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# Impacts of climate change on extreme discharges in France using climate projections in the SHYREG method

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# Goal of the work

A method of flood pre-determination regionalized on French territory (SHYREG method) is used to study the impact of climate change on extreme floods.

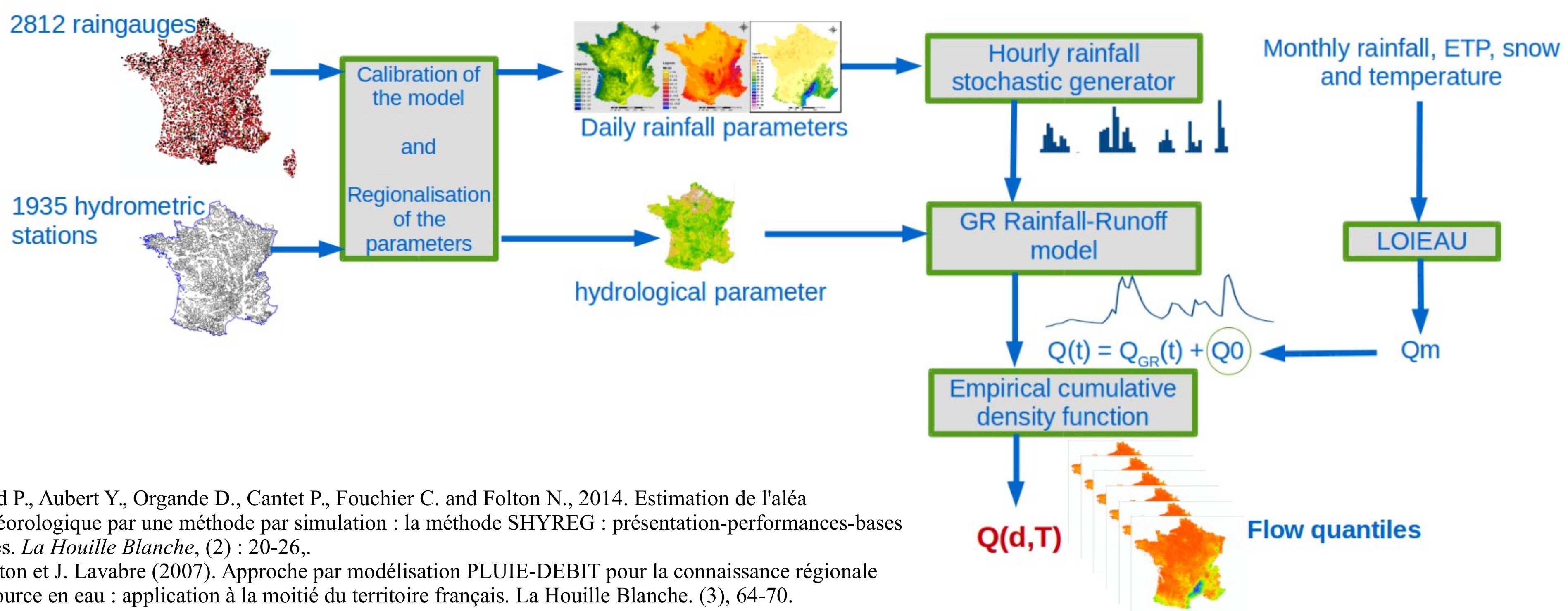
For this purpose, outputs from several RCM (data) previously corrected (bias correction) are used as an input of the method to study the convergence of trends induced by these models, on the evolution of the hydrological hazard.

# Contents

# 1. SHYREG method (Arnaud *et al.*, 2014[1])

- Couples a stochastic generator of hourly rainfall events and an event-based hydrological model generating a large number of flow events.
- Three daily rainfall parameters:
  - average number of events : frequency,
  - average maximum daily rainfall of events : intensity,
  - average duration of events,

  and one hydrological parameter (soil moisture condition) are calibrated and regionalized on each km² of France.
- “base flow“ from monthly rainfall-runoff model LOIEAU (Folton et Lavabre, 2007[2]) added to simulated flow events.
- Flow quantiles deduced from long period simulation for different return-periods and different durations.

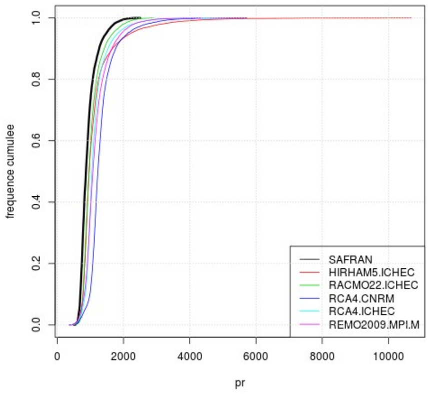



(1) Arnaud P., Aubert Y., Organde D., Cantet P., Fouchier C. and Folton N., 2014. Estimation de l'aléa hydrométéorologique par une méthode par simulation : la méthode SHYREG : présentation-performances-bases de données. *La Houille Blanche*, (2) : 20-26,.
(2) N. Folton et J. Lavabre (2007). Approche par modélisation PLUIE-DEBIT pour la connaissance régionale de la ressource en eau : application à la moitié du territoire français. La Houille Blanche. (3), 64-70.

# 2. Data

- Data from CORDEX project (Coordinated Regional Climate Downscaling Experiment, www.cordex.org):
  - 5 RCM (Regionalized Climate Model): HIRHAM-ICHEC, RACMO22-ICHEC, RCA4-CNRM, RCA4-ICHEC and REMO2009-MPI-M.
  - 2 RCP (Representative Concentration Pathway): RCP 4.5 and RCP 8.5
  - 2 future periods: 2046-2065 (named 2065) and 2081-2100 (named 2100) and a reference period 1986-2005 named « historical »
  - Variables: total precipitation “pr”, snow “prsn” and temperature “tas”.
    - Introduction of “pr-liquid” = pr – prsn
    - Calculation of ETP by Oudin *et al.* formula (2005)

- SAFRAN data from Météo France on “historical” period for comparison and bias-correction.



