Title
Setting up CoastSnap stations for Imperial Beach: Using community science as a tool to monitor dynamic coastlines and inform adaptations to rising sea levels in vulnerable regions.

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Capstone Project

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Topic:

Setting up CoastSnap stations for Imperial Beach: Using community science as a tool to monitor dynamic coastlines and inform adaptations to rising sea levels in vulnerable regions.

Signature has been redacted for privacy purposes.

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Table of Contents

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2 Abstract:

Sea level rise resulting from human-induced global warming poses a grave threat to our planet, particularly endangering low-lying coastal areas susceptible to flooding. Effective beach monitoring can help vulnerable coastal communities anticipate the adverse impacts of sea level rise. CoastSnap, a worldwide beach monitoring program, collects and analyses coastline photos contributed by smartphone users. The primary objective is to study how beaches change over time while engaging and educating communities about the dynamic nature of their coastlines. CoastSnap employs community science, which empowers communities to actively participate in the scientific data collection and inquiry process, catering to the unique needs of each community. This capstone project focuses on establishing CoastSnap stations in and around the City of Imperial Beach, an exceptionally vulnerable coastal region within San Diego County. Three locations, including two on Imperial Beach Pier and one at Border Field State Park, have been identified as suitable sites for new stations. Additionally, an analysis of CoastSnap data from the Torrey Pines station explored the accuracy of image-derived beach width measurements in comparison to data obtained through physical beach surveying (in-situ), to demonstrate CoastSnap's suitability for monitoring coastlines in Southern California. The comparison of CoastSnap measurements with in-situ measurements revealed an overall mean deviation of 1.35 meters, with CoastSnap measurements tending slightly more seaward. When considering tide levels, low tide events resulted in a lower mean deviation (mean = 0.94 meters) compared to high tides (mean = 1.78 meters). The analysis also found that CoastSnap-derived shorelines from Winter showed the strongest seaward deviation (mean = 4.30 meters), while Fall measurements tended to deviate slightly landward on average (mean = -0.61 meters).

3 Motivation:

3.1 Sea Level Rise:

Sea level rise (SLR) is one of the most significant threats facing our planet today. Global warming – driven by human activity – has resulted in an accelerated rise of the global mean sea level over the last century (*Oppenheimer et al., 2019).* The major pathways for SLR are the melting of ice caps and glaciers, and the thermal expansion of upper ocean layers (*Durand et al., 2022*). Between 1900-2018, there has been between 15-25 cm of SLR observed globally, of which 7-15 cm occurred in just the last 5 decades. Looking ahead, the Intergovernmental Panel on Climate Change (IPCC) predicts an additional rise of 10-25cm by the year 2050 (*Fox-Kemper et al., 2021*) (**Figure 1**).

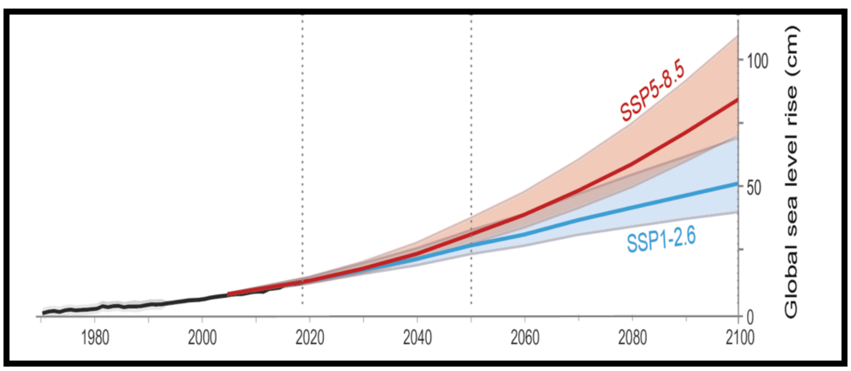

Figure 1: Projected Global Mean SLR between 1970-2100 under emission scenarios SSP1- 2.6 and SSP5-8.5 (Source: IPCC AR6: Chpt 9, 2021)

As sea levels continue to rise and these projections unfold, the frequency and severity of extreme sea level (ESL) events are anticipated to increase significantly (*Oppenheimer et al., 2019*). Consequently, low-lying coastal areas face heightened vulnerability to recurrent and severe flooding events. Considering the immense ecological and socio-economic importance of coastal regions worldwide, it is imperative that these vulnerable areas adapt to the evolving coastlines to mitigate the adverse impacts of SLR and coastal flooding events (*Magnan et al., 2022*).

3.2 Community Science:

Community science refers to the practice of scientific data collection and inquiry, in a manner that is community-driven and controlled, incorporates local knowledge and collective action, and aims to transform governance to improve stewardship and socio-ecological sustainability (*Charles et al., 2020).* This practice not only helps scientists collect a diverse data set at a relatively low cost but also cultivates public interest in important subjects - such as climate change, SLR, conservation, etc.

One distinguishing feature of community science projects is the active involvement of community members throughout the entire research process, beyond data collection. This inclusive approach enables community members to participate in problem identification, project design, and data interpretation. By co-creating and executing research projects alongside scientists, community science empowers communities to advocate for policy changes that align with their best interests (*Spellman et al., 2021*). The terms ‘Citizen Science’ and ‘Community Science’ are sometimes used interchangeably due to a shared component of collaboration between professional scientists and public participants. While 'citizen science' and 'community science' are often used interchangeably, some scientific groups are moving away from the former term due to its exclusionary connotations in the political context (*California Academy of Sciences, 2023*).

In the context of climate change, community science projects provide an additional advantage by instilling a sense of agency and hope. Unlike discussions surrounding larger-scale climate issues, where feelings of hopelessness and powerlessness may prevail, community members participating in every stage of the research process can witness how their work can contribute to sustainable policymaking in their own communities (*Spellman et al., 2021*).

4 Background:

4.1 CoastSnap Community Beach Monitoring:

CoastSnap Community Beach Monitoring is a globally implemented photo-point monitoring program that utilizes smartphone photos to study the dynamic changes occurring in coastlines over time. This initiative aims to collect high-quality beach monitoring data while fostering public engagement and interest in coastal dynamics. Scientists use these photos to investigate coastal phenomena, such as beach erosion and recovery, and ultimately, understand how coastal communities can effectively adapt to changing coastlines (*CoastSnap, UNSW & CoastSnap, San Diego).*

A typical CoastSnap station comprises a stainless-steel phone cradle strategically positioned to capture a scenic coastal view (**Figure 2**). Accompanying the cradle is an educational sign featuring instructions, a QR code, and educational material about coastal changes and SLR. Smartphone users can follow these instructions to place their phones in the cradle, capturing and submitting real-time images of the coastline. The CoastSnap initiative is driven by three main objectives:

1) Obtain high-quality beach monitoring information to study coastal phenomena such as beach erosion and recovery.
2) Understand how coastal communities can adapt to changing coastlines and sea-level rise.
3) Cultivate public engagement and interest in dynamic coastlines, SLR, and climate change.

Figure 2: A CoastSnap station overlooking a beach (Source: CoastSnap, UNSW)

As of 2022, the CoastSnap program included 200 globally distributed coastal monitoring locations across 21 countries (*Harley & Kinsela, 2022)*. The images submitted by the community are digitally compiled using a MATLAB toolbox to create time-lapse videos that track shoreline changes over time. Furthermore, the collected images can be analyzed digitally to derive important coastal measurements, including beach width, slope, and usage statistics (*CoastSnap – How it Works*).

In San Diego County, there are currently five operational stations. The Scripps Institution of Oceanography (SIO) has installed three stations at Torrey Pines, the SIO Pier, and Marine Street, La Jolla, while the Cities of Encinitas and Oceanside have recently set up stations at Grandview Beach and the Oceanside Pier, respectively.

