Trend in extreme precipitation in the French Alps, with link to changes in the generating Western Europe circulations

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CAFE
Climate Advanced Forecasting of sub-seasonal Extremes

cnrs
dépasser les frontières

UGA
Université Grenoble Alpes

IGE
Institut des géosciences de l'environnement

Introduction

- Extreme precipitation in the French Alpine region

St Martin de Vésubie (Alpes-Maritime), Oct 2, 2020 – storm Alex

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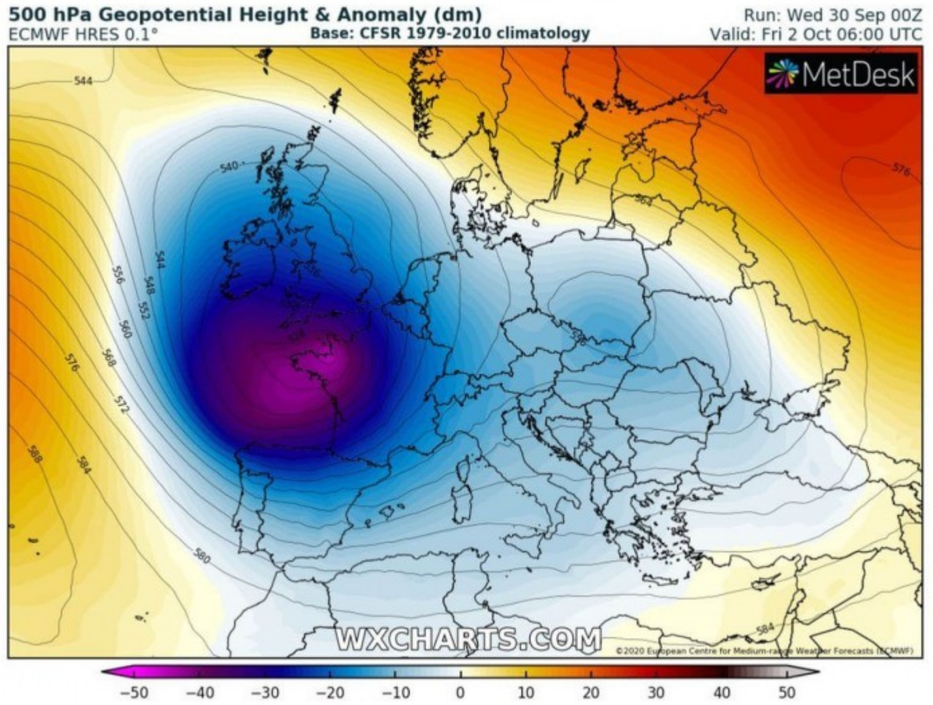


Introduction

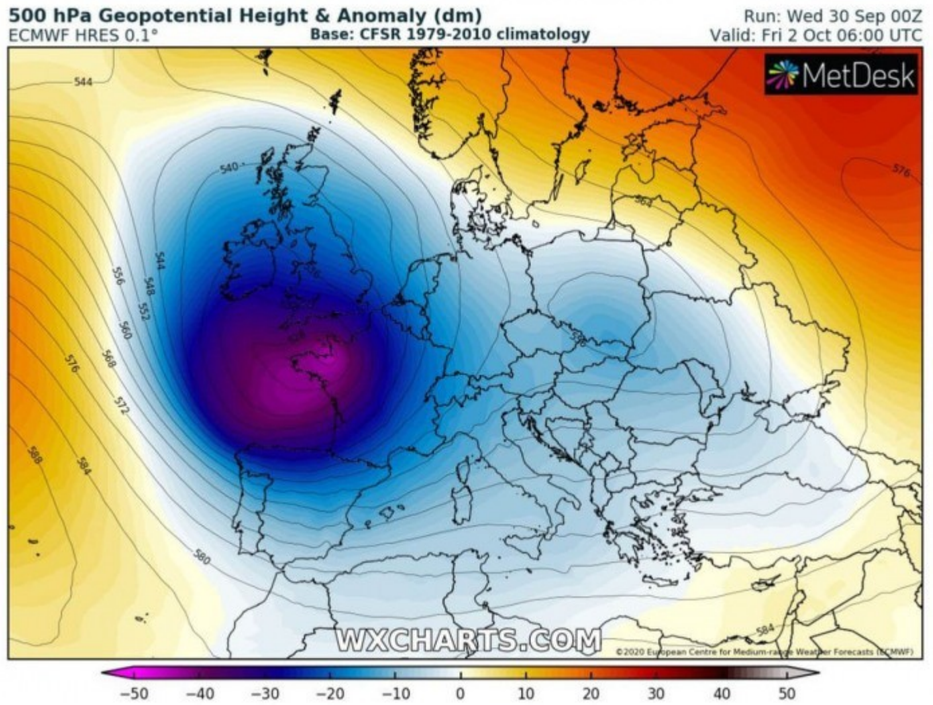
- Extreme precipitation in the French Alpine region
- Two main goals :

Quantifying trends in extreme precipitation

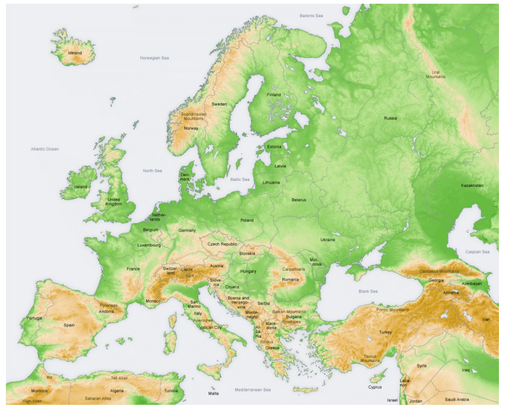
Linking extreme precipitation to some circulation feature

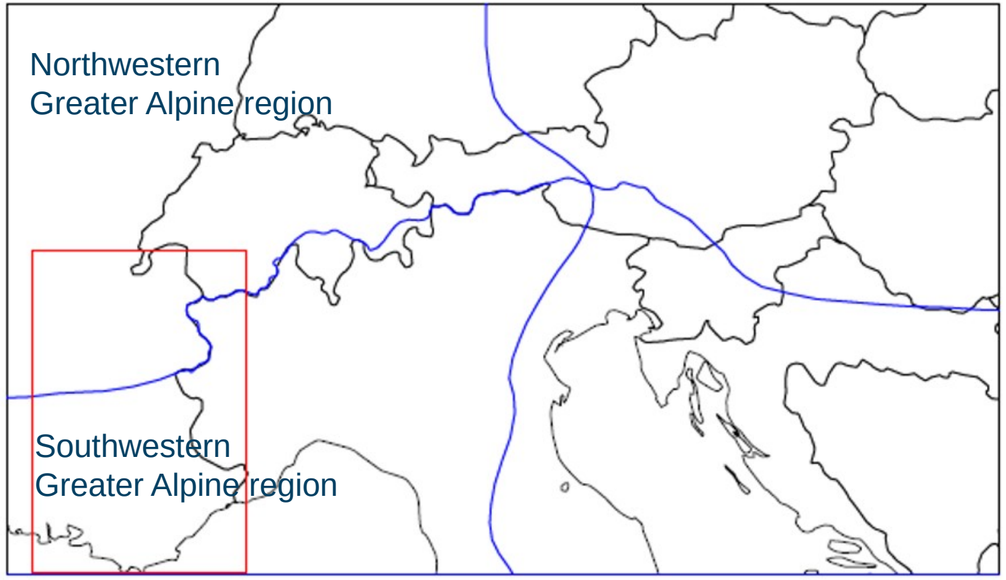
Linking these changes to changes in circulations

St Martin de Vésubie (Alpes-Maritime), Oct 2, 2020 – storm Alex

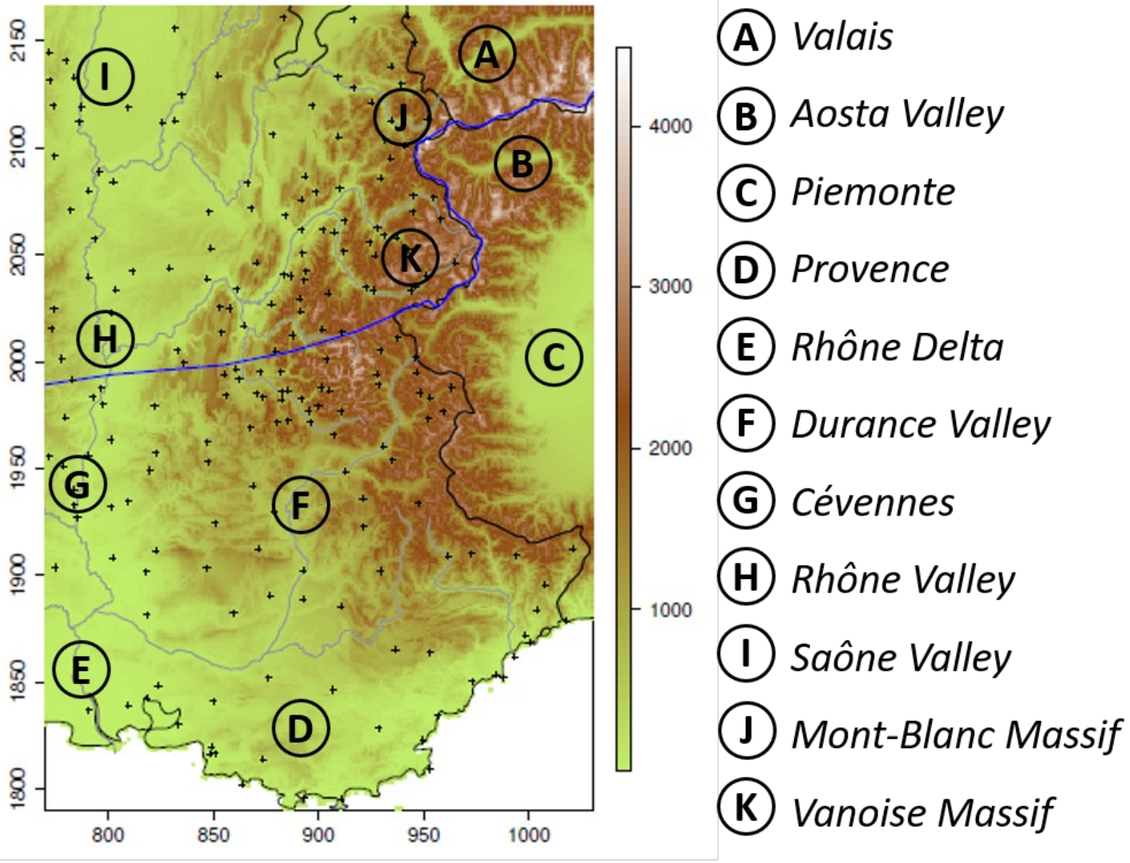


Region of study





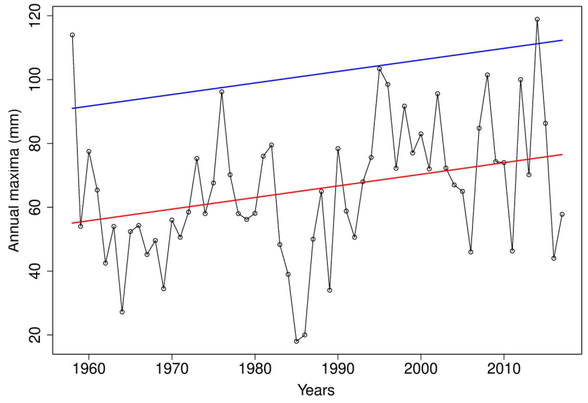
Auer et al. 2007

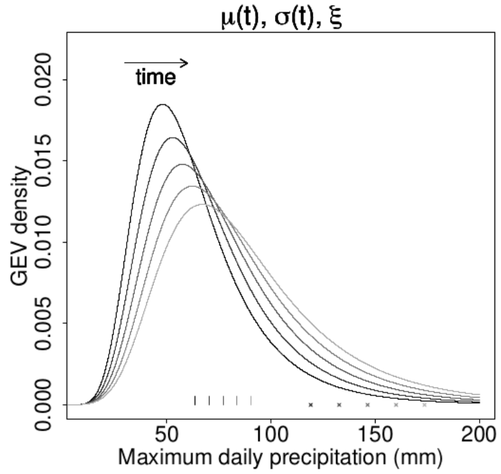


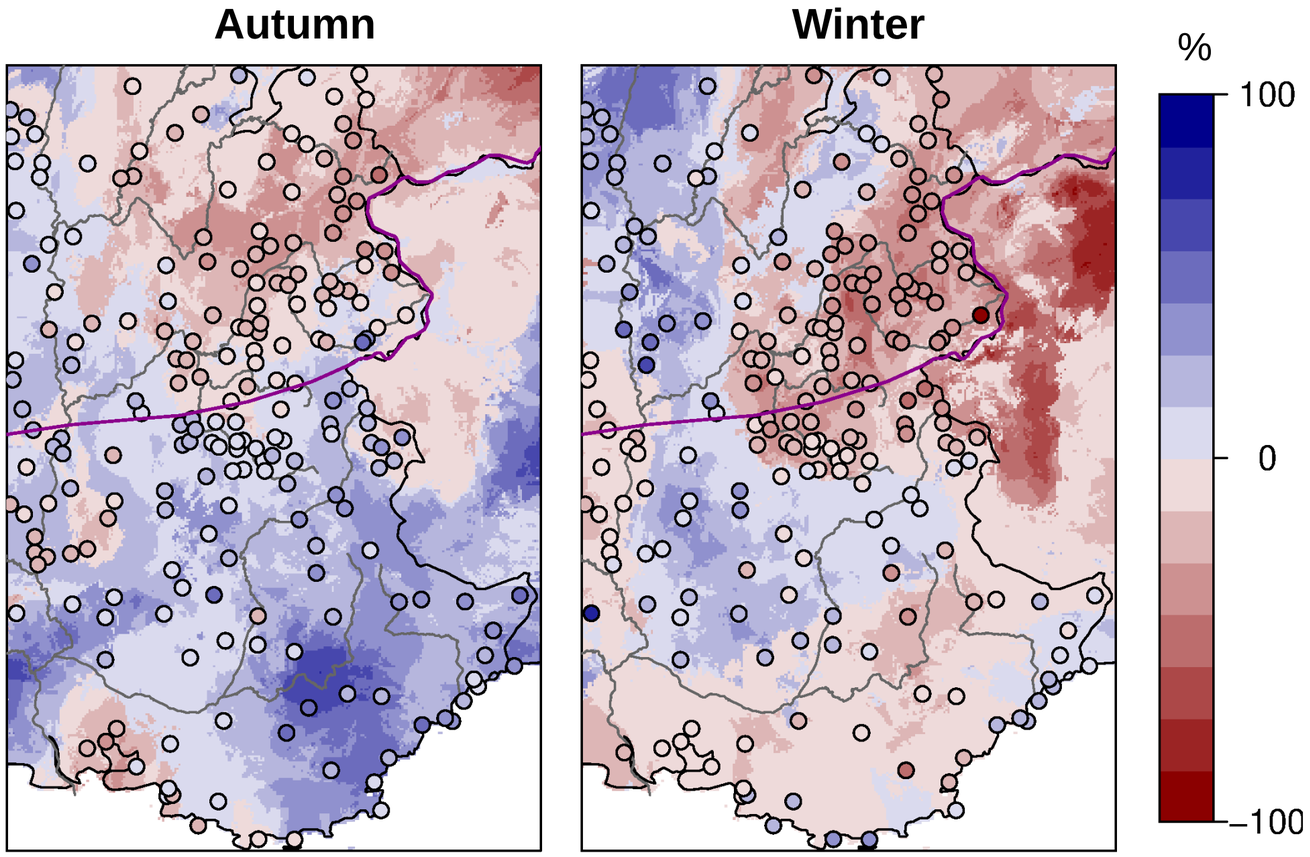
Change in extreme precipitation (1958-2017)

