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IS-ENES2 DELIVERABLE (D11.6)

Report on derived products in CLIMATE4IMPACT

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Abstract

The climate change impact communities' users and researchers need more than only climate model output variables. They often require specialized products, such as climate indices and indicators, as well as derived variables. Higher spatial and temporal resolutions are also generally needed. This report describes the scope of the derived products and how they are made accessible through the climate4impact operational service. The access to the products is supported through operational services in SA2.

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Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants including the Commission Services	
RE	Restricted to a group specified by the partners of the **IS-ENES2** project	
CO	Confidential, only for partners of the **IS-ENES2** project	

CAPACITIES

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Executive Summary

The climate change impact communities' users and researchers need more than only climate model output variables. They often require specialized products, such as climate indices and indicators, as well as derived variables. Higher spatial and temporal resolutions are also generally needed. This report describes the scope of the derived products and how the operational climate4impact portal https://climate4impact.eu/ enables users to generate themselves tailored products for their own needs.

Most of the tailored derived products made available by climate4impact are not pre-computed, and this is because of two main reasons: an interactive statistical downscaling interface is now accessible and integrated; a very fast indices and statistics calculation module has been integrated. A detailed case study of the hydrology of the lower Danube basin (especially the delta) will be available from climate4impact, with a focus on extreme hydro-meteorological events. Finally, there is a real need of documentation and guidance in how to use these tools: it must not be overlooked. Consequently, proper guidance is included.

These functionalities have been tested in a number of 2-day courses that focussed on the use of climate4impact. Feedback from these courses helped to improve the portal, while its successful usage during these courses proved its high usability.

1. The climate4impact Portal – Objectives and Interface

The objective of the Climate4impact (C4I) portal is to enhance the use of climate research data by users: climate change impact modellers, impact and adaptation consultants, as well anyone else wanting to use climate change data.

To reach this objective the portal offers web interfaces for searching, visualizing, analysing, processing and downloading climate data datasets. C4I is connected to the Earth System Grid Federation (ESGF) infrastructure, using certificate based authentication, ESGF search, OpenID, OPeNDAP and Thredds catalogs.

Besides the ESGF data, it enables users to use own data. Data can be uploaded or referenced using OPeNDAP URLs.

1.1 Main portal functionalities

The climate4impact portal has the menu structure as depicted in the figure below.

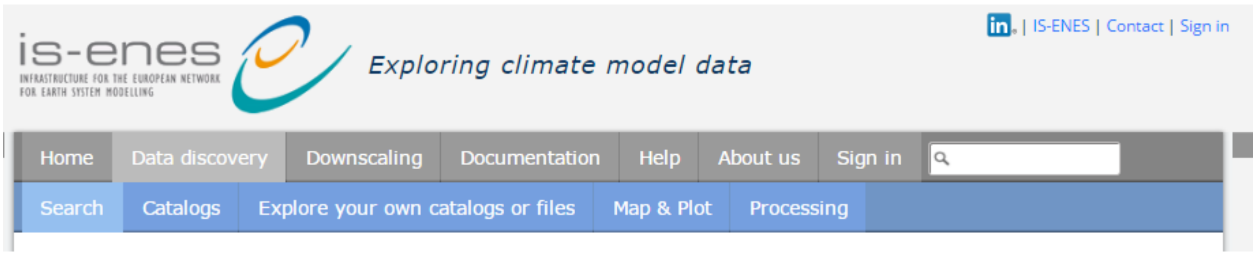


Figure 1 Main functionality climate4impact

In the main structure (in grey) the user has access to the main functions of the portal: Data discovery, Downscaling, Documentation, Help, About us and Sign in. Clicking on a menu item will open the corresponding page or open a submenu (in blue), as shown in figure 1.

Available functionality in the portal:

- Data discovery:
    - **Search**: faceted search for datasets on ESGF (see chapter 1.2)
    - **Catalogs**: Access to dataset catalogs, which are not available on ESGF, like the climate4impact catalog, CLIPC, EUPORIAS, etc.
    - **Explore your own catalogs or files**: the possibility to explore catalogs
    - **Map and plot**: here is explained how to use the ADAGUC visualization
- **Downscaling**: access to the downscaling functionality: explained in chapter 2.4
- **Documentation**: here the user guidance is implemented: use cases are described, climate background topics are explained, a glossary of terms is provided.
- **Help section**: explains how the portal functionality can be used
- **About us**: shows who are behind the climate4impact portal

- **Sign in**: here the user can sign in to use the downloading, uploading and processing functionality. The user can login using ESGF OpenID or a google OpenID.

The menu structure as explained above is liable to change over time, as we are continuously improving the portal.

1.2 Searching and Locating data

Figure 2 C4I Search interface

The C4I search interface is co-developed with climate impact researchers from Wageningen University. Base is the ESGF search facets, but it is extended with pre-selection within the facets and extended with improved guidance and access to guidance (meta)data (e.g., linking to the ES-DOC model descriptions).

For example, there are 1913 parameters on which the user filter the datasets. The C4I search interface groups these parameters around higher level categories (e.g., Temperature, precipitation) to enable the impact researcher to easily find the parameter of interest. Also, the facet names are extended to more familiar names (e.g., tas is named temperature in the portal interface). This is shown in Figure 2 C4I Search interface. The 1913 parameters are still available for more advanced users in the 'all parameters' tab.

All possible filters are displayed in the top part of the search interface. Clicking on it will open the filter to enter the filter parameters. Selected filters are displayed in the 'Selected' filter section and can easily be deselected (removed).

Filters are applied automatically and the search results are automatically updated. The C4I also checks if the data node containing the data is available (nodes can be down for e.g., maintenance) and if not, a replication of the dataset is available on a different data node. From the result list the user can select the datasets of interest for download or processing. A dataset can be selected and added to the user basket as an aggregation of data files by clicking on the 'basket' or the user can select individual files by clicking on the triangle in the result list. Individual files can be downloaded or visualized directly.

The search interface is dynamically built. New facets will automatically be added when they become available in ESGF.

The C4I Search GUI can be prepopulated in advance with facets by using a hashtag link, e.g. http://dev.climate4impact.eu/impactportal/data/esgfsearch.jsp#query=temperature&bbox=0,40,10,60&time_start_stop=2000/2010&project=CORDEX&time_frequency=day

Special facets are:

- bbox - bounding box in degrees in the form west,south,east,north. E.g. bbox=0,40,10,60
- query - Free text query
- time_start_stop - Year start and stop in the form startyear/stopyear. E.g. 2000/2010

1.3 Visualizations

Climate4impact allows you to view your data in the form of maps or more analytical plots before actually downloading the data you need. This functionality helps users to select more precisely the subset of the data they need. As a consequence, this should considerably reduce the amount of data you need to transfer over the internet to your own computer, as the visualization and analyses services run at the archive, not on your own computer.

Climate4impact can visualize any OPeNDAP server over HTTP port 80 (port 8080 is currently not supported), and a selected set of secured ESGF OPeNDAP servers over HTTPS using port 443. In the latter case, you will need an ESGF account which can be created according to these instructions. The data served by the OPeNDAP server must comply to the Climate and Forecast Conventions (CF conventions) in order to be correctly visualized. Currently regular latlon grids, projected grids, timeseries and swath data is supported. Data is visualized using the ADAGUC geographical information system.

