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# Detection of Shifts in the Southeastern Coastline of the Caspian Sea with Landsat MSS, TM and ETM+ Images in 1977, 1987 and 2001

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## Abstract

Shorelines are the most important linear phenomena on earth's surface that have a dynamic nature. Thus, favorite coastal management and environmental protection towards sustainable development requires the extraction of the coastline and its changes. For this purpose, coastal zone monitoring in an appropriate time context is of great importance. As one of reliable and rather accurate sources, remote sensing data and satellite imagery in different periods are used for investigation and interpretation of shoreline changes and quantitative measurements. In this study, we tried to apply a new method to determine the shoreline changes using remote sensing and geographic information system. This method possesses simplicity and has acceptable results as well and is able to control and evaluate the results of the research process and its reliability is approved. For this aim, Mean Shift Clustering algorithm was developed for segmentation of MSS, TM and ETM+ images of 1977 (June 6th), 1987 (14 June) and 2001 to investigate the changes of south-eastern coastline of the Caspian Sea over a length of 16 km. After determination of shorelines over the intended years, we extracted the coastline of 1977 as the baseline, and then determined the changes between 1987 and 2001. The average measurements show a 14.03 meters recession of sea water for 1987 compared to that of 1977. However, the results for 2001 show an advancing sea water around 69.8 meters in 1977. Since the results of coastline changes are considered as the fundamental basis for analysis and other related applications, the data integrity and no other possible errors are essential. To control the accuracy of the extracted data on cross sections perpendicular to the coastline, statistical tests of sample, median absolute deviation, Z-Score and box plot was used. The results, confirms that the extracted data have no errors.

**Keywords:** Caspian Sea; Coastline changes; Remote sensing; andsat; Segmentation

## Introduction

Because of the influence of dynamic morphologic phenomenon and the adverse effects incurred from a variety of usages, coasts are always exposed to destruction. As a result, the preparation and implementation of comprehensive protection programs have involved the experts and authorities for a long time to balance the usages, reduce the destruction of resources and achieve a sustainable development [1]. For optimized coastal management, the knowledge of past, present and future position of coastline and its changes is essential. Shorelines are the most important features on earth and are constantly changing in short-term and long-term. These changes may be caused by natural or human factors. About 60 percentages of the populations live in coastal areas. Knowledge of the behaviour of coastline helps experts in beach management, designing and construction of shore facilities, and determining the safe coastal margins [2-5]. After determining and comparing the coastline in different periods, as well as investigating the reasons and factors of the changes, it is possible to forecast and make decisions about the future locations and conditions of the beach. The knowledge of the coastline behaviour also provides way to deal with the negative impacts and to benefit from the positive effects [6].

Previous studies related to monitoring the coastline changes can be explained as below; from 1807 to 1927, all coastline mappings were carried out by field surveying. In 1927, the true potential of aerial photography to complete maps of the coastline was found. During 1927 and 1980, aerial photographs were considered to be a special source for coastline mapping. However, the limitation of these photos were the large number of aerial photos even in regional scale, high cost time-consuming of collection, correction, analysis and transmission of data to the map, as well as the black and white nature of the photos. Moreover, their non-digital format, small time coverage and low geometric accuracy of aerial photos can be mentioned as well. Following the evolution of the researches related to monitoring the coastline changes with the arrival of satellite images, remote sensing and geographic information systems, the analysis of coastline changes and the related researches were and are being carried out with a very high accuracy, high spatial and temporal coverage and accurate and understandable outputs. Nowadays, application of satellite images is regarded as the newest and most economic method [7]. In addition to the low cost and high precision, the remote sensing methods have made it possible to continuously observe and manage the beaches. These changes may be caused by natural or human factors. About 60 percentages of the populations live in coastal areas. Knowledge of the behaviour of coastlines helps beaches management in designing and construction of shore facilities and determining safe coastal margins. After determining coastline in different periods and comparisons of them and investigating reasons and factors of changes, forecast and decision making about the future locations and conditions of the beach is possible. Having the knowledge of the behaviour of coastline also provides a way to deal with the negative impacts and to exploit the benefits of the positive effects [2].

