Models for Nearshore Sandbar Behavior

Abstract
Alongshore sandbars are often present in the nearshore zones of storm-dominated micro- to mesotidal coasts. The processes generated by waves and wave-breaking cause changes in sandbar shape and location. Predicting sandbar behavior on timescales of months to years has proven to be difficult with models based on small- and short-scale processes because of exponential accumulation of errors in the model. On a more abstract level however, cross-shore sandbar behavior can be described as migration toward a stable equilibrium location that depends on the wave height. Here we perform an empirical investigation into the performance of different representations and corresponding models for cross-shore sandbar behavior.

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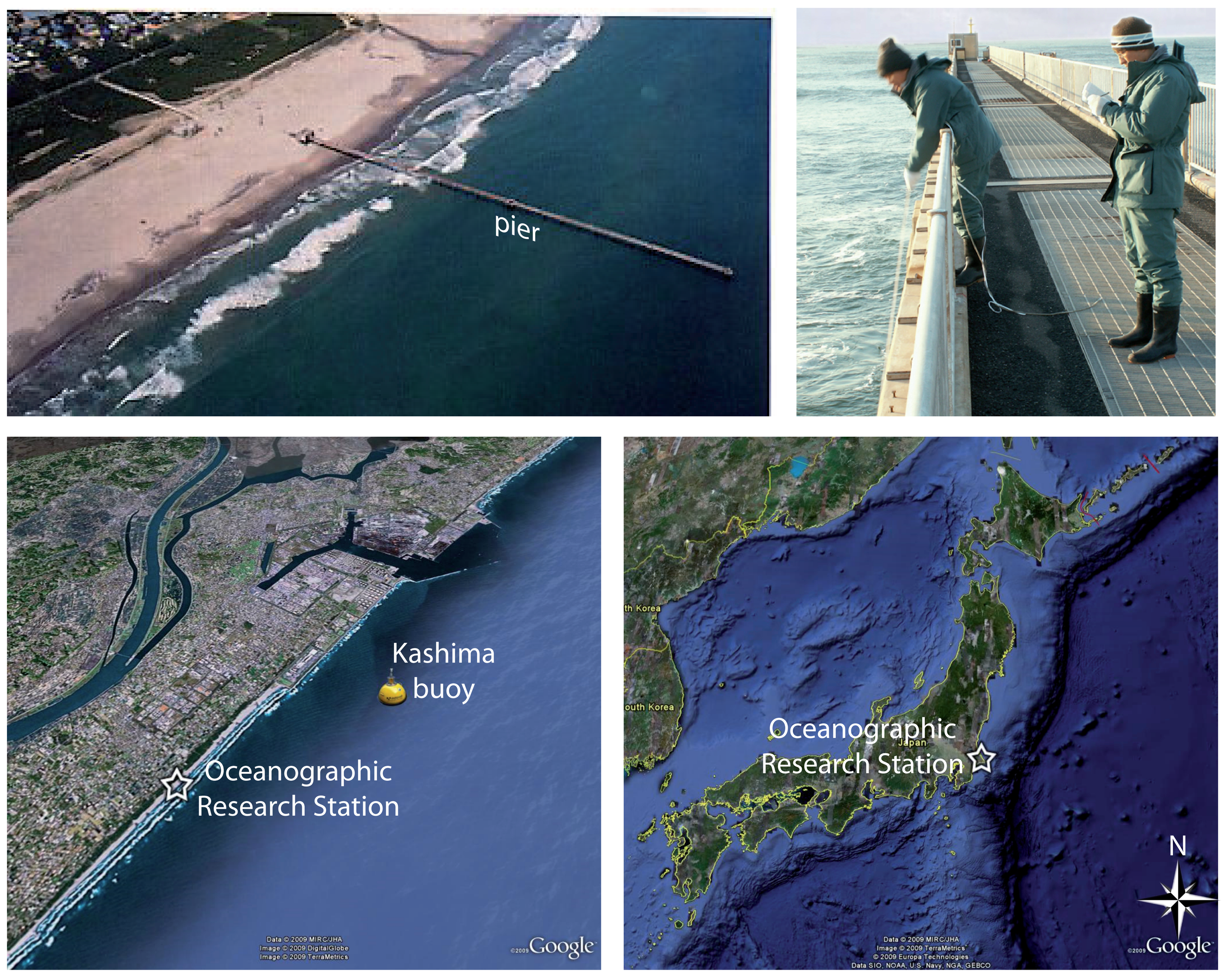

