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Study of sea level variations during passage of meteorological cyclones over the Qeshm channel

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Abstract

The main purpose of this study is the survey of the atmospheric low pressure effects at sea level oscillations in the Qeshm Channel. For this purpose, the curves of the pressure on the Persian Gulf and Oman Sea, during the passing of the atmospheric low pressure system, are extracted across the region. During the time of occurrence of these events, sea level oscillations in the coastal areas of northern Persian Gulf and Oman Sea at the time of the presence of atmospheric low pressure system, with the same surface pressure in Qeshm channel, has been analyzed. In this analysis by filtering the dominant tidal components, the share of atmospheric low pressure are extracted at the sea level oscillations The results show that fluctuations of sea level due to atmospheric low pressure in Qeshm Channel is about 70 to 100 percentage larger than fluctuations of sea level in other parts of the low pressure systems with similar surface pressure. The presence of atmospheric low pressure systems usually increases daily average of Qeshm Channel water level by about 20 to 40 cm.

Keywords: Non-tidal seal level variation, Qeshm channel, storm surge
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1. Introduction

Storm surges are occasionally severe enough to lead to a significant loss of life and damage to property in coastal areas (McRobie al., 2005; Wolf and Flather, 2005; Wang et al, 2008). Disturbance of sea level at the time of passing storm has two reasons: the first reason is the winds, which by applying stress to the water surface cause momentum transfer to the water and caused sea level change and surface waves which are able to move energy to distant area further from shaping locations. The second reason is change of the atmospheric pressure at the sea surface at the moment of storm, which can cause the change of the sea level. This effect which usually has been known as the "inverse barometer effect" is expressed a sea level change (decrease/increase) in terms of the atmosphere pressure change on the sea surface (in millibar). For every millibar decrease/increase the sea water level variations will increase/decrease by one centimeter.(Khalilabadi et al, 2005).

In this study the effect of movement of tropical cyclones over the northern part of the Persian Gulf including the Qeshm channel is considered. The non-tidal component of the sea level change as a result of the cyclone movement over the open sea and in the Qeshm channel is compared. The predicted tidal component of the sea level change is subtracted from the original signals of the sea level variations to extract the non-tidal components at the stations in and outside the channel. The two non-tidal components of the station in and outside the channel are compared in order to consider the effect of the channel on this storm surge.

2. Materials and Methods

2.1. The Study Area

To considering the effects of Qeshm channel on storm surge that are situated in Bandar Abbas and Basaeedoo stations in the North East and South-West channels respectively, have been compared by storm surge in Kangan and Jask stations. The reasons of this comparison are as follows:

On the subjected days, the presence of atmospheric low pressures at these stations is similar, and they have been in the same pressure range. These stations are almost having the identical depths. Because the Storm surge is a long wave and the depth of water effecting on it. Except Basaeedoo, the permanent tide gauges are installed and are measuring sea levels continuously throughout the year.

Fig. 1: The Qeshm Island in the Hormoz strait

2.2. Data Analysis

In the present work the tidal analysis in the time domain is performed using the TASK-2000 package (Bell et al., 1999). One complete year of observations, namely 2009 for Jask, Bandar-Abbass, Basaeedoo and Kangan analyzed up to 58 tidal constituents, with periods ranging from sixth-diurnal to diurnal and including some long period too.

In order to consider the effect of Qeshm channel on the storm surge, the storm surges (the non-tidal component) in Bandar Abbas and Basaeedoo stations, which are respectively on the north east coast of the channel and south west inside of the Qeshem channel, were compared with the storm surge in the Kangan and Jask stations. And thereby can achieve the non-tidal oscillations of sea level in the periods of storm occurrence. Analysis of meteorological and sea level data is described in the previous sections. More, how to influential and surge of several storms that listed in Table 1 is studied. Fig. 2 shows an example of measured oscillations of sea level water and the oscillations in sea level (S.L) after filtrate of the calculated tide (calculated non-tidal oscillations) in Jask station, for (a) March 2006 and (b) January 2006.

The atmospheric pressure at sea level derived from FNMOC model. FNMOC is one of the DoD's primary central production site for worldwide computer-generated operational meteorological and oceanographic analysis and forecast products. FNMOC is an echelon IV command aligned under the Naval Meteorology and Oceanography Command (NMOC) and a service provider of U.S. Fleet Forces. FNMOC is co-located with Naval Research Laboratory (NRL) Marine Meteorology Division, a representation of successful transition of research into operations. FNMOC maintains close ties with the nearby Naval Postgraduate School (NPS). FNMOC runs operationally a global numerical weather model called the Navy Global Environmental Model (NAVGEM) which replaced Navy Operational Global Atmospheric Prediction System (NOGAPS) in February 2013. (Rosmond et. al., 2013).

