

UAV BASED HYDROMORPHOLOGICAL MAPPING OF A RIVER REACH TO IMPROVE HYDRODYNAMIC NUMERICAL MODELS

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ABSTRACT: Unmanned Aerial Vehicles (UAVs) are increasingly used in the field of engineering surveys. In river engineering, or in general, water resources engineering, UAV based measurements have a huge potential. For instance, indirect measurements of the flow discharge using e.g. large-scale particle image velocimetry (LSPIV), particle tracking velocimetry (PTV), space-time image velocimetry (STIV) or radars became a real alternative for direct flow measurements. Besides flow detection, topographic surveys are also essential for river flow studies as the channel and floodplain geometry is the primary steering feature of the flow. UAVs can play an important role in this field, too. The widely used laser based topographic survey method (LIDAR) can be deployed on UAVs, moreover, the application of the Structure from Motion (SfM) method, which is based on images taken by UAVs, might be an even more cost-efficient alternative to reveal the geometry of distinct objects in the river or on the floodplain. The goal of this study is to demonstrate the utilization of photogrammetry and videogrammetry from airborne footage to provide geometry and flow data for a hydrodynamic numerical simulation of a 1 km long river reach in Albania. First, the geometry of the river is revealed from photogrammetry using the SfM method. Second, a more detailed view of the channel bed at low water level is taken. Using the fine resolution images, a Matlab based code, BASEGRAIN, developed by the ETH in Zürich, will be applied to determine the grain size characteristics of the river bed. This information will be essential to define the hydraulic roughness in the numerical model. Third, flow mapping is performed using UAV measurements and LSPIV method to quantitatively assess the flow field at the free surface and to estimate the discharge in the river. All data collection and analysis will be carried out using a simple, low-cost UAV, moreover, for all the data processing, open source, freely available software will be used leading to a cost-efficient methodology. The results of the UAV based measurements will be discussed and future research ideas will be outlined.

1. UAV

A DJI Phantom 3 Professional drone was applied for the measurements. It is a low-cost and user friendly UAV with factory mounted 4K camera.



