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Large-Scale, Accurate, High Resolution, Measurements of River Surface Velocity and Turbulence Metrics Using Thermal Infrared Images

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We present a velocimetry method, which we refer to as Infrared Quantitative Velocimetry (IR-QIV), that uses images of thermal patterns, captured in the infrared, on the surface of rivers or other water bodies, to calculate the time-resolved instantaneous two-dimensional surface velocity field. The method works in all natural light conditions (day or night), and under most weather conditions, by tracking thermal patterns in the surface of the water, and is therefore suitable for a large range of flows and environments. The method, is a form of remote sensing and has significant advantages over traditional (visible-light) PIV (Particle Image Velocimetry) or LSPIV (Large Scale PIV) methods for non-contact measurement of water surface velocity field, as it requires no particle 'seeding' or contact with the water.

Measurements of instantaneous water flow velocity, from which turbulence metrics are calculated, are important for advancing the understanding of river hydrodynamics beyond fundamentals such as discharge and mean velocity. However, most velocity measurement methods used in the field are capable of measuring at a point, or along a transect, but not over a two-dimensional area. Additionally, tools such as ADCPs generally require temporal and spatial averaging, and therefore can not resolve instantaneous velocities.

Image-based velocimetry methods, including IR-QIV and LSPIV, measure at the surface of the water and over a large area. However, methods that utilize visible-light imagery, such as LSPIV, require external illumination at night, and are challenged by the relatively homogeneous appearance of the water surface, often requiring either naturally occurring, or added 'seeding' particles, that are advected by the flow. Due the intermittent availability of seeding or surface texture, spatial or temporal averaging is often required, limiting the technique to mean velocity measurements.

These limitations do not apply to IR-QIV since under natural conditions a rich texture of temperature differences exist at the surface of the water due to spatially heterogeneous air/water heat exchange. IR-QIV is capable of calculating the instantaneous velocity at high accuracy and resolution, in space and time (centimeter scale, several Hz), over large areas—up to thousands of square meters. The instantaneous velocity measurements can be used to calculate metrics of turbulence to inform applications such as the study of river and other surface water dynamics; small-scale hydrodynamics near flow features such as water diversions, junctions, obstacles, and river bends; fishery management; gas transfer measurement; non-contact estimation of bathymetry, discharge and bed stress, and more.

We present instantaneous velocity and turbulence metrics measured at sites in the Sacramento River, (California, USA,) made using IR-QIV. Additionally, we discuss issues related to uncertainty analysis in velocimetry techniques using oblique camera viewing angles, and pattern tracking in images containing gradients of intensity (not discrete particles), as well as effects of camera noise. These considerations are relevant to all types of large scale image-based velocimetry, regardless of wavelength of image collection (visible-light or IR), and can be used to inform and improve measurements from both fixed and mobile platforms such, as UASs.