Geophysical Research Abstracts
Vol. 18, EGU2016-10673, 2016
EGU General Assembly 2016

A High Order Element Based Method for the Simulation of Velocity Damping in the Hyporheic Zone of a High Mountain River

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Groundwater – Surface water interaction is a topic that has gained relevance among the scientific community over the past decades. However, several questions remain unsolved inside this topic, and almost all the research that has been done in the past regards the transport phenomena and has little to do with understanding the dynamics of the flow patterns of the above mentioned interactions.

The aim of this research is to verify the attenuation of the water velocity that comes from the free surface and enters the porous media under the bed of a high mountain river. The understanding of this process is a key feature in order to characterize and quantify the interactions between groundwater and surface water. However, the lack of information and the difficulties that arise when measuring groundwater flows under streams make the physical quantification non reliable for scientific purposes. These issues suggest that numerical simulations and in-stream velocity measurements can be used in order to characterize these flows.

Previous studies have simulated the attenuation of a sinusoidal pulse of vertical velocity that comes from a stream and goes into a porous medium. These studies used the Burgers equation and the 1-D Navier-Stokes equations as governing equations. However, the boundary conditions of the problem, and the results when varying the different parameters of the equations show that the understanding of the process is not complete yet.

To begin with, a Spectral Multi Domain Penalty Method (SMPM) was proposed for quantifying the velocity damping solving the Navier – Stokes equations in 1D. The main assumptions are incompressibility and a hydrostatic approximation for the pressure distributions. This method was tested with theoretical signals that are mainly trigonometric pulses or functions. Afterwards, in order to test the results with real signals, velocity profiles were captured near the Gualí River bed (Honda, Colombia), with an Acoustic Doppler Velocimeter (ADV). These profiles were filtered, treated and set up to feed the SMPM that solves the Navier – Stokes equations for the theoretical case. Besides, the velocity fluctuations along the river bed were calculated according to the mesh that was proposed to solve the numerical problem. This mesh required more refinement near the boundary conditions in order to calculate all the turbulent flow scales near the boundary.

As a result, the velocity damping inside the porous media with real velocity pulses behaves similarly to the damping of the theoretical signals. However, there is still doubt about the use of the Navier – Stokes equations with the assumptions of incompressibility and hydrostatic approximation for the pressure distributions. Furthermore, the boundary conditions of the model suggest a great theme of discussion because of their nature.

To sum up, the quantification of the interactions of groundwater and surface water have to be studied using numerical models in order to observe the behavior of the flow. Our research suggests that the velocity damping of water when entering the porous media goes beyond the approximations used for the Navier-Stokes equations and that this is a pressure driven flow that does not hold the hydrostatic simplification.