Improving the Height of Burst (HOB) Map

With no buoyancy or other length scales, point sources blasts are self-similar.

Yield scaling allows us to relate overpressures between blasts of different strengths.

Buoyancy introduces an additional length-scale breaking the self-similarity of the blasts -- can be neglected for "small" blasts (< 5-10MT) since:
- Propagation times are short so acceleration due to gravity doesn’t have time to act.
- Distances are small as compared to the scale-height of the earth's atmosphere (~7-8 km).

Yield scaling predicts that a 100 MT blast at a burst height of 13.6 km will have the same scaled ground overpressure as a 5 MT blast detonated at an altitude of 6 km.

Introducing Buoyancy

Buoyancy enters through the pressure gradient due to gravity, \( \Delta p \). This introduces a second characteristic length: the scale height of the atmosphere.

With this second length scale, the two blasts are no longer strictly self-similar.

When the scale height (~7-8 km) is large compared to the blast footprint, buoyancy effects are small.

However, at high energy levels associated with asteroids whose diameter is greater than about 100m, these effects can be significant.

Here is the yield scaled equivalent setup for the 5 & 100 MT airburst in \( \Omega \) with Buoyancy. Note that while the blasts themselves are similar, the background pressure gradient in the atmosphere is significantly steeper at the larger yield.

Updated Height of Burst Map

Used simulation to numerically generate HOB maps for blasts of various yields at dozens of altitudes.

Buoyancy significantly decreases the height of the "buoyant" blast.

This can increase the radius of lethal overpressures for airbursts of asteroids in the 100-200m range.

Since the ground footprint scales with the square of the blast radius, estimates of the affected population are significantly improved.

Outcome

The probabilistic risk tool (Mathias, 2017) now interpolates between appropriate numerically generated HOB maps to give improved prediction of ground footprint for larger entry energies. Since large asteroids typically have lower burst heights, these predictions can be significantly affected by the steep gradients seen in the HOB map above. This modified risk tool was used for analysis supporting NASA’s Science Definition Team’s work to quantify the threat posed by Near Earth Objects.

Acknowledgements

This work is a part of the Asteroid Threat Assessment Project (ATAP). The research is funded through the NASA Planetary Defense Coordination Office (PDCO) in the Planetary Science Division of NASA’s Science Mission Directorate.

References


