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Forecasting the Sea Level Change in Strait of Hormuz

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***Abstract*—**Recent investigations have demonstrated the global sea level rise due to climate change impacts. In this study, climate changes study the effects of increasing water level in the strait of Hormuz. The probable changes of sea level rise should be investigated to employ the adaption strategies. The climatic output data of a GCM (General Circulation Model) named CGCM3 under climate change scenario of A1b and A2 were used. Among different variables simulated by this model, those of maximum correlation with sea level changes in the study region and least redundancy among themselves were selected for sea level rise prediction by using stepwise regression. One of models (Discrete Wavelet artificial Neural Network) was developed to explore the relationship between climatic variables and sea level changes. In these models, wavelet was used to disaggregate the time series of input and output data into different components and then ANN was used to relate the disaggregated components of predictors and input parameters to each other. The results showed in the Shahid Rajae Station for scenario A1B sea level rise is among 64 to 75 cm and for the A2 Scenario sea level rise is among 90 t0 105 cm. Furthermore, the result showed a significant increase of sea level at the study region under climate change impacts, which should be incorporated in coastal areas management.

***Keywords*—**Climate change scenarios, sea-level rise, strait of Hormuz, artificial neural network, fuzzy logic.

I. Introduction

STUDIES show, Increasing water level of seas and oceans due to warming of the Earth's atmosphere over the past century, massive melting of ice and water is expanding [4]. If sea level rise occurs, it would be a significant impact on the coastline. The sea level rise in people's lives and the economy of coastal areas, especially in areas adjacent to the sea, which always have high flood potential, will have a significant impact [7].

The recent investigations all over the world demonstrated the global temperature (land and sea) increase by 0.76°C from 1850–1899 to 2001–2005 [3]. This temperature increase is more intensify in the northern hemisphere. In some years (e.g., 1998 and 2005) it the temperature has increased more than 1°C [3]. The global warming highly affects the living environment. These effects may result in changes in river flow patterns and sea level. Based on the Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC), for the 20th Century, the average rate of global mean sea level rise (SLR) was estimated about 0.5-1.7 mm/yr [1]. It was predicted that the global sea level rise by the end of the 21st Century would be between 0.18 m and 0.4 m [1]. The results of analyses on tide gauge records and satellite altimetry in open oceans showed that the range of sea level changes is different in various regions [1]. In some cases, the predicted SLR is higher than the global mean whilst in some cases predictions show sea level descends. The assessment of coastal zone vulnerability to sea level rise and application of adaptation strategies are the key issues in dealing with climate change impacts. The projections of global sea level changes under probable climate change scenarios showed that the flooding risk is increasing over low lying coastal regions [3].

The recent applications of Artificial Intelligence (AI) techniques have demonstrated their high capability in dealing with stochastic time series such as sea level. When the underlying physical relationships in time series are not fully understood, AI techniques provide an effective approach to model them. Two of these models which are widely used in recent decades especially in field of hydrological analyses and for prediction purposes, are artificial neural network (ANN) and neuro-fuzzy inference system (ANFIS) models [7]. ANNs have been used widely and successfully for hydrological modeling as well as prediction purposes because of their ability to discover patterns in data that cannot be explored by human researchers and conventional statistical methods [1].

The use of ANFIS model which is a hybrid of ANN and fuzzy system has been a research focus to provide the opportunity to use the advantages of both ANN and fuzzy systems [3]. In spite of high flexibility of ANN and ANFIS, in case of sea level rise prediction the results of their application are not that much satisfactory because signal fluctuations are highly non-stationary and the physical hydrologic process operates under a large range of scales. In these cases pre-processing of the input and/or output data before feeding into prediction model, is necessary [6].

Assess the vulnerability of coastal areas due to sea level rise and the use of appropriate strategies, key issues facing the effects of climate change. Forecasts of global sea level change under different scenarios of possible climate change, show flood risk in coastal areas because of rising sea levels and increased depending on the increase in water level, the vulnerability of coasts and ports also will vary [7].

The objective of this study was to investigate the effects of climate change on sea level changes in the Strait of Hormuz and the vulnerability of the region's water level is rising.

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II. Methodology

Data recorded on Earth measuring stations show an upward trend rising sea levels and in different areas of the planet is ocean that Attributed mainly to the effects of climate change. The recent records of sea level in different places of the world show the ascending trend of sea level changes due to climate change impacts. This increasing will affect the people life and economy in coastal areas especially in flat regions with high flooding potential. The recent studies have demonstrated the correlation of sea level changes with climatic variables. This study was aimed to use climatic variables to evaluate the sea level rise at the strait of Hormuz in next 100 years under different climate change scenarios. Two simulation approaches which are combination of Wavelet theory with Artificial Neural Network and Neuro-Fuzzy models were considered [1].

III. Climate Change Scenarios

Climate change scenarios under different scenarios of climate model output by the International Panel on Climate Change and other scientific institutions are being published [2].

