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Analysis of the Southern Caspian Sea Level Fluctuations from GRACE Gravimetric Satellite

Mobin Eftekhari[1]*, Mohammad Akbari[2], Saeid Gholinejad[3]

1- Master of Science (MSc), Civil Engineering, Water and Hydraulic Structures, Young Researchers and Elite Club, Mashhad Branch, Islamic Azad University, Mashhad, Iran.
2- Assistant Professor at Civil Engineering Department, University of Birjand, Iran. moakbari@birjand.ac.ir
3- Ph.D. student of remote sensing, Department of Geomatics Engineering, Faculty of Civil Engineering and Transportation, University of Isfahan, Isfahan, Iran, email: Saeid.Gholinejad@trn.ui.ac.ir

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Abstract

The Investigation of the changes in sea level, which directly affects various industries, such as shipping, fishing and power plants, is of great importance in environmental studies. As the largest enclosed water body in the world, the Caspian Sea is one of the most important water resources and has a significant impact on the environment and lives of its neighboring countries' people. In this regard, determining variations of mass distribution of the Earth through gravimetric data can be helpful in monitoring Caspian Sea level fluctuations. Accordingly, in this study, the Caspian Sea level fluctuations from 2003 to 2017 were investigated using the Gravity Recovery and Climate Experiment (GRACE) monthly mass grids. This product includes three equivalent water thickness bands, produced by the Center for Space Research (CSR), GeoForschungsZentrum (GFZ), and Jet Propulsion Laboratory (JPL). Since, these three bands were processed independently, some differences may exist between their results, and therefore, it is more reliable to consider all of them. The investigations indicated that in a point in the center of the southern Caspian Sea, the fluctuations were between -42.5 and 26 cm. In a point in the southwestern part of the study area, the fluctuations were in a range of -42.7 cm and 22.5 cm. Also, the fluctuations varied between -37.1 and 23.1 cm in a point in the southeastern part of the Caspian Sea. Furthermore, it can be inferred from our investigations that changes in water level are due to seasonal changes, climate change and irregular dam building on rivers flowing into the sea.

Keywords: Water level fluctuations, Caspian Sea level, GRACE Gravimetric Satellite

1. Introduction

The knowledge of sea level is a long-standing concern to humanity (Taibi and Haddad., 2019). Sea level rise is a slow-onset disaster that has become one of the main threats to humanity as the world experiences global warming (Qingrong et al., 2019). The Sea level fluctuations that have occurred in the Caspian Sea and their detrimental effects on marine structures, fish ports, power plants, and on the

* Email: Mobineftekhari@yahoo.com

environment have been considered as one of the most important problems in recent years (Ardalan and Jafari, 2006). The Caspian Sea is one of the largest enclosed water zones on the Earth, surrounded by five large countries. Its fluctuations have a significant impact on the lives of the people who reside near the coasts of these countries. For example, the rapid 3-meter decline in the Caspian Sea level during the years 1930 to 1978 caused serious environmental problems and caused serious difficulties to the marginal areas such as the Gulf, some major islands and the Volga River Delta (Kosarev & Kostianoy, 2005). Moreover, rapid fluctuations in the Caspian Sea level created unstable conditions in coastal areas during the 20^{th} and 21^{st} centuries, resulting in significant damage to economic and social infrastructure (Khoshravan et al., 2019). Considering such environmental damages and the fact that high population coastal cities with economic importance exist along the Caspian Sea, it is essential to study its water level fluctuations for water resource management purposes.

