University of Utrecht

Morphodynamics of Wave-dominated Coasts
GEO4-4434
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Practical 6

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1 6.1.2 Comparison with the empirical fit defined by Ruessink et al. (2012)

- *Define a vector containing values of Ur varying between 0.01 and 100. Compute the corresponding As and Sk.*
- *Create a new figure divided in 2 subplots:*
  - *On the top part, plot the evolution of the skewness as a function of the Ursell number (using the vectors defined above)*
  - *On the bottom part, plot the evolution of the asymmetry as a function of the Ursell number*
- *Plot also in the figure the values of As and Sk computed in Section 6.1.1. Compare your results to Figure 1 of Ruessink et al. (2012)'s paper.*

Figure 1.1 shows the skewness and asymmetry as a function of the Ursell number. The blue line is calculated from the Ruessink empirical fits and the data points are obtained in section 6.1.1 for the Egmond data for the three different tides. The Ursell number indicates the non-linearity of a wave and is a dimensionless parameter given by the following formula

$$U_r = \frac{3ak}{4(kh)^3} \tag{1.1}$$

where a is the wave amplitude, k the wavenumber and h the water depth. For low Ursell numbers, waves can be approximated as linear and linear wave theory is applicable. For larger values of the Ursell number, the wave becomes more non-linear and shifts from a skewed wave to an asymmetric wave. As visible by the blue line in Figure 1.1, low values of the Ursell number (Ur <0.02) are associated with zero skewness and asymmetry, i.e. a linear wave. When the Ursell number starts to increase to higher values than 0.02, it is observed that the skewness starts to increase, while the asymmetry remains equal to zero. This happens in the shoaling area, where the wave transforms from a linear wave into a skewed wave. For an even larger Ursell number, i.e. for $Ur \approx 0.3$, the asymmetry starts to decrease and the skewness reaches its maximum around $Ur = 10^0$. This happens at the edge of the shoaling and surf zone. Note that the skewness is always positive, while the asymmetry becomes negative. For increasing Ursell number, the asymmetry becomes increasingly negative and the skewness decreases until it reaches zero. This happens in the surfzone, where the waves start to break and their shape transforms from a skewed wave to an asymmetric wave. The asymmetry increases from the outer surf zone into the inner surf zone.

The data points in Figure 1.1 are associated with the skewness and asymmetry of the Egmond data for different tides. First, it can be observed that the asymmetry points closely follow the blue line obtained from the Reussink fits, while the skewness points show to be more scattered. Furthermore, in case of high tide, the skewness increases and the asymmetry decreases at lower Ursell numbers than in case of low or mid tide. Also the skewness and asymmetry of the mid tide starts to in- or decrease at lower Ursell numbers than for low tide, although this difference is more difficult to see. This effect can be explained by equation 1.1, where it is shown that the Ursell number decreases for higher water depths, i.e. for higher tides.

Figure 1.2 shows the skewness and asymmetry as a function of the Ursell number from the Ruessink et al. (2012)'s paper. The same trends can be observed as in Figure 1.1 with a clear increase of the skewness around $Ur = 10^{-1}$ and a maximum of the skewness and associated decrease in asymmetry around $Ur = 10^0$. It can therefore be concluded that the output is fairly similar to the output of the Reussink et al. paper.