A. Scenarios A1 Family

In this family assumed a future of rapid economic growth. Population growth will continue until mid-century and then decline until the end of the century, with the rapid growth of technology. In the world of globalization, capacity building and promoting the culture and economy and reduce the substantial difference in the rate for the move and Most of logics is considered and globalization strategies. This family is comprised of three scenarios, A1FI scenarios in which the group assumes the continued use of fossil fuels, A1T group in which no use of fossil fuels is assumed, And A1B, which assumes a balance between the use of fossil fuels Renewable energy is dominant [2].

B. Scenarios A2 Family

In this complex, heterogeneous world that rely on trust and keeping regional values are predicted, the world population is growing, while the growth patterns and growth process will slow down economic models based on the central region [3].

IV. Simulate Changes in Sea Level

In the next step, the sea level simulation models were developed. For this purpose, two different hybrid simulation models were considered. The first model was a hybrid of wavelet theory and ANN named DWNN and the second one was a hybrid of wavelet theory and ANFIS called DWANFIS. In each of these models, wavelet theory was employed to decompose the input and output data into several simple waves and then the relation between decomposed inputs and outputs were explored using ANN/ANFIS [5].

For development of DWANFIS model, the MATLAB software was employed which includes trimf, trapmf, gbellmf, gaussmf, gauss2mf, pimf, dsigmf and psigmf membership functions. In this study, the gausmf-2 was selected as the best membership function which provided the minimum RMSE during the model training. Three membership functions were considered for each predictor. The best number of model training epochs was determined by trial and error as 20.

V. Study Area

The Strait of Hormuz is a strait between the Gulf of Oman and the Persian Gulf. It is the only sea passage from the Persian Gulf to the ocean and is one of the world's most strategically-important choke points. On the north coast is Iran, and on the south coast is the United Arab Emirates, an exclave of Oman. At its narrowest, the strait is 21 nautical miles (39 km) wide. About 20% of the world's petroleum, and about 35% of the petroleum traded by sea, passes through the strait making it a highly important strategic location for international trade (WOTC). Shahid Rajae Port in the north of Hormuz strait connects to more than 80 ports worldwide and the highest rate of cargo transit through the Iran and towards the Central Asia passes through this port. The location of the considered Shahid Rajae port and its character are given in Fig. 1 and Table I, respectively.

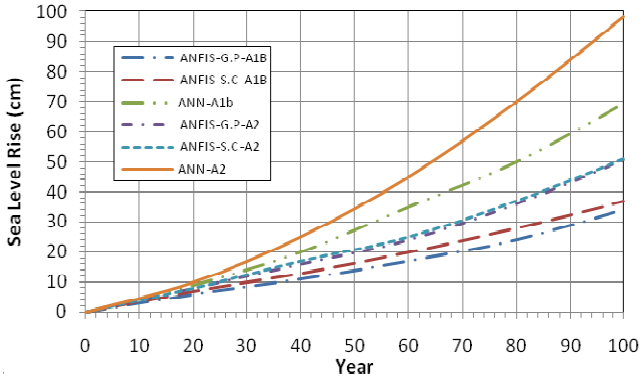


Fig. 1 Average changes in sea level and climate change scenarios for various models Shahid Rajae station

TABLE I
CHARACTERISTICS OF SHAHID RAJAE PORT, IRAN

Station	Y (latitude)	X (longitude)	Establishment Year	Mean Sea Level (mm)
Shahid Rajae	27.10	57.07	1989	3242.569

VI. Results and Discussion

To consider the climate change impacts 2 data set of A1B and A2 were used. CGCM3 surface network of the 3.75×3.75 and the latitude and longitude of this station is covered. The water level changes until 2100 for two scenarios of climate change and wavelet functions are presented in Fig. 1, increasing amounts of water level stations Shahid Rajae 2100.

The results of the water level changes for different models of the climate change scenarios are presented, Changes in water level stations, in Shahid Rajai for A1B scenario is between 75 to 64 cm. Amounts of water level changes in climate change scenarios A2 scenario over the other, and between 105 to 90 cm is expected. The difference between to scenario in the scope of this scenario is about 15 cm.

A. Zoning of Water Level in the Strait of Hormuz

Through the Strait of Hormuz connecting the Persian Gulf to the open sea occurs. This area is one of the most sensitive parts of the world is the Persian Gulf's energy needs; Fig. 2 is shown in the present circumstances. Fig. 3, the rate of advance in coastal waters in the Strait of Hormuz, has been determined.

VII. Conclusion

Suitable estimate of sea-level is important for navigation in different coastal and offshore engineering applications as well as for marine recreational activities; especially when they will have development program in coastal region. In this study, a methodology was proposed to project the impacts of climate change on sea level rise (A1B and A2 climate change scenarios). Based on studies, results show increase in sea level by the year 2100 in the Strait of Hormuz would be less than 100 cm and this increase in water level at the coasts of Shahid Rajae port will reach to an extent to create main difficulties in the region.

