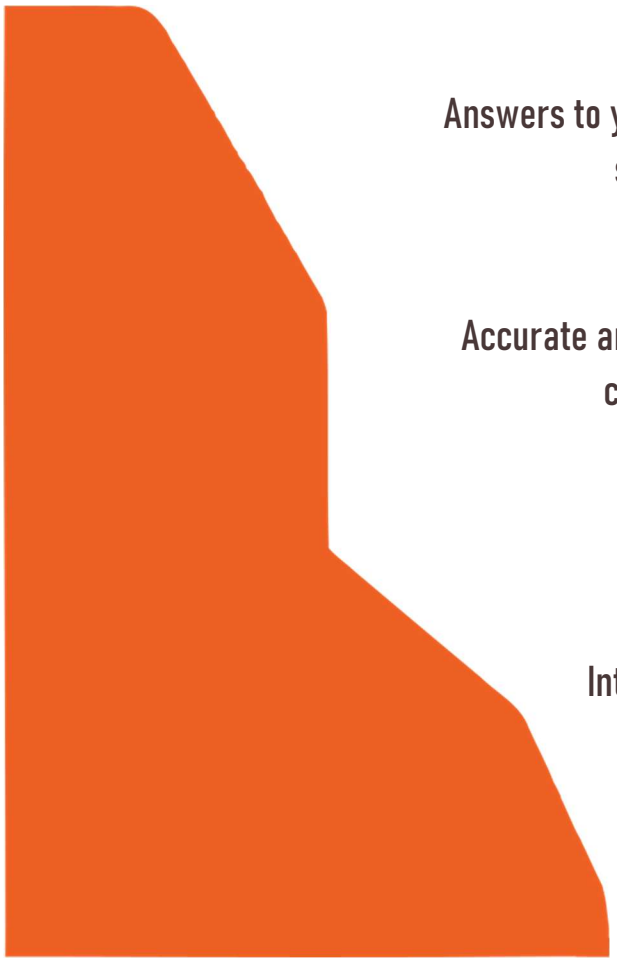
RocPro3D

3D assessment of rockfall hazard and risk mitigation

Professional 3D stochastic trajectometric simulation software for:

- **Land-use planning** to assess the risk of rockfall at the desired scales
- **Civil engineering** to dimensioning the protective works
- **Extractive industry** to evaluate rockfall hazard after each cutting phase for protecting workers and the industrial infrastructure



Answers to your rockfall problems thanks to exhaustive 3D simulations (without a priori hypotheses on the trajectories path)

Accurate and fast calculations, allowing simulations to be carried out at very low probabilities (10^{-4} to 10^{-6})

Intuitive and user-friendly interface

Integrated tools for a rapid statistical analysis of trajectometric calculations, allowing the dimensioning of protective structures and the production of hazard maps following the CADANAV or MEZAP methodologies