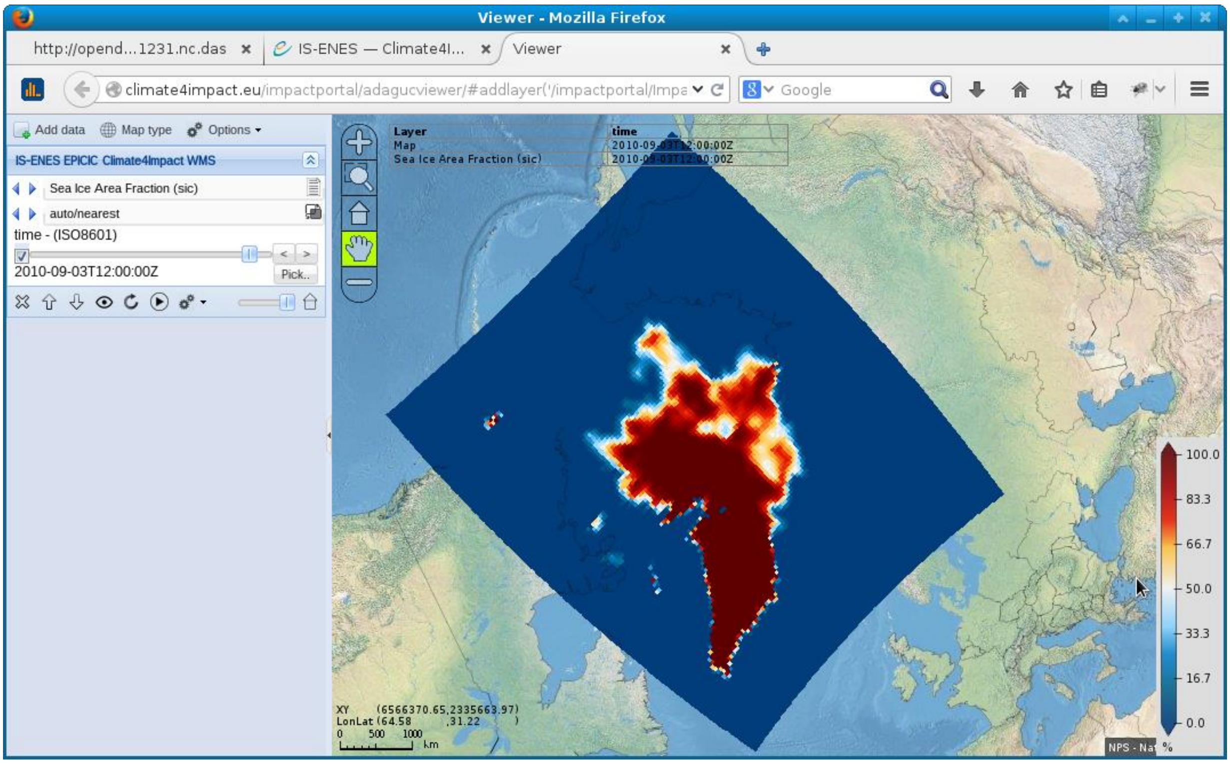


Figure 3 ADAGUC viewer with Sea Ice visualization over the north pole.

The viewer is available from several places within the portal, e.g the data selection, the user basket, browse catalog.

C4I uses ADAGUC. ADAGUC is a geographical information system to visualize NetCDF files via the web. The software consists of a server side C++ application and a client side JavaScript application. The software provides several features to access and visualize data over the web, it uses OGC standards for data dissemination. ADAGUC is an open source project and is available via GitHub:
https://github.com/KNMI/adaguc-server
https://github.com/KNMI/adaguc-viewer

How the viewer can be used is explained here:
https://climate4impact.eu/impactportal/data/mapandplot.jsp

1.4 Documentation

C4I has put a lot of effort in providing background documentation and example use cases for our users as guidance. We provide documentation in 4 area's:

1) Use cases, showing how others use climate model data;
2) Background and topics: explaining general climate concepts, climate scenario's, climate models, climate data, seasonal and decadal prediction and observed climate data.

3) Glossary, terms and definitions used in the C4I portal. This is also use to highlight terms.

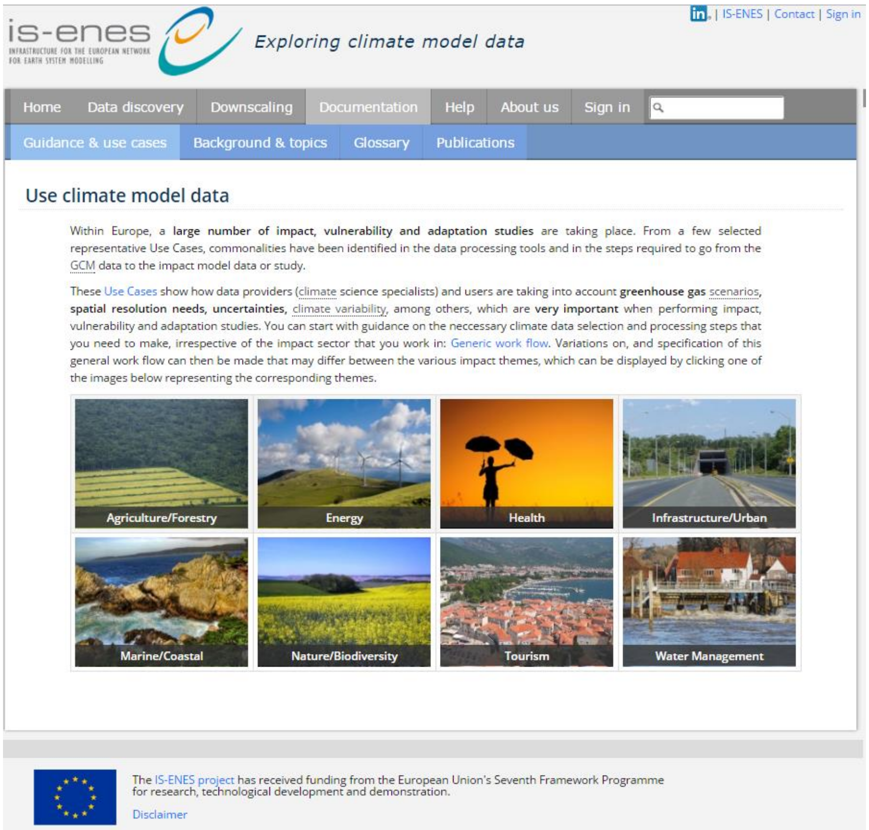


Figure 4 C4I documentation and use cases

1.5 User Storage

Climate4impact has a personal basket where users can upload their own data and do research with the provided tools. The basket supports formats like NetCDF and GeoJSON. The basket has an access token mechanism to make data sharing and command line access to webservices easier. This enables client side scripting of the climate4impact portal possible and makes it possible to connect third party portals, like the EU FP7 CLIPC portal.

Every user in the CLIPC/Climate4impact ecosystem has a personal basket where he can store and upload his own data. For each user data is secured by X509/OpenID and access tokens. The data stored in the basket becomes accessible via OPeNDAP, enabling other webservices like WMS and WCS to visualize and access the data in an easy way. Results from processing services is stored in the same basket in a scratch folder and can be reused for further processing.

