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Driving factors of hard rock cliff erosion in Brittany, France

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Unravelling mechanisms contributing to hard rock cliff erosion is still challenging due to the range and the high spatial and temporal variability of the different marine and subaerial processes involved. In times of recent and anticipated climate change it can be expected that the morphodynamics of rocky coasts will have an increasingly noticeable effect on society and infrastructure.

We aim at relating different sources of mechanical stress (e.g. wave loading, direct wave impact, hydrostatic pressure, thermal expansion) to cliff-scale strain (cliff-top swaying and shaking) and micro-fracturing (generation and expansion of micro-cracks), with the objective to discriminate triggering mechanisms of cliff failure and to gain understanding on the role of rock micro-fracturing as a precursor to cliff failure.

A continuous and multiparameter monitoring during the winter period of 2017 (February-May) was carried out at a 22 m high hard rock cliff-face located at the macrotidal embayed beach of Porsmilin (Brittany, France). The cliff is mainly composed of orthogneiss including intrusions of granodiorite and exhibits a high fracture density, which dictates the direction of block removal. The selected cliff section is exposed to Atlantic swell from the south/southwest with a significant wave height of ca. 1.5 m during typical storm events, and reaching up to 4 m during extreme storm events.

The characterization of cliff micro-fracturing was accomplished through in-situ monitoring of cliff-top ground motion with a seismometer as well as one geophone installed at the cliff top and three geophones installed in horizontal boreholes within the cliff-face. Wave impact was monitored by setting up a real-time video system in front of the cliff-face in combination with pressure and wave load sensors that were installed on the beach and the rocky platform in a cross-shore array, up to the cliff toe. Four temperature sensors were placed in shallow boreholes at the cliff-face in order to record surface rock temperature. In addition, a weather station and a piezometer were deployed to monitor local weather and groundwater conditions at the study site. The monitoring program was complemented by repeated topographic data collection using an UAV and a TLS to survey the selected cliff section, and by DGPS profiles of the beach section in front of the cliff.

Our results confirm that vertical cliff-top ground motions can be used as a proxy for environmental processes that transfer energy to the cliff. We were also able to show that combined tide, wave and wind conditions during energetic marine conditions exhibit a high energy transfer to the cliff. A clear relationship between the number of microseismic events recorded by the geophones and the peak of the high tide during spring tides was found. Our results also highlight a relationship between solar-induced thermal heating of the cliff-face, a daily opening and closing dynamics of the fractures at the cliff-face and the number of recorded geophone events, thus potentially providing original evidence on the influence of solar-induced thermal stress of the rocky cliff on rock micro-fracturing and hence on rock weathering and cliff erosion.