A SYNOPTIC CIRCULATION PATTERNS EVALUATION FRAMEWORK FOR CMIP6 GCMS OVER THE EURO-MEDITERRANEAN REGION

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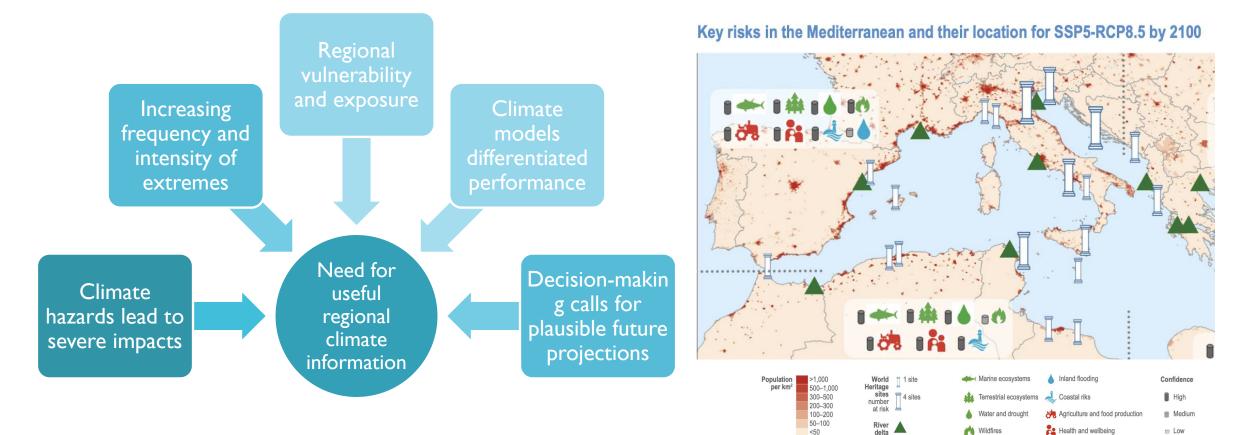
CLIMATE SERVICES TEAM – EARTH SCIENCES DEPARTMENT - BSC





Barcelona Supercomputing Center Centro Nacional de Supercomputación

MOTIVATION

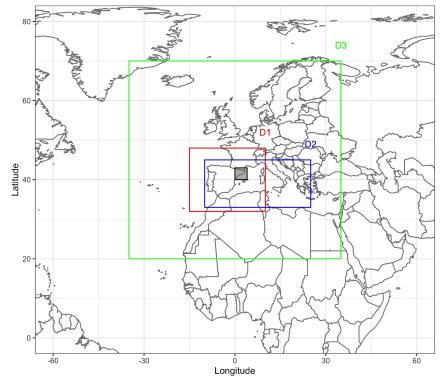


IPCC AR6 WGII, CCP4 Mediterranean Region.

OBJECTIVE

Design a cross time-scales evaluation framework for CMIP6 GCMs based on synoptic circulation patterns and their impacts over the Euro-Mediterranean.

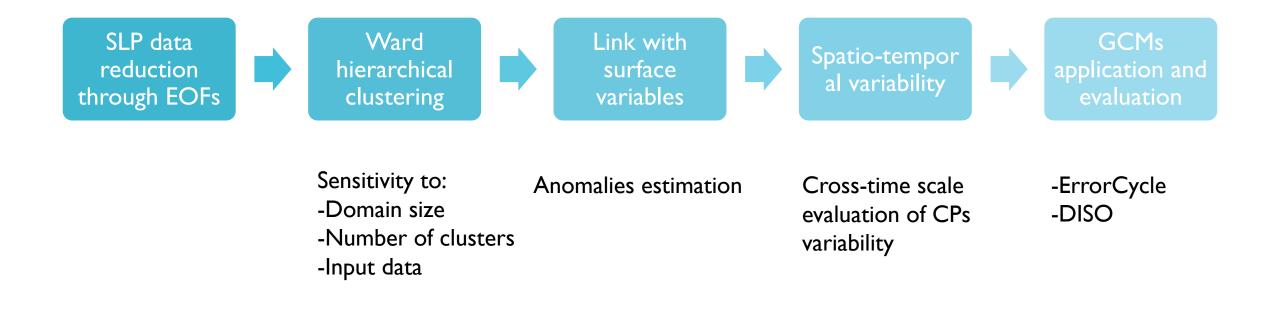
ECMWF ERA5 DAILY DATA (REFERENCE) 32 CMIP6 GCMS 1950-2014



Domains selected for the CPs.

- Atmospheric circulation domains
 - Mean sea level pressure (SLP)
 - Geopotential Height at 500 hPa
 - Zonal and meridional winds at 850 hPa
- Surface variables
 - Precipitation
 - Maximum temperature
 - Minimum temperature

METHODS AND WORKFLOW



METHODS: EVALUATION METRICS

ErrorCycle

Absolute difference in the daily frequency of each CP. Sum

$$\operatorname{Error}_{\operatorname{CP}} = \frac{\sum_{i=1}^{D} |f E RA5_{\operatorname{CP}}i - f G C M_{\operatorname{CP}}i|}{D}$$

Summary of a Taylor Diagram.

