Sciences de l'environnement

Institut Pierre Simon Laplace

ESPRI

MÉSOCENTRE IPSL

MODULE 3

Tools for climate science

ESMValTool
Earth System Model eValuation Tool

CliMAF
Sharing – Simplifying – Optimizing

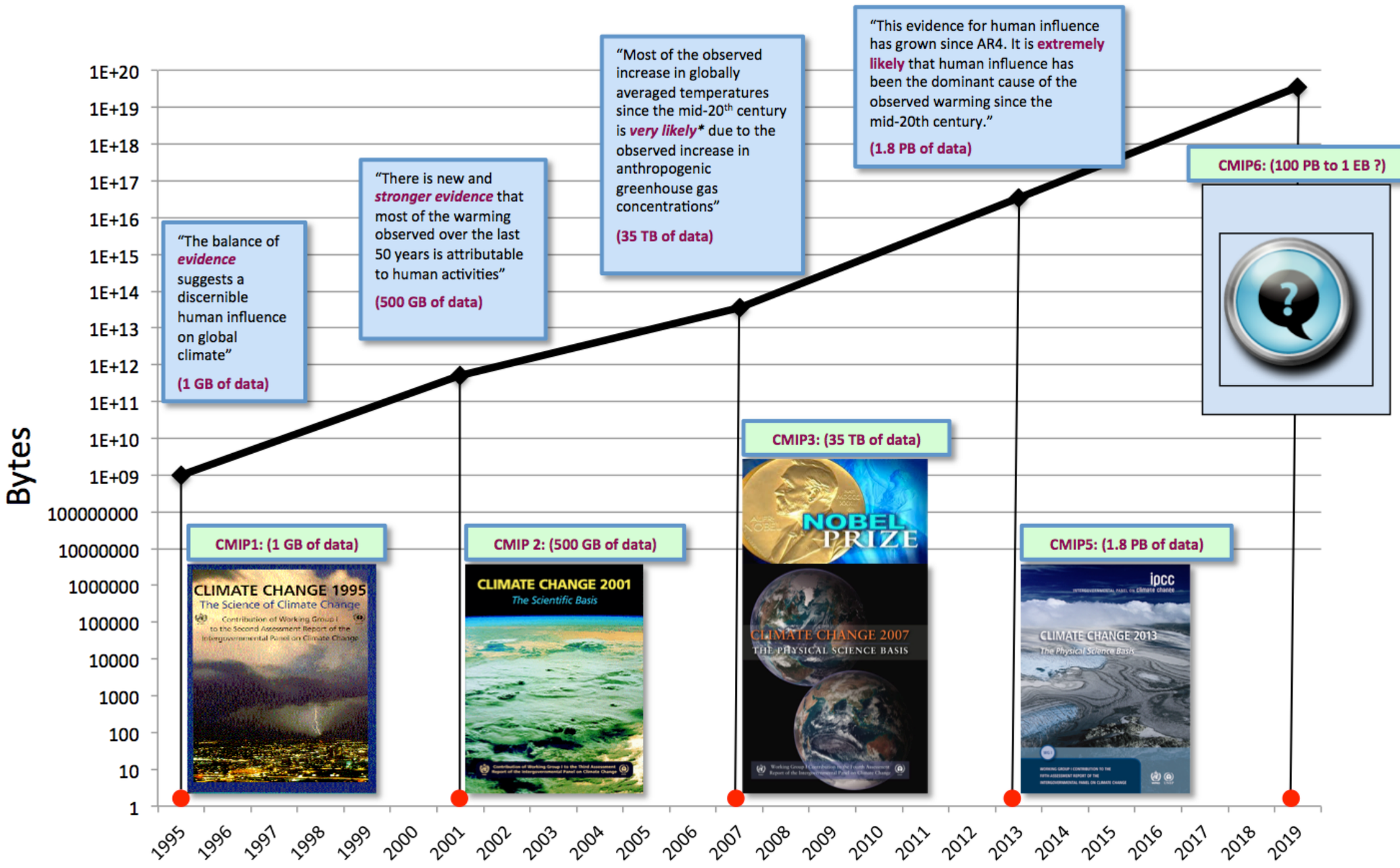
INTRODUCTION

CMIP: +76%/year

Moore's law: +42%/year

WCRP World Climate Research Programme

CMIP The World Climate Research Programme's Coupled Model Intercomparison Project



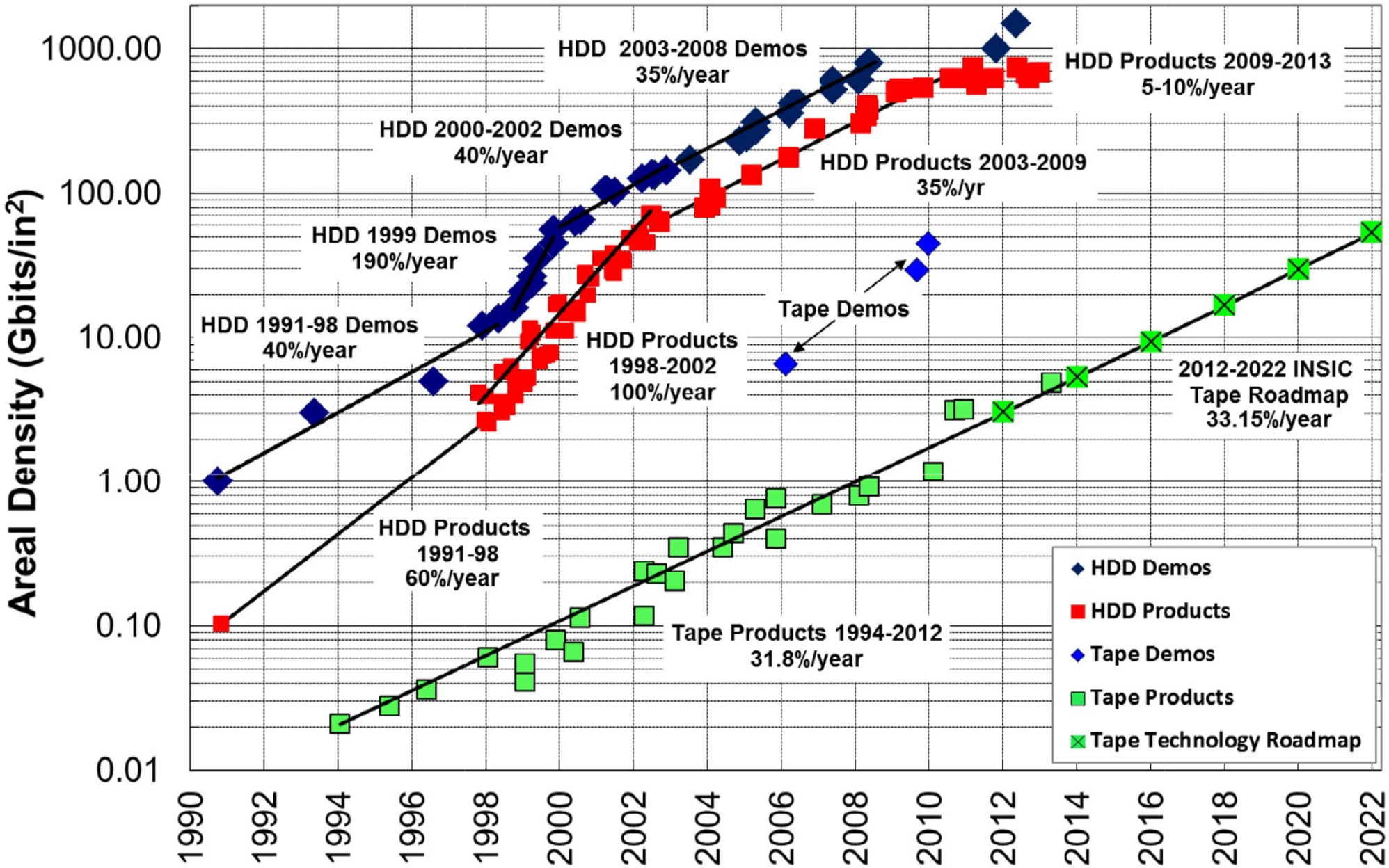
INTRODUCTION

WCRP World Climate Research Programme

CMIP: **+76%/year**

HDD: **+45%/year**

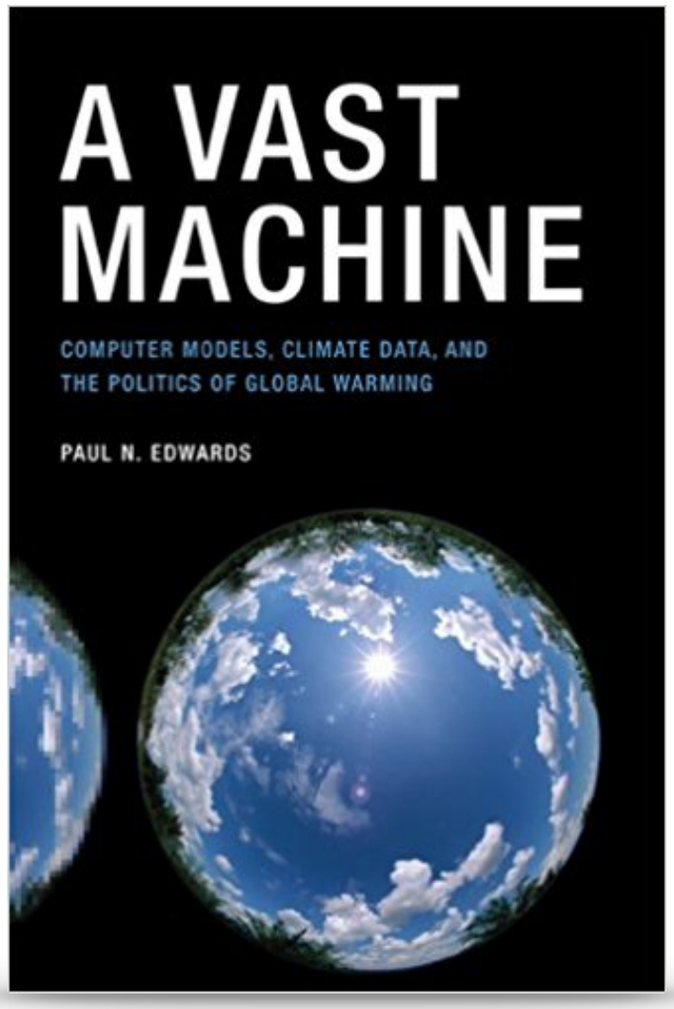
CMIP The World Climate Research Programme's Coupled Model Intercomparison Project



INTRODUCTION

Global data infrastructure

CMIPs, and in general any science involving cross-model comparisons, critically depend on the global data infrastructure – the “vast machine” (Edwards 2010) – making this sort of data-sharing possible.



INTRODUCTION

Data producers

Observational and model output data in the climate-ocean-weather (COW) community is initially generated in some “native” non-standard format, and any subsequent relative analyses requires considerable effort to systematise. Issues include moving and transient data sources, lossy data formats, curvilinear and other “exotic” coordinates.

INTRODUCTION

Data organisers

Data organisers are the community within this ecosystem that facilitates the transformation of source dependent data to a neutral and readily consumable form. They maintain the standards for describing data in a manner that permits these transformations, and develop tools to perform them.

