Revisiting the Historical Drying of the Mediterranean in the LargeEnsembleSingleForcingModelIntercomparisonProject Simulations

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Context and Objectives

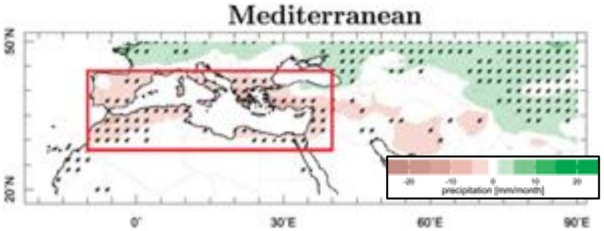
Context

- ❑ Ridging and Drying, associated with Climate Change, are projected across the Mediterranean.
- ❑ The degree of Medit. drying vary across models projections.
- ❑ Drying dynamical mechanism and signal emergence timing are not clear.

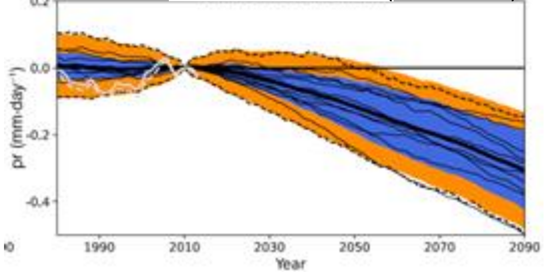
Objective

Use **LESFMIP** experiments to understand inter-model spread across models and explore the role of various climatic measures for the spread.

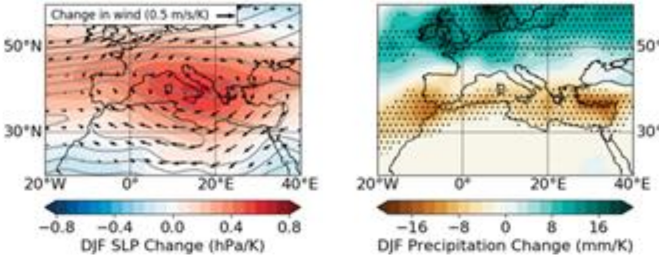
Winter Precip Trend 1901-2016



Annual mean anomalies (2001-2020)



Projected Change (2071-2100 vs 1976-2005)



R. Seager et al., J. Clim, 32, 2887 (2019)
R. Seager et al., Int. J. Climatol., 44, 3792 (2024)
A. Tuel et al. J. Clim. 33, 5828 (2020)

LESFMIP Data – Models Ensemble members

Exp. \ Model	ACC	Can	CMCC	FG	GISS	Had	IPSL	MIROC	MPI	Nor	CESM2
hist-GHG	10	50	10	3	43	55	10	50	30	23	15
hist-aer	3	30	10	3	45	55	10	10	30	23	
hist-AAER+hist-BMB											15

Σ members

hist-GHG: **299**

hist-aer: **219**

<u>Models</u>: ACCESS-ESM1-5, CanESM5, CMCC-CM2-SR5, FGOALS-g3, GISS-E2-1-G, HadGEM3-GC31-LL, IPSL-CM6A-LR, MIROC6, MPI-ESM1-2-LR, and NorESM2-LM

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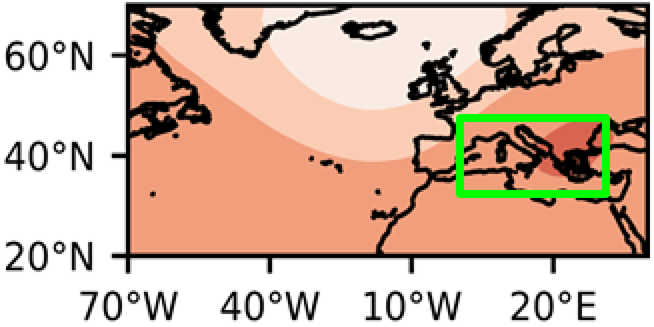
1. Analyzing **DJF** response and intermodel spread in the NA/Europe

Δ = 1990-2014 vs. 1851-1920



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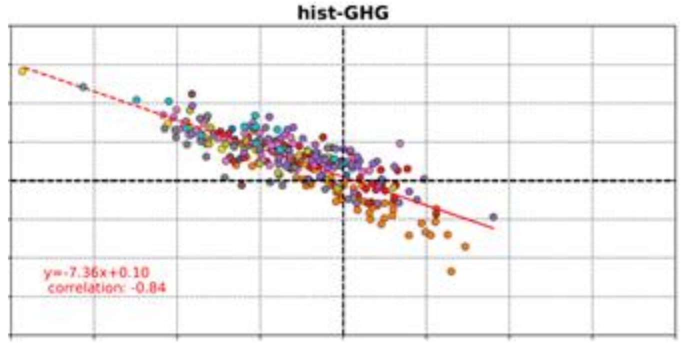
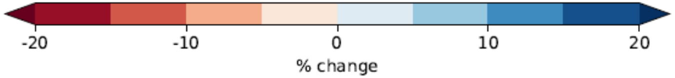
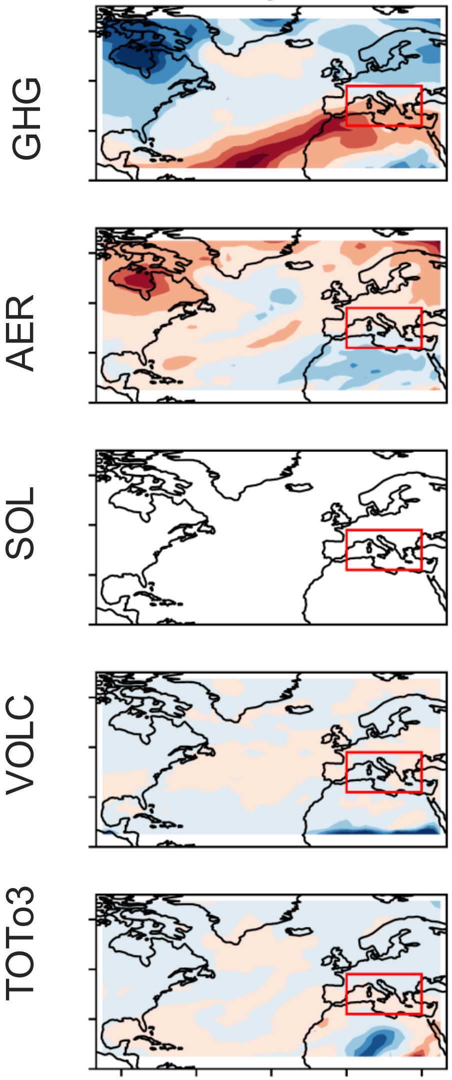
1. Analyzing **DJF** response and intermodel spread in the NA/Europe
2. Understand source of intermodel spread



