Revisiting Megacusp Embayment Occurrence in Monterey Bay and Beyond

High Spatiotemporal Resolution Satellite Imagery Provides New Insight into the Wave Conditions Necessary for Embayment Formation and Persistence

EP11D-1300 – Monday, 9 December 2024

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1 What are Megacusp Embayments?

Rip current embayments are erosional features in the beach face at the shoreward head of rip current channels. Under the right wave and tide conditions, namely consistent swell at a shore normal incident angle, very large **"megacusp" embayments or MCE** (Fig. 1) can form with alongshore lengths ranging from 100-1000m and cross-shore amplitudes exceeding 50m.[3,10,11]

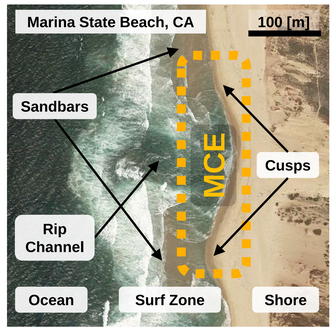


Fig. 1. *(right) Aerial view of a typical MCE structure in Monterey Bay, CA. Alongshore sandbars are split by deep rip current channels with MCE at their heads.*

2 Episodic Extreme Erosion Events

While MCE are transient, *O*(days-months), during large wave events, energy is focused at embayment heads **leading to extreme erosion hotspots**.[11] Understanding MCE formation and tracking their occurrence in near real-time could improve coastal resilience planning and pre-storm preparation.

Fig. 2. *(left) A post-storm erosion scarp, O(10m) in the cross-shore direction, at the head of an MCE in Lacanau, France (Ph. Julien Lestage).[2]*

3 Goals and Data — Can We "See" MCE?

MCE have been studied using a variety of methods (Fig. 3). PlanetScope (PS) provides ~daily imagery of any beach at a 3m pixel resolution. **This work seeks to:**

(I) Determine if MCE are detectable using PlanetScope imagery.
(II) Compare wave conditions causing MCE formation to previous findings.
(III) Explore the potential value of an expanded MCE dataset.

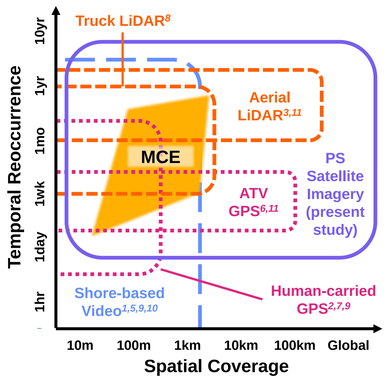


Fig. 3. *(above) Spatial-temporal comparison of previous MCE study methods[12]*

Imagery and Wave Data

- **Three sites**, Marina, CA (Monterey Bay), Montara, CA, and Duck, NC were selected for varied beach and wave conditions.
- **Six years** (Sep. 2017 - Sep. 2023) of imagery was used to generate **>600 "shorelines" per site**, ~1 every 3-4 days on average.
- **Nearshore wave data** is from the Coastal Data Information Program Monitoring and Prediction System (CDIP MOP) and the Wave Information Study (WIS) for Marina/Montara (15m depth) and Duck (24m depth) respectively.

