damage in the coastal areas of those countries bordering the Indian Ocean. The casualty list amounted to nearly 300 000. The majority of these victims were drowned. It was one of the deadliest **natural disasters** in recorded history.

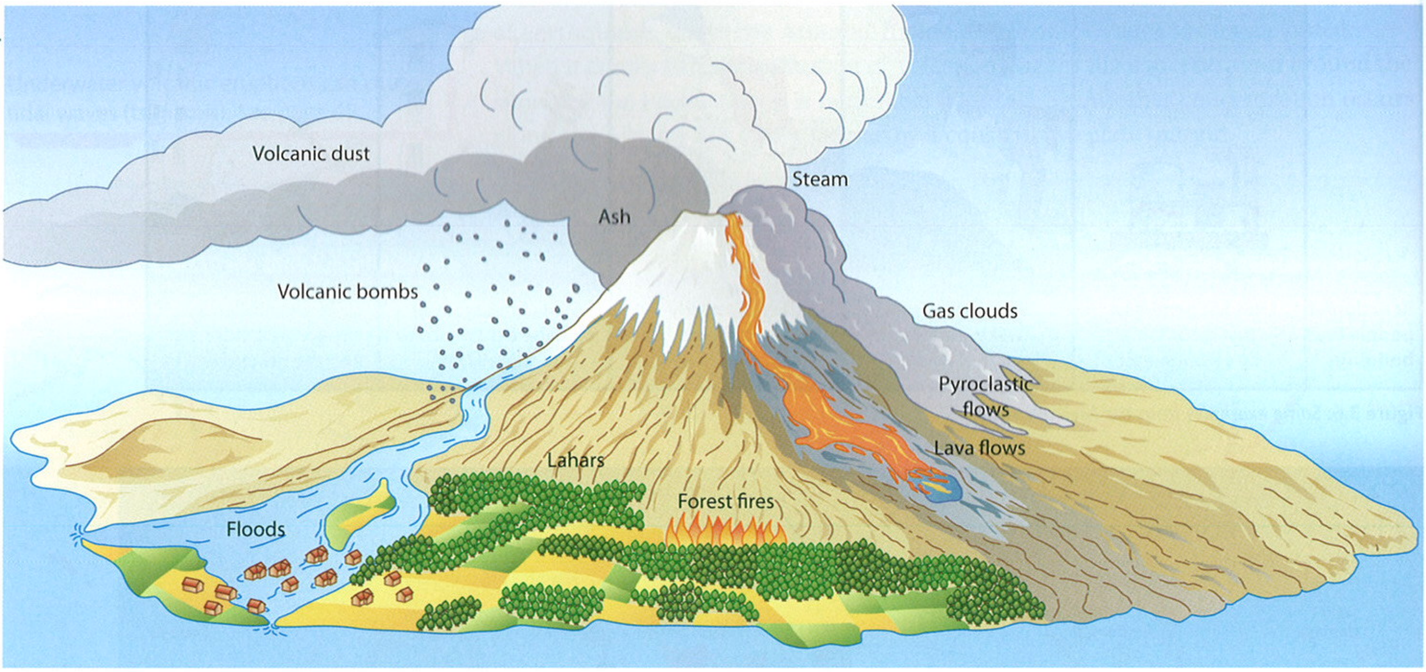

Figure 3.8: *Hazards associated with volcanic eruptions*

Volcanic eruptions

There are several different hazards associated with volcanic eruptions (Figure 3.8):

- **lava flows** – since few lava flows reach much beyond 10 km from the volcanic crater, they do not cause as much death and destruction as you might think. Lava flows may destroy farmland, buildings and lines of transport, but lives are rarely lost
- **ash** – ash may be thrown into the air during a violent eruption. Often this is carried in the wind and therefore can affect quite a large area. This happened over much of Europe in 2010 when a volcano in Iceland erupted. The ash cloud brought air travel to a halt. The further away from the volcano, the thinner will be the deposits of ash. Ash can cause much damage by simply blanketing everything, from crops to roads. Roofs of buildings will collapse if the weight of the deposited ash is great. Air thick with ash can asphyxiate humans and animals
- **gas emissions** – sulphur is not the only gas to be emitted during an eruption. Other gases emitted, notably carbon dioxide and cyanide, can kill. Being dense, they keep close to the ground

Under the heading of gas emissions, remember to include pyroclastic flows (see page 84).

