Investigation and prediction of fluctuation level and SST in Oman Sea due to wind variation using Satellite altimetry Data

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Abstract: Prediction level of volatility in coastal waters is necessary to prevent marine disaster and planning and management of beaches. In order to predict the level of volatility and SST and space, updated information is needed. Providing information about coastal waters and marine areas are time-consuming and costly. Today, much information are available by using data of satellites. In this study, by using data from satellites and ground stations, the SST was developed on the shores of the Sea of Oman. Then to predict the water level fluctuations in the wind artificial neural network algorithm was used which involved information about wind speed, wind direction, air pressure and water level at any point. ANN algorithm was used to predict fluctuations which has negative bias (-7.14%) and absolute error was 0.13 meters. This means that the model significantly predicted the long-term estimate which is close to reality, but the amount of error is much closer to reality. The results also showed a standard deviation of SST maps derived from satellite data which was 0.56 meters.
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1. Introduction

Sea level changes especially in coastal areas have significant impact in shipping, coastal construction and people living in coastal areas, so study of sea level changes in most parts of the sea has interest to oceanographers and marine scientists which was due to tidal measurements and the mean sea level of the oldest sea views (Mahdizade and Kasbi, 2014). Water level in different parts of the seas and oceans is variable, with some ups and downs. This change is due to various factors such as tides, the sea currents in the area, gravity, wind or changes in air pressure (Azarmsa, 2002).

The level of the water basins was considered as an important factor in the process of their normal activities. Volume and surface area of coast is considered as a function of determination for basin water level. The level of the water basin and range of it will change over time. Long-term changes in water level of oceanic basins and seas changed slowly due to climate change and geological processes. Closed water and basin water level fluctuations arises in a shorter time and in addition to these factors, human factors show its effectiveness quickly (Mahdizade, 2002).

Waves caused by fluctuations on the coast, causing flooding, destruction of coastal areas, including infrastructure, residential and agricultural areas and causes of mortality that the extent of damage depends on the height of the beach and wave height. To proceed to the design and construction of marine structures must first pay review and predicted water height (Mahdizade, 2002). Research on Evaluation and prediction of coastal waters fluctuations since it is important that it is possible to identify dangerous areas and warning systems, in order to minimize the possible damage. Wind is one of the parameters that play an important role in some areas, especially in the southern regions. Generally, process of change of coastline winds along the coast are in line with the longshore currents and changes in sea level, longshore currents and pressure changes of the winds perpendicular to the beach. Because they can cause relatively unobstructed flow along the open coast, but winds perpendicular to the coast, at least are strong enough and have an important role in this respect (Rahnama Nia, 2003). In total sea level fluctuations are of great importance and can have a significant impact on the coastal economy.

In the southern coastal areas, these fluctuations varies according to wind speed and direction. Therefore, according to the free zone and parts of southern Iran, related shores of the sea could determine the rate of advance and recession of water in the region. Coast of Oman Sea as well as geographical positions include natural, coastal water depth with multiple bowls and without major ports in Asia and dozens of other privileges, especially in terms of international trade and commerce, fisheries and industry specific economic development. Oman Sea is in the range of 56 to 60 degrees east longitude and 22 to 27 degrees of north latitude and its length is 360 km. Its port is near to the southern coast of the Strait of Hormuz and Gulf of Oman. The Sea of Oman and the Strait of Hormuz is about 610 kilometers and an area of 903×103 kilometers square. The sea was quite deep and the depth of it is around 3,500 meters. Near the West coastline, it has been reduced from the depth of 72 meters. Due to the Tropic about Oman Sea, one of the warm seas Southwest Asia. Waves that are formed in the Oman Sea is mostly under the influence of monsoon. In Oman Sea, the Indian monsoon wind (wind direction is from the south in summer), sometimes advancing low pressure from centers and fronts of tropical Indian Ocean to Oman Sea. Waves that appear in Oman Sea are divided into two categories: waves caused by winds and waves caused by tropical storms and it's noteworthy that tropical storms in this area happen very rare. The area affected by the wind pattern, and pattern changes in water level fluctuations have a direct impact on the region's environment and why should the oscillations of the wind effect on the volatility of its control over the region should be determined (Fahimnia, 1998).

