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The generation of a tsunami from the impact of a massive comet in the Indian Ocean (U)

Bob Weaver
Los Alamos National Laboratory, Los Alamos, NM 87545
Galen Gisler
Physics of Geological Processes, University of Oslo, University of Oslo, Oslo, Norway
Dale Ranta and Michael L. Gittings
Science Applications International Corporation, La Jolla, CA

Abstract

We use the Los Alamos SAGE code to perform 2D and 3D simulations the impact of a massive comet in the Indian Ocean. We examine quantitatively the extent of material ejected from the impact site and whether such ejecta could be entrained in the resulting Tsunami wave at extreme distances from the impact site (~1200 km). We start with simpler 2D runs of comet (ice) impacts and compare comet impacts to asteroid impacts (rock/metal) of similar kinetic energy. One goal of this work is to understand whether such a massive comet impact could lead to the partially melted fossils in the Chevrons on Madagascar from an apparent impact location in the Indian Ocean (Burckle crater).

1. Previous impact work

We have simulated the impact of many different types of bolides on the Earth with the Los Alamos SAGE code. The SAGE code has had extensive verification and validation for complex hydrodynamic computer simulations [1,2,3,4]. Most of the work in this area have The initial simulations we performed with SAGE in this area were of “asteroid” impacts in the deep ocean. Several papers [5,6,7] were published on this work that provided a modern estimation of the source cavity size for these impacts as well as the initial tsunami wave height and speed. This SAGE code used for this initial asteroid impact work was validated against high explosive (HE) and water impact laboratory experiments [2,3].

The next major area of research for large scale Earth impacts were 3D simulations of simulations of the K–T Impact event. These simulations were performed and analyzed as a probable source for the extinction of the dinosaurs. Recent work has been done on underwater landslide generated Tsunamis [9] and explosively driven tsunamis [10].

2. Simulations of a massive comet impact in the Indian Ocean

Our current simulations are being performed with comet impacts instead of asteroids. The significant differences between comets and asteroids are their density and velocity. Typical comets are composed mainly of ice and have density ~1g/cm^3 and a velocity of ~50 km/s while asteroids are typically rocky material (modeled with dunite of density ~2.8 g/cm^3) or metallic (e.g. iron with a density of ~7.8 g/cm^3) and typical asteroid velocities are ~20 km/s. Here we compare the initial water crater sizes and distances of ejected material for asteroid and comet impacts. The main goal of this work is to quantitatively assess the largest distance that material can be ejected from the impact site. Some material directly above the impact point has a velocity greater than the Earth’s escape velocity and leaves the Earth. Most displaced material in the original crater forms a crown wave similar to that formed by drop of water into a cup of water. There is a optimal ejection angle (~45 degrees) where material will travel the greatest distance from the initial impact. To demonstrate this point we have simulated a “dirty” comet, one that is composed of a granite core surrounded by a large volume of ice. This rocky core is merely for computational issues in the SAGE code. These first simulations are done in two spatial dimensions (2D) (cylindrical symmetry) to explore this parameter space with less expensive 2D runs. 3D runs will be done as appropriate. We choose the comet parameters to be as follows:

- diameter = 5 km with a 1 km granite core
- mass = 3.5 x 10^{16} g
- velocity of 50 km/s
- this results in the kinetic energy of the impacting comet E_0 = 4.4e27 ergs or 0.1 million MT

The target (Earth Indian Ocean) is a stratified series of regions with 100 km of air above 5 km of ocean water and 6 km basalt mantle and 7 km of Earth's crust. All regions are pre-stressed with a standard atmosphere. The results from this simulation (2D Impact) is a maximum crater size of 36 km diameter and a crown splash that reaches ~100 km height. We have placed calculational tracer particles along the sea floor at various distances from the impact point. A plot of the motion of several of these tracers is shown in Fig. 1, and the calculated temperatures along these trajectories is shown in Fig. 2.

