Morphodynamic investigation of the Danube River by a novel sediment transport modelling method

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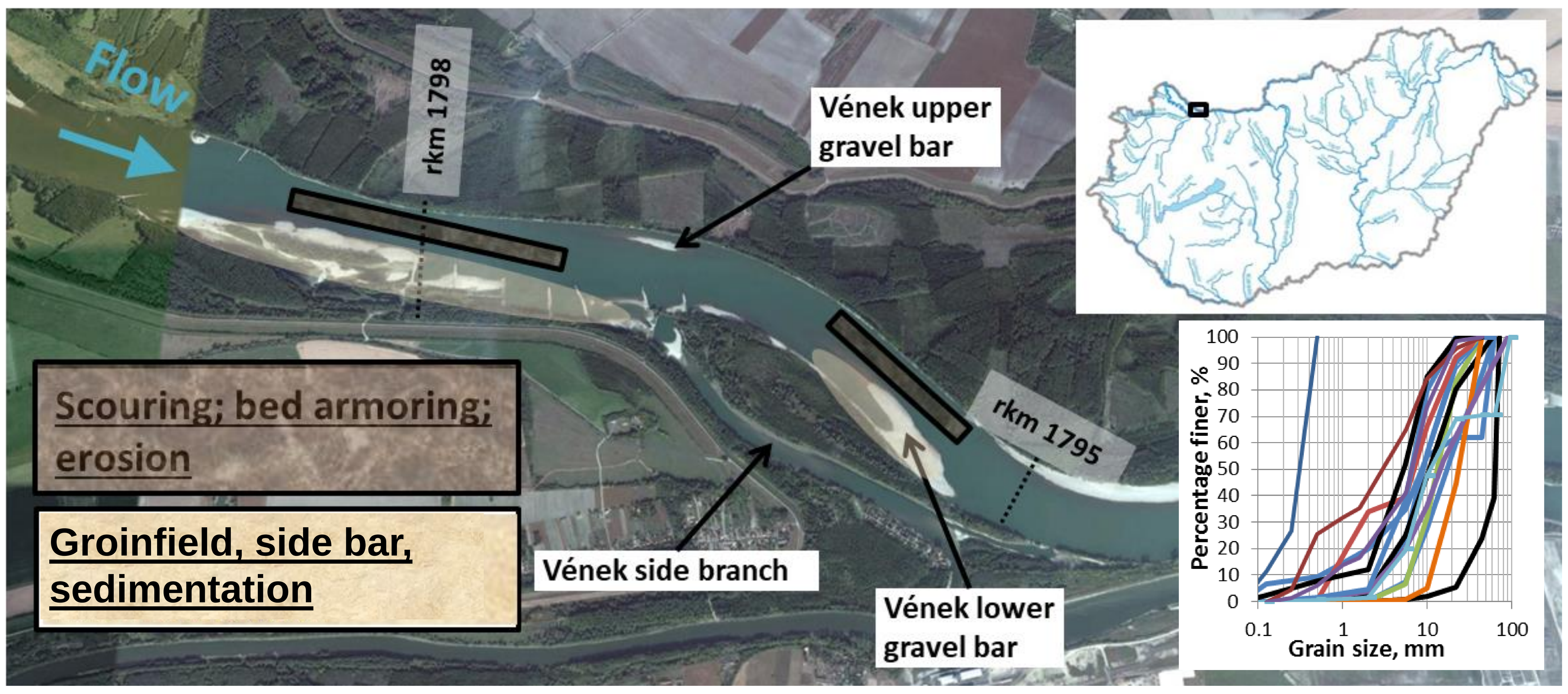
Introduction

The reliable quantitative calculation of sediment transport in large rivers is still a challenge, especially in case of non-uniform bed material. Although plenty of sediment transport formulas can be found in the literature, none of them works well for any general case. Because of this, a novel sediment transport calculation method was developed and presented in Török et al. [1]. The principal core of the method is the combined use of the van Rijn formula [2] and the Wilcock and Crowe model [3]; the local sediment transport is calculated by the formula, which is supposed to be the more reliable, at given morphodynamic conditions. Thus, the morphological processes can be calculated more reliably at river reaches where strong spatial and temporal variation of the flow and sediment features is typical.

