# ENSO teleconnection over the Euro-Mediterranean sector: the role of extratropical Pacific modulation

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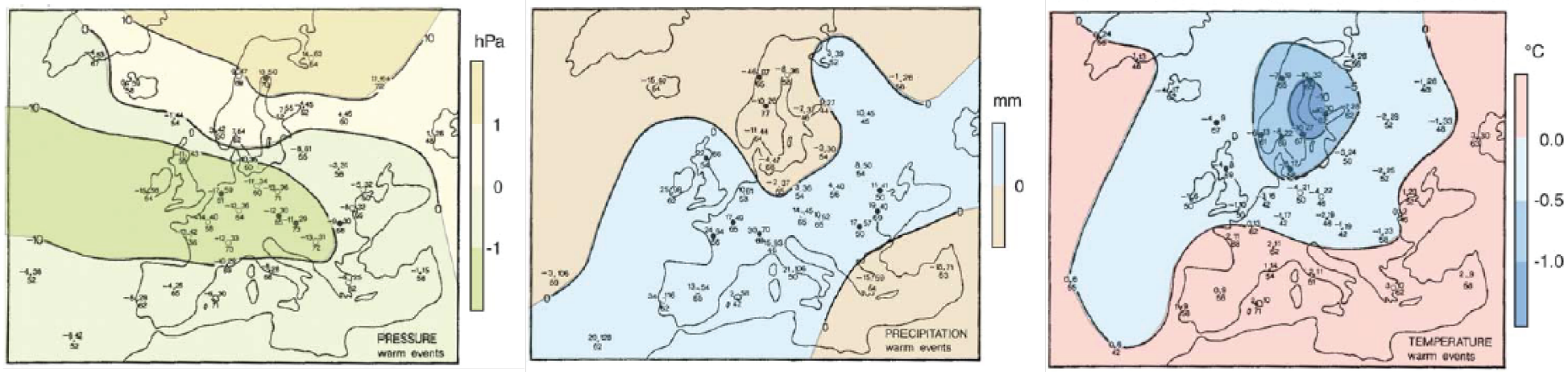
# ENSO teleconnection over the Euro-Med sector

The **canonical late winter signal** of ENSO over the Euro-Med domain



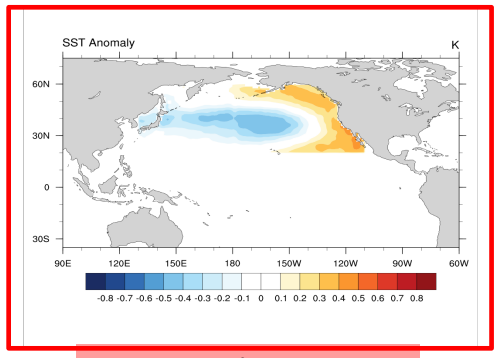

(Adopted from Bronniman, 2007)

The aim of this research is to study if and how the **low frequency variability** over the extratropical Pacific (*e.g.* **different PDO phases**) affects the **ENSO teleconnection** over the Euro-Mediterranean domain.

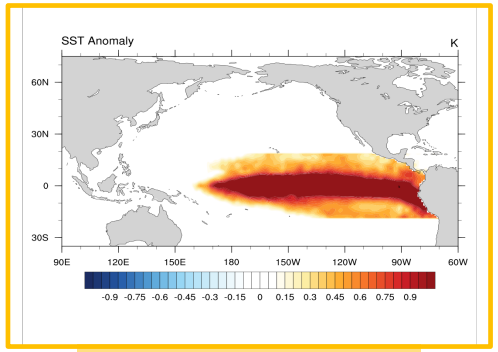
**Different mechanisms** have been identified as involved in **spreading** the ENSO signal **remotely** (*e.g.* planetary wave propagation, changes in Hadley and Walker circulation).
The **working hypothesis** is that **changes** in the **mean state** may affect the **efficacy** of these mechanisms.

# Experimental Setup

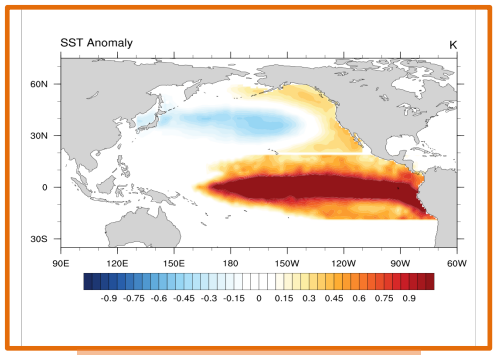
**Multi model ensemble** of sensitivity experiments including different SST boundary conditions



