Preserving the space-time dependence structure of precipitation for hydro-meteorological forecasting:

A case study with analog-derived PQPF

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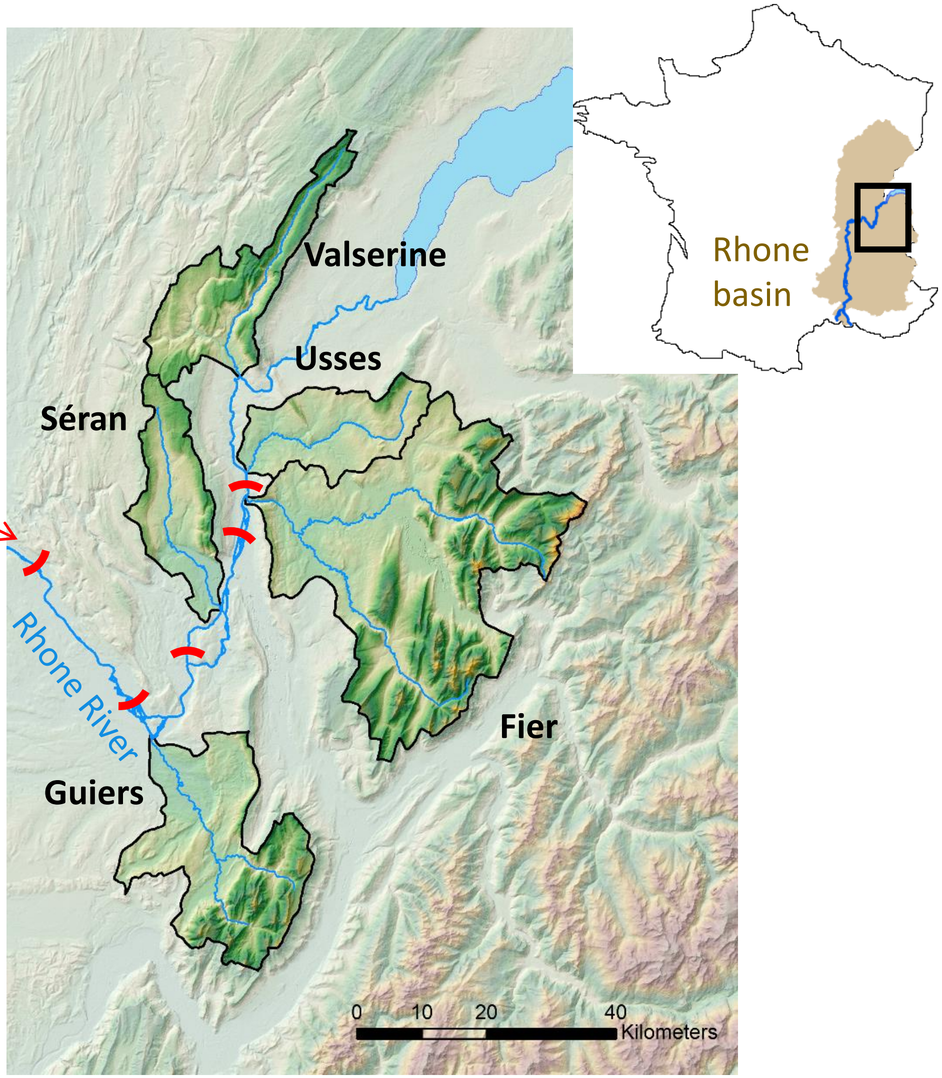
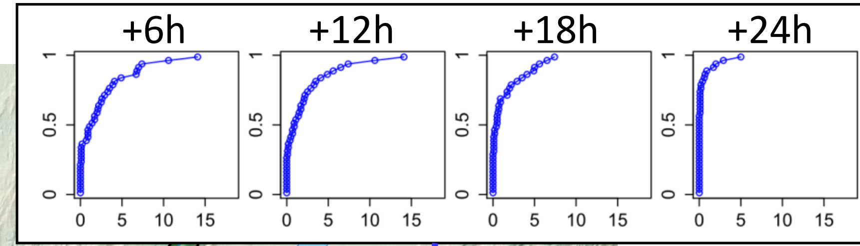
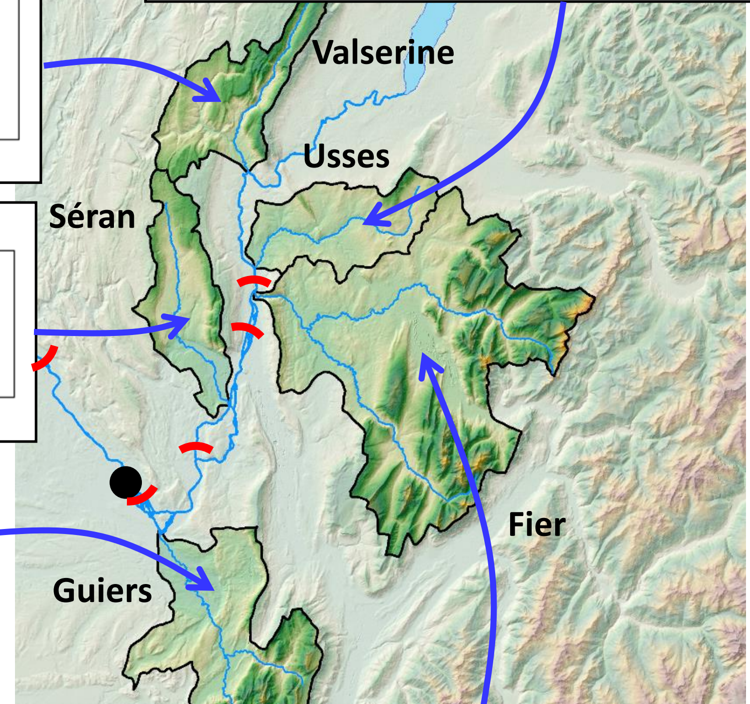
hydropower dams

