Sediment transport study for rough sand bed using CT scan and PIV measurements

C.B. Brunelle, P. Francus, M. Des Roches, L.F. Daigle, E. Perret, B. Camenen

RCEM2017 - 10th Symposium on River, Coastal and Estuarine Morphodynamics

SEDIMENT TRANSPORT STUDY FOR ROUGH SAND BED USING CT SCAN AND PIV MEASUREMENTS

Corinne B. Brunelle[1], Pierre Francus[1], Mathieu Des Roches[1], Louis-Frederic Daigle[1], Emeline Perret[2] & Benoît Camenen[2]

[1] Institut national de la recherche scientifique (INRS),
Multidisciplinary Laboratory of CT Scan for Non-Medical application, Québec, Canada
[2] Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture (IRSTEA)
Villeurbanne, France.

Lab CT Scan
Laboratoire multidisciplinaire de tomodensitométrie pour les ressources naturelles et le génie civil

INRS
UNIVERSITÉ DE RECHERCHE

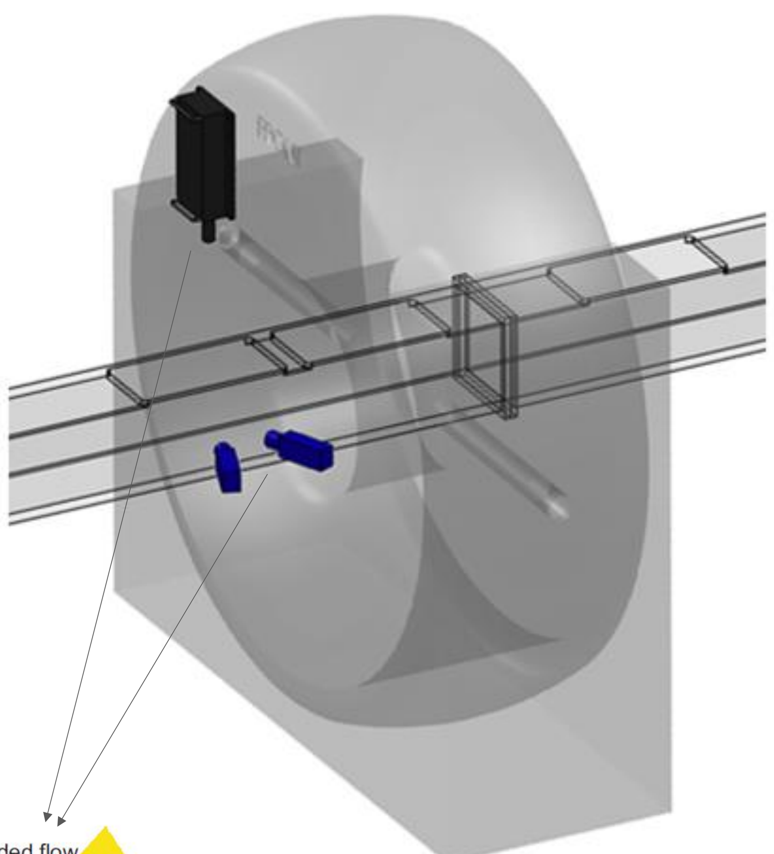
1. Research context

- The fluid-particle interface dynamics is important to understand the physical mechanisms involved in sediment transport
- This thin boundary layer is however difficult to sample without disturbing the flow
- The X-ray computed tomography (CT) coupled with others non-destructive technologies are then useful tools

