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Predicting the Consequences of NEO Impacts on Earth

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Introduction: Small NEO's can impact Earth with little warning time. Especially smaller NEOs are difficult to be detected, and are more numerous than larger ones. In such a scenario, Emergency Agencies require fast and accurate predictions of the impact consequences. However, the time might not be sufficient for running accurate shock physics codes. Here, we present a new approach that allows for fast but still reasonably accurate predictions for a set of input parameters (e.g. speed, size and impact angle of a NEO) defining a giving impact scenario in terms of overpressure, wind speed, thermal radiation on the surface, and the cratering process.

Approach: The atmospheric entry of a NEO depends on its physical properties. An iron asteroid is much denser and has a larger strength than a rocky body. Asteroids could be monolithic or a rubble-pile, which also affects their bulk properties. Based on these properties and the asteroid size, we defined the following regimes: 1.) airbursts from relatively small rocky asteroids, 2.) cratering events from larger rocky asteroids, 3.) strewn field formation by relatively small (<30 m) iron asteroids, and 4.) cratering events from larger (>30 m) iron asteroids. Depending on the regime, we use a suite of pre-calculated shock physics models using the SOVA shock physics code [1], the separate fragment approach [2,3,4], or recent interpolation equations [5,6].

Application to test cases: Our approach has been tested against available data from observed asteroid falls, and numerical models. A well-studied observed case is the Chelyabinsk event, which occurred on 15.02.2013 [e.g. 7], but we have also used simulation results for a Tunguska-like event, for which data on surface effects was provided [e.g. 8, 9,10] (Figure 1), and results for the Morasko [11] and Campo del Cielo [12] strewn fields (Figure 2). Our tool calculates effects in agreement with these literature results. The calculation of crater sizes is done using scaling relationships that provide the crater size for a given impactor [e.g. 13, 14].

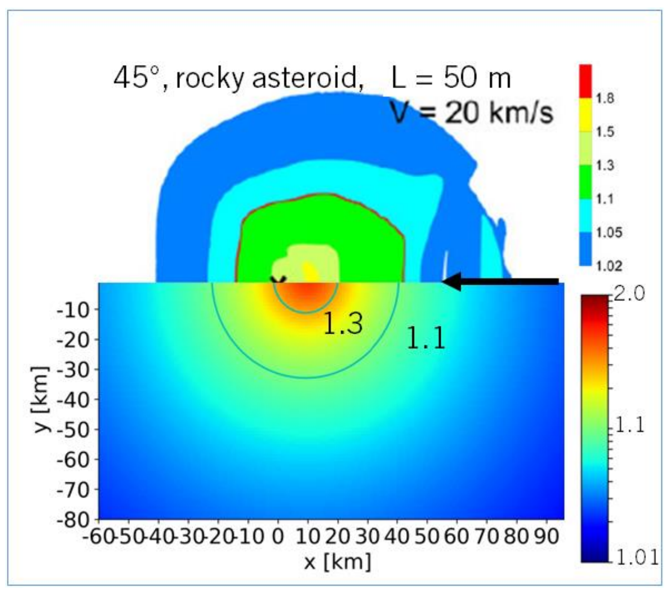

Figure 1: Comparison of the tool results for overpressure for a Tunguska like scenario (lower half) to data from [9] (upper half). Contours for 1.1 and 1.3 P/P_0 are in close agreement. The black arrow shows the flight direction.

