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Égalité
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INRAE

Calage par régularisation d'un modèle GR semi-distribué

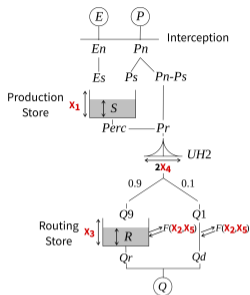
4^{es} Rencontres HydroGR 2021

Alban de Lavenne

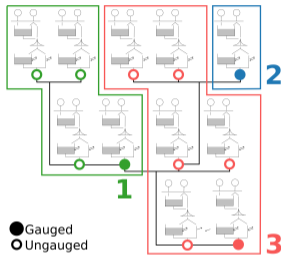
7-8 décembre 2021

INRAE, HYCAR, Antony, France

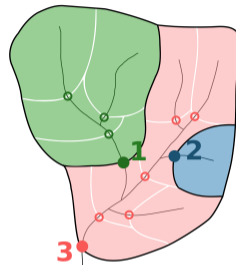
GRSD: A semi-distributed hydrological model based on GR models



GR5J



GRSD (example)



Example catchment

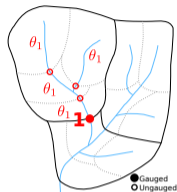
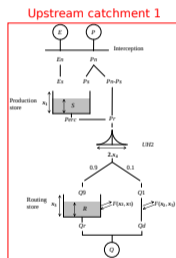
[de Lavenne et al., 2019]

- Based on GR5J: 5 parameters for each modeling unit
- Mixing gauged and ungauged catchments
- Lead to the definition of Intermediary Contributing Area (ICA)



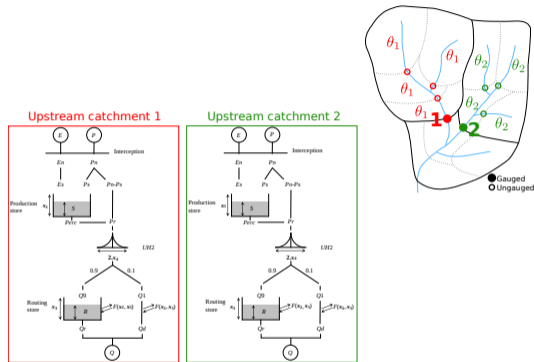
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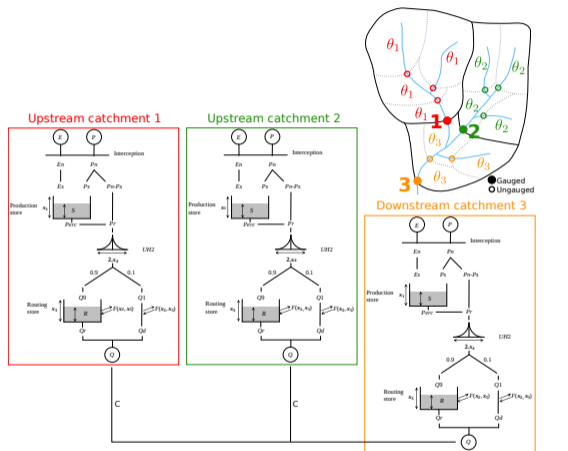
1. Upstream catchments are calibrated first

Traditional sequential calibration strategy [Lerat et al., 2012]



