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Capacity of climate models to capture multi-decadal hydrological variations over France

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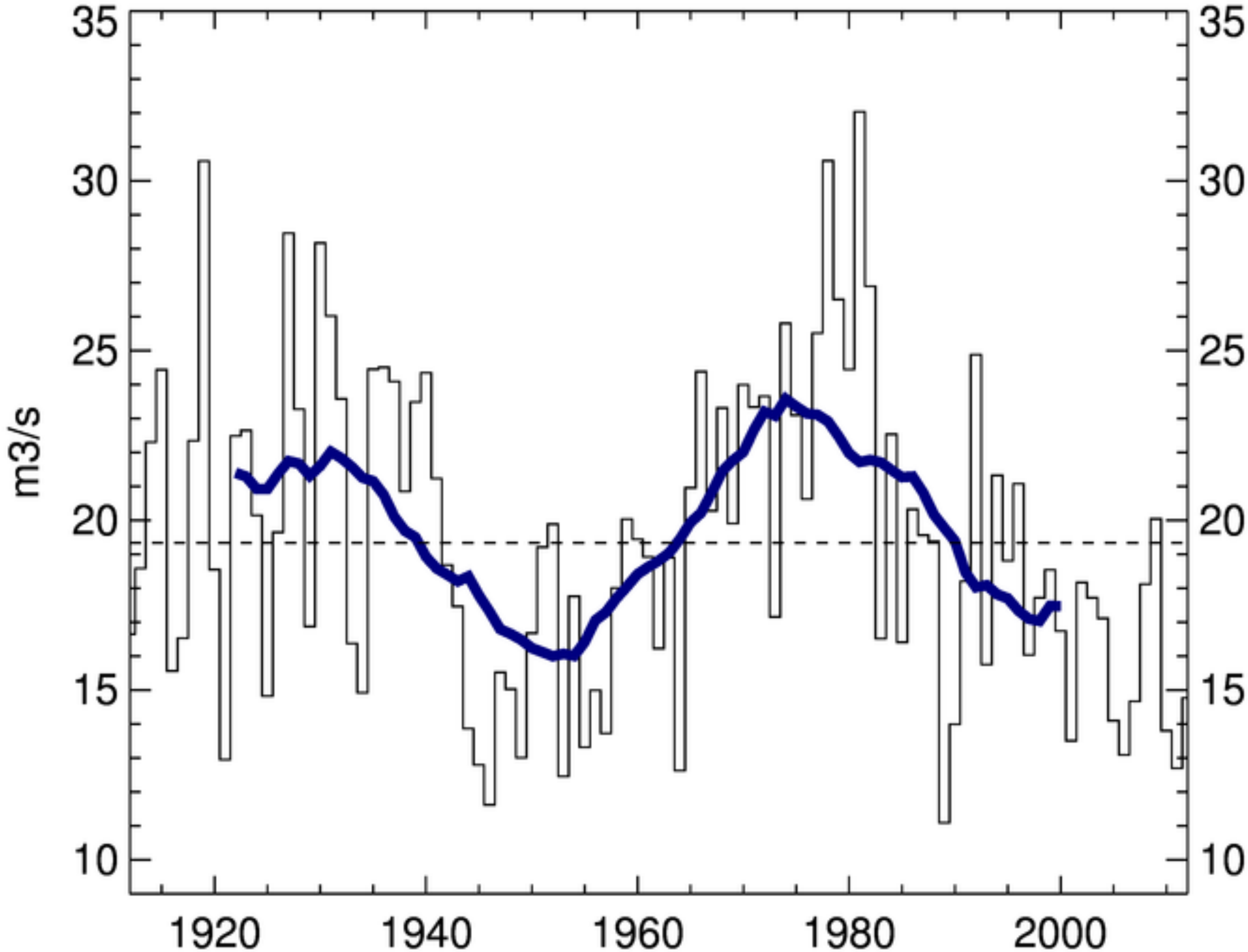
EGU 2020, 07/05/2020

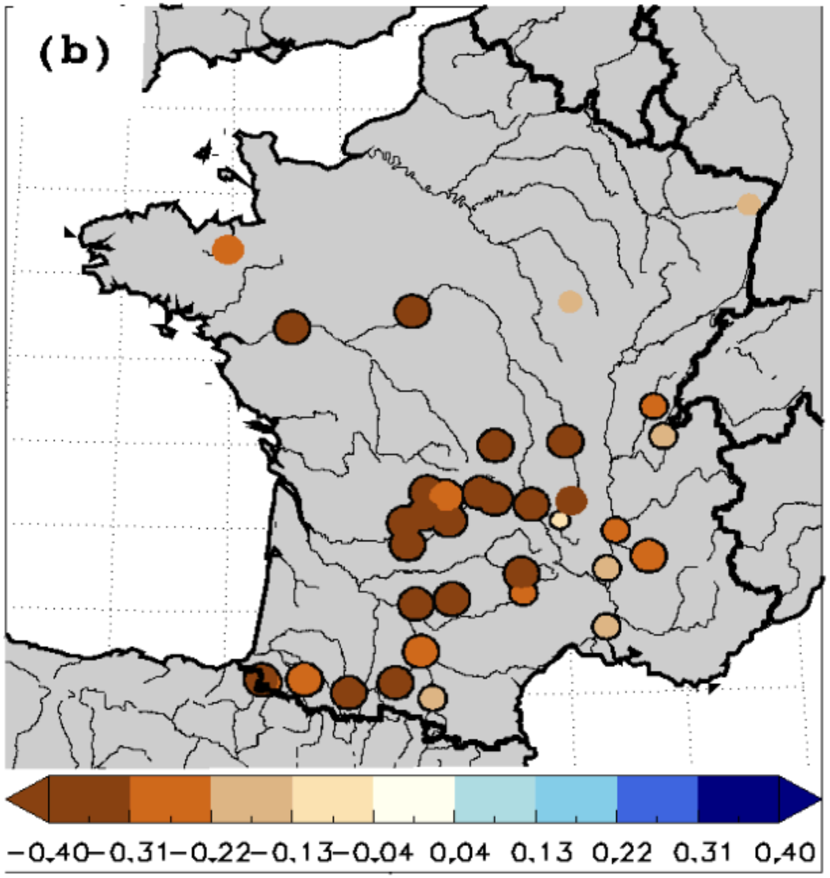
Context: observed multi-decadal variations in river flows over France



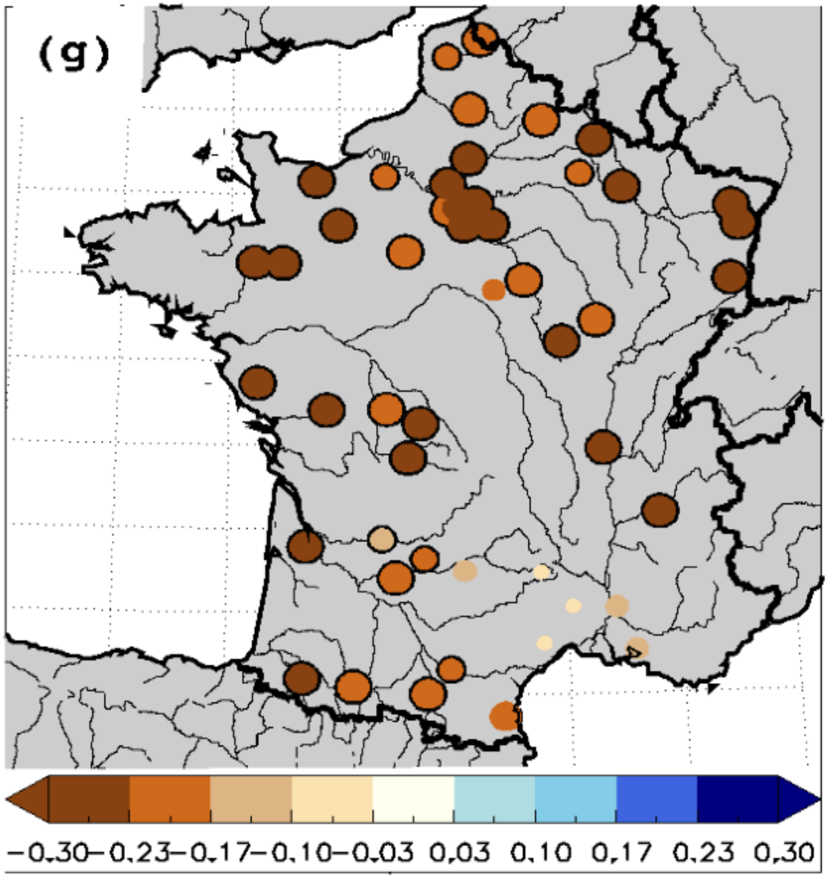
Gave d'Ossau river flows at Oloron-Sainte-Marie