A wide range of research has been conducted in the field of Caspian Sea level monitoring. Alizadeh katk lahijani (2003) examined the effect of Caspian Sea level fluctuations on coastal ecosystems and predicted long-term changes on the Caspian Sea surface based on the available evidence (Alizadeh katk lahijani., 2003). Ghanghermeh and Malek (2005) found that the changes in Caspian Sea level are a function of changes in the rivers' flow into the sea and evaporation intensity, as well as sudden short-lived fluctuations due to meteorological and hydrological factors and components that depend on climate conditions in the region (Ghanghermeh and Malek.,2005). Furthermore, in another study, they reported Caspian Sea level fluctuations and related environmental factors in the 2010–2011 water years. They explained that the Caspian Sea level fluctuations were due to rainfall reduction in the Volga basin as well as a reduction in the discharge rate of the Volga River and other rivers flowing into the Caspian Sea (Ghanghermeh and Malek.,2012). Bani Hashemi et al. (2012) evaluated the variations of the southern shores of Caspian Sea due to seawater fluctuations and human factors, using remote sensing data over time intervals of between 1983 and 2004. They concluded that different coastal regions respond differently to sea level fluctuations (Bani Hashemi et al., 2012). Yosefi Roshan (2013) investigated the Caspian Sea level fluctuations and the coastline of the Caspian Sea in the Babolsar County and concluded that the coastline progressed between 50 and 100 meters from 1966 to 2013 (Yosefi Roshan., 2013). Moreover, they inferred that the Caspian Sea coastal area dipped between 83% and 100%. Hence, the Caspian Sea coastal area practically lost its function; therefore, it is necessary for it to be revisited. Removing sand dunes in Babolsar played a key role in the erosion process and the rise of the Caspian Sea level. The construction programs that have occurred near the Sea over the past 50 years increased the adverse vulnerable conditions of the coastal zone (Yosefi Roshan., 2013).

In a study in 2017, Chen et al. (2017) investigated the Caspian Sea level fluctuations between 1995 and 2015 through observing the Caspian Sea level variations which were results of rainfall, river entrance runoffs and evaporation. The results of this study indicated a significant drop and a downward trend in the Caspian Sea level over the case study years, with an average annual sea level drop of approximately 6 centimeters (Chen et al., 2017). In another study, Dehbashi et al. (2017), analyzed Caspian Sea level fluctuations using time series stochastic models in which the results suggested a direct relationship between Caspian Sea level fluctuations and the discharge of the rivers flowing into the Sea (Dehbashi et al.,2017). Salehpour et al. (2017) predicted the Caspian Sea level using artificial neural networks. In their study, tide gauge station data obtained from the Caspian Sea coastline were used and the results indicated that the Caspian Sea will face a significant drop in the future (Salehpour et al., 2017). Babagholi Mat Kelaei (2018) analyzed Caspian Sea level fluctuations using level gauge data obtained from the Anzali Port and NeftyanyeKamni from 2013 to 2018. It was concluded that the Caspian Sea level dropped due to some factors including the decrease in rainfall, the increase in temperature and the drop in river discharge of those that flow into the Caspian Sea (Babagholi Mat Kelaei., 2018). In another study, Bani Hashemi and Hosseini (2018) examined the effects of climate change on Caspian Sea level fluctuations. The outcome of this study indicated a drop in the discharge of the southern rivers that flow into the Caspian Sea and an increase in the temperature of the Caspian Sea which resulted in a large amount of evaporation, which can be a reason for downward drop of the sea level (Bani Hashemi and Hosseini., 2018).

Traditionally, long-term changes in sea water levels were determined by tide gauges, placed in several coastal stations. Although these stations provided accurate local sea water level information, it was difficult to incorporate the data obtained from the gauges due to the problems in equating the datum level. Furthermore, the tide gauges only measure their surrounding environment, therefore, the land surface and coastlines have a significant impact on the measured data (Lebedev and Kostianoy., 2008).

Determining the gravity field, and subsequently the variations of the Earth’s mass distribution, is widely considered as an effective way to monitor water level fluctuations. Changes in the Earth's mass over a short period of time can be attributed to changes in a very thin layer (about several kilometers) of water thickness at the surface of the Earth. In other words, the short-time variations in the Earth’s gravity are mainly due to changes in water resources. Therefore, information regarding of the Earth’s gravity and its mass distribution can be useful in monitoring water level fluctuation. In this regard, the Gravity Recovery and Climate Experiment (GRACE) satellite facilitates the act of eliciting information on the changes in water levels by analyzing changes in the Earth's gravity field through monthly-provided information on Earth’s gravity field. Indeed, the GRACE project consists of two similar satellites that are move with a 220 km distance between them. The variations in the distance between these two satellites during their movements provide information about the changes in the Earth's gravity field (Swenson and Wahr, 2002). In this study, GRACE monthly mass grid products were used to monitor the southern Caspian Sea level fluctuations between 2003 and 2017. These products were released on the Google Earth Engine platform and consist of time series of the equivalent water thickness. The GRACE Monthly mass grids have three bands produced by the Center for Space Research (CSR), the Jet Propulsion Laboratory (JPL), and the GeoForschungsZentrum (GFZ), respectively.

