



**Barcelona
Supercomputing
Center**

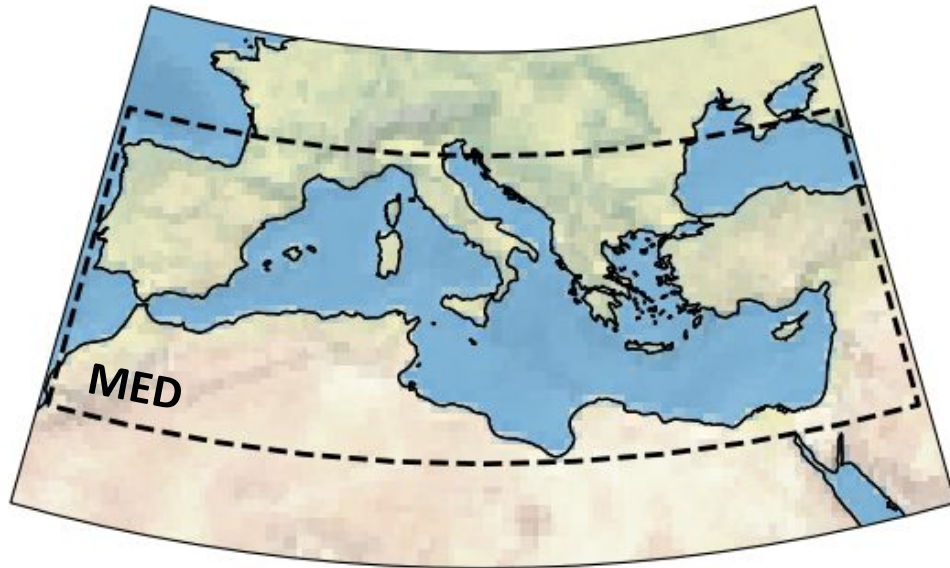
Centro Nacional de Supercomputación

CMIP5 and CMIP6 Mediterranean climate change projections

Josep Cos, Francisco Doblas-Reyes and Martin Jury

Region and Data context

Mediterranean Region

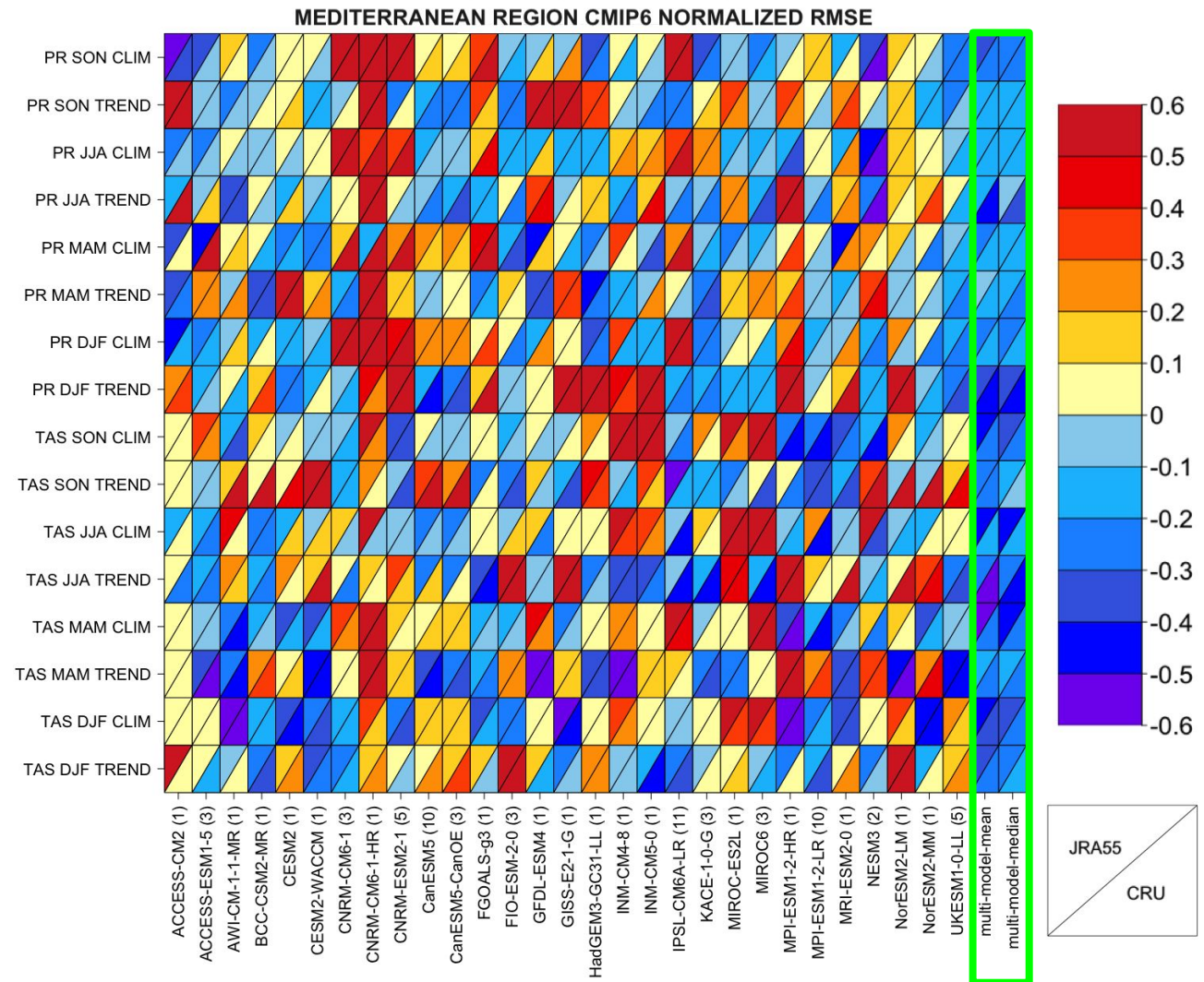


- CMIP5 (1960-2100)
 - historical:RCP2.6
 - historical:RCP4.5
 - historical:RCP8.5
- CMIP6 (1960-2100)
 - historical:SSP1-2.6
 - historical:SSP2-4.5
 - historical:SSP5-8.5
- HighResMIP (1960-2050)
 - hist-1950:highres-future (SSP5-8.5)
- Observational data
 - BerkeleyEarth, ERA5, JRA55, CRU, E-OBS, GPCC, WFDE5

