Présentation du simulateur de pluies horaires de bassin

SCHYPRE : Simulation Continue d'HYdrogrammes pour la PREdétermination

FRANCE 2030

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

INRAE

SCHYPRE : Simulation Continue d'HYdrogrammes pour la PREdétermination

➢ **Objectif** : simuler de très longues chroniques de débits statistiquement équivalentes aux observations, utilisables pour faire de l'hydraulique (dimensionnement d'ouvrages, PPRi, ...).

1. Calages
2. Simulations des variables climatiques
3. Simulation des débits par le modèle hydrologique

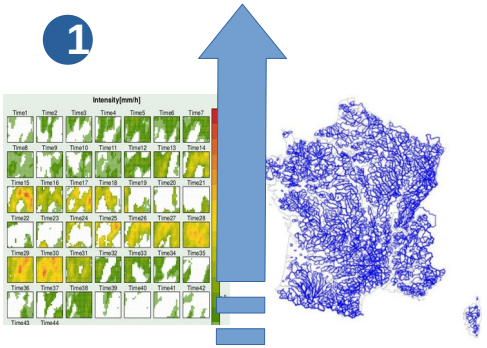
Approche globale
(spatialement uniforme)

OBSERVATIONS

- **Pluie de bassin (mm/h)**
- Pourcentage de surface mouillée
- Coefficient de variation de la pluie

- ETP de bassin
- Température de bassin

1



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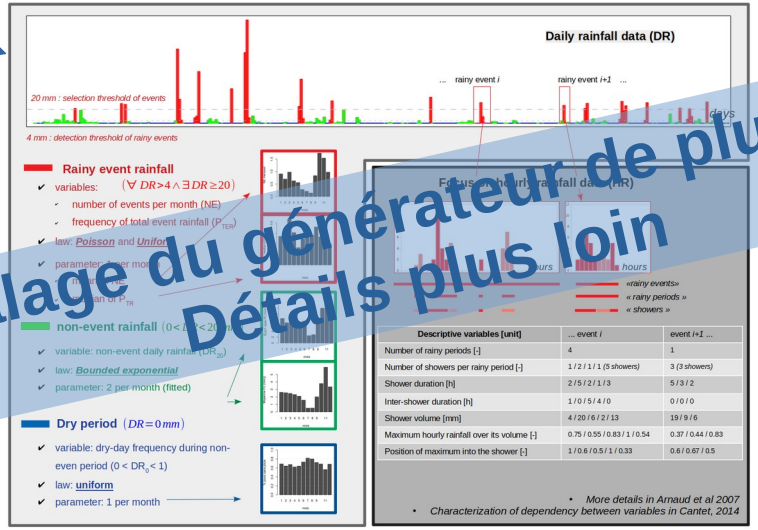
- Données spatiales SAFRAN

- Chroniques de débits (calage des modèles hydrologiques)



Calage du générateur de pluies : Détails plus loin

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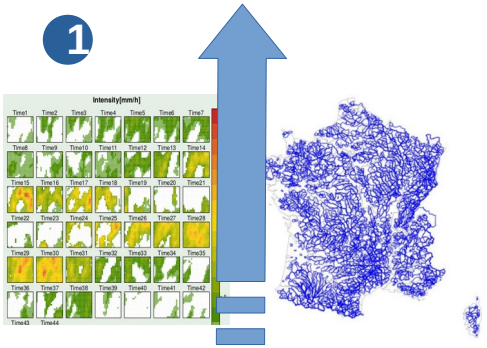

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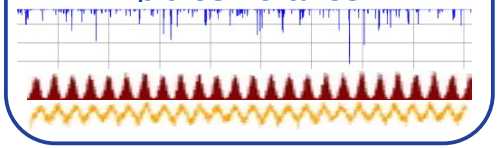
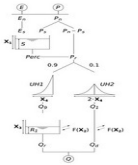
Générateur continu de pluies horaires



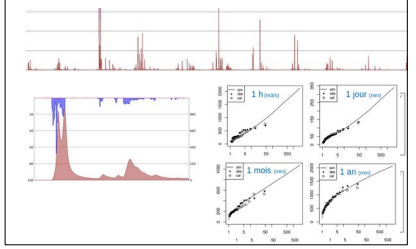
GR4H + cemaneige

(modèle global)



3

Longues chroniques de pluies et débits simulés



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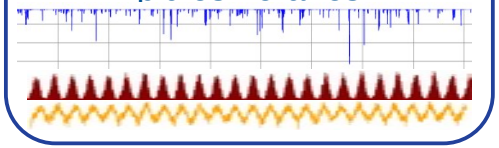

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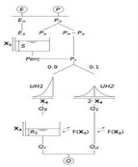

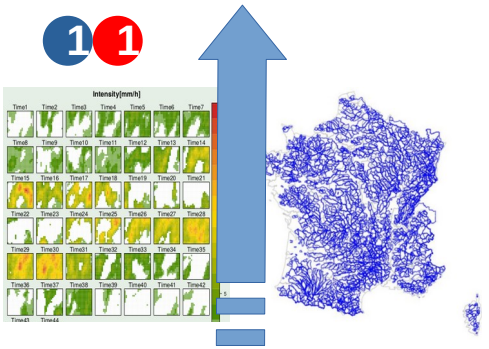

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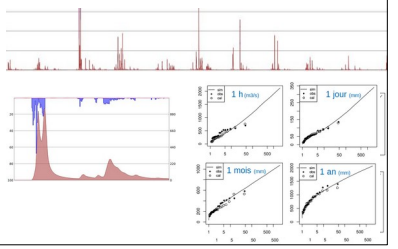

Approche spatiale

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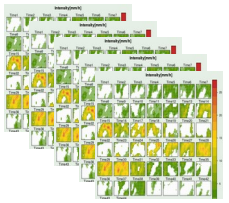
GRAFFAS