20-year return level

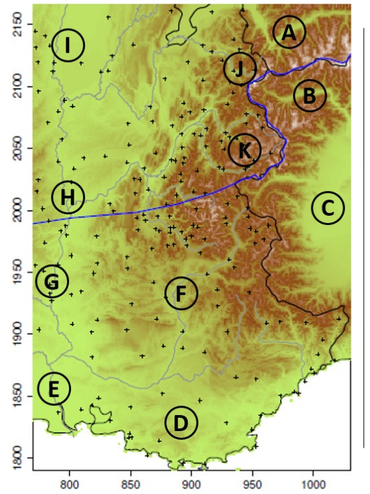
SPAZM (Gottardi et al 2012)
+ stations 1958-2017







% change 1958-2017 w.r.t. average value over the period



Blanchet et al. 2021

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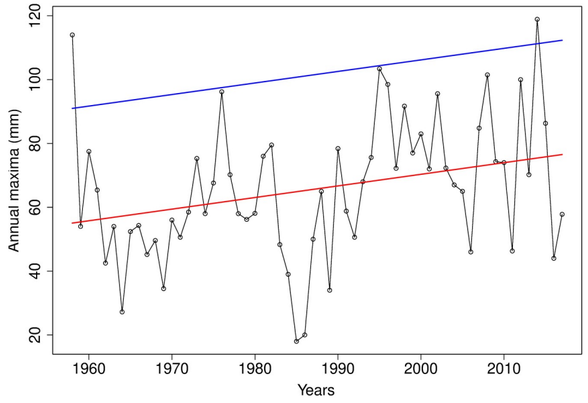

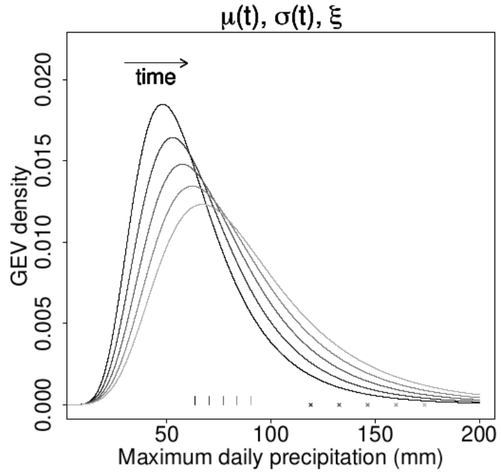

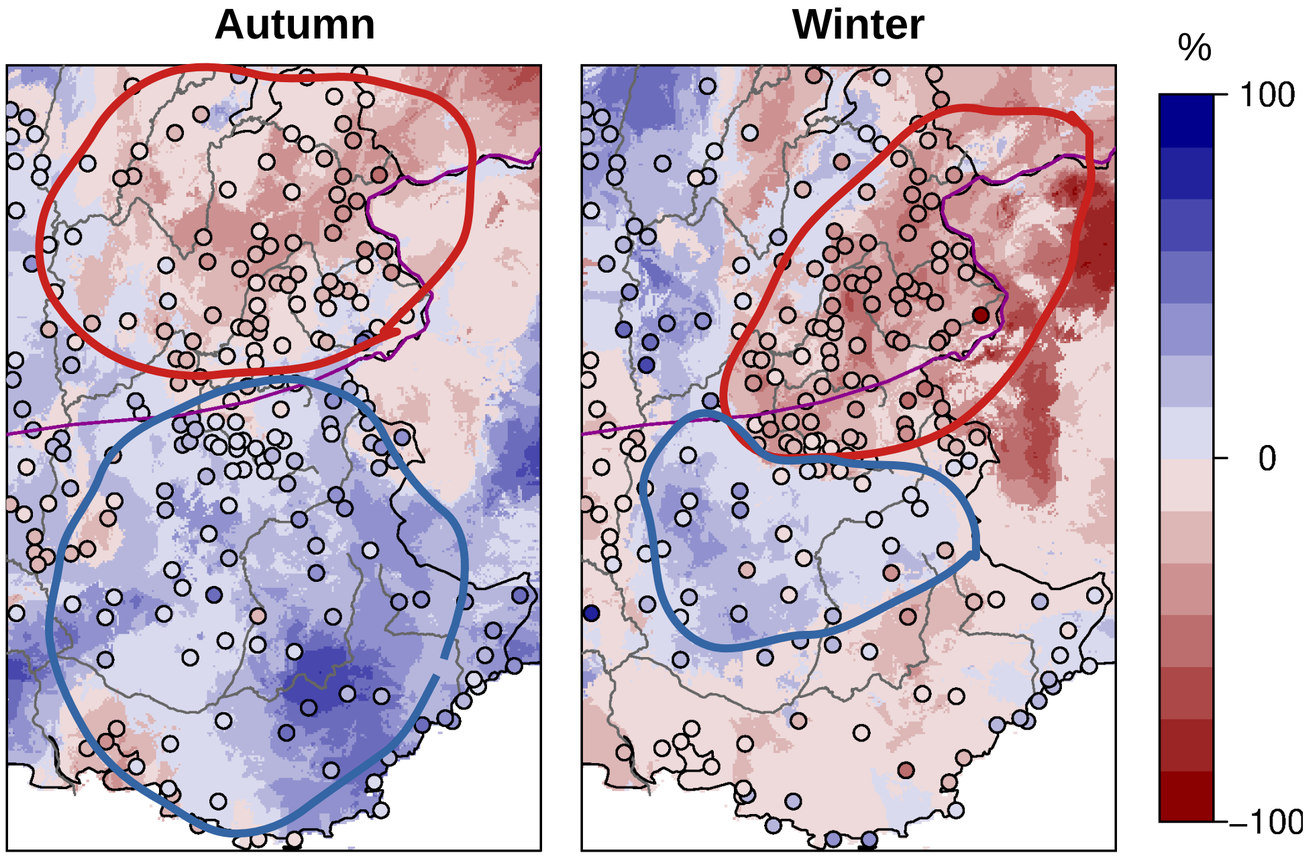

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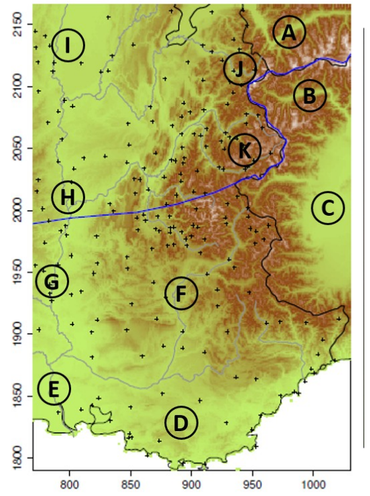
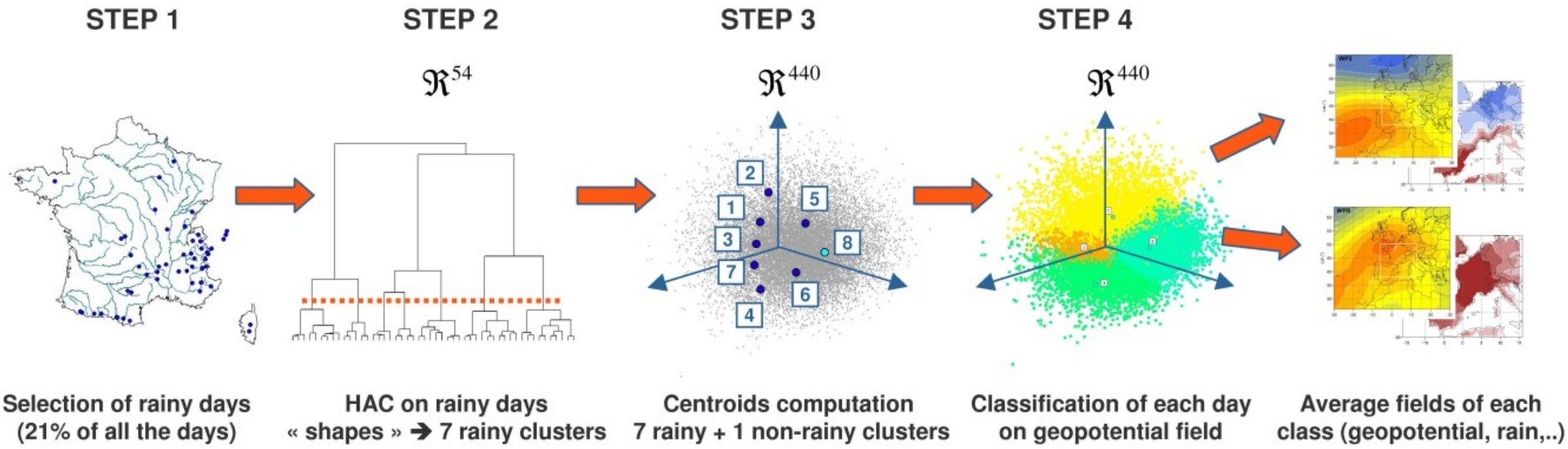


% change 1958-2017 w.r.t. average value over the period

Garavaglia et al. 2014 circulation types

Bottom-up approch : the definition of the classes uses precipitation data.



8 classes

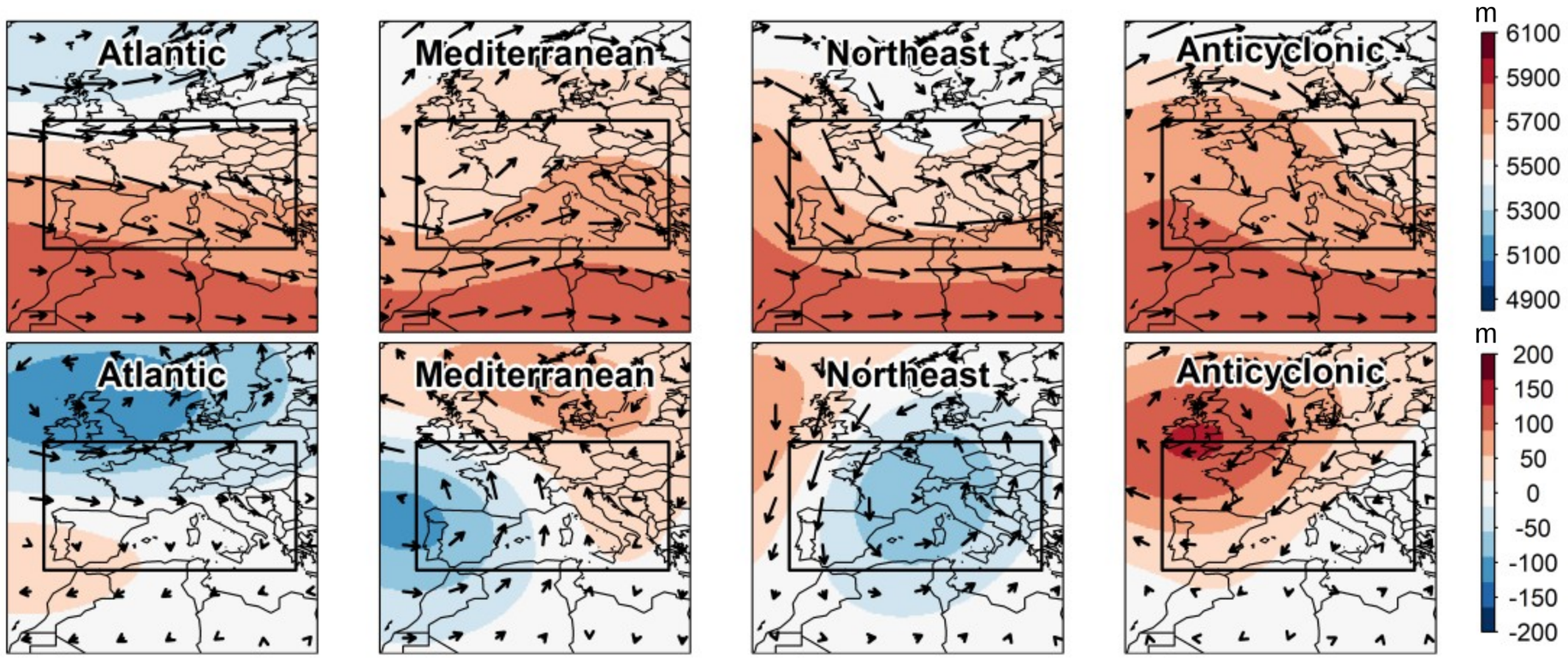
Main circulation types

4 main classes derived from Garavaglia et al 2014 weather type classification (daily scale)

500hPa geopotentail height fields from ERA5 1950-2017

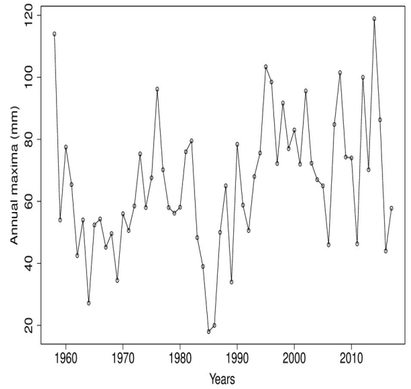
composites

anomalies



Blanc et al 2022

What type of circulations generate the extremes ? (1958-2017)



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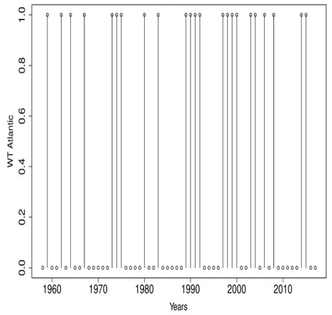
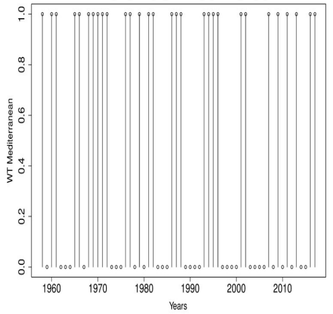
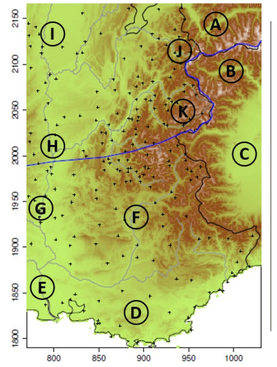
Atlantic

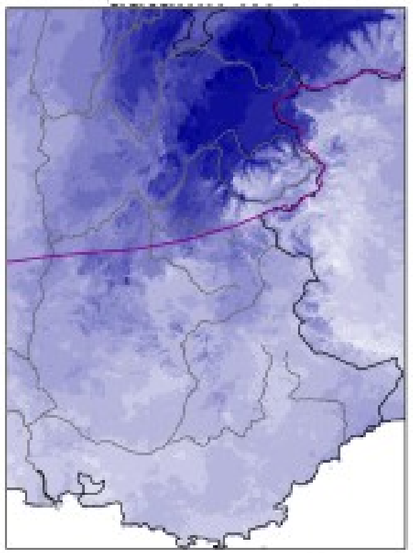


Mediterranean

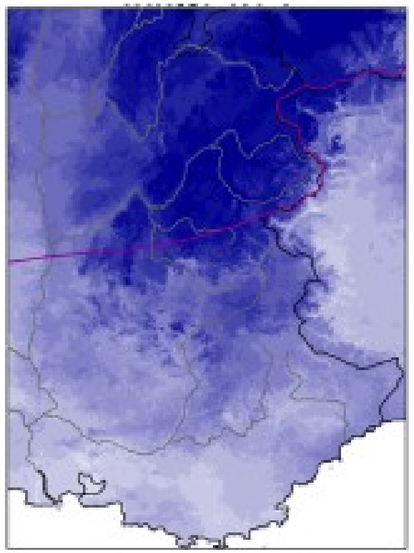


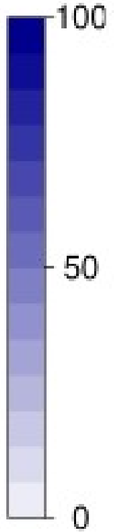


Autumn Atlantic



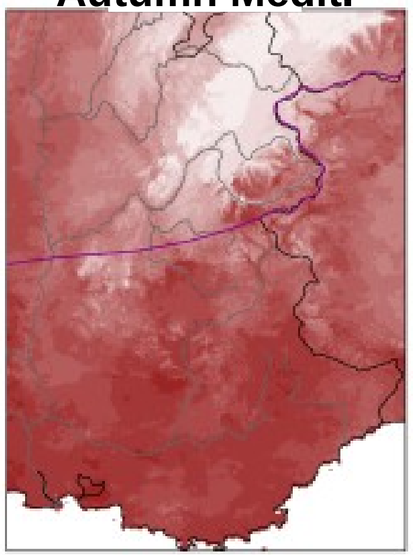
Winter Atlantic



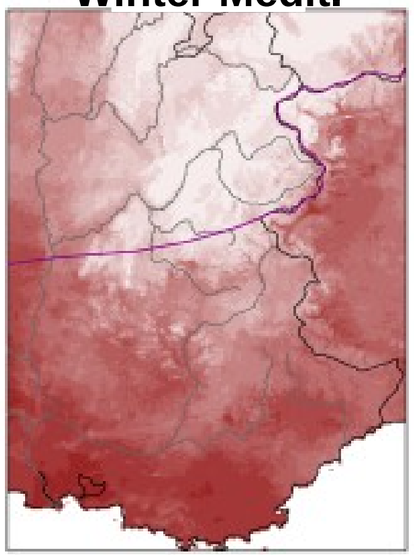


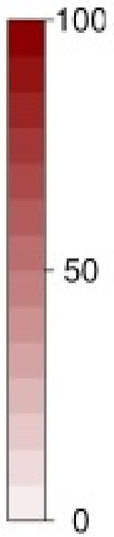
%

Autumn Medit.



