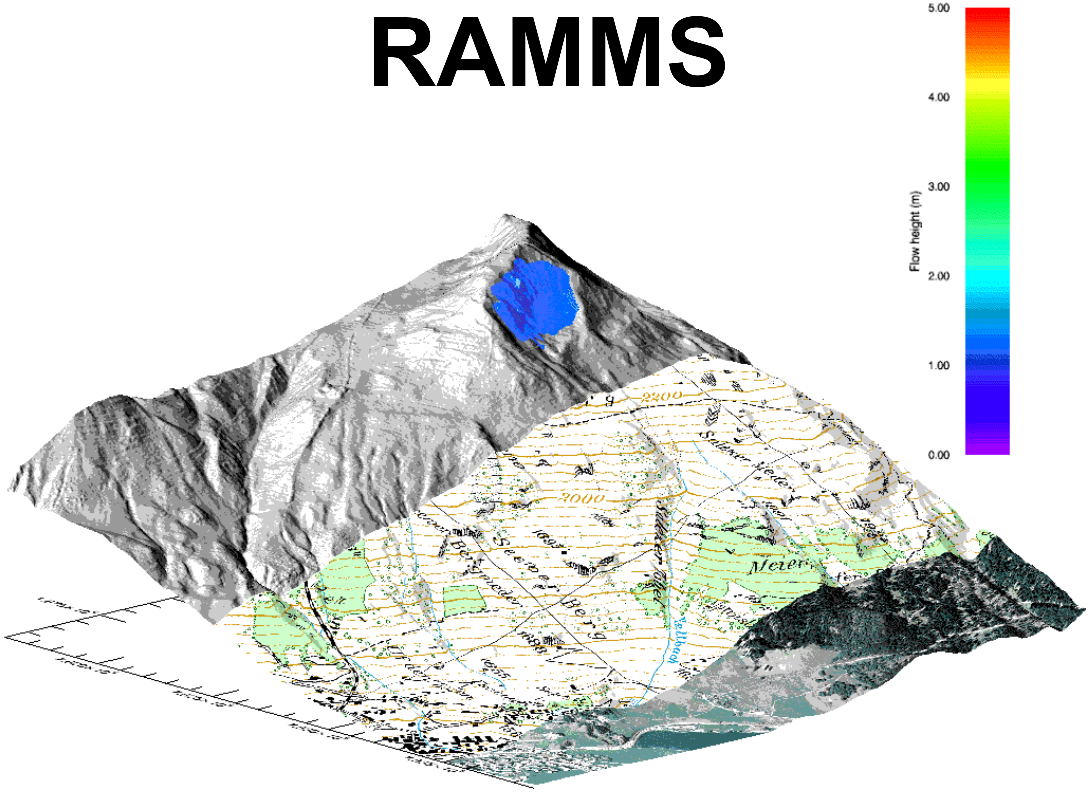
Rapid Mass Movements System RAMMS



Yves Bühler, Marc Christen, Perry Bartelt, Christoph Graf, Werner Gerber, Brian McArdell

WSL
SLF

Swiss Federal Institute for Forest, Snow and Landscape Research WSL
WSL Institute for Snow and Avalanche Research SLF

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

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

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

ETH-Domaine

Swiss Federal Institutes of Technology
and Research Institutes

EPF Lausanne

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

ETH Zürich

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

EMPA Materials Science & Technology

eawag aquatic research

PAUL SCHERRER INSTITUT PSI

WSL

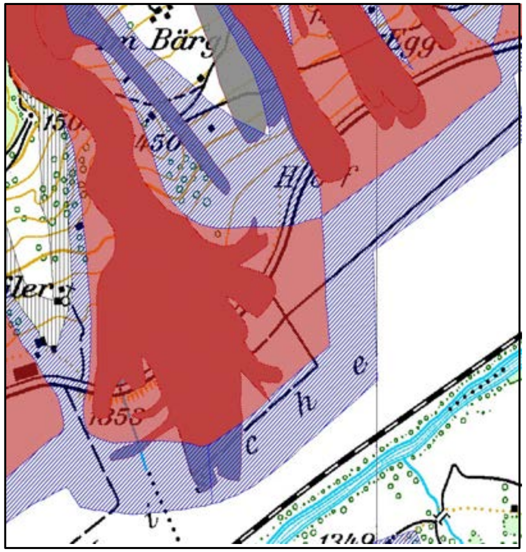
SLF

What is RAMMS?

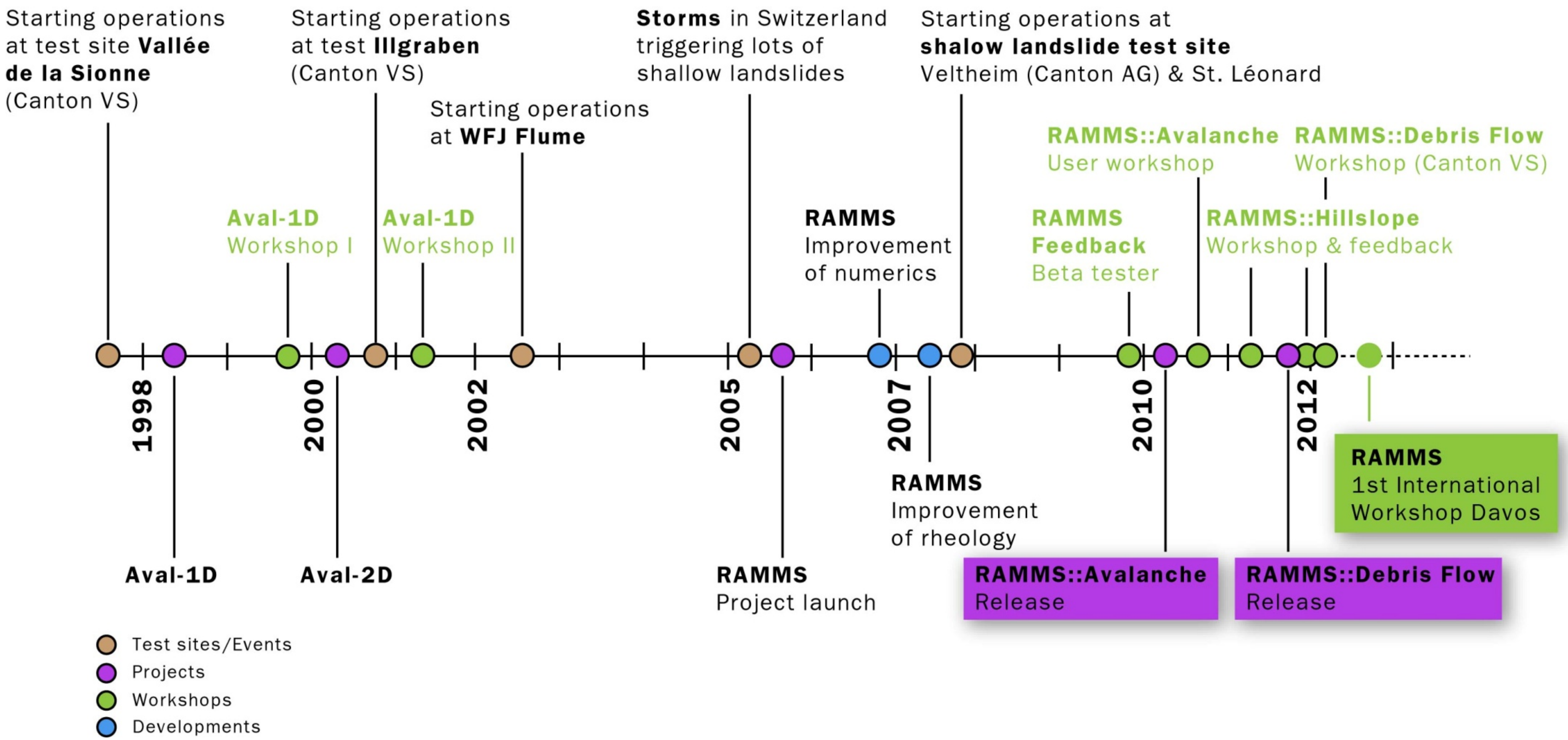
- Numerical **Avalanche** and **Debris Flow** simulation software (**Rockfall** and **Hillslope** module under development)
- Basic input: Digital Elevation Model **DEM** & **Release** volume
- **Output:** Run-out distance, flow heights and velocities, impact pressures
- Based on **real scale measurements** 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

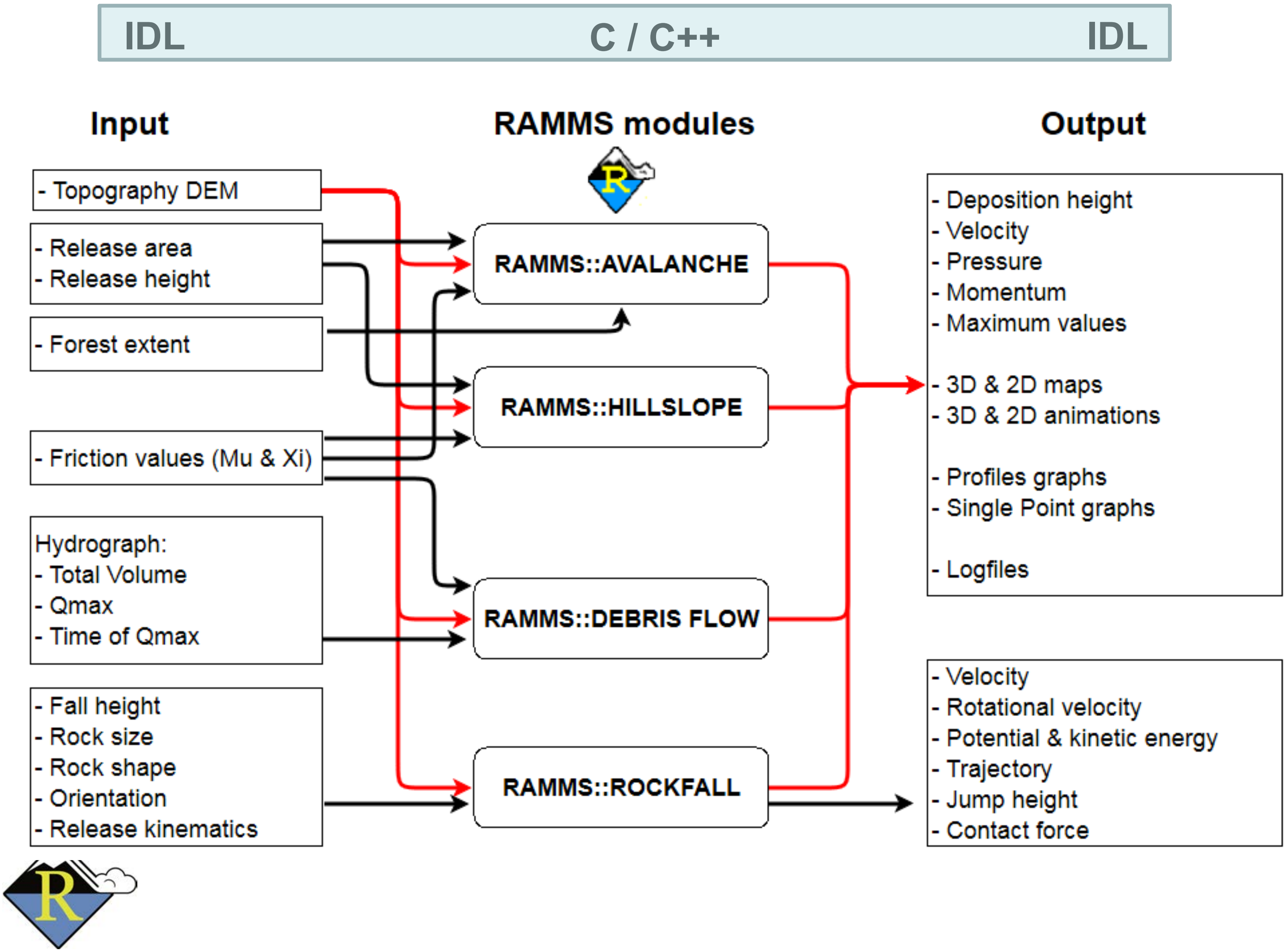


Users today

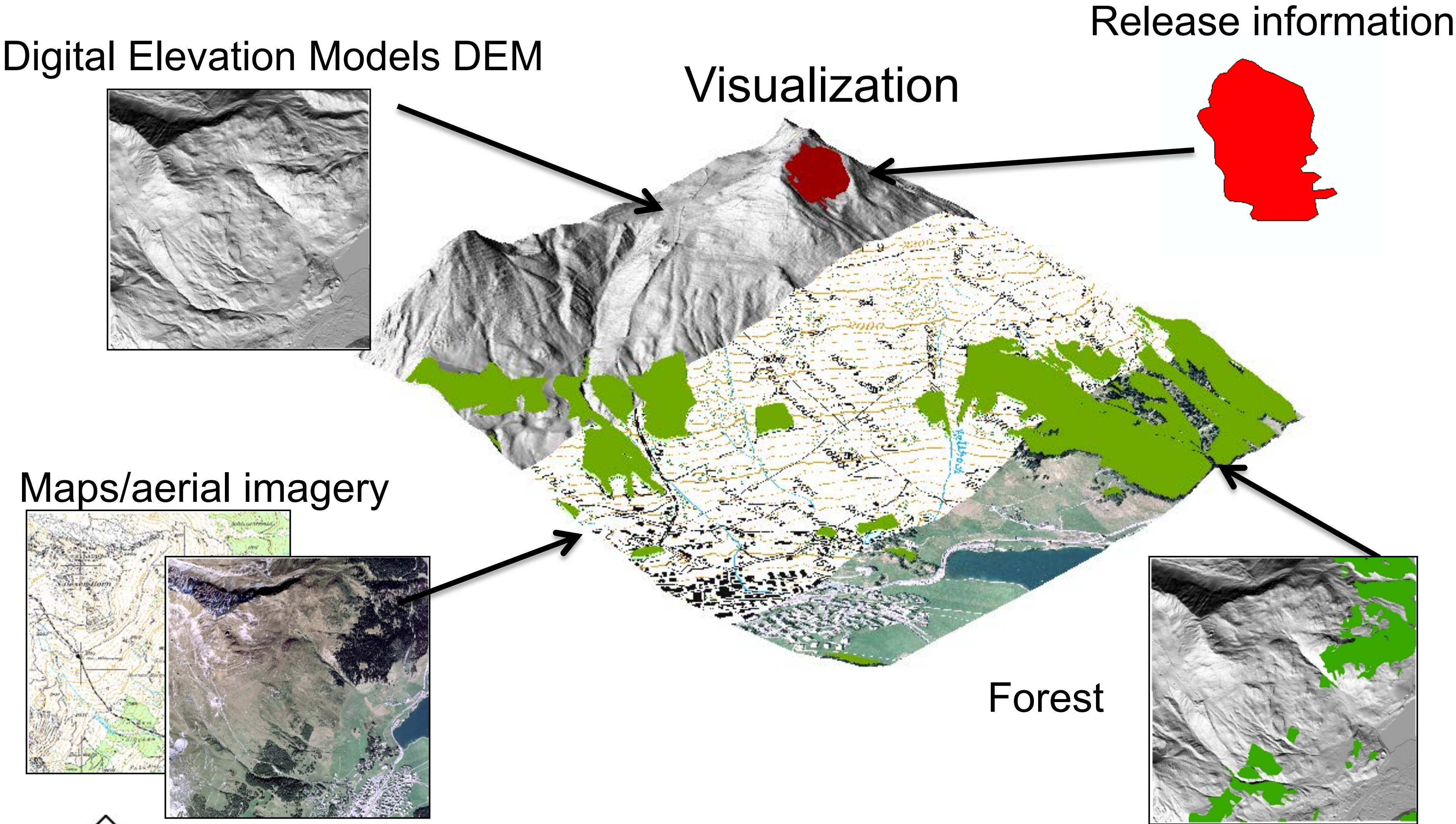
- Engineering offices
- National, regional and local authorities
- Universities / Research institutions

