


# Changing atmospheric circulations in a future warmer Europe

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 CAFE Final Conference | Barcelona

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 PedroLormendez



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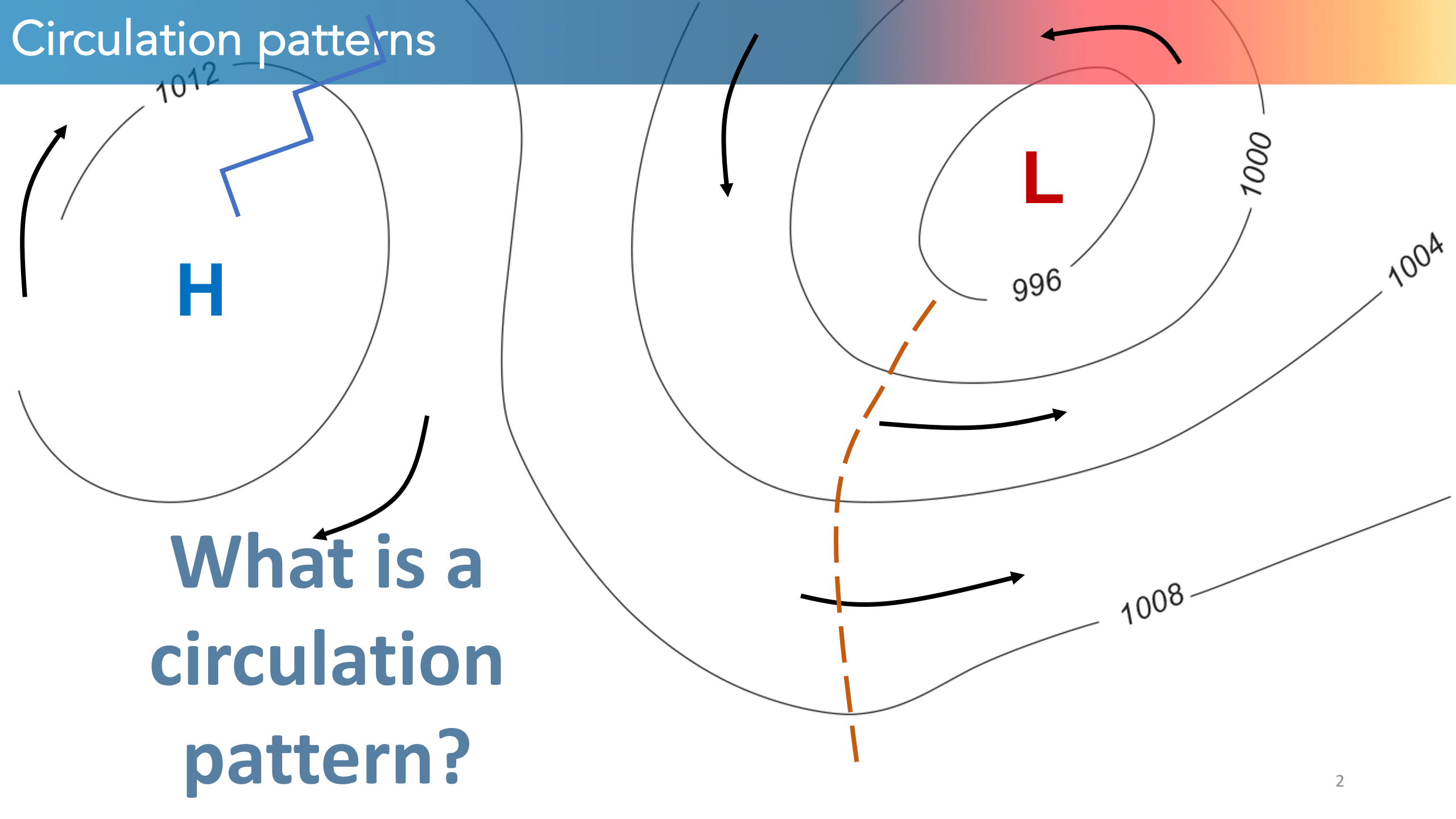
**CAFE**

