Berlin-Workshop on Bias Correction in Climate Science

jointly organized by

4th-6th of October 2016
Berlin, Germany

www.climate-bias-correction.de
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Contents

1 Programme

1.1 Tuesday, 4th of October

1pm **Registration and Coffee**

2pm **Welcome**

2.15pm **Overview and Motivation**

slides
2.15 pm
How to define a bias for climate models?
Henning Rust | Institut für Meteorologie FU Berlin | Germany

abstract slides
2.50 pm
Climate modelling and bias corrections: climate services provider's perspective
Patrick Josse | Météo-France | France

abstract slides
3.20 pm
Bias Correction in Climate Studies: Road to progress or dead end street?
Uwe Ehret | KIT - Karlsruher Institut für Technologie | Germany

4pm **Coffee break**

4.30pm **Applications**

abstract slides
4.30 pm
On the needs of bias correction of climate data for agriculture
Benjamin Sultan | IRD - LOCEAN-IPSL | France

abstract slides
5.05 pm
Climate change impacts on hydrological processes in Norway based on two methods for transferring regional climate model results to meteorological station sites
Stein Beldring | Norwegian Water Resources and Energy Directorate (NVE) | Norway

abstract slides
5.25 pm
Small scale hydrological impact study based on raw and bias-corrected RCM outputs
Anna Kis | Eötvös Loránd University | Hungary

abstract slides
5.45 pm
Evaluation of bias correction methods for future sea surface temperatures and sea-ice concentrations
Julien Beaumet | Université Grenoble Alpes | France

6.05pm

Poster Session

abstract poster **Preliminary Calculations of Wave Energy Flux Trends Europe 1900-2010**
Alain Ulazia | Spain

abstract poster **Bias correction of daily precipitation and temperature for Norway**
Wai Kwok Wong | Norwegian Water Resources and Energy Directorate (NVE) | Norway

abstract poster **Adaptation of the German transport infrastructure towards climate change and extreme events**
Christoph Brendel | Deutscher Wetterdienst | Germany

abstract poster **Rainfall changes impacts on groundwater balance of coastal aquifers:A case study in Greece**
Panagiota Venetsanou | Aristotle University of Thessaloniki | Greece

abstract poster **Regression Quantile Mapping (RQM) - A new approach to bias correction with consistent quantile trends**
Christian Passow | Potsdam Institute for Climate Impact Research (PIK) | Germany

abstract poster **Bias correction with harmonic functions – Exploiting the smoothness in time**
Madlen Fischer | Freie Universität Berlin, Institute of Meteorology | Germany

abstract poster **Intercomparison of statistical and dynamical downscaling models under the EURO- and MED-CORDEX initiative framework: present climate evaluations**
Pradeebane Vaittinada Ayar | CNRS | France

abstract poster **Discontinuous daily temperatures in the WATCH forcing data sets**
Henning Rust | Freie Universität Berlin | Germany

abstract poster **Spatial interpolation for bias correction**
Carole Harry | Ecole des mines de Paris, Paris, France | France

abstract poster **JAMSTEC Application Laboratory: Innovations from Earth Sciences**
Pascal Oettli | JAMSTEC | Japan

abstract poster **High resolution simulations of air quality in the Berlin/Brandenburg area: model evaluation, potential applications and need for bias correction**
Friderike Kuik | Institute for Advanced Sustainability Studies | Germany

abstract poster **Calibrating probabilistic decadal predictions for categories**
Alexander Pasternack | Freie Universität Berlin | Germany

abstract poster **A Measure of Drift Quantification in Decadal Predictions**
Igor Kröner | Freie Universität Berlin | Germany

8pm **Dinner at Seminaris**

1.2 Wednesday, 5th of October

9am

Seasonal-to-decadal

abstract slides
9.00 am
On a hierarchy of a posteriori adjustment methods for seasonal to decadal climate predictions
Neven Fuĉkar | Barcelona Supercomputing Center | Spain

abstract slides
9.35 am
Parametric drift correction for decadal hindcasts on different spatial scales
Jens Grieger | Freie Universität Berlin | Germany

abstract slides
9.55 am
Can bias correction methods improve the accuracy and reliability of seasonal forecasts?
Jose Manuel Gutierrez | CSIC / Universidad de Cantabria | Spain

abstract slides
10.15 am
Calibration of decadal ensemble predictions
Alexander Pasternack | Freie Universität Berlin | Germany

10.35am **Coffee break**

11am

Seasonal-to-decadal / Development

abstract slides
11.00 am
Bias correction methods for skewed variables based on quantile relations
Frank Sienz | Max-Planck Institute für Meteorologie, Hamburg | Germany

abstract slides
11.35 am
Bias correction of CCLM simulated temperature and precipitation in Europe using cross validated model output statistics
Jingmin Li | University of Wuerzburg | Germany

abstract slides
11.55 am
Recommendations of the Decadal Climate Prediction Project for bias correction of decadal hindcasts
Jens Grieger | Freie Universität Berlin | Germany

abstract slides
12.10 am
A novel bias correction methodology for climate impact simulations
Sebastian Sippel | Max-Planck Institut für Biogeochemie, Jena | Germany

10.35am **Lunch at Seminaris**

2pm

Development

abstract | slides
2.00 pm
A path to multivariate statistical bias correction
Claudio Piani | American University of Paris | France

abstract | slides
2.35 pm
Correcting biases in multiple climate model variables: A multivariate generalization of quantile mapping
Alex Cannon | Environment and Climate Change Canada | Canada

abstract | slides
3.10 pm
Bias correction with the CDF-Transform Method
Komlam Agbeko Kpogo-Nuwoklo | Freie Universität Berlin | Germany

3.30pm

Coffee break at posters

4.30pm

Development

abstract | slides
4.30 pm
Multivariate - Intervariable, Spatial, and Temporal - Bias Correction
Petra Friederichs | University of Bonn | Germany

abstract | slides
5.05 pm
Using a standardized framework to evaluate, compare, and guide the development of new empirical-statistical downscaling methods
Anne Stoner | Texas Tech University | United States

abstract | slides
5.40 pm
Bivariate bias correction: is it worth it?
Sylvie Parey | EDF/R&D | France

1.3 Thursday, 6th of October

9am

Applications

abstract slides

9.00 am
Application of bias correction methods for climate predictions tailored to the wind energy sector
Verónica Torralba | Barcelona Supercomputer Center | Spain

abstract slides

9.35 am
Bias correction of multi-variate parameters: a case study of heat stress in Europe
Ana Casanueva | Federal Office of Meteorology and Climatology MeteoSwiss | Switzerland

abstract slides

9.55 am
Bias-correction of daily precipitation in the ACRP project DynAlp
Alrun Jasper-Tönnies | Germany

abstract slides

10.15 am
The PostClim project: Post-processing of Climate Projection Output for Key Users in Norway
Andreas Dobler | Norwegian Meteorological Institute | Norway

10.35am **Coffee break**

4.30pm

Development

abstract slides

11.00 am
Spatial analog method for temporal disaggregation of daily precipitation
Julie Carreau | Hydrosciences Montpellier - IRD | France

abstract slides

11.20 am
Influence of bias correcting predictors on statistical downscaling models
Pradeebane Vaittinada Ayar | CNRS | France

abstract slides

11.40
Scaling of precipitation extremes with temperature over Europe: impact of statistical downscaling and/or bias correction on this relationship.
Sophie Bastin | CNRS/INSU | France

abstract slides

12.00 pm
Conclusions from the IPCC WG1 Focus group on Bias correction
Claudio Piani | American University of Paris | France

10.35am **Lunch at Seminaris**

2 Participants

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3 Abstracts

3.1 Development

Multivariate - Intervariable, Spatial, and Temporal - Bias Correction

Petra Friederichs[1], **Mathieu Vrac**[2]
(1) University of Bonn, (2) CNRS, Centre d'Etudes de Sacaly

back slides

Statistical methods to bias correct global or regional climate model output are now common to get data closer to observations in distribution. However, most bias correction (BC) methods work for one variable and one location at a time and basically reproduce the temporal structure of the models. The intervariable, spatial, and temporal dependencies of the corrected data are usually poor compared to observations. Here, we propose a novel method for multivariate BC. The empirical copula-bias correction (EC-BC) combines a one-dimensional BC with a shuffling technique that restores an empirical multidimensional copula.