Figure 1: Hasaki Oceanographic Research Station

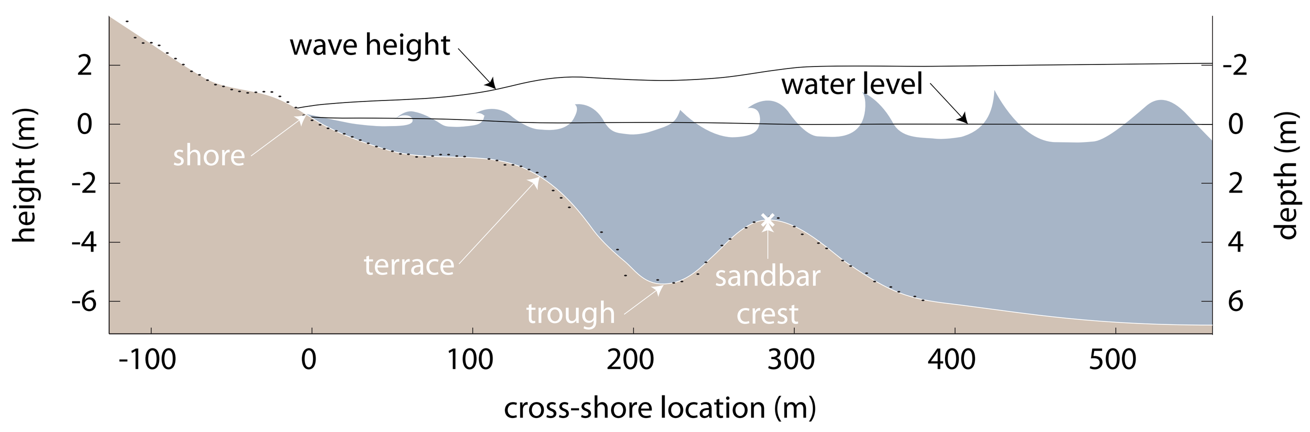

Figure 2: cross-shore profile

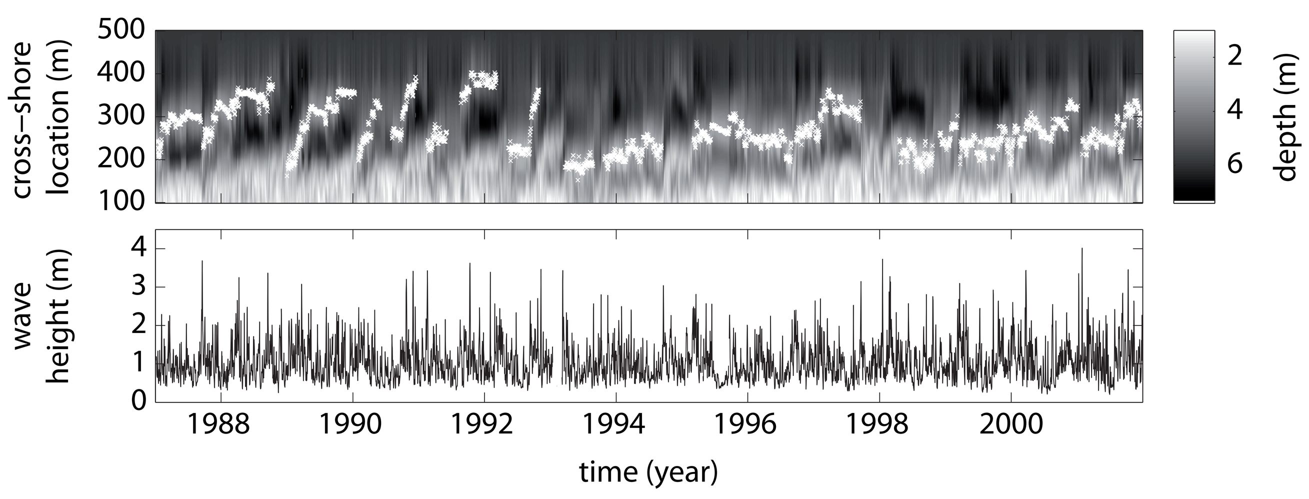

Figure 3: observations with sandbar locations (white)

