Spatial lag effects for dunes migrating over forced bars

Timo V. de Ruijsscher *Wageningen University, Wageningen, Netherlands – timo.deruijsscher@wur.nl*
Suleyman Naqshband *Wageningen University, Wageningen, Netherlands – suleyman.naqshband@wur.nl*
A.J.F. (Ton) Hoitink *Wageningen University, Wageningen, Netherlands – ton.hoitink@wur.nl*

ABSTRACT: A fortnightly morphological dataset was used to analyse the relation between dune characteristics and forced bars in the river bend. Using a cross-correlation technique, it is shown that for a slight negative lag, dune height is negatively correlated with the bed level of the bar profile. This indicates that dunes reach their minimum height just downstream of a bar top, when migrating over a forced bar.

1 INTRODUCTION

In fluvial morphodynamics, bed forms have been a popular research topic for years. However, there appears to be a clear separation between studies dealing with bed forms on different spatial scales, being focussed on in different communities. The dune community focusses on e.g. the relation between dune dimensions and flow characteristics (Shields, 1936) three-dimensionality of dunes (Venditti et al., 2005) and the transition to upper stage plane bed (Naqshband et al., 2016). On the other side of the spectrum, the bar community focusses on e.g. the (slower) evolution of alternate bars (Lanzoni, 2000), the regime change from meandering to braiding (Crosato and Mosselman, 2009) and the relation between bars and sediment supply (Nelson et al., 2015).

Interestingly, both communities operate largely independently, filtering out bed forms of other spatial scales as a first step. In the dune community, the study of superimposed bed forms (dunes and ripples) is a topic of interest (Best, 2005), yet the interaction with larger scale features is relatively unexplored. Dunes and alternate bars often coexist and will therefore most probably have an influence on each other's evolution. In the present study, the authors aim to quantify the effect of bars on both dune height and dune length using an extensive dataset of multi-beam echo-sounding measurements on a large domain both in space and in time.

2 METHODS

Data and measurement location

For the present study, an extensive bed level dataset from the Waal River is used. The Waal River is the main Rhine branch in the Netherlands. This dataset consists of fortnightly multi-beam echo-sounding (MBES) measurements of the fairway of the Waal River, covering a width of 170 m. A total length of 80 km is available, over a period from March 2011 onwards. The data is gridded on a 1 m x 1 m grid, with at least 95% of the cells containing ten or more data points.

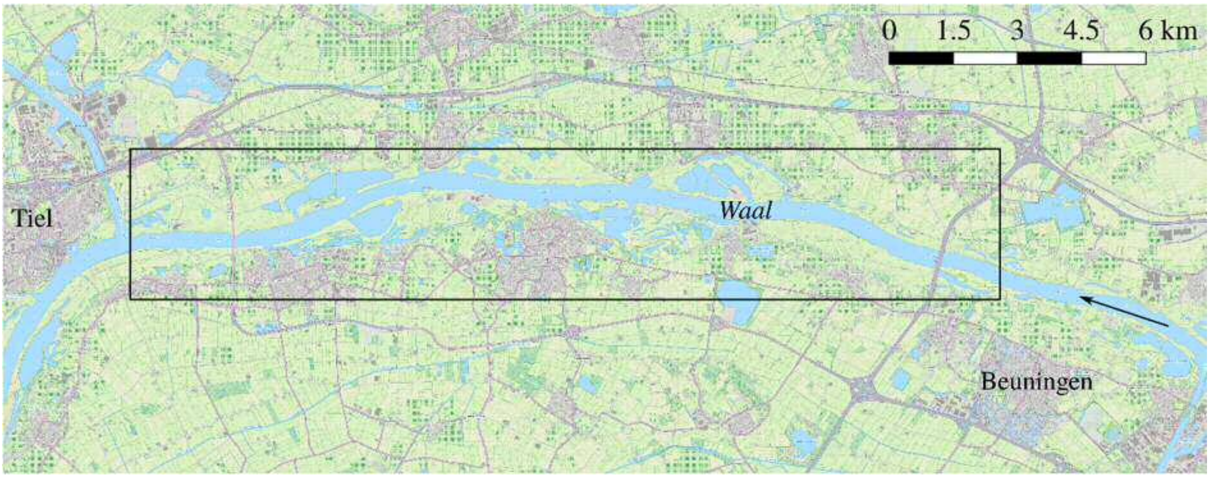

Figure 1. The part of the Waal River under study, with the arrow indicating the flow direction.

Only part of the total river length is taken into account, to make sure that factors like for instance changes in grain size distribution along the river and varying bar wavelengths do not have a large influence on the quality of the results. Moreover, for the time being only the first year of the dataset has been studied. The region of the river under study is shown in Figure 1.

Data analysis

Bed form characteristics

For the present study, we determined dune characteristics by using the bed form tracking tool by Van der Mark & Blom (2007). After detrending the bed level profile, using a moving average filter, this tool detects individual bed forms by means of a zero-crossing method. For each dune, both height and length are determined.

