Antarctic Subglacial Processes and Interactions: the role of transition zones in ice sheet stability (ASPI)

Duration of the project: Phase 1: 15/12/2005 – 14/12/2007
Phase 2: 15/12/2007 – 14/12/2009
Budget phase 1: 421.070
Keywords: Ice dynamics, grounding line, subglacial lake, continental shelf, modeling, ice analysis

Context

ASPI (Antarctic Subglacial Processes and Interactions: the role of transition zones in ice sheet stability) is an interdisciplinary research project that focuses on the stability of marine ice sheets, ice shelves and subglacial lakes within a global climate change context. ASPI forms part of the Belgian ACSYS/CliC-related activities and is part of the IPY endorsed research programme SALE-UNITED (Subglacial Antarctic Lake Environments). ASPI is the follow-up of AMICS (Antarctic ice sheet dynamics and climate change: Modelling and Ice Composition Studies).

Project description

Objectives

The aim of ASPI 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 such quantification and impact assessment is the existence of transition zones within the ice sheet. Typical examples of such transition zones are the 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. These transition zones are probably among the least understood elements of ice sheets, although they determine to a large extent the processes and dynamics of lateral expansion and retreat of ice sheets as well as the stability of marine ice sheets.

Methodology

Work Package 1: Grounding line migration

In most large scale ice sheet models of the Antarctic ice sheet, transition zones at the grounding line are considered to be small in extent and hence smaller than the grid size used in these models. However, in ice streams, transition zones are several hundreds of kilometres large, even for continental ice streams that drain large parts of the East Antarctic ice sheet. The need to elaborate models that treat both the mechanical coupling between ice shelf and ice sheet and simulate the migration of the grounding line in an appropriate way became clear after the recent observed grounding line retreat (Rignot, 1998) and inland thinning of Pine Island Glacier (PIG; Shepherd et al., 2004), due to rapid upstream thinning propagation. These studies thus imply a tight coupling between the ice sheet interior and surrounding ocean. ASPI intends to shed a light on both mechanisms of stress transmission and grounding line migration in a marine ice sheet for different perturbations in both the ice shelf and at the grounding line with a higher-order ice sheet model. Our treatment would use a sub-grid accuracy determination of the grounding line and a full 3D determination of the stress field across the grounding line (transition zone), leading to a proper grounding line migration in the plane.

Work Package 2: "Welding" at grounding lines by marine ice formation

Transition zones at grounding lines are the seat of marine ice formation in the large-scale bottom crevasses occurring at the hinge and between individual ice streams getting afloat. Marine ice thus has a great potential to stabilize the ice shelf flow, especially at those transition zones where the ice gets afloat (grounding line) and where it impinges on pinning points. Pinning points are considered to be equally important in stabilizing the ice flow in ice shelves and ice sheets. In January 2005, a deep ice core was retrieved within the framework of the (French-British) Berkner Island Ice Core Drilling Project (Dr. R. Mulvaney, pers. com.). Bedrock has been reached at 948.5 m depth and the bottom of the core consists of more than two metres of debris-loaded ice. This would provide the first opportunity to investigate the ice-substrate interface of an island which acts as a major pinning point for the Filchner-Ronne Ice shelf. ASPI proposes to study these mechanical properties of marine ice by analysing ice cores formed in rifts near grounding lines or close to pinning points. Parts of these cores will be used for deformation experiments, others for measuring fabrics, bulk salinity, and water stable isotopes properties in order to document the ice types and select the appropriate samples for rheological studies. The basal part of the Berker Island deep ice core (at a pinning point of a major Antarctic ice shelf) will be analysed in conjunction. Control methods will be employed to perform inverse model experiments. Such inversion procedure identifies the main features of rheological weakening within the shelf including rifts.

Work Package 3: Subglacial lakes
More than 150 subglacial lakes have been identified beneath the Antarctic ice sheet. At this point we do not know if the known subglacial lakes are transient or permanent features of the sub-glacial hydrological system and whether they are subject to dramatic changes, such as sudden outbursts, which may lead to a destabilization of the overlying ice sheet. To understand the stability of Antarctic subglacial lakes over time it is important to develop an understanding of what conditions would trigger the (catastrophic) draining of such a lake, which has its impact on the stability of the ice sheet in general. ASPI will analyse the basal part of deep ice core drillings across and in the vicinity of subglacial lakes and will model the ice flow across subglacial lakes at high resolution. Model experiments aim at understanding the relation between the water body and the overlying ice, especially with respect to the stability of subglacial lakes with changing environmental conditions.

Work Package 4: Basal ice properties and processes
Not only large water bodies (like ocean or subglacial lakes) can be held responsible for anomalous flow in the basal layers of ice sheets. Liquid water exists in natural ice masses well below their pressure melting point and forms thin films. Interactions between these water films and enhanced deformation in the debris-rich ice at the proximity of the bed have been shown to alter both the rheology and the palaeoclimatic signature of the ice. Furthermore, subglacial lakes are present in the immediate vicinity of major drilling sites, which makes it plausible that lake ice is present at the base. ASPI intends to increase the knowledge of the modification processes of basal ice layers properties in large ice sheets, both from ice measurements and from laboratory deformation experiments. Results should enable us to correctly interpret the reliability of the paleoclimatic signal at depth. ULB has access to the study of the basal ice from the two EPICA drilling sites (EDC and EDML).