Volcanic eruptions can also generate tsunamis. The huge eruption of Krakatoa in 1883 created waves up to 35 m high. These waves drowned over 36 000 people.

3.3 Tropical storms

In this part of the chapter, we focus on a third and very different natural hazard – the tropical storm. As in Part **3.2**, the same three aspects will be investigated, namely distribution, causes and hazard characteristics.

Distribution

Tropical storms or cyclones are large areas of low air pressure. They bring torrential (fast and heavy) rain and very strong winds to tropical regions. Figure 3.9 shows their distribution and what they are called in different parts of the world. For example, severe tropical storms are called hurricanes in North and Central America and the North Atlantic. Depending on the location, there may be from six to over 20 each year, but most occur between mid-summer and early autumn when the sea is warmest.

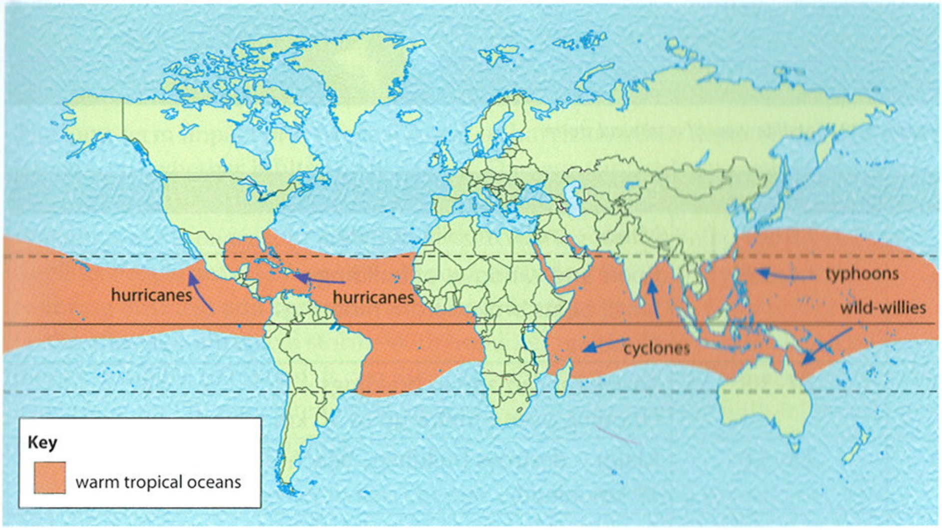

Figure 3.9: *Global distribution of tropical storms*

Look closely at Figure 3.9. What do you notice about the limits to tropical storms in the two hemispheres?

Causes

Tropical storms need warm water over 27°C to form. The water heats the air above it, (Figure 3.10), creating an area of very low pressure in the centre or 'eye'. In the northern hemisphere, the storm winds rotate anti-clockwise; in the southern hemisphere they rotate clockwise. The rising air quickly cools down, forming thick, dense cumulo-nimbus clouds which bring very heavy rainfall.

This area of rotating low pressure (wind) can be over 100 km wide and travel at up to 50 kph. Inside wind speeds can reach over 250 km/h around the edges of the central eye. The eye itself is calm. Figure 3.11 is a satellite image showing the swirling mass of cloud and the clear 'eye' at the centre of a hurricane in the Atlantic Ocean off Florida in the USA. Tropical storms need warm water for energy – once they reach land they quickly lose power.