1. Models' DJF Precip response

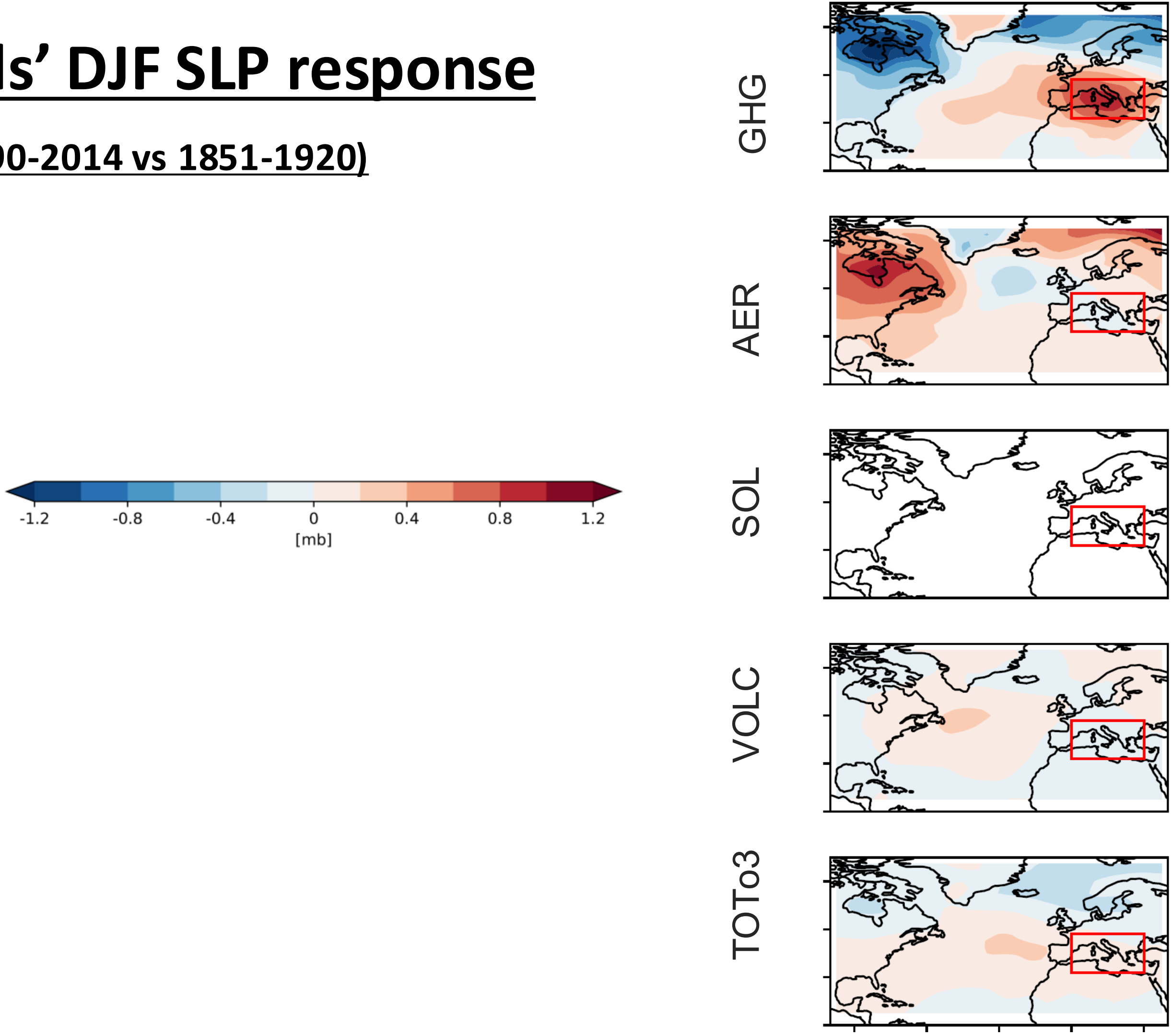
(1990-2014 vs 1851-1920)



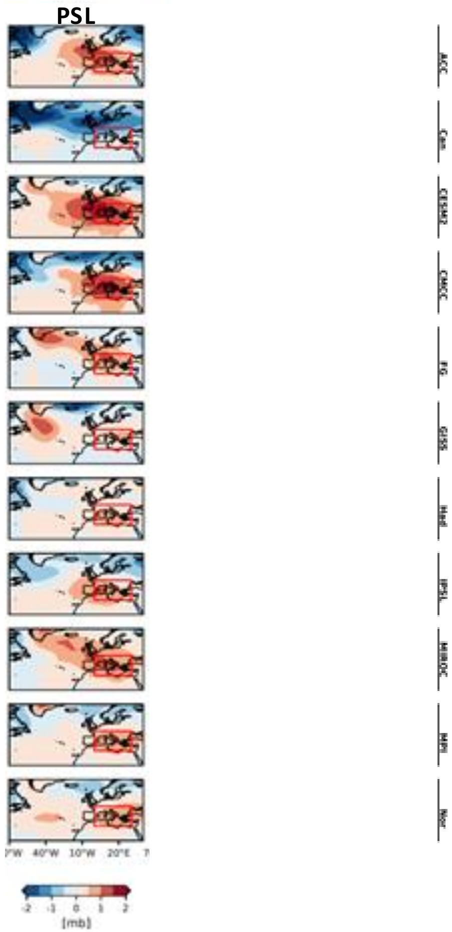


1. Models’ DJF SLP response

(1990-2014 vs 1851-1920)



1. Models’ DJF Responses Spread (1990-2014 vs 1851-1920)



hist-GHG

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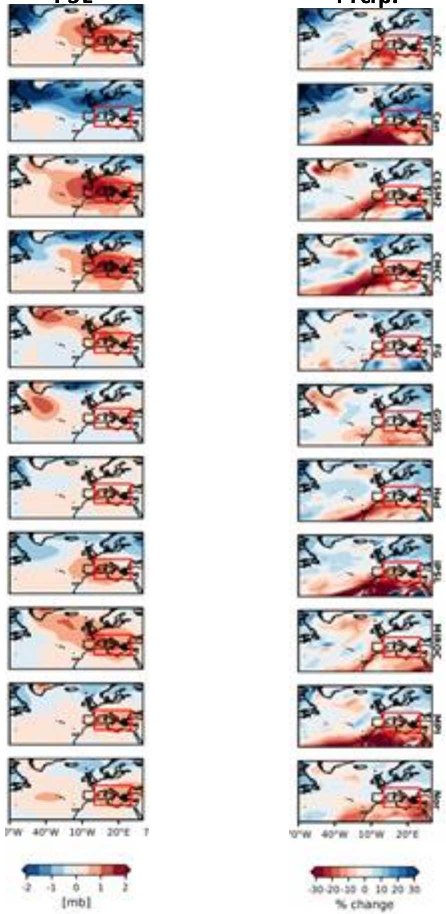
PSL Prcip.



hist-GHG

	hist-GHG
GPH @500hPa	+
PSL (Medit)	+
T2m	+ (*NA)
Prcip. (Medit)	-

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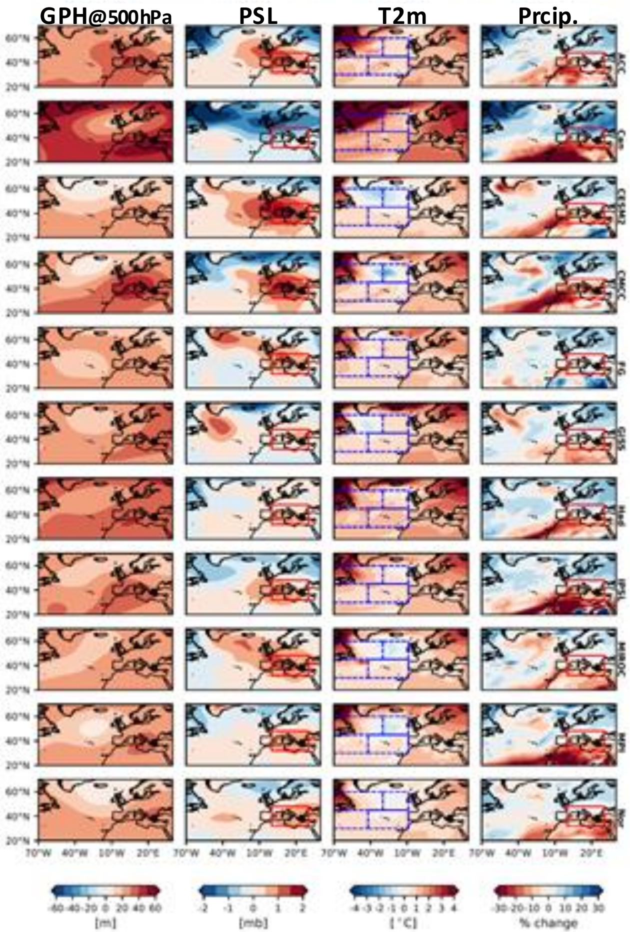