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

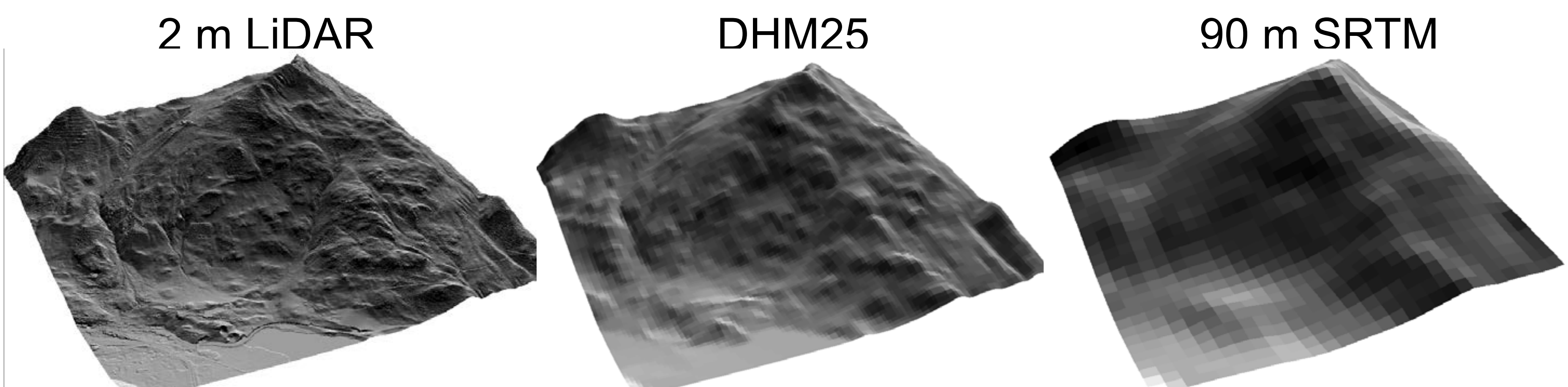

IDL
C / C++
IDL
Input
RAMMS modules
Output
- Topography DEM
- Release area
- Release height
- Forest extent
- Friction values (Mu & Xi)
Hydrograph:
- Total Volume
- Qmax
- Time of Qmax
- Fall height
- Rock size
- Rock shape
- Orientation
- Release kinematics
RAMMS::AVALANCHE
RAMMS::HILLSLOPE
RAMMS::DEBRIS FLOW
RAMMS::ROCKFALL
- Deposition height
- Velocity
- Pressure
- Momentum
- Maximum values
- 3D & 2D maps
- 3D & 2D animations
- Profiles graphs
- Single Point graphs
- Logfiles
- Velocity
- Rotational velocity
- Potential & kinetic energy
- Trajectory
- Jump height
- Contact force

Input Data

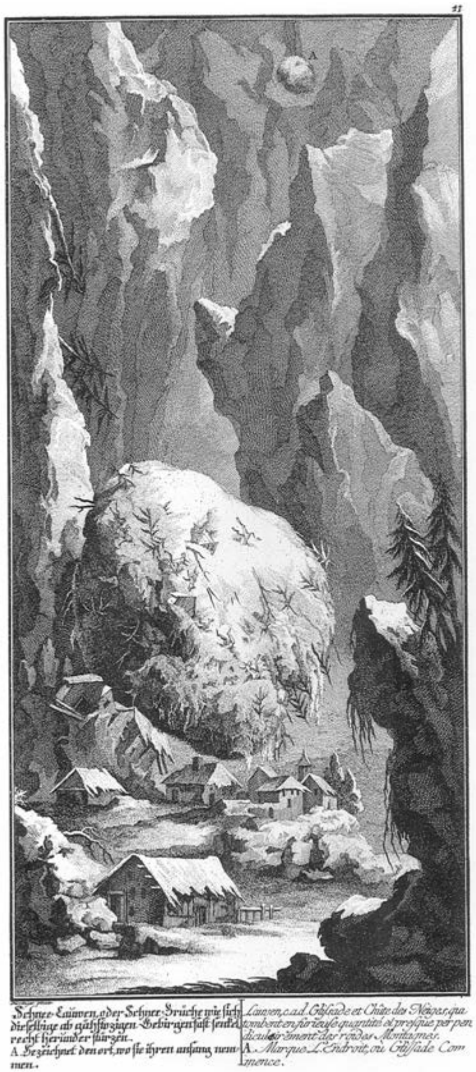

Digital Elevation Models DEM
Visualization
Release information
Maps/aerial imagery
Forest

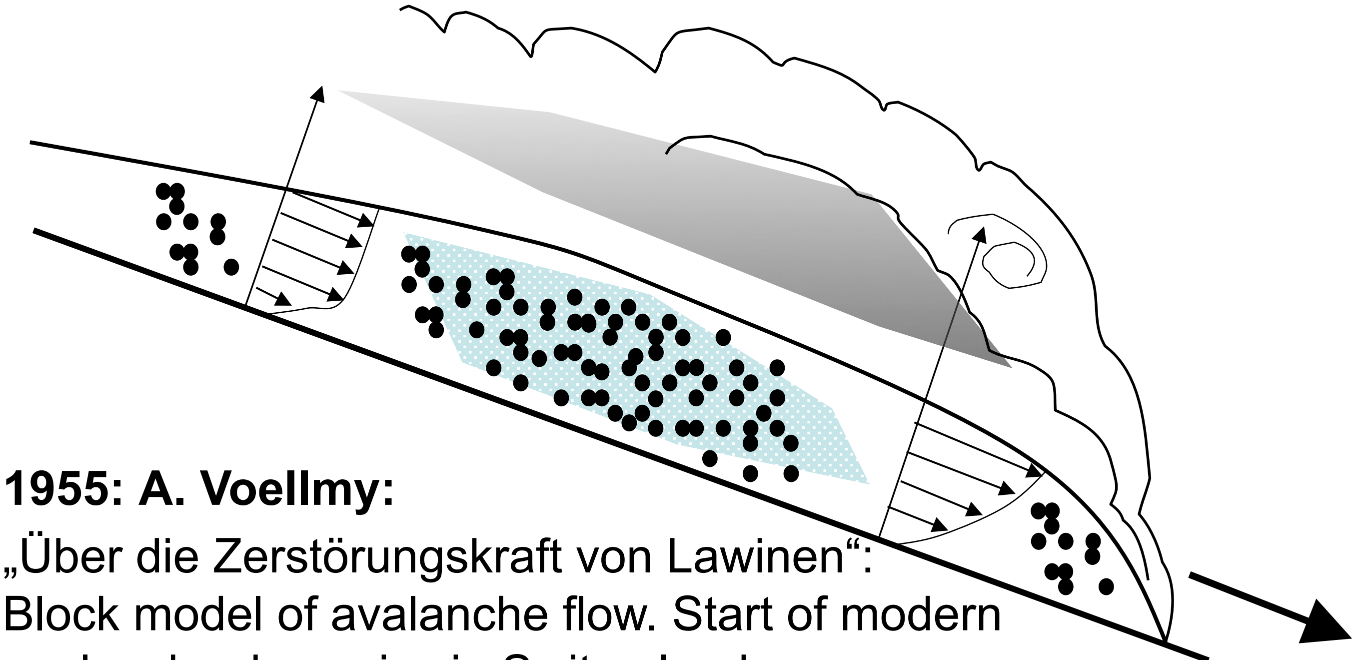
Digital Elevation Models DEM

- **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!)



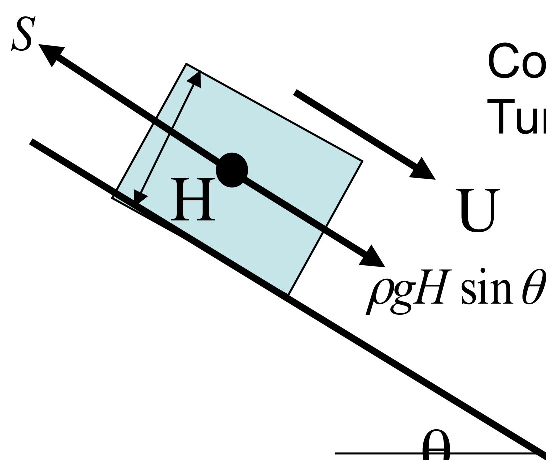
RAMMS::AVALANCHE





1955: A. Voellmy:

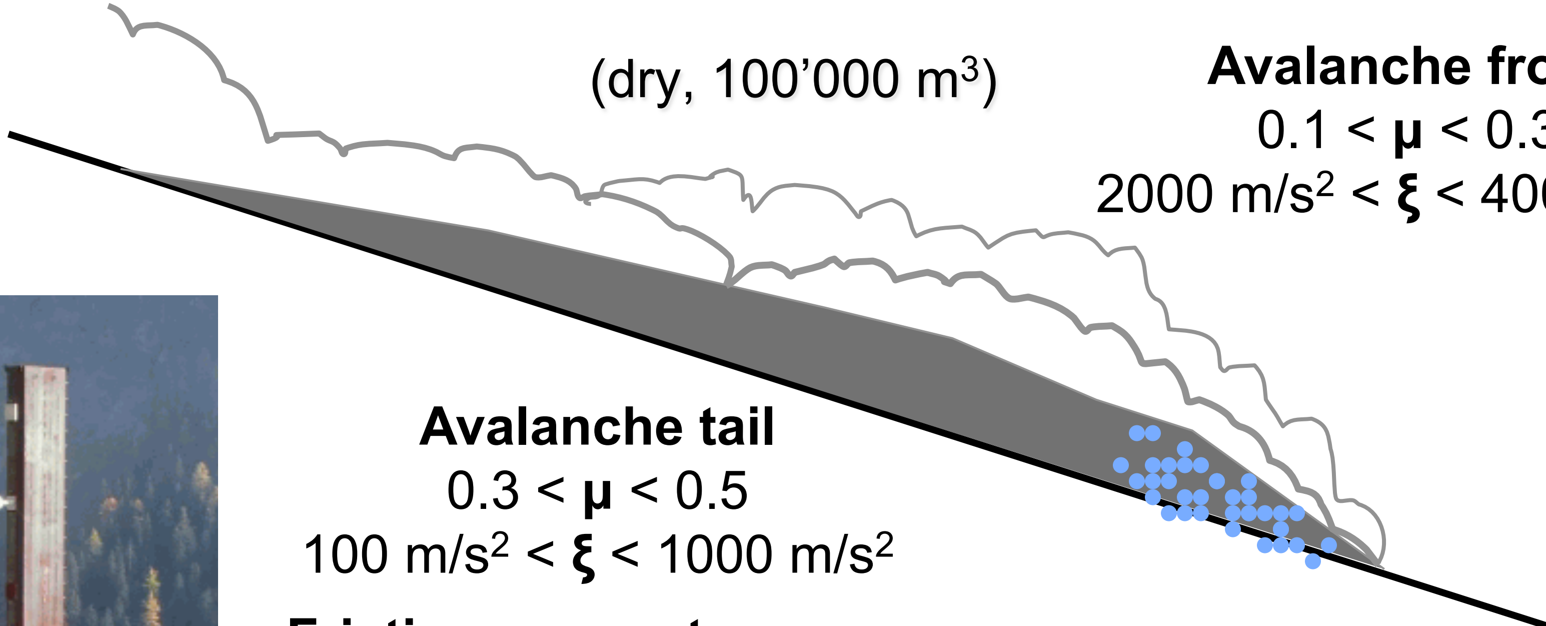
„Über die Zerstörungskraft von Lawinen“:
Block model of avalanche flow. Start of modern avalanche dynamics in Switzerland.



Coulomb Friction : μ (solid, flow height)
Turbulent Friction: ξ (fluid, velocity)

$$S = \mu(\rho g H \cos\theta) + \frac{\rho g U^2}{\xi}$$

Test Site Vallée de la Sionne, VS, CH



(dry, 100’000 m^3)

Avalanche front

$0.1 < \boldsymbol{\mu} < 0.3$

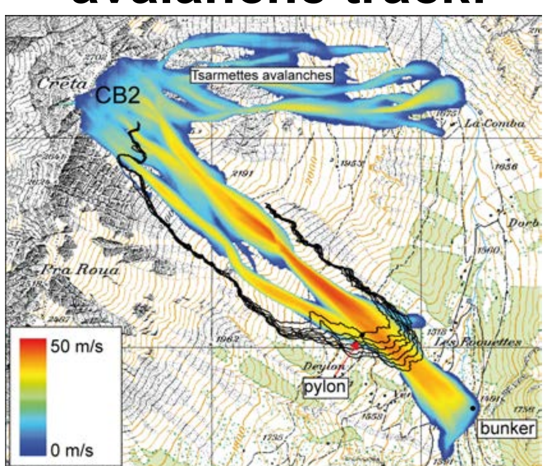
$2000\ m/s^2 < \boldsymbol{\xi} < 4000\ m/s^2$

Avalanche tail

$0.3 < \boldsymbol{\mu} < 0.5$

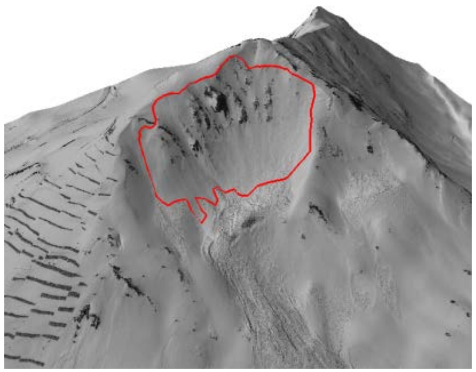
$100\ m/s^2 < \boldsymbol{\xi} < 1000\ m/s^2$

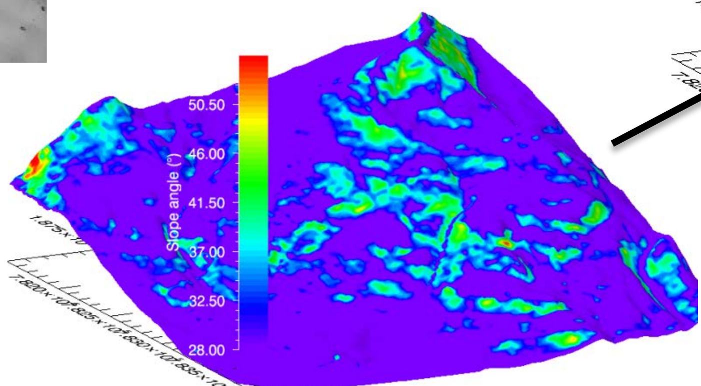
Friction parameters vary strongly along the avalanche track!