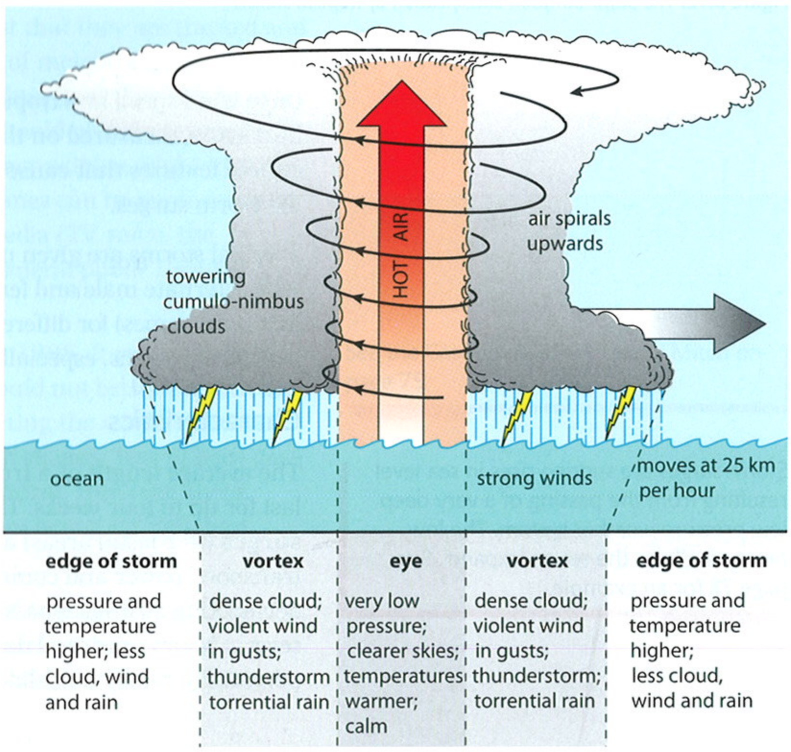

Figure 3.10: *Cross-section through a tropical storm*

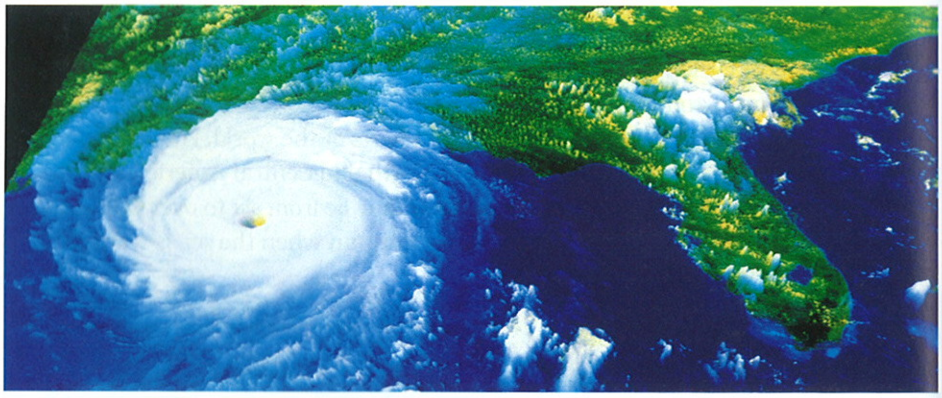

Figure 3.11: *Satellite view of a tropical storm*

Catergory	Wind speed (kph)	Pressure (mb)	Storm surge (m)	Damage
1	119–153	<980	1.0–1.7	Minor – trees, mobile homes
2	154–177	979–965	1.8–2.6	Roofs and windows of buildings Small boats broken from moorings Flooding
3	178–209	964–945	2.7–3.8	Structural damage to buildings Flooding over a metre up to 10 km inland
4	210–249	944–920	3.9–5.6	Major – destroys buildings, beaches and floods up to 10 km inland
5	<250	>920	Over 5.7	Catastrophic – destruction up to 5 metres above sea level Mass evacuation needed
Note that tropical storms have wind speeds between 55 and 118 km/h.				

Figure 3.12: *The Saffir-Simpson classification of tropical storms*

Once wind speed in a tropical storm reaches 119 km/h, it is classified as a hurricane, measured on the five-point Saffir-Simpson scale (Figure 3.12). The critical features that cause the most damage are the wind speeds and the scale of the storm surges.

Tropical storms are given names by meteorologists. These are from alphabetical lists, with alternate male and female first names over a six-year cycle. There are different lists (and names) for different parts of the world. Names help to identify and track individual storms, especially as there may be more than one happening at a time.

Characteristics

Storm surges are sudden rises in sea level resulting from the passing of a very deep low pressure weather system. The low pressure allows the sea to 'expand'. See page 78 for an example.

The average length of a tropical storm or hurricane is 10 days, but the biggest can last for up to four weeks. They cause three main types of damage – wind, **storm surges** (in coastal areas) and floods. Winds can destroy trees, crops, buildings, transport, power and communications. Storm surges along coastal areas can be devastating as huge waves hit the land (Figure 3.13). Torrential rainfall can last for several hours or several days, causing widespread flooding inland. This can cause potentially deadly landslides and mudslides.