Winter Medit.





%

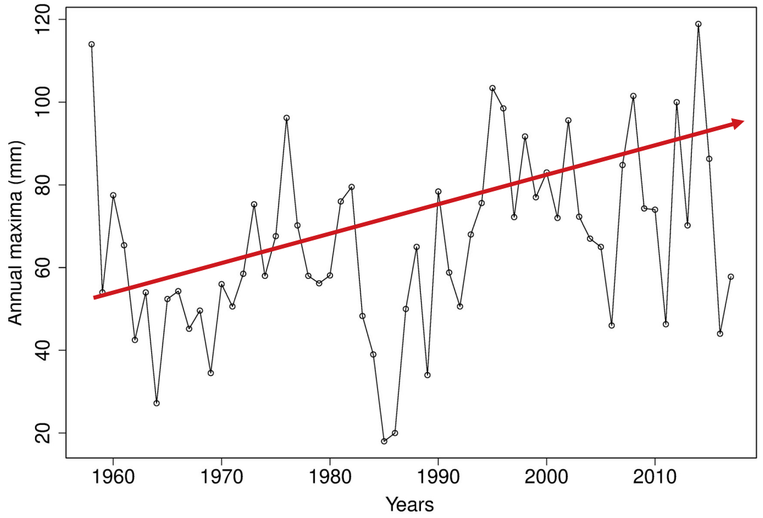
P(circulation|extreme) = proportion of extremes that are generated by a given circulation

Clear North-South divide (Auer)

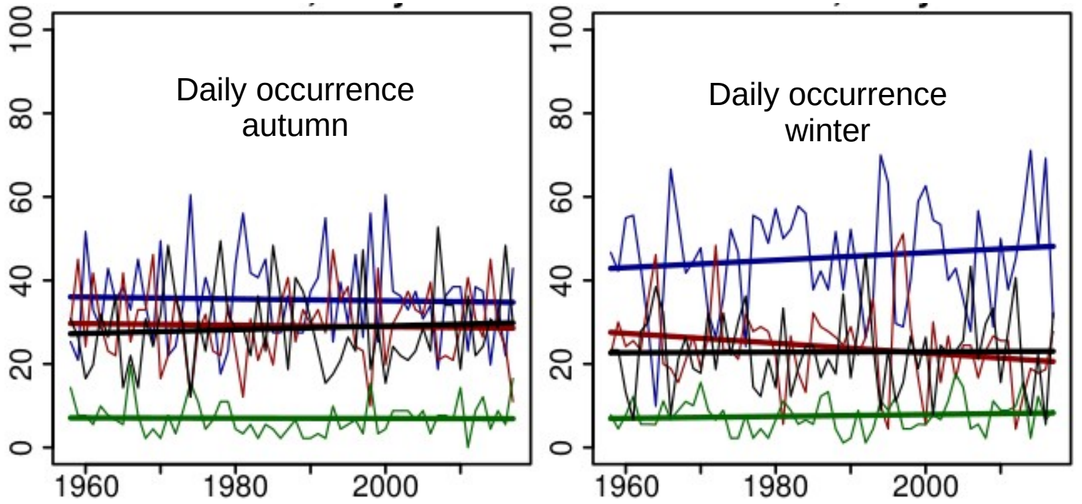
Blanchet et al 2021

What type of circulations generate the extremes : change ?

Previously : Change in P(extreme)



But P(circulation) almost stationary



Blanchet et al 2021

Atlantic

Mediterranean

Anticyclonic

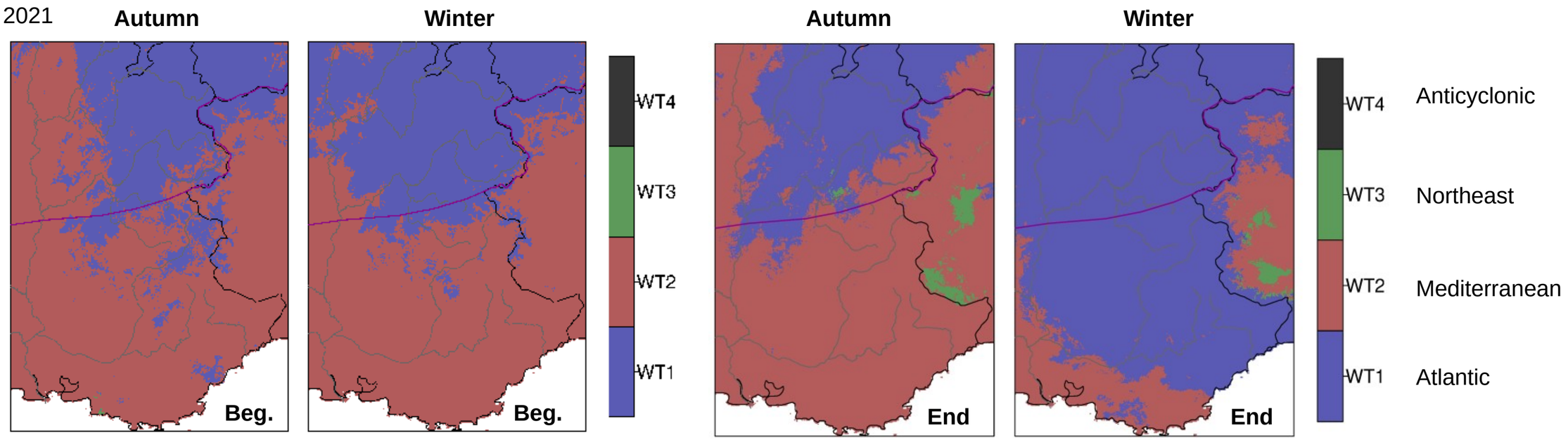
Northeast

Is there a change the type of circulations generating the extremes = change in P(circulation|extreme) ?

Change in the max-leading circulations (1958-2017)

Blanchet et al 2021

Most likely circulation generating the max



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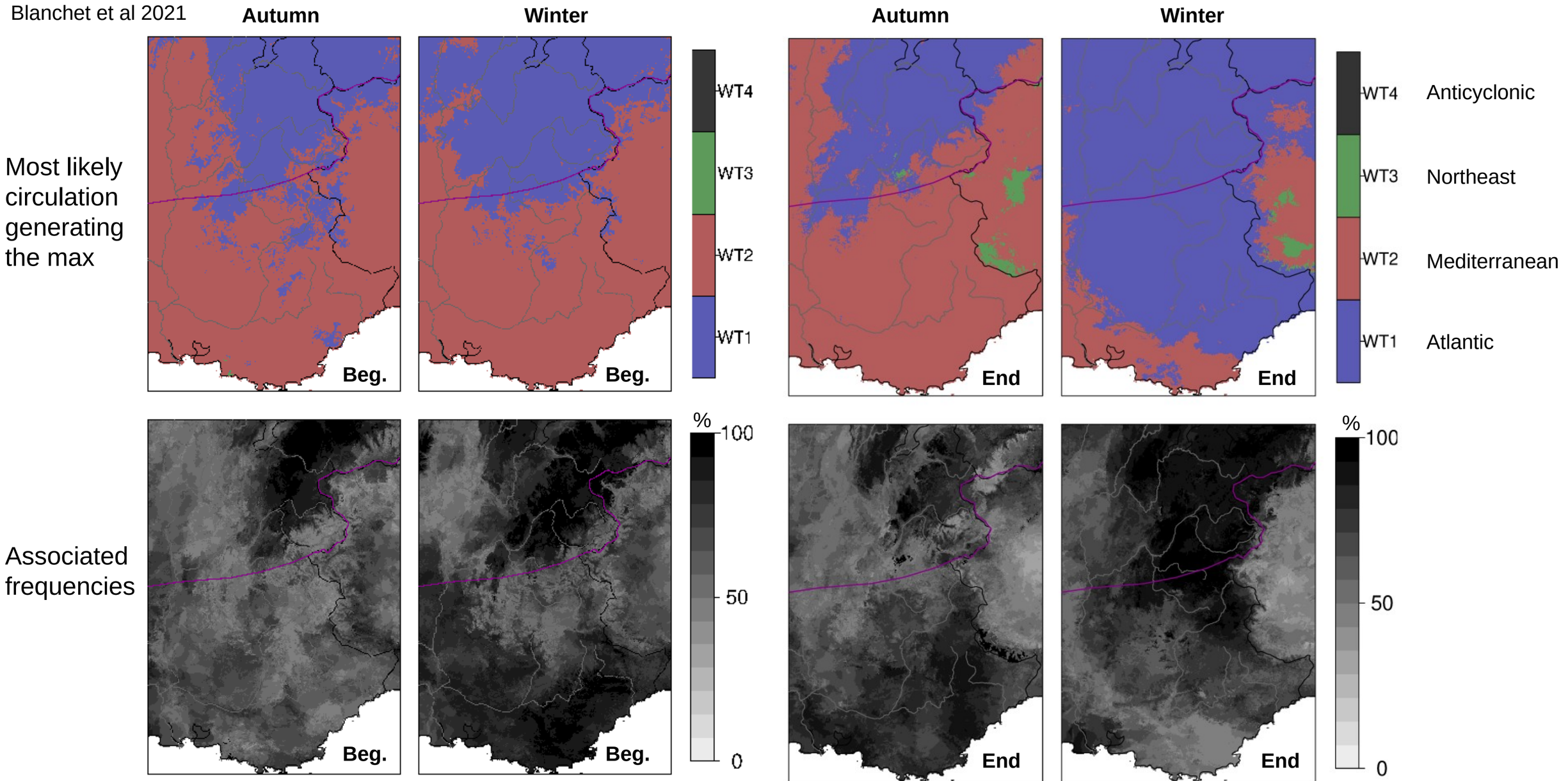

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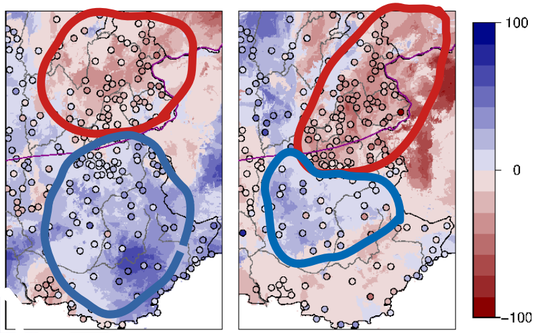

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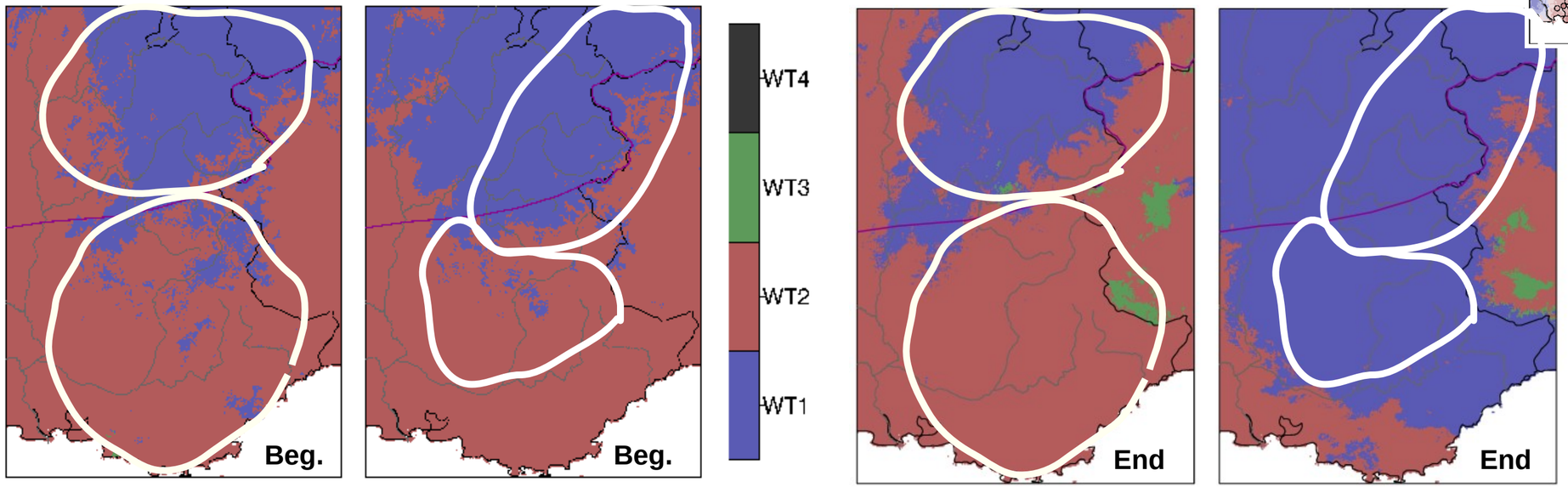
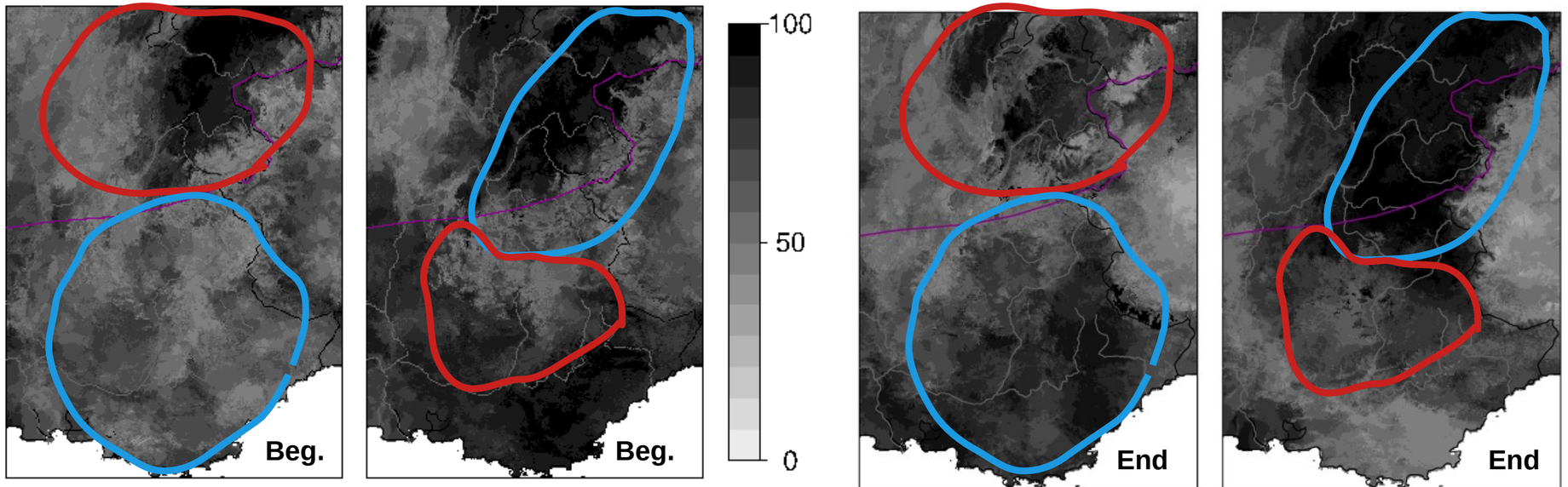


