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Characterizing the dynamics of a slowly surging glacier using a two-dimensional flowband model

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Glacier surges are a well-known example of an internal dynamic oscillation whose occurrence appears generally unconnected to the external climate forcing, but whose character (e.g. period, mechanism) may depend on the glacier's environmental or climate setting. We examine the dynamics of a small ($\sim$5 km^2) valley glacier in the Yukon Territory of Canada for which two previous surges have been photographically documented and that is thought to be currently surging, but at a much slower pace than ordinary. To characterize the unusual dynamics of the present surge, and to speculate on the future dynamics of this glacier, we employ a higher-order flowband model of ice dynamics with a Coulomb-friction sliding law in both diagnostic and prognostic simulations. Diagnostic (force balance) calculations capture the measured ice-surface velocity profile only when high basal water pressures (60–90% of flotation) are prescribed over the central region of the glacier, consistent with where evidence of the surge has been identified. This leads to sliding accounting for 50–100% of the total surface motion. Prognostic simulations, where the glacier geometry evolves in response to a prescribed surface mass balance, reveal a significant role for a large bedrock bump beneath the current equilibrium line of the glacier. This bump provides resistance to ice flow sufficient to cause the formation, and under some conditions propagation, of a bulge in the ice-surface profile. We suggest that this bedrock bump contributes to the propensity for surges in this glacier, such that conditions suppressing bulge formation may also inhibit surges. In our calculations such a situation arises for sufficiently negative mass balance profiles. Collectively, these results corroborate our interpretation of the current glacier flow regime as indicative of a "slow surge", and suggest a relationship between surge incidence or character and the net mass balance. Our results also highlight the importance of glacier bed topography in controlling ice dynamics, as is observed in many other glacier systems.