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

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

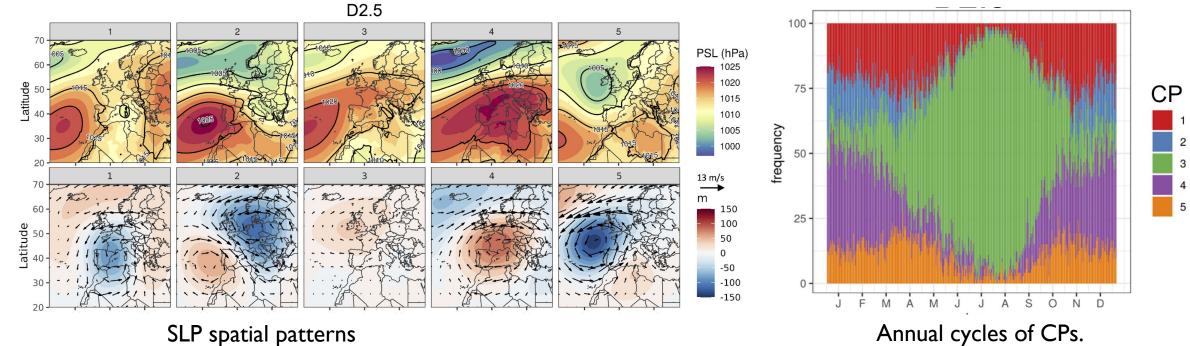
$$RMSE = \sqrt{\frac{1}{n} \sum_{k=0}^{n} (b_i - a_i)^2},$$

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

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

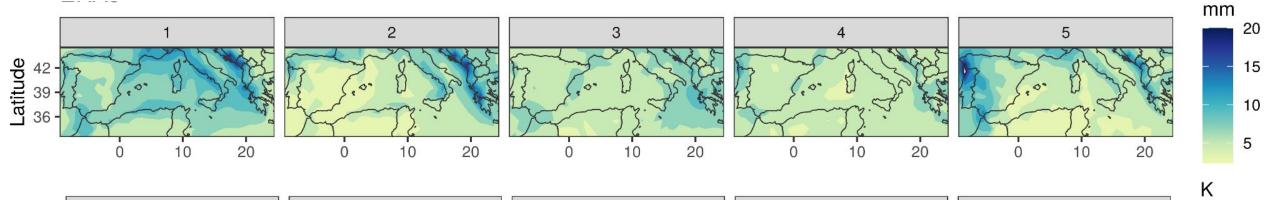
Olmo et al. 2022 Agudelo et al. 2023 Hu et al. 2018 Liu et al. 2018

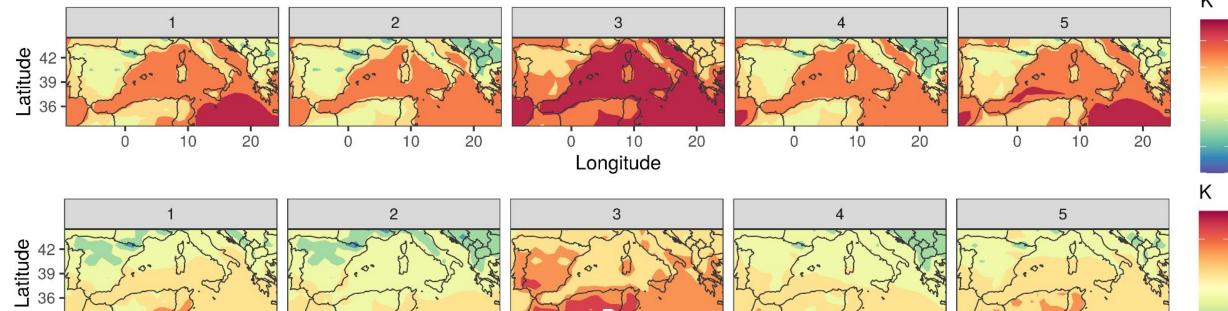
MAIN RESULTS: OBSERVATIONAL REFERENCE



SLP spatial patterns Z500 (shaded) and low-level winds (vectors)

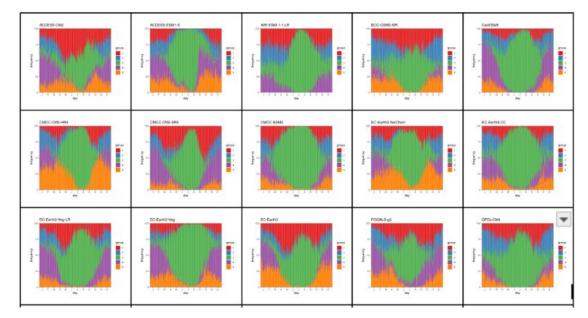
Olmo et al. 2024 JOC, under review.



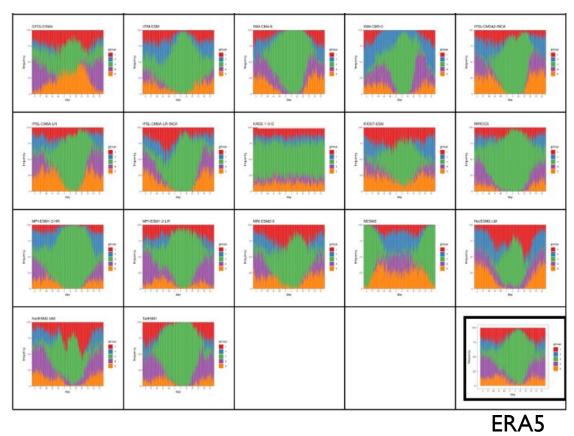


Longitude

CP SURFACE PATTERNS: PR, TN AND TX



Annual cycle of CPs by GCM.