Annual mean. Thick line: low-pass filtered series

Relative differences, spring
1938/1958 – 1965/1985
Detrended variables



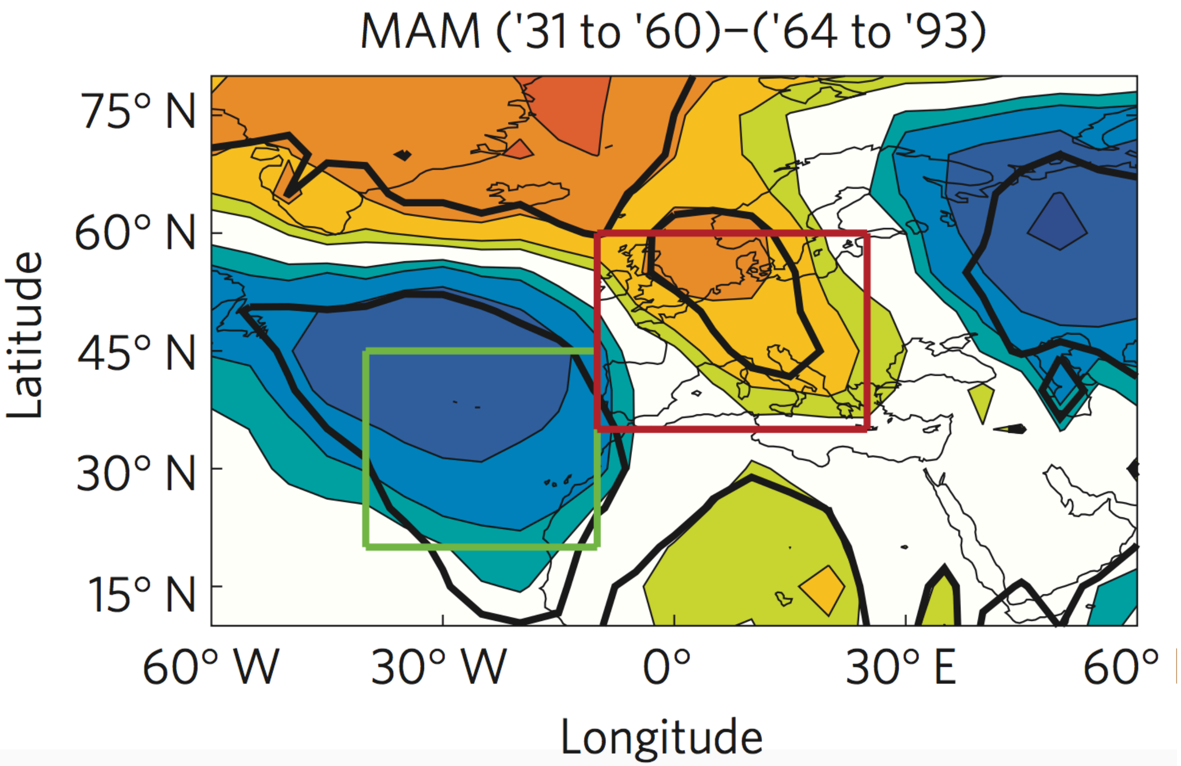
River flows (no unit)



Precipitation (no unit)

Boé and Habets (2014)

O: significance avec p<0.1



Composite anomalies of SLP in MAM between positive and negative phases of the AMV *Sutton and Dong (2012)*

=> The Atlantic Multi-decadal Variability (AMV) may influence the western European climate in spring through changes in atmospheric circulation (*Sutton and Dong, 2012*).

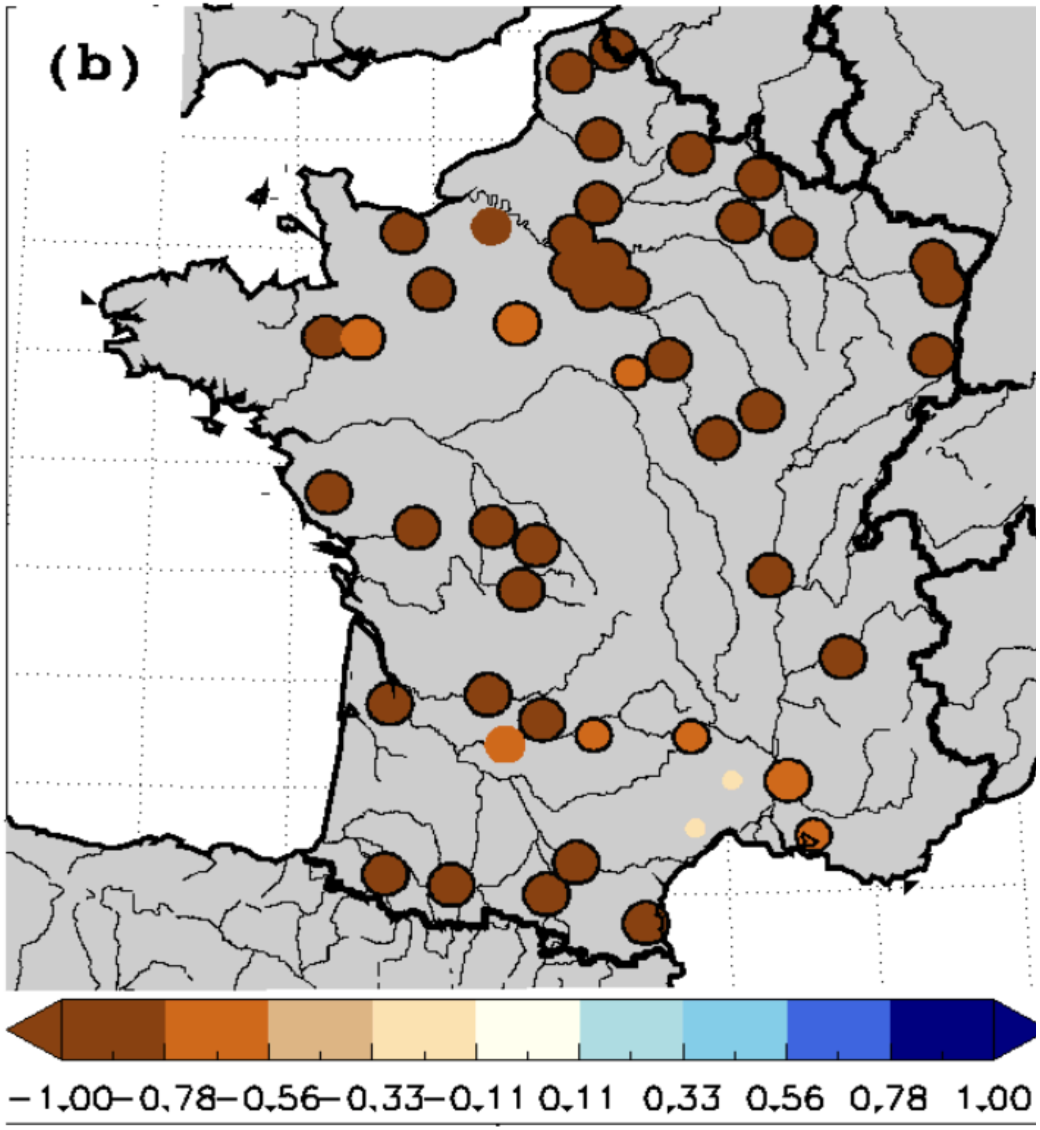
SLP index to capture the potential impact of the AMV on atmospheric circulation:

=> Spatial averages of SLP Red – Green boxes above

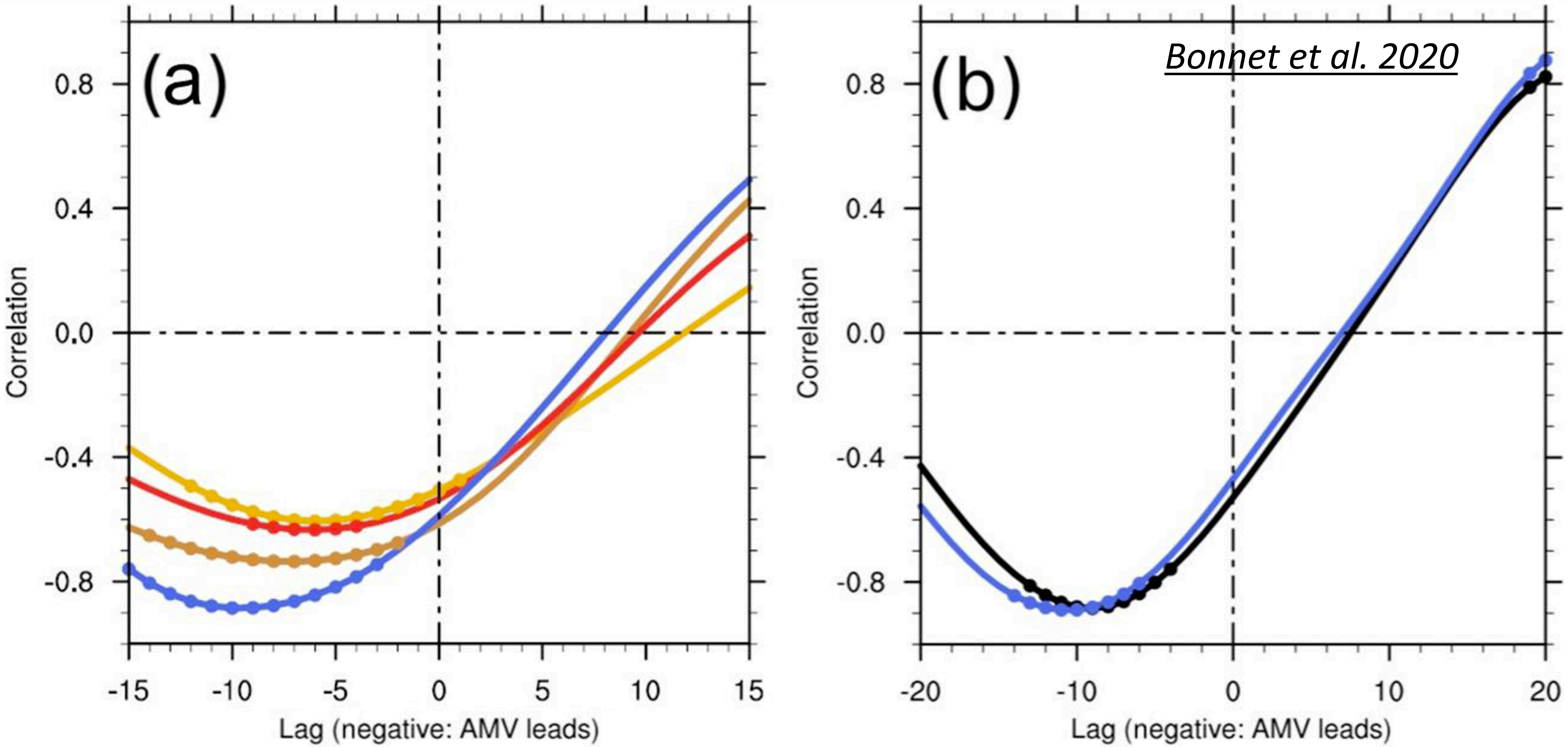
Context: origin of multi-decadal variations in spring precipitation

Correlation
SLP index / precipitation
Low-pass filtered series, detrended
MAM
1910-1991

O: signif. avec p<0.1

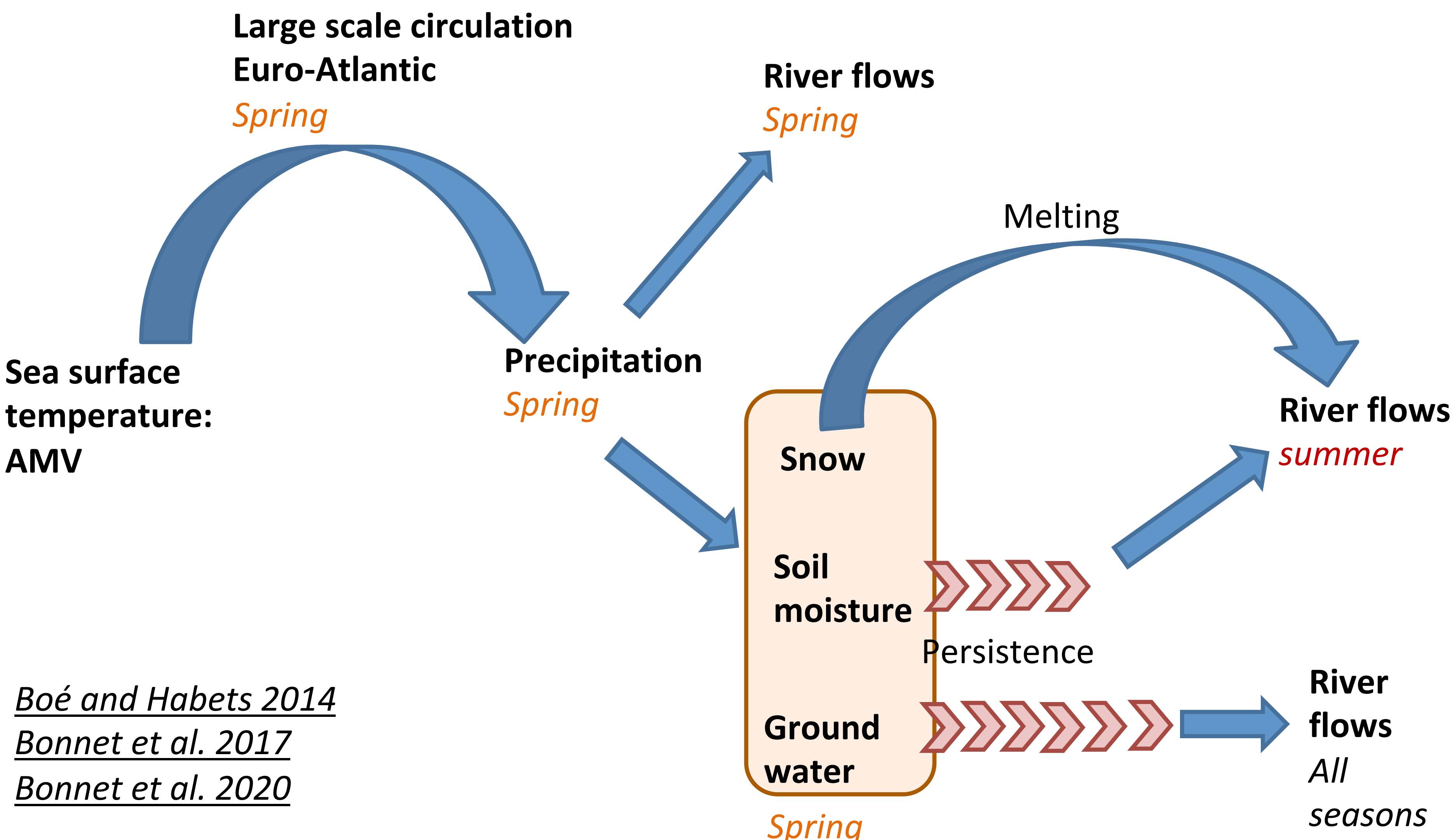


Boé and Habets (2014)



