Mathematicians provide new insight into tsunamis

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A new mathematical formula that could be used to give advance warning of where a tsunami is likely to hit and how destructive it will be has been worked out by scientists at Newcastle University.

The research, led by Newcastle University's Professor Robin Johnson, was prompted by the 2004 Boxing Day tsunami disaster which devastated coastal communities in Indonesia, Sri Lanka, India and Thailand.

In this instance, an earthquake in the depths of the ocean triggered a long surface wave which resulted in six massive wave fronts, one after the other.

Of these waves it was the third and largest one that caused the most devastation, hitting the beaches with terrifying speed. Reaching a height of 20m, it is this wave that lifted a train from its tracks as it travelled along the Sri Lankan coastline, killing almost 1,000 people.

Professor Johnson and his colleague Professor Adrian Constantin, based at the University of Vienna, Austria, felt that if we could understand more about how these long water waves behave we could predict where they might hit and how devastating they might be.

Their research is published in the academic journal *Science Direct:* Fluid Dynamics *Research*, and this paper has just been named the Journal's best paper of the year.

"What we found was that the number and height of the tsunami waves hitting the shoreline depends critically on the shape of the initial surface wave in deep water," explained Professor Johnson, Professor of Applied Mathematics at Newcastle University.

"From this it is possible to work out whether a 'trough' or a 'peak' is the leading wave. In the case of a trough then the familiar sight of the tide suddenly going out is the precursor to an approaching tsunami.

"If a peak is the leading wave, there is no warning except a fast-approaching wall of water.

"Potentially this could provide vital information for areas facing an impending disaster."

The maths

The primary aim of the work was to present a new theory for very long waves over variable depths, in particular tsunamis.

Until now the behaviour of this type of wave has been explained using 'Soliton theory' but Professor Johnson says he had doubted for many years this could accurately calculate the behaviour of such a large wave.

"The difficulty is that to understand in detail how a tsunami wave moves and behaves you need to know how it started in the deep ocean and we can never know that in any particular case," he said.

"However, it is possible to monitor seismic activity and then to give sufficient warning to vulnerable coastal regions that a tsunami is on its way. Automatic sensors have been in the Pacific Ocean for a number of years and sensors have now been placed in the Indian Ocean."

The research shows that the number of peaks and troughs in the initial disturbance out at sea will dictate the number of wave fronts that will steepen and eventually produce tsunami waves.

Professor Johnson said that by calculating the number of waves that will coalesce or 'join together' as the faster ones catch up the slower ones, it is possible to predict how many and how big and fast the final waves hitting the shoreline will be.

"We have shown that it is possible to use the initial wave pattern to work out how the wave will evolve and, importantly, how it might interact with the complicated motions close inshore to produce the tsunamis that we experience," he explains.

"With a time delay of maybe two or three hours between the initial wave trigger and the tsunami hitting the shore, this could prove vital."

Source: Newcastle University

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