In this study, we will investigate the changes of 16 km of south eastern coastline of the Caspian Sea. Fluctuations in this area are

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very high in recent years and studying the changes is necessary for management of coastal areas in the region [8-10]. In recent years, the performed studies have focused on advancement and retreatment of the coastal line of the Caspian Sea. Moreover, the coastal vulnerability requires extensive research. One of these methods uses aerial photos and GIS to deal with changes of natural landscape and land use in southern coast of the Caspian Sea in Noor city coasts [11-15]. As investigated the coastal changes of Kiashahr-Dastak area (North East Rasht) in a 26-year period (1967 to 1993). In this study, comparison of coastlines indicates regressive coasts (sedimentation areas) at the arrival of the rivers to the sea and progressive coasts (eroded or sunk beaches) in the eastern parts of Sefidrood delta, especially in the northern parts of the Dastak. They studied shoreline changes in Amirabad area over the years 1966, 2004 and 2012. Their study showed that the coastal area has lost the state balance and stability due to the port facilities and on the banks of the upstream (west side) and downstream (east side), sedimentation and erosion can be seen respectively. Because of the importance of the changes and forecasting the coastline mount changes of the Caspian Sea. Recent studies calculated the coastline changes in the deltaic range of Gorgan River. He predicted the future changes of the line based on field evidences and assessing the efficiency of the methods [16-19]. They studied the coastline changes of the Caspian Sea off the coast of Iran for a period of 26 years (1975 to 2001) using MSS, TM and ETM$^+$ Landsat images. In their research, they partitioned the Caspian Sea in Iran into 22 coastal areas and calculated the coastline changes by creating cross sections perpendicular to the coastline for each area. They used high pass filters to identify the coastline on each of the images and the results showed the rapid advance of the coastline during 1977 to 2001 [20].

In this study we tried to apply a new method to determine the shoreline changes using remote sensing and geographic information system. This method possesses simplicity and has acceptable results as well, and is able to control and evaluate the results of the research process and its reliability is approved [21].

## Materials and Methods

In this study MSS, TM and ETM$^+$ images of 1977 (June 6th), 1987 (14 June) and 2001 (15 August) were used to investigate the changes of 16 km of south-eastern coastline of the Caspian Sea. In selection of these images, the existence and availability of data were taken into account; therein the best images were of the Landsat satellite images archive [22]. The Mean Shift Clustering algorithm was developed for segmentation of images existing on ArcGIS software to investigate the changes as well. Having determined the shorelines over the intended years, we extracted the coastline of 1977 as the baseline and then determined the changes through developing cross sections perpendicular to coastlines [23-25].

It is critically important to identify the potential errors. To tackle this issue, the statistical tests were used including sample, median absolute deviation, Z-Score and box plot tests.

### Pre-processing

Before using the remote sensing data, it is essential to conduct a series of pre-processing operations (radiometric and geometric corrections). Since the obtained images from USGS have a good geo-referenced feature, the accuracy of images was controlled by visual controlling the images that have natural features such as rivers and other linear phenomena and Sharp [26-29]. This examination was conducted on ArcGIS and the results confirmed them as to be geo-referenced and also proved that the three images are properly overlapping.

### Choosing the best band

Since the reflection of water on infrared bands is almost zero and the reflection of absolute majority land- covers is greater than water, coastlines can be extracted from one band of the image. According to Tables 1 and 2, the best band for detecting the coastline on MSS, TM and ETM$^+$ images is band 4 [27-30].

### Image segmentation and extraction of coastline

In this step, the Mean Shift Segment tool on ArcGIS was used for coastline detection operations. This algorithm is the developed form of Clustering Mean Shift that has been added to ArcGIS 10.3 for segmentation [31]. The algorithm is considered as a non-parametric algorithm for clustering and is widely used in image segmentation. Compared to the k-means method, its advantage is that even number of categories not considered as input [32-34]. After acquiring the segments from images of different years (Figures 1-3), the coastline was digitized by hand on ArcGIS so that in the following steps their changes can be calculated by putting the coastline on different years (Figures 4 and 5).

## Results and Discussion

We used the coastline of 1977 as the baseline, and then determined the changes by developing the cross sections perpendicular to the coastlines. Therefore, the common length of the coastline that was determined for all three years was divided at regular intervals (530 m) through developing cross sections perpendicular to the coastline. Then, we determined the changes from 1987 and 2001 and compared to 1977 (Figures 6 and 7). The average measurements show a 14.03 meters recession of sea water for 1987 compared to that of 1977. However, the

| Band | Wavelength | Useful for mapping |
|---|---|---|
| Band 1-Blue | 0.45-0.52 | Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation |
| Band 2-Green | 0.52-0.60 | Emphasizes peak vegetation, which is useful for assessing plant vigor |
| Band 3-Red | 0.63-0.69 | Discriminates vegetation slopes |
| Band 4-Near Infrared | 0.77-0.90 | Emphasizes biomass content and shorelines |
| Band 5-Short-Wave Infrared | 1.55-1.75 | Discriminates moisture content of soil and vegetation; penetrates thin clouds |
| Band 6-Thermal Infrared | 10.40-12.50 | Thermal mapping and estimated soil moisture |
| Band 7-Short-wave Infrared | 2.09-2.35 | Hydrothermally altered rocks associated with mineral deposits |
| Band 8-Panchromatic (Landsat 7 only) | 0.52-0.90 | 15 meter resolution, sharper image definition |

