On the use of a Nash cascade to improve the lag parameter transferability at different time-step

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Objectives

Context

Conceptual bucket-type hydrological models often use lag functions. The lag parameters that govern these functions are dependent on the modelling time-step and are difficult to transpose between them. It is an issue because daily flow data are more easily available than hourly data.

Objectives

- ✗ To avoid that the lag parameter depends on the time-step
- ✗ To more easily transpose parameters from daily to hourly time-step

Method

- ✗ Substitution of the lag function with a "Nash cascade" (Nash, 1957)
- ✗ Use of a near-continuous resolution to solve the model equations

1. Structural modifications

Model used: GR4 (Perrin et al., 2003)

- ✗ Lag function replaced by stores to obtain a strict state-space representation

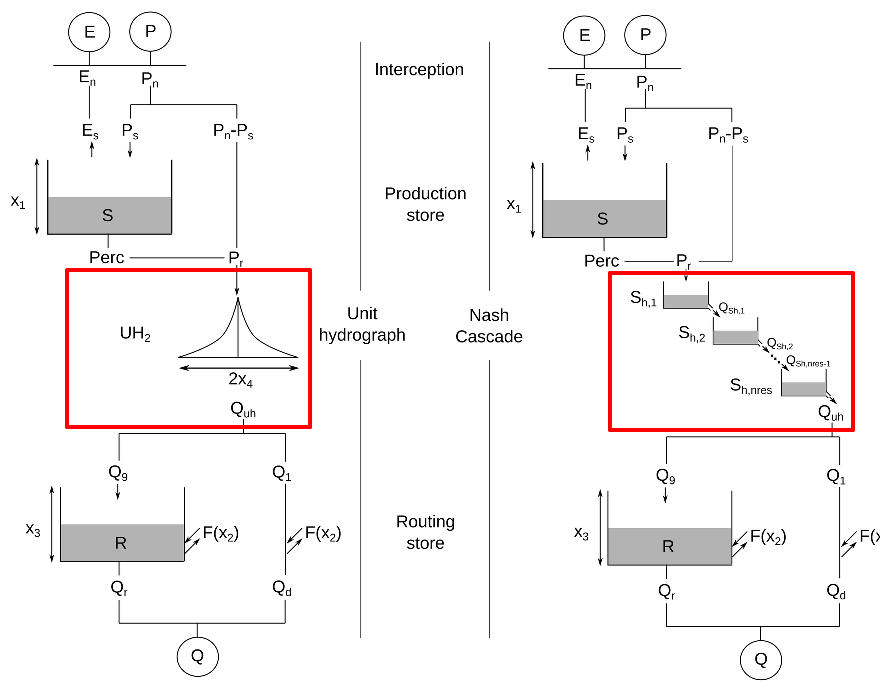

Fig. 1: Substitution of the unit hydrograph of the original GR4J model (left) by a "Nash cascade" to form a state-space model (right)

2. Parametrisation of the Nash cascade

Two parameters in the Nash cascade: number of stores and outflow coefficient

- ✗ Number of stores fixed at $nres = 11$
- ✗ Outflow coefficient linked to the x_4 parameter of GR4 with the relation: $k = \frac{nres-1}{x_4}$

Nash cascade and GR4 unit hydrograph responses have the same timing

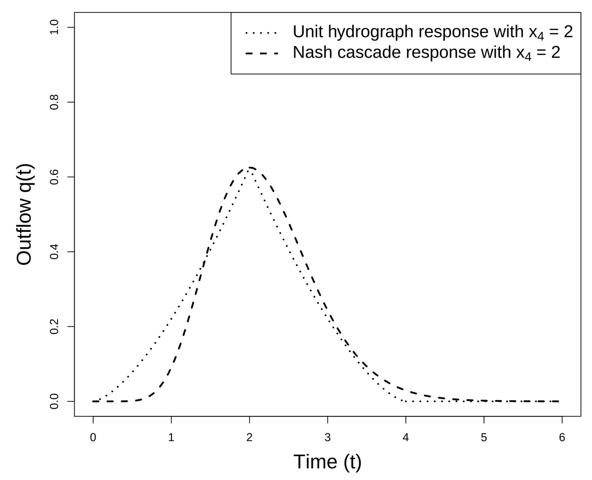

Fig. 2: Shapes of the unit hydrograph and Nash cascade responses

3. Robust numerical temporal integration

Initial integration technique

- ✗ Inputs added at the beginning of the time-step
- ✗ Water balance equations solved using a sequential technique