Associated frequencies



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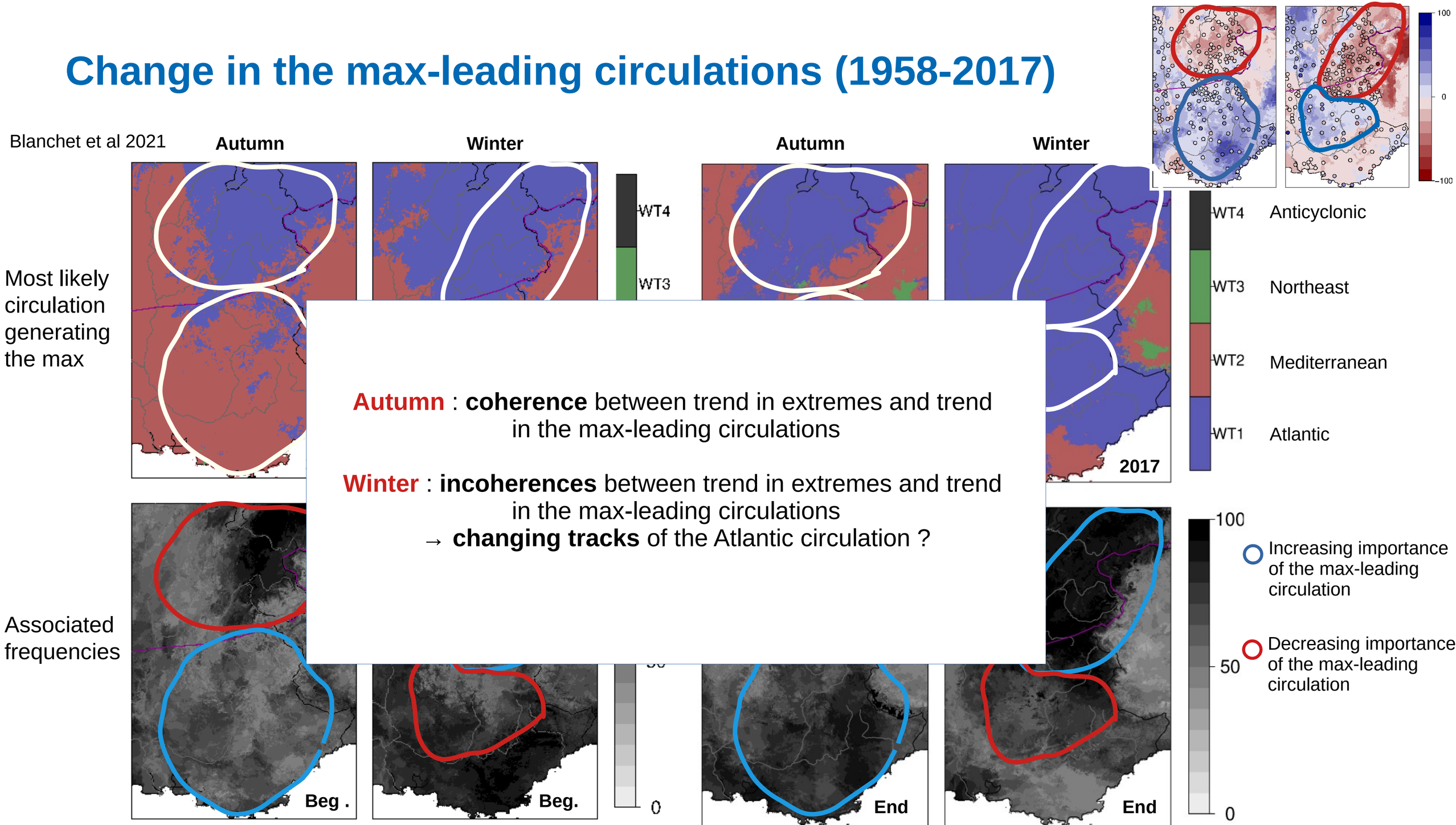
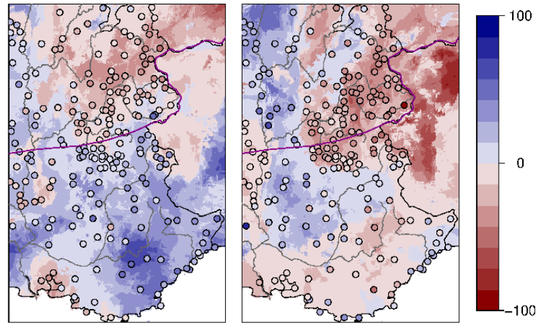
Blanchet et al 2021



Autumn : **coherence** between trend in extremes and trend in the max-leading circulations

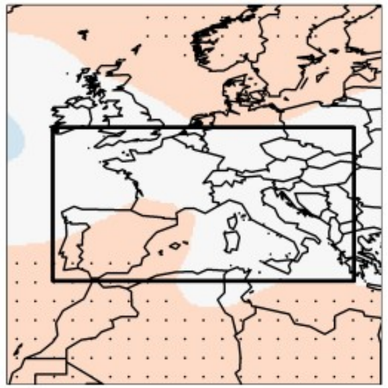
Winter : **incoherences** between trend in extremes and trend in the max-leading circulations
→ **changing tracks** of the Atlantic circulation ?

Change in daily circulation type (1950-2019)

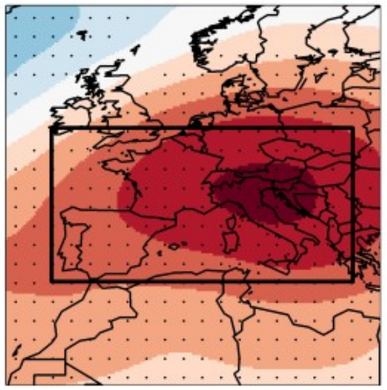


Difference 1985-2019 minus 1950-1984

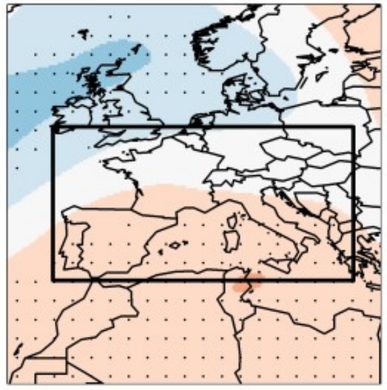
Atlantic autumn



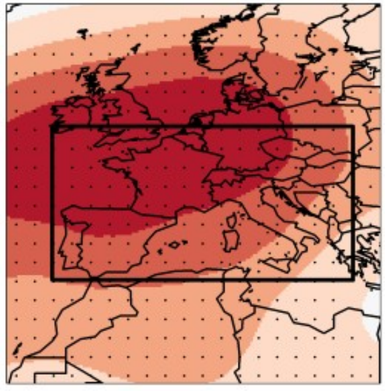
Atlantic winter

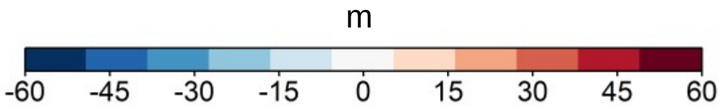


Mediterranean autumn

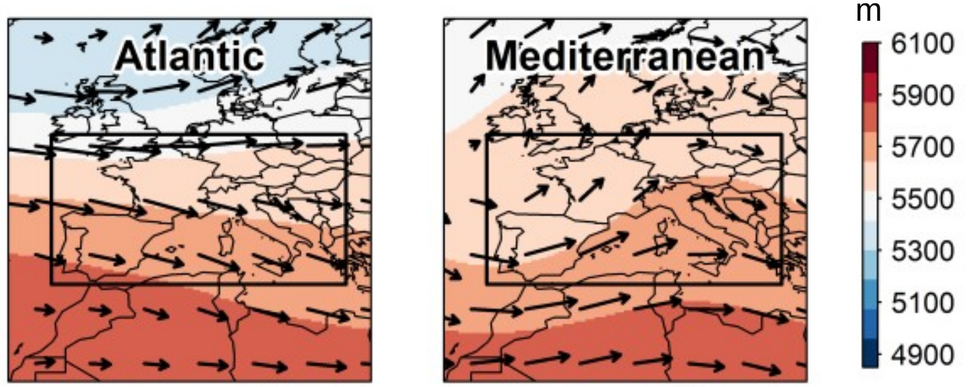


Mediterranean winter





Composites



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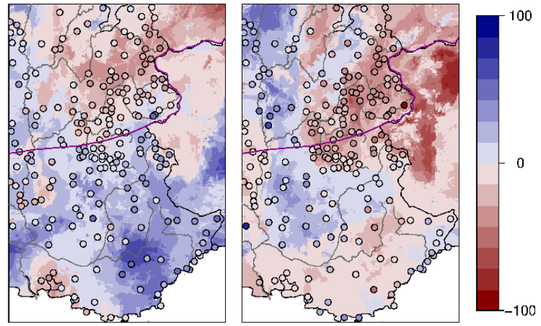
Autumn : stronger centers of action of the Mediterranean circulation
→ in coherence with the increasing extremes in the South

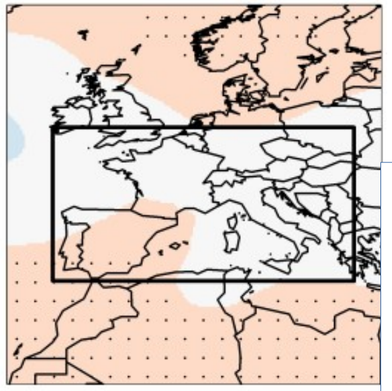
Winter : northward shift of Atlantic circulations, flattening of the Mediterranean circulations
→ in coherence with the decreasing extremes in the South and in the northern French Alps ?

Change in daily circulation type (1950-2019)

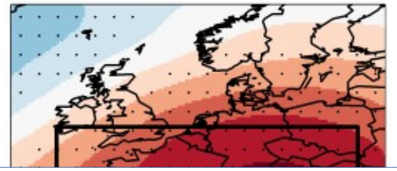


Difference 1985-2019 minus 1950-1984

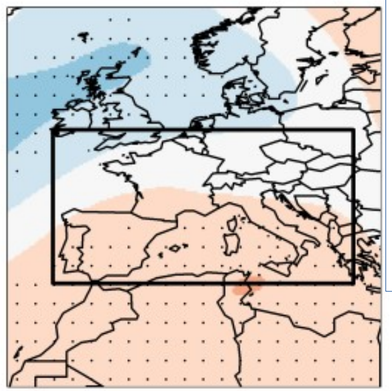
Atlantic autumn

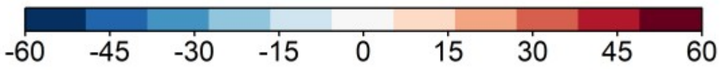


Atlantic winter



Mediterranean autumn



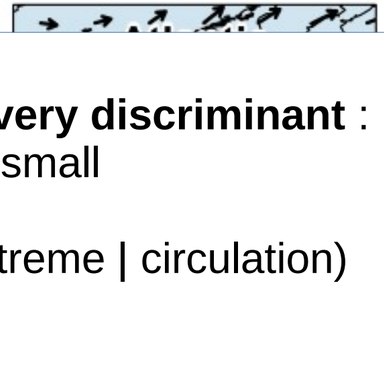


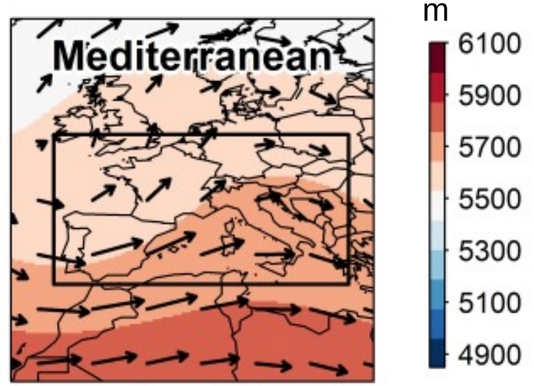
Some insight but circulation types are **not very discriminant** :
P(extreme | circulation) very small

e.g. for the 1 % largest precipitation, P(extreme | circulation)
no larger than 2 %...
Many false positive

What makes a given circulation **favorable** to the generation of extremes ?
=> atmospheric features

Composites





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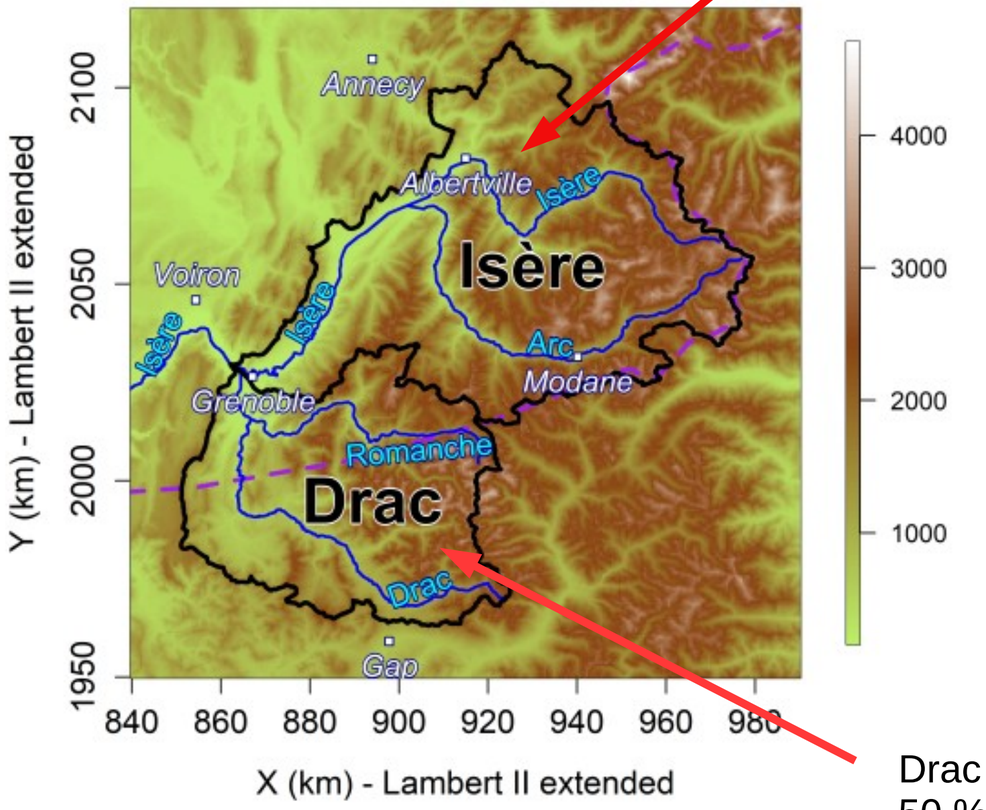
of the Mediterranean

extremes in the South

Winter : northward shift of Atlantic circulations, flattening of the Mediterranean circulations
→ in coherence with the decreasing extremes in the South and in the northern French Alps ?

