ICCLIM & Climate4impact Tool

Christian Pagé
CERFACS, Toulouse, France

Alessandro Spinuso, Ian van der Neut Hans Verhoef, Friedrich Striewski, Mats Veldhuizen
R&D Data Technology and Observations, KNMI

IS-ENES3 Workshop Climate Indices: Eastern European perspective
Monday, May 17 2021

Climate indices calculation

icclim (Index Calculation Climate)

- Developed by CERFACS within FP7 IS-ENES2, H2020 IS-ENES3 and FP7 CLIPC projects
- Written in python, with selected parts optimized in C for very fast performance (version 4.x but newer upcoming 5.x version will instead use xarray/dask)
  - Open Source
  - Support to on-the-fly calculations: fast performance is needed
  - Propagation of Metadata from input to output
  - Adds processing historical information in Metadata (provenance)
  - Comprehensive Documentation
- Can also be used as an independent library in other environments
- ECA&D, ETCCDI climate indices

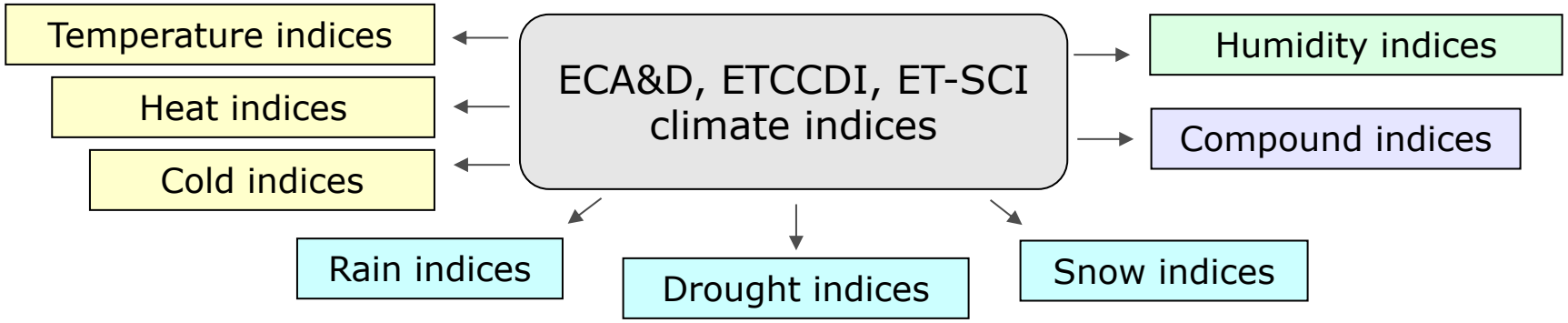
Documentation: https://icclim.readthedocs.io/en/latest/python_api.html

Source code: https://github.com/cerfacs-globc/icclim

Current Version 4.2.18: https://github.com/cerfacs-globc/icclim/releases/tag/4.2.18

Climate indices calculation

icclim: climate indices



- Intra-period extreme temperature range [° C] - **ETR**
- Warm days (days with mean temperature > 90th percentile of daily mean temperature) - **TG90p**
- Summer days (days with max temperature > 25 ° C) - **SU**

Climate indices calculation

icclim: climate indices

`icclim.indice()` - Compute indice

This is the main function to compute an indice:

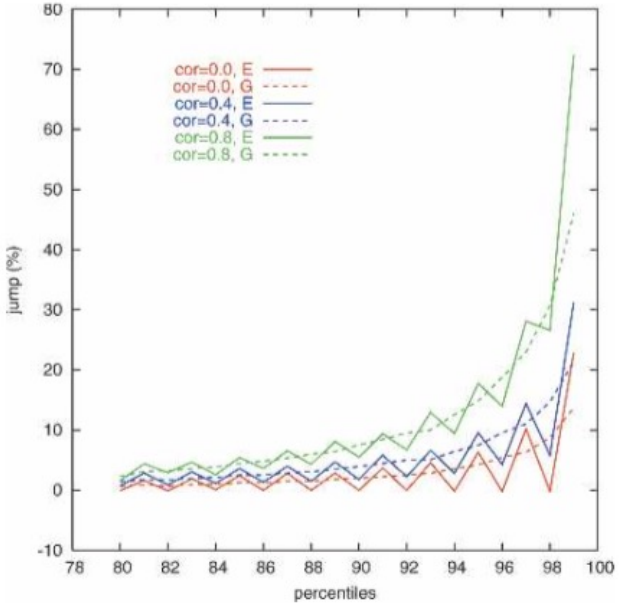
`icclim.icclim.` **`indice`**(*in_files, var_name, indice_name=None, slice_mode='year', time_range=None, out_file='./icclim_out.nc', threshold=None, N_lev=None, lev_dim_pos=1, transfer_limit_Mbytes=None, callback=None, callback_percentage_start_value=0, callback_percentage_total=100, base_period_time_range=None, window_width=5, only_leap_years=False, ignore_Feb29th=False, interpolation='linear', out_unit='days', netcdf_version='NETCDF3_CLASSIC', user_indice=None, save_percentile=False*)

