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Investigation of mass changes with GRACE and GRACE-FO satellite

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Abstract

The Gravity Recovery and Climate Experiment-Follow-On (GRACE-FO) satellite is a continuation of the GRACE satellite mission in 2018. GRACE-FO provides relevant information about the water cycle and TWS. Based on GRACE-FO observations, mass changes can be studied temporarily. Greenland, South Africa, Antarctica, parts of Alaska and Bangladesh have a lot of mass loss. In the Middle East, Saudi Arabia and the Caspian Sea also mass loss on average between mid-2019 and mid-2020. The Caspian Sea is bordered by Iran, Russia to the north, Russia and the Republic of Azerbaijan to the west, and the Republics of Turkmenistan and Kazakhstan to the east. The northern part of the Caspian Sea is very shallow. Caspian Sea Level (CSL) has been declining in recent years. In this research, gravimetric satellites have been investigated for CSL. The rate of decrease of the Caspian Sea is 3.87 cm/year. The results also show that the decrease in CSL in the north compared to the center and south is almost half, which needs further investigation.

Introduction

The monthly changes observed in gravity are due to the monthly changes in mass. Most monthly gravity changes are caused by changes in water storage in hydrological reservoirs, the movement of the ocean, atmospheric, and terrestrial ice masses, as well as mass change between the Earth system. In this way, measuring gravity from space provides an accurate measure of the redistribution of the Earth's water cycle. Their vertical value is measured at Equivalent Water Height (EWH) (also known as equivalent water thickness (EWT)) (Wen et al., 2018).

Boergens et al. (2020) researched the quantification of Central European droughts in 2018 and 2019 with GRACE-FO. Water deficits are the highest in the total time of satellite observations in 2018 and 2019.

Landerer et al. (2020) examined GRACE-FO Global Mass Change. During this period, GRACE-FO observed large inter-annual water changes associated with drought (Europe, Australia), heavy rainfall (Central United States, Middle East), and melting ice (Greenland).

Sasgen et al (2020) have identified rapid ice loss in Greenland in 2019 by GRACE-FO satellites. The reduction in ice loss stems from two unusually cold summers in western Greenland, which are accompanied by snow-rich autumn and winter conditions in the east. Velicogna et al (2020) examined the continuation of ice sheet mass loss in Greenland and Antarctica from

GRACE and GRACE-FO missions. The massive 980 Gt increase in Queen Maud Land since 2009 has led to a halt in the mass loss rate of Antarctica since 2016. Deep learning has been used in many studies to predict which could also be useful on the Grace satellite (Sorkhabi et al., 2021; Sorkhabi, 2021).

In this article, Surface Mass Anomaly (SMA) in Iran with GRACE and GRACE-FO satellite has been investigated.

GRACE and GRACE-FO

GRACE-FO's mission is to replace the GRACE satellite. GRACE-FO was launched in March 2018, which is a continuation of the GRACE mission. The GRACE and GRACE-FO tools are designed to measure the mean and time variables of gravity change variables. They can tell the difference in gravity on the planet's surface is equivalent to a 300-kilometer of water only one centimeter thick. GRACE-FO uses the same method to measure gravitational fields as the GRACE mission. The two GRACE-FO satellites are in orbit around each other, about 137 miles (220 km) apart. Small changes in the distance between two satellites, which are caused by the variable pressure of gravity each time it passes through the earth's surface, constitute the measurement. Both satellites are capable of flying forward or backward in the atmosphere. Each GRACE-FO satellite weighs approximately 600 kg, including about 30 kg of nitrogen fuel used for orbital control maneuvers (Wen et al., 2018). In this paper, the steps of Ciracì et al (2020) are used to obtain mass change.

Results and Discussion

Figure 1 (a) shows the mass changes from 2018183 to 2019183. Greenland, South Africa, Antarctica, parts of Alaska and Bangladesh have a lot of mass loss. In the Middle East, Saudi Arabia and the Caspian Sea have also average mass loss. Figure 1 (b) shows the mass changes from 2019183 to 2020183. Greenland, Antarctica, parts of Argentina, the United States and Bangladesh have a lot of mass loss. In the Middle East, Saudi Arabia and the Caspian Sea have also average mass loss.

