# IS-ENES – WP11 - JRA5

# D 11.1 – Final description of selected Use Cases including user requirements specification


**Abstract:**

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 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.

This document is a compilation of these national Use Cases, along with discussions about their common aspects and workflow, the sources of uncertainties, and the evaluation/feedback from potential users. The Use Cases selected for the e-impact-portal prototype are also identified.


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# Executive Summary

**I**nfra**S**tructure for the **E**uropean **N**etwork for **E**arth **S**ystem Modelling (IS-ENES) will develop a virtual Earth System Modelling Resource Centre (v.E.R.C.), integrating the European Earth system models (ESMs) and their hardware, software, and data environments. The overarching goal of this e-infrastructure is to further integrate the European climate modelling community, to help the definition of a common future strategy, to ease the development of full ESMs, to foster the execution and exploitation of high-end simulations, and to support the dissemination of model results and the interaction with the climate change impact community. The v.E.R.C. encompasses models, the tools to prepare, evaluate, run, store and exploit model simulations, the access to model results and to the European high-performance computing ecosystem – in particular the EU large infrastructures DEISA2 and PRACE. The v.E.R.C. developed by IS-ENES is based on generic ICT, Grid technology and subject-specific simulation codes and software environments.

IS-ENES is the infrastructure project of the European Network for Earth System Modelling (ENES). ENES gathers the European climate and Earth system modelling community working on understanding and prediction of future climate change. This community is strongly involved in the assessments of the Intergovernmental Panel on Climate Change and provides the predictions on which EU mitigation and adaptation policies are elaborated.

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. Networking activities will increase the cohesion of the European ESM community and advance a coherent European Network for Earth System modelling.

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. For that purpose a number of selected and representative national Use Cases for climate data has been selected.

This document is a compilation of these national Use Cases, along with discussions about their common aspects and workflow, the sources of uncertainties, and the evaluation/feedback from potential users. The Use Cases selected for the e-impact-portal prototype are also identified.

The main commonalities found are the need for global climate model data atmospheric parameters on a regional scale at the surface layer, although some use cases also need more layers (CMCC, WUR use cases). Also important to notice is the need to use regional downscaling models for providing high resolution parameters.

The selected Use Cases are the base for the User Requirements Document (URD), the Architectural Design Document (ADD) and software Specification document (SDD). The selected Use Cases will be implemented in the prototype e-impact portal. Users who were involved in defining the selected Use Cases will be part of the development process. They will review and approve relevant document and be involved in testing and improving thee-impact portal prototype.

# 1. INTRODUCTION

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. For that purpose a number of selected and representative Use Cases for climate data will be selected.

A Use Case is a document that describes the type of information needed, the intended use of the information, the way the end-users want to access the information and the requested flexibility. The Use Case also provides documentation about the information tailoring between the climate parameters and the parameters used by the stakeholders. The treatment of sources of uncertainties are also discussed in a Use Case.

The most common and important national Use Cases have been documented, covering a range of applications, such as water resources, forestry, agro and ecosystems, etc. These national Use Cases have been proposed for evaluation/revision and feedback to potential users by each partners, and corrected with these feedbacks. These Use Cases are compiled and discussed here.

Among these Use Cases, for each national partners, the most important and common ones will be selected for implementation in the e-impact-portal prototype. For these Use Cases, a much more detailed description (IT-oriented) will have to be provided so that they can be implemented in the e-impact-portal. Furthermore, these Use Cases will have to share a common workflow, glossary and common tools, which will be described in D11.2 (Baseline documents on e-resources/tools and transverse themes).

In the following sections, the national Use Cases for each partner will be presented, followed by a discussion about their common aspects and workflow, the sources of uncertainties, and the evaluation/feedback from potential users. The Use Cases selected for the e-impact-portal prototype will also be identified.

# 2. NATIONAL USE CASES COMPILATION

This section is a compilation of national Use Cases, classified by countries and partners. After each partners' Use Cases compilation, a discussion is provided about the general workflow and stakeholders interactions that these Use Cases are describing.

## 2.1. FRANCE

### 2.1.1. Météo-France - CNRM

Météo-France has more than fifteen-year experience in providing high-resolution climate change scenarios covering France for a wide range of communities. The first interested communities were impact research communities, particularly in the field of agriculture and hydrology, and the mode of exchange of data and expertise was though direct interaction with the research teams within the context of research projects. However, in the recent years, the requests from the impact communities increased dramatically and the range of users diversified a lot with in particular requests from governmental institutions or private companies. Within this new context, direct interaction between providers and users remains possible, in particular in the context of research projects, but difficult to generalize to all the modes of exchanges.

#### 2.1.1.1. General Use Cases discussion

The two chosen use cases illustrates the transition towards new ways of providing climate information on climate change that are no more direct interaction with research teams but are not yet a complete service for a wide range of communities including impact researchers, private companies and stake holders as this will be the case in a few years at the national level (GICC-DRIAS[1] project coordinated by Météo-France associating CERFACS and IPSL). They have been chosen because they are rather completed and because they illustrate the service to completely different communities, governmental institutions for the first one and selected research teams that answered a call of opportunity for the second.

The two use cases are the following:

1. Scenarios for the evaluation of impacts and adaptation to climate change in France This use-case describes the communication of information on future climate provided by the scientific community, in order to conduct studies on the cost of impacts and adaptation to climate change in France. An interdepartmental working group was settled to produce a report. The working group considered nine different domains: agriculture, forest / health / tourism / biodiversity / water / risk / transport infrastructure and building / energy / territories. The objective of the public stake-holders leading the group was to share the same information on climate change among the different participants of the group.

2. Scenarios for adaptation studies to climate change over the Loire Basin This use-case describes the communication of information on future climate provided by the scientific community, in order to conduct studies on the adaptation of the Loire Basin management plan to the impacts of climate change. The objective of the public managers is to develop a common knowledge on this topic that relies on research results. They have prepared and launched a call of opportunity open to the French scientific community to improve the knowledge of the vulnerabilities of human activities and environments to the effects of climate change over this region. They have appealed French climate research groups for choosing and providing climate change scenarios that could be used by other research groups working in a wide range of fields (hydrology, sociology …) to lead their research in response to the call of opportunity.

The detailed description of these use cases are given in Appendix “Météo-France Uses Cases”

[1] Donner accès aux scenarios climatiques Régionalisés français pour l’Impact et l’Adaptation de nos Sociétés et environnements (Give access to French regionalised climatic scenarios for impact and adaptation of our society and environments

#### 2.1.1.2. Selected use cases for implementation on the e-impact portal

The Use Case “Scenarios for the evaluation of impacts and adaptation to climate change in France” detailed in section G.1 has been selected for implementation in the e-impact portal, because it reflects the climate information delivery to stake holders and experts from a very wide range of disciplines (Agriculture, Health, DIACT, tourism) that is a challenge in satisfying all the needs.

#### 2.1.1.3. Common Tools

The two ensembles of scenarios associated to the two use cases have in common the provision of some “corrected” climate variables to account, whenever possible, for model systematic errors. For these “corrected” fields (temperature and precipitation) one common tool is used, the so-called “correctmod” software.

#### 2.1.1.4. Treatment of Sources of uncertainties

These use case also mark a progression towards a better accounting of uncertainties in climate projections. The first indeed only considers one downscaling methodology (dynamical), only two climate models and two different emission scenarios, when the second considers two different downscaling methodologies (dynamical from Météo-France, statistical from CERFACS), several models (global models from CMIP3 and one regional climate model), and three emission scenarios. We have to speak about ensemble of simulations of greater complexity in the second use case compared to the first. This has an implication on how to manage this complexity for users who generally ask for a few reference scenarios.

#### 2.1.1.5. User Support and Tailoring

For the two uses cases, different modes of support have been put in place. For the first one, it consists an interaction between one coordinator and the research team, for the second trough an e-mail link. For the two cases, a documentation associated to the ensembles of scenarios was provided on a web site and climatologist providing the data where invited to several workshops.

### 2.1.2. CNRS - IPSL

IPSL covers a wide range of scientific activities and has a strong investment in several projects dealing with hydrology or ecosystems, including the coupling between land surface model and agriculture. It provides large scale and regional scale simulations that are used as input in different impact studies. It has also a strong involment in the development of new statistical methods to analyse extreme events or provide appropriate downscaling strategies. Several analyses also use the land surface scheme ORCHIDEE to drive other models and analyse the impact of climate change at scales varying from global to regional, and even local. The work with the other communities, including the impact community is in general based on a two by two basis. Several projects are now emerging where in collaboration with CNRM and CERFACS the modelling groups gather their efforts in the distribution of climate output, and share their expertise to answer specific users.

#### 2.1.2.1. General Use Cases discussion

The selected use cases illustrate the diversity of approaches developed at IPSL and different degree of maturity in the treatment of uncertainties or in the interactions with users. In a first example a statistical method is used to direcly connect large scale model outputs and the aquatic biodiversity (fishs) in a river. The second case is dedicated to the link between model outputs and crop yields in Africa. The third case illustrates the different steps that are needed to produce a climate indicator that makes sense for the sector of energy supply and that can be computed from model outputs. This case was treated in partnership with CNSM and CERFACS. Finally the last case connects climate change, agriculture and land use with economy and the feedbacks of surface changes in the carbon cycle and atmospheric greenhouse gases.

#### 2.1.2.2. Selected use cases for implementation on the e-impact portal

Four use cases are proposed in the appendix. They concern:

1. Developing a hydro-climatic-ecological (HCE) model-chain to link large scale climate data to local scale occurrence of aquatic biodiversity

2. Assess the impacts of climate change on crop yields in the tropics

3. Developing and analysing an indicator to describe vulnerability of energy sector to climate change in term of power distribution

4. Impact of climate change on crop yields, interaction with economical models

In a first step only the first two will be considered for implementation on the e-impact portal.

##### 2.1.2.3. Common Tools

Specific softwares have been developed for downscaling and can be provided in R. A common solution to several cases was to use idl to transfom ascii format into the netcdf format.

A flexible fortran program has been developed to compute rapidly climate indices using daily timesteps from GCM outputs. Some of these indices are also directly computed using CDOn NCO and ferret libraries. Idl, R, ferret of excel are used for graphical display.

For the link with agriculture and economy FORCHIDEE (crop modelling tool in the tropics) and NEXUS land use & IMACLIM (land use module and economical model) are used, together with Fortran and C programs to drive the data flow between models.

Several correction methods are used considering either :

CDFT correction method.
Aggregated boosted trees (ABT) statistical method for the HCE model.
Model evaluation based on mean, standard deviation and pdf comparisons of observed and simulated data. For the pdf one the Kolmogorov-Smirnov test has been used.

Quantile-quantile correction method.

In addition Kendall test for trend significativity evaluation …is used in the agriculture cases.

##### 2.1.2.4. Treatment of Sources of uncertainties

In the different cases the sources of uncertainties are treated by first considering the ability of climate models to reproduce observed data, and the use of multi-model ensembles. Correction of model biases via different methods is also considered, but this aspect is in general not entirely represented in the production of error bars.

##### 2.1.2.5. User Support and Tailoring

There is no specific user support on these use cases. Up to now, researchers involved in the different studies, maintain the products by themselves and work in close collaboration with the end-users.

### 2.1.3. CERFACS

CERFACS is a provider of high-resolution statistically downscaled climate scenarios (associated with expertise) to impact modellers and expert study teams in France, within and outside research projects. Two Use Cases were chosen to be described here in the IS-ENES framework. These Use Cases are describing workflows that cover the most common data request types. Most of the data requests we receive are from the water resource management community, but some are also from the agricultural and land-use management communities.

#### 2.1.3.1. General Use Cases discussion

The Use Cases are detailed in Appendix "CERFACS Use Cases". The first Use Case is described in section D.1 is quite generic and describes very well the general workflow of most of the data requests received at

CERFACS for high-resolution downscaled climate scenarios. The second Use Case is described in D.2: it is more common in data requests embedded in research projects, and is thus more complicated. However, the users are more specialized people compared to the first Use Case, and it changes the workflow because the expertise needed by the users is not the same because they are also scientific people working in the same field, hence requiring less information than normal data users as in the first case.

Among these Use Cases, common requirements on climate model data and workflow can be identified :

1) Weather measured parameters: Temperature, humidity, wind and precipitation (total, or liquid and solid), radiation (infra-red, shortwave).
2) Derived parameters, such as potential evapotranspiration.
3) Geographical Coverage: France, river basins, smaller regions.
4) Time period: 1950-2100
5) Frequency: Daily data, but also hourly data (!)
6) Grid: Regular or individual points.
7) Format: ASCII or CSV (Excel), very rarely NetCDF.
8) Data delivery: FTP or Hard Disks.
9) Support: Emails, meetings, phone calls.

### 2.1.3.2. Selected use cases for implementation on the e-impact portal

The Use Case "Providing high-resolution climate change scenarios for impacts and adaptation in an Estuary" detailed in section D.1 has been selected for implementation in the e-impact portal, because it is quite generic and describes very well the general workflow of most of the data requests received at CERFACS for high-resolution downscaled climate scenarios

From this Use Case, an Information Technology (IT) Use Case will be derived to describe the necessary functions to be implemented in the e-impact portal using common tools, workflows and themes identified among all national Use Cases provided.

### 2.1.3.3. Common Tools

Some common tools used can be extracted from the Use Cases presented :

1) Spatial interpolation
2) Statistical downscaling methodology: CERFACS' dsclim.
3) Data extraction: NetCDF to CSV using CERFACS' extract_nc.
4) Data tailoring and mapping: derived parameters from base parameters.

The common tools draft is available in the document IS-ENES_11_MI11_2_common_tools.doc. For completeness, its draft version has been inserted in Appendix B.

### 2.1.3.4. Treatment of Sources of uncertainties

Users are generally aware of uncertainties, but don't know how to handle them. Therefore, we always suggest them to use 4 scenarios if possible, and never only one scenario. From past research projects, we know that the greatest uncertainties come from the global climate models (e.g. GICC-REXHYSS project), compared to the green house gas concentration scenarios or the downscaling methodologies themselves. Most, if not all of the users, have realized the importance of the uncertainties in climate data scenarios, and the need to take into account these uncertainties.

#### 2.1.3.5. User Support and Tailoring

For now, the data mapping and tailoring is done by using semi-automated scripts. The support is done manually (emails, phone calls, meetings). In the e-impact portal, in-depth documentation along with an organized way for user support must be implemented: automated user-support system, e.g. ticketing system. The data mapping and tailoring should be automatic and implemented, such as data reformatting, calculation of derived parameters, spatial interpolation, etc.

## 2.2. NETHERLANDS

### 2.2.1. KNMI

KNMI provides climate information and scenario's for the Netherlands to the Dutch policy makers, climate impact and climate effect communities. For IS-ENES we focus on delivering Climate Model Data to the climate effect community. We have interviewed 4 different user communities (hydrology, ecology, land use, and agriculture) and derived 4 use cases from 3 user communities. The agriculture community is interested in using climate model data, but does not want to be involved in this stage. They will join as soon as we have the demonstration portal ready and climate model data available. Another use case which was discussed was to validate evapotranspiration from a land use model using climate data, but this was regarded as model validation, and therefore not a suitable use case fro the e-impact portal.

The four defined use cases are:

1) FEWS/NHI: providing climate model data to the National Hydrological model suite using the FEWS interface
2) EU-CLUE Scanner: providing climate model data to a land use prediction model for Europe
3) Climate data for METAPHOR, a Spatial Population Analysis model
4) PBL-Nature planner, a model suite for planning the ecological main infrastructure of the Netherlands

The individual use cases can be found in the Appendix KNMI Use Cases**Erreur ! Source du renvoi introuvable.**.

Goal of specifying different use cases is to derive a common base set of requirements. With this set the core functionality of the e-impact portal tools can be developed. The core set of functionality can be expanded to incorporate specific use case requirements.

The use case are analysed to find common requirements on the climate model data. Of course each use case requires a different derived set of the climate model data, but by analysing the use cases e a common base climate data model set for further specialisation can be derived. Common requirements found:

1) All parameters at surface level (2 m)
2) Parameters needed are:
    a. weather parameters (like temperature, wind, precipitation)
    b. Derived parameters (like rain free days, summer temperature, daily min/max, extremes)
3) Scale: National coverage or European coverage
4) Grid: regular grid
5) Need for extra data processing functionality like averaging, interpolation, accumulation, … but with different needs
6) netCDF3/4 preferred format, but own community standard format would be better
7) FTP and/or OGC services preferred for data delivery

There are of course also many differences in requirements between the use cases. Differences are i.e. specific parameters needed (derived for e.g. growing season), time scale (ranging from 6 hourly data to decadal averages). With these aspects we need to deal with besides the common requirements.

From the list of common requirements, the following conclusions can be drawn:

1) The need for surface and weather parameters on European scale results in a significant data reduction. This information can be used to create base climate model datasets from which sub datasets can be derived.

2) The need for derived parameters and the need for data processing functionality indicates tools are needed to perform calculations on the base model data. As the derived parameters and data processing needs vary in each use case, datasets cannot be prepared in advance. However, we do see commonalities in calculations required.

3) Regular Grid: This indicates the native model grid needs to be transformed, which has to be done with great care.

4) For data delivery services and FTP can be used, netDCF is the preferred common format, but if possible conversion to domain specific formats must be provided.

#### 2.2.1.1. Selected use cases for implementation on the e-impact portal

The goal will be to develop the common functionality base for the use cases, and use this to expand and implement the four use cases found. To enable this, a common e-impact portal usage use case is derived. In this abstract use case, the user is modelled as the Climate Effect User (CE-User), where the CE-User can be a Land Use scientist, a Ecologist or a Hydrologist

The 'Compose climate model data set (CMDC)' use case can be described using one user goal level use case and four sub-function level use cases. For the e-impact portal it is foreseen that registration and login credentials will be needed. This can be modelled using a login and logout user level use case. These use cases will be defined in the next stage of the project and are not stated here.

In principle a CE user can make a simple climate model selection, i.e. no additional calculations are needed to make the dataset. Or a complex model selection, i.e. additional calculation is needed to make the dataset.

Use Case (CMDC-1): "Compose climate model data set"

- User-goal level
- Principle Actor: Climate Effect User (CE-User)
- Description:
    1 CE-User: Connects to climate model data center
    *CE-user repeats steps 2-3 until indicates finished*
    2 CMDC: Provides overview of available model data
    3 CE-User: Does one of the following:
    - Selects climate model data (CMDC-1.1)
    - Makes a complex climate model data selection (CMDC-1.2)
    - Checks status of complex selection (CMDC-1.3)
    - Downloads climate model data (CMDC-1.4)
    4 CE-User: Leaves climate model data center

Use Case (CMDC-1.1): "Select climate model data"

- Sub-function level
- Principle Actor: Climate Effect User (CE-User)
- Description:
    1 CE-User: Selects climate model, scenario and model parameter
    2 CMDC: Provides default for area, resolution, layer (height) and time range
    3 CE-User: Adjusts area, resolution, layer and time range
    4 CMDC: Puts data selection on overview of available data

Use Case (CMDC-1.2): "Complex climate model data selection"

- Sub-function level

- Principle Actor: Climate Effect User (CE-User)
- Description:
  1. CE-User: Selects al least one input model data selection by:
     a. Selecting climate model, scenario and model parameter and/or
     b. Selecting a data selection from the overview of available data
  2. CMDC: Provides default for area, resolution, layer (height) and time range
  3. CE-User: Adjusts area, resolution, layer and time range
  4. CE-User: Selects calculation to be performed on the selected model data (e.g. averaging, subtract, min/max values) and sets the calculation method parameters, if needed
  5. CMDC: Informs CE-User the calculation will be performed. Progress and result will be made available in the overview of available model data
  6. CMDC: Calculates the data selection and puts the status and result on the overview of available model data

Use Case (CMDC-1.3): “Check Status complex model data selection”

- Sub-function level
- Principle Actor: Climate Effect User (CE-User)
- Description:
  1. CE-User: Selects the overview of complex model data selections
  2. CMDC: Provides an overview of complex model selections

Use Case (CMDC-1.4): “Download climate model data”

- Sub-function level
- Principle Actor: Climate Effect User (CE-User)
- Description:
  1. CE-User: Selects climate model data from the overview of available model data
  2. CE-User: Selects one of the data transfer methods
  3. CMDC: Provides data via selected method

Technology variation: Data can be delivered via FTP, OGC Service and email.

