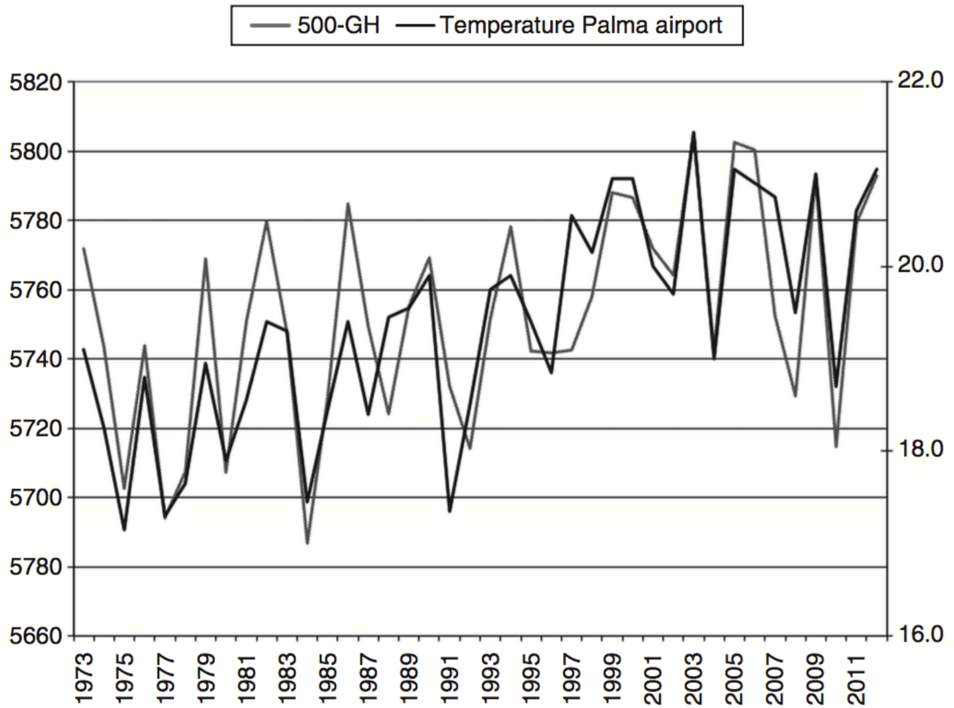
Attribution of an anomalous summerization of the springtime detected over the Western Mediterranean; from climate energy fluxes to modelling risks of renewable energy penetration under climate change scenarios

Universitat de les Illes Balears

Grup de Meteorologia

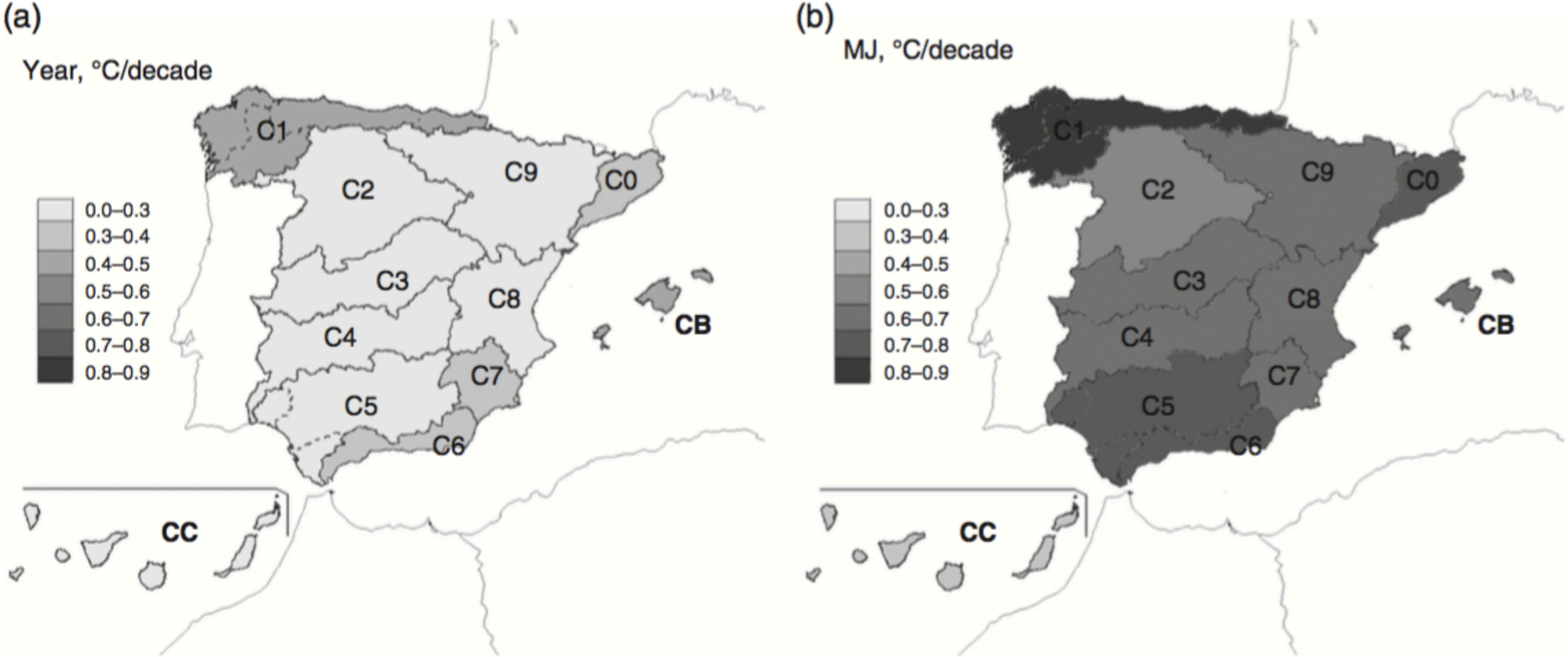
Climate energy fluxes

The origin of this study: a 2-m temperature tendency in Palma exceeding 0.7ºC/dec in May-June over the 1973-2012 period (Jansà et al. 2017)



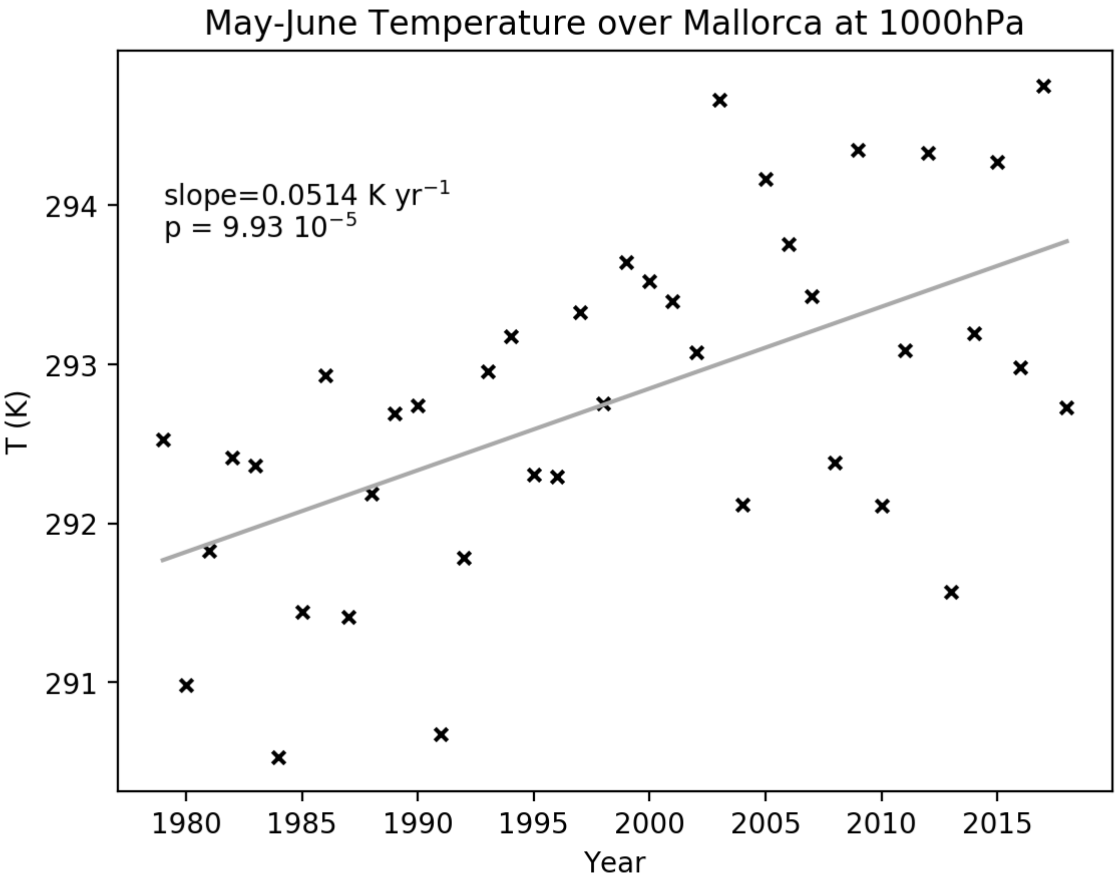
This tendency was highly correlated with 500 hPa geopotential height

This was found to be a regional tendency for 1973-2012, not just a local feature

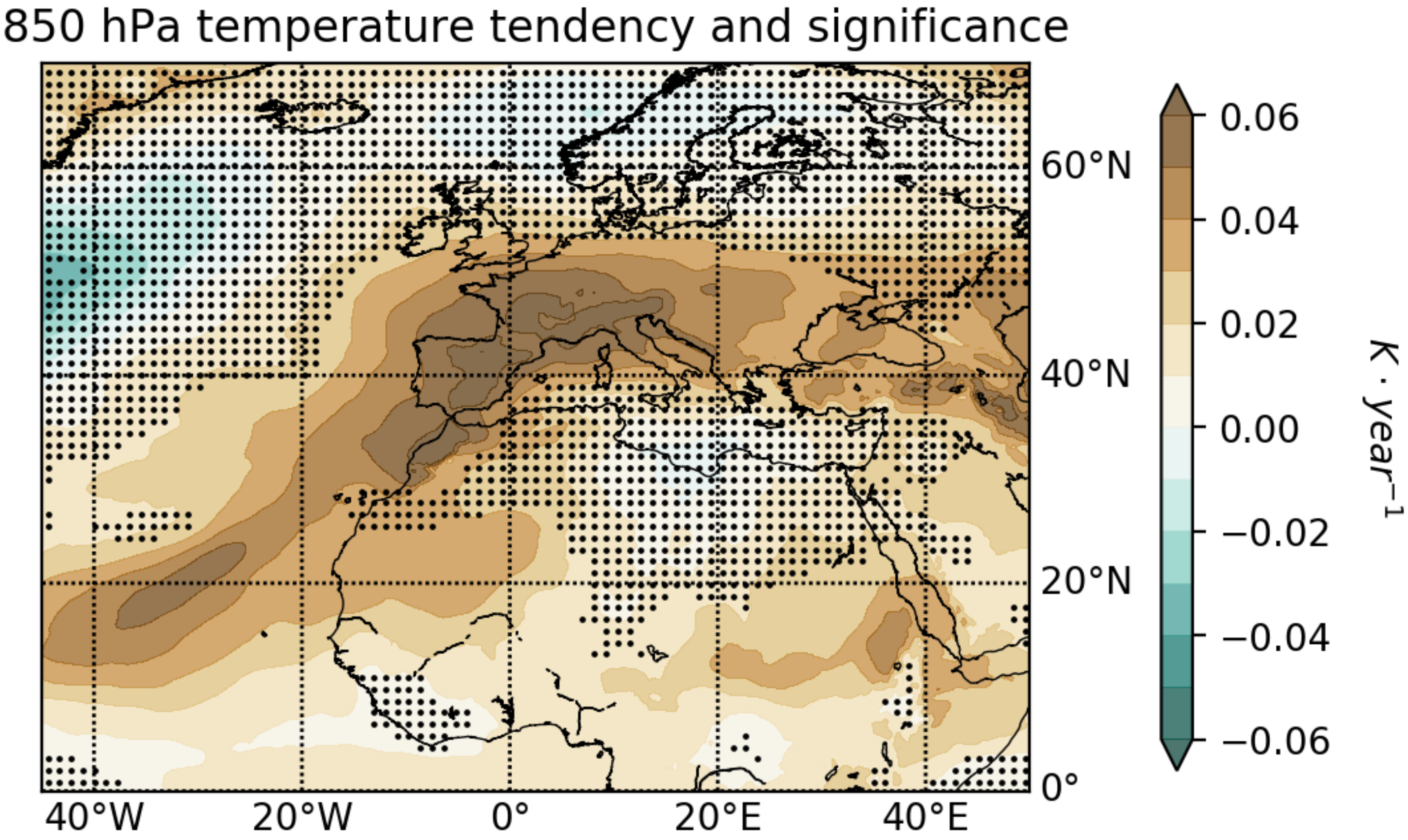


From Jansà et al., 2017

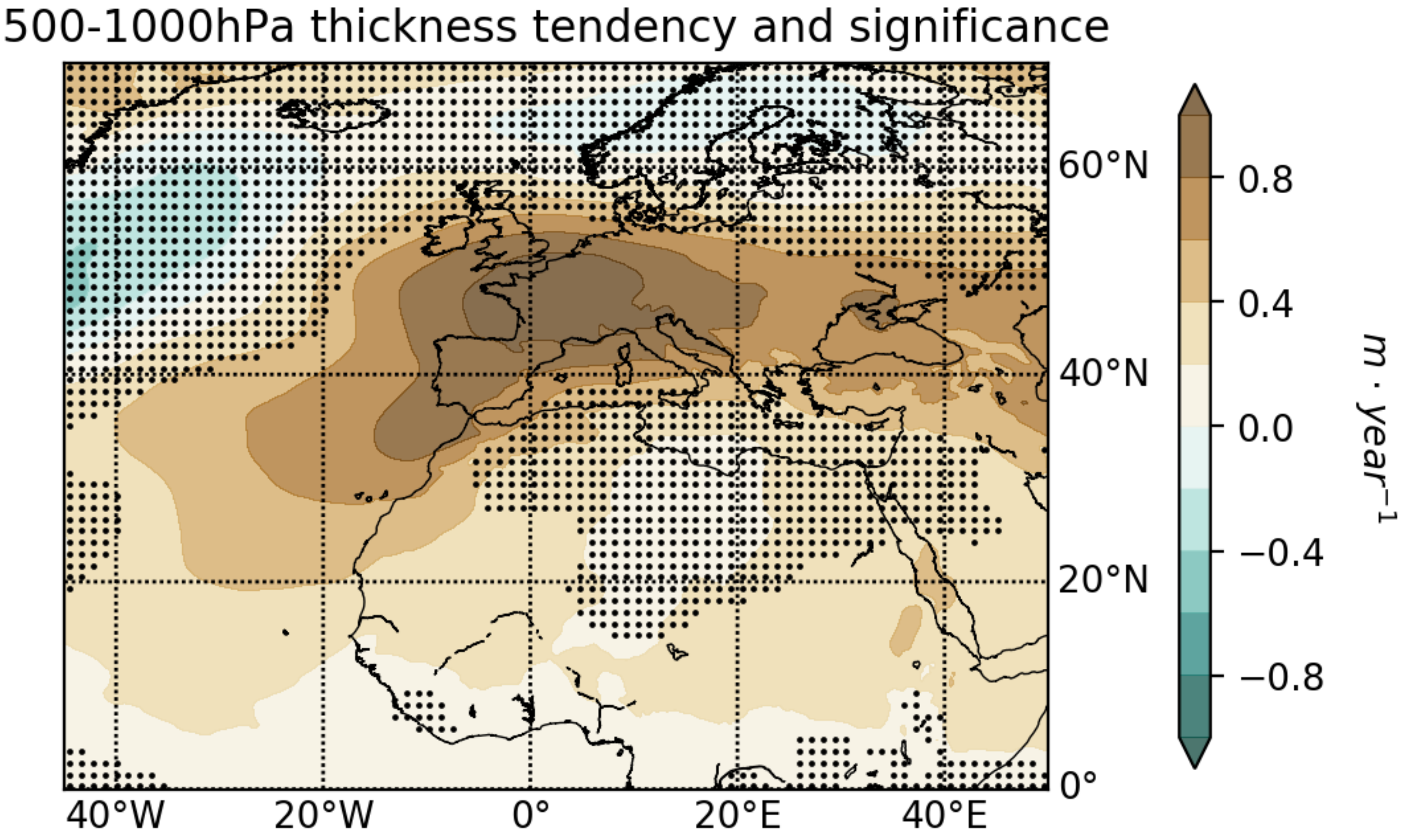
ERA5 tendency is coherent with observations