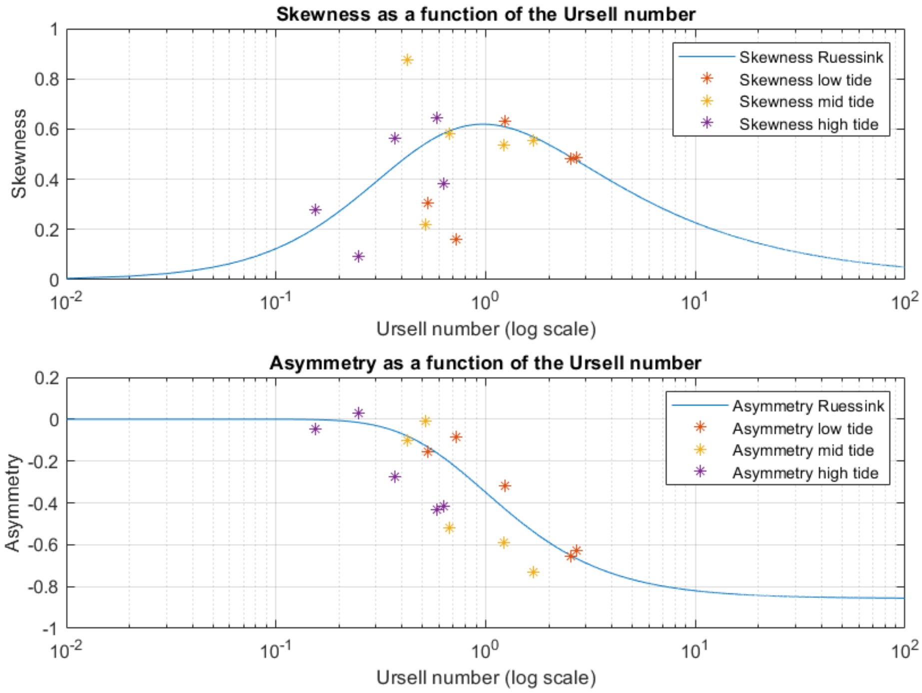

Figure 1.1: Skewness and asymmetry as a function of the Ursell number. The blue line represents the skewness or asymmetry calculated from the Ruessink empirical fits. The points define the observations as calculated in section 6.1.1 for the Egmond data for different tides.

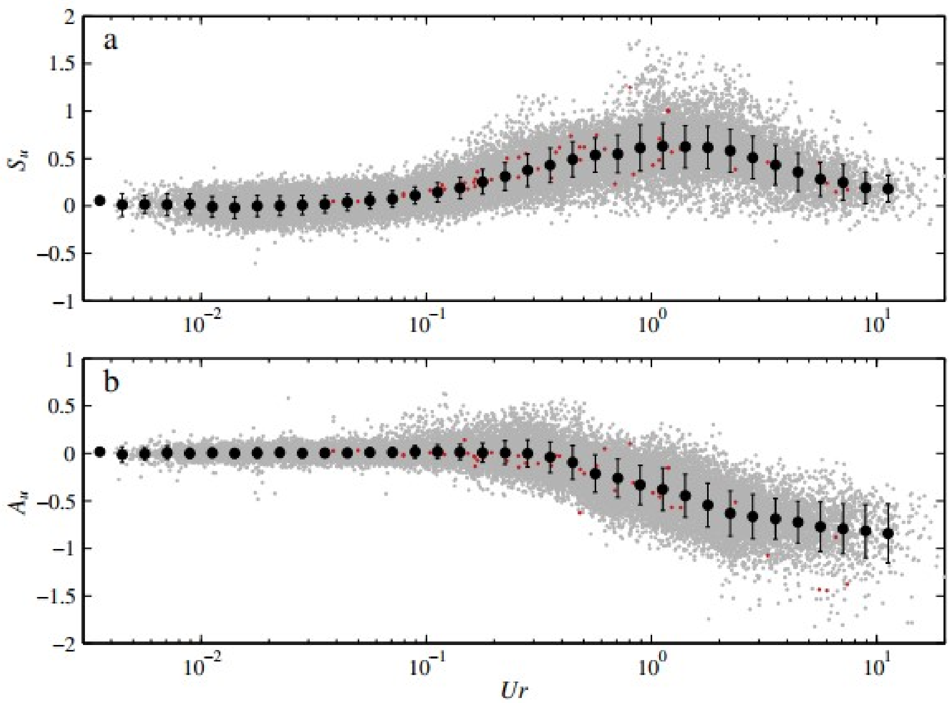

Figure 1.2: Skewness and asymmetry as a function of Ursell number from the Ruessink et al. (2012)'s paper.

2 6.2 Modelling Sk and As

- *Create three figures, one for each tide, each of them divided in three sub-plots:*
  - *in the top part, plot the cross-shore evolution of the skewness predicted by the model. Add also the observed values (computed on Section 6.1.1);*
  - *in the middle part, plot the corss-shore evolution of the asymmetry as well as the observed values;*
  - *in the bottom part, plot the cross-shore evolution of the bed profile.*
- *Comment of your findings.*

In this section, the outputs of the Battjes and Janssen model is used to compute the asymmetry and skewness at each location over the bed profile.