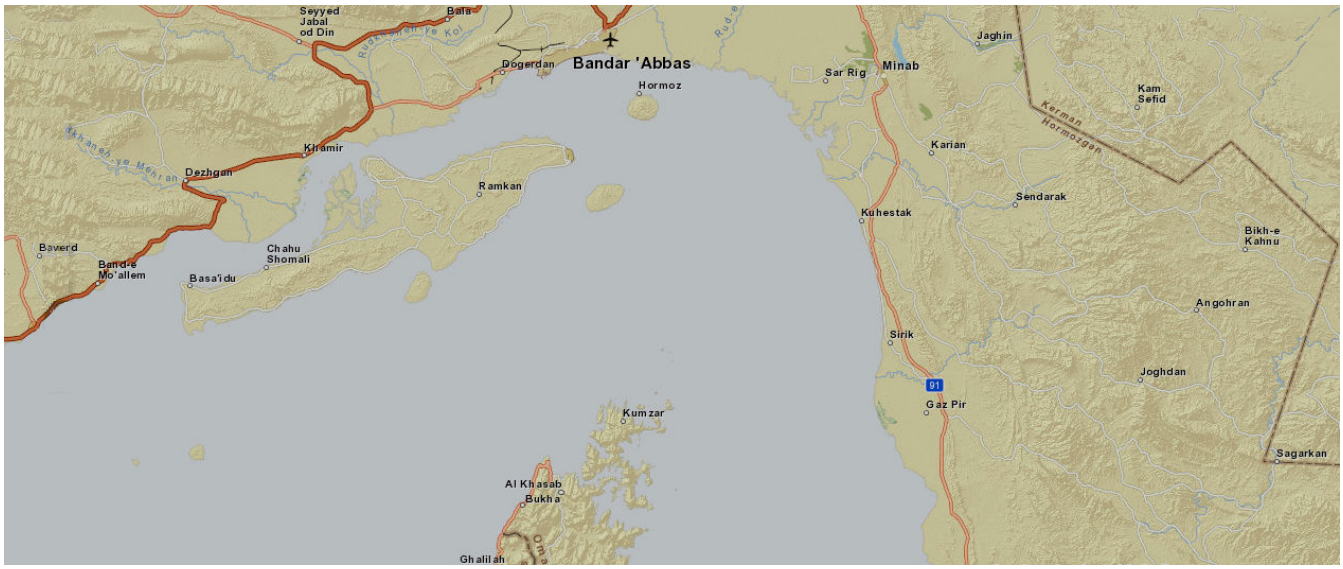


Fig. 2 Current conditions in Strait of Hormuz Shoreline

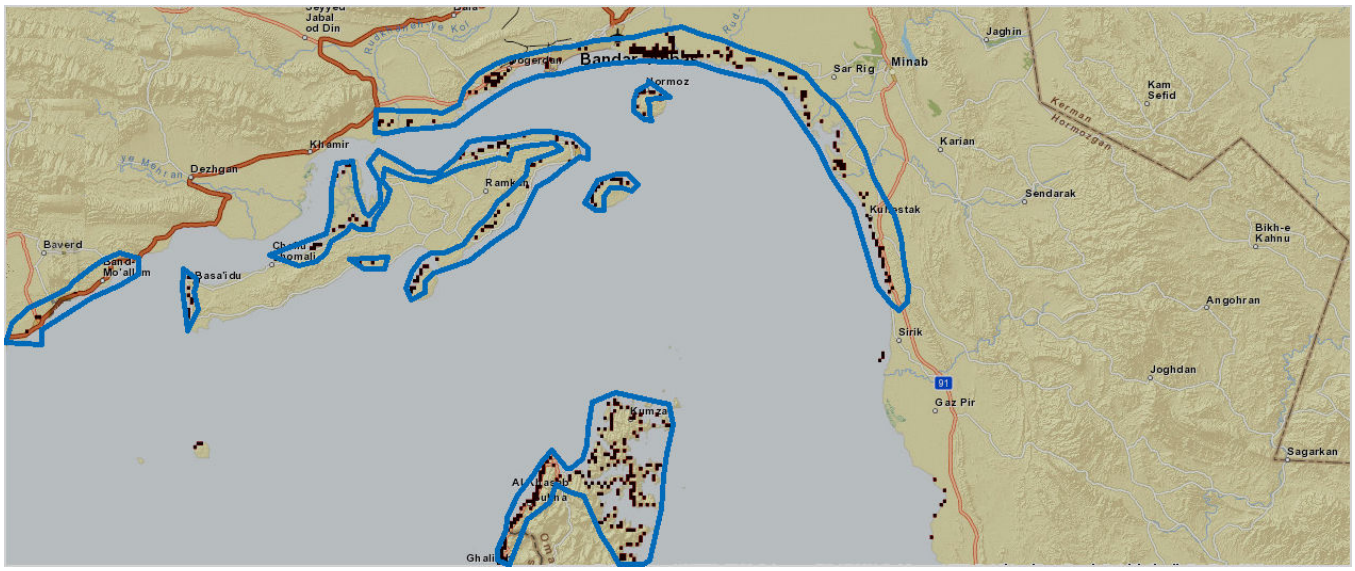


Fig. 3 Conditions in Strait of Hormuz Shoreline to 2100

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