Where has our beach

The impacts of the UK's 2014 storms

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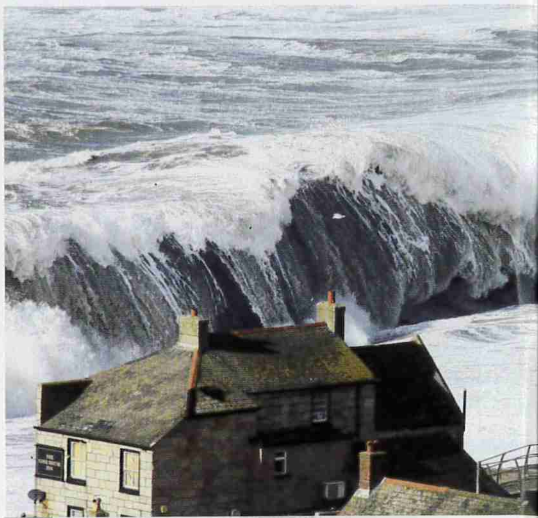
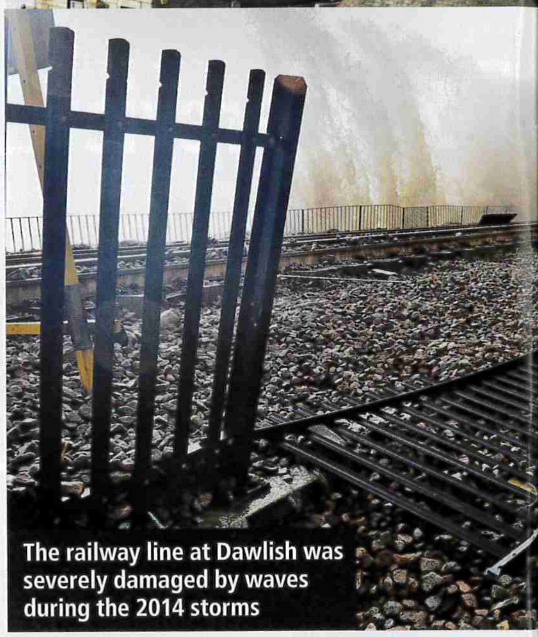
Destructive storm waves tend to erode coasts and beaches, removing beach sand and gravel. A frequent question after a storm is, 'Where has our beach gone?' This article looks at where the beach sediment goes, what takes it there, whether it will come back and how long that recovery will take, and puts this in the context of the UK 2013/14 storms. If you are studying coasts, read on





The railway line at Dawlish was severely damaged by waves during the 2014 storms

The coastal zone is a popular area for people to live. It houses 10% of the world's population but represents only 2% of the global land surface. It is also important to society from an infrastructural, environmental and economic point of view. At the same time, the coastal zone is a hazardous environment. There are short-term threats (storms) and long-term threats (sea-level rise), for coastal communities and resources.

Living and working in the coastal zone makes society vulnerable to coastal hazards, as demonstrated by recent events, including:

- Hurricane Katrina, 2005 (US Gulf coast)
- Cyclone Yasi, 2011 (Australia)
- Hurricane Sandy, 2012 (US northeast coast)
- Typhoon Haiyan, 2013 (Philippines)

The UK's 2014 winter storms

More recently, and closer to home, the Atlantic coast of Europe experienced an unprecedented sequence of energetic wave conditions during the 2013/14 winter. Coastal wave heights reached over 10 metres and peak **wave periods** — the time between successive waves — often exceeded 20 seconds.

What caused these huge waves? During winter 2013/14 the jet stream was particularly vigorous and positioned unusually far south over central England. This caused the winds and waves associated with a sequence of deep depressions (extreme storms) to focus their effects on the southwest of England. Wave data from this region (Figure 1) show that the measured waves frequently exceeded 5.9 metres, a value they only usually exceed for 1% of the time.

The 8-week sequence of Atlantic storms from mid-December 2013 to mid-February 2014 was the most energetic winter of waves since at least 1950. It therefore represents at least a 1:60 year event. The extensive physical impacts (beach and dune erosion) and socioeconomic impacts (flooding, damage to infrastructure) of this sequence of storms highlight the vulnerability of the UK to such coastal hazards (see also The Big Picture on the back cover).