2. Material and Methods

2.1. Study Area

The Caspian Sea is the largest enclosed water body on the Earth, surrounded by Iran from the south, by Russia from the north, by Turkmenistan and Kazakhstan from the east, and by Azerbaijan from the west. Covering ~371,000 km2, the Caspian Sea is known as the largest lake in the world. The Caspian Sea level is about 28 meters below mean sea level, with about 130 rivers flow into it, most of which come from the northwest. Annually pouring about 241 km3 into the Caspian Sea, the Volga River is the largest river flowing into it. Recently, the water level of the Caspian Sea has fluctuated frequently in a range of -24 to -28 meters. Since variations in

Caspian Sea level are generally large in the short-term, it is very important to investigate and anticipate Caspian Sea level variations. Fig. 1 illustrates the location of the Caspian Sea along with the depths of its different parts (Kosarev et al., 2009).

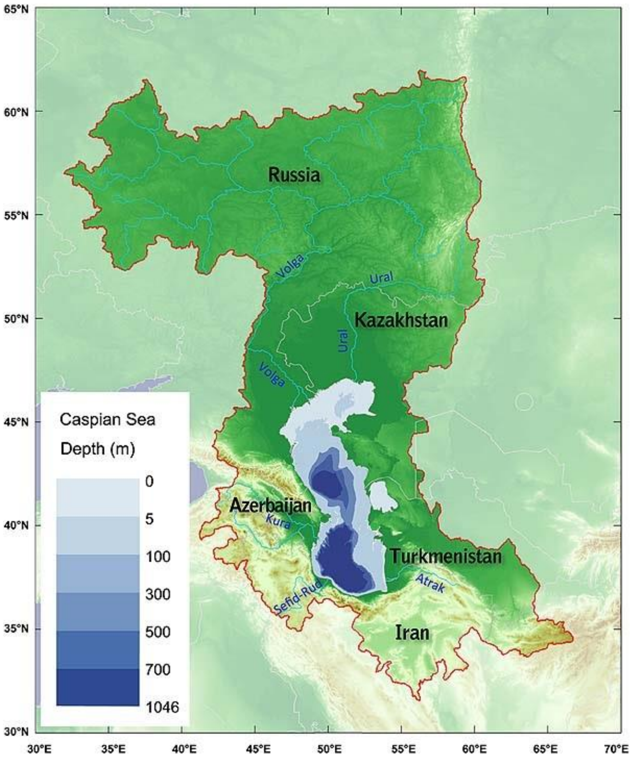

Fig 1: Location and depth of Caspian Sea

2.2. GRACE Data

The GRACE satellite was launched on March 17, 2002 from a Russia station by the National Aeronautics and Space Administration (NASA) and the German Aerospace Center. Its scientific mission ended on October 27, 2017. The GRACE mission consisted of two co-orbital satellites at an altitude of 450 Kilometers from mean sea level with a plunge of 89.5˚. The approximate distance between the two satellites was about 220 kilometers. Momentarily, measurement of the distance and relative velocities of the two satellites was performed by a Radar system at the K band with an accuracy of 1μm/s (Tapley et al., 2004). In this study, we intended to investigate and evaluate the status of Caspian Sea level fluctuations based on analyses using GRACE gravimetric satellite data.

2.3. Processing GRACE images

Variations in the mass distribution of the Earth change its gravity field. Therefore, the variations of the mass distribution, and also the increase or decrease in the mass of a region, can be determined through measuring changes in Earth's gravity field. One of the main aspects of change in the mass distribution of the Earth is the changes in water resources. In other words, changes in water levels in a region can change the mass distribution, and therefore, change the local gravity field. Given this issue, changes in water levels can be deduced from the information of variations in the Earth's mass distribution and its gravity field. In this regard, by estimating the gravity field of the Earth, the GRACE gravimetric satellite can establish the relationships between the variations of the Earth's gravity field and the levels of water resources (Voss et al., 2013). First, the Global Land Data Assimilation System (GLDAS) hydrological model is used to determine the optimum status of the Earth's surface, eliminating the contributions of water in soil, water in snow, and ground surface water from the GRACE observations. Spherical harmonic coefficients are then calculated and finally the hydrological effects are eliminated from these coefficients (Wahr et al., 1998). Next, the difference between the spherical harmonic coefficients, from which the hydrological effects were removed, and the coefficients obtained from the GRACE satellite are calculated. Finally, a wavelet transformation is applied for filtering in order to estimate the available water changes. Changes that resulted from monthly harmonic coefficients can be converted to water fluctuations in the case study area (Eq. 1).