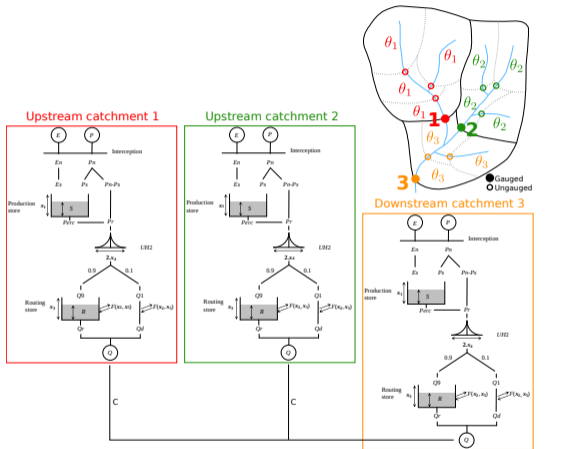
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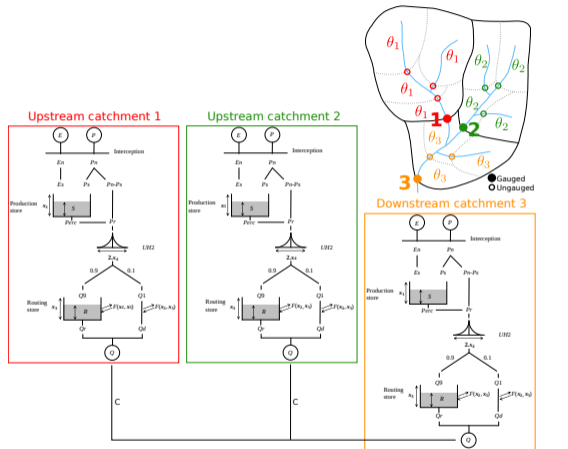
1. Upstream catchments are calibrated first
2. Simulated outflow is routed to downstream station (parameter C)
3. Contribution of downstream ICA (intermediary sub-catchment) is calibrated



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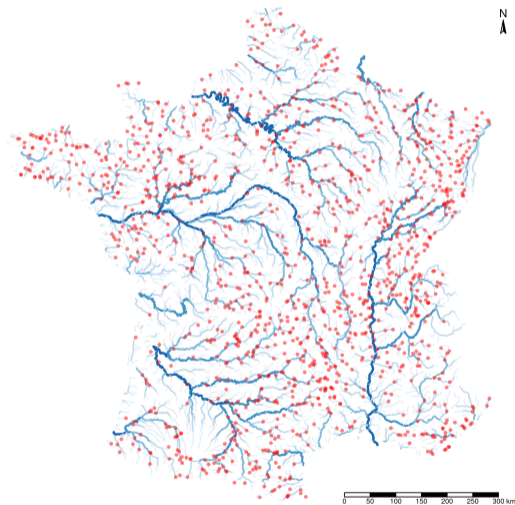
Traditional sequential calibration strategy [Lerat et al., 2012]



1. Upstream catchments are calibrated first
2. Simulated outflow is routed to downstream station (parameter C)
3. Contribution of downstream ICA (intermediary sub-catchment) is calibrated
4. Repeat steps 1,2,3 to the last outlet



Implementation over France



Spatial resolution 1305
gauged catchments, 250
km²/modeling units

Temporal resolution Daily
time step

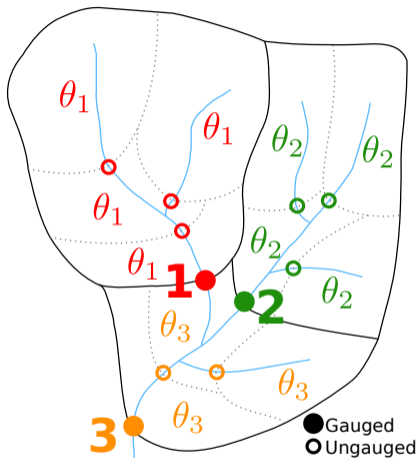
Period 1980–2010, split in 2
sub-periods



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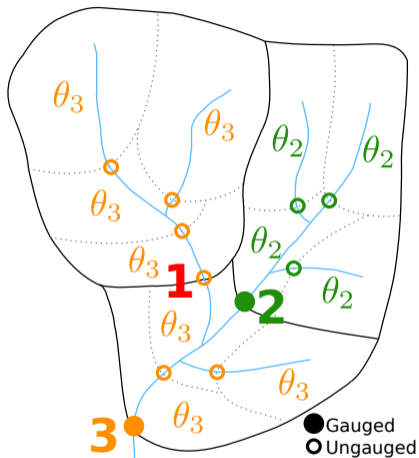
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A leave-one-out evaluation for ungauged catchments



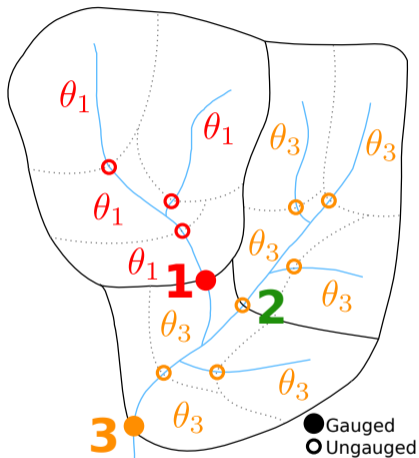
- Gauged stations considered ungauged one after another during calibration

