INVESTIGATING THE DYNAMIC RESPONSE OF THE ANZALY LAOON TO SEA-LEVE CHANGES USING MULTI-SOURCES REMOTELY SENSED DATA

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ABSTRACT

The Caspian Sea, the biggest inland water body worldwide, is characterized by rapid sea-level changes, about 3 m oscillation, during the 20th century. These sea level fluctuations results in back-barrier lagoon formation. Due to the unique condition of the CS and its dynamic fluctuations which alter the coastal areas it seems necessary to monitor the effect of these dramatic fluctuations on shrinkage and expansion of connected water bodies (e.g., Lagoons). Therefore, this study was conducted to find the dynamic response of the Anzali lagoon, the largest freshwater reservoir of the southern Caspian Sea, to the Caspian sea-level changes during the last 42 years, between 1975 and 2016, using the remotely sensed data. For this purpose, an automatic procedure including the combination of the Tasseled- Cap and texture filter methods was applied on the existing Landsat satellite imagery and to extracting the shoreline and calculating the area and perimeter of the Anzali Lagoon, during the study period. The sea level changes of the CS, were extracted from the multiple altimetry satellite data. Finally the relationship between the relative sea level variability and shoreline changes of the Anzali lagoon was studied. Results show that there is a positive linear correlations between area of Anzali Lagoon and Caspian Sea relative water level with the values of Pearson correlation coefficient and coefficient of determination of 0.832 and 0.6919, respectively. This linear relation indicates that Anzali lagoon is directly affected by Caspian Sea level fluctuations.

Keywords: Remote sensing, Shoreline change, Altimetry satellite data, Anzali Lagoon, Caspian Sea.

1. Introduction

The Caspian Sea (CS) with a surface area of 371,000 km^2; is the biggest inland water body worldwide, has experienced an approximately 3 m oscillation during the 20th century, whereas the global sea is fluctuated approximately 20 cm in the same period (Kroonenberg et al., 2007, Kakroodi et al., 2015., Haghani et al., 2016). These huge and rapid sea level fluctuations of CS, have impacted on global climate (Arpe et al., 2012; Farley-Nichols & Toumi, 2014), coastal geomorphology changes including beach-ridge formation, barrier-lagoon development and general erosion (Kaplin & Selivanov, 1995; Naderi Beni et al., 2013, Kakroodi et al., 2015), lives of people (Dolotov & Kaplin, 2005; Kosarev, 2005; Leroy et al., 2009) by flooding, land demolition and etc. So, this unique natural laboratory made an opportunity in a short time frame of investigating the global sea level changes impacts on coastal environments which happens in the long-term (Haghani et al., 2016). These sea level fluctuations has a strong impact on the wetlands and lagoon formation and shoreline change, as one the most important responses of the coastal area to rapid sea-level rise, (Kroonenberg et al., 2007, Le Cozannet et al., 2014).

Wetland areas containing unique properties such as; fish, fuel wood, wildlife, fertile land for agriculture, flood control, storm protection, ground water recharge and sediment–pollutant– nutrient retention (Mitsch & Gosselink, 2000; Ramsar, 2004; Kuleli et al., 2011), are a component of world coastal ecology (Kuleli et al., 2011). Especially, the river sediment refinement property, made the Lagoons as a crucial natural refinery feature in ecosystem. The balance lagoon system may be disrupted by uncontrolled construction, dredging to collect sand, land reclamation, and urban, industrial and agricultural waste discharge activities. So, it seem necessary to eliminate the negative effects on lagoons and regulate the human activities for preserving the ecological balance (Ozturk & Sesli, 2015). For this purpose, the shorelines extraction is an important issue (Cracknell, 1999; El Mrini et al., 2012), which achievement this criteria for a large region is difficult, time consuming and sometimes impossible by using the traditional ground survey techniques (Cracknell, 1999). In this way, recent changes of shorelines can be projected by the remotely sensed data (White & El Asmar, 1999; Shaghude et al., 2003) and provided preliminary valuable estimation of coastal changes (Yang et al., 1999; Moussaid et al., 2015) which confirmed by some researchers such as (e.g. Van der Wal et al. (2002), Kuleli (2005), Vanderstraete et al. (2006), Ekercin (2007), Genz et al. (2007), Wu (2007), Sesli et al. (2008), Bayram et al. (2008), Ghanavati et al. (2008), Rebelo et al. (2009), Kuleli (2010), Maiti & Bhattacharya (2009), Kuleli et al. (2011), Pardo-Pascual et al. (2012), Haghani et al. (2016)). In these purposes, researches have been used several different methods such as Tasseled Cap Transform (TCT), supervised and unsupervised classification, Principal Component Analysis (PCA), single-band thresholds, band rationing, and many other indices.