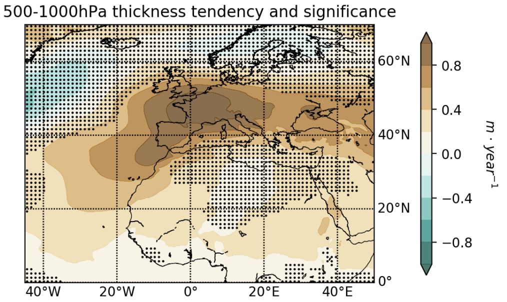
ERA5 shows also the shape of the regional temperature tendency

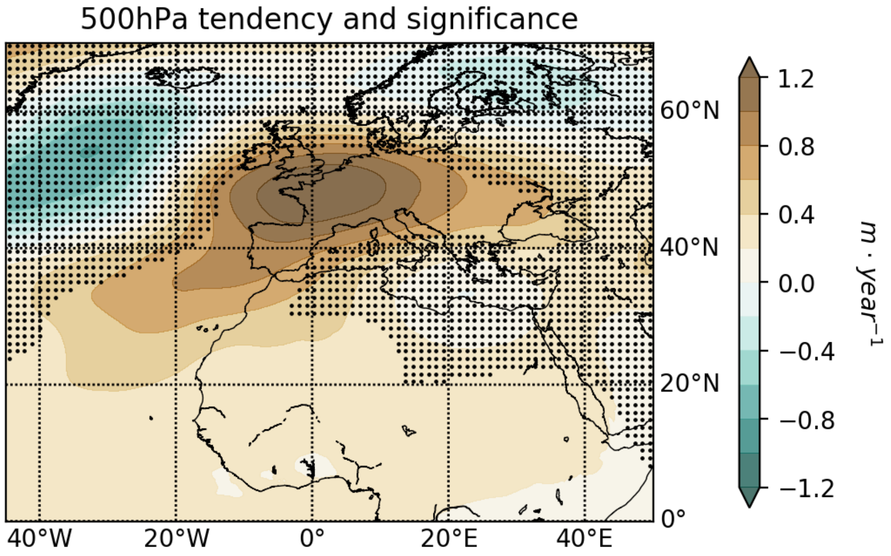


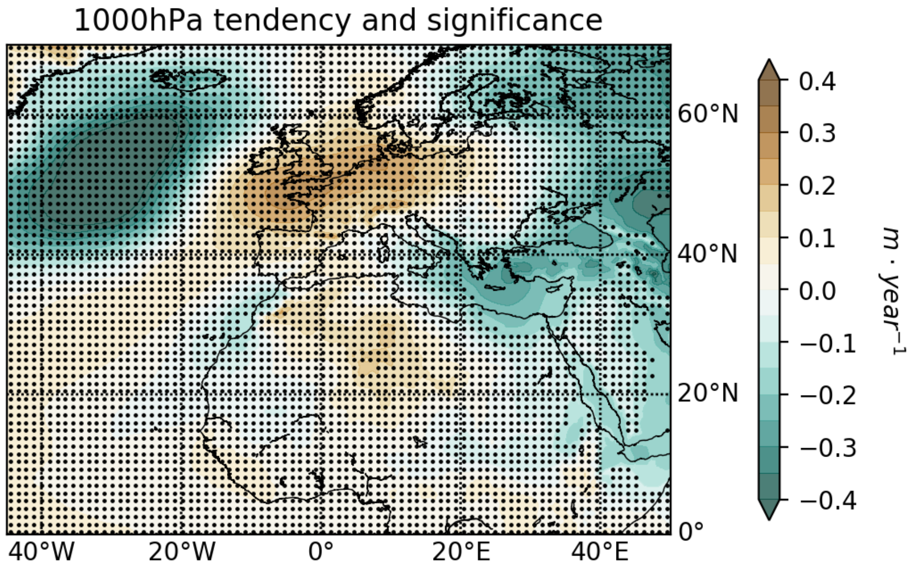
Thickness and geopotential height tendency and significance for May-June



Thickness and geopotential height tendency and significance for May-June

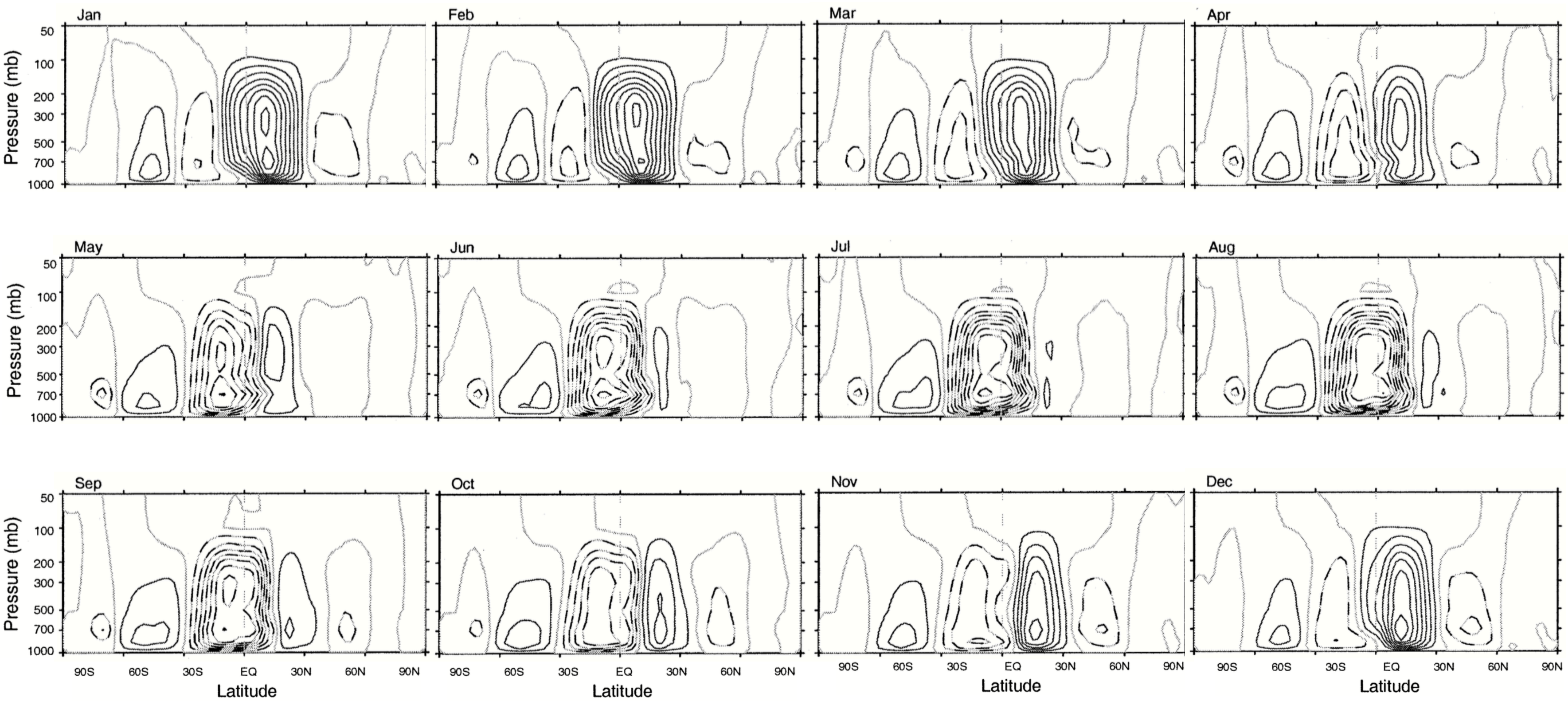






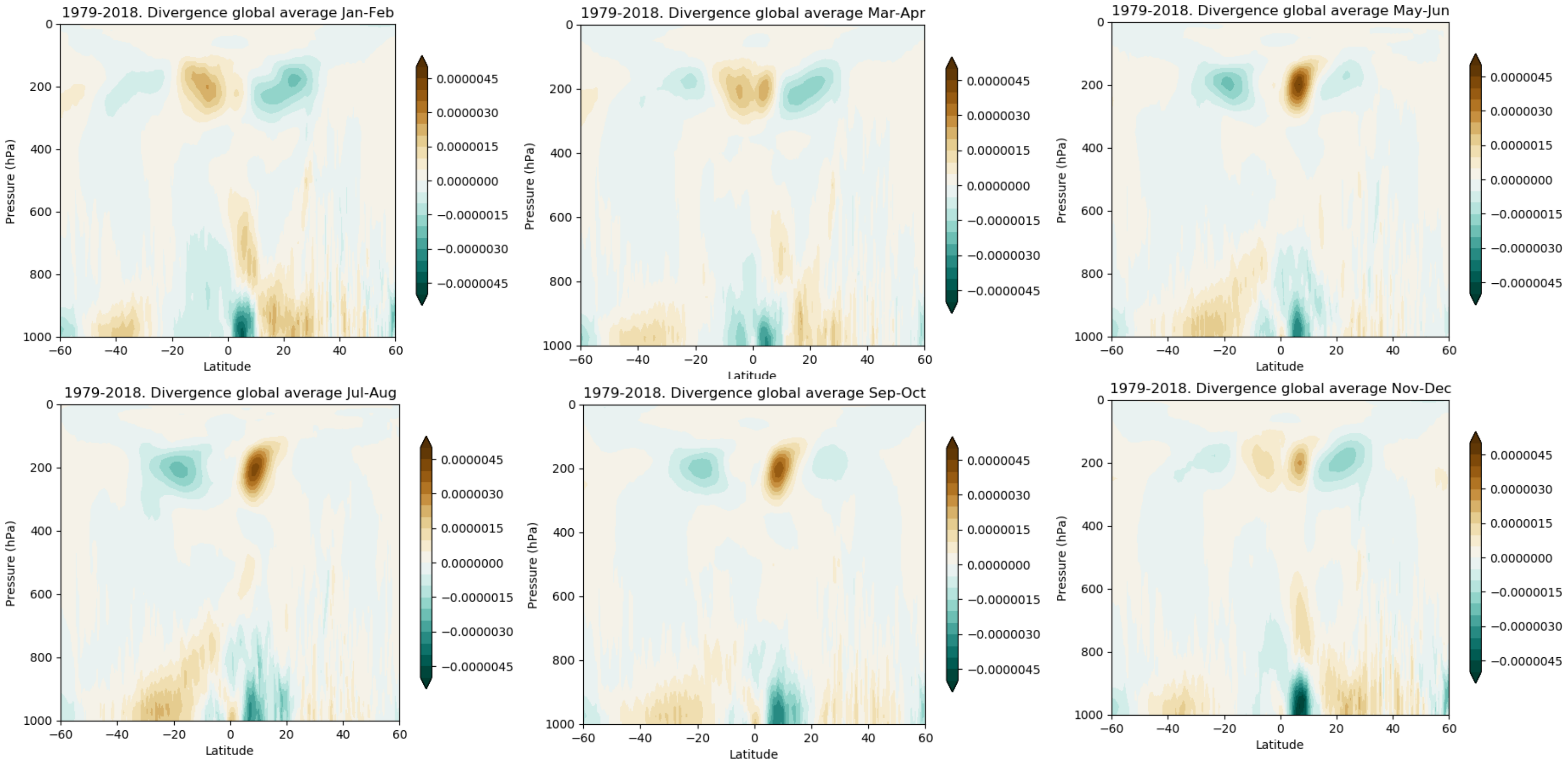
Attribution: the Hadley circulation
Divergence

The Hadley cell

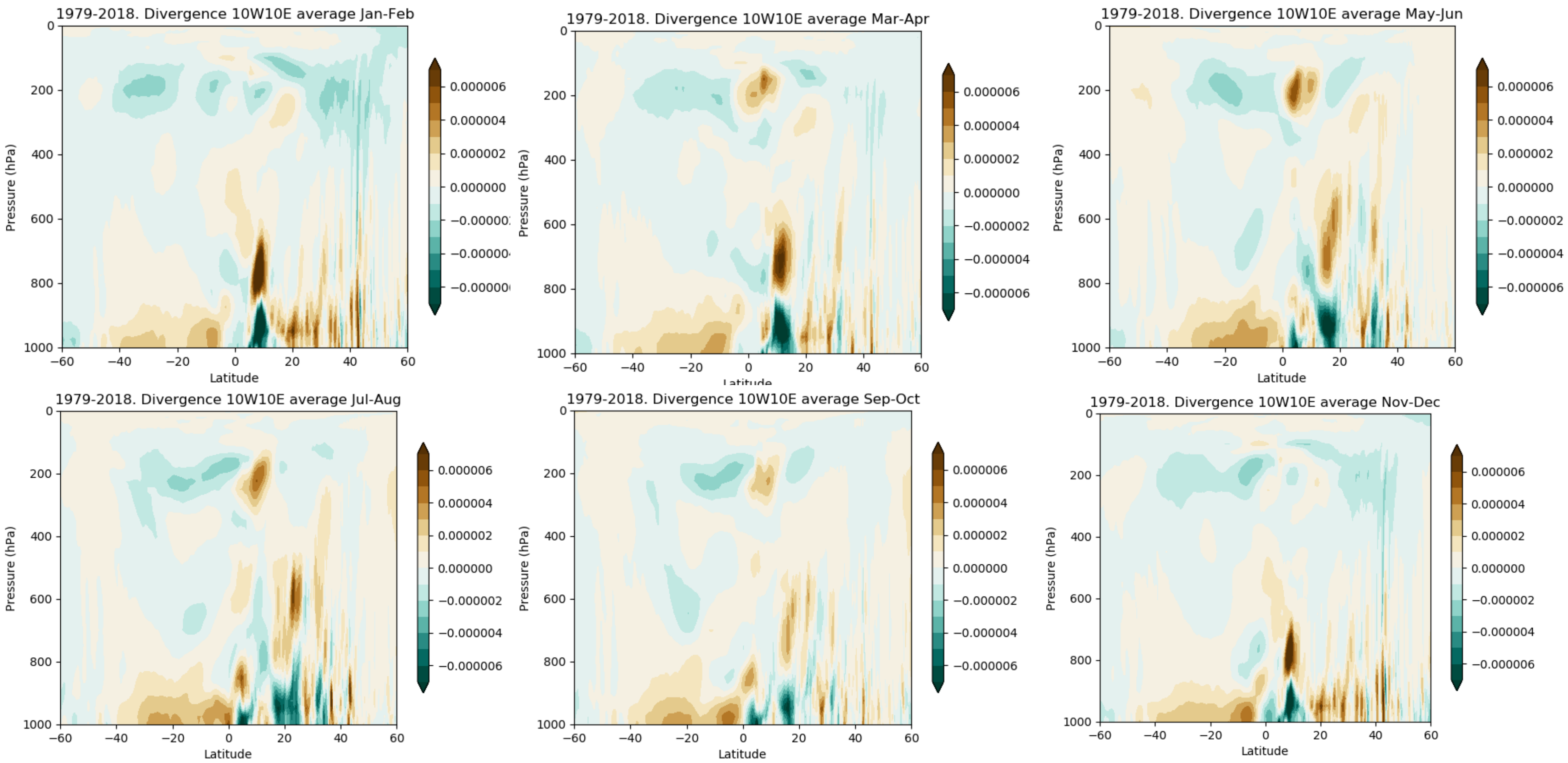


From Dima and Wallace, 2003

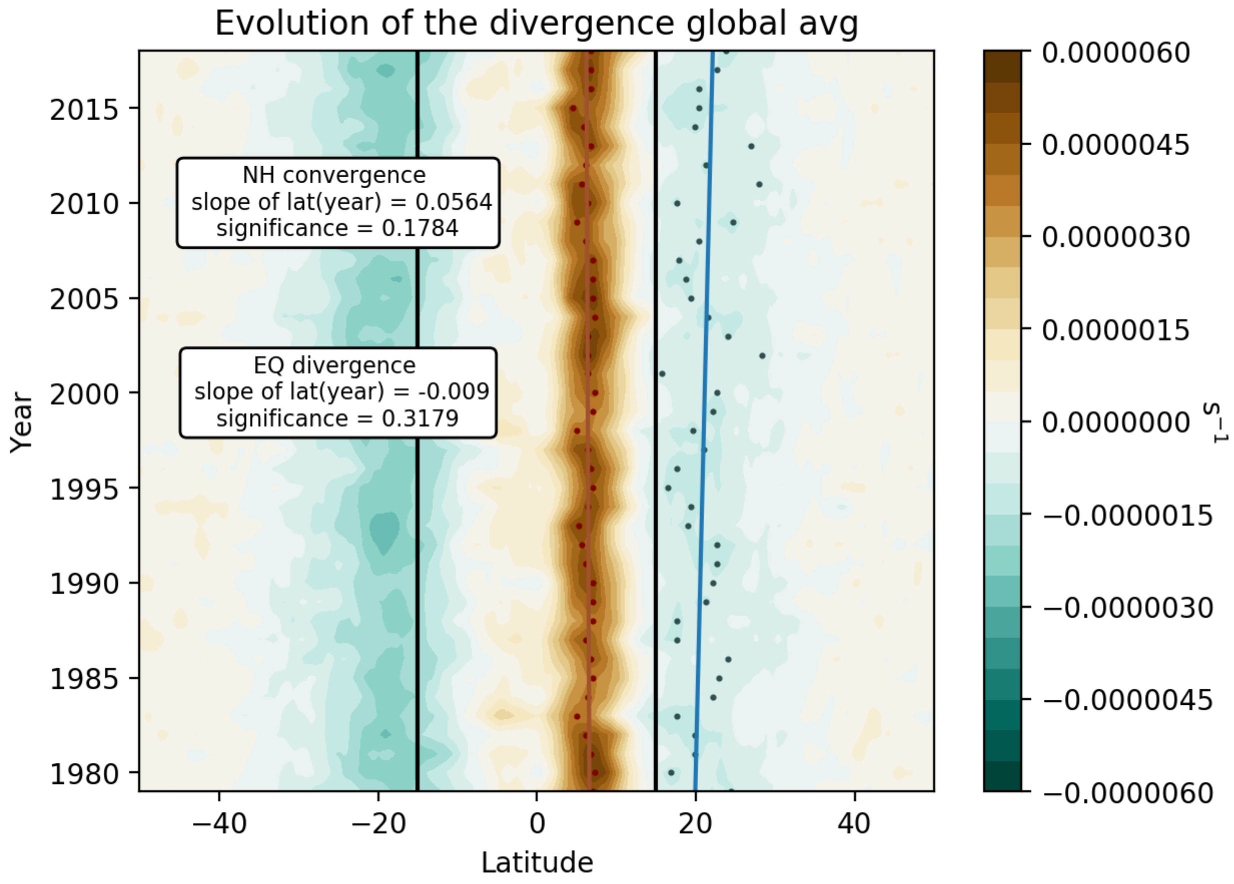
Divergence averaged for all longitudes and 1979-2018