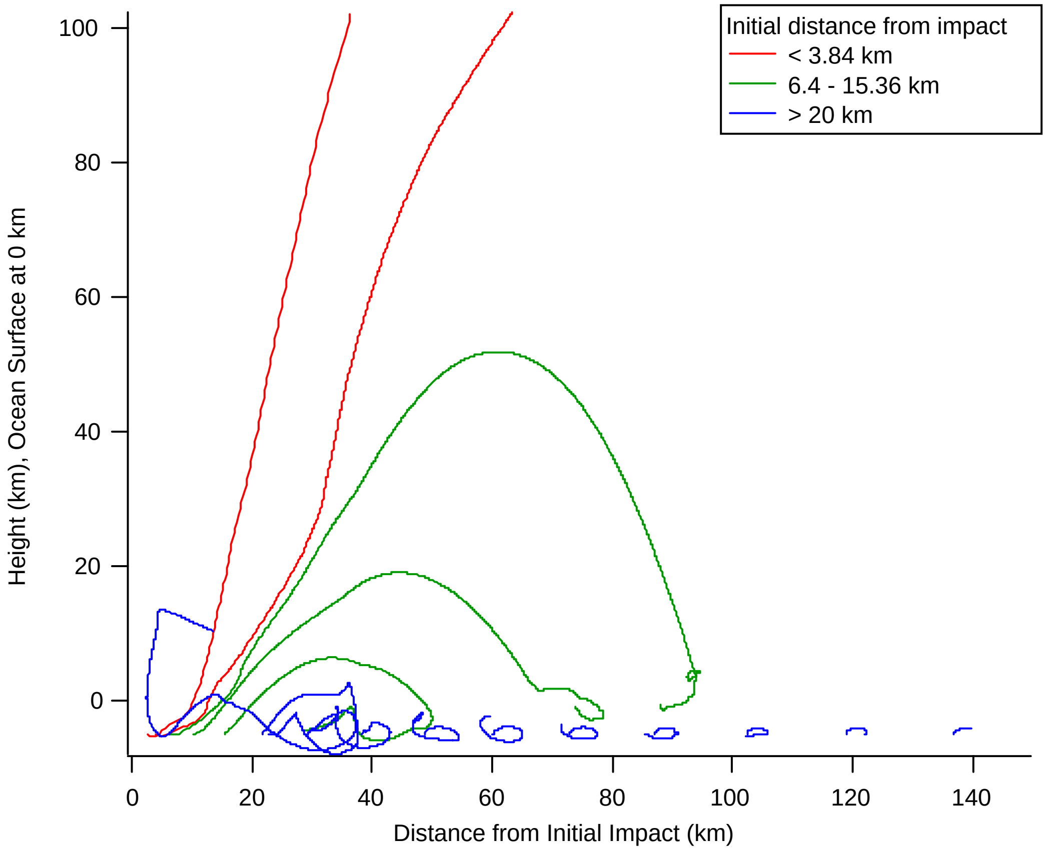


Fig.1 Trajectory of tracers in the simulation.

