Gravity flow on steep slope: Part I

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Outline

Today (physical aspects)

- Physical picture of debris flows and avalanches
- Flow anatomy

Tomorrow (mathematical aspects)

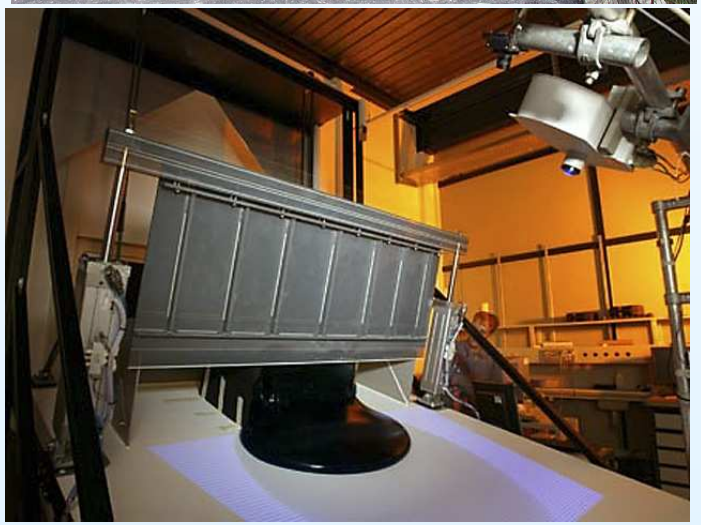
- Fluid-mechanics approach to gravity flows
- Inertia-dominated flows
- Friction-dominated flows

Dilute particle-laden flows

Powder snow avalanche in the La Sionne field site (Switzerland) in Jan. 2004; pyroclastic flow from the Montserrat volcano in Jul. 1997; rockfalls in the Hunza valley (Pakistan) in Jan. 2010; turbidity experiments (Cemagref, 2001).

Dense particle-laden flows



Powder snow avalanche in the La Sionne field site (Switzerland) in Jan. 2004; pyroclastic flow from the Montserrat volcano in Jul. 1997; rockfalls in the Hunza valley (Pakistan) in Jan. 2010; dam-break experiment in the lab (EFPL, 2008).

Debris flow

Debris flow usually occur after heavy rainfalls (erosion of poorly sorted soils or acceleration of landslides)

Initiation

Conditions for initiation of most debris flows usually include:

- *Steep slopes*. Slopes in excess of 70% are liable to surface erosion (sediment transport induced by runoff) and landslides (soil failure leading to large masses of saturated materials coming loose).
- *Abundant supply of unconsolidated materials*. Debris flows originate either from the simultaneous contributions of many material sources or from a single source (landslides):
  - Slow and continuous erosive processes on slopes in the drainage basin form deposits of materials in the torrent bed. Such deposits can be subsequently mobilized during intense floods and then transform into debris flows.
  - Old ill-consolidated deposits (moraines, massive rockfall deposit, etc.) can mobilize into landslides to form debris flows. In this case, the volume of materials involved can be very large ($> 10^5$ m^3) depending on the total volume made available by the source.
- *Large source of moisture*. Most of debris flows occur during or after heavy and/or sustained rainfalls.
- *Sparse vegetation*.

Muddy debris flow

Granular debris flow

Lahar

Debris flow: related phenomena

Floods with sediment transport and landslides are not debris flows

Landslides

In February 2010 a landslide occurred near Maierato (South Italy)

Swelling clays

Flash floods

In Feb. 2010, 42 people killed in flash floods (Madeira islands)

Transition from lahar

On 18 March 2007, the dam which had been holding back the crater lake broke, sending a lahar down the mountain (1.4×10^6 m^3).

Snow avalanches

Snow avalanches result from the loss of stability of the snow cover.

The release often takes the form of a slab

Flow classification

Two limiting cases:

- Powder-snow avalanche: cloud of snow particles maintained in the air by turbulence
  - high velocity: 50–100 m/s,
  - flow depth: 20–100 m,
  - mean density: $\rho \sim 20$ kg/m^3, but significant density stratification through the depth
  - weak influence of topography,
  - significance of snow entrainment
- flowing avalanche: dense flow of snow along the topography
  - relatively low velocity: 10–25, but for some events up to 50 m/s,
  - flow depth: 1–2 m, but thick deposits are not uncommon (10–20 m)
  - density: $\rho \sim 300 - 500$ kg/m^3,
  - key role played by topography.