Several BC methods are investigated and compared to high-resolution reference data over the French Mediterranean basin: notably, (i) a 1D BC method applied independently to precipitation and temperature fields, (ii) a recent conditional correction approach developed for producing correct two-dimensional intervariable structures, and (iii) the EC-BC method. Assessments are realized in terms of intervariable, spatial, and temporal dependencies, and an objective evaluation using the integrated quadratic distance (IQD) is presented. As expected, the 1D methods cannot produce correct multidimensional properties. The conditional technique appears efficient for intervariable properties but not for spatial and temporal dependencies. EC-BC provides realistic dependencies in all respects: intervariable, spatial, and temporal. The IQD results are clearly in favor of EC-BC.

As many BC methods, EC-BC relies on a stationarity assumption and is only able to reproduce patterns inherited from historical data. However, because of its ease of coding, its speed of application, and the quality of its results, the EC-BC method is a very good candidate for all needs in multivariate bias correction.

Correcting biases in multiple climate model variables: A multivariate generalization of quantile mapping

Alex Cannon
Environment and Climate Change Canada

back slides

The MBCn bias correction algorithm is a multivariate generalization of quantile mapping that transfers all aspects of an observed continuous multivariate distribution, i.e., marginal distributions and joint dependence structure, to the corresponding multivariate distribution of variables from a climate model. When applied to climate model projections, changes in all quantiles of each variable between the historical and projection period are also preserved. The MBCn algorithm is demonstrated on two case studies. First, MBCn is used to correct biases in the spatiotemporal dependence structure of Canadian Regional Climate Model (CanRCM4) precipitation fields. Second, the method is used to correct 3-hourly surface temperature, pressure, specific humidity, wind speed, incoming shortwave radiation, incoming longwave radiation, and precipitation outputs from CanRCM4 across a North American domain. Components of the Canadian Forest Fire Weather Index (FWI) System, a complicated set of multivariate indices that characterizes the risk of wildfire, are then calculated and verified against observed values. Results are compared against a univariate quantile mapping algorithm, which neglects the dependence between variables, and two multivariate bias correction algorithms, each of which corrects a different form of inter-variable correlation structure. MBCn outperforms these alternatives, often by a large margin. For instance, in the FWI example univariate quantile mapping does not correct model biases in dependence structure and is therefore unable to reproduce observed annual maxima of the FWI distribution. While the correlation-based multivariate bias correction algorithms lead to some improvements, they are not able to match the ability of MBCn to simulate the entire distribution of FWI values. In the precipitation example, MBCn successfully corrects simulated biases in spatial and temporal autocorrelation.

Using a standardized framework to evaluate, compare, and guide the development of new empirical-statistical downscaling methods

Anne Stoner, Katharine Hayhoe, Ian Scott-Fleming
Texas Tech University

back slides

Government agencies, non-profit organizations, cities and even the private sector increasingly require the use of relevant climate projections as input to long-term planning. The empirical-statistical downscaling methods (ESDMs) often used to develop such projections, however, can vary widely in their accuracy and ability to reproduce local to regional variability and extremes.

Here, we use a generalized framework for evaluating statistical downscaling methods to highlight strengths and weaknesses that are unique to specific statistical methods including delta and bias correction approaches, as well as both empirical and parametric quantile mapping. These include key questions such as whether to work with absolute values or anomalies, and how to account for shifts in the timing of seasonal weather patterns over time. The framework, called a perfect model approach (Dixon et al., 2016), consists of both historical and future coarsened model simulations and high-resolution "pseudo-observations," consisting of 25km global simulations using the GFDL-HiRAM model.

From the lessons learned from the perfect model framework, we designed a new non-parametric statistical downscaling method that uses kernel density estimation of the distribution of observed and GCM simulated historical values for each calendar day, by decomposing the signal into 3 components (long-term trend, slowly-varying climatology and daily anomalies) using digital filtering techniques and building a 3D mapping surface, which is then applied to future projected GCM output to yield high-resolution bias corrected future projections for the location of interest, -station or grid cell. Evaluating this new method using the perfect model framework shows that it improves on previous errors and inaccuracies while retaining a high computational efficiency even at the tails of the distribution where events are relatively rare but would have a proportionally greater impact on infrastructure, agriculture, human health, etc.

Bivariate bias correction: is it worth it?

Sylvie Parey, Léonard Dekens, Mathilde Grandjacques, Didier Dacunha-Castelle
EDF/R&D

back slides

Different multivariate bias correction approaches have been proposed recently to tackle the difficult question of consistency when individually bias correcting two or more variables which are then used in an impact study. The aim here is to suggest an extension of the univariate quantile mapping approaches to bivariate distributions, and to test it with a toy model. This toy model is based on autoregressive Gaussian processes, used to simulate two observed variables and their model counterparts. Its design allows controlling both the correlation between both variables and the bias of the simulated "model variables" compared to the simulated "observations". We will discuss the mathematical background and the assumptions generally made when using such types of bias correction. Then, different tests using the toy model will be described and used to estimate the added value of different types of bivariate bias corrections (typically Schaake-shuffle and the proposed approach with or without shuffle) compared to separate univariate ones.

A novel bias correction methodology for climate impact simulations

Sebastian Sippel[1], Friederike E.L. Otto, Matthias Forkel, Myles Allen, Benoit Guillod, Martin Heimann, Markus Reichstein, Sonia I. Seneviratne, Kirsten Thonicke, Miguel D. Mahecha
(1) Max-Planck-Institut für Biogeochemie, Jena

back slides

Understanding and quantifying the impacts of extreme weather and climate events across various sectors is crucial for societal adaptation in a changing climate. However, regional climate model simulations generated for this purpose typically exhibit biases in their output that impede any straightforward assessments of impacts. To overcome this issue, various bias correction strategies are routinely used to alleviate climate model deficiencies, most of which have been criticized for physical inconsistency and their non-preservation of the multivariate correlation structure. Here, we first present a recently introduced resampling-based bias correction scheme designed for assessing the impacts of climate extremes that fully preserves the physical consistency and multivariate correlation structure of the model output. Second, the bias correction scheme is evaluated using large ensemble simulations generated with a regional climate model over Central Europe (HadRM3P, generated through climateprediction.net/weatherathome). The procedure is demonstrated to yield a substantial improvement in the representation of variability and extremes i) in individual climate variables such as summer heat or dryness, and ii) in multivariate heat-health related indicators such as the "wet-bulb globe temperature". Finally, we conduct a climate impact assessment in the terrestrial biosphere by simulating biosphere–atmosphere fluxes of carbon and water using a terrestrial ecosystem model (LPJmL). The resampling-based bias correction yields strongly improved statistical distributions of carbon and water fluxes, including the extremes. Our results thus highlight the importance of physical consistent bias correction schemes for climate impact simulations, particularly if these assessments focus on variability and extremes in climate or its associated impacts. Whilst the resampling-methodology currently requires relatively large ensembles of climate simulations, we present some ideas how the approach could be extended to ensembles of fewer members or multiple models.

A path to multivariate statistical bias correction

Claudio Piani[1], Jan Haerter[2]
(1) American University of Paris, (2) Niels Bohr Institute

back slides

In very simple terms, bias correction can be defined as a class of heuristic methodologies that aim to reduce or remove systematic error from climate model output. Different methodologies are plagued, at least to some degree, with one or another short fall or limitation. Examples include, non-stationarity, modification of the climate signal, a requirement for large observational datasets, the role of timescales and grid resolution, etc.. In particular, in one dimensional climate model bias-correction procedures, in which variables are corrected separately, the representation of their dynamical link is likely to be degraded within the model. This is famously the case for bias correction of temperature and precipitation. Methodologies exist for the bias correction of the joint intensity distribution of two, and conceivably more, variables. Here we will propose and discuss solutions to all the above problems. In particular we will propose and discuss a methodology for bi-variate statistical bias correction along with its applicability and extension to multivariate methods.