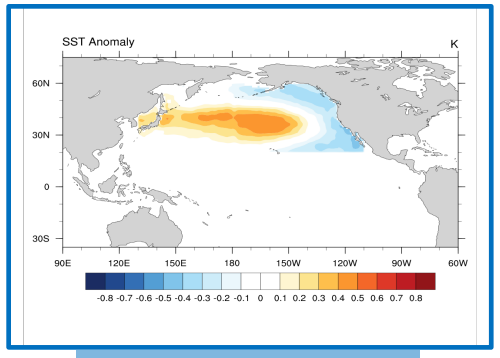

Extratropical Positive PDO




Positive ENSO-like

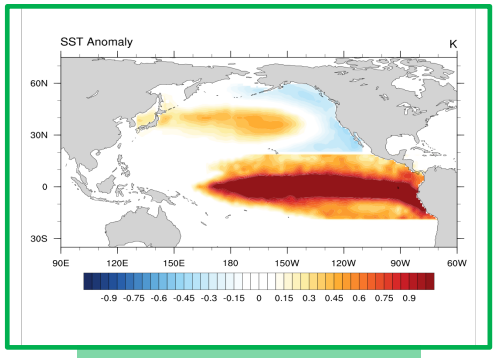



ENSO + ET positive PDO




Extratropical Negative PDO

PDO-like pattern -> stationary
ENSO-like pattern -> annual cycle

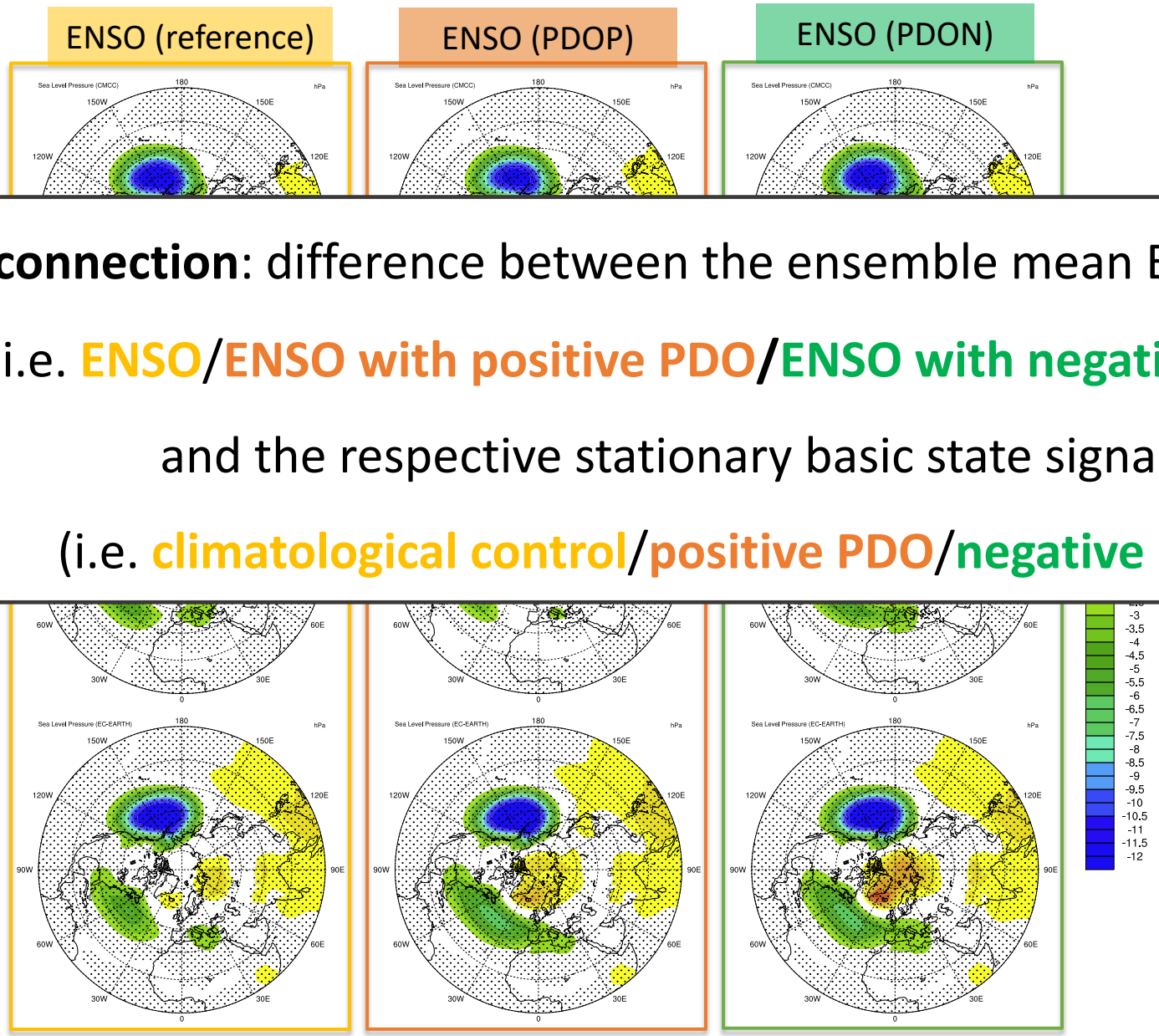



ENSO + ET negative PDO

- **AMIP-like experiments: focus on the atmospheric response**
- For each experiment: 50 ensemble members
- Recursive 2000 condition control run with climatological SST
- Simulations lasting one year (June-to-May)
- **CMCC, CNRM, EC-EARTH models following the same protocol**

# ENSO signal and PDO modulation: JFM MSLP

ENSO (reference) | ENSO (PDOP) | ENSO (PDON)




ENSO **teleconnection**: difference between the ensemble mean ENSO forced signal

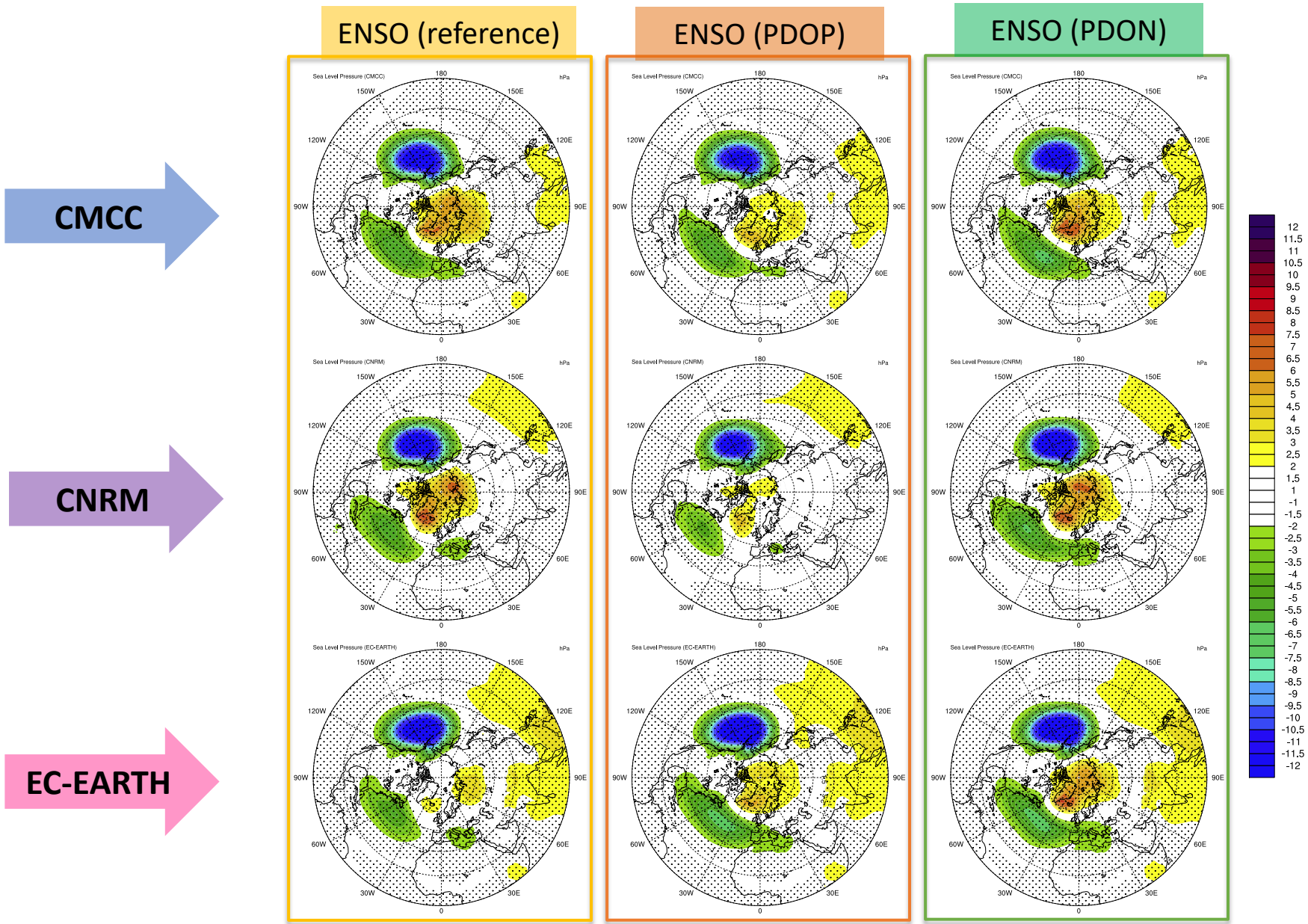
(i.e. **ENSO**/**ENSO with positive PDO**/**ENSO with negative PDO**)