The further detailing of this abstract common use case is part of the next stage of the project and will be described in deliverable D11.3 The e-impact-portal Software Requirements/Architectural Design/IO Specification.

#### 2.2.1.2. Common Tool Usage

As concluded from the common set of requirements, an important part of the e-impact portal will be the availability of tools to calculate specific parameters (like averages or derived parameters like rain free days) and re-projections (from native climate model grid to a regular grid). The users interviewed for the KNMI use cases do not have preference for certain tools but leave it to the portal developers to decide.

Within JRA5 a document describing a common tools list was written and reproduced in Appendix. From this list, tools will be selected to perform the calculations and conversions.

#### 2.2.1.3. Treatment of Sources of uncertainties

For the transformation from the original climate model data Gaussian Reduced Grid to Regular (lat lon) grid, standard tooling (e.g. Ferret) will be used. This transformation may introduce interpolation errors, especially at land-sea transitions. There are no regular grids matching exactly the Gaussian Reduced Grid, i.e. interpolation is unavoidable. This should be well documented and provided to the user of the data.

The users we interviewed are aware of the climate model uncertainties. Therefore they will use several different models/ensemble members. Bias corrections are made by the users by comparing their model results using historical station based data with user model runs using climate model data.

#### 2.2.1.4. User Support and Tailoring

The e-impact portal should provide the mentioned data processing and format conversion possibilities, besides the data download. With this, the user can make its own tailored dataset.

The KNMI use cases are representative for the climate effect community in the Netherlands. Other users might need more specific tailoring than is described in these use cases. Specific tailoring at KNMI is done on request by the Climate Services department

### 2.2.2. WUR

#### 2.2.2.1. Selected use cases for implementation on the e-impact portal

Many researchers / institutes worldwide, most in developing countries, are using PRECIS. Delivery of 4D climate data to be used as forcing data for dynamical downscaling of climate scenarios using the Hadley Centre PRECIS model, or alternative regional models. Data should be processed to PRECIS compatible format (or other relevant formats) and should be delivered on hard disks due to volume of the data.

#### 2.2.2.2. Common Tool Usage

- CDO for the data transform, extraction, re-projection and interpolation

#### 2.2.2.3. Treatment of Sources of uncertainties

#### 2.2.2.4. FORTRAN for output formatting to .pp : User Support and Tailoring

For user support a website containing detailed information on required input/output must be provided. Access to results of climate model post processing (regridding, reprojection to PRECIS and .pp requirements) must be provided through this website. A point of contact for further information is needed.

## 2.3. ROMANIA - INHGA

INHGA within IS-ENES project provides the climate information on the changes occurred in the extreme hydro meteorological events, obtained from climate scenarios by a statistical downscaling procedure for the Danube basin, especially for the lower basin. This information is providing to impact modellers, other researchers groups and to Romanian policy makers (Romanian Ministry of Environment and National Administration "*Romanian Water* ").

Details on the use-case are described in the Appendix INHGA Use Case. If the new users want to be involved other use cases will be included.

The results of post processing procedure will be presented in the synthetic representations (indices, graphs, maps). For user support a website containing detailed information must be provided. Access to climate model information must be provided through this website.

### 2.3.1. Common Tools Usage

- CDO for the data transform from GRIB to netCDF and for the data extraction and interpolation
- FORTRAN for spline interpolation
- MatLab for graphical representation
- R for running the routines for extremes, trends, etc.
- Tools for the downscaling precipitation by Hidden Markov Model (HMM).

The references for this tool are found at: http://iri.columbia.edu/climate/forecast/stochasticTools/

### 2.3.2. Treatment of Sources of uncertainties

Using four climate models, the optimal solution from these models must be found. This will be selected by means of the informational entropy methods.

For other sources of uncertainties, bias correction methods and estimations of signal – to - noise ratio are used.

### 2.3.3. Support to users

For user support a website containing detailed information must be provided. Access to results of climate model post processing (statistical downscaling) must be provided through this website. A point of contact for further information is needed.

## 2.4. ITALIA - CMCC

**(CMCC)** is the Italian research centre on climate science and policy. Its activities focus on the development and applications of models of climate dynamics, impacts of climate change and adaptation and mitigation policies. The CMCC produces numerical simulations of global and regional models of climate change, as well economic analysis of its impacts on terrestrial and marine ecosystems and on economic activities. Climate policies are also evaluated, jointly with their implications on energy investments, research and development and the diffusion of climate-friendly technologies. For IS-ENES we aim to improve the output of climate models taking into account the requirements of the community working on impacts of climate change. on extreme events (landslides).

Two use cases have been defined:

1) Evaluation of the effects of intense rainfall on landslides phenomena (mud strain).
2) Evaluation of the effects of climate changes on landslides phenomena triggered by precipitation events (clay strain).

The individual use cases can be found in Appendix CMCC Use Cases.

The use cases have been analysed in order to find common requirements on the climate model data The common requirements found are:

1) Parameters needed (minimum and maximum value of daily two meters temperature, precipitation, wind at 10 meters, relative humidity)
2) Scale: local coverage
3) Grid: regular grid
4) GRIB2 format, but also NETCFD could be used
5) FTP, WEB or Hard Disk exchange for data delivery

### 2.4.1. Selected use case for implementation in the e-impact-portal

The second Use Case has been selected for implementation in the e-impact-portal, because it describes very well the general workflow to provide data to the hydrogeological community studying landslides.Discuss about common tools used

In the e-impact portal, it will be necessary to make available some tools and procedures in order to calculate some derived variables and in order to perform some statistical analysis of the results (cumulate precipitations, averages, probability density functions and so on). It will be also necessary to include the algorithm for the statistical downscaling, for spatial interpolation and for data format conversion, if required.

### 2.4.2. Treatment of sources of uncertainties

The goal is to reproduce as well as possible the observation, in order to produce some realistic warning one or two days before the event. All the limitations existing for the simulation of reality, by using a model, must be taken into account. This limitation represents a *boundary* that has to be accepted, taking into account that a big improvement of the climatic model is still possible. It is important that the error estimation is quantified and provided to the users. Of course, bias correction can be done by the users, by comparing the model results with observed data.

### 2.4.3. User Support and Tailoring

The user support is ensured manually, by using e-mail exchange and phone calls. Some UNIX (LINUX) based script are provided, in such a way that the user could make its own tailored dataset.

## 2.5. SWEDEN - SMHI

SMHI is a government agency under the Ministry of the Environment. SMHI is responsible for managing and developing information on weather, water and climate that provides knowledge and advanced decision-making data for public services, the private sector and the general public. SMHI aims to contribute to increased social benefit, safety and a sustainable society. An integral part of the operations is the Research Department that develops methods, models and tools through vigorous international collaboration and participation in numerous research and development projects. The Rossby Centre is the unit under the Research Department that is responsible for climate research and modelling. Key tools in this research are the regional Rossby Centre Atmospheric model RCA3 and the regional coupled Rossby Centre Atmospheric Oceanic model RCAO. The Centre provides regional climate scenario information and expertise to stakeholders – both through research collaborations and tailored information to decision makers and end users at the national, Nordic and international level.

### 2.5.1. General Use Cases discussion

The Use Cases are detailed in Appendix J. The use cases provide a generic but realistic description of several similar use cases related to the forestry sector. The forestry sector was chosen because it is one of the few activities where the century-scale time perspective of climate scenarios is directly relevant today. Seedlings that are planted today should have optimum growth characteristics both in present day and future climate conditions, as well as being resistant to pest and pathogens throughout their lifetime. In general, tree biomass production is projected to increase in a warmer climate due to more favourable climate conditions further enhanced by the $CO_2$ fertilisation effect. To optimise the production, plant breeding materials as well as forest management practices need to adapt and take the changing conditions 50-100 years into the future into account already today. These requirements cannot be solved using climate model data directly. Instead, a range of 'forest models' (forest production, forest ecology, models of insects and pathogens, etc.) are forced by climate models scenario data. These impact models are typically developed within forestry research communities, and they carry out much of the end-users (forest owner) contacts.

### 2.5.2. Typical workflow and Common Tools

The virtually identical workflow encountered several related use cases concerning climate change impact to the Swedish and north European forestry sector. Common tools extracted are listed in bold italics:

1) Import GCM lateral boundary data from relevant GCMs (from originating institute, or from in-house runs). ***web portals, ftp/scp/rsync download***

2) Manipulation of GCM lateral boundary data for input to RCM: input formats NetCDF, ***GRIB1, GRIB2,*** handled by ***CDO, GRIB-API, Fortran***.

3) Dynamical downscaling by means of an ***RCM*** to spatial resolution of 50-10 km, in our case the ***RCA3*** or ***RCAO***.

4) Manipulation of RCM output files: ***GRIB, NetCDF, CDO, NCO***

5) Data analysis and tailoring: ***CDO, CDI, Matlab, Matlab-CDI toolbox, IDL, R***,
6) Data delivery: ***web portal, ftp, scp,*** formatted as ***NetCDF, Excel, ASCII, as well as image files (png, eps)***.

The common tools draft is available in the document IS-ENES_11_MI11_2_common_tools.doc. For completeness, its draft version has been inserted in Appendix B.

### 2.5.3. Treatment of Sources of uncertainties

Users are generally aware of the concept of uncertainties in climate models and climate scenarios, but do not know any details or how to manage the issue in the context of their applications. Therefore, we always suggest them to use several scenarios and always avoid focussing on only one scenario. From past research projects, we know that the greatest uncertainties come from the global climate models when it comes to seasonal means and otherwise large-scale aspects (e.g. PRUDENCE, ENSEMBLES projects), but for regional/local climate extremes the regional climate model formulation becomes important and may even dominate depending on which climate extreme is studied. Using a RCM as the principal downscaling tool allow us to disentangle some of the uncertainty into components related i) to scale translation (from the GCM to the RCM grid scale) and the possible need for further calibration/downscaling using statistical methods, ii) the RCM's own biases which are known from perfect boundary experiments where the RCM is driven at the lateral boundaries by data from a reanalysis dataset (i.e. ERA40 and ERA-Interim), iii) uncertainties related to future emission scenarios, iv) GCM biases and dependence on initial conditions (can sometimes be quantified if initial condition ensemble experiments are available from the GCM data provider). These aspects are explicitly discussed with the user and depending on their aim and preference a suitable RCM scenario ensemble is formed.

### 2.5.4. User Support and Tailoring

The user support is basically done in two ways. The primary and most important is to interact with the impact researchers to establish what they need in terms of climate scenarios and present day climate reference data. This involves in-depth discussions on climate scenario uncertainty, grid-scale data vs. point measurements, possibility to use an ensemble based (i.e. as many climate scenarios as possible/available) approach to their research. The climate scenarios are typically taken from databases of RCM output having a spatial resolution of 50-25(10) km and a temporal resolution of monthly to daily (sometimes sub-daily). For Sweden, the most basic data is available through a simple web interface, but an extended dataset can be produced using semi-automatic scripts (based on CDO, NCO). Further tailoring, which is more and more often requested, is carried out on demand. This typically involves calculation of some kind of 'specific climate index'. These indices are very often based on a set of standard basic components or calculation steps that are combined and tailored to create the requested index. This support is directed at highly qualified impact researchers and is carried out manually through (emails, phone calls, meetings). The second kind of support is to assist the impact researchers in their communication with end-users/stakeholders. This typically takes the form of overview presentations, panel discussions, expert support during stakeholder meetings, etc.

# 3. DISCUSSION AND CONCLUSION

The National Use Cases presented here are representative of a broad range of stakeholders and sectors: water resources and management, agro- and ecosystems, forestry, spatial planning and energy management. Every partner has submitted their Use Cases for users' evaluation to ensure that they are suitable and that they satisfy users' needs.

Following their evaluation, Use Cases for e-impact portal implementation have been selected among all these National Use Cases (see Appendices). Alternatively, a common e-impact portal Use Case can be derived from individual National Use Cases (e.g. KNMI).

The analyses of the different use cases show that, even though there is wide diversity between the cases, common practices and requirements emerge. In most cases, analyses of raw model data need to be transformed and/or corrected: several methods are proposed. Also, high resolution data is needed in most cases to have it at a scale that is relevant for impact studies. This is achieved through a combination of tools mixing regional models, statistical downscaling and data correction. These steps requires that data set of good quality are available for the learning phase of the method, as well as to estimate the vulnerability of the system or to isolate particular climate event that are particularly relevant for the impact under consideration. The different steps are in general not trivial and several guidelines are needed for the users.

An important service of the e-impact portal is the common tools set (see Appendix B). These tools will have to be generalized to provide needed common functionalities, such as calculations of derived parameters, averages, unit's changes, spatial and temporal interpolations, output reformatting, parameters tailoring, etc. The e-impact portal IT-like Use Cases will have to use this set of common tools.

The uncertainties are difficult to really quantify in an objective manner, but it is necessary to inform the users that they must take into account these uncertainties in the climate scenarios provided. The most common way among the National Use Cases to evaluate uncertainties is to use an ensemble of scenarios.

For User Support, extensive documentation is needed on the following subjects, along with a dedicated interactive support:

1) Downscaling methodologies and the climate models
2) Climate scenarios
3) Variables, derived or native
4) Uncertainties

All these Use Cases have common similarities, and these will have to be mainstreamed for their proper implementation in the e-impact portal (Table 1).

**Table 1: Use Cases summary (implemented Use Cases in the portal are grayed out)**

| Group and use case number/title | Sector | Region /Period | Period | Data Users | Released information | Short overview / objectives |
|---|---|---|---|---|---|---|
| **KNMI:** 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:** 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:** 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:** 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:** 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:** impact on Somme and Seine river basins | hydrology | Seine and Somme river 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 |

| Group and use case number/title | Sector | Region /Period | Period | Data Users | Released information | Short overview / objectives |
|---|---|---|---|---|---|---|
| **CMCC:** 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:** 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:** 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:** 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:** 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. |

| Group and use case number/title | Sector | Region /Period | Period | Data Users | Released information | Short overview / objectives |
|---|---|---|---|---|---|---|
| **IPSL:** 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:** 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:** 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 information 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 |

The main commonalities found are the need for global climate model data atmospheric parameters on a regional scale (5 to 50 km) at the surface layer, although some use cases also need more layers (CMCC, WUR use cases). Also important to notice is the need to use regional downscaling models for providing high resolution parameters, the need of long-term observations of good quality for the "learning phase" of these algorithms (preferably gridded). Finally, it must be stressed that many impact models work only with station data points, and not gridded data points. This almost invariably involves the added uncertainties of using data from a grid point as if it was a station data point.

In summary, a compilation of user evaluated National Use Cases have been presented. A total of 17 use cases have been defined and analysed. From the National Use Cases, Use Cases have been selected (or derived) for implementation in the e-impact portal. A strong interaction with the Common Tools deliverable is needed to mainstream all of the selected Use Cases into the portal. IT-like versions of the selected Use Cases will have to be prepared for the e-impact portal architecture design.

# APPENDIX A : ACRONYMS

AI: Authentication and Authorization Infrastructure: A service allowing access to restricted information in distributed centres based on permissions of the user kept in a database distributed amongst these centres

AEROCOM: (http://nansen.ipsl.jussieu.fr/AEROCOM/) Aerosol Comparisons between Observations and Models -International project devoted to evaluate the aerosol component of ESMs.

AOMIP: (http://efdl.cims.nyu.edu/projectaomip/overview.html )Arctic Ocean Model Inter-comparison Project, ARn: Assessment report number n – see IPCC

BFG: Bespoke Framework Generator (http://intranet.cs.man.ac.uk/cnc/projects/bfg.php) - a prototype technology supporting the flexible and rapid coupling of model components at a relatively high level, independent of specific coupling technology. Developed at the University of Manchester,

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.

CDO: Climate Data Operators (http://www.mpimet.mpg.de/cdo) - collection of about 100 functions developed by the MPI-M for handling and analyzing data produced by a variety of climate and NWP models - e.g. for file operations, simple statistics, or the calculation of climate indices. The code is used by around 150 groups (220 users) world-wide, including some of the project partners, calling the CDO around 200000 times per day.

CECILIA: The project's primary mission is to improve the understanding of local climate change in Central and Eastern Europe and its impacts into forestry, agriculture, hydrology and air quality (From: http://www.cecilia-eu.org/)

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

CFMIP: Cloud Feedback Model Inter-comparison Project (http://cfmip.metoffice.com/) -International project devoted to investigate cloud feedbacks in climate models and compare with available satellite data.

CGCM: Coupled global circulation model

CICLE: Calcul Intensif pour le CLimat et l'Environnement (http://dods.ipsl.jussieu.fr/omamce/ CICLE/) - A French project funded by Agence National de la Recherche to improve the portability and performance of French climate models.

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

CLIVAR: Climate Variability and Predictability (http://www.clivar.org/) - CLIVAR is one of the WCRP programs, and aims to understand the physical processes responsible for climate variability and predictability on different scales

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.

COMBINE: Project applied for within FP7 developing component models

CSW: OGC Catalogue Service for Web interface standard

DDC: Data Distribution Centre (http://www.ipcc-data.org/) - Distributes observational datasets and model results for a wide community of users involved in IPCC.

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.

EB: IS-ENES Executive Board

EC:European Commission

EGEE: Enabling Grids for E-sciencE (http://www.eu-egee.org/) - A European infrastructure project to help the development and dissemination of the use of Grid-technology for both computing and data access purposes.

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.

EPM: IS-ENES European Project Manager

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.

ESMF: Earth System Modelling Framework (http://www.esmf.ucar.edu/)- Devoted to define standards in the designing of climate model components for easier exchange and coupling, US-led

EUROCLIVAR: European Climate Variability and Predictability (http://www.knmi.nl/euroclivar/) - A concerted action under FP4 Environment program devoted to prepare the European implementation plan of the international WCRP CLIVAR programme EuroPlanet: A European Network for the Development of Planetary Sciences in Europe (http://europlanet.cesr.fr/) - FP6 integrated project for planetary sciences

FPn: Framework program number n – FPs are the funding programs for Research and Science of the EC g-Eclipse: Access the power of the Grid (http://www.geclipse.eu/) – Grid extension of the well-known

ECLIPSE programming environment

GEMS: Global and regional Earth-system (Atmosphere) Monitoring using Satellite and in-situ data (http://gems.ecmwf.int) - This EU-funded project is developing comprehensive data analysis and modelling systems for monitoring the global distributions of atmospheric constituents important for climate, air quality and ultra-violet radiation, with a focus on Europe.

GMES: Global Monitoring for Environment and Security (http://www.gmes.info/) - European initiative for the implementation of information services dealing with environment and security. Will be based on observation data received from Earth Observation satellites and ground based information. These data will be coordinated, analysed and prepared for end-users.

GO-ESSP: Global Organization for Earth System Science Portal (http://go-essp.gfdl.noaa.gov/) - Addresses the development and dissemination of standards for exchange of datasets in the field of Earth system science.

