Geophysical Research Abstracts
Vol. 14, EGU2012-12695, 2012
EGU General Assembly 2012

Continuum damage modeling of ice shelves: inversion of surface velocities for a state damage variable

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Continuum damage mechanics is a promising alternative to fracture mechanics for representing rifting, crevassing and calving processes in ice sheet models. The constitutive relations describing ice rheology can be modified using state variables which describe the effects of cracking and damage without explicitly seeking to resolve individual cracks. The challenge in formulating a damage model for application in a large-scale ice sheet model is in the computational cost associated with the increase in model complexity and the addition of a differential equation describing the evolution of damage.

We present an investigation of the spatial distribution of damage for the Larsen C ice shelf using a scalar isotropic damage model implemented in the Ice Sheet System Model (ISSM). The representation of damage using a single scalar is a simple but numerically efficient approach to accounting for the effects of fractures on ice flow. InSAR-derived surface velocities are used to invert for the scalar damage variable, leading to a spatial map of damage analogous to that produced by inverting for the ice rigidity itself. The key distinction in inverting for the damage variable is that thermal and mechanical components of the constitutive relation are formally separated in the inversion. This spatial mapping of damage is a key first step in forward modeling of the stability of ice shelves using damage mechanics, and we discuss ongoing work to implement a transient damage model in ISSM to project the mechanical integrity of ice shelves in a warming climate.