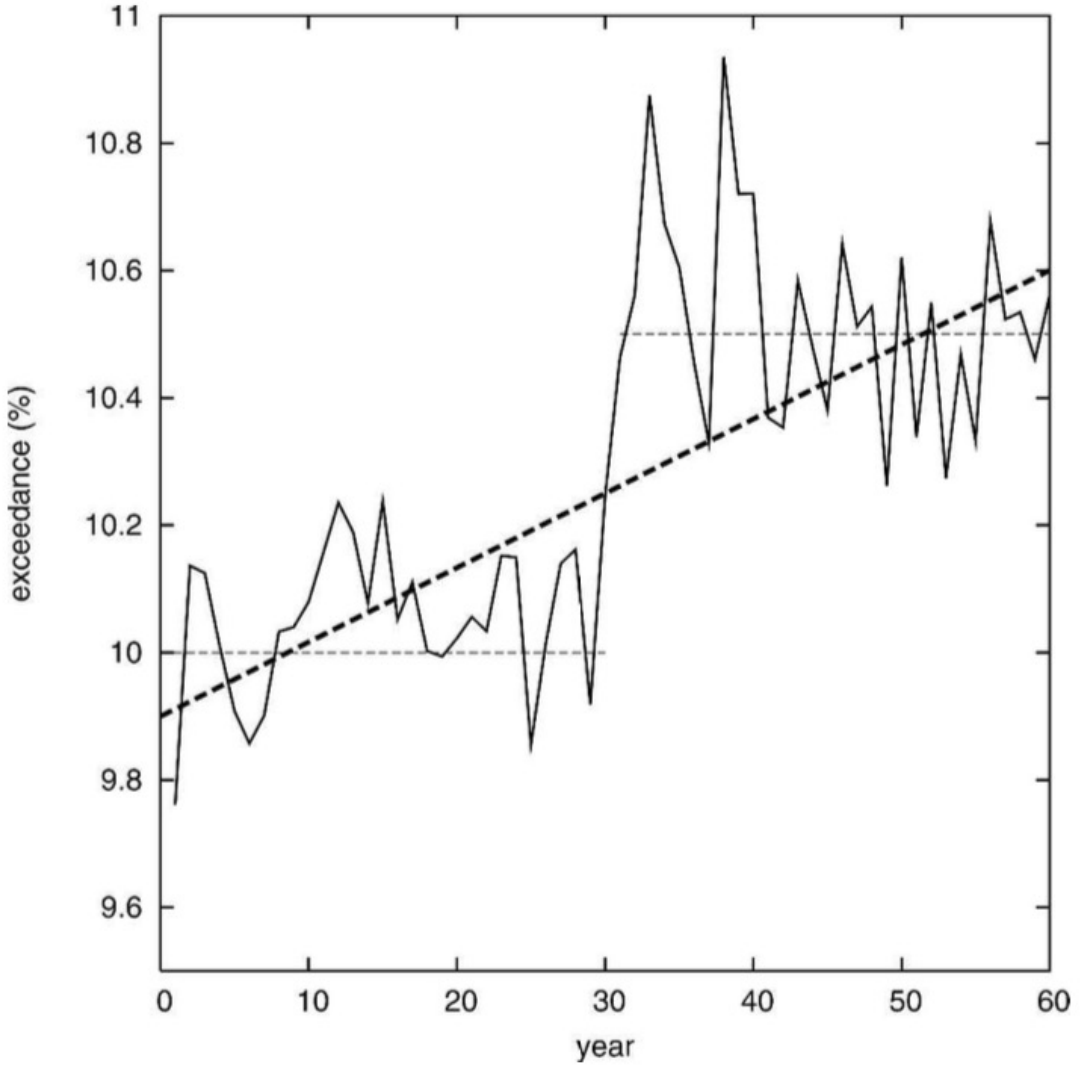
Indice	Source variable
TG, GD4, HD17, TG10p, TG90p	daily mean temperature
TN, TNx, TNn, TR, FD, CFD, TN10p, TN90p, CSDI	daily minimum temperature
TX, TXx, TXn, SU, CSU, ID, TX10p, TX90p, WSDI	daily maximum temperature
DTR, ETR, vDTR	daily maximum + daily minimum temperature
PRCPTOT, RR1, SDII, CWD, CDD, R10mm, R20mm, RX1day, RX5day, R75p, R75pTOT, R95p, R95pTOT, R99p, R99pTOT	daily precipitation flux (liquide phase)
SD, SD1, SD5cm, SD50cm	daily snowfall flux (solid phase)
CD, CW, WD, WW	daily mean temperature + daily precipitation flux (liquide phase)

Climate indices calculation

icclim: climate indices

- Implements the bootstrapping method for percentile indices
- Avoid spurious artificial tendencies
- Especially a problem for heavy or extreme values
- Description in Zhang et al. (2005)

