Monitoring Snow Cover Extent over Eastern Canada Combining Fuzzy Logic and Remote Sensing Data

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ABSTRACT

Snow cover plays an important role in the hydrological cycle of the provinces of Quebec and Labrador (Eastern Canada). It is responsible for the recharge of groundwater and the generation of most spring floods. Remote sensing provides an invaluable amount of spatially distributed data (> 1 km) with a high temporal frequency on the state of snow cover in comparison with traditional observation network. Several approaches to monitor snow cover extent (SCE) have been developed but some of them need to be improved in some parts of the world. The region of Eastern Canada is known to be a challenge in monitoring SCE by remote sensing because of its very thick snowpack and the diversity of its land cover including boreal forest. Snow cover extent products, particularly those generated from thresholding procedures, provide binary information on snow cover (presence or absence). Thresholding methods are known to be hard classifiers, the pixel is snow-covered or not. Therefore, a fuzzy logic approach might be appropriate to determine if a pixel is likely to be snow-covered or not. Fuzzy logic can be easily implemented in a thresholding method, providing a soft classification. The objective of this study is to develop a snow cover extent product over Eastern Canada providing the probability of observing snow combining fuzzy logic and remote sensing data from NOAA-AVHRR.

The SCE mapping procedure developed here is a dynamic thresholding method to detect snow, no-snow and clouds on daily NOAA AVHRR imagery (visible and thermal infrared data, 1.1 km spatial resolution) taken during onset of snow cover and snowmelt of each year, over the years 1988 to 2015. It is made of a set of hierarchical thresholds, applied sequentially, pixel by pixel, and the pixel satisfying all threshold conditions (6 in total) is classified as snow, otherwise it is classified as no-snow or cloud. Thresholds have been calibrated over a large amount of pixel samples taken in various land cover and meteorological conditions to capture the variability of seasonal snow cover over Eastern Canada. Empirical thresholds are second order polynomial functions relating the variation of a quantile value calculated for a specific parameter from AVHRR (T4, ΔT45, NDVI, ΔT34, R1) according to air temperature, and threshold values are specific to land cover categories. (Air temperature from NCEP-NARR Reanalysis (32 km) and Canada’s Land Cover products (1 km and 500 m) are used here as ancillary data). Ten (10) models of quantile values have been implemented to separate snow from other surfaces. For each threshold included in the classification procedure, fuzzy logic functions (z-shaped and s-shaped membership functions) are implemented to establish the membership, or probability, of a pixel to be snow-covered. Then, a simple multiplication rule gives the probability of a pixel to be likely snow-covered.