Region of study

Hydrological scale : Isère and Drac catchments at Grenoble



Isère Maxima : 79 % Altlantic
19 % Mediterranean

Drac Maxima : 50 % Altlantic
50 % Mediterranean

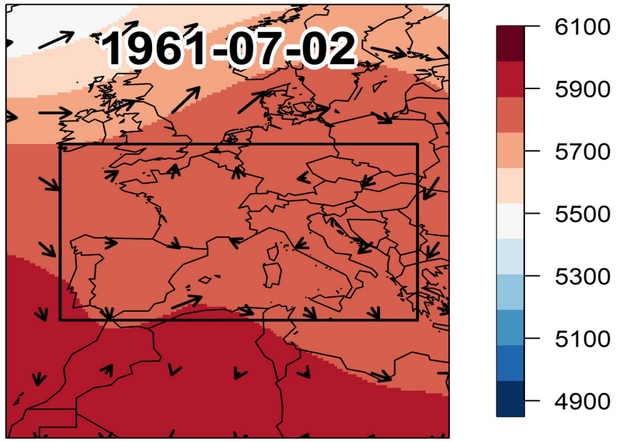
Catchment precipitation

Atmospheric features

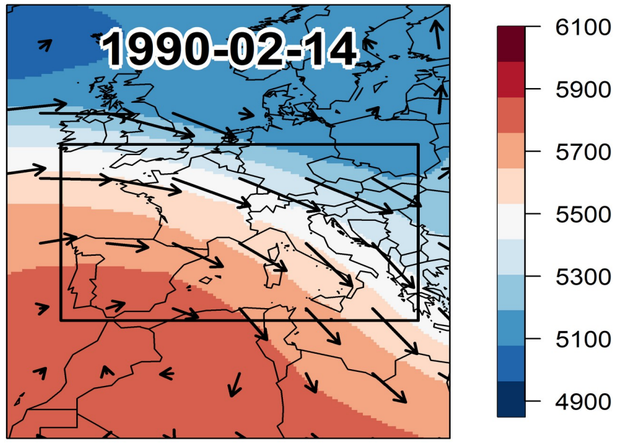
Describing both the amplitude (= flow strength) of the 500hPa geopotential fields and its shape (= flow direction).

1) **Amplitude**: Range of the geopotential heights of day D→ strength of the centers of action.

Low amplitude



Large amplitude



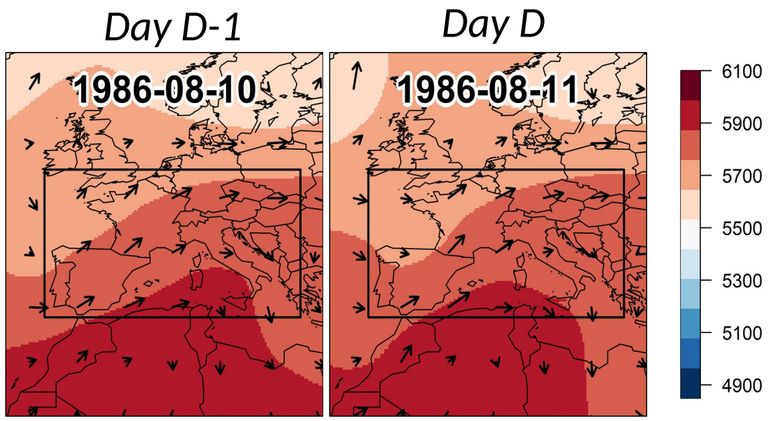
Atmospheric features

Describing both the amplitude (= flow strength) of the 500hPa geopotential fields and its shape (= flow direction).

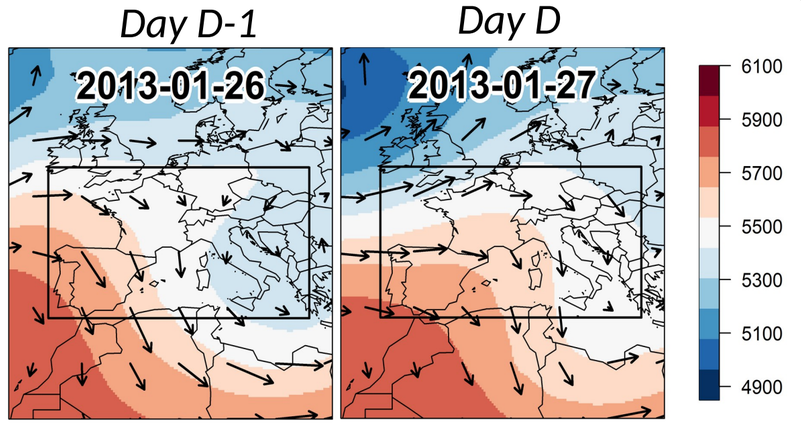
1) **Amplitude**: Range of the geopotential heights of day D→ strength of the centers of action.

2) **Celerity** : Ressemblance in geopotential shapes between day D and day D-1 → « quasi-stationary ».

Low celerity



Large celerity



Atmospheric features

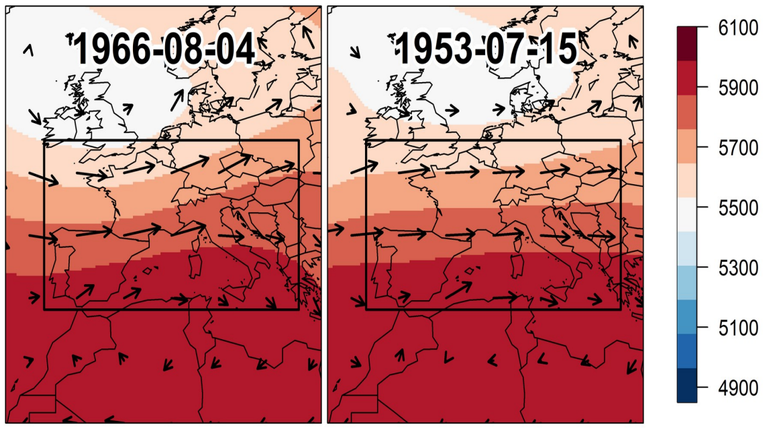
Describing both the amplitude (= flow strength) of the 500hPa geopotential fields and its shape (= flow direction).

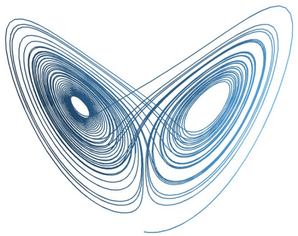
1) **Amplitude**: Range of the geopotential heights of day D→ strength of the centers of action.

2) **Celerity** : Ressemblance in geopotential shapes between day D and day D-1 → « quasi-stationary »

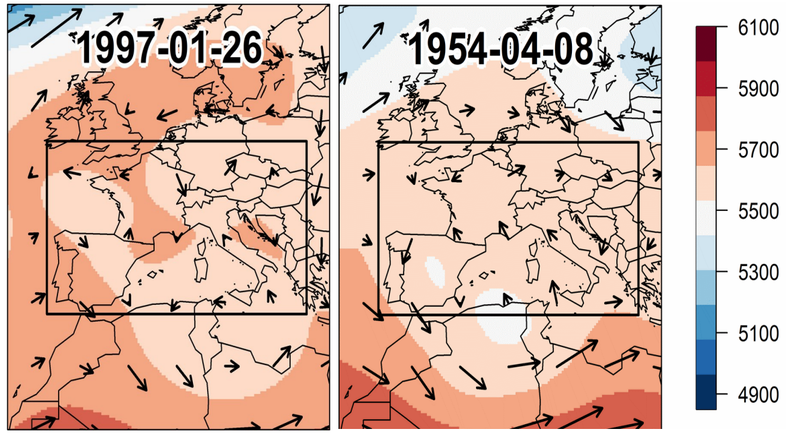
3) **Singularity** : Ressemblance in geopotential shapes between day D and its closest analogs (0.5%) → « attractor » (theory of dynamical system, Faranda et al. 2016).

Low singularity





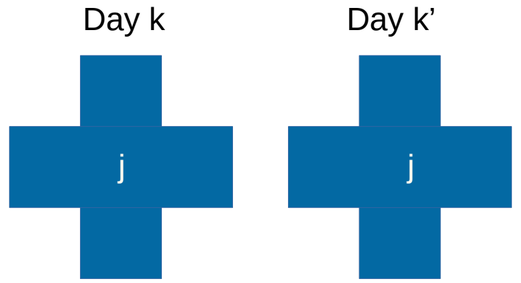
Large singularity

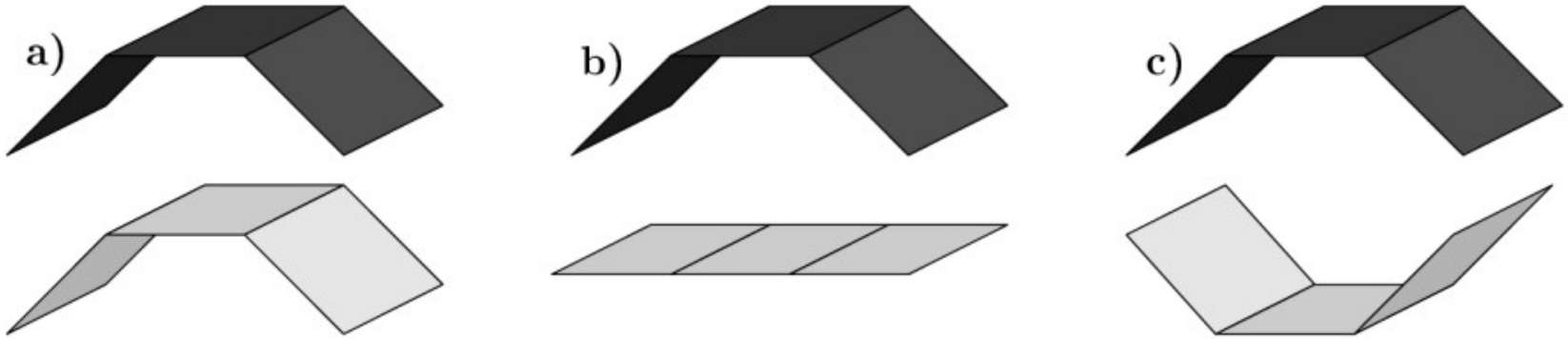


Ressemblance in shape : Teweless-Wobus score

For two geopotential height fileds at day k and k’,

$$TWS_{k,k'} = \frac{\sum_{(j,j')\in Adj} |(z_{jk} - z_{j'k}) - (z_{jk'} - z_{j'k'})|}{2\sum_{(j,j')\in Adj} \max(|z_{jk} - z_{j'k}|, |z_{jk'} - z_{j'k'}|)}$$

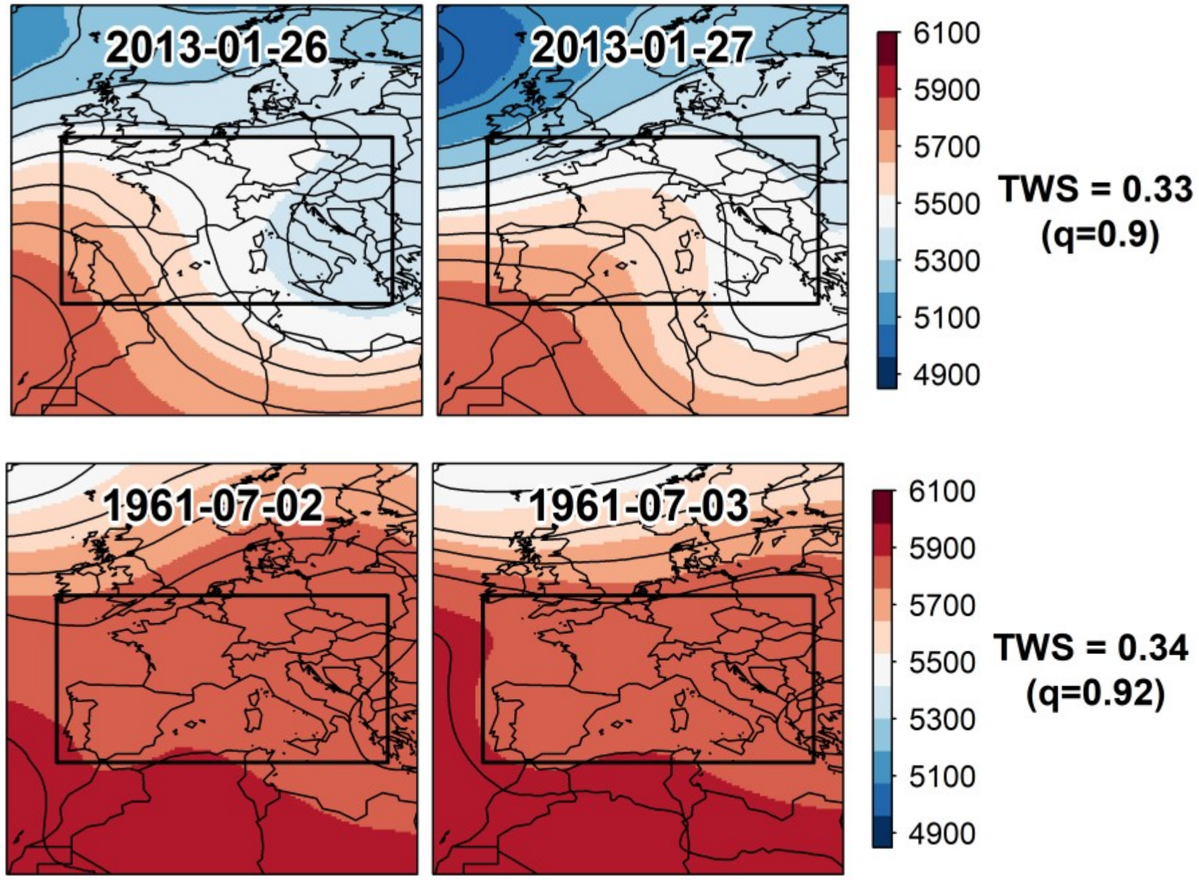




TWS=0 TWS=0.5 TWS=1

The lower the TWS, the more similar the shapes.

