Research in Marine Sciences
Volume 5, Issue 3, 2020
Pages 764 - 770

Mass water transfer and water-level fluctuations in Farur Island, Persian Gulf

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Received: 2020-06-02 *Accepted: 2020-09-10*

Abstract

In this paper, a theoretical model is presented for coastal flows where parameters such as water level fluctuation, current, and mass transfer on the shallow shores of Farur Island are discussed. Parameters used include uniform coastal area (constant depth), interval wave breaks, and the slope of the coast after constant depth and water depth during wave break. There are two very important fractions in this context: constant depth relative to the balance between pressure gradient, and tension induced by the wave associated with the current on the shallow coral reef. The average of water transfer obtained 0.277 Sverdrup which was more in the north and northeast of Farur Island and less in northwest and southwest parts. A mean sea level variation up to 77 cm was calculated. Regarding the different slops over the study area, the vertical shears around the Island have been considered. It is notable that the water level fluctuation and transfer have been calculated after changing the parameters to non-dimensional and in dimensional analysis frame, and also based on the results derived from previous studies.

Keywords: Coral coast; Water transfer; Water fluctuation; Coastal currents; Wave.

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1. Introduction

The Persian Gulf is a semi-enclosed, sub-tropical marginal sea surrounded by a very dry land and is located in the subtropical northwest of the Indian Ocean. The Gulf is very shallow with average depth of 35m. Its water flows through the Strait of Hormuz in exchanging water with the open ocean (Bower *et al*., 2000). The Gulf with high evaporation rate 1.5-2 m/yr, is among the saltiest water environment in the world and freshwater inputs come from a few rivers that flow from Iran and Iraq, that have little contribution compared to the extreme evaporation rates in the Gulf. These conditions, particularly the arid desert climate and extensive areas of shallow water, cause extreme environments for coral growth, with the highest variations in salinity and temperatures in the world. Thus, coral reefs and communities in the Gulf generally have relatively low biodiversity, and the ability of corals to survive is probably due to their strong genetic adaptability (Symonds *et al*., 1995).

The Persian Gulf is home to many small and large islands. The most important Iranian Islands included Abu Musa, Greater Tunb, Lesser Tunb, Hendurabi, Hengam, Hormuz, Khark, Kharku, Kish, Larak, Lavan, and Sirri. The Farur Island is one of the Iranian Islands that is situated in west of Hurmoz strait with a geographic position from 26.14 to 26.17 North degree and 54.30 to 56.55 East degree, in 66 km and 260 km away from Abu Musa Island and Bandar Abbas port, respectively. The location of Farur Island is shown in Figure 1.

The synoptic and climatological stations show that the Farur Island is a warm region with high humidity and an average annual temperature of 27°C. The wind currents in the Persian Gulf approach the island from the south, while common winter winds blow from the west. The study of the Island's winds in two times of different period's shows the prevailing winds (in terms of duration, number and intensity) from west to south. Furthermore, marine meteorology in the Persian Gulf has been conducted by Symonds *et al*. (1995) and the results demonstrated its effects on currents and waves in the area.

Water level fluctuations in freshwater ecosystems enhance efficiency and influence the timing of other biological events among fauna. They also modify habitat availability, quality and complexity. The minor changes in water level can lead to large variations in a