Today, Oman Sea is the most effective, most cost and broadest way of communication for military, commercial and economic activities and ties between different countries. Therefore, recognizing the depth and shape of the substrate material, water currents, tides, salinity, climate, winds and marine biologists is important. According to the information and documents on the International Hydrographic Organization, the northern Persian Gulf and Oman Sea, much more information is available (Dindar et al., 2012). Although satellites with global coverage in just a few days on the Earth and with unparalleled precision, wave height, sea surface temperature, ocean color, and is difficult to measure wind speed and direction harvested water surface topography (Menard et al., 2003). There is a limited view of the ocean in the last thirty years. At that time, only partial and discrete and fixed data were available locally. Now the satellites are flying the full surface of the planet in just a few days and with unparalleled precision, wave height, sea surface temperature, ocean color, wind speed and direction to measure the surface topography water harvest (Menard et al., 2003). Therefore, the effect of climate change on the wind and SST fluctuations coastal waters of Oman Sea will be examined with the help of satellite data.

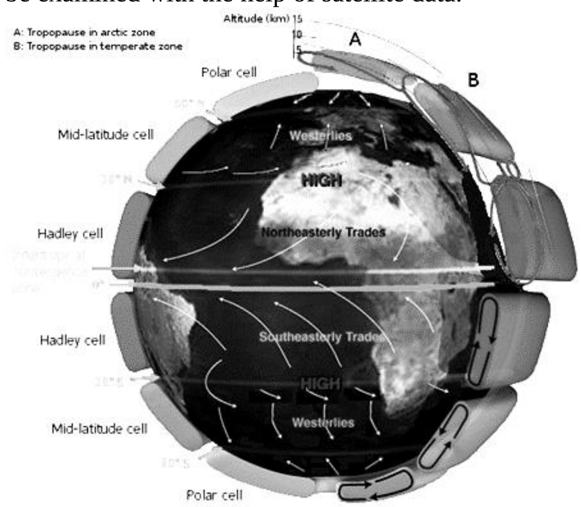

Figure 1. Marine currents (Babaei, 1997)

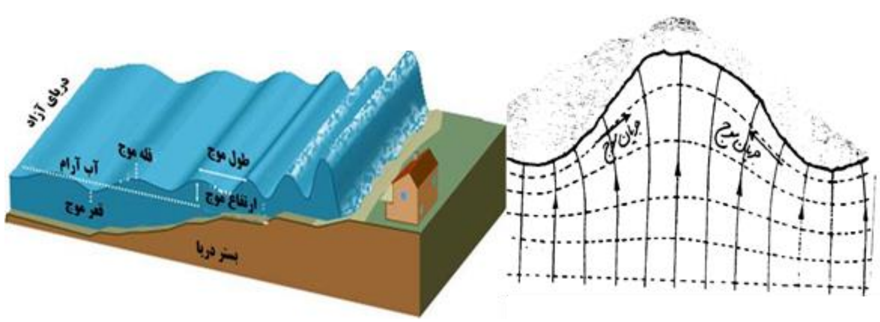

Figure 2: Over the waves in the beach

Surface elevations and traditional basis in different countries is based on tide gauge observations and field observations data which was one of the most important factors in determining the absolute height of geodesy and mapping projects. For determining these parameters, define the basis for measuring the height has utmost importance. Of the surfaces that will be used as the basis elevation, geoid was evaluated. Gauss and Listing, defined geoid surface, (Ardalan et al., 2002). The definition of the geoid, which is a physical level by measuring the height of it can be achieved anywhere with absolute height. Measured by precise leveling geoid height anywhere to require the exact location of the surface is known. But because the geoid is based entirely on the open sea average level in all areas of the high seas not comply, the measure is in trouble. Separation between the geoid at every point with the average open sea, as sea surface topography (SST) is defined. After 1980, the satellites measure SST were increasingly used and its capabilities has been a major transition from observations of SST changes. Measurements made from space by radio Sensors in a few wavelengths in the infrared part of the spectrum of satellite sensors embedded in the built magnet (Esfandiyarnejad et al., 2004).