4.2 Imperial Beach:

Imperial Beach, situated in San Diego County, California, occupies a significant position at the extreme southwest corner of the continental United States, along the border with Tijuana, Mexico. With a population of approximately 26,000 and encompassing 3.5 miles of scenic beaches, Imperial Beach faces several challenges due to its coastal location and low-lying topography (*Imperial Beach, CA - About Us*). The presence of the Tijuana

River Estuary to the south and San Diego Bay and Otay River to the north further exacerbates the region's vulnerability to wave and tidal flooding events, which are particularly pronounced during the winter months (Revell Coastal, LLC., 2016). In light of ongoing climate change and the associated rise in sea levels, it is expected that the frequency and intensity of these flooding events will increase (*Merrifield et al., 2021*).

Beyond the immediate disruptions to livelihood, traffic, and safety, coastal flooding poses a persistent risk of inflicting permanent damage to local infrastructure, thereby presenting a pressing threat of substantial economic impacts for the city and its residents (Revell Coastal, LLC, 2016). Consequently, there is a crucial need to gather accurate and comprehensive coastline data to facilitate a better understanding of the coastal dynamics in this region. Such data are essential for both local and global scientists seeking to study the impacts of SLR and ESL events. This information can aid in informing and developing adaptive measures to mitigate environmental and socio-economic consequences. Moreover, the collection of photos generated can also provide qualitative data to visually assess changes to the beach, calculate beach-use statistics, and interpret the quantitative data.

4.3 Project Objectives:

In response to these challenges, this project aims to establish new CoastSnap stations in Imperial Beach (IB). IB city officials and relevant local stewardship groups will be identified and contacted, to determine locations in IB that would best serve the needs of the community (specifically, areas with significant foot traffic, vulnerable beaches, or inadequate monitoring). The site selection criteria described by *Harley & Kinsela, 2022* will be used to identify specific sites at the determined locations that meet the requirements for the operation of a CoastSnap station.

Additionally, data analysis will be performed to compare CoastSnap data from the Torrey Pines Beach to in-situ data from the same location. This data analysis serves as a valuable tool for understanding the potential limitations associated with utilizing the existing CoastSnap technology to model the unique coastal geography of Southern California. The analysis conducted in this study will enhance the understanding of beach variability and the associated errors for users of the CoastSnap data, thereby facilitating informed decision-making in coastal management.

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5 Methodology:

5.1 Summary:

Imperial Beach city officials and relevant local stewardship groups were identified and contacted, to determine locations that would best serve the needs of the community. Project proposals and station mockups were sent to all relevant authorities, and information was collected regarding the legal permissions required to set up each proposed station site. The site selection procedure described by the CoastSnap group (*Harley & Kinsela, 2022)* was used to identify the most suitable sites for new CoastSnap stations in the desired areas of Imperial Beach. Additionally, data analysis was conducted by comparing the CoastSnap data from the Torrey Pines CoastSnap station in San Diego, CA, with beach survey (in-situ) data from the same location. This comparison aimed to demonstrate the accuracy and reliability of CoastSnap for studying the coastlines of Southern California, showcasing its effectiveness as a coastal monitoring tool.

5.2 Identification of Stakeholders:

To initiate the introduction of CoastSnap stations in IB and align them with the city's coastal resiliency plans (Revell Coastal, LLC, 2016) IB city officials played a crucial role. These officials were already familiar with the existing CoastSnap stations operated by SIO in San Diego, creating a favorable environment for the installation of similar stations in IB. Through productive discussions with the Environmental and Natural Resources Director of the city, coastal areas with (i) significant foot traffic - to encourage greater public participation and engagement about coastal dynamics – (ii) vulnerable beaches, or (iii) inadequate monitoring were identified as prime locations that would best serve the community's needs.

Once the potential sites were identified, the city officials facilitated connections with the relevant regional authorities responsible for overseeing these locations, as the sites were not owned by the city. We presented a comprehensive project pitch to these authorities, either through private meetings or public comments during their group meetings, highlighting the potential benefits of implementing CoastSnap in these areas. The project pitch involved describing the aims and objectives of CoastSnap Beach Monitoring, the expected benefits to the community, the logistics of installing a station, and addressing any questions and concerns the authorities may have. The stakeholders were also provided virtual mockups of the proposed stations, to demonstrate the proposed layout, installation steps, and appearance of the station.

Upon receiving positive feedback and interest from the authorities, further discussions were initiated to address the logistical aspects of setting up, operating, and maintaining the CoastSnap stations. These discussions also focused on the collection of necessary legal permissions and approvals required for the installation. Throughout this process, we placed significant emphasis on ensuring the seamless integration of the CoastSnap stations into the existing coastal landscape, prioritizing the preservation of both the utility and aesthetics of the chosen locations.

5.3 CoastSnap Data Collection:

Data from the new CoastSnap stations, after their installation, will be collected via a QR code provided on the accompanying signage. Once participants submit the image using the provided link it will be publicly accessible online - at https://siocpg.ucsd.edu/projects/coastsnap/coastsnap-arcgis-dashboard/ and https://www.coastsnap.com/ for any community members interested in accessing the data. Additionally, the data will be available for use in local projects by University of California at San Diego students to develop remote coastal monitoring, data processing, and analysis skills. Eventually, the photos also will be used to calibrate local coastal flooding models at sites of interest.

5.4 *Data Analysis:*

MATLAB was used to compare the beach width data obtained from the existing CoastSnap location in Torrey Pines with the corresponding beach survey data along the same coastline. The Torrey Pines CoastSnap location provided a relatively large dataset (~750 images) collected between August 2022 and February 2023. Coastal Data Information Program (CDIP) Monitoring and Prediction (MOP) transects 581 to 587 (Figure 3) (O'Reilly et al., 2016), located on Torrey Pines beach, were selected as the sites for analysis due to their presence in the field of view of the CoastSnap station and the availability of in-situ data from these transect points. Beach width - for the purpose of CoastSnap - is defined as the distance from the backbeach (i.e., the part of the beach furthest from the water's edge) to the shoreline edge.

Figure 3: A photo taken from the CoastSnap station at Torrey Pines, showing the MOP lines 581-587 analyzed in this project

First, the CoastSnap MATLAB code was used to obtain data on the beach width at each MOP from the images collected from the Torrey Pines station. For each in-situ data point all CoastSnap-derived beach width measurements within a 24-hour range were indexed. Deviation (D) was calculated once indexing was performed to find all CoastSnap entries within a 24-hour range of each survey measurement, using the following formula:

$$D = CoastSnap\_BeachWidth - Survey\_BeachWidth$$

(*this formula was applied to all CoastSnap measurements with a 24-hour range of each In-Situ measurement)

The mean, standard deviation, and root-mean-square of D were calculated, and the deviation data was visualized as a histogram and box-and-whiskers plot.

Further analysis involved indexing the data according to tide levels, using five tide datums defined by the National Oceanic and Atmospheric Administration (NOAA) (**Table 2**) at the nearby La Jolla (Scripps) tide gauge, and by season. The August to February time period, for which the CoastSnap data were available, was divided into two seasons, with Aug-Nov representing Fall and Dec-Feb as Winter. A similar analysis was then performed to assess the deviations between CoastSnap and in-situ trends and to observe any differences in error based on tide level or season.

Datum Name	Tide Level (m)
Mean Higher-High Water (MHHW)	1.566
Mean High Water (MHW)	1.344
Mean Sea Level (MSL)	0.77
Mean Low Water (MLW)	0.218
Mean Lower-Low Water (MLLW)	-0.058

Table 2: Tide Level Datum

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6 Results:

6.1 Data Analysis:

Data Analysis: MATLAB was used to perform data analysis on CoastSnap beach width data, by comparing it with beach survey data for multiple MOP points on Torrey Pines beach (**Figure 4**). The analysis began by calculating the mean beach width for both CoastSnap and MOP data. The mean Torrey Pines beach width, from Aug-Feb, was found to be 33.93 m using CoastSnap, while for beach survey data, it was 30.24 m.