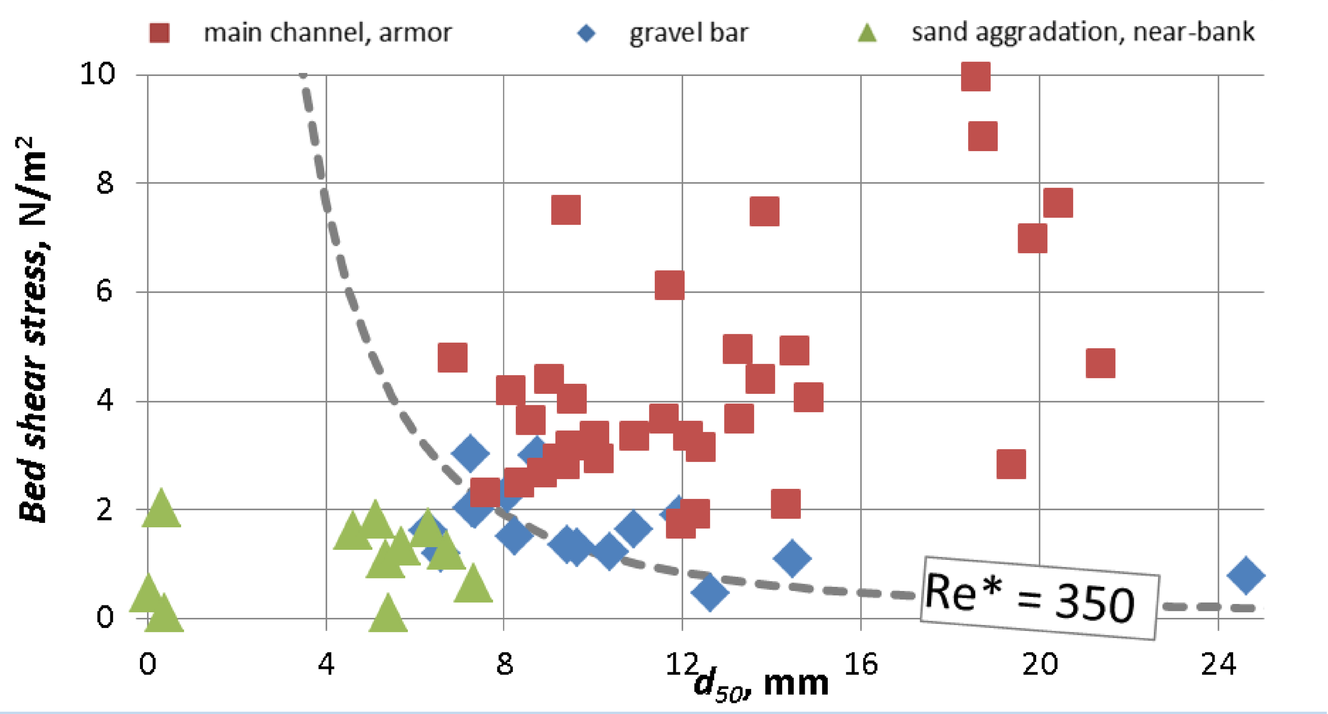
The investigated Hungarian Danube reach

The upper-Hungarian Danube reach shows diverse planform characteristics; the bed material is spatially varied gravel-sand mixture and the flow conditions are also complex [4].



Combined sediment transport modelling approach

Because of the complex and spatially varied bed material and dominant sediment transport nature, a novel combined approach of the van Rijn and the Wilcock and Crowe bed load sediment transport formulas was applied. Török and Baranya [5] pointed out a novel decision criteria, which is a suitable method for indicating whether the sand or rather the sand transport dominates locally.



