RAMMS::Rockfall Workflow

Data Preparation, Model Setup and Result Interpretation

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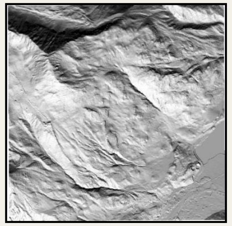
Rockfall Modelling Workflow

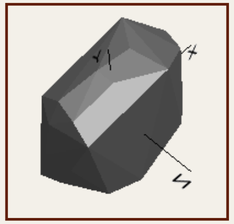
Input Data

- DEM (Digital Elevation Model)
- Release zones (points, lines, areas)
- Orthophotos / maps (for visualization)
- Forest distribution
- Rock shapes / volumes



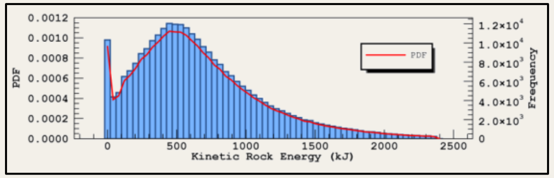
Simulation Setup

- Define starting conditions (random rock orientations)
- Assign terrain parameters (ground category)
- Define rock geometry (RockBuilder / point clouds)
- Configure simulation settings (number of rocks, domain)



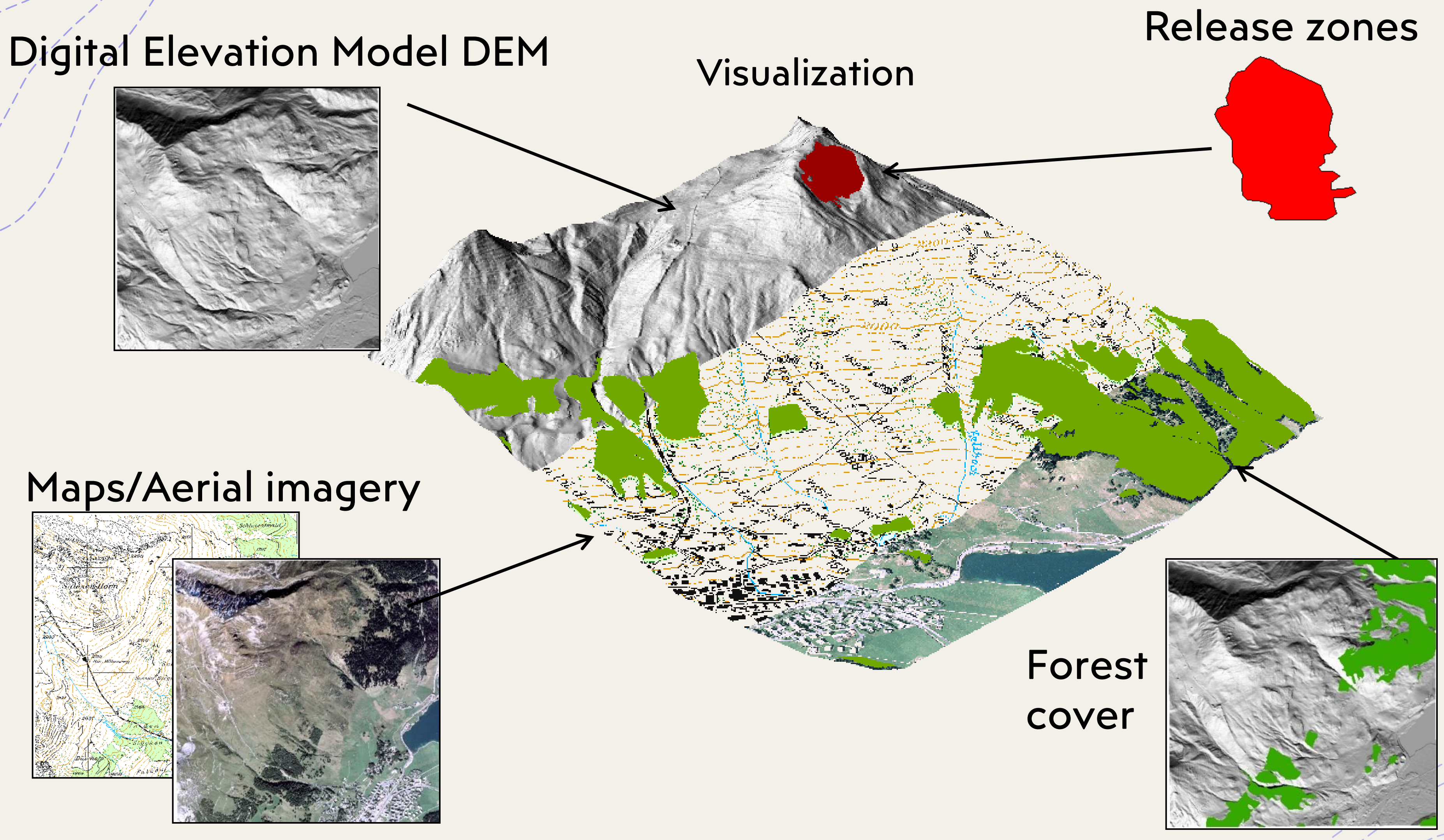
Output and Analysis

- Rock trajectories
- Velocity and energy maps
- Jump height and runout
- Source reach probability
- Export to GIS (GeoTIFF / shapefiles)



RAMMS integrates **terrain data**, **physical rockfall modelling**, and **statistical trajectory analysis** within a **single modelling environment**.

Required Input Data

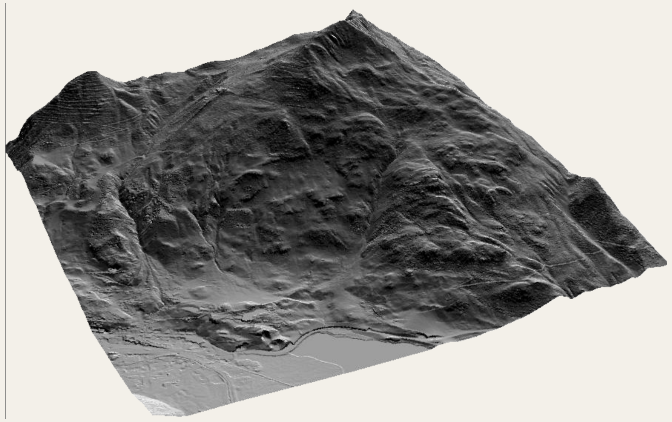


Digital Elevation Model (DEM)

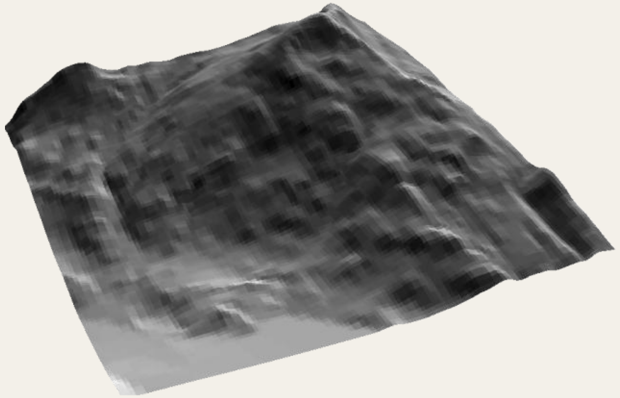
The DEM is the most important input for rockfall simulations and forms the basis for all numerical calculations.

- Simple, homogeneous slopes: **DEM resolution of approximately 2-5 m is usually sufficient.**
- Check the DEM carefully – holes, artifacts or interpolation errors can strongly affect results.
- Complex terrain (gullies, ridges, cliffs) or small events: Higher-resolution DEMs are required (e.g. 0.5–2 m LiDAR).

