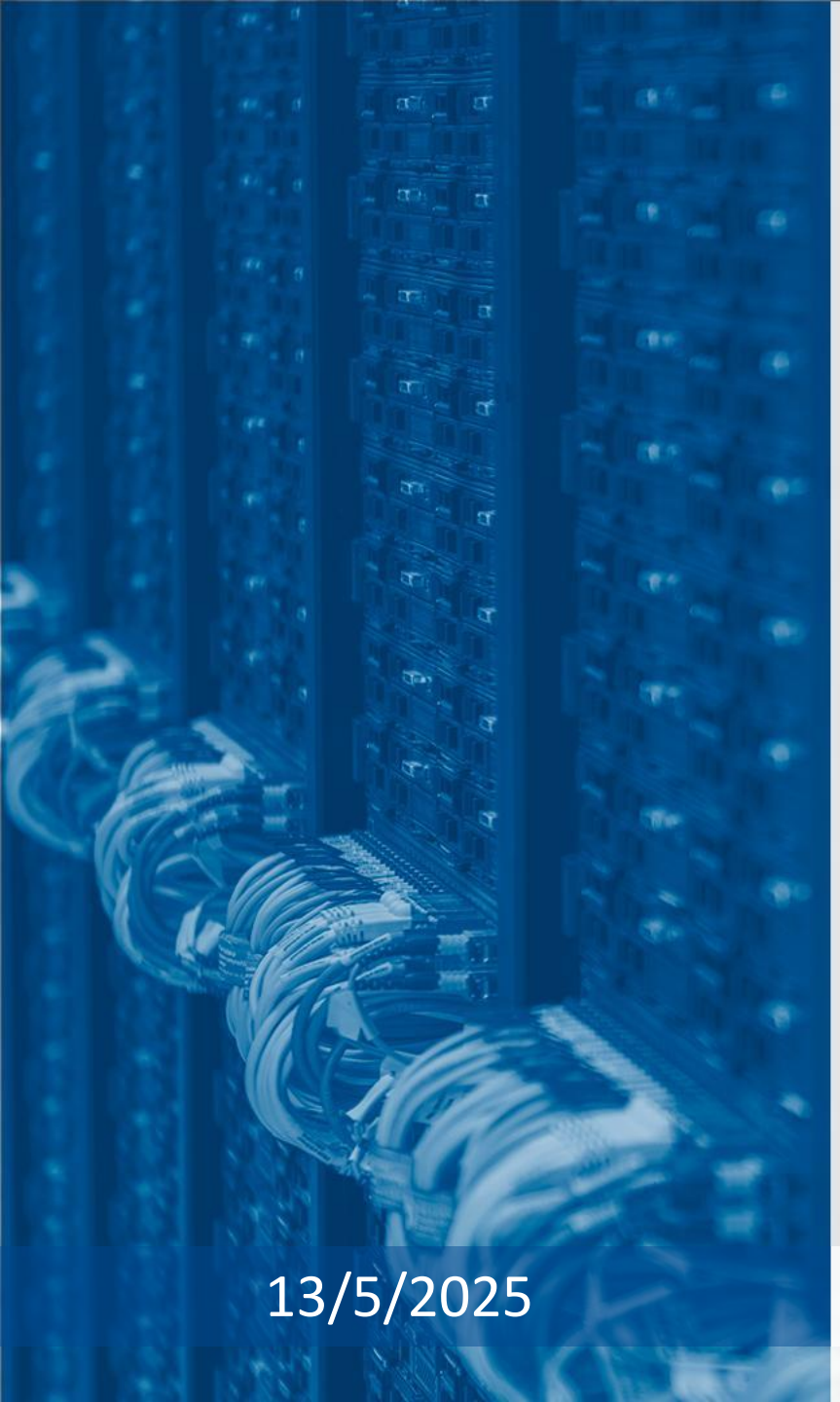

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Climate projections in the Euro-Mediterranean region: atmospheric circulation patterns, temperature and rainfall changes

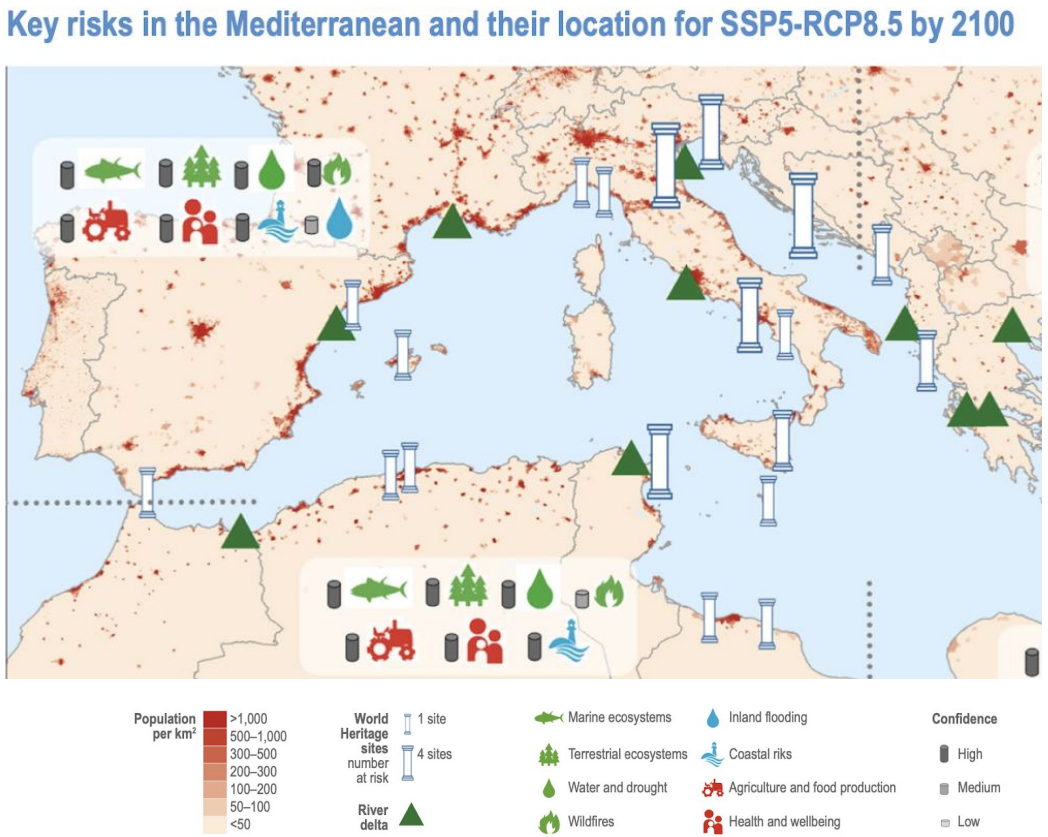
Matías Olmo, Cos P,Campos D, Muñoz A, Soret A, Doblas-Reyes F

Climate Services Team - Earth Sciences Department BSC-CNS

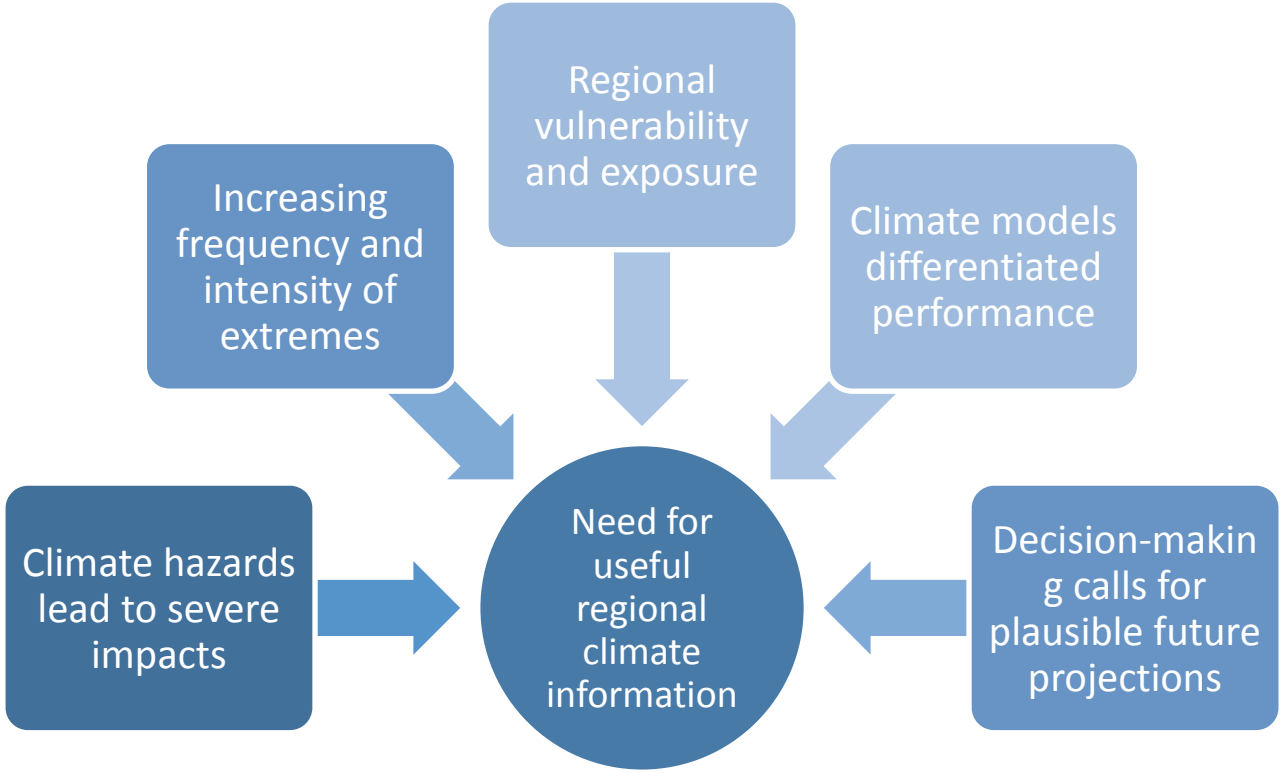
13/5/2025

ICTP 6th Summer School on Theory, Mechanisms and Hierarchical Modelling of Climate Dynamics

Motivation



IPCC AR6 WGII, CCP4 Mediterranean Region.