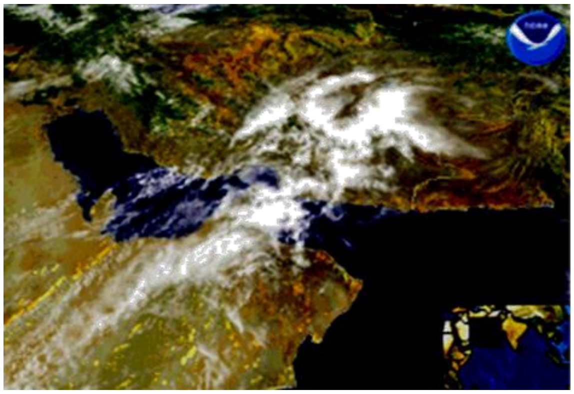

Figure 3: NOAA satellite image of the Gulf of Oman.

Examples of applications of NOAA satellites include:

• Mapping of land cover;

• Study of natural disasters such as flood prone zones;

• Study of marine pollution;

• The desertification and creeping deserts;

• Provide vegetation index;

• Mapping the Earth's surface temperature;

• Study of volcanic activity;

• Locating forest fires;

• Estimate the amount of moisture, snow cover and snow and ice cover mapping;

• To examine the areas of cloud and environmental applications;

• Mapping the pattern of sea surface temperature;

• Mapping the overall density of ozone and water vapor sounder.

Literature Review:

In recent years, many activities were carried out to model the use of satellite altimetry and sea level changes in the Caspian Sea, Persian Gulf and Oman Sea. Including Rostami (2002) and Poursharifi (2006) to model the topography of the sea surface in the Persian Gulf and Oman Sea via satellite altimetry. Mosayebzadeh (2002) determined the topography of the surface of the water in Oman Sea and the Persian Gulf through a combination of GPS data and tide gauge observations; Hashemi Farahani (2003) Maped tidal amplitude and phase via satellite altimetry be determination on a global scale; Sohrabi (2004) issue of marine chart using three-dimensional coordinates of GPS and satellite altimetry observations; Arab Sahebi (2004) determined gravity field of satellite by altimetry observations; Sanaei (2005) checked the validity of marine gravity data via satellite altimetry and Adnani (2002) examined the capabilities by Gauss method and using satellites data for determination marine gravity. Also, Jafari (2006) attempted to model the trend of the Caspian Sea level using satellite altimetry observations and coastal tide gage; Jalil Nejad (2006) evaluated the different models used in determining MSL by satellite altimetry observations. In addition to the AVHRR sensor and MODIS sensor, 36 bands of 20, 22 and 23 bands are in the range of 4 micron spectral imaging capability and also mid-infrared spectral bands 31 and 32 in the range of 10 to 12 microns in the infrared range to optimize and accurate measure of embedded SST (Martin, 2004).

Azarmsa et al (2007) showed that how the monthly average and seasonal changes were examined in water level in the Persian Gulf and Oman Sea during 1994. For this purpose, 365 daily pictures of the satellite altimetry in the region were prepared and analyzed. The changes observed in the region during 1994 was equal to +57.5 and -47.5 that. The maximum change in water level observed in October and January and the lowest water level change was observed in the months of June and August. The annual average amount of changes during 1994 was zero. In addition, most of the coast of Iran, especially in the Strait of Hormuz, average monthly water level variated from less than 15 cm and also values of these changes near the mouth of the Arvand River was recorded about 20 to 30 cm.