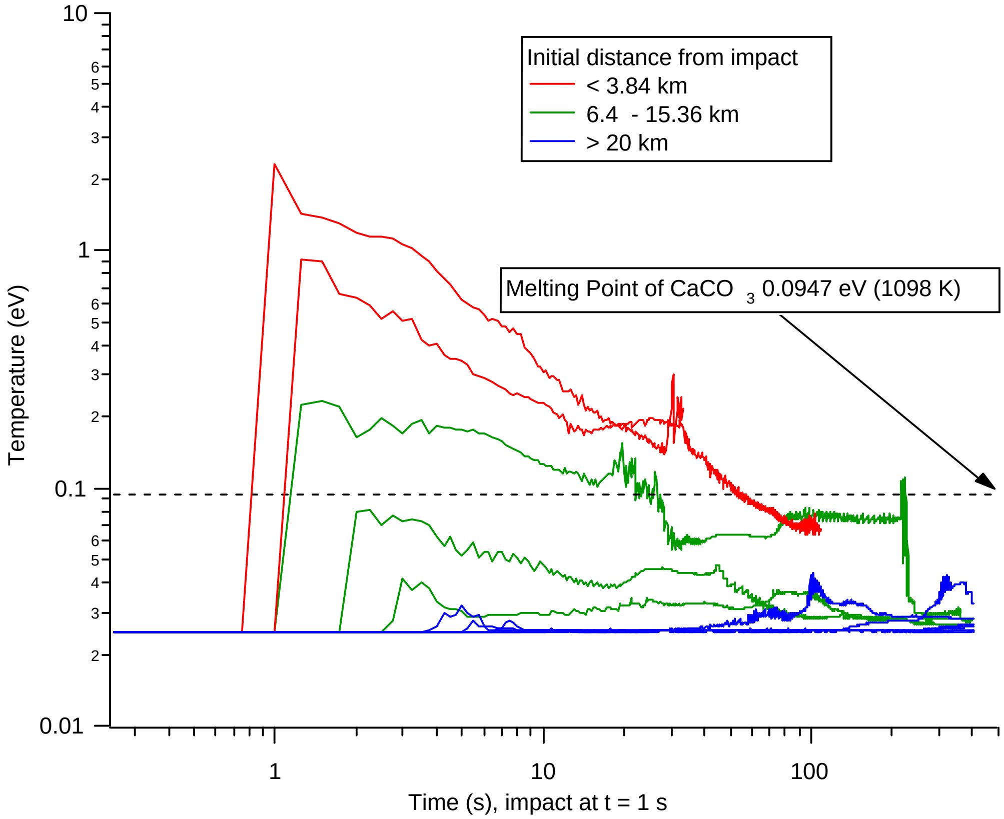


Fig. 2. Temperature calculated along the tracer trajectories (1eV = 11,600 deg. K)

Some of the ejecta from the impact reach temperatures above the melting point of calcium carbonate (1098 K or 0.095 eV), the main material in marine animal shells. If these melted materials are ejected from the impact site far enough away to be entrained in the resulting tsunami wave, then we could understand a potential mechanism for explaining the deposits in the chevrons on Madagascar.

While most of the ejecta from the impact site returns to the ocean within about 100 km of the impact point, some material is actually lofted with escape velocity and leaves the planet. There is a very small range between 3.8 km and 6.4 km from SQZ that small size material could potentially be ejected at angles around 45 degrees and travel significant distances from the impact site. Higher resolution simulations in 2D and subsequent 3D simulations at a low impact angle may result in calculated sea floor melted material at extreme distances from the impact point. The probablility of such an occurrence is small.

We compare simulations of comet impacts (density of ice ~1g/cm^3 and velocities of ~50 km/s) to asteroid impacts (density of stone ~2.6 g/cm^3 or metal density ~ 8 g/cm^3 and both with velocities of ~20 km/s) with the same imcoming kinetic energy. This comparison is shown in Fig. 3. From these simulations, we infer that the impactor material is not as important 9comet vs asteroid) as the magnitude of the impactor kinetic energy.

