The four avalanche fronts

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(April 3, 2001)

Avalanches at the surface of a sandpile are investigated experimentally in a half flat hourglass. Evidences are presented that there is not only one kind of avalanche front but four. If grains are added at the top of the pile, a classical (downward propagating) front is observed but is followed by a stopping front propagating upward the pile. Symmetrically, if grains are removed from the bottom of the sandpile, an upward propagating avalanche occurs which is followed by a downward stopping front. It is shown that the four fronts are recovered in the Saint-Venant model previously proposed by the authors. On this theoretical basis, we discuss the dynamical mechanisms leading to the main properties of these fronts.

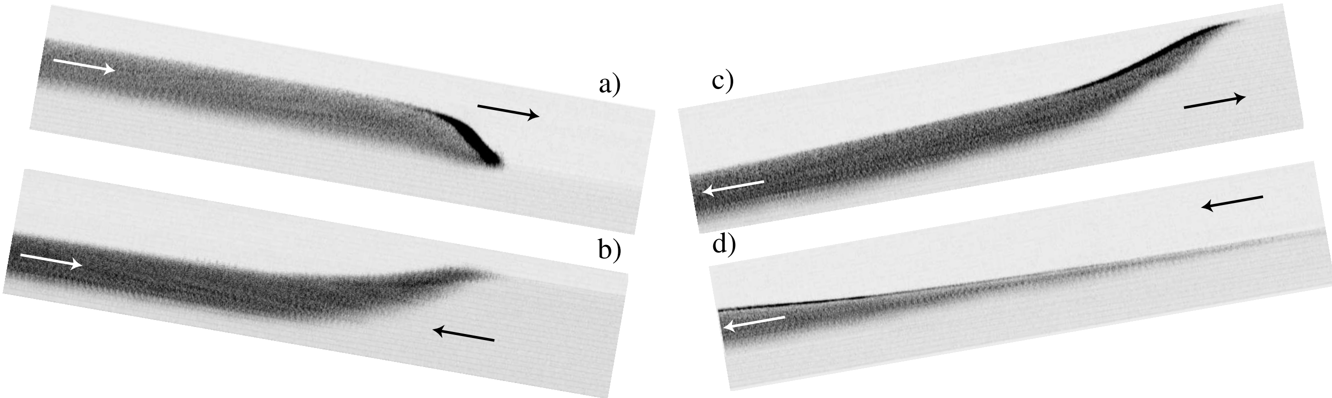

FIG. 1. Side view of the four kinds of fronts : the flowing layer appears in black and the static pile in gray. In the four cases, the grains moves downward the pile (white arrows) but not the fronts (black arrows). Left : filling experiment. Right : Emptying experiment. Top : the two starting fronts. Bottom : the two corresponding stopping fronts. The vertical scale is 4 times the horizontal one.

In geophysics, avalanches usually refers to a large mass of material (snow, ice, rocks or soil) or mixtures of material (debris flows) falling rapidly down a solid slope [1–3]. The existence of these avalanches is intimately related to the existence of a subcritical transition between fluid-like and solid-like behaviors controlled by the slope [4–6]. This is a characteristic property of granular matter : as in solid friction [7], a sandpile starts flowing when the free surface angle φ exceeds the static angle φ_{start}, and stops when this angle has decreased below the dynamical angle φ_{stop}. Between these two angles, the equilibrium is metastable so that a small perturbation is sufficient to induce the flow of a large amount of matter.

Previous works on avalanches have mainly focused on global behaviors like overall mass, statistics, etc (see [5] and references therein). Besides, the shape and dynamics of avalanche fronts have been studied in the case of flows rushing down a rough bottom [8,9]. Our first aim is here to study the fronts details in the case of avalanches at the surface of a sandpile whose grains can be mobilized by the avalanche. Second, we wish to investigate the physical mechanisms governing the dynamics of these fronts.

Setup – The experimental cell (Fig. 2) is a half flat hourglass whose two parts are connected by a hole of variable width w ($0 < w < 1\ cm$). The granular media is composed by spherical glass beads of diameter $d = 200\ \mu m$. The two vertical glass plates ($40 \times 40\ cm^2$) are separated by a $2.5\ cm \simeq 125\ d$ gap. The flow rate Q_0 between the top reservoir and the bottom cell is controlled by the gap w and turns out to be steady during most of the experiment. By tuning w, the flow rate Q_0 can be adjusted from 0 to $500\ g^{1/2} d^{3/2}$.

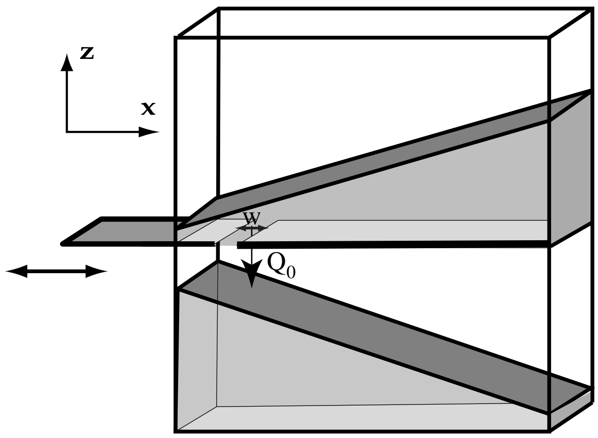

FIG. 2. Experimental setup.

Side views of avalanches are obtained using a 50 Hz video camera. The depth of the flowing layer is visualized by computing images difference (Fig. 1) and the free surface profiles are measured by detection on the images.