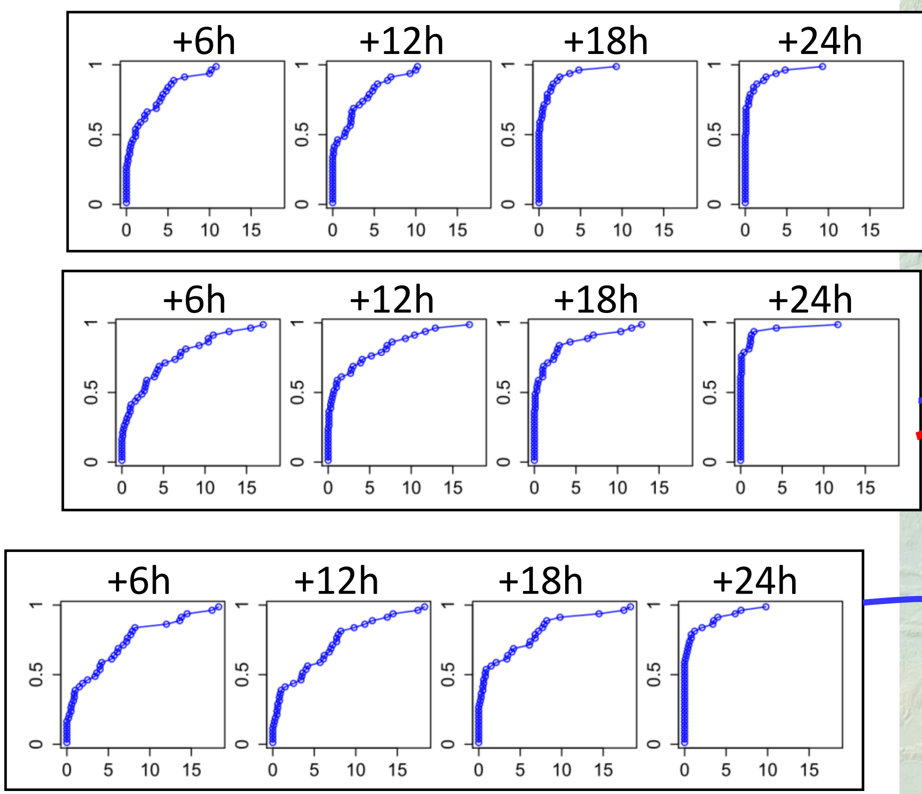


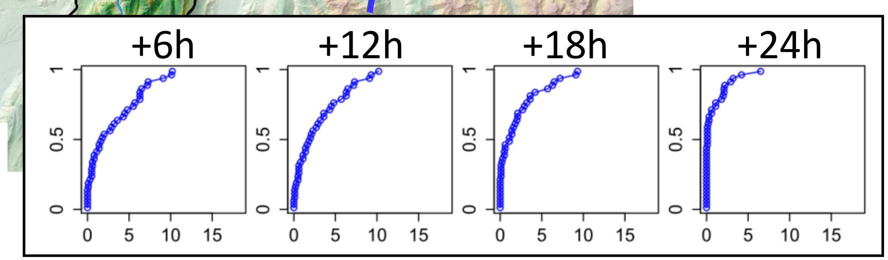
Case study:
5 catchments of the Rhone River:

Required **precipitation forecasts** for a +24h streamflow forecast :









M = 40 members

5 catchments
4 lead times

20 **univariate** forecasts

1 **multivariate** forecast

Problem:

Because of { post-processing, scale mismatch, … } $\Rightarrow$ Wrong (or any) **space-time dependence structure**

How can we reconstruct the space-time coherence?

How can we evaluate it?

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How can we evaluate it?

Case study :

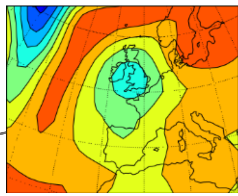
Precipitation forecasts from an analog method

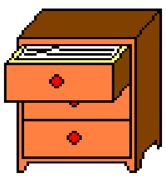
Papers:
Obled et al. (2002)
Bontron (2004)
Marty et al. (2012)
Ben Daoud et al. (2016)

Analog method used:

deterministic forecast

*« **Target** » synoptic situation*





***Archive** of reanalysis*

Analogy levels

Level 1 Temperature

Level 2 Geopotential heights

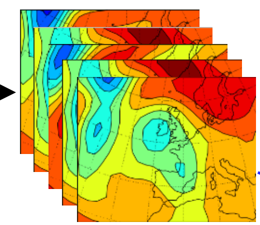
Level 3 Humidity

M = 9000

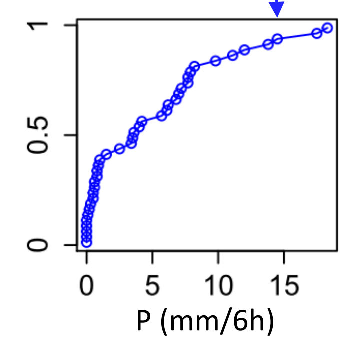
M = 175

M = 40

*« **Analog** » synoptic situations*



Precipitation observed on these dates



6-hour forecast for a given - catchment
- lead time

Problem:

Because of { scale mismatch, post-processing, … } $\Rightarrow$ Wrong (or not all) **space-time dependence structure**

How can we reconstruct the space-time coherence?

I. Reordering methods:

- Existing methods
- Adaptation of the Schaake shuffle using analogs

How can we evaluate it?

II. 3-step verification:

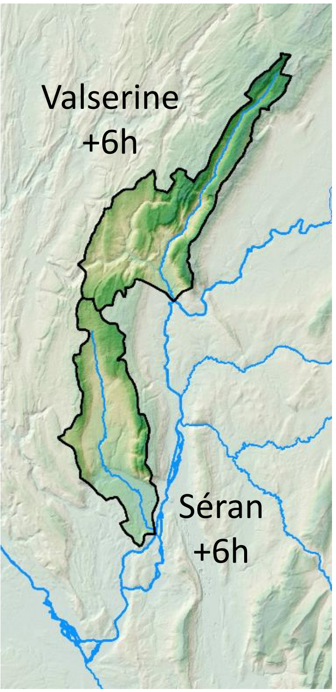
- Correlations check
- Multivariate verification score
- Verification on streamflow

Case study :

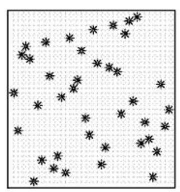
Precipitation forecasts from an analog method

Exemple in 2D:

What is a reordering?



Ranks :



=

Valserine +6h | **Séran +6h**

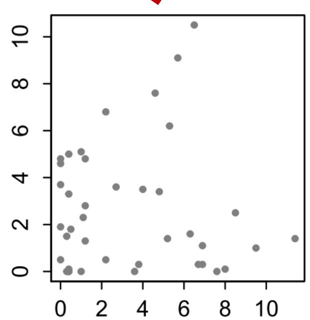
40^{th} member | 40^{th} member
39^{th} member | 39^{th} member
38^{th} member | 38^{th} member

… | …

1^{st} member | 1^{st} member

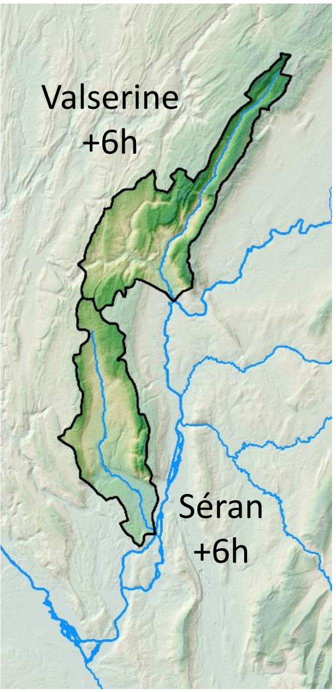
Univariate distributions

Valserine +6h
Séran +6h



Multivariate forecast

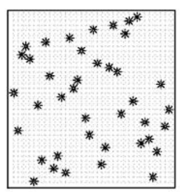
Exemple in 2D:



What is a reordering?