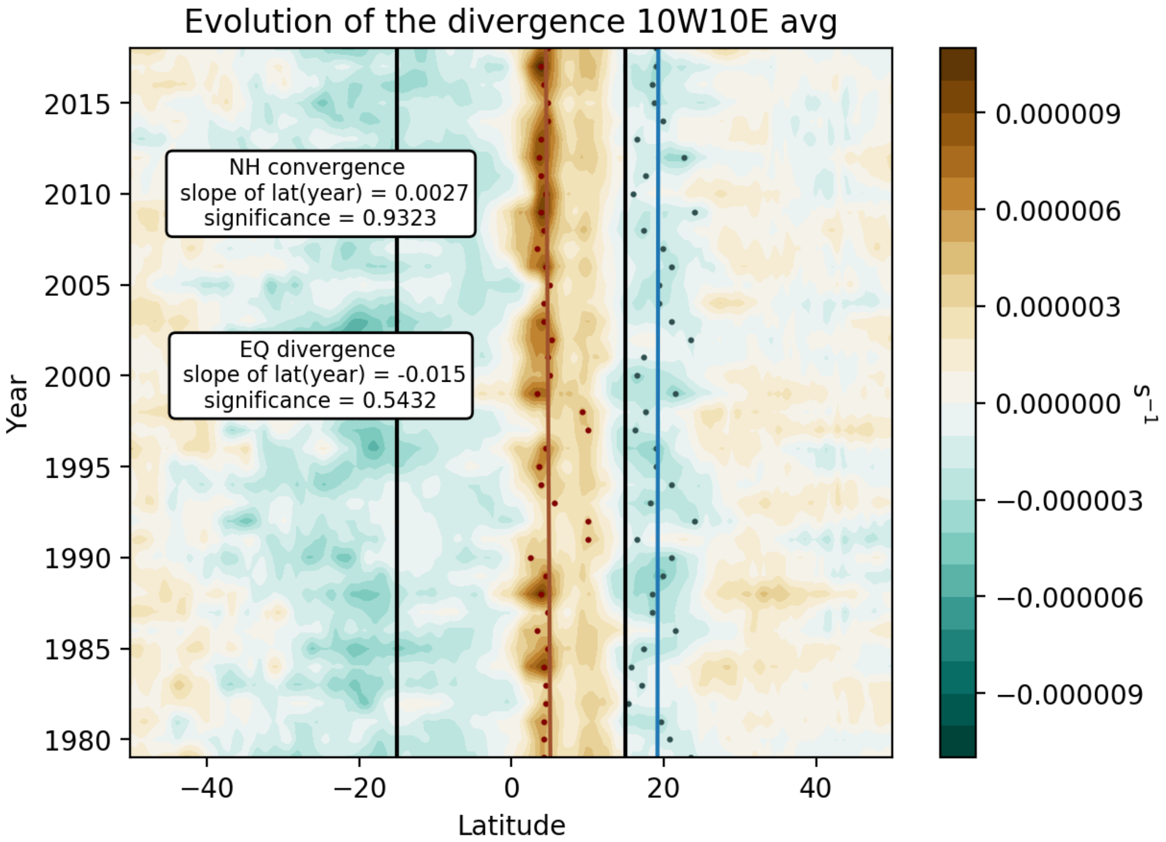
Divergence averaged for 1979-2018 between 10W and 10E



Hovmoller diagram for the global divergence

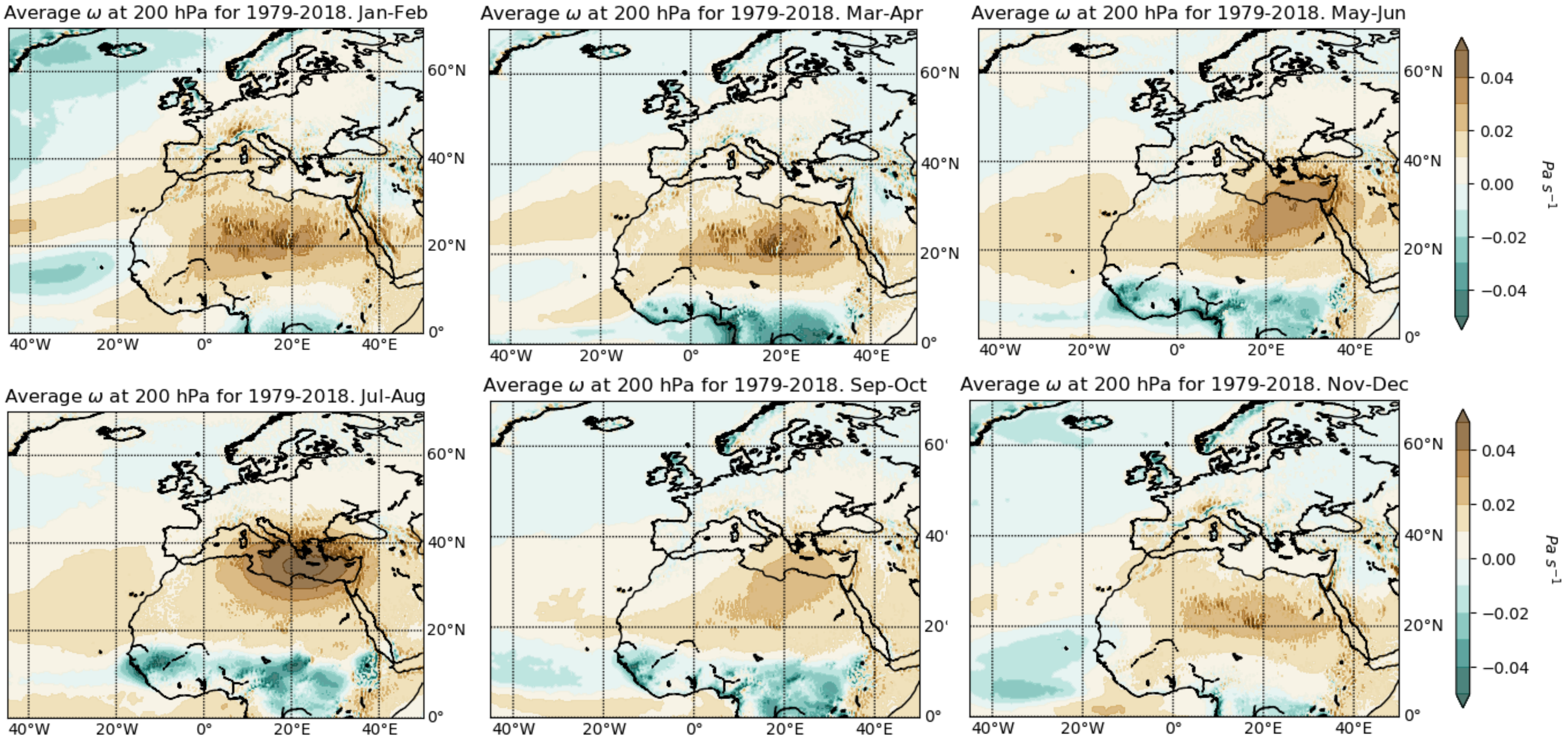


Hovmoller diagram for the 10W-10E divergence

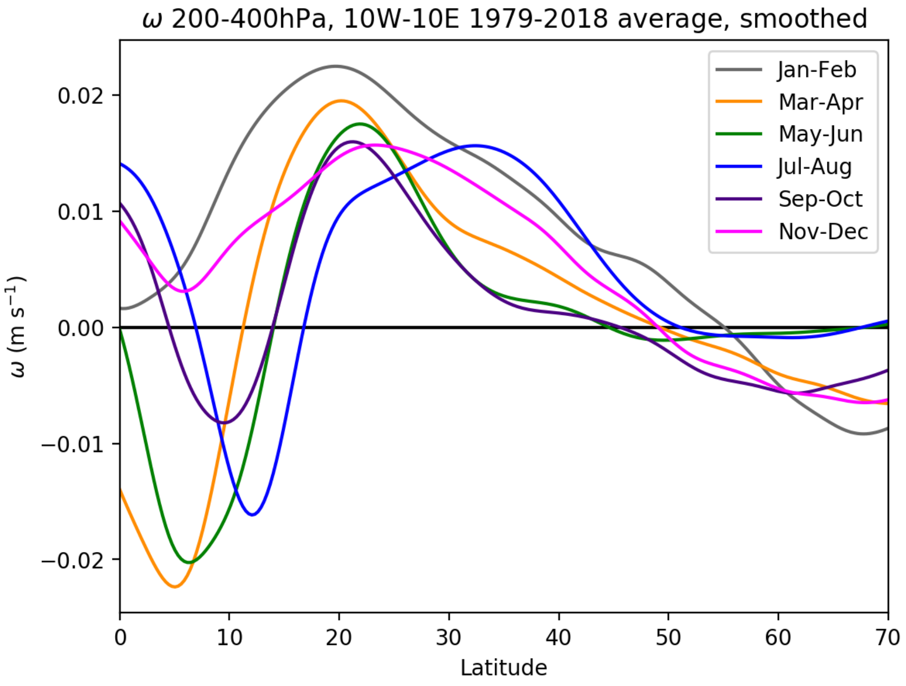


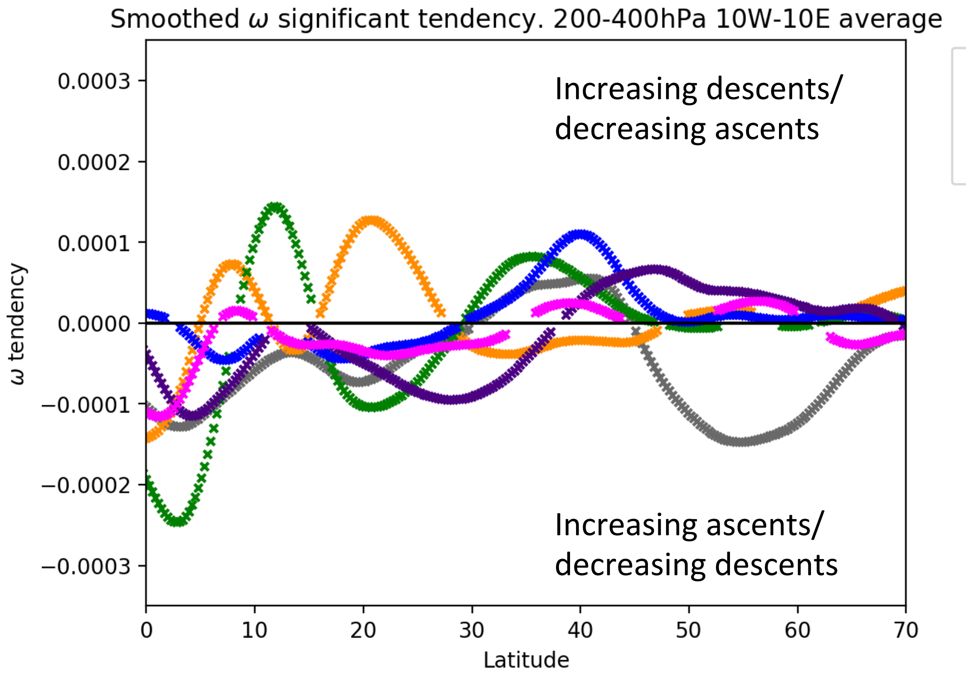
Attribution: the Hadley circulation
Vertical velocity

Yearly cycle of ω in 200-400 hPa averaged for 1979-2018

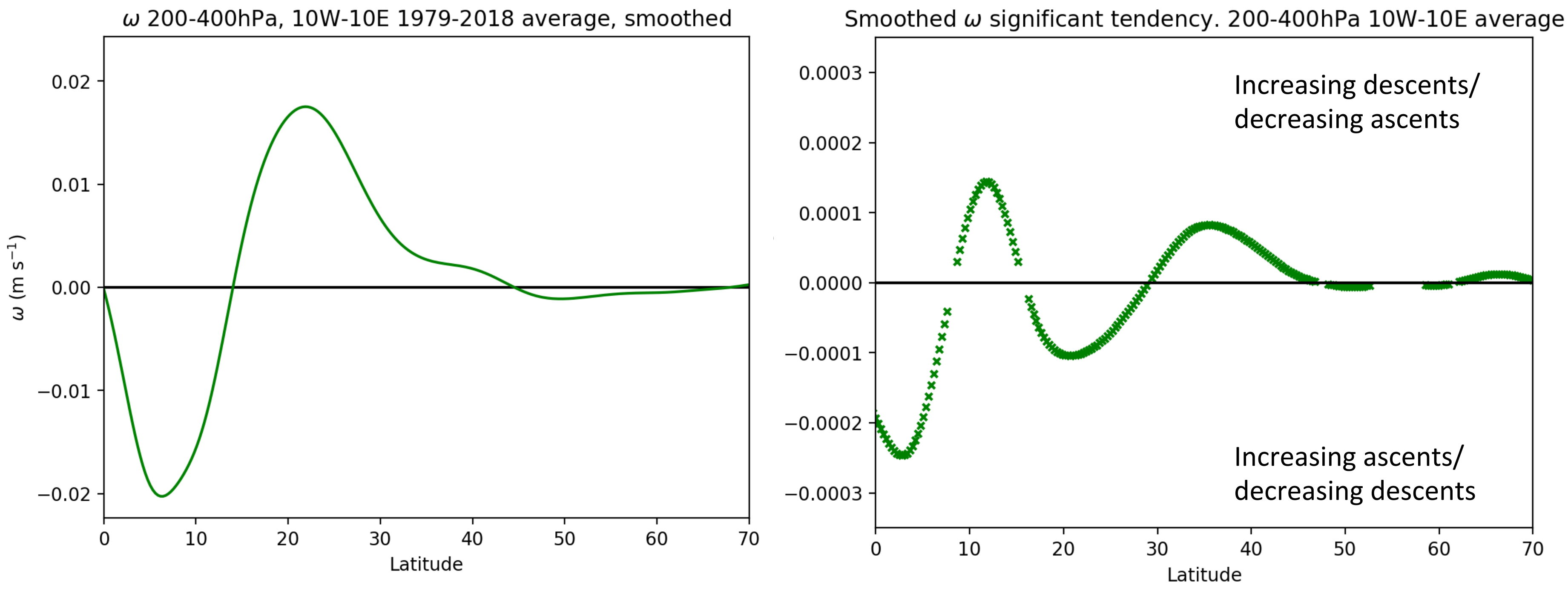


Zonally averaged ω over the Iberian region: yearly meridional variation and tendency at 200-400 hPa