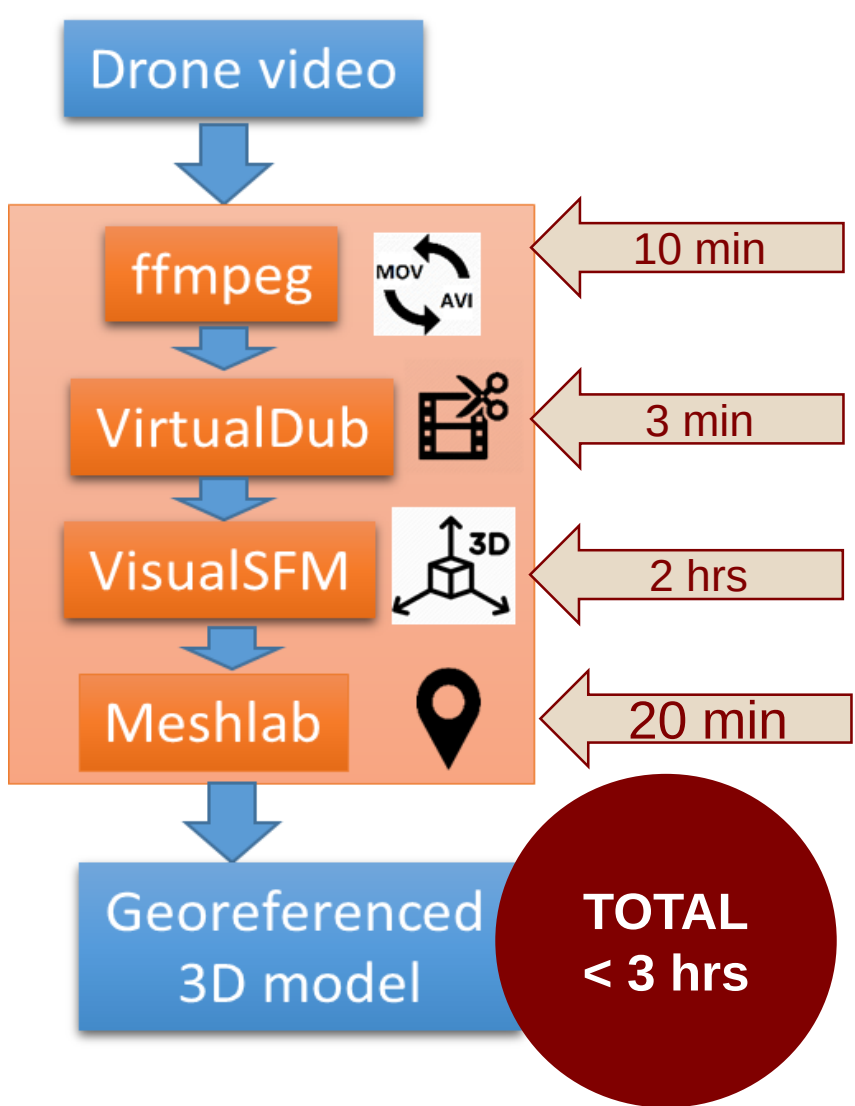
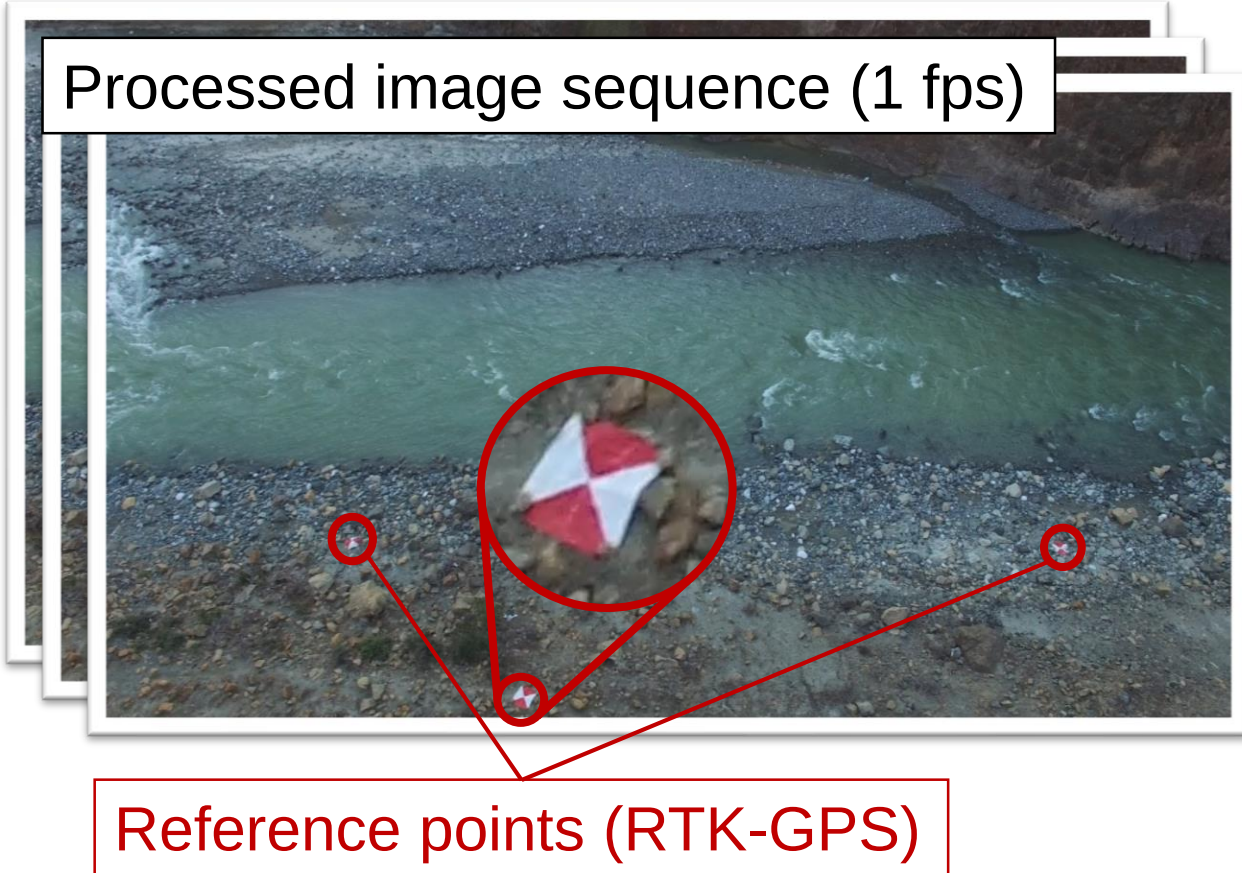
2. Measurement campaign

A three-day long measurement campaign was carried out in a 1 km long reach of the Devoll River in Albania near Kokel. The following surveys were performed:

- UAV videos of the topography (Structure from Motion)
- RTK-GPS measurements (georeferencing)
- UAV videos for Large Scale Particle Image Velocimetry
- UAV images for bed composition analysis (BaseGrain)
- Flow survey with ADCP

3. Topography measurements (SfM)

The Structure from Motion (SfM) (Rootwelt, 2014) method creates a 3D model from an image sequence of an object. First overlapped photos are needed of the object from different angles of view. The method seeks the same, so called, „good feature“ points in different images. Then a mathematical transformation calculates camera positions and the point cloud from the relative positions of these points in the images. Here, only freely available software were used for postprocessing of the video data.