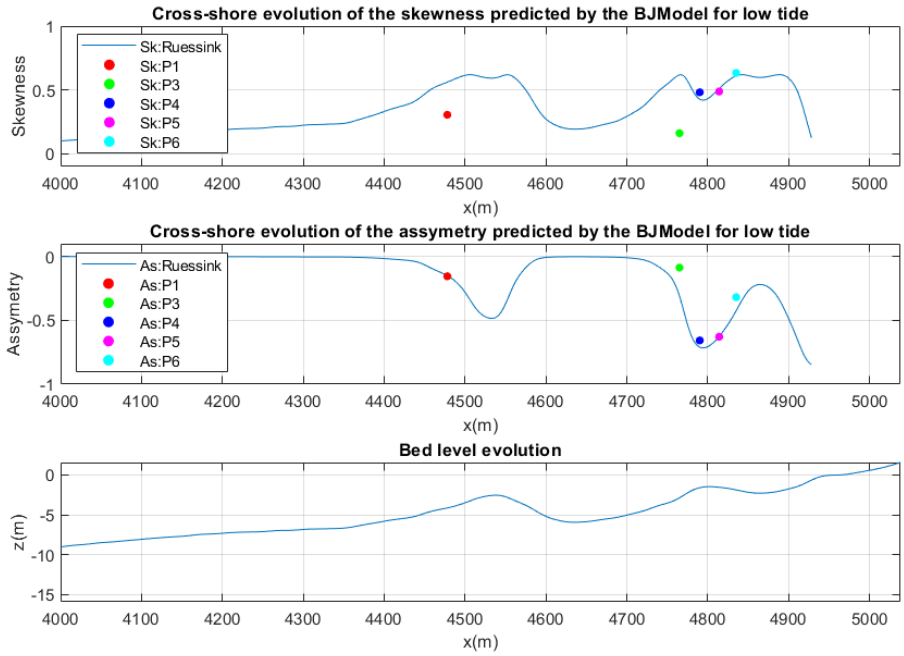

Figure 2.1: Cross-shore evolution of the skewness (top) and asymmetry (mid) predicted by the BJ model for low tide. The blue line represents the skewness or asymmetry as calculated from the Ruessink empirical fits and the points refer to the Egmond data points for different sensor locations. The bottom plot shows the bed level evolution.

In Figure 2.1, it can be observed that the skewness is increasing up to the point $x = 4500m$ because of the gradual shoaling of the waves due to the sandbar located there. After that point, there is an increase of the water level and skewness decreases. The same behaviour follows in the second sandbar $x \sim 4800m$ and close to the shore. The magnitude of asymmetry is also increasing above the sandbars and close to the shore. This is due to the fact that the waves start to feel the sea bottom and they break. Seawards, as the depth increases, both skewness and asymmetry come closer to zero values.
The model seems to agree with the observations as most of the observed data are on or close to the line, except the first two data points at the skewness graph where a large deviation from the model can be noted.

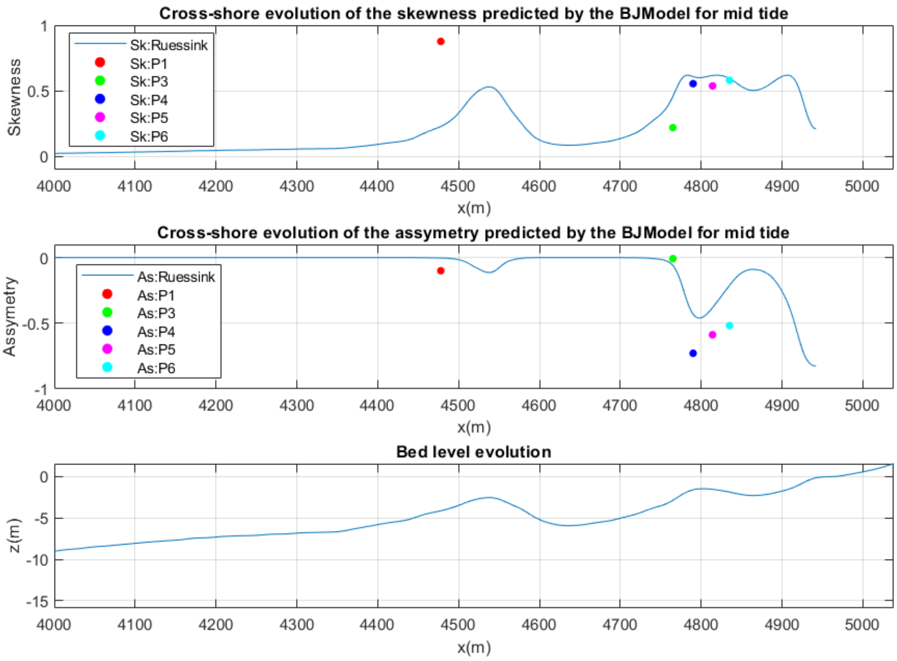

Figure 2.2: Cross-shore evolution of the skewness (top) and asymmetry (mid) predicted by the BJ model for mid tide. The blue line represents the skewness or asymmetry as calculated from the Ruessink empirical fits and the points refer to the Egmond data points for different sensor locations. The bottom plot shows the bed level evolution.