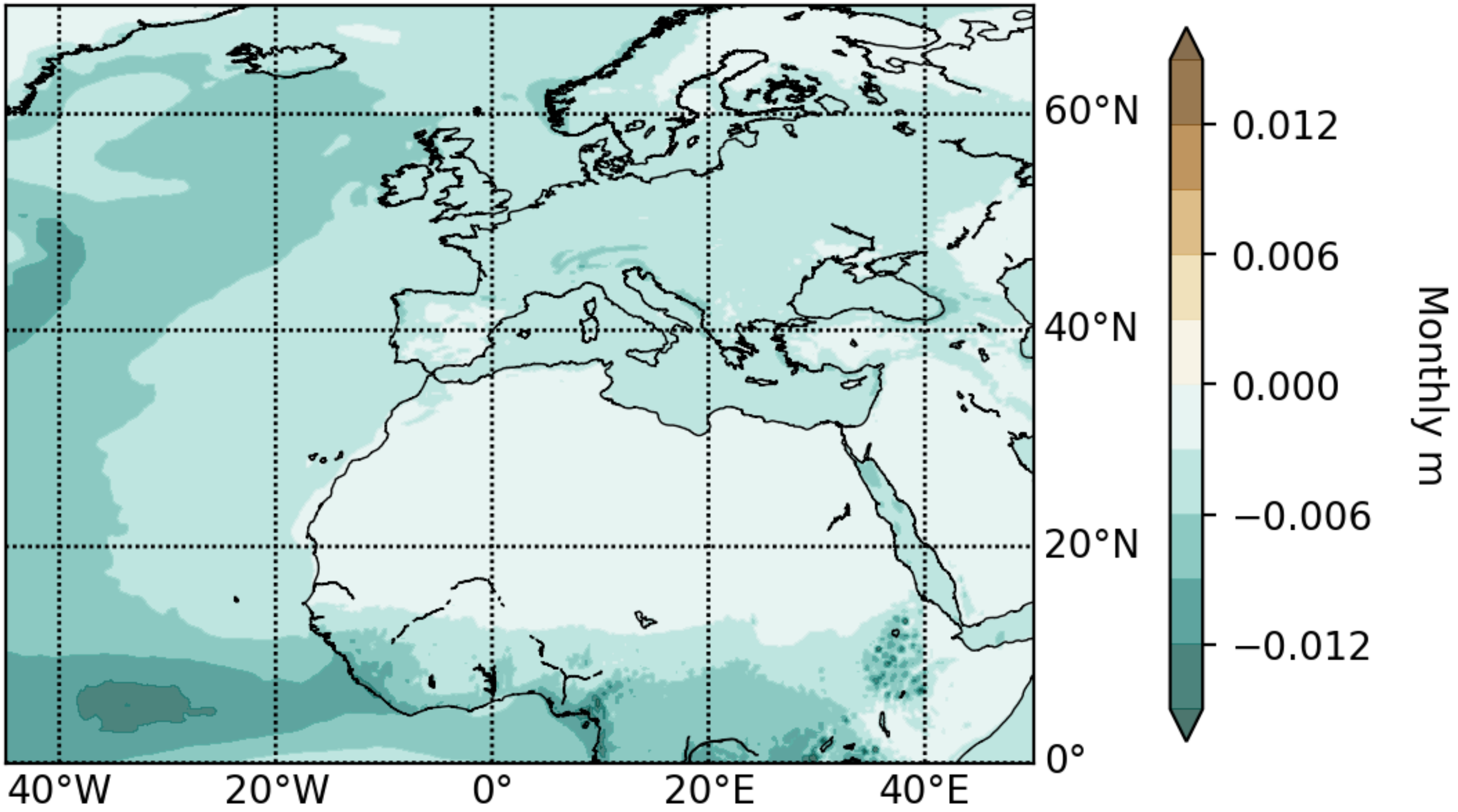
Zonally averaged ω over the Iberian region: yearly meridional variation and tendency at 200-400 hPa



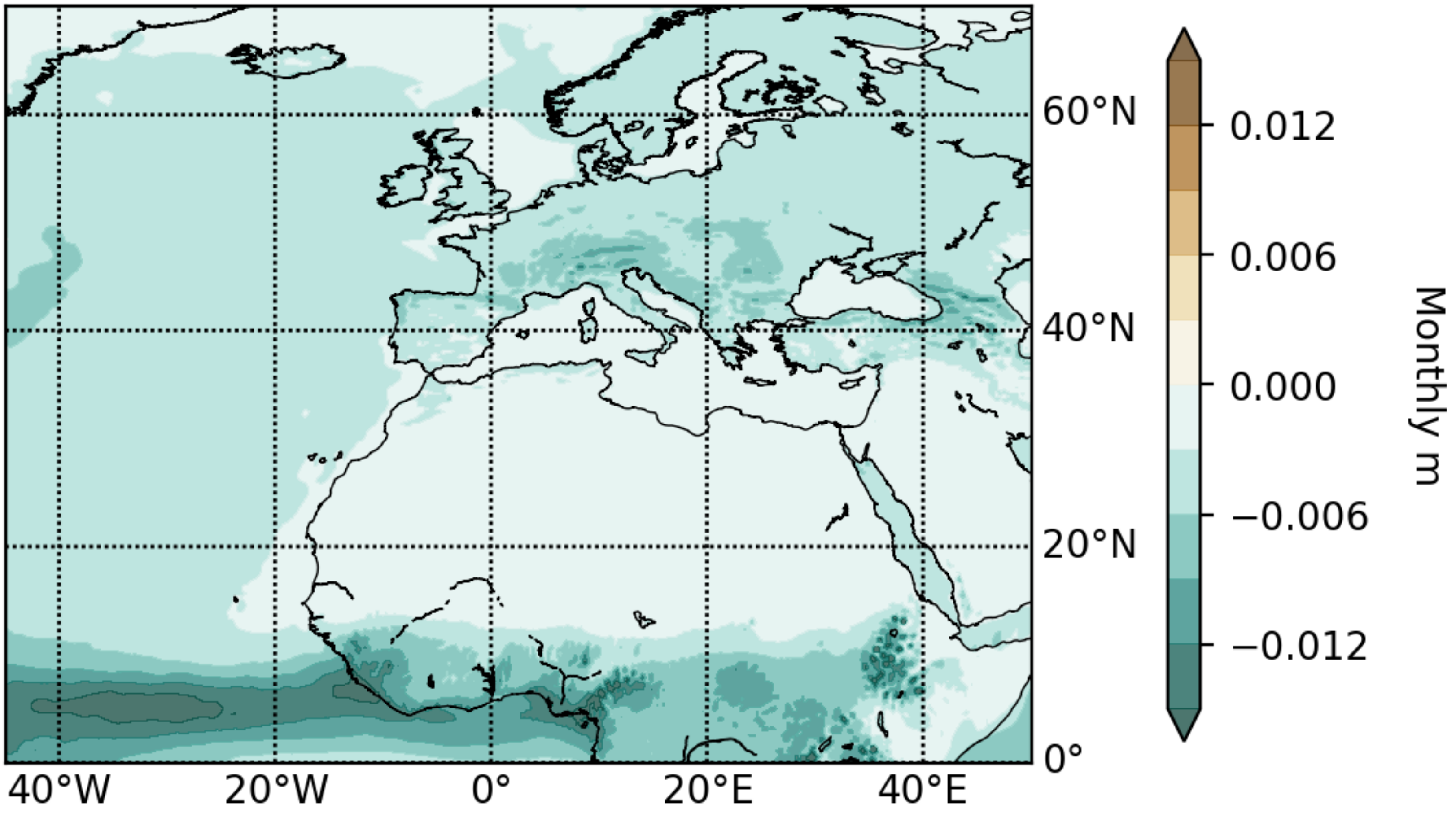
Attribution: the Hadley circulation
Evaporation - Precipitation

From Previdi and Liepert, 2007

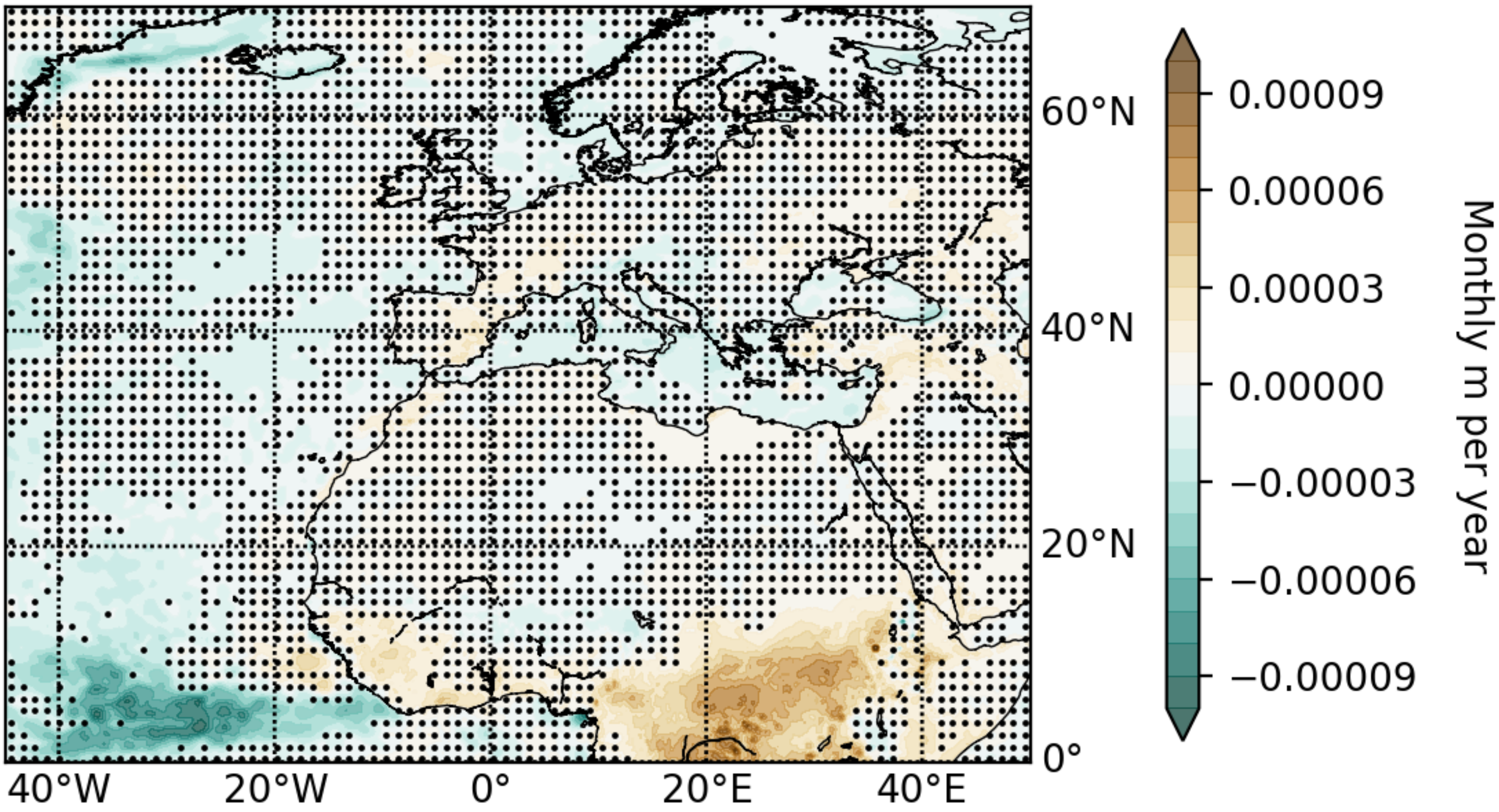
Evaporation − Precipitation yearly mean 1979 - 2018



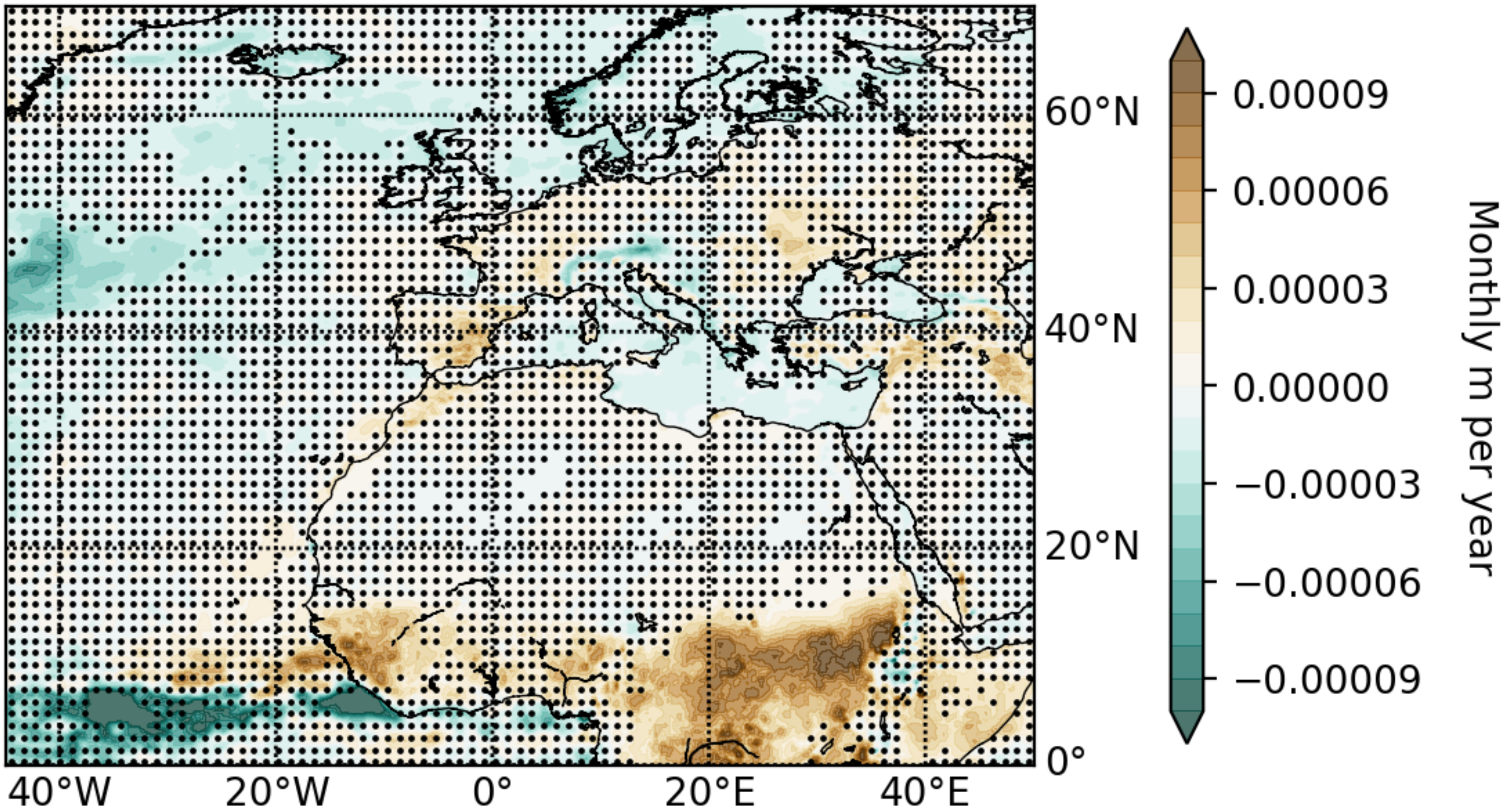
Evaporation − Precipitation May-June mean 1979 - 2018



Evaporation − Precipitation yearly tendency and significance



Evaporation − Precipitation May-June tendency and significance



Attribution: the Hadley circulation
Jets

Definition of the jet stream

$$WS_{i,j} = \frac{\sum_{k=400hPa}^{k=100hPa} m_k \times \sqrt{u_{i,j,k}^2 + v_{i,j,k}^2}}{\sum_{k=400hPa}^{k=100hPa} m_k}$$

← Mass-weighted average wind speed between 400 and 100 hPa

Mass-flux weighted pressure. Average pressure of flows near tropopause, average altitude of these flows →

