IS-ENES – WP 11

D 11.2 – Baseline documents on e-resources/tools and transverse themes

Abstract

A central objective of JRA5 is to provide a prototype for a web service interface (the e-impact-portal thereafter) to bridge the gap between the climate modelling community, the climate impact community and decision makers (the users or stakeholders thereafter) for developing adaptation and mitigation policies. For that purpose a number of selected and representative national Use Cases for climate data has been selected and described (deliverable D 11.1).

A detailed analysis of these national Use Cases has been performed in task 2. It brings out commonalities in term of user needs, work processes, tools and limits of data use for impact studies. The D 11.2 deliverable presents the main results resulting from this analysis. It will serve as a basis to design and build the e-impact portal (task 3).

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Reference Documents

Title	Reference	Date of issue
Description of IS-ENES work	ISENES_DoW_Final.doc	04/2009
D 11.1 – Final description of selected Use Cases including user requirements specification	IS-ENES_11_DI_11-1_USECASES_A07.doc	06/2010
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Table of Contents

Executive Summary

IS-ENES is the infrastructure project of the European Network for Earth System Modelling (ENES). IS-ENES combines expertise in Earth system modelling, in computational science, and in studies of climate change impacts. IS-ENES will provide a service on models and model results both to modelling groups and to the users of model results, especially the impact community. Joint research activities will improve the efficient use of high-performance computers, model evaluation tool sets, access to model results, and prototype climate services for the impact community.
The work package WP11/JRA5 is aimed at Bridging Climate Research Data and the Needs of the Impact Community. The central objective of JRA5 is thus to provide a prototype for a web service interface (the e-impact-portal thereafter) to bridge the gap between the climate modelling community, the climate impact community, the climate effect community and decision makers (the users or stakeholders thereafter) for developing adaptation and mitigation policies. Building this service requires in a first time to precise user needs and determine the best way to provide the information.

The methodology adopted in JRA5 has consisted in gathering several case studies performed by the partner institutes. 17 national and representative use cases have been selected. They give a more precise idea of user requests in term of objectives, areas, periods, parameters, resolution, and final format. They inform about the ways to deliver climate information to different type of users, covering a range of applications, such as water resources, forestry, agro and ecosystems, etc. Use cases documentation provides information about the main phases of the work that has been done to answer user request. It includes workflow, data features, data processing, user/provider interaction, uncertainty assessment. This information has been synthesised in the IS-ENES deliverable D11.1.

The deliverable D11.2 presents a finer analysis of these 17 use cases. Despite the small size of the sample (17 experiences done by 8 research institutes coming from 5 countries); there is a large diversity in the use cases features: diversity in objectives, users, final products, data features, methods and tools. A first task was to classify this information in order to have a better overview of the request and the available resources to answer.

First key classification concerns the type of users. It influences the type of final product, users/providers interaction, type of documentation and also processing steps. First class is composed of scientists and engineers that are used to work with climate data, format, volume, analysis methods and uncertainties. They ask generally for raw data they process themselves. The second class of users is members and deciders of different organisation (NGO, firms, government…). They need "elaborated products" like maps, plots or statistics to elaborate their decisions. Design of the e-impact portal should take into account the needs of these two categories of users.
Second classification focuses on data. Many different parameters (final climate parameters, sectorial parameters, auxiliary parameters, indices specifically developed to answer user needs), area (points, cities, rivers, countries, regions of all continents), periods (different time slices of the 20th and 21st centuries), horizontal resolution (global, regional and very local resolution); temporal resolution (from hourly time step to decadal one) and format (model native formats versus users specific format) are needed to fulfil all user requests. Implementing this diversity in the e-impact portal will be a major challenge. Further work will be launched to tackle this technical issue (task 3).

Methods and tools use to get final product from raw data have also been considered. Data processing that must be done between climate model output and the delivery of information to users is complex, underestimated and often not well understood by the user community. Some methods and tools are specifically developed or adapted for user request and are still in the field of research activity (especially statistical downscaling methods). Other ones are used routinely in many use cases: averaging, regridding, extraction… Until now, each institute has developed its own set of tools based on different numerical languages and software with no synchronisation between teams. Then one can find several tools with same functionalities (especially for routine operation). Only a limited set of selected tools will be implemented in the e-impact portal. Selection will be done according to the strengths and weaknesses of each tool.

A second task was devoted to best understand the way of proceeding to answer user request. Objective was to define how we could improve the actual methodology. Workflows described in the 17

use cases are very different and focus on specific steps or actions (data processing, data delivering, users/providers interaction…). They have been analysed and combined in order to propose a first draft of an "ideal process". It includes 7 steps: collection, analysis and validation of the requests; definition of proceeding instructions; planning; data processing; quality assessment; data packaging and data release. This first draft should be improved in task 3 with the objective to define what will be the "ideal" way of doing. This work will be completed by the identification of what is missing in the actual studies and will serve to facilitate the implementation of the e-impact portal.

Data uncertainties and reliability issue has also be addressed in this analysis. Beyond the inherent climate uncertainty sources, one must also take into account the errors due to misuse methods and tools. No consideration of these factors leads to erroneous interpretation of the results. Sources of errors are numerous as well as the methods to tackle them. Quantifying and reducing uncertainties and biases require a good knowledge of datasets, methods and model skills. It needs also complex analyses that are time expensive. Use cases show that few users are able to evaluate uncertainties by themselves. This introduces a double question: What is the best way to introduce the quality/uncertainty assessment in the e-portal? How do we deal with data that present low reliability? For this second part of the question, it could be envisaged to limit data access and proposed tailored help to user. Further analysis will be done on this topic in task 3.

This analysis highlighted the technical challenges that e-portal implementation team should face. It also enables to define a set of recommendation:

- The e-portal should be flexibly implemented because it is a prototype (it will be improved with time), methods dataset and tools change rapidly and because the interaction with users about the climate questions is not well-known.
- The e-portal should include large documentation and illustration to help users starting to use its functionalities and to become familiarized with the large volume of information.
- Special interest will be given to user feedback in order to improve our knowledge of user needs, adapt the e-portal and improve the service.

1. INTRODUCTION

As stated in the IS-ENES work document, the central objective of JRA5 is to provide a prototype for a web service interface (the e-impact-portal thereafter) to bridge the gap between the climate modelling community, the climate impact community, the climate effect community, and decision makers (the users or stakeholders thereafter) for developing adaptation and mitigation policies.
Building this service requires in a first time to precise user needs and determine the best way to provide the information. Usually, users work directly with a given institute in a “2 by 2” mode. This binary mode without any further coordination results in an important number of methods and tools. The e-impact portal has to deal with this diversity in order to bring a comprehensive overview of the possible use of climate information and data.

The methodology developed in IS-ENES consists in gathering several case studies performed into the partner institutes and making a more precise analysis of the needs, methods and tools using these examples. For that purpose, 17 national and representative use cases have been selected. These use cases inform about the way to deliver climate information to different type of users, covering a range of applications, such as water resources, forestry, agro and ecosystems, etc. Use cases documentation provides information about workflow, data features, data processing, user/provider interaction, uncertainty assessment... They have been synthesised in the IS-ENES deliverable D11.1.

The 17 IS-ENES use cases show wide ranges of objectives, products, methods, datasets and tools to process and deliver final products to users. JRA5 covers only a small sample and this diversity would be likely higher considering more cases. However the detailed analysis of these use cases points out the existence of commonalities that will facilitate their implementation in the e-impact portal. The objective of this document is thus to define the main differences and commonalities of the use cases. We first focus on the general structure of cases (section 2). Then we make deep analysis of data needs (section 3) and resources (methods and tools) available to answer user request (section 4). We present commonalities regarding the general process that has been applied to fill user requests (section 5). Section 6 is devoted to quality investigation. The last section concerns recommendations, questions and warnings for the e-impact portal implementation. Web engineering is not tackled here: e-implementation aspects will be considered in task 3.

2. USE CASES DESCRIPTION

The IS-ENES use cases sample has been set up from experiences of 8 research institutes; 5 countries and includes 17 cases. Table 1 gives a general insight of use cases. It specifies sector, region, period and type of information provided to users (raw data; elaborated data; indices, visualization …). Use cases selected by the JRA5 consortium for implementation in the e-portal are highlighted in grey.

Table 1 outlines the wide range of selected use cases in term of sectors, objectives, user types, requests… A first objective of this work is to see how this info can be classified to give a clearer overview.

2.1. USE CASE CLASSIFICATION

Use cases can be sorted in two categories. The main category includes cases that focus only on climate information: climate raw data, climate indices and maps, plots or statistic of these data and indices. They are delivered for running impact model and sometimes making vulnerability assessment. The second category considers sectorial information: sectorial indices are computed using climate data and provided to user for vulnerability assessment.
Initially, it was planned to focus only on the first category. However, impact studies involve multidisciplinary knowledge and teams. Impact climatologists are often led to make more than climate analysis and help for computing sectorial data. Thus, for some cases, it was difficult to separate climate information and sectorial one (see IPSL-2 case about impact of global changes on freshwater fish biodiversity). For this reason, we extend the selection of use cases to the second category. These cases are referred by "*" in table 1.

2.2. AREA & PERIOD

Areas extend from very local area like rivers or cities to very large region like continent. One of the use cases addresses global question. European rivers and countries are the most frequent requested area. Some cases are also related to non European countries like developing countries or China.
Projections are done and provided for mid-term (2030-2060) and long-term periods (2100). Present-day data are also provided. They are used in comparisons and validations as reference period.