Figure 2.2 illustrates the results for the mid tide. Overall, the behaviour of the skewness and the asymmetry remain the same. However, there are some significant differences to indicate. One of them is that after the second sandbar the change in skewness is much less than the low tide case. Also, the change of magnitude of asymmetry in both sandbars has decreased. Both cases can be explained by the higher water level for the mid tide in comparison with the low tide. As the tide is getting higher, water depths are larger with less dissipating waves which result in less skewness and asymmetry.
Comparing the model and observations, it can be concluded that the model is efficient.

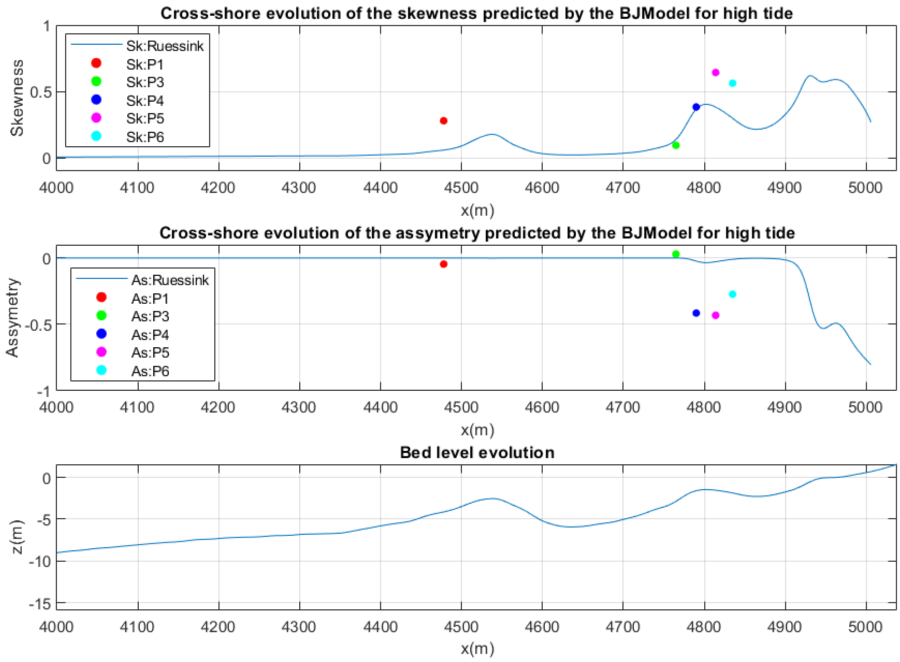

Figure 2.3: Cross-shore evolution of the skewness (top) and asymmetry (mid) predicted by the BJ model for high tide. The blue line represents the skewness or asymmetry as calculated from the Ruessink empirical fits and the points refer to the Egmond data points for different sensor locations. The bottom plot shows the bed level evolution.

Regarding the high tide case and Figure 2.3, it is noticed that the wave shoaling is much less resulting in even lower values for the skewness than the previous cases. In the first sandbar no change of asymmetry is observed while a slight increase can be seen in the second sandbar. This results in the waves being asymmetrical and breaking near the coast.
In this case, the model describes the observations in an efficient way but with large deviation.

3 6.3 Cross-shore evolution of the orbital velocity

- *Analyse the changes in wave shape for the three following cases and discuss the respective roles of r and Φ.*
  - Φ = *-pi/2 and* r = *0,0.3, 0.6*
  - Φ = *0 and* r = *0,0.3, 0.6*
  - Φ = *-pi/2, -pi/4 and 0 and* r = *0.6*