Climate Advanced Forecasting  
of sub-seasonal Extremes



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 813844

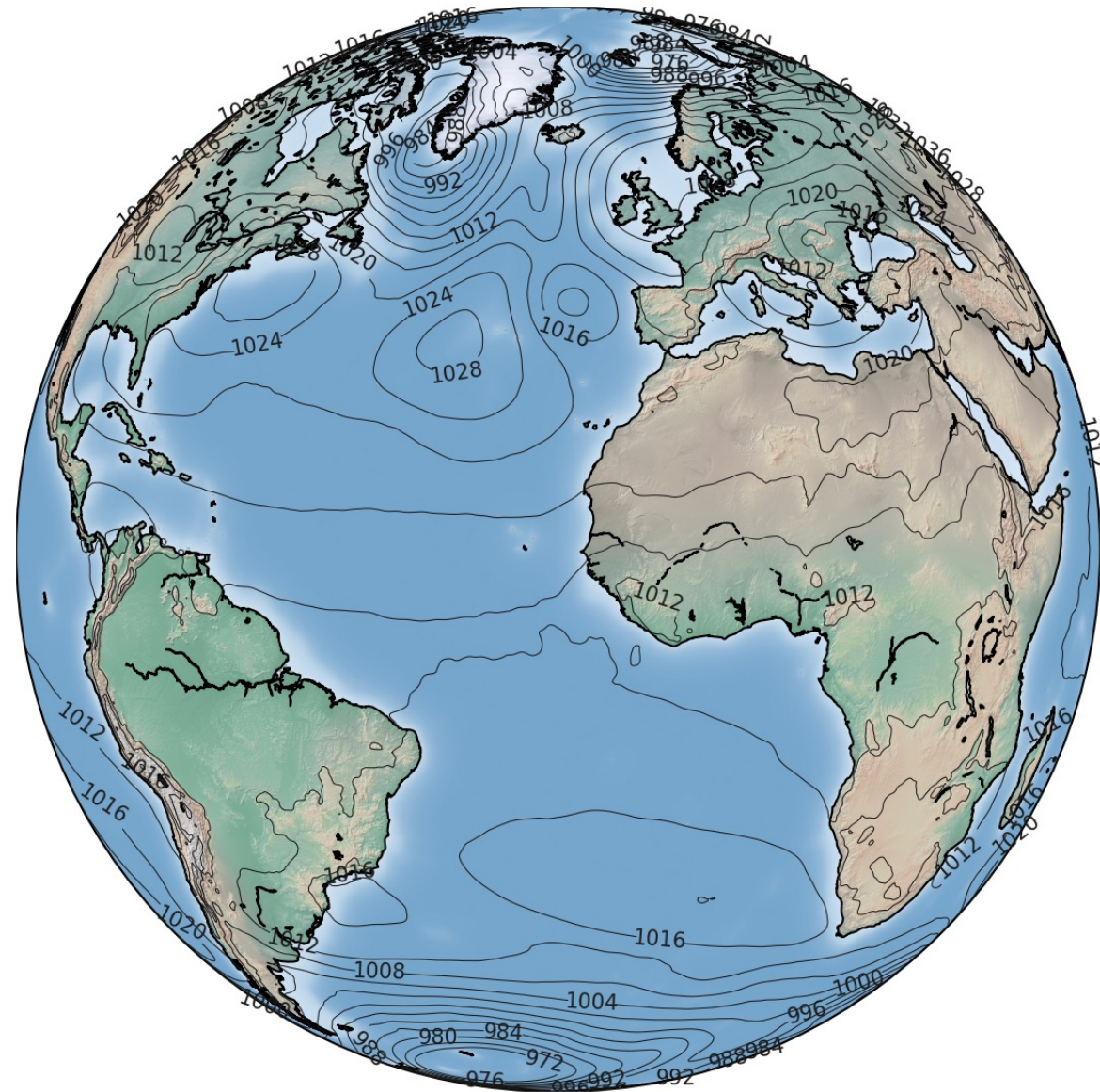
# Circulation patterns



**What is a circulation pattern?**

# Circulation patterns

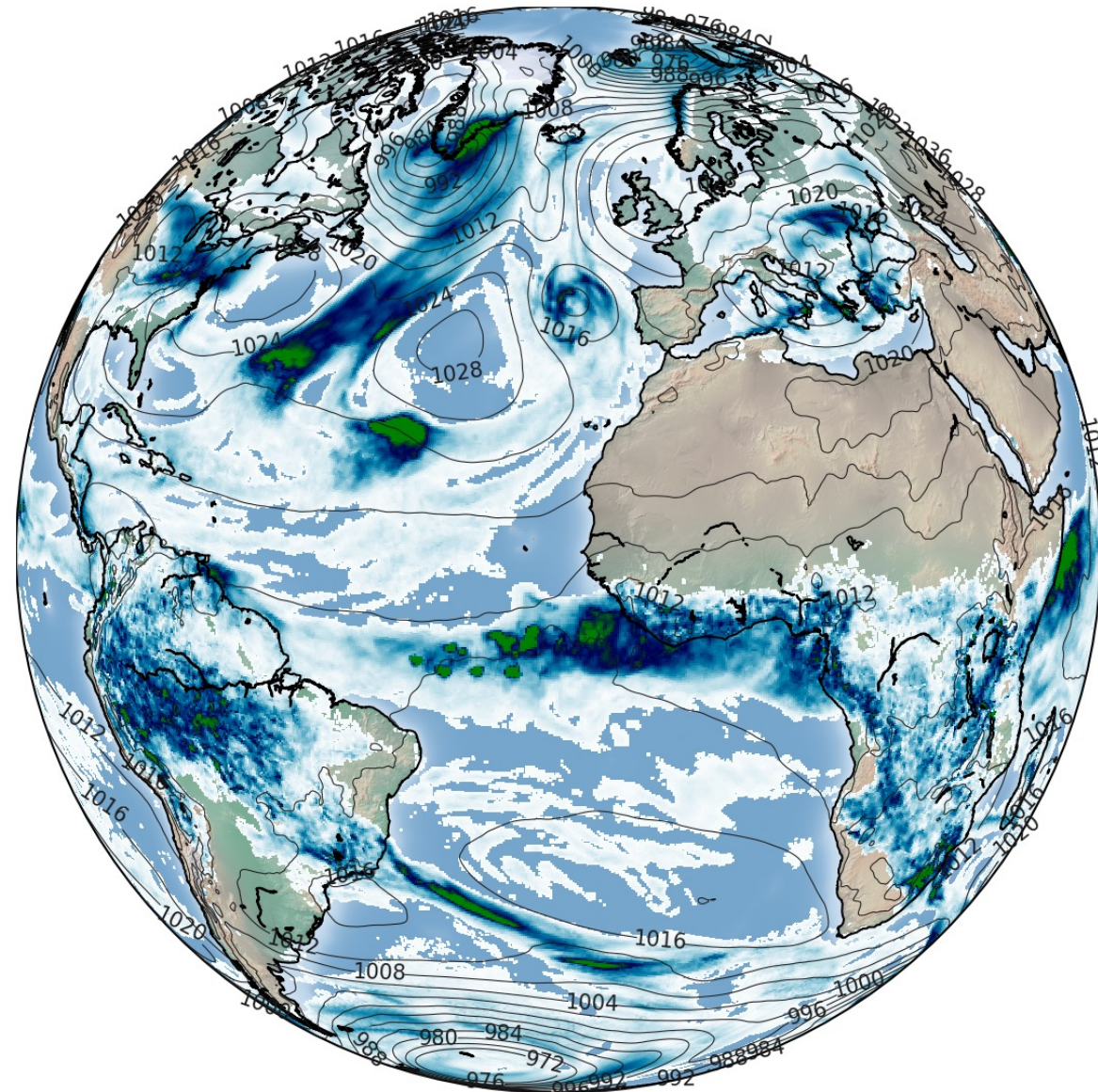
1990-12-15



**Why grouping  
them?**

# Circulation patterns

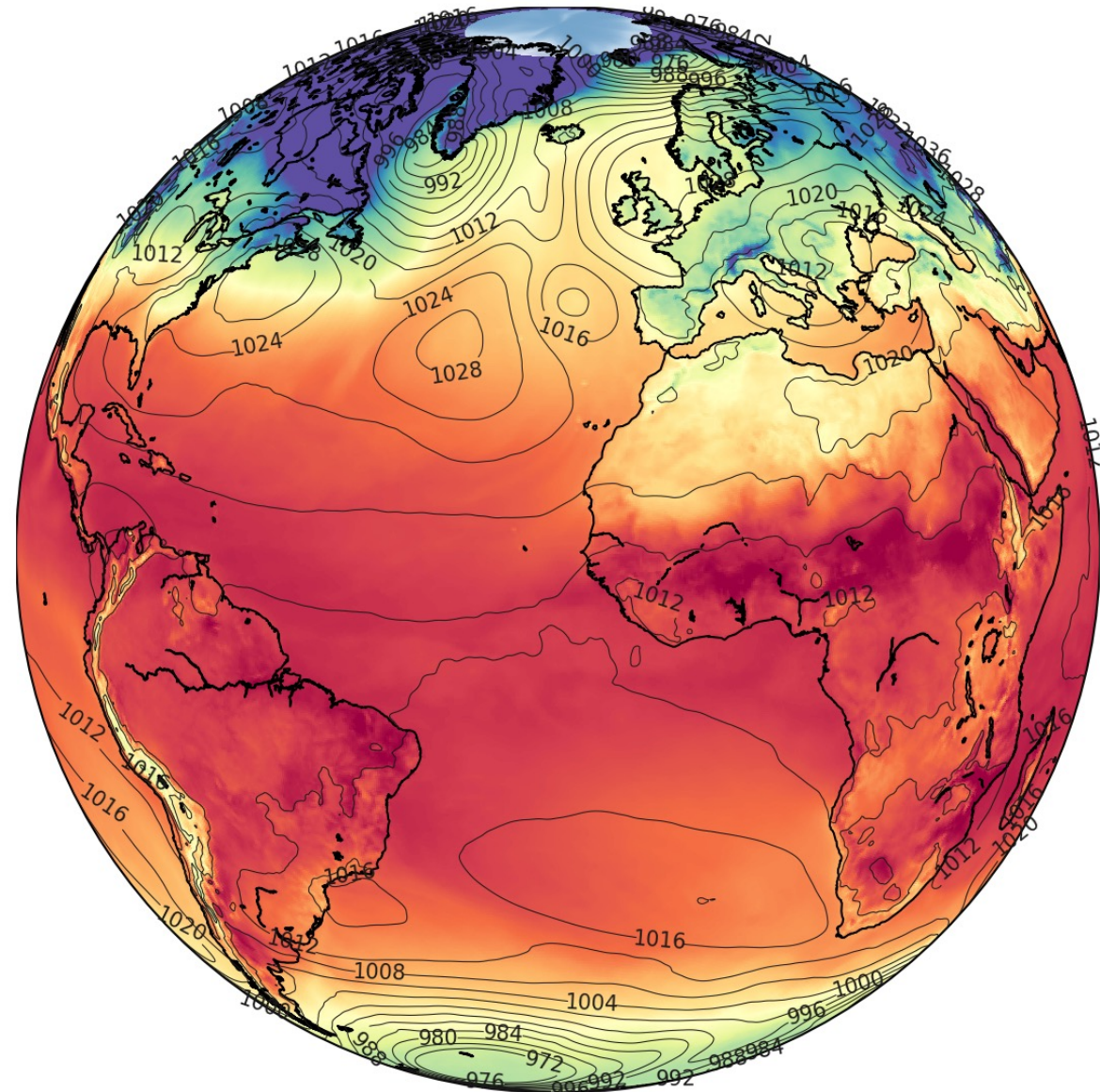
1990-12-15



**Influence on  
regional rainfall**

# Circulation patterns

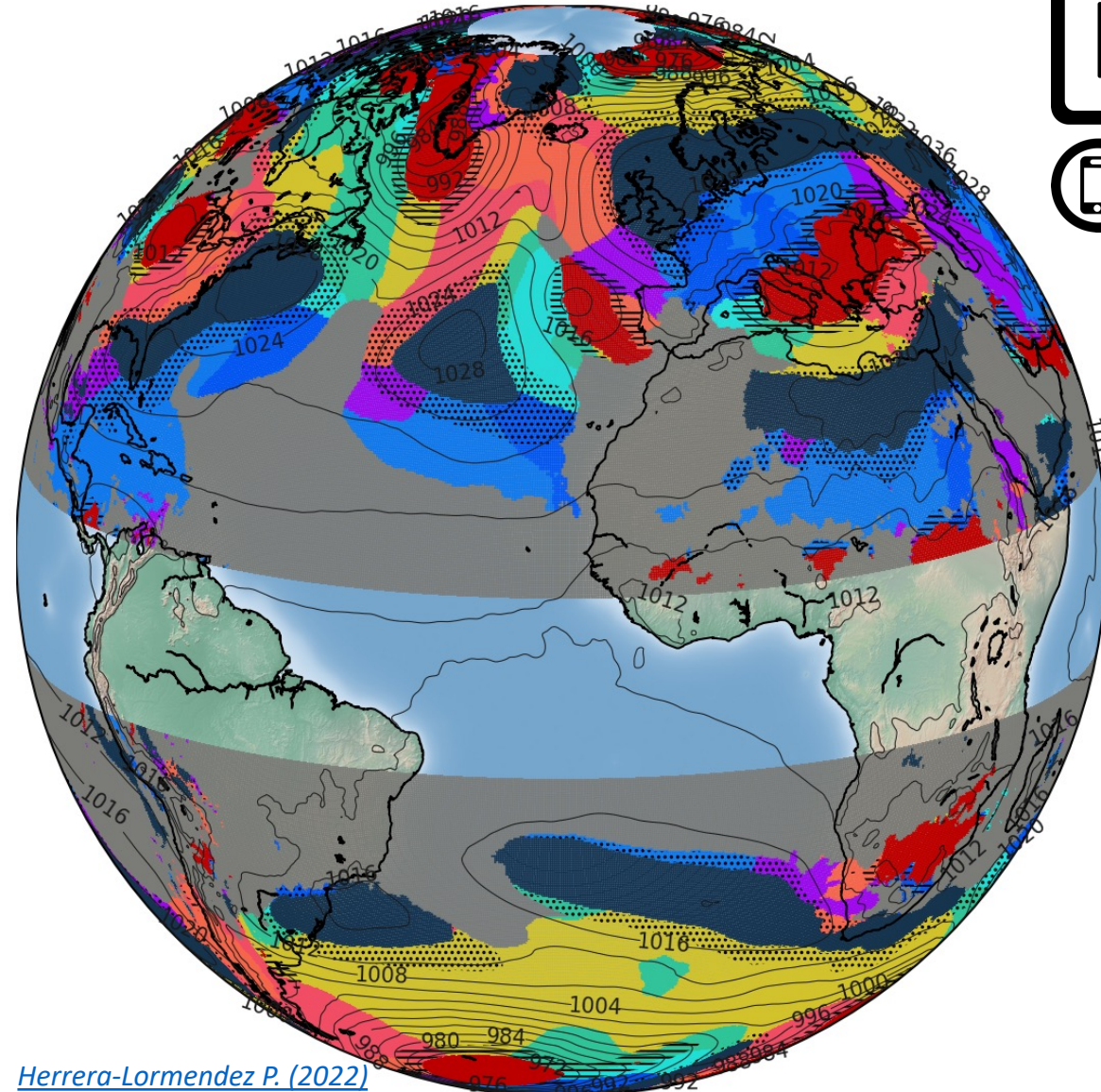
1990-12-15



**Influence on  
temperature and  
moisture  
advection**

# One way of classifying them

1990-12-15



SCAN ME

- LF
- A
- NE
- E
- SE
- S
- SW
- W
- NW
- N
- C
- Partly Cyclonic
- Partly Anticyclonic

Large-scale circulations derived from mean sea level pressure data based on the automated Jenkinson-Collison classification (Lamb Weather types).

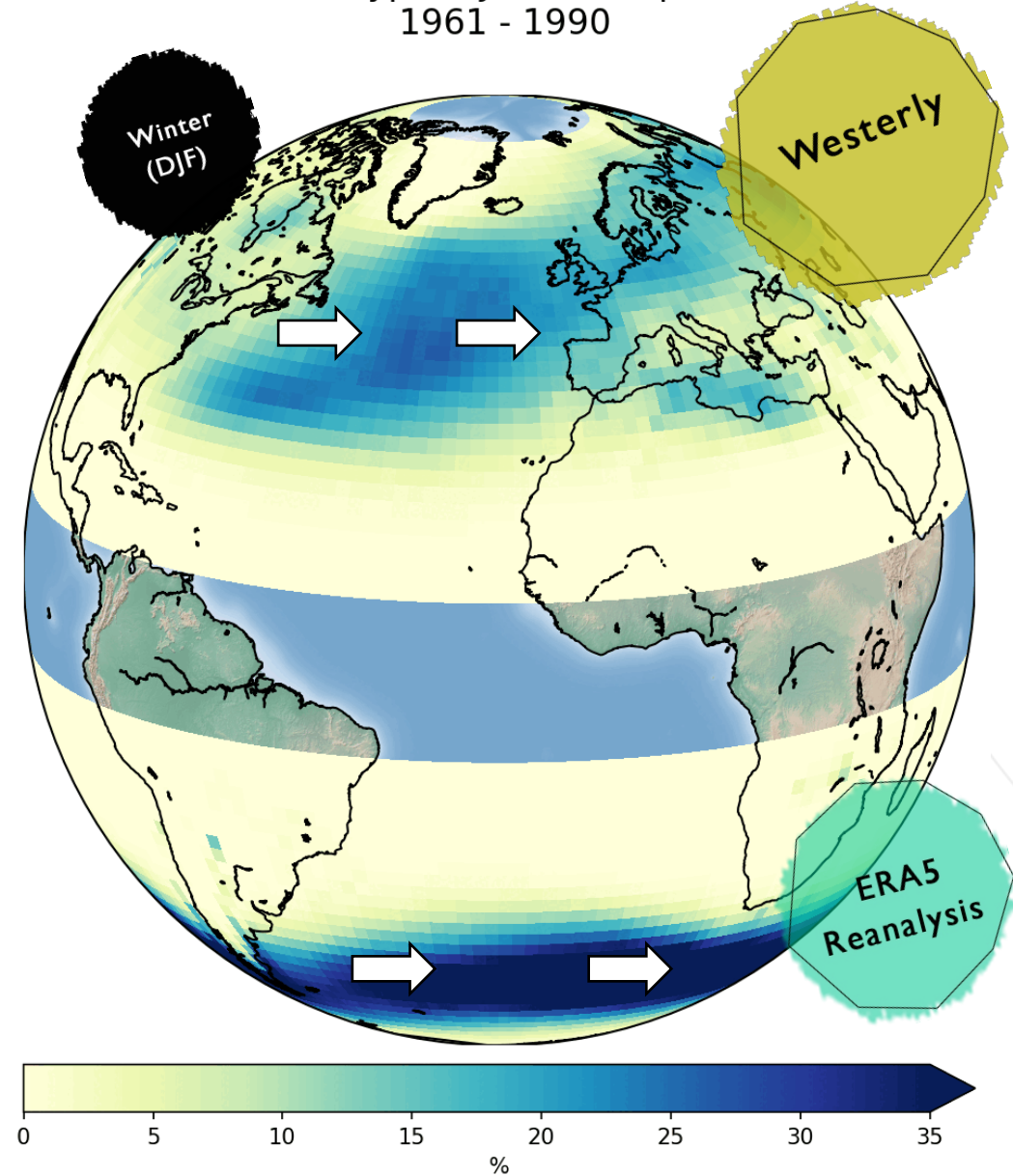
**A Python package to derive and visualise gridded synoptic circulations globally**

[Click here to DOWNLOAD](#)

```
pypi pip install jcclass
```

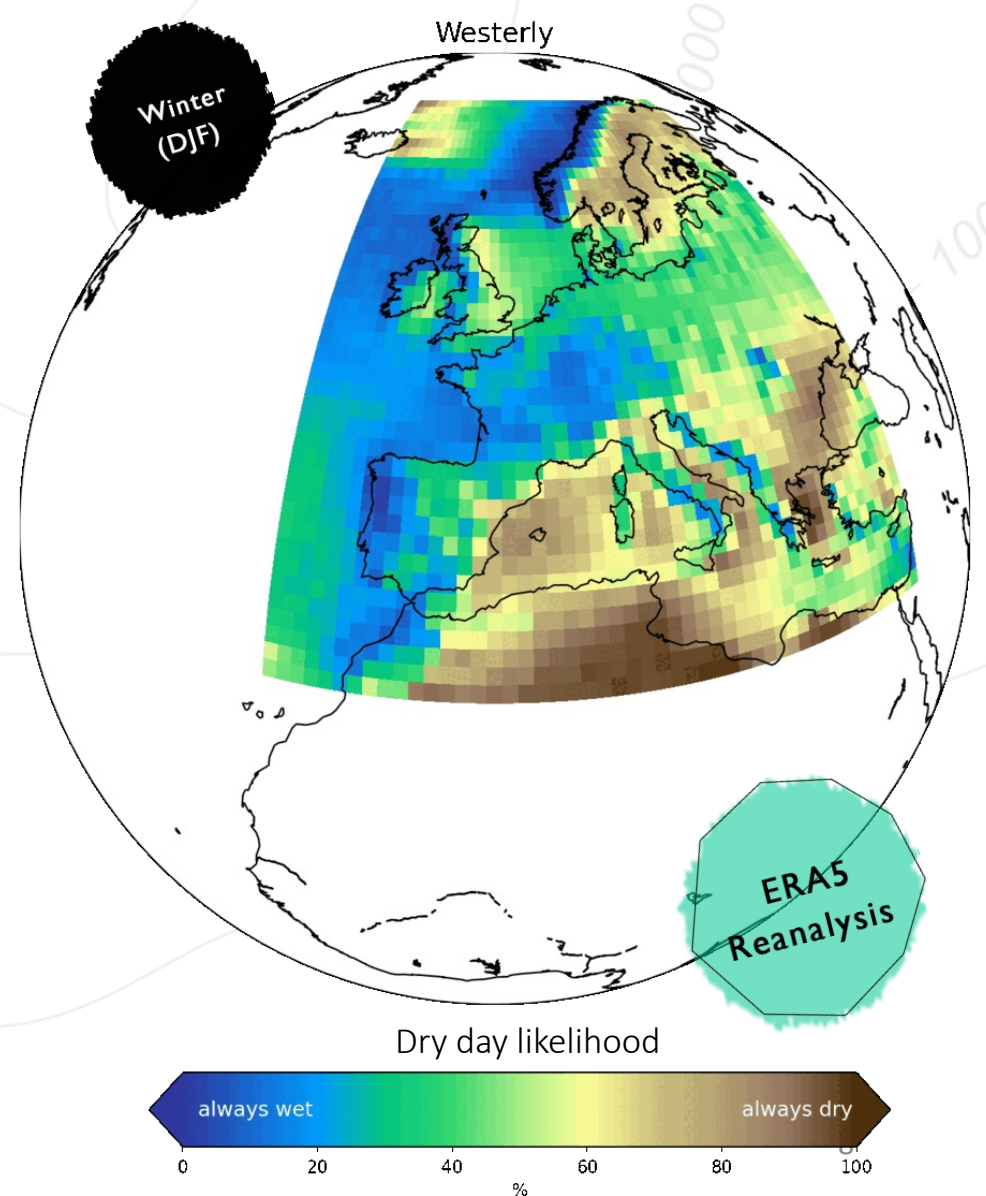
# Seasonality

W type, DJF Rel. freq.  
1961 - 1990



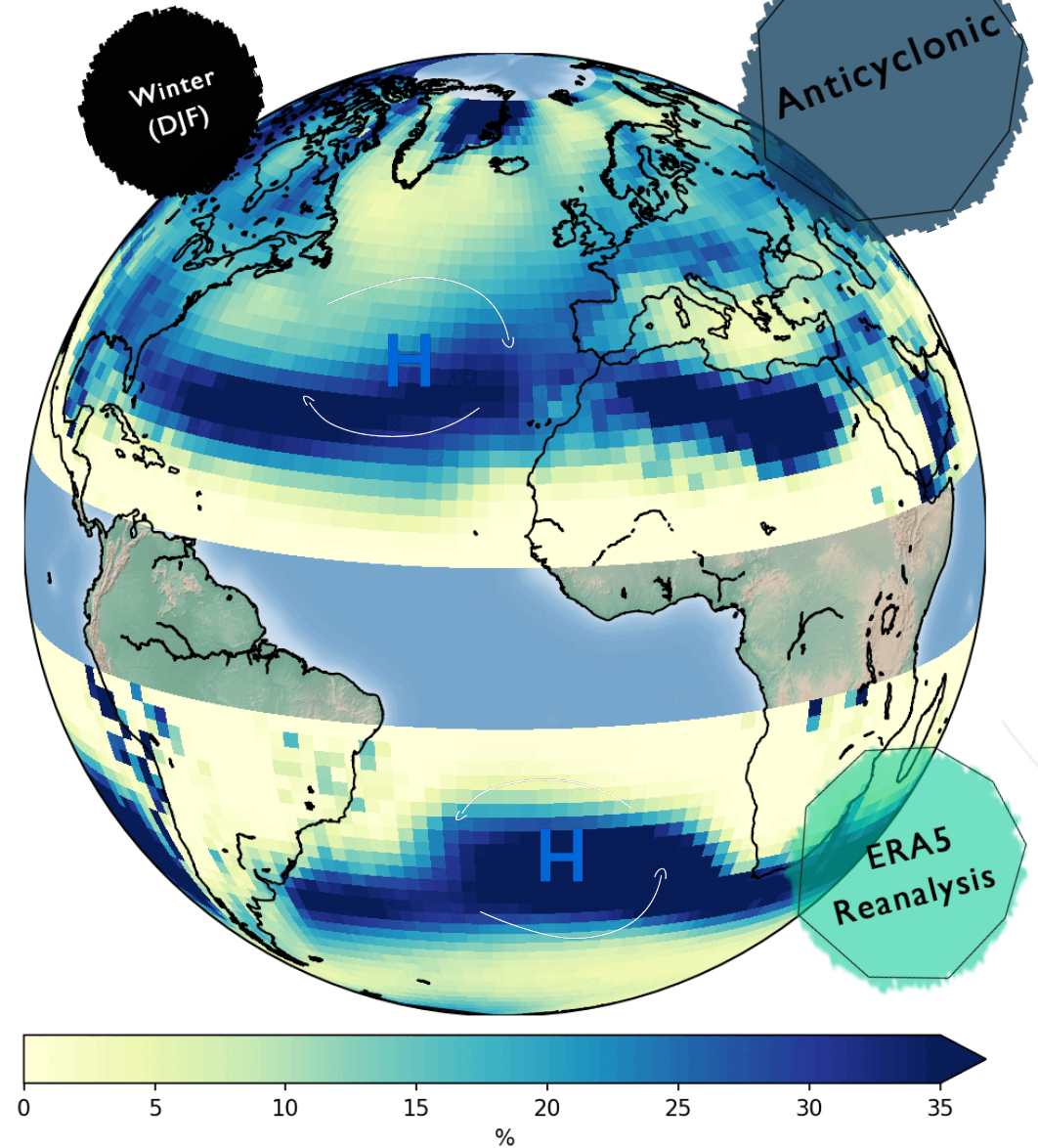
**Westerly**  
circulations are  
strong seasonal  
rainfall  
moderators for  
western Europe

