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SENSITIVITY STUDY OF IMPACT RISK MODEL RESULTS TO THERMAL RADIATION DAMAGE MODEL FOR LARGE OBJECTS

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ABSTRACT

Asteroid impacts and airbursts can cause multiple different hazards, including local ground damage, tsunami inundation, or large-scale global effects. NASA's Probabilistic Asteroid Impact Risk (PAIR) model uses fast-running models to assess the potential damage from these hazards across a wide range of uncertain asteroid properties and impact factors. Local ground damage can consist of both blast and thermal radiation effects, and the larger of the two is used to define zones at risk of different damage level severities. Typically, blast is the leading hazard, but thermal radiation can become important particularly in large object cases such as the current PDC 2023 impact exercise. As we look beyond smaller airburst cases to these larger impacts, a need has developed to determine the size ranges and parameter regimes where impact risks become sensitive to thermal damage, and where further model refinement may become pertinent.

This study performs the needed sensitivity analysis of PAIR to thermal radiation damage. It determines when thermal radiation damage becomes the dominant local ground hazard based on object size and other relevant parameters (entry angle, strength, etc.). PAIR currently uses an empirical thermal radiation model based on nuclear data. This model is the basis of the sensitivity study, however, other models with different approaches do exist. Two additional thermal radiation models are considered as comparisons, including a scaling relation for calculating thermal exposure based on a series of entry and impact simulations developed by the Institute of Geospheres Dynamics of the Russian Academy of Sciences, and a new correlation for ground radiative flux that is based on detailed flow field and radiation simulations by NASA's Asteroid Threat Assessment Project.

The three models are evaluated and compared for an 800m diameter object representative of the current PDC 2023 impact scenario. Results for this case show significant differences in thermal damage radius across a range of damage severity levels. Including uncertainties in thermal modeling parameters produces differences of an order of magnitude and more between the lowest and highest values. These differences affect when thermal radiation dominates the blast overpressure threat, impacting the sensitivity study. For this 800m diameter case, the model predicting the largest thermal damage radii exceeded the blast radius for all severity levels, while the model with the smallest damage radii was within the blast radius for all severity levels. The empirical model that PAIR uses produced damage radii between the other two models and only exceeded the blast damage radius at the highest severity level.

Understanding these thermal sensitivities is relevant not only to model development, but also to emergency response planning which relies on the best available damage zone estimates and risk level determinations. An outcome of this work will be identifying key areas where additional model refinement and better knowledge of asteroid properties may be important for improving these estimates.

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