Summer Deep Depressions Increase Over the North Atlantic

Fabio D'Andrea, Jean-Philippe Duvel, Gwendal Rivière, Robert Vautard, Christophe Cassou, Julien Cattiaux, Dim Coumou, Davide Faranda, Tamara Happé, Aglaé Jézéquel, Aurelien Ribes, Pascal Yiou.

(*Paris – Toulouse – Amsterdam*)

dandrea@lmd.ipsl.fr
Laboratoire de Météorologie Dynamique/IPSL, ENS, PSL Research University, École Polytechnique, Institut Polytechnique de Paris, Sorbonne Université, CNRS, Paris France

Vienna, 18/4/2024

Summer Deep Depressions Increase Over the North Atlantic

Fabio D'Andrea, Jean-Philippe Duvel, Gwendal Rivière, Robert Vautard, Christophe Cassou, Julien Cattiaux, Dim Coumou, Davide Faranda, Tamara Happé, Aglaé Jézéquel, Aurelien Ribes, Pascal Yiou.

(*Paris – Toulouse – Amsterdam*)

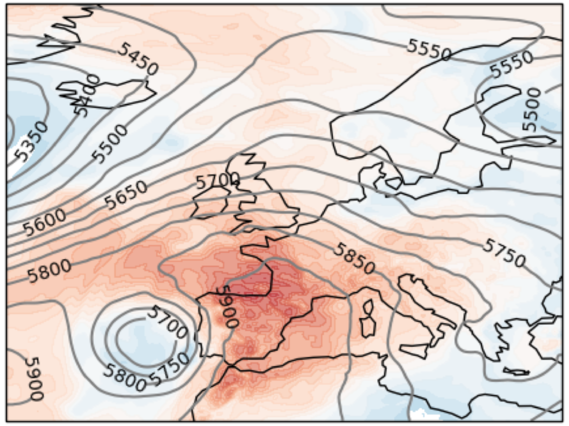
dandrea@lmd.ipsl.fr
Laboratoire de Météorologie Dynamique/IPSL, ENS, PSL Research University, École Polytechnique, Institut Polytechnique de Paris, Sorbonne Université, CNRS, Paris France

Vienna, 18/4/2024

2022

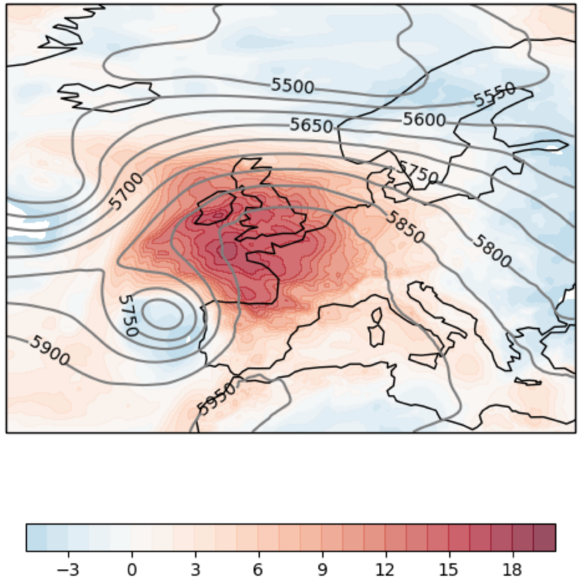
June

500mb geopotential height contours (m)
850mb Temperature anomaly (C)
18 juin 2022, 12:00\n



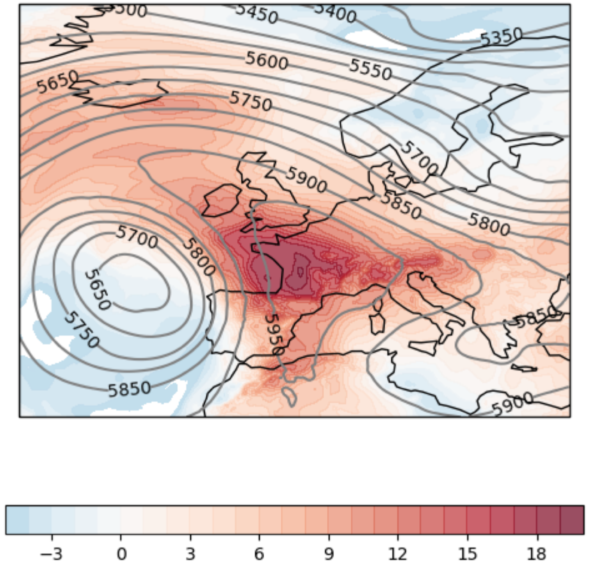
July

500mb geopotential height contours (m)
850mb Temperature anomaly (C)
18 juillet 2022, 12:00\n



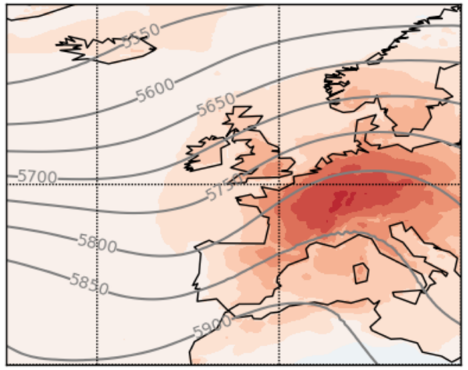
Record number of days

500mb geopotential height contours (m)
850mb Temperature anomaly (C)
27 juin 2019, 12:00\n

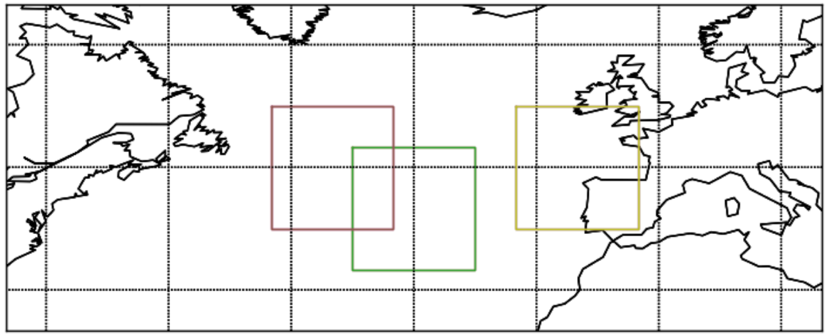


2019
Record breaking
Temperature !

500mb geopotential height contours (m)
2m Temperature (C)
Mean Heatwave



Counting Summer Depressions

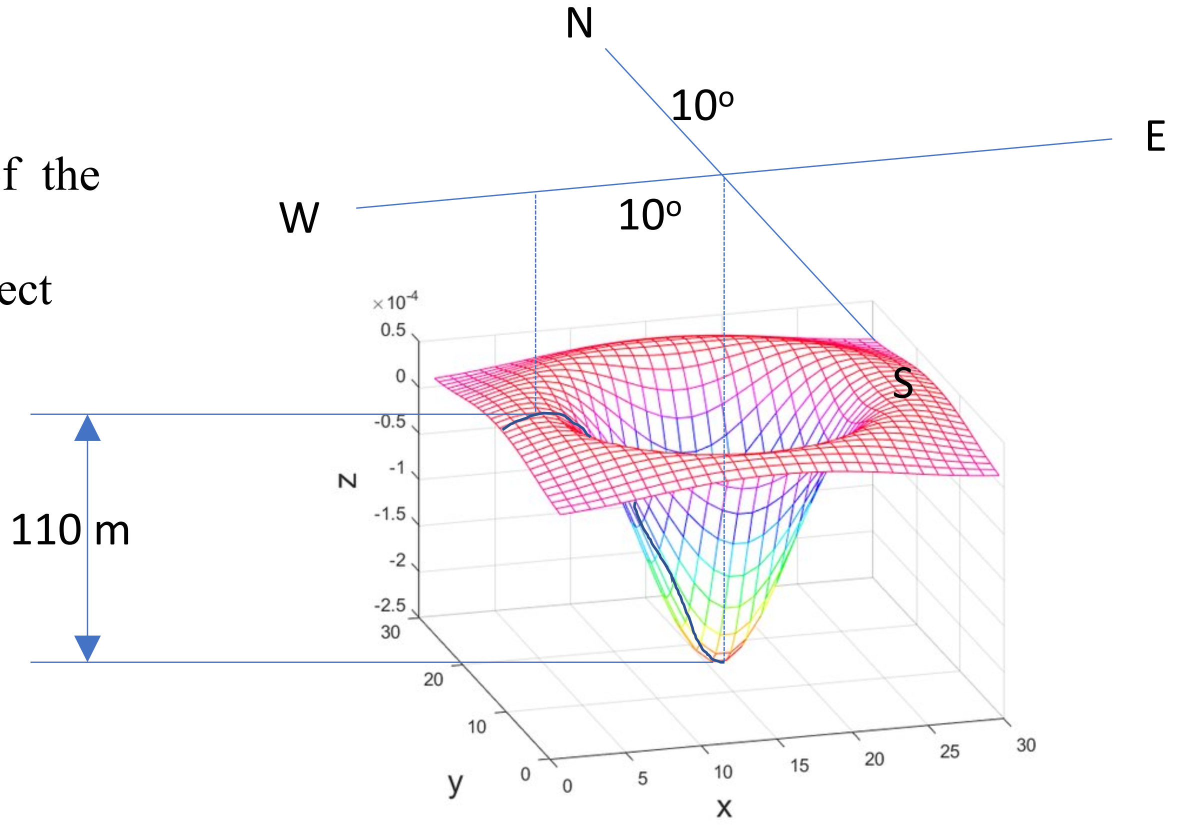


1) We consider squares of 15°x15° in the Euro-Atlantic region with a
2) step of 1° of latitude and longitude between 65 and 20°N and between 80W and 20°E.

2) The smallest local minimum of z500 is found in each square.

3) This minimum is tested for depth: starting from the gridpoint of the minimum, we consider a segment of 10 degrees of longitude or latitude in the four cardinal directions. Along the segment we select the maximum z500 anomaly; if the difference between this maximum and the central minimum exceeds an amplitude A=110 meters in all the directions, we retain it as a deep depression (DD).

4) If a given day has a DD selected, it is retained as a DD day for the central point of the square of 15°x15°.



Counting Summer Depressions

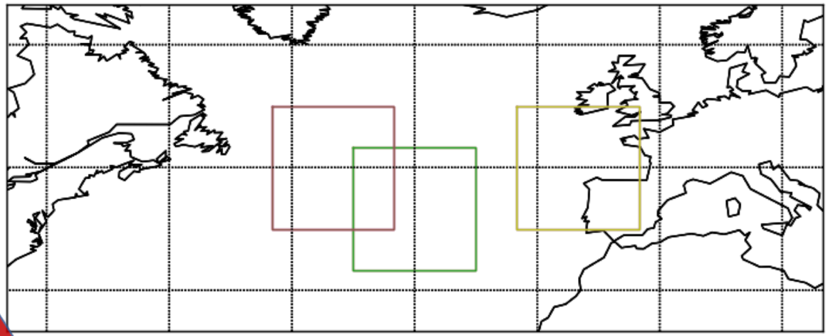
1) We consider squares of 15°x15° in the Euro-Atlantic region with a
2) step of 1° of latitude and longitude between 65 and 20°N and between 80W and 20°E.

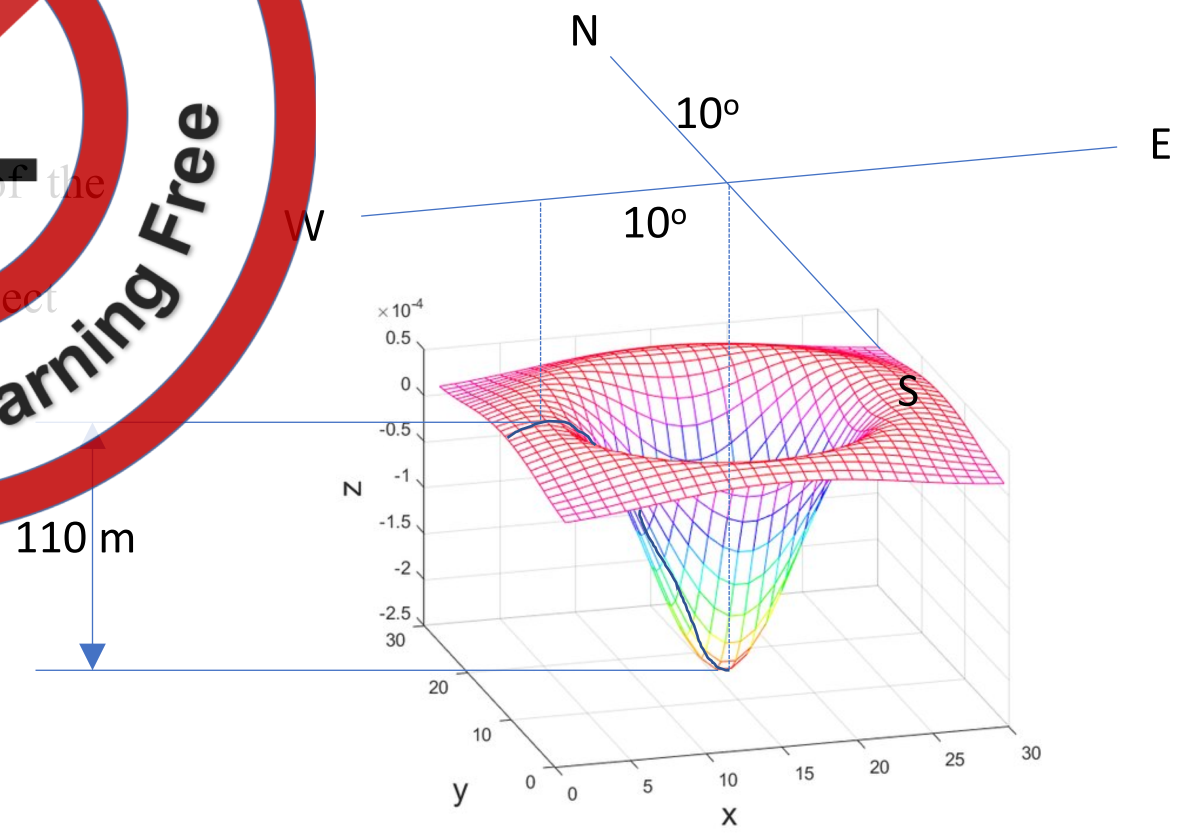
2) The smallest local minimum of z500 is found in each square.

3) This minimum is tested for depth: starting from the gridpoint of the minimum, we consider a segment of 10 degrees of longitude or latitude in the four cardinal directions. Along the segment we select the maximum z500 anomaly; if the difference between this maximum and the central minimum exceeds an amplitude A=110 meters in all the directions, we retain it as a deep depression (DD).

