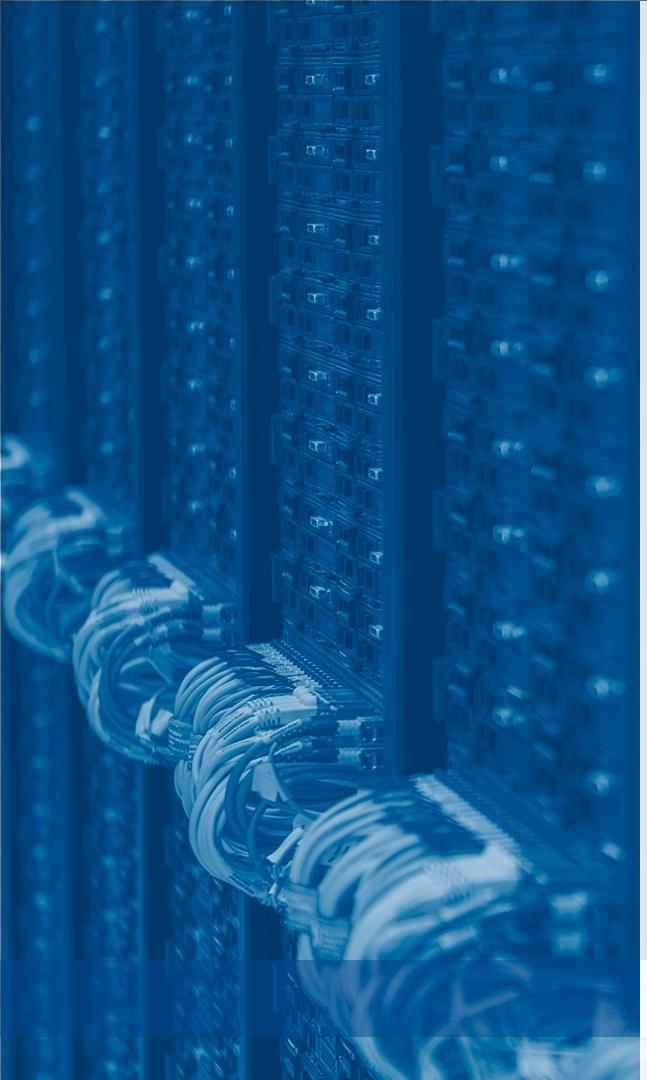


Barcelona Supercomputing Center
Centro Nacional de Supercomputación

ESMValTool
Earth System Model Evaluation Tool

.UBA Universidad de Buenos Aires
CONICET
CIMA

IFAECI
cnrs CONICET IRD

Taller ESMValTool

Una herramienta para el procesado sistemático de grandes volúmenes de datos climáticos

contacto: josep.cos@bsc.es

```
ssh -XY <usuario>@157.92.28.14
```

```
wget https://github.com/conda-forge/miniforge/releases/latest/download/Mambaforge-Linux-x86_64.sh
```

```
bash Mambaforge-Linux-x86_64.sh
```

```
source activate /home/pepcos/envs/esmvaltool
```

ESMValTool

Web:
https://esmvaltool.org/

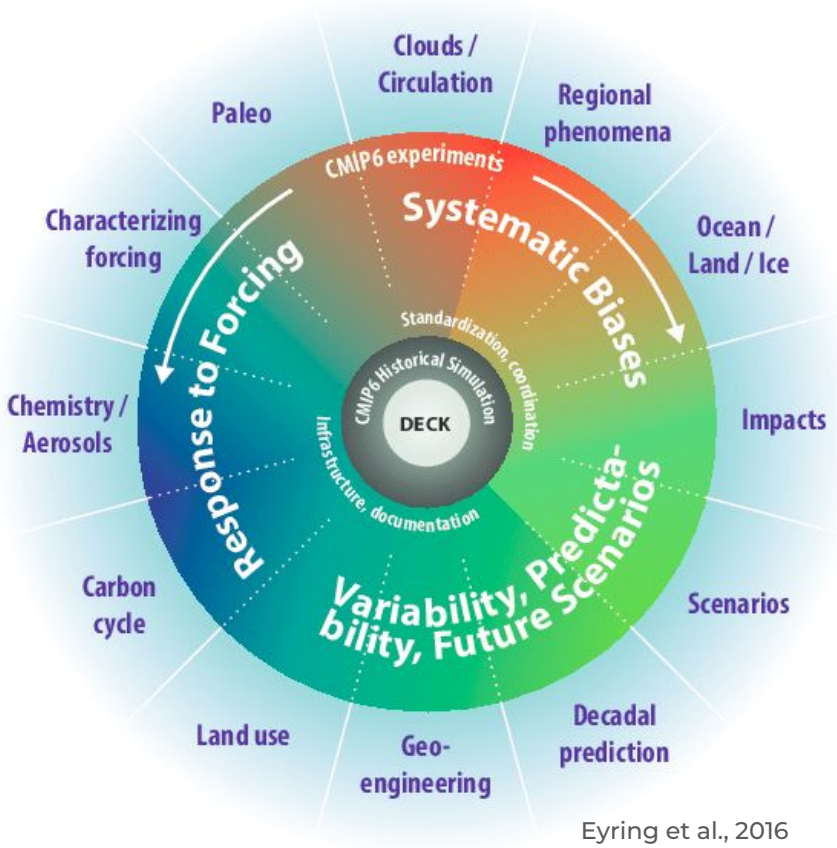
Documentación:
https://docs.esmvaltool.org/projects/ESMValCore/en/latest/index.html