Cross-correlation

To determine whether bars influence dune characteristics, we performed a cross-correlation analysis between dune height and the bar profile. The latter is determined as the bed level profile after removal of the dune signal. For each of the profiles, a confidence bound (at the 0.05 level) was determined. Moreover, the *p*-value was determined using Student's *t*-distribution. The same procedure was followed for dune length.

3 RESULTS

Figures 2 and 3 show the distribution of dune height and length in the region and period under study. Median values are a dune height of 0.94 m and a dune length of 76.8 m.

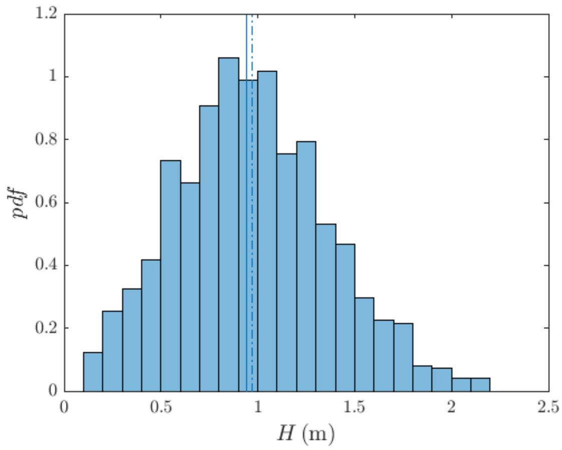

Figure 2. Probability density function of the dune height in the region under study, where values outside a band of 5 standard deviations are omitted. The solid and dash-dotted lines represent median and mean values, respectively.

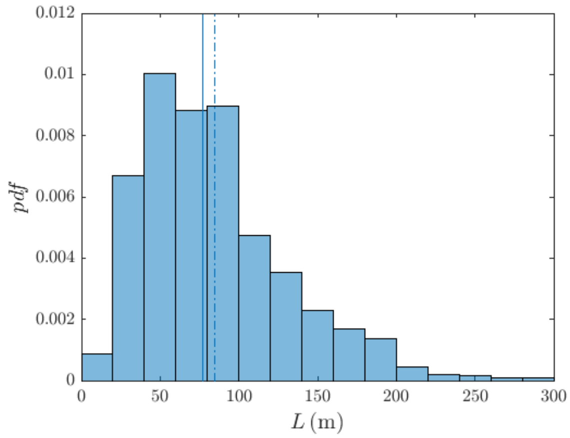

Figure 3. Probability density function of the dune length in the region under study, where values outside a band of 5 standard deviations are omitted. The solid and dash-dotted lines represent median and mean values, respectively.

The cross-correlation between the dune height and the bar profile has a negative peak for a slightly negative lag (Figure 4).

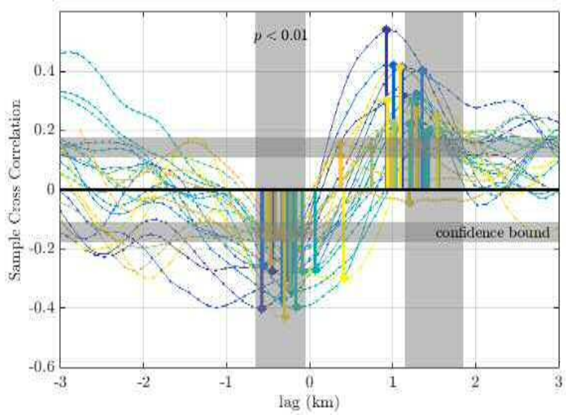

Figure 4. Cross-correlation of dune height and bar profile for one year of biweekly data 41 m right of the river axis. Values of the cross-correlation exceeding the confidence bound and within regions of $p < 0.01$ are considered significant.

This is the case for all biweekly bed profiles under consideration. Most of the peaks of the individual profiles are above the confidence bound and fall within the band of $p < 0.01$, indicating that the result is significant. A negative cross-correlation at a lag less than 1 km indicates that dune height is lowest just downstream of the bar top.

For the dune length, the same analysis is carried out, although no clear relationship with the bar profile is found.

4 DISCUSSION

Although only one year of data is taken into account, containing one discharge peak, a relation between the dune height and the bar profile is found. The negative correlation with slightly negative lag suggests that dunes have a decreased height just downstream of the bar top. Physically, this can be explained by a reduced water depth on the bar top, reducing the dune height as dune height generally scales with water depth (Allen, 1968; Yalin, 1992). The spatial lag might be a result of the adaptation time of the dunes needed to adjust to the changing hydraulic conditions while migrating over the bar.

The fact that no clear correlation is found between dune length and the bar profile, might be due to the skewed distribution (Figure 3). For both dune height and length, an investigation with the lag expressed in units of bar length might also reduce the noise in the results. This might also allow for taking into account a larger stretch of the river, where forced bars range in wavelength from 4 km to 10 km.

5 CONCLUSIONS

From a cross-correlation of dune height and bar profile, it follows that dune height reaches its minimum value just downstream of the bar top. For dune length, no clear relationship is found, which deserves attention in future analysis.

6 ACKNOWLEDGEMENT

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converting the data to profiles parallel to the river axis.

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