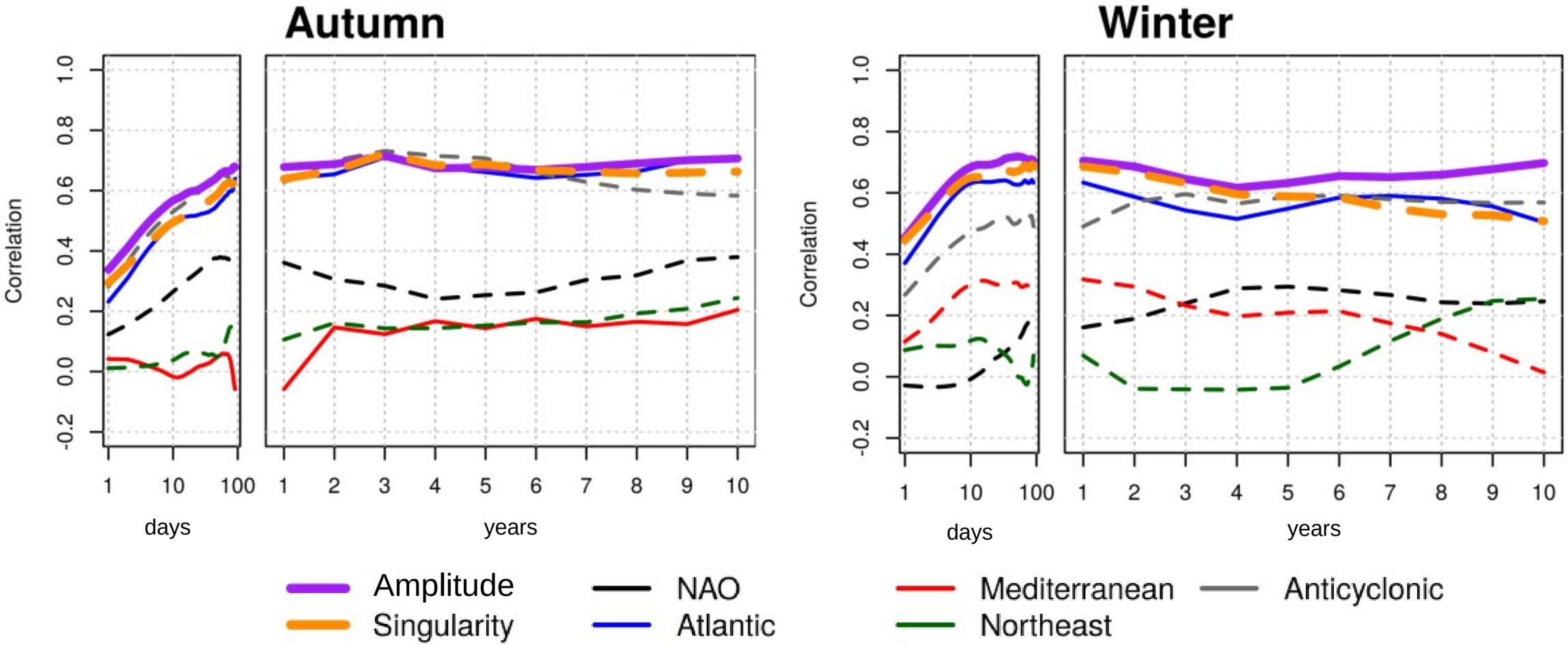
Ressemblance in shape : Teweless-Wobus score



The TWS tends to be large for flat fields → better suited **for pronounced shapes** (contrarily to the Eudidean distance).

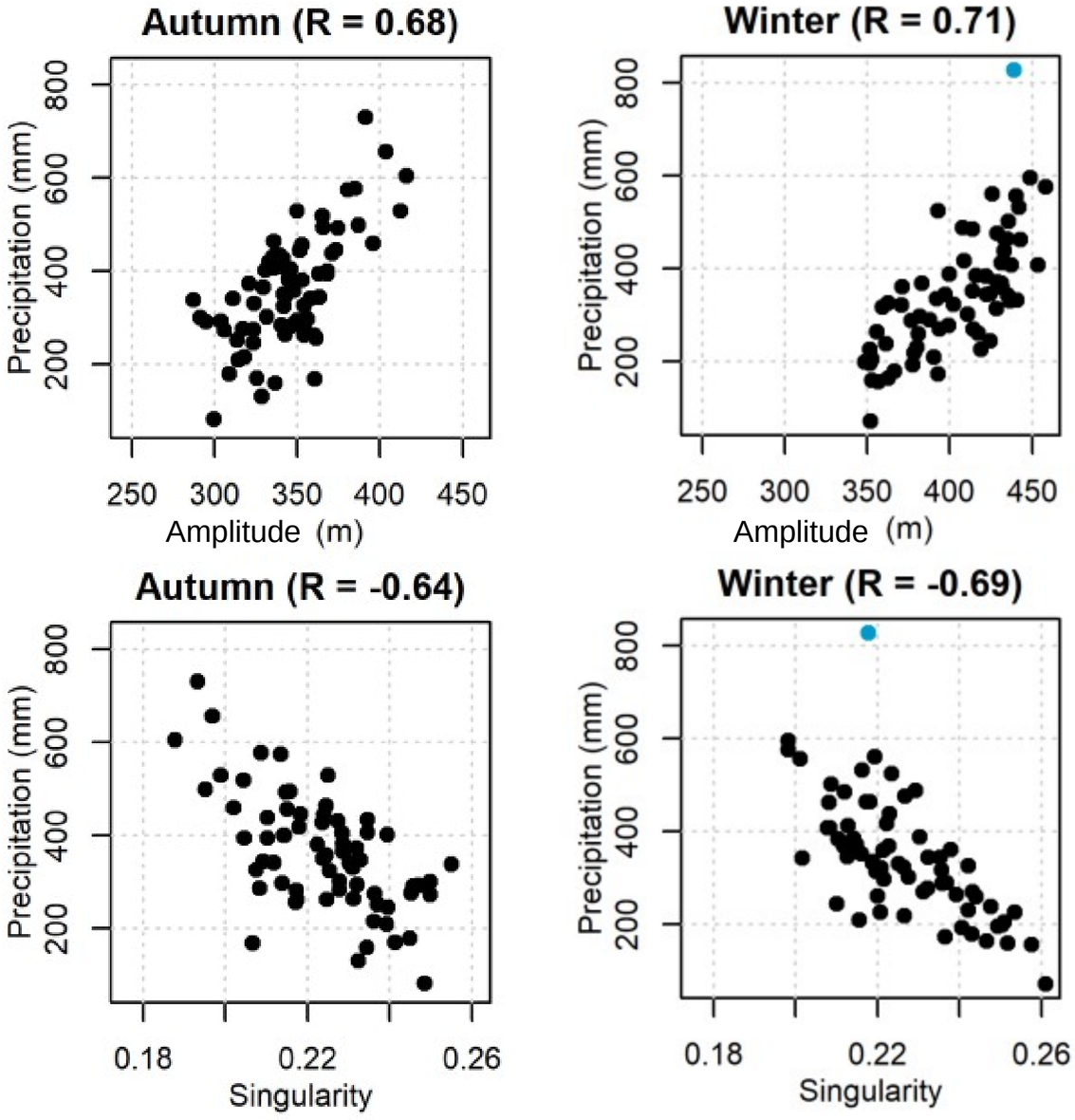
The features are correlated to precipitation variability (1958-2017)

Correlation to precipitation accumulation

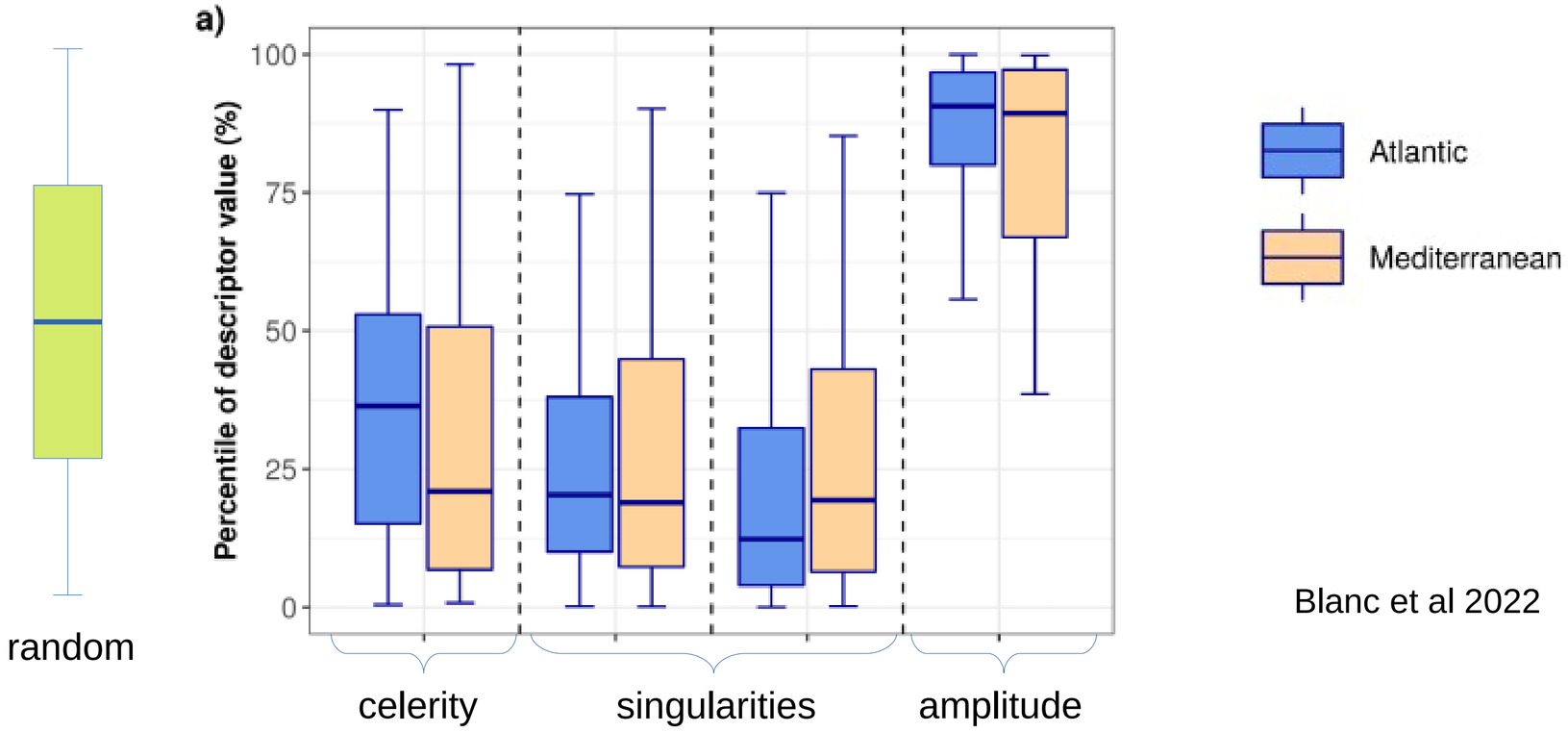


The features are correlated to precipitation variability (1958-2017)

Correlation to seasonal precipitation



The features take unusual values during extreme precipitation



Blanc et al 2022

Significantly lower celerity (quasi-stationary), **lower singularity**, stronger centers of action (amplitude) in both circulations, but **particularly for the Atlantic circulation.**

Mediterranean : stronger influence of humidity.

Being little singular is rare !

Analogy with twins !

AFP/Getty Images

Twins are « less singular » than the rest of the population.
Being twin is rare.

Geopotentials of extremes

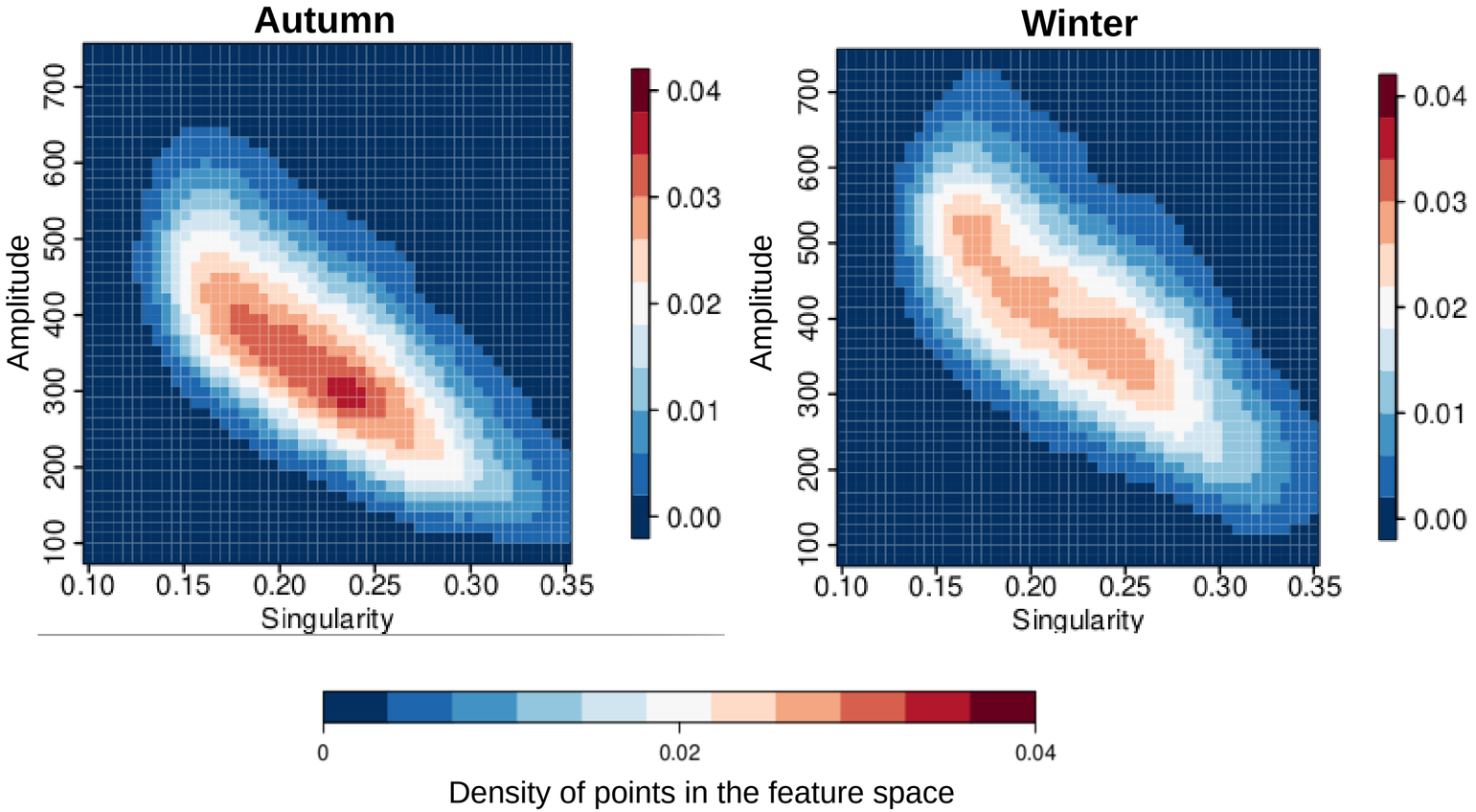
Basically « **twinned** » shapes with **large aplitude** and **little change** during several days

Geopotentials showing these three features are rare.