Accordingly:

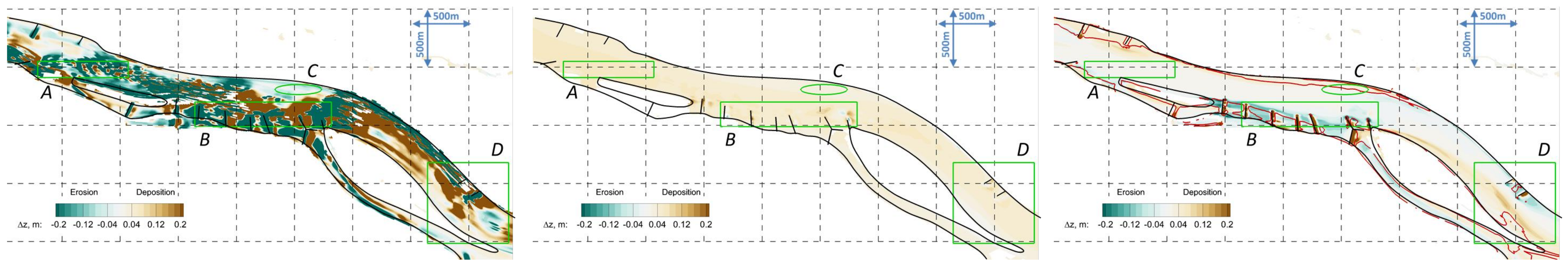
- **Re^* < 300 → van Rijn formula is activated,**
- **$Re^* \geq 400$ → Wilcock and Crowe formula is activated,**
- **otherwise $f \cdot q_{bi,W\&C} + (1-f) \cdot q_{bi,vR}$, where**

$$f = \frac{1}{100}(Re^* - 300)$$

$Re^* = \frac{u_* D}{\nu}$, where u* is the shear velocity and D is the grain diameter and ν is the kinematic viscosity