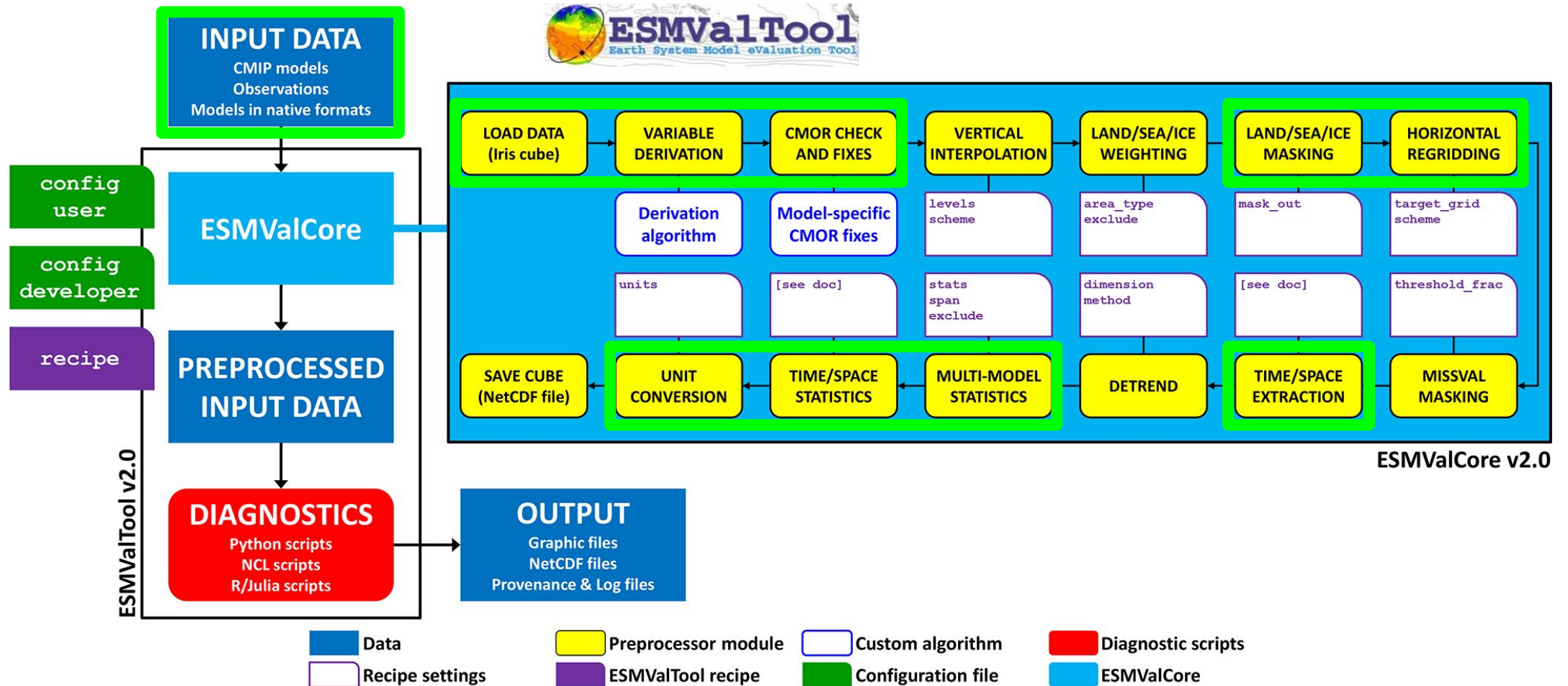
CMIP5	RCP2.6	RCP4.5	RCP8.5	CMIP6	SSP1-2.6	SSP2-4.5	SSP5-8.5
ACCESS1-0	-	rlilp1	rlilp1	ACCESS-CM2	rlilp1f1	rlilp1f1	rlilp1f1
ACCESS1-3	-	rlilp1	rlilp1	ACCESS-ESM1-5	r(1-3)ilp1f1	r(1-3)ilp1f1	r(1-3)ilp1f1
BCC-CSM1-1	rlilp1	rlilp1	rlilp1	AWI-CM-1-1-MR	rlilp1f1	rlilp1f1	rlilp1f1
BCC-CSM1-1-M	rlilp1	rlilp1	rlilp1	BCC-CSM2-MR	rlilp1f1	rlilp1f1	rlilp1f1
BNU-ESM	rlilp1	rlilp1	rlilp1	CanESM5	r(1-10)ilp1f1	r(1-10)ilp1f1	r(1-10)ilp1f1
CanESM2	r(1-5)ilp1	r(1-5)ilp1	r(1-5)ilp1	CanESM5-CanOE	r(1-3)ilp1f1	r(1-3)ilp1f1	r(1-3)ilp1f1
CCSM4	r(1-5)ilp1	r(1-5)ilp1	r(1-6)ilp1	CESM2	rlilp1f1	rlilp1f1	rlilp1f1
CESM1-BGC	-	-	rlilp1	CESM2-WACCM	rlilp1f1	rlilp1f1	rlilp1f1
CESM1-CAM5	r(1-3)ilp1	r(1-3)ilp1	r(1-3)ilp1	CMCC-CM2-SR5	-	-	rlilp1f1
CMCC-CESM	-	-	rlilp1	CNRM-CM6-1	r(1-6)ilp1f2	r(1-3)ilp1f2	rlilp1f2
CMCC-CM	-	rlilp1	rlilp1	CNRM-CM6-1-HR	rlilp1f2	rlilp1f2	rlilp1f2
CMCC-CMS	-	rlilp1	rlilp1	CNRM-ESM2-1	rlilp1f2	r(1-5)ilp1f2	rlilp1f2
CNRM-CM5	rlilp1	rlilp1 (only pr)	r(1-2,4,6,10)ilp1	FGOALS-g3	rlilp1f1	rlilp1f1	rlilp1f1
CSIRO-Mk3-6-0	r(1-10)ilp1	r(1-10)ilp1	r(1-10)ilp1	FGOALS-f3-L	rlilp1f1	rlilp1f1	rlilp1f1
EC-Earth	r(2,12)ilp1	r(2,9,12)ilp1	r(2,8,9,12)ilp1	FIO-ESM-2-0	r(1-3)ilp1f1	r(1-3)ilp1f1	r(1-3)ilp1f1
FGOALS-s2	-	rlilp1	r(1-3)ilp1	GFDL-ESM4	rlilp1f1	rlilp1f1	rlilp1f1
FGOALS-g2	-	-	rlilp1 (no pr)	GISS-E2-1-G	rlilp3f1	r(1,3)ilp3f1	rlilp3f1
FIO-ESM	r(1-3)ilp1	r(1-3)ilp1	r(1-3)ilp1	HadGEM3-GC31-LL	rlilp1f3	rlilp1f3	r(1-3)ilp1f3
GFDL-CM3	rlilp1	rlilp1	rlilp1	INM-CM4-8	rlilp1f1	rlilp1f1	rlilp1f1
GFDL-ESM2G	rlilp1	rlilp1 (no pr)	rlilp1	INM-CM5-0	rlilp1f1	rlilp1f1	rlilp1f1
GFDL-ESM2M	rlilp1	rlilp1 (no pr)	rlilp1	IPSL-CM6A-LR	r(1-4,6)ilp1f1	r(1-6,10,11,14,22,25)ilp1f1	rlilp1f1
GISS-E2-H	rlilp1	r(1-5)ilp1	r(1-2)ilp1	KACE-1-0-G	r(1-2)ilp1f1	r(1-3)ilp1f1	rlilp1f1
GISS-E2-H-CC	-	rlilp1 (no pr)	rlilp1	MIROC-ES2L	rlilp1f2	rlilp1f2	rlilp1f2
GISS-E2-R	rlilp1	r(2,5,6)ilp3	r(1-2)ilp1	MIROC6	r(1-3)ilp1f1	r(1-3)ilp1f1	r(1-3)ilp1f1
GISS-E2-R-CC	-	rlilp1 (no pr)	rlilp1	MPI-ESM1-2-HR	rlilp1f1	rlilp1f1	rlilp1f1
HadGEM2-AO	rlilp1	rlilp1 (only pr)	rlilp1	MPI-ESM1-2-LR	r(1-10)ilp1f1	r(1-10)ilp1f1	r(1-10)ilp1f1
HadGEM2-CC	-	rlilp1	rlilp1	MRI-ESM2-0	rlilp1f1	rlilp1f1	rlilp1f1
HadGEM2-ES	r(1-4)ilp1	r(1-4)ilp1	r(1-4)ilp1	NESM3	r(1-2)ilp1f1	r(1-2)ilp1f1	r(1-2)ilp1f1
INMCM4	-	rlilp1	rlilp1	NorESM2-LM	rlilp1f1	rlilp1f1	rlilp1f1
IPSL-CM5A-LR	r(1-4)ilp1	-	r(1-4)ilp1	NorESM2-MM	rlilp1f1	rlilp1f1	rlilp1f1
IPSL-CM5A-MR	rlilp1	rlilp1	rlilp1	UKESM1-0-LL	r(1-4,8)ilp1f2	r(1-4,8)ilp1f2	r(1-4,8)ilp1f2
IPSL-CM5B-LR	-	rlilp1	rlilp1	HighResMIP	SSP5-8.5		
MIROC-ESM	rlilp1	rlilp1	rlilp1	CMCC-CM2-HR4	rlilp1f1		
MIROC-ESM-CHEM	rlilp1	rlilp1	rlilp1	CMCC-CM2-VHR4	rlilp1f1		
MIROC5	r(2-3)ilp1	r(2-3)ilp1	r(2-3)ilp1	CNRM-CM6-1-HR	rlilp1f1		
MPI-ESM-LR	r(1-3)ilp1	r(1-3)ilp1	r(1-3)ilp1	EC-Earth3P-HR	r2ilp2f1		
MPI-ESM-MR	rlilp1	r(1-3)ilp1	rlilp1	HadGEMGE3-GC31-HH	rlilp1f1		
MPI-CGCM3	-	rlilp1	rlilp1	HadGEMGE3-GC31-HM	rlilp1f1		
NorESM1-M	rlilp1	rlilp1	rlilp1	HadGEMGE3-GC31-MM	rlilp1f1		

Multi-model evaluation

- Single model diagnostics performance against observations.
- Multi-model mean and median are closer to observations across diagnostics.
- Dependencies between models **bias** the ensemble.