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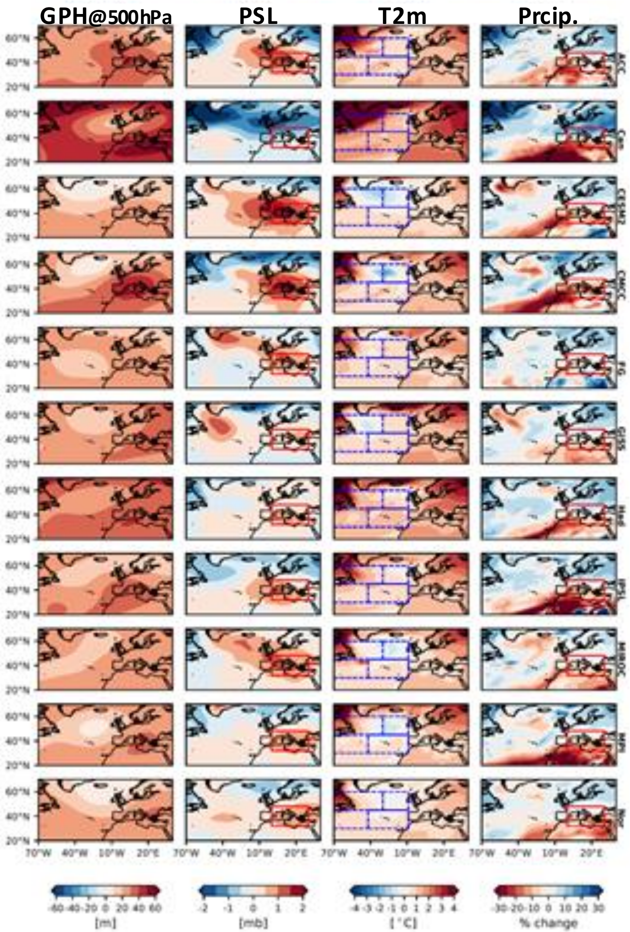
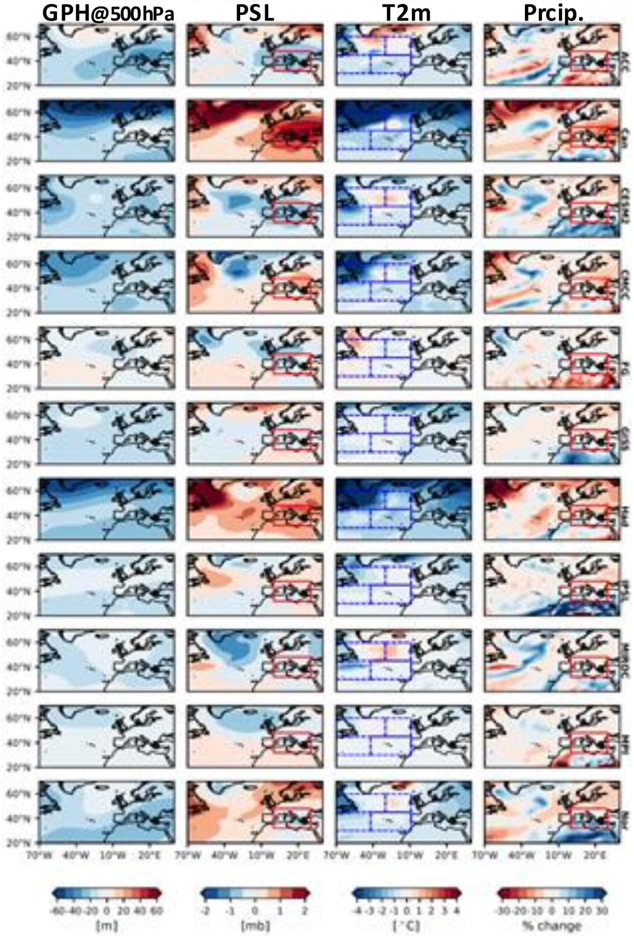


hist-aer



	hist-GHG	hist-aer
GPH @500hPa	+	-
PSL (Medit)	+	-
T2m	+ (*NA)	- (*NA)
Prcip. (Medit)	-	+

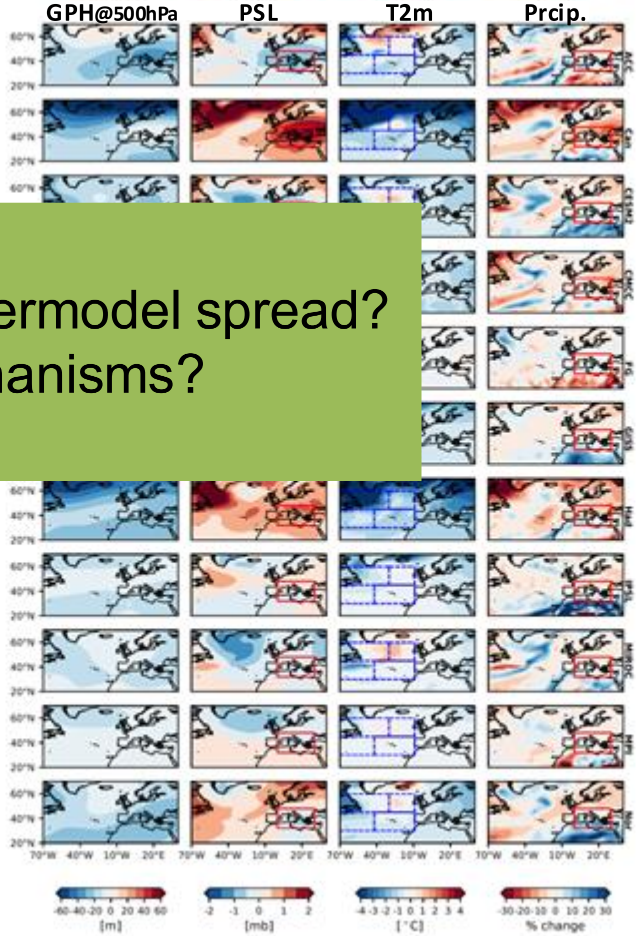
1. Models' DJF Responses Spread (1990-2014 vs 1851-1920)

hist-GHG

hist-aer

What might account for this intermodel spread?
Are there implications for mechanisms?

(Medit)	+	-
T2m	+ (*NA)	- (*NA)
Prcip. (Medit)	-	+



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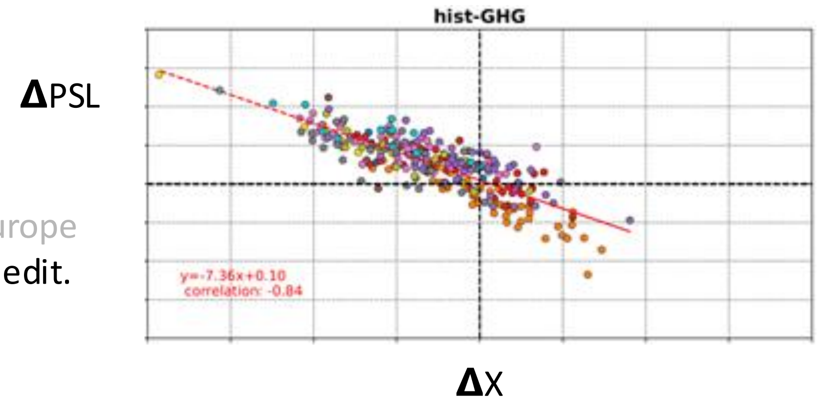
1. Analyzing models' **DJF** responses spread across the NA/Europe
2. Correlate **DJF** spread of Pressure@Sea-Level across the Medit. with spread of various measures, X:

X = Medit Land-Sea contrast, NA/Global t2m, SPV, etc.

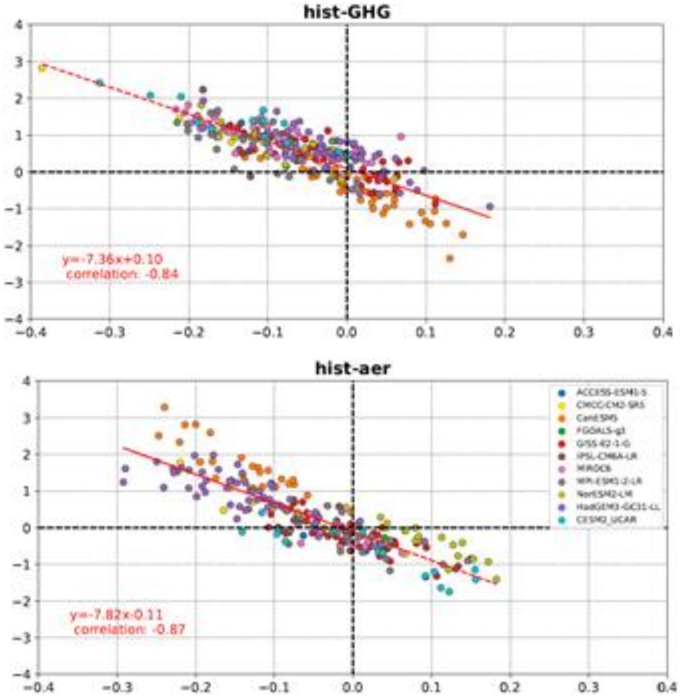


2. ΔPSL response vs. ΔX response (1990-2014 vs 1851-1920)

X
Mediterranean land-ocean contrast
NA t2m, NW
NA t2m, NE
NA t2m, SE
NA t2m, SW
Global t2m
Stratospheric polar vortex
Polar amplification
Edge of tropical belt (ψ_{500})
Lat. of Sub-Trop. Jet (STJ)
Lat. of Eddy-driven Jet (EDJ)

