Determination of meteoroid entry parameters for terrestrial strewn fields

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Introduction an motivation

The goal of this study

- to reconstruct atmospheric entry scenario for several known terrestrial strewn fields,
- to estimate the range of entry parameters resulting in craters on the ground.

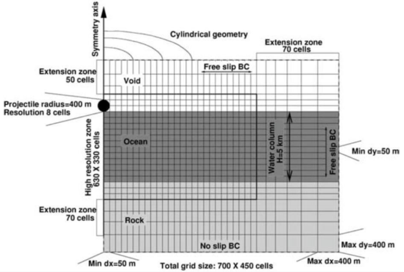
Motivation

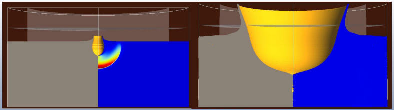
- Impact events resulting in crater strewn field can happen within time interval 500 years (Bland & Artemieva (2006)),
- crater strewn fields are natural laboratories for studies on the dynamic of big meteoroids during their flight through the atmosphere.

Methodological approach in general

1. Construction of material model representative for target material of studied terrestrial strewn field,
2. determination of material-depending scaling parameters for estimation of energy required for the formation of crater with a given diameter,
3. Atmospheric entry simulations for the whole entry parameters space,
4. Exclusion of non-suitable entry parameters, which can not reproduce observed crater field

Scaling on impact craters size





$$\left.\begin{array}{l} \left\{\dfrac{\rho V}{M}\right\} = \pi_V \\ \left\{D\left(\dfrac{\rho}{M}\right)^{\frac{1}{3}}\right\} = \pi_D \\ \left\{d\left(\dfrac{\rho}{M}\right)^{\frac{1}{3}}\right\} = \pi_d \end{array}\right\} = \mathrm{F}'[\pi_2,\pi_3,\pi_4] = \mathrm{F}'\left[\left\{1.61\dfrac{gL}{U^2}\right\},\left\{\dfrac{Y}{\rho U^2}\right\},\left\{\dfrac{\rho}{\delta}\right\}\right],$$

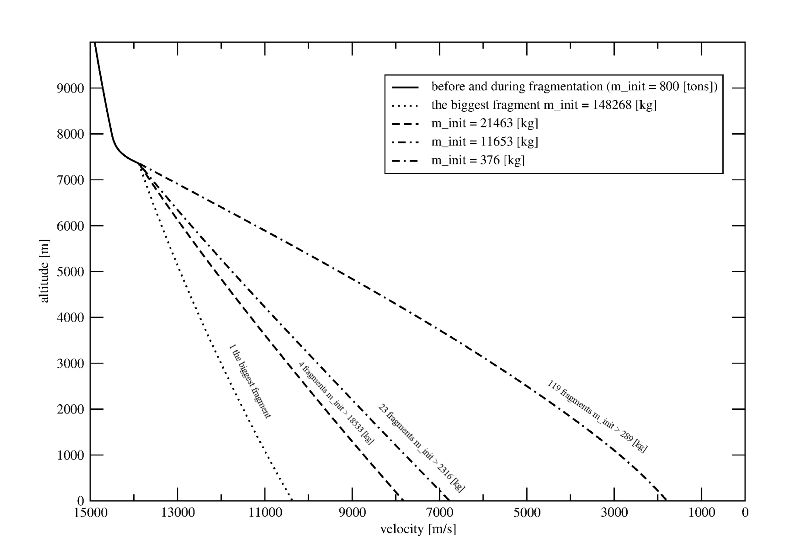
$$\pi_D = \pi_2^{\alpha} \cdot \pi_4^{\beta}$$

α , β - material-dependent parameters

iSALE2D hydrocode (Wünnemann et al. (2006), Amsden A. A. et al. (1980))

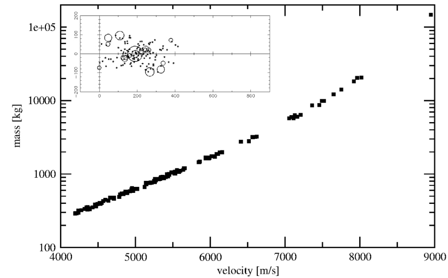
Atmospheric entry model

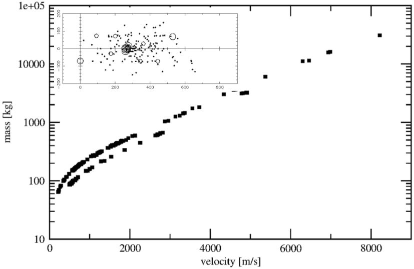
1. We integrate numerically standard equations for ablation and deceleration,
2. meteoroid internal strength in each time-step is described by Weinbull statistics ($\alpha = 0.1$),
3. when dynamic loading exceeds meteoroid internal strength, we solve the equation describing projectile deformation (Pancake model) with the restriction of pancake growth to 3.5 relative to its initial radius,
4. we draw masses of fragments using the standard cumulative size frequency distribution ($N_{>m} = Cm^b \quad b = 0.8$),
5. we certain random positions of fragments as well as their velocities and directions



$m_{init} = 800$ [$tons$] $\theta_{init} = 40$ [^{o}] $v_{init} = 16$ [km/s]