**Table 1:** Wavelengths and applications of TM and ETM$^+$ bands.

| Landsat MSS 1, 2,3 Spectral Bands | Landsat MSS 4,5 Spectral Bands | Wavelength | Useful for mapping |
|---|---|---|---|
| Band 4-Green | Band 1-Green | 0.5-0.6 | Sediment-laden water, delineates areas of shallow water |
| Band 5-Red | Band 2-Red | 0.6-0.7 | Cultural features |
| Band 6-Near Infrared | Band 3-Near Infrared | 0.7-0.8 | Vegetation boundary between land and water, and landforms |
| Band 7-Near Infrared | Band 4-Near Infrared | 0.8-1.1 | Penetrates atmospheric haze best, emphasizes vegetation, boundary between land and water, and landforms |

**Table 2:** Wavelengths and applications of MSS bands.

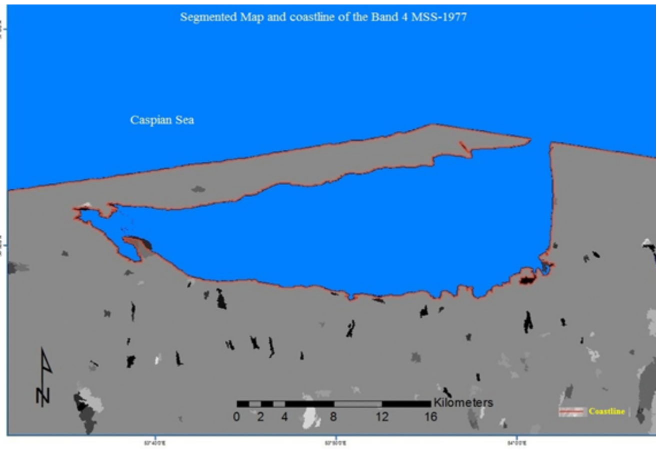


**Figure 1:** Segmented map and coastline of the band 4 MSS-1977.

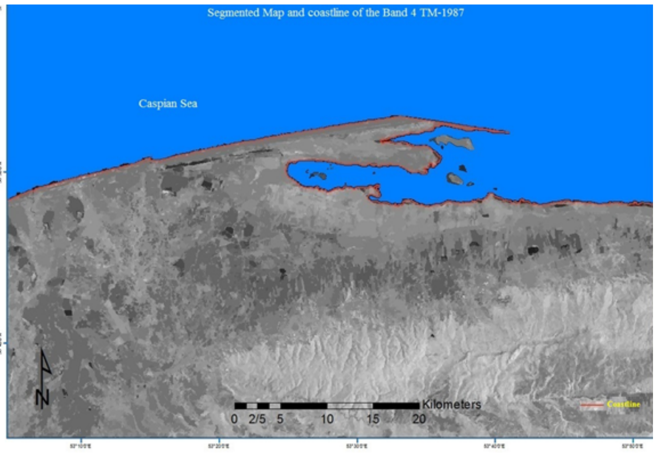


**Figure 2:** Segmented map and coastline of the band 4 TM-1987.

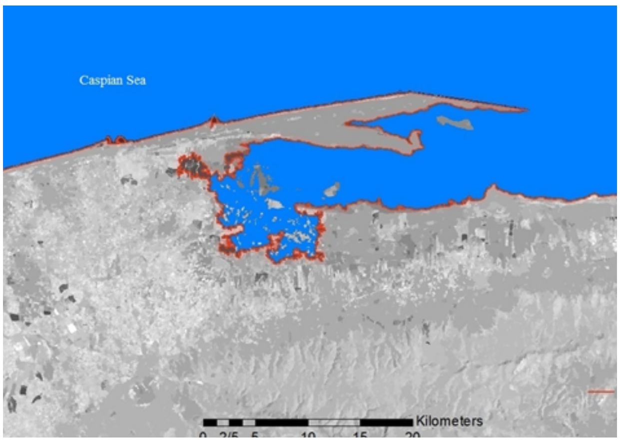