$$\Delta\sigma(\theta,\lambda) = \frac{a.\rho_{ave}}{3}\sum_{n=0}^{\infty}\sum_{m=0}^{n}\frac{2n+1}{1+k_n}.\bar{P}_{nm}(\cos(\theta)).(\Delta J_{nm}\cos m\lambda + \Delta K_{nm}\sin m\lambda) \quad (1)$$

In this equation, $\rho_{ave=5517\,Kg/m^3}$ is the average surface density of the Earth, kn represents Love numbers, ΔJ_{nm} and ΔK_{nm} are the monthly variations of spherical harmonic coefficients, $\overline{P}_{nm}$ represents normalized Legendre functions, θ is the relative deflection of the vertical axis, Δσ represents the change of surface density, α is the outer radius of the sphere and λ is the average gravity. .

In order to improve the estimation of the Earth's gravity field, we can introduce the coefficient Wn (Potential coefficient) into Eq. 1, (Wahr et al., 1998).

$$\Delta\sigma(\theta,\lambda) = \frac{a.\rho_{ave}}{3}\sum_{n=0}^{\infty}\sum_{m=0}^{n}\frac{2n+1}{1+k_n}.W_n.\bar{P}_{nm}(\cos(\theta)).(\Delta J_{nm}\,cos\,m\lambda + \Delta K_{nm}\,sin\,m\lambda) \quad (2)$$

$$b = \frac{\ln 2}{1-\cos\left(\frac{r}{a}\right)} \quad (3)$$

$$W_0 = \frac{1}{2\pi} \quad (4)$$

$$W_1 = \frac{1}{2\pi}\left(\frac{1+e^{-2b}}{1-e^{-2b}} - \frac{1}{b}\right) \quad (5)$$

$$W_{n+1} = -\frac{2n+1}{b}W_n + W_{n-1} \quad (6)$$

In Eq. 3, r is the averaging radius and a is the mean radius of the Earth. Eq. 4 is also a recursive relation for calculating the average kernel of W. The value of W changes with the change of average radius. The result of Eq. 2 is also the surface density anomaly which, when divided by the water density, results in the height fluctuations of water for the case study area.

2.4. GRACE Monthly Mass Grids on Google Earth Engine

Several analysis centers produce monthly global Stokes coefficients using level-1B GRACE observations. Among different centers, the Center for Space Research, University of Texas (CSR) in Austin (TX), the Jet Propulsion Laboratory (JPL) in Pasadena (CA), and the Geo Forschungs Zentrum (GFZ) in Potsdam (Germany) are the most famous, whose outputs include spherical harmonic coefficients of the gravity field and of the dealiasing fields used to compute them.

The GRACE monthly mass grids are free data sets consisting of times series of the equivalent water thickness. These data sets include three bands, each of which is produced by one of the above mentioned centers. In the last two decades, the GRACE monthly Mass Grids have been released on the Google Earth engine (GEE) platform. The web-based GEE platform make it possible to analyze geo-spatial data in a wide spatial range at different time intervals. Therefore, in this study, we extracted the GRACE monthly mass grids of the study area from 2003 to 2017. This time interval consists of 151 different times.

In order to investigate the sea in more detail, three pixels were arbitrarily selected from in the southern, southeastern, and southwestern areas of the Caspian Sea. The position of the investigated pixels is illustrated in Fig. 2. One of the major reasons we considered three points in this study was that, given the large size of each of the GRACE satellite pixels, there is no need to examine a large number of pixels. The pixel size of the used GRACE monthly mass grids is 1 arc degree, which is about 111 kilometers.

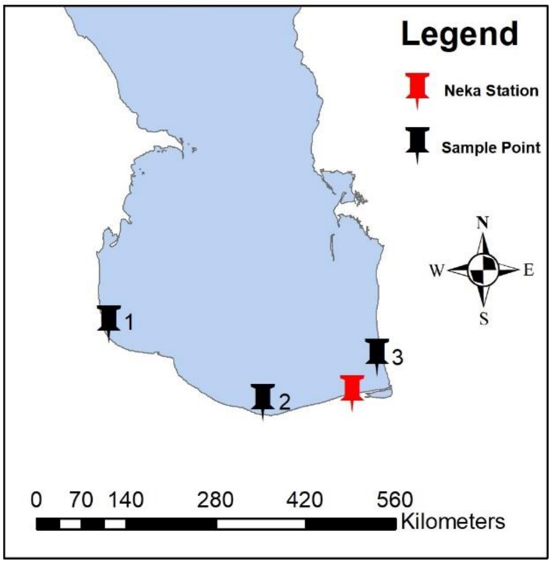

Fig 2: The three case study points chosen to investigate the changes in Caspian Sea level from 2003 to 2017 using the GRACE satellite

