Workshop IS-ENES

Statistical downscaling of climate scenarios for the impact communities.
A CMIP5 perspective.

Workshop minutes

Description

This Workshop was organized under the IS-ENES European project at the Laboratoire de Météorologie Dynamique (Jussieu UPMC Campus) in Paris on 16th and 17th October 2012.
One of the main aims of IS-ENES (Infra-structure for the Network for the Earth System Modelling) is to bridge the gap between the climate modellers and the climate change impacts communities. The spatial resolution of data provided by Global Circulation Models (GCMs) are not suitable for climate change impacts studies. A finer resolution and some bias correction of the simulated data have to be considered prior to the use of these results in various impact studies..
The purpose of these two days was to discuss statistical downscaling and bias correction methodologies that have been used to fulfill impacts community needs. It also raises fundamental questions, such as which methodologies should be used to select a representative subset of model output for the specific impact studies in order to qualify and quantify the uncertainties of the results. The expected outcomes of the workshop will include an inventory of downscaling and data correction methods; a collection of ideas about new methodologies regarding the analysis of a large number of scenarios in the context of downscaling, and a summary of the best practices on how to deal with climate scenarios and uncertainties.

Venue of the Workshop: Meeting room, LMD/IPSL (UPMC – Jussieu) Tower 45-55 (3rd floor)
Organization:C. Pagé, S. Lassonde, M. Garcia and P. Braconnot

List of presentations

PDFs of presentations are available at:
https://is.enes.org/eu-internal/exchange-platform-2/jra5/downscaling-workshop

Mathieu Vrac	M.Vrac_SDS,pdf
José Manuel Gutierrez	2012_DownscalingWorkshop_Gutierrez,pdf
Jonathan Winter	AgMIP_IS-ENES.pdf
Sabrina Donner	BC_paper_paris_final.pdf
Sandro Calmanti	IS-ENES_enea-cnr.pdf
Short contributions	
Marco Turgo	Turco_IS_ENES_2012.pdf
Abdelkader *Mezghani*	IS-ENES_Metno_2012.pdf
Petra Friederichs	Friederichs.pdf
Edoardo Bucchignani	Bucchignani_IS_ENES_2012.pdf
Stefan Hagemann	paris_bias_correction_overview.pdf

Distributed documentation

Programme of the workshop	Annex 1
Agenda of the workshop	Annex 2
List of Participants	Annex 3

Introduction *Christian Pagé & Pascale Braconnot*

The large amount of datasets available with CMIP5 opens many new perspectives of research in climate sciences. Regarding many scientific aspects, a more precise evaluation and quantification of climate change and its related uncertainties is now reachable.

IS-ENES attempts to bridge the gap between the climate modellers and the climate change impacts communities. A prototype for a web service interface (e-impact-portal) is developed in order to communicate toward the impact communities (climate4impact.eu). IS-ENES does not produces new results or studies, but it compiles previous results of current and past impact case studies.

Impact and adaptation studies require climate information at regional and local scales that are not well reproduced in most climate models. The 17 Use Cases of IS-ENES represent a large diversity of impact community needs. Different sectors (hydrology, ecology, energy, agriculture, forest, geotechnics) covering regions (rivers basin, estuary) to country or continental spatial-scales have been studied. Many different methods are used with the aim to correct bias, downscale data from global or regional scale to local-scale using dynamical or statistical methods.

In this context, statistical downscaling and bias correction methodologies represent a key step regarding data provision to impact users because these methods can efficiently process several climate scenarios while removing biases. The 3 initials objectives develop in the workshop are to:

- ***Inventory*** the diversity of downscaling and data correction methods with strengths/limitations
- ***Collect ideas***: new methodologies for the analysis of a large number of scenarios in the context of downscaling and climate impacts
- ***Summary*** of the best practices to deal with climate scenarios and uncertainties

Session I: Broad context – keynotes

Statistical Downscaling: The current "Why?" and "How?" & Future steps... - *Mathieu Vrac*

Mathieu Vrac provided an overview of different statistical downscaling methods highlighting the context in which they should be used.
Simulations of climate change still have a coarse spatial resolution and are not adapted to economic and social scales required in most impact studies. This raises the necessity to downscale data down to a finer local scale. Two major types of methods are used:

- Dynamical downscaling using Regional Climate Models (RCM)
- Statistical downscaling using:
    - Transfer Functions: Linear, non-linear
    - Clustering: Weather typing, Analogues
    - Stochastic Weather Generator (WGs): stationarity, non-stationarity
    - MOS (Model Output Statistic)/Bias correction.

