Journal of Glaciology, Vol. 36, No. 124, 1990

CORRESPONDENCE

The Editor,
Journal of Glaciology

SIR,

Recent change in ice thickness in Windless Bight, Ross Ice Shelf, Antarctica?

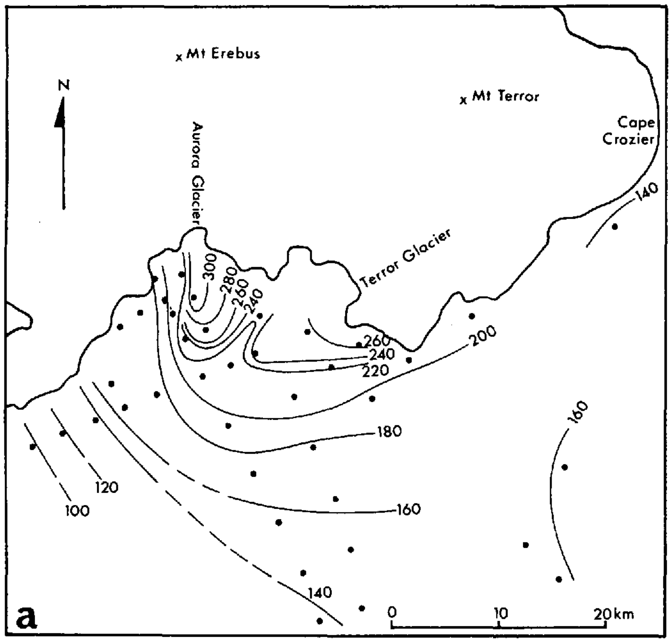
Data on ice thickness of the Ross Ice Shelf in Windless Bight were gathered in the early 1960s by various researchers and again by this author in 1985. Comparison of both data sets reveals remarkable differences.

The floating ice shelf in Windless Bight is nourished by ice flow from the Ross Ice Shelf to the south-east, glaciers descending from Mount Erebus and Mount Terror (see Fig. 1a), and finally by snow accumulation on the surface. Ice is lost by calving at the ice-shelf boundary and by melting at the bottom (see e.g. Risk and Hochstein, 1967).

In Figure 1b, the ice-thickness distribution, as published by Risk and Hochstein (1967) is shown. The data are based on seismic soundings (Crary and others, 1962) and two separate radar soundings by A.H. Waite and G.R. Jiracek (in Risk and Hochstein, 1967). The paper by Crary and others, however, cautions the reader about the difficulties of interpreting seismic data and of obtaining accurate thickness data from this part of the Ross Ice Shelf. No details on the radar measurements by Waite and Jiracek are known except the information in the above reference.

The results of the radar survey conducted in 1985 consist of 38 spot readings of the ice thickness in Windless Bight by radio echo-sounding (RES) in support of seismic investigations on the Ross Ice Shelf (see Stern and others, 1990). The positions of profiles, along which readings were taken, were determined by repeatedly taking the bearings of landmarks.

The RES recording instrument used was a back-pack unit (developed by BGR). Signals were transmitted (peak transmitter power = 150 W) with a frequency of 65 MHz. Antenna spacing during measurement was 10 m. All measurements yielded — in particular near the center of Windless Bight — single and clearly identifiable reflected signals, sometimes accompanied by a multiple.



