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Experimental LSPIV configurations for flow observations

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Abstract

Large Scale Particle Image Velocimetry (LSPIV) is a powerful technique to remotely monitor surface flows based on high-speed cross-correlation between pairs of images. Traditional LSPIV configurations (TLC) involve the use of mast-mounted cameras that are installed along river banks and inclined with respect to the water surface to capture large fields of view. Such experimental apparatuses require the images to be orthorectified before LSPIV processing and, therefore, imply the acquisition of ground reference points (GRPs). In a recent contribution by the authors [Tauro et al., Water Resources Research 2014], a novel experimental approach has been proposed to perform remote image calibration based on the use of laser modules. Specifically, a novel self-contained LSPIV configuration (NLC) comprising a miniature camera with its axis perpendicular to the stream surface and two green laser modules oriented orthogonally to the flow are used to develop surface flow maps. Such approach allows for circumventing image orthorectification and prevents in-the-field acquisition of GRPs.

In this contribution, we apply and compare findings obtained with the two LSPIV experimental configurations on the Rio Cordon mountainous stream in the Italian Alps, Figure 1. Specifically, we consider an artificial rectilinear reach of the stream that extends for approximately 10 m, is less than 1 m wide, and 9 cm deep. We perform benchmark flow measurements with an impeller flowmeter up to 3 cm below the stream surface. Further, we execute a set of 10 videos with each LSPIV configuration during the same day by using both naturally occurring and artificial tracers to enhance image visibility. Experimental findings demonstrate that both sets of data from the LSPIV apparatuses tend to underestimate the actual surface flow velocity. In particular, the methodology is severely affected by illumination issues and inhomogeneous tracer density. Further, both LSPIV configurations suffer from a number of practical criticalities that may hamper their implementation in topographically-difficult to access areas.

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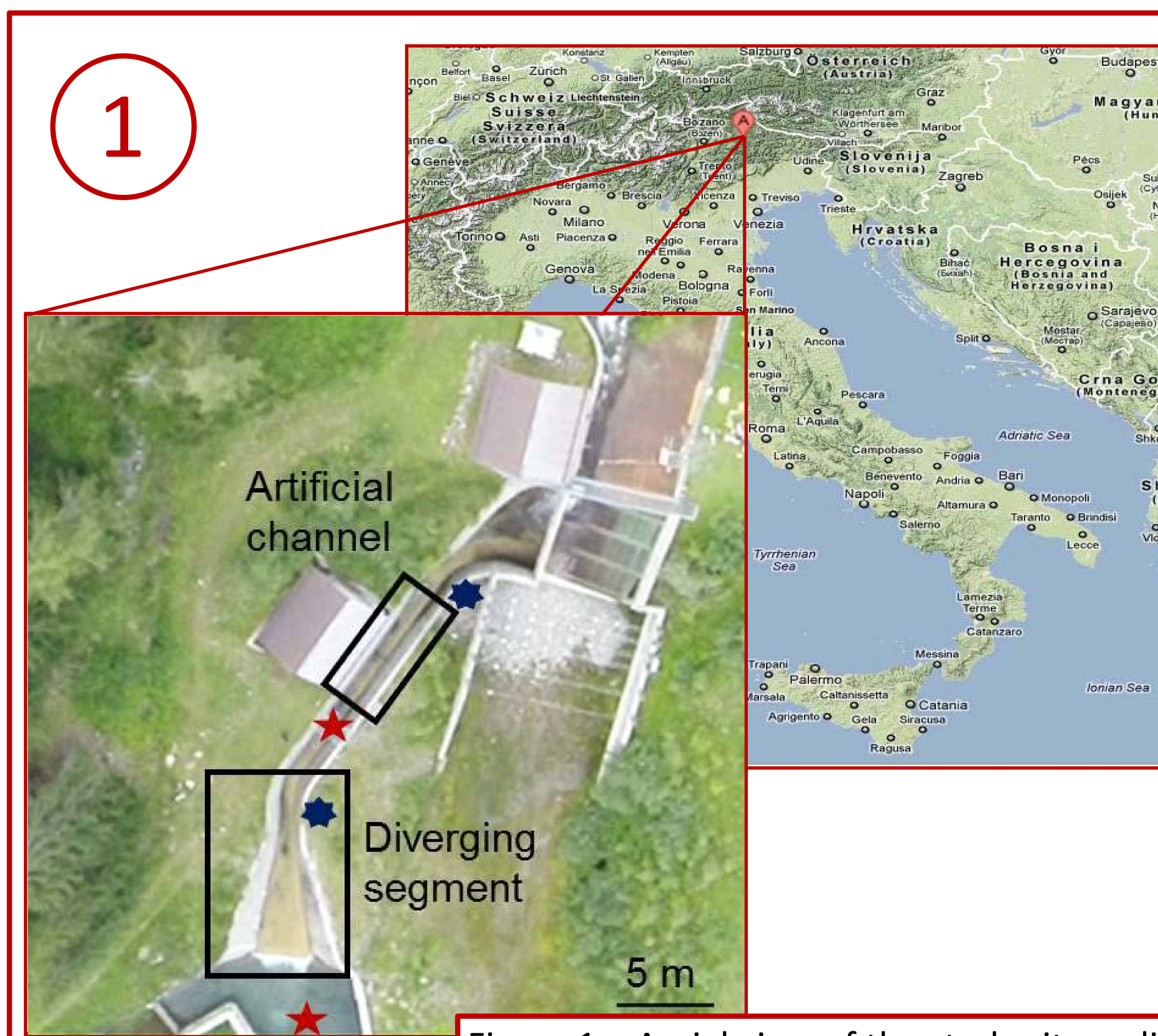

