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The effect of directional spreading in hydrodynamic and sediment simulations (Case study Roudik coast)

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Abstract

Considering a large number of beaches in the south and the north of the country, the issue of sedimentation in ports and erosion of beaches around the marine structures has great importance, and not paying attention to it can affect the efficiency of the port. One of the most important parameters in the detailed study of coastal sediment transport is the directional spreading of waves in this study by using Delft-3D software, the effect of directional spreading in the sediment transport is investigated. The results of this study show that wave height, changes in radiation stress gradient and flow velocity will change with a change in directional spreading. Simulation with a constant directional spreading coefficient reduces the accuracy of the results.

Keywords: Coastal sediment, Directional Spreading, Delft-3D, 2D Simulation, Roudik Coasts

1. Introduction

By considering a large number of beaches in the south and the north of the country, the issue of sedimentation in ports and erosion of beaches around the marine structures has great importance, and not paying attention to it can affect the efficiency of the port. Wave activity is a major factor in the long shore sediment transport in sandy beaches. Accurate prediction of this phenomenon is required for the proper design of ports and coastal protection schemes. Numerical models are used to predict the distribution of coastal sediment transport across the wave breaking zone. One of the most important parameters in the detailed study of coastal sediment transport is the directional spreading of waves. Yoshika Kuriyama in 1991 addressed the issue of two-dimensional long shore current transmission in the presence of sediment traps. For this purpose, he developed a model whose current information is obtained from the wave spectrum [1]. In 1994, Yoo developed a model for calculating wave height and sediment transport under the influence of the frequency spectrum [2] .in 2001, Kitou investigated the effect of wave directional and frequency spectrum on long shore current. They concluded that the form of the directional spectrum could make up to 50% difference in long shore current calculations [3]. Feddersen in 2004 examined the effects of wave directional spread on radiation stress as a function of wave frequency-directional spectrum. They conclude that the radiation stress is directly related to the directional spreading of the wave [4]. In 2015, Anika

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O'Dea Discussed the effect of asymmetric directional spreading on total radiation stress. Net radiation stresses were calculated for a wide range of frequencies with symmetric and asymmetric directional distributions and then compared with those that are narrow in frequency and direction [5]. Cheng Yee in 2020 found that the effect of directional spreading on wave energy at high angles has a greater decreasing effect. They showed Force reduction was found due to the directional spreading angles, whereby 1.20 percent of total wave force were reduced with every one degree of angle incremental. Overall, greater reductions are expected for bigger angles as the wave energy distribution area is expected to be increased [6].

In this study by using Delft-3D software, the effect of directional spreading in the sediment transport is investigated. The results of this study show that wave height, changes in radiation stress gradient and flow velocity will change with a change in directional spreading. Simulation with a constant directional spreading coefficient reduces the accuracy of the results.

2. Methodology

According to the numerical modeling process and the needs of this research, the method of the present study has been selected in accordance with the standard model of these modeling. Figure 1 shows the methodology of this research.

