Geophysical Research Abstracts
Vol. 15, EGU2013-11822, 2013
EGU General Assembly 2013

Fracture Mechanical Analysis of Frost Wedging in Ice Shelves as Break-Up Mechanism

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Disintegration events in ice shelves have been the subject of extensive investigations in the past years, however comprehensive explanations applicable to a majority of events are still missing. A popular assumption made by Scambos et al. (2000) [1] links disintegration events to a general thinning of the ice shelf in conjunction with growing melt-water ponds leading to hydro fractures. This explanation seems reasonable for break-up events that happened in Antarctic summers.
Large parts of the Wilkins Ice Shelf, however broke-up in fall and winter periods. Therefore, the aim of the present study is to analyse the possibility of frost wedging of water filled surface crevasses in an ice shelf as a source of break-up events.
Configurational forces are used to assess crack criticality. The simulations are performed on a 2-dimensional single crack with a mode-I type load, body forces and additional crack-face pressure due to freezing of the water. Depth-dependent density profiles are considered. The relevant parameters, Young's modulus, Poisson's ratio and external loading are obtained from literature, remote sensing data analysis and modelling of the ice dynamics. The investigation is performed using the finite element software COMSOL. The simulations show that in comparison to water filled crevasses without ice, thin layers of frozen water may lead to a decreasing criticality at the crack tip as long as the ice 'bridge' is allowed to take tensile loads. An increasing crack criticality can be seen for thicker layers of ice. The results are compared to findings from previous finite element analyses of dry and water filled cracks as presented in Plate et al. (2012) [2].

[1] Scambos, T., Hulbe, C., Fahnestock, M., & Bohlander, J. (2000). The link between climate warming and break-up of ice shelves in the Antarctic Peninsula. Journal of Glaciology, 46(154), 516–530.

[2] Plate, C., Müller, R., Humbert, A., & Gross, D. (2012). Evaluation of the criticality of cracks in ice shelves using finite element simulations. The Cryosphere, 6(5), 973–984.