Geophysical Research Abstracts
Vol. 14, EGU2012-11766, 2012
EGU General Assembly 2012

A numerical investigation of flow separation over bedforms in tidal flows

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In sandy shallow water environments, the transport of sediment by currents and waves frequently generates rhythmic wavy features on the seabed. These bedforms have a strong influence on the hydrodynamics and sediment dynamics and vice-versa. In particular, flow separation at the bedform crest and subsequent recirculation over the bedform downstream side generates a significant friction that retards the flow and is responsible for bedform roughness. It has been suggested that flow separation and recirculation happens only when the bedform downstream slope is steep enough and becomes intermittent or inexistent for slopes smaller than 10 to 20°. In tidal environments where flow reverses but large bedforms stay asymmetric, flow may therefore separate only during one tidal phase, when going over the bedform steep downstream side whereas during the following tidal phase, the flow may not separate due to the gentle slope of the downstream side. In other words, it is suggested that flow separates only during, e.g., the ebb over ebb-oriented bedforms. Based on measurements of steady flow over equilibrium bedforms it has been shown that the shape of the recirculation zone depends on bedform shape at the flow separation point and is independent of flow conditions.
In this study we test whether these results are also valid for unsteady tidal flows, at which angle of the downstream side flow separation is permanent and assess how bedform shape and flow velocity influences the size/shape of the recirculation cell during a tidal cycle. The non-hydrostatic version of the numerical modelling system DELFT3D (Deltares, NL) was used to simulate the hydrodynamic structure over bedforms. The model approach was verified by inter-comparison with laboratory results. The model was then used to simulate the flow patterns over bedforms of different shape (backward step, triangular bedforms and complex “natural” shapes) and the presence and shape of the recirculation zone was characterised.
Preliminary results confirm that the presence and shape of the recirculation zone is independent of current velocity but depends on the angle of the downstream side slope; flow separation occurs only for angle of 11° or more. The separation streamline is well approximated by a third-order polynomial. The length of the recirculation zone is about 6 times the bedform height and its shape shows little variations during a tidal phase. The relationship between the bedform shape (particularly at the crest) and the shape of the recirculation zone will be analysed.
Because flow resistance and sediment transport are particularly sensitive to the presence of a recirculation cell on the downstream side of bedforms, these results are relevant for the understanding and modelling of hydrodynamics and sediment dynamics in the coastal zone.