Geophysical Research Abstracts,
Vol. 10, EGU2008-A-00250, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-00250
EGU General Assembly 2008

Glacial isostatic adjustment in a 3D spherical self-gravitating viscoelastic earth with composite rheologies

W. van der Wal (1,2), P. Wu (2), H. Wang (3), M. G. Sideris (1)

(1) Department of Geomatics Engineering, University of Calgary, Canada, (2) Department of Geoscience, University of Calgary, Canada, (3) Institute of Geodesy and Geophysics, Chinese Academy of Sciences, Wuhan, China (wvander@ucalgary.ca / Phone: +1 403-2204113)

Most Glacial Isostatic Adjustment (GIA) modeling is based on linear (Newtonian) rheology, i.e., a linear relation between stress and strain rate resulting from diffusion creep. Laboratory experiments show that dislocation creep, which gives rise to non-linear or power-law creep, also operates in the mantle. For a given temperature and pressure, the mechanism (either diffusion or dislocation creep) that gives the higher strain rate becomes the dominant creep mechanism in that part of the mantle. Although GIA observations are well explained with linear rheology, realistic modeling should be in accordance with findings from micro-physics. In this presentation we will consider two types of composite rheologies that combine diffusion and dislocation creep in a way that the tensoral nature of stresses is retained. Case 1 is the Ellis model, where the strain rate is a summation of Newtonian and non-linear strain rate. In case 2, the state of stress decides between a purely linear and non-linear rheology. The aim of this paper is to compare the results from a purely linear, a purely non-linear, and the two composite rheologies to have a better understanding of the behavior of the latter. It is shown that composite rheologies may also explain the GIA observations.

Our model couples the Laplace equation to a finite element model for a layered 3-D spherical Earth with self-gravitation and material compressibility. ICE-5G with self-consistent sea-levels is used as surface loading. Composite rheology is assumed to be uniform in the mantle, with Newtonian viscosity fixed at a value of 1 x 10^{21} Pas, and

the stress exponent of the nonlinear rheology to be 3. The pre-exponent factor A is varied as 3.3 x 10^{-33}, 3.3 x 10^{-34} and 3.3 x 10^{-35}, in agreement with earlier studies with a purely non-linear rheology. The model results are compared with observations of relative sea level, uplift rate and gravity rate of change.

For A = 3.3 x 10^{-33}, the composite case 2 behaves close to a pure non-linear rheology; for A = 3.3 x 10^{-35}, it behaves close to the pure linear rheology. This indicates that the GIA response is dominated by either purely linear or purely non-linear rheology, depending on the value of the pre-exponent factor, the stress and the Newtonian viscosity. The Ellis model shows a slightly different response for A = 3.3 x 10^{-35}: it reaches the relative sea level of the linear case at last glacial maximum, and then relaxes faster and approximates the purely non-linear case.