Research goals

- The SST fluctuations in the coastal waters of the Gulf of Oman;

- Short term forecast wave level in Oman;

- Preparation of sea surface topography using satellite data;

- Comparison of the results with the current status of field data in some areas and validation;

- Determination of the standard deviation obtained from integrating field data with satellite data;

- Comparison of forecast accuracy.

Materials and methods

To calculate the water level fluctuations caused by wind in the North Sea of Oman coasts, as mentioned, these fluctuations were written as equations of motion and then a final calculation model was obtained as follows:

$$\frac{dv}{dt} = -\frac{\nabla P}{\rho} - 2\overline{\Omega} \times \overline{V} + g + \frac{F}{\rho} \quad (1)$$

The overall equation has three components along the x-axis and y and z-axis. Therefore, the sum of the values of changes $\frac{dv}{dt}$ ، $\frac{du}{dt}$ و $\frac{dw}{dt}$ would determine W, V and U, including spatial and temporal variations. Therefore, by changing wind speed fluctuations, the water level can be calculated. In this study, the slope of the seabed hydrographic maps and wind data were determined, including wind speed and wind direction and the wind was extracted from satellite data. The effect of changes in wind speed mass conveyed in the Eikman layer that is perpendicular to the wind direction, the effect of changes in wind speed mass conveyed in the Ekman layer that is perpendicular to the wind direction varies and will be different in the two places together. Therefore, any change in wind speed (assuming constant wind direction and its actions after calculating initial displacement) and convergence divergence is important. By solving the equations of continuity oscillating currents at the desired points respectively. By calculating the movements of the forces, the fluctuation of the water level was just a network of points and curves to predict fluctuations and wind direction.

In the final stage, sea surface topography obtained using computational interpolation and therefore short term forecast by regulation the swing shift points of the surface water.

The next step is to simulate sea-level fluctuations and artificial neural network model was used. The model inputs are as Figure 4:

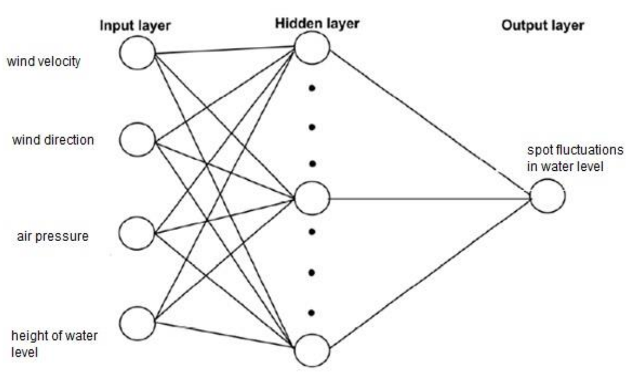

Figure 4: A schematic representation of neural network used in this study

Results:

After extracting data, it was analyzed for the study area in order to estimate mean sea level. After determining the parameters mean sea level, due to the low accuracy of satellite altimetry data in near-shore areas, the global geoid data for these areas were calculated by using EGM08 (Beckley et al., 2007).

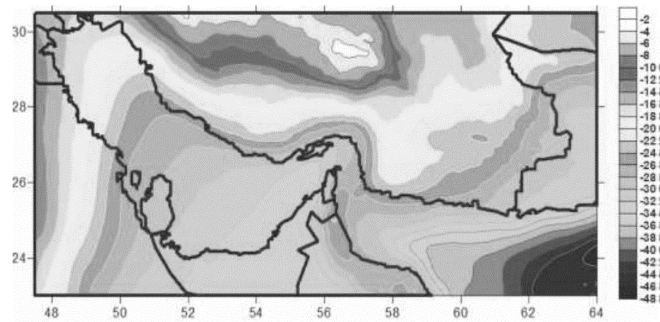

Figure 5: geoid height in meter based on EGM08

Anomaly values of regional gravity for average water level was calculated for geoid determination and then the data were converted (Sandwell and Smith., 1997).