One of the most important and famous lagoons next to the southern part of the Caspian Sea is the Anzaly lagoon, which is strongly affected by the sea level changes, and it is necessary to study the impact of sea level changes on this lagoon. Therefore, this paper mainly aimed to investigate the dynamic response of the Anzali lagoon to sea-level changes by using remotely sensed data.

2. Study area

The study area are the western part of the Anzali Lagoon, located between 37° 35′ - 37° 26′ N and 49° 15′ – 49° 27′ E in the south western of Caspian Sea of Iran (Fig. 1). This lagoon is a famous wetland by a certificated Ramsar sites in the world and is the largest freshwater reservoir of the Southern Caspian (Leroy et al., 2011). Anzali wetland contains four sections: the eastern, the southern (or Siah-keshim), the central, and the western section or Abkenar (Hassanzadeh et al., 2014).

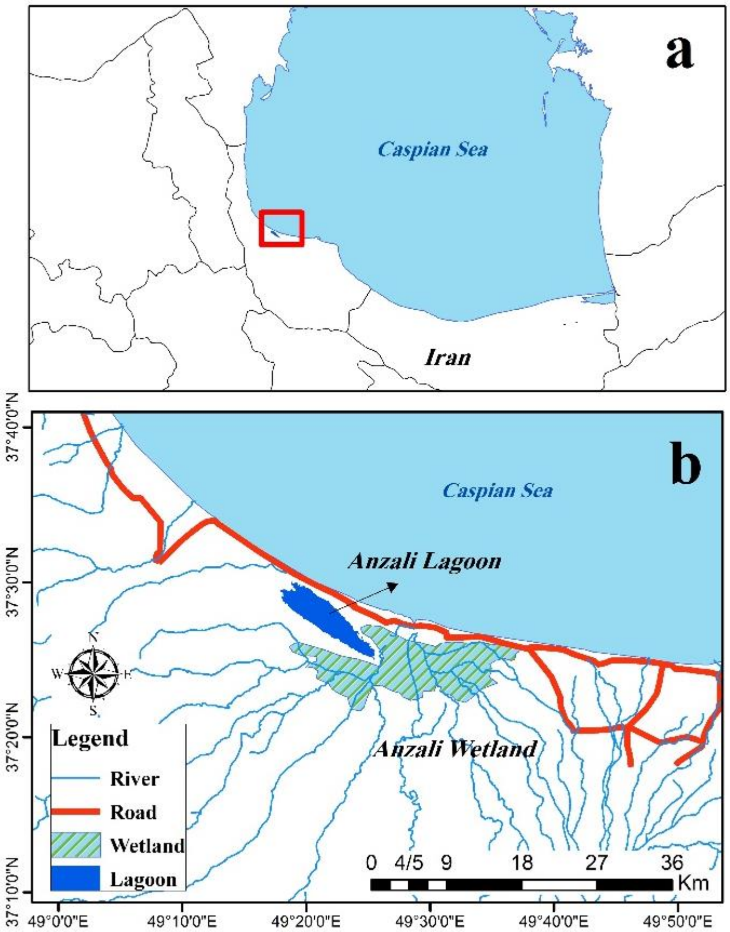

Fig. 1. Location map of the study area (a) Showed Iran country, (b) is the location of study in south west of Caspian Sea

3. Material and Methods

In the present study to assess the impact of sea level changes on the Anzali lagoon different remotely sensed data were used. For this purpose, the all available Landsat imagery with cloud cover <30% including MSS (Multi spectral Scanner), TM (Thematic Mapper), ETM+ (Enhanced Thematic Mapper) and OLI (Operational Land Imager) in the period of 1975 - 2016 which covered the Anzali Lagoon were used for extracting the lagoon area. Also relative Caspian Sea level variations products from TOPEX/POSEIDON (T/P), Jason-1 and Jason-2/OSTM altimetry were used for calculating the sea-level changes. Finally, we computed relation between the Anzali lagoon results and Caspian Sea level changes

3.1. Extraction of Lagoon area and Change detection

In this study, the combination of Tasseled Cap Transformation and Texture Filter was performed for extracting the shorelines. Tasseled Cap Transformation (TCT) was developed by Kauth and Thomas (1976) and linearly combines the Landsat bands in order to create three principal components, i.e., brightness, greenness, and wetness (Scott et al., 2003). So, in order to differentiate between lands from water, the wetness component is utilized. In this study, the coefficients were used for TCT of Landsat data derived from Kauth et al. (1979), Crist (1985), Huang et al. (2002) and Baig et al. (2014). In order to achieve unique value of brightness rather than variation in brightness, the Texture Filter has been used, too. In this filter, the data range, mean, variance, entropy, and skewness statistical methods for each gray level within local processing kernel have been calculated. Finally, the water body boundary was extracted by convert the image to binary format by using the manual trial-and-error thresholding and then the raster to vector procedure, and visual interpretation and editing.

