Jupiter Icy Moons Tidal Signatures and Ocean Mapping from Orbit. X. Wu, Y. E. Bar-Sever, W. M. Folkner, J. G. Williams, and J. F. Zumberge, Jet Propulsion Laboratory, California Institute of Technology, MS238-600, 4800 Oak Grove Drive, Pasadena, CA 91109, USA, Email: Xiaoping.Wu@jpl.nasa.gov

Introduction: Following the Galileo spacecraft encounters with Europa, Ganymede, and Callisto, evidence emerged suggesting that these Galilean moons of Jupiter may have liquid oceans underneath their icy shells. Detection of the oceans on one or all three moons will have profound implications on probability of life beyond the Earth. The icy satellites also have tidal environments that are among the strongest in the solar system. The leading time-varying tidal forcing term on the surface of Europa is at least 9 times larger than those on the inner planets. Tidal forcing on the surfaces of Ganymede and Callisto are about 10% and 7%, respectively, of that on Europa. Since a planetary body with internal fluid deforms more than an otherwise solid body, tidal measurements offer exciting opportunities to detect the oceans.

Tidal Deformation Models: We have computed tidal gravity and surface displacement signatures of a spherical, non-rotating and elastic Europa with and without a global liquid ocean using a suite of possible interior structure models. For such models, tidal responses are proportional to the 2nd degree forcing potential on the surface. The proportionality coefficients, or Love numbers k_2 and h_2, increase drastically when the ocean is present. Their values also depend significantly on the rigidity and thickness of the ice shell, rigidity of the mantle, and density of the salty ocean water. A comprehensive geodetic experiment measuring a number of geodetic quantities is required to separate effects of these interior parameters for ocean detection [1].

Orbit Simulation: We have also carried out fairly realistic orbit simulations to assess possible uncertainties in k2, static gravity field and orbit parameters using X-band Doppler tracking to a Europa orbiter. For an 83°-inclination near-circular orbit at 200 km altitude, and with 15 days of tracking from 2-DSN stations, the uncertainties for k2 and radial orbit component will be 0.0004 and 5.7 m respectively. The uncertainty results depend critically on factors such as orbit inclination and duration, number of tracking stations, and the length of continuous orbit arcs [2].

Ocean Inference: Based on the tidal models and orbit simulations, a simple inference in the linear regime can be made for measuring the ocean and ice. Assuming h2 and ice rigidity can be measured to sufficient accuracies by surface displacement observations, the high k2 accuracy indicates that detection of the ocean and an accuracy of 200 m to 1 km in ice shell thickness determination could be expected for Europa. If the k2 uncertainty is scaled by the tidal forcing, uncertainties of 0.004 and 0.006 can be expected for k2 values of Ganymde and Callisto. Again, assuming complications from other interior parameters can be controlled by other geodetic measurements, the k2 uncertainties are still small enough to detect hidden global oceans for these moons. Differential libration between the ice shell and rocky mantle determined beyond statistical doubt will provide another unequivocal evidence for global liquid oceans on these moons. Mantle libration can be measured by Doppler tracking through orbital effects of the gravity field attached to the mantle. With a slightly better tracking scenario and reasonable surface displacement measurements, uncertainty at 1-arcsec level in differential libration may be achievable for Europa. The expected amplitude for the differential libration is about 10 arcsec.

Non-Global Oceans: With the large current uncertainties about compositional and density profiles on the icy moons, there is a possibility that some of the oceans may be non-global. Shallow liquid water may be trapped in basins by bottom topography just like the oceans on the Earth but covered by ice. In such a case, the tidal response will be much more complex than that of a nearly spherically symmetric body. A whole spectrum of spherical harmonic deformation will result from a 2nd degree harmonic forcing term. Simulation results on the determination of the "extended Love numbers" will also be reported.

Discussion and Conclusions: The bold JIMO initiative to orbit all 3 icy moons is an unprecedented scientific endeavor. For any satellite with a global oceanic layer, reasonable tracking and surface displacement measurements over a month would provide enough accurate data for ocean detection and ice thickness determination. However, the thickness of the ocean layer will remain poorly constrained using the data types we have considered. Given the possibility of non-global oceans and the consequent complex tidal deformation patterns, near global data coverage and sufficiently high accuracy and resolution measurements would be preferred subject to engineering and technological constraints.

References:

[1] Yoder, C. F., (2003) *Icarus, in press.* [2] Wu X. et al. (2001) *Geophys. Res. Lett., 28,* 2245-2248.