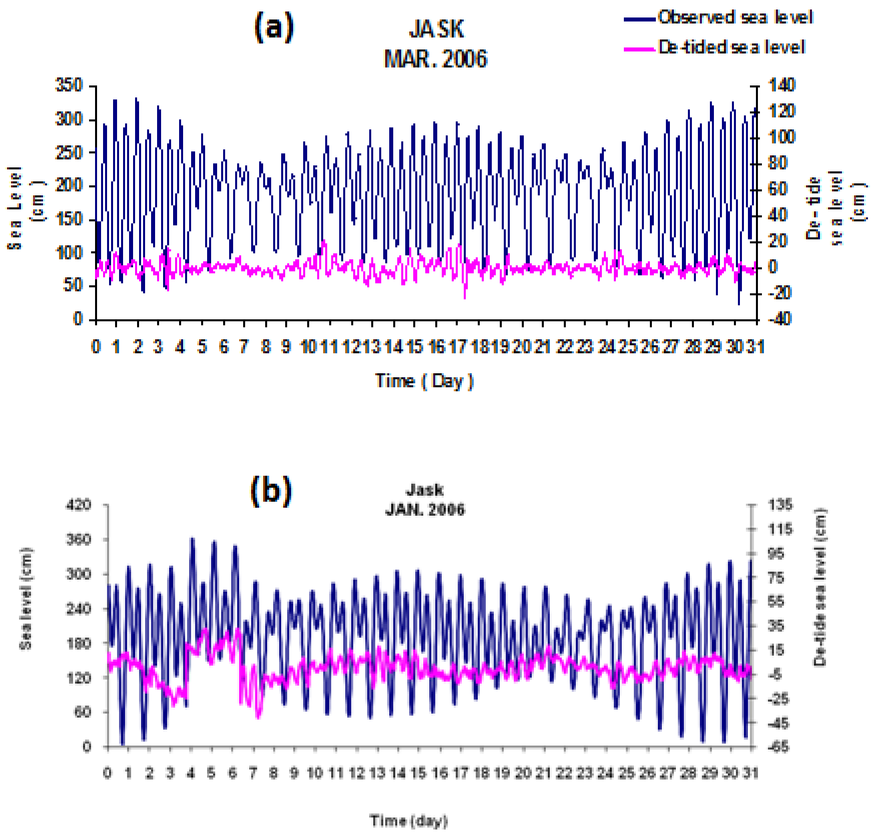

Fig. 2: Time series of S.L measured and calculated non-tidal changes of S.L for Jask, in (a) Mar. 2006 and (b) Jan. 2006.

3. Results and Discussion

3.1. Event 1: Passing an atmospheric low pressure cross Persian Gulf on October 2009

As Fig. 3(a) shows, an atmospheric low pressure system has been entered from the south of Persian Gulf on October 23, 2009. This low pressure system is moving to north side, so that atmospheric pressure in Iran's Persian Gulf coast is lower than the previous day on October 24 (Fig. 3-b). Then again, the atmospheric low pressure is decrease from the south of area (Fig. 3-c)) and gradually, disappears from the Persian Gulf, So that there is no trace of the low pressure system presence in this area on 27 October (Fig. 3-d).

As Fig. s 3a, 3b, 3c and 3d show, the presence of a fore mentioned atmospheric low pressure system on Kangan and Bandar Abbas has been the same (both are located between two similar same-pressure lines) so non-tidal oscillations comparison (storm surge) in these stations, will be determined the affection of Qeshm channel on the surge height. Fig. s 4a and 4b show the observed oscillations of sea level with oscillations due to climatic factors, respectively in Kangan and Bandar Abbas stations. Figures 3a, 3b, 3c and 3d show the most affected storm on these two stations has been occurred on October 24. In Figures 4a and 4b the maximum storm wave height is observed on the same day. If the geometry and situation of Kangan and Bandar Abbas was the same in the Persian Gulf, and was expected shape and height of surge is also similar in these two stations because the atmospheric low pressure had similar presence on both stations and the rate of pressure drop was similar in both. But the comparisons of surge height between two stations show that the surge height in Bandar Abbas is about 66% more than Kangan.