Model validation

van Rijn | Wilcock and Crowe | Combined method



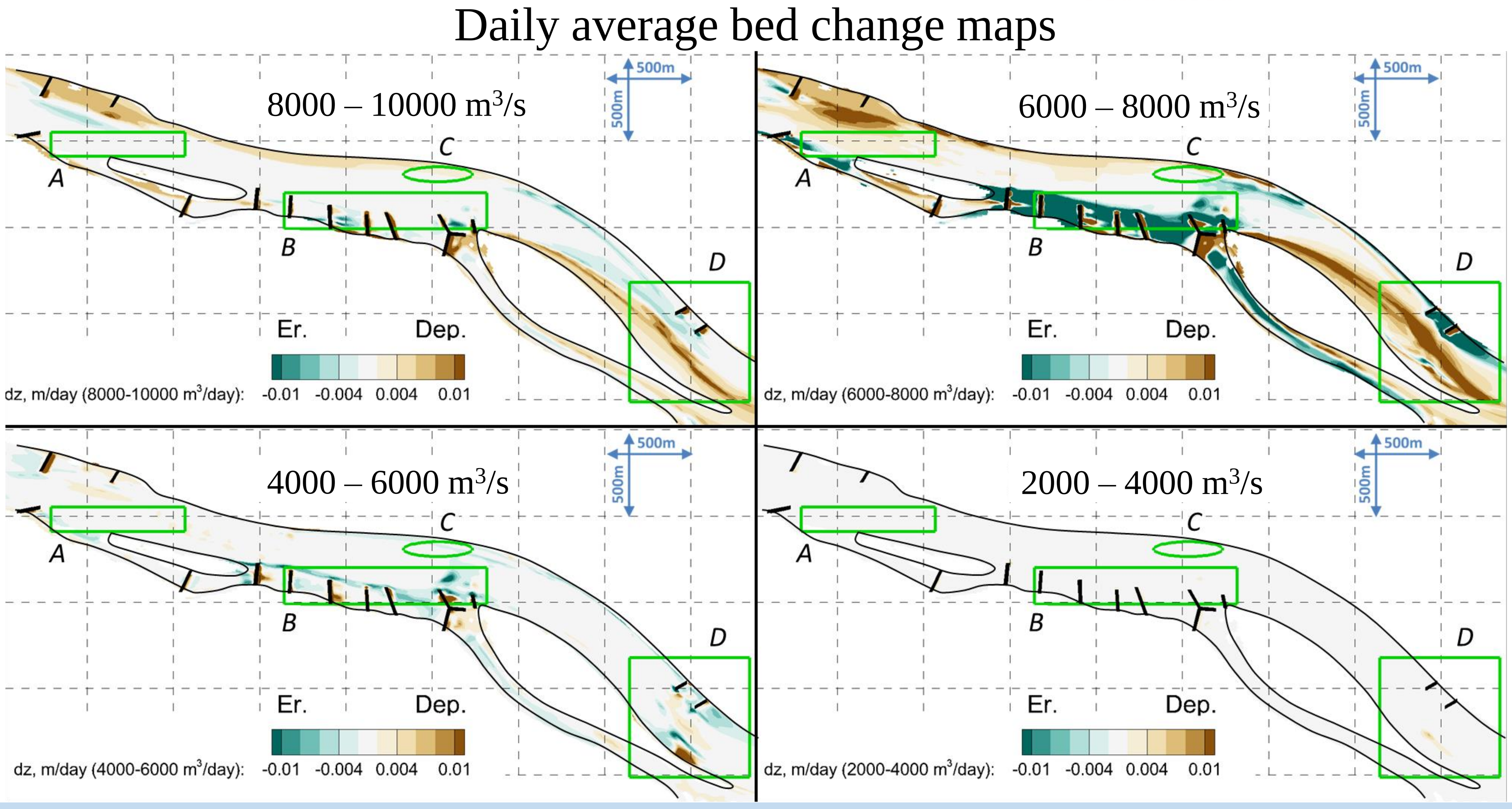
The comparative analysis shows that the most reliable bed changes were calculated by the combined use of the van Rijn and Wilcock & Crowe sediment transport formulas. The results were compared to measured bed changes also (see the Table), which emphasizes the benefit of the method.

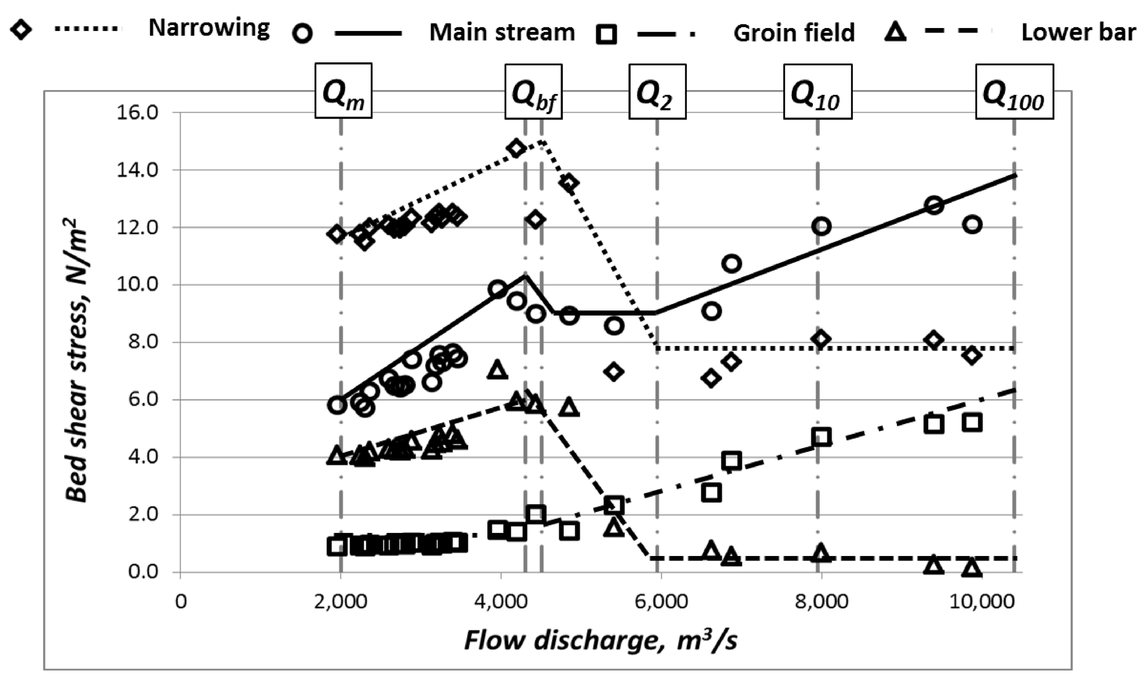
		Sediment transport model		
		van Rijn	W&C	Combined
ΔV / day	Deposition	48.71	4.9	3.45
	Erosion	7.19	0	0.57