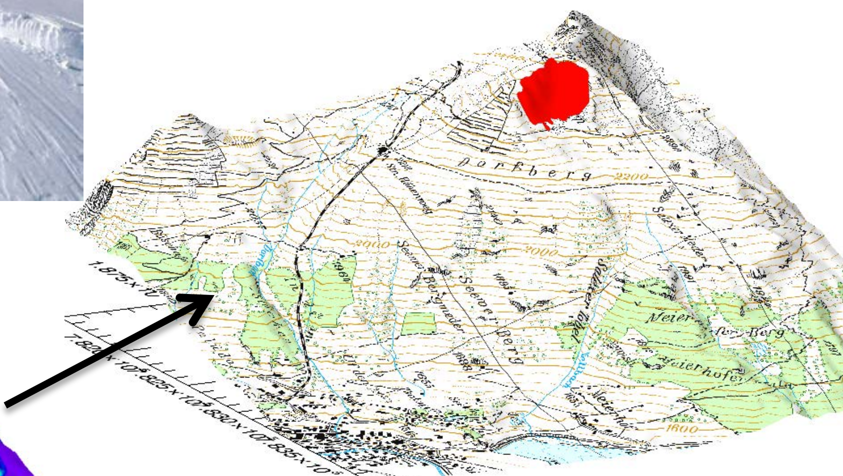


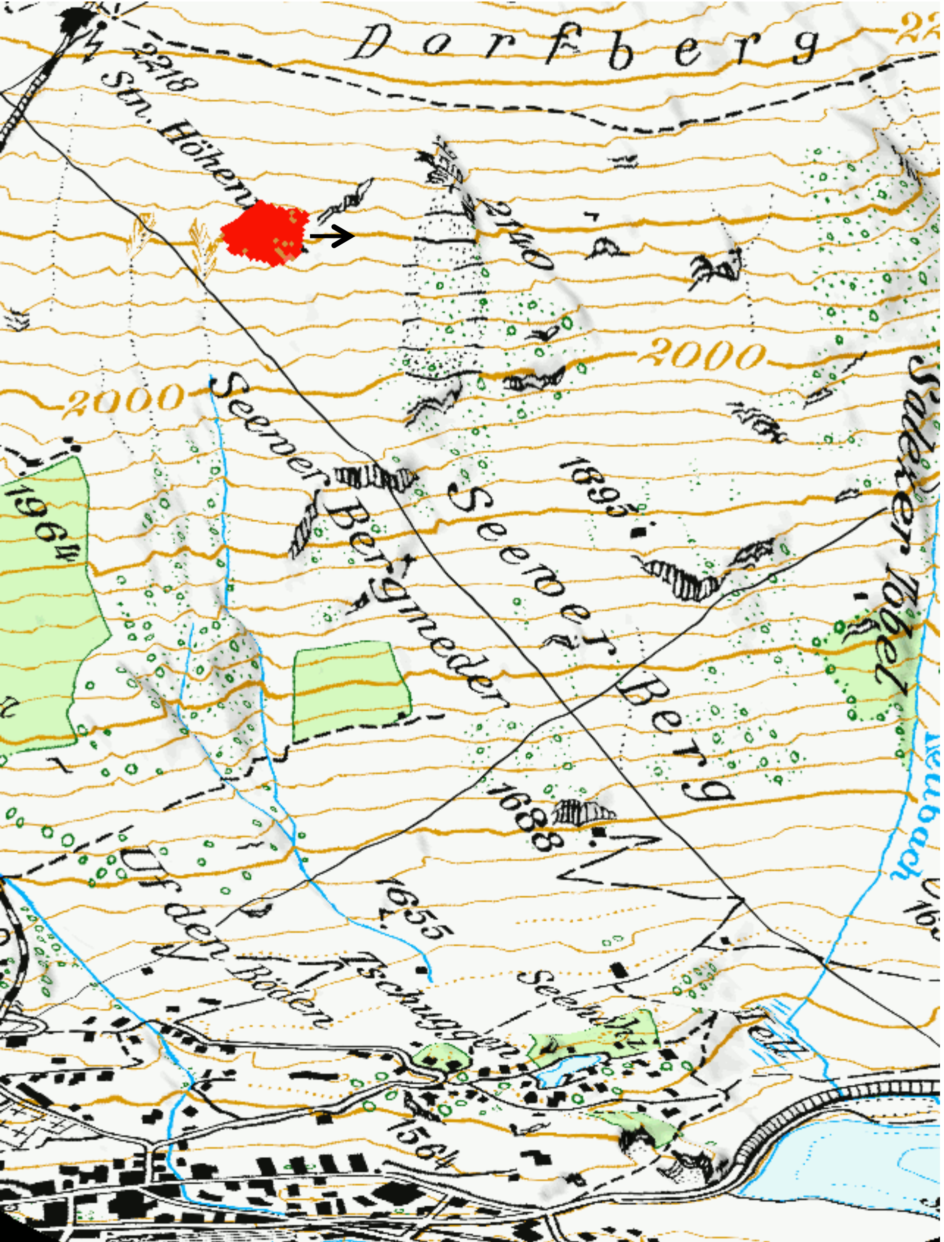
Release (AVAL)

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








Dorfberg
2218
Stn. Höhenweg
2140
2000
2000
Seewer Bergmeder
Seewer Berg
1893
1964
1688
1655
Urden Böden
Tschuggen
1564


Dorfberg
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Stn. Höhenweg
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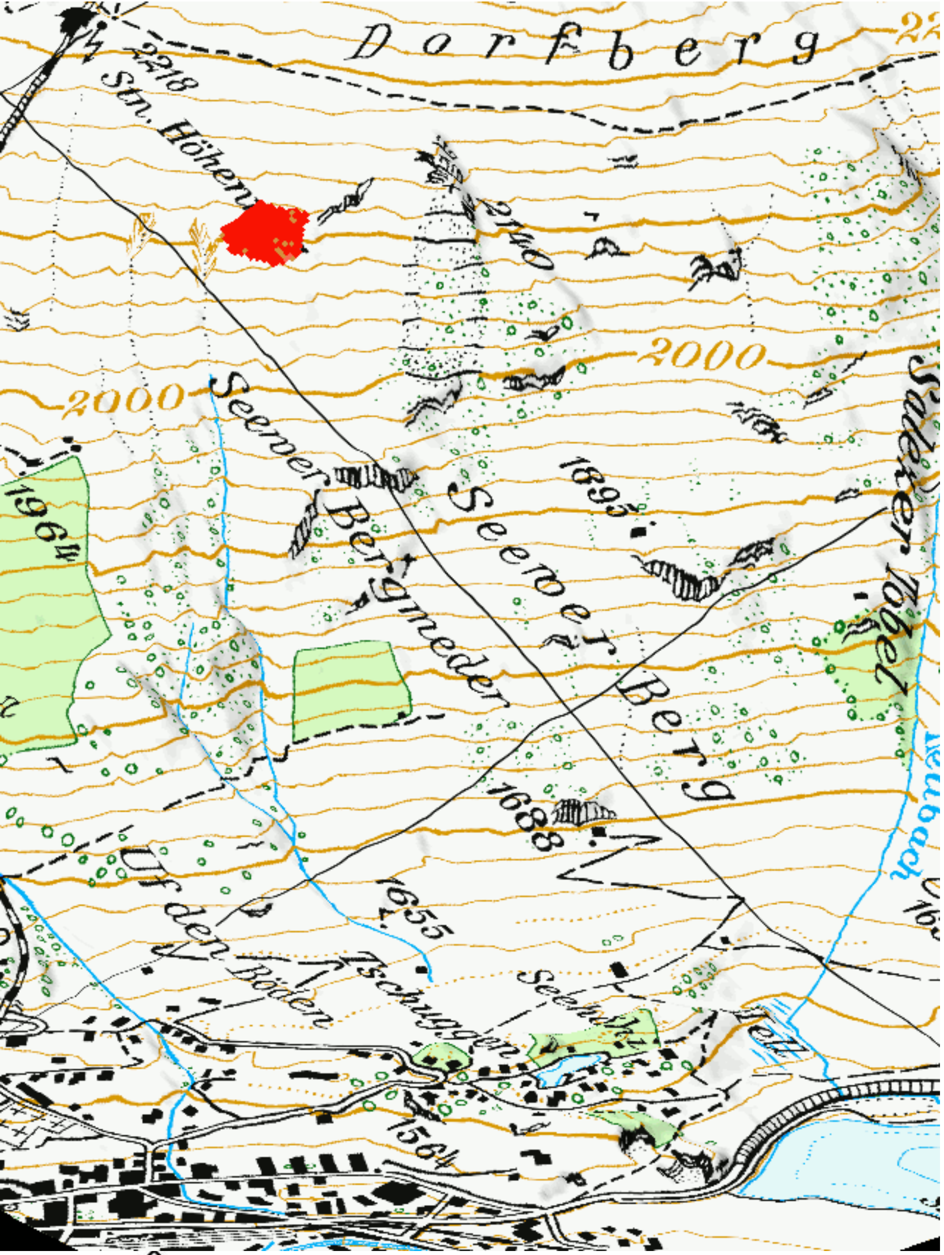
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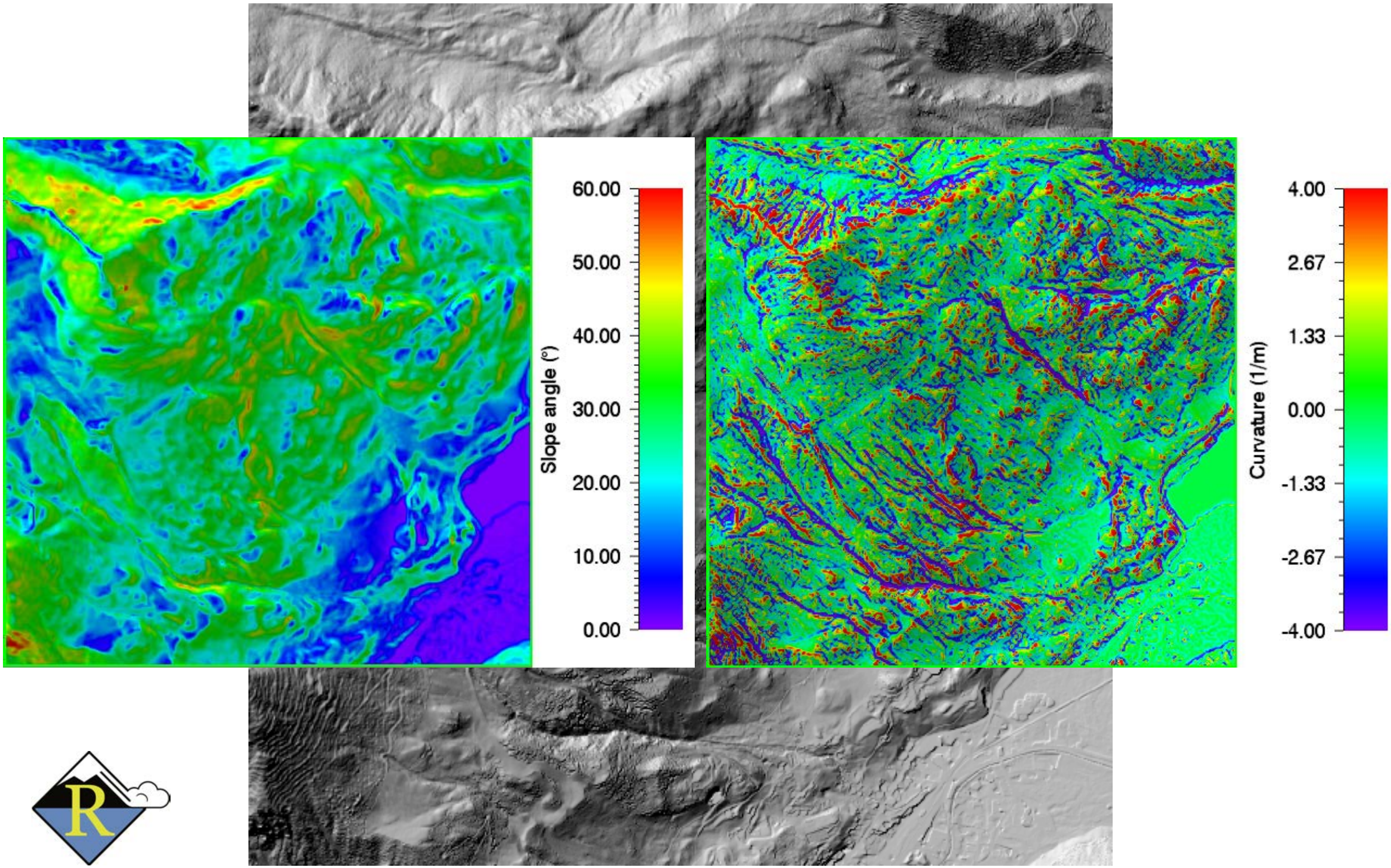
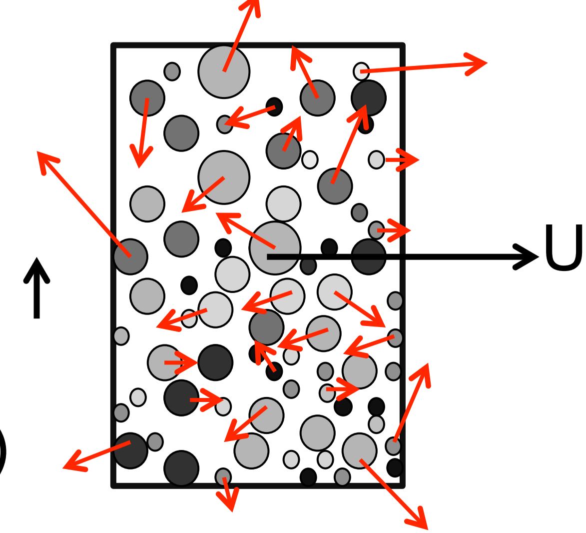
Seewer Bergmeder
Seewer Berg
1895
1688
1655
Ur den Böden
Tschuggen
1564