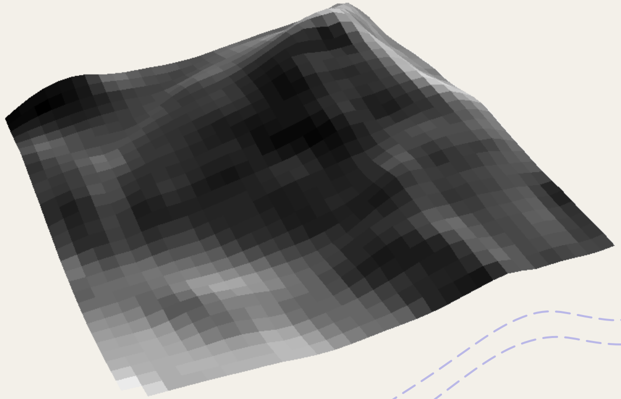
2 m LiDAR



DHM25



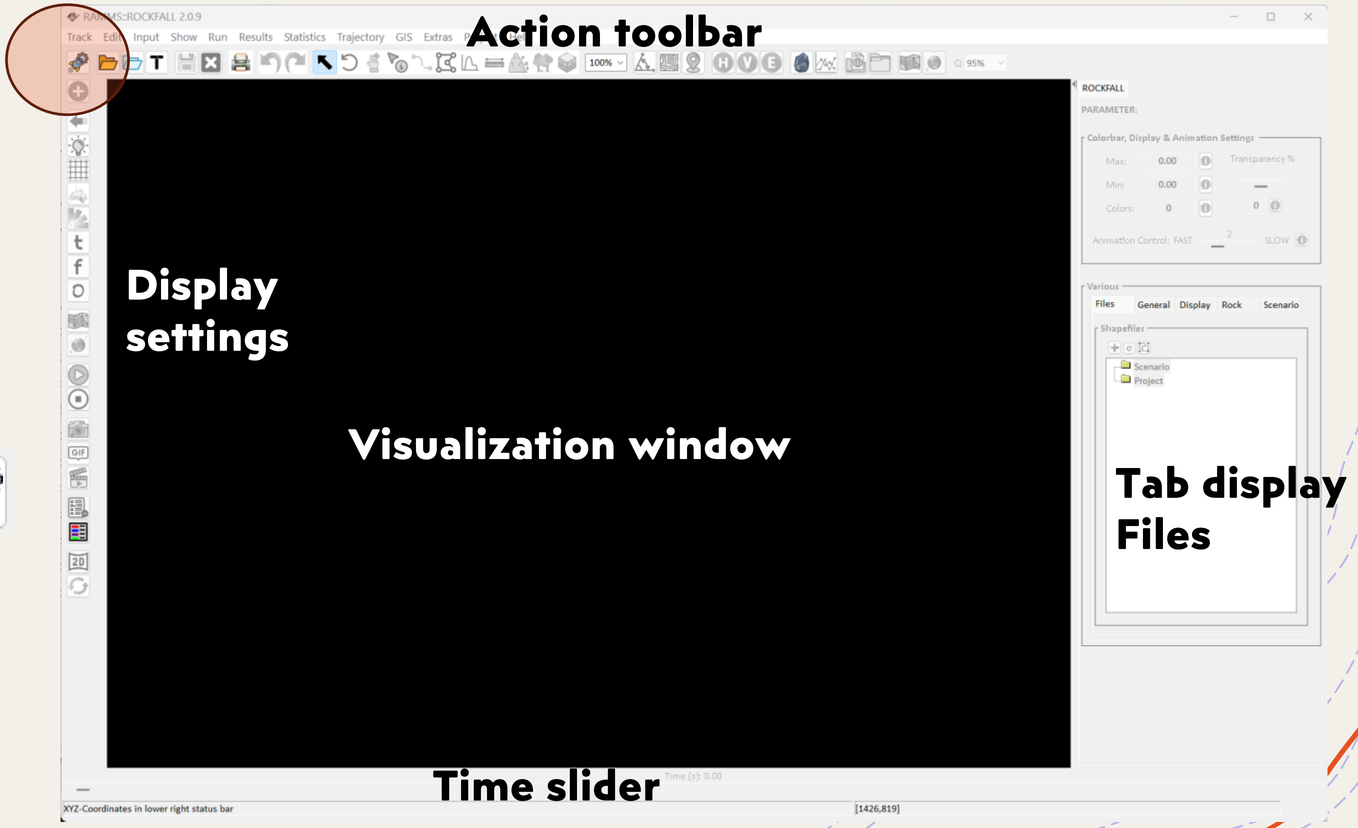
90 m SRTM



Starting a RAMMS Project

Once an appropriate **Digital Elevation Model (DEM)** is prepared, the next step is to create a **RAMMS project**, which links the simulation workflow to the terrain model.

- Start the **RAMMS::Rockfall Graphical User Interface (GUI)**
- The GUI provides the workspace for **data preparation, simulation and visualization**
- A new project is created using the **Create Project** icon in the action toolbar 
- Existing projects or scenarios can also be opened from this menu



Project Creation

Every RAMMS simulation begins with the creation of a **project linked to a Digital Elevation Model (DEM).**

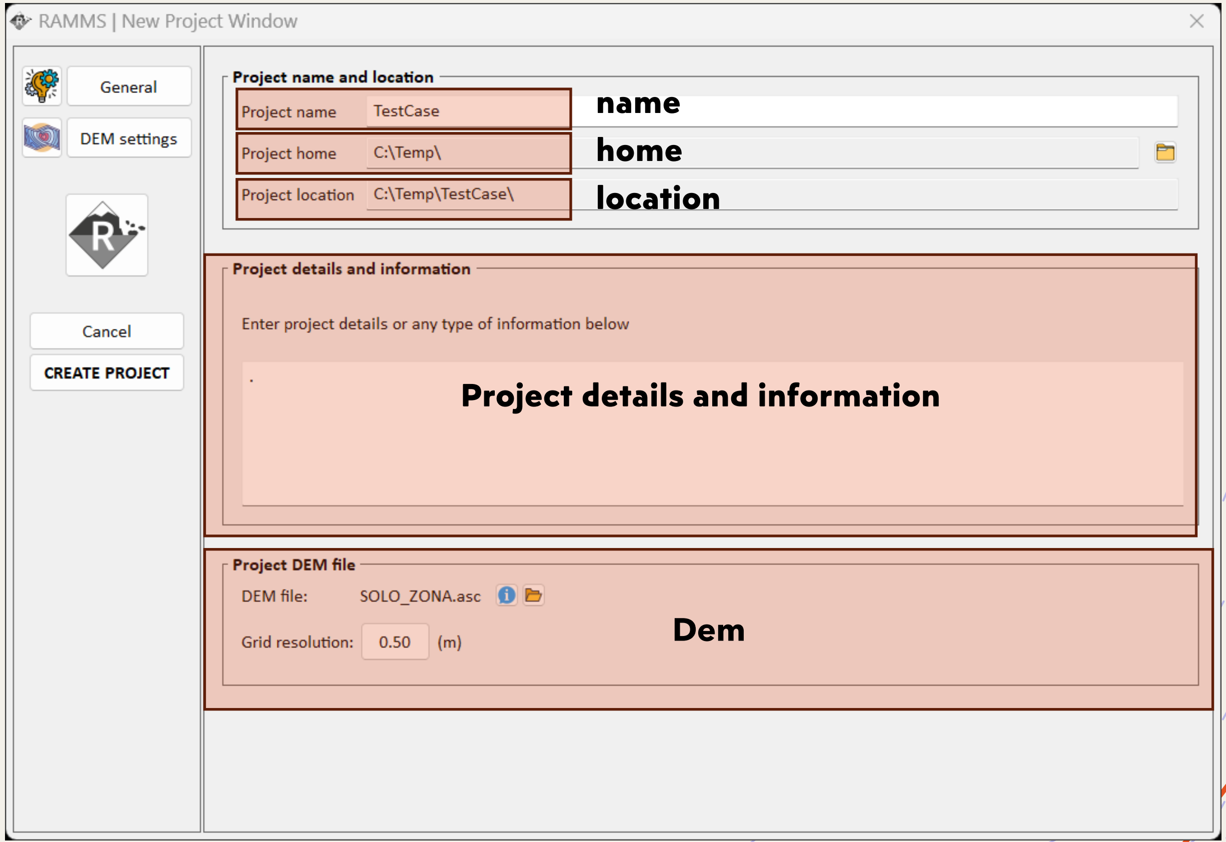
Project name:
unique identifier for the project.

Project home:
The directory on the user's computer where project will be created, select with .

Project location:
Full project file path, read-only.

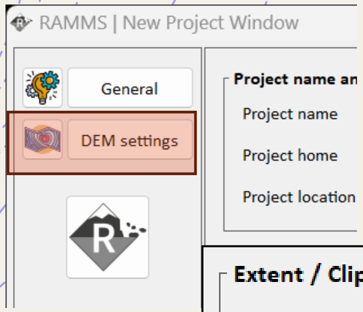
Project details and information:
This section allows users to input descriptive text about the project.

