The formation and spatial distribution of rogue waves

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Aims and Objectives:

1) Collect a large and reliable dataset of field evidence of oceanic waves to observe rogue waves to address the fundamental need for more observational evidence

2) Investigate whether sea state parameters can be used as a cheap predictor of rogue wave likelihood.

3) Investigate the spatial variability of rogue wave occurrence.

Results:

- Of 1.6 Billion waves 263,000 were rogue waves of at least twice the 20-minute Hs.
- Rogue seas lie within the normal seas for both parameters and there are steeper normal seas than rogue seas, therefore sea state steepness is not a factor in their formation.
- Nonlinear focusing is not the cause of rogue wave formation.
- Rogue wave occurrence is not spatially uniform.

- Scatter displaying sea state steepness - rogue seas lie within the normal seas for both parameters and there are steeper normal seas than rogue seas, therefore sea state steepness is not a factor in their formation.
- The majority of rogue waves in the dataset occur in small seas.

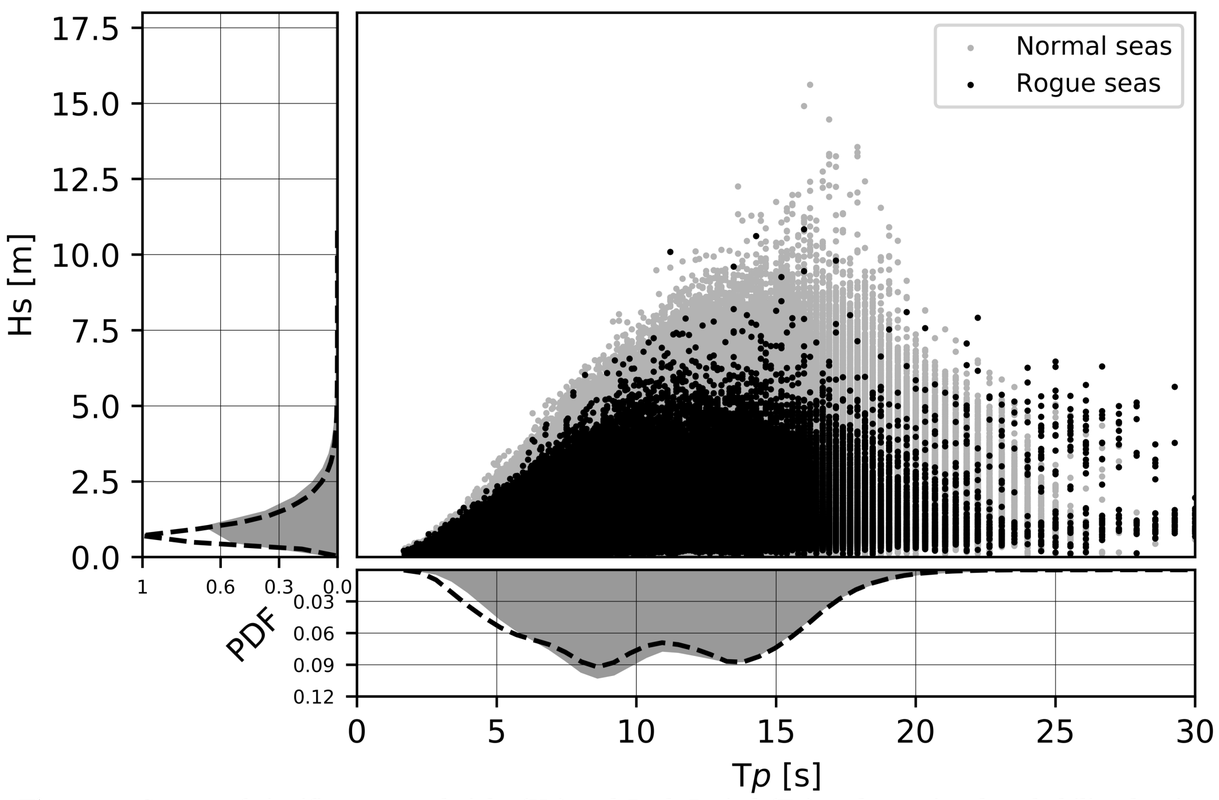


Figure 1: Scatter of significant wave height (Hs) and Peak Period (Tp) and associated probability density functions for seas containing rogue waves (black) and those without (grey). The majority of seas are less than 2m and the majority of rogue waves are less than 1m high.

- PDF's of spectral width parameters ε and ν, show seas containing rogue waves have broader spectral widths. This indicates that nonlinear focusing is not the reason for their formation.

