



Impact of climate change on the French part of the River Meuse - the CHIMERE 21 project

Guillaume Thirel, Lila Collet, Fabienne Rousset, Olivier Delaigue, Didier Francois, Joël Gailhard, Matthieu Le Lay, Charles Perrin, Mathieu Reverdy, Raphaëlle Samacoits, et al.

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➤ Impact of climate change on the French part of the River Meuse -the CHIMERE 21 project

AG HYCAR 27 septembre 2021

➤ Context and goals of the project

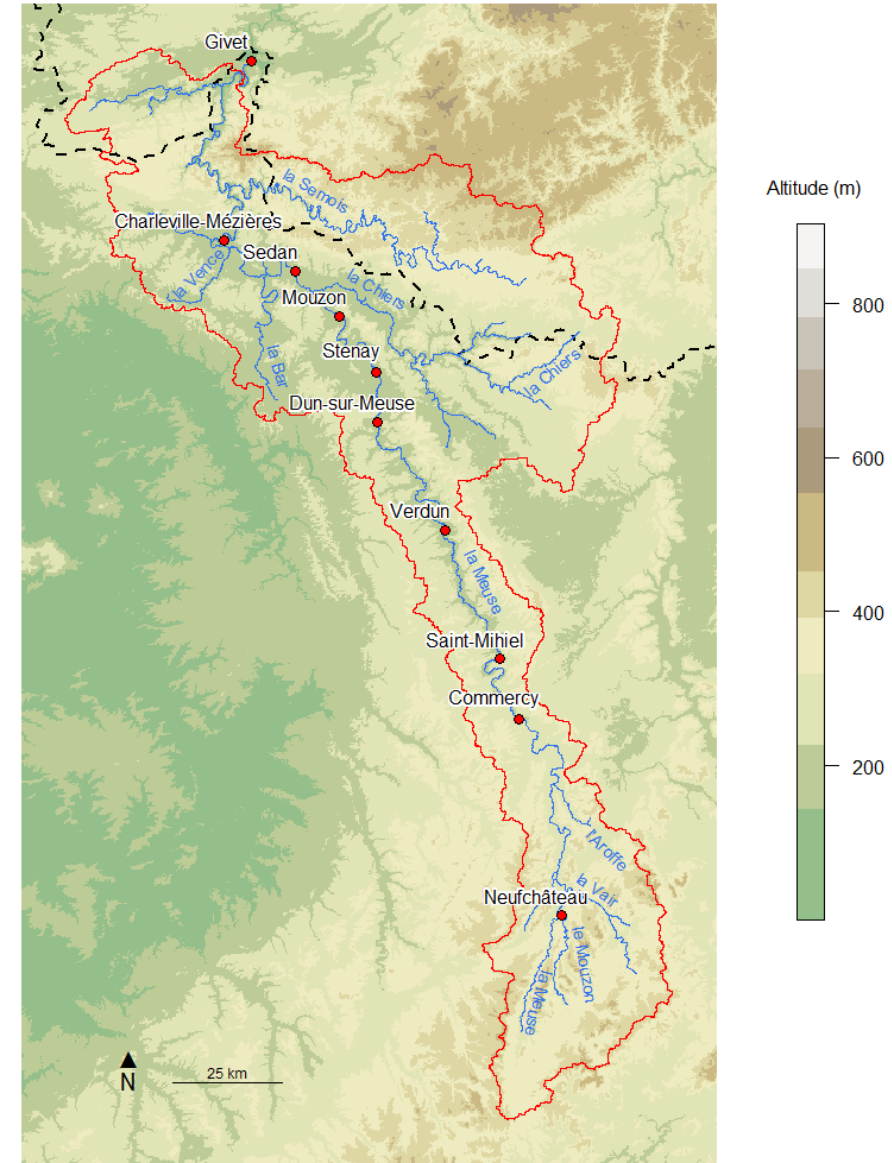
➤ The CHIMERE 21 project

CHlers - MEuse: hydrological Regime Evolution in the 21st century

Topic of the project: Study of the impact of climate change on the streamflows of the Chiers and Meuse Rivers

Partners: INRAE (formerly Irstea), Météo-France, EDF, Université de Lorraine, DREAL Grand-Est

Funding by Agence de l'Eau Rhin-Meuse



> The context

CHlers - MEuse: hydrological Regime Evolution in the 21st century

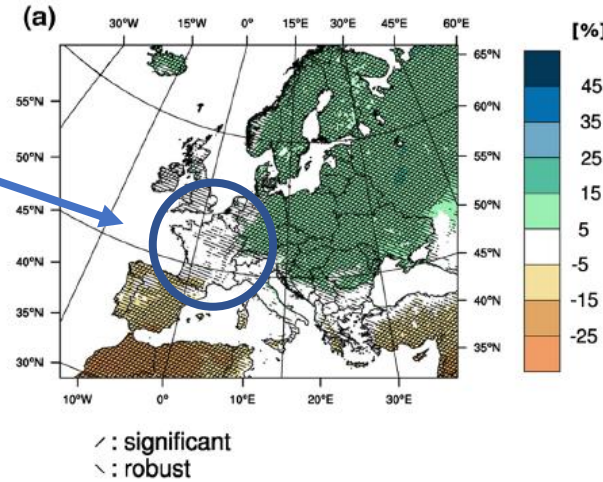
Global scale evolutions need to be refined at the local scale through specific studies

Past studies:

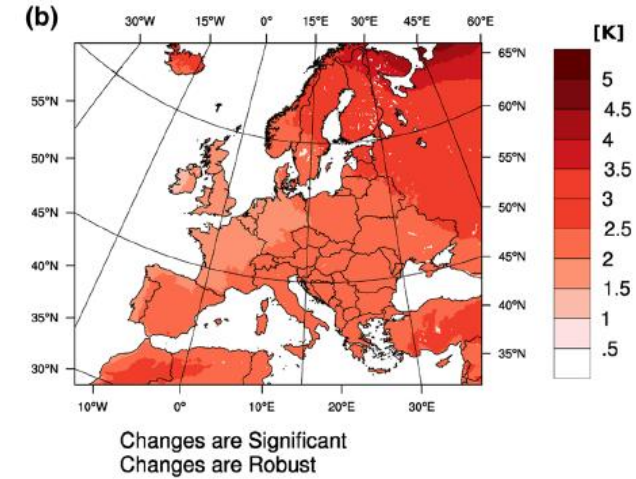
- Explore 2070: France-wide project
- Amice: Meuse-wide project

Jacob et al. (2013)

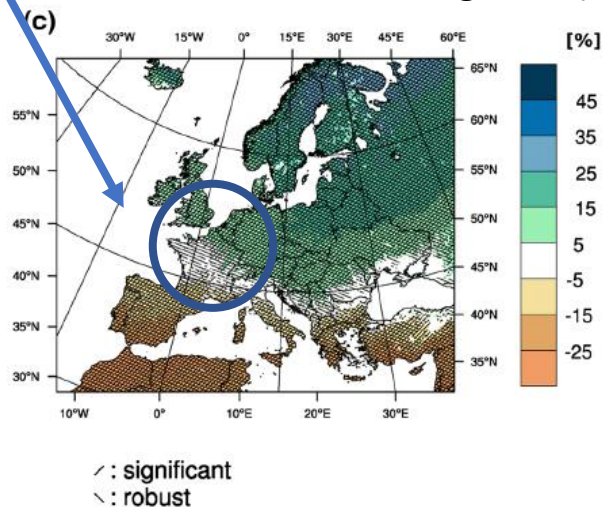
Intermediate scenario (P)