2.3. SECTOR, USER TYPE AND RELEASED INFORMATION

Figure 1 presents the distribution of use case in term of sector, user type and released information.
The use cases consider various sectors including: agriculture, hydrology, land use, ecology, geotechnics, energy, forestry. Figure 1.a shows that hydrology and ecology are the most frequent sectors in our sample. Agriculture and geotechnics appears also several times. Private sector is not well represented. That illustrates the difficulty for companies to become aware of the climate change and adaptation issues.
Users are mainly scientists and engineers who are used to deal with climate data format, volume, climate analysis software and uncertainties. They need raw data and climate indices to run impact models. In many cases, they also ask for more information about file contents, data uncertainties, used methodologies … This information can be provided in special report.
Some of the use cases have been performed for members and deciders of association, industrial firms and governments that are not able to use raw data by themselves. This second category of users asked for "elaborated products" like maps, plots or statistics of raw data and various indices. Most often, reports are also provided including results of analysis, uncertainties assessment and various recommendations.
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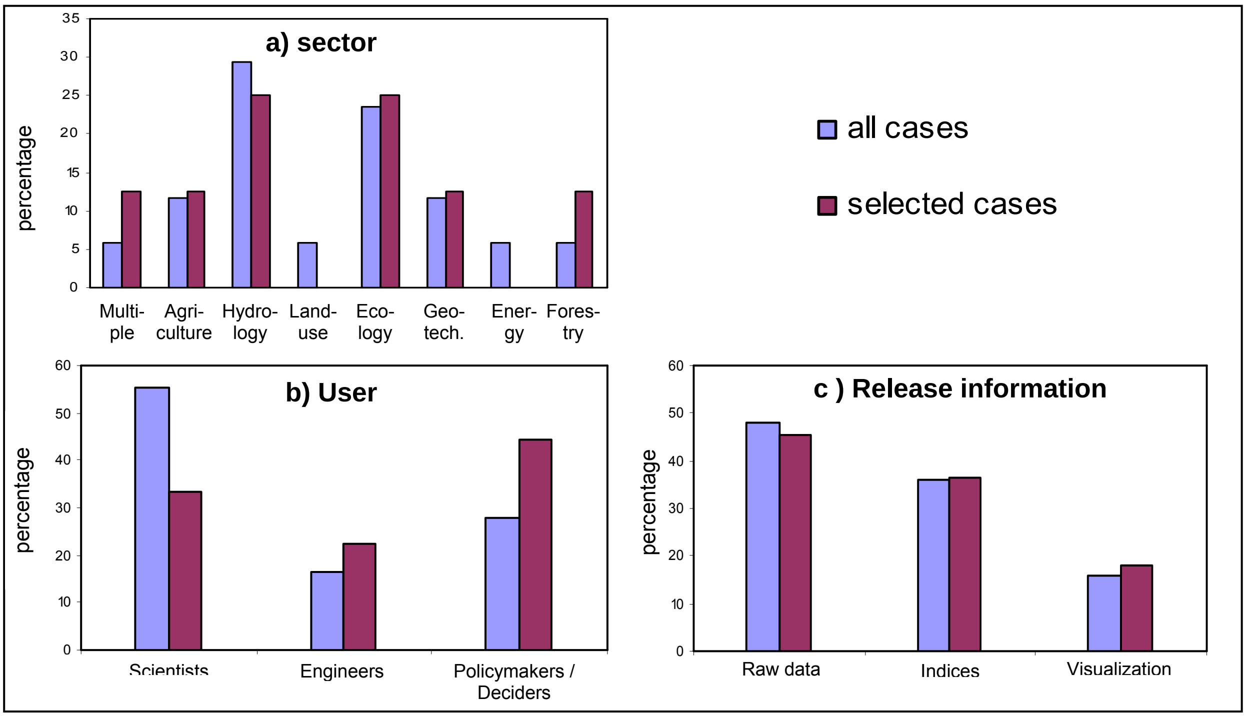

Figure1: Distribution of the use case sector, type of user and release information. The selected use cases are the cases selected for implementation in the e-impact portal (highlighted in grey in table 1).

Group and use case number/title	Sector	Region /Period	Period	Data Users	Released information	Short overview / objectives
KNMI-1: FEMS/NHI	Hydrology (droughts, floods)	Netherlands	present period	Scientist: hydrologists	Simulated data	Delivering data to run the FEWS/NHI system in order to support decision making relative to drought period
KNMI-2: EU-CLUE SCANNER	Land use change	Europe	1990-2030	Scientist: land-use researchers	Simulated data, indices	Delivering data to run the EU CLUE scanner model in order to propose adaptation and mitigation strategies relative to land use change
KNMI-3: WUR-Climate data for metaphor	Ecology (analysis of population)	De Veluwe (Netherlands)	1980-2100	Scientist: ecologists	Simulated data, indices	Delivering data to run the Metaphor model in order to assess long-term viability of population
KNMI-4: PBL-Nature planner	Ecology (management of ecological infrastructure)	Netherlands and Europe	1980-2100	Scientist: ecologists	Simulated data	Delivering climate data to run the Nature planner in order to assess change in the main ecological infrastructure
CERFACS-1: impact / adaptation in an estuary	hydrology	Gironde Estuary (France)	1960-2040	Hydro-consulting engineers;	Simulated data, report	Providing high resolution climate change scenarios in order to assess impacts and adaptation strategy in the Gironde Estuary
CERFACS-2: impact on Somme and Seine river basins	hydrology	Seine et Somme basins, France	time-slices (1960-2100)	Scientists: hydrologists	Simulated data; report	Providing high resolution climate change scenarios and evaluating uncertainties in the France Seine and Somme river basins
INHGA: Climate change scenario in Danube middle and lower Basin	hydrology	Danube middle and lower basins	1958-2100	Scientist: climatologists hydrologists	Simulated data	Processing regional climate change scenarios and evaluating uncertainties to assess changes in the hydro meteorological extremes in the Danube basins
CMCC-1: effect of intense rainfall on landslide events	Geotechnics	Mediterranean region; Italy	Projection at 24-48h	Geotechnical engineers	Simulated data	Processing regional model data to run the I-Modsoil and TRIGRS models and evaluate the effect of intense rainfall on landslides phenomena
CMCC-2: Effect of climate change on landslide events	Geotechnics	Mediterranean region; Italy	20^{th}, 21^{st} century	Geotechnical engineers	Simulated data	Processing regional model data to run the SEEP/W and I-Modsoil models in order to evaluate effects of climate change on landslides phenomena
MF-1: scenarios for the evaluation of impacts and adaptation in France	Agriculture/forest - Health - Tourism - Biodiversity - Risk Water - Transport infrastructure & building - Energy - Territories	France	1960-2099	Policy maker; Experts; Members of French ecology & energy department	Report on data, methods, averaged values, maps	Providing climate change scenarios to an interdepartmental working group in order to assess impacts, adaptation and associated costs, of climate change in France
MF-2: Climate change over the Loire Basin	Hydrology	Loire Basin region	1950- 2100 (time slices)	Scientist: hydrologist	Climate data, reanalysis (1970-2007)	Providing climate change scenarios for vulnerability studies of human activities and environment to the effects of climate change on flood regimes and droughts in the Loire Basin.

WUR: regional climate modelling using PRECIS	All sectors (no specific)	Mostly developing countries	20^{th},21^{st} century	Impact researchers	Regional model 4D forcing data for PRECIS	Delivering 4D climate data to perform dynamical downscaling of climate scenarios with PRECIS model and then run impact models.
IPSL-1: impact of global changes on freshwater fish biodiversity*****	Ecology (population analysis)	Adour river, France	1970-2100	Scientist: ecologists	Indices	Processing and delivering ecological indices in order to assess the effect of climate change on the viability of main freshwater fishes.
IPSL-2: impact of climate change on crop yields in the tropics*****	Agriculture	West Africa	1968-2100	Expert in agriculture	Indices	Processing regional climate data and running crop models in order to provide scenarios of crop yields evolution in the future for the tropics.
IPSL-3: sensitivity of power distribution to high temp. variation	Energy sector	Europe and China	1961-2000	Deciders in firms	Report on indices trends, and methods	Developing and analysing an indicator to describe vulnerability to climate change of an industrial firm of the energy sector.
IPSL-4: impact of climate change on agrosystems,	Agriculture (forestry, crops and pasture); land use and GHG budget	Global; Europe; France	1960-2100	Scientist: land use researchers; climatologists	Indices	From yields and agrosystems changes, assess land use change impacts on GHG budget
SMHI: development of climate scenario informa-tion for the Swedish forestry sector	Forestry	Sweden	1961-2100, with 30-years time-slices	Scientists: forestry impact researchers Forestry sector representatives	Climate data and climate indices	Providing regional climate scenario data and information to run impact model and support decision makers in the forestry sector

* Use case providing sectorial information rather than climate information (second category of use case)

Table 1: Use cases overview: description of sector, category, region and period of interest, type of users, requested information and brief description of the 17 Use Cases gathered in task 1 of the IS-ENES WP 11.

3. DATA NEEDS

Table 2 summarizes features of information that has been requested to perform impact studies in the 17 Use Cases. Parameters, resolution, format and grids are included. Use cases present a wide diversity relatively to data features. As in the previous section, we organize the information so as to provide the best overview of the Use Case diversity.

3.1. PARAMETERS

3.1.1. Terminology

One must distinguish 2 types of parameters: climate parameters and sectorial parameters. The first category refers to climate as the second one is specific to studied sector. Examples are river flows for the hydrological sector; fish occurrence or population viability for ecological cases, etc.
Parameters can also be divided in two sub-categories: raw data and indices. Raw data are direct output of climate model; generally they are not directly used to assess impact but to run impact models. Indices are post-processed variables. They are developed to bring specific information on vulnerabilities or impact. Indices can be computed from simple operations or can be determined using an impact model based on statistical or dynamical methods.
Finally, the third distinction refers to the way of using data. Final parameters are delivered to users. It can be climate raw data, climate indices or sectorial indices. Auxiliary parameters are used in some use cases to develop and run statistical downscaling methods, regional model or impact model; to make data correction, to validate results or to develop climate indices.
The links between these different types of parameters are shown in Figure 2. Auxiliary parameters are in blue and final parameters are in green. Though auxiliary parameters are of first importance in some use cases workflow, they are too numerous to be all described. In this section, description will focus on final parameters of the 17 Use Cases. Auxiliary parameters issue will be more largely addressed during the e-portal implementation phase (deliverable D11.3). A short discussion is proposed in section 3.1.3.

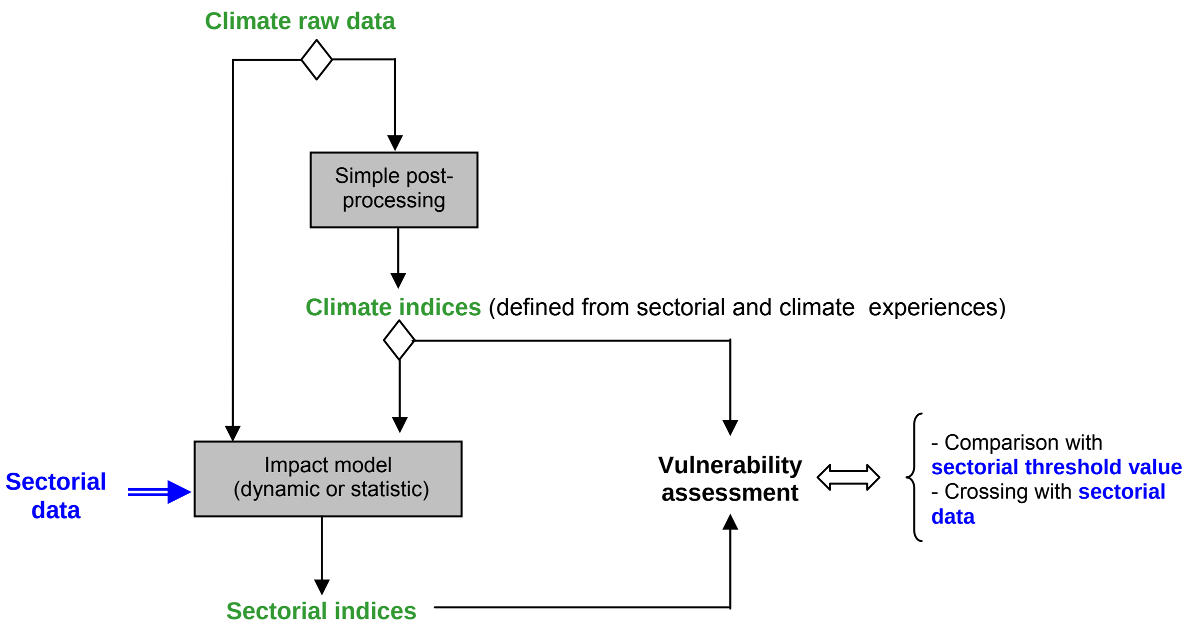

Figure 2: Links between climate parameters (raw data, indices) and sectorial parameters (raw data and indices). Final parameters that are delivered to users are in green, intermediary parameters that are used to compute or validate final parameters are in blue.