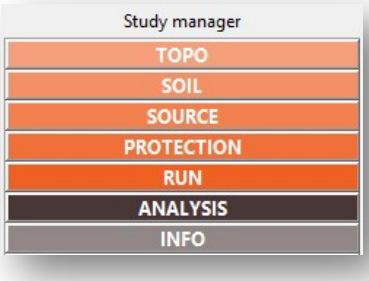
Quick to get started, intuitive to use

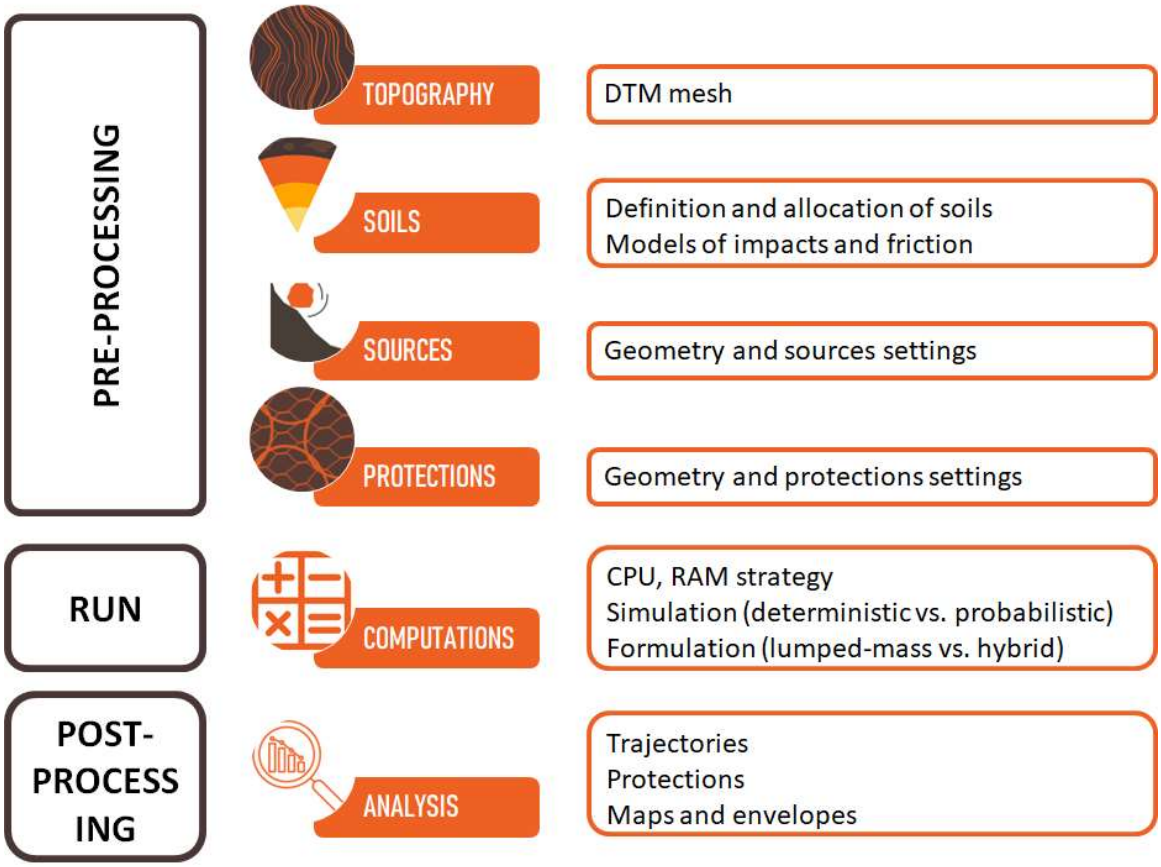
Full integration via the study manager

Pre-processing, calculation and post-processing tools

Simplified model setup, with step-by-step guidance

Integrated and optimized pre-processing (DTM, creation and assignment of soils, sources and protections), allowing you to focus on interpreting the results





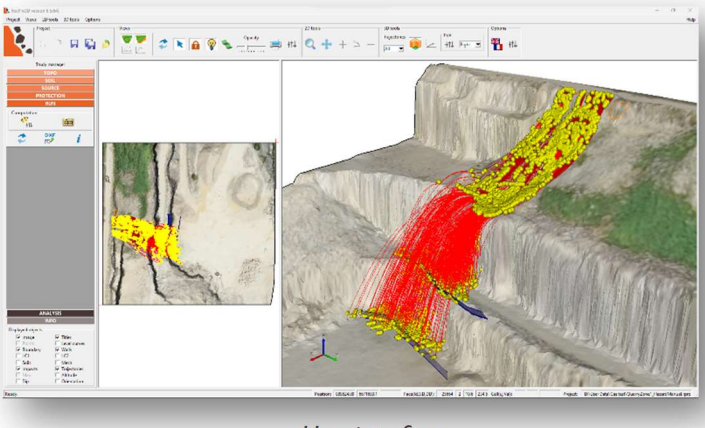
Steps for implementing the simulations

Rapid visualization and analysis of results, facilitated by interactive and scalable views

2D and 3D views, with results at each impact (XYZ coordinates, height, soil, time, velocities before and after impact, energies)

Vertical profile view of the analysed result (energies, velocities, height, time) for each trajectory or to the right of the protections

Statistical analysis (histograms, indicators, tables) on trajectories, protections, envelopes



User interface

Physical models

Formulation

Hybrid (lumped-mass with finite size block), for free-fall, impacts and frictional rolling

Impacts

Dissipation via restitution coefficients (R_N, R_T), R_N being constant or velocity dependent $R_N(V_N)$

Effects related to block rotation considered

Frictional rolling

Dynamic frictional (Coulomb) rolling model, numerically integrated with geometric accuracy control

Transitions

Geometrical conditions to allow switching between free-fall and translation kinematics and vice versa

Stochastic approach

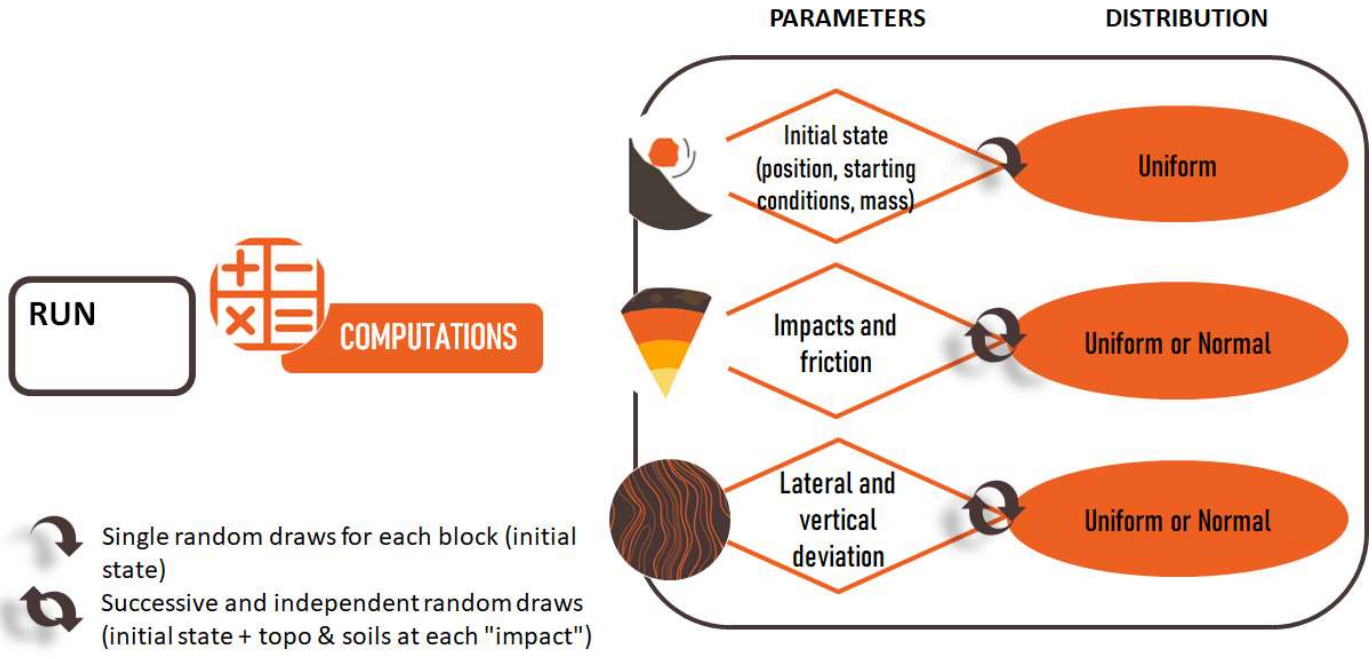
Computation modes

Deterministic mode

Probabilistic mode (Monte-Carlo type stochastic) with choice of variables (Gaussian or equiprobable) for the properties:

- Soils (restitution and friction coefficients, lateral deviation, rebound flattening)
- Blocks (initial starting condition, initial position, mass, rebound perturbation)

Different RAM management strategies for the simulations, adapted to the purpose of each study (e.g. design of mitigation structures or hazard assessment)



Principle of the probabilistic approach used in RocPro3D

Topography

Creation of DTM

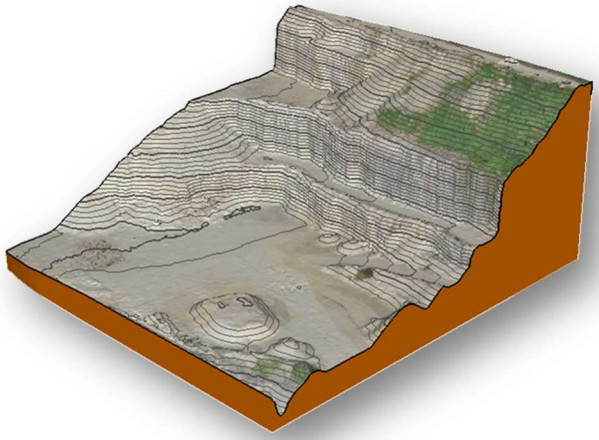
From 2D profiles, imported DTMs (DEM, regular or irregular triangular meshes) or topographic maps

DTM realism

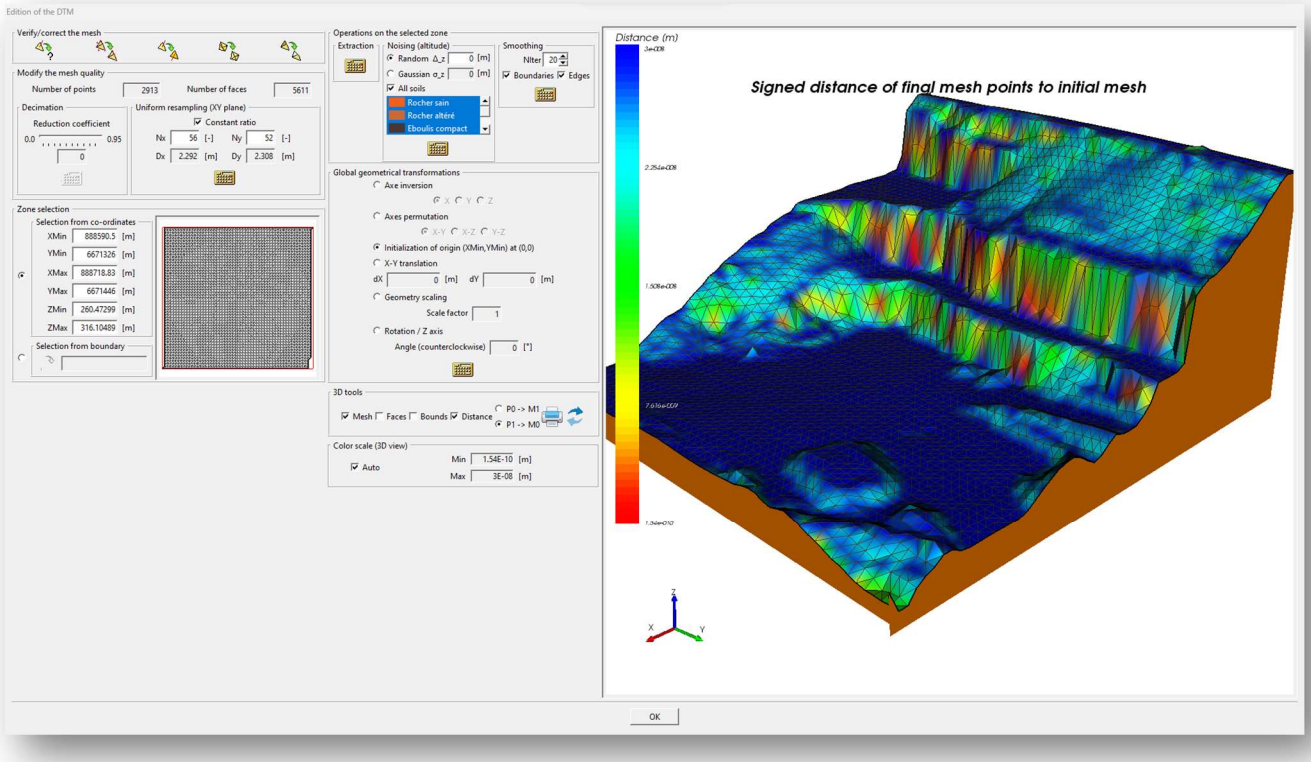
Overlay of topographic contour lines and image mapping