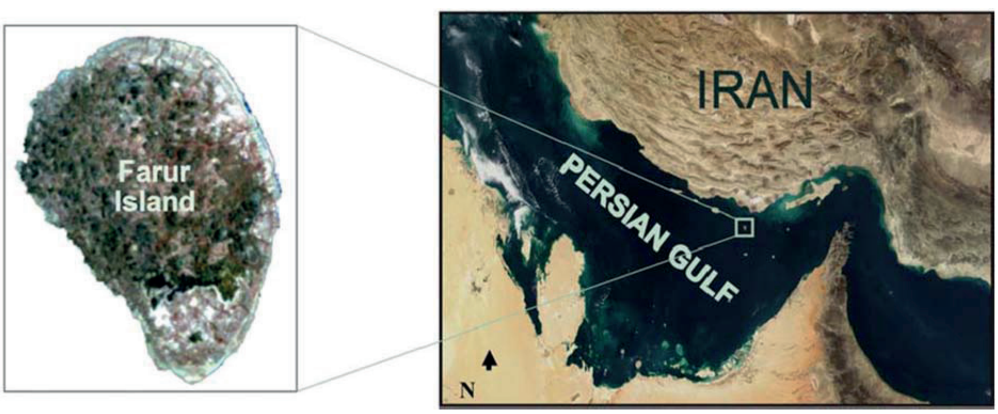

Figure 1. Location of Farur Island, Persian Gulf.

coastal area, depending on the morphology of the system (Kolding and van Zwieten, 2006; Gownaris *et al*., 2017). Gownaris *et al*. (2018) discovered relationships between interannual and seasonal water level fluctuations. Their results indicated that interannual water level fluctuations are positively correlated with the primary and overall production and they are negatively correlated with food chain length, fish diversity, and water transfer efficiency.

Li *et al*. (2011) used the Environmental Fluid Dynamics Code (EFC) and a three-dimensional numerical model to study the impacts of water transfer on the transport of dissolved substances in the lake using the concept of water age. Model results showed that the effect of water transfer on transport processes in the lake is intensely influenced by hydrodynamic conditions induced by inflow/outflow branches and wind.

Wave setup over coral reefs has been explained by Tait (1972) and Jensen (1991) and has been described using the concept of radiation stress presented by Longuet-Higgins and Stewart (1964). The gradient in the radiation stress over the reef is balanced by an offshore pressure gradient analogous to the plane beach solution described by Longuet-Higgins and Stewart (1964) and Bowen *et al*. (1968).

2. Material and method

In this study, different slopes in four directions (1) northwest, (2) northeast, (3) southeast, and (4) southwest with different terms of topography in the Farur Island are considered. In order to solve the differential equations, the numerical solution method in MATLAB program and the explicit implicit method are used. The slope area in surf zone according to its topography is calculated. While around the island there are four stations and each side is influenced by its topography and local slope, the effect of different parameters on the waves is considered. Therefore, at these points, there will be differences between breaking waves, wave height and distance from shore. Two parameters (water level fluctuation) and d_w (water transfer) are calculated at each station.

The wave profile on the coast is shown in Figure2 and displays the state of water particles are the result of a balance between two forces of radial stress in the U direction and the force of gravity, which is the same as the equation of motion. In the wave profile on the coast observed that the force of waves is greater on the surface and less on the floor for the reason that the impact of the wave on the shore creates a reaction force (R_X) on the wave. This force

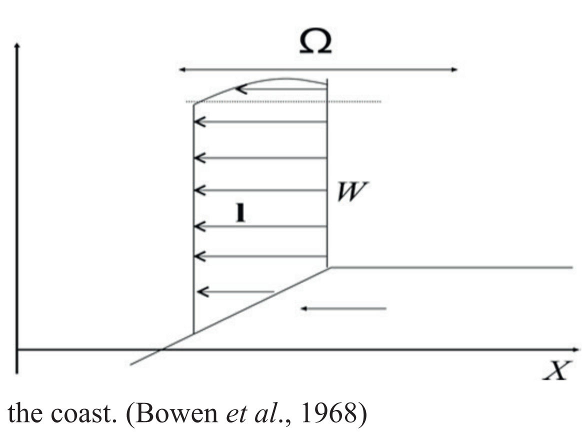

Figure 2. Wave profile on the coast. (Bowen *et al*., 1968)