The annual linear trend is estimatesd to be more accurate (Figure 1 c). Linear mass loss trends are estimated in Greenland more than 0.2 m/year, in Argentina more than 0.05 m/year, in Alaska more than 0.1 m/year, in Bangladesh more than 0.05 m/year, in the Caspian Sea more than 0.03 m/year, in northern Colombia more than 0.0 5 m/year, in Antarctica more than 0.1 m/year and in South Africa more than 0.03 m/year

In Iran, the Caspian Sea has the most mass loss. The Caspian Sea Level (CSL) linear trend shows that the northern regions are less declining than the southern regions. The central and southern regions of CSL have a decrease of more than 0.04 m/year, which in the northern regions reaches less than 0.01 m/year.

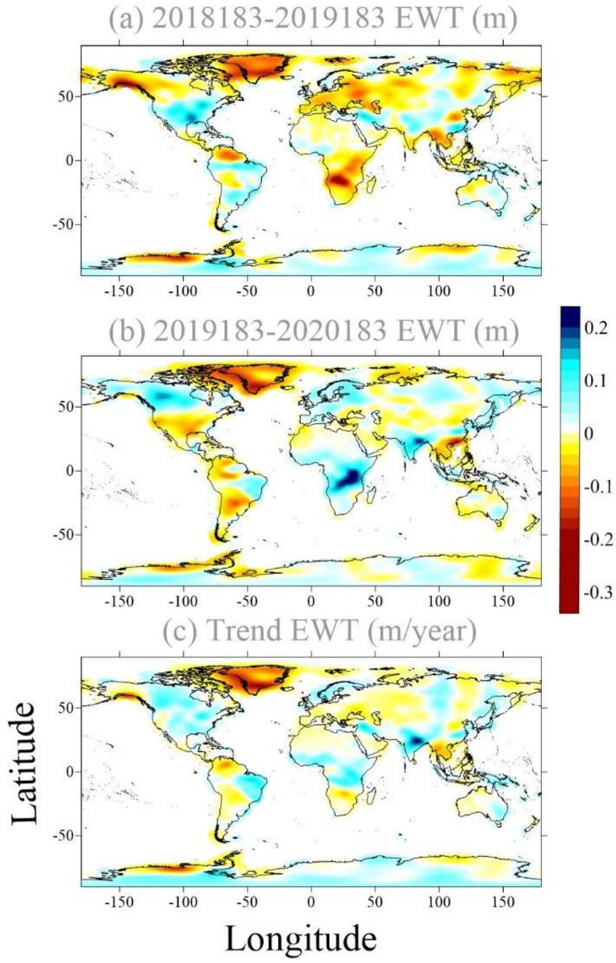

Fig. 1 (a), (b) EWT (m) (C) Trend (m/year)

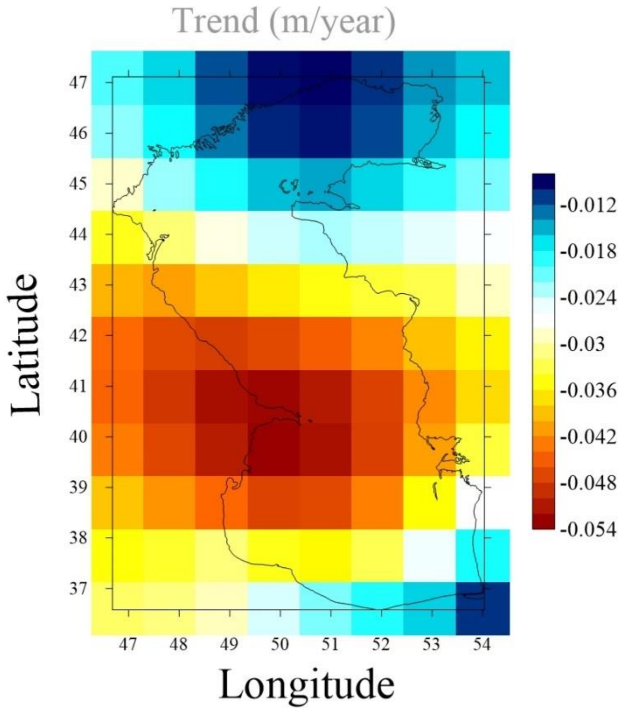

Fig. 2 CSL Trend

Figure 3 shows the changes in the time series north, south, center of the Caspian Sea Level (CSL) with a linear trend. The results show that the CSL is generally declining and an average rate of -3.87 cm/year.

The center and south of the Caspian Sea have almost the same level of decline and the north of the Caspian Sea has a reduced rate of almost half compared to the center and south. Temperature changes in the north and south of the Caspian Sea are not the same, and in the north of the Caspian Sea, cold weather prevails, which causes less decrease of level than in the south.