Δ PSL

Δ PSL



Δ Medit. Precipitation (mm/day)

75% **drying** under GHG

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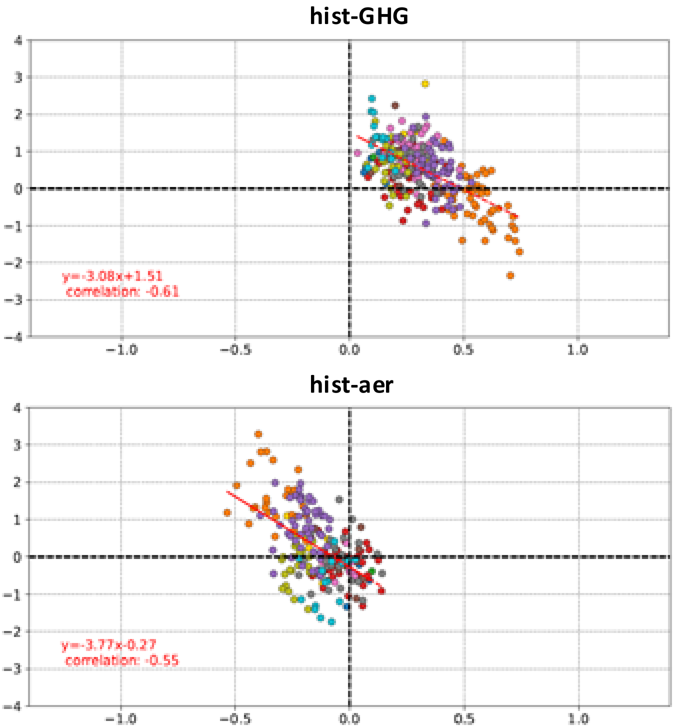
Opposite to
Tuel et al. J Clilm 2020

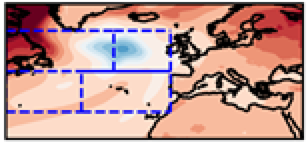
Δ PSL

Δ PSL



Δ Medit. Land-Sea Contrast (K)

2. ΔPSL response vs. ΔX response (1990-2014 vs 1851-1920)



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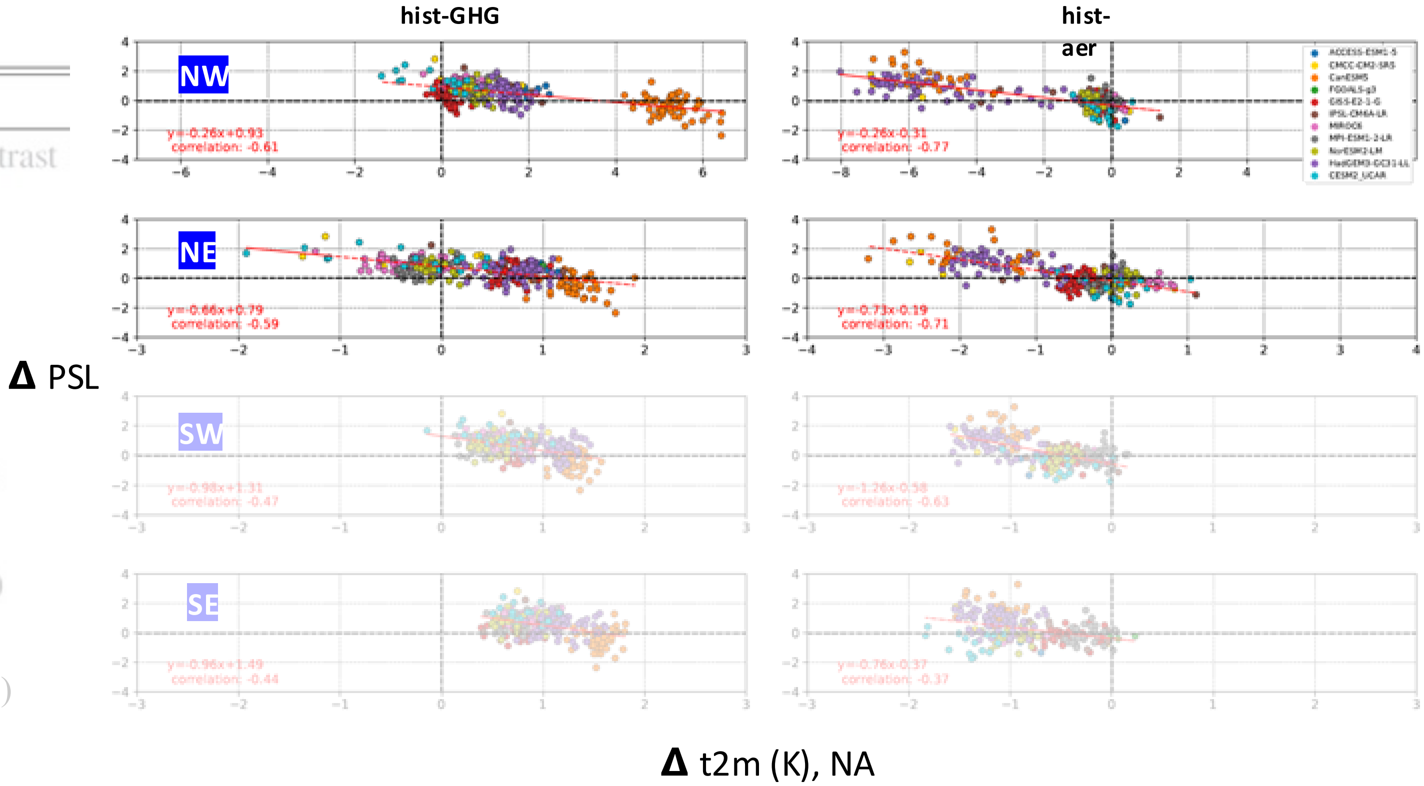

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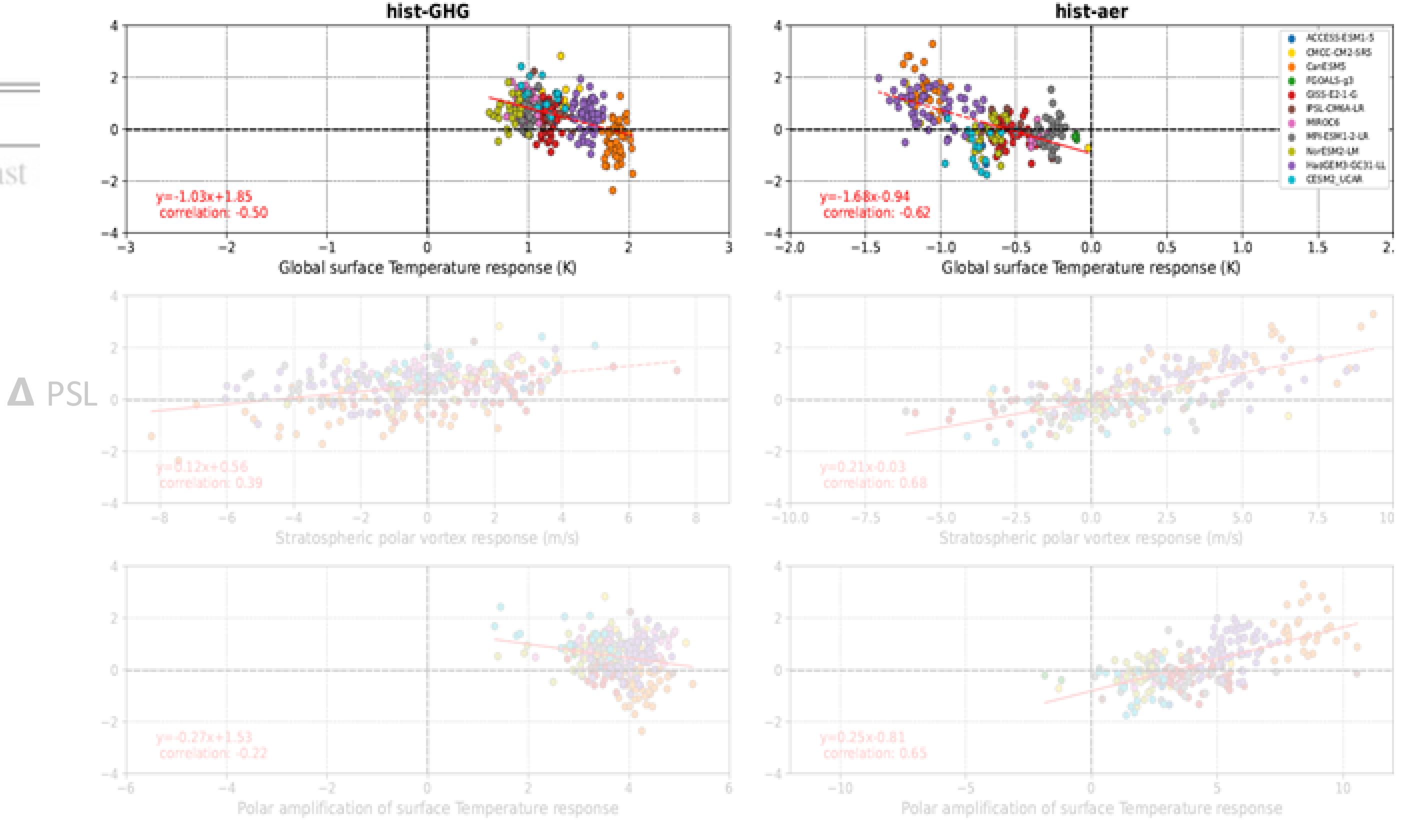

