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Determination of Ice and Water Layer Thickness of Jovian Moon Europa from a Viscoelastic Tidal Deformation Analysis

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Although Europa is tidally phase locked, its eccentric orbit still allows for a temporal variation in tidal deformation with the Europan orbital period of 3.5 Earth days. Europan daily/monthly deformation due to this tidal forcing of Jupiter and its largest moons is determined by means of a normal mode analysis for a radially stratified, self-gravitating spherical model with a Maxwell rheology. Stratification of the model is consistent with observations obtained by the Galileo mission. The tidal gravity potential caused by Jupiter is calculated numerically and applied as forcing.

It was found that, for realistic models of Europa, the maximum vertical surface displacements range between 14 and 30 m for models that have an ocean, while they range between 41 and 95 cm for models without an ocean. This order of magnitude difference between a model with an ocean and an oceanless model is mainly caused by the difference in boundary conditions between ice - ocean or solid earth - ocean, and ice - solid earth boundaries. The ranges of variations are not only caused by uncertainties of ice and water layer thickness, but also by uncertainties of ice rigidity.

Using a crossover technique to enhance orbit determination precision, a future satellite altimetry mission to Europa should be able to detect displacements of 14 to 30 m, but likely not 41 to 95 cm with the present state of technology. However, such sub-meter differences might become discernable if also altimetry measurements could be made over the tidal nodes on Europa, assuming that these experience no net deformation. Although a satellite altimetry mission could thus detect the presence of an ocean, we would need to know more about ice rigidity under situations that are prevailing on Europa to also deduce ice and ocean thickness if such an ocean were present.