Geophysical Research Abstracts
Vol. 12, EGU2010-13390, 2010
EGU General Assembly 2010

Data assimilation of rheology on ice shelves in the Antarctic Peninsula, using a new finite element formulation of rifting and faulting processes.

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Ice shelves evolve under the influence of many factors, the main ones being melting at the grounding line, refreezing downwards of the grounding line and up to the icefront, melting and calving at the icefront, and of course, ice flow under its own weight. In addition, ice shelf flow is often undercut by the presence of rifts, i.e. cracks that penetrate the entire ice shelf thickness and that are filled with seawater or ice melange, that perturb the flow significantly. Satellite radar interferometry observations of LarsenC, Larsen B and the Brunt ice-shelf also reveal the presence of faults, i.e. cracks with shear stress
along the flanks of the rift, that have a significant impact on ice shelf
flow, and yet differ completely from rifts.

Inverse control methods have been applied to ice shelves (Rommelaere 1997, Larour 2005, Vieli 2006, Khazendar 2007) to infer the unknown rheology, but these methods rely on continuum mechanics. One of the consequences is that weak rheology is systematically inferred wherever faults are rifts or present. This issue in inverse control methods precludes any quantitative use of the inferred rheologies.

This work presents a new formulation, based on penalty methods, that can model the behavior of rifts and faults (with shear stress along the flanks of rifts, opening rates, and fill-in by melange), and that can be integrated in current inverse control methods. We use ISSM (Ice Sheet System Model), developed at JPL/UCI to model thermal-mechanical steady-state and transient flow, to implement this new formulation. We apply the improved inverse control methods on several key ice shelves in the
Antarctic Peninsula, and account for the main rifts and faults. The model is capable of replicating features in the ice flow that up to now were never captured, and it improves data assimilation results by correctly capturing the discontinuous mechanics of rifts, therefore providing a more realistic map of rheology. By including rifts and faults where needed, the physics of ice shelf flow is improved, as the models do not try to accommodate for unknown features in the flow by tuning the rheology, but instead capture the features using an improved formulation of fracture.

This work was performed at the California Institute of Technology's Jet Propulsion
Laboratory under a contract with the National Aeronautics and Space Administration's
Cryosphere Science Program.