Sample:

Ranks :



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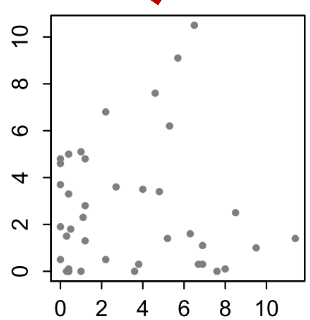

Multivariate forecast

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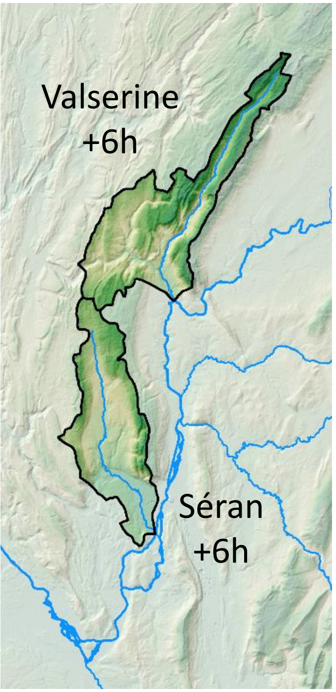
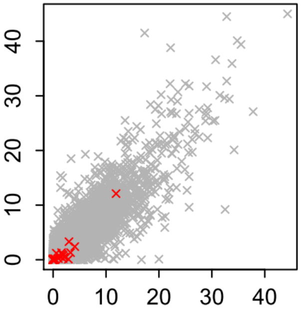
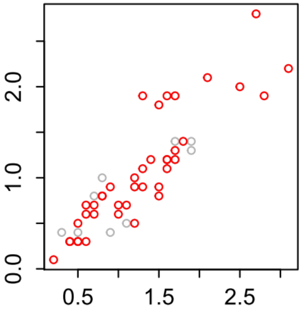


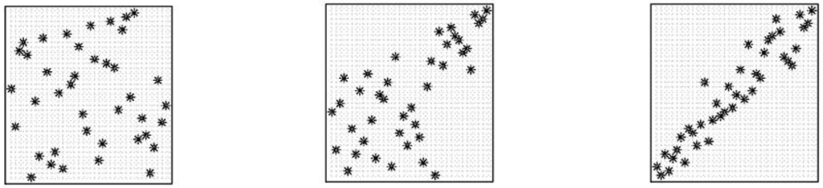
Random	Clark et al. (2004) Schaake shuffle	Schefzik et al. (2013) Ensemble copula coupling (ECC)
No sample	Sample from climatology	Sample from a raw ensemble forecast

Sample:



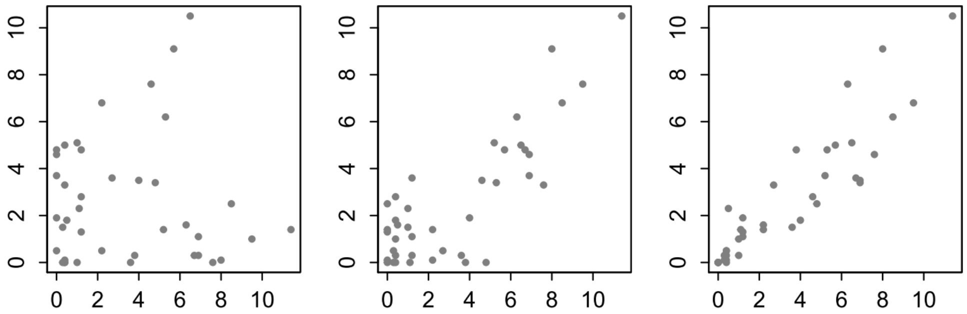


Ranks :



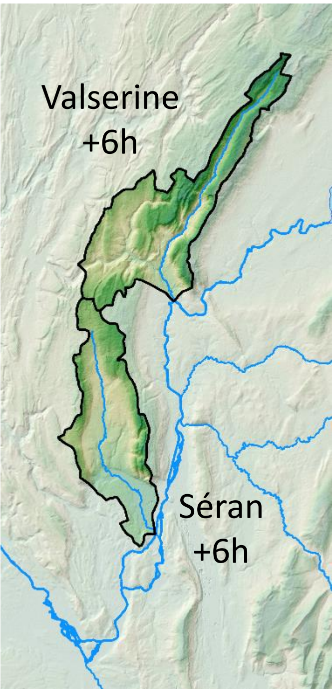
Univariate distributions

Valserine +6h
Séran +6h



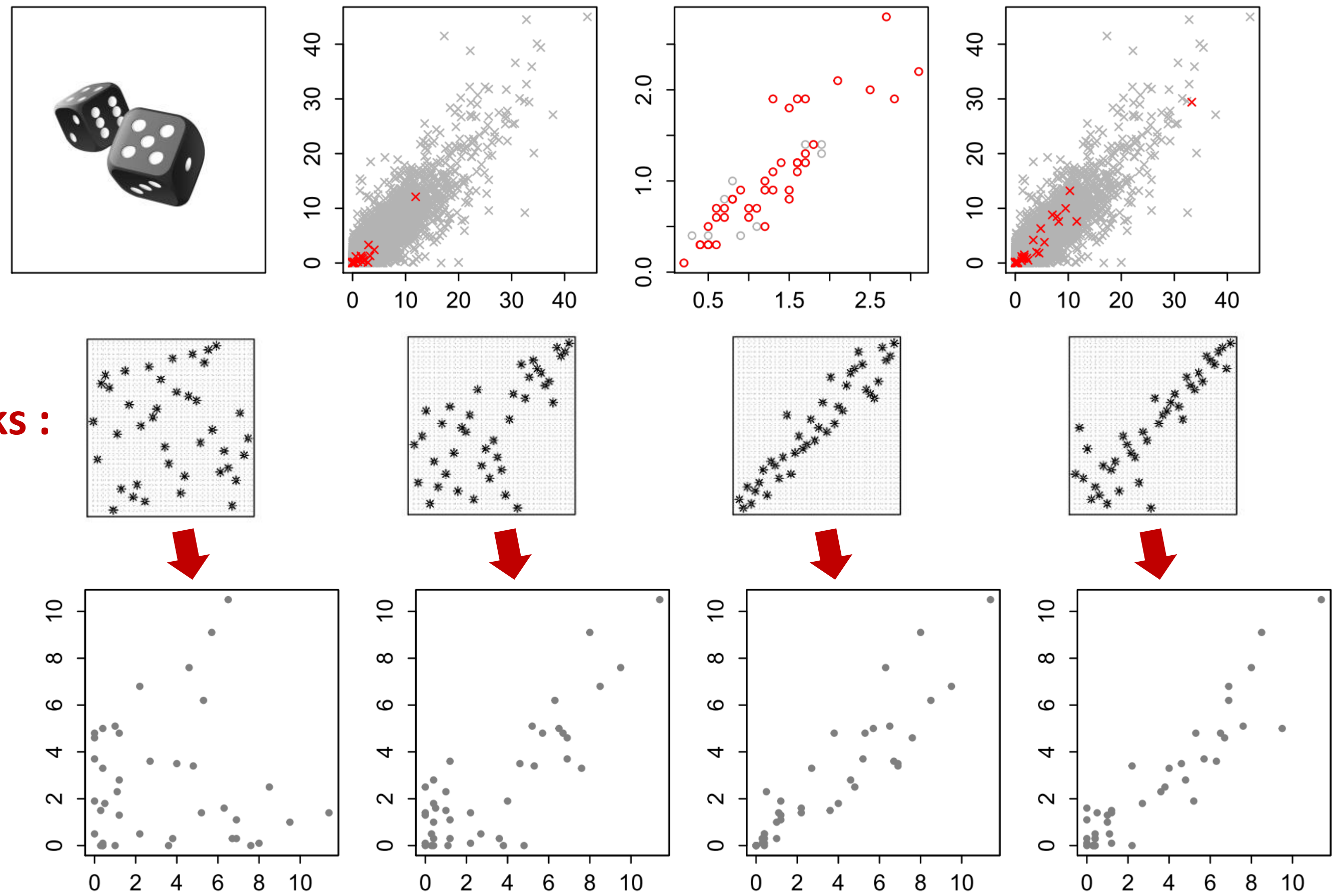
Random	Schaake shuffle	Ensemble copula coupling (ECC)	*Analog* Schaake shuffle
	Clark et al. (2004)	Schefzik et al. (2013)	
No sample	Sample from climatology	Sample from a raw ensemble forecast	Sample from analog situations

