Automated Extraction of Shoreline in Tuban Regency, East Java from Google Earth Imagery by Integrating Canny Edge Detector

Luhur Moekti Prayogo[1], Sarono[2]

[1]Marine Science Study Program, Faculty of Fisheries and Marine, Universitas PGRI Ronggolawe, Tuban, 62381, Indonesia
[2] PT. Techno GIS Indonesia, Sleman, Yogyakarta, 55283, Indonesia
*E-mail: luhur.moekti.prayogo@unirow.ac.id

Abstract. *The shoreline is an area that becomes the boundary between land and sea and experiences morphological changes over time. This region has a dynamic condition where various components (air, rocks, water) are interconnected. Multitemporal shoreline analysis is one of the critical parameters for monitoring coastal areas. This information can be used for morphodynamic modeling, coastal area management, and erosion and accretion studies. This study aims to analyze shoreline changes in the North Coast of Tuban Regency, East Java using the Canny Algorithm and Google Earth Imagery from 2000 to 2020. The Canny algorithm was chosen because it has been tested to produce sharp and good edges compared to other edge detection algorithms. From this research, it can be concluded that in the north coast of Tuban Regency, based on the sample years taken, the area's shoreline experienced the erosion of 0.297 - 1.566 meters/ five years. The edges generated using the Canny algorithm are practical in interpreting shorelines and making analysis faster. In the future, there is a need for more elaboration regarding the use of Google Earth imagery in shoreline analysis, especially in geometric corrections (Georeference). This elaboration is essential because it will affect the analysis results, especially the shoreline position.*

Keywords: Shoreline, Edge Detection Technique, Canny Algorithm, Google Earth, Tuban

Abstrak. Garis pantai merupakan wilayah yang menjadi pembatas antara daratan dengan lautan serta mengalami perubahan morfologi dari waktu ke waktu. Wilayah ini memiliki kondisi yang sangat dinamis dimana berbagai komponen (udara, bebatuan, air) saling berhubungan. Analisis garis pantai multitemporal menjadi salah satu parameter penting untuk monitoring kawasan pantai. Informasi tersebut dapat digunakan untuk pemodelan morfodinamik, pengelolaan kawasan pesisir dan studi erosi dan akresi. Penelitian ini bertujuan untuk menganalisis perubahan garis pantai di Pesisir Utara Kabupaten Tuban, Jawa Timur menggunakan Algoritma Canny dan Citra Google Earth tahun 2000 hingga 2020. Algoritma Canny dipilih karena sudah teruji menghasilkan tepi yang tajam dan baik dibandingkan dengan algoritma deteksi tepi yang lain. Dari penelitian ini dapat disimpulkan bahwa di Pesisir Utara Kabupaten Tuban, berdasarkan sampel tahun yang diambil, garis pantai wilayah tersebut mengalami erosi sebesar 0,297 - 1,566 meter/ lima tahun. Tepi yang dihasilkan dengan algoritma Canny sangat membantu dalam proses interpretasi garis pantai dan membuat analisis menjadi lebih cepat. Kedepannya, perlu adanya elaborasi lebih mendalam mengenai penggunaan citra Google Earth dalam analisis garis pantai, khususnya pada koreksi geometriknya *(Georeference)*. Hal ini penting untuk dilakukan karena akan mempengaruhi hasil analisis terutama posisi garis pantainya.

Kata kunci: Garis Pantai, Teknik Deteksi Tepi, Algoritma Canny, Google Earth, Tuban

Introduction

Tuban Regency is one of East Java districts from all 38 districts and cities in the province (Tuban Regency Government, 2018). Tuban Regency is located on the northern coast of Java Island with a shoreline of about 65 km with an area of 1,904.70 km² (Tuban Regency Government, 2018). In some of its areas, Tuban Regency is located in a coastal environment that makes these communities rely on the sea's produce by becoming fishermen. The coast becomes one of the areas of human activity that can be used for various fishing activities and

settlements (Driptufany, 2020). The utilization will reduce land in the coastal area, and the land is carrying capacity, which causes erosion and sedimentation (Driptufany, 2020).

