(a) to predict the motions of groups of wind-driven detached ice floes over periods of 12, 36, and 60 h;

(b) to determine sea-ice thickness and the surface and sub-surface drag coefficients associated with these motions.

Wind stress, water drag, and Coriolis force were assumed to be at equilibrium for a drifting group. Surface wind speed and ice motion velocity were obtained from three-day sequences of surface weather charts and Landsat-1 MSS images. The angle of sea-ice deflection, the cross-isobar angle, sea-ice thickness, and the surface and sub-surface drag coefficients were determined by solving the equilibrium equation of motion. Weather data from a fourth day were used to predict the motions for this day.

If used in conjunction with data from microwave sensing systems, these predictions and parameters could be applied to support marine traffic and exploration of natural resources in the Polar Oceans. Sea-ice parameters, which were formerly practically unavailable, can now be derived by the method.

DISCUSSION

O. H. Løken: To what extent are the results of your study being used in the preparation of operational ice forecasts for the Beaufort Sea?

U. Feldman: This method is not yet operational because the MSS images of Landsat-1 provide useful data only if the images are cloud free. The method may be applied in the future with remotely-sensed data from microwave systems.

J. B. Mercer: How many tests of your method have you made? You mentioned two in your talk. What is the success rate?

Feldman: Out of approximately 3 000 Landsat-1 MSS images recorded during the period 1972–76 over the study area, 35 images, belonging to 6 cycles, were found suitable for analysis. From the 6 cycles tested 4 were successful.

SURGING GLACIERS—THE DILEMMA CONTINUES

By M. F. Meier

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Abstract. A glacier surge, according to most definitions, is a short-lived phase of unusually rapid glacier flow, after which the glacier returns to more normal behavior, with the surge–non-surge phases recurring on a regular or periodic basis. Recent interest is largely directed toward analyzing the effect of water at the bed on the periodic change in flow regime and on the rapid flow during a surge phase. For instance, study of a local depression of basal shear stress that depends on a "friction lubrication factor" which becomes important as the ice velocity increases, is one promising phenomenological approach. An important physical approach focuses on a water "collection zone" that occurs where and when the longitudinal pressure gradient in the subglacial water film approaches zero. The data necessary for properly verifying these and other similar theories do not yet exist. Computer modeling of rapidly-surging glaciers based on a "friction lubrication factor" has been quite successful in duplicating their major features. Once rapid movement (10^2–10^3 m a^{-1}) has begun, sufficient water is generated at the bed, from ice melted by heat dissipated in sliding, to produce some

decoupling of the glacier from its bed and to maintain the surge, but only if this water is not lost by rapid drainage. Some glaciers exhibit periodic pulses in which the basal sliding velocity during the fastest part of the pulses appears to be in the range for "normal" glaciers ($<10^2$ m a^{-1}). Some evidence suggests a continuum of behavior from steady (normal) glaciers through these "mini-surges" to classic surges. This continuum and the "mini-surges" seem to be difficult to explain quantitatively by existing theories. A few glaciers flow continuously at surging speeds ($>10^3$ m a^{-1}) in certain reaches. The up-glacier transition reaches show speeds decreasing to "normal" with no indication of intermediate surging regime, but the down-glacier transition reaches may be areas where surges are triggered.

Critical to an explanation of glacier surges is better knowledge of the amount, location, and drainage characteristics of water at the ice–bed interface. Small-scale laboratory experiments may not accurately simulate surges unless water drainage is properly modeled. The water produced by melting at the surface is commonly orders of magnitude greater than that produced at the bed, so the behavior of surface melt water also needs to be considered. And the old problem remains as to why in some areas most glaciers surge, where in other areas none do so.

DISCUSSION

S. M. HODGE: Did you say that the Black Rapids Glacier "pot-holes" are characteristic of the accumulation zones of surging glaciers?

M. F. MEIER: Yes.

G. K. C. CLARKE: I agree that the pot-hole terrains you mentioned are extremely curious features of glaciers in the quiescent phase. Another striking thing is the large water-filled crevasse field which often form during surges; these may simply be filled with surface melt, but on the other hand they could be telling us something interesting.

MEIER: I am sure that they are. Even if the high water table is an effect, not a cause, it probably results in very high water pressures at the bed, facilitating fast sliding.

K. PHILBERTH: Could you comment on the time period of cyclic surging glaciers and how it is related to the size of the glacier?

MEIER: Observed time periods range from the order of 10 years to of the order of 100 years. There is only a *very* poor correlation, however, between size and period. Many relatively small glaciers have relatively short periods, but exceptions to this generalization are common.

G. DE Q. ROBIN: Your estimates of basal water-pressure gradient were made in relation to present-day geometry of the glacier. The predictions of Robin and Weertman (1973) apply to glacier geometry immediately before surging, with a well-developed "trigger zone". Will this not be quite different from your estimates?

MEIER: Your comment is absolutely correct, but we have estimated what the generalized pressure gradient might be just before a surge for Variegated and Black Rapids Glaciers. The estimates are, of course, very uncertain, but they do not seem to support a zero or reversed pressure gradient.

REFERENCE

Robin, G. de Q., *and* Weertman, J. 1973. Cyclic surging of glaciers. *Journal of Glaciology*, Vol. 12, No. 64, p. 3–18.