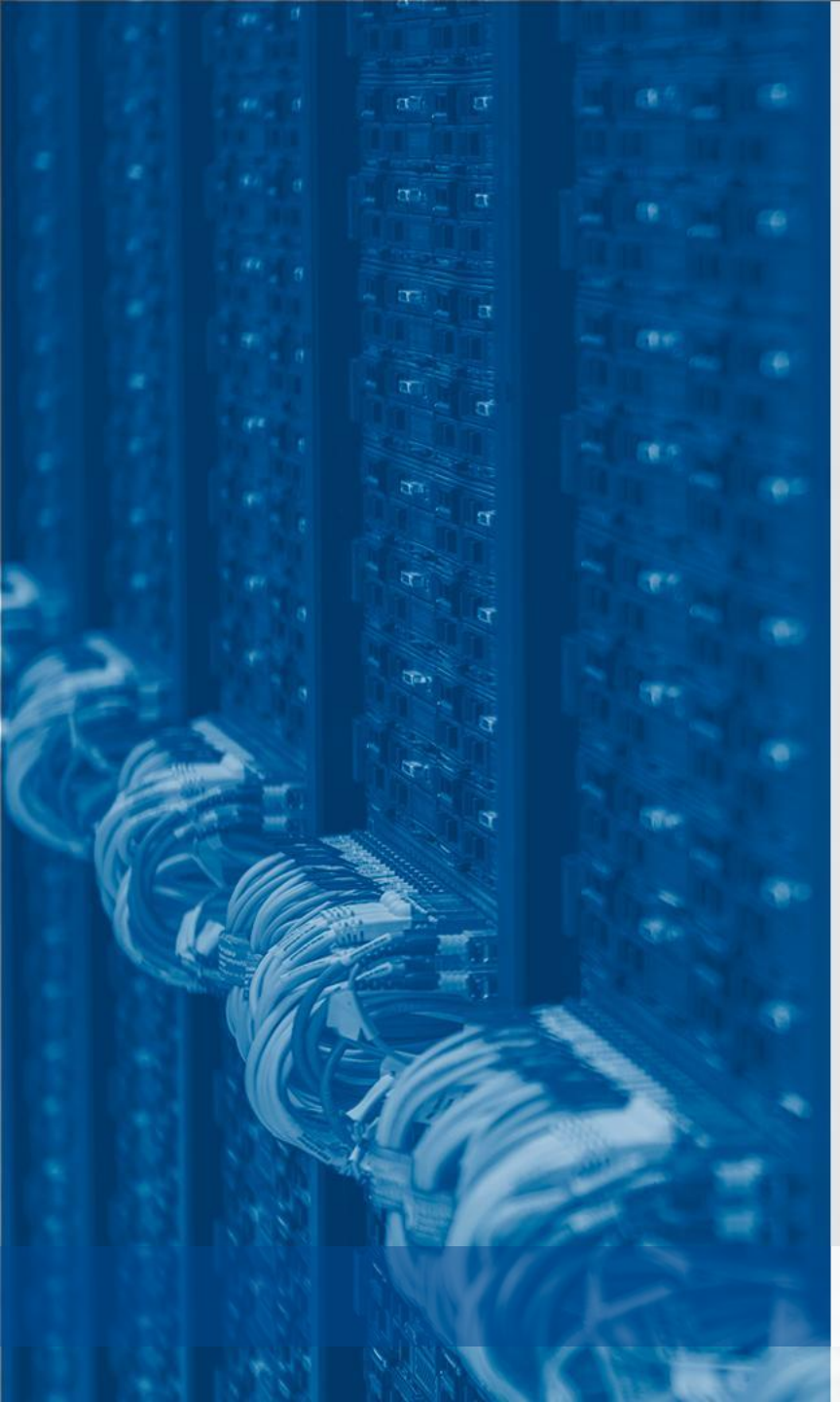

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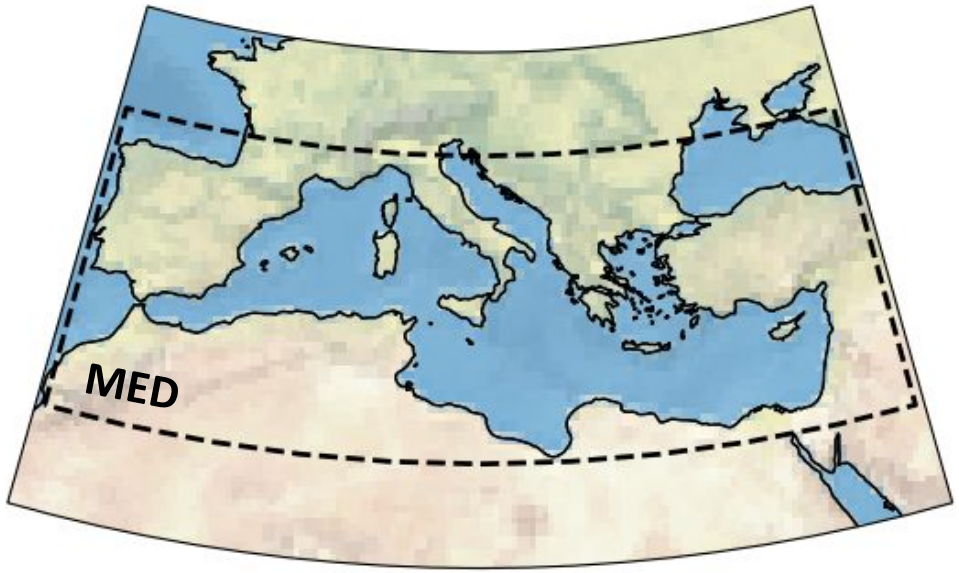
CMIP5 and CMIP6 Mediterranean climate change projections

Josep Cos, Francisco Doblas-Reyes and Martin Jury

IS-ENES3 Virtual workshop on requirements for a fast and scalable evaluation workflow