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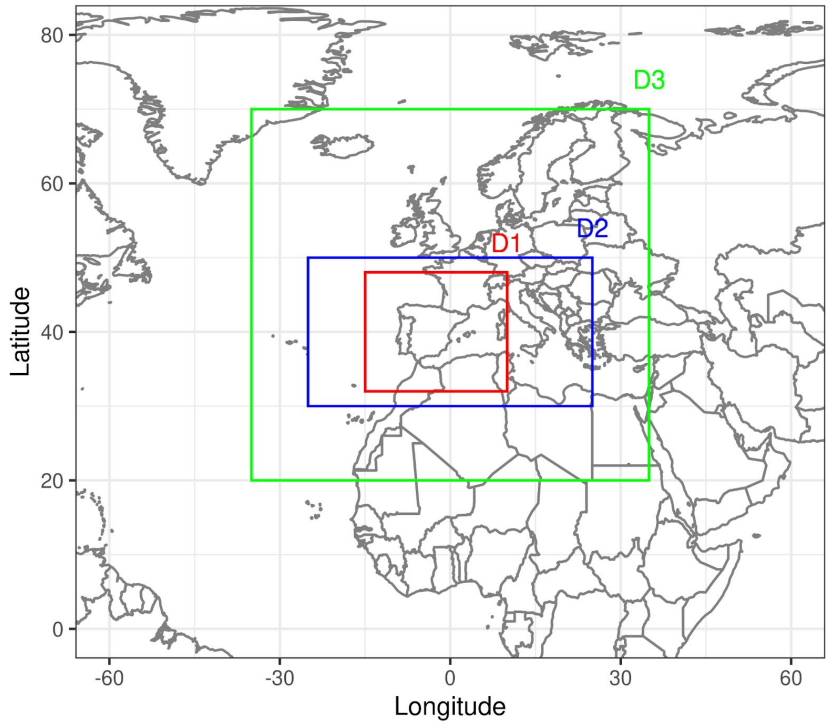
Objective

Design a process-based evaluation framework for CMIP6 GCMs based on atmospheric circulation patterns for climate diagnosis and performance ranking to get improved understanding of future projections.

Data



Blue box: circulation domain

ERA5 reanalysis reference (1950-2022)
26 CMIP6 GCMs (1950-2100)

Atmospheric circulation domains (historical)
Mean sea level pressure (SLP)
Geopotential Height (Z) at 500 hPa
Zonal and meridional winds at 850 hPa

Surface variables (historical)
Precipitation (PR)
Maximum temperature (TX)
Minimum temperature (TN)

Extreme indices (SSP585 vs. historical)
ETCCDI indices, such as: TNn, TXx, TN90p, TX90p and RX1day

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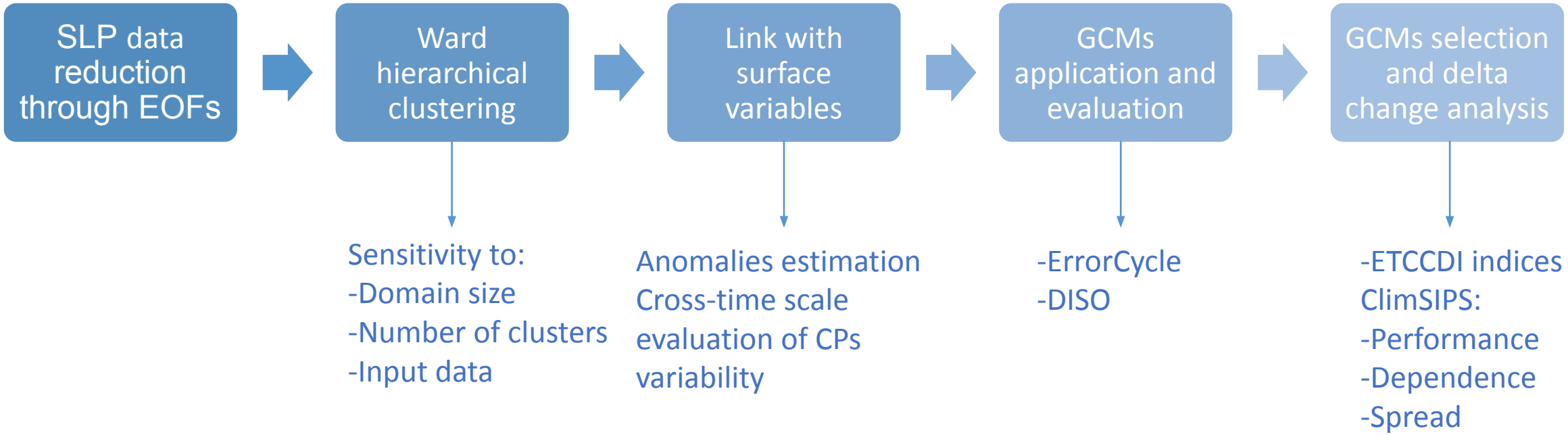
Olmo et al. (2024)
Journal of Climate DOI 10.1175/JCLI-D-23-0735.1

Methods and Workflow



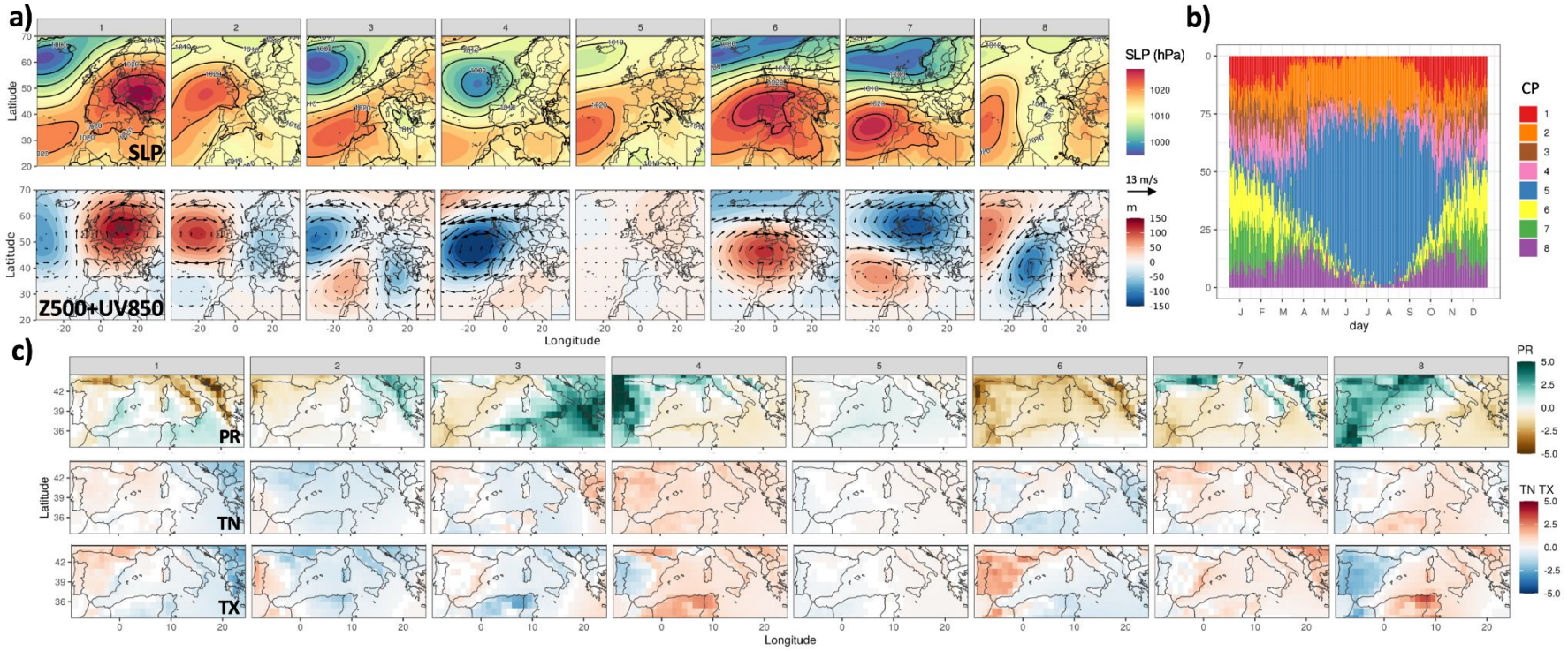
Reference CP classification

SLP structures present different mid-level geopotential and low-level wind anomalies

One dominant CP during summer (CP5, blue). Dry and warm conditions.