Exemple in 2D:



Sample:

Ranks :



Univariate distributions

Valserine +6h
Séran +6h

How can we evaluate these methods?

Verification period: 2008-2014
1 forecast/day (00 UTC)

1. Check of space-time climatological correlations:

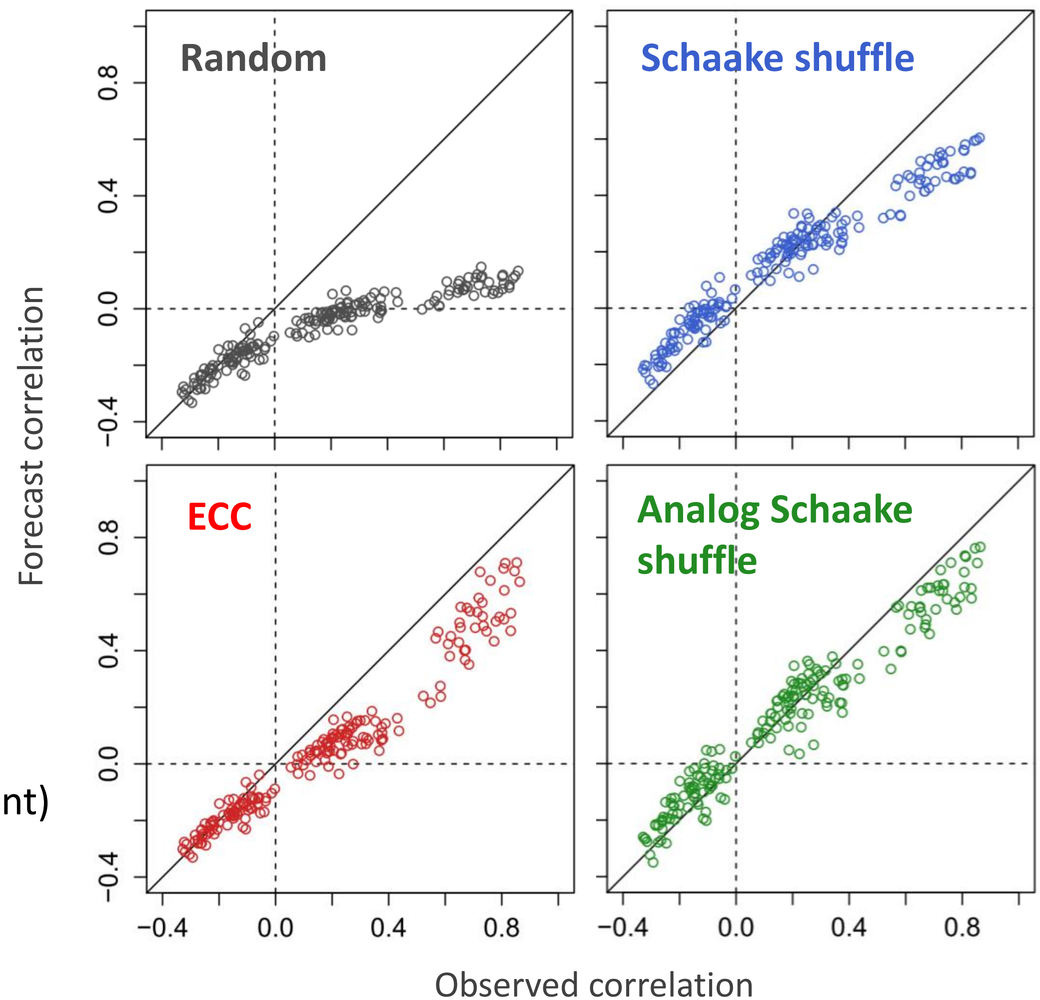
Points on the diagonal = Good

Multivariate forecast of dimension 20
(5 catchments × 4 lead times)

⇒ 190 possible pairs of dimension
⇒ 190 points

X-coordinate = Observed correlation
Y-coordinate = Forecast correlation

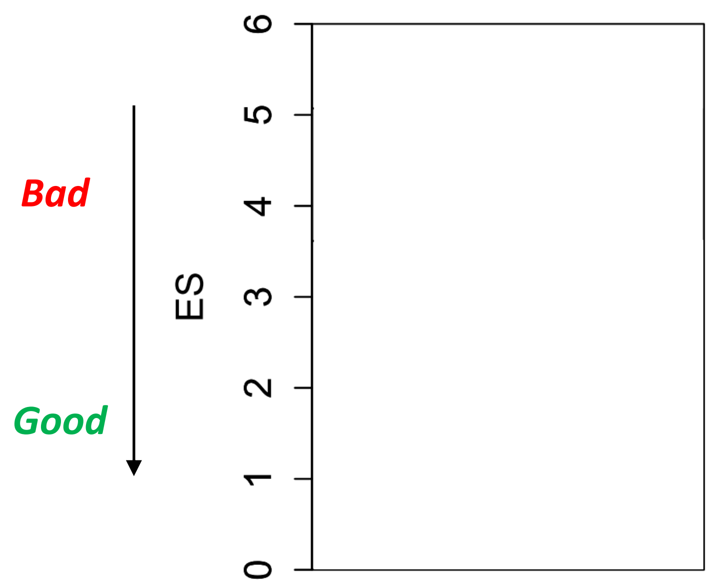
(using Spearman's rank correlation coefficient)



2. Use of a multivariate verification score:

- **Energy Score (ES)**: extension of the CRPS in dimensions > 1. (Gneiting and Raftery, 2007)