DTM edition

Non-conforming mesh detection, decimation, resampling, zones extraction, noising, smoothing, geometric transformations



DTM with level curves and ortho-image



DTM edition: distance map (Hausdorff) between initial mesh and resampled mesh

Soils

Soils and physical parameters

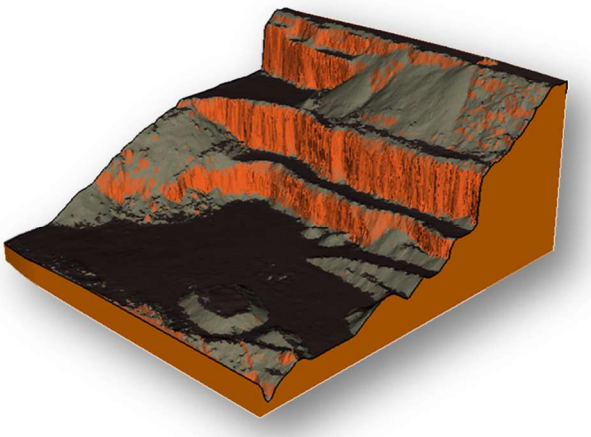
Predefined or user defined

Dissipative model $R_N(V_N)$

Specific to each soil

Quick assignment of soils to the DTM

By faces, by zones or by filters (XY coordinates, elevation, dip, orientation)

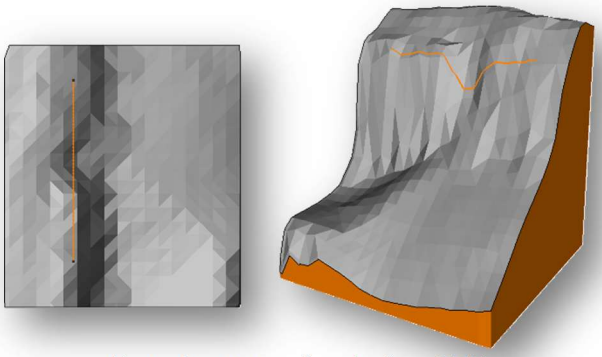


Soils assigned by multiple filters

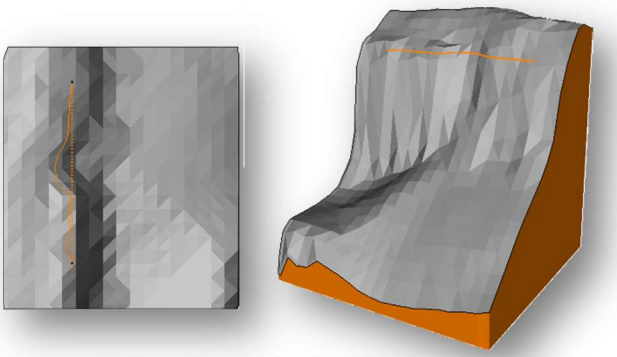
Sources of starting blocks

Easy positioning by projecting (horizontally or vertically) the source baseline onto the **DTM**
Possible **import** from **shapefiles** or **points files**
Linear or **surface geometry**
Number of blocks per source or **global block density** for all sources. **Selection of:**

- **Initial conditions:** initial fall, initial velocity or mixed
- **Block properties**: size, density, shape



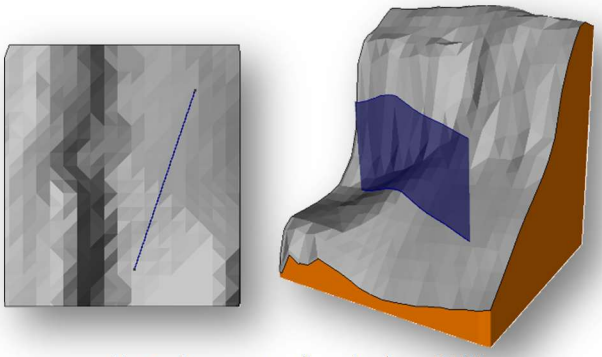
Vertical projection (baseline) on DTM



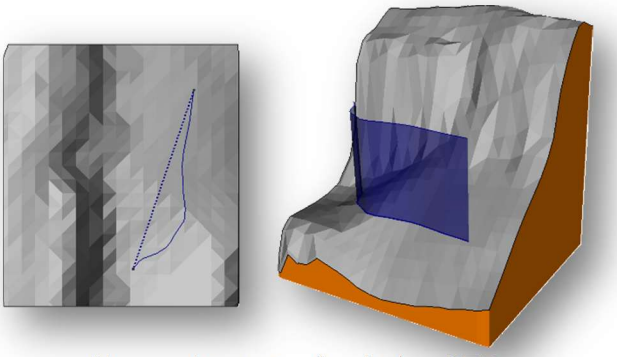
Horizontal projection (baseline) on DTM

Protection structures

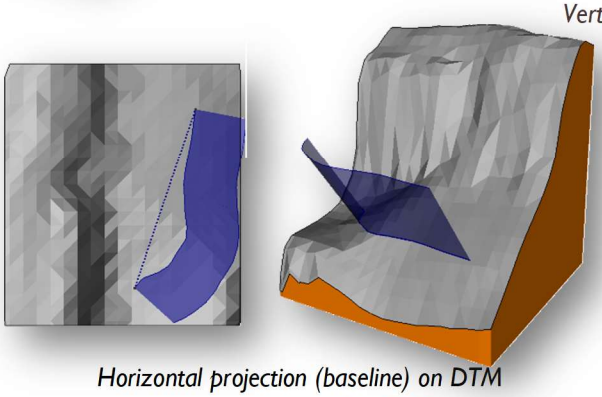
Easy positioning by projecting (horizontally or vertically) the protection baseline onto the **DTM**
Possible **import** from **shapefiles** or **points files**
Real (nets, merlons) **or fictive** (data collectors) **protection**, with an inclination **vertical, normal** to the DTM, or **angular** to the vertical)



