

# Parameters identifiability of a semi-distributed hydrological model

Model structure evaluation and implementation all over France

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20th May 2016

Irstea, Antony, France

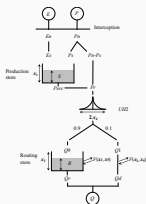


# Introduction

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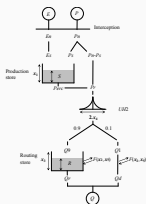
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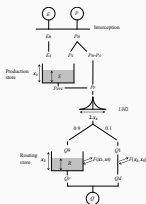


## identifiability

property of the parameters to be estimated from the data

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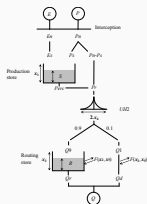
property of the parameters to be estimated from the data

Usually, calibration of:

- Independent periods
- Contrasting climatic periods
- Several consecutive periods

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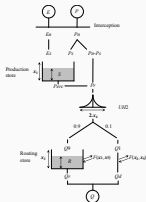
- Independent periods
- Contrasting climatic periods
- Several consecutive periods

and related to:

- Climatic trends
- Modification of catchments processes
- Model structure ...

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GRSD : A GR semi-distributed model. Applied at a country scale.



## identifiability

property of the parameters to be estimated from the data

**Identifiability in a semi-distributed model vs lumped model?**  
**What can we do after this evaluation?**

## **GRSD: a semi-distributed model**

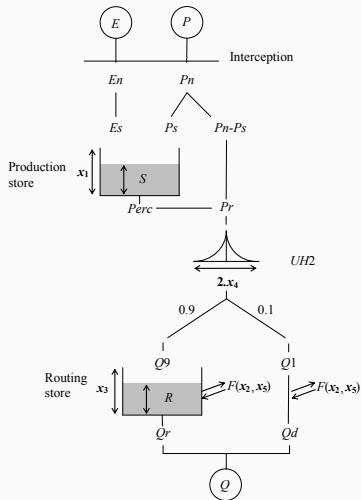
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# The GR5J model

A conceptual model with 5 parameters:

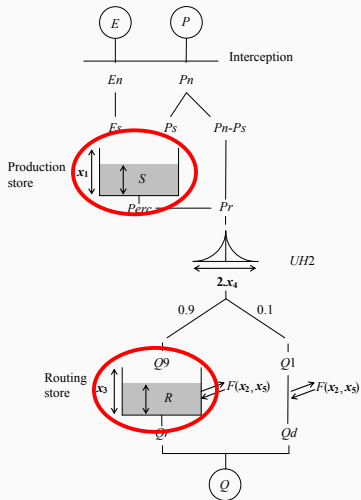
- 2 buckets  
(parameter  $X1$  and  $X3$ )



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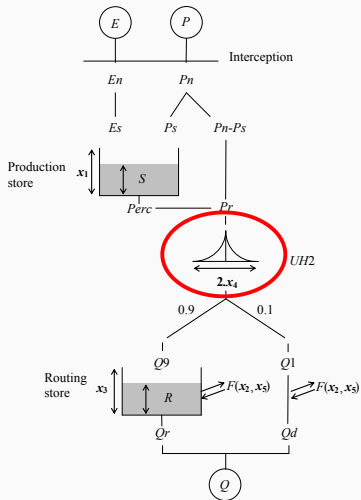
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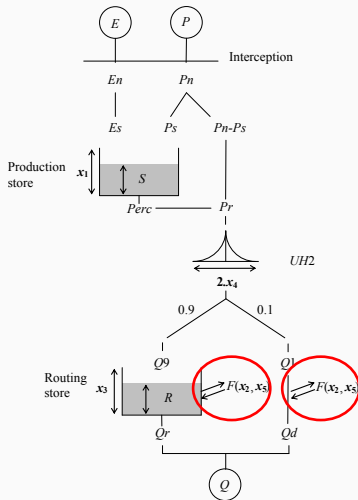
- 2 buckets  
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(parameter  $X4$ )



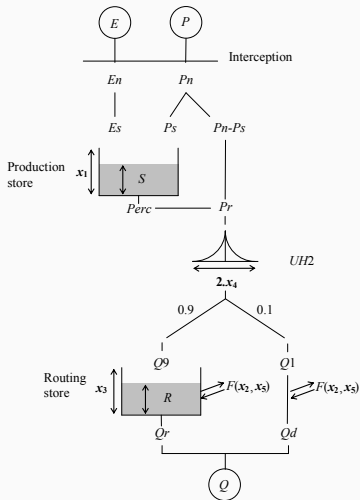
# The GR5J model

A conceptual model with 5 parameters:

- 2 buckets (parameter X1 and X3)
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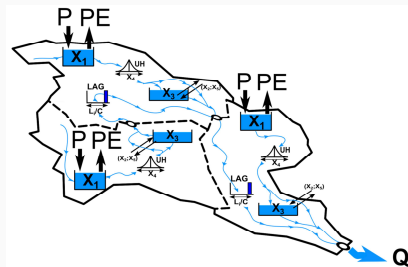


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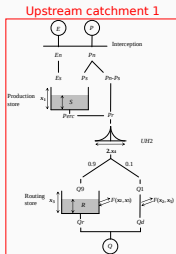
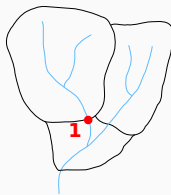
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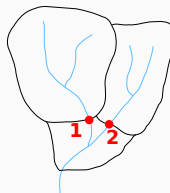
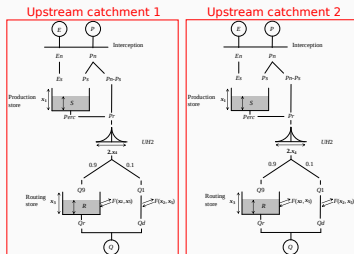
(Lobligeois et al., 2014)