Project DEM file:
Import the DEM file, which defines the terrain for the simulation. Specify project home first! You can change DEM grid resolution, if necessary.

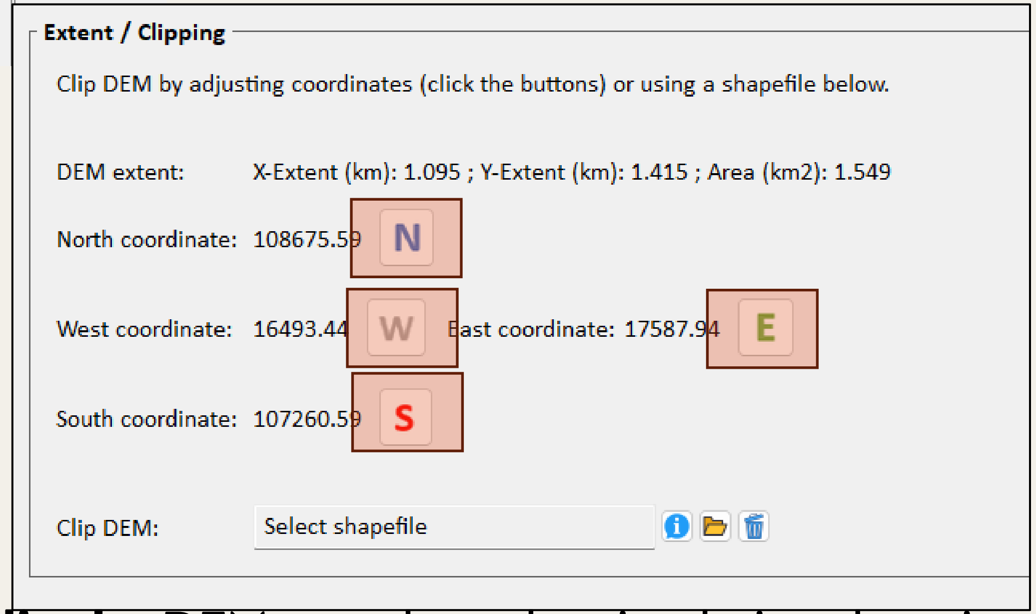


DEM Settings

The **DEM Settings panel** allows users to inspect the DEM properties and optionally clip the terrain to the desired simulation domain.

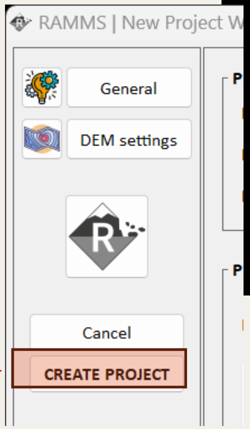


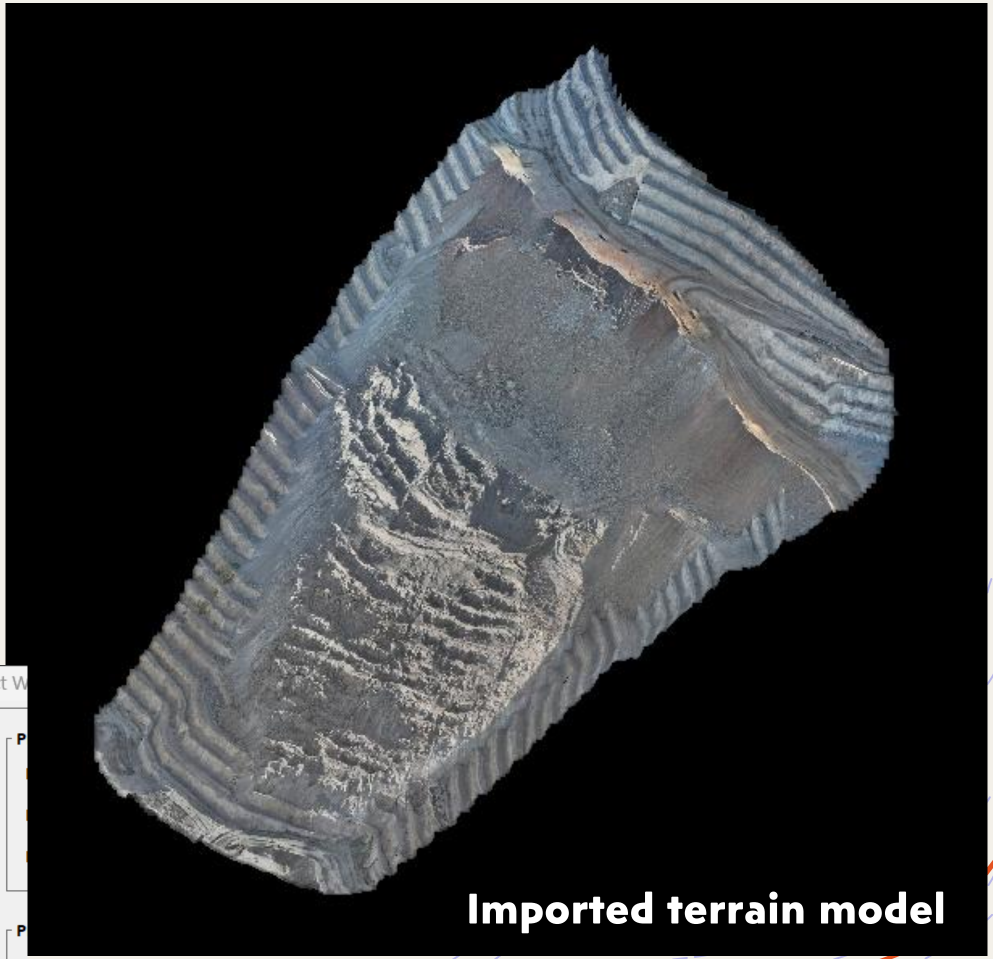
Inspect **DEM extent and spatial coordinates**



Clip the DEM to reduce the simulation domain

Confirm settings and **create the project**





Imported terrain model

RAMMS Project File Structure

Creating a RAMMS project automatically generates a **project directory containing the terrain data**, **configuration files**, and **folders required for simulations**.

Folders

• doc (folder):	logfiles
• hillshade (folder):	hillshade image (<project_name>_hillshade.tif + .tfw)
• logfiles (folder):	project creation logfiles
• output (folder):	simulated scenarios (trajectories)
• rocks (folder):	default folder for rocks (pts-files)

Files

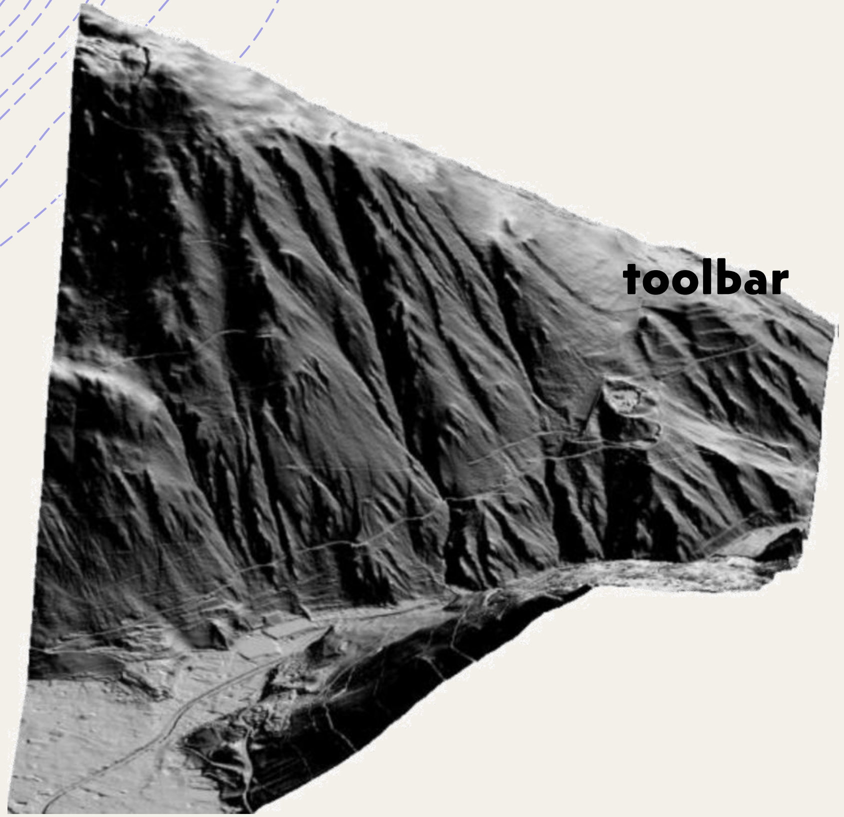
• aspect.tif:	GeoTIFF aspect file
• dhm.sav:	caching of DEM information
• dhm.tif:	DEM file used in project
• slope.asc:	ASCII file of slope, used internally
• slope.tif:	GeoTIFF slope file
• <project_name>.xml:	Input-file after project creation
• <project_name<.xyz:	DEM information, internally used

```
Project Folder
|
|—— doc
|   log files
|
|—— hillshade
|   terrain visualization
|
|—— rocks
|   rock geometry files (.pts)
|
|—— output
|   simulation results |
|—— dhm.tif
|—— aspect.tif
|—— slope.tif
└—— project.xml
```