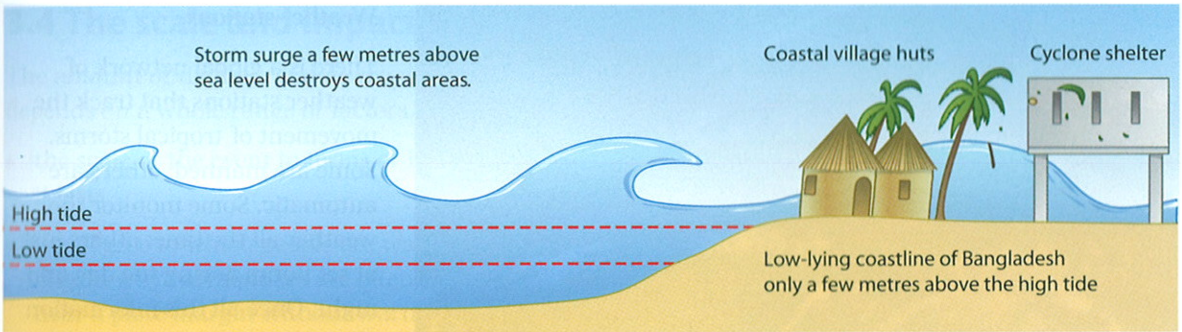

Figure 3.13: *The effects of a storm surge*

The long-term impact of a tropical storm or hurricane often depends not just on its ferocity, but whether it hits an HIC or LIC. Damage cannot be prevented. However, people in wealthier HICs can board-up properties and be evacuated in time. Warnings are broadcast in advance of approaching storms being monitored via satellite. People are also more able to cope with clearing up the damage and restoring business and economic activities after the event. LICs can be devastated by the effects of a tropical storm. With buildings and farmland ruined and little money available to rebuild, it can take years for the people and economy to recover. Even then, an LIC may often be dependent on international aid both for emergency help and long-term rebuilding.

Remember:

- HIC = high-income country
- MIC = middle-income country
- LIC = low-income country

The three hazards looked at in this chapter all have one thing in common. The scale of their damage and destruction is related to where they occur. Death tolls and damage are almost invariably higher in densely populated areas.

Methods of monitoring weather conditions

Since tropical storms are a moving hazard, it is important that they are tracked and forecasts made of their future progress. This is the work of meteorologists. If meteorologists are able to measure how they are developing, then they will be able to warn people in the predicted path of the storm. This should give those people some time in which to prepare for the storm. Precautionary actions might include moving to higher ground or to an emergency shelter. Homes can be made ready by boarding up windows, moving furniture upstairs. The media (TV, radio, the Internet) have an important role to play in keeping the general public updated about the storm and where it is expected to go.

Hurricane Mitch passed over Central America in October 1998. It proved to be a particularly tricky hurricane. First, the meteorologists could not be sure where the storm would come ashore. Another challenge was predicting the storm's speed of movement. In the event, it moved much slower than most storms. This at least gave areas in the predicted path more time to prepare for the storm. However, those areas beneath the slow-moving storm received much more heavy rainfall than normal (see Part **3.4**).

See the Case study of Hurricane Mitch on page 75.

How do meteorologists track and predict the movement of tropical storms? The data they work on comes from a number of different sources.