Bias correction with harmonic functions – Exploiting the smoothness in time

Madlen Fischer, Henning W. Rust, Uwe Ulbrich
Freie Universität Berlin

back

Systematic differences between climate model simulation and observed data exist and often hamper the direct use of simulated data for climate impact modelling. Climate model simulations are thus typically post-processed using bias correction approaches. A popular approach is to adjust daily simulated data such that the monthly mean matches the observed monthly mean. Here, we suggest using harmonic functions to model a smooth seasonal cycle for observation and simulation instead of each month's daily data with a separate value. This approach allows us to adjust each day in the year individually and avoid artifical jumps in the bias-corrected data. Additionally to exploiting temporal smoothmess, we use paramter transformations to ensure physical consistency (i.e. only positive values or daily maximum larger than daily minimum values) We apply this method in the EU BINGO project (Bringing Innvoation to onGOing water resource management) for several different parameters with the WFDEI dataset (WATCH forcing data ERA-Interim) as reference.

Regression Quantile Mapping (RQM) - A new approach to bias correction with consistent quantile trends

Christian Passow, Reik V. Donner
Potsdam Institute for Climate Impact Research (PIK)

back

Quantile mapping (QM) is an established concept that allows to correct systematic biases in multiple quantiles of the distribution of a climatic observable. It shows remarkable results in correcting biases in historical simulations through observational data and outperforms simpler correction methods which relate only to the mean or variance. Since it has been shown that bias correction of future predictions or scenario runs with basic QM can result in misleading trends in the projection, adjusted, trend preserving, versions of QM were introduced in the form of detrended quantile mapping (DQM) and quantile delta mapping (QDM). Still, all versions and applications of QM bias correction rely on the assumption of time-independent quantiles over the investigated period, which can be misleading in the context of a changing climate. With the combination of quantile regression (QR) with the classical QM method it is possible to introduce a consistent, time-dependent and trend preserving approach of bias correction for historical and future projections. Since QR is a regression method, it is possible to estimate quantiles in the same resolution as the given data and include trends or other dependencies. Here, the corresponding regression quantile mapping (RQM) is used to correct biases in precipitation products from historical runs (1959 - 2005) of the COSMO model in climate mode (CCLM) from the Euro-CORDEX ensemble relative to gridded E-OBS data of the same spatial and temporal resolution. The aim of this study is to examine how RQMs performs as a bias correction algorithm, identify potential methodological challenges and demonstrate its prospective application to future model projections.

3.2 Application

On the needs of bias correction of climate data for agriculture

Benjamin Sultan, IRD - LOCEAN-IPSL

back slides

Climate information offers interesting potential benefits to agriculture. For instance, numerous studies have tried to link seasonal prediction outputs from global climate modelsto crop models, thus translating climate forecasts into seasonal crop predictions. On longer time scales, combining climate models and crop models also provides a tool to assess the impacts of future climate change on crop production.

However, such impact studies ultimately rely on the accuracy of climate input data. Climate models but also satellite retrievals errors inevitably propagate through the combined climate/crop modelling system. In particular, climate models show systematic biases in rainfall: precipitation patterns are often poorly represented, and rainfall temporal characteristics (frequency, intensity) are biased.

This talk will illustrate the needs of bias correction of climate data for agriculture modelling purpose with different examples in semi-arid areas of West Africa.

The PostClim project: Post-processing of Climate Projection Output for Key Users in Norway

Andreas Dobler, Inger Hanssen-Bauer
Norwegian Meteorological Institute

back slides

The main objective of the recently started PostClim project is to produce tailored climate information for key Norwegian user groups. Additionally, the project involves an evaluation and improving of post-processing methods and user-defined climate products, estimating the value added by post-processed climate data in climate impact studies and quantifying the uncertainty in post-processed climate variables. A main focus lies on the development of post-processing methods that preserve the frequency of and consistency between atmospheric variables and consider non-linear effects and extreme values, as well as to quantify the uncertainty and evaluate the strength of the post-processing methods.

This presentation gives an introduction to the project and the basic challenges of post-processing/bias-correcting climate data for (Norwegian) user groups and shows some first results from a climate services scoping exercise with stakeholders.

Application of bias correction methods for climate predictions tailored to the wind energy sector

Veronica Torralba, Francesco J. Doblas-Reyes, Omar Bellphrat
Barcelona Supercomputing Center

back slides

Climate predictions tailored to the wind energy sector represent an innovation in the use of climate information to better manage the future variability of wind energy resources. Current energy practices at seasonal time scales employ a simple approach based on an estimate of a retrospective climatology. Instead, probabilistic climate prediction can better support the balance between energy demand and supply, as well as decisions relative to the scheduling of maintenance work. Climate forecast systems are affected by biases, which have until now prevented the use of climate predictions because the user models need variables with similar statistical properties to those observed. These systems tend to be overconfident in their representation of the climate variability. Different techniques for the bias adjustment of probabilistic climate forecasts are considered in this paper to overcome this problem: simple bias correction, quantile-quantile mapping and calibration method. These approaches are linear, parsimonious and robust, which are essential features for the small samples typical of current climate forecast systems, and assume that the distributions are Gaussian. We explore the impact of the necessary bias adjustments on the forecast quality of near-surface wind speed to produce useful information for wind energy users. In addition, we will illustrate how the same bias correction methods can be used in event attribution with a single climate model. Event attribution benefits from ensemble calibration to account for the same model inadequacies that affect operational climate forecast systems.

PRELIMINARY CALCULATIONS OF WAVE ENERGY FLUX TRENDS IN EUROPE.1900-2010

Alain Ulazia, Jon Saenz, Gabriel Ibarra, Markel Penalba, John Ringwood

back

This is a preliminary study about wave energy trends in Europe using ERA20c. The first reanalysis of the 20th century, ERA20c, was released in May 2015 by the European Centre for Medium-Range Weather Forecasts (ECMWF) and includes datasets of 110 years (1900-2010) with three hours time resolution and 125 km original space resolution. It offers wave data series for wind waves, swell waves and combined waves or for maximum individual wave height and its period. Therefore, it allows for a complete study of the last century to obtain a more historical view of decadal trends for significant wave height (SWH) and its zonal and meridional components, wave period (P), and ,as a consequence, for wave energy flux and its components. To that purpose Theil-sen decadal trends of these oceanic variables have been calculated at a 95% confidence level for European Atlantic coast. These results have been plotted and indicate a very hot area in the West of Ireland with a decadal wave energy flux increment of 1.1 kW/m and with 14 cm increment of the maximum individual wave height. This increment of wave height is general in Europe and the wave period also increases, both of which lead to an important increment in the wave energy flux (WEF) according to pure ERA20c data without correction.

ERA20c incorporates a decreasing number of observations as we move back in time so calculated trends may be affected by this fact which needs to be estimated and corrected. To that purpose ERAInterim data for the same variables at a given location in the Bay of Biscay has been used. The ERA-Interim reanalysis offers wave data from 1979, but it is based on the physical model WAM and assimilates more wave observations from buoys than ERA20c. Therefore, the authors think it may be a good comparative model against ERA20c in the last 21 years of the 20th century and an appropriate source for correction and calibration for the whole century. A nonparametric method via empirical Cumulative Density Function has been used to obtain the calibrated 110-year series for SWH and P, and therefore for WEF. The bidimensional SWH-P state probability density function (PDF) has been obtained for each do-decade and also each differential PDF with respect to the first do-decade. This allows to analyse the evolution of the historical PDF and to estimate the energy production of a standard WEC (wave energy converter) by implementing the power matrix of the converter in the PDF. A 5 m diameter generic point absorber has been considered with a linear PTO (power take-off) model which is composed by an optimized damping coefficient. The preliminary results with corrected data show considerable variations at the specific location: the wave energy increment is significant in the last three do-decades of the century and the difference between the energy production in the last two do-decades of the century implies a 10% increase.