More patterns needed for winter and transition seasons.

Annual cycle of CPs frequency



Discriminated surface patterns (anomalies)

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Olmo et al. (2024)
Journal of Climate DOI 10.1175/JCLI-D-23-0735.1

Evaluation metrics

- *ErrorCycle*

Percentage of difference in the daily frequency of each CP.

$$Error_{CP} = \frac{\sum_{i=1}^{D} \left| fERA5_{CP}i - fGCM_{CP}i \right|}{D.fERA5_{CP}i}$$

Olmo et al. 2022
Agudelo et al. 2023

- *Distance between Indices of Simulation and Observation (DISO)*

Summary of a Taylor Diagram.

$$r = \frac{\sum_{k=0}^{n}(a_i - \bar{a})(b_i - \bar{b})}{\sqrt{\sum_{k=0}^{n}(a_i - \bar{a})^2}\sqrt{\sum_{k=0}^{n}(b_i - \bar{b})^2}},$$

$$\mathrm{AE} = \frac{1}{n}\sum_{k=0}^{n}(b_i - a_i),$$

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{k=0}^{n}(b_i - a_i)^2},$$

$$DISO = \sqrt{(r-1)^2 + NAE^2 + NRMSE^2}$$

DISO mean = weighted mean of PR, TN and TX DISOs

Hu et al. 2018
Liu et al. 2018

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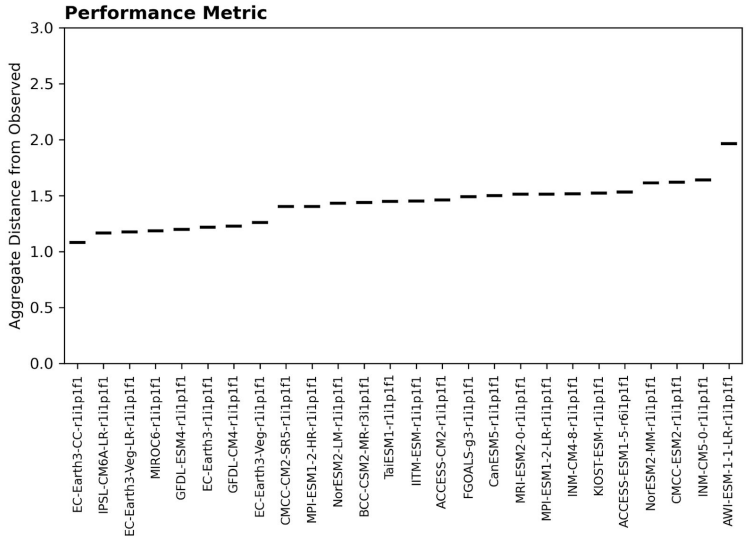
Model filtering

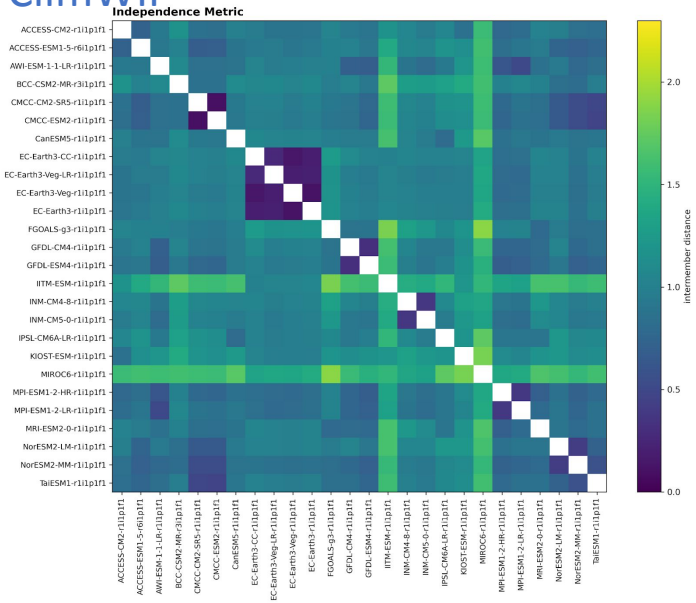
- *CPs framework (Olmo et al. 2022) + ClimSIPS (Merrifield et al. 2024)*

Suggests multi-model ensembles based on the degree to which the user prioritizes model performance (CPs evaluation), spread and independence (ClimSIPS).

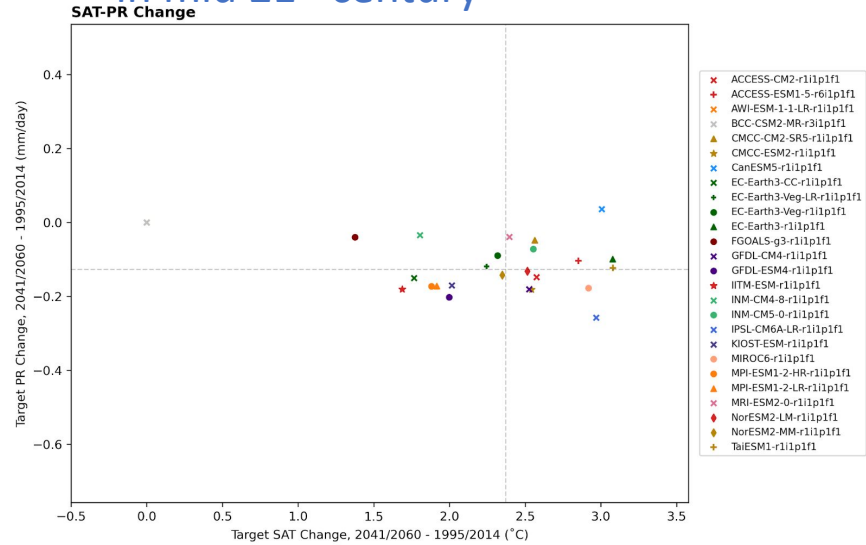
Circulation patterns framework



Similarities in global climatologies ClimWIP



Summer and winter T and PR changes in mid 21st century



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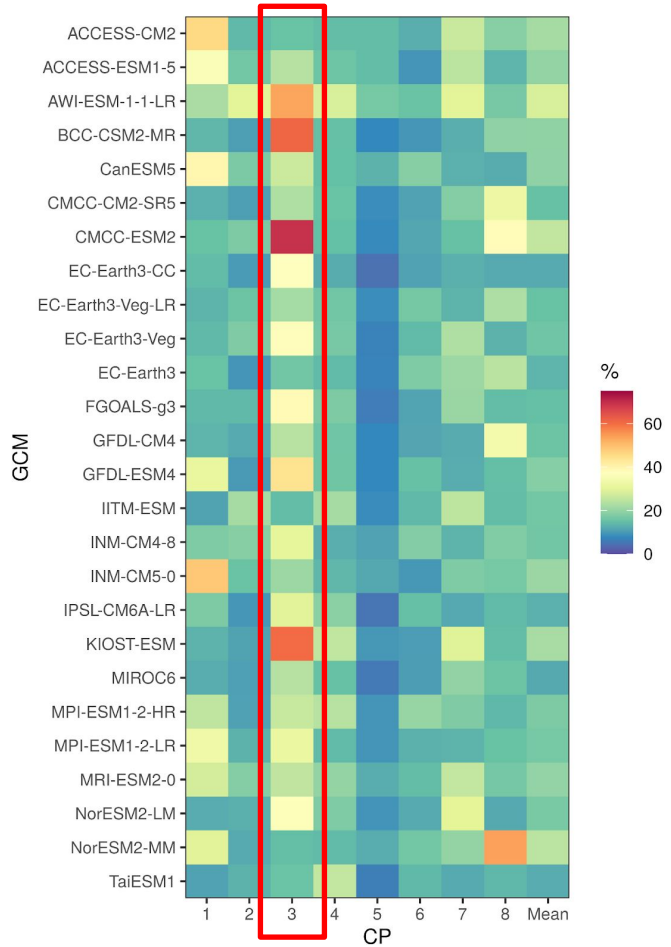
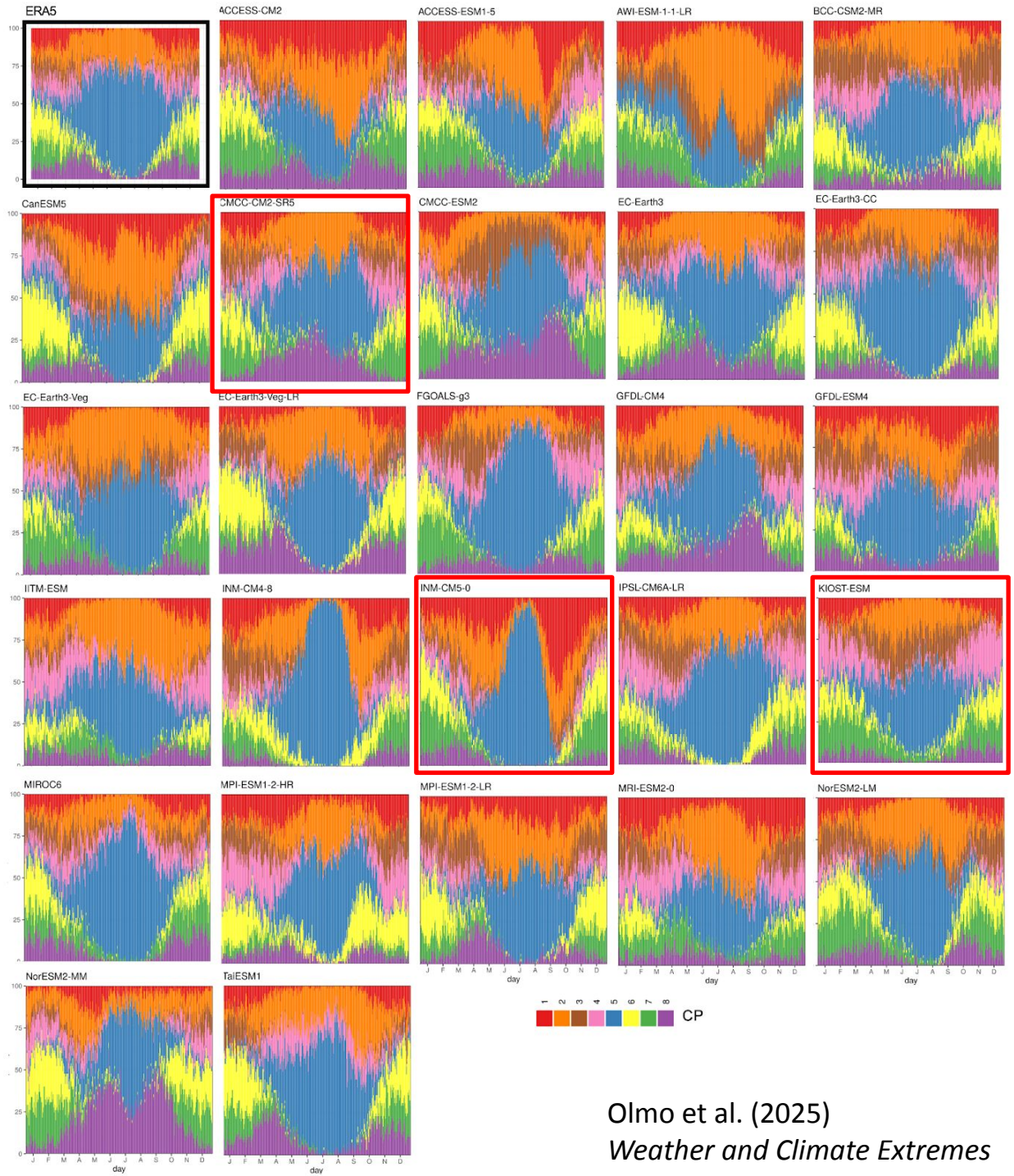
CP frequency and ErrorCycle