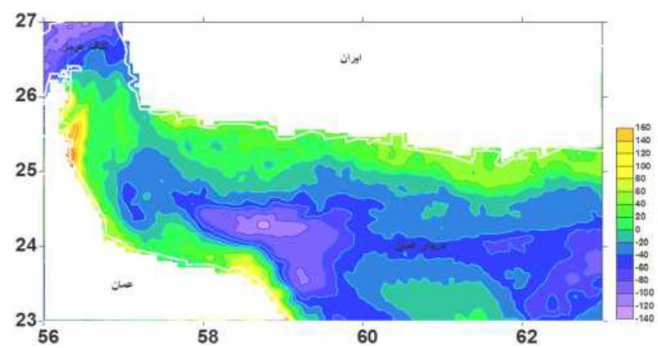

Figure 6: Map of anomaly gravity

Map SST (SST) is the difference between mean sea level and geoid layer information pixel by pixel, respectively. SST maps were prepared on that basis.

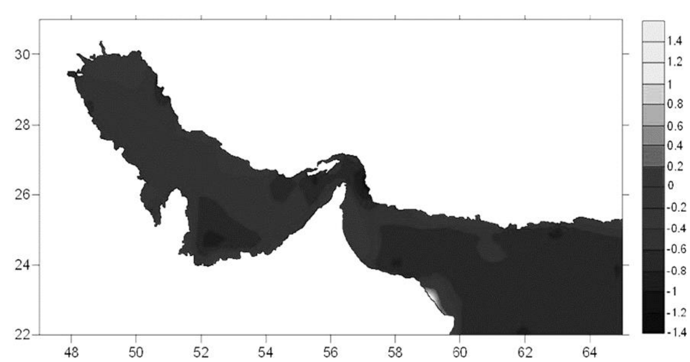

Figure 7: Water surface topography in units of m

Ocean currents, wind velocity and conditions based on obtained data for the years 2009 to 2013 are as follows:

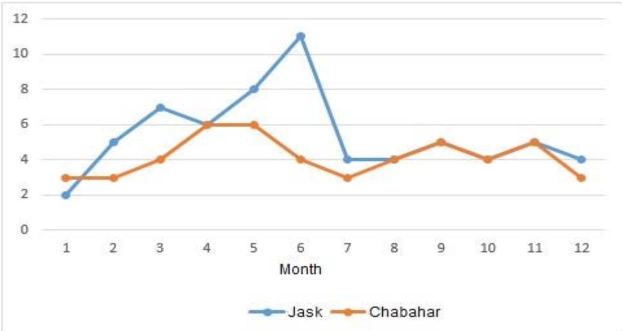

Figure 8: Comparison eastern winds of Jask and Chabahar in the early months of 2009

The study of ocean currents and wind velocity and conditions based on data for the years 2009 and 2013 are as follows:

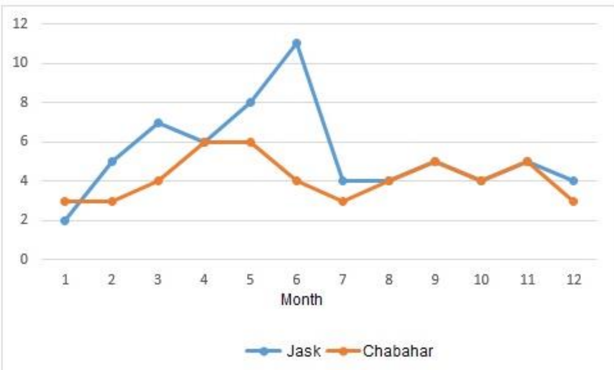

Figure 9: Comparison speed of eastern winds on Jask and Chabahar coast in early months of 2009

