ON THE PODCAST

KILLER WAVES

Stories of rogue waves as big as 10-storey buildings appearing out of nowhere aren't just fishy tales. But, as **Andy Ridgway** discovers, what causes these marine monsters remains unclear

On 10 November 1975, while sailing on Lake Superior during a gale, the SS Edmund Fitzgerald sank in Canadian waters. At 220m long and 22m wide, this cargo ship was no minnow. But all 29 crew-members died without broadcasting a mayday and their bodies have never been recovered.

A US Coast Guard report claimed the tragedy was the crew's fault for failing to secure covers on the huge hatches on top of the ship's hold. But that conclusion has always been controversial; many fellow seafarers doubt the crew would have been so careless. And earlier this year, a documentary for the Discovery Channel, *Dive Detectives*, reached a different conclusion: that the Fitzgerald was unlucky enough to encounter a rogue wave – a wave so massive that it snapped the freighter in two while it was still on the surface.

Maritime history is filled with stories of monstrous waves that appear from nowhere. Legendary explorer Ernest Shackleton described an encounter with a huge wave during a voyage from Elephant Island in the Southern Ocean to South Georgia in the Atlantic in 1916. "It was a mighty upheaval of the ocean, a thing quite apart from the big, white-capped seas that had been our tireless enemies for many days. I shouted 'For God's sake, hold on! It's got us!'" Somehow the boat survived, sagging and shuddering under the blow.

Despite such tales, the existence of sudden monster waves has always been greeted with a degree of scepticism. After all, even if your seafaring witness isn't prone to the odd exaggeration, judging the height of a wave by eye is extremely difficult. But 1995 marks something of a watershed in the history of rogue waves. On 1 January, the Draupner oil platform in the North Sea off the coast of Norway experienced a 26m ▸

▶ wave – that's roughly the height of a 10-storey building. And this time, it wasn't measured by eye, but by an on-board laser device. This giant was more than twice the size of the highest waves around.

Statistics show that such terrifying anomalies should only occur once every 10,000 years. But in 2001, two European Space Agency satellites were used to survey the oceans. During a three-week period, the MaxWave project detected no fewer than 10 giant waves, all of which were over 25m high.

"Over the centuries, stories of rogue waves emerged where there were survivors," says Craig Smith, author of *Extreme Waves*. "But it's hard to tell the height of objects at sea, so a lot of things were dismissed as sailors' exaggerations. But since the MaxWave project, there's been a flurry of meetings and technical conferences around the world where people have been trying to look at the mechanisms involved." In other words, rogue waves have become a science.

The need to know

Revealing the mechanisms behind rogue waves isn't simply a matter of academic interest. "What's surprising is that 50-100 ships go down every year. Of course, that isn't all down to large waves, but a good fraction of it is and we rarely hear about that," says Smith.

But researching these waves is frustratingly difficult – getting the

Each year ships are sunk by rogue waves

ALAMY X3, NOAA, GETTY X2, PHOTOLIBRARY.COM

HOW ROGUE WAVES FORM

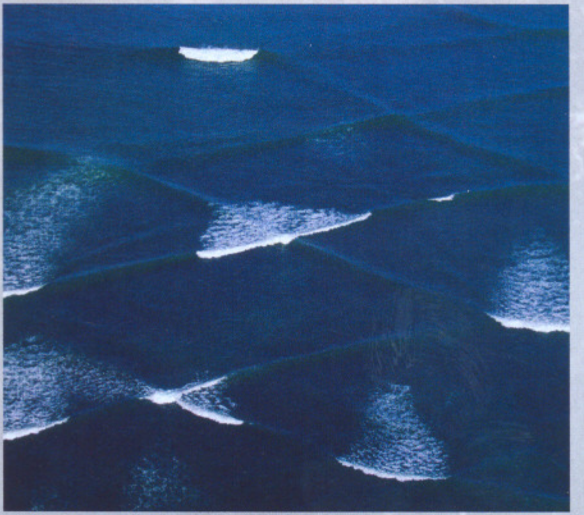
We're a long way from understanding what creates every rogue wave, but we've got a good idea how many of them develop