DJF Dry day (< 1 mm) conditional probability  
(1951-2000)



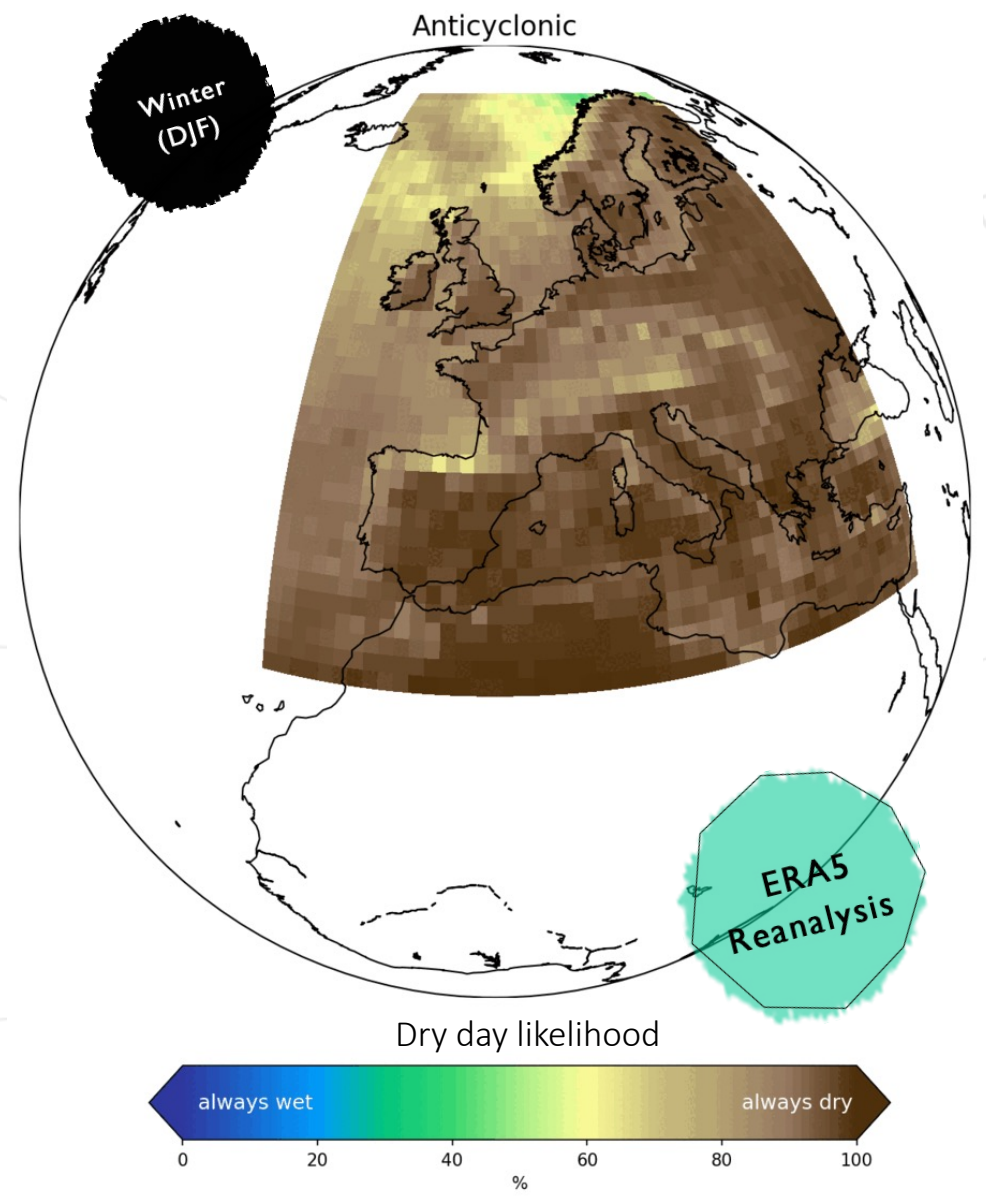
# Seasonality

A type, DJF Rel. freq.  
1961 - 1990



Anticyclones associated with lack of precipitation days.

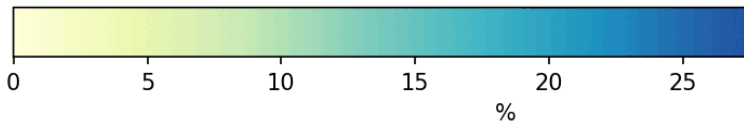
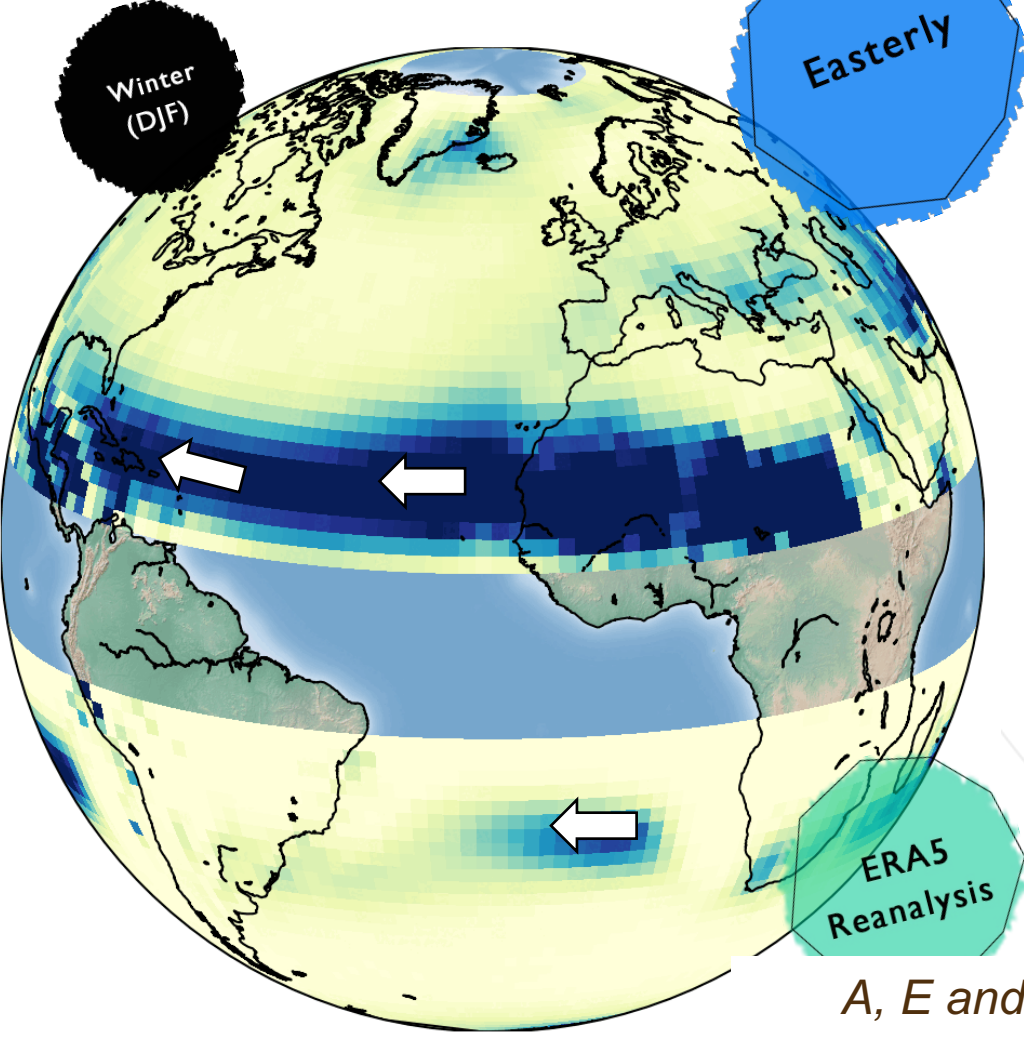
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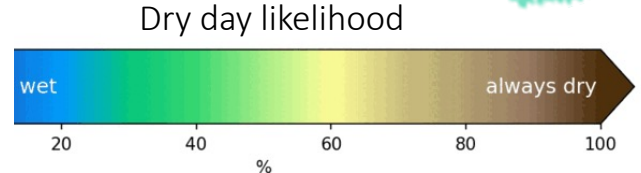
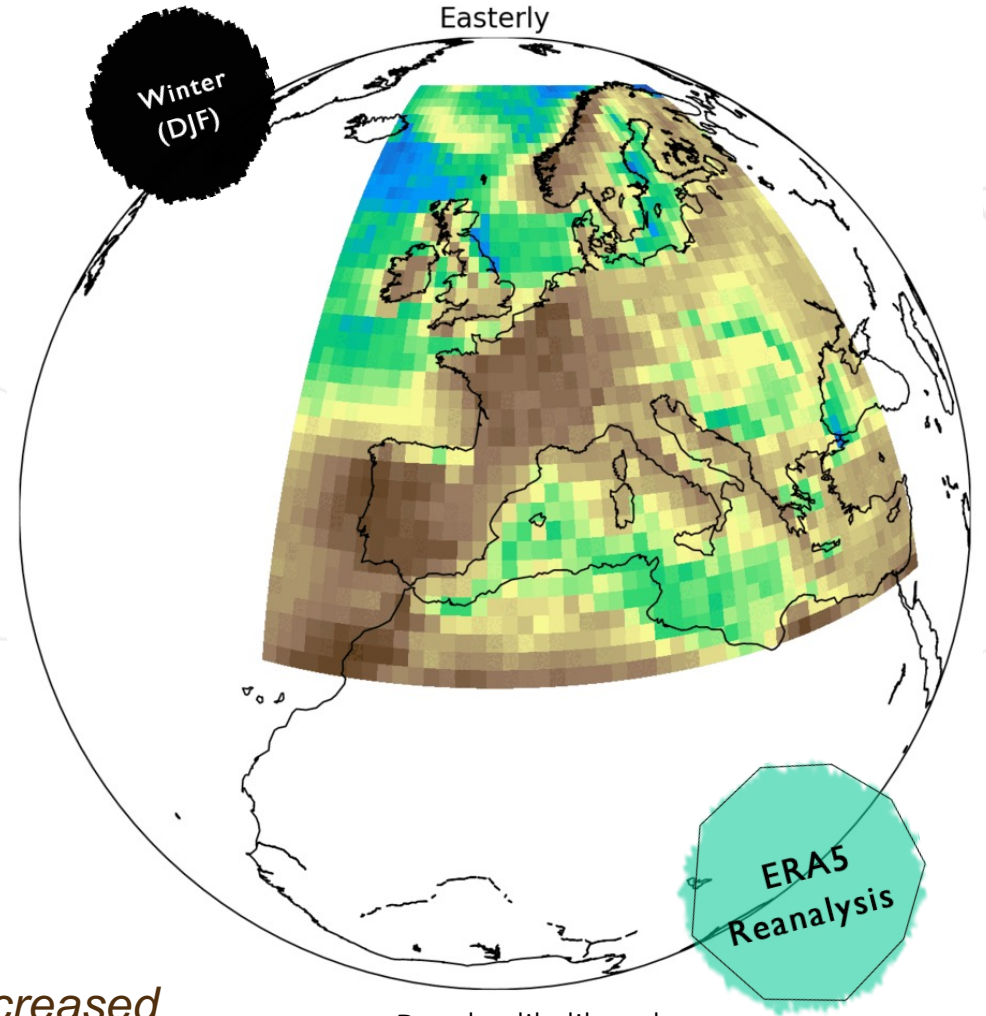
# Seasonality

E type, DJF Rel. freq.  
1961 - 1990



Easterlies not very frequent but responsible for dry days over western Europe.