Figure 1 – Aerial view of the study site: solid boxes indicate the locations where surface flow observations were conducted. Red stars indicate the location of the fixed sensing platforms. Blue markers denote the locations along the stream banks where tracer deployment occurred.

Large Scale Particle Image Velocimetry

LSPIV implementations include: i) a digital image acquisition system; ii) surface flow tracers; and iii) a processing unit to extract flow velocity from images. After acquisition, digital images are orthorectified, calibrated, and applied a high-speed cross-correlation algorithm to extract the surface velocity field, Figure 2.

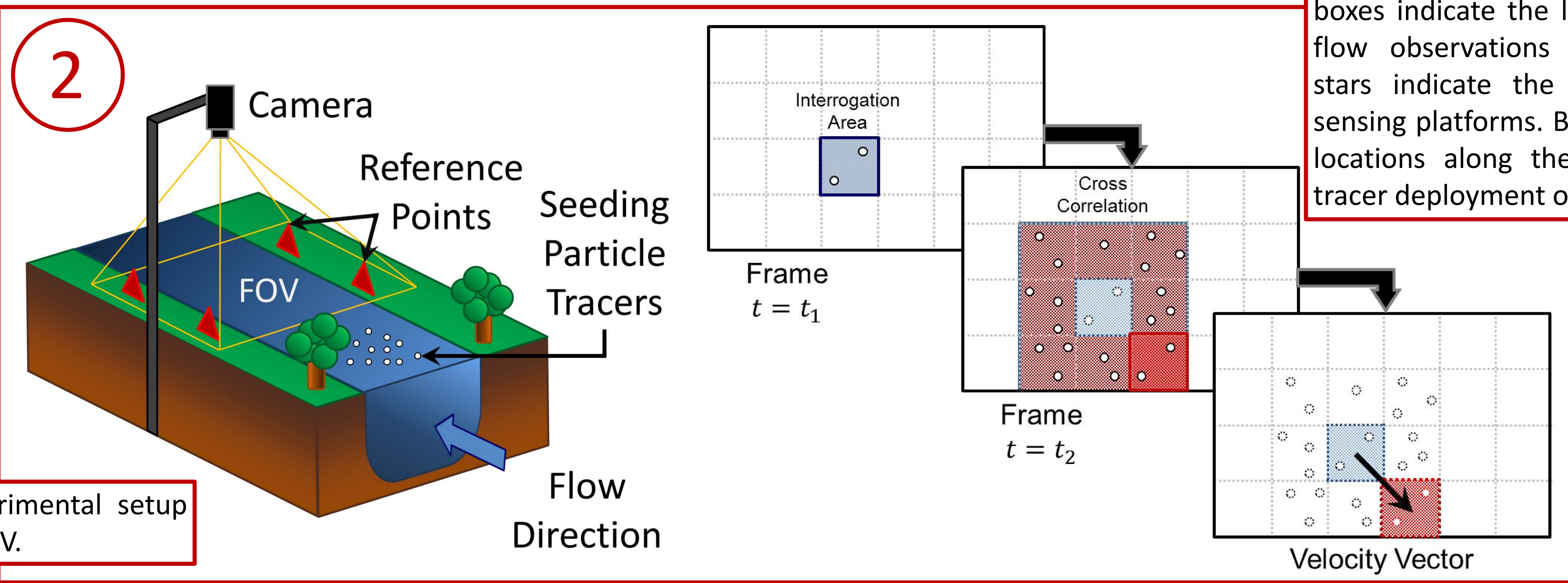

Figure 2 – Schematic experimental setup and working principle of LSPIV.

Experiments

At the artificial channel, tests are executed with two experimental configurations, two types of tracers, and in the absence of floating material, Table 1. At the diverging segment, videos are captured from a fixed-inclined LSPIV configuration. Debris and water reflections are therein used as tracers.

Table 1 – Synoptic table of the experimental tests.

Artificial channel							Diverging segment						
Configuration	Tracer	Replicates	Resolution (pixels)	Frequency (Hz)	Observation time (s)	Interrogation window (pixels)	Configuration	Tracer	Replicates	Resolution (pixels)	Frequency (Hz)	Observation time (s)	Interrogation window (pixels)
Fixed-ortho	beads	10	1280 x 720	60	0.7	32 x 32							
	--	10	1280 x 720	60	0.8	64 x 64							
Fixed-inclined	debris	10	720 x 735	20	2.9	32 x 32	Fixed-inclined	debris	10	Full HD	30	2.7	64 x 64
	--	10	720 x 735	20	1.5	32 x 32		--	6	Full HD	30	2.7	64 x 64

Results

Surface flow velocity maps are generated by averaging LSPIV velocity estimates in time. For each experimental configuration, subareas of the stream consistently captured in each video are identified, and time-averaged profiles of selected cross-sections in the subareas are computed, Figure 3.