More difficulties in winter and transitional CPs (CP1, CP3, CP8).



Olmo et al. (2025)
Weather and Climate Extremes

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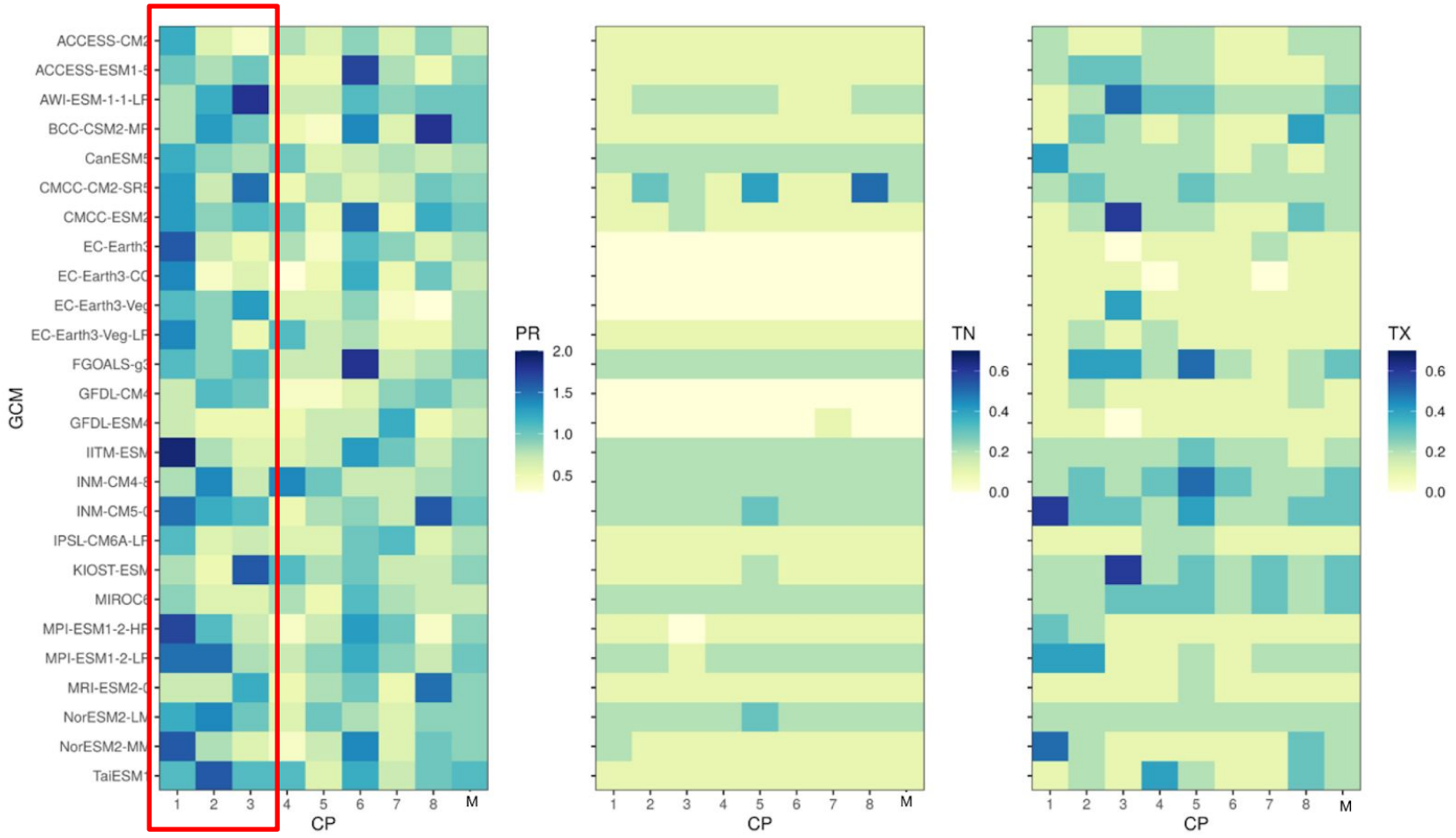
Surface patterns: DISO metric

