Rapid Mass Movements System
RAMMS

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Where do we come from?
WSL/SLF in the ETH Domaine

**Swiss Federal Department of Economic Affairs, Education and Research (EAER)**

**ETH-Domaine**

Swiss Federal Institutes of Technology and Research Institutes

- EPF Lausanne
- ETH Zürich
- EMPA
- eawag
- PSI
- WSL/SLF
What is RAMMS?

- Numerical **Avalanche** and **Debris Flow** simulation software (*Rockfall* and *Hillslope* module under development)
- Basic input: Digital Elevation Model **DEM** & **Release** volume
- **Output**: Run-out distance, flow heights and velocities, impact pressures
- Based on **real scale measurements** from SLF/WSL test sites (Vallée de la Sionne VS, Flüelapass GR, Illgraben VS, Dorfbach VS, Walenstadt SG, St. Léonard VS)
- **GIS functions** (slope, curvature, elevation, DEM adaptions)
- Advanced **visualization** of the results (animations, maps, profiles etc.)
- **User friendly** and PC based (32 and 64bit, Windows7, Windows XP)
- Continuous **scientific development** in the background
Main Applications

- Hazard mapping
- Safety assessment for building and infrastructures
- Planning and evaluation of mitigation measures
- Back calculation of specific events
- Visualization of hazard impact
History of RAMMS

Starting operations at test site Vallée de la Sionne (Canton VS)

Aval-1D Workshop I

Aval-1D Workshop II

Starting operations at WFJ Flume

Storms in Switzerland triggering lots of shallow landslides

Starting operations at shallow landslide test site Veltheim (Canton AG) & St. Léonard

RAMMS Improvement of numerics

RAMMS Feedback Beta tester

RAMMS::Avalanche User workshop

RAMMS::Debris Flow Workshop (Canton VS)

RAMMS::Hillslope Workshop & feedback

1998

Aval-1D

2000

Aval-2D

2002

2005

RAMMS Project launch

2007

RAMMS Improvement of rheology

2010

2012

RAMMS 1st International Workshop Davos

RAMMS::Avalanche Release

RAMMS::Debris Flow Release

Test sites/Events
Projects
Workshops
Developments
Users today

- Engineering offices
- National, regional and local authorities
- Universities / Research institutions

Sold licenses per 15. August 2013:
- Avalanche: CH 45, abroad 78 -> 123 (+93 Demo), release 2010
- Debris Flow: CH 22, abroad 25 -> 47 (+44 Demo), release 2011
- Norway (25), India, Chile, Russia, Turkey, USA, Uzbekistan, Taiwan, New Zealand, Italy, Austria, Germany, Poland, Brazil, Peru, Spain, Argentina, Korea, Canada
Input Data

Digital Elevation Models (DEM)

Maps/aerial imagery

Visualization

Forest

Release information
Digital Elevation Models DEM

- **Base** for numerical calculations
- DEM **errors** (holes, artifacts etc.) can have big impact on results -> Check the DEM
- For simple, **homogeneous topography** -> DEM resolution of ca. 25m is OK
- **Complex topography** (gullies, ridges etc.) or small events -> Better DEM resolution needed (Debris Flow, Rockfall!)

2 m LiDAR    DHM25    90 m SRTM
1955: A. Voellmy:
„Über die Zerstörungskraft von Lawinen“:
Block model of avalanche flow. Start of modern avalanche dynamics in Switzerland.

\[ S = \mu (\rho g H \cos \theta) + \frac{\rho g U^2}{\xi} \]
Test Site Vallée de la Sionne, VS, CH

(dry, 100’000 m³)

Avalanche front
0.1 < \( \mu \) < 0.3
2000 m/s² < \( \xi \) < 4000 m/s²

Avalanche tail
0.3 < \( \mu \) < 0.5
100 m/s² < \( \xi \) < 1000 m/s²

Friction parameters vary strongly along the avalanche track!
Release (AVAL)

- **Critical parameter**, big impact on simulation results
- **Field observation** on location (GPS, aerial imagery etc.)
- Simulating several release areas simultaneously possible
Terrain Analysis
Ongoing research

- Random Kinetic Energy Model RKE
  - Better deposition patterns
  - **Small** scale avalanches (< 10’000 m³)
  - Levées

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Energy Hierarchy

- Potential Energy: $P$
- Kinetic Energy: $K$
- Fluctuation energy: $R$
- Heat: $H$
- Granular avalanches: Fluid + Solid
- Gravitational Work Rate $W_g$