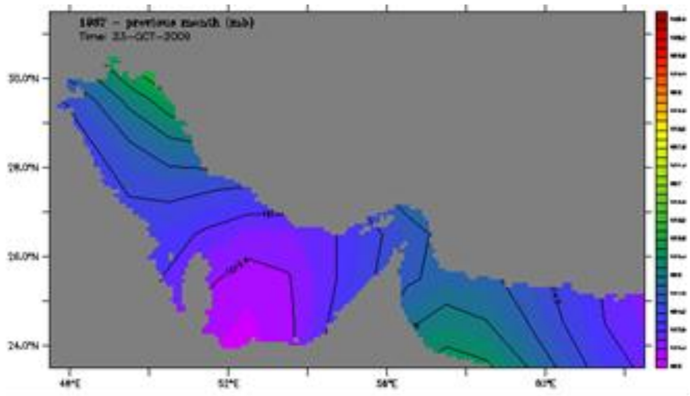

Fig. 3a: An atmospheric low pressure system entered fom South of Persian Gulf on Oct 23, 2009.

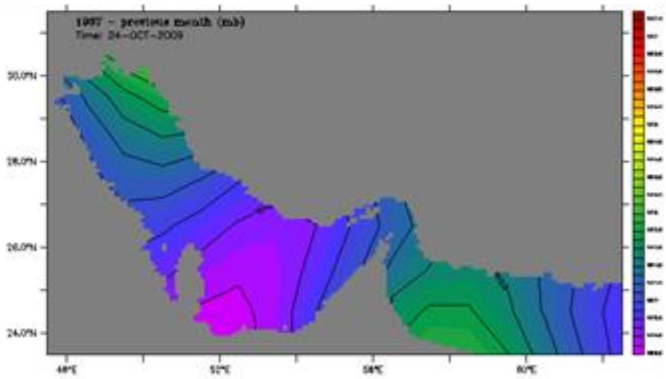

Fig. 3b: The atmospheric low pressure system movement is from South toward the North of Persian Gulf.

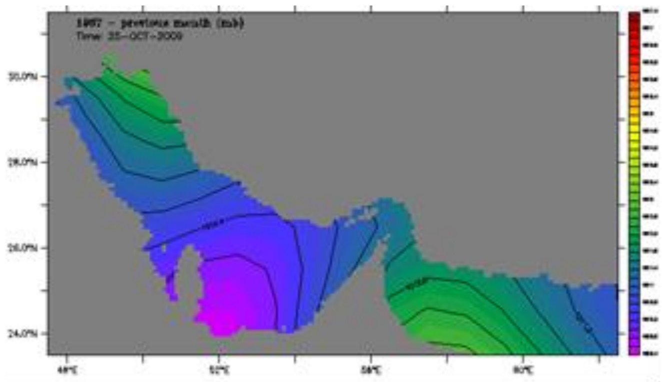

Fig. 3c: An atmospheric low pressure is evacuated of South part of Persian Gulf on Oct 25, 2009.

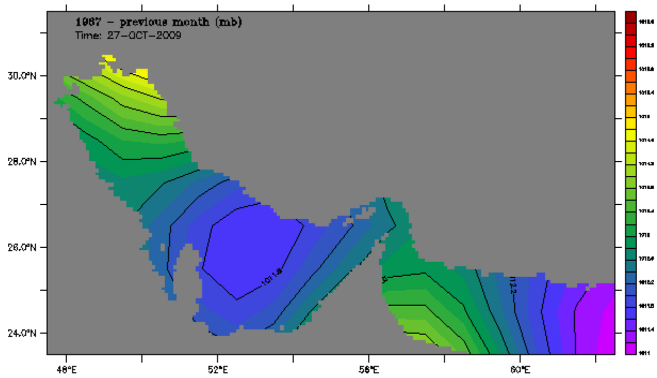

Fig. 3d: Evacuating of atmospheric low pressure across the Persian Gulf on Oct 25, 2009.