The shoreline becomes the barrier between the land and the ocean, which changes in morphology from time to time, which can be influenced by the sea level rise (Utami et al., 2017). This region has a very dynamic condition where air, rocks, and water are interconnected (Kasim, 2012). The coastal dynamics process is closely related to the coastal areas' management (Kasim, 2012). Alesheikh et al. (2007); Kasim (2012) argues that multitemporal shoreline analysis is one of the critical parameters for monitoring coastal areas. This information can be used for morphodynamic modeling, coastal area management, and erosion and accretion studies (Chand & Acharya, 2010; Kasim, 2012).

Fuad et al. (2019); Suniada (2015) states that remote sensing techniques can analyze shoreline change. Along with the development of technology, one of the methods for shoreline extraction is to use edge detection techniques. Edge detection is the image processing stage to produce each object's edges in the image (Munir, 2019). The image's edge can be seen from the neighboring points' grey points (x and y). The benefits of edge detection can also reduce the amount of data processed and can be used for change detection on the shoreline (Munir, 2019). In remote sensing, distinguishing the two objects is necessary because the image classification process will not be optimal if only using color characteristics.

Previous researchers have researched shorelines. Mulyadi et al. (2022) conducted a study of shoreline changes in the city of Dumai for three decades (30 years) using Landsat imagery and the Digital Shoreline Analysis System (DSAS). This research shows that there is an average accretion and abrasion of 1.17 and 2.04 meters at the research location. Setyawan (2021) conducted research in Kuala Pesisir District, Nagan Raya Regency, Aceh using the Digital Shoreline Analysis System (DSAS) and Thresholding method in 2016-2020. This research shows changes in the shoreline by accretion and abrasion of 30.16 and 34.49 m/year.

Primasti et al. (2021) conducted a study to identify coastal vulnerability in Demak Regency using the Coastal Vulnerability Index (CVI) and the United States Geological Surveys (USGS) methods with five categories of coastal vulnerability. This research shows that the shoreline of the Demak Regency has a tendency to Erosion compared to Abrasion. Fuad (2021) conducted a study of shoreline changes on the coast of Situbondo Regency, East Java, using the one-line model method. The study results indicate that accretion and Abrasion occur in several research locations. Maulana et al. (2021) Conducted research on predicting shoreline changes in Bengkulu using the GENESIS (Generalized Model for Simulating Shoreline Change) method. The results showed that during the five years, the shoreline changes at the research site occurred 2.823 m of Abrasion and 1.677 m of sedimentation.

Adriat et al. (2021) Conducted shoreline research in Kijing Coastal Waters, Bengkayang Regency, West Kalimantan using the Single Transect (ST) and End Point Rate (EPR) methods on the DSAS tool. These studies indicate that at the study site, the dominant accretion occurred ranging from 0.5 to 21.34 m. Atmojo et al. (2021) Conducting shoreline research using remote sensing techniques and data such as Landsat imagery with Unsupervised Classification, digitization, and overlapping methods.

The research location shows that there is abrasion and accretion at the research location. Research on shorelines was carried out by Ramadhani et al. (2021) in the Coastal District of Saying, Demak Regency using remote sensing methods and the Digital Shoreline Analysis System (DSAS). The results showed a change in shoreline abrasion and accretion by 82% and 18%, with a tendency to abrasion.

From the explanation above, a problem of how edge detection performs detecting shorelines in Google Earth imagery arises. Identifying the object's edge is vital because it is a preliminary study to observe changes in the shoreline more quickly. Therefore, this study aims to analyze changes in the shoreline in the North Coast of Tuban Regency, East Java using the *Canny* Algorithm. We have conducted a canny edge detector in Gili Raja Island, Sumenep (Prayogo & Hidayah, 2021). This algorithm was chosen because it has been tested to produce sharp and good edges compared to other edge detection algorithms (Maini & Aggarwal, 2009).