and the respective stationary basic state signal

(i.e. **climatological control**/**positive PDO**/**negative PDO**)

**EC-EARTH**

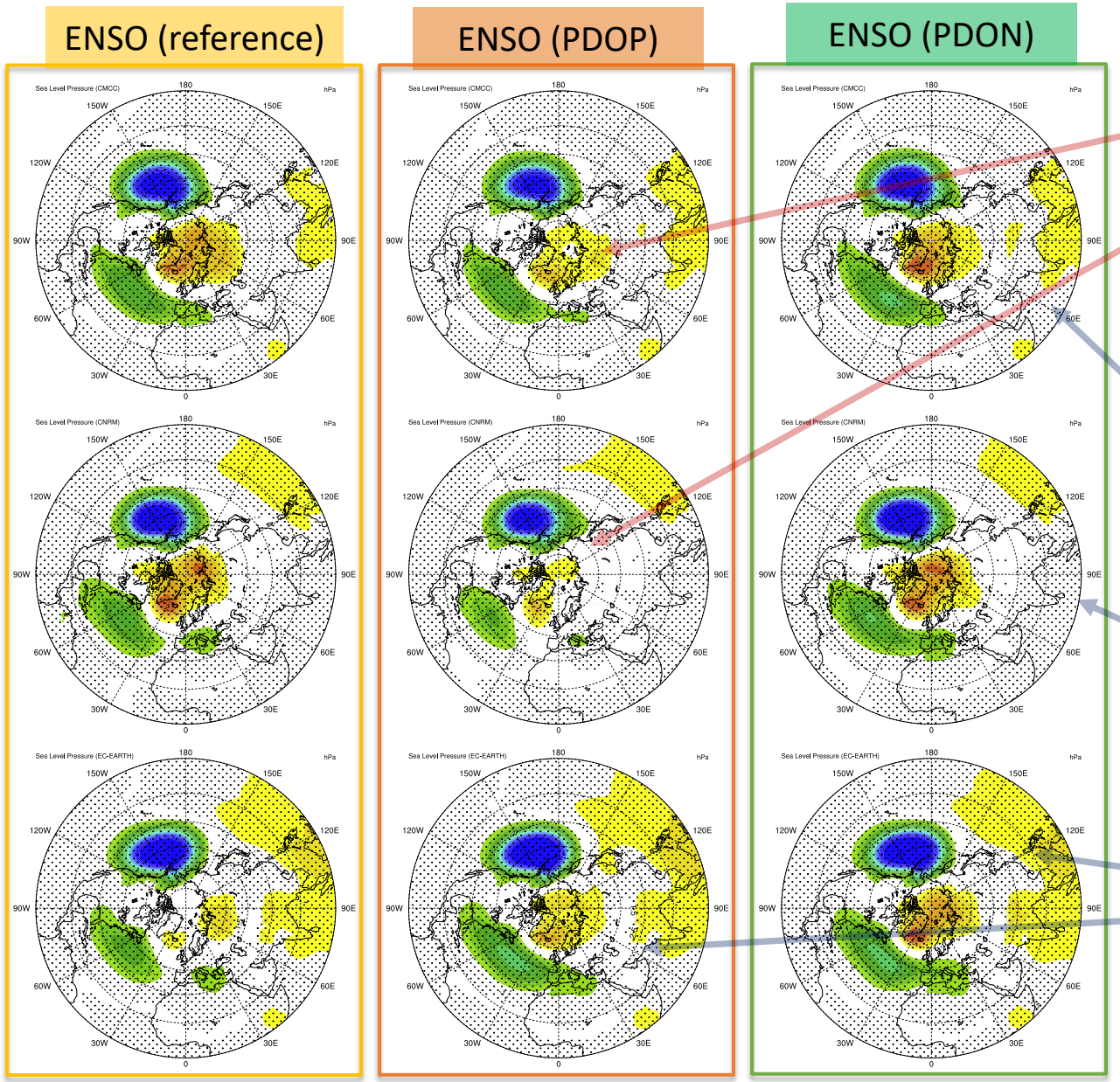
# ENSO signal and PDO modulation: JFM MSLP




- reference El Nino teleconnection well captured by the different models
- the presence of an anomalous PDO signal in the SST mean state interacts with the El Nino fingerprint through a **modulation** of the pattern, *especially* over the **North Atlantic** sector

