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Can the super model (SUMO) method improve hydrological simulations? Exploratory tests on lumped rainfall-runoff models

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Objectives

✗ Improve the robustness of rainfall-runoff models
✗ Test an unusual multimodel method: the SUMO (SUper MOdel) method

1. What is a Super Model?

✗ Dynamical multimodel method created by climatologists (van den Berge *et al.* , 2011)
✗ Based on the continuous correction of internal variables during the run
✗ Addition of linear correction terms to the differential equation of the model variables
✗ Correction terms depend on other model variables and are parameterized by coefficients

The equation for a Super Model with two models (model 1 with a state vector $\overrightarrow{x_1}$ and model 2 with a state vector $\overrightarrow{x_2}$) and parameterized by two diagonal matrices $\mathbf{C_1}$ and $\mathbf{C_2}$ is:

$$\dot{\overrightarrow{x_1}} = f_1(\overrightarrow{x_1}) + \mathbf{C_1}(\overrightarrow{x_2} - \overrightarrow{x_1})^T$$
$$\dot{\overrightarrow{x_2}} = f_2(\overrightarrow{x_2}) + \mathbf{C_2}(\overrightarrow{x_1} - \overrightarrow{x_2})^T$$

basic equation | SUMO correction

2. The first tested hydrological Super Model

✗ Two GR4J models (Perrin *et al.* , 2003, represented as state-space, see EGU2017-4851) with different parameterizations
✗ Calibrated using a simple “split-sample test” and the KGE' as an objective function, the first GR4J model is calibrated on the high flow component and the second one on the low flow component (log)
✗ Correction of the levels of the production and routing stores

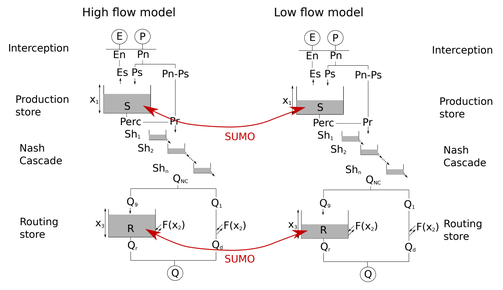

Fig. 1: Location of SUMO corrections in the GR4J conceptual structure

3. Evaluation methodology

✗ 250 French catchments to test the robustness of the Super Model
✗ Calibration of the SUMO coefficients using the KGE' calculated on square root transformed flows
✗ Performances comparison with a benchmark GR4J model calibrated on the same objective function to test the real added value of the Super Model
✗ Sensitivity analysis of the Super Model coefficients
✗ Analysis of behaviour of the store levels during the run

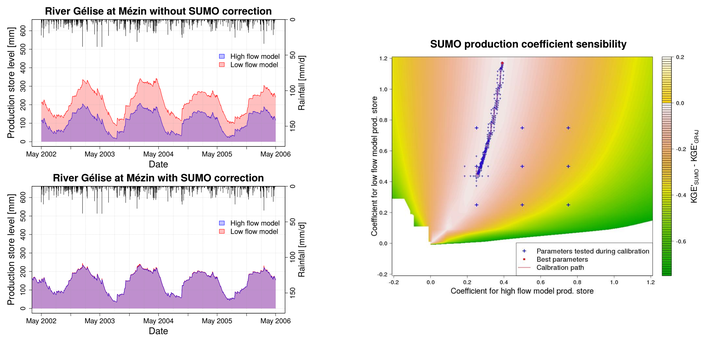

Fig. 2: Synchronization of the production store levels in the Super Model for the River Gélise at Mézin, the production store levels of the 2 GR4J models are different which makes the SUMO coefficients sensitive

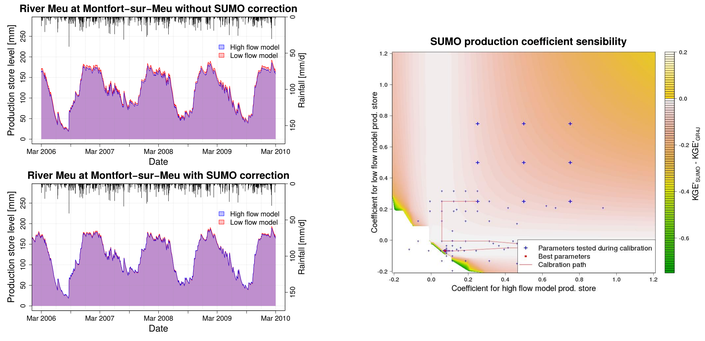

Fig. 3: Synchronization of the production store levels in the Super Model for the River Meu at Montfort-sur-Meu, the production store levels of the 2 GR4J model are similar which makes the SUMO coefficients non sensitive

4. Results

Performances

✗ No global improvement on average for the 250 tested catchments regarding the performances of the simple model GR4J
✗ BUT interesting results in particular catchments

SUMO behaviour

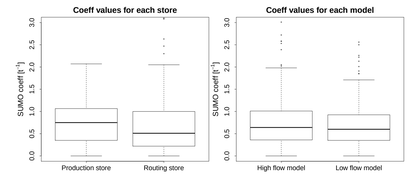

Fig. 4: Calibrated SUMO coefficient values for the 250 tested catchments

✗ SUMO coefficient values are informative (figure 4)
✗ The high flow model and the production store coefficients seem more sensitive in the Super Model
✗ Internal variables synchronize themselves, the two models come to a “compromise” (figure 2 left)
✗ Parameter sensitivity may depend on initial difference between internal variables (figure 2 and 3)

5. Test on different models

✗ With simple models implemented using the SUPERFLEX framework (Fenicia *et al.* , 2011)
✗ The Super Model significantly improve the simulations of the 2 simple models on the tested catchments

Conclusion

✗ The Super Model does not improve the performances on average
✗ Tests on models which are different (*e. g.* SUPERFLEX) could lead to more interesting conclusions
✗ SUMO still shows interesting behaviour and can help to understand how its constitutive models work

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