Western Lefkada Shoreline Displacement Rates Based on Photogrammetric Processing of Remote Sensing Datasets from Various Sources

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Roufi Amalia, Vassilakis Emmanuel, Poulos Serafeim

Dpt of Geography & Climatology, Faculty of Geology and Geo-environment, National and Kapodistrian University of Athens, Greece |

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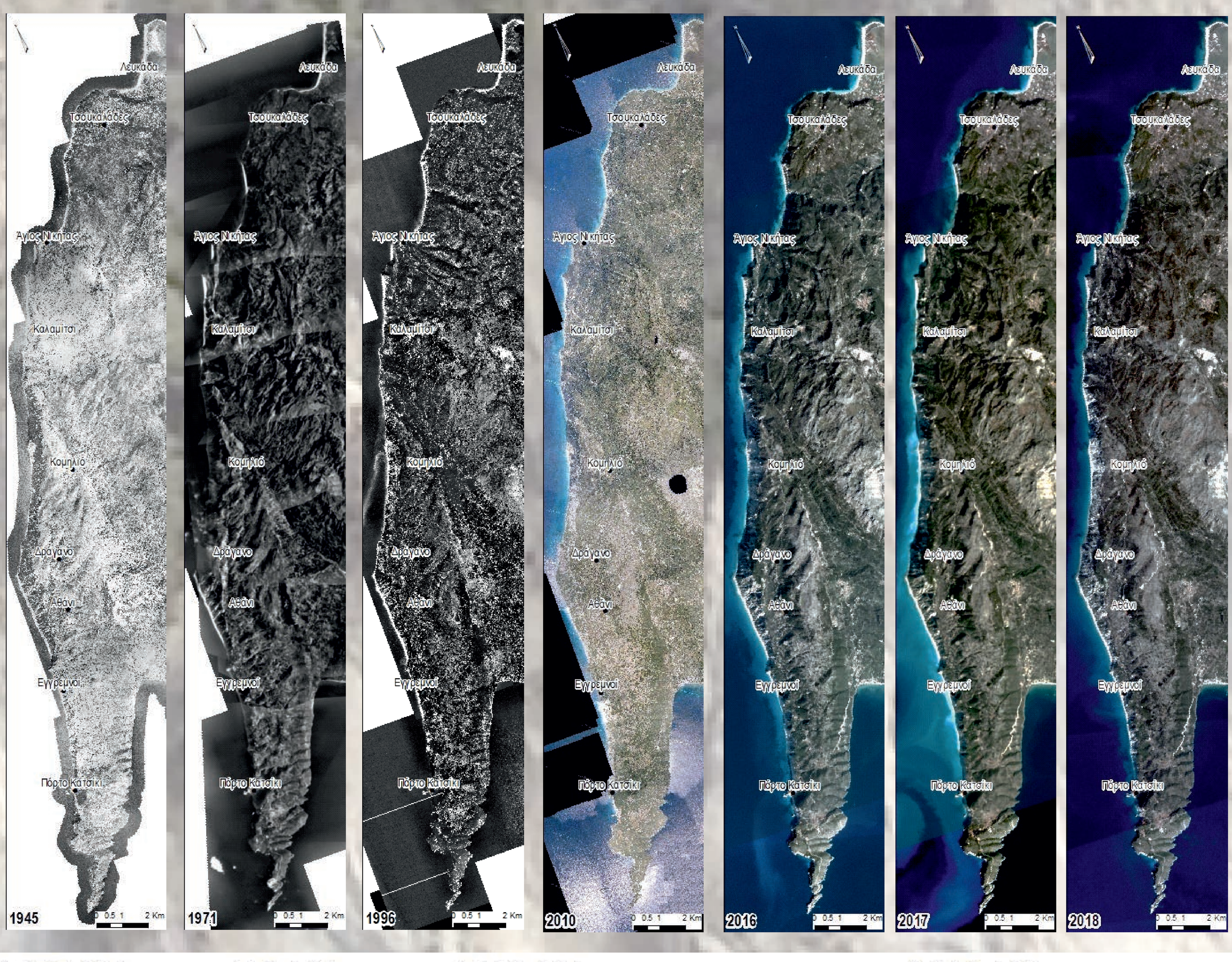
ABSTRACT

The aim of this study is to calculate the displacement rates of the coastline at the western part of the island, which is characterized of the escarpment coast. The shape of this coastal zone is caused mainly by tectonism which is very frequent in this wider area (Valkaniotis et al., 2018). The western coast of the island from Cape Agios Ioannis (NW) to the southernmost point of the peninsula, Cape Doukato is steep and precipitous, as a result of the high seismicity of the Ionian Sea area (Bornovas, 1964). Along this side of the island, several landslides and rock falls are observed. The situation changes only at the northern part of the island, with a distinctive coastal landform over the narrow zone called "Zostiras" (Leivaditis & Verikiou - Papaspyridakou, 1986).

