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# Observing hydrological processes: recent advancements in surface flow monitoring through image analysis

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Recently, several efforts have been devoted to the design and development of innovative, and often unintended, approaches for the acquisition of hydrological data. Among such pioneering techniques, this presentation reports recent advancements towards the establishment of a novel noninvasive and potentially continuous methodology based on the acquisition and analysis of images for spatially distributed observations of the kinematics of surface waters. The approach aims at enabling rapid, affordable, and accurate surface flow monitoring of natural streams. Flow monitoring is an integral part of hydrological sciences and is essential for disaster risk reduction and the comprehension of natural phenomena. However, water processes are inherently complex to observe: they are characterized by multiscale and highly heterogeneous phenomena which have traditionally demanded sophisticated and costly measurement techniques. Challenges in the implementation of such techniques have also resulted in lack of hydrological data during extreme events, in difficult-to-access environments, and at high temporal resolution.

By combining low-cost yet high-resolution images and several velocimetry algorithms, noninvasive flow monitoring has been successfully conducted at highly heterogeneous scales, spanning from rills to highly turbulent streams, and medium-scale rivers, with minimal supervision by external users. Noninvasive image data acquisition has also afforded observations in high flow conditions. Latest novelties towards continuous flow monitoring at the catchment scale have entailed the development of a remote gauge-cam station on the Tiber River and integration of flow monitoring through image analysis with unmanned aerial systems (UASs) technology. The gauge-cam station and the UAS platform both afford noninvasive image acquisition and calibration through an innovative laser-based setup. Compared to traditional point-based instrumentation, images allow for generating surface flow velocity maps which fully describe the kinematics of the velocity field in natural streams. Also, continuous observations provide a close picture of the evolving dynamics of natural water bodies.

Despite such promising achievements, dealing with images also involves coping with adverse illumination, massive data handling and storage, and data-intensive computing. Most importantly, establishing a novel observational technique requires estimation of the uncertainty associated to measurements and thorough comparison to existing benchmark approaches. In this presentation, we provide answers to some of these issues and perspectives for future research.