DJF Dry day (< 1 mm) conditional probability (1951-2000)

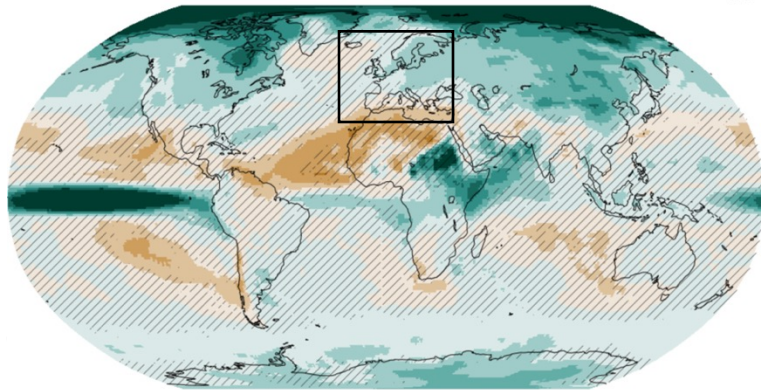


*A, E and SE types linked to increased summer drought severity in Central EU*  
*([Lhotka et al 2020](#))*

# Future of Europe

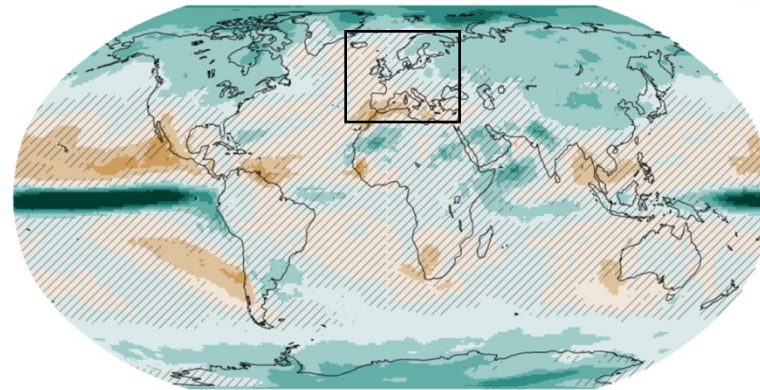
Multi-model seasonal mean precipitation percentage change for SSP2-4.5 (2081-2100 vs 1995-2014)

(a) DJF



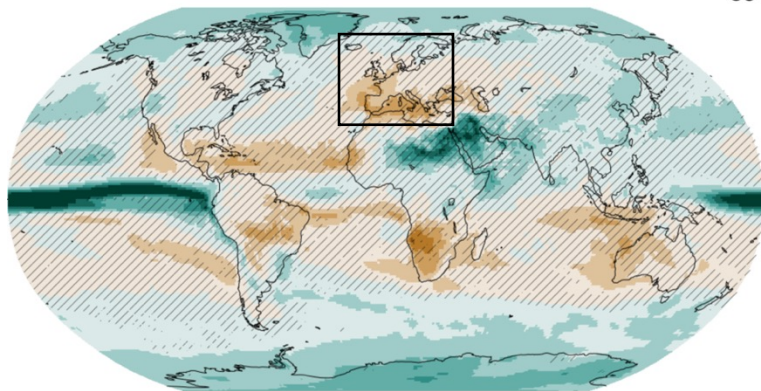
38

(b) MAM



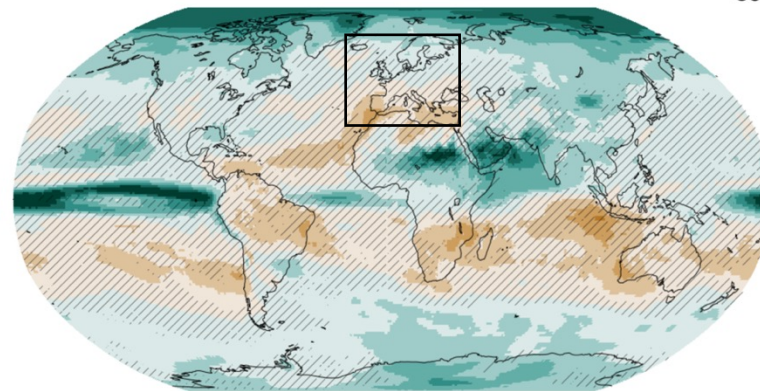
38

(c) JJA

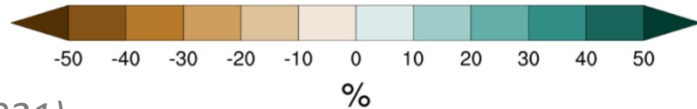


38

(d) SON



38



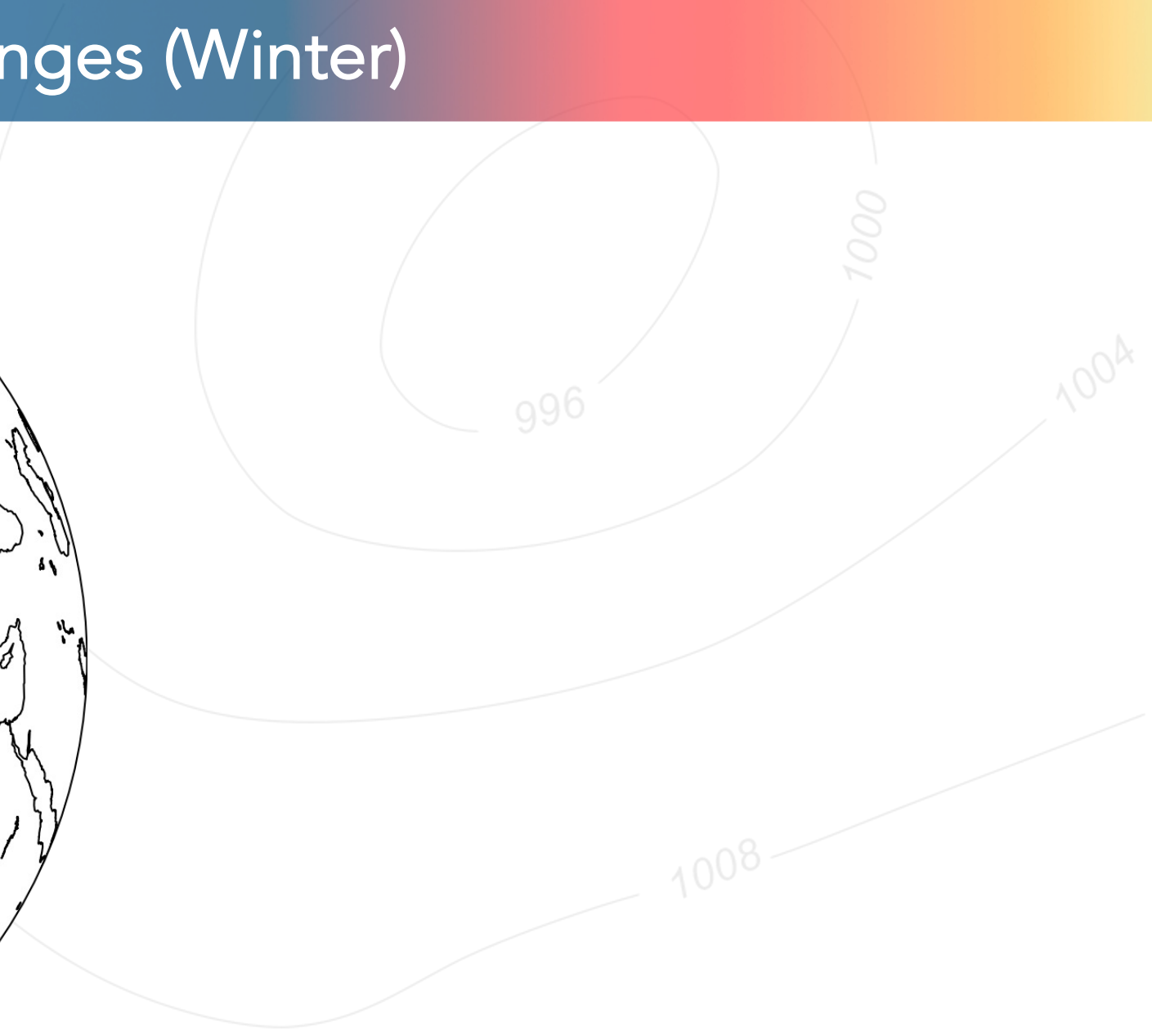
Color High model agreement ( $\geq 80\%$ )  
Low model agreement ( $< 80\%$ )

(IPCC AR6, 2021)

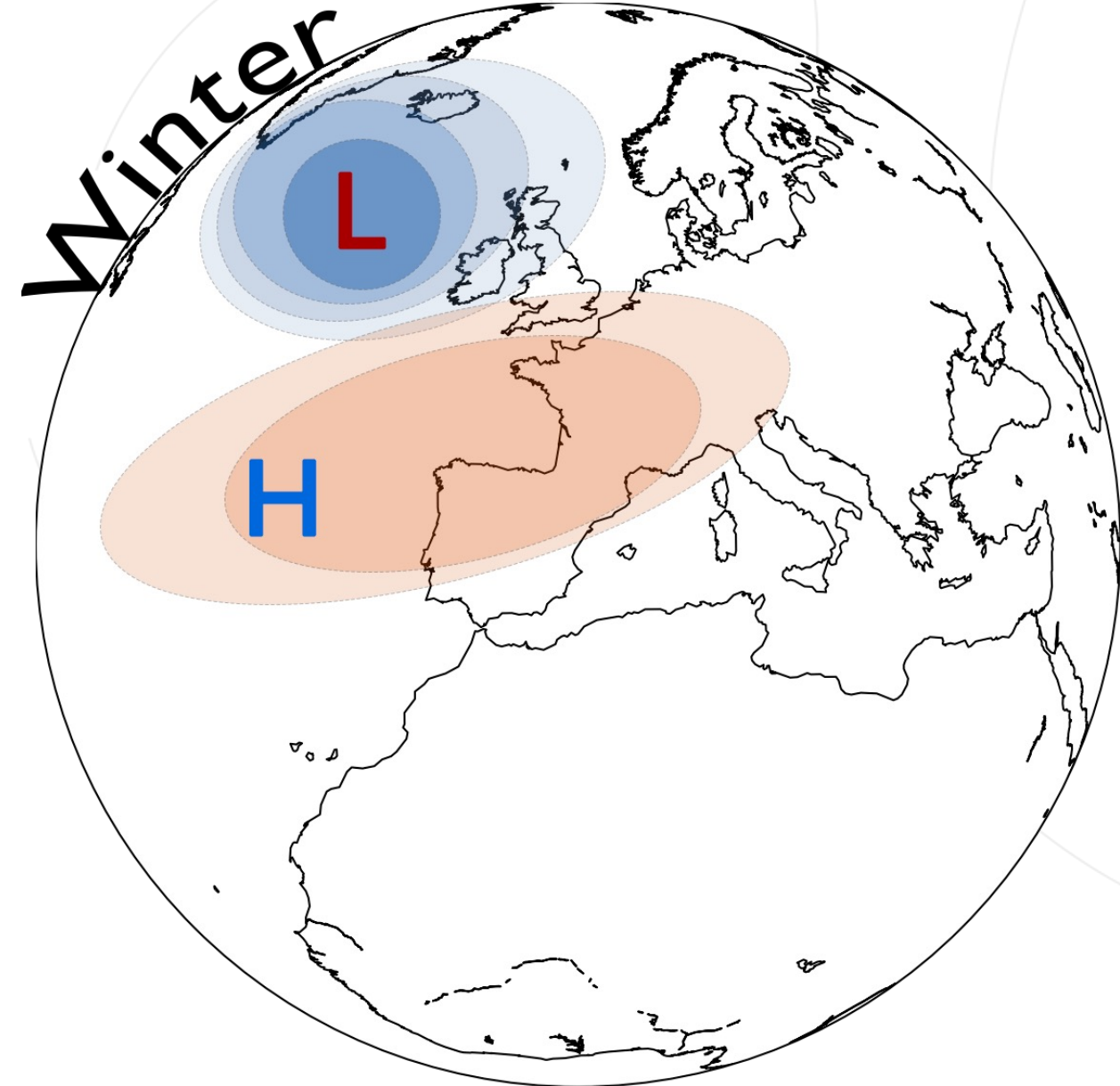
- **Drier summers over S. Europe**
- **Wetter winters over N. Europe**

*“Projected changes in regional precipitation also arise as a response to changes in large-scale atmospheric circulation”*

# A review of the projected changes (Winter)

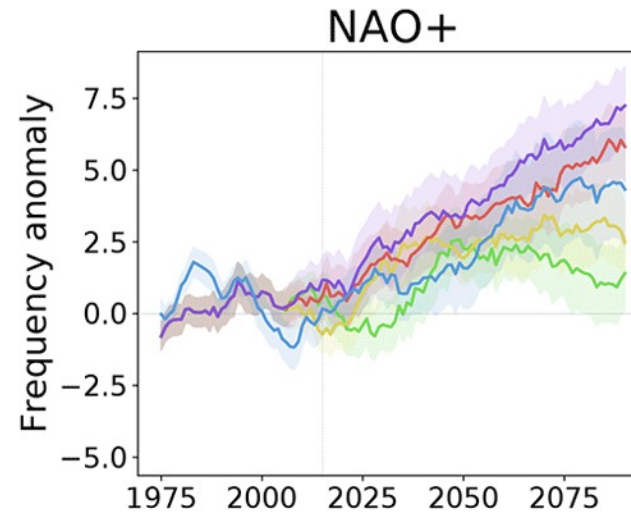


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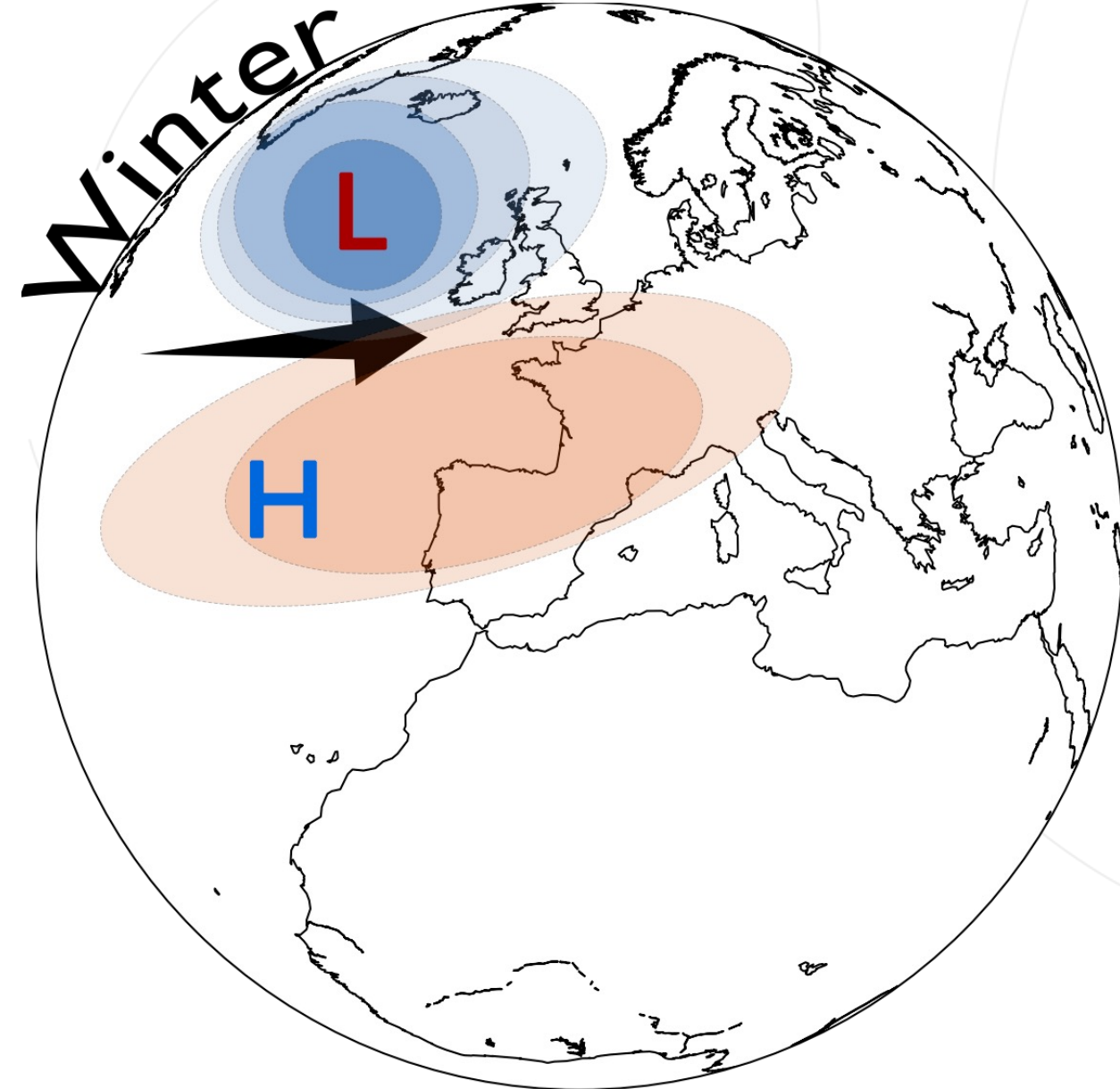
- Increase in NAO+ conditions over NW Europe favourable for milder and wetter conditions (Pope et al 2021, Fabiano et al 2020).

