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Estimates of the dissipative heat and torque generated by ocean tides on icy satellites in the outer solar system

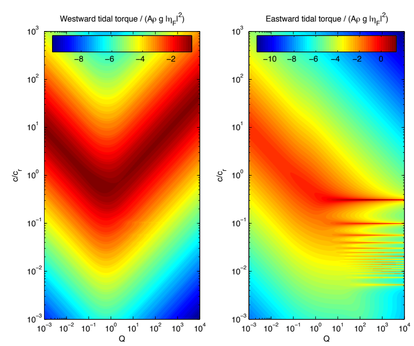
Robert Tyler, Planetary Geodynamics Laboratory, Code 698, NASA Goddard Space Flight Center, Greenbelt, MD 20771, and Department of Astronomy, University of Maryland College Park, Email: robert.h.tyler@nasa.

The tidal flow response generated in a satellite ocean depends strongly on the ocean configuration parameters as these parameters control the form and frequencies of the ocean's natural modes of oscillation; if there is a near match between the form and frequency of one of these natural modes and that of one of the available tidal forcing constituents, the ocean can be resonantly excited, producing a strong tidal response. The fundamental elements of the response are described by the tidal flow and surface fluctuations. Derivative elements of the response include the associated dissipative heat, stress, and forces/torques.

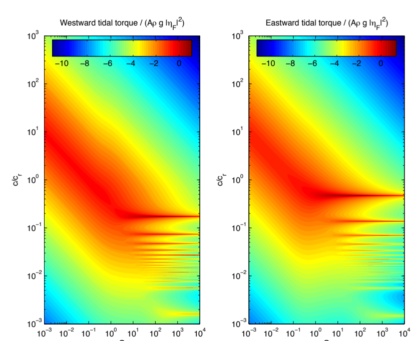
The dissipative heat has received much previous attention as it may be important in explaining the heat budget on several of the satellites in the Outer Solar System. While these estimates will be reviewed and compared with the tidal dissipation estimates compiled in Hussman et al. (2010), the primary goal in this presentation is to extend the analysis to consider the tidally generated axial torque on the satellites and the potential consquences for rotation.

Interestingly, even a synchronously rotating satellite will, if a global fluid layer is included, experience a complex set of opportunities for torques in both the prograde and retrograde sense. The amplitude and sense of the torque sensitively depends on the ocean parameters controlling the tidal response. This sensitivity, combined with expected feedbacks whereby the tides affect the orbital parameters, suggests that the evolution of the satellite system will experience phases of both prograde and retrograde tidal torques during its evolution. A related point is that parameters of the ocean might be inferred from inferences or observations of torque or rotational deviations.

In the panels to the right we show the non-dimensional tidal torques associated with obliquity (top) and eccentricity (bottom). The parameters described in the labeling are the fluid density ρ, surface gravity g, ocean surface area A, tidal equilibrium height η_F, dissipation quality factor Q, and $c=(gh)^{1/2}$, $c_r=\Omega a$, with ocean thickness h, rotation rate Ω, and radius a.



Torque due to tides forced by obliquity as a function of the parameters c/c_r and Q. Retrograde (“Westward”) and prograde (“Eastward”) components shown in left and right panels, respectively. Log10 scale shown in colorbar.



Same as above but for tides forced by eccentricity.

References:

[1] Hussmann H. and Choblet G. and Lainey V. and Matson D. L. and Sotin C. and Gabriel T. and Van Hoolst T. (2010) Space Sci. Rev. 153: 317-348.