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

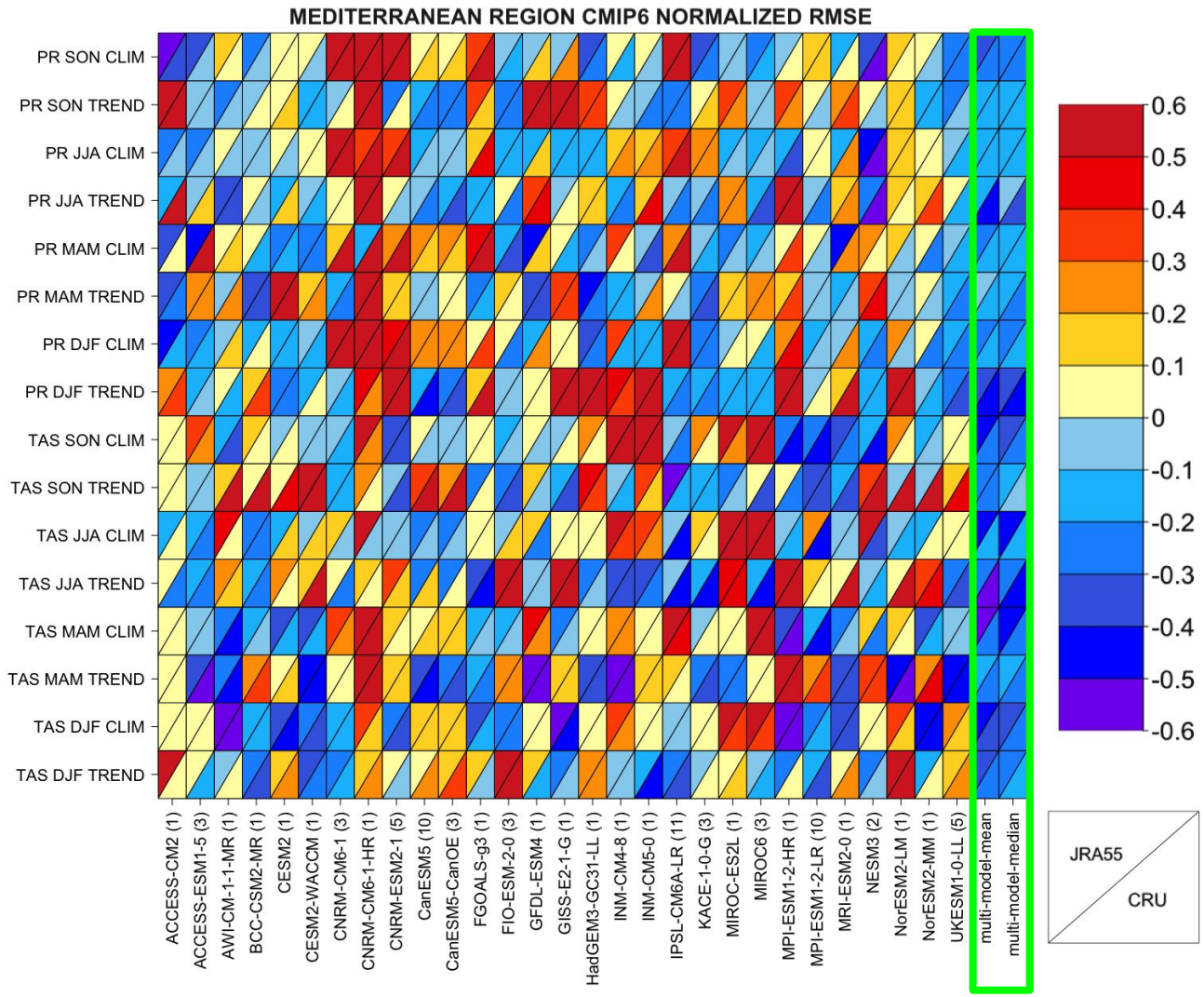
CMIP5	RCP2.6	RCP4.5	RCP8.5
ACCESS1-0	-	r1i1p1	r1i1p1
ACCESS1-3	-	r1i1p1	r1i1p1
BCC-CSM1-1	r1i1p1	r1i1p1	r1i1p1
BCC-CSM1-1-M	r1i1p1	r1i1p1	r1i1p1
BNU-ESM	r1i1p1	r1i1p1	r1i1p1
CanESM2	r(1-5)i1p1	r(1-5)i1p1	r(1-5)i1p1
CCSM4	r(1-5)i1p1	r(1-5)i1p1	r(1-6)i1p1
CESM1-BGC	-	-	r1i1p1
CESM1-CAM5	r(1-3)i1p1	r(1-3)i1p1	r(1-3)i1p1
CMCC-CESM	-	-	r1i1p1
CMCC-CM	-	r1i1p1	r1i1p1
CMCC-CMS	-	r1i1p1	r1i1p1
CNRM-CM5	r1i1p1	r1i1p1 (only pr)	r(1-2,4,6,10)i1p1
CSIRO-Mk3-6-0	r(1-10)i1p1	r(1-10)i1p1	r(1-10)i1p1
EC-Earth	r(2,12)i1p1	r(2,9,12)i1p1	r(2,8,9,12)i1p1
FGOALS-s2	-	r1i1p1	r(1-3)i1p1
FGOALS-g2	-	-	r1i1p1 (no pr)
FIO-ESM	r(1:3)i1p1	r(1-3)i1p1	r(1-3)i1p1
GFDL-CM3	r1i1p1	r1i1p1	r1i1p1
GFDL-ESM2G	r1i1p1	r1i1p1 (no pr)	r1i1p1
GFDL-ESM2M	r1i1p1	r1i1p1 (no pr)	r1i1p1
GISS-E2-H	r1i1p1	r(1-5)i1p1	r(1-2)i1p1
GISS-E2-H-CC	-	r1i1p1 (no pr)	r1i1p1
GISS-E2-R	r1i1p1	r(2,5,6)1i1p3	r(1-2)i1p1
GISS-E2-R-CC	-	r1i1p1 (no pr)	r1i1p1
HadGEM2-AO	r1i1p1	r1i1p1 (only pr)	r1i1p1
HadGEM2-CC	-	r1i1p1	r1i1p1
HadGEM2-ES	r(1-4)i1p1	r(1-4)i1p1	r(1-4)i1p1
INMCM4	-	r1i1p1	r1i1p1
IPSL-CM5A-LR	r(1-4)i1p1	-	r(1-4)i1p1
IPSL-CM5A-MR	r1i1p1	r1i1p1	r1i1p1
IPSL-CM5B-LR	-	r1i1p1	r1i1p1
MIROC-ESM	r1i1p1	r1i1p1	r1i1p1
MIROC-ESM-CHEM	r1i1p1	r1i1p1	r1i1p1
MIROC5	r(2-3)1i1p1	r(2-3)i1p1	r(2-3)i1p1
MPI-ESM-LR	r(1-3)i1p1	r(1-3)i1p1	r(1-3)i1p1
MPI-ESM-MR	r1i1p1	r(1-3)i1p1	r1i1p1
MPI-CGCM3	-	r1i1p1	r1i1p1
NorESM1-M	r1i1p1	r1i1p1	r1i1p1

CMIP6	SSP1-2.6	SSP2-4.5	SSP5-8.5
ACCESS-CM2	r1i1p1f1	r1i1p1f1	r1i1p1f1
ACCESS-ESM1-5	r(1-3)i1p1f1	r(1-3)i1p1f1	r(1-3)i1p1f1
AWI-CM-1-1-MR	r1i1p1f1	r1i1p1f1	r1i1p1f1
BCC-CSM2-MR	r1i1p1f1	r1i1p1f1	r1i1p1f1
CanESM5	r(1-10)i1p1f1	r(1-10)i1p1f1	r(1-10)i1p1f1
CanESM5-CanOE	r(1-3)i1p1f1	r(1-3)i1p1f1	r(1-3)i1p1f1
CESM2	r1i1p1f1	r1i1p1f1	r1i1p1f1
CESM2-WACCM	r1i1p1f1	r1i1p1f1	r1i1p1f1
CMCC-CM2-SR5	-	-	r1i1p1f1
CNRM-CM6-1	r(1-6)i1p1f2	r(1-3)i1p1f2	r1i1p1f2
CNRM-CM6-1-HR	r1i1p1f2	r1i1p1f2	r1i1p1f2
CNRM-ESM2-1	r1i1p1f2	r(1-5)i1p1f2	r1i1p1f2
FGOALS-g3	r1i1p1f1	r1i1p1f1	r1i1p1f1
FGOALS-f3-L	r1i1p1f1	r1i1p1f1	r1i1p1f1
FIO-ESM-2-0	r(1-3)i1p1f1	r(1-3)i1p1f1	r(1-3)i1p1f1
GFDL-ESM4	r1i1p1f1	r1i1p1f1	r1i1p1f1
GISS-E2-1-G	r1i1p3f1	r(1,3)i1p3f1	r1i1p3f1
HadGEM3-GC31-LL	r1i1p1f3	r1i1p1f3	r(1-3)i1p1f3
INM-CM4-8	r1i1p1f1	r1i1p1f1	r1i1p1f1
INM-CM5-0	r1i1p1f1	r1i1p1f1	r1i1p1f1
IPSL-CM6A-LR	r(1-4,6)i1p1f1	r(1-6,10,11,14,22,25)i1p1f1	r1i1p1f1
KACE-1-0-G	r(1-2)i1p1f1	r(1-3)i1p1f1	r1i1p1f1
MIROC-ES2L	r1i1p1f2	r1i1p1f2	r1i1p1f2
MIROC6	r(1-3)i1p1f1	r(1-3)i1p1f1	r(1-3)i1p1f1
MPI-ESM1-2-HR	r1i1p1f1	r1i1p1f1	r1i1p1f1
MPI-ESM1-2-LR	r(1-10)i1p1f1	r(1-10)i1p1f1	r(1-10)i1p1f1
MRI-ESM2-0	r1i1p1f1	r1i1p1f1	r1i1p1f1
NESM3	r(1-2)i1p1f1	r(1-2)i1p1f1	r(1-2)i1p1f1
NorESM2-LM	r1i1p1f1	r1i1p1f1	r1i1p1f1
NorESM2-MM	r1i1p1f1	r1i1p1f1	r1i1p1f1
UKESM1-0-LL	r(1-4,8)i1p1f2	r(1-4,8)i1p1f2	r(1-4,8)i1p1f2

HighResMIP	SSP5-8.5
CMCC-CM2-HR4	r1i1p1f1
CMCC-CM2-VHR4	r1i1p1f1
CNRM-CM6-1-HR	r1i1p1f1
EC-Earth3P-HR	r2i1p2f1
HadGEMGE3-GC31-HH	r1i1p1f1
HadGEMGE3-GC31-HM	r1i1p1f1
HadGEMGE3-GC31-MM	r1i1p1f1

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.