  $\Rightarrow$ dependent of the correlation structure



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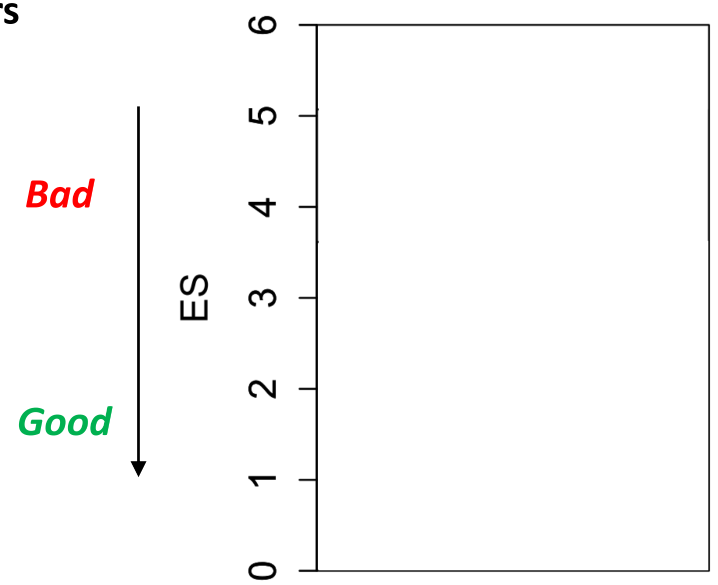
⇒ For each multivariate forecast of **40 members** in **dimension 20** (5 catchments × 4 lead times):

$(40!)^{20-1}$ possible reordering

→ **$(40!)^{20-1}$** different ES



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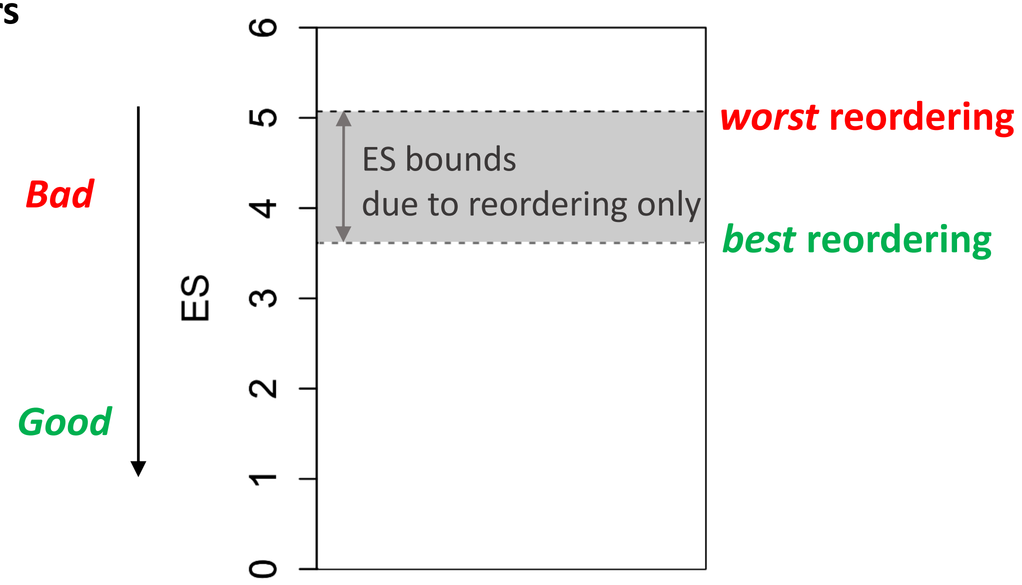
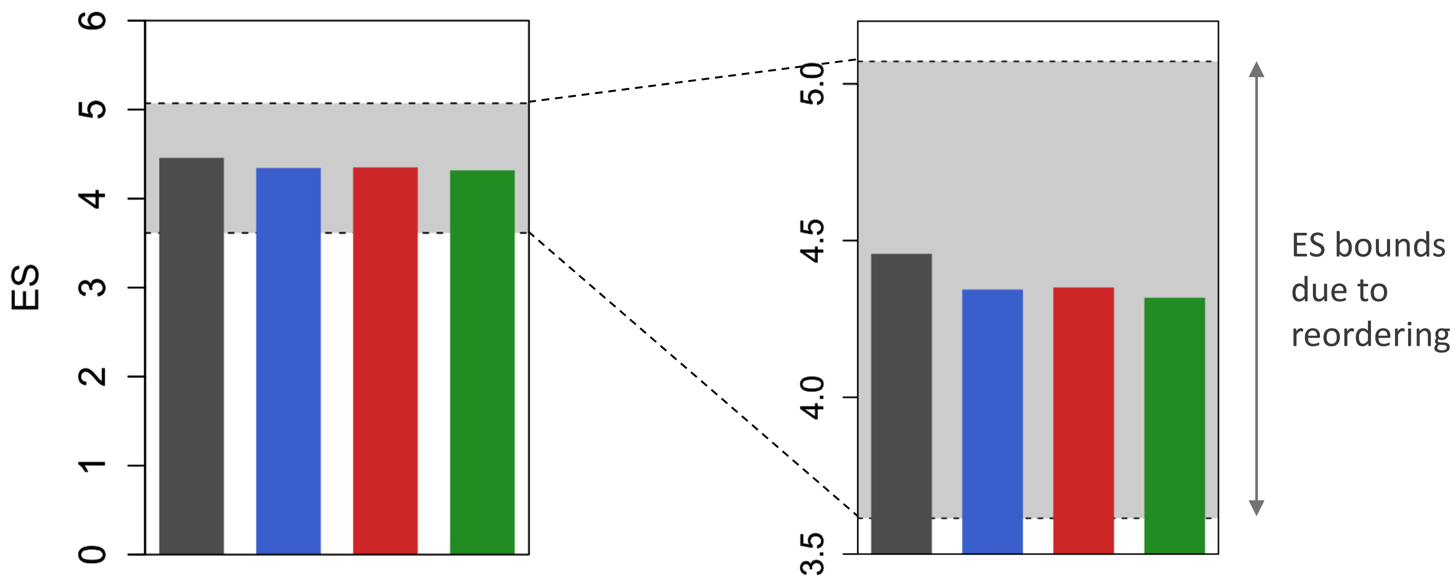


Mean ES over all forecasts:

Bad

Good



Random
Schaake shuffle
ECC
Analog Schaake shuffle

⇒ Potential of improvement!

3. Verification on streamflow

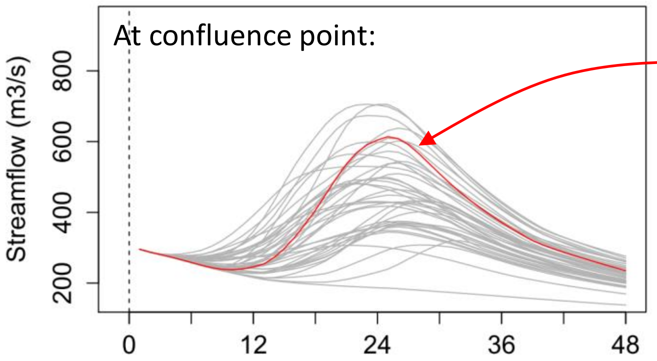
20 precipitation forecasts
5 catchments
4 lead times: +6h, +12h, +18h, +24h

+
- **Random**
- **Schaake shuffle**
- **ECC**
- **Analog Schaake shuffle**

↓

5 lumped hydrological models + propagation model

↓



Simulated streamflow
(with observed precipitation)

