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MAPPING SWE IN NEAR REAL TIME ACROSS A LARGE TERRITORY USING A PARTICLE FILTER

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Canada

EGU 2020: Sharing Geoscience Online
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CONTEXT

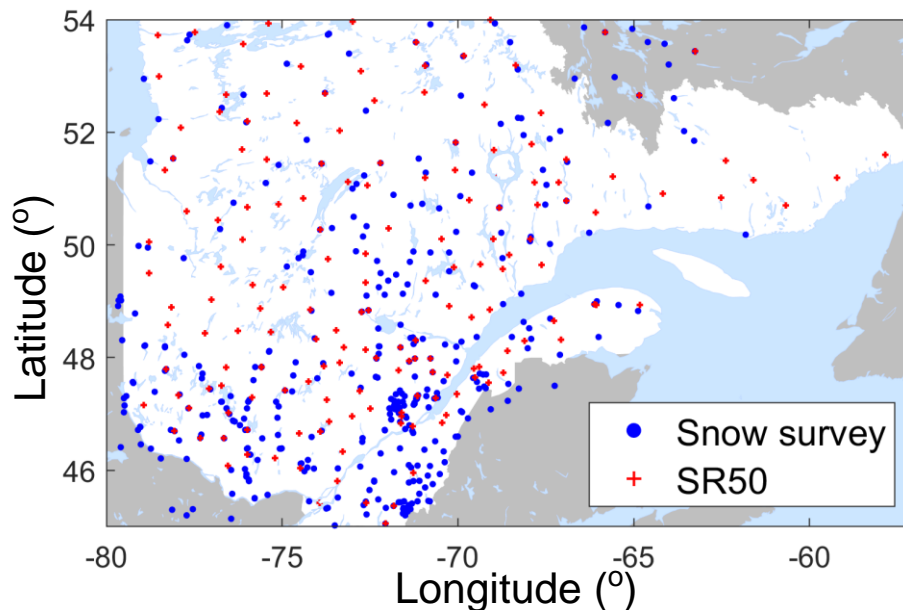
- Quebec (Canada)
 - 1.5 million km²
 - **Cold and humid** climate
 - Quebec city:
 - ❖ Mean annual total precip: 1286 mm
 - ❖ Mean annual snow: **305 cm**
- Snow accumulation during winter.
- Importance of the estimation of the **Snow Water Equivalent** (SWE).
 - Spring freshet
 - Reservoir management



Montmorency Forest – 27th March 2019

SNOW DATA

	Manual snow survey	SR50 sonic sensors
Variable	Depth, SWE, Density	Depth*
Frequency	≈ Bi-weekly	1 hour
Sites	394	160
Period	1970-2015	2005-2015
Spatiality	≈300 m	Punctual
Reliability	High	Medium



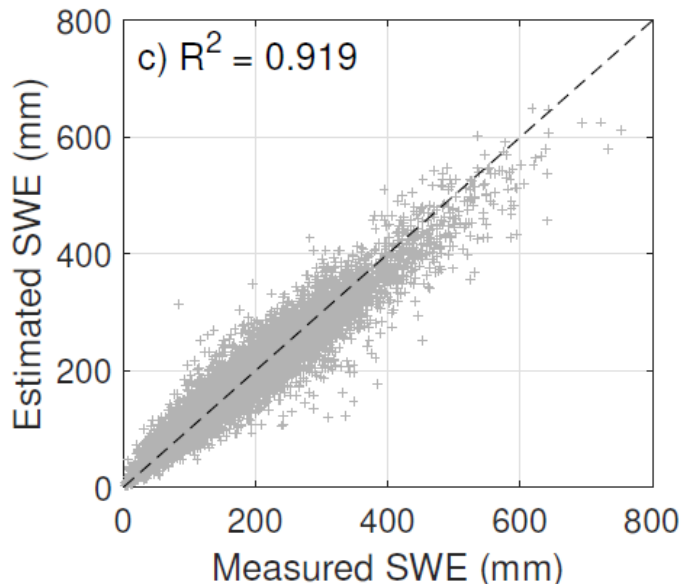
ESTIMATION OF SWE FOR SR50

Using artificial neural networks to estimate snow water equivalent from snow depth