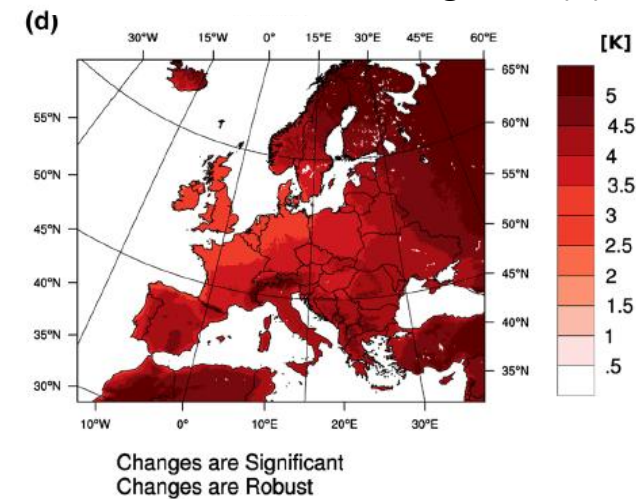
Intermediate scenario (T)



Scenario without mitigation (P)



Scenario without mitigation (T)



Mean evolution of precipitation (left) and air temperature (right) by 2071-2100

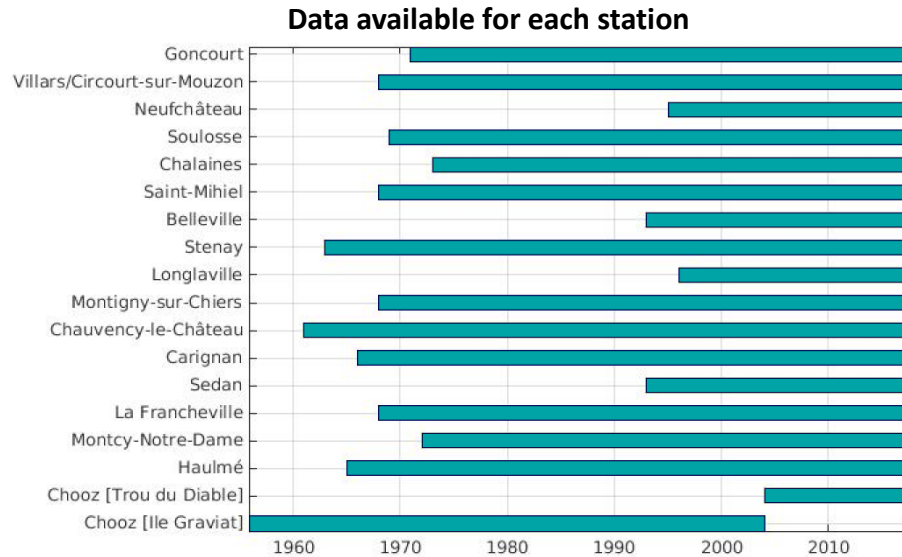
➤ Objectives of CHIMERE 21

Objectives of the project:

- Study of the impact of climate change on future Meuse streamflows (Explore 2070 and Amice are beginning to be old)
- Focus on uncertainties and low flows
- Production of synthetic sheets

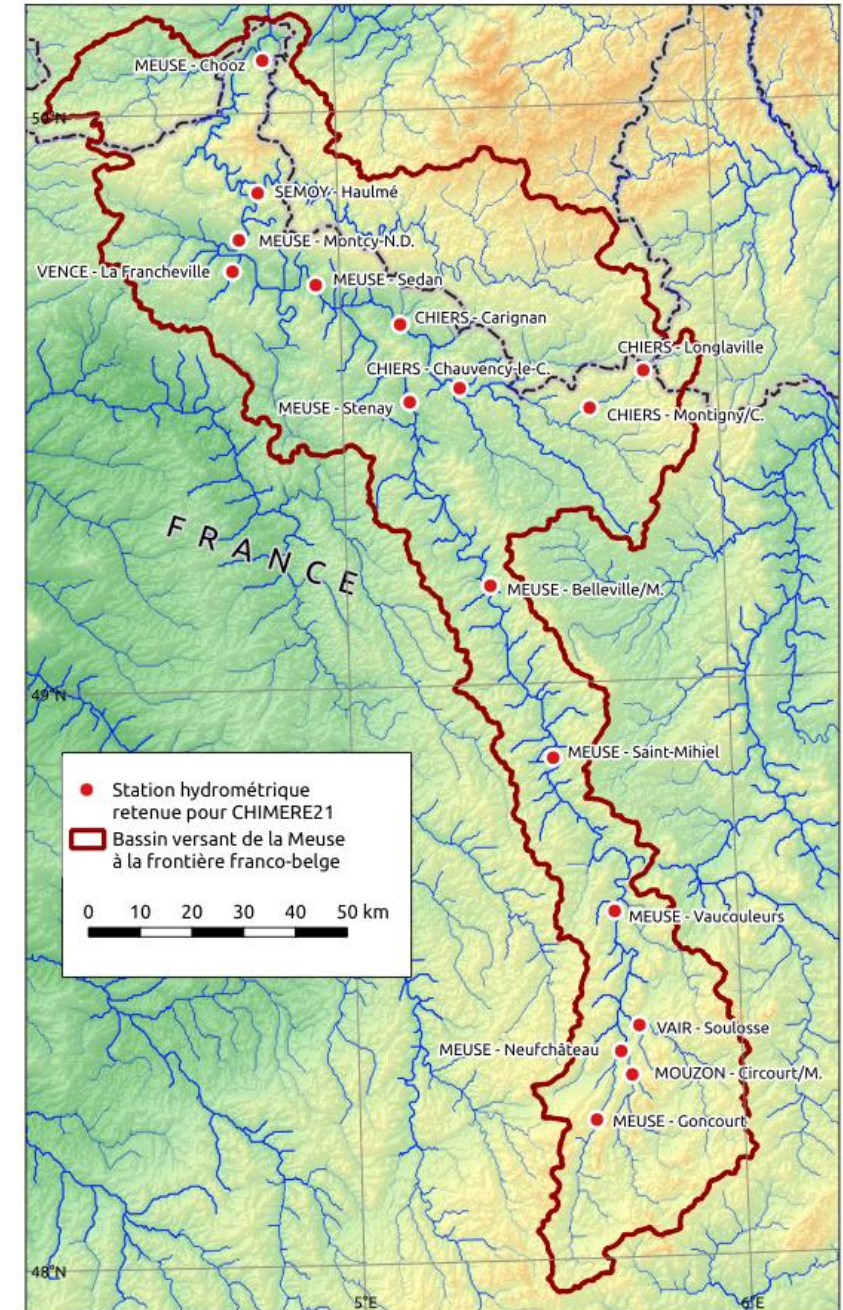
➤ Presentation of the basin and data

➤ Hydro data



➤ 16 stations (one for around 480 km²)

- Dubious daily discharge values removed through visual inspection
- At Chooz, the evaporation water consumption was estimated using daily air temperature and the nuclear power plant charge
- Other influences were not removed from time series:
 - Either low impact at the basin scale
 - Or too much uncertainty so data were just discarded