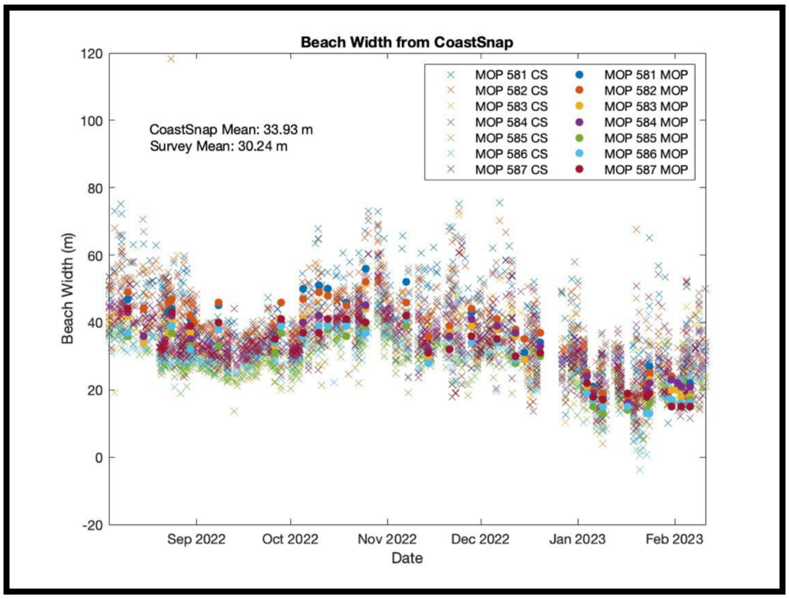


Figure 4: Time series of Torrey Pines beach width data from CoastSnap and Beach Surveys (Aug 2022 - Feb 2023)

To validate the CoastSnap data, the code identified the indices of CoastSnap data that fall within a 1-day range of each beach survey and calculated their deviation (using the formula presented in **Section 5.4**). The root-mean-square deviation (RMSD) was calculated to assess the overall agreement between CoastSnap and survey data. Additionally, the standard deviation and mean of the deviation (D) were computed. A histogram is plotted to visualize the deviations between CoastSnap and survey beach width (**Figure 5**). The mean cross-shore deviation between our image-derived and in-situ data was found to be 1.35 m, which suggests that the CoastSnap measurements were slightly more seaward than the survey measurements, on average.

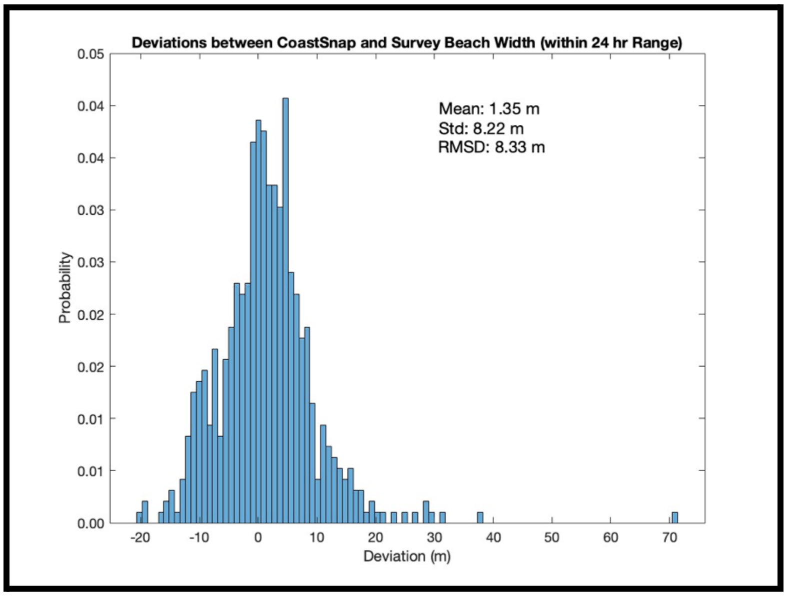


Figure 5: Histogram of the deviations between CoastSnap and Survey beach width measurements in a 24hr range of each other (Mean, Standard Deviation, and RMSD are provided on the plot.)

To further analyze the deviations by MOP/transect number, a box and whisker plot was generated. The distribution of deviations for each MOP provide a visual comparison of the beach width agreement between CoastSnap and MOP data (**Figure 6**). The median deviation was found to be highest for MOP 581 and 582. Further inspection revealed a handful of outlier beach-width measurements derived from CoastSnap, at these MOPs. These outliers were significantly wider than measurements from their neighboring MOP transects at the same time point. This points to the possibility of a misidentification of the shoreline by the image-processing algorithm for a few images.

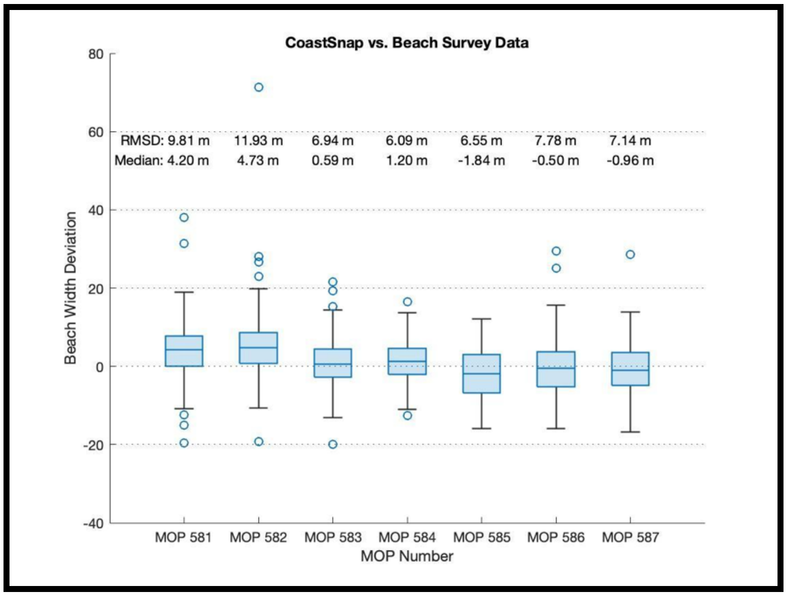
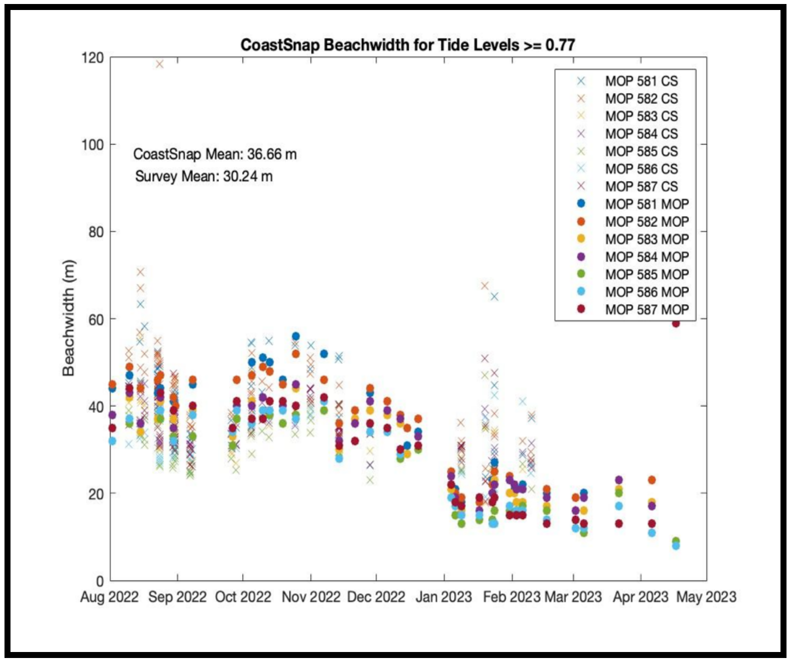
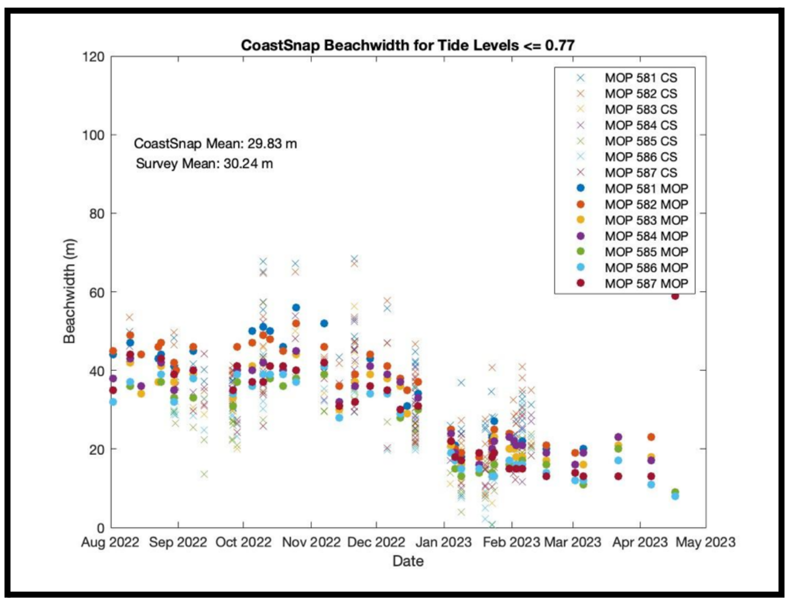