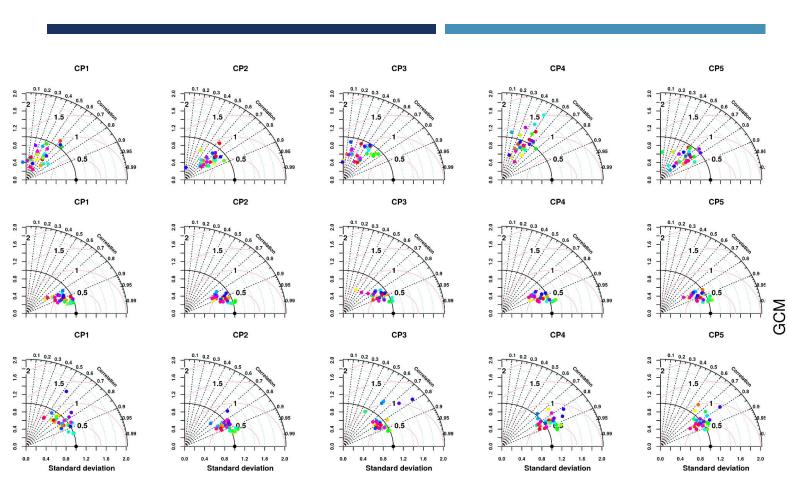


CP ANNUAL CYCLE

Larger ErrorCycle in CP3 (most frequent) and in
transitional patterns (CPI, CP5)