# A sequential calibration



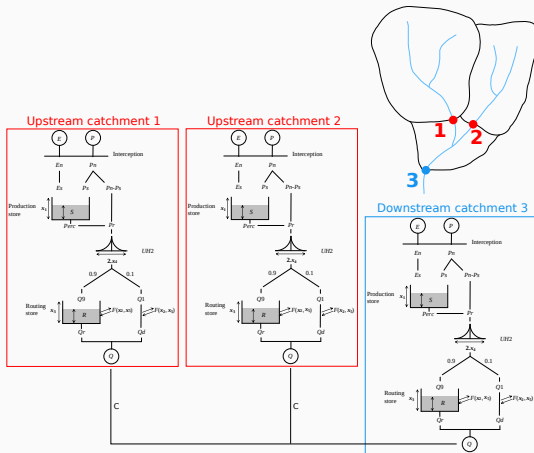
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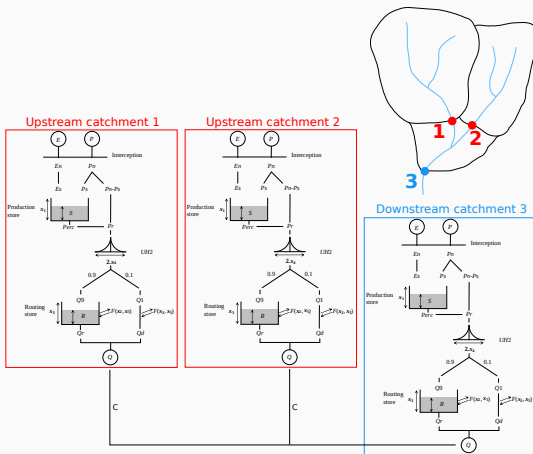
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1. Upstream catchments are calibrated first
2. Simulated outflow is routed to downstream station (parameter C)

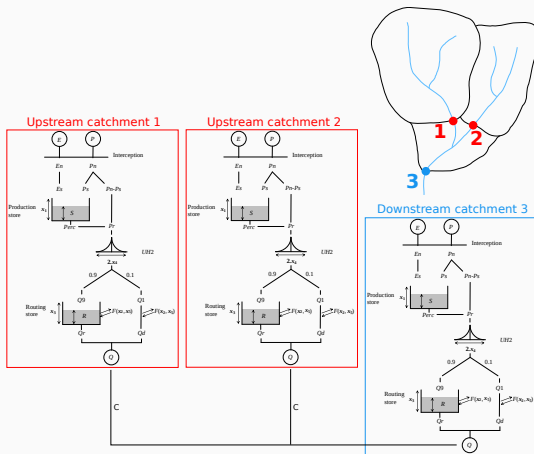


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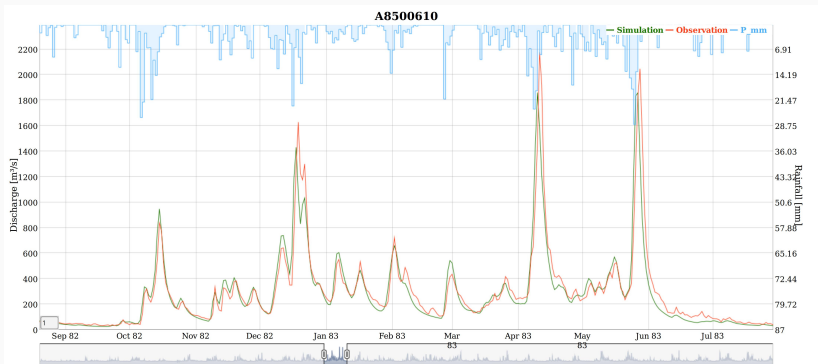
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3. Contribution of downstream intermediary sub-catchment is calibrated

# A sequential calibration



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

# Goodness of fit criteria



$$KGE_m(S, O) = 0.5 \cdot \left( KGE(S, O) + KGE\left(\frac{1}{S + \epsilon}, \frac{1}{O + \epsilon}\right) \right) \quad (1)$$

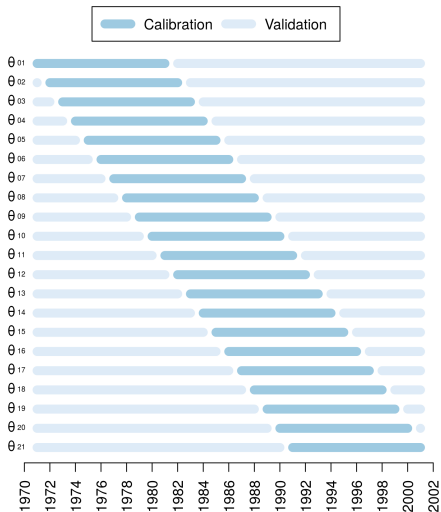
where  $O$  and  $S$  are the observed and simulated discharges

# Parameter identifiability

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# Rolling calibration period methodology

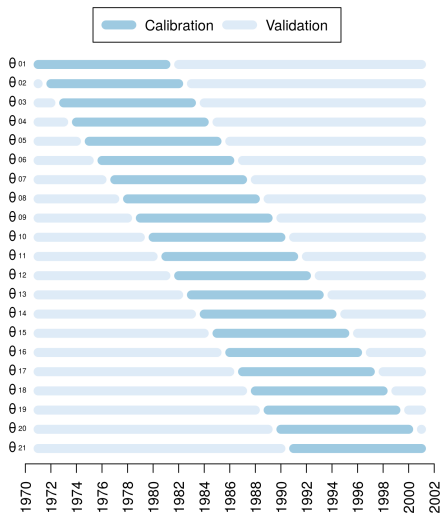
A benchmark for identifiability of parameters:



21 parameter sets  
 $\theta_i^j$  can be  
identified for each  
catchment  $j$

# Rolling calibration period methodology

A benchmark for identifiability of parameters:



**Temporal  
coefficient of  
variation**

of parameter  $X$   
between  
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$$CV(X) = \frac{\sigma(X_i)}{\bar{X}_i}$$

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# Moselle, Sarre and Rhine

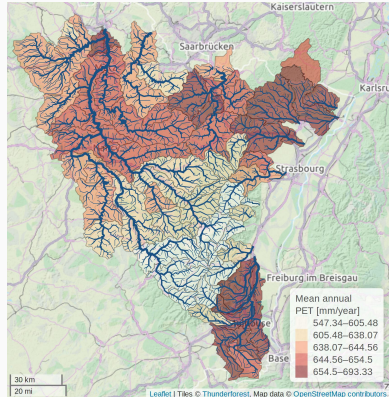
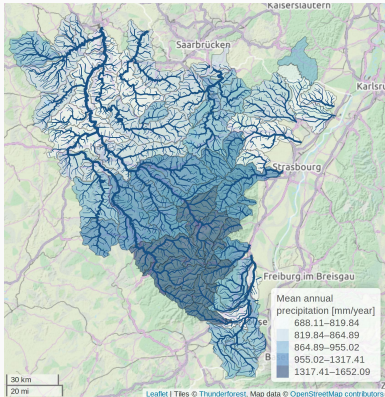