Coastal impacts

Almost all the coastal towns and villages of southwest England were affected by coastal flooding and/or damage to coastal infrastructure at some time, or several times, during the 2013/14 winter. The most costly impact was the damage to the main London–Penzance railway line at Dawlish, south Devon, which led to its closure. This is estimated to have cost the regional economy between £1 million and £20 million per day for the 2-month duration of the closure.

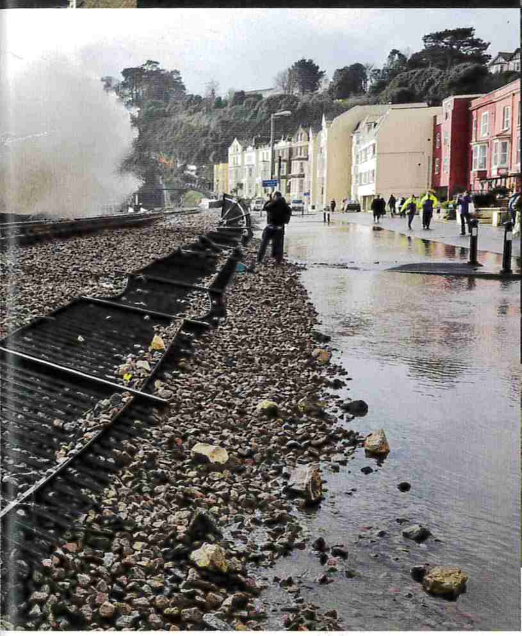
Erosion of coastal dunes by the storm was widespread and many beaches lost considerable quantities of sediment, exposing the underlying rocky shore platforms or the foundations of coastal-protection structures. Some or all of this beach sediment may return in due course, but permanent changes to the coast were also observed. For example, a natural arch at Porthcothan in Cornwall and a stack at Pom Pom Rock in Dorset (see the photos top right) both collapsed during the storm of 6 January 2014.

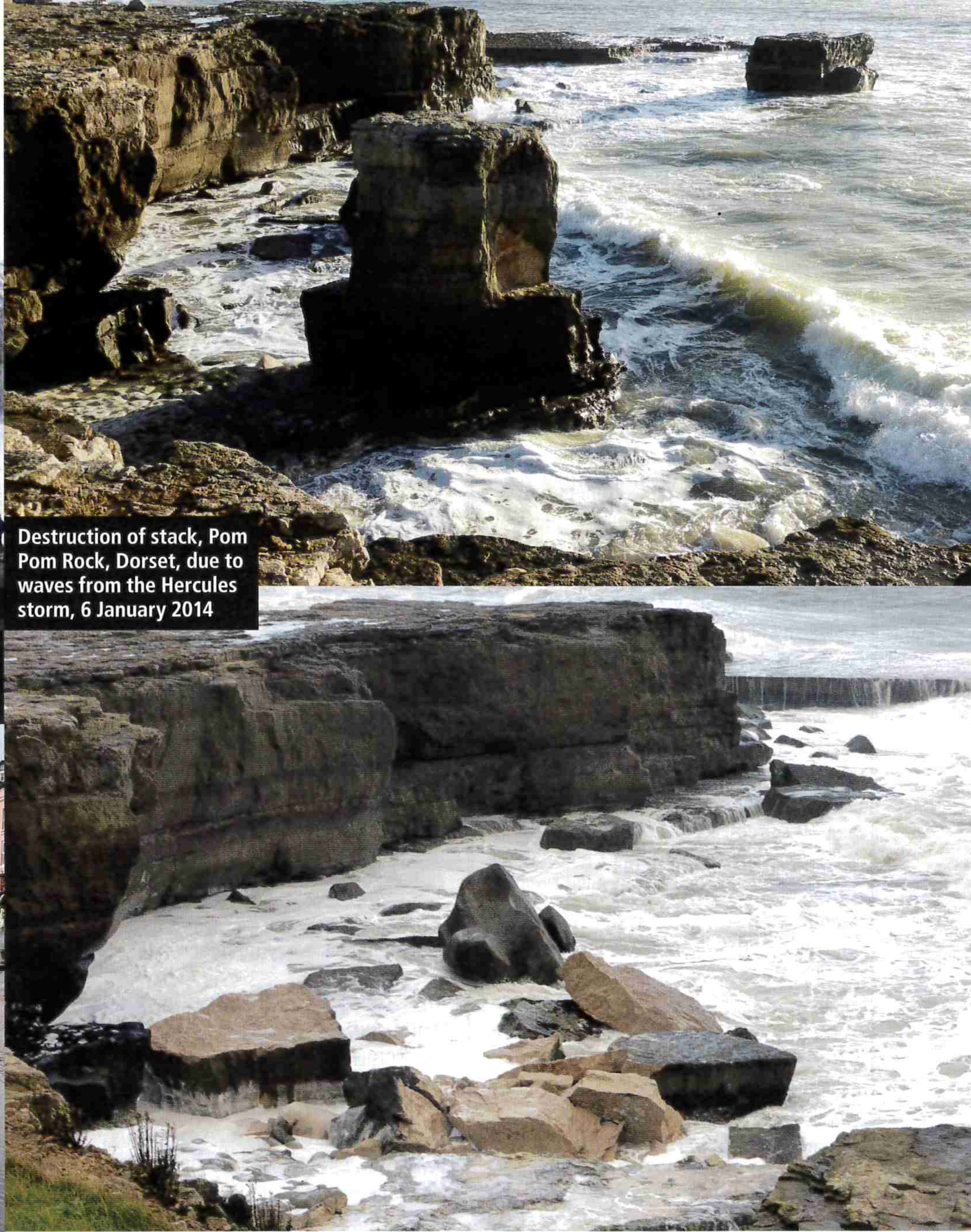
Why did the impacts of each storm vary?