GRB: Grid Resource Broker

GRelC: The Grid Relational Catalog project (http://grelc.unile.it/) - Developed in Italy to manage databases on the Grid

HPC: High Performance Computing

I/O: Input/Output is the generic process of exchanging data during a simulation, either as input to the model or as output of model simulations

ICSU: International Council for Science (http://www.icsu.org)

ICT: Information & Communication Technology

IGBP: International Geosphere Biosphere Programme (http://www.igbp.kva.se/).

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…

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

LIM: Louvain-la-Neuve sea ice model (http://www.astr.ucl.ac.be/index.php?page=LIM Description) – A Sea Ice 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.

MPI: Message Passing Interface (http://www.mpi-forum.org/ )– A library for parallel programs

MT: IS-ENES Management Team

NASA: National Aeronautics and Space Administration (http://www.nasa.gov/home/)

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

NERC: National Environmental Research Council - Funding agency in the UK (http://www.nerc.ac.uk/)

NEMO: Nucleus for European Modelling of the Ocean (http://www.locean-ipsl.upmc.fr/NEMO/) - State-ofthe-art modelling framework including 3 components: an ocean general circulation model (OPA), a sea-icemodel (LIM) and a biogeochemistry model (TOP); NEMO is interfaced with all European atmospheric models via the OASIS coupler.

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

NWP: Numerical Weather Prediction (http://en.wikipedia.org/wiki/Numerical_weather_prediction or http://www.ecmwf.int) – The prediction of the development of the weather up to 14 days ahead; mostly by national meteorological services, or private companies

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.

OMIP: Ocean Model Inter-comparison Project - An international project devoted to investigate the ocean component of ESMs.

OPA: An ocean model (http://www.locean-ipsl.upmc.fr/opa/) - An Ocean General Circulation modelling System shared by projects (research and operational) in oceanography and Climate change studies

PMIP: Paleoclimate Modelling Inter-comparison Project (http://pmip.lsce.ipsl.fr/) - An international project devoted to the evaluation of climate models under past conditions.

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.

PRISM: Program for Integrated Earth System Modelling (http://prism.enes.org/) - An FP5 project on the development of common interfaces. The PRISM Support Initiative now continues the goals of PRISM, associating several IS-ENES partners with the general goal to foster common developments and exchange of expertise.

RAPS: Real Application on Parallel Systems (http://ecmwf.int/newsevents/meetings/workshops/2007/RAPS/index.html) - A network of experts discussing benchmarks for high-performance computers in the field of weather forecast and climate modelling.

SAB: Scientific Advisory Board (IS-ENES)

SB: Steering Board of ENES

SW: Software

TGICA: Task Group on Data and Scenario Support for Impact and Climate Analysis

TOP: An ocean biogeochemistry model consisting of a transport component based on OPA9 tracer advection-diffusion equation and a biogeochemistry model

UNEP: United Nations Environment Programme (http://www.unep.org/)

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

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

WDCC: World Data Centre for Climate (http://www.mad.zmaw.de/wdc-for-climate/) - Provides observational and model results datasets to a wide community of users.

WGCM: Working Group on Coupled Models (http://www.clivar.org/organization/ wgcm/wgcm.php) - Under WCRP defines the international strategy for climate model evaluation and simulations for IPCC reports

Workflow: A workflow is a depiction of a sequence of operations, declared as work of a person, work of a simple or complex mechanism, work of a group of persons,[1] work of an organization of staff, or machines. Workflow may be seen as any abstraction of real work, segregated in workshare, work split or whatever types of ordering. For control purposes, workflow may be a view on real work under a chosen aspect, [2] thus serving as a virtual representation of actual work (from: http://en.wikipedia.org/wiki/Workflow)

WP: Work package

XML: Extensible Markup Language

# APPENDIX B : COMMON TOOLS DRAFT LIST

**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' 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.

**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.

**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.

**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.

**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.

**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.

**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.

**Ferret**
Data visualization and powerful analysis tools with support for netCDF data.

**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.

**GNU GSL**
The GNU Scientific Library (GSL) is a numerical library for C and C++ programmers. It is free software under the GNU General Public License. The library provides a wide range of mathematical routines such as random number generators, special functions and least-squares fitting. There are over 1000 functions in total with an extensive test suite.

**GNU C, Fortran**
C and Fortran compilers from GNU.

**METAFOR**
Within METAFOR a Common Information Model will be developed to describe climate data and the models that produce it in a standard way

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

**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.

**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.

**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.

**MARS**
ECMWF's Meteorological Archive and Retrieval System (MARS) is software system to manage archived meteorological data and to provide access to the data. MARS is based on the GRIB format but has some (rudimentary?) support for output in NetCDF (CF convention). Further, there is a web interface (WebMARS).

**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.

**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.

**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

**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.

## B.1 TOOLS BY CATEGORY

**File formats**
netCDF4, netCDF3, GRIB1, GRIB2

**Model output archiving system**
MARS

**Metadata**
CF conventions, ISO 19115 (INSPIRE), CMOR, METAFOR

**File conversion tools**
GDAL, CDO

**Interpolation tools**
CDO, R, OASIS3

**Downscaling technologies:**
CDO, Ferret, R, stochasticTools, CERFACS' dsclim, Météo-France' correctmod

**Data visualization and analysis tools:**
CDO, NCO, Ferret, Matlab, R, web portal, NCL, GMT

**Interface with GIS tools**
WMS, WCS

**Data retrieval**
WCS, OpenDap, FTP

**Data processing**
OGC Web Processing service (WPS), CERFACS' extract_nc

**Computational software**
GNU GSL, GNU Fortran, GNU C

**Web Portal**
OpenLayers

## B.2 REFERENCES

| | |
|---|---|
| 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 |
| MARS | http://www.ecmwf.int/products/data/software/mars.html |
| 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 |

# APPENDIX C : KNMI USE CASES

## C.1 FEWS/NHI

**Title:** FEWS/NHI

**Author(s):**
Marc van Dijk[1], Willem van Verseveld[1], Ronald Vernimmen[1], Jaap Schellekens[1], Frederiek Sperna-Weiland[1], Maarten Plieger[2], Wim Som de Cerff[2]
[1]Deltares
[2]KNMI

**Date:** March 8, 2010

**Version:** 1.1

**Purpose:**

Use of climate model data in the FEWS/NHI hydrological framework.

**Actors:**

Hydrologist, FEWS, ClimateScientist, SystemAdmin, DataCenter

**Summary:**

Delivery of climate model data from different runs to the FEWS/NHI system. Delft-FEWS, originally Flood Early Warning System, is a operational forecasting system to manage data and models in a real time environment. Delft FEWS retrieves and prepares hydrological and meteorological data for the models. FEWS is able to handle many protocols and data formats, like FTP, Grib and netCDF. Internally a XML model is used for hydrographical data and netCDF for binary data. FEWS can make use of R and PCRaster for data preparations like interpolation and averaging. FEWS is written in Java.

One of the models running operationally under FEWS is the National Hydrological Instrument (NHI). The NHI is a model which provides insight into the actual and forecasted states of the surface, ground and soil water in the Netherlands to support decision making during periods of droughts. NHI is driven by measured and forecasted precipitation and evaporation (ECMWF-DET and -EPS). The tool also gives insight in the actual and forecasted water demands. To predict future hydrology in the Netherlands, NHI can be used in combination with climate model data.

The NHI model can make use of daily gridded data. In this use case, raw data pre-processing will be done at the DataCenter, but once the data processing is completed, the data retrieval can be directly done from within the FEWS system. FEWS will be able to import data directly from the DataCenter, making the data available to the models. The system has several tools to perform operations on the data, like regridding and averaging. FEWS is able to manipulate the data to make it suited for use in these models.

**Related Use Cases**

WUR-Natuurplanner

**Data needs:**

1) All data on surface level, (2 meter ground level)
2) Parameters: precipitation, potential evaporation, relative humidity, radiation, pressure, temperature, minimum temperature
3) Resolution: Current resolution of 100 km is already suitable, but a higher spatial resolution in

the order of 10 km is desired on the long term. Space and time resolutions should be in balance

4) Period: Current time resolution of 6 hours is suitable
5) Projection: Data will be delivered in a regular grid according to EPSG:4326 (WGS84 latitude longitude).
6) Area and location: cutout for the Netherlands is preferred, but not required
7) Different climate scenarios and multiple ensembles.
8) Data format: netCDF4
9) Data delivery: FTP and OGC services

**Typical course of events:**

*Preconditions:*

1) ClimateScientist has prepared datasets on the DataCenter
2) SystemAdmin has provided credentials for the Hydrologists
3) FEWS is able to read netCDF4 files
4) FEWS is able to connect to OGC services

*Typical course of events:*

1) Hydrologist connects to the DataCenter portal
2) Hydrologist repeats steps 2-11 until indicates done
3) Hydrologist searches for scenario, ensembles, parameters, GCM model
4) Hydrologist selects one of the following
5) A scenario
6) A model (GCM / RCM) and its realization (ensemble member)
7) Hydrologist selects a parameter
8) Hydrologist selects a data transformation (e.g. averaging, min/max, bias correction)
9) DataCenter asks for credentials
10) Hydrologist provides login information
11) DataCenter provides the processed data
12) Hydrologist selects time, projection, resolution and area, preferred format
13) DataCenter provides dataset
14) Hydrologist downloads data from the DataCenter

**Support to users:**

Hydrologist wants to be able to select different climate models, models runs (ensemble members) and scenarios. Metadata has to be provided describing the differences between the different models, model runs and provided scenarios. Methods used for data transformation must be described and provided.

**Requested flexibility:** none.

**Alternative course of events:**

4a) Ecologist skips data transformation and continues at step 11

8a) Datacenter returns message with time indication data processing

11a) Hydrologist downloads data using FEWS

**References for the Use Case:**

FEWS/NHI: http://www.wldelft.nl/soft/fews/int/index.html

**Software used:**

1) FEWS
2) CDO for conversion of grib files to netCDF files
3) Ferret for the reprojection of Gaussian reduced grid to regular grids
4) R: Custom R scripts or software to transform the data to daily averages and specific data format needs to be implemented

**File format(s):**

NetCDF 4 with CMOR and CF conventions

**Miscellaneous Notes:**

The DataCenter will work internally on regular grids, while the source data is in a Gaussian reduced grid. The input Gaussian reduced grids are converted to regular grids before data processing can take place. The Hydrologists should always be able to order the original Gaussian reduced grids; but data transformation will always be applied on regular grids.

The communication interface details need to be specified further.

**Consistent data format:**

Within subsequent data deliveries, the data must comply to the same data format, units and metadata.

**Sources of Uncertainty**

In the transformation from the original Gaussian Reduced Grid to Regular (lat lon) grid, Ferret is used. This transformation may introduce interpolation errors, especially at land-sea transitions. There are no regular grids matching exactly the Gaussian Reduced Grid, i.e. interpolation is unavoidable. This should be well documented and provided to the user of the data. Deltares is aware of this and knows how to deal with it.

To study the sensitivity of the FEWS models for climate model data several scenarios will be used as input.

## C.2 EU-CLUE SCANNER

**Title :** EU-CLUE Scanner

**Author(s):**

Eric Koomen (Free University Amsterdam, VU),

Wim Som de Cerff, Maarten Plieger (Royal Netherlands Meteorological Institute)

**Date:** 29 March 2010

**Version:** 1.2

**Purpose:** Use of climate model data in CLUE scanner.

**Actors:** LandUseScientist

**Summary:**

Delivery of climate model data from different scenario runs for the EU CLUE scanner model. The EU CLUE and the Land Use Scanner models simulate (future) land-use change over Europe.

Socio-economic and climatic changes are expected to alter the current land-use patterns in the Europe. In order to study these uncertain developments and propose adaptation and mitigation strategies to cope with the possible changes in the physical and societal environment a set of future scenarios is developed. These scenarios integrate possible socio-economic and climatic changes and are used in the Land Use Scanner model to simulate future land-use patterns. Based on these simulations sector-specific adaptation and mitigation measures can be developed in related research projects. Currently WorldClim data are used on a 10 km grid. Ensembles data (ECA&D) for current climate are used. Result data is loaded into a GIS system for further analysis.

**Related Use Cases:** None

**Data needs:**

5) Vertical resolution: only surface layer is required
6) Spatial resolution: as high as possible (1x1 km), but lower resolution is not a problem (current model 100x100 km resolution is usable).
7) Temporal: decadal, yearly (1990, 2000, 2010) until 2030,
8) Parameters (TBC):
    a. Annual Mean Temperature
    b. Mean Diurnal Range (Mean of monthly (max temp - min temp))
    c. Max Temperature of Warmest Month
    d. Min Temperature of Coldest Month
    e. Annual Precipitation
    f. Precipitation of Wettest Month
    g. Precipitation of Driest Month
    h. Total precipitation for crop/growing season
9) Projection: Lambert
10) Area: Europe (minimum is 27 EU member states
11) Data format: ASCII Grid (GIS format, usable in ARCGIS)

12) Data delivery: INSPIRE compliant OGC services

**Typical course of events:**

13) LandUseScientist connects to the DataCenter portal, using credentials

*LandUseScientist repeats step 2-9 until indicates done*

14) LandUseScientist selects scenario, GCM, ensemble member
15) LandUseScientist selects parameters of interest
16) LandUseScientist selects area of interest (Europe)
17) LandUseScientist selects averaging method for each of the the selected parameters
18) LandUseScientist select data projection and data format
19) LandUseScientist submits the job to the DataCenter
20) The DataCenter calculates the specified data
21) LandUseScientist downloads the data
22) LandUseScientist leaves DataCenterPortal

**Support to users:**

Land use scientists want to be able to run their model analysis using different scenarios, preferable coupled to the IPCC CO2 scenarios. Important is to be able to calculate the bias in the climate model data. The model uses a GIS system for doing its calculations. Data could be provided as OGC services for direct coupling to this GIS system. Also, help for calculation of growing season averages should be provided. For user support a website containing detailed information must be provided. Access to climate model metadata must be provided through this website. A point of contact for further questions is also needed.

**Requested Flexibility:**

It must be possible to choose the interpolation method used. Data should be provided in Lambert projection. It must be possible to use services to process and download the data.

**Alternative course of events:**

2a-6a) LandUseScientist uses OGC service to select and process data

9a) LandUseScientist uses OGC service to download the data

**References for the Use Case:**

E. Koomen, W. Loonen, M. Hilferink, Climate-Change Adaptations in Land-Use Planning; A Scenario-Based Approach,The European Information Society, Springer, 2008, Berlin, ISBN 978-3-540-78945-1 (Print) 978-3-540-78946-8 (Online)

**Software used:**

23) CDO for conversion of grib files to netCDF files
24) Ferret for the reprojection of gaussian reduced grid to regular grids (Lambert)
25) R: Custom R scripts or software to transform the data to requested averages and specific data format needs to be implemented

**File format(s):**

ASCII Grid

**Miscellaneous Notes:**

Interpolation methods: nearest neighbor is not the suitable interpolation method for the EU CLUE scanner, this because of the sensitivity of the model for discontinuous transitions. It is better to use bilinear interpolation to transform the intervals to smoother data set.

Resolution is not a mayor issue, as the spatial variability in the data is (probably) small on short distances.

The effect of different scenarios will be studied.

**Sources of uncertainty:**

Using different scenarios and using model data for both current situation (1990-2010) and future prediction (2030).

It is useful to also use observational data for the current situation (1990-2010) for studying CLUE model behavior, using observational data and climate model data respectively. This to obtain insight in the uncertainty when using the CLUE model for future predictions and to gain understanding on the properties of climate model data. Note that using climate model data or observational data can lead to different predictions. This is because climate models simulate different realizations of the current conditions, which can be different from the observed data.

The CLUE scanner needs to know bias in the model data and also if and which bias corrections are made.

## C.3 WUR-CLIMATE DATA FOR METAPHOR (WAGENINGEN UNIVERSITY)

**Title:** WUR-Climate data for METAPHOR (Wageningen University)

**Author(s):**

Jana Verboom[1], Wieger Warmelink[1], Anouk Cormont[1], Rene Jochem[1]
Maarten Plieger[2], Wim Som de Cerff[2]
[1]WUR, Wageningen University
[2]KNMI, Royal Netherlands Meteorological Institute

**Date:** February 25, 2010

**Version:** 1.1

**Purpose:**

Use of climate model data in the Metaphor model.

**Actors:**

Ecologist, ClimateScientist, SystemAdmin, DataCenter

**Summary:**

Delivery of climate model data from different scenario runs for the Metaphor model. The Metaphor model is a tool for Spatial Population Analysis. With the Metaphor model the survival probability of a certain species in a certain area can be examined. The model provides insight in which parameters have the strongest effect on population viability, which is useful to find the most effective way to improve the population viability. This can be achieved by the comparison of different scenarios. The main processes in spatial population dynamics are reproduction, mortality and dispersal. METAPHOR simulates these processes over time in order to estimate long term viability of a fragmented population (a metapopulation). METAPHOR can calculate effects on metapopulation processes due to changes in landscape patterns caused by habitat redesign or management.

Currently daily averages from the KNMI weather stations are used as input data. These daily averages are shuffled in order to generate multiple generic datasets. These daily averages are also adjusted and corrected to represent a future climate scenario. One of the drawbacks of this approach is that specific events may occur multiple times, because they are still resembled in the data even after shuffling and adjustments.

Climate model input data could be a valuable addition to the Metaphor model. This would allow the model to run on predefined climate scenarios. Required input parameters for the Metaphor model are: daily precipitation, daily precipitation duration, daily temperature, daily maximum temperature and cloud cover. Daily averaged, high resolution model data from several ensemble runs is desired.

**Related Use Cases**

The WUR-Natuurplanner use case

**Data needs:**

1) All data at the earths surface (one layer)
2) Parameters: temperature, precipitation, precipitation duration, cloud cover, evaporation, surface radiation
3) Temporal resolution: daily averaged data
4) Period: 1980-2100
5) Weather extremes are important
6) Data is needed on local scale (habitat of species)

7) Resolution: Current resolution of 100 km is already suitable, but a higher spatial resolution in the order of 10 km is desired in the long term.

8) Projection: EPSG: 4326 (WGS84 latitude longitude).

9) Area and location: De Veluwe in the Netherlands

10) Different climate scenarios and multiple ensembles.

11) Data format: ASCII files with data for certain locations. Currently the model accepts ASCII files which contains values for certain dates at a single location.

12) Data delivery: FTP

**Typical course of events:**

*Preconditions:*

1) ClimateScientist has prepared datasets on the DataCenter.
2) SystemAdmin has provided credentials for the Ecologist.
3) Transformation tools are available

*Typical course of events:*

4) Ecologist connects to the DataCenter with the given credentials
5) Hydrologist repeats steps 2-7 until indicates done
6) Ecologist selects data by choosing model, scenario, ensembles and parameters needed for a certain run of the METAPHOR model
7) Ecologists creates a job on the DataCenter
    a. Ecologist chooses certain locations of interest
    b. Ecologist selects a data transformation tool to convert the data to daily averages
    c. Ecologist selects a data transformation tool to convert the data to his favorite format
8) Ecologists submits the job on the DataCenter
9) DataCenter processes job
10) Ecologist downloads data from the DataCenter (using FTP/HTTP)
11) Ecologist leaves DataCenter portal

**Support to users**

Ecologist wants the data transformed into his favorite format, a data transformation tool needs to be incorporated in the system to match the Ecologist needs. The Ecologist does not specifically need grid data, the Ecologists is also interested in certain locations (point data). The DataCenter should provide functionality to allow the Ecologist to choose certain locations of interest and create ASCII files with data for these locations.

Ecologists want to be able to select different climate models, models runs (ensemble members) and scenarios. Clear metadata has to be provided describing the differences between the different models, model runs and provided scenarios. Methods used for data transformation must be described and provided.

