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The effects of bedform-related roughness on hydrodynamics and sediment transport patterns in Delft3D

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To contribute to solving scientific and practice-inspired questions, the morphological development of coastal systems is predicted using numerical morphodynamic models like Delft3D. In such models, many of the processes are parameterized, for which various assumptions have to be made. One of the estimated variables is the bedform-related hydraulic roughness, which affects the magnitude and vertical structure of the flow and consequently also the magnitude of the sediment transport. A comparison is missing between model-predicted and observed hydraulic roughness values and it is unknown how this affects the hydrodynamics and sediment transport. Furthermore, the roughness is often used as a calibration parameter. The calibrated value might be very different from observed values and models might possibly do a good job for the wrong reasons.

The aim of this study is to determine the effect of the roughness caused by small-scale ripples (length ≈ 10 cm, height ≈ 1.5 cm) on hydrodynamics and sediment transport computed by a high-resolution, fully-coupled Delft3D model that is forced by waves, tides, wind, and atmospheric pressure. The study site is the wave-current dominated environment of the Ameland ebb-tidal delta in the north of the Netherlands. In 2017, a six-week field campaign was executed here, in which bedform heights and lengths, water levels, wave orbital velocity and direction, and current velocity and direction were measured.

The model was run for the duration of the field campaign with various bedform roughness scenarios, in which the roughness was either coupled to the hydrodynamics (thus varying over space and time), or it was set to a constant and spatially uniform value based on the observed mean ripple heights. Of all scenarios, we compared the predicted ripple heights, wave orbital velocities, depth-averaged current velocities and sediment transport magnitudes and directions. In addition, we compared the modelled and observed ripple heights, wave heights and flow velocities.

A previous study focused on the field campaign showed that observed ripple heights were much more constant than the ones computed by the default ripple predictor in Delft3D. Ripple heights were found to be related to orbital velocity and no other relations between ripple characteristics and hydrodynamics were found. However, first results of the present study indicate that the predicted roughness used to calibrate Delft3D to the water levels and currents is quite similar to the measured roughness. The main difference is that the predicted roughness is highly variable through time, which is not observed in the field. The simulations also show that the ripple-related roughness especially affects the magnitude of the depth-averaged current velocity, while its effect on the wave-orbital velocity is negligible. This also affects the sediment transport magnitude, while its direction is not affected. The cumulative suspended load transport magnitude can increase with more than 50% when a constant roughness is used instead of a spatio-temporally variable roughness.