Vertical projection (baseline) on DTM
Vertical protection



Horizontal projection (baseline) on DTM
Vertical protection



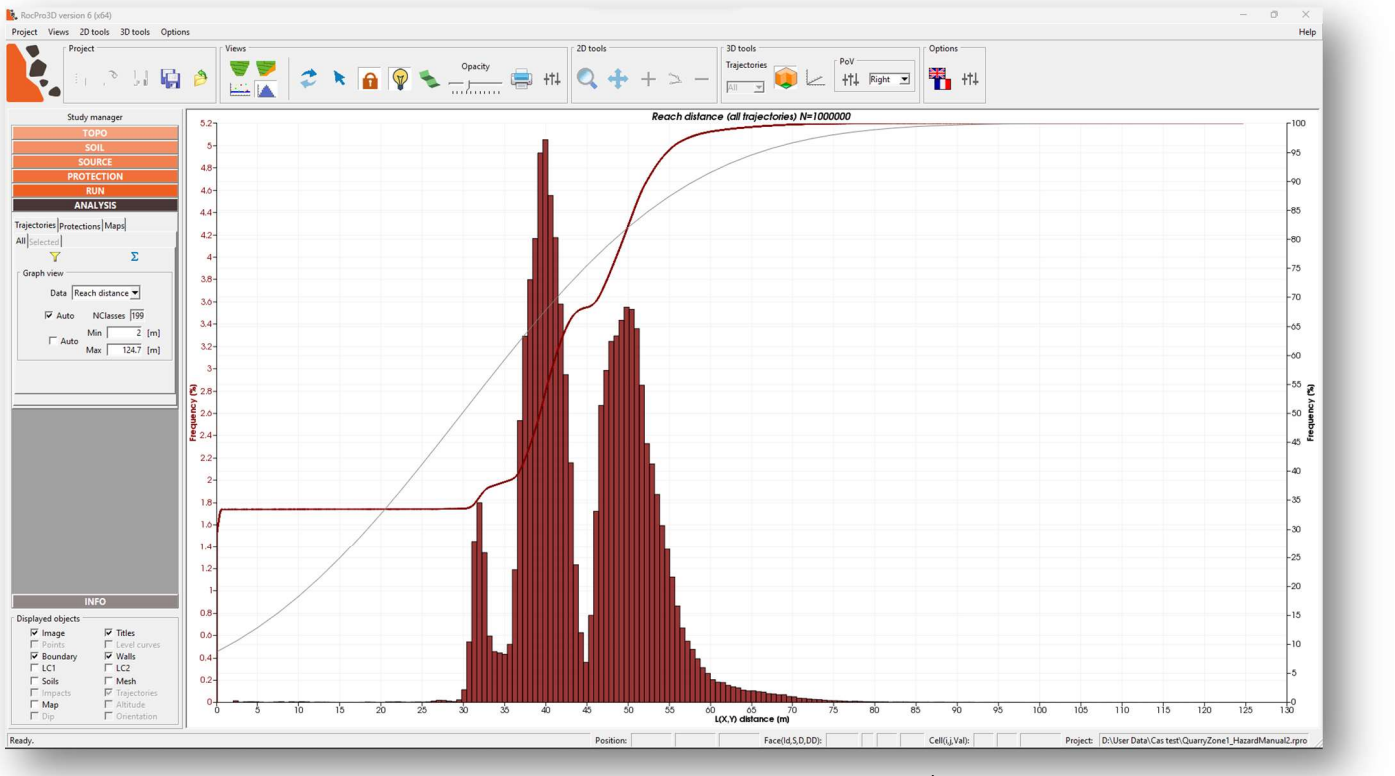
Horizontal projection (baseline) on DTM
Protection normal to DTM

Trajectories: from global to local scale

Global analysis of all the trajectories

Visualization of block trajectories and impacts in 2D and 3D views

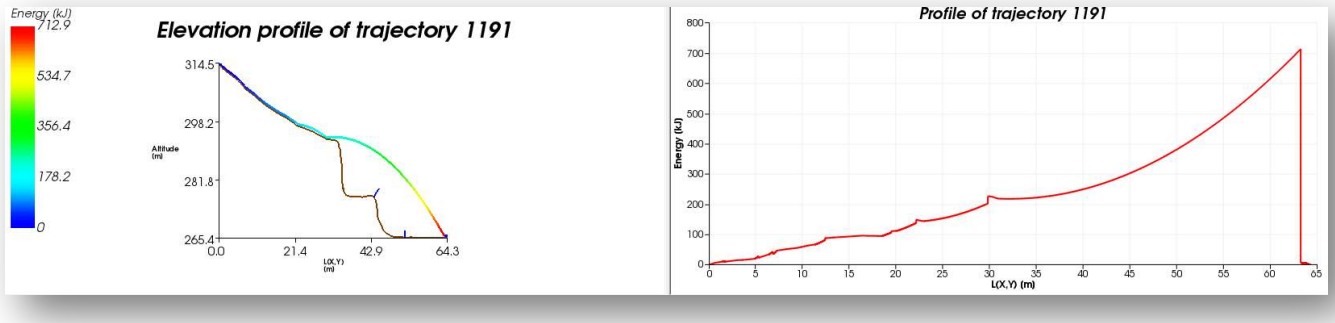
Analysis of the **distribution of reached distances** and **travel times** for **all blocks**, with possible filtering by **block source**