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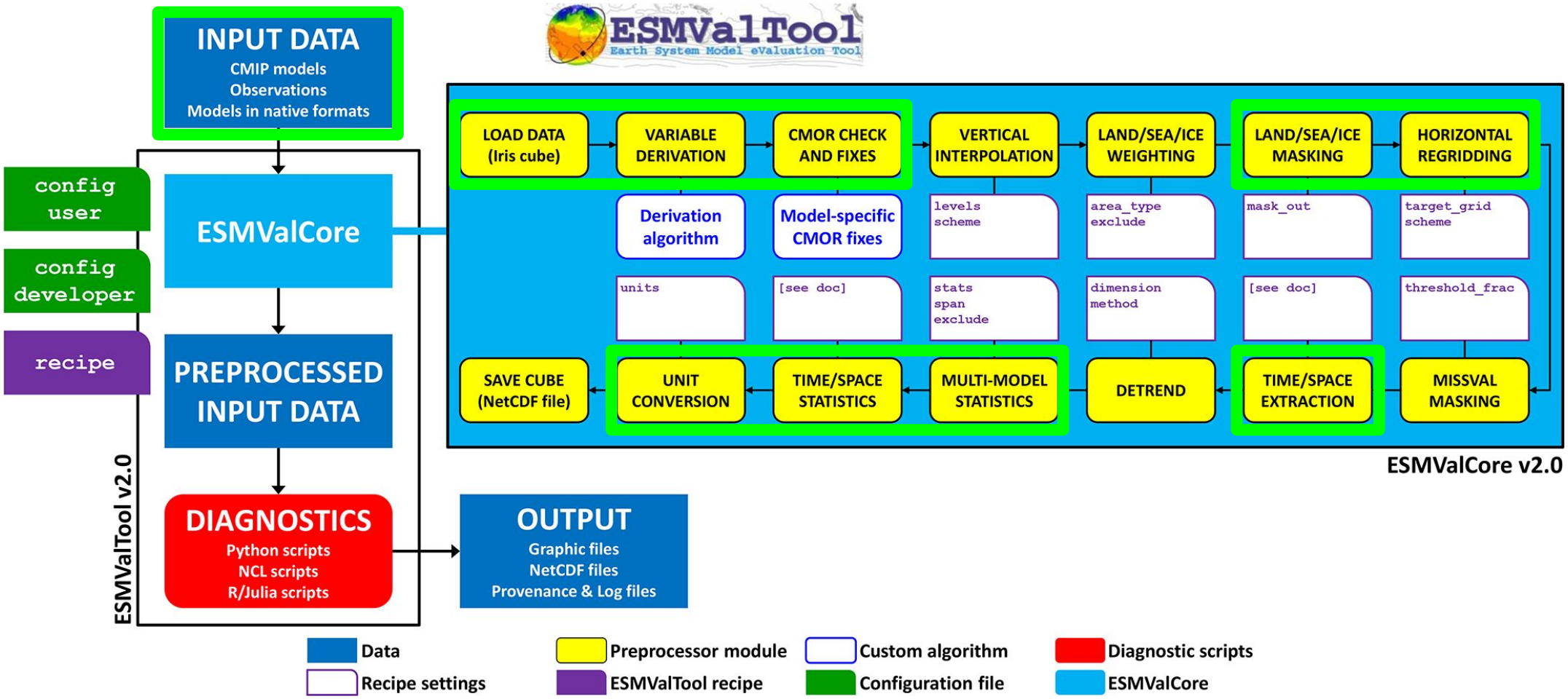
Earth System Model Evaluation Tool



Righi et al. 2020

Recipe structure

```yaml
- &cmip5_h-rcp85 {project: CMIP5, exp: [historical, rcp85], dataset: ACCESS1-0, expid: [historical_i0p1, rcp85_i1p1], ensemble: r1i1p1, start_year: 1960, end_year: 2100}

- {<<: *cmip5_h-rcp85, dataset: ACCESS1-3}

- {<<: *cmip5_h-rcp85, dataset: bcc-csm1-1}

- {<<: *cmip5_h-rcp85, dataset: bcc-csm1-1-m}

- {<<: *cmip5_h-rcp85, dataset: BNU-ESM}

- {<<: *cmip5_h-rcp85, dataset: CanESM2, ensemble: r(1:5)i1p1}
```

...

Datasets call

```yaml
- &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}

- {<<: *cmip6_h-ssp585, dataset: ACCESS-ESM1-5, ensemble: r(1:3)i1p1f1, grid: gn}

- {<<: *cmip6_h-ssp585, dataset: AWI-CM-1-1-MR}

- {<<: *cmip6_h-ssp585, dataset: BCC-CSM2-MR}

- {<<: *cmip6_h-ssp585, dataset: CESM2, ensemble: r1i1p1f1, grid: gn}

- {<<: *cmip6_h-ssp585, dataset: CESM2-WACCM, grid: gn}
```

...

Preprocessor definition

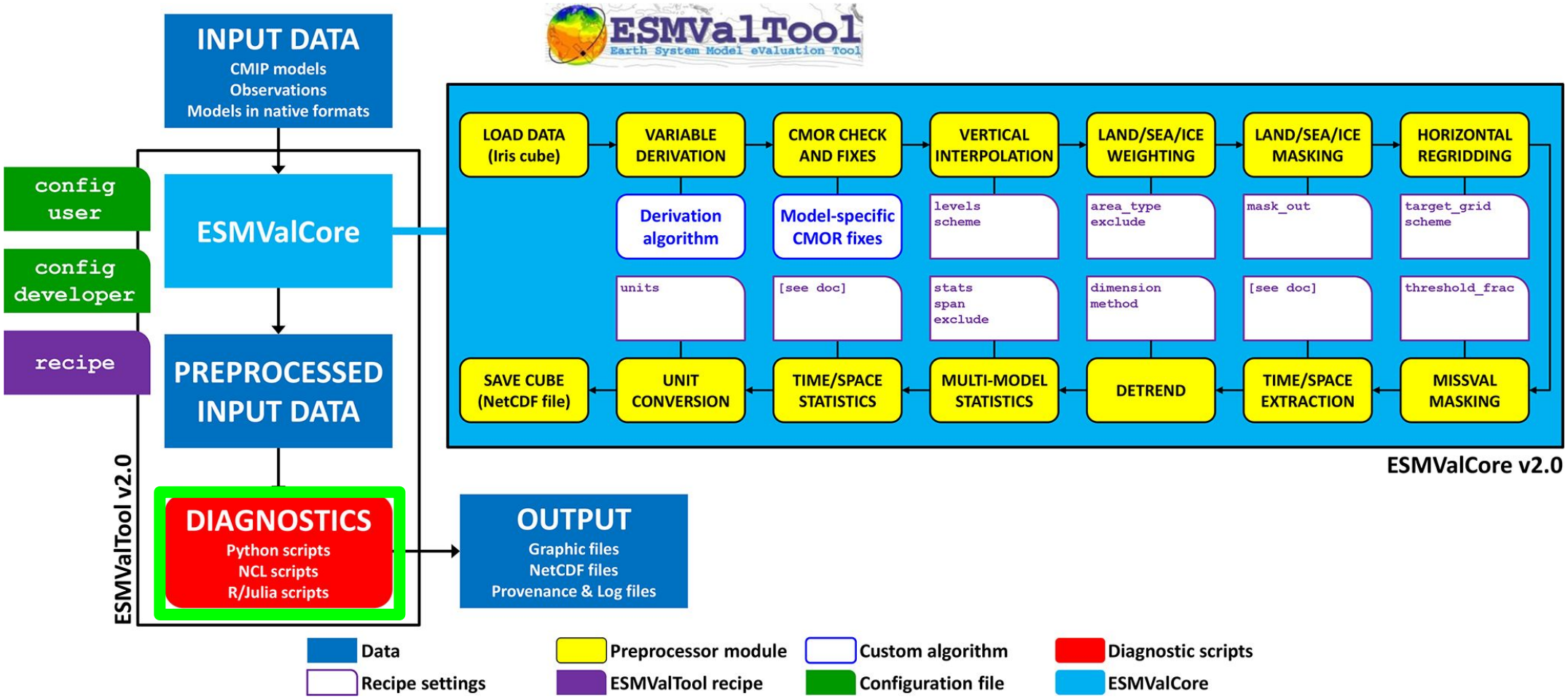
```yaml
preprocessors:
  general_conservative: &general_cons
    mask_landsea:
      mask_out: sea
    regrid:
      target_grid: 1x1
      scheme: area_weighted
    extract_region:
      start_longitude: -10
      end_longitude: 40
      start_latitude: 25
      end_latitude: 50

  djf_conservative:
    extract_season:
      season: 'djf'
    seasonal_statistics:
      operator: 'mean'
    <<: *general_cons
```