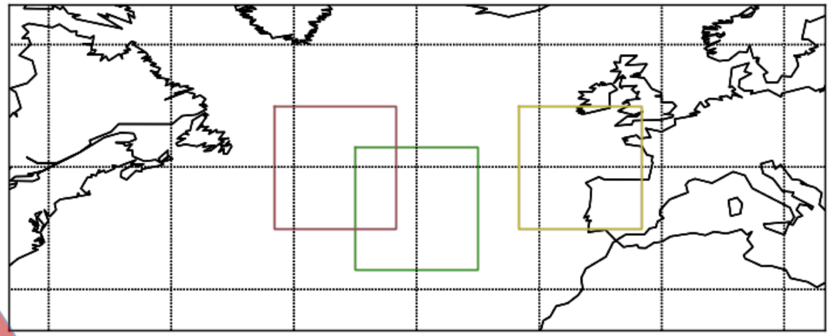
4) If a given day has a DD selected, it is retained as a DD day for the central point of the square of 15°x15°.

This Talk is ML 100% Machine Learning Free





Counting Summer Depressions

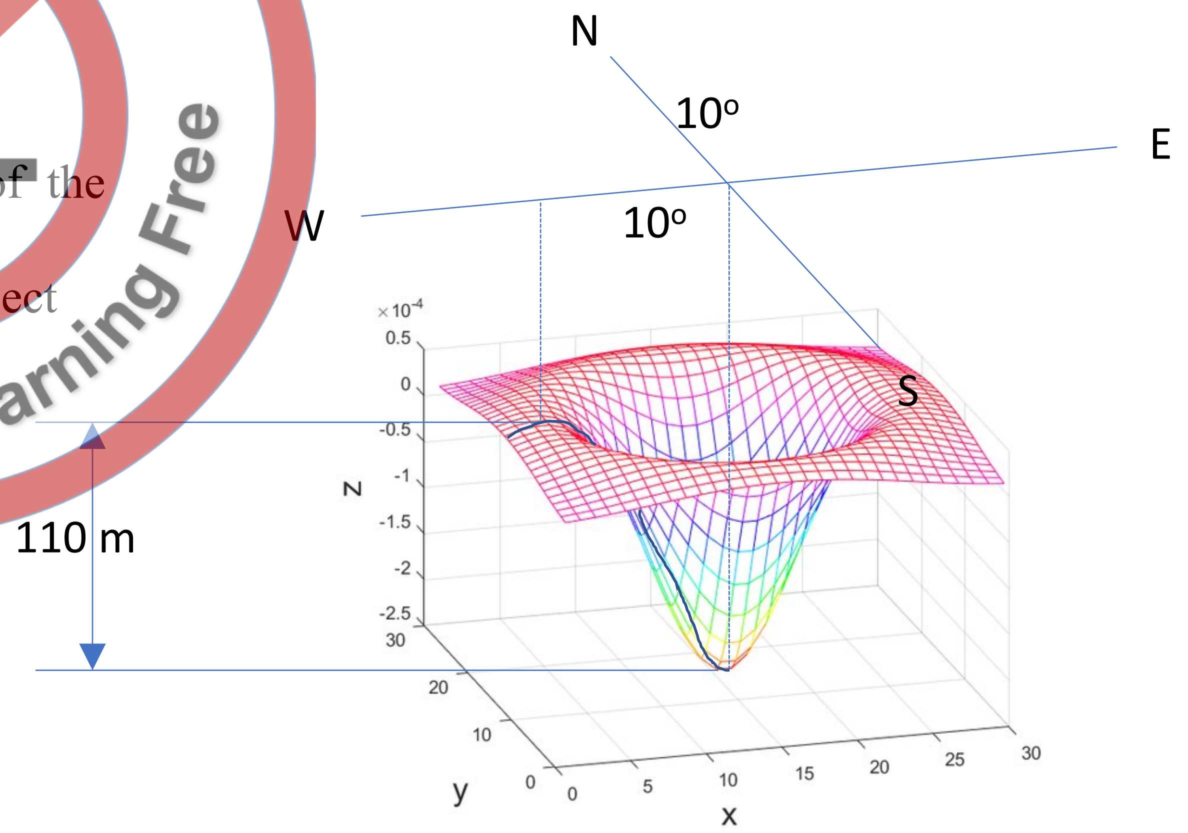


1) We consider squares of 15°x15° in the Euro-Atlantic region with a
2) step of 1° of latitude and longitude between 65° and 20°N and between 80W and 20°E.

2) The smallest local minimum of z500 is found in each square.

3) This minimum is tested for depth: starting from the gridpoint of the minimum, we consider a segment of 10 degrees of longitude or latitude in the four cardinal directions. Along the segment we select the maximum z500 anomaly; if the difference between this maximum and the central minimum exceeds an amplitude A=110 meters in all the directions, we retain it as a deep depression (DD).

4) If a given day has a DD selected, it is retained as a DD day for the central point of the square of 15°x15°.



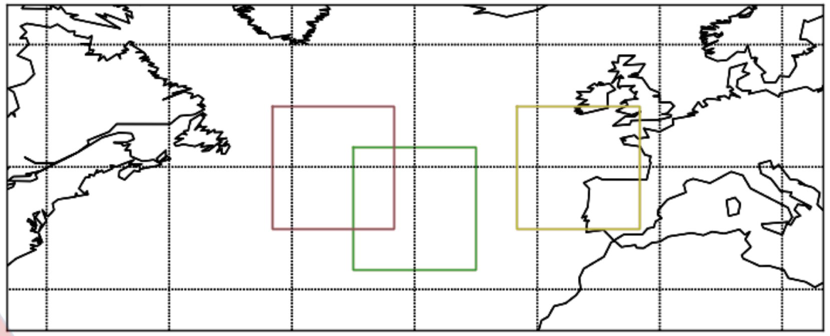
Counting Summer Depressions

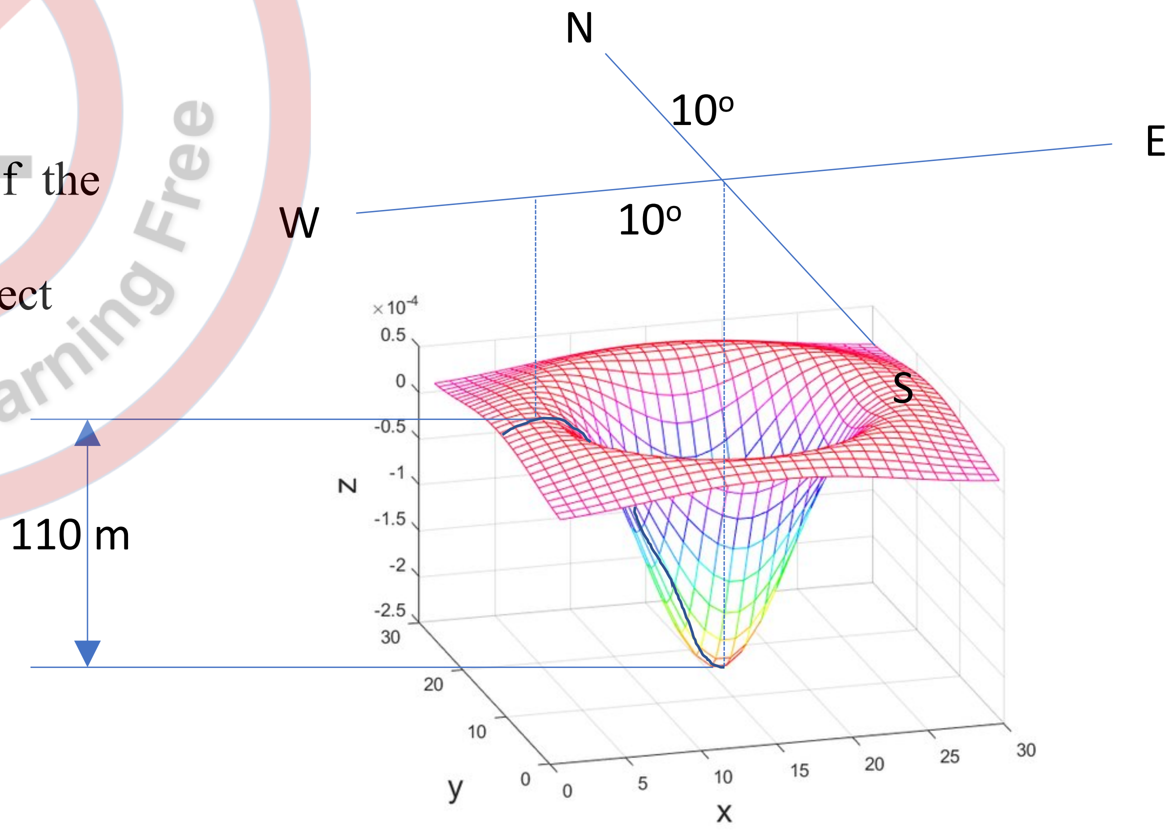
1) We consider squares of 15°x15° in the Euro-Atlantic region with a
2) step of 1° of latitude and longitude between 65 and 20°N and between 80W and 20°E.

2) The smallest local minimum of z500 is found in each square.

3) This minimum is tested for depth: starting from the gridpoint of the minimum, we consider a segment of 10 degrees of longitude or latitude in the four cardinal directions. Along the segment we select the maximum z500 anomaly; if the difference between this maximum and the central minimum exceeds an amplitude A=110 meters in all the directions, we retain it as a deep depression (DD).

4) If a given day has a DD selected, it is retained as a DD day for the central point of the square of 15°x15°.





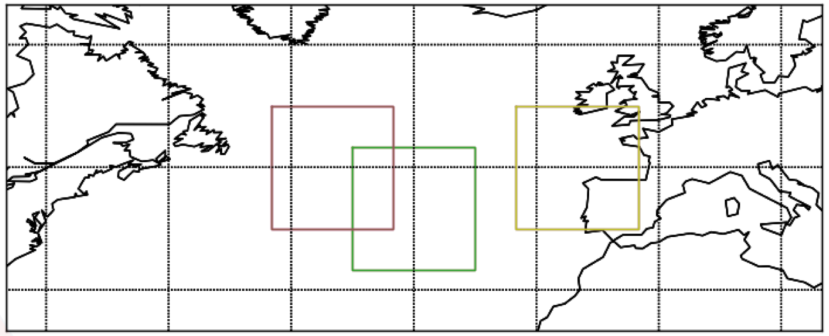
Counting Summer Depressions

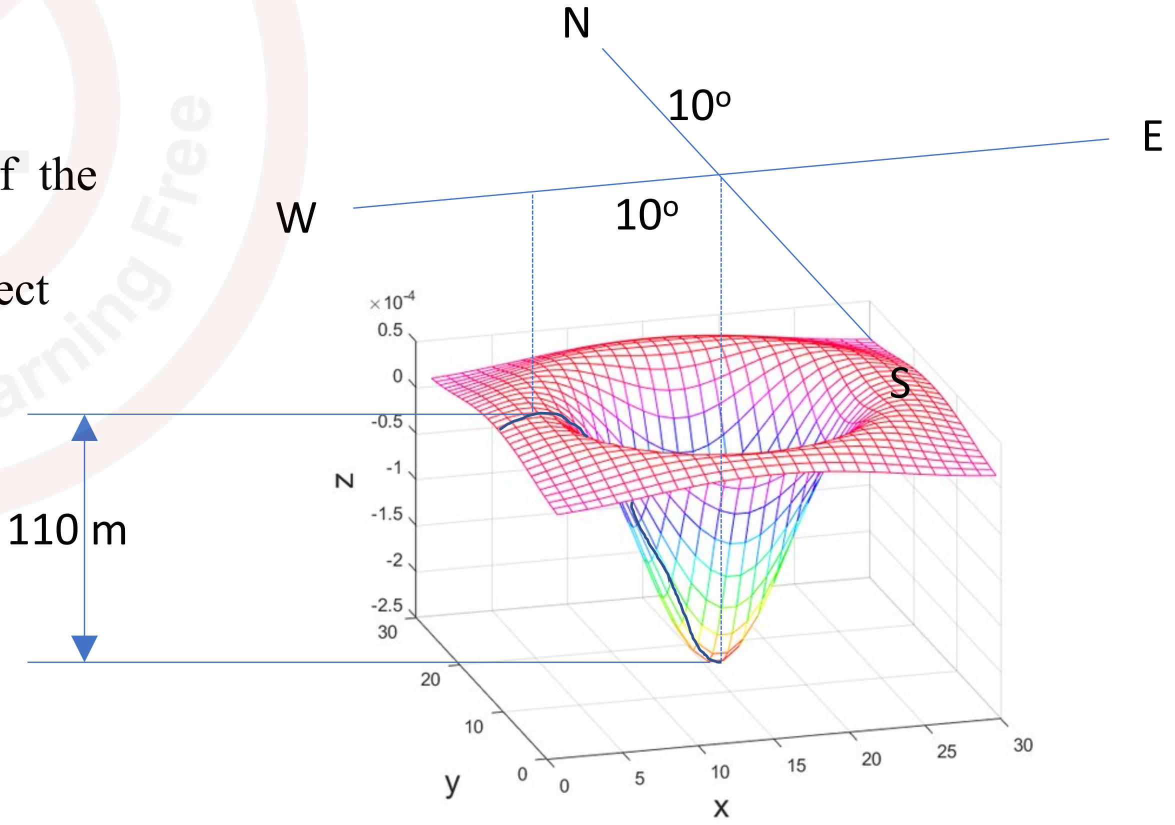
1) We consider squares of 15°x15° in the Euro-Atlantic region with a
2) step of 1° of latitude and longitude between 65 and 20°N and between 80W and 20°E.

2) The smallest local minimum of z500 is found in each square.

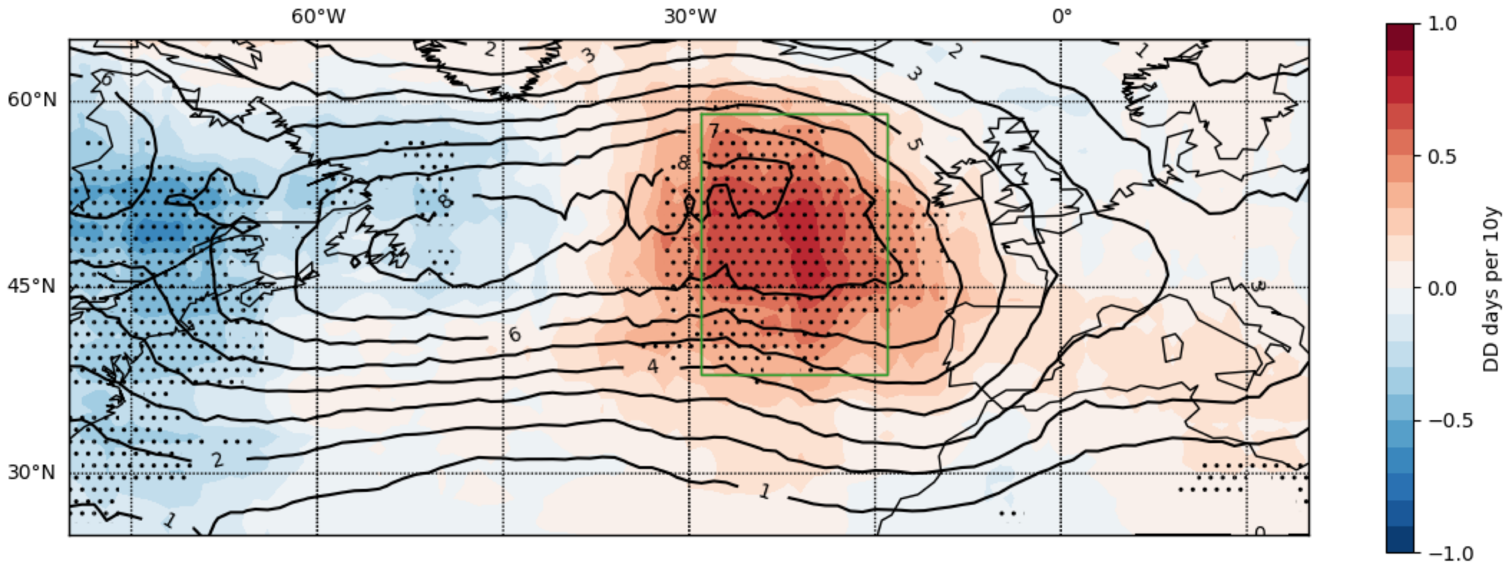
3) This minimum is tested for depth: starting from the gridpoint of the minimum, we consider a segment of 10 degrees of longitude or latitude in the four cardinal directions. Along the segment we select the maximum z500 anomaly; if the difference between this maximum and the central minimum exceeds an amplitude A=110 meters in all the directions, we retain it as a deep depression (DD).