Powder snow avalanche

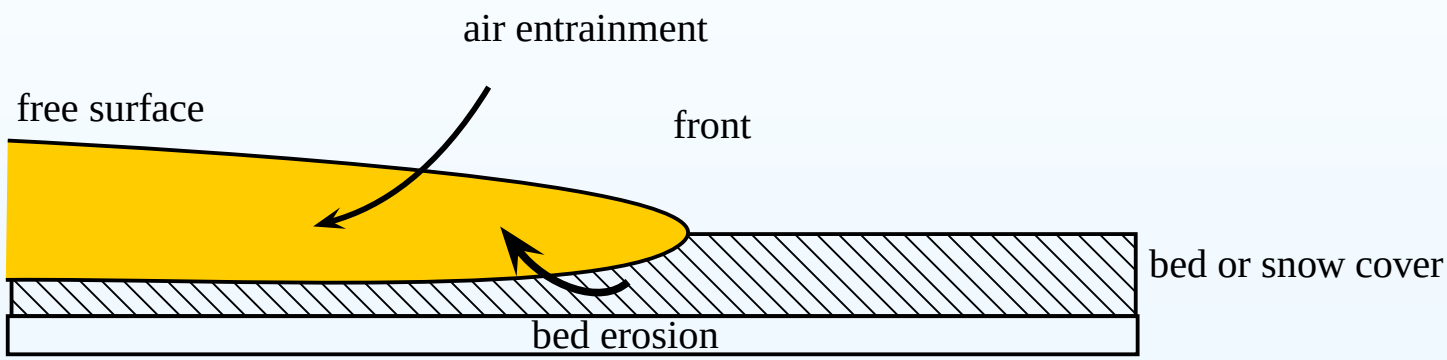
Flowing avalanche

Related phenomena

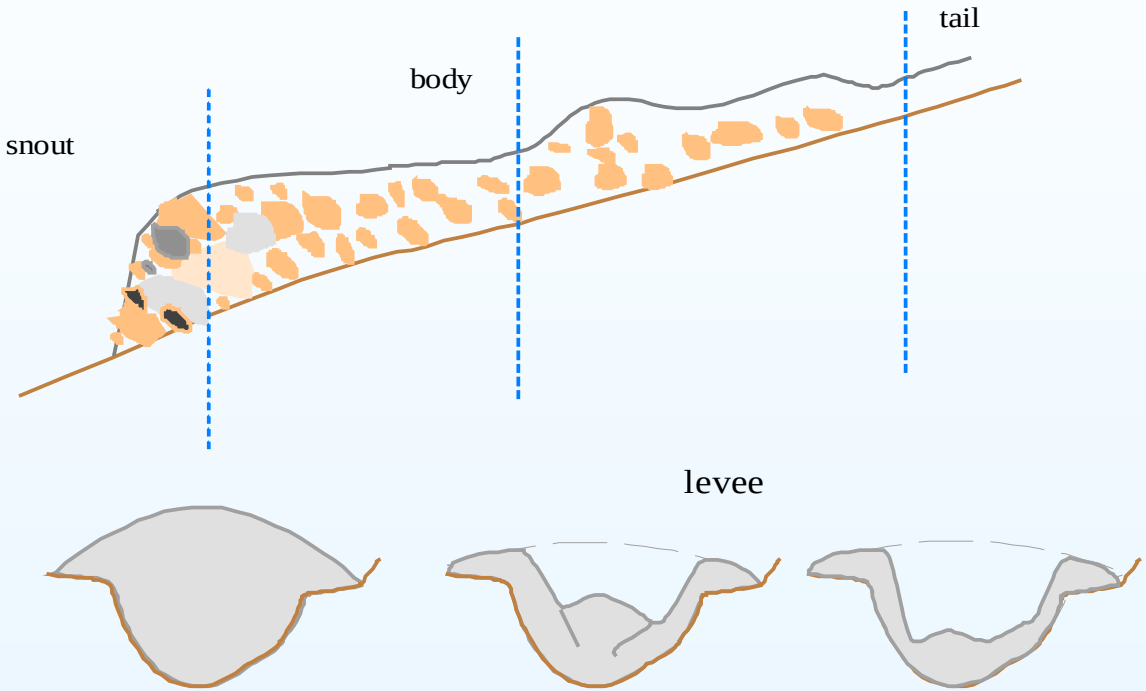
Rock avalanche of about 3×10^6 m^3 detached from the South-East flank of the Punta Thurwieser ridge (18 September 2004).