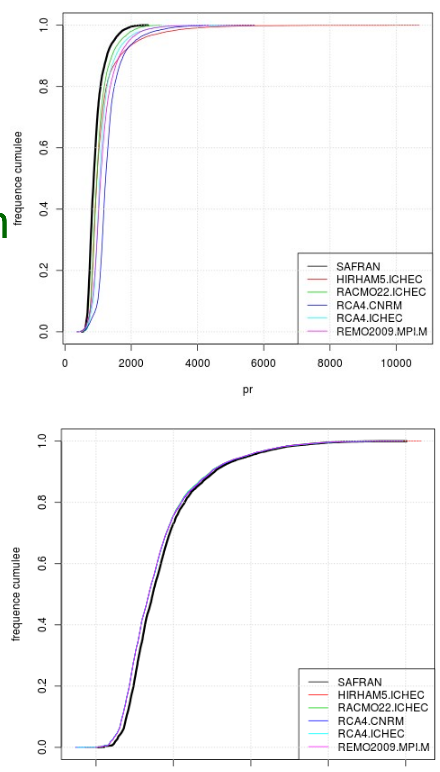

Oudin L., Hervieu F., Michel C., Perrin C., Andréassian V., Anctil, F. et Loumagne,C., 2005. Which potential evapotranspiration input for a rainfall-runoff model? Part 2 - Towards a simple and efficient PE model for rainfall-runoff modelling. Journal of Hydrology, 303(1-4), 290-306.

# 3. Bias correction

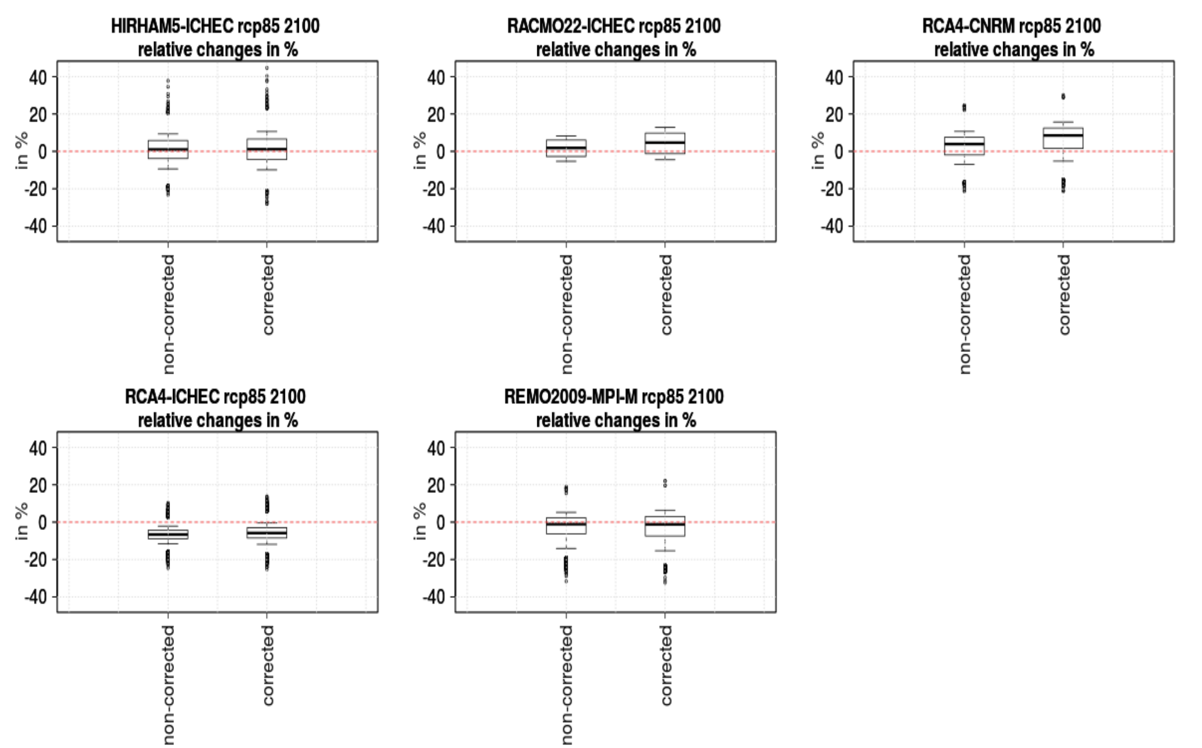
- Quantile-Quantile approach using *biasCorrection* function from R package *downscaleR*. For “pr” and “prsn”, correction taking into account events and no-events with a threshold of 1 mm.
- Control :
  - Bias-corrected model simulations have small bias on all grid points.
  - Relative changes between future and historical on bias-corrected model simulations are consistent with changes for non-corrected model simulations.