3. Results

Table 1 illustrates the characteristics of the sampling point during 2003 to 2017. As previously mentioned, these three points were selected from the southwestern, southern and southeastern areas of the Caspian Sea. Because of the large volume of data, and also due to the constant sinusoidal trend, the monthly fluctuations of the southern Caspian Sea in the last year of the study period (2016-2017) were selected to be statistically analyzed. Graphs regarding the water level fluctuations of the southern part of the Caspian Sea, based on the obtained equivalent water thickness of the CSR, GFZ, and JPL, are presented in Figure 3.

Table 1: Characteristics of sample point fluctuations

	Average (centimeters)	Maximum (centimeters)	Minimum (centimeters)	Standard deviation (centimeters)
Variations of the point 1 fluctuations	0.125	22.5	-42.7	12.5
Variations of the point 2 fluctuations	0.11	26.1	-42.5	15.01
Variations of the point 3 fluctuations	0.118	23.1	-37.1	12.1

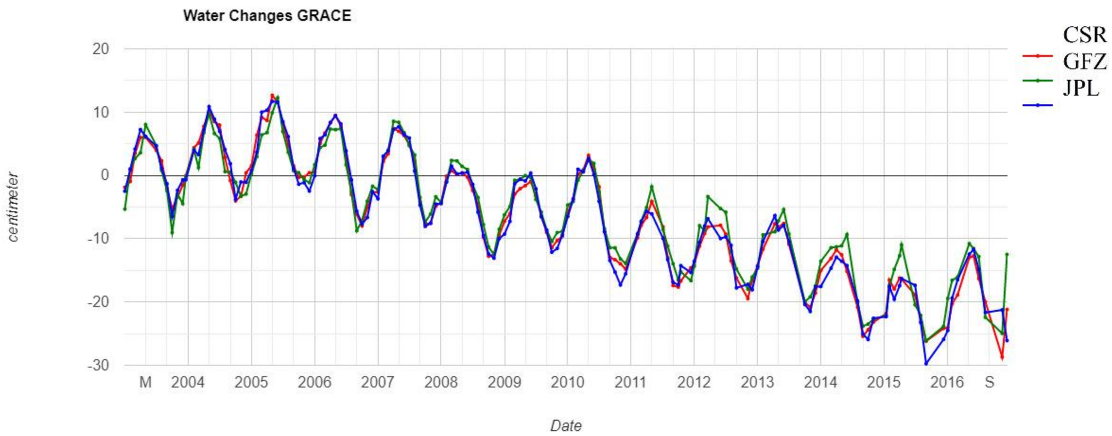

Fig 3: Comparison of the variations of southern Caspian Sea level fluctuations using the three Equivalent Water Thickness products GFZ, JPL, and CSR from 2003 to 2017 using GRACE satellite.

Based on the results of this process, the standard deviation of the water level data is about 14 centimeters lower than its average value in 2016 and about 9 centimeters lower than that of 2017. This decrease indicates the fact that the rate of Caspian Sea level fluctuations in 2017 has a better order. Moreover, the small and near-zero values of skewness, which is a measure of the symmetry or asymmetry of the distribution function, indicates that the normal distribution of Caspian Sea level is approximately symmetrical. In addition, the elongation value, which is an indicator of the height of the distribution and a measure for the curvature height at the maximum point, was indicated to have a value of -1.03 in 2016 compared to the value of -0.63 in 2017. This comparison suggests that the dispersion of water level values in 2016 is more than that of 2017. Furthermore, the calculated values of skewness and elongation for both years are in the range of (-2, 2) indicating that the distribution of the Caspian Sea level is normal every year.

