Introduction of a SWE-SCA hysteresis in a degree-day snow model for rainfall-runoff modelling

Philippe Riboust, Guillaume Thirel, Nicolas Le Moine, Pierre Ribstein

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Riboust Philippe[1,2], Thirel Guillaume[1], Le Moine Nicolas[2] & Ribstein Pierre[2]

1: HYDRO - HYCAR – Irstea, Antony, France
2: UPMC Univ. Paris 06 – Sorbonne Universités, Paris, France
guillaume.thirel@irstea.fr

1. Rationale

Snow models used for rainfall-runoff (RR) modelling are often calibrated jointly with a hydrological model against discharge (Q) only, leading to poor snow simulation.

Drawbacks:

- Optimisation can force snow model to compensate RR model flaws
- Assimilation of snow data is very difficult

Here (Riboust et al., 2018), we implement a SWE-SCA linear hysteresis (LH) and use MODIS SCA data to improve the snowpack modelling.

Fig. 1: Heterogeneity of the snowpack during melt at Edelbodenalm, Austria (Parajka et al., 2012)

2. The CemaNeige snow model

Characteristics:

- Degree-day
- 5 altitude bands
- Coupled to GR4J RR model
- 2 parameters to calibrate
- With LH: 2 more parameters

Variables (extrap. with altitude):

