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Mapping of erosional changes in South Coast, Iceland

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Abstract:

The exposure of the South Coast of Iceland to storms and strong North Atlantic waves makes it one of the most erosion-exposed coastlines in the world. The study area, stretching from Torlakshofn to Hofn i Hornafirdi, is characterized by glacial rivers that continuously transport large volumes of sediment to the ocean. The area lies near rich fishing grounds, and there are several towns and part of the main road that are located close to the coast. Therefore, it is important to understand the dimensions and time frame of the processes influencing the erosion along the South Coast.

The work is based on several studies. In the book J. W. Kamphuis's "Introduction to Coastal Engineering," basic shore processes, wave generation, and transformations are explained. Kamphuis's (1991) expression on alongshore sediment transport rate that includes the influence of several beach and wave parameters was used in the calculations of sediment transport. This equation will be discussed further in the next chapter.

The final report of DHI and the Icelandic Maritime Association (2013) was dedicated to the revision of the sediment balance at Landeyjahofn. The calculations were performed by the LITDRIFT model, whose input data included coastal profiles, grain size distribution (both normal and along the shoreline), nearshore wave characteristics, and other model parameters. The results of the calculations are presented, and the major causes of sedimentation at the harbor were discussed. The distribution of sediments along the coast depending on the angle of wave incidence was also described.

A similar study on coastal changes in southeastern Iceland during the period 1903-2021 was conducted by Ingibjorg Jonsdottir and Sigurdur Sigurdarson in 2023. The findings were presented in a map showing tendencies of each part of the coast: stability, erosion, or sediment accumulation. It was, therefore, observed that accretion of the coastline in several places is connected with the material that was discharged by glacial lakes and rivers and subsequently carried along the shore by tidal currents. Erosion also occurred in Hofn i Hornafirdi and Reynisfjara.

In order to better understand the drivers of coastal change and identify the most dynamic areas, in this work, the alongshore sediment transport capacity was calculated using a Python-based implementation of the Kamphuis equation of alongshore sediment transport rate:

$$Qs = 2.27 H_{sb}^{2} T_{p}^{1.5} m_{b}^{0.75} D^{-0.25} \sin^{0.6} 2\alpha_{b}$$

where

H_{sb} = significant breaking wave height

T_p = peak wave period

m_b = beach slope in the breaking zone

D = median grain size (0.25 mm)

α_b = angle of wave incidence at breaking

The calculations are based on hindcast wave data from 2000 to 2022 provided by the Icelandic Road and Coastal Administration, combined with coastal slope and orientation derived from bathymetric profiles.

These modeled sediment transport capacities were then compared to observed shoreline changes, which were mapped using digitized coastlines extracted from aerial photographs. The shoreline was digitized manually in a GIS environment at a scale of 1:10,000, based on the visible land–water boundary in each image. Each line in the GIS dataset is attributed with metadata indicating its acquisition year. Coastline detection was complicated by tidal variations, which may obscure clear boundaries, but in more recent years, the time of the imagery was known, which allowed linking the shoreline position to tidal stages.

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Tidal variation along the South Coast of Iceland ranges between 1.5 and 2.3 meters, while the coastal slope in the study area varies from 0.009 to 0.042, with the average slope being approximately 0.0169. Therefore, the horizontal position of the shoreline could shift by approximately 89 to 136 meters. The result is a line dataset of lines corresponding to each year, which made it possible to observe trends in coastal changes.

The coastal changes were mapped using the line dataset. The classification of each coastal segment as accretion, little change, varied conditions or erosion was based on the net change in the shoreline position between 2000 and 2022. Segments with a shoreline retreat greater than 50 meters were categorized as erosion, while those with an advance greater than 50 meters were classified as accretion. Segments showing no clear directional trend and only minor (between -25 m and +25 m) fluctuations were labeled as little change. Greater changes (out of the range of -25 m and +25 m) were marked as varied conditions.

Figure 1. The map of changes in South Coast © Aleksandra Kallaur 2024

While the calculated sediment transport capacity generally aligns well with the observed coastal changes along most part of the coastline, the easternmost part appears to be an exception, as the actual changes indicate greater erosion than expected according to the calculations. The observed erosion is likely driven by intensified inland erosional activity, particularly due to the presence of glacial lagoons, which increase sediment delivery and local erosion independently of alongshore transport.

This method to calculate sediment transport capacity can contribute to a more comprehensive analysis of erosion versus deposition on coastlines.

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