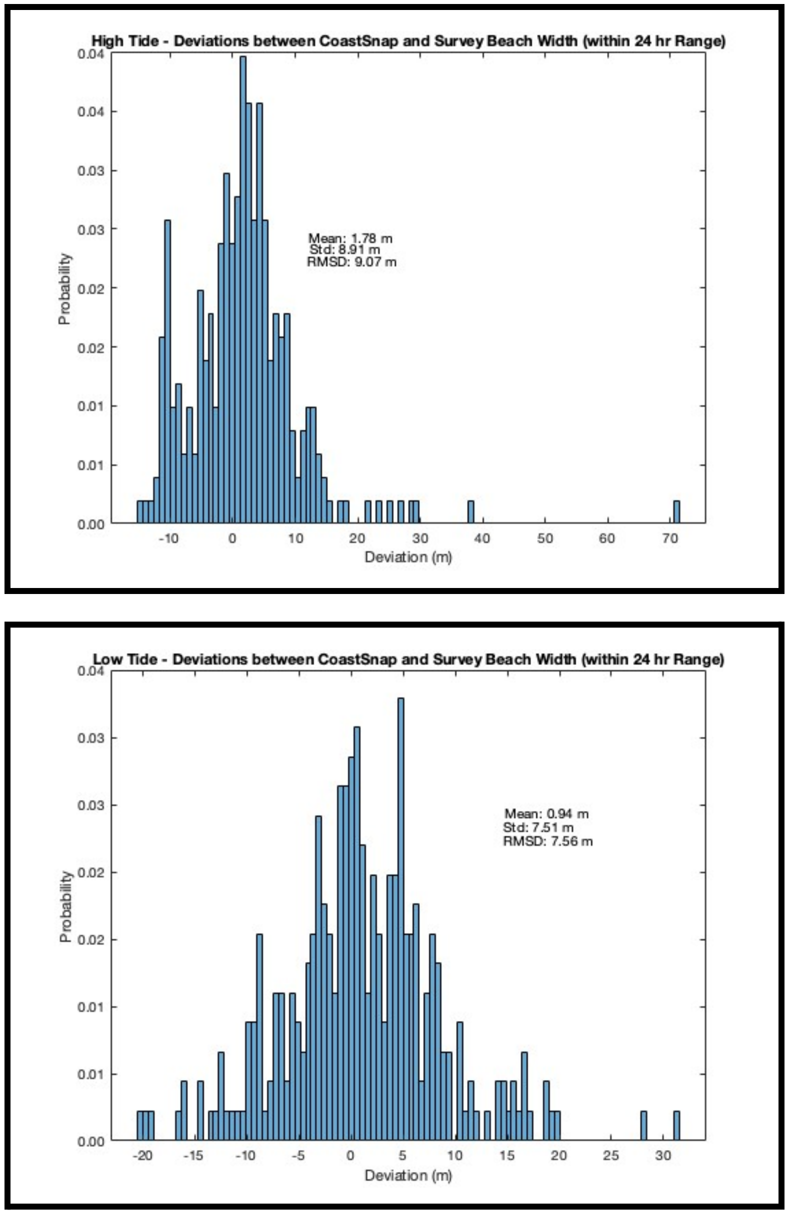
Figure 6: Box and Whiskers plot of deviation between CoastSnap and Survey beach width (within a 24hr range) for each MOP. RMSD is provided for each MOP.

Next, the analysis focused on limiting the data to certain tide ranges (**Figure 6**). Additional box and whisker plots and histograms were created specifically for beach width deviation at low tide levels below mean sea level (MSL = 0.77m) and high tide levels (above or equal to 0.77m) (**Figures 7,8**). An error chart was created to visualize differences in the observed error when indexing the data for each of the five selected tide level datum (**Figure 8**). CoastSnap beach width measurements at higher tide levels were found to have a stronger mean deviation from the survey measurements (mean=1.78 m), in the seaward direction, when compared to lower tides (mean=0.94 m). The phenomenon observed in **Figure 6,** where MOP numbers 581 and 582 were found to have the highest Median deviations, was observed at both high and low tide ranges. Interestingly, the median deviation for these transects was higher for the low tide index, despite the overall mean deviation being lower for measurements taken at lower tides.

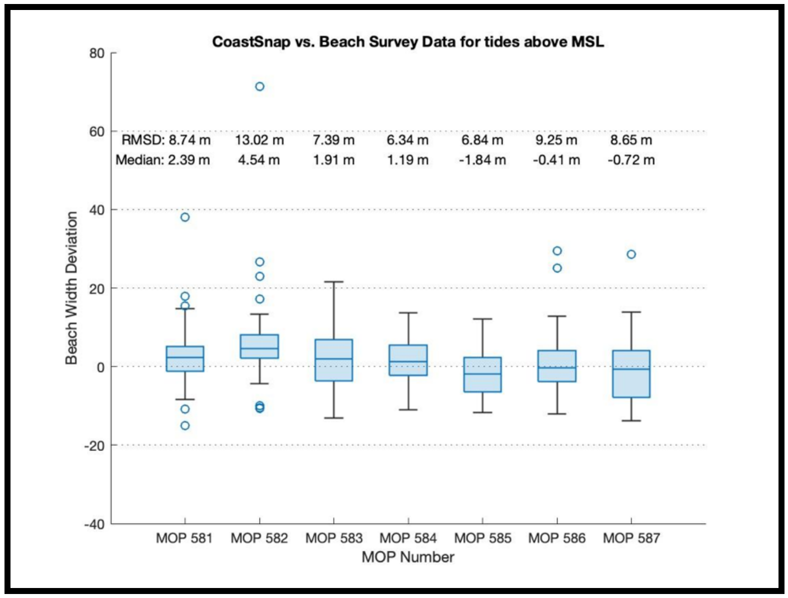




<u>Figure 6:</u> Time series of beach width data from CoastSnap and Beach Survey - within a 24 hr range of each other - for tides (a) above MSL and (b) below MSL