Rainfall changes impacts on groundwater balance of coastal aquifers:A case study in Greece

Panagiota Venetsanou, Christina Anagnostopoulou, Konstantinos Voudouris
Aristotle University of Thessaloniki

back

Groundwater is one of the major parameters in maintaining ecology in many regions. As climate is one of the main factors which affects groundwater resources, the main objective of the present study is to assess the impact of rainfall changes on the groundwater system by projecting the future changes in the middle and the end of 21st century. For this reason, the RegCM3 climate model precipitation data was entered in the steady-state groundwater flow model MODFLOW for a coastal aquifer case study in North Greece. The increasing urbanization in combination with the intensive cultivation have led to the overexploitation of the coastal aquifer and seawater intrusion. The groundwater flow simulation by using the MODFLOW code indicates a negative water budget and estimates the quantities of the seawater intrusion. According to the RegCM3 climate model, the precipitation reduction is estimated to be about 5% during the period of 2021-2050, while the precipitation decrease is expected to be almost 20% during the period of 2071-2100. Furthermore, the natural recharge of the coastal aquifer is expected to be influenced by the precipitation reduction. Finally, the seawater intrusion amounts are expected to increase during these future periods and more specifically during the second period of 2071-2100.

It is well known that in hydrological climate change impact research, parameters as future river runoff or catchment water balance are impeded by different sources of modeling uncertainty, especially when raw RCMs data used in hydrological models. Under this assumption, further research should be carried out on evaluating and comparing the performance of different bias corrections methods over specific Greek catchments. There will be an attempt to find out if the application of bias correction methods is justified and which approach give the most promising results.

Conclusions from the IPCC WG1 Focus group on Bias correction

Claudio Piani, American University of Paris

back slides

In September 2015, the IPCC Working Group 1 steering committee convened a workshop on regional climate projections and their use in impacts and risk analysis studies in São José dos Campos, Brazil. The workshop produced a concise information paper that provides recommendations to the IPCC for future assessment reports. In particular, this paper includes a section dedicated to bias correction of climate model output, including applicability of bias correction, common errors in the literature, unavoidable issues and best practice recommendations.

Bias correction with the CDF-Transform Method

Komlan Agbeko Kpogo-Nuwoklo, Henning W. Rust, Uwe Ulbrich, Christos Vagenas, Edmund Meredith
Freie Universität Berlin

back slides

Despite the increasing use of regional climate model (RCM) simulations in hydrological climate-change impact studies, their application remains challenging due to the often considerable biases present. To deal with these biases, several bias correction methods have been developed, ranging from simple scaling to more sophisticated approaches. The most commonly used bias correction method is the quantile-mapping method, which aims to correct the distribution function of a modelled climate variable to agree with the observed distribution function. The quantile-mapping method is only suitable when observations are available for the same time period as for the model output. For instance, for bias correction of model predictions, the quantile-mapping method does not take into account any information on the distribution of the future modelled dataset. The CDF-Transform method is proposed to overcome this issue. It can be perceived as an extension of the quantile mapping method. The method has been developed by [Michelangeli et al., 2009] and applied in many climate-related studies. Here, the CDF-Transform method is successfully used for the bias correction of climates variables (precipitation, temperature, wind, sea level pressure, etc.) output by the COSMO-CLM RCM in the context of the BINGO project.

Bias-correction of daily precipitation in the ACRP project DynAlp

Alrun Jasper-Tönnies[1], Thomas Einfalt[1], Manfred Kleidorfer[2]
(1) hydro & meteo & Co. KG, (2) Universität Innsbruck

back slides

We present findings from the ACRP funded project DynAlp (Dynamic Adaptation of Urban Water Infrastructure for Sustainable City Development in an Alpine Environment). In this project a statistical bias-correction and downscaling of precipitation was done for the alpine region Tirol. The basis were regional climate projections with CLM for Austria on a 10x10 km^2 grid from the reclip:century project (Loibl et al. 2011). The bias corrections were done using a two-dimensional quantile mapping method, using the observation datasets EUR04M-APGD (Alpine precipitation grid dataset, 5x5 km^2, by MeteoSuisse) and temperature stations from ECA&D. We show how the bias-correction of daily precipitation is affected by the following factors: - scales of observation datasets - mean daily temperature - decadal variability - spatial variability in the Alpine region with a special focus on extreme daily precipitation.

Small scale hydrological impact study based on raw and bias-corrected RCM outputs

Anna Kis, Rita Poncraácz, Judit Bartholy, János Adolf Szabó
Eötvös Loránd University, Budapest

back slides

As a consequence of climate change, extreme hydrological conditions may occur more often in the future than in the past. To mitigate the potential hazards relating to this environmental problem (e.g. floods, flash floods, drought and extreme low or high runoff characteristics), the estimation of future trends is a key starting step. For this purpose, linking a hydrological model to a climate model is clearly necessary. Our investigation focuses on the Upper-Tisza basin, located in Central-Eastern Europe. To analyse the hydrological consequences of climate change, we use the physically-based DIWA (DIstributed WAtershed) hydrological model and the RegCM4 regional climate model. The validation of precipitation and temperature simulations of RegCM4 shows that the climate model produces systematic errors. In order to use as accurate meteorological input data for DIWA as possible, a bias correction method is applied to the raw RegCM4 outputs. We chose the percentile-based correction method: for each month and each gridpoint within the target region a correction factor is determined, using the CARPATCLIM database as a reference. We run DIWA hydrological model for 1971–2000 with different meteorological input data (CARPATCLIM reference data, the raw and bias-corrected outputs of RegCM4). Analysing the resulted yearly and seasonal runoff values, we can conclude that DIWA simulation driven by raw RegCM4 substantially differs from the reference. Hydrological simulation, driven by bias-corrected RegCM4 is close to the reference; however, the shape of the distribution of runoff values is modified and differs from the CARPATCLIM driven simulation, especially in the case of extremes. Our aim is to find the most appropriate bias correction method for this hydrological impact study, which does not change the shape of the distribution of runoff values, and eliminates the systematic errors. After finding the appropriate bias correction method, hydrological analyses for the past and also for future time periods are planned using DIWA simulations driven by RegCM4 projections for two different RCP scenarios.

Evaluation of bias correction methods for future sea surface temperatures and sea-ice concentrations

Julien Beaumet, Gerhard Krinner, Michel Déqué
Université Grenoble Alpes

back slides

Coupled Atmosphere-Ocean General Circulation Models (AOGCM), such as those used in CMIP5, show considerable biases for the modeling of sea surface temperature (SST) and sea-ice concentration (SIC). The reliability of projected SST and SIC from scenarios for the end of the 21st Century using such models is thus highly questionable. Moreover, Krinner et al., (2014) demonstrated a very high sensitivity of uncoupled Atmospheric General Circulation models (AGCM) to oceanic boundary conditions such as SST and SIC, especially for polar regions such as Antarctica. In this work, we present and evaluate different bias correction methods for the reconstruction of both future SST and SIC. A simple absolute anomaly method as well as a quantile-quantile method, inspired by the work of Ashfaq et al., (2010), have been used for bias correction of sea surface temperatures. A relative anomaly method proposed by Krinner et al., (2008) and an empirical method using the relationship between sea surface temperatures and sea-ice concentration have been used for sea-ice concentration. These methods have been evaluated by an application over ERA-Interim period (1979-2014) as well as by using a perfect model approach for future's climate. Results for sea surface temperatures are satisfactory for both methods, while for sea-ice concentration, each method has disadvantages and exhibits artifacts. Reconstructed future sea surface temperatures and sea-ice concentration will be used to force AGCM such as LMDZ from Laboratoire de Météorologie dynamique and CNRM-ARPEGE from MétéoFrance as boundary conditions for future climate scenarios with a focus over Antarctica.

Bias correction of daily precipitation and temperature for Norway

Wai Kwok Wong, Norwegian Water Resources and Energy Directorate (NVE)

back

Outputs of global or regional climate models (GCM/RCMs) are often flawed with systematic biases despite recent progress in climate modelling, particularly in simulations of present day climate. The modelling results can be very different from what have been observed which hamper their direct use in climate change impact studies. Moreover, impact models often require data of higher spatial resolution than climate models usually can provide. A post-processing of GCM/RCM outputs is therefore necessary to obtain plausible time series in an appropriate scale for use in local impact studies. It is, however, important to bear in mind the drawbacks of post-processing when interpreting the study results.