Terrain Analysis

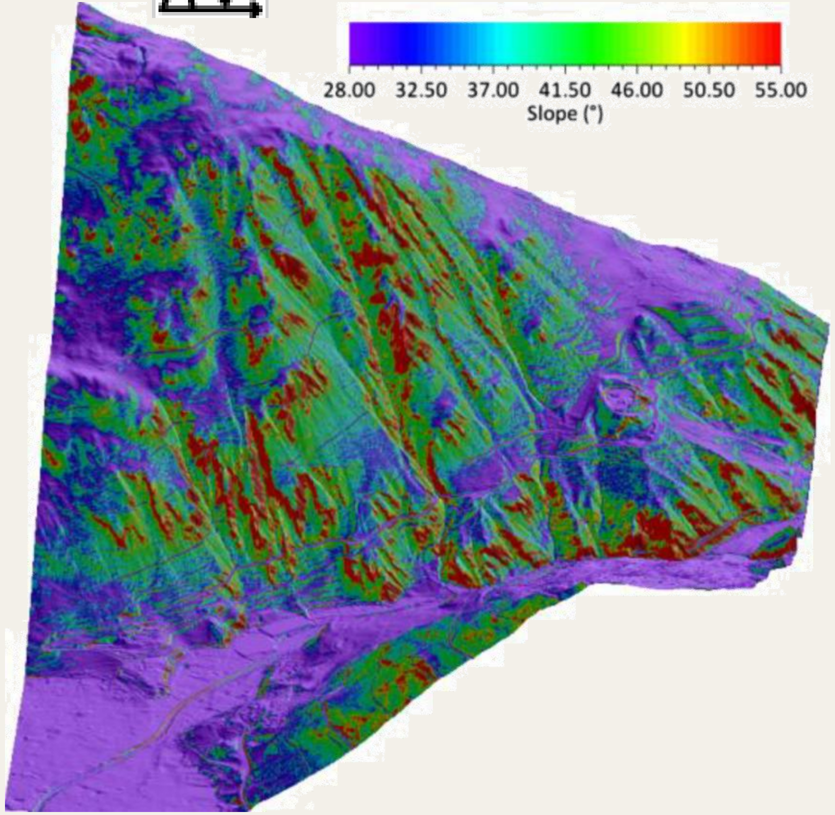
Immediately after creating a project, RAMMS provides **several tools to analyze and visualize the terrain** derived from the DEM.

Hillshade



toolbar

Slope Angle



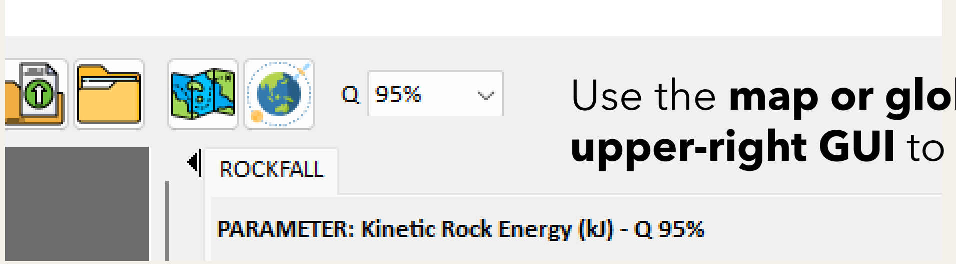
Contour Lines

Using the **toolbar**, users can quickly display **hillshade**, **slope angles**, and **contour lines** to better understand terrain features controlling rockfall trajectories.

Orthophotos and Maps

Orthophotos and map layers can be added to the DEM to **improve terrain interpretation** and help identify **release zones and important terrain features**.

Load Map/Orthophoto Layers

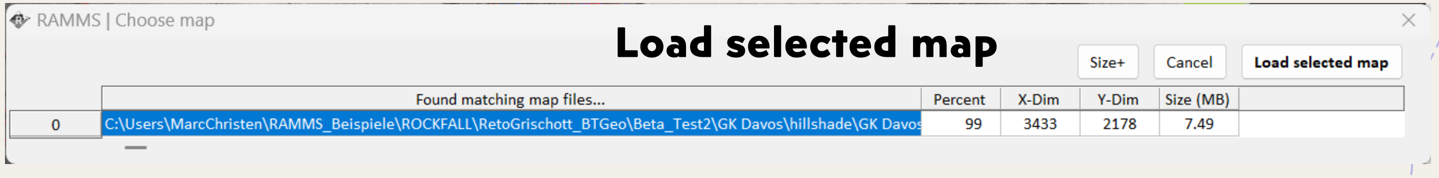


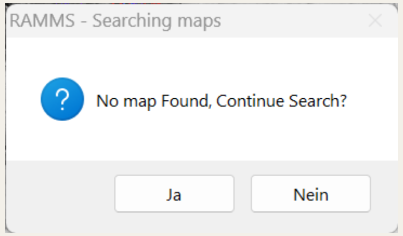
Use the **map or globe icon in the upper-right GUI** to load map layers.

If TIFF files are found

RAMMS automatically lists available **TIFF map files**. Select the desired file and click **Load selected map** to overlay it on the DEM.

Load selected map





If no TIFF files are found

RAMMS will display a dialog window asking whether to **search another folder**. Click **Yes** and choose the directory containing your map files.

Required Format

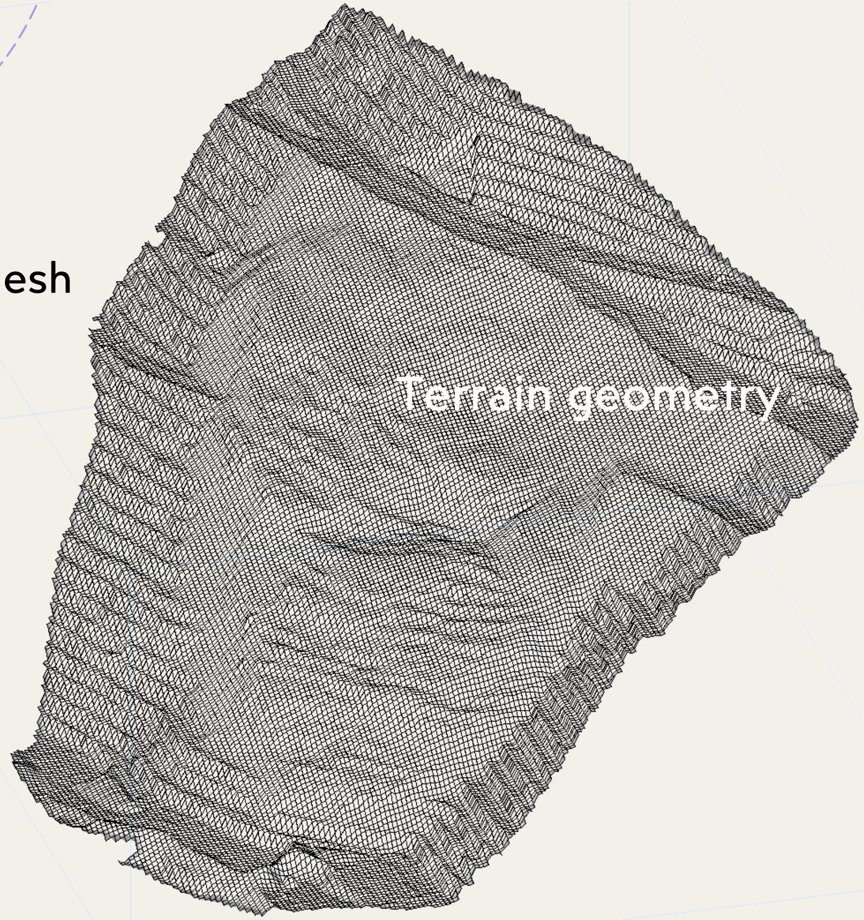
Maps must be provided as **TIFF + TFW (world file)**. If only a **GeoTIFF** is available, you can generate the required **TFW file directly in RAMMS**: ***Extras → Create TFW from GeoTIFF (World File)***

Orthophoto Overlay

Orthophotos can be overlaid on the terrain model to provide realistic surface context.

