Geometric properties of hydraulically-relevant tidal bedforms

C. Winter[(1)], Y. Ferret[(1)], A. Lefebvre[(1)] and V. B. Ernstsen[(2)]

1. MARUM - Center for Marine Environmental Sciences, University of Bremen, Leobener Str, D 28359 - Bremen, Germany, E-mail: cwinter@marum.de
2. Department of Geography & Geology, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen, Denmark

ABSTRACT

Large compound tidal bedforms (also termed dunes, sandwaves, megaripples by different authors) constitute prominent roughness elements in tidal channels and estuaries. Quantitative knowledge on their geometry, dynamics and hydraulic effect is crucial for coastal system understanding and process based numerical modelling. The ubiquitous large bed elements (lengths 10-1000m, heights 1-10m, celerity 10-100m/year) are often asymmetric (with steep slopes facing in the dominant tidal direction) and display super-imposed highly mobile secondary smaller bedforms. As a deterministic prediction of bedform genesis and dynamics is not yet available, various empirical descriptors have been formulated based on extensive data compilations (e.g. Allen, 1968; Flemming, 1988; Francken, 2004). Mean bedform heights H and lengths L were found to scale, e.g H = a * L b in which a=0.03-0.07 and b=0.7-0.9. Due to technical constraints and data reduction the (historic) data bases mostly are restricted to information on mean geometrical states, whereas individual bedform properties are often not reported. Recently Lefebvre et al. (2011) showed that the hydraulic effect of asymmetric compound tidal bedforms depends on the tidal stage: Whereas the secondary bedforms act as roughness elements throughout the tidal cycle, the large primary bedforms dominate the hydraulics when the tidal flow is in the (dominant) direction of the bedform orientation (e.g. ebb-directed primary bedforms act during ebb currents) when the bedforms are expected to induce flow recirculation behind the steep lee side.

Based on the analysis of a large high-resolution bathymetric dataset (multi beam echo sounder mapping of the tidal channel Jade, and Weser and Elbe estuaries, German North Sea coast in 2008), approximately 40,000 individual datasets on bedform geometry (heights, lengths, slopes, etc.) have been identified and analysed. These bedforms range in heights from 0.05 to 8.9m and lengths from 4 to 490m; less than 40% of which scale with the known relations. Bedforms here are defined as "hydraulically-relevant" if they feature a lee slope of 10° or more; which is considered as a threshold condition for the development of flow separation and recirculation eddies in the bedform lee. Only 4.2% of all identified bedforms meet this criterion (n=1,250). These scale with $H=0.1923L^{0.6311}$ ($R^2=0.92$) when taking into account weighted bedform heights (generalized extreme value method).

It is stressed out that the majority of the latter subset scales well above the mentioned mean relationships: 91% of these are steeper than predicted by Allen, 89% steeper than predicted by Flemming, 96% are steeper than predicted by Francken.

It is concluded that common relationships describe independent datasets to some extent (approximately 40% of all bedforms in our case). If the hydraulic effect of bedforms needs to be considered in the analysis or the development, set-up and application of numerical models, the mentioned formulations underestimate the height of bedforms. For these cases a new relationship is proposed. The common formulations form a lower limit of bedform steepness (H/L), as more than 89% of the identified hydraulically relevant subset exceeded their dimensions.

REFERENCES

Allen, J.R.L., 1968. The nature and origin of bed-form hierarchies. Sedimentology, 10(3), 161-182.

Flemming, B.W., 1988. Zur Klassifikation subaquatischer, strömungstransversaler Transportkörper.

Bochumer geologische und geotechnische Arbeiten, 29, 44-47.

Francken, F., Wartel, S., Parker, R., Taverniers, E., 2004. Factors influencing subaqueous dunes in the Scheldt Estuary. Geo-Marine Letters, 24(1), 14-21.

Lefebvre A, Ernstsen VB, Winter C, 2011. Influence of compound bedforms on hydraulic roughness in a tidal environment. Ocean Dynamics.