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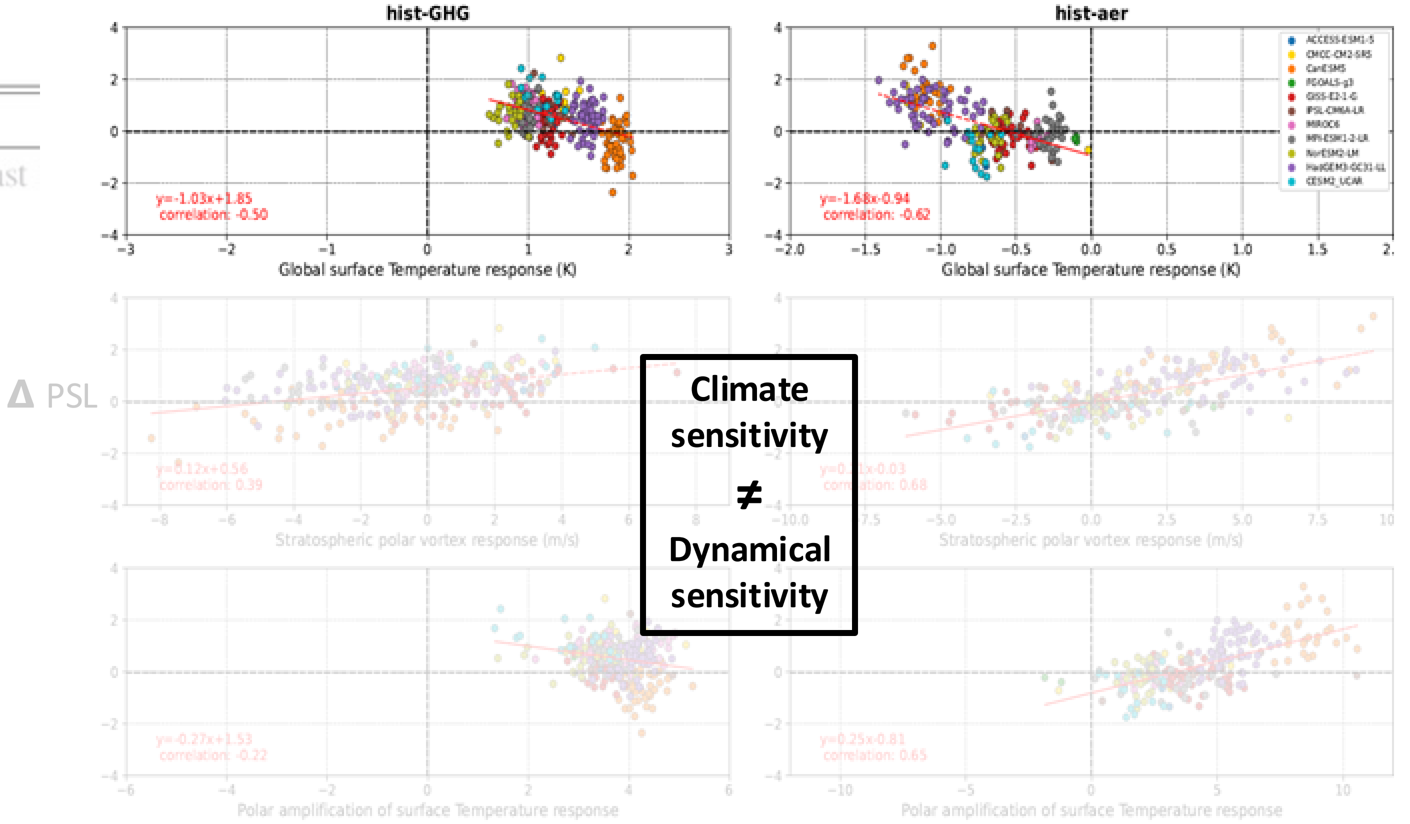

Climate sensitivity ≠ Dynamical sensitivity

2. ΔPSL response vs. ΔX response (1990-2014 vs 1851-1920)

X

Mediterranean land-ocean contrast

NA t2m, NW

NA t2m, NE

NA t2m, SE

NA t2m, SW

Global t2m

Stratospheric polar vortex

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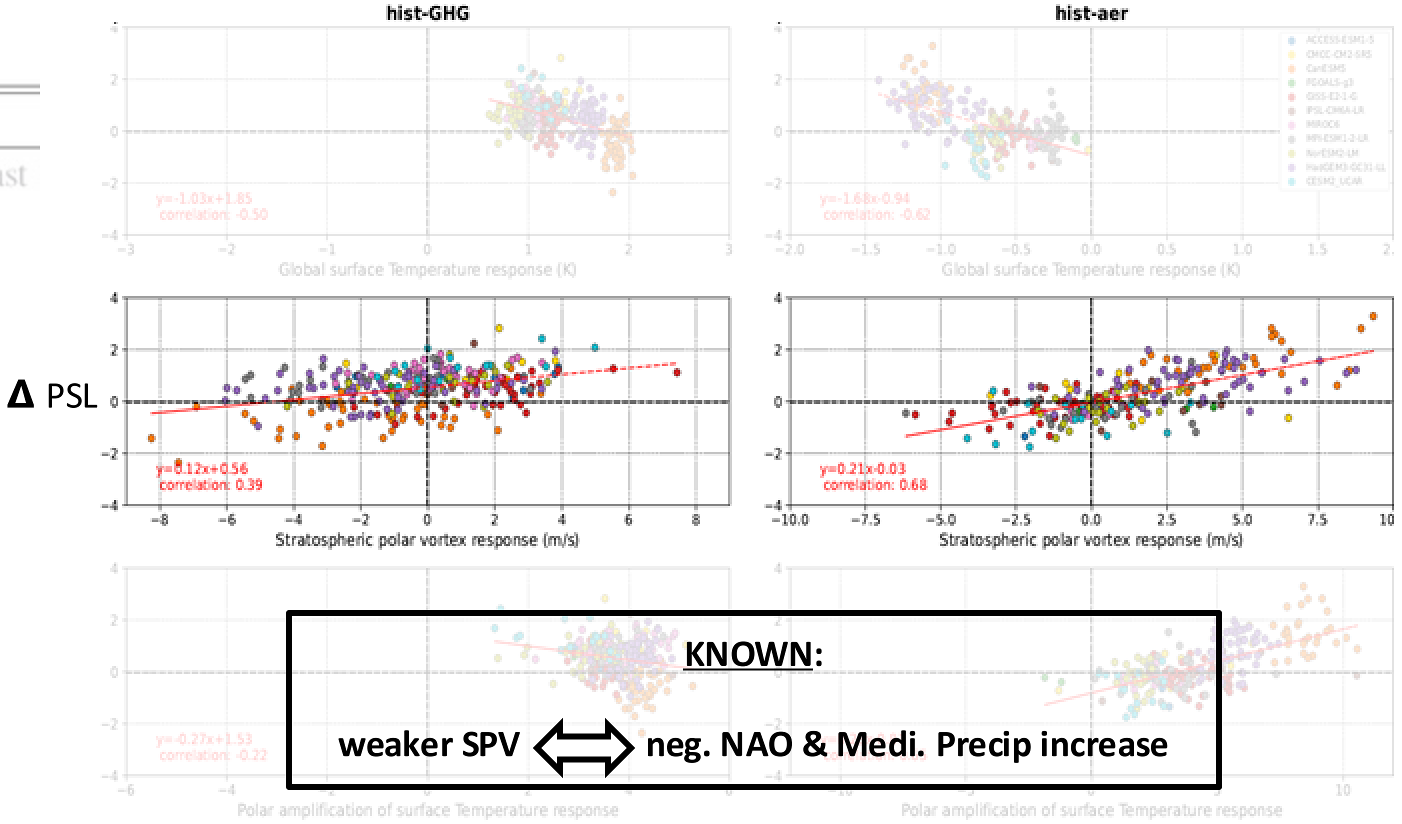

