COMPUTATIONAL ICE DYNAMICS

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Background

Numerical ice sheet modeling is a comparatively young discipline it started in the 1950ies. At that time, numerical ice models exploited the fact that ice sheets (Greenland, Antarctica) are essentially 'flat', allowing to treat ice dynamics by equations that are simplified by using a shallowness parameter. The corresponding ice codes are known as zero order Shallow Ice Approximation (SIA) codes, and are still in use today.

While the SIA models work reasonably well in the interior of the ice sheets, they fail to capture their behavior at the highly dynamic ice margins. There, rapid channelized ice flow features ('ice streams') are frequently encountered, with ice velocities up to two orders of magnitude higher than in the slower moving bulk ice mass. The rapid flow in ice streams is often interlinked with (changes in) subglacial boundary conditions, and/or subglacial hydrology, but the treatment of subglacial processes remains a challenge for numerical ice models. Therefore, the 'first-generation' SIA ice sheet models need to be replaced by more complex models, examples of which are so-called higher order-, hybrid- or Full Stokes-models. Full Stokes models are the most exact models available to date in numerical ice sheet modeling, but also the most costly ones to run. Yet, there is increasing agreement that Full Stokes models are needed to make improved predictions of the behavior of the Antarctic or Greenland ice sheet in a warming climate. Also, paleo-ice sheet simulations will benefit substantially from the use of hybrid- of Full Stokes models, although this issue very likely requires involvement of HP computing strategies, or, as an intermediate step, coupling of Full Stokes- with higher order- or hybrid-models.

Projects

In collaboration with the Bolin Center for Climate Research/ Stockholm University, we offer the following four masters projects, which are all closely tied in with ongoing research at the Bolin Center:

(1) Application of the Full-Stokes ice sheet code Elmer/ICE to model the Greenland ice sheet, focusing on ice stream dynamics in general, and on comparing ice stream dynamics as obtained from a Full Stokes model to dynamics obtained from higher order-, hybrid-, and/or SIA models. This project has strong links to an ongoing PhD project, jointly hosted by UU and SU, see [1].

(2) Application of the Full-Stokes ice sheet code Elmer/ICE to model former glaciations on Svalbard, focusing especially on paleo ice stream dynamics and the influence of

basal boundary conditions at the ice sheet/bed interface. This is a follow-up project to a recently finished project concerning SIA modeling of Svalbards ice cap, see [2].

(3) Application of the hybrid-model ARCTIC-TARAH to model the Eurasian Ice Sheet with special emphasis on the role of hydrology (from subglacial scales to ice dammed lakes fringing the ice sheet) on the spatio-temporal evolution of the ice sheet configuration. This project is intended as a pilot project, exploring the capabilities of ARCTIC-TARAH beyond the scenarios it has been used for until now within the Bolincenter, see [3].

(4) Coupling of the Full Stokes code Elmer/ICE, aiming to resolve ice sheet-ice stream dynamics in the Amundsen Sea Sector of the West Antarctic ice sheet in detail, to a SIA model applied over the remainder of continental Antarctica. This project is in support of recent geological evidence of ormer ice shelf disintegration and rapid ice stream retreat in Pine Island Bay that has been obtained in unprecedented detail during the 'Southern Ocean 0910' expedition of the swedish icebreaker Oden, with participation of Bolincenter scientists, see [4].

References

[1] Ahlkrona, J.. Implementing Higher Order Dynamics into the Ice Sheet Model SICOPOLIS. *Master's Thesis, Uppsala University*, 2011.

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[3] Kirchner, N., Lwemark, L., Gyllencreutz, R. Catastrophic drainage of ice-dammed lakes during the Late Pleistocene: a numerical modeling and paleoproxy approach. Bolin Center proposal, Stockholm University, 2011.

[4] Jakobsson, M, Anderson, J.B., Nitsche, F., Dowdeswell, J.A., Gyllencreutz, R., Kirchner, N., O'Regan, M., Alley, R.B., Anandakrishnan, S., Mohammad, R., Eriksson, B., Fernandez, R., Kirshner, A., Minzoni, R., Stolldorf, T.. Geological Record of Ice Shelf Break-up and Grounding Line Retreat, Pine Island Bay, West Antarctica. *Geology*, 39 (2011), 691–694.

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