Histogram of the blocks reached distances [simulation with 10^6 blocks]

Detailed analysis of individual trajectories

Evolution of energies, velocities, heights, and time on the elevation profile of the trajectory or along the selected trajectory



Example of energy analysis for a trajectory: elevation profile (left) and profile (right)

Possibility to export all calculated results for trajectories as ASCII or DXF files

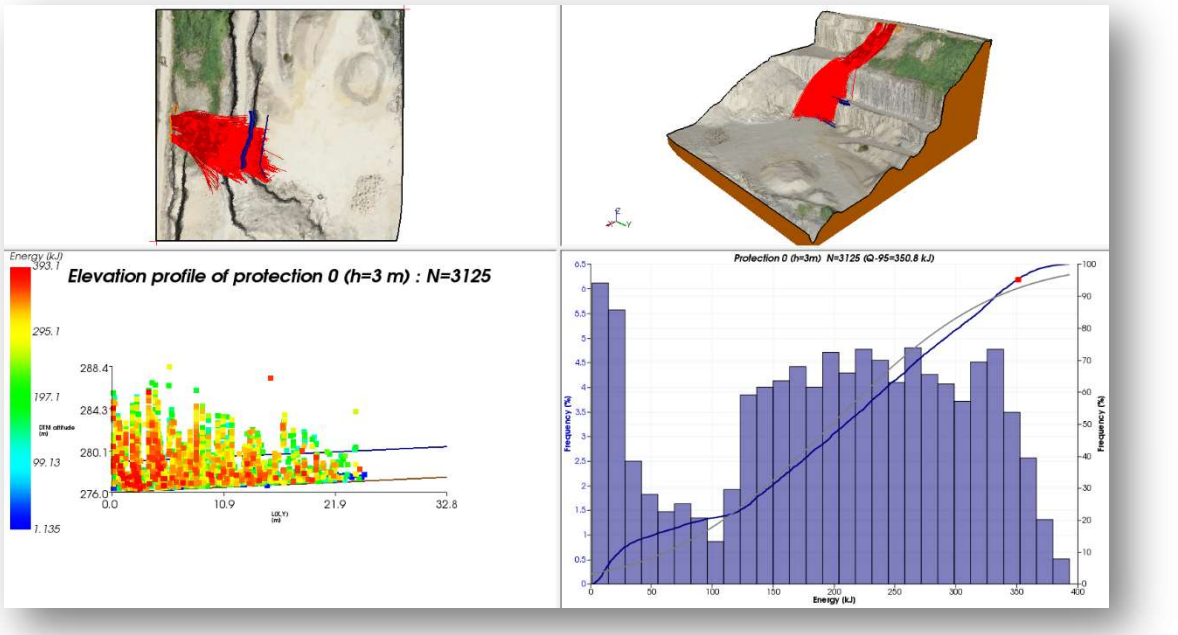
Protections structures: elements for dimensioning

Visual analysis of the trajectories in line with protections

For all blocks intersecting the polyplane of a protection, visualization of the analysed result (travel time, energy, velocity, impact height) according to the elevation profile of the protection

Statistical analysis of the trajectories in line with protections

Statistics (mean, max, confidence limits, quantiles, Kolmogorov-Smirnov hypothesis test), **cumulative frequency curves** and **statistical convergence indicator** for all blocks crossing a protection (travel time, energy, velocity, height)



Example of analysis on protection: elevation profile (left) and associated statistics (right) – [simulation with 10^4 blocks]

Possibility of refining the analysis by applying filters on the block sources, on the protection part and on the type of impact

Synthesis of the analysis as summary tables for the different types of intersection

Protection Id 1 (full length: 0-33.16 m)
Net: height=2 m, capacity=500 kJ
Properties of blocks reaching or passing over the protection :
Mass[kg] : Min=654.5, Max=1963.5
Volume[m3] : Min=0.2618, Max=0.7854
2/2 sources taken into account, Ids:
0, 1

Tables 1-3 | Tables 4-5

All the blocks (N=1209 ; 100%)

	Min	Max	Mean	StDev	CL-99	CL-95	CL-90	CL-68	Q-99	Q-95	Q-90	Q-80	Q-50	KS-d	KS-p
Energy [kJ]	0.008	638.6	125.5	175.1	576.6	468.7	413.5	299.6	596	512.1	440.6	284	22.39	0.263	0
Energy(T) [kJ]	0.005	606.4	112.8	165.1	538	436.4	384.3	277	561.5	483.5	413.5	261.8	16.39	0.286	0
Energy(R) [kJ]	0.002	88.95	12.68	13.28	46.88	38.7	34.52	25.88	51.16	36.07	32.18	25.5	6.26	0.186	0
Velocity(T) [m/s]	0.094	25.43	9.631	8.911	32.58	27.1	24.29	18.49	25	24.66	24.14	23.12	5.157	0.195	0
Velocity(R) [m/s]	0.192	30.55	11.97	7.4	31.03	26.48	24.15	19.33	26.35	23.18	21.72	19.59	10.36	0.142	0
Height [m]	0	18.2	1.541	2.419	7.772	6.282	5.52	3.946	13.25	6.777	4.653	1.746	0.539	0.374	0
Time [s]	6.145	14.23	9.066	1.308	12.43	11.63	11.22	10.37	12.05	11.08	10.76	10.21	9.207	0.082	0