3.1.2. Final climate parameters

In the 17 use cases, parameters are most often requested at surface (at 2m): ***liquid precipitation*** appears in almost all requests as ***mean temperature***, ***minimal temperature***, ***maximal temperature*** and ***short wave radiation*** appear in more than 50% of the requests.
Solid precipitation, ***wind (at 10 meters)***, ***IR radiation***; ***relative humidity*** and ***potential evaporation*** are also often provided.
Pressure, cloud cover, diurnal temperature range, geopotential, soil temperature, soil moisture and gust wind speed are only occasional requests.

More generally (from KNMI Workshop discussion), parameters used for impact studies can be classified from 7 main variables (appendix B): ***precipitation, temperature, wind, radiation, humidity, pressure and orography***.
We distinguish:

- ***Derived parameters*** that are directly connected to these 7 main variables (for example as convective or large scale precipitation). They are diagnosed and stored during climate simulations.
- ***Climate indices*** that are calculated from the 7 main variables and/or derived parameters: for example "number of dry days per year", "number of frost days per season", "total rainfall from events > 60mm/days", etc.… Climate indices can be univariate or multivariate, most often they are computed from temperature and precipitation derived parameters. An important climate indices database has been developed during the STARDEX project (http://www.cru.uea.ac.uk/projects/stardex/). Since, the STARDEX core indices (http://www.cru.uea.ac.uk/projects/stardex/deis/Core_Indices.pdf) have been used in many impact studies and could serve as a reference for the e-portal implementation. Indices from the ECA&D database could also be used to complete the STARDEX list. In addition, in some of the 17 IS-ENES Use Cases, specific indices have been specifically adapted to answer user needs (SMHI; IPSL-energy use cases). They would also be implemented for illustration.

3.1.3. Final sectorial parameters

Final sectorial parameters are associated to the second category of use cases (see section 2.1): those ones for which it is not possible to distinguish climate information and sectorial information during processing (IPSL-1 and IPSL-2 use cases). Sectorial parameters are specific and depend on objectives and vulnerabilities that are adressed. There isn't a limited list of such parameters. Here, we give examples coming from the 2 IPSL use cases.
The first case is associated to agriculture sectors. An agro-impact model developed by climatologist and agro-scientists has been ran using climate forcing. The final parameter for this use case is crop yields. They have been analysed by multidisciplinary team to assess vulnerability of Africa agriculture to climate change.
The second use case is related to ecological topics. In this case, a "HCE" model including both downscaling computation and impact assessment has been developed by a team of climate statisticians. The "HCE" model allows to derive directly ecological indices (fish occurrence in the Adour river) from global climate data. In that case, it is impossible to separate climate information from sectorial one.

3.1.4. Auxiliary parameters

For many cases (more than 50%), auxiliary parameters are used to process data and compute final products. They could be climate data or sectorial data. They include historical parameters for a

reference period (observation, reanalysis); and simulated parameters for the projected period. They are used to implement downscaling and correction methods, to develop indices or to validate some results. For example, mean sea-level pressure is used for classifying weather types in the downscaling method developed at CERFACS, SAFRAN reanalysis dataset is used for making correction of climate parameters of the Meteo-France data (see MF-1, MF-2 and CERFACS-2 use cases) and topography parameters are used to downscale climate data at very local scale in the CMCC cases.
Because they come from a very wide range of data set and data centre having different data policy, it will be difficult to include these data in the e-impact portal. However, without these data, part of the use case workflow could not be implemented. This problem should be addressed and solved in task 3.

3.2. GEOGRAPHICAL AREA & HORIZONTAL RESOLUTION

Geographical areas extend from points to any square selected from lat/lon or other projection. Use cases include also specific areas like river basins or countries. They can be selected using masking techniques based on EU NUTS2 region. Few cases consider vertical profiles (WUR, INHGA, IPSL-4 use cases).
Data are used on different type of grids: regular lat/lon; Lambert; National grids like Rijksdriehoekstelsel (NL) that often implies regridding from natural grid.
Three kinds of temporal resolution appear in the use cases: global (100-300km), regional (7-50 km) and very local (< 1km) ones. Regional data can be divided in two categories following modelling consideration: resolution of 25-50 km for the first generation of regional models and resolution of about 10km for the new generation of regional models and for statistical methods.
As expected, the ***most frequent request is for regional data*** (46%), but we record also ***large score for global data*** (42%). In fact, regional data are not systematically available in specific region and then replaced by global ones. Requests for local data are still minor (12%) presumably because of the difficulty to compute such data and higher uncertainties.

3.3. TEMPORAL RESOLUTION

In term of temporal resolution, daily data are requested in most cases (58%) following by “sub-daily” data (29%) which include data at 6 hours or hour time steps. Then, we have request for yearly and monthly data with a same percentage (18%) and interest for decadal data appears only in one of the use cases (6%).
It’s worth noting the high rate of sub-daily data request that will surely still increase in the next years. In fact, hourly data are often used to run impact models in hydrology and geotechnics. It will probably be extended to other sectors. Actually, confidence in this temporal resolution is very weak. It is important to ensure that hourly data are used with care and with suitable uncertainty assessment.

3.4. FORMAT

Format depends strongly on user own practice and flexibility. Most often ASCII data are provided because many users do not how to use specific format. Other users request NETCDF or GRIB data that are input format of their impact models. In practice these formats have been promoted by the climate and numerical weather prediction communities respectively.
PP file format is used in the WUR use case which is the input format for PRECIS regional model. However this format presents several drawbacks and will not be conserved in the e-impact portal.

Group; use case title	climate parameters [1]	Climate and sectorial indices	Horizontal resolution	Temporal resolution	Grid or projection	Final data format
KNMI-1: FEMS/NHI	Pr (L), PE, RH, Rad, P, T and T_{min} at surf.	None	100km is ok; 10km is better	6 hours	Regular lat/lon grid: EPSG 4326	Netcdf 4 with CMOR and CF convention
KNMI-2: EU-CLUE SCANNER	T ; Pr at surface	- Mean Diurnal Range [2] - Max(min) T of warmest(coldest) month - Pr of wettest /coldest month - Total Pr of crop /growing season	100km is ok; better if 1km	Monthly and Yearly or decadal	Lambert	Ascii (GIS format)
KNMI-3: WUR-Climate data for metaphor	Pr(L); T; T_{max} at surface ; CC	- Daily precipitation duration - Weather extremes	Local scale; 10km; 100km	Daily;	Regular lat/lon grid: EPSG 4326	ASCII
KNMI-4: PBL-Nature planner	RH, T, Pr(L) at surface	- Weather extremes (occurrence of wet and dry years)	100km	yearly	Regular lat/lon grid: EPSG 28992 (Rijksdriehoeks)	ASCII
CERFACS-1: impact/adaptation in an estuary	T; Pr (L); PE at surface	none	8km	daily	Lambert	ASCII
CERFACS-2: impact on Somme and Seine river basins	T_{max}; T_{min}; Pr (L+S); PE; Rad (SW & IR) at surface; W_{10m}	none	8km	Daily and hourly (except T_{max}; T_{min}; PE)	Lambert	ASCII
INHGA: Danube middle and lower Basin	Pr(S+L); T ; T_{max}; T_{min}; P; RH; G at surface, 500/800hPa	none	1 degree	daily	Regular lat/lon grid	ASCII; NetCDF
CMCC-1: effect of intense rainfall on landslide events	T; Tmin; Tmax; Pr(L); RH at surface; W_{10m}	none	7 or 2.8 km; downscaling at 100m	hourly	Regular lat/lon grid: WGS84	Grib2, NetCDF and ASCII
CMCC-2: Effect of climate change on landslide events	T; T_{min}; T_{max}; Pr(L); RH at surface; W_{10m}	none	8 or 14 km	6 hours	Regular lat/lon grid: WGS84	Grib2, NetCDF and ASCII
MF-1: scenarios for the evaluation of impacts and adaptation in France	T; T_{min}; T_{max}; Pr (S+L); Rad (SW & IR) at surface W_{10m}	Climate extreme indices: hot-days threshold, frost days; longest heat-waves; heavy rainfall threshold; greatest 5-days rainfall; longest dry period; maximum wind…	50 km and 150 km	daily	Model grids: stretched grid (50km) and irregular lat/lon (150km)	ASCII
MF-2: Climate change over the Loire Basin	T; Pr (S+L); Rad (SW & IR) at surface W_{10m} T_{min}; T_{max} only for	none	50 km and 8km	Daily for simulation; Hourly for	Model stretched grid (simulation 50km) and	ASCII

	simulated data			reanalysis	Lambert (reanalysis 8km)	
WUR: regional climate modelling using PRECIS	4D forcings; T; T_{min}; T_{max}; Pr (S+ L); RH; Rad (SW) ; EP; runoff at surface &W_{10m}	None	Global data (100-300km)	Daily and 30 year monthly mean	Not specified in Use Case	PP format
IPSL-1: impact of global changes on freshwater fish biodiversity	Data derived from T, P, Pr, Rad (SW)	Occurrence of 13 most prevalent freshwater fish species.	Global data (100-300km)	monthly	Point (measure stations)	ASCII
IPSL-2: impact of climate change on crop yields in the tropics	T_{min}; T_{max}; Pr (S+ L); Rad (SW,IR) ; PE	Crop yields	Global (100-300km) and regional (50km) data	daily	Irregular lat/lon grid	ASCII
IPSL-3: sensitivity of power distribu-tion to high temp. variation	DTR, T_{min}, T_{max}	$DTR\text{-}DTR_{ref} \geq 5°C$	Global (100-300km)	daily	Regular lat/lon grid	Image and text document
IPSL-4: impact of climate change on agrosystems,	T; Pr (S+L); RH; Rad (SW & IR) at surface W_{10m}	Not specified in Use Case	Global (100-300km); higher resolution for Europe/France	Not specified in Use Case	Regular lat/lon grid	NetCDF, ASCII
SMHI: development of climate scenario informa-tion for the Swedish forestry sector	T; T_{min}; T_{max}; Pr (S+ L); PE; Rad at surf. W_{10m}, gust wind speed, soil T, soil moisture	Various climate indices based on: T; T_{min}; T_{max}; Pr (S+L); RH; PE; P at surface wind speed, gust wind speed, soil temperature, soil moisture.	50 or 25 km	daily	Regular lat/lon	ASCII, NetCDF CF- convention GRIB1; image (.jpeg, …) text document

(1) Pr = Precipitation (L = Liquid, S = Solid) ; PE = Potential Evaporation ; RH = Relative Humidity ; Rad = radiation (SW= short wave; IR = Infra Red) ; P = Pressure ; T = Mean Tempeature ; Tmin = Minimum Temperature ; Tmax = Maximum Temperature ; CC = Cloud cover; W_{10m} = wind speed at 10 meters; DTR = Diurnal temperature Range (T_{min} - T_{max})
(2) Mean Diurnal Range = Mean of monthly (Tmax –Tmin)

Table 2: Description of data used in the 17 use cases: parameters/indices; horizontal end temporal resolution; grid projection and format.

4. TOOLS AND METHODS

IS-ENES cases show that there is a large variety of practices, methods and tools used to fulfill the user needs. A list of the tools used in the IS-ENES use cases has been presented in Appendix B of the D 11.1 deliverable related to the Use case description. Here, we completed the list and reorganized tools regarding their category of use. We define three categories:

- Data producing tools → Climate science component
- Data delivering tools → IT component
- Communication tools → Transverse component

4.1. DATA PRODUCING TOOLS

Data producing tools are used for processing, analyzing and reformatting data. They are also used to assess uncertainties and quality.

