Analysis of the run-out time and distance of slow-moving gravitational flows: a possible modeling concept and simulation.

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INTRODUCTION

Mud/debris flows are in general fast-moving gravitational flows with a velocity from 1 to more than 10 m.s-1. A number of gravitational flow models have been developed based on a two dimensional finite difference solution of a depth–averaged form of the Navier-Stokes equations of fluid motion. In these models, the flows are treated as a one phase medium which behavior is controlled by different rheological characteristics depending on the liquid/solid ratio.

OBJECTIVE

The aim of this work is to test whether these models are also able to describe accurately both the run-out time and the run-out distance of shear flows with a relatively lower velocity and probably a higher viscosity .

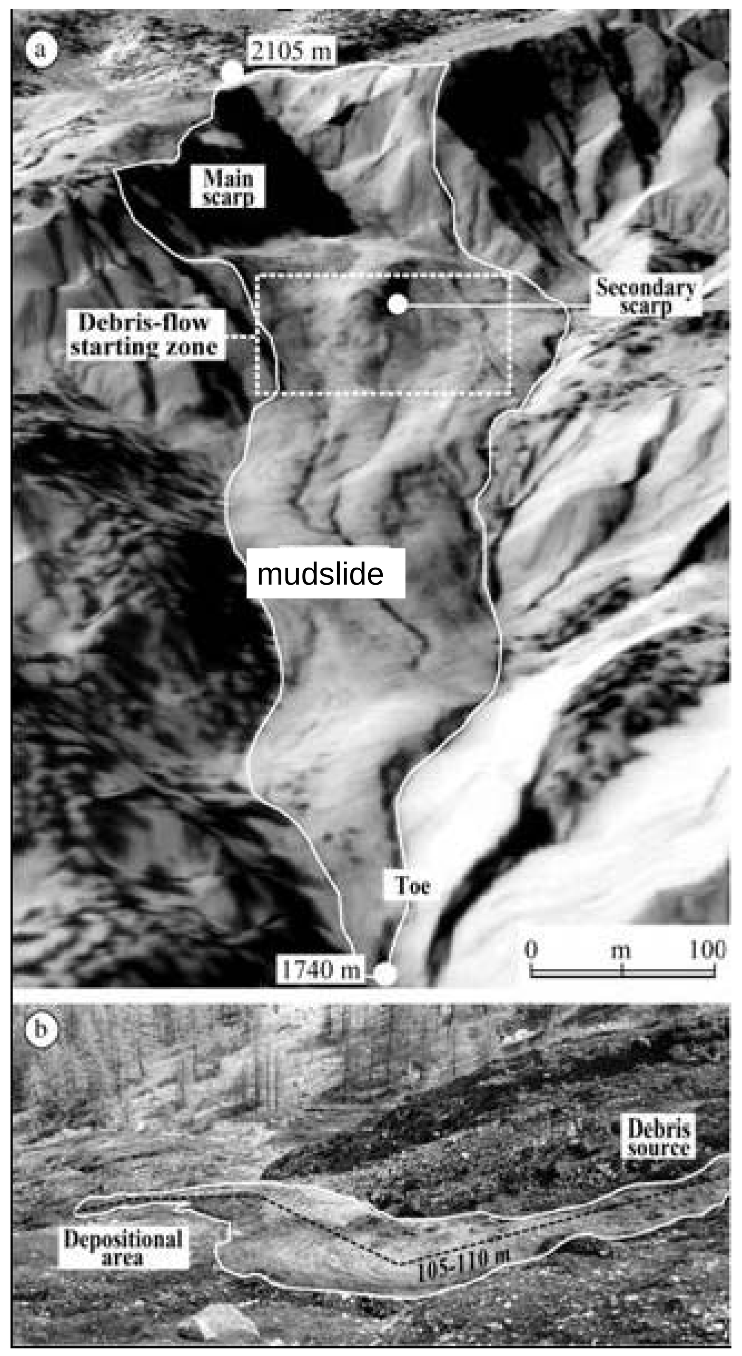

Figure 1 The Super Sauze mud slide and the 1999 secondary mud/debris flow

Slow moving mud flows at the Super Sauze mudslide

A mud/debris flow with an initial volume of about 100m^3 failed in May 5th 1999 suddenly from a secondary scarp of the Super-Sauze mudslide (Southern French Alps) (Fig 1) and reached a distal point of about 105 m from the source area. It flowed on the hillslope in the first 30 minutes with a relative low mean velocity of **2 m.min^{-1}** until a distance of 40 m from the source area, and then continued flowing at a slower mean velocity of **1 m.min^{-1}.** Similar patterns of velocity and run-out distance for small volume mudflows triggered in May 2008 at Super-Sauze have also been observed (Fig.2)

