Title: Improved estimation of seafloor dynamics for optimising hydrographic resurvey planning.

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Introduction

Optimising the national hydrographic survey planning and monitoring scheme of the Netherlands Continental Shelf (NCS) towards an efficient and sustainable outcome requires a more comprehensive evidence-based approach to decision making. The NCS is experiencing increasing economic activity across various sectors ranging from ports and navigation, tourism, renewable energy, coastal defence, submarine cables, mineral extraction, fishing and military activities among others. With limited resources for hydrographic surveying, to support these marine activities, the added knowledge and interpretation of seafloor dynamics is essential for developing a probabilistic approach to prioritising resurvey frequencies in the NCS.

Process Model Selection, Fitting and Validation

A deformation analysis method is developed for detecting and estimating the seafloor parameters that attribute to the changing seafloor depths. This allows us to identify to what extent the changes are due to noise or real changes between surveys. The mathematical models are therefore used as a systematic approach to translate the problem for predicting the depths. The models consists of two parts, the functional model and the stochastic model. The functional model is in the form of observation equations. These observation equations consists of a vector of observations, vector of unknown parameters, linear functional relation between the observations and the unknowns and the stochastic model describes the stochastic characteristics of the observations which take into account the variability of the observations.

Through exploratory data analysis, a library of basic mathematical models is set up for evaluating the reliability of the estimated parameters (such as the crests and troughs, wavelength and migration rates) by assessing the residuals, which are the differences between observed depths and the fitted model. This is done by developing a testing procedure which investigates whether the residuals are due to the random errors in the measurements or model misfits. The first model used to represent the seafloor morphodynamics is a simple, stable or flat seafloor representation called the null hypothesis. To check the validity of this assumption, the parameters can be estimated as a Best Linear Unbiased Estimation (BLUE) with a least squares method and the sum of the squares of the residuals computed. Large residuals indicate that the observations do not fit the model under the null hypothesis and vice versa. This is used to decide whether to accept the null hypothesis as the best representation of the seafloor dynamics.

However, we know it is unlikely that the seafloor will behave purely in this manner. Assuming the errors are due to a model misfit, the present study considers adapting the mathematical models accordingly by introducing more complicated models with additional spatial and temporal extensions for the characterization of seafloor dynamics using the available data. Therefore alternative models that give a better description of the morphodynamics for different areas of the NCS are considered and referred to as alternative hypotheses. Dorst(2009) considered alternative representations for the morphodynamics which included a sloping plane and a sinusoidal wave superimposed on the sloping plane (refer to figure 2). The assumption under the sinusoidal model of a constant wavelength for the sandwaves is limiting when estimating the depths and migration rates. We introduce more complicated alternatives (additional parameters) which include a spectral model, sawtooth, continuous least squares (CLSQ) model fit between crests and troughs and an exponential fit between crests and troughs (refer to figure 3).

These additional models attempt to represent additional variations in the morphodynamics of the seafloor such as asymmetry, crests and troughs detection and non-linear growth patterns. For the given cross-section (refer to figure 1), by assessing the squared norm of the residuals, the adequacy of the functional part of the models can be assessed. Figure 4 quantifies the residuals for the alternative models, where there is an 80-85% reduction in the errors when using the CLSQ model and an exponential model. Adaptation of these alternatives can still be done if errors are detected to further reduce the modelling errors. For areas of interest in the NCS, these models can be tested against the null hypothesis until one arrives at the model that is most likely to give an adequate description of the seafloor dynamics. The selection of the best model will be used for predicting the depths in the future where the variance in the predictions are minimized.

Outlook – Time Series Analysis

The bathymetric surveys for specific case study areas will be represented on quadtree gridded structures, where each node has an easting, northing, depth and depth variances assigned to it. Having the depths represented in a multiresolution grid structure allows for optimal use of the available bathymetric data for the NCS. Also the variability in the depths are accounted for by improving the sampling density of the data. The next step is the cross sectional analysis using the time series of bathymetric surveys to compute the estimated trends and the parameters of interest for areas in the NCS that exhibit dynamic behaviour. Using the statistical testing procedure described, one will arrive at the most likely model which gives a more realistic representation of the cross-sectional dynamics of the seafloor. This will lead to better parameter estimates and more reliable predictions of the depths. Ongoing research will use the results of the improved estimated seafloor parameters to define indicators that will be useful in decision making and prioritisation of resurvey frequencies.