DEM with grid

Show mesh

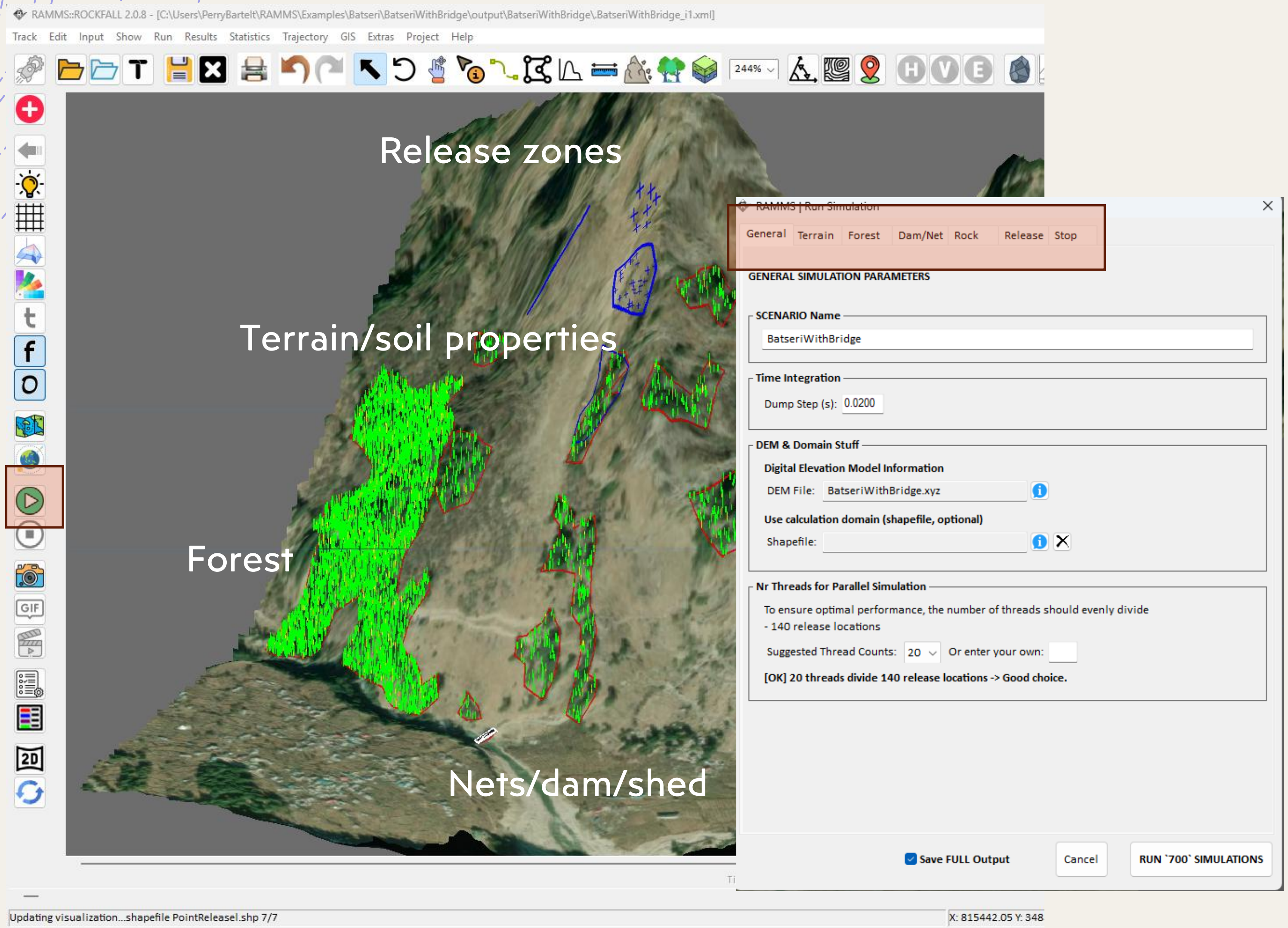


DEM with orthophoto

Orthophotos help identify:
- release zones
- roads and infrastructure
- vegetation patterns

Scenario Setup

After loading the DEM and creating the project structure, the **simulation scenario must be defined**. This is done using the **Scenario Tab** in RAMMS.



Using the Scenario Tab the user defines:

- **Starting conditions** – release points, lines, or areas
- **Rock properties** – size, mass, and shape of falling rocks
- **Terrain interaction** – ground types controlling rebound and friction
- **Forest interaction** – effects of trees on rock motion
- **Protective structures** – barriers and dams (Dam/Net tab)
- **Simulation parameters** – scenario name, dump step, and run settings

Initial State of Rockfall Simulations

1. Release geometry (n_S)

Release locations are defined as **Point**, **Line**, or **Area**, which determine the number and spatial distribution of starting locations.

2. Random orientations (n_O)

At each starting location the rock is randomly rotated, generating a statistical distribution of trajectories.

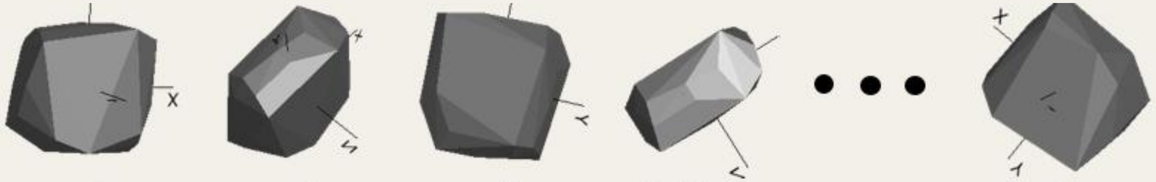
3. Initial conditions

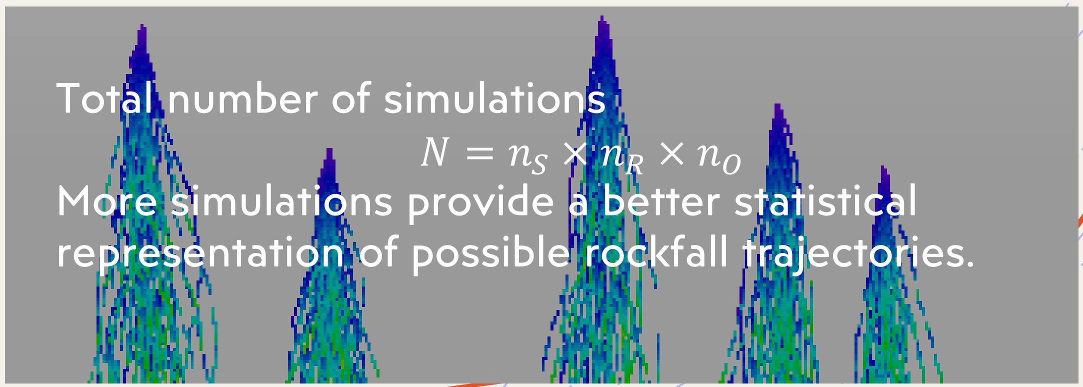
The initial energy of the rock depends on:

- Release height (z-offset)
- Initial velocity
- Initial rotation

See presentation: Starting Zones and Initial Conditions
Defining the Initial State of Rockfall Simulations in RAMMS