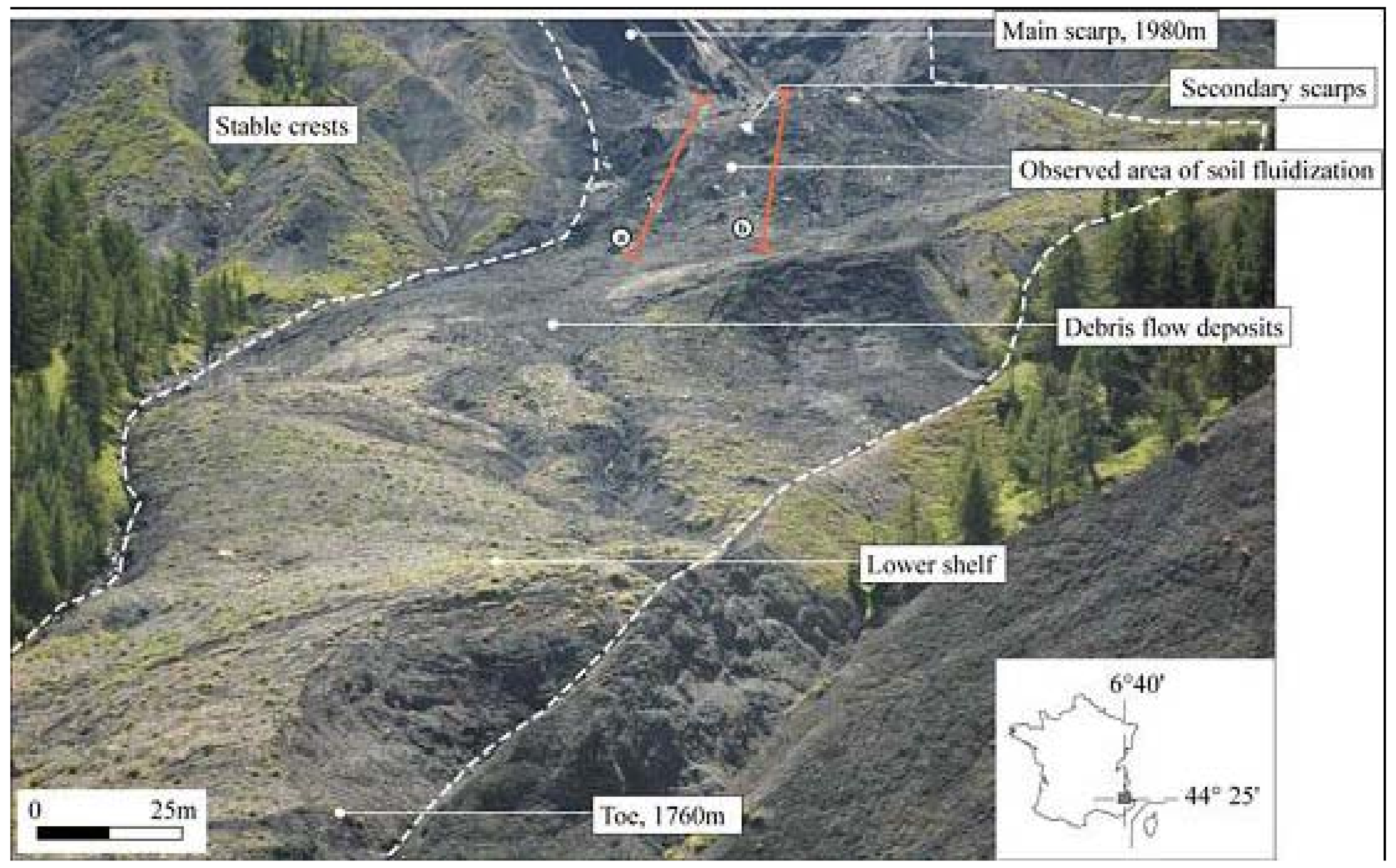

Figure 2 Mud/Debris flow development at the Super Sauze mud slide; situation 2008

