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Modelling snow albedo over space and time using cellular automata and radiative transfer

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Snow albedo is a critical parameter controlling snow melt. Light absorbing impurities including dusts, black carbon, brown carbon and living microbes have both direct and indirect albedo-reducing effects. The direct effect is the enhancement of solar energy absorption by the snowpack because of the presence of materials that absorb solar energy more efficiently than the ice. The indirect effects include modification of snow optical properties as a consequence of the direct effects. Microbial cells – dominated by snow algae - are unique among the suite of light absorbing impurities in that they can self replicate in situ, meaning that algal blooms can darken and spread over time. Furthermore, their light absorbing properties can also change according to external stimuli at a variety of time-scales. Therefore, the albedo reducing power of snow algae is highly dynamic over both space and time, necessitating the incorporation of spatiotemporal changes into models of biological albedo reduction.

Here we present a coupled snow radiative transfer model and cellular automaton that can account for variations in snow optical properties and various impurities over three spatial dimensions and time. In particular, biological growth is incorporated into the cellular automaton using an empirical growth model and carrying capacity. Several applications are presented, including predictive modelling of biological albedo reduction and investigation of processes operating at finer spectral, spatial and temporal scales than can be resolved by contemporary orbital remote sensing platforms, which may aid the interpretation of remotely sensed measurements of snow albedo.