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ANTARCTIC SUBGLACIAL PROCESSES AND INTERACTIONS: ROLE OF TRANSITION ZONES IN ICE SHEET STABILITY

"ASPI"

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ANTARCTIC SUBGLACIAL PROCESSES AND INTERACTIONS: ROLE OF TRANSITION ZONES IN ICE SHEET STABILITY
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The aim of ASPI (Antarctic Subglacial Processes and Interactions) is (i) to understand the interactions between the ice sheet and the subglacial environment and the processes that control the Antarctic ice sheet, and (ii) to quantitatively determine the stability of the ice sheet in a changing climate and the impact of climatic variations on the coastal ice sheet. A key factor in both such qualification and quantification is the existence of transition zones within the ice sheet, such as grounding lines, i.e. the interface between the ice sheet and an ice shelf, between an ice sheet and a subglacial lake, as well as between an ice shelf and its pinning points. Especially grounding lines in marine ice sheets, such as the West-Antarctic Ice Sheet (WAIS), are extremely vulnerable, as small perturbations at the grounding line, such as basal melting or variations in sea level, might lead to an important grounding line retreat, as has been observed recently in the Amundsen Sea sector. ASPI therefore investigated the factors that influence the physics and mechanics of the grounding lines, such as rheology and the impact of marine ice formation in rifts at the grounding line (which could either stabilize or destabilize the ice flow), as well as how to represent the processes that are responsible for grounding line migration in ice sheet models.

On behalf of modelling and model development, we analyzed the response of a marine ice sheet to different perturbations near the grounding line using a numerical ice sheet model that takes into account longitudinal stress coupling and grounding line migration. The model is based on an existing flowline model, but extended with a novel subgrid determination of the grounding line position and migration as a function of the size of the transition zone between the ice sheet and the ice shelf. For instance, a wide transition zone is typical for an ice stream, a small transition zone typical in many areas around the East Antarctic ice sheet where the ice sheet rather suddenly changes into an ice shelf. Model results show that stress transmission or longitudinal coupling across the grounding line plays a decisive role. The grounding line migration is a function of the length scale over which the basal conditions change from frozen to the bed to floating, the "transition zone". Perturbations at the grounding line, such as reduction in buttressing of the ice shelf, substantially thins the grounded ice sheet. Marine ice sheets with large transition zones - such as ice streams - seem highly sensitive to such perturbations, compared to ice sheets with small transition zones, such as an abrupt ice sheet/ice shelf junction.

Deformation experiments are meant to shed more light on how marine ice formation at the grounding line influences the flow properties of the ice sheet system in the transition zone. Therefore, a new analysing facility was devised and tested and is installed during ASPI Phase I at the ULB laboratory. Preliminary experiments clearly demonstrate the importance of such marine ice inclusions on the ice flow: marine ice is harder to deform than meteoric ice in a typical ice-shelf stress field (vertical uniaxial compression with lateral and longitudinal extension) and may therefore exert a stabilizing effect on the whole system. The importance of such result is in conjunction with results from inverse modelling of the transition zone. The latter technique allows for a determination of the ice viscosity properties and/or the basal characteristics in the transition zone, based on observed ice sheet configuration (ice thickness, surface topography) and observed surface velocities. Inverse modelling is therefore capable of determining the size of the transition zone, which is an important factor for predictive modelling. For instance, the application to Pine Island Glacier (WAIS) clearly allows us to determine to position of the onset of the ice stream as well as to delineate areas where stress coupling is essential.

But not only is the ocean influence an important boundary condition. Basal thermal conditions influence to a large extent the behaviour of the Antarctic ice sheet. Whenever the ice reaches pressure melting point, melt water is generated that may lead to enhanced ice flow. Also the presence of subglacial lakes is governed by the basal thermal conditions. Using a 3D thermomechanically-coupled ice sheet model, the influence of spatial variability of the geothermal heat flux on the basal temperature regime of the Antarctic ice sheet was investigated. Results were compared with observations of known basal temperatures (e.g. ice core drill sites) as well as the spatial distribution of subglacial lakes. This way it was possible to determine what dataset is more suitable for future model experiments and what basal conditions are more likely to reign underneath the Antarctic ice sheet.

Subglacial lakes are yet another type of transition zones that are currently gaining attention. Recent observations demonstrate that subglacial lakes may drain and add significant amounts of basal water to the subglacial hydrological system. Hence, they have the potential of destabilising ice sheets through sudden lake outbursts, of which evidence exist along the coast of the East Antarctic ice sheet. In ASPI we investigate the effect of subglacial lake drainage on the stability of the ice sheet and especially how sensitive the subglacial lake system is towards drainage and flooding. Preliminary experiments show that only slight changes in surface topography might easily lead to partial drainage of such a lake.

Transition zones in the Antarctic ice sheets, whether it be grounding lines, subglacial lakes or the subglacial interface are key elements in the dynamic behaviour of the Antarctic ice sheet and its stability. Although this is the first phase of the ASPI project, we start to better understand the subglacial processes and interactions that occur at these interfaces. They seem even more important as a controlling factor as previously thought of.