Possibility to modify the geometry and position of fictitious protections in post-processing, allowing to refine the geometry of protection structures

Maps and envelopes: elements of dimensioning and hazards assessment

Analysis grid

Definition of raster grids for maps and envelopes (cells dimensions independent of the mesh)

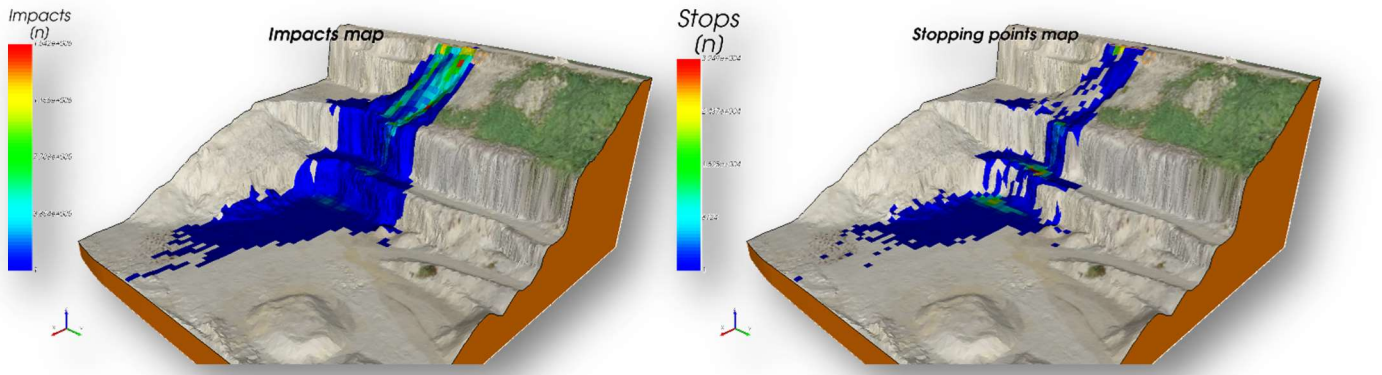
Maps and envelopes

Maps are the spatial representation of the analysed result as a field. In order to refine the analysis for certain fields, specific maps, **the envelopes**, make it possible to select the statistical indicator considered relevant.

A total of 9 maps and 3 envelopes are available to evaluate the dimensioning of protection structures or to assess hazards

Generic maps	Protections dimensioning	Hazards assessment
Map of number of trajectories	Envelope of energies	Map of energy classes
Map of number of trajectories/SrcCell	Envelope of velocities	Map of trajectories density
Map of impacts	Envelope of height	Map of P(propagation)
Map of stop points	Map of minimum travel time	Map of classes of P(propagation)

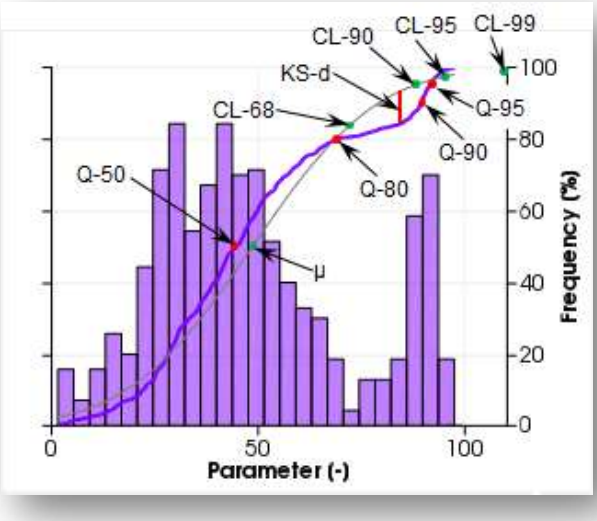
Generic maps



Example of impacts map (left) and stop points (right) – [simulated with 10^7 blocks]

Statistical indicators of envelopes

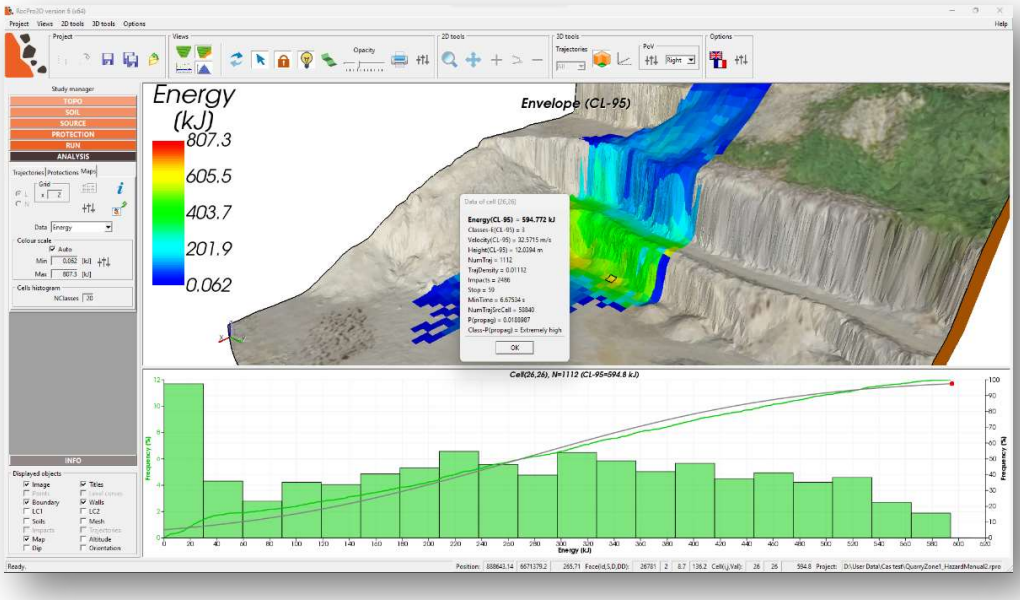
Various statistical parameters (min, max, mean, quantiles, confidence limits, normality test) are available to select the relevant envelopes for analysis