Example outputs

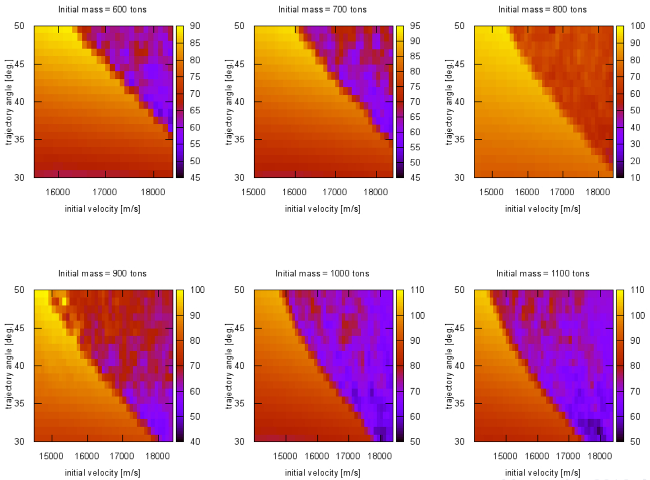




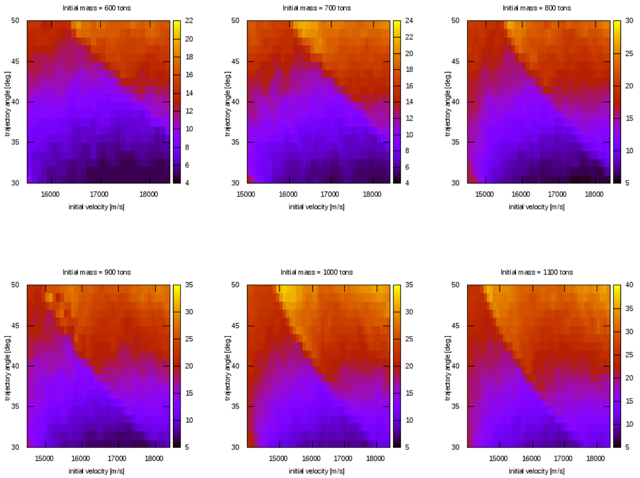
left: $m_{init} = 1000\ [tons]\ \ \theta_{init} = 30\ [^{\circ}]\ \ v_{init} = 15\ [km/s]$

right: $m_{init} = 1000\ [tons]\ \ \theta_{init} = 30\ [^{\circ}]\ \ v_{init} = 18\ [km/s]$

Parameters study

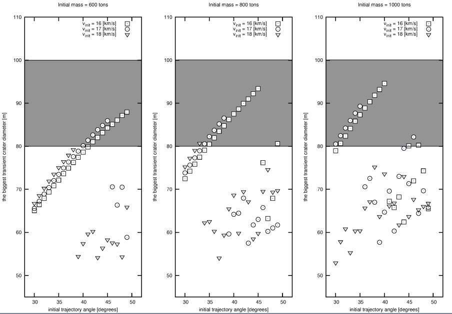


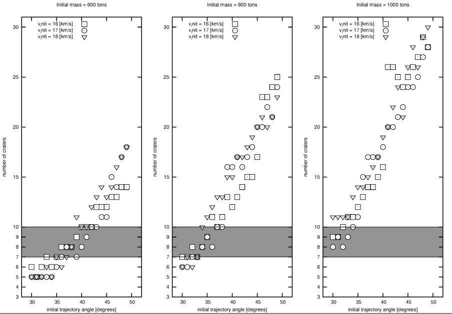
Parameters study



Example results - the Morasko strewn field

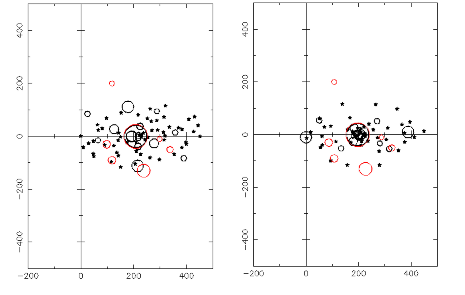
1. The biggest crater diameter > 80 meters and < 100 meters,
2. Avarage number of craters 7 - 10,

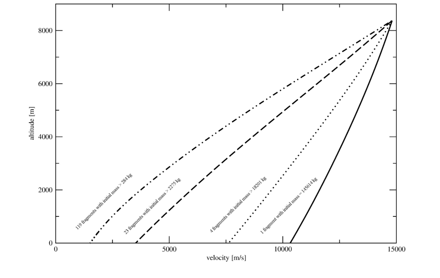




Example results - the Morasko strewn field

$m_{init} = 800\ [tons],\ v_{init} = 17\ [km/s],\ \theta_{init} = 35\ [^o]$





Entry parameters which can be considered as likely for the Morasko strewn field.

M_{init} [tons]	v_{init} [km/s]	θ	N	$D_{biggest}$
600	16	41 - 42	10	81 - 82
600	17	40 - 43	8 - 10	80 - 83
700	16	40	10	82
700	17	37 - 40	8 - 9	80 - 84
700	18	36	7	80
800	16	35 - 37	9 - 10	80 - 83
800	17	34 - 38	8 - 10	80 - 86
800	18	33	7	81
900	16	33	9	82
900	17	32 - 35	7 - 10	81 - 86
1000	16	31 - 32	9 - 10	80 - 83
1000	17	30 - 34	8 - 10	80 - 88
1100	16	30 - 32	9 - 10	82 - 87
1100	17	31 - 32	9 - 10	84 - 85

Conclusions

- It is impossible to find one unique scenario of strewn field formation,
- however we can consider some scenarios as more or less likely (some of them also as totally impossible),
- determination of initial conditions for crater-forming meteoroids allow to reconstruct of the whole impact process: from energy deposition in the atmosphere, radiation, to the energy of impacting fragments, possible shock metamorphism, the distribution of ejected material and environmental effects of such events.