Github:
https://github.com/ESMValGroup

Galería:
https://docs.esmvaltool.org/en/latest/gallery.html

Coupled Model Intercomparison Project 6

https://esgf-node.llnl.gov/search/cmip6/

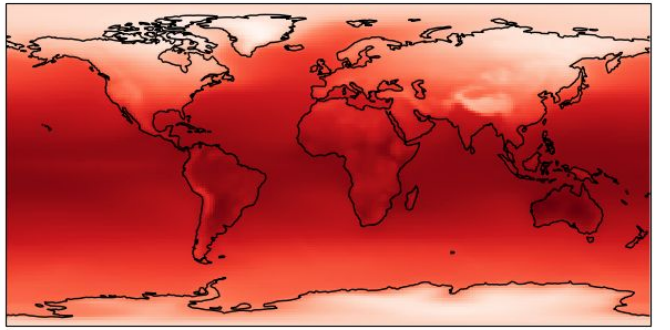


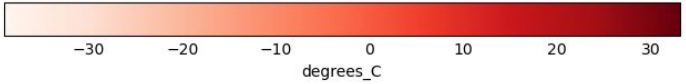
Eyring et al., 2016

	Model name	Ocean component	Horizontal	Vertical	Reference
1	ACCESS-CM2	MOM5	1 x 1	z* 50	N/A
2	ACCESS-ESM1-5	MOM5	1 x 1	z* 50	Ziehn et al. (2017)
3	BCC-CSM2-MR	MOM4-L40	1 x 1	z 40	Wu et al. (2019)
4	BCC-ESM1	MOM4-L40	1 x 1	z 40	Wu et al. (2019)
5	CAMS-CSM1-0	MOM4	1 x 1	z 50	Rong et al. (2019)
6	CESM2	POP2	1 x 1	z 60	Danabasoglu et al. (2020)
7	CESM2-FV2	POP2	1 x 1	z 60	Danabasoglu et al. (2020)
8	CESM2-WACCM	POP2	1 x 1	z 60	Danabasoglu et al. (2020)
9	CESM2-WACCM-FV2	POP2	1 x 1	z 60	Danabasoglu et al. (2020)
10	CNRM-CM6-1	NEMO3.6	1 x 1	z* 75	Voldoire et al. (2019)
11	CNRM-ESM2-1	NEMO3.6	1 x 1	z* 75	Séférian et al. (2019)
12	CanESM5	NEMO3.4.1	1 x 1	z 45	Swart et al. (2019)
13	EC-Earth3	NEMO3.6	1 x 1	z* 75	N/A
14	EC-Earth3-Veg	NEMO3.6	1 x 1	z* 75	N/A
15	GFDL-CM4	MOM6	0.25 x 0.25	ρ - z* 75	Held et al. (2019)
16	GFDL-ESM4	MOM6	0.5 x 0.5	ρ - z* 75	N/A
17	GISS-E2-1-G	GISS Ocean	1.25 x 1	z 40	N/A
18	GISS-E2-1-G-CC	GISS Ocean	1.25 x 1	z 40	N/A
19	GISS-E2-1-H	HYCOM	1 x 1	z - ρ - σ 32	N/A
20	HadGEM3-GC31-LL	NEMO-HadGEM3-GO6.0	1 x 1	z* 75	Kuhlbrodt et al. (2018)
21	INM-CM5-0	INM-OM5	0.5 x 0.25	σ 40	Volodin and Gritsun (2018)
22	IPSL-CM6A-LR	NEMO3.6	1 x 1	z* 75	Lurton et al. (2020)
23	MCM-UA-1-0	MOM1	2 x 2	z 18	N/A
24	MIROC-ES2L	COCO4.9	1 x 1	z - σ 62	Hajima et al. (2020)
25	MIROC6	COCO4.9	1 x 1	z - σ 62	Tatebe et al. (2019)
26	MPI-ESM-1-2-HAM	MPIOM1.6.3	1.5 x 1.5	z 40	Mauritsen et al. (2019)
27	MPI-ESM1-2-HR	MPIOM1.6.3	0.4 x 0.4	z 40	Müller et al. (2018)
28	MPI-ESM1-2-LR	MPIOM1.6.3	1.5 x 1.5	z 40	Mauritsen et al. (2019)
29	MRI-ESM2-0	MRI.COM4.4	1 x 0.5	z* 60	Yukimoto et al. (2019)
30	NESM3	NEMO3.4	1 x 1	z 46	Cao et al. (2018)
31	NorCPM1	MICOM	1 x 1	z - ρ 53	Counillon et al. (2016)
32	NorESM2-LM	MICOM	1 x 1	z - ρ 53	Tjiputra et al. (2020)
33	NorESM2-MM	MICOM	1 x 1	z - ρ 53	Tjiputra et al. (2020)
34	SAM0-UNICON	POP2	1 x 1	z 60	Park et al. (2019)
35	UKESM1-0-LL	NEMO-HadGEM3-GO6.0	1 x 1	z* 75	Sellar et al. (2020)