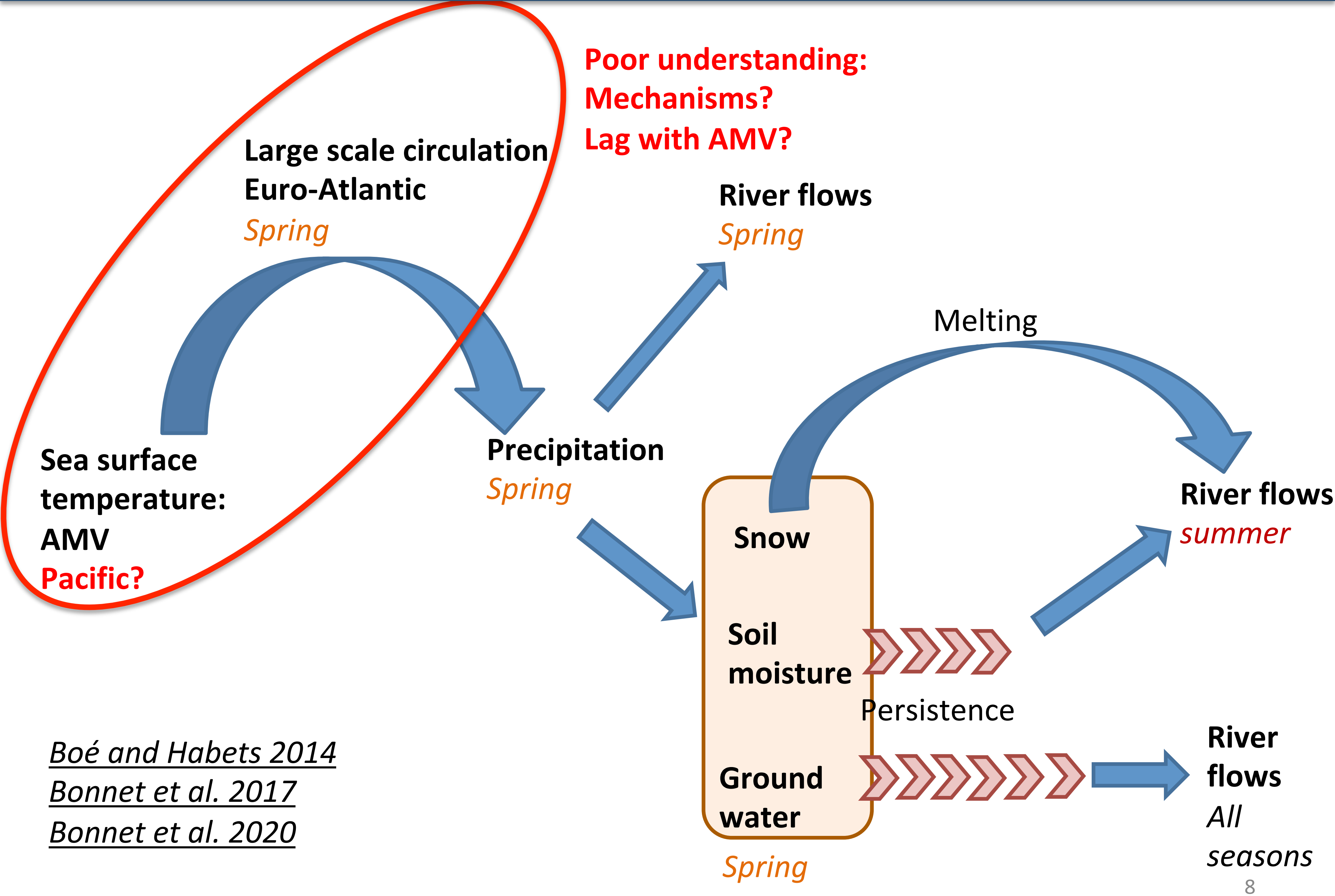
Lagged correlations (lag in years):
(a) Paleoclimate AMV index (*Wang et al. 2017*) & spring precipitation at Paris: 1780–1889, 1890–1989, **1779–1989**. **Observed AMV index and MAM precipitation, 1882–1979**.
(b) Observed AMV index & spring river flows at Paris from (blue) **hydrological analysis** (black) **observations**, 1882–1979.
Low-pass filtered series (21-year Lanczos filter). Points: significant correlations (p <0.05)

In summary, mechanisms of multi-decadal hydrological variations in France



Boé and Habets 2014
Bonnet et al. 2017
Bonnet et al. 2020

In summary, mechanisms of multi-decadal hydrological variations in France



<u>*Boé and Habets 2014*</u>
<u>*Bonnet et al. 2017*</u>
<u>*Bonnet et al. 2020*</u>

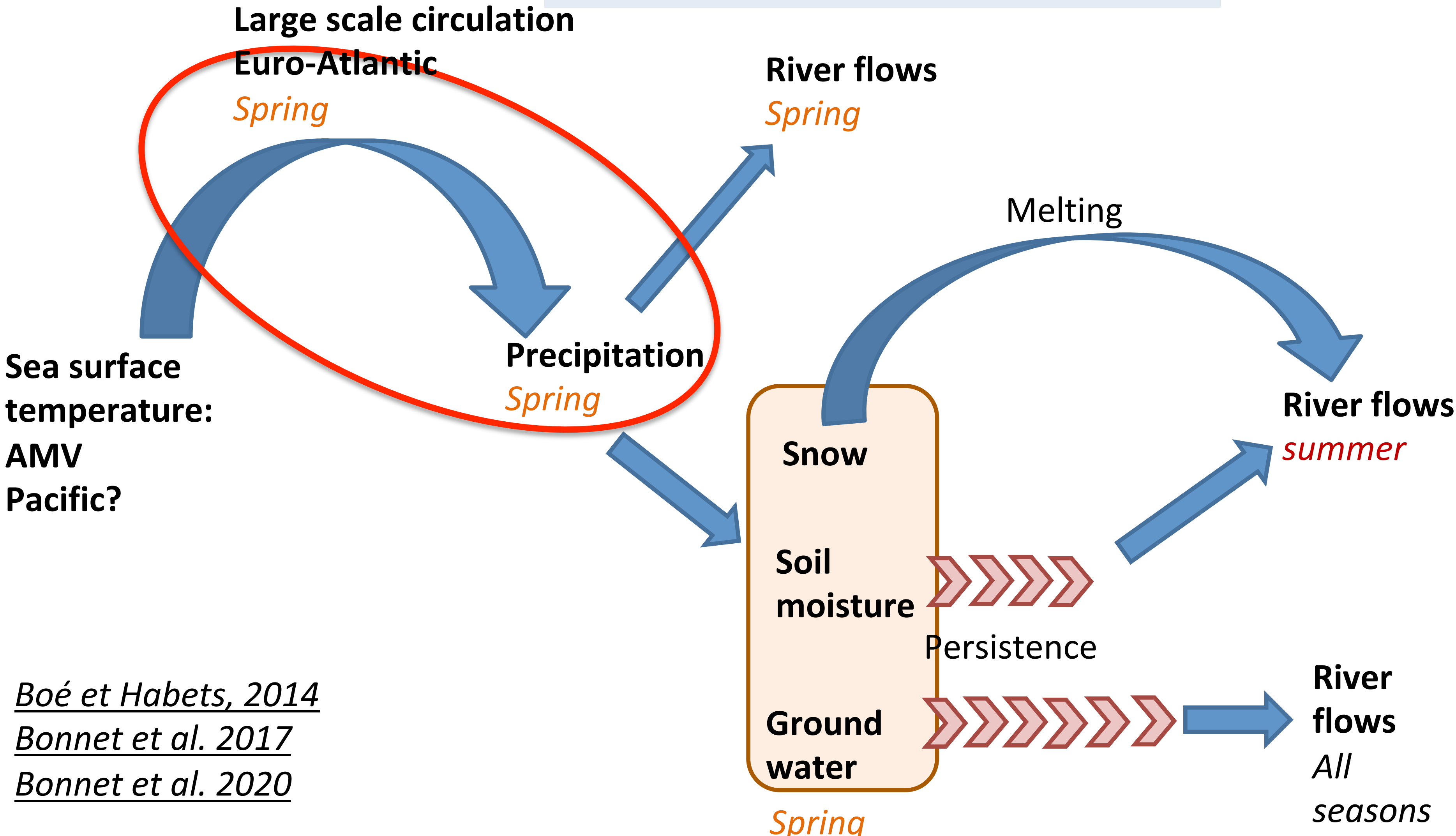
Question

Do new generation climate models correctly capture the multi-decadal variability of the hydrological cycle in France?