A leave-one-out evaluation for ungauged catchments



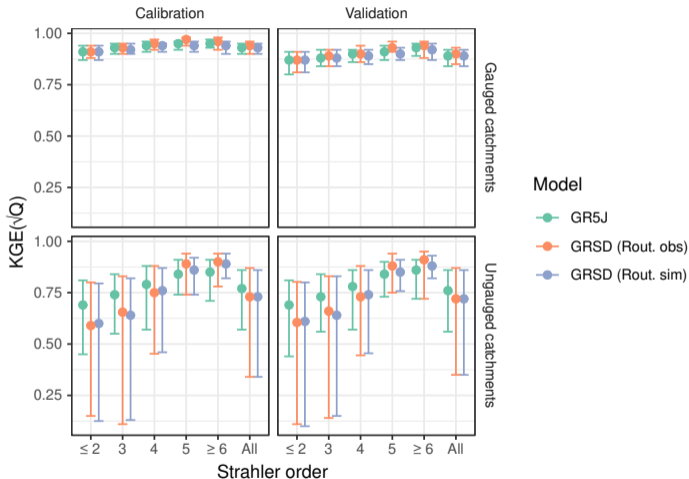
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A leave-one-out evaluation for ungauged catchments



- Gauged stations considered ungauged one after another during calibration

Performance of streamflow simulation



Gauged Robust perf.,
similar to GR5J

Ungauged Better with
GR5J, especially for
small catchments

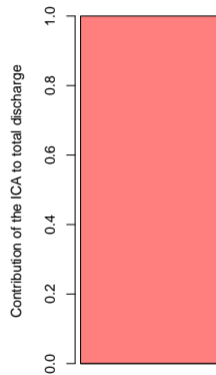
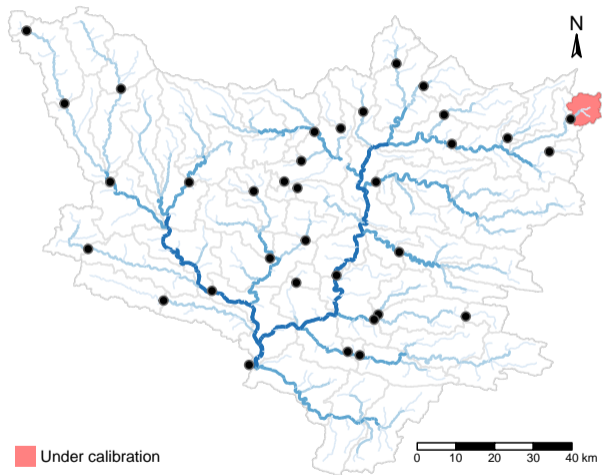
**Why poor performance at
ungauged locations?**



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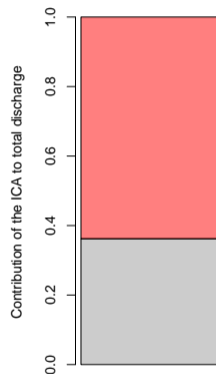
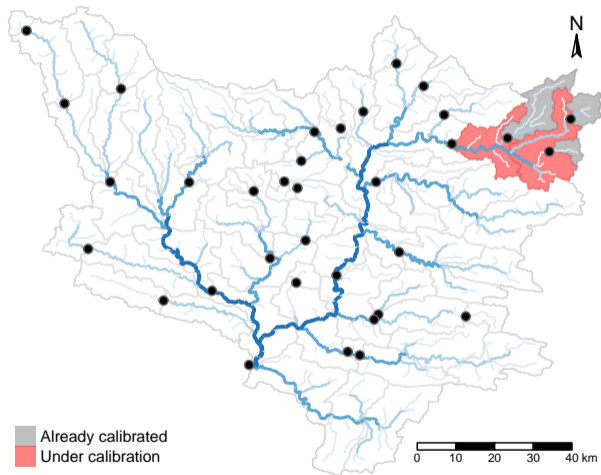
Sensitivity issues of the sequential calibration