EAT



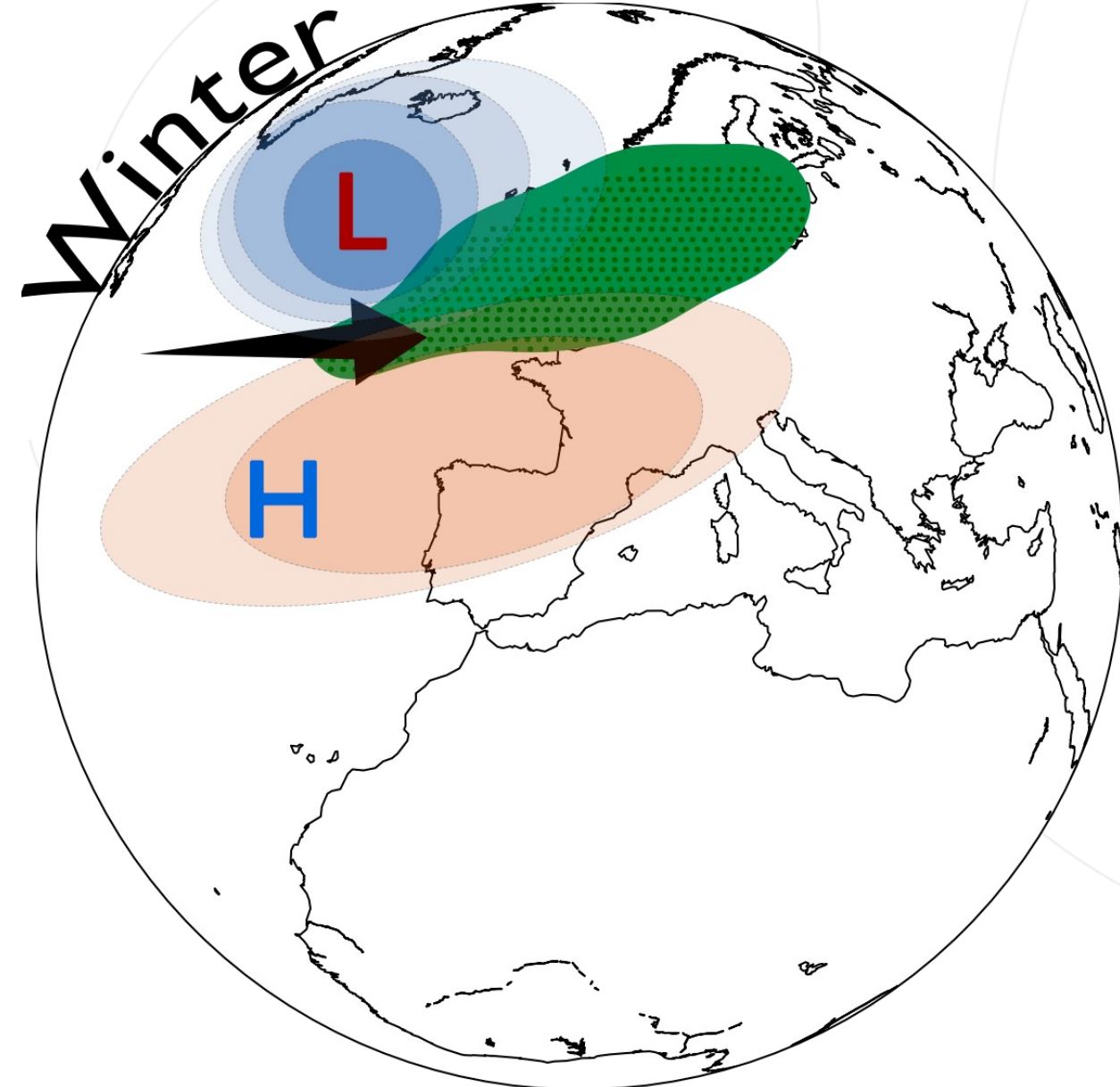
(Fabiano et al 2020)

# A review of the projected changes (Winter)



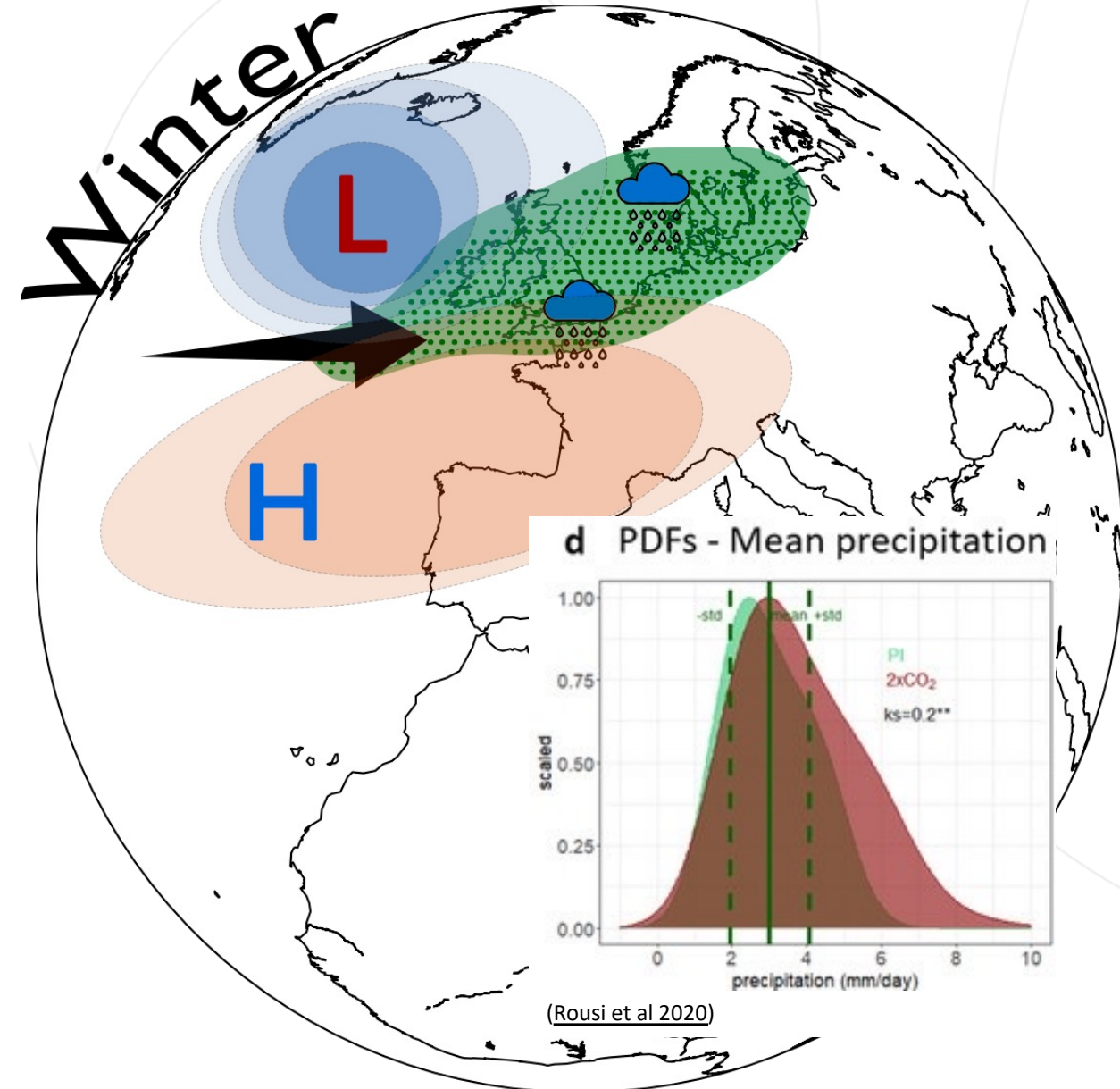
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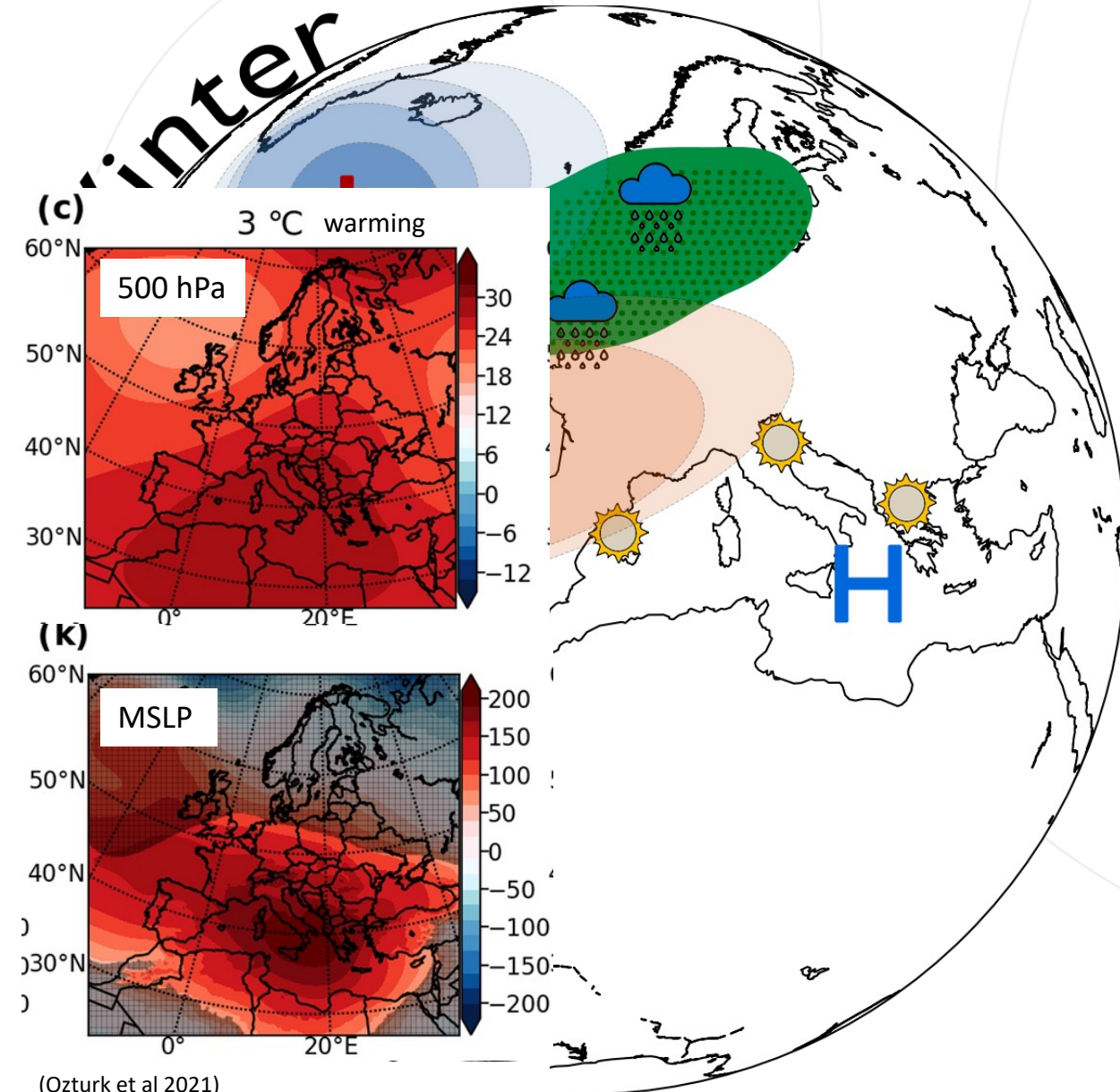
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- Increase in zonal flow regime (and flood risk over NW Europe (Rousi et al 2020))
- Enhanced westerly transport of warm and moist air (Ozturk et al 2021).