The coastal impact of the individual storms varied due to slight changes in the direction

gone?

Huge storm waves pound Chesil Beach, Dorset during the extreme storms of winter 2013/14





Destruction of stack, Pom Pom Rock, Dorset, due to waves from the Hercules storm, 6 January 2014

of approach of the storms and their associated waves.

The storm of 6 January 2014 was the most extensive. It represented a 1:5 to 1:10 year wave event in terms of wave height and also had exceptionally long wave periods of up to 23 seconds. These huge waves approached from the west and impacted both the north and south coasts of the southwest England peninsula.

The storm of 5 February was not one of the most energetic storms in terms of wave height. However, because its storm track was further south, it sent huge waves into the normally sheltered south coasts of Cornwall and Devon and was responsible for the damage to the Dawlish railway.

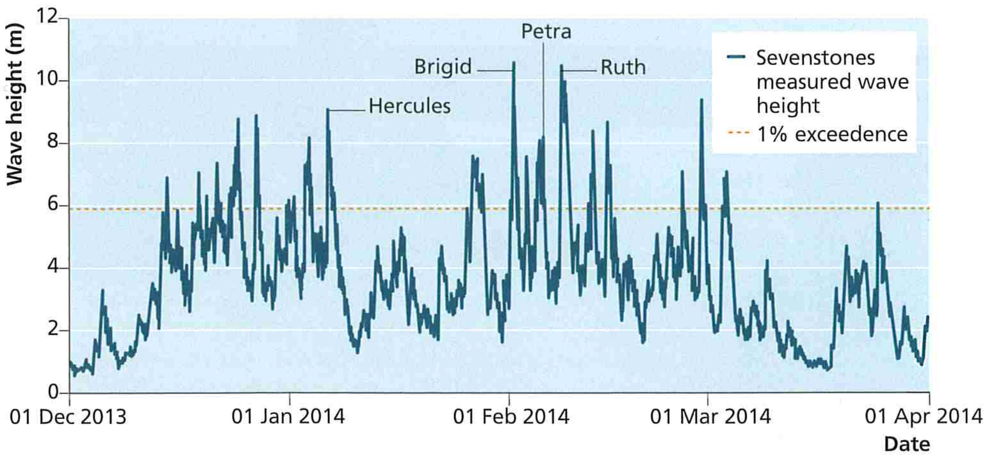


Figure 1 Time series of significant wave height measured at Sevenstones Lightship at the southwest tip of Cornwall from 1 December 2013 to 1 April 2014. Four of the most extreme storms are named: Hercules (6 January), Brigid (1 February), Petra (5 February) and Ruth (8 February)

Further research

For pictures of the damage and repairs to the main London–Penzance railway line at Dawlish, see: **www.bbc.co.uk/newsround/26889145**

Have a look at our video from Porthleven on the morning of 5 February 2014, the same day the damage occurred at Dawlish. See the huge storm waves impacting the cliff, and watch for sections of the cliff collapsing: **www.youtube.com/watch?v=B3fxbVVDZ9Q**

Our presentation on storms from the Geographical Association conference (scroll down to Lecture 2): **http://geography.org.uk/cpdevents/annualconference/#1**

Butt, T. and Russell, P. (2004) *Surf Science*, University of Hawaii Press.