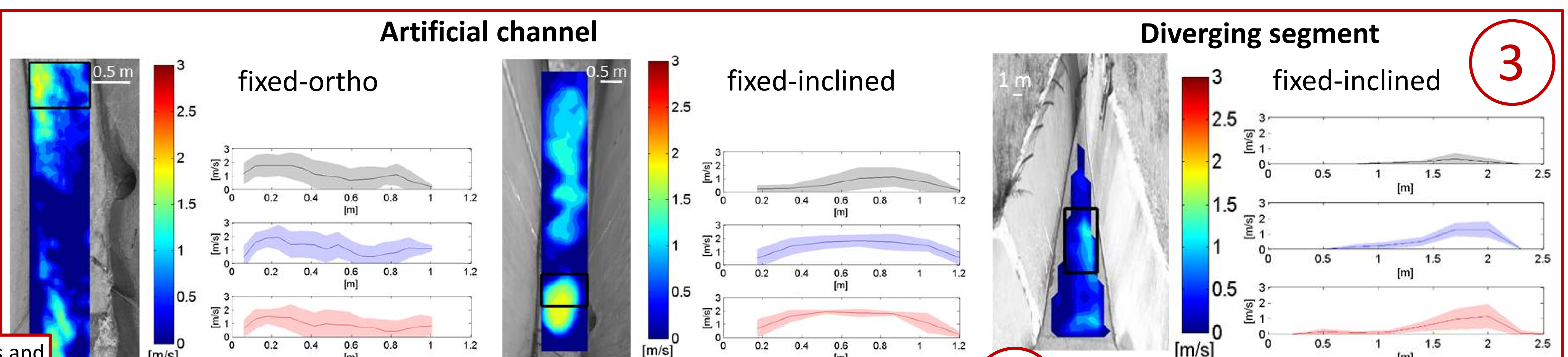

Figure 3 – Time averaged maps and surface cross-sectional profiles.

