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SPH Simulations of the LCROSS impact

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Purpose of the simulations

- Investigations of

  - **the crater formation**

  - **ejecta dynamics**

  - **provenance of ejecta** (initial depth in the target)

- Influence of the **surface topography**?

- Target material properties: **effect of porosity**?

  → Results can help to determine an appropriate impact site

Numerical Method

- Our numerical tool is based on the 3D Smooth Particle Hydrodynamic (SPH) method

- To simulate solids, standard SPH was extended to include a strength and fracture model (Benz & Asphaug 1994)

- Our **3D SPH impact code** can be used to model impacts and collisions involving solid bodies in the strength- and gravity-dominated regime.

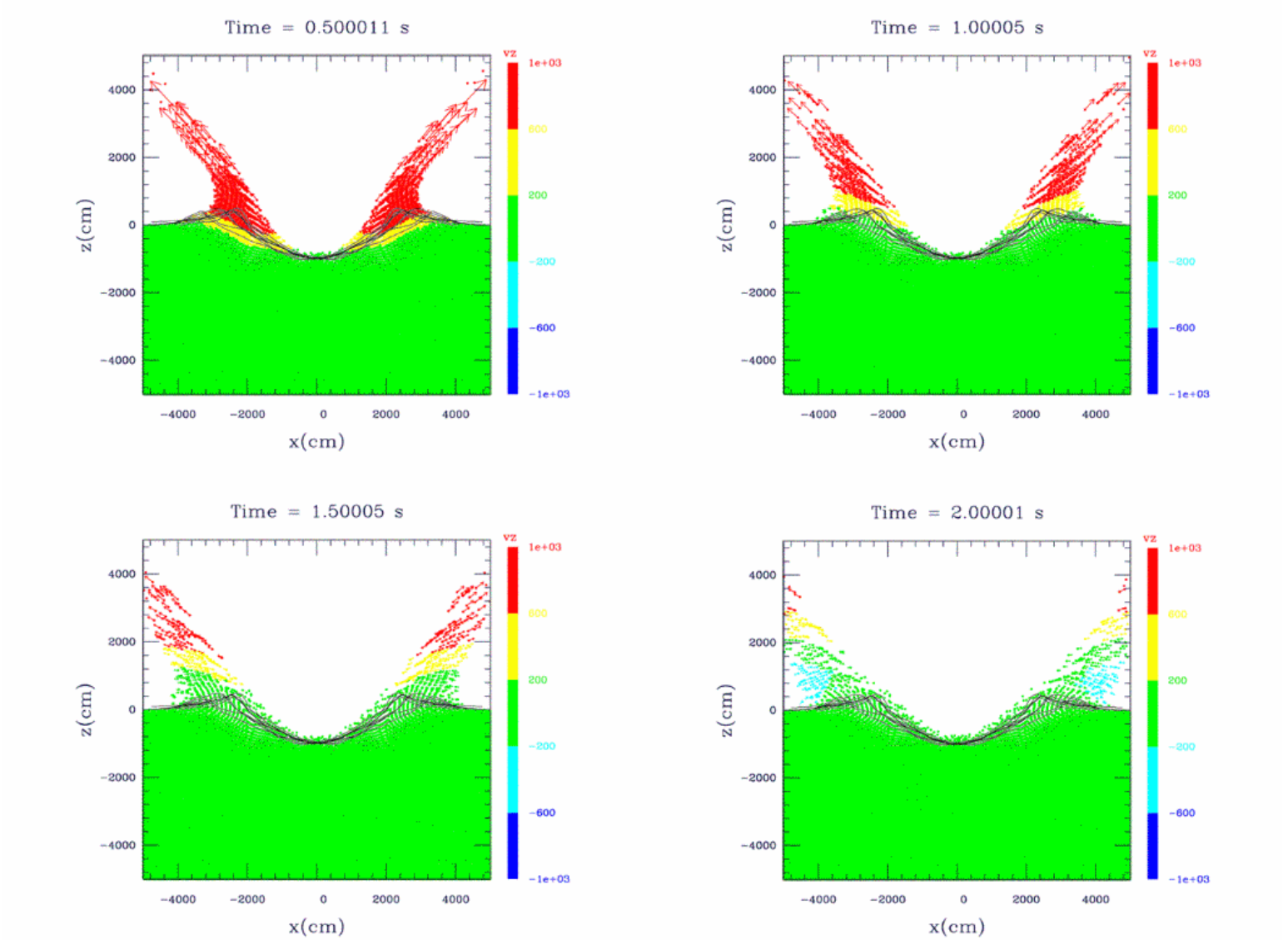
- Recently, our code was extended to include a porosity model. The model is based on the P-alpha model (Herrmann 1968) which was adapted for implementation in our code.

Example

Explosion crater (0.5KTon TNT)

Example

SPH simulation compared to craterprofile



Initial conditions (Target)

- Three different **target** types are investigated:

  1) Flat surface, target density: $\rho_0 = 1.8 g/cm^3$

  2) Flat surface, $\rho_0 = 1.8 g/cm^3$, porosity (33%) is explicitly modelled

  3) Little hill (6m) on an otherwise flat surface, $\rho_0 = 1.8 g/cm^3$

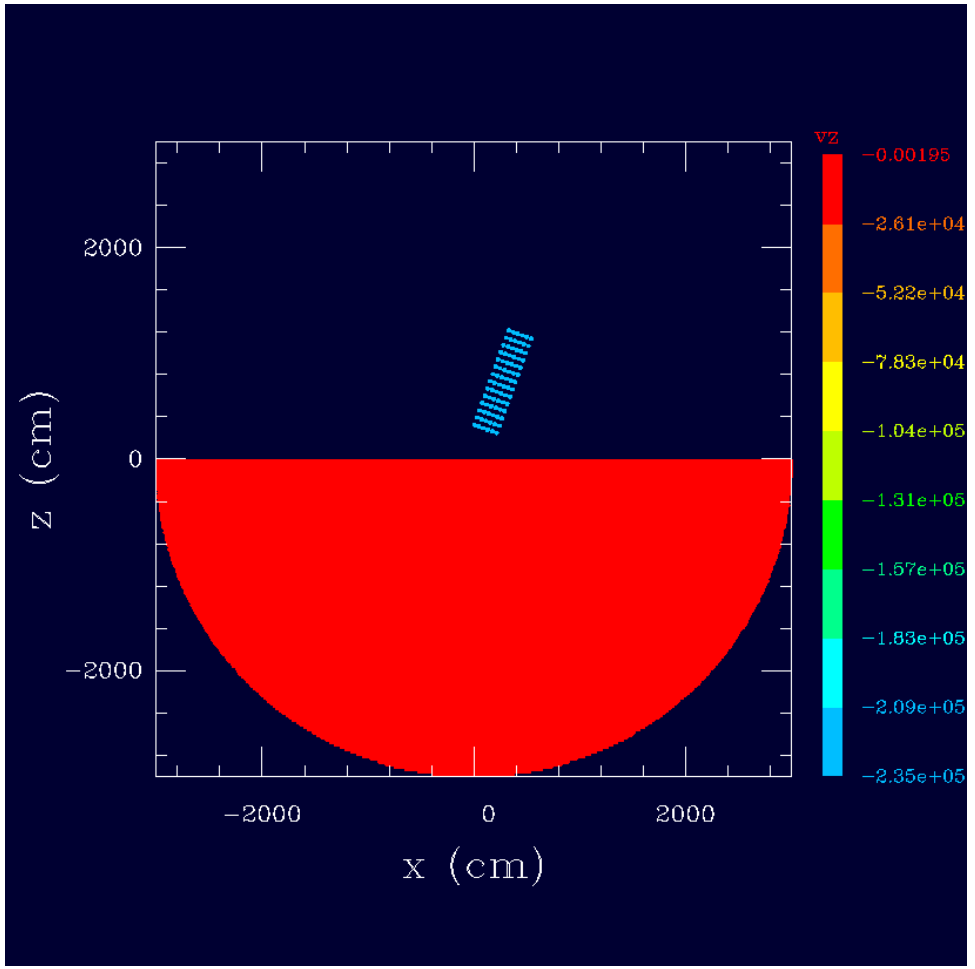
Initial conditions (Target)