Masselink, G. and Hughes, M. (2011) *Introduction to Coastal Processes and Geomorphology*, Hodder Education.

Masselink, G. and Russell, P. (2013) 'Impacts of climate change on coastal erosion,' *MCCIP Science Review*: **www.tinyurl.com/pjcmuj2**

Geography Review articles

Evans, M. and Rowson, J. (2014) 'Centrepiece: Why was last winter so wet and windy?' Geography Review Vol. 28, No. 1, pp. 20–21.

Holiday, A. (2014) 'Storm damage and coastal protection, a case study of Chesil Cove', Geography Review Vol. 28, No. 1, pp. 38–41.

Masselink, G. et al. (2014) 'Rip currents, researching a natural hazard,' Geography Review, Vol. 27, No. 3, pp. 37–41.

The RCRU's 7.5-m aluminium tower, mounted with two digital video cameras on the crest of the gravel barrier at Westward Ho!

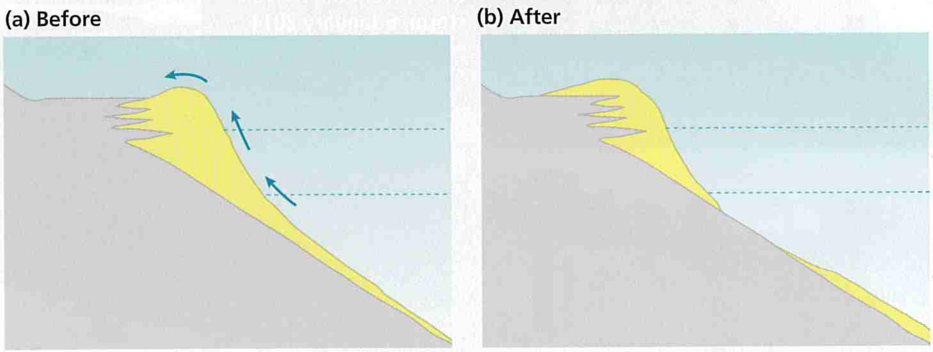


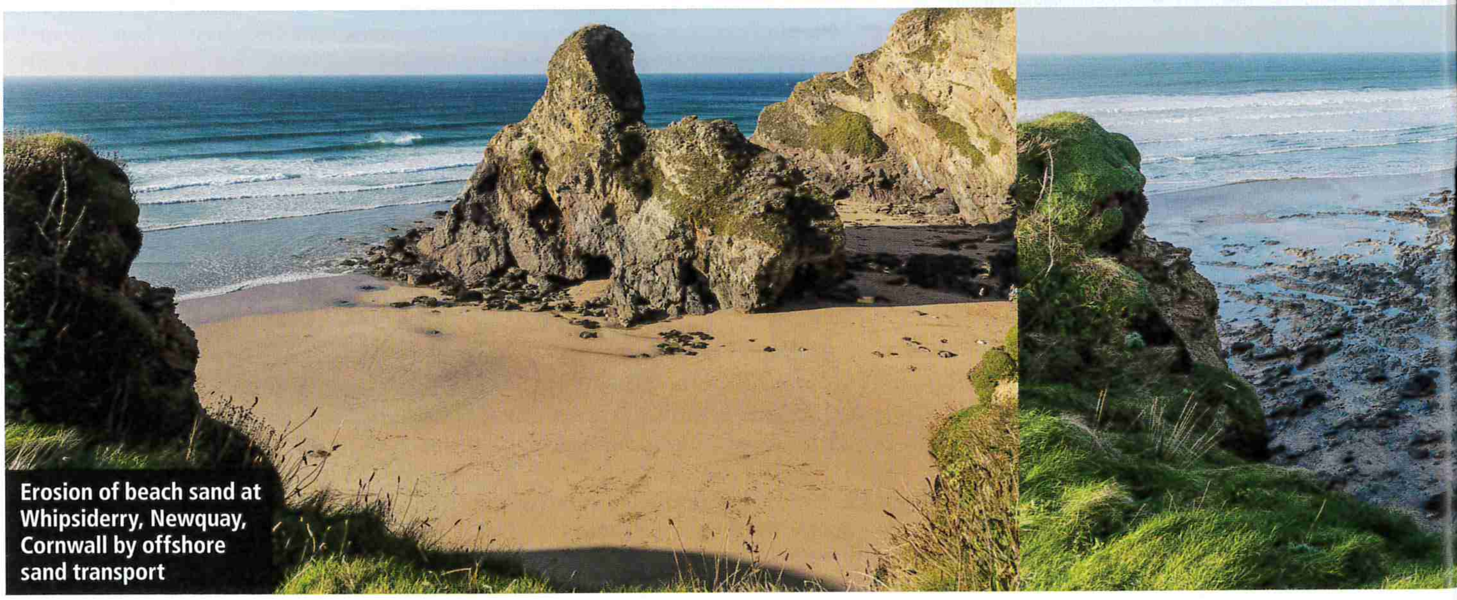
Figure 2 Onshore 'over the top' removal of beach sediment. Large waves overtop the crest of the beach, carrying beach sediment inland