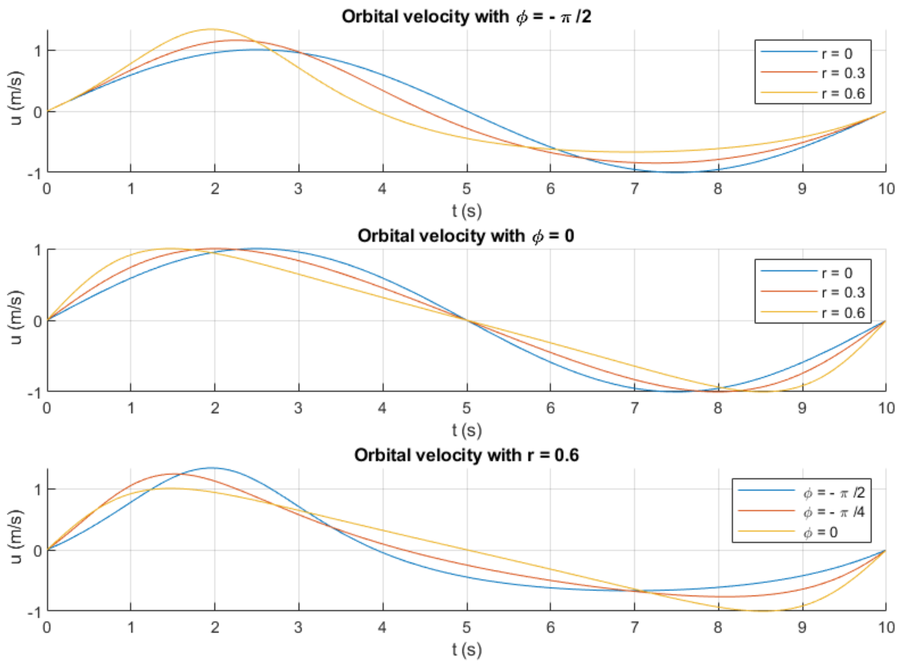

Figure 3.1: Orbital velocity as a function of time. Top subplot: Φ = -$pi/2$ and r = 0,0.3, 0.6. Middle subplot: $\Phi = 0$ and r = 0,0.3, 0.6. Bottom subplot: Φ = -$pi/2$, -$pi/4$ and 0 and $r = 0.6$

This section focuses on the changes of the wave shape through the evolution of the orbital velocity and the influence of the parameters r and Φ.

From the top subplot of Figure 3.1, it can be seen that skewness and asymmetry increase with the increase of the value r. Setting the value of Φ to zero, in the middle subplot, it is noticed that when $r = 0$ the orbital velocity is a sinusoidal curve. Asymmetry is detected with the increase of r, however, there is no increase in skewness. From the above, it can be concluded that r controls the degree of non-linearity. When r increases, non-linearity increases. On the other hand, Φ controls the phase, meaning that a decrease in Φ leads to an increase in skewness and a decrease in asymmetry.

- *Compute U_w for each location along the profile for the low tide case and examine its evolution*

Figure 3.2 demonstrates the evolution of the velocity amplitude across the bed profile. It is possible to observe that U_w increases with bed elevation. The velocity amplitude can be expressed as:

$$U_w = \frac{\pi}{T} \frac{H_{rms}}{\sinh(kh)} \tag{3.1}$$

With the help of equation 3.1 it can be seen that U_w is analogous to H_{rms} which increases with the decrease in water depth resulting in the increase of the orbital velocity.