INTRODUCTION

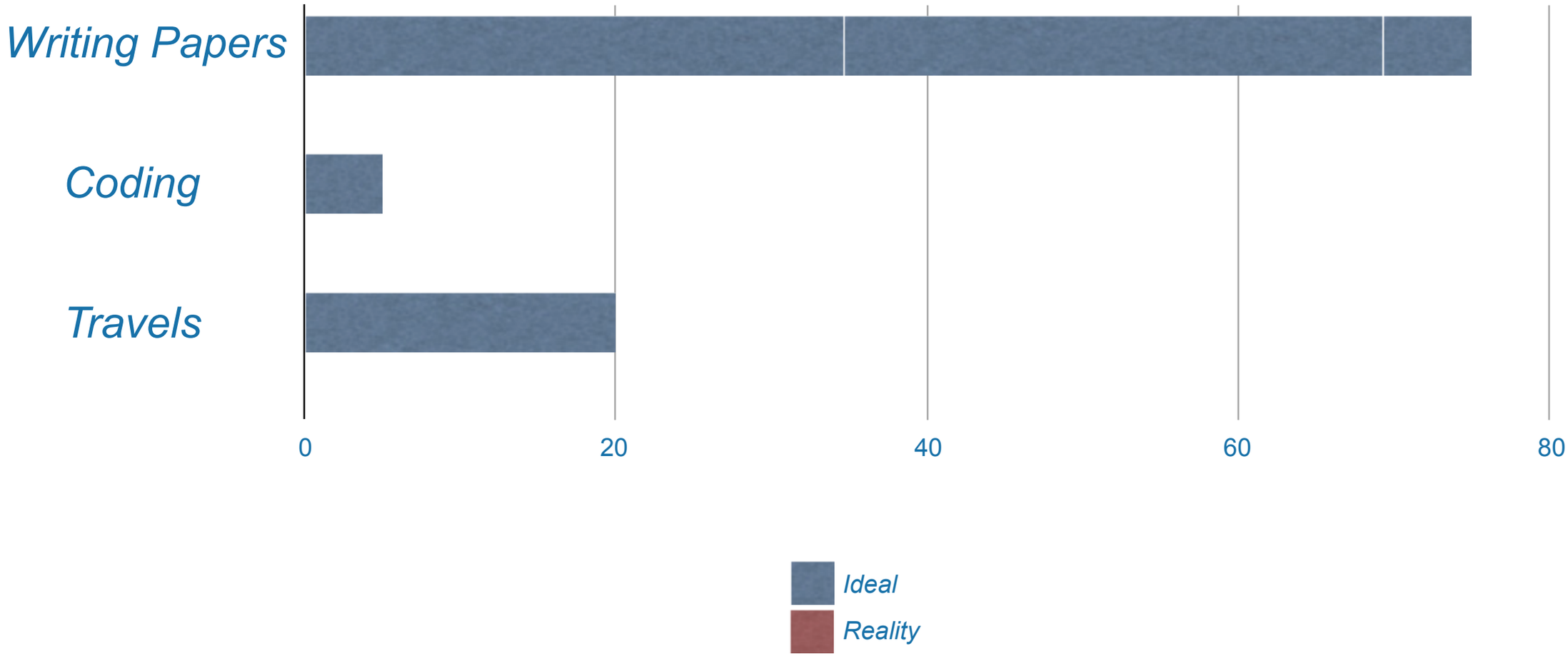
Data consumers

Scientists perform sequences of computations (e.g. “poleward heat transport”, “length of growing season”) on datasets. Typically this is scripted in some data analysis language, and ideally it should be possible to apply the script to diverse datasets.

INTRODUCTION

Efficiency

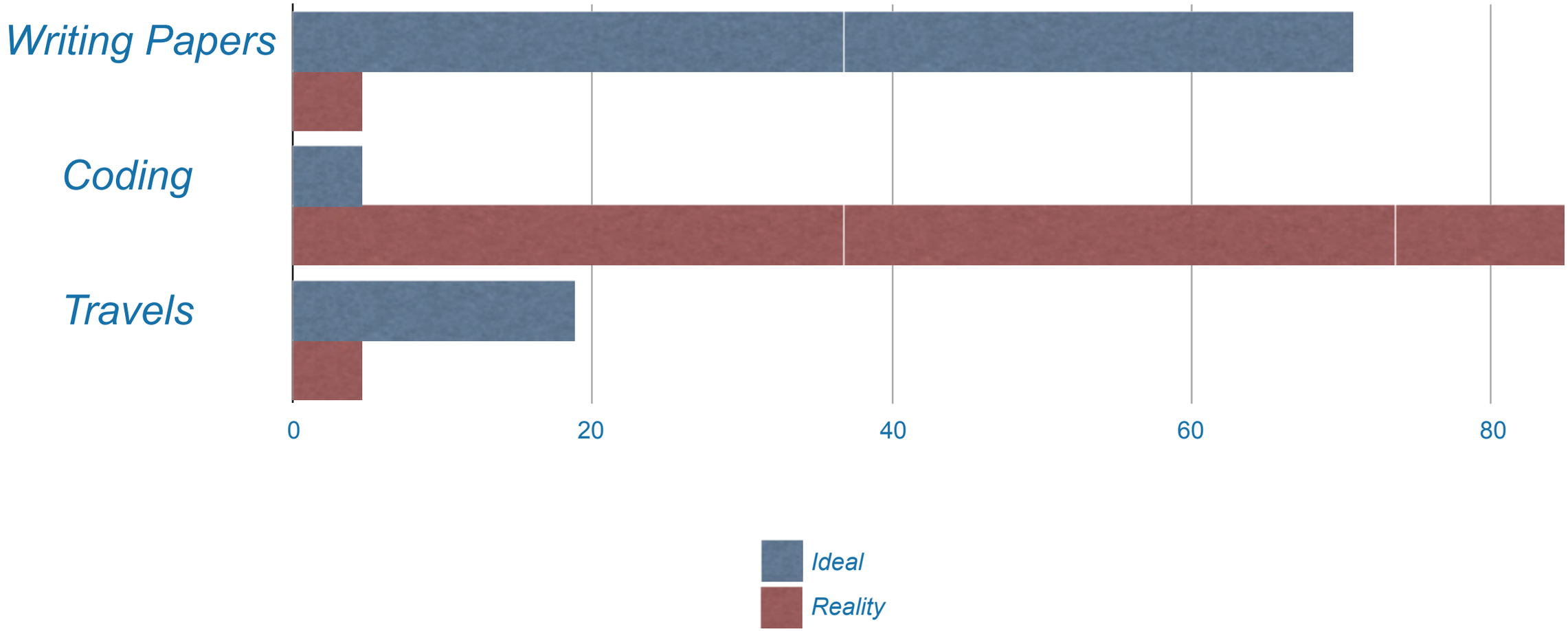
Distribution of labor in a scientist's job



INTRODUCTION

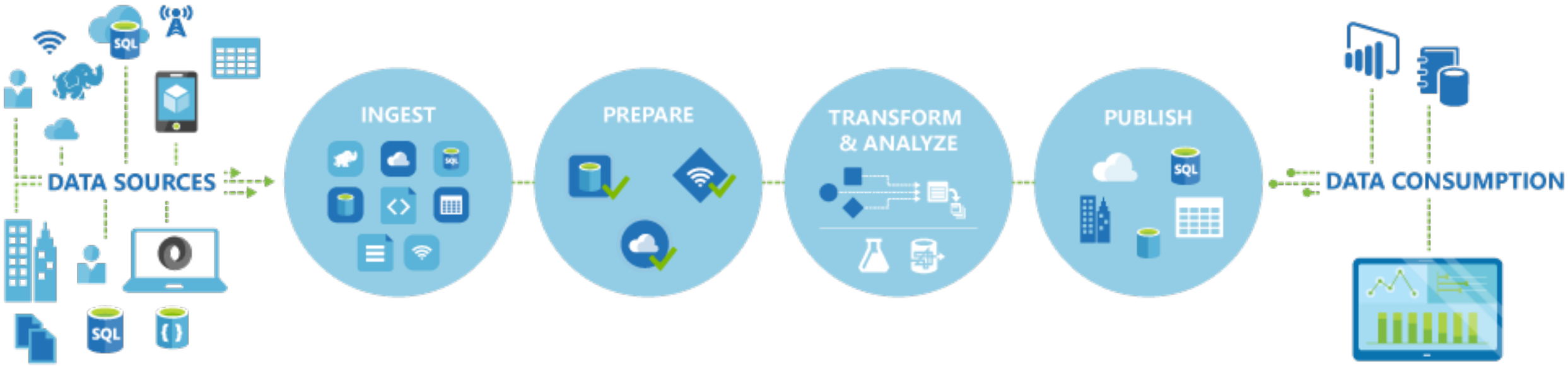
Efficiency

Distribution of labor in a scientist's job



INTRODUCTION

Data fabric



INTRODUCTION

How to improve support for climate analyses?

Researcher

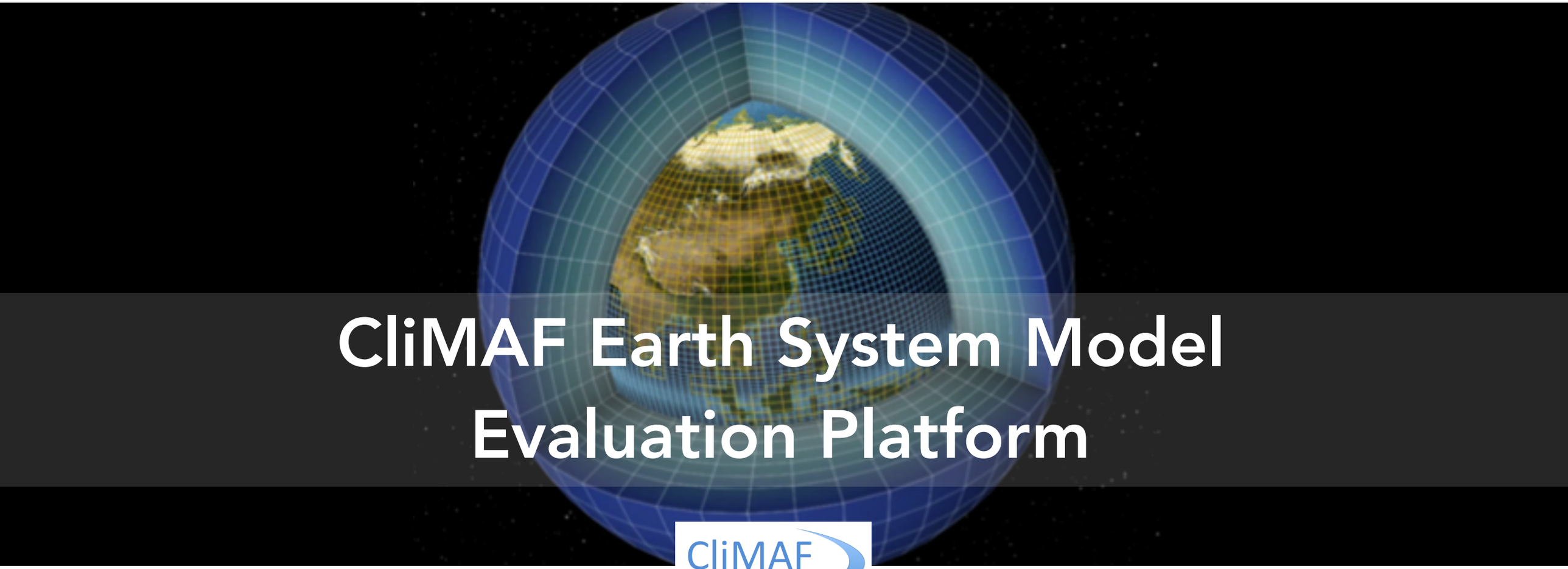
- Specific simulations, variables, frequency, time periods, etc.,
- to run their simulations,
- Overviews on data with simple graphics or maps,
- Complex analyses using different languages (R, Python, Ferret, etc.)
- Reproducibility of their analyses
- Analyse reproducibility.

Researcher-friendly platform

- Clarifying access to available data,
- Simplifying simulations runs,
- Automating recurring needs (means, anomalies, etc.),
- Applying specific script,
- Ensuring support and data management.

Climate engineer

- Model code & libIGCM interface,
- Data management,
- Documentation and trainings,
- Search API,
- HERMES,
- Web (Mapping) Services,
- (Inter-)Monitoring,
- Automated atlas.