Point – Line – Area





Total number of simulations

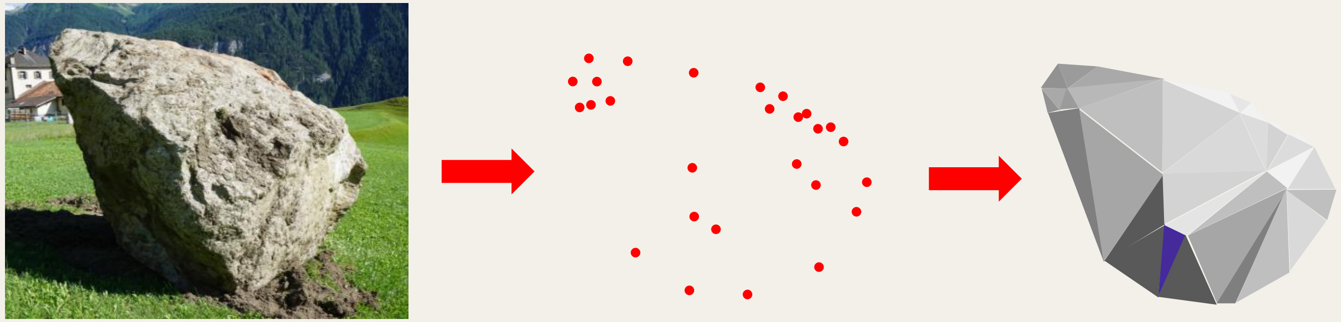
$$N = n_S \times n_R \times n_O$$

More simulations provide a better statistical representation of possible rockfall trajectories.

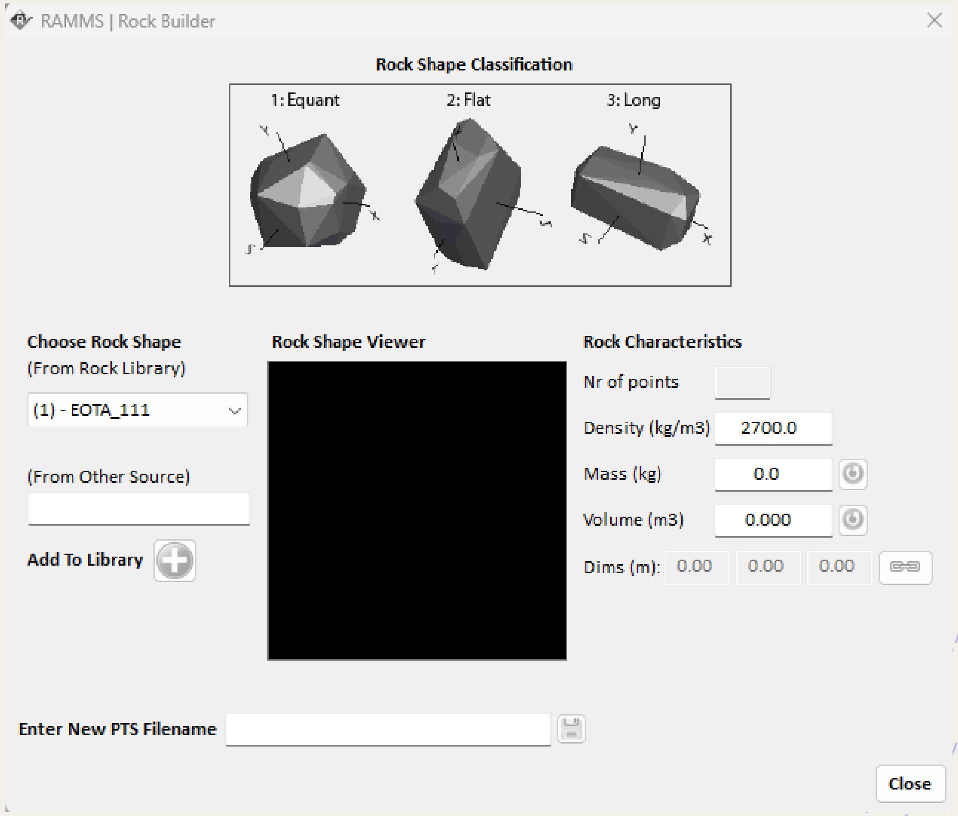
Defining Rock Shape and Size

Rock shape controls rockfall dynamics. Impact configuration determines **rotation, rebound and energy dissipation**.

Rocks in RAMMS are convex-hull point clouds Real rocks → point cloud (.pts) → convex hull geometry used to compute impacts and rotations.



Real rocks **Point-cloud** **Convex hull**



The RockBuilder creates realistic rock geometries

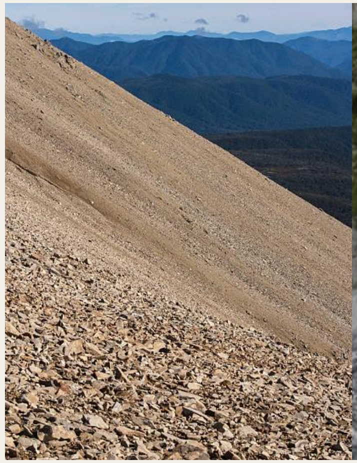
- Select or generate rock shapes
- Define volume, dimensions and density
- Save reusable rock libraries

See presentation: The RockBuilder
Generating Rock Geometry for Rigid-Body Rockfall Simulation in RAMMS::Rockfall

Energy Dissipation from Ground Impact

Field experiments show that rocks do not simply bounce — energy is dissipated through soil deformation and surface interaction.

- Impacts create **ground scars**, compacting soil and reducing rock energy
- Energy loss depends on **terrain type and soil stiffness**
- RAMMS models this using a **ground interaction (scarring) model**

