Simulating iceberg calving in 3D

Iceberg calving, the detachment of icebergs from the front of glaciers, is a major factor in ice mass loss. Researchers at the University of St Andrews and University of Stirling have developed a computer model to gain new insights into this poorly understood process.

Gary Bembridge

University of St Andrews

St Andrews Glaciology

International Thwaites Glacier Collaboration DOMINOS

elmer ICE

University of Stirling

www.archer2.ac.uk

Figure 1: A small calving event at Store Glacier (Sermeq Kujalleq), West Greenland. Photo credit: Samuel Cook, University of Lausanne.

The detachment of icebergs from the front of glaciers, known as calving, accounts for 40% of the ice mass loss from Greenland (Figure 1). Although calving does not directly increase global sea levels, the loss of ice from the front of glaciers leads to the acceleration of glacier flow and dynamic ice loss. The process of calving is poorly understood and is missing from most glacier models. As such, it is widely recognised that calving accounts for a large proportion of uncertainty in global sea level rise predictions.

Although calving does not directly increase global sea levels, the loss of ice from the front of glaciers leads to the acceleration of glacier flow and dynamic ice loss.

The St Andrews Glaciology Group has developed a new calving model within the glacier model Elmer/Ice that allows unlimited 3D calving to be simulated. They applied this model to Jakobshavn Isbrae (Sermeq Kujalleq), Greenland's largest glacier, accurately simulating the glacier terminus evolution during the 2016-2017 season (Figure 2). This represented the first time this glacier had been modelled in 3D and provided valuable insights into iceberg calving processes.

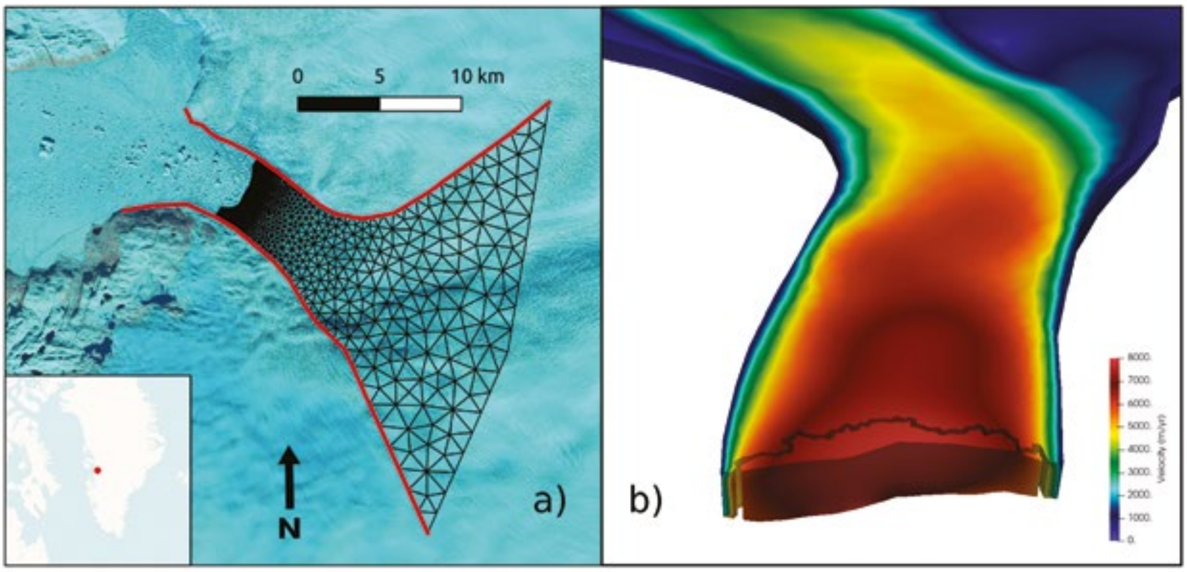

Figure 2: An example of a large iceberg breaking off the front of Jakobshavn Isbrae. a) Top view of the surface elements of the 3D mesh in black with a Sentinel 2 image in the background. The inset shows the location of Jakobshavn Isbrae in Greenland. b) An example of a large iceberg breaking off the front of the 3D model. The colour shows the velocity field of the glacier which accelerates towards the terminus. This view is rotated to face the glacier terminus.