Before correction

After correction



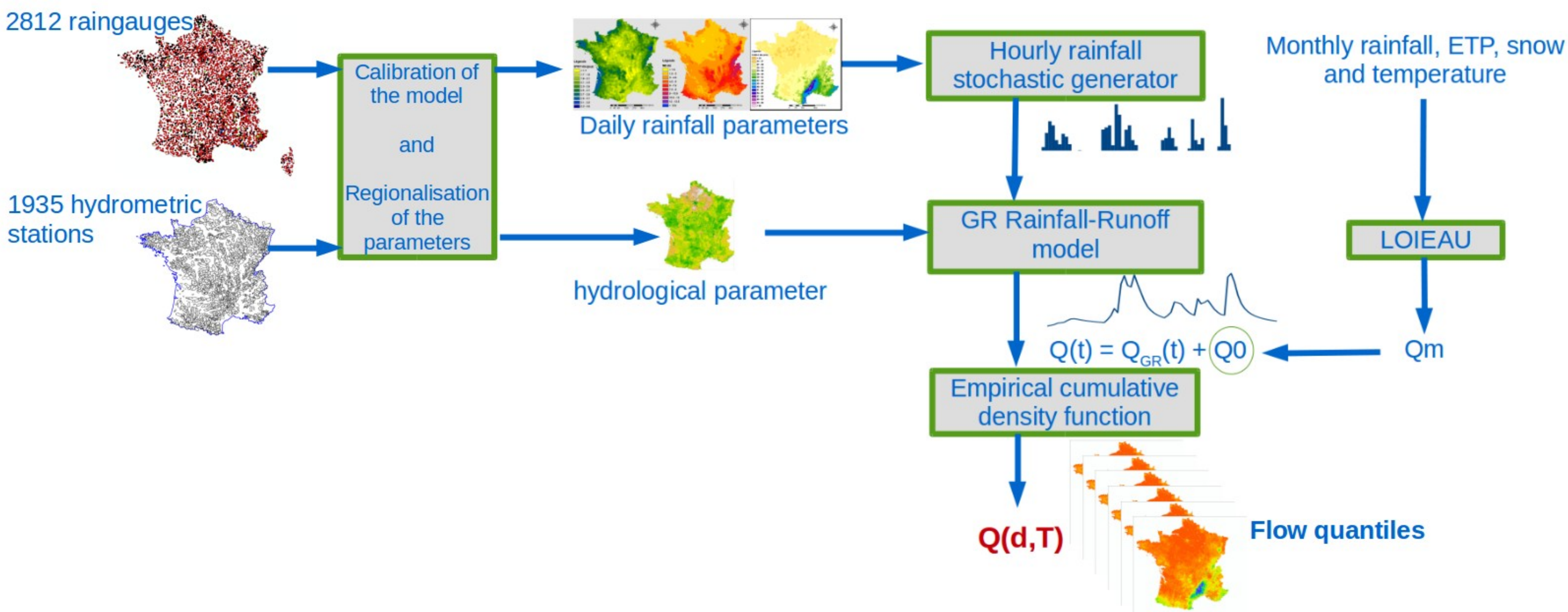

*Cumulative density distribution of average annual “pr” in mm from non-corrected (top) and bias-corrected (bottom) RCM simulations compared to SAFRAN reference*




*Relative changes (in %) of average annual “pr” from non-corrected (top) and bias-corrected (bottom) RCM simulations*

# 4. Climate change in SHYREG method (1/4)

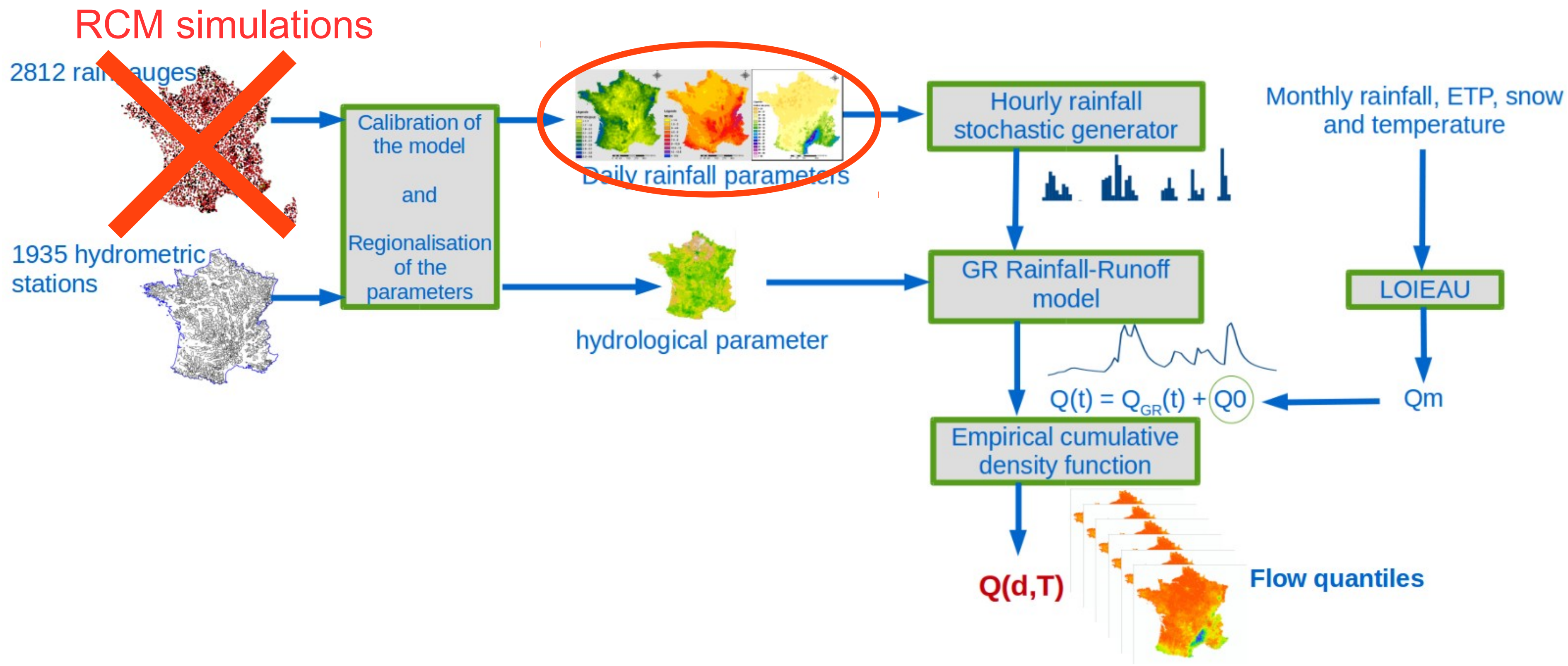
Evolution of:



# 4. Climate change in SHYREG method (1/4)

Evolution of:

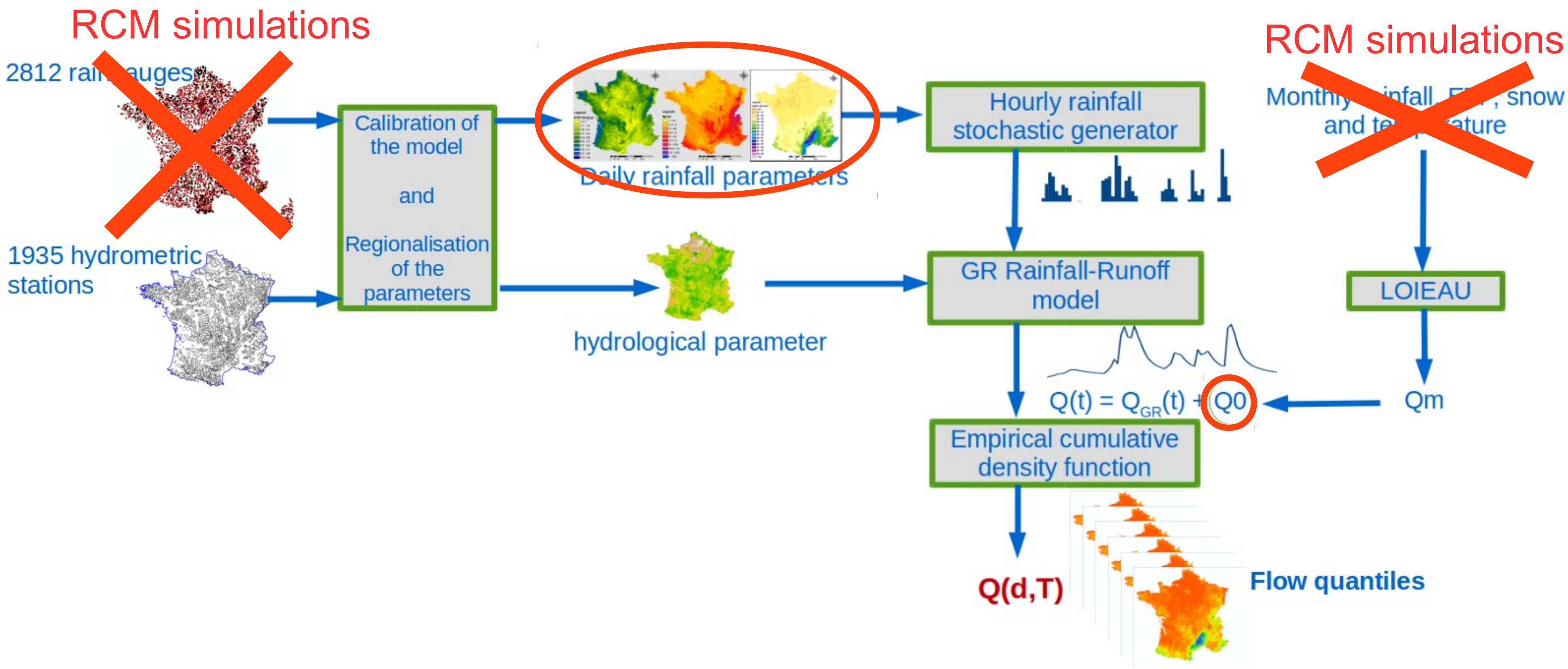
- Hourly rainfall stochastic generator parameters defined from corrected RCM simulations



# 4. Climate change in SHYREG method (1/4)

Evolution of:

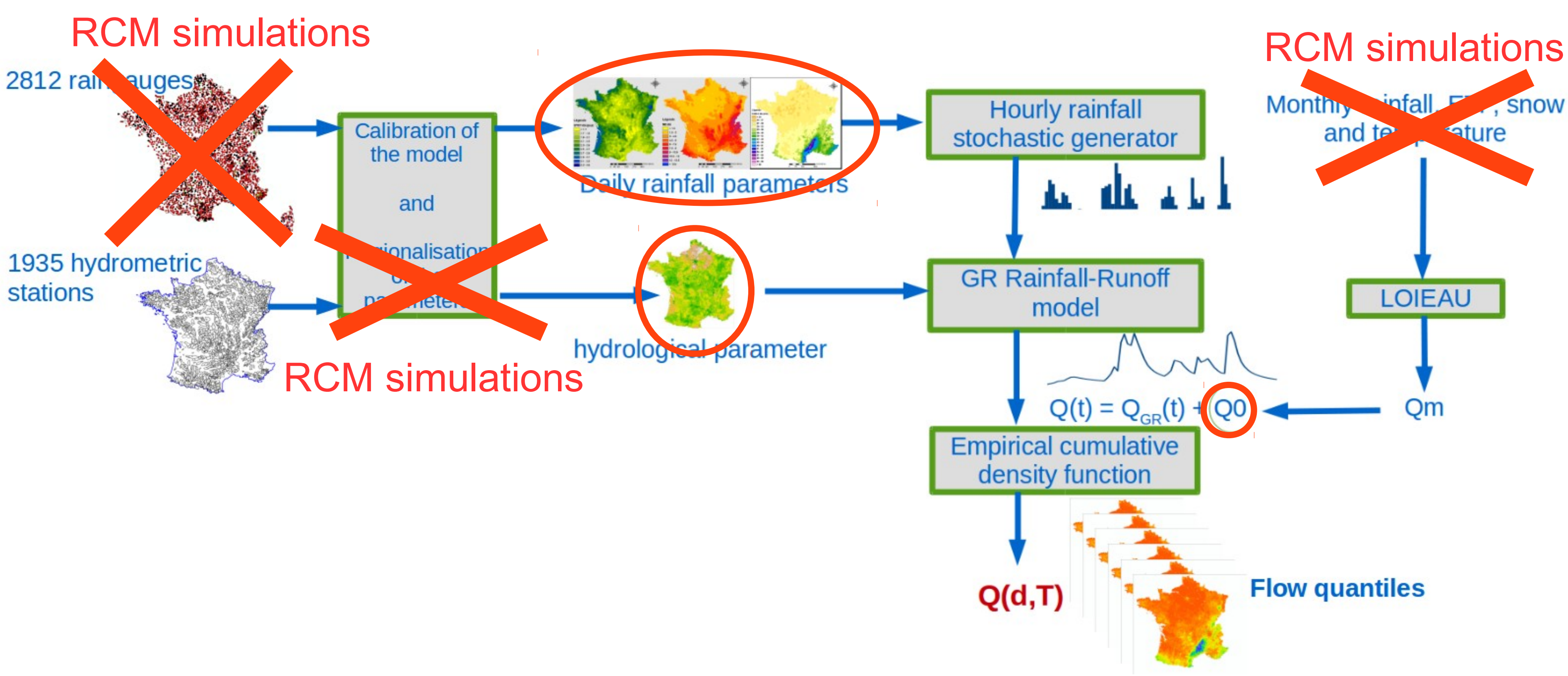
- Hourly rainfall stochastic generator parameters defined from corrected RCM simulations
- “Base flow”: from LOIEAU



# 4. Climate change in SHYREG method (1/4)

Evolution of:

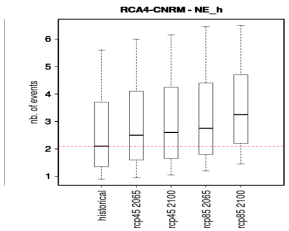
- Hourly rainfall stochastic generator parameters defined from corrected RCM simulations
- "Base flow": from LOIEAU
- Hydrologic parameter due to soil moisture evolution.