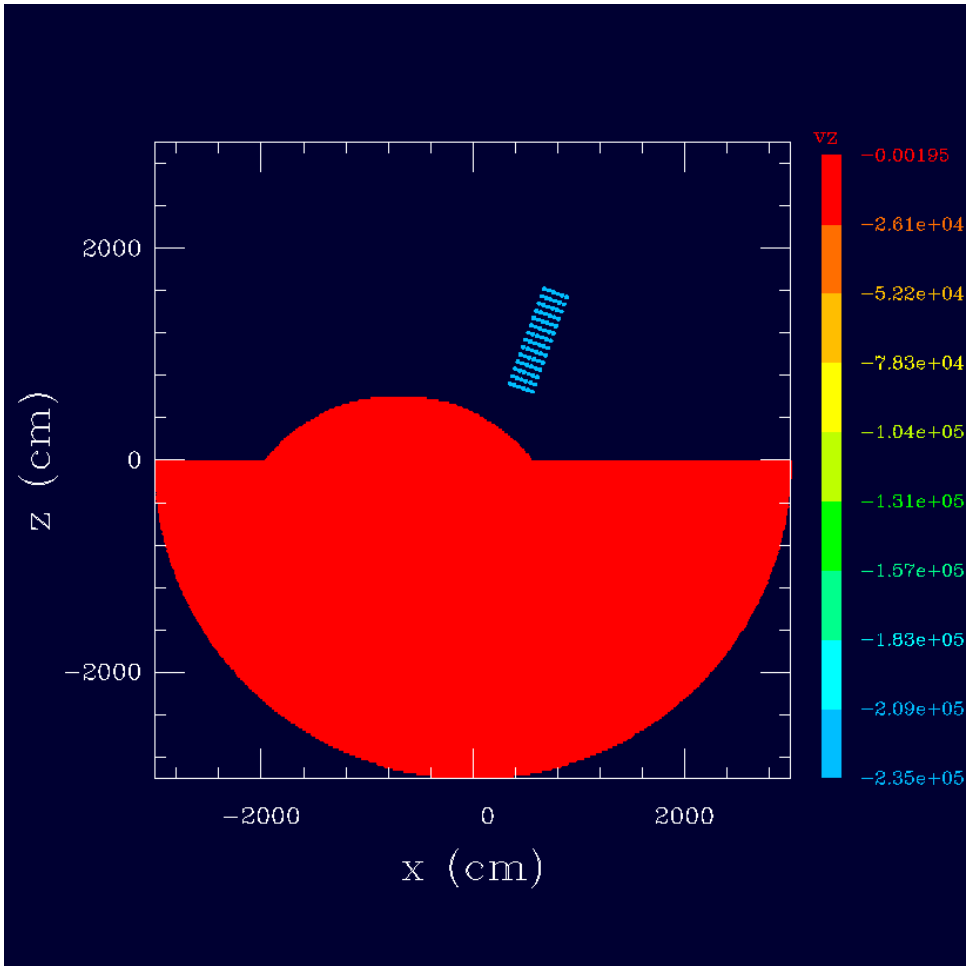
- **Target** material type:
  - pre-damaged (strengthless) basalt (with a modified ρ_0)
  - material described by the Tillotson EOS
  - ANEOS: low density of the projectile is a problem...

Initial conditions (Projectile)

- **Projectile**
  - 3 x 10m Aluminium cylinder of m=2000Kg
  - Density: ρ=0.03g/cm^3
  - Impact angle: 70° (from horizontal)
  - Impact velocity: 2.5km/s

Initial conditions (Impact geometry)





Initial conditions (Resolution)

- **Resolution**:
  - A volume of $6*10^{10}$ cm^3 is simulated (half-sphere of 30m radius)
  - 3.5 million SPH particles are used (placed on a hcp grid)
    - → particle mass: 28 Kg
    - → spatial resolution: 25 cm

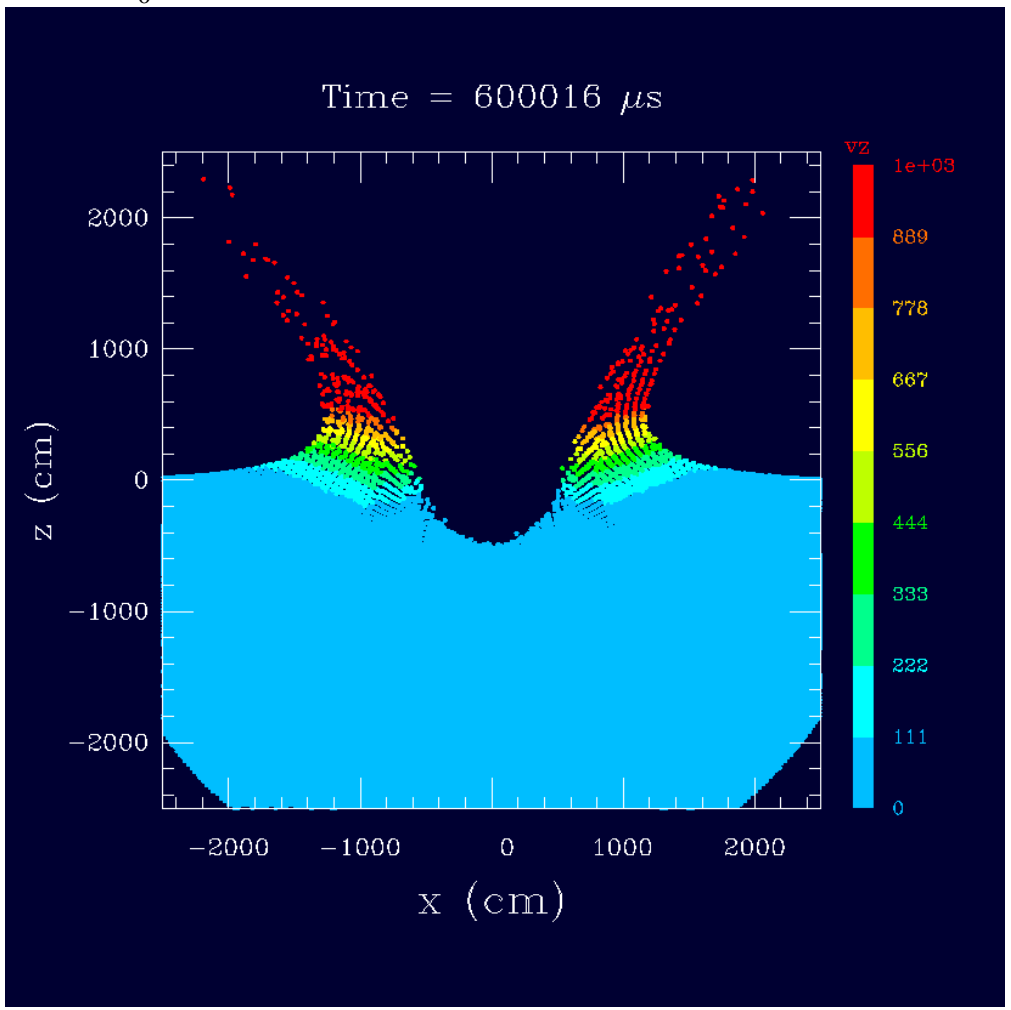
Simulation

- It is not possible to simulation the whole crater formation (time step problem)
  - Only the **first stage** (t<0.6s) is simulated using SPH
  - The outcome of the simulation (position and velocity) is then used to compute the **ballistics** of the particles