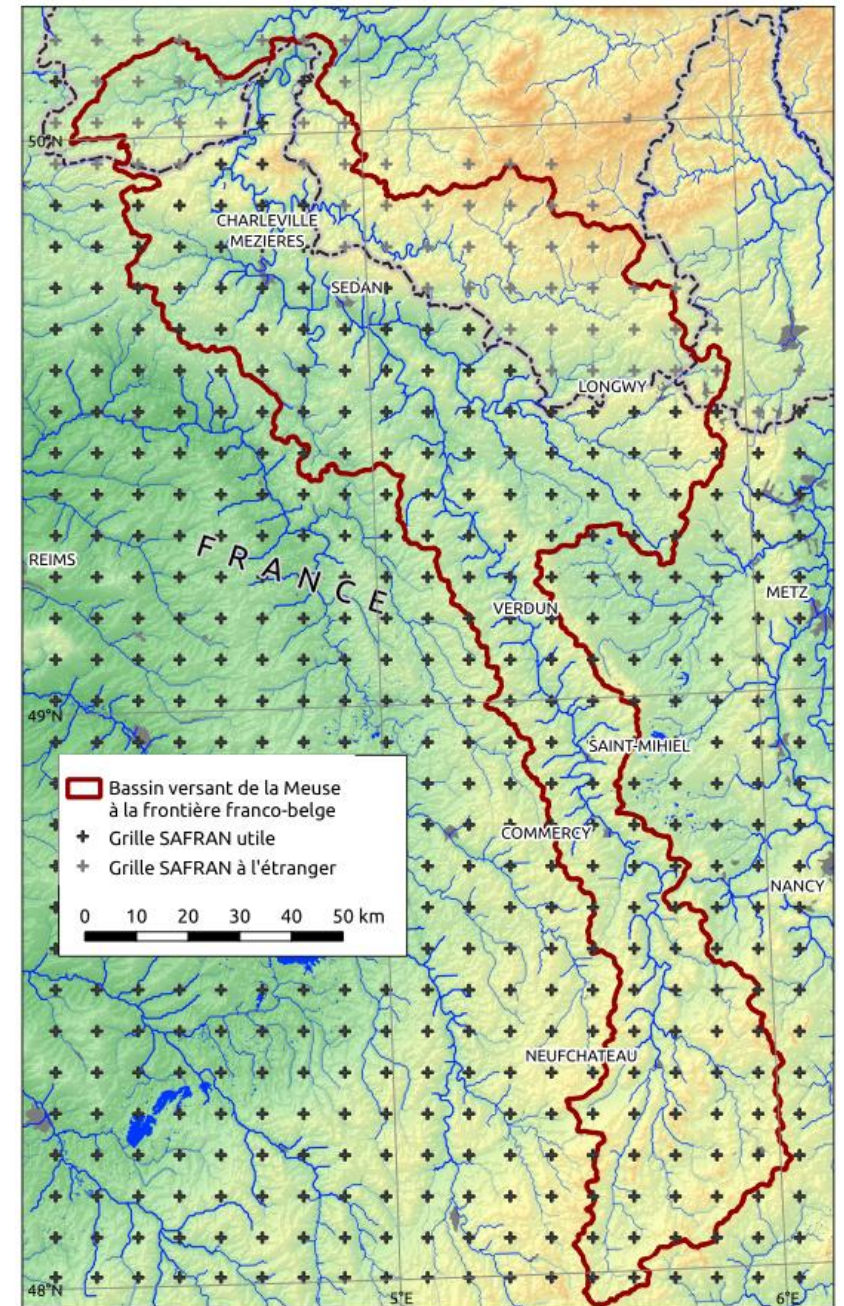
➤ Observed meteo data

Météo-France SAFRAN reanalysis: combination between observed in situ data and model simulations

➤ Spatialised data on a regular grid: 8 km x 8 km

➤ Daily data

- Potential evapotranspiration = Penman-Monteith (using SAFRAN variables)



➤ Climate change over the Meuse basin

➤ Climate change over the Meuse basin

Modelling chain: composed of several steps

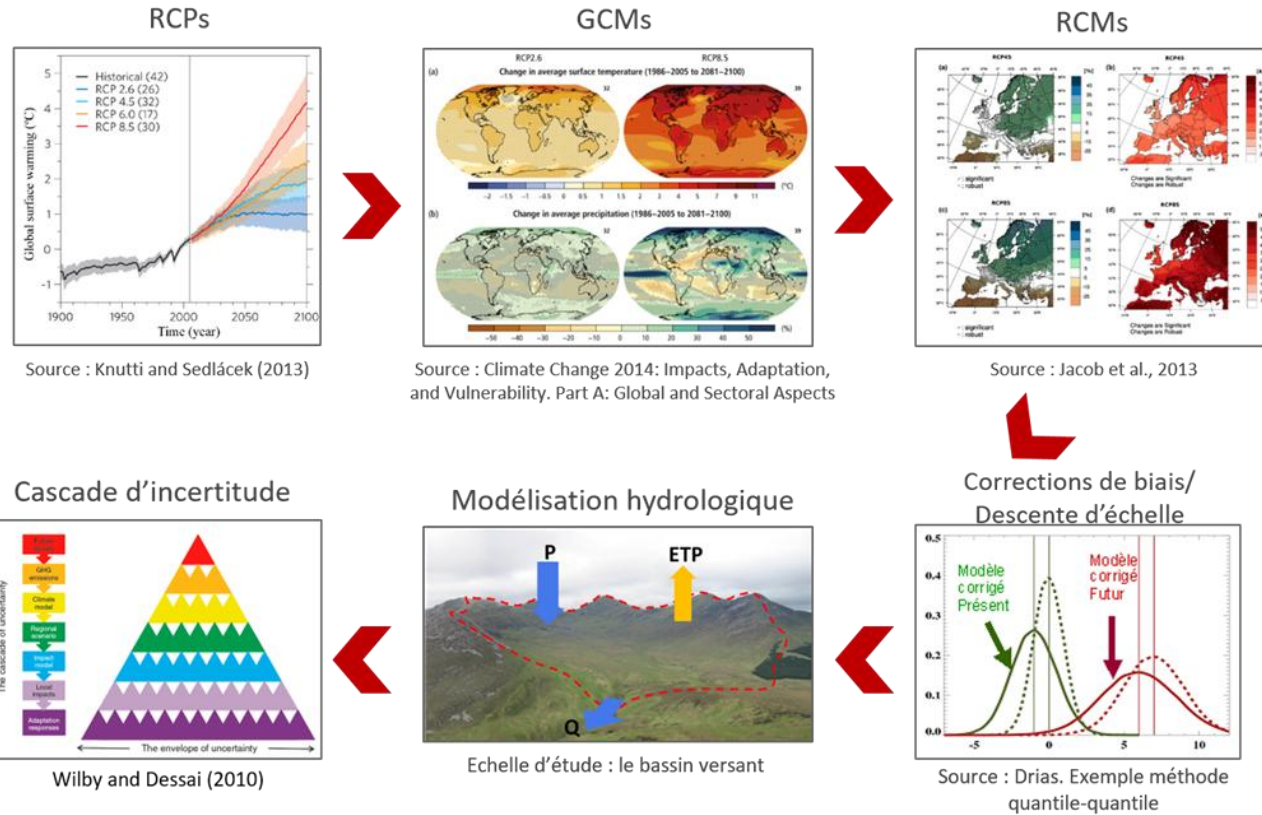
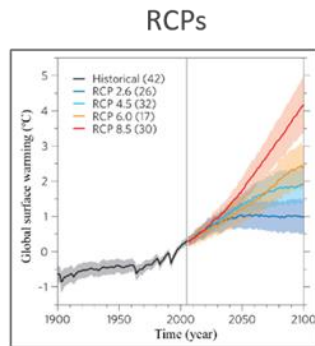


