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Effects of Lateral Inhomogeneity in a Spherical Earth on Gravity Earth Tides

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Since Love (1909) first modeled the tidal deformation of a spherically stratified and non-rotating earth, many theoretical studies on Earth tides have been performed for different Earth models. Tidal deformations were studied for a spherically symmetric, perfectly elastic and isotropic Earth by Longman (1962, 1963), Saito (1967), Farrell (1972), Takeuchi and Saito (1972), etc. Expressions for computing different kinds of tides (such as gravity, tilt, strain) for the symmetric model were presented using Love numbers. Wahr (1981) developed the tidal theory with considering the effects of the Earth's rotation and elliptical stratification. That study showed that the effects of rotation and ellipticity within the mantle on tidal observation are about 1%; the Love numbers became latitude dependent. Based on Wahr's theory, Dehant (1987a, b) studied tidal deformation for an elliptical uniformly rotating Earth with an inelastic Earth mantle. Those studies presented computation of the gravimetric factors and revealed an increase of gravimetric factors by ca. 0.4% with respect to Wahr's value and an increase of Love numbers by ca. 1.4-3% compared to the elastic case.

For a 3-D spherical earth model, Dehant et al. (1999) presented the values of the tidal gravimetric factor as well as the Love numbers for the tidal surface displacement and the tidal mass redistribution potential for two rotating, nonspherical Earth models. Molodenskiy (1977, 1980) proposed a theory to study the effects of lateral weak inhomogeneity in the mantle and presented expressions to calculate the effects of seismic waves, but ignored the contribution from lateral density changes. In those reports, he claimed without verification that the density contribution is very small. According to that theory, Molodenskiy and Kramer (1980) calculated the derivatives of Love numbers with respect to the seismic waves. Their computations were based on a simple inhomogeneous model, the Ocean-Land model. Based on the approach of Molodenskiy (1977, 1980), Wang (1991) studied the tidal deformations on a rotating, spherically asymmetric, viscoelatic and laterally heterogeneous earth.

The present study develops the theory of Molodenskiy by reformulating the expressions with new notation and calculation. We present novel expressions for computing the effects of lateral density inhomogeneity and introduce a new 3-D lateral inhomogeneous Earth model (Zhao, 2001) to compute these effects. Our numerical results show that the effects of density are of the same level as those of seismic waves: they are not negligible. The effects of the lateral inhomogeneous structure calculated for the real 3-D inhomogeneous model are much less, by a factor of about 0.2, than those of the simple Ocean-Land model presented in Molodenskiy and Kramer (1980). Collecting contributions from the seismic wave and density models, we obtain the completed total effect of the real 3-D inhomogeneous Earth structure on semidiurnal gravimetric factors, with a magnitude of about -0.16-0.1%. This result is less than, but almost of the same order as that of Earth's elliptical effect (ca. 0.7%; Dehant, 1995). Finally, we calculate the corresponding effects on tidal gravity for all three kinds of Earth tide: semidiurnal, diurnal, and long period ones. Compared to the tidal gravity changes, the gravity variations caused by the increments are about 0.15% for the semidiurnal tide and 0.1% for the diurnal and long period tides.