What makes the giant freak wave 'stable'

June 18 2010, by David Meyers

The dreaded giant freak wave that can appear on the open sea out of nowhere, can now for the first time be theoretically calculated and modelled. Researchers at Umea University and the Ruhr-Universitat Bochum in Germany have developed a new statistical model for non-linear, interacting waves in computer simulations.

It explains how the water-wave system evolves, behaves and, above all, how it stabilises itself. The model is also suitable for the calculation of other "extreme occurrences" - for example on the stock market - or more complex phenomena in plasma physics. Bengt Eliasson, a physics research associate at Umea University along with Bochum's physicist Prof. Padma Kant Shukla report on their findings in Physical Review Letters.

Eliasson and Shukla already managed to simulate how the giant freak wave occurs on the computer four years ago. If two or more waves meet at a certain relatively small angle, they can progressively "amplify" each other. Two non-linear interacting waves therefore act very differently to a single wave which shows normal instabilities and breaks up into several small waves, which then run diagonally to each other.

Two non-linear waves, however, cause the water to behave in a new way, for example, the emergence of downright "wave packets" with amplitudes three times higher than that of a single wave. Buoyed by strong currents and powerful - opposing - winds, the giant wave can continuously build up from there.

With their new statistical model, the scientists have now succeeded in taking another crucial step towards explaining this freak wave: it results from combined non-linear effects in the wave-to-wave interaction and the dispersion of the "wave packets" in a certain direction. This causes the energy of the water to be concentrated "in a narrow band across a confined wavelength spectrum", and with sudden, large amplitude.

The actual instability of individual waves is "saturated" through the broadening of the wave spectrum, thus the water-wave system temporarily stabilises itself. This behaviour is typical for the localised giant wave, the researchers explain. Their calculations tally with observations from experiments in large water tanks.

"These show that long-crested water waves, i.e. groups of waves propagating in approximately the same direction, have an increased tendency to evoke extreme events," said Eliasson and Shukla.

The fact that the giant wave is no "sailor's yarn" has been known at least since the cruise liner Queen Elizabeth 2 encountered such a freak wave in 1995. The damage to passenger and cargo ships, but also for example to oil platforms at sea can be considerable. Eliasson's and Shulka's statistical model is a contribution to being able to predict freak waves in certain regions - for example in the North Atlantic or the Mediterranean - and providing early warning in future. The deeper physical understanding of the giant wave and statistical calculation would have to be combined with new, improved methods of observation, the researchers say.

More information: Bengt Eliasson and P. K. Shukla: Instability and Nonlinear Evolution of Narrow-Band Directional Ocean Waves. Physical Review Letters. Available: arxiv.org/abs/0912.0474

Provided by Umea University