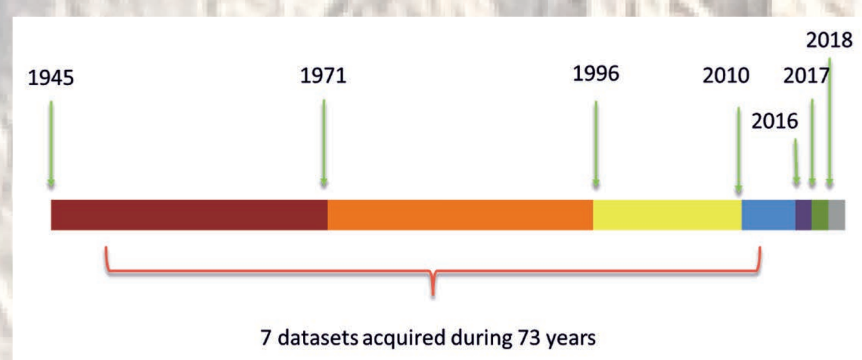
This work was conducted using two different types of data. Historical analogue panchromatic aerial images of high resolution (Zuidam and Van Zuidam-Cancelado, 1979) and contemporary digital high resolution multi-spectral satellite images were combined for extracting the coastline at the time period of acquisition. The acquisition of the aerial photographs took place during 1945 and 2010, while the satellite images where acquired during 2016, 2017 and 2018 (Figure 1). In all cases the images were digitally processed and optically optimized in order to produce a highly accurate representation of the shoreline at each time period. All the data were imported in a Geographic Information System platform, where they were subjected into comparison and geo-statistical analysis (Tsokos et al., 2018). Several transects were drawn normally to the coast and the distance between them was set at every 200 m as the relative displacement of the coastline was calculated for each one of them.

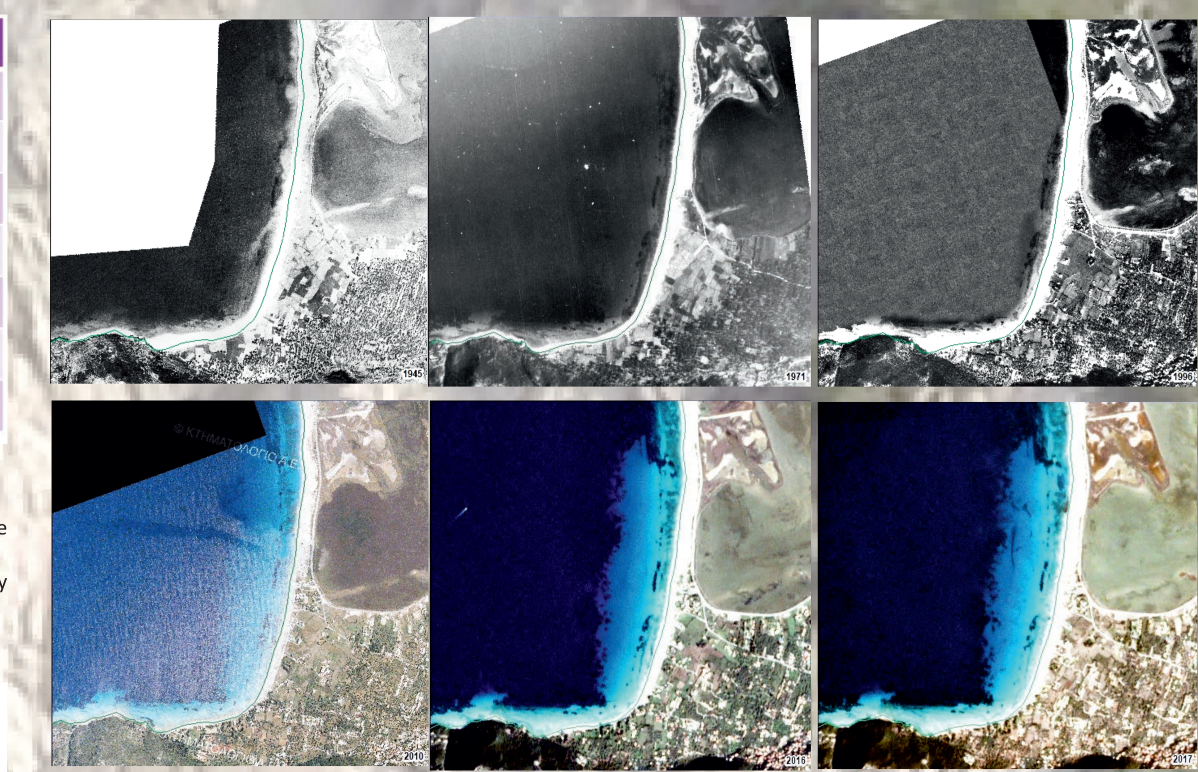
In a way to achieve this, an extension of the ESRI ArcGIS v.10.6.1 software was employed as published by USGS and named Digital Shoreline Analysis System v.5 (DSAS). The DSAS extension (Thieler et al., 2009) lets the user define a constant straight line in a specific distance from the shoreline and take transects perpendicular to it among the evolving coastlines. The measurements give quantitative information on the change of the position of the shoreline, as well as more useful statistical data. Even if this seems to be an arbitrary value, it worked rather sufficiently at this almost 12 km long segment of the shoreline as it can be characterized as rather curvy and either a smaller value would result an oversampled area with transects intersect each other mixing the calculations or a larger value would result quite sparse transect locations without any representative outcome.