CliMAF Earth System Model Evaluation Platform

CliMAF
Sharing – Simplifying – Optimizing

Evaluating/comparing a set of simulations/ models on CICLAD

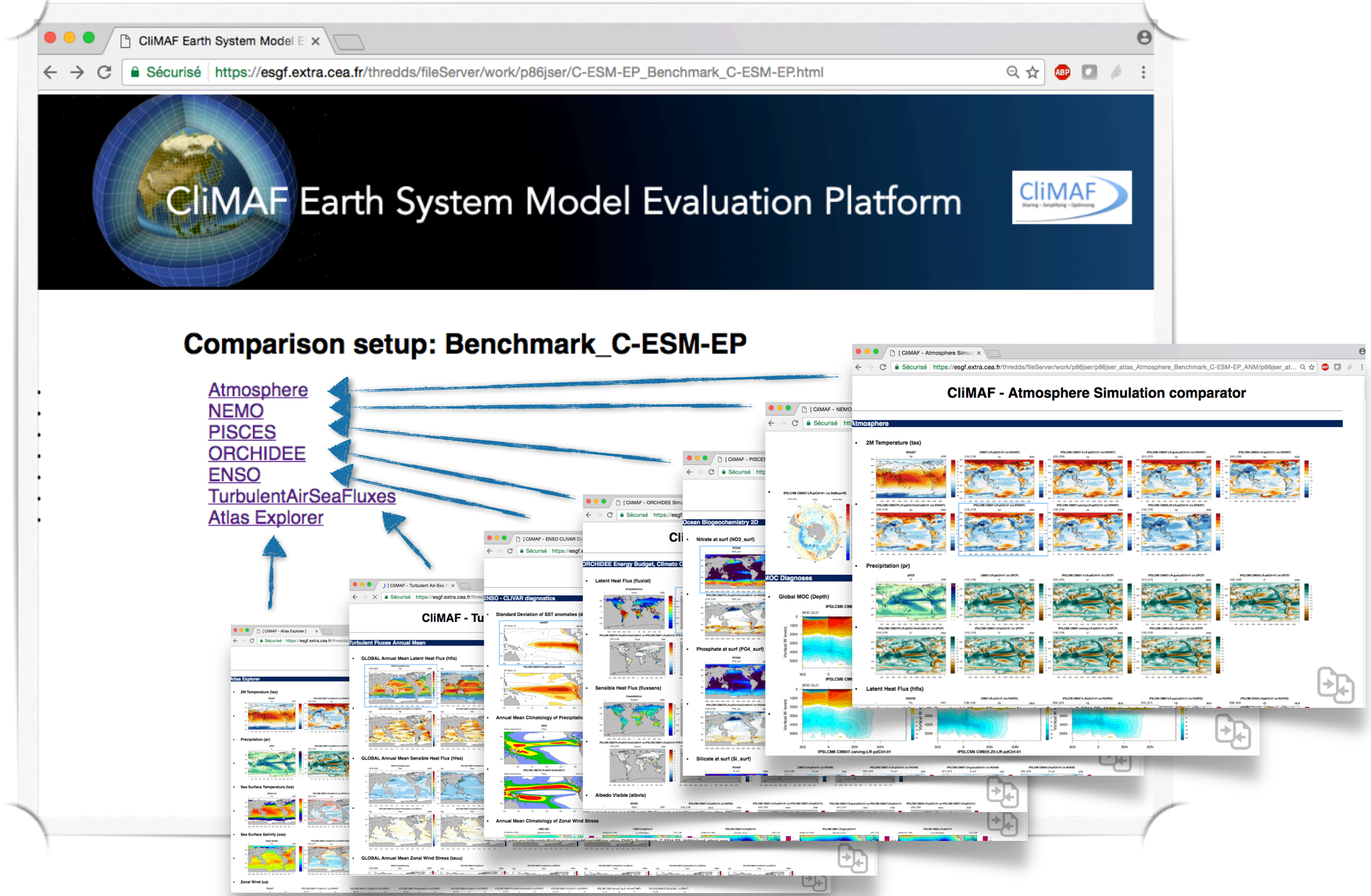
CLIMAF

The C-ESM-EP — Definition

- A predefined – community validated (IPSL-CNRM-CERFACS) set of evaluation diagnostics by component/thematic
- An efficient way to systematically compare results of different simulations while benefiting from ways to finess the diagnostics (choosing the periods for a set of diagnostics, controlling the plot parameters…)
- A front HTML page with links to the html pages of the atlases of the different components/thematics.

CLIMAF

The C-ESM-EP



CLIMAF

The C-ESM-EP

CliMAF
Sharing – Simplifying – Optimizing

The C-ESM-EP is based on **CliMAF** (http://climaf.readthedocs.io/en/latest/), an advanced python framework developed in collaboration between CNRM-GAME and IPSL to provide the french community with an efficient way to gather-share diagnostics and apply them routinely on the climate models outputs.

S. Sénési, J. Servonnat, L. Vignon, O. Marti, P. Brockmann, S. Denvil
Contact: climaf@meteo.fr

CLIMAF

The C-ESM-EP

CliMAF

Sharing – Simplifying – Optimizing

Main strengths:

- Standardised way to access the data ⇨ Can be adapted to any CF-compliant NetCDF files ⇨ Encourage sharing the diagnostics!
- Automatically manage the output in a smart cache (uses the existing results) ⇨ Fast!
- Simplified way to do those daily pretreatments (averaging, period/ geographical domain selection, etc.) based on CDO
- Easy way to do plots (using an NCL script) and put them in an html page
- Easy to plug your own script of diagnostic

Main weaknesses:

- It's not magic! You will get errors at some point (sorry)
- Potentially slows down when the cache is loaded with results

The C-ESM-EP in a nutshell

The quick way to use the C-ESM-EP on CICLAD:

```
# Copy the sources in a working directory
> cd my_working_directory
> mkdir -p C-ESM-EP ; cd C-ESM-EP
> cp -r ${sources} . ; cp -r src work
> cd work

# Setup your comparison
> cp -r comparison_example/ my_comparison/

# Enter your datasets
> vi my_comparison/datasets_setup.py

# Run all the components together or just a subset:
> python run_C-ESM-EP.py my_comparison [Atmosphere_Surface,ENSO]

# See the results on the URL returned by run_C-ESM-EP.py
[..]
-- The CliMAF ESM Evaluation Platform will be available here:
-- https://vesg.ipsl.upmc.fr/thredds/fileServer/IPSLFS/jservon/C-ESM-EP_Benchmarck_Ciclad.html
```

CMIP5 and IGCM_OUT data access

Definition of a CMIP5 dataset and an IPSLCM6 simulation (SE):

```
models = [
    dict(
        project = 'CMIP5',
        model = 'IPSL-CM5A-LR',
        experiment = 'historical',
        simulation = 'r1i1p1',
        frequency = 'monthly',
        period = '1980-2005'
         ),
    dict(
        project = 'IGCM_OUT',
        root = '/ccc/store/cont003/thredds',
        login = 'p86caub',
        model = 'IPSLCM6',
        simulation = 'CM605-LR-pdCtrl01',
        frequency = 'seasonal',
        clim_period = '2020_2029'
         )
]
```

More details on the data access in the demo/TP.

CLIMAF

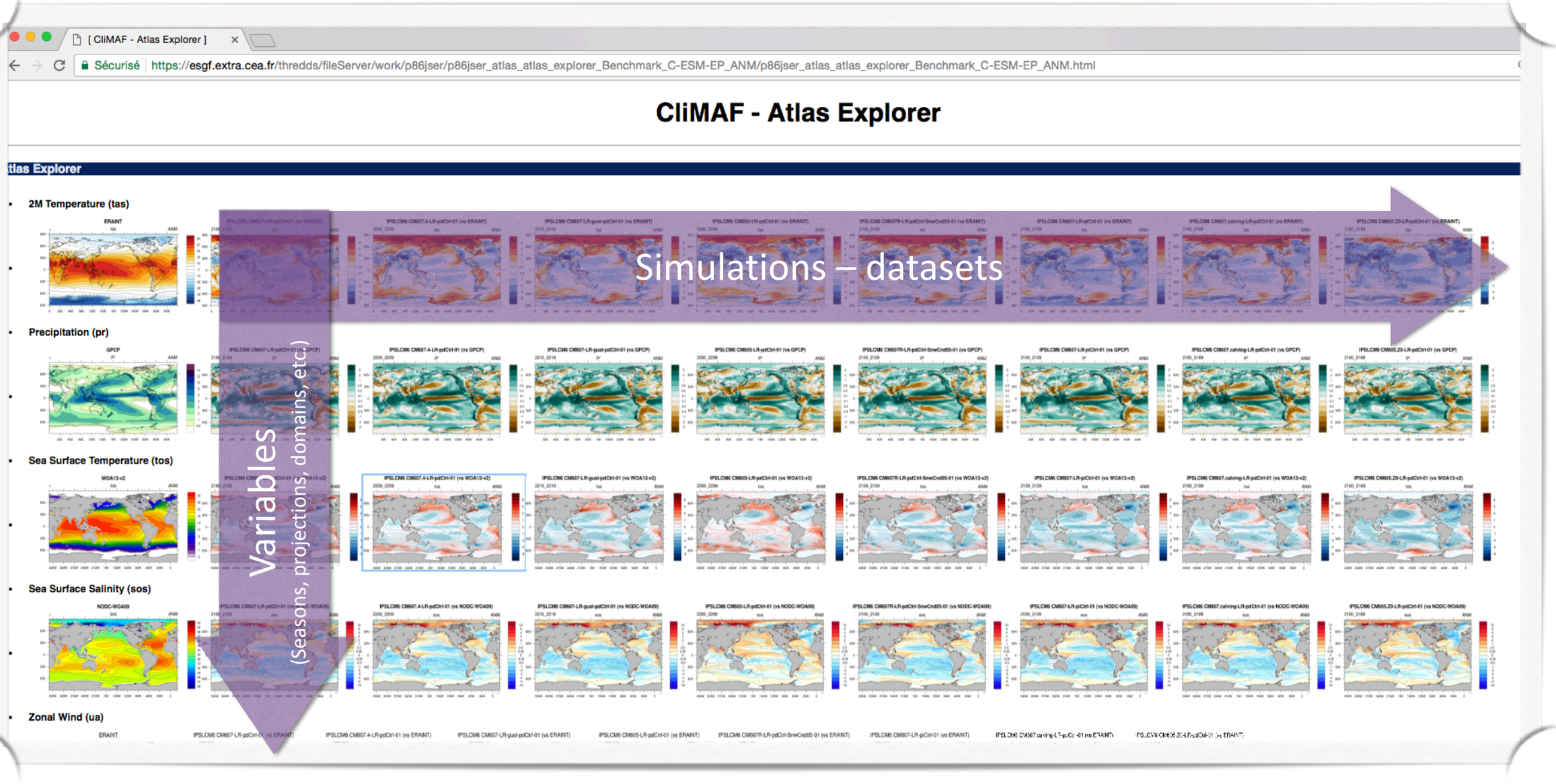
Atlas Explorer — Definition

- **An easy and flexible working space within the C-ESM-EP** to produce an HTML page showing climatologies and difference maps (with a reference) on a set of datasets (simulations, models, different periods…)

- Provide the user with a set of predefined features to assess a variable (plotting parameters, default observational reference) while keeping control on the diagnostics from only one parameter file.

CLIMAF

Atlas Explorer



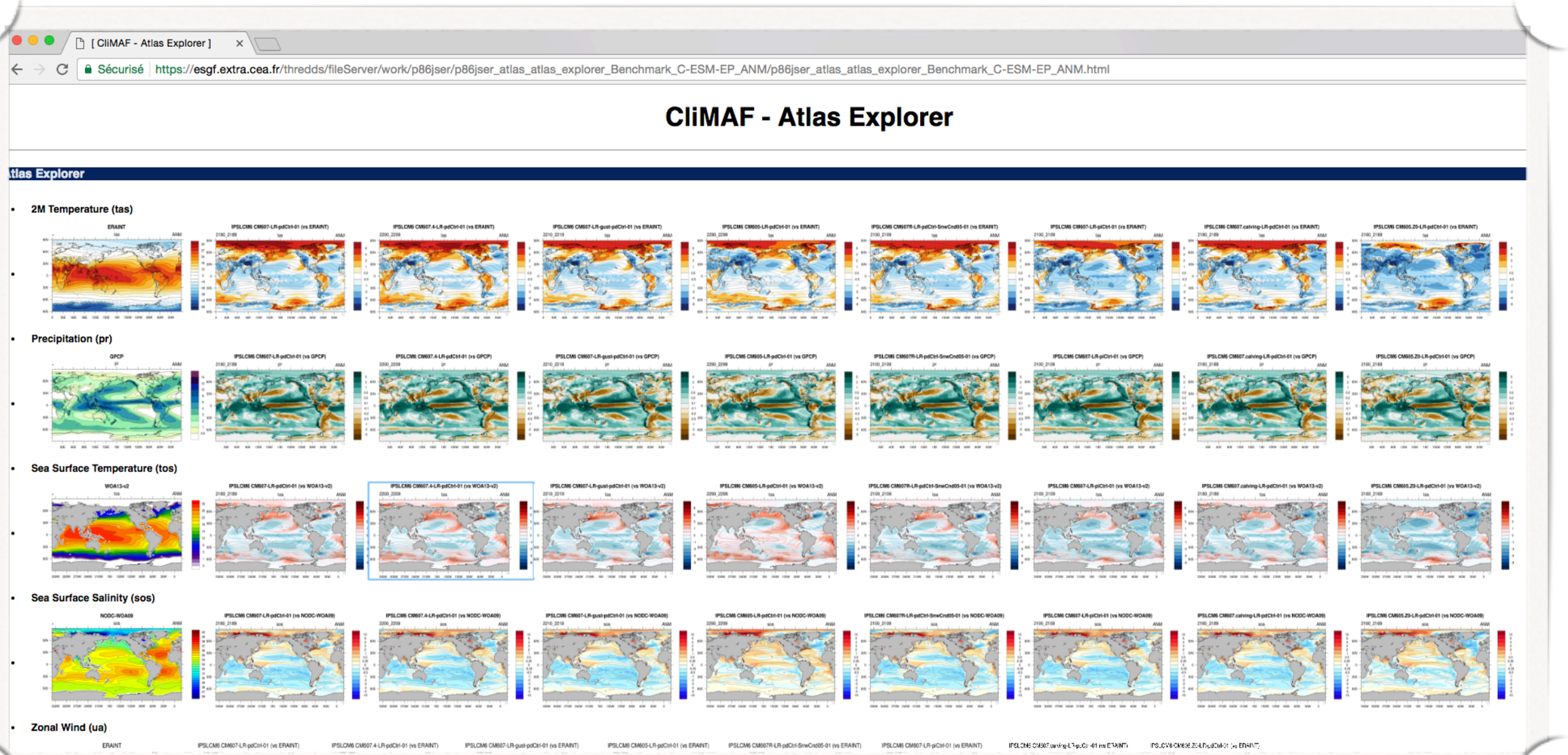
Atlas Explorer

The quick way to use Atlas Explorer on CICLAD:

```
# Install the C-ESM-EP and setup a comparison
# (as seen for the C-ESM-EP)
# Go into the directory of your comparison

# Add your datasets in datasets_setup.py
> cd my_comparison
> vi datasets_setup.py

# Edit the Atlas Explorer parameter file to setup what you need
> vi AtlasExplorer/params_AtlasExplorer.py

# Run the Atlas Explorer interactively:
> ./job_C-ESM-EP.py AtlasExplorer

# See the results on the URL returned at the end of the execution
# Or submit a job from the main directory
> cd ../
> python run_C-ESM-EP.py my_comparison/ AtlasExplorer
```

