Role of the 670 km density discontinuity and the lithospheric viscosity on polar wander speed of ice age cycles

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Predicted polar wander speed due to the Late Pleistocene glacial cycles is sensitive to the lower mantle viscosity(LVM), the density jump at 670 km depth (M1 mode), and the lithospheric thickness and viscosity. The sensitivity to the M1 mode and the lithospheric viscosity (LV)is clearly recognized for the earth models of LVM~10**21 Pa s. For models with LVM~10**21 Pa s and LV of ~10**24 Pa s, the relaxation time of the M1 mode and the lithosphere are similar to the timescale of the ice age. Thus, the excitation of the M1 mode is consequently confused by the viscous relaxation of the lithosphere. On the other hand, the relaxation time of the M1 mode for models with LVM~10**22 Pa s is about 3 Myr and insensitive to the M1 mode.

A compressible earth model with elasticity and density given by the seismological model PREM is used in predicting polar wander rates due to the Late Pleistocene glacial cycles. Predicted polar wander speed is sensitive to the lower mantle viscosity, the density jump at 670 km depth, and the lithospheric thickness and viscosity. The sensitivity to the M1 mode related to the density jump at 670 km depth and the viscosity of the viscoelastic lithosphere is clearly recognized for the earth models with a lower mantle viscosity (LVM) of about 10**21 Pa s. For models with hlm~10**21 Pa s and lithospheric viscosity (LV) of 10**23~10**24 Pa s, the relaxation time of the M1 mode is about 1.5 Myr and the Maxwell relaxation time of the lithosphere is 100~1000 kyr. These relaxation times are similar to the timescale of the ice age examined here.

Equations describing the secular term of polar wander are composed of two terms. One is associated with the surface loads and the deformation of the Earth due to surface loads, referred to as loading term. The other is associated with the deformation induced by the shift of the rotation axis, referred to as rotational term. Polar wander prediction associated with the loading term is mainly sensitive to the load history for the last glacial cycle during the past 100 kyr. That for the rotational term is sensitive to the memory of polar wander, which is represented by the convolution of the tidal Love number and polar wander m1(t) and m2(t). For the earth models with a relaxation time of 1 Myr for the M1 mode, earth models with LVM~10**21 Pa s, prediction of polar wander speed is mainly determined by the rotational term. Predictions for these models are also sensitive to the rheology of the lithosphere, i.e., elastic or viscoelastic. In the earth models with a lithospheric viscosity of 10**23~10**24 Pa s, the excitation of the M1 mode is consequently confused by the viscous relaxation of the lithosphere. This results in a significant reduction of polar wander speed compared with that for an elastic lithosphere. On the other hand, the relaxation time of the M1 mode for models with LVM~10**22 Pa s is about 3 Myr and much longer than the timescale of the ice age. Predicted polar wander speed for these earth models is determined by the loading term. If the M1 mode is not excited by surface loads associated with the glacial cycles, polar wander speed is consequently determined by the loading term. Then, predictions of polar wander speed as a function of lower mantle viscosity have the well known profile of an inverted parabola, with a maximum value of about 1-Ma for models with LVM~10**22 Pa s. An approximately similar profile is predicted for models with a lithospheric viscosity of 10**23~10**24 Pa s, regardless of the dynamic behaviour of the 670 km density discontinuity. As a consequence of the sensitivity of polar wander speed to the lithospheric viscosity, however, polar wander speed may be affected by the lateral heterogeneity of the rheological structure of the lithosphere.