Modified integration technique

- ✗ Inputs considered as uniform over the time-step
- ✗ Implementation of an Euler-implicit method using adaptive sub-step (approaches a continuous time model)

4. Evaluation methodology

- ✗ 240 French catchments to get general conclusions
- ✗ Calibration of the models using the KGE' (Kling et al., 2012) with square root transformed flows at daily and hourly time-steps
- ✗ Comparison of performances and parameter values between daily and hourly time-steps

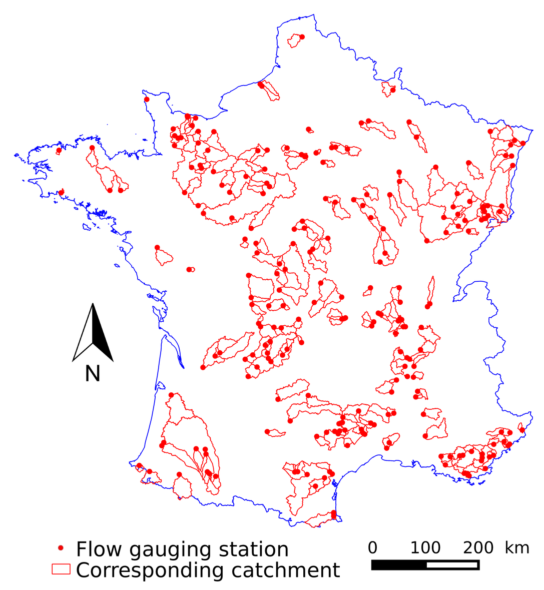

Fig. 3: Locations of the 240 test catchments in France

5. Results

Impact of the substitution with a Nash cascade

- ✗ Performances are similar to the reference GR4 at daily and hourly time steps
- ✗ No improvement of parameter temporal stability

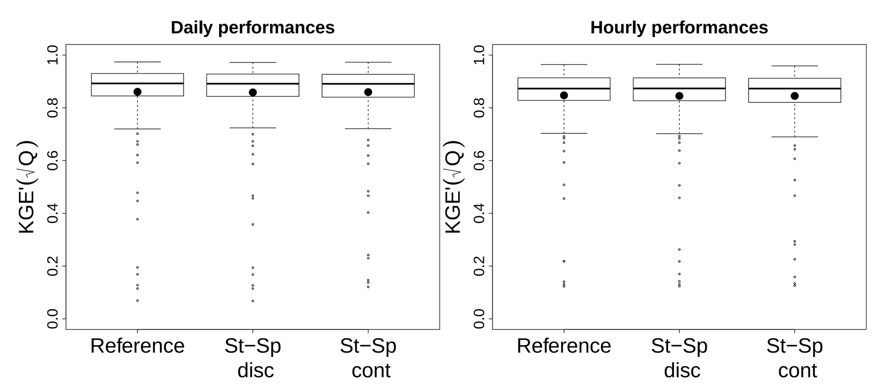

Fig. 4: Performances distribution of the different models, in validation, on the 240 catchments

References

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Perrin, C., Michel, C., and Andréassian, V.: Improvement of a parsimonious model for streamflow simulation, Journal of Hydrology, 279, 275289, doi:10.1016/s0022-1694(03)00225-7, 2003.