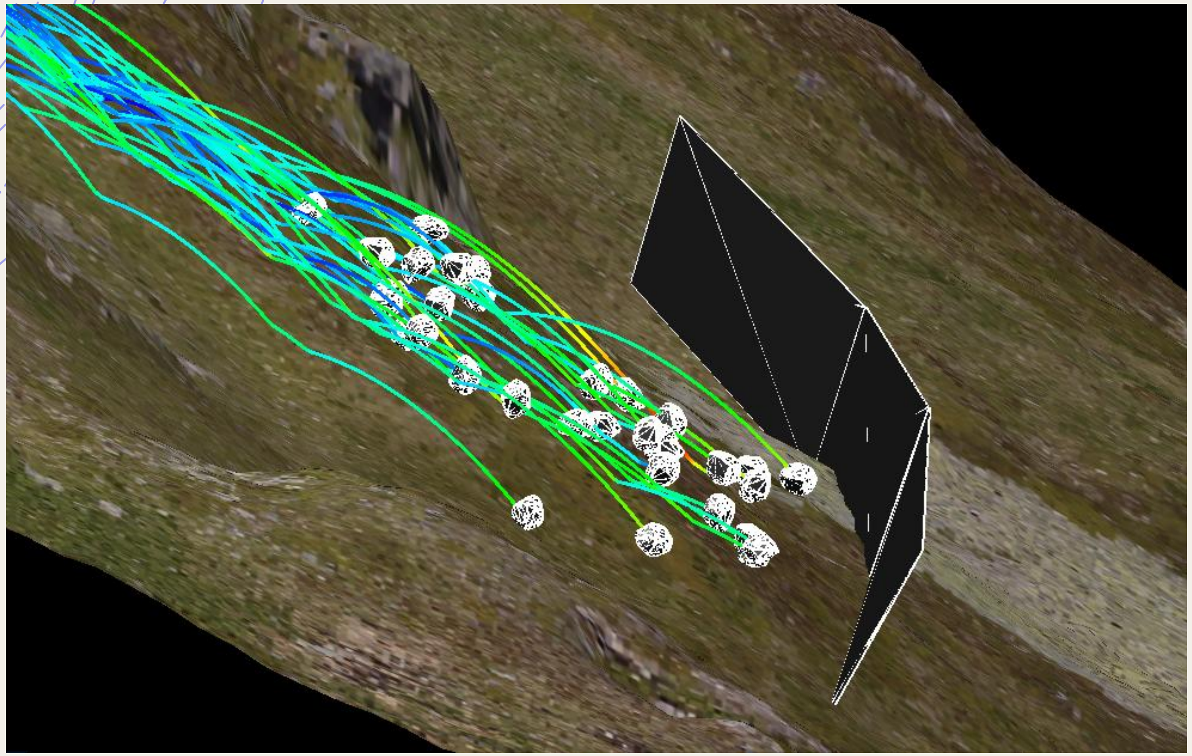


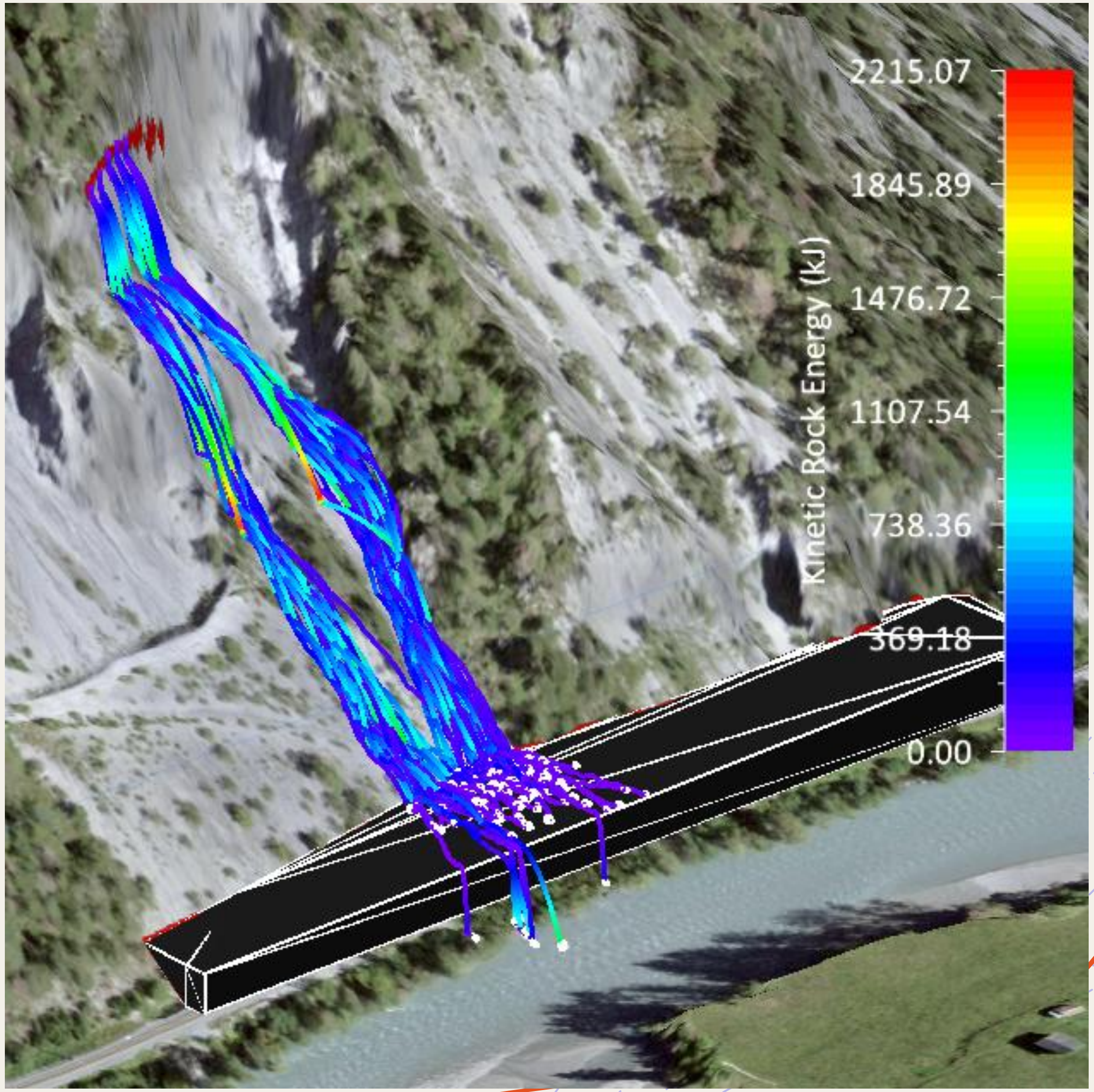


Talus Fine	**Talus Coarse**	**Talus Blocs**	**Moraine**	**Bedrock**
M_E = 7 Mpa	M_E = 10 Mpa	M_E = 15 Mpa	M_E = 20 Mpa	M_E = 100 Mpa
C_D = 2.30	C_D = 2.70	C_D = 3.50	C_D = 3.50	C_D = 4.00

Protective Structures in RAMMS

RAMMS can simulate rockfall interaction with mitigation structures such as barriers, dams, and sheds.





See presentation: Protective Structures in RAMMS::ROCKFALL
Modeling, Simulation and Performance Evaluation of Rockfall Protection Systems

Rockfall Simulation Workflow

DEM loaded

↓

Define Starting Conditions *(Release tab)*

↓

Define Rock Properties *(Rock tab)*

↓

Define Terrain Interaction *(Terrain tab)*

↓

Define Forest Interaction *(Forest tab)*

↓

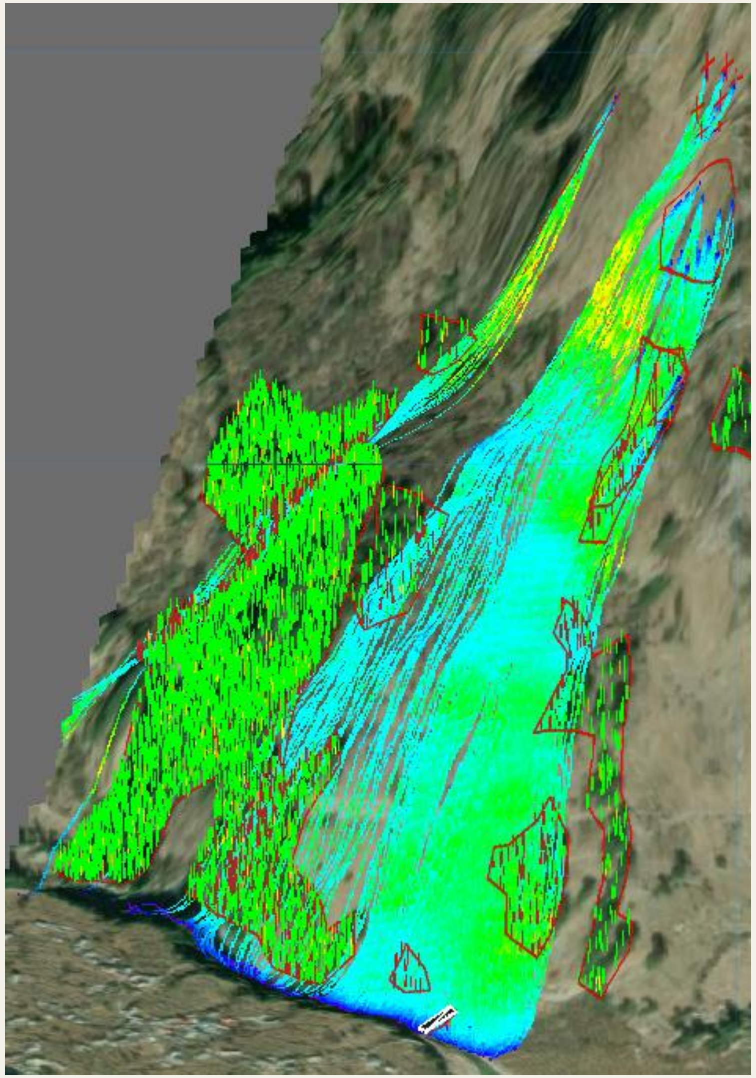
Define Barriers / Dams *(Dam/Net tab)*

↓

Set Simulation Parameters *(General tab)*

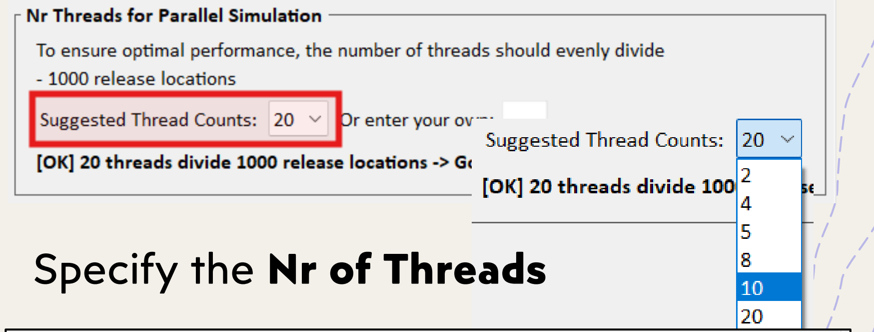
↓

Run Simulations

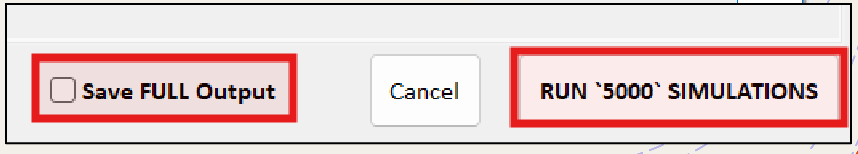


General Tab

Specify **Scenario** name



Specify the **Nr of Threads**



Before running the simulation

- Verify all tabs
- Enable **Save FULL Output** for detailed trajectories
- Disable to reduce output files