Better representation of TX, TN than PR

CP1, CP2, CP3 and CP6 more challenging to capture



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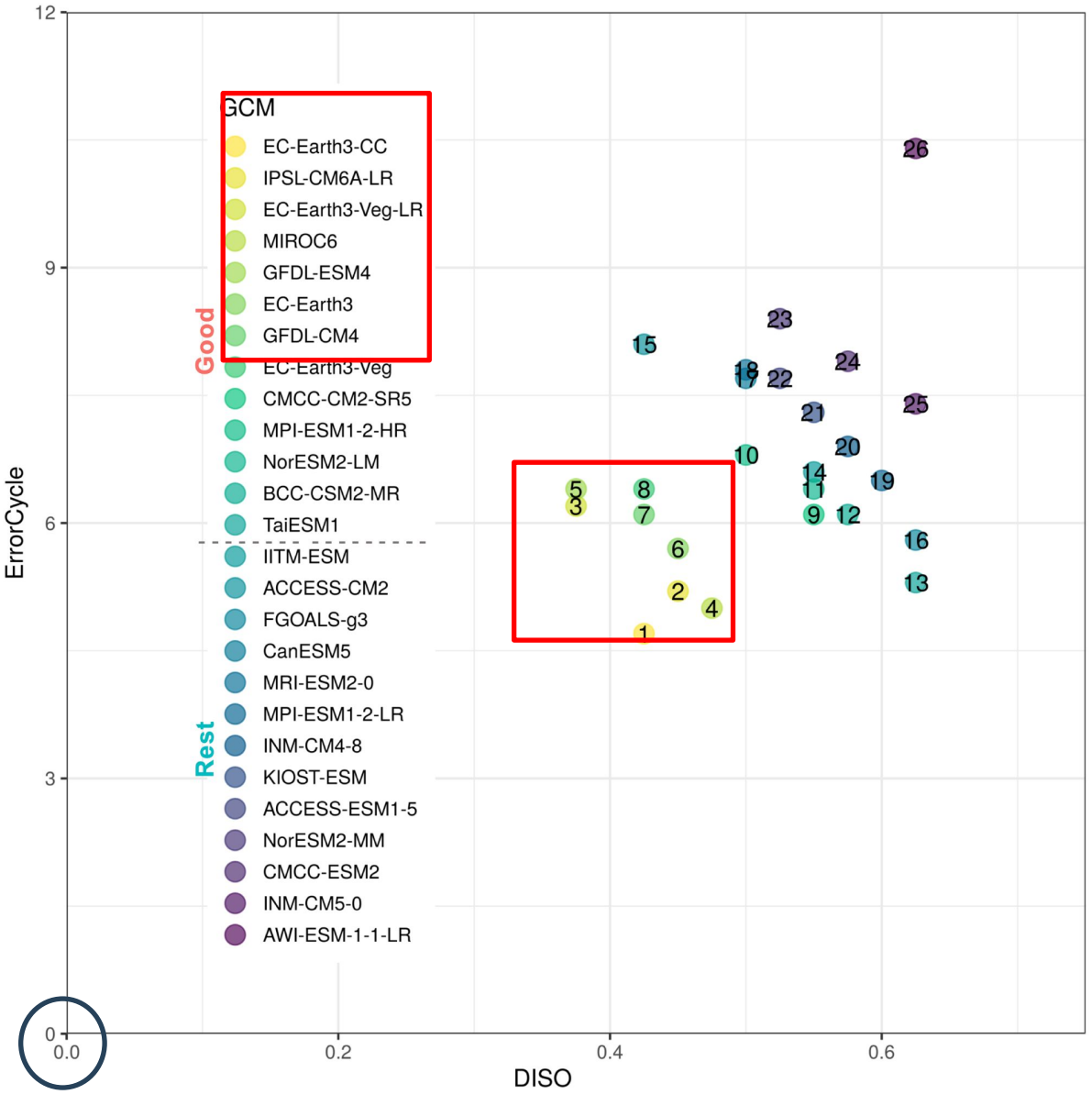
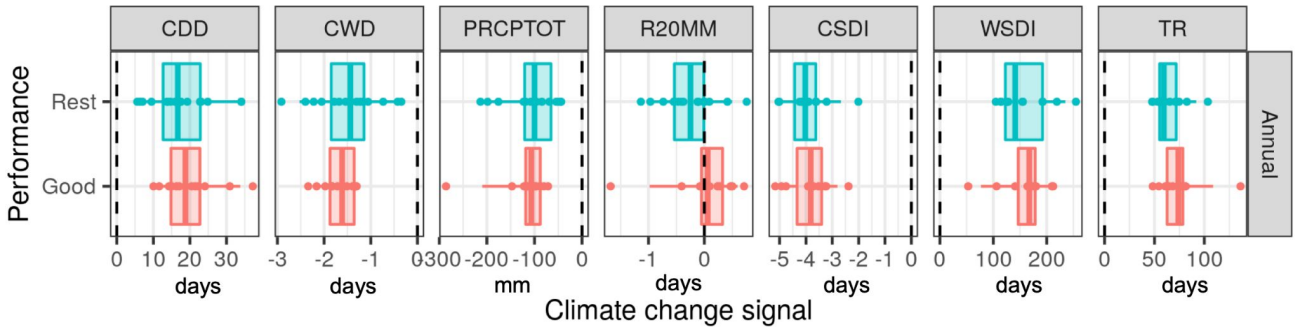
Weather and Climate Extremes

Model ranking





Enhanced warming and drying signals in better-performing GCMs

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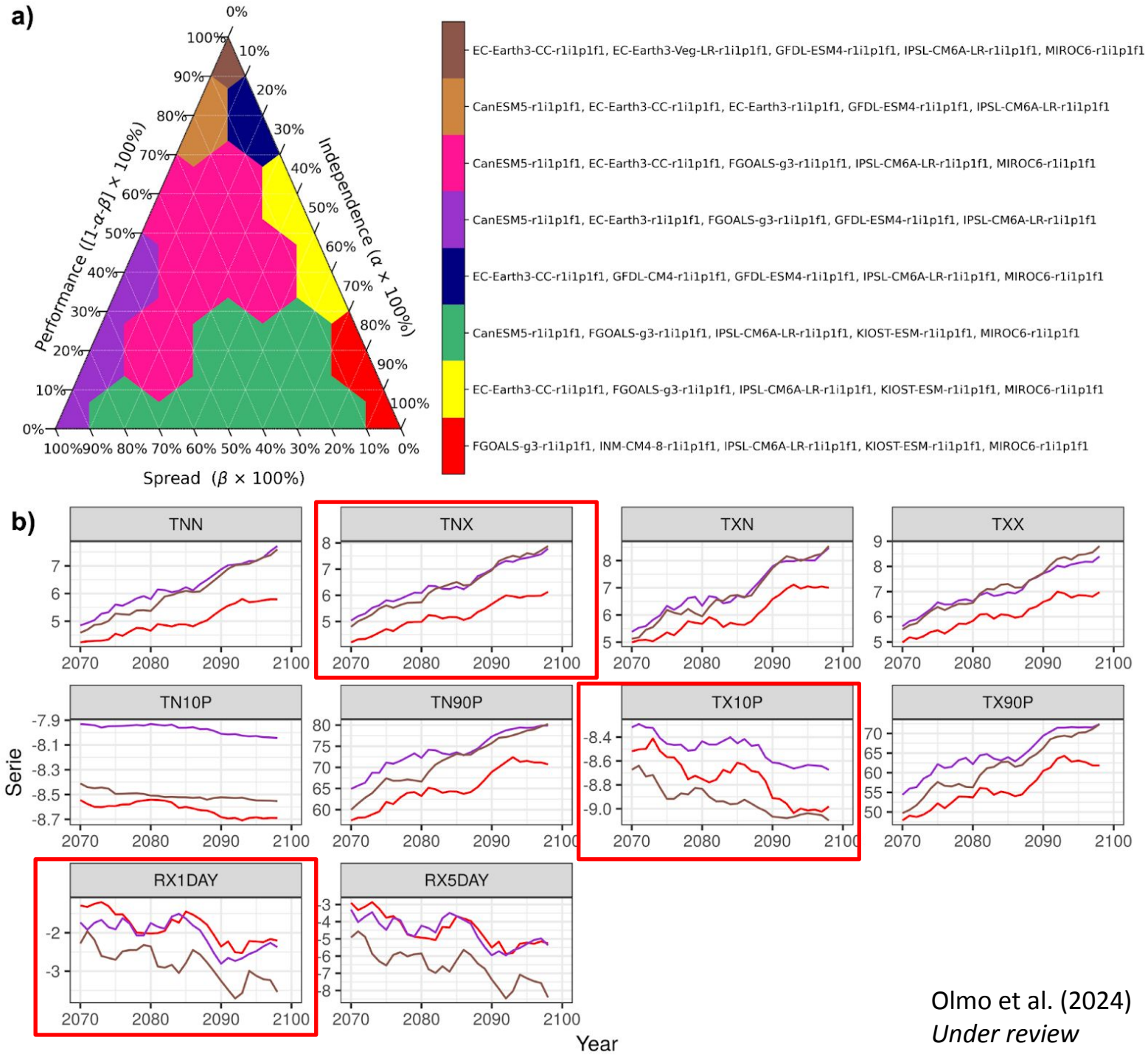
Summer projections

Sub-ensembles based on Ternary triangles (ClimSIPS)

Delta-change for 2070-2100

Enhanced warming and drying signals in better-performing GCMs



Olmo et al. (2024)
Under review

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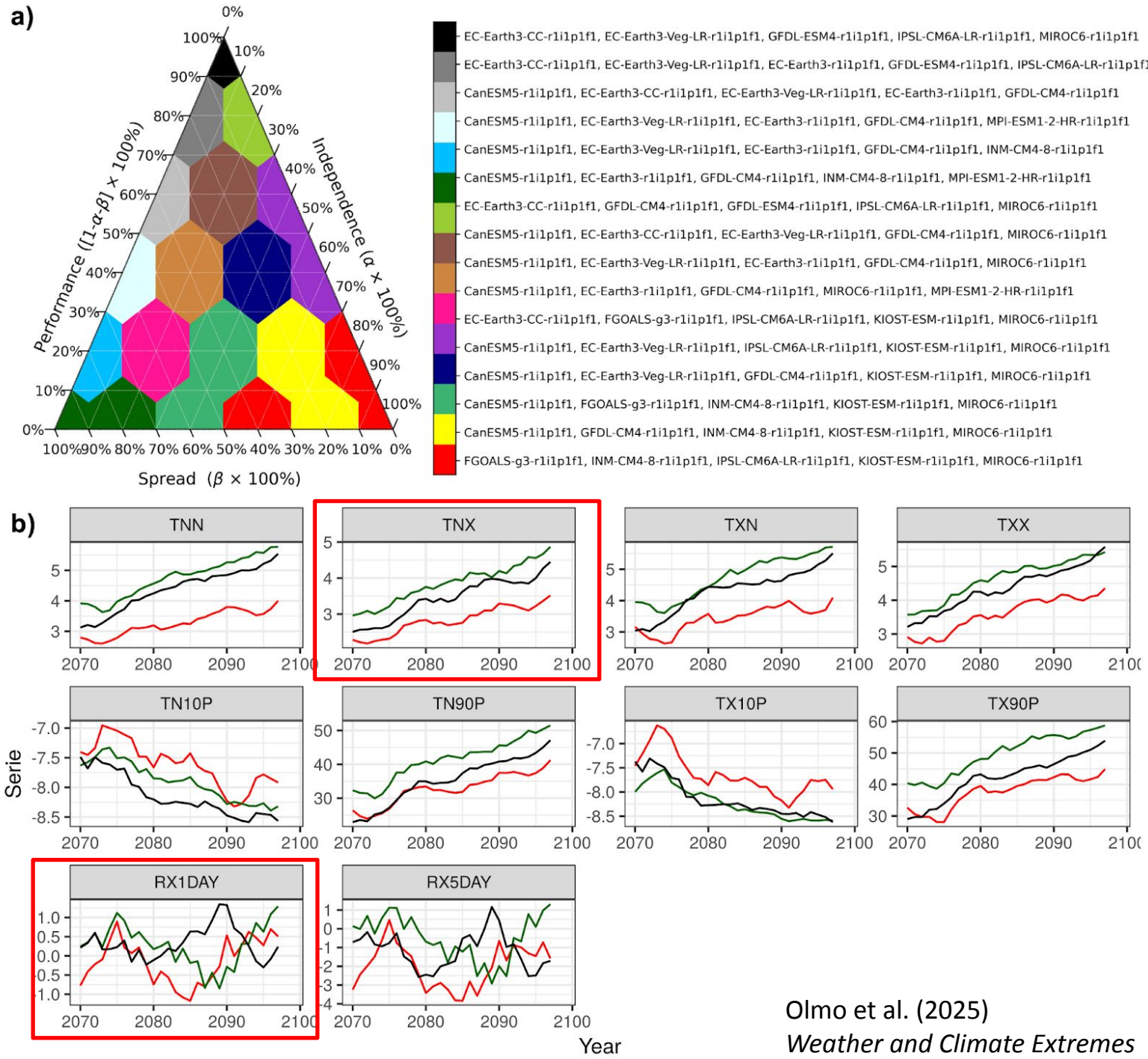
Winter projections