- Mean air temperature
- Precipitation

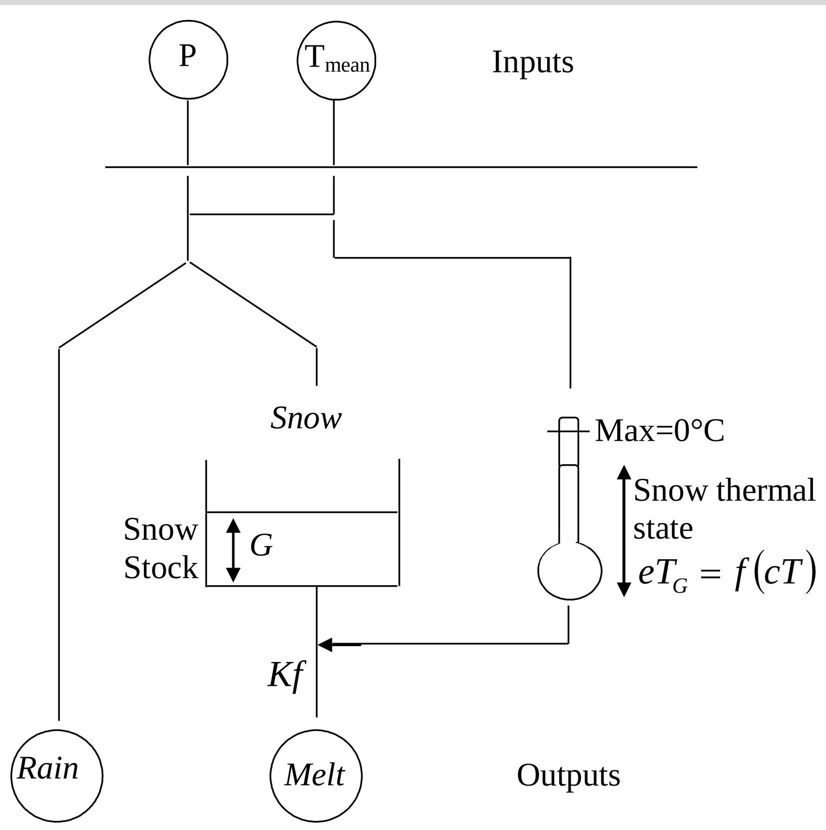


Fig. 2: The CemaNeige model

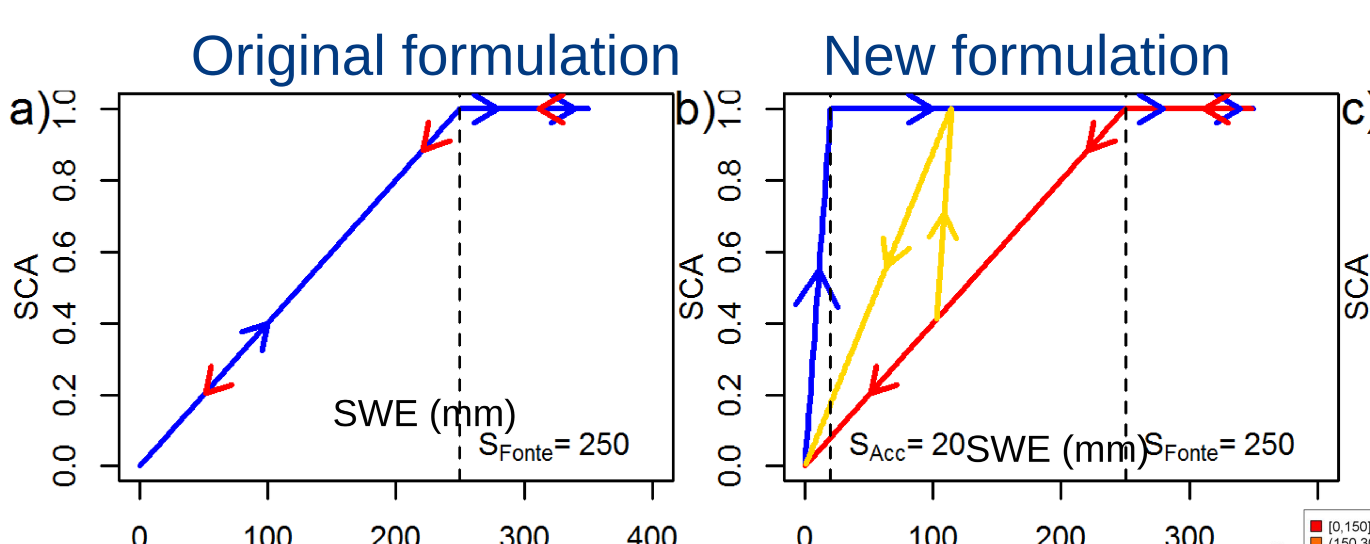
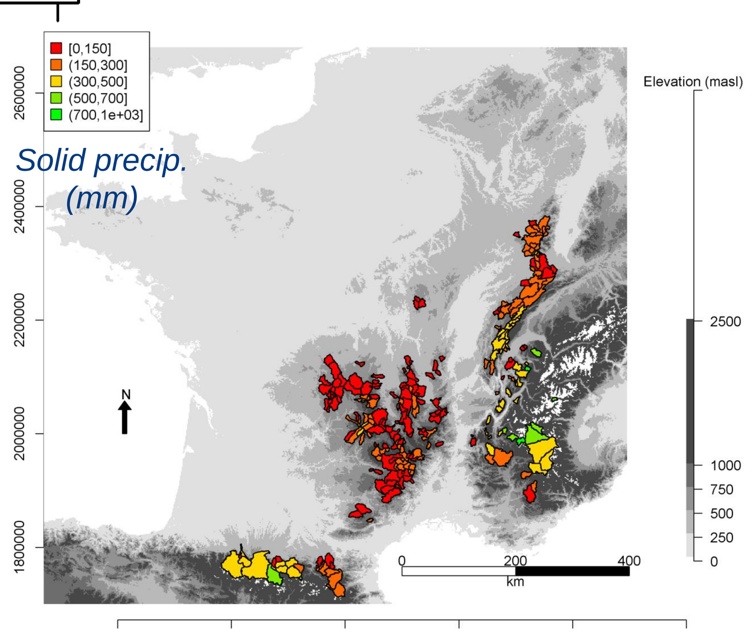


Fig. 3: The SWE-SCA LH (right) represents the heterogenous spatial melt of snow at the basin scale