Statistical methods should not be seen as competing with dynamical downscaling ones. There are both complementary. The presentation mainly focused on stochastic WGs and MOS/Bias correction.

WGs are stochastic models simulating daily weather statistically similar to observations. It is based on parameters determined from historical records (historical key-tool = Markov Chains). Simulations are performed according to PDFs. Non-Stationary WGs model could include large-scale information. The local scale data are simulated from conditional PDF.
Model Output Statistics (MOS) / Bias correction methodologies are used to calibrate GCM/RCMs. The CDFs of the downscaled variable is adjusted from the CDFs of observations. There exist different variants, parametric or non-parametric approach, using the CDF-t. .A classical approach could consists in a quantile mapping methods whereas a visualisation interpretation use a quantile-quantile plot to correct simulated data.

The numbers of statistical downscaling methods is still increasing. There is not a "perfect" statistical downscaling methods appropriate for all variables and all regions for all applications. There are specific skills according to regions, variables and applications studies.

Only few Statistical Downscaling Methods (SDMs) have been inter-compared. More inter-comparaisons are required between SDMs but also against RCMs. We need to highlight to users that downscaled data have uncertainties inherent to the downscale methodologies. The quality of the downscaling thus needs to be evaluated. This can be done with a statistical indicator of quality, ensemble of SDMs, model merging (linear; non-linear; Bayesian...), etc.

Statistical Downscaling: A CMIP5 Perspective (open issues/problems) - *José Manuel Gutierrez*

J.M. Gutierrez presented a brief history of international programs where downscaling and bias correction methods were assembled and provided to users, as well as downscaled data.

- *ENSEMBLE*

The ENSEMBLES downscaling portal (http://www.meteo.unican.es/downscaling) allows to perform statistical downscaling based on predictors (large scale reanalysis & GCM fields), Predictands (local variables of interest).

- COST (The main objective is to establish a network to systematically validate and improve downscaling methods for climate change research.)
- WCRP CORDEX

<u>The perfect prognosis approach</u>

There are some difficulties with respect to the use of statistical downscaling methods, such as choosing a consistent predictor or problems of stationarity and robustness. Statistical downscaling assumes stationarity in predictor-predictand relationships. Predictors selected should at least satisfy they have "similar" distributions for reanalysis and GCMs.

A Kolmogorov-Smirnov (KS) test is found more appropriate than the PDF-score to compare reanalysis data. Results are generally insensitive to the applied score and the PDFs scores are spatially correlated, for many predictors. The use of the MOS approach avoid to choose a consistent predictor. This method achieves a temporal and spatial "calibration while preserving the accuracy. MOS approach is promising. since some above limitations have been solved.

The consistency between reanalysis and different GCM differs from one region to another one and for different predictors. In order to characterize if the difference are significant or not, a , taylor diagrams summarize the standard deviation and the correlation coefficient between RCM, SDMs, MOS-RCM and reanalyses for spatial mean, and spatial standard deviation. SDMs and MOS are

more correlated to observation than RCMs data. Analogs and Weather Typing Methods are not able to properly capture the present warming signal. There should not be used for trend analyses. Bias correction of GCM output is necessary but is not enough for consistency.

Session II: Downscaling and User Needs

Climate Information for the Impacts Community: The Agricultural Model Intercomparison and Improvement Project (AgMIP) *Jonathan Winter*

AgMIP is a climate-scenario simulation exercise for historical model intercomparison and future climate change conditions using crop and agricultural economics model region throughout the world. AgMIP looks for improving world food security and reduce the risk of hunger due to climate change.

AgMIP team works according 2 tracks: improvement and intercomparison of simulations using historical climate conditions and climate change multi-model assessment. It uses crop and agricultural economics models in combination with future climate scenarios to adaptation and mitigation on agricultural sector.