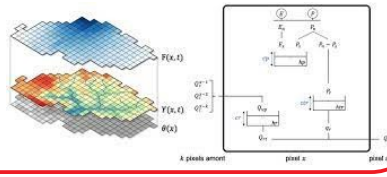
Désagrégation spatiale de la pluie

Champs de pluies (cohérence temporelle et spatiale)

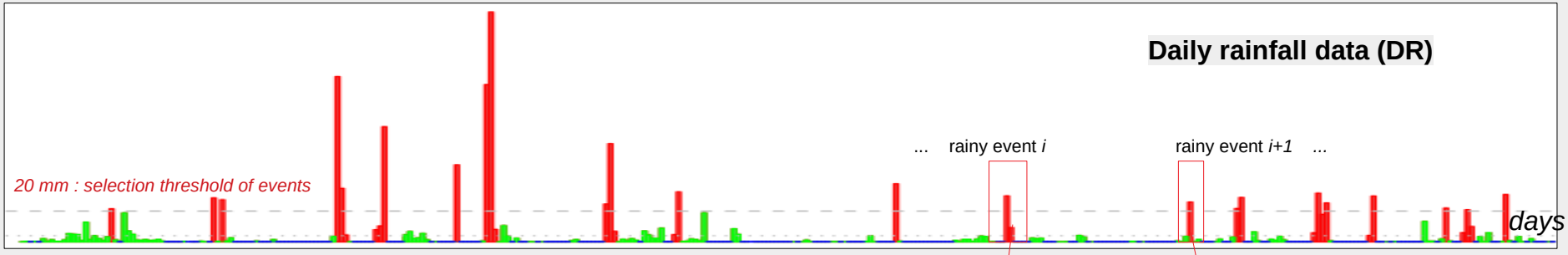


SMASH

(modèle distribué)



SCHYPRE : Analyse descriptives des séries observées



Rainy event rainfall

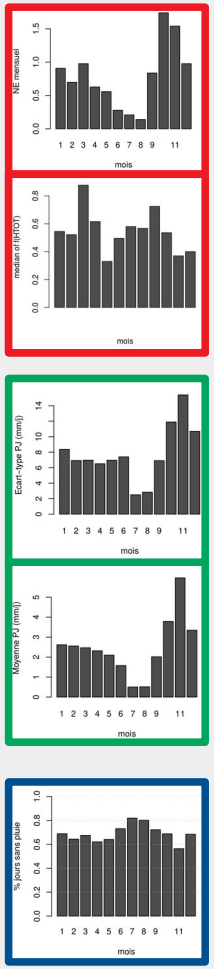
- ✔ variables: $(\forall\, DR>4 \wedge \exists\, DR \geq 20)$
  - ✔ number of events per month (NE)
  - ✔ frequency of total event rainfall (P_{TER})
- ✔ law: ***Poisson*** and ***Uniform***
- ✔ parameter: 1 per month
  - ✔ mean of NE
  - ✔ median of P_{TR}

non-event rainfall $(0< DR<20\ mm)$

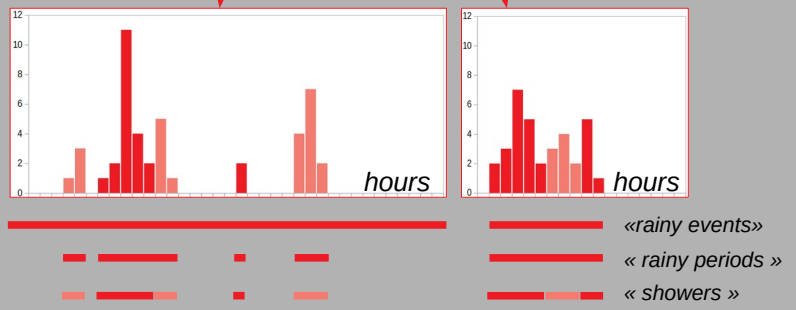
- ✔ variable: non-event daily rainfall (DR_{20})
- ✔ law: ***Bounded exponential***
- ✔ parameter: 2 per month (fitted)

Dry period $(DR=0\ mm)$

- ✔ variable: dry-day frequency during non-even period ($0 < DR_0 < 1$)
- ✔ law: **uniform**
- ✔ parameter: 1 per month



Focus on hourly rainfall data (HR)



Descriptive variables [unit]	... event *i*	event *i+1* ...
Number of rainy periods [-]	4	1
Number of showers per rainy period [-]	1 / 2 / 1 / 1 *(5 showers)*	3 *(3 showers)*
Shower duration [h]	2 / 5 / 2 / 1 / 3	5 / 3 / 2
Inter-shower duration [h]	1 / 0 / 5 / 4 / 0	0 / 0 / 0
Shower volume [mm]	4 / 20 / 6 / 2 / 13	19 / 9 / 6
Maximum hourly rainfall over its volume [-]	0.75 / 0.55 / 0.83 / 1 / 0.54	0.37 / 0.44 / 0.83
Position of maximum into the shower [-]	1 / 0.6 / 0.5 / 1 / 0.33	0.6 / 0.67 / 0.5

- *More details in Arnaud et al 2007*
- *Characterization of dependency between variables in Cantet, 2014*