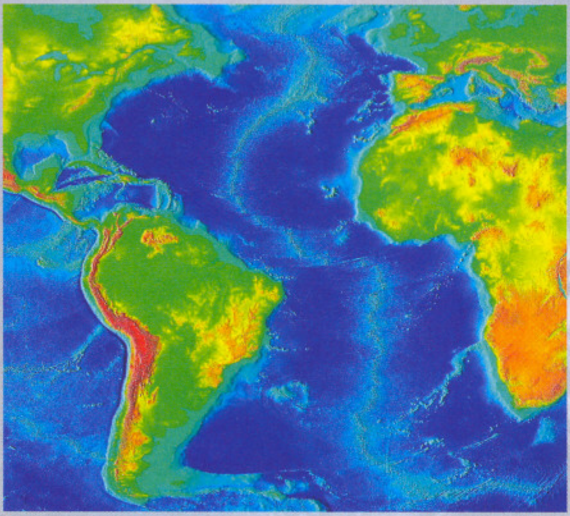
CURRENT CLASH

If a current is moving in the opposite direction to the predominant direction of the waves, as is the case off Cape Agulhas in South Africa, it's not good news. The current decreases the speed the waves are travelling at and causes them to swell upwards.

But the problems don't end there. The waves will get squashed concertina-style: the ones at the front will slow down first because they're meeting the current first. This can push several waves together and end up producing one huge monster.

As well as opposing currents, other current formations can act as lenses, focusing waves in the sea and producing rogue waves.





SEA DEPTH CHANGE

If a wave is travelling in deep water and then suddenly comes across shallow water, its height will increase rapidly. This is what happens in certain conditions off the east coast of the US where the continental shelf extends quite a way offshore.

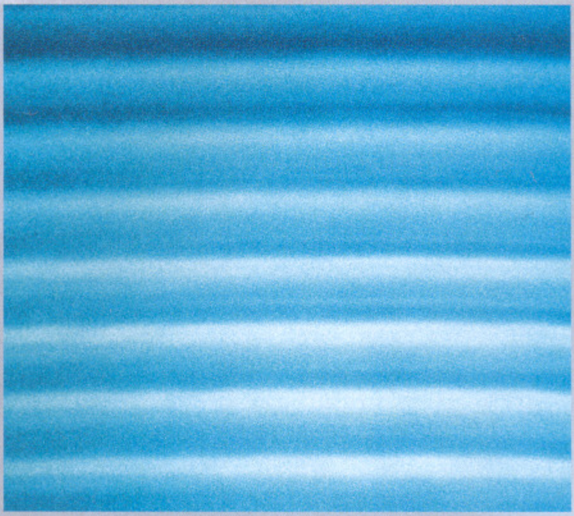
It happens because water is incompressible, so if a wave travels into an area that's much shallower, the only way it can go is up.

NON-LINEAR INSTABILITY

In the early 1960s, Cambridge physicist Brooke Benjamin and his graduate student Jim Feir found they couldn't make a regular train of waves in a wave tank. No matter what they tried, some waves were always larger than others.

But it wasn't down to poor equipment. It turns out that even with a regular input of wave-producing energy, wind, for example, some will be larger than others, effectively taking on the energy of those before and after. In other words, there's not a simple linear relationship between the energy input and the size of the wave produced.

In their wave tank, this 'Benjamin-Feir' instability as it became known, was an intriguing phenomenon. At the scale of an ocean, it could spawn potentially deadly rogue waves.



ght data being the fundamental roblem. Wave researcher Professor fim Pelinovsky at the Institute of pplied Physics in Russia is someone ho knows that all too well.

Prof Pelinovsky collects data from orth Sea oil platforms – when the ompanies are prepared to give it to im. Even then it's not that simple. We can't reconstruct the history of he rogue wave because we have no easurements within a mile of the latform," he says. As well as being uge, rogue waves are also fleeting, isting just one or two minutes. So he chances of even capturing one on n oil platform's sensor or a sensor-arrying buoy are slim to say the least.

Another physicist, Eric Heller at arvard University, says wave tanks don't offer much help either. "You can create eddies and waves in a tank, but it would have to be pretty big to have enough eddies and a long enough run to see the effects you want to see. You might think, 'well why not use shorter waves in a smaller tank?' But then the capillary effect, the surface tension of the water, starts to dominate."

As such, Pelinovsky collects data on rogue waves from wherever he can. "We look at anything that's available," he says. "We try to process all the information from newspapers as well as the BBC and CNN."

But it's here that a little scepticism comes in handy again. "In the media any big wave gets called a rogue," says Chris Garrett, an oceanographer at the University of Victoria in Canada. "I'm sure you'll have seen headlines like 'cruise ship gets hit by rogue wave'. Well, the cruise ship was probably just in a place where it was extremely rough anyway."