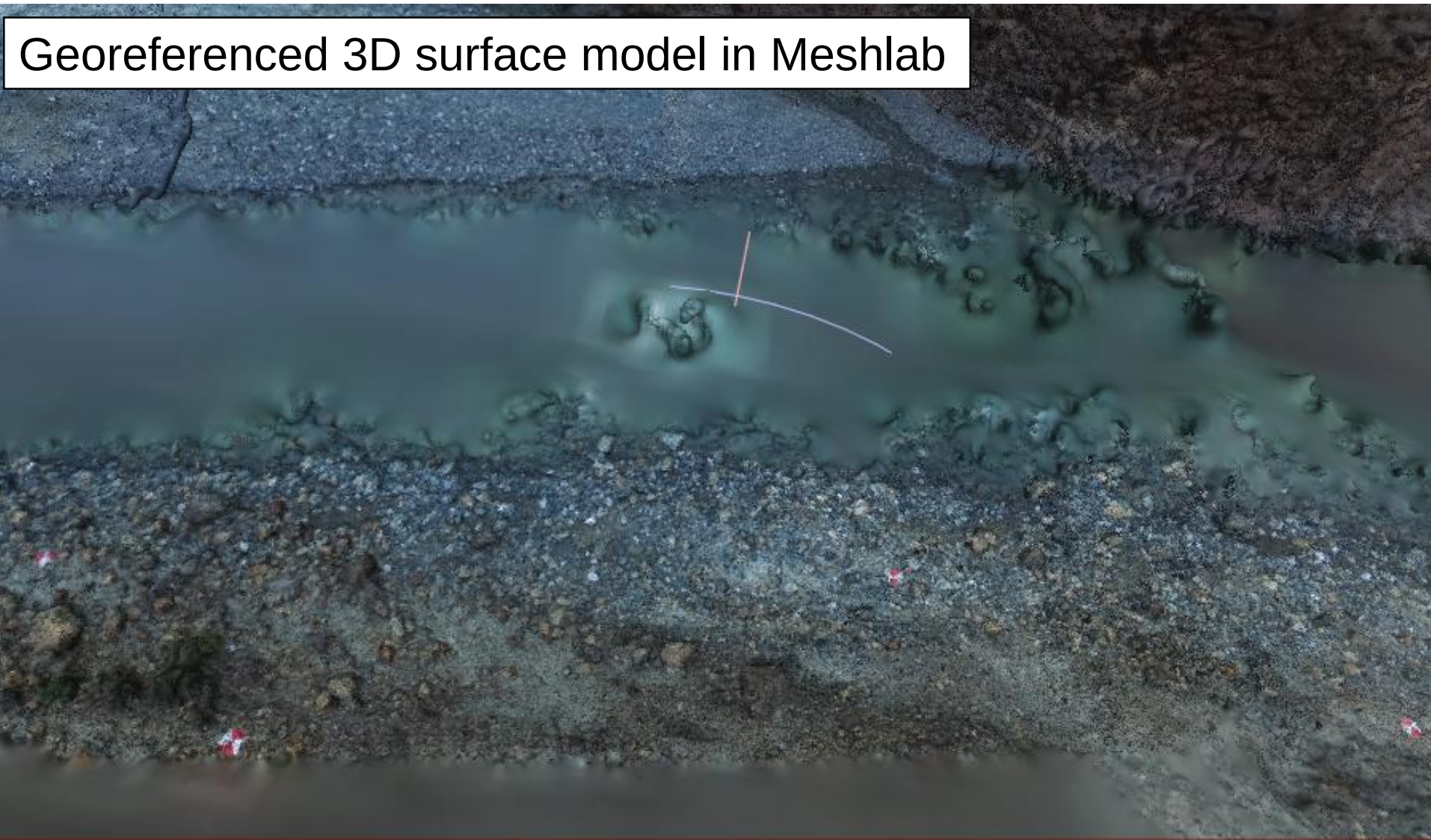


The time demand of the SfM procedure for a 300 meter long reach is shown above. The free software package and the low processing time yield a cost-efficient method, however, at some parts the software provided uncertain topography data which calls for further tests.