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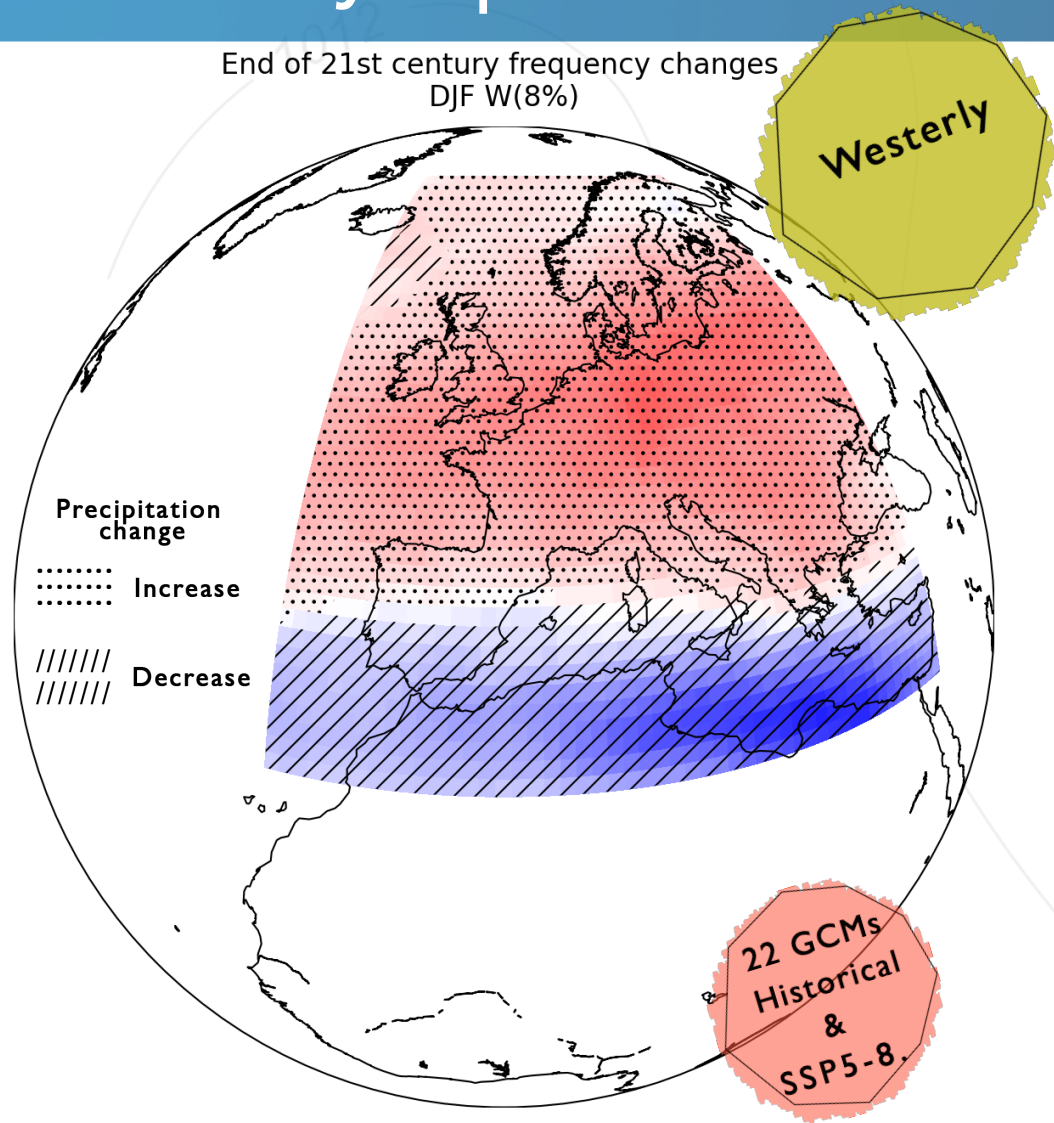


- Increase in NAO+ conditions over NW Europe favourable for milder and wetter conditions ([Pope et al 2021](#), [Fabiano et al 2020](#)).
- Increase in winter patterns associated with cyclonic and westerly types ([Pope et al 2021](#)).
- Poleward shift of moisture corridors ([Sousa et al 2020](#))
- Increase in zonal flow regime ([Oudar et al 2020](#)) and flood risk over NW Europe ([Rousi et al 2020](#))
- Enhanced westerly transport of warm and moist air ([Ozturk et al 2021](#)).
- Increase in 500 hPa and MSLP over the Mediterranean and Central EU ([Ozturk et al 2021](#)).



# Winter synoptic circulation changes

End of 21st century frequency changes  
DJF W(8%)



Total seasonal change in precipitation within the circulation type:

$$\Delta PR = PR(\text{future})_{CT} - PR(\text{present})_{CT}$$

future = 2071 - 2100

present = 1951 - 2000

$\Delta PR > 0$  (Precipitation increase)

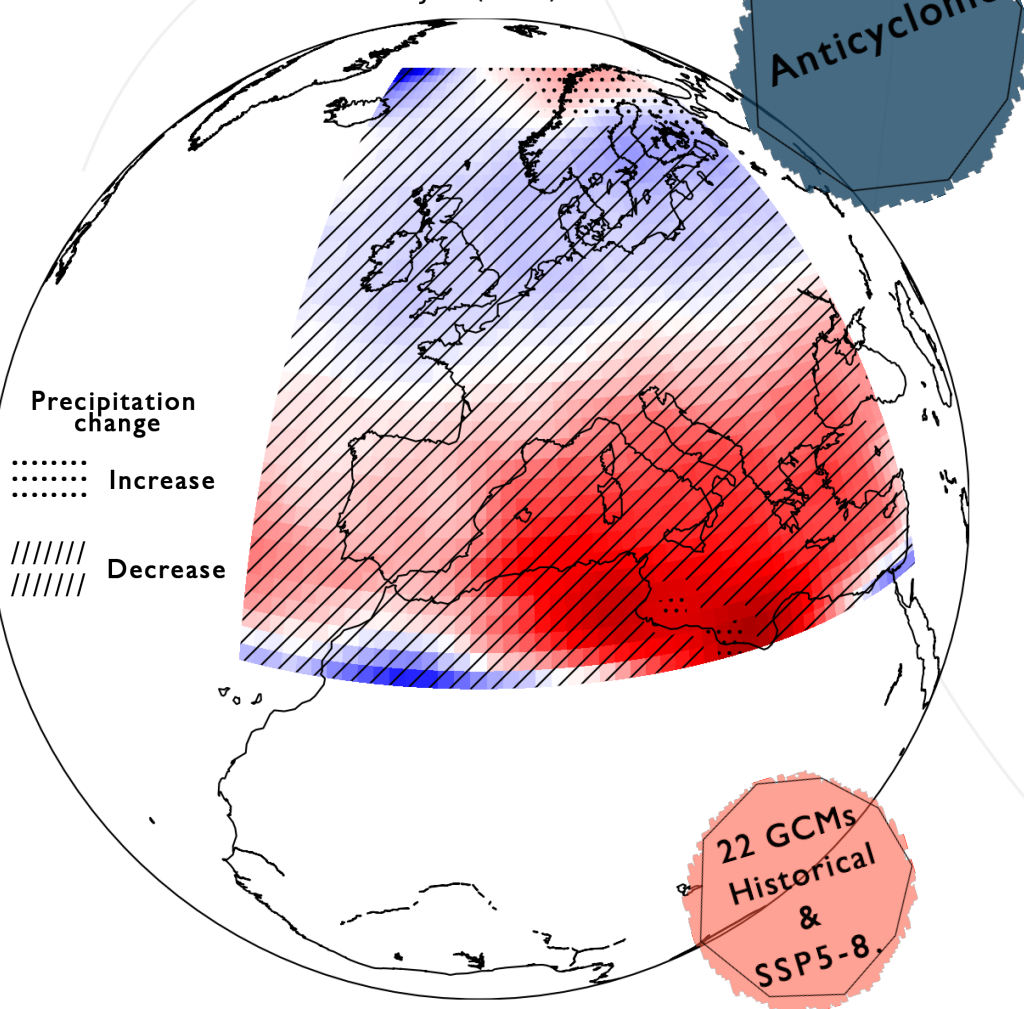
$\Delta PR < 0$  (Precipitation decrease)

- Strengthening of westerlies over Europe and weakening over the Mediterranean.

Strongly responsible for the rainfall increase over Western Europe during winter?

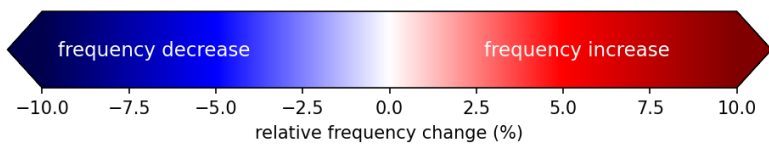
# Winter synoptic circulation changes

End of 21st century frequency changes  
DJF A(16%)

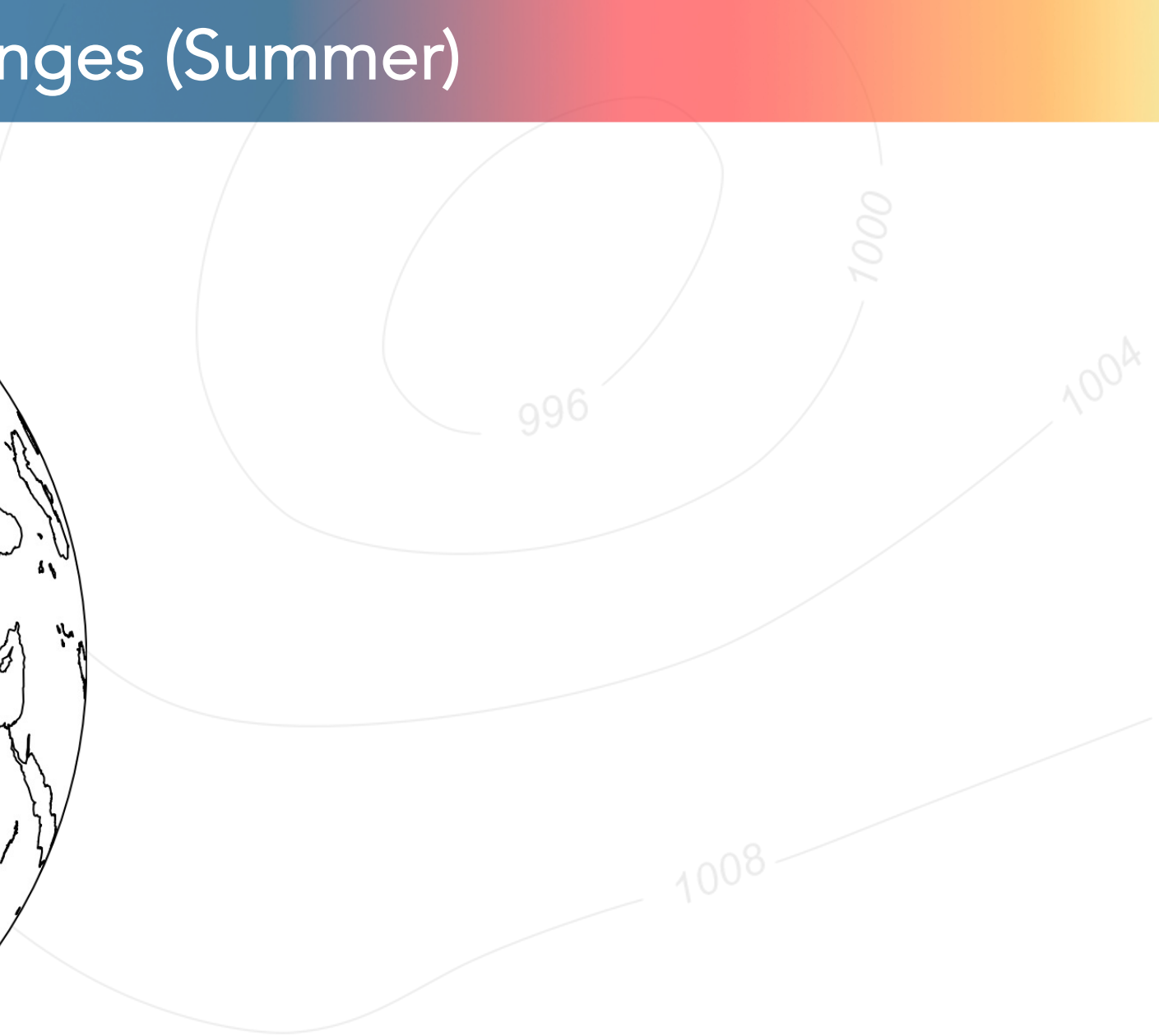


- Increasing Anticyclonic conditions over the Mediterranean.

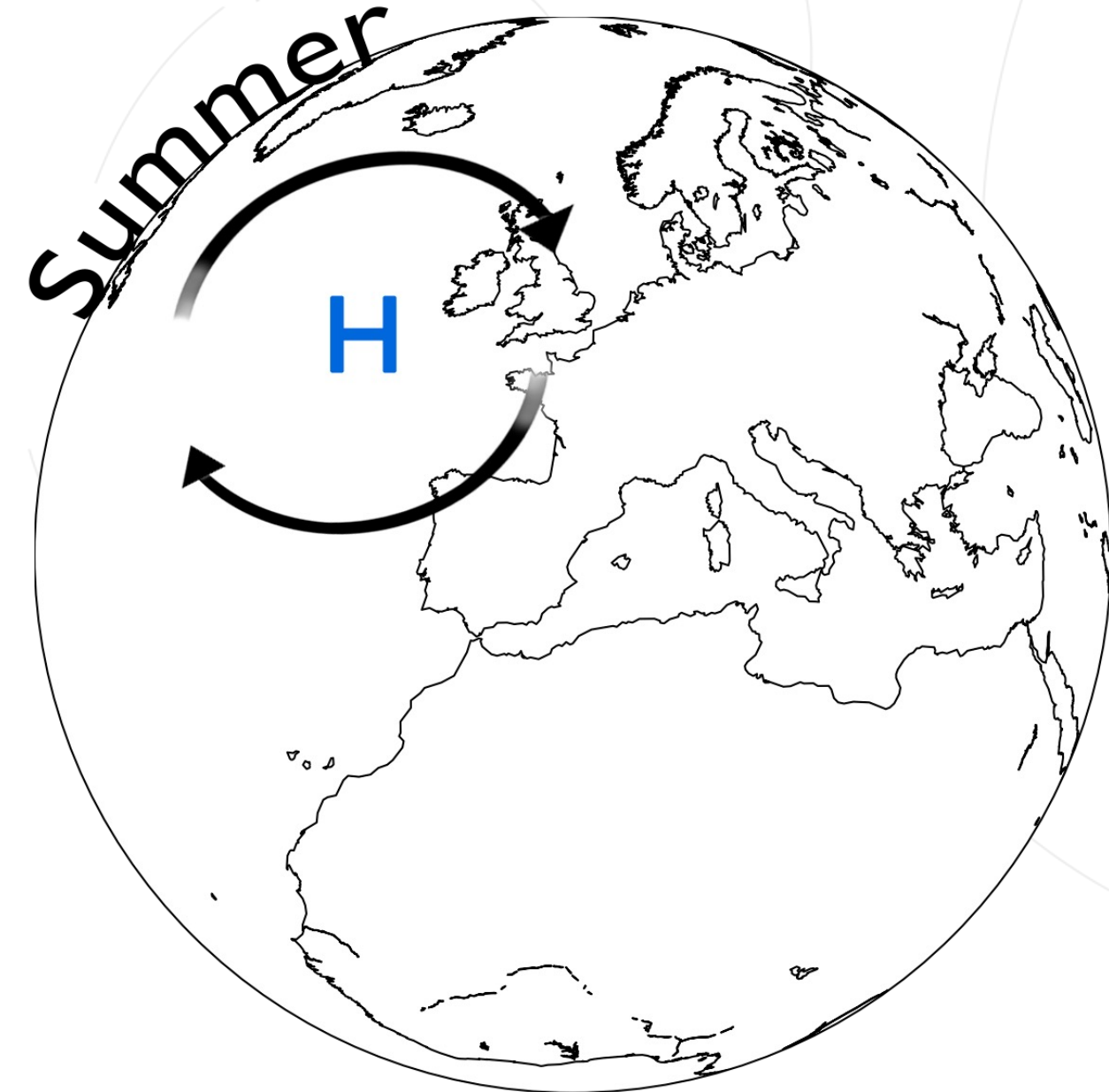
Driver for the projected drying over that region?