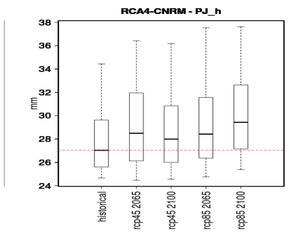


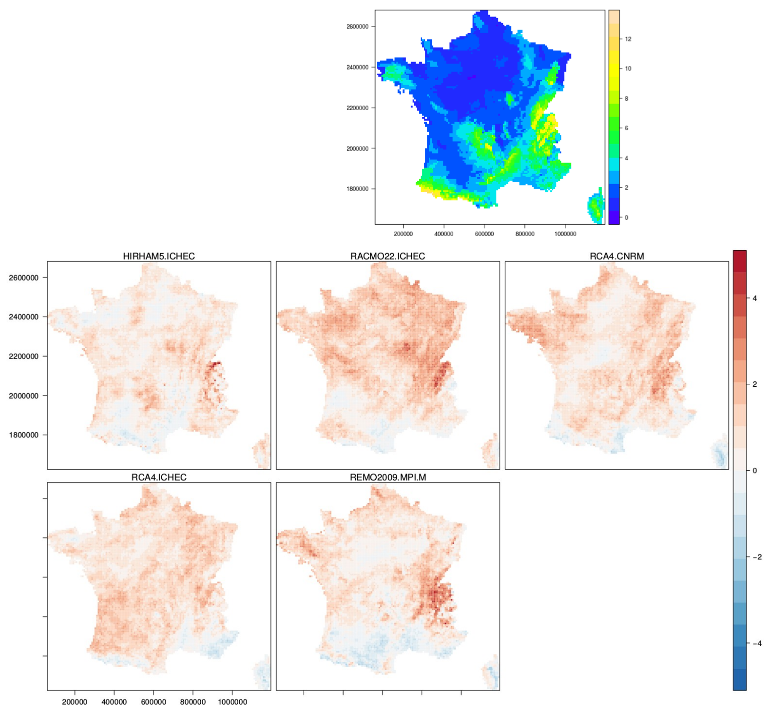
# 4. Climate change in SHYREG method (2/4)

Evolution of:

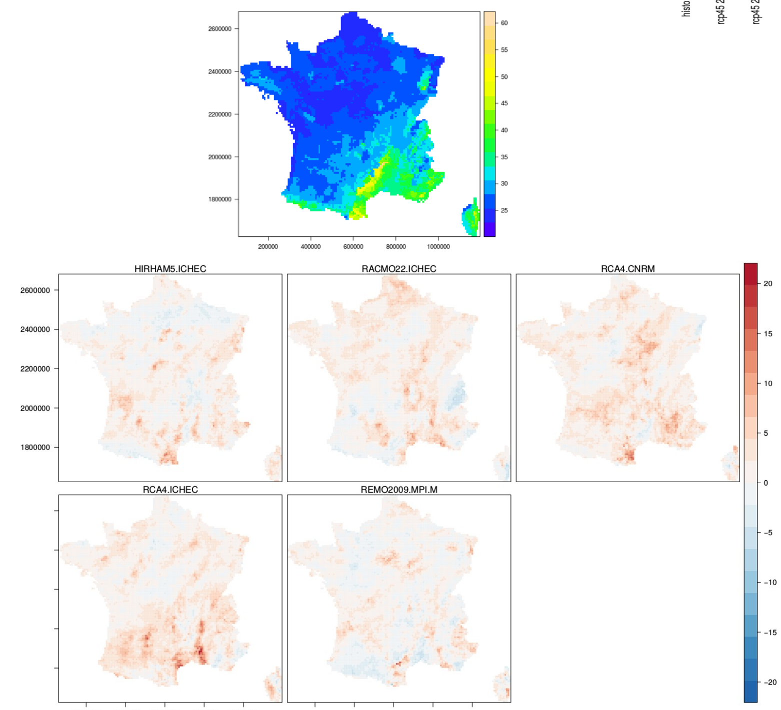
- Hourly rainfall stochastic generator parameters
  - ➔ **Frequency**:
    - ✗ General increase for the different RCP and the different scenarios
    - ✗ except around Mediterranean coast for RCP 8.5 - 2100
    - ✗ Variability of changes depending on the different RCM
  - ➔ **Intensity**:
    - ✗ General **increase of changes,**
    - ✗ **heterogeneous** spatially and depending on the different RCM, especially on Mediterranean area.




