Better Physics in Embedded Models: Iceberg arcing and Lake-surface profiles

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The commonly used shallow ice approximation neglects all stresses except the basal drag, an assumption that is very good for inland ice but may be very poor for fast-flowing, low-surface slope ice streams, where longitudinal stresses may not only be important, but may in fact be the dominant stress.

Treating the ice streams as barely-grounded ice shelves is another approach, which may be seen as the opposite end member in a spectrum of approximations. In this approximation the only stresses are the longitudinal stresses, the basal drag is not included in the fundamental formulation, but instead is added on as a small correction after integrating the vertical dimension with the assumption of no basal drag.

The only way to truly quantify the importance of longitudinal stresses is to solve the full momentum equation with none of the limiting assumptions that go into either the shallow-ice or the barely-grounded ice shelf approximations.

An implementation of a 2D solution of the full momentum equation is presented. Two examples dealing with 1) iceberg arcing and 2) lakes beneath ice sheets are also presented.

Icebergs observed by Ted Scambos are found to fit into two categories, toe-down and toe-up, and the categories appear to be associated with different temperature regimes. Toe-down icebergs are well-explained by beam theory, but the toe-up configuration is not. A proposed configuration with a submerged bulb was tested with the 2D solver and found to yield good agreement as shown in Figure 1.

Lake Vostok presents an inland situation where longitudinal stresses become dominant as the bed coupling disappears completely over the floating portion. A berm-and-trough feature observed in transects across the lake is modeled successfully using the 2D solver. Time-stepping from an initial parabolic profile shows the evolution of a flat lake surface with berm-and-trough features similar to those observed. Figure 2 shows the longitudinal stress component responsible for this feature.

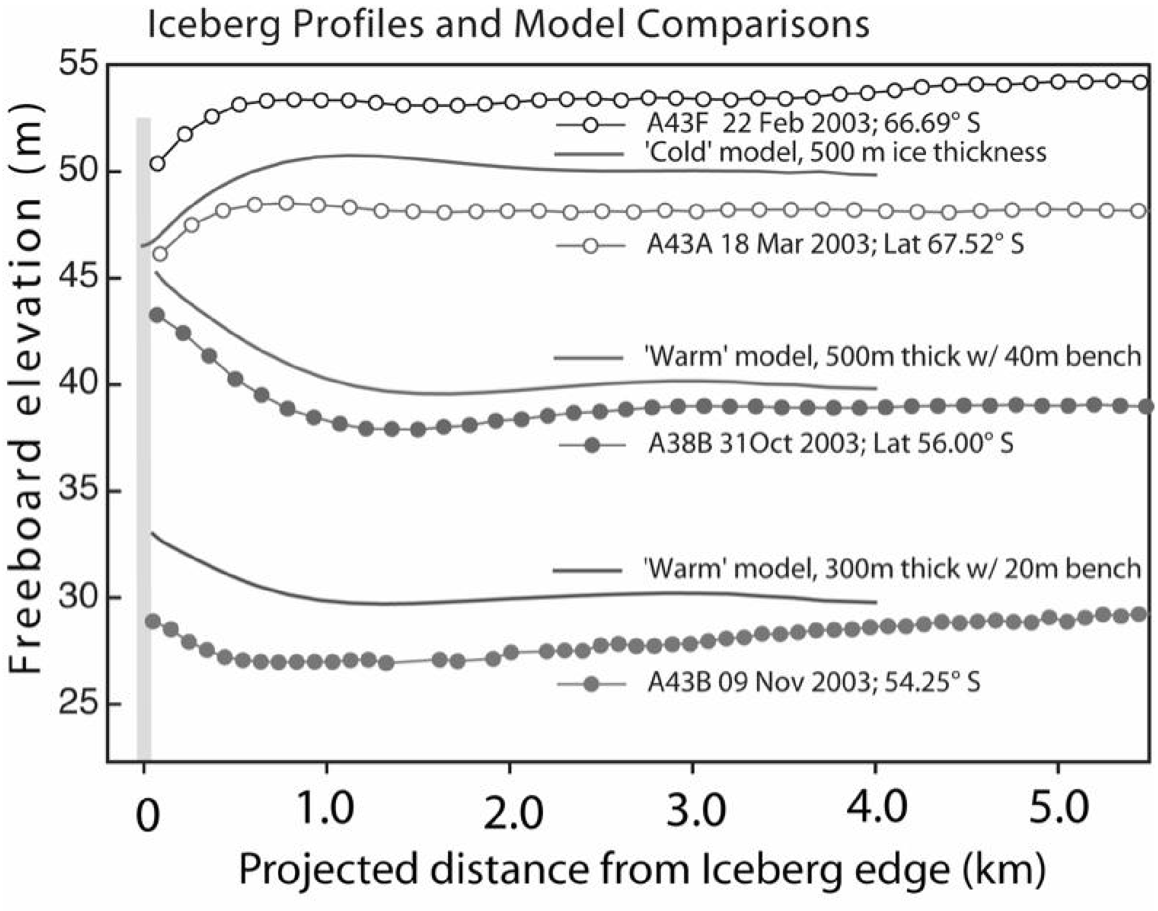
Iceberg Profiles and Model Comparisons
Freeboard elevation (m)
55
50
45
40
35
30
25
A43F 22 Feb 2003; 66.69° S
'Cold' model, 500 m ice thickness
A43A 18 Mar 2003; Lat 67.52° S
'Warm' model, 500m thick w/ 40m bench
A38B 31Oct 2003; Lat 56.00° S
'Warm' model, 300m thick w/ 20m bench
A43B 09 Nov 2003; 54.25° S
0
1.0
2.0
3.0
4.0
5.0
Projected distance from Iceberg edge (km)

