Modeling of rainfall infiltration and runoff coupling on watersheds

1. Context

Rainwater infiltration into soil plays a critical role in hydrological processes, particularly in the management of water resources and soil conservation. Understanding how rain infiltrates into porous soils—both flat and sloped—is crucial for predicting runoff, flood risks, designing effective drainage systems, erosion process and maintaining soil stability.

This research aims to model the infiltration of rainfall (hyetographs) using novel analytical/semi-analytical solutions, then implementing, test and validate these models numerically. The models should incorporate flows in both unsaturated and partially saturated regions, depending on the presence of a water table and the state of soil saturation. Both infiltration during rainfall and moisture redistribution after rainfall events will be studied. In the case of sloped terrains, the modeling challenge becomes more complex due to the interaction between infiltration and surface runoff. Moreover, by simulating both flat and sloped terrains at local scales, the model will provide a framework for extending the local model to larger watershed scale.

2. Research Objectives

The primary objective of this research is to develop, test and validate models of rainfall infiltration under different conditions and scenarios. The specific objectives are:

- Modeling infiltration on horizontal soils, including:
  - Rainfall infiltration before and after ponding at soil surface
  - Water redistribution in the soil after a finite duration rainfall
  - Infiltration under multiple rainfall events or complex hyetograms
- Modeling infiltration on slopes
  - Extend the infiltration model to sloped terrains
  - Explore the coupling between infiltration and surface runoff

3. Expected Outcomes

- A set of simplified analytical and semi-analytical models for rainfall infiltration in flat & sloped soils
- Implementation of these models in PYTHON or MATLAB, providing an accessible tool for scientists
- Different scenarios will be studied for better understanding of hydrological processes on field sites

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