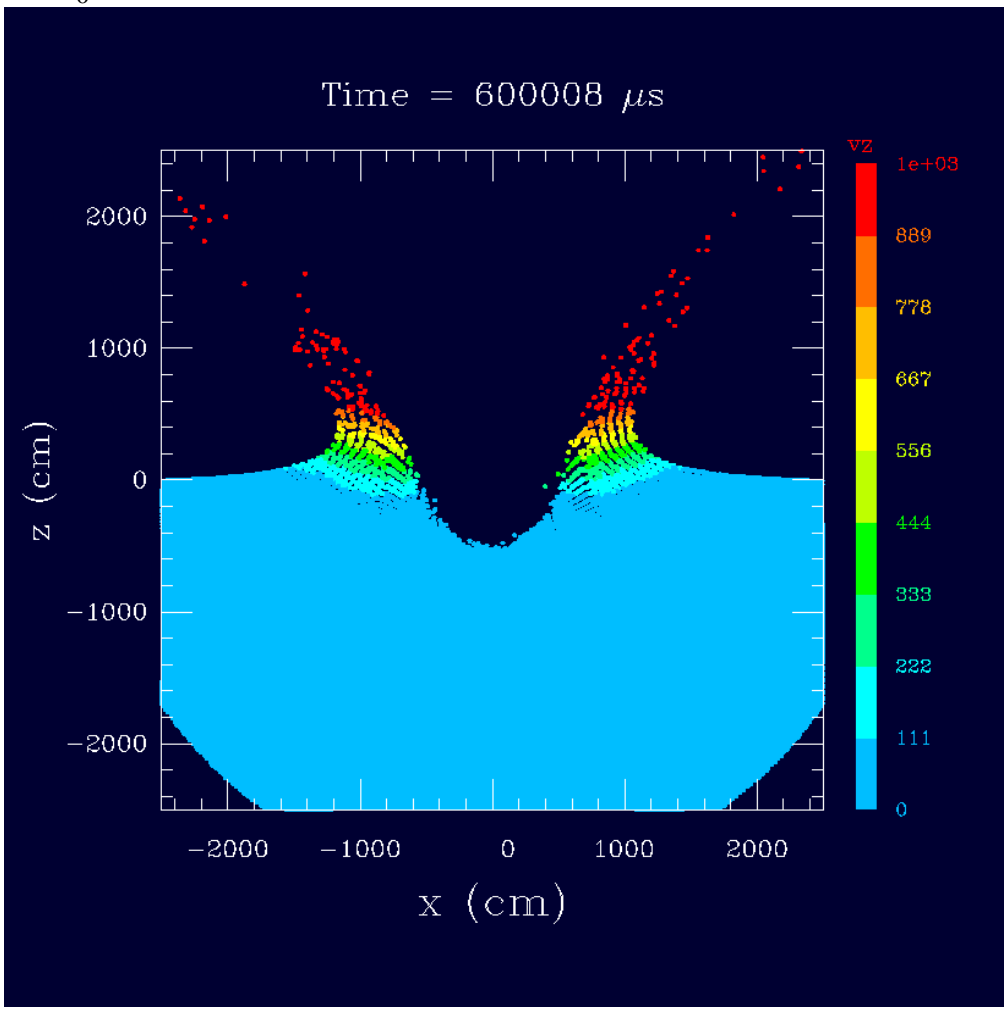
Results

Simulation after 0.6s

ρ_0=1.8g/cm^3, no porosity model



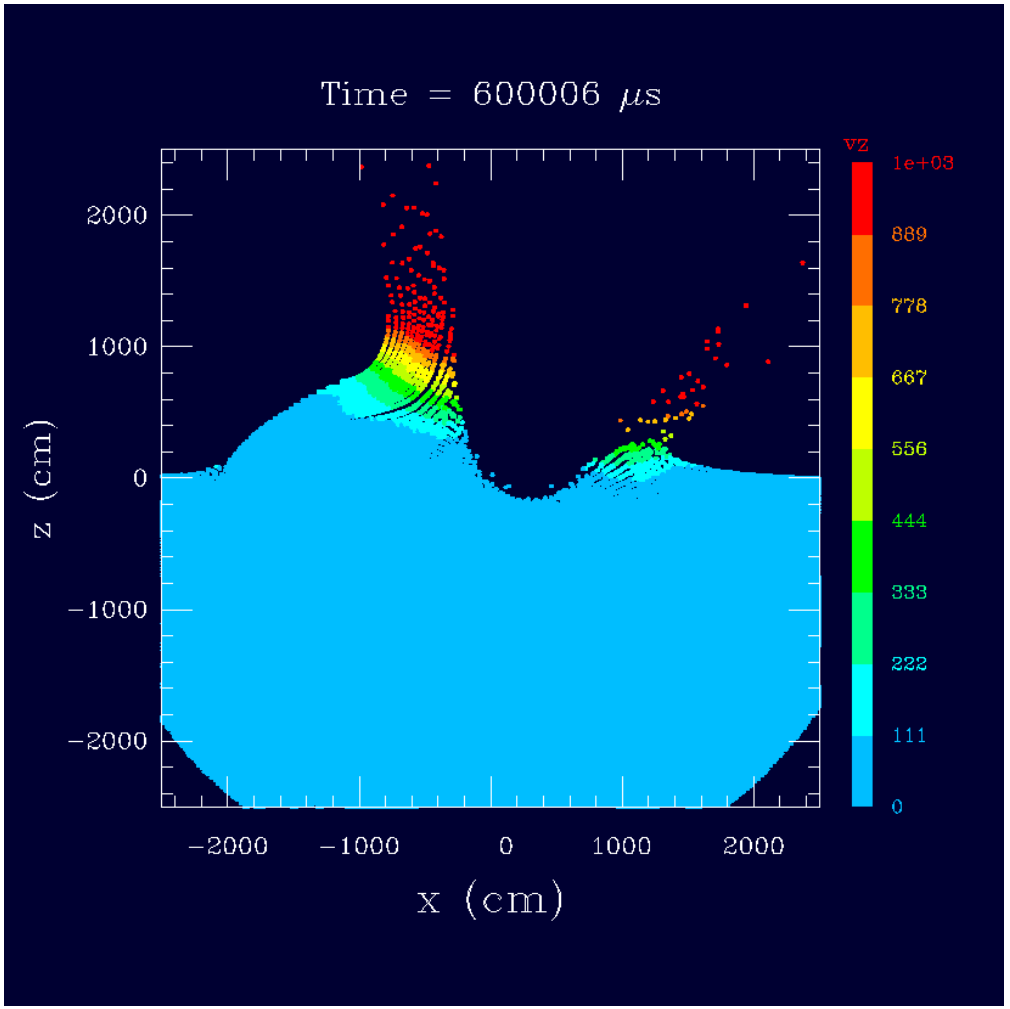
ρ_0=1.8g/cm^3 , porosity is explicitly modelled



