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Over winter persistence of supraglacial lakes on the Greenland Ice Sheet: results and insights from a new model.

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We present a newly developed 1-D numerical energy balance and phase transition lake model, IceLake, which incorporates snowfall, in situ snow and ice melt, incoming water from the surrounding catchment, ice lid formation with or without snow cover, basal freeze-up, thermal stratification, and the temperature profile of underlying ice. IceLake is coupled to Greenland Ice Sheet RACMO 2.3 data allowing latitudinal, longitudinal, and elevational variation in the formation and evolution of supraglacial lakes to be understood from an energy balance perspective. Along an elevational transect at Upernavik Issrtøm Glacier, supraglacial lakes with end of melt season depth $\geq$1.9 m are modelled to persist through winter with snow cover, not elevation, being the dominant control on freeze-up rates. These buried lakes provide a latent heat source at the start of the melt season, expedite future lake formation if no advection occurs, and warm underlying ice even in winter, with potential implications for lake drainage events. IceLake's parameter space is comprehensively tested, and its performance is compared to in situ data, with excellent results. The use of the backward Euler method greatly decreases model run time and increases stability compared to previous lake models, making IceLake more suitable for inclusion in a holistic glacier-hydrology model.