Mapping Cliff Retreat Patterns along California Coast

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Background

Coastal cliffs comprise ~70% of the California coast. Their erosion presents a significant hazard to safety, public resources, and coastal infrastructure. Airborne lidar surveys provide a method to map coastal change over large spatial scales and improve our understanding of the processes driving erosion at regional scales, critical for improved coastal management. However, high resolution lidar surveys at large spatial scales of the California coast are limited.

Objective:

Quantify the spatial and temporal trends of cliff retreat along the entire California coast

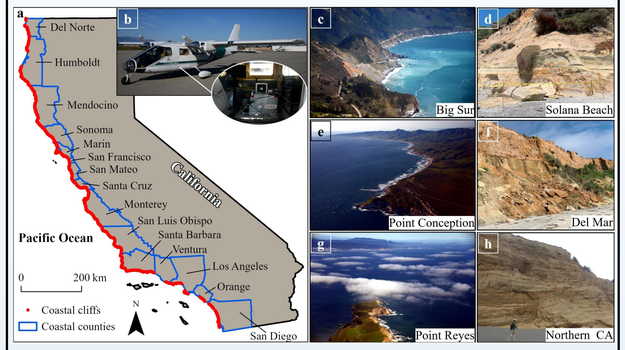

Fig. 1: Overview of the California coastal cliff setting. (a) Map of coastal counties in California. (b) Airplane-based scanning system equipped with the Modular Aerial Sensing System. (c-h) Example of California's diverse coastal cliff settings.

Lidar Dataset

Data Collected Period	Vertical Accuracy (m)	Source
Oct. 2009 – Aug. 2011	0.09	NOAA
Apr. – May 2016	0.11	NOAA
Oct. 2023	**0.04**	**Scripps**

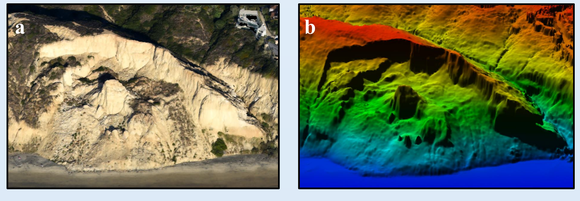

Fig. 2: Lidar point cloud (a) and corresponding elevation model (b).

Cliff Analysis Steps

1. Process point cloud, e.g., denoise and create DEM (LAStools).
2. Generate cross-shore transects at 5-m alongshore distance (ArcGIS Pro)
3. Identify cliff top and base locations along transects (Python)
4. Analyze cliff retreat patterns along California coast (MATLAB)

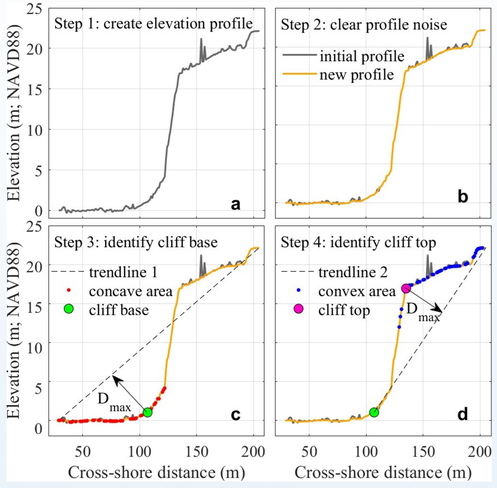

Fig. 3: Cliff top and base identification process.

Cliff Top Retreat Comparison

- Retreat rate: slightly slower in 2016–2023 compared to 2009–2016.
- Fraction of retreated cliffs: decreased during 2016–2023.

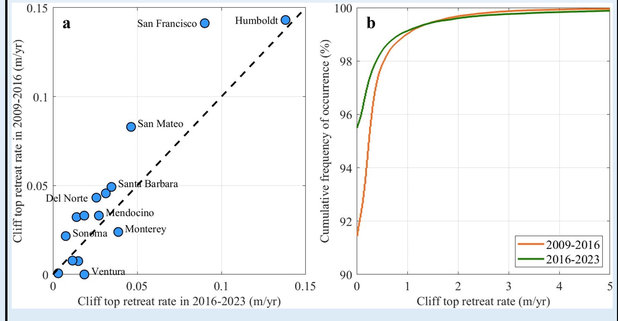

Fig. 6: Comparison of cliff top retreat rates between two time periods, 2009–2016 and 2016–2023. (a) County-level comparison of retreat rates, and (b) cumulative distribution of retreat occurrences.