The trend of Caspian Sea level fluctuations was evaluated using the statistical data obtained from the GRACE gravimetric satellite. In this statistical study, the total data acquired were validated and adjusted based on the Baltic Sea elevation code: i.e. -28 meters. It was attempted to evaluate the annual fluctuation period of the Caspian Sea based on its increasing and decreasing oscillatory rate over a year in accordance with the normal distribution curve of Caspian Sea level changes. This had not been the case in Iran before, and the use of the hydrological water year for fluctuations analysis mainly resulted in computational errors for officially announcing the rate of decrease or increase in annual water levels. In addition, the use of this method was inconsistent with other countries' numerical results in such a way that, although some authorities inside the country had reported an increase in the Caspian Sea level during 2017, the Caspian Sea hydrological reality indicated a decrease in the Caspian Sea level in 2017 compared to 2016. Therefore, a time model of normal distribution curve should be used for the accurate analysis of the annual trend of fluctuations in the Caspian Sea level. According to Fig. 3, the annual mean of the Caspian Sea level was -27.28 meters in 2017, and the annual mean difference of its water level in the drought and dehydration periods was equal to 27 centimeters. Upon examining the time series of the GRACE satellite data, we see that the Caspian Sea level in 2016 and 2017 shows an increasing trend in the first 6 months of the year, and then has a decreasing trend in the second half of the year (from July to December). If we take a look at the time series in different years, for example from 2013 to 2014, periodic fluctuations can be observed (Fig. 3). These fluctuations occur periodically every year, indicating changes in water levels as the seasons change. Various factors cause these changes, but the most prominent is the tide phenomenon. Data regarding the changes in Caspian Sea level were acquired from 2003 to 2017 using the GRACE satellite and the three algorithms GFZ, JPL and CSR, which had fluctuation variations between 13.7 centimeters to -25.6 centimeters (Fig. 3).

Furthermore, the linear trend calculated by integrating the three GRACE satellite algorithms had a slope of -5.12 centimeters/year. To evaluate the results, the output of the GRACE satellite was compared with the output of the Neka tide gauge station.

The two time series of the Neka tide gauge station and the GRACE satellite output are shown in Fig. 4. Data from the Neka station includes observations at a rate of every 30 minutes. However, there is a gap, in the data due to the lack of information in the 2005-2006 intervals. According to figure 4, although both of the two time series have a shift, they have identical periods in the observation interval of the Neka tide station which confirms the GRACE satellite results. The difference of the data obtained from the Neka tide gauge station and the GRACE satellite data, which is illustrated in Fig. 4, is due to the different resolutions of observations and measurements of these two sets of data. In fact, it can be argued that for large case study areas where the entire pixel of the satellite is located, using GRACE satellite data is more logical. The present case study surface area, which covers the southern Caspian Sea, is more than 80000 square kilometers, applying GRACE satellite data may be more proper than the observations of the tide gauge stations.

In the next step, according to Fig. 5, the time series trend of the GRACE satellite was calculated using the moving average, which indicated a drop in the southern Caspian Sea level. Its level had decreased from +10 in 2003 to -26 in 2017.