4 Shoreline Processing, MCE Identification, Shoreline Metrics, and Wave Conditions

Fig. 4. *PS Sat. Imagery*

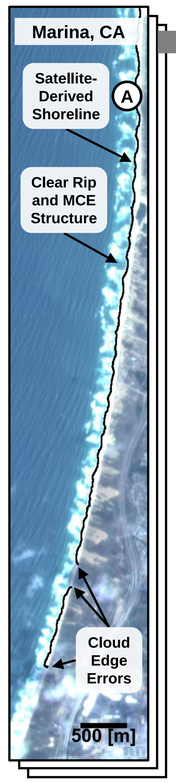


Fig. 5. *Satellite-Derived Shoreline Processing and MCE Identification*

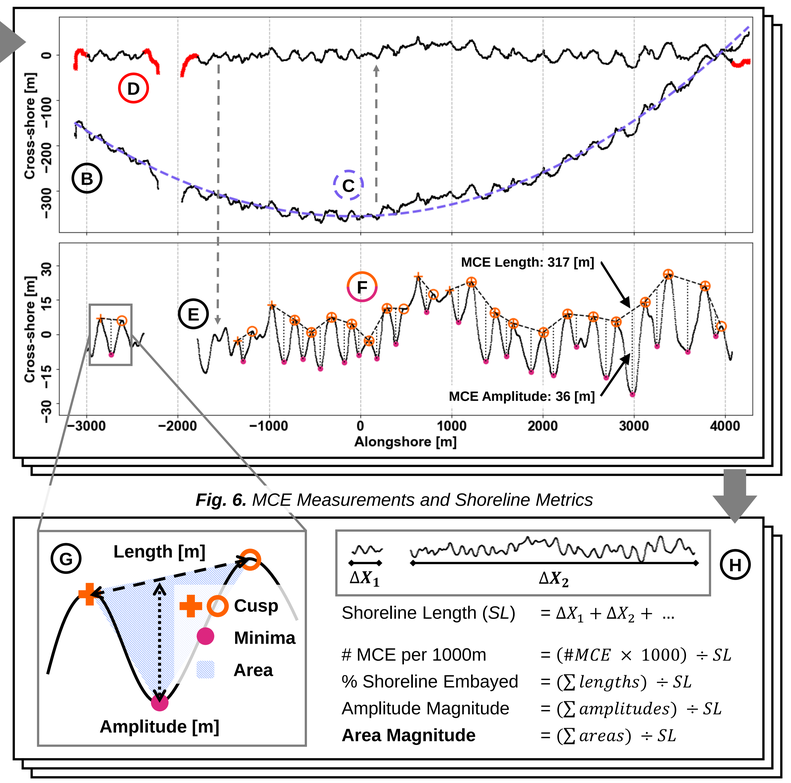
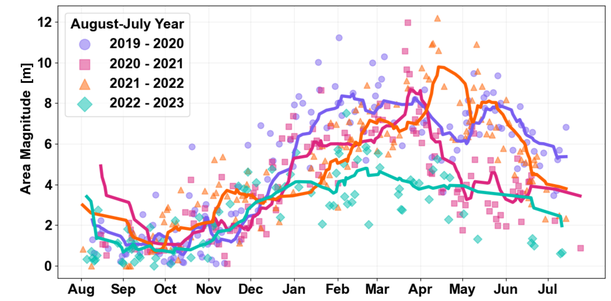


Fig. 6. *MCE Measurements and Shoreline Metrics*

Shoreline Data Processing Completed for Each Site (Figs. 4, 5, and 6)

A - The CoastSat toolbox[4] is used to generate satellite-derived shorelines
B - Shorelines are rotated and coordinates are converted for processing
C - Shorelines are straightened using a quadratic fit[11] of all >600 shorelines
D - Automated cleaning of anomalies, tails, and short chains is preformed
E - Bandpass filters[3] are applied to remove signal above/below thresholds
F - Peaks/minima are identified and MCE are filtered by size thresholds
G - Measurements[3] are recorded for each MCE present
H - MCE statistics are aggregated for each shoreline to create metrics

Fig. 7. *Area magnitude metric for 4 years of shoreline detections (points) and their 10-sample rolling average (lines) for the Marina, CA site.*



Wave Data Processing

For each date that a shoreline was detected at a given site, the average and variance of the wave parameters (significant wave height H_s, mean period T_a, peak period T_p, and mean wave direction) of the five prior days were calculated to approximate rough antecedent conditions for comparison with compiled shoreline MCE metrics.

5 Wave Forcing Findings

Preliminary analysis of correlations between antecedent wave conditions and MCE metrics agree well with previous studies.[10,11] Waves from a consistent direction generated numerous large MCE at Marina and Montara. At Duck, where wave direction is rarely consistent, MCE were only observed sporadically. Spearman correlation found the **H_s average was positively correlated with all metrics at Marina and Montara** and that **wave direction variance was negatively correlated with all metrics at all sites.** Notably, if wave direction is shore-normal, MCE appear to scale with H_s unbounded.

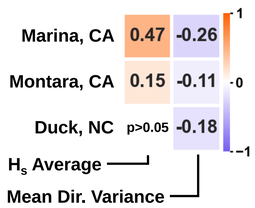
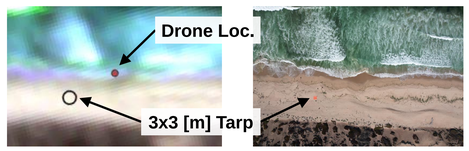


Fig. 8. *(left) Spearman correlation between the area magnitude metric and two wave conditions for all three sites. Marina showed the strongest correlations for all metric-wave condition pairs.*

6 Discussion & Next Steps

Drone field work to quantify MCE identification uncertainty is ongoing (Fig. 9). In future work, wave parameters will be shoaled to shore to better resolve the relationship between forcings and metrics as MCE scale differences were observed over <1km at Marina. The effects of individual storm events will be quantified along with tracking of individual MCE evolution. While there is a clear seasonal trend at Montara and Marina (Fig. 7), significant yearly variation is evident, raising questions about the influence of climactic patterns. Finally, additional sites with varying wave conditions will be added to further strengthen the analysis.

Fig. 9. *PlanetScope (left) and drone (right) imagery taken <1s apart during a ~20 minute drone timelapse.*



7 Citations

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8 Thank You!

Thank you to **Kyle Cavanaugh**, **Kate Cavanaugh**, and **Lori Berberian** of UCLA for help accessing PlanetScope imagery!
Thank you to WHOI's COFDL group for thoughtful comments along the way and to Tori Chen for editing help!
And BIG thank you to **NASA SARP** for funding my AGU travel!