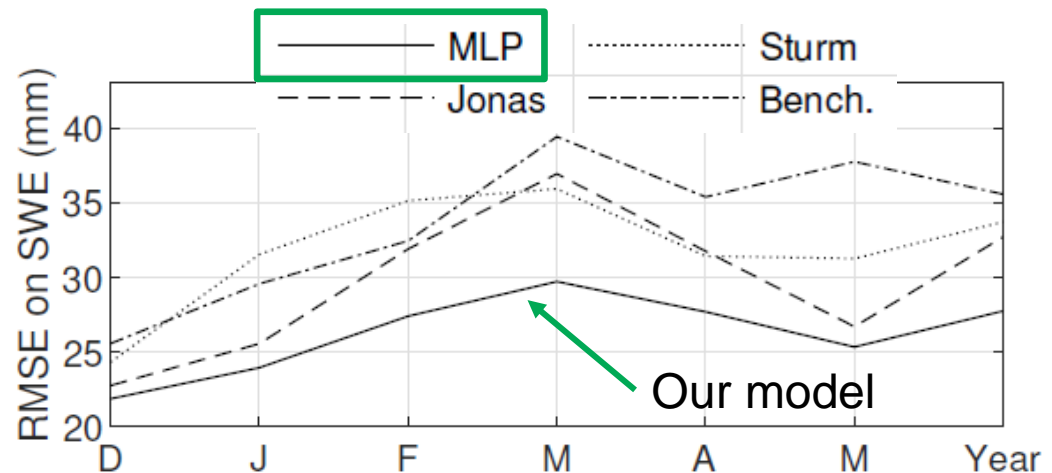
J. Odry, MA. Boucher, P. Cantet, S. Lachance-Cloutier, R. Turcotte, and PY. St-Louis.

Canadian water resources journal (under review)

Estimated SWE vs measured SWE
on validation subset



Comparison of error for different models



SNOW MODEL

- HYDROTEL Snow Module
 - Temperature index based
 - **Operational** in Quebec
 - Recalibrated for the project
- Distributed: **0.1° resolution**
- Inputs: gridded precipitation, min and max temperature
- 6 parameters **calibrated globally**
- 5 state variables including SWE

