Transverse bed slope effects in an annular flume

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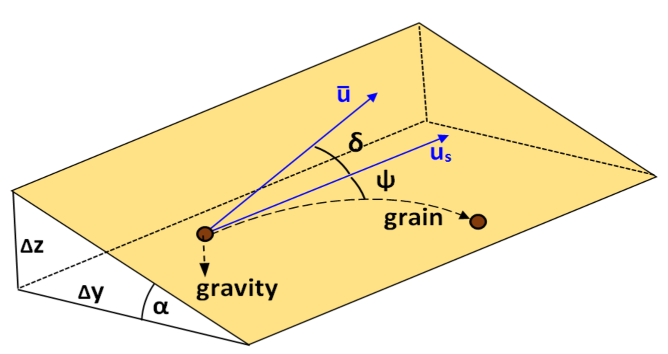
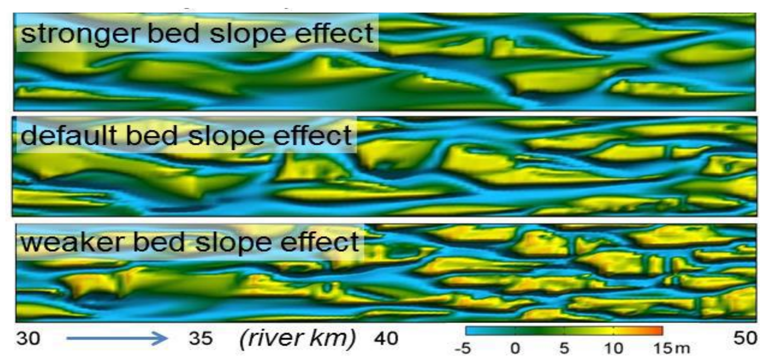
Problem definition

A crucial part of morphodynamic models is the transverse bed slope effect, which determines the deflection of sediment transport on a transverse sloping bed due to gravity. Overestimating this effect leads to flattening of the morphology, while underestimating leads to unrealistic steep bars and river banks. Therefore, incorrectly estimating the transverse bed slope effect also has major consequences for the predicted large-scale morphology, since it influences the development of river bifurcations, meander wave length and the degree of braiding in rivers and estuaries.



Transverse bed slope effect

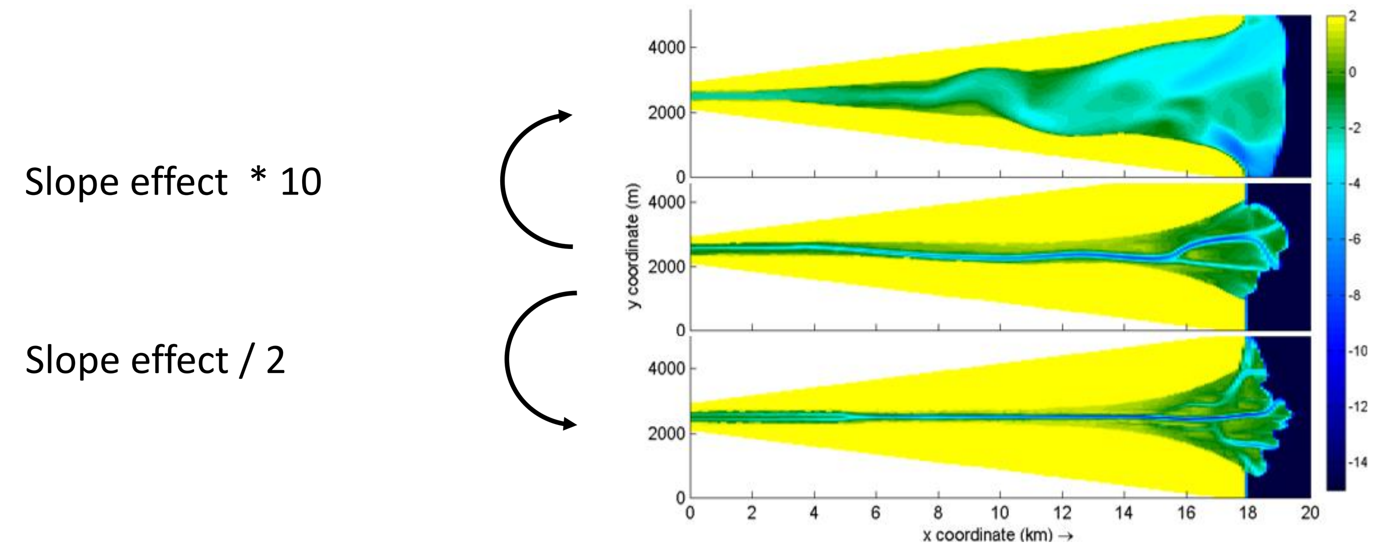


Effect of stronger and weaker transverse bed slope effect on channel morphology

Previous bed slope predictors

Based on experiments with small range of flow conditions & small range of grain sizes (0.01 – 0.8 mm). Furthermore, the effect of helical flow is not isolated.