SCHYPRE : Loi de probabilité pour chaque variable descriptive

Variable	Description of the variable	Unit	Probability law	Parameter estimation [1]	Estimated for ...
Variables required to simulate rainy events					
NE	Number of rainy event per month	-	Poisson	$\theta = \mu$	**12 months**
NP	Number of rainy period per rainy event	-	Geometric	$\theta = 1/\mu$	2 seasons
NS	Number of shower per rainy period	-	Geometric	$\theta = 1/\mu$	2 seasons
NpS	Number of "principal" shower [2]	-	Binomial	θ =f (μ) [3]	2 seasons
IPD	Inter rainy period duration	hours	Truncated geometric	$\theta_1 = 1/\mu$ θ_2 = Prob(IPD>12h)	2 seasons
SD_p et SD_o	Shower duration, for the two types of shower [2]	hours	***(p)*** Truncated Poisson ***(o)*** Truncated Poisson	$\theta_1 = \mu$ θ_2 = Prob(SD_p>9h) $\theta_1 = \mu$ θ_2 = Prob(SD_p>6h)	2 seasons and 2 types
SV_p et SV_o	Shower volume, for the two types of shower [2]	mm	***(p)*** Truncated Log-normal ***(o)*** Truncated Gamma	$\theta_{1,2,3}$ = f(μ, σ, min) $\theta_{1,2,3}$ = f(μ, σ, min)	2 seasons and 2 types
RX_p et RX_o	Ratio of shower maximun hourly rainfall over its volume, for the two kind of shower [2]	-	Normal	$\theta_1 = f_1$(SD) [4] $\theta_2 = f_2$(SD) [4]	2 seasons and 2 types
PX	For a shower, relative position of the maximum hourly rainfall in the shower	-	Normal	$\theta_1 = \mu$ $\theta_2 = \sigma$	2 seasons
P_{TER}	Probability of the total event rainfall	-	Uniform	θ = median	**12 months**
τ_p and τ_o	Kendall's Tau for copula between duration and volume probabilities		***(p)*** Franck copula ***(o)*** Gumbel copula	Kendall's Tau	2 seasons and 2 types
Variables required to simulate "non-event" rainfall periods					
$DR_{<20}$	Depth of non-event daily rainfall	mm	Exponential	θ_1 , θ_2 optimised	**12 months**
HR0	Proportion of hourly rainfall equal to zero within a non-event daily rainfall	-	Uniform	$\theta = \mu$	**12 months**
Variables required to simulate dry periods					
DR0	Probability of days with no rain during a non-even period	-	Uniform	$\theta = \mu$	**12 months**

[1] μ = mean of the variable values, σ = standart deviation of the variable values and min = minimum of the variable values

[2] Only the variables SD, SV, and RX are considered for the two shower types.

[3] The binomial distribution parameter describing the variable NpS is a regionally calibrated function of the variable's mean. Using our dataset, θ =0,15 . ln(μ_{NpS}) for season 1 (1) and θ =0,122 . ln(μ_{NpS}) for season 2.

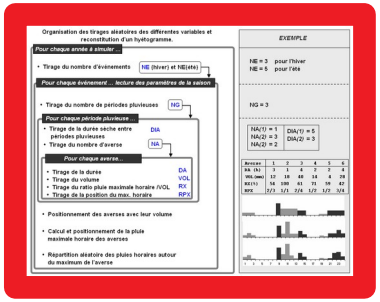
[4] The mean and standard deviation of the normal distribution used to randomly sample the variable RX are estimated as functions of shower duration SD. For each randomly drawn duration, the variable RX is generated from a normal distribution N(θ_1 ,θ_2), where $\theta_1 = a + b$ ln(SD) and $\theta_2 = c + d$. ln(SD). The parameters a, b, c et d are regionally optimized to match the observed mean and standard deviation of RX. These four parameters are determined separately for both seasons and both shower types.

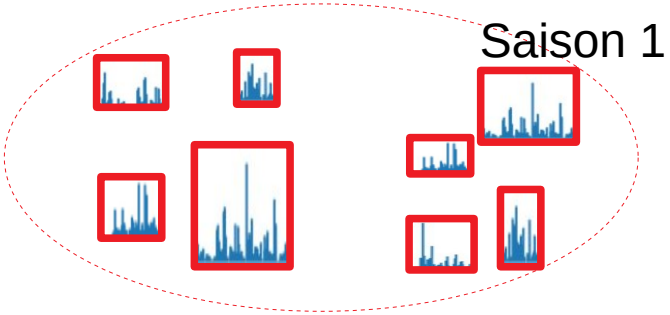
Particularités :

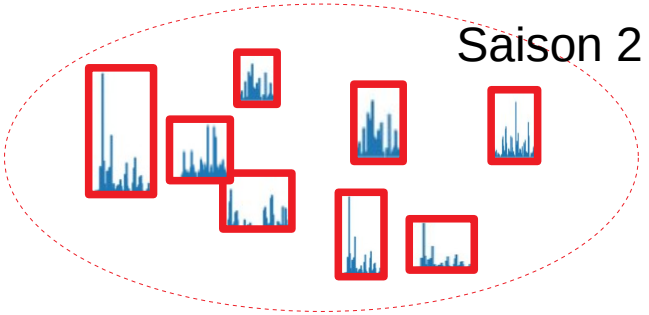
- 2 types d'averses
- 2 saisons
- 12 mois
- Calage de relations « nationale »
- Dépendance de certaines variables

SCHYPRE : simulation

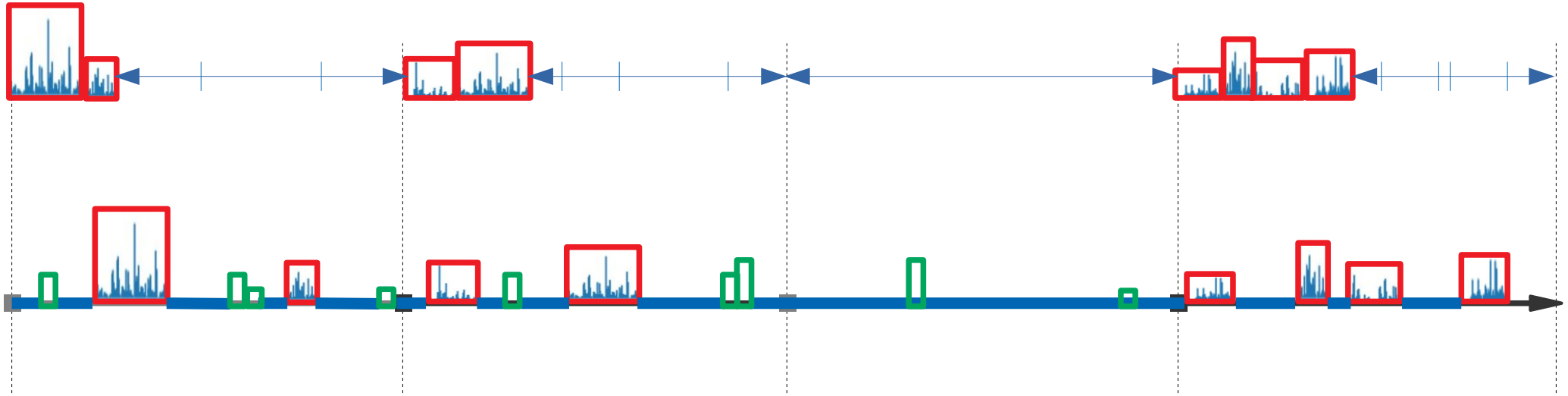
1 - Simulation des événements pluvieux (idem événementiel)