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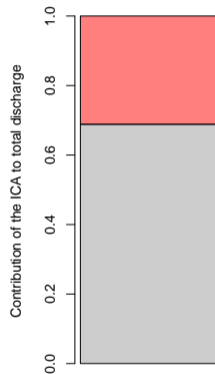
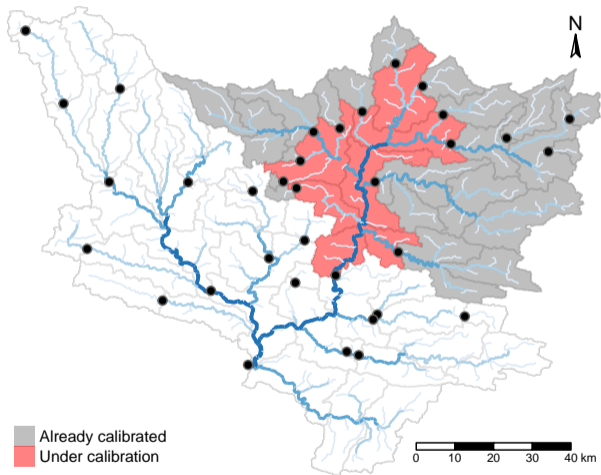
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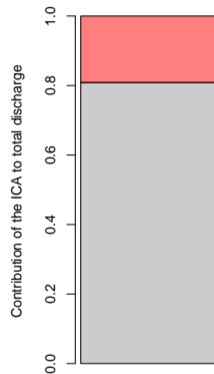
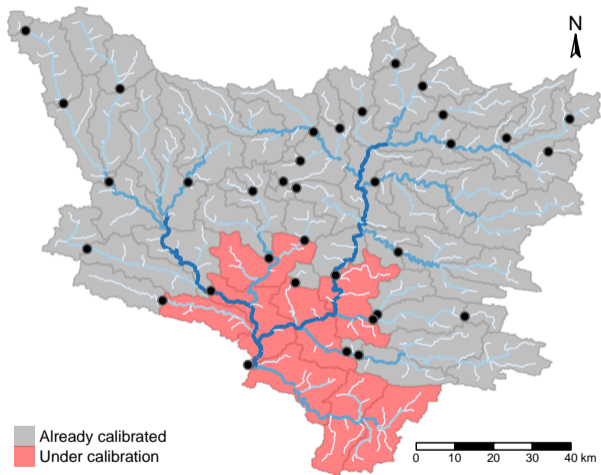
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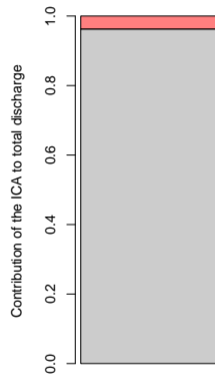
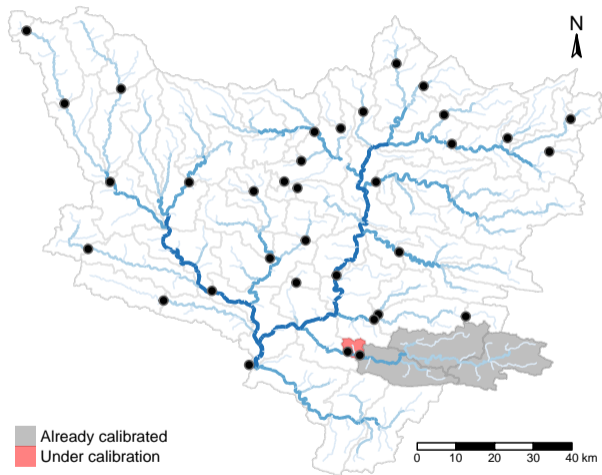
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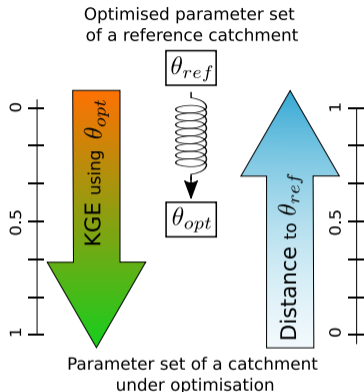
The concept idea of regularization