4) If a given day has a DD selected, it is retained as a DD day for the central point of the square of 15°x15°.





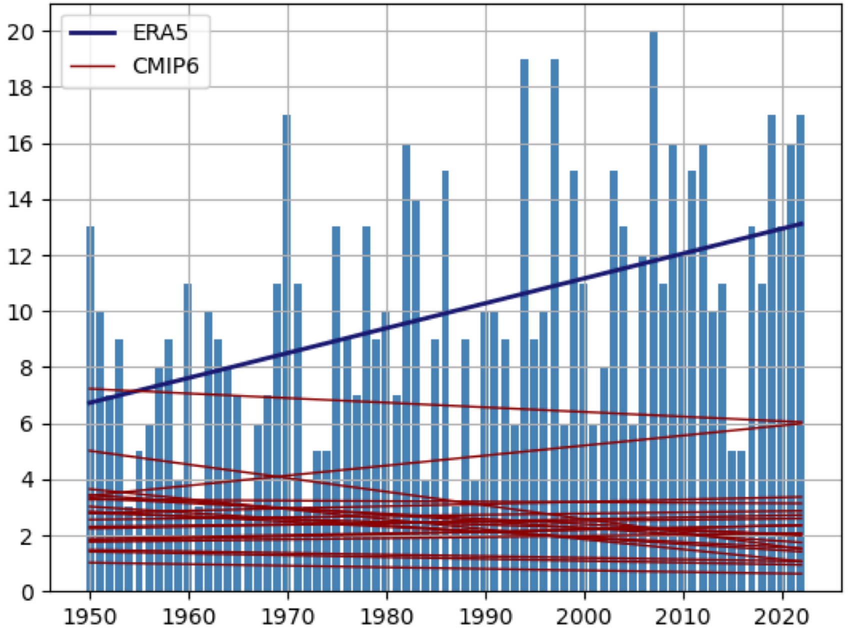
Number of DD per summer, and trend over the ERA5 period 1950-2022



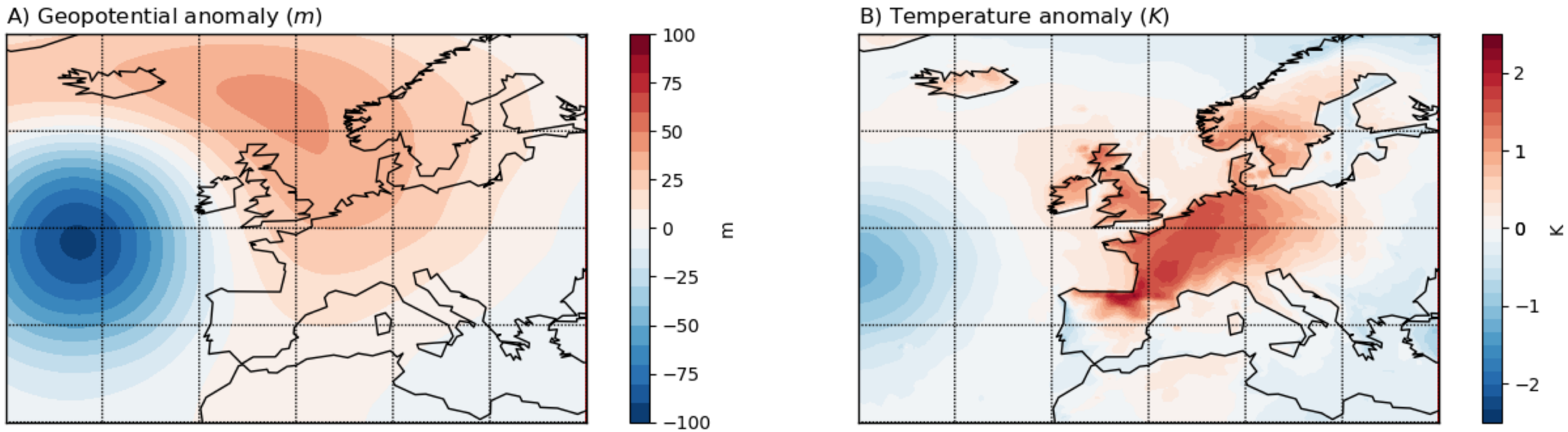
Average number of DD days per summer (contours) and slope of the linear trend in the number of DD expressed in number of DD days per ten years (colors). See text for exact definition. Hatching indicates regions for which the trend is significant to a Mann-Kendall test with p<0.05. The green square indicates the chosen region for the analysis in the next section.

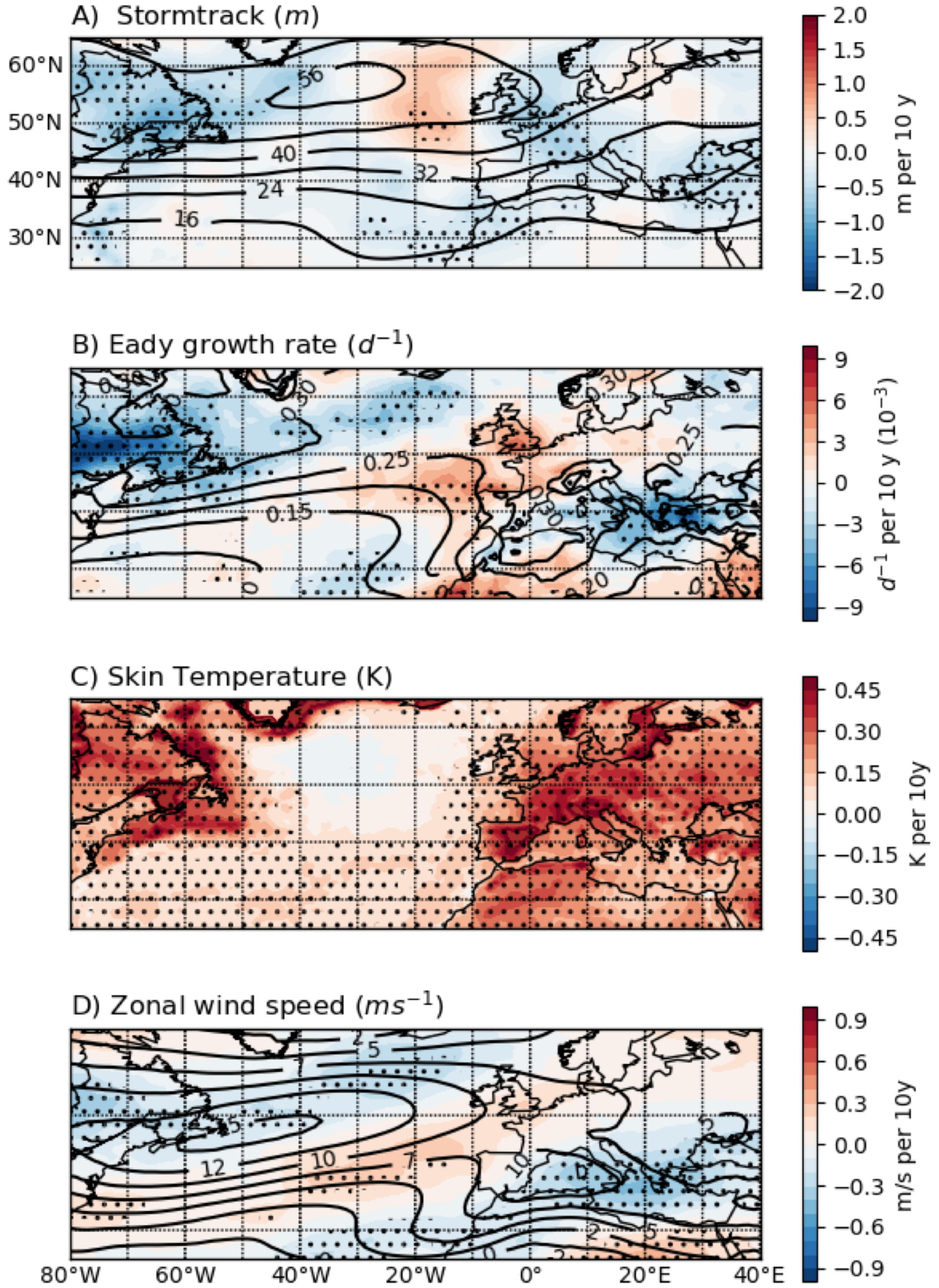
Eastern Atlantic Region

Number of DD days



Composites





Dynamical trends

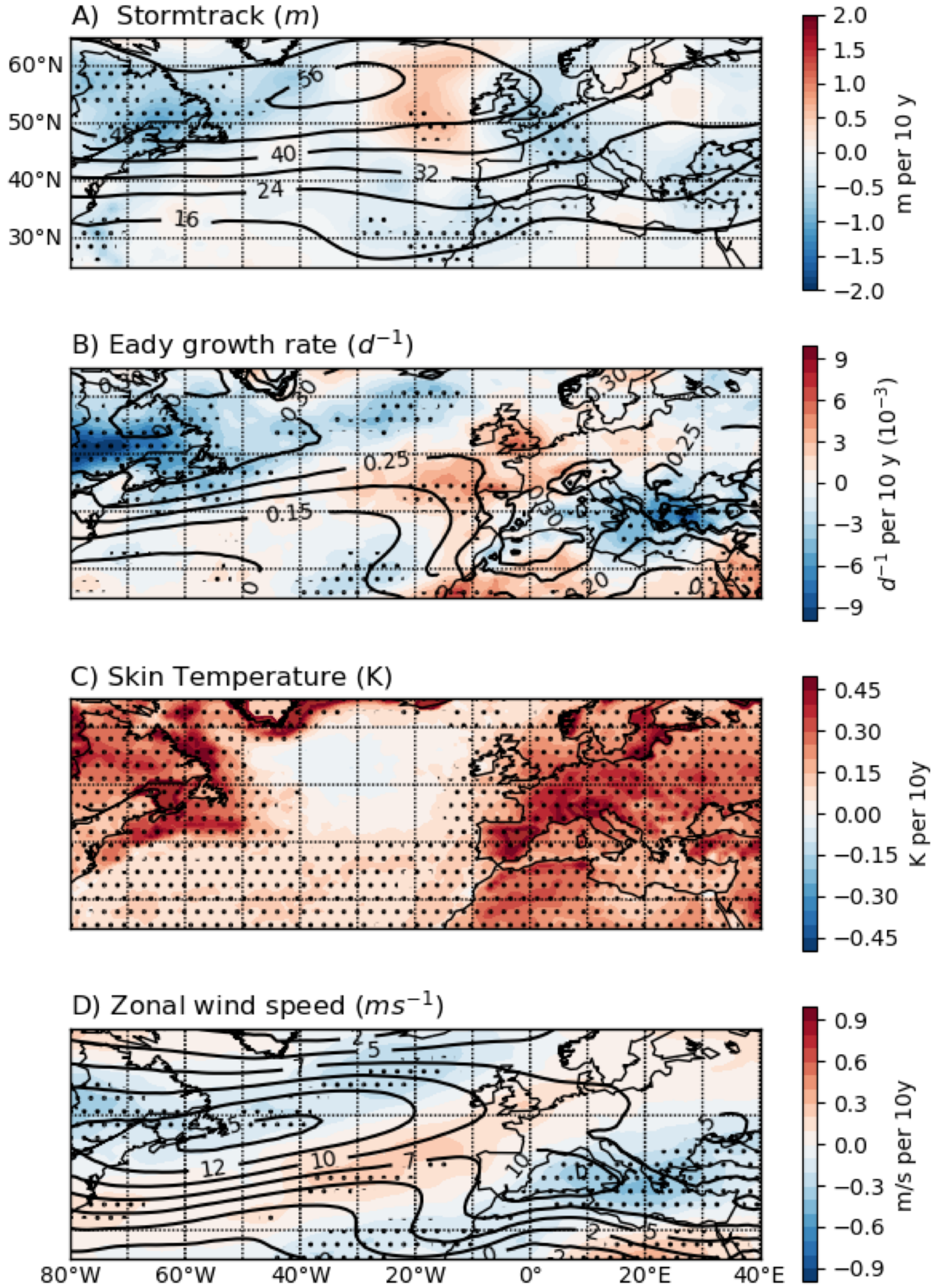
A) *Summer storm-track as standard deviation of high-frequency of geopotential height at 500hPa. Mean field for JJA in the period 1950-2022 in contour. In color the linear trend on JJA yearly mean fields expressed as meters per 10y periods.*

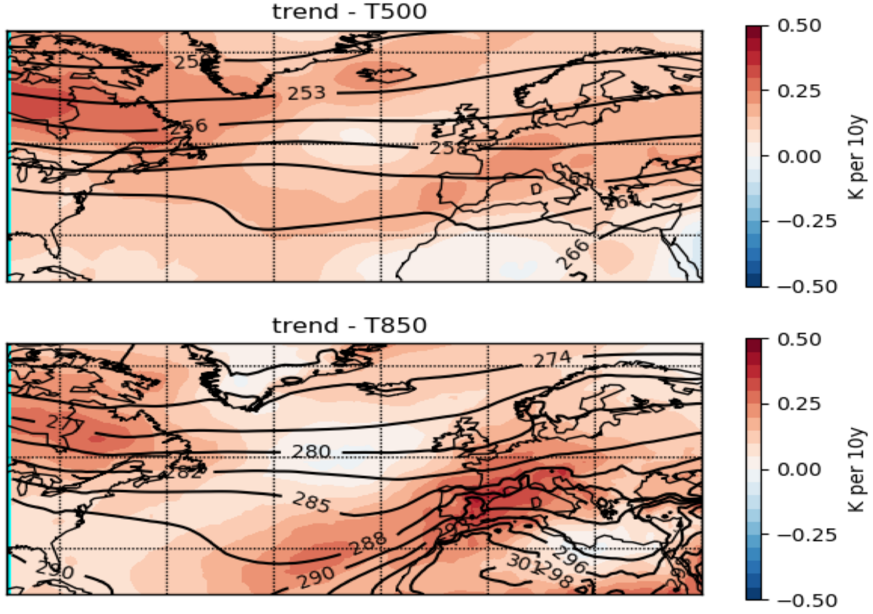
B) *Eady growth rate in the 500-850 hPa layer. As in A, the black contours are the mean field expressed in days-1, in color is the linear trend in this case expressed as days-1 per 10y period.*

