Exploring the science of rogue waves

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Philip Weld, the former owner/publisher of the Gloucester Daily Times, lived on Cape Ann for many years. Late in life, he became interested in a dangerous form of racing -- sailing solo across the Atlantic. He had a large trimaran built and named it Gulf Streamer. His plan was to enter the solo, cross-Atlantic race that was sponsored by the London Observer, an English newspaper.

In 1976, while on his way to England to join the start of the race, Weld's vessel was hit by a huge "rogue wave" north of Bermuda. This caused his vessel to capsize. Once a trimaran turns turtle, it does not recover as would the typical ocean-going yacht with a large, self-righting keel. Weld and his companion on the trip over, Bill Stephens, had to cut their way through the bottom and crawl out onto the tri-hull. The exhausted mariners clung to the wet, slippery bottom for five days before a British container ship rescued them.

So, what is a rogue wave that could cause such a calamity? Although there were many anecdotal reports of very large, freakish waves before Weld had his encounter, experts thought rogues were a myth. Scientists didn't understand how such waves could emerge from the storm systems that they studied, and no such wave had ever been measured reliably.

But, in January of 1995 on the Draupner oil-drilling platform in the stormy North Sea, a wave was digitally recorded with a maximum height of 84 feet, while the average waves in the area were a fraction of that size. A true rogue wave. This changed everything.

Scientists became excited now that there was good evidence of the phenomena. Many studies, both theoretical and experimental, have been conducted around the world over the last 20 years. As a result, a much better understanding of the phenomena has been developed. But, the work still has a long way to go before useful predictions about the presence of rogues can be made.

One interesting finding in the research to date is that rogue waves are not as rare as once thought. The European Space Agency has been doing research using radar images of the world's oceans to identify rogue waves. Dr. Wolfgang Rosenthal, a German scientist, said of the results, "They are more frequent than we expected." He estimates that at any given moment, there are ten rogues "churning through the world's oceans."

Compared to the ambient waves in the area, a rogue is very large, unexpected, and appears suddenly from any direction. Such phenomena can be very dangerous, even for major ships. The reason is that the rogue can impact an unsuspecting vessel with tremendous, breaking force.

For example, in a major storm, like the Perfect Storm of 1991, a NOAA buoy east of Cape Cod reported maximum sustained winds of 56 mph. It also recorded average waves of 39 feet in height. These waves have a breaking pressure of 8.5 pounds per square inch (psi) on a ship's hull. Modern ships are designed to withstand a breaking wave with 21 psi, so normally the waves in the Perfect Storm would not have been a problem. However, a large rogue wave created in such a storm can be 80 to 100 feet, or even larger, and reach a breaking pressure of 140 psi, well beyond the design limit of a ship.

The goal of the ongoing research is to understand how these waves are formed, and then to predict their genesis. Mariners can be informed of areas to be avoided or be made aware of the likelihood of encountering a rogue while in particular conditions.

No one explanation for the formation of rogues has emerged thus far. There are several theories that appear reasonable, and most may be predictive enough to someday provide early warnings to mariners.

There are several current rogue genesis theories. First, for some locations, a mechanism of rogue wave formation is the focusing of smaller waves by the shape of the coast or seabed. When conditions are right, the waves come together in phase. This means the waves reach their maximums at the same time. Then their crest heights combine and cause a freak wave that might be double or more of the average wave height in the area.

Another mechanism for rogue formation occurs when waves along a significant ocean current, like the Gulf Stream, are driven into an opposing current, or a strong wind from the opposite direction. This produces a shortening of the wave lengths, or the distance between waves. As a result, the wave heights increase, and oncoming wave trains compress, potentially causing a rogue wave to form. This mechanism accounts for the relatively common occurrence of rogues off the coast of South Africa, where a strong, southwest ocean current is often opposed by the prevailing winds from the west.

This mechanism might have been the genesis of the rogue wave that capsized Philip Weld's trimaran. The Gulf Stream passes by Bermuda in the area where his accident occurred, and if there was an opposing wind at the time, the conditions could have been right for the formation of a rogue.

Yet another mechanism scientists have studied is when a very large group of stable waves in cold water moves into warm water. Because of the change in temperature, the wave physics demands that the wavelength gets shorter and the wave height gets larger. The waves seek equilibrium by displacing energy from the front and back of the group toward the center. This action can cause the formation of a rogue near the center of the wave group.

Physicists have been studying the behavior of waves for over one hundred years.

Several equations have been developed which describe how different types of waves proceed over time. One such model is known as the non-linear Schrodinger (NLS) equation. A solution for this equation found by a British scientist named Howell Peregrine in 1983, shows an unusual wave-type that "sucks" energy from other waves, growing to a huge size and then becoming unstable and collapsing. This solution was tested in a wave tank by a team of scientists in 2011 at the University of Technology in Hamburg, Germany. A rogue wave consistent with the NLS was produced. So, this mechanism can also be a source of large, rogue waves in the open ocean.

The waters off Massachusetts are not immune to the occurrence of rogues. In 2011, two mariners from Germany were in their 45-foot sailing boat, Eva, southeast of Nantucket. They described the wave conditions at the time as high, but not rough so they weren't concerned. Then a rogue wave hit their boat, capsized it, broke the mast, the hatchways and portholes, tearing up part of the deck. The boat started to sink. Fortunately for the crew, they were able to salvage their life raft along with a hand-held satellite phone and an old GPS unit. They contacted the Boston Coast Guard which sent a helicopter to rescue them. Two hours later, the sailors were safe aboard and headed to a hospital on Cape Cod. These mariners survived because they planned ahead and had the right equipment.

Now we know that rogue waves are real, large, unexpected and dangerous. To make it worse, they can come from a direction other than the prevailing wind. Fortunately, rogues are relatively rare. But, when they hit a boat, there is little to be done. Survival, as in the case of the German couple and Phil Weld, will depend on the preparations made before the voyage. Gloucester mariners, therefore, would do well to take appropriate precautions when they venture out to the open ocean.

Anthony J. Marolda is a resident of Annisquam and the author of a maritime adventure, "Purgatory Island", where a rogue wave hits a Gloucester schooner during a storm on the Grand Banks. The novel is available from Amazon.