Regeneration of dredged sand waves

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Abstract

Sand waves form a wavy pattern in the offshore sandy seabed. Since their crests reduce the navigability, it is important to know their evolution. A simple model is presented to estimate the recovery of sand wave amplitudes. This model is partially based on the similarity with sea ripples and partially on bathymetry measurements. No further information is needed. The model reproduces the data very well. Using this model, it is possible to evaluate different dredging strategies.

Introduction

The seabed is usually not flat, but is covered with a variety of bedforms. These bedforms vary from the small ripples, which are often found sandy beaches, up to enormous tidal sandbank structures with wavelengths in the order of kilometres and wave heights in the order of tens of meters.

The nature of these features is not yet fully understood. Most authors agree that one of the most important driving forces for the occurrence of large-scale bedforms is the tidal movement. Another important factor is the diameter of the sediment grains on the sea bed.

Sand waves are a separate category of bedforms on the continental shelf. Their wavelengths range from 100 metres up to 1 kilometre. The height of a sand wave is related to its wavelength. It varies from 1 metre up to 10 metres, although sand waves of 17 metres in height have been reported. Sand wave crests are usually orientated perpendicular to the principal direction of the tidal current. Sand waves tend to migrate in the direction of the principal tidal current, although some, like the ones in the approach area to the Eurogeul in the Netherlands, do not seem to move at all. Since dredging works are executed all over the world for large sums of money, it is interesting to model sand wave behaviour. When dredging the sand waves, one can vary parameters as dredging depth, spatial distribution (i.e. overall or only the crests) and the frequency. The latter is often determined by the navigation depth. The dredging strategy could well be optimised if sand wave behaviour is understood better.

2-The sand wave model

In analogy to an earlier presented model for small ripples under sea waves (Blondeaux, 1990), a sand wave model has been derived. The sand wave model is a one-dimensional description of sand wave amplitude evolution. The model sand waves are presented as sinusoidal shaped, non-migrating waves:

$$\frac{h}{H} = A\cos(2\pi x / L)$$

$$\frac{\partial A}{\partial \tau} = \alpha_1 A + \alpha_2 A^3$$

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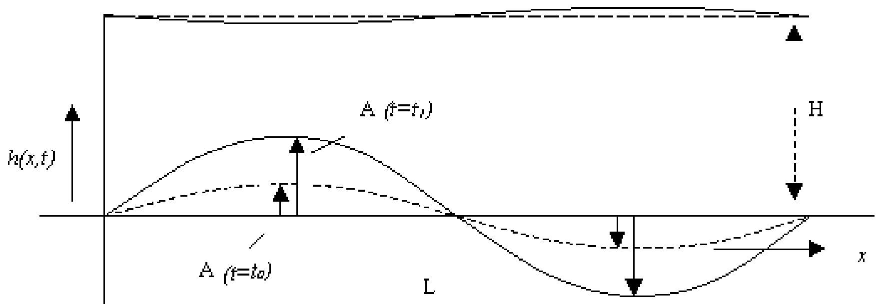


Figure 1 Situation sketch

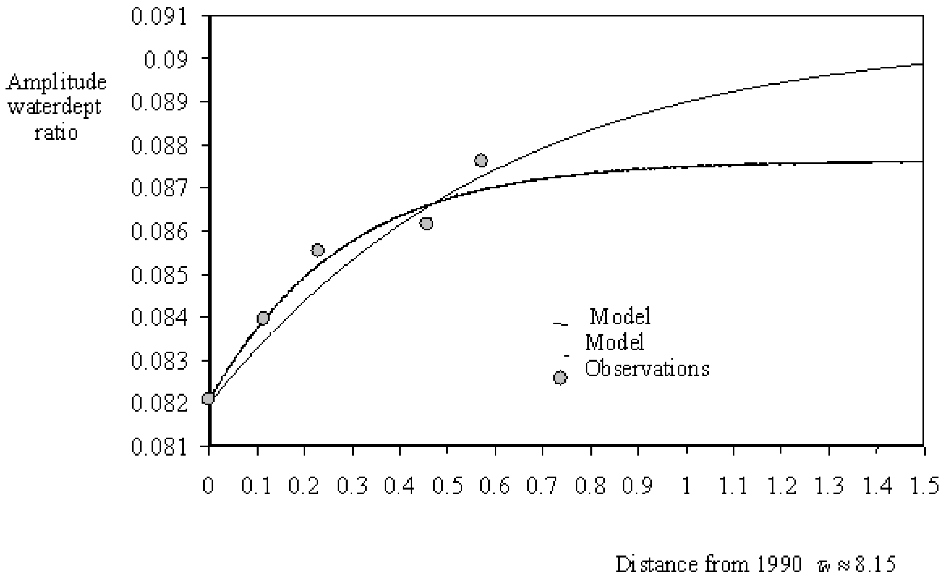
in which z_b is the sand wave, with amplitude A and wavelength L. x denotes the spatial co-ordinate and τ the morphological time scale. The undisturbed water depth H is assumed to vary little on a long time scale. The idea behind the model is that sand waves with very small amplitudes tend to grow exponentially, which is consistent with the work of Hulscher [1996].