Larger number of suggested sub-ensembles than in summer

Less clear differences based on these metrics, particularly for PR changes



Olmo et al. (2025)
Weather and Climate Extremes

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Final remarks

The CPs classification discriminates synoptic and surface structures with clear **seasonal behaviour**.

CMIP6 GCMs have **different performances** in terms of spatio-temporal variability.

This is a **flexible** framework for process-based model ranking and **filtering** of climate projections.

Larger delta changes are typically identified in the **best-performing** GCMs.

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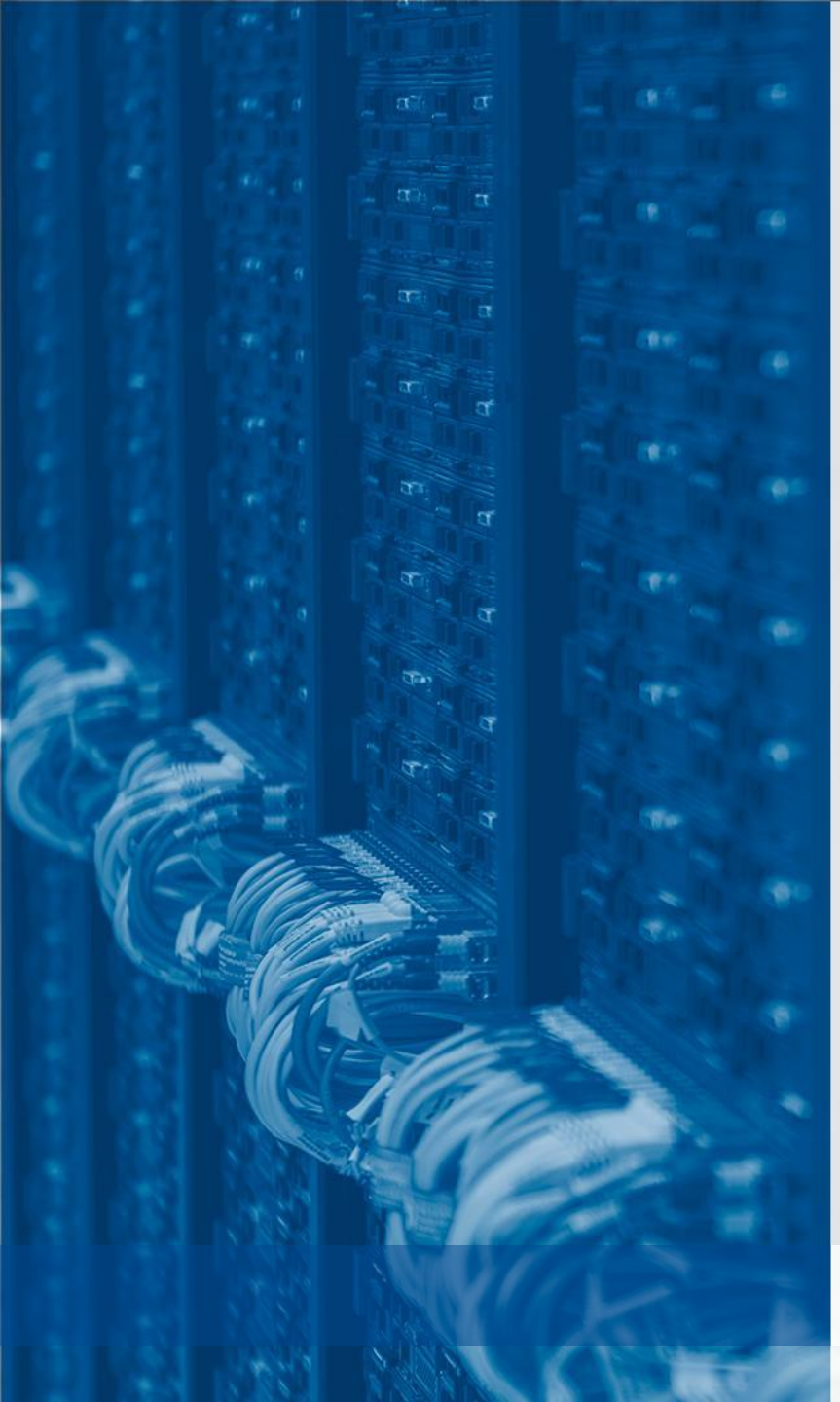

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Thanks!

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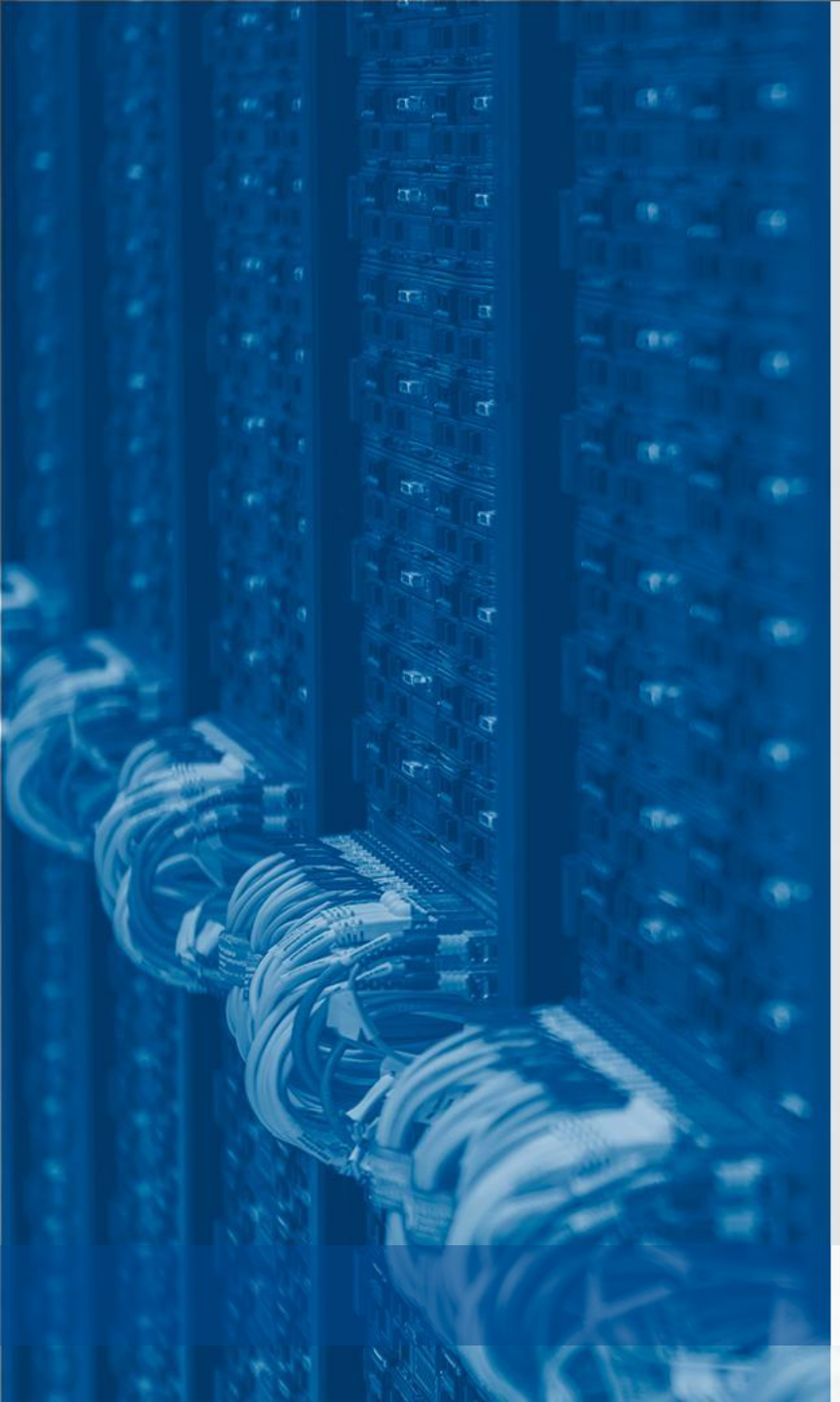