ERRORCYCLE

AWI-ESM-1-1-LR 5.9 7.5 9.4 6.8 11.5 8.2 BCC-CSM2-MR 13.1 12.1 10.9 14.3 6.1 11. CanESM5 9.4 6 9.2 8.9 7.1 8.1 CMCC-CM2-HR4 8.9 6 9.5 10.9 18.2 10. CMCC-CM2-SR5 11.5 4 11.9 7.8 5.6 8.1 CMCC-CM2-SR5 7.2 4.8 15.9 7.9 5.9 8.3 EC-Earth3-AerChem 7.5 4.6 7.4 9.8 13.5 8.5 EC-Earth3-Veg-LR 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg-LR 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg-LR 13.9 4 9 8.6 10.4 9.1 FGOALS-33 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-CM4 10.4 10.6 7.8 11.2 7.1 9.4 JINM-CM48 9.6 3.7 10.4 </th <th>ACCESS-CM2 -</th> <th>15.8</th> <th>4.2</th> <th>15.9</th> <th>6.6</th> <th>5.8</th> <th>9.66</th>	ACCESS-CM2 -	15.8	4.2	15.9	6.6	5.8	9.66
BCC-CSM2-MR - 13.1 12.1 10.9 14.3 6.1 11. CARESM5 - 9.4 6 9.2 8.9 7.1 8.1 CMCC-CM2-HR4 - 8.9 6 9.5 10.9 18.2 10. CMCC-CM2-SR5 - 11.5 4 11.9 7.8 5.6 8.1 CMCC-ESM2 - 7.2 4.8 15.9 7.9 5.9 8.3 EC-Earth3-AerChem - 7.5 4.6 7.4 9.8 13.5 8.5 EC-Earth3-Veg-LR - 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg-LR - 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3 - Veg-LR - 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3 - Veg - LR - 13.9 4 9 8.6 10.4 9.1 FGOALS-g3 - 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-ESM4 - 8.8 4.2 20 7.3 16.1 11.2 IITM-ESM - 5.7 <	ACCESS-ESM1-5 -	8.8	4.8	12.5	7.3	8.4	8.36
CanESM5 9.4 66 9.2 8.9 7.1 8.1 CMCC-CM2-HR4 8.9 6 9.5 10.9 18.2 10. CMCC-CM2-SR5 11.5 4 11.9 7.8 5.6 8.1 CMCC-ESM2 7.2 4.8 15.9 7.9 5.9 8.3 EC-Earth3-AerChem 7.5 4.6 7.4 9.8 13.5 8.5 EC-Earth3-Veg-LR 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg-LR 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3 13.9 4 9 8.6 10.4 9.1 FGOALS-33 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-ESM4 8.8 4.2 20 7.3 16.1 17.2 GFDL-ESM4 8.8 4.2 20 7.3 16.2 14.2 INM-CM48 9.6 3.7 11.4 7.5	AWI-ESM-1-1-LR -	5.9	7.5	9.4	6.8	11.5	8.22
CMCC-CM2-HR4 8.9 6 9.5 10.9 18.2 10.0 CMCC-CM2-SR5 11.5 4 11.9 7.8 5.6 8.1 CMCC-ESM2 7.2 4.8 15.9 7.9 5.9 8.3 EC-Earth3-AerChem 7.5 4.6 7.4 9.8 13.5 8.5 EC-Earth3-Veg-L8 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg-L8 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg-L8 13.9 4 9 8.6 10.4 9.1 FGOALS-93 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-EM4 10.4 10.6 7.8 11.2 7.1 9.4 JITM-ESM 5.7 10.4 9.5 13.3 4.7 11.2 GFDL-EM4 8.6 7.3 9.7 15.5 10.5 8.7 IITM-CM4 9.3 4.1 7.5 <td< td=""><td>BCC-CSM2-MR -</td><td>13.1</td><td>12.1</td><td>10.9</td><td>14.3</td><td>6.1</td><td>11.3</td></td<>	BCC-CSM2-MR -	13.1	12.1	10.9	14.3	6.1	11.3
CMCC-CM2-SR5 11.5 4 11.9 7.8 5.6 8.1 CMCC-ESM2 7.2 4.8 15.9 7.9 5.9 8.3 EC-Earth3-AerChem 7.5 4.6 7.4 9.8 13.5 8.5 EC-Earth3-Veg-L8 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg-L8 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg-L8 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg-L8 13.9 4 9 8.6 10.4 9.1 FGOALS-93 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-CM4 10.4 10.6 7.8 11.2 7.1 9.4 GFDL-ESM4 8.8 4.2 20 7.3 16.1 11.2 INM-CM48 9.6 3.7 11.1 7.7 9.2 8.2 IPSL-CM6A-LR-INCA 9.3 5.9 7.1	CanESM5 -	9.4	6	9.2	8.9	7.1	8.12
CMCC-ESM2 7.2 4.8 15.9 7.9 5.9 8.3 EC-Earth3-AerChem 7.5 4.6 7.4 9.8 13.5 8.5 EC-Earth3-Veg-LR 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg-LR 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg 8.9 3.9 10.5 8.2 4.8 7.2 EC-Earth3-Veg 8.9 3.9 10.5 8.2 4.8 7.2 EC-Earth3 13.9 4 9 8.6 10.4 9.1 FGOALS-93 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-ESM4 8.8 4.2 20 7.3 16.1 11.2 IITM-ESM 5.7 10.4 9.5 13.3 4.7 11.2 IINM-CM49 9.6 3.7 11 7.7 9.2 8.2 IINM-CM50 11.6 17.1 9.5 13.	CMCC-CM2-HR4 -	8.9	6	9.5	10.9	18.2	10.7