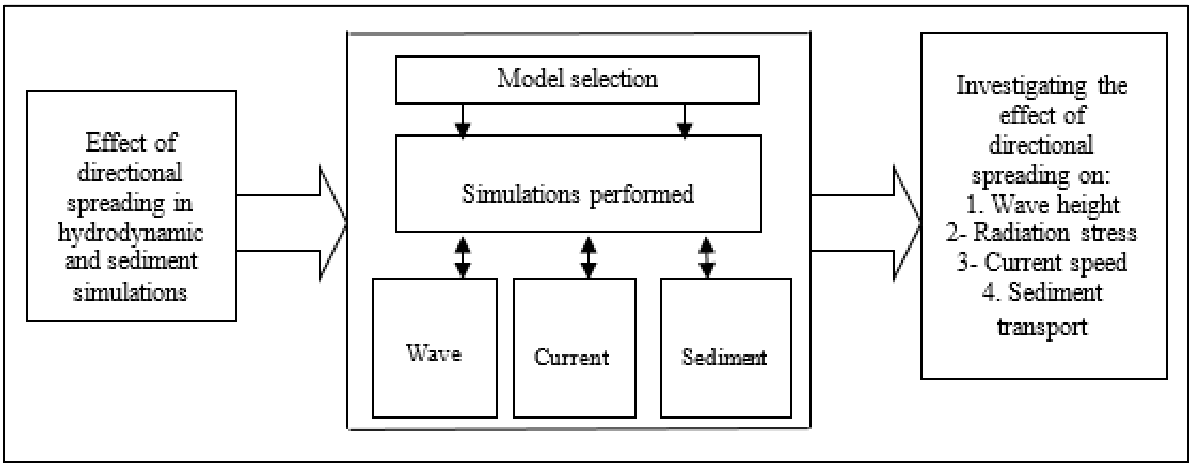

Fig. 1: Methodology

3. Introduction of numerical model

The model used in this research is the Delft 3D numerical model. In this model, by calculating the unstable current and the transfer due to tides and atmospheric forces on a two- or three-dimensional solution network, it simulates the desired phenomenon. The flow modeling in this software is calculated directly, but the wave equations are solved through the Swan numerical model of a third-generation spectral model. This model also has modules for transferring cohesive and non-cohesive sediments and water quality assessment that can be updated throughout the hydrodynamic simulation. This model is suitable for a wide range of different issues including ports, tidal lagoons and rivers and can be used for small and medium time periods. One of the disadvantages of this model is that it is not suitable for large-scale time simulations (for example, hundred years) or for simulating large areas that require high computational power.

3.1. Numerical modeling

After selecting the Deltf-3D numerical model as a computational model, it is necessary to introduce the computational domain and boundary conditions for it. The computational domain has been selected according to the study is show in Figure 2 and Figure 3. According to the sensitivity measurements performed in this simulation, the wave model has been simulated with a nested grid, which becomes smaller in each step and in the area. The morphologic grid is also resized as shown in Figure 3, the more complete information is shown in Table 2. The wave boundary condition used in this model according to the wave information of Makran coast is as in Table 1. To show the effect of directional spreading in hydrodynamic, simulations are performed for 37.5, 14 and 3 degree directional spreading. Another information required for the simulation is the hydrography of the study area. Using the depth measurement information performed on the Makran coast, the hydrography used in the simulation is Figure 4.

Table 1: Wave Input

	Wave Input		
	Test 1	**Test 2**	**Test 3**
Hs (m)	2	2	2
t (s)	10	10	10
Direction (deg)	187	187	187
Dsd (deg)	3	14	37.5