**Requested flexibility**

The DataCenter will provide the methods for data transformation. For the Ecologist this will be averaging to yearly averages and transforming the data to the Ecologists favourite format. On the long term higher resolution data (10x10 km) is requested.

**Alternative course of events:**

5a) Ecologist checks the status and progress of the submitted job

**References for the Use Case:**

METAPHOR: http://www.alterra.wur.nl/UK/research/Specialisation+Landscape/Fclts+mdls/METAPHOR/

Natuurplanner: http://www.abiotic.wur.nl

**Software used:**

26) Natuurplanner, METAPHOR model

27) CDO for conversion of grib files to netCDF files

28) Ferret for the reprojection of gaussian reduced grid to regular grids

29) R: Custom R scripts or software to transform the data to daily averages and specific data format needs to be implemented

**File format(s):**

ASCII data

**Miscellaneous Notes:**

The DataCenter will work internally on regular grids, while the source data is in a Gaussian reduced grid. The input gaussian reduced grids are converted to regular grids before data processing can take place. The Ecologists should always be able to order the original Gaussian reduced grids; but data transformation will always be applied on regular grids.

The communication interface details need to be specified further.

**Area:**

The area is a small location called the Veluwe which is located in the Netherlands. About 2-4 grid cells are usable. The values in these grid cells can be stored in separate ASCII files in which the values for several dates are represented.

**Data size:**

The long time span and the vast amount of different realizations of the data are specific to this use case. It might be problematic to store all pre-calculated model data. The amount of data will be huge because of the high resolution in space and time and the number of required model runs.

One of the solutions to this problem is to allow the Ecologist to run the model himself and letting him create different realizations. One of the advantages is that the user can select in advance which part of the model output needs to be stored, limiting the data overhead by disregarding the areas which are not needed. Whether this approach is feasible needs to be investigated.

**Streaming use case:**

One of the problems with climate model data is the storage of the huge amount of data. Storing all the data from the model run is often not needed, one of the actions taken to reduce dataset size is to store a limited set of results from the model output. The EC-Earth model runs internally on a 20 minute time resolution. For most of the cases a six hour time interval or even a monthly time interval is sufficient, therefore data is stored on this basis. For this use case however, a higher temporal resolution is desired.

One of the solutions to solve this problem is a streaming data server. By using a streaming data server, which streams data from the model to the user while the model is running, not all data needs to be stored at the same time. When the model is running, all model output is temporarily stored on a server. Users who are interested in the data need to hook up to the server and obtain the data they desire. Users are informed when a model run is scheduled to start, if they are too late the stream is over and they have missed the data. Further investigation is required to see whether this futuristic approach is feasible.

**Sources of uncertainty**

In the transformation from the original Gaussian Reduced Grid to Regular (lat lon) grid, Ferret is used. This transformation may introduce interpolation errors, especially at land-sea transitions. There are no regular grids matching exactly the Gaussian Reduced Grid, i.e. interpolation is unavoidable. This should be well documented and provided to the user of the data. WUR is aware of this and knows how to deal with it

WUR is aware of the uncertainties in the model data. Therefore WUR will use several different models/ensemble members. Bias corrections are made by WUR by comparing Natuurplanner model results using historical station based data with Natuurplanner model runs using climate model data.

## C.4 PBL-NATURE PLANNER

**Title :** PBL-Nature planner

**Author(s):**
Wieger Warmelink[1], Jana Verboom[1],
Wim Som de Cerff[2], Maarten Plieger[2]
Ronald Hutjes[1]
[1]WUR, Wageningen University
[2]KNMI, Royal Netherlands Meteorological Institute

**Date:** February 22, 2010

**Version:** 1.3

**Purpose:**

Use of climate model data in the ecological modeling for the Netherlands

**Actors:**

Ecologist, ClimateScientist, SystemAdmin

**Summary:**

The Nature planner consists of several model modules, which can benefit from climate model data, especially the SMART2 and SUMO2 models. SMART2 simulates soil dynamics. SUMO2 is a dynamic model that simulates vegetation succession in relation to the nitrogen and carbon cycle. Nature planner acts as an interface: providing model data to the Nature planner enables the use of data in all models of the Nature planner . The Nature planner is used to model the ecological main infrastructure of the Netherlands (e.g., vegetation dispersion) taking into account vegetation dynamics, land use change, nitrogen deposition, climate change, etc.

At the moment historical station data on climate is used. Modeled data on climate (temperature, precipitation) could improve performance by providing better information on extremes (occurrence wet and dry years).

**Related Use Cases:**

FEWS-NHI (hydrological data from FEWS-NHI is also used in SMART2-SUMO2)

**Data needs:**

1) All data on one layer (2 meter, ground level)
2) Parameters: Humidity, temperature (yearly average), precipitation (yearly total average)
3) Resolution: Global Climate Model resolution, cutout for the Netherlands, 100x100km. In additional cases data is needed on European scale.
4) Ensemble of model runs, based on (IPCC) scenarios
5) Projection: EPSG 28992 (Rijksdriehoeks stelsel)
6) Period: 1980 – 2100 (from 1980 vegetation is known)
7) Data format: ASCII Grid
8) Data delivery: OGC services

**Typical course of events:**

*Preconditions:*

1) ClimateScientist has prepared datasets on the DataCenter.
2) SystemAdmin has provided credentials for the Ecologist

*Typical course of events:*

1) Ecologists connects to the DataCenter portal

*Ecologists repeats steps 2-11 until indicates done*

2) Ecologist searches for scenario, ensembles, parameters, GCM model
3) Ecologist selects one of the following
    a. A scenario
    b. A GCM model and its realization (ensemble member)
4) Ecologist selects a parameter
5) Ecologist selects a data transformation (e.g. averaging, min/max, bias correction)
6) DataCenter asks for credentials
7) Ecologist provides login information
8) DataCenter provides the processed data
9) Ecologist selects time, projection, resolution and area, preferred format
10) DataCenter provides dataset
11) Ecologist downloads data
12) Ecologist leaves DataCenter portal

**Support to users:**

Ecologists want to be able to select different climate models, models runs (ensemble members) and scenarios. Clear metadata has to be provided describing the differences between the different models, model runs and provided scenarios. This includes the summarized effects of the scenarios, e.g. on average a temperature raise of 2 °C and a raise in precipitation of 100 mm in the year 2050. Methods used for data transformation must be described and provided. Also for downscaling and projection changes the effects must be described and provided to the Ecologist.

This information will be provided by providing relevant metadata at each step in the typical course of events. Also a point of contact for further information will be provided.

**Requested Flexibility:**

The DataCenter will provide the methods for data transformation. For the Ecologist this will be averaging to yearly averages, reprojection from Gaussian reduced grid to EPSG 28992 (Rijksdriehoeks stelsel), resolution downscaling to 100x100 km, geographical selection using a bounding box.

It must also be possible to use a service based approach in selecting and retrieving the data.

**Alternative course of events:**

4a) Ecologist skips data transformation and continues at step 9

8a) Datacenter returns message with time indication for data processing

10a) Datacenter returns message with time indication for data download

In cases 8a and 10a processing takes too long to be done interactively in the session. The Ecologist can decide to wait or to leave the DataCenter portal and come back later for the data.

**References for the Use Case:**

Nature planner: http://www.abiotic.wur.nl

Wamelink, G.W.W., 2007, Simulation of vegetation dynamics as affected by nitrogen desposition. PhD thesis, Alterra, Wageningen, The Netherlands, 232pp., ISBN 978-90-8504-844-2

**Software used:**

1) CDO and Ferret to prepare dataset
2) Downscaling: (step 5) R
3) Averaging:(step 5) R
4) Reprojection: (step 9) GDAL or OGC services

**File format(s):**

ASCII Grid (either 5*5 km grid or 1*1 km grid)

**Miscellaneous Notes:**

1) The DataCenter will work internally on regular grids, while the source data is in a Gaussian reduced grid. The input Gaussian reduced grids are converted to regular grids before data processing can take place. The Hydrologists should always be able to order the original Gaussian reduced grids; but data transformation will always be applied on regular grids.
2) Clear documentation is needed to provide links between model runs, IPCC scenarios and National Climate scenarios
3) For interface testing, data will be prepared by the DataCenter and provided via FTP or WURsendit.
4) ASCII Grid files are transferred to DAC files. It will be investigated if we can provide DAC files directly
5) The CheckStatus, PrepareDataSet and Manage Security use cases in the Use-Case Diagram are not described yet
6) This high level use case (and the other use cases) will be further detailed and described using the Alistair Cockburn use case template. This of course in interaction with the Ecologist.

**Sources of uncertainty:**

In the transformation from the original Gaussian Reduced Grid to Regular (lat lon) grid, Ferret is used. This transformation may introduce interpolation errors, especially at land-sea transitions. There are no regular grids matching exactly the Gaussian Reduced Grid, i.e. interpolation is unavoidable. This should be well documented and provided to the user of the data. WUR is aware of this and knows how to deal with it.

WUR is aware of the uncertainties in the model data. Therefore WUR will use several different models/ensemble members. Bias corrections are made by WUR by comparing Nature planner model results using historical station based data with Nature planner model runs using climate model data.

# APPENDIX D : CERFACS USE CASES

## D.1 PROVIDING HIGH-RESOLUTION CLIMATE CHANGE SCENARIOS FOR IMPACTS AND ADAPTATION IN AN ESTUARY

**Title :** Providing high-resolution climate change scenarios for impacts and adaptation in an Estuary

**Author(s):** Christian PAGÉ

**Date:** 15 February 2010

**Version:** 2

**Purpose:**

Providing climate change scenarios for impacts and adaptation in an Estuary in the context of adaptation to climate change.

**Actors:**

Climate research group (CERFACS2), study and expertise team (EAUCÉA), Gironde Estuary Managers (SMIDDEST3, Agence de l'Eau Adour-Garonne), public stake-holders (MEEDM4).

**Summary:**

This use-case describes the course of actions starting from public stake-holders call of opportunity about vulnerability of current activities in the France Gironde Estuary region associated to climate change.

**Related Use Cases:**

Providing high-resolution climate change scenarios and evaluating uncertainties in the France Seine and Somme river basins.

**Data needs:**

***Data needed:***

*Atmospheric variables*

High-resolution (less than 10-km mesh) daily climate data is needed covering the period 1960-2040, and the France Gironde Estuary region (24 data points), for the following variables:

- 2-meters Daily Mean Temperature
- Cumulated Daily Precipitation
- Cumulated Daily Potential Evapotranspiration

***Data provided:***

*Atmospheric variables*

For the 1960-2040 period, only A1B $CO_2$ emission scenario is currently available, and only one climate model (ARPEGE Météo-France model). The fact that only A1B emission scenario data is available is not a problem because there is hardly any difference between the different emission scenarios for the first part of the 21st century. However, the uncertainty evaluation is limited given that output from only one climate model is used.

The 50-km spatial resolution ARPEGE model output is used as input to a statistical downscaling

[2] Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique
[3] Syndicat Mixte pour le Développement Durable de l'Estuaire de la Gironde
[4] Ministère de l'Ecologie, de l'Energie, du Développement durable et de la Mer

methodology which uses also the 8-km SAFRAN Météo-France and the 250-km NCEP re-analyses covering the period 1981-2005. This statistical downscaling methodology is based on weather types, and provides data at an 8-km resolution over France.

In this case, 4 data sets are provided, generated from the statistical downscaling of 4 ARPEGE A1B simulations, in order to evaluate part of the scenario uncertainties. The 3 needed variables are provided over the 1960-2040 period, using the nearest data points at 8-km resolution, covering the 24 data points of the Gironde Estuary region.

**Typical course of events:**

1) The stakeholders launch a call of opportunity to evaluate vulnerability and impacts on current and future activities in the Gironde Estuary region in the context of climate change.
2) A study expert team is chosen to perform the vulnerability study.
3) The study expert team contacts the climate research group and request climate change scenario data to perform the vulnerability study.
4) The climate research group provide information about available data as well as estimated data volume to the study expert team, and ask about the requested file format output. The study expert team reformulate the data request.
5) The study expert team and climate research group both agree to the data request.
6) The climate research group produces four statistically downscaled climate scenarios using four ARPEGE 50-km resolution data simulation (1960-2040), 250-km resolution NCEP re-analysis (1981-2005) and 8-km resolution SAFRAN re-analysis (1981-2005) data and a satistical weather-typing downscaling software package (dsclim). Data is output in the NetCDF format using the CF-1.0 convention.
7) The climate research group performs partial uncertainty assessment using four different climate simulations from one climate model, one emission scenario and one downscaling methodology using spatial maps and summary graphs.
8) The climate research group extracts data of the downscaled scenario data over the requested data points covering the domain of interest and calculate complementary parameters (in this case, only potential evapotranspiration), and reformats this data into ASCII data files for easy processing by the study expert team. To perform this process, a tool is used which can read NetCDF CF-1.0 files, select data covering a given region or individual points, and output into easy ASCII files following the specifications of the study expert team.
9) The climate research group prepares documentation describing the data, the data access method, the uncertainty evaluation and recommendations for data use.
10) The climate research group copy data files to ftp server for data retrieval access by the study expert team.
11) The study expert team retrieves the downscaled ASCII data files from the climate research group ftp server.
12) The study expert team analyse data and write a report for stakeholders, about climate change vulnerabilities and impacts. They evaluate the uncertainties using the four different provided downscaled scenarios, combined with the uncertainties from their impact models. Support from the climate research group to the study expert team during the duration of their analysis through e-mails, phone or meetings (practical use, scientific aspects).
13) Stakeholders receive the report and take decisions using report conclusions and summary.

**Support to users:**

Support is given using technical documentation, email and phone. The support is related to the methodology and includes scientific expertise.

**Requested flexibility:**

Data parameters needs are determined by interactions between the climate research group and the study expert team before data delivery.

**Alternative course of events:**

4) In step 4, the climate research group, using its expertise, may need to modify the initial request to match available data, ensure that the request take into account the uncertainties.

8) In step 8 and 11, data could be provided in NetCDF format instead of ASCII. However, experience have proven that this is a rare occurrence.

**References for the Use Case: internal notes, papers, web sites or web portal, etc.**

Boé, J., L. Terray, F. Habets, and E. Martin, 2006: A simple statistical-dynamical downscaling scheme based on weather types and conditional resampling. J. Geophys. Res., 111 :D21106, 2006.

Pagé, C., L. Terray et J. Boé, 2009: dsclim: A software package to downscale climate scenarios at regional scale using a weather-typing based statistical methodology. Technical Report TR/CMGC/09/21, CERFACS, Toulouse, France. http://www.cerfacs.fr/~page/dsclim/dsclim_doc-latest.pdf

Pagé, C., J. Boé, et L. Terray, 2008 : Projections climatiques à échelle fine sur la France pour le 21ème siècle : les scénarii SCRATCH08. Technical Report TR/CMGC/08/64, CERFACS, Toulouse, France. http://www.cerfacs.fr/~page/publications/report_cerfacs_regional_scenarii_scratch08.pdf

Russell, K. R., E. J. Hartnett, and J. Caron, 2006: NetCDF-4: Software Implementing an Enhanced Data Model for the Geosciences. 22nd International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology. http://www.unidata.ucar.edu/software/netcdf/

Quintana-Segui, P., Le Moigne, P., Durand, Y., Martin, E., Habets, F., Baillon, M., Canellas, C., Franchisteguy, L. and Morel, S., 2008: Analysis of Near-Surface Atmospheric Variables: Validation of the SAFRAN Analysis over France. J. Appl. Meteor. Climatol. 47, 92–107.

*udunits-1*: http://www.unidata.ucar.edu/software/udunits/udunits-1/

*Convention CF-1.0 NetCDF*: http://cf-pcmdi.llnl.gov/documents/cf-conventions/1.0

**Software used**

1) CERFACS dsclim downscaling software and library
2) NetCDF-4 library
3) udunits-1 library
4) CERFACS extract_nc data-extraction software

**File format(s)**

1) The provided files containing the data (downscaled scenarios) are provided in ASCII format.
2) The native format for CERFACS statistical downscaling data is in the NetCDF format using the CF-1.0 convention.

**Miscellaneous Notes:**

This is a basic and quite common case for data requests in France, not only for hydrological applications.

**Sources of uncertainty:**

To evaluate uncertainties, the user selects more than one climate scenario. Since an important part of uncertainty resides in the global climate model downscaled, at least 4 downscaled climate model scenarios are selected. If possible, the user can choose to also analyse the uncertainties related to different downscaling methodologies and SRES scenarios. The SRES scenarios impacts are more important for end of century period, while being quite marginal for mid-century period.

**Use-Case Diagram:** none.

## D.2 PROVIDING HIGH-RESOLUTION CLIMATE CHANGE SCENARIOS AND EVALUATING UNCERTAINTIES IN THE FRANCE SEINE AND SOMME RIVER BASINS

**Title:** Providing high-resolution climate change scenarios and evaluating uncertainties in the France Seine and Somme river basins

**Author(s):** Christian PAGÉ

**Date:** 15 February 2010

**Version:** 2

**Purpose:**

Providing climate change scenarios for evaluating impacts on France Seine and Somme river basins, as well as evaluating changes in hydrological extremes and uncertainties using several downscaling methodologies, climate and hydrological models.

**Actors:**

Climate research groups (CERFACS[5], CNRM-GAME[6]), hydrological research groups (Sisyphe[7], Armines, CEMAGREF Lyon[8], BRGM Orléans[9], SOGREAH[10], Hydratec, INRA[11]), public stake-holders (MEEDM[12]).

**Summary:**

This use-case describes the course of actions needed to evaluate the impact of anthropogenic climate change on hydrologic extremes in the Seine and Somme river basins. Uncertainties will be evaluated using several downscaling methods, climate and hydrological models.

**Related Use Cases:**

Providing high-resolution climate change scenarios for impacts and adaptation in an Estuary.

**Data needs:**

This Use Case is a special case since it is part of a research project. Hence, most of the data needs are specified beforehand using available data.

***Data needed and provided:***

*Atmospheric variables*

High-resolution DAILY climate data is needed covering the France Seine and Somme river basins (1660 data points), for the following variables. This dataset is thereafter called DAILY_SET.

- 2-meters Daily Maximum and Minimum Temperatures
- Cumulated Total (liquid + solid) Daily Precipitation

[5] Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique SUC URA 1875
[6] GMGEC/CNRM Météo-France/CNRS URA 1357
[7] UMR 7619 Sisyphe – UPMC / CNRS / EPHE / ENSMP
[8] Centre National du Machinisme Agricole, du Génie Rural, des Eaux et des Forêts
[9] Bureau de Recherches Géologiques et Minières
[10] SOciete GRenobloise d'Etudes et d'Application Hydrauliques
[11] Institut National de la Recherche Agronomique
[12] Ministère de l'Ecologie, de l'Energie, du Développement durable et de la Mer

- Cumulated Daily Potential Evapotranspiration
- Daily Mean Surface Incoming Shortwave Radiation

High-resolution HOURLY climate data is needed covering the France Seine and Somme river basins (re-aggregated over each basin individually, 29 basins for the Seine river and 1 basin for the Somme river), for the following variables. This dataset is thereafter called HOURLY_BASIN_SET.

- 2-meters Temperature
- Surface Incoming Shortwave Radiation
- Surface Incoming Longwave Radiation
- 2-meters Specific Humidity
- 10-meters Wind Module
- Liquid Precipitation
- Solid Precipitation

High-resolution HOURLY climate data is needed covering the whole Metropolitan France (9892 data points) for the following variables. This dataset is thereafter called HOURLY_FRANCE_SET.

