Use of Precipitation Data from the Regional Climate Model CLM for Hydrological Modelling in the *dynaklim* Project

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ABSTRACT

For the development of adaptation strategies in the research project *dynaklim* (Dynamic Adaptation of Regional Planning and Development Processes to the Effects of Climate Change in the Emscher-Lippe-Region) numerous models (e. g. sewer models) which need rainfall data as input are used. These models need data with a temporal and spatial resolution beyond the resolution provided by regional climate models. Therefore downscaling of the precipitation data is performed with the help of weather radar data. Comparisons of measurement and model data during 1961-1990 show systematic bias and differing statistical characteristics between the two data types; thus the model data requires preliminary correction before use. A critical point is the corrections´ impact on extreme event data that are applied in extreme value statistics for structure design, e.g. for retention basins. Different characteristics of the analysed rainfall data and correction procedures are described.

KEYWORDS

Regional Climate Model, Rainfall, Downscaling, Hydrological Modelling, Bias Correction, Adaptation Strategies

INTRODUCTION

The networking and research project *dynaklim* stands for "Dynamic Adaptation of Regional Planning and Development Processes to the Effects of Climate Change in the Emscher-Lippe-Region (Ruhr Basin)". The project is financed by the German Federal Ministry of Education and Research (BMBF) within the "KLIMZUG – Regions Adapt to Climate Change" (BMBF, 2008) programme. *dynaklim* has a duration of five years (2009 – 2014). Its main objects of research are the potential impacts of climatic change on the regional water balance and possible adaptation strategies for population, economy and the environment (Merkel et al., 2010).

The project region encompasses 52 cities and municipalities and is a part of the federal land North Rhine-Westphalia in the western part of Germany. Approximately 3.8 million people live in the catchment areas (4.200 km²) of Emscher and Lippe rivers, forming the central part of one of the most densely populated conurbations in the European Union.

For the development of adaptation strategies, numerous models such as ground water models, hydrological catchment models, sewer models, water supply models, as well as economic models are used. Hydrological catchment models and sewer models in particular require more than only mere trends on the development of air temperature and precipitation, but depend on data of a temporal and spatial resolution beyond the resolution provided by regional climate models. For the *dynaklim* project, precipitation data from both measurements and the regional climate model CLM (Hollweg et al., 2008) are analysed. This analysis comprises two realisations of CLM simulations which differ in their initialisation point.

REQUIREMENTS ON CLM DATA

The CLM regional climate model is one of the four (CLM, REMO, WETTREG, STAR2) most important regional climate models for Germany (Walkenhorst and Stock, 2009; Quirmbach et al., submitted). Its spatial resolution is approximately 18 x 18 km and the hydrological and meteorological parameters have a temporal resolution of 1 h or 24 h. The rather low resolution of the precipitation data parameter is not sufficient for hydrological and sewer models. At least for heavy rainfall events, a downscaling to higher resolution in both space (1 x 1 km) and time (5 min) is required.

Additionally, the CLM precipitation data systematically contain too much humidity. This is the result of a bias in the driving global model ECHAM-5 (Hollweg et al., 2008). Therefore, a bias correction is necessary to use model data in impact models.

Aiming at a multidisciplinary adaptation strategy to climate change, impact models of several disciplines are used in parallel, having their own characteristic requirements concerning precipitation data. Therefore, a consistent data set of corrected precipitation data is needed to satisfy the differing requirements in spatial and temporal resolution (Table 1) in selected subcatchments of Emscher and Lippe rivers.

Table 1. Model-specific requirements for preparation of CLM precipitation data in the *dynaklim* project.

Model / Application	Trends / Signal of Climate Change	Bias Correction	Downscaling
Ground Water	X		
Water Supply	X	X	
Sewage Treatment Plants	X	X	
Hydrological Catchments	X	X	X
Sewer Systems	X	X	X

BIAS CORRECTION OF PRECIPITATION DATA

For bias correction of the precipitation data, measured data and CLM time series of the years 1961 – 1990 (WMO climate normal period) are analysed. Already a comparison of annual precipitation sums reveals significant differences between measured and modelled data. While CLM data provide values of 916 – 1062 mm/a, the measured values are in the range of 714 – 826 mm/a. This corresponds to an average overestimation of approximately 30%. One reason for this overestimation can be found in differing numbers of dry days ($N \leq 0.1$ mm/d) per year. In CLM data the number of dry days per year (105 – 113 d/a) is more than one third lower than in measured data (178 – 189 d/a).