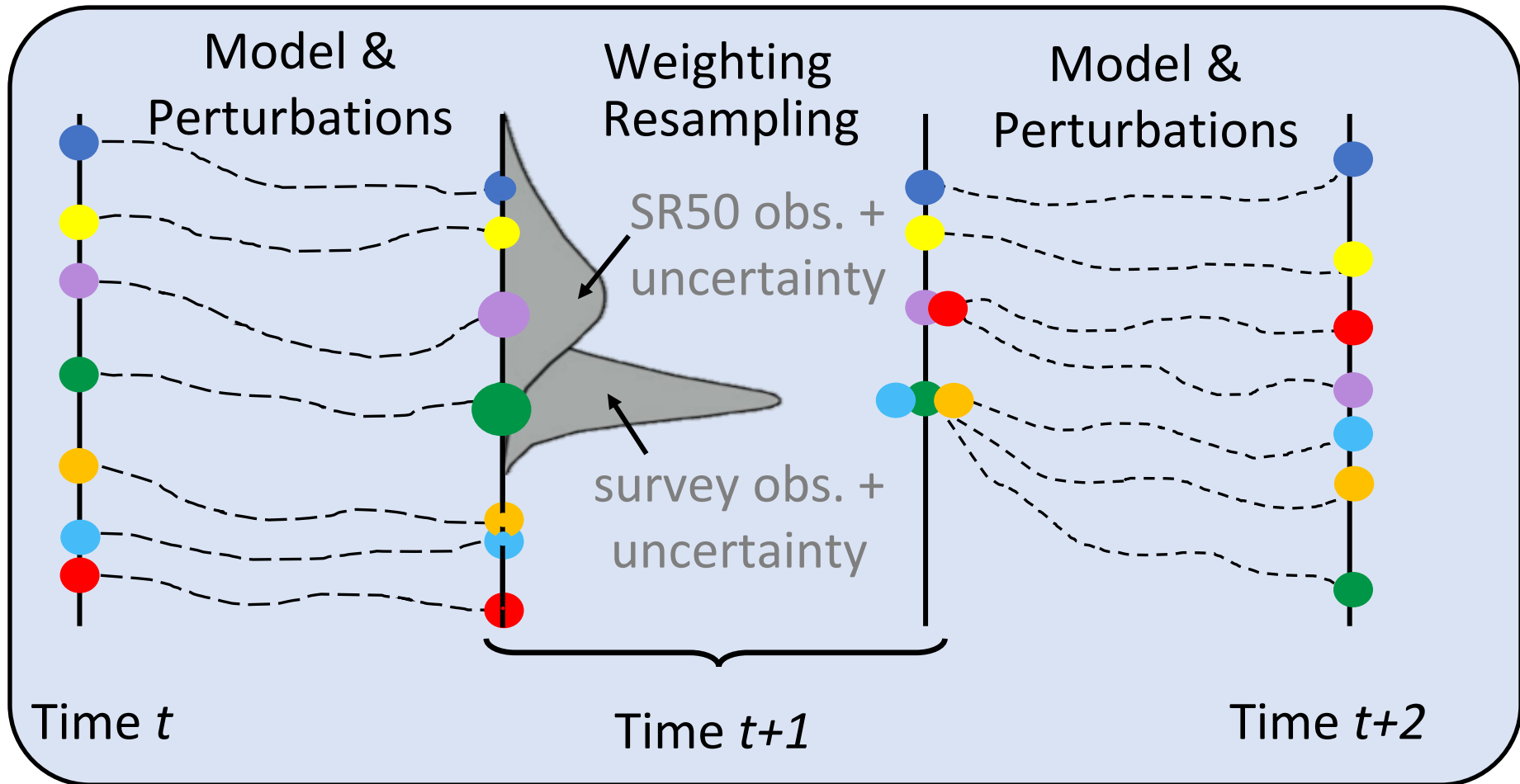
Operational analysis of the spatial distribution and the temporal evolution of the snowpack water equivalent in southern Québec

Turcotte, R., Fortin, L., Fortin, V., Fortin, JP., Villeneuve, JP.

Water Policy, 2007 (38).

PARTICLE FILTER

- Scenarios created by randomly perturbing meteo and model



SPATIAL PARTICLE FILTER

Using a particle filter to estimate the spatial distribution of the snowpack water equivalent

Cantet, P., Boucher, M.-A., Lachance-Coutier, S., Turcotte, R.,
Journal of Hydrometeorology, 2029 (20).

- All perturbations drawn with **space and time dependence**
=> each scenario is coherent :
 - **In time:** from t to $t+1$
 - **In space:** from a location to a neighbouring point