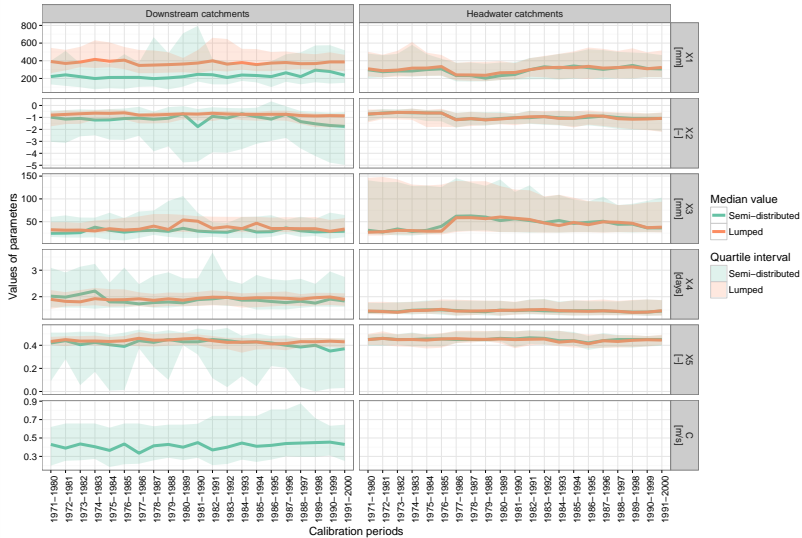
# Moselle, Sarre and Rhine



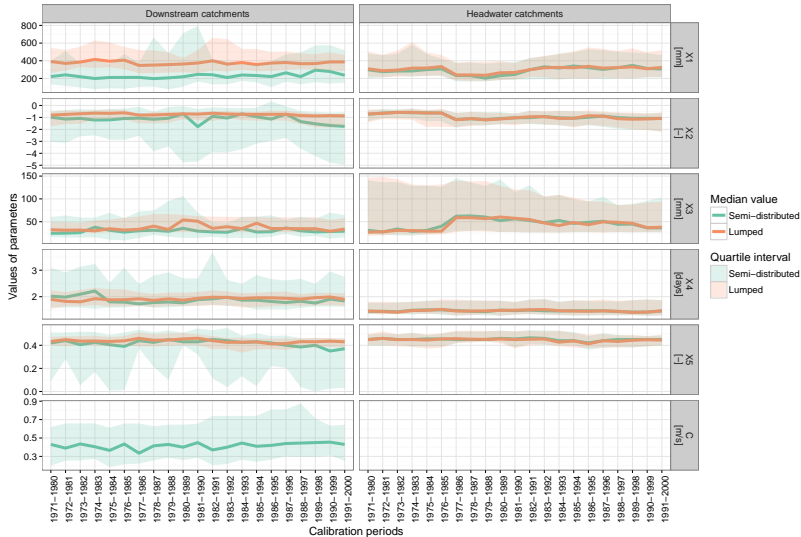
64 sub-catchments  
Total area: 4340 km<sup>2</sup>



# Parameters value

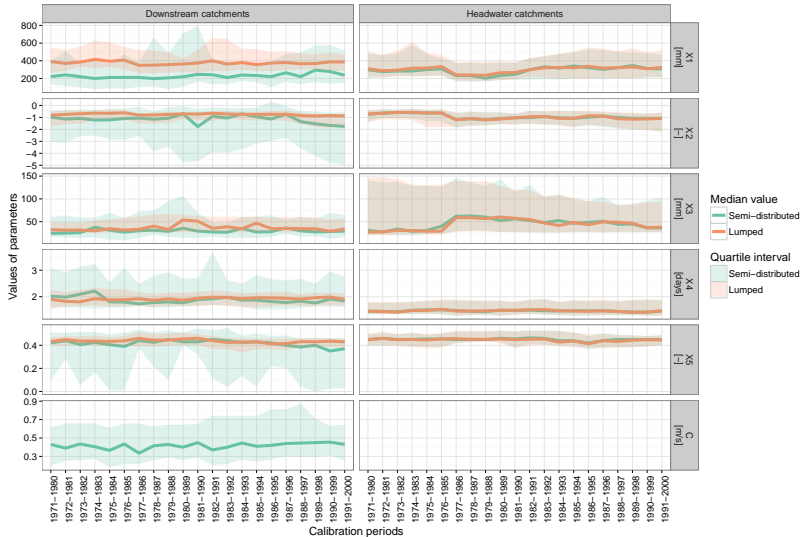


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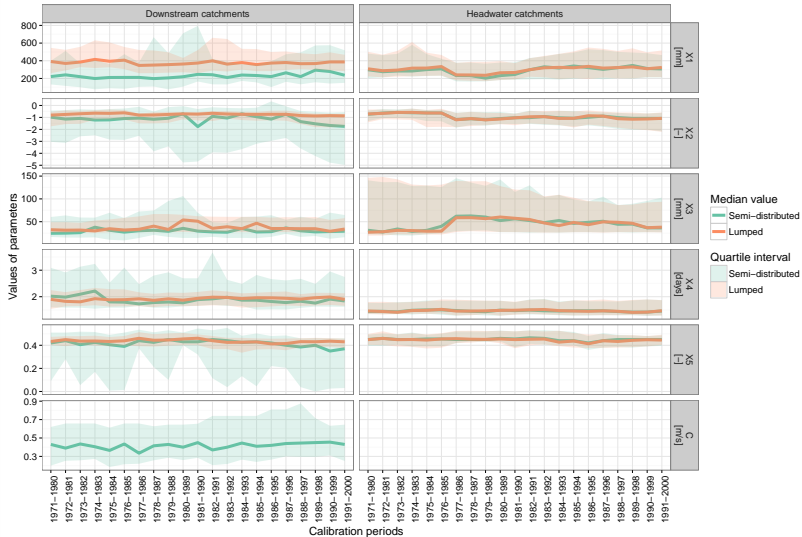
No temporal trends of parameter

# Parameters value



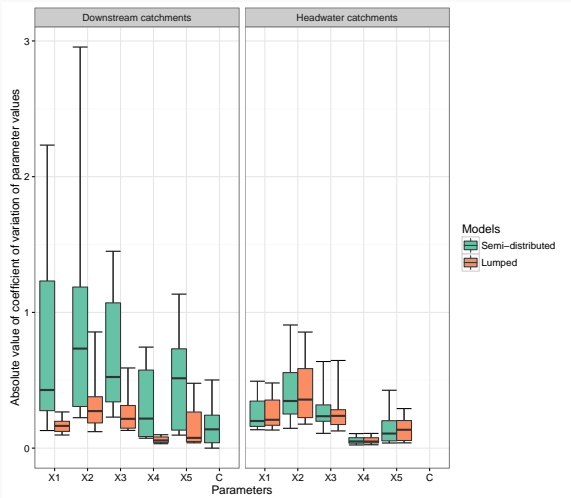
Headwater catchments = same results between models

# Parameters value



Relative stability overall but what about inside each catchment?