Diagnostics definition

```yaml
diagnostics:
  djf_pr:
    description: "MedRegion winter precipitation diagnostic"
    variables:
      pr:
        short_name: pr
        mip: Amon
        preprocessor: djf_conservative
        additional_datasets: *OBS_pr
    scripts:
      djf_pr:
        script: /esarchive/scratch/jcos/esmvaltool/scripts/concurrent_diagnostics.py
```

Earth System Model Evaluation Tool



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Righi et al. 2020

Diagnostic

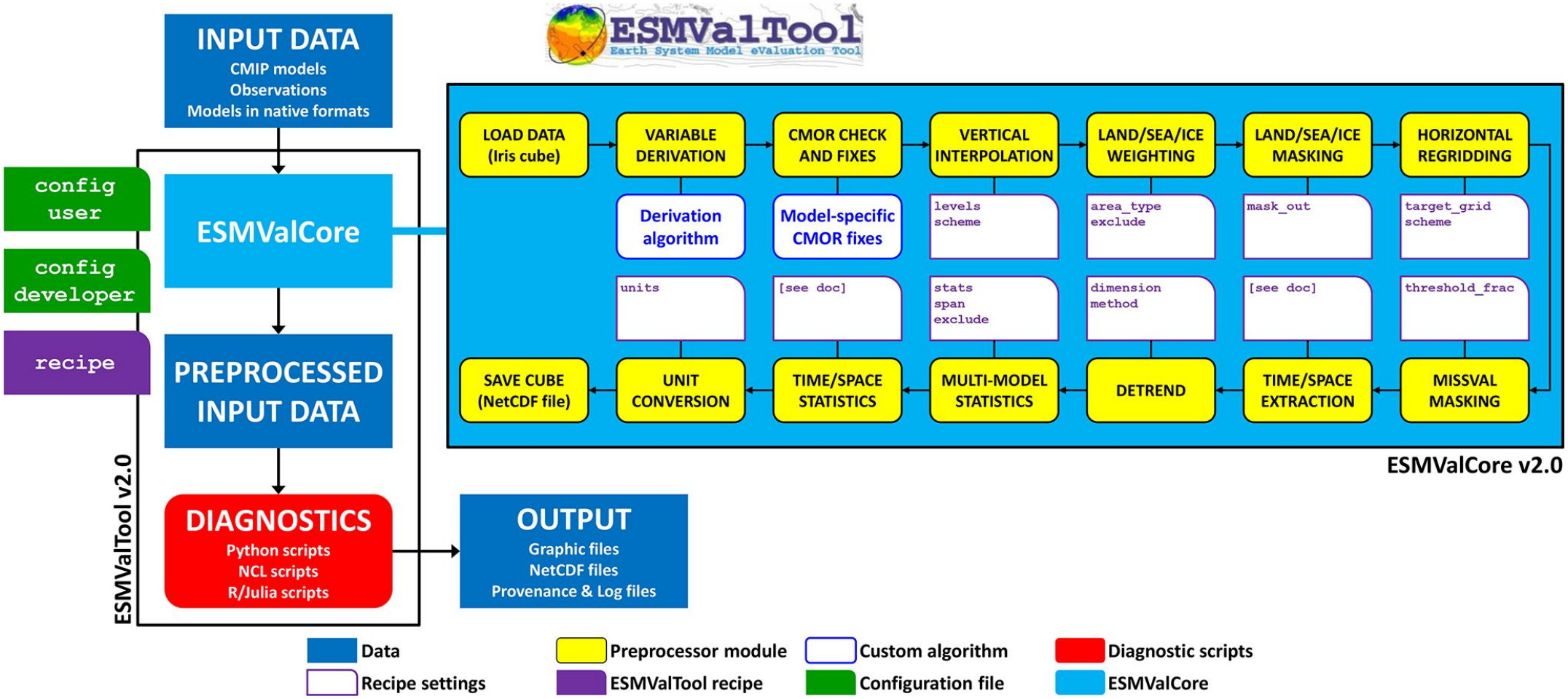
- Upload the preprocessed data through ESMValTool metadata handling utilities
- Further postprocessing of the data in case more metrics or diagnostics must be extracted
- Generate new files with results and use the language's plotting modules to output relevant figures

```python
from esmvalcore.preprocessor._area import area_statistics, extract_region
from esmvalcore.preprocessor._mask import mask_landsea