***Changes in the frequency** of rainfall events (nb. of events): future (RCP 8.5 – 2100) minus “historical”*

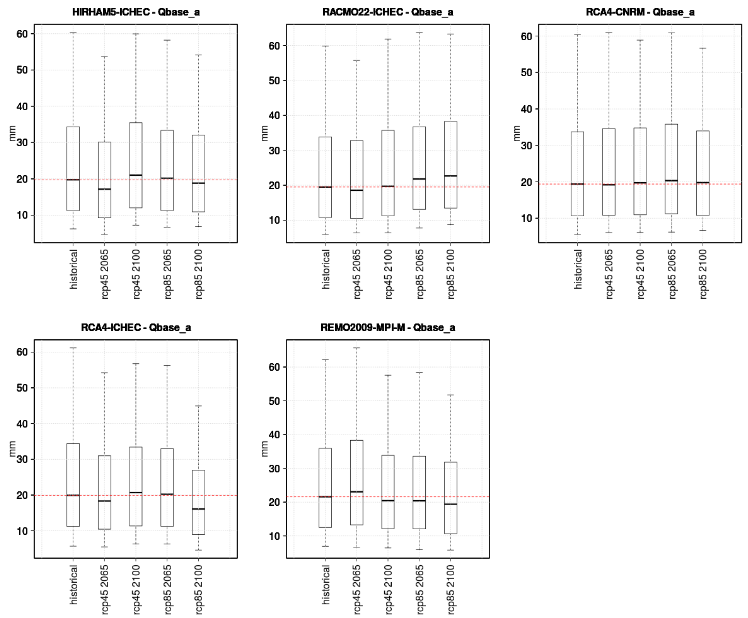



***Changes in the intensity** of rainfall events in mm: future (RCP 8.5 – 2100) minus “historical”*

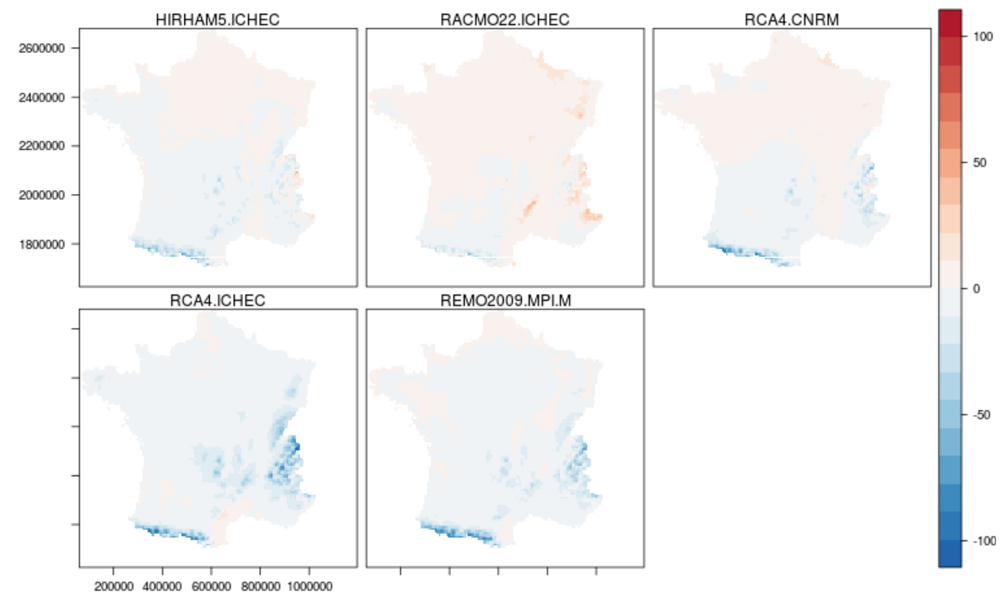
# 4. Climate change in SHYREG method (3/4)

Evolution of:

- "Base flow"
  - Variables trends depending on RCP and periods,
  - RCP 8.5 – 2100: general increase of "base flow" in the North and decrease in the South




***"Base flow"** : average monthly specific discharge in mm for each RCM and for different RCP and periods*

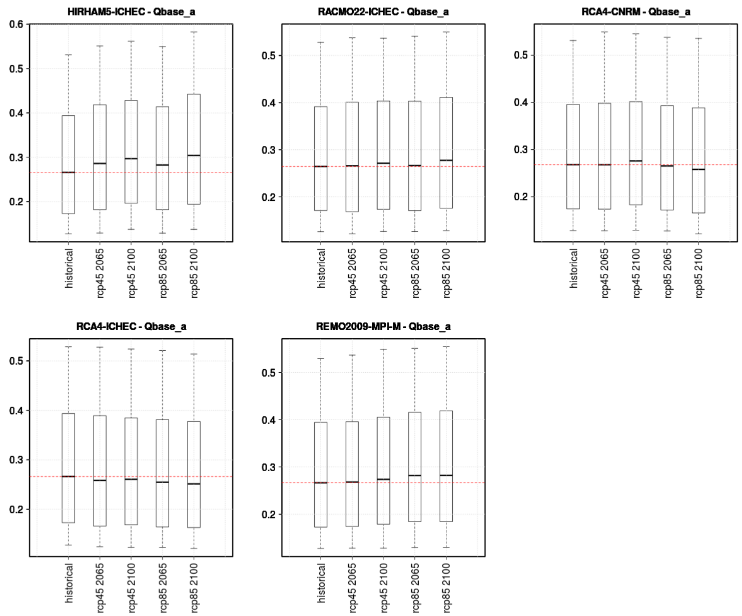



***Changes in "base flow"** in mm:*
*future (RCP 8.5 – 2100) minus "historical"*

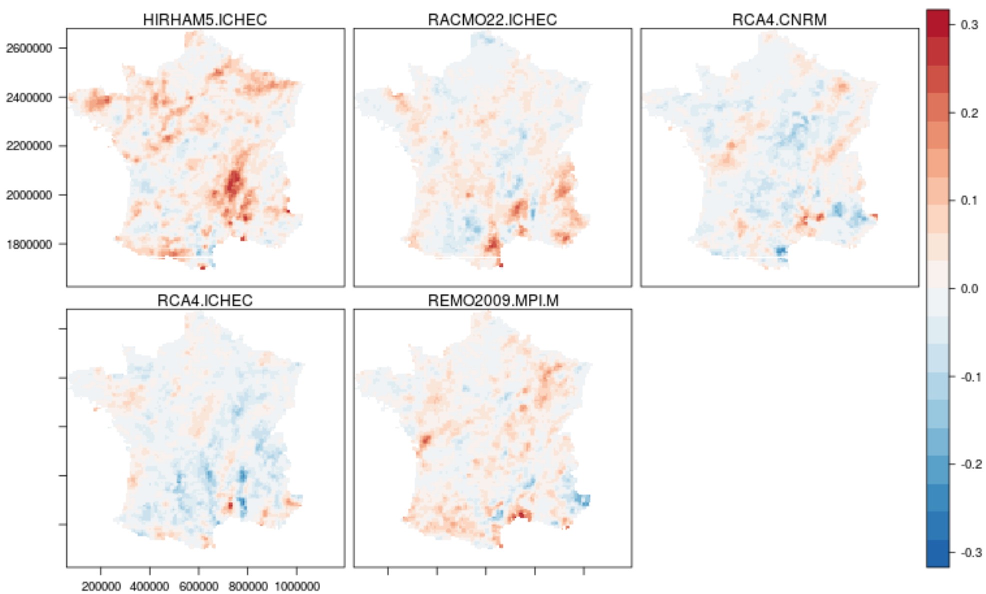
# 4. Climate change in SHYREG method (4/4)

Evolution of:

- Hydrologic parameter: statistical indicator of soil moisture conditions included between 0 (dry soil) and 1 (saturated soil)
    - Important spatial variability in changes and heterogeneity according to the different RCM



