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State of Stresses at the Icy Surface of Europa: A Strong Case for the Existence of a Subsurface Ocean

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We have developed a new normal mode model for simulating deformation and stresses of icy moons based on solid-earth deformation models that, apart from solid and purely inviscid layers, can also have layers with extremely low viscosities. This numerical model is self-gravitating, linearly viscoelastic, radially stratified and can deal with both internal and external loads and forcings.

We have applied the model to simulate induced stresses in the presence of a subsurface ocean underneath the ice shell of Jovian moon Europa and to correlate these stresses with the shape of the lineaments of cracks and ridges observed on the surface. Stresses at the surface might be induced by several different mechanisms, from which only the two most important are analyzed: the eccentricity tide acting on Europa and non-synchronous rotation (NSR) of the ice shell. The eccentricity-tide forcing induces a highly variable stress field that explains the formation of cycloidal features without taking into account NSR stresses. The NSR mechanism induces a nearly static stress field that explains the formation of both regional slightly-curved and global lineaments. As both types of lineaments exist on the surface of Europa, the strength of NSR stresses should have changed throughout the geological history of Europa. Such a change can be driven by a variable rate of non-synchronous rotation, which can be the result of thickness variations in the ice shell.

Another important result derived from this study is that tensile stresses at the surface of models without a subsurface ocean are too small to originate a crack at the surface if NSR is not taken into account. If NSR stresses are added to the modeling of the stress field, tensile stresses only become large enough to break ice when the stress field is practically static. As a result, the existence of cycloidal features strongly suggests the existence of a subsurface ocean underneath the ice shell of Europa.