Earth System Model Evaluation Tool



Recipe structure

```
12 - &cmip5_h-rcp85 {project: CMIP5, exp: [historical, rcp85], dataset: ACCESS1-0, expid: [historical_i0p1, rcp85_i1p1], ensemble: r1i1p1, start_year: 1960, end_year: 2100}
13
14 - {<<: *cmip5_h-rcp85, dataset: ACCESS1-3}
15
16 - {<<: *cmip5_h-rcp85, dataset: bcc-csm1-1}
17
18 - {<<: *cmip5_h-rcp85, dataset: bcc-csm1-1-m}
19
20 - {<<: *cmip5_h-rcp85, dataset: BNU-ESM}
21
22 - {<<: *cmip5_h-rcp85, dataset: CanESM2, ensemble: r(1:5)i1p1}
```

...

Datasets call

```
108 - &cmip6_h-ssp585 {project: CMIP6, exp: [historical, ssp585], dataset: ACCESS-CM2, expid: [historical_i0p1, ssp585_i1p1], ensemble: r1i1p1f1, grid: gn, start_year: 1960, end_year: 2100}
109
110 - {<<: *cmip6_h-ssp585, dataset: ACCESS-ESM1-5, ensemble: r(1:3)i1p1f1, grid: gn}
111
112 - {<<: *cmip6_h-ssp585, dataset: AWI-CM-1-1-MR}
113
114 - {<<: *cmip6_h-ssp585, dataset: BCC-CSM2-MR}
115
116 - {<<: *cmip6_h-ssp585, dataset: CESM2, ensemble: r1i1p1f1, grid: gn}
117
118 - {<<: *cmip6_h-ssp585, dataset: CESM2-WACCM, grid: gn}
```

...

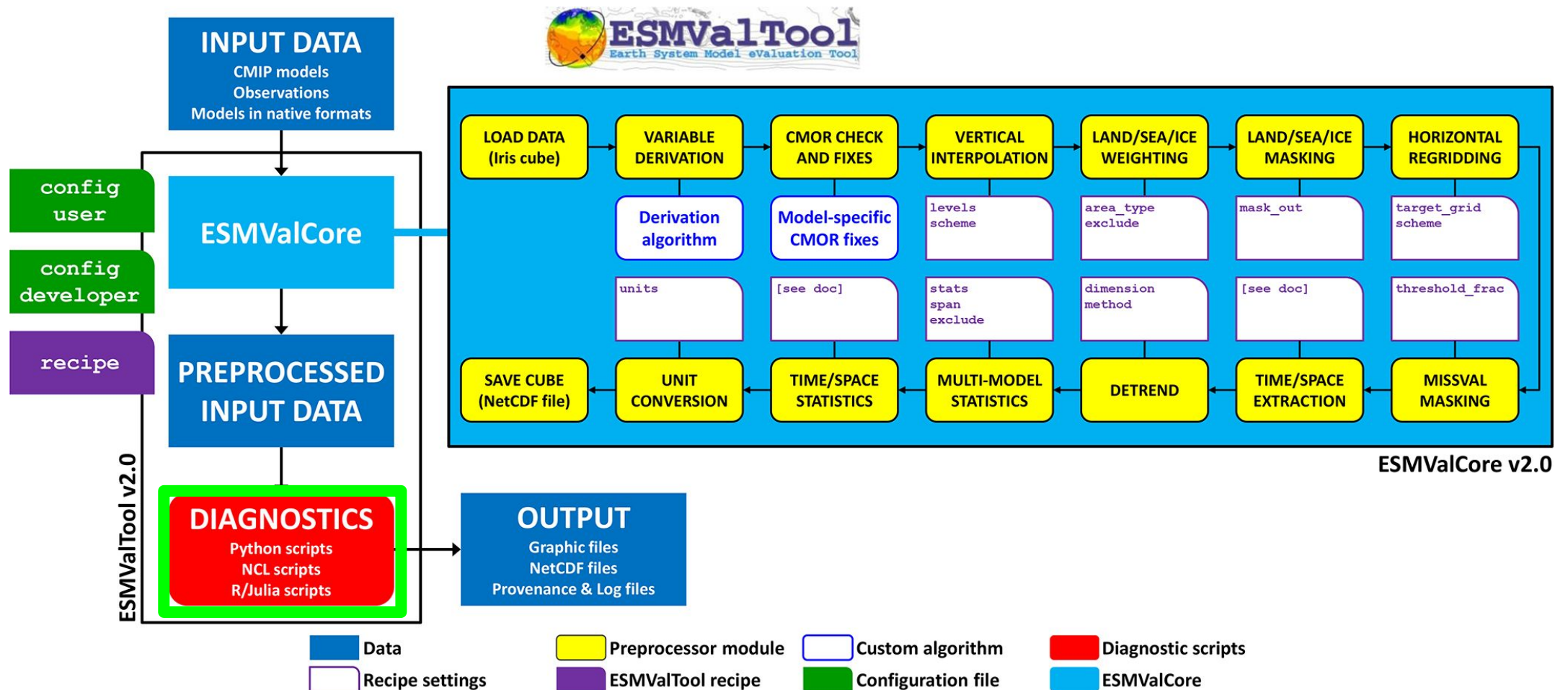
Preprocessor definition

```
279 preprocessors:
280   general_conservative: &general_cons
281   mask_landsea:
282     mask_out: sea
283   regrid:
284     target_grid: 1x1
285     scheme: area_weighted
286   extract_region:
287     start_longitude: -10
288     end_longitude: 40
289     start_latitude: 25
290     end_latitude: 50
291
292   djf_conservative:
293     extract_season:
294       season: 'djf'
295     seasonal_statistics:
296       operator: 'mean'
297     <<: *general_cons
```

Diagnostics definition

```
428 diagnostics:
429   djf_pr:
430     description: "MedRegion winter precipitation diagnostic"
431     variables:
432       pr:
433         short_name: pr
434         mip: Amon
435         predecessor: djf_conservative
436         additional_datasets: *OBS_pr
437     scripts:
438       djf_pr:
439         script: /esarchive/scratch/jcos/esmvaltool/scripts/concurrent_diagnostics.py
```