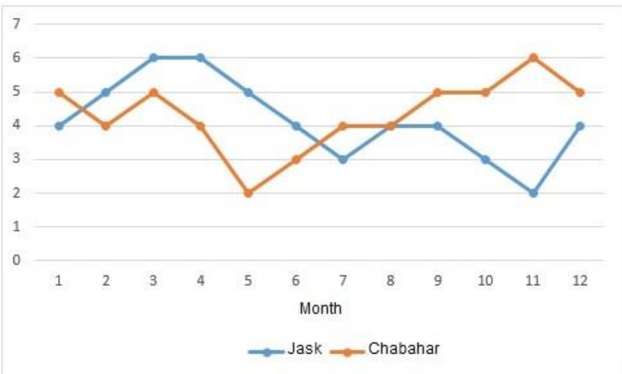

Figure 10: Comparison speed of western winds on Jask and Chabahar coast in early months of 2009

Based on the results of predictive artificial neural network model developed in this study and comparison of the results with observations, true information was validated to specific locations at certain times of the oscillations they existed and evaluation model.

Discussion:

Nowadays, the lack of sufficient information and also time consuming and expensive methods to obtain hydrographic map have prompted researchers using satellite altimetry data to estimate SST sea level fluctuations. In the present study, the altimeter satellite data of Topex-Poseidon become general to calculate the geoid vertical deviation angles. According to the shortcomings of satellite altimetry in coastal areas, in the areas geoid global model EGM 2008 was extracted precisely. In the next step, geoid height values from a combination of satellite data and global geoid model using the inverse formula became Gravity anomaly parameter. Finally, comparison the results with the bathymetry obtained from audio hydrographic ship and the consistency of these two models is studied in most areas. The standard deviation of the two models in a common area of about 41 m was evaluated and due to changes in the depth of one kilometer, the accuracy may be appropriate. This model in future studies is applicable for analyzing geophysical, geological, tectonic and hydrographic procedures. For future studies, comparisons between anomaly data of ground and satellite gravity are recommended and more data would be obtained by using satellite altimetry.

In order to prepare a new map of SST within the Oman Sea, the integration of data of Topex-Poseidon satellite altimetry were used during the years 2009 to 2013.

Differences in average sea levels resulting from global geoid models and satellite altimetry was less than half a meter. Therefore, this model can be corrected based on the elevation of the free water level measured by tide gauge medium. SST model also used for modeling of sea currents in the ocean and has particular importance. For better evaluation which is recommended in case of dense gravity, data for proper distribution of the region were obtained using local models rather than using global geoid models (Kiamehr, 2006).

Mean level pressure values of Oman sea was up to 996.3 to 1019 mm that these changes are superficial differences between 16.7 to -6 cm on the sea. Southeast winds and west winds had higher speed than the speed of flow in this direction and therefore have the greatest speed.

Changes in sea level along the coast (x) on a contour line (D = cte) have direct relationship with square of the wind speed, so in months when wind speed is higher than in other months, these changes have increased the level changes along the x axis between 0 to 2.16×10^{-6} for the depth of 10 m. Sea currents are exponentially decreases with depth.

From 2009 to 2013, the maximum wind speed was 6 meters per second and the least one was 4 meters per second. The amount of the flows at up level was 0.7 meters per second, and at least was 0.11 meters per second at an angle of 45 degrees relative to the direction of the wind and Eikman spiral decreases with depth.

By comparing the speed and direction, all kind of winds can be determined by taking into account by Coriolis force. For example, if the wind is western, Coriolis force go to the West and thus are flowing toward the sea. As a result, sea level rises and the enables a rich source of food for sea creatures and what will contribute for the beach. If the east wind is the flow Coriolis force to the East and move to the coast, the water level is coming down and benefits of this process is that oxygen and other materials transferred to the sole and provides a good environment for aquatic activities.