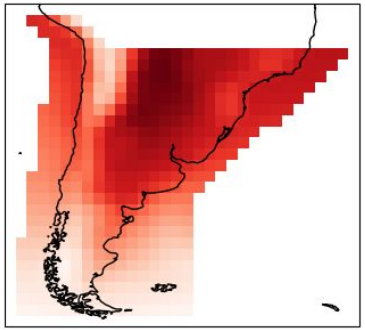
37 modelos de CMIP6

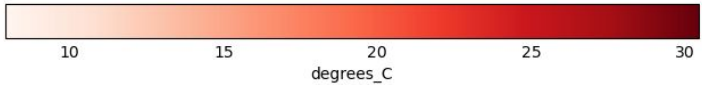
Global map of near-surface air temperature in period 2001-2030.



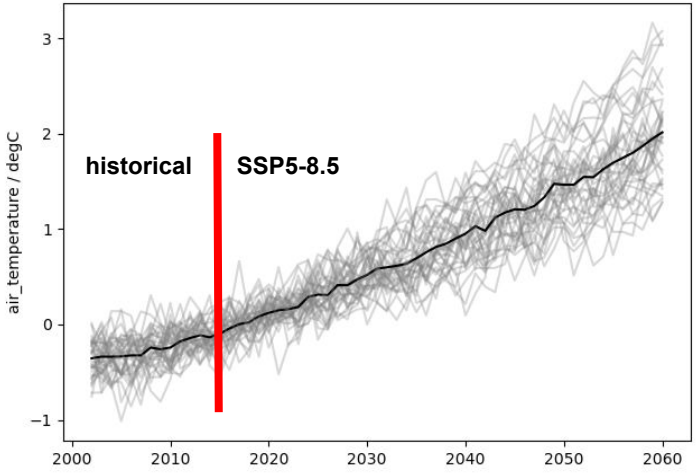


Regional map of near-surface air temperature in period 2001-2030.

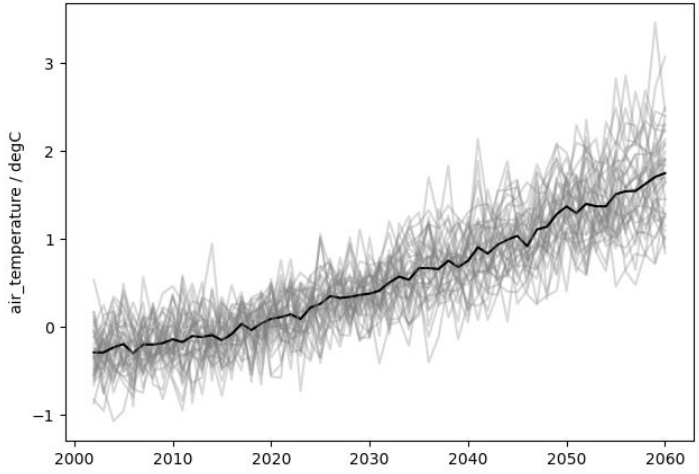




near-surface air temperature; climatology 2001-2030.



near-surface air temperature regional mean containing: SES, SWS, SSA; climatology 2001-2030.



historical

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SSP5-8.5

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- /shera/datos/CMIP/CMIP6/ScenarioMIP/THU/CIESM/ssp585/r1i1p1f1/Amon/tas/gr/20200605/tas_Amon_CIESM_ssp585_r1i1p1f1_gr_201501-210012.nc

Cómo procesar los datos?

python/R:

- cargar todos los datos en el script -> procesarlos -> plotearlos
  - pros: ¿
  - cons: Script muy largo, consumiendo mucha memoria y sin puntos donde guardar ficheros intermedios
- partir el workflow en distintos scripts que generen archivos intermedios
  - pros:
    - Más fácil de trak los pasos intermedios (debugar)
    - Se pueden modificar las últimas partes del workflow sin tener que correrlo todo de nuevo
  - cons:
    - Gestionar la lectura de tantos datos se tiene que hacer de cero y de forma organizada
    - Se tienen que programar funciones específicas para el procesado de datos climáticos (seasonal_statistics, multi_model_mean…)
    - Metadata de los cambios se debe hacer explícitamente

CDO+python/R:

- generar archivos intermedios con CDO y plotear usando python o R
  - pros:
    - Funciones preexistentes para el procesamiento de datos climáticos (regrid, sellonlatbox…)
  - cons:
    - Bash
    - Fixes no implementados automaticamente
  - pro/con:
    - No requiere archivos en formato CMOR (pro o con)

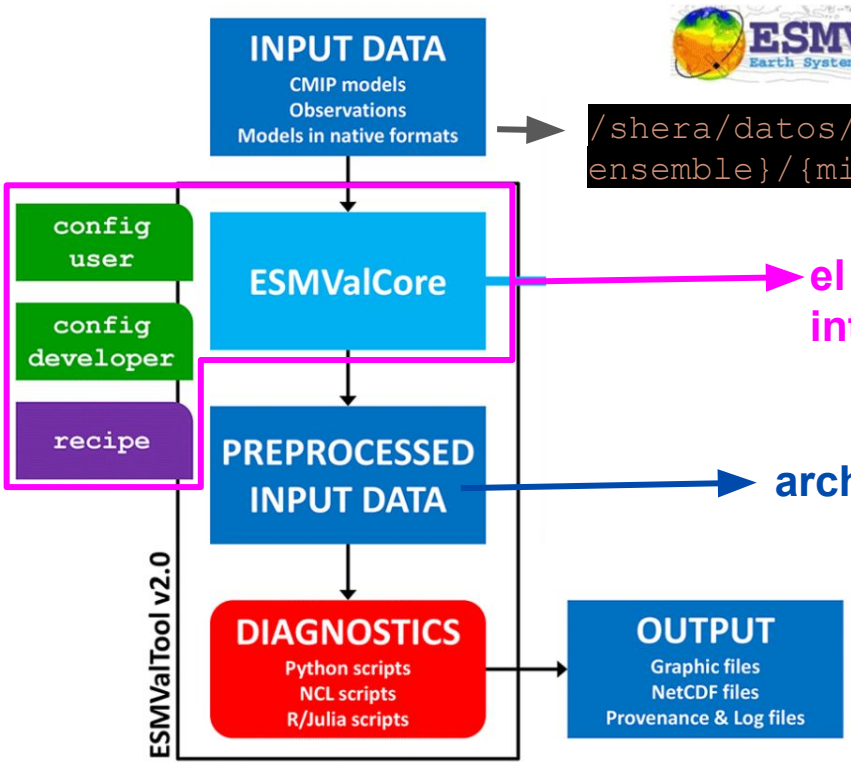
ESMValTool + python/R

pros:

- Búsqueda automática de datos en el sistema de archivos (config_files)
- Generación automática de ficheros intermedios (preprocessor)
- Aplicación de fixes en archivos de CMIP y CMORizador de observaciones (https://docs.esmvaltool.org/projects/ESMValCore/en/latest/recipe/preprocessor.html#dataset-specific-fixes)
- Funciones para procesar explicitamente datos climáticos (https://docs.esmvaltool.org/projects/ESMValCore/en/latest/recipe/preprocessor.html#preprocessor)
- Documentación

cons:

- Curva de aprendizaje
- Estricto con la calidad de los datos de entrada

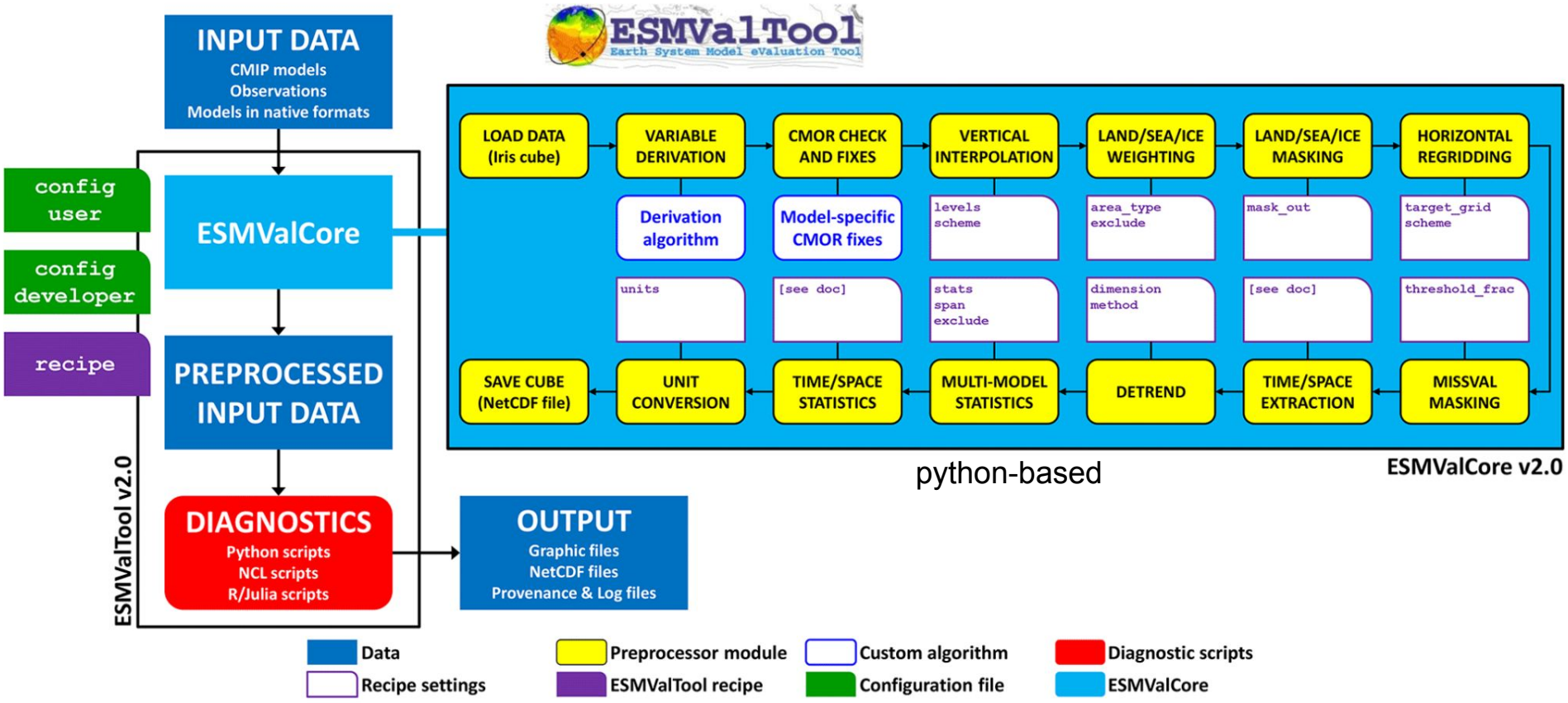


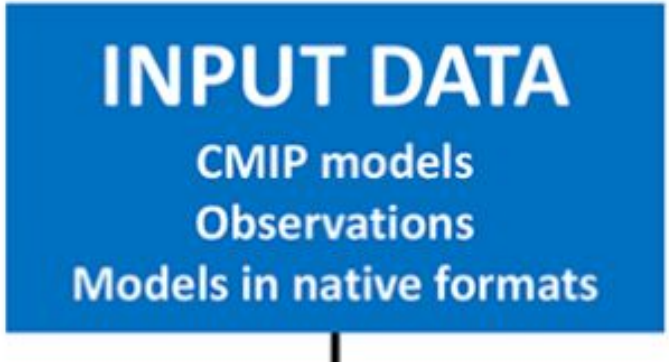
ESMValTool
Earth System Model eValuation Tool

```
/shera/datos/CMIP/CMIP6/{activity}/{institute}/{dataset}/{exp}/{
ensemble}/{mip}/{short_name}/{grid}/{version}/*.nc
```

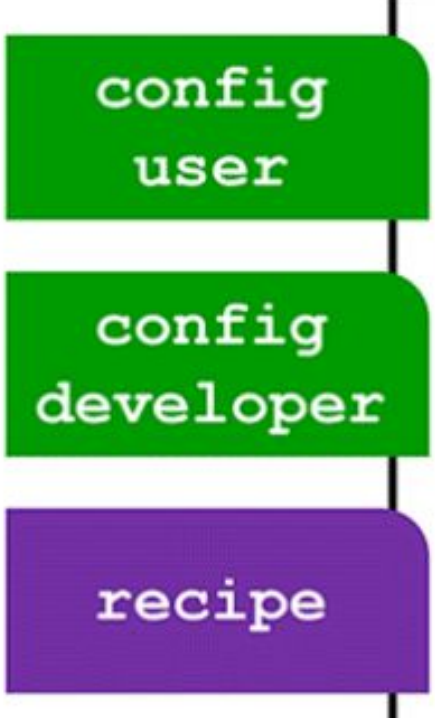
el bloque que produce archivos intermedios