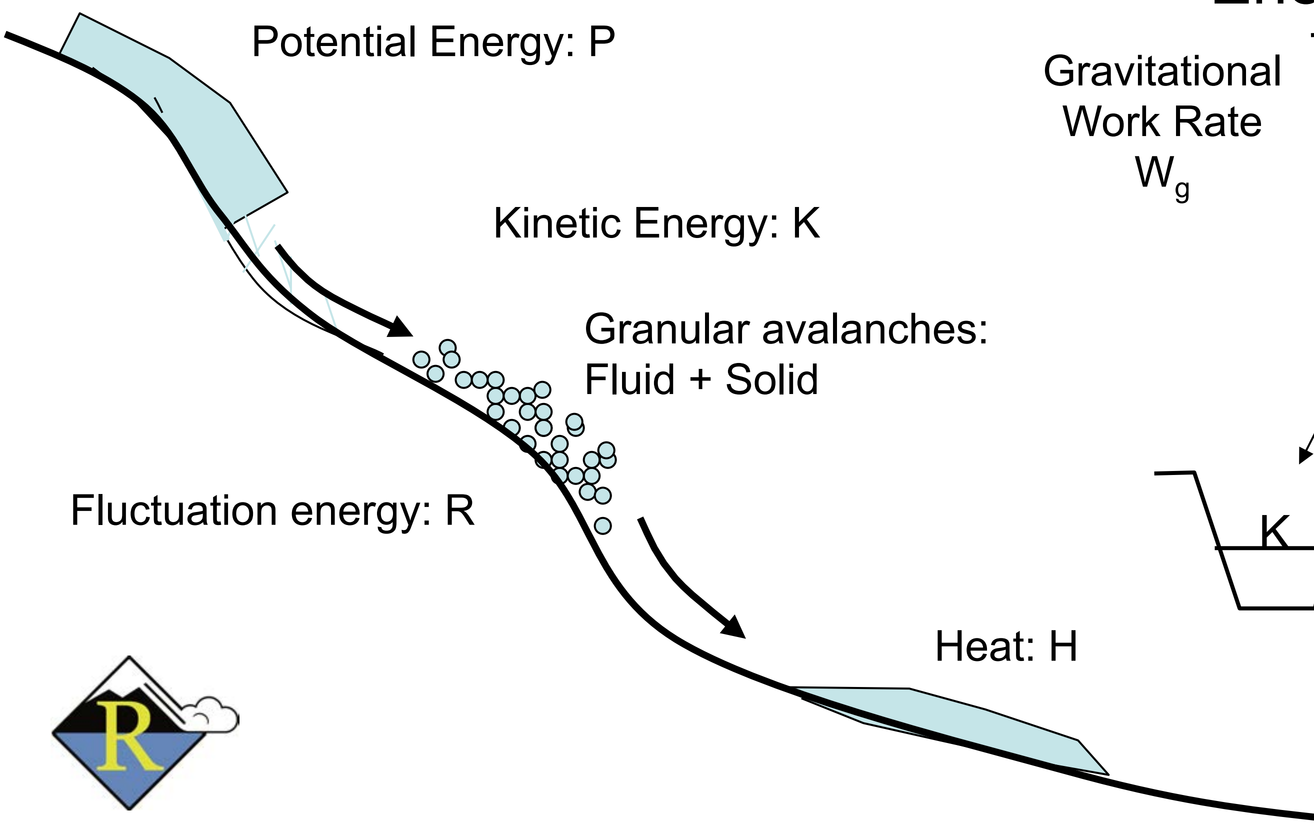
Terrain Analysis



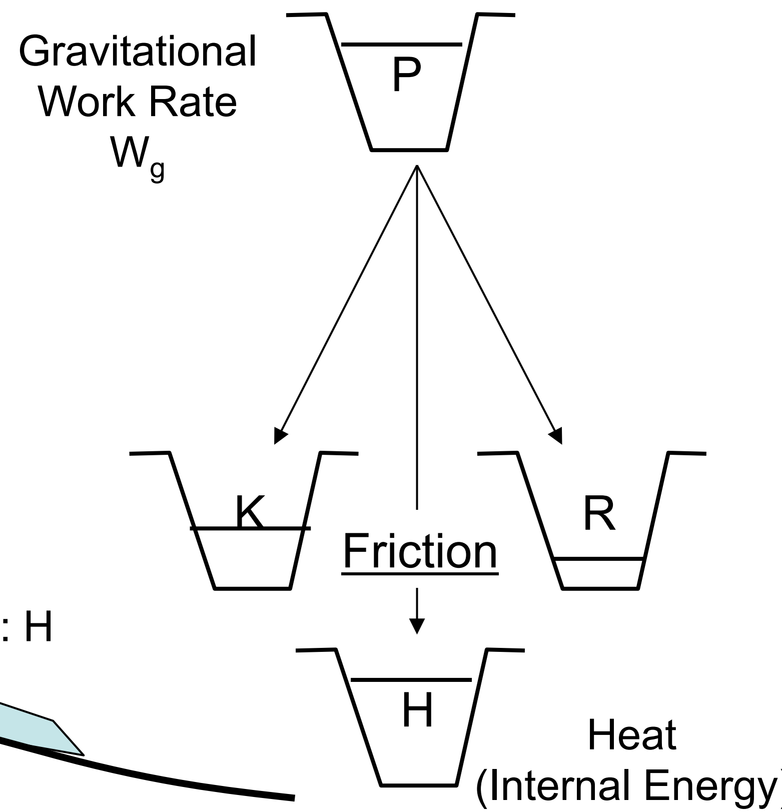
Ongoing research



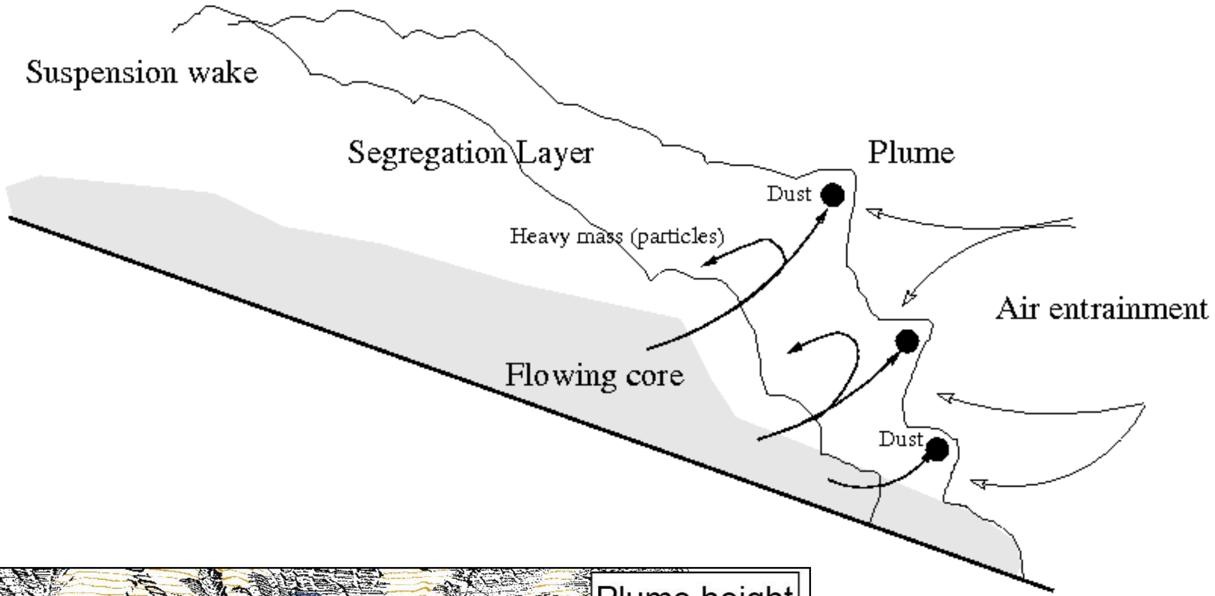
- **Random Kinetic Energy Model RKE**
  - Better **deposition** patterns
  - **Small** scale avalanches (< 10’000 m^3)
  - Levées

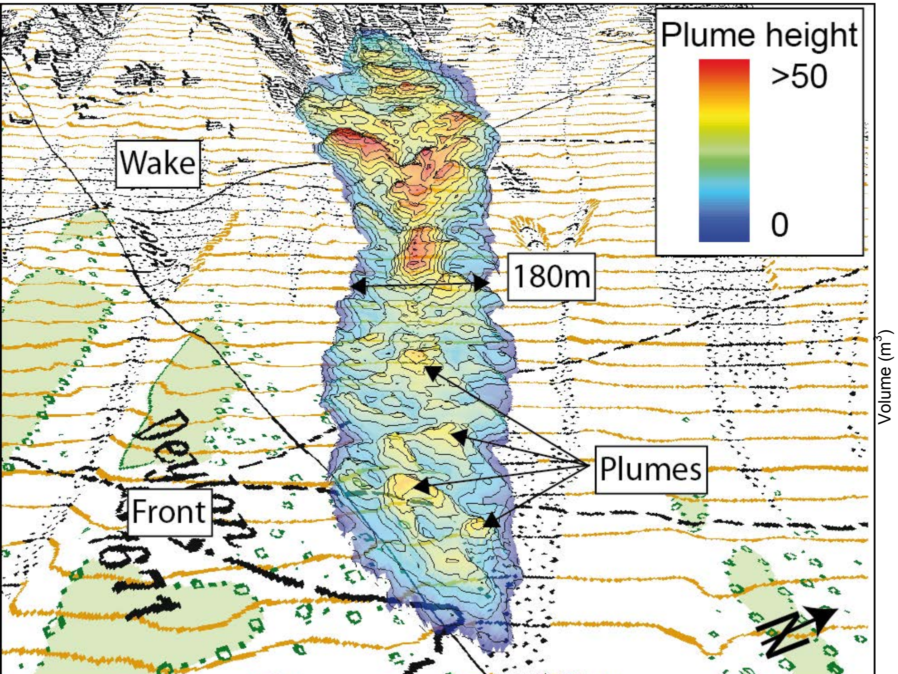


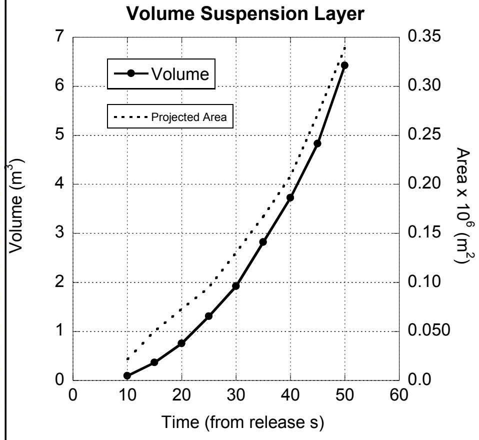
Energy Hierarchy



- **Powder cloud**



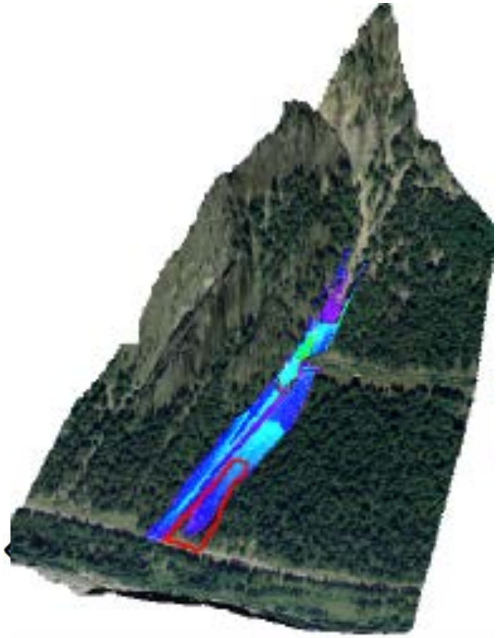


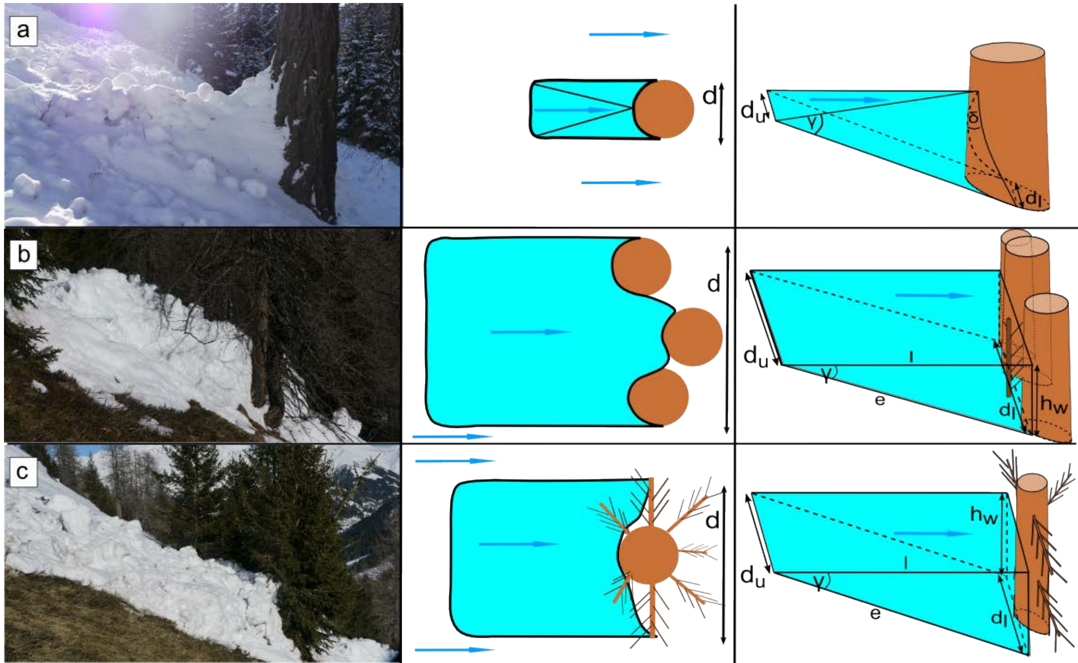


• Forest effects on avalanche dynamics

- How does forest stop avalanches?
- What forest structures are most effective?