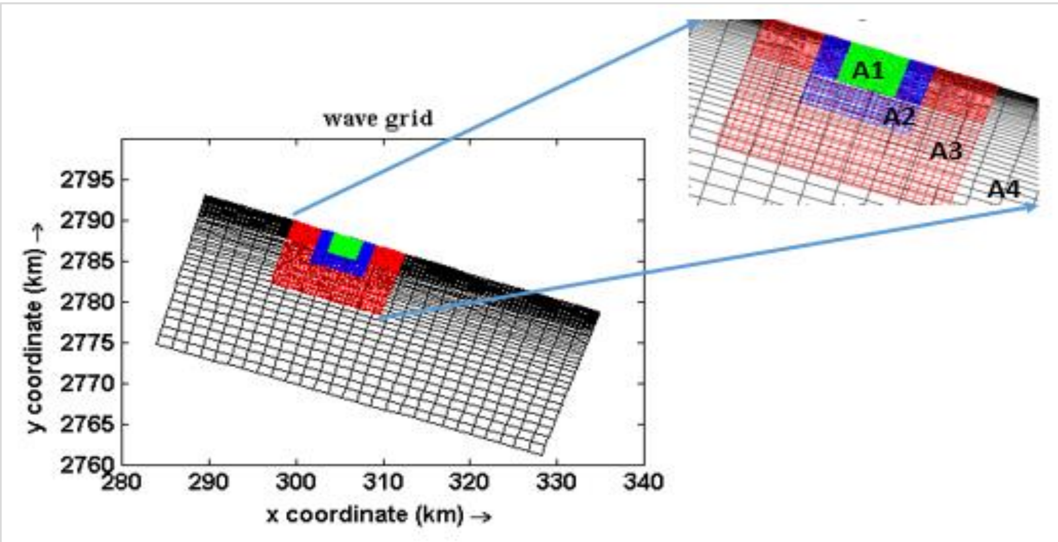

Fig. 2: Wave grid

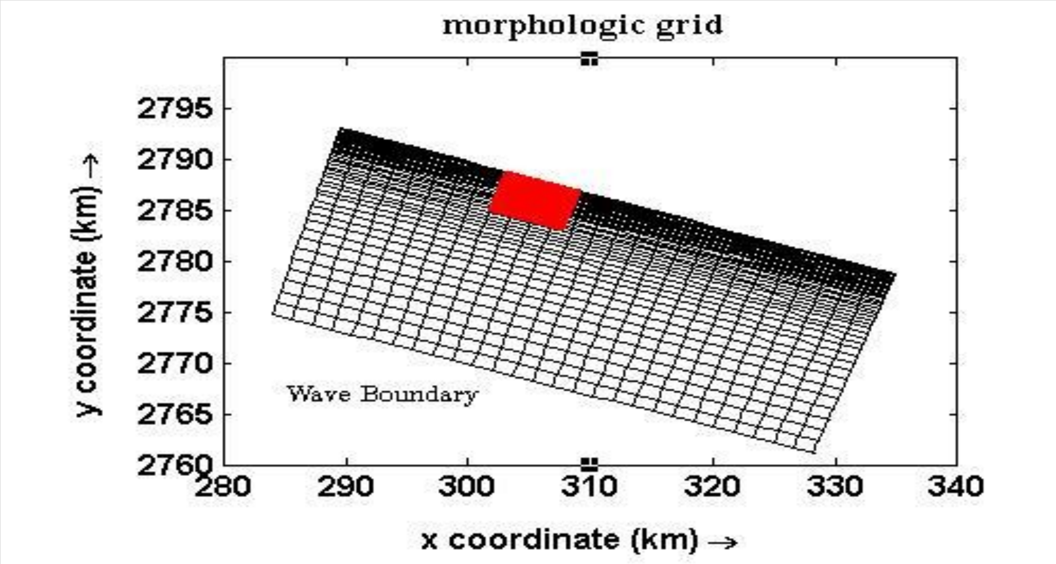

Fig. 3: Morphologic grid

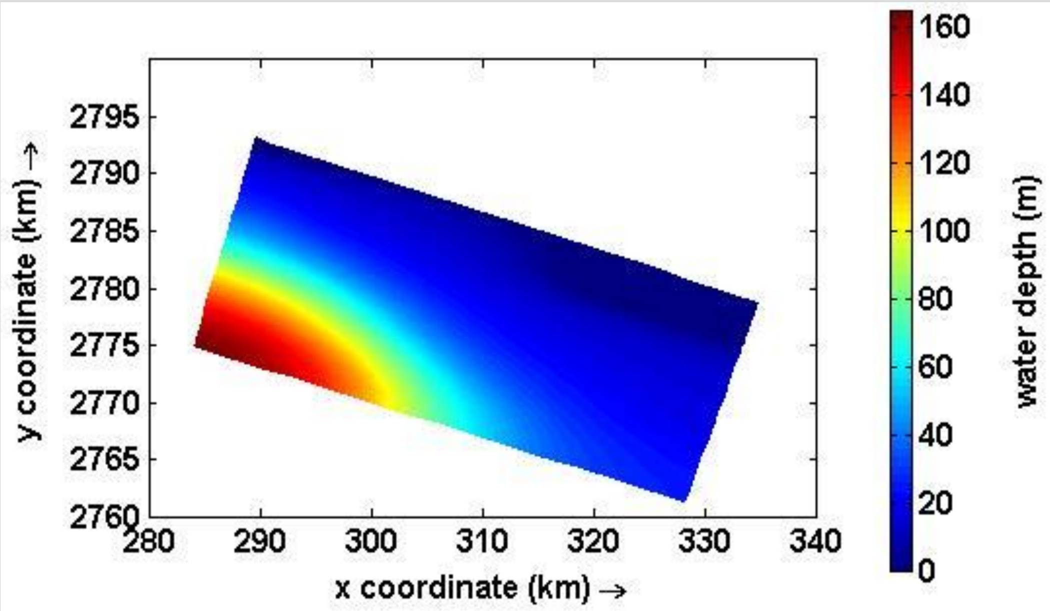

Fig. 4: Water depth

Table 2: Grid dimension

	Grid dimension				
	A4	**A3**	**A2**	**A1**	**Flow**
Delta x (m)	1700	490	330	165	165
Delta y (m)	1200	100	65	33	33