# Temporal variability

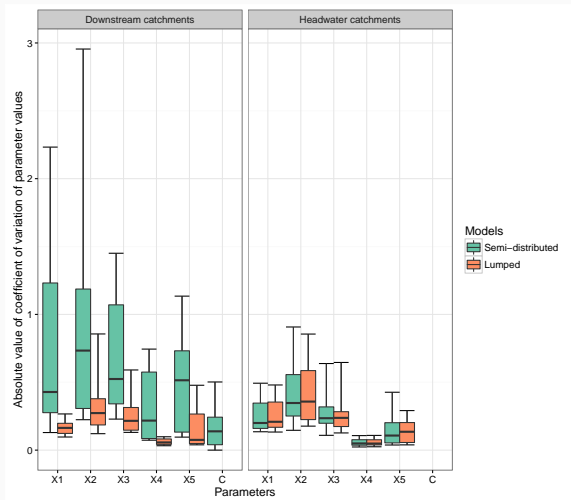


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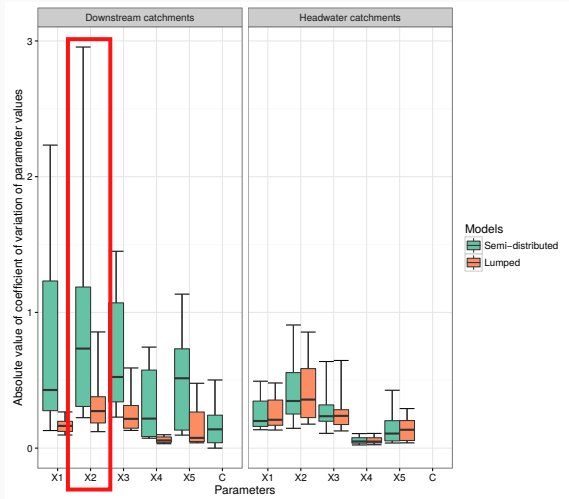
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Greater variability with GRSD at downstream catchments

# Temporal variability



**Temporal  
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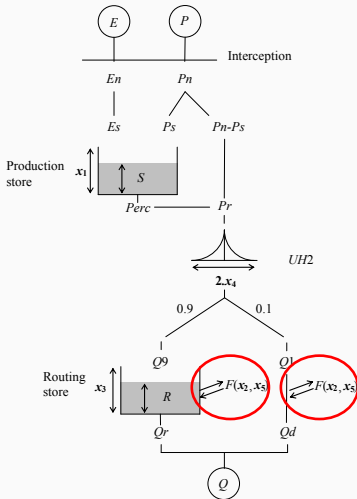
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X2 the more unstable parameter (related to IGF)



# Temporal variability



## Temporal coefficient of variation

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$X_2$  the more unstable parameter (related to IGF)

## Temporal variability: what does that spatially mean?

## Temporal variability: What should we understand?

THE FACTS:

**Parameters identifiability** Lumped > Semi-distributed model

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**Model's component** Intercatchment Groundwater Flows (IGF)

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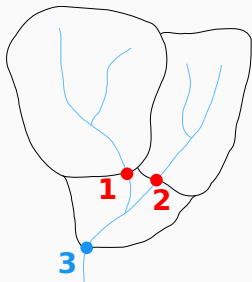
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**Observation issue** Sequential calibration  
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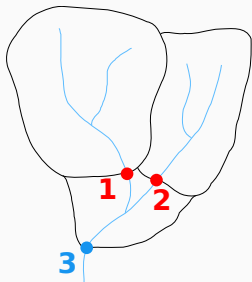
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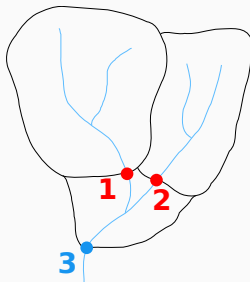
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## THE POSSIBLE REASONS:

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**Model structure** Sensibility issue at  
downstream station?

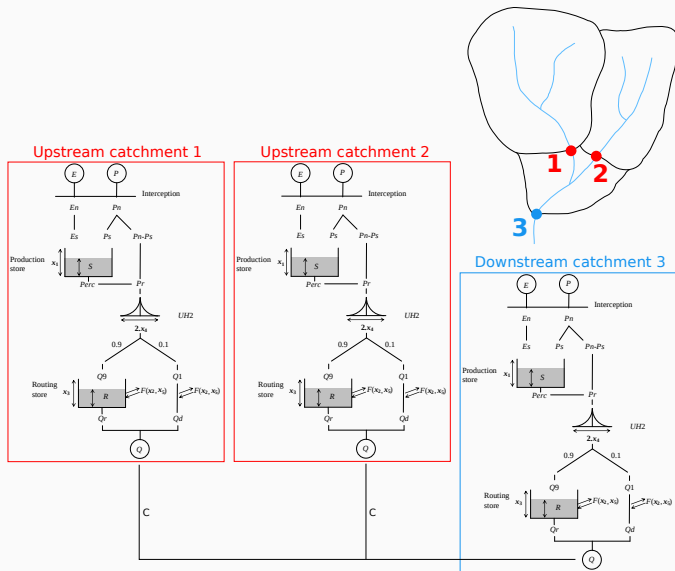


# Rewriting IGF modelling

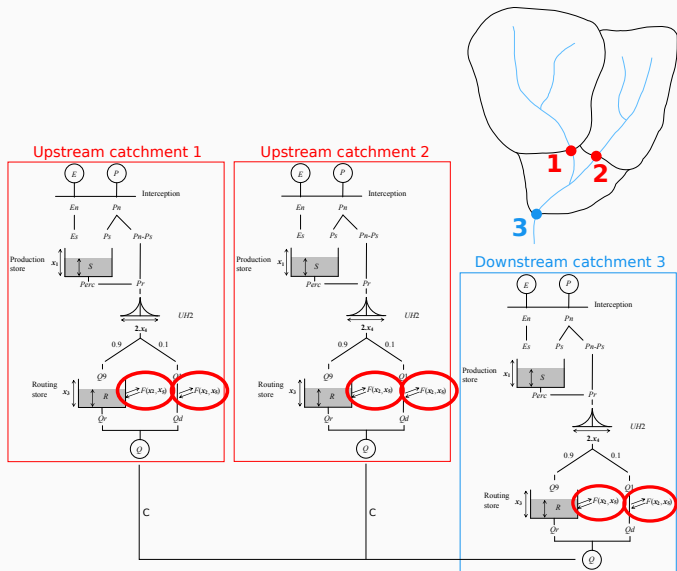
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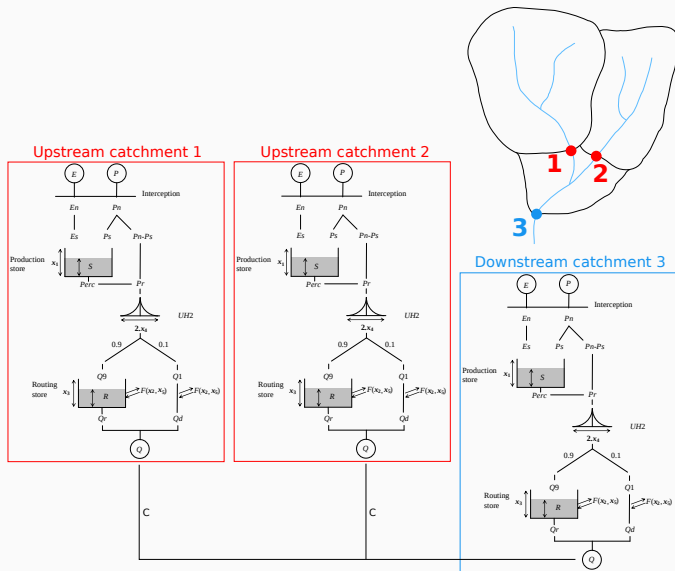
# The original model structure