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

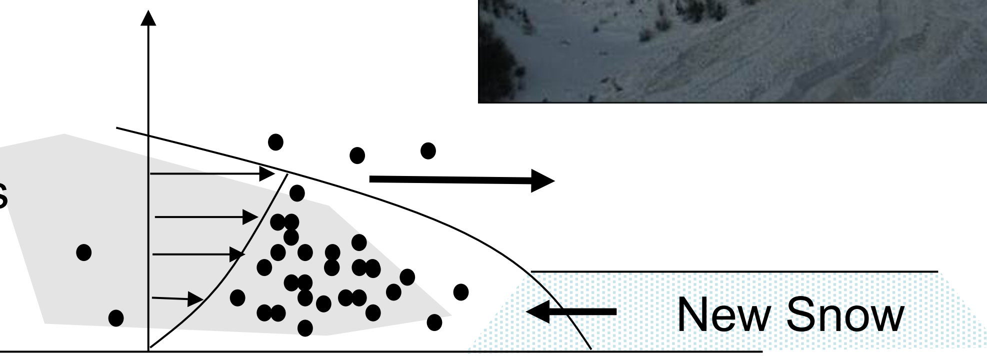




- **Snow entrainment**

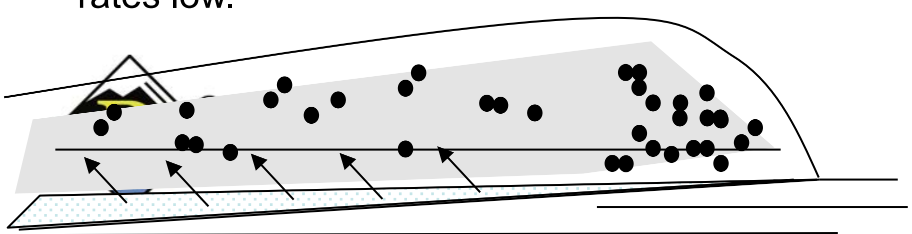
Frontal Entrainment

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



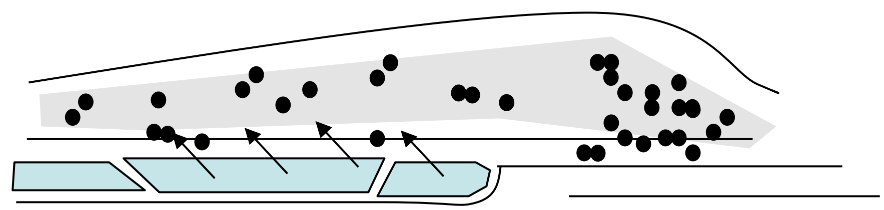
Basal Erosion

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

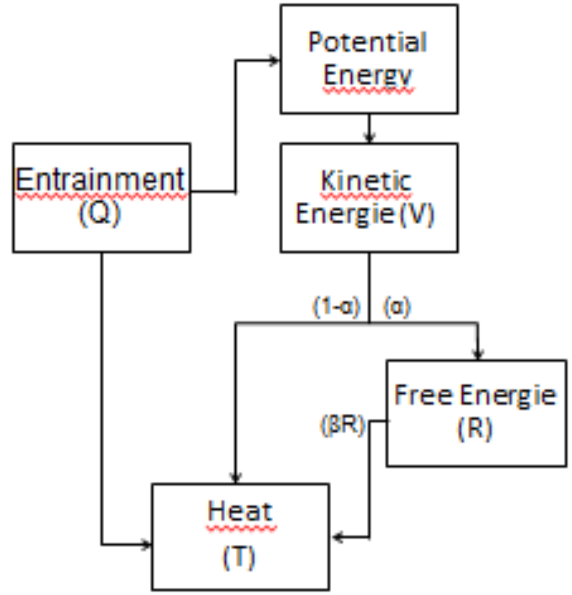


Fracture Entrainment

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

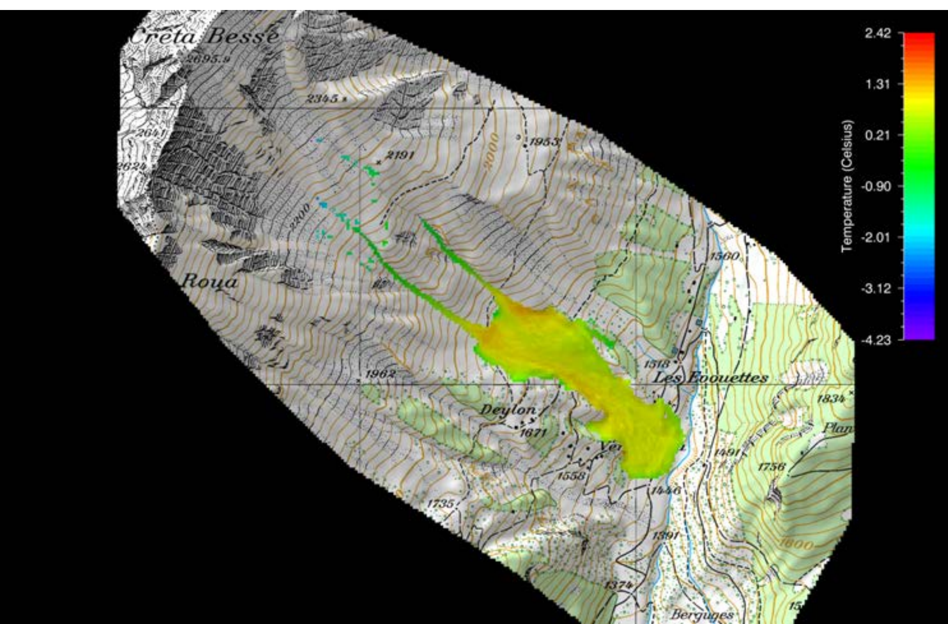


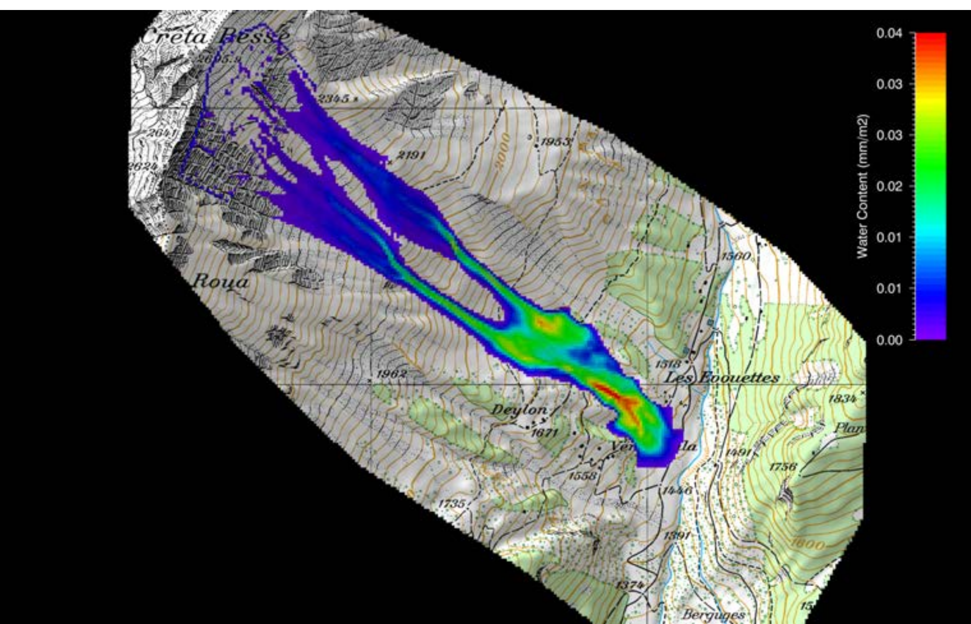
- **Wet snow avalanches**



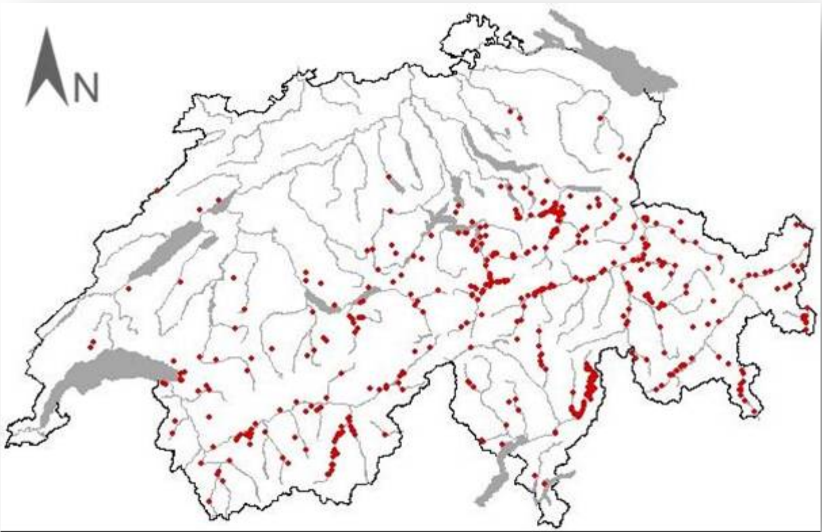
Temperature simulation.

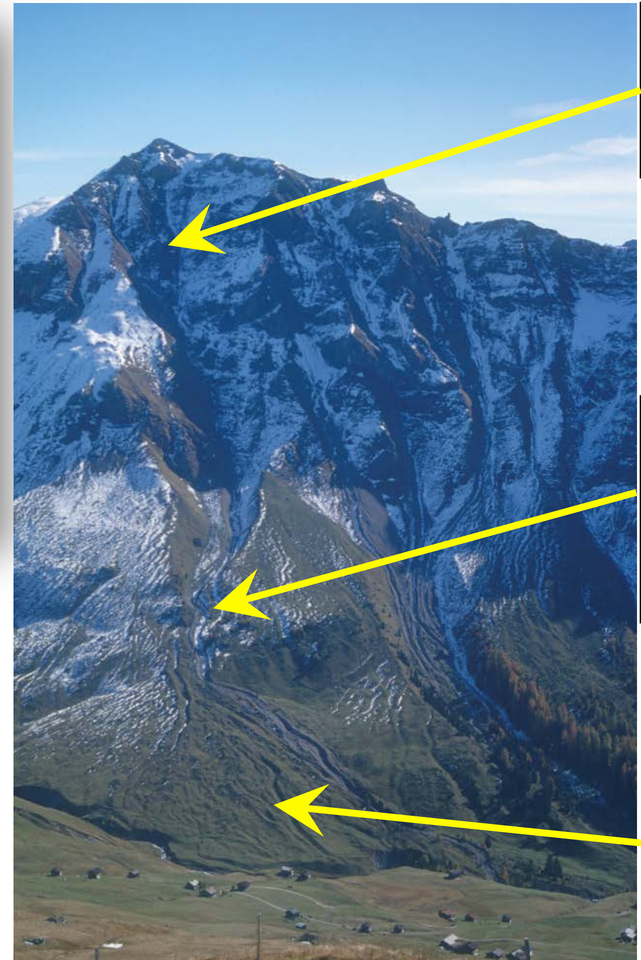
Water production simulation





RAMMS::DEBRISFLOW





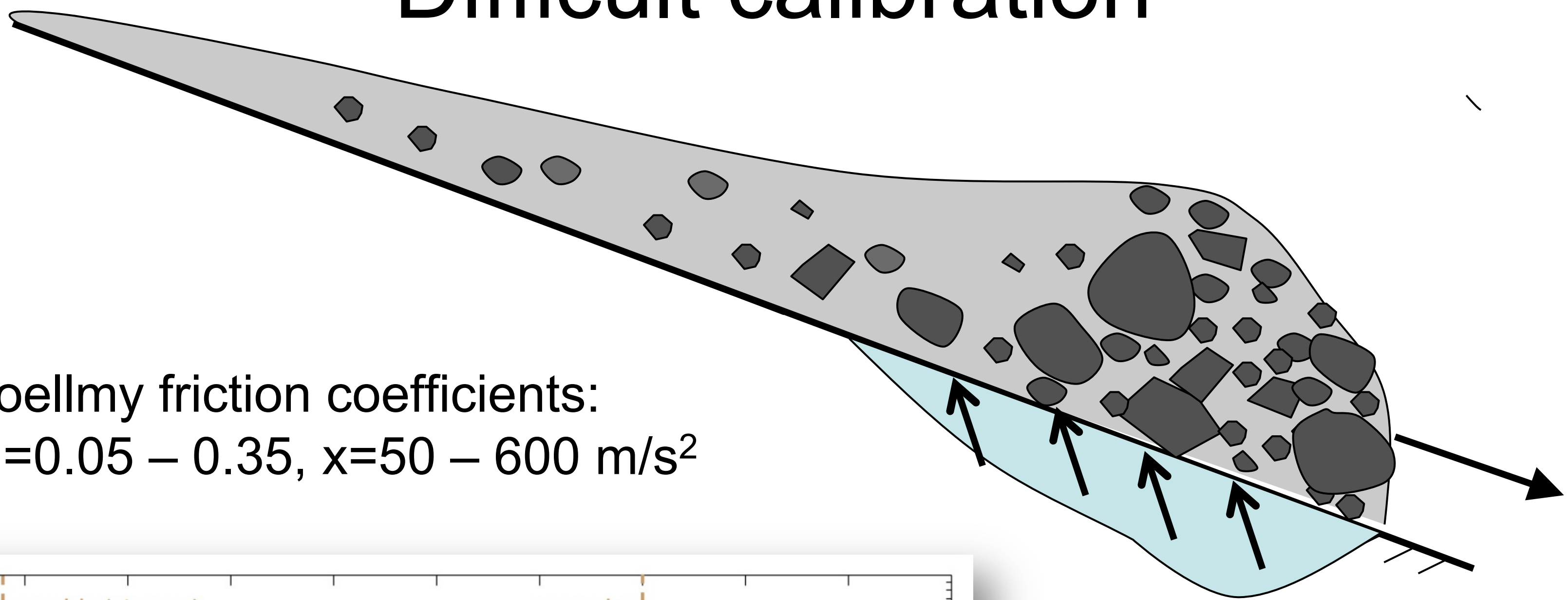
Initiation zone:
Rainfall, landslides, erosion, …

Transit zone:
Erosion + deposition, levee formation, …

Deposition zone (alluvial fan):