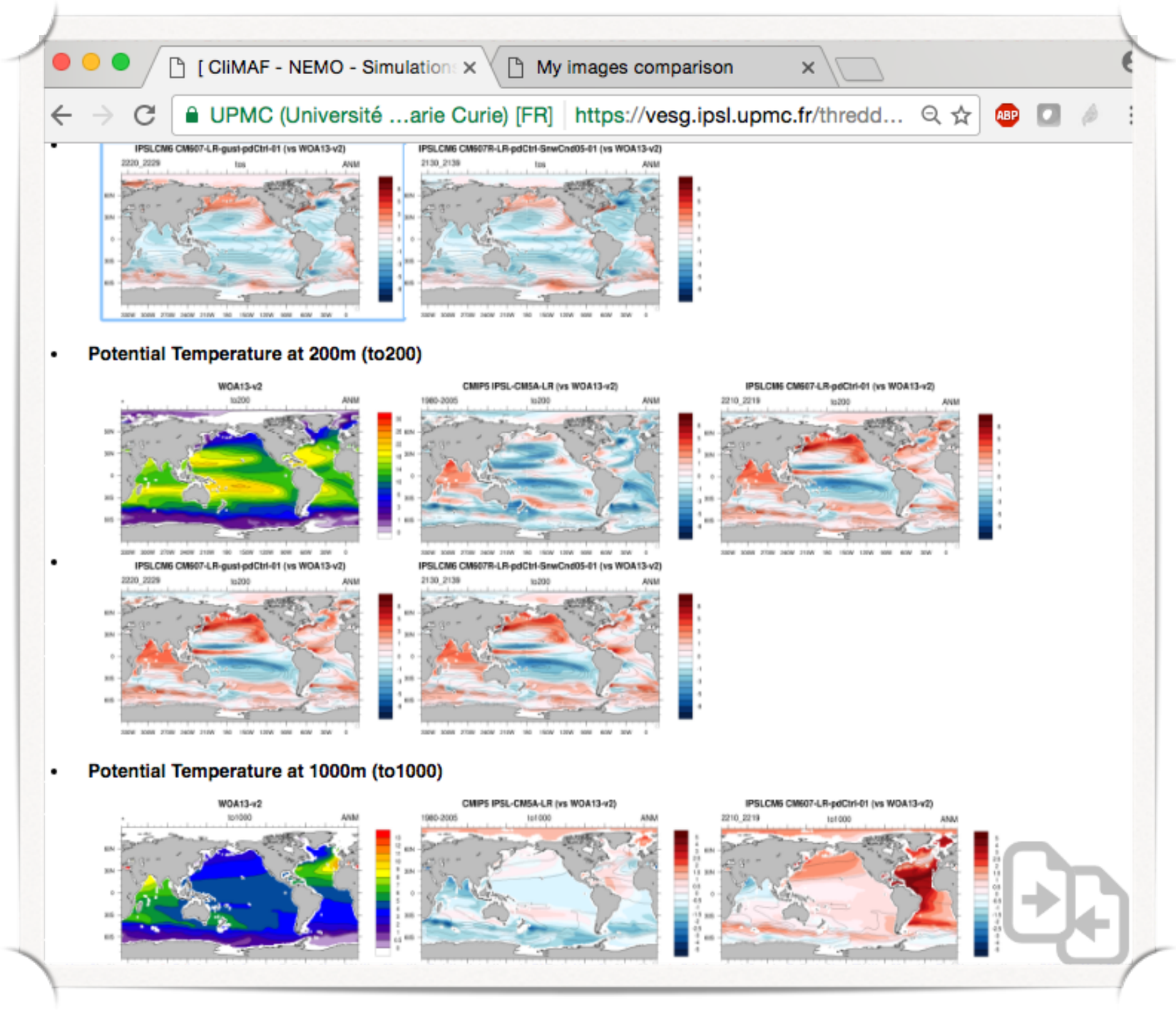
Atlas Explorer — The ‘compareCompanion’

Display a selection of figures on the fly:



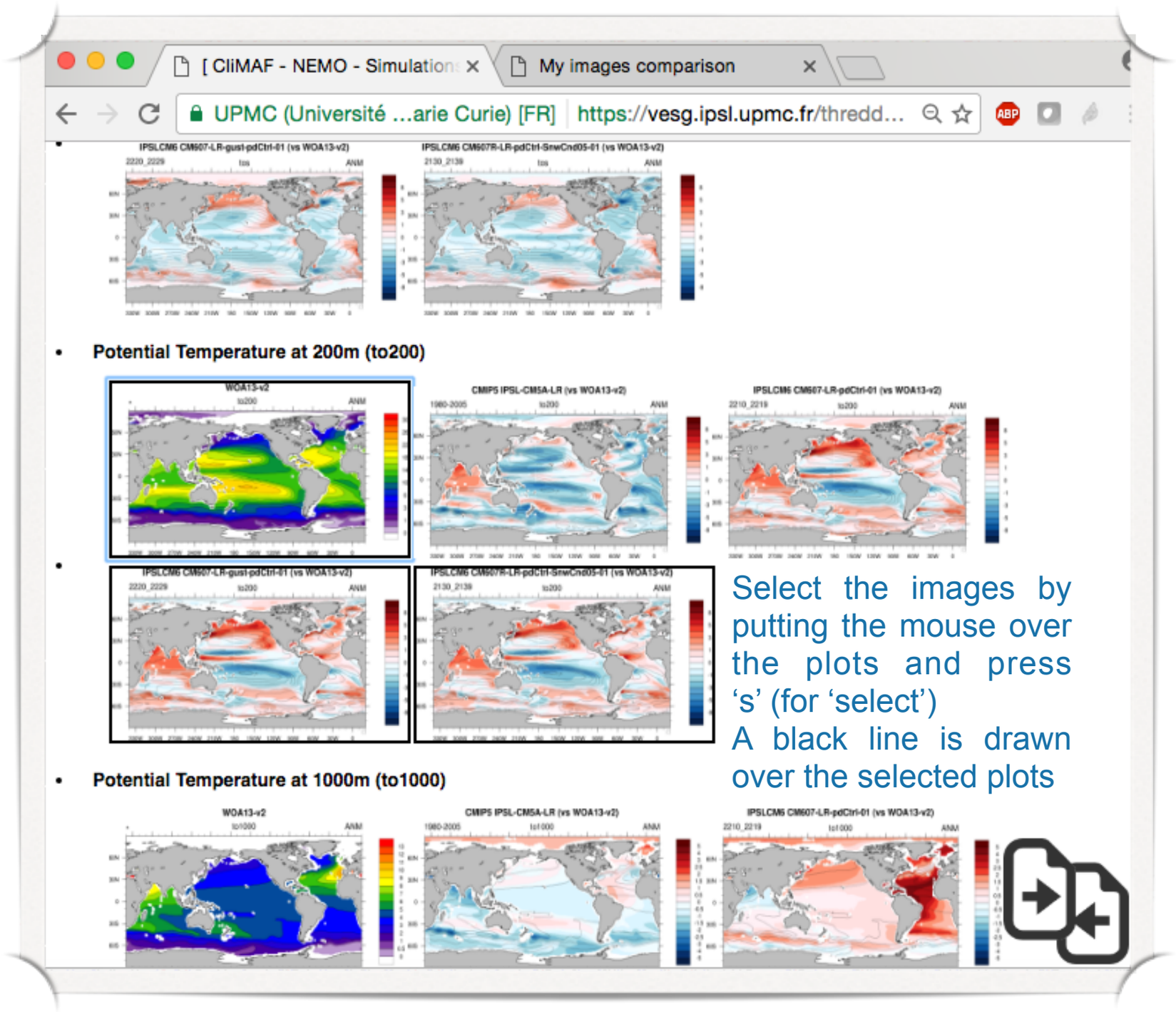
Atlas Explorer — The ‘compareCompanion’

Display a selection of figures on the fly:



Atlas Explorer — The ‘compareCompanion’

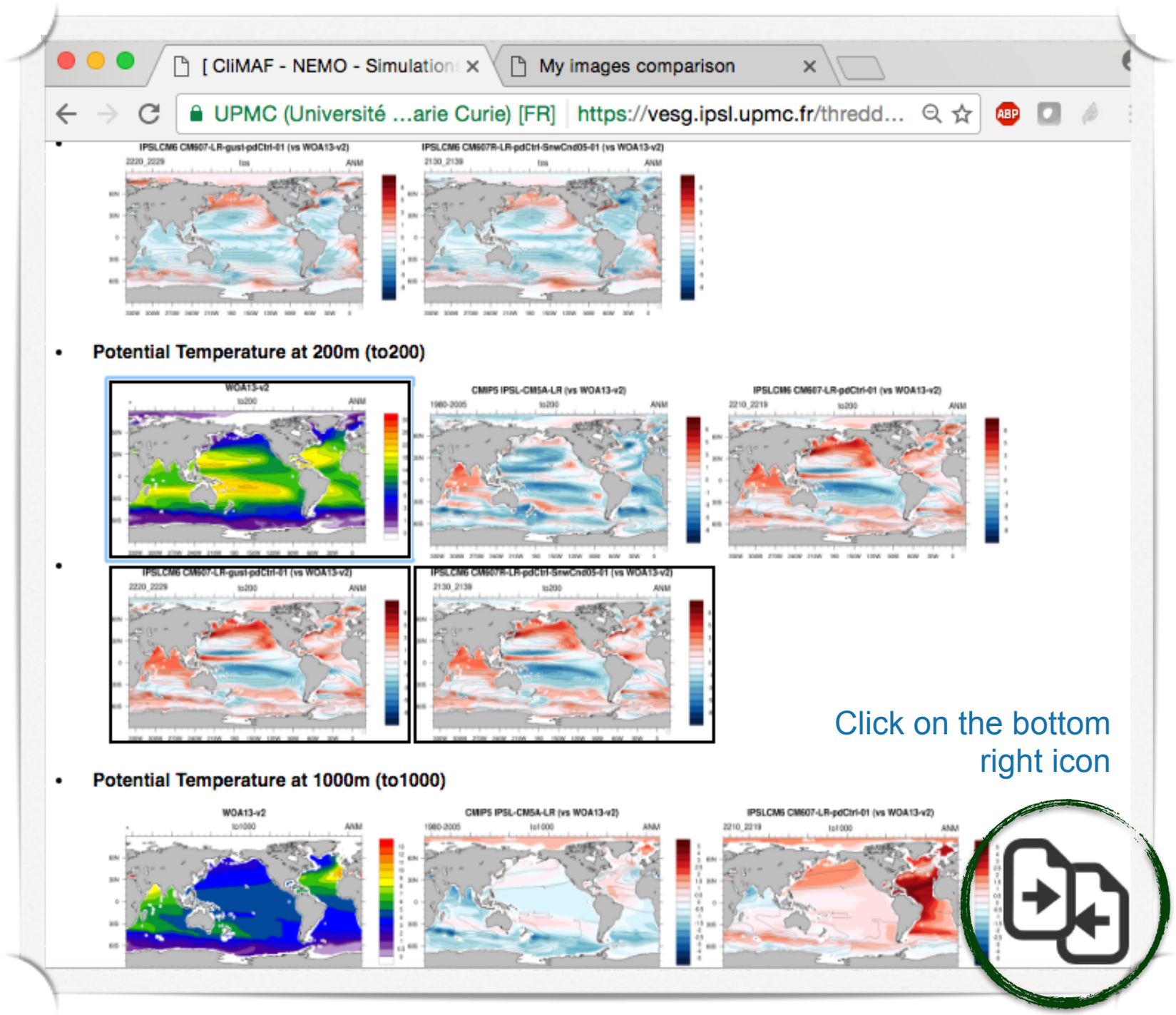
Display a selection of figures on the fly:



Select the images by putting the mouse over the plots and press ‘s’ (for ‘select’)
A black line is drawn over the selected plots

Atlas Explorer — The ‘compareCompanion’

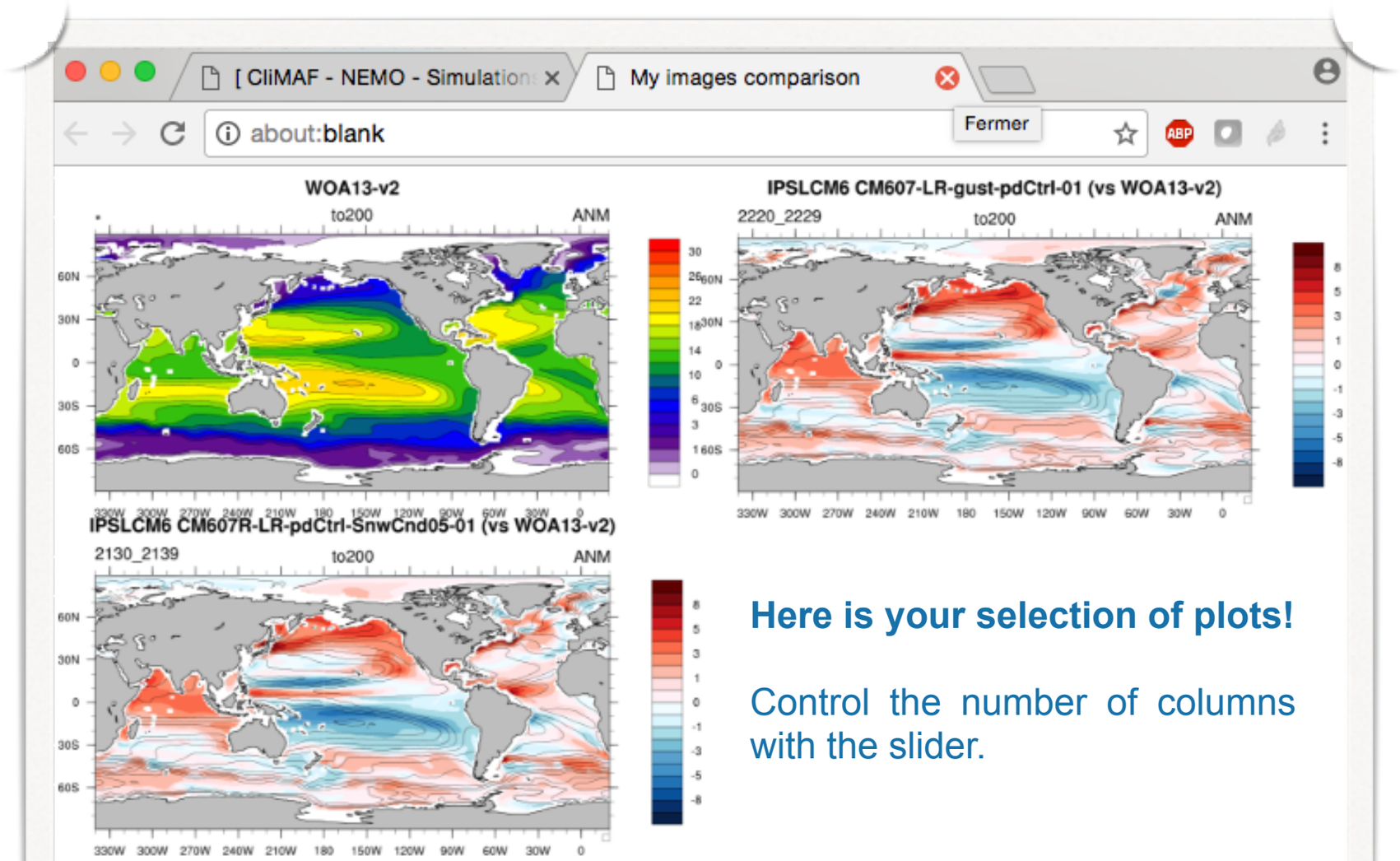
Display a selection of figures on the fly:



Click on the bottom right icon

Atlas Explorer — The ‘compareCompanion’

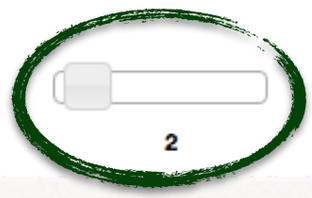
Display a selection of figures on the fly:



Here is your selection of plots!

Control the number of columns with the slider.

And switch their positions by dragging the image you want at the position of your choice



CLiMAF

Contributions

The CliMAF Earth System Model Evaluation Platform, 2017
J. Servonnat, S. Sénési, L. Vignon, O. Marti, P. Brockmann, S. Denvil

Contributors:
F. Hourdin, I. Musat, M.P. Moine, E. Sanchez, M. Chevallier, R. Msadek, J. Deshayes, M. Van Coppenolle, C. Rousset, J. Mignot, J. Ghattas, P. Peylin, N. Vuichard, P. Cadule, A. Ducharne, F. Maignan, R. Séférian

Beta-testers:
O. Marti, J. Mignot, J. Deshayes, P. Braconnot, P. Sepulchre, M. Kageyama, S. Denvil, R. Séférian, A. Cozic

The authors would like to give special credit to A. Voldoire for showing the way for CliMAF, and to F. Hourdin and the LMDz team for the structure of the C-ESM-EP that is largely inspired from the LMDz evaluation atlas.

Questions: jerome.servonnat@lsce.ipsl.fr

ESMVALTOOL

Introduction

- **Community diagnostics and performance metrics tool** for the evaluation of Earth System Models (ESMs) that allows for routine comparison of single or multiple models, either against predecessor versions or against observations.

- Allows quick looks at **standard diagnostic plots** and **output diagnostic variables**
- Allows to compare models participating in CMIP and CMIP6-Endorsed MIPs.
- Useful for model groups and those analysing models
- Useful for model development
- Community development allows for multiple developers from different institutions to contribute and join

- More than 60 developers from 20 institutions lead by DLR (ESMValTool, Eyring et al., 2016a)
- First version is available on GitHub: https://github.com/ESMValGroup/ESMValTool

ESMVALTOOL

Introduction

- ESMValTool can be used as one of the documentation functions in CMIP to help understand the origins and consequences of model errors. The goal of this aspiration is **to develop a benchmarking and evaluation tool** that produces well-established analyses as soon as model results become available on the ESGF. This is realised through **standard namelists** that reproduce a certain set of diagnostics and performance metrics that have demonstrated its importance in benchmarking ESMs in a **previous papers or assessment reports**.

- The expectation is that in this way the **routine and systematic** evaluation of model results could be made more efficient, thereby enabling scientists to focus on developing more innovative methods of analysis. The goal is to run tool on model output of CMIP6 alongside ESGF.

- The ESMValTool utilises obs4MIPs, ana4MIPs, ESACCI plus additionally available observations to evaluate the models. In many diagnostics and metrics, more than one observational dataset or meteorological reanalysis is used.

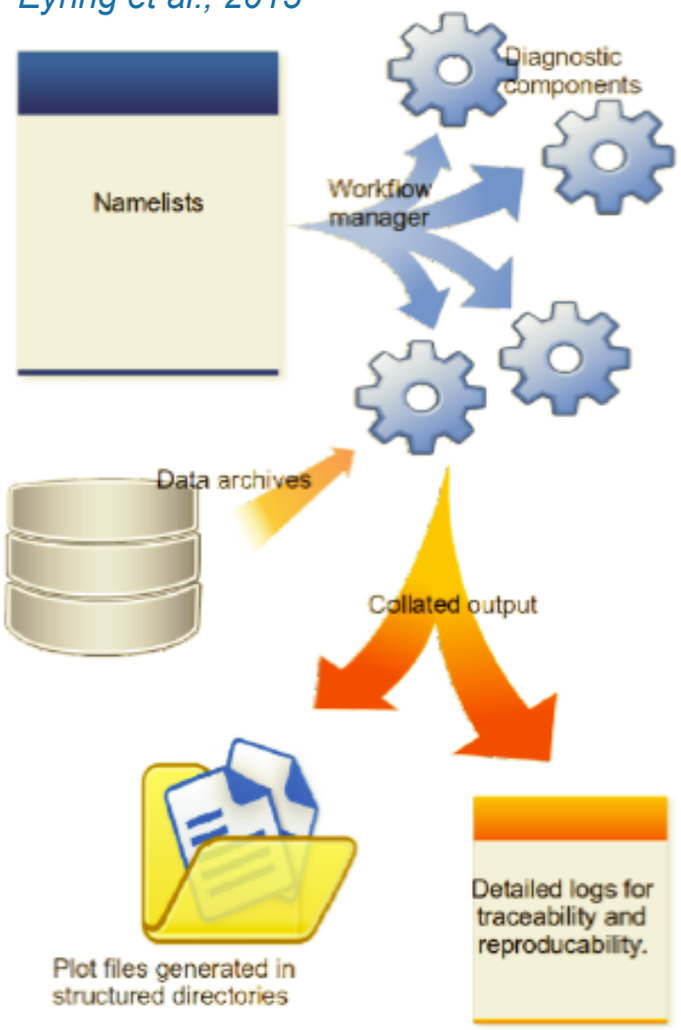
ESMValTool
Earth System Model eValuation Tool