Results

Simulation after 0.6s

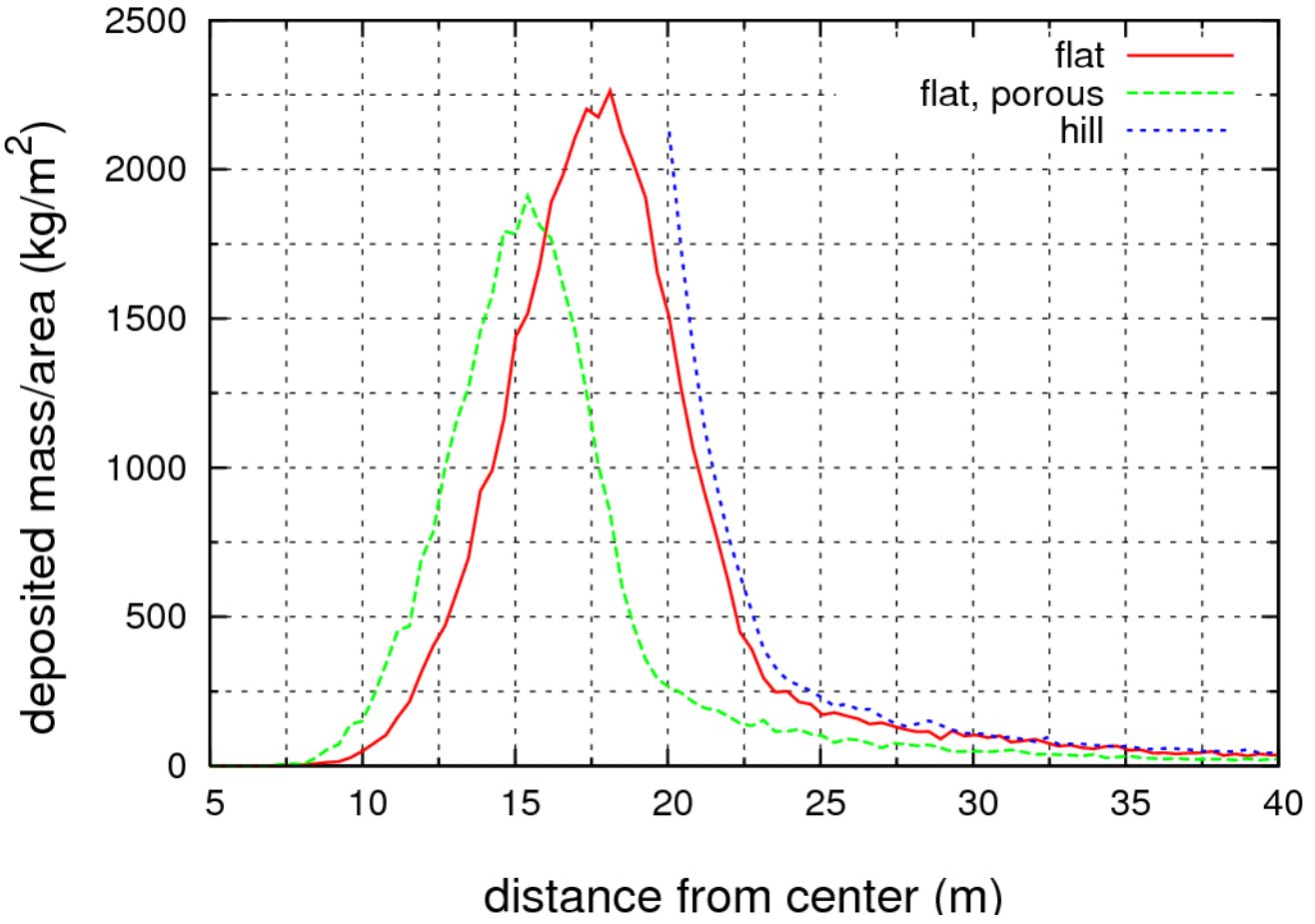
hill



Asymmetric ejecta plume

Results

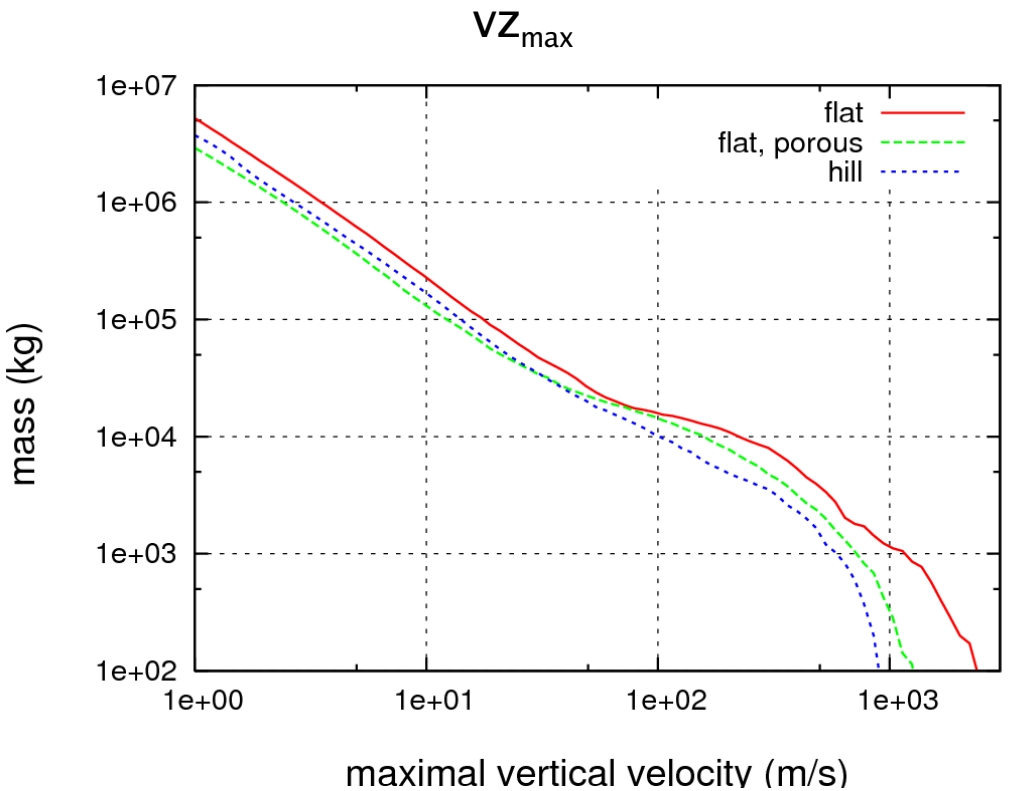
Ejected mass deposited (per area) on the surface as a function of the distance from the center:

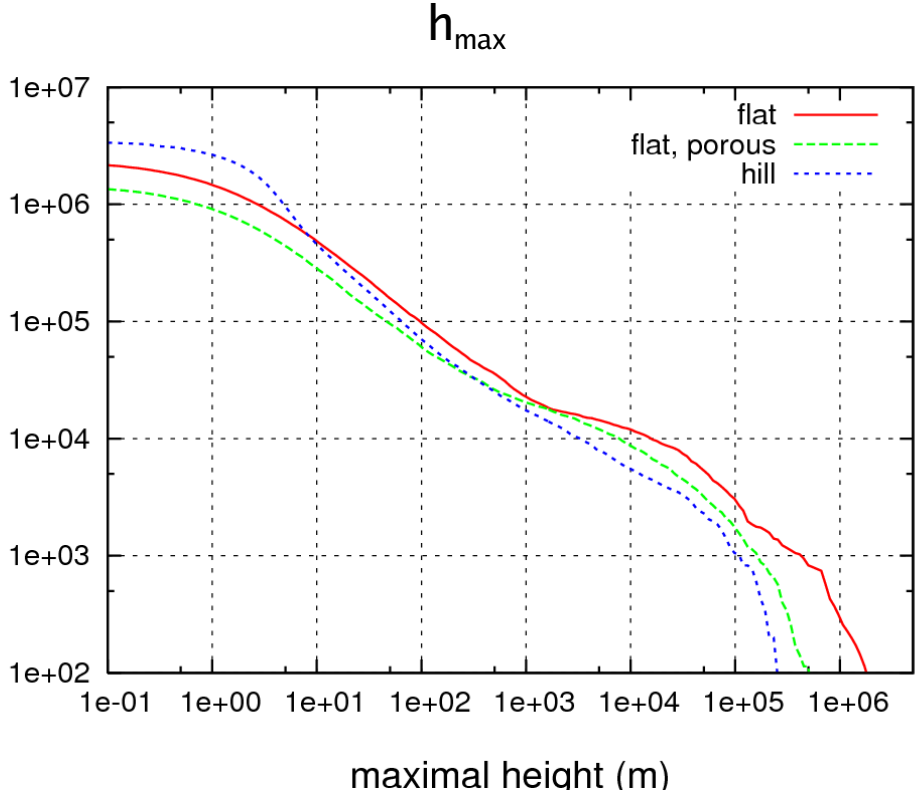


Not the final rim!!!

Results

Amount of mass ejected with a velocity higher than a certain velocity and the corresponding height:





Results

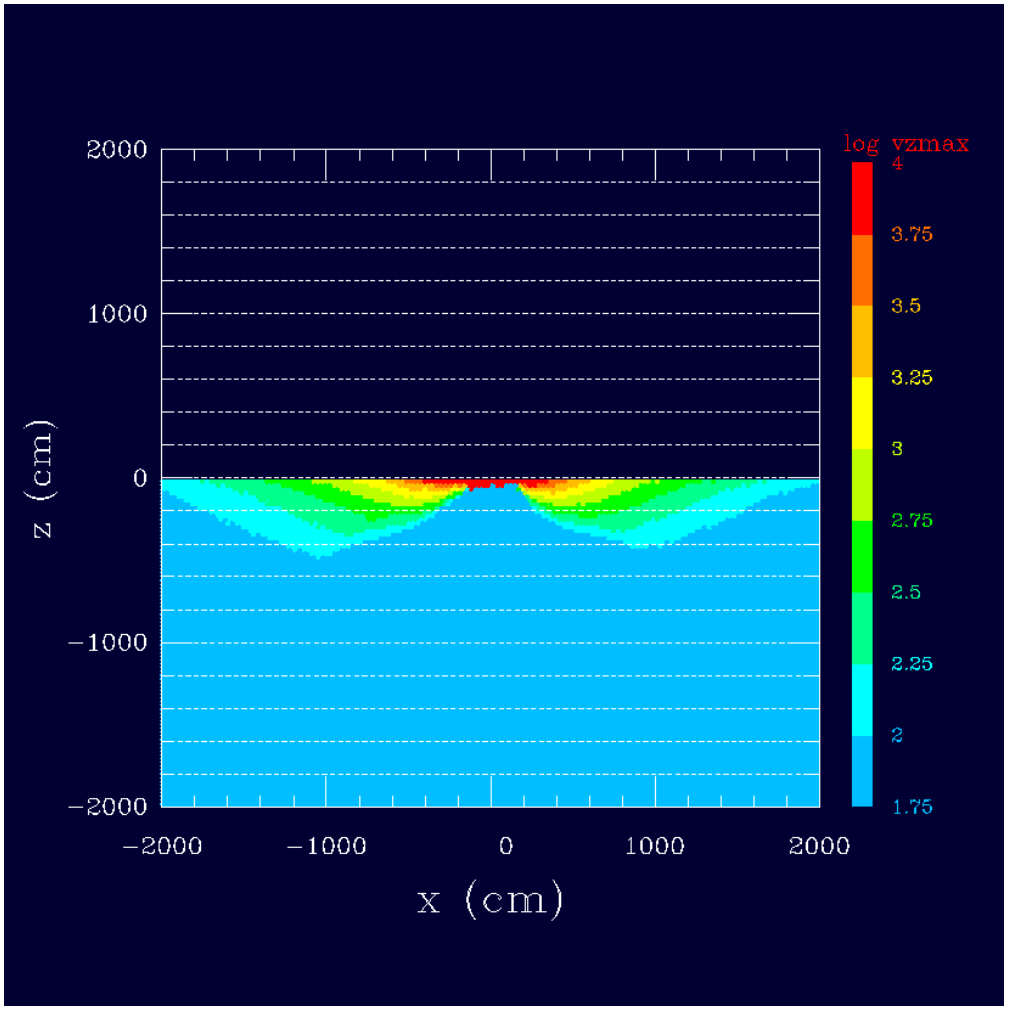
Amount of mass ejected higher than

Height	100	1000	10000	100000	m
Flat	9.5e4	2.2e4	1.2e4	2.6e3	Kg
Porous	5.9e4	2.0e4	8.6e3	1.5e3	Kg
Hill	6.9e4	1.7e4	5.5e3	1.0e3	Kg