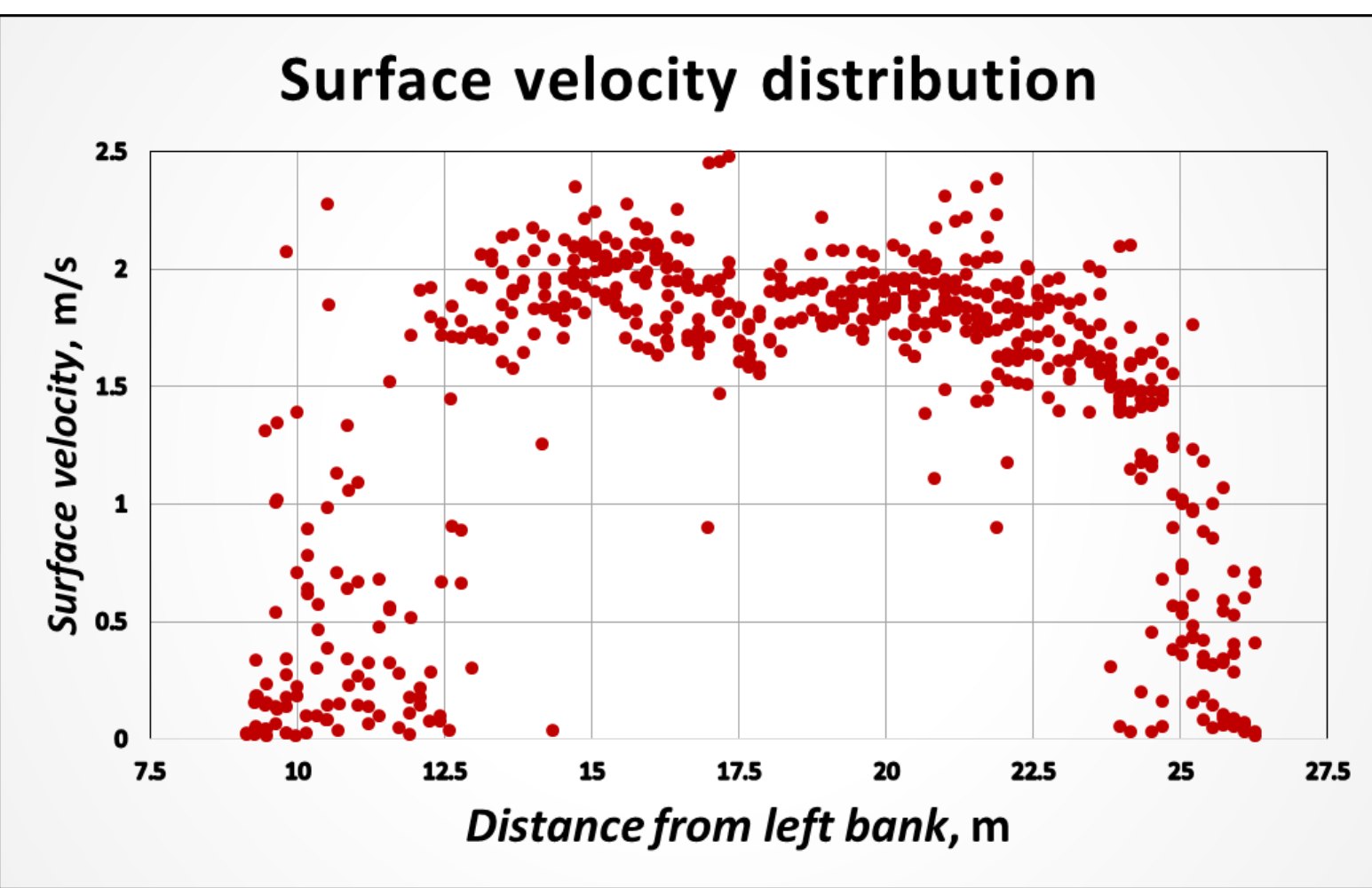
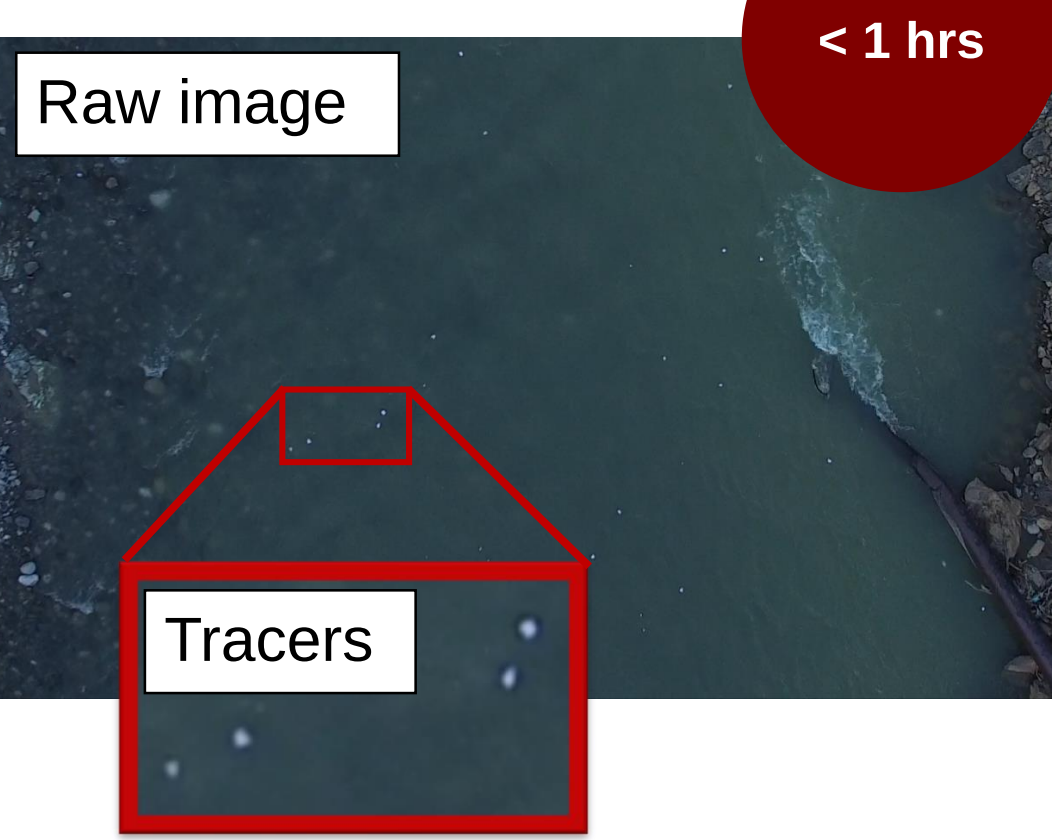
The SfM method eventually provided a georeferenced 3D point cloud of the 1 km long study reach. Note that the reproduction of the main channel geometry is not feasible with UAV based videos. For the complete DEM, interpolation of 1D cross-section data was carried out.

