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Mapping SWE in near real time across a large territory using a particle filter

Philippe Cantet (1), Jean Odry (1), Marie-Amélie Boucher (1), Simon Lachance Cloutier (2), Richard Turcotte (2), and Vincent Fortin (3)

(1) Université de Sherbrooke, Civil and Building Engineering, Canada (jean.odry@usherbrooke.ca), (2) Quebec Government, Direction of Hydrologic Expertise, Quebec, Canada, (3) Hydro-Québec Research Institute (IREQ), Varennes, Canada

In nordic regions, snowmelt constitutes a large part of the total runoff. The knowledge of the spatial distribution of snow water equivalent (SWE) in near real time is necessary for operational purposes. One of the most common source of SWE information is the manual snow surveys, which provide reliable measurements of SWE even though the information is limited in both space and time. Such snow surveys can only take place in a limited number of sites and only a few times per season (typically twice per month).

Snow modeling is one possible solution to fill the gap between the availability of data and operational needs. At the provincial government of Quebec (eastern Canada), the availability of meteorological data on a 0.1 degree mesh enables to perform the HYDROTEL Snowpack Model (HSM) on the whole territory. Then SWE measurements are assimilated into the HSM by direct insertion and errors are interpolated in order to propose a SWE estimation everywhere in Quebec.

Due to the limitations of the direct insertion, the implementation of a particle filter to assimilate SWE observations in the HSM in Quebec was proposed. The uncertainty on meteorological data is used to introduce the perturbations required by the particle filter. The SWE estimated by the model is also perturbed to obtain a large panel of possible SWE scenarii. The likelihood of each particle (weight) is evaluated at measurement sites when an observation becomes available. Because all perturbations are implemented to be coherent in space and time, particle weights are spatially coherent and then, can be spatially interpolated. Consequently, the assimilation scheme (called the spatial particle filter) can be applied over the whole territory and, so, used to estimate SWE at unobserved locations. To avoid the filter to crash, the sampling importance resampling algorithm is employed cell by cell.

Cantet et al. (2019) show that the spatial particle filter outperforms the open loop simulations and the direction insertion scheme in terms of bias and accuracy. These performances are tested on observed and unobserved sites. Nevertheless, they underline the fact that the resampling step threatens the integrity of the spatial structure of SWE forecasts.

In order to preserve the spatial structure during the resampling step of the spatial particle filter, we propose a method based on the Schaake-Shuffle.

Reference:
Cantet, P., Boucher, M.-A., Lachance-Coutier, S., Turcotte, R., 2019. Using a particle filter to estimate the spatial distribution of the snowpack water equivalent. Journal of Hydrometeorology, Under Review.