EDGE WAVE INDUCED BY AN ATMOSPHERIC PRESSURE DISTURBANCE MOVING ALONG A SLOPING BEACH

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ABSTRACT
Edge wave can be generated by an atmospheric pressure disturbance moving along the shoreline on a sloping beach. A two-dimensional numerical model based on non-linear shallow water equations is established and a set of numerical experiments are conducted to study the edge wave packets evolution in coastal ocean. In light of the analytical solutions by Greenspan, some dominant factors are discussed, such as disturbance spatial size, translation speed, its location and the slope inclination, that influence the generation conditions and evolution process of edge waves. The results indicate on what circumstances significant edge waves will be excited and how long it takes for the wave growth.

KEY WORDS
Edge wave; Atmospheric pressure disturbance; Generation conditions; Evolution process; Growth time

INTRODUCTION

Edge wave is a resurgent wave motion which is characterized by the phenomena that waves propagate along the shoreline and are confined within a certain distance offshore. Edge waves have been observed when storms travel approximately parallel to the coastline or landslides occur in neighboring coast. According to wave spectrum theories, different modes of edge waves would be excited when frequency of the forcing agency matches with the eigenfrequency or lies in the frequency band of the coastal system.

Analytical solutions for edge waves have been derived in the full linear wave equation by Ursell (1952) and the linear shallow water equation by Eckart (1951). The features of shallow water edge wave are delineated including the maximum amplitude, the wave length, wave range, and wave mode, etc. Greenspan (1956) studied the waves generated by a moving atmospheric pressure disturbance on a sloping beach by solving inhomogeneous shallow water equations in Fourier and Laplace transform. The stationary solution showed that the wave amplitude would be amplified when edge wave occurs, which is known as the Greenspan resonance. After that, analytical solutions of edge waves generated by transient disturbances (landslides or atmospheric pressure systems) are supplemented and improved by Seo & Liu (2013,2014). In recent years, numerical methods are conducted by using shallow water equation models, in order to investigate some complicated cases when the disturbances moving close to coastline at an angle or the transient disturbance is anomalous.

Waves amplitude sometimes can be largely amplified by Greenspan resonance, thus significant edge waves can cause great harm to coastal areas. In this study, a series of numerical experiments is conducted to simulate the development process of edge wave. Some practical conclusions are extracted that under what circumstances significant edge waves can be generated and how long it takes to evolve into significant waves.

GENERATION OF SIGNIFICANT EDGE WAVES

In cases when edge waves are generated by atmospheric pressure disturbances, the disturbance features and coastal topography are the governing factors which decide whether the edge waves are generated or how strongly they act. According to the law derived from the analytical solution of fundamental wave by Greenspan (1956), disturbance translation speed, spatial size, distance offshore and the slope inclination are principle factors which influence the wave height. A series of numerical experiments are carried out to study the effects of those key factors. The range of the factors are selected according to the real situations.

It can be seen from figure 1 to figure 4, numerical solutions show good consistency with the analytical solutions. Some differences are mainly caused by the existence of higher edge wave modes, which was not taken into consideration in the solution by Greenspan. What's more, friction and viscosity also show damping effect in numerical models.

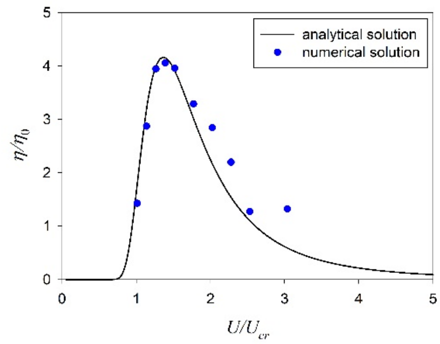

Figure 1 - influence of disturbance translation speed on the maximum water elevation

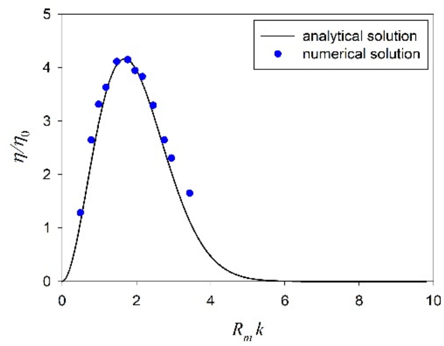

Figure 2 - influence of disturbance spatial size on the maximum water elevation

Figure 1 shows the influence of translation speed of the disturbance. Here, U_{cr} is the phase speed of the fundamental edge wave whose wavelength is the width of the pressure disturbance (An, 2012), which is served as the critical translation speed to generate fundamental edge wave. η_0 is the water elevation when a static atmospheric disturbance acts on the water surface. In general, 1hPa of the air pressure drop results in about 1cm water elevation increase. When the translation speed is too small, no edge wave fluctuation occurs. But when the speed is too high, higher wave mode becomes dominant whose wave amplitude is not as high as the fundamental wave. Thus the medium speed results in the highest wave.