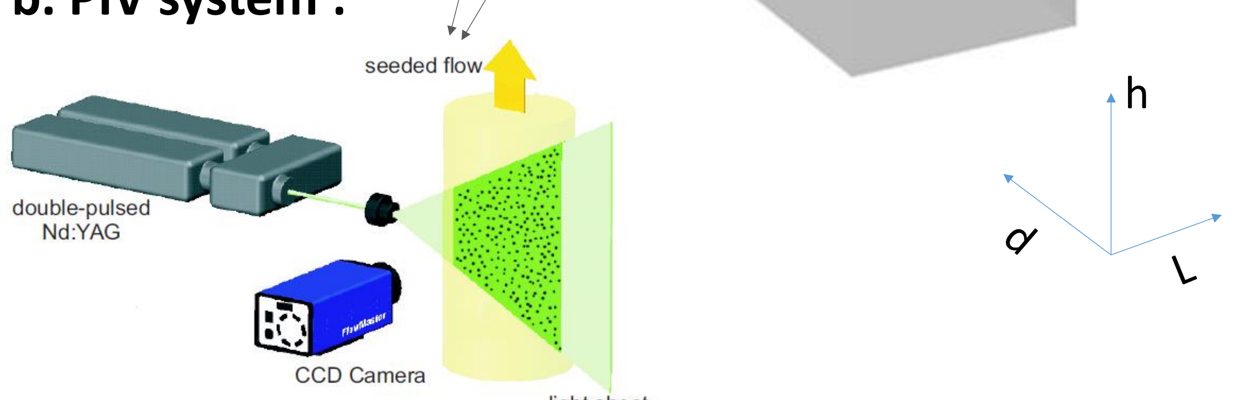
2. Experimental methods

- A movable sand-bed model was built in a rectangular flume (0.30 m x 0.30 m x 7.0 m) (Brunelle et al., 2016)
- The flume is inserted into a medical X-ray CT scan (Siemens, Somatom Definition AS+ 128) which moves on 2.6 meters rails along the flume
- A steady flow is created using a water pump joining the two water tanks placed at each extremity of the flume
- The CT scan is coupled with a Particle image velocimetry (PIV) system which measures fluid velocity

a. CT scan :



b. PIV system :



Detection of particle motion
LaVision (Scarano, 2012)

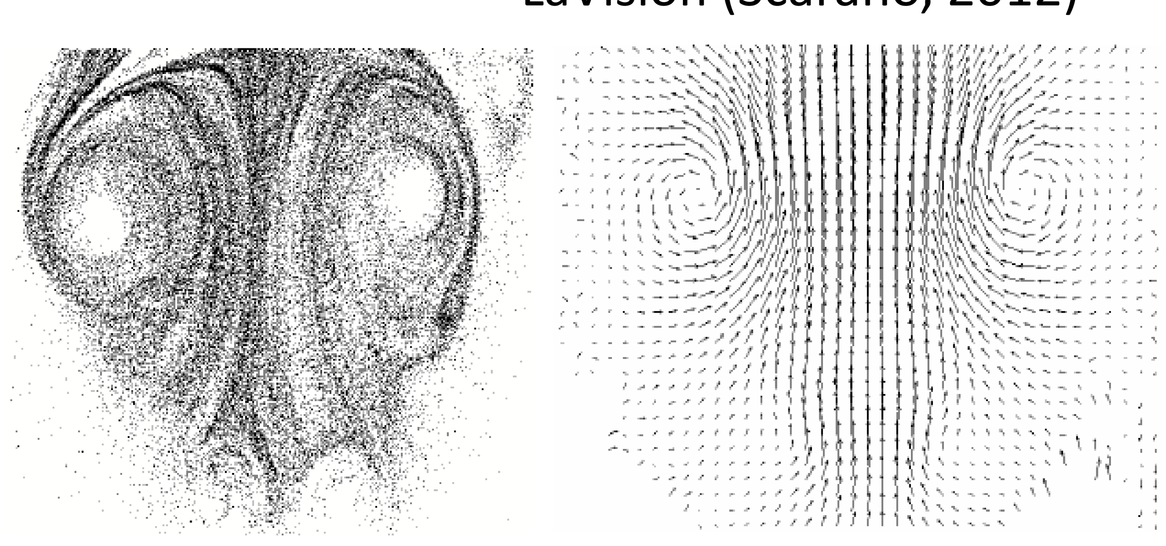


Figure 1. Experimental setup : a) Rectangular hydraulic flume inserted into a medical X-ray CT scan. **B)** The PIV system, laser (black) and cameras (blue), is fixed to the CT scan which moves on rails along the flume. The tube current is 287 mAs and the tube voltage is 140 kV. The beam collimation is 1.2 mm. The field of view used in the cross-section is 0.30 m x 0.30 m with a pixel size of 0.6 mm x 0.6 mm, and 2,0 mm in the longitudinal axis.