AgMIP Team activities is organised between:

- Baseline Analysis and Intercomparison: A large database of daily observations from 1980 to 2009 combined to weather generators and satellite observations
- Climate Sensitivity Scenarios: Test of sensibility of crop model according to temperature and rainfall variability and extremes weather.
- Scenarios for Each Future Climate Period: Statistical (BCSD, WorldClim) and dynamical (NARCCAP, CORDEX) downscaling methods using 3 different time periods (Mid-term, Mid-centrury, End-of-century) of GCMs to achieve a local-scale resolution.

Bias Correction The ISI-MIP Method *Sabrina Hempel*

ISI-MIP is a research program considering inter sectoral impact models to study climate change. Mains questions concern impact in agriculture, water, biomes, health and infrastructure sector at different level of climate change. In this project the outputs of 5 GCMs have been used and bias corrected.
Bias correction provides more realistic climate results, however, they are limited by the quality of observation and stationarity must be assumed. These could destroy physical consistency and potentially change the projected trend. The new statistical correction developed by Piani preserve the trend.

Data from GCMs are spatially and temporally interpolated. The biases correction is split between correction of long-term monthly mean and adjustment of daily variability
Two different algorithms have been used to conserve the absolute trend of temperature or the relative trend (precipitation,pressure, radiation and wind).

The ongoing challenge of ISI-MIP is to classified dry month and dries days, resolved unphysically problems of multiplicative correction (concerning high daily precipitation values); adjust the frequency of dry days and the daily variability of normalized data. The monthly variability is still uncorrected.

Stochastic rainfall downscaling *Sandro Calmanti*

The objective of this study is to reproduce rainfall at a local scale (1km) from simulated GCM data. In a first step dynamical downscaling is done using a RCM model (PROTHEUS). Resolution of this RCM is 10-30 km. PROTHEUS overestimates the total precipitation but underestimates precipitation intensity and the number of dry days. Precipitations are more frequent than in the observations in this model.
For the second step, a statistical downscaling model, RainFARM, has been used. RainFARM is a "Metagaussian models", based on a non-linear transformation of a linearly correlated stochastic field, obtained by extrapolating to small scales the power spectrum of the original field.

The stochastic downscaling of precipitation from PROTHEUS reproduces the seasonality and amplitude distribution of observed rain, including the extremes events.
However, RainFARM does not consider orography biases and large-scale model output are not corrected.

Plenary session I:

The aim of this plenary session is to prepare the discussions and determine a road-map for each working group. In order to complete the keynotes of the morning, all participants have been invited to shortly present an impact study.

Statistical downscaling of climate scenarios for impact communities: A CMIP5 perspective. *Marco Turco*

Problematic: Can we apply a GCM-RCM-MOS model chain to study the impact of climate change on hydrology?

RCM (COSMO-CLM) is applied to the region the Po basin. A MOS analogue and a hydrological and hydraulic model is used. MOS Analog Method assumes that "analogue" weather patterns should cause "analogue" local effects. It's able to calibrate and downscale several RCMs to maintain the spatial coherence of precipitation but the hypothesis of stationarity should be more tested notably about temperature.
Discussion underline that statistical model could not provide a good and realistic simulated data without proper data.

Statistical Downscaling / Climate Change applications *Abdelkader MEZGHANI*

Problematic: How to generate reliable local weather meteorological scenarios for use in impact studies under present and future climate conditions?

In this approach, statistical methods (transfer function, analog) were chosen to downscale large scale synoptic data and reanalysis. Firstly statistical downscaling use a transfer function for regional extrapolation. Then a spatio-temporal disaggregation method that uses an analog approach for space-time structure and coherence between variables is applied.

Global modeling chain in watch, waterMIP *Stefan Haddeland*

Problematic: Assessment of water resources using climate output from GCM simulations as input to hydrological and impact models.

A simple correction of the mean is not sufficient and a correction of the whole distribution is required. It assumes that biases and transfer functions are not dependent on time.
The quality of the observations used ,temporal errors with respect to major circulation systems that can not be corrected (e.g. Monsoon) limit the quality of correction.
Bias correction is improving but also impacting climate model results, so that it should always be taken with care. It is difficult to estimate if the corrected signal is more realistic than the original one.

