The solution that I would like to propose is that Meier's terms, apart from the cumulative totals mentioned in the last paragraph, should be used only for measurements made with probes that move with the ice. For measurements made by photogrammetry, or any other method that works by comparing the situation from time to time at one particular point in geographical coordinates, different terms should be used. In particular, I suggest that the terms accumulation, ablation and specific net budget should not be used in such measurements, but rather terms such as height variation of the surface.

I am well aware that many people who have measured changes in glacier surface height have kept this distinction in mind, this is particularly clear in the discussions of glacier mass budget determination by photogrammetric means given recently by Finsterwalder (1961, 1962). My purpose in writing this letter is simply to prevent a possible confusion entering in the proposed definition of terms.

I would like to thank Professor H. C. Hoinkes and Dr. M. F. Meier for useful discussions on this topic.

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19 December 1962

J. W. GLEN

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SIR,

I read with great interest the letter from Dr. Glen concerning my recent article on mass budget concepts and terms. One of his points deserves considerable emphasis: methods (such as photogrammetry) which compare changes in surface elevation of a glacier with time at a given location cannot be used to deduce specific mass budget information. We need terms to describe the thickening or thinning of a glacier as measured from points fixed in geographical coordinates. However, these are not mass budget concepts and therefore I did not deal with them in my article.

As Glen states, my definitions are not completely clear as to whether mass budget quantities are to be measured with fixed or moving probes. The problem is whether to investigate what happens in time to an individual parcel of ice as it rides along (the Lagrangian method of description in fluid mechanics) or to investigate what is happening as the ice flows past a fixed location in space (the Eulerian method). It is obvious that my mass budget definitions are strictly correct only for the Lagrangian method of description, because on p. 253 I discussed the gain or loss from a hypothetical prism extending through a glacier from surface to bed. This prism must move and deform with the ice if we are to avoid the complication of apparent gains or losses of mass due to compressive or extending strains within the glacier.

If we restrict ourselves to surface phenomena only, however, we can see that the Eulerian method is valid for mass budget measurements. Imagine a small cloud fixed in position over a moving glacier. Snowfall from this cloud would produce accumulation on the glacier at a point fixed in geographical coordinates. An observer also fixed in these coordinates near the glacier surface (perhaps in a helicopter) could measure the amount of snow which is delivered to the glacier at this spot. This Eulerian observer would obtain just as valid a measurement of accumulation as his Lagrangian colleague riding along on the glacier surface. Admittedly it is far easier in actual field work to adopt the Lagrangian approach. However, if the glacier is moving rapidly, and if appreciable mass budget gradients exist in space, then the Lagrangian, space-averaged data may be harder to interpet. When we assume that the geographical (vertical and horizontal) variation of mass budget has significance, we necessarily imply validity in the Eulerian approach.

My article on mass budget terms was written to stimulate discussion so that a proper conceptual framework can be evolved. I believe that Dr. Glen has definitely contributed to this aim, and I would welcome further discussion.

U.S. Geological Survey,
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7 February 1963

MARK F. MEIER

SIR,

Observations of rapid water-level fluctuations in ice sink-hole lakes, Martin River Glacier, Alaska

During the summer of 1962 a series of rapid fluctuations of water levels in ice sink-hole lakes was observed on the Charlotte Lobe of the Martin River Glacier which is located in south-central Alaska, lat. 60° 28′ N., long. 144° 10′ W., approximately 97 km. east of Cordova (USGS Cordova B–1 Quad.). This glacier is unusual in that the outer 11 km. is covered with ablation till ranging from less than 0·3 to more than 6 m. thick and averaging about 0·7 m. The marginal zone, which is up to 4 km. wide, is characterized by numerous ice sink-holes most of which have standing water in them. These sink-holes average 250 to 300 m. in diameter and 30 to 90 m. in depth.

Investigation of the Charlotte Lobe is being undertaken by members and students of the Department of Geology, University of North Dakota and is financed by a grant from the National Science Foundation.

On 28 June Lake A (Figs. 1 and 2) was at 190 m. elevation and had a maximum depth of approximately 28 m. while Lake B at 213 m. elevation had a maximum depth of approximately 29 m. (personal communication from W. M. Laird and S. J. Tuthill). The water level in both of these lakes rose as much as 1 m. after prolonged rainy periods, but did not lower appreciably after subsequent dry periods.

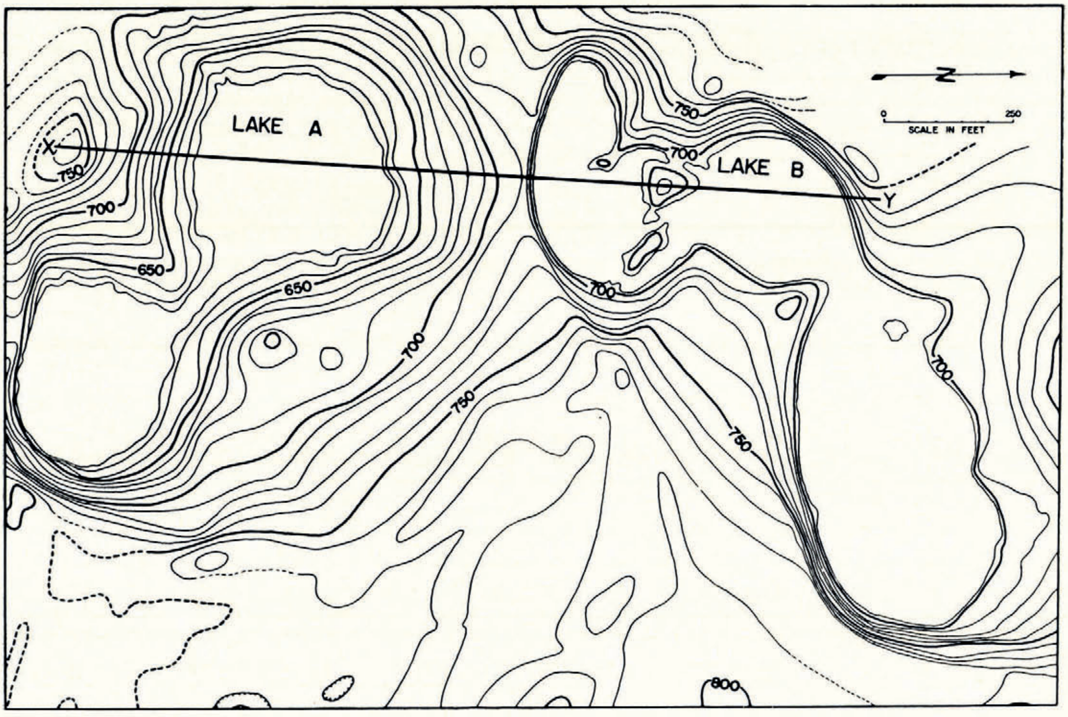

Fig. 1. Topographic map of described portion of ice sink-hole lake area, Charlotte Lobe, Martin River Glacier, showing line of cross-section