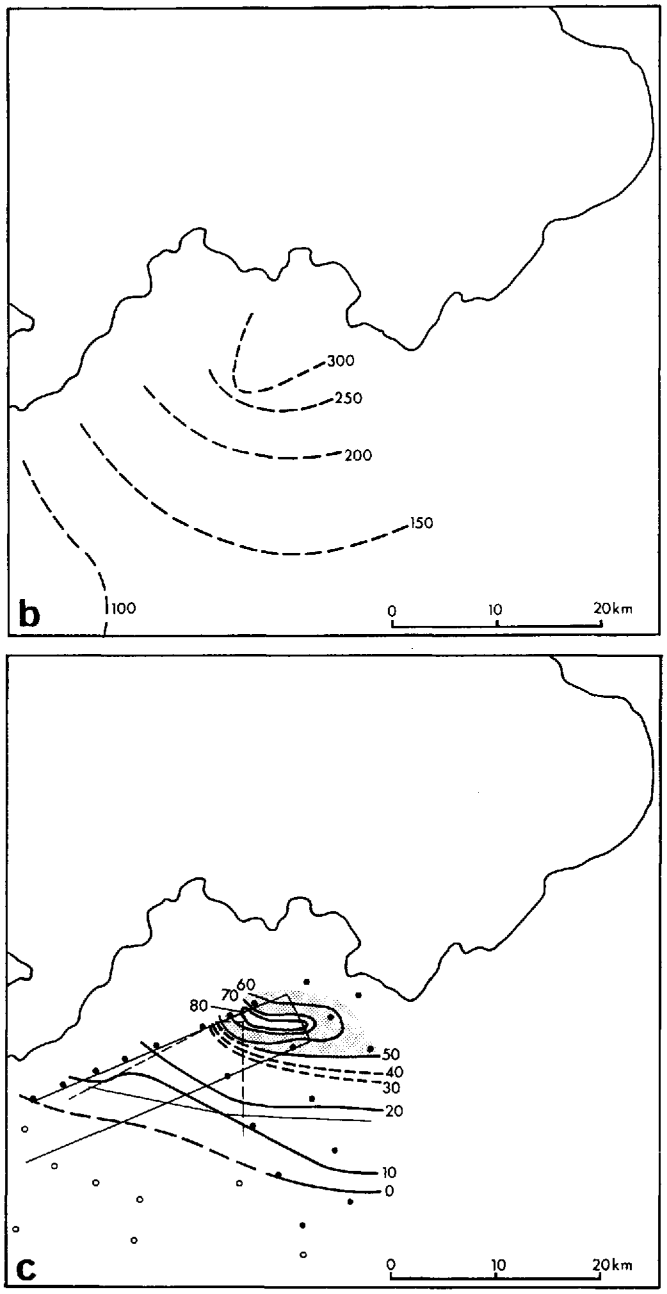


Fig. 1. a. Ice-thickness distribution in Windless Bight based on the 1985 survey. Ice thickness in m. Measuring points are shown as dots. b. Ice-thickness distribution in Windless Bight as measured by Crary and others (1962) (after Risk and Hochstein, 1967). Ice thickness in m. c. Difference in ice thickness in m revealed by comparison of surveys in the early 1960s and 1985. Open circles: seismic soundings by Crary and others; thin line: radar survey by Waite; dashed line: radar survey by Jiracek.

Ice thickness was calculated for each point assuming a constant EM-wave velocity of 168 m μs^{-1} within the ice. The resulting ice-thickness variation is summarized in Figure 1a.

The Ross Ice Shelf terminates to the west near Scott Base. According to our data, its ice thickness rapidly increases continuously eastward to values of more than 200 m in the center of Windless Bight. The latter area is known for its high amount of annual snow precipitation due to the blocking action of the south face of Ross Island to moist air masses from the south.

Aurora Glacier, descending from the south-east face of Mount Erebus, and Terror Glacier, descending from the south-west face of Mount Terror, cause additional thickening of the ice shelf near the coast, as shown in Figure 1a. No radar data are available from the area of the "rollers", which extend from Cape Crozier south-westwards. Further RES data on the thickness of the Ross Ice Shelf to the south-east of Ross Island have been published in Stern and others (1990).

A comparison of Figure 1a and b reveals considerable, but systematic, differences in ice thickness on a local scale. Most noticeable, the terminus of Terror Glacier appears to have receded east-north-eastwards by about 5 km. The differences in ice thickness were mapped. The estimated ice-thickness difference at each measuring point of the 1985 survey — the corresponding ice thickness in the early 1960s was interpolated from Figure 1b — is indicated in Figure 1c.

The apparent discrepancy between both data sets cannot be attributed to systematic positioning errors of points of measurement. Whatever systematic errors one might assume, no reasonable scheme can be evoked that might explain the considerable and systematic differences in measured ice thickness. In the light of the limited amount of information available from the radar measurements in the 1960s, the recently discovered discrepancy between both data sets should be viewed with caution. On the other hand, the alternative — substantial thinning of the ice shelf in Windless Bight within the last 25 years — should also be considered. What effects could possibly cause such a change?

Strong reflections can potentially be produced by brine-soaked layers near the base of the ice-absorbing EM waves attempting to travel to deeper levels. No direct evidence to this effect is available. Brine-soaking has been shown to exist at the western edge of Windless Bight (Stuart and Bull, 1963; Risk and Hochstein, 1967). Detailed studies on brine-infiltration mechanisms and the limit of brine infiltration along the McMurdo Ice Shelf — as the front part of the Ross Ice Shelf near McMurdo is also called — have been published by Kovacs and Gow (1975), Kovacs and others (1982), and Cragin and others (1983). Their results clearly indicate brine-soaking to be confined to areas west of Windless Bight. Brine-soaking, therefore, is very unlikely to be the underlying cause of the discrepancy between the above data sets.