Material And Method

Research Location

This research is located at 6° 53'27.51 "S and 112° 3'38.10" E in the North of Tuban Regency, East Java. After all, this location is suspected of experiencing abrasion yearly because it is located directly opposite the open sea. The shoreline observed in this study is approximately 650 meters long. Figure 1 shows the research location displayed on the Basemap World imagery.
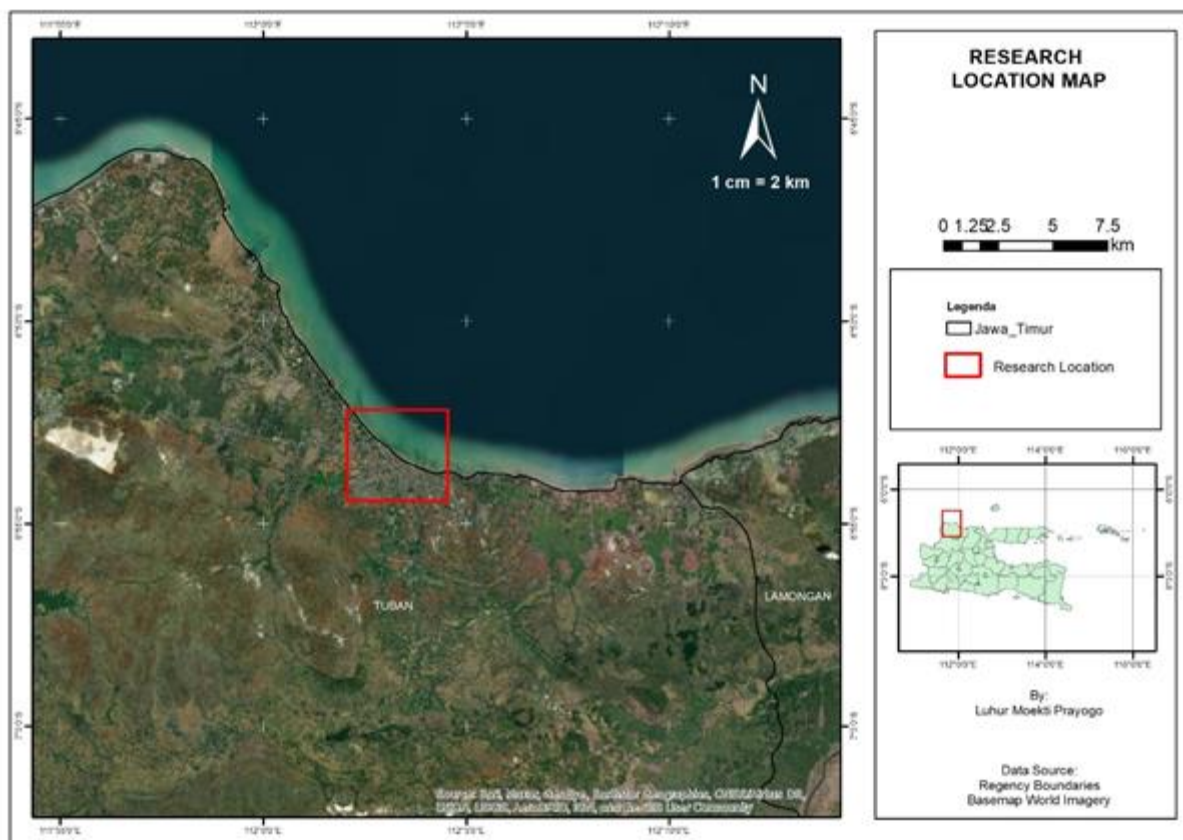

Figure 1. Research Location in Tuban Regency, East Java

Canny Algorithm

Canny edge detection is a technique for extracting structural information that aims to reduce processed data. Based on *Canny* (1986); Deriche (1987) states that this process consists of at least five stages, namely: Applying a Gaussian filter so that the image becomes smoother and minimizes noise with the following equation (Gaussian filter $(2k + 1) \times (2k + 1)$)) (equation 1):

$$H_{ij} = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{(i - (k+1))^2 + (j - (k+1))^2}{2\sigma^2}\right); 1 \leq i, j \leq (2k + 1) \dots\dots\dots..(1)$$

Then determine the image intensity gradient with the following equation (equation 2)

$$G = \sqrt{G_x^2 + G_y^2} \dots\dots\dots\dots..(2)$$

The edge direction angles represent vertical, horizontal, and two diagonals ($0°$, $45°$, $90°$, and $135°$). Then it can apply steps such as (1) applying non-maximum compressions to eliminate spurious responses to edge detection, (2) specifying a double threshold for determining potential image edges, and (3) Track edges with hysteresis: suppressing all other weak edges and not connected to the firm edge (*Canny*, 1986; Deriche, 1987).