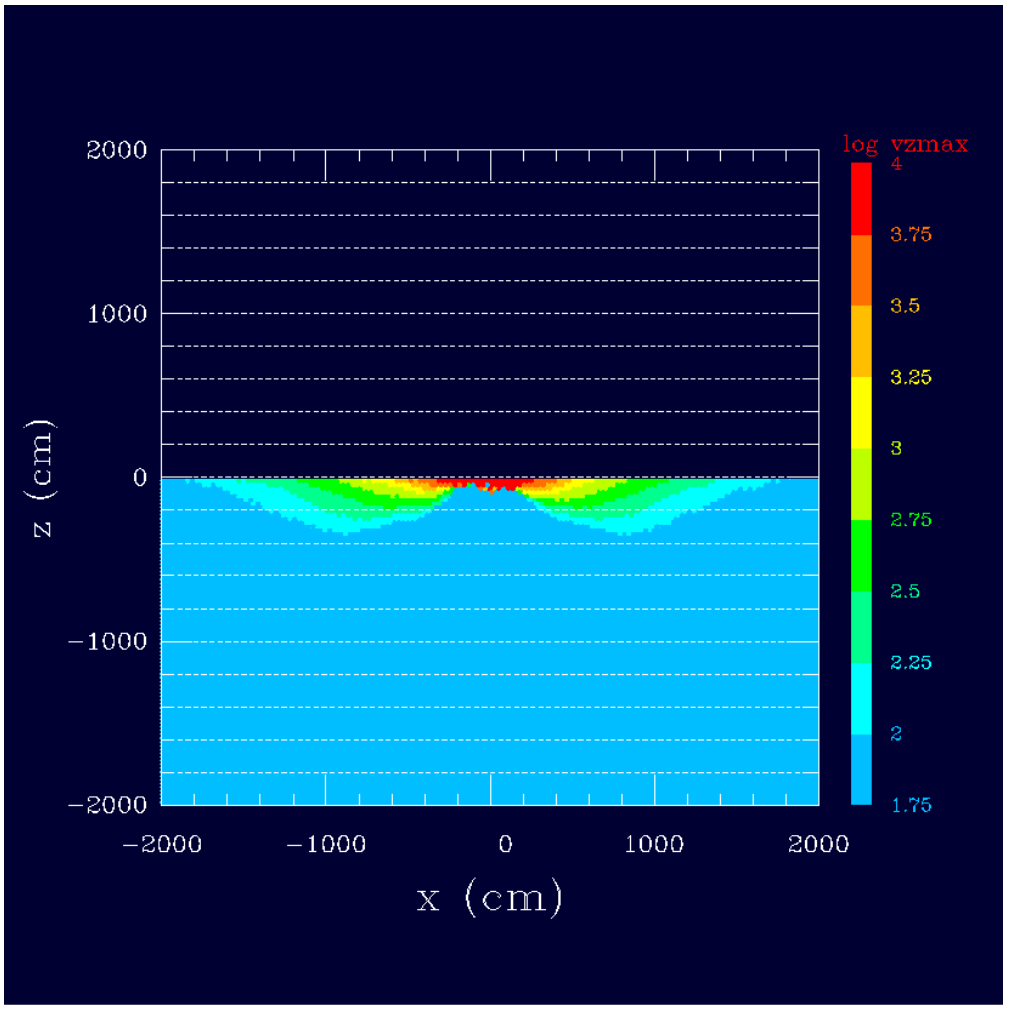
Results

vz_{max} as a function of initial depth

nonporous



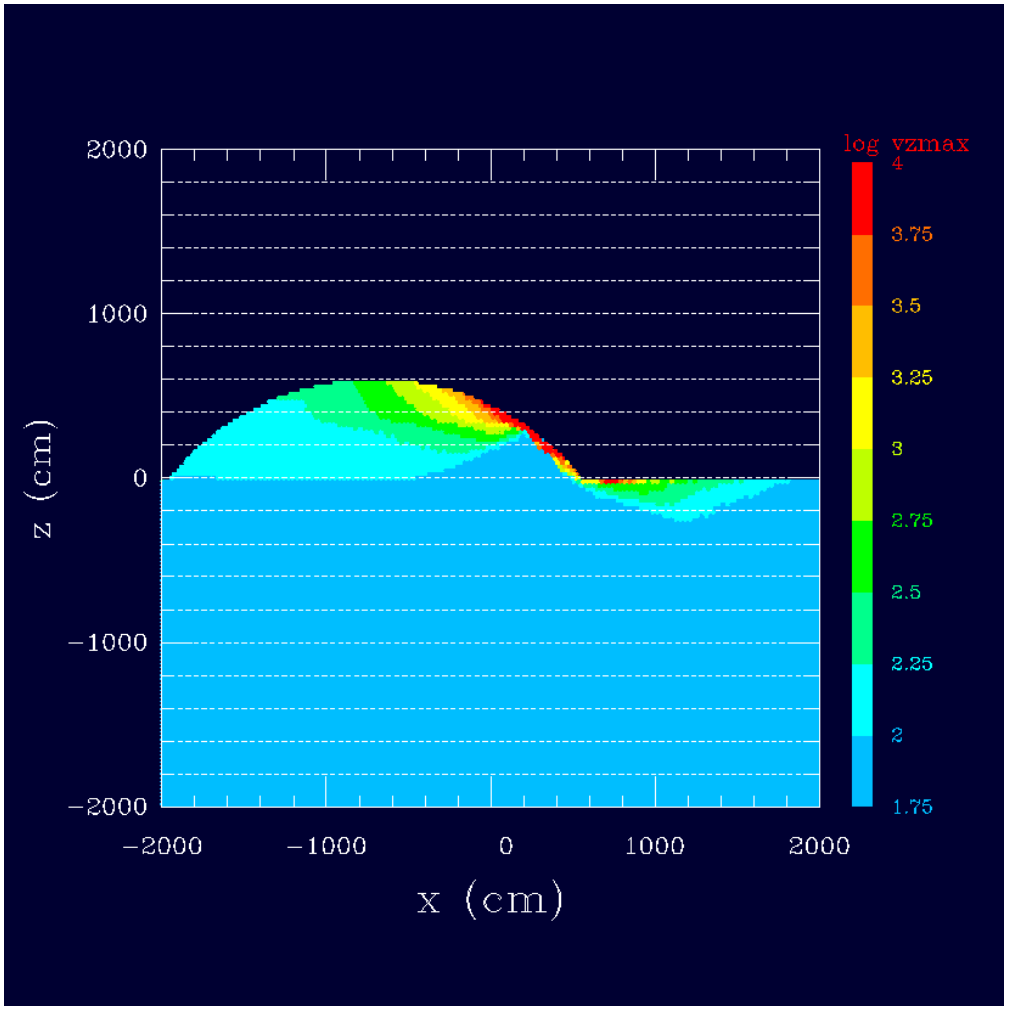
porous



Colors: log scale 10^2 – 10^4 cm/s

Results

$\mathbf{vz_{max}}$ as a function of initial depth

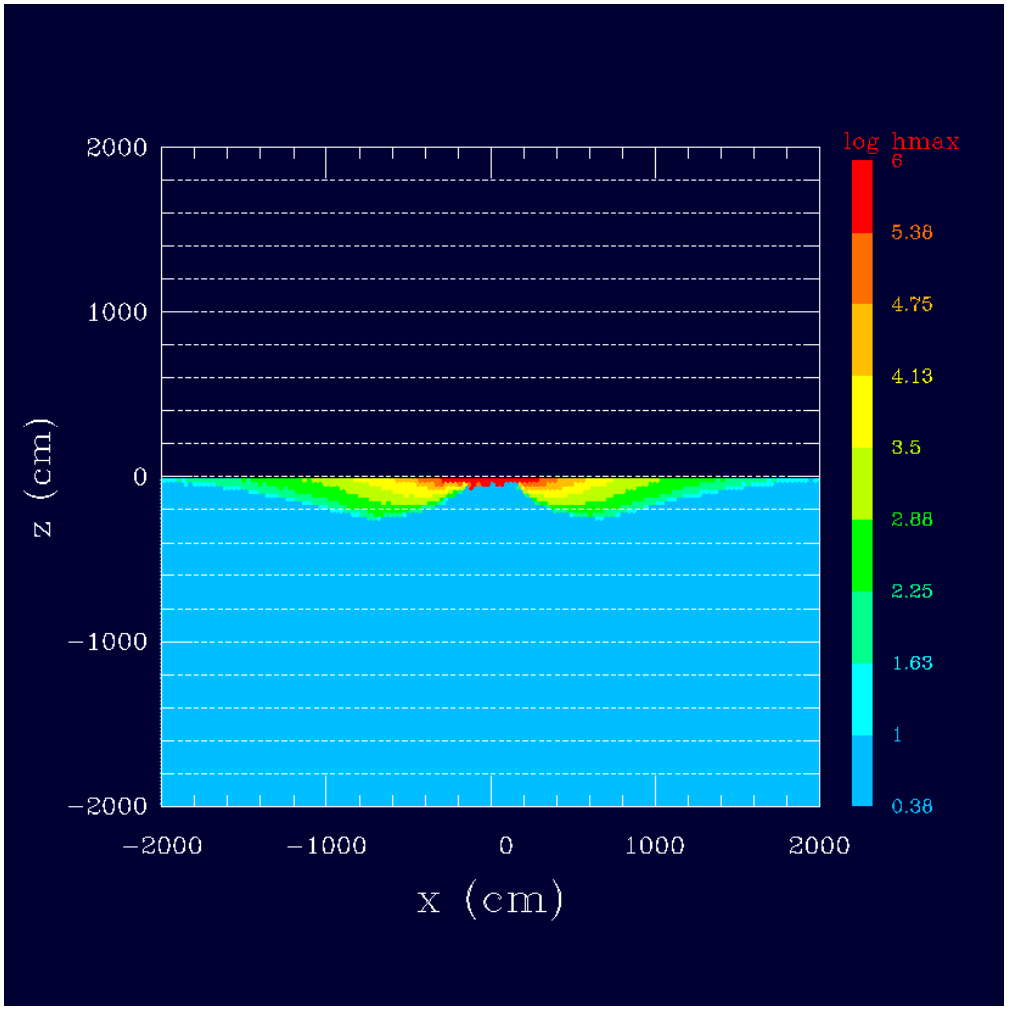


Colors: log scale 10^2 – 10^4 cm/s

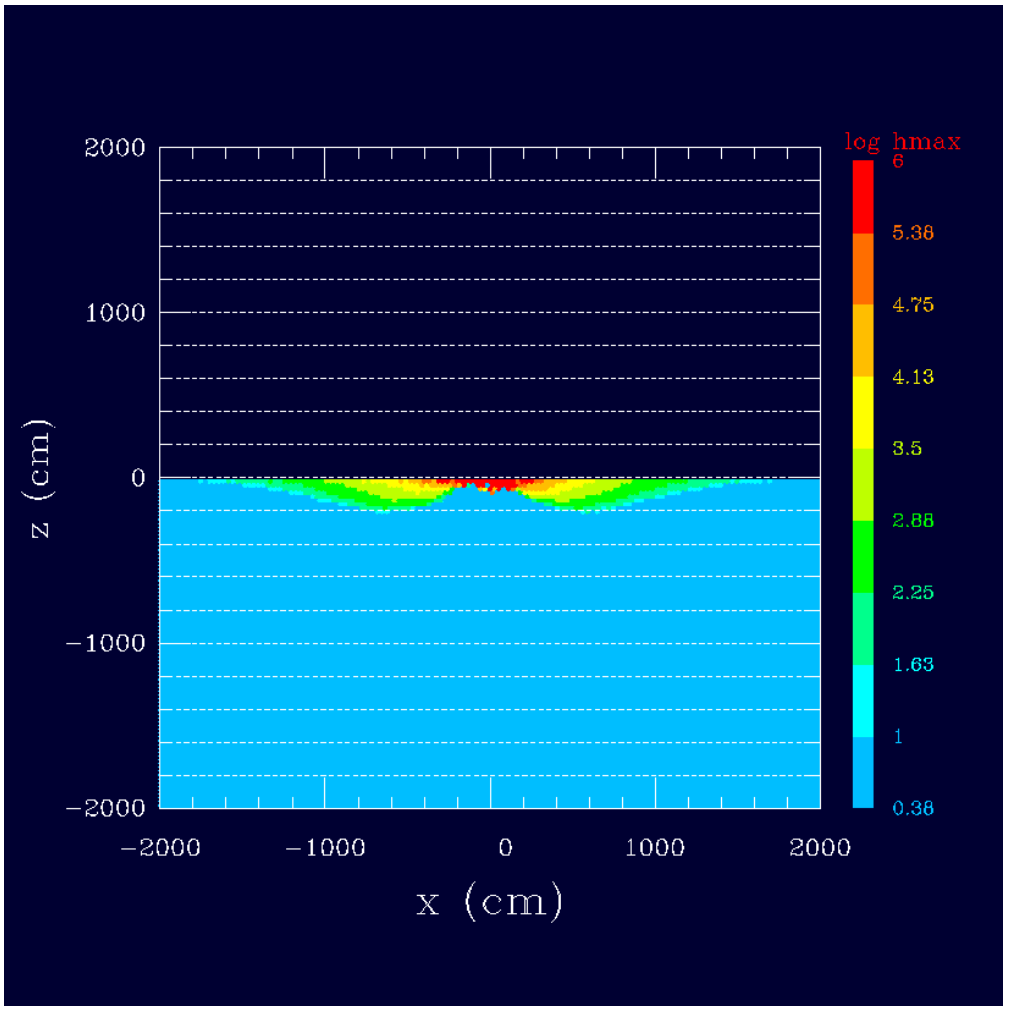
Results

$\mathbf{h_{max}}$ as a function of initial depth