Table 3 summarizes tools considering the different type of transformation and related methods. Though there are a limited number of transformations, the table shows the diversity of methods and tools developed in each institute to deal with data and impact studies. Strengths and weaknesses of each tools/methods should be assessed; the best ones will be implemented in the e-portal. The choice will rely on technical and scientific criteria. For example, free software (FERRET, NCL; R) will be preferred to commercial one (IDL, Matlab, Excel). This evaluation will be performed in task 3. Detailed information and reference for each tool are given in appendix C.

Action	Methods	Tools
Data extraction	Masking techniques, region/point selection, period selection, parameter selection	NUTS regions, CERFACS extract_nc (C), NCO
Regridding interpolation	Nearest neighbor ; bilinear ; bicubic; spline	CDO ; OASIS ; R ; Ferret; FORTRAN
Data correction	Mean correction Quantile-quantile correction CDF transformation	Météo-France correctmod ; IPSL indices-software (Fortran) LSCE R-package « cdf-transform »
Common data manipulation	mean, max, min, …	Custom R script ; CDO; NCL
Downscaling	Dynamical downscaling Statistical downscaling	ARPEGE-Climat, PRECIS; COSMO-LM; LMDZ-zoomed; … Computational software: FORTRAN HCE models (ABT method) CERFACS 'dsclim' (weather types method) CMCC_downscaling method Stochastic tools (Based on: CDO, FERRET, R softwares
Indices calculation	STARDEX and tailored indices	IPSL indices-software (FORTRAN)
Subsetting	*ND*[*]	*ND*[*]
Statistical analysis	Significativity test (kendall,	Custom R-script; Matlab; Excel

	kolmogorov-smirnov….); trends ; extrem events; comparison; validation	
Data visualisation	Maps, plots…	Ferret ; Matlab ; R ; NCL ; GMT, WMS; ARCGIS; GRADS; IDL
reformatting	**In**: GRIB, NetCDF3/4, PP **Out**: ASCII, NetCDF3/4 (with CF-convention), Grib2, PP	GDAL, CDO; OGC services; IDL; CMOR
reporting	/	Word; office and other word processors

*ND: Not described in Use Cases

Table 3: tools and methods used in the 17 IS-ENES Use Cases regarding data producing actions

4.2. DELIVERING TOOLS

Several secure download protocols enable to restrict data access to specific person using credentials. They are generally used in most cases. Sometimes and for specific product like report, information has been sent by simple mail.
The tools used in the 17 IS-ENES Use Cases are listed below (table 4):

Action	Methods	Tools
Data retrieval	Secure download system Non-secure download system	FTP, INSPIRE compliant OGC services; HTTP protocol Mail

Table 4: tools used in the 17 IS-ENES use cases for delivering products.

4.3. COMMUNICATION TOOLS

Communication is a transverse component as it occurs at each step of the process. Needs for communication encompass :

- Information on climate system and climate modeling
- Information on products: dataset, area, period, resolution parameters, indices, analysis, visualisation...
- Information on methods and tools to process data
- Discussion to define the request considering data and methods availability and their performance
- Technical information like data volume, delivering methods/tools, format...
- Information concerning job status and completion
- Uncertainties, quality and limit of the final products
- Guidance for data use and vulnerability/risk assessment

In the 17 use cases, information has been shared between users and providers through direct contact: mail, phone or meeting. Web interface like web portal is not much used.

5. PROCESS

Workflows differ from one case to another one. However it is possible to compare and gather the information of each use case in order to create a global process. By process we mean the usual way to "deliver climate information for impact studies". The process proposed here includes several main sub-processes. Sub-processes are the main and common functions of the workflow described in the 17 IS-ENES use cases. They allow to pass from one state of the data delivering process to another one and then reach objectives and get final products with required standards. Each sub-process is generally composed of several single actions (not defined in this section - actions can vary from one use case to another one). The process is different of "protocol" or "procedure" which is a description step by step of proceeding ("who is doing what"). Protocol should be considered further in order to implement the e-portal in task 3.

The process presented here has been built up in order to give the best representation of use cases diversity. No use case includes the whole process. Generally each case focuses on one part of the global process (data delivering, data processing …). Here we propose a synthesis of the information gathered in the workflow of the 17 IS-ENES use cases. Finally, the result can be considered as the "best manner" according to the 17 use cases to provide climate products to user communities. Further discussions about the "ideal" way of proceeding to complete this first analysis will be carried out in task 3.

5.1. MACRO-PROCESS

First, it is important to clearly define the framework of our system and specify the main input, output, actors and objectives. This information is summarized in the diagram shown in figure 3.
IS-ENES JRA5 deals with the common practice for the climate modelling community to deliver climate information to many different users of both impact and decision-maker communities. Objective is to provide services to users and help data providers in this mission. The e-portal will serve as a support for this purpose. There is indeed a growing interest to use climate information, but work to be done between climate variables as model outputs and the delivery to users for impact studies is in general not well understood and underestimated.

Process design depends on the main objective. From the user point of view, the objective is, first, to retrieve data and visualisations of different parameters (see section 3) in order to perform vulnerability assessment and, second, to get quality information and guides for using these products. From the provider point of view; the objective is to give easy access to these products whilst minimizing their intervention and ensuring that the products will be used with adapted cautions and for adapted purposes. Here, we adopt the "provider point of view".

Inputs of our system include first needs for impact and vulnerability assessment leading to specific request; but also the availability of a large amount of data, methods and expertise to fulfil the requests. Actors for our system are scientists from climate and meteorological research institutes and people from impact and decision-making communities (engineers, scientists, decision makers). At the end of the process, users will get:

- processed data, indices, visualisation responding to their initial request
- guide for using information and recommendations depending on data quality
- information on methods and tools used for data processing

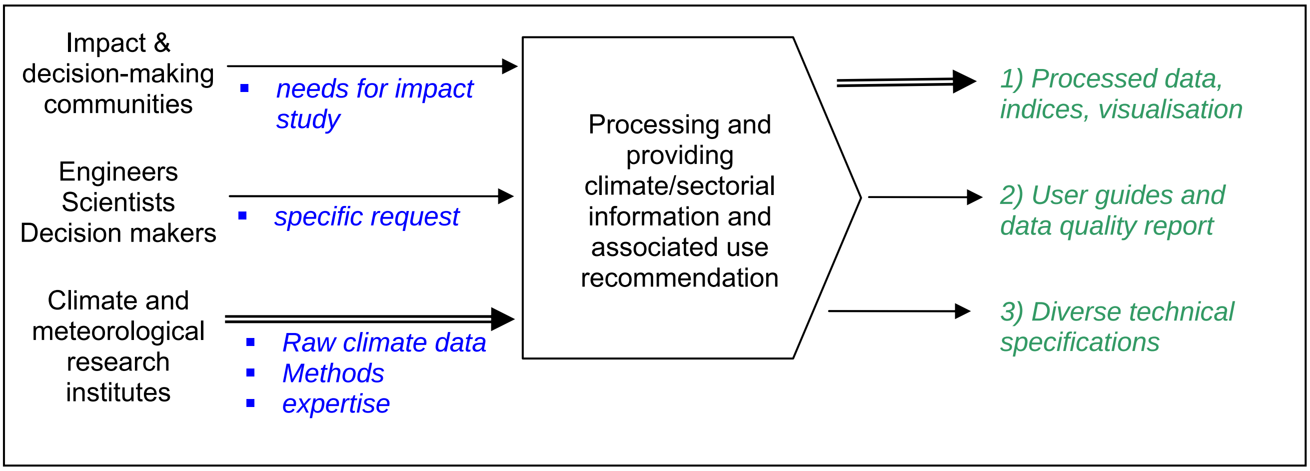

Figure 3: Macro-process related to climate information delivering for users of both impact and decision maker communities. Data provider point of view is adopted.

5.2. DETAILED PROCESS

The macro-process can be derived in several detailed sub-processes that require different scientific and technical skills. Seven sub-processes have been selected to link inputs (climate raw data) and outputs (data and information used in impact studies):

1. Collecting, analysing and validating the requests
2. Defining proceeding instructions: dataset & methods
3. Planning
4. Data Processing
5. Quality assessment
6. Data Packaging
7. Data Release

Sub-processes and their connections are presented in the figure 4. Further information for each sub-process is given hereafter. Sub-processes are discussed in term of actors, tools, support, content, input, and output. The sub-processes n°4 "Data Processing", n°5 "Quality assessment", n°6 "Data Packaging" are more complex. Further information is detailed section 5 and section 6.

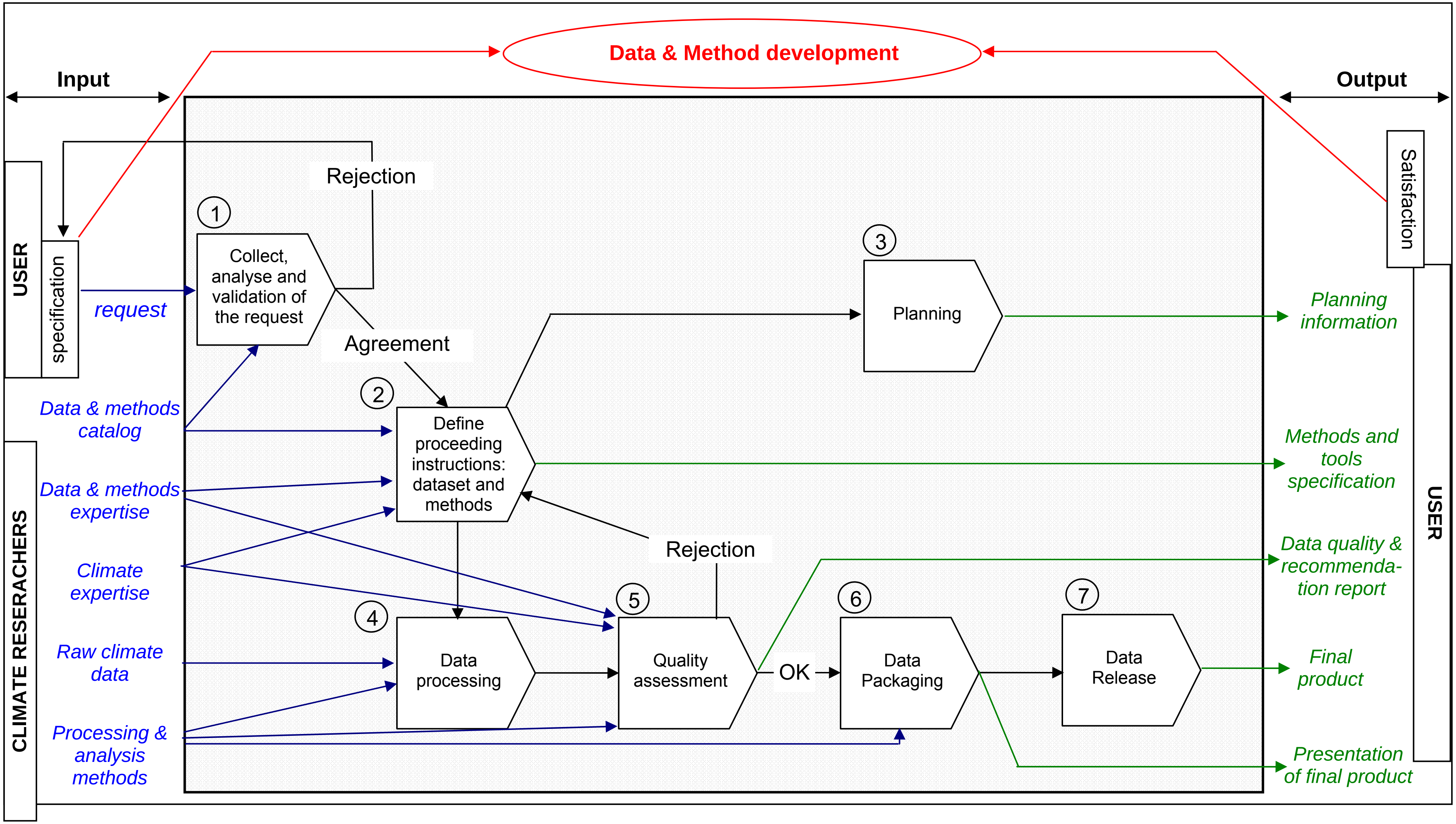

Figure 4: Processus concering the production and release of climate information for users of impact and decision-making communities. It has been defined from the analysis of the 17 IS-ENES use cases.