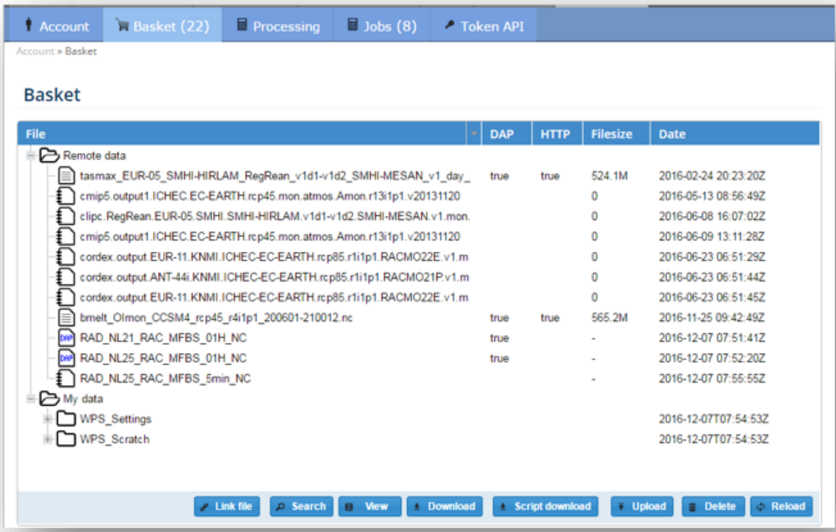


Figure 5 User basket

For details see: https://dev.knmi.nl/projects/impactportal/wiki/API#Basket-requests

1.6 Access Token service

The webservice that can be accessed over PKI is the accesstoken API at climate4impact. The accesstoken API can register new users and generates tokens (uuid v4) for designated users. These tokens can be used temporarily in URL's to gain access to most webservices at C4I, like WMS, WCS, WPS and the user basket with its per user secured OPeNDAP server. An important aspect here is that this is done over HTTPS, as the accesstoken is part of the URL.

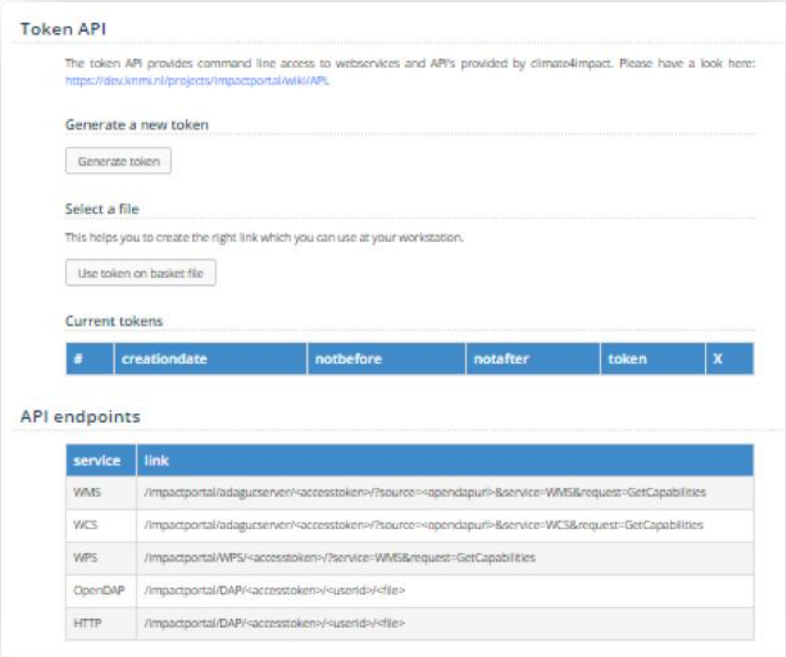


Figure 6 Token API page on C4I

More information on: https://dev.knmi.nl/projects/impactportal/wiki/API

2. Tailored derived products

In C4I, different types of tailored derived products are provided to the user. This range from bias-corrected data, to climate indices and indicators, statistical downscaling, specific Use Cases, and also through the integration with other portals.

2.1 Bias-corrected data

IS-ENES2 provided major input and support to BCIP initiative (Bias Correction Inter-comparison Project) that was initiated across several European projects. Four IS-ENES2 partners (CNRS-IPSL, SMHI, UC, MetNo) were involved in the initiative, which focussed on bias adjustment of key variables produced by the Euro-CORDEX collaboration. IS-ENES2, in particular WP5 (cf. Deliverable 5.4) has together with the CLIPC project provided essential support in developing the meta-data standards and tools necessary for publishing the data onto ESGF. These standards have been formally endorsed by the World Climate Research Programme as contribution to the international CORDEX initiative under the ESGF Project heading “CORDEX-Adjust”. In addition to the development of meta-data standards controlled vocabularies etc., publication of the bias adjusted data benefitted substantially from technical collaboration within IS-ENES2 and the resulting development of software tools and quality control procedures.

The BCIP bias adjustment methods and some example results are described in the CLIPC project deliverable “D6.1 Climate Model Data for Europe” (http://www.clipc.eu/content/content.php?htm=45)

Currently, CORDEX-Adjust datasets are published the two ESGF nodes operated by LIU/SMHI and CNRS-IPSL. As of end of March 2017 in total 639 datasets have been published, cf. Table 1 and Table 2.

Table 1 Overview of bias-adjusted variables published on ESGF

Variable	ESGF acronym	Count of Datasets
Precipitation	prAdjust	140
Relative Humidity	rsdsAdjust	62
Wind Speed	sfcWindAdjust	62
Mean Temperature	tasAdjust	179
Maximum Temperature	tasmaxAdjust	98
Minimum Temperature	tasminAdjust	98

Table 2 Number of bias adjusted datasets for different scenarios and spatial resolution published onto ESGF. The scenario datasets contain the historic period 1961-2005.

Emission Scenario	Euro-CORDEX 11	Euro-CORDEX 44
rcp26	16	16
rcp45	230	82
rcp85	193	102

All datasets available from ESGF are available to through the climate4impact portal.

2.2 On-demand climate indices calculations

The users of climate scenario data are very heterogeneous. Having access to pre-computed climate indices and indicators can support many of the needs, but users very often require more flexibility for better tailored analyses given their specific needs. The climate4impact (C4I) platform now offers the possibility for users to calculate climate indices and indicators with their own parameters using any input datafile accessible in either their C4I Basket, or on any ESGF datanode or OPeNDAP server.

This C4I Service is using the open-source software icclim https://github.com/cerfacs-globc/icclim as a backend. The software icclim has been developed within both the IS-ENES2 as well as the FP7-CLIPC projects at CERFACS. It is a very versatile and efficient python code that can calculate climate indices and indicators on NetCDF files. It can access files on local filesystems or through the OPeNDAP protocol. The main characteristics of icclim are:

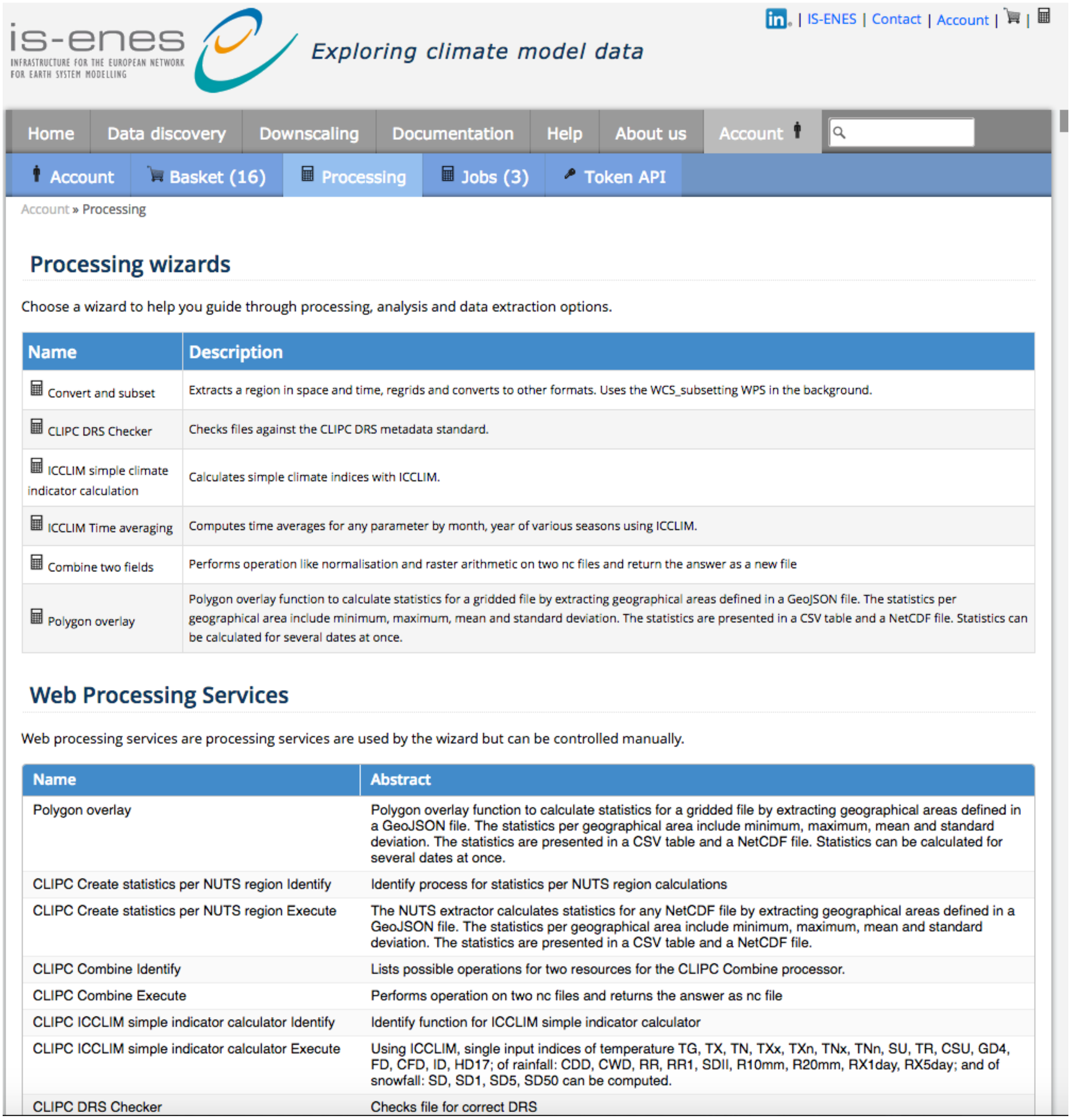
- Implements all ETCCDI indices
- Open Source (Apache License 2.0)
- Python code with embedded C
- Access NetCDF as local files or remotely through OPeNDAP
- Assumes NetCDF files are CF-compliant (CF-Convention 1.x)
- Integrated within the Open Source OCGIS software
- Implements auto-adjusting temporal and spatial chunking for memory and network efficiency
- Easily extended with new indices and indicators
- Already used outside originating projects
- Fully validated against R.ClimDex
- Implements bootstrapping for percentile indices when reference period overlaps

In C4I several wizards and processing interfaces are available to access icclim functionalities. Results are stored in User Basket and are available for download, further processing, and/or visualization. They can also be accessed using external remote tools using the C4I Token API, as they are served with the OPeNDAP protocol. Other processing functions are available apart from climate indices and indicators, too.

Currently the C4I portal does not manage available resources, consequently the following risks are not addressed:

- Unreasonable queries
- Too many concurrent queries

In the future, the C4I will have to evaluate the resources needed by each query, and manage them not to overload the system. One of the current solution is to, at least, delegate calculation as much as possible to external resources, such as the future ESGF Computing nodes using the API, the EGI FedCloud (through the EUDAT GEF API). This is already the case for statistical downscaling that delegates the calculations to the Cantabria Downscaling Portal.



Processing wizards

Choose a wizard to help you guide through processing, analysis and data extraction options.

Name	Description
Convert and subset	Extracts a region in space and time, regrids and converts to other formats. Uses the WCS_subsetting WPS in the background.
CLIPC DRS Checker	Checks files against the CLIPC DRS metadata standard.
ICCLIM simple climate indicator calculation	Calculates simple climate indices with ICCLIM.
ICCLIM Time averaging	Computes time averages for any parameter by month, year of various seasons using ICCLIM.
Combine two fields	Performs operation like normalisation and raster arithmetic on two nc files and return the answer as a new file
Polygon overlay	Polygon overlay function to calculate statistics for a gridded file by extracting geographical areas defined in a GeoJSON file. The statistics per geographical area include minimum, maximum, mean and standard deviation. The statistics are presented in a CSV table and a NetCDF file. Statistics can be calculated for several dates at once.

Web Processing Services

Web processing services are processing services are used by the wizard but can be controlled manually.

Name	Abstract
Polygon overlay	Polygon overlay function to calculate statistics for a gridded file by extracting geographical areas defined in a GeoJSON file. The statistics per geographical area include minimum, maximum, mean and standard deviation. The statistics are presented in a CSV table and a NetCDF file. Statistics can be calculated for several dates at once.
CLIPC Create statistics per NUTS region Identify	Identify process for statistics per NUTS region calculations
CLIPC Create statistics per NUTS region Execute	The NUTS extractor calculates statistics for any NetCDF file by extracting geographical areas defined in a GeoJSON file. The statistics per geographical area include minimum, maximum, mean and standard deviation. The statistics are presented in a CSV table and a NetCDF file.
CLIPC Combine Identify	Lists possible operations for two resources for the CLIPC Combine processor.
CLIPC Combine Execute	Performs operation on two nc files and returns the answer as nc file
CLIPC ICCLIM simple indicator calculator Identify	Identify function for ICCLIM simple indicator calculator
CLIPC ICCLIM simple indicator calculator Execute	Using ICCLIM, single input indices of temperature TG, TX, TN, TXx, TXn, TNx, TNn, SU, TR, CSU, GD4, FD, CFD, ID, HD17; of rainfall: CDD, CWD, RR, RR1, SDII, R10mm, R20mm, RX1day, RX5day; and of snowfall: SD, SD1, SD5, SD50 can be computed.
CLIPC DRS Checker	Checks file for correct DRS

Figure 7 C4I Processing Wizards list and WPS Generic Interface

As an example, here is the main icclim wizard for simple climate indice calculation. It shows that values can be entered manually, but the wizard can also suggest values given the input file and the climate indice to calculate. The indicator is described in the drop-down list, and it is possible to calculate using different types of Time Slice Mode, such as specific seasons.