dotted areas: 95% confidence level

# ENSO signal and PDO modulation: JFM MSLP

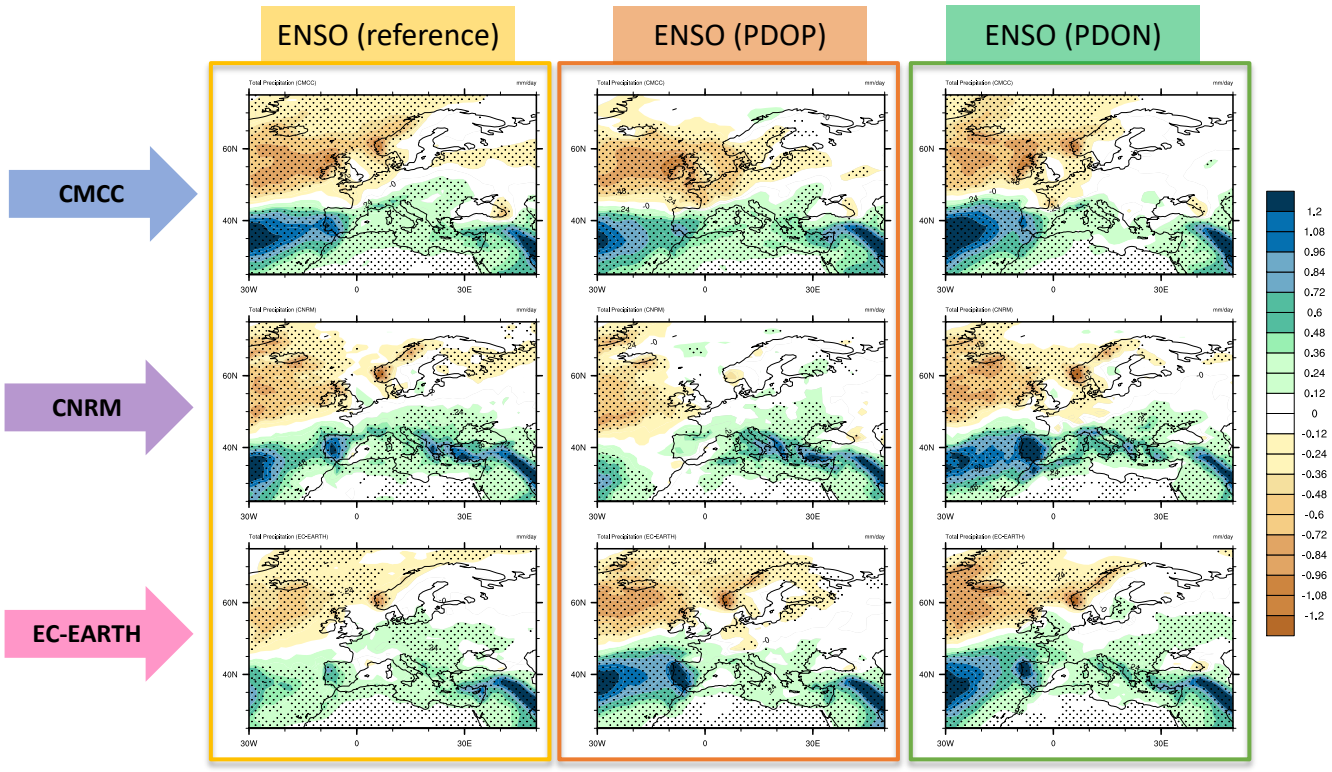



**Weaker Auletian low and damped Atlantic dipole**

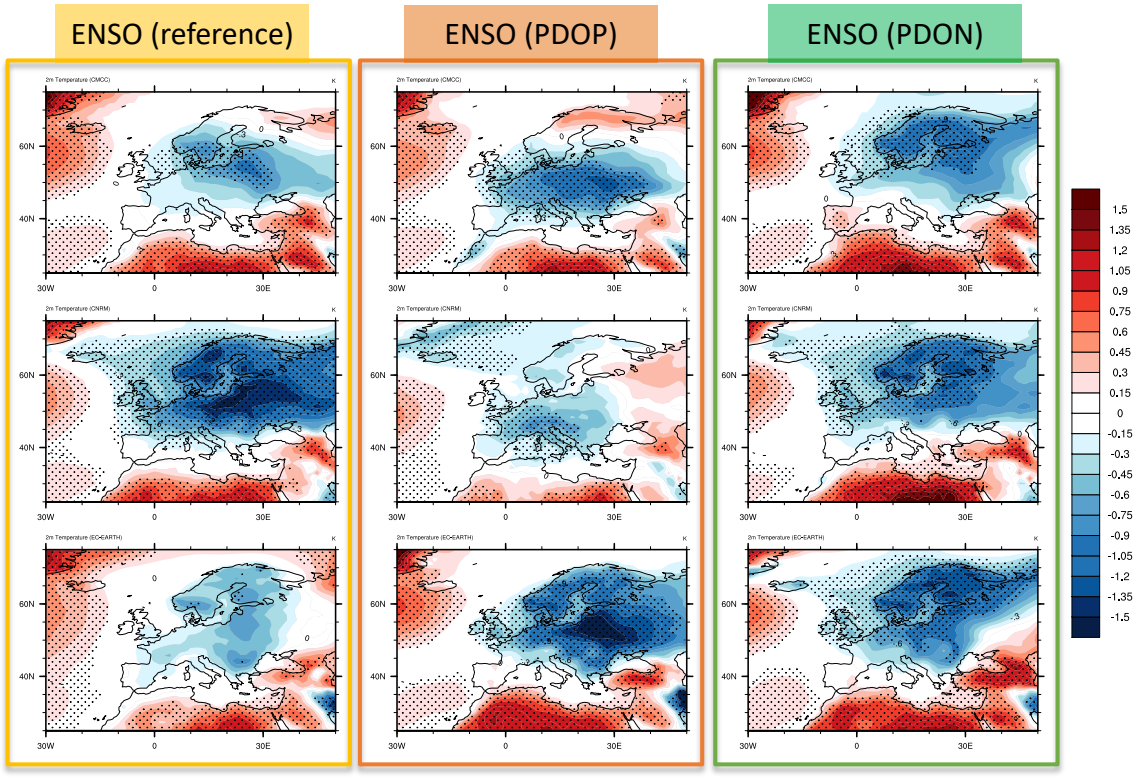
**Deeper Auletian low and enhanced Atlantic dipole**