Interaction between the partners

The project relies on a tight collaboration between scientist involved in ice analysis and laboratory experimentation (ULB) and those involved in ice sheet modelling (ULB and VUB). Results of these analyses will directly constrain the development and refinement of (existing) ice sheet and ice shelf models by determining the rheology and deformation characteristics of marine ice inclusions at the grounding line (ULB). Coupling of the different models will furthermore allow large-scale simulations over the last glacial-interglacial transition, where grounding line evolution was the most prominent (VUB). These will enable us to assess the global change impact on the Antarctic cryosphere.

ASPI is a contribution to the SCAR-SALE (Scientific Committee on Antarctic Research – Subglacial Antarctic Lake Environments) research programme and the EU Framework VI project "EPICA-MIS (European Project on Ice Coring in Antarctica): New paleoreconstructions from Antarctic ice and marine records". The results of the impact research will also be beneficial to the SCAR-ACE (Scientific Committee on Antarctic Research – Antarctic Climate Evolution) programme. ASPI is also a Belgian contribution to the SALE-UNITED proposal #42 to the International Polar Year (IPY).

Partners

Contact Information

Project website: http://homepages.ulb.ac.be/~fpattyn/aspi

Coordinator

Frank Pattyn
Université Libre de Bruxelles (ULB)
Laboratoire de Glaciologie
Département des Sciences de la Terre et de l'Environnement (DSTE), CP 160/03
Avenue F.D. Roosevelt 50
B-1050 Brussels
Tel: +32 (0)2 650.22.27
Fax: +32 (0)2 650.22.26
fpattyn@ulb.ac.be
http://dev.ulb.ac.be/glaciol/index.htm

Promoters

Jean-Louis Tison
Université Libre de Bruxelles (ULB)
Laboratoire de Glaciologie
Département des Sciences de la Terre et de l'Environnement (DSTE), CP 160/03
Avenue F.D. Roosevelt 50
B-1050 Brussels
Tel: +32 (0)2 650.22.27
Fax: +32 (0)2 650.22.26
jtison@ulb.ac.be
http://dev.ulb.ac.be/glaciol/index.htm

Philippe Huybrechts
Vrije Universiteit Brussel (VUB)
Department of Geography
Pleinlaan 2
B-1050 Brussels
Tel: +32 (0)2 629.33.84
Fax: +32 (0)2 629.33.78
phuybrec@vub.ac.be
http://www.vub.ac.be/DGGF/

Follow-up Committee

Since the ASPI project is imbedded in the SCAR core project SALE (Subglacial Antarctic Lake Environments) as a Belgian contribution to the SALE program and since ASPI is also a Belgian contribution of the SALE-UNITED project for IPY the SCAR-SALE group members are part of the follow-up committee (http://salepo.tamu.edu/).

J. Priscu (USA) - Conevner, Department of Land Resources and Environmental Sciences, Montana State University (Microbial Ecology, Limnology) jpriscu@montana.edu
M. Kennicutt (USA) - Secretary, Office of the Vice President for Research (Chemical Oceanography, Environmental Protocols) m-kennicutt@tamu.edu
R. Bell (USA) - Lamont-Doherty Earth Observatory (Geophysical Surveys, Geology) robinb@ldeo.columbia.edu
S. Bulat (Rus) - Department of Molecular and Radiation Biophysics, Petersburg Nuclear Physics Institute RAS (Microbial Genomics) bulat@omrb.pnpi.spb.ru
C. Ellis-Evans (UK) - British Antarctic Survey (Limnology, Ecology) jcel@bas.ac.uk
V. Lukin (Rus) - Artic & Antarctic Research Institute (Glaciology, Ice Drilling Technology) lukin@raexp.spb.su
C. Mayer (Ger) - Commission for Glaciology, Bavarian Academy of Sciences (Glaciology, Ice Modeling) Christoph.Mayer@lrz.badw-muenchen.de
R. Powell (USA) - Department of Geology and Environmental Geosciences (Geology, Paleoclimate) ross@geol.niu.edu
J.R. Petit (Fra) - LGGE-CNRS BP 96 (Glaciologist, Geochemistry) petit@glaciog.ujf-grenoble.fr
M. Siegert (UK) - Bristol Glaciology Centre, University of Bristol (Glaciology, Geology) m.j.siegert@bristol.ac.uk
Y. Li (China) - Polar Research Insitute of China (Glaciology) yshli@sh163e.sta.net.cn
S. Imura (Japan) - National Insitute of Polar Research (Ecology) imura@nipr.ac.jp
C. Barbante (Italy) - University of Venice (Geochemist) barbante@unive.it