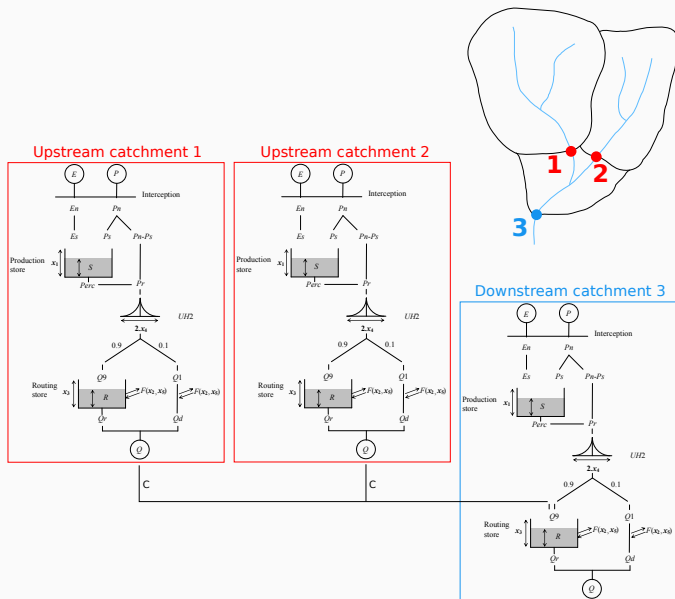
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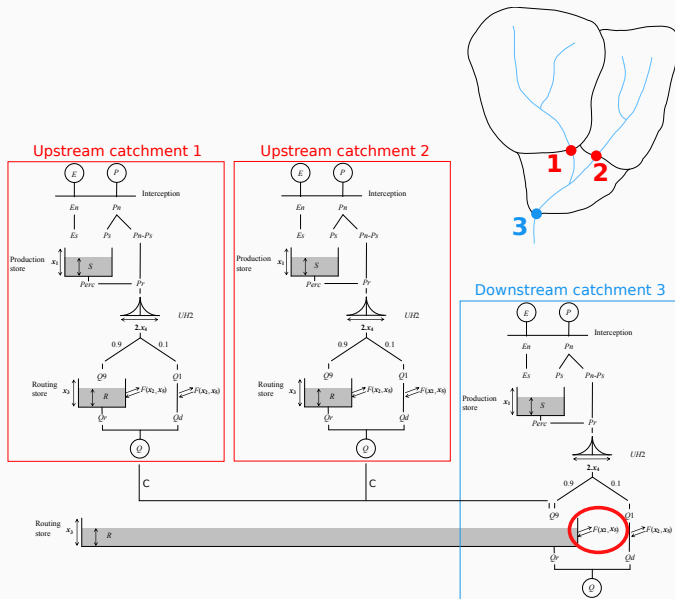
# A second model structure



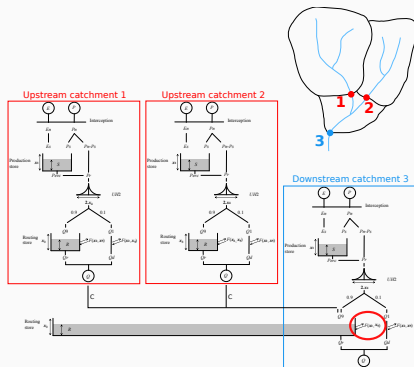
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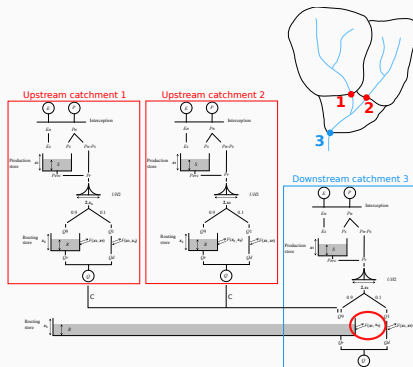


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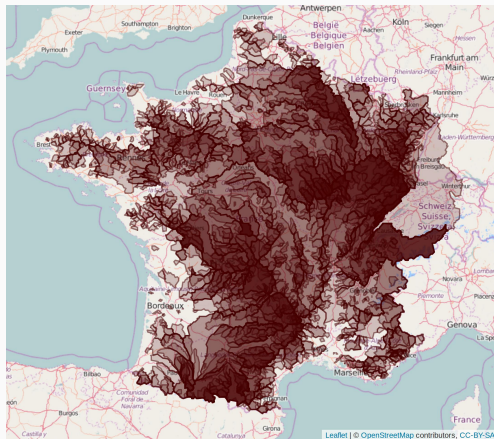
- Upstream water can now be exchanged with groundwater

# A second model structure



- Upstream water can now be exchanged with groundwater
- We have a reservoir common to all catchments that can help to reach spatial consistency

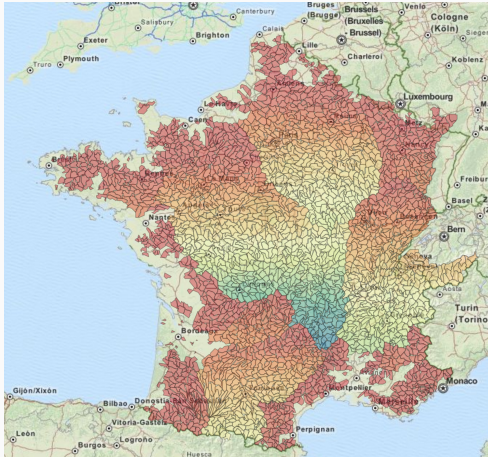
# A database all over France



1980-2010: 2037 catchments not influenced, with  $\geq 5$  years ( $\leq 10\%$  of missing data)