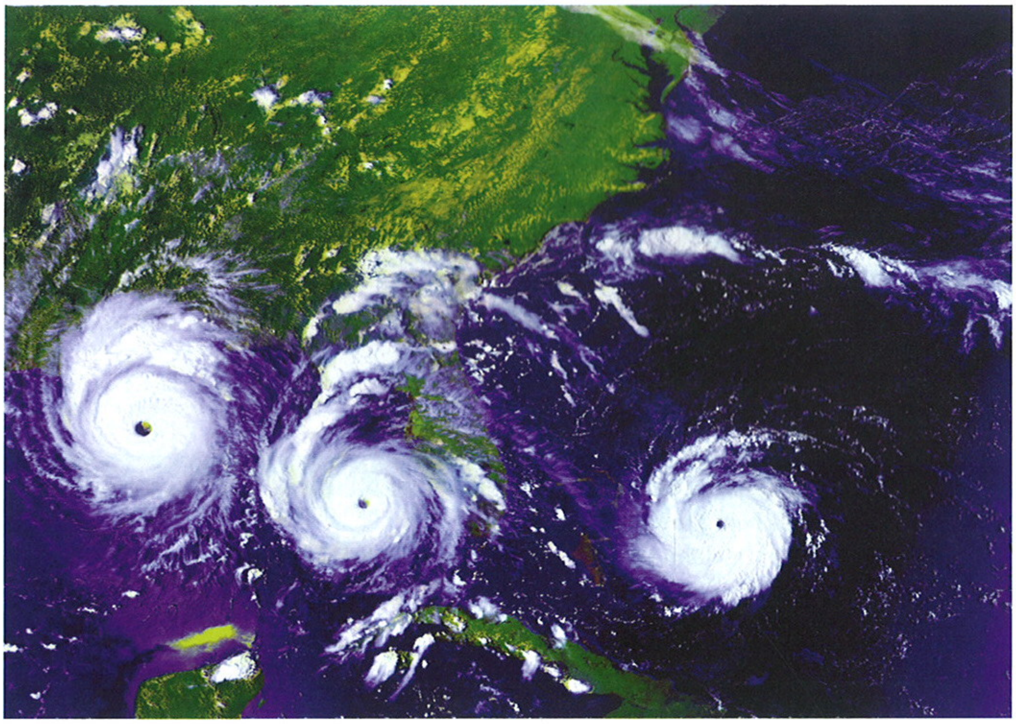

Figure 3.14: *Superimposed satellite images showing the progress of a hurricane from right to left*

Weather stations

There is a global network of weather stations that track the movement of tropical storms. Some are manned; others are automatic. Some monitor the weather all the time; others just at set hours during the day and night. Once all this information about pressure, temperature, humidity, winds and so on is collected and put together, it can be used to predict what will happen to the storm. Will it deepen, with an increase in rainfall and wind speeds or will the storm begin to weaken and fizzle out?

Weather satellites

For viewing large weather systems on a worldwide scale, weather satellites are invaluable (Figure 3.14). They show cloud formations, large weather events such as hurricanes, and other global weather systems. With satellites, forecasters can see weather systems such as tropical storms. On each satellite, there are two types of sensor (Figure 3.15). One is a visible light sensor called the **imager**. This works like a camera in space and helps gather information on cloud movements and patterns. This sensor can only be used during daylight hours, since it works by capturing reflected light to create images.

The second sensor is called the **sounder**. It is an infrared sensor that reads temperatures. The higher the temperature of the object, the more energy it emits. This sensor allows satellites to measure the amount of energy radiated by the Earth's surface, clouds, oceans, air and so on. Infrared sensors can be used at night which is helpful for forecasters, considering that the images can only pick up data during daylight hours.

Figure 3.15: *A weather satellite*

Radar

Doppler radar is another important meteorological tool. Radar works a little differently from satellite sensors. Instead of reading reflected light or energy, radar measures reflected sound waves. When sound waves are broadcast from a radar mast and come into contact with a moving object, such as a rain cloud, radar will give information about the direction and speed of the object's movement. By using radar and getting a 'picture' of precipitation (water falling to the ground) on the radar screen, meteorologists are able to track a storm's progress over time.

3.4 The scale and impacts of natural disasters

The amount of damage and destruction caused by a particular natural disaster depends on a whole range of factors. These include:

- the scale of the event in terms of its energy, the area affected and how long it lasts
- the degree to which people are warned in advance of the event. This is one reason why earthquakes are often so devastating. They occur almost anywhere near a plate margin without warning
- the density of human settlement in the area affected. The more people and economic activities there are in a disaster area, the greater will be the potential damage
- the degree to which people are prepared for a possible natural hazard. Are there emergency shelters? Have people been educated in what should be done in an emergency? Are houses, factories and businesses located in areas of low risk? Have buildings been constructed in such a way that they may be able to withstand the hazard?
- the ability of a country to cope with the aftermath of a hazard, both immediately and in the longer term.

It is with respect to the last two points that a basic contrast is so often seen. The contrast is between LICs and HICs in terms of their ability to prepare for hazards and their ability to cope with the damage caused. The next two cases illustrate these two different 'hazard worlds'.

A lack of capital and technology also helps to explain why natural hazards often have a more devastating impact on LICs.

Case study: Hurricane Mitch hits Central America

Figure 3.16: *The path of Hurricane Mitch through Central America (1998)*

Check back to Table 3.12 on page 72 to remind you of the features of a Category 5 hurricane.

Look back at page 74 to remind you how meteorologists would have tracked Hurricane Mitch.

Reference has already been made in Part **3.3** to Hurricane Mitch which passed over Central America in October 1998. Its path is shown in Figure 3.16. It was the most destructive tropical storm for 200 years. Mitch began as tropical depression on 21 October to the south of the Caribbean. A day later it became, first, a tropical storm and then a hurricane as wind speeds increased rapidly. By 26 October it had become a category 5 hurricane with speeds of over 250 km/h, moving west across the Caribbean.