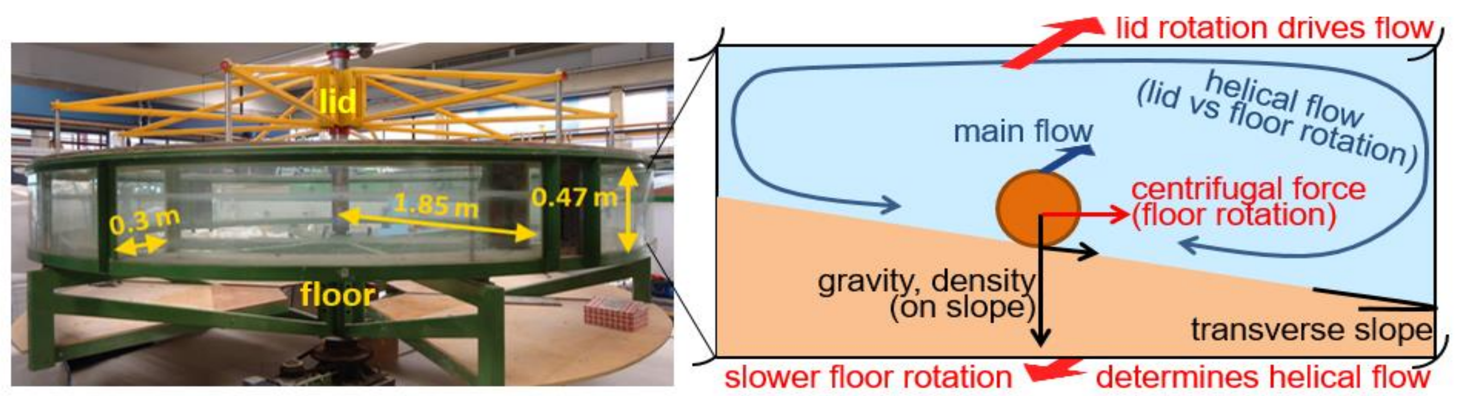
→ Current models need to be calibrated on existing morphology:



(Braat et al., *in prep.*)