The thing is, a rogue wave isn't simply a big wave, like you'd get in any storm. It's one that's 'freakishly' big, towering above any of its neighbours. The rather more precise, scientific, definition is a wave whose height is more than twice the significant wave height (the significant wave height being the mean of the largest third of waves). And it's this 'freakishness' that makes them so dangerous. "Sometimes we have hurricanes and typhoons, but there are no rogue waves because all of the waves are very high," says

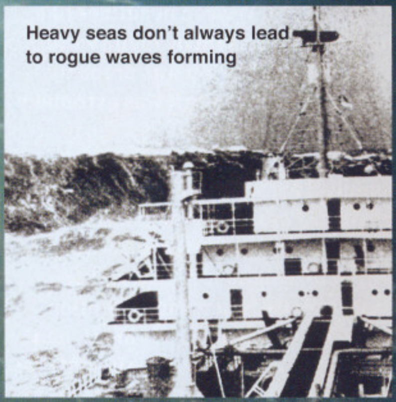
Rogue waves present a huge danger to oil platforms

MONSTER COUSINS

Rogue waves aren't the only leviathans that rise suddenly from the sea and cause chaos – there's also tsunamis. But the fact that they can both wreak havoc is where the similarities end.

Tsunamis are displacement waves generated by phenomena such as earthquakes, landslides or volcanic eruptions – their cause is much easier to define than it is for rogue waves. And unlike rogue waves, tsunamis are more or less unnoticeable in deep water: their true scale only emerges when they reach the shore. Out at sea they have a huge wavelength (the distance from crest to crest) of 200km (120 miles). As it approaches the shore, its wavelength diminishes and its amplitude, or height, increases enormously.

The 2004 Indian Ocean tsunami was caused by the movement of the Indian Plate beneath the Burma Plate, known to geologists as a subduction. This movement caused the sea floor to rise by several metres, displacing an estimated 30km^3 (seven cubic miles) of water and resulting in waves that killed over 230,000 people when they hit land. Despite the scale of the Asian tsunami, the only ships lost were in port – none were out at sea.



Heavy seas don't always lead to rogue waves forming

▸ Pelinovsky. "It's more important for us to look at waves that are two or even three times the size of the background waves."

If data's scarce and wave tanks don't offer much help, then surely the best approach is to determine where they're most likely to occur and dip your instruments into the water there. And if there's a world capital of freak waves, then that dubious honour has to go to the treacherous waters off Cape Agulhas, a rocky headland in South Africa. Here the waters at the meeting point of the Indian and Atlantic oceans have claimed a huge number of vessels and terrifying 30m walls of water have been reported.

Off Cape Agulhas, strong winds known as the Roaring Forties blow from east to west, producing waves that travel in the same direction. These then meet the Agulhas current running in the opposite direction. And it's this clash, that's thought to spawn rogue waves (see 'How rogue waves form,' p52).

But conflict between waves and a powerful current can't be behind all rogue waves, as it's a combination that's not found at all locations where rogues have been confirmed.

In their quest for answers, physicists have found an excellent substitute for water – electromagnetic radiation. Microwaves and light are waves and behave in a strikingly similar way to their counterparts in the sea. In one study, involving Heller at Harvard and researchers at the University of Marburg in Germany, microwaves were fired into a cavity inside two metal plates. Random currents in the sea were simulated by placing metal cones in random positions in the cavity. The team found that microwave hotspots emerged in the cavity and these 'freak microwaves' cropped up far more often than expected. What it showed was that even in the chaotic conditions of the sea, with random currents and waves coming from more than one direction, the currents can still act like a lens, focusing the waves to produce larger rogues.

WAVE HUNTING FROM SPACE

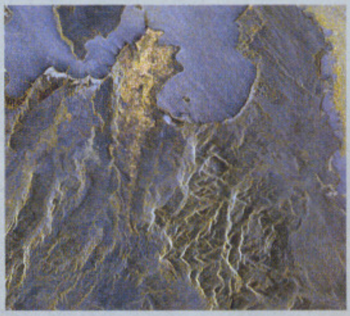
How satellites track down the rogues

Perhaps the single piece of research that changed the face of rogue wave science the most was the MaxWave project. Using European Space Agency satellites, rogue waves were shown to be fairly frequent events.

The ERS satellites used in this study, and the craft used since MaxWave, use a technique known as synthetic aperture radar. Here pulses of radio waves are sent out from an antenna on the satellite. When the radio waves bounce back, they're processed through complex algorithms to produce a representation of the surface they were aimed at – in this case, the sea.