- 2-meters Temperature
- Surface Incoming Shortwave Radiation
- Surface Incoming Longwave Radiation
- 2-meters Specific Humidity
- 10-meters Wind Module
- Liquid Precipitation
- Solid Precipitation

The period covered by the scenarios needed are variable. These periods will be needed, and they are selected because of scenario data availability:

- 1950-2100
- 1960-2000; 2046-2065; 2081-2100
- 2070-2100

For the DAILY_SET and the HOURLY_BASIN_SET, the following climate scenarios are provided. For the HOURLY_FRANCE_SET, the climate scenarios provided are highlighted in gray. The downscaled methodologies are statistical (RT: weather typing; ANOM: anomaly) and dynamical (QQ: quantile-quantile).

| Climate Model Name | $CO_2$ scenario | Time period | Data Centre | Downscaling methodology |
|---|---|---|---|---|
| CCCMA CGCM3.1 T63 | A1B | 1960-2000<br>2046-2065<br>2081-2100 | CCCMA | RT |
| CNRM-CM3 | | | CNRM Météo-France | RT |
| CSIRO-MK3.0 | | | CSIRO | RT |
| GFDL-CM2.0 | | | GFDL | RT |
| GFDL-CM2.1 | | | | RT |
| GISS-AOM | | | GISS | RT |
| GISS-ER | | | | RT |
| IAP-FGOALS | | | FGOALS | RT |
| INGV ECHAM4 | | | INGV | RT |
| IPSL CM4 | | | IPSL | RT |
| MIROC 3.2 MEDRES | | | MIROC | RT |
| MIUB ECHO-G | | | MIUB | RT |
| MPI-ECHAM5 | | | MPI | RT |
| MRI CGCM 2.3.2a | | | MRI | RT |
| NCAR CCSM3 | | | NCAR | RT |
| ARPEGE V4 | A1B | 1950-2100<br>1 simulation from an ensemble of 4 members with different initial conditions on 01/01/1950 | CNRM Météo-France | RT + QQ + ANOM |
| | A2 | 1950-2000<br>2070-2100 | | RT + QQ + ANOM |

**Typical course of events:**

5) The stakeholders launch a France National Research Program for the Management and Impacts of Climate Change (GICC).

  1) A research project proposal is written by several research groups. This specific case describes a project to evaluate the impact of anthropogenic climate change on hydrologic

extremes in the Seine and Somme river basins (REXHYSS). The project proposal specifies the objectives, the problematic, the data needs, the methodologies, the tools, the uncertainties.

2) Research projects are selected by the stakeholders.

3) The research project team organises a kick-off meeting to begin the project.

4) Communications between research groups is done through emails, phone calls, meetings.

5) The hydrologic models research groups ask for downscaled climate change scenarios atmospheric data to the climate models groups. There are several hydrological models involved to evaluate uncertainties related to these models.

6) Each climate group produces downscaled climate scenario data using different methodologies (dynamical and statistical) for the selected scenarios, to quantity uncertainties related to the climate models as well as to the downscaling methodologies. The statistical methodologies used are anomalies and weather typing, while the dynamical downscaling uses the ARPEGE regional model associated with a quantile-quantile correction. For the dynamical downscaling methodology, the choices of climate scenarios is more limited because it is model-specific (in this case, only the ARPEGE regional model could be downscaled).

7) Because there are too many available climate scenarios for the statistical downscaling methodology, most of the hydrological research groups ask for a reduced set.

8) The climate research group, responsible for the weather typing statistical downscaling methodology, select a subset of the climate scenarios using a partially objective methodology (involving spatial maps and summary graphs) which tries to keep as much dispersion as possible compared to the full scenarios set and hence, keeping most of the uncertainties of the full set.

9) The climate research group extracts data of the downscaled scenario data over the requested data points covering the domain of interest and calculate complementary parameters (in this case, potential evapotranspiration and total precipitation for the DAILY set), and reformats this data into ASCII data files for easy processing by the hydrologic research teams. One of the team used some binary files. To perform the process of ASCII output, a tool is used which can read NetCDF CF-1.0 files, select data covering a given region or individual points, and output into easy ASCII files following the specifications of the hydrological research teams.

10) The climate research group prepares documentation describing the data, the data access method.

11) The climate research group copy data files to ftp server for data retrieval access by the hydrological research teams.

12) The hydrological research teams retrieve the downscaled ASCII data files from the climate research groups ftp servers.

13) The hydrological research teams perform hydrological simulations with the climate scenarios subset as input to their hydrological numerical models. Uncertainty assessment is evaluated using the different climate scenarios in the dataset.

14) The project team analyse data and write a report for stakeholders, about climate change vulnerabilities and impacts. They evaluate the uncertainties of different types using three downscaling methods, two SRES scenarios, several climate and hydrological numerical models. The project team communicates through the means of e-mails, phone and meetings.

15) The report is presented in a series of seminars to the other project teams and the stakeholders.

16) Stakeholders receive the report and take decisions using report conclusions and summary.

**Alternative course of events:** none.

**References for the Use Case: internal notes, papers, web sites or web portal, etc.**

Boé, J., L. Terray, F. Habets, and E. Martin, 2006: A simple statistical-dynamical downscaling scheme based on weather types and conditional resampling. J. Geophys. Res., 111 :D21106, 2006.

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Gibelin, A.L. and Déqué, M., 2003 : Anthropogenic climate change over the Mediterranean region simulated by a global variable resolution model. Climate Dynamics, 20 : 327-339.

Habets F., A. Boone, J.L Champeaux, P. Etchevers, L. Franchistéguy, E.Leblois, E. Ledoux, P. Le Moigne, E. Martin, S. Morel, J. Noilhan, P.Quintana Segui F. Rousset-Regimbeau, P. Viennot (2008). The SAFRAN-ISBA-MODCOU hydrometeorological model applied over France, Journal of Geophysical Research (D: Atmospheres), 113, D06113(2008)18.

Korkmaz S, Ledoux E, Önder H (2009). Application of the coupled model to the Somme river basin, Journal of Hydrology, 366, 21-34.

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Thiéry D., Moutzopoulos, C. (1995). Un modèle hydrologique spatialisé pour la simulation de très grands bassins : le modèle EROS formé de grappes de modèles globaux élémentaires. VIIIèmes journées hydrologiques de l'ORSTOM "Régionalisation en hydrologie, application au développement". In Le Barbé et E. Servat (Ed.) ORSTOM Editions, pp. 285-295.

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*udunits-1*: http://www.unidata.ucar.edu/software/udunits/udunits-1/

Russell, K. R., E. J. Hartnett, and J. Caron, 2006: NetCDF-4: Software Implementing an Enhanced Data Model for the Geosciences. 22nd International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology. http://www.unidata.ucar.edu/software/netcdf/

Convention CF-1.0 NetCDF: http://cf-pcmdi.llnl.gov/documents/cf-conventions/1.0

**Software used:**

1) CERFACS dsclim downscaling software and library (Pagé et al., 2009)
2) NetCDF-4 library (Russel et al., 2006)
3) udunits-1 library
4) CERFACS extract_nc data-extraction software
5) Météo-France-CNRM Quantile-Quantile software (Déqué 2007)
6) Météo-France-CNRM ARPEGE climate numerical model (Gibelin et Déqué, 2003)
7) Hydrological models

| Hydrological model | Model Type | Basin | References |
|---|---|---|---|
| **CLSM** | Hydro-meteorological | Seine Somme | Ducharne et al., 2007<br>Gascoin et al., 2009 |
| **EROS** | Hydrological with tanks | Seine | Thiéry et Moutzopoulos, 1995 |
| **GARDENIA** | Hydrological with tanks | Somme | Thiéry, 2003 |
| **GR4J** | Hydrological with tanks | Seine Somme | Perrin et al., 2003 |
| **MARTHE** | Hydro-geological | Seine | Thiéry, 1990 |
| **MODCOU** | Hydro-geological | Seine | Ledoux et al., 2007<br>Korkmaz et al., 2009 |
| **SIM** | Hydro-meteorological | Seine | Habets et al., 2008 |

**File format(s):**

1) The provided files containing the data (downscaled scenarios) are provided in ASCII format. The HOURLY_FRANCE_SET was provided directly in the native SIM binary file format.
2) The native format for CERFACS statistical downscaling data is in the NetCDF format using the CF-1.0 convention.

# APPENDIX E : INHGA USE CASE

## E.1 POSTPROCESSING CLIMATE CHANGE SCENARIOS AND UNCERTAINTY EVALUATION IN THE DANUBE MIDDLE AND LOWER BASIN

**Title:** Postprocessing climate change scenarios and uncertainty evaluation in the Danube middle and lower basin

**Author(s):** Constantin Mares, Petre Stanciu, Ileana Mares, Antoaneta Stanciu

**Date:** 14 April 2010

**Version:** 2

**Purpose:**

Use of climate model data by UMP_IS-ENES / INHGA for evaluating changes in the hydro meteorological extremes and uncertaintes in the Danube basin using statistical downscaling methods

**Actors:**

ClimateScientists, Hydrologists, Researcher, System Administrator, DataCenter

**Summary:**

UMP IS-ENES / INHGA will analyse the ensemble outputs of the global climate models (CNRM-CM3, ECHAM5-MPI, EGMAM and IPSL) and regional climate models as well as seasonal forecasting models (provide by ECMWF) in order to make usable the output data of these models. Downscaling procedures (nonhomogeneous hidden Markov model and analogy) in association with hydrological variables to evaluate hydro climatic risk in the Danube lower basin region will be applied. Data provided by ECA&D and ECMWF (ERA-40) for the current climate is used.

**Related Use Cases:** none.

**Data needs:**

Atmospheric variables at Northern Hemisphere level;

Daily variables:

precipitation_flux, convective_precipitation_flux, large_scale_precipitation_flux, snowfall_flux, maximum and minimum temperatures at 2m, sea level pressure as well humidity, geopotential - height and temperature at 2 levels ( 850 hPa and 500 hPa);

The periods covered by the scenarios are 2009-2050 and 2051-2099. The A1B Scenario from stream 1 experiment developed in the ENSEMBLES project is used. In oder to apply bias correction the period of 42 years (1958-1999) both for observations and for the historical data simulated by models is considered.

Data can be delivered in original format ( GRIB / NetCDF), INHGA will do conversion in ASCII, interpolation and spatial downscaling;

Resolution requirements for climate and forecasting data: 1 degree, daily

**Typical course of events:**

1) ClimateScientists ( meteorologists) search for data appropriate for a good representation of Danube basin (spatial and temporal);
2) Climate research group achieve the bias corrections of the variable simulated by climate models;

3) Climatologists and hydrologists reveal the extreme events in the hydrometeorological variables from Danube middle and lower basin and provide the information about these extreme events;
4) UMP-IS_ENES_/ INHGA researchers select the predictors at large scale with the influence on the extreme events occurrences at the regional and local scale from Danube basin;
5) Climate Scientists achieve the statistical downscaling procedures and validation the results;
6) The downscaling results will be processed in the forms requested by users;
7) SystemAdmin from INHGA arranges access to the data for users;
8) Hydrologists prepare the input in order to estimate the hydroclimatic risk

**Alternative course of events:** none.

**Support to users:**

At the first stage the hydrologist wants to have an qualitative information about trends, extremes for the provided variables in order to be able to select different climate models, models runs (ensemble members) and scenarios.

Also stakeholders want the data in the synthetic representations (indices, graphs, maps). For user support a website containing detailed information must be provided. Access to climate model output processed for the interested region must be provided through this website. A point of contact for further information is needed.

**References for the Use Case: internal notes, papers, web site, etc.**

Gilleland, E, Katz R.W., 2005: Tutorial for the Extremes Toolkit: Weather and Climate Applications of Extreme Value Statistics (http://www.asssessment.ucar.edu/ toolkit)

Kirshner, S., 2005: Modeling of multivariate time series using hidden Markov models, Ph.D. Thesis, University of California, Irvine, 202pp.

Mares I, Mares C, Stanciu P, Mihailescu M, 2010: Statistical downscaling of global climate scenarios for the 21-st century to estimate hydrological extreme events in the Danube basin. Geophysical Research Abstracts, Vol. 12, EGU2010-13322, 2010, EGU General Assembly 2010.

Pagé, C., L. Terray et J. Boé, 2009: dsclim: A software package to downscale climate scenarios at regional scale using a weather-typing based statistical methodology. Technical Report TR/CMGC/09/21, CERFACS, Toulouse, France. http://www.cerfacs.fr/~page/dsclim/dsclim_doc-latest.pdf

**Software used**:

1) CDO, MatLab, FORTRAN, R, etc.
   a. CDO for the data transform from GRIB to netCDF and for the data extraction and interpolation
   b. FORTRAN for spline interpolation
   c. MatLab for graphical representation
   d. R for running the routines for extremes, trends, etc.
2) Tools for the downscaling precipitation by Hidden Markov Model (HMM). The references for this tool are found at: http://iri.columbia.edu/climate/forecast/stochasticTools/

**File format(s):**

NetCDF, ASCII.

**Miscellaneous Notes:**

UMP IS-ENES/ INHGA use case will process the outputs of the models developed by IPCC and stream 1 of ENSEMBLES project, using A1B scenario. For the bias of simulated data, the team will need of observations from ECMWF centre as well as of seasonal forecasting in grid points provided by ECMWF as input for hydrological model. Interpolation methods: in the case in which the bilinear interpolation does not give rigorous results, the spline method will be used which will eliminate some uncertainties in the interpolation technique

**Source of uncertainty**:

In models and their processing, there are multiple sources of uncertainty

In order to find a minimum uncertainty from an ensemble of solutions, the informational entropy method is used;

The elimination of an important part of the uncertainty is achieved by the bias correction of the climatic simulation models;

The emphasizing of the anthropogenic signal in the variables simulated by in the A1B emission scenario is achieved by means of signal-to-noise ratio estimation.

# APPENDIX F : CMCC USE CASES

## F.1 EVALUATION OF THE EFFECTS OF INTENSE RAINFALL ON LANDSLIDES PHENOMENA (MUD STRAIN)

**Title:** Evaluation of the effects of intense rainfall on landslides phenomena (mud strain).

**Author(s):** E. Bucchignani[1], R.Mella[1], P. Mercogliano[1], B.Sikorski[1], V. Savastano[2], L.Comegna[2], L.Olivares[3]
[1]CMCC
[2]AMRA
[3] Seconda Università di Napoli

**Date:** February 25, 2010

**Version:** 1

**Purpose:**

Evaluation of the effects of intense rainfall on landslides phenomena in the AMRA/CMCC landslide framework.

**Actors:**

AMRA Geotechnical Engineers, CMCC Meteo Climate Scientists, System administrator, Data center

**Summary:**

This test case describes the procedure used by CMCC-AMRA team in order to make usable the output data of regional model COSMO-LM to the I-ModSOIL and TRIGRS models, that are used for stability analysis in order to evaluate the shallow landslide risk scenarios triggered by intense precipitation events. The procedure includes the development of a downscaling tool in order to adequate the spatial resolution of atmospherical data (7 km or 2.8 km, depending from the COSMO-LM configuration used) to the one used by stability models (about 100 m); this procedure is already implemented in the I-ModSOIL code.

**Related Use Cases:**

Evaluation of the effects of climate changes on landslides phenomena triggered by precipitation events (clay strain).

**Data needs:**

1) Atmospheric variables on mesoscale (obtained by using the COSMO-LM regional model initialized by the global model IFS) for the Mediterranean region.
2) Parameters are: precipitation, minimum and maximum value of daily temperature, wind at 10 meters, relative humidity and temperature at 2 meters.
3) Data can be delivered in original format (GRIB/NetCDF); CMCC provides conversion in ASCII or other formats and spatial downscaling to the resolution of the I-ModSoil stability analysis.
4) Data about soil properties and topography.
5) Resolution requirements for meteorological date: 0.0625 degrees (7 km) and/or or 0.025 (2.8 km), every 1 hour.

**Typical course of events:**

1) CMCC Climate Scientists prepare datasets in the Data Center, containing the solutions (saved every 1 hour) related to a well defined domain (i.e. Italy) for a period of 24-48 hours.
2) System Administrator arranges access to the data for the Geotechnical Engineers, if needed.

3) CMCC researchers prepare downscaled atmospherical parameters to a resolution of about 100 m in a selected area, the one interested by landslide phenomena (in order to perform downscaling, it is necessary to have information about the topography of an area with an extension of at least 40 km x 40 km), for successive applications.
4) Geotechnical Engineers search for data on the CMCC Data Center.
5) Geotechnical Engineers take downscaled data needed for a certain run of I-ModSOIL (TRIGRS).
6) Geotechnical Engineers download data via FTP or WEB
7) Geotechnical Engineers runs their Finite Elements models.

**Support to users:**

**-**

**Requested Flexibility:**

Spatial and temporal means data can be easily obtained.

**Alternative course of events:**

-

**References for the Use Case:**

Schiano P., Mercogliano P., Picarelli L. "Simulation chains for the forecast and prevention of landslide induced by intensive rainfall", Proc. First Italian Workshop on landslide (1st IWL) –Rainfall – Induced Landslides, Naples June 2009

Dierer S.,Arpagaus M., Seifert A., Avgoustoglou E., Dumitrache R., Grazzini F., Mercogliano P. Milelli M., Starosta K., Deficiencies in quantitative precipitation forecasts: sensitivity studies using the COSMO model, Meteorologische Zeitschrift, 18 (6)2009) pp. 631 – 645.

**Software used:**

1) COSMO-LM: regional meteorological model
2) CDO: software used to manipulate GRIB/NETCDF files
3) GRADS : visualization software
4) ARCGIS 9.3: spatial visualization
5) I-ModSOIL: Finite Element Stability Analysis model
6) TRIGRS: Finite Element Stability Analysis model

**File format(s):**

1) GRIB2: 1,2,3,4,5,6,7
2) NetCDF : 1,2,3,4,5,6,7

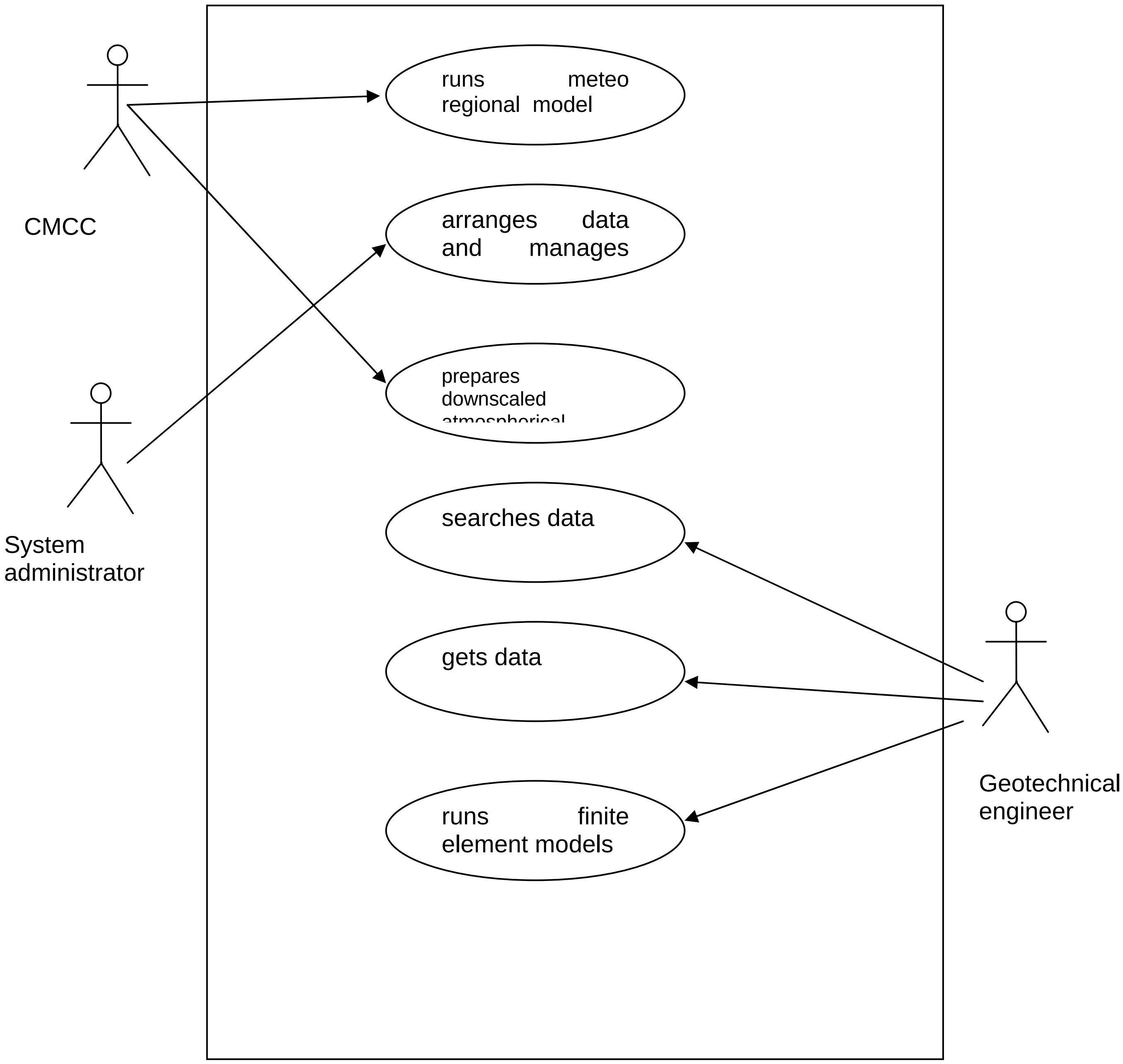
**Miscellaneous Notes:**

For the downscaling procedure, it has been used a function taking into account the areal morphologic characteristics and the geographical location. There is a good correlation among observed rain values, forecast values and the interpolated ones.