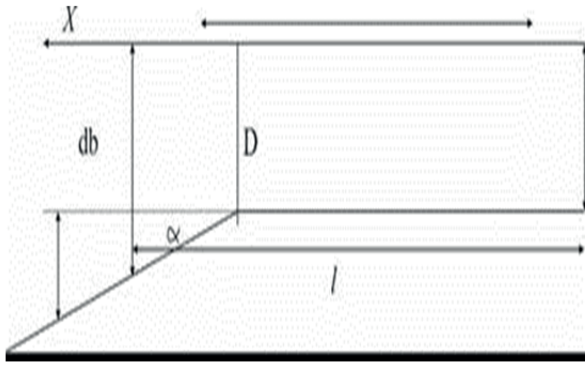

Figure 3. Effective parameters on the beach (Bowen *et al*., 1968)

affects the wave and the effect of the wave force decreases according to profile (Thornton and Kim, 1993). The Equations (1) and (2) that determine the state of a particle of water are due to the equilibrium of two forces, radial stress and pressure gradient.

$$\frac{\partial\sigma}{\partial x}\frac{1}{hgl} = -\frac{dC_{xx}}{dx} \quad (1)$$

$$\frac{\partial\sigma}{\partial x} = -\frac{1}{bg(l+\sigma)}\frac{dc_{xx}}{dx} \quad (2)$$

where, c is radial stress, b is the pressure, d is the depth of water in any location and is the water level fluctuation. Effective parameters on the beach are shown in Figure 3. The bed and the beach equations in terms of parameters are given as follows (Equations 3 to 10).

A flat-bottom is assumed as the initial condition, where it has a constant depth, the surface of the coral reef is uniform, and the depth of water increases with movement towards the sea. (Bowen *et al*., 1968)

$$g\frac{\partial\sigma}{\partial x} = \frac{1}{bl}\frac{\partial C_{xx}}{\partial x} - \frac{rw}{l} \quad (3)$$

$$\alpha = \gamma l \quad \gamma = 0.349 \quad (4)$$

$$d = (X - X_r)\tan\beta \quad (5)$$

$$g\frac{\partial\sigma}{\partial x} = \frac{3}{2}y\gamma^2 + \tan\alpha \quad (6)$$

$$C_{xx} = \frac{3}{2}E \quad (7)$$

$$E = \frac{1}{2}\rho g a^2 \quad (8)$$

$$R = C_r W_u \quad (9)$$

$$\frac{\partial(d_w)}{\partial x} = 0 \quad (10)$$

where, is the slope of the bottom; X, Positively facing the sea; X_r, a width where the coral layer is uniform and almost inclined; D, the depth of water above the uniform coral layer; $d_{b,}$ the depth at which the waves break; d, depth of water in any location; X = L, the distance where the wave breaks; W, the vertical velocity obtained by integrating with respect to depth; C_r=1, friction factor; and W_u is the vertical speed from surface to depth.

In order to obtain the nondimensionl solutions, divide the outer shore distance by the width of the breakwater zone and divide the depth by the breaking point of the first wave. To dimensionless equations of sea-level fluctuations (Equations 11-14), it is assumed that the coast to be smooth and with the same slope of the failure zone (Mei and Liu, 1997).

$$x^* = \frac{x}{L - x_r} \quad (11)$$

$$h^* = \frac{D}{D_b} \quad (12)$$

$$\varepsilon^* = \frac{\varepsilon}{\frac{3}{2} r^2 (L + x_r) \cdot tg\beta} \quad (13)$$

$$u^* = \frac{u}{\frac{3}{2} g y^2 tg\beta \frac{D}{r}} \quad (14)$$

In this research, the effects of shallow waves are ignored.

3. Results and Discussion

The results in four geographical locations of (1) northeast, (2) northwest, (3) southeast, and (4) southwest in Farur Island are calculated and represented in Table 1 in different stations, where the breaking wave zone is between 2×10^2m to 2×10^3m.

Table 1. Calculated parameters on stations of 1, 2, 3, and 4.