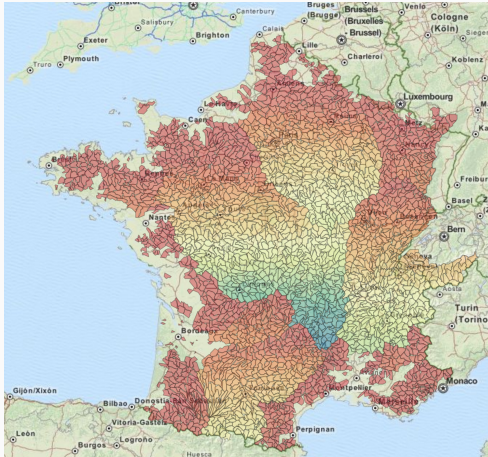
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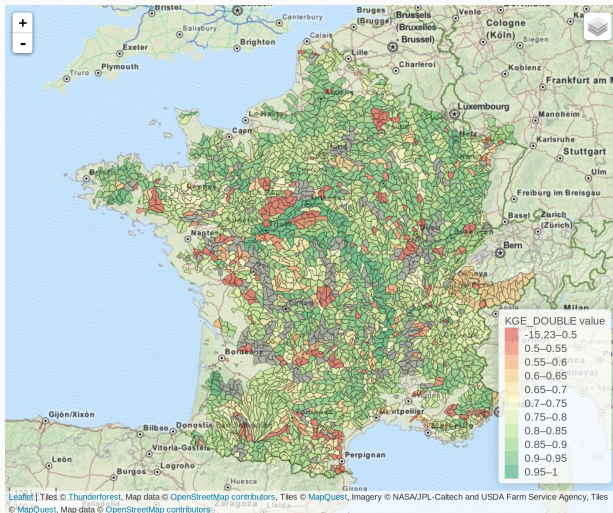
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Ungauged sub-catchment use parameters of downstream gauged catchment

# Performance results

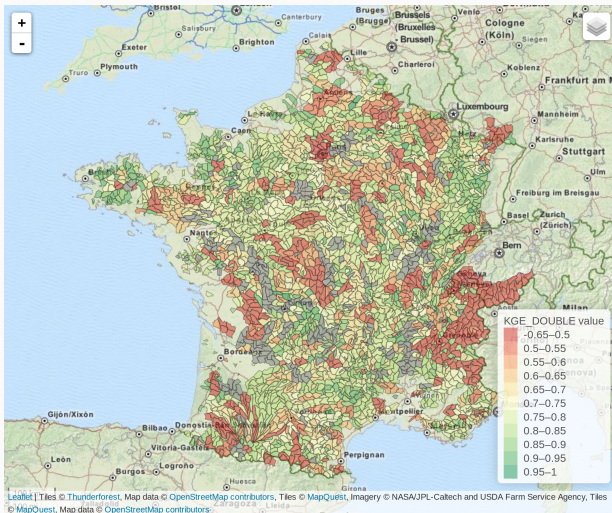
$$0.5 ( KGE(Q) + KGE(1/Q) )$$

Semi-distributed GR5J v1.0 (Calibration 1980-1994)



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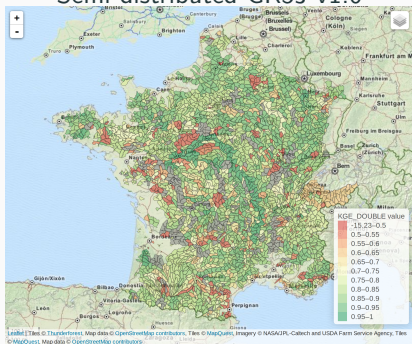
0.5 ( KGE(Q) + KGE(1/Q) )  
Semi-distributed GR5J v2.0 (Calibration 1980-1994)



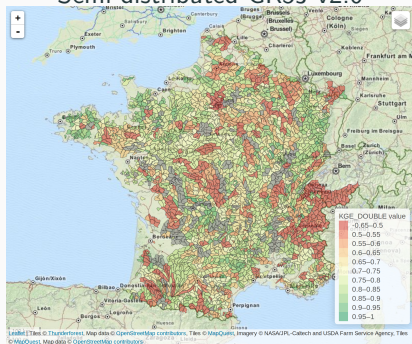
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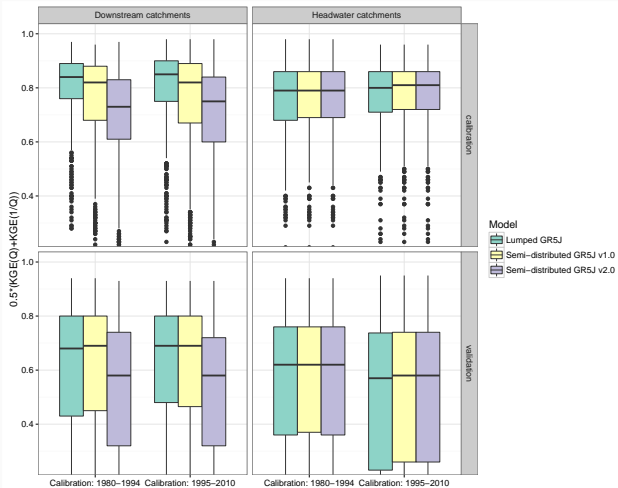
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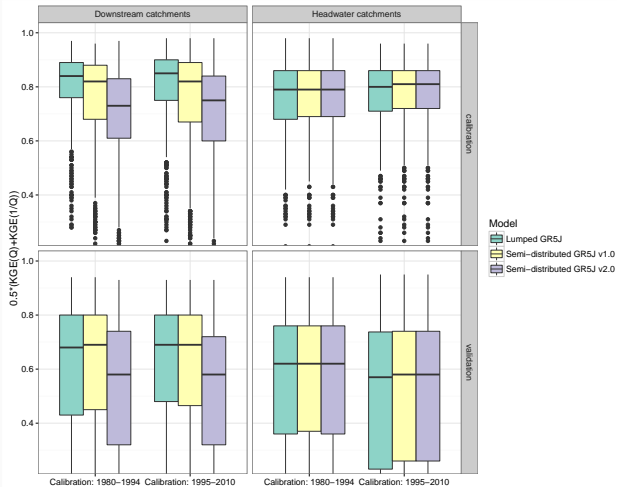
## Semi-distributed GR5J v2.0