Adding information, and use both:

- 1. Observation of Q** Discharge at the outlet of the ICA
- 2. A priori on θ** on parameters' values

Update the objective function:

$$CRIT(\theta_{opt}) = (1 - k) \cdot KGE(\theta_{opt}) - k \cdot DIST(\theta_{ref}, \theta_{opt})$$



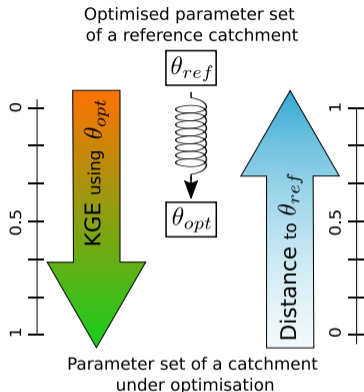
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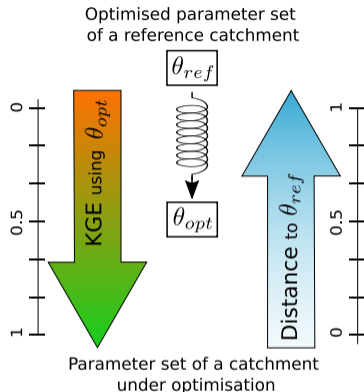
$$CRIT(\theta_{opt}) = (1 - k) \cdot KGE(\theta_{opt}) - k \cdot DIST(\theta_{ref}, \theta_{opt}) \cdot MAX(0, KGE(\theta_{ref}))$$



The concept idea of regularization

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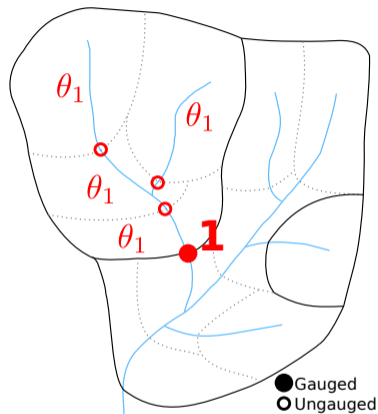


Update the objective function:

$$CRIT(\theta_{opt}) = (1 - k) \cdot KGE(\theta_{opt}) - k \cdot \sqrt{\sum_{i=1}^n \left(\frac{\theta_{ref}^i - \theta_{opt}^i}{\theta_{range}} \right)^2} \cdot MAX(0, KGE(\theta_{ref}))$$

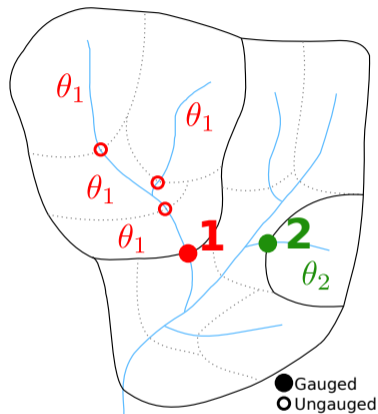


How to define the *a priori* and move away from it?



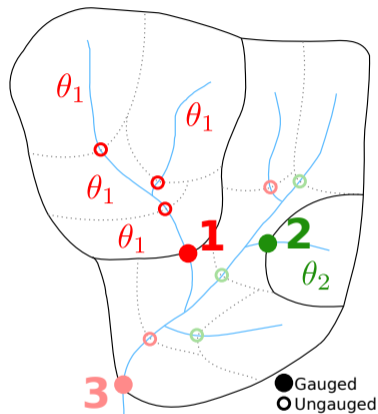
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1. Calibrate upstream catchments

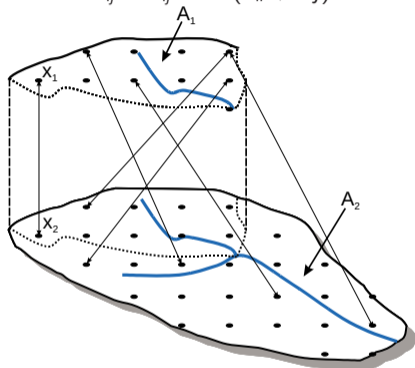
How to define the *a priori* and move away from it?