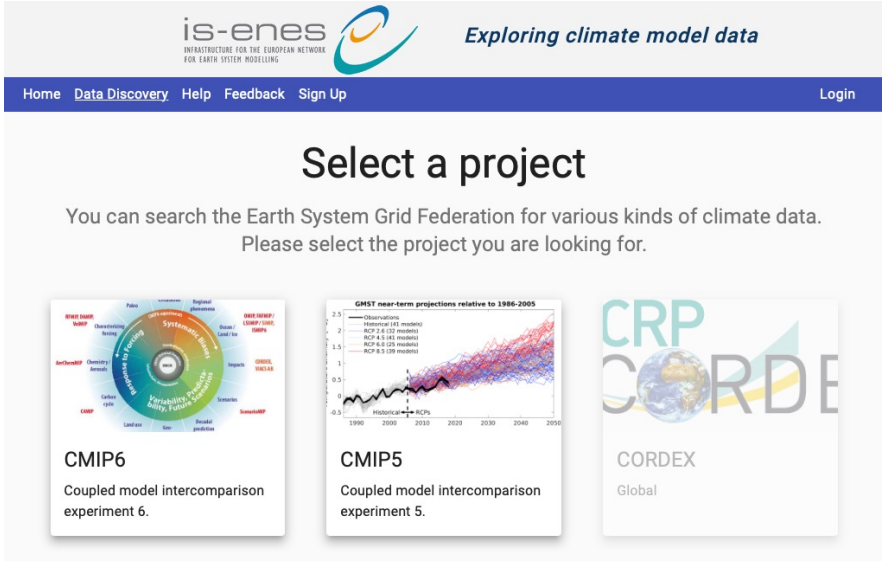


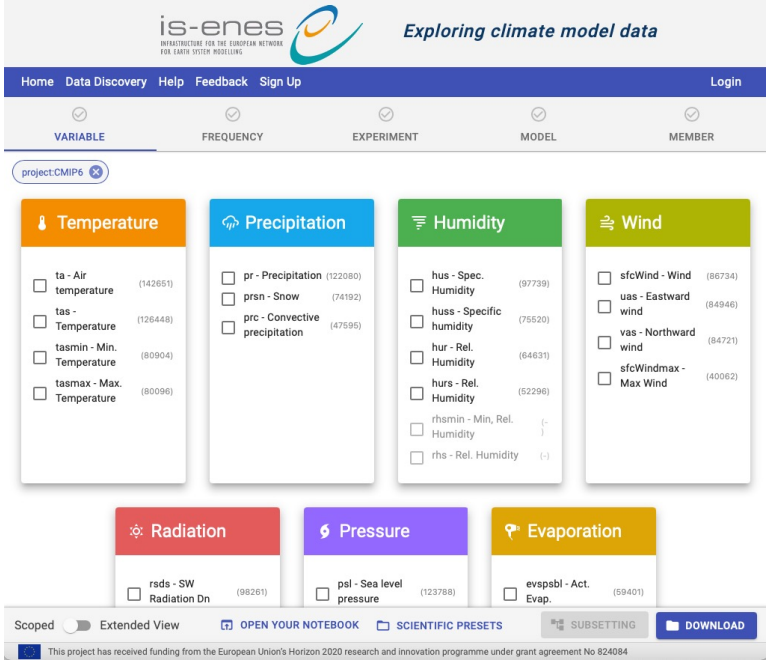


Climate4Impact (C4I) 2.0

- **GUI usability** (Search, Selection, Subsetting)
- **Flexible analysis features** (Integration of Notebooks,ICCLIM and Workflows/Batch-Processing)
- **Automated reproducibility mechanisms** (Datasets Version/GitHub/Binder/Provenance)
- **Making FAIRness of Data and Methods accessible**
- **New front-end technology**

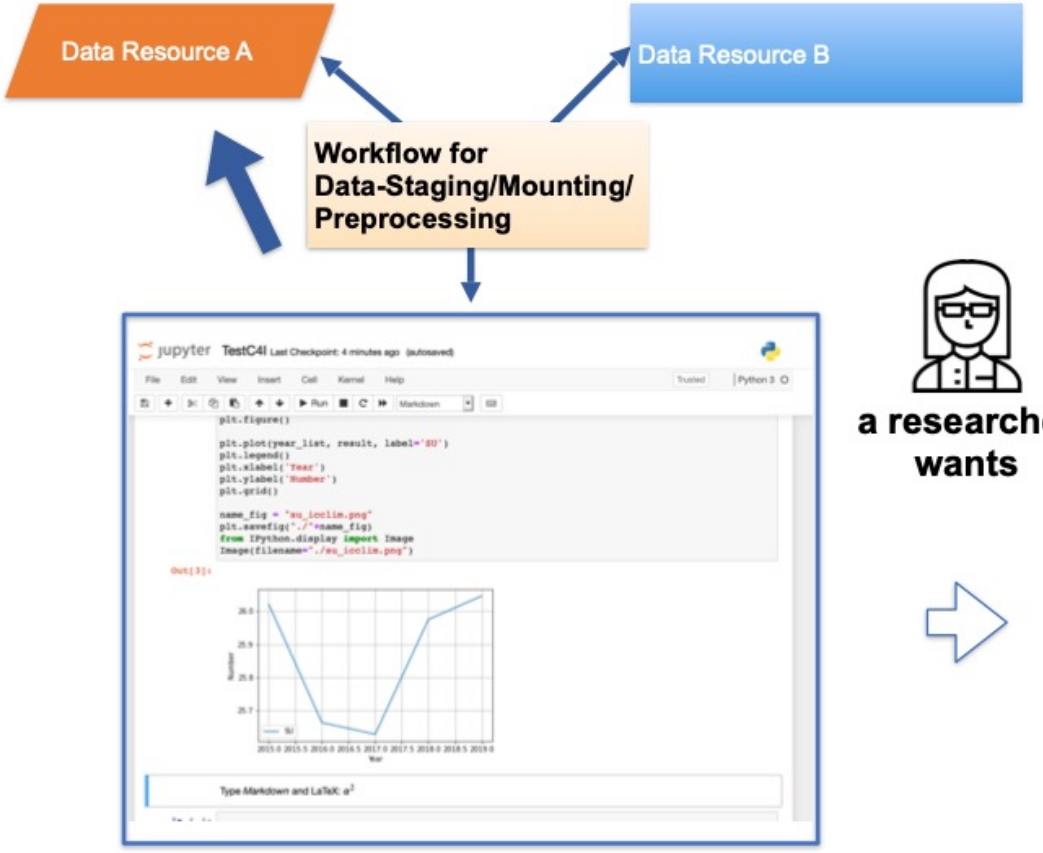
- **Alpha Evaluation Stage**: Will be released soon
- Current Operational C4I 1.0 is available: IS-ENES3 Autumn School Presentations for further information