In this study, an empirical quantile mapping method (EQM) was used to bias-correct and downscale precipitation and temperature for Norway for an ensemble of 10 EURO-CORDEX GCM/RCM simulations, each representing two alternative emission pathways (RCP4.5 and RCP8.5). The original GCM/RCM outputs with a resolution of 12.5 x 12.5 km were first re-gridded to 1 x 1 km using a simple nearest neighbour method. SeNorge precipitation and temperature gridded data, which also have 1 km resolution, were then used as the 'observed' data for the bias correction procedure. A transfer function based on empirical cumulative distribution functions for both observed and modelled variables in the reference period (1970-2005) was applied to adjust values from the climate projection quantile by quantile so that they yield a better match with the observed. Calendar-month and grid-cell-specific transfer functions were derived and EQM was used to the daily simulated data. For precipitation, the probability of wet days was first calculated from observational dataset on a monthly basis and modelled precipitation was modified accordingly with the same probability prior to correction. The results generally show that the EQM method is capable of removing biases in GCM/RCM outputs in the reference period. When comparing future (2071-2100) and present (1971-2000) climates, the median precipitation change for Norway as a whole is approximately a 10% increase for RCP4.5 and a 20% increase for RCP8.5. Similarly, the median temperature change is an increase of 3K for RCP4.5 and 5K for RCP8.5 respectively.

Adaptation of the German transport infrastructure towards climate change and extreme events

Christoph Brendel, Thomas Deutschländer, Stephanie Hänsel, Simona Höpp, Andreas Walter, Sabrina Wehring
Deutscher Wetterdienst

back

Operating traffic and transport infrastructure in Germany sustainably requires an enhanced resilience to the increasing impacts of climate change and related extreme meteorological events. Specific threats to the infrastructure are posed for instance by landslides, wind throw and floods. Adaptation measures have to be determined and implemented in order to enforce the resilience of the transport sector. Therefore thousands of kilometers of the federal road, waterway, and railroad infrastructure need to undergo a scientific assessment of potential climate change impacts.

In Germany the adaptation to the impacts of climate change is formalized in the German Strategy for Adaptation to Climate Change (DAS). This strategy applies to the whole public sector, including transport and infrastructure, and constitutes the legal basis for putting science and strategy into practice. The Federal Ministry of Transport and Digital Infrastructure (BMVI) – being responsible for the transport infrastructure in Germany – funded a comprehensive national research program on safe and sustainable transport in Germany. One column of this project is the "Adaptation of the German transport infrastructure towards climate change and extreme events".

The participating research institutes and agencies include the Federal Highway Research Institute (BASt), the German Meteorological Service (DWD), the Federal Railway Authority (EBA), the German Federal Institute of Hydrology (BfG), the Federal Waterways Engineering and Research Institute (BAW) and the Federal Maritime and Hydrographic Agency (BSH). This network of departmental research institute operates at the interface between science and practice, with the goal of providing effective knowledge transfer and advice for decision makers in government and industry.

The task of DWD within this network is to provide climate data (observations and climate projections) appropriate for impact modelling and further studies. Bias correction methods are going to be applied to an ensemble of regional climate models. This is particularly important with regard to statistically robust conclusions about climate indices using fixed threshold definitions like frost days, tropical nights or heat days. Simple bias correction methods like linear scaling and quantile mapping have already been used in previous projects. Here, we are aiming at a multivariate bias correction method, in order to maintain the dependency between different climate variables. This consistency is particularly important for water balance related impacts.

Climate change impacts on hydrological processes in Norway based on two methods for transferring regional climate model results to meteorological station sites

Stein Beldring, Torill Engen-Skaugen, Eirik Forland, Lars Roald
Norwegian Water Resources and Energy Directorate (NVE)

back slides

Climate change impacts on hydrological processes in Norway have been estimated through combination of results from the IPCC SRES A2 and B2 emission scenarios, global climate models from the Hadley Centre and the Max-Planck Institute, and dynamical downscaling using the RegClim HIRHAM regional climate model. Temperature and precipitation simulations from the regional climate model were transferred to meteorological station sites using two different approaches, the delta change or perturbation method and an empirical adjustment procedure that reproduces observed monthly means and standard deviations for the control period. These climate scenarios were used for driving a spatially distributed version of the HBV hydrological model, yielding a set of simulations for the baseline period 1961-1990 and projections of climate change impacts on hydrological processes for the period 2071-2100. A comparison between the two methods used for transferring regional climate model results to meteorological station sites is provided by comparing the results from the hydrological model for basins located in different parts of Norway. Projected changes in runoff are linked to changes in the snow regime. Snow cover will be more unstable and the snowmelt flood will occur earlier in the year. Increased rainfall leads to higher runoff in the autumn and winter.

3.3 Seasonal-to-Decadal

On a hierarchy of a posteriori adjustment methods for seasonal to decadal climate predictions

Neven Fučkar, Virginie Guemas
Barcelona Supercomputing Center

back slides

Climate forecasts initialized from an observationally based state (OBS) inevitably drift toward the state of the unconstrained model, which makes the use of empirical post-processing adjustment crucial to separate the climate signal of interest from the model drift and bias. We discuss a hierarchy of a posteriori correction methods that expand the mean bias correction method through an additional correction term linear in start time or in OBS space of initial conditions (IC). The mean bias correction method replaces the long-term mean (over start times) of the model with the long-term mean of the OBS for each forecast time. However, many climate models exhibit conditional bias, i.e. manifest drift that can have short-term and/or long-term components. To account for a model error in a long-term trend, the trend bias correction method replaces a linear regression of the model forecast on start time with a linear regression of OBS on start time. It encompasses the mean bias correction as the first order term, but this adjustment method cannot account for possible conditional bias dependence on the IC. For monthly and longer climate predictions, instantaneous IC at the beginning of the 1st day in a month is too noisy to be considered directly. Hence, in the IC bias correction method we use monthly mean OBS as a smoothed proxy in time for OBS IC (Om) and replace a linear regression of the forecasts on Om with a linear regression of OBS on Om. The IC bias correction method also incorporates the mean bias correction as the first order term, but through the second order term dependent on OBS (Om) it can also capture conditional dependence on near-term climate variability that was smoothed out in the trend bias correction method. The impacts of these two higher order post-processing adjustment methods are examined on monthly means of key climate indices in a state-of-the-art climate forecast system.

Bias correction methods for skewed variables based on quantile relations

Frank Sienz, Max-Planck-Institut für Meteorologie

back slides

Climate models exhibit systematic departures from the observed climate state, especially on small regional scales. This bias reduces prediction skill and restricts usability and value of the predicted quantities. The deviations, however, can often be corrected with statistical post-processing methods to obtain more meaningful results. Here, the interest is on bias correction for skewed variables, like wind speed and precipitation. It is shown that distance measures (mean squared error or mean absolute error) are inadequate to quantify differences in the performance of bias correction methods. In contrast, probabilistic measures are able to identify deviations. Bias correction methods accounting for the higher order moments offer the potential to improve probabilistic scores to a large extent. The consistency of the ensemble members and the accuracy of probability forecasts for multiple categories are improved. Further, the differences between the predicted and the observed distribution functions are reduced. Thus bias correction methods not only reduce systematic errors, they additionally lead to better calibrated ensembles. The findings are based on a simulation study and first results for the MiKlip prediction system are presented.

Parametric drift correction for decadal hindcasts on different spatial scales

Jens Grieger[1], Igor Kröner[1], Tim Kruschke[2], Henning W. Rust[1], Uwe Ulbrich[1]
(1) Freie Universität Berlin, (2) GEOMAR Helmholtz Center for Ocean Research Kiel

back slides

This study compares two different drift correction approaches for a decadal hindcast experiment within the German initiative on decadal predictions (MiKlip). On the one hand, the model bias is calculated for each lead-time separately and subtracted from model output. On the other hand, a parametric approach is used, i.e.

a third order polynomial is fitted to the lead-time dependent bias. This approach additionally takes parameter dependency of initialization time into account. This contribution investigates whether decadal hindcast skill depends on the spatial scale for which parameter estimation for a drift correction model is performed. By means of the Mean Square Error Skill Score (MSESS) it can be shown that parametric drift correction for near surface temperature outperforms the correction for each lead-time separately on all spatial scales. The parametric drift correction approach also accounts for deviations of simulated linear trends from their observational counterparts. This part of the parametric model plays an important role for its performance. The added value of the different components of the parametric model is discussed.