2 – Attribution des événements pluvieux à un mois (**NE**) et calcul de la durée totale « inter-événements »

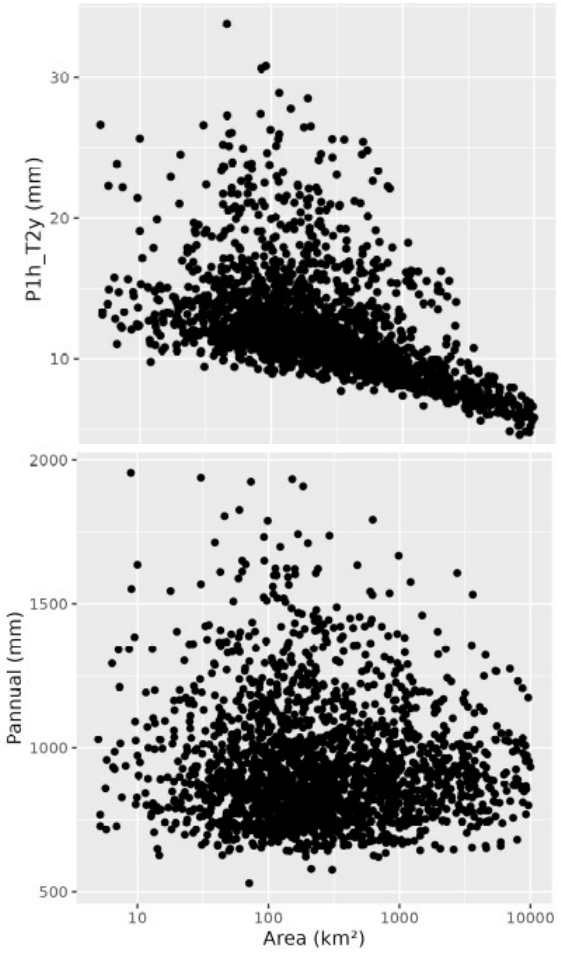


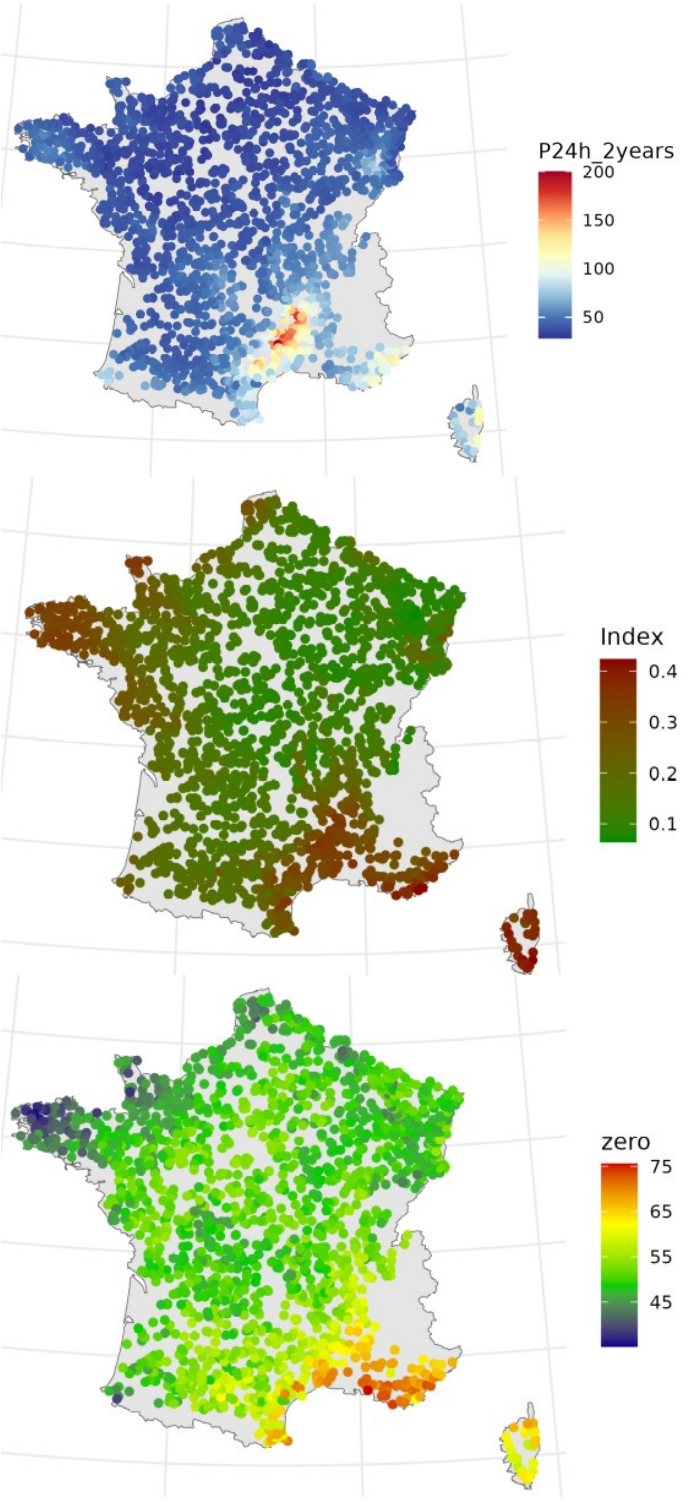
3 – Calcul de la durée sèche du mois : **P0**