C) *Skin temperature: linear trend in degrees Kelvin per 10 y period.*

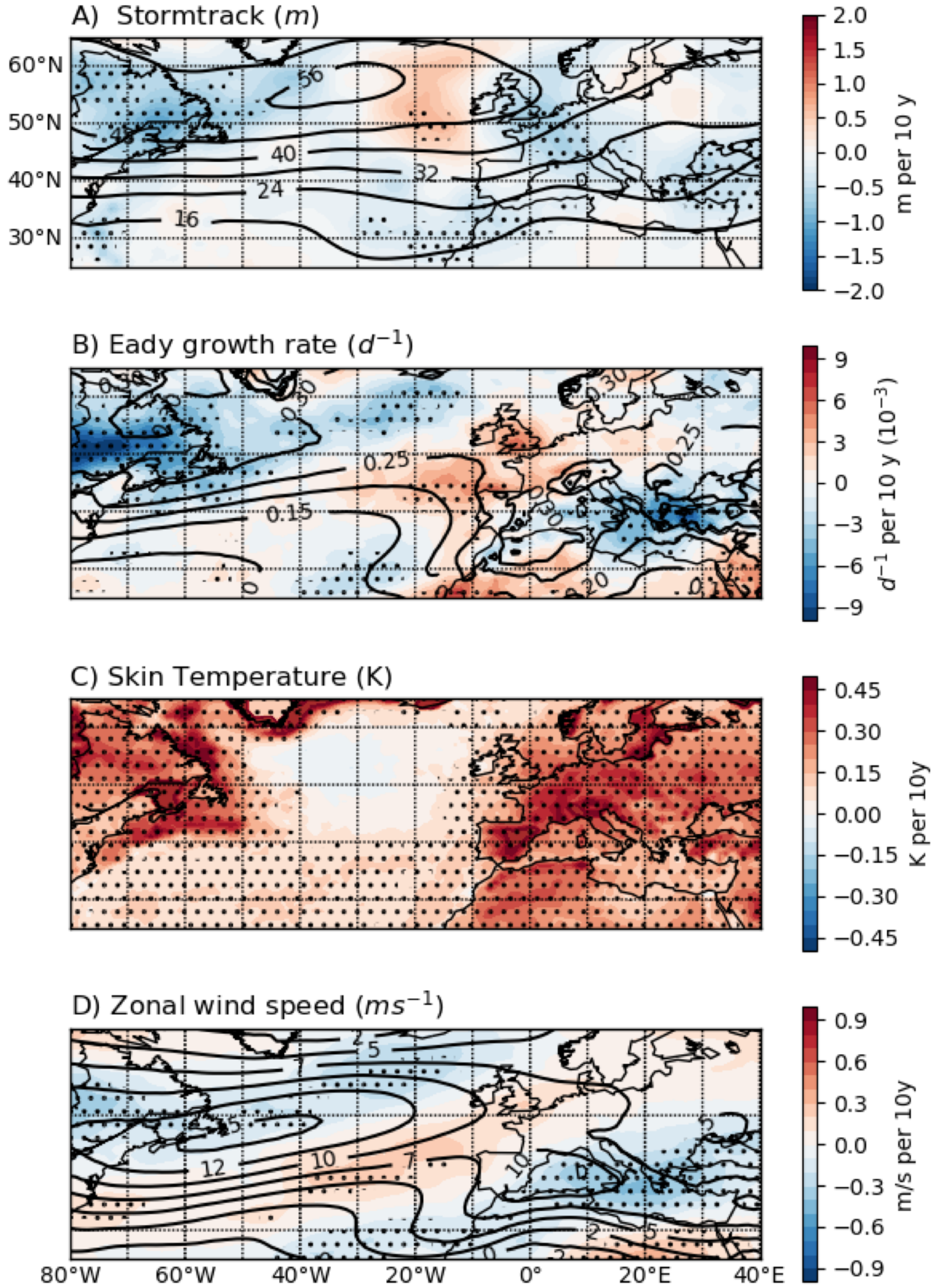
D) *Linear trend of the 500 hPa zonal wind in meters per second per 10 years. The mean field for the whole period is in contours.*

Dynamical trends





Temperature at 500hPa and 850hPa. Black contours represent the mean field in Kelvin, and the colors represent the linear trend in kelvin per 10 years period.



Dynamical trends

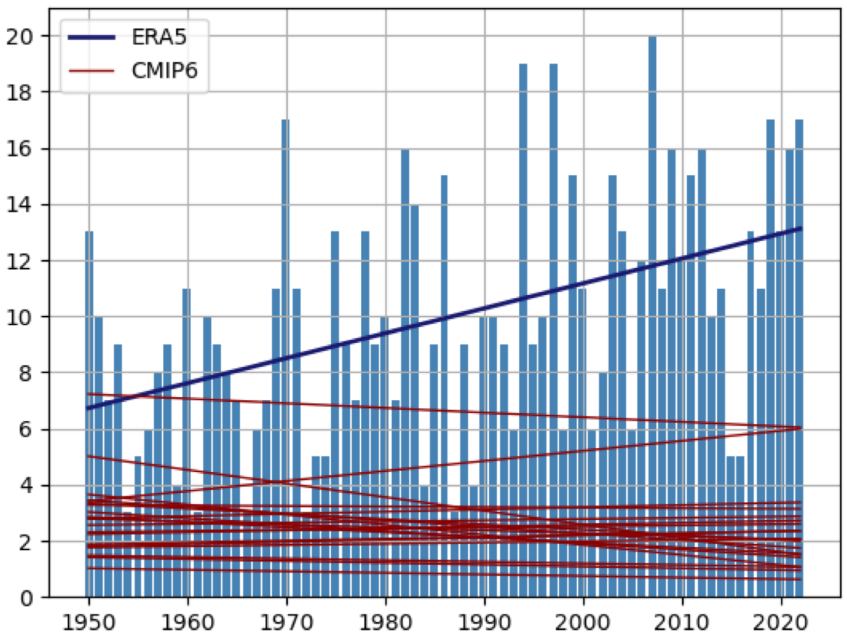
A) *Summer storm-track as standard deviation of high-frequency of geopotential height at 500hPa. Mean field for JJA in the period 1950-2022 in contour. In color the linear trend on JJA yearly mean fields expressed as meters per 10y periods.*

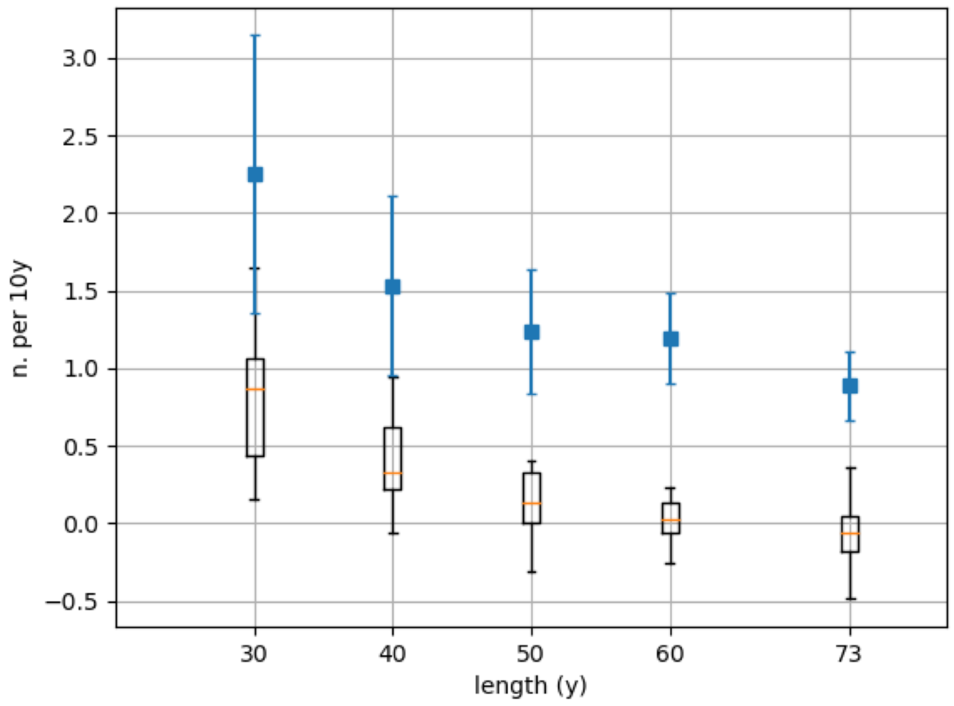
B) *Eady growth rate in the 500-850 hPa layer. As in A, the black contours are the mean field expressed in days-1, in color is the linear trend in this case expressed as days-1 per 10y period.*

C) *Skin temperature: linear trend in degrees Kelvin per 10 y period.*

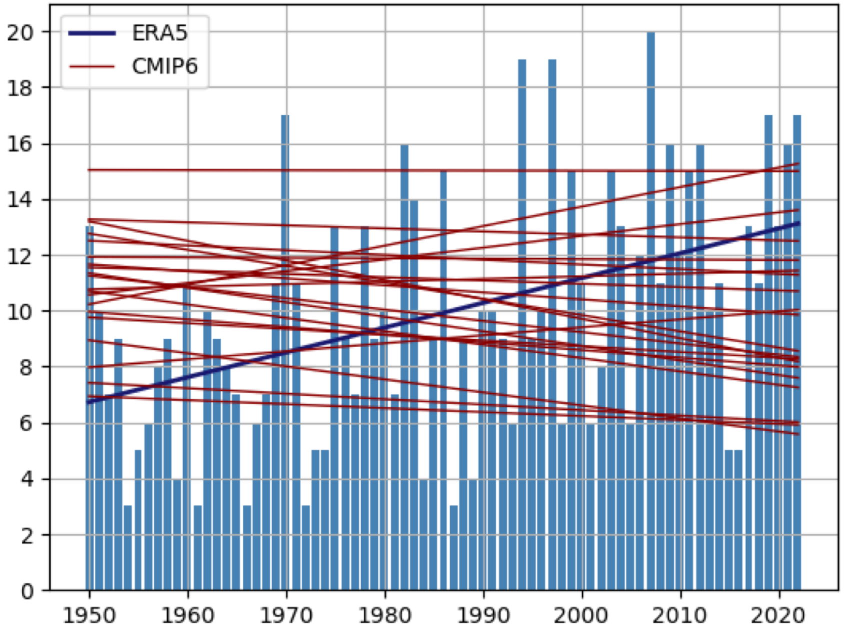
D) *Linear trend of the 500 hPa zonal wind in meters per second per 10 years. The mean field for the whole period is in contours.*

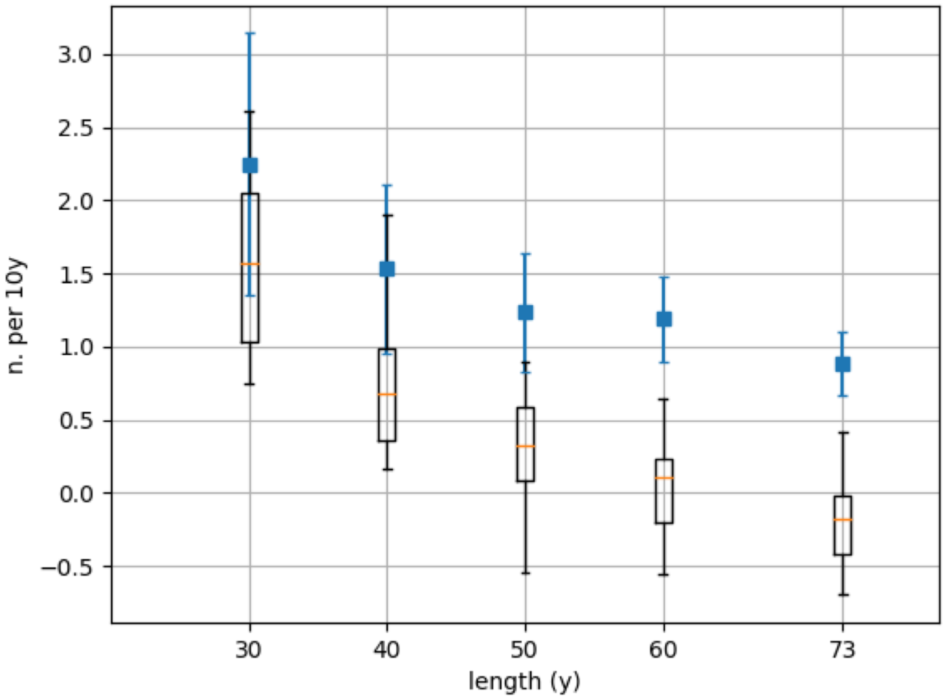
CMIP6 models don't reproduce the trend.





CMIP6 models don’t reproduce the trend.
(even with a boost)





Take home:

Deep depressions occurrence have significantly decreased over the Western side and increased over the Eastern side of the North Atlantic.

Deep depressions are linked to high surface temperatures in western continental Europe

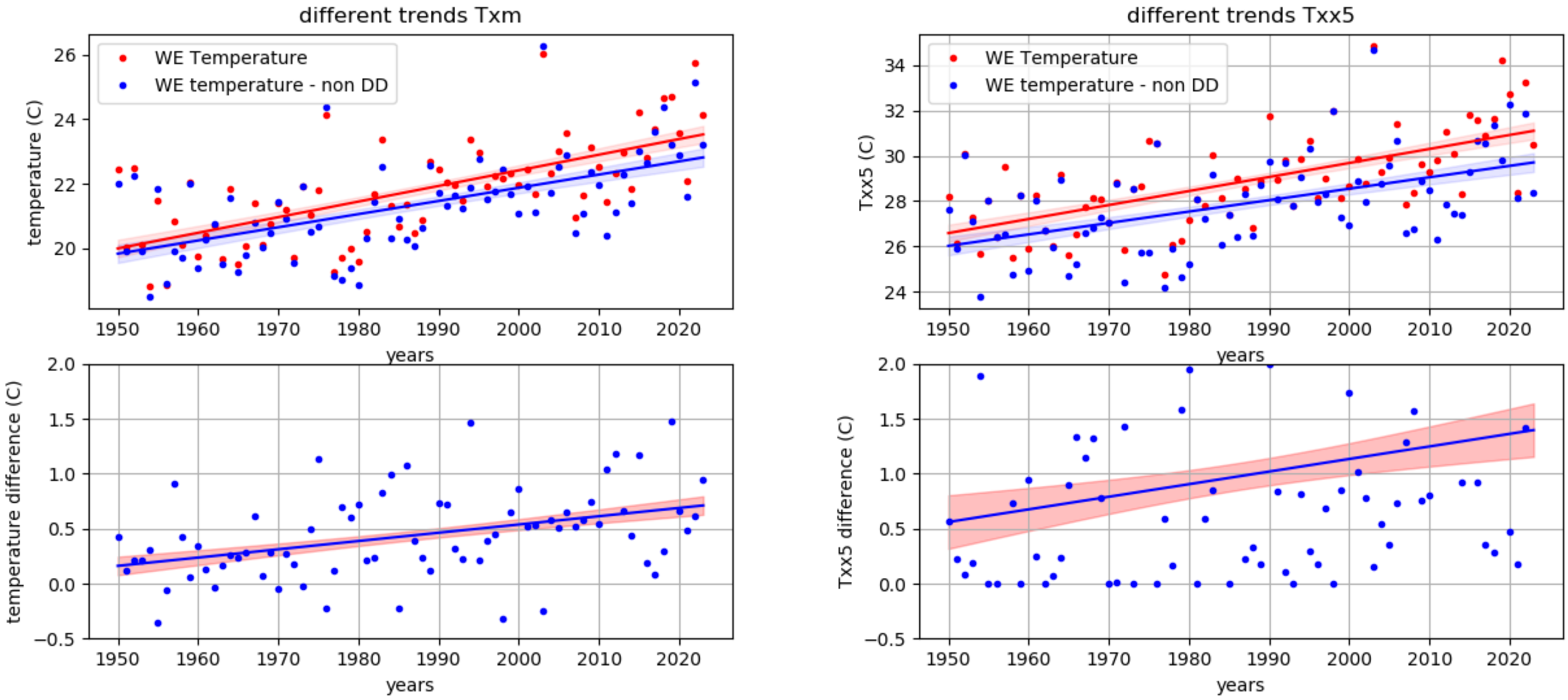
Global Climate Model fail to reproduce correctly the observed trends in deep depressions

AND WHAT ABOUT HEATWAVES THEN?
(IS THERE TIME?)