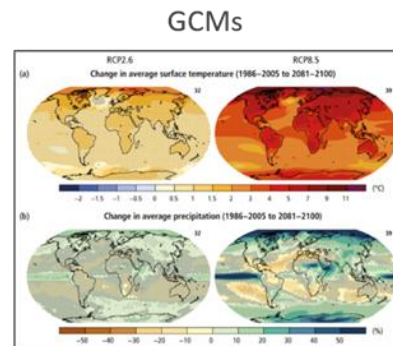
Figure from Lemaitre-Basset (2020)

➤ Climate change over the Meuse basin

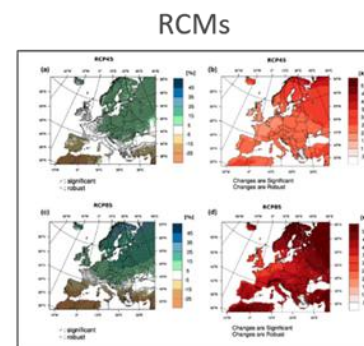
Selection of climate data for CHIMERE 21:



Source : Knutti and Sedláček (2013)



Source : Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects



Source : Jacob et al., 2013

.RCP 4.5

.RCP 8.5

| | GCM | RCM |
|----------|-----------|------------------|
| Couple 1 | CNRM-CM5 | ALADIN53 |
| Couple 2 | IPSL-CM5A | IPSL-INNERIS-WRF |
| Couple 3 | CNRM-CM5 | RCA4 |
| Couple 4 | IPSL-CM5A | RCA4 |
| Couple 5 | MPI-ESM | RCA4 |

3 different GCMs, 3 different RCMs

➤ Climate change over the Meuse basin

Seasonal climate evolution

| Summer (all models and RCPs) | Temperatures | Precipitation |
|---------------------------------|-------------------|---------------|
| Near future | + 0,4 to + 1,2 °C | -14 to + 23 % |
| Far future | + 1 to + 4,4 °C | -39 to + 21 % |

| Winter (all models and RCPs) | Temperatures | Precipitation |
|---------------------------------|-------------------|----------------|
| Near future | + 0,8 to + 1,5 °C | + 1 to + 35 % |
| Far future | + 1,8 to + 4,4 °C | + 18 to + 57 % |

Large uncertainty

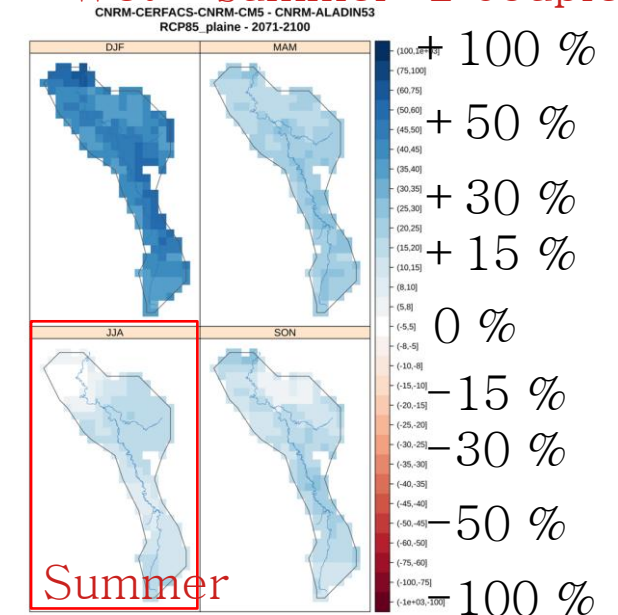
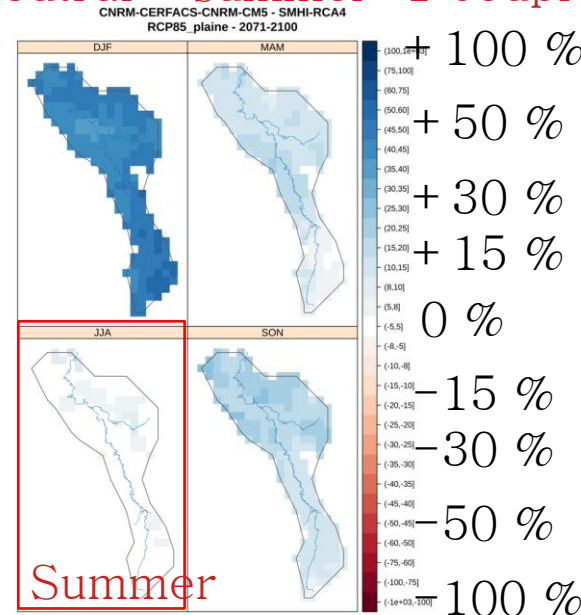
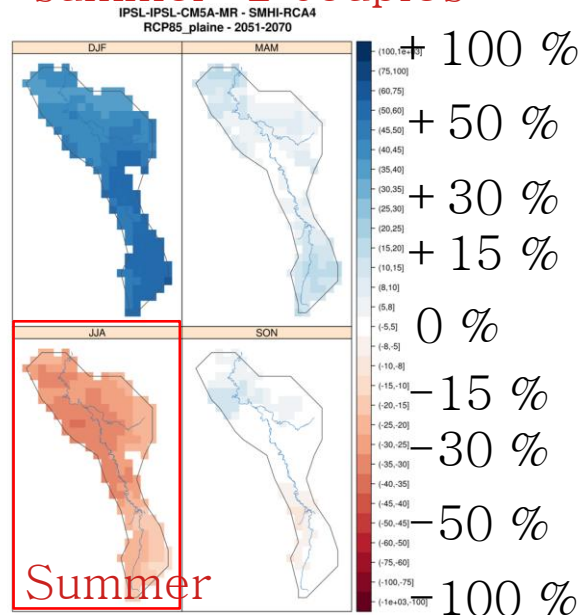
« Dry » summer: 2 couples

« Neutral » summer: 1 couple

« Wet » summer: 2 couples

Far future
RCP 8.5

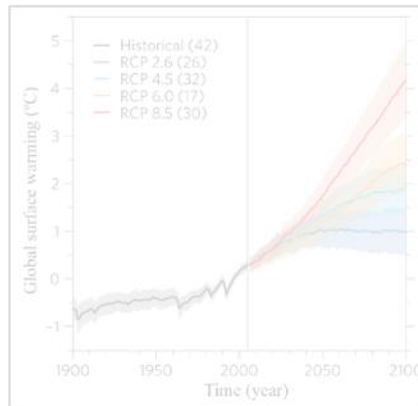
Difference related to
the historical period