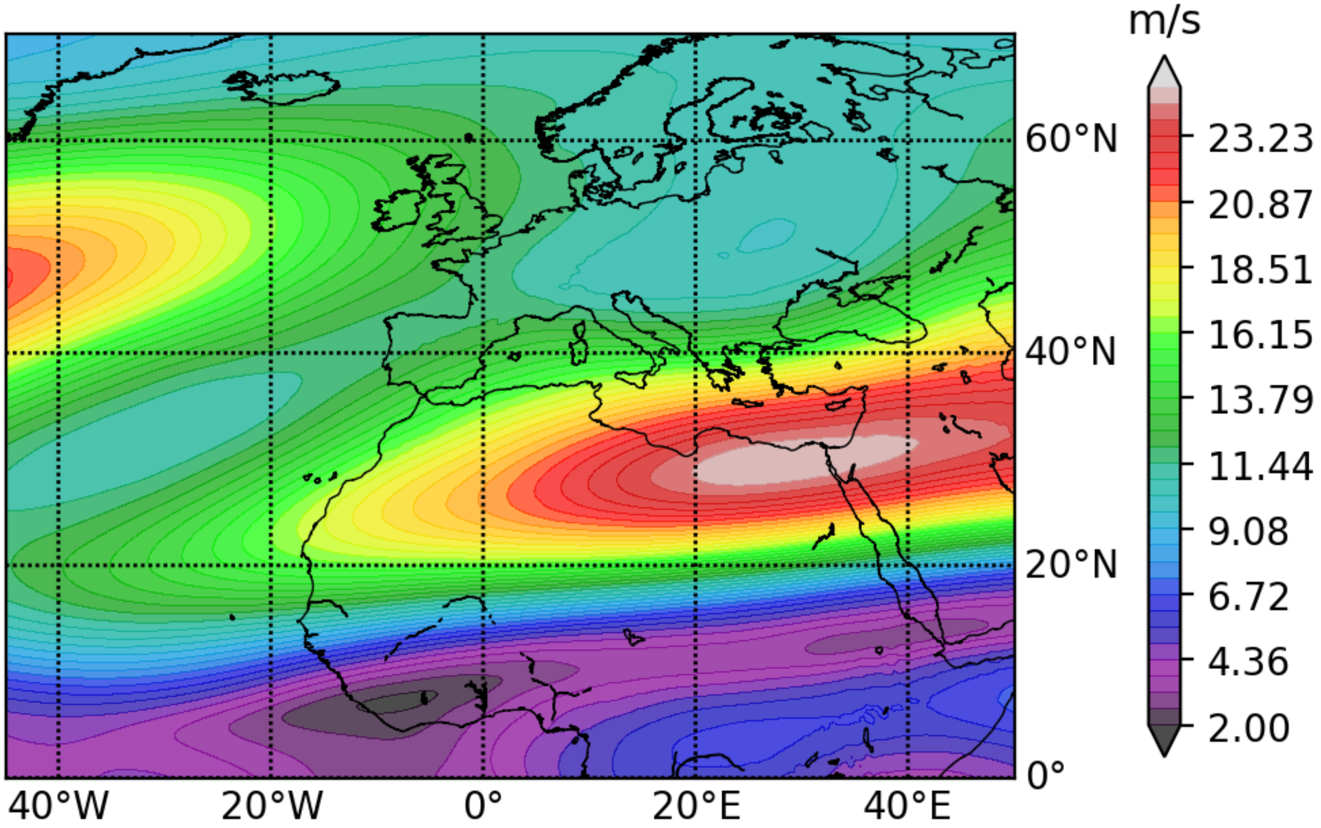
$$P_{i,j} = \frac{\sum_{k=400hPa}^{k=100hPa} \left(m_k \times \sqrt{u_{i,j,k}^2 + v_{i,j,k}^2} \right) \times p_k}{\sum_{k=400hPa}^{k=100hPa} m_k \times \sqrt{u_{i,j,k}^2 + v_{i,j,k}^2}}$$

$$L_i^{NH} = \frac{\sum_{j=15N}^{j=70N} \left[\sum_{k=400hPa}^{k=100hPa} \left(m_k \times \sqrt{u_{i,j,k}^2 + v_{i,j,k}^2} \right) \right] \times \phi_{i,j}}{\sum_{j=15N}^{j=70N} \sum_{k=400hPa}^{k=100hPa} m_k \times \sqrt{u_{i,j,k}^2 + v_{i,j,k}^2}}$$

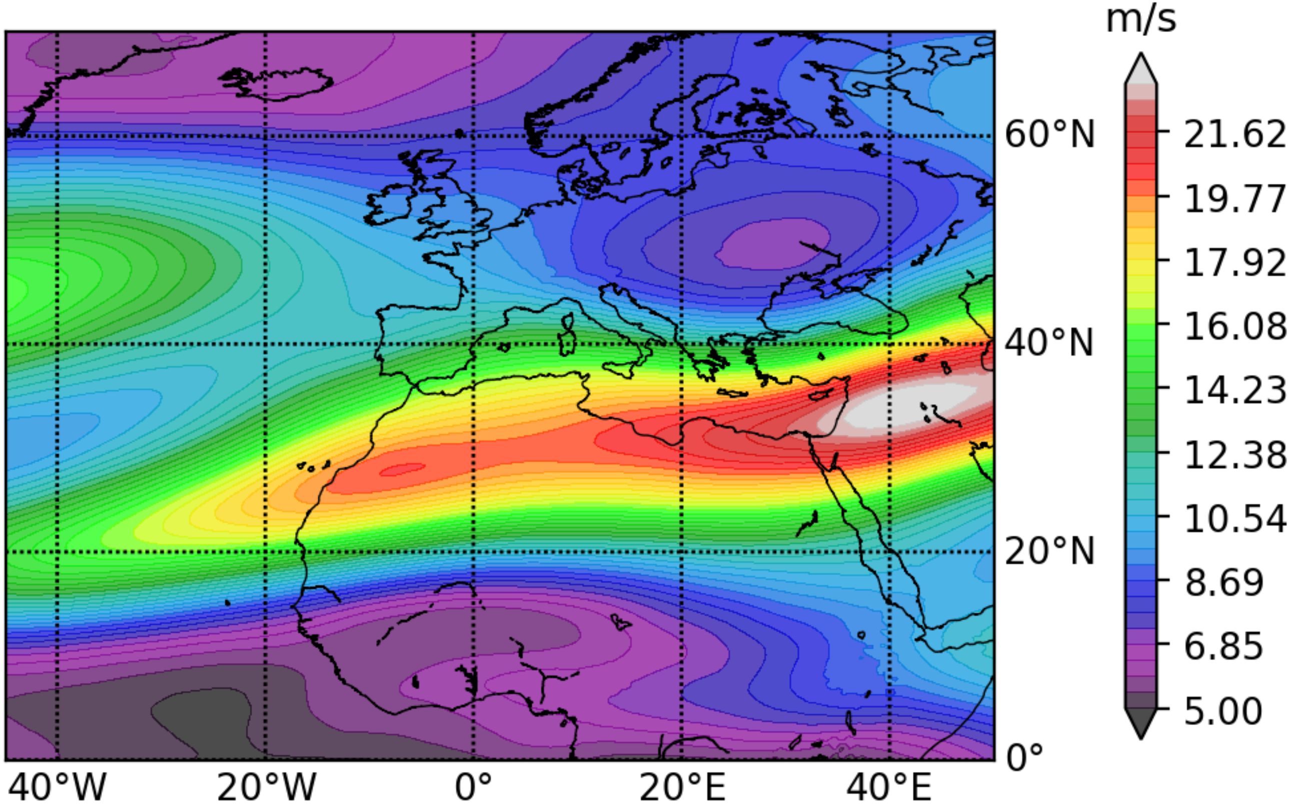
← Mass-flux weighted latitude in the NH. Latitude of the NH jet stream at each longitude