ACQUISITION DATE	TYPE
1945	Mosaic of Aerial Photographs
1971	Mosaic of Aerial Photographs
1996	Mosaic of Aerial Photographs
2010	Mosaic of Aerial Photographs
2016	Planet Satellite data
2017	Planet Satellite data
2018	Planet Satellite data

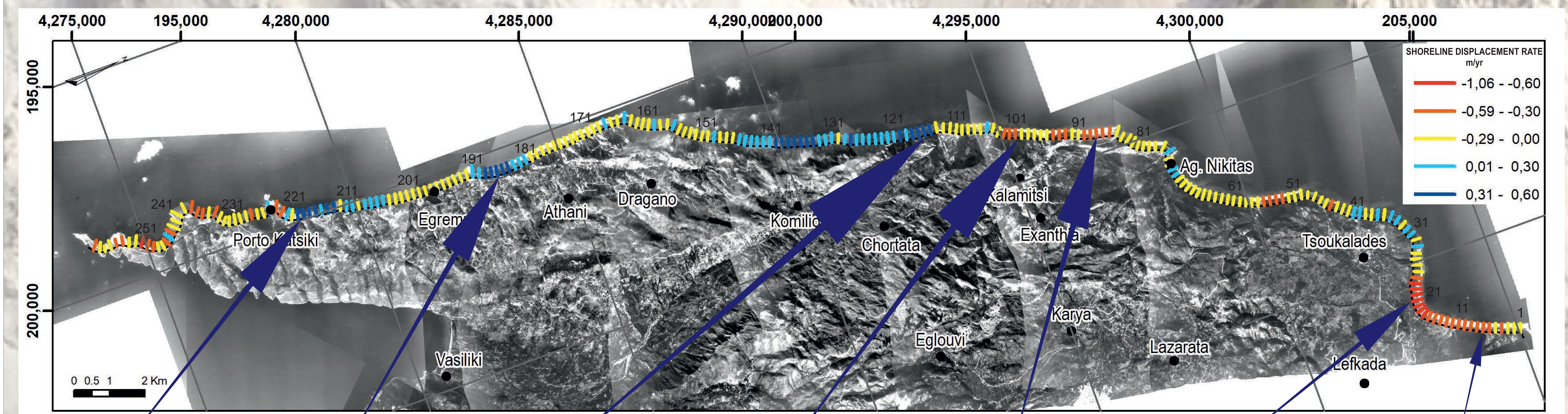
The remote sensing datasets, from various sources, which were used in this study, covering a time frame of 73 years.
The spatial resolution of the aerial photograph mosaics was 1m, as the satellite data acquired by Planetscope constellation use a pixel size of 3 m.