Earth System Model Evaluation Tool



Diagnostic

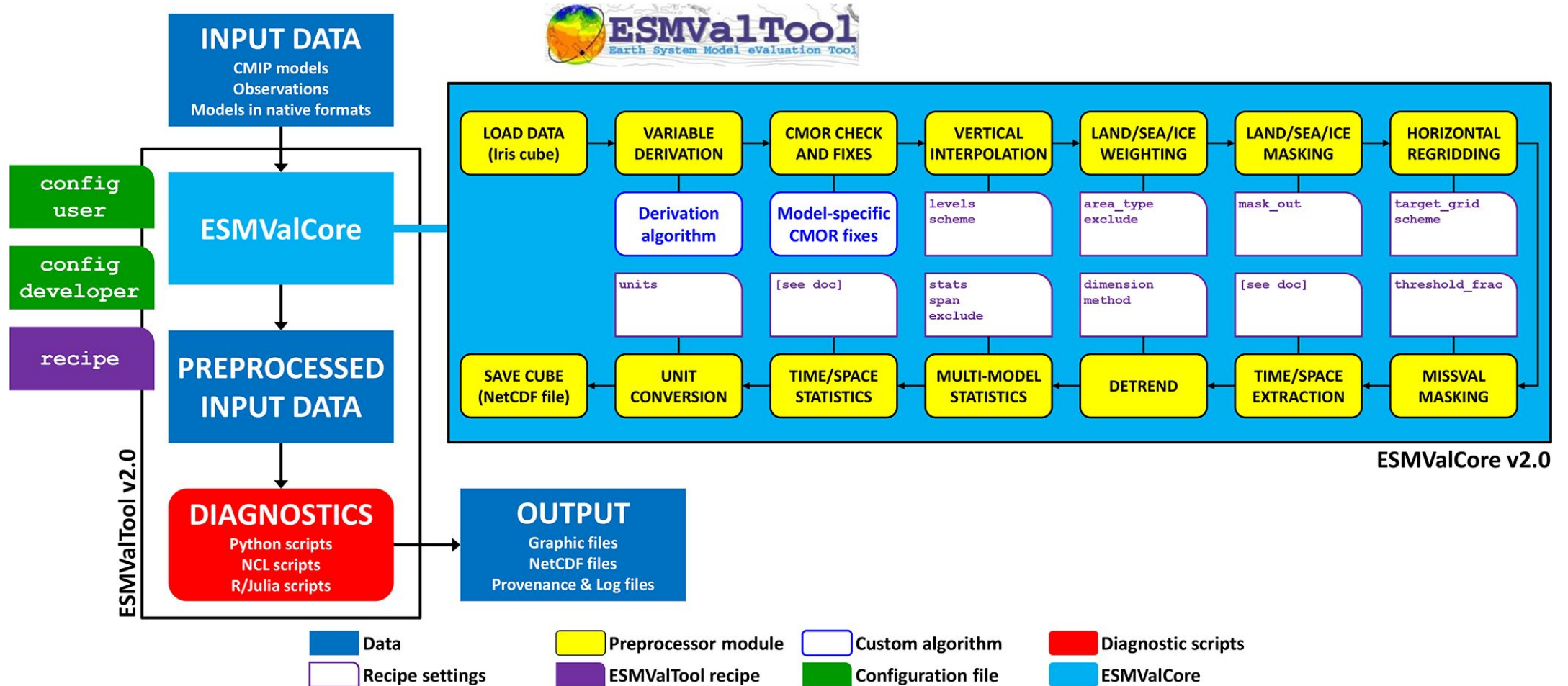
- Upload the preprocessed data through ESMValTool metadata handling utilities
- Further postprocessing of the data in case more metrics or diagnostics must be extracted
- Generate new files with results and use the language's plotting modules to output relevant figures

```
3 from esmvalcore.preprocessor._area import area_statistics, extract_region
4 from esmvalcore.preprocessor._mask import mask_landsea
5 from esmvalcore.preprocessor._time import (
6     extract_time,
7     climate_statistics,
8 )
9 from esmvalcore.preprocessor._multimodel import multi_model_statistics
10 from esmvaltool.diag_scripts.shared import group_metadata
11 import esmvaltool.diag_scripts.shared.names as n
12 import esmvaltool.diag_scripts.shared as e
```

```
baseline_cube = area_statistics(
    climate_statistics(
        extract_time(
            cube.copy(),
            baseline_period["start"],
            1,
            1,
            baseline_period["end"],
            12,
            31,
        ),
        "mean",
    )
)
```

- Ability to call preprocessors from within the diagnostic script
- Compatibility with Iris, a python Earth science data handling and visualisation package (SciTools)

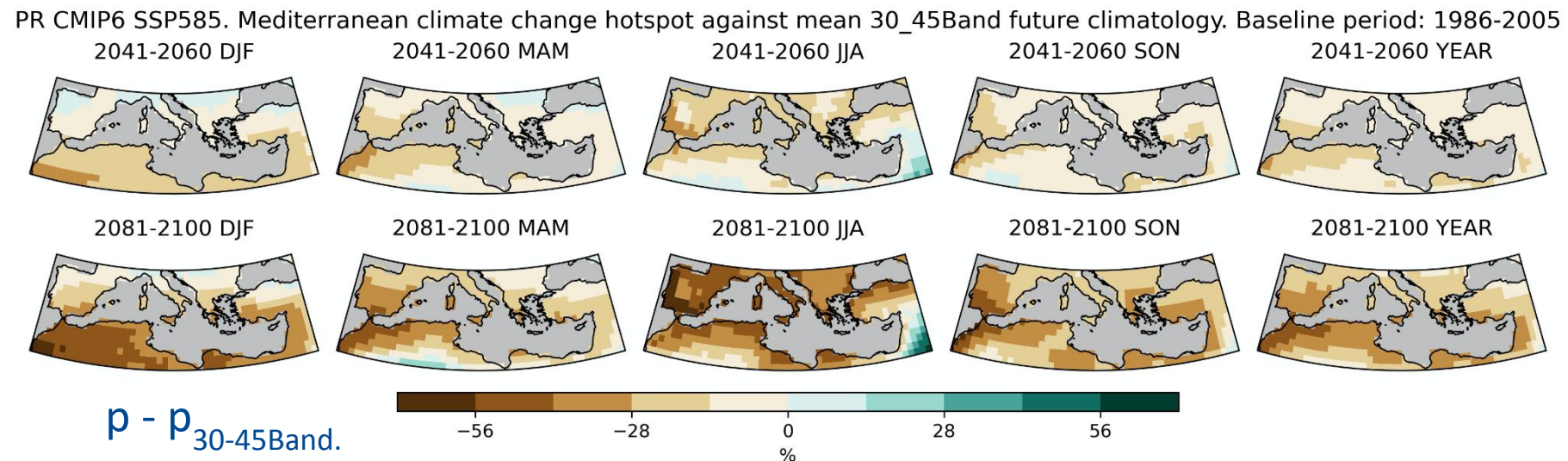
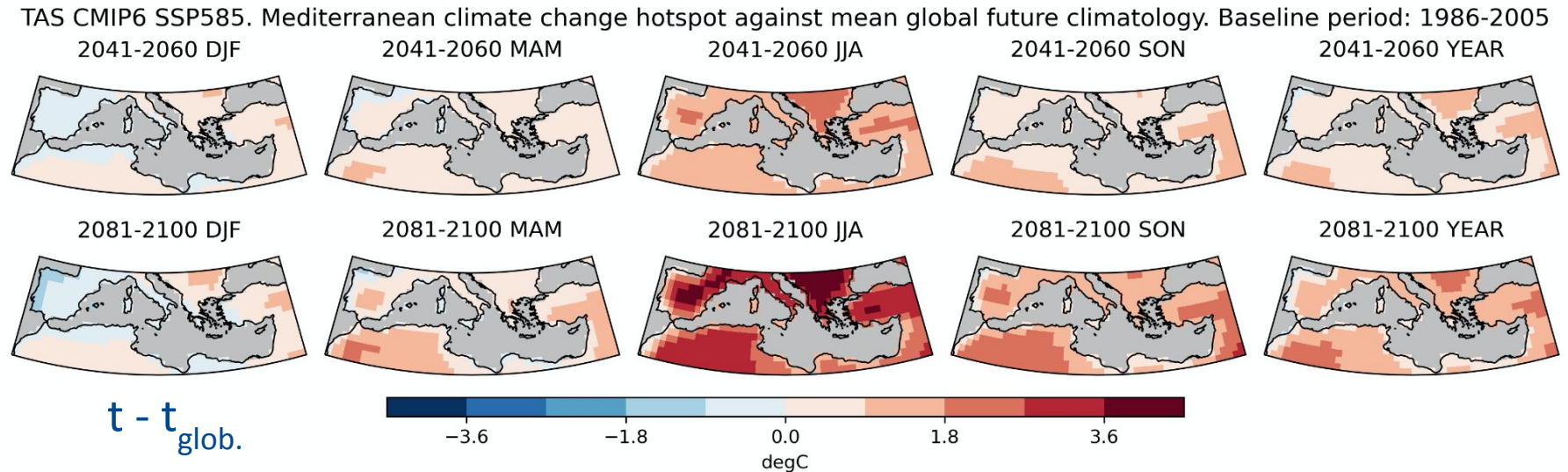
Earth System Model Evaluation Tool