=> And therefore: are models able to capture correctly the uncertainties due to internal variability in future climate projections?

Question

Here, evaluation of this branch in climate models



Boé et Habets, 2014
Bonnet et al. 2017
Bonnet et al. 2020

Method (for precipitation)

✓ 30 CMIP6 models: historical and piControl simulations

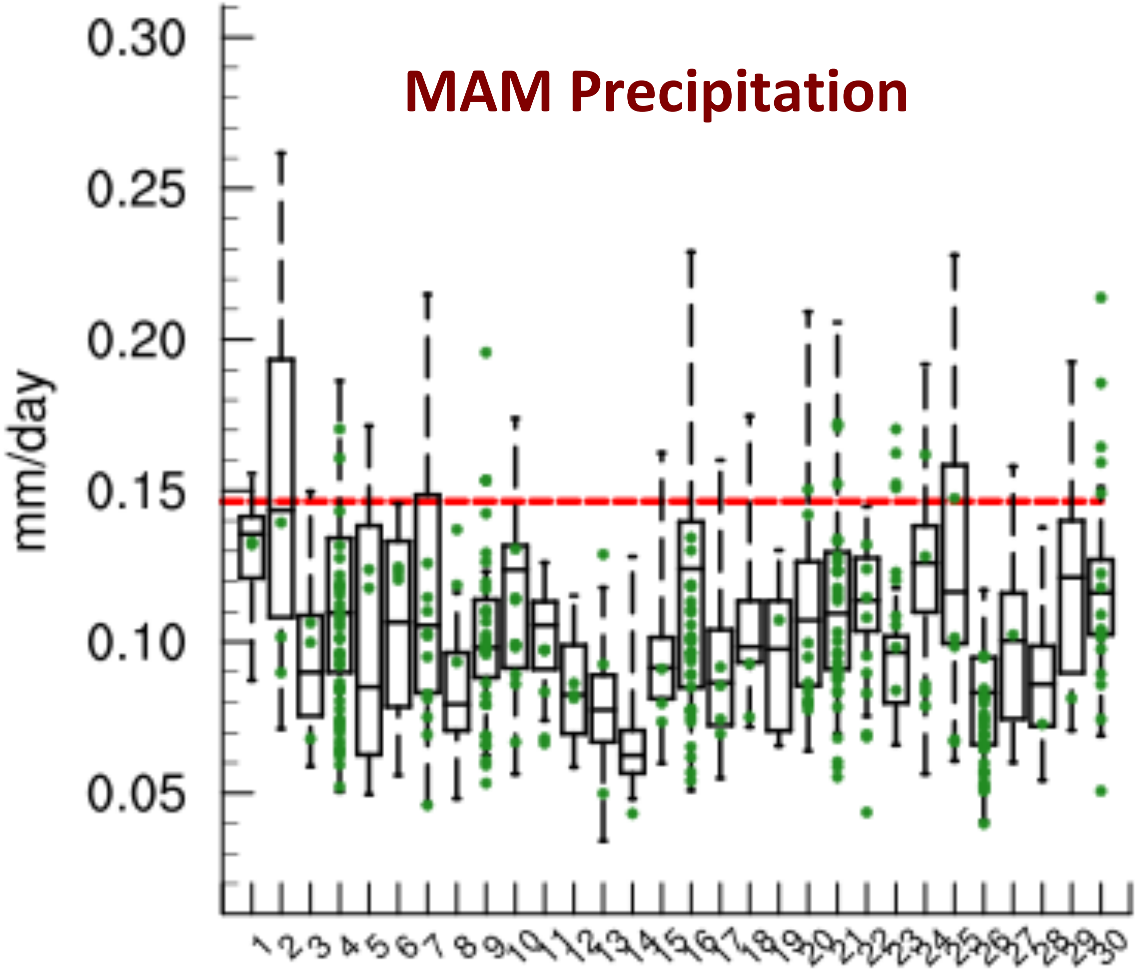
✓ Observations: CRU-TS 1901-2014

Average over France & seasonal averages → Detrending → (21-year running average) → Standard deviation

➢ **Historical simulations**:
same as obs. for all members on 1901-2014

➢ **piControl simulations**:
same as obs for all 114-year periods (with overlap)

Multi-decadal variability in CMIP6 models: spring precipitation



Note: detrending has little impact

=> Only 7% of historical members (from 8 models) with larger standard deviation than observed