Specificities of flow

Moving-boundary flow: existence of free surface, a front, and a basal surface



Anatomy of debris flows

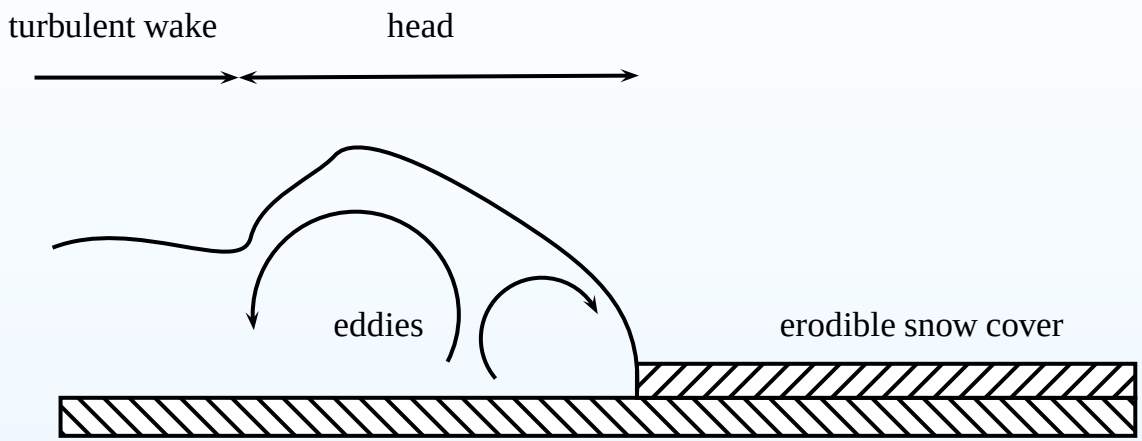


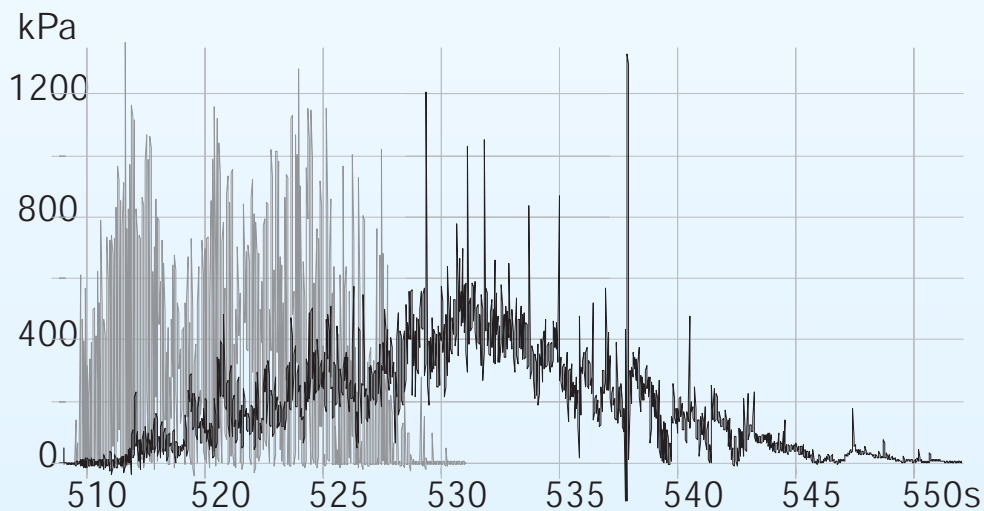
Levees

Levees (2)

