Using vertical aerial photography to estimate mass balance at a point

L. A. RASMUSSEN [1] and R. M. KRIMMEL[2]

[1] Geophysics Program, University of Washington, Seattle WA 98195, U.S.A.
[2] US Geological Survey, Tacoma Washington, U.S.A.

Geografiska Annaler (1999) vol. 81A, no. 4, p. 725-733

ABSTRACT. The mass balance distribution over a 0.5 km^2 area of the lower part of South Cascade Glacier is obtained from remotely sensed measurements of its geometry and velocity field over two periods, 1992-93 and 1993-94. Vertical aerial photography from late summer 1992, 1993, and 1994 is analyzed photogrammetrically to get surface topography of South Cascade Glacier on a 100-meter square grid. The known bed topography is subtracted from the surface topography to get thickness, and the surface topographies are subtracted from each other to get the thickness change. Annual displacement vectors, determined at points where natural features could be tracked from one year to the next, are contoured by hand and interpolated to the grid. Assuming that the ice follows Glen's flow law with exponent $n = 3$, and that 10% of the ice flow is due to sliding at the bed, the surface velocity is scaled by 0.82 to get the average velocity in the vertical ice column. The average velocities are combined with the thicknesses to calculate the flux divergence at each of 46 gridpoints on the 100-meter square grid, where it is subtracted from the thickness change to get the mass balance.

Use of the same control points from year to year makes any systematic error in photogrammetric coordinates temporally constant, so such error has no effect on the mass balance estimate. Random error in coordinates is assumed to be uncorrelated from coordinate to coordinate, from point to point, from year to year; the standard error is estimated to be 1 m, resulting in a standard error in coordinates of about 1.5 m. A 1 m error in a vertical coordinate has nearly twice the effect on the estimated balance that one in a horizontal coordinate has and more than ten times the effect that one in ice thickness has. Compared with measurements at a stake, the estimated balances are about 1 m too negative.