**Figure 3:** Segmented map and coastline of the band 4 ETM+-2001.

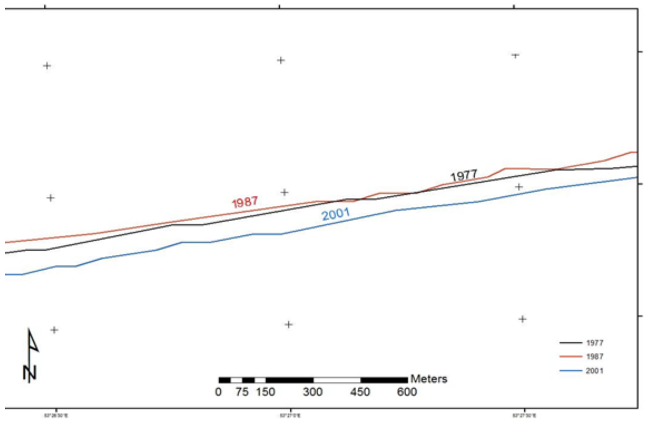


**Figure 4:** A part of Caspian sea coastline change in 1977, 1987 and 2001.

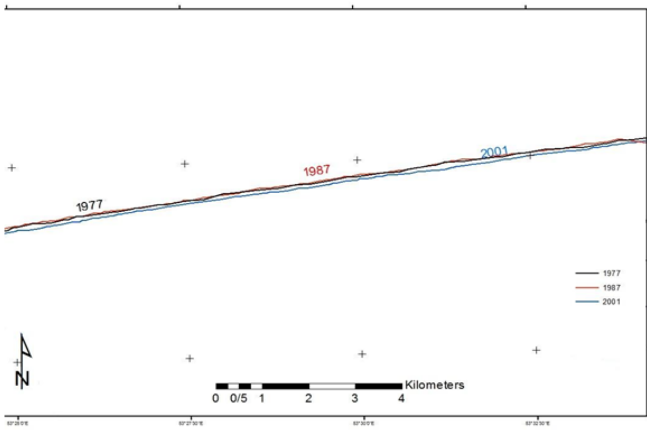


**Figure 5:** A part of Caspian sea coastline change in 1977, 1987 and 2001.

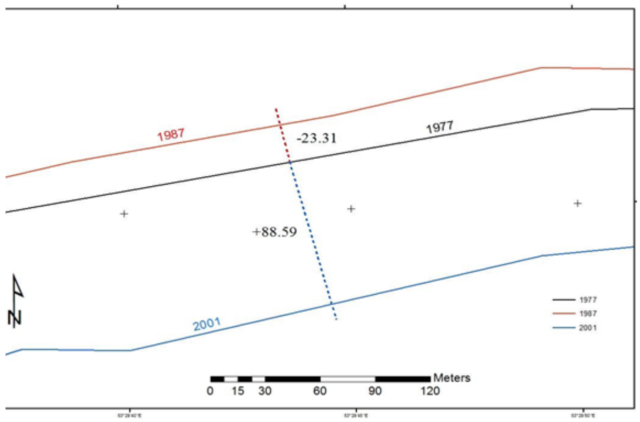


**Figure 6:** Measurement part of Caspian sea coastline change in 1977, 1987 and 2001.

results for 2001 show advancing sea water around 69.8 meters in 1977 (Table 3 and Figure 8).

## Assessing and controlling the results (identifying errors)

Since the results of coastline changes are considered as the fundamental basis for further analysis and other related applications, the data integrity and errorless being of them are essential. Various factors may cause errors in the results. Some of these factors include:

- Various errors in different levels of coastline extraction on spatial data (such as photos, maps, satellite images etc.).