**Sources of uncertainty**

The goal is to reproduce as well as possible the observation, in order to produce some realistic warning one or two days before the event. All the limitations existing for the simulation of reality, by using a model, must be taken into account. This limitation represents a boundary that has to be accepted, taking into account that a big improvement of simulation model is still possible.

**Use-Case Diagram:**



## F.2 EVALUATION OF THE EFFECTS OF CLIMATE CHANGES ON LANDSLIDES PHENOMENA TRIGGERED BY PRECIPITATION EVENTS (CLAY STRAIN).

**Title:** Evaluation of the effects of climate changes on landslides phenomena triggered by precipitation events (clay strain).

**Author(s):** E. Bucchignani[1], R.Mella[1], P. Mercogliano[1], B.Sikorski[1], E. Damiano[2], E.Savastano[2], L.Olivares[3]
[1]CMCC
[2]AMRA
[3]Seconda Università di Napoli

**Date:** February 25, 2010

**Version:** 1

**Purpose:**

Evaluation of the effects of climate changes on landslides phenomena in the AMRA/CMCC landslide framework triggered by precipitation events.

**Actors:**

AMRA Geotechnical Engineers, CMCC Meteo Climate Scientists, System Administrator, Data center

**Summary:**

This Use Case describes the procedure used by CMCC-AMRA team in order to make usable the output data of the regional climatological model COSMO-CLM to the SEEP/W (GEO-SLOPE International Ltd.) and I-ModSOIL models, that are used for stability analysis in order to evaluate landslide risk scenarios. The procedure includes a the development of a downscaling tool in order to adequate the spatial resolution of atmospherical data to the one used by stability models (about 100 m); this procedure is already implemented in the I-ModSOIL code.

**Related Use Cases:**

Evaluation of the effects of intense rainfall on landslides phenomena (mud strain).

**Data needs:**

1) Atmospheric variables on mesoscale (obtained by using the COSMO-CLM regional model initialized by the global model ECHAM) for the Mediterranean region.
2) Parameters are: precipitation, minimum and maximum value of temperature, wind at 10 meters, relative humidity and temperature at 2 meters.
3) Data can be delivered in original format (GRIB/NetCDF); CMCC provides conversion in ASCII or other format, data averaging or spatial downscaling to the resolution of the stability analysis models.
4) Data about soil properties and topography.
5) Resolution requirements for climate date: 0.125 degrees (14 km), every 6 hours.

**Typical course of events:**

1) CMCC climatological researchers prepare datasets in GRIB format containing the solutions (saved every 6 hours) related to a well defined domain (i.e. Italy) for one or more centuries (e.g. XX and XXI).
2) System Administrator arranges access to the data for the Geotechnical Engineers, if needed

3) Geotechnical Engineers search for data on the CMCC Data Center the information related to the subdomain and to the period of their interest. If this subdomain contains more than one grid points, data are averaged in order to produce a single value for each variable (at each time step).
4) Geotechnical Engineers download data via FTP or WEB
5) Geotechnical Engineers runs their Finite Elements models.

**Support to users:**

**-**

**Requested Flexibility:**

Spatial and temporal means data can be easily obtained, as well as other statistical values.

**Alternative course of events:**

-

**References for the Use Case:**

E. Damiano, E. Bucchignani, P. Mercogliano, Un approccio alla valutazione del rischio frane indotte da cambiamenti climatici nella regione campania, *Proc. Environment Including Global Change*, Palermo (Italy), October 2009

Rockel B., Will A., Hense A., The regional climate model COSMO-CLM (CCLM), *Meteorologische Zeitschrift, 17 (4)2008)* pp. 347 – 348.

**Software used:**

1) COSMO-CLM: regional climatological model
2) CDO: software used to manipulate GRIB/NETCDF files
3) GRADS : visualization software
4) ARCGIS 9.3: spatial visualization
5) I-ModSOIL: Finite Element Stability Analysis model
6) SEEP/W: Finite Element Stability Analysis model

**File format(s):**

1) GRIB2: 1,2,3,4,5
2) NetCDF : 1,2,3,4,5

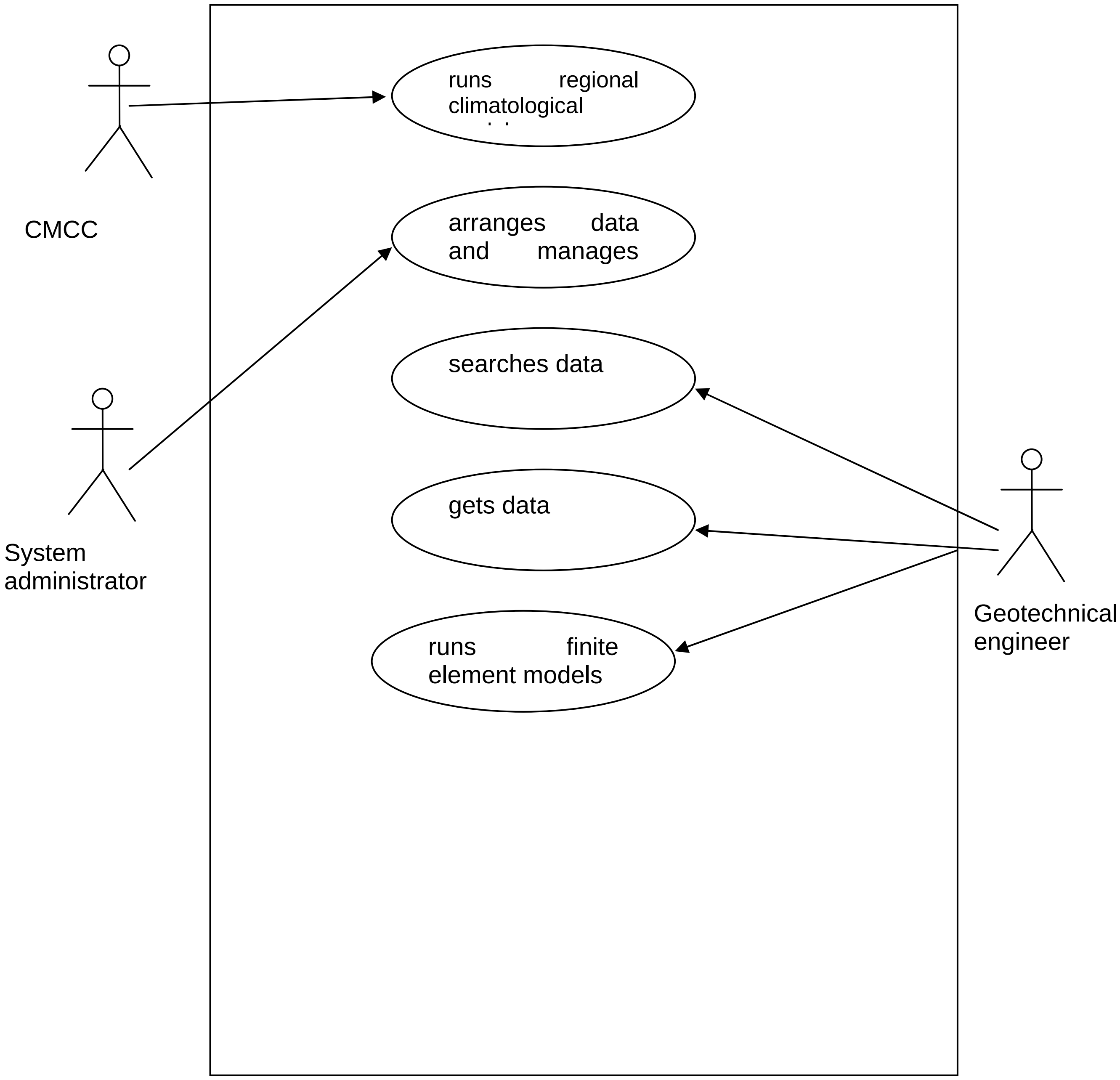
**Miscellaneous Notes:**

The finite element code SEEP/W has been validated using the results of a monitoring in a sample site in the region of interest, by using the Thornthwaite (1948) formulation for the evaluation of the potential evapotranspiration, and using the temperature values simulated by COSMO- CLM.

**Sources of uncertainty:**

The comparison between data by COSMO-CLM and observations in four stations shows that the model estimates in reliable way the temperature, while annual precipitations are underestimated, even if the trend is simulated in an acceptable way. Concerning the extreme events, the model shows a quite good forecast capacity, even the frequencies are underestimated.

**Use-Case Diagram:**



# APPENDIX G : MF USE CASES

## G.1 SCENARIOS FOR THE EVALUATION OF IMPACTS AND ADAPTATION TO CLIMATE CHANGE IN FRANCE

**Title:** Scenarios for the evaluation of impacts and adaptation to climate change in France

**Author(s):** S. Planton[1]
[1]Météo-France/CNRM

**Date:** March 4, 2010

**Version:** v. 1.1

**Purpose**:

Providing climate change scenarios to an interdepartmental working group on assessment of impacts, adaptation and associated costs , of climate change in France.

**Actors:**

Climate scientists (Météo-France, IPSL/LMD), impact scientists (INRA[13], …), members of the group, led by ONERC[14] from the French department of ecology and energy (MEEDDM[15]), and including representative from different departments (Agriculture, Health, DIACT, tourism) and many experts to assess the cost impacts of climate change and measures relevant to adaptation.

**Summary:**

This use-case describes the communication of information on future climate provided by the scientific community, in order to conduct studies on the cost of impacts and adaptation to climate change in France. An interdepartmental working group was settled to produce a report. The working group considered nine different domains: agriculture, forest / health / tourism / biodiversity / water / risk / transport infrastructure and building / energy / territories. The objective of the public stake-holders leading the group was to share the same information on climate change among the different participants of the group.

**Related Use Cases:**

None yet

[13] Institut National de Recherche Agronomique
[14] Observatoire National sur les Effets du Réchauffement Climatique
[15] Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer

**Data needs:**

Scenario simulations, downscaled with a dynamical method developed and applied at Météo-France and at IPSL/LMD[16], were made available. For Météo-France, they consist in one present climate simulation over the period 1960-1999 and two climate change scenarios (A2 and B2) over the period 2000-2099, performed with a variable resolution GCM (ARPEGE-Climat; Gibelin and Déqué, 2003) and given on the model grid (about 50km of resolution over France). For IPSL/LMD, they consist in one present climate simulation over the period 1970-1999 and one climate change scenarios (A2) over the periods 2030-2059 and 2070-2099, performed with a variable resolution GCM (LMDz; Hourdin et al, 2006) and given on the model grid (about 150km of resolution over France). For the two models, the provided variables include near surface (2m) daily maximum, minimum temperature and humidity, incoming surface solar and infrared radiations, near surface (10m) wind speed, solid and liquid precipitation. The variables are also corrected using a regional re-analysis: re-analysis of French meteorological observations (SAFRAN, Météo-France; Quintana-Segui et al, 2008) and a quantile-quantile correction method. The corrected variables are used to produce indices of extremes (hot-day threshold, cold-night-threshold, frost days, longest heat-wave, heavy rainfall threshold, greatest 5-day rainfall, longest dry period, maximum wind, …) using the standard of the STARDEX project (Goodess, 2003).

**Typical course of events:**

1) Production by the climate research group of climate scenario datasets: simulations of climate scenarios using global low resolution atmosphere/ocean/sea-ice climate models, downscaling of climate scenarios using variable resolution climate models, development and application of a correction method, calculation of climate extreme indices within the context of research projects.
2) Creation by the French department of ecology and energy (MEEDDM) of the working group for the evaluation of impacts and adaptation to climate change in France.
3) Selection of reference scenarios in interaction between ONERC and Météo-France to provide to the members of the working group.
4) Workshops associating climatologists and the members of the working group in particular to exchange knowledge on the chosen climate change scenarios.
5) Preparation of a documentation describing the data, the methods for data production, tables of averaged values and maps.
6) Delivery of the documentation to the members of the working group through the ONERC web site.
7) Recovery of the documentation by the members of the working group.
8) Publication of the report of the working group.

**Support to users:**

A documentation describing the data, the methods for data production, tables of averaged values and maps, is provided to the users through the ONERC web site (http://www.developpement-durable.gouv.fr/Climat-futur-en-France.html). Climatologists were associated to some workshops of the working group to exchange information on the scenarios.

**Requested Flexibility:**

New indices (seasonal values, other type of extremes, other definitions of extreme indices …) were requested by different members of the working group and the most part were calculated and provided.

**Alternative course of events:**

1) New requests of indices by different members of the group (seasonal values, other type of extremes, other definitions of extreme indices, regional indices …) and communicated to the

[16] Institut Pierre Simon Laplace / Laboratoire de Météorologie Dynamique

climatologists by the chairman of the group or through direct interaction.

2) Meeting associating ONERC and climatologists to examine some new requests and select those retained.

3) Calculation of selected new indices and adaptation of the documentation.

**References for the Use Case:**

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.

Gibelin, A.L., and M. Déqué, 2003 : Anthropogenic climate change over the Mediterranean region simulated by a global variable resolution model. Climate Dyn., 20, 327-339.

Goodess, C., 2003 : STAtistical and Regional dynamical Downscaling of Extremes for European regions : STARDEX. European Geophysical Union Information Newsletter 6, available on line at http://www.the-eggs.org/articles.php?id=37.

Hourdin, F., I. Musat, S. Bony, P. Braconnot, F. Codron, J.-L. Dufresne, L. Fairhead, M.-A. Filiberti, P. Friedlingstein, J.-Y. Grandpeix, G. Krinner, P. LeVan, Z.-X. Li and F. Lott, 2006: The LMDZ4 general circulation model: climate performance and sensitivity to parametrized physics with emphasis on tropical convection. Climate Dynamics 27, 787-813.

ONERC, 2008: Climat future en France. Documentation on climate indices in France from reference climate change scenarios. Available at : http://www.developpement-durable.gouv.fr/Climat-futur-en-France.html.

ONERC, 2009: Changement climatique, coûts des impacts et pistes d'adaptation. Report from the interdepartmental working group on assessment of impacts, adaptation and associated costs of climate change in France. Available at : http://www.developpement-durable.gouv.fr/IMG/spipwwwmedad/pdf/rapport_onerc_cle098a8d-1.pdf.

Quintana-Segui, P., Le Moigne, P., Durand, Y., Martin, E., Habets, F., Baillon, M., Canellas, C., Franchisteguy, L. and Morel, S., 2008: Analysis of Near-Surface Atmospheric Variables: Validation of the SAFRAN Analysis over France. J. Appl. Meteor. Climatol. 47, 92–107.

**Software used:**

1) ARPEGE-Climat (variable resolution version): Météo-France regional climate model

2) LMDz (variable resolution version): IPSL/LMD regional climate model

3) Météo-France correctmod: software to correct simulated variables from regional climate scenarios using available observations of these variables

4) GMT: graphical software.

**File format(s):**

The provided documentation is provided as PDF files.

**Miscellaneous Notes:**

The reference scenarios were chosen in order to maintain some continuity within the long-duration chain covering climate change scenario production, climate change impact studies, construction of adaptation scenarios, assessment of the cost of impacts and of adaptation. The choice is "conservative" in order to benefit from completed studies that used at least one of the reference scenarios.

**Sources of uncertainty:**

The sources of uncertainty of the downscaled scenarios are the internal climate variability, the choice of the emission scenario, the choice of the climate model and the choice of the downscaling method.

The uncertainty from the scenario is accounted for by using 2 different emission scenarios (B2 and A2). The uncertainty of the model choice is taken into account by selecting 2 different GCMs forcing 2 different regional climate model to calculate the statistically downscaled scenarios. The two other sources of uncertainties are here not taken into account and users were warned.

## G.2 SCENARIOS FOR ADAPTATION STUDIES TO CLIMATE CHANGE OVER THE LOIRE BASIN

**Title:** Scenarios for adaptation studies to climate change over the Loire Basin

**Author(s):** S. Planton[1], C. Pagé[2]
[1]Météo-France/CNRM
[2]CERFACS

**Date:** March 4, 2010

**Version:** v. 1.1

**Purpose**:

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.

**Actors:**

Climate scientists (Météo-France, CERFACS[17]), hydrologists (ISTO[18], Sisyphe[19], BRGM[20], …), geographers (CITERES[21]), Loire Basin managers (Etablissement Public Loire, Agence de l'eau Loire Bretagne, ..), public stake-holders (DGPR[22]).

**Summary:**

This use-case describes the communication of information on future climate provided by the scientific community, in order to conduct studies on the adaptation of the Loire Basin management plan to the impacts of climate change. The objective of the public managers is to develop a common knowledge on this topic that relies on research results. They have prepared and launched a call of opportunity open to the French scientific community to improve the knowledge of the vulnerabilities of human activities and environments to the effects of climate change over this region. They have appealed French climate research groups for choosing and providing climate change scenarios that could be used by other research groups working in a wide range of fields (hydrology, sociology …) to lead their research in response to the call of opportunity.

**Related Use Cases:**

None yet

**Data needs:**

Two types of data are made available:

- Regional re-analysis: re-analysis of French meteorological observations (SAFRAN, Météo-France; Quintana-Segui et al, 2008) covering several decades (1970-2007) on a regular grid (grid mesh of 8km) including hourly near surface (2m) temperature and humidity, incoming surface solar and infrared radiations, near surface (10m) wind speed, solid and liquid precipitation. Calculated evapotranspiration from the re-analysed variables is also added.