# Performance results

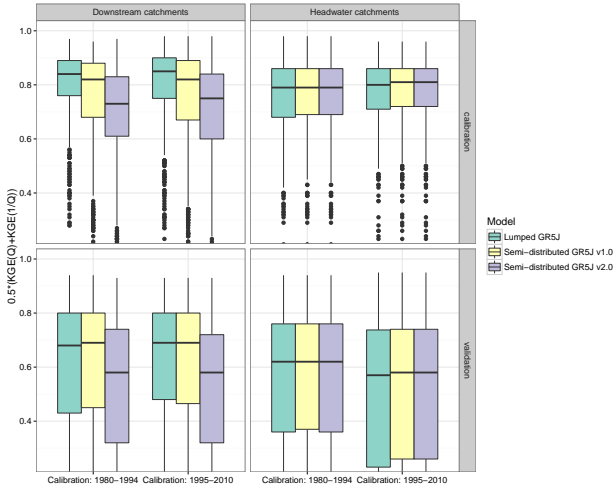


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Perf. semi-distributed  
 $\approx$  lumped model

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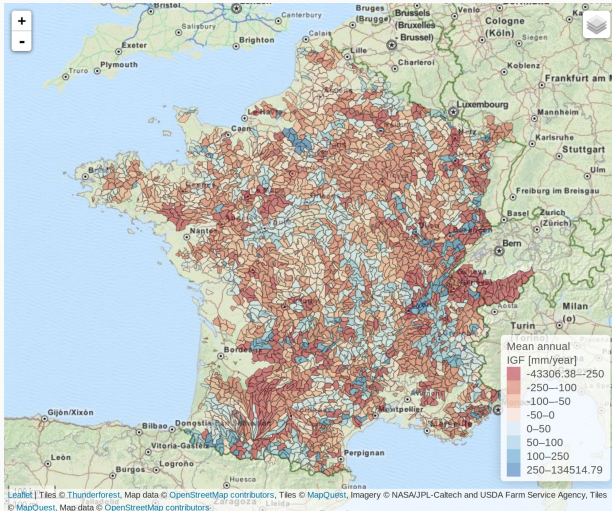
Perf. semi-distributed  
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Less efficient new  
semi-distributed  
structure



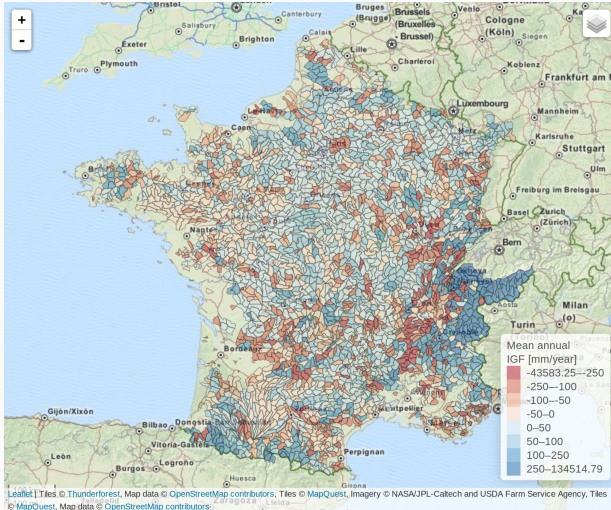
# Spatial coherence of IGF

Inter-catchment groundwater flow (IGF) in mm/year  
Semi-distributed GR5J v1.0 (Calibration 1980-1994)



# Spatial coherence of IGF

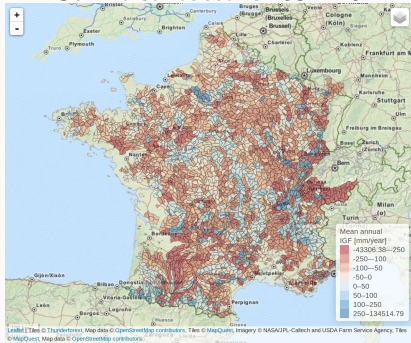
Inter-catchment groundwater flow (IGF) in mm/year  
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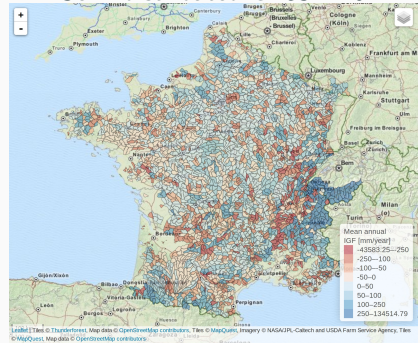
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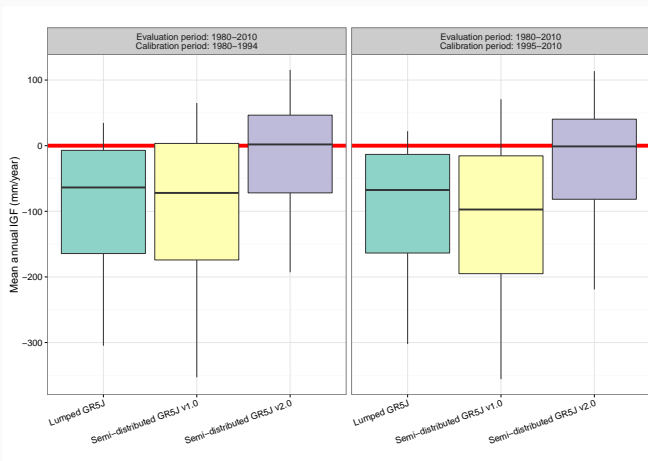
Semi-distributed GR5J v1.0



