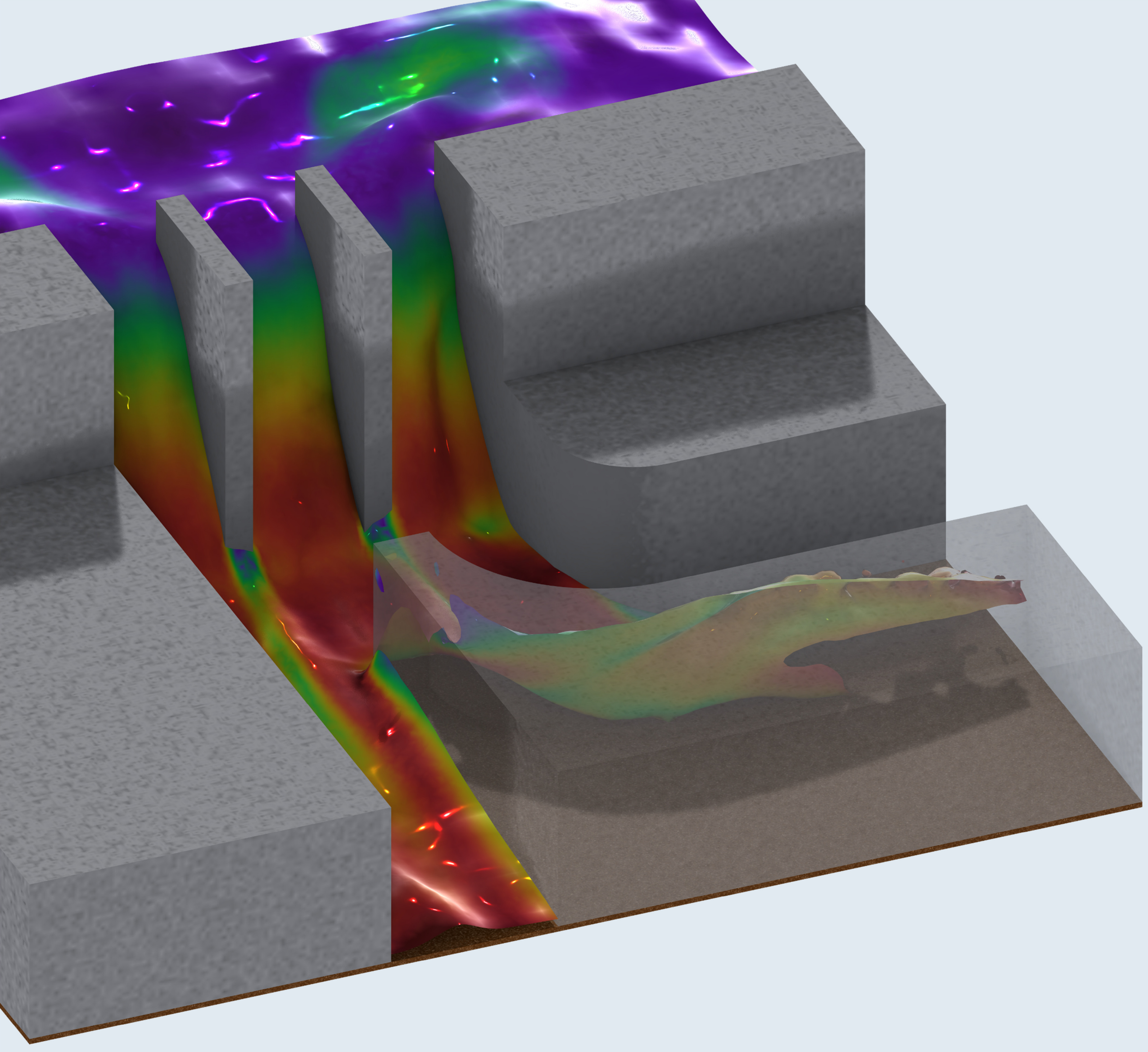

A Comparison between Shallow Water and Level Set Methods in Simulating Water Flooding

Highlights on strong and weak points of each approach in simulating free-surface flows

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Abstract

Flooding is an argument of high interest both in **industrial engineering** and in **environmental science**. Dam breaks, rivers overflowing as well as tsunami effects are just a few exemplar applications that can be mentioned

Managing a **free-surface flow** and **handling** the transient **shape change** of the fluid domain is a challenging aspect for this kind of simulations.

The **Level Set method <LS>** and the **Shallow Water Equations <SWE>** are two numerical techniques suitable to **track free liquid surfaces** without using a moving mesh method. Both approaches present points of strength and weakness, including model **flexibility** and **complexity**, **CPU-time** required to obtain a solution and results **accuracy**. A **comparison** between these methods - exploited to solve the same application - is proposed.

