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Morphodynamics of cyclic steps: a depth-resolved numerical model

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Although the majority of sediment transport is associated to high-discharge events, and such events are prone to Froude-supercritical flow conditions, there are only limited outcrop examples of supercritical-flow deposits. These low numbers of outcrop examples are often explained as being the result of poor preservation potential of upper-stage flow-regime deposits, due to reworking by subcritical flows in the waning stages of these high-discharge events. However, an alternative explanation for this might be that there is not enough knowledge on supercritical-flow deposits to recognise these deposits. This last argument is supported by the fact that numerical and physical experiments in recent years have strongly increased the number of recognised supercritical-flow deposits. Although large progress has been made in the study of the architecture of supercritical-flow deposits, using experimental data and depth-averaged models, scaling issues and measurement difficulties in experiments, and the limitations of depth-averaged models, are impeding further insights in the interaction between the flow and the bed development.

Froude-supercritical flows can lead to the formation of bedforms such as antidunes, chutes-and-pools and cyclic steps, the last of which will be focussed of this study. Cyclic steps are described as a series of upstream migrating steps, each step is characterized by a lee-side of the bedform which is eroded by a Froude-supercritical flow and depositional stoss-side of the bedform associated with subcritical flow. The transition between the two flow-regimes is characterized by a hydraulic jump which is located roughly in the trough of a cyclic step bedform. The deposits of cyclic steps can be characterised by backset laminations terminating upstream against the erosional or transportational lee-side of the cyclic step, the backsets can also be eroded by the lee-side of the next upstream-migrating bedform on the downstream end.

A novel approach is taken by using a fully depth-resolved computational fluid dynamics model, capable of rendering complex 3D geometries, allowing for a more detailed picture on morphodynamic interaction between flows and cyclic step bedforms than ever before. The study presented provides a quantification of physical parameters, such as Froude number, shear stresses and sediment concentrations. These physical parameters will characterise the facies associated to cyclic step deposits.