➤ Hydrological modelling

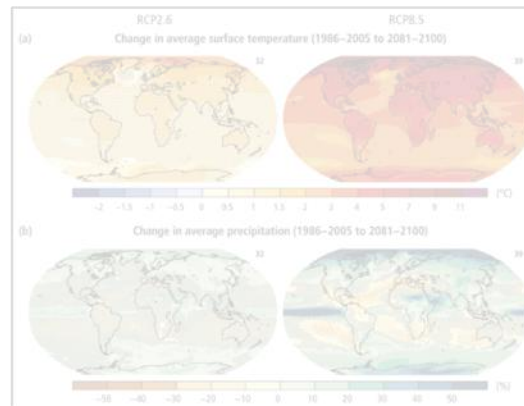
➤ Hydrological modelling

RCPs



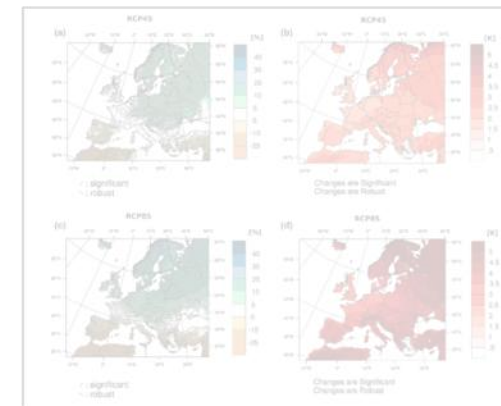
Source : Knutti and Sedláček (2013)

GCMs



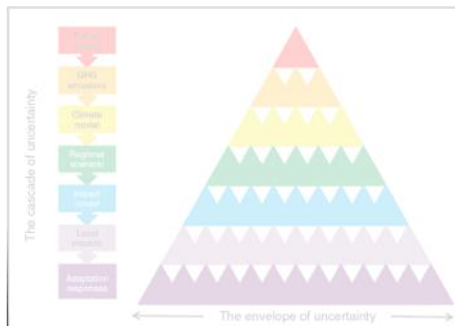
Source : Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects

RCMs



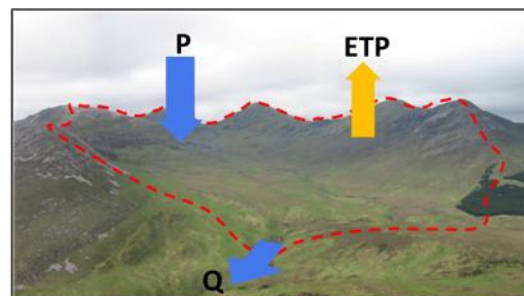
Source : Jacob et al., 2013

Cascade d'incertitude



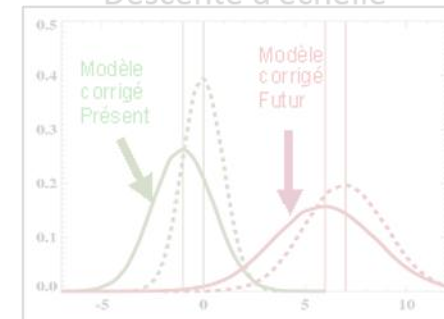
Wilby and Dessai (2010)

Modélisation hydrologique



Echelle d'étude : le bassin versant

Corrections de biais/
Descente d'échelle



Source : Drias. Exemple méthode quantile-quantile

Figure from Lemaitre-Basset (2020)

➤ Hydrological modelling

Four hydrological models

Several models are necessary to verify to which extent all models provide similar trajectories



Conceptual
Semi-distributed
(sub-basins)



Conceptual
Semi-distributed
(sub-basins)



Conceptual
Lumped

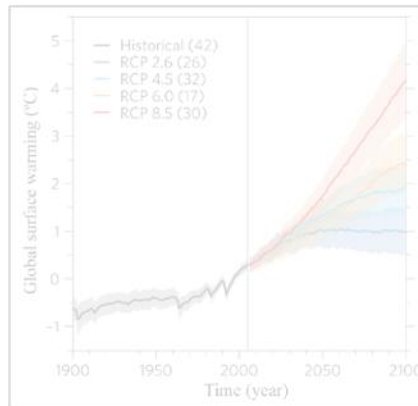


Physically-based
Distributed
(regular grid)

➤ Impact of climate change on hydrology

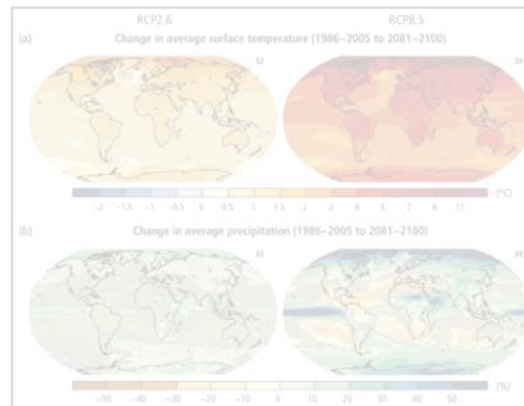
➤ Impact of climate change on hydrology

RCPs



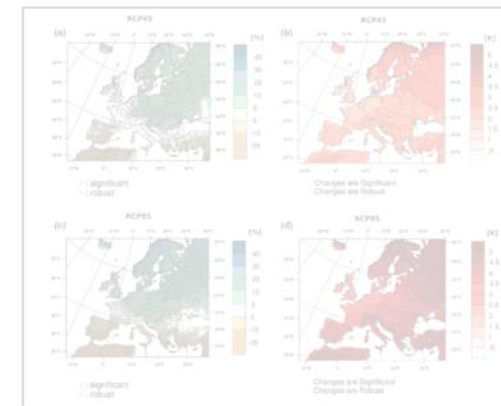
Source : Knutti and Sedláček (2013)

GCMs



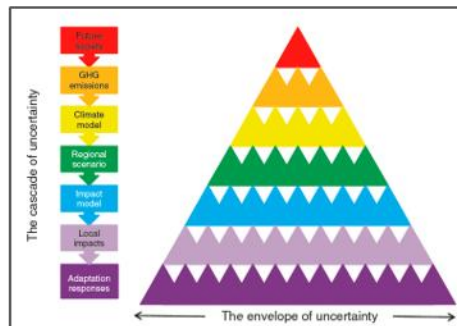
Source : Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects

RCMs



Source : Jacob et al., 2013

Cascade d'incertitude



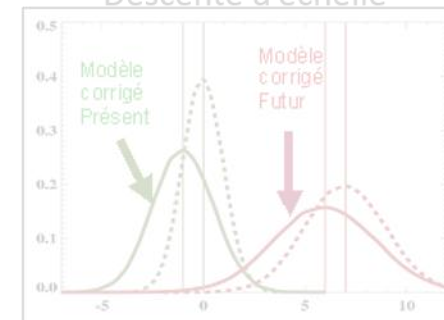
Wilby and Dessai (2010)

Modélisation hydrologique



Echelle d'étude : le bassin versant

Corrections de biais/
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Source : Drias. Exemple méthode quantile-quantile