Figure 2 shows the influence of disturbance spatial size. Here, R_m is the influence radius of the disturbance, k is the wave number. Similar law is also found that medium-sized atmospheric disturbances cause highest water elevation near shore, which pose great threat to coastal area. R_m decides the critical speed and the wave mode. No edge wave is generated when R_m is too large and higher modes become dominant when R_m is small.

Figure 3 shows the influence of disturbance center location. Here, y_0 is the distance between the disturbance center and the coastline. y_0 have nothing to do with the wave mode, but edge wave only occurs near shore. When the disturbance is too far away from coastline (here y_0k is larger than 3), the wave packet is no longer obvious.

Figure 4 shows the influence of the slope, and α is the slope inclination. Due to the high relevance with the critical speed and wave mode, a moderate slope creates opportunities for the generation of violent edge waves.

Overall, both analytical and numerical results show that maximum water elevation occurs when a medium-sized disturbance moves with a medium translation speed within a certain distance offshore. What's more, the slope inclination must also lie in a medium value.

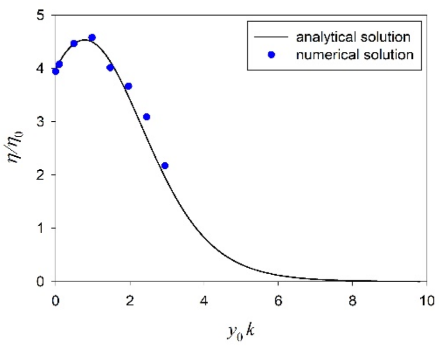

Figure 3 - influence of disturbance center location offshore on the maximum water elevation

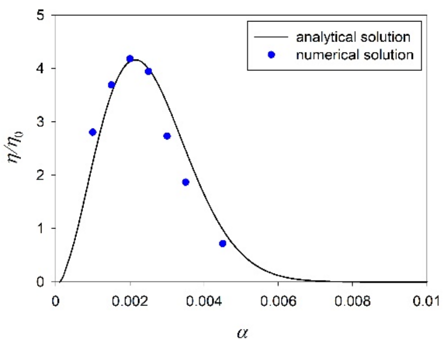

Figure 4 - influence of slope inclination on the maximum water elevation

EVOLUTION OF THE EDGE WAVE PACKET

It takes a period of time for the wave to become significant. Research on the wave evolution will provide good application value to the marine forecasting. To investigate the evolution process of edge wave, growth time T_s is imported as the time when edge wave becomes significant. T_s is defined according to wave height and the number of wave crests in the packet. Numerical experiments are conducted among those conditions in which significant edge waves occur according to the generation conditions mentioned above.

Figure 5 indicates the influences of the 4 principle factors on the growth time of edge wave. Here, λ is the wave length, and T is the period of the wave. R_m/λ is the dimensionless parameter in which U, R_m, y_0 and α are all included.

The results show it takes about 3.5-5.0T for the wave to grow up, and an approximate positive correlation exists between T_s and R_m/λ . Thus the dimensionless parameter R_m/λ can be used to speculate the growth time of edge wave.

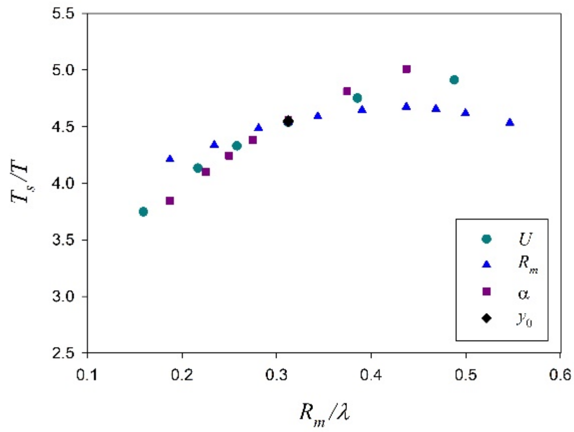

Figure 5 - Influences of different factors on the growth time of edge wave

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