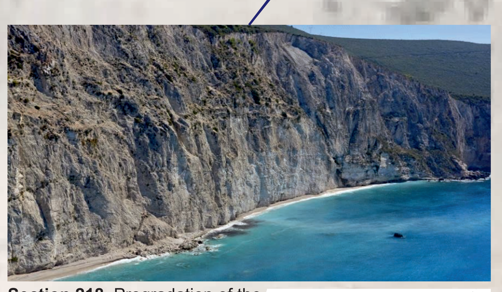


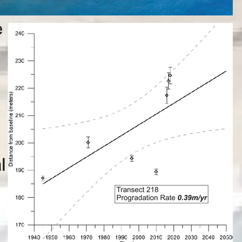


Sample area at the north of the island coastline, where the shoreline displacement is obvious related to the baseline, which is shown at every image for comparison reasons.

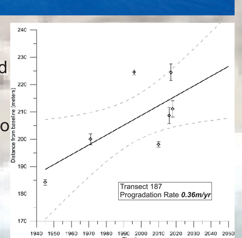
The described methodology introduces a simple but very convenient way of combining a dataset containing all the available shoreline traces throughout a given time period, in order to quantify its displacement rate for certain segments and therefore evaluate the risk or vulnerability of a coastal zone. We suggest that all kinds of remote sensing data (with similar spatial resolution) could be included in this change detection procedure and the objective difficulty should be how far back in time one could find reliable datasets and hence increase the reliability of the methodology. The most labored issue would be to make all the collected datasets free from distortions and consequently comparable to each other, combine them in a Geographic Information System platform and finally determine and quantify the shoreline displacement rate and especially the erosion rate at certain segments.



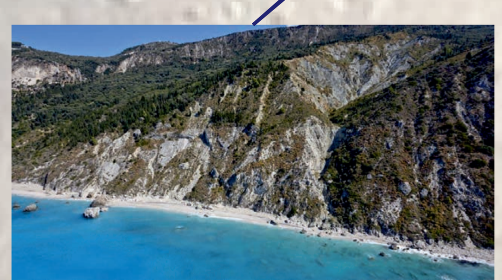


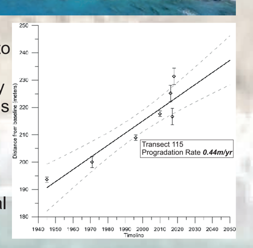


Section 218. Progradation of the shoreline reaching the rate of 0.39 meters per year, due to continuous rock-falls especially after the seismic succession of 2015 (6.1,5.1,4.8). It is obvious from the diagram that the recent earthquakes reversed the coastal displacement from the previous state of erosion.

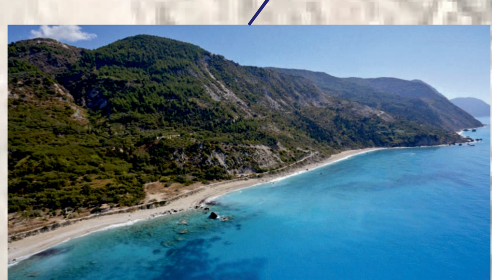


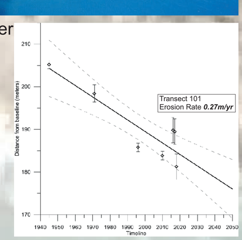
Section 187. During the earthquakes of 2003 and 2015 massive rock-falls were observed along the steep slopes. This fact is repeated after every major earthquake in these areas, due to the high elevation and steep slopes, causing coastline progradation of 0.36 meters per year.



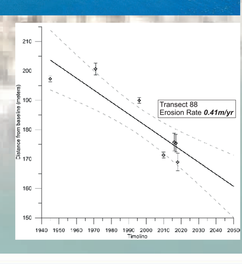


Section 115. The prone facets consist of carbonates (Jurassic to Paleocene limestones). During the local earthquakes (especially 2003 and 2015) several rock-falls of boulder size rocks happened, with material coming from the higher existing terraces. This caused a progradation of the shoreline forming a wider coastal zone.

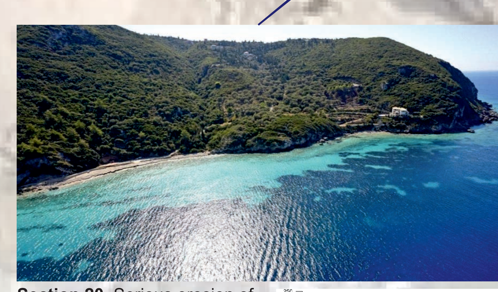


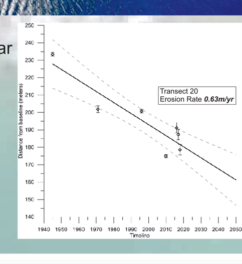


Section 101. Erosion of the order of 0.27 meters per year is observed in contemporary coastal formations (Holocene) cropping out in between Vigla limestones (E. Senonian)