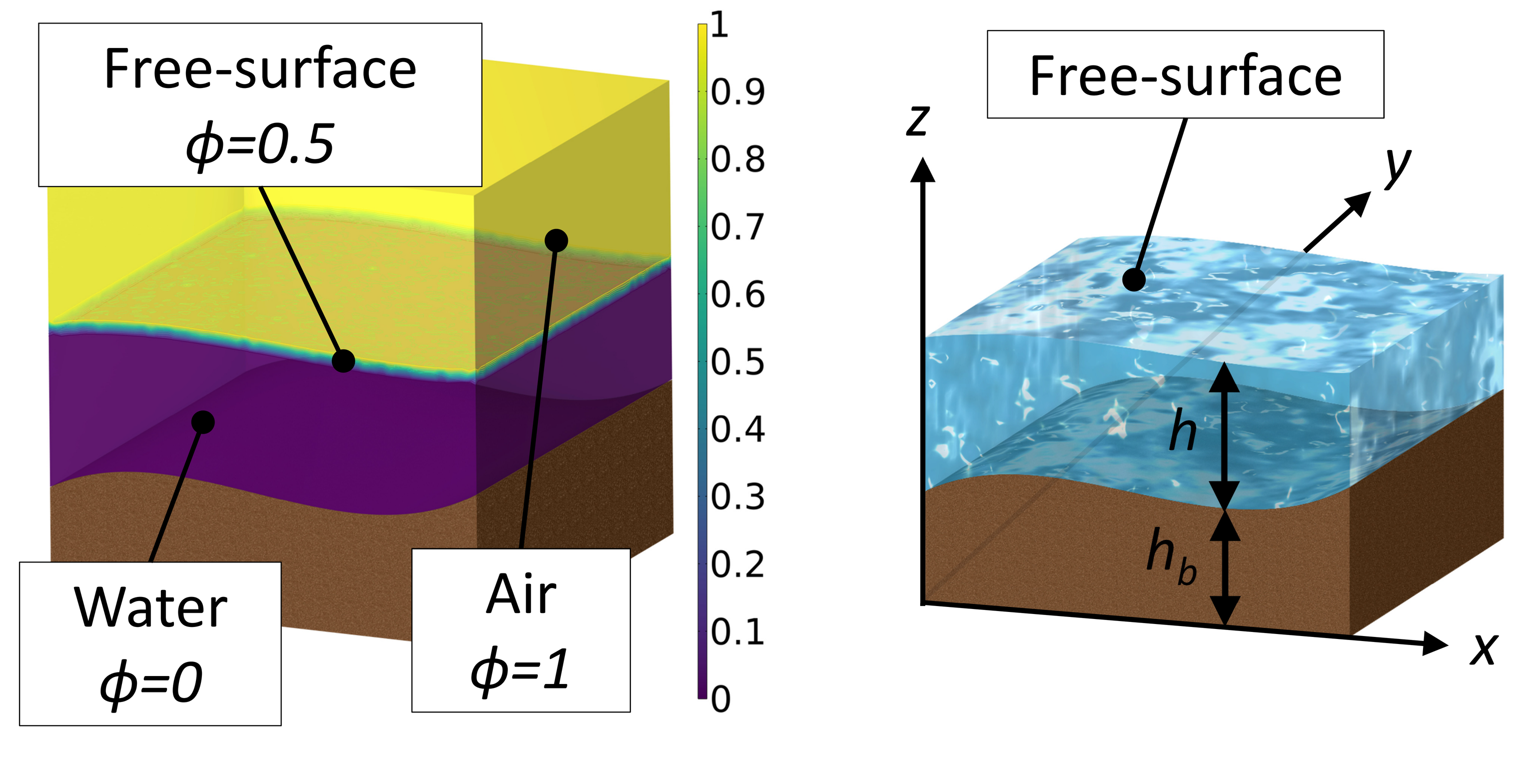

FIGURE 1. Left: Level set function (ϕ) representation. Right: Shallow water equations water depth (h) and bottom height (h_b) representation.

Methods

Level Set method <LS> – Method devoted to track a moving interface between immiscible fluid phases by solving a further PDE together with the Navier-Stokes equations. One scalar variable (ϕ) - defined in the [0; 1] range - identifies each phase in fluid-dynamic solution (ϕ =0.5 marks the interface location).

Shallow Water Equations <SWE> - Navier-Stokes equations solved in a reduced dimension (2D). The horizontal length scale is assumed much greater than the fluid depth (h): the vertical velocity is not solved, and its value is recovered from the continuity equation. Bottom geometry (slope, step, obstacle) is not designed but introduced as by a function $h_b(x,y)$)

Results

Free-surface shape is **different** between two methods: **<LS>** allows the **interface** to **break** and **gather** (Figure 2, left side).