<u>Figure 7:</u> Histogram for CS and survey beach width deviation for each MOP at tides (a) above MSL and (b) below MSL



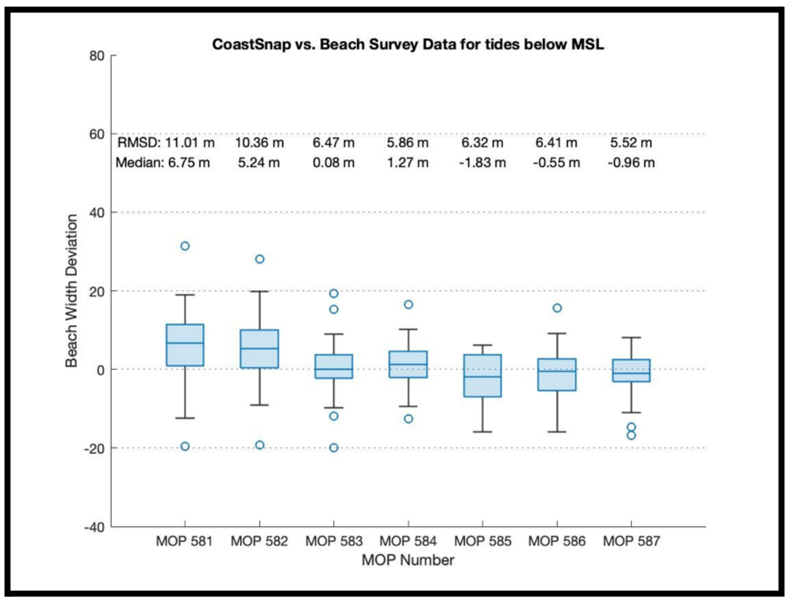
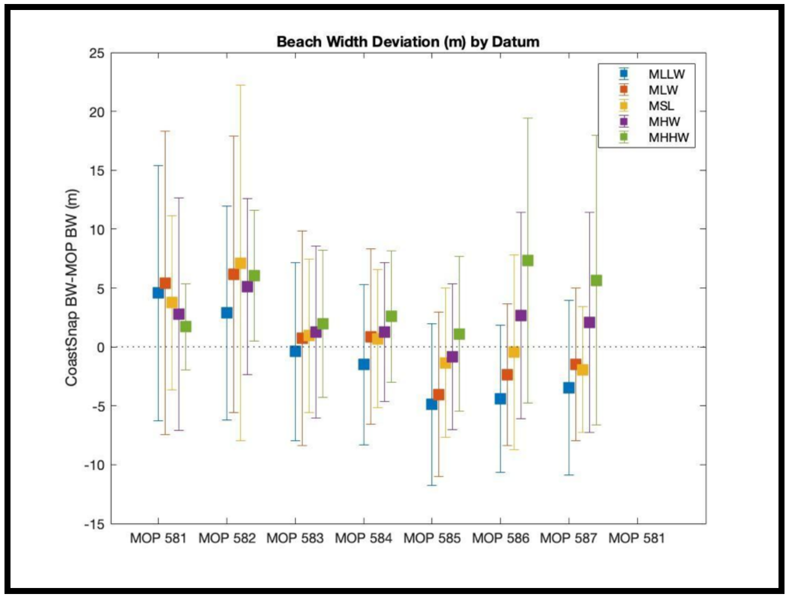
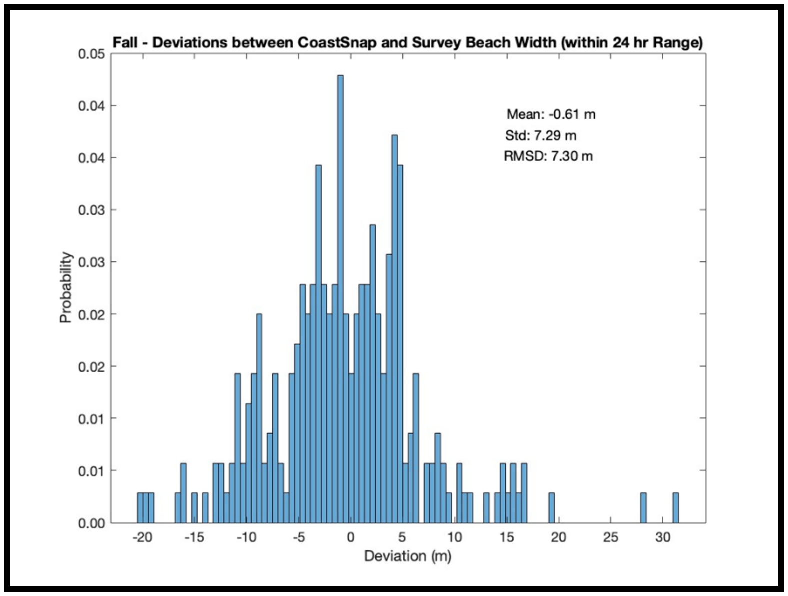


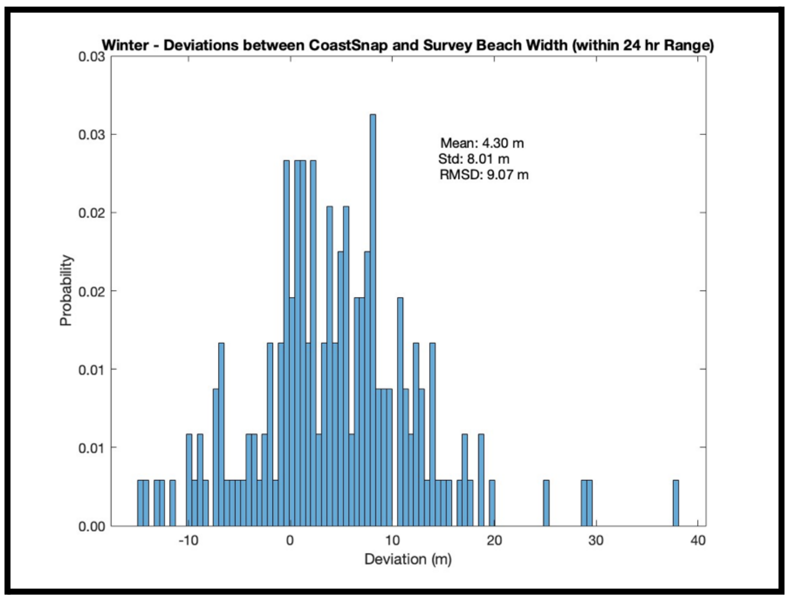
Figure 8: Box and Whiskers plots for CS and survey beach width deviation for each MOP at tides (a) above MSL and (b) below MSL



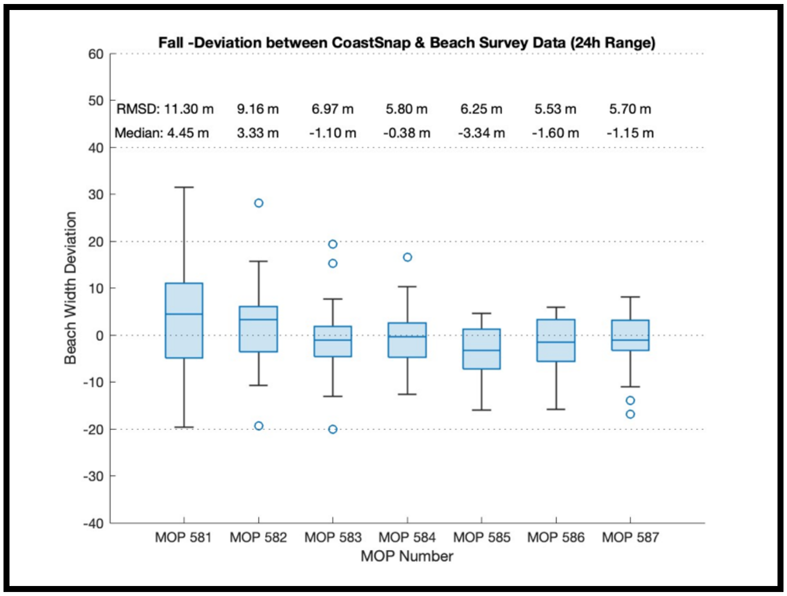
<u>Figure 9:</u> Error plot for CS and survey beach width deviation for each MOP at five different tide datum. The colored squares represent the mean deviation at each tide datum at that MOP, and the vertical lines are the error bars.