Both annual bias and underestimated number of dry days is found to vary over the year. Thus, the bias correction, according to the quantile mapping principle (Piani et al., 2010; Mudelsee et al., 2010) and based on daily precipitation sums, is performed separately for each month. Means and frequency distribution of modelled precipitation are fitted to distributions of the measured values. Empirical distribution functions of measured and modelled data are plotted against each other (values ordered by size). For two adjacent CLM raster cells (GP_086_088, GP_0_86_089) with two measurement stations, empirical distributions of daily precipitation sums of month May (1961 – 1990) are exemplified in Figure 1. It reveals that:

1. There is a threshold in modelled precipitation where measured values are still 0 (dry days).
2. The shape of distribution curves are similar for adjacent raster cells with comparable orographic characteristics. This applies to both CLM realisations CLM1 and CLM2 and for a wide range of precipitation values (up to the 97%- quantile). In this range, the model overestimates precipitation.
3. A considerable dispersion is visible for the very high precipitation values. Here, the CLM model underestimates the measured values.

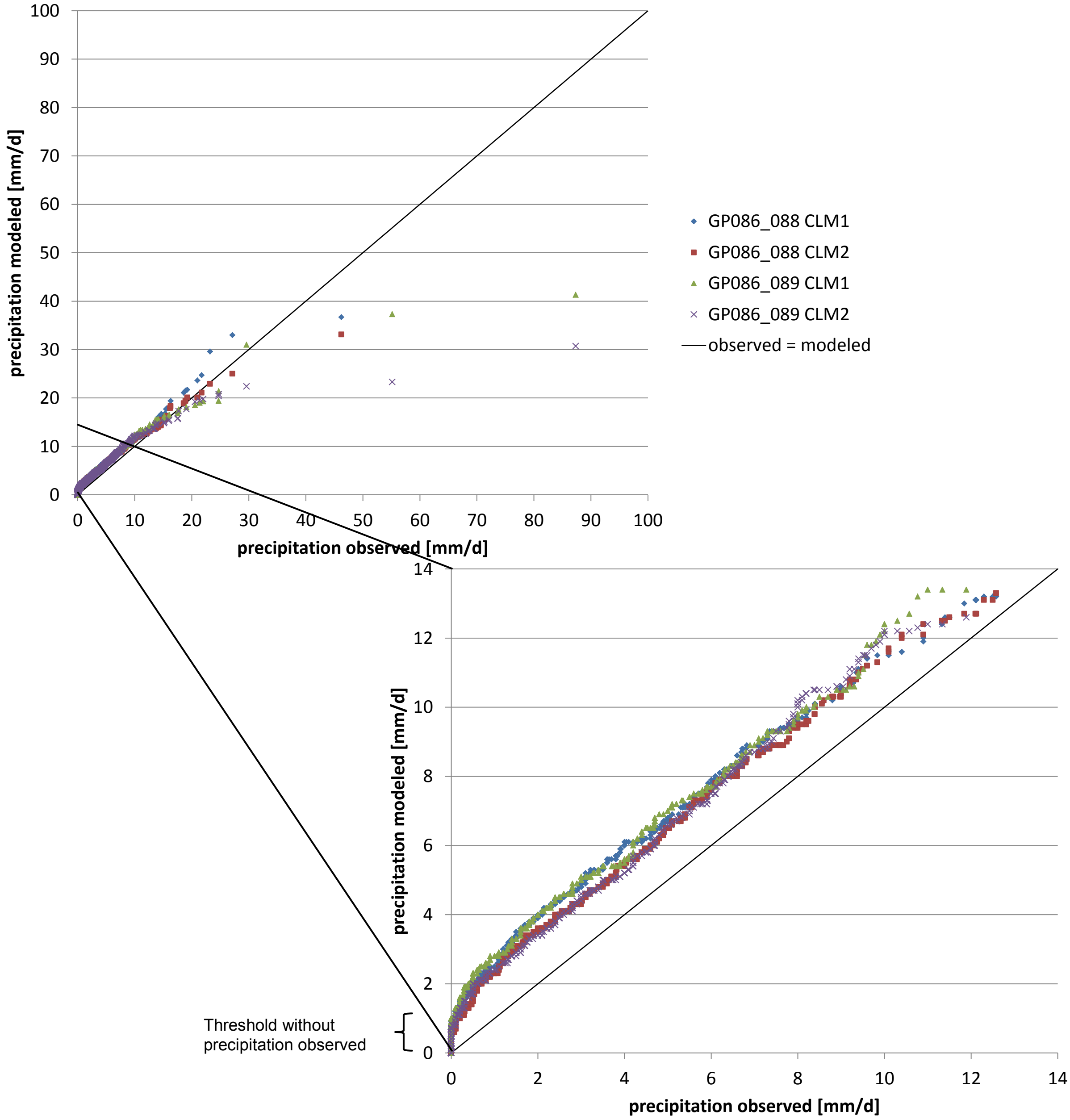

Figure 1. Comparison of the empirical distribution of observed and modelled daily precipitation sums [mm/d], example: month of May (1961 -1990)

The first two aspects are valid for all month of the year, with a seasonal variation in dry day threshold values and shape of the curves. Concerning the very high daily precipitation sums, winter and summer need to be distinguished. In the project region, highest daily precipitation occurs in summer due to convective heavy rainfall events. The model is unable to properly represent those, which can be seen in the underestimated values in Figure 1. In winter, the advective rainfall does not produce such precipitation peaks and CLM results usually overestimate even the high daily sums.

