty are amongst the causes of Haiti's huge death toll, as much as Hurricane Jeanne itself.

(3) ***The distribution of the population throughout the Caribbean islands is responsible for much of the heightened natural hazard risk associated with the region*****.** Coastal settlement

patterns predominate throughout the islands and the adjacent continental coastline, with incomes strongly linked to tourism, fishing and export-orientated agriculture.

(4) *Hazard mitigation depends primarily upon the effectiveness of the social response to these natural events*. Hurricanes, like tectonic plate movements, are a form of natural hazard that cannot be prevented from occurring. Effective local governance is therefore vital, encompassing urban planning laws, emergency planning and evacuation measures and the effectiveness of subsequent relief operations, including re-housing schemes and the distribution of food aid and clean water. Different societies have demonstrated hazard governance with quite varying degrees of success this year. It is notable that the highly authoritarian government of Castro in Cuba suffered no deaths from Hurricane Ivan, for instance.

(5) *LEDCs continue to lose more lives to natural hazards, due to inadequate planning and preparation.* By way of contrast, insurance costs continue to be greatest in American states such as Florida, where multi-million-pound waterfront homes proliferate.

Writing and researching about hazards

Students following most A-level specifications may encounter an essay question along the following lines:

***Examine the factors that determine the impact of natural hazards*.**

Preparation for this topic could involve using this article and other resources to make comparisons between the four hurricanes (a table could be drawn up). Important factors may include:

· *Hurricane path* – did the hurricane path cross inhabited areas? Were they rural or urban? What kind of different land uses can be identified? Are some land uses especially vulnerable to hurricane damage?

· *Hurricane magnitude* – how did the events vary in terms of their actual strength? Did the strongest event cause the greatest loss of life and property damage? If not, why not? What aspect of the hurricane event caused the greatest damage? (*choose from*: wind speeds, sea-level rises, rainfall levels, looting and burglary)

· *Building construction* – were some buildings more resilient than others? Where were they located? How do planning laws and building controls vary between different nations?

· *Prediction, risk assessment & preparation* – were the paths of the hurricanes accurately predicted? Were appropriate measures taken? Why was evacuation more successful for some hurricanes than others? Why were some societies more effective at staging evacuations than others?

· *Hazard response* – how were damages dealt with? How effective were re-housing schemes and the police and emergency service response?

· *Long-term issues* – was lost property insured? Can lost earnings also be claimed for? What are the long-term implications for tourism and agriculture in the region?