archivos intermedios


ESMValTool
Earth System Model eValuation Tool
INPUT DATA
CMIP models
Observations
Models in native formats
config user
config developer
recipe
ESMValCore
PREPROCESSED INPUT DATA
DIAGNOSTICS
Python scripts
NCL scripts
R/Julia scripts
OUTPUT
Graphic files
NetCDF files
Provenance & Log files
ESMValTool v2.0
LOAD DATA (Iris cube)
VARIABLE DERIVATION
CMOR CHECK AND FIXES
VERTICAL INTERPOLATION
LAND/SEA/ICE WEIGHTING
LAND/SEA/ICE MASKING
HORIZONTAL REGRIDDING
Derivation algorithm
Model-specific CMOR fixes
levels
scheme
area_type
exclude
mask_out
target_grid
scheme
units
[see doc]
stats
span
exclude
dimension
method
[see doc]
threshold_frac
SAVE CUBE (NetCDF file)
UNIT CONVERSION
TIME/SPACE STATISTICS
MULTI-MODEL STATISTICS
DETREND
TIME/SPACE EXTRACTION
MISSVAL MASKING
python-based
ESMValCore v2.0
Data
Recipe settings
Preprocessor module
ESMValTool recipe
Custom algorithm
Configuration file
Diagnostic scripts
ESMValCore



- https://esgf-node.llnl.gov/search/cmip6/
- Base de datos CMIP → compartido, local…
  - /shera/datos/CMIP/CMIP6/CMIP/BCC/BCC-CSM2-MR/historical/r1i1p1f1/Amon/tas/gn/20181126/tas_Amon_BCC-CSM2-MR_historical_r1i1p1f1_gn_185001-201412.nc
  - /home/pepcos/climate_data/CMIP6/CMIP/BCC/BCC-CSM2-MR/historical/r1i1p1f1/Amon/tas/gn/v20181126/tas_Amon_BCC-CSM2-MR_historical_r1i1p1f1_gn_185001-201412.nc



Archivos YAML en ESMValTool

→ YAML es una estructura parecida a los diccionarios de python

- diccionario:
  → {“etiqueta”: valor, “etiqueta2”: valor2}
  → {“etiqueta”: {“etiqueta_dict2”: valor_dict2}, “etiqueta2”: valor2}

config user

config developer

recipe

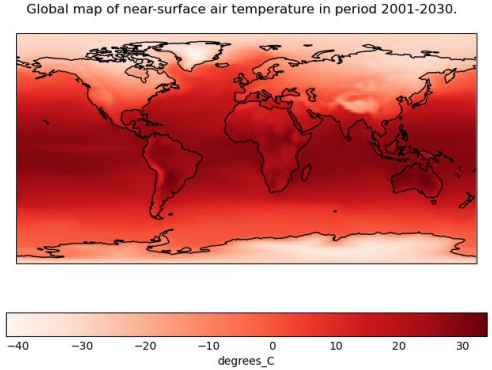
Archivos YAML en ESMValTool

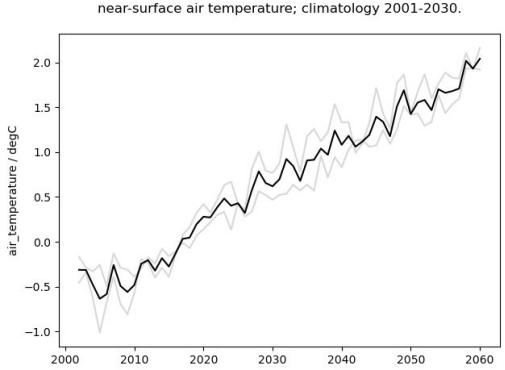
https://yaml.org/spec/1.2.2/

- .esmvaltool/config_user.yml:
  → Configuración básica del usuario de ESMValTool
- .esmvaltool/config_developer.yml:
  → Cómo están estructurados los datos dentro de tu computadora/cluster
- recipe.yml
  → Como queremos que ESMValTool procese los datos y que scripts .py o .R queremos llamar para plotear o seguir procesando los datos con los datos

Simulaciones historical-ssp585:

- BCC-CSM2-MR_r1i1p1f1
- GISS-E2-1-G_r1i1p1f2





Archivos YAML en ESMValTool

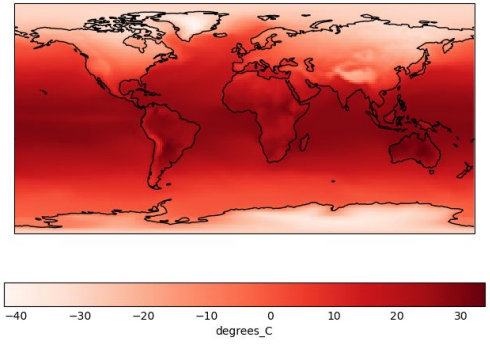
```
# Destination directory where all output will be written
output_dir: ~/esmvaltool_output
# Auxiliary data directory
auxiliary_data_dir: ~/auxiliary_data
# Automatic data download from ESGF ---
search_esgf: never
# Directory for storing downloaded climate data
download_dir: ~/climate_data
# Run at most this many tasks in parallel --- [null]/1/2/3/4/...
max_parallel_tasks: 1
# Log level of the console --- debug/[info]/warning/error
log_level: info
# Remove the ``preproc`` directory if the run was successful --- [true]/false
remove_preproc_dir: false
# Path to custom ``config-developer.yml`` file
config_developer_file: null

# Rootpaths to the data from different projects
rootpath:
 CMIP5: /shera/datos/CMIP/CMIP5/output1
 CMIP6: [/shera/datos/CMIP/CMIP6, /home/pepcos/climate_data/CMIP6]
 OBS: home/pepcos/rawobs
 default: ~/climate_data

# Directory structure for input data -- [default]/ESGF/BADC/DKRZ/ETHZ/etc.
drs:
 CMIP5: DKRZ
 CMIP6: BADC
```

Archivos YAML en ESMValTool

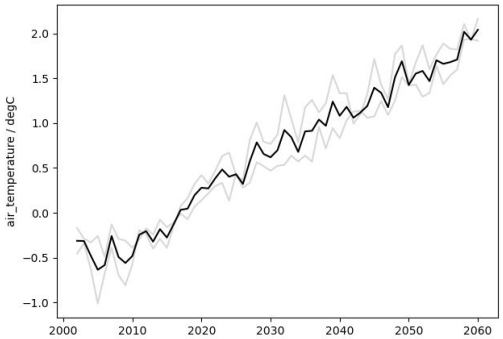
```yaml
CMIP6:
 cmor_strict: true
 input_dir:
   default: '/'
   BADC: '{activity}/{institute}/{dataset}/{exp}/{ensemble}/{mip}/{short_name}/{grid}/{version}'
   DKRZ: '{activity}/{institute}/{dataset}/{exp}/{ensemble}/{mip}/{short_name}/{grid}/{version}'
   ESGF: '{project}/{activity}/{institute}/{dataset}/{exp}/{ensemble}/{mip}/{short_name}/{grid}/{version}'
   ETHZ: '{exp}/{mip}/{short_name}/{dataset}/{ensemble}/{grid}/'
   SYNDA: '{activity}/{institute}/{dataset}/{exp}/{ensemble}/{mip}/{short_name}/{grid}/{version}'
 input_file: '{short_name}_{mip}_{dataset}_{exp}_{ensemble}_{grid}*.nc'
 output_file: '{project}_{dataset}_{mip}_{exp}_{ensemble}_{short_name}_{grid}'
 cmor_type: 'CMIP6'
```

recipe

Global map of near-surface air temperature in period 2001-2030.



near-surface air temperature; climatology 2001-2030.



Datasets:

simulaciones: BCC-CSM2-MR_r1i1p1f1 y GISS-E2-1-G_r1i1p1f2
experimentos: historical-ssp585
datos:

Preprocessor
https://docs.esmvaltool.org/projects/ESMValCore/en/latest/api/esmvalcore.preprocessor.html

Global map of near-surface air temperature period 2001-2030:

- Cargar datos 2001-2030 (`timerange`)
- Interpolar los modelos a una gridilla común (`regrid`)
- Extraer meses DJF (`extract_season`)
- Calcular la media en el eje “tiempo” (`climate_statistics`)
- Media entre modelos (`multi_model_mean`)

Global map of near-surface air temperature period 2001-2030:

- Cargar datos 2001-2060 (`timerange`)
- Extraer meses DJF (`extract_season`)
- Calcular la media DJF de cada año (`seasonal_statistics`)
- Calcular la media espacial (`area_statistics`)
- Anomalia con respecto al periodo 2001-2030 (`anomalies`)
- Media entre modelos (`multi_model_mean`)
- Guardar modelos procesados (`keep_input_datasets: True`)