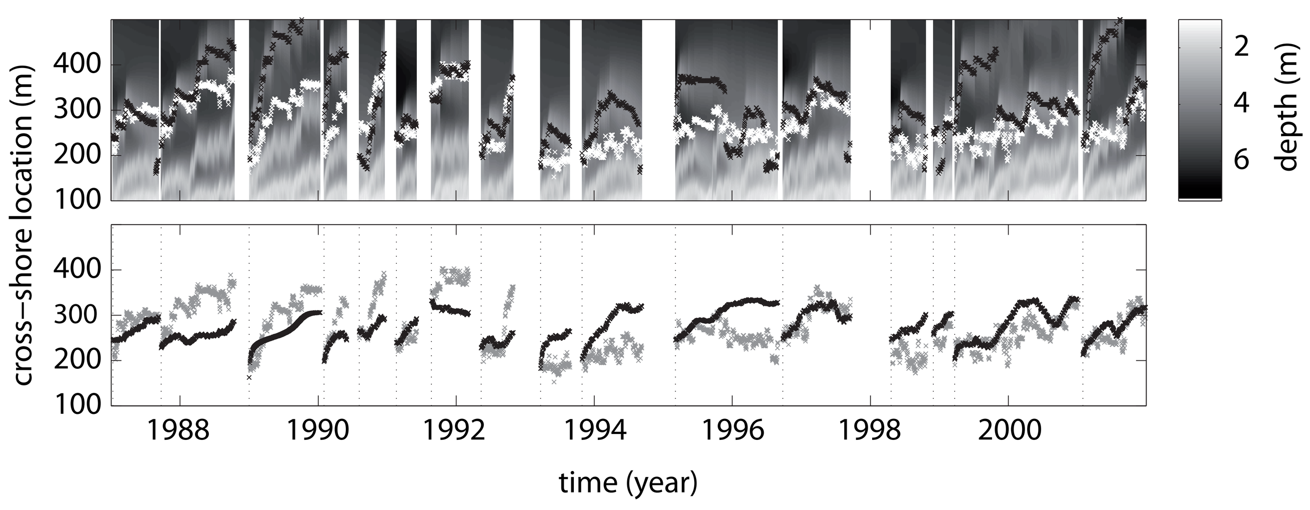

Figure 4: observed (gray / white) and predicted (black) sandbar locations for Unibest (top) and NARX (bottom) models

Models

Nearshore sandbar behavior is usually modeled in terms of wave and sediment transport processes represented on temporal scales of seconds to hours. It is however difficult to predict cross-shore sandbar migration on timescales of months to years with such models because of exponential accumulation of errors. Plant et al. (1999) proposed a mechanism by which small- and short-scale processes drive the nearshore zone toward a stable configuration and corresponding sandbar location. Sandbar behavior might therefore better be described directly on the level of the sandbar itself, instead of the underlying small-scale processes. Here we investigate the performance of different representations and corresponding models for cross-shore sandbar behavior on timescales of months to years.

As representative of the small- and short-scale modeling paradigm we use the Unibest model (Ruessink et al., 2007). The other end of the modeling spectrum consists of models that represent cross-shore sandbar behavior as migration toward a wave-height dependent cross-shore location. Here, we use a NARX neural network (Pape et al., 2007) as instance of this class of models.

Data

The data used for training and calibrating, and testing the performance of the different models consists of cross-shore profiles measured daily in the period between 1987 and 2002 along a 400 m long pier situated at the Hasaki Oceanographic Research Station (HORS) in Japan (see Figures 1 and 2). Hourly-observed water level and daily-averaged wave height and wave period data are included as forcing variables. The observations, extracted sandbar positions and wave heights are depicted in Figure 3.

Results

The neural networks were trained on parts of the data not used for prediction, while the parameters found by Ruessink et al. (2007) were used for the Unibest runs. Model predictions together with original sandbar crest observations are depicted in Figure 4. For both models we found a rather poor performance of 87 (Unibest) and 52 (NARX) meter root-mean-squared difference between observed and predicted sandbar crest locations. Additional Unibest calibrations using all data other than the currently predicted set produced parameter settings for which sandbars were immediately destroyed, resulting in even worse performance for the Unibest model.

Conclusion

The Unibest model predicts offshore migration and subsequent new sandbar formation at the shore, a feat that is not easily achieved with the NARX model. The neural network model also correctly predicts annual and interannual offshore migration. However, in both models the slope of this offshore trend deviates significantly from the observations, which is the main cause for the rather large error values. Additional calibration for Unibest does not result in increased performance. We find that the NARX model yields more accurate predictions than Unibest, which provides empirical support for our hypothesis that long-term sandbar migration can better be described on the level of daily-observed sandbar crest locations and daily-averaged wave height.

References

Pape, L., Ruessink, B. G., Wiering, M. A., and Turner, I. L., 2007. Recurrent neural network modeling of nearshore sandbar behavior. Neural Networks, 20:509-518.

Plant, N. G., Holman, R. A., Freilich, M. H., and Birkemeier, W. A., 1999. A simple model for interannual sandbar behavior. Journal of Geophysical Research, 104:755-776.

Ruessink, B. G., Kuriyama, Y., Reniers, A. J. H. M., Roelvink, J. A. and Walstra, D. J. R., 2007. Modeling cross-shore sandbar behavior on the timescale of weeks. Journal of Geophysical Research, 112:F03010.

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