Can modelling noise help us to make better predictions?
Analyzing flood depth and velocity fields using stochastic two-dimensional shallow water equations

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Background
The shallow-water equations (SWEs) are a set of hyperbolic partial differential equations that are used to generate two-dimensional time-varying estimates of flood water depth and velocity, with topography of the region and flow from a flooding source as boundary conditions. However, there is considerable uncertainty in the results generated by these equations due to errors in the specification of the boundary conditions and the myriad of sub-processes that are neglected, or simplified, by the flood models based on these equations.

Objectives
One way to deal with this uncertainty is to generate probabilistic forecasts (Figure 1). In this thesis, we will explore the applicability of introducing noise within the SWEs and converting them into standard stochastic differential equations to obtain more informative two-dimensional flood predictions. The specific research lines to be pursued in this thesis will focus mainly on:

- Introducing various types of noise within the SWEs, converting then into stochastic differential equations (SDEs) and seek numerical solutions for a suite of simple initial and boundary conditions;
- Generating an ensemble of water depth and flow velocity fields using these stochastic SWEs, while purposefully misrepresenting some sub-processes to introduce model errors;
- Comparing the stochastic SWEs model results with synthetic observations from detailed deterministic simulations from the deterministic SWEs (e.g., Figure 2) where all initial and boundary conditions are simulated with the right level of detail.

By the end of the Master thesis valuable insights into the usability and added-value of converting SWEs into stochastic SWEs that provide probabilistic solutions for depth and velocity will be obtained and discussed.

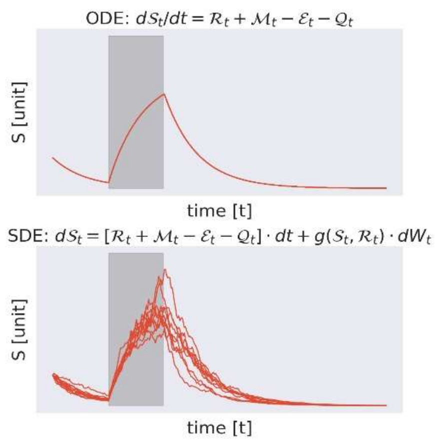

Figure 1. Evolution of storage in a catchment when modelled as a reservoir. SDE are able to capture the dependence of storage evolution on physical noise induced

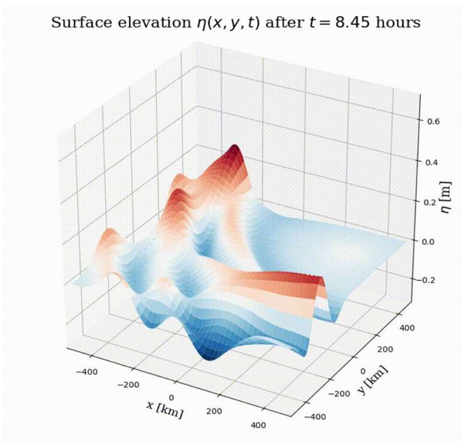

Figure 2. Snapshot of a surface profile generated by surface gravity waves within a shallow pool of water (credit: Jostein Brændshøi)

by interacting sub-processes (shaded area is the unit pulse of rainfall)

Specific information/ Requirements

The main steps of this master thesis will be conducted mainly using an existing SWEs Python code (https://github.com/jostbr/shallow-water) and include the following tasks:

1. Literature review on numerical methods to solve SWEs and flood simulation;
2. Get familiar with the SWEs Python code, using a simple to case;
3. Improve the SWEs Python code to incorporate the uncertainty term and make the SWEs stochastic;
4. Analyze the impact of different error terms in the stochastic SWEs results;
5. Compare the stochastic SWEs results with the results obtained using a detailed deterministic SWEs model;
6. Discuss the pros and cons of stochastic SWEs and their engineering applicability on flood predictions;
7. Thesis writing.

The student will gain in-depth knowledge on flood and stochastic modelling. A good knowledge of Python (or other) programming language is essential. Pre-knowledge of hydraulic modelling is an advantage.

Supervisors

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