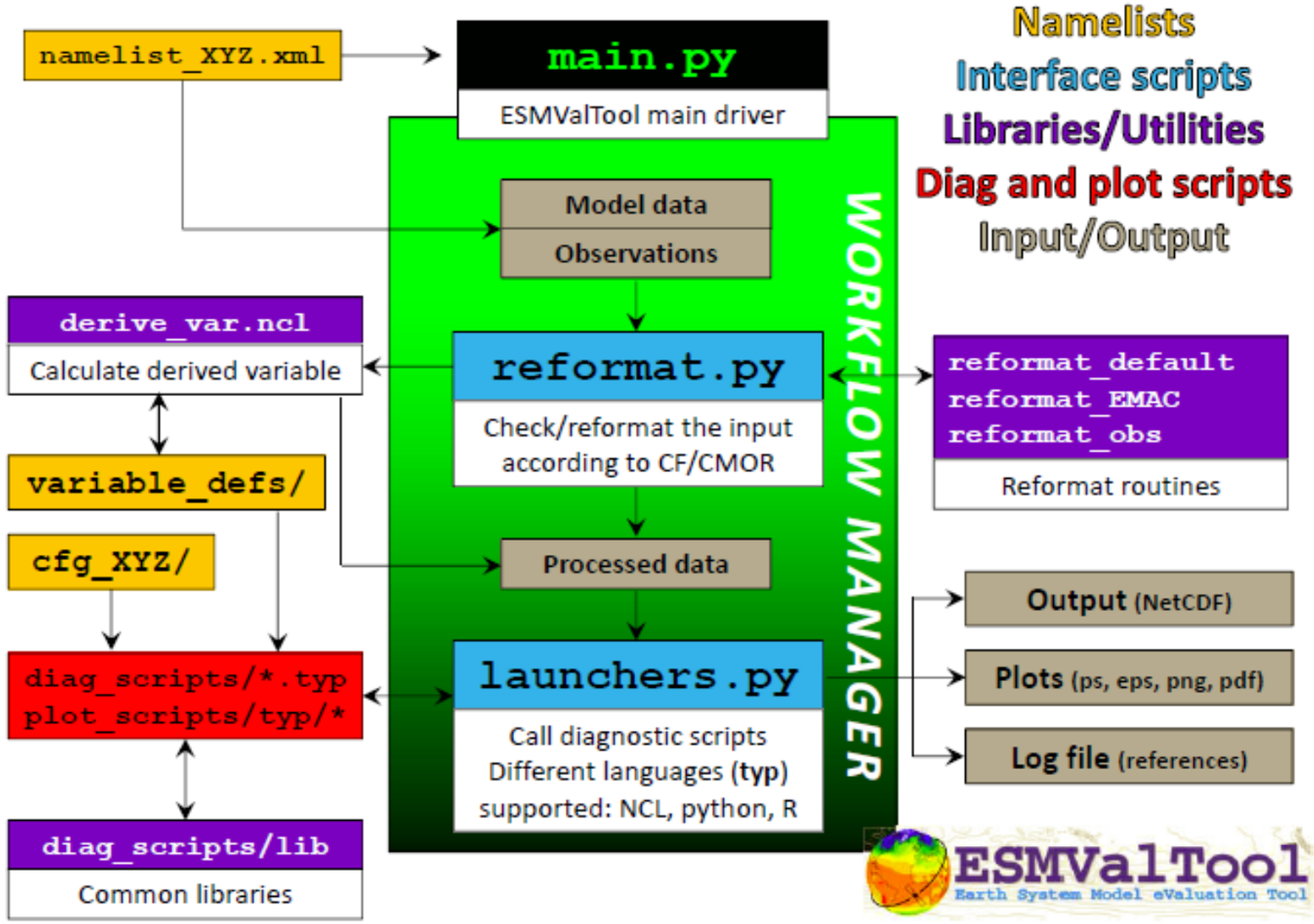
MODÈLES NUMÉRIQUES - CONVERGENCE

ESMVALTOOL

Overview

Eyring et al., 2015





The workflow manager (Python script `main.py`) runs a set of diagnostics on data provided by IPSL local ESGF archive. The configuration and the settings of each diagnostic are specified in namelists. The results which typically comprise of NetCDF files and/or plots are stored in output folders along with log-files summarising the data used, references, and technical details to ensure traceability and reproducibility of the results.

ESMValTool

Evolution

Current status, on CICLAD:

- No automatic search: at every institute users have to prescribe local data DRS through local Python classes…
- If the model results are not available – the request should be made to IPSL ESGF data manager to replicate the data
- Code mainly based on NCL programming language (but with multi-language support for diagnostics: R, Python, NCL…)
- Still contains some 'hard-coded' parts

Under development *(Eyring et al., 2016)*:

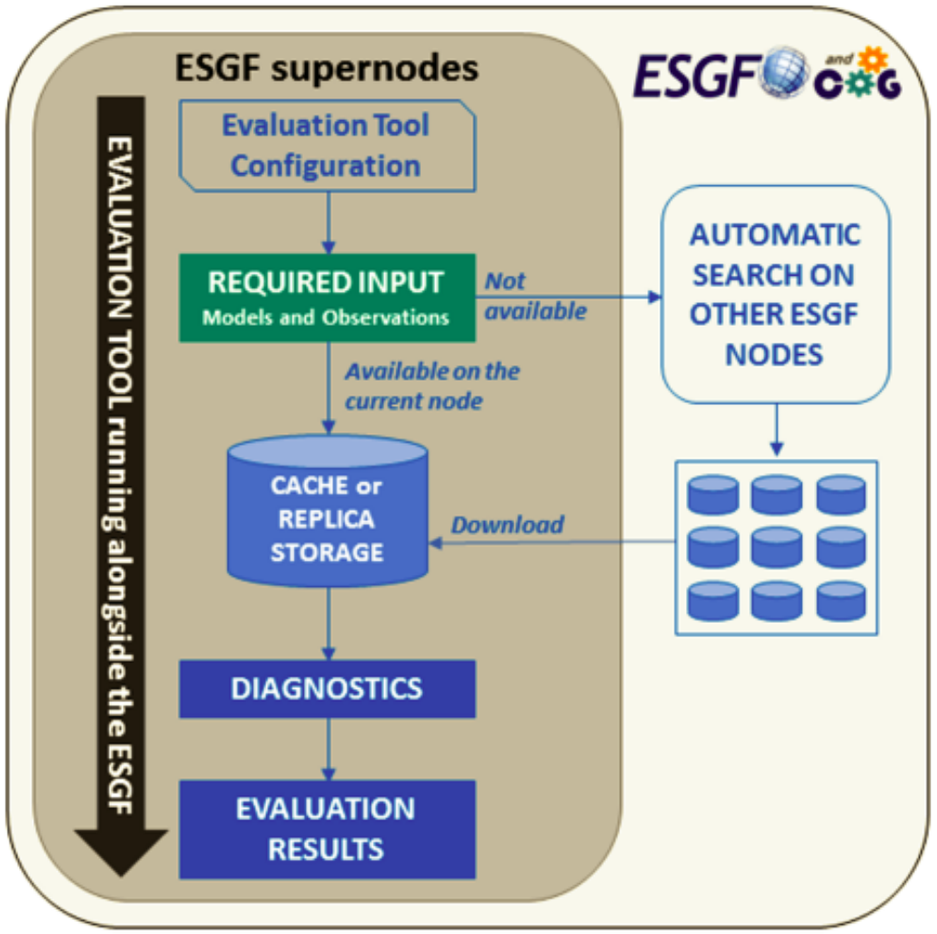


Figure 5. Schematic diagram of the envisaged evaluation tool processing stream for CMIP6. The schematic displays how the tools will be executed directly on ESGF supernodes exploiting optimized ESGF data organization and software solutions (see details in Sect. 2.3).

Backend code is migrating to **Python**

ESMVALTOOL

Available diagnostics

- Aerosol Diagnostics
- Cloud Diagnostics
- Cloud Regime Error Metric (CREM)
- Diurnal Cycle of Convection
- Emergent Constraints on Carbon Cycle Feedbacks
- Evapotranspiration, global climatology
- IPCC AR5 Chapter 9
- Land and Ocean components of the carbon cycle
- NCAR's Climate Variability Diagnostics Package (CVDP)
- Performance Metrics for Essential Climate Parameters
- South Asian Summer Monsoon Diagnostics
- SeaIce Diagnostics
- Southern Hemisphere
- Standardised Precipitation Index diagnostics
- Tropical Variability
- West African Monsoon Diagnostics

And others, see detailed manual here: https://github.com/ESMValGroup/ESMValTool/blob/master/doc/ESMValTool_Users_Guide.pdf

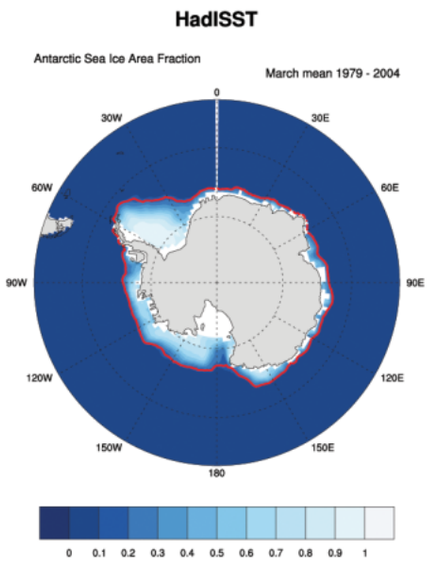
Some diagnostics are hardcoded and need further work for adaptation.

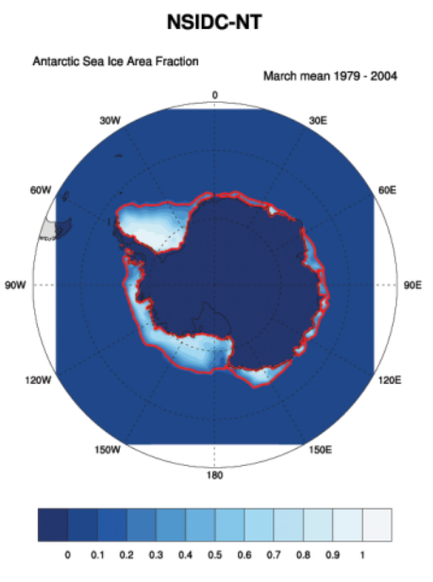
Also not all the observations are available yet.

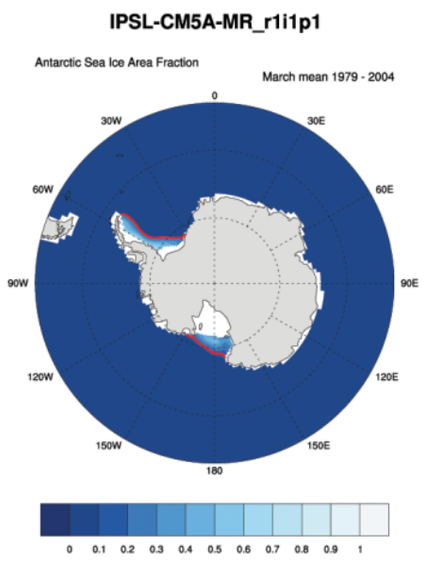
The work is ongoing.