RAMMS Scenario Folder: File Structure

```
Scenario Folder
│
├── data (trajectory data + cell values)
│
├── doc (simulation log files)
│
├── obst_logs (obstacle impact logs)
│
├── reports (simulation reports)
│   └── stat_plots (statistical plots)
│
├── traj_files (trajectory files .rts / .rtc)
│
├── tree_logs (tree impact logs)
│
├── rocks.txt
├── orientations.txt
├── positions.txt
│
└── terrain files
    (scarCd.asc, scarME.asc, scarRho.asc)
```

Each simulation scenario generates a folder containing trajectory results, statistics, and simulation logs.

Key scenario outputs

- **Trajectories** – rock paths and motion data
- **Statistics** – summary plots and tables
- **Impact logs** – obstacles and tree impacts
- **Reports** – HTML and CSV simulation summaries
- **Terrain files** – parameters controlling ground interaction

Simulation results are stored **per scenario**, allowing multiple simulations within a single project.

RAMMS Scenario Folder: Key Files

Each scenario generates files used for trajectory analysis, visualization, and optional forest interaction.

- **GeoTIFF outputs** → raster maps of simulation results
- **Shapefiles** → GIS outputs of trajectories and rock locations
- **Cache files** → internal files used by RAMMS
- **Forest files** → tree interaction results (optional)

📁 Scenario Folder

- 📄 <scenario>_paCells.sav (grid cell information cache)
- 📄 <scenario>_trajAnalysis.sav (trajectory analysis cache)
- 📄 <scenario>_trajSettings.sav (trajectory settings cache)
- 📊 GeoTIFF Outputs
  - jump height
  - kinetic energy
  - velocity
  - number of rocks
  - source reach probability
- 📍 Shapefiles
  - StartPoints.shp release points
  - EndPoints.shp deposition points
  - Trajectories.shp trajectory paths
- 🌲 Forest Interaction (optional)
  - forest_trees_<scenario>.txt
  - forest_trees_<scenario>.txt.sav
  - <scenario>_treecollisions.sav
  - <scenario>_treecollisions.shp
  - <scenario>_destroyed_trees.shp

Statistics Mode vs Trajectory Mode

RAMMS rockfall simulations produce **thousands of trajectories**.

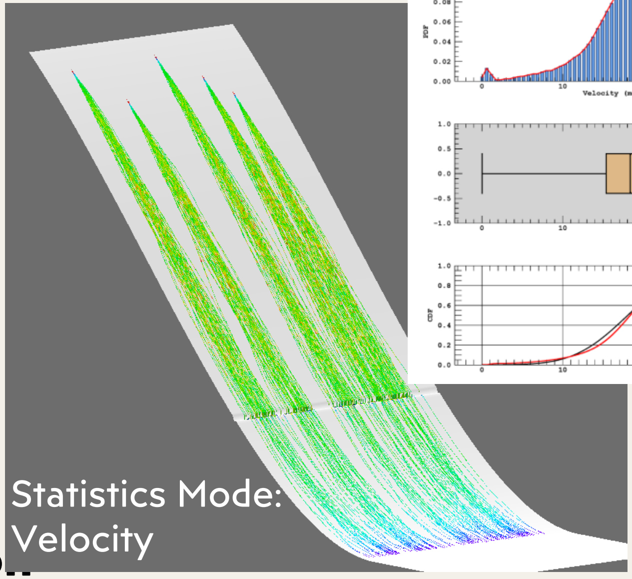
Statistics Mode answers: *What is the representative impact in this location?*
Trajectory Mode answers: *What actually happened to individual rocks?*

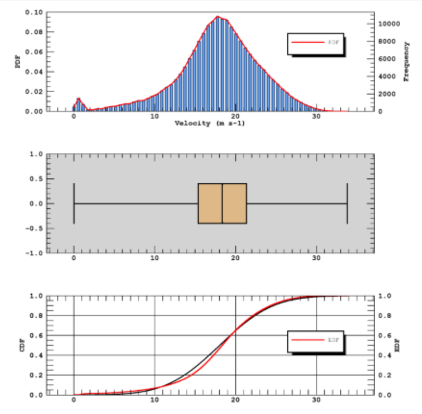
Statistics Mode

- Evaluates **all trajectories together**
- Results stored **per raster cell**
- Produces **hazard maps**
- Used for **engineering design**

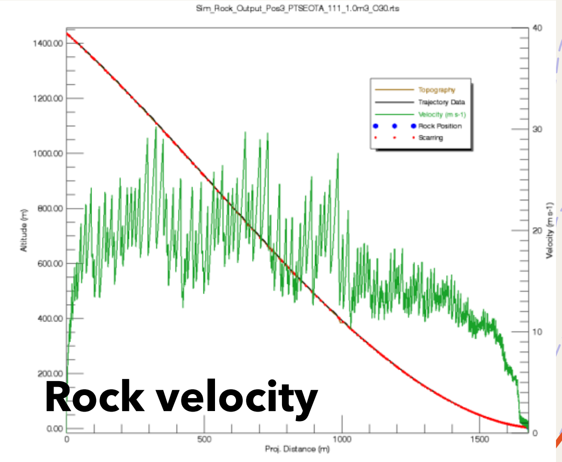
Trajectory Mode

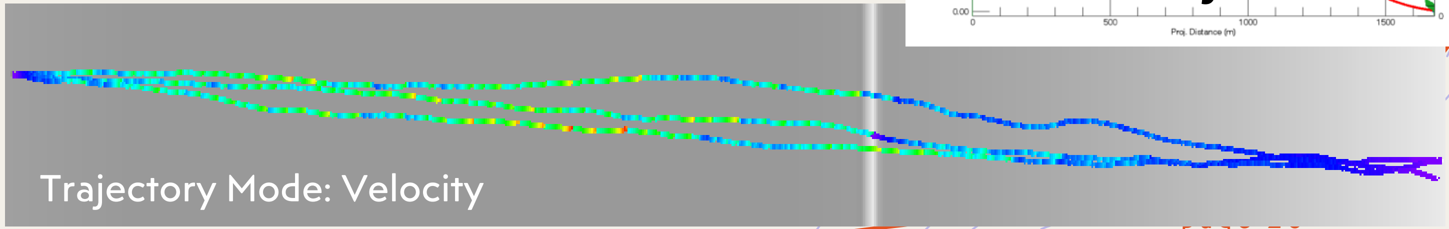
- Shows **individual rock paths**
- Used to inspect **specific events**
- Useful for **debugging** or **interpretation**





Statistical distribution PDF/CDF
kinetic energy Q95 map
jump height map
reach probability





See presentation: Understanding RAMMS Outputs:
Statistics Mode vs Trajectory Mode
Interpreting rockfall simulations for engineering analysis

Summary

1. **Terrain data forms the foundation of the simulation**
   A high-quality Digital Elevation Model (DEM) defines the terrain geometry and strongly controls simulated rockfall trajectories.

2. **A RAMMS project links terrain data to the simulation environment**
   Creating a project automatically generates the file structure and prepares the terrain model for analysis and simulation..

3. **Scenario setup defines the physical rockfall problem**
   Users specify release zones, rock properties, terrain interaction, forests, and protective structures.

Summary

4. **Initial conditions determine the statistical ensemble of trajectories**
   Release locations, random rock orientations, and initial energy conditions produce many possible rock paths.

5. **Ground interaction controls energy dissipation**
   Rock impacts dissipate energy through soil deformation and terrain roughness, which are represented using terrain categories.

6. **Simulation results must be interpreted statistically**
   Thousands of trajectories are analysed using **Statistics Mode** (hazard maps) and **Trajectory Mode** (individual rock paths).

Thank you for your attention!