Bottom melting: Pillsbury and Jacobs (1985) gave an average value of 0.3 m a^{-1} for the basal melting rate of the Ross Ice Shelf, Risk and Hochstein (1967) a rate of ~1 m a^{-1} for the ice shelf near Windless Bight. Jacobs and others (1981) estimated the melting rate of the floating Erebus Glacier ice tongue to be in the range of 0.3–3.0 m a^{-1}. An assumed melting rate of 3.5 m a^{-1} (80 m in 23 years; 1962–85) at the under-side of the floating terminus of Terror Glacier appears to be at the upper limit of the range of acceptable values. If such a high amount of bottom melting occurs today, then one has to assume — at least on a local scale — a considerable build-up in ice thickness in the recent past.

Recent slow-down of glacier movement: the terminus of Terror Glacier has receded. The downward velocity of the glacier has possibly been reduced by decreased snow accumulation in the source area in recent times, such that bottom melting at the glacier terminus currently exceeds the supply rate.

Recent surge event: heat flow from the interior of an active volcano is potentially quite variable with time. An increase in heat flow (e.g. caused by a high-level intrusion into the flank of the volcano) has conceivably changed in recent times the thermal conditions at one or both glacier beds, causing a minor surge event and increased glacier velocities over a restricted period of time in the recent past. At the same time, more than the usual amount of ice would be supplied to the ice shelf. However, such an effect is more likely for Aurora Glacier descending from Mount Erebus (Mount Terror appears to be extinct). After cessation of the surge, bottom-ice melting would take over until a new balance between supply and melting rate is reached.

Only a continuing systematic monitoring effort in the near future might unequivocably resolve the question, whether the ice thickness in Windless Bight currently experiences significant changes or not.

Acknowledgement

The measurements were carried out as part of event K 101 (Ross Island Loading Study) of the N.Z. Antarctic Program 1985. I gratefully acknowledge the logistical assistance of all K 101 team members and staff of Scott Base.

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1 February 1990, revised 11 May 1990

REFERENCES

Cragin, J.H., A.J. Gow, and A. Kovacs. 1983. Chemical fractionation of brine in the McMurdo Ice Shelf, Antarctica. *CRREL Rep.* 83-6.

Crary, A.P., E.S. Robinson, H.F. Bennett, and W.W. Boyd, *jr.* 1962. Glaciological studies of the Ross Ice Shelf, Antarctica, 1957–1960. *IGY Glaciol. Rep.* 6.

Jacobs, S.S., H.E. Huppert, G. Holdsworth, and D.J. Drewry. 1981. Thermohaline steps induced by melting of the Erebus Glacier tongue. *J. Geophys. Res.*, **86**(C7), 6547-6555.

Kovacs, A. and A.J. Gow. 1975. Brine infiltration in the McMurdo Ice Shelf, McMurdo Sound, Antarctica. *J. Geophys. Res.*, **80**(15), 1957-1961.

Kovacs, A., A.J. Gow, J.H. Cragin, and R.M. Morey. 1982. The brine zone in the McMurdo Ice Shelf, Antarctica. *CRREL Rep.* 82-39.

Pillsbury, R.D. and S.S. Jacobs. 1985. Preliminary observations from long-term current meter moorings near the Ross Ice Shelf, Antarctica. *In* Jacobs, S.S., *ed. Oceanology of the Antarctic continental shelf.* Washington, DC, American Geophysical Union, 87-107. (Antarctic Research Series, **43**.)

Risk, G.F. and M.P. Hochstein. 1967. Subsurface measurements on the McMurdo Ice Shelf, Antarctica. *N.Z. J. Geol. Geophys.*, **10**(2), 484-497.

Stern, T.A., F.J. Davey, and G. Delisle. 1990. Lithospheric flexure induced by the load of Ross Archipelago, southern Victoria Land, Antarctica. *In* Thomson, M.R.A., J.A. Crame, and J.W. Thomson, *eds. Geological evolution of Antarctica. Proceedings of the Fifth International Symposium on Antarctic Earth Sciences, ..., Cambridge, 23–28 August 1987.* Cambridge, etc., Cambridge University Press, 323-328.

Stuart, A.W. and C. Bull. 1963. Glaciological observations on the Ross Ice Shelf near Scott Base, Antarctica. *J. Glaciol.*, **4**(34), 399-414.

Sir,

Vapor-pressure dependence on temperature in models of snow metamorphism

The modelling of heat and vapor flows through snow continues to be of interest in work on snow metamorphism and heat transfer. The effect of temperature on the vapor pressure of ice is of interest in several fields and it is worth reviewing how vapor pressure is approximated, and in examining some of the consequences of those approximations. While most are good approximations to the vapor pressure, they are not necessarily good approximations to its derivatives.