MODELING GLOBAL IMPACT EFFECTS ON MIDDLE-SIZED SATURNIAN SATELLITES.

L. S. Bruesch[1] and E. Asphaug[1], [1] Department of Earth Sciences, University of California – Santa Cruz, 1156 High Street, Santa Cruz, CA 95064; lbruesch@es.ucsc.edu.

Introduction: Impacts are invoked routinely to explain disrupted terrains on many bodies in our solar system. In particular, impacts are thought to cause antipodal disruption [e.g. 1-2], which occurs on the opposite side of the body to the impact site. Through the modeling of large impact events and the analysis of their global effects, we are able to test the validity of the impact-antipode correlation hypothesis, and to probe the compositions of Saturn's satellites and hence their modes of origin.

The Saturnian satellites Tethys and Mimas are two of the best examples of satellites with giant impact craters. Antipodal to very large craters, one finds disrupted surface terrains. The antipode of Odysseus Crater (d=400 km) on Tethys (d=1048 km) is a planar region within Ithaca Chasma, a trough system extending nearly 270 degrees around Tethys [2]. The anti-Herschel side of Mimas (d=394 km) is also a trough system thought to have formed during the event that created Herschel Crater (d=135 km) [3]. At issue is whether, and to what degree, these features may be correlated, and what such correlation implies for each satellite's interior.

Watts et al. [4] modeled antipodal pressures and surface accelerations caused by large impacts into Tethys and Mimas, among other bodies, using a 2D Simplified Arbitrary Lagrangian Eulerian (SALE) code. They found that the impact on Tethys produced sufficient disturbance to account for the observed antipodal terrain (i.e. the modeled surface accelerations and pressures were greater than the assumed surface material strength). However, a 2D model is not a good choice for studying antipodal effects, as all wave energy comes to a perfect focus artificially.

Methods: We are modeling the formation of Odysseus on Tethys and Herschel on Mimas using a 3D smooth particle hydrodynamics code (SPH). The modeled craters are formed by the impact of another body into the surface of each satellite, rather than by the introduction of a high-temperature, high-density cell representing an impactor, as was used by Watts et al. [4]. Moreover, in 3D we can introduce the modest oblateness of these satellites [5-6].

There are two mechanisms by which an impact can cause terrain disruption elsewhere on a satellite: (1) via fracture damage produced by seismic wave propagation through the body and (2) via the impacts of secondaries. Terrain disruption could also be caused by a combination of these mechanisms. We are studying global impact effects by modeling both mechanisms for terrain disruption. We are interested in finding areas of maximum terrain disruption, whether this occurs at the antipode or not.

Because much of the current knowledge of the internal structures of satellites in the Saturnian system is based on moment of inertia calculations obtained from Voyager limb data and previous estimates of the mass of each satellite [5-6], core and mantle sizes and densities are not tightly constrained and we are free to vary these parameters in our model. For our baseline runs, the target bodies contain a pure water ice (ρ=0.917 g cm^{-3}) mantle and a basalt (ρ=2.7 g cm^{-3}) core, modeled using Tillotson equations of state.

The impactors are assumed to be comets composed of pure water ice with no core. Impact velocities in all cases are ~20 km s^{-1} (based on impact velocities found in [7]). Impact angle is vertical (although other impact angles can be used). The diameter of the impactor in each case (12.7 km to 15.6 km to form Odysseus; 2.9 km to 3.6 km to form Herschel) is calculated using pi-scaling [8] and assumed transient crater diameters (d=246 km for Odysseus; d=95 km for Herschel) [9].

To investigate global fracture damage, our model calculates the peak surface velocity and peak surface tensile stress. The peak pressure throughout the body is also calculated. To investigate terrain disruption due to the impacts of secondaries, our model calculates the where ejecta will land based on the ballistic range of the ejecta.

Results: The figures below are a sampling of our modeling effort. They depict peak surface velocity, peak surface tensile stress and peak pressure on Tethys and Mimas during impact events similar to those that formed Odysseus Crater (on Tethys) and Herschel Crater (on Mimas). The core size and density in these cases are our baseline, based on values from [5] and [6]. All impacts occur at the top of each figure. The Tethys figures are at ~1.5 wave-crossing times after the impact, and the Mimas figures are at ~1.2 wave-crossing times after the impact. These calculations are being run to at least 2 wave-crossing times, but our preliminary analysis is that we see antipodal disturbance on Tethys (see Figures 1-2), but not on Mimas (see Figures 3-4), which is to be expected since Tethys experiences a larger impact. Figures 1-4 are surface plots and Figures 5-6 are vertical slices through the interior of each satellite.

Future Work: We plan to use our SPH code to model other giant impact features, including Tirawa on Rhea, Amata on Dione, Valhalla on Callisto, Calloris on Mercury, South Pole Aitken on the Moon, and the 460 km diameter south polar crater on Vesta. In each case we will use the best available geodesy and internal material parameters.

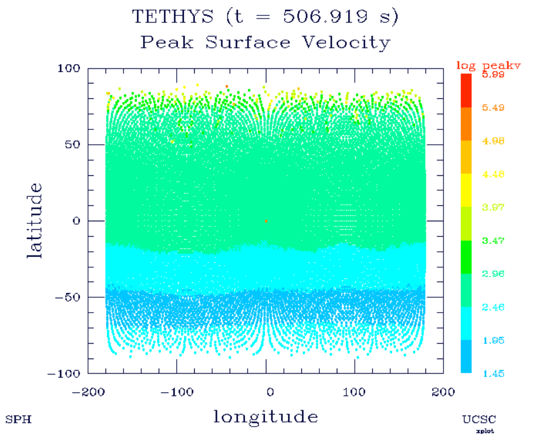

Figure 1: Peak surface velocity on Tethys. The antipode (bottom of the figure) is marked by an increase in surface velocity.

