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Modelling of basal melt of Antarctic ice sheet based on a one-dimensional Stefan problem approach

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This paper presents a mathematical and numerical model of basal melt of Antarctic glaciers. At each point of the continent, for which the heights above sea level of the lower and upper ice edges are known, a one-dimensional three-phase Stefan problem with moving phase boundaries is solved along the vertical direction. The model allows to calculate the dynamics of the temperature distribution and the law of motion for phase boundaries under real life conditions, as well as the possibility of the appearance/degeneration of a liquid phase under the glacier and on its surface. The calculations were carried out using data of the international project Bedmap2, which contain the topological characteristics of Antarctica on a uniform grid with a step size of 1 km.

The equations were discretized using the finite difference method with an implicit difference scheme of the first order of accuracy in time and space on an inhomogeneous grid which gets finer near the phase boundaries.

The model allows for full data parallelism. The simulation was carried out in the MATLAB environment in a parallel asynchronous mode. The software implementation showed very good scalability both in computing on an SMP node and on a cluster.

A number of optimizations were carried out with help of the profiler built into MATLAB, which significantly reduced the simulation time. In particular, a tridiagonal matrix algorithm for solving systems of linear equations was implemented in C with the MEX API for integration with MATLAB, which made it possible to reduce the calculation time by a factor of five.

The calculation for a grid of 120,000 points on 28 cores took about 2.5 hours. The basal melt rate of the mainland of Antarctica of 29 Gt/year was obtained.

Summary

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