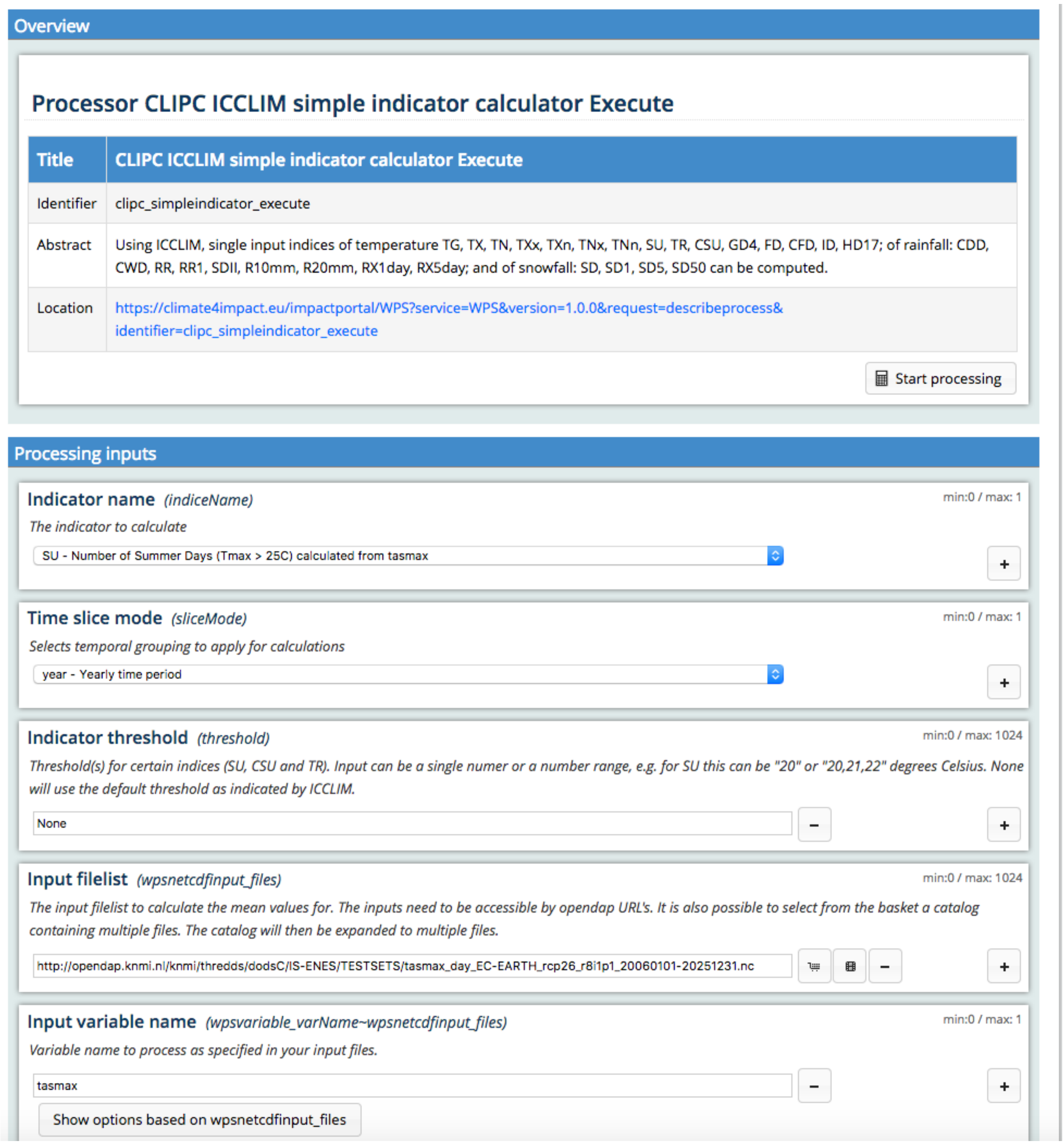
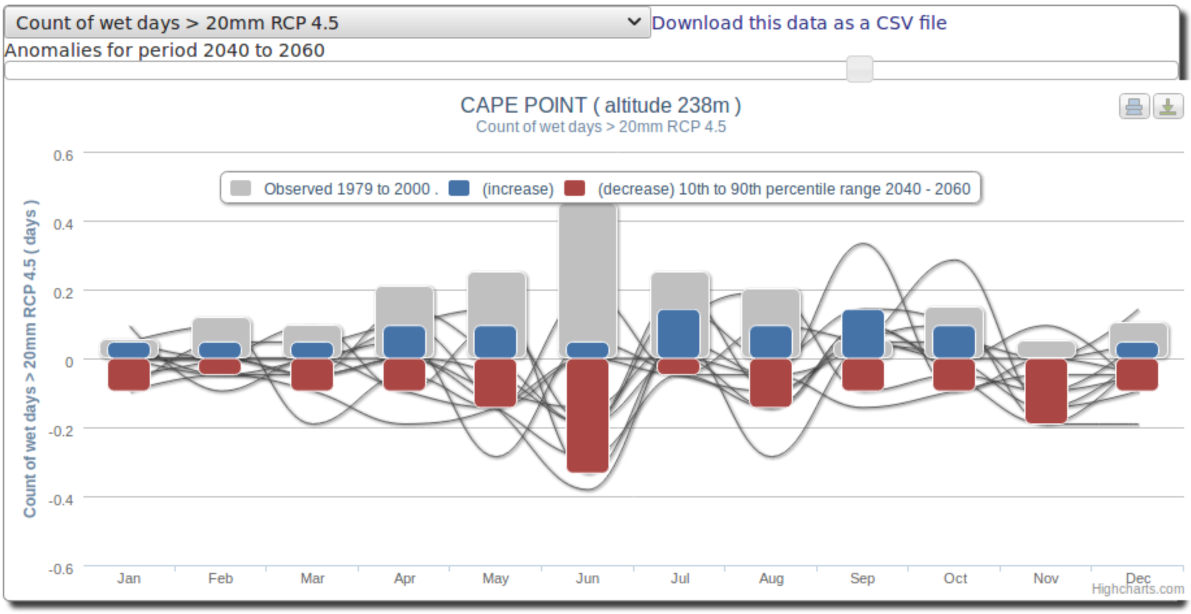


Figure 8 C4I Processing Wizards: CLIPC ICCLIM simple indicator calculator

2.3 Integration with CSAG Climate Information Platform

The Climate System Analysis Group (CSAG) Climate Information Platform provides observed and statistically downscaled climate data across Africa based largely on point (station) observations. The focus has been on point locations and real time analysis of climate statistics such as thresholds, spells, and monthly multi-model ensemble anomalies of these. An example visualisation from CIP can be seen in the figure 9 below. As such it offers a distinctly different view of climate data compared with the C4I interface.



It was therefore decided to explore the integration of ESGF/C4I data services into the CIP platform to provide similar point time series analysis of ESGF hosted datasets through the CIP platform.

Current status

Two significant challenges have emerged and still need to be resolved. The first is the authentication workflow to allow the CIP backend server to access original daily time series data from ESGF nodes in real time. The current ESGF and C4I authentication relies on locally installed and trusted certificates and proxy clients. While there has been some discussion about how to extend this to the CIP use case a suitable/workable workflow has yet to emerge.

In response to this a local THREDDS server (part of the JRA3 Task 1 ESGF node installation) hosted at CSAG is being used as local copy of a subset of ESGF CORDEX data for CIP development work. However, performance for real time requests of daily data for long time periods (100+ years) is poor and makes real time web based interaction difficult. The existing CIP platform utilised the performance advantages of an optimised (indexed) SQL database including multiple instances to allow parallel request. This architecture provides response times in the order of 2-3 seconds which his acceptable for real time interaction.

Development of the software continues while authentication and performance issues remain unresolved. A prototype implementation is planned for March 2017.

2.4 On-demand statistical downscaling

The climate4impact portal is also providing statistical downscaling services. A *Downscaling Tab* has been added on the main climate4impact page (see Figure 9).