3 – Simulation des pluies « hors-événements » : **DR_{20}**

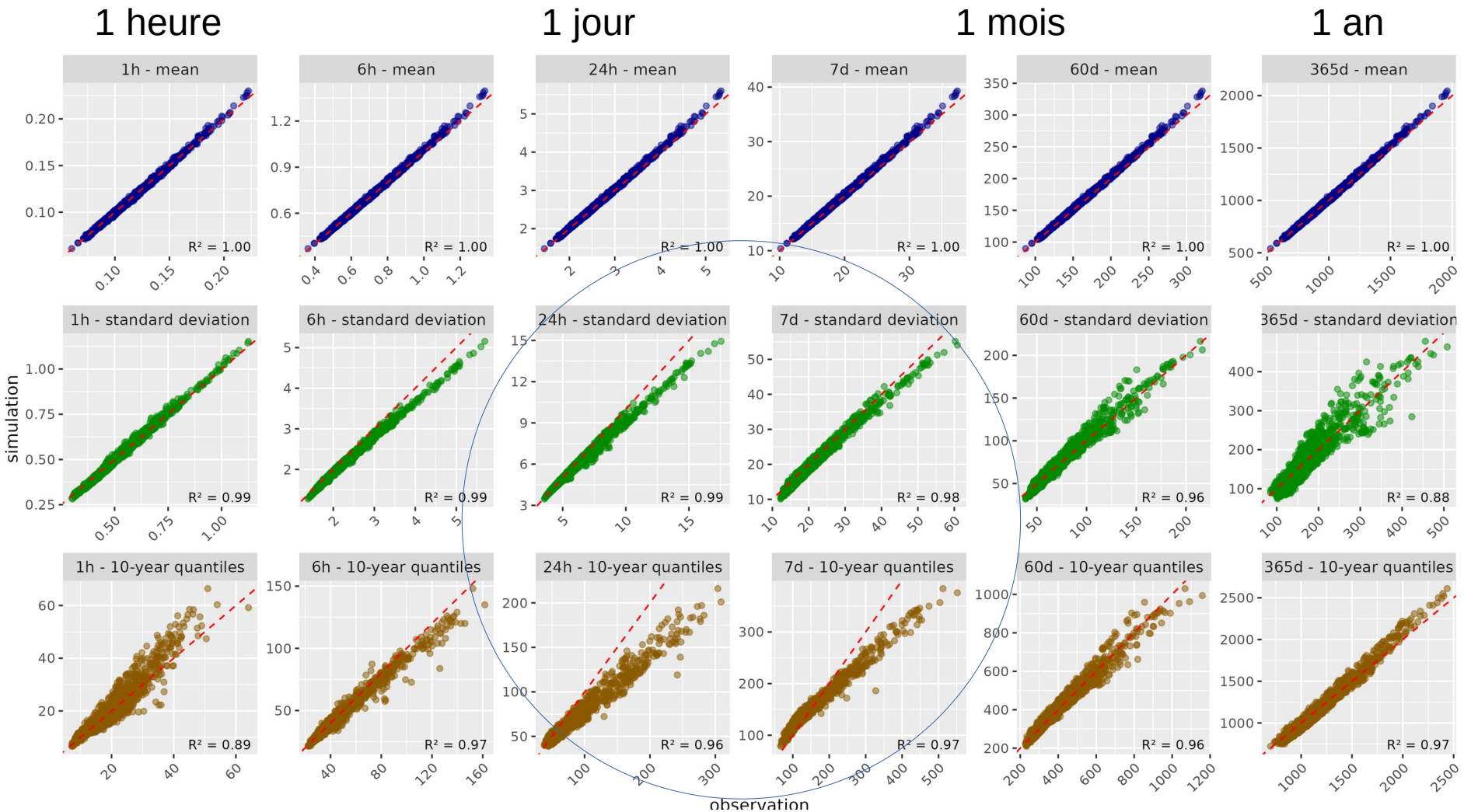
SCHYPRE : application

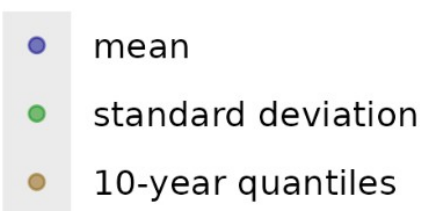
- Calage sur 2108 bassins [5, 10000] km².
- Chroniques de pluies horaires sur 28,5 années.
- Forte variabilité climatique : cumuls, saisonnalité, ...
- Dépendance à la surface d'agrégation.