X	Y	Z
440309.417	4514415.635	302.662
440309.395	4514415.994	302.687
440309.287	4514416.062	302.686
440310.133	4514414.495	302.665
440310.078	4514414.581	302.667
440310.008	4514414.646	302.664
440309.707	4514415.407	302.665
440309.709	4514415.425	302.646
440309.577	4514415.597	302.59
440309.457	4514415.734	302.558
440309.481	4514415.81	302.597
440309.439	4514415.84	302.653
440309.338	4514416.027	302.61
440309.348	4514416.006	302.6



4. River flow measurements (LSPIV)

The Large-Scale Particle Image Velocimetry (LSPIV) (Muste et al., 2008) is an indirect method for discharge measurements. The main 3 steps of the method: i) videos are taken of the water surface with tracers; ii) transformation of the images to a 2D undistorted coordinate system; iii) image processing method (PIV) is done based on the motion of the tracers. The result is a velocity distribution of the free surface.

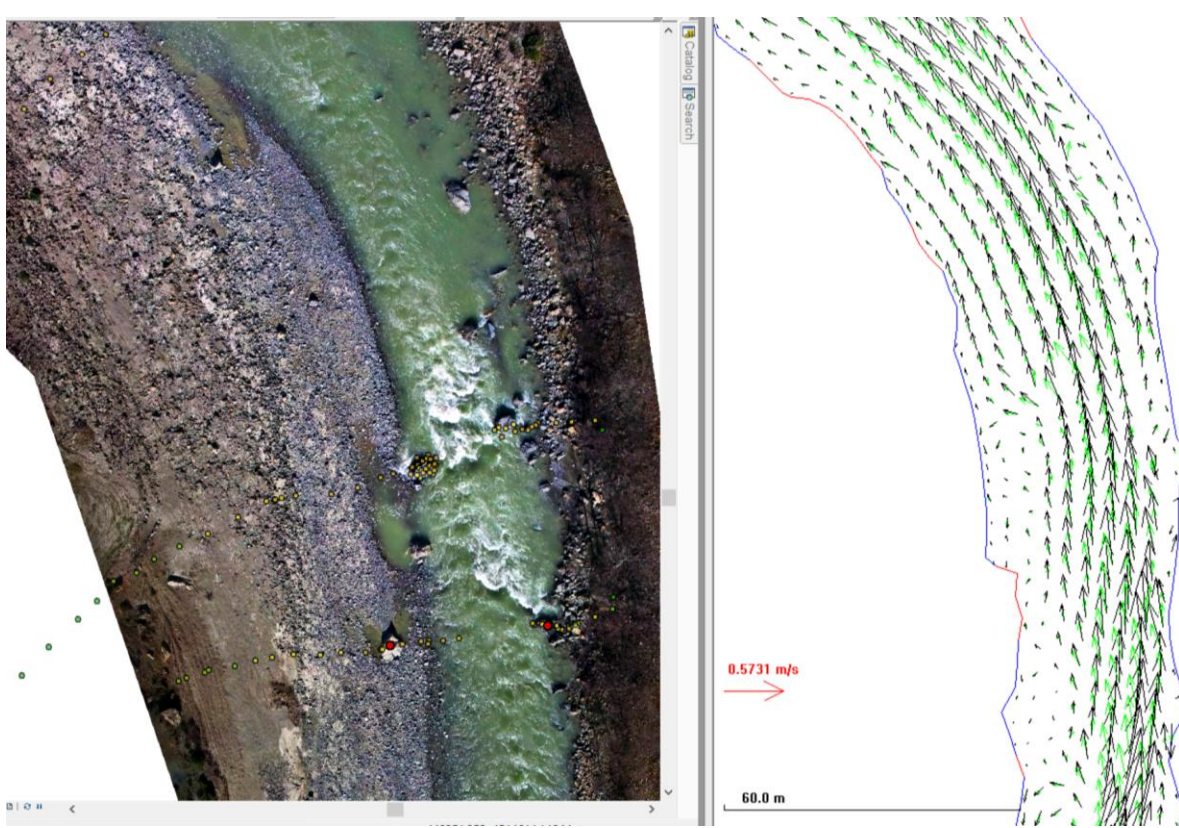


Assuming the vertical logarithmic velocity profile, the mean velocity equals 0.9 times the surface velocity. The estimated discharge was:

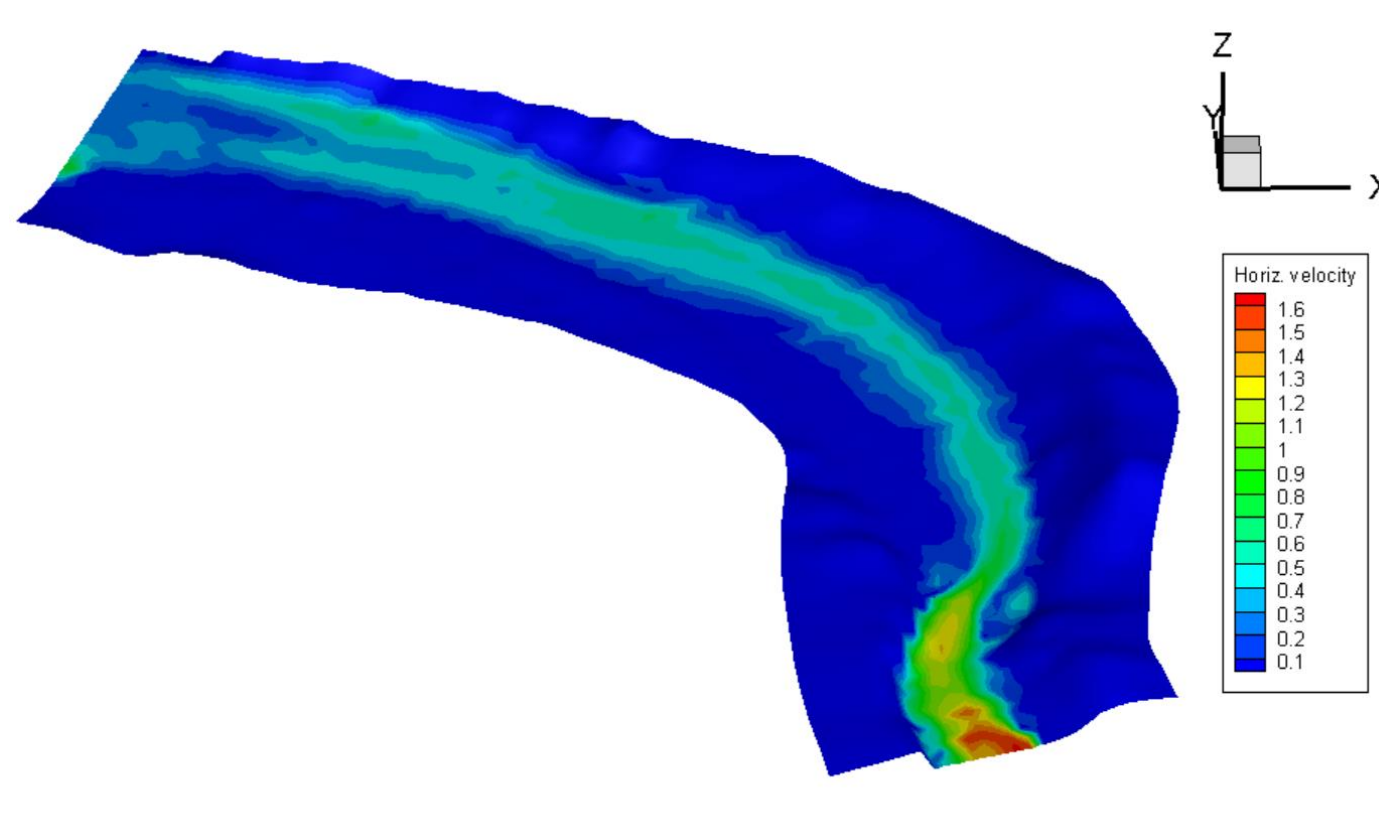
$$Q_{LSPIV} = 15.13 \text{ m}^3/\text{s}$$
$$Q_{ADCP} = 15.27 \text{ m}^3/\text{s} < 1\%$$

6. Simulation

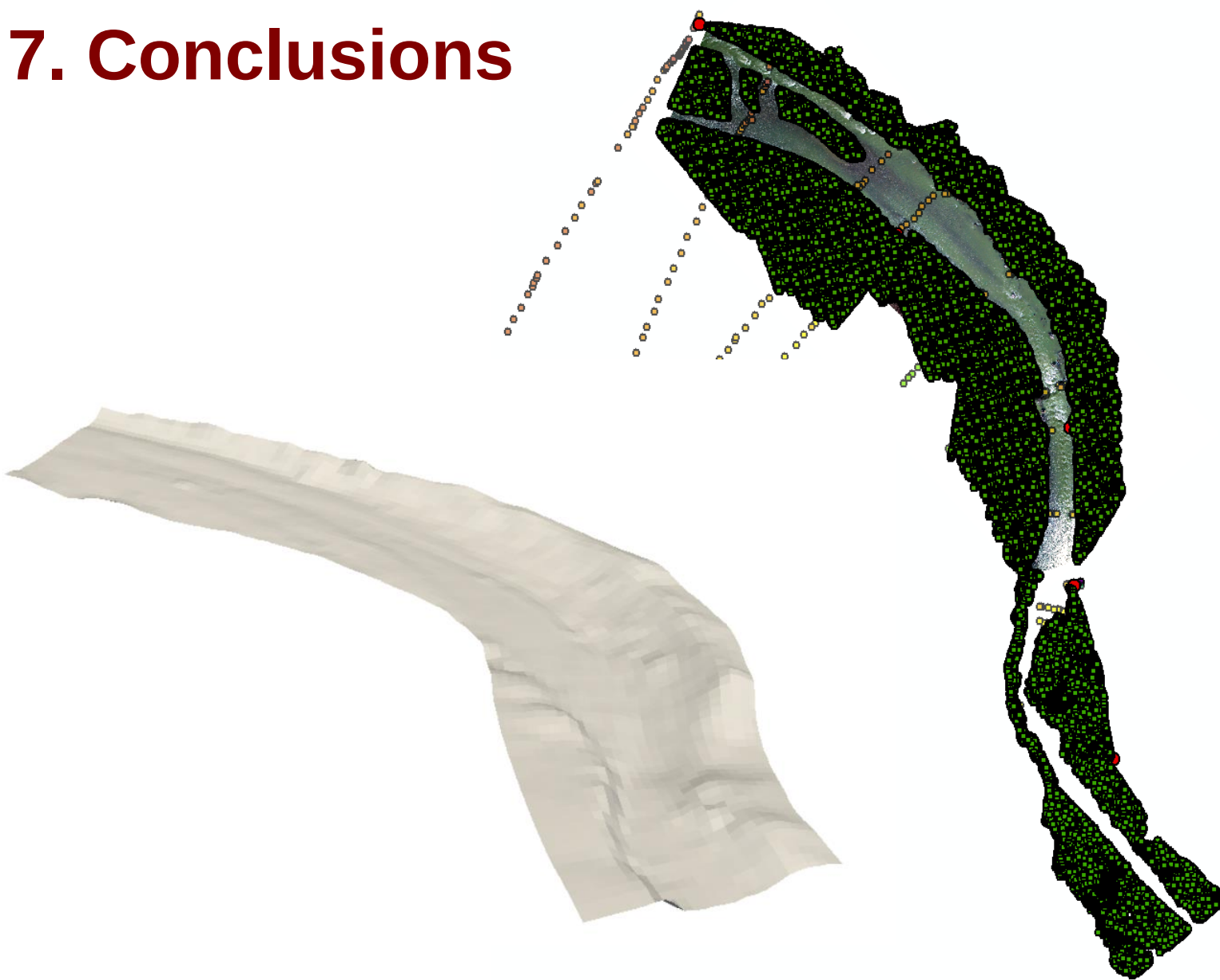
The numerical model used is the fully three dimensional computational fluid dynamics model for open channel flows, SSIIM. SSIIM is developed at the Norwegian University of Science and Technology and is free ware. <http://folk.ntnu.no/nilsol/ssiim/>. The model solves the Reynolds averaged Navier stokes equation with a k-e turbulence closure and the SIMPLE algorithm for the pressure calculation.