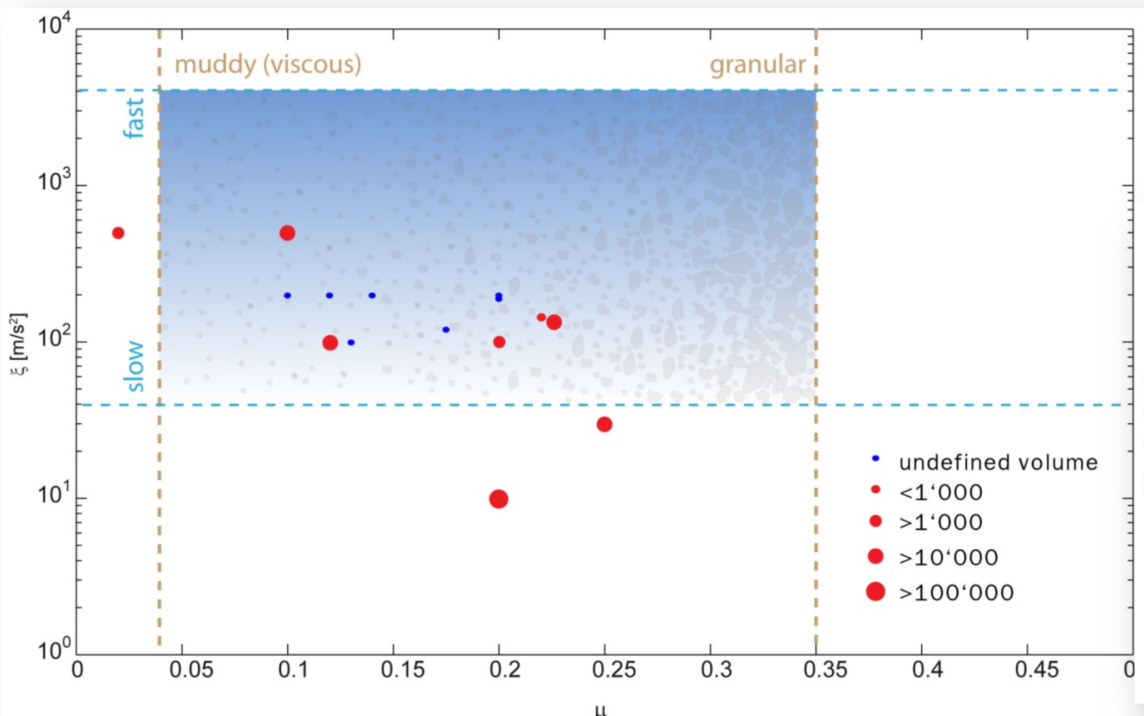
Deposition, dewatering, …

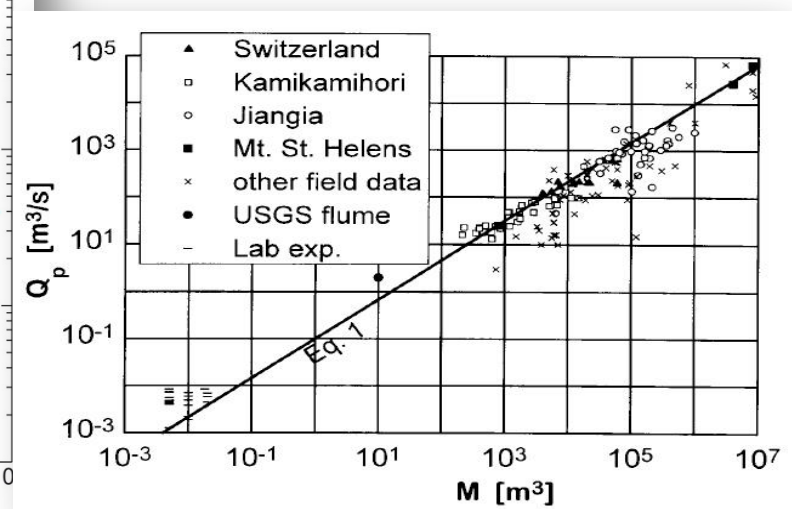
Difficult calibration



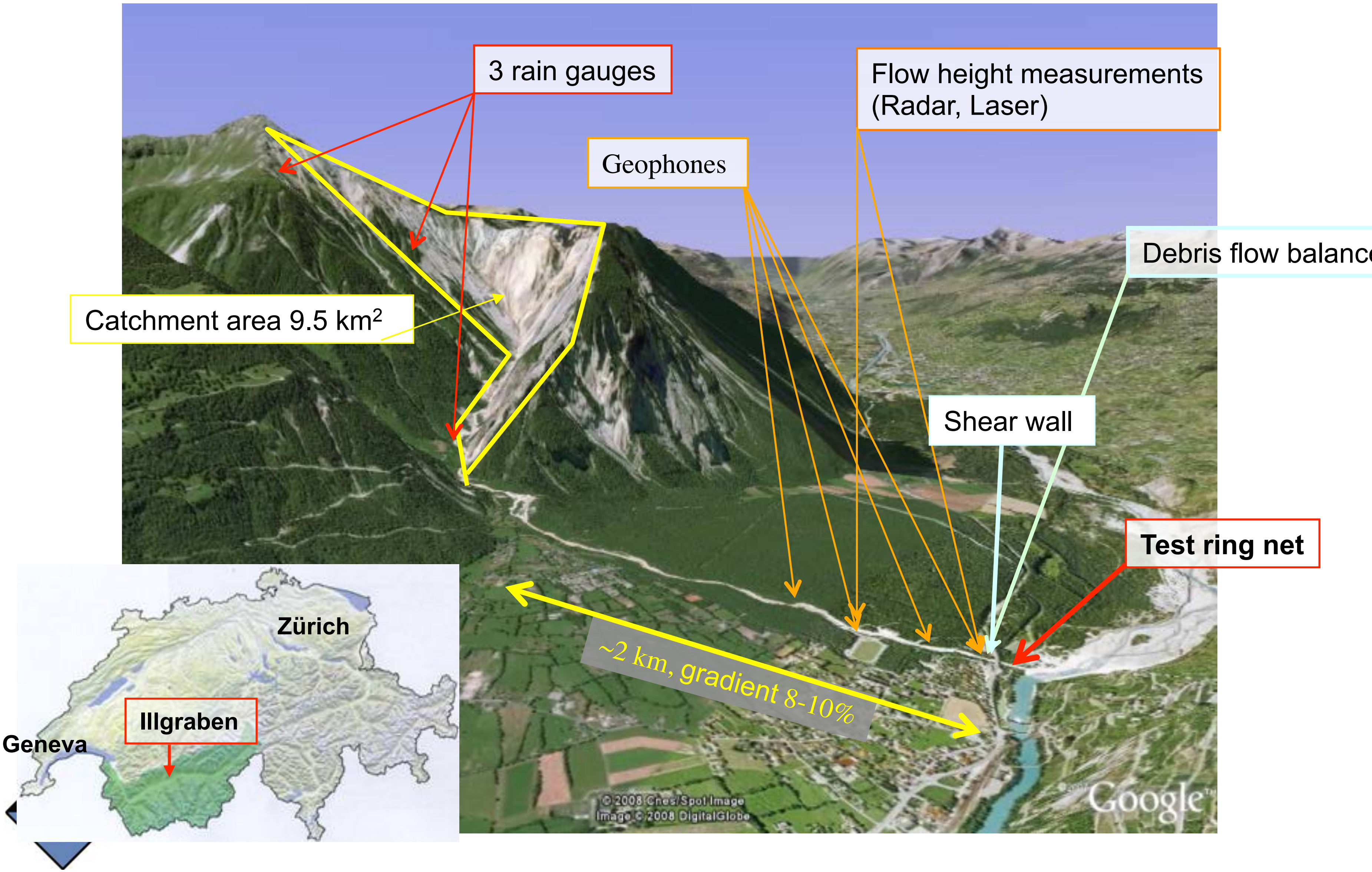
- Voellmy friction coefficients:
  m=0.05 – 0.35, x=50 – 600 m/s²

Maximum velocity 10 m/s





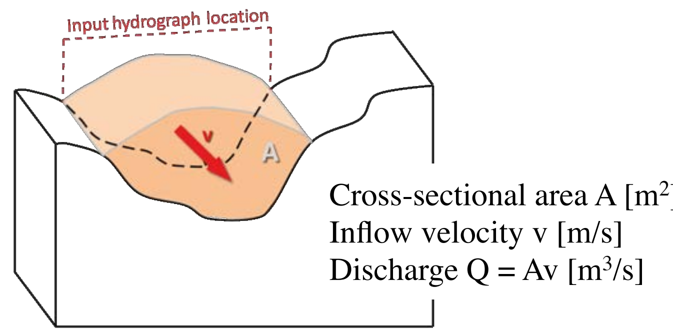
Illgraben Debris Flow Test Site, VS, CH

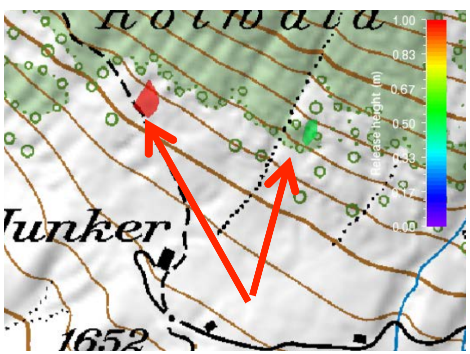


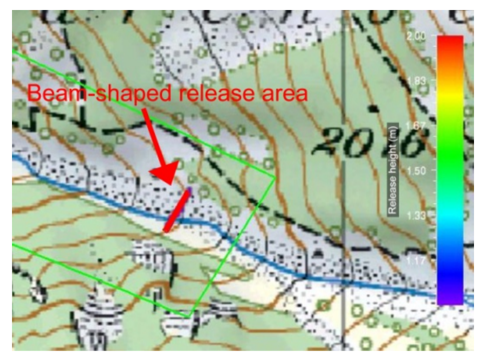
Release (DBF)

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

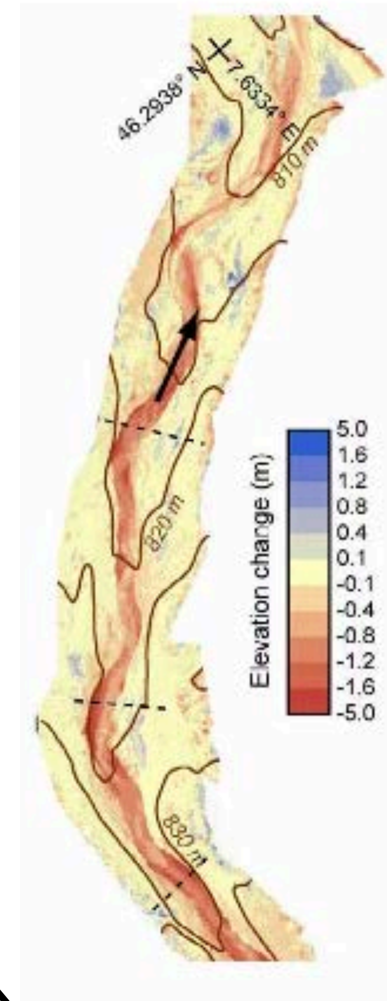


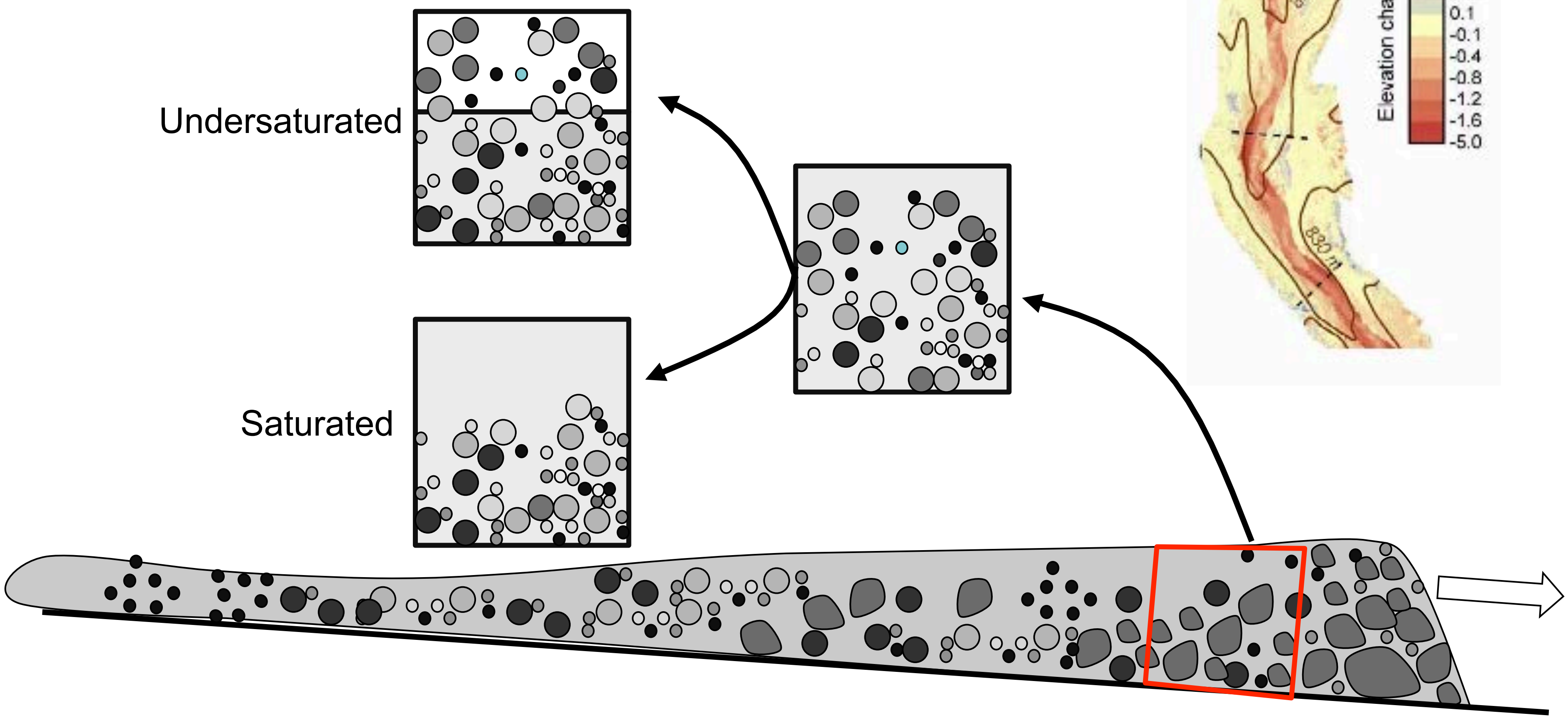




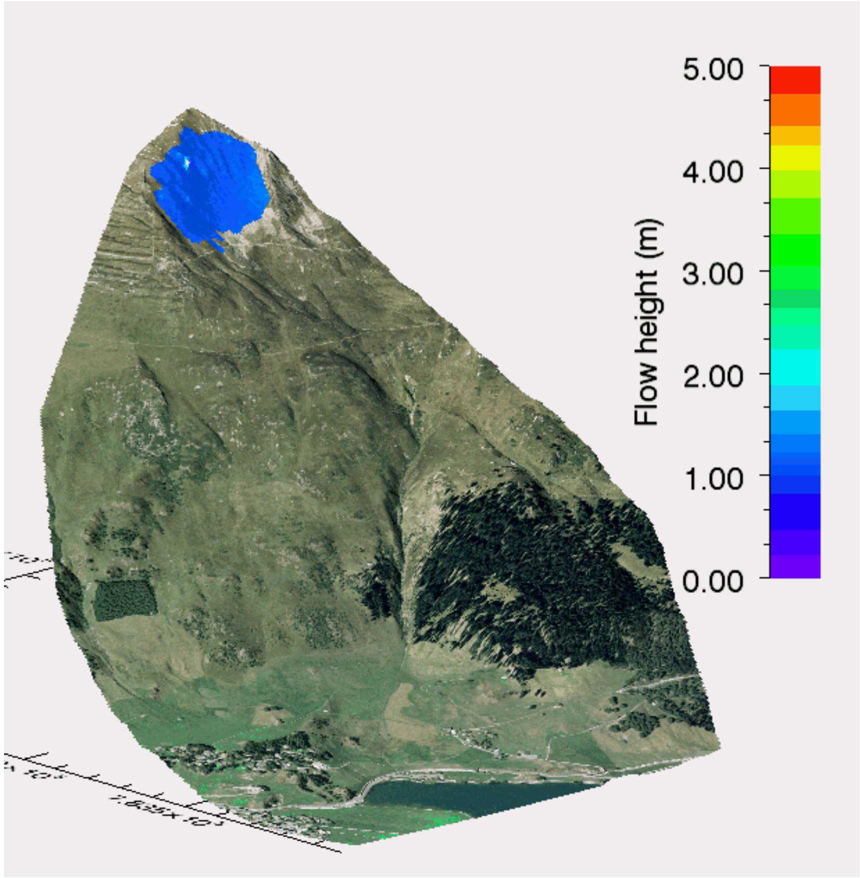
Ongoing research

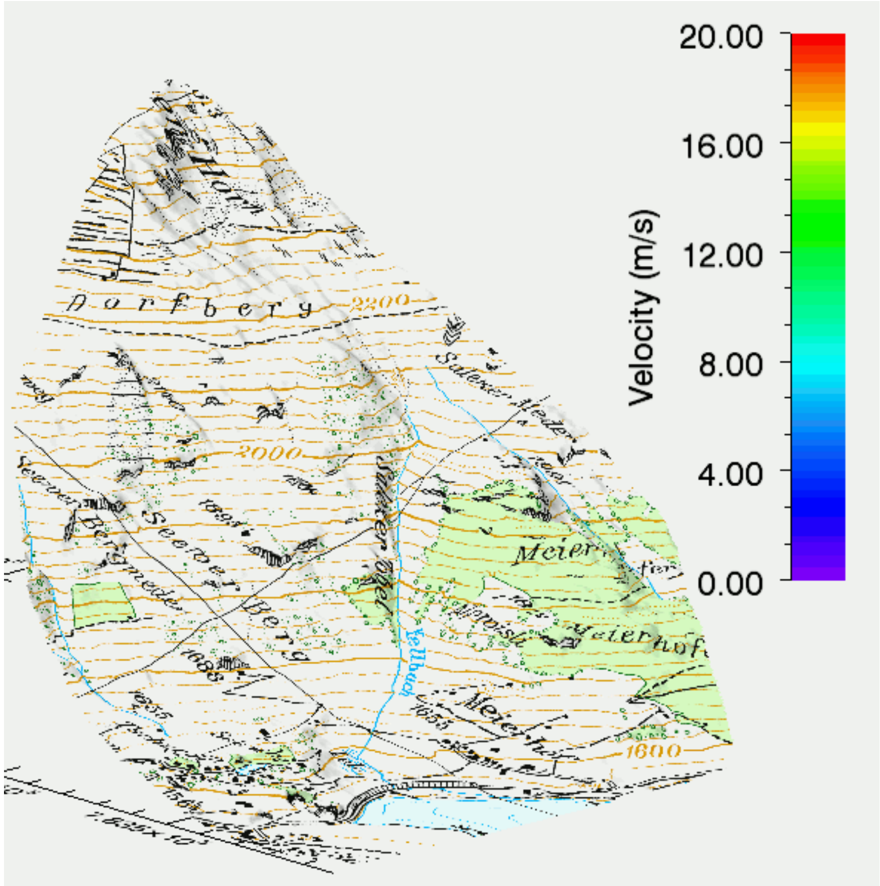
- 2 Phase Model
- NoFlux: Buildings and Dams
- Erosion / Deposition
- More field measurements for calibration