From Archer et al., 2008

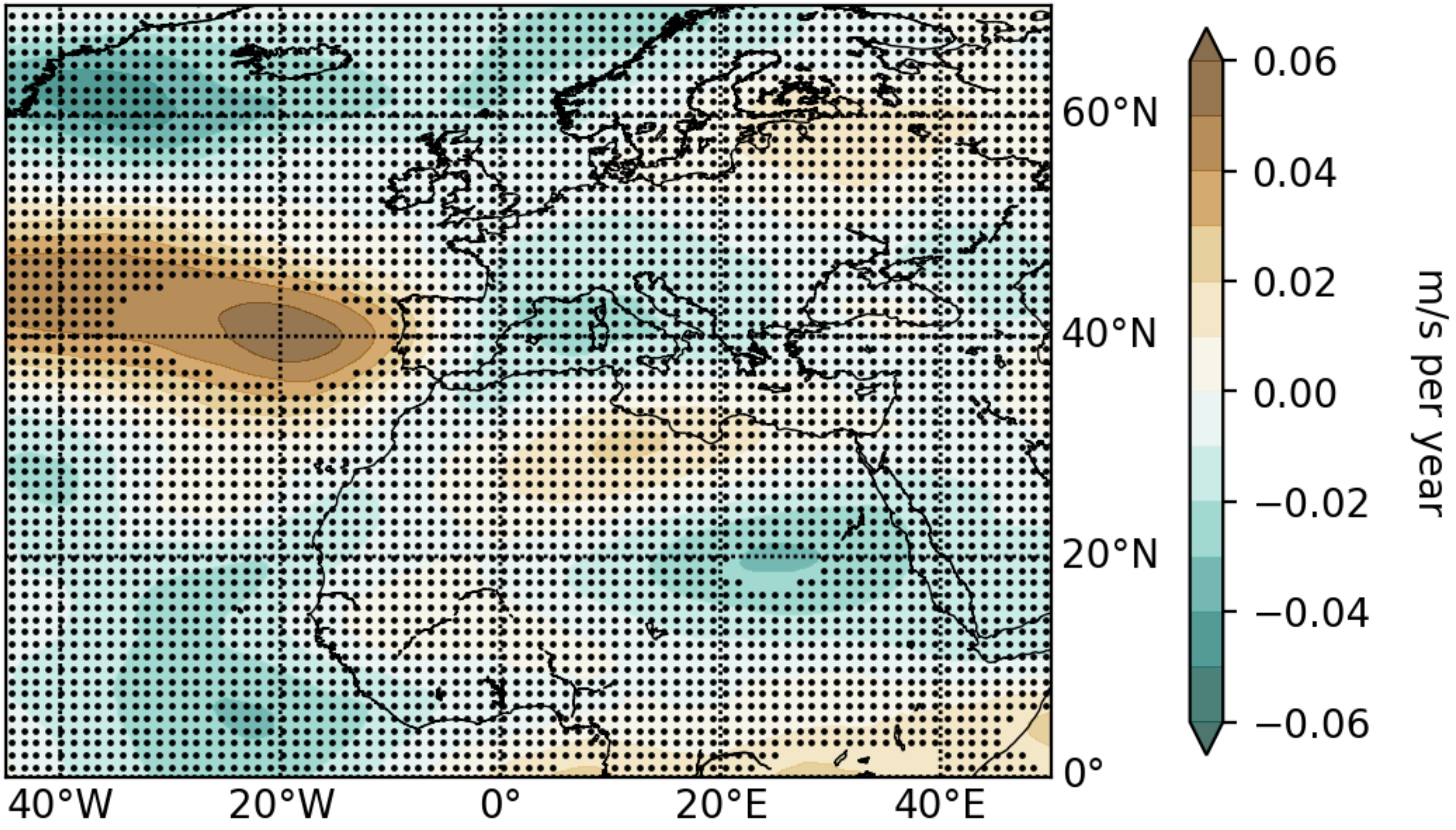
Jet windspeed mean 1979 - 2018



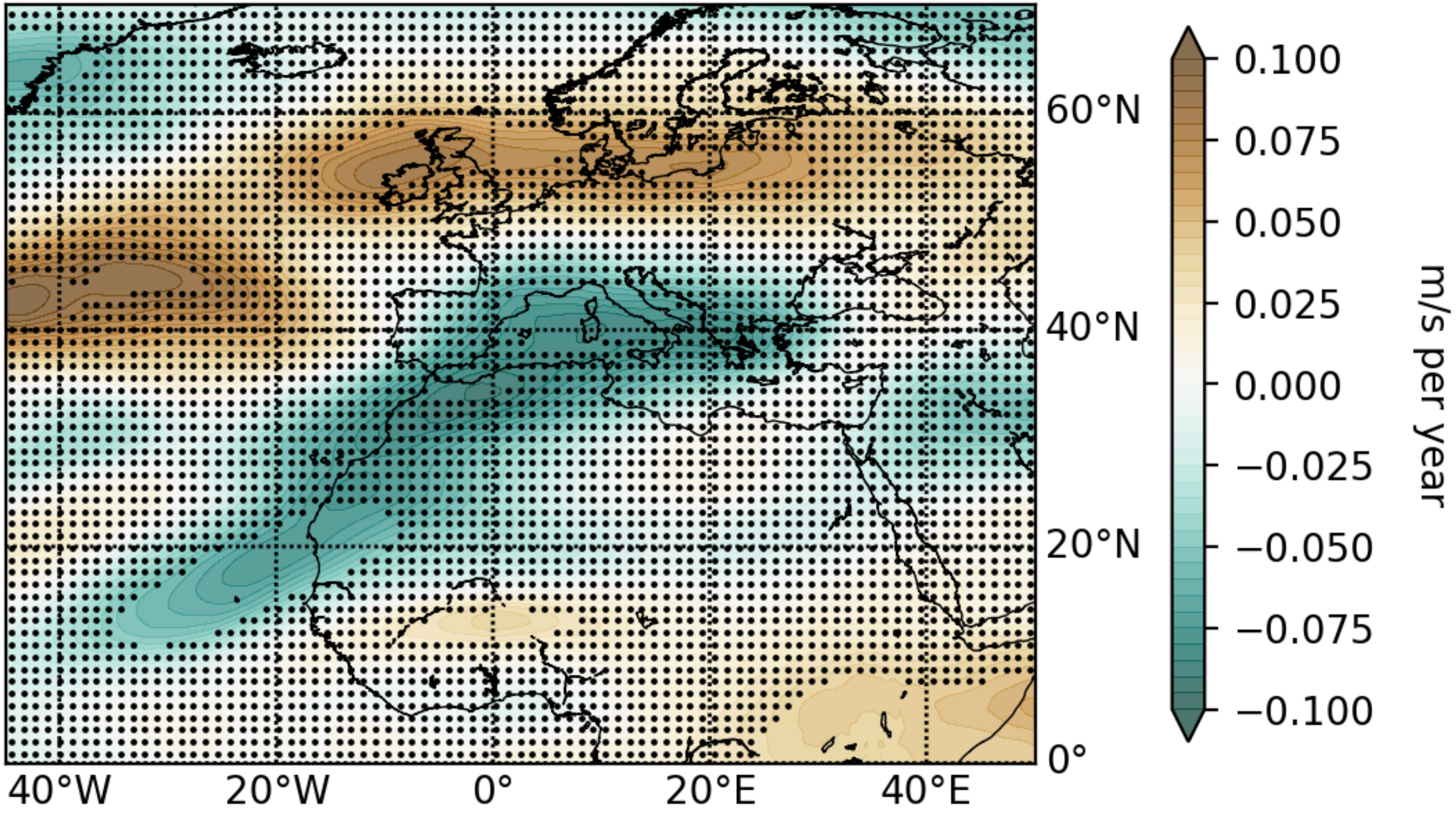
Jet May-June windspeed mean 1979 - 2018



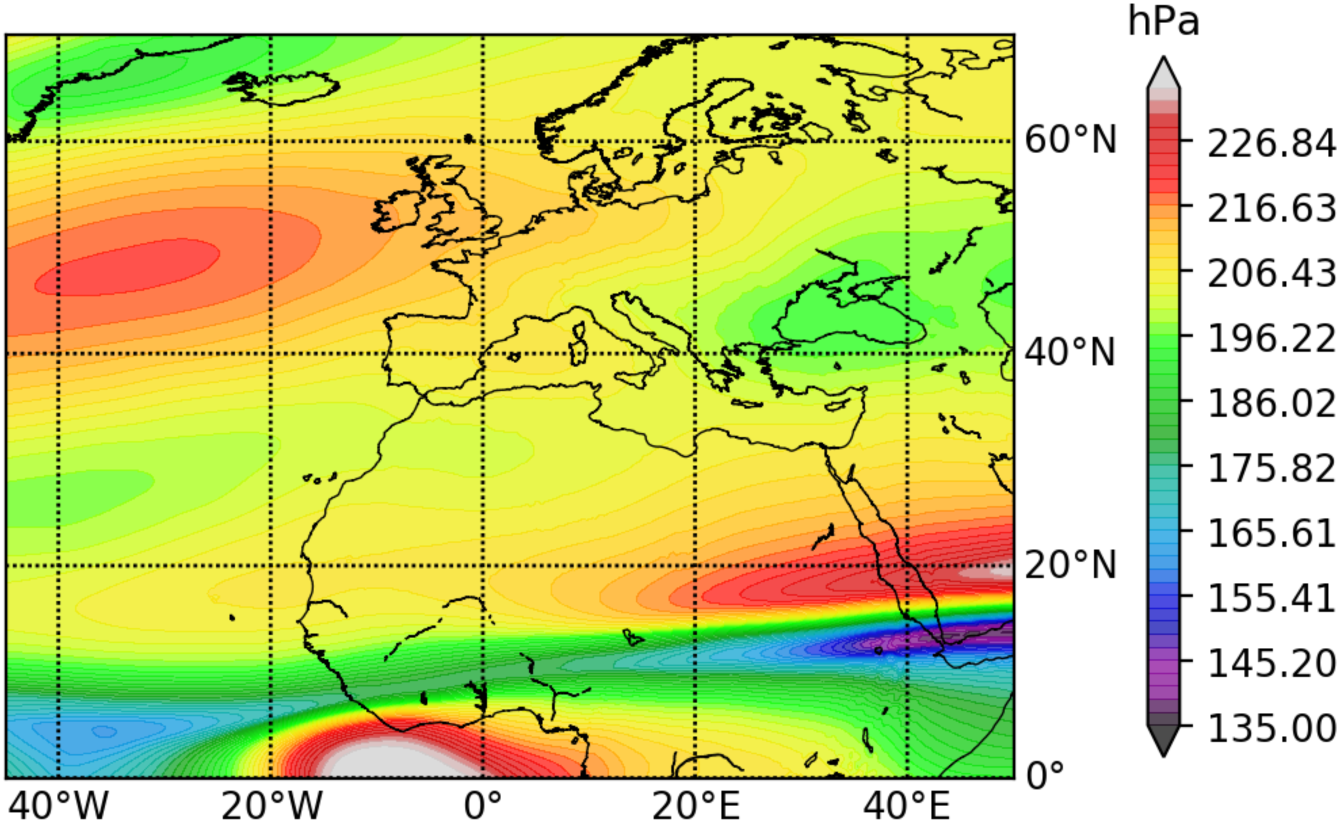
Yearly jet windspeed tendency



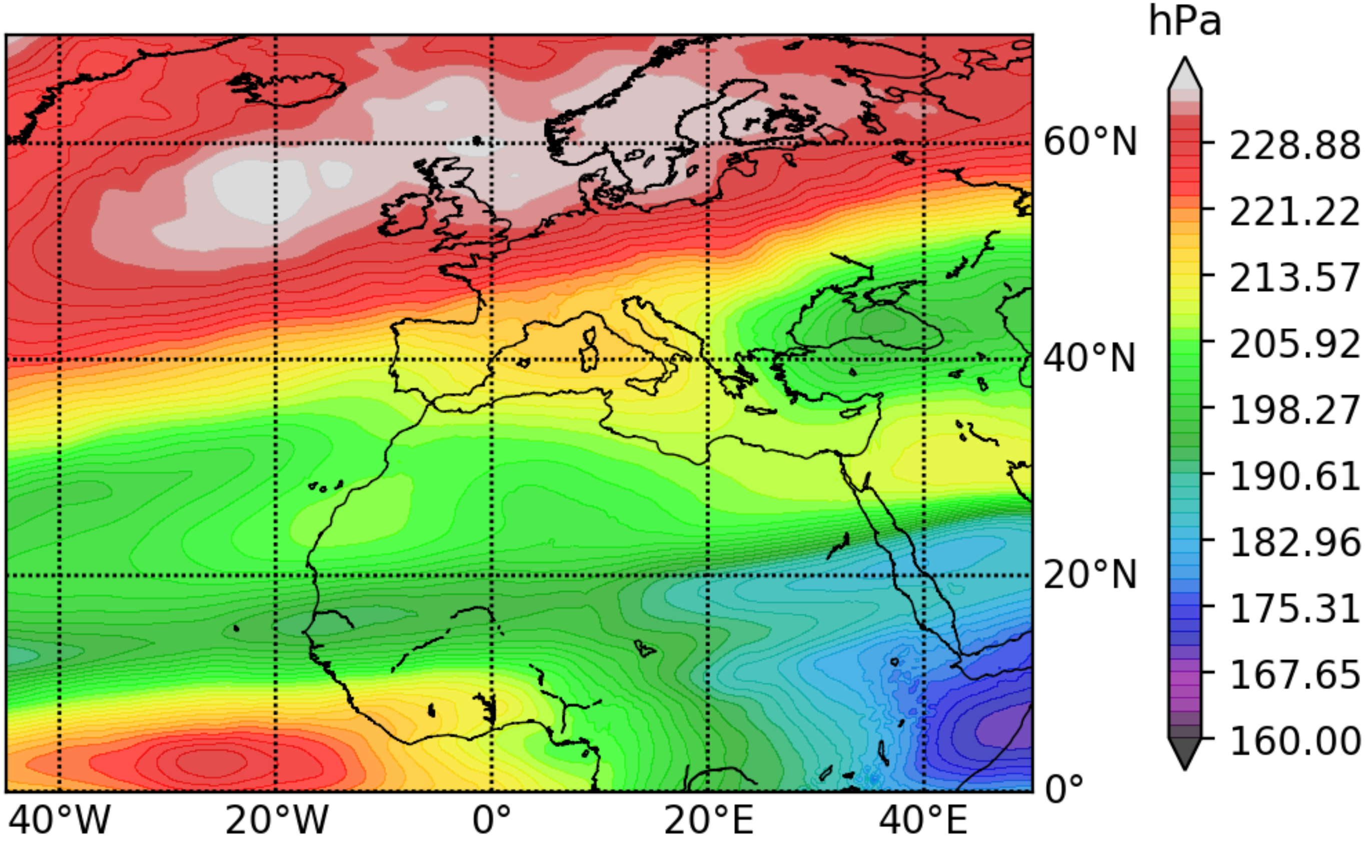
May-June jet windspeed tendency



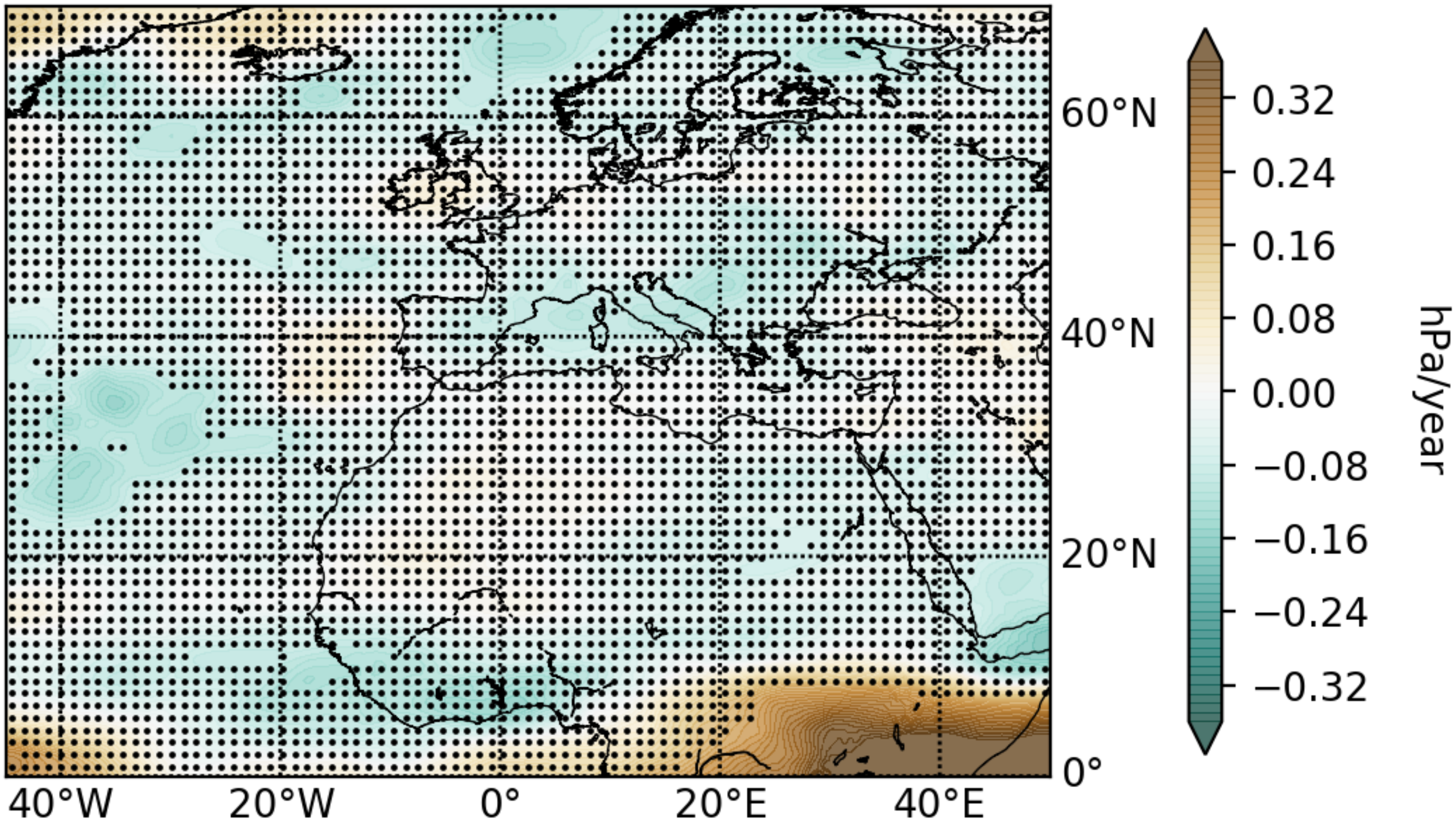
Jet pressure mean 1979 - 2018



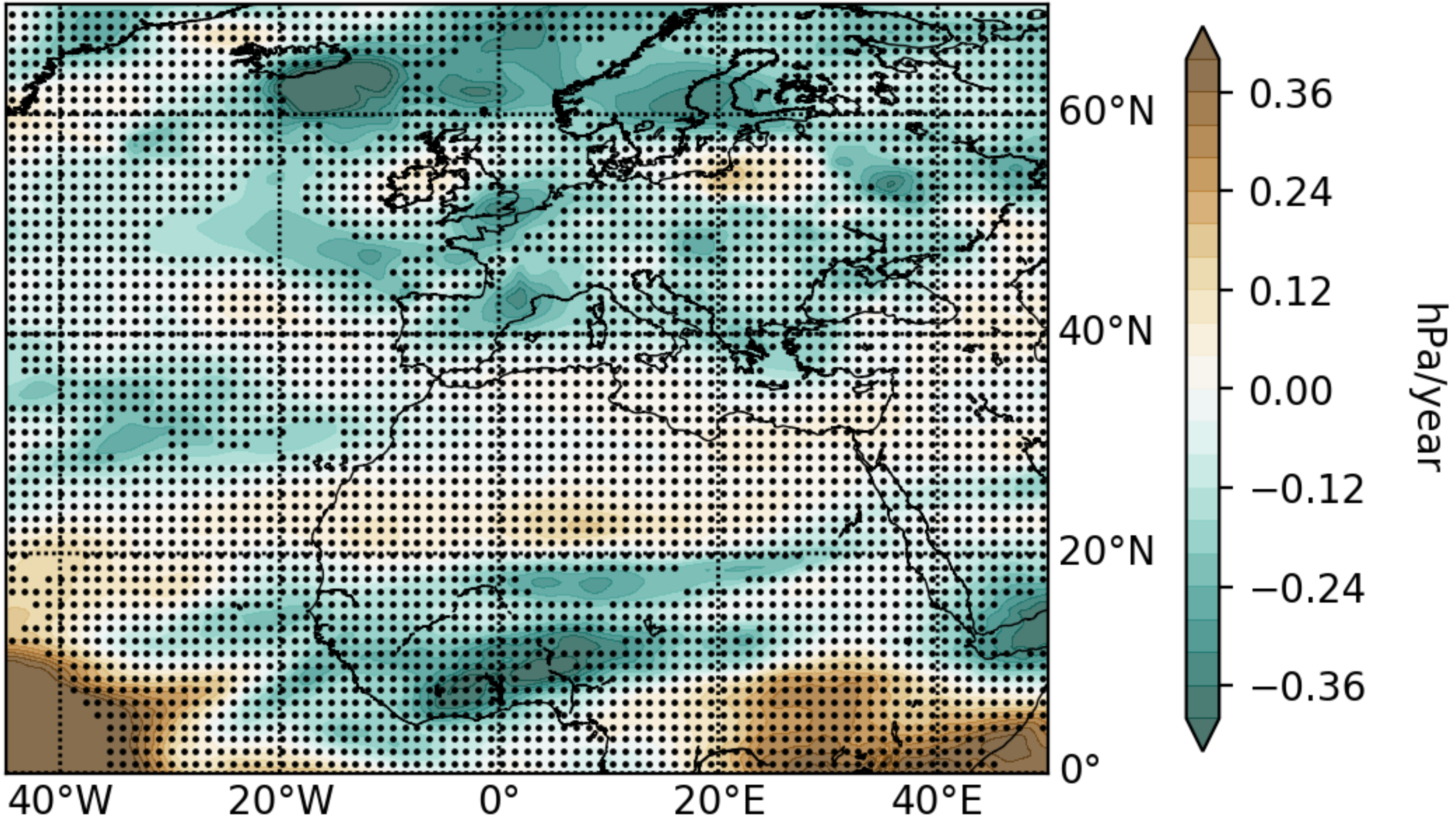
Jet May-June pressure mean 1979 - 2018



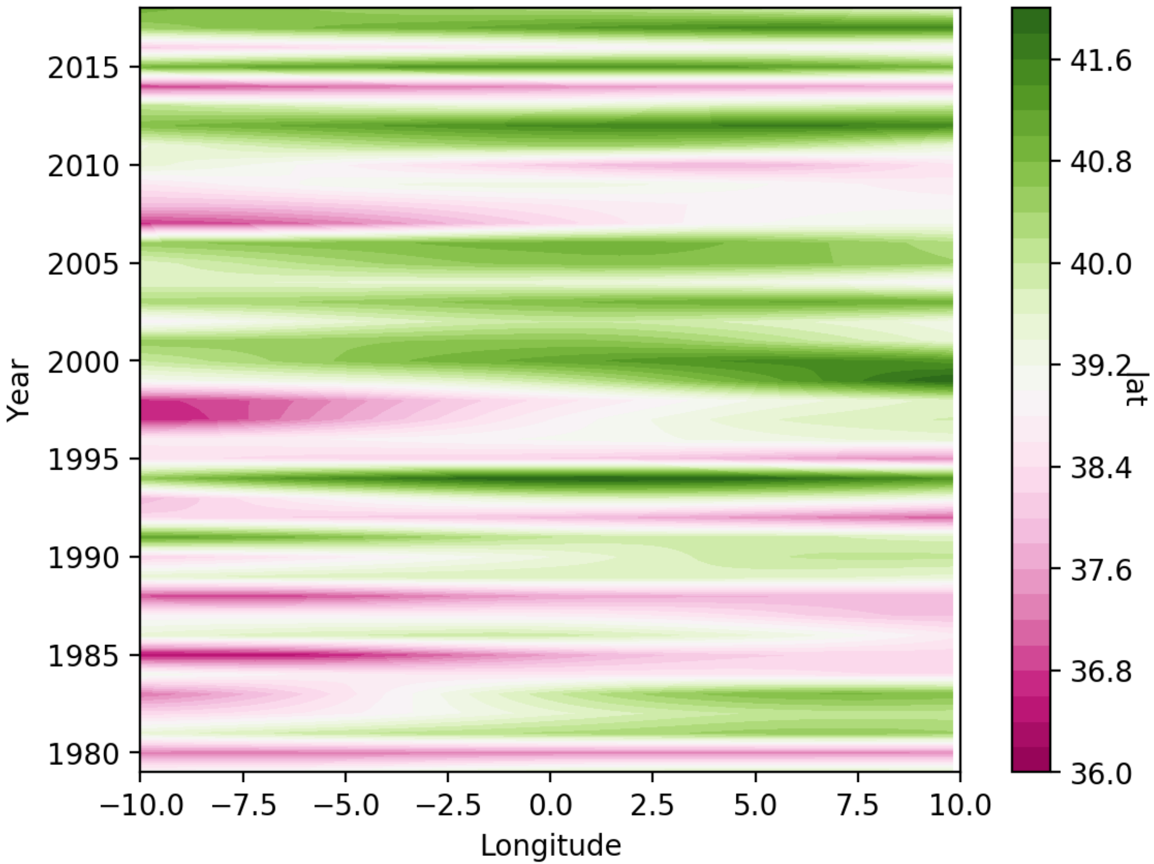
Yearly jet pressure tendency



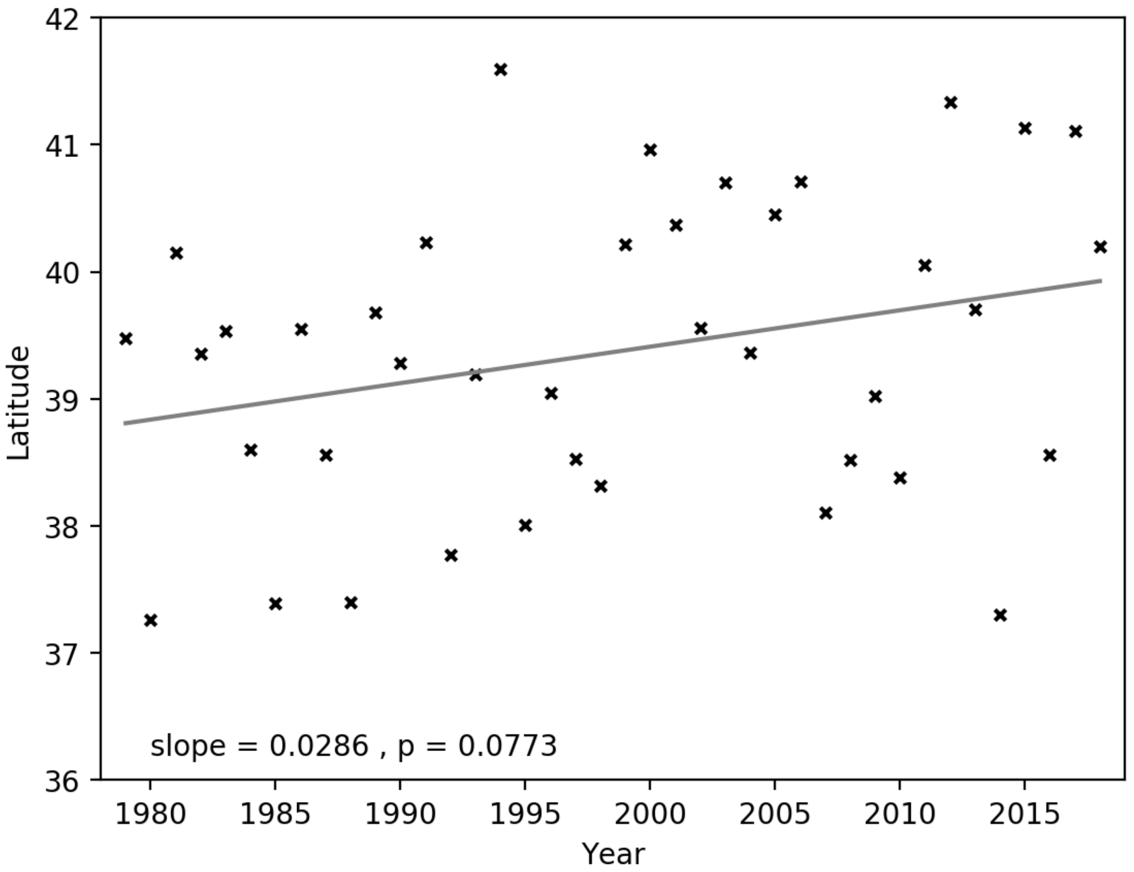
May-June jet pressure tendency



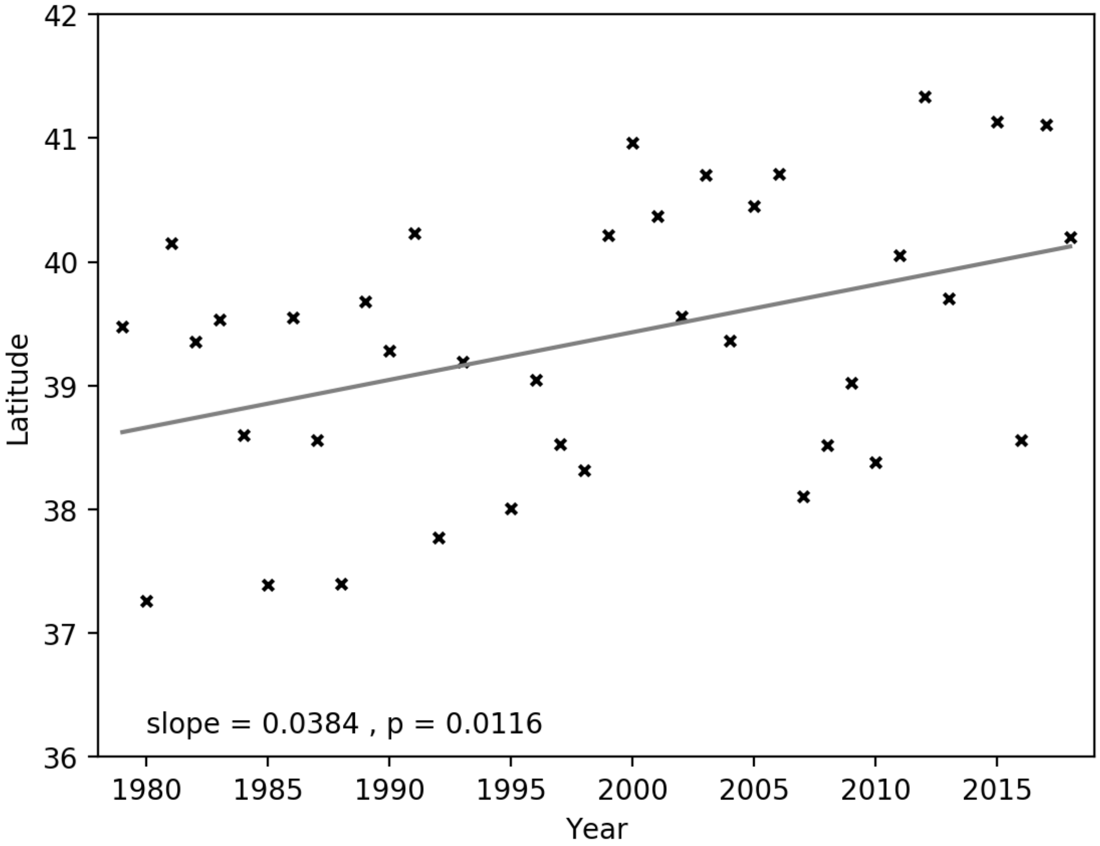
Jet latitude May-June Hovmoller diagram



Jet latitude May-June



Jet latitude May-June (removing the 1994 and 2014 outliers)



An attemp to identify the physical processes: the temperature tendency equation

Temperature tendency equation

Local time rate of change of temperature → $\frac{\partial T}{\partial t}$