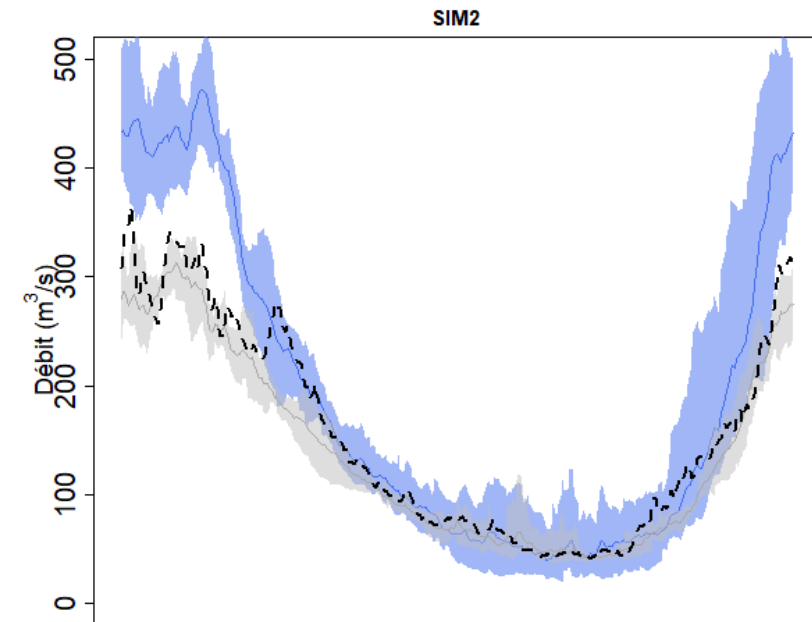
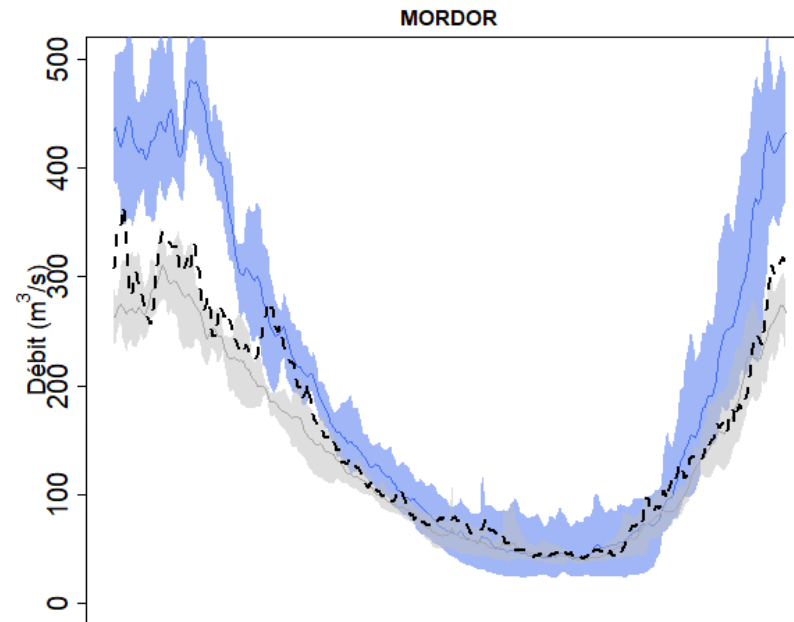
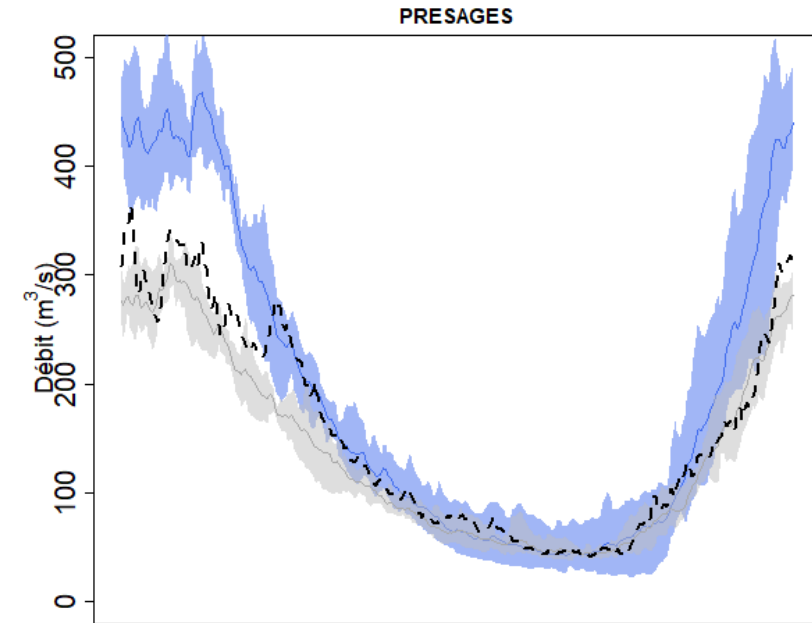
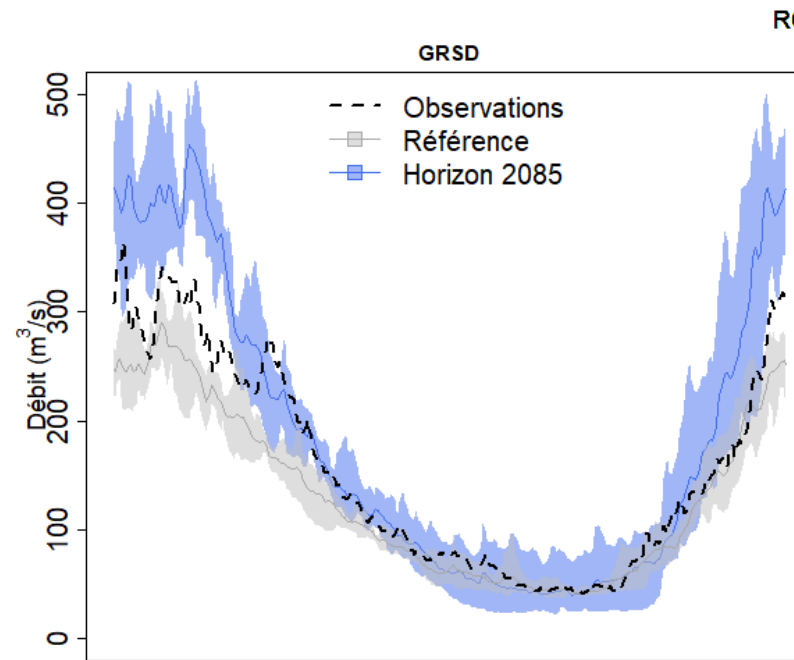
➤ Future regimes