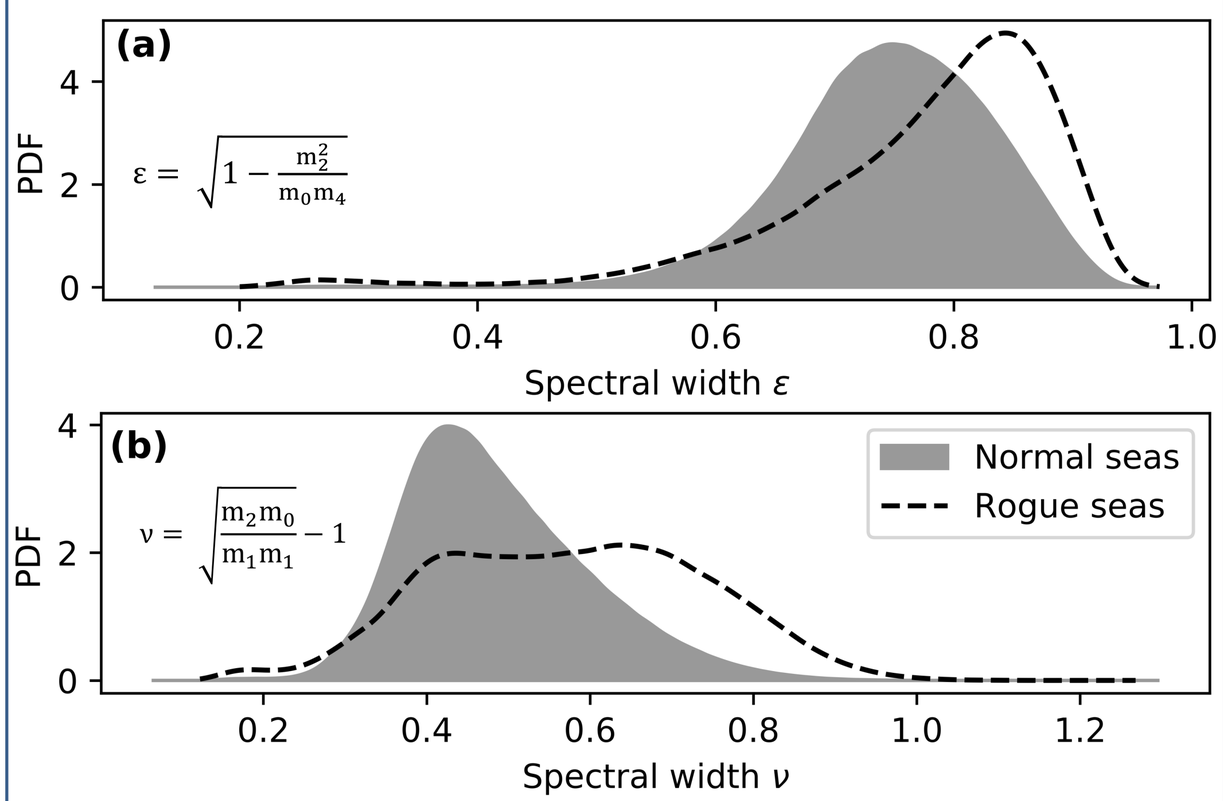
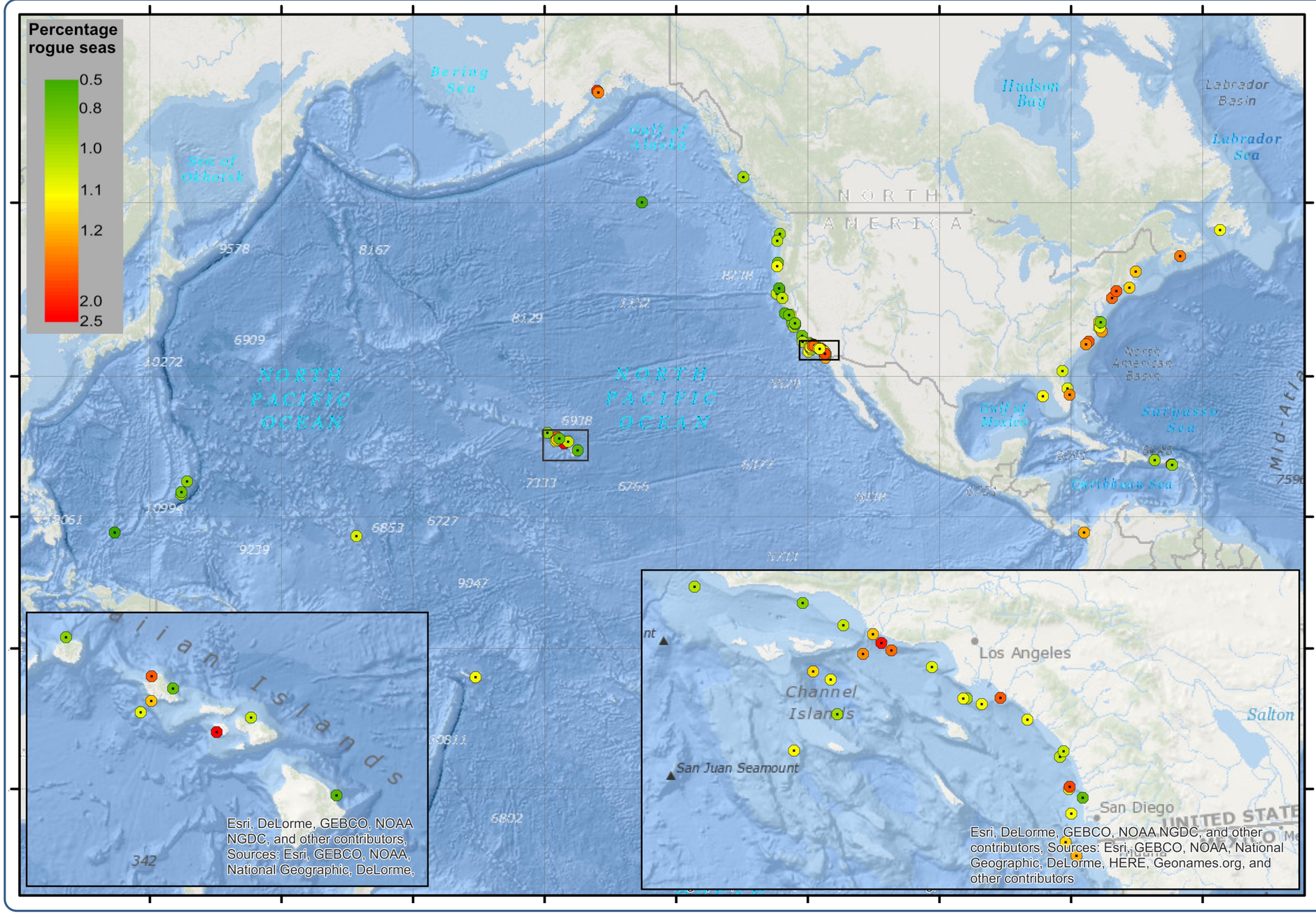