Experiments in annular flume

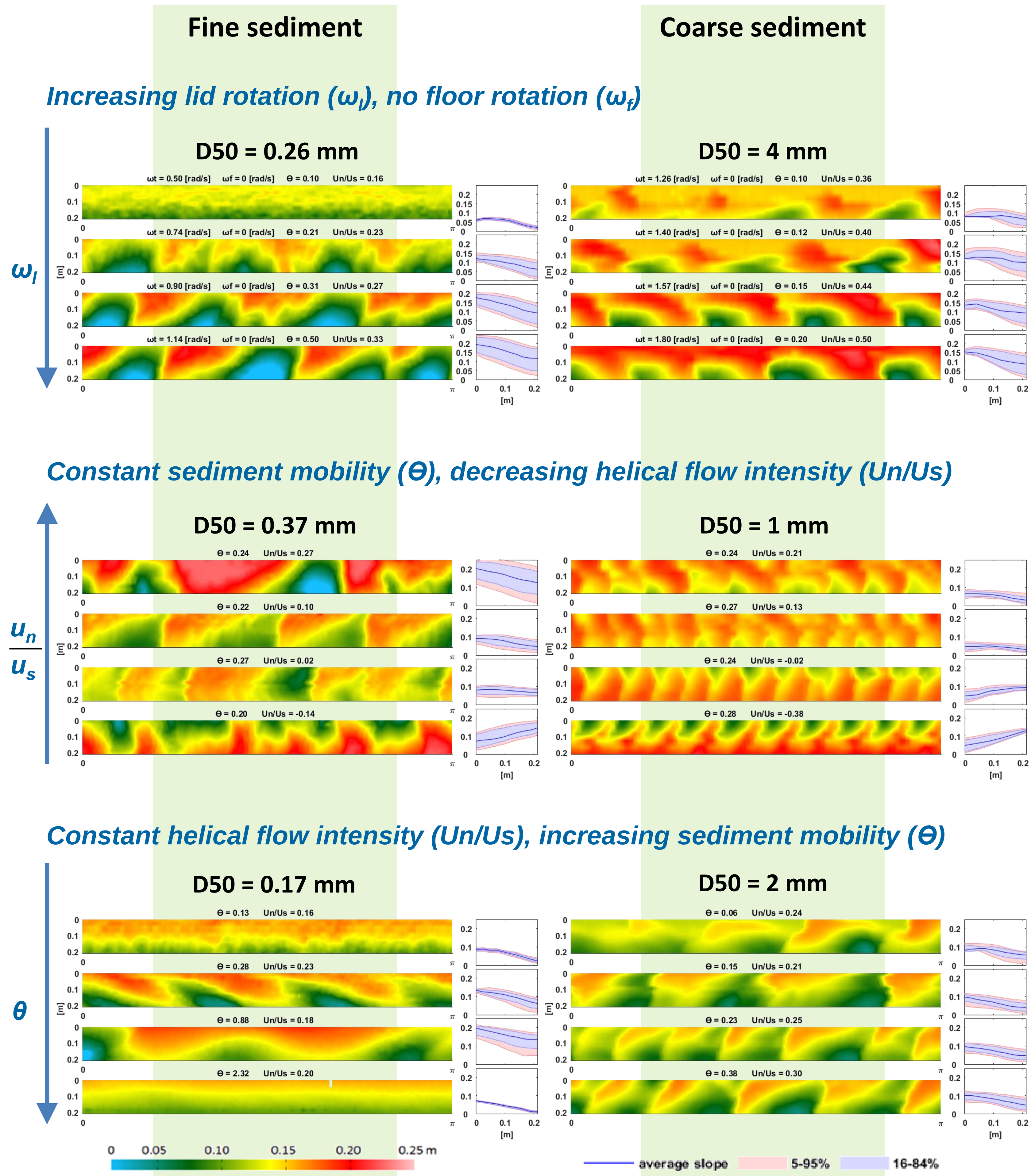
Objective: quantify the bed slope effect for a large range of flow velocities, helical flow intensities and sediment properties



The annular (rotating) flume (Booij & Uijttewaal 1999) allows to control forces on particles

- Uniform sediment: 0.17, 0.26, 0.38, 1, 2, 4 mm
- Large range of lid rotation velocities > determines flow velocity & helical flow intensity
- Large range of floor angular velocities > determines centrifugal force which counteracts helical flow