RCP 8.5, Horizon 2071-2100

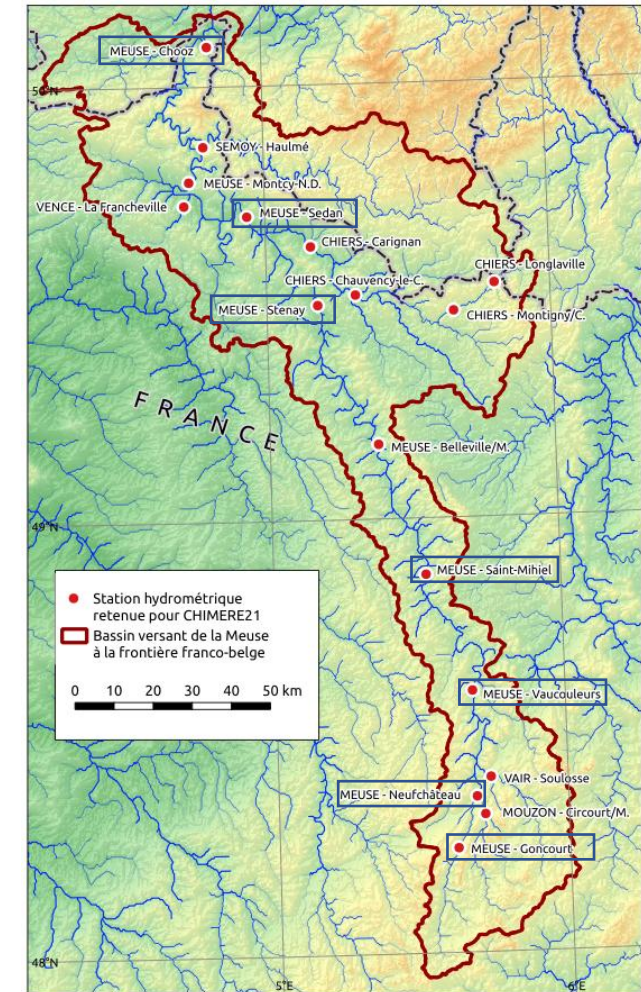
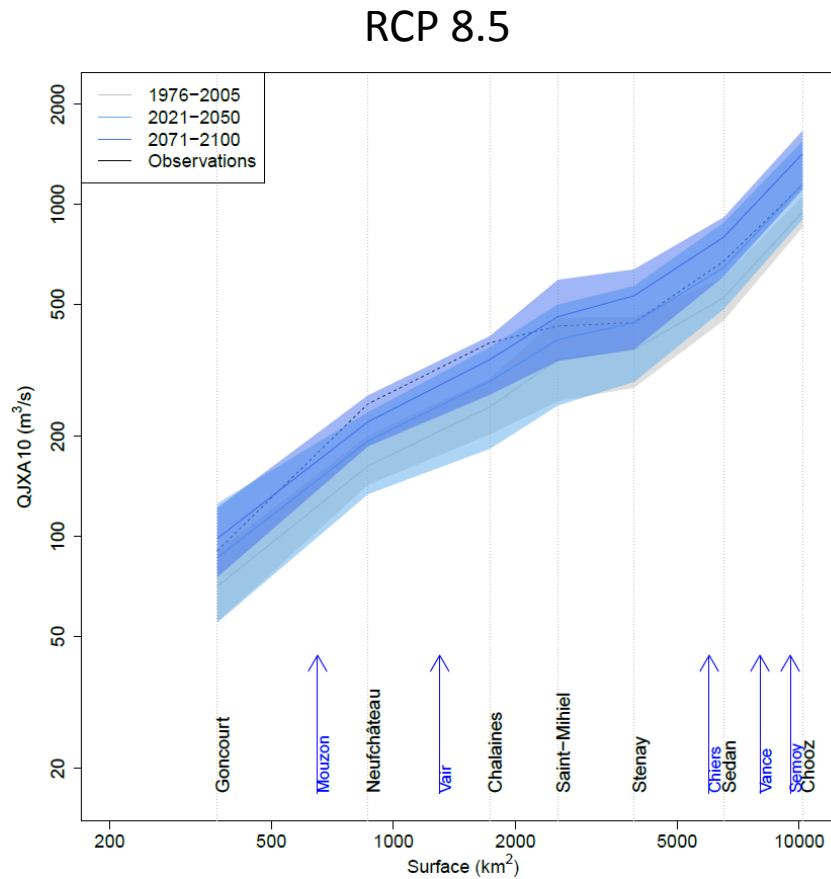
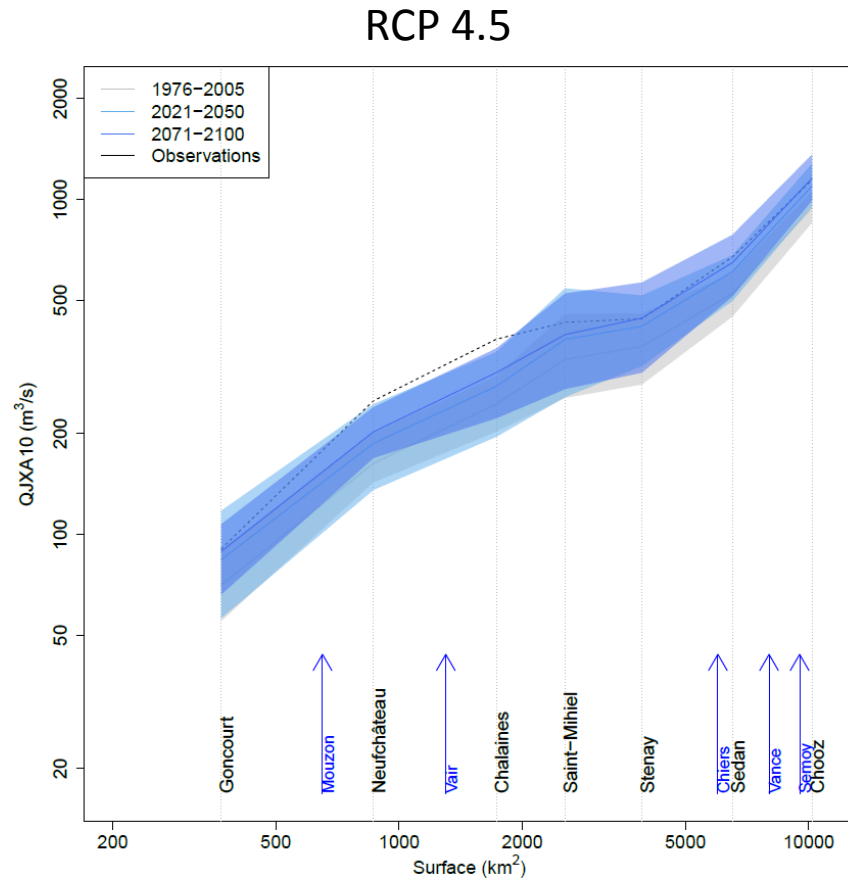
Analysis of future regimes (all climate models included) at Chooz

Large increase of streamflows during the high flow period

Large uncertainty of low flows



➤ Evolution of high flows along the Meuse



RCP 4.5: moderate increase (only for the far future)
 RCP 8.5: important increase, especially downstream