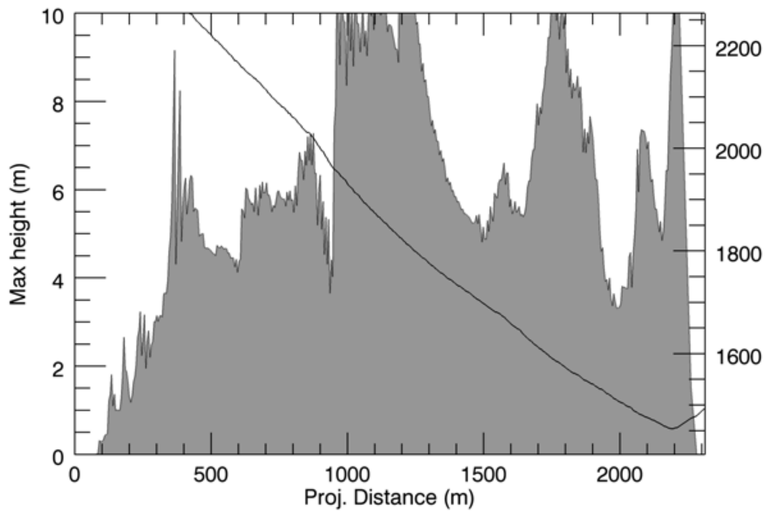


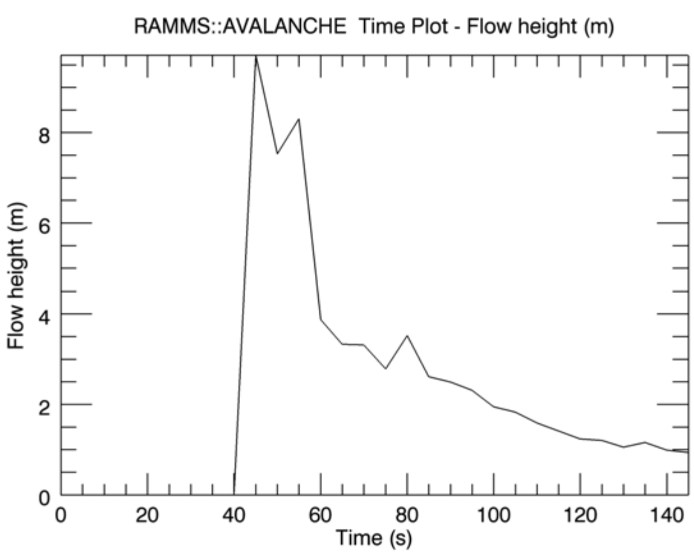
RAMMS output: Visualization of simulated processes

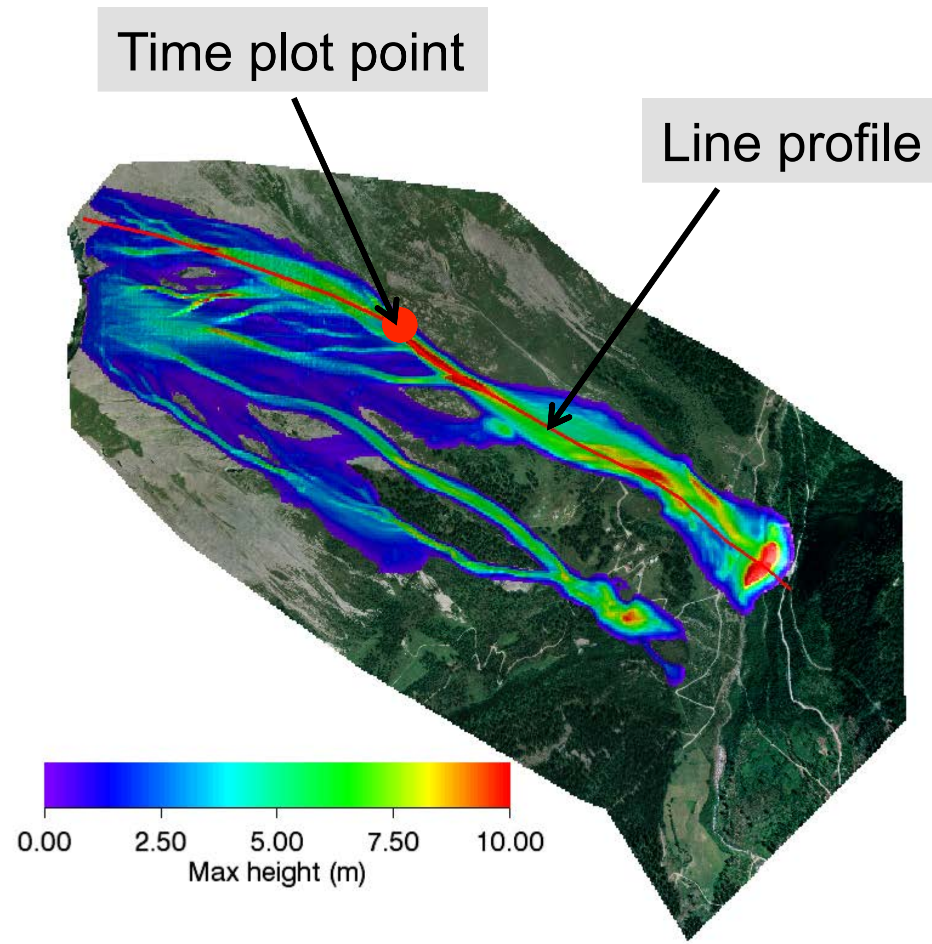




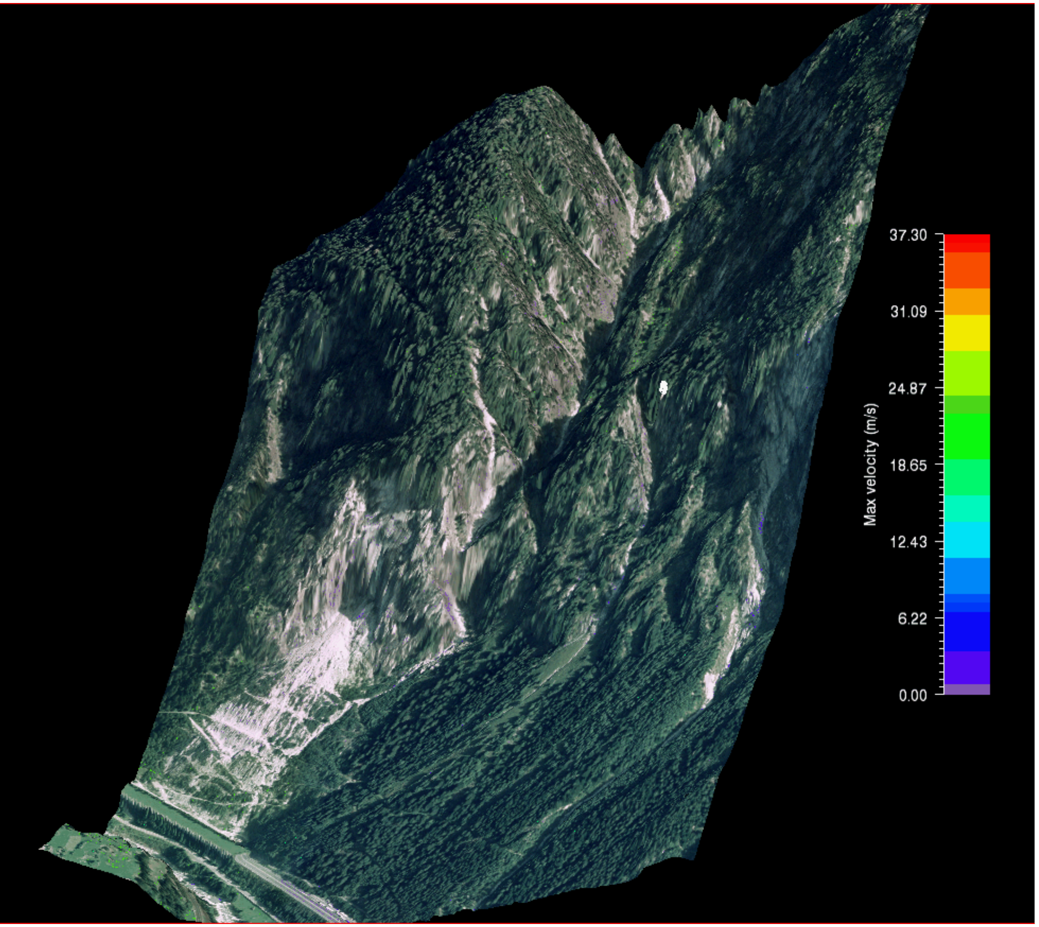
Interpretation of the results: Line Profiles (1D), XY-Time plots