1. Calibrate upstream catchments
2. Associate each sub-catchments to a reference calibrated catchment

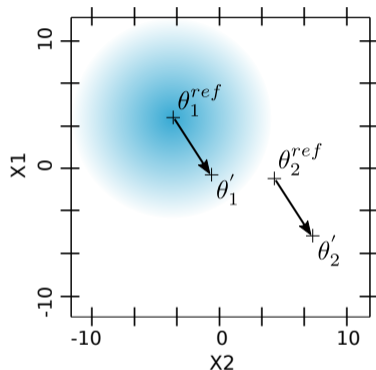
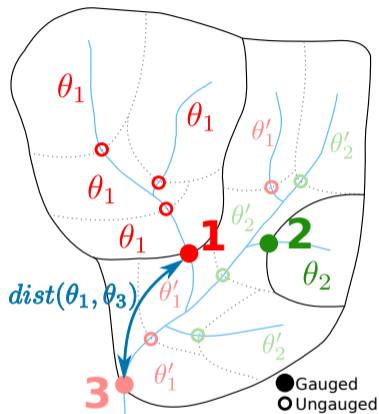
A rescaled Ghosh distance:

$$D_{ij} = G_{ij} - 0.5(G_{ii} + G_{jj})$$



[de Lavenne et al., 2016]

How to define the *a priori* and move away from it?

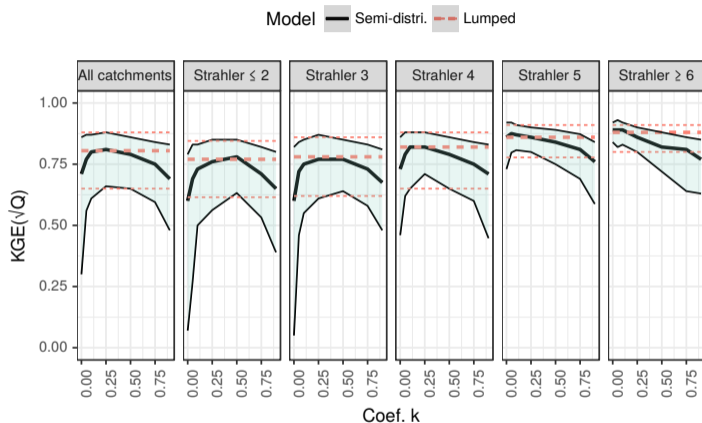


1. Calibrate upstream catchments
2. Associate each sub-catchments to a reference calibrated catchment
3. Calibrate a distance to their reference

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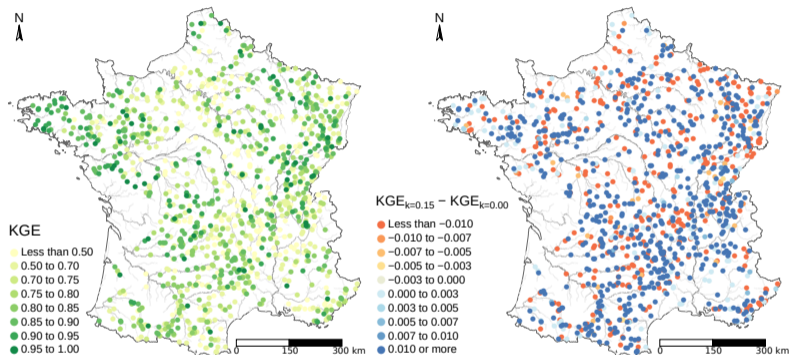
Impact of regularization on model performance at ungauged catchments



- Significant performance improvement on small catchments
- Best compromise of both information (Q_{obs} and $a priori$) depends on catchments size