KNOWN:

weaker SPV ⟺ neg. NAO & Medi. Precip increase

2. ΔPSL response vs. ΔX response (1990-2014 vs 1851-1920)

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NA t2m, NW
NA t2m, NE
NA t2m, SE
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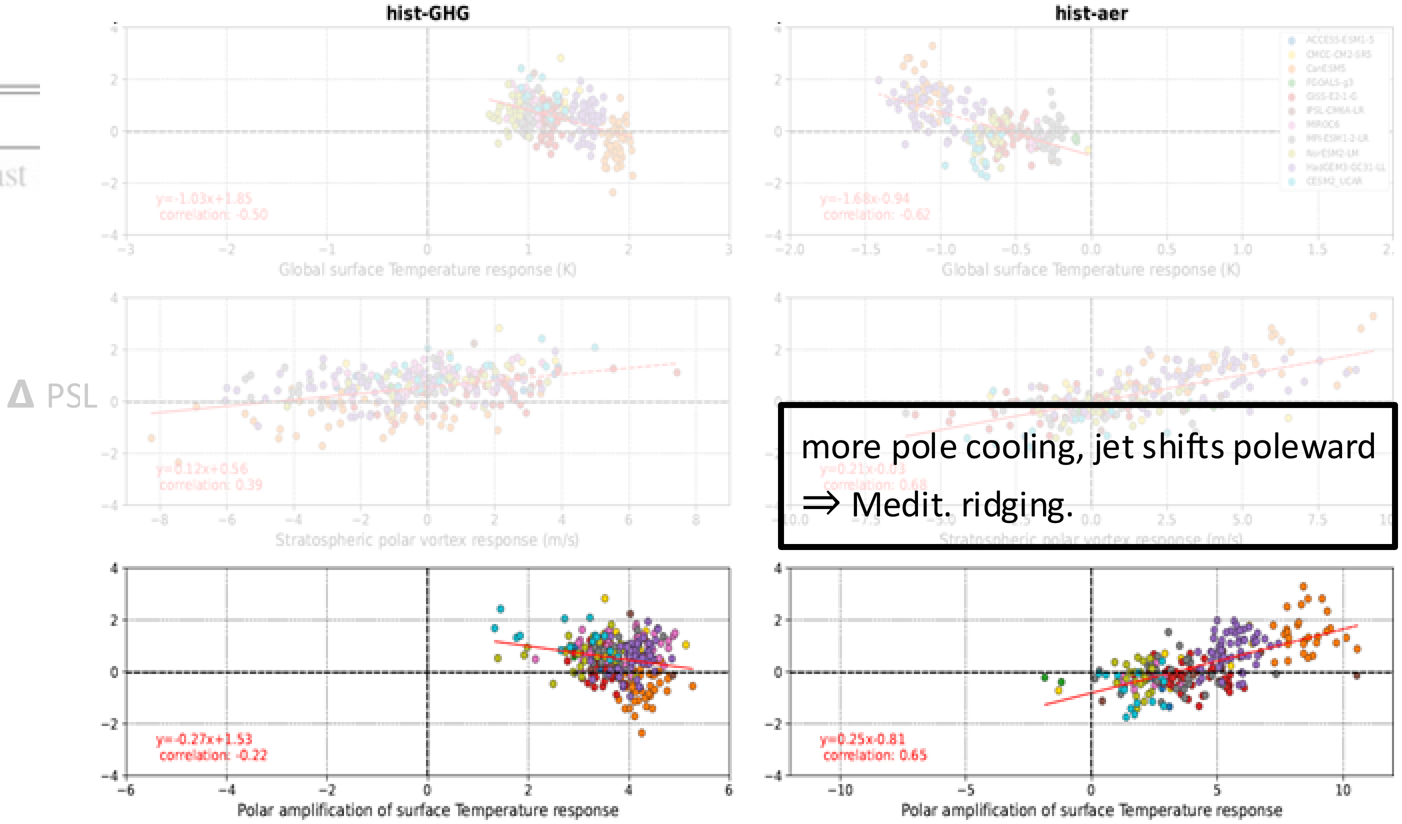

more pole cooling, jet shifts poleward
⇒ Medit. ridging.

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NA t2m, NW
NA t2m, NE
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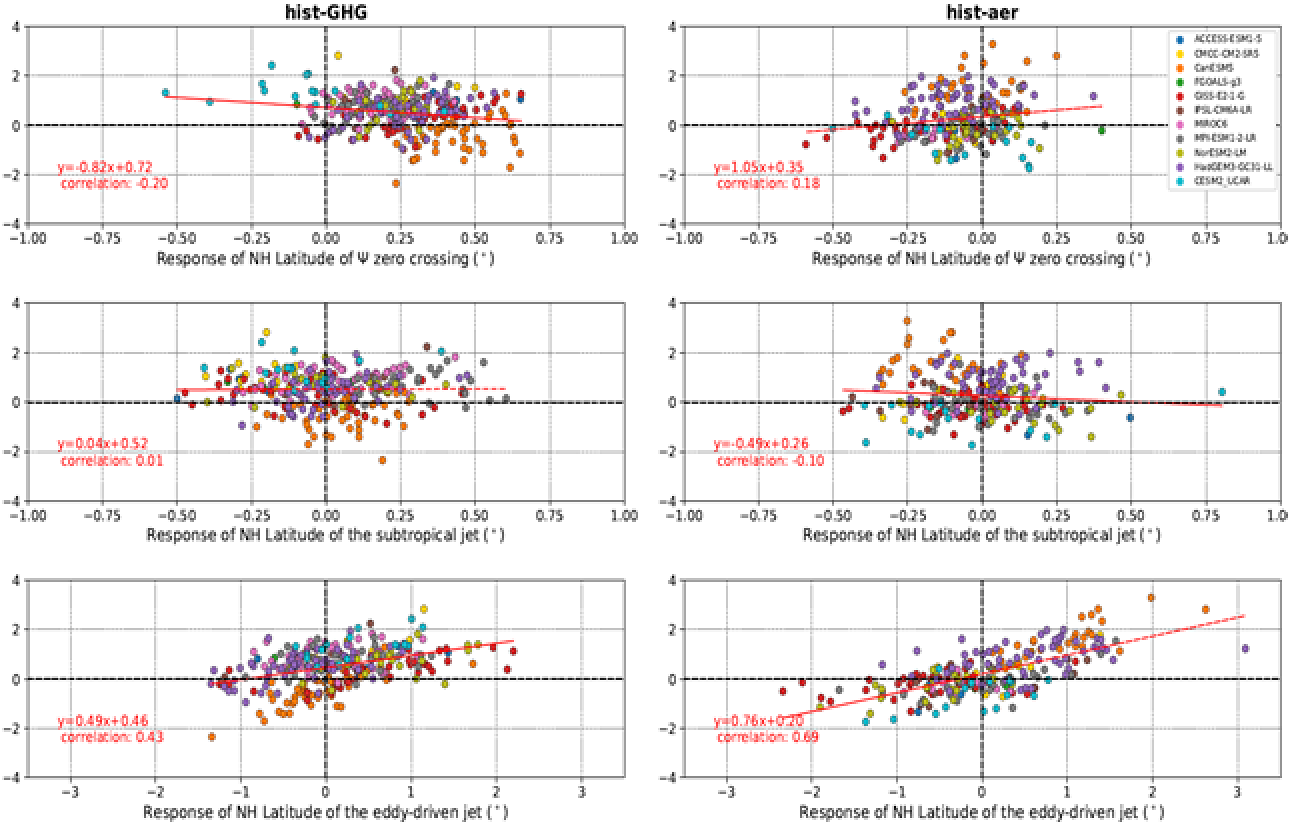
✗ Lat. of Sub-Trop. Jet (STJ)
✓ Lat. of Eddy-driven Jet (EDJ)