Results

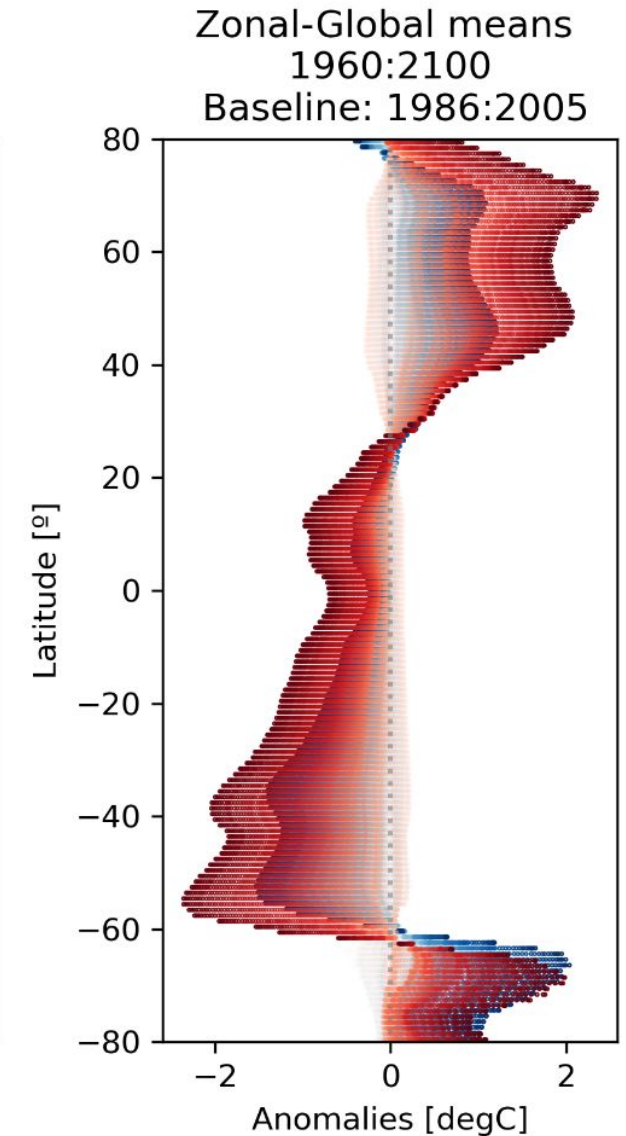
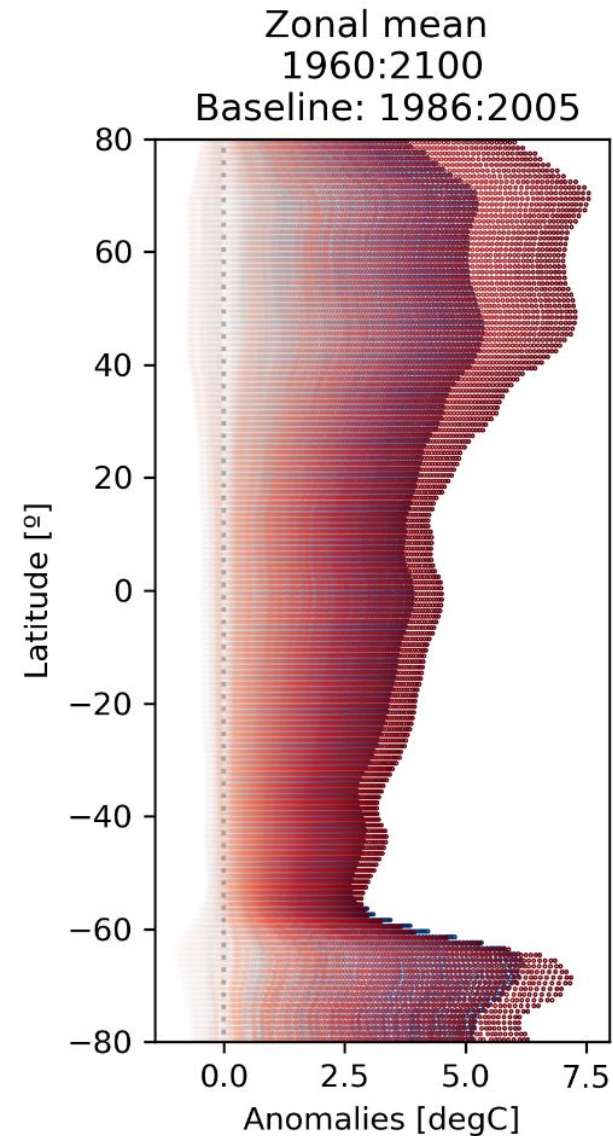
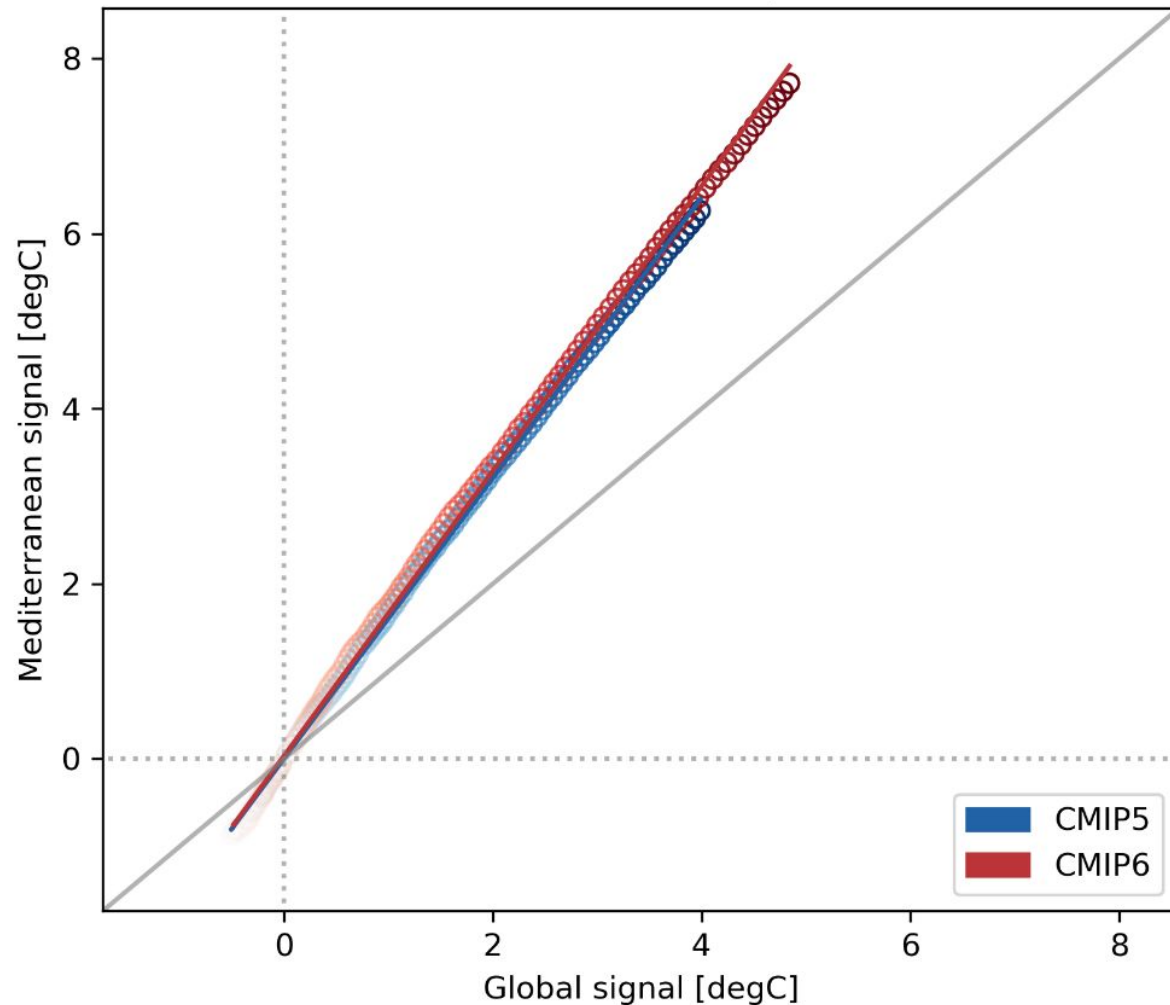
The Mediterranean as a climate change hotspot

