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# Frozen waterfall (or ice cascade) growth and decay: a thermodynamic approach

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The ice volume evolution of an ice cascade was studied using a thermodynamic model. The model was developed from meteorological data collected in the vicinity of the waterfall and validated from ice volume measurements estimated from terrestrial LiDAR images. The ice cascade forms over a 45 m high rockwall located in northern Gaspésie, Québec, Canada. Two stages of formation were identified. During the first stage, the growth is mainly controlled by air convection around the flowing and freefalling water. The ice cascade growth rate increases with the decreasing air temperature below 0°C and when the water flow reaches its lowest level. During the second stage, the ice cascade covers the entire rockwall surface, water flow is isolated from the outside environment and ice volume increases asymptotically. Heat is evacuated from the water flow through the ice cover by conduction. The growth is mainly controlled by the radiation energy balance but more specifically by the longwave radiation emitted at the ice surface during the night. In spring, melting of the ice cascade is clearly dependant on the sensible heat carried by the increasing water flow and the diffuse solar radiation received at the ice surface during the day.