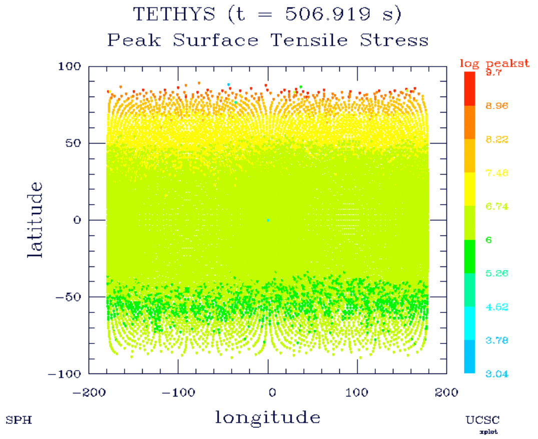

Figure 2: Peak surface tensile stress on Tethys. The antipode (bottom of the figure) is marked by an increase in surface tensile stress.

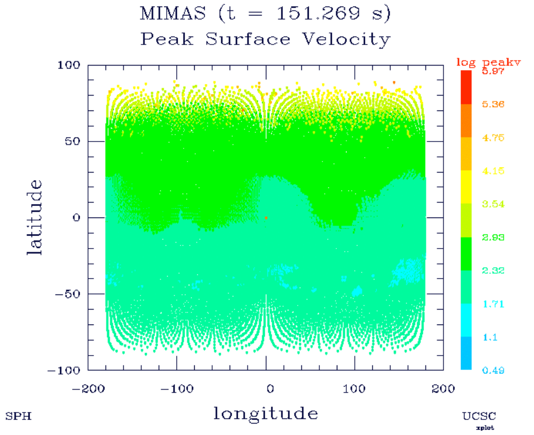

Figure 3: Peak surface velocity on Mimas. The antipode (bottom of the figure) shows no increase in surface velocity.

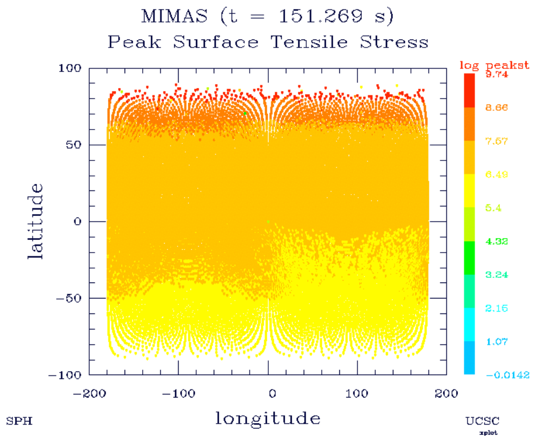

Figure 4: Peak surface tensile stress on Mimas. The antipode (bottom of the figure) shows no increase in surface tensile stress.

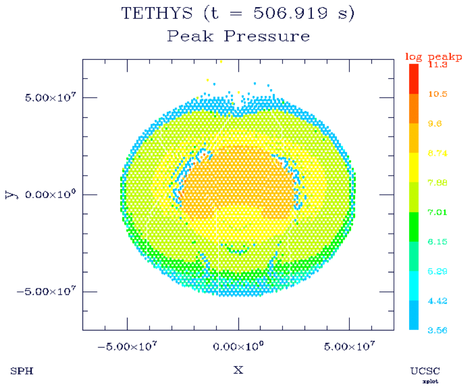

Figure 5: Peak pressure on Tethys.

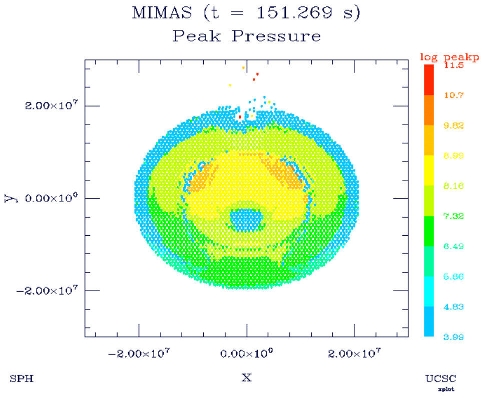

Figure 6: Peak pressure on Mimas.

References: [1] Scultz, P. H. and Gualt, D. E. (1975) *Moon* 12, 159-177. [2] Moore, J. M. and Ahern, J. L. (1983) *LPSC Proc.* 88, A577-A584. [3] McKinnon, W. B. (1985) in *Ices in the Solar System*. [4] Watts, A. W. et al. (1994) *Icarus* 93, 159-168. [5] Dermott, S. F. and Thomas, P. C. (1988) *Icarus* 73, 25-65. [6] Thomas, P. C. and Dermott, S. F. (1991) *Icarus* 94, 391-398. [7] Lissauer, J. J. et al. (1988) *JGR* 93, 13776-13804. [8] Melosh, H. J. (1989) *Impact Cratering: A Geologic Process* Oxford U. Press. [9] Moore, J. M. personal communication.