5.2.1. Sub-process 1: "Collecting, analysing and validating the requests"

In some cases because different languages and understanding between communities several interactions are needed between users and climate scientists to design a product that fits well the needs and the model/data skills and availability. Objective of the first sub-process is to retrieve and check user request. If the request is feasible regarding the available data, methods, etc…; it will be possible to launch the 2nd sub-process. Otherwise, users will adapt their requests and submit them again for evaluation in sub-process 1.

Actors:	- Data Providers / users
Tools:	- Phone/mail/meeting
Content:	- Selection 1: released information - Selection 2: parameter/indices - Selection 3: period/area - Selection 4: temporal and horizontal resolution - Selection 5: format - Selection 6: type of uncertainties that will be taken into account
Input:	- List of possible choice for each selection criterium
Output:	- Description of the final product
Support:	- Use case description as illustration for inexperienced user - General documentation about climate impact studies, uncertainties, models

5.2.2. Sub-process 2: "Defining proceeding instructions: dataset & methods"

Here, the objective is to define the best way for proceeding depending on the available datasets and methods. The selected procedure will serve especially for the "data processing" phase. It is called "workflow" in the next sections. It can be modified if the quality of the results is considered as insufficient (sub-process n°4).

Actors:	- Data Providers
Tools:	- Phone/mail/meeting
Content:	- Selection 1: dataset => scenario/model/realisation => reanalysis/observation - Selection 2: methods for data processing and packaging - Selection 3: methods for data analysis
Input:	- List of available methods, dataset, resolutions …
Output:	- proceeding instructions - report on proceeding instructions
Support:	- Documentation to link available global climate projections (CMIP or other multimodel ensembles) and national scenarios - User guide to describe each method (data processing and data analysis) - Description of available dataset

5.2.3. Sub-process 3: "Planning"

Some of the request implies treatment of large volume of data even if small regions are considered (for example a NetCDF file including global daily temperatures on a coarse resolution over the 1960-2100 period requires more than one Megabyte). Usually, this information is gathered in a technical sheet or given by an informal way.

Actors:	- Data providers
Tools:	- Personal experience of data processing - Planning board or other tools
Content:	- Defining production time and date for data retrieval - Defining data volume - Defining proceeding for data retrieval
Input:	- proceeding instructions from sub-process n°2 - data engineer schedule;
Output:	- planning report for users
Support:	/

5.2.4. Sub-process 4: "Data processing"

This sub-process consists in preparing data following user specification and proceeding instructions. Tools and software used for processing data are specific at each transformation. They have been described in section 4 "Tools and Methods". The order of the transformation sequence is also very important and needs to be considered in the analysis of uncertainties. Indeed erroneous sequence could lead to misleading results (for example comparison of data on different grid is not allowed, regridding step should first be applied). This point will be detailed in section 6.
In this sub-process, one deals with raw data and "heavy" transformation. A second set of transformation is performed to obtained final products (see sub-process n°6).

Who:	- Data provider
Tools:	- Depending on action
Content:	- Action 1: data extraction - Action 2: regridding - Action 3: data correction - Action 4: common transformation (mean, max, min…) - Action 5: statistical interpolation (for hourly data) - Action 6: downscaling (statistical and dynamical methods) - Action 7: indices calculation
Input:	- raw data; methods; expertise, tools
Output:	- processed data
Support:	- User guide to describe each tools describing function/functionality/use

5.2.5. Sub-process 5: "Quality assessment"

Facilitating data access to many users is very important, especially to encourage vulnerability assessment, climate awareness, and also to discharge climatologists schedule. But being ensured that data are used in a good way is a matter of concern. Any data should be delivered with a set of recommendations, use guide and warning concerning data validity.
Moreover, if quality assessment shows a lack of confidence for a given request, different actions could be envisaged. In some cases, dataset and processing methods (sub-process 2) could be revised in order to improve final products quality and reliability. In other cases, products could be delivered with caution. And in "high uncertainty" cases, data should likely not be provided because. This problem must be addressed before retrieving the e-impact portal.

Who:	- Data provider
Tools:	- Depending on action
Content:	- model uncertainties via multi-model analysis - natural variability via multi-realisation analysis - socio-economical uncertainties via multi-scenario analysis - effect of the correction method via comparison of corrected and non-corrected data - effect of downscaling via comparison of => global vs regional results => several downscaling methods - regridding effect via evaluation of interpolation error - data confidence via adequacy of model physics with design of the impact study (parameter, resolution, data use…)
Input:	- processed data
Output:	- recommendation for data use - data quality assessment and uncertainty assessment.
Support:	- User guide describing each tools - User guide describing uncertainty types and methods to deal with.

5.2.6. Sub-process 6: "Data packaging"

Here, data are already processed; they only need final shaping to match user requirements before delivering. The actions performed in this sub-process depend also on quality conclusions (sub-process n°5).

Actors:	- Data provider
Tools:	- Depending on actions
Content:	- Action 1: subset selection - Action 2: analysis => statistical analysis (mean, trends, regression…) => comparison / validation => report or fact sheet production - Action 3: graphical representation / visualisation - Action 4: format transformation
Input:	- Processed data - Quality specifications
Output:	- packaged processed data
Support:	- User guide describing each tools

5.2.7. Sub-process 7: "Data delivering"

The last sub-process considers data delivering with suitable secure level and easy processing for user. Instructions for data retrieval are provided to users during the planning sub-process (n°2).

Actors:	- IT engineer / Data provider
Tools:	- secure download protocol software - mail
Content:	- Action 1: providing access authorization and identification (credentials) - Action 2: data release/retrieving
Input:	- packaged and processed data
Output:	- packaged and processed data
Support:	- User guide to describe function/functionality/use of software

6. QUALITY ASSESSMENT

6.1. UNCERTAINTIES AND ERRORS

Several sources of uncertainties are responsible for decreasing quality of impact studies:

- inherent uncertainties of climate study:
  - Limited understanding of climate system that limits modelling performance
  - Limited knowledge of initial conditions (particularly ocean circulation).
  - Stochastic behaviour of climate system that is not completely caught by models
  - Socio-economical projections that are not precisely predictable
- Imperfection of models and methods :
  - Imperfection of global models concerning the representation of sub-scale processes (parameterisation) and missing processes because of their CPU cost.
  - Imperfection of regional models concerning forcing, parameterisation, missing processes …
  - Shortcoming of statistical transformations like downscaling, hourly interpolation, grid interpolation… (including poor understanding of how uncertainty is propagated and possibly amplified through the processing chain)

It is also worth noticing there are insufficient observations to constrain the model uncertainty. Actually, we don't have observational back-up (over the last 100 or 150 years) to check that models are able to describe the observed change before using them to predict future changes. Then we use an "ensemble of opportunity" in which all models predict a change in some quantity. Such consensus predictions need to be used with great cautions.

In addition, errors due to an inappropriate use of methods or data set decrease also the quality of impact studies:

- Error due to an unsuitable use of methods:
  - correction of data with unsuitable observations or reanalysis dataset.
  - inappropriate statistical method (weighted averaging, interpolation, …)
  - incorrect sequences of transformation: applying data transformation (averaging, indices calculation…) on a non regular grids
- Error due to not suitable use of available dataset
  - Using "incoherent" dataset for multi-simulation analysis
  - studying region that displays no data confidence
  - using hourly data of global models…

6.2. HOW DO WE IMPROVE QUALITY OF STUDY?

It is important to assess quantitatively uncertainties and reduce bias if it is possible. Except for the first type of uncertainty "limited understanding of climate system", uncertainties can be (at least partly) assessed. Methods that are currently used have been listed in section 4. We remind them below:

To assess inherent uncertainties of climate study:

- Multi-realisation analysis to deal with natural variability
  - Make distinction between variability noise and anthropogenic signal.
- Multi-scenario analysis to deal with socio-economical uncertainties
  - Assess range of values depending on "socio-economic" decisions and time frame.

To assess imperfection of model and methods:

- Multi-model analysis to deal with model uncertainties
  - Assess range of values
- Comparison of several downscaling methods (dynamical and statistical)
  - Assess range of values due to downscaling
- Comparison of different statistical method (temporal downscaling, extreme analysis, interpolation…)

  - Select the best one or assess uncertainties coming from correction
- Calculating model bias to assess model performance and then
  - Making data correction to reduce bias
  - Subsetting dataset to get a “best dataset” and reduce bias

Some of the errors due to inappropriate use of models and datasets could be easily avoided. It requires to have a good knowledge of dataset, methods and model skills. It needs also additional and deeper analyses that are often time expensive. For example, it is possible to control methods and data use in:

- Comparing of corrected and non-corrected data to assess real effect of the correction method
- Evaluating strengths and weaknesses of available observation and reanalysis data set before use for data correction
- Comparing global results versus regional ones to confirm the benefit of downscaling
- Evaluating interpolation errors to assess regridding effect
- Evaluating adequacy between physics of models / bias evaluation and the design of the impact study (parameter, resolution, data use…) to assess data confidence.

6.3. USE CASE ANALYSIS

Uncertainties have been taken into account in almost all use cases. But all sources of uncertainties have not been investigated. The most frequent analyses consist in multi-scenario, multi-model, multi-ensemble and multi-downscaling assessment, bias evaluation and also climate data correction. Moreover methods used to assess uncertainty differ from one case to another one. For example analysis of multi-model dataset has been performed via:

- Unweighted method (most frequent)
- Weighted method or subsetting (in a few cases)
- Entropy method (only in one case)

Few cases have assessed interpolation error and tested several interpolation methods though it is a main issue or discussed correction method. No study has assessed benefit of downscaling.
The analysis of use cases does not bring any information about the reason that led climatologist to make these choices and analyses. One of the main reason for this is that these choices of methodology by the climatologist have already been done outside the Use Case and it is not contained in the workflow, as the climatologist is often specialized in only a few methods, that the number of methods is often very limited, and that he is evaluating if the tool is appropriate or not before accepting to work on the data request. Deeper investigation would be useful to answer this question.