EC-Earth3-AerChem 7.5 4.6 7.4 9.8 13.5 8.5 EC-Earth3-CC 7.6 6 9.8 6.3 4.9 6.9 EC-Earth3-Veg-LR 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg 8.9 3.9 10.5 8.2 4.8 7.2 EC-Earth3-Veg 8.9 3.9 10.5 8.2 4.8 7.2 EC-Earth3-Veg 8.9 3.9 10.5 8.2 4.8 7.2 EC-Earth3 13.9 4 9 8.6 10.4 9.1 FGOALS-93 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-ESM4 8.8 4.2 20 7.3 16.1 11.2 IINM-CM4-8 9.6 3.7 11.4 7.7 9.2 8.2 IINM-CM54-6 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM5A2-INCA 8.6 7.3 3.4 <t< td=""><td>CMCC-CM2-SR5 -</td><td>11.5</td><td>4</td><td>11.9</td><td>7.8</td><td>5.6</td><td>8.16</td></t<>	CMCC-CM2-SR5 -	11.5	4	11.9	7.8	5.6	8.16
EC-Earth3-CC 7.6 6 9.8 6.3 4.9 6.9 EC-Earth3-Veg-LR 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg 8.9 3.9 10.5 8.2 4.8 7.2 EC-Earth3-Veg 8.9 3.9 10.5 8.2 4.8 7.2 EC-Earth3 13.9 4 9 8.6 10.4 9.1 FGOALS-93 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-CM4 10.4 10.6 7.8 11.2 7.1 9.4 GFDL-ESM4 8.8 4.2 20 7.3 16.1 11.2 IITM-ESM 5.7 10.4 9.5 13.3 4.7 11.2 IINM-CM48 9.6 3.7 11 7.7 9.2 8.2 IINM-CM50- 11.6 17.1 9.3 4.7 11.2 IPSL-CM6A-LR-INCA 9.3 5.9 7.1 7.1 9.3 <td>CMCC-ESM2 -</td> <td>7.2</td> <td>4.8</td> <td>15.9</td> <td>7.9</td> <td>5.9</td> <td>8.34</td>	CMCC-ESM2 -	7.2	4.8	15.9	7.9	5.9	8.34
EC-Earth3-Veg-LR 9.5 4.1 6.4 7.5 6.1 6.7 EC-Earth3-Veg 8.9 3.9 10.5 8.2 4.8 7.2 EC-Earth3-Veg 13.9 4 9 8.6 10.4 9.1 FGOALS-g3 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-CM4 10.4 10.6 7.8 11.2 7.1 9.4 GFDL-ESM4 8.8 4.2 20 7.3 16.1 11.6 IITM-ESM 5.7 10.4 9.5 13.3 4.7 11.2 INM-CM4-8 9.6 3.7 111 7.7 9.2 8.2 INM-CM50 11.6 17.1 9.5 13.3 4.7 11.2 IPSL-CM5A2-INCA 8.6 7.3 9.7 7.5 10.5 8.7 IPSL-CM6A-LR 9.3 4.1 7.3 7.6 11.4 7.9 KACE-1-0.6 9.4 7.2 30.9 14.3	EC-Earth3-AerChem -	7.5	4.6	7.4	9.8	13.5	8.56
EC-Earth3-Veg 8.9 3.9 10.5 8.2 4.8 7.2 EC-Earth3 13.9 4 9 8.6 10.4 9.1 FGOALS-g3 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-CM4 10.4 10.6 7.8 11.2 7.1 9.4 GFDL-ESM4 8.8 4.2 20 7.3 16.1 11.2 IITM-ESM 5.7 10.4 9.5 13.7 5.6 8.9 INM-CM4-8 9.6 3.7 11 7.7 9.2 8.2 INM-CM5-0 11.6 17.1 9.5 13.3 4.7 11.2 IPSL-CM5A2-INCA 8.6 7.3 9.7 7.5 10.5 8.7 IPSL-CM6A-LR-INCA 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM6A-LR 9.3 4.1 7.3 7.6 11.4 7.9 KACE-1-0-G 9.4 7.2 30.9 14.3 6.2 13.3 MIROC6 7.3 3.4 16.5 6.5<	EC-Earth3-CC -	7.6	6	9.8	6.3	4.9	6.92
EC-Earth3 - 13.9 4 9 8.6 10.4 9.1 FGOALS-g3 - 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-CM4 - 10.4 10.6 7.8 11.2 7.1 9.4 GFDL-ESM4 - 8.8 4.2 20 7.3 16.1 11.2 IITM-ESM - 5.7 10.4 9.5 13.7 5.6 8.9 INM-CM4-8 9.6 3.7 111 7.7 9.2 8.2 INM-CM5-0 - 11.6 17.1 9.5 13.3 4.7 11.2 IPSL-CM6A-LR-INCA - 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM6A-LR-INCA - 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM6A-LR-INCA - 9.3 4.1 7.3 7.6 11.4 7.9 IPSL-CM6A-LR-INCA - 9.3 4.1 7.3 7.6 11.4 7.9 KACE-1-0-G - 9.4 7.2 30.9 14.3 6.2 13.3 MIROCE - 7.3 3.4	EC-Earth3-Veg-LR -	9.5	4.1	6.4	7.5	6.1	6.72
FGOALS-93 11.1 6.2 14.1 7.4 6.5 9.0 GFDL-CM4 10.4 10.6 7.8 11.2 7.1 9.4 GFDL-ESM4 8.8 4.2 20 7.3 16.1 11.2 IITM-ESM 5.7 10.4 9.5 13.7 5.6 8.9 INM-CM4-8 9.6 3.7 11 7.7 9.2 8.2 INM-CM50 11.6 17.1 9.5 13.3 4.7 11.2 IPSL-CM5A2-INCA 8.6 7.3 9.7 7.5 10.5 8.7 IPSL-CM6A-LR-INCA 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM6A-LR 9.3 4.1 7.3 7.6 11.4 7.9 KACE-1-0-G 9.4 7.2 30.9 14.3 6.2 13.3 KIOST-ESM 9.2 7.7 11.2 10.9 10.2 9.8 MIROC6 7.3 3.4 16.5 6.5 6.6 8.0 MPI-ESM1-2-HR 10.7 8.1 15.6 <td< td=""><td>EC-Earth3-Veg -</td><td>8.9</td><td>3.9</td><td>10.5</td><td>8.2</td><td>4.8</td><td>7.26</td></td<>	EC-Earth3-Veg -	8.9	3.9	10.5	8.2	4.8	7.26