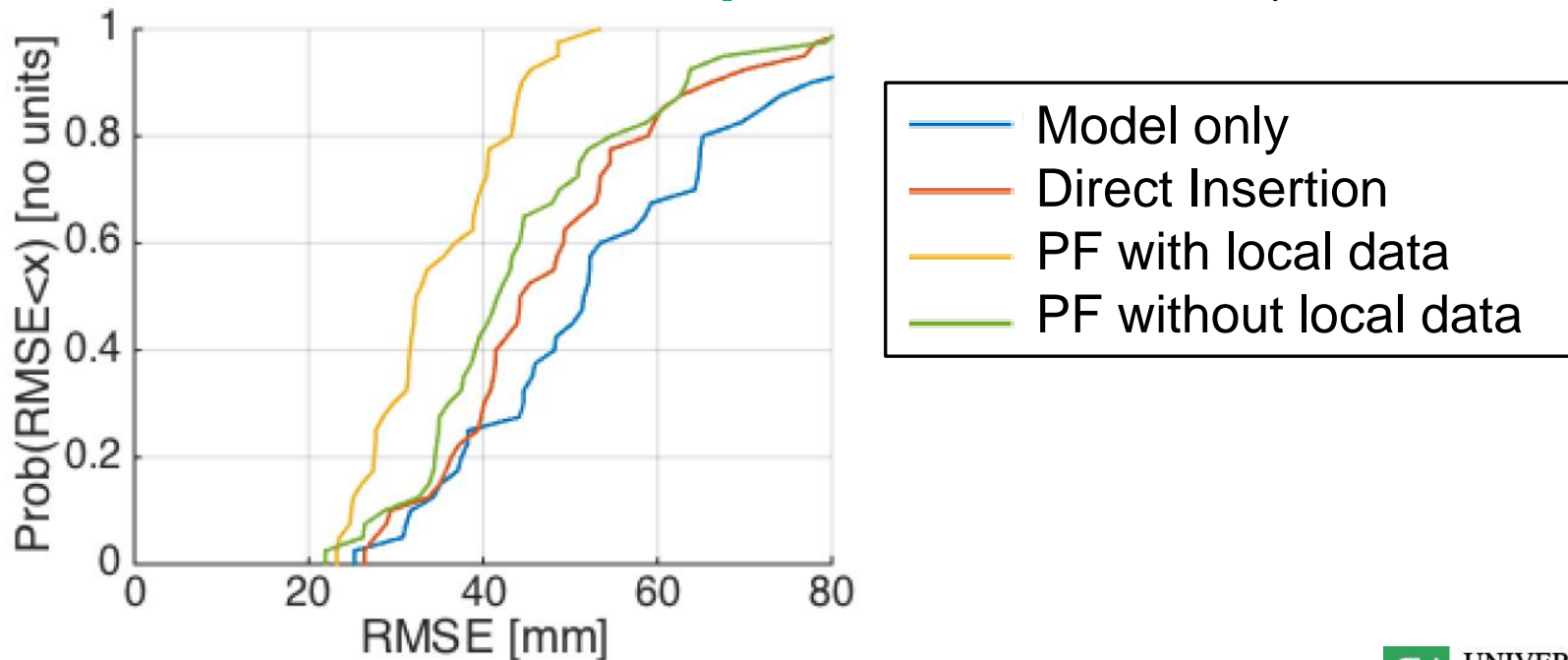
Hypothesis:

Particle weights can be interpolated in space.

=> If a particle is good at a given location, it is also good at neighbouring grid cells.