# A review of the projected changes (Summer)



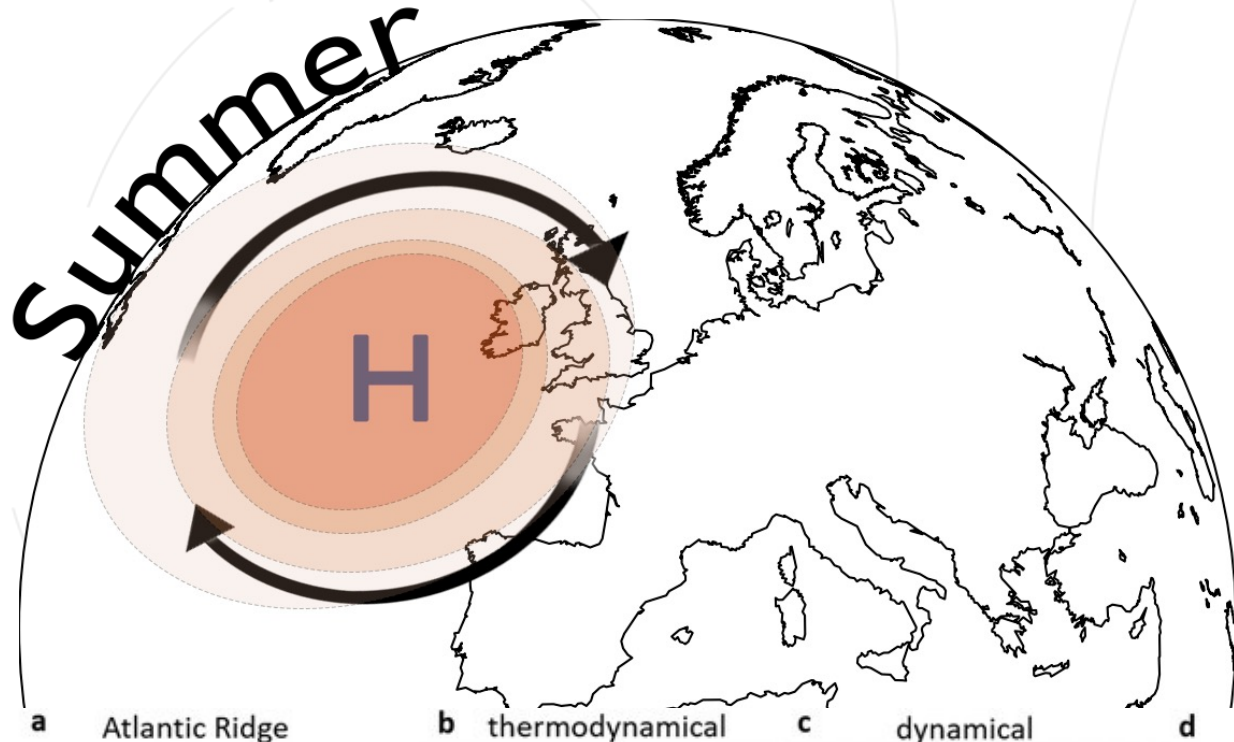
# A review of the projected changes (Summer)



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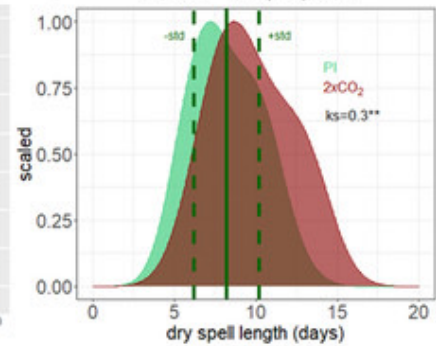
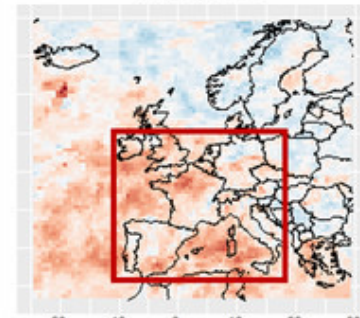
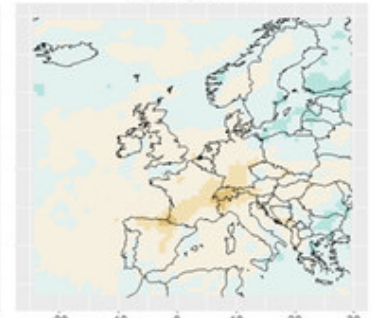
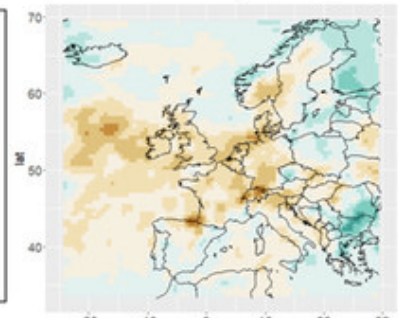
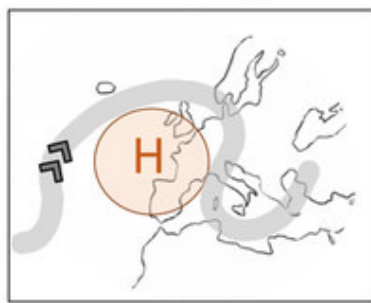
a Atlantic Ridge