Assessment of climate change effects on soil risks *Edoardo Bucchignani*

The RCM (COSMO-CLM) was driven by reanalysis and GCM data. The MOS technique is then used to correct data from COSMO-CLM. An impact model of soil hydromechanical reproducing slope behavior is driven by climate data.

Ensemble post processing and verification *Petra Friederichs*

Problematic: Provide multiple predictions/realisations of multivariate spatial fields with realistic inter-variable relation on local scales, along with verification.

Live Discussion

The objective of the live discussion was to refine the questions to be discussed in the working groups. Several points were highlighted.

- Impact model are developed for many different sectors that could be affected by climate change. Some of these models can be as complex as climate models. This complexity brings many uncertainties (spatial and temporal scale) added to climate models uncertainties already known.
- Sub-setting is needed to limit the cost of impact studies, but should provide a representative distribution of uncertainties.
- The quality of datasets limits the performance of downscaling, calibration and bias correction methods. A particular emphasis needs to be given to the conservation of the physical coherence (spatial, temporal, and variable).

Two working groups were finally settled with the following objectives:

1. ***Inventory***: diversity of downscaling, data correction methods and datasets with a focus on strengths/limitations and reference to user needs. Trends and stationarity (link with the IS-ENES Use cases)

   9 persons attended this working group (S. Calmanti, J.M. Gutiérrez,S. Hagemann, S. Hempel, S. Lassonde, B. Sultant, M. Turco M. Vrac, J. Winter).

2. ***Collection of ideas***: new methodologies for the analysis of a large number of scenarios in the context of downscaling and climate impacts. **Best practices** to deal with climate scenarios and uncertainties.

   8 persons attended this working group (P. Braconnot, E. Bucchignani, P. Friederichs, R.Hutjes ,A. Mezghani, J. Najac, C. Pagé, S. Parey)

Wednesday 17th October

The second day of the workshop started with a short report of the work progress with respect to each group.

WGI: diversity of downscaling and data correction methods

There is a large diversity of statistical downscaling and data bias correction methods. Each one has its strengths and limits. These methods should be used with respect to specific user needs.

Bias correction methods are using daily and monthly observations. Corrections are validated against climatology, and in general for one parameter at a time. Methods of bias correction that are commonly used are the delta method, quantile mapping, and local scaling.

Statistical downscaling methods are based on circulation at daily time scale. These methods are evaluated using PDF and correlation using multiples parameters. Some SDs are more deterministic (Analogues) and other more stochastic (e.g. Weather Generators). It was discussed that some GCMs sometimes simulate an opposite trend than observations, and that in few specifics cases, a SD approach may be able to correct this opposite trend for a given parameter.

Some impact studies need information at a sub-daily time scale but GCM results (in particular precipitation) are in general not reliable at this temporal resolution. Weathers Generators are usually preferable. In order to validate methods many observed data sets are required. It must also be considered that for some studies there is really a lack of data.

Discussions followed to underline the need for the impact community to synthesize the strengths and weaknesses of statistical downscaling and bias correction methods. During the second part of the Working Group I a matrix will be compiled (cf. Report WGI).

WG II: Collection of ideas and uncertainties:

Impact models could be as complex than climate models. Starting from this observation the WGII listed different levels of uncertainties and corresponding methods to assess them.

As for climate model uncertainty, the impact community is starting to use ensembles simulations (multi-model) and stochastic models. Ensemble of simulations is a new approach with respect to uncertainty for climate impact model. They are used to characterized the internal variability of the impact model but also allow a better determination of threshold crossing.

This working group should continuous to work on a matrix of uncertainties. Uncertainties depend on different factors such as seasonality, internal variability, time horizon. Local features are also sources of uncertainty not necessarily well reproduced in the climate model. Uncertainty can be characterized by data homogenization and correction or the use of statistical approach such as weather typing. The “perfect models” approached is also very powerful but it implies a strong verification of the stationarity.

The best methods for the treatment of the uncertainty,should minimizes bias. It can be based on a Bayesian approaches,a model family tree . Whatever the approach used minimum transformation should be applied to the initial variables to avoid the artificial grow up of the uncertainty due to these intermediate methods

It is important to characterize and diagnose uncertainties resulting from the heterogeneous processing of climate variables used as entries to the impact models. Delta of the mean (anomalies)are usually use. But plots of dT/dP could be very useful in some specific cases. It is also important to consider higher order moments Other questions concern the robustness of the resulting patterns as well as a better characterization of the uncertainties of the models and observations.