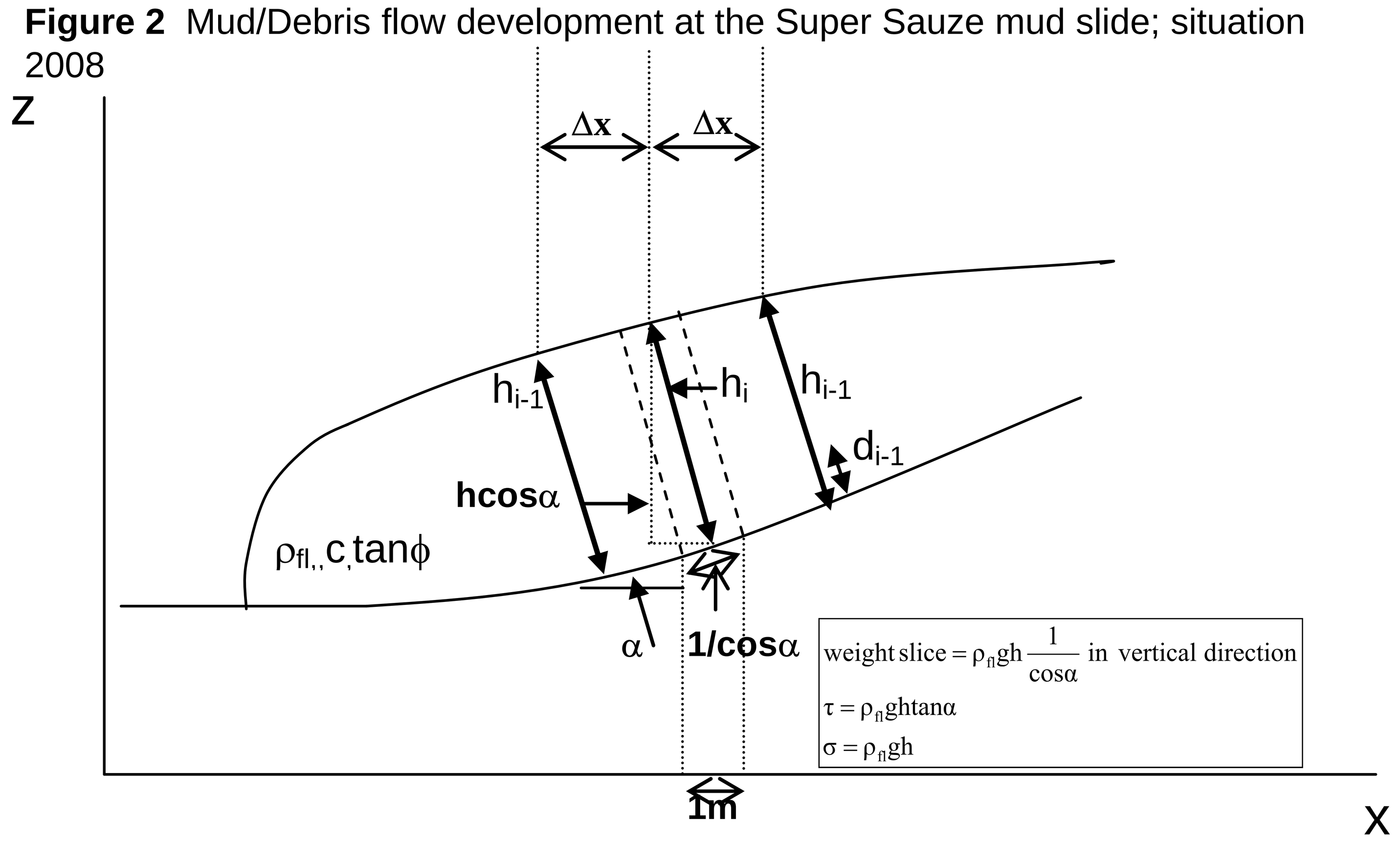

Figure 3 Scheme for the numerical modeling of a debris flow

Model description

Two models are tested. *Model 1* is a currently used model with the governing equations of the MassMov2D model (Bégueria at al. submitted) which follows the form of the Saint Venant shallow water equations, which have been applied previously to mass movement modelling by a number of authors (a.o.: Savage and Hutter 1989, Hungr, 1995; Laigle and Coussot,1997). This delivers the following mass and momentum conservation equations (Eq1,2) with a simplified form of the third-order Bingham expression for the bottom shear stress (Sf, Eq 3) as suggested by Laigle and Coussot (1997).

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} = 0 \quad \text{(mass balance)} \qquad (1)$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} = g\cos\alpha_x \left[\tan\alpha_x - k\frac{\partial h}{\partial x} - S_f \right] \qquad (2)$$

$$S_f = \tan\varphi' + \frac{1}{\rho g h}\left(\frac{3}{2}\tau_c + \frac{3\eta}{h}u \right) \qquad (3)$$

In *Model 2* we assume a permanent equilibrium between the friction and driving forces, thus ignoring the local and convective acceleration terms (Eq.4). Using a simple Coulomb friction term (Eq 5) we get the following modifications of Eq. (2,3):

$$g\cos\alpha_x \left[\tan\alpha_x - k\frac{\partial h}{\partial x} - S_f \right] = 0 \qquad (4)$$

$$S_f = \tan\varphi' + \frac{1}{\rho g h}\left(\tau_c + \frac{\eta}{d}u \right) \qquad (5)$$