4. Results

In order to demonstrate the effect of directional spreading in hydrodynamic, sediment, wave and current calculation the Delft3D Model simulated for 300 days and the details showed in table 3. The results showed that the directional spreading has changed in computational grid. Fig.5 showed by nearing to the coast the effect of directional spreading is decreased.

Table 3: Model Setup

Simulation Mode	generation Mode	Wave Setup	Break Alpha	Break Gamma	Bed Friction	Bed Friction Coef	Quadruplets
stationary	Third generation	active	1	0.8	Jon swap	0.038	De. Active

Wave Forces	Delta teta	Delta frequently	Time	Morphological factor	Sediment Type	D50	Ro-s
radiation stresses	36	21	30 day	10	sand	0.2 mm	2650

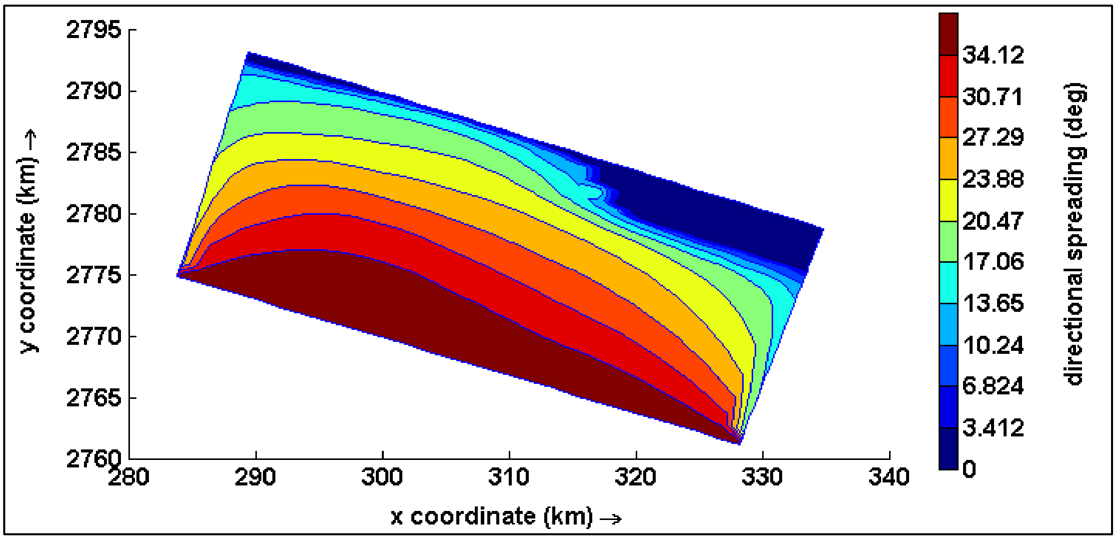

Fig. 5: Change in directional spreading along the computational grid

Figure 6 compares the simulated wave height for waves with different directional spreading. As can be seen, with increasing the directional spreading index, the rate of drop in wave height before break and the rate of loss in the wave breaking band range (from where the largest wave train waves begin to break to where all irregular wave train waves will be broken) have slightly decreased. Figure 7 shows the Wave force for different directional spreading of the wave. As observed, the effect of the directional spreading of the wave on the intensity of the long shore current is quite decisive and significant and increasing the directional dispersion index in the normal range for the Iranian coast can more than double the intensity of long shore current. The reason for this is not the effect on the angle or height of the wave, but the effect on the radiation stresses of the waves and their gradients.

