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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 and model 2 with a state vector) and parameterized by two diagonal matrices \( C_1 \) and \( C_2 \) is:

\[
\begin{align*}
\dot{x}_1 &= f_1(x_1) + C_1 (x_2 - x_1) \quad \text{basic equation} \\
\dot{x}_2 &= f_2(x_2) + C_2 (x_1 - x_2) \\
\end{align*}
\]

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

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

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

- 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., 2013)
- 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

References