from esmvalcore.preprocessor._time import (
    extract_time,
    climate_statistics,
)
from esmvalcore.preprocessor._multimodel import multi_model_statistics
from esmvaltool.diag_scripts.shared import group_metadata
import esmvaltool.diag_scripts.shared.names as n
import esmvaltool.diag_scripts.shared as e
```

```python
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

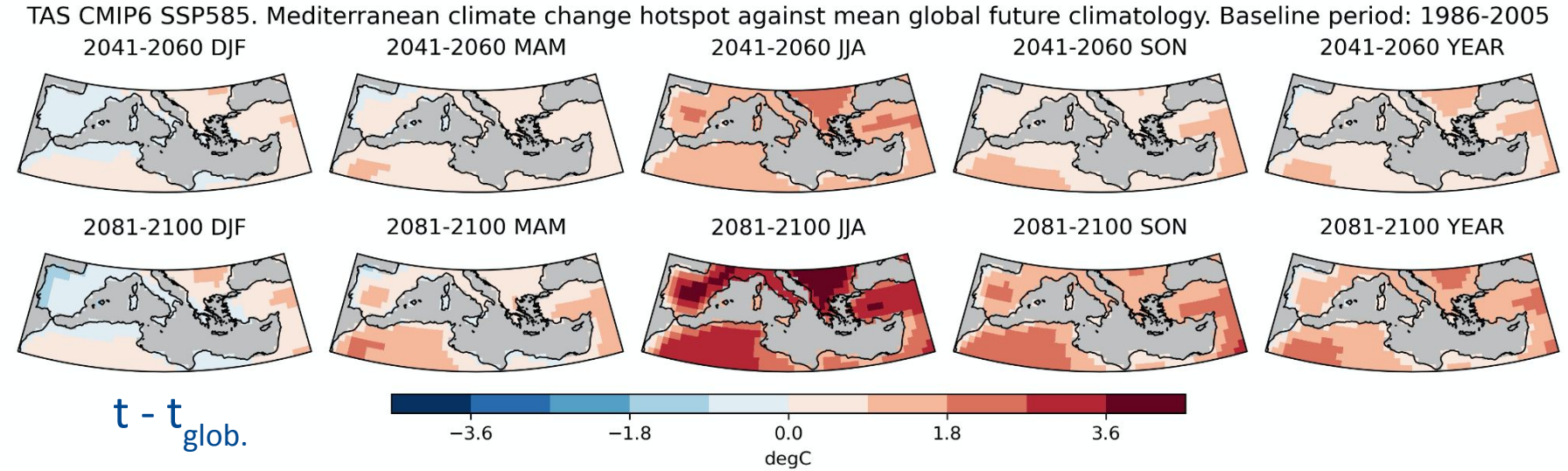


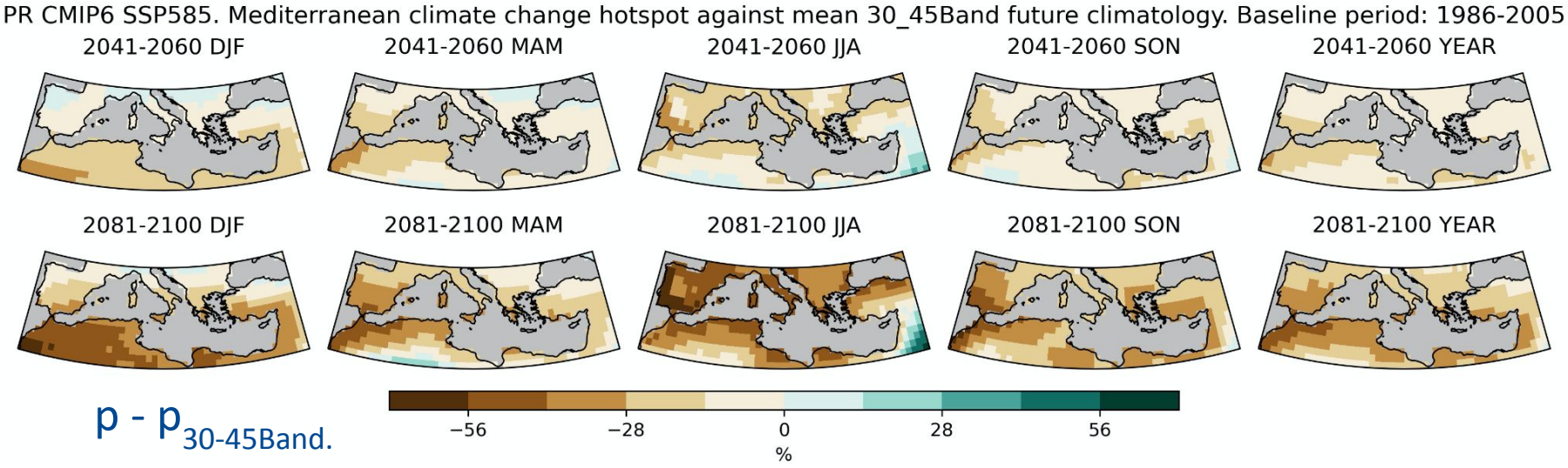