GFDL-CM4 10.4 10.6 7.8 11.2 7.1 9.4 GFDL-ESM4 8.8 4.2 20 7.3 16.1 11.2 IITM-ESM 5.7 10.4 9.5 13.7 5.6 8.9 INM-CM4-8 9.6 3.7 11.1 7.7 9.2 8.2 INM-CM5-0 11.6 17.1 9.5 13.3 4.7 11.2 IPSL-CM5A2-INCA 8.6 7.3 9.7 7.5 10.5 8.7 IPSL-CM6A-LR-INCA 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM6A-LR 9.3 4.1 7.3 7.6 11.4 7.9 KACE-1-0-G 9.4 7.2 30.9 14.3 6.2 13.7 KIOST-ESM 9.2 7.7 11.2 10.9 10.2 9.8 MIROC6 7.3 3.4 16.5 6.5 6.6 8.0 MPI-ESM1-2-HR 10.7 8.1 15.6 9.	EC-Earth3 -	13.9	4	9	8.6	10.4	9.18
GFDL-ESM4 8.8 4.2 20 7.3 16.1 11.2 IITM-ESM 5.7 10.4 9.5 13.7 5.6 8.9 INM-CM4-8 9.6 3.7 11 7.7 9.2 8.2 INM-CM50-0 11.6 17.1 9.5 13.3 4.7 11.2 IPSL-CM5A2-INCA 8.6 7.3 9.7 7.5 10.5 8.7 IPSL-CM6A-LR-INCA 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM6A-LR-INCA 9.3 4.1 7.3 7.6 11.4 7.9 IPSL-CM6A-LR 9.3 4.1 7.3 7.6 11.4 7.9 IPSL-CM6A-LR 9.3 4.1 7.3 7.6 11.4 7.9 KACE-1-0-G 9.4 7.2 30.9 14.3 6.2 13.3 KIOST-ESM 9.2 7.7 11.2 10.9 10.2 9.8 MIROC6 7.3 3.4 16.5 6.6 6.4 9.7 MPI-ESM1-2-HR 10.7 8.1 15.6 <td>FGOALS-g3 -</td> <td>11.1</td> <td>6.2</td> <td>14.1</td> <td>7.4</td> <td>6.5</td> <td>9.06</td>	FGOALS-g3 -	11.1	6.2	14.1	7.4	6.5	9.06
INM-CM4-8 9.6 3.7 11 7.7 9.2 8.2 INM-CM5-0 11.6 17.1 9.5 13.3 4.7 11.2 IPSL-CM5A2-INCA 8.6 7.3 9.7 7.5 10.5 8.7 IPSL-CM6A-LR-INCA 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM6A-LR-INCA 9.3 4.1 7.3 7.6 11.4 7.9 IPSL-CM6A-LR 9.3 4.1 7.3 3.09 14.3 6.2 13. KACE-1-0-G 9.4 7.2 30.9 14.3 6.2 13. MIROC6 7.3 3.4 16.5 6.5 6.6 8.0 MPI-ESM1-2-HR 10.7 8.1 15.6 9.7 7.5 7.5 MRI-ESM2-0 10.6 <td>GFDL-CM4 -</td> <td>10.4</td> <td>10.6</td> <td>7.8</td> <td>11.2</td> <td>7.1</td> <td>9.42</td>	GFDL-CM4 -	10.4	10.6	7.8	11.2	7.1	9.42
INM-CM4-8 9.6 3.7 11 7.7 9.2 8.2 INM-CM5-0 11.6 17.1 9.5 13.3 4.7 11.2 IPSL-CM5A2-INCA 8.6 7.3 9.7 7.5 10.5 8.7 IPSL-CM6A-LR-INCA 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM6A-LR-INCA 9.3 4.1 7.3 7.6 11.4 7.9 IPSL-CM6A-LR 9.3 4.1 7.3 3.09 14.3 6.2 13. KACE-1-0-G 9.4 7.2 30.9 14.3 6.2 13. MIROC6 7.3 3.4 16.5 6.5 6.6 8.0 MPI-ESM1-2-HR 10.7 8.1 15.6 9.7 7.5 7.5 MRI-ESM2-0 10.6 <td>GFDL-ESM4 -</td> <td>8.8</td> <td>4.2</td> <td>20</td> <td>7.3</td> <td>16.1</td> <td>11.28</td>	GFDL-ESM4 -	8.8	4.2	20	7.3	16.1	11.28
INM-CM5-0 11.6 17.1 9.5 13.3 4.7 11.2 IPSL-CM5A2-INCA 8.6 7.3 9.7 7.5 10.5 8.7 IPSL-CM6A-LR-INCA 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM6A-LR 9.3 4.1 7.3 7.6 11.4 7.9 IPSL-CM6A-LR 9.3 4.1 7.3 7.6 11.4 7.9 KACE-1-0-G 9.4 7.2 30.9 14.3 6.2 13.3 KIOST-ESM 9.2 7.7 11.2 10.9 10.2 9.8 MIROC6 7.3 3.4 16.5 6.6 8.0 MPI-ESM1-2-HR 10.7 8.1 15.6 9.7 4.4 9.7 MPI-ESM1-2-HR 6.3 4.5 6.6 6.4 5 5.7 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 MRI-ESM2-0 10.6 4.8 7.7 8.5 15.7 24. NorESM2-LM 16.1 11.5 18.6 8	G IITM-ESM -	5.7	10.4	9.5	13.7	5.6	8.98
IPSL-CM5A2-INCA 8.6 7.3 9.7 7.5 10.5 8.7 IPSL-CM6A-LR-INCA 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM6A-LR-INCA 9.3 4.1 7.3 7.6 11.4 7.9 IPSL-CM6A-LR 9.3 4.1 7.3 7.6 11.4 7.9 KACE-1-0-G 9.4 7.2 30.9 14.3 6.2 13. KIOST-ESM 9.2 7.7 11.2 10.9 10.2 9.8 MIROC6 7.3 3.4 16.5 6.6 8.0 MPI-ESM1-2-HR 10.7 8.1 15.6 9.7 4.4 9.7 MPI-ESM1-2-HR 10.6 4.8 7.7 8.5 6 7.5 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 MRI-ESM2-0 16.1 11.5 18.6 8 11.7 13.7 NorESM2-LM 16.1 11.5 12.8 6.1 5.5 8.9 MRI-ESM2-M 15.5 5 12.8 6.1 <td>INM-CM4-8 -</td> <td>9.6</td> <td>3.7</td> <td>11</td> <td>7.7</td> <td>9.2</td> <td>8.24</td>	INM-CM4-8 -	9.6	3.7	11	7.7	9.2	8.24