dotted areas: 95% confidence level

# ENSO signal and PDO modulation over the Med




**JFM Precipitation**

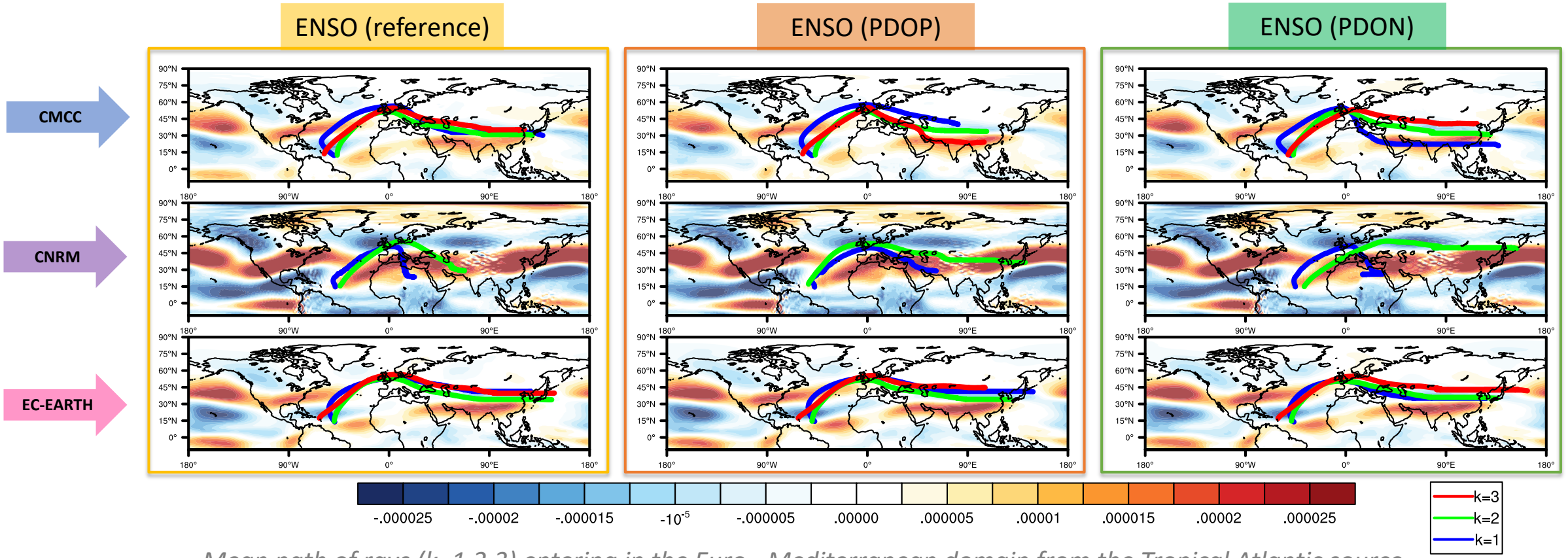



**JFM 2m Temperature**

dotted areas: 95% confidence level

# Rossby Wave Ray tracing analysis (I)

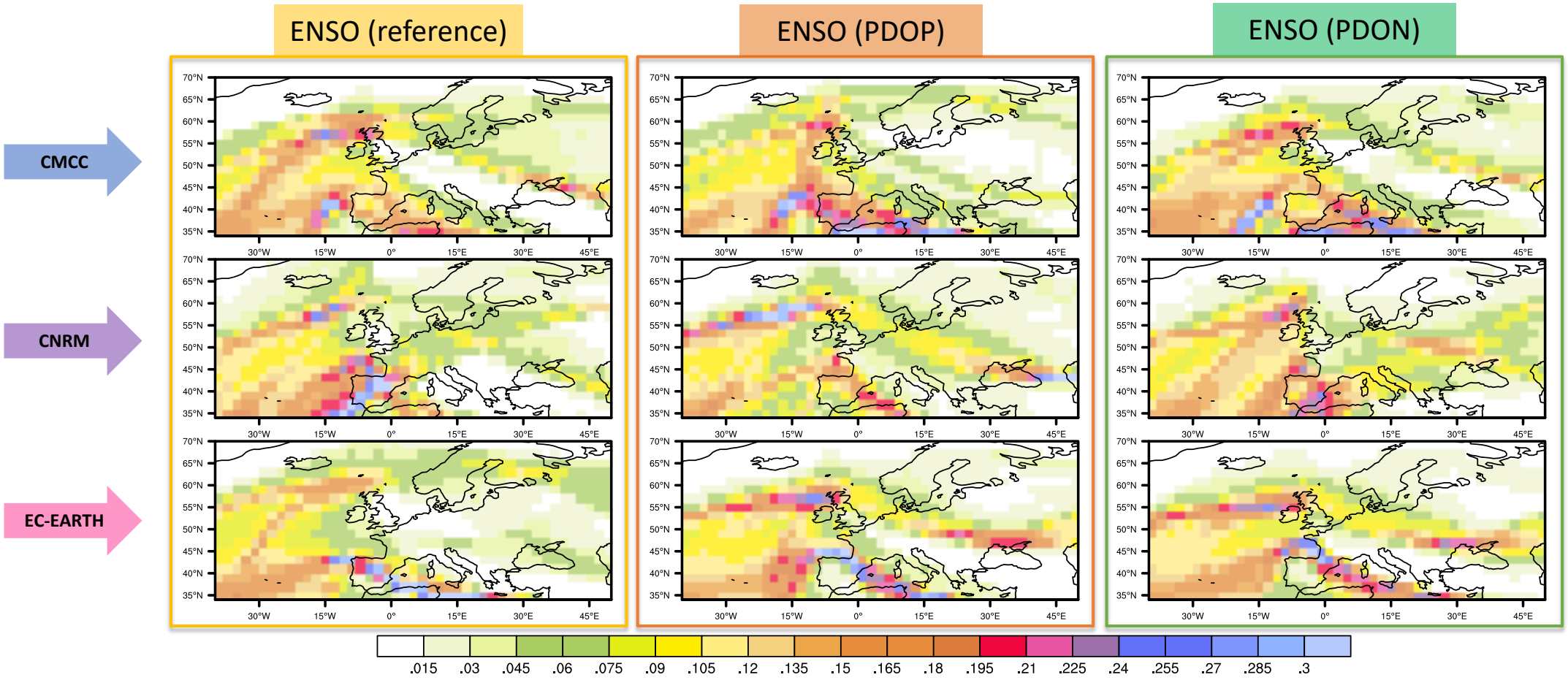
In order to detect how the different PDO phases interact with the Rossby wave propagation, a **ray tracing analysis** with **different mean states** (i.e. JFM 200hPa wind components for ENSO, ENSO/PDOP, ENSO/PDON) have been performed. Based on the **Rossby Wave Source** induced by El Nino forcing, the source region has been located over the **Tropical Atlantic** sector. From this region, the propagation of planetary waves show a *strong meridional* component, at least for the lowest zonal wave numbers (**k=1,2,3**).




*Mean path of rays (k=1,2,3) entering in the Euro - Mediterranean domain from the Tropical Atlantic source*