➤ Hierarchy of uncertainties for low flows

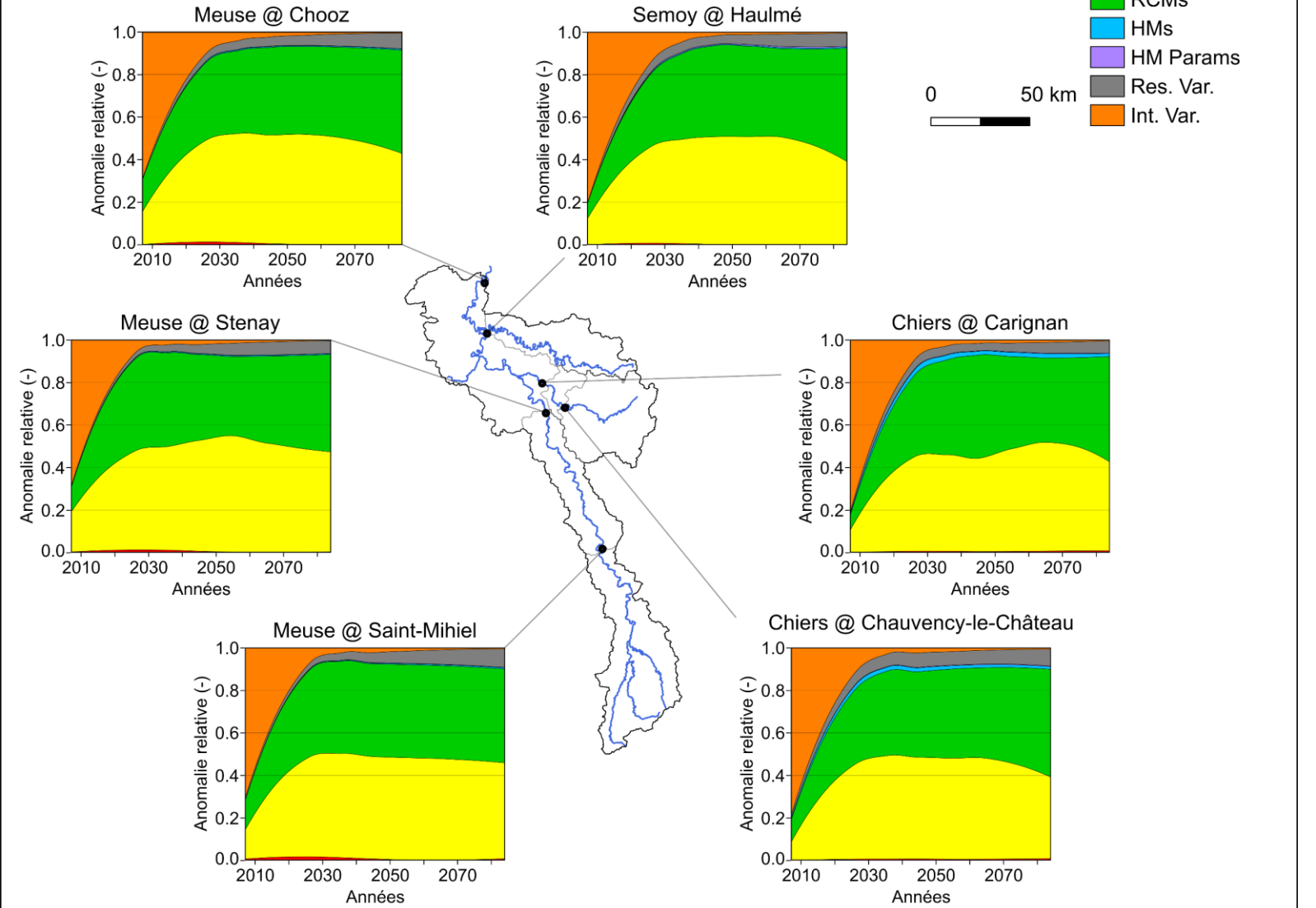
Indicator = VCN3

Internal variability dominates for near future

GCMs and RCMs dominate then

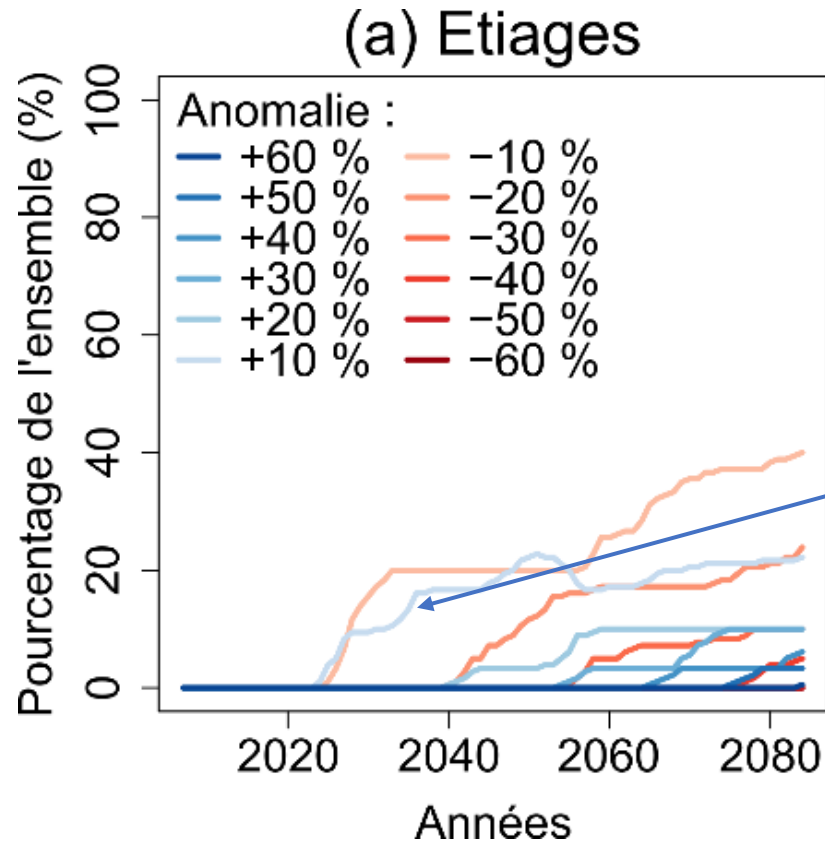
Other sources remain limited

Hiérarchisation d'incertitude : étiages



➤ Probabilities of different trends

Need to answer the following questions: « What is the probability that an indicator change of X % under climate change? » et « At which temporal horizon could this trend emerge? »



Pourcentage of all simulations indicating a trend of at least 10% of low flows(VCN3)

➤ Conclusions and perspectives

➤ Main conclusions of CHIMERE 21

Hydroclimate evolutions

Climate:

- Temperature increase, especially for RCP 8.5 and far future
- Heterogeneous precipitation evolution: increase for winter, large uncertainty for summer
- Projections of CHIMERE 21 warmer and wetter than previous works

Hydrology:

- Large uncertainties for summer, possible decrease of streamflows for upstream
- Increase during winter, especially downstream
- Climate brings most of uncertainties on Meuse streamflows

> Perspectives

The CHIMERE 21 study gave thoughts for food regarding adaptation strategies

- Evolutions of streamflows question strong stakes:
 - Increase of streamflow downstream, which is already identified as a territory with high risk of floods
 - Possible decrease of low flows upstream

Explore 2: a France-wide project aiming at evaluating impacts of climate change using Drias 2020 (started recently)

LIFE Eau&Climat (<https://www.gesteau.fr/life-eau-climat>): a project aiming at helping local water stakeholders to evaluate climate change impacts, to take them into account for planning and to undertake adaptation strategies

➤ The CHIMERE 21 team



Guillaume Thirel
(INRAE Antony, coordination)



Lila Collet
(INRAE Antony)



Fabienne Rousset
(Météo-France)

Olivier Delaigue
(INRAE Antony)



Joël Gailhard
(EDF)



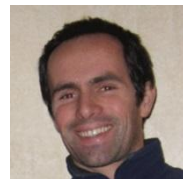
Mathieu Reverdy
(INRAE Lyon)



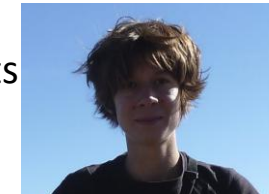
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Morgane Terrier
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