[17] Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique
[18] Institut des Sciences de la Terre d'Orléans
[19] Système Hydrique et Géophysique
[20] Bureau de Recherches Géologiques et Minières
[21] Centre Interdisciplinaire Cités, TERritoires, Environnement et Sociétés
[22] Direction Générale de la Prévention des Risques

- Downscaled scenario: Two ensemble of data from scenario simulations downscaled either with a dynamical method or with a statistical method. The dynamically downscaled ensemble (Météo-France) consists in one present climate simulation over the period 1950-2000 and three climate change scenarios (A1B, A2 and B1) over the period 2001-2100, performed with a variable resolution GCM ((ARPEGE-Climat; Gibelin and Déqué, 2003)) and is given on the model grid (about 50km of resolution over France). The statistically downscaled ensemble (CERFACS) consists in present climate simulations over the period 1961-2000 and climate change scenarios (A1B) over the periods 2046-2065 and 2081-2100, derived by means of a weather typing method from re-analysis (SAFRAN and NCEP) and CMIP3 simulations performed with 15 AOGCMs, and is given over the SAFRAN grid (resolution of 8km). The dynamically downscaled simulation are also statistically downscaled. For the two ensembles, the available variables are the same than those given in the previous section but are given at the daily time step and include the daily maximum and minimum for temperature. The dynamically downscaled variables also include corrected temperature and precipitation using reference daily observations from the French meteorological station network and a quantile-quantile correction method (Déqué, 2007).

**Typical course of events:**

1) Production by the climate research group of climate scenario datasets within the context of research projects: simulations of climate scenarios using global low resolution atmosphere/ocean/sea-ice climate models, downscaling of climate scenarios using a statistical method and a variable resolution climate model combined with a correction method.
2) Workshop associating climatologists and Loire Basin managers to exchange knowledge on climate change scenarios and selecting the scenarios and variables that will be provided in the context of the call of opportunity. The importance of uncertainty in the scenarios is re-assessed.
3) Data extraction (regional re-analysis and downscaled scenario data) over the domain of interest and calculation of complementary variables (evapotranspiration, minimum and maximum daily temperature, relative humidity).
4) Preparation of a documentation describing the data, the methods for data production, the data access methods, the uncertainty evaluation and recommendations for data use.
5) Data delivery by the climate research groups in a data repository located in a centre in contact with the selected research teams (provisional before the settlement of a web data portal).
6) Launch of the call of opportunity including documentation on the available climate change scenarios and selected of variables.
7) Selection of the research teams by the scientific committee of the program.
8) Workshop associating the climatologists, the Loire Basin managers and scientists from the selected research teams to present the research project and the data made available for the studies, along with recommendations for data use (uncertainty).
9) Data recovery by the selected research teams from the data repository with the associated documentation.
10) Support from the climatologists to the data users during the duration of their projects through e-mails, phone or meetings (practical use, scientific aspects), initiated by means of a unique e-mail contact point.

**Support to users:**

A documentation describing the data, the methods for data production, the data access methods, the uncertainty evaluation and recommendations for data use, is provided to the users. Support from the climatologists is provided to the data users during the duration of their projects through e-mails, phone or meetings (practical use, scientific aspects), initiated by means of a unique e-mail contact point.

**Requested Flexibility:**

No requested complementary data.

**Alternative course of events:**

none.

**References for the Use Case:**

Call of opportunity of « Plan-Loire »: « Appel à projets de recherche sur la connaissance des vulnérabilités des activités humaines et des milieux du bassin de la Loire par rapport aux effets du changement climatique sur les régimes d'inondation et de sécheresse », June 2008, available at :

http://www.plan-loire.fr/fileadmin/pce/PF_RDI/ILCC/Docs/AppelaProjetsCC.pdf.

Boé, J., L. Terray, F. Habets, and E. Martin, 2006: A simple statistical-dynamical downscaling scheme based on weather types and conditional resampling. J. Geophys. Res., 111 :D21106, 2006.

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.

Gibelin, A.L., and M. Déqué, 2003 : Anthropogenic climate change over the Mediterranean region simulated by a global variable resolution model. Climate Dyn., 20, 327-339.

Pagé, C., L. Terray et J. Boé, 2009: dsclim: A software package to downscale climate scenarios at regional scale using a weather-typing based statistical methodology. Technical Report TR/CMGC/09/21, CERFACS, Toulouse, France. http://www.cerfacs.fr/~page/dsclim/dsclim_doc-latest.pdf

Pagé, C., J. Boé, et L. Terray, 2008 : Projections climatiques à échelle fine sur la France pour le 21ème siècle : les scénarii SCRATCH08. Technical Report TR/CMGC/08/64, CERFACS, Toulouse, France.
http://www.cerfacs.fr/~page/publications/report_cerfacs_regional_scenarii_scratch08.pdf

Russell, K. R., E. J. Hartnett, and J. Caron, 2006: NetCDF-4: Software Implementing an Enhanced Data Model for the Geosciences. 22nd International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology. http://www.unidata.ucar.edu/software/netcdf/

Quintana-Segui, P., Le Moigne, P., Durand, Y., Martin, E., Habets, F., Baillon, M., Canellas, C., Franchisteguy, L. and Morel, S., 2008: Analysis of Near-Surface Atmospheric Variables: Validation of the SAFRAN Analysis over France. J. Appl. Meteor. Climatol. 47, 92–107.

*udunits-1*: http://www.unidata.ucar.edu/software/udunits/udunits-1/

*Convention CF-1.0 NetCDF*: http://cf-pcmdi.llnl.gov/documents/cf-conventions/1.0

**Software used:**

1) CERFACS dsclim : downscaling software and library
2) CERFACS extract_ds : data-extraction software
3) ARPEGE-Climat (variable resolution version): Météo-France regional climate model
4) Météo-France correctmod : software to correct simulated variables from regional climate scenarios using available observations of these variables
5) NetCDF-4 library
6) udunits-1 library

**File format(s):**

1) The provided files containing the data (regional re-analysis and downscaled scenario) are in ASCII format.
2) The native format for CERFACS statistical downscaling data is in the NetCDF format using the CF-1 convention.

**Miscellaneous Notes:**

Only one research team selected after the first call of opportunity needed the data but, due to direct interaction with the climatologists in the context of a previous research project, the data was already at their disposal. The facility of the data repository was thus not used within the context of the first call of opportunity.

**Sources of uncertainty:**

The sources of uncertainty of the downscaled scenarios are the internal climate variability, the choice of the emission scenario, the choice of the climate model and the choice of the downscaling method. The first one is generally addressed by using ensemble of simulations for each climate model and each emission scenario. It is not here taken into account. The uncertainty from the scenario is accounted for by using 3 different emission scenarios (B1, A1B and A2). The uncertainty of the model choice is taken into account by selecting 15 different GCMs and one regional climate model to calculate the statistically downscaled scenarios. The uncertainty from the downscaling method is addressed by using two different methods: statistically downscaled scenarios from GCMs simulations and dynamically downscaled scenarios (regional climate model) with corrected precipitation and temperature to reproduce observed spectra of variability under present climate conditions.

# APPENDIX H : WUR USE CASES

**Title :** Regional climate modeling using PRECIS

**Author(s):** Ronald Hutjes (WUR), Christian Seiler (FAN)

**Date:** 11 jan 2010

**Version:** v2

**Purpose:** Dynamical downscaling of climate scenarios using the Hadley Centre PRECIS model requires forcing data to run. Downscaled data are used as input for impact models and assessments on biodiversity and carbon stocks.

**Actors:**
user/climate scientist: Christian Seiler, from Fundación Amigos de la Naturaleza (FAN), a nature conservation NGO in Bolivia

**Summary:**
Delivery of 4D climate data to be used as forcing data for dynamical downscaling of climate scenarios using the Hadley Centre PRECIS model. Data should be in a PRECIS compatible format and should be delivered on hard disks due to volume of the data. Many more researchers / institutes worldwide, most in developing countries, are using PRECIS.

**Related Use Cases:**
n/a

**Data needs:**

- Needed are 4D forcing data in a format specific to PRECIS
    - Boundary condition data are supplied on an IDE hard drive of roughly 230GB (or possible a DLT tape).
    - Currently only a selection of GCM runs are available as boundary conditions, mostly from HadAM3, HadCM3, ECHAM4/5, and the re-analyses projects of NCEP and ECMWF.
    - using forcing data from other GCMs is currently not available due to conversion issues
- Needed are 3D data (2D +time) of observed or analysed fields for 20th century for validation and bias-corrections
- Typical meteorological variables for climate impact studies include minimum, maximum and mean air temperature, precipitation, relative humidity, windspeed, incoming solar radiation, evapotranspiration and runoff. Variables should be presented as daily values and 30-year monthly means.

**Typical course of events:**
User decides:

- which experiment she would like data for (i.e. ERA40, control, A2)
- whether she desires punctual or spatial data,
- which input parameters she needs for her model,
- what time resolution the input data should have,
- what physical unit the data should have,
- what format the data should be in (e.g. ascii, ArcGIS grids, .ctl)

Provider then:

- extracts the requested data from the model output, using Hadley-Centre-specific *.pp*-scripts.
- converts the data to desired format,
- passes data to user.

**Requested Flexibility:**

- To deal with the wide range of user's expectations we provide 30-year monthly mean data of the meteorological variables mentioned above, choosing the grid format of ArcGIS. However, experience shows that this is insufficient and ArcGIS inappropriate tool for temporal analysis.
- We therefore want to train users to use GrADS and provide them free access to daily data.

**Alternative course of events:**

Many input models require daily data and information on climatic indices (e.g. consecutive dry days). To reduce the work of the provider we have passed all crude model outputs and installed PRECIS for the user. PRECIS includes a Hadley-centre specific analysis tool for *.pp*-files (optional output next to NetCDF). This gives the user total freedom on data manipulation and analysis.

**References for the Use Case:**

Jones, R.G., Noguer, M., Hassell, D.C., Hudson, D., Wilson, S.S., Jenkins, G.J. and Mitchell, J.F.B. (2004) Generating high resolution climate change scenarios using PRECIS, Met Office Hadley Centre, Exeter, UK, 40pp

Christian Seiler (2009) Implementation and validation of a Regional Climate Model for Bolivia. Fundación Amigos de la Naturaleza (FAN-Bolivia)

**Software used:**

- PRECIS: Regional Climate Modeling and data manipulation
- ArcGIS: spatial visualization. ArcGIS has turned out to be an inappropriate tool, due to its lacking capability to analyze large time series. Alternative: GrADS.
- Excel: Statistical analysis. Excel has turned out to be inappropriate. Alternative: MatLab.
- Input models:
  Hydrology: Soil Water Assessment Tool (SWAT, implemented in ArcGIS); Agricultural production: DSSAT; Biodiversity: Maxent

**File format(s):**

Output data from PRECIS is written in the Met Office's own *PP binary data*
format. PP format is easily read and processed by Fortran, and can be reformatted into either NetCDF or GRIB data at any point, but the reverse is not possible.
End-users typically desire ascii-files, but also the ArcGIS grid format.

**Miscellaneous Notes:**

- Limitations: Impact-assessment-model-inputs are very specific and vary largely among models and applications. There are too many users, making it impossible for the provider to elaborate the desired data sets. We therefore want to provide daily data, giving the user total freedom on data analysis and manipulation. GrADS appears to be a reasonable tool for this purpose. However, this step also increases the complexity on how to obtain input data, potentially leading to fewer applications. Educational needs: In FAN-Bolivia we are planning to train people in the use of GrADS.

**Sources of uncertainty:** [How does the user deal with the uncertainty in the climate data]

- If uncertainty can be spatially located (e.g. in case of Bolivia, the highlands are related to higher uncertainty compared to the lowlands), then the application of impact assessments are reduced to regions with least uncertainty.
- Users are interested in ranges, thus A2 and B2 scenarios are typically demanded.

**Use-Case Diagram:**

none

# APPENDIX I : IPSL USE CASES

## I.1 IMPACT OF GLOBAL CHANGES ON FRESHWATER FISH BIODIVERSITY AT LARGE SCALE

**Title:** Impact of global changes on freshwater fish biodiversity at large scale

**Author(s):** Mathieu Vrac (LSCE/IPSL, France)

**Date:** 2010-05-02

**Version:** v2

**Purpose**:

Developing a hydro-climatic-ecological (HCE) model-chain to link large scale climate data to local scale occurrence of aquatic biodiversity

**Actors:**

IPSL (Paris) ;

EDB laboratory (Evolution et Diversité Biologique, Paul Sabatier University, Toulouse) ;

People implied in the Euro-Limpacts European project

**Summary:**

The Water Framework Directive (WFD) aims to improve the chemical and ecological status of European freshwaters (European Parliament, 2005). Such improvement is likely to be achieved by reductions in pollutant. However natural freshwater ecosystems are structured by regional (altitude, geology, slope, land use) and local (point or diffuse inputs of elements, stream depth and width, stream velocity) environmental factors which are highly variable in space and time and likely to be sensitive to future climate variations, particularly those in temperature and precipitation. To understand how projected climate change will impact the freshwater ecology it is important to determine the inter-relationships between climate and hydrology and the response of the aquatic ecology to changes in habitat and food-web structure. This understanding is required to develop informed management plans regarding the use of water resources whilst protecting the ecological services of surface waters. As part of this research effort, a hydro-climatic-ecological (HCE) model-chain was developed for south-west France to test hypotheses regarding how the climate controls fish communities through invoked changes in the regional hydrology and temperature.

**Related Use Cases:**

None

**Data needs:**

Observation data:
Hydrological data: Adour river monthly flows for 1970-2000 period from MEDDAD database,
Meteorological data: monthly temperature and precipitation of SouthWest France observation stations for 1970-2000 period from Météofrance database,
Biodiversity data: occurrence (presence or absence) for the 13 most prevalent freshwater fish species in the region. The ONEMA ("Office National des Eaux et des Milieux Aquatiques") database includes values from 50 sites for the 1992-2000 period.

Modelling data:
Monthly data from 13 IPCC models for 1970-2000. 4 variable groups around 1) temperature, 2) pressure, 3) precipitation, 4) short wave radiation are used.
Monthly data from 5 IPCC models for 2005-2100 period. Same variables.

Reanalysis:
NCEP data for the same variable than modelling data. Period:1970-2000.

**Typical course of events:**

Gathering observed data sets needed for the study from several agencies, laboratories…

Development and validation of the HCE model:
The HCE model is composed of 2 parts:
a statistical downscaling step (SD) converts global gridded data (temperature, pressure, precipitation, short wave radiation groups) into local fields measured at stations (temperature, precipitation, flow);
an “ecological niche” model (EN) turns the local fields into freshwater fish occurrence.
These two parts of the HCE model are based on aggregated boosted trees (ABT) statistical method.
HCE model has been developed from NCEP reanalysis data, local meteorological data from Météofrance, local flows from MEDDAD and occurrence data for the 1970-1985 period (apprentissage phase).
Validation phase of the model has been performed from the 1985-2000 period.
The lack of biodiversity data (available only for 1992-2000) is tackled in mixing data from the 50 sites in the same data set.

Selection of the “best” model data sets:
Analysing the main strengths and weaknesses of 13 IPCC model data in comparison to the NCEP reanalysis fields for both periods 1970-1985 and 1985-2000. The analysis is based on the 3 following indicators:
mean;
standard deviation;
pdf deviation (Kolmogorov-Smirnov test).
Selection of the most appropriate simulated datasets for the study (5 models have been chosen).

Correction of modelling data:
Selection of a correction method regarding the data biases, the geographical zones of interest and the data availability (cdft method).
Selection of a data set to perform the correction: observations, re-analyses. NCEP reanalysis has been selected for this step.
Development or adaptation of correction code source.
Validation of corrected data.

Testing the HCE model performances for model corrected data:
Period: 1985-2000.
Comparison with observed flow, temperature, precipitation, and fish occurrence data.

Performing fish occurrence projections from climate model data set (2005-2100)

Statistical analysis of the multi-models results:
Trend and variability
Evaluation of the signal trend compared to natural variability
Results significativity and robustness

Interpretation and graphical display

Writing papers for international scientific review and thesis report.

**Support to users:**

.

**Requested Flexibility:**

**Alternative course of events:**

**References for the Use Case:**

Tisseuil C., 2009. Impact of global changes on freshwater fixh biodiversity at large scale. PhD Thesis.

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

**Methods:**

CDFT correction method.

Aggregated boosted trees (ABT) statistical method for the HCE model.

Model evaluation based on mean, standard deviation and pdf comparisons of observed and simulated data. For the pdf one the Kolmogorov-Smirnov test has been used.

**Software used**:

R

**File format(s):**

NetCDF
Ascii

**Miscellaneous Notes:**

**Sources of uncertainty:**

## I.2 IMPACTS OF CLIMATE CHANGE ON CROP YIELDS IN THE TROPICS

**Title**: Impacts of climate change on crop yields in the tropics

**Author**: Benjamin Sultan (LOCEAN, France)

**Date**: 2010-05-11

**Version**: 2

**Purpose**: Assess the impacts of climate change on crop yields in the tropics

**Actors**: IPSL

**Summary**:

Agriculture is considered as the most weather-dependant of human activities. Although average levels of crop productivity across the world mostly depend on local non-climatic factors, the temporal variability in crop yields often reflects the variability in weather conditions. Fluctuations in climate can lead to severe socio-economic impacts in developing countries in the tropics for three main reasons: (i) crop production is often the main source of food and income, (ii) levels of crop management technology are low and (iii) in many cases these countries are exposed to high variability in climate. We thus propose to translate climate outputs from GCMs into crop yields in the tropics. We will first validate the accuracy of the simulated yields by using yield database at various scales and then propose scenarios of crop yields evolution in the future.

**Related use cases**: None

**Data needs**:

data type:

daily maximum and minimum temperatures, daily potential evapotranspiration, global radiation, daily rainfall

period: 1968-2100,

spatial covering: global data and regional data at higher horizontal resolution for Africa

data set

Simulated data from the stream 2 data set of the European project ENSEMBLE. It includes 7 models and several simulations per models.

RCM data from ENSEMBLES in Africa

Observation gridded data for model correction. Three available datasets: the the reanalyses ERA40, ERAinterim, or NCEP. Rainfall datasets at stations (Hulme, IRD).

Yield database from FAO at the national scale, district-scale and local scale yields database in West Africa

**Typical course of events**:

- Correction of modelling data

  Selection of a correction method functions of the data biases, the geographical zones of interest and the data availability.

  Selection of a data set to perform the correction : observations, re-analyses

  Development or adaptation of correction code source

  Validation of corrected data

- Yields simulation in the actual period

  Run the crop model with bias-corrected actual outputs from GCMs.

  Aggregate simulated yields at various scale corresponding to yields data base

  Compare simulated and observed yields

- Yields simulation in the futur period

  Run the crop model with bias-corrected future outputs from GCMs.

  Aggregate simulated yields at various scale corresponding to yields data base

  Analyse the trends of future yields

  Identify vulnerable regions in the tropics

**References**: None

**Methods**:

Quantile-quantile correction method.

Crop modelling

Method to compare several data-sets (trend, seasonal cycle, inter-annual variability).

Multi-model analysis.

Kendall test for trend significativity evaluation …

**Software**:

ORCHIDEE-MIL (crop modelling tool in the tropics)

IDL to change format data from ascii to netcdf.

Fortran program for the data correction and the indicator calculation

CDO, NCO, ferret, for data treatment and data analyses (DTR, indicator..)

NCL, EXCEL for graphical display.

