Rogue Waves

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What are Rogue waves?

- Also known as freak waves, monster waves, episodic waves, killer waves, extreme waves and abnormal waves.
- They have been reported in oceans, optical fibers, atmosphere, microwave cavities and liquid helium
- In the ocean, they are large, unexpected and suddenly appearing surface waves that can be extremely dangerous even to large ships such as ocean liners
- In oceanography, rogue waves are more precisely defined as waves whose height is more than twice the significant wave height, which is defined as the mean of the largest third of waves in a wave record.
- Therefore, rogue waves are not the biggest wave found on water, rather an unusually large wave for a given sea state.

Why study Rogue waves?

- Rogue waves are known to have sunk over 20 super-carriers since 1970 and carry a force of 16-30 times (100 metric ton/m^2)that of a 12 meter wave.
- Rogue waves are an eminent threat to shipping industry, offshore industry (oil and gas), cruise-ships and naval activities
- Their occurrences seem to be increasing with climate-change weather patterns
- They happen most frequently in the south east coast of South Africa
- Insurance industry searches for new models to predict them.
- Should rogue waves be accounted for in design of ships, ship loads, ship response and offshore infrastructure?

What sea-state are amenable to Rogue waves?

- They may occur in low, intermediate and high sea states.
- In the south-east coast of South Africa, they occur as a result of the wave swell and Aghulhas current
- Different mechanisms may be responsible for generating these waves such as linear focusing of energy (wave-wave interactions), wave-current interactions, crossing seas (wind sea and swells) quasi-resonant nonlinear interactions

Modelling Rogue Waves I

- In 1950, British Mathematician and Oceanographer, Michael Selwyn Longuet-Higgins, stated that when two or more waves collide, they can combine to create a large wave through a process called **constructive interference**.
- According to the principle of linear superposition the height of the resulting wave should simply be the sum total of the heights of the original waves.
- Thus, a rogue wave can only form if enough waves come together at the same point

Modelling Rogue waves I

- In the 1960's Thomas Brooke Benjamin and his student Jim Feir, at Cambridge University, studied the dynamics of waves in a long tank of shallow water.
- They noticed that while waves might start out with constant frequencies and wavelengths, they would change unexpectedly shortly after being generated.
- Waves with longer wavelengths were catching those with shorter ones.
- That means, energy was transferred to large waves short-lived waves.

Modelling Rogue Waves II

- In 1995, when the rogue wave of height 26 meters hit the Draupner platform, the situation changed.
- The EU's MAXWAVE project analysed 30 000 satellite images covering a 3 week period during 2003, and found 10 waves around the globe within a reach of 25 meters or more.
- This frequent appearance of rogue waves caused a rethinking about Longuet-Higgings linear model.

Modelling of Rogue waves II

- It turned out that under certain conditions, rogue waves can be modelled by certain forms of nonlinear evolution equations, for example, the Korteweg-de Vries (KdV) equation, the nonlinear Schrödinger (NLS) equation, the Kadomtsev-Petviashili (KP) equation or systems thereof.
- Why these equations? Their solutions are solitary waves which travels longer without losing shape, due to the interaction between **dispersion** and **nonlinearity**.
- However, none of these models were able to give suitable initial conditions from which Rogue waves form

Can we predict Rogue waves?

- Some researchers Steinmeyer and Simon Birkholz studied rogue waves in different media and concluded in the 2015 publication that *"to some degree rogue waves in the ocean are predictable"*
- Steinmeyer continued to say "It could give ships and oil platforms 2-3 minutes of warning before a rogue wave formed"

Can we predict Rogue waves?

- In 2015 Themis Sapsis and Will Cousins of MIT, used mathematical models to show how energy can be passed between waves within the same group, potentially leading to the formation of rogue waves.
- They found that they could accurately predict the focusing of energy that can cause rogue waves, using only the measurements of the distance from the first to the last waves in a group, and a height of the tallest wave in the pack.
- *"if the algorithm was combined with data from Lidar scanning technology, it could give ships and oils platforms 2-3 minutes of warning before a rogue wave formed"*, said Sapsis

Can we predict Rogue waves?

- Fedele from Atlanta Georgia says "there is no such thing as unidirectional stormy sea. In real-life ocean's energy can spread lateraly in a broad range of directions"
- In 2016 Fedele and his colleagues used data from the Draupner, Andrea and Killard rogue waves which struck respectively in 1995, 2007 and 2014, looked at linear interference causing rogue waves and their model failed.

Can we predict Rogue waves?

- In 2016, Steinmeyer and colleagues also proposed that linear interference can explain how often rogue waves are likely to form, which he termed "effective number of waves"
- They found that rogue waves are more likely when (1) low pressure leads to converging winds; (2) when waves heading in different directions cross each other; (3) when wind changes direction over a wide range; (4) when coastal shapes and subsea topographies push waves together
- They concluded that rogue waves could only occur when these and other factors combine to produce an effective number of waves of 10 or more.

Conclusion

There are two main considerations for the modelling of rogue waves:

1. high amplitude models
2. initial conditions for this optimization to occur
3. develop a warning criteria for the shipping and offshore industry

Thank you