Title MSc project:
Modeling form roughness from river dunes

Assignment number: **19.24**	**Internal/external project** Internal
Head graduation committee Prof. dr. Suzanne Hulscher or dr. ir. Pieter Roos	**Daily supervision** Dr. ir. Wessel van der Sande (w.m.vandersande@utwente.nl) Dr. ir. Vasileios Kitsikoudis
	Start of the project Q3 (proposal in Q2)

Required courses:
Mathematical Physics of Water Systems
Data Analysis in Water Engineering and Management
River Flow Processes

Short description project aim and motive

River dunes are large-scale dynamic bedforms subject to unidirectional flow. Their dynamic behavior poses a threat to navigation, and their presence imposes roughness on the flow. Increased roughness means increased water levels for a given discharge, and thus has implications for flood safety.

From literature, we know that dune-induced flow roughness is attributed to flow separation and vortex shedding over the crest of these bedforms, which has been measured in experiments (Kwoll et al., 2017) and the field (Kostaschuk, 2000). Existing numerical modelling approaches can capture the physics of such highly complicated turbulent flows, however, it is not clear what the required model complexity should be. This introduces a tradeoff between simpler models based on the Reynolds-averaged Navier-Stokes (RANS) equations with fast computational times and eddy-resolving, e.g., detached eddy simulation (DES) or large eddy simulation (LES) models that are more detailed but typically have longer running times.

Examples of the former category are the models of flow over dunes developed in a 2DV (i.e., 2D assuming uniformity in the cross-river direction, Lefebvre et al., 2014) and 3D setting (Lefebvre, 2019). These studies led to new parameterizations of form roughness of river dunes. Lefebvre (2014, 2019) used Delft3D to model the flow over bedforms. However, we believe that OpenFOAM is a more suitable tool, as it is probably better capable of capturing all the turbulent flow features. Furthermore, OpenFOAM enables the user to switch between a wide variety of modelling approaches (RANS, DES, LES) turbulence closure models (e.g., $k-\varepsilon$, $k-\omega$, $k-\omega$ SST, etc.), boundary conditions, and meshing options.

Your task is to develop a hydrodynamic model of flow over dunes within OpenFOAM, to analyze the effect of the induced turbulence on the flow, and to quantify the form roughness. The model will be validated against data from the literature (Lefebvre, 2014). Subsequently, with the developed model, you will design and perform additional numerical experiments to systematically investigate the influence of form roughness on the flow and develop appropriate parameterizations. A foreseen challenge herein is to generalize the results to the great variety of dune dimensions and shapes as they are observed in the field. The modelling approach will be 2DV, which will allow fast running times.

During this project you will get the opportunity to develop your numerical modelling skills in turbulent flows with the very popular OpenFOAM software. In addition, you will get acquainted with using high-performance computing, as the modelling runs will be carried out on the Dutch supercomputer Snellius. You will receive support in developing these skills, however, you need to have affinity with modelling turbulent flows.

References

Kostaschuk, R. (2000). A field study of turbulence and sediment dynamics over subaqueous dunes with flow separation. *Sedimentology*, *47*(3), 519–531. https://doi.org/10.1046/j.1365-3091.2000.00303.x

Kwoll, E., Venditti, J. G., Bradley, R. W., & Winter, C. (2017). Observations of Coherent Flow Structures Over Subaqueous High- and Low- Angle Dunes. *Journal of Geophysical Research: Earth Surface*, *122*(11), 2244–2268. https://doi.org/10.1002/2017JF004356

Lefebvre, A. (2019). Three-Dimensional Flow Above River Bedforms: Insights From Numerical Modeling of a Natural Dune Field (Río Paraná, Argentina). *Journal of Geophysical Research: Earth Surface*, *124*(8), 2241–2264. https://doi.org/10.1029/2018JF004928

Lefebvre, A., Paarlberg, A. J., & Winter, C. (2014). Flow separation and shear stress over angle-of-repose bed forms: A numerical investigation. *Water Resources Research*, *50*(2), 986–1005. https://doi.org/10.1002/2013WR014587