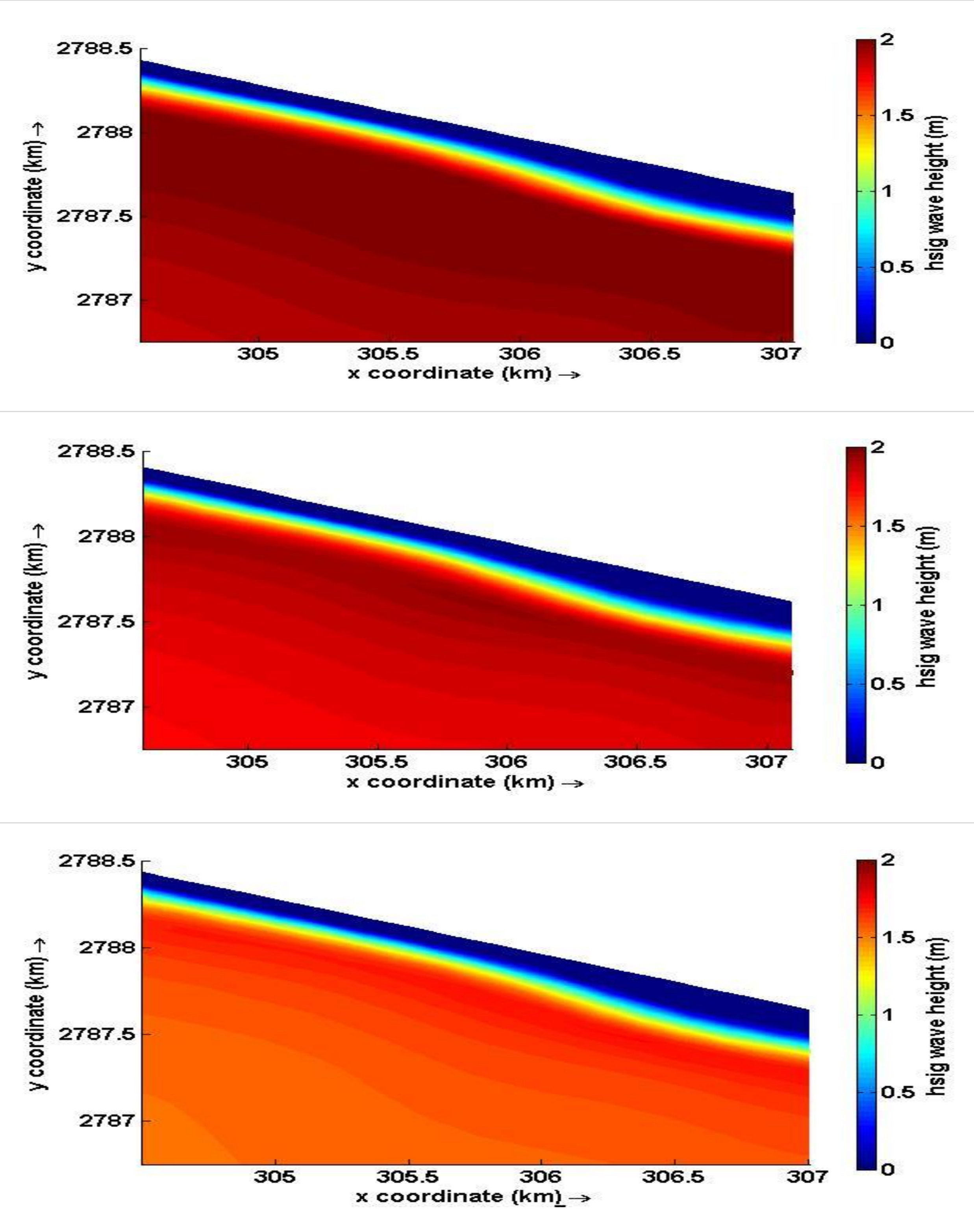

Fig. 6: Change in wave height in computational domain

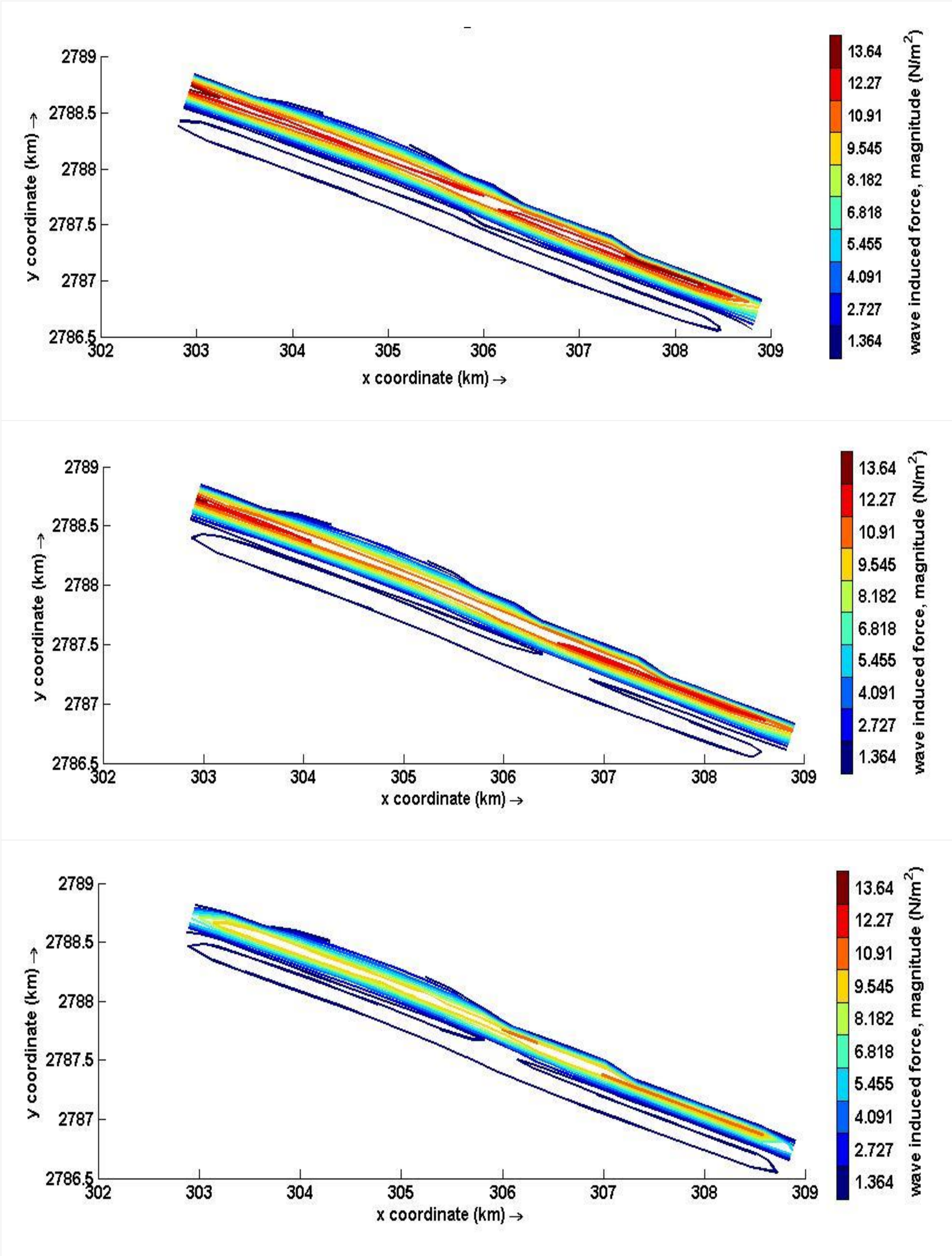

Fig. 7: Change in wave force in computational domain

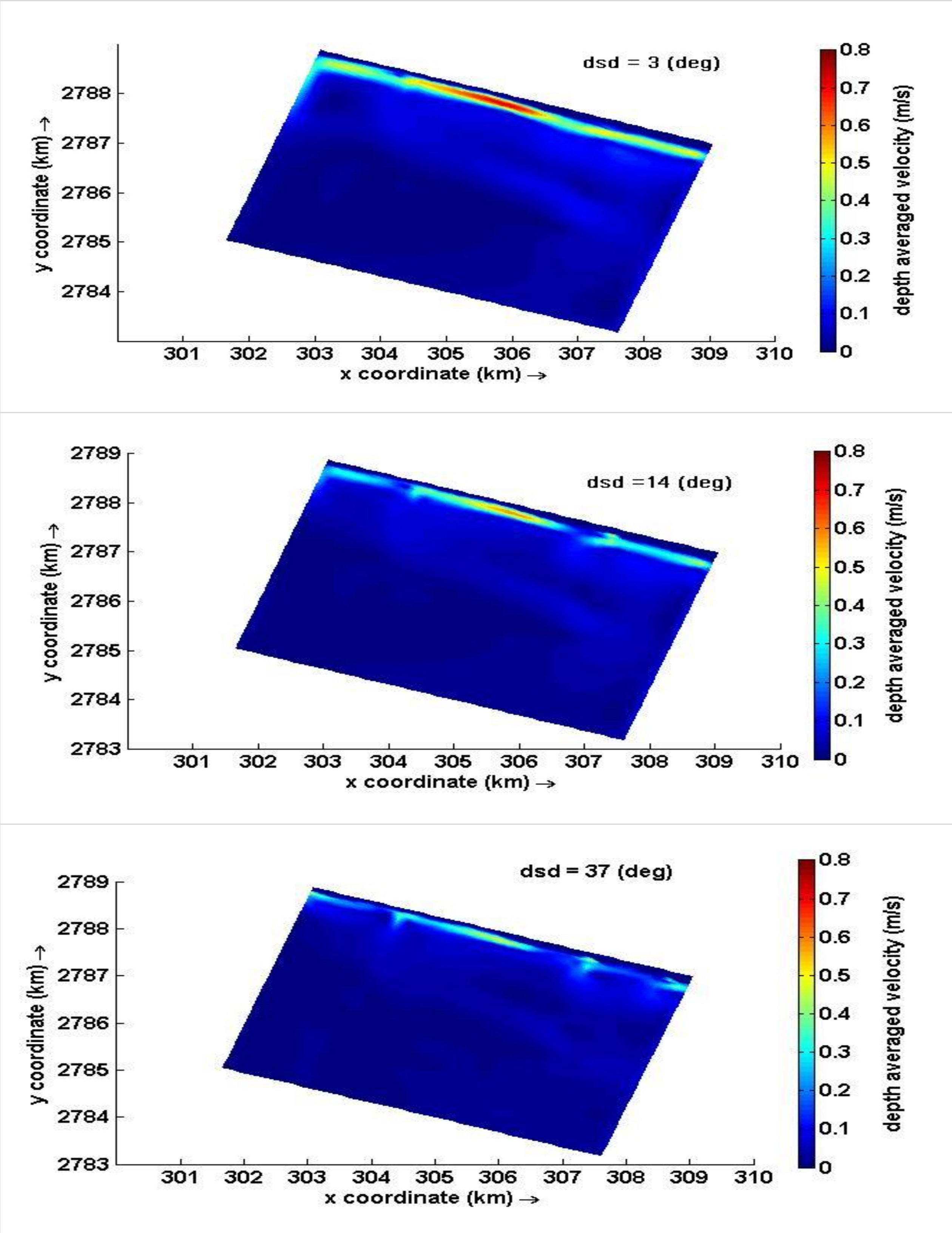

Fig. 8: Change in depth averaged velocity along the computational grid for different directional spreading factors

Figure 9 shows the long shore sediment transport rate of the simulated shore for different directional wave spread. The sediment transport long shore to the shore is affected by two main factors: a) the amount of suspension of bed sediments due to wave breaking, and b) the intensity of long shore current. So irregular effect on the amount of sediment transport is also effective.

In the calculations of wave transport, long shore current and sediment transport, it was found that these values do not change for spread more than 40 degrees, which is due to the way the Swan model is calculated and that more spreading than this are only surface water fluctuations.