Extreme precipitation in the feature space (1950-2014)

Based on the singularity & amplitude

ERA5 period 1950-2014



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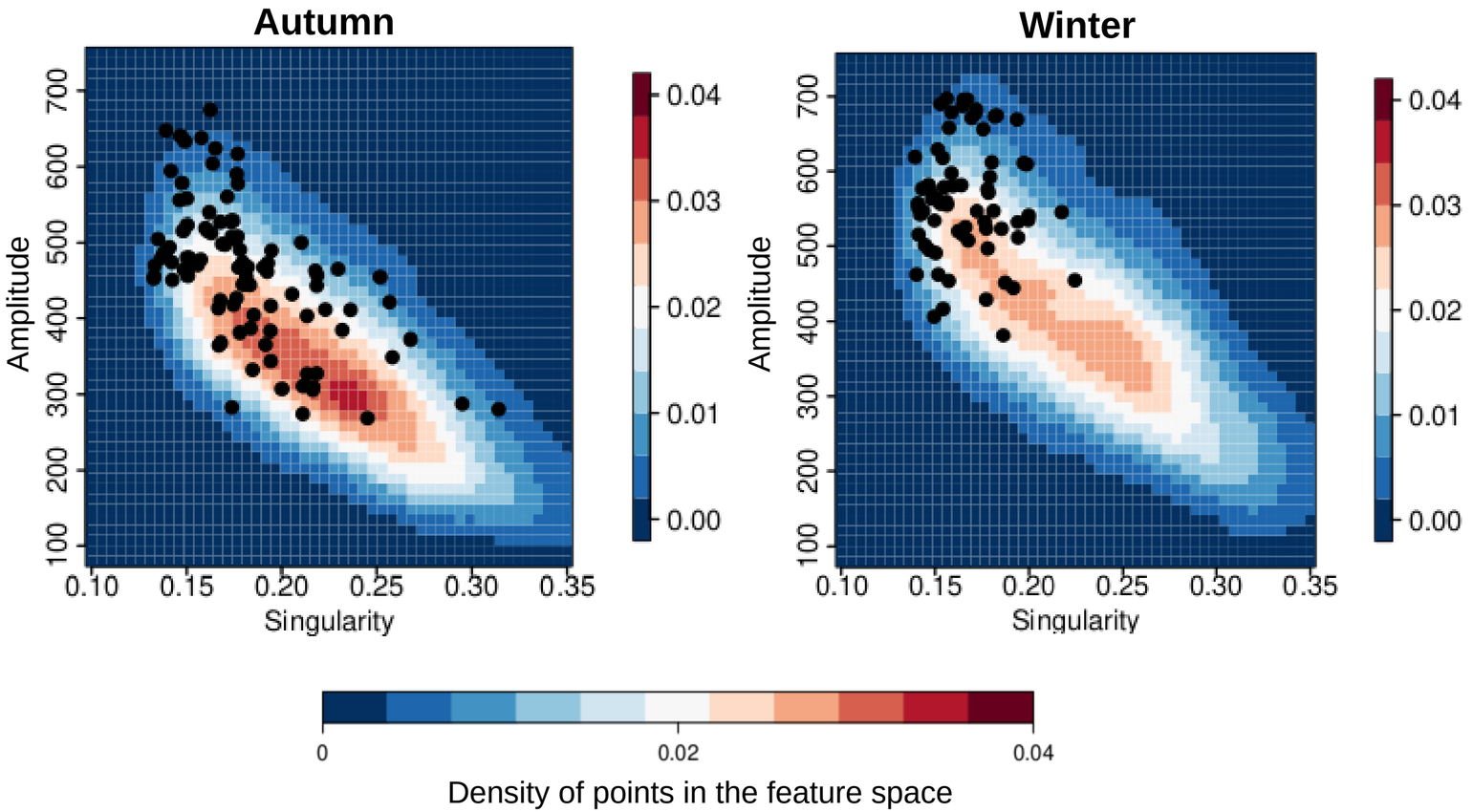
Extreme precipitation in the feature space (1950-2014)

Based on the singularity & amplitude

ERA5 period 1950-2014



- 1 % largest precipitation (irrespective of the season)

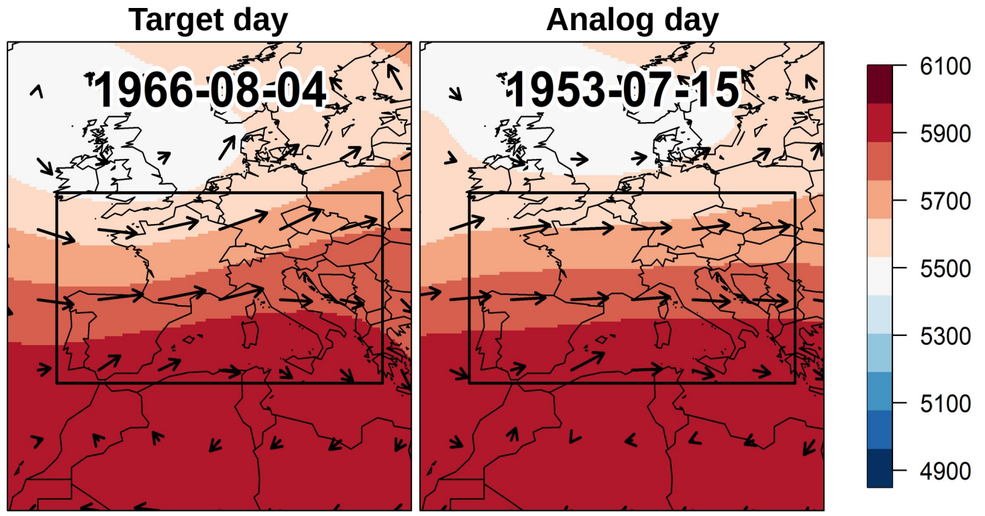
Extremes tend to cluster in the top-left corner

How predictive of extreme precipitation are the features ?

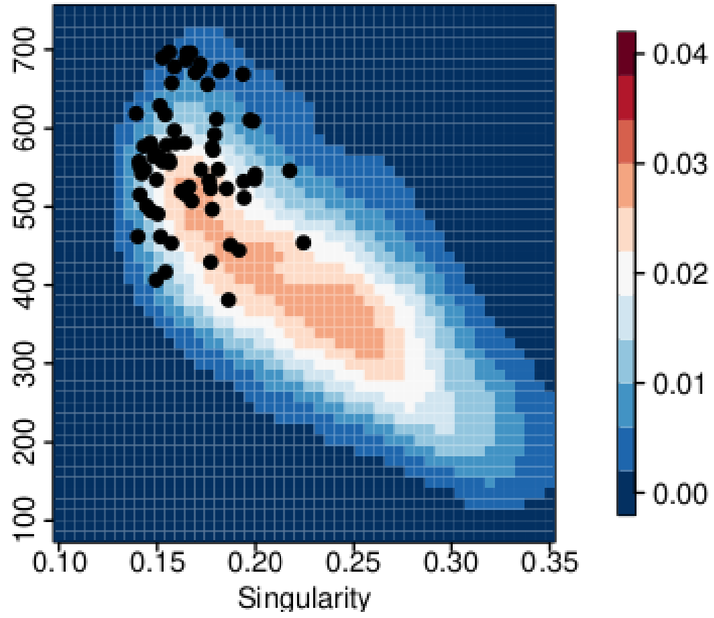
Blanchet et al 2022

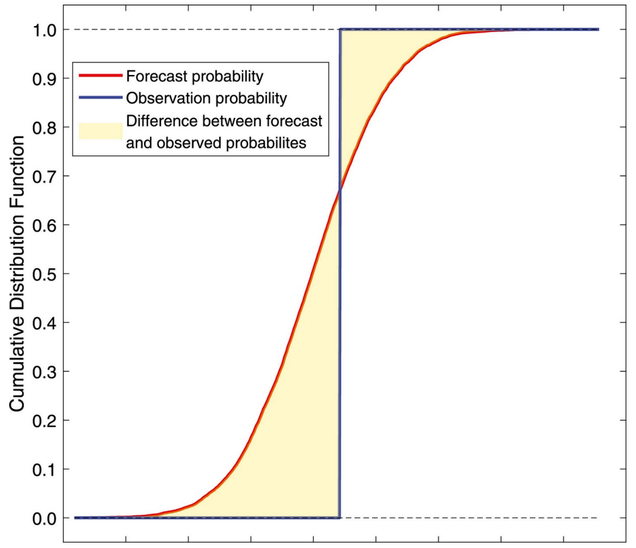
Predicting extreme precipitation with analogy in the feature space

Classical analogy :



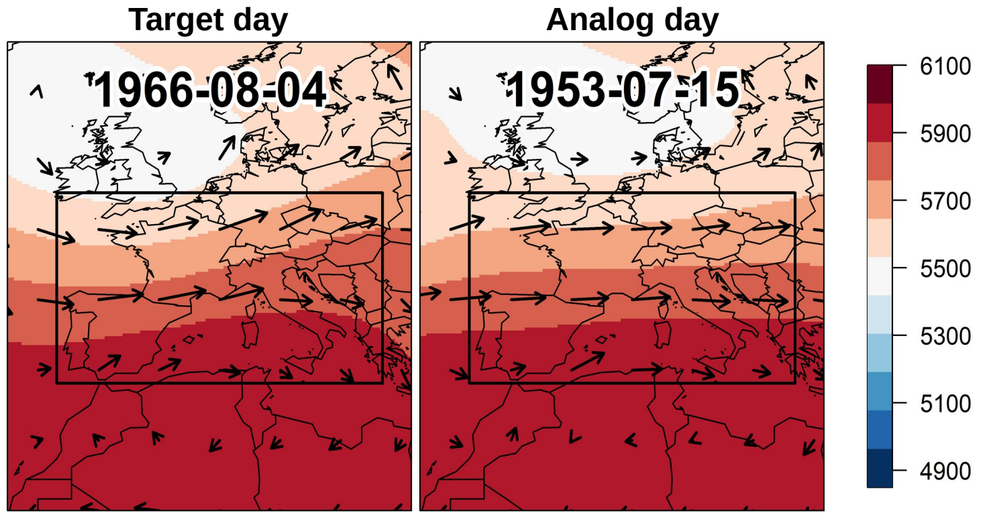
Feature analogy :



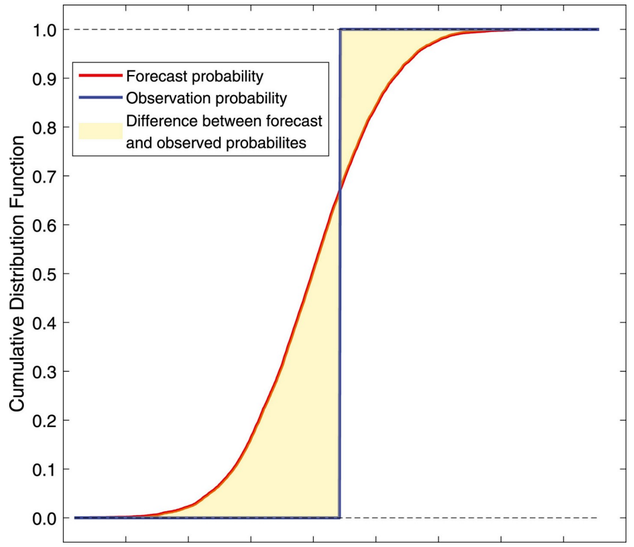


Predicting extreme precipitation with analogy in the feature space

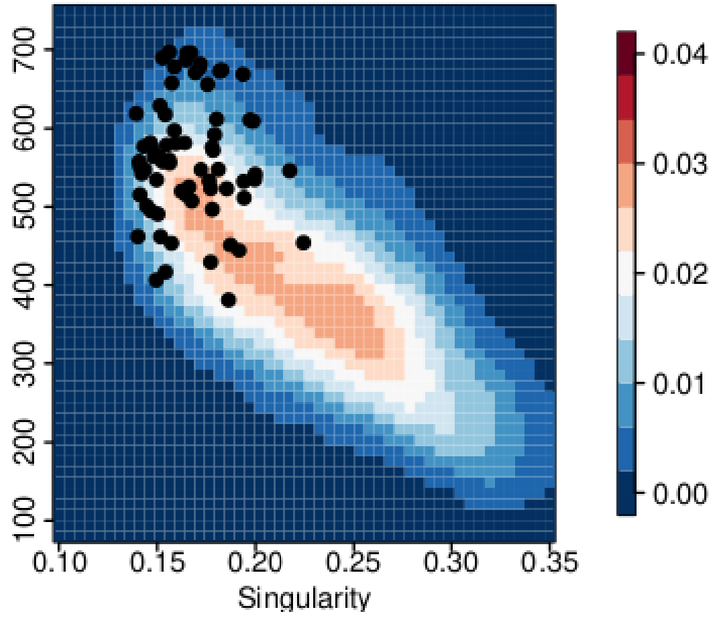
Classical analogy :



CRPS=0.42



Feature analogy :



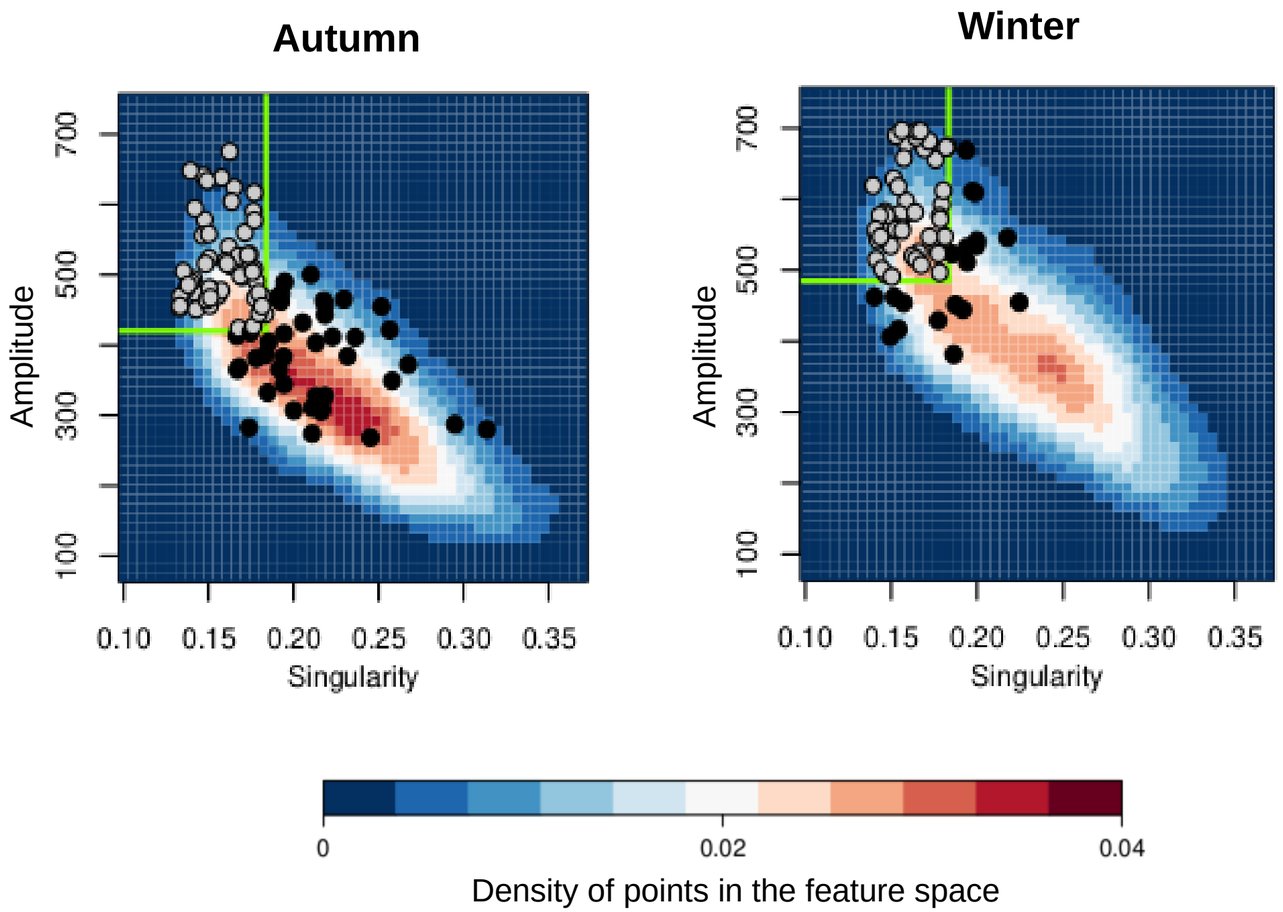
CRPS=0.32

But only 2 dimensions !