Finally, the analysis of the IS-ENES use cases show that more than 50% of users are aware of these sources of error and ask for information about uncertainties. Most of them are not skilled concerning methods and recommendation to deal with. This must be taken into account in the e-portal implementation, as users will be in charge to choose process and retrieve products.

7. WEB IMPLEMENTATION

Here, we propose recommendations for web implementation. They result from the previous analysis of the use cases and from discussions occurring during the KNMI workshop (august 2010) with the partners of JRA5.

7.1. PROCESS MODIFICATION

Actually, data providers are responsible for each step of the process defined section 4. They make choices and perform data processing. Implementation of the e-impact portal will support data providers in their task:

- In sub-processes n°1 and n°2, web catalogue browsing will replace direct communication with data provider. Users could directly describe their request and selecting methods and tools considering many possibilities.
- Sub-process n°3 could be processed with automated planning tools. Users will be informed of status and completion by e-mail.
- For data processing, one should distinguished 3 kinds of processed data:
    - Pre-cooked data that are stored on portal or upload from data centre.
    - Interactive processing
    - Long running / offline / batch processing

  The last category should still be support by data providers. But precooked data and interactive processing will be directly carried out by users.
- Quality assessment is specific to each case. It can not be easily applied generally. It is an important part of the transfer of knowledge between data providers and users that needs to be better highlighted in different studies. However, a work will start in task 3 to define generic tools or metrics that could help users in quality assessment. Some specific documentation and user guide could also be standardised into the e-portal.
- In sub-process n°6, part of transformations (format, sub-setting, extraction …), graphical representations, and statistical analysis could be directly done via the e-portal. However, some specific analysis will need expertise of climatologists and some specific software can be misused without sufficient knowledge of the methods.
- In sub-process n°7, providers will only continue in managing the authorization procedure.

7.2. PROCEDURES – USERS POINT OF VIEW

With the e-portal implementation, users will become the main actors of the process. It's important to define procedure following the user point of view. As defined in section 4; objective for user is first, to retrieve needed data and visualisations of different parameters/indices via an easy way and, second, to get quality information and guides for using these products.

A first "step by step" procedure from the user point of view has been envisaged during the KNMI workshop (August 2010). We propose in figure 5, an example of procedure gathering actions and interactions between the different actors for the data processing phase. It is a first draft that doesn't include all possibilities. It will be completed and improved in task 3. Procedures will be created for each phase of the process. The final procedure that will be used to design the e-portal should consider all users proceeding possibilities in order to be suitable for very different cases and requests.

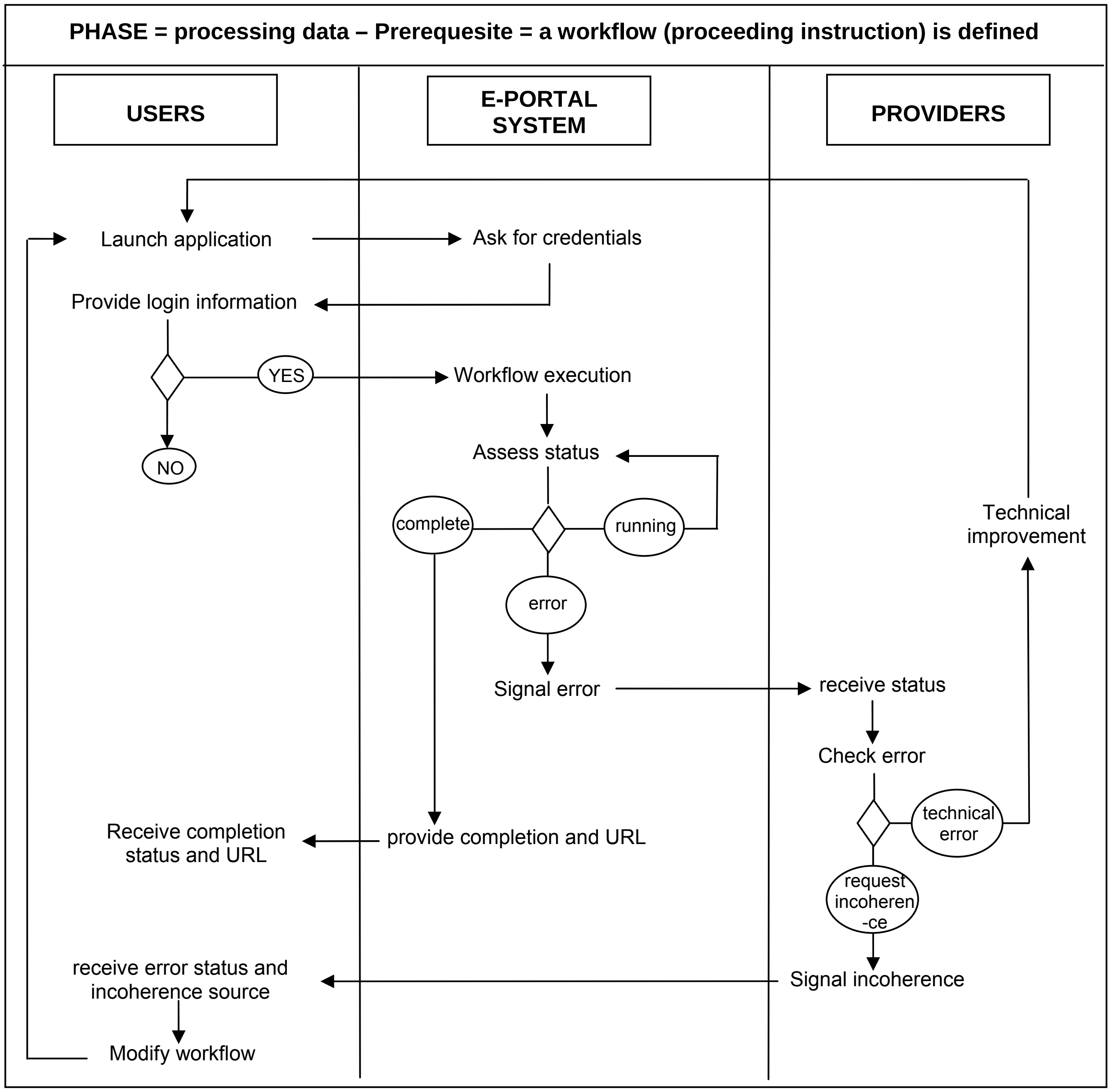

Figure 5: example of procedure for the data processing phase

7.3. DATA PROCESSING CAPABILITIES

In the first version (prototype), the e-impact portal could not support the process in full. Part of the data transformation (downscaling) will not be on-line. The related products will be pre-cooked and stored on the portal. The capacity of the e-portal will be extended with time and include more and more possibilities. Considering web services capabilities, the "building bricks" that a user can apply on data in the prototype portal will include:

- Extraction
  - For a certain time period, geographical coverage, different parameters, scenarios
  - Spatially according to a geographical mask (river basin)
    - Masks available from NUTS-2 regions

    - Discussion going on in CF conventions about large scale masks
  - with modification of data type (output can be point data)
- Subsetting
- Simple operation like averaging over 30 years
- Aggregation
- Output reformatting
  - Precision of data
  - For example limit the number of digits in ASCII files.
- Reprojection
- Regridding
  - Gaussian reduced → regular grids
- Indices calculation using existing tools like CDO
- Comparison
  - Compare parameters from different scenarios / ensembles
  - Compare parameters from simulation to those from observation ones.
- Graphical visualisation

In the prototype, the following action will not be supported:

- Downscaling will be done offline because:
  - dynamic downscaling is very computer intensive and some use cases will start directly from climate output of regional models.
  - statistical downscaling requires expert knowledge. Support cannot be done in an automated manner.

Discussions are going on about data correction. Problems concern auxiliary data (e.g. OBS data) that should not be stored on the portal itself but via references to other places. This could impede to perform correction on-line.

7.4. USERS/PROVIDERS INTERACTION - DOCUMENTATION

The implementation of the e-portal will reduce direct interaction between experts and users. Documentation, guidance, website links, illustration will be strongly developed in the e-portal in order to bring help to users.
Currently, the dialog between users and providers is done through direct way: mail, phone, and meeting. Users can clarify their needs at each step of the process and ask for further information at anytime. The e-portal supposed that users are able to deal with climate information, climate methods, uncertainties… For example, in sub-process 1, users should define a realistic request regarding climate data availability, model skills and uncertainties. Without a minimum knowledge, request will be rejected or not filled. In subset 2, users are expected to know enough about processing methods and data set to define their own proceeding instructions. If some users have these skills, most of them haven't. Then, in addition to the web documentation and guides, contact point for specific information must also be maintained.
Four levels of information should be supplied:

- Data description via metadata, DRS which is a naming conventions of data entities within data archives, it facilitates documentation and discovery
- Interactive documentation via fact sheet, user guide, illustration…
- Electronic Helpdesk via:
  - Request/question form
  - Wiki
  - FAQ
- Contact point to get specific expertise from climate experts
  - Phone
  - Mail
  - meeting

Here, we propose a list of interactive documentation gathered from the analysis of the Use Cases and that must be implemented:

- General documentation about:
  - climate impact studies, uncertainties, models
  - link between model runs from available global climate projections and national ones.
  - models (see CIM developed in METAFOR)
  - methods available for data processing, packaging and data analysis
  - data processing tools including function/functionality/use information
  - data packaging tools
  - data delivering way
  - uncertainty types and methods to deal with.
- List of do's and don'ts (Never use one climate scenario/ensemble, etc…)
- Use case description as illustration for inexperienced user. The use cases will be implemented with predefined procedures, including documentation. The portal will demonstrate the procedure including interaction between user and climate expert.
  - Each step implemented from a use case should be thoroughly explained (Why which scenarios)
  - Downscaling and correction method even if they are not included will be also explained
  - Expert knowledge must be included
- Advices to make workflows (proceeding instructions defined in sub-process 2) in a human readable form.
- Examples of workflow.

It will be completed with documentation about the e-portal like:

- Description of how use the portal, how does it work…
- About the services provided by the e-Impact portal.

The realization of these documents should be performed in strong interaction with the national and international projects that consider also the link between climate and user communities.

7.5. WEB PRESENTING TOOLS

With the e-portal interface, a new category of tools will be needed: the "web presenting tools". They include five categories of services: Discovery service, view service, download service, transformation service and documentation. In addition, the e-Impact portal needs to comply with the EU INSPIRE directives. That means that the data must be described, discoverable, viewable and downloadable according to INSPIRE standards.

7.5.1. Discovery service

It allows searching and identifying climate data and climate data services. It is based on metadata content. Tools for this purpose are OGC CSW Catalogue service (GeoNetworks). It could rely on the SA2 portal that also provides catalogue.

7.5.2. View service

It allows navigating, browsing and graphically displaying the climate data and associated metadata. Tools for maps are OGC WMS: for example KNMI WMS Server; THREDDS WMS Server. For time series and box plots; NCL or R scripts could be used.

7.5.3. Download service

It allows the users to obtain the digital data in various formats according to their specifications and using standard protocols (http, ftp). Tools for this service are:

- OGC WCS
  - KNMI WCS Server
  - THREDDS WCS
- OpenDAP
  - THREDDS
- FTP
  - THREDDS
- HTTP, HTTPS

7.5.4. Optional Transformation Service and Invoke Spatial Data Service

It allows to pre- or post process climate data on the fly in the e-Impact portal. Some question should be resolved as:

- Do we only provide pre-calculated data or do we allow users to do transformations?
- Interactive or non interactive processing? (Store data temporary, or stream it directly to the user).