Climate4Impact (C4I) 2.0

C4I Workspace Use Case



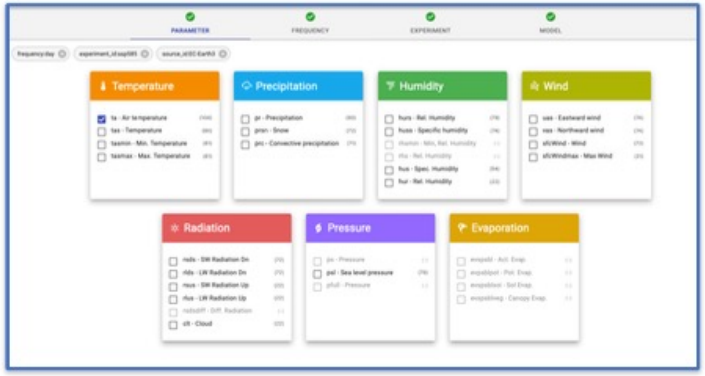
a researcher wants

- **access distributed raw data**
- **develop, document and reuse** methods for processing and visualisation.
- **update/extend** raw data and software
- **Track changes and rollback** (Traceability/Recovery)
- **keep old versions of the data** after updates (Reproducibility)
- **snapshot and restore** the state of a workspace software (Reproducibility)

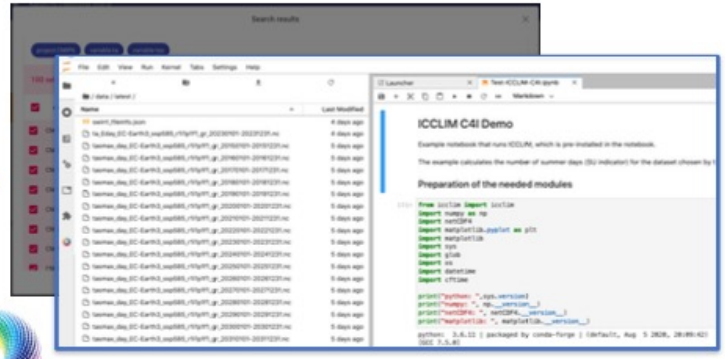
Climate4Impact (C4I) 2.0

Objective: Extend C4I with Data Driven & Reproducible Workspaces

Climate4Impact Search for CMIP5/6 Cordex Data (Distributed Data)



Incremental data staging/subsetting onto customisable and Reproducible Notebooks (extensible to other tools..)