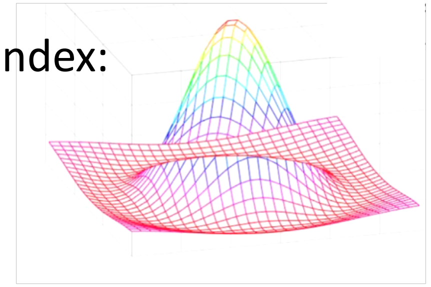
D’Andrea et al (2024). Summer deep depressions increase over the Eastern North Atlantic. *Geophysical Research Letters*, *51*, e2023GL104435

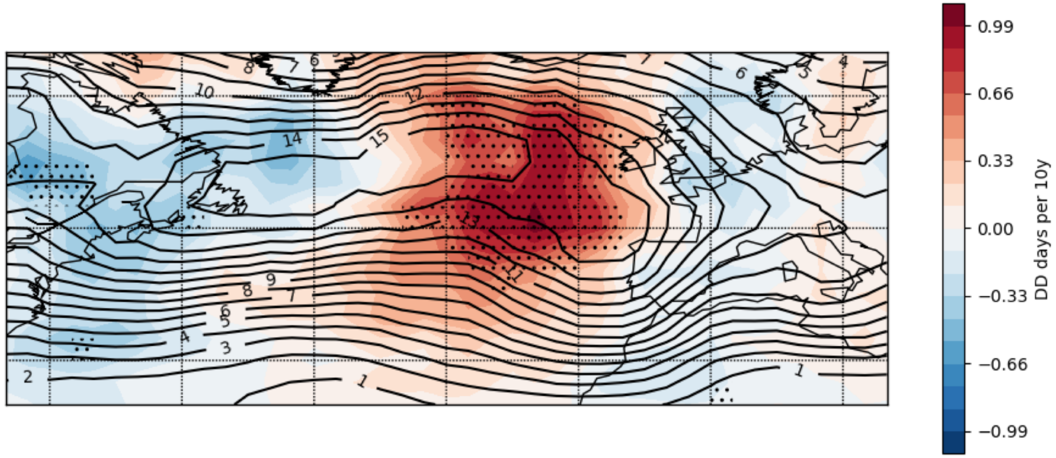
AND WHAT ABOUT HEATWAVES THEN?
(IS THERE TIME?)

DD contribution to West European Temperature increase

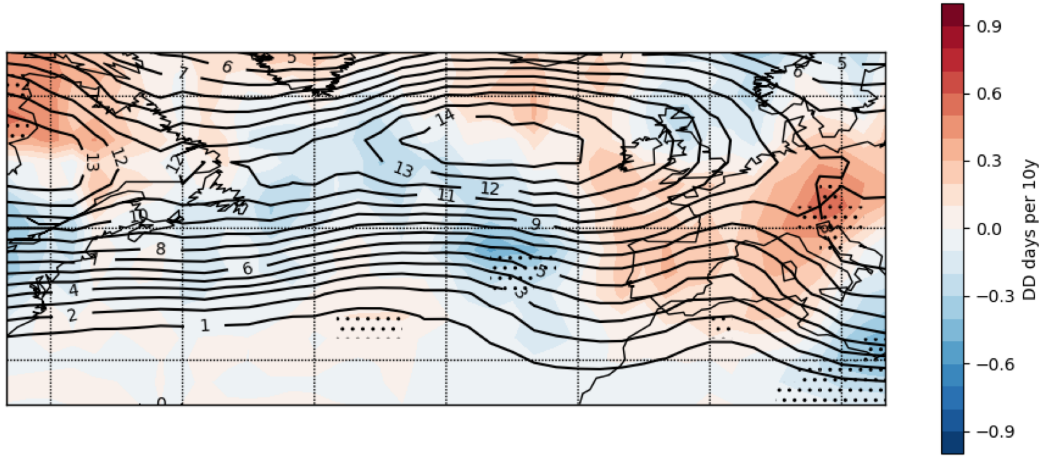


If one flips sign to the depression counting algorithm above, one gets an atmospheric blocking index:





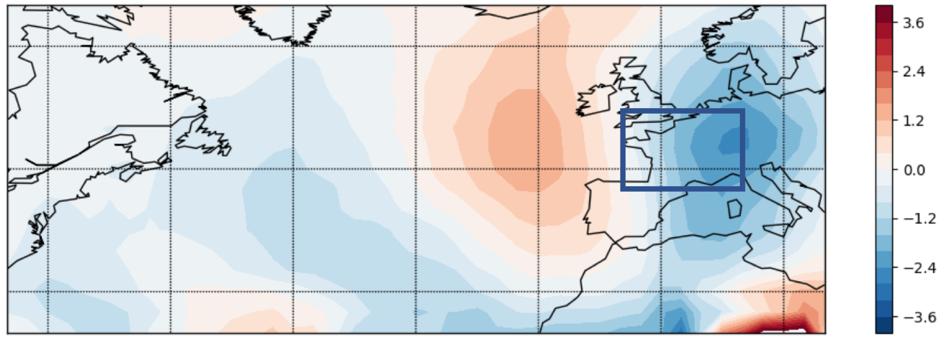
Deep Depressions and trend



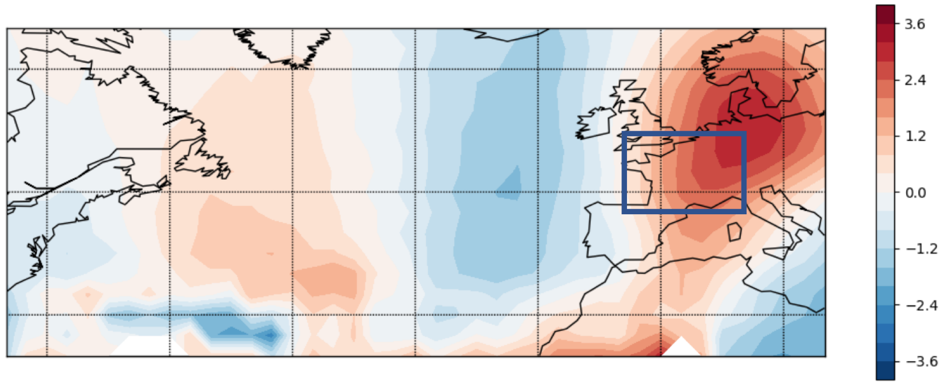
Blockings and trend

Same analysis a s before, only on low pass filtere data (5 days runnning mean) and a smaller minimal depth A

Sensitivity maps of WE termperature. Depressions and Blockings.

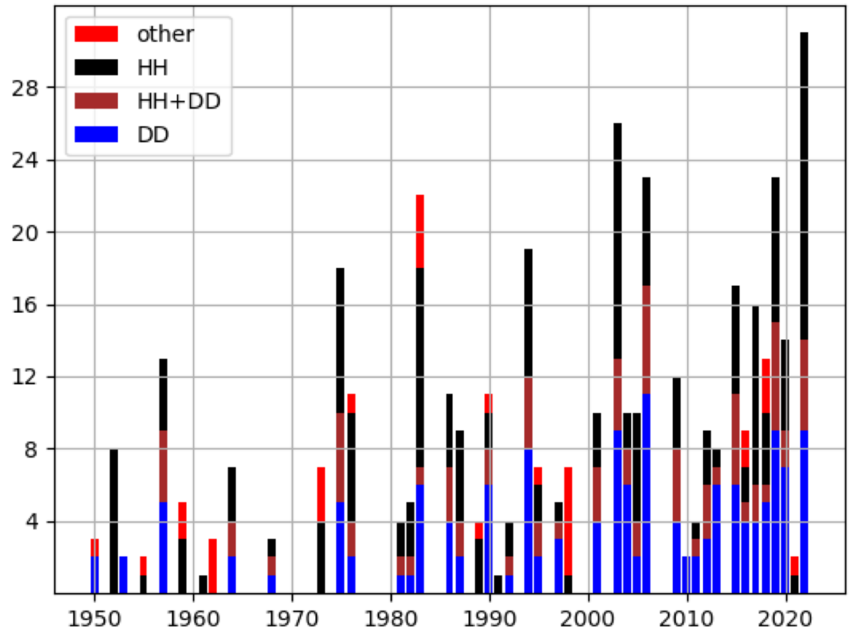


Influence of DD location on 2m temperature in Europe



Influence of blocking high location on 2m temperature in Europe

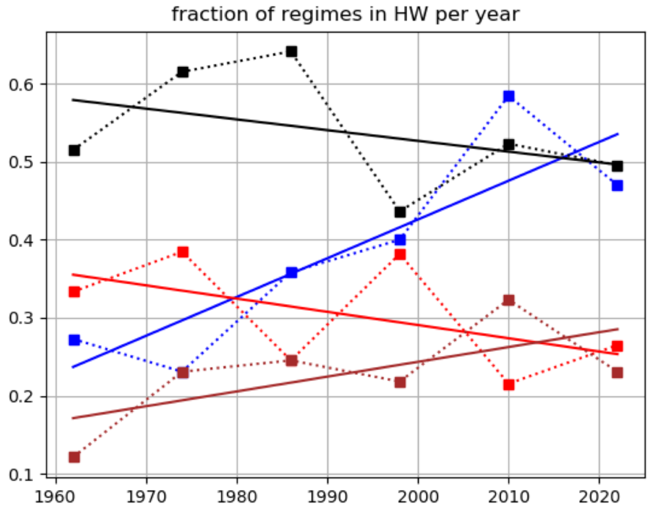
The fraction of Heat Waves due to Atlantic depression could be increasing



Number of HW days per summer in WE

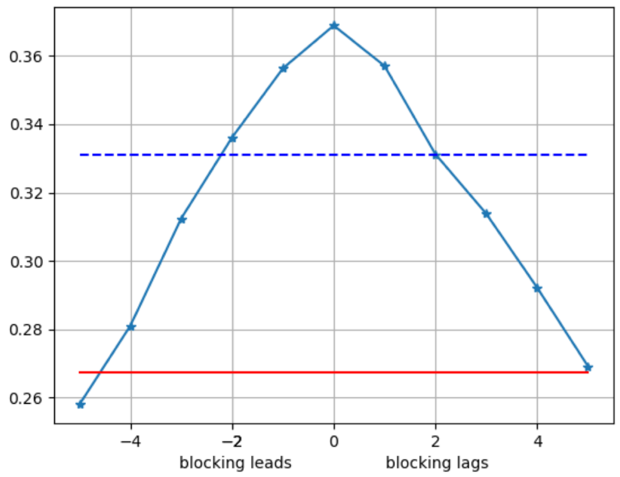
Blocking : black

Atl Depression : Blue



Depression related HW are increasing, or are they?

A little correlated



Take this home:

Deep depressions occurrence have significantly decreased over the Western side and increased over the Eastern side of the North Atlantic.

Deep depressions are linked to high surface temperatures in western continental Europe

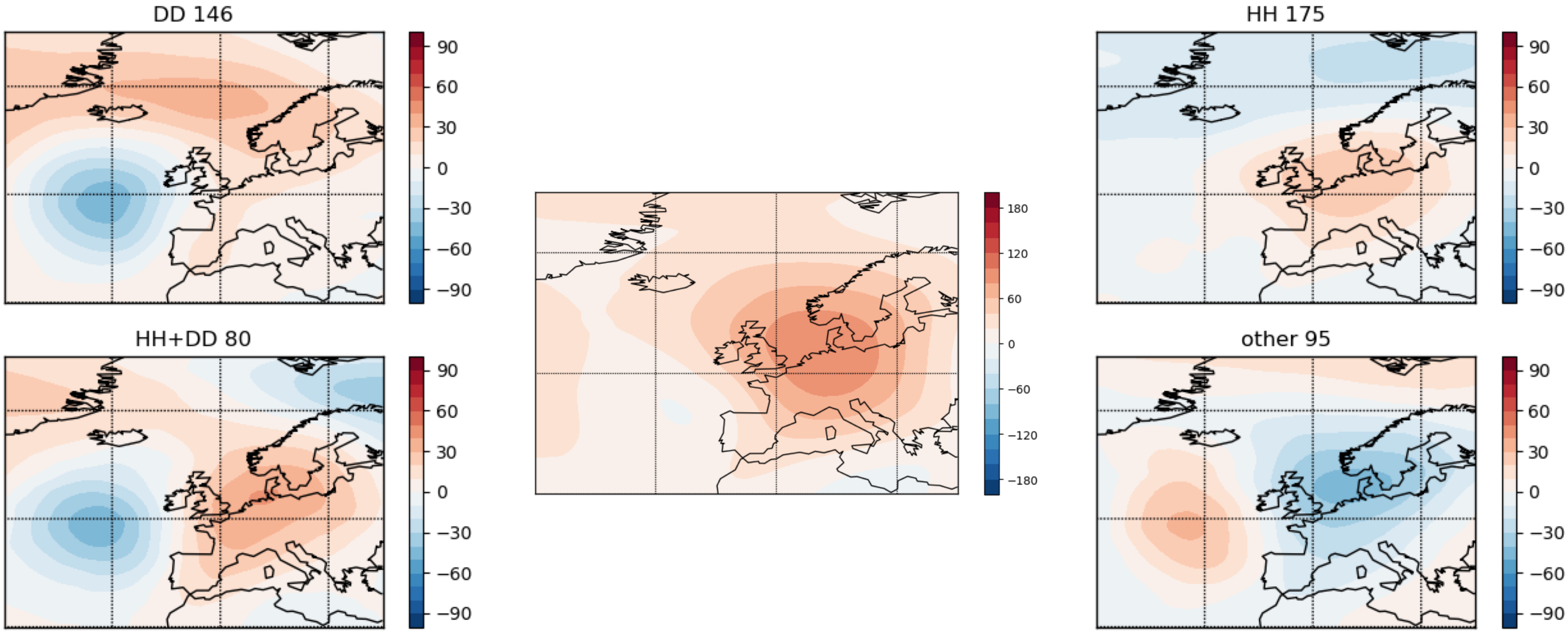
Global Climate Model fail to reproduce correctly the observed trends in deep depressions