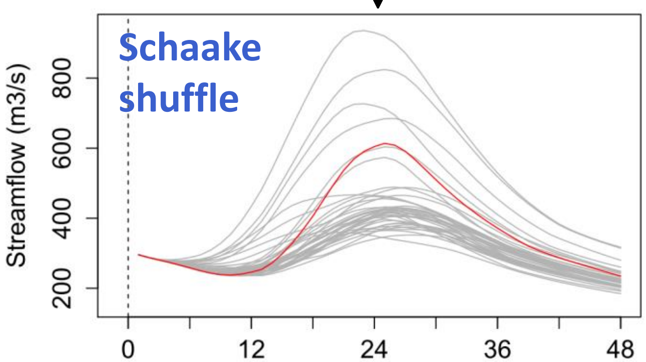
⇒ Cancels out hydrologic uncertainty

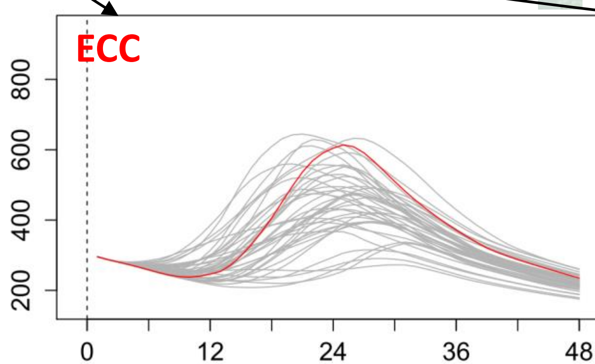
3. Verification on streamflow

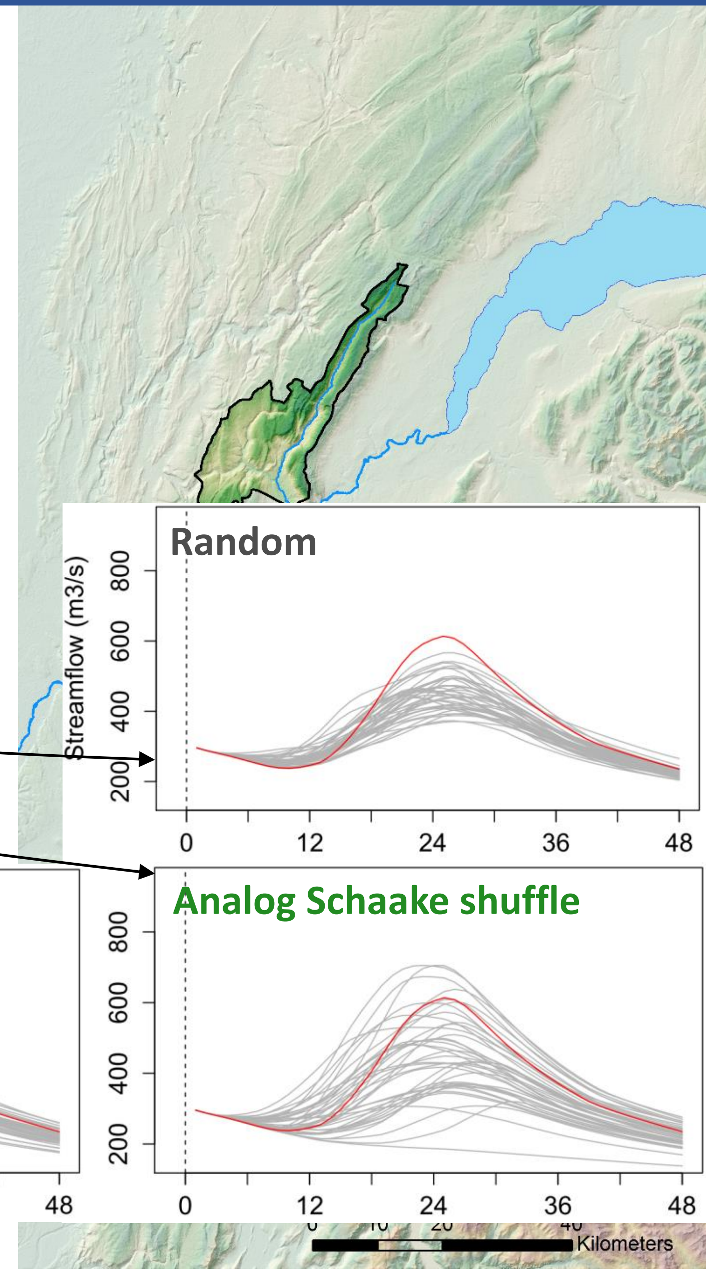
20 precipitation forecasts
5 catchments
4 lead times: +6h, +12h, +18h, +24h

\+ Random / Schaake shuffle / ECC / Analog Schaake shuffle

5 lumped hydrological models + propagation model

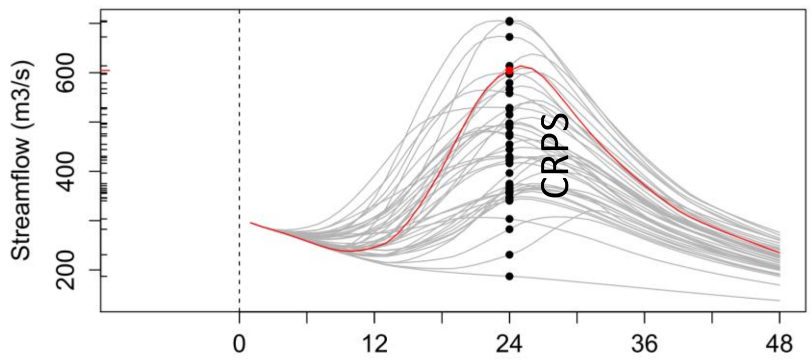






What is the variable of interest?

In a **hydropower production forecasting** context:



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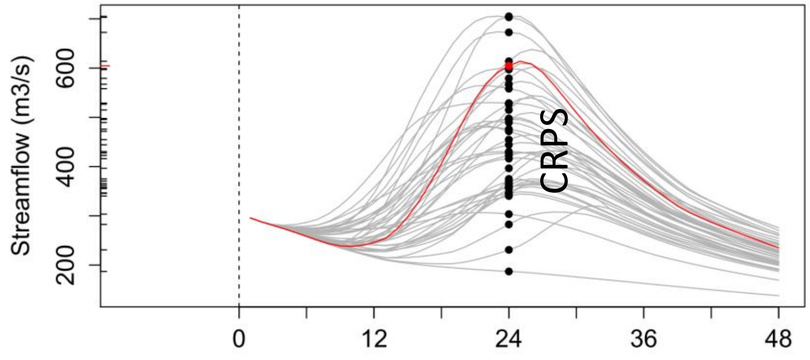