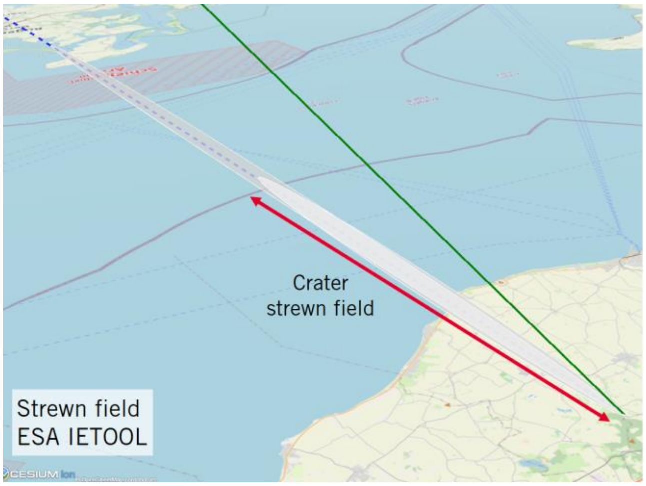

Figure 2: Tool results for an iron impactor in a scenario like Campo del Cielo: v=14.5 km/s, L=12.8 m, and ϑ=16.5°. The green line shows the trajectory, the red arrow marks the crater strewn field ellipse of 19.6 km length, and the longer ellipse shows the range where meteorite fragments are expected to fall. The strewn field length agrees with observational constraints summarised by [12].

Application to a hypothetical case: In the light of the recent successful DART mission, we calculated the effects for a Dimorphos sized rocky impactor that impacts in Berlin with a velocity of 20 km/s at an angle of 45° (Figure 3). In such a scenario, we would expect a crater with a diameter of ~2 km. A large area (~40 km x 25 km) would be affected by overpressures sufficient to let multistorey buildings collapse (~40 kPa), while trees would fall in an even larger area, and window glasses would break in an area of the size of Germany. In such a hypothetical scenario, the overall destructions would be extremely severe.

Conclusion: Our impact effects prediction tool has been developed to allow for fast and accurate predictions of the impact effects for the encounter of small NEOs with Earth. In contrast to previous tools, it is designed to render maps of the predicted effects on a map, which helps emergency agencies for their risk assessment.

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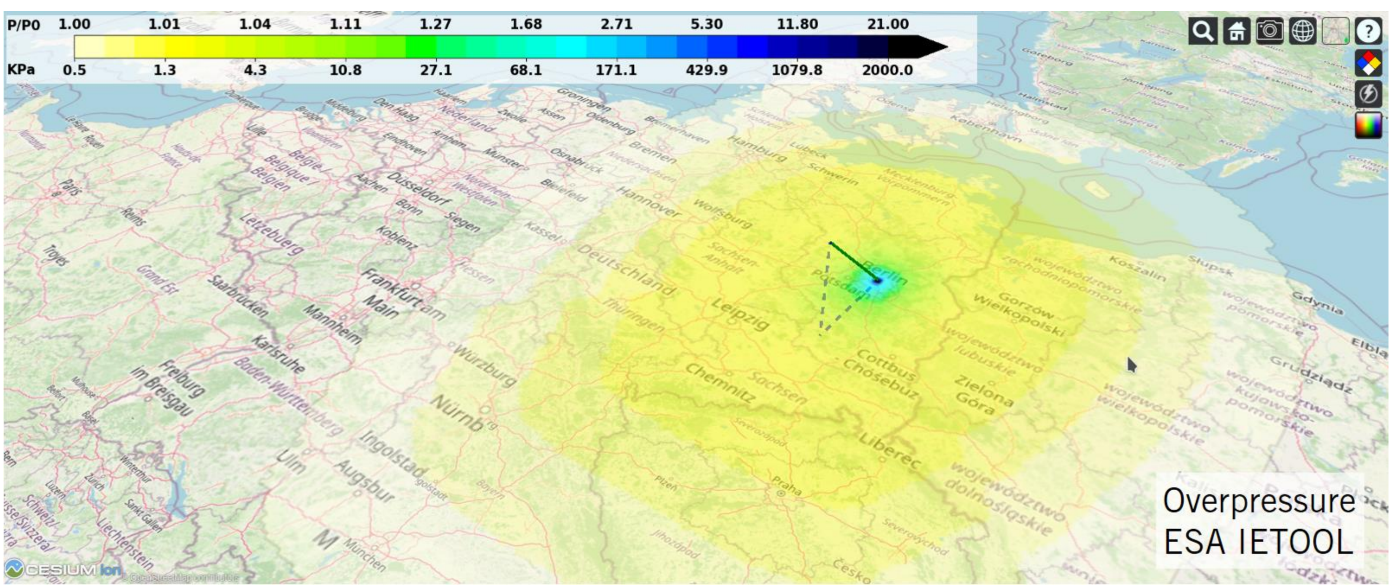

Figure 3: Tool results for the overpressure caused by a rocky impactor with: v=20 km/s, L=170 m, and ϑ=45°.