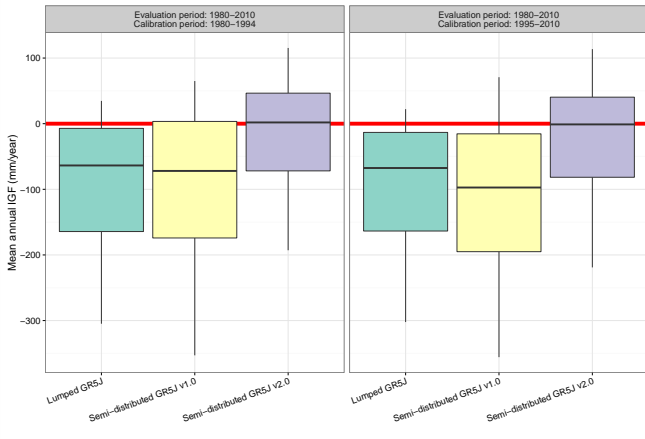
Semi-distributed GR5J v2.0



# Spatial coherence of IGF: Catchment distribution

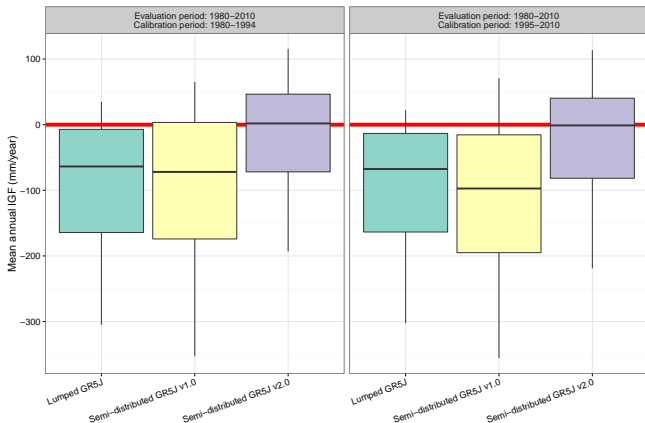


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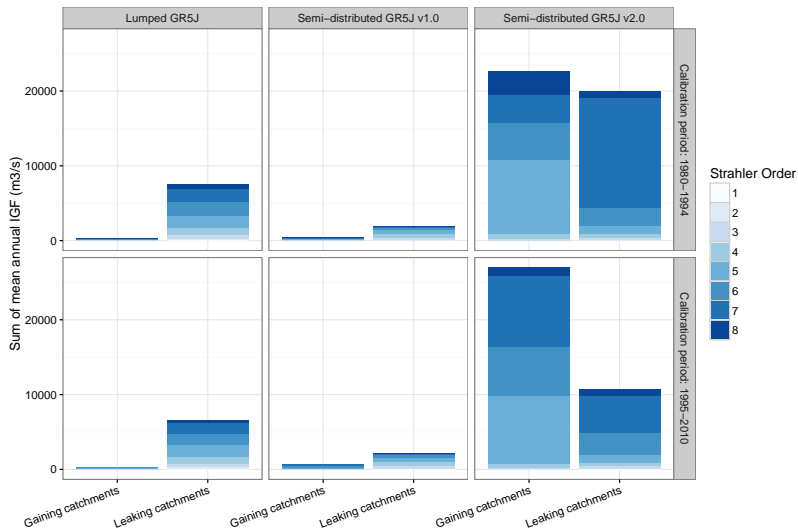
- Lumped model and semi-distributed model v1.0  
→ almost all catchments are leaking

# Spatial coherence of IGF: Catchment distribution



- Lumped model and semi-distributed model v1.0  
→ almost all catchments are leaking
- Semi-distributed model v2.0  
→ IGF vary around 0 (some are leaking, some are gaining)

# Spatial coherence of IGF: water balance



## Conclusion

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A new semi-distributed model able to run over France  
based on GR5J lumped model

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**New challenge to reach spatial consistency of the modelling**

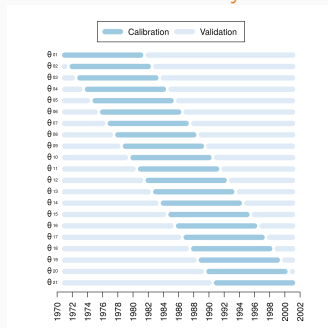
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Model evaluation from:

Parameter  
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# Conclusion

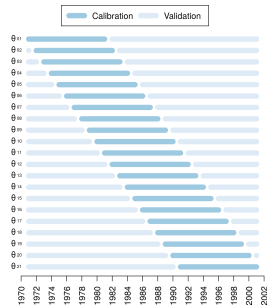
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Model structure  
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**New challenge to reach spatial consistency of the modelling**

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Model structure  
inconsistency

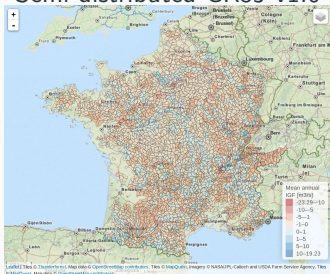


Parameter  
identifiability



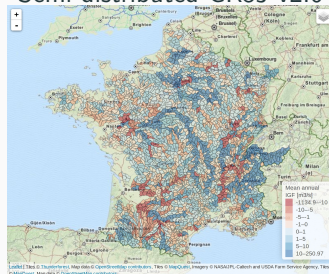
Spatial inconsistency  
of internal fluxes

Semi-distributed GR5J v1.0



IGF

Semi-distributed GR5J v2.0



# Conclusion

A new semi-distributed model able to run over France  
based on GR5J lumped model

**New challenge to reach spatial consistency of the modelling**

Model evaluation from:

Model structure  
inconsistency

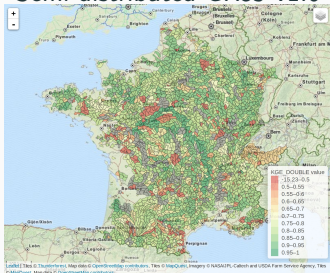


Parameter  
identifiability



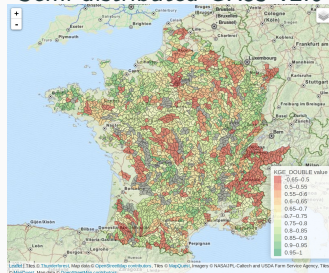
Spatial inconsistency  
of internal fluxes

Semi-distributed GR5J v1.0



$KGE_m$   
Performance

Semi-distributed GR5J v2.0



# Parameters identifiability of a semi-distributed hydrological model

Model structure evaluation and implementation all over France

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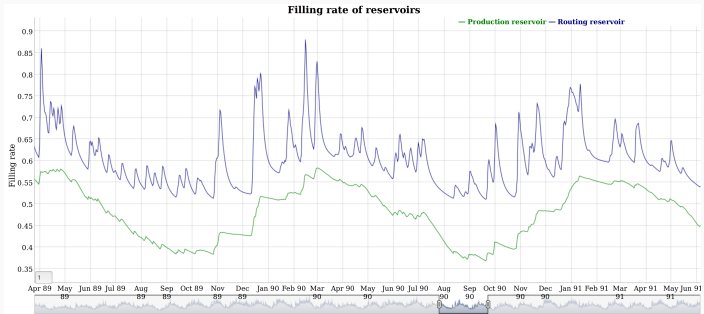
A. de Lavenne, G. Thirel, V. Andréassian, C. Perrin, M.-H. Ramos

20th May 2016

Irstea, Antony, France

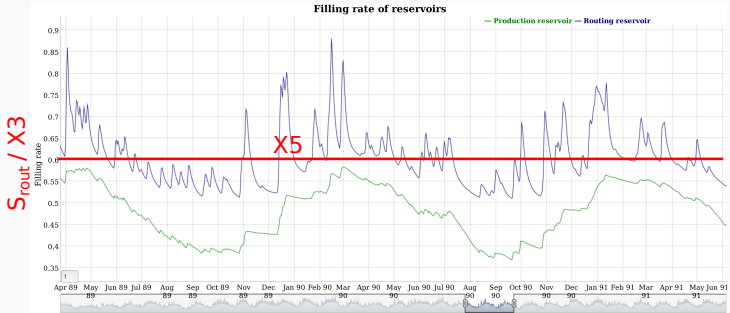


# The GR5J model: Intercatchment Groundwater Flow (IGF)





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