Result and Discussion

Image Preprocessing

Before the image is filtered, the first thing to do is create a Ground Control Point (GCP) in Google Earth. GCP aims to adjust the coordinates on the map with coordinates in the field (Danoedoro, 2012). There are four GCPs used for georeferencing on five Google Earth maps. Tables 1 and 2 are information on the recording date of images and GCP used in this study.

Table 1. Google Earth imagery 2000-2020

No	Recording Date	Cloud Cover Condition
1	July 11, 2000	Minimum
2	July 28, 2003	Minimum
3	August 16, 2010	Minimum
4	July 8, 2016	Minimum
5	September 6, 2020	Minimum

Table 2. GCP Information

| No	Latitude	Longitude
1	6°52'54.43"S	112° 3'22.49"E
2	6°52'54.71"S	112° 4'53.18"E
3	6°53'55.11"S	112° 3'27.80"E
4	6°53'55.19"S	112° 4'48.98"E

Image Processing

Image edge processing using the *Canny* algorithm is carried out at least in several steps (Chapter 2). This step is carried out to obtain structural information for each observed object, namely the shoreline in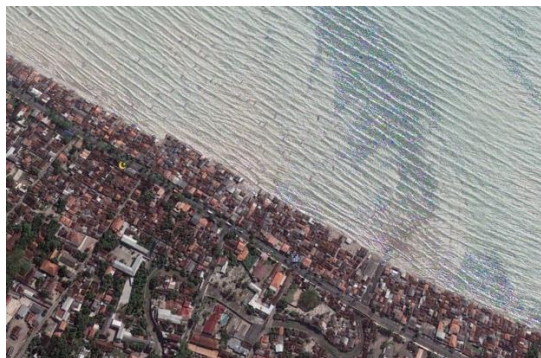 Google Earth imagery, from 2000 to 2020. This detection has a strict definition compared to other edge detections, so that the results of *Canny* detection are better than other edge detection. Figure 2 shows the Google Earth multitemporal imagery data from 2000 to 2020 used in this study.
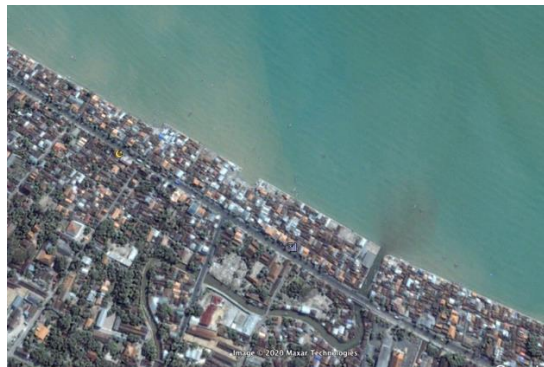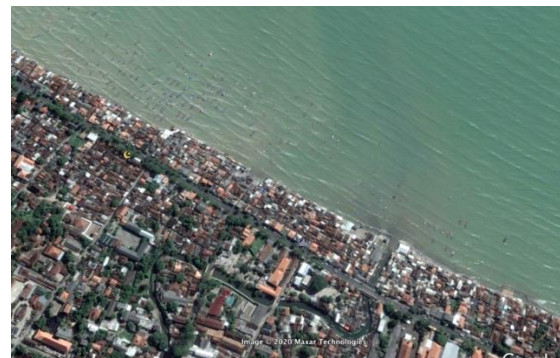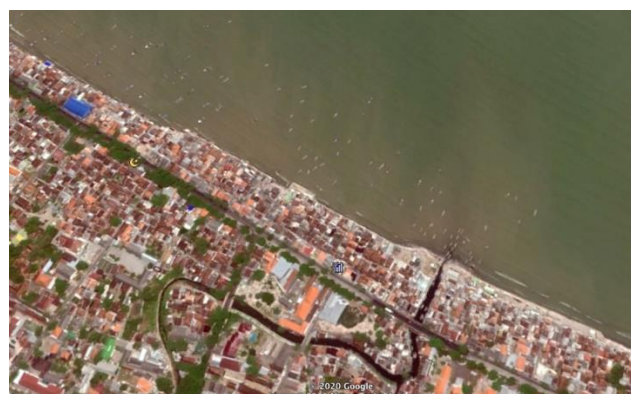

