What are the hazards associated with tropical storms?

When a tropical storm makes landfall it brings with it a deadly cocktail of high seas, strong winds and torrential rain. With a large proportion of the world's population living close to the coast, there is a significant potential for loss of life and damage to property.

Strong winds

By definition, a tropical storm packs a powerful punch, with average wind speeds in excess of 120 km/h (75 mph), although gusts of over 250 km/h have been recorded at the eye wall. The strong winds are capable of causing significant damage and disruption by tearing off roofs, breaking windows and damaging communication networks (Figure **5**). Debris forms flying missiles whisked up by the wind. Damaged power lines often lead to widespread electricity cuts (power outages) and occasionally even fires. Debris strewn over roads can cause major transport disruption.

Storm surges

This is a surge of high water, typically up to about 3 m in height, which sweeps inland from the sea, flooding low-lying areas (Figure **6**). It is caused by a combination of the intense low atmospheric pressure of the tropical storm (enabling the sea to rise vertically) together with the powerful, driving surface winds.

Storm surges are the major cause of widespread devastation and loss of life. (Hurricane Katrina in the USA in 2005 recorded a storm surge of 7.6 m, one of the largest ever recorded.) In addition to loss of life, storm surges inundate agricultural land with saltwater and debris, pollute freshwater supplies and destroy housing and infrastructure. Enhanced coastal erosion can lead to the undermining of buildings and highways.

Did you know?

In 2004 tropical storm Catarina became the first recorded hurricane in the South Atlantic. It came ashore in the Brazilian state of Santa Catarina with 145 km/h (90 mph) winds and torrential rainfall. Tropical storms do not usually form in this region due to the lack of the Earth's 'spin' and the fact that high-level winds tend to shear off the storms, preventing their formation. Could this be a reflection of global warming?

Figure 5 *Damaged caused by strong winds, Cyclone Winston, Fiji, 2016*

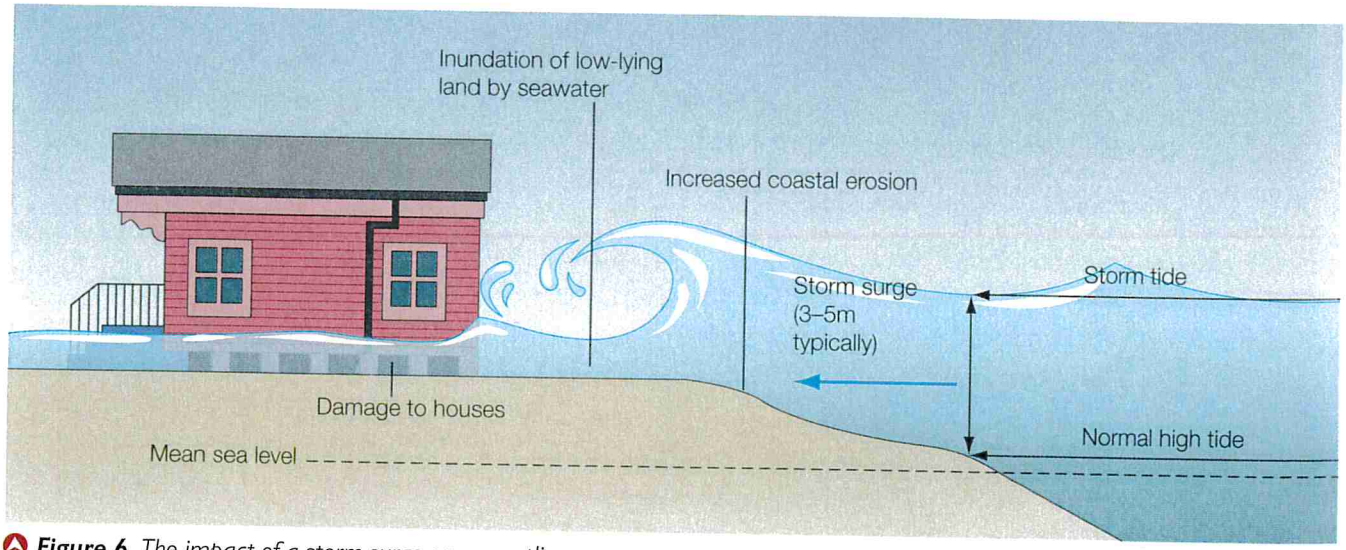

Figure 6 *The impact of a storm surge on a coastline*

Coastal and river flooding

The warm, humid air associated with a tropical storm can generate torrential rainfall, often in excess of 200 mm in just a few hours. This can trigger flash flooding at the coast, particularly in urban areas where surface water can overwhelm the drainage system. Urbanisation – with its system of drains, impermeable surfaces and high density of buildings – exacerbates the flood hazard by encouraging rapid overland flow and causing flash flooding.

As a tropical storm moves inland, it gradually weakens as its moisture (and energy) supply is cut off. However, it may still result in significant river flooding due to the intensity and sheer quantity of rain falling on the river basin. In August 2011, intense rainfall associated with Hurricane Irene caused widespread river flooding throughout New Jersey, USA, resulting in the evacuation of over one million people (Figure **7**). The damage was estimated at over US$1 billion.

Figure 7 *New Jersey after flooding by the Passaic River as a result of Hurricane Irene, 2011*

Landslides

It has been estimated that up to 90 per cent of landslides each year are caused by heavy rainfall, and many are triggered by tropical storms. The intense rainfall increases pore water pressure (hydrostatic pressure within a slope), which weakens cohesion and triggering slope failure. The additional weight of water exacerbates the problem. In 1998 Hurricane Mitch – one of the North Atlantic's most powerful tropical storms – triggered multiple landslides that killed 18 000 people in Central America (Figure **8**).

There is some evidence that load release caused by tropical storm-induced landslides may trigger earthquakes in tectonically stressed regions. For example, the 2010 Taiwan earthquake occurred just two years after Typhoon Morakot had dumped 300 mm of rain in just five days. Research carried out at the University of Miami found that 85 per cent of earthquakes of magnitude 6 and above occurred within the first four years after a very wet storm.

Figure 8 *Landslide caused by Hurricane Mitch, 1998*

The Saffir–Simpson scale

Tropical storms be classified according to the Saffir–Simpson scale (Figure **9**), which was developed in 1971 as a means of enabling storms of different magnitudes to be compared. It is an absolute scale based on sustained wind speeds, and has five separate categories. Despite being widely used, particularly in the North Atlantic region, it is of limited value in assessing impact, as it does not take into account rainfall, or the area affected by a storm. So, a low-category cyclone that hits a densely populated urban area can be a far more damaging event than a high-category storm that makes landfall in a remote region.

Saffir–Simpson Hurricane scale				
Category	**Wind speed**		**Storm surge**	
	mph	(km/h)	ft	(m)
Five	>156	(>250)	>18	(>5.5)
Four	131–155	(210–249)	13–18	(4.0–5.5)
Three	111–130	(178–209)	9–12	(2.7–3.7)
Two	96–110	(154–177)	6–8	(1.8–2.4)
One	74–95	(119–153)	4–5	(1.2–1.5)
Additional classifications				
Tropical storm	39–73	(63–17)	0–3	(0–0.9)
Tropical depression	0–38	(0–62)	0	(0)

Figure 9 *The Saffir–Simpson scale*