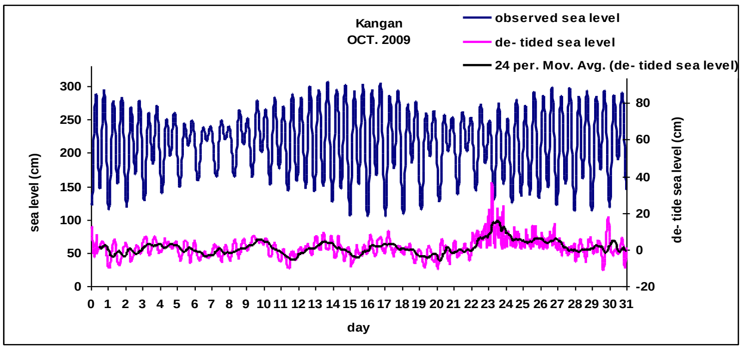

Fig. 4a: The observed oscillations of sea level (blue) with oscillations due to climatic factors (red) in Kangan.

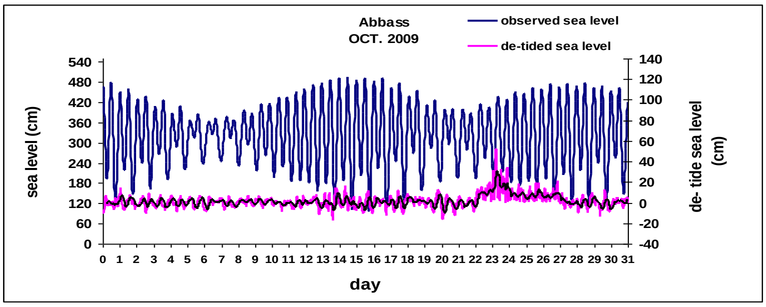

Fig. 4b: The observed oscillations of sea level (blue) with oscillations due to climatic factors (red) in Bandar Abbas.

3.2. Event 3: Passing of low pressure cross on Persian Gulf and Oman Sea, Aug. 2009

An atmospheric low pressure system has been affected the middle part of Persian Gulf, and parts of Oman Sea West side on Aug 10, 2009. (Fig. 7a). this atmospheric low pressure system has been moved toward the south and the storm eyes area is dropped. As Fig. s 7a and 7b show the presence of this atmospheric low pressure system has been the same on Basaeedoo and Jask port both are located between the two similar same-pressure lines) on Aug 10 so the non-tidal fluctuations comparison (storm surge) in these two stations will be determined the effects of Qeshm channel on the wave height. In Fig. s 8a and 8b the observed fluctuations of sea level with fluctuations due to climatic factors, respectively, are shown in Basaeedoo and Jask port stations. The comparison of these fluctuations in two stations show that storm surge height in Basaeedoo port is 100% more than Jask port.

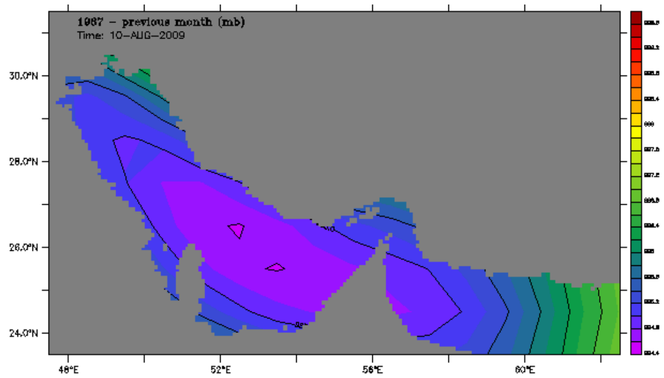

Fig 7a: A low pressure system has been affected the middle part of Persian Gulf, and parts of Oman Sea west side on Aug10, 2009.

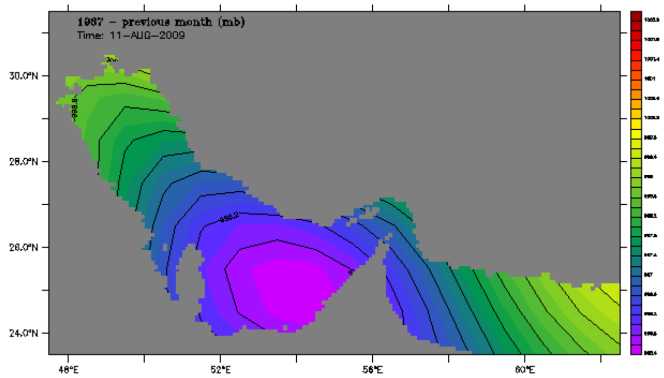

Fig 7b: A low pressure system has been moved toward the south and the storm eyes area is dropped on Aug11, 2009.