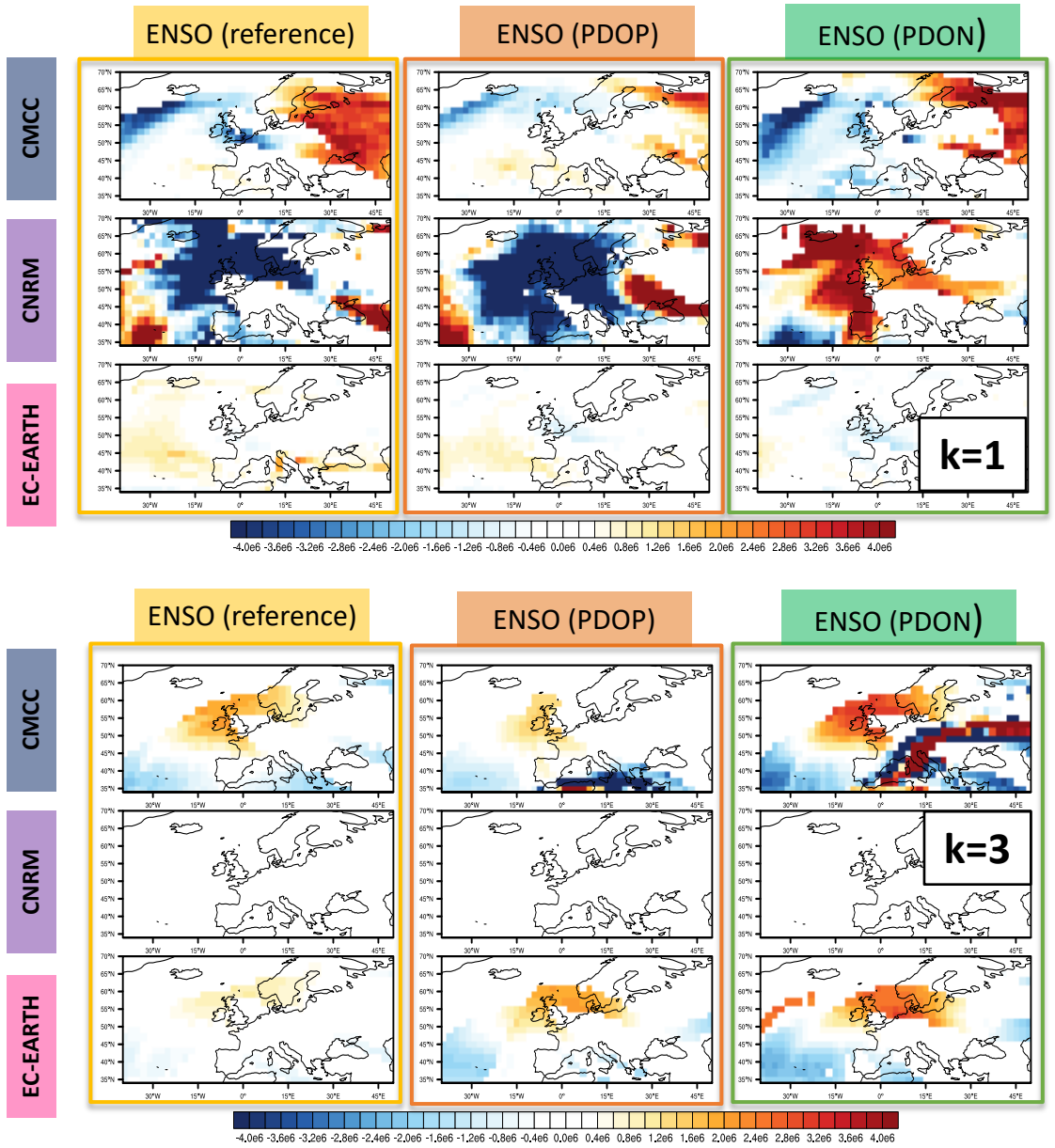
# Rossby Wave Ray tracing analysis (II)

Changes in the shape of the PDF maps compared to the benchmark ENSO signal suggest a possible **coherence mechanism**, with more (less) waves hitting the same region and consequently modifying the distribution of the anomalous momentum transported in the target domain.



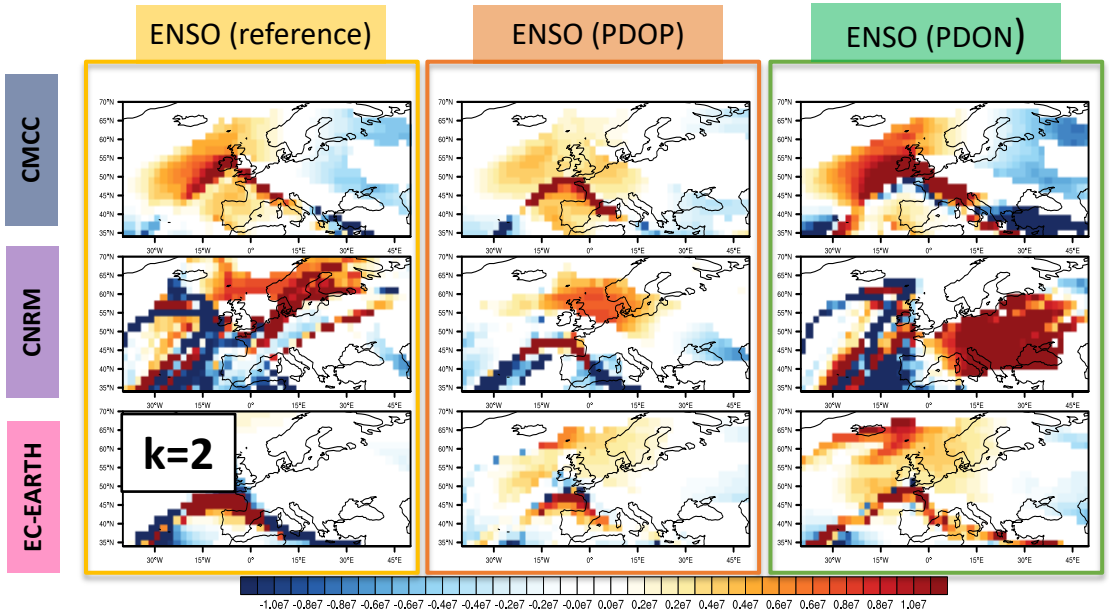

*2D probability density function map of rays (k=1,2,3) entering in the Euro - Mediterranean domain*

# Rossby Wave Ray tracing analysis (III)




The **anomalous stream function** is estimated separately for each wavenumber (k=1,2,3) under a zonal approximation:

$$\psi(x,y) = \psi_0 exp\left[i(kx + \int^y ldy)\right]$$




The sign of the patterns strongly depends on the (arbitrary) initial condition sign. However, some evidence of a reinforcement/damping mechanism is found (in particular for CMCC and EC-EARTH), showing some coherence with the modulation observed in the teleconnection patterns.