Standard deviation for 21-year running averages, 1901-2014

Observations

Green dots: historical simulations

Boxplot: distribution for all 114-year periods in piControl simulations

Multi-decadal variability in CMIP6 models: precipitation, all seasons

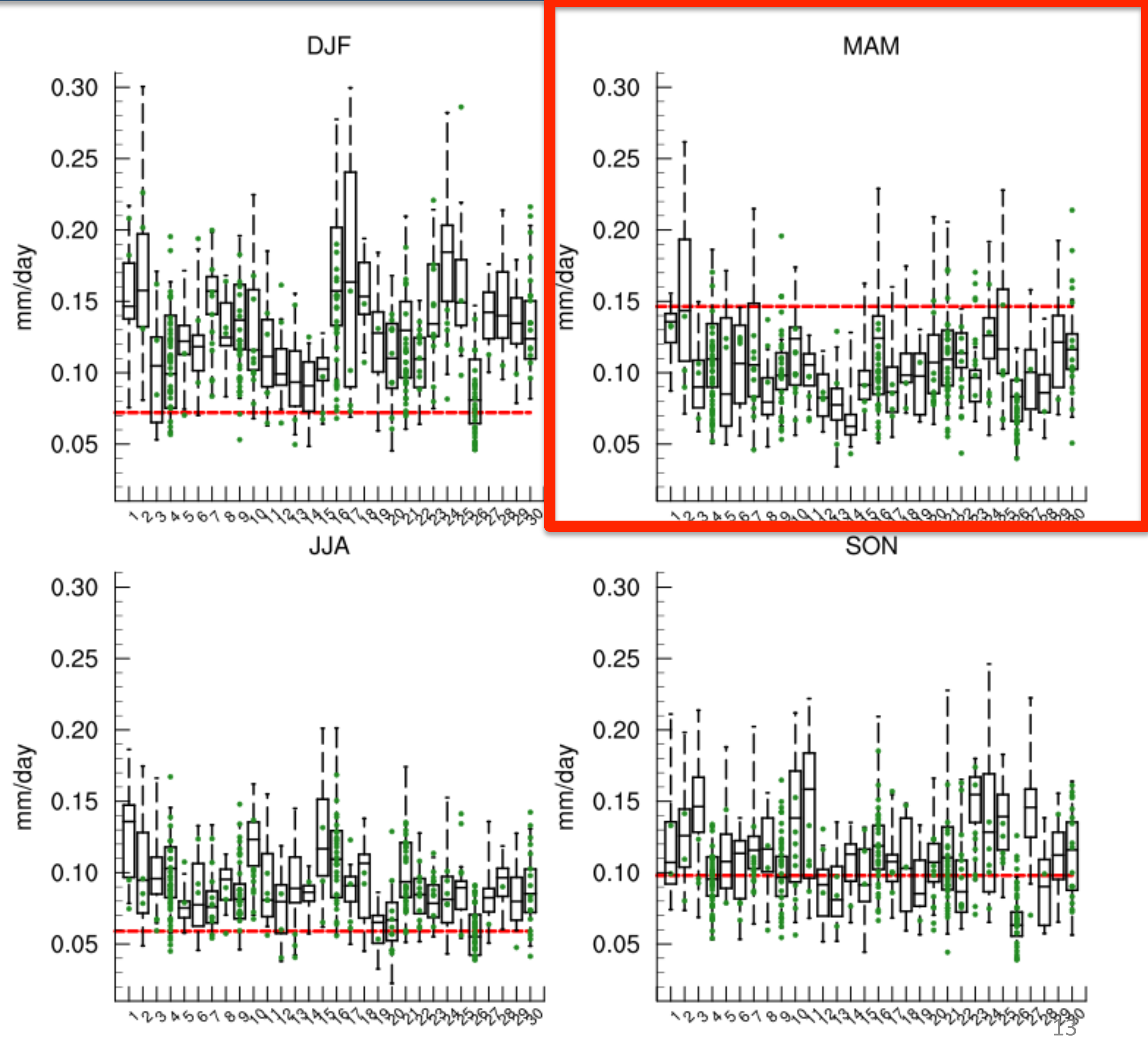
Precipitation

Standard deviation for 21-year running averages, 1901-2014

Observations

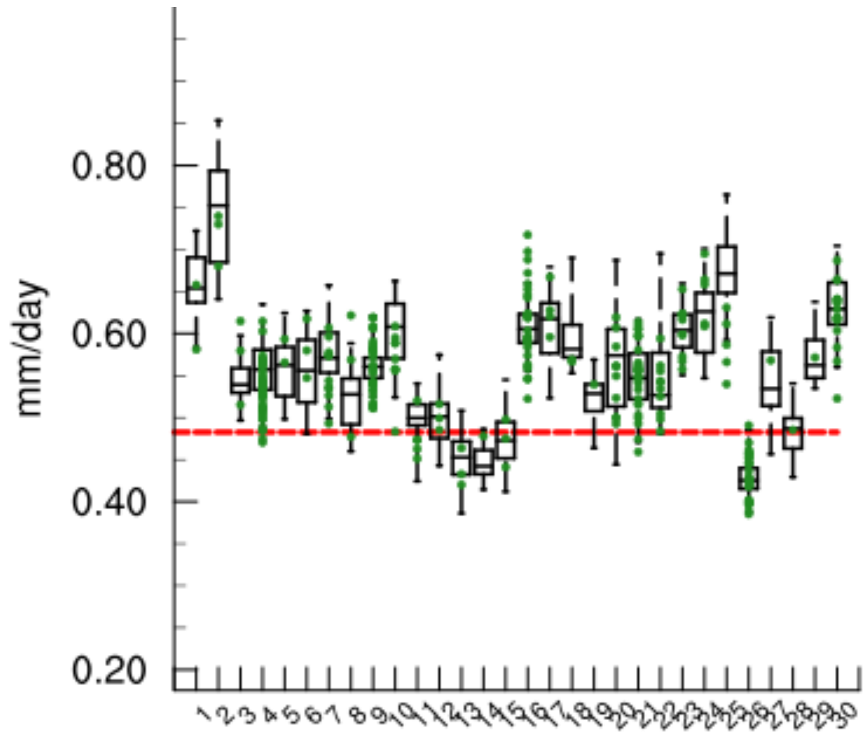
Green dots: historical simulations

Boxplot: distribution for all 114-year periods in piControl simulations

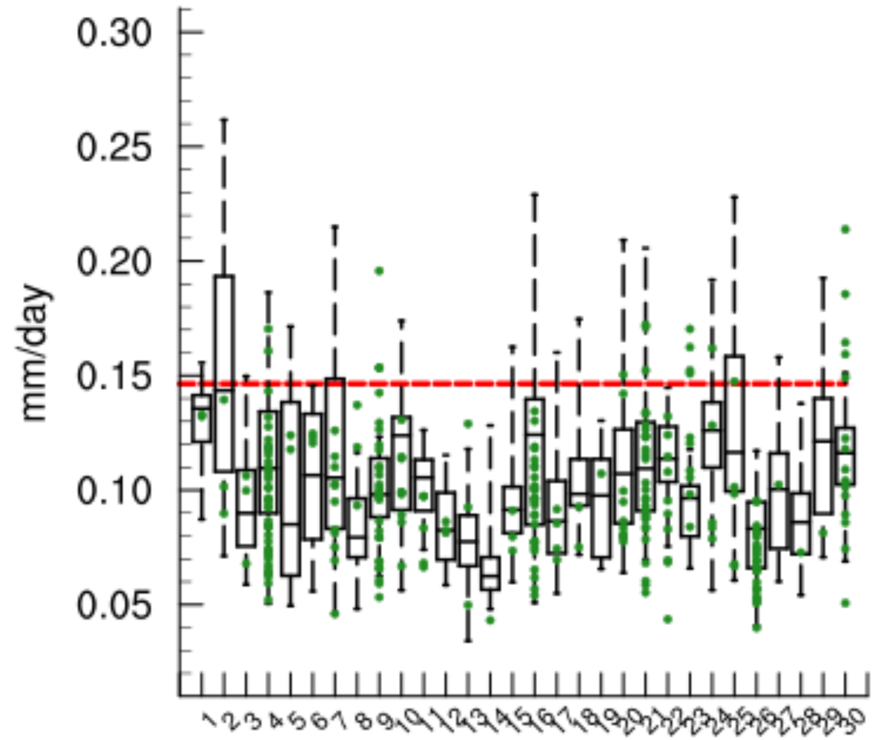


Multi-decadal versus inter-annual variability in spring precipitation

MAM Precipitation



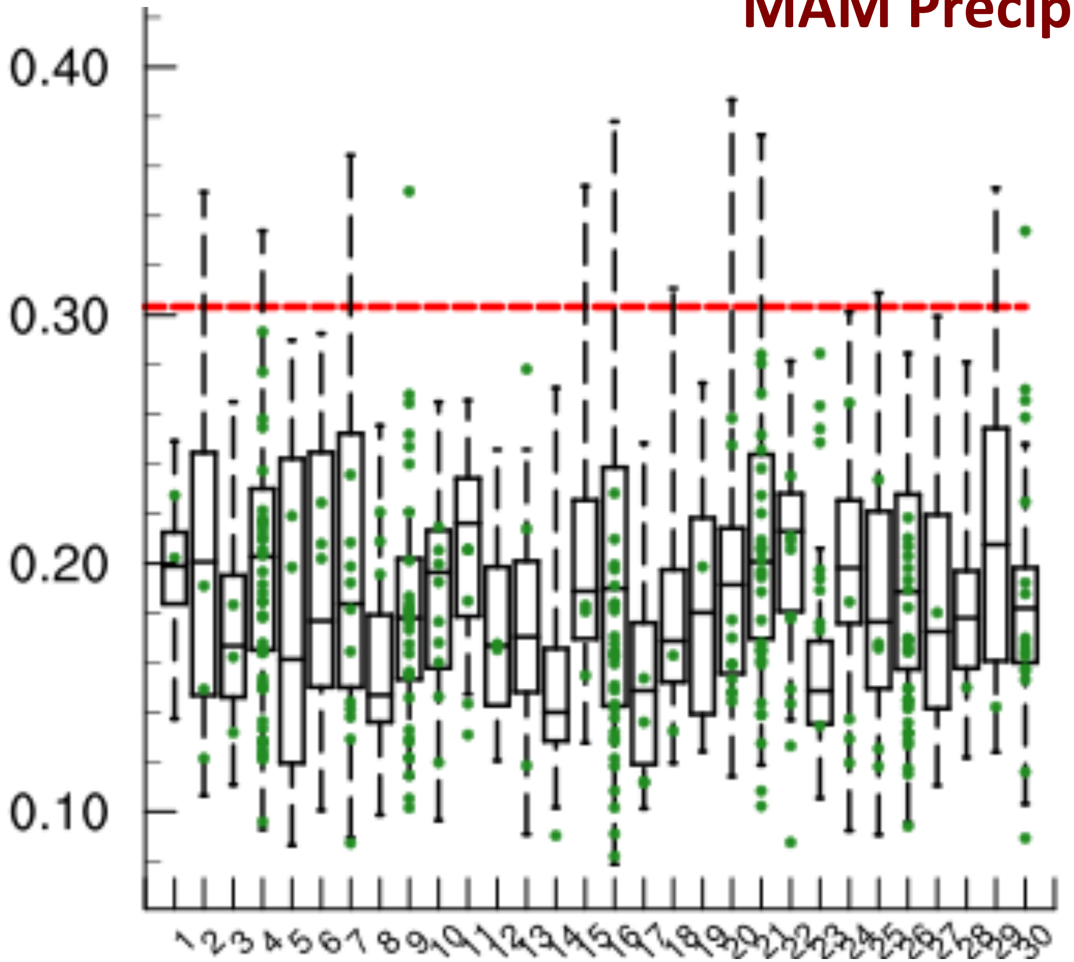
Inter-annual



Multi-decadal:
21-year running averages

Standard deviation 1901-2014
Observations
Green dots: historical simulations
Boxplot: distribution for all 114-year periods in piControl simulations