Software and Environment to Git

SWIRRL-API

Trace Changes to Software and Data
Restore Environments

Data

MyBinder
Reproduce

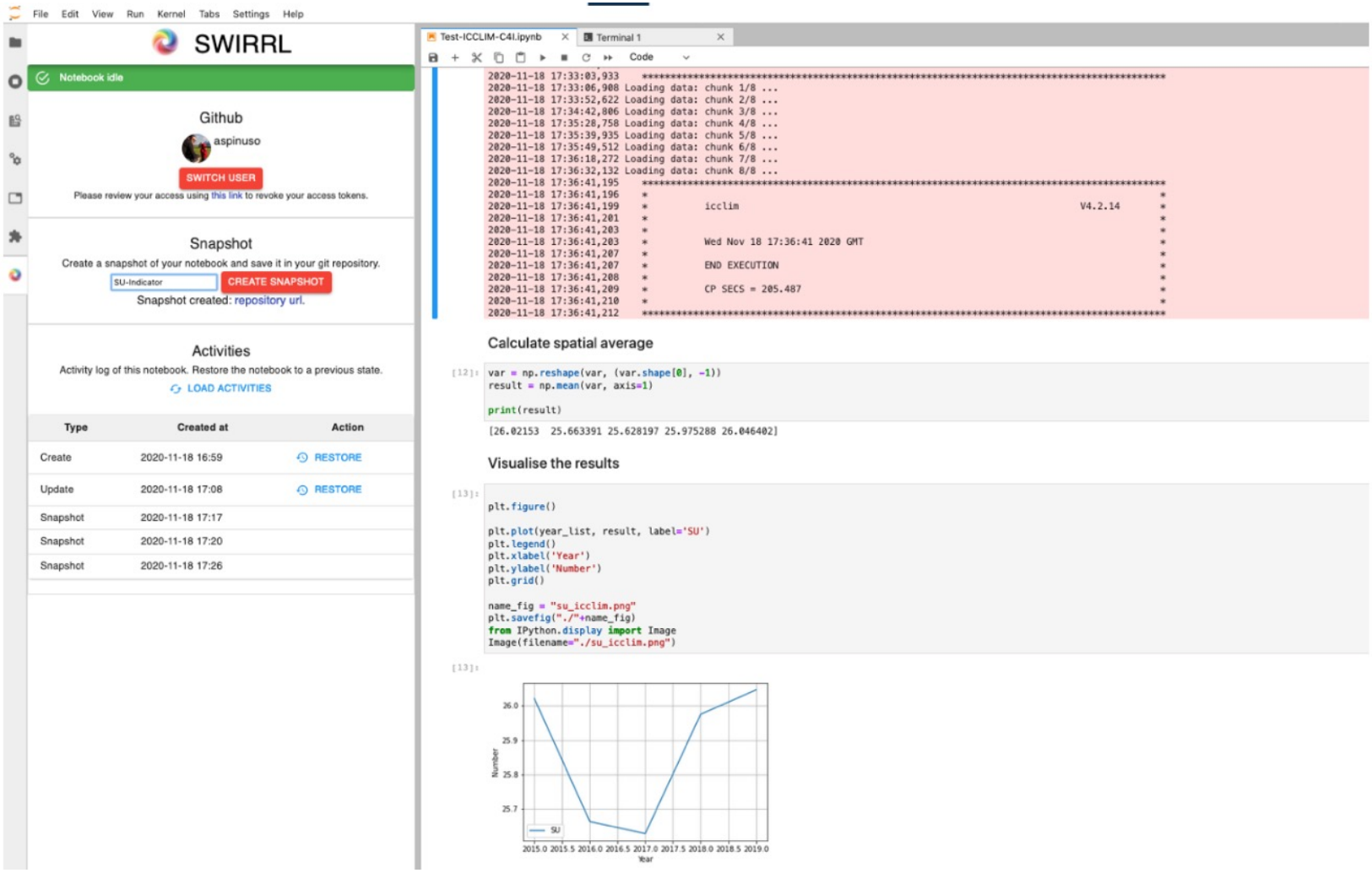
Climate4Impact (C4I) 2.0

SWIRRL Jupyter Lab Extension

Monitor Jobs

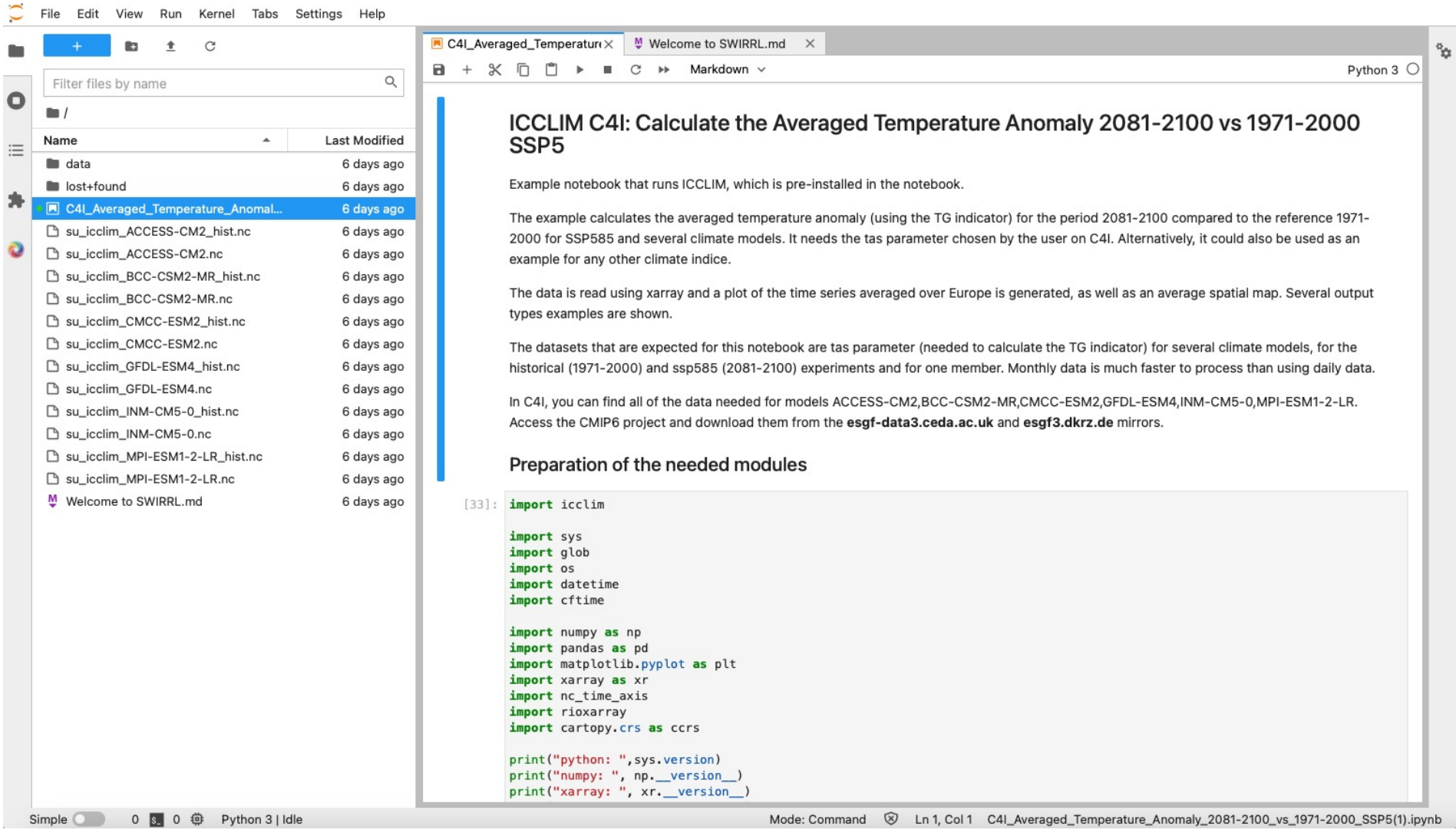
Snapshot Controls

Trace Activities and trigger rollback actions



Climate4Impact (C4I) 2.0

Example Notebook



Climate4Impact (C4I) 2.0

Example Notebook

[34]:
```
# studied period
dt1 = datetime.datetime(2081,1,1)
dt2 = datetime.datetime(2100,12,16)

# reference period
dtr1 = datetime.datetime(1971,1,1)
dtr2 = datetime.datetime(2000,12,16)

models=['ACCESS-CM2','BCC-CSM2-MR','CMCC-ESM2','GFDL-ESM4','INM-CM5-0','MPI-ESM1-2-LR']
out_f={}
out_hist_f={}
files=[]
files_hist=[]
for model in models:
  print("Processing model: "+model)
  out_f[model] = 'su_icclim_'+model+'.nc'
  out_hist_f[model] = 'su_icclim_'+model+'_hist.nc'
  files.append('su_icclim_'+model+'.nc')
  files_hist.append('su_icclim_'+model+'_hist.nc')
  #tas_Amon_MPI-ESM1-2-LR_historical_r1i1p1f1_gn_199001-200912.nc
  filenames_hist = glob.glob('./data/latest/tas_Amon_'+model+'_historical_*.nc')
  filenames = glob.glob('./data/latest/tas_Amon_'+model+'_ssp585_*.nc')

  icclim.indice(indice_name='TG', in_files=filenames, var_name='tas', slice_mode='year', time_range=[dt1, dt2], transfer_l
  icclim.indice(indice_name='TG', in_files=filenames_hist, var_name='tas', slice_mode='year', time_range=[dtr1, dtr2], tra
```

```
2021-05-10 13:40:43,575    ********************************************************************************
2021-05-10 13:40:43,576    *                                                                              *
2021-05-10 13:40:43,579    *         icclim                                                 V4.2.17       *