3. Preliminary results

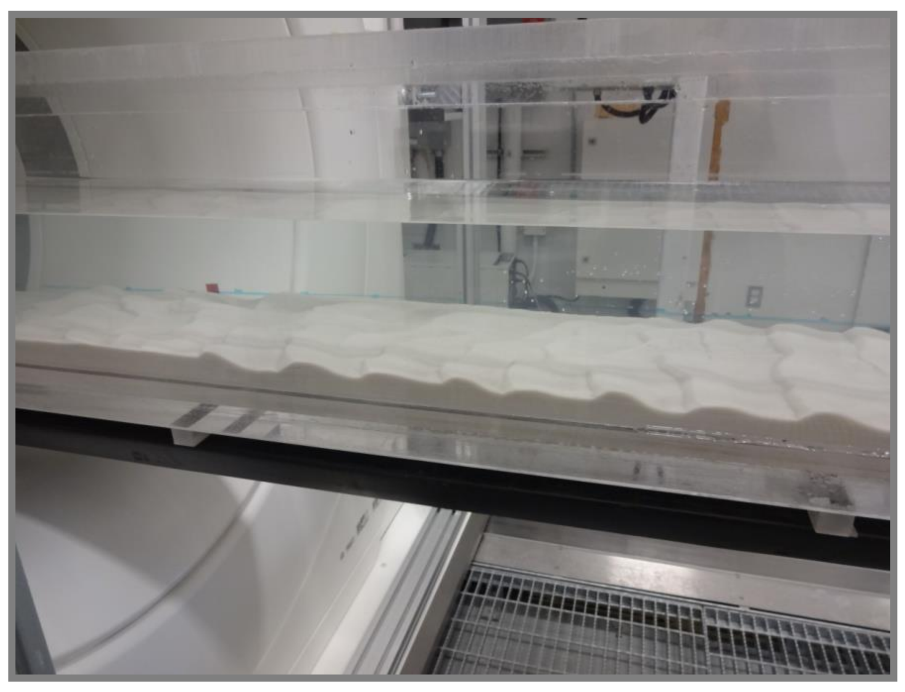


Figure 2. Hydraulic flume : Different steady flows (0.15 to 0.60 m s^{-1}) were generated over a sand bed to create distinguishable sand ripple features. The deformation of the sand bed is measured with the CT scan.