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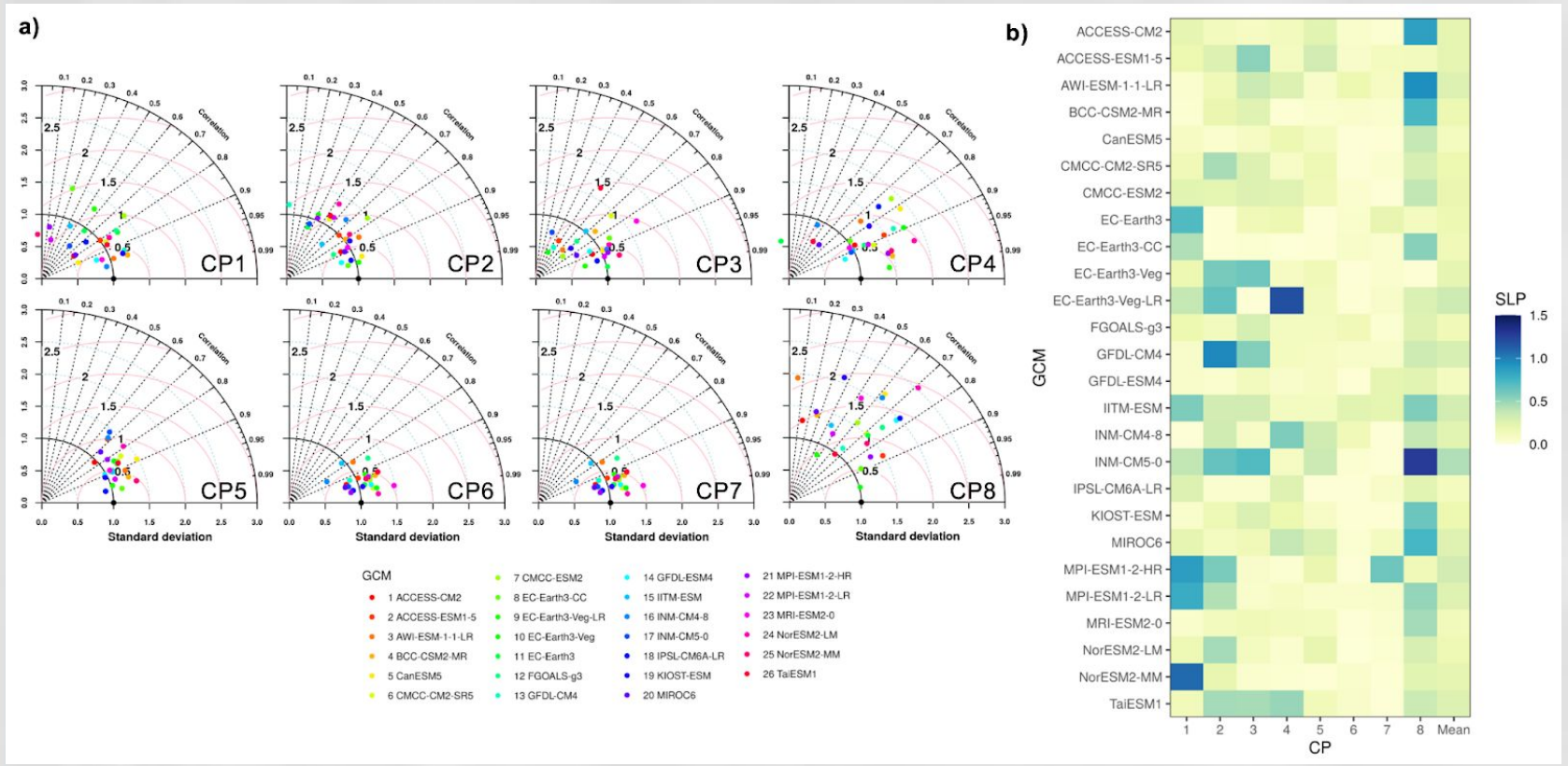