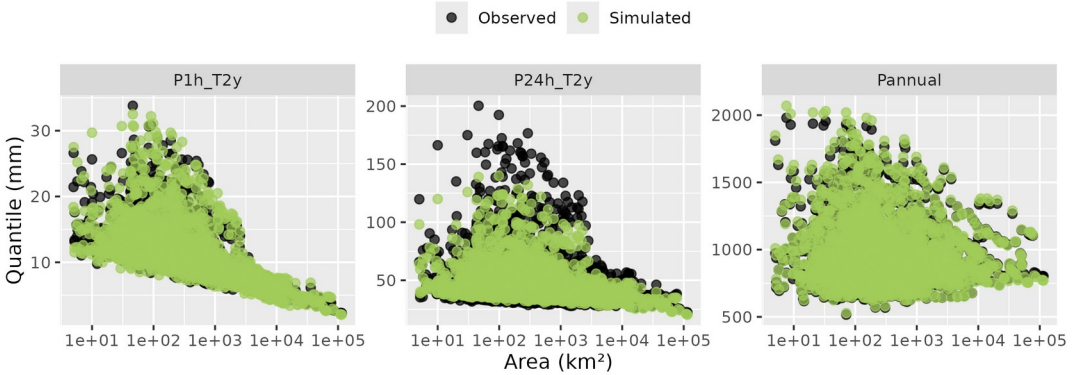




SCHYPRE : restitution des caractéristiques observées







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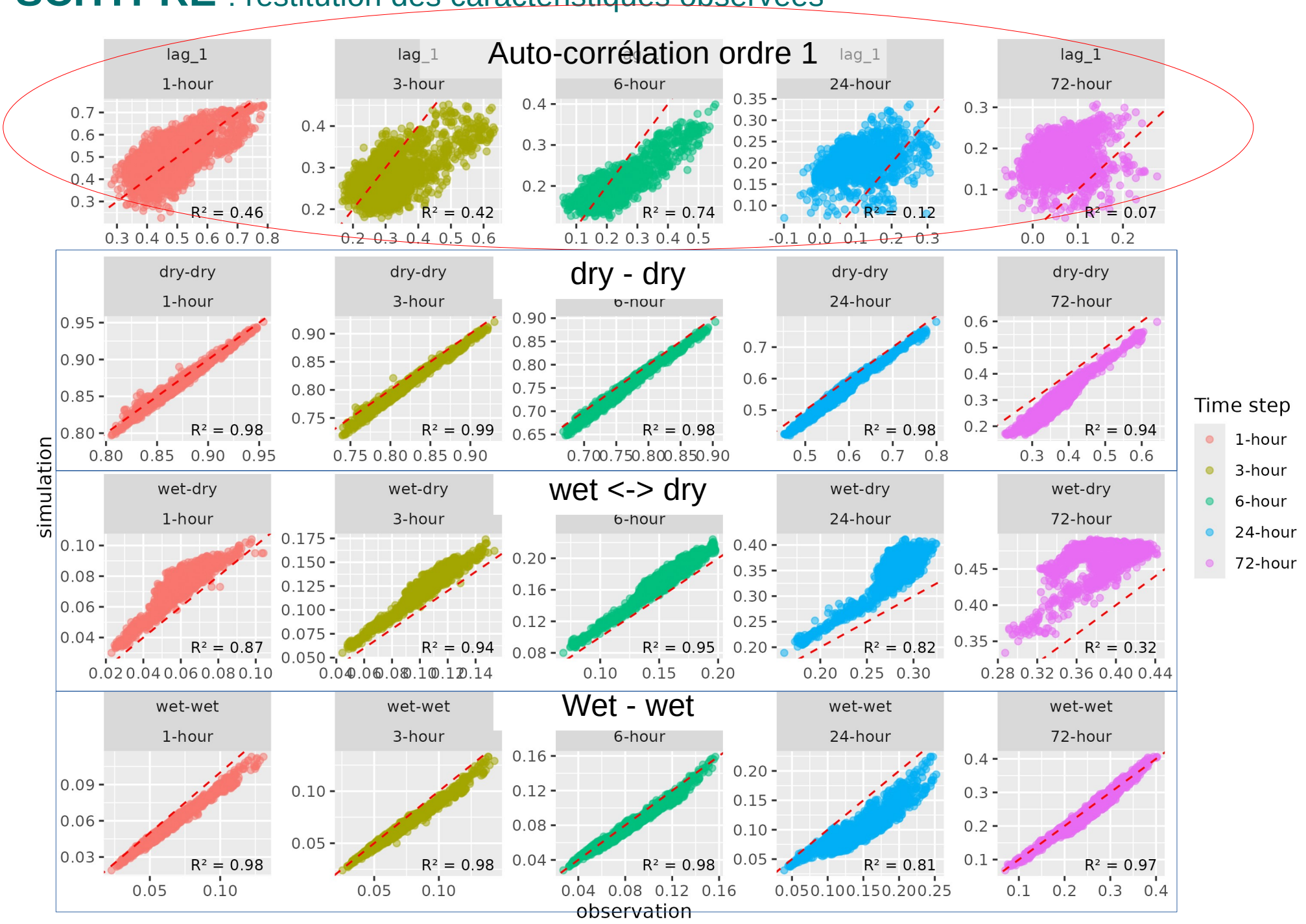