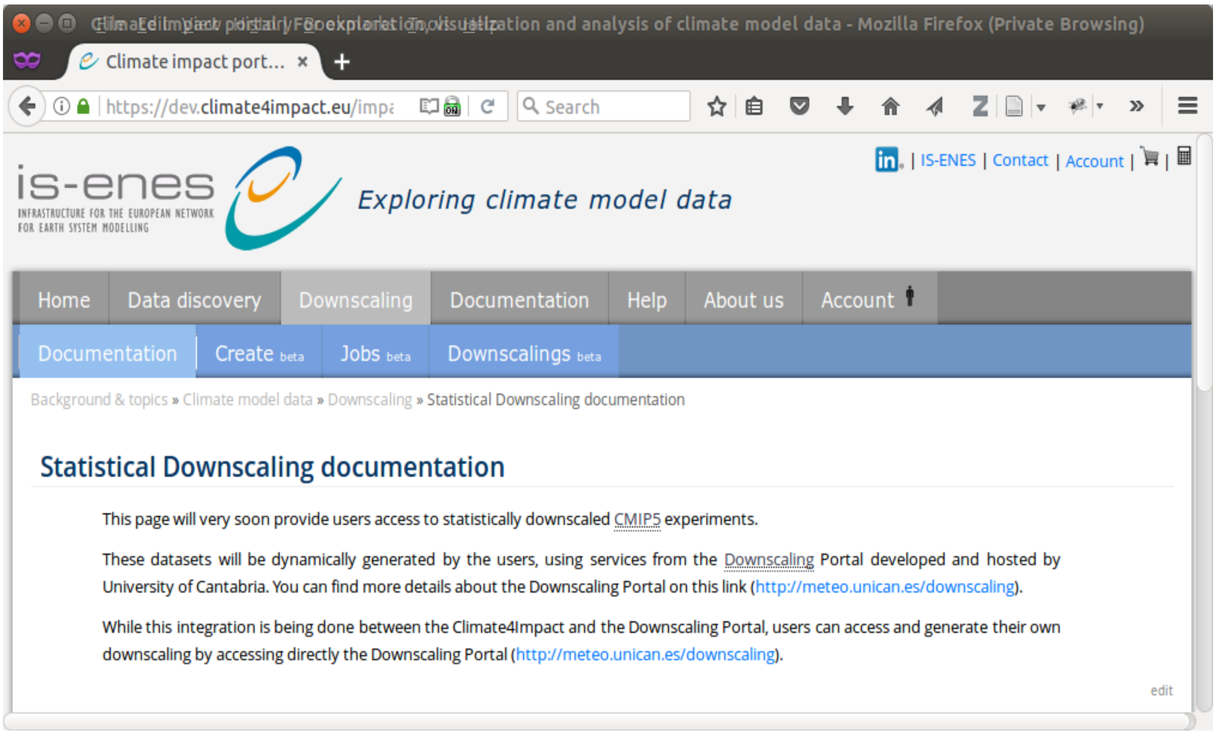


Figure 9 Statistical Downscaling Tab

This service is an integration of the University of Cantabria (UC) *Ensembles Downscaling Portal*[1] (DP) into C4I. The C4I services access the DP through web services and delegated Open ID certificates authentication in a seamless and transparent access for C4I users.

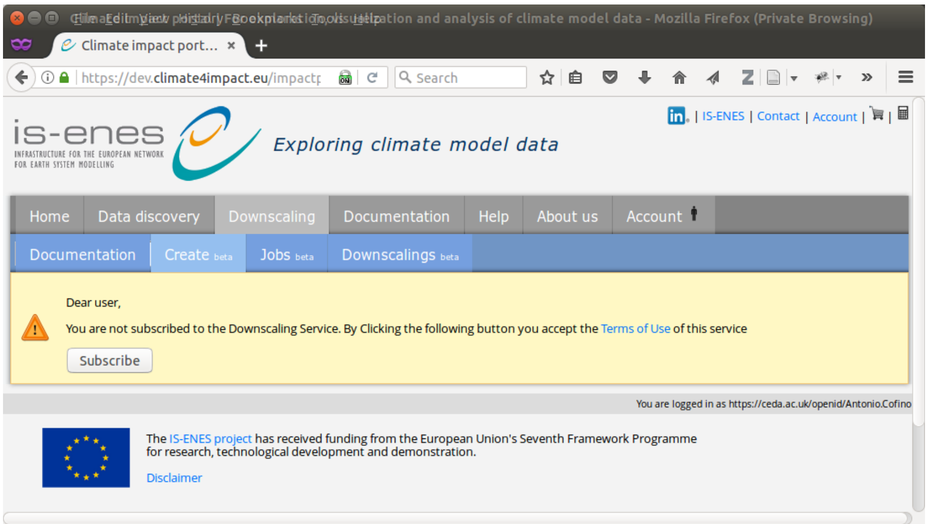


Figure 10 Statistical Downscaling Create Downscaling Terms of Use Tab

1 ENSEMBLES Downscaling Portal (version 2) : http://meteo.unican.es/downscaling

The *Downscaling Tab* will contain tabs and interactive form elements to guide users to complete a downscaling. Users have to accept the terms of use to access to *UC Downscaling Services*. The request is sent to the *Downscaling Portal* which registers the user through retrieved user details by C4I. This process allows them to have their own account and downscaling information and data (see Figure 10.

The *Create* tab guides users to configure their downscaling and will allow users to load and save downscaling configurations for future sessions. The downscaling configuration has these steps (see Figure 11):

1. Variable of interest selection
2. Observation database (predictand) of selection
3. Downscaling method selection including validation and verification report
4. Model/Dataset selection
5. Scenario and period of interest selection

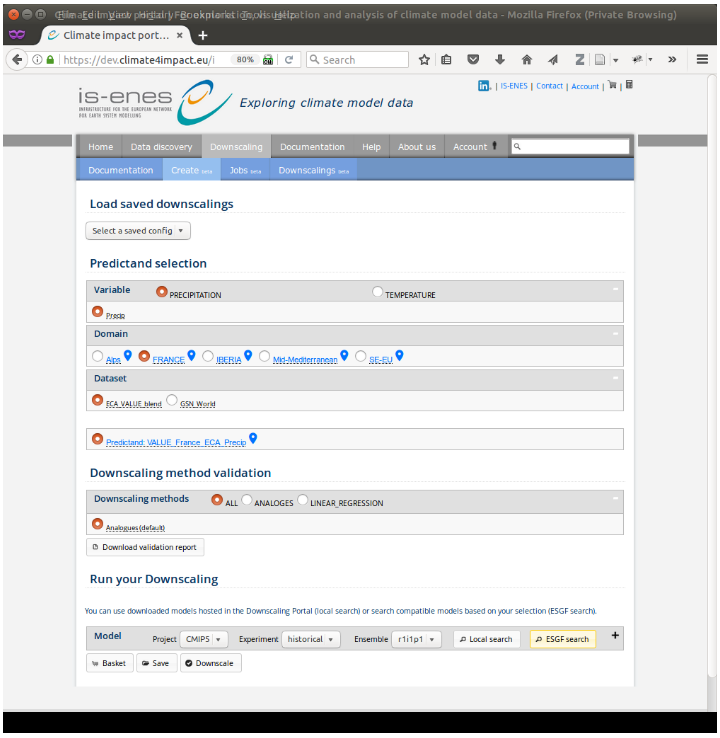


Figure 11 Statistical Downscaling Create Downscaling Form Tab

The *Domain* and *Predictand* sub-forms has the ability to represent on a map the geographical coverage and station points been used for the downscaling (see Figure 12)