July 11, 2000
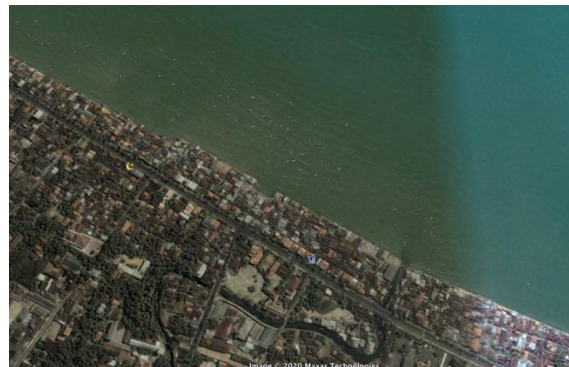
July 28, 2003

August 16, 2010

July 8, 2016

September 6, 2020

Figure 2. Google Earth Multitemporal Imagery from 2000 to 2020

The *Canny* algorithm has general criteria for detecting object edges. The operator's detected edge must be accurately localized in the center with marked once in each object. The detection must capture as many edges as possible to produce a suitable edge with minimal errors. According to

requirements, the technique used in *Canny* detection to obtain edge information uses the calculus of variations function. The first derivative of Gaussian can explain this function. Figure 3 shows the results of *Canny* edge detection for shoreline analysis in the Tuban Regency, East Java.

2000

2003

2010

2016
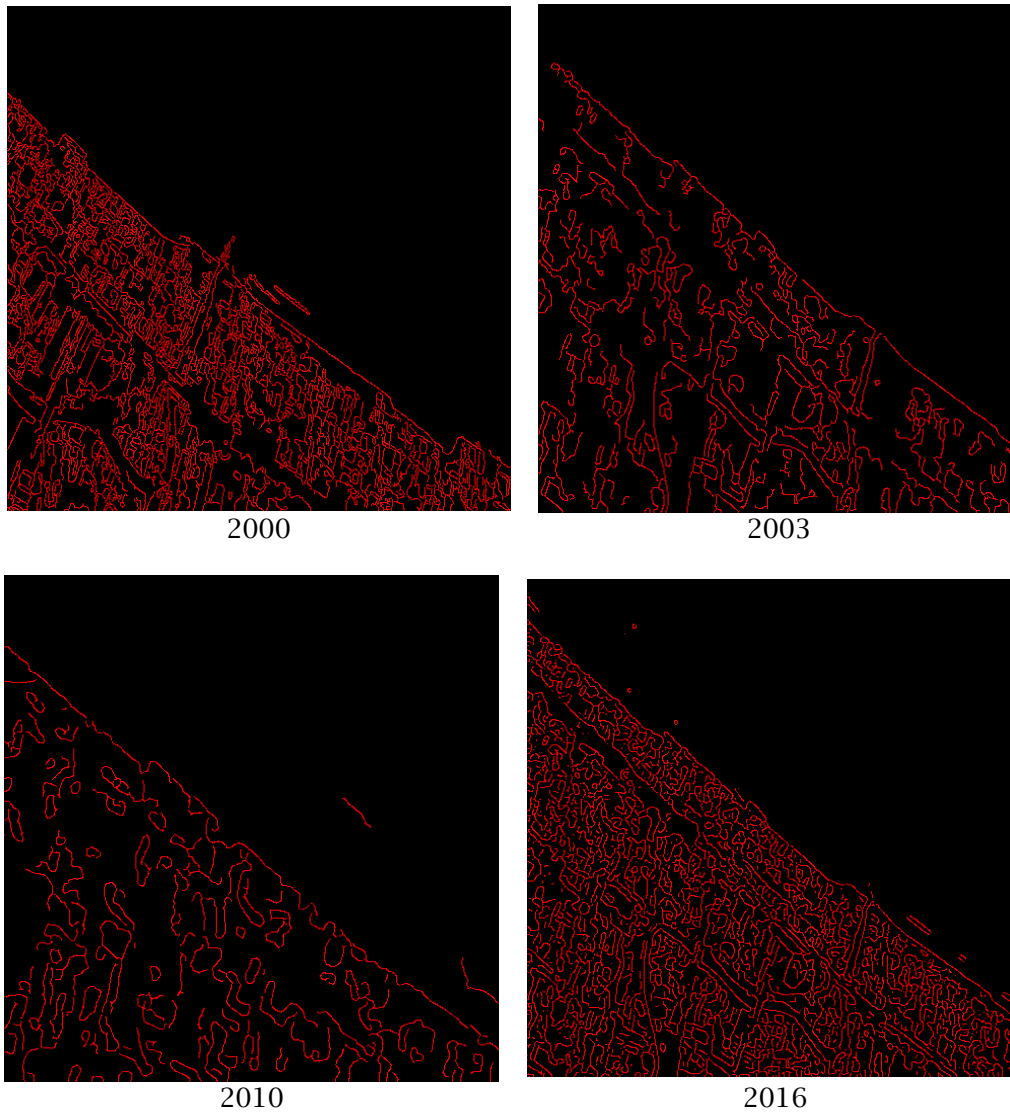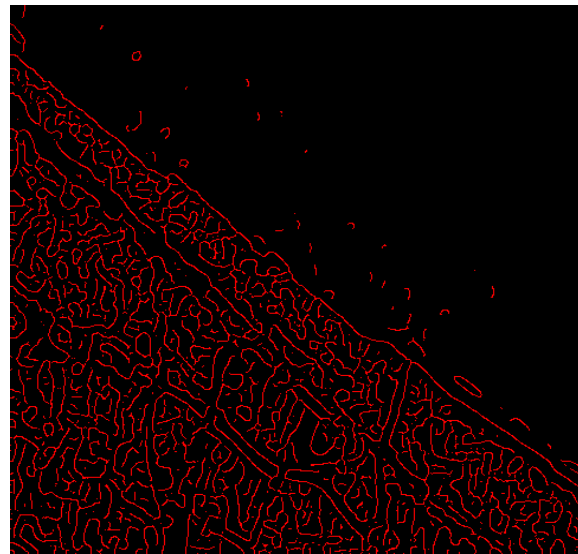
2020