Finally, for change detection of Anzali lagoon, the polygon area and perimeter assessment method; both spatially and quantitatively, was used. In order to evaluate the dynamic response of Lagoon to Sea Level changes, the lagoon area and relative sea level were related by Pearson correlation and R^2 coefficients.

4. Results and Discution

The Relative Caspian Sea level variations recorded by the TOPEX/POSEIDON (T/P), Jason-1 and Jason-2/OSTM altimetry for the period of 1993 till 2016 is presented in the Figure 2.This plot shows the monthly and daily variation.

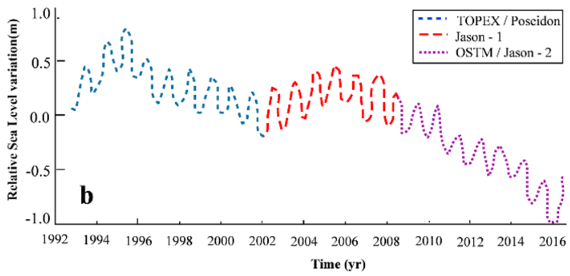

Fig. 2. Relative Caspian Sea Level Variation from 1993 to 2016.

4.1. Changes of the Area and Perimeter of Anzali Lagoon

The temporal area and perimeter changes of the Anzali lagoon between years of 1975 till 2016 in compare with the relative Caspian Sea level variation are given in Table 1.

Table 1. Area and Perimeter changes of the Anzali lagoon between 1975 till 2016 and relative sea level of CS between 1993 and 2016.

Yr.	Area (Km^2)	Perimeter (Km)	Perimeter Changes	Area Changes			Relative sea level (m)	Relative sea level changes (m)
				Cumulative to 1975	Year by Year	Event Years		
1975	37.28	51.22						
1978	37.23	45.39	-5.83	-0.05	-0.05			
1985	26.09	57.52	6.29	-11.19	-11.14	-11.19		
1987	34.92	55.02	3.79	-2.36	8.83			
1989	38.18	44.59	-6.63	0.90	3.26			
1993	37.52	45.23	-5.99	0.25	-0.66	11.44	0.46	
1998	37.94	44.35	-6.88	0.66	0.41		0.43	-0.03
1999	37.44	42.75	-8.47	0.16	-0.49		0.3	-0.13
2001	37.77	45.33	-5.89	0.49	0.33		0.17	-0.13
2002	37.18	47.92	-3.3	-0.10	-0.59		0.24	0.07
2003	39.74	51.11	-0.12	2.46	2.56	2.21	0.2	-0.04
2006	35.76	48.05	-3.17	-1.52	-3.98		0.29	0.09
2007	36.49	44.81	-6.41	-0.78	0.74		0.3	0.01
2008	36.75	44.89	-6.32	-0.52	0.26	-2.99	0.2	-0.1
2009	36.09	47.08	-4.15	-1.18	-0.66		-0.1	-0.3
2010	36.85	50.78	-0.44	-0.43	0.75		0.1	0.2
2011	35.43	42.38	-8.84	-1.85	-1.42	-1.32	-0.17	-0.27
2013	34.51	49.61	-1.62	-2.77	-0.92		-0.49	-0.32
2014	34.56	44.17	-7.05	-2.71	0.06		-0.5	-0.01
2015	34.31	44.46	-6.76	-2.97	-0.25		-0.59	-0.09
2016	32.95	48.19	-3.03	-4.33	-1.36	-2.48	-0.58	0.01

Based on the given results in the table 1, the greatest and lowest value in terms of the area in Anzali lagoon were happened at years of 2003 and 1985 respectively. These criteria in terms of the perimeter have been confronted in the lagoon at 1985 and 2011, respectively. While the area of the Lagoon have been increased during 1985-1987, 1987-1989, 1993-1998, 1999-2001, 2002-2003, 2006-2007, 2007-2008, 2009-2010, 2013-2014, it decreased over all other during years. The area of lagoon has been fluctuated and totally decreased 4.33 Km2 between 1975 and 2016.

