User-defined subroutine for non-linear mantle deformation in postglacial rebound

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The effect of stress-dependence (dislocation creep) in models for postglacial rebound has been shown to improve fit with observations compared to models with diffusion creep only. Because diffusion and dislocation creep can occur simultaneously in mantle materials, they both need to be implemented in postglacial rebound models. A uni-axial creep law in Abaqus can simply be implemented in the user-defined subroutine CREEP. Individual stress tensor elements are not available in this routine but the von Mises equivalent stress is. However, it is not immediately obvious that individual strain rate elements can be derived from it. Also it might not be clear how the CREEP routine can be extended in case of a large number of elements each with different creep properties. Here the CREEP subroutine is tested in a simple axisymmetric model and combined with another subroutine to load an external database.

The CREEP subroutine with a non-linear flow law with stress-exponents 1 and 3 is tested against the standard creep laws in the material model definition (option *CREEP, LAW=STRAIN) for an axisymmetric model. Differences in von Mises stress and displacement are negligible. This suggests that also the combination of diffusion and dislocation creep can be correctly implemented with the CREEP subroutine. This subroutine is subsequently used in a 3D model for a spherical Earth subjected to glacial loading. In order to implement lateral varying creep parameters the creep parameters are computed from olivine flow laws with local pressure and temperature derived from seismology and stored to a file. The user subroutine UEXTERNALDB reads from this file the properties for each element which are then used in the creep subroutine to compute the strain increment for the same element.
Creep parameters can have very small numerical values, therefore future work should include tests for numerical stability. For more realistic stress-dependence access to individual stress tensor elements is required, which can be implemented using the user subroutine UMAT.