Whilst meteorologists could track Mitch via satellite, they could not accurately predict which direction it might eventually take. Even had they known where it would make landfall, very little could be done to protect the area. Nor could people be evacuated in time easily. By 28 October, Mitch had started to move south-west towards Honduras (Figure 3.16). Although wind speeds inside the hurricane were still high, they had started to fall. The main problem for Honduras and neighbouring Nicaragua and El Salvador was the relatively slow movement of the whole system. As a result of this, rainfall was intense and 180 cm fell in just three days.

Figure 3.17: *Damage caused by mudslides*

The huge volume of water created widespread flooding, destroying buildings, roads, bridges, crops and live-stock. It also caused many mudslides which claimed a large number of victims. By the time Mitch turned north to Mexico, at least 10 000 people had lost their lives. Even then it had not finished as winds increased again before it reached Florida in the USA.

In the end Hurricane Mitch entered the record books. It was:

- the second longest-lasting category 5 hurricane (33 hours)
- the third longest period of continuous high winds (15 hours)
- the fourth strongest hurricane on record (winds of 249 km/h)
- the fourth lowest air pressure every measured (905 mb).

Country	Dead or missing	Homeless or evacuated
Honduras	14 000	2 million homeless
Nicaragua	3000	0.75 million homeless
Costa Rica	7	3000 evacuated
El Salvador	400	50 000 homeless
Guatemala	200	80 000 evacuated
Belize	0	10 000 evacuated
Mexico	6	Unknown number evacuated

Table 3.2: The human impact of Hurricane Mitch

For most of the countries hit by Mitch, there was neither much warning nor anywhere to go for shelter. Two million people in Nicaragua were affected by Mitch (Table 3.2). Mudslides triggered by torrential rain destroyed villages, schools, health facilities and farms (Figure 3.17). The final death toll is thought to have been about 20 000 - but many bodies have never been found. In Honduras, even optimistic estimates think it will be at least 2015 before the country will have repaired all the damage caused by a disaster which made 2 million of its 5 million population homeless. The overall cost of damage caused by Mitch was an estimated $10 billion.

After Mitch hit Central America, short-term **emergency aid** in the form of medicines, food, water and shelter came from governments and non-governmental organisations (NGOs) across the world. However, its effects are still being felt today by its peoples, economies and environments. Most of the countries in Central America are relatively poor LICs, with economies based primarily on farming. The money needed to repair the damage is simply not available within the region.

Longer term, much of the funding needed to rebuild homes and **infrastructure** has come from international aid, agencies or organisations like the World Bank. Much of this was organised via a new Central America Emergency Trust Fund and included money for a road-rebuilding project and repairs to schools and clinics. Some of these projects also created jobs for local people.

The impact of natural disasters like Hurricane Mitch in LICs is far greater than in HICs. Long-term recovery is often dependent upon aid outside of the region affected. Some experts believe that Hurricane Mitch caused so much damage that it set back development in Honduras and Nicaragua by 30 years.

Why has it taken the Central American countries so long to fully recover from the damage caused by Hurricane Mitch?

Case study: Hurricane Floyd hits the USA

Hurricane Floyd hit the east coast of the USA in September 1999. Heavy rain caused flooding across 13 states and led to the evacuation of 4 million people - a million from Florida alone. Over 70 people were killed, the highest death toll in the USA from a hurricane since 1972. The final bill for damage was estimated at $6 billion.

Floyd started life on 2 September 1999 as a tropical wave off the West African coast. Five days later it had become a tropical depression and was 1500 km east of the Caribbean (Figure 3.18). A day later it had become a tropical storm.

By the time it was 400 km from the Leeward Islands, it had been upgraded to hurricane status. As it turned north-west, the winds started to drop. Turning west once more, it quickly gained strength until winds reached 230 km/h and pressure dropped to 921 mbs (the air pressure of hurricanes is measured in millibars – mbs) . Floyd was now a category 4 hurricane, causing widespread damage to the Bahamas as it passed through on 13–14 September.