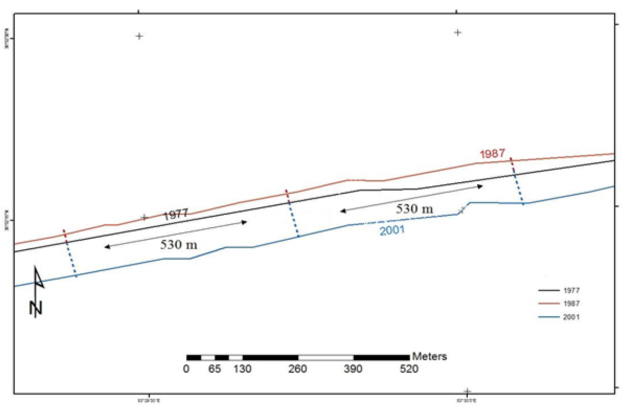


**Figure 7:** Measurement part of Caspian sea coastline change in 1977, 1987 and 2001.

| Year | 1987 | 2001 |
|---|---|---|
| First 530 meters | -12.78 | 99.18 |
| Second530 meters | 2.66 | 103.97 |
| Third 530 meters | 9.11 | 86.76 |
| Fourth 530 meters | 15.13 | 68.68 |
| Fifth 530 meters | -29.04 | 86.52 |
| Sixth 530 meters | -30.34 | 118.01 |
| Seventh 530 meters | -44 | 76/82 |
| Eighth 530 meters | -31.41 | 94.92 |
| Ninth 530 meters | -22.29 | 89.14 |
| Tenth 530 meters | -25.73 | 71.45 |
| Eleventh 530 meters | -19.86 | 62/81 |
| Twelfth 530 meters | 1.8 | 54.9 |
| Thirteenth 530 meters | -12.16 | 55.19 |
| Fourteenth 530 meters | -0.6 | 96.67 |
| Fifteenth 530 meters | -5.98 | 93.02 |
| Sixteenth 530 meters | -24.43 | 79.06 |
| Seventeenth 530 meters | -15.47 | 94.06 |
| Eighteenth 530 meters | -21.87 | 86.25 |
| Nineteenth 530 meters | -23.31 | 88.59 |
| Twentieth 530 meters | -36.34 | 74.89 |
| Twenty-first 530 meters | -20.38 | 55.68 |
| Twenty-second 530 meters | -2.36 | 94.59 |
| Twenty-third 530 meters | -27.38 | 119.13 |
| Twenty-fourth 530 meters | -41.32 | 110.98 |
| Twenty-fifth 530 meters | 1.33 | 103.21 |
| Twenty-sixth 530 meters | -24.39 | 90.89 |
| Twenty-seventh 530 meters | 8.69 | 88.39 |
| Twenty-eighth 530 meters | 8.22 | 87.1 |
| Twenty-ninth 530 meters | -56/82 | 60.15 |
| Thirtieth 530 meters | -37.83 | 65.13 |
| **Average changes** | **-14.03 m** | **69.08 m** |

**Table 3:** The average measurements of Caspian sea coastline change by cross sections perpendicular to coastlines (equal intervals of 530 meters) for 1987 and 2001 based on 1977 coastline.

- Errors related to data: aerial photos for example are most common source of coastline determination. The photos have various sources of error. Factors such as radial or axial distortion and tilt causing error.
- Errors related to measurement methods.
- Errors related to ground control points.

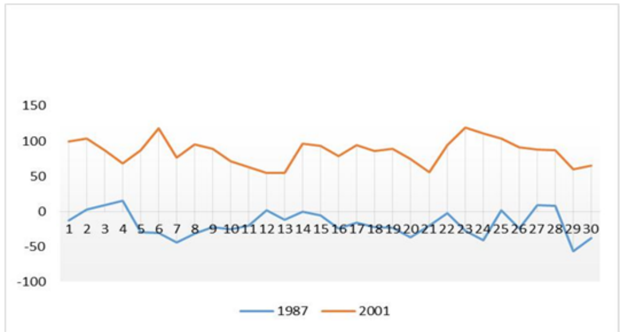


**Figure 8**: Diagram of measurements of Caspian sea coastline change with cross sections perpendicular to coastline (equal intervals of 530 meters) in 1987 and 2001 based on 1977 coastline.

- Measuring errors.
- Human errors.

Typically the data that are inconsistent with the other members can be reprehensive of error data. Errors normally occur farther than the rest of the data set so that it is supposed that they were produced by a different process. Given the critical importance of identifying the potential errors, adding the ability to identify errors is essential. Researchers have offered a variety of methods to detect errors. Statistical methods include wide range of these methods. In the following, we have discussed identifying errors using resume statistical tests of Hample, median absolute deviation, Z-Score and box plot on cross sections perpendicular to the determined coastline.

**Hample test:** Hample Test is one of statistical methods used in identifying errors in univariate datasets. The test is theoretically a sustainable way, that is not sensitive to errors (the number and amount of errors does not affect its capability). The following steps are necessary to conduct the test:

1. Median calculation (Med)

2. Calculate the deviation from the median of the data set ($r_i$)
$r_i = (x_i - Med)$

$x_i$ is a member of data-set.

3. Calculate median of deviations from the median of the data set ($Med_{|r_i|}$)

4. Check the proviso $|r_i| \geq 4.5Me_{|r_i|}$, if the proviso confirmed for $x_i$ data, it can be said that $x_i$ is an error.

Hample Test was calculated on cross sections perpendicular to the coastline (Tables 4-6). According to Table 7, none of cross section values ($|r_i|$) exceed 57.275 for 1987, 50.31 for 2001. Therefore, it confirms that the extracted data have no errors.

