of a pool about 10 m. long and 75 cm. broad at its widest point. The characteristics of each performance were similar. Particulars of the third spout were recorded:

(1) Perfect calm on the pool after the previous spout.
(2) Noise of much bubbling (unseen) in a crack leading into the pool—2.29 p.m.
(3) Spouting began at 2.29½ p.m. after bubbles had begun to appear. At first there was a fountain about 50 cm. in diameter which rose to a height of 1 m. It narrowed somewhat and rose rapidly to 5 or 7 m. It then gradually subsided until it ceased at 2.30½ p.m.
(4) At 2.32½ p.m. the accompanying bubbling in the pool and noises in the crack ceased.

Although we waited until 3.10 p.m. no further display was seen. The ice where the phenomenon occurred was relatively level and not far west of the ice fall which is situated just below the chalet Triest on the north side of the glacier opposite the Aletschwald. The water-spout itself was approximately in line with the Tällihütte under the Triestgletscher and shown on the Siegfriedkarte 1: 50,000.

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6 November 1962

(There does not appear to be any previous record of a water-spout on the Aletsch Glacier or indeed on any Swiss glacier. A water-spout in Spitsbergen was described in this Journal, *Vol. 2, No. 19, 1956, p. 637–39 by M. A. Rucklidge together with a suggested scheme of the arrangement of the subglacial water channels which caused it.*

The exact position of the Tällihütte is shown on the 1957 Aletschgletscher map of the Eidg. Landestopographie, Wabern-Bern, 1960, Blatt 3.—Ed.)

SIR,

Proposed definitions for glacier mass budget terms

In his recent paper on the definition of glacier mass budget terms, Dr. Meier (1962) has brought some much-needed clarity of thought into this rather confused and confusing subject. However, there is one point that he has left rather vague which seems to me to be of importance, particularly where glacier mass budgets are determined by photogrammetric means.

When defining *specific budget quantities*, Meier refers to the accumulation and ablation *measured at a point*. He does not make it clear whether this is a point on the glacier and moving with it, or whether it is a point fixed in geographical coordinates. From what follows it is apparent that Meier had in mind a point on the glacier and moving with it, for this is what is defined by an accumulation or ablation stake or by a pit. For such a point it will be reasonable to find a net budget in the way Meier describes, and to refer to the result as the *apparent accumulation* if it is positive and the *apparent ablation* if it is negative. A relatively simple glacier will then have apparent accumulation in its upper part and apparent ablation in its lower part, the two being separable into the accumulation area and the ablation area.

If, however, a particular point in geographical coordinates is considered, as for example if the height at the surface of the glacier is determined photogrammetrically for a particular point on the map, then a glacier which was in a steady state would have its surface at the same height in the same place each year (this is the *annually repeating state* defined by Nye (1958, p. 142)). If we applied Meier's definitions to this situation without modification we would reach the surprising conclusion that there was, summed over the budget year, no apparent accumulation and no apparent ablation anywhere on the glacier. Similarly in a year in which the ablation had been considerably less than normal, it is quite thinkable that a glacier might at all points be higher than it had been the preceding year—and a direct application of Meier's definitions would then mean that we spoke of an apparent accumulation over the whole of the glacier, and that the whole glacier was in the accumulation area—despite the fact that large amounts of ice from preceding years had been melted away from the surface in the lower parts.

I think these simple examples are sufficient to show that the question of whether we concentrate attention on a particular parcel of ice moving with the glacier or on a particular point on the map is of great importance. Of course, when the budget quantities are integrated over the whole glacier, the totals will be the same whichever method is used, provided the boundaries for the integration are correctly chosen; both will give the same cumulative budget quantities over the whole area of the glacier in Meier's terminology.

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.