	$tg\alpha$	$B = \frac{D}{d_b}$	$A = \frac{X_r}{L}$	d_b (m)	L (m)	D (m)	X_r (m)
Station 1	3.3×10^{-3}	0.56	0.241	2.5	952	0.71	230
Station 2	4.1×10^{-3}	0.612	0.217	1.23	829	0.74	180
Station 3	4.9×10^{-3}	0.628	0.297	1.85	370	0.65	110
Station 4	2.6×10^{-3}	0.718	0.216	1.43	1500	0.72	410

Table 2. Value of σ*, d*, w*, and σ, d_w around the Farur island

	Station 1	Station 2	Station 3	Station 4
σ^*	0.9	0.7	0.7	0.7
$d^*.w^*$	0.1	0.18	0.16	0.17
σ	0.69	0.91	0.64	0.87
The mean value of fluctuation is 0.77 m				
d_w	0.23	0.29	0.47	0.12
The mean value of water transfer is 0.277 sv				

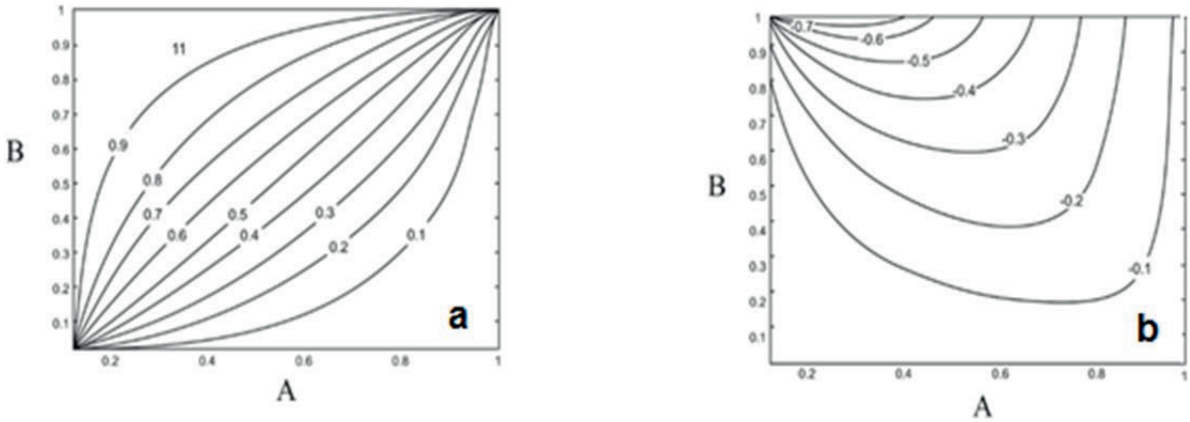

Figure 4. a) The diagram of sea-level fluctuations, b) Water transport along the coral reef

Furthermore, different parameters of σ*, d*, w*, and σ, d_W are calculated and represented in Table 2 around the Farur island.

In the calculations, it was assumed that the wave breaking depth is the same as the water depth on the Farur coral reef, and water level fluctuation in the dimensionless mode is as small as possible. As shown in Figure 4 a diagram of sea-level fluctuations and water transport along the coral reef, when the calculated water transfer shows the lowest, the value of nondimensionl Parameter $A=X_r/L$ is also will be minimized. It means that the water transfer will be reduced in the southeastern and northeastern regions of the Farur Island and the region with more depth of water will not change significantly.

In the coastal areas of Farur, when the parameter B is minimized, calculated fluctuations tend to be one and water transfer move to the minimum value and when the water arrives in the coastal area the water level fluctuation will increase and when it reaches to the centre, the water transfer will be the lowest and tends to zero. When the nondimensionl parameter $B= D/d_b$ (water transfer) increases, it means that the width of the shore is considered equal to the depth of the breaking wave point and the calculated water level fluctuation is also greater than the values and the calculated water transfer to the lowest value. Due to the prevailing west and northwest winds on the shores of Farur Island, the highest water mass transfer is seen on the west and northwest coasts. Moreover, most of the water level changes are observed in these coasts. Therefore, there is more movement and mixing in the water column on the southwestern coast of Farur Islands. Environmental conditions on the north to southeast coast of Faruar Island are more stable. Farur Island coral colonies are more concentrated in these areas. Farur coral reefs due to its location in areas with unfavorable environmental conditions for growth and life, such as shallow depths, extreme temperature fluctuations from 12 °C in winter to more than 40 °C in summer, high sea level variations and oil tanker traffic, they are under ecological stress and are on the verge of enduring their ecology. According to the results of Pour Sheikhi *et al.* (2015), the maximum wave height before the breaking point was about 0.71 m and the depth at the breaking point was about 91.0 m in coasts of Farur Island. According to the assumptions of this study, the results are well consistent.