**Median absolute deviation test:** Median absolute deviation test (BEN-GAL 2005) is a basic strong method for identifying errors in univariate datasets. The test is a sustainable way and is not affected from errors in dataset.

$$2\,MAD_e\,Method = Median \pm 2MADe$$

$$3\,MAD_e\,Method = Median \pm 3MADe$$

For normal data the following relationship is established:
$MAD_e = 1.483 \times MAD$

| Year | $Med_{\|r_i\|}$ | *Med* | $4.5Me_{\|r_i\|}$ |
|---|---|---|---|
| 1987 | 12.715 | -21.125 | 57.2175 |
| 2001 | 11.18 | 87.745 | 50.31 |

**Table 4:** Haple test parameters on cross sections perpendicular to coastlines 1987 and 2011 based on 1977.

| Year | Median | MAD | MADe | $2\ MAD_e$ Method | | $3\ MAD_e$ Method | |
|---|---|---|---|---|---|---|---|
| | | | | + | - | + | - |
| 1987 | -21.125 | 12.715 | 18.851 | 16.57754 | -58.8275 | 35.42881 | -77.6788 |
| 2001 | 87.745 | 11.18 | 16.57548 | 120.896 | 54.59404 | 137.4714 | 38.01857 |

**Table 5:** Median absolute deviation test parameters on cross sections perpendicular to coastlines 1987 and 2011 based on 1977 coastline.

| Year | $Q1$ | Median | $Q3$ | $IQR$ | $1.5 \times IQR$ |
|---|---|---|---|---|---|
| 1987 | -29.365 | -21.125 | -0.1175 | 29.2475 | 43.87125 |
| 2001 | 70.7575 | 87.745 | 95.3575 | 24.6 | 36.9 |

**Table 6:** Box plot parameters on cross sections perpendicular to coastlines 1987 and 2011 based on 1977 coastline.

That:

$$Mad = Median\,(|xi - Median\,(x)|)$$

The median absolute deviation test of extracted data (Table 5) shows that no data fall outside this range and indicates the presence of any errors.

**Z-Score test:** Z-Score Test is a method that can be used for identifying errors in univariate datasets. Z-Score test used mean and standard deviation for identifying errors. Therefore, it is affected from dataset members that are effective on its function as well. The Z-score Test is expressed as follows:

$$Z_i = \frac{x_i - x}{SD}$$

Where, $x_i$ is the member of data-set $\bar{x}$ is Mean and *SD* is the Standard deviation of data. The $Z_i$ values that their absolute value does not exceed 3 are considered as error. According to Table 7, absolute values of none of cross sections perpendicular to coastline exceed 3 which indicate that the extracted data have no errors.

**Box plot:** Box Plot is a graphic univariate method which calculate the data distribution using five main characteristics: smallest outlier data, the lower quartile ($Q1$), median, upper quartile and the greatest outlier data. The $Q3 - Q1$ value determines the middle quartile range ($IQR$). Using this parameter, normal or outlier (error) being one of data can be determined. The data that are $1.5 \times IQR$ times smaller than $Q1$ or $1.5 \times IQR$ greater than $Q3$ can be considered as error.

The values needed for identifying errors on cross sections calculated using box plot (Table 6). According to Table 7, none of 1987 cross section values are smaller than -73.3675 and greater than 43.859. For 2011, as well, none of cross section values are smaller than 33.8575 and greater than 132.257 which indicate that the extracted data have no errors.

