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Estimating snow water equivalent from snow depth and climate data using artificial neural networks

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Snow water equivalent (SWE) is the most important snow characteristic for hydrological forecasting in Nordic territories. Nevertheless, measuring SWE through field surveys is time consuming and expensive. Snow depth measurements can be conducted more rapidly and can also be automated, thus allowing for continuous measurement. For those reasons, snow depth records are generally larger both in time and space than manual snow survey records. Consequently, converting snow depth into SWE has the potential to increase considerably the amount of available information for hydrological modelling in Nordic regions.

SWE is obtained by multiplying snow depth by the snow's bulk density. Most of the variability of SWE is related to the variability of snow depth, so there is a high correlation between SWE and snow depth. However, the variation of snow bulk density is influenced by different complex and non-linear phenomena: melting and refreezing, settlement, fresh snow fall, etc.

Several empirical equations relating snow bulk density to snow depth have been proposed in the literature over the years. They are generally based on snow classification and linear regressions. Considering the complex, non-linear relationship between snow depth and bulk density, the use of artificial neural network can be considered to convert snow depth to SWE.

Here, we use a dataset comprising manual SWE and corresponding snow depth and bulk density measurement for more than 400 sites in Quebec (eastern Canada) over a period of 45 years. The measurements were conducted bi-monthly. In total, the dataset contains 40521 data points. Those data were used to train multiple single-layer perceptrons with different configurations (input data, number of hidden neurons, etc). The subdivisions of the dataset into different sub-periods of time or geographic regions was also investigated. All tests were conducted in a cross-validation framework to ensure the validity of the transferability of the neural network models. Finally, the neural networks were also compared to existing regression relationships. Our results show that neural networks are indeed efficient at converting snow depth to SWE, with an accuracy comparable or superior (depending on data availability) to existing regression models.