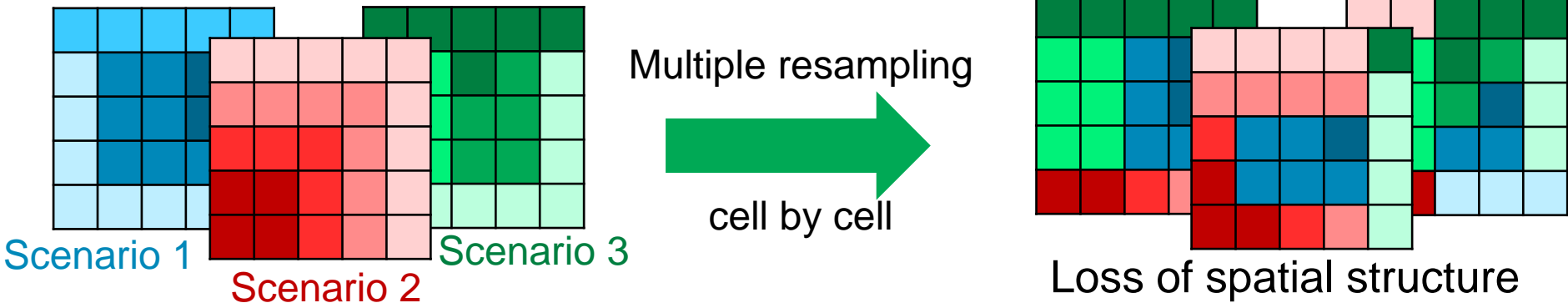
PERFORMANCES

- From Cantet et al. (2019)
- Using manual snow surveys only
- Weekly assimilation and resampling
- Evaluation on an **independent data set** (new survey sites)

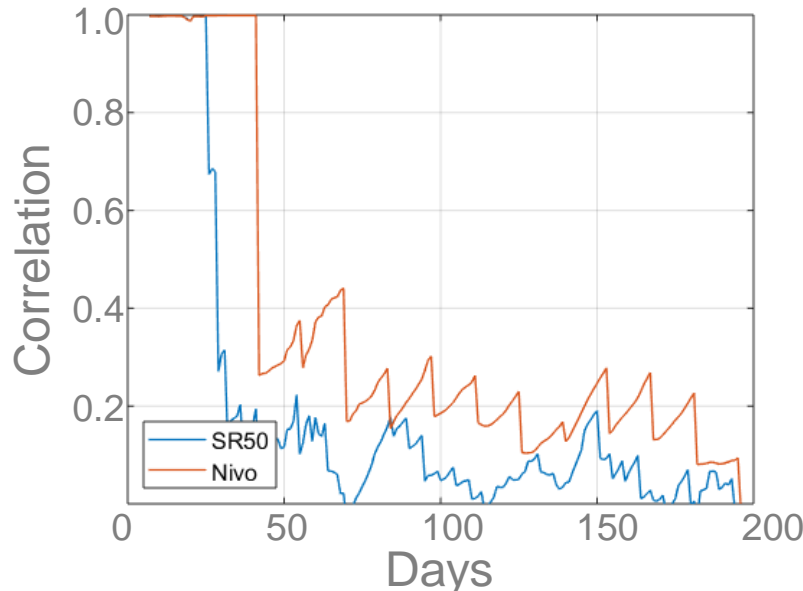


INTEGRATING SR50 DATA : PROBLEMS

- Higher observation frequency
=> Resampling is more frequent

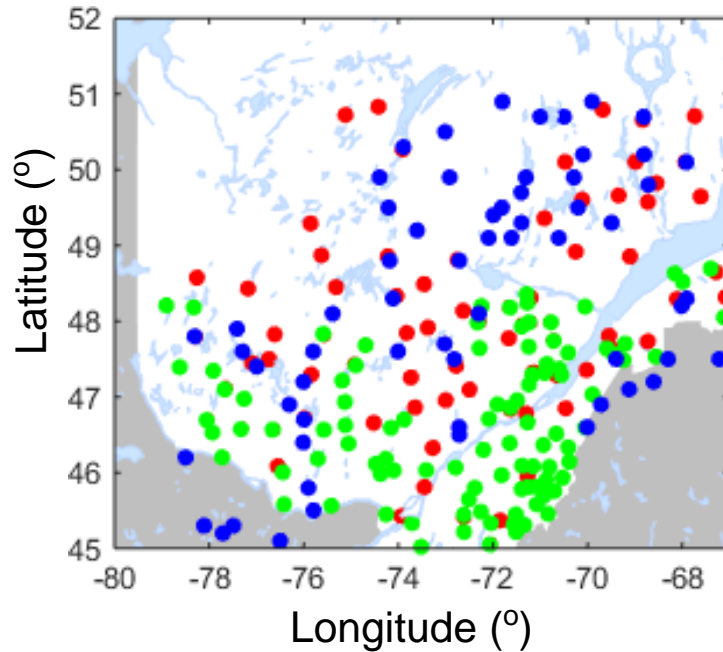


Correlation between scenarios at neighbouring sites (synthetic data sets)



- ⇒ The underlying hypothesis for interpolation is not valid anymore
- ⇒ The problem can be solved by reordering the particles.