Acknowledgements

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References

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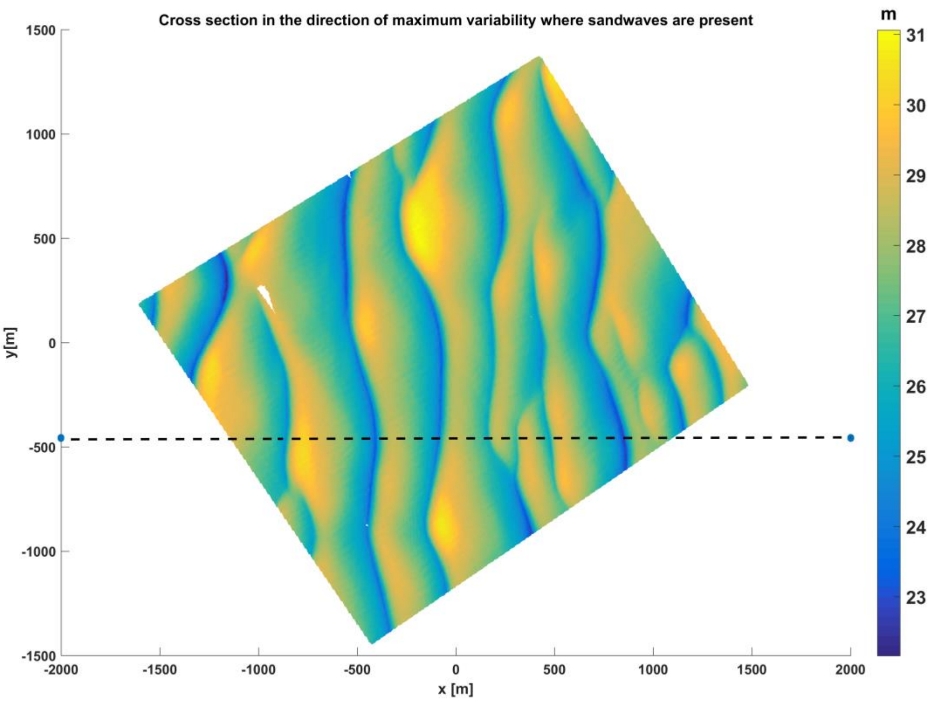

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Figure 1: Example of a MBES dataset where sand waves are present showing the cross section taken in the direction of maximum variability.

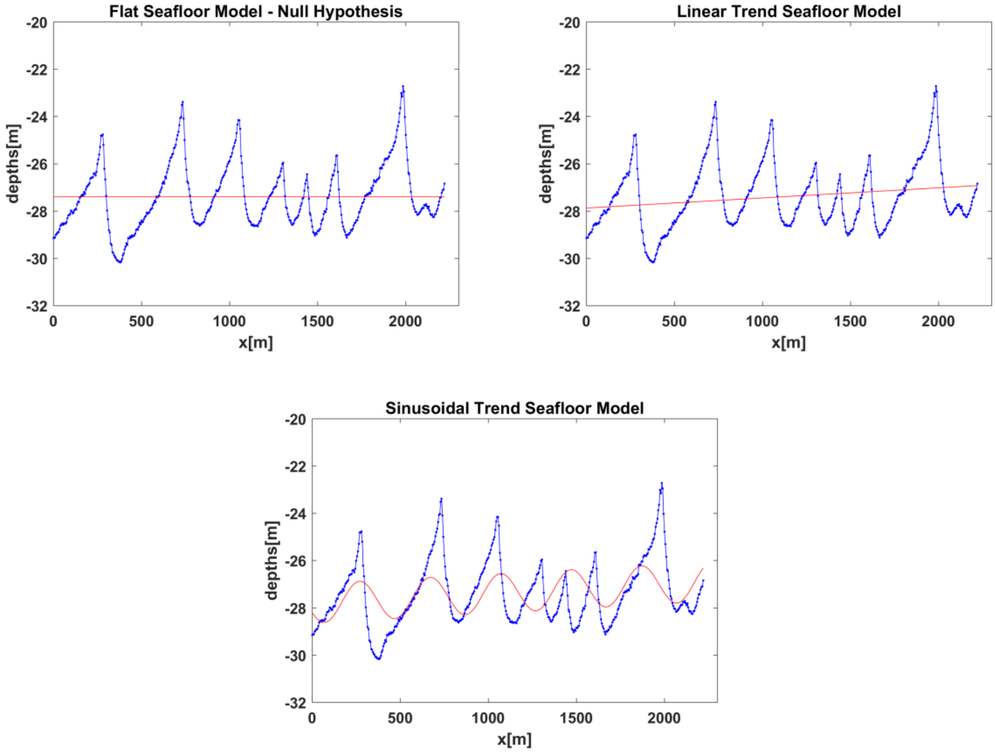

Figure 2: Blue line shows depth cross section of observations. Red line shows the stable, linear trend and sinusoidal model.