Finally, the same analysis was repeated after indexing the data by season (Fall: Sept-Nov and Winter: Dec-Feb) to identify any effects of seasonality on deviation between CoastSnap and in-situ data. Histograms and Box and Whisker plots were generated to visualize this data (**Figure 10, 11).** The mean deviation in the Fall was the only category in this analysis found to have a mean deviation in the landward direction (mean = -0.61 m.) CoastSnap measurements from the winter were found to have the highest mean deviation from survey measurements (mean = 4.30 m,) highlighting that the image-derived beach width measurements tend to be much more seaward than survey measurements, on average, in winter months. Analysis of individual MOPs when indexed by season, showed the same pattern of higher deviation in MOP 581 and 582, with the highest median deviation observed in the winter season, at these transects.





<u>Figure 10:</u> Histogram for CS and survey beach width deviation in (a) Fall and (b) Winter



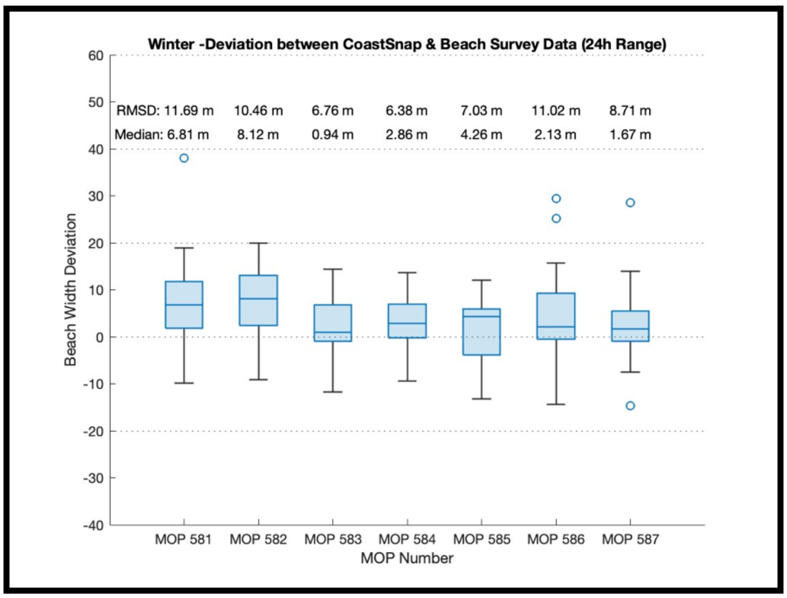


Figure 11: Box and Whiskers plots for CS and survey beach width deviation for each MOP in (a) Fall and (b) Winter

6.2 Site Selection:

The site selection procedure for the CoastSnap stations followed the guidelines provided by the CoastSnap group at UNSW – Sydney. The selection criteria encompassed various factors to ensure the identification of the most suitable locations. These criteria are summarized in the following table (**Table 1**):

Criterion	**Rationale**
Safe To Access	The selected sites should provide safe access for participants to use the CoastSnap stations
Sufficient Foot Traffic	The sites should have a reasonable amount of foot traffic to ensure a consistent flow of participants
Elevation between 5-50m above mean sea level (MSL)	An increased elevation can reduce the distortion encountered when mapping the submitted photos to real-world coordinates, as each pixel will cover a shorter horizontal distance
Close to, and overlooking, the beach	The sites should be situated in close proximity to the beach, offering a clear view of the coastline.
Stable features in the frame of view	Presence of stable features within the frame of view serve as guiding points for digital analysis of submitted photos
Engaged/active community	Preference was given to locations with an engaged and active community, fostering a sense of participation and collaboration
Stable padding or existing handrail	Provides a stable site to set up the CoastSnap phone cradle and signage
Internet access available	Internet is required for photo submission

Scenic view	A scenic view of the coastline is likely to encourage greater public participation
Minimal visual impact	The CoastSnap stations should have minimal visual impact to preserve the natural aesthetics of the surroundings
Not susceptible to erosion	Locations that are not prone to erosion were preferred to ensure the longevity and stability of the CoastSnap stations
Dynamic site (in terms of coastline changes)	A dynamic coastline can provide valuable data to study changes over time.

Table 1: CoastSnap Site Selection Criteria

Through these selection criteria, we aimed to identify sites that would meet the objectives of the CoastSnap program and facilitate effective coastal monitoring and community engagement.

IB Pier and Friendship Park (at Border Field State Park) were selected as potential locations for setting up CoastSnap stations. The City of Imperial Beach specifically expressed interest in setting up a station at Border Field. The ownership and operation of these locations are divided, with the IB Pier being owned and operated by the Port of San Diego, and Friendship Park falling under the management of California State Parks.

To gauge their interest in installing a new station, a project pitch was presented to officials from the Port Authority. Additionally, State Park officials were approached by delivering a public comment during the Tijuana River Advisory Council's quarterly meeting, which had multiple relevant stakeholders in attendance. Both the Port Authority and State Park authorities expressed their interest in installing CoastSnap stations.

Following the positive responses from the Port and State Park authorities, further surveying was conducted to identify specific sites that met all the CoastSnap selection criteria.

6.2.1 IB Pier:

During the site visit to IB Pier, a visual survey was conducted to identify locations along the pier that offered an unobstructed and panoramic view of the coastline. Several spots on the pier were disqualified from consideration due to the presence of existing structures on or near the pier railing, such as lampposts and signage. After identifying multiple potential sites, a smartphone was used to capture images of the coastline from these shortlisted locations. The purpose was to assess the visual quality of images submitted from this station and ensure the presence of fixed structures like houses and lifeguard towers within the field of view, which are useful when deriving coastline data from the images.

Ultimately, two station sites were chosen approximately 60 m offshore on the IB Pier. One station will face the coastline to the north, while the other will face south. The stations, including the metal cradle and accompanying signage, will be mounted on top of the existing pier railing. To provide a better understanding, **Figure 9** illustrates the proposed IB Pier South and North CoastSnap Station mockups, showcasing their respective field of view.