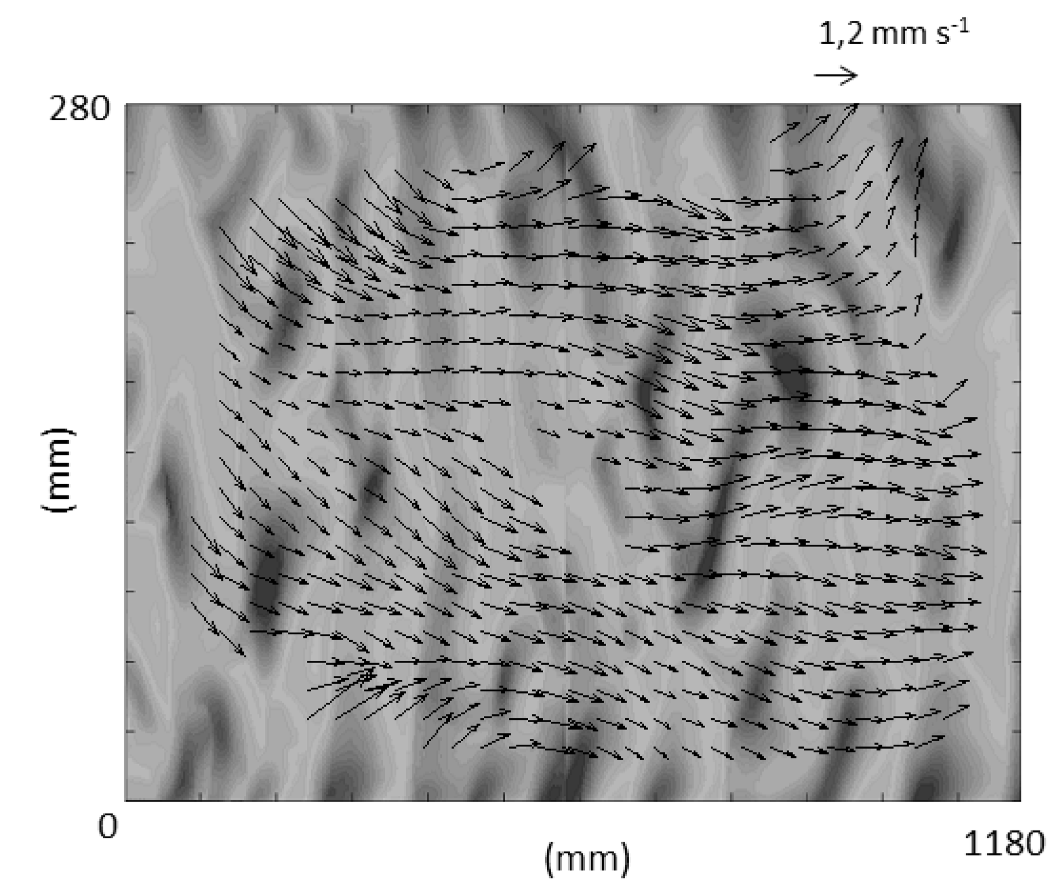
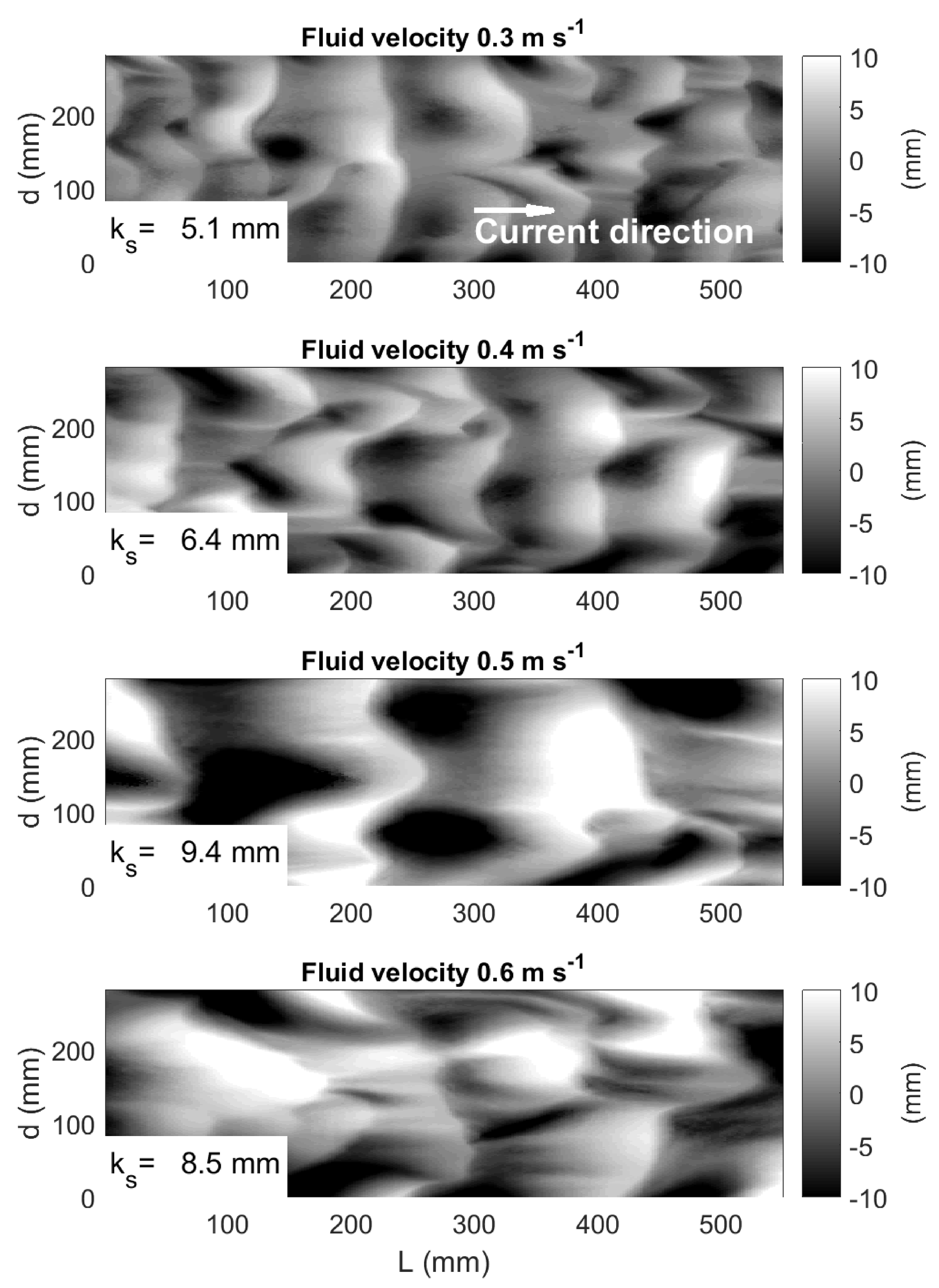


Figure3. Dune tracking : The cross-correlation algorithm of the particle image velocimetry (PIV) technique is used to compute the velocity vector fields of ripples displacement using the 4D CT scan measurements.

