



Towards understanding the role of fatigue and rock damage accumulation on sea cliff erosion using seismic methods

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Though they comprise ~80% of global coastlines, rocky shores are significantly understudied in comparison to their depositional counterparts. As winter wave heights and variability intensify across Western Europe, understanding the susceptibility of these coasts is becoming increasingly important. Though sea cliffs are subjected to persistent wave action, cliff erosion and collapse is episodic, making prediction difficult. Observations of cliff failures do not always coincide with the highest magnitude waves. In addition, there is a significant mismatch between the maximum pressures exerted by individual breaking waves (kPa) and the intact tensile strength of the bedrock that comprises these cliffs (MPa), suggesting that under almost all wave conditions, erosion should not occur as the tensile strength of the cliff rock is almost never exceeded by wave forcing.

These observations suggest that sea cliff stability is not purely dependent on the magnitude of a single wave, but is likely related to the additive effects of the full history of past wave action due to accumulated damage via fatigue. Here, we explore the influence of variable wave action on cliff flexure using seismic methods. We present data from a coastal seismic observatory established on the Orkney Islands of Scotland, where 30m sea cliffs are subject to wave heights from 1-15 m, making it an ideal natural laboratory to characterize the contribution of varying wave heights towards cliff rock weakening and eventual erosion.

We pair high-resolution wave buoy data with a cliff-top seismic network to characterize the relationship between delivered wave energy and sea cliff response. Through comparison of wave and seismic spectra, we constrain the portion of ocean waves that most effectively translate into mechanical work. We characterize the relationship between wave height and cliff shaking. We hypothesize that this relationship will evolve with time as rock damage develops via low-magnitude, cyclic cliff flexure. Preliminary data confirm this hypothesis, indicating temporally coherent variations in the relationship between cliff displacement and wave height, implying damage accumulation due to repetitive stressing of the cliff rock. To more explicitly characterize the extent and development of damage, we also measure temporal and spatial variations in seismic velocity. Using these results, we move towards constraining the role of the past wave forcing history on driving sea cliff erosion and modifying cliff stability.