When reports started coming in that southern Britain had been hit by a tsunami, they were hard to believe. But it turns out there really had been one – just not the kind we usually hear about. Dave Tappin describes the scientific detective work that uncovered the truth.

The 2011 UK meteotsunami

A study in science

'When you have eliminated the *impossible*, whatever remains, however improbable, must be the truth,' Sherlock Holmes said. This was always in my mind after a 'tsunami' struck south-west England. My work on the subject is usually overseas, studying the Indian Ocean tsunami of 2004 and Japan in 2011, but in June 2011 we got to investigate an event much closer to home.

Two years on, I still get a kick when I think of this event and how we worked it out – elementary, my dear Watson. Our initial conclusions met with disbelief, but now after a really exciting journey we know they were correct. It is the UK's first proven example of a meteorological tsunami.

What do I mean by that? Most tsunami are geological, generated from the bottom up by earthquakes, submarine landslides or volcanic collapses that make the seabed move vertically. This causes an ocean wave that travels outward from its source. By contrast, a meteorological tsunami wave is generated from the top down by a change in air pressure, with the wave being pushed along ahead of the atmospheric disturbance.

If the wave starts off in deep water it is very small, maybe just a few centimetres high. But when it travels into shallow water, it grows taller, especially when the atmospheric disturbance moves at the same speed as the tsunami – we call this 'resonance'. But the wave may still be only 20-30cm high. It's in the final period of travel, when the wave approaches the shore and enters a harbour or estuary, that it becomes dangerous, because here further resonance or the 'focusing' effect of more and more water being forced into an ever-smaller channel can create a wave several metres high.

Video screenshot of the Yealm tsunami, 9.30GMT, 27 June 2011.

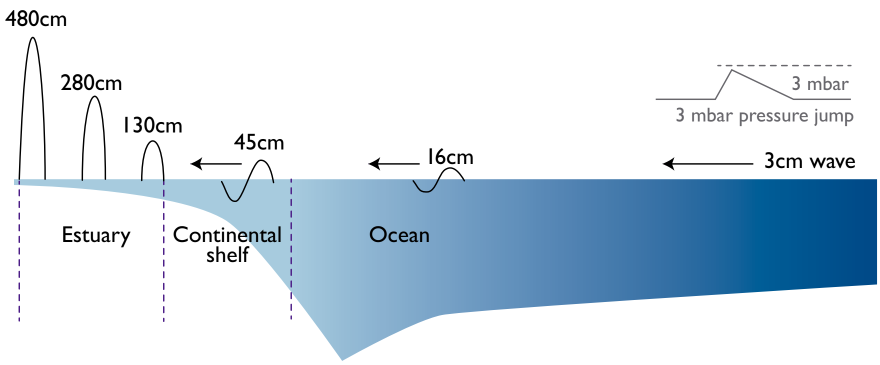
Simon Fitch

Spotting the tsunami

We first learned about the tsunami from newspaper articles on 29 June reporting a strange event in the Yealm Estuary in Devon two days earlier; an amazing video showed a 40-50cm high wave passing upstream. UK tide gauge data from farther east in the English Channel confirmed the wave had affected a long stretch of coastline. At St Michael's Mount in Cornwall, the causeway was suddenly flooded and people reported their hair standing on end. Near Marazion, Simon Evans was digging for bait and compared it to a horror movie; it was foggy, and suddenly the sea disappeared; he knew what it meant and got out of there quickly.

HOW A METEOTSUNAMI FORMS

A 3 millibar pressure jump over the ocean causes a 3cm wave. As it travels, this increases in height due to resonance. By the time it reaches the head of an estuary it is nearly 5m high.



> *At St Michael's Mount in Cornwall, the causeway was suddenly flooded and some people reported their hair standing on end.*

The monitoring system of the British Geological Survey (BGS) hadn't picked up an earthquake, so the first suggestion was that the wave came from an undersea landslide far to the west. Yet the wide extent of the event and the sensation of hair standing on end didn't fit with a landslide. After checking the weather conditions on the 27th, my colleague Dave Long at BGS in Edinburgh and I both independently suggested that a storm in the Channel was to blame.

The initial results were posted on the BGS website, and we immediately received an email from a French colleague at the Naval Hydrographic and Oceanographic Service (SHOM) in Brest. He agreed with our overall conclusions, but said the tsunami had been recorded on French tide gauges from the southern part of the Bay of Biscay all the way to Calais in the eastern English Channel – a distance of over 1000km. It was staggering.

More UK tide gauge data confirmed the tsunami extended from Wales to Dover. I contacted some friendly meteorologists about getting hold of satellite weather data. Luckily, the son of a BGS colleague runs the surfers' weather site www.magicseaweed.com. The meteorologist there was intrigued and at first dismissive of a tsunami, but after some research agreed it was a possibility.

What about the weather?

Met Office scientists had also been following the event, and Andrew Sibley in Exeter provided meteorological data that quickly began to support the oceanographic model we had produced. Satellite and radar imagery revealed that on the 27th there was a major low-pressure weather system west of the UK, and that storm cells to the south-west were tracking north-eastwards from Spain to England. It turned out that they passed at exactly the same time as the unusual readings from the tide gauge data.

Some simple calculations on the tsunami's expected speed supported these observations. But we still didn't have the whole picture. One of the missing aspects was the rapid change in atmospheric pressure needed to generate the tsunami. Andrew managed to get hold of data from buoys off Brittany and south-west England. These measurements showed rapid pressure changes as the storm cells passed overhead. Measurements of temperature, pressure and wind speed and direction over Coruna, Spain, taken from a weather balloon, revealed an unstable air mass that would produce downdraughts, again supporting our idea about how the tsunami was generated.

Pulling it all together

Although we'd already established the overall picture of the relationships between the weather systems, the tide gauge data and the tsunami, once we had all the data we could see some very interesting details. The weather system that originated over Portugal/Spain created the tidal anomalies there, and simple calculations of their speed matched the way we knew the wave had moved.

Yet this weather system could not explain the tidal anomalies along the east coast of France or in the English Channel. For these the source had to be off Brittany, as recorded by the rapid atmospheric changes and seen in the satellite imagery and buoy data. But the timing of the tsunami in the Yealm ruled out a source off Brittany – there had to be a local source, and the radar imagery of the weather system over the western Channel showed there was one. So there were three weather systems, and three separate tsunamis. It was brilliant and unexpected how it all fitted together, and very exciting building the model as the data came in.

Thankfully the UK event wasn't destructive, but we do know that in the western Mediterranean meteotsunamis can cause serious damage. In the Great Lakes region of North America, an event the previous year created a wave six metres high.

As the oceans warm with climate change, 2011's meteostunami may be a taste of what's to come. We now need to consider how we might better record, model and predict these events. For example, UK tide gauges take measurements every 15 minutes, compared to the continuous recording of our nearest European neighbours. The UK also has highly-developed models to forecast storm surges and tides, but we need to link them to high-resolution weather forecast models. All possible; it just costs money. If meteotsunamis are going to become more common, and perhaps more damaging, this could be money well spent.

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