- **Summer** warming amplification.
- The **divergence** between global and regional signals grows with time for the largest radiative scenario.
- Drying with respect to the 30_45Band precipitation mean.
- Heterogeneity within the region.

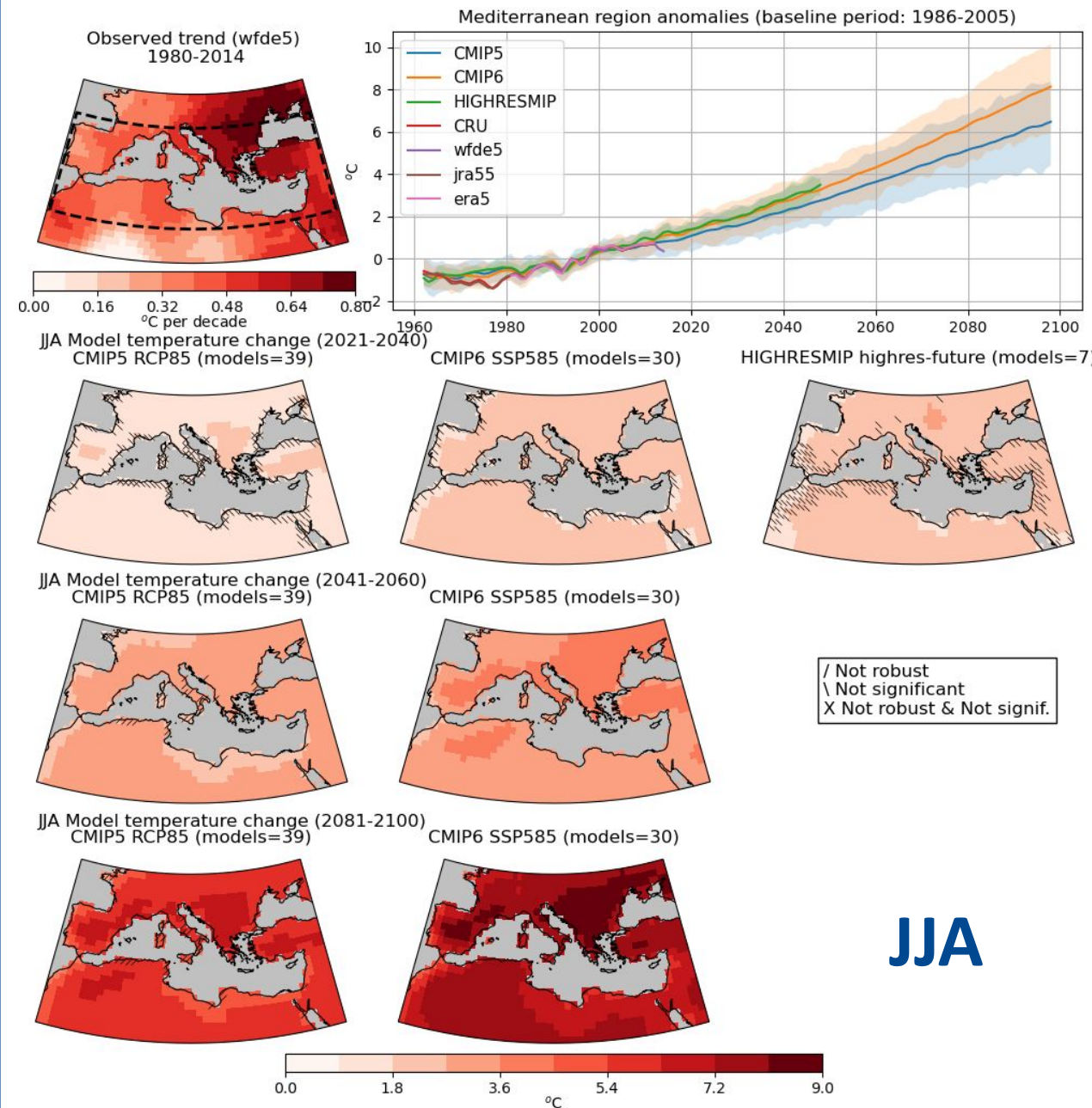
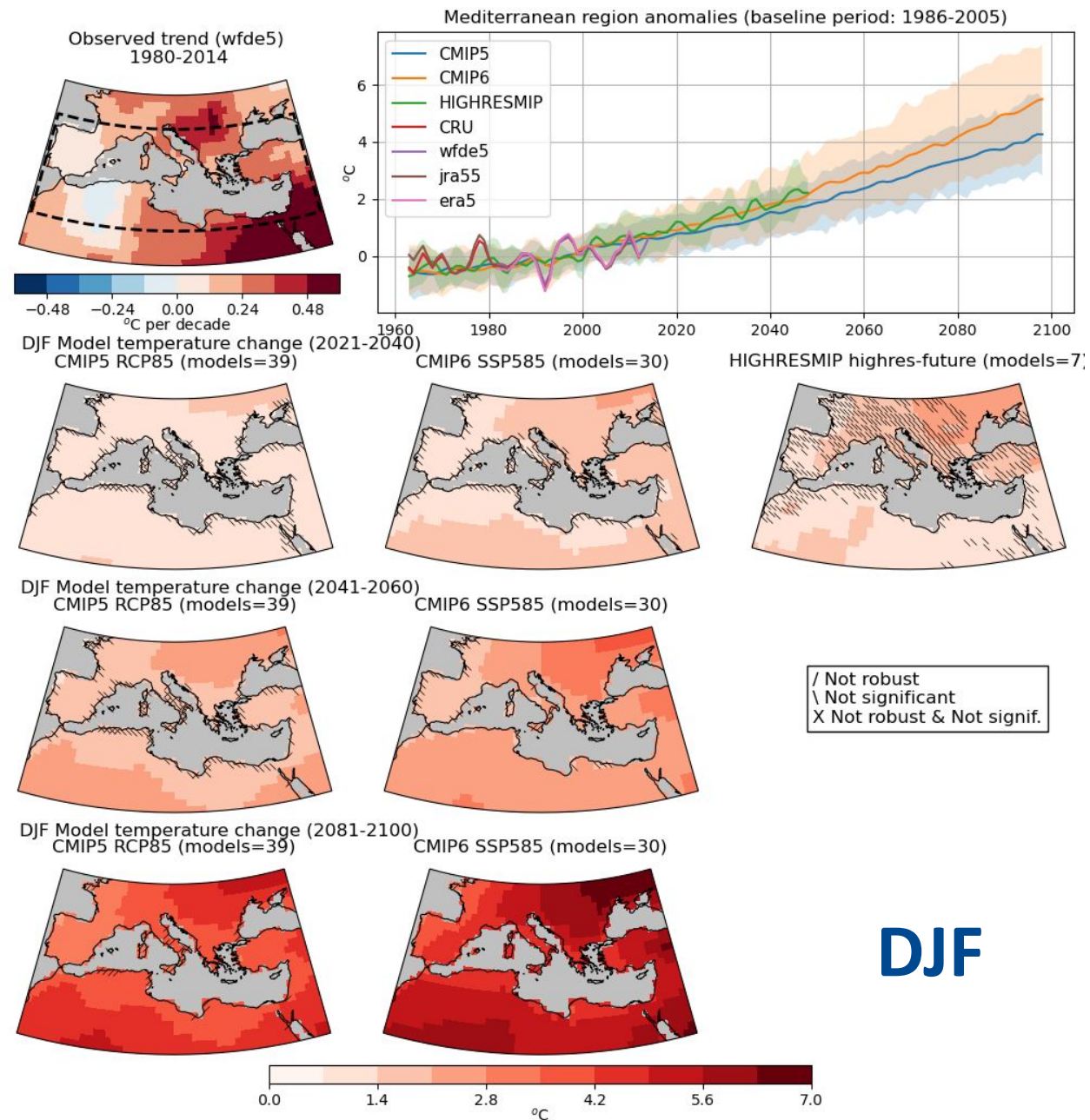