Other storms had less impact because they coincided with smaller (**neap**) tides or were associated with less strong onshore winds. While the impacts of the 6 January and 5 February storms were severe, luckily neither of these events coincided exactly with large (**spring**) high tides, when the overtopping and damage would have been much worse.

Box 1 explains why waves from extreme storms are so destructive. Box 2 explains how we measure coastal processes during storms.

Where has our beach gone?

So, returning to the original question, the answer is that the beach material has gone in any of three directions.



Erosion of beach sand at Whipsiderry, Newquay, Cornwall by offshore sand transport

'Over the top' in action at Slapton Sands, south Devon. Beach sediment has been carried up on to the coast road

Box 1 Why are waves from extreme storms so destructive?

The size of the waves produced by a given storm depends on three factors: wind speed, duration (how long the wind blows for) and fetch (the distance over which the wind blows). Where strong winds blow for a long time over long distances, large waves are produced.

These large waves are characterised by their height and also by their long wave periods. The longer the wave period the faster the wave will be travelling. The energy carried by a wave is proportional to its height squared, so that a slightly bigger wave will have a lot more energy.

Wave power is a product of the wave energy multiplied by the wave speed, so the large, long-period waves generated by extreme storms have incredible power, and it is this wave power that transports large amounts of beach sediment and changes the shape of the coast.

For example, one extreme storm wave approaching a 1 km section of coast contains around 1 billion watts (or 1 gigawatt) which is about the same as the power generated by a coal or nuclear power station.

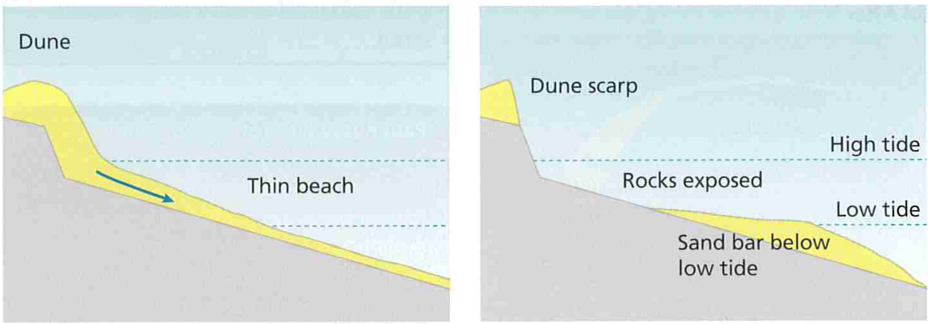


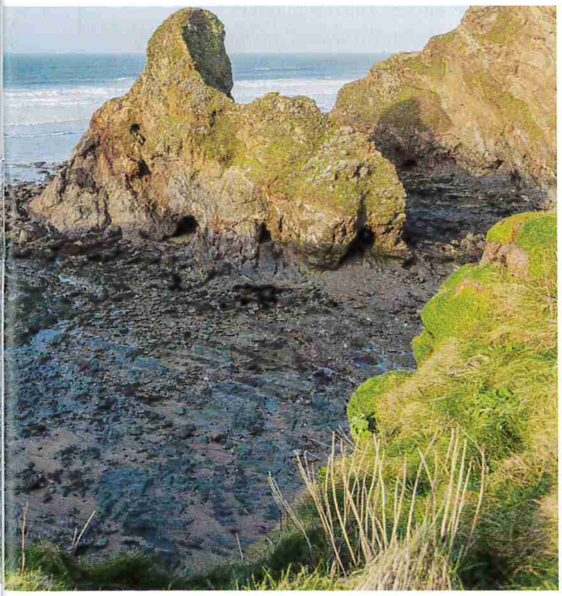
Figure 3 Offshore sand transport removes sand from exposed beaches, depositing it in sand bars in deeper water