a. Sand bed topography : Top view (CT scan)



k_s = 2 x (standard deviation of bed elevation)

b. Fluid flow properties : Side view (PIV)

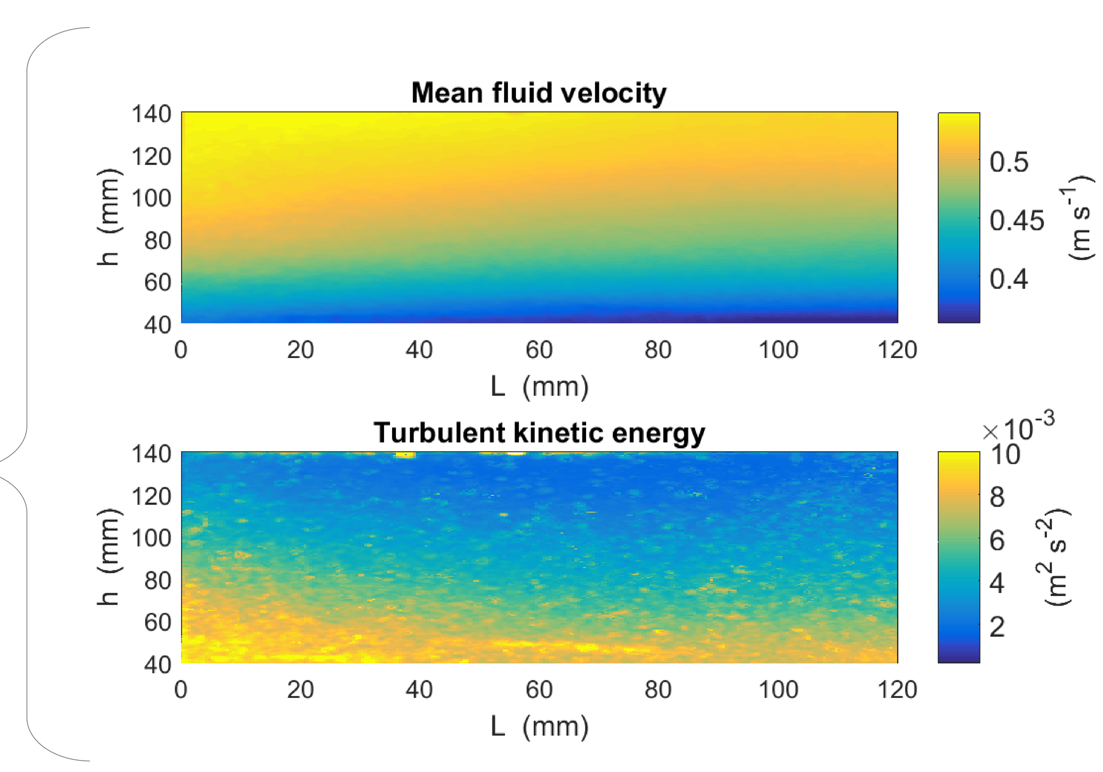


Figure 4. a) CT scan : Sand bed roughness (k_s) with increasing flow velocity (0.3 to 0.6 m s^{-1}). The mean bed elevation is 0 mm. **b) PIV (2D plane – 3D components) :** Flow velocity profile at 0,4 m s^{-1} velocity near the bed. The flow deceleration towards the bottom is related to the bottom roughness. The turbulent kinetic energy is related to the bed shear stress (τ_0), which determines the total sediment transport (Soulsby, 1983).

4. Highlights

- This study characterizes the relation between the sand bed roughness and different flow types with a high resolution
- The experimental setup promising a way to better understand the underlying mechanisms of fluid-particle interface dynamics
- This combined technique is a powerful method to review classical models of sediment transport
- Further work will focus on porosity estimation using the CT scan data
- Many applications could benefit from this technique, especially studies of fluid interaction with porous material.

Brunelle B. C., M. Des Roches, L.-F. Daigle, P. Francus, B. Long, P. Després (2016) Combining CT scan and particle imaging techniques: applications in geosciences. Conference: The 4th International Conference on Image Formation in X-Ray Computed Tomography, Bamberg, Germany. **Scarano F.** (2012) Tomographic PIV: principles and practice. Measurement Science and Technology, 24(1), 012001. **Soulsby, R. L.** (1983) The Bottom Boundary Layer of Shelf Seas. Elsevier Oceanography Series, 35: 189–266.

Acknowledgements : Carl Amos and Hachem Kassem - National Oceanography Centre of Southampton University (UK)