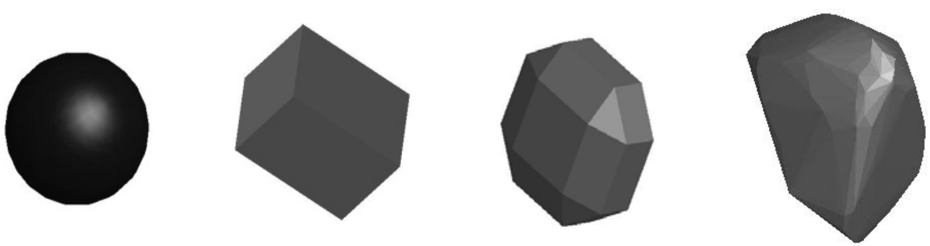




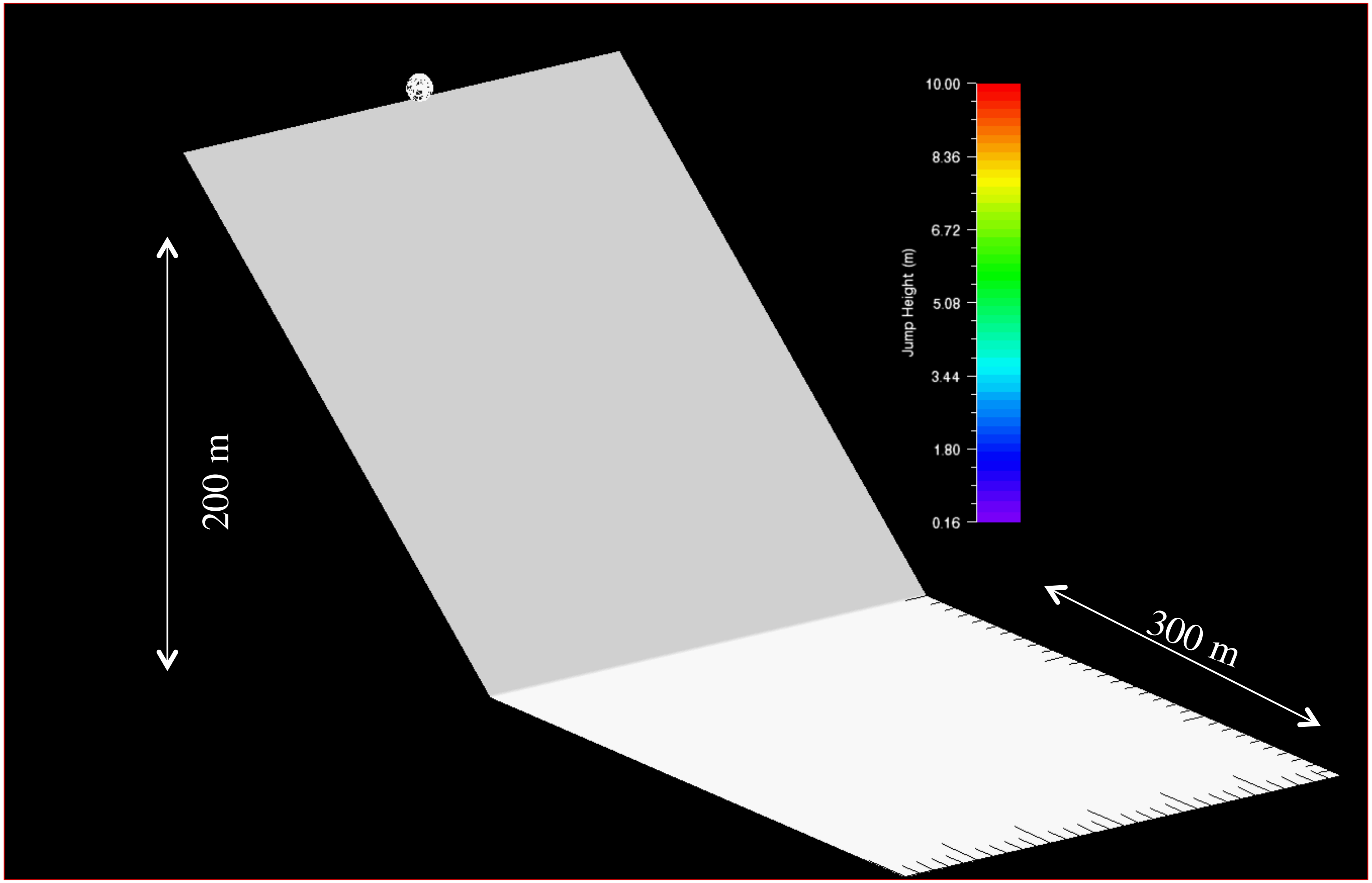
RAMMS::ROCKFALL



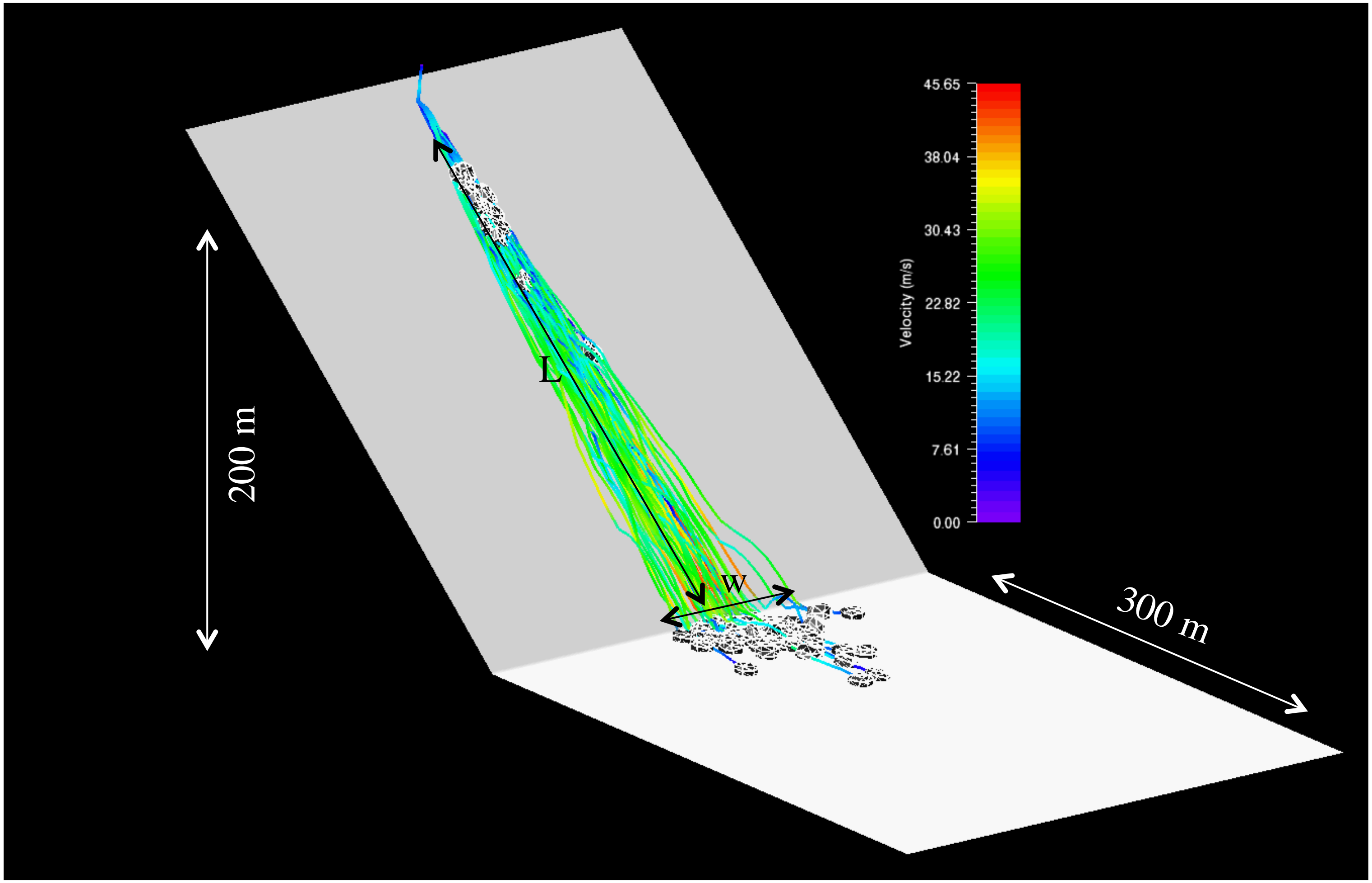
- Based on real physics
- Rigid body contact impact
- Considers rock shape
- Variability of rockfall
- Calibration with dynamic sensors



Batch simulations & rockfall variability



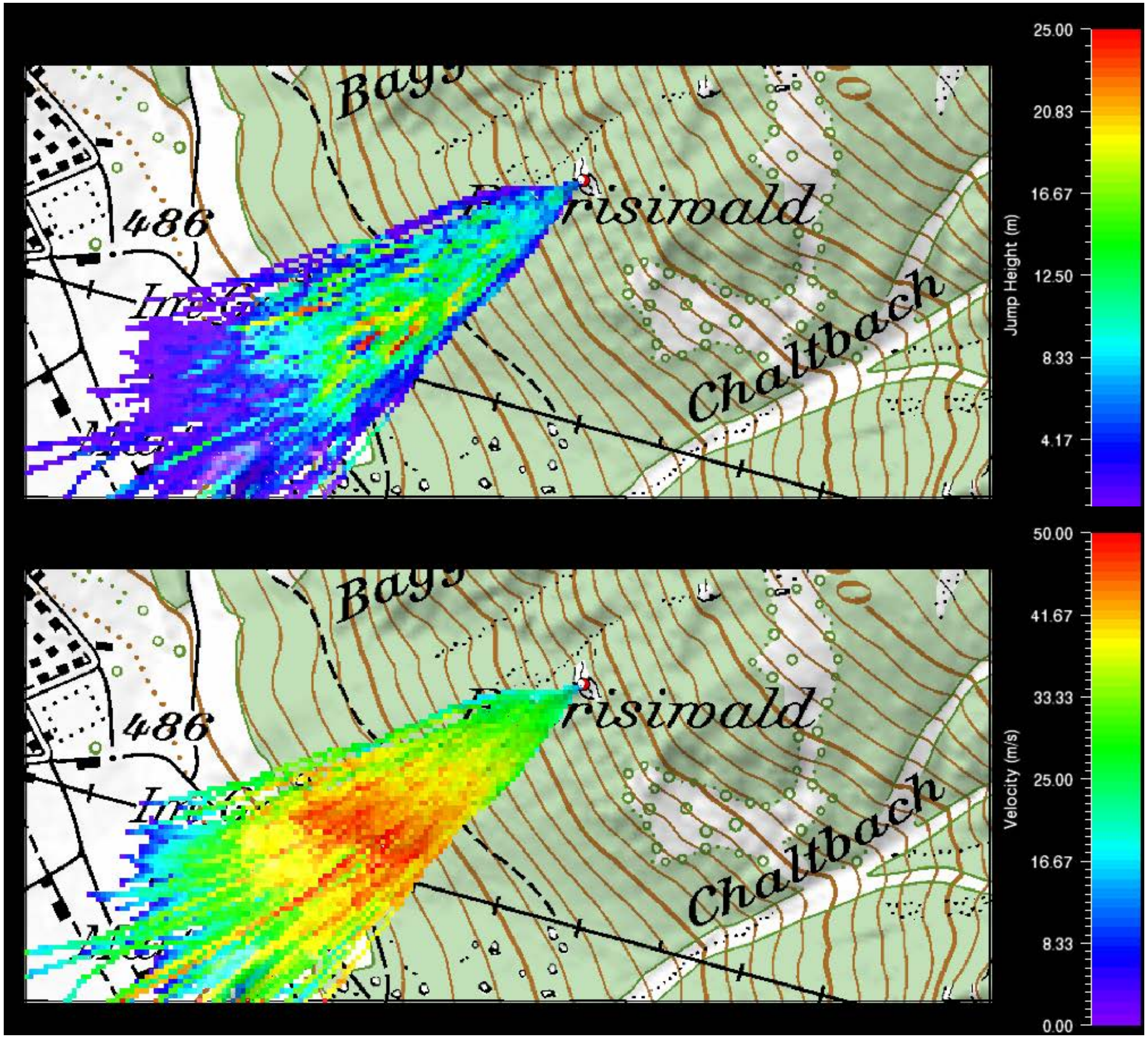
Batch simulations & rockfall variability



Simulation data: Shape files

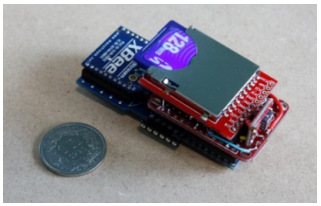
Jump Height

Velocity

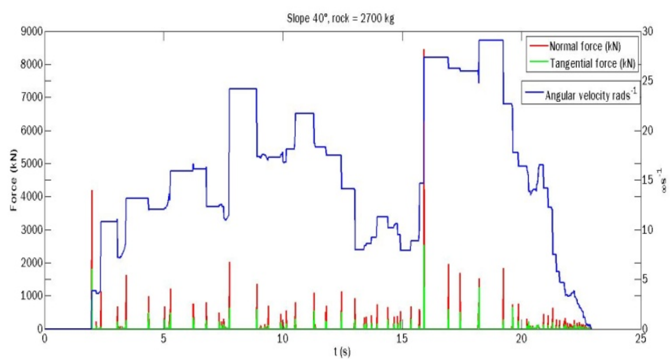


Experiments

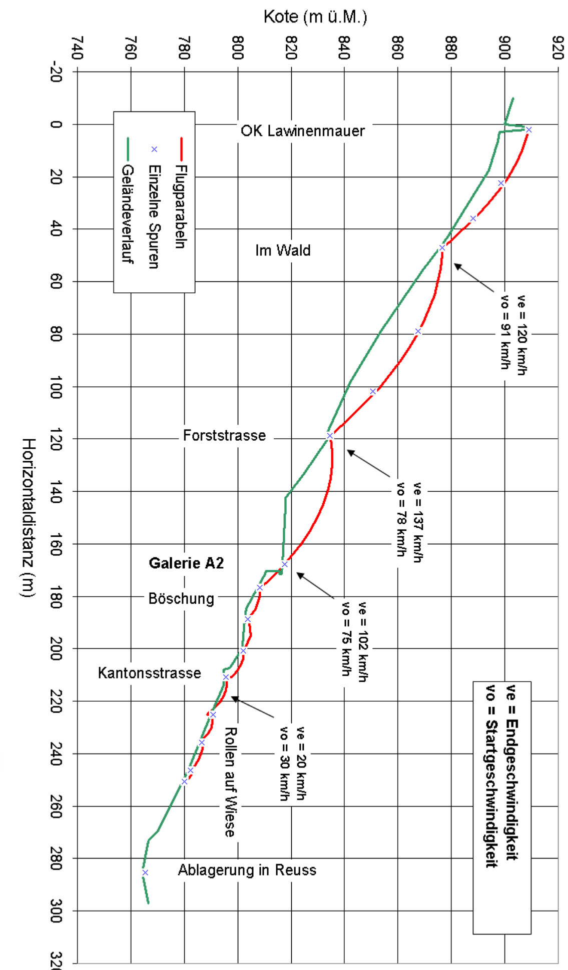
Lab



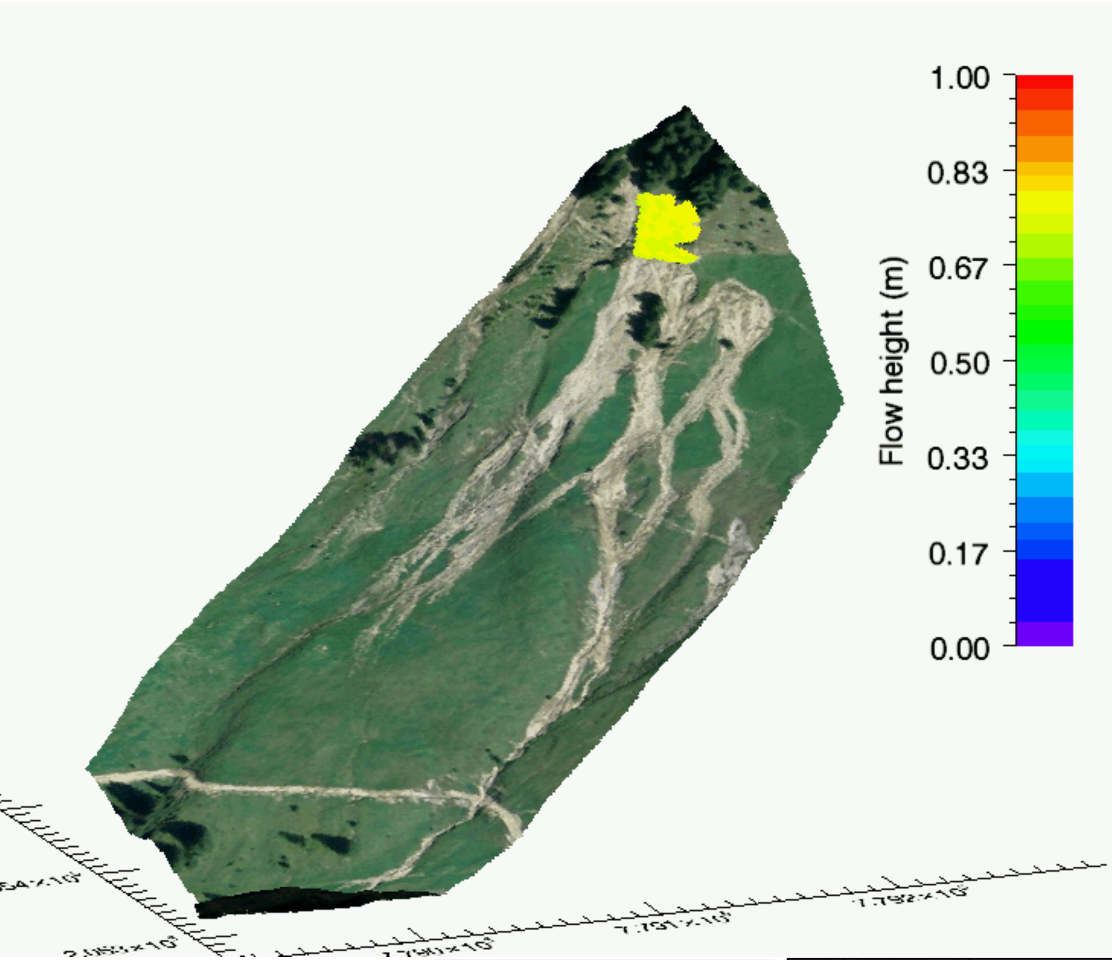
Field



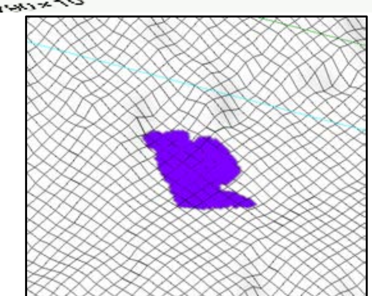
Case studies

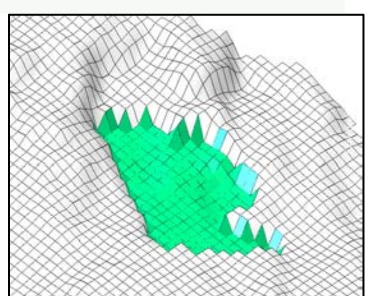


RAMMS HILLSLOPE



- Release and volume very hard to predict
- Stopping at steeps slops
- Problem for Voellmy model
- Random Kinetic Energy RKE extension



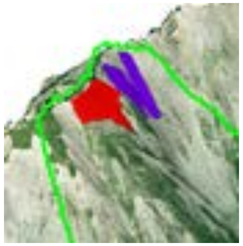


Interpretation of simulation results

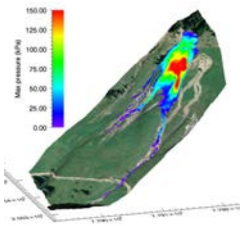
- RAMMS is a numerical **model** (≠ reality)

  → 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!

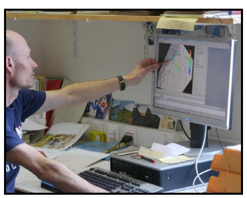
Summary



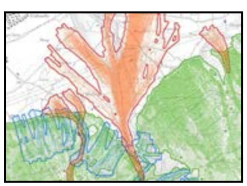
- RAMMS is a tool for **numerical simulation** of rapid mass movements
- Modules: **Avalanche**, **Debris Flow**, Rockfall and Hillslope



- Most important input data are the **DEM** as well as location of **release area** and release height
- Voellmy-Salm model with two friction values (μ & ξ)



- **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