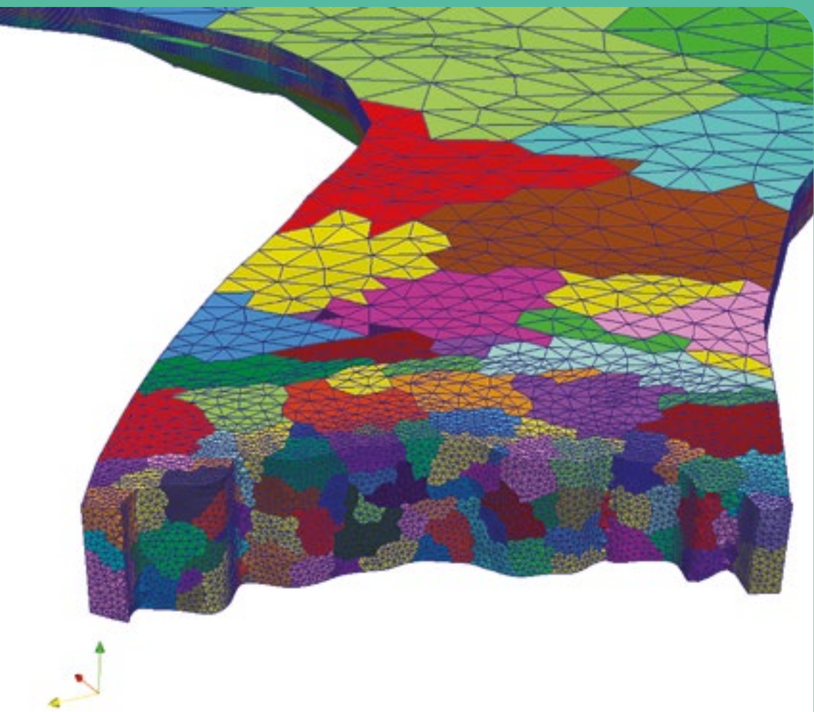

Figure 3: The highly partitioned mesh of Jakobshavn Isbrae as used on ARCHER2 viewed from the glacier terminus. Each colour represents a partition where the glacier flow is solved on a particular processor.

Importantly, the new model is very flexible. By allowing for unrestricted calving geometries, it can be applied at any other location. Testing on a synthetic setup has shown the model can capture a wide range of calving processes such as collapse induced by melt undercutting, buoyant tabular iceberg break-off, or calving suppression due to ice-mélange buttressing. (Ice-mélange is a mixture of sea-ice and previously calved icebergs jammed near the glacier terminus.) The group will now be focusing on applying it to Thwaites Glacier, Antarctica, in the hope of better predicting the retreat of a glacier that could increase global sea level by 65cm.

The use of ARCHER2 was invaluable for developing and testing the new model and producing the first real world application at Jakobshavn Isbrae. The model simulations were conducted on 128 cores, allowing the model code and output performance to be assessed (Figure 3). Larger scale simulations will be possible in the future as the group works towards improving the scalability of the model. Future access to ARCHER2 will be essential for these planned large-scale applications.

The development of this new model will allow further improvements to our understanding of glacier calving and so help constrain global climate and sea level rise predictions.

Authors:
Iain Wheel (University of St Andrews)
Doug Benn (University of St Andrews)
Anna Crawford (University of Stirling)

Contact Details:
Iain Wheel **iw43@st-andrews.ac.uk**
St Andrews Glaciology: **https://glaciology.wp.st-andrews.ac.uk**

Kristine Riskær

About ARCHER2

ARCHER2 is the UK's National Supercomputing Service, a world class advanced computing resource for UK researchers. ARCHER2 is provided by UKRI, EPCC, HPE and the University of Edinburgh. ARCHER2 is the latest in a series of National Supercomputing Services provided to UK researchers.

More ARCHER2 case studies can be found at:
https://www.archer2.ac.uk/research/case-studies/