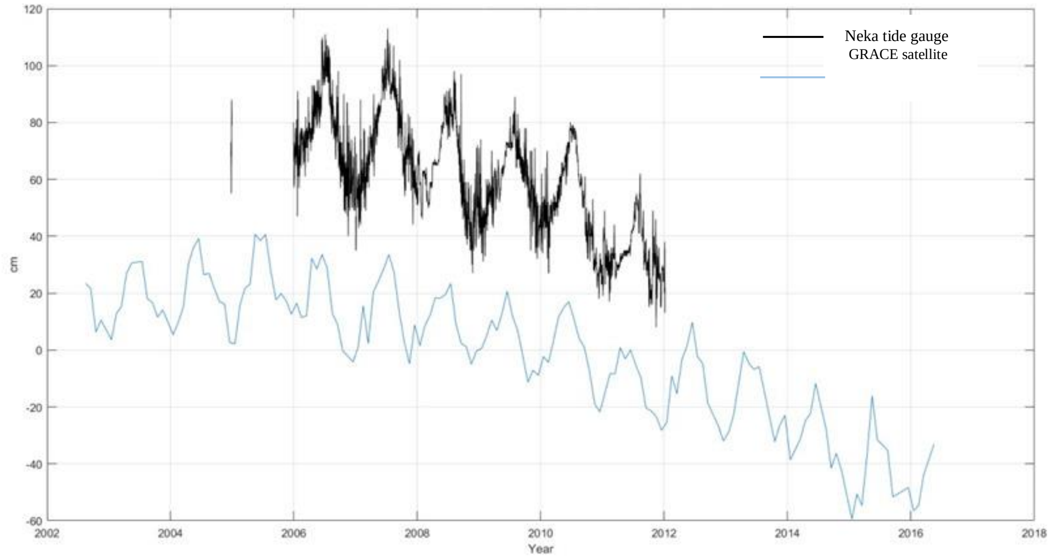

Fig 4: Two time series data from the Neka tide gauge station and GRACE satellite

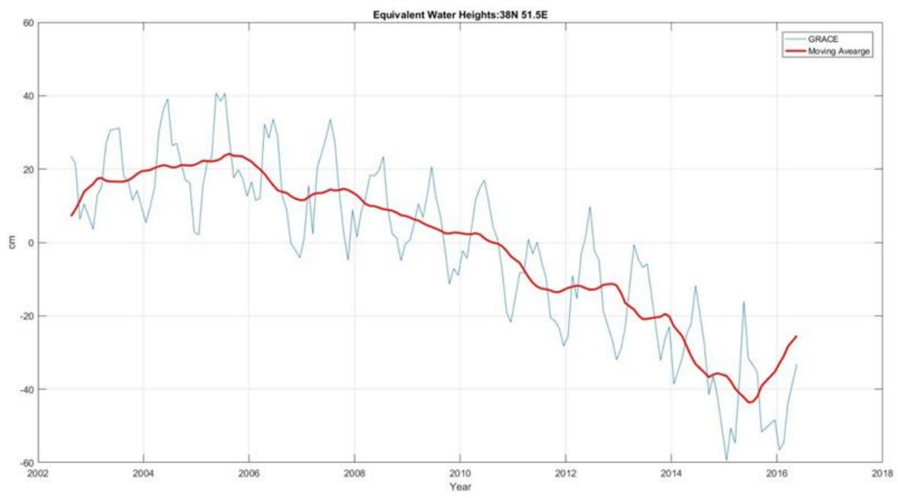

Fig 5: Moving average trend and time series of GRACE satellite

4. Discussion

In recent years, researchers in various marine and oceanographic sciences have conducted numerous studies in this field and have provided various patterns for short and long term prediction of sea water levels. In this research, the Caspian Sea, having an area of about 370000 square kilometers with a length of 2222 kilometers, a width of 222 to 552 kilometers and a water volume of more than 77222 cubic kilometers, was investigated. In this paper, changes in the southern part of the Caspian Sea were estimated using the GRACE satellite. The magnitude of surface changes was investigated at three different points: in the southern, southwestern and southeastern parts of the Caspian Sea.

The outputs from the GRACE satellite results, as displayed in Fig. 3, show the downward trend of the three algorithms in different years. As shown in Figure 5, periodic fluctuations are observed in the time series of each year. These fluctuations occur periodically every year, indicating changes in water levels as the seasons change. Various factors such as climate change, precipitation and river discharge into the Caspian Sea (Loomis and Luthcke, 2017) cause these changes. However, based on the Neka tide gauge information, the tide phenomenon is also effective.

Generally, by comparing the Caspian Sea level in 2017 with that of 2016, it was found that there was a decrease in the water level in 2017 compared to the previous year which was 3.86 centimeters on average. The difference between the amplitudes of the seasonal fluctuations in the above mentioned years was about 14 centimeters and the fluctuation rate in 2016 was more irregular than that of 2017. Also, the velocity of changes in water level in 2017 had decreased by an average of 2 centimeters per month compared to 2016. A similar investigation for Makhachala station shows that at this station, like other control stations, the maximum water level had occurred in June, indicating a correlation between the Caspian Sea level and Volga River inflows. This station also had a higher water level in most of the months of 2012 than in 2011, although this difference is negligible in most of the months. By comparing the data from this station with that of the other coastal stations, it can be concluded that this station is directly affected by the change in the Volga River regime (Arpe et al., 2014).Based on this research, one of the challenges of the Caspian Sea has been the downward trend of water level and its drop in recent years. This issue of water level has been investigated in other studies and the results of this study confirmed this fact. Ozyavas and Shuhab Khan, for example, assessed the fluctuations of the Caspian Sea level using Topex/Poseidon (Ozyavas and Shuhab Khan., 2008), results of which indicated a significant drop in the Caspian Sea level from 1992 to 2005. The researchers found a significant relationship between the drop in the Caspian Sea level and the decrease in the discharge of the Volga River. Loomis and Luthcke (2017), during a long period (2004-2014) and without the consideration of seasonal variability, reported a significant negative trend for the full span of the mission based on GRACE data. (Loomis and Luthcke., 2017).

