



Measuring cliff top and cliff face retreat rates of a coastal drumlin using Structure-from-Motion in Galway Bay, Ireland

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Sea cliffs comprise approximately 80% of the world's coasts. Rapidly retreating cliffs are a widespread problem that threatens property, transport infrastructure and public safety. Cliff retreat rates depend on highly localised characteristics of the cliff itself, as well as on the land behind the cliff and the intertidal and marine environments in front of it. In addition to these physical properties, retreat rates are also influenced by the methodology applied. Traditionally, estimates of coastal cliff top retreat have been based on historic map and aerial photograph (century scale) analyses that provide long-term rates but fail to provide information in short-term processes driving coastal evolution. Newer datasets from satellite imagery and uncrewed aerial vehicles (UAV's) are being coupled with new techniques like Structure-from-Motion (SfM) to dismantle cliff top and cliff face dynamics at shorter timescales (weeks to months). It is now accepted that estimates of cliff retreat rates can differ substantially when calculated from cliff top versus cliff face analyses, usually finding that cliff-top retreat rates are higher than cliff-face retreat rates.

This study combines historical data (maps and aerial photographs 1842 – 2000) with contemporary UAV imagery (2019 – 2023) to analyse cliff top and cliff face dynamics of a 250 m wide coastal drumlin at Silverstrand in Galway Bay on the west coast of Ireland. The cliff top changes were analysed using the Digital Shoreline Analysis System (DSAS) in the ESRI ArcGIS Desktop platform. Cliff face change detection was done using a Multiscale Model to Model Cloud Comparison (M3C2) in CloudCompare. By using these different types of data and methods, we were able to calculate retreat rates of the cliff top and the cliff face independently. The average cliff top retreat rate between 1842 and 2023 (181 years) was estimated to be 0.14 +/- 0.02 m/year. The average cliff face retreat between 2019 and 2023 (4.45 years) was estimated to be 0.08 +/- 0.02 m/year. For both, cliff top and cliff face retreat rate, we found that the long-term retreat rates are lower than the short-term retreat rates and that the western part of the cliff experiences higher erosion than its eastern counterpart. This variability might reflect multiple erosional processes and differences in magnitude-frequencies of erosional events at the cliff top and cliff face, or even the application of various methods and datasets.

Our results are consistent with other soft rock cliffs in Ireland and globally in similar settings.

Nonetheless, more detailed observations using shorter timescales and monitoring intervals are warranted to identify and quantify the rates, patterns, timing and magnitude- frequency of cliff retreat phenomena.