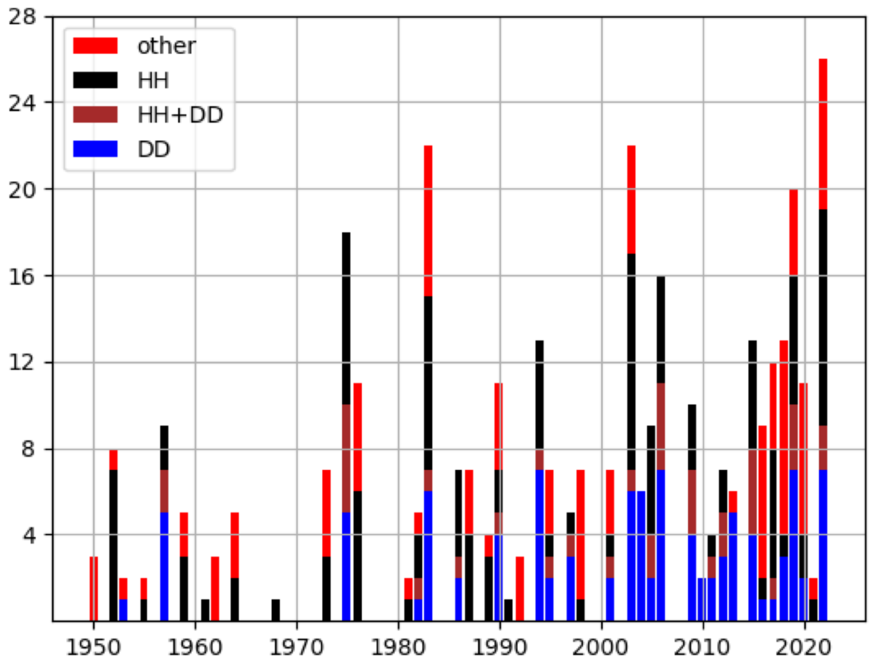
Don’t Take this home:

Heatwaves in WE seem to be increasingly due to cyclonic patterns off the European Atlantic coast, and less so to blockings.

D’Andrea et al (2024). Summer deep depressions increase over the Eastern North Atlantic. *Geophysical Research Letters*, *51*, e2023GL104435

Backup slides…..

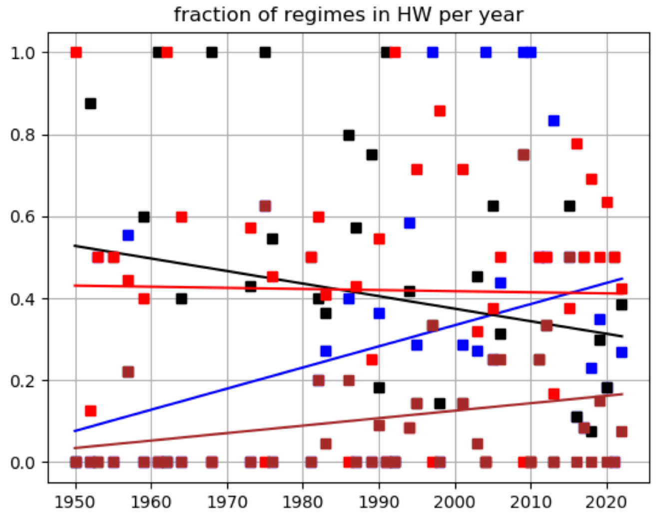

DD 146
90
60
30
0
−30
−60
−90
HH+DD 80
180
120
60
0
−60
−120
−180
HH 175
other 95



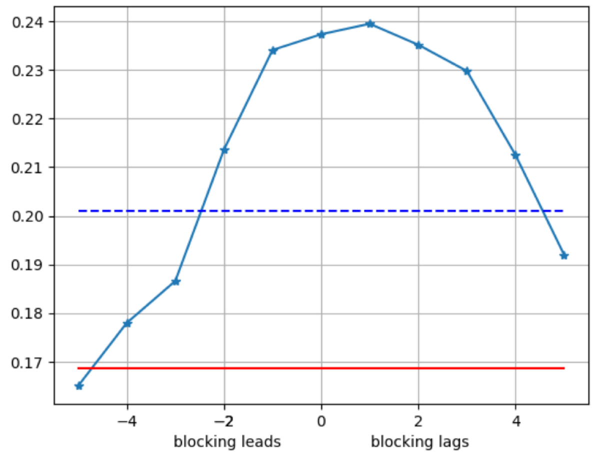
Number of HW days per summer in WE

Blocking : black

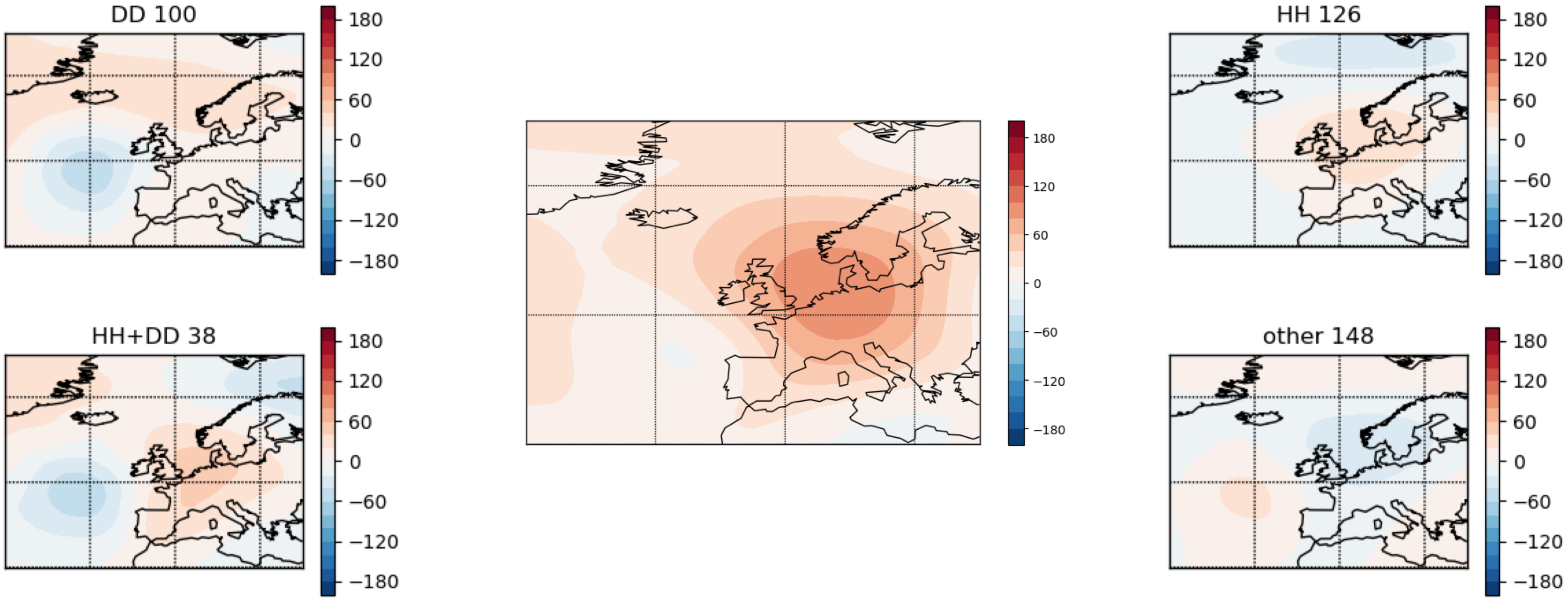
Atl Depression : Blue

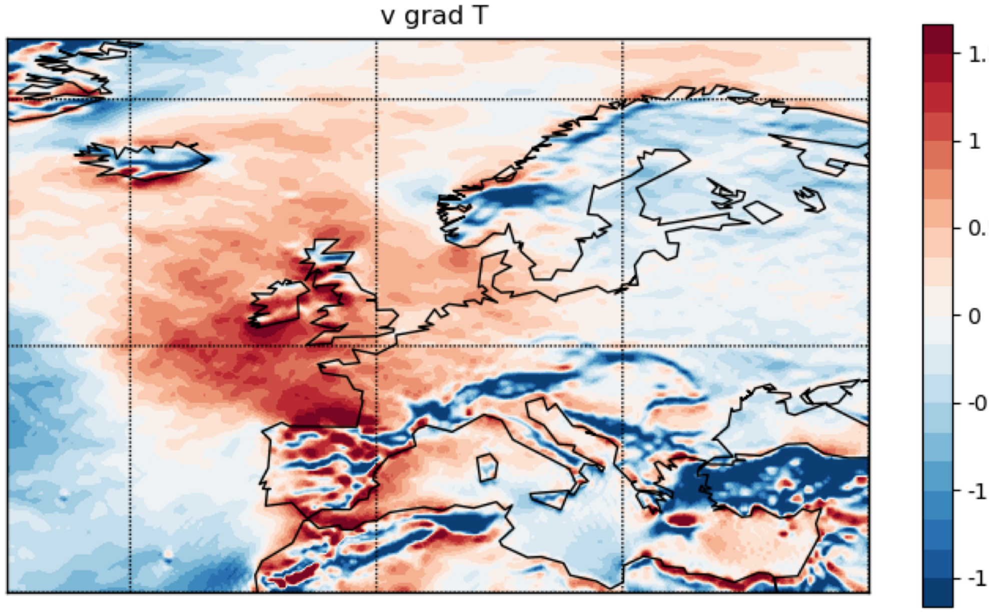


Depression related HW
are increasing, or are they?

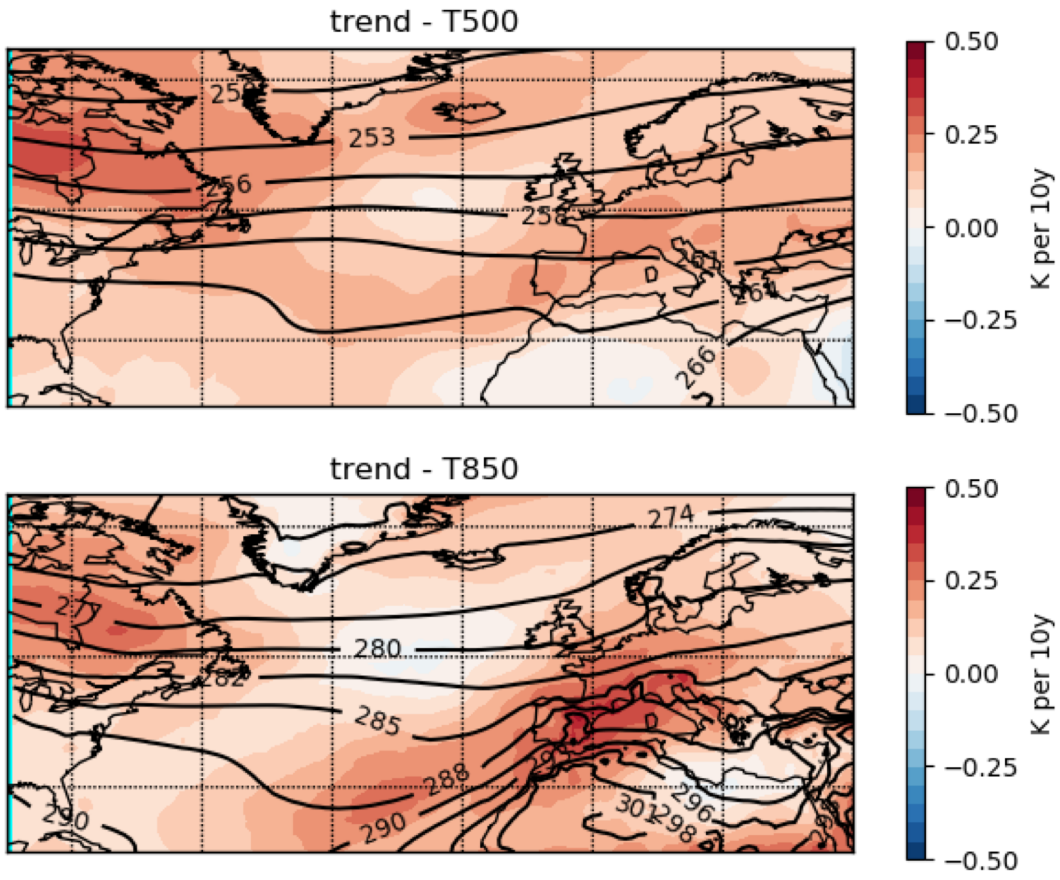


Little correlated

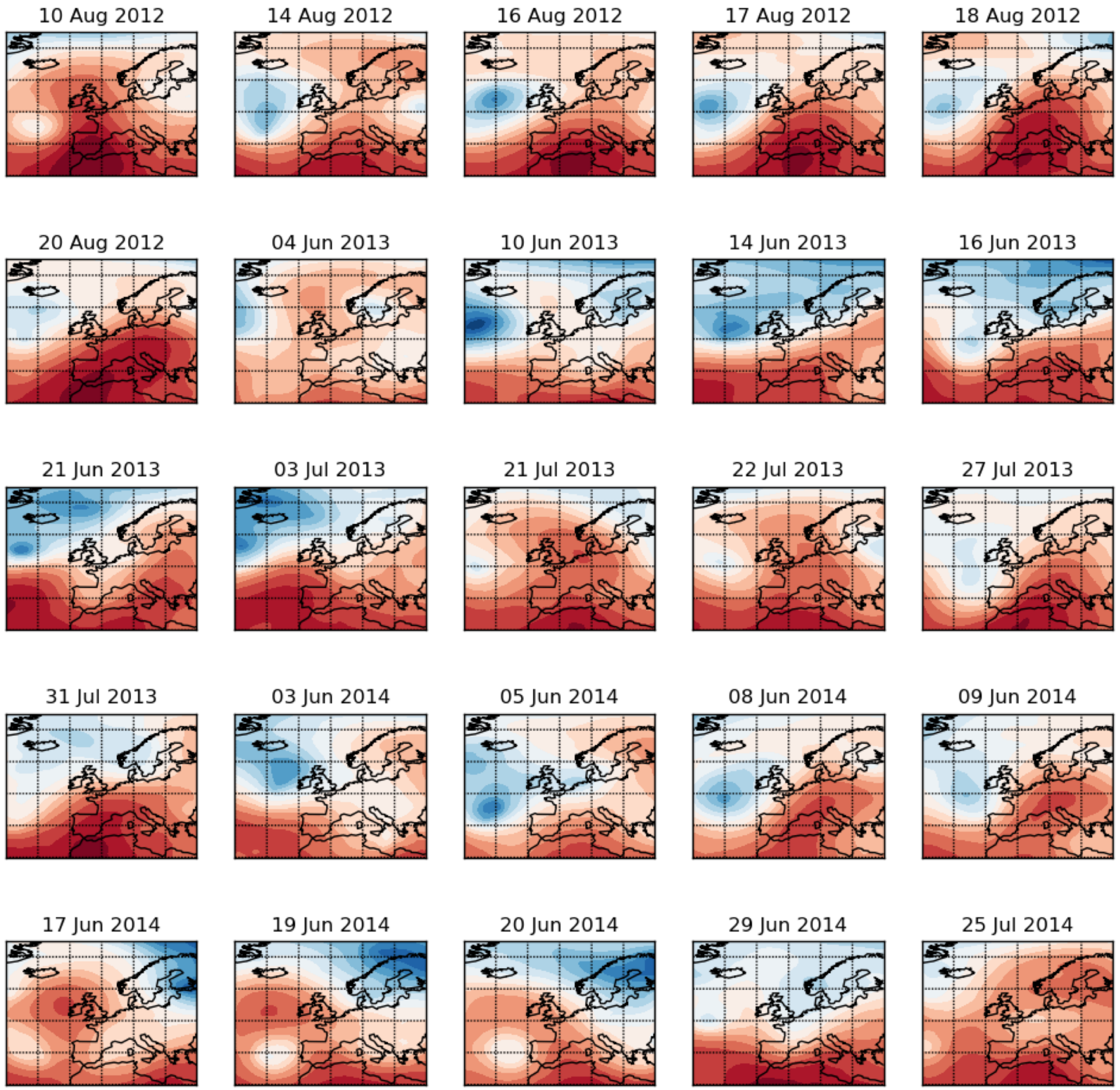

DD 100
HH+DD 38
HH 126
other 148
180
120
60
0
−60
−120
−180



$v\,\nabla T$ composite $-$ 850mb



Temperature at 500hPa and 850hPa levels. Black contours represent the mean field in Kelvin, and the colors represent the linear trend in kelvin per 10 years period.