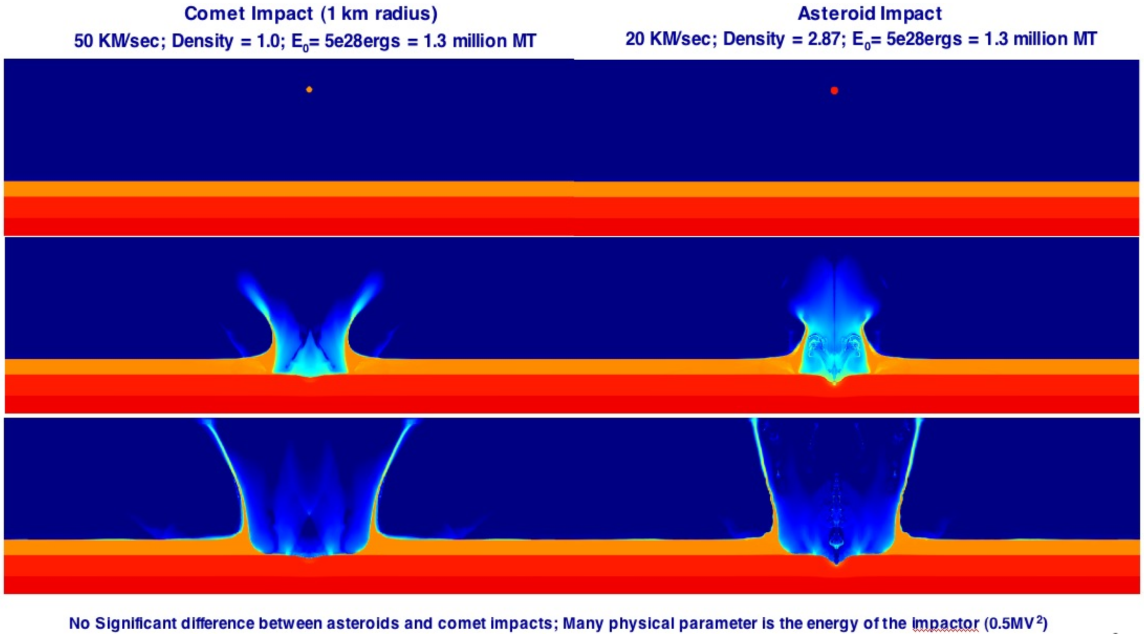
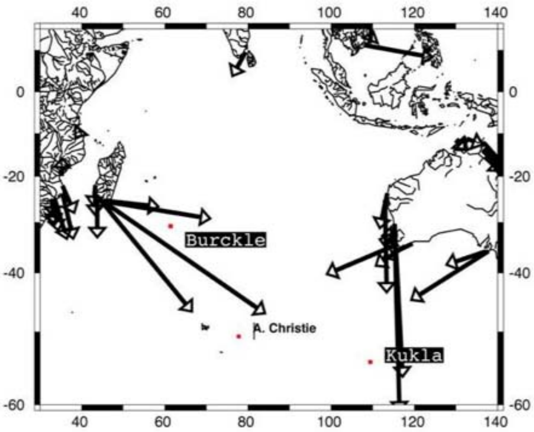
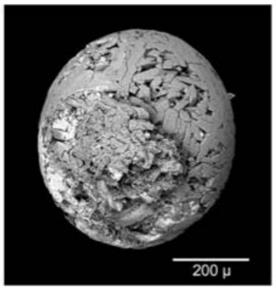


Fig 3. A comparison of the simulated initial crater size from a comet impact and an asteroid impact with similar kinteic energies.

One possible impact site in the Indian Ocean is the Burckle crater some 1600 km SE of Madagascar as shown in Fig. 4. From our current simulations, it is highly unlikely that the impact that formed the Burckle crate resulted in the partially melted fossils in the Chevrons on Madagascar, further simulations are required to either confirm or deny this suggestion. It seems reasonable to perform low angle impact 3D simulations with higher resolution around the 3-6 km distancve from SGZ in order to give further simulation justification for the hypoothethesis that some material ejected from the Burckle crater impact became entrained in the megatsunami that formed the chevrons on madagascar.





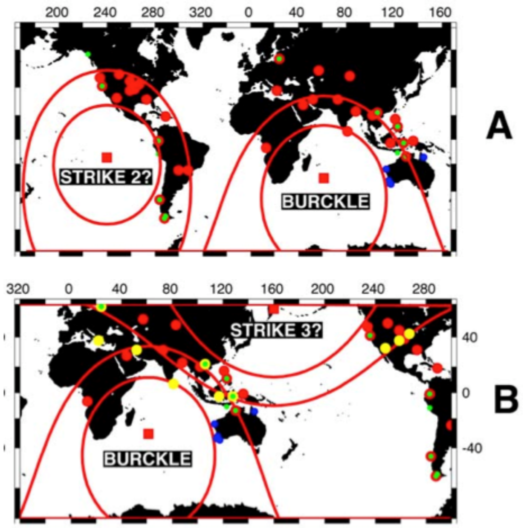


Fig. 4. Location of the Burkle crater on the floor of the Indian Ocean relative to Madagascar (~1600 km SE).

8. References

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