EXPERIMENTAL DESIGN

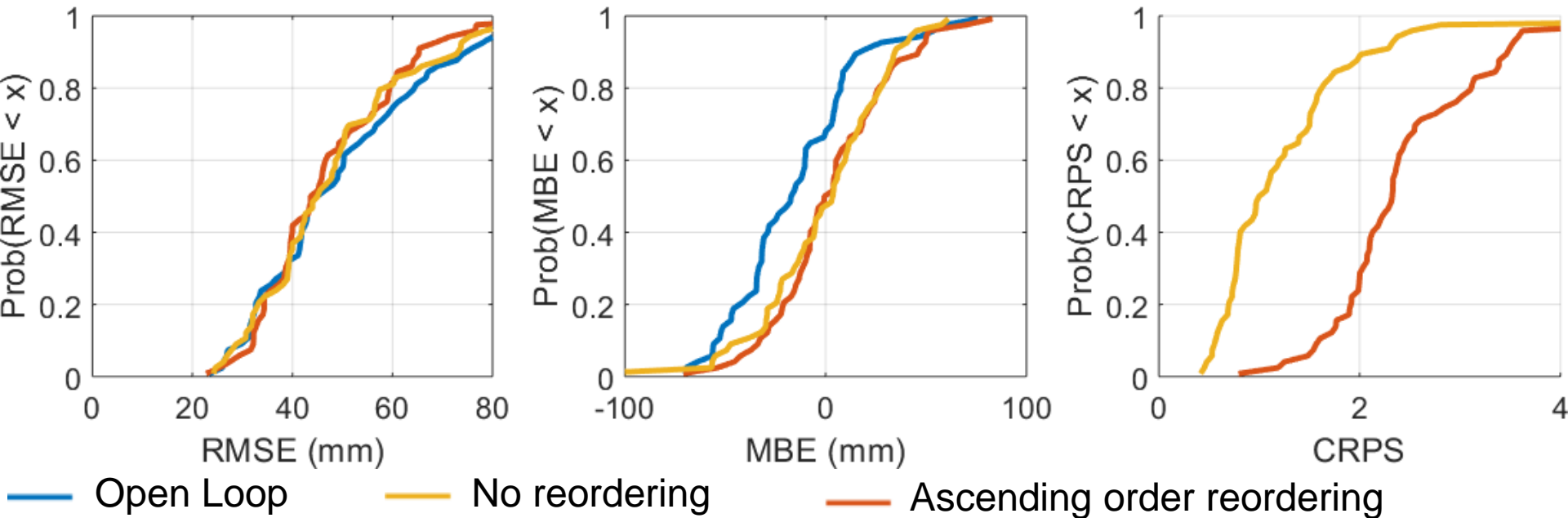


- SR50
- Snow survey
- Validation snow survey

- Time period : 2005-2015
- Independent set of snow surveys used for validation

RESULTS ON VALIDATION SUBSET

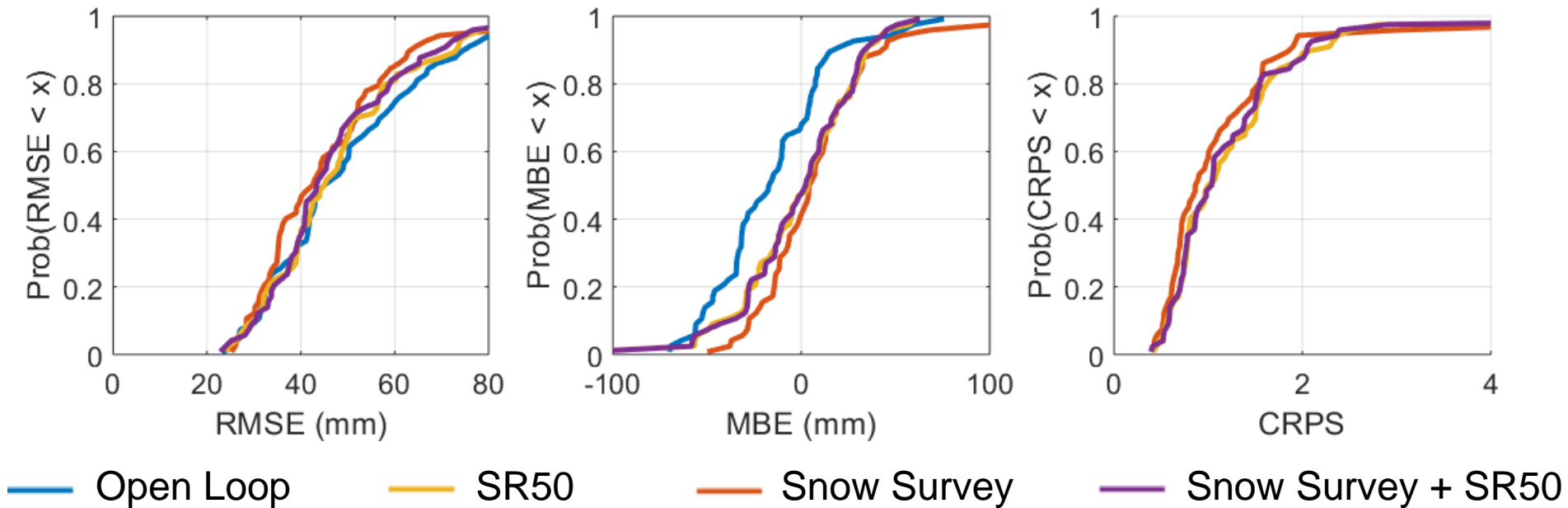
- Effect of reordering on SR50 assimilation



- ⇒ The reordering largely improves the CRPS by **reducing the spread of the ensemble**.
- ⇒ Without reordering, the **weights may be attributed wrongly and randomly**. By correctly weighting the particles, the spread is reduced.

RESULTS ON VALIDATION SUBSET

- Comparison of the type of data that is assimilated



- ⇒ All assimilations are better than Open Loop.
- ⇒ Assimilation of snow surveys is preferable but the validation sites are snow surveys (possible bias).
- ⇒ Assimilation of SR50 still achieves nice results, especially regarding model bias reduction.

CONCLUSION

- The Spatial Particle Filter is a useful tool to find a **compromise between observations and modeling in ungauged sites**.
- **Reordering the particles** is necessary to correctly weight the particles and avoid loss of spatial structure.
- **Assimilation of indirect SWE from SR50** sensors can reduce the model bias.
- The **compromise between the two types of data** depends on expert judgment and the data used for validation.

THANK YOU FOR YOUR ATTENTION.

Due to jet lag, our participation to the chat might be difficult, sorry.
Questions are very welcome by email.

Contact:

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References:

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.* J. Hydrometeorol. 20.

Odry, J., Boucher, MA., Cantet, P., Lachance-Cloutier, S., Turcotte, R., and St-Louis, PY. (2020). *Using artificial neural networks to estimate snow water equivalent from snow depth.* Canadian Water Ressources Journal (under review)

Turcotte, R., Fortin, L.-G., Fortin, V., Fortin, J.-P., Villeneuve, J.-P., (2007). *Operational analysis of the spatial distribution and the temporal evolution of the snowpack water equivalent in southern Québec.* Nordic Hydrology, 38.