Meanwhile, the lowest and greatest value of the relative sea level variation of Caspian Sea between 1993 and 2016 in acquisition date of images which used in this research, was happened in 2015 and 1993; -0.59 and 0.46, respectively. We considered the relative sea level variation of CS between 1993 and 2016 due to absence of data of Relative Sea Level before 1993 in USDA. The sea level of CS was fluctuated but the overall trend of sea level is descending. Also, the insignificant ascending trend are happened in 2001-2002, 2003-2007, 2009-2010 and 2015-2016, too.

The most significant area changes occurred in the Lagoon for 1978-1985, because the low stand of CS have happened in 1977. In table 1, Relative Sea Level change was calculated by the difference between Relative Sea Level of one year from the before one. The Relative Sea Level change and Lagoon area is directly related due to the connection between the Lagoon and Sea. By comparing these results, whereas the agreement between them were inferred over 1998-1999, 2006-2007, 2008-2009, 2009-2010, 2010-2011, 2011-2013 and 2014-2015, in other periods, the disagreement was cleared.

4. 2. Relationship between the changes of the area of Anzali lagoon and sea-level variation

For assessment the dynamic response of the Anzali lagoon to the Caspian Sea level changes, the Pearson correlation and coefficient of determination (R^2) between area of this lagoon and Relative Sea Level Variation of CS between 1993 and 2016 was examined. For this purpose the linear relationship between the area of the Anzali lagoon and Relative Sea Level Variation of Caspian Sea between 1993 and 2016 was calculated and is given in figure 3.

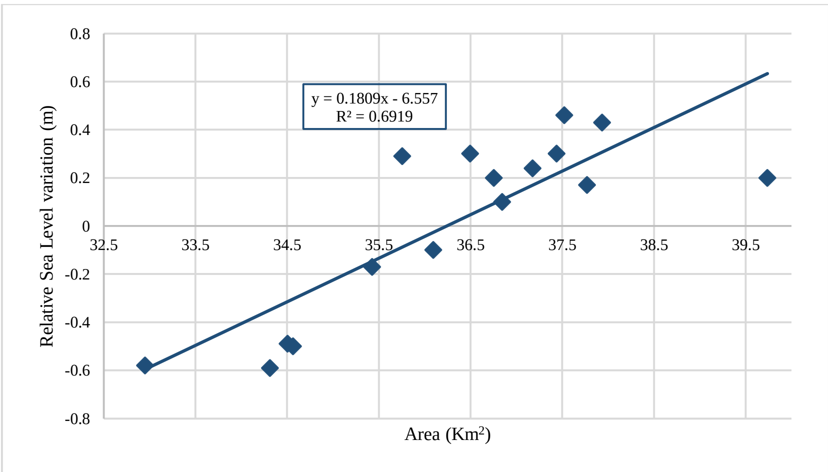

Fig. 3. Correlation between Area of the Anzali Lagoon and Relative Sea Level Variation of Caspian Sea between 1993 and 2016.

A Pearson correlation coefficient and coefficient of determination were 0.832 and 0.6919, respectively. It indicates that there is positive correlations between area of Lagoon and fluctuation of Caspian Sea. In addition to the effect of Sea Level variation on Anzali lagoon, another environmental reasons such as precipitation, create dam on the river, not dredging and etc., and also anthropogenic activity are lead to the different behavior of this lagoon, and there is a need to more study on that.

5. Conclusions

The present study has been carried out to finding the shoreline change of Anzali lagoon using Landsat satellite data and their relationships with sea level fluctuation of Caspian Sea through altimetry data acquisition by Jason-1, TOPEX/Poseidon, and Jason-2/OSTM. Therefore, the area and perimeter of the Anzali lagoon have been calculated by an automatic shoreline extraction during the last 42 years, between 1975 and 2016. Results show that the Caspian Sea has experienced an approximately 2 m oscillation during the last 42 years. These huge and rapid sea level fluctuations of CS, have impacted on costal area and especially on the lagoons next to this environment. The results of Pearson correlation indicate that there is a positive linear correlations between Anzali lagoon and CS level. At this time, there is no research on the relationship between Caspian Sea level and lagoon changes. Based on the results of present study, it can be concluded that Caspian Sea level changes has a strong positive impact on Anzali lagoon and other lagoons next to these sea. Also results indicate the capability and great importance of remotely sensed data for monitoring of costa and marine aria and study the continues dynamic behavior of the lagoons and their relation with Caspian Sea level variation.

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