10 Aug 2012
14 Aug 2012
16 Aug 2012
17 Aug 2012
18 Aug 2012
20 Aug 2012
04 Jun 2013
10 Jun 2013
14 Jun 2013
16 Jun 2013
21 Jun 2013
03 Jul 2013
21 Jul 2013
22 Jul 2013
27 Jul 2013
31 Jul 2013
03 Jun 2014
05 Jun 2014
08 Jun 2014
09 Jun 2014
17 Jun 2014
19 Jun 2014
20 Jun 2014
29 Jun 2014
25 Jul 2014

Patterns most increasing in frequency

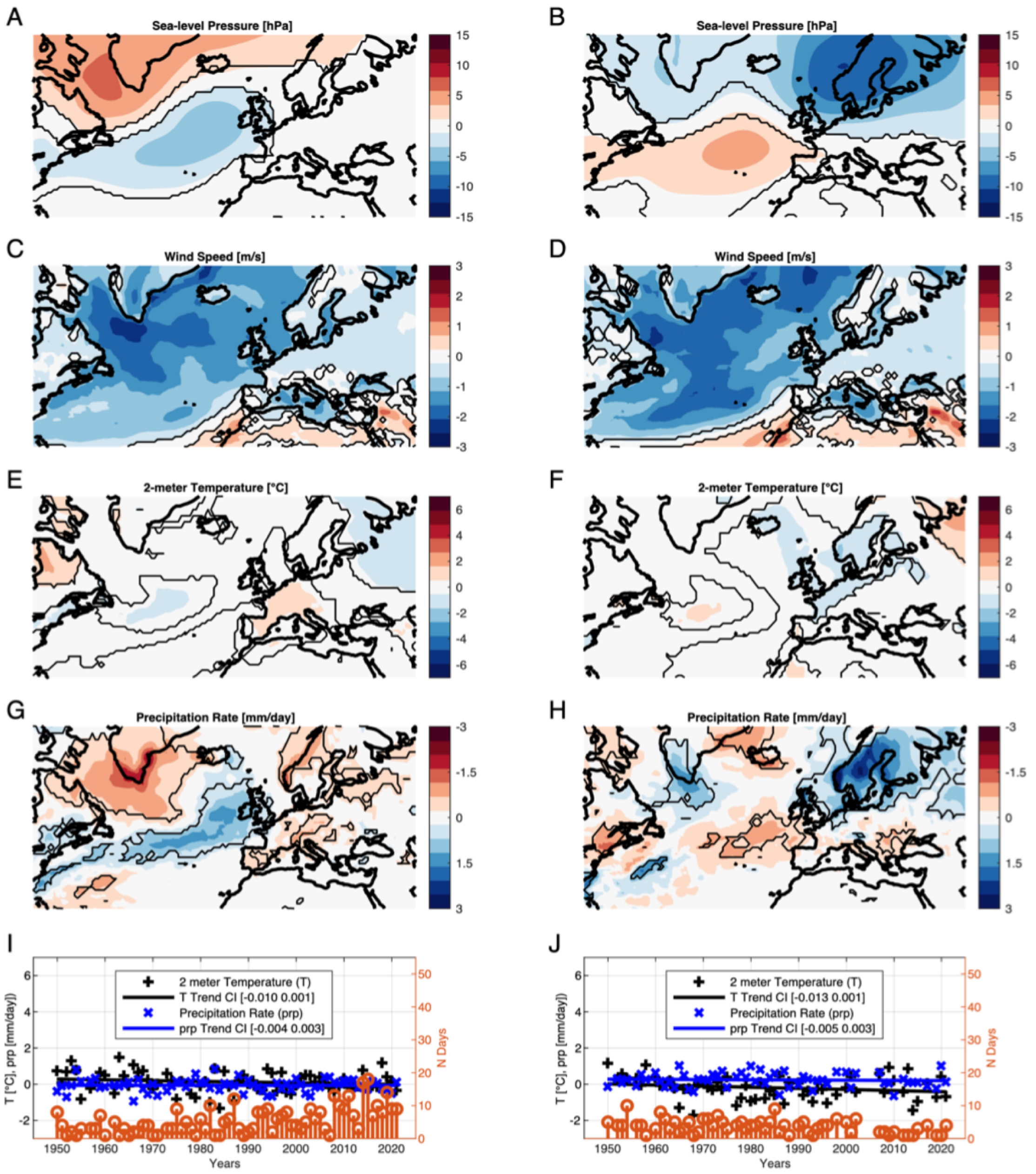
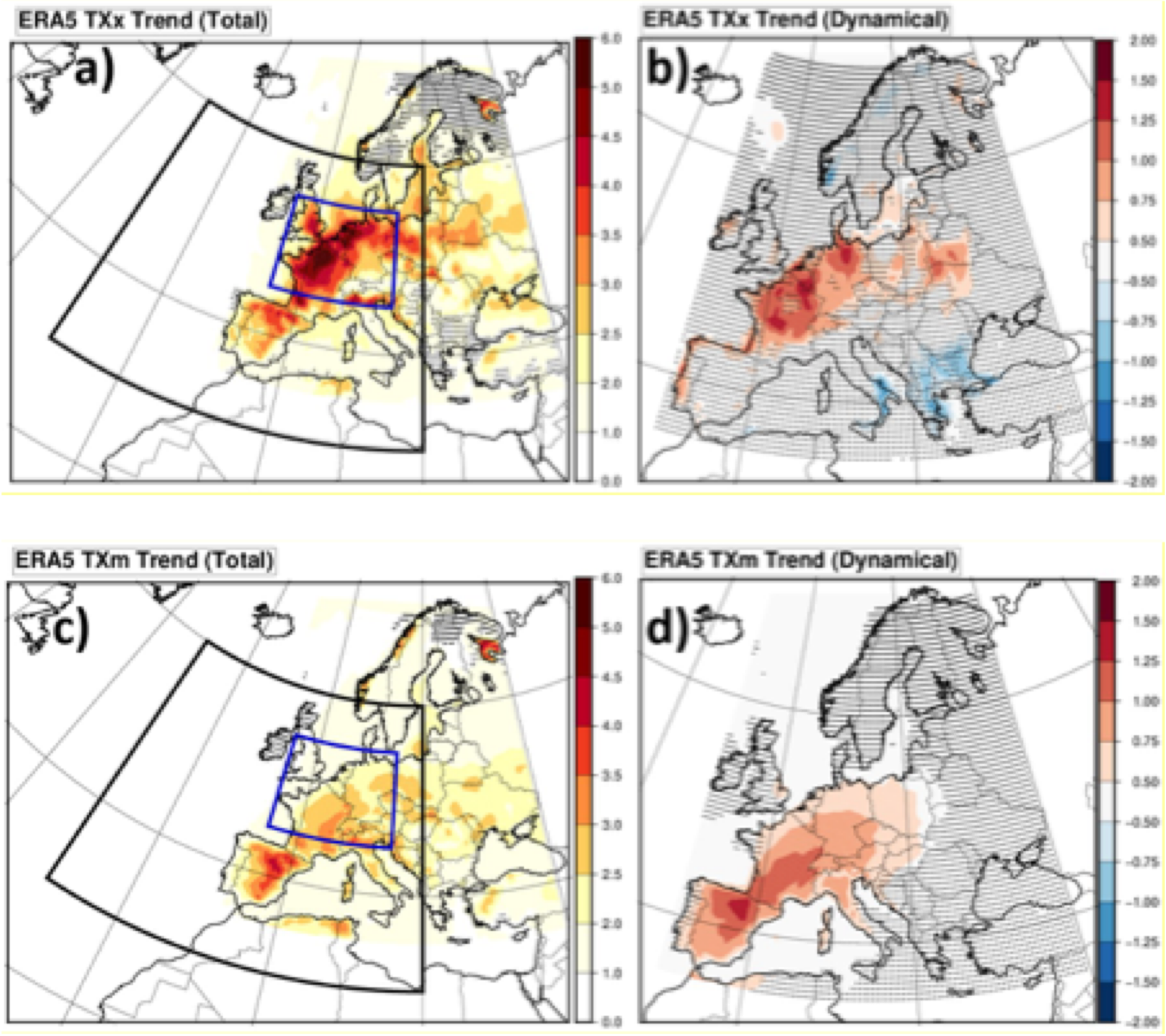


Fig. 2. Sea-level pressure summertime atmospheric circulation patterns with significant occurrence trends and associated surface anomalies: Composite anomalies of DJF sea-level pressure (*A* and *B*), 10-m horizontal wind speed (*C* and *D*), 2-m temperatures (*E* and *F*), and precipitation rates (*G* and *H*) for days with increasing (*A*, *C*, *E*, and *G*) or decreasing (*B*, *D*, *F*, and *H*) occurrence trends. In the composites (*A* – *H*), contours indicate regions with changes significant at the one-sided 5% level, computed with a bootstrap sample size of 500. Spatial averages of seasonal temperature anomalies (black) and precipitation rates (blue) during the days with increasing (*I*) or decreasing (*J*) occurrence trends and count of days displaying the corresponding occurrence trend (orange stems) during DJF. Solid lines represent linear trends of the spatial averages with the 95% confidence intervals of the two linear fits in each panel shown in the legends. The averages in (*I*) and (*J*) are computed on all European land points (*SI Appendix*, Fig. S3).

Faranda, D., G. Messori, A. Jezequel, M. Vrac, P.Yiou: Atmospheric circulation compounds anthropogenic warming and impacts of climate extremes in Europe. *Proceedings of the National Academy of Sciences* March 21, 2023,120 (13) e2214525120 https://doi.org/10.1073/pnas.2214525120

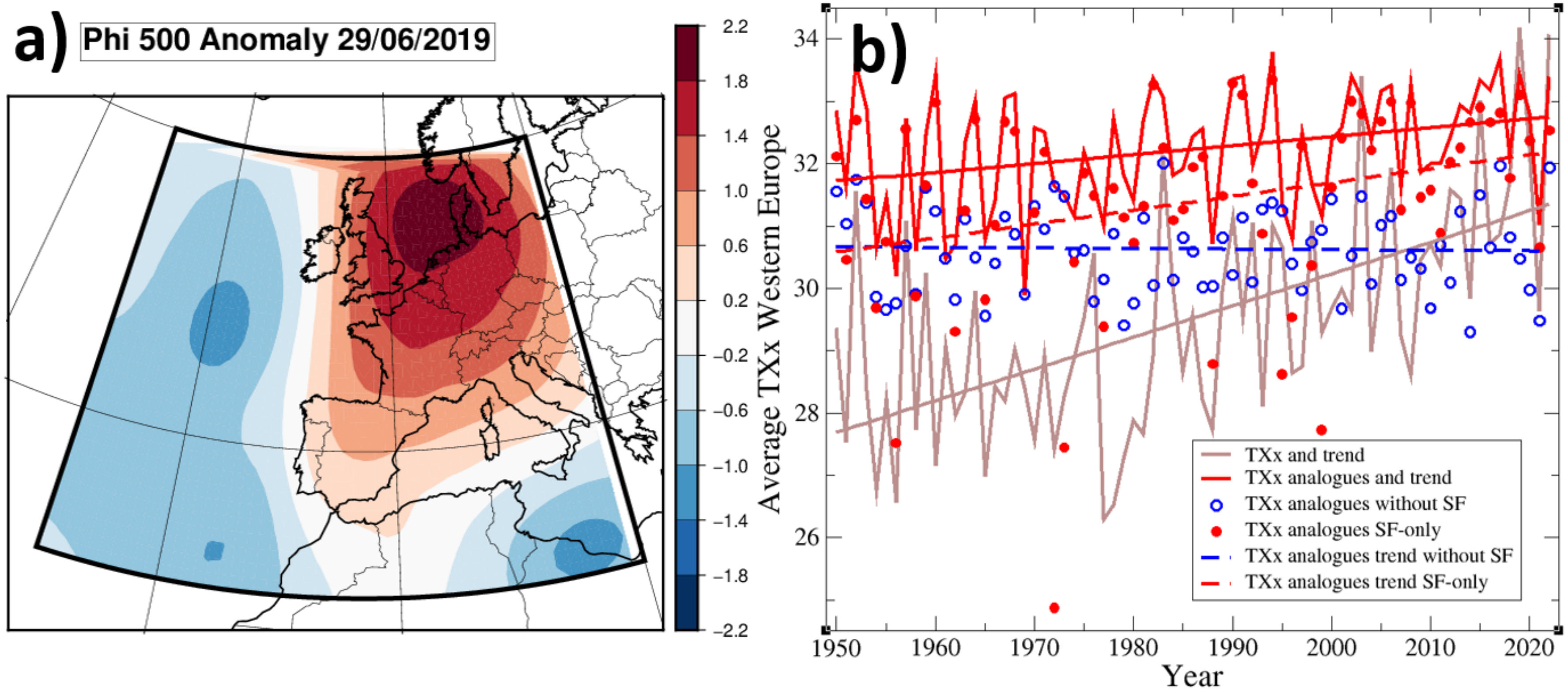
West European Tmax trends



ERA5 temperature trends relative to the global warming level (°C/GWD), for summer Mean daily Tmax (TXm) (top row) and summer Maximum Tmax (TXx, bottom row).

