Morphology of tidal bedforms, Weser Estuary, Germany

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The distribution and morphology of tidal bedforms in the Weser Estuary, Germany, between the tidal limit (Weser-km 0 in Bremen) and the open North Sea (Weser-km 110) has been analysed for a five-year period (2009-2013) based on monthly bathymetric surveys carried out along the main waterway. Bedforms were detected from gridded bathymetry data (2x2 m) and their geometric properties described. In particular, the presence and position of a slip face, here defined as the portion of the lee side steeper than 15°, were determined. In earlier studies, this was shown to be a practical criterion for the presence of a permanent flow separation and a turbulent wake in the lee of bedforms. Here it is used as a simplified indicator of bedform roughness: if a bedform does feature a slip face, it is assumed to be an active roughness element. The results were related to measured river discharge and water levels and modelled flow velocities.

Bedforms properties varied spatially and temporally along the estuary. Along the main bedform field (Weser-km 12 to 55) bedforms were mostly flood-oriented upstream, gradually becoming symmetrical then ebb-oriented downstream. In times of high discharge, all bedforms were more ebb-oriented than in times of low discharge. Bedforms in the Weser Estuary can be described as predominantly low angle dunes and their steepest slope is situated near the bedform crest. The analysed bedforms (in the main navigational channel, which is deepened and constrained) are also very two-dimensional, with little variations of three-dimensionality in time or space.

Although the Weser bedforms are mainly low angle, a significant proportion of bedforms possesses a slip face. This implies that they have a strong potential to induce bed roughness. This roughness is likely to change spatially along the estuary due to the variations of bedform properties, but also vary in time as a function of the tidal phase (ebb and flood) and discharge. This has wide implications in terms of modelling hydrodynamics and sediment transport in estuaries.