3. Experimental set up

277 natural snowy basins

Fig. 4: Study area



- Periods: 2000-2010 divided into 2 calibration/validation periods
- All results presented on valid. Periods here
- Criterion: KGE' (Kling et al., 2012) on Q (and SCA in some cases, see Eq. 1)

4. Impact of the linear hysteresis and sensitivity to SCA weights in the objective function

Fig. 5 shows that:

- Calibrating CemaNeige with Q and SCA improves SCA but deteriorates Q compared to ref.
- Using in addition a LH improves SCA even more with similar Q performance compared to ref.

Fig. 6 shows that 75% of weight on Q (and 25% on SCA) seems a reasonable compromise

Eq. 1: Objective function

$$Crit = \alpha\, KGE'(Q) + \sum_{i=1}^{5} \beta_i\, KGE'(SCA_i)$$

Tab. 1: Experimentation setup for Fig. 5

Model	Q weighting α	β 1 … 5 weighting for altitude bands
CemaNeige reference (C Q)	1	0
CemaNeige SCA (C Q SCA)	0.75	0.05 x 5
CemaNeige linear hysteresis (LH*)	0.75	0.05 x 5

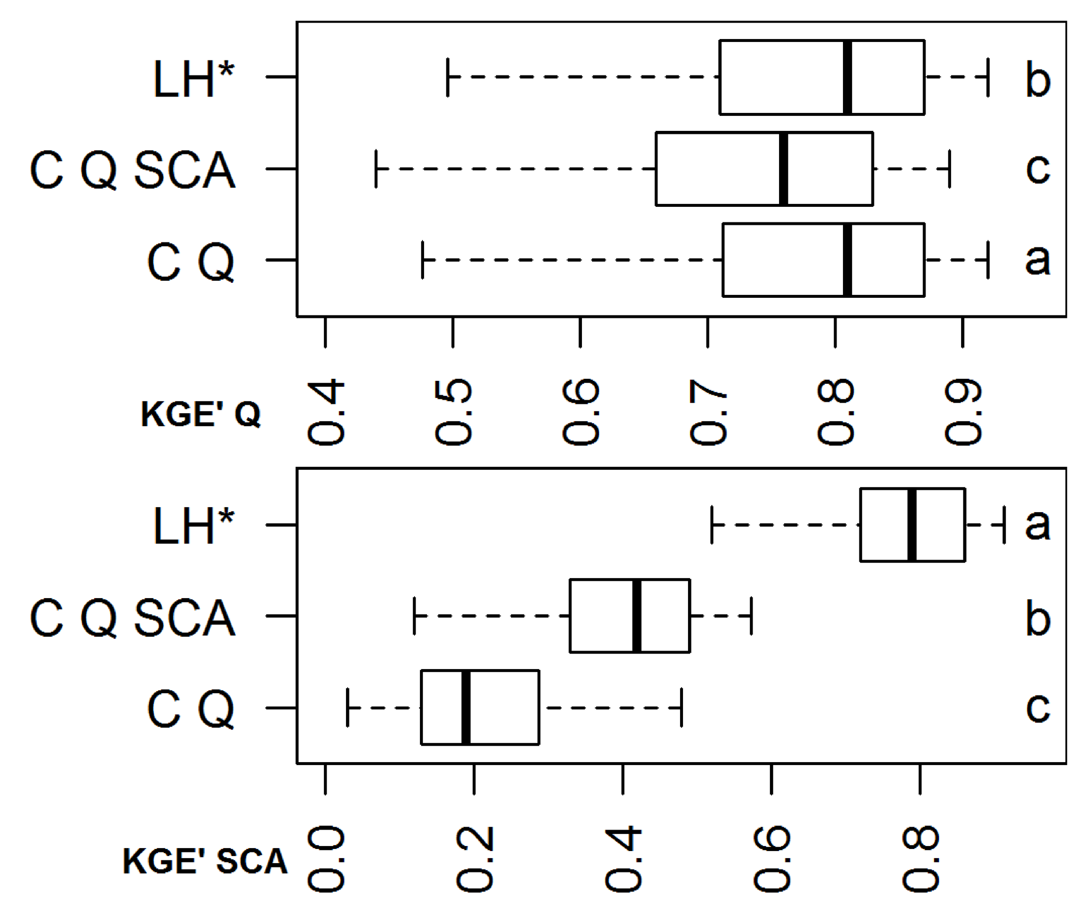


Fig. 5: Q and SCA performances for the experiments of Tab. 1 (letters on the right are results of Friedman test)

