Geophysical Research Abstracts
Vol. 18, EGU2016-626, 2016
EGU General Assembly 2016

A Framework for Sediment Particle Tracking via Radio Frequency IDentification (RFID)

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The study of sedimentary and morphodynamic processes in riverine environments has recently been shifting from the traditional Eulerian, static perspective to a Lagrangian perspective, which considers the movement characteristics of the individual transported particles, such as their travel and resting distance and time. The Lagrangian framework, in turn allows to better study processes such as bedload particle diffusion, erosion and deposition within a river reach, to more accurately predict bedload fluxes especially through the use of stochastic Discrete Particle models. A technology that goes hand-in-hand with this Lagrangian perspective is Radio Frequency IDentification (RFID), which has been recently applied for tracking the movement of tagged sediment particles within the river continuum. RFID allows the wireless, bidirectional exchange of information between a base station, known as the reader, with a typically large number of transponders (or tags) via an (excitation) antenna. RFID allows essentially the unique, wireless detection and identification of a transponder over a distance. The goal of this study is to further enhance the utility of RFID in riverine applications by developing a framework that allows extracting the 3D location of RFID tagged sediment particles in nearly real-time. To address the goal of this coupled theoretical and experimental study, a semi-theoretical approach based on antenna inductive coupling was combined with experimental measurements for developing a relationship that provides an estimate of the distance between a tagged particle and the antenna using the Return Signal Strength Indication (RSSI). The RSSI quantifies the magnetic energy transmitted from the transponder to the antenna. The RFID system used in this study was a passive, Low-Frequency (LF) system, which ensured that the LF radio waves could penetrate through the river bed material. The RSSI of the signal transmitted from each transponder was measured with an oscilloscope during a set of experiments, where the distance and angle of transponders placed in various media (e.g., water, sand and gravel) representative of river beds were systematically varied. The measurements were used to validate a semi-theoretical relationship that yields the RSSI as a function of the distance and orientation between the transponder axis and the antenna loop plane as well as the type of medium surrounding the transponder. The derived semi-theoretical relationship provides a kernel for developing a real-time, 3D tracking system for RFID tagged particles. In doing so, future work aims to further enhance the RFID reader, in order to support multiple antennas. This enhancement will allow estimating the tagged particle coordinates by supplying the distances to each antenna evaluated from the RSSI measurements to a triangulation algorithm.