Can bias correction methods improve the accuracy and reliability of seasonal forecasts?

Jose Manuel Gutierrez, Rodrigo Manzanas
CSIC / Universidad de Cantabria

back slides

Statistical downscaling techniques range from simple and pragmatic bias correction methods, which directly adjust the model outputs according to the available observations, to more complex perfect prognosis methods, which infer the local predictions from appropriate large-scale model predictor variables. All these techniques have been extensively used and critically assessed in climate change applications; however, their advantages and limitations for (probabilistic) seasonal forecasting are not well understood yet, and there is currently some controversy on whether or not these techniques can improve the skill of the forecasts. This is a complex problem due to the multifaceted aspects involved in the validation of probabilistic predictions (accuracy, sharpness, reliability).

In this contribution we analyze this problem by applying two bias correction and two perfect prog state-of-the-art methods to downscale seasonal precipitation forecasts from the ENSEMBLES multi-model hindcast in a challenging skilfull region in the tropics with high quality observational data. We show that bias correction provides no significan skill improvement for those skill scores not affected by data scaling (ie. those robust to a change in the mean and/or variance of the data). As a consequence, the skill improvement found in previous works is just a consequence of a mean/variance correction of the data and could be achieved with a simple linear scaling correction. However, perfect prog methods can yield significant skill increments (due to effective improvements of the iter-annual variability) in certain cases for which the large-scale predictor variables used are better predicted by the model than the target precipitation. Moreover, these windows of opportunity might be related to the existence of significant ENSO teleconnection signals.

We conclude on some recommendations on the use of the different post-processing approaches in the framework of seasonal forecasting.

Bias correction of CCLM simulated temperature and precipitation in Europe using cross validated model output statistics

Jingmin Li[1], Heiko Paeth[1], Felix Pollinger[1], Hans-Jürgen Panitz[2]
(1) University of Wuerzburg, (2) Karlsruher Institut for Technology

back slides

A cross validated model output statistics (MOS) method is applied to the output of a regional climate model (CCLM) from Module C of project Miklip II, with the aim of removing its systematic errors and providing a reliable and physically consistent decadal prediction system. The predictand is observed monthly precipitation or temperatures given by the E-OBS data, the predictors are local and EOF time series of CCLM simulated precipitation, temperature and sea level pressure. Results indicate a regional variation in the CCLM precipitation predicting ability, CCLM explains 60-99% of E-OBS variance for Western Europe but only 10-40% for Eastern Europe. MOS results in an overall improvement in CCLMs precipitation predicting ability with stronger improvement (up to 40% increase in the explained E-OBS variance) found for Middle and Eastern Europe. MOS correction for CCLM temperature (up to 10% increase in the explained E-OBS variance) is less obvious than that for precipitation, due to a better performance of CCLM for temperature (after removing the temperature seasonal cycle from both data sets, CCLM explains 75%-90% of E-OBS temperature variance).

Recommendations of the Decadal Climate Prediction Project for bias correction of decadal hindcasts

Jens Grieger[1], Doug Smith[2], George Boer[3]
(1) Freie Universität Berlin, (2) Met Office Hadley Centre, (3) Environment and Climate Change Canada

back slides

The Decadal Climate Prediction Project (DCPP) is a coordinated initiative to investigate decadal climate predictions. It defines the protocol for the decadal experiments in the framework of the upcoming Sixth Coupled Model Intercomparison Project (CMIP6). The CMIP6 experiment design includes hindcast experiments as well as near term forecasts and additionally some experiments to investigate the physical processes involved, focusing on periods of retarded or accelerated global temperature trends and the effects of volcanoes.

No model is perfect and the result is a difference, or bias, between simulated and observed climatologies. This bias may introduce errors into a forecast that are large compared to the predictable signal. This contribution describes the DCPP recommendations for bias correction of decadal forecasts. We also highlight areas where further research is needed.

Calibration of decadal ensemble predictions

Alexander Pasternack, Freie Universität Berlin

back slides

Given the uncertainties due to, e.g. initial conditions, weather and climate forecasts should be and are increasingly issued in a probabilistic way. One issue frequently observed for probabilistic forecasts is that they tend to be not reliable, i.e. the forecasted probabilities are not consistent with the observed relative frequencies of the associated events. These predictions need to be re-calibrated to obtain reliable probabilistic forecasts. While re-calibration methods for seasonal time scales are available and are frequently applied, these methods still have to be adapted for decadal time scales and its characteristic problems like climate trend and lead time dependent bias. We propose a method to re-calibrate decadal ensemble predictions taking the above mentioned characteristics into account. Finally, this method will be applied and validated to decadal forecasts from the MiKlip (Germany's initiative for decadal prediction) system.

Calibrating probabilistic decadal predictions for categories

Alexander Pasternack, Freie Universität Berlin

back

Decadal climate predictions are of great socio-economic interest due to the corresponding planning horizons of several political and economic decisions. Due to uncertainties of weather and climate, forecasts (e.g. due to initial condition uncertainty), they should be and are increasingly issued in a probabilistic way. Similar to seasonal forecasts, also the decadal predictions are often issued in a categorical way, e.g. tercile (above normal, normal, below normal). Analogously to their continuous counterpart, also categorical probabilistic predictions need to be calibrated to ensure their usefulness. While re-calibration methods for seasonal time scales are available and frequently applied, these methods still have to be adapted for decadal time scales and its characteristic problems like climate trend and lead time dependent biases. We propose a method to re-calibrate probabilistic categorical predictions that takes the above mentioned characteristics into account and apply this method to decadal predictions from the MiKlip (Germany's initiative for decadal prediction) system.

A Measure of Drift Quantification in Decadal Predictions

Igor Kröner, Jens Grieger, Henning W. Rust
Freie Universität Berlin

back

After initialisation, a decadal prediction system typically drifts away from observations towards its prefered stated. Statistical post-processing can be used to correct for this lead-time dependent bias. After a correction, the amount corrected for is usually not further considered. However, for interpreting the resulting forecast, it might be useful to quantify the drift. Thus a measure for its quantification is under development. Relevant properties of the measure are magnitude, spatial distribution or even its dependency of initial conditions.

The measure is based on the L2 norm; for a linear change of bias with lead-time its magnitude can thus be interpreted as a mean speed - the larger it is the faster the drift. Exploring a spatial distribution allows to locate hot spots as well as drawing conclusions about potential causes and forcings of drifts. The questions where drift appears and of what magnitude it is, are aims of this study. Comparing results on different grids and variables (temperature, climate indices) helps to discuss properties of the measure as well as interpreting the present drifts. In addition, we compare differing drift estimation methods (parametric, non-parametric) and diverse initialisation strategies (full-field, anomaly).

3.4 Miscellaneous

Climate modelling and bias corrections : climate services provider's perspective

Patrick Josse
Météo-France

back slides

Climate services users' expectations about the impact of climate change and variability on their activities are high. The expectations are generally focussed on a specific area, a specific set of parameters and a quantitative description of the associated uncertainty is also required.

Climate simulations produced by the scientific community of course provide the best starting material. Some work is however required to bridge the gap between raw outputs and the end users' needs : a value of temperature anomaly average over a large area is of course useful for climate change studies, but can not be used directly as an input to elaborate an adaptation strategy or more generally for decision making processes. Sectorial indicators are almost always based on specific thresholds: number of frost days, number of (consecutive) dry days, heating/cooling degrees-day. . . etc. The calculation of such indices implies to have model biases correctly removed from the raw outputs.

Example of climate services developed in France will be given, both for on line services (DRIAS - Futures of Climate, ClimatHD) and specific sectorial impact studies will be presented to illustrate the possible uses of corrected regional climate simulations

Bias Correction in Climate Studies: Road to progress or dead end street?