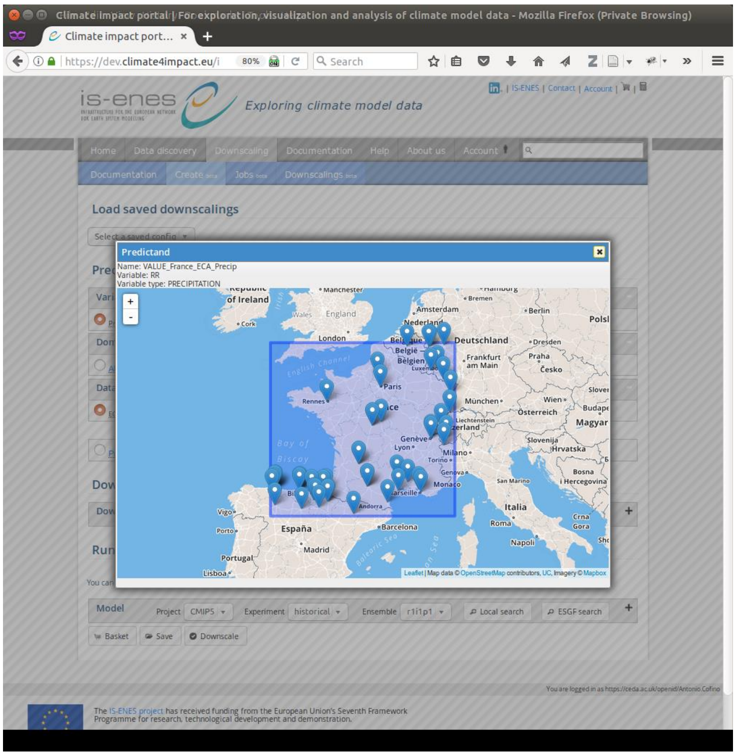


Figure 12 Statistical Downscaling Predictand Geographical View

The model, scenario and member selection can be done over datasets available on ESGF and resembles to the C4I's *Data Discovery* main tab (see Figure 13)

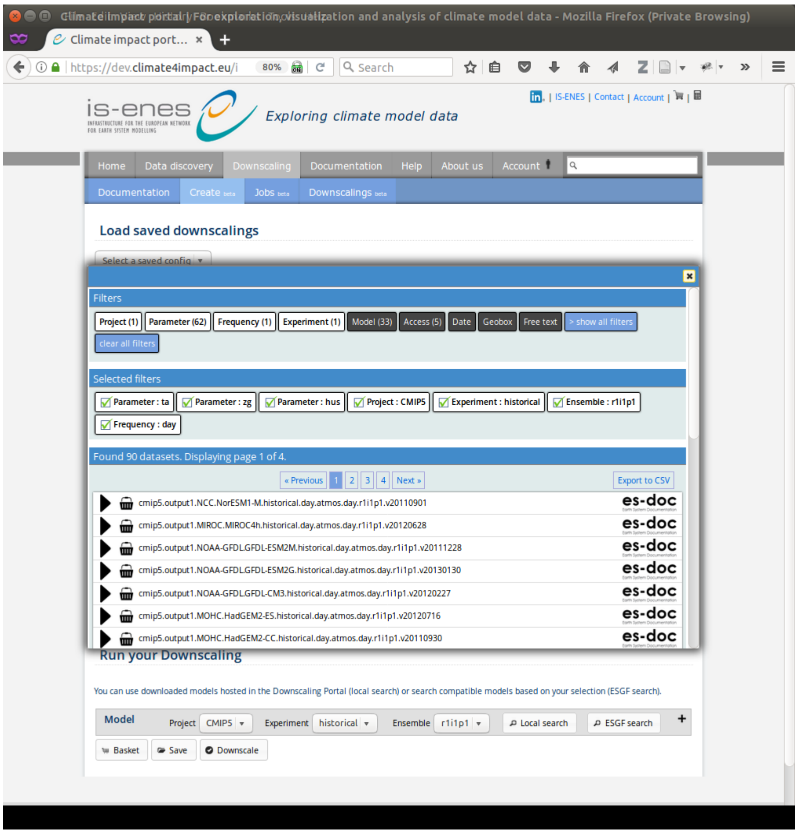


Figure 13 Statistical Downscaling Data Selection

Once all the requirements are fulfilled to run the downscaling the user can click on *Downscale* button and the C4I portal sends requests to the DP. All user's downscaling jobs are accessible in the Downscaling's *Jobs* tab (see Figure 14).

Downscalings

Downscalings for: **https://ceda.ac.uk/openid/Vega.Manuel**

Job ID:	Type	Predictand	Downscaling Method	Model	Experiment	Start year	End year	Status	Operations
33040	CLIMATE_CHANGE	VALUE_Iberia_ECA_Tmax	Analogues (default)	CANESM2	historical_r1i1p1	1941	1951	Processing	

Figure 14 Statistical Downscaling Jobs Tab

All this functionality is provided by a *RESTFul API* which is secured by token access. C4I has a special user which is allowed to get valid *tokens* from the DP. C4I background services use this *token* to gain access to the Downscaling RESTFul API[2]. The following services are available:

1. Subscribe users
2. Retrieve a list of users
3. Delete a subscribed user
4. Get user stored data
5. Retrieve a list of Predictors
6. Manage downscalings

Documentation resources for users are:

- the ES-DOC documentation for ESGF CMIP5 models.
- New documentation resources about how the Downscaling process works will be available at KNMI's drupal.
- The info is retrieved from KNMI's drupal and showed at C4I Downscaling section.
- Wiki documentation about the REST API services.

2.5 Specific Use Cases

a) Danish Use Case

As a part of the effort to aid users of the http://climate4impact.eu/ portal, the DMI has been working on documenting a use case to be shown in the help section. This use case is based on an actual delivery to the Danish municipality of Aarhus, the 2nd largest city in the country. The interest of this municipality concentrated on expected anthropogenic local changes in precipitation, particularly in extremes, and on changes in local sea level and storm surge probability; part of the actual work consisted on a historical framing based on station observations. The use case is a repetition of work already delivered and calculated with different tools, but this time calculated entirely within the climate4impact toolbox.

The part of this work where the climate4impact portal can be of use is the part related to calculation of future precipitation change, including change in extremes; the remainder of the

2 https://meteo.unican.es/trac/wiki/DownscalingPortal/RESTfulAPI/Climate4Impact

actual delivery, dealing with station observations and with sea level rise and storm surge probability will not be addressed in this climate4impact use case.

A help page has been constructed, which is currently being reviewed and integrated into the climate4impact list of use cases; it is already accessible as https://climate4impact.eu/impactportal/documentation/guidanceandusecases.jsp?q=DMI_use_case_future_impacts_of_climate_change. Here it is described how to select the bias adjusted data, how the tools on the portal have been used to calculate climate change information, and how results can be obtained. One example was given in the help page: One of the available bias-adjusted daily precipitation datasets from the CORDEX-adjust datasets was chosen, and the number of days with more than 10mm of precipitation (r10mm) was calculated with the available tool for relevant periods. The change between a 30-year control period and a 30-year future period was calculated. From this example, it is trivially possible to extend the analysis to all available simulations and scenarios, and to compute several other indices, which formed part of the Aarhus study.

This work has been possible due to the recent addition of several useful tools to the portal. Only one feature necessary to replicate the entire analysis is still missing: The possibility to calculate user-specified percentiles and not just a few predefined ones.

b) Danube Use Case

The Danube case study have the following main objectives:

- To present representative use cases on the climate4impact.eu portal the assessment of potential climate change impact on the hydrological regime on the Danube Basin, especially on the lower Danube, with a focus on extreme hydro-meteorological events.
- To provide specific robust simplified hydrological simulation tools, implemented using free software, in order to allow potential users to investigate the impact of climate change scenarios on different basins within the entire Danube River Basin.