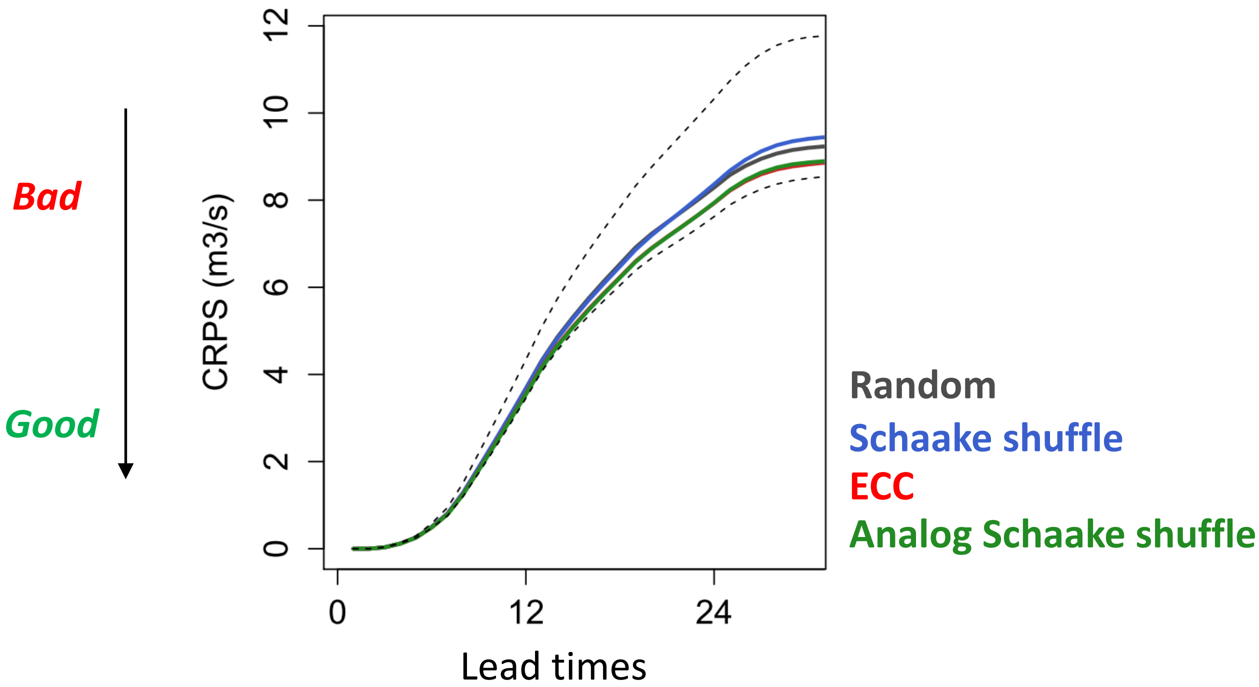

II. Verification strategies: ○ Correlation check ○ Multivariate score ● Verification on streamflow

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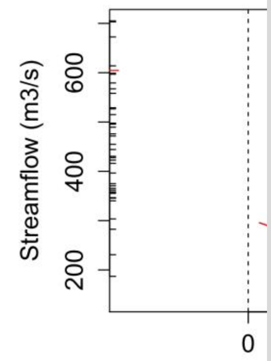
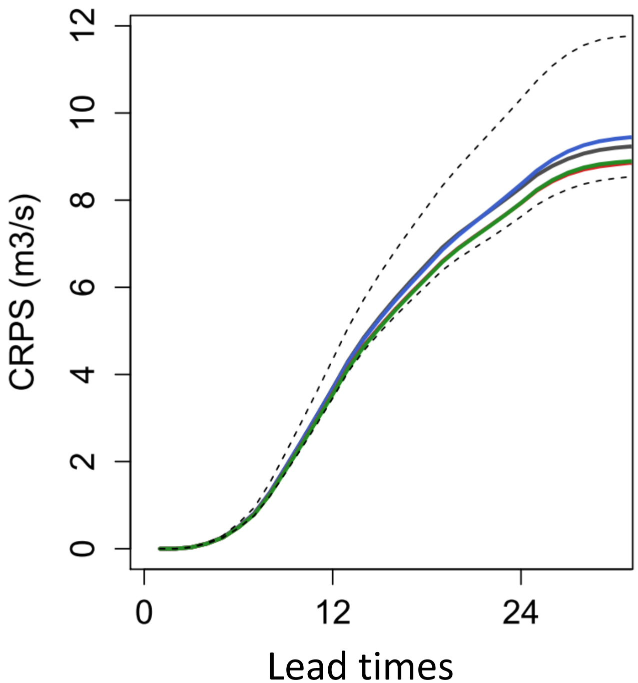
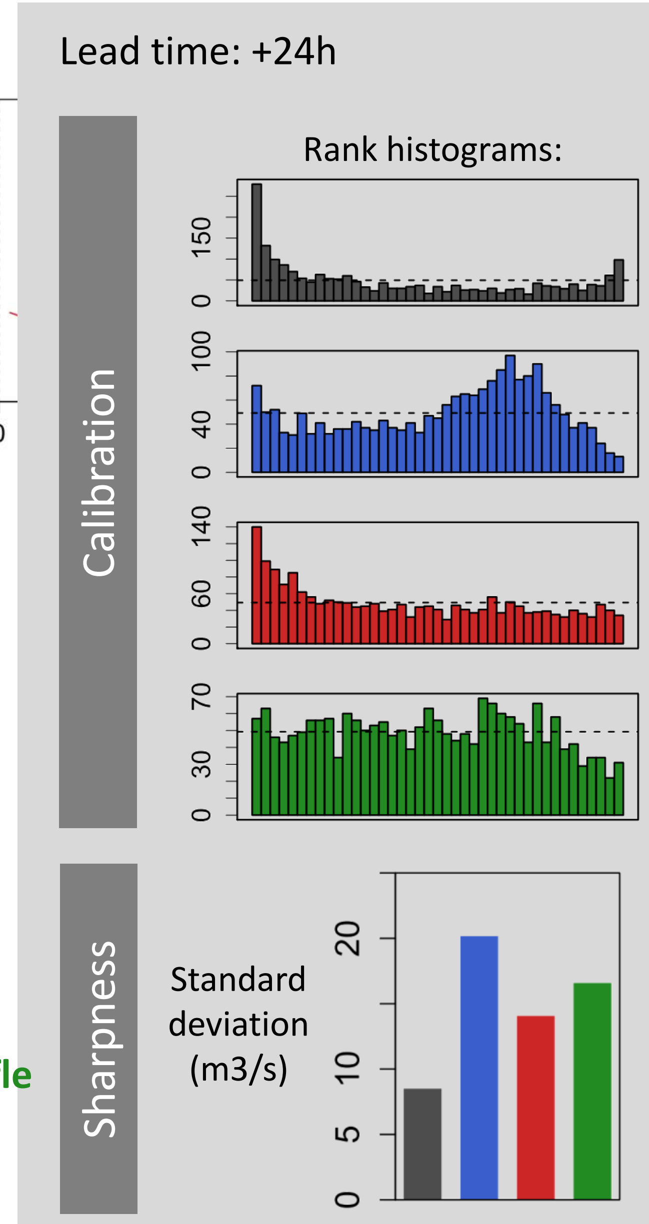