The different statistical indicators available for the envelopes

Statistical analysis of the envelopes at the level of the grid cells

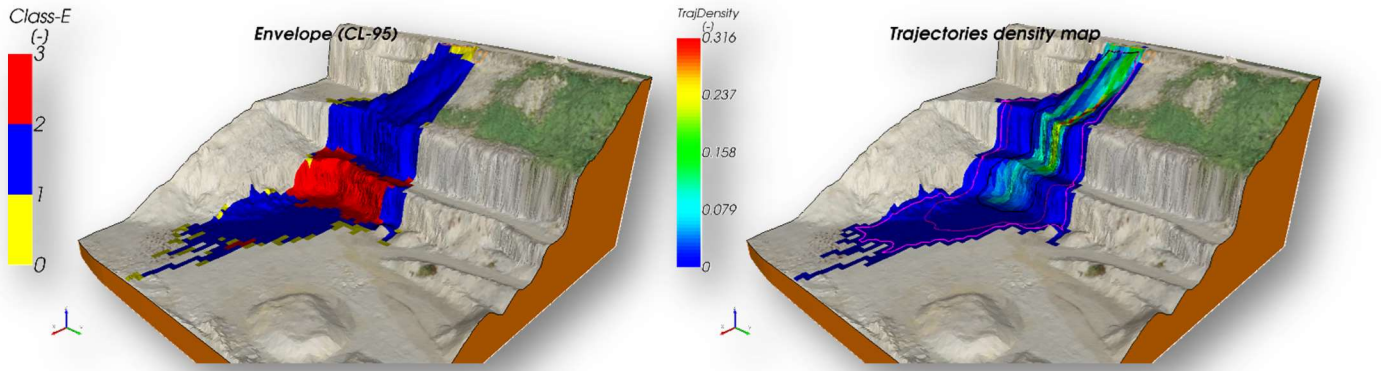
In some cases, statistical analysis (mean, standard deviation, median, histogram and cumulative frequency curves) of the population of each cell may be required to verify the relevance of certain high statistical values observed locally (in particular for the confidence limits)



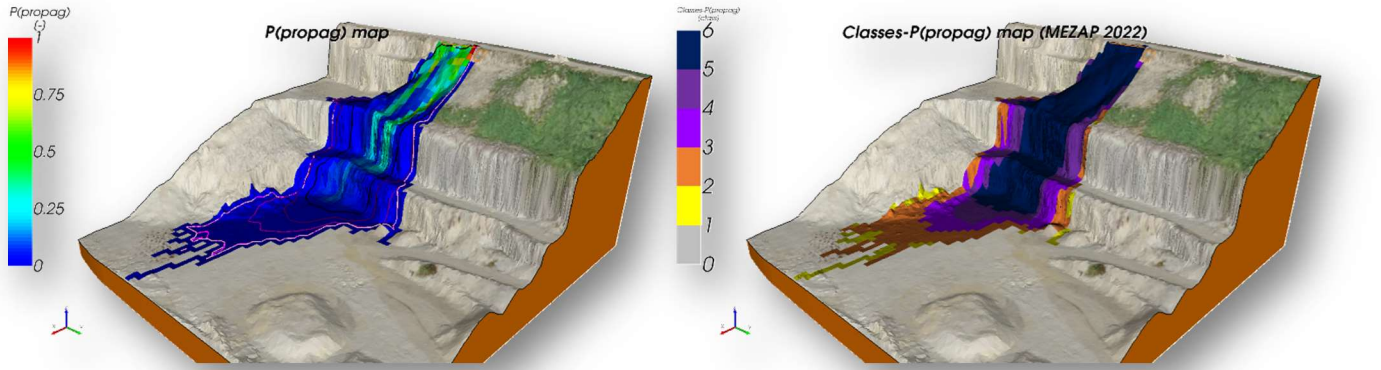
Example of statistical analysis at the scale of an envelope cell – [simulation with 10^5 blocks]

Hazard assessment

Various maps allow to evaluate different hazards according to the CADANAV (2013) or MEZAP (2022) methodologies



Example of energy classes envelope according CADANAV (2013) (left)
and trajectories density map (right) – [simulation with 10^7 blocks]



Example of P(propagation) map (left)
and classes of P(propagation) maps according MEZAP (2022) (right) – [simulation with 10^7 blocks]

RocPro3D

Would you like a trial or demonstration of the software?
Contact us

rocpro3d@rocpro3d.com
www.rocpro3d.com

Several licensing types to suit your needs

- Node-locked or floating (with possibility of roaming)
- Professional or education
- Perpetual or subscription (monthly, half-yearly or annual)
- Maintenance contract including upgrades

Required configuration

- 64 bits Windows 7, 8, 10 or 11
- Intel Core i5, i7, i9 (Xeon strongly not recommended), AMD Ryzen 5, 7, 9
- Minimal disk space of 200 Mb
- 3D graphic card