Horizontal advection → $-\vec{v} \cdot \nabla T$

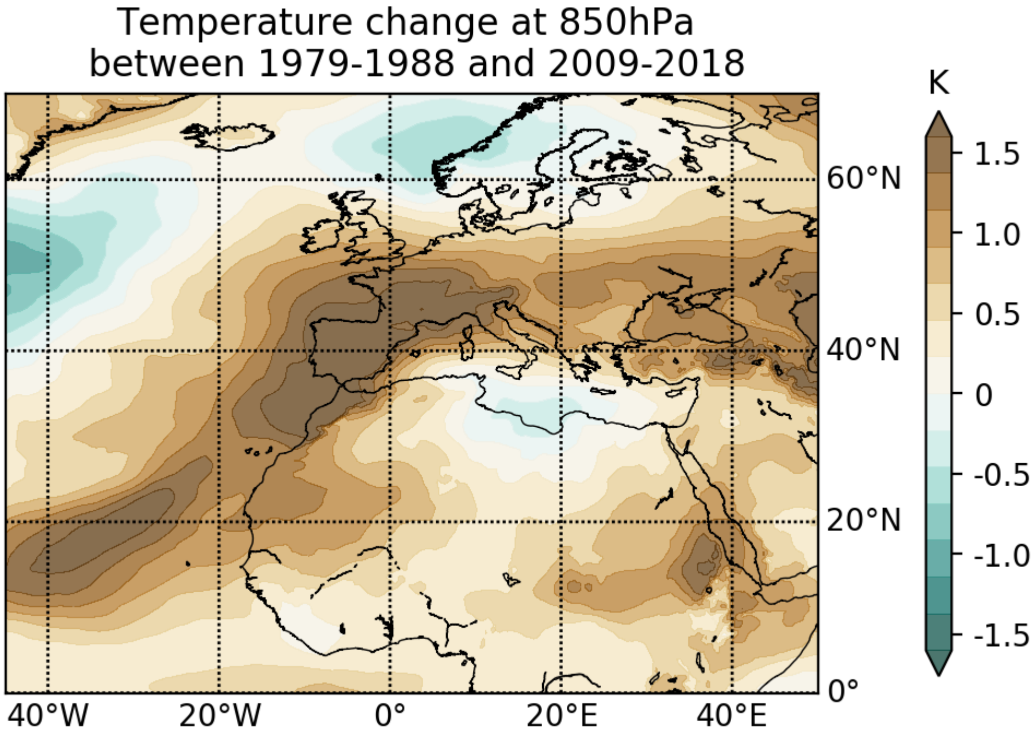
Adiabatic compression → $\omega\kappa\frac{T}{p}$

Vertical advection → $-\omega\frac{\partial T}{\partial p}$

Diabatic heating or cooling → $\frac{Q}{c_p}$

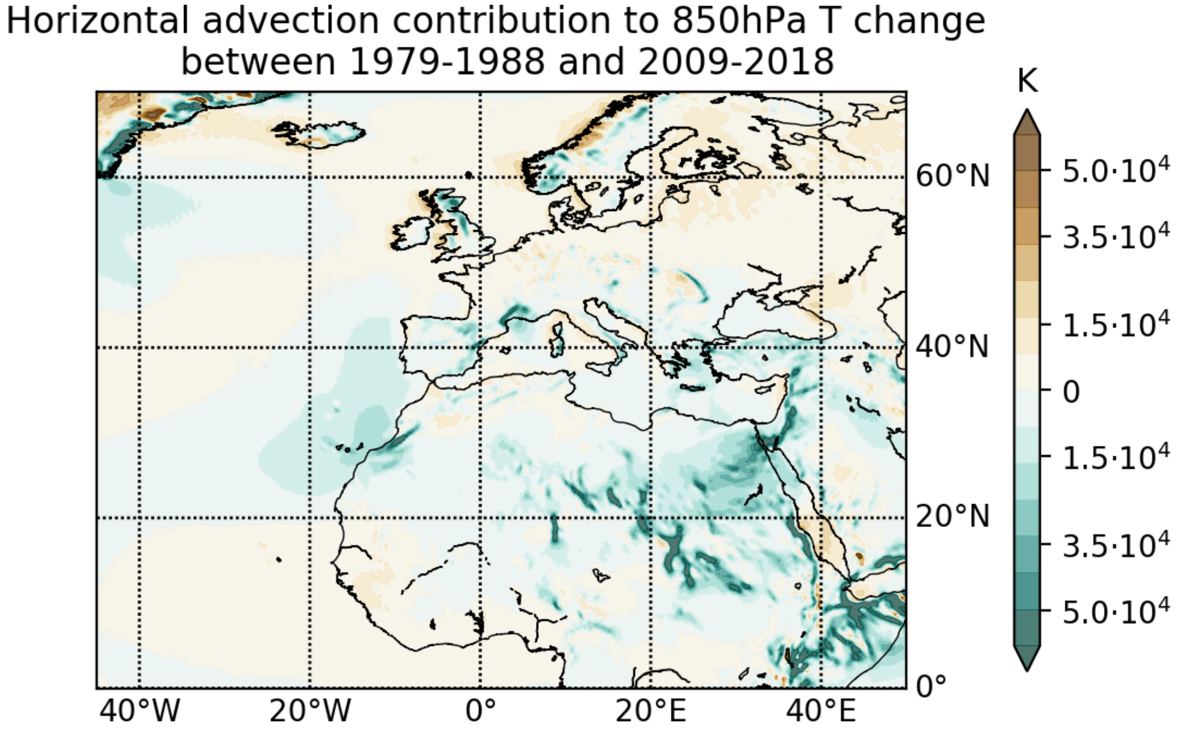
$$\frac{\partial T}{\partial t} = -\vec{v} \cdot \nabla T + \omega\kappa\frac{T}{p} - \omega\frac{\partial T}{\partial p} + \frac{Q}{c_p}$$

Time integrated contribution of the temperature tendency equation terms



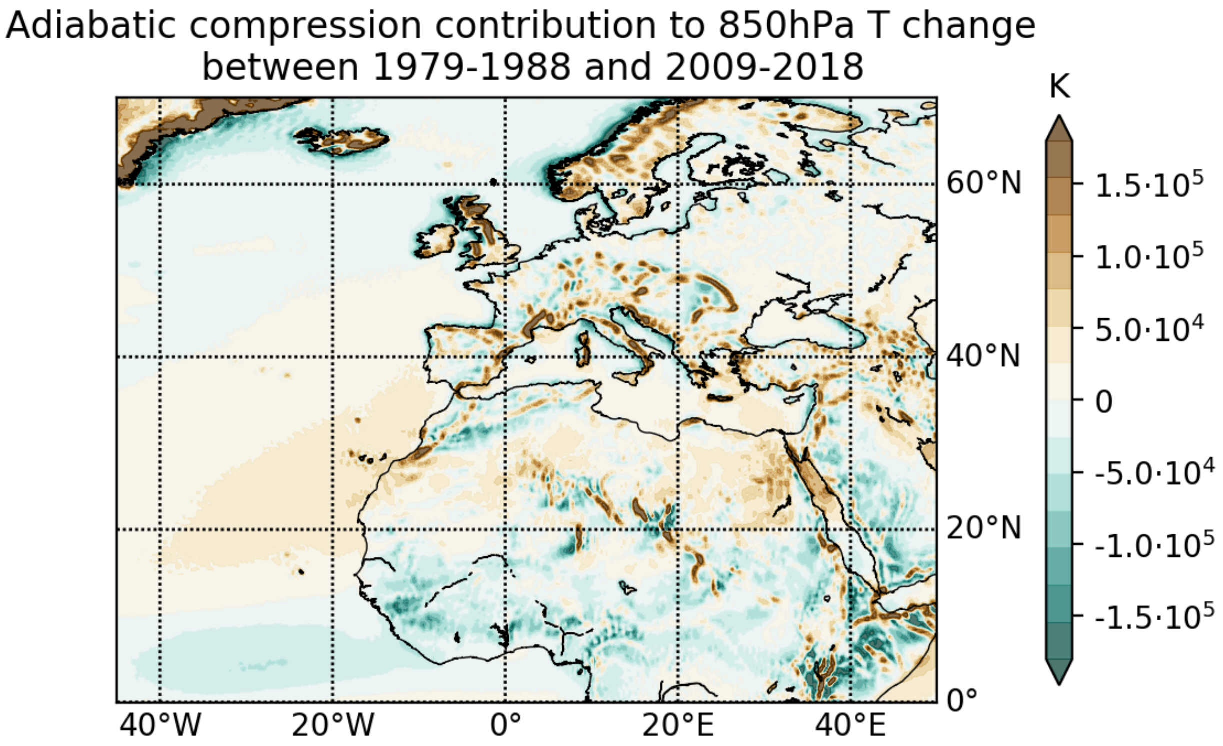
$$\frac{\partial T}{\partial t} = -\vec{v} \cdot \nabla T + \omega \kappa \frac{T}{p} - \omega \frac{\partial T}{\partial p} + \frac{Q}{c_p}$$

Time integrated contribution of the temperature tendency equation terms



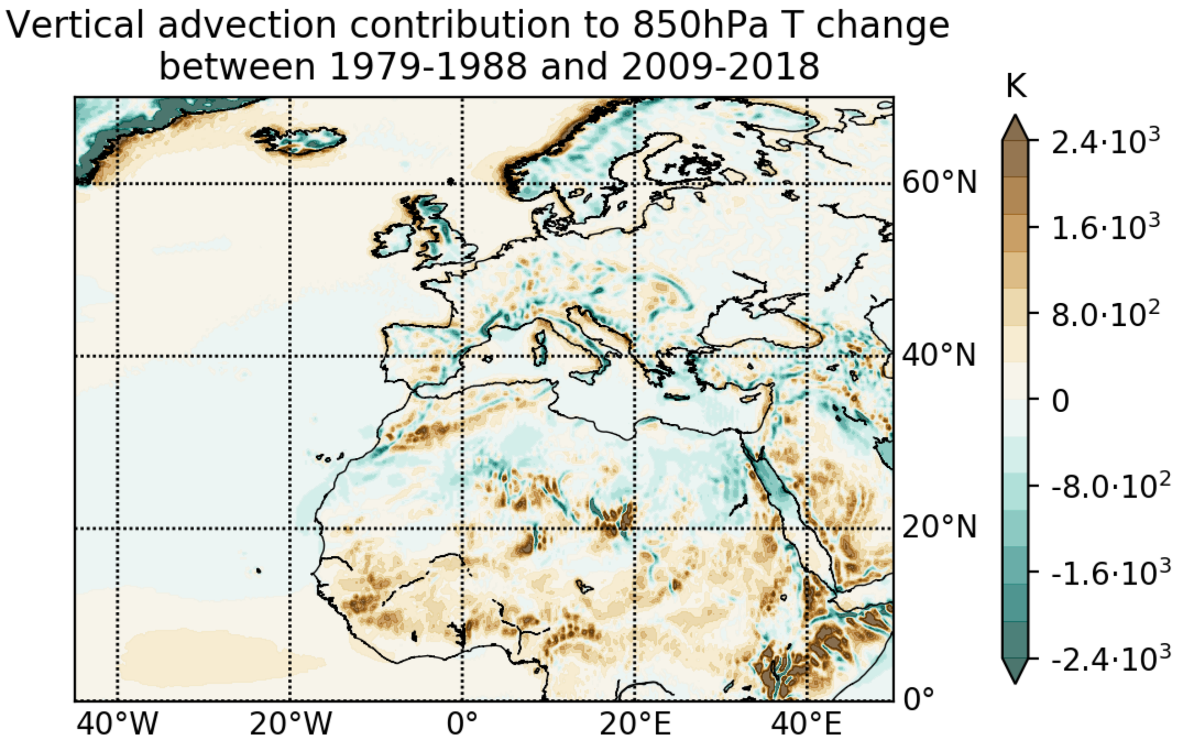
$$\frac{\partial T}{\partial t} = -\vec{v} \cdot \nabla T + \omega \kappa \frac{T}{p} - \omega \frac{\partial T}{\partial p} + \frac{Q}{c_p}$$