Bad

Good



Random
Schaake shuffle
ECC
Analog Schaake shuffle



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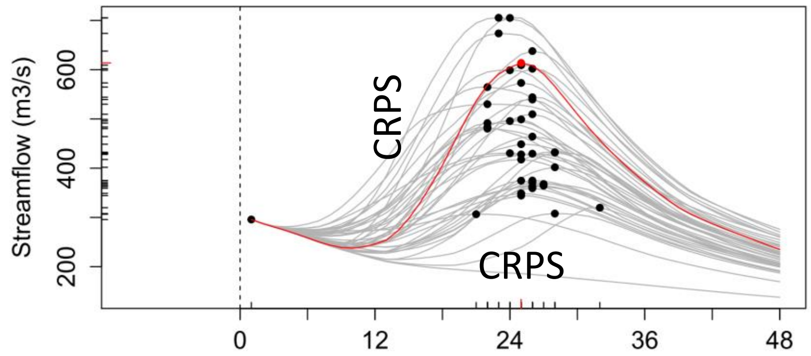
In a **flood warning** context:



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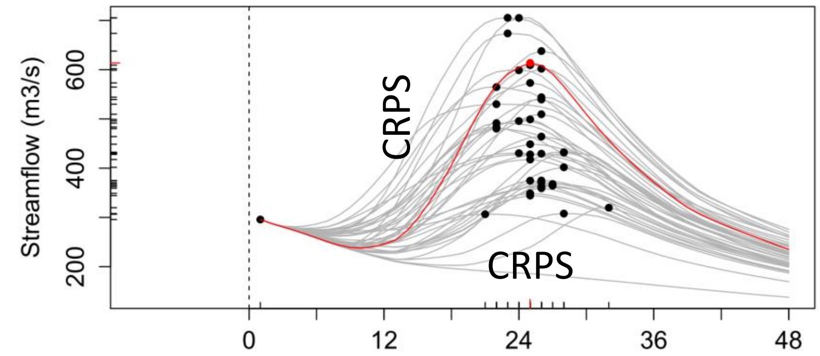


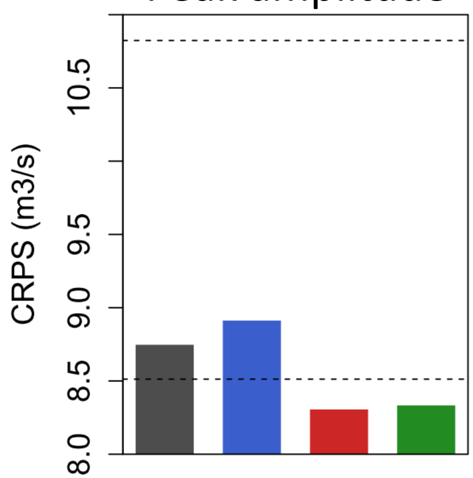
Random

Schaake shuffle

ECC

Analog Schaake shuffle

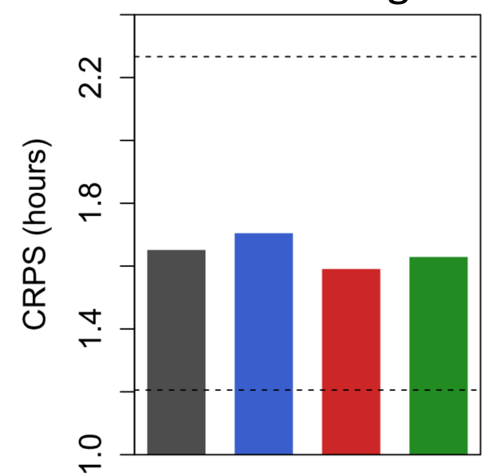
Peak amplitude



with **worst** reordering (according to ES)

with **best** reordering (according to ES)

Peak timing



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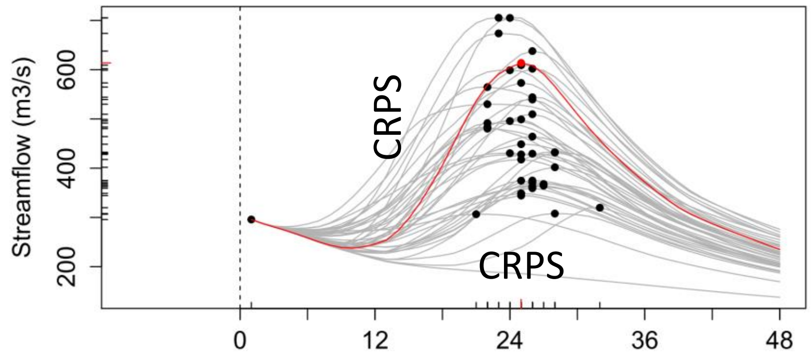
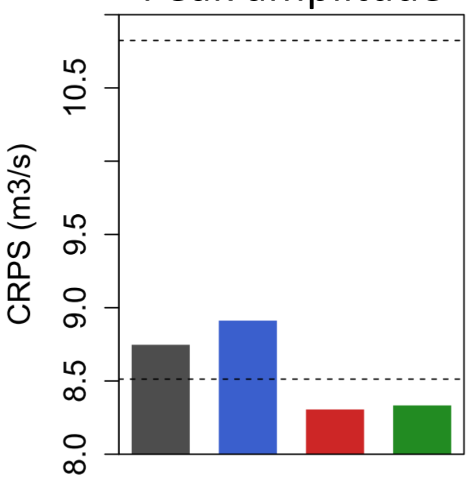
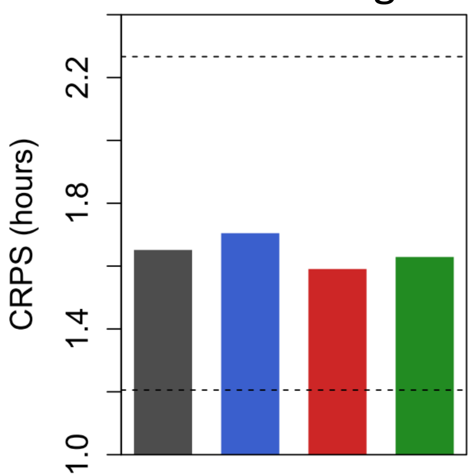


Random
Schaake shuffle
ECC
Analog Schaake shuffle





⇒ Is the ES the best metric to evaluate precipitation forecasts for hydrological purposes?
⇒ Best precipitation forecasts always lead to best streamflow forecasts?

Conclusion

- Existing reordering methods

  \+ **Adaptation of the Schaake shuffle**
  Reordering depending on the atmospheric situations

- **3-step verification strategy:**

  1. Correlation check — ⇒ Necessary but not sufficient (climatology only)
  2. Multivariate score — ⇒ In case of no *a priori* about the use of forecasts
  3. Verification on streamflow — ⇒ Necessary since conclusions may be different!

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  ⇒ Necessary but not sufficient (climatology only)

  ⇒ In case of no *a priori* about the use of forecasts

  ⇒ Necessary since conclusions may be different!

Perspectives

⇒ Search numerically for **"best"** and **"worst" reordering** on **streamflow forecasts**.
  → To evaluate the potential of improvement
  → To conclude about the impact of reordering on streamflow forecasting
  → To better understand links between **Energy Score** and **Streamflow verification**

⇒ With other forecasts (including Temperature?)

Conclusion

Thank you for your attention

Example of a streamflow forecast:
(12/30/2009 00:00)