MAM Precipitation



=> Only 0.7% of historical members (from 2 models) with larger ratio of standard deviation than observed

Ratio of standard deviation multi-decadal/inter-annual 1901-2014

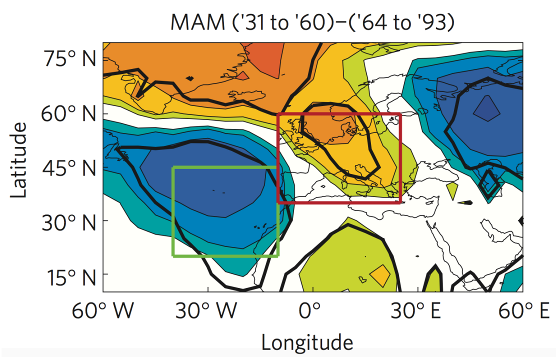
Observations

Green dots: historical simulations

Boxplot: distribution for all 114-year periods in piControl simulations

Multi-decadal variability of SLP in CMIP6 models: spring

Sutton and Dong (2012)



Red - Green

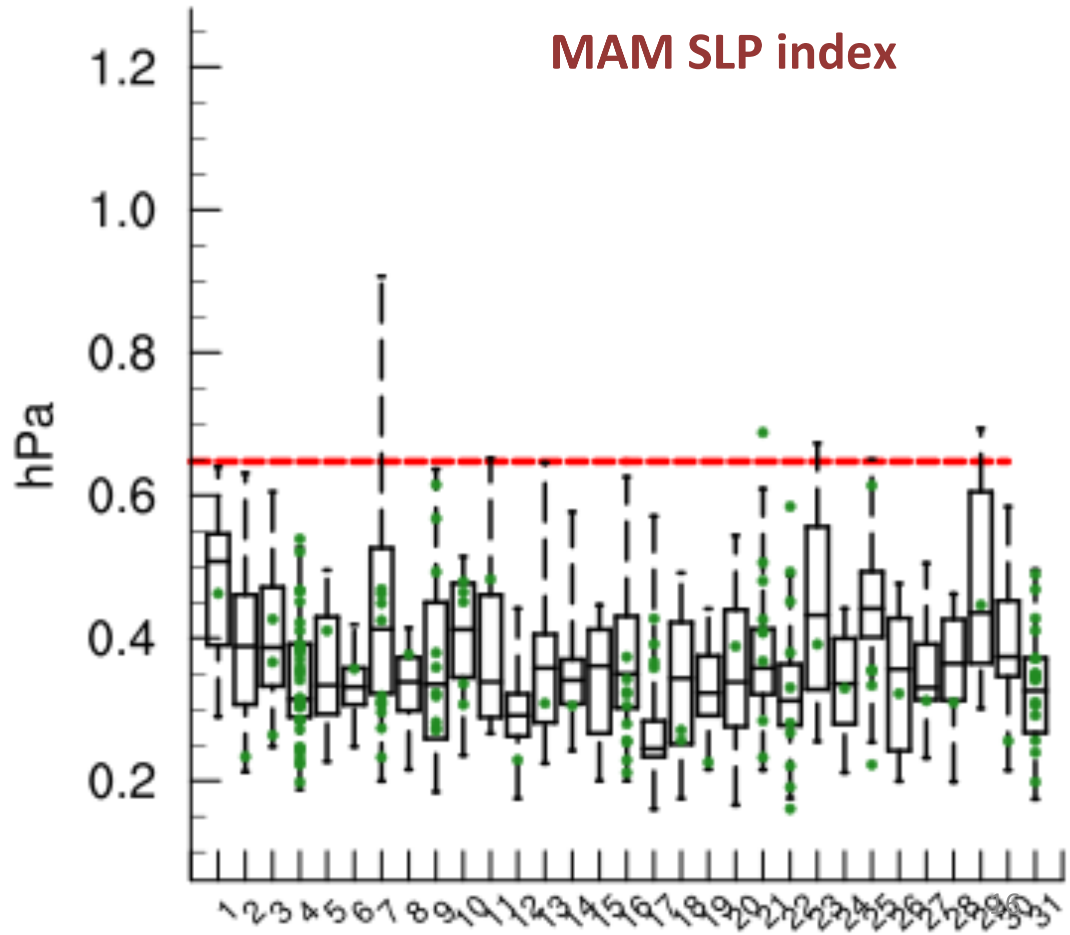
Sea level pressure index that captures the impact of large scale circulation on precipitation at multi-decadal time-scale in spring

Standard deviation 1901-2014, 21-year running mean

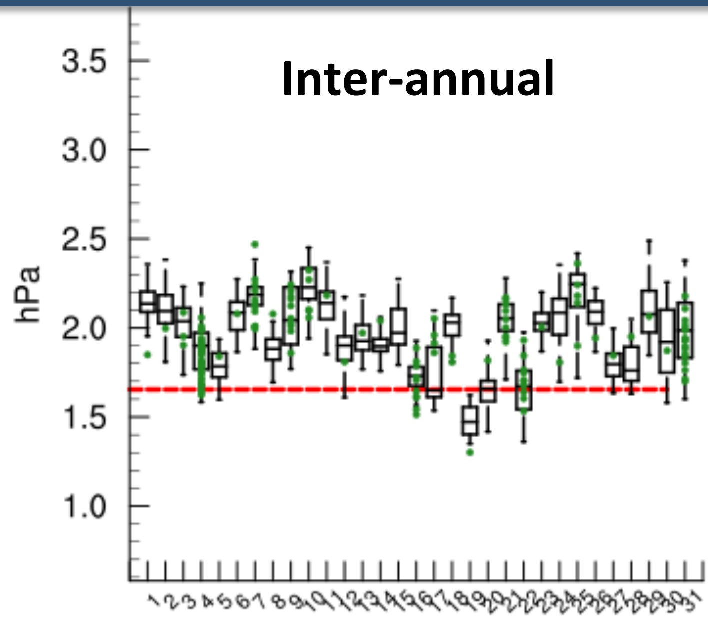
Observations

Green dots: historical simulations

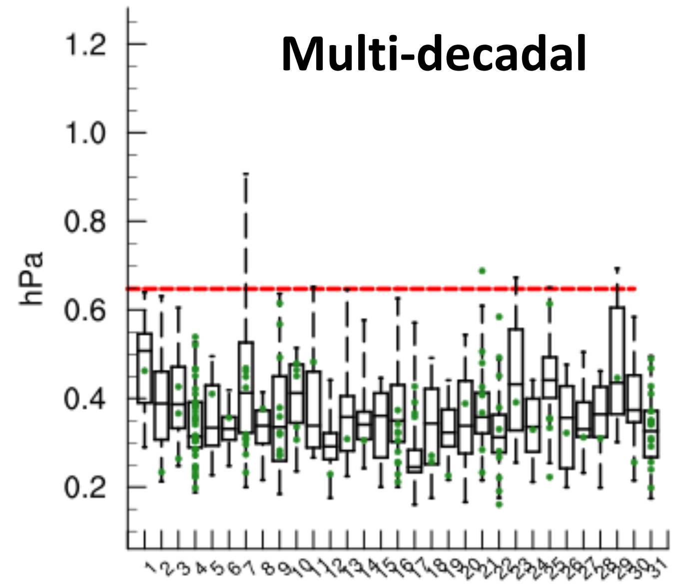
Boxplot: distribution for all 114-year periods in piControl simulations