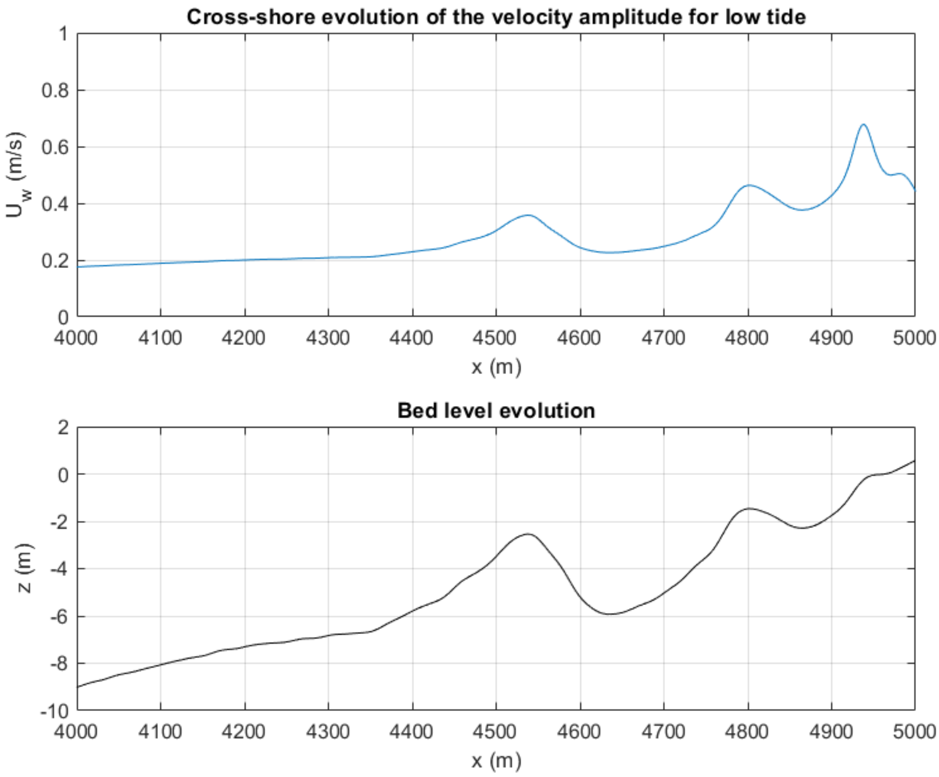

Figure 3.2: Cross-shore evolution of the velocity amplitude for low tide (top subplot). The bottom subplot depicts the depth profile of the bed.

- *Compute now the predicted time-series of orbital velocity (Eq. (6.7)) at x=1000, 4400, 4500, 4700 and 4920 m (for the low tide).*
- *Discuss your results.*

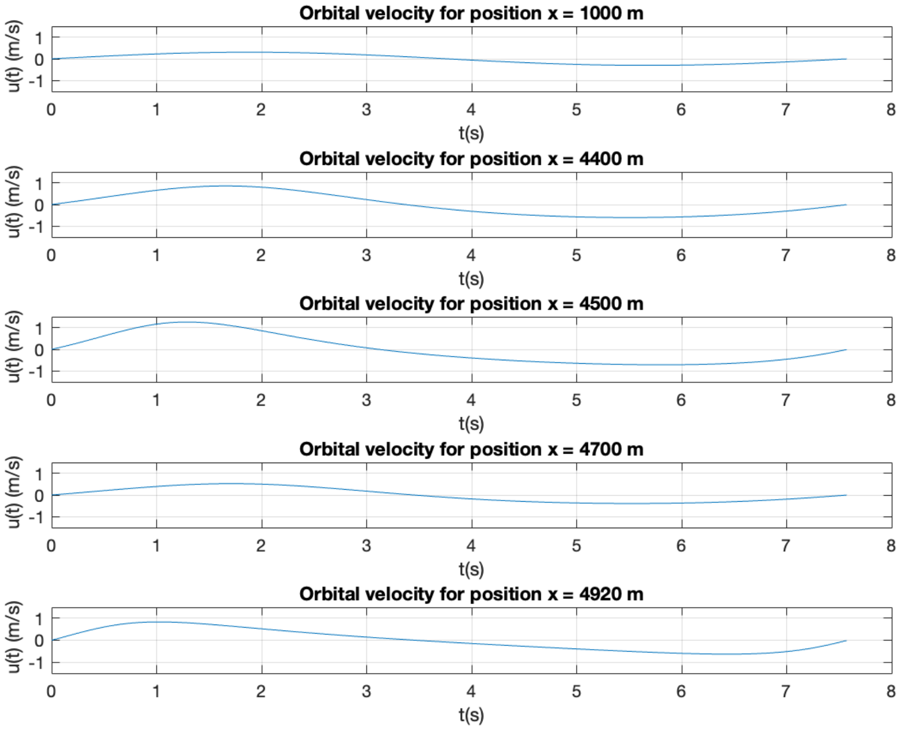

Figure 3.3: Time series of the orbital velocity for the new positions (low tide)

The predicted time-series of the orbital velocity is computed at the different locations for the low tide. The evolution of the wave is visible in Figure 3.3. At location $x = 1000m$ the wave is in deep waters with low amplitude and sinusoidal shape. Afterwards, at $x = 4400m$, the wave shoals and its amplitude and skewness has slightly increased. Just before it goes through the sandbar, at $x = 4500m$ a further increased in amplitude and skewness is noticed and also it becomes asymmetric. At $x = 4700m$, the wave is passed the sandbar and is in deeper waters resulting in a decrease in asymmetry and skewness. Finally, near the coast at $x = 4920m$, the wave is strongly asymmetrical due to shallower depths leading to the break of the wave.