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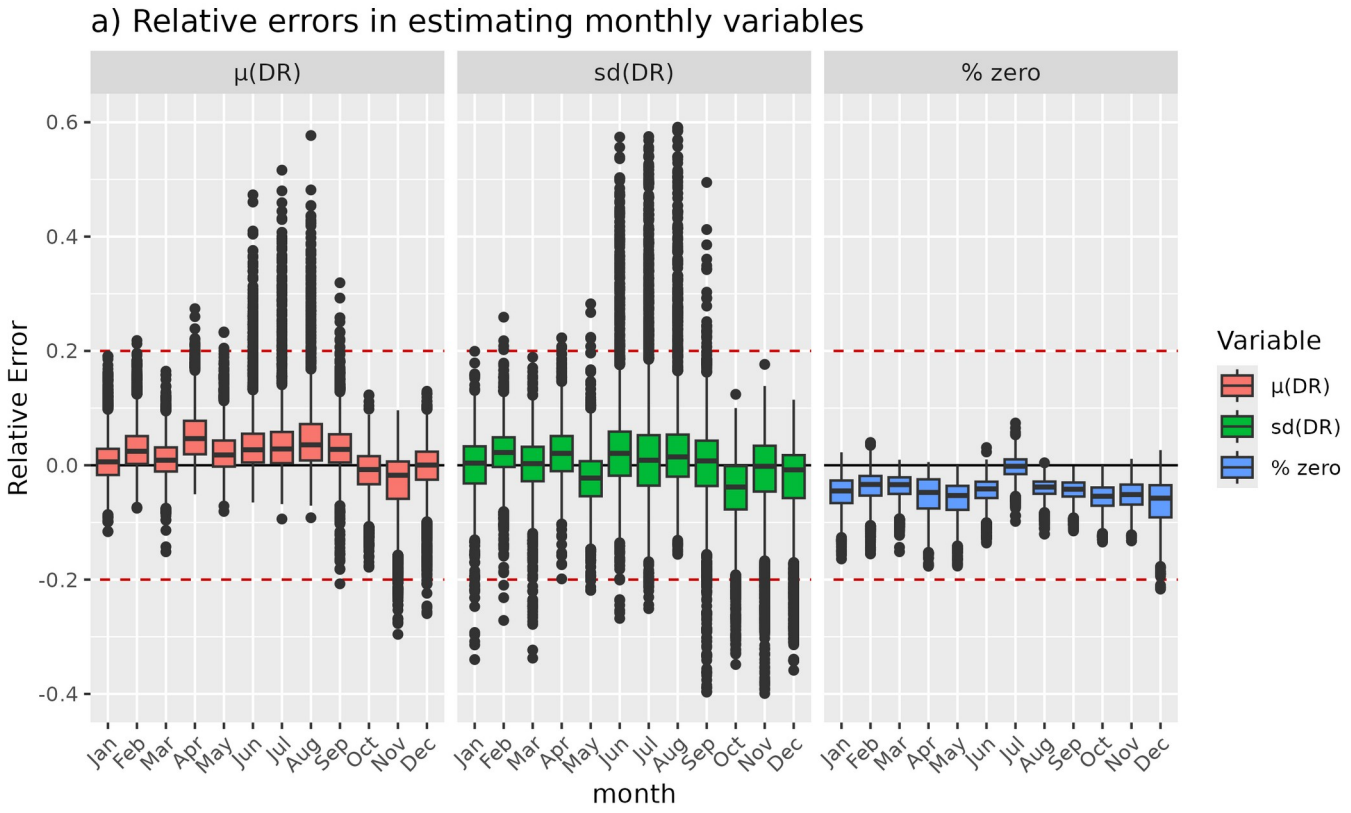
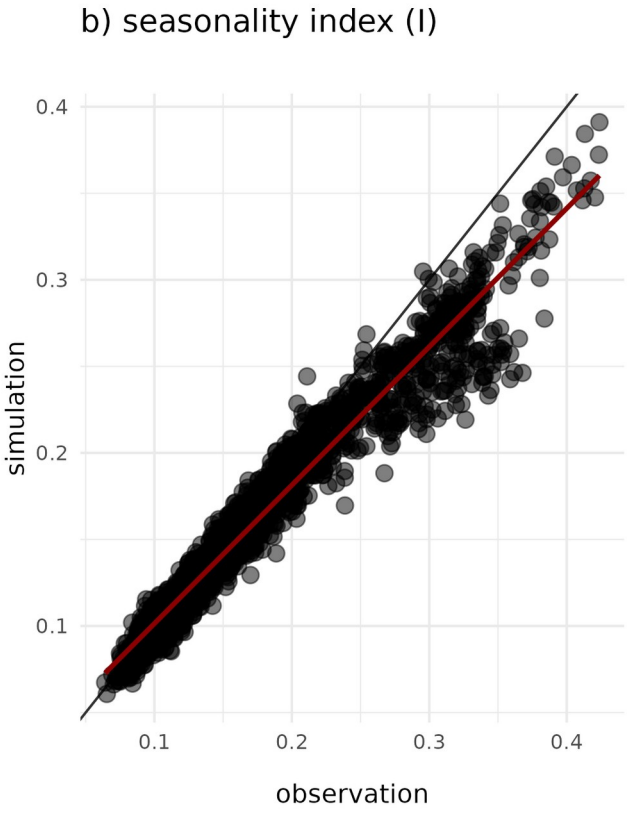
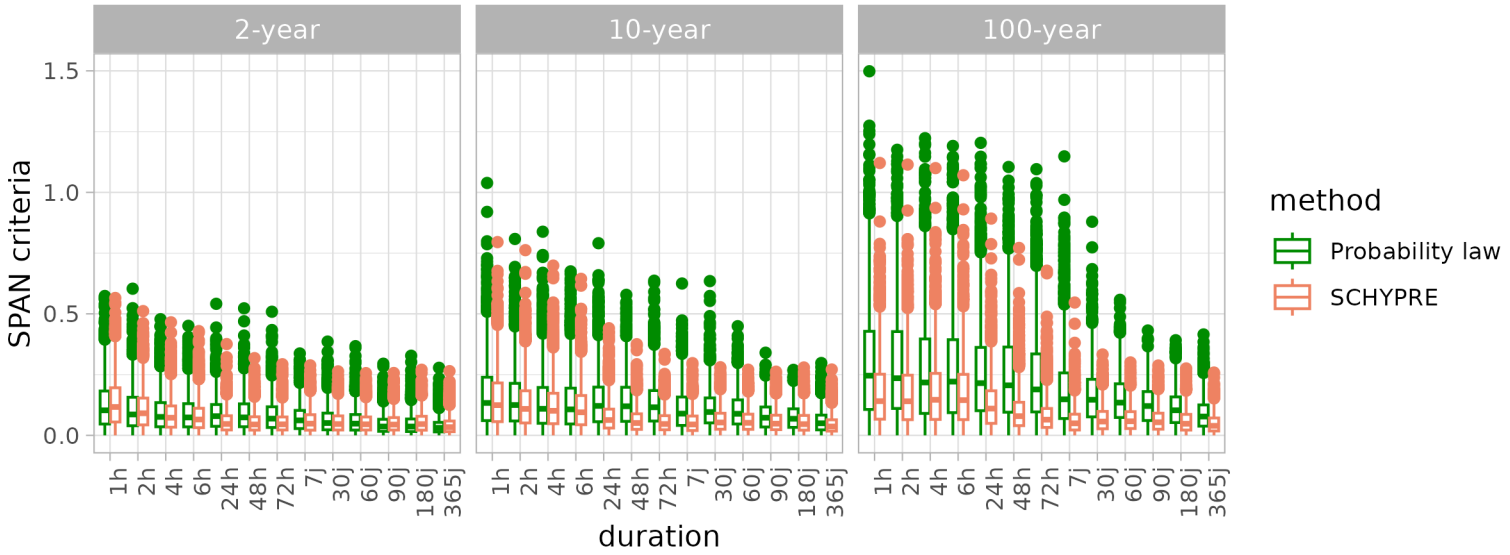