Cliff Dimensions in 2023

1. Typical cliff height and width were 12 and 21 m, with mean and variability increasing northward.
2. Average cliff slope was 38° with a standard deviation of 15°.

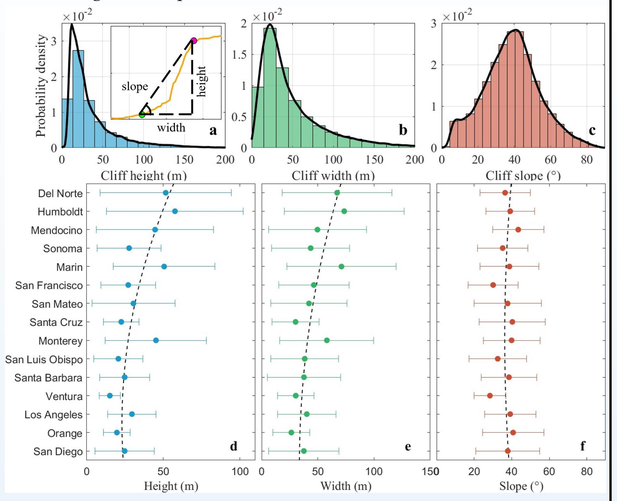

Fig. 4: Dimensions of coastal cliffs across California. (a-c) Probability density distributions of cliff height, width and slope. (d-f) Spatial variations in cliff height, width and slope along counties.

Volume Change Analysis

- Characterize and remove vegetated area
- Quantify the amount of sediment loss from cliff retreat

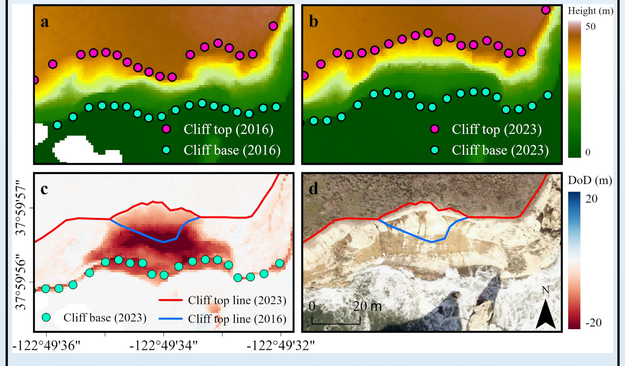

Fig. 7: Example of a cliff face erosion. (a-b) Detected cliff top and base positions. (c-d) Elevation change during the period of 2016-2023.

Cliff Top Retreat in 2016-2023

1. Cliff top retreat hotspots are concentrated in central and northern counties, with rates exceeding 15 m/yr in some areas.
2. In general, cliff top retreat rates increase towards the north.
3. The overall average cliff top retreat rate is 0.04 m/yr.

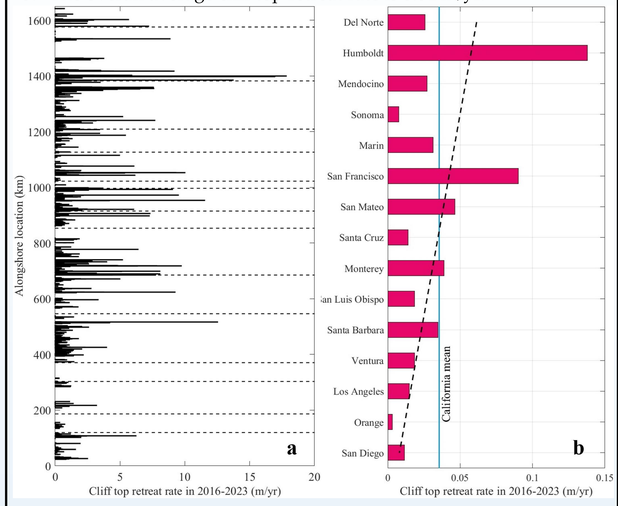

Fig. 5: Cliff top retreat rate in CA in 2016-2023. (a) Alongshore cliff top retreat rate and (b) mean cliff top retreat rate within each county.

Conclusions

- California coastal cliffs were measured with a 5-meter alongshore resolution over different time periods.
- The typical cliff height, width, and slope are 12 m, 21 m, and 38°, respectively. Both height and width increase progressively towards the north.
- Cliff top retreat is most concentrated in central and northern California, with retreat rates generally increasing towards the north.
- Compared to the period from 2009 to 2016, the rate of cliff top retreat slowed slightly in 2016–2023, with nearly half the fraction of cliffs experiencing retreat.

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