Responding to the seasonal distinctions described, several steps were used for bias correction. First, the number of dry days was corrected to take into account possible future changes in dry period lengths. For each month, the CLM threshold was calculated and subtracted from the modelled values in both the reference period (1961 – 1990) and the future projections.

Next, days with precipitation up to a given threshold (e.g. 97% quantile) are corrected with a monthly variable quantile mapping approach. Here, the empirical function from measured and modelled data is directly used for the future projections.

The highest precipitation sums (e.g. > 97%-quantile) are corrected separately. As described above, the highest rainfall events occur in the summer months and are underestimated by the CLM model, while the highest rainfall in winter tends to be overestimated. This is pointed up in Figure 2, where the empirical distributions of the highest daily precipitation sums (> 97 % quantile) are displayed separately for winter (Nov - Apr) and summer (May - Oct) period.

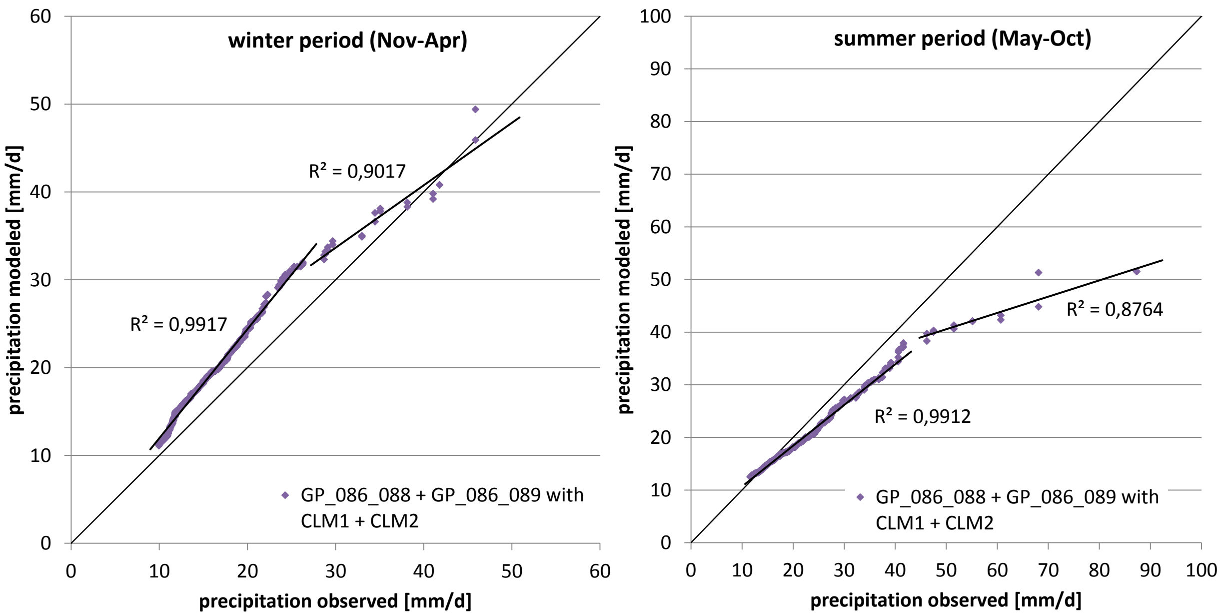

Figure 2. Comparison of the empirical distribution of observed and modelled high daily precipitation sums [mm/d] (> 97%-quantile; 1961 -1990) in winter (left) and summer (right)

Heavy rainfall events occur randomly concerning localisation and time. In order to reduce this randomness not only several months of data but also data of the two raster cells and both CLM realisations are put together and examined as one data set.

High precipitation sums of up to approximately 30 mm/d (winter period) and approximately 40 mm/d (summer period) can be corrected reasonably well with a linear fit (Figure 2). The most extreme rainfall events however are stochastic to an extent that a fit of modelled to measured data is challenging. This is especially the case when projected future precipitation increases and therefore extrapolation is needed. Statistical approaches such as multiple regression are currently tested.

DOWNSCALING OF PRECIPITATION

An approach relying on indirect information based on analogues can remove some of the above described problems. Such a process is a two step process, where first the analogue