IPSL-CM6A-LR-INCA 9.3 5.9 7.1 7.1 9.3 7.7 IPSL-CM6A-LR 9.3 4.1 7.3 7.6 11.4 7.9 KACE-10-G 9.4 7.2 30.9 14.3 6.2 13.4 KIOST-ESM 9.2 7.7 11.2 10.9 10.2 9.8 MIROC6 7.3 3.4 16.5 6.6 8.0 MPI-ESM1-2-HR 10.7 8.1 15.6 9.7 4.4 9.7 MPI-ESM1-2-HR 10.7 8.1 15.6 6.4 5.7 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 NorESM2-LM 16.1 11.5 18.6 8 11.7 13.7 NorESM2-LM 15.5 5 12.8 6.1 5.5 8.9 MOFESM2-LM 9 3.9 12.6 6.1 4.8 7.2<	INM-CM5-0 -	11.6	17.1	9.5	13.3	4.7	11.24
IPSL-CM6A-LR 9.3 4.1 7.3 7.6 11.4 7.9 KACE-1-0-G 9.4 7.2 30.9 14.3 6.2 13. KIOST-ESM 9.2 7.7 11.2 10.9 10.2 9.8 MIROC6 7.3 3.4 16.5 6.5 6.6 8.0 MPI-ESM1-2-HR 10.7 8.1 15.6 9.7 4.4 9.7 MPI-ESM1-2-HR 6.3 4.5 6.6 6.4 5 5.7 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 NGESM3 12.4 18.8 54.6 22.5 15.7 24. NorESM2-LM 16.1 11.5 18.6 8 11.7 13.7 NorESM2-LM 15.5 5 12.8 6.1 5.5 8.9 TaiESM1 9 3.9 12.6 6.1 4.8 7.2	IPSL-CM5A2-INCA -	8.6	7.3	9.7	7.5	10.5	8.72
KACE-1-0-G 9.4 7.2 30.9 14.3 6.2 13. KIOST-ESM 9.2 7.7 11.2 10.9 10.2 9.8 MIROC6 7.3 3.4 16.5 6.65 6.6 8.0 MPI-ESM1-2-HR 10.7 8.1 15.6 9.7 4.4 9.7 MPI-ESM1-2-LR 6.3 4.5 6.6 6.4 5 5.7 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 NORESM2-1 10.6 4.8 7.7 8.5 6 7.5 NorESM2-LM 16.1 11.5 18.6 8 11.7 13.7 NorESM2-MM 15.5 5 12.8 6.1 4.8 7.2 MORESM2-MM 15.5 5 12.6 6.1 4.8 7.2	IPSL-CM6A-LR-INCA -	9.3	5.9	7.1	7.1	9.3	7.74
KIOST-ESM 9.2 7.7 11.2 10.9 10.2 9.8 MIROC6 7.3 3.4 16.5 6.6 8.0 MPI-ESM1-2-HR 10.7 8.1 15.6 9.7 4.4 9.7 MPI-ESM1-2-HR 6.3 4.5 6.6 6.4 5 5.7 MPI-ESM1-2-LR 6.3 4.5 6.6 6.4 5 5.7 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 NESM3 12.4 18.8 54.6 22.5 15.7 24. NorESM2-LM 16.1 11.5 18.6 8 11.7 13.7 NorESM2-LM 15.5 5 12.8 6.1 5.5 8.9 TaiESM1 9 3.9 12.6 6.1 4.8 7.2	IPSL-CM6A-LR -	9.3	4.1	7.3	7.6	11.4	7.94
MIROC6 7.3 3.4 16.5 6.5 6.6 8.0 MPI-ESM1-2-HR 10.7 8.1 15.6 9.7 4.4 9.7 MPI-ESM1-2-LR 6.3 4.5 6.6 6.4 5 5.7 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 MRI-ESM2-0 10.6 4.8 54.6 22.5 15.7 24. NorESM2-LM 16.1 11.5 18.6 8 11.7 13.7 NorESM2-MM 15.5 5 12.8 6.1 5.5 8.9 TaiESM1 9 3.9 12.6 6.1 4.8 7.2	KACE-1-0-G -	9.4	7.2	30.9	14.3	6.2	13.6
MPI-ESM1-2-HR 10.7 8.1 15.6 9.7 4.4 9.7 MPI-ESM1-2-LR 6.3 4.5 6.6 6.4 5.7 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 NESM3 12.4 18.8 54.6 22.5 15.7 24. NorESM2-LM 16.1 11.5 18.6 8 11.7 13.7 NorESM2-MM 15.5 5 12.8 6.1 5.5 8.9 TaiESM1 9 3.9 12.6 6.1 4.8 7.2	KIOST-ESM -	9.2	7.7	11.2	10.9	10.2	9.84
MPI-ESM1-2-LR 6.3 4.5 6.6 6.4 5 5.7 MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 NESM3 12.4 18.8 54.6 22.5 15.7 24. NorESM2-LM 16.1 11.5 18.6 8 11.7 13.7 NorESM2-MM 15.5 5 12.8 6.1 5.5 8.9 TaiESM1 9 3.9 12.6 6.1 4.8 7.2	MIROC6 -	7.3	3.4	16.5	6.5	6.6	8.06
MRI-ESM2-0 10.6 4.8 7.7 8.5 6 7.5 NESM3 12.4 18.8 54.6 22.5 15.7 24. NorESM2-LM 16.1 11.5 18.6 8 11.7 13.7 NorESM2-MM 15.5 5 12.8 6.1 5.5 8.9 TaiESM1 9 3.9 12.6 6.1 4.8 7.2	MPI-ESM1-2-HR -	10.7	8.1	15.6	9.7	4.4	9.7
NESM312.418.854.622.515.724.NorESM2-LM16.111.518.6811.713.7NorESM2-MM15.5512.86.15.58.9TaiESM193.912.66.14.87.2	MPI-ESM1-2-LR -	6.3	4.5	6.6	6.4	5	5.76
NorESM2-LM 16.1 11.5 18.6 8 11.7 13.7 NorESM2-MM 15.5 5 12.8 6.1 5.5 8.9 TaiESM1 9 3.9 12.6 6.1 4.8 7.2	MRI-ESM2-0 -	10.6	4.8	7.7	8.5	6	7.52
NorESM2-LM 16.1 11.5 18.6 8 11.7 13.7 NorESM2-MM 15.5 5 12.8 6.1 5.5 8.9 TaiESM1 9 3.9 12.6 6.1 4.8 7.2	NESM3 -	12.4	18.8	54.6	22.5	15.7	24.8
TaiESM1 - 9 3.9 12.6 6.1 4.8 7.2	NorESM2-LM -						13.18
	NorESM2-MM -	15.5	5	12.8	6.1	5.5	8.98
1 2 3 4 5 Mea	TaiESM1 -	9	3.9	12.6	6.1		7.28
CP	,	1	2			5	Mean