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Impact of the integration technique modification

- ✗ Performances also remains similar
- ✗ Increase of the lag parameter temporal stability

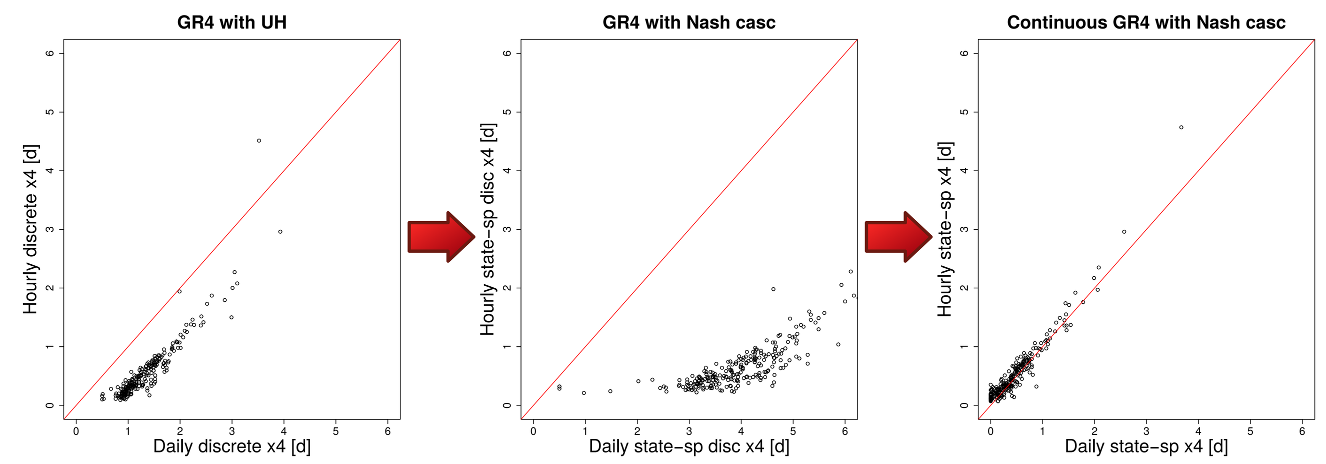

Fig. 5: Lag parameter values obtained at hourly time-step compared to those obtained at daily time-step

Example: River Sauldre flood, June 2016

River Sauldre at Romorantin (© La nouvelle République)

- ✗ Calibration at daily time-step
- ✗ Test on the hourly flood hydrograph
- ✗ Better timing for the continuous integration

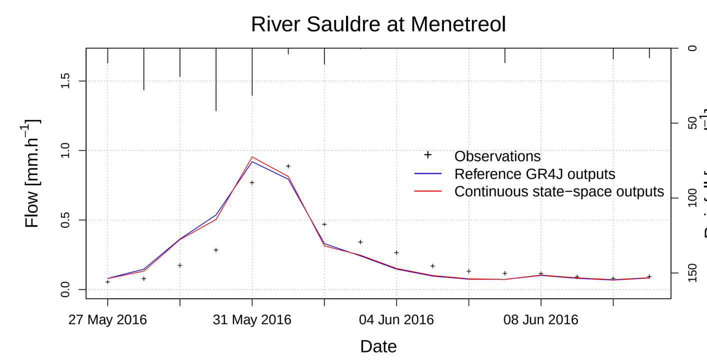

Fig. 7: Daily hydrograph during the flood

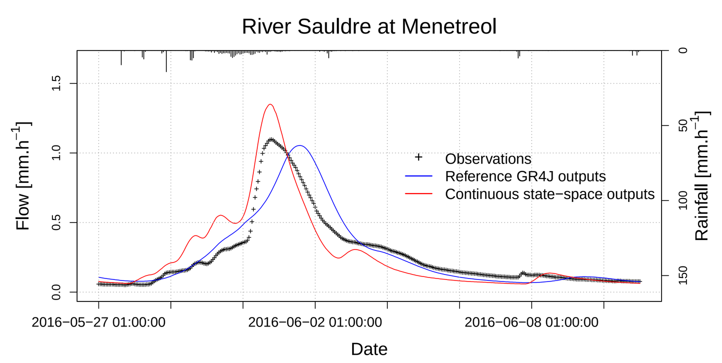

Fig. 8: Hourly hydrograph during the flood

Conclusion

- ✗ Sequentially integrated model leads to different lag parameters at different time-steps
- ✗ Continuity in integration technique improves the stability of the lag parameter
- ✗ More information in Santos et al. (2018)

Application

- ✗ For catchments with only daily flow measurements available
- ✗ To set-up an adaptive time-step model