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Surges of tidewater glaciers initiated at the terminus: observations and mechanisms

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There have been numerous reports that surges of tidewater glaciers in Svalbard were initiated at the terminus and propagated up-glacier, in contrast with downglacier-propagating surges of land-terminating glaciers. Most of the tidewater glacier surges were poorly documented, however, and the cause of this anomalous behavior was unknown. In this study we present detailed data on the recent surges of Aavatsmarkbreen and Wahlenbergbreen, two tidewater glaciers in western Spitsbergen. High-resolution time-series of glacier velocities and evolution of surface crevasse patterns clearly show that both surges propagated up-glacier in a series of abrupt steps. Prior to the surges, the glaciers underwent strong retreat and significant steepening of their terminal zones, and in the case of Aavatsmarkbreen this can be shown to have caused a doubling of driving stress between 1990 and surge onset in 2013. We conclude that the surges developed in response to two distinct processes. 1) During the late quiescent phase, the terminal zones underwent gradual acceleration due to steepening and increasing driving stress. 2) Acceleration of the glacier termini caused surface crevasses to propagate up-glacier, allowing surface melt- and rain-water to access the bed. Upward migration of the surge velocities coincided with stepwise the expansion of the crevasse field. Despite a short-lived reactivation in the summer of 2015, the surge of Aavatsmarkbreen terminated gradually, which we interpret as the result of gradual leakage of stored water. The behavior of these glaciers can be understood in terms of the enthalpy cycle model.