Over the top

During storms, raised water levels and large wave run-up can cause waves to overtop coastal barriers, dunes and infrastructure, flooding the land behind and carrying beach material into coastal towns and onto coastal roads (Figure 2). This is common on gravel beaches, and once the beach material has been moved inland it cannot return to the beach, unless it is carried back there by human intervention, using diggers and lorries.

Offshore

On exposed beaches where storm waves approach directly, such as the west-facing beaches of Devon and Cornwall, beach sediment is eroded from the dunes and beach by undertow and large rip currents (called 'mega-rips'). **Undertow** is a gentle seaward flow of water that occurs under breaking waves, and **rip currents** are strong, narrow seaward flows that occur in channels along the beach and against headlands. These currents take the beach sand offshore into deeper water and deposit it in large sandbars under the sea (Figure 3). The sand is gradually returned to the beach in smaller wave conditions but, after such extreme storms, beaches may take a number of years to recover fully.



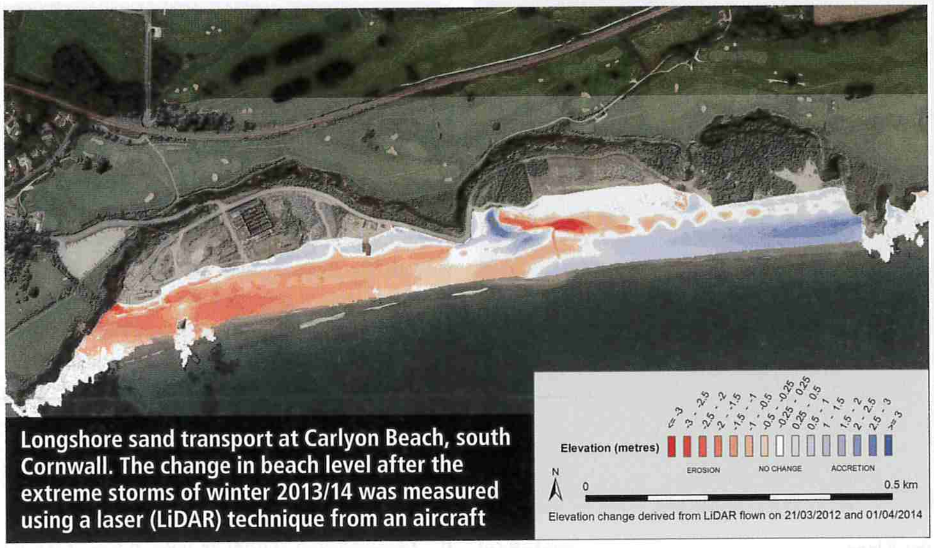
Box 2 Measuring coastal processes during extreme storms

It has only recently become possible to make measurements of waves and coastal impacts during peak storm conditions. Over the past few years Plymouth University has developed a specialised unit, the Rapid Coastal Response Unit (RCRU), to enable the collection of data on extreme storm wave conditions and beach response. In addition to low-tide surveys using GPS on foot or on an all-terrain quad bike, the key instruments used are:

- remote-sensing equipment mounted above the high-tide line, including digital video cameras and a laser scanner
- wave and current sensors deployed across the intertidal beach at low tide

Aluminium tower sections provide high and secure vantage points for video cameras, and a trailer is used as a mobile field laboratory.

The advantage of video data is that it allows us to assess how high the waves run up the beach. For example at Chesil Beach, Dorset, during the storm of 5 February, wave heights of up to 8 m offshore resulted in vertical run-up on the beach of up to 12 m. That means the waves reached 12 m higher (in the vertical direction) than had the sea been calm.