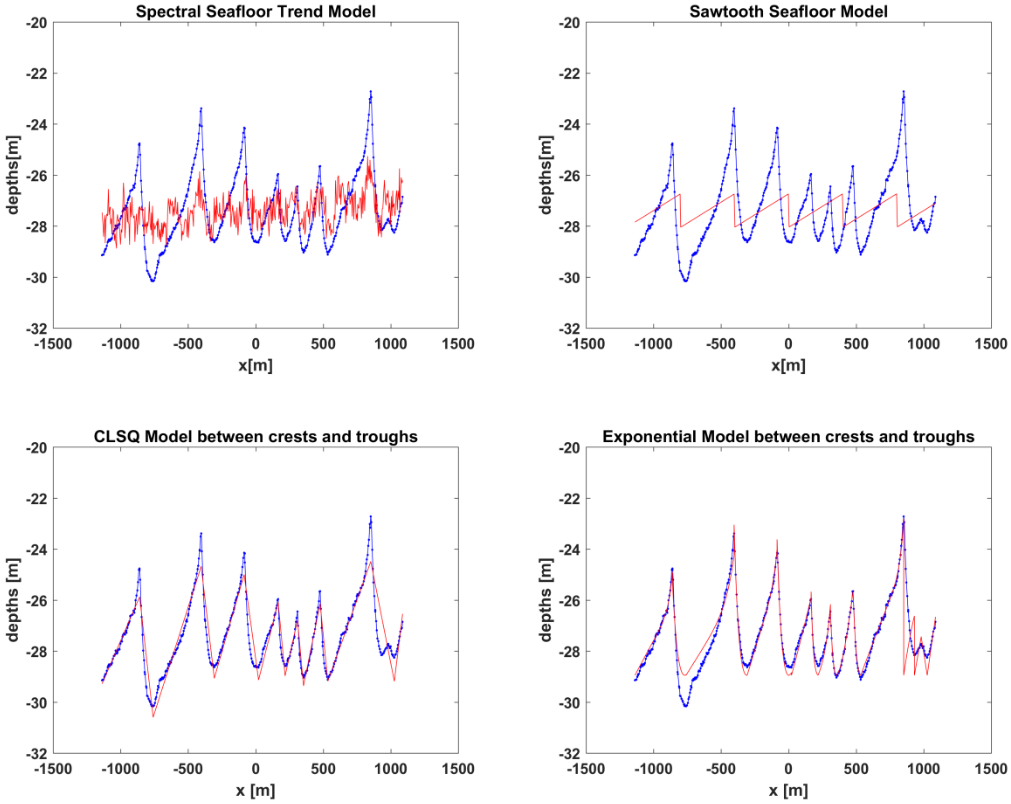

Figure 3: Additional alternative models; spectral, sawtooth, CLSQ between crests and troughs and exponential model between crests and troughs.

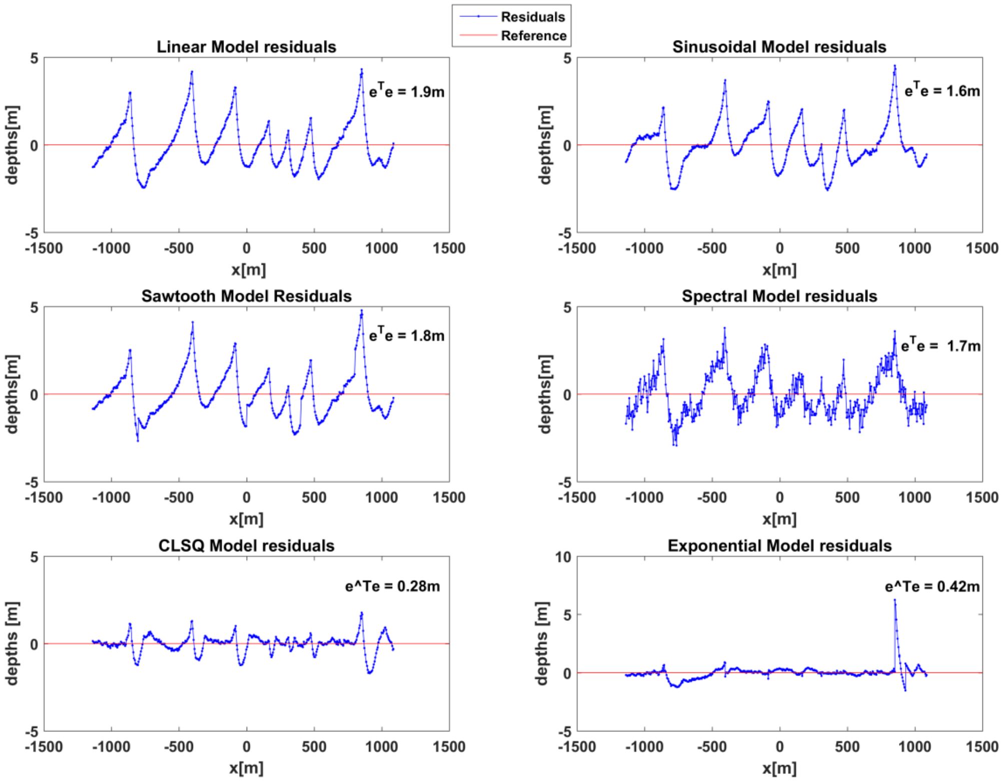

Figure 4: Residuals of the alternative models.