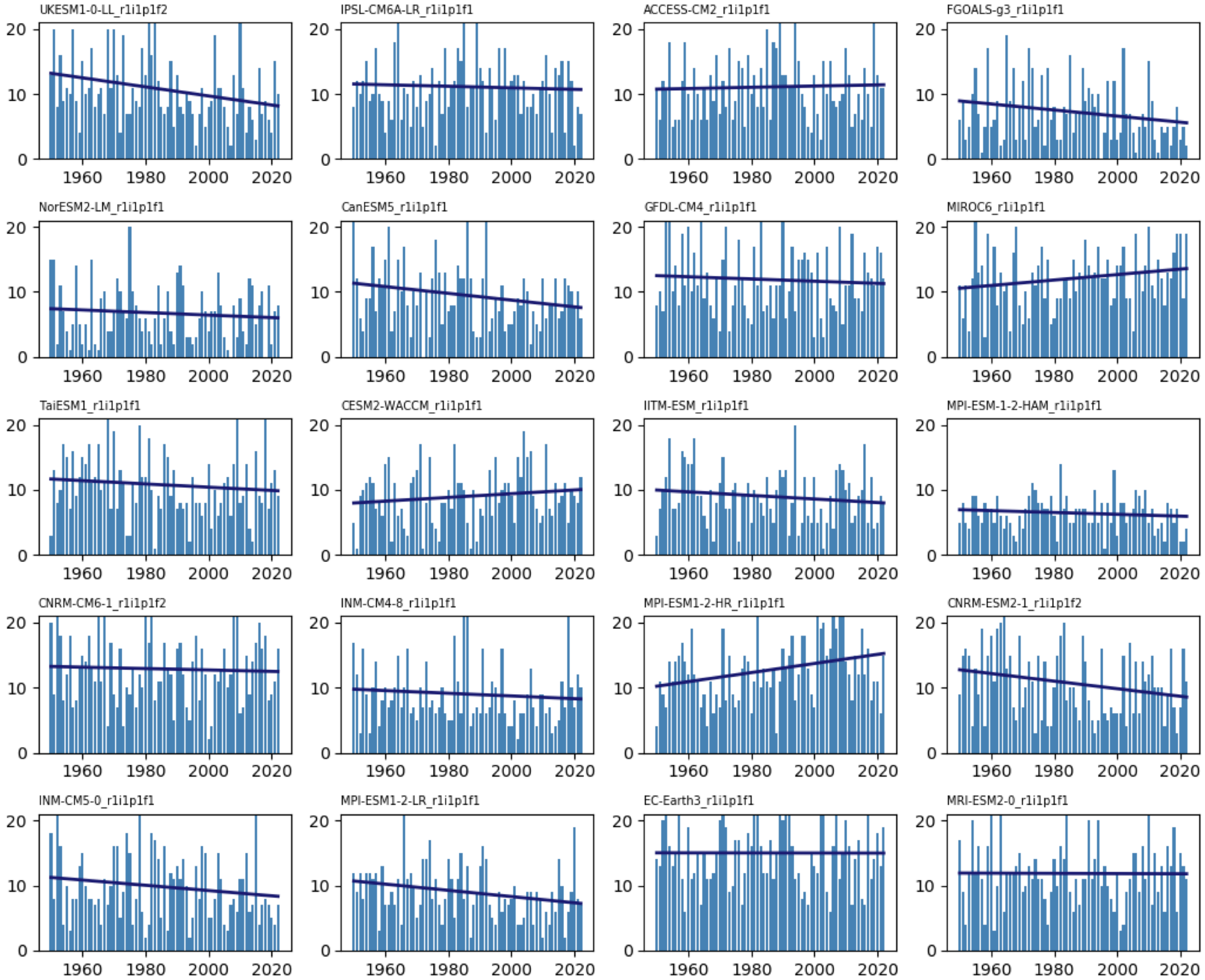
The raw trend (left panels) is compared to the estimated dynamical contribution to these trends (right panels), obtained by replacing daily temperatures by those of best circulation analogues
with a thermodynamic correction (see Methods). The areas highlighted are: (black frame) the area used to calculate the anomaly correlation of 500 hPa streamfunction for the definition of analogues; the Western Europe focus area, where maximal daily temperature trends are averaged in this study. Dotted points show areas where statistical significance of trends is less than 95% (two sided). The statistical test uses a 2-sigma rule for the regression coefficient,
accounting for the total number of well-separated analogues

Vautard et al 2023

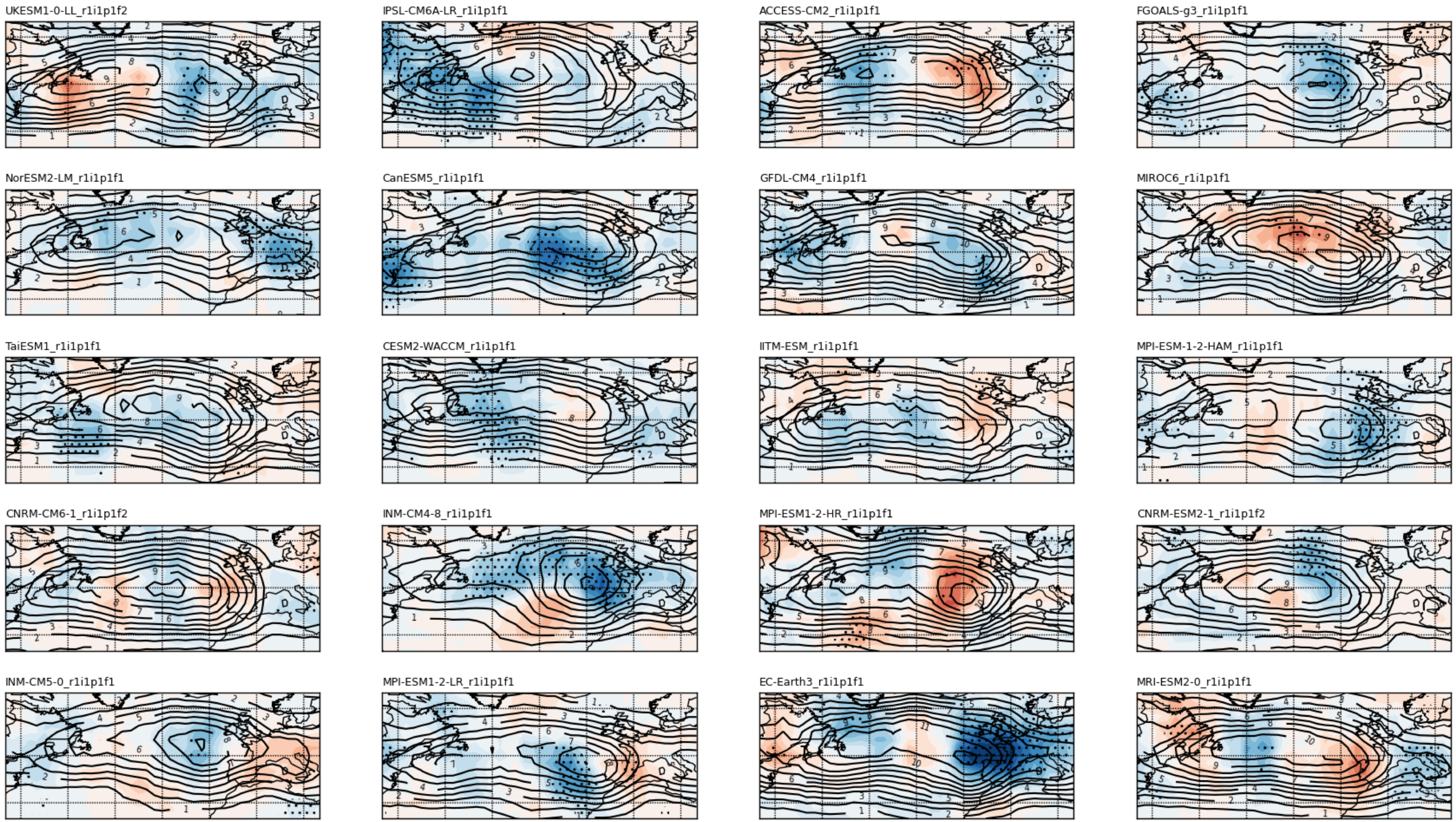


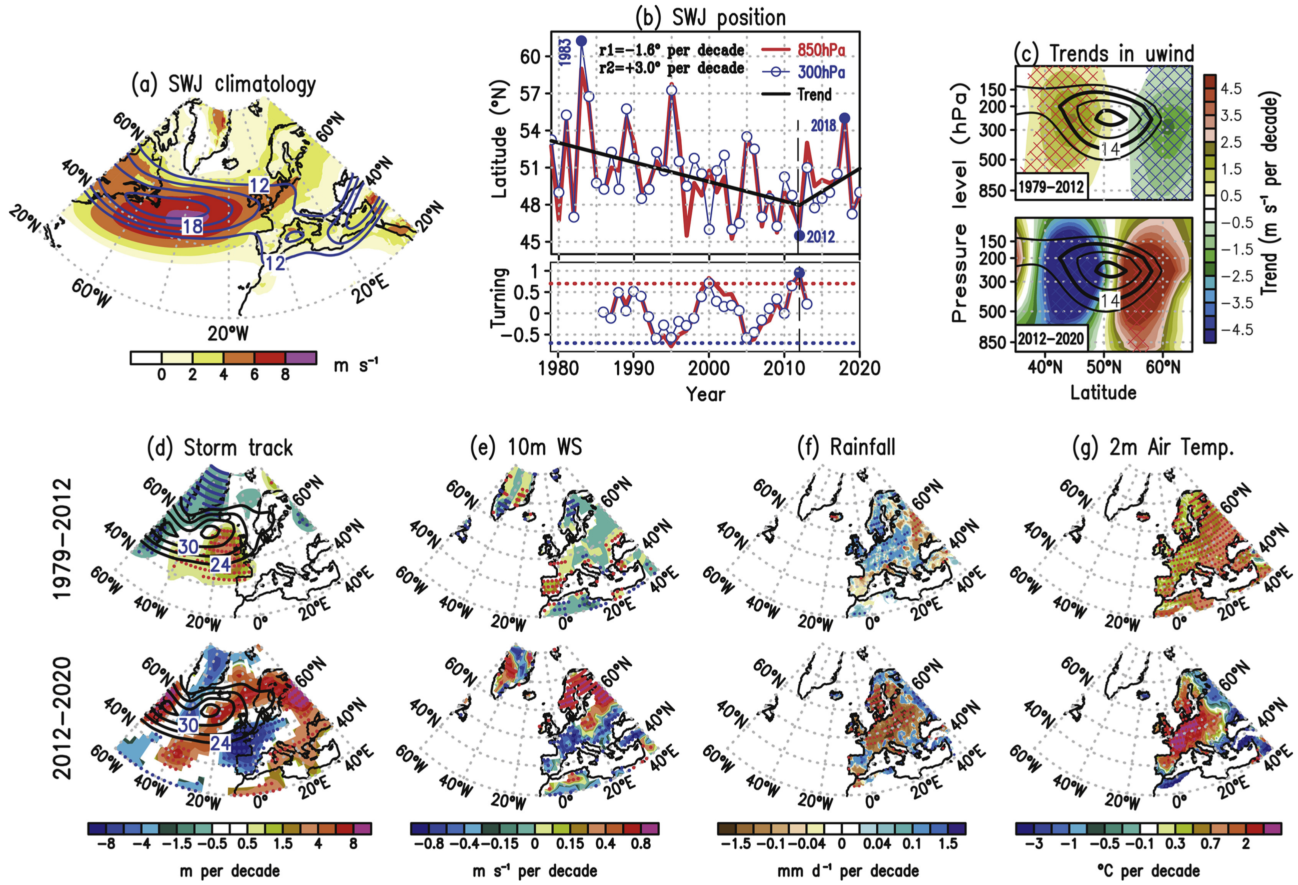
(left) Streamfunction anomaly of the 29/06/2019; (right) yearly time series of the Western Europe average of TXx (brown), the TXx of the analogue time series, averaged over Western Europe and the 3 best analogues (red curve) (see Methods), and the corresponding time series obtained by excluding (resp. including only) Southerly Flow (SF) pattern dates before calculating the analogue TXx values (blue circles, resp. red circles). The sets of dates (SF dates or non-SF dates) within a year over which the yearly maximum is sought are therefore complementary. In each case, analogues are calculated using the full set of patterns (i.e. for non-SF dates, analogues may contain SF patterns). Linear trends for all series are also shown, with the same color as the series. The dashed red trend is that of the SF-only.

Vautard et al 2023



UKESM1-0-LL_r1i1p1f2
IPSL-CM6A-LR_r1i1p1f1
ACCESS-CM2_r1i1p1f1
FGOALS-g3_r1i1p1f1
NorESM2-LM_r1i1p1f1
CanESM5_r1i1p1f1
GFDL-CM4_r1i1p1f1
MIROC6_r1i1p1f1
TaiESM1_r1i1p1f1
CESM2-WACCM_r1i1p1f1
IITM-ESM_r1i1p1f1
MPI-ESM-1-2-HAM_r1i1p1f1
CNRM-CM6-1_r1i1p1f2
INM-CM4-8_r1i1p1f1
MPI-ESM1-2-HR_r1i1p1f1
CNRM-ESM2-1_r1i1p1f2
INM-CM5-0_r1i1p1f1
MPI-ESM1-2-LR_r1i1p1f1
EC-Earth3_r1i1p1f1
MRI-ESM2-0_r1i1p1f1
0
10
20
1960
1980
2000
2020


UKESM1-0-LL_r1i1p1f2
IPSL-CM6A-LR_r1i1p1f1
ACCESS-CM2_r1i1p1f1
FGOALS-g3_r1i1p1f1
NorESM2-LM_r1i1p1f1
CanESM5_r1i1p1f1
GFDL-CM4_r1i1p1f1
MIROC6_r1i1p1f1
TaiESM1_r1i1p1f1
CESM2-WACCM_r1i1p1f1
IITM-ESM_r1i1p1f1
MPI-ESM-1-2-HAM_r1i1p1f1
CNRM-CM6-1_r1i1p1f2
INM-CM4-8_r1i1p1f1
MPI-ESM1-2-HR_r1i1p1f1
CNRM-ESM2-1_r1i1p1f2
INM-CM5-0_r1i1p1f1
MPI-ESM1-2-LR_r1i1p1f1
EC-Earth3_r1i1p1f1
MRI-ESM2-0_r1i1p1f1



Trends in Jet and stromtrack in summer

Deng, Kai-Qiang, Cesar Azorin-Molina, Song Yang, Chun-Di Hu, Gang-Feng Zhang, Lorenzo Minola, Sergio Vicente-Serrano, Deliang Chen, 2022: Shifting of summertime weather extremes in Western Europe during 2012– 2020, Advances in Climate Change Research, Volume 13, Issue 2. 218-227, ISSN 1674-9278, https://doi.org/10.1016/j.accre.2022.01.008.