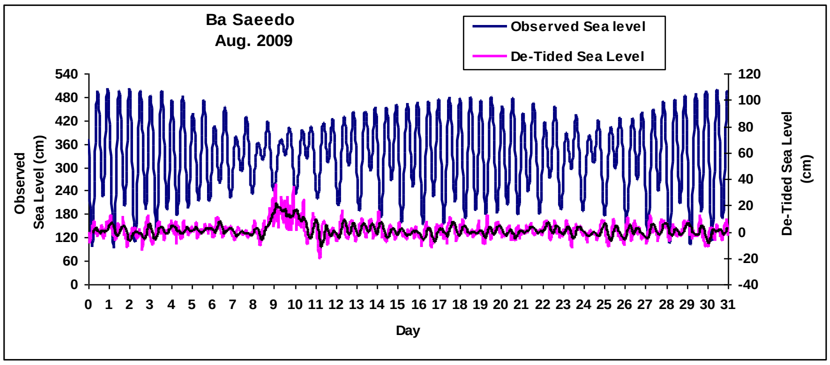

Fig. 8a: The observed fluctuations of sea level due to climatic factors in Basaeedoo Port.

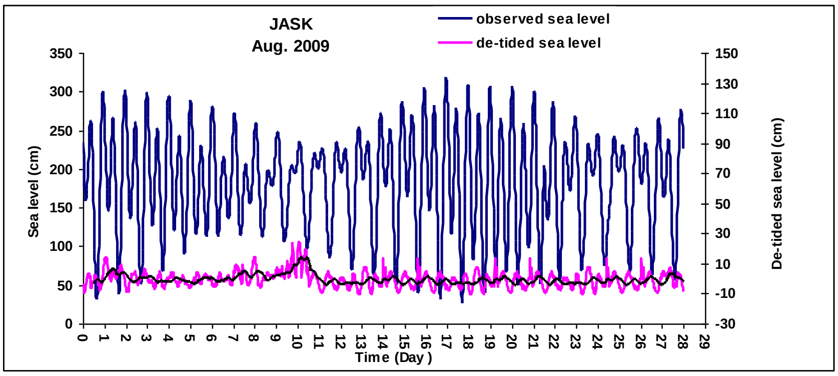

Fig. 8b: The observed fluctuations of sea level with fluctuations due to climatic factors, Jask port.

In this study, about 20 occurrences have reviewed that feature of several under consideration waves are shown in table 1. Table 1 shows the wave height, the amount of air pressure reduction on sea level and date of wave occurrence on 2009. The first column of the table, are the events that have been studied, the second column is name of the stations, and the third column is the wave height in the existing stations, the forth column is the date of wave occurrence and the fifth column shows the air pressure on the sea level.

The results show that the Qeshm channel is much more affected by the storms which are coming from south and south east to this region. The variations of the sea level caused by atmospheric low pressure systems in the Qeshm channel is greater than (about 70 to 100 percent) those outside the channel with similar sea level pressure. These changes of sea surface in the other regions which have had the same surface pressures were found to be much smaller than those inside the channel. Typically, the presence of the atmospheric low pressure system causes the change in mean sea level in the Qeshm channel by about 20 to 40 cm larger than those outside the channel.

Table 1: The surge height and the amount of air pressure reduction during some storm sure occurrence on 2009.

Event No.	Station	Mean Sea level increasing during storm surge [cm]	date	Atmospheric pressure [mb]
	Kangan	18		
1	Bandar abbass	30	24 Oct. 2009	990
	Kangan	20		
2	BaSaeido	40	20 Jul. 2009	996
	BaSaeido	20		
3	Jask	10	10 Aug. 2009	995

4. Conclusion

Comparison of storm surge in strait of Hormuz with another parts that are affected by a similar atmospheric low pressure system and a pressure range shows that fluctuations of sea level due to atmospheric low pressure in Qeshm Channel is about 70 to 100% is larger than fluctuations of sea level in other parts that these low pressure systems have the similar presence.

The statistic consideration shows that Qeshm Channel is more under the affection of the storms that are coming from South or South East that these storms are Tropical storms mainly that are weak by moving toward the North. The storms that are entering to Persian Gulf from North West, rarely, can reach to Strait of Hormuz and Qeshm Channel.

Alternation period of storm surge is between one to two days in the Qeshm Channel. The presence of atmospheric low pressure systems usually increases daily average of Qeshm Channel water level about 20 to 40 cm. Tide is mainly semi-diurnal in Qeshm Channel. Because of Channel geometrical shape, tidal currents and the currents due to storm are strong in the Channel that the presences of these currents cause increase of interaction of tide - surge.

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