**File format**:

NetCDF

Ascii

**Miscellaneous Notes:**

**Sources of uncertainty:**

## I.3 SENSITIVITY OF POWER DISTRIBUTION INFRASTRUCTURE TO DAYS OF HIGH TEMPERATURE VARIABILITY.

**Title**: Sensitivity of power distribution infrastructure to days of high temperature variability.

**Author:** Céline Déandreis (IPSL, France)

**Date**: 2010-05-11

**Version**: 2

**Purpose**:

Developing and analysing an indicator to describe vulnerability of energy sector to climate change in term of power distribution.

**Actors**:

Energy sector firms (mainly environment department manager) and climatologists from IPSL, CERFACS and CNRM, Model Developer from IPSL.

**Summary**:

In order to provide the private sector with the best benefits of the progress of climate science, a collaborative project with climatologists and industries (INVULNERABLe) has been launched to develop physical and vulnerability indicators with operational relevance. Especially, we propose to study energy sector vulnerability to climate change. A first case study has been launched to analyse the impact of climate change on the management of power distribution installation (distribution running). This activity is sensitive to fast temperature changes. A climatic indice has been defined. It describes the number of day with diurnal range temperature values much higher than the normal ones. The analysis includes indice actual values and future projections over Europe and China. Both long (end of 21st century) and midrange-term (2030-2050) are examined.

**Related use cases**: None

**Data needs**:

- data type:

  daily maximum and minimum temperatures

  period: 1961-2100,

  spatial covering: global data and regional data at higher horizontal resolution for Europe and China

- data set

  Simulated data from the stream 2 data set of the European project ENSEMBLE. It includes 7 models and several simulations per models.

  Observation gridded data for model correction. Three available datasets: the Hadley Centre data set (HADGHCND) and the reanalyses ERA40 or NCEP.

**Typical course of events**:

- Indices definition

Setting up the dialog between industrial partners and climatologists (dealing with cultural, vocabulary differences…; reciprocal education on climate sciences, modelling limits, company interest, economics….). Conception of aid materials (synthetic report, glossary,…) to facilitate the dialog.

Writing fact sheets on several topics addressed in the 4th IPCC report, review of scientific studies on diurnal temperature range and other physical processes.

Finding the « best interlocutor » within the industrial companies.

Department leader, engineer, plant workers…

Detecting vulnerabilities of industrial partners (events, zones and periods of interest…)

In our study: the « difficulty to adapt the running of power distribution installation when fast temperature changes happen (during the day or between consecutive days) » has been mentioned as a main problem.

Regions : China, Europe

Period : 2030-2050

Translating vulnerability in terms of meteorological fields.

DTR > DTRref + threshold

Indices illustration from data available and easy-to-use.

Indices ratification by the industrial partners

Reiteration of stages 4 and 5 to improve indices definition (seasonality, vulnerability threshold, signal by-products …).

- Data sets selection :

Analysing the main strengths and weaknesses of each data-sets (confidence in the data relatively to the study aim, availability …).

Selection of the most appropriate dataset for the study

Assess the dataset performance for describing physical fields and indices defined in the first step of the process

- Correction of modelling data

Selection of a correction method functions of the data biases, the geographical zones of interest and the data availability.

Selection of a data set to perform the correction : observations, re-analyses

Development or adaptation of correction code source

Validation of corrected data

Writing synthetic report on targeted physical fields (Diurnal Temperature Range) as a complement to the review of scientific knowledge. This report contains information about variability, statistical distribution, main geographical structures, physical processes…

Indices calculation from corrected data

Developing source code

Running source code

- Indices statistical analysis

Trend and variability

Evaluation of the signal trend compared to natural variability

Results significativity and robustness

Interpretation and graphical display

Describing results to industrial partners (staff from strategy, risk, insurance or environmental departments) in order to define vulnerability, adaptation measures.

**References**: None

**Methods**:

Quantile-quantile correction method.

Method to compare several data-sets (trend, seasonal cycle, inter-annual variability).

Multi-model analysis.

Kendall test for trend significativity evaluation …

**Software**:

IDL to change format data from ascii to netcdf.

Fortran program for the data correction and the indicator calculation

CDO, NCO, ferret, for data treatment and data analyses (DTR, indicator..)

NCL, EXCEL for graphical display.

**File format**:

NetCDF

Ascii

**Miscellaneous Notes:**

**Sources of uncertainty:**

Several sources of uncertainty are accounted for in this study

- observation dataset
- model biases
- model structural differences

Multi-reanalyses datasets and multi-model analyses are used to provide a measure of these uncertainties.

## I.4 IMPACTS OF CLIMATE CHANGE ON AGROSYSTEMS, INTERACTION WITH ECONOMICAL MODELS

**Title**: Impact of climate change on crop yields, interaction with economical models

**Author**: Nicolas Viovy (LSCE, France)

**Date**: 2010-05-11

**Version**: 1

**Purpose**:

- Assess the impacts of climate change on main agrosystems (forestry,crops and pasture)
- Assess the impact of agrosystems on main GHG budget.
- Provide information to feed land use models

**Actors**: IPSL, CIRED

**Summary**:

Agriculture is considered as the most weather-dependant of human activities. Although average levels of crop productivity across the world mostly depend on local non-climatic factors, the temporal variability in crop yields often reflects the variability in weather conditions. In return, land use as an impact on climate thru interaction with hydrologic and energetic budget of the surface and contribution to the GHG budget. In particular the ability of agriculture to mitigate carbon is related to land conversion. The first purpose of this case, initiated in the French AUTREMENT project, is to evaluate impact of climate change on crop yield, animal and wood production. Second purpose is to evaluate impact of climate change and land use change on GHG budget. This requires scenarios from models simulating land use change based on economical constraints. In return, these models needs data on yields that are in general held constant in the future and don't take into account for impact of climate change on yields. Hence there is an urgent need to couple land use model with yield models to fully account for feedback between climate/yield and land use change. The third purpose of this case is then to couple a yield model to a land use model.

**Related use cases**: None

**Data needs**:

data type:

- main climate drivers (temperature, precipitation, radiation, air humidity, wind speed)

period: 1900-2100,

spatial covering: global data and regional data at higher horizontal resolution for Europe and France

- Data on management (eg. fertilizer, irrigation, crop rotation, tillage intensity, wood demand, animal load …)
- Land use scenarios

data set

For historical period: combination of reanalysis and climatology (ex. CRUNCEP dataset). For future. Scenarios for sveral models and contrasted climate scenarios.+disagragated scenarios for EUROPE

For historical period: Dataset on forest age distribution, historical data on land management (e.g tillage intensity, fertilizer input, intensity of grassland managment etc..)

For future period: Wood and production demand, land use scenarios

Soil properties maps.

For validation: Yield database from FAO at the national scale, district-scale and local scale. Sol map properties Flux tower measurements

**Typical course of events**:

- Compilation of data on management and validation data
- Development and improvement of models
- Yields simulation in the actual period, comparison with observed yields
- Yields simulation for the future period based on several contrasted climate scenarios

  Analyse of trends of future yields

  Identify vulnerable regions and analyse change in region where each crop can growth

  Analyse of change in GHG budget
- Provide yield response curves for land use change model
- Projected land use change based on economical scenarios and yield response
- Impact of land use change on GHG budget

**References**:

**Gervois S., N Noblet-Ducoudré, N Viovy, P Ciais N Brisson, B Seguin, A Perrier (2004)** Improving croplands in the global biosphere model"Coupling" methodology and evaluation at specific sites *Earth interaction***, *8*,** *pp 1-25*

**Krinner G. ,N. Viovy ,N. de Noblet, J. Ogée, P. Friedlingstein P. Ciais, S. Sitch ,J. Polcher , I. C. Prentice (2005b)**, A dynamic global vegetation model for studies of the coupled atmosphere-biosphere system *Global Biogeochemical Cycles*, ***19, doi:1029/2003GB002199****,pp1-33*

**Vuichard N. , P. Ciais N. Viovy, J.F. Soussanna, C. Ammann P. Calanca J. Clifton-Brown, J. Fuhere,M. Jones, C. Martin (2006)** Estimating the greenhouse gas fluxes of European grasslands with a process based model: Part1. Model evaluation from in-situ measurements *Global Biogeochemical Cycles 21 (1), GB1004*

**Vuichard N., P Ciais, N Viovy, P Calanca and J.F. Soussanna (2006)** Estimating the Greenhouse Gas Fluxes of European Grasslands with a Process Based Model: Part 2. Simulations at the continental level *Global Biogeochemical Cycles 21 (1), GB1005*

**Methods**:

Crop and land use modelling

Method to compare several data-sets (trend, seasonal cycle, inter-annual variability).

Multi-model analysis.

Kendall test for trend significativity evaluation …

**Software**:

ORCHIDEE (crop modelling tool in the tropics)

NEXUS land use & IMACLIM (land use module and economical model

Fortran and C programs for data preprocessing and postprocessing

CDO, NCO, ferret, for data treatment and data analyses (DTR, indicator..)

**File forma**t:

NetCDF

Ascii

**Miscellaneous Notes:**

**Sources of uncertainty:**

Several source of uncertainties are considered:

**-** Uncertainties on input data that are treated by providing several simulations based on forcing data for climate, land use scenarios etc.. .

- Uncertainties on model are trated by considering several model hypotheses.

# APPENDIX J : SMHI USE CASES

## J.1 INITIAL ASSESSMENT OF CLIMATE CHANGE IMPACTS ON THE FORESTRY SECTOR

**Title:** initial assessment of climate change impacts on the forestry sector

**Author(s):** Lars Bärring (SMHI Rossby Centre, Sweden)

**Date:** 2010-06-07

**Version:** v2

**Purpose**: Providing the Agricultural and Forestry Expert Panel within the Swedish Commission on Climate and Vulnerability (2005-2007) with initial ideas of climatic factors relevant for impacts and not covered by more comprehensive impact modelling efforts.

**Actors:**

SMHI Rossby Centre

Swedish Commission on Climate and Vulnerability: Secretariat

Agricultural and Forestry Expert Panel of the Commission

**Summary:**

The Swedish Commission on Climate and Vulnerability was instigated by the Swedish Government to carry out a comprehensive cross-sectorial assessment of climate and vulnerability in the Swedish society (SOU, 2007:60). Some forestry impacts of climate changes were already well covered by impact modelling or otherwise research findings. Other possible climate change impacts were identified during the course of the Panel discussions. Such identified impacts spawned a more technical/scientific discussion regarding possible ways to capture the essential elements of the climate change that directly relate to the identified impact. In this way a number of “impact relevant climate indices” were suggested. The overarching aim was to provide the Panel with a rough initial of possible future impacts where more sophisticated impact models were not available or could be developed within the time frame of the Commission.

All in all, some 50 different indices were developed on request from the Commission (Persson et al, 2007)

**Related Use Cases:**

None

**Data needs:**

Modelling data:
Available regional climate model data at daily time resolution. Regional climate change scenarios simulation and ERA-40 driven simulations.

**Typical course of events:**

- Climate scientists attended a Panel meeting at an early stage. The focus of the meeting was climate models, climate scenarios, scenario uncertainty, necessity to use more than one scenario, as well as possibilities to use the model output for tailoring climate indices.
- The Expert Panels held one or two internal meetings.
- Climate scientists participated in a further Panel meeting focussing on brainstorming and discussions of possible ways to capture possible forestry impacts in terms of climate indices derived from the available regional climate model dataset. Suggested indices were submitted to the Commission secretariat.

- The Commission secretariat compiled requested indices form the different expert panels and discussed these with the climate scientists. The feasibility and relevance of the different indices were discussed and the possibility to combine similar indices were explored. This resulted in that some indices were excluded for scientific or technical reasons, and some other similar indices were merged. The reduced and updated list of climate indices were presented to the expert panels and discussed with the climate scientists, This process were iterated until agreement were reached.

- In parallel with the preceding steps the climate scientists developed the software to carry out calculation of the tailored indices. Selected preliminary results were presented to the expert panel and feedback was used to adjust the system and sometimes the indices as such.

- Climate scientists participated in expert panel meetings, as well as supporting the Commission secretariat, to explain the results and assist in climatic science aspects of the interpretation of the results.

- Report writing and presentation of the results at a series of outreach events and public meeting.

**Support to users:**

See above.

**Requested Flexibility:**

See above.

**Alternative course of events:**

**References for the Use Case:**

Persson, G., Bärring, L., Kjellström, E., Strandberg, G. & Rummukainen, M., 2007: Climate indices for vulnerability assessments. SMHI Reports Meteorology and Climatology No. 111, SMHI, SE-60176 Norrköping, Sweden, 64 pp + DVD.

SOU, 2007:60: Sweden facing climate change – threats and opportunities. Final report from the Commission on Climate and Vulnerability. *Swedish Government Official Reports 2007:60*. 679 pp. <http://www.sweden.gov.se/sb/d/574/a/96002>

**Methods:**

**Software used**:

RCA, RCAO, CDO, NCO, Fortran, Matlab

**File format(s):**

Input: NetCDF, GRIB1. Output: image formats (png, eps), html,

**Miscellaneous Notes:**

**Sources of uncertainty:**

Several sources of uncertainties are considered:

**-** Uncertainties on emission scenarios are to some extent dealt with by using two emission scenarios.

- Uncertainties related to choice of GCM and initial condition is dealt with by using two GCMs.

- Uncertainties related to the RCM formulation is dealt with by including two significantly different versions of the RCM.

- The resulting maps were produced after being spatially smoothed and using a deliberately coarse colour scale to help the users to focus on large-scale and robust features and changes rather than local peculiarities that could be more prone to influence form noise and random variations.

## J.2 ASSESSMENT OF CLIMATE IMPACT ON A RED-LISTED MOSS (BRYOPHYTA) SPECIES

**Title**: Assessment of climate impact on a red-listed moss (*Bryophyta*) species

**Author**: Lars Bärring (SMHI Rossby Centre, Sweden)

**Date**: 2010-06-07

**Version**: 2

**Purpose**: Assess the impacts of climate change on a vulnerable species at a specific forest site.

**Actors**:

SMHI Rossby Centre

Ecology Department, Swedish University of Agricultural Sciences

**Summary**:

Forest production alters and puts pressure on forest ecosystems. To monitor the status of the forest ecosystem a number of vulnerable species are used as indicators. In addition to the pressure from the forest production as such, there might be additional pressure induced from climate changes. To assess the climate change impact on the sporophyte stage of the plant an impact model driven by climate data had been developed.

**Related use cases**:

None

**Data needs**:

Observed meteorological data from the closely located research station. The impact model requires monthly/season temperature and precipitation, but for the statistical downscaling daily data is needed.

An ensemble of regional climate model data statistically calibrated/downscaled to the meteorological station.

**Typical course of events**:

- Initial discussions, selection of a test regional climate scenario for driving the impact model. Assessment of first results.
- Assessment of differences among the regional climate change simulations with respect to the reference ERA-40 driven simulation. Assessment of the statistical calibration/downscaling method with respect to the station data. Downscaling the extracted model data.
- Discussion of different ways to use the ensemble to gain insight into various aspects and sources of uncertainty.
- Running the impact model using the downscaled scenario data.
- Writing reports for scientific journals and thesis.

**References**:

Yang, W., Bárdossy, A. and Caspary, H-J. 2010a: Downscaling daily precipitation time series using a combined circulation- and regression-based approach. *Theoretical and Applied Climatology*, **10**.1007/s00704-010-0272-0.

Yang, W., Andreásson, J., Graham, LP., Olsson, J., Rosberg, J. and Wetterhall, F. 2010b: Distribution-based scaling to improve usability of regional climate model projections for hydrological climate change

impacts studies. *Hydrology Research*, **41**.3–4, 211-228.

**Methods**:

Correction method (Yang et al. 2010a,b) derived from the quantile-quantile correction method

**Software**:

RCA3, CDO, Matlab, Matlab-CDI toolbox, Fortran.

**File format**:

NetCDF, Ascii

**Miscellaneous Notes:**

**Sources of uncertainty:**

Several sources of uncertainties are considered:

**-** Uncertainties on emission scenarios are dealt with by using different emission scenarios.

- Uncertainties related to choice of GCM are dealt with by using several GCMs.

- Uncertainties related to initial conditions are dealt with by using one GCM runs only differing by their initial conditions.

- Uncertainties related to the RCM formulation is to some extent dealt with by relating the performance of the employed RCM (RCA3) to other RCMs that were participating in the ENSEMBLE project.

## J.3 CLIMATE CHANGE IMPACT ON SPRUCE BARK BEETLE (IPS TYPOGRAPHUS)

**Title**: Climate change impact on spruce bark beetle

**Author:** Lars Bärring (SMHI Rossby Centre, Sweden)

**Date**: 2010-06-02

**Version**: v3

**Purpose**:

Analysing the climate change impact on spruce bark beetle phenology and voltinism.

**Actors**:

SMHI Rossby Centre

Department of Physical Geography and Ecosystems analysis, Lund University

**Summary**:

In forest ecosystems, insects are often the primary disturbance agents, and in coniferous forests, bark beetles (*Coleoptera, Scolytidae*) are the most destructive pests. In Europe, mass-propagation of the spruce bark beetle, *Ips typographus* L., following windfalls and drought is a serious threat to mature spruce forests. Newly windthrown spruce trees are suitable as brood trees for *I. typographus*, and could thereby cause a significant increase of the bark beetle population. In turn, the risk of lethal bark beetle attacks on living spruce trees increases with population size. This makes *I. typographus* rank among the major insect pests of European forests. The activity and voltinism of *I. typographus* depend of latitude and elevation. In the Nordic countries, one generation of *I. typographus* is normally produced per year with the exception of Denmark where the climate generally allows the establishment of a second generation. Two generations per year are common in Central Europe, except at higher elevations. There are thus reasons to believe that in southern

Sweden the population dynamics of *I. typographus* will be sensitive to temperature increase, and that this is one of the regions were a change in population dynamics due to climate change will first be observed.

**Related use cases**: None

**Data needs**:

An ensemble of RCM simulations of daily mean and maximum temperatures, both forced by ERA40 and GCM climate change simulations using different emission scenarios.

High-resolution gridded surface observations 1987-2005 (Mesan, ERA-Mesan, which both are SMHI mesoscale atmospheric gridded products).

E-OBS gridded observations <http://eca.knmi.nl/download/ensembles/ensembles.php>

Various field data, e.g. insect abundance in pheromone traps.

**Typical course of events**:

This use case builds on a close research collaboration that spans several years. For the purpose of this Use Case the focus here is on the development of the impact model for direct use of gridded data rather than using point observations. In subsequent climate change impacts this has the distinct advantage that statisitcal calibration/downscaling from the RCM grid-scale (50/25 km) is not needed.

**References**:

Jönsson, A.-M. & Bärring, L., 2011: Future climate impact on spruce bark beetle life-cycle in relation to uncertainties in regional climate model data ensembles. *Tellus A*, **63**, in press.

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Schlyter, P., Stjernquist, I., Nilsson, C., Jönsson, A.M. & Bärring, L., 2006: Assessment of the impacts of climate change and weather extremes on boreal forests in northern Europe, focusing on Norway spruce. *Clim. Res.*, **31**, 75-84.

**Methods**:

Development of an impact model based on gridded data. Calibration of the model using different gridded observational datasets (E-OBS, Mesan, ERA-Mesan, RCA3/ERA40) and using observational datasets.

Running the impact model using various regional climate change scenarios.

**Software**:

CDO, Matlab, Matlab-CDI toolbox

**File format**:

NetCDF, Ascii

**Miscellaneous Notes:**

**Sources of uncertainty:**

Several sources of uncertainties are considered:

**-** Uncertainties on emission scenarios are dealt with by using different emission scenarios.

- Uncertainties related to choice of GCM are dealt with by using several GCMs.

- Uncertainties related to the RCM formulation is to some extent dealt with by relating the performance of the employed RCM (RCA3) to other RCMs that were participating in the ENSEMBLES project.