Uwe Ehret
KIT - Karlsruher Institut für Technologie

back slides

Understanding and quantifying the causes and effects of climate change is currently one of the most challenging questions in science. Today, the best tools we have to understand Earth's climate dynamics and evolution are Atmospheric Circulation Models (ACMs). Confidence in their predictions comes from their foundation in established physical laws, process insight from a wealth of observations, their ability to simulate important aspects of current climate and to reproduce features of past climate variability. But despite considerable progress, output of ACMs, especially the hydrologically relevant variables like precipitation are still afflicted with systematic errors in an order of magnitude that precludes their direct use for Climate Change Impact Studies. This is well known and has been recognized by many. To overcome this Bias Correction (BC) procedures have been established which correct the output of ACMs with and towards observations in observed periods under manifold assumptions such as time invariance of the bias, minor role of spatiotemporal field covariance and feedbacks among variables, etc. The question is open whether these assumptions are valid and whether BC methods are basically a quick fix to hide ACM deficiencies from their users, or whether they really add value in the sense of reliably improving predictions of future climate. In this talk, I will discuss typical assumptions behind state-of-the-art BC methods and the related implications, and I will draw conclusions on the validity of

BC methods and propose ways to cope with biased ACM output. This talk is intended to support a critical and constructive discussion on the Pros and Cons of Bias Correction.

Scaling of precipitation extremes with temperature over Europe: impact of statistical downscaling and/or bias correction on this relationship.

Sophie Bastin[1], Pradeebane Vaittinada[2], Philippe Drobinski[1], Mathieu Vrac[1], Nicolas Da Silva[3]
(1) CNRS/INSU, (2) LSCE/IPSL, (3) UPMC

back slides

In this study we investigate the scaling of precipitation extremes with temperature in the Mediterranean region by assessing against observations (from long-term ground based stations or E-OBS product (Haylock et al., 2008)
i) different statistically downscaled simulations performed in the framework of the french ANR STARMIP project using different methods. Simulations for which the predictors are corrected are compared with simulations without corrections.
ii) different bias corrected dynamically downscaled EURO-CORDEX simulations.

Over the 1979-2008 period, despite differences in quantitative precipitation simulation across the various models/methods, the change in precipitation extremes with respect to temperature is robust and consistent. The temperature-precipitation extremes relationship display a hook shape across the Mediterranean, with negative slope at high temperatures and a slope following Clausius-Clapeyron (CC)-scaling at low temperatures. The temperature at which the slope of the temperature-precipitation extreme relation sharply changes (or temperature break), ranges from about 20°C in the western Mediterranean to less than 10°C in Greece. In addition, this slope is always negative in the arid regions of the Mediterranean (Israel). Differences between corrected and uncorrected simulations are assessed. The study also analyses the evolution of the temperature-precipitation extremes relationship under future climate scenario (RCP85) for the period 2070-2100.

Spatial analog method for temporal disaggregation of daily precipitation

Nada Ben Mhenni, Julie Carreau, Frederic Huard
Hydrosciences Montpellier - IRD

back slides

Precipitation is the main input in many impact models such as hydrological models. Very often, observations are available only at daily time intervals. However, certain hydrological processes typically take place at sub-daily scale and therefore required sub-daily precipitation observations. Temporal disaggregation methods have been developped in order to exploit daily precipitation databases.

Despite being conceptually simple, the analog methods for temporal disaggregation have proved to compete favorably with other methods. In this work, we develop a temporal disaggregation approach based on the analogs in a spatial context. More precisely, we define two days as similar if they are similar in their spatial distribution of daily precipitation.

A crucial issue of temporal disaggregation is the ability to reproduce the sub-daily dynamics based on daily information. To evaluate this ability, we put forward a rain shower characterization that provides a description of the sub-daily dynamics.

We show that, in a small Mediterranean catchment in the South of France, the spatial analog method is able to reproduce the sub-daily dynamics. In addition, the spatial analog method is little sensitive to variants in the definition of similarity.

The spatial analog method can be thought of as part of a regionalized approach and be combined with spatial disaggregation.

Influence of bias correcting predictors on statistical downscaling models

Pradeebane Vaittinada Ayar, Mathieu Vrac
CNRS

back slides

Statistical downscaling models (SDMs) and bias correction (BC) methods are commonly used to provide regional or debiased climate projections. However, most SDMs belong to the "perfect prognosis" context, meaning that they are calibrated on reanalysis predictors before being applied to GCM simulations. If the latter are biased, SDMs might suffer from discrepancies with observations and therefore provide unrealistic projections. It is then needed to study the influence of bias correcting large-scale predictors for SDMs, since it can have impacts on the local-scale simulations: such an investigation for daily temperature and precipitation is the goal of this study. Hence, four temperature SDMs and three precipitation ones are calibrated over a historical period.

First, the SDMs are forced by historical predictors from two GCMs, corrected or not. The two types of simulations are compared to reanalyses-driven SDM outputs, to characterize the quality of the simulations.

Second, changes in basic statistical properties of the raw GCM projections and those of the SDM simulations – driven by bias corrected or raw predictors from GCM future projections – are compared.

Finally, the stationarity of the SDM changes brought by the BC of the predictors is investigated. Changes are computed over a historical (1976-2005) and future (2071-2100) time period and compared to assess the (non-) stationarity.

Globally, bias correction can have impacts on the SDM simulations although its influence varies from one SDM to another, from one GCM to another, with different spatial structures, and depends on the considered statistical properties. Nevertheless, corrected predictors generally improve the historical projections, can impact future evolutions, with potentially strong non-stationary behaviors.

Bias correction of multi-variate parameters: a case study of heat stress in Europe

Ana Casanueva, Sven Kotlarski, Mark A. Liniger
Federal Office of Meteorology and Climatology MeteoSwiss

back slides

High resolution Regional Climate Model (RCM) simulations are important tools to provide the meteorological variables required in climate impact assessments. Despite the advances towards higher spatial resolution and better resolved physical processes, often RCMs cannot be directly used in impact studies due to their partly substantial biases. In the climate change context, distributional bias correction (BC) methods are frequently used to deal with systematic model biases. BC methods can correct either some parameters of the distribution (e.g. the mean via distributional shift or scaling) or all quantiles (e.g. via the empirical quantile mapping). The empirical quantile mapping is widely used in the literature to bias correct individual variables (e.g. temperature, precipitation), in a few cases also for variables such as humidity or wind. The corrected values are then used to derive climate impact indices or drive an impact model.

In the present work we analyze the suitability of empirical quantile mapping to be used for a multi-variate index based on a case study of heat stress in Europe in the framework of the H2020 project Heat-Shield. We consider the wet bulb temperature (WBT) as a simple, but non-linear multi-variate index to quantify heat stress conditions. Therefore the interest is to investigate whether the separate correction of temperature and humidity information would allow to reproduce the distribution of WBT. First, hourly station data is employed to assess the sensitivity of the WBT to the use of daily aggregated values in its calculation, which are usually available from RCMs. Secondly, we test the ability of the separately bias corrected variables to reproduce the main characteristics of the WBT in present climate, using a selection of EURO-CORDEX RCM simulations. Finally, we show first results on the difference in the climate change signal of the WBT derived from bias corrected and raw RCM data.

High resolution simulations of air quality in the Berlin/Brandenburg area: model evaluation, potential applications and need for bias correction

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back

Despite extensive regulations, air pollution remains a challenge in Europe, especially in urban areas. For studying air quality in the Berlin-Brandenburg urban area (Germany), the Weather Research and Forecasting Model with chemistry (WRF-Chem), with online coupled meteorology and chemistry, is set up with three nested domains of 15km, 3km and 1km. Simulations are done for June-August 2014. This work presents the evaluation of simulated meteorology and air quality against surface observations and discusses in which situations bias correction would be useful.

A suitable model setup for simulating the observed meteorology reasonably well is found. Compared with air quality measurements, ozone in and around the urban areas is simulated reasonably well (results from the 1km domain biased by ca. -1 μg m-3 on average), but the maximum daily eight hour average (MDA8) is underestimated (results from the 1km domain biased by ca. -8 μg m-3 on average). Diurnal average NOx concentrations are simulated reasonably well, but urban daytime concentrations are underestimated, which we suspect is likely due to both an overestimation of modeled mixing and too low anthropogenic emissions in the urban area. The representation of mixing within the planetary boundary layer is crucial for correct simulation of air pollutant concentrations, and is an area in which we suspect that biases still exist. Unfortunately however, mixing within the planetary boundary layer is difficult to evaluate as observations are scarce.

