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Effects of a Slush Layer on Tidal Deformation and Differential Rotation of Europa

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Grooves and ridges on the surface of Jovian moon Europa show a possibility of a low-viscosity layer between the icy surface and Europa's solid interior. Such a low-viscosity layer is likely to be caused by tidal heating as a consequence of Europan eccentric orbit about Jupiter.

It is unclear whether this fluid layer is purely liquid or whether it is more slush-like. A purely liquid water layer would be effectively inviscid; a slush layer would have viscosities that are finite but which could be extremely low. Dynamic consequences of a purely liquid layer are relatively simple to model numerically compared to those of an extremely low-visous slush layer. We have numerically investigated the dynamic behavior of an Europan model having a low-viscosity slush layer by means of a gravitational self-consistent normal mode relaxation model based on Sabadini & Vermeersen (Global Dynamics of the Earth, Kluwer, 2004).

For Maxwell viscoelastic models we can go down to viscosities as low as 10ˆ13 Pas, equivalent to Maxwell relaxation times of 100 - 10,000 s, depending on rigidities. We will show results for two dynamic responses: daily tidal deformation of the Europan crust and a possible phase lag between the tidal bulge of Europan solid interior and Europan surface. We have found that an altimetry mission might not only be able to distinguish whether Europa has a shallow low-viscosity layer indeed, but also whether such a layer is purely liquid or slush-like. To some extent this is dependent on the question whether insight from future (laboratory) studies on the rheology of Europan ice could limit present uncertainties on ice rigidity.