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

Introduction

- Dilute particle-laden flows
- Dense particle-laden flows

Debris flow

Avalanches

Anatomy of flow

Dense particle-laden flows

Introduction

- Dilute particle-laden flows
- Dense particle-laden flows

Debris flow

Avalanches

Anatomy of flow

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

Introduction
Debris flow
- Debris flow
- Initiation
- Muddy debris flow
- Granular debris flow
- Lahar
- Debris flow: related phenomena
- Landslides
- Swelling clays
- Flash floods
- Transition from lahar

Avalanches

Anatomy of flow
Granular debris flow

Introduction

Debris flow
- Debris flow
- Initiation
- Muddy debris flow
- Granular debris flow
- Lahar
- Debris flow: related phenomena
- Landslides
- Swelling clays
- Flash floods
- Transition from lahar

Avalanches

Anatomy of flow
Lahar

Introduction

Debris flow
- Debris flow
- Initiation
- Muddy debris flow
- Granular debris flow
- Lahar
- Debris flow: related phenomena
- Landslides
- Swelling clays
- Flash floods
- Transition from lahar

Avalanches

Anatomy of flow
Debris flow: related phenomena

Flooding with sediment transport and landslides are not debris flows
Landslides

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

Introduction
- Debris flow
  - Debris flow
  - Initiation
  - Muddy debris flow
  - Granular debris flow
  - Lahar
  - Debris flow: related phenomena
- Landslides
- Swelling clays
- Flash floods
- Transition from lahar

Avalanches

Anatomy of flow
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 ($1.4 \times 10^6$ m$^3$).
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

Introduction

Debris flow

Avalanches
- Snow avalanches
- Flow classification
- Powder snow avalanche
- Flowing avalanche
- Related phenomena

Anatomy of flow
Flowing avalanche

Introduction

Debris flow

Avalanches
- Snow avalanches
- Flow classification
- Powder snow avalanche
- Flowing avalanche
- Related phenomena

Anatomy of flow
Related phenomena

Rock avalanche of about $3 \times 10^6$ 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

Introduction

Debris flow

Avalanches

Anatomy of flow
- Specificities of flow
- Anatomy of debris flows
- Levees
- Levees (2)
- Anatomy of powder snow avalanches
- Effect of a powder snow avalanche
- Role of snow entrainment
- Deposit
- In the laboratory

Snout

Body

Tail

Levee

Levee
Levees

Introduction
Debris flow
Avalanches
Anatomy of flow
- Specificities of flow
- Anatomy of debris flows
  - Levees
- Levees (2)
- Anatomy of powder snow avalanches
- Effect of a powder snow avalanche
- Role of snow entrainment
- Deposit
- In the laboratory
Levees (2)

USGS Flume (Oregon): formation of levees
Anatomy of powder snow avalanches

- Turbulent wake
- Head
- Eddies
- Erodible snow cover

- Specificities of flow
- Anatomy of debris flows
- Levees
- Levees (2)
- Anatomy of powder snow avalanches
- Effect of a powder snow avalanche
- Role of snow entrainment
- Deposit
- In the laboratory
Effect of a powder snow avalanche

Vigorous flow

Light flow

Role of snow entrainment

Introduction
Debris flow
Avalanches

Anatomy of flow
- Specificities of flow
- Anatomy of debris flows
- Levees
- Levees (2)
- Anatomy of powder snow avalanches
- Effect of a powder snow avalanche
- Role of snow entrainment
- Deposit
- In the laboratory

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

Schattenbach, Walenstadt (Saint-Gall) 7 février 2003
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 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