For applying the model setup, for example to analyze scenarios of air pollutant emission changes, to assess air quality changes under climate change scenarios, or to use the model results as a basis for assessing the health impact of air pollution, it would be necessary to correct for the model biases. This particularly applies to health- or policy relevant metrics such as MDA8 ozone, hourly NO2 concentrations or 24h averages of particulate matter (PM10 and PM2.5). Bias correction would be necessary both for “hindcast” simulations aiming at reproducing observations, but also for “scenario” simulations with modified emission input data or meteorological conditions.

Distances between Butterflies and their applications to detection in dynamical systems.

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back

The climate system can been described by a dynamical system yielding a strange attractor. This strange attractor depend on natural or anthropogenic forcings, like the seasonnal cycle or an increase of CO2. It is argued that quantifying the difference between two attractors allows to measure the influence of the forcing. Currently, the distance-based methods (such as "analogs") use the Euclidean distance or similar measures. Those distances do not consider the dynamics that transforms attractors. I will highlight the problem of the distance definition by introducing a toy example. This motivates the use of a Wasserstein distance, ste mming from optimal transport theory. Two applications on Lorenz systems are proposed to perform a recognition of attractors and the detection of forcing in the case of non-autonomous dynamics. We will ask some (still) open questions to employ a Wasserstein distance-based method to perform a climate bias correction allowing to account for the dynamics.

JAMSTEC Application Laboratory: Innovations from Earth Sciences

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back

Application Laboratory (APL) is one of key pillars of the Strategic Research and Development Area under the new structure of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). The main goal of APL is to devise solutions for the well-being of human society based on JAMSTEC’s research developments in ocean and climate sciences.

As part of APL, the Climate Variability Prediction and Application Research Group (CVPARG) is designed to carry out climate predictions that aim to forecast events, such as El Niño, up to two years in advance. For this purpose, a state-of-the-art coupled ocean-atmosphere model, “SINTEX-F”, has been developed. This coupled model can calculate the evolution of atmosphere and ocean simultaneously. The skill of El Niño forecasts ranks as one of the highest among the world' s leading prediction centers. Our group is also working on applying these prediction toward human society, focusing agriculture, infectious disease and water management. Finally, our vision is to develop a prediction system that can predict climate events with time scales ranging from one month to one decade, hopefully leading to efficient early-warning systems.

Current projects are focusing on the prediction of climate variations, such as El Niño Southern Oscillation, Indian Ocean Dipole, Subtropical Dipole, and Ningaloo Niño/Niña, and its societal application in southern Africa and over Asia-Australia. One challenge is to provide accurate regional forecast from global seasonal forecast, using dynamical downscaling and dealing with the inherent bias of boundary conditions. At present, the correction of bias is made by substituting the climatological component of reanalysis (ERA-Interim) to the climatological component of the SINTEX-F data. The unbiased variables are downscaled by use of the Weather Research and Forecasting (WRF) model. This correction appears to provide somehow improved seasonal prediction at regional scale.

However, another challenge is to apply the seasonal prediction data toward reducing the spread of infectious diseases in South Africa and toward agriculture and water management in South East Asia-Australia. This is performed using dedicated dynamical models, which require (as possible) unbiased data to generate accurate simulation. It is shown that statistical tools can be useful to perform such correction from the grid scale to the plot scale.

Our group is interested in discussing the choice of the method of bias correction, depending on 1) the use of the variables (dynamical downscaling, societal application...), 2) the type of distribution of the variables (Gaussian, gamma. . .), 3) the time step we consider the variables (daily, monthly. . .).

Spatial interpolation for bias correction

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back

It is well known that climate model output cannot be used directly as input for impact models, e.g. hydrological models, due to climate model errors. Recently, it has become customary to apply statistical bias correction to achieve better statistical correspondence with observational data. As climate model output should be interpreted as the space-time average over a given model grid box and output time step, the status quo in bias correction is to employ matching gridded observational data to yield optimal results. Thus, one often needs to interpolate the primary observational data, which are generally point measurements, to the model grid. In this study, we consider three spatial interpolation methods -ordinary kriging, inverse distance weighting, and B-spline - with the goal of determining which is most appropriate for the interpolation of point-measured temperature data to the model grid. We use the Wupper catchment (Germany) as a showcase.

Another topic addressed in this study is the meaningful definition of bias. Indeed, the international definition of bias according to the WMO is the correspondence between a mean forecast and mean observation averaged over a certain domain and time. According to the recommendation of the Joint Working Group on Forecast Verification Research (JWGFVR), the comparison should be performed between gridded data sets, with the grid resolution of the models degraded by a factor of 3-4 to take into account numerical filter effects. Following this recommendation, the model output, whose initial resolution is 0.11°, is averaged over a 3x3 window. Regarding the interpolation of observations, the effect of the altitude is first removed by using the lapse rate formula. To check the performance of the three interpolation methods, we proceed by cross-validation. Results show that there is no meaningful advantage of one method compared to the others.

Discontinuous daily temperatures in the WATCH forcing data sets

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back

The WATCH forcing data sets have been created to support the use of hydrological and land surface models for the assessment of the water cycle within climate change studies, e.g. for bias correction of climate models. They are based on ECMWF reanalysis products (ERA-40 or ERA-Interim) with temperature (among other variables) adjusted such that their monthly means match the monthly temperature data set from the Climatic Research Unit. To this end, daily minimum, maximum and mean temperatures within one calendar month have been subjected to a correction involving monthly means of the respective month. As these corrections can be largely different for adjacent months this procedure is potentially leading to unplausible differences in daily temperatures across the boundaries of calendar months. We analyze day-to-day temperature fluctuations within and across months and find that across months differences are significantly larger, mostly in the tropics and frigid zones. Average across-months differences in daily mean temperature are typically between 10% to 40% larger than their corresponding average within-months temperature differences. However, regions with differences up to 200% can be found in the tropical Africa. Daily maximum and minimum temperatures are affected in the same regions but in a less sever way.

Intercomparison of statistical and dynamical downscaling models under the EURO- and MED-CORDEX initiative framework: present climate evaluations

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back

Given the coarse spatial resolution of General Circulation Models, finer scale projections of variables affected by local-scale processes such as precipitation are often needed to drive impacts models, for example in hydrology or ecology among other fields. This need for high-resolution data leads to apply projection techniques called downscaling. Downscaling can be performed according to two approaches: dynamical and statistical models. The latter approach is constituted by various statistical families conceptually different.

If several studies have made some intercomparisons of existing downscaling models, none of them included all those families and approaches in a manner that all the models are equally considered. To this end, the present study conducts an intercomparison exercise under the EURO- and MED-CORDEX initiative hindcastframework. Six Statistical Downscaling Models (SDMs) and five Regional Climate Models (RCMs) are compared in terms of precipitation outputs. The downscaled simulations are driven by the ERAinterim reanalyses over the 1989–2008 period over a common area at 0.44° of resolution. The 11 models are evaluated according to four aspects of the precipitation: occurrence, intensity, as well as spatial and temporal properties. For each aspect, one or several indicators are computed to discriminate the models.

The results indicate that marginal properties of rain occurrence and intensity are better modelled by stochastic and resampling-based SDMs, while spatial and temporal variability are better modelled by RCMs and resampling-based SDM. These general conclusions have to be considered with caution because they rely on the chosen indicators and could change when considering other specific criteria. The indicators suit specific purpose and therefore the model evaluation results depend on the end-users point of view and how they intend to use with model outputs. Nevertheless, building on previous intercomparison exercises, this study provides a consistent intercomparison framework, including both SDMs and RCMs, which is designed to be flexible, i.e., other models and indicators can easily be added. More generally, this framework provides a tool to select the downscaling model to be used according to the statistical properties of the local-scale climate data to drive properly specific impact models.