Time integrated contribution of the temperature tendency equation terms



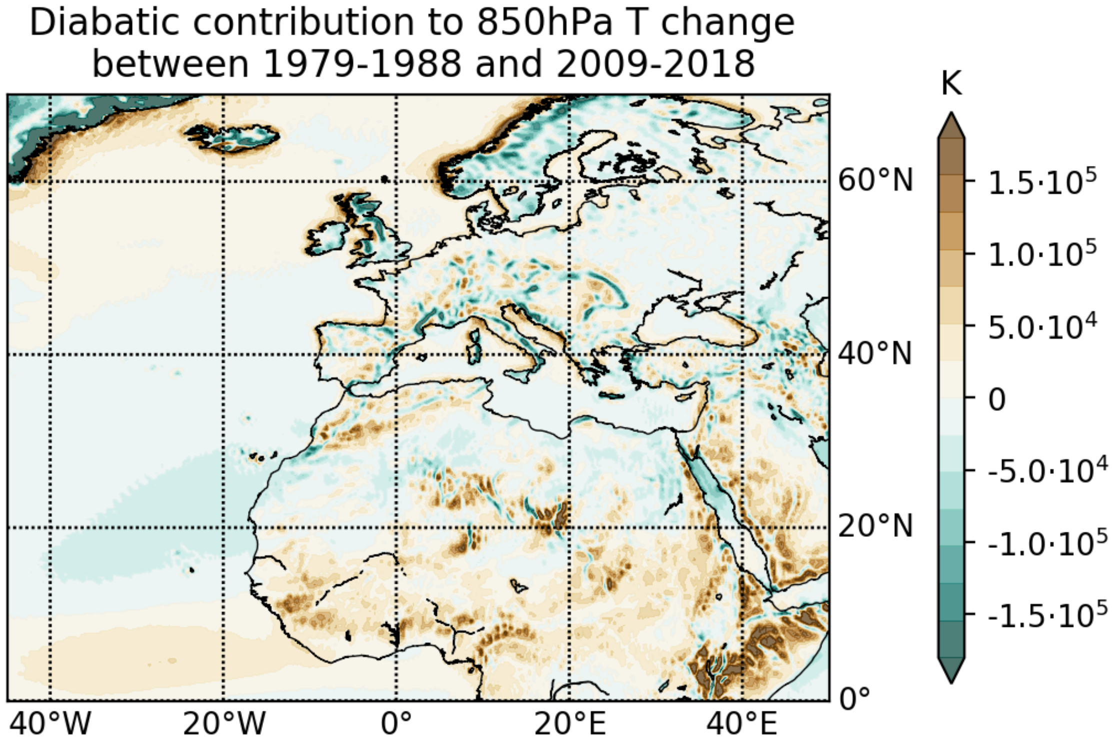
$$\frac{\partial T}{\partial t} = -\vec{v} \cdot \nabla T + \boxed{\omega \kappa \frac{T}{p}} - \omega \frac{\partial T}{\partial p} + \frac{Q}{c_p}$$

Time integrated contribution of the temperature tendency equation terms



$$\frac{\partial T}{\partial t} = -\vec{v} \cdot \nabla T + \omega\kappa\frac{T}{p} \boxed{- \omega\frac{\partial T}{\partial p}} + \frac{Q}{c_p}$$

Time integrated contribution of the temperature tendency equation terms



$$\frac{\partial T}{\partial t} = -\vec{v} \cdot \nabla T + \omega \kappa \frac{T}{p} - \omega \frac{\partial T}{\partial p} + \boxed{\frac{Q}{c_p}}$$

Modelling risks of renewable energy penetration

What are we trying to do?

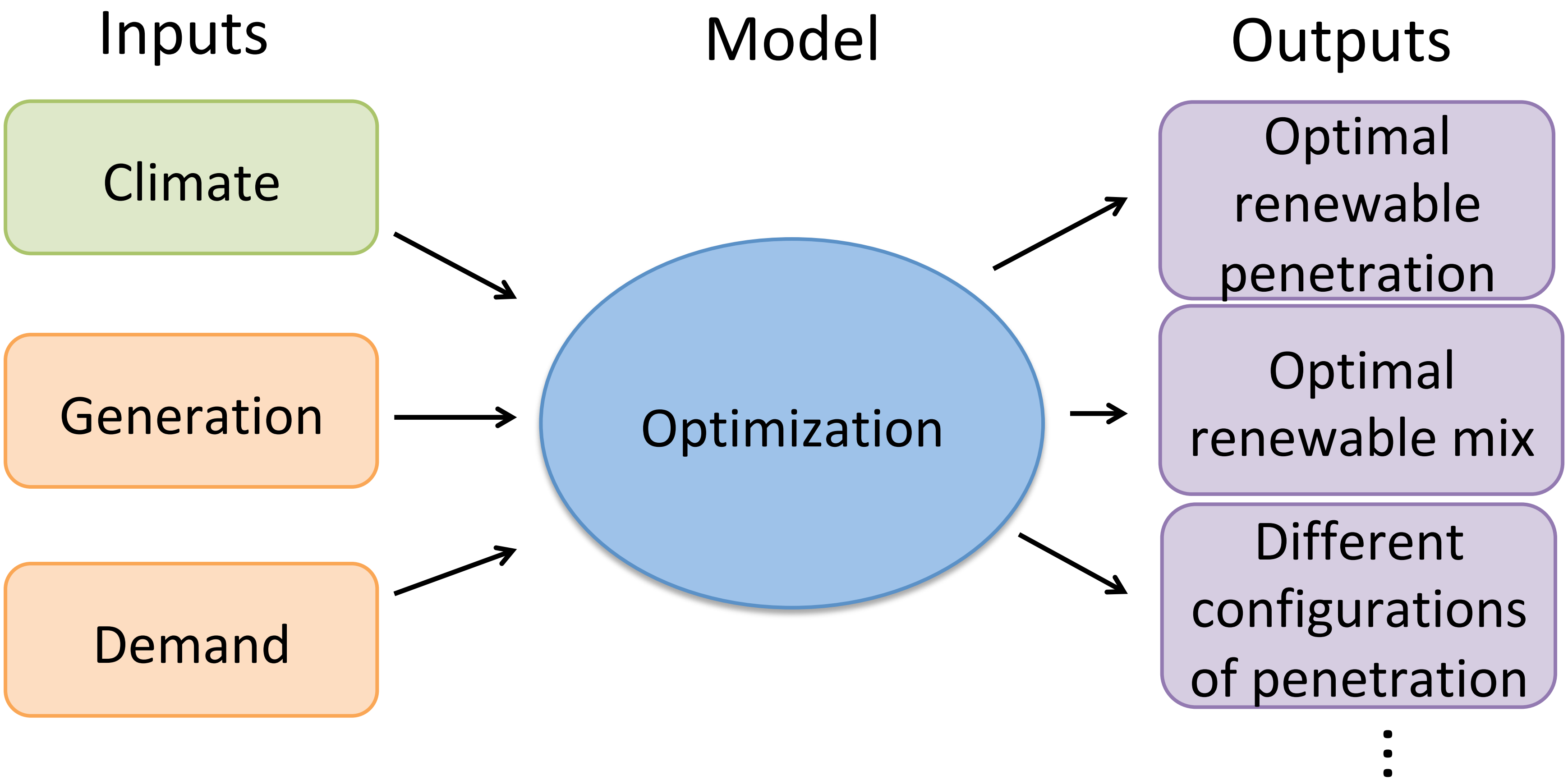
For the current climate:

- Analyze the effect of climate variability on the electric system with a focus on renewable energy sources
- Study the risk of saturation and shortage of the system

For the future climate:

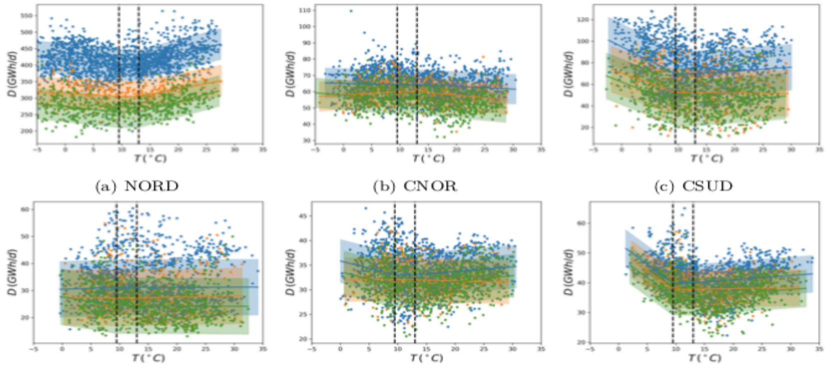
- Estimate these features in future scenarios under a climate change context

The e4clim model



An example: the Italian case

(a) Italian electrical regions.



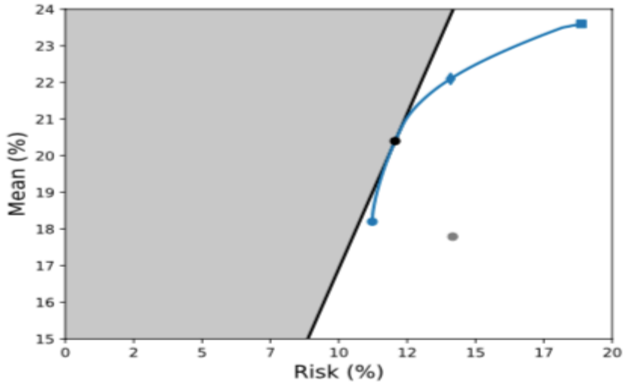
(a) NORD (b) CNOR (c) CSUD

(d) SUD (e) SARD (f) SICI

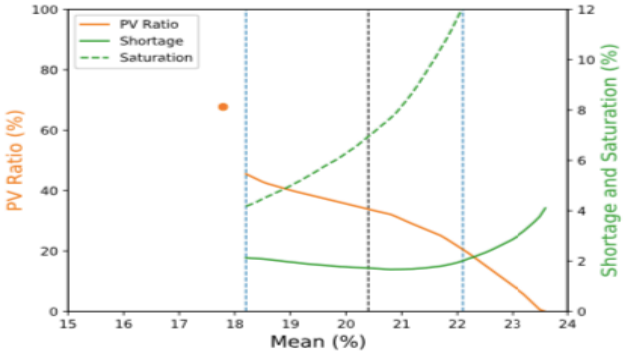
$$
\begin{aligned}
\min_{\mathbf{w}} \quad & \sigma^2_{\text{global|regional}}(\mathbf{w}) \\
\max_{\mathbf{w}} \quad & \sum_{\mathbf{k}} w_{\mathbf{k}} \mathbb{E}[\eta_{\mathbf{k}}] \\
\text{subject to} \quad & \sum_{\mathbf{k}} w_{\mathbf{k}} = w_{\text{total}} \\
& w_{\mathbf{k}} \geq 0 \quad \forall\, \mathbf{k}.
\end{aligned}
$$

From Tantet et al., 2019

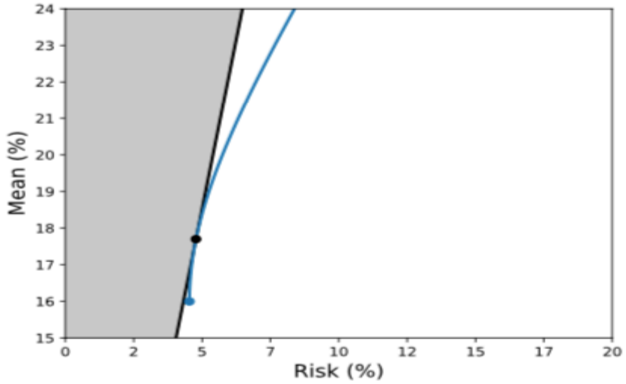
An example: the Italian case



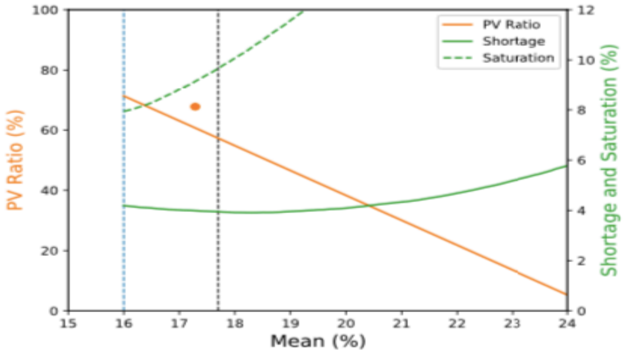
(a) $\alpha_{\text{global}} = 1.69$



(b)



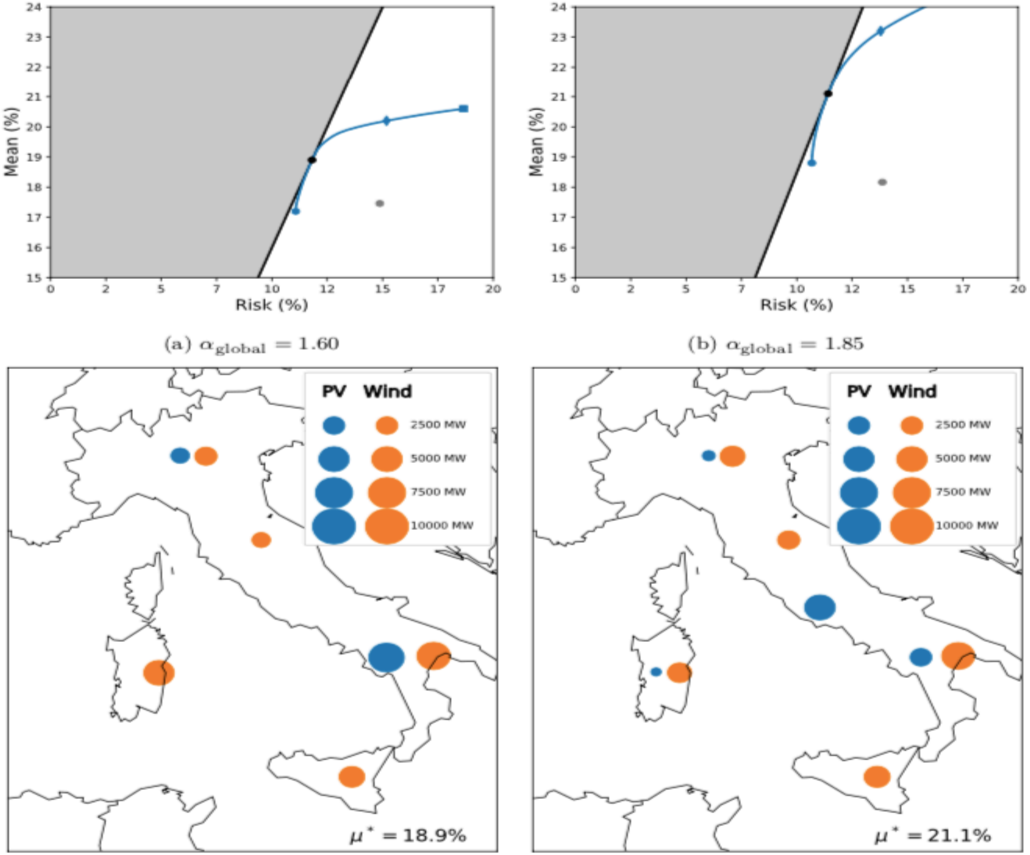
(c) $\alpha_{\text{regional}} = 3.71$



(d)

From Tantet et al., 2019

An example: the Italian case



(a) $\alpha_{\text{global}} = 1.60$ (b) $\alpha_{\text{global}} = 1.85$

(c) 1989 (d) 1996

From Tantet et al., 2019

Our changes

- Implementation of the model to the Spanish electricity system
- Experimentation with the reduced system of the Balearic Islands
- Introduction of conventional energy sources
- Application to climate change scenarios

Overview

- A temperature rise is found in the Western Mediterranean and Occidental Continental Europe

- The warming is found to be associated with the 500 hPa geopotential height

- An analysis based on divergence and vertical velocity indicates a northward shift and an intensification of the downside branch of the Hadley circulation-

- A study of precipitation and evaporation indicates a drying of the Iberian zone

- The 100 − 400 hPa jet shows a shift of the downward circulation

- An attribution analysis based on the temperature tendency equation may reveal physical processes behind this regional warming

- The e4clim model for renewable energy studies is introduced

Thank you for your attention

Acknowledgements

METEOforSIM (PCIN-2015-221)
COASTEPS (CGL2017-82868-R)

MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD

AGENCIA ESTATAL DE INVESTIGACIÓN

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
"A way to make Europe"

UIB Universitat de les Illes Balears