Water **tank levels** at P1 and P2 (Figure 2, right side) are quite **different** during the **initial transient** of the **waterfall**. When flow becomes permanent (18-20s) difference is low (≈1m).

CPU-time to run **<LS>** is **8 times greater** than <SWE> despite a mesh size one order of magnitude higher.

<SWE> is **suitable** to have **quick** and **rough results** but present some flexibility **limits**: **modelling** is essentially **2D** and h_b has to be defined by discrete or analytical functions (not suitable for complex geometries).

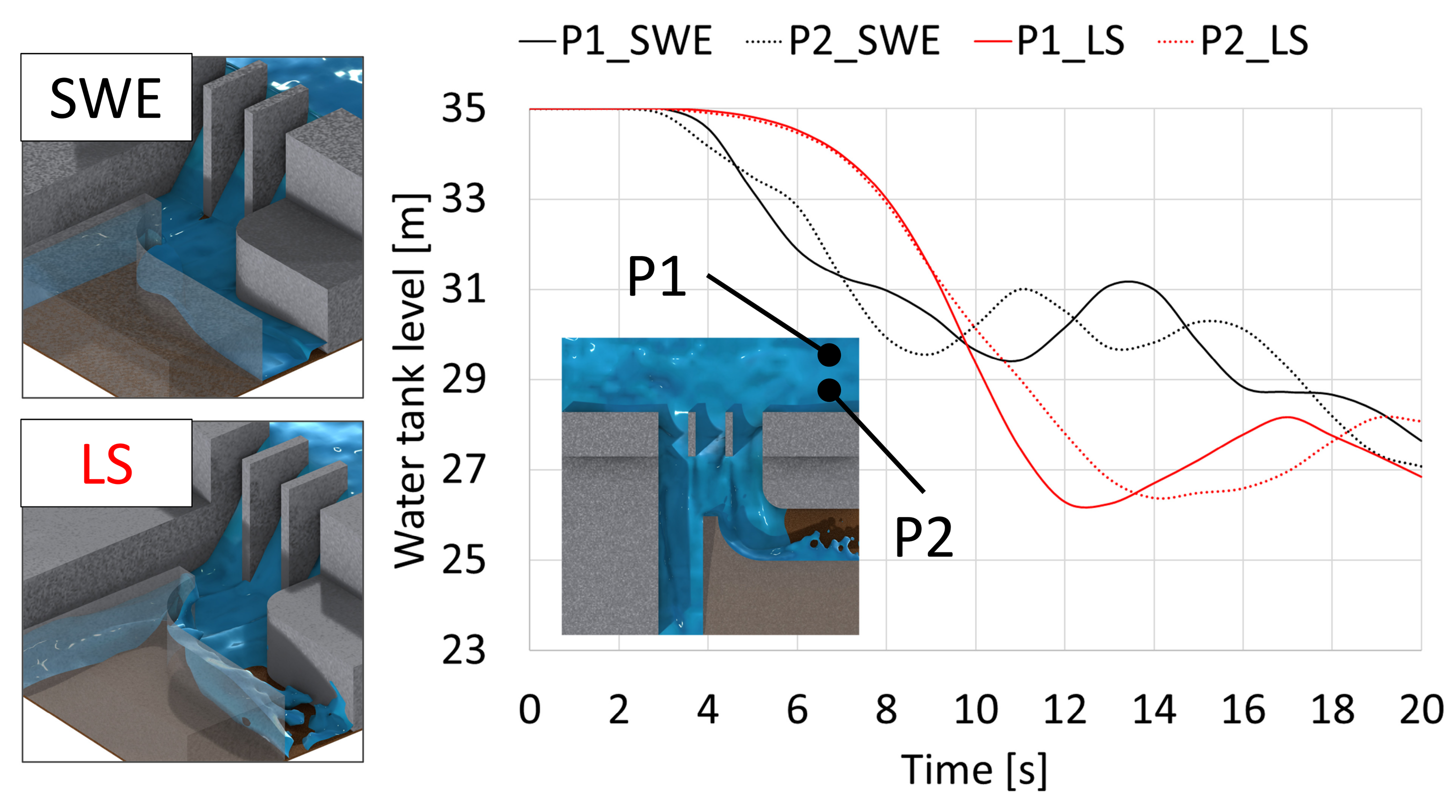

FIGURE 2. Left: Free water surface @20s (<SWE> on top, <LS> on bottom). Right: Water tank level over time on points P1 and P2 (<SWE> black lines, <LS> red lines).

REFERENCES

1. Fontes E., COMSOL Blog, May 15, 2018
2. COMSOL 6.1, CFD Module User's Guide

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