Friction

Heat (Internal Energy)
• **Powder cloud**

![Diagram of powder cloud](image)

- **Suspension wake**
- **Segregation Layer**
- **Plume**
- **Flowing core**
- **Air entrainment**

**Graph**

- **Volume Suspension Layer**
- **Plume height**
- **Plumes**
- **Front**
- **Wake**
- **180m**

**Legend**

- **Volume**
- **Projected Area**

**Graph axes**

- **Time (from release)**
- **Volume**
- **Projected Area**

**Colors**

- **Red**
- **Yellow**
- **Green**
- **Blue**
- **Black**

**Key**

- **>50**
- **0**

**Scale**

- **0.0**
- **0.050**
- **0.10**
- **0.15**
- **0.20**
- **0.25**
- **0.30**
- **0.35**

**Range**

- **0.0**
- **0.35**
- **0.00**
- **0.050**
- **0.10**
- **0.15**
- **0.20**
- **0.25**
- **0.30**
- **0.35**
• Forest effects on avalanche dynamics

• How does forest stop avalanches?

• What forest structures are most effective?

New approach:
Mass and momentum extraction dependent on forest structure.
• Snow entrainment

Frontal Entrainment

Highest entrainment rates
(500 kg m\(^{-2}\) s\(^{-1}\))

New Snow

Basal Erosion

Shear forces at avalanche base scrape and abrade running surface. Entrainment rates low.

Fracture Entrainment

Brittle snow layers are entrained suddenly at the base of the avalanche. Not necessarily at front.
• Wet snow avalanches

Temperature simulation.

Water production simulation
RAMMS::DEBRISFLOW

Initiation zone:
Rainfall, landslides, erosion, ...

Transit zone:
Erosion + deposition, levee formation, ...

Deposition zone (alluvial fan):
Deposition, dewatering, …
Difficult calibration

- Voellmy friction coefficients: $m = 0.05 - 0.35$, $x = 50 - 600 \text{ m/s}^2$

Maximum velocity $10 \text{ m/s}$
Illgraben Debris Flow Test Site, VS, CH

- Catchment area 9.5 km²
- 3 rain gauges
- Flow height measurements (Radar, Laser)
- Geophones
- Shear wall
- Test ring net
- Debris flow balance
- ~2 km, gradient 8-10%
- Geneva
- Zürich
- Illgraben
Release (DBF)

**Block Release**
Block with initial height to match the total volume of debris flow

**Input Hydrograph**
Controlled inflow of material according to a discharge hydrograph at specific location

Cross-sectional area $A$ [m$^2$]
Inflow velocity $v$ [m/s]
Discharge $Q = Av$ [m$^3$/s]
Ongoing research

- 2 Phase Model
- NoFlux: Buildings and Dams
- Erosion / Deposition
- More field measurements for calibration
RAMMS output:
Visualization of simulated processes
Interpretation of the results:
Line Profiles (1D), XY-Time plots
RAMMS::ROCKFALL

- Based on real physics
- Rigid body contact impact
- Considers rock shape
- Variability of rockfall
- Calibration with dynamic sensors
Batch simulations & rockfall variability
Batch simulations & rockfall variability
Simulation data: Shape files

Jump Height

Velocity
Experiments

Lab

Field

Case studies
RAMMS HILLSLOPE

- Release and volume very hard to predict
- Stopping at steeps slopes
- Problem for Voellmy model
- Random Kinetic Energy RKE extension
Interpretation of simulation results

- RAMMS is a numerical **model** (≠ reality)
  → Even if the visualization looks very nice, other aspects such as **field visit, climatic situation, scenarios, cadastre and expert knowledge** are very important.

- Careful **interpretation** of the results is mandatory (expert knowledge)!
  → session tomorrow and in the advanced sessions

- Location of **release area**, release height and volume have a strong influence on the results → **experience necessary**!

- **Knowledge** about the terrain and the avalanche situation is essential!
Summary

- RAMMS is a tool for **numerical simulation** of rapid mass movements.
- Most important input data are the **DEM** as well as location of **release area** and release height.
- Voellmy-Salm model with two friction values ($\mu$ & $\xi$).
- **Calibration** with real scale experiments.
- **Output**: Flow paths, run-out distances, velocities, flow heights, pressures.
- Results must be interpreted by **experts** (model ≠ reality).
RAMMS Info

http://ramms.slf.ch

- Manuals
- Information about new software updates
- News and general information
- Glossar, features and background information
- Forum → answers to questions and problem-discussions