The WGII suggests that it should be useful to provide generic “best practice recommendation” :

- A cross fertilization between methods using numerical weather predictor (NWG) for instance the seasonal to decennial analyse compared to climate change could be used for verification.
- Be aware of under-sampling effects in stochastic methods
- Be aware of all sources of uncertainties (models, parameters, data, methods)

OUTCOME OF THE WORKSHOP

Several actions have been listed that will constitute the outcome of the workshop

1. Table on downscaling and bias correction methods

The WGI table about classification of downscaling and bias correction methods will be filled by José Manuel Gutierrez and will send to all for comments and modifications. This table should be the main output of the WGI report and will be posted on the IS-ENES portal for a wide dissemination.

2. Interactions with other projects

The main goal of IS-ENES is to bring the gap between scientist and impact community. The need to develop interactions with other European and international programs which address the climate change impact communities (COST VALUE, STaRMIP) emerged from the general debate.

3. Report on uncertainties

The WGII report will mainly focus its output on a matrix of uncertainty. The IS-ENES Use Cases should be revisited considering how uncertainty was considered and on the change with respect to the consideration of uncertainties since the studies have been documented.

4. Set up of a working group to discuss new methods to estimate uncertainties.

During this workshop emerging methods to estimate uncertainties have been discussed. A summary of impact studies using these novel methods will be included.

5. IS-ENES JRA5 workshop report

The major conclusions and recommendations from the breakout groups and actions 1 and 2 will be included in a short project report.

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ANNEX 1: Tentative programme

Scientific programme

In the context of the IS-ENES project, there is currently a European collaboration that work on bridging the gap between the climate modellers and the climate change impacts communities. In this context, several use cases are implemented in a dedicated portal. One of the objectives was to identify commonalities in the workflow of information from global climate change scenarios to impact and adaptation studies throughout Europe.

At the same time, CMIP5 data is now being made gradually accessible to users. This significant dataset opens large possibilities in climate science, regarding many scientific aspects of global climate change, but also on uncertainties with a more precise evaluation and quantification being now reachable.

Impact and adaptation studies require climate information at regional and local scales that are not well reproduced in most climate models. In this context, statistical downscaling and bias correction methodologies represent a key step regarding data provision to impact users because these methods can efficiently process several climate scenarios while removing biases. It also raises fundamental questions, such as which approaches should be used to select a representative subset of model output for the specific case impact studies in order to qualify and quantify the uncertainties of the results. Indeed, impact modellers cannot necessarily cope with the large number of scenarios and model outputs. On the other hand, climate data providers do not necessarily have the analysis power to downscale all these scenarios neither.

The aim of the workshop is to process on these questions in order to better guide the users from the existing use cases and identify new approaches and requirements for network configuration, disk storage and data processing that should be provided with climate model outputs.
The expected outcomes of the workshop will include :

- **Inventory** of the diversity of downscaling and data correction methods
- **Collection of ideas** about new approaches regarding the analysis of a large

number of scenarios in the context of downscaling;

– **Summary of the best practices** to deal with climate scenarios and uncertainties

These outcomes will be summarized in a workshop report. They will serve as guidelines for the documentation and best practice section of the IS-ENES e-impact portal (CLIMATE4IMPACT http://climate4impact.eu/).
The workshop will be organized along a few keynote lectures to introduce the different points and breakout groups on specific questions.

The WG will have specific questions to address, with the first day morning presentations putting in context the questions.
A chairman and a rapporteur will be selected for each WG.
A team will be selected to lead the report writing.

Please come with one or two slides summarizing a impact question, and the means to address them. These contributions will feed reflexions of each working groupe.