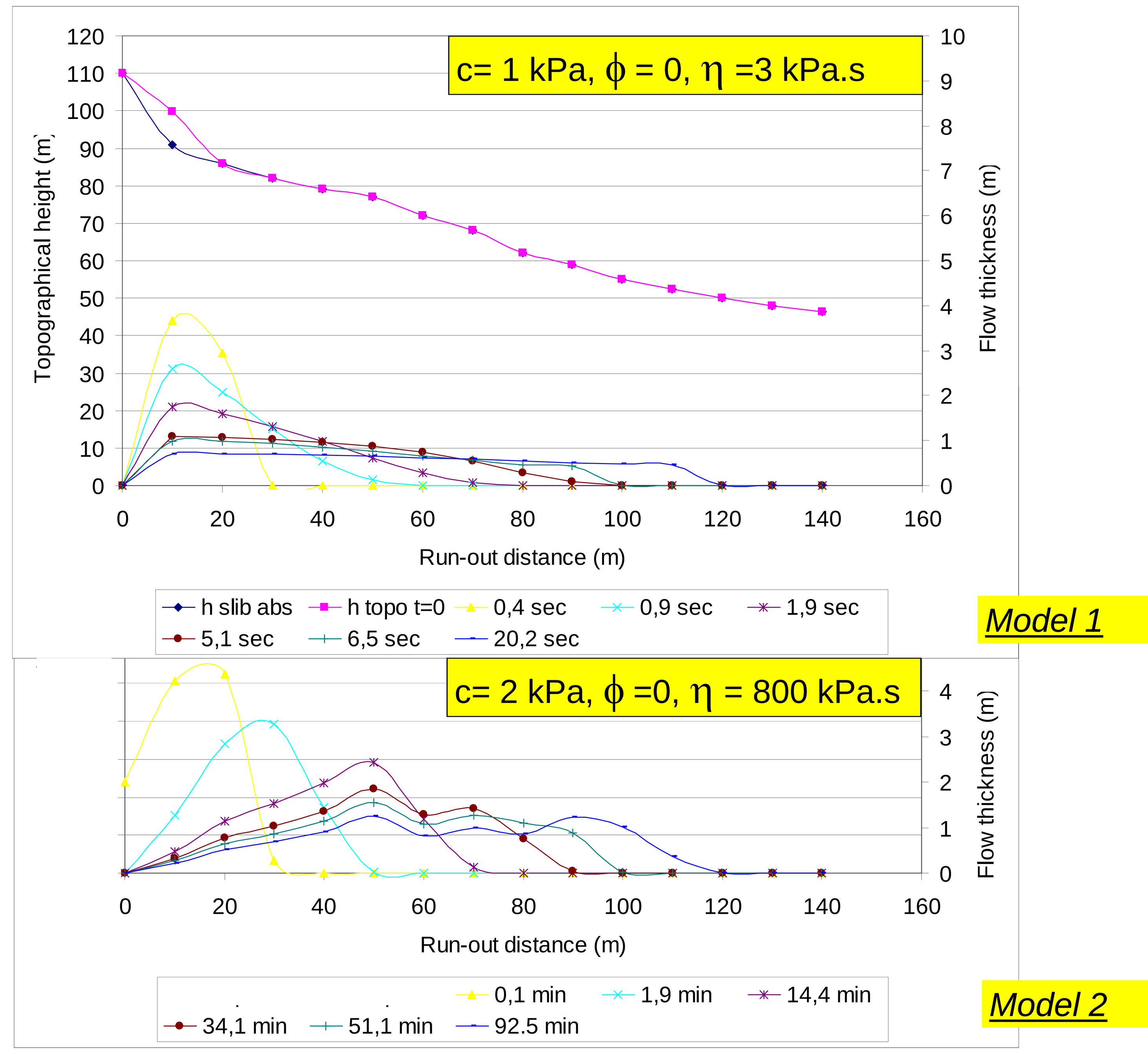

Figure 4 The topographical section of the 1999 mud/debris flow and the calculated run-out distance in time for the *Model1* and *Model 2* concept

Results and conclusions

Model 1 (Fig 4) was able to simulate the run out distance but the run out time was only 20 seconds instead of the observed 90 minutes. Calculated mean velocities varied between 25 m s^{-1} for the first 40 m of run-out and 5 m s^{-1} for the remaining track. Viscosity was increased to slow down the flow but in that case the friction was to high to overcome the first flattening at 30 m along the track (see Fig 4 topographical section). *Model 2* (Fig. 4) simulates this slow moving mud flow quite well regarding run-out distance and time. The calculated mean velocity was 1.5 m min^{-1} for the first 40 m and 0.5 m min^{-1} for the last phase.

References

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