USGS Flume (Oregon): formation of levees

Anatomy of powder snow avalanches



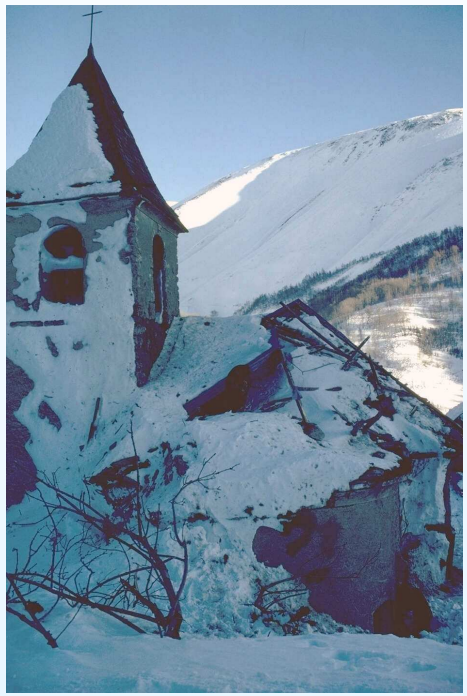


Effect of a powder snow avalanche

Vigorous flow

Avalanche of Taconnaz (Haute-Savoie, 11 Feb. 1999) and of Arinsal (Andorre, 8 Feb. 1996).

Light flow



Avalanche of Clavans (Isère, 20 Jan. 1981) and Loèche-les-Bains (VS, 25 Feb. 1999).

Role of snow entrainment

Schattenbach, Walenstadt (Saint-Gall) 7 février 2003

Snow entrainment is essential: without snow entrainment, the cloud dilutes

Deposit

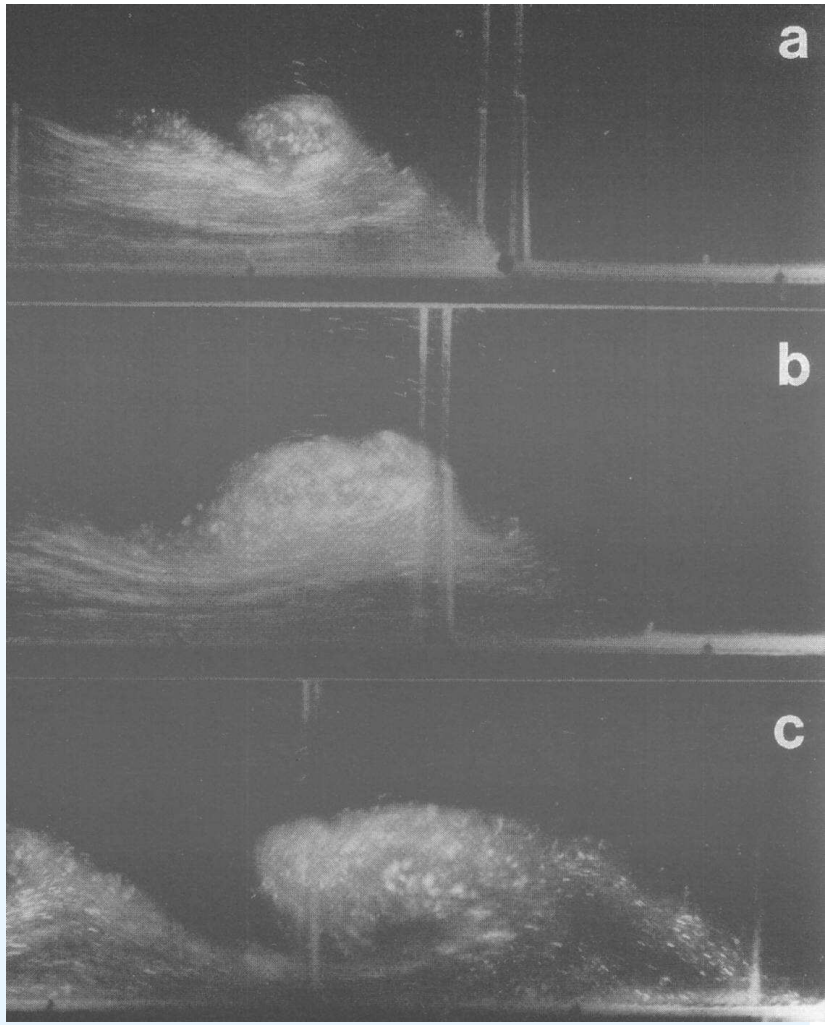
Different types of deposit: dilute clouds settle and form thin and extended deposits while some powder-snow avalanches develop dense core that separate from them.

Avalanches of Roux d'Abriès (19 Jan. 2004) and of Crévoux (18 Jan. 2004), Hautes-Alpes, France

In the laboratory

Spread of a dense fluid (blend of aluminium particles and dense fluid)

- Two large vortices
- wedged-shape front



[J.E. Simpson, *Gravity Currents in the Environment and the Laboratory* (Cambridge University Press, Cambridge, 1997) pp. 174]