Boundary conditions
-discharge and water stage
-water level from SfM model

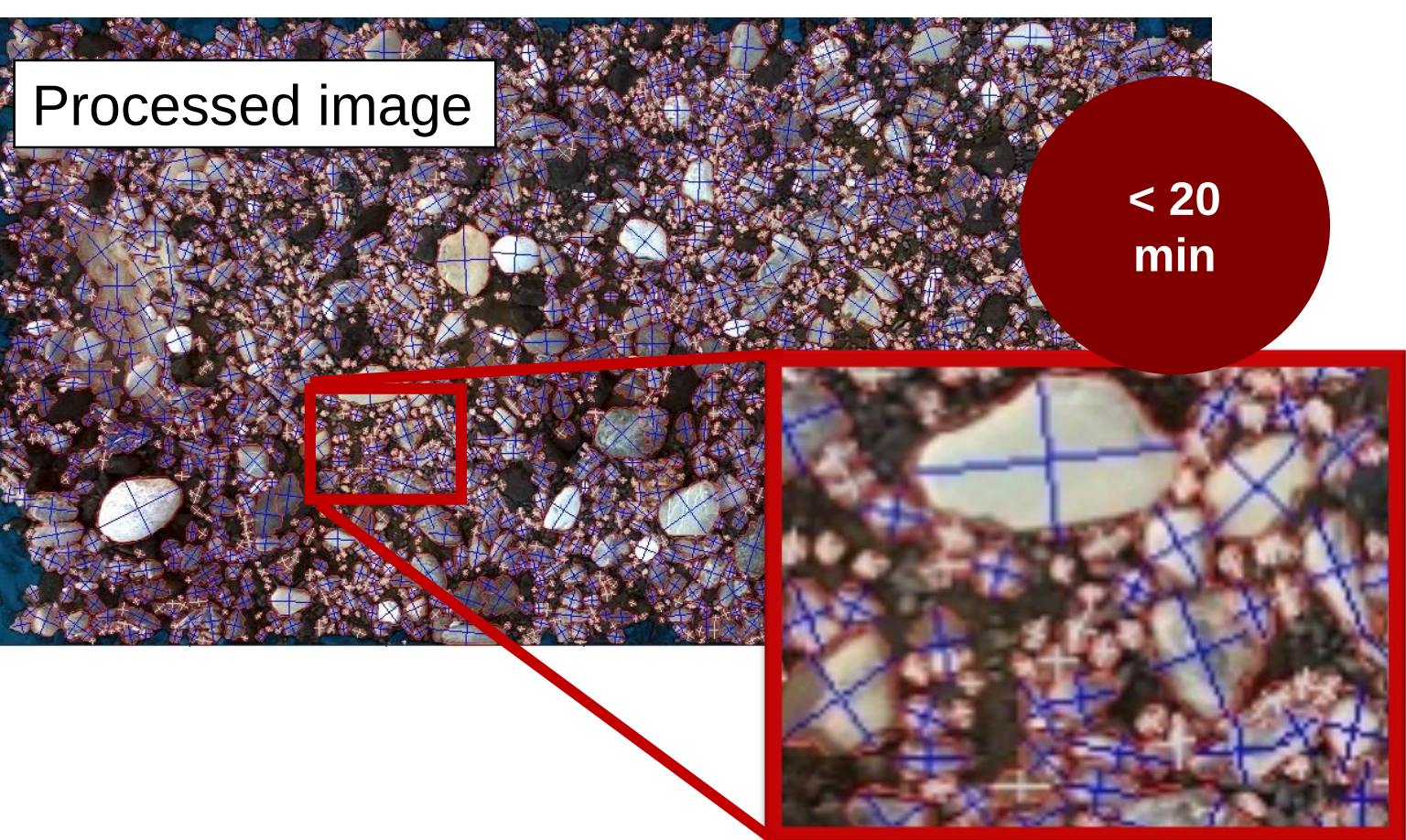


7. Conclusions

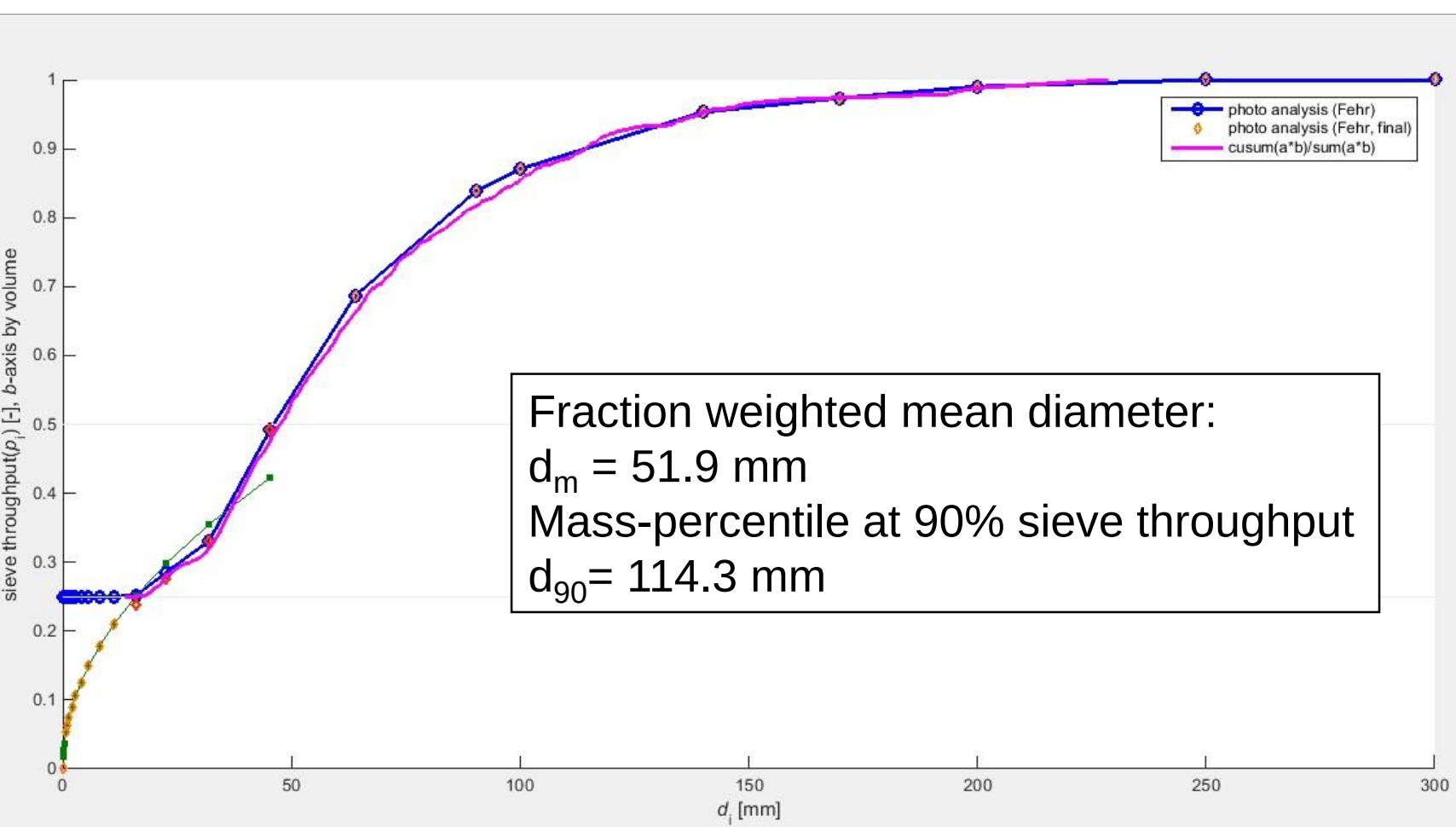


5. Image based bed composition analysis (BASEGRAIN)

The software BASEGRAIN (Detert and Weitbrecht, 2013) was used, which estimates grain size distribution (GSD) of the gravel bed by analyzing the UAV images of the bed material. The results of the final operation can be seen on the right. Straight lines show a-axis and b-axis of the fitted ellipses.



The resulted grain size distribution can be seen on the left. The Manning's roughness (k), generally used in numerical models, can be estimated from the d_{50} and d_{90} values.



Digital Elevation model
Grain size distribution
Surface velocity

3D CFD numerical model

References

1. Rootwelt, T.: Structure from motion, turntable based reconstruction, Norwegian University of Science and Technology. 2014
2. Muste, M., Fujita, I., Hauet, A.: Large-scale particle image velocimetry for measurements in riverine environments, *Water Resources Research*. Vol. 44, 2008
3. Detert, M. and Weitbrecht, V.: User guide to gravelometric image analysis by BASEGRAIN. 12th International Symposium on River Sedimentation Kyoto, Japan, 2013