Figure 3. *Canny Algorithm* Results from 2000 to 2020 in the Tuban Regency, East Java

The Gaussian filter on the image minimizes noise so that the object's edges are easily detected. The image's noise significantly affects the shoreline's extraction, so smoothing is needed at this stage. Besides, this filter uses a kernel window that is not static and can be changed according to each object's needs being filtered.

The next step is to thin the edges of the image. This process is carried out to determine the change's location in the highest / sharpest intensity value to produce a more authentic and accurate image edge. The final process of shoreline detection with *Canny* is edge tracking with hysteresis. This stage aims to trace the edges of the weak pixels caused by the unconnected image's noise response. From the detection process, the following is the appearance of the shoreline in 2000, 2003, 2010, 2016, and 2020 in the North Coast of Tuban Regency, East Java (Figures 4).

Figure 4. Shoreline 2000, 2003, 2010, 2016 and 2020

From the picture, we can see that the shoreline has shifted every year in the image sample due to erosion. In the first location, in 2000-2003, there was a shift of 1,148 m, in 2003-2010 it shifted of 1,439 m, in 2010-2016 it shifted of 1,022 m, and 2016-2020 experienced a shift of 0.796 m. Then in the second location, in 2000-2003, there was a shift of 0.861 m, in 2003-2010 it shifted of 1.051 m, in 2010-2016 it shifted of 0.667 m, and 2016-2020 experienced a shift of 0.313 m. Finally, in the third location, in 2000-2003, there was a shift of 0.974 m, in 2003-2010 it shifted by 1.566 m, in 2010-2016 it shifted 0.297 m, and 2016-2020 experienced a shift of 1.157 m. Table 3 shows the shoreline shift information for each sample of the study locations.

Table 3. Shoreline change for each location

Time	Shift Locations 1 (meters)	Shift Locations 2 (meters)	Shift Locations 3 (meters)
2000-2003	1,148	0,861	0,974
2003-2010	1,439	1,051	1,566
2010-2016	1,022	0,667	0,297
2016-2020	0,796	0,313	1,157

Conclusion

From this research, it can be concluded that in Pesisir Utara, Tuban Regency, based on the sample years taken, the area's shoreline experienced the erosion of 0.297 - 1.566 meters / five years. The edges generated using the Canny algorithm are very helpful in interpreting shorelines and making analysis faster. In the future, there is a need for more elaboration regarding the use of Google Earth imagery in

shoreline analysis, especially in geometric corrections. This elaboration is essential because it will affect the analysis results, especially the shoreline position.

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