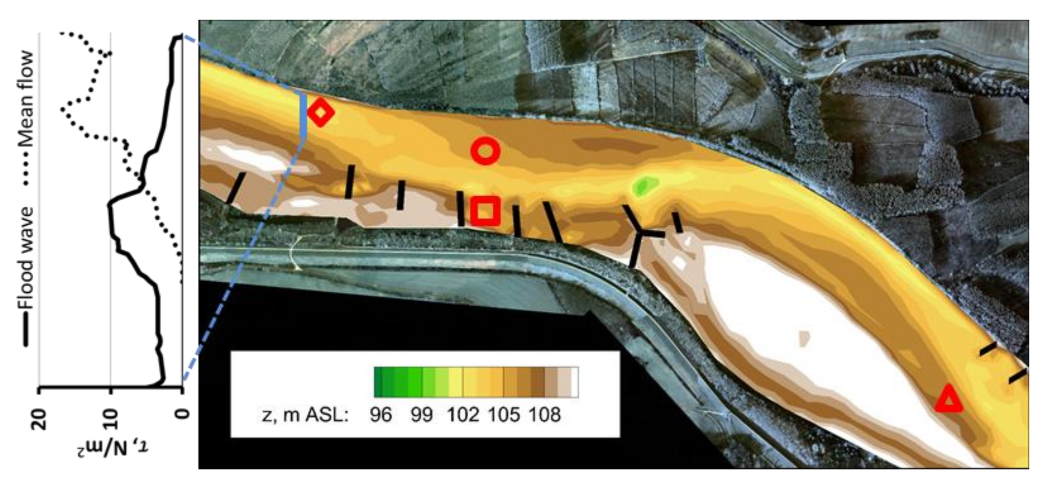
$\Delta V_c/\Delta V_{m}$, where ΔV is the average daily volume changes. ΔV_c presents the model results, while ΔV_m indicates to the measurements.

Results

Daily average bed change maps







The model results suggest:

- **The bed surface remain stable under 4000 m³/s (bankfull water discharge ~ 4300 m³/s)**
- **Scouring in the front of the groins, sedimentation in the groin fields (region *B* and *D*) and the erosion of the lower end of the Vének lower gravel bar (region *D*) are expected in the discharge range of 4000 – 6000 m³/s.**
- **The flushing of the groin field is the most important process in the discharge range of 6000 – 8000 m³/s. In turn, major sediment deposition occures along the Vének lower gravel bar**
- **The daily bed changes regarding the discharge range of 8000 – 10000 m³/s shows similar patterns, as the previous, but in lower range.**
- **The Vének upper gravel bar stays stable in each discharge ranges.**
- **The local connections between the flow discharge and the bed shear stress (right Figure) confirm the calculated bed changes. For instance, the bed shear stress falls off above the bankfull discharge, resulting in the deposition of gravels and the fomring of the gravel bar (see the triangles in the Figure).**

References

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