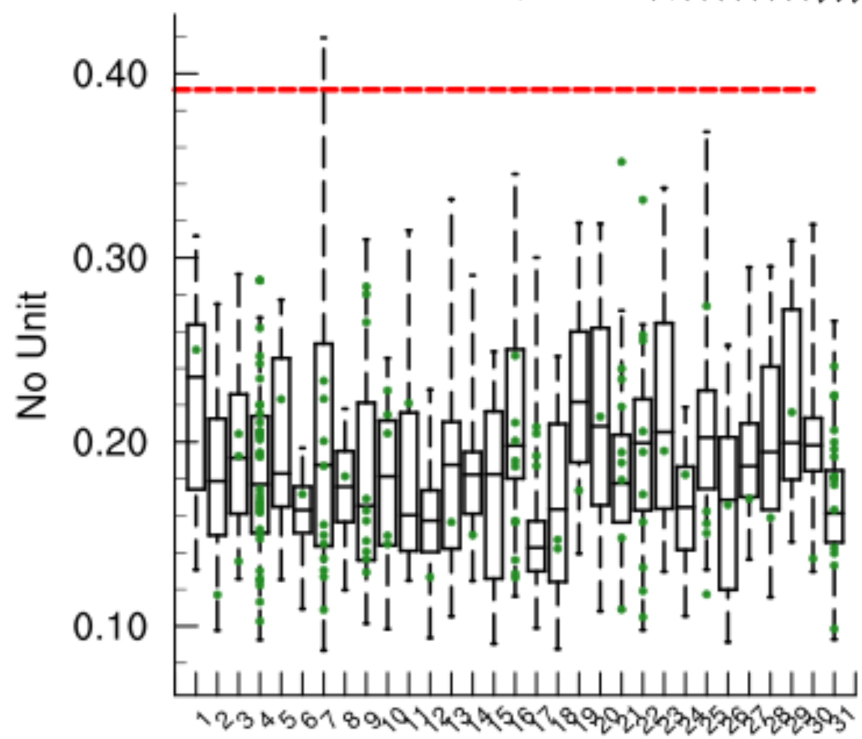
Multi-decadal versus inter-annual variability in CMIP6 models: SLP index in spring



MAM SLP index

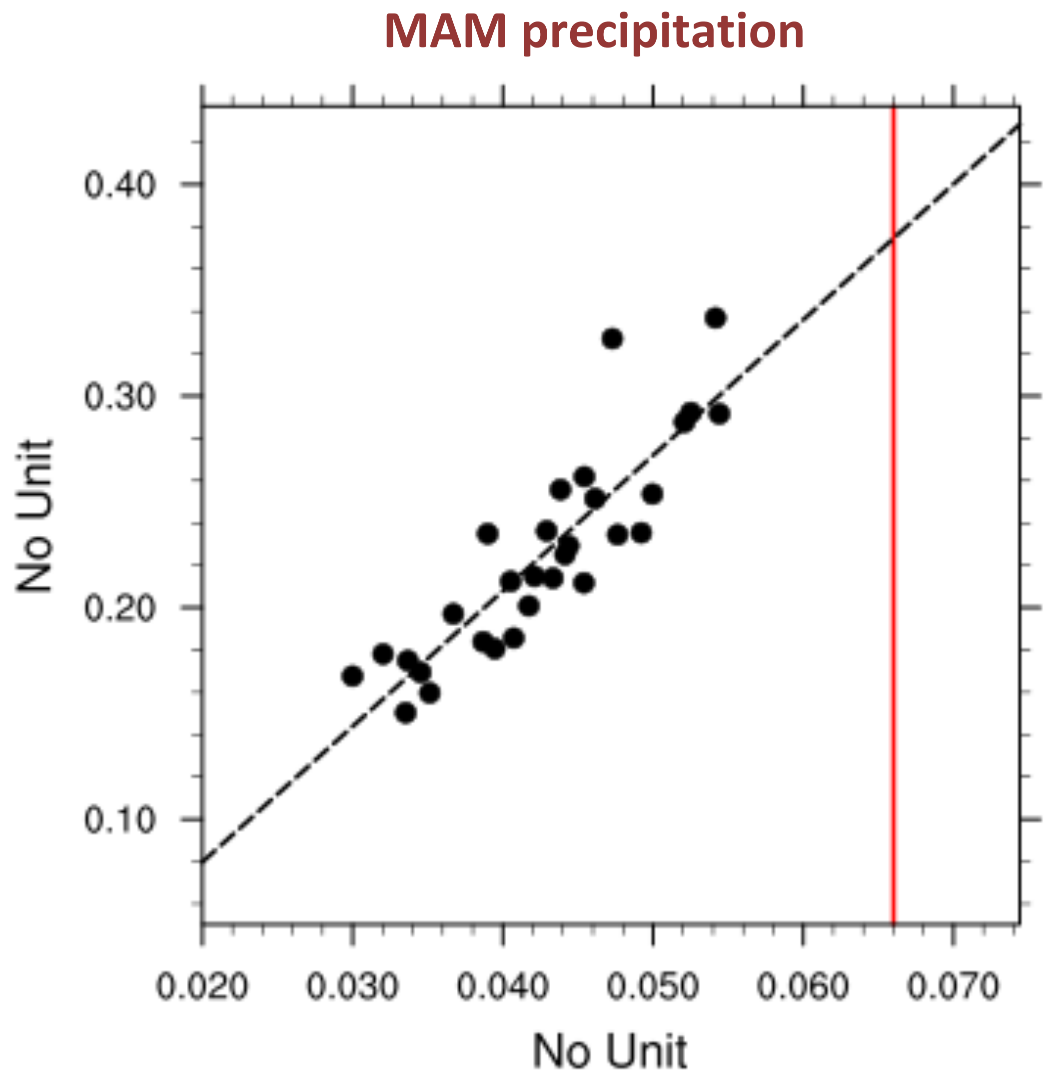


Ratio of standard deviation
multi-decadal/inter-annual
1901-2014
Observations
Green dots: historical simulations
Boxplot: distribution for all 114-year periods in piControl simulations



1 point : 1 CMIP6 model

Relative differences between the wettest and driest 21-year periods in piControl simulations



Standard deviations of 21-year running mean of relative precipitation **piControl simulations** and **observations 1901-2014**

Difficulties to evaluate internal low-frequency variations in climate models:

- ✓ Short instrumental period, major sampling uncertainties
- ✓ Difficulty to estimate robustly the forced signal (small here for spring precipitation) to extract internal variations in the observations and in the models with few historical members
- ✓ The use of piControl simulations may be interesting, but:
  - -the external signal should be correctly taken care of in the observations
  - -it is hypothesized that there is no interaction between forced and internal variability

Conclusions

- In many climate models, it is highly unlikely to see multi-decadal variations in spring precipitation as large as observed on 1901-2014, even if most models overestimate the inter-annual variability.

- This is related to an underestimation of the multi-decadal variability in large-scale atmospheric circulation over the North Atlantic / Europe sector at multi-decadal time scales

=> The uncertainties in projected hydrological changes over France due to internal variability might be underestimated (either directly in climate models, or based on off-line hydrological modelling after either dynamical or statistical downscaling)

- ➢ Next step: to understand why multi-decadal variability in large scale atmospheric circulation in spring is underestimated in models.
  - ➢ Bad representation of the teleconnection between AMV and sea level pressure?
  - ➢ Interestingly, some difficulties in CMIP5 climate models to capture spatial and temporal properties of the AMV (Qasmi et al. 2017)