Righi et al. 2020

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.





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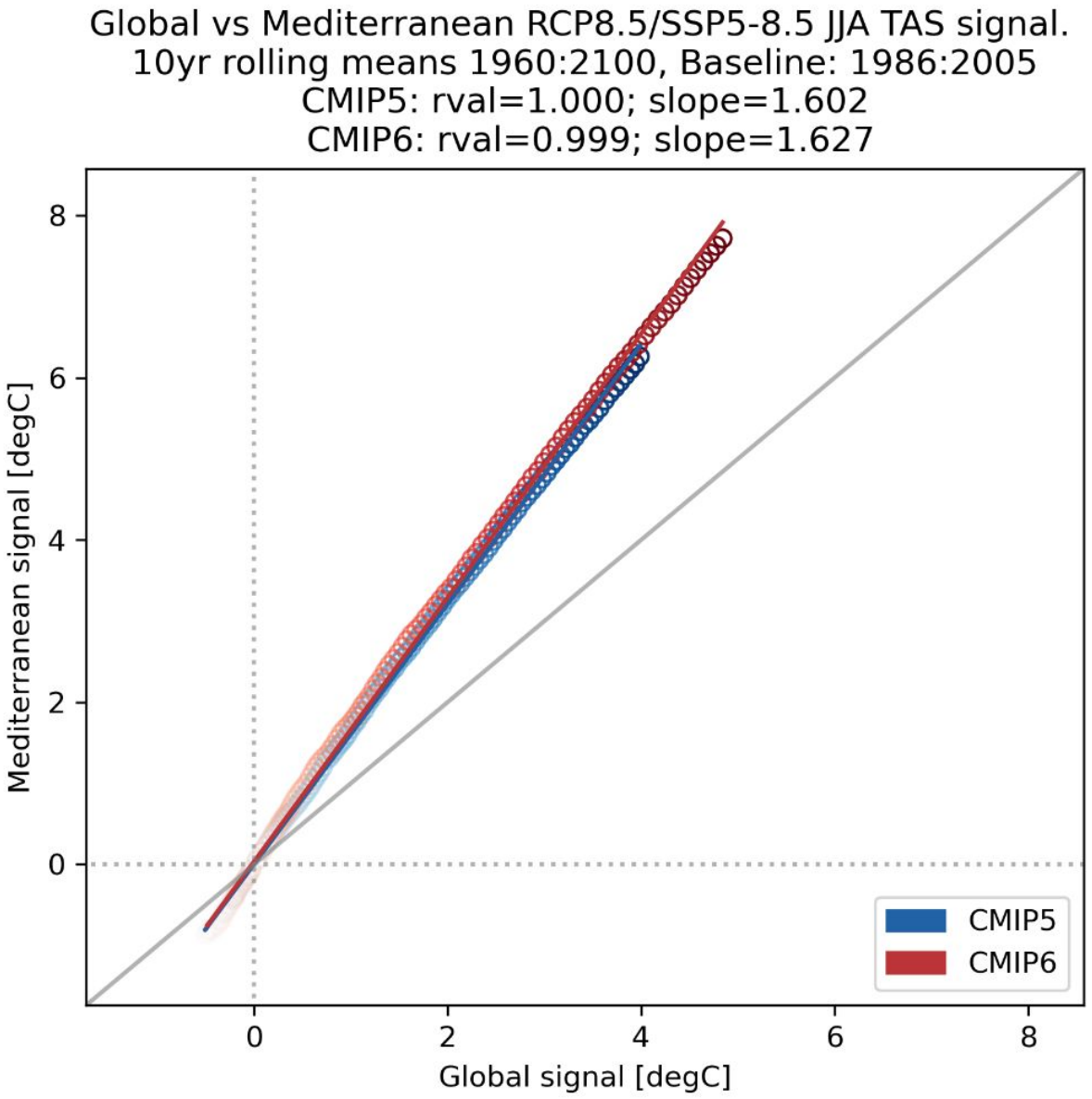
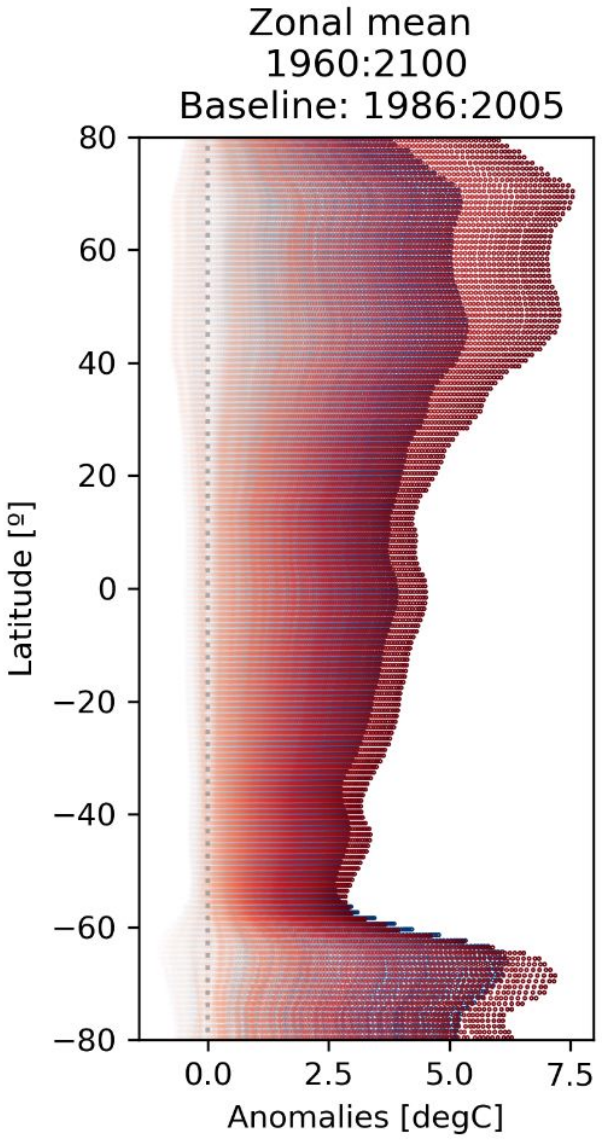
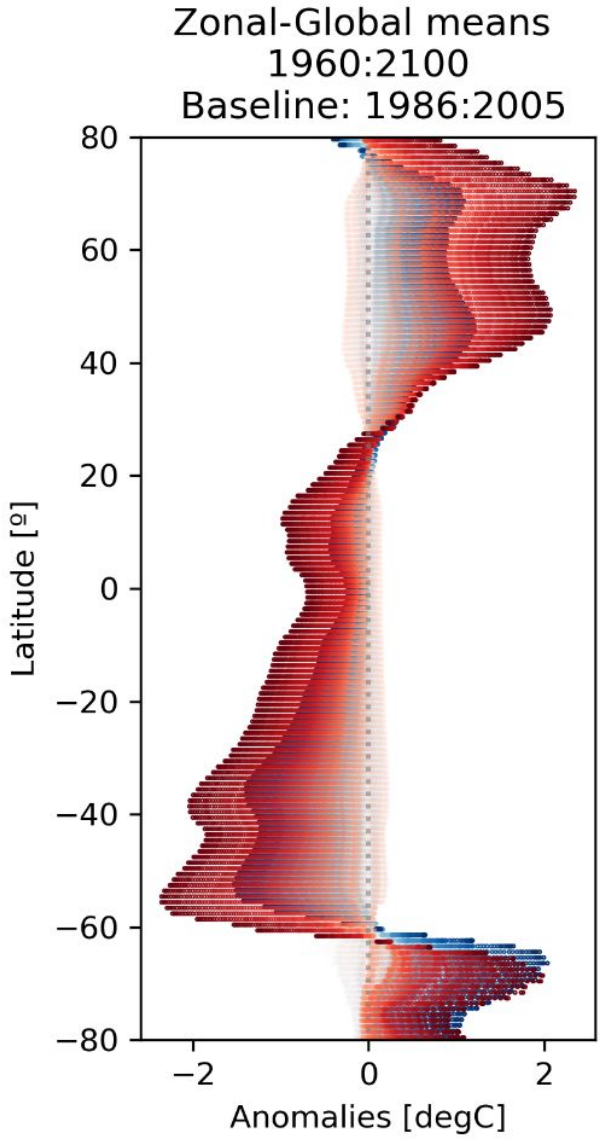
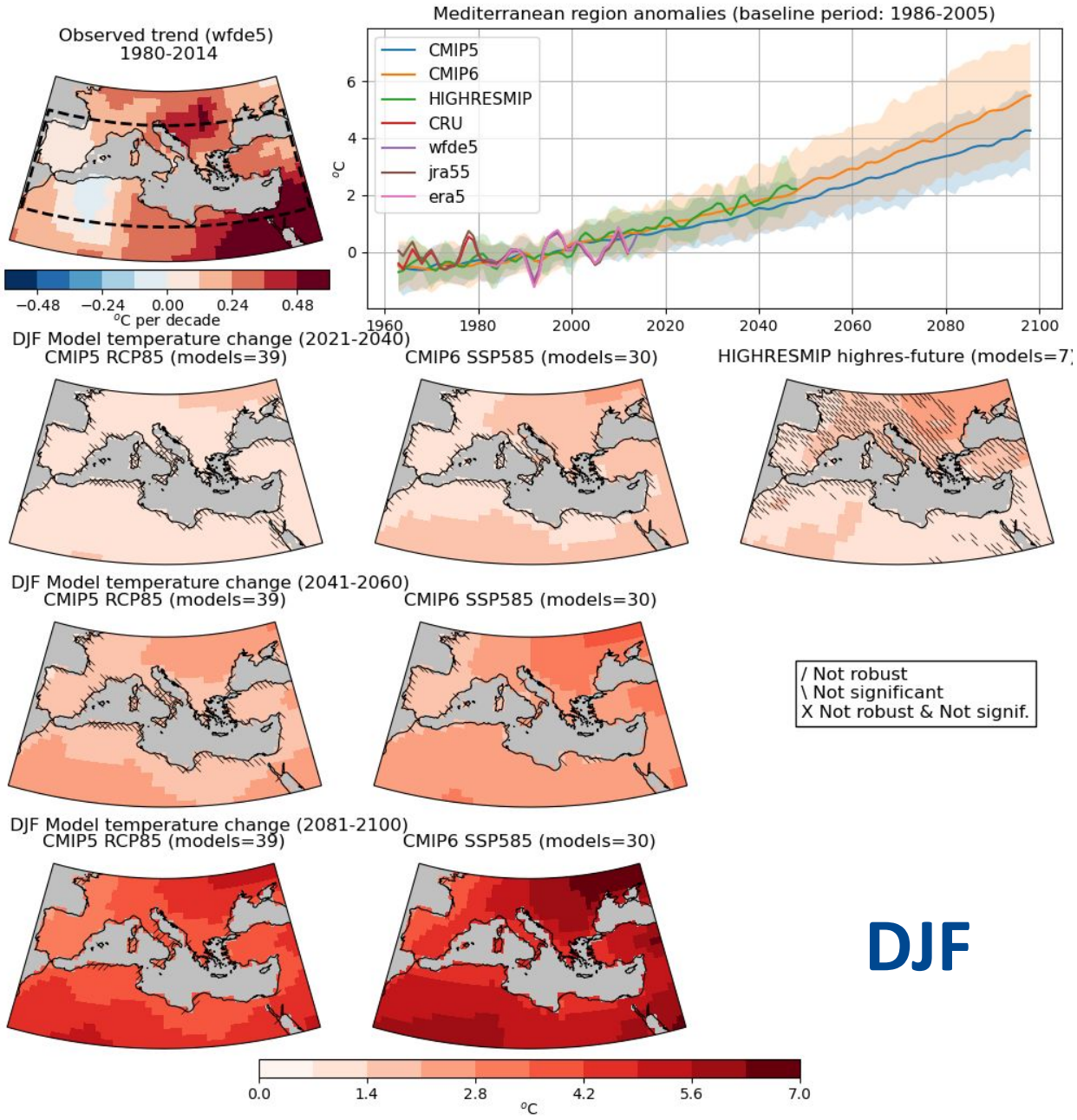
The Mediterranean as a climate change hotspot

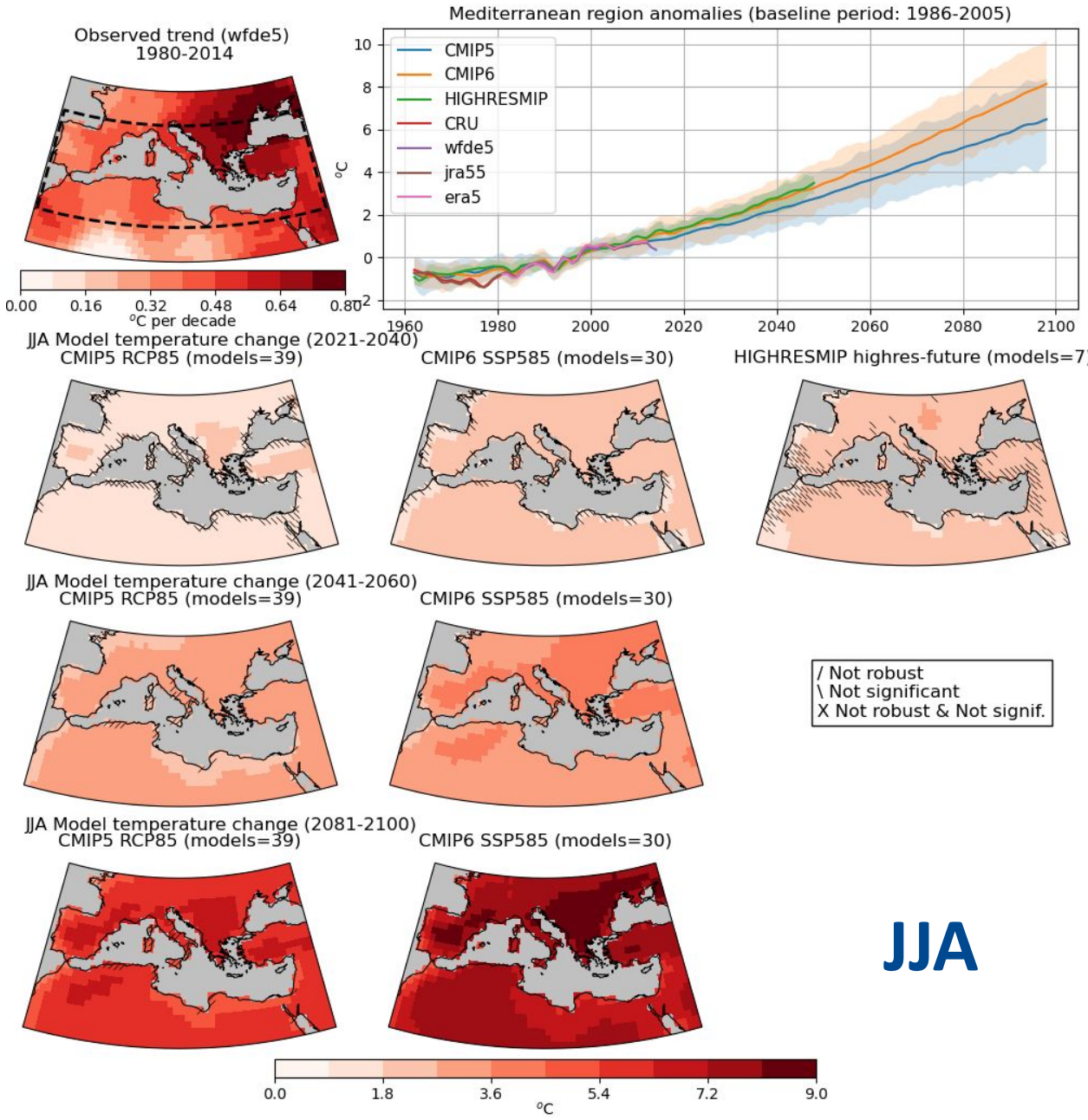




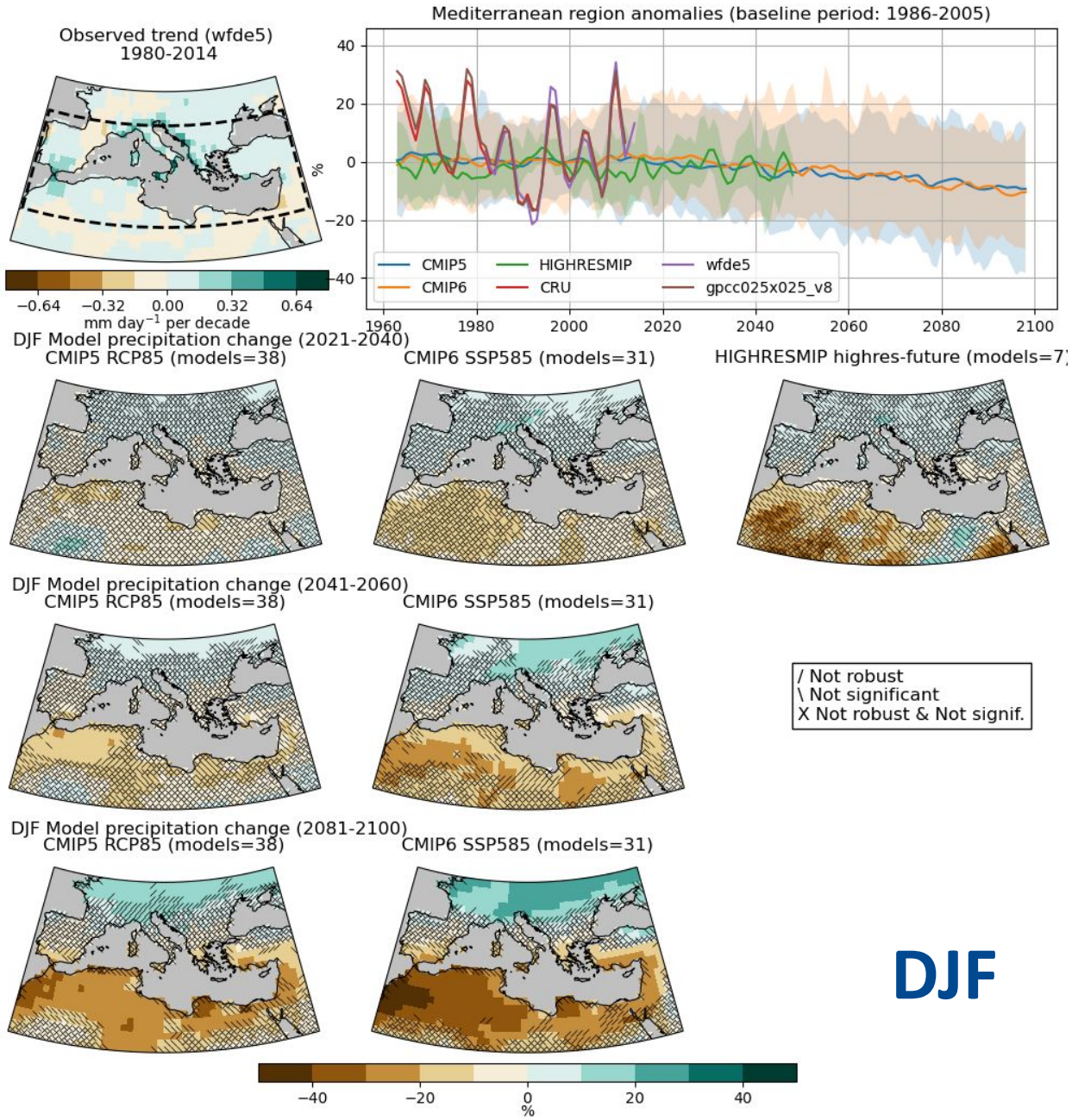


Temperature change RCP8.5/SSP5-8.5 with respect to 1986-2005