# Take-home messages

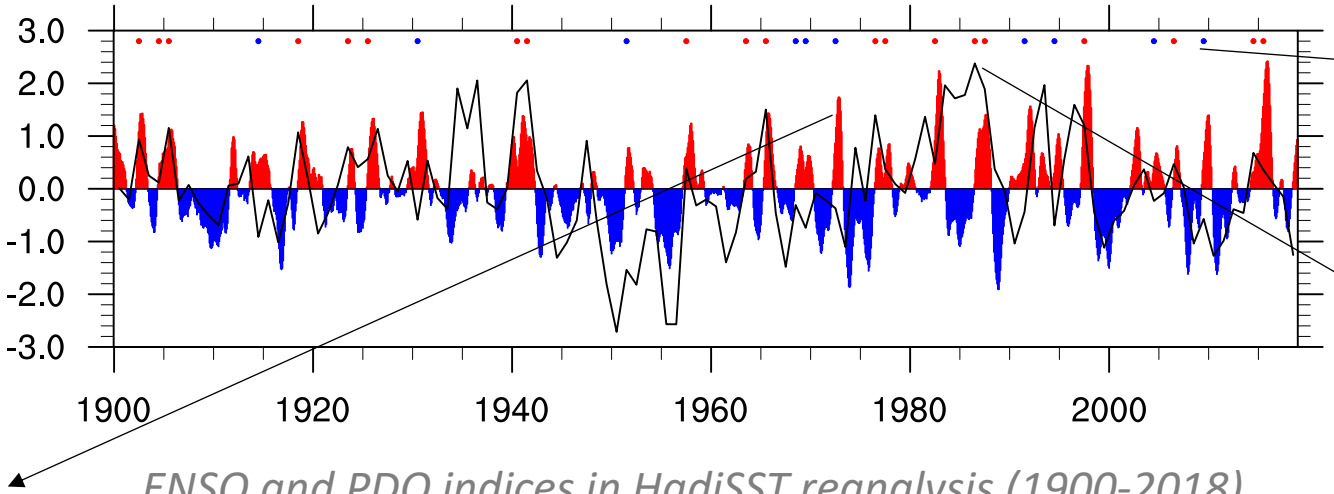
The aim of this research is to study if and how the **low frequency variability** over the extratropical Pacific affects the **ENSO teleconnection** over **the Euro-Mediterranean domain**.

- From our sensitivity analysis we have detected a **statistically significant spread** of the **El Nino signal** both with and without the extratropical PDO forcing
- Some **modulation** of the ENSO fingerprint due to the different extratrpical PDO phases has been found. This modulation is concentrated over the North Atlantic sector and its features are **model-dependent**.
- The Rossby wave ray tracing analysis suggests a possible **coherence** and incoherence interference **mechanism**, consistent with the amplified or dampened teleconnection patterns.

The Tropical Atlantic region is just one of the possible sources linked to the teleconnection mechanism based on the propagation of planetary waves. Its position far from the jet allows to detect a modulation in the propagation through the Rossby wave ray tracing analysis. However, in order to explain the entire El Nino pattern the complete set of possible sources should be taken into account.