Practical information
2-day workshop (Cf. Agenda attached)

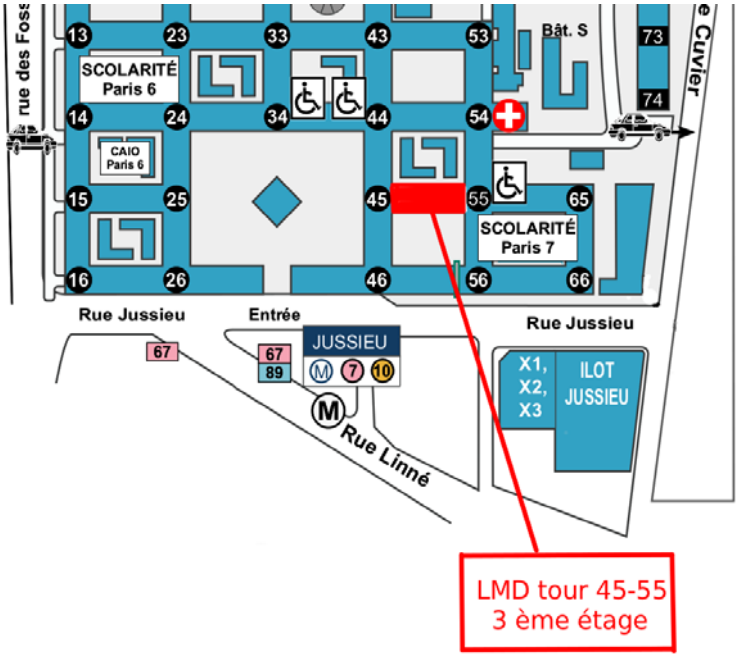
Location of the event:

Meeting Room of the LMD at Jussieu
3rd floor Tower 45/55
(please enter by the Tower 45)

Public Transportation:

Bus : Lines n°63,67, 86,87,89
Metro : Jussieu station
(line 7 and 10)

*To consult the public transport options in Paris,visit:*http://www.ratp.info/informer/anglais/index.php



Workshop IS-ENES

ANNEX 2: Agenda

Statistical downscaling of climate scenarios for the impact communities.
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Tuesday Oct 16

09h00 *Welcome, coffee*

09h30 *Introduction*

IS-ENES Use Cases: what have we learned?

09h50 *Broad Context: Keynotes*

Mathieu Vrac, LSCE-IPSL, France (25')

José Manuel Gutierrez, U Cantabria, Spain (25')

Discussions on Keynotes

11h00 *Coffee Break*

11h30 *Downscaling and User Needs*

Jonathan Winter, U Columbia, USA (10')

Sabrina Donner: ISMIP, PIK, Germany (10')

Sandro Calmanti, ENEA, Italy (10')

Short contributions (1-2 slides)

12h30 *Lunch at La Baleine Restaurant (near Jussieu) (offered)*

14h00 *Plenary Session*

Live Discussion: Summary of key points

Short questions list and Priorities

15h30 *Coffee Break*

16h00 *Working Groups Parallel Discussions*

17h30 End of day

19h30 *Dinner (offered) L'atelier maître Albert - 1, rue Maître Albert - 75005 PARIS*

Wednesday Oct 17

09h00 *Welcome, coffee*

9h30 *Plenary Session*

Short report from each Working Group (10' each)

Reorganize Working Groups if needed

10h15 *Working Groups Parallel Sessions*

11h00 *Coffee Break*

11h30 *Working Groups Reporting preparation*

12h30 *Lunch at Le buisson Ardent Restaurant (near Jussieu) (offered)*

14h00 *Plenary Session*

Working Groups reports (10' each)

Live Summary and Outcomes

Follow-up actions, Synthetis Report

16h00 *Closing Workshop*

ANNEX 3: List of Participants

Statistical downscaling of climate scenarios for the impact communities.
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France		
	CERFACS	Christian Pagé
	LSCE-IPSL	Pascale Braconnot
	LSCE-IPSL	Mathieu Vrac
	LSCE-IPSL	Benjamin Sultan
	LSCE-IPSL	Sylvain Lassonde
	EDF	Sylvie Parey
	EDF	Julien Najac
Germany		
	Uni Bonn	Petra Friederichs
	ZMAW	Stefan Hagemann
	PIK	Sabrina Hempel
Italy		
	CMCC	Marco Turco
	CMCC	Edoardo Bucchignani
	ENEA	Sandro Calmanti
Nederlands		
	Wageningen Uni	Ronald Hutjes
Norway		
	Met.no	Abdelkader Mezghani
Spain		
	U Cantabria	José Manuel Gutiérrez
USA		
	Columbia	Jonathan Winter