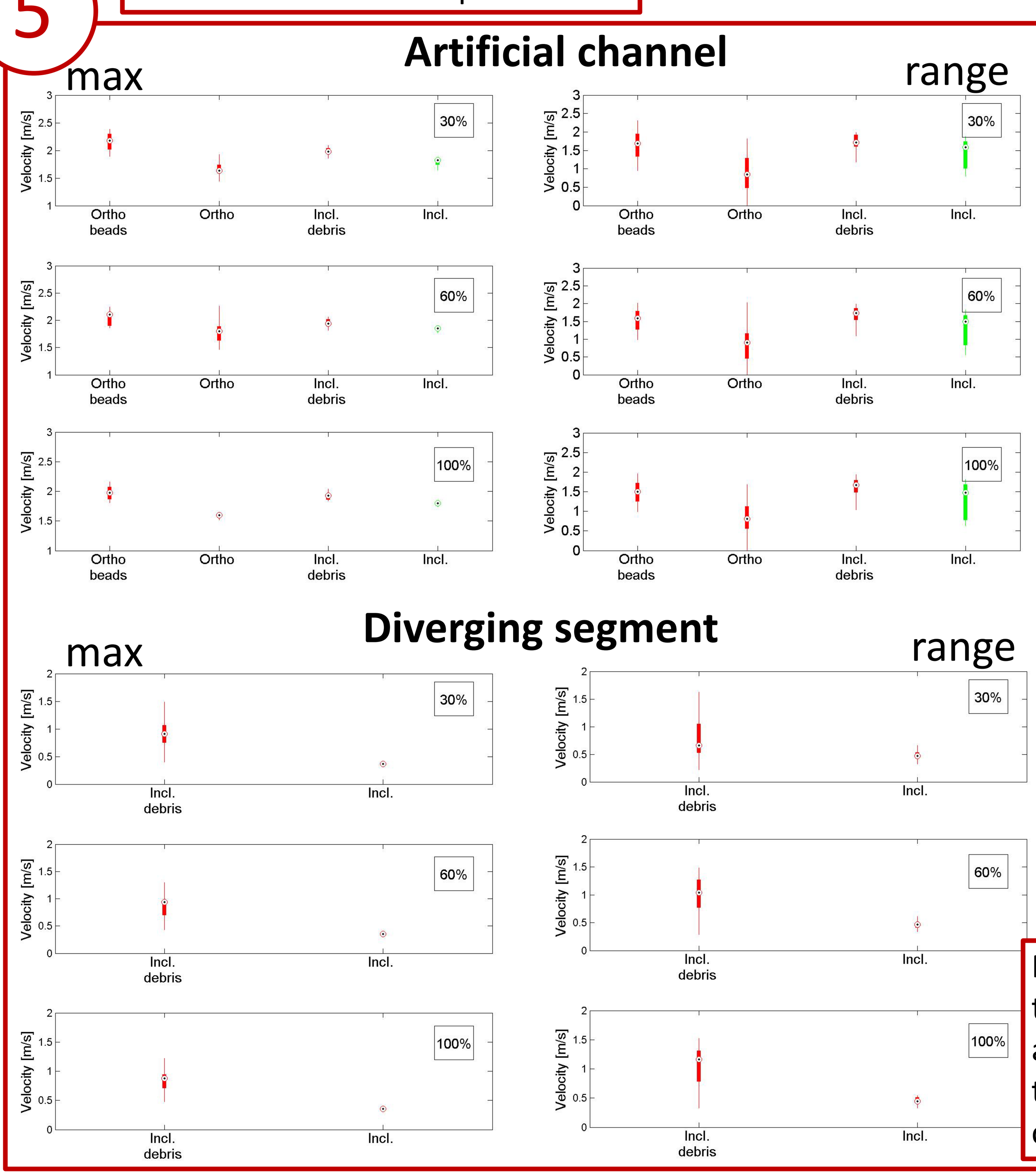

Table 2 – Synoptic statistical results for the experiments.

Artificial channel	Max	Range
Ortho	Significance to tracers and observation time	Significance to tracers
Inclined	Significance to tracers	Significance to tracers
Diverging segment	**Max**	**Range**
Inclined	Significance to tracers	Significance to tracers and observation time

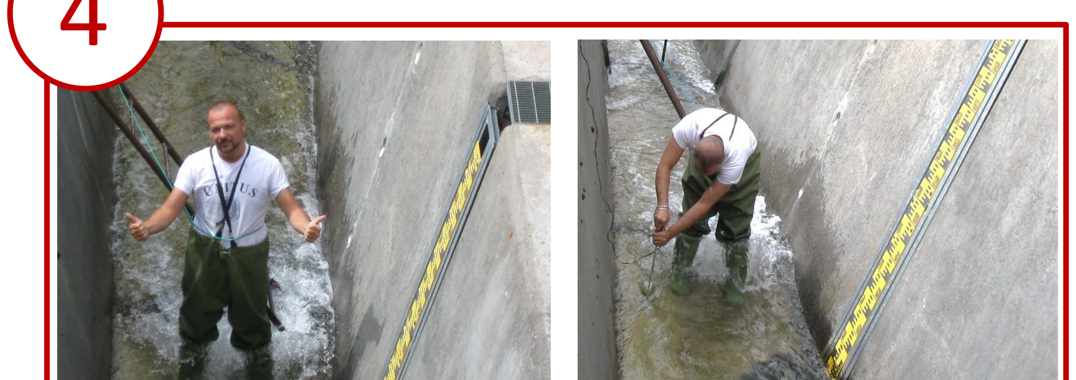

Figure 4 – Measurements with the current meter in the artificial channel.

To assess the effect of the observation time length, velocity maps are generated by considering 30%, 60%, and 100% of the total number of images for each replicate, thus corresponding to 30%, 60%, and 100%, respectively, of the total observation time length.

Benchmark flow velocity for experiments in the artificial channel is obtained using an OTT C2 small current meter, Figure 4. The instrument is set to the time measurement mode, whereby the number of impulses recorded in 10 s are counted and related to flow velocity. Measurements result in an average velocity of 2.54m/s at 0.5m in the center of the stream) and at 3 cm underneath the water surface. In the diverging segment of the stream, benchmark velocity is obtained by manually tracking floating objects in images captured from the fixed-inclined configuration. Specifically, average velocities equal to 1.5-1.8m/s are found for the central portion of the diverging segment.

In Figure 5, maximum velocities in the shared subarea and range values for three surface cross-sectional profiles are reported. Significance with respect to different tracers and observation time is illustrated in Table 2.

Figure 5 – Maximum velocities and range values for the experimental tests. Markers indicate medians. The edges of the box indicate the 25th and 75th percentiles, and the whiskers extend to extreme data points that are not outliers. For each replicate, maximum velocity values are computed considering 30%, 60%, and 100% of the image sequences.

References

Tauro F., Porfiri M., Grimaldi S: Water Resources Research, 50 (9), 7470-7483, 2014

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