# BACKUP SLIDES

# ENSO and PDO in observational records



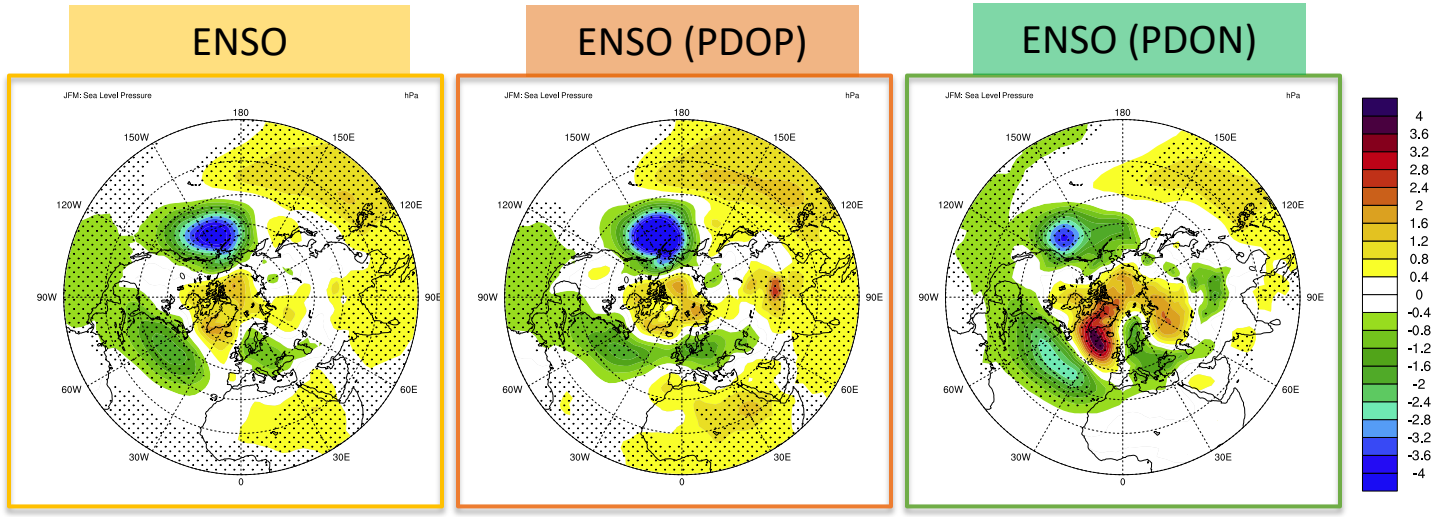

sign of the PDO phase (+/-) corrisponding to different El Nino events

**PDO index**

*ENSO and PDO indices in HadiSST reanalysis (1900-2018)*

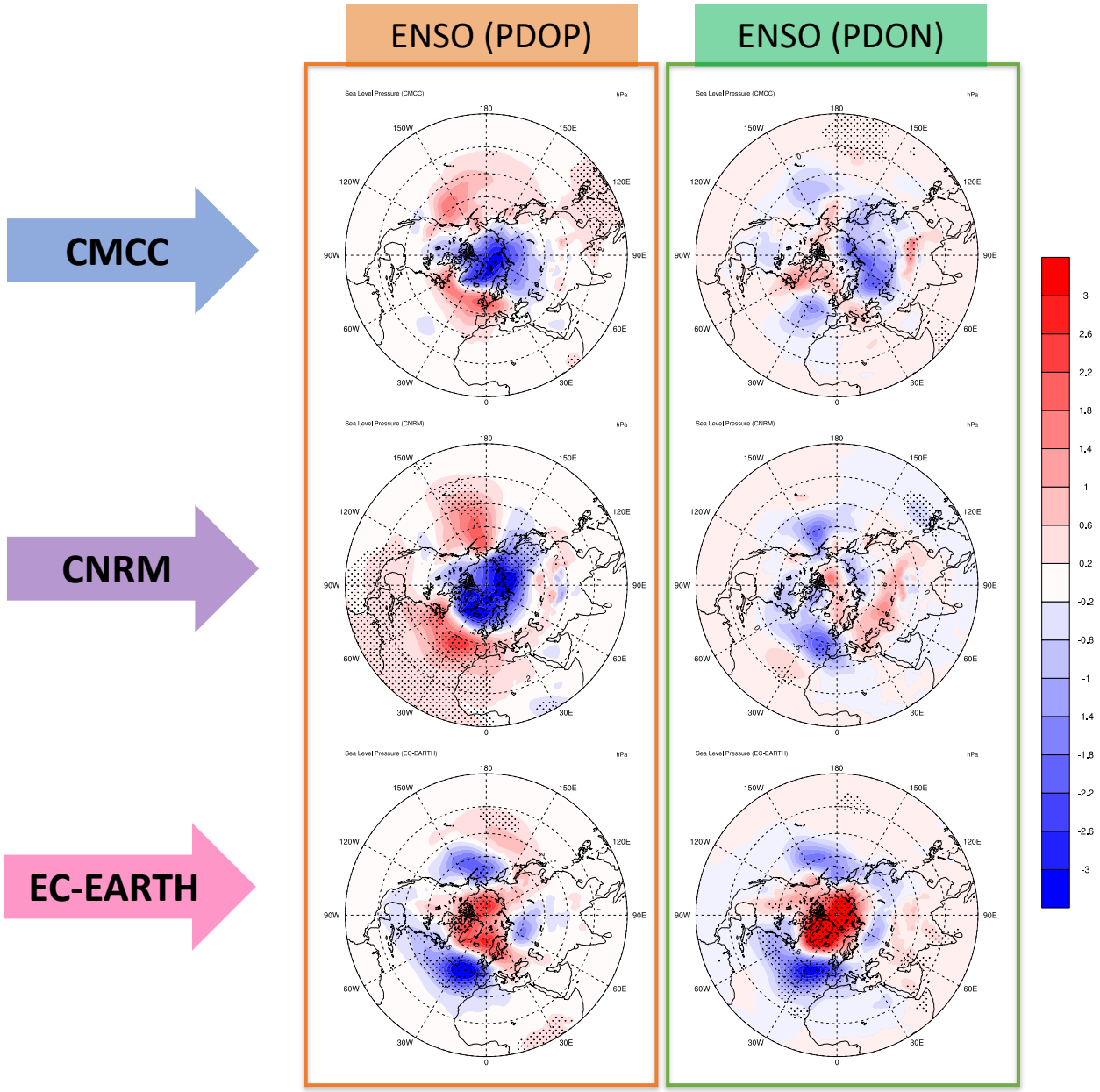
**NINO3.4 index**

From the composite of El Nino events under different PDO phases, some modulation of the El Nino signal is found, decoupled between the Pacific (Auletian low) and the Atlantic (Atlantic dipole) sector.




*JFM MSLP composit from NCEP reanalysis (from 1949 to 2016)*

# JFM MSLP and PDO modulation



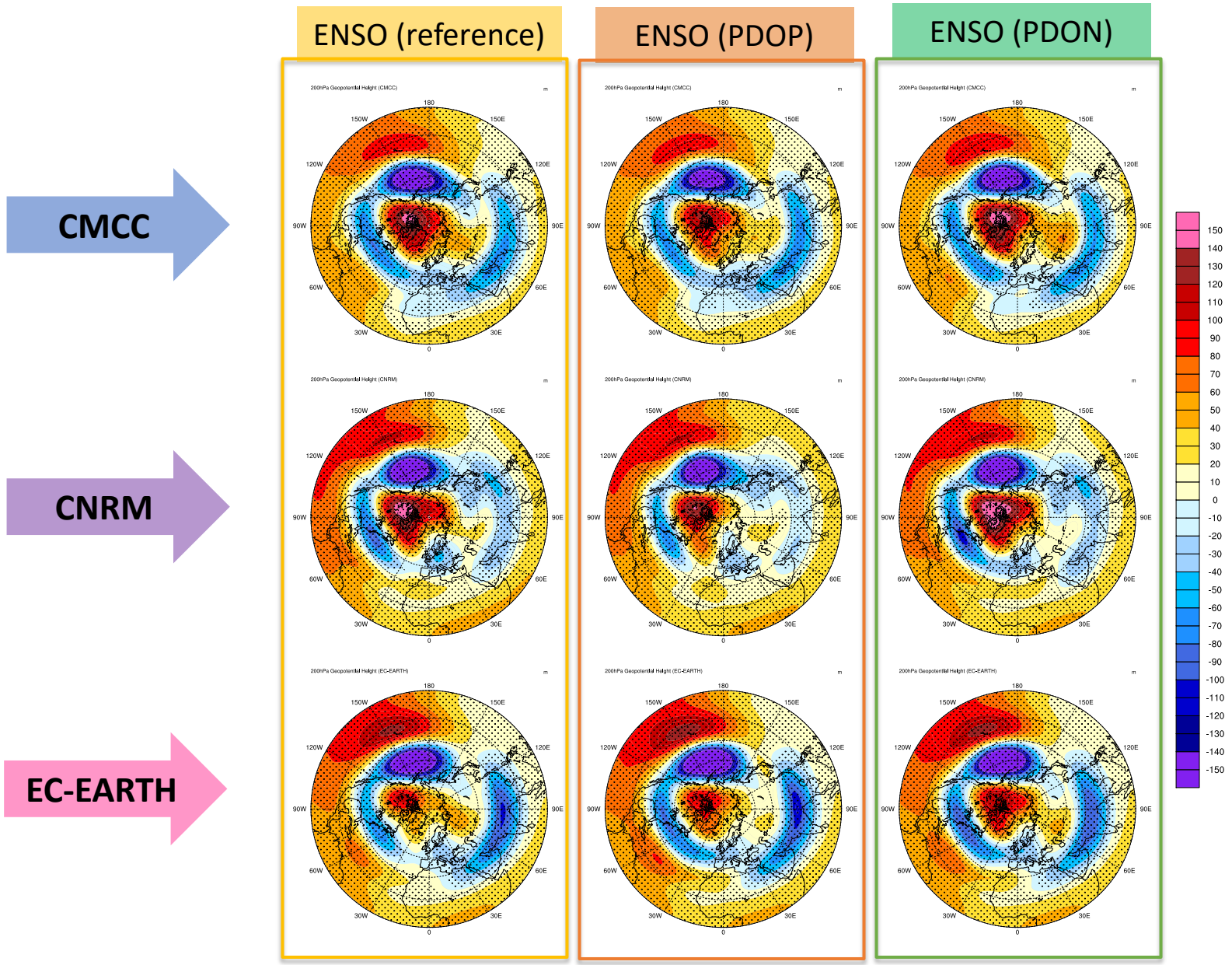

**PDOP modulation**

- CMCC/CNRM: weakening of Aleutian low/ NAO+ like-dipole
- EC-EARTH: reinforcement of Aleutian low/ NAO- like-dipole

**PDON modulation**

- CMCC/CNRM: reinforcement of Aleutian low/ NAO- like-dipole
- EC-EARTH: reinforcement of Aleutian low/ NAO- like-dipole

# ENSO signal and PDO modulation: JFM Z200




dotted areas: 95% confidence level

# El Nino induced JFM Rossby Wave Source

**CMCC**

**CNRM**

**EC-EARTH**