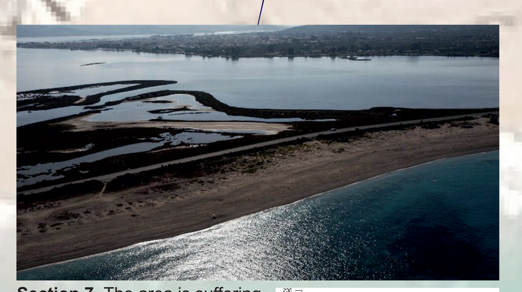


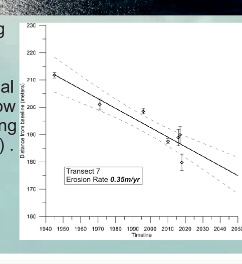
Section 88. The shoreline has receded with high erosion rates of the order of 0.41 meters per year although the coastal displacement pattern is rather peculiar, possibly due to strong affection of the earthquake activity.



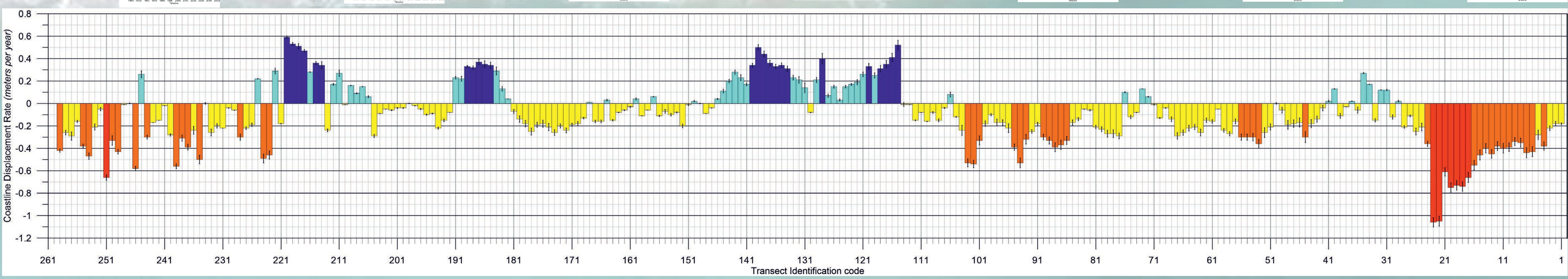


Section 20. Serious erosion of the order of 0.63 meters per year is calculated at the beaches consisting of contemporary coastal formations (Holocene) between the hills comprised by Pantokrator (L. Triassic) limestones .

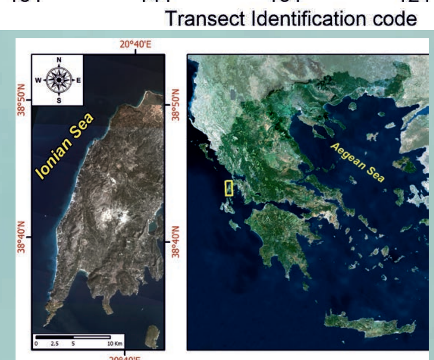




Section 7. The area is suffering from serious erosion, reaching the 0.35 meters per year, as observed in the interpreted aerial photographs since 1945. The low relief and the lithology (consisting of Holocene coastal formations) .



Statistical analysis diagram for the coastal displacement rate at transects sketched every 100 meters. Bluish colors show progradation areas, whilst yellow to reddish show erosion. By employing the methodology described above, at the area of investigation we have calculated the displacement rate of the coastline position over the past 75 years. The rates of change that were calculated were not homogeneous along the full length of the coastline. Specifically, the average value of the rate of receding is 10 cm/year, while extreme values of order 1 m/year were also observed, increasing the riskiness of specific positions. In those positions it has been estimated that the shoreline has receded over 55 m in the last 75 years and is strongly affected by the earthquake activity along with the human intervention in some cases. In conclusion we calculated that the extreme coastline displacement values reach the 1.06 m/yr (erosion) and 0.59 m/yr (progradation). The combination of geological formations and intense seismicity seems to be the main factor leading to these results.



Planet satellite image of Lefkada (321/RGB), acquired on 15/9/2018. The map on the right shows the location of the Landsat image in the mainland Greece.

References

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