Figure 2: Probability density functions of the spectral width parameters ε (a) and ν (b) for seas containing rogue waves (black) and those without (grey). A narrow spectral bandwidth can be an indicator of strong nonlinear focusing, whereas larger values of ε or ν indicate a broad spectrum, where the wave energy is widely distributed across many frequencies.



- Map showing the percentage of 20-minute seas that contain rogue waves, displaying the non-uniform spatial distribution.
- At each location there are between 200 and 600 rogue waves per year.
- Sheltered sites with low wave height have higher frequencies of occurrence, but these rogue waves are of low height.
- Sites with lower frequency of occurrence tend to have higher significant wave height and much larger rogue waves.

Figure 3: The percentage of 20-minute seas that contain rogue waves that are over twice as high as the surrounding significant sea state of at least 1 metre at 80 wave buoy locations. A colour scale of green through red depicts low to high occurrence, respectively. The data used shown is based on the 2.2 million seas with a Hs > 1m, of these 23 thousand rogue waves were seen.

A clear spatial distribution in the occurrence of rogues can be seen, with the North Atlantic being more frequent than the North Pacific; however, these rogue are smaller than those on the Pacific coast. Within the North Pacific there is spatial variation that has been attributed to extent of exposure to the long fetch wave field.

Dataset:

Individual wave profiles with a cumulative sampling time of 436 years, forming a dataset of 1.2 billion individual wave profiles from 80 directional wave buoys (Figure 3) were furnished by the Coastal Data Information Program, operated by the Scripps Institution of Oceanography.

Further Analysis:

Modulational instability is shown not to be the cause of majority of the rogues; therefore, directionality of the wave field needs investigating for evidence of crossing seas. The average wave shapes of rogue waves will be calculated and utilised for model scale seakeeping trails in the Boldrewood Towing Tank facility at the University of Southampton. Furthermore, with such a large dataset, machine learning could be applied to find novel causal relationships between wave parameters, to facilitate fast and computationally efficient rogue wave prediction.

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