The Mediterranean as a climate change hotspot

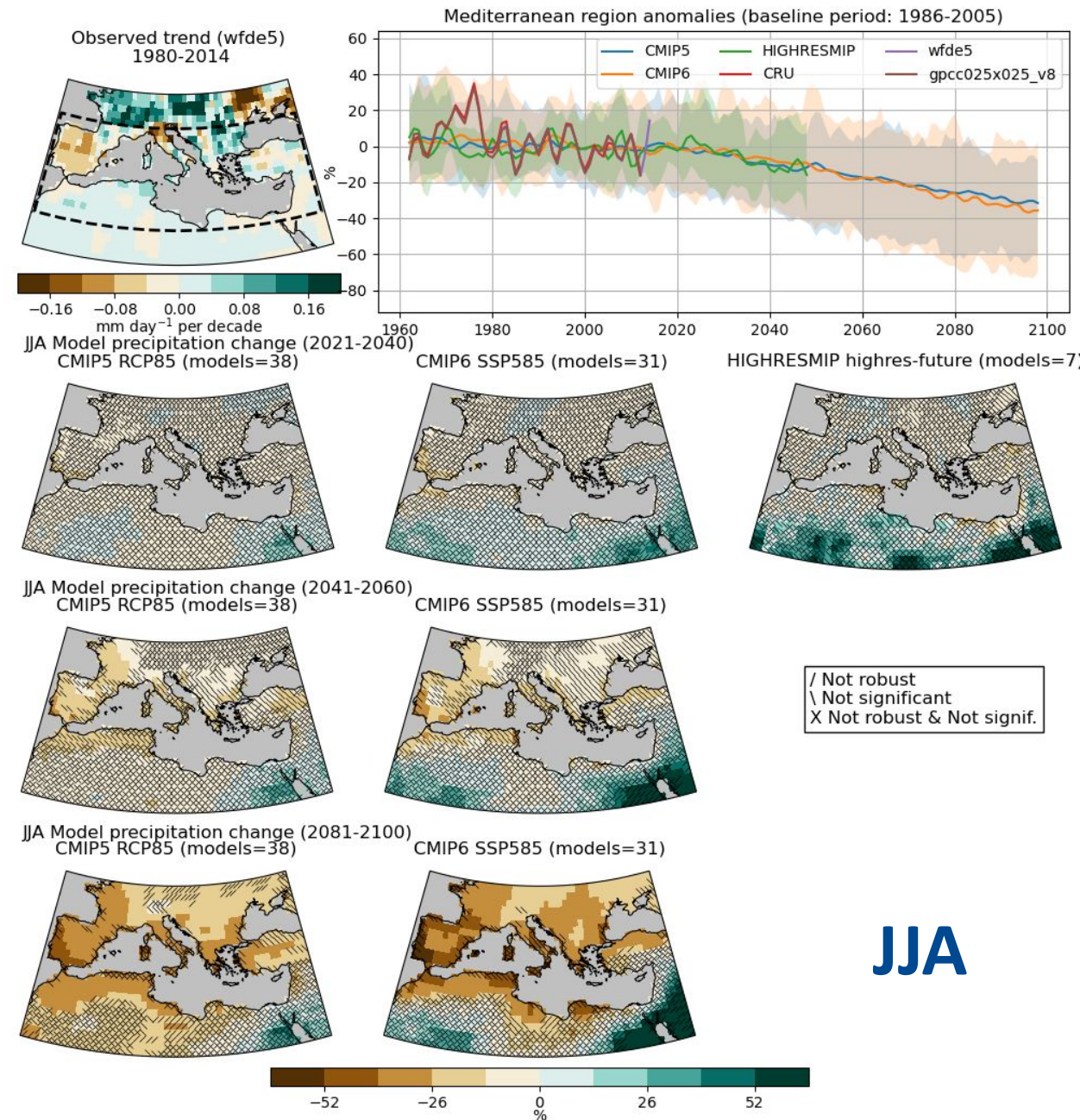
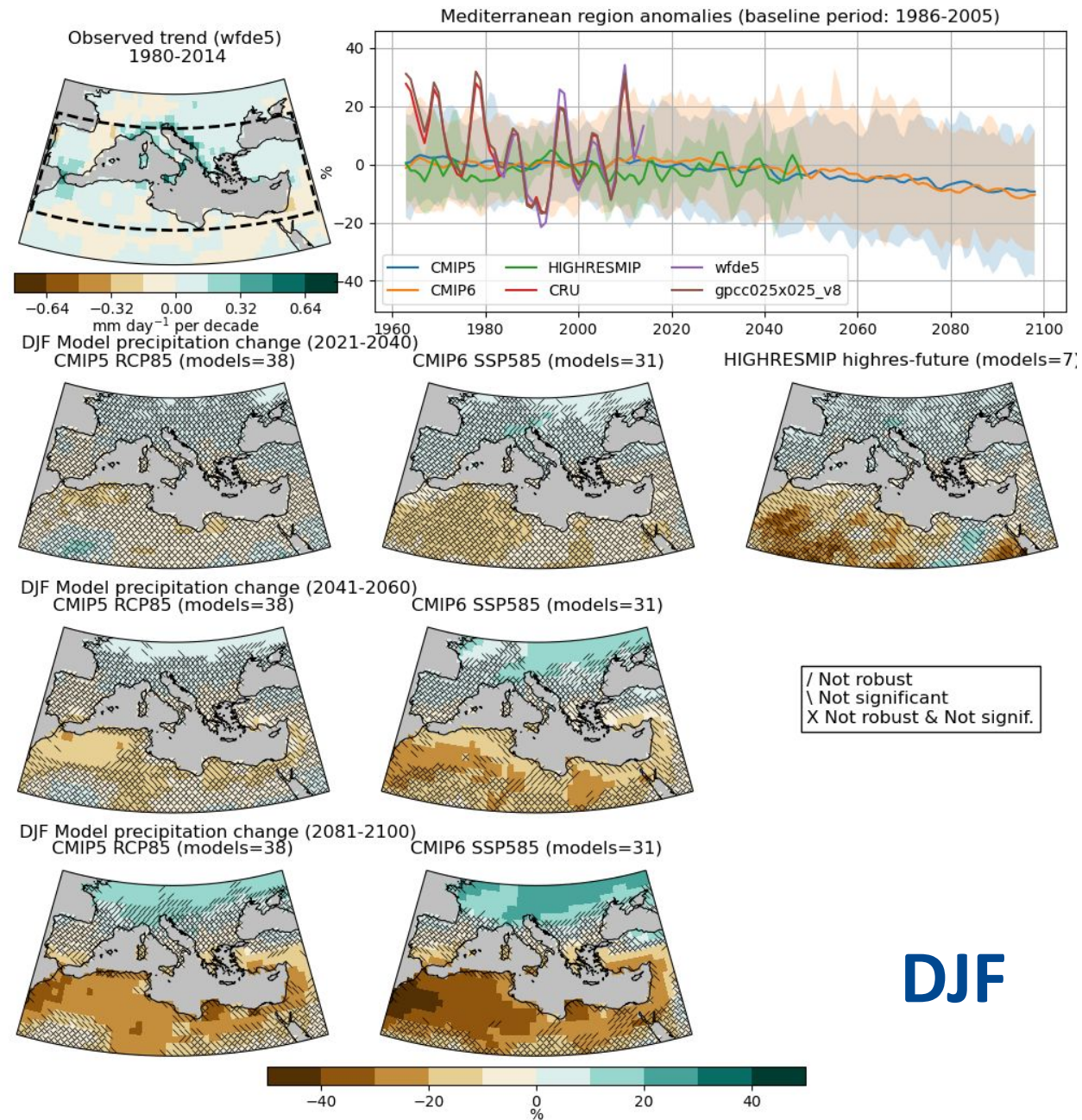
Global vs Mediterranean RCP8.5/SSP5-8.5 JJA TAS signal.
10yr rolling means 1960:2100, Baseline: 1986:2005
CMIP5: $r_{\text{val}}=1.000$; slope=1.602
CMIP6: $r_{\text{val}}=0.999$; slope=1.627