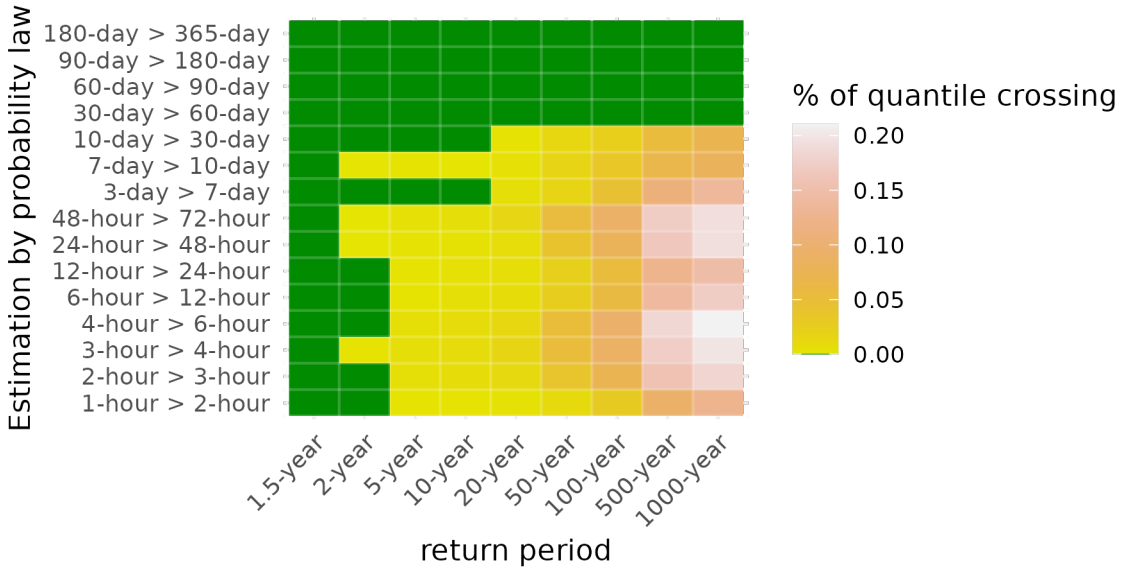


SCHYPRE : stabilité et cohérence

- Application sur 2 périodes de 14 ans
- SCHYPRE vs Probability law (GEV pour d ≤ 7j et log-normale pour d > 7 j)
- calcul du SPAN

$$SPAN_T = 2 \cdot \frac{\left| \left(q_T(P_1) - q_T(P_2) \right) \right|}{\left(q_T(P_1) + q_T(P_2) \right)}$$





SCHYPRE : poursuite ...

OBSERVATIONS	SIMULATIONS

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Pluie de bassin (IMF)
Pourcentage de surface mouillée (WAR)
Coefficient de variation de la pluie (CV)

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- Température de bassin

SCHYPRE
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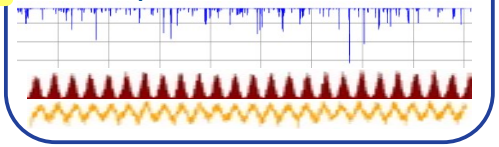

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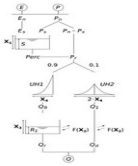
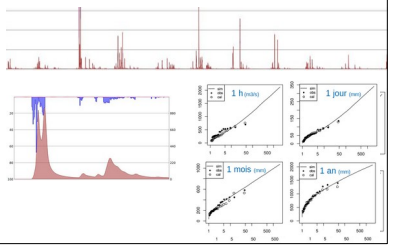
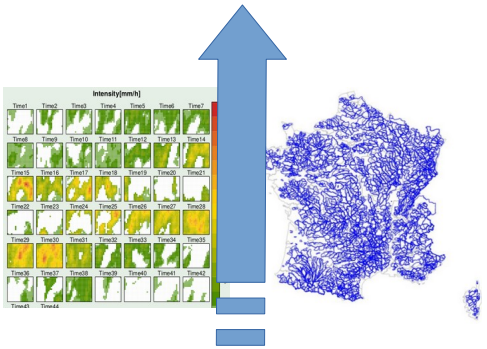


Longues chroniques de pluies et débits simulés



Approche spatiale



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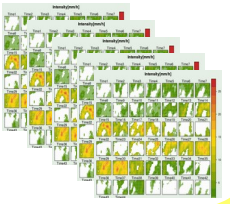
Désagrégation spatiale de la pluie

Champs de pluies (cohérence temporelle et spatiale)



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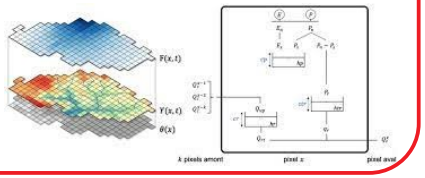
(modèle distribué)



- Simulation conditionnelle des caractéristiques de pluies de bassin (IMF/CV/WAR)
- Amélioration de la désagrégation spatiale des pluies (advection ?)
- Couplage au modèle SMASH

The end