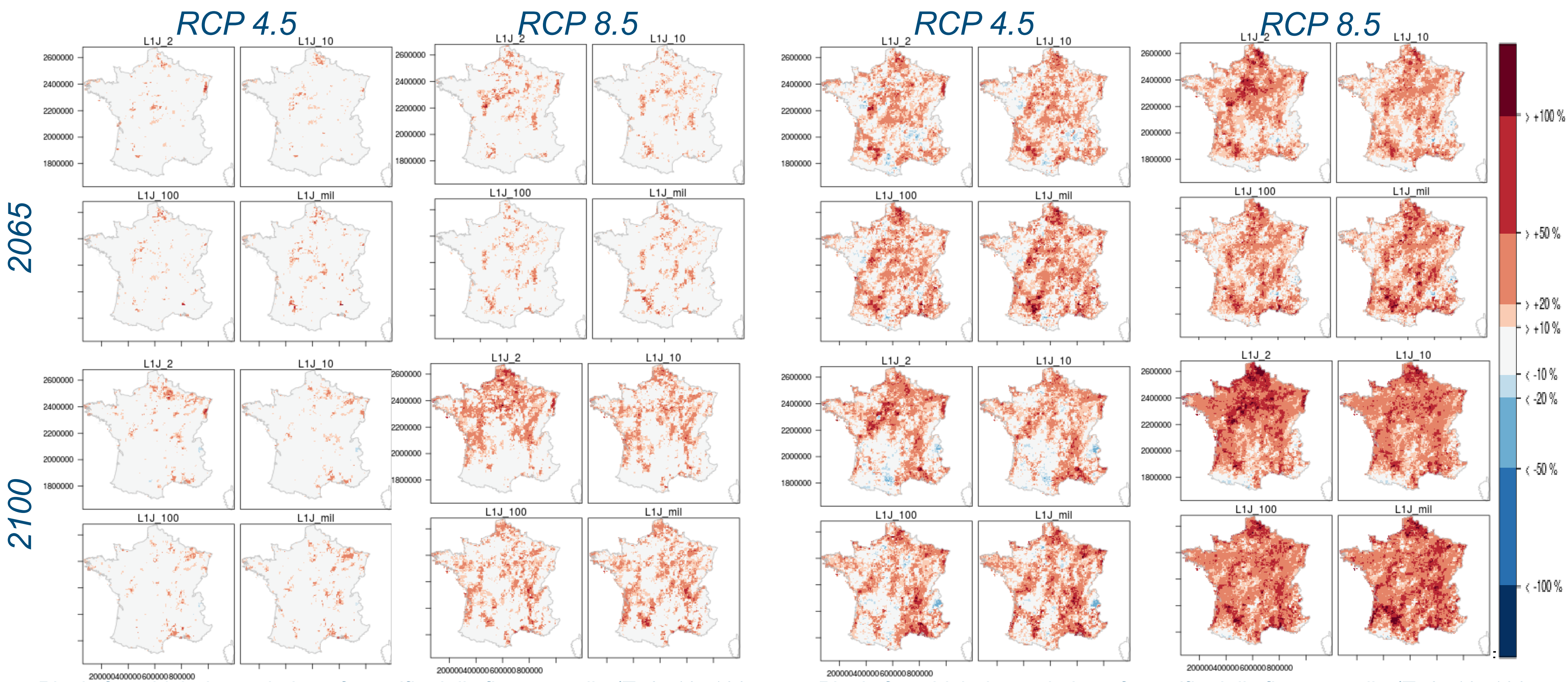

***Hydrological parameter** for each RCM and for different RCP and periods*




***Changes in hydrological parameter**:*
*future (RCP 8.5 – 2100) minus "historical"*

# 5. Impact on specific daily flow quantiles

- General increase of specific flow quantiles. This trend is geographically variable and depends on the RCM.
- Mediterranean area:
  - the majority of the RCM induces an increase of flow quantiles with maximum trends around Languedoc and Bouches-du-Rhône,
  - trend is not much significant in the extreme South East of the Mediterranean French coast.




*Pixels for which the variation of specific daily flow quantile (T=2, 10, 100 and 1000 years) is upper than x% or lower than -x% for the 5 RCM*

*Pixels for which the variation of specific daily flow quantile (T=2, 10, 100 and 1000 years) is upper than x% or lower than -x% for 3 out of 5 RCM*

# 6. Conclusion

A general increase of flow quantile over France mainly due to changes in the characteristics of rainfall events (more frequent and more intense).

Geographical variability of the trends and uncertainty (climate modelling, downscaling method, bias correction...).

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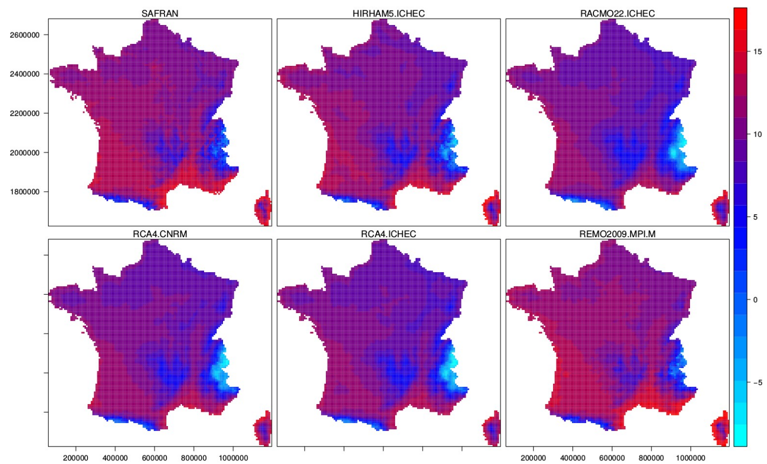
**Further developments:**

- Working with a large number of RCM for more robust results (computing power).
- Taking into account:
  - scenarios of land use changes,
  - accumulation and melt of glaciers.