A satellite that's recently been called into action measuring waves is the German Earth observation satellite, TerraSAR-X, which was sent into space in 2007. The satellite, a collaboration between the German Aerospace Centre and aerospace company EADS Astrium, has a resolution of up to 1m, allowing more waves to be tracked than had previously been possible.

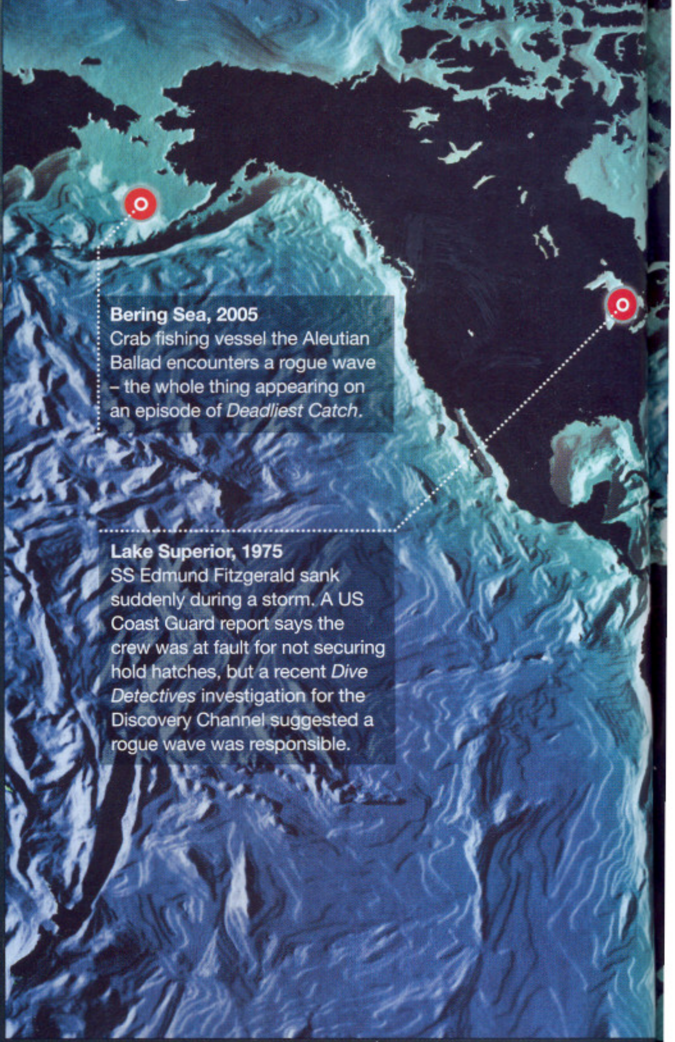
Terra SAR-X tracks waves from space



Satellite images help measure waves

WHEN

The sites across the world where rogue waves have hit



ALAMY, NOAA, DLR X2

WAVES ATTACK

Advances in imaging technology are also allowing this to be studied in more detail. During the MaxWave project, the satellites were relatively 'blunt' wave-watching instruments. But today, the techniques have been honed, so the oceans can be studied in much greater detail (see 'Wave hunting from space', left). Dr Susanne Lehner, at the German Aerospace Centre, was instrumental in developing the techniques used to measure wave heights from radar data. "We could only observe wavelengths longer than 200m. Now we have much better resolution and can see how they are breaking and interacting with currents."

When he's not being a physicist at Harvard, Heller is sailing his 40ft yacht along the west coast of Canada up towards Alaska – an area he describes as having "lots of currents and lots of waves". So, to him, the need for a clearer understanding of rogue waves is obvious. "We'd like to say that one day there'll be a marine weather forecast that speaks of the probability of freak waves. But they will always be a statistical event, they'll never be a certainty." And our new knowledge of how ferocious the sea can be is prompting research into boat design.

But are rogue waves frequent enough to warrant this kind of forecast – just like you'd have for other sailing conditions? "I think they are devastating enough that you'd like one," says Heller. "But whether it would actually affect a ship captain's decision to go somewhere, I don't know. The wind and rain are the same – people go out anyway, but you'd like to know if they're likely and if you should wear a coat that day or not." ■

Andy Ridgway is Deputy Editor of Focus

FIND OUT MORE

http://bit.ly/a8TMVw
Rare video footage of a rogue wave as it strikes the Aleutian Ballad

coast.gkss.de/projects/maxwave/
More on the MaxWave project

Extreme Waves by Craig Smith (National Academies Press, 2006)