Blanchet et al 2020

Class of potentially extreme precipitation (1950-2014)

Based on the singularity & amplitude



Blanchet et al 2022

Definition of a « **potentially extreme class** » as a tradeoff between true positive and false negative (optimistation).

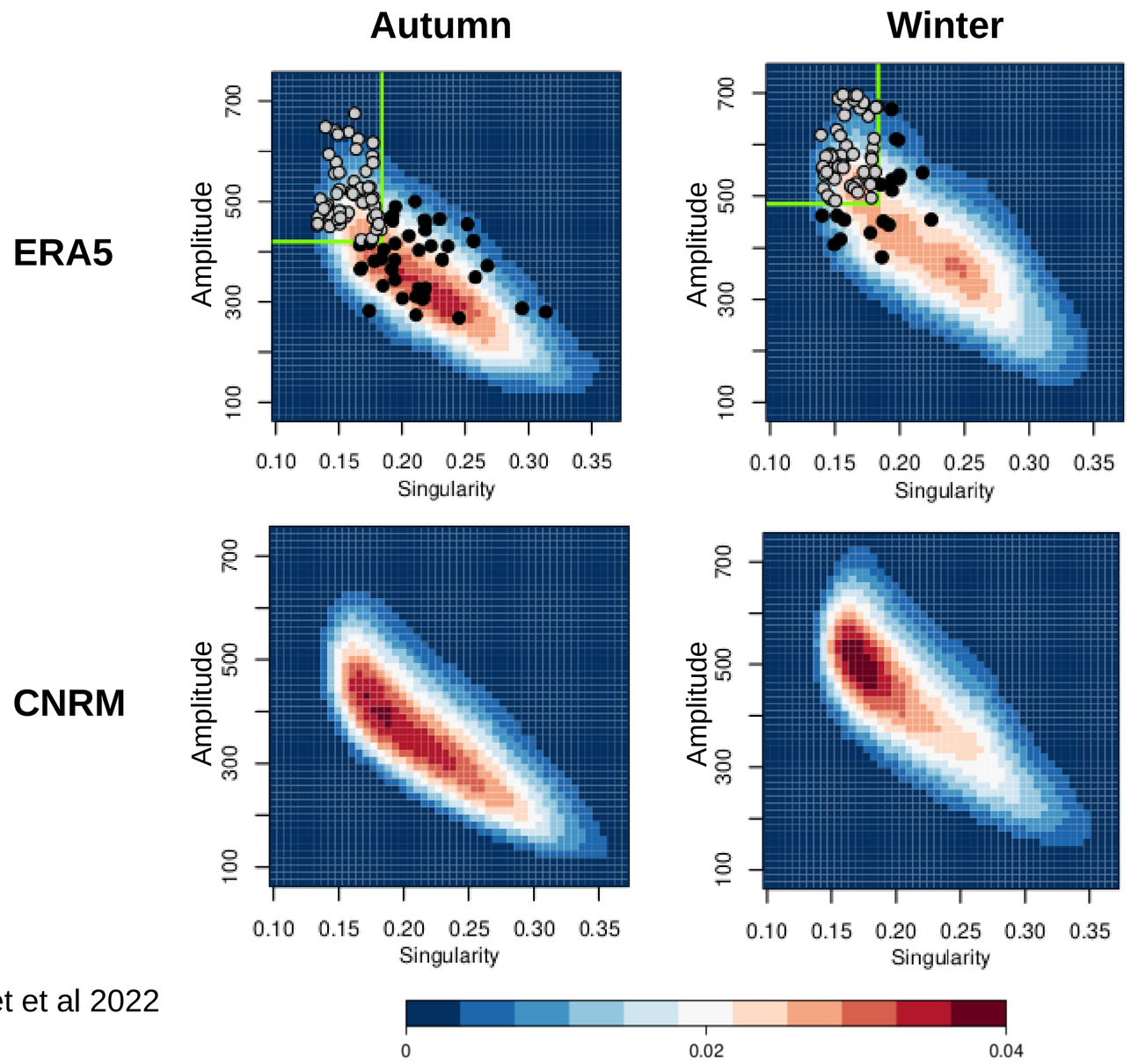
The classes contain 15 % of the days (the Atlantic and Mediterranean circulations contain 40 % each)

- **60 %** of extreme precipitation days are in the class in autumn
- **70 %** in winter

P(extreme | class) = 6%
1 chance in 16 to experience an extreme precipitation in these classes of circulations

This is much larger than **1/100 in the climatology** but also than **1/50 in the circulation types**

ERA5 versus CNRM CM6 (1950-2014)



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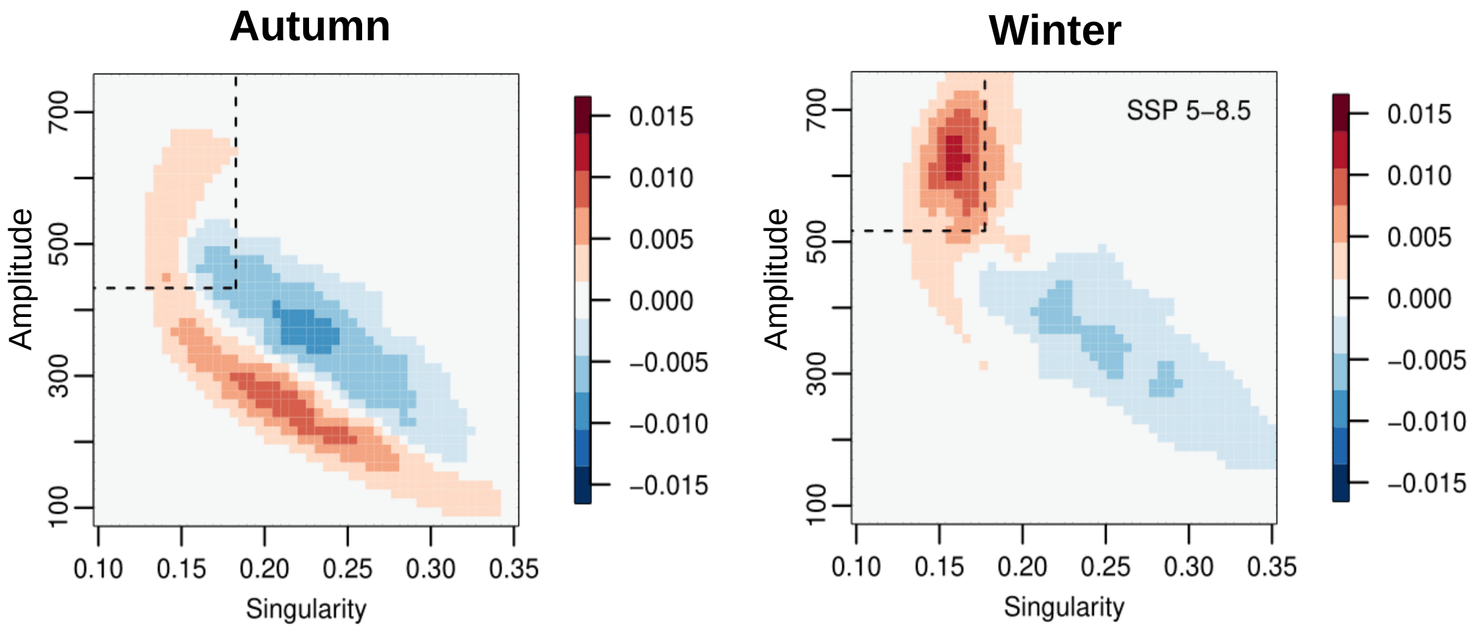
Change in the recurrence of the potentially extreme class (1980-2100)

CNRM CM6 2070-2100 minus 1980-2010



Blanchet et al 2022

For scenario SSP5-8.5:

10% increase in the occurrence of the class **in autumn**

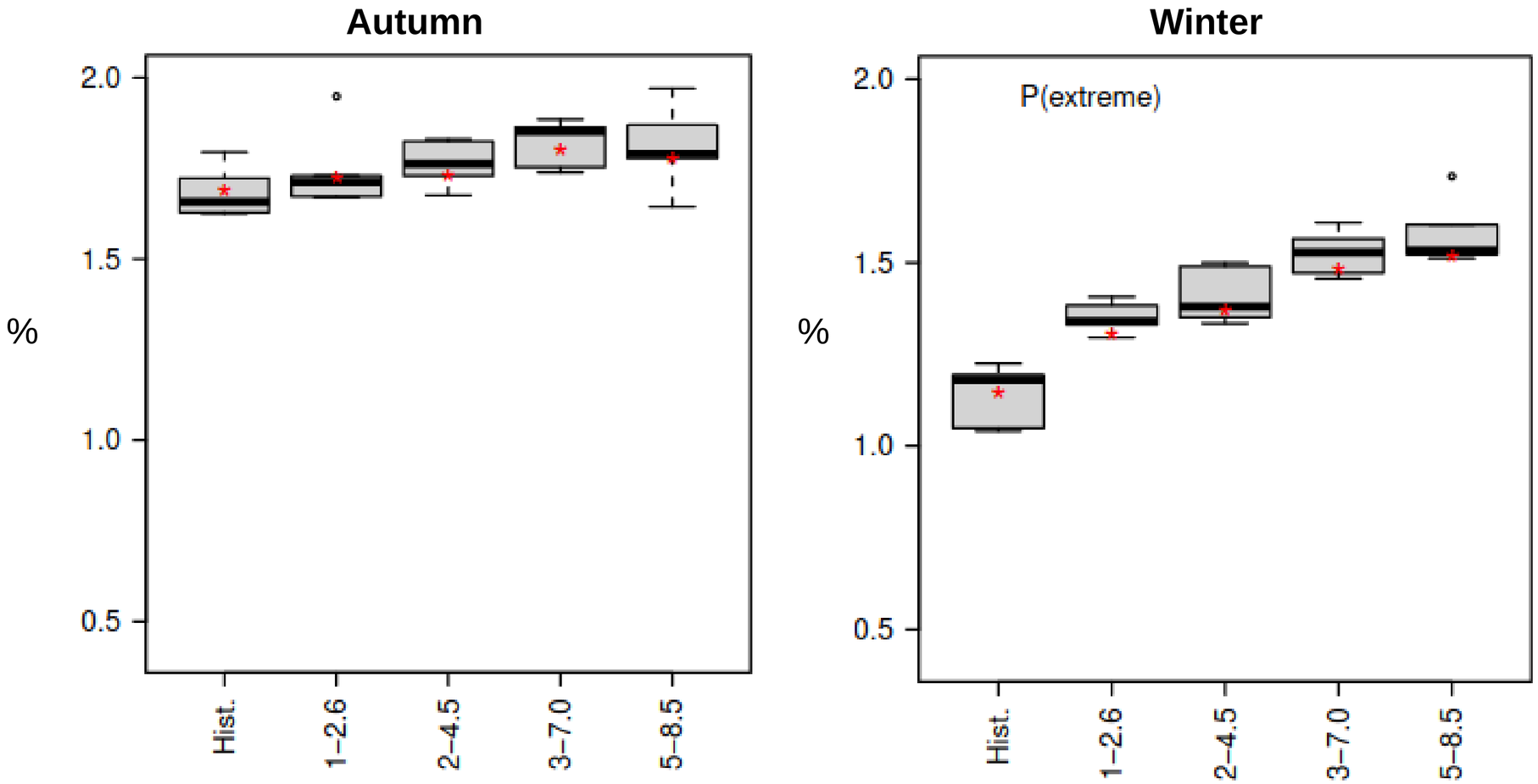
50% increase in the occurrence of the class **in winter**

Using P(extreme) = P(extreme | class) P(class) + P(extreme | notclass) P(notclass)
In total, **15% of class-driven increase** in extreme precipitation occurrence

Change in feature-driven extreme precipitation (1980-2100)

CNRM CM6 2070-2100 minus 1980-2010

P(extreme) = P(extreme | class) P(class) + P(extreme | notclass) P(notclass)

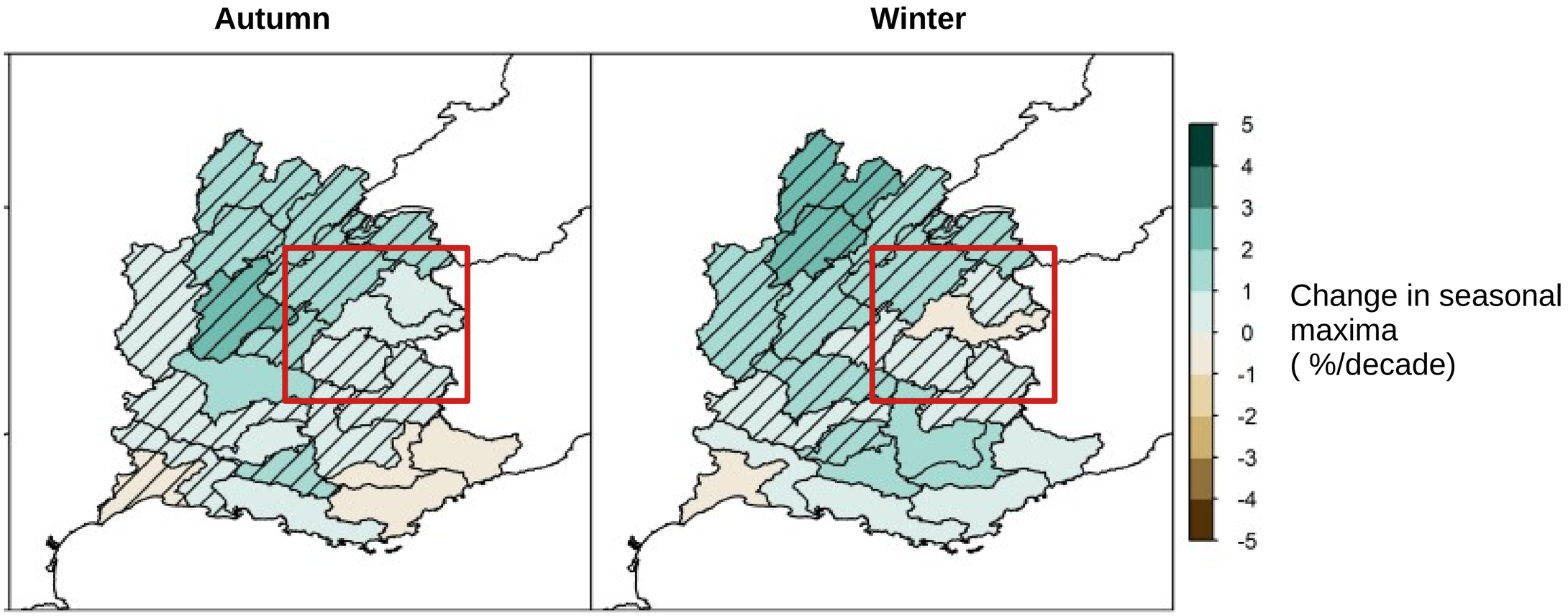


Little variability among members

Blanchet et al 2022

Coherence with changes in extremes in climate models (2018-2100)

EURO-CORDEX RCP 8.5



Castellanos 2022

Not stronger in winter than in autumn... Other circulation features ? Other variables ? Changed link ?

Conclusion

Another way of looking at the link beween circulation and extreme precipitation.

Based on very low dimensional features

More discriminant than circulation type

Some insight on changes in extreme precipitation in link to changes in atmospheric features

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