| Year | 1987 | 2001 | Z-Score 1987 | Z-Score 2001 | $r_i$ 1987 | $r_i$ 2001 |
|---|---|---|---|---|---|---|
| First 530 meters | -12.78 | 99/18 | 0.06956 | 1.690154 | 8.345 | 11.435 |
| Second530 meters | 2.66 | 103/97 | 0.928022 | 1.959162 | 23.785 | 16.225 |
| Third 530 meters | 9.11 | 86/76 | 1.286641 | 0.992642 | 30.235 | -0.985 |
| Fourth 530 meters | 15.13 | 68/68 | 1.621352 | -0.02274 | 36.255 | -19.065 |
| Fifth 530 meters | -29.04 | 86/52 | -0.83449 | 0.979163 | -7.915 | -1.225 |
| Sixth 530 meters | -30.34 | 118/01 | -0.90677 | 2.747653 | -9.215 | 30.265 |
| Seventh 530 meters | -44 | 76/82 | -1.66627 | 0.434408 | -22.875 | -10.925 |
| Eighth 530 meters | -31.41 | 94/92 | -0.96627 | 1.45091 | -10.285 | 7.175 |
| Ninth 530 meters | -22.29 | 89/14 | -0.45919 | 1.126304 | -1.165 | 1.395 |
| Tenth 530 meters | -25.73 | 71/45 | -0.65046 | 0.132827 | -4.605 | -16.295 |
| Eleventh 530 meters | -19.86 | 62/81 | -0.32409 | -0.3524 | 1.265 | -24.935 |
| Twelfth 530 meters | 1.8 | 54/9 | 0.880206 | -0.79663 | 22.925 | -32.845 |
| Thirteenth 530 meters | -12.16 | 55/19 | 0.104032 | -0.78034 | 8.965 | -32.555 |
| Fourteenth 530 meters | -0.6 | 96/67 | 0.746766 | 1.549191 | 20.525 | 8.925 |
| Fifteenth 530 meters | -5.98 | 93/02 | 0.447639 | 1.344206 | 15.145 | 5.275 |
| Sixteenth 530 meters | -24.43 | 79/06 | -0.57818 | 0.560207 | -3.305 | -8.685 |
| Seventeenth 530 meters | -15.47 | 94/06 | -0.08 | 1.402613 | 5.655 | 6.315 |
| Eighteenth 530 meters | -21.87 | 86/25 | -0.43584 | 0.964 | -0.745 | -1.495 |
| Nineteenth 530 meters | -23.31 | 88/59 | -0.51591 | 1.095415 | -2.185 | 0.845 |
| Twentieth 530 meters | -36.34 | 74/89 | -1.24037 | 0.326018 | -15.215 | -12.855 |
| Twenty-first 530 meters | -20.38 | 55/68 | -0.353 | -0.75282 | 0.745 | -32.065 |
| Twenty-second 530 meters | -2.36 | 94/59 | 0.64891 | 1.432378 | 18.765 | 6.845 |
| Twenty-third 530 meters | -27.38 | 119/13 | -0.7422 | 2.810553 | -6.255 | 31.385 |
| Twenty-fourth 530 meters | -41.32 | 110/98 | -1.51726 | 2.352846 | -20.195 | 23.235 |
| Twenty-fifth 530 meters | 1.33 | 103/21 | 0.854074 | 1.91648 | 22.455 | 15.465 |
| Twenty-sixth 530 meters | -24.39 | 90/89 | -0.57595 | 1.224584 | -3.265 | 3.145 |
| Twenty-seventh 530 meters | 8.69 | 88/39 | 1.263289 | 1.084183 | 29.815 | 0.645 |
| Twenty-eighth 530 meters | 8.22 | 87/1 | 1.237157 | 1.011736 | 29.345 | -0.645 |
| Twenty-ninth 530 meters | -56.82 | 60/15 | -2.37906 | -0.50179 | -35.695 | -27.595 |
| Thirtieth 530 meters | -37.83 | 65/13 | -1.32322 | -0.22211 | -16.705 | -22.615 |
| Average changes | **-14/03** | **69/08** | - | - | - | - |
| Standard deviations | **17. 98566** | **17. 80615** | - | - | - | - |

**Table 7:** Coastline change values, Z-Score test and $X_i$ of Hample test on cross sections perpendicular to coastlines 1987 and 2011 based on 1977 coastline.

## Conclusion

As the results show, the average measurements revealed a 14.03 meters recession of sea water for 1987 compared to that of 1977. However, the results for 2001 show advancing sea water level around 69.8 meters in 1977. The results show an oscillating nature and high sensitivity for the Caspian Sea compared to the High Seas against unstable coastal factors. Comparison of these results with those of other researchers studying the changes in the Caspian coast confirms the results. This issue confirms the segmentation method to be as one of accurate and rapid coastline determination methods that possesses simplicity, and produces similar results compared to other methods. However achieving accurate results is not only depended on extraction methods, but is also possible by considering the following:

- Identifying and using convenient and reliable data.
- Appropriate pre-processing on the used data will have important effects on results.
- Using the efficient algorithms of extraction and separation of water from land that pay attention to the required inputs will also play an important role in the output results.
- Applying appropriate way to coastline change determination and developing cross sections perpendicular to coastline are crucial.
- Controlling and assessment of extracted data by cross sections perpendicular to coastline that are usually accepted without any control are necessary in most studies.

