Geophysical Research Abstracts
Vol. 17, EGU2015-2301, 2015
EGU General Assembly 2015

The rotational feedback on linear-momentum balance in glacial isostatic adjustment

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The influence of changes in surface ice-mass redistribution and associated viscoelastic response of the Earth, known as glacial-isostatic adjustment (GIA), on the Earth's rotational dynamics has long been known. Equally important is the effect of the changes in the rotational dynamics on the viscoelastic deformation of the Earth. This signal, known as the rotational feedback, or more precisely, the rotational feedback on the sea-level equation, has been mathematically described by the sea-level equation extended for the term that is proportional to perturbation in the centrifugal potential and the second-degree tidal Love number.

The perturbation in the centrifugal force due to changes in the Earth's rotational dynamics enters not only into the sea-level equation, but also into the conservation law of linear momentum such that the internal viscoelastic force, the perturbation in the gravitational force and the perturbation in the centrifugal force are in balance. Adding the centrifugal-force perturbation to the linear-momentum balance creates an additional rotational feedback on the viscoelastic deformations of the Earth. We term this feedback mechanism as the rotational feedback on the linear-momentum balance.

We extend both the time-domain method for modelling the GIA response of laterally heterogeneous earth models and the traditional Laplace-domain method for modelling the GIA-induced rotational response to surface loading by considering the rotational feedback on linear-momentum balance. The correctness of the mathematical extensions of the methods is validated numerically by comparing the polar motion response to the GIA process and the rotationally-induced degree 2 and order 1 spherical harmonic component of the surface vertical displacement and gravity field. We present the difference between the case where the rotational feedback on linear-momentum balance is considered against that where it is not. Numerical simulations show that the resulting difference in radial displacement and sea-level change between these situations since the Last Glacial Maximum reaches values of $\pm$ 25 m and $\pm$ 1.8 m, respectively. Furthermore, the surface deformation pattern is modified by up to 10% in areas of former or ongoing glaciation, but by up to 50% at the bottom of the southern Indian ocean. This also results in the movement of coastlines during the last deglaciation to differ between the two cases due to the difference in the ocean loading, which is seen for instance in the area around Hudson Bay, Canada, and along the Chinese, Australian, or Argentinian coastlines.