Longshore sand transport at Carlyon Beach, south Cornwall. The change in beach level after the extreme storms of winter 2013/14 was measured using a laser (LiDAR) technique from an aircraft

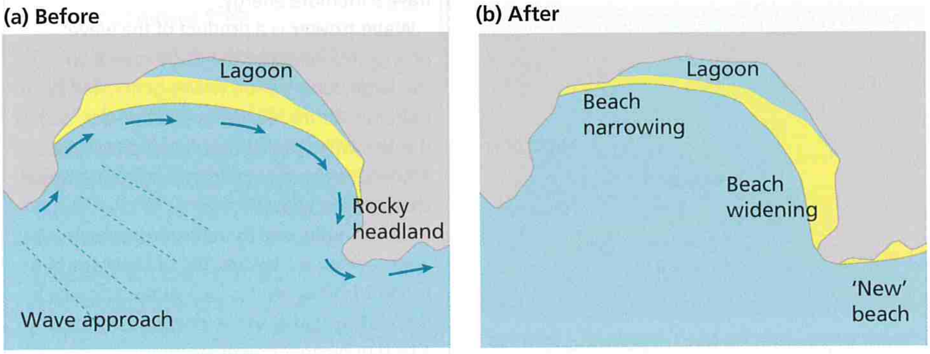


Figure 4 Longshore sand transport moving sand alongshore from west to east causes erosion and beach narrowing at the western end and accretion and beach widening at the eastern end

Alongshore

On beaches where the storm waves approach at high angles, such as the south-facing beaches on the south coast of Devon and Cornwall, longshore currents drive **littoral drift**, transporting beach sediment alongshore (Figure 4). During the winter of 2013/14 the storm waves coming in from the Atlantic Ocean moved sediment from west to east along the English Channel, causing many south-coast beaches to erode at their western ends and **accrete** (build up) at their eastern ends. The beach was effectively 'rotated'. It can only return to its previous formation if there is a sustained period of reverse longshore drift caused by waves coming from the east. If the sediment has gone round a nearby headland ('headland bypassing') it may not come back at all.

Damage to cliffs, arches and stacks

Where the coast is backed by cliffs rather than a beach, extreme storm waves can shake the cliffs. This makes them unstable, and can lead to cliff collapse. It is what caused the collapse of the arch at Porthcothan and the destruction of the stack at Pom Pom Rock.

Plymouth University had a seismometer deployed in the cliffs at Porthleven in Cornwall during the storm of 5 February 2014. The seismometer recorded higher levels of cliff shaking than had been previously recorded anywhere in the world. Laser scanning of the cliff face showed the rate of cliff retreat at the time to be 100 times greater than the long-term average. This implies that erosion of coastal cliffs happens mainly during extreme storms and that future long-term rates of cliff retreat will depend on the frequency and severity of extreme storm-wave impacts.

Conclusions

Extreme storms represent a hazard to coastal areas. Storm waves drive rip currents and changes in longshore drift that cause coastal erosion. Storm waves can also overtop coastal structures and barriers, causing coastal flooding and damage to coastal infrastructure. Following extreme storms it may take several years for beaches to recover and there can be permanent changes to the coast through processes such as cliff recession, the collapse of natural arches and the destruction of sea stacks.

Glossary

Littoral drift Transport of sediments along the coast: longshore drift.

Neap tides Lower tides which occur in the weeks between the spring tides when the sun, moon and Earth are not in alignment.

Rip currents Strong localised currents which flow away from the sea shore at a right angle to the beach.

Spring tides High tides that occur twice a month when the sun, the moon and the Earth are aligned.

Wave period The time between one wave crest and the next wave crest passing a fixed point.

Wave power The ability of a wave to do work, calculated as wave energy × wave speed.

Paul Russell is professor of coastal dynamics at Plymouth University and a former European surfing champion. His love of breaking waves led him to a BSc and PhD in oceanography and a career dedicated to understanding how those breaking waves change our coasts. His co-authors all work in the Department of Marine Science and Engineering at Plymouth University. This particular work is funded by an NERC Urgency grant.

Key points

- Extreme storms generate high waves with long periods that have exceptional power and so provide the potential to dramatically impact and change the coast.
- The largest coastal impacts occur where the storm waves are substantially bigger than the normal (prevailing) wave conditions and when they coincide with spring high tides and strong onshore winds.
- Enhanced wave run-up during storm conditions can lead to the waves overtopping coastal barriers, causing coastal flooding and damage to infrastructure.
- The impacts depend on the angle at which the storm waves approach the coast. Beach sediment can either be taken offshore (when the waves approach directly) or alongshore (when the waves approach obliquely).
- Extreme storms also cause permanent changes to the coast through processes such as cliff recession.