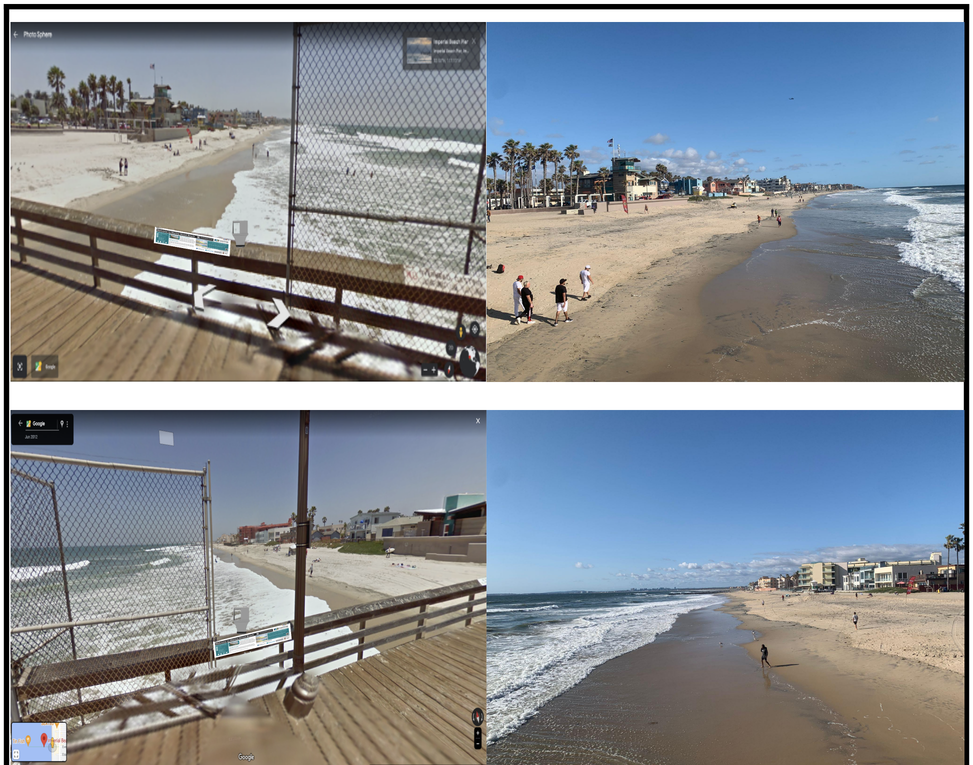


Figure 9: Proposed IB Pier South (top) and North (bottom) CoastSnap Station Mockups and Field of View

The installation of these stations has been delayed because of upcoming construction and renovation work on parts of the pier that include the spots selected for the CoastSnap stations. The final installation will be carried out upon completion of this renovation work, when the selected sites on the pier are accessible again.

6.2.2 Border Field State Park:

Due to flooding the Border Field State Park was inaccessible during the project timeline. Hence, the surveying of this location was carried out virtually using the Google Earth Street View feature. Friendship Park on Monument Mesa, situated adjacent to the USA-Mexico Border fence, was identified as an ideal site within the State Park. It was selected based on its elevated position and extensive coastline view from the northwest corner. The Street View feature was also used to assess the expected field of view from this chosen location.

A single station site was selected within the Friendship Park/Monument Mesa region of Border Field State Park. The designated site is situated at the northwest corner of the park, on an elevated area that provides a panoramic outlook of the coastline. Installation of the station is planned for June/July 2023, once the park becomes accessible again. Initially, the proposed mockup involved mounting the station on the existing adobe wall at the park boundary. However, considering the delicate nature and cultural significance of the adobe wall, State Park officials expressed concerns. As a result, a new mockup was developed, involving the installation of a 4-foot, 4*4 Hardwood Post adjacent to the wall, which would serve as the attachment point for the station. **Figure 10** showcases the final mockup and the field of view for this specific station.

Since there is a lack of distinct fixed structures within the field of view from this station, image calibration will be conducted using GPS surveying. SIO scientists will perform this surveying after October 2023, respecting the restrictions imposed during the breeding season of native bird species and the limited access to the overlooked coastline and its surroundings.

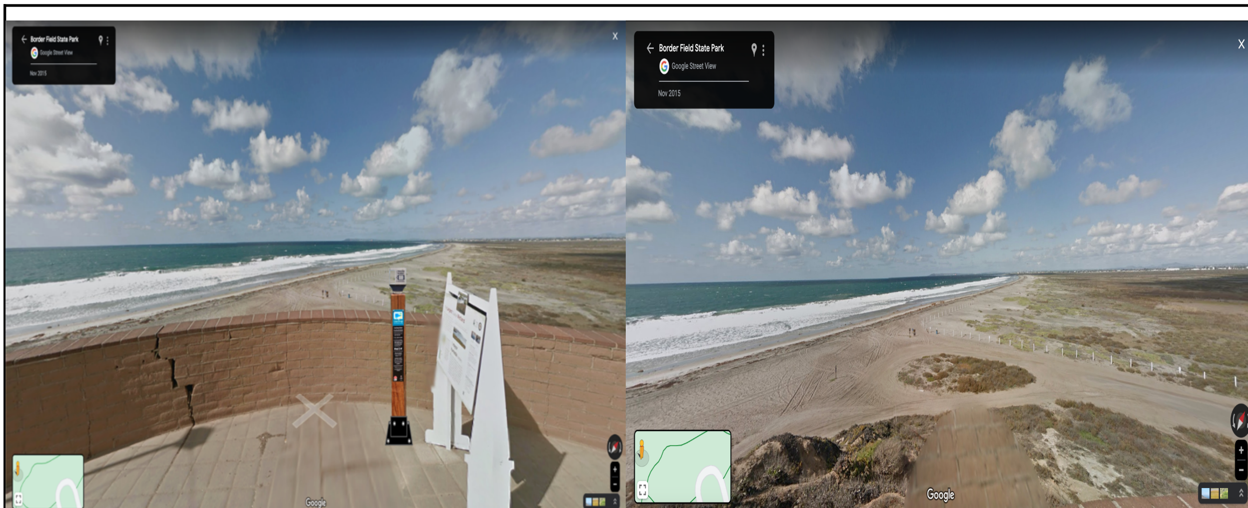


Figure 10: Proposed Border Field State Park CoastSnap Station Mockup and Field of View

6.3 Installation:

After identifying suitable sites, detailed instructions and information on setting up the CoastSnap stations were shared with the relevant local authorities. This comprehensive package included virtual mockups of the proposed stations (**Figures 9 and 10 in the 'Results' section**), precise dimensions of the metal cradles (**Appendix A**), and sample signage featuring instructions and educational content for participants (**Appendix B)**. Due to temporary restrictions accessing the selected sites – due to upcoming renovation work at IB Pier, and flooding at Border Field State Park – we were unable to install the stations in the timeline of this project. Instead, the respective authorities were equipped with all the necessary resources to install these stations at the designated locations in the coming months. Additionally, they have been provided with contact information for points-of-contact at Scripps who are available to offer guidance and support throughout the installation process, ensuring a smooth and successful setup.

7 Discussion:

7.1 Data Analysis

The overall results from our data analysis found a slight seaward deviation of CoastSnap derived beach width measurements, when compared to beach survey measurements taken within a 24-hour range of each other. The mean deviation was calculated to be 1.35 m, with a standard deviation of 8.91 m. The high standard deviation is possibly influenced by outlier measurements included in the dataset, that were largely observed in CoastSnap-derived beach width measurements from transect MOPs 581 and 582 – i.e., the transects closest to the CoastSnap station. A possible explanation for this encountered error is that the closest MOPs offer a more overhead view in the submitted images, resulting in a wider gradient of wet-sand colors being captured in the photo. Because the CoastSnap technology relies on the color difference between wet and dry sand to determine the shoreline location, a gradient of colors may cause an incorrect location to be selected as the shoreline. Transect locations that are further away from the CoastSnap station can be seen in a more oblique view in the submitted images, which is why a sharper delineation between the wet and dry sand is seen the image, resulting in a more accurate identification of the shoreline. This phenomenon is demonstrated in the following **Figure 11,** which shows an example shoreline from our dataset that has been misidentified by the CoastSnap MATLAB toolbox.

Figure 11: A shoreline from January 2023 mapped using the CoastSnap MATLAB Toolbox. A portion of the mapped shoreline (red line) closest to the camera is deviated in the seaward direction due to a misattribution of the edge of white water as the shoreline.