Δ PSL



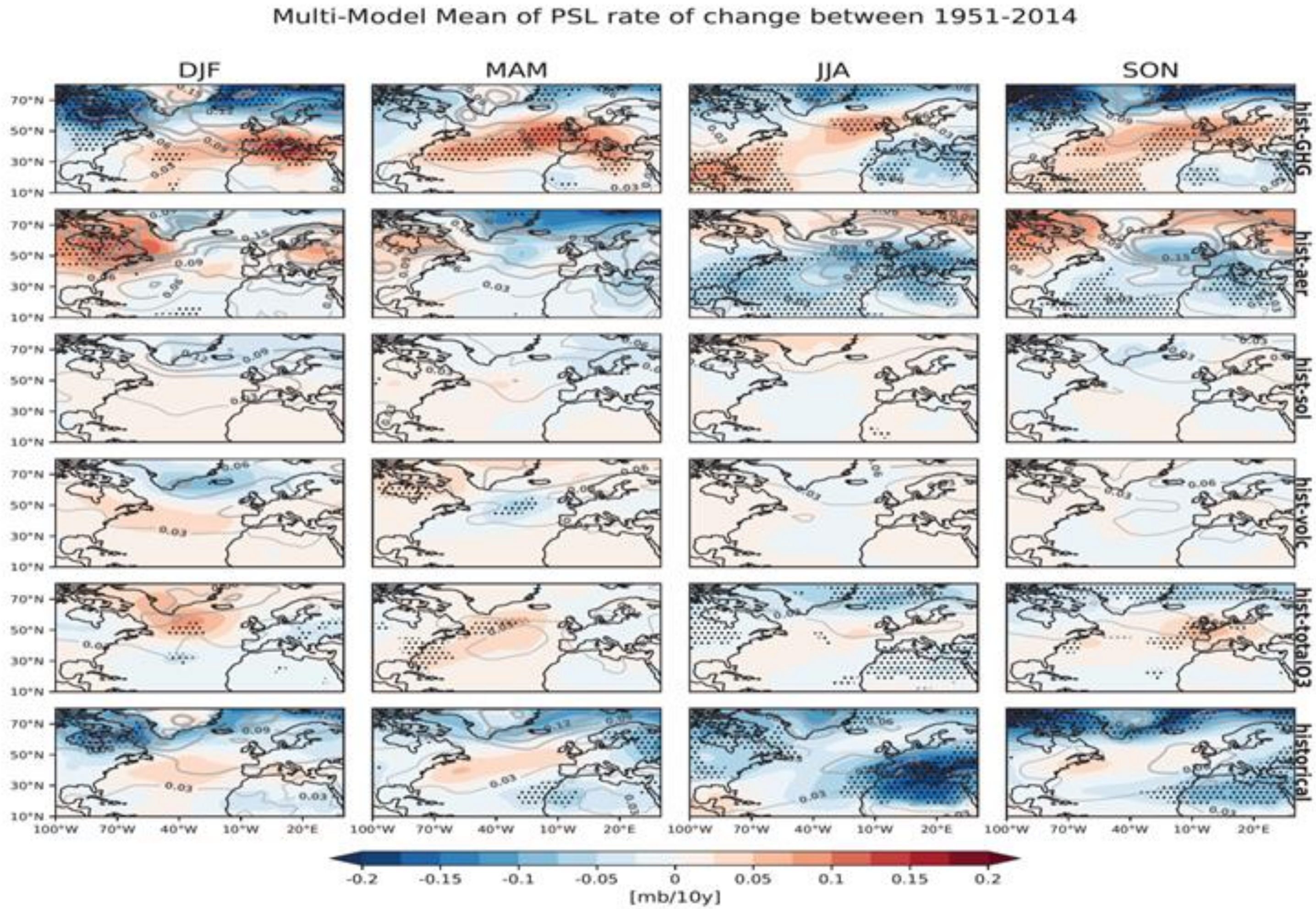
Conclusions

- Time varying GHG and aer single-forcings show comparable (opposite) impact on Medit. PSL (ridging and troughing); GHG show a clear Medit. drying signal.

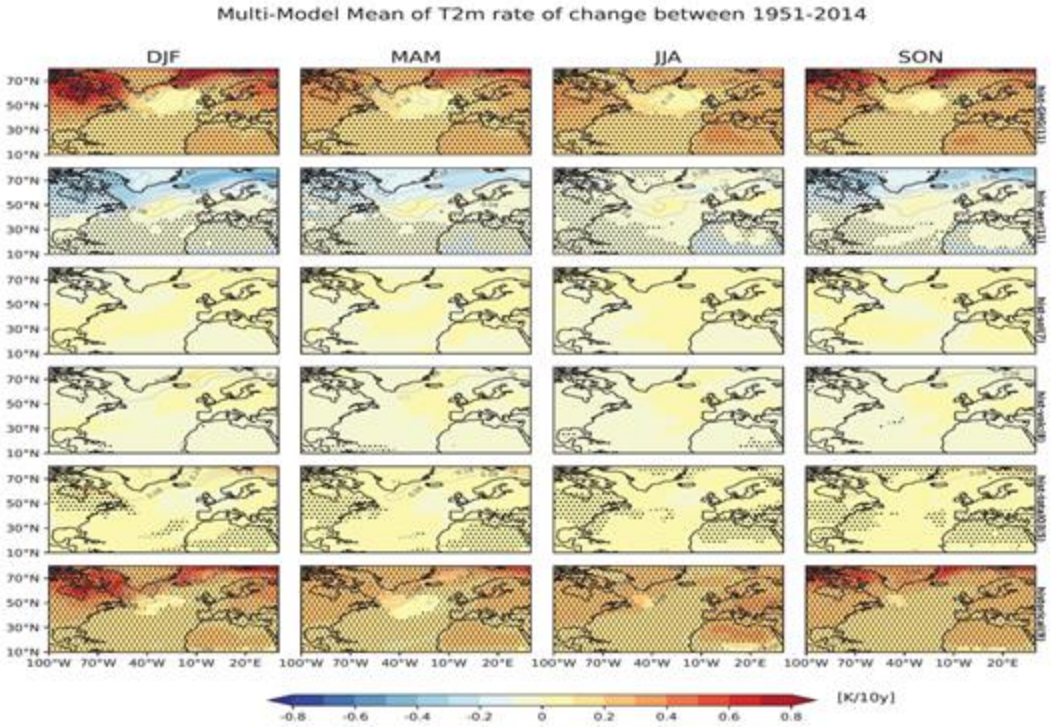
- There's a pronounced inter- and intra-model spread in PSL and Precip. response.