Danube river basin is located in the central and south-eastern part of the European continent, it springs from the Black Forest (Schwarzwald), having an elongated shape from west to east; in relation to the bed the Danube basin is relatively symmetrically arranged, with about 56% of the area on the left bank and 44% on the right.

Danube basin is divided into three main sectors:

- upstream (running from the source to the gate Devin, until the town of Bratislava, with a length of 1060 km);
- the middle (stretching from Devin Gate, Bratislava respectively, to Bazias, its length is 725 km);
- the lower (stretching from Bazias until it flows into the Black Sea and covers a length of 1075 km, representing about 38% of the total length of the river).

As a preliminary step, before starting the assessment of potential future impact of climate change scenarios, the tendencies in the variability of annual, monthly, medium, maximum and minimum flow was investigated, by applying the non – parametric Mann –Kendall test, on the recorded historical discharges time series, for the entire period of observation, on the lower Danube and on the main tributaries from the Romanian sector of the Danube, at the following representative hydrometric stations: Danube - H.S. Bazias, Danube - H.S. Braila, Jiu – H.S. Podari, Buzau – H.S. Racovita, Ialomita – H.S. Cosereni, Siret – H.S. Lungoci, and Prut at H.S. Radauti-Prut and H.S. Falciu.

The comparative analysis of the largest floods recorded lately in the lower basin of the Danube River (April 2006 and respectively June-July 2010) shows the importance of the contribution from the Siret and Prut river basins on the severity of floods on the last sector of the Lower Danube and respectively the Danube Delta, therefore it is very important in terms of the potential impact of climate change on the maximum runoff on this sector, to analyze the potential changes induced by climate change on the flood overlapping probability on the main sectors / tributaries of the Danube, both upstream from entering the country (Bazias section) and the Romanian sector.

In order to estimate how climate change influences the overlap of floods in the Danube river basin, a robust approach based on the use of indices for the spatial-temporal rainfall distribution in specific areas of runoff formation in the main tributaries was proposed, using fuzzy modeling systems, an approach adequate to the high degree of uncertainty associated with climate change simulations obtained by applying regional climate models.

The proposed fuzzy hydrological model, is an event type hydrological model, and can be used for the analysis of potential impacts of climate change on flood events regime at the level of the river basin.

In the case of a basin with very large areas, which at one time generally has areas with different hydrological regimes, as is the case of the Danube river basin, the modeling is done at the level of each representative sub-basin and the composition of results obtained at the level of each sub-basin is integrated by an additional component, also based on fuzzy system approach, given the associated high degree of uncertainty.

The hydrological impact assessment demonstration case studies include also a local scale investigation, consisting in the application of the SAC-SMA soil moisture accounting model, a conceptual hydrological model with global parameters, for a selected medium size River Basin: Bistrita River Basin – Frumosu hydrometrical station (F= 2858 km^2), situated in the upper part of Siret River Basin – Romania, the most important tributary on the Lower Danube.

Assessment of climate change potential impact on hydrological regime is a complex use case, and it have been used to test different C4I functionalities for getting the needed climate simulations data, and based on some specific needs (e.g. arbitrary River Basin boundary mean time series values computation) existing functionalities have been improved or some new functionalities have been proposed and implemented within the portal.

3. User evaluation and courses

3.1 Student course

The portal is the main data search tool for the annual Wageningen University M.Sc. level course "Design of climate change mitigation and adaptation strategies", given in March each year and attended by 35-50 international students. As part of the course the students do a 3-afternoon-long scenario analysis workshop focussed on finding appropriate data for a specific use case through C4I, and subsequent mapping, sub-setting and processing to indicators. The course is given by members of the C4I development team (Ronald Hutjes, Maarten Plieger), facilitating immediate feedback on strengths and weaknesses of the portal functionalities guidance and documentation. Especially the most recent event (22-24 March 2017) showed a high degree of C4I usability and an easy and steep learning curve in climate data handling for users with no prior knowledge of the portal, though with a background in climate / earth system science.

3.2 Professional course

In addition, the C4I portal has also been taught during the joint IS-ENES (WP6-T2)/Copernicus-SWICCA masterclass "Climate Services Training: application of climate data in policy, management and planning for knowledge purveyors", held 13-15 March 2017 and taught by Ronald Hutjes, Maarten Plieger and Fokke de Jong. This course was attended by 17 international professionals, generally consultants from SME’s working with climate services. For this audience, the C4I portal proved a bit more difficult to use, primarily due to a more diverse background and more limited knowledge of climate science.

See also D6.3 for previous courses and feedback to C4I.

4. Conclusions and Perspectives in on-demand derived products generation

The developments of the climate4impact platform and services has been quite intensive, with many coding sprints being organized throughout Europe to bring designers, users and developers together. The interface has benefited from large improvements since the beginning of IS-ENES2, and a significant number of services were added. The re-use of climate4impact services into other portals has been successfully demonstrated with the FP7 CLIPC portal http://clipc.eu/ .The ability for climate4impact users to calculate their own climate indices and indicators, as well as performing their specific tailored statistical downscaling is clearly a large step forward. All climate4impact services are OGC compliant: coupled with new metadata standards to support climate indices, it maximizes current and future interoperability. Some perspectives are presented in the next subsections.

4.1 ESGF CWT

Because the CMIP6 data volume will be too large to move, server-side computing is a necessity. To assist in remote computing, the ESGF CWT is developing modularized compute capabilities to allow use of multiple analysis engines within the ESGF framework.
The ESGF CWT is designing a robust and powerful API, based on the Open Geospatial Consortium/WPS standard, for executing remote computations on climate data distributed across the Earth System Grid Federation. IS-ENES climate4impact developers are participating in the ESGF CWT to contribute to and to follow the latest developments.
Next step is to connect the climate4impact WPS to the ESGF CWT. Part of the calculations can be delegated to the ESGF CWT's API to maximize calculations near the data storage, minimizing data transfers, and make calculations faster.

4.2 EUDAT B2 Services and EGI

The EUDAT CDI[3] provides services available to European Researchers. As of now, a large number of services are already available:
https://eudat.eu/services/userdoc/eudat-primer#EUDATPrimer-ServiceDescriptionsServiceDescriptions
Since processing within C4I is done locally on the server, delegating some calculations to other platforms can be beneficial, as it will also be done using the ESGF CWT on the computing nodes. Currently within the H2020-EUDAT2020[4] project, work is done to enable users of EUDAT B2[5] Services to access the EGI FedCloud to increase the capability to perform large data analysis. This will be done through the GEF EUDAT Service, which will execute data processing onto the EGI FedCloud[6], and use other B2 Services (such as B2DROP, B2SHARE, B2STAGE/B2SAFE) to stage data in and out, B2FIND/B2HANDLE to easily locate referenced data resources, and B2ACCESS to have proper authentication and authorization.
Following the end of IS-ENES2, if suitable funding/resources are found, C4I will be inter-connected with the EUDAT GEF[7] Service to enable C4I users to access powerful compute resources through the EGI FedCloud. More EUDAT B2 Services could also be integrated into C4I to bring and extend further capabilities to C4I users.

[3] https://eudat.eu/services/userdoc/eudat-primer
[4] http://cordis.europa.eu/project/rcn/194928_en.html
[5] https://eudat.eu/services/userdoc/eudat-primer#EUDATPrimer-HowtoUseEUDAT
[6] https://www.egi.eu/services/cloud-compute/
[7] https://github.com/EUDAT-GEF