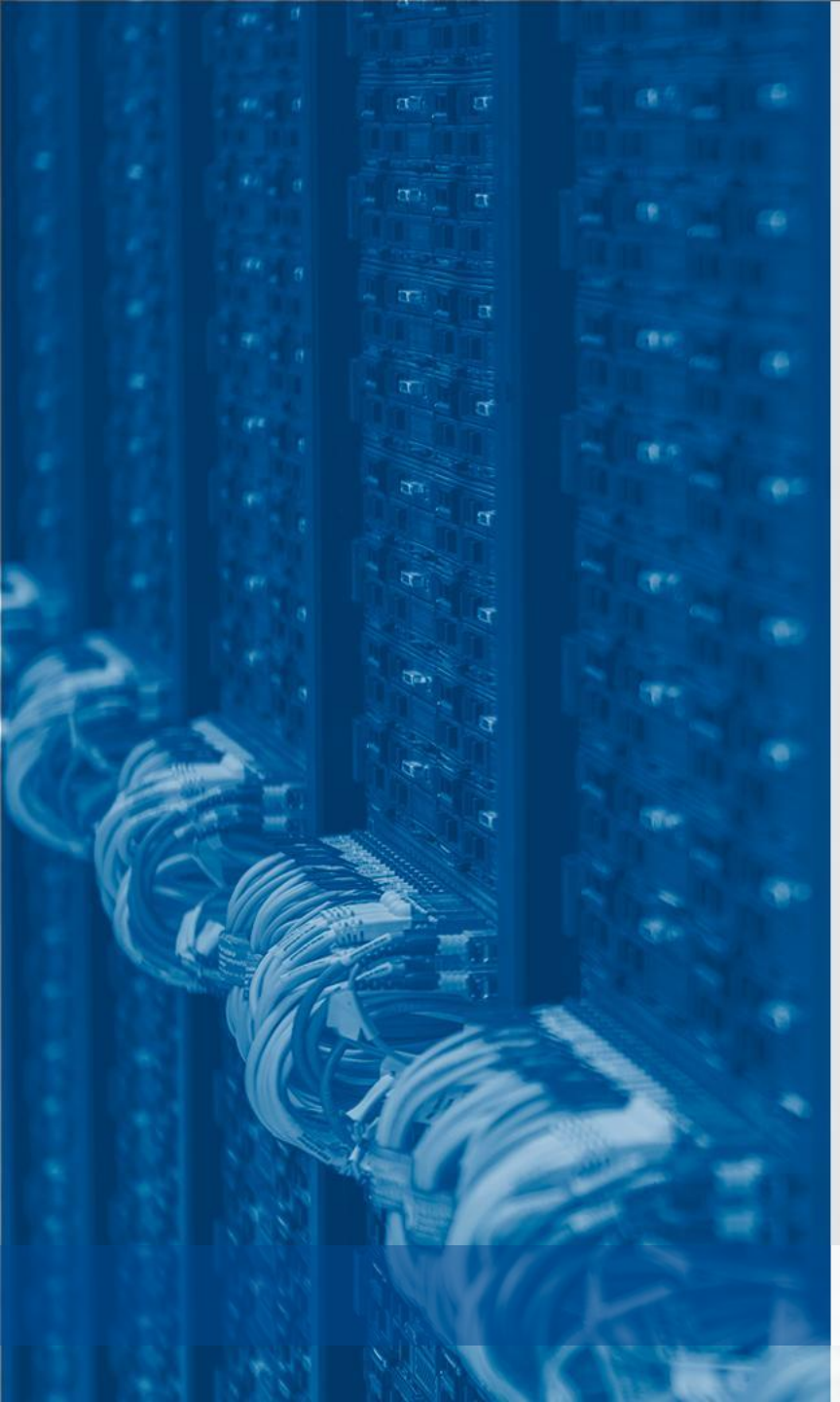

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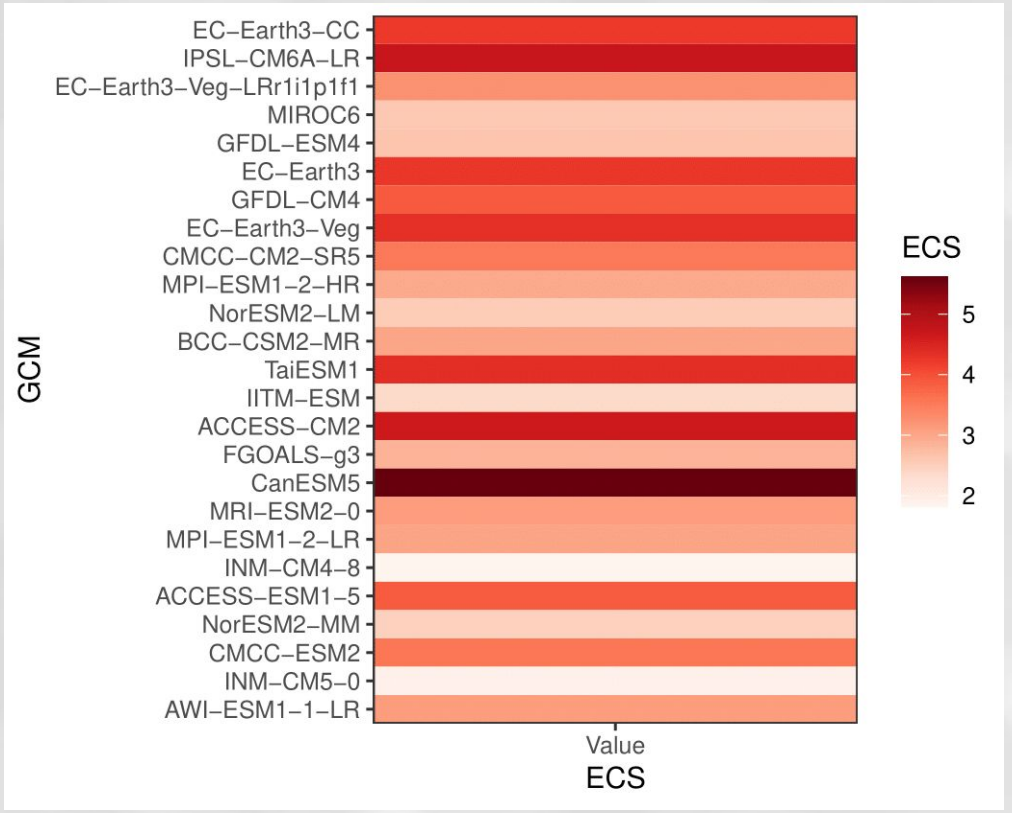

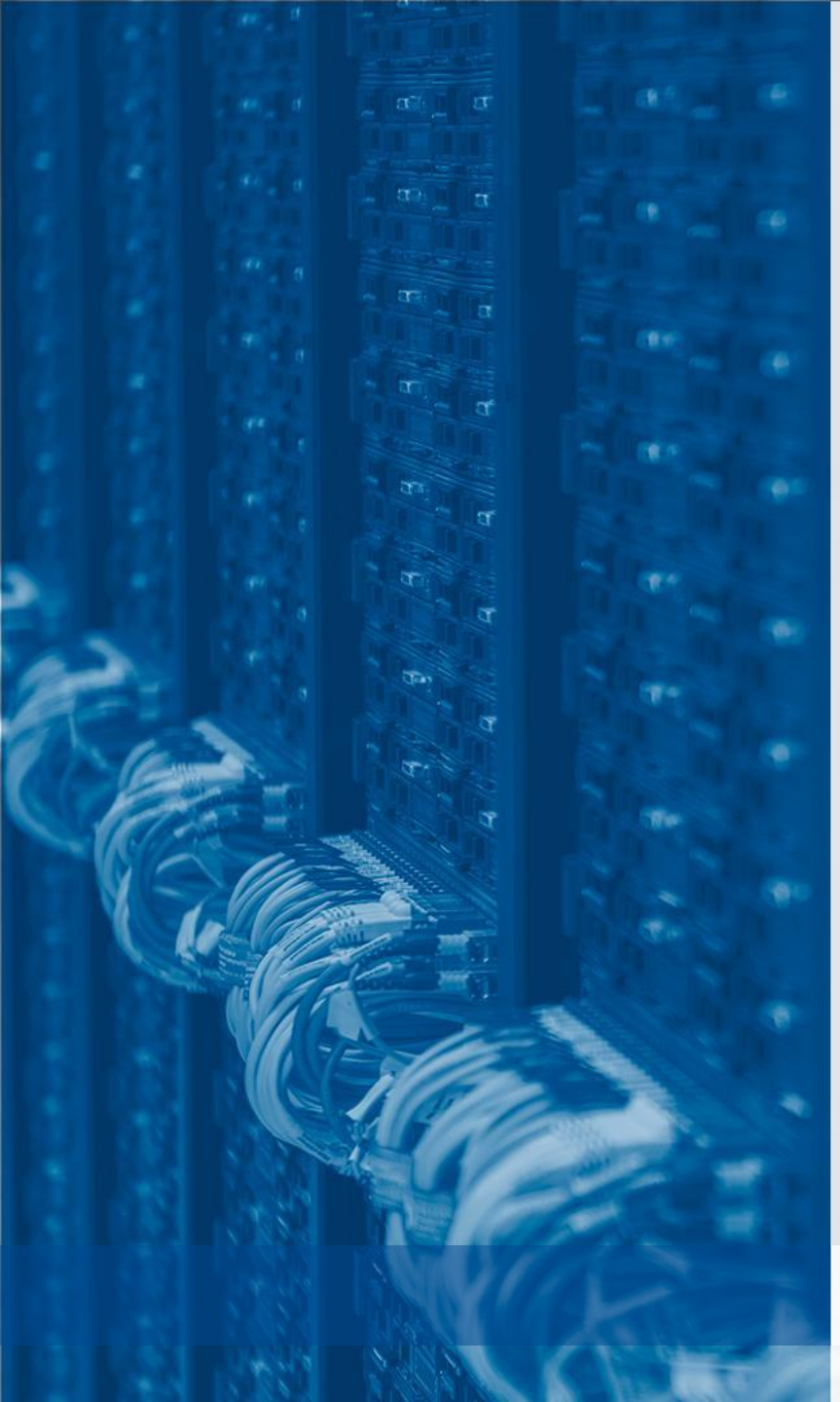

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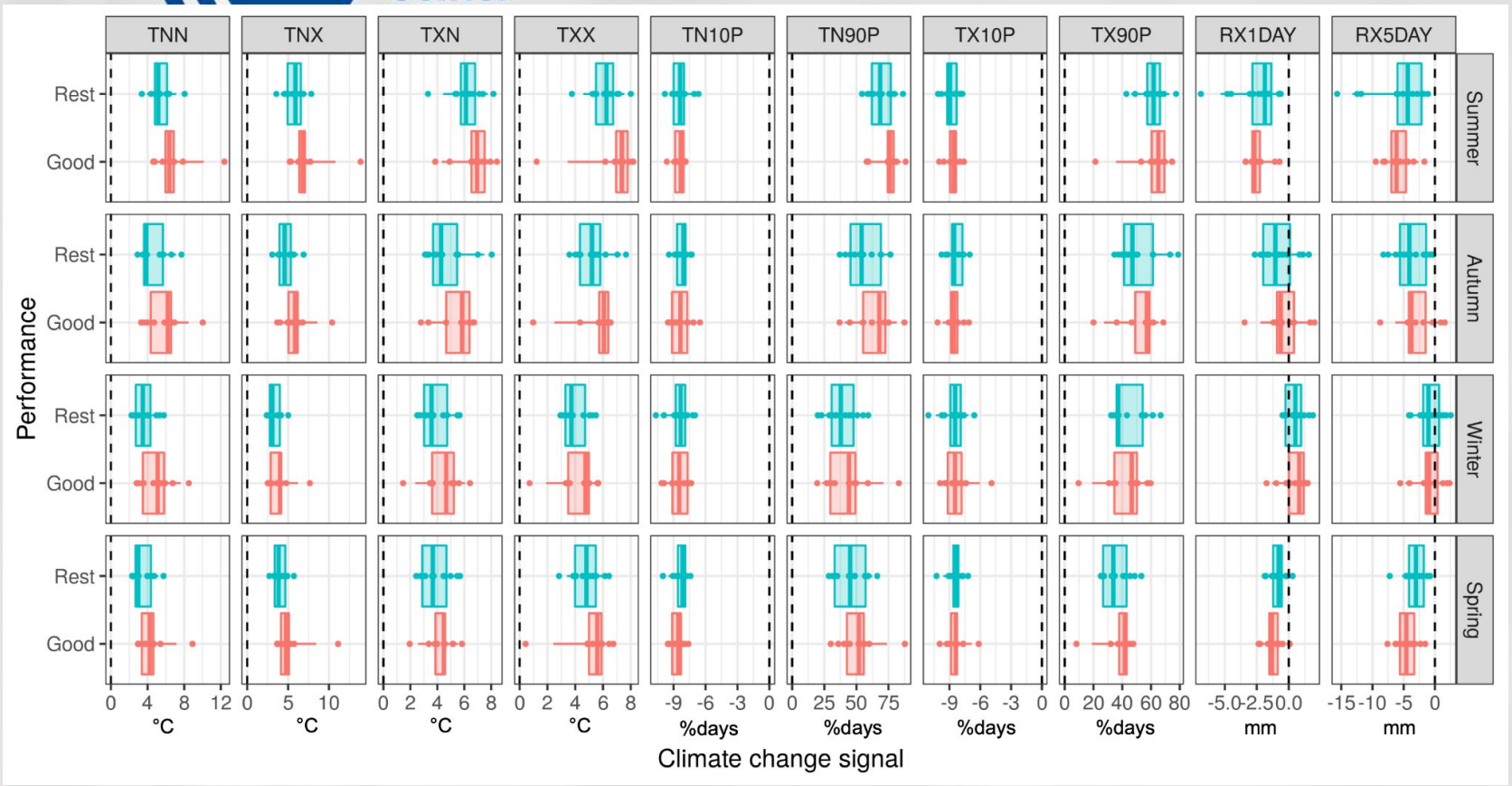

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