Therefore, the initial situation can give an exponential growth of sand wave amplitudes. Due to the non-linear term, the sand waves tend to grow to some equilibrium height, which is dictated by local circumstances. The equilibrium height is in the North Sea approximately 18% of the water depth.

The scales of sand waves and ripples are different, but the processes involved are considered to be similar. In order to create an applicable model for a concrete situation, the various model coefficients need to be determined for that particular situation, which is done using measurement data.

3-Results

The model parameters have been determined for sand waves in both the Bisanseto Sea in Japan (Katoh et al, 1998), and the North Sea in the Netherlands. This has been done by means of data from the sea bottom in both cases (Details are given in Scholl, 1999). After fitting of the parameters the model gives the growth as given in figures 2 and 3. The found parameters are in agreement with the theoretical values as given by (Hulscher, 1996).



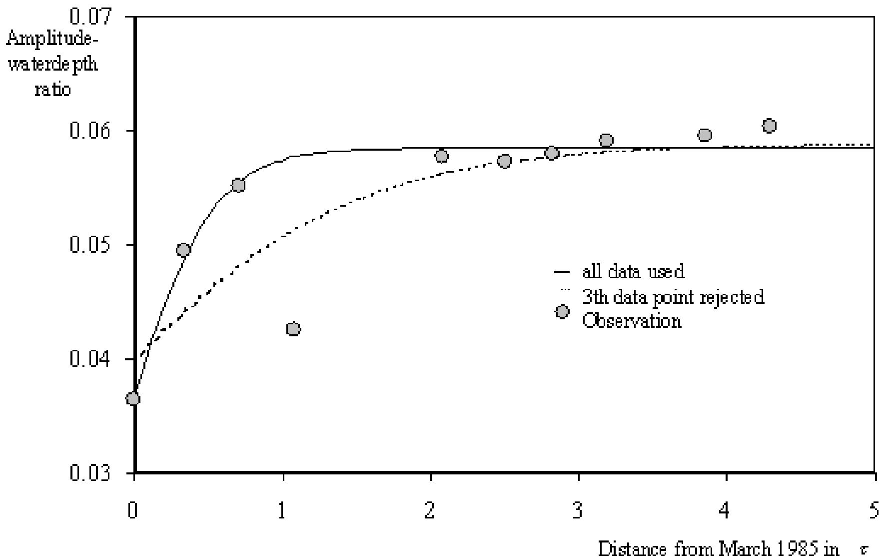


Figure 1: Growth of sand waves in the Bisanseto Sea. The model reproduces the data, but is very sensitive to outliers (the fourth data point).

Figure 2: Growth of sand waves in the North Sea. 2 possible model runs vs. measurement data. Note that there has been dredged before the final measurement.

4-Application: Dredging strategies

Based on the conditions in the North Sea area, dredging strategies are tested using the model. The only selection criterion we considered is the time it takes for the sand waves to decrease the navigational depth to a reference depth.

The model is used to compare 2 strategies, in which the sand waves are topped off.

1. the sand is transported out of the area for commercial use.
2. the sand is redeposit in the troughs. It is assumed that the extracted sand causes a net transport into the area (See Katoh et al. 1998).

For case (1) we find a period of recovery of almost 10 years. For case (2) this period is very sensitive for the net inflow of sand, see table 1.

S_{in} **in cm/year^{-1}**	τ	**t in years**
1	2.33	19
2	1.1	9
3	0.81	6.6
4	0.66	5.4
5	0.56	4.6
6	0.49	4
7	0.44	3.6

Table 1 Changes in the recovery time due to changes in net deposition of sand (S_{in}).

5-Conclusions and recommendations

The sand wave model presents an adequate estimate of complete trajectory of the sand wave growth. The simple model, combined with a parameter fitting procedure, makes the model useful for strategic decision making. No physical knowledge is required. However, to get an accurate parameter fit, long period data sets are necessary, which makes monitoring necessary.

Reference

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