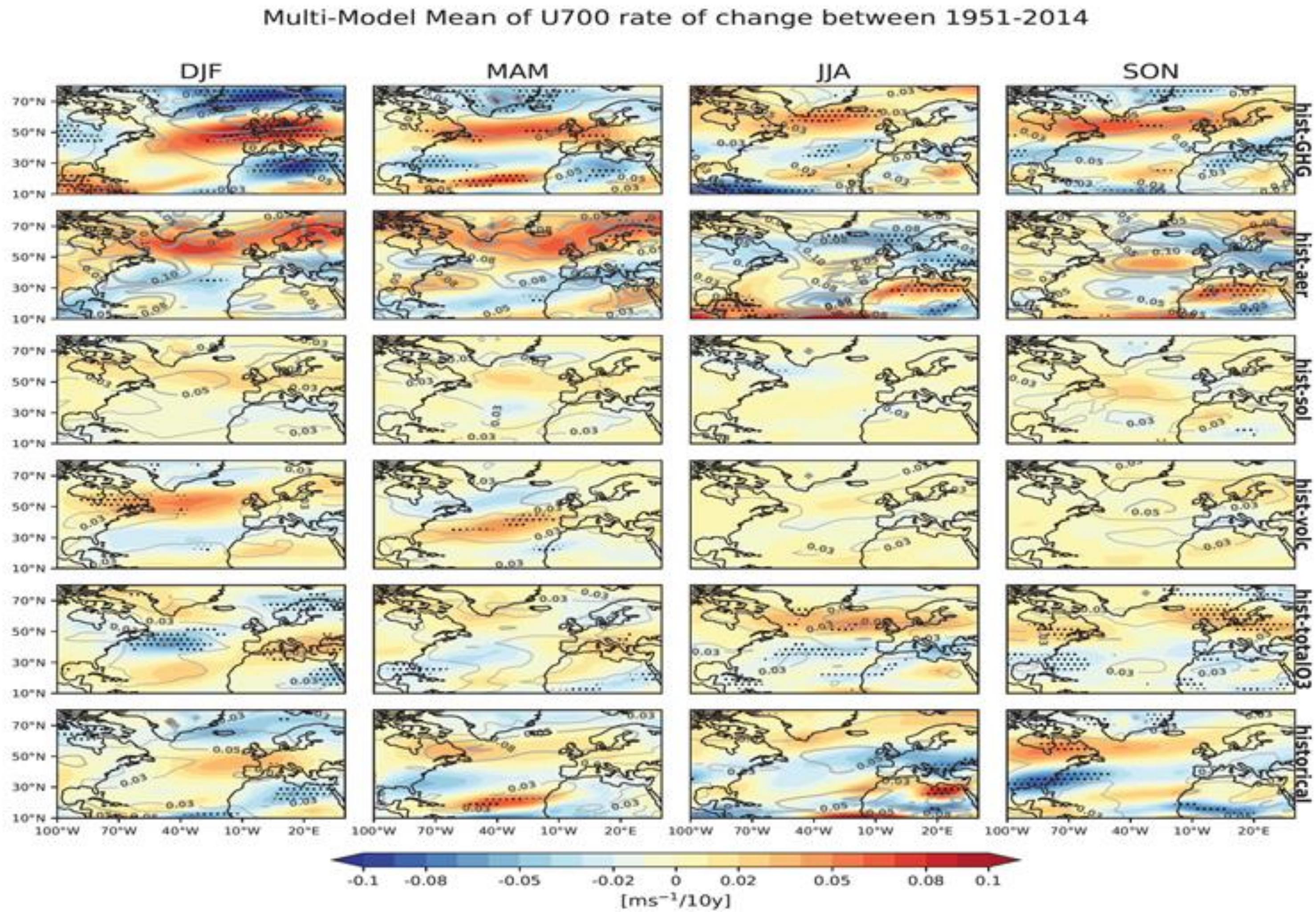
- Medit. ridging is related with:
  - a more pronounced NA warming hole,
  - a stronger SPV,
  - a larger poleward shift of the EDJ,
  - a **decrease** of global mean temperature,
  - a **cooler** land relative to Medit. sea

- Further work:
  - Partitioning uncertainties
  - Reduce uncertainty based on emergent constraints, with the help of obs

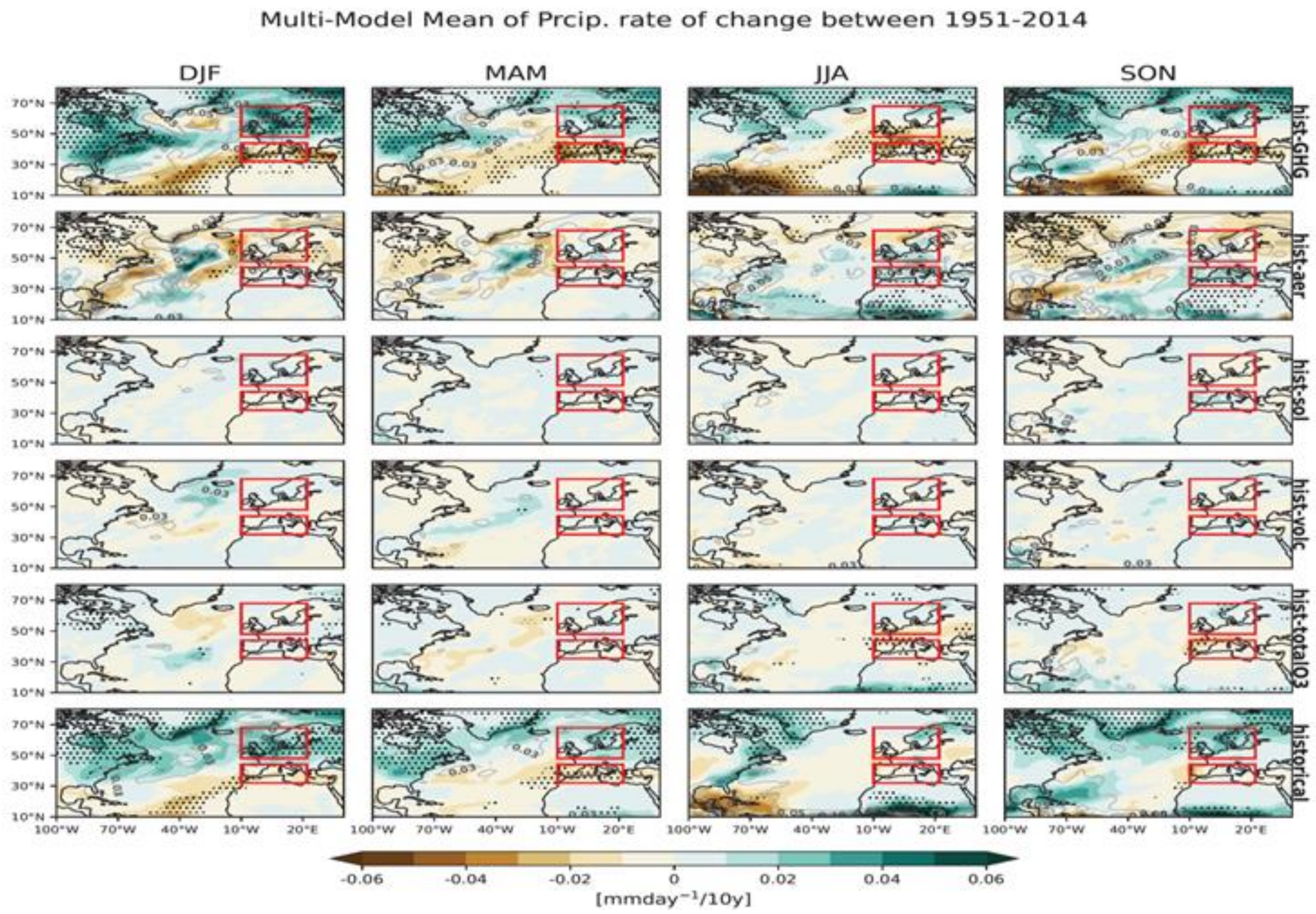


Multi-Model Mean of PSL rate of change between 1951-2014
DJF
MAM
JJA
SON
hist-GHG
hist-aer
hist-sol
hist-volc
hist-totalO3
historical
70°N
50°N
30°N
10°N
100°W
70°W
40°W
10°W
20°E
-0.2
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
[mb/10y]


Multi-Model Mean of T2m rate of change between 1951-2014
DJF
MAM
JJA
SON
70°N
50°N
30°N
10°N
100°W
70°W
40°W
10°W
20°E
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
[K/10y]



Multi-Model Mean of U700 rate of change between 1951-2014
DJF
MAM
JJA
SON
hist-GHG
hist-aer
hist-sol
hist-volc
hist-totalO3
historical
70°N
50°N
30°N
10°N
100°W
70°W
40°W
10°W
20°E
-0.1
-0.08
-0.05
-0.02
0
0.02
0.05
0.08
0.1
[ms⁻¹/10y]


Multi-Model Mean of Prcip. rate of change between 1951-2014
DJF
MAM
JJA
SON
hist-GHG
hist-aer
hist-sol
hist-volc
hist-totalO3
historical
70°N
50°N
30°N
10°N
100°W
70°W
40°W
10°W
20°E
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
[mmday^{-1}/10y]

Experiment name	Description
hist-GHG	Well-mixed greenhouse-gas-only historical simulations (WMGHGs)
hist-aer	Anthropogenic-aerosol-only historical simulations (BC, OC, SO2, SO4, NOx, NH3, CO, NMVOC)
hist-sol	Solar-only historical simulations (solar irradiance)
hist-volc	Volcanic-only historical simulations (stratospheric aerosol)
hist-totalO3	Ozone-only historical simulations (stratospheric and tropospheric ozone)
hist-lu	Historical simulations with only land use changes

Mainly DAMIP simulations but >10 ensemble members from 1850-2020

Additional runs to assess non-linearity and sensitivity to background state

~13 modeling centers. Data from ten is already on ESGF. Three of the models spontaneously simulate a QBO.

Phase 2 (2026) will include operational decadal forecasts