Modeling global impact effects on middle-sized icy bodies: applications to Saturn's moons

Summary: Vanessa M. Lauburg   Authors: Lindsey S. Bruesch and Erik Asphaug

ABSTRACT

Many ongoing studies in planetary science aim to explain the formation of the Solar System. One approach is to study the formation of moons around gas giants and apply the results to the larger system. Information about the internal structures of these icy moons is integral to the understanding of the formation of satellite systems. Several methods, such as seismology, and estimates of moments of inertia and mass, have provided details about the interiors of some satellites. It has also been suggested that analysis of global damage caused by large impacts can be used to determine internal structure. In this paper, the authors investigate the correlation between the internal structures of icy moons and the global damage suffered by the satellites due to large impacts. They simulate impacts on model satellites, varying the sizes and densities of the cores. Next, they determine how these changes in internal structure change global effects such as surface fragmentation, and damage at the point directly opposite to the impact site (the antipode). Finally, they simulate impacts on three of Saturn's moons, Rhea, Mimas, and Tethys, which have large impact craters and significant terrain damage.

The simulations are performed with a 3D smooth particle hydrodynamics code capable of modeling triaxial bodies and calculating fragmentation. During each simulation, the peak surface velocity is measured. This quantity is representative of the strength of seismic disturbances and the amount of terrain damage taking place. The peak surface tensile stress, which indicates surface rupturing, is also determined. The model satellites have silicate cores and water ice mantles, and the impactor is a comet modeled as an undifferentiated sphere of water ice. The size of each impactor is determined by the diameter of the crater on the target body, and information about the gravity of objects consisting of water ice. Nine simulations for each satellite are run, varying the density and size of the core while maintaining the correct value of bulk density. The impact sites on the model satellites coincide with the crater locations on the moons, and the impact angle is varied.

The authors find in each simulation that seismic energy from the impact is only weakly focused at the antipode. Also, variation in core radius is more strongly correlated with terrain damage at the antipode than variation in core density, which suggests that observations of antipodal damage will provide information about the geometry of the core. The simulated impacts on Tethys produce higher peak surface velocities and tensile stresses than on Mimas and Rhea. This result is expected because the impact crater on Tethys is larger relative to the moon's diameter than the craters on the other two satellites. The calculations of rupture and fragmentation in the targets did not produce useful results due to the limited resolution of the SPH code, but future improvements in the code and better understanding of ice fragmentation will resolve this issue.

Reference: Bruesch, L.S., Asphaug, E., 2004. Modeling global impact effects on middle-sized icy bodies: applications to Saturn's moons. Icarus 168, 457-466.