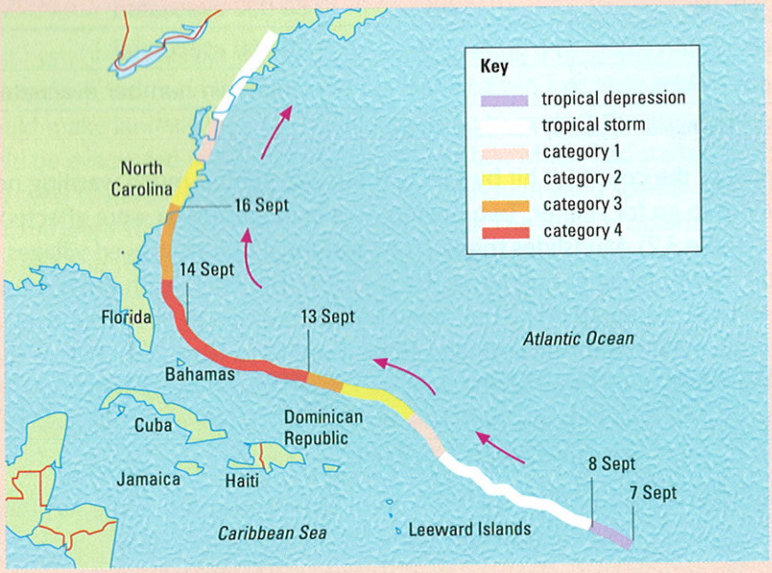

Figure 3.18: *The track taken by Hurricane Floyd*

Still uncertain as to where along the USA coast Floyd would make landfall, the south-eastern states began to evacuate coastal residents inland – Disney World in Florida was shut down for the first time ever. However, Floyd started to move north up the Atlantic coastline, missing Florida. It hit land in North Carolina on 16 September. Wind speeds had dropped as Floyd became a category 2 hurricane. However, it was the rain which did most of the damage, partly because Floyd was a very wide hurricane. Between 16 and 17 September almost 50 cm of rain fell on ground which was still saturated by heavy rain from Hurricane Dennis two weeks earlier.

Check back to page 72 for more information on storm surges.

Storm surges along the coast, up to 3 m high, and exceptionally heavy rainfall caused extensive flooding across 13 states. All were declared major disaster areas, with North Carolina the worst hit. Rivers peaked at over 7 m above normal levels, 51 people were drowned and 7000 homes were completely destroyed. Tens of thousands of homes were damaged and 10 000 inhabitants forced into temporary accommodation. Roads were destroyed and damaged and hundreds of thousands of cattle, pigs and poultry were drowned. Electricity supplies were badly affected.

Despite extensive damage to property and land, the quality and timing of early warning systems and subsequent organised evacuation saved many lives. National agencies monitor and track hurricanes via planes and satellites. If a storm is approaching, a 'Hurricane Watch' is announced 36 hours ahead. A 'Hurricane Warning' is issued 24 hours before expected arrival, usually leading to evacuation orders.

Although it took many months before everyone was re-housed and damage repaired, over $2 billion of government aid was made available by the US

Congress. Individual states, insurance companies and business funding also helped recovery. With sophisticated warning systems in place and the ready availability of emergency funds, the impact of tropical storms in a wealthy HIC like the USA will almost always be far less destructive than in poorer LICs.

Figure 3.19: *The evacuation of almost 4 million people under way*

Why were most people evacuated by road rather than by air or sea?

3.5 Reasons for living in high-risk areas

History tells us where in the world specific types of natural hazard are likely to occur. We have a fairly good idea of where the high-risk areas are. Figures 3.4 (page 67) and 3.9 (page 71) show the global distributions of two natural hazards (earthquakes and tropical storms) that cause the greatest number of deaths and the largest amount of damage. Compare those maps with the map showing the global distribution of major cities and therefore areas with high population densities (Figure 3.20). What we find may be quite surprising. Many of those cities and areas of high population density are located within the risk areas of earthquakes and tropical storms. Why do so many people continue to live and work in what are clearly hazardous areas?

There are a number of possible explanations.

- A lack of education and information may mean that residents are unaware of the real risks, particularly if the hazards occur only infrequently. This can be the case particularly in poor undeveloped areas
- People may be aware of the risks but decide to live in the area anyway. Perhaps the area offers some tempting benefits (see below)
- It may be that people are unable to move away from hazardous areas, owing to a lack of money or they are concerned about not being able to find a job elsewhere

It has been estimated that between 2000 and 2010 close to 1 million people were killed by earthquakes. This is not surprising because there are billions of people living in the world's earthquake zones.

Compare Figure 3.4 (page 67) with Figure 3.20 (page 80).