In another study, Chen et al. (2017), investigated the Caspian Sea level fluctuations from 1995 to 2015 by observing Caspian Sea level variations which were results of rainfall, river entrance runoffs and evaporation (Chen et al.,2017). The results indicated a significant drop and a downward trend in the Caspian Sea level over the case study years, with an average annual sea level drop of approximately 6 centimeters, confirming the results of the present study. Dehbashi et al. also analyzed and anticipated Caspian Sea level fluctuations using time series stochastic models (Dehbashi et al., 2017). Their results suggested a direct relationship between Caspian Sea level fluctuations and the discharge of the rivers flowing into the Sea. This indicates the success of the GRACE satellite in monitoring Caspian Sea level fluctuations, since one of the reasons for the downward trend of satellite diagrams is the frequent building of dams on the rivers that flow into the Caspian Sea.

It is worth mentioning that a vast majority of studies have investigated Caspian Sea level fluctuations in different ways, with results similar to those obtained in this study. In a research by Salehpour et al. (2017) the Caspian Sea level was predicted by using an artificial neural network (Salehpour et al., 2017). In their study, data obtained from tide gauge stations on the Caspian Sea coastline were used and the results indicated that the Caspian Sea would face a significant drop in future. This result was is in accordance with the results of GRACE gravimetric satellite method. In another study, Bani Hashemi and Hosseini examined the effects of climate change on Caspian Sea level fluctuations (Bani Hashemi and Hosseini., 2018). The outcome of this study indicated a drop in the discharge of the southern rivers flowing into the Caspian Sea and an increase in the temperature of the Caspian Sea which resulted in a large amount of evaporation as a cause for the downward drop of the sea level. Kherolahzadeh Chari et al. investigated the factors affecting Caspian Sea level changes using a spectral analysis of coastal tide gauge data (Kherolahzadeh chari et al., 2017). The results of their study confirm the findings of the present study and indicate the downward trend of the Caspian Sea level. They found that the factors of tide and wind speed have an effect on Caspian Sea level fluctuations.

In another study, Babagholi mat kelaei analyzed Caspian Sea level fluctuations (Babagholi mat kelaei., 2018). In this study, using the Anzali Port and NeftyanyeKamni station level gauge data from 2013 to 2018, they concluded that the Caspian Sea level drops was due to a number of factors including decreasing rainfall, increasing temperature and drops in the discharge of the rivers flowing into Caspian Sea. It can also be mentioned that changes in water level were mainly controlled by river inflows, rainfall, temperature change, and water salinity, surface evaporation and changes in basin water balance (Kosarev et al., 2009). However, the effects of factors such as groundwater flow on these fluctuations can be considered negligible (Zekster et al., 1996). The drying up or drowning of coastal zones, the drying up or formation of lagoons and the changing of the range of gulfs and deltas are of the first consequences of Caspian Sea level fluctuations. Changes in the physical and chemical parameters of water, changes in fauna habitat, changes in density and biodiversity and also socioeconomic problems are other consequences of sea water level fluctuations (Mammadov et al., 2016).

5. Conclusion and future works

As a general conclusion, it can be argued that the declining process of the Caspian Sea level has continued since the year 1995, and the impact of global warming and irregular dam buildings on the rivers flowing into the sea have caused a rapid decline of the water level of the largest lake in the world. This issue can have severe economic, social and environmental consequences in the future. Areas like Miankaleh Peninsula, Gomishan Wetland, and Gorgan Bay are drying up, and without necessary preparations we will face serious environmental crises at the northern coast of Iran. Accordingly, in this study, the Caspian Sea level fluctuations between 2003 and 2017 were investigated using the Gravity Recovery and Climate Experiment (GRACE) monthly mass grids. The investigations in three points in the southern part of the Caspian Sea showed fluctuations between a minimum of -42.7 to a maximum of 26 cm. Furthermore, it can be inferred from our investigations that changes in water level are due to seasonal changes, climate change and irregular dam building on rivers flowing into the sea. Therefore, it is suggested that each of the above-mentioned factors affecting the Caspian Sea be evaluated in future research. Another suggestion of this research is to study and evaluate two Challenging Mini-satellite Payload (CHAMP) and Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) satellites in monitoring Caspian Sea level fluctuations and verify them by satellite altimetry.

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