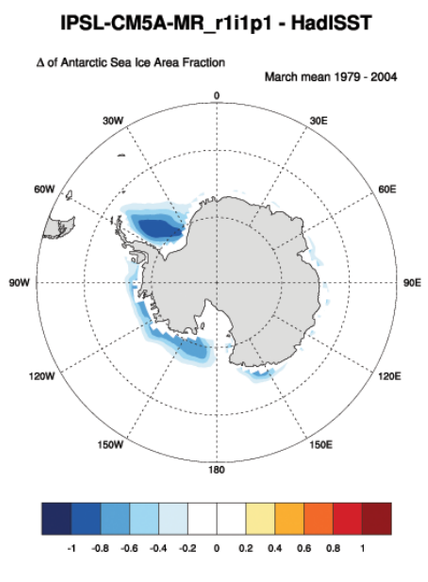
ESMValTool

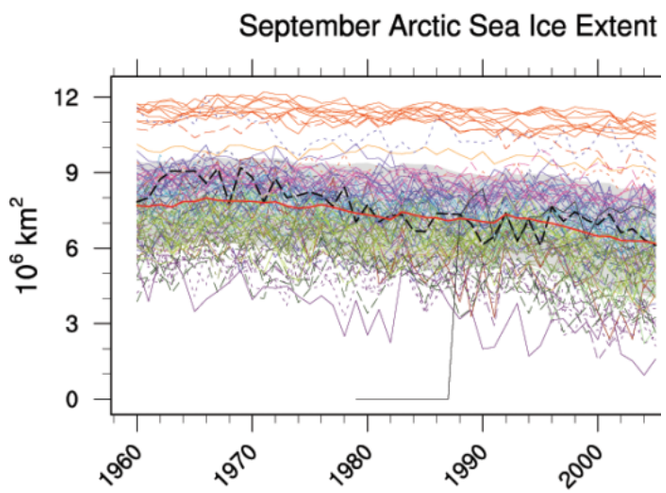
Example of diagnostics results: Sea Ice

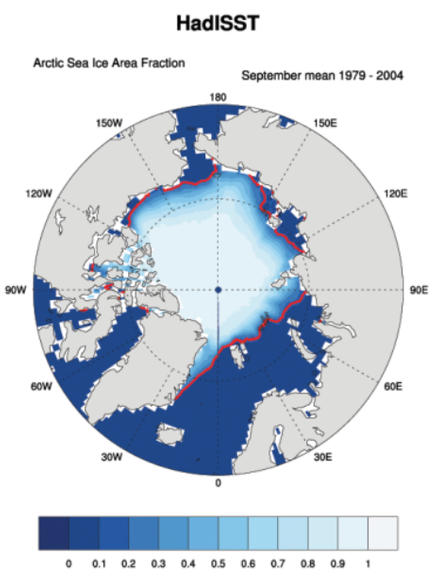


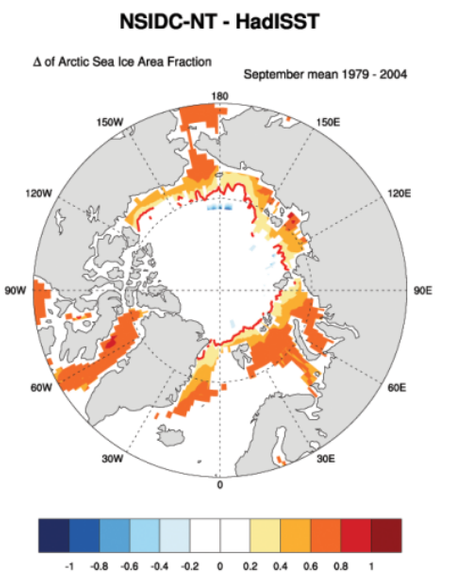


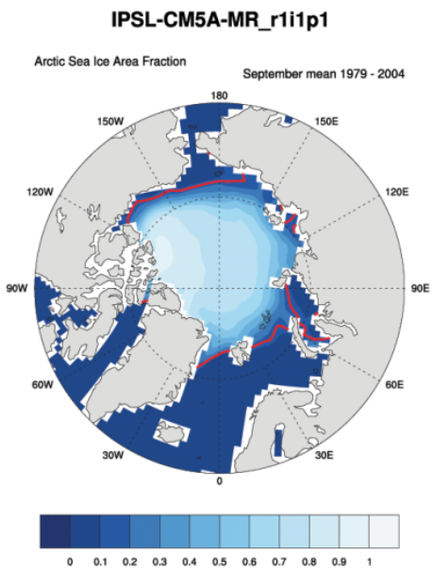


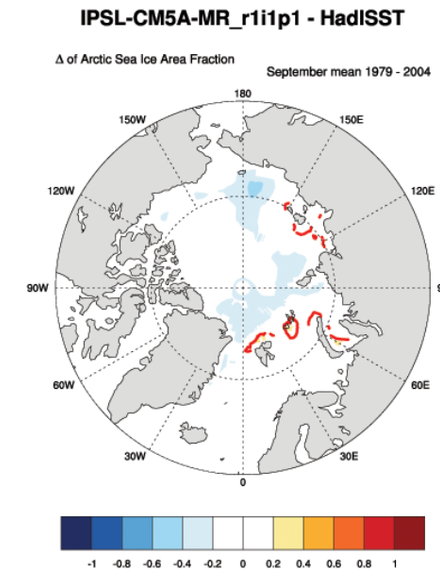


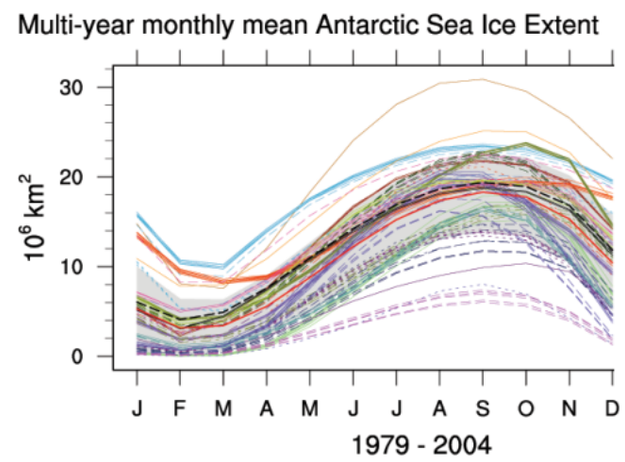






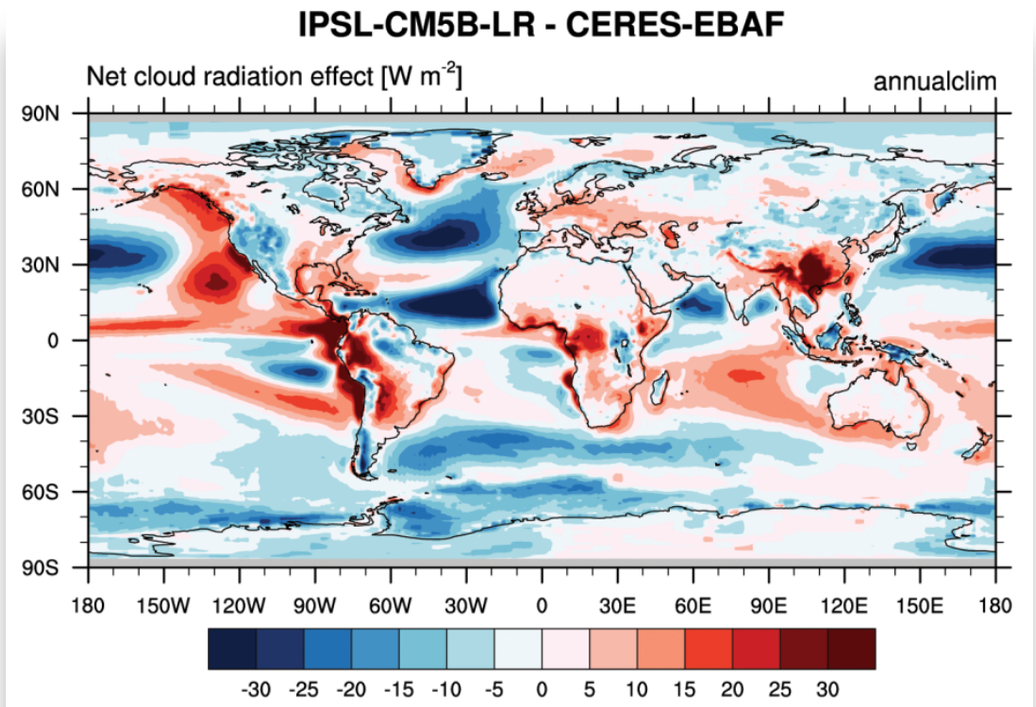


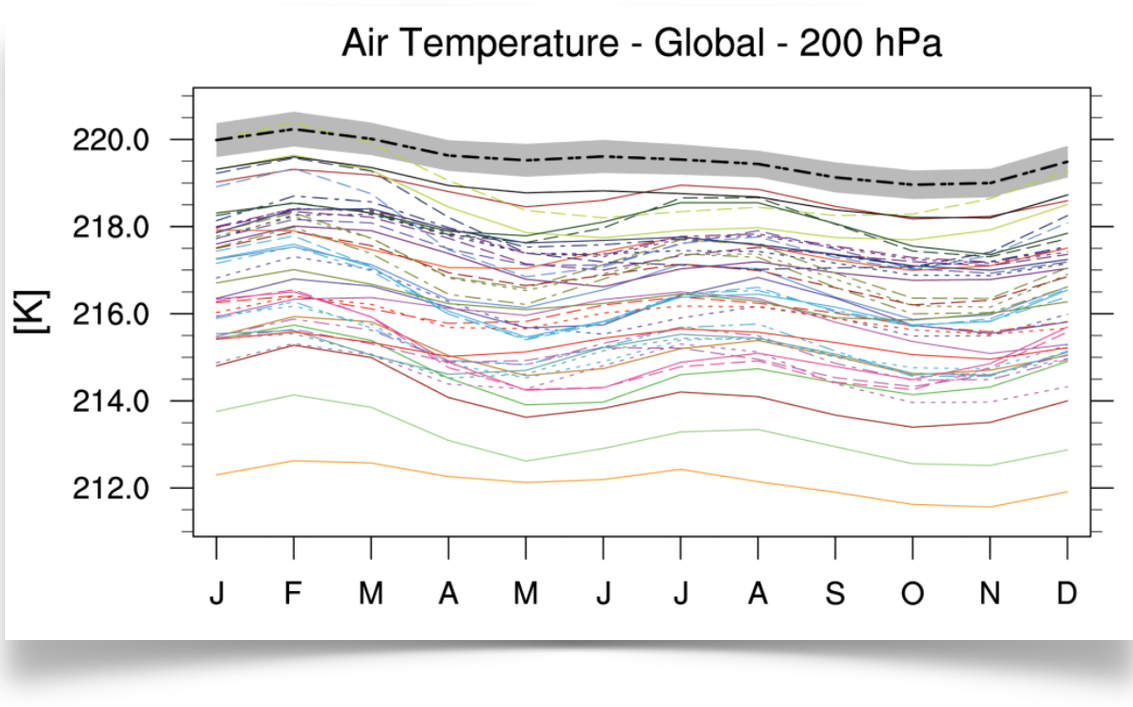


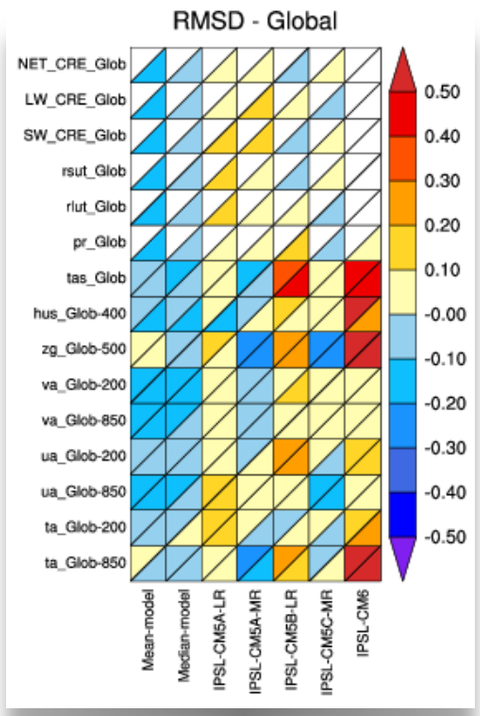


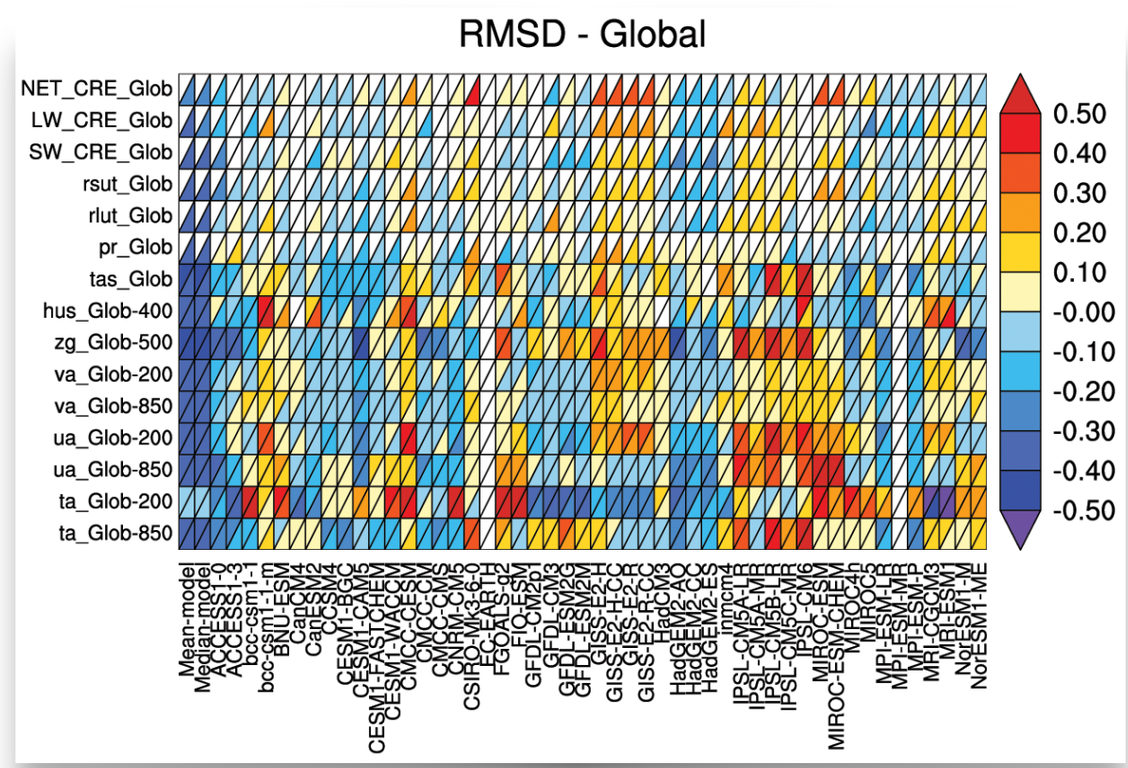
ESMValTool

Performance metrics









ESMVALTOOL

HTML output

NCAR UCAR | CGD's Climate Analysis Section
Climate Variability Diagnostics Package

Methodology
Climatological Period Used: Full
Input Namelists: OBS | Models
Derived Namelists: MOC | PR | PSL | SND | TAS | TS
Created: lun. nov. 23 16:03:22 CET 2015
CVDP Version 3.7.0

Example with MPI-ESM-LR and CNRM-CM5

Means

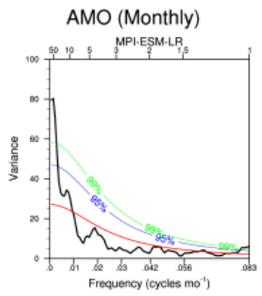
SST	DJF	MAM	JJA	SON	Annual
TAS	DJF	MAM	JJA	SON	Annual
PSL	DJF	MAM	JJA	SON	Annual
PR	DJF	MAM	JJA	SON	Annual