The next steps in our analysis involved indexing our data by tide level and season. High tide events were found to result in a slight increase in the mean deviation between the CoastSnap and survey measurements (mean = 1.78 m), while low tide events resulted in a decrease in deviation (mean = 0.94). The mean deviation in the Fall was the only category in this analysis found to have a mean deviation in the landward direction (mean = -0.61 m), which CoastSnap measurements from the winter were found to have the highest mean deviation from survey measurements, with a mean deviation of 4.30 m. The increased mean deviation seen for high tide events and the winter is likely due to the drastic changes in beach morphology that occur at Torrey Pines (and many other Southern Californian Beaches) in the winter. As strong winter waves and high tide events erode sand off the beach the beach becomes much narrower and rockier in the winter months. The rockier beach has an overall darker color, and thus the contrast between wet and dry sand reduces greatly during these months. Inspection of the CoastSnap toolbox-identified shorelines for datapoints with the highest deviation found that the toolbox occasionally considered the edge of the whitewater as the shoreline, when it could not identify a clear delineation between wet and dry sand. An example of this misidentification is also seen in **Figure 11.**

Overall, however, the mean deviation between CoastSnap-derived and survey-derived values (1.35 m) is a 4.4% deviation from the mean beach width at Torrey Pines (30.24 m.) This suggests that CoastSnap-derived data offers a reasonable degree of reliability as a tool to study coastlines in Southern California. Additionally, the error in shoreline identification in winter is a subject of ongoing work by Coastal Processes Group at SIO, and a rectification of this error will only further increase the reliability of CoastSnap derived data. Knowing this, it is safe to say that CoastSnap presents great promise as a cheap and efficient tool to monitor vulnerable coastlines in Southern California.

7.2 CoastSnap Installation

Working to installing new CoastSnap stations in San Diego offered several important lessons that can inform future projects that aim to install stations in Southern California. Contrary to our initial expectations, a project timeline of three months proved to be an insufficient duration to see through the complete installation of the proposed stations. While a major factor for this delay can be attributed to bad luck – upcoming renovation work at the IB pier and unexpected flooding at Border Field State Park – there were several backend processes that extended the time taken at various steps of the process. Our initial contact was with IB City Officials, who informed us of where a CoastSnap station would serve the community best. However, when suitable locations for these stations were identified, it turned out that these properties were not operated by the city itself, but by other local authorities (i.e., the Port of San Diego operates the IB Pier and California State Parks and Tijuana River National Estuarine Research Reserve oversees the Border Field State Park). The process of meeting with the appropriate officials from these organizations, discussing the station installation logistics, and acquiring the required permits and approvals took a considerable amount of time. An important consideration in our meetings with these authorities was finding an installation method that would not harm the existing infrastructure at these locations. Several station layout mockups and installation strategies – e.g., securing the station on existing walls with drills or epoxy, mounting the station on a freestanding wooden post, etc. – would have to be deliberated before arriving on a strategy that met the requirements of the local authorities.

All in all, however, there was an overwhelmingly positive response from the city officials and local authorities to the proposal to install CoastSnap stations in their community. Some of the involved parties were already aware of this technology, while others were introduced to the CoastSnap program by our team. There was an overall sense of enthusiasm for the benefits these stations offered their community both through the monitoring of their vulnerable coastlines, and also through the engagement and education of community members on the important issue of sea level rise.

8 List of Abbreviations:

Abbreviation	Name
CDIP	Coastal Data Information Program
D	Deviation
ESL	Extreme Sea Level
IB	Imperial Beach
MHHW	Mean Higher High Water
MHW	Mean High Water
MLW	Mean Low Water
MLLW	Mean Lower Low Water

MOP	Monitoring and Prediction
MSL	Mean Sea Level
NOAA	National Oceanic and Atmospheric Administration
RMSD	Root Mean Square Deviation
SIO	Scripps Institution of Oceanography
SLR	Sea Level Rise

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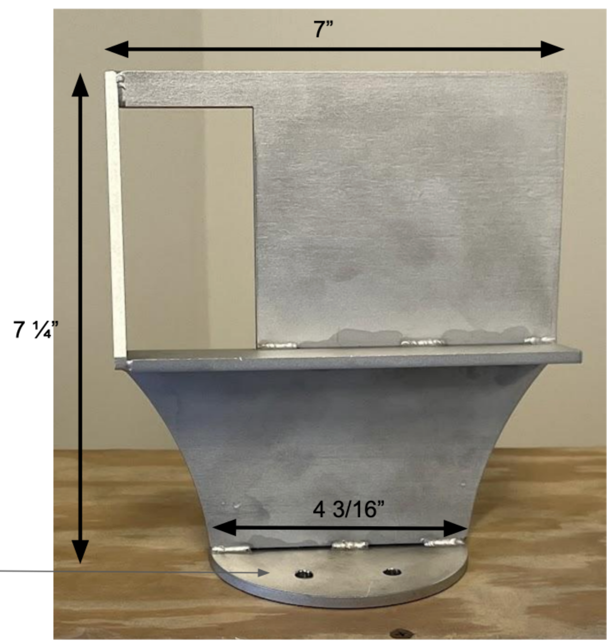
10 Appendix

A:

Cradle:
Electro-polished ⅛" stainless steel
4 3/16" diameter circular base
7 ¼" height
7" width

¼" screw holes, 4 total.



B (1, 2):

Welcome to Marine Street Beach

#CoastSnapMarineStreet
Scan the QR code to see the latest snaps

CoastSnap
community beach monitoring

How to get involved:

1. Place your phone on its side in the cradle
2. Take a photo (no zoom)
3. Share by using the free CoastSnap App at **coastsnap.com** and select "UPDATE SPOT" or
   - Post to social media using **#CoastSnapMarineStreet**

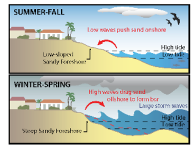
What is CoastSnap?

CoastSnap is a global citizen science network that harnesses your snaps to capture changing coastlines. Our beaches are constantly evolving; by contributing a photo you will help record short and long-term beach erosion and recovery. Over time CoastSnap will help us better understand beach processes and contributing factors.

How does it work?

The images are analyzed using markers along the beach to precisely measure the shoreline location on any given day. These photos can be compiled to produce time-lapse videos that capture shoreline position and beach width as it evolves through time.

Share your snap and see how our beaches change over time.



For more information, visit: **www.coastsnap.com**

Help us record our changing coastline

Our coast is always changing. At Marine Street, powerful winter waves can move sand offshore, exposing bedrock. The sand typically returns during calmer conditions in the summer. Increasing sea levels may change these dynamics.

Your photos help us to understand and manage coastal environments for future generations.

Scan to learn more about beach science at **siocpg.ucsd.edu**

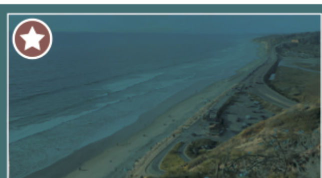
SCRIPPS INSTITUTION OF OCEANOGRAPHY | SOUTHERN CALIFORNIA COASTAL OCEAN OBSERVING SYSTEM | human good | UNSW SYDNEY

Welcome to Torrey Pines State Beach

Help us record our changing coastline

How to get involved:

1. Place your phone on its side in the cradle
2. Take a photo (no zoom)
3. Share by using the free CoastSnap App at **coastsnap.com** and select "UPDATE SPOT" or
   - Post to social media using **#CoastSnapTorreyPines**



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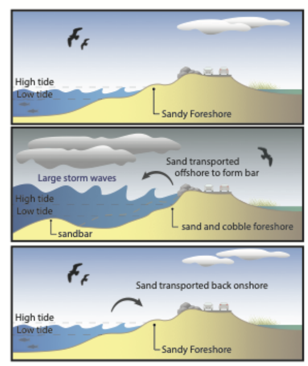
Share your snap and see how our beaches change over time.

To learn more about beach science at Torrey Pines, visit **siocpg.ucsd.edu**

Our dynamic coastline

Our coast is always changing. At Torrey Pines, powerful winter waves move sand offshore, exposing cobbles. The sand typically returns during calmer conditions (summer). Increasing sea levels may change these dynamics. Your photos help us to understand and manage coastal environments for future generations.



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