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Holocene – historical - decadal - annual retreat rates along the eastern Mediterranean coastal cliff of Israel

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The Israeli coastal cliff extends about 50 km along the eastern Mediterranean and is comprised of late Quaternary eolianites and paleosols that reach heights of up to 50 meters above current sea-level. Variable cliff-top inland retreat rates of up to a few tens of centimeters per year have been previously measured along the cliff line usually by comparing aerial photos from the last decades. Commonly, these locally constrained retreat rates have been: 1) extrapolated as representative of the entire cliff length, and 2) adopted by hazard-mitigation and planning authorities. Here, we re-evaluate the current understanding of retreat patterns and rates along this cliff line using a suite of ground-based LiDAR observations, airborne LiDAR, aerial photography, archeology and numerical (OSL) age determination of older coastal cliff locations.

Annual retreat rates and patterns were constrained using repeat high-resolution ground based LiDAR. In places, storm induced landward cliff retreat reached 7 m/yr, which is comparable to the total retreat previously documented along this coastal stretch during the past 60 years. Yet, spatially - cliff-retreat activity per given year was documented along less than 5% of the entire cliff length. Decadal-scale retreat rates along the entire coastal cliff were mapped by comparing the cliff-top location in aerial photos from 1945 and 2004. These revealed cliff-top retreat rates of less than 0.1 m/yr along 58 % of the cliff length and >0.4 m/yr retreat rates along only several % of the cliff length. Extended stretches of the cliff line ($\sim$50%) did not experience detectable retreat in the past 60 years and thus appear to have remained stable during this time period.

Local retreat rates at centennial to millennial time scales were constrained at a cliff-top archeological site where a Crusader castle appears to have lost <20 m of its outer walls as well as at a natural site where the past locations of the cliff are marked by multiple cliff parallel rock-blocks lines formed by past cliff failure events, that occurred up to 45 m seaward of the present-day cliff location. Here, OSL age determination of beach-rock developed in-situ around the rock-block lines ranged consistently between hundreds to thousands of years. Both sites indicate longer term cliff retreat rates of 0.01-0.05 m/yr.

In summary, highly variable annual-decadal scale retreat rates (0 - 0.5 m/yr) occur along the Israeli coastal cliff, whereas the range of longer-term retreat rates appears to be an order of magnitude lower. We find that apparent retreat rates decrease with increasing observation time while the affected cliff length increases with increasing observation time. Thus, we suggest that the characteristic time-scale for inland retreat of this sea cliff is on the order of hundreds-thousands of years and that its long-term 'background' natural retreat rate is on the order of 0.01-0.05 m/yr.