Tools used for this purpose are OGC Web Processing Service (WPS). Processing will be preferentially based on R-Scripts and CDO.

7.5.5. Documentation tools

- Content management system: Plone (thorough testing is required)
- Wiki
- Forum for users

Feedback from the users is very important. A procedure will allow to get users "feeling" in order to improve the service. Workflow statistics will help develop the service.

7.6. TECHNICAL ISSUES

Diversity in data needs leads to several technical issues:
- Do we provide all parameters that are available in ESG data nodes? If we make a limited the list of parameters we might restrict ourselves for the future.
- Parameters should be according to the CMOR2 convention: (standard names/units, like stricter CF-conventions). CMOR = Climate Model Output Rewriter
- Do we store (downscaled) data on the portal? Best would be to put the data on the ESG nodes.

- We need upload functionality
- In case of our own e-Impact portal:
  - SCP, FTP
  - Web interface
  - In case of ESG nodes
  - Use ESG publisher

Diversity of users leads also to problems. We have to consider at least two types of users:

- Users who like to explore
- Users with a specific purpose in mind

Different way to proceed will be defined regarding type of users. How can the user choose what input data he needs?

- List of ESG data node URLS?
- Different models / emission scenarios / ensembles

8. CONCLUSION

The 17 IS-ENES use cases give a good overview of the user request and its extent in term of objectives, parameters, areas, periods, resolution, final format, processing methods and tools. Inventories and classifications have been made for each of these factors. The major bias of this sample concerns the studied region: many cases focus on countries, cities or rivers of the European region but it is without consequences for our analysis.

This sample confirms some common and well-known results. There is a strong interest for higher and higher resolution data; many requests are for very located area like cities and specific rivers or ecosystem zones. The use cases show also the difficulty for users to select by themselves good datasets, processing methods and tools because of their large number. This sample points also out newer features. For example, sub-daily data has been used in many cases though confidence in this temporal resolution is very weak. It is often needed because of the technical limits of the impact models used. This example shows the need to adapt the available products to the new request. Use cases highlight also an increase of the user's awareness especially concerning the limits of climate study. In more than 50% of use cases, users are aware of the existence of several sources of uncertainty and ask for information. Users know also the risk associated to use short-term projections and request most often information for middle term period (2050).

The use cases highlighted the difficulty to answer user request. There are three main reasons for that. First the wide range of request that leads to different processing steps. Second, work that must be done between climate model output and the delivery of information to users is complex, underestimated and often not well understood by the user community. Third, most impact studies are still in the field of research activity and based on new results and new methods. This emphasizes the importance to keep flexibility in the way of providing data, methods and tools and to implement them in the e-impact portal. In order to help users to use the e-portal, dataset, methods and tools should be organised and well documented. Examples of cases including specific workflows, methods, dataset and tools will be completely illustrated.

A detailed analysis of use cases workflow has enabled to best identify the key steps that must be achieved to deliver data to users community. We select seven main sub-processes including collection, analysis and validation of the requests; definition of proceeding instructions; planning; data processing; quality assessment; data packaging and data release phases. This first draft should be improved in task 3 with the objective to define what will be the "ideal" way of proceeding. This work will be completed by the identification of what is missing in the actual studies and will serve to facilitate the implementation of the e-impact portal.

We also analysed how uncertainties have been addressed in the use cases. Beyond the inherent climate uncertainty sources, one must also take into account the errors due to misuse methods and tools. No consideration of these factors leads to erroneous interpretation of the results. Sources of errors are numerous as well as the methods and tools to deal with them. Quantification and/or reduction of uncertainties and bias need to have a good knowledge of datasets, methods and model skills and need also complex analysis that are time expensive. Use cases show that few users are able to determine uncertainties by themselves. This introduces a double question: What is the best way to introduce the quality/uncertainty assessment in the e-portal? How do we deal with data that present low reliability? For this second part of the question, it could be envisaged to limit data access and impose climatologist help.

Finally it is worth noting that the development of common tools must be done in interaction with initiatives coming from other national, European and international projects. Actually the WGCM (Working Group on Coupled Modelling of the Word Climate Research Program) is in charge of the supervision on this topic at the international level via the CMIP5 project. IS-ENES is the European contribution to this. Information that will be diffused by the e-impact portal should be in phase with international progress.

APPENDIX A : ACRONYMS

ARPEGE: regional model developed at Météo-France.

BADC: The British Atmospheric Data Centre is the Natural Environment Research Council's (NERC) Designated Data Centre for the Atmospheric Sciences. The role of the BADC is to assist UK atmospheric researchers to locate, access and interpret atmospheric data and to ensure the long-term integrity of atmospheric data produced by NERC projects.

C4MIP: Coupled Climate-Carbon Cycle Model Inter-comparison Project (http://c4mip.lsce.ipsl.fr/) - International project devoted to run and evaluate coupled climate-carbon models as part of ESMs.

CCMVal: Chemistry-Climate Model Validation Activity (http://www.pa.op.dlr.de/CCMVal/) - International project devoted to evaluate the chemistry component of ESMs.

CERFACS: European Centre for Research and Advanced Training in Scientific Computation

CF: Climate and Forecast Metadata Convention (http://cf-pcmdi.llnl.gov/) - International standard for model data files format. .

CGCM: Coupled global circulation model

CIM: Common Information Model - The FP7 METAFOR project develops this standard.

CMCC: Italian Ltd company realizing scientific and applied activities in the field of climate change

CMIP-5 is the Coupled Model Intercomparison Project Phase 5. CMIP is a standard experimental protocol for studying the output of coupled ocean-atmosphere general circulation models (GCMs) that will be used to analyse multi-model simulations ensemble performed in the frame of the IPCC AR5 report

CMOR: Climate Model Output Rewriter (http://www2-pcmdi.llnl.gov/cmor) – Comprises a set of FORTRAN 90 functions that can be used to produce CF-compliant netCDF files that fulfill the requirements of many of the climate community's standard model experiments. The output resulting from CMOR is "selfdescribing" and facilitates analysis of results across models.

COSMO-LM: Members of the **C**limate**L**imited-area**M**odelling-Community (CLM-Community) are applying and developing the COSMO-CLM or CCLM, which is the COSMO model in CLimate Mode. The COSMO model is the nonhydrostatic operational weather prediction model applied and further developed by the national weather services joined in the COnsortium for SMall scale MOdelling (COSMO).

CSW: OGC Catalogue Service for Web interface standard

DEISA: Distributed European Infrastructure for Supercomputing Applications - an EC infrastructure project to optimise the access to high-performance computers for European users (http://www.deisa.org). After a first phase during FP6, a second phase, DEISA2, is funded under FP7.

DRS: Data reference syntax

ECA&D: The European Climate assessment and Dataset project aims to present information on changes in weather and climate extremes, as well as the daily dataset needed to monitor and analyse these extremes. ECA&D is initiated by the European Climate Support Network and supported by the Network of European Meteorological Services EUMETNET.

ENES: European Network for Earth System Modelling (http://www.enes.org) - A consortium of European institutions aiming at helping the development of use of ESMs for climate and Earth System studies.

ENSEMBLES: EU FP6 funded Integrated Project (http://ensembles-eu.metoffice.com/) -Provides future climate change projections in Europe.

ESM(s): Earth System Model(s). These models are developed to simulate the climate system in its full complexity, i.e. atmosphere, ocean and land which are the basic components included in climate models together with biogeochemical cycles, i.e., carbon cycle, vegetation, aerosol and chemistry processes.

HCE: Hydro-climate-ecological model

ICT: Information & Communication Technology

INHGA: Romania national authority in hydrology, hydrogeology and water management

INSPIRE: Infrastructure for Spatial Information in the European Community (http://www.ecgis.org/inspire)

IPCC: Intergovernmental Panel on Climate Change (http://www.ipcc.ch) - Provides regular scientific assessments reports (AR) on climate change issue under the auspices of UNEP and ICSU. The last one is the AR4 produced in 2007; the next one is AR5 to be issued in 2013…

IPSL: Institut Pierre Simon Laplace, federation of 5 research laboratories working on global environment and climate studies.

IS-ENES: InfraStructure for the European Network for Earth System Modelling

JRA: Joint Research Activity

KNMI: Royal Netherlands Meteorological Institute

LMDZ-zoomed is the regional version of the “Laboratoire de Méteorologie Dynamique” model.

METAFOR: Common Metadata for Climate Modelling Digital repositories (http://ncascms.nerc.ac.uk/METAFOR/) - FP7 infrastructure project under ENES, which focuses on developing common standards for data and model information exchange that will be implemented in IS-ENES.

MF (Météo-France): French weather Institute.

NCAR: National Center for Atmospheric Research in Boulder, USA (http://www.ncar.ucar.edu/)

netCDF: network Common Data Form (http://www.unidata.ucar.edu/software/netcdf/) - A set of software libraries and machine-independent data formats that support the creation, access, and sharing of arrayoriented scientific data

NUTS: The Nomenclature of Units for Territorial Statistics is a hierarchical system for dividing up the economic territory of the EU for 1) the collection, development and harmonisation of EU regional statistics; 2) socio-economic analyses of the regions; 3) framing of EU regional policies. This geocode standard is developed and regulated by the European Union, and thus only covers the member states of the EU in detail. For each EU member country, a hierarchy of three NUTS levels is established. NUTS 1 corresponds to major socio-economic regions; NUTS 2 to the basic regions for the application of regional policies and NUTS3 as small regions for specific diagnoses.

OASIS: Ocean Atmosphere Sea Ice and Soil coupler (http://www.cerfacs.fr/globc/software/oasis/) – A software component allowing synchronized exchanges of coupling information between numerical codes representing different components of the climate system. The latest versions, OASIS3 and OASIS4, were developed in the framework of the EU FP5 PRISM project, and are now supported and developed further by CERFACS (3), NEC (14) and CNRS (1) within the PRISM Support Initiative. Approximately 25 groups use the OASIS coupler internationally.

OGC: Open Geospatial Consortium - The OGC Catalog Service defines common interfaces to publish, discover, browse, and query metadata about geospatial data, services, and related resource information. It is applicable to the implementation of interfaces on catalogues of a variety of information resources.

PCMDI: The Program for Climate Model Diagnosis and Intercomparison has been established in 1989 at the Lawrence Livermore National Laboratory. The PCMDI mission is to develop improved methods and tools for the diagnosis and intercomparison of general circulation models (GCMs) that simulate the global climate.

PP file format is a record-based binary format used in a number of the BADC's datasets. It is a Met Office proprietary format so is mainly associated with Met Office products.

PRACE: Partnership for Advanced Computing in Europe (http://www.prace-project.eu/) - An FP7 infrastructure project devoted to prepare the implementation of world-class high-performance computers in Europe.

PRECIS: **P**roviding **RE**gional **C**limates for **I**mpacts **S**tudies". PRECIS is a regional climate modelling system developed at the Hadley Centre at the UK Met Office. PRECIS can be easily applied to any area of the globe to generate detailed climate change projections.

SAFRAN: Atmospheric reanalysis developed by Meteo-France at a national scale.

SMHI: Swedish institute providing operational services on climate, oceanography, meteorology and hydrology.