nonporous



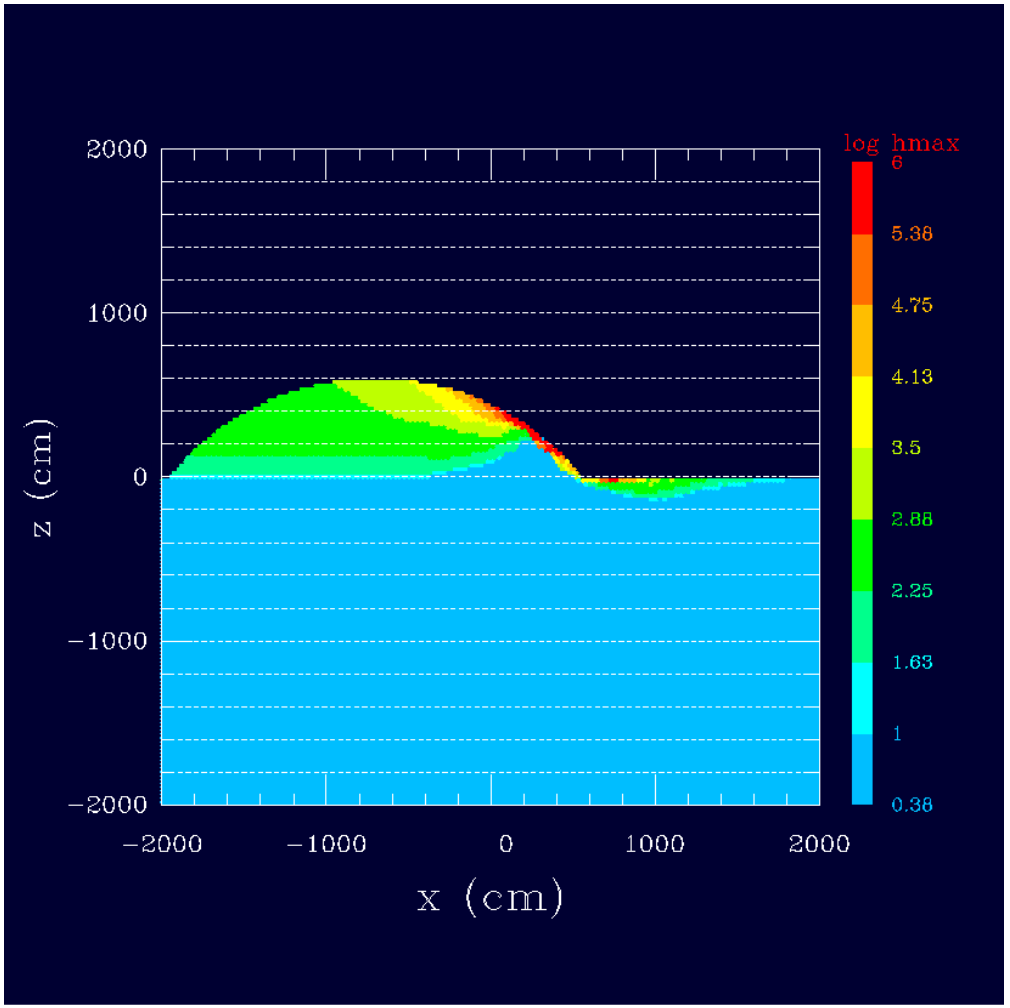
porous



Colors: log scale 10 – 10^6 cm

Results

$\mathbf{h_{max}}$ as a function of initial depth

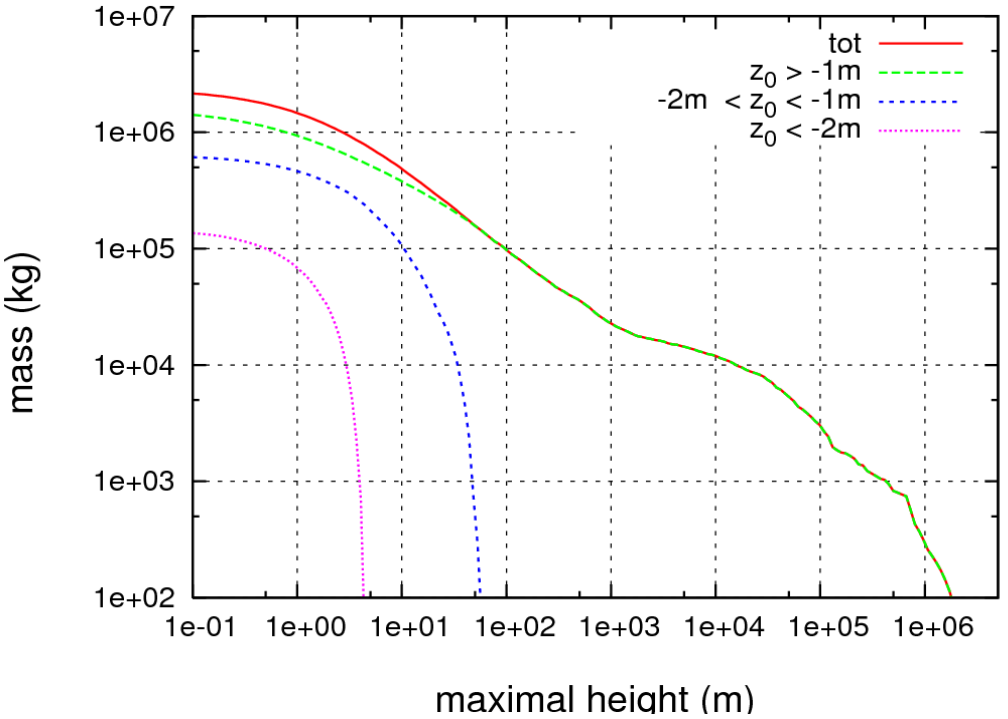


Colors: log scale 10 – 10^6 cm

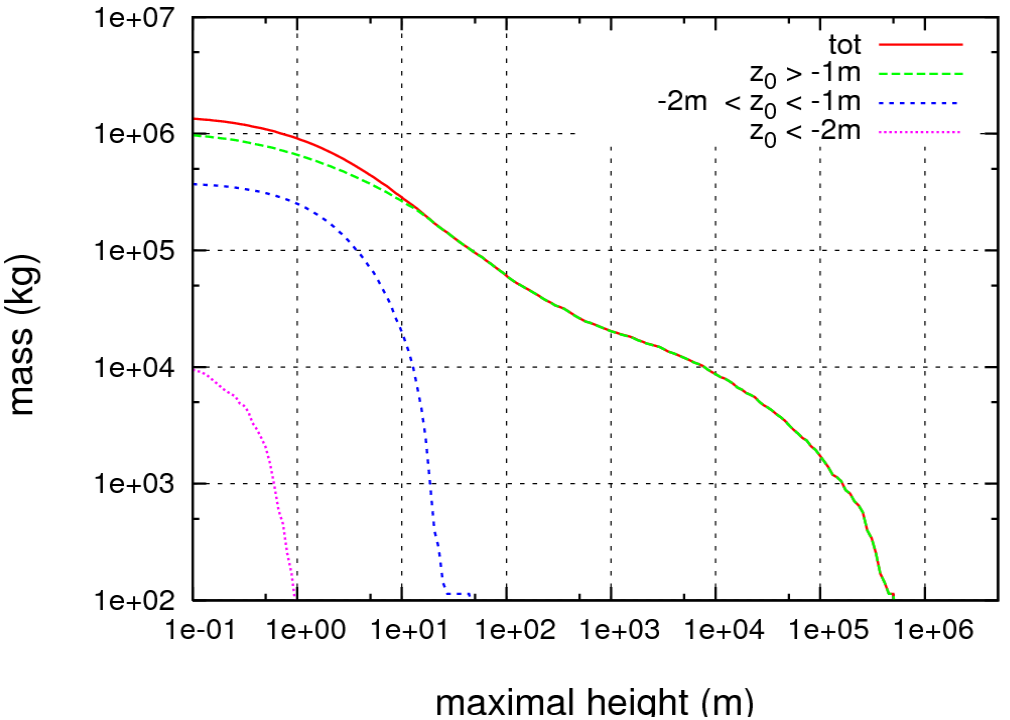
Results

Amount of mass ejected higher than a certain height for **different initial depths**:

nonporous



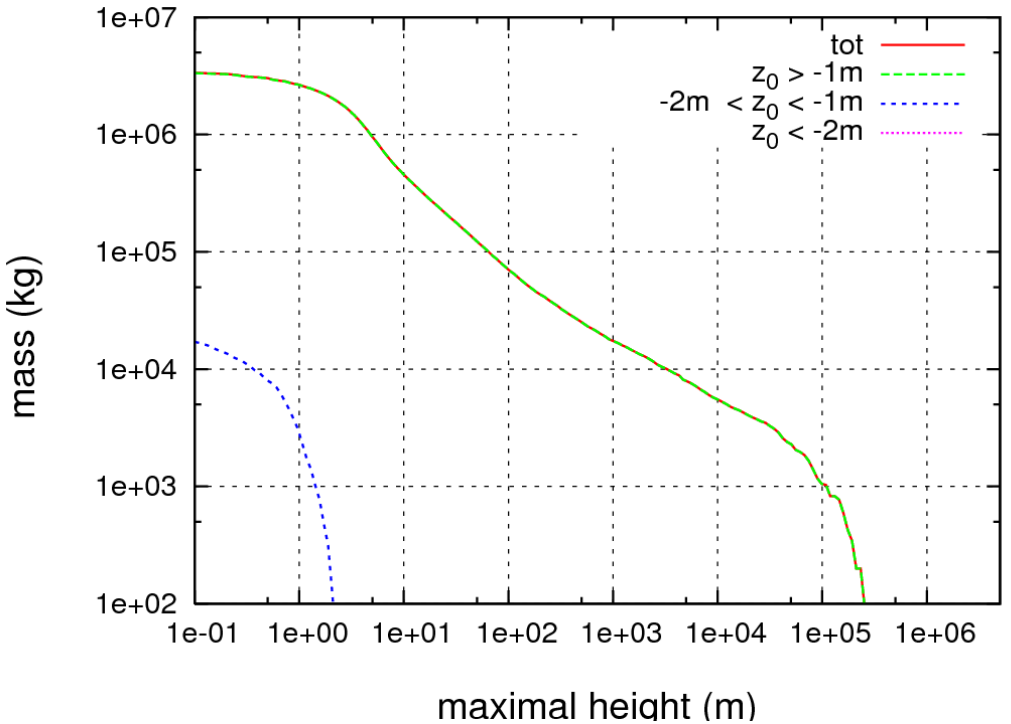
porous



Results

Amount of mass ejected higher than a certain height for **different initial depths**:

hill



No material is ejected from z0 < -2m

Summary

- Porosity leads to a smaller amount of ejecta
- The surface topography significantly affects the results (ejecta plume, provenance of ejecta etc.)
- The provenance of most of the ejecta is near the surface. Only a small fraction is ejected from depths < -1m