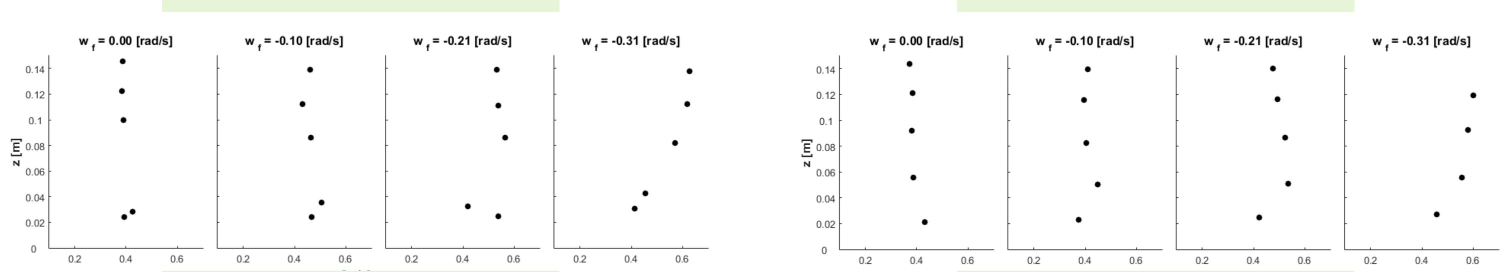
Morphology and transverse bed slopes



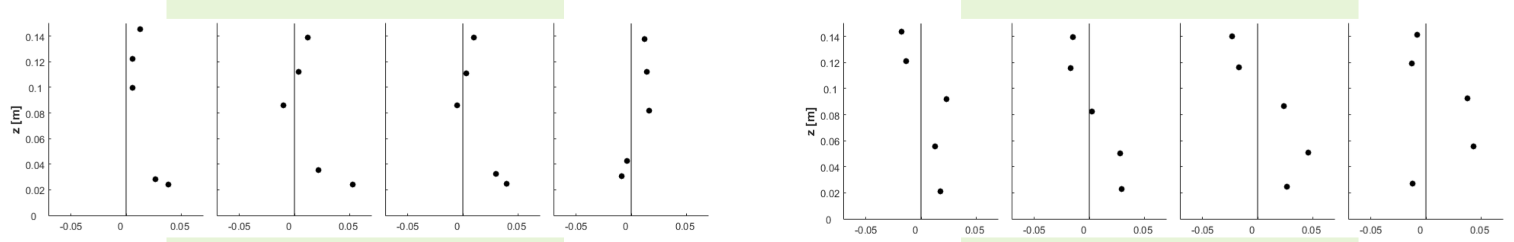
Resulting morphology (top view) of several experiments with a large range in sediment mobility (Θ) and helical flow intensity (Un/Us), and corresponding transverse slopes. The width is measured from the inner bend

Flow velocity

Streamwise flow velocity (Us)



Normal flow velocity (Un)

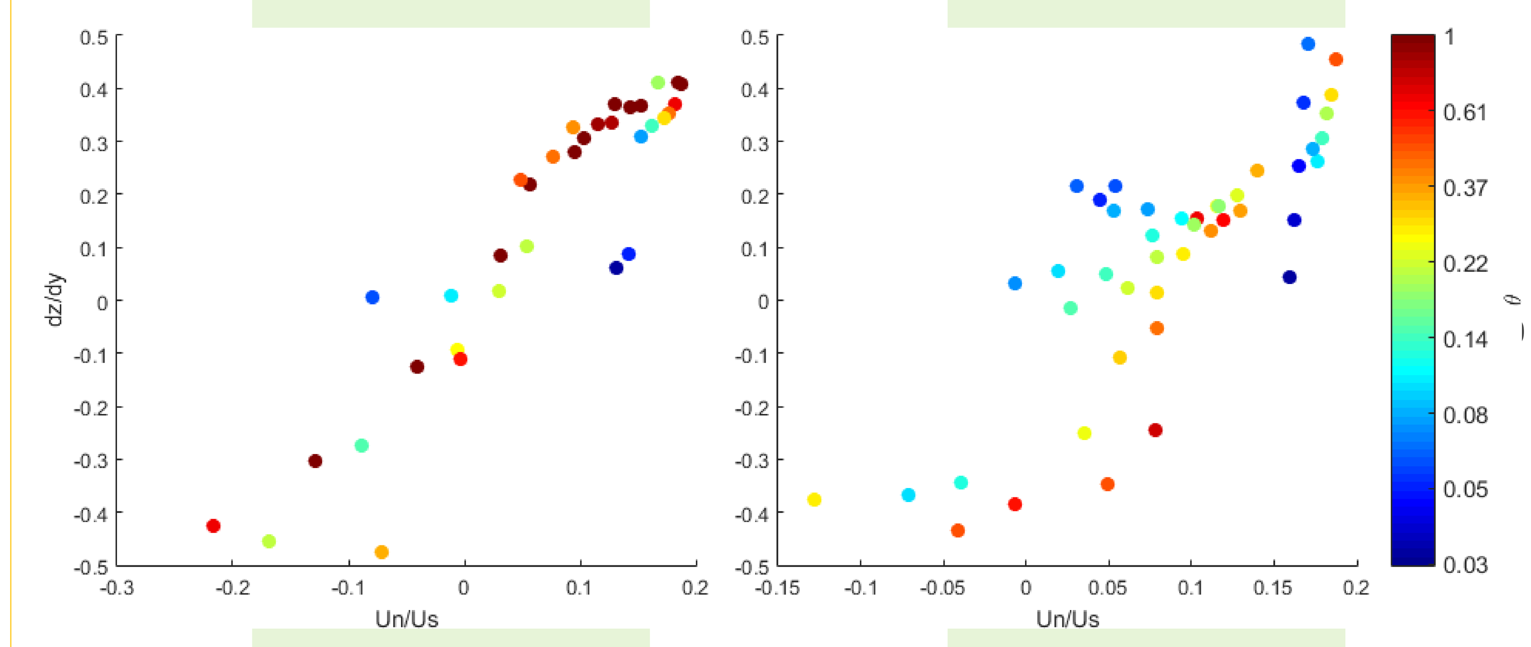


Flow velocity measurements for constant lid rotation and increasing floor counter-rotation. Preliminary results.