STARDEX: STAtistical and Regional Dynamical Downscaling of EXtreme for European Region, research project supported by the European Union Framework 5 Program http://www.cru.uea.ac.uk/projects/stardex/reports/STARDEX_FINAL_REPORT.pdf

v.E.R.C.: virtual Earth System Modelling Resource Centre

WCRP: World Climate Research Programme (http://www.wmo.ch/pages/prog/wcrp)

WP: Work Package

WU: Wageningen University and Reasearch Center

XML: Extensible Markup Language

APPENDIX B : CLASSIFICATION OF IMPACT MODEL PARAMETERS

Main Variables	Derived parameters	Indices
Precipitation	convective large scale liquid solid total total atmosphere water vapor content	Rain free days Drought (definition) Extremes Return period Peak intensity Wettest/coldest month
Temperature	2meter and other heights, Air, soil, sea surface Avg, max, min (2meter)	Tropical days (WMO) Warm days (WMO) Frost days (WMO) Ice days Heat waves Degree days Return period Diurnal (daily/monthly) temperature range
Wind	u, v component (multiple heights) speed direction	Peak Gust (10 meter) Return period
Radiation	incoming/downwelling long & short wave outgoing/upwelling cloud fraction	Sunshine hours
Humidity	2meter (multiple heights) specific relative (incl. avg, min, max) dew point soil moisture	Potential evapotranspiration Actual evaporation
Pressure	multiple heights mean sea level geo potential height	
Orography	land sea mask (mask or fraction) Ice cover (mask or fraction) Terrain (mask or fraction)	

APPENDIX C : DATA PRODUCING TOOLS

C.1. DESCRIPTION

CDO - Climate Data Operators
CDO is a collection of command line Operators to manipulate and analyze Climate and forecast model Data. Supported data formats are GRIB, netCDF, SERVICE, EXTRA and IEG. There are more than 400 operators available.

CERFACS' extract_nc
Small C program written by CERFACS used to extract 3D fields stored in netCDF file format and output data in ASCII format.

CERFACS' dsclim
A software package to downscale climate scenarios at regional scale using a weather-typing based statistical methodology. An innovative statistical downscaling methodology based on a weather-typing method described in Boé (2007); Boé and Terray (2008a,b); Boé et al. (2006). This methodology has already been used to provide downscaled climate scenarios over France for many groups in the climate impacts community.

CMCC' downscaling method
Statistical downscaling method based on areal morphological characteristic and geographical location developed at CMCC for landslide phenomena studies.

CMOR - Climate Model Output Rewriter
CMOR is a tool that produces CF-compliant netCDF files that fulfill the requirements of many of the climate community's standard model experiments. It is developed and distributed by PCMDI.

Ferret
Data visualization and powerful analysis tools with support for netCDF data. Ferret was developed as an adjunct to the numerical modeling studies of the Thermal Modeling and Analysis Project (NOAA/TMAP) from 1985.

Geospatial Data Abstraction Library - GDAL
File converter that can translate to and from many GIS formats including NetCDF. GDAL can also be used to warp rasters from one projection to another projection using different interpolation methods. The GDAL maintainership is actually done by the GDAL/OGR Project Management Committee under the Open Source Geospatial Foundation.

GMT
GMT is an open source collection of ~60 tools for manipulating geographic and Cartesian data sets (including filtering, trend fitting, gridding, projecting, etc.) and producing Encapsulated PostScript File (EPS) illustrations ranging from simple x-y plots via contour maps to artificially illuminated surfaces and 3-D perspective views. GMT supports ~30 map projections and transformations and comes with support data such as GSHHS coastlines, rivers, and political boundaries. GMT is developed and maintained by Paul Wessel and Walter H. F. Smith with help from a global set of volunteers, and is supported by the National Science Foundation. It is released under the GNU General Public License.

IDL - Interactive Data Language (commercial)
IDL is a programming language (developed by ITT Visual Information Solutions) used for data analysis. IDL is vectorized, numerical, and interactive, and is commonly used for interactive processing of large amounts of data (including image processing). The syntax includes many constructs from Fortran and some from C.

IPSL' indices-software

A FORTRAN package developed to calculate more than 50 indices coming from the STARDEX project database. It is also possible to apply correction to the raw simulated data following mean or quantile-quantile methods. It is usable with any gridded data set (model and observation). It has been developed for large dataset using parallel computation.

MATLAB (commercial)
Data visualization and powerful analysis tool. The MATLAB product family provides a high-level programming language, an interactive technical computing environment, and functions for: algorithm development, data analysis and visualization, numeric computation. Builtin support for NetCDF. support for GRIB through free third-party toolboxes.

IPSL/LSCE' cdf-transform
This R-package has been developed at LSCE to perform correction of data distribution. This method is very closed from the quantile-quantile data correction but is based on cdf function rather than pdf one. Moreover this method takes into account the shape of the future distribution in the correction process.

IPSL/LSCE' HCE model
The Hydro-climatic-ecological chain has been developed at LSCE to analyse the sensitivity of fish population in South France. It includes a downscaling step to convert global gridded data into local data (temperature, precipitation, flow) and an ecological niche model to turn local fields into freshwater fish occurrence. The two sub-models are based on aggregated boosted trees (ABT) statistical method.
Reference
Tisseuil C., Vrac M., Lek S., Wade A.J.,2009 (in revision). Statistical downscalling of river flows.
Tisseuil C., Vrac M., Wade A.J., Grenouillet G., Gevrey M., Lek S., 2009 (in preparation). Validating a hydro-ecological model to project fish community structure from general circulation models using downscaling techniques

Météo-France' correctmod
A software package, written in fortran programming language, to correct simulated variables from regional climate scenarios using available observations of these variables. The method is the so-called "quantile-quantile" method described in Déqué (2007). This methodology has already been used to provide corrected downscaled climate scenarios over France and eastern Europe for users coming from the impact community and for end-users.
Reference: Déqué, M., 2007: Frequency of precipitation and temperature extremes over France in an anthropogenic scenario: model results and statistical correction according to observed values. Global and Planetary Change, 57, 16-26.

NCL
(The NCAR Command Language (NCL), a product of the Computational & Information Systems Laboratory at the National Center for Atmospheric Research (NCAR) and sponsored by the National Science Foundation, is a free interpreted language designed specifically for scientific data processing and visualization.

NCL has robust file input and output. It can read and write netCDF-3, netCDF-4 classic (as of version 4.3.1), HDF4, binary, and ASCII data, and read HDF-EOS2, GRIB1, GRIB2 (as of version 4.3.0), and OGR files (shapefile, MapInfo, GMT, TIGER) (as of version 5.1.1). The graphics are world class and highly customizable.

NCO
Similar to CDO, NCO (netCDF Operators) are a suite of programs known as operators. NCO primarily aids manipulation and analysis of gridded scientific data in the netCDF format. Compared to CDO, NCO is limited to the netCDF format but provides some added functionality in manipulating attributes, as well as better compatibility with the CF convention.

OASIS3
OASIS3 is the direct evolution of the OASIS coupler developed since more than 10 years at CERFACS (Toulouse, France). OASIS3 is a portable set of Fortran 77, Fortran 90 and C routines. At run-time, OASIS3 acts as a separate mono process executable, which main function is to interpolate the coupling fields

exchanged between the component models, and as a library linked to the component models, the OASIS3 PRISM Model Interface Library (OASIS3 PSMILe). OASIS3 supports 2D coupling fields only. It can be used as a general 2D interpolator.

OpenDAP
OpenDAP is used for scientific data transfer and retrieval. OpenDAP is a framework for simplifying scientific networking. With OpenDAP local data can be made remotely accessible without the need of transferring the whole file

OpenLayers
OpenLayers be used within a web portal for visualization of geographic information. OpenLayers is a Javascript Library that can be used to put a dynamic map in any web page. Provides support for Web Mapping Services. OpenLayers is a project of the Open Source Geospatial Foundation.

R
Free software environment for statistical computing and graphics. R is a scripting language in which powerful operations on data can be applied. Within R libraries from other parties can be used to add extra functionality. The current R is the result of a collaborative effort with contributions from all over the world. R was initially written by Robert Gentleman and Ross Ihaka—also known as "*R & R*" of the Statistics Department of the University of Auckland.

stochasticTools
These are a set of programs made to predict daily rainfall sequence, developed in Matlab by Vincent Moron. The Matlab programs are converted to stand-alone c programs using the mcc tool. A set of scripts (mpg.tar.gz), developed by Lulin Song, allow the user to more easily convert the Matlab program to a stand-alone C program.

Web coverage Service - WCS
OGC defined standard for transferring geospatial data in the form of coverages over the internet. The Web Coverage Service can be used to provide access to raster data. WCS provides access to detailed sets of geospatial information, in forms that are useful for client-side rendering, multi-valued coverages, and input into scientific models and other clients. WCS provides data together with their detailed descriptions; allows complex queries against these data; and returns data with its original content (instead of images). A web coverage service provides functionality for transforming datasets to other projections and resolutions.

Web mapping Service - WMS
Visualization - OGC standard for visualizing any kind of geographical data in the form of images on the web. A WMS produces maps of spatially referenced data dynamically from geographic information.

Web processing Service – WPS
OGC standard which provides rules for standardizing how inputs and outputs for geospatial processing services are handled

Format description

Network Common Data Form - netCDF4 & netCDF3
Machine independent data format for the creation, access and sharing of array-oriented scientific data

Climate and Forecast conventions - CF conventions
Metadata convention designed to promote the processing and sharing of files created with the NetCDF API. The conventions define metadata that provide a definitive description of what the data in each variable represents, and the spatial and temporal properties of the data.

GRIB1 and GRIB2
WMO standard format for machine-independent storage and exchange of gridded meteorological data. Output format for several regional models, as well as for EC-Earth.

PP file format
It is a record-based binary format used in a number of the BADC's datasets. It is a Met Office proprietary format so is mainly associated with Met Office products.

C.2. REFERENCE

CDO	http://www.mpimet.mpg.de/fileadmin/software/cdo/
CMOR	http://www2-pcmdi.llnl.gov/cmor
CF conv	http://cf-pcmdi.llnl.gov/documents/cf-conventions/1.4
CERFACS' dsclim	http://www.cerfacs.fr/~page/
GDAL	http://www.gdal.org/
GMT	http://gmt.soest.hawaii.edu/
GNU GSL	http://www.gnu.org/software/gsl/
GNU Fortran	http://gcc.gnu.org/fortran/
GNU C	http://gcc.gnu.org/
GRIB1, GRIB2	http://www.wmo.int/pages/prog/www/WMOCodes.html
Ferret	http://ferret.pmel.noaa.gov/Ferret/
Matlab	http://www.mathworks.com
Metafor	http://metaforclimate.eu/
NCO	http://nco.sourceforge.net/
NCL	http://www.ncl.ucar.edu/
netCDF4,netCDF3	http://www.unidata.ucar.edu/software/netcdf/
OASIS3	http://www.prism.enes.org/PAEs/coupling_IO/software_OASIS3.php
Inspire	http://inspire.jrc.ec.europa.eu/
OGC	http://www.opengeospatial.org/
OpenDAP	http://opendap.org/
OpenLayers	http://openlayers.org/
R	http://www.r-project.org/
stochasticTools	http://iri.columbia.edu/climate/forecast/stochasticTools/
WCS	http://www.opengeospatial.org/standards/wcs
WMS	http://www.opengeospatial.org/standards/wms
WPS	http://www.opengeospatial.org/standards/wps