SPATIAL PATTERNS: TAYLOR DIAGRAMS AND PR DISO

More difficulties in PR than TN and TX, particularly CPI.

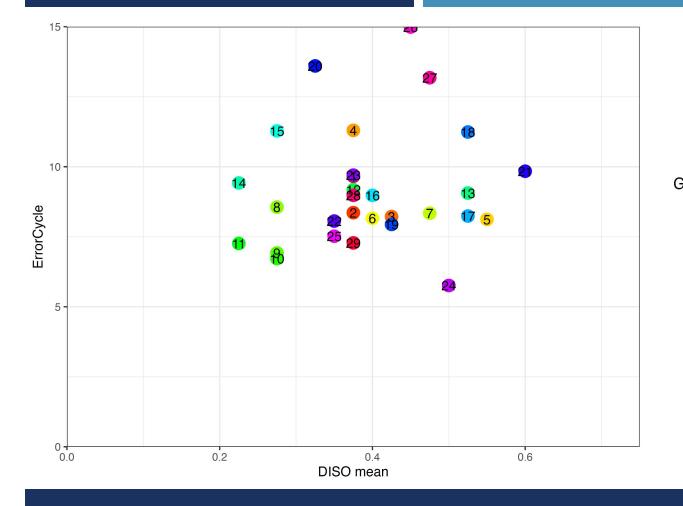
ACCESS-CM2 -	0.6	0.6	0.6	0.5	0.6	0.6		
ACCESS-ESM1-5 -	0.7	0.4	0.5	0.7	0.5	0.6		
AWI-ESM-1-1-LR -	0.9	0.5	1	0.8	0.6	0.7		
BCC-CSM2-MR -	0.6	0.6	0.8	0.8	0.4	0.6		
CanESM5 -	1.1	0.6	1.1	0.9	0.7	0.9		
CMCC-CM2-SR5 -	0.8	0.4	0.6	0.6	0.5	0.6		
CMCC-ESM2 -	0.8	0.7	0.6	0.8	0.8	0.8		
EC-Earth3 -	0.6	0.4	0.4	0.6	0.5	0.5		
EC-Earth3-AerChem -	1	0.3	0.3	0.6	0.4	0.5		
EC-Earth3-CC -	0.7	0.4	0.3	0.6	0.5	0.5		
EC-Earth3-Veg -	0.6	0.4	0.3	0.4	0.4	0.4		
EC-Earth3-Veg-LR -	0.7	0.4	0.5	0.5	1.1	0.6		
FGOALS-g3 -	1.1	0.7	1	0.8	0.6	0.8		
GFDL-CM4 -	0.5	0.4	0.5	0.5	0.3	0.4		
GFDL-ESM4 -	0.4	0.3	0.5	0.6	0.7	0.5		
IITM-ESM -	0.6	0.6	0.5	0.7	0.5	0.6		
INM-CM4-8 -	0.9	0.5	1	0.9	0.7	0.8		
INM-CM5-0 -	1.4	0.5	0.8	0.7	0.5	0.8		
IPSL-CM6A-LR -	1	0.5	0.9	0.5	0.4	0.7		
KACE-1-0-G -	0.5	0.3	0.5	0.7	0.6	0.5		
KIOST-ESM -	1	1.2	1.2	1	0.7	1		
MIROC6 -	0.5	0.4	0.6	0.5	0.4	0.5		
MPI-ESM1-2-HR -	0.9	0.5	0.8	0.5	0.4	0.6		
MPI-ESM1-2-LR -	1.2	0.5	0.9	0.7	0.6	0.8		
MRI-ESM2-0 -	0.8	0.5	0.5	0.6	0.4	0.6		
NESM3 -	0.7	0.6	0.8	0.8	0.6	0.7		
NorESM2-LM -	0.9	0.6	0.8	0.8	0.5	0.7		
NorESM2-MM -	1	0.4	0.7	0.6	0.4	0.6		
TaiESM1 -	1	0.4	0.5	0.5	0.4	0.6		
	1 2 3 4 5 Mean CP							

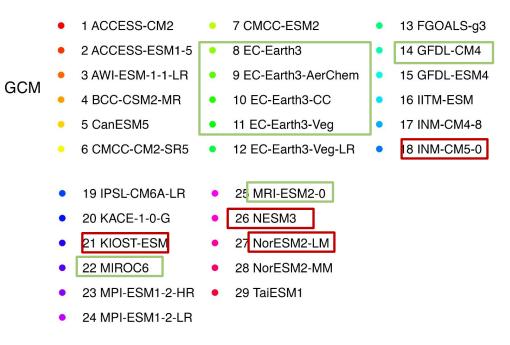
1.0 0.5

1.5

PR

0.0





MODEL PERFORMANCE: ERRORCYCLE VS. DISO MEAN (PR, TN AND TX)

MAIN CONCLUSIONS

The classification of CPs can discriminate 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 follow-up filtering of climate projections.

THANKS!

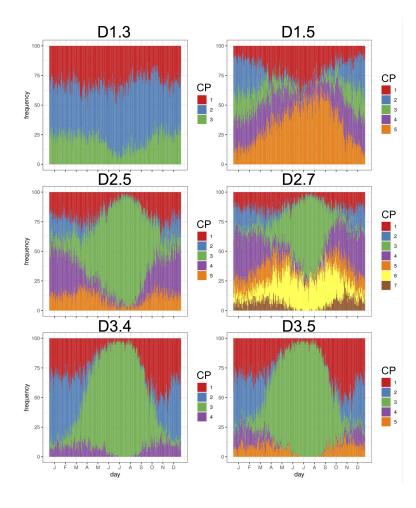
MATIAS.OLMO@BSC.ES

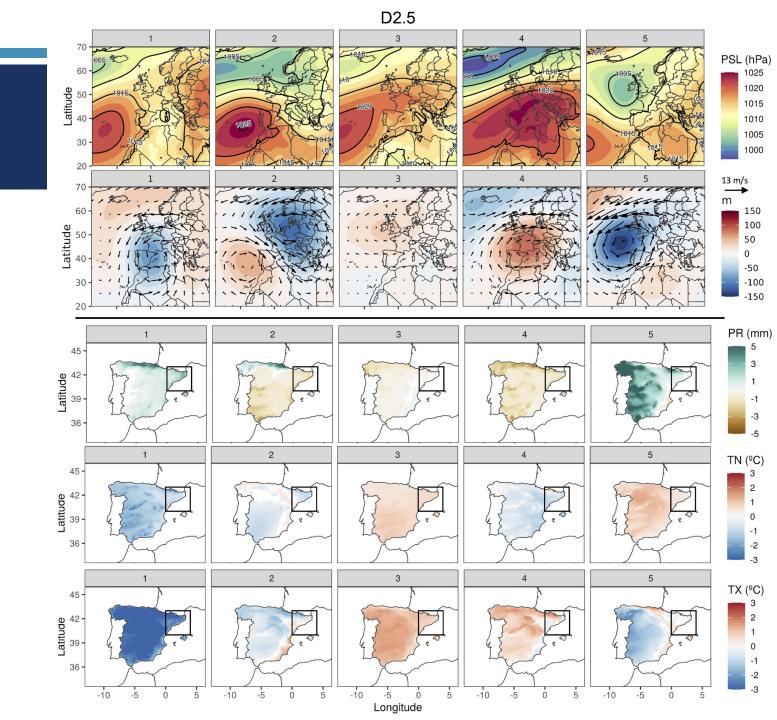


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EXTRA SLIDE I





EXTRA SLIDE II