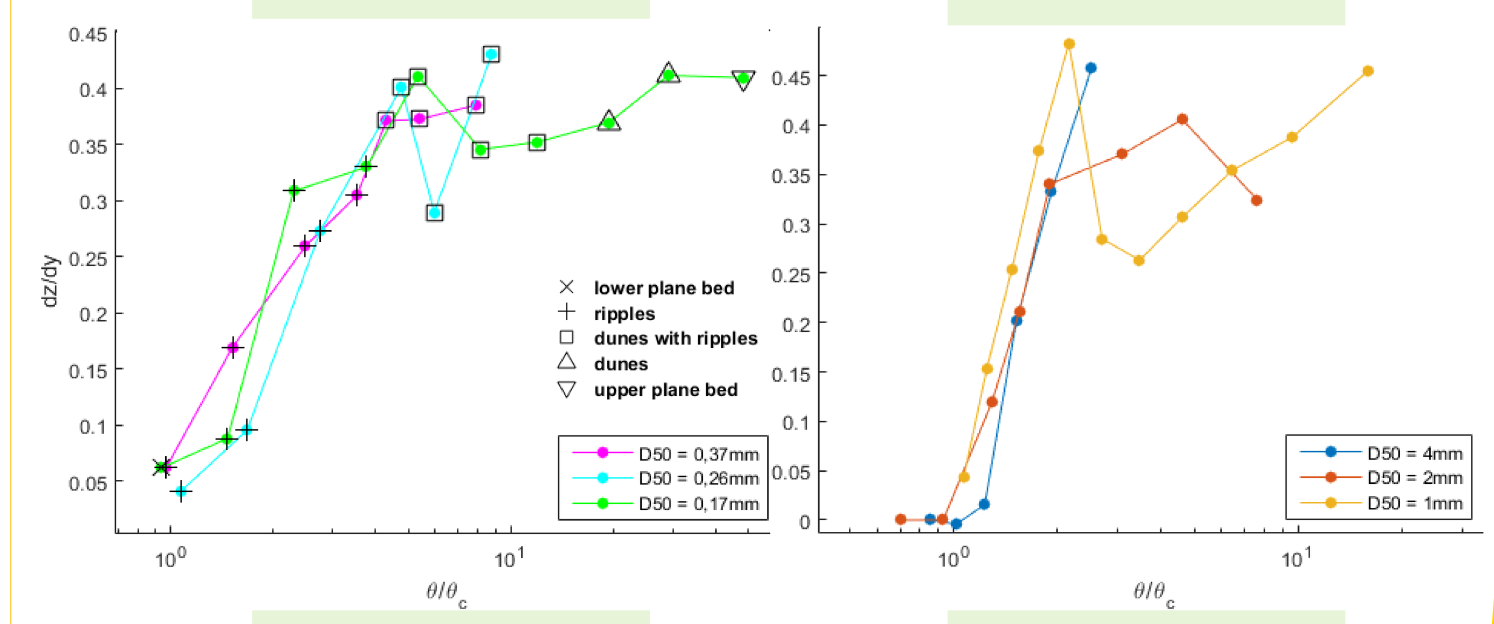
Data reduction

For each experiment the average transverse bed slope (dz/dy) is determined and compared with corresponding sediment mobility (θ) and a first estimate of the helical flow intensity (u_n/u_s). The objective is to develop an equation with the form:

$$\tan\psi = \frac{u_n}{u_s} - \frac{r}{\sqrt{\theta}}\frac{dz}{dy}$$



Average transverse bed slope (dz/dy) against helical flow intensity (u_n/u_s). Colors indicate sediment mobility (θ).



Average transverse bed slope (dz/dy) against sediment mobility (θ), for experiments with no floor rotation.

Future work

- Study helical flow effects with a Large Eddy Simulation model of the annular flume including bedforms
- Second set of experiments with poorly sorted sediment, focusing on sorting processes on transverse bed slopes
- Implement results in Delft3D and study other model weaknesses

Conclusions

- New experimental setup: transverse bed slope effect for a large range of flow conditions and sediment sizes
- The effect of bedforms, roughness and sediment transport mode needs to be studied in more detail

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Collaboration
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