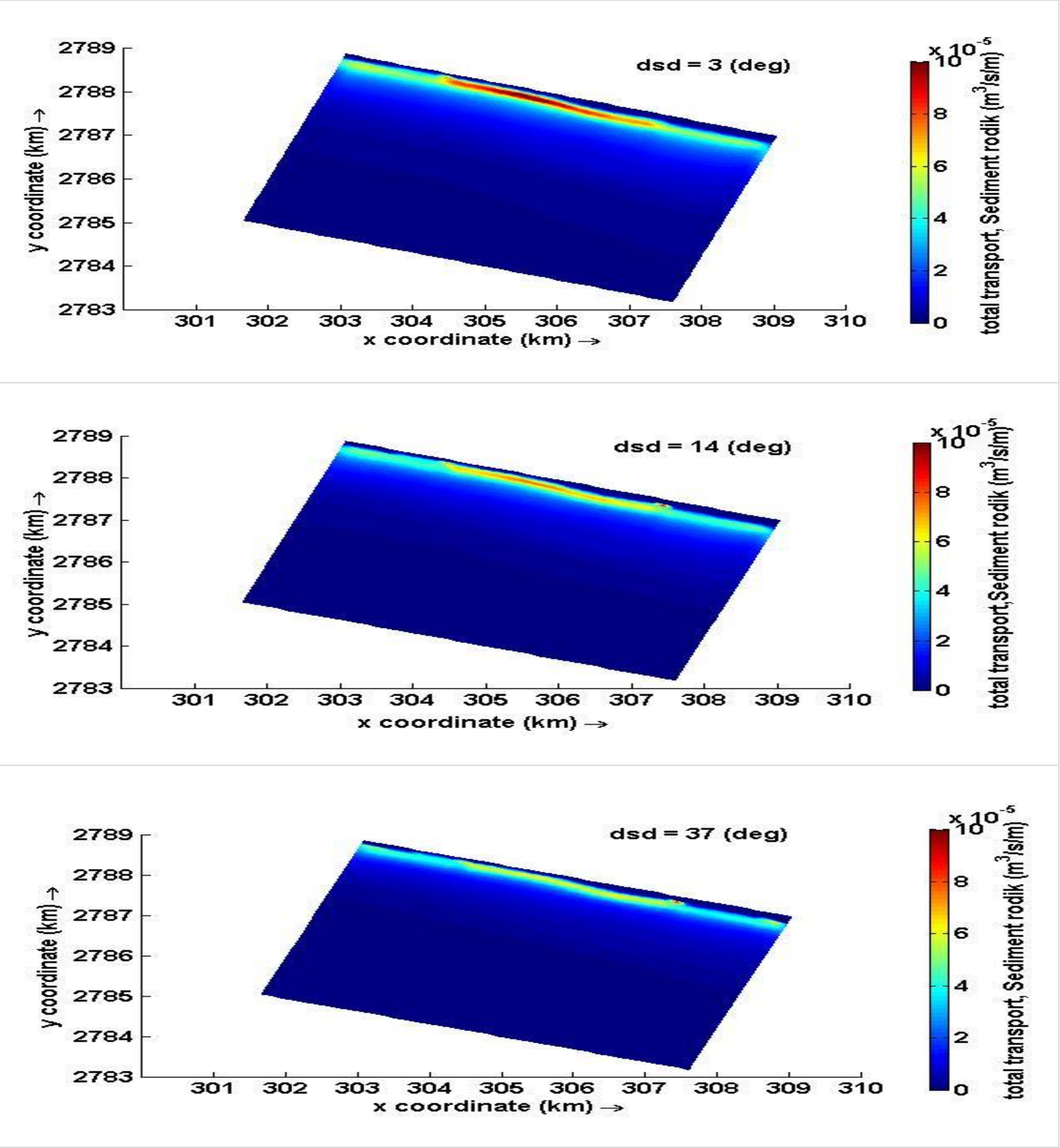

Fig. 9: Total transport sediment in computational grid for different directional spreading factors

5. Conclusion

In this study by using the Delft3D numerical modeling simulated the effect of directional spreading in hydrodynamic modeling. Results showed that the wave height, current velocity and sediment transport has changed by changing in directional spreading and it is necessary to change the directional spreading in a wave time series. The same consideration of the directional spreading in a simulation leads to a decrease in the accuracy of the results, all of which have been investigated for the Rudick coast. Failure to consider it will reduce the accuracy of the simulation results.

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