Figure 1

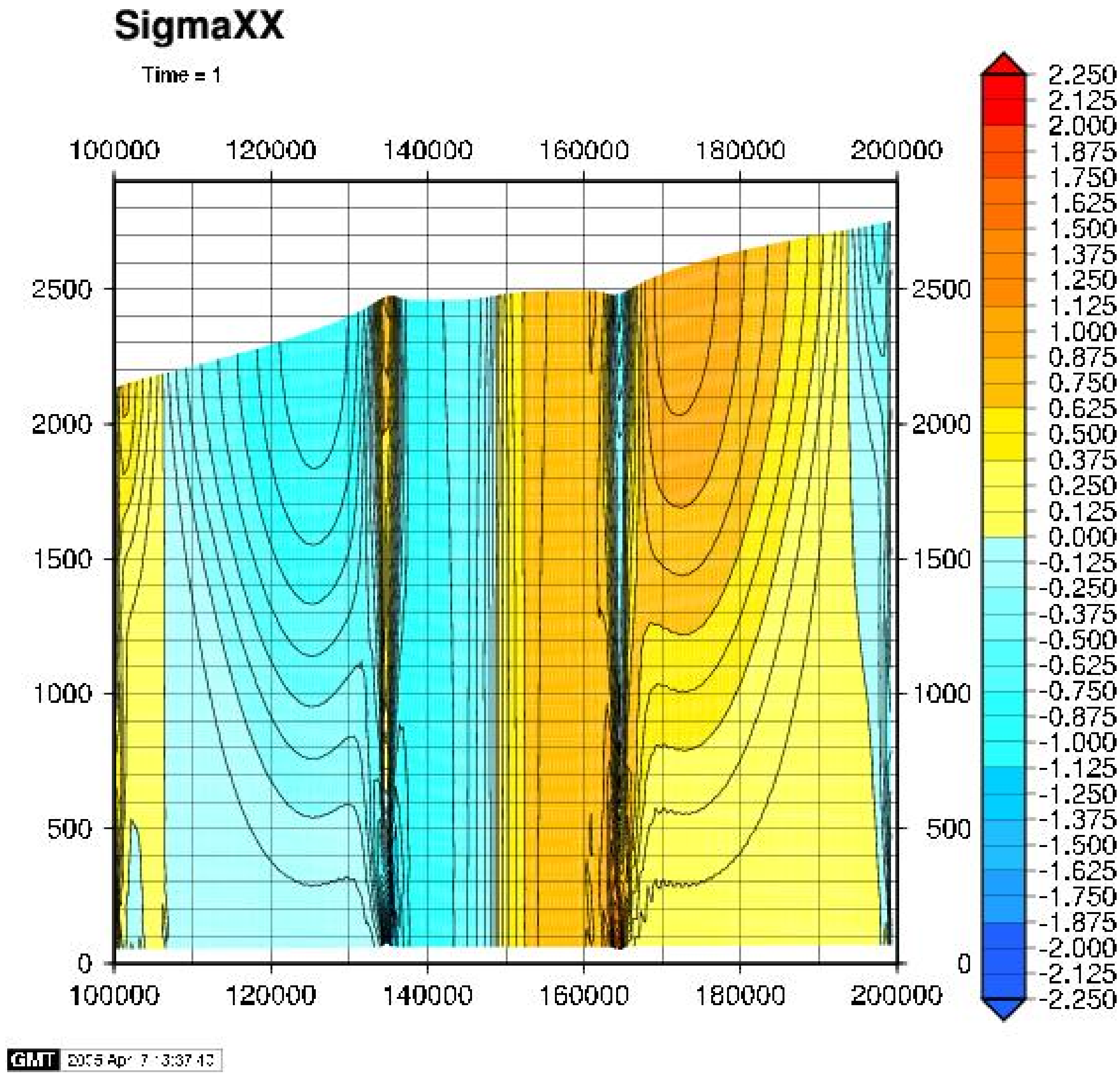
SigmaXX
Time = 1
100000
120000
140000
160000
180000
200000
0
500
1000
1500
2000
2500
2.250
2.125
2.000
1.875
1.750
1.625
1.500
1.375
1.250
1.125
1.000
0.875
0.750
0.625
0.500
0.375
0.250
0.125
0.000
-0.125
-0.250
-0.375
-0.500
-0.625
-0.750
-0.875
-1.000
-1.125
-1.250
-1.375
-1.500
-1.625
-1.750
-1.875
-2.000
-2.125
-2.250
GMT

Figure 2