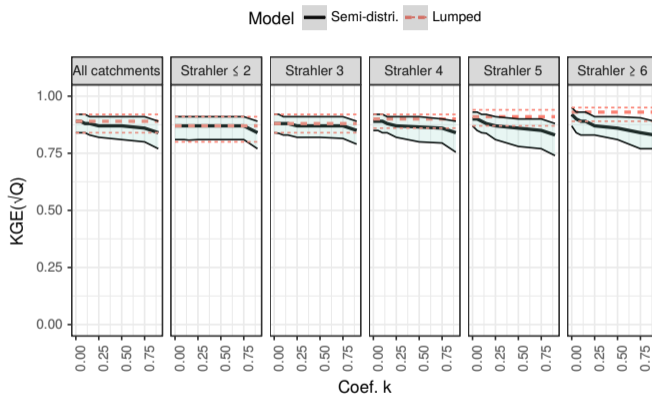
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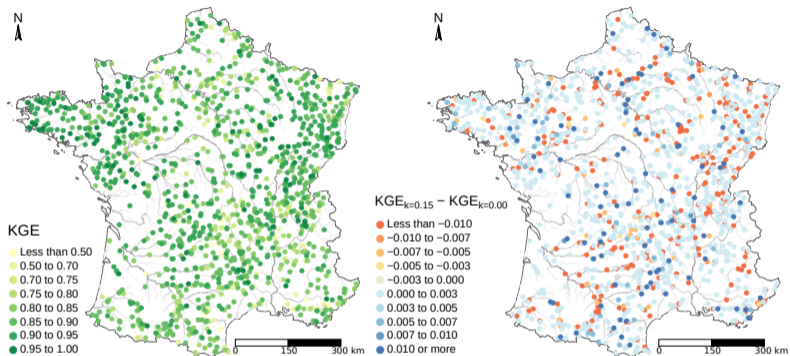
Impact of regularization on model performance at gauged catchments



- No significant impacts at gauged locations (median KGE = 0.90 during validation)



Impact of regularization on model performance at gauged catchments

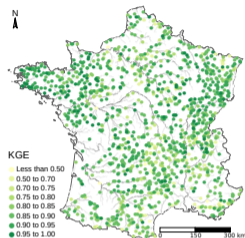
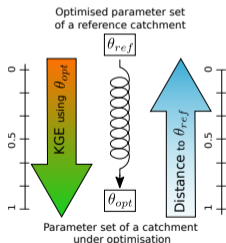


- No significant impacts at gauged locations (median KGE = 0.90 during validation)



Conclusion

- A semi-distributed GR model running at national scale
- The benefit of semi-distributed model is not straightforward
- High perf. at gauged sites may hide low perf. at ungauged sites



Regularization strategy:

- Improves performance at ungauged sites with little compromise at gauged sites
- Reduces the sensitivity issues by adding new information (*a priori*)
- Could be extended to any kinds of *a priori*



Thank you for your attention

For more details:



Water Resources Research

RESEARCH ARTICLE

10.1029/2018WR024266

Key Points:

- Sequential calibration without regularization yields low performance in small ungauged catchments
- Sequential calibration constrained by regularization strategy helps improving model regionalization
- Regularization benefits from a priori parameter values of neighboring catchments

A Regularization Approach to Improve the Sequential Calibration of a Semidistributed Hydrological Model

A. de Lavenne^{1,2}, V. Andréassian¹, G. Thirel¹, M.-H. Ramos¹, and C. Perrin¹

¹HYCAR Research Unit, Irstea, Antony, France, ²Swedish Meteorological and Hydrological Institute (SMHI), Norrköping, Sweden




Abstract In semidistributed hydrological modeling, sequential calibration usually refers to the calibration of a model by considering not only the flows observed at the outlet of a catchment but also the different gauging points inside the catchment from upstream to downstream. While sequential calibration



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References

-  de Lavenne, A., V. Andréassian, G. Thirel, M.-H. Ramos, and C. Perrin (2019). “A Regularization Approach to Improve the Sequential Calibration of a Semidistributed Hydrological Model”. In: *Water Resources Research* 55. ISSN: 0043-1397. DOI: 10.1029/2018WR024266.
-  de Lavenne, A., G. Thirel, V. Andréassian, C. Perrin, and M.-H. Ramos (May 2016). “Spatial variability of the parameters of a semi-distributed hydrological model”. In: *7th International Water Resources Management Conference of ICWRS*. Oral presentation + PIAHS paper. Bochum, Germany.
-  Lerat, J., V. Andréassian, C. Perrin, J. Vaze, J. M. Perraud, P. Ribstein, and C. Loumagne (2012). “Do internal flow measurements improve the calibration of rainfall-runoff models?” In: *Water Resour. Res.* 48.2, W02511. ISSN: 1944-7973. DOI: 10.1029/2010WR010179.