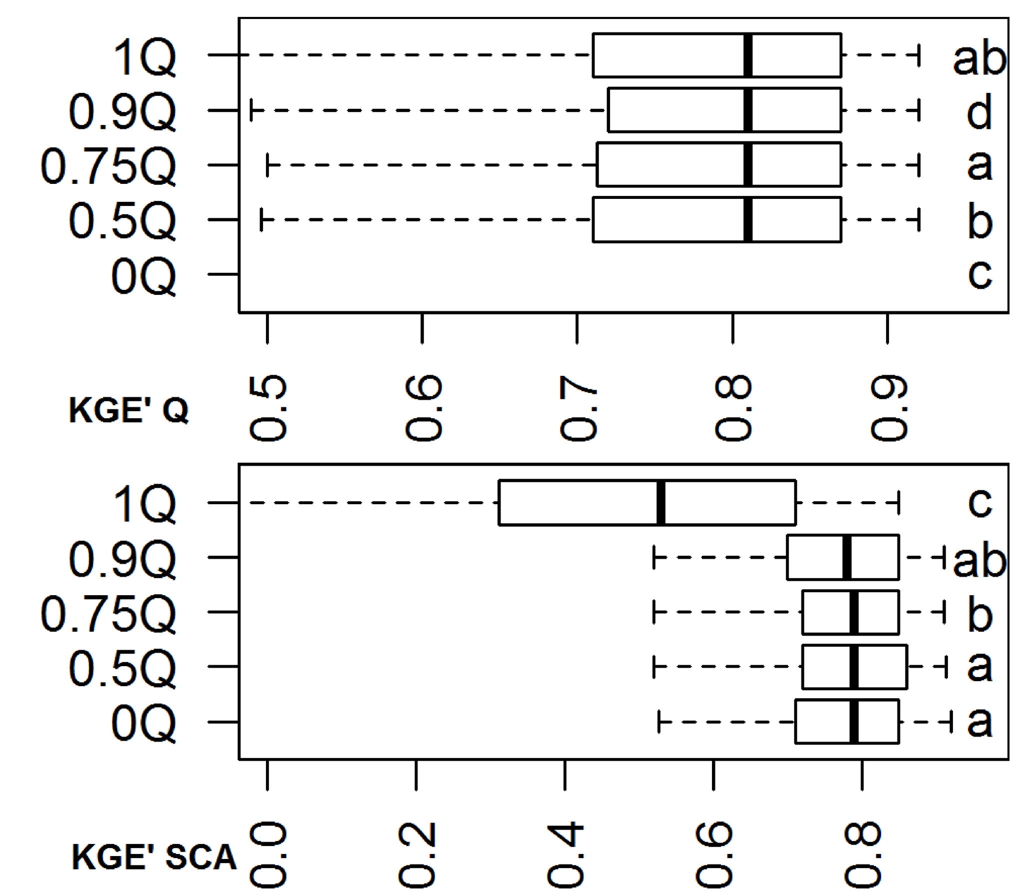


Fig. 6: Q and SCA performances with differentQ and SCA weights

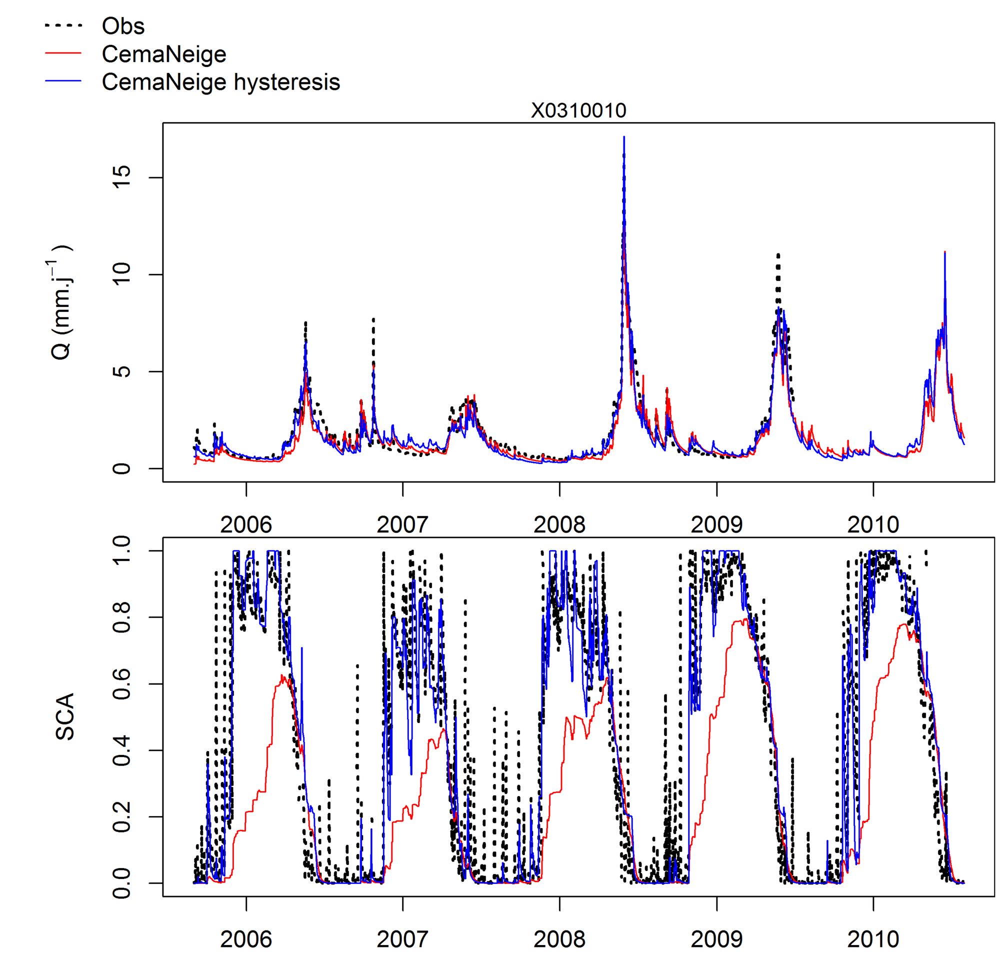


Fig. 7: Improvement of Q and SCA for the River Durance with the new CemaNeige version (LH exp.)*

5. The linear hysteresis improves the model robustness

The implementation of LH in CemaNeige improves its parameters stability when coupled to another RR model (HBV, Fig. 8) and improves the performances on Q on contrasted and independent periods (Fig. 9).