b thermodynamical

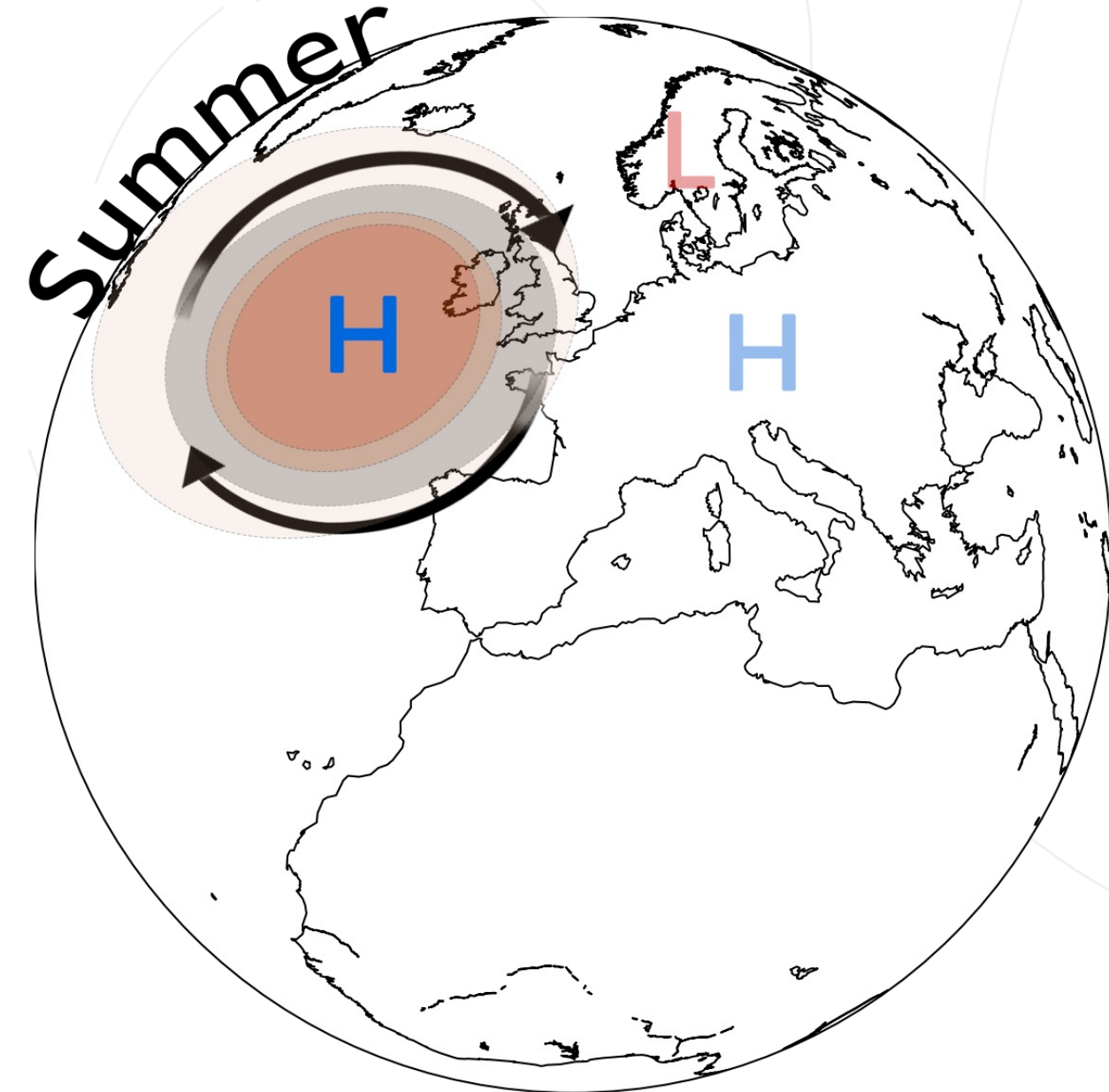
c dynamical

d dry spells

e PDFs - dry spells

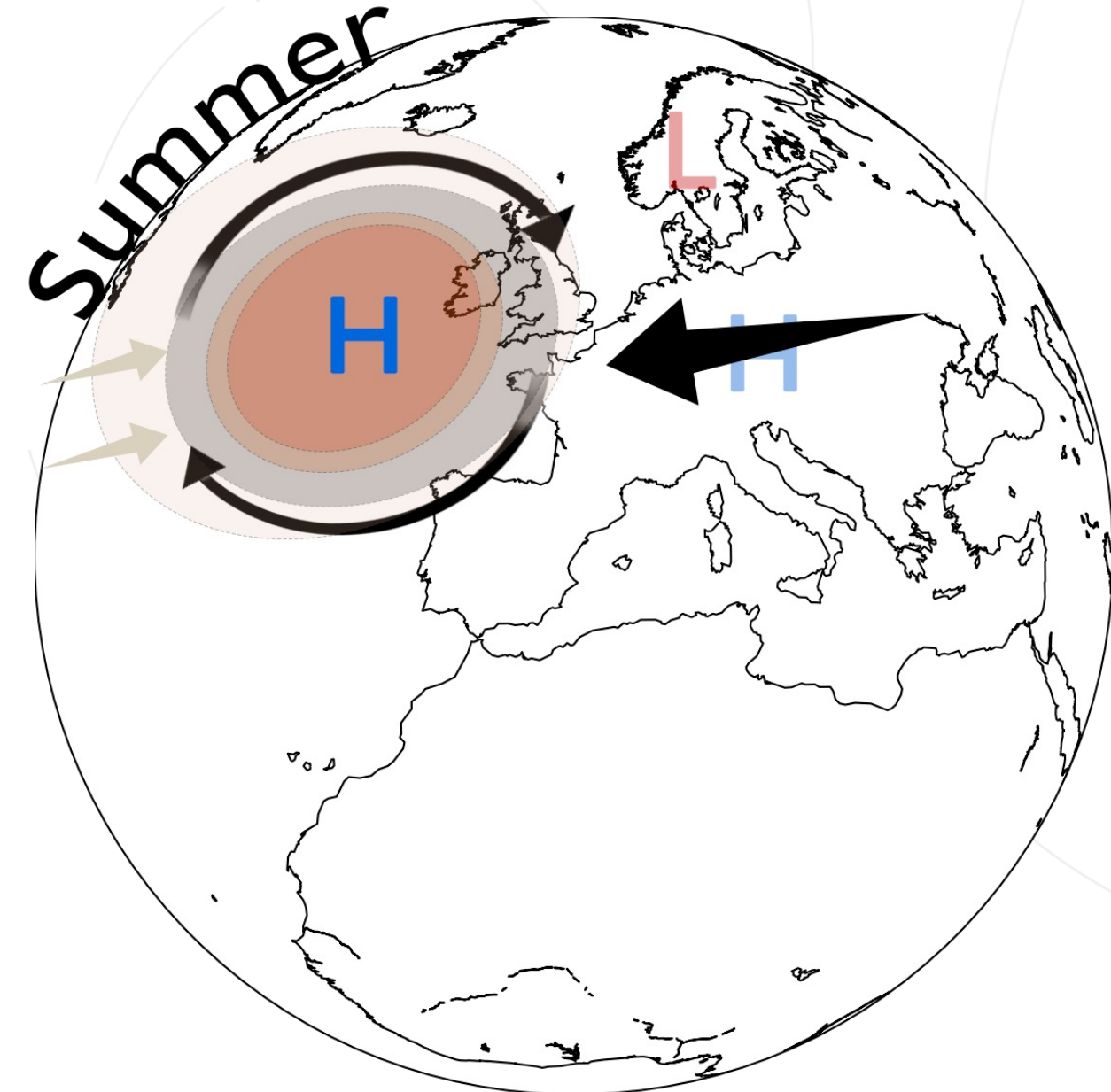


# A review of the projected changes (Summer)



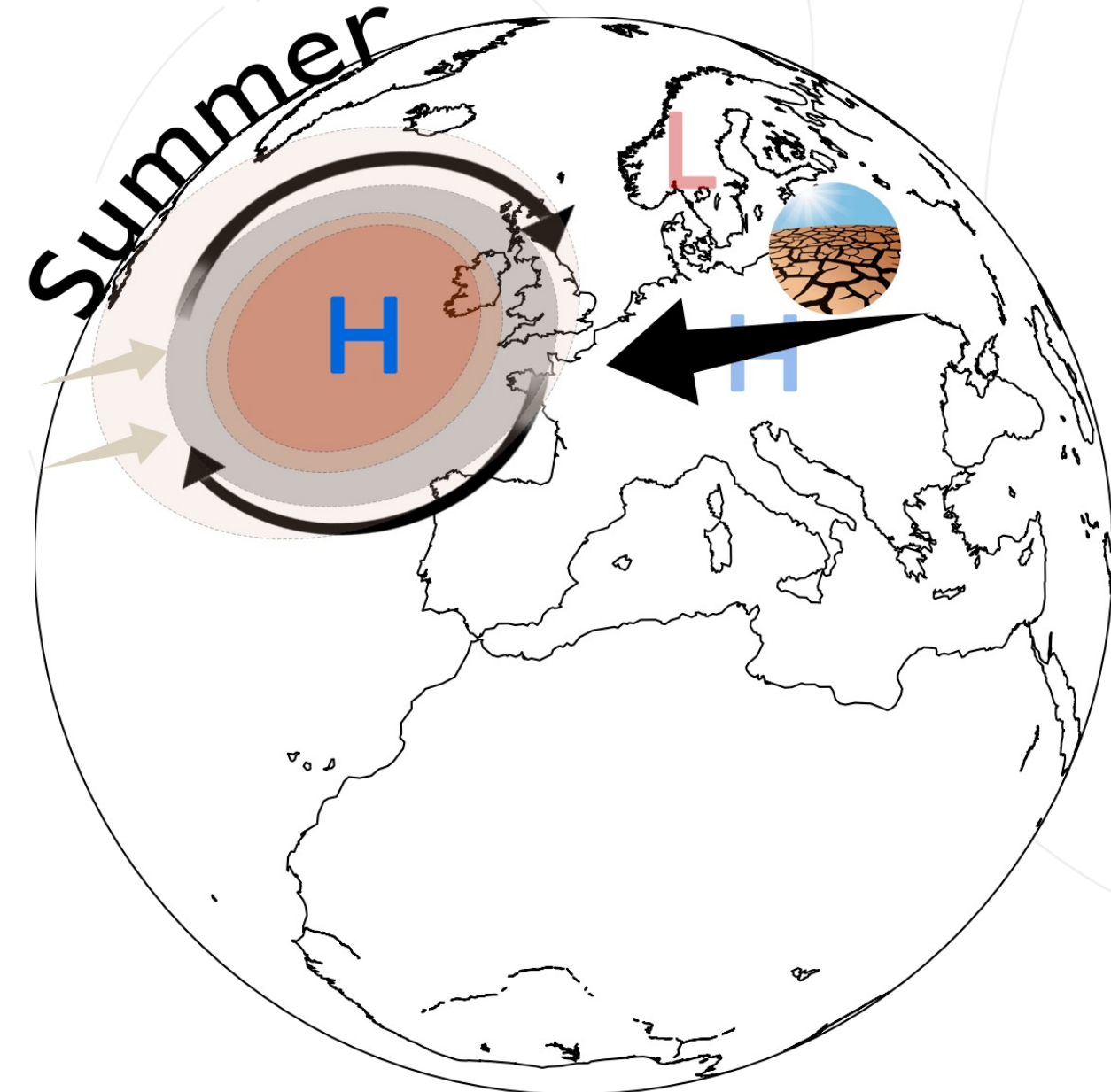
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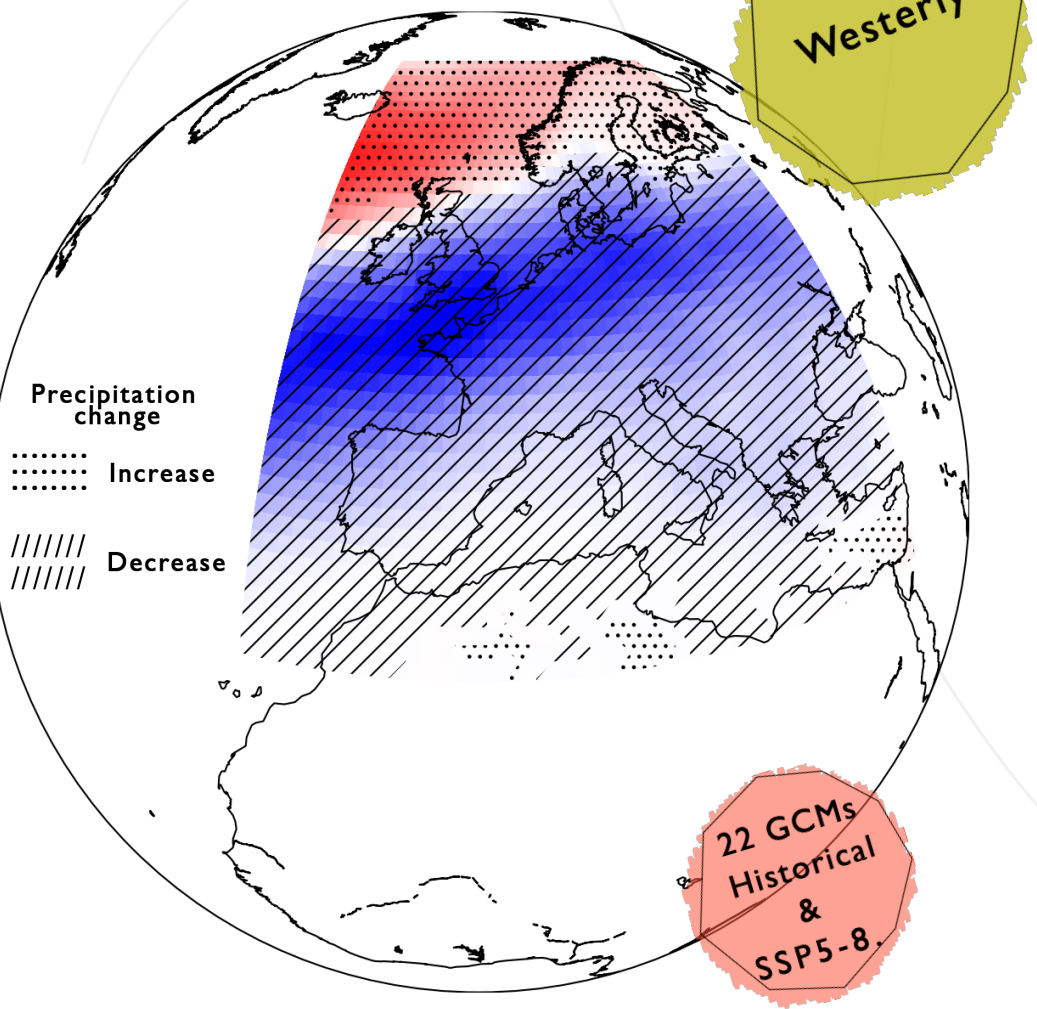


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- Decrease of Central-Eastern European high and Scandinavian Low (Røste and Landgren 2022)
- Weakening of westerlies and strengthening of easterlies over Central EU (Herrera-Lormendez et al 2021).
- More severe droughts in Central EU linked to more frequent E, SE and S types (Lhotka et al 2020, Řehoř et al 2020).



# Summer synoptic circulation changes

End of 21st century frequency changes  
JJA W(8%)

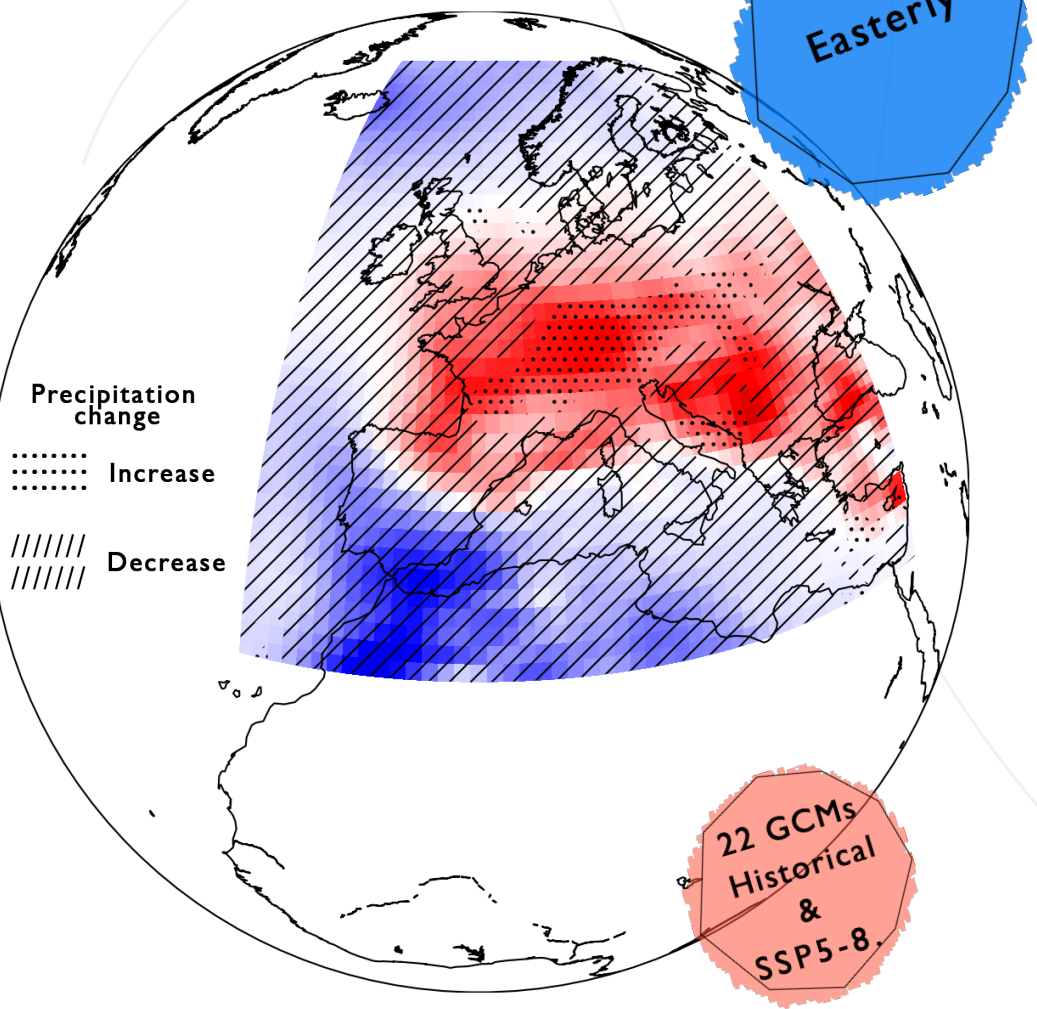


- Weakening of westerlies over Western Europe and strengthening in the North.

Driving the observed and projected drying over Central and Southern Europe?

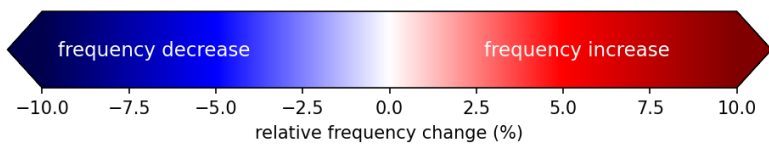
# Summer synoptic circulation changes

End of 21st century frequency changes  
JJA E(6%)



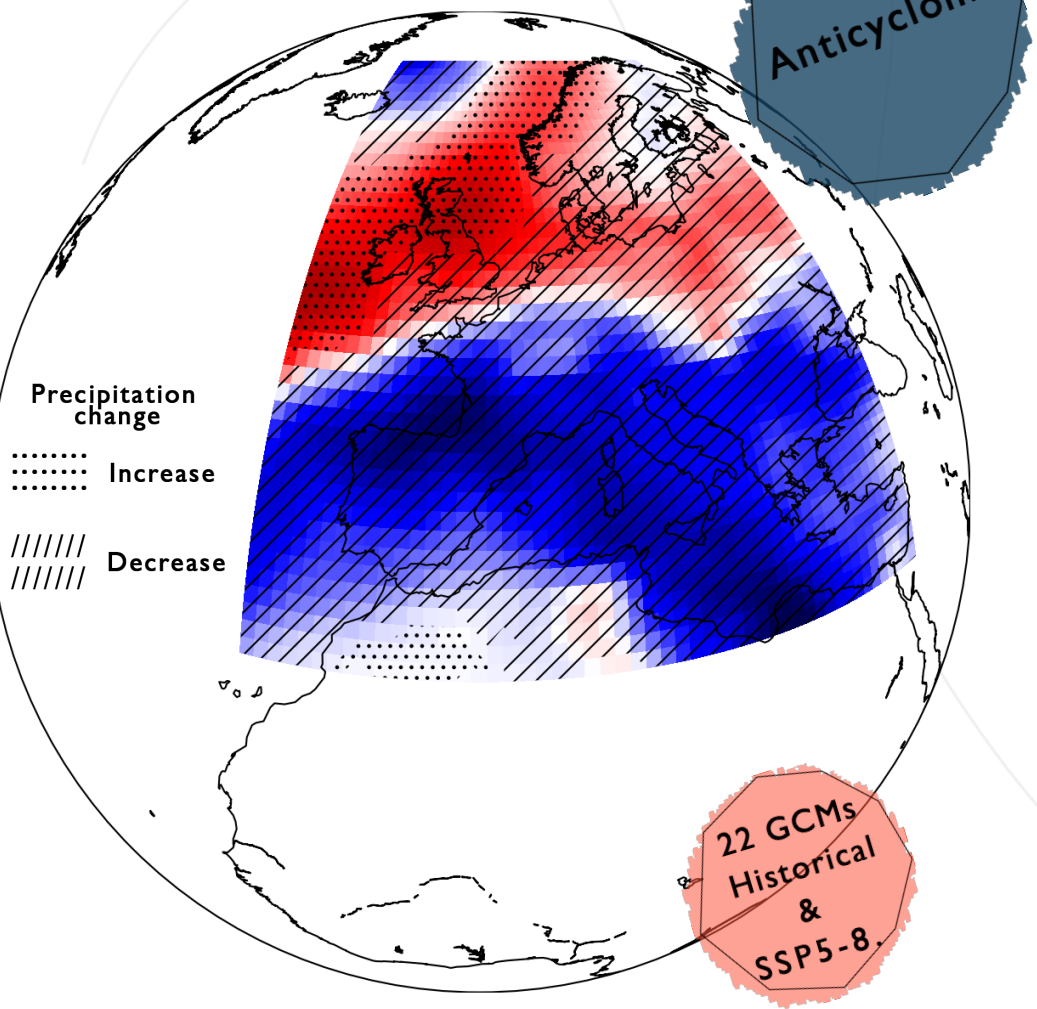
- Considerable strengthening of Easterly circulation over continental Europe.

Mixed influence on rainfall changes



# Summer synoptic circulation changes

End of 21st century frequency changes  
JJA A(15%)



- Increasing frequency over NW Europe and over the West of the UK.

Increase over the Atlantic linked to the projected increase in AR regime days?

# Challenges

*“... models project warmer and drier future summer conditions in Central Europe, but no consistent shift to a more persistent summer or winter circulation. Most of the frequency changes are small and either within the internal variability or inconsistent across models”*  
*([Huguenin et al 2020](#))*

*“While the latitudinal expansion of the tropics would induce both a poleward shift and reinforcement of the westerlies, Arctic changes might counterbalance this effect”*  
*([Cattiaux et al 2016](#))*

*“Intermodel spread in climate projections due to: Arctic amplification, upper-troposphere tropical amplification and the stratospheric vortex”*  
*([Oudar et al 2020](#)).*

Preprint available!

arXiv



**Projected changes in synoptic circulations over Europe and their implications for summer precipitation: A CMIP6 perspective**

*Pedro Herrera-Lormendez, Amal John, Hervé Douville and Jörg Matschullat*

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