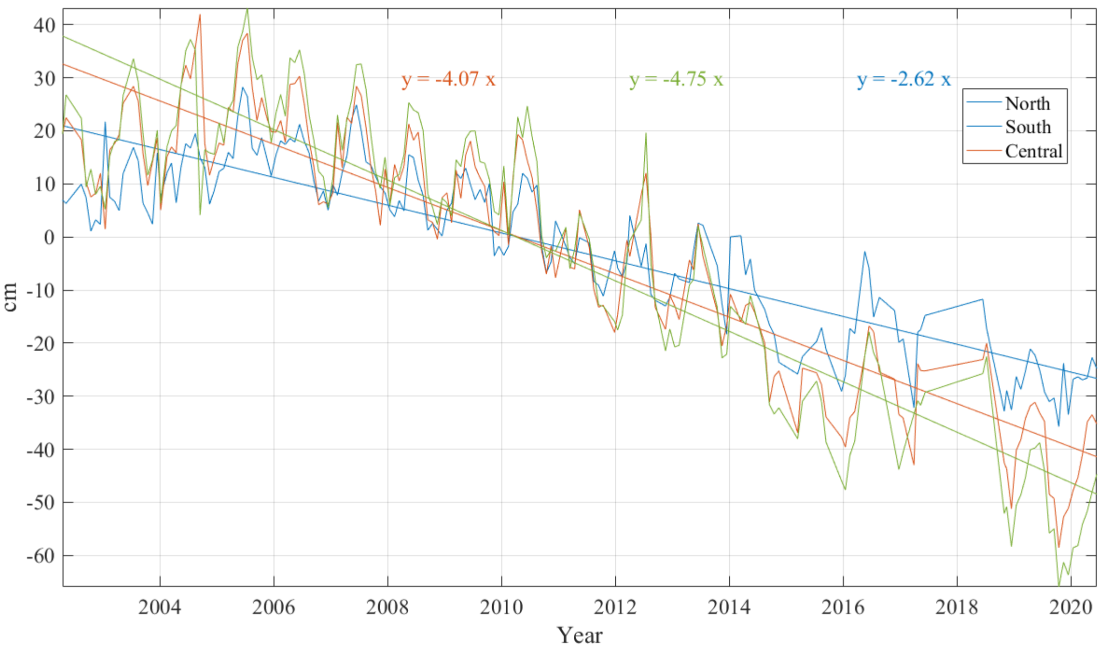

Fig. 3 the changes in the time series north, south, center of the Caspian Sea Level

Statistical characteristics of the north, south and center of the CSL are shown in Figure 4. The minimum CSL in the north is about half that of the minimum in the south and center of CS. Also, the maximum CSL in the center and south is almost twice that of north CS. In general, due to the elongation of CS at sea latitude, the sea level does not change uniformly and needs further research.

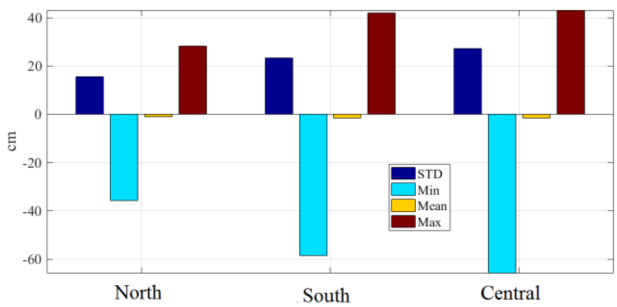

Fig. 4 Statistical characteristics of the CSL

Conclusion

In this research, mass changes were evaluated based on GRACE and GRACE-FO. Greenland is one of the most sensitive areas to mass loss of more than 0.2 m per year due to melting ice. Also, CSL is decreasing at an annual rate of 0.03m and has different decreasing rates from north to south and center (Bruneau et al., 2016; Van Baak et al., 2019; Kostianoy et al., 2019).

CSL was investigated with GRACE and GRACE-FO satellites. Significant results have been achieved by applying preprocessing steps to reach sea level.

So the changes in CSL in the north and south are not the same. In the north of the CSL, the changes are twice as small as in the south and center of the CSL. A closer look requires measuring in-situ observations and other sensors. However, according to research, the temperature in the north of CS is much lower than the south and center (Bruneau et al., 2016;

Van Baak et al., 2019; Kostianoy et al., 2019), which can be the main cause of the difference in CSL. Also, the depth of the CS in the north is less than in the south and center, which can be another effective factor. According to research, the flow of the Volga River is also a reduction that is the main feeder of CS (Seyedvalizadeh et al., 2020). Further research to predict CSL and TWS can also be done with artificial intelligence (Sorkhabi et al., 2022a; Sorkhabi et al., 2022b).

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