Conclusion

In this study, the results of the analysis two nondimensionl Parameter $A=X_r/L$ and $B= D/d_b$ illustrate water level fluctuation and water transfer in the Farur Island. These parameters estimate that the Minimum and maximum amount of water transfer are in the southeast and northeast and the northwest and southwest, respectively. The average of water transfer obtained 0.277 Sverdrup, which was more in the north and northeast of Farur Island and less in the northwest and southwest parts. A mean sea level variation up to 77cm was calculated. Regarding the different slops over the study area, the vertical shears around the Island have been considered. By reason of the north and northwest dominant winds on the shores of Farur Island, the highest water mass transfer is observable on the west and northwest coasts. Furthermore, most of the water level variations are seen in these coasts. Thus, there is more movement and mixing in the water column on the northwestern coast of Farur Islands. Environmental conditions on the north to the southeast coast of Faruar Island are more stable, so the Farur Island coral colonies are more concentrated in these areas.

References

Bowen, A., Inman, DL., and Simmons, VP. 1968. Wave set-down and setup. Journal of Geophysical Research, 73(8): 2569–2577.

Bower, A., Hunt, HD., and Price, J.F. 2000. Character and dynamics of the Red Sea and Persian Gulf outflow. Journal of Geophysical Research, 105(C3): 6387–6414.

Gownaris, N., Pikitch, E., Aller, J., Kaufman, L., Kolding, J., Lwiza, K., and et al. 2017. Fisheries and water level fluctuations in the world's largest desert lake. Ecohydrology, 10: e1769.

Gownaris, N.J., Rountos, K.J., Kaufman, L., Kolding, J., Lwiza, K.M., Pikitch, E.K. 2018. Water level fluctuations and the ecosystem functioning of lakes. Journal of Great Lakes Research, 44(6):1154-63.

Jensen, O. 1991. Waves on coral reefs. In Coastal Zone '91' Proceedings of the Seventh Symposium on Coastal and Ocean Management. Long Beach, California. American Society of Civil Engineers. New York. pp. 2668-2680.

Kolding, J., and van Zwieten, PM. 2006. Improving productivity in tropical lakes and reservoirs.

Li, Y., Acharya, K., and Yu, Z. 2011. Modeling impacts of Yangtze River water transfer on water ages in Lake Taihu, China. Ecological Engineering, 37(2): 325-334.

Longuet-Higgins, M., and Stewart, R.W. 1964. Radiation stresses in water waves; a physical discussion, with applications. Deep Sea, 11:529-562.

Mei, C., and Liu, P. 1977. Effects of topography on the circulation in and near the surf-zone– Linear theory. Estuarine and Coastal Marine Science, 5:25–37.

Pour Sheikhi, H., Ashtari Larki, A., and Najjarpour, M.A. 2015. Qualitative Comparison of Wind Wave Data at the Farur Coasts. Journal of Hydrophysics, 2(1):13-23.

Symonds, G., Kerry, P. Black, and Young, Ian R. 1995. Wave- driven flow over shallow reefs. Journal of geophysical Research, 100(C2): 2639-2648.

Tait, R. 1972.Wave setup on coral reefs. Journal of Geophysical Research, 77: 2207-2211.

Thornton, E., and Kim, C. 1993. Longshore current wave height modulation at tidal frequency inside the surf zone. Journal of Geophysical Research, 98(16):509-519.