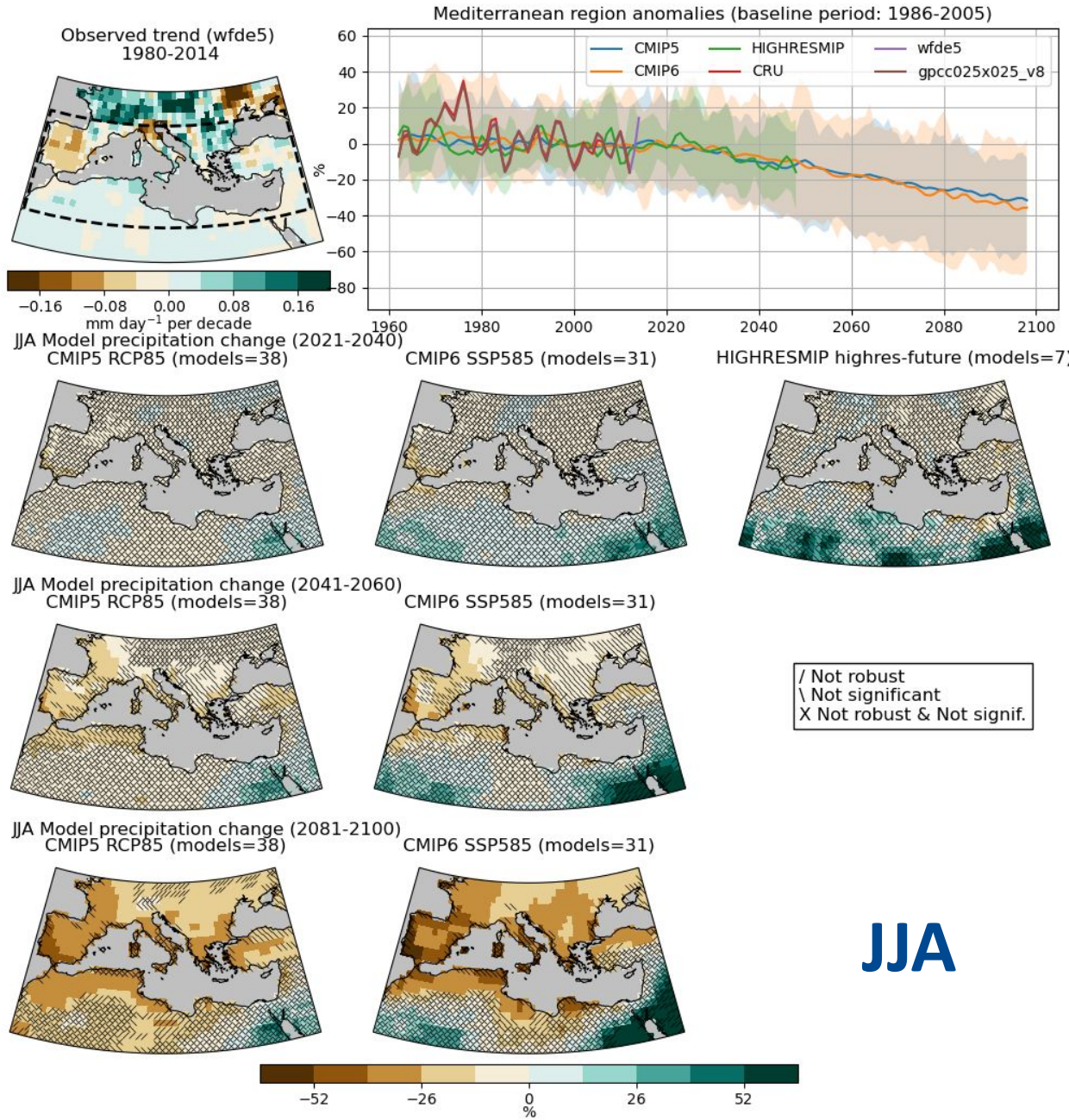




Precipitation change RCP8.5/SSP5-8.5 with respect to 1986-2005

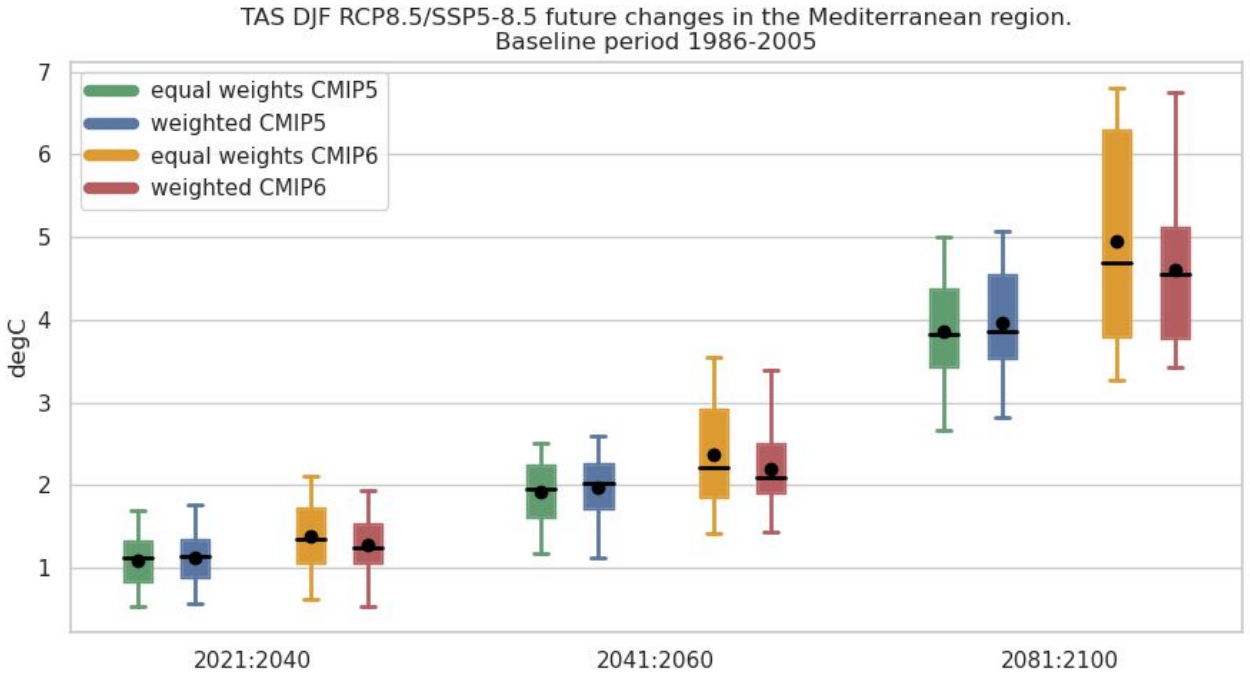


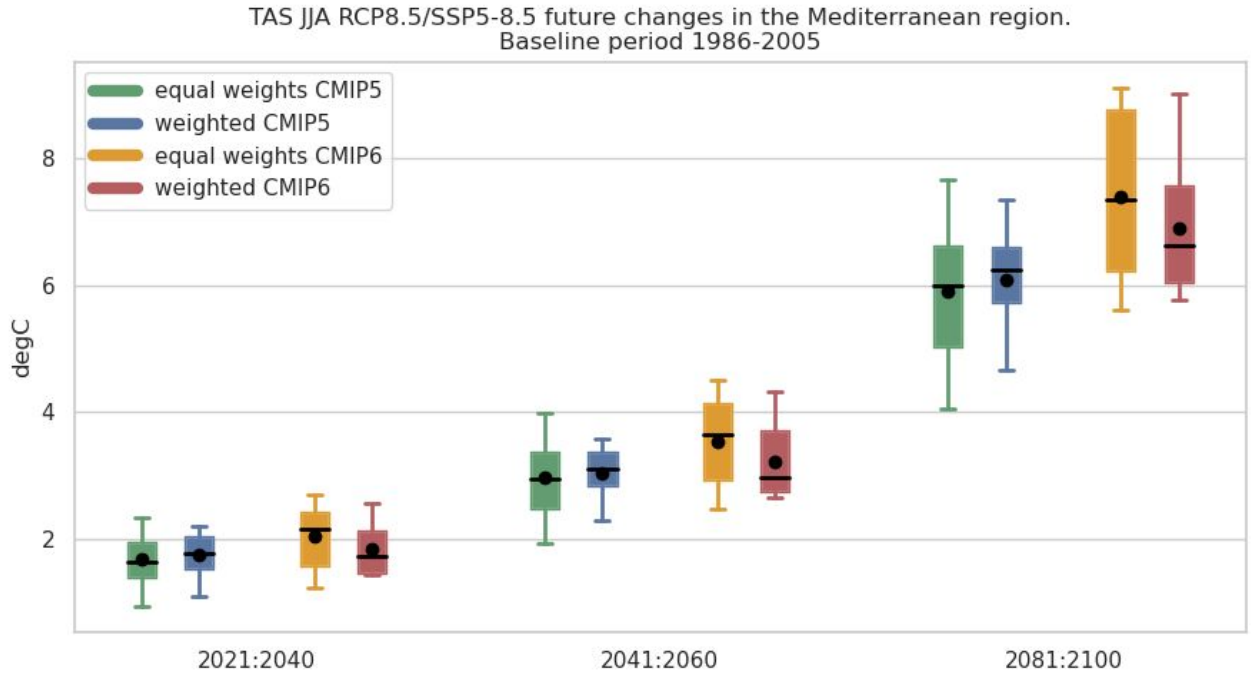
DJF



JJA

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





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.

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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. “

https://shiny.rstudio.com/