To save computational time and good sea volatility, knit network of information is provided in areas close to the coast. The development of this network of information is time consuming and requires several researches. The various models are designed to predict various events. The artificial neural network is applicable through a combination of quantitative and qualitative input data and the ability to predict stratification information which is frequently higher than regression methods. The results shows good accuracy in the prediction of the model in the wind for fluctuations in Oman Sea. Although the accuracy of the model should be at a lower speed but overall accuracy is high (absolute error: -7.14 percent). Based on ANN models generally predict results which have been negatively skewed reality that is less than predicted one. These results are consistent with similar studies of Chen et al (2012) as well.

Based on the results of this study, it is possible to predict the water level fluctuations caused by hurricanes and this model could be used in the design of traffic routes in the coastal areas of Oman Sea. In coastal areas, uncertainty for predicting volatility is always high, but by simulation the possibility of conditional situation, better coastal management would be possible.

Suggestions:

There is some uncertainty about coastal areas' data for predicting volatility, so the possibility to simulate the conditions make better situation for coastal management. Some of these activities are ROPME1 or naval patrols which was carried out in the Strait of Hormuz in 1996 and 1998 by experts from the University of California. Although today there is a good complement satellite data to measure the surface area, but the need for further measures and extensive investigations in this area is necessary. Since Oman Sea has an important role for Iran's political and business and that's why there is need to work and make research on them, and of course, require too much cost and time. Also, knowing the parameters of the region's weather for more precise work is needed. To obtain an equation that can be converted by temperature, brightness temperatures, measured ground temperatures have a greater demand to use field data, brightness temperature difference among bands as well as an equation for calculating the temperature achieve the task itself which is actually ground calibration data is required.

Thus, in this field, different parts and organs which need to the data; a national center for all matters relating to the preparation and collection of environmental data, should do more researches about sea surface temperature. It is possible that in terms of the jobs of the National Oceanography Centre or the National Center climatology or meteorology, before they need to get the exact relationship of the harvesting period in Oman Sea and other seas around the country and calibrate the satellite data to prepare the final algorithm.

References:

1. Adnani, SA, 2003. Capability of satellites CHAMP, GRACE, GOCE in Gravimetry", Seminar of M.Sc at University of Tehran.
2. Adnani, A. 2002, features satellite Champ, Grace and Gauss in gravity surveys, seminars, M.Sc., Department of Geodetic Surveying Engineering, and Technical Faculty of Tehran University.
3. Alavi Panah, S., K., (2003). Application of Remote Sensing of Earth Sciences, Tehran University Press, p 375.
4. Alizadeh Rabie, H. (1993). Principles and Applications of Remote Sensing, publications and compiled the study of Humanities Books (SAMT). p 292.
5. Anding, D., and R. Kauth, 1970. Estimation of sea surface temperatures from space, Remote Sens. Environ., (4), 217-220.
6. Anonymous, 1990: marine meteorology, marine and fishing Kish Institute of Science and Technology, First Edition.
7. Ardalan, A. A., Grafarend, E. W. and Kakkuri, J. (2002). National height datum, the Gauss-Listing geoid level value W and its time variation W. Journal of Geodesy, Vol. 76, PP. 1-28.
8. Azamsa, S.; Shafiei, SA. And Kamyabi Gol., A. 1387. The monthly mean water level changes in the Persian Gulf, Sea of Oman and the North