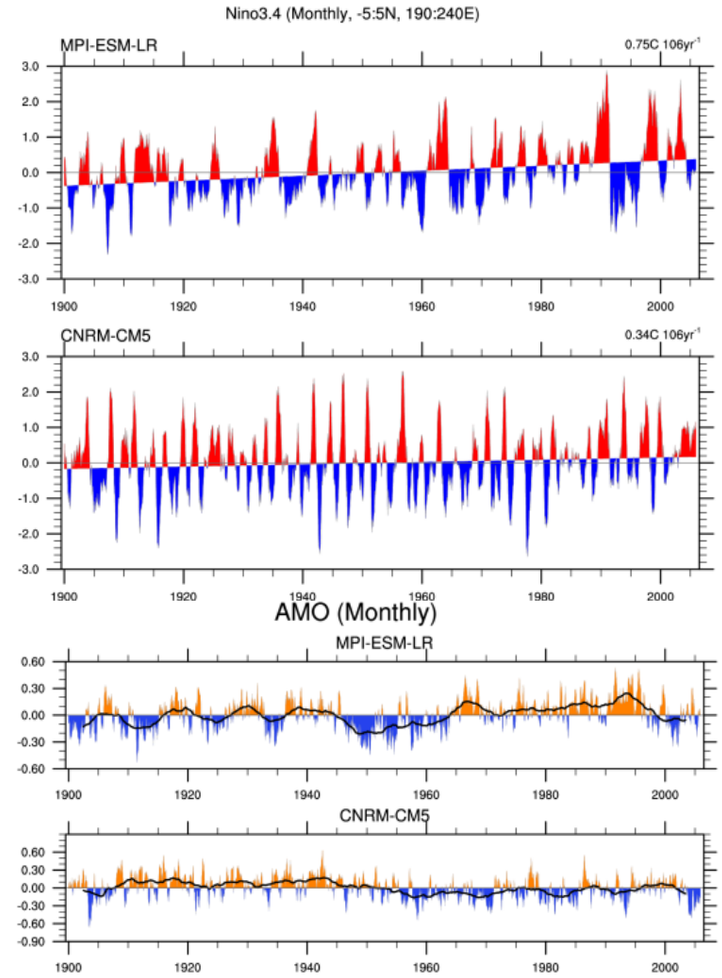
Standard Deviations

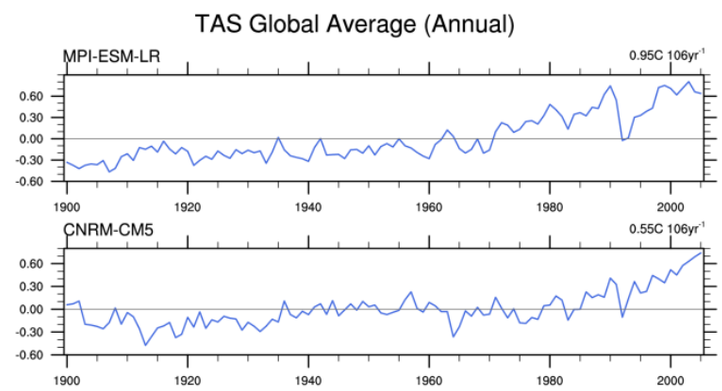
SST	DJF	MAM	JJA	SON	Annual
TAS	DJF	MAM	JJA	SON	Annual
PSL	DJF	MAM	JJA	SON	Annual
PR	DJF	MAM	JJA	SON	Annual

Coupled Modes of Variability

AMO	Pattern	Timeseries	Power Spectra
PDO	Pattern	Timeseries	Power Spectra
ENSO	Spatial Composites	JJA^{0}	SON^{0}
		DJF^{+1}	MAM^{+1}
		El Niño Hovmöller	La Niña Hovmöller
	Niño3.4	Timeseries	Power Spectra
		Monthly Std. Dev.	Running Std. Dev.







ESMVALTOOL

HTML output

NCAR UCAR | CGD's Climate Analysis Section

Climate Variability Diagnostics Package

Methodology
Climatological Period Used: Full
Input Namelists: OBS | Models
Derived Namelists: MOC | PR | PSL
SND | TAS | TS
Created: lun. nov. 23 16:03:22 CET 2015
CVDP Version 3.7.0

Example with MPI-ESM-LR and CNRM-CM5

Means

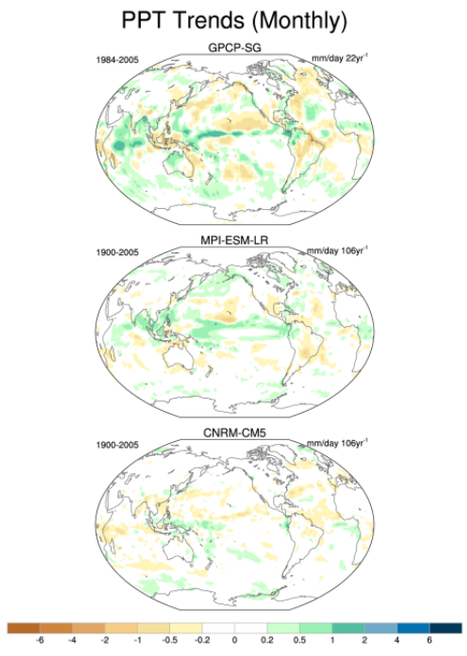
SST	DJF	MAM	JJA	SON	Annual
TAS	DJF	MAM	JJA	SON	Annual
PSL	DJF	MAM	JJA	SON	Annual
PR	DJF	MAM	JJA	SON	Annual

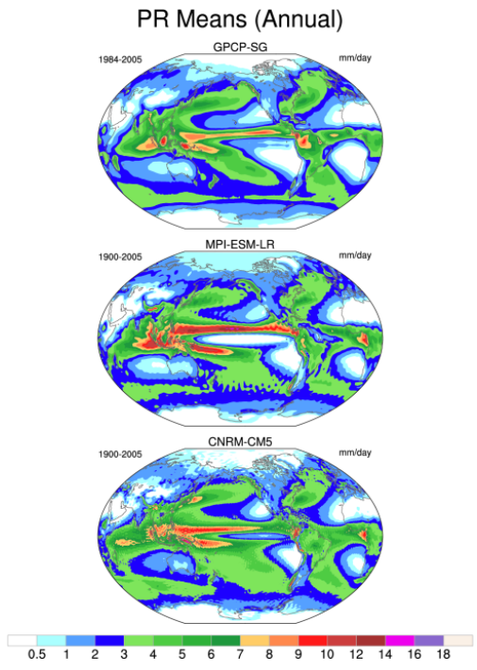
Standard Deviations

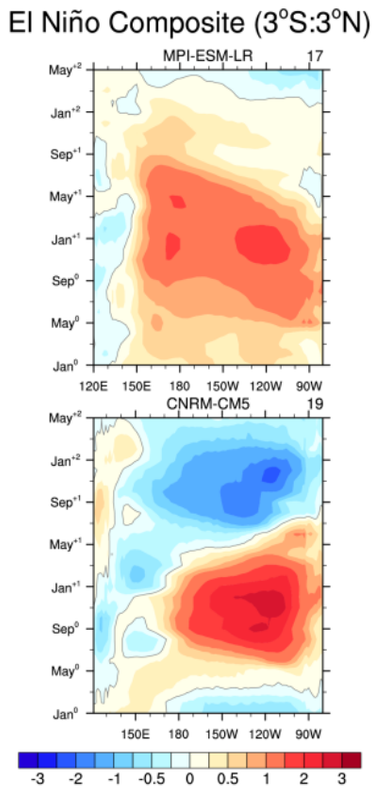
SST	DJF	MAM	JJA	SON	Annual
TAS	DJF	MAM	JJA	SON	Annual
PSL	DJF	MAM	JJA	SON	Annual
PR	DJF	MAM	JJA	SON	Annual

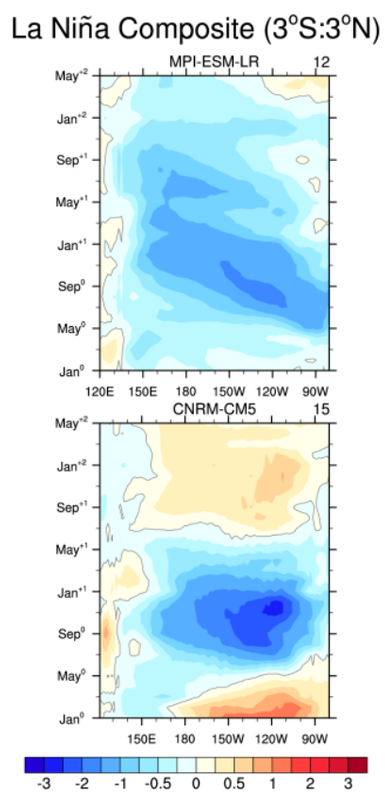
Coupled Modes of Variability

AMO	Pattern	Timeseries	Power Spectra
PDO	Pattern	Timeseries	Power Spectra
ENSO	Spatial Composites	JJA^{0}	SON^{0}
		DJF^{+1}	MAM^{+1}
		El Niño Hovmöller	La Niña Hovmöller
	Niño3.4	Timeseries	Power Spectra
		Monthly Std. Dev.	Running Std. Dev.









ESMVALTOOL

Operational support on LMDZ model evaluation

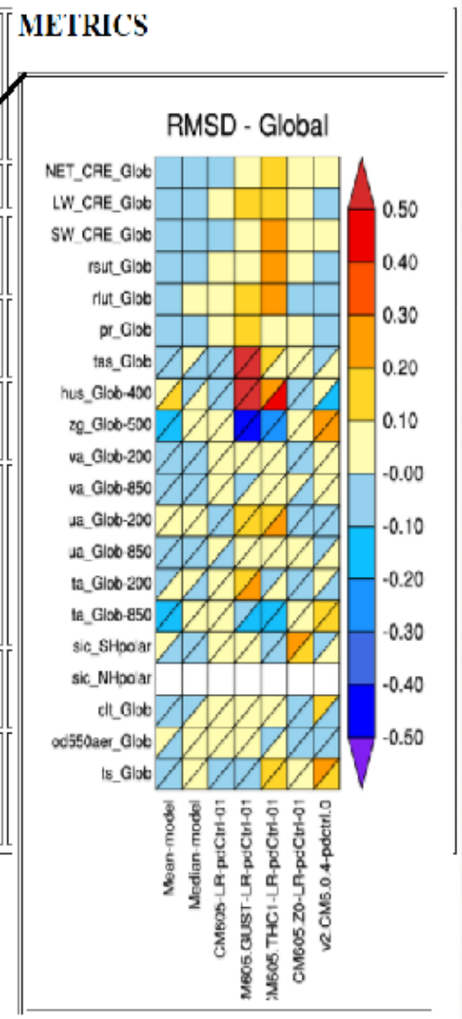
UPMC (Université Paris 6 Pierre et Marie Curie) [FR] https://vesg.ipsl.upmc.fr/thredds/fileServer/IPSLFS/fabric/lmdz/MultiSimu/CM603to5/entete.html

Série de simulations préparatoires à CMIP6, LMDZ-Orchidee, CTRL : CM603T02V01

ACCUEIL comparaisons | Atlas YEAR | Atlas DJF | Atlas JJA | ESM val tool | METRICS | Axes d'évaluation

ESM val tool:
- Variability
- ta_zonal
- clt_latlon
- tas_latlon
- SW_CRE_latlon
- LW_CRE_latlon
- NET_CRE_latlon
- Metrics

RUN	Atlas YEAR	Atlas -- DJF- -	Atlas -- JJA- -	Cloud Fraction	Outputs	Model Parameters	Tested Parameter	Period	bils	rt				crest	crelt
CLIMATOS									7.097	0.7823				-47.05	29.84
CM603T02V01	G - S	G - -	G - -	X	X	X	6.0.3 CTRL	2000_2049	0.8319	-0.617				-50.1209	27.358
v2.CM6.0.4-pdctrl.0	G - S	- - -	- - -	X	X	X	6.0.4 CTRL	1910_1959	1.4756	0.277				-42.4116	24.156
CM605-LR-pdCtrl-01	G - S	- - -	- - -	X	X	X	6.0.5 CTRL	2150_2199	1.2563	0.062	240.03	239.968	266.44	-45.4929	26.472
							6.0.5								
C														.456	26.111
C														.9246	26.916
C														.0412	28.334



Cloud Cover - clt