## References

1. Alesheikh AA, Ghorbanali A, Nouri N (2007) Coastline change detection using remote sensing. Int J Environ Sci Technol 4: 61-66.
2. Ayadi K, Boutiba M, Sabatier F, Guettouche MS (2015) Detection and analysis of historical variations in the shoreline, using digital aerial photos, satellite images and topographic surveys DGPS: case of the Bejaia bay (East Algeria). Arab J Geosci 9: 1-18.
3. Bagheri H, Khodabakhsh S, Gharib RM, Mohseni H (2006) Studying the coastal changes of Kiashahr-Dastak area from 1967 to 1993 using GIS. Science magazine of Bu Ali Sina University 2: 34-25.
4. Barnett V, Lewis T (1992) Outliers in statistical data (3rd edn.). John Wiley & Sons, New York.
5. Ben GI (2005) Outlier detection, data mining and knowledge discovery handbook: A complete guide for practitioners and researchers. Kluwer Academic Publishers, USA.
6. Boak EH, Turner IL (2005) Shoreline definition and detection: a review. J Coast Res 21: 688-703.
7. Carter R (1988) Coastal environments: An Introduction to the physical, ecological and cultural systems of coastlines. Academic Press, USA.
8. Chen LC, Rau JY (1998) Detection of shoreline changes for tideland areas using multi -temporal satellite images. Int J Remote Sens 19: 3383-3397.
9. Comanicu D, Meer P (2002) Mean shift: A robust approach toward feature space analysis. IEEE Trans Pattern Anal Machine Intel 24: 603-619.
10. Cracknell AP (1999) Remote sensing techniques in estuaries and coastal zones an update. Int J Remote Sens 19: 485-496.
11. Crowell M, Leatherman SP, Buckley MK (1991) Historical shoreline change: Error analysis and mapping accuracy. J Coast Res 7: 839-852.
12. Ford M (2013) Shoreline changes interpreted from multi-temporal aerial photographs and high resolution satellite images: Wotje Atoll, Marshall Islands. Remote Sensing of Environment 135: 130-140.
13. Gens R (2010) Remote sensing of coastlines: Detection, extraction and monitoring. Int J Rem Sens 31: 1819-1836.
14. Hawkins D (1980) Identification of Outliers. Chapman and Hall, London.
15. Hodge V, Austin J (2004) A survey of outlier detection methodologies. Artificial Intelligence Review 22: 85-126.
16. Iglewicz B, Hoaglin D (1993) How to detect and handle outliers. ASQC Quality Press, Mexico.
17. Lorestani G (2015) Forecasting annual changes of the Caspian Sea coastline (Gorgan-Rud river delta area). Physical geography research 47: 254-241.
18. Kakroodi AA, Kroonenberg SB, Goorabi A, Yamani M (2014) Shoreline response to rapid 20th century sea-level change along the Iranian Caspian coast. J Coast Res 30: 1243-1250.
19. Kankara RS, Selvan CS, Rajan B, Arockiaraj S (2014) An adaptive approach to monitor the Shoreline changes in ICZM framework: A case study of Chennai coast. Ind J Mar Sci 43: 1271-1279.
20. Kannan R, Kanungo A, Murthy MVR (2016) Detection of shoreline changes Visakhapatnam Coast, Andhra Pradesh from multi-temporal satellite images. J Remote Sensing & GIS 5: 1-8.
21. Kermani S, Boutiba M, Guendouz M, Guettouche MS, Khelfani D, et al. (2016) Detection and analysis of shoreline changes using geospatial tools and automatic computation: Case of jijelian sandy coast (East Algeria). Ocean & Coast Manag 132: 46-58.
22. Kumar A, Narayana AC, Jayappa KS (2010) Shoreline change sand morphology of spits along southern Karnataka, west coast of India: A remote sensing and statistics based approach. Geomorphology 120: 133-152.
23. Mahmoudi K, Saybany M, Moradi A (2015) Presentation a new computational modules for digital coastline analysis system, to identify errors in coastal changes data. Marine Eng J 21: 94-83.
24. Maiti S, Bhattacharya AK (2009) Shoreline change analysis and its application to prediction: a remote sensing and statistics based approach. Mar Geol 257: 11-23.
25. Malek J, Bani HM, Ghlamnzhad K (2012) Assessment of changes in the coastline of the Caspian Sea in the Amirabad port area. Tenth International Conference on Coasts, Ports and Marine Structures, Tehran, Iran.
26. McGill R, Larsen WA (1978) Variation of Boxplots. The American Statistician 32: 12-16.
27. Moore L (2000) Shoreline mapping techniques. J Coast Res 16: 111-124.
28. Natesan U, Parthasarathy A, Vishnunath R, Kumar GEJ, Ferrer VA, et al. (2015) Monitoring long-term shoreline changes along Tamil Nadu, India using geospatial techniques. Aquat Procedia 4: 325-332.
29. Redman TC (2001) Data quality: The field guide.
30. Selvan CS, Kankara RS, Rajan B (2014) Assessment of shoreline changes along Karnataka coast, India using GIS & Remote sensing techniques. Ind J Mar Sci 43: 1293-1298.
31. Schiffle RE (1988) Maximum Z score and outliers, The American Statistician 42: 79-80.
32. Shatayi JS, Malk J (2005) Investigating the changes of natural landscape and land use in the southern coast of the Caspian Sea using aerial photography and GIS (Case study: coastal city of Noor). Geographical research 51: 105-195.
33. Singh K, Upadhyaya S (2012) Outlier detection: Applications and techniques. Int J Comp Sci 9: 307-323.
34. Tukey JW (1977) Exploratory data analysis. Addison-Wesley Publication, Boston.