Arabian Sea. Earth and Space Physics Journal, Volume 34, Number 2: 83 -96.
9. Becker, F., and Z.-L. Li, 1990.Towards a local split window method over land surfaces, Int. J. Remote Sens., 3, 369- 393.
10. Beckley, B.D., Lemoine, F.G., Luthcke S.B., Ray R.D., Zelensky N.P. 2007. A reassessment of global and regional mean sea level trends from TOPEX and Jason-1 altimetry based on revised reference frame and orbits. Geophys. Res. 34: 5-12.
11. Donlon, C. J., Minnet, P. J., Barton, I. J., Nightingale, T. J. and Gentemann, C.(2002). The character of skin and subsurface sea surface temperature.
12. Esfandyarnejad, A., Kamaliyan, R., Kiyanipour, M., 2004. Determine sea surface temperature (SST) using satellite data, Proceedings of the Sixth International Conference on Coasts, Ports and marine structures.
13. Hunter, J.R. (1983). A review of the residual circulation and mixing processes in the kap region, with reference to applicable modeling techniques. In oceanographic modeling of the Kuwait action plane (kap) region (M.I.El-Sabh, el.), PP.37-57.UNESCO reports in Marine SCIENCE, 28. Paris.
14. Iranian Water News Network. (2006). Iran Resources Management Authority, preparation and management, Office of Management Insights, p 9.
15. Jafari, A., 2006. The trend of the Caspian Sea level changes using satellite altimetry observations and beach Master's thesis, Department of Geodetic Surveying Engineering, Technical Faculty of Tehran University.
16. Jalilnejad, 2006. Mean Sea Level assessment models based on satellite altimetry, Master Thesis, Department of Geodetic Surveying Engineering, and Technical Faculty of Tehran University.
17. Mosayyib zadeh., 2002: Water surface topography in the Persian Gulf and Oman Sea through a combination of GPS observations, Master Thesis, Department of Geodetic Surveying Engineering, Faculty of Engineering, Tehran University.
18. Mahdizade MM, Kasbi M.s, 214. Predicting the height of the waves caused by storm surge on the Coast of Oman Sea, Marine Science and Technology Journal, Volume 31, Number 3:1-10.
19. Ménard, Y., Fu, L. L., Desai, S., Escudier, P., Haines, B., Kunstmann, G. Parisot, F., Perbos, J. And Vincent, P. (2003). the Jason-1 Mission. Mar. Geod. 26 (3–4): pp.131–146.
20. Narendra Nath. A. Rao. M. Rao. K. H. (1993). Observed High Temperatures In The Sunglint Area Over The Indian Ocean. VOL 14. NO5. 849-853(27).
21. Obaidual, M. and Azimul. A.1984. Sea surface temperatures of the bay of Bangal from NOAA (AVHRR) satellite and associated data with their possible application. Journal of Asian-Pacific Remote sensing.Vol 7. pp: 22-37.
22. Poursharifi, A., 2006. sea surface topography in the Persian Gulf and Oman Sea by combining altimetry data of T / P and ERS1 using tidal models derived from altimetry, Master Thesis, Department of Geodetic Surveying Engineering, School of Geography, University of KN Toosi.
23. Robinson, I. S. and Donlon, C. J. (2000). Global measurement of sea surface temperature: some new perspectives.
24. Rostami, GH, 2002: Persian Gulf and Oman sea surface topography through satellite observations, Master Thesis, Department of Geodetic Surveying Engineering, Faculty of Engineering, Tehran University.Smith, WHF, and DT, Sandwell, 1997, "Global seafloor topography from satellite altimetry and ship depth soundings", Science, v. 277, p. 1957-1962.
25. Sobrino, J. A., and V. Caselies, 1991. A methodology for obtaining the crop temperature from NOAA 9 AVHRR data, Int. J. Remote Sens., 12, 2461-2475.
26. Sohrabi Athar, M., 2003, Sea charts prepared using 3-dimensional coordinates of GPS and satellite altimetry observations, Master Thesis, Department of Geodetic Surveying Engineering, Technical Faculty of Tehran University.
27. Sanayei, 2005, to investigate the validity marine gravity data via satellite altimetry, Master Thesis, Department of Geodetic Surveying Engineering, Technical Faculty of Tehran University.
28. Taherkia, H. (1996). Principles and Applications of Remote Sensing, Publishing Tehran University Jihad. p 480.
29. Torabi, M., 2006. Spectral analysis of satellite altimetry observations point T/P to mean sea surface modeling, Master Thesis, Department of Hydrographic Surveying Engineering, Technical Faculty of Tehran University.

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