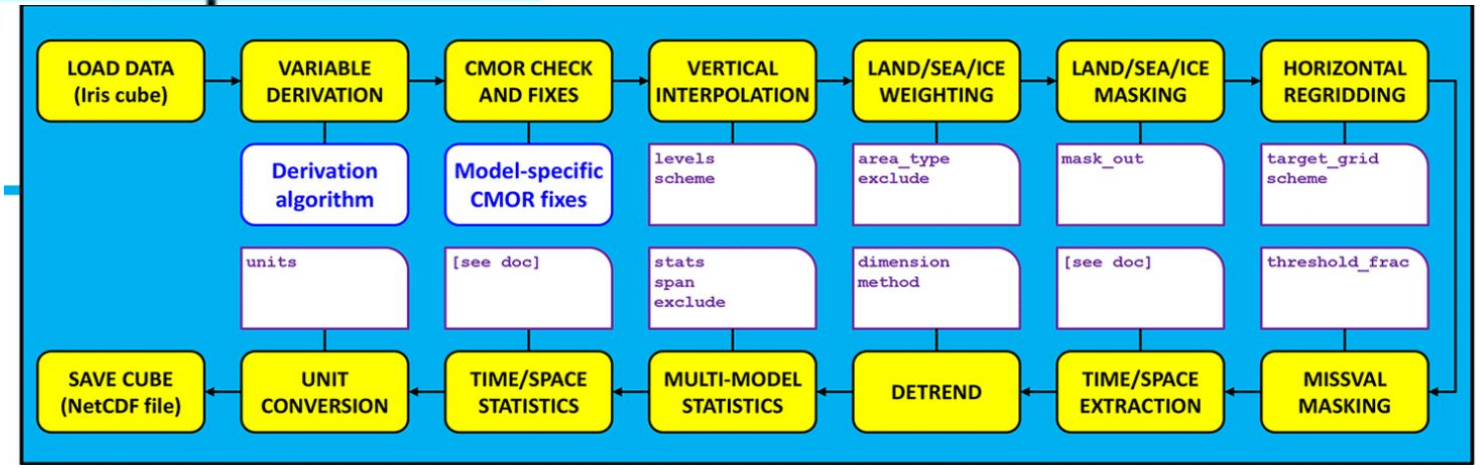
Correr ESMValTool

```
esmvaltool run recipe_example.yml

esmvaltool run --config_file /path/to/config-user.yml recipe_example.yml

esmvaltool run --max_datasets=NDATASETS --max_years=NYEARS recipe_example.yml

esmvaltool run --skip_nonexistent=True recipe_example.yml

...
```

https://docs.esmvaltool.org/projects/ESMValCore/en/latest/quickstart/run.html#running

ESMValCore

Generación de archivos intermedios



Orden por defecto tiene sentido científico para la mayoría de aplicaciones. Se puede modificar con `custom_order: true`

__all__ order:
https://github.com/ESMValGroup/ESMValCore/blob/main/esmvalcore/preprocessor/__init__.py#L94


```
(base) josep.cos@vegeta:~$ tree /home/josep.cos/output/recipe_python_curs_u_20231101_201653/preproc
/home/josep.cos/output/recipe_python_curs_u_20231101_201653/preproc
└── global_vs_regional
    ├── tas_clim_global
    │   ├── CMIP6_MultiModelMean_historical-ssp585_Amon_tas_2001-2030.nc
    │   ├── CMIP6_MultiModelMean_historical-ssp585_Amon_tas_2001-2030_provenance.xml
    │   └── metadata.yml
    └── tas_mean_global
        ├── CMIP6_BCC-CSM2-MR_Amon_historical-ssp585_r1i1p1f1_tas_gn_2001-2060.nc
        ├── CMIP6_BCC-CSM2-MR_Amon_historical-ssp585_r1i1p1f1_tas_gn_2001-2060_provenance.xml
        ├── CMIP6_GISS-E2-1-G_Amon_historical-ssp585_r1i1p1f2_tas_gn_2001-2060.nc
        ├── CMIP6_GISS-E2-1-G_Amon_historical-ssp585_r1i1p1f2_tas_gn_2001-2060_provenance.xml
        ├── CMIP6_MultiModelMean_historical-ssp585_Amon_tas_2001-2060.nc
        ├── CMIP6_MultiModelMean_historical-ssp585_Amon_tas_2001-2060_provenance.xml
        └── metadata.yml

4 directories, 10 files
```

INFO [2151310] To re-run this diagnostic script, run:
cd /home/josep.cos/output/recipe_python_curs_u_20231101_201653/run/global_vs_regional/script1;
MPLBACKEND="Agg" /home/josep.cos/mambaforge/envs/esmvaltool/bin/python
/home/josep.cos/examples/esmval_diagnostic.py
/home/josep.cos/output/recipe_python_curs_u_20231101_201653/run/global_vs_regional/script1/settings.yml

-main_log.txt

recipe_output_<date>_<hour>/run/<diagnostic_name>/<script_name>/settings.yml

recipe_output_<date>_<hour>/preproc/<diagnostic_name>/<variable_name>/metadata.yml

Los archivos .yml generan un diccionario de información que nos va a ser útil para gestionar los datos preprocesados

```
1
2  from esmvaltool.diag_scripts.shared import (
3      group_metadata,
4      run_diagnostic,
5  )
6
7  def main(cfg):
8      input_data = cfg['input_data'].values()
9      grouped_input_data = group_metadata(input_data,
10                                         'variable_group',
11                                         sort='dataset')
12
13 if __name__ == '__main__':
14     with run_diagnostic() as config:
15         main(config)
```