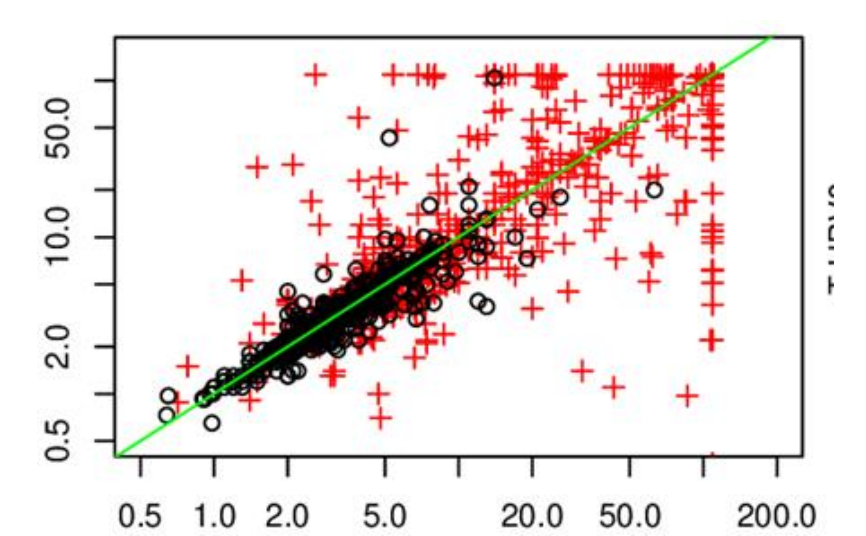


Fig. 8: CemaNeige melt factor (mm/° C/d) when coupled to HBV or GR4J with original CemaNeige or linear hysteresis

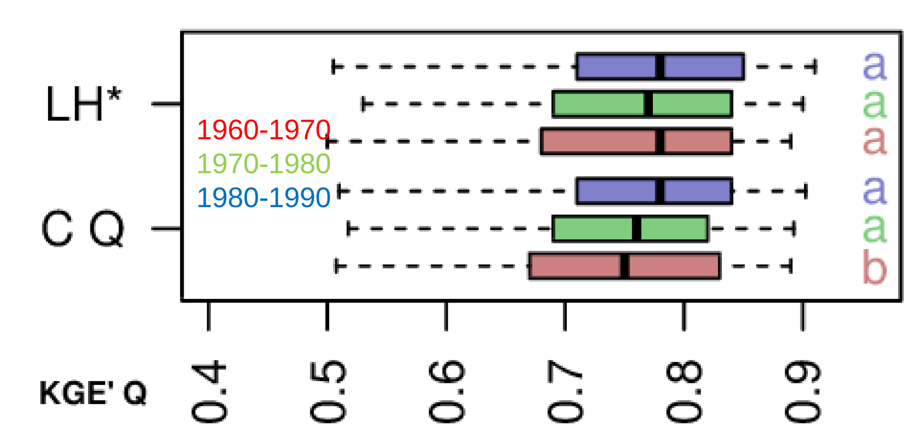


Fig. 9: Performance of original and new CemaNeige versions on independent past periods (with GR4J)

6. Conclusions and perspectives

The newly-implemented SWE-SCA LH improves the quality of SCA without deteriorating Q. Results suggest that:

- Use of additional MODIS SCA data for calibration or data assimilation is now allowed
- Climate change applications are facilitated due to more stable parameters and better performances on past periods

This new CemaNeige version will be available shortly in the **airGR** R package (Coron et al., 2017).

7. References

Coron, L., Thirel, G., Delaigue, O., Perrin, C., Andréassian, V., 2017: The Suite of Lumped GR Hydrological Models in an R package, **Environmental Modelling & Software**

Kling, H., M. Fuchs, and M. Paulin (2012), Runoff conditions in the upper Danube basin under an ensemble of climate change scenarios. **Journal of Hydrology**

Parajka, J., Haas, P., Kirnbauer, R., Jansa, J., Blöschl, G., 2012. Potential of time-lapse photography of snow for hydrological purposes at the small catchment scale. **Hydrol. Process.**

Riboust, P., Thirel, G., Le Moine, N., and Ribstein, P.: Revisiting a simple degree-day model for integrating satellite data: implementation of SWE-SCA hystereses. **Journal of Hydrology and Hydrodynamics**, DOI: 10.2478/johh-2018-0004, accepted, 2018