Temperature change RCP8.5/SSP5-8.5 with respect to 1986-2005

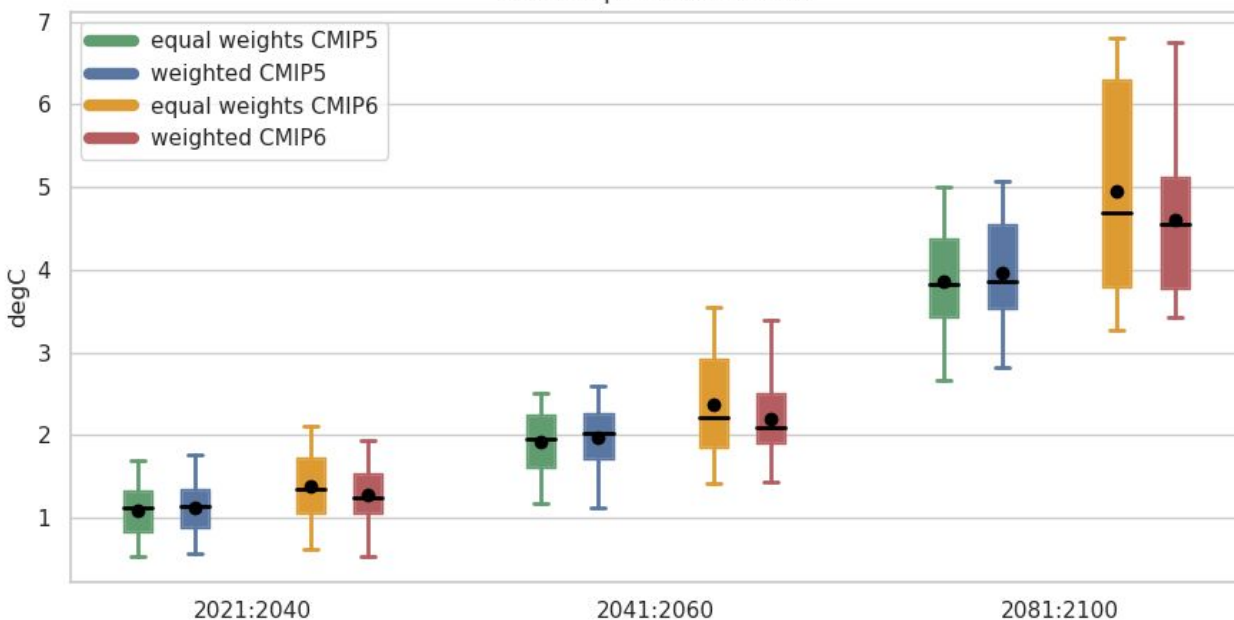


Precipitation change RCP8.5/SSP5-8.5 with respect to 1986-2005

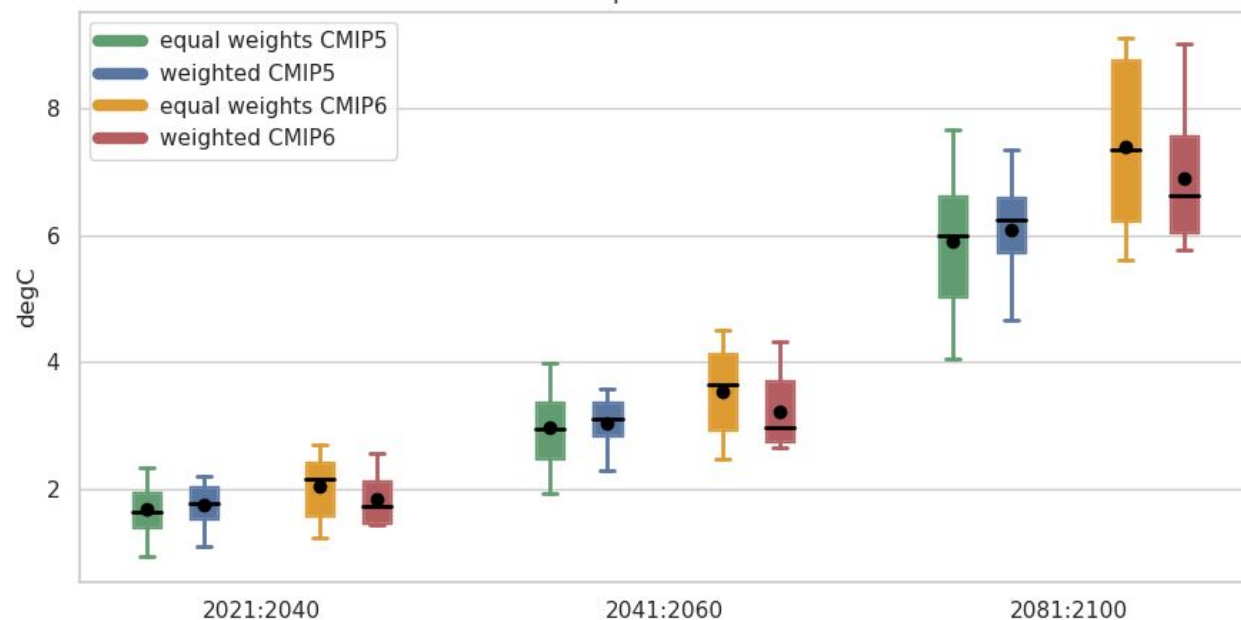


Surface Temperature weighted projections. RCP8.5/SSP5-8.5

TAS DJF RCP8.5/SSP5-8.5 future changes in the Mediterranean region.
Baseline period 1986-2005



TAS JJA RCP8.5/SSP5-8.5 future changes in the Mediterranean region.
Baseline period 1986-2005



Based on the work by *Brunner et al. 2020*.
Currently in the ESMValTool recipe:

ESMValTool/esmvaltool/recipes/recipe_climwip_test_basic.yml

- Downweighting of the most sensitive CMIP6 models.
- Summer reduction of the CMIP5 IQR.
- Closer CMIP5 and CMIP6 means.

What about the rest of the figures generated?

Shiny app

“Shiny is an R package that makes it easy to build interactive web apps straight from R. You can host standalone apps on a webpage or embed them in R Markdown documents or build dashboards. You can also extend your Shiny apps with CSS themes, htmlwidgets, and JavaScript actions. “