3-D Turbulent Process Modeling of the Dynamical Flow-Bottom Interaction

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The application of mathematical modeling in sedimentological studies is still in its infancy for practical purposes due to several reasons: complexity of the problems, lack of theoretical models, simplicity and drawbacks of mathematical models, and suspicion by the geological community. Despite that, the growing evidence of these studies as a complementary approach is being demonstrated by the increasing number of papers dealing with the subject in the last years.

The mechanism of turbulent flows transporting and depositing a huge amount of sand is a good example of a relevant problem being investigated by numerical models. Historically, Depth-Averaged models have been extensively used to represent the Navier-Stokes equation that governs fluid flows. The Depth-average models are a simplified version in the sense that they do not take into account the vertical variability of flow properties. More recently, Direct numerical simulations (DNS) have been used, in which the full 3D Navier- Stokes is solved, allowing the vertical reproduction of the flow properties as well as the complete scale representation of the turbulence, because of the adoption of very refined grid. The main drawback of the DNS is the computational time, since the full 3D equation is solved for a grid built to represent every scale of the turbulence. This alternative reduces the ability to simulate geological situations, because of the time involved for reproducing each flow.

In this work we present a method to simulate a full 3D Navier - Stokes equation in unstructured grids, in which the turbulence is solved only for the larger scales, with a technique named Large Eddy Simulation (LES). This allows the reproduction in 3D of the flow properties, and can be run in a significantly coarser grid than the DNS.

The sedimentation obtained in our model is quantitatively validated against the more precise DNS results. We implemented a dynamical interaction between the flow and the bottom that allows the flow to be influenced by the previous sedimentation, either in one or multiple flows, without the necessity of remeshing.

We validate the reproduction of the depositional elements (lobes and channel levee systems) against quantitative outcrop data, and performed a preliminary comparative study of steady vs unsteady flows. We also tested the flow over irregular surfaces, mimicking real cases, benefiting form the unstructured grids characteristics to deal with complex geometries.