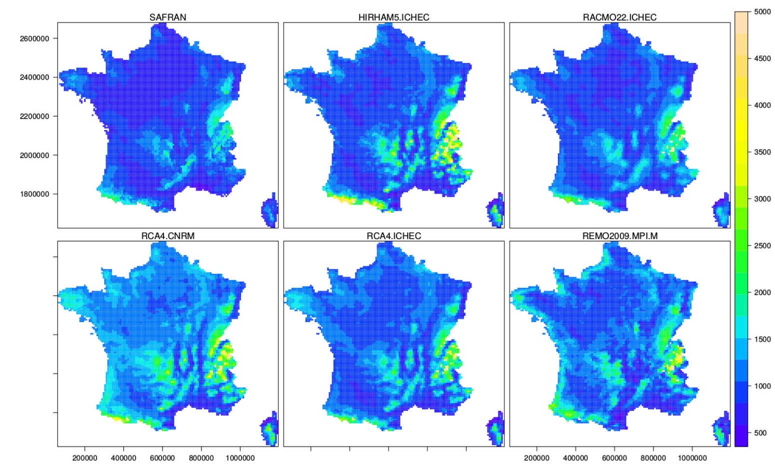
Thank you for your attention...

# 2. Data

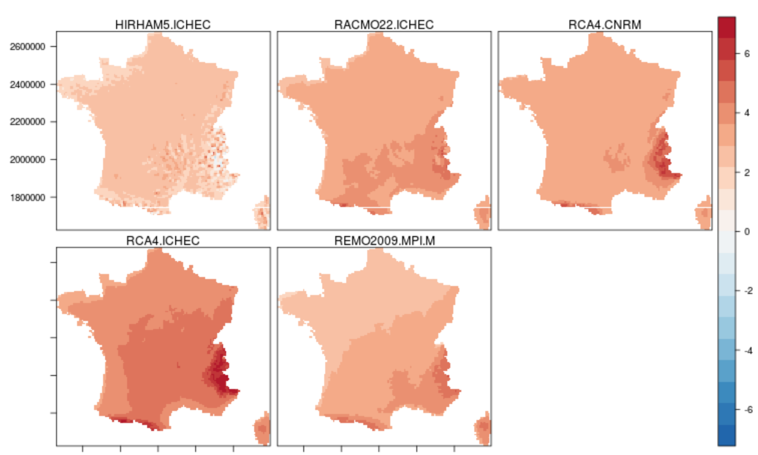
- Variability of “historical” values and changes depending on the different RCM
- “historical” period: difference between RCM simulated variables and SAFRAN



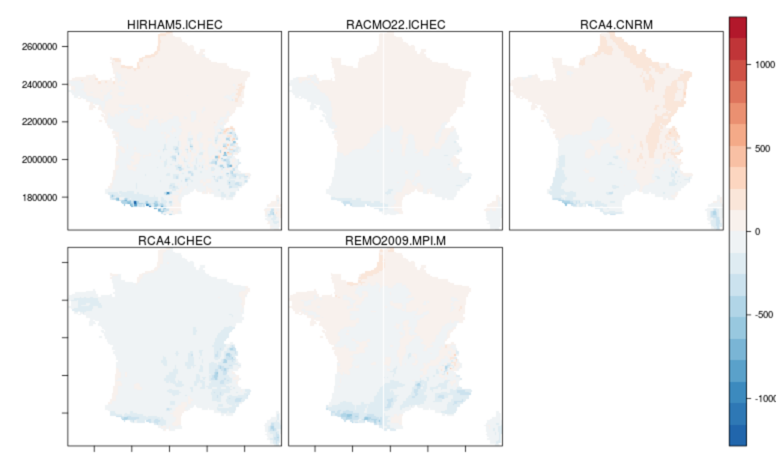

average annual temperature in °C, “historical” period




average annual “pr” in mm, “historical” period




Changes of average annual temperature in degrees: future (RCP 8.5 – 2100) minus “historical”

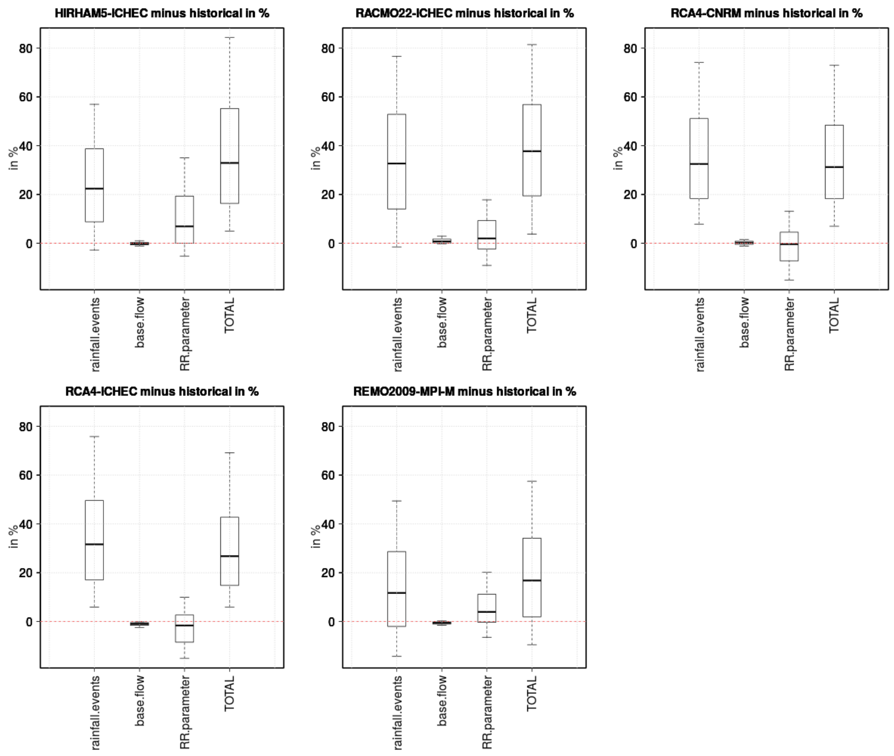



Changes of average annual “pr” in mm: future (RCP 8.5 – 2100) minus “historical”

# 5. Impact on specific daily flow quantiles

Each factor of changes (rainfall events, base flow and hydrological parameter) is applied independently and commonly

- Significant impact of changes in the characteristics of rainfall events : **increase** of 10-years return period daily quantiles,
- Little impact of changes in hydrologic parameter and moreover in “base flow”. Variable trend according to the different RCM.




*Changes in specific daily flow of 10-years return period according to the different influences.*
*future (RCP 8.5 – 2100) minus “historical”*