2021-05-10 13:40:43,580    *                                                                              *
2021-05-10 13:40:43,581    *                                                                              *
2021-05-10 13:40:43,581    *         Mon May 10 13:40:43 2021 GMT                                         *
2021-05-10 13:40:43,582    *                                                                              *
2021-05-10 13:40:43,582    *         BEGIN EXECUTION                                                      *
2021-05-10 13:40:43,583    *                                                                              *
2021-05-10 13:40:43,584    ********************************************************************************
Processing model: ACCESS-CM2
2021-05-10 13:40:43,839 Loading data...
2021-05-10 13:40:44,330    ********************************************************************************
2021-05-10 13:40:44,335    *                                                                              *
2021-05-10 13:40:44,339    *         icclim                                                 V4.2.17       *
2021-05-10 13:40:44,340    *                                                                              *
2021-05-10 13:40:44,341    *                                                                              *
2021-05-10 13:40:44,342    *         Mon May 10 13:40:44 2021 GMT                                         *
```

Climate4Impact (C4I) 2.0

Example Notebook

time360

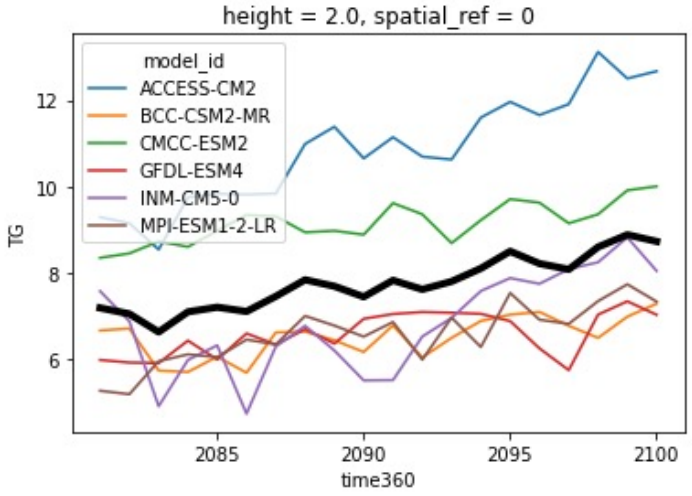
Plot a time series of the anomaly of temperature

Anomaly of temperature for SSP585 of the period 2080-2100 compared to 1971-2000.

The multi-model average is shown in bold black line.

[40]:
```
# Plot temperature anomaly compared to historical period and superimpose multi-model average in bold black line
full_tg_anomaly.plot(hue='model_id')
full_tg_anomaly.mean(dim='model_id').plot(color='black', linewidth=4)
```

[40]:
```
[<matplotlib.lines.Line2D at 0x7f660d036a60>]
```



Example Notebook

ICCLIM C4I: Calculate the number of Summer Days

Example notebook that runs ICCLIM, which is pre-installed in the notebook.

The example calculates the number of summer days (SU indicator) for the dataset chosen by the user on C4I.

The data is read using xarray and a plot of the time series over a specific region is generated, as well as an average spatial map. Several output types examples are shown.

The dataset that is expected for this notebook are tasmax parameter (needed to calculate the SU indicator) for one specific climate model and experiment as well as one member. The time period should be continuous.

To keep this example fast to run, the following period is considered: 2015-01-01 to 2019-12-31, and plots are shown over European region.

Preparation of the needed modules

In [1]:

```
import icclim

import sys
import glob
import os
import datetime
import cftime

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import xarray as xr
import rioxarray
import cartopy.crs as ccrs

print("python: ",sys.version)
print("numpy: ", np.__version__)
print("xarray: ", xr.__version__)
print("pandas: ", pd.__version__)
print("icclim: ", icclim.__version__)
```

Climate4Impact (C4I) 2.0

Example Notebook

Specification of the parameters and period of interest

In [2]:

```
# studied period
dt1 = datetime.datetime(2015,1,1)
dt2 = datetime.datetime(2019,12,31)

out_f = 'su_icclim.nc'
filenames = glob.glob('./data/latest/tasmax_day*.nc')

icclim.indice(indice_name='SU', in_files=filenames, var_name='tasmax', slice_mode='JJA', time_range=[dt1, dt2], transfer_limit_Mbytes
```

Out [2]:

```
2021-04-07 14:36:25,956    ********************************************************************************
2021-04-07 14:36:25,957    *                                                                              *
2021-04-07 14:36:25,958    *          icclim                                                  V4.2.17     *
2021-04-07 14:36:25,958    *                                                                              *
2021-04-07 14:36:25,959    *                                                                              *
2021-04-07 14:36:25,959    *          Wed Apr  7 14:36:25 2021 GMT                                        *
2021-04-07 14:36:25,960    *                                                                              *
2021-04-07 14:36:25,960    *          BEGIN EXECUTION                                                     *
2021-04-07 14:36:25,961    *                                                                              *
2021-04-07 14:36:25,961    ********************************************************************************
2021-04-07 14:36:28,512 Loading data: chunk 1/8 ...
2021-04-07 14:36:35,739 Loading data: chunk 2/8 ...
2021-04-07 14:36:42,434 Loading data: chunk 3/8 ...
2021-04-07 14:36:48,978 Loading data: chunk 4/8 ...
2021-04-07 14:36:55,094 Loading data: chunk 5/8 ...
2021-04-07 14:37:01,426 Loading data: chunk 6/8 ...
2021-04-07 14:37:07,981 Loading data: chunk 7/8 ...
2021-04-07 14:37:14,473 Loading data: chunk 8/8 ...
2021-04-07 14:37:20,686    ********************************************************************************
2021-04-07 14:37:20,686    *                                                                              *
2021-04-07 14:37:20,687    *          icclim                                                  V4.2.17     *
2021-04-07 14:37:20,688    *                                                                              *
2021-04-07 14:37:20,689    *                                                                              *
2021-04-07 14:37:20,689    *          Wed Apr  7 14:37:20 2021 GMT                                        *
2021-04-07 14:37:20,690    *                                                                              *
```

Climate4Impact (C4I) 2.0

Example Notebook

Plot preparation

In [3]:

```
with xr.open_dataset(out_f, decode_times=False) as ds:
    su_xr = ds.rio.write_crs("epsg:4326", inplace=True)
    ds['time'] = xr.decode_cf(ds).time

print(su_xr)

# For later - grab the crs of the data using rioxarray
climate_crs = su_xr.rio.crs

# Select a single x,y combination from the data
longitude = su_xr["SU"]["lon"].sel(lon=3.5, method='nearest')
latitude = su_xr["SU"]["lat"].sel(lat=44.2, method='nearest')

print("Long, Lat values:", longitude, latitude)
```

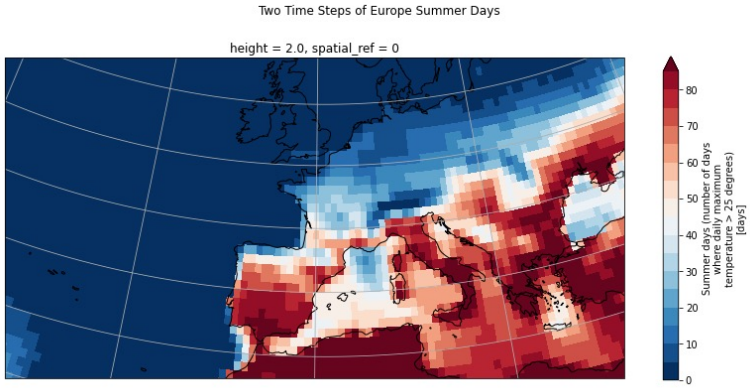
Out [3]:

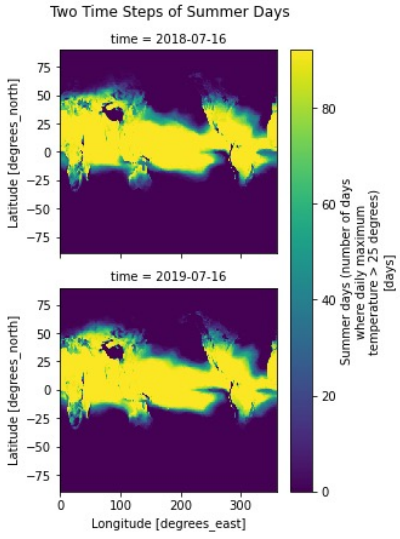
```
<xarray.Dataset>
Dimensions:      (bnds: 2, lat: 256, lon: 512, nv: 2, time: 5)
Coordinates:
  * time         (time) datetime64[ns] 2015-07-16 2016-07-16 ... 2019-07-16
  * lat          (lat) float64 -89.46 -88.77 -88.07 -87.37 ... 88.07 88.77 89.46
  * lon          (lon) float64 0.0 0.7031 1.406 2.109 ... 357.9 358.6 359.3
    height       float64 ...
    spatial_ref  int64 0
Dimensions without coordinates: bnds, nv
Data variables:
    time_bnds    (time, bnds) float64 ...
    lat_bnds     (lat, nv) float64 ...
    lon_bnds     (lon, nv) float64 ...
    SU           (time, lat, lon) float32 ...
Attributes:
    title:         ECA heat indice SU
    institution:   Climate impact portal (http://climate4impact.eu)
    source:
    references:    ATBD of the ECA indices calculation (http://eca.knmi.nl/do...
    comment:
```

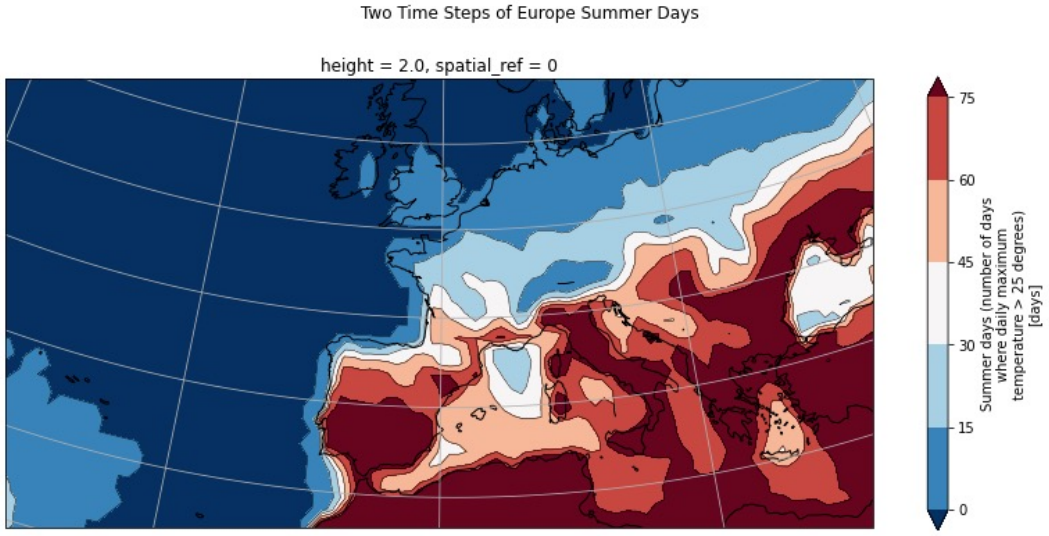
Climate4Impact (C4I) 2.0

Example Notebook

	lat	lon	height	spatial_ref	SU
time					
2015-07-16	43.859545	3.515625	2.0	0	66.0
2016-07-16	43.859545	3.515625	2.0	0	70.0
2017-07-16	43.859545	3.515625	2.0	0	67.0
2018-07-16	43.859545	3.515625	2.0	0	79.0
2019-07-16	43.859545	3.515625	2.0	0	48.0







Collection of Notebooks

https://gitlab.com/is-enes-cdi-c4i/notebooks

For now 2 Notebooks are available, many more will be available soon

- ICCLIM C4I: Calculate the number of Summer Days
- ICCLIM C4I: Calculate the Averaged Temperature Anomaly 2081-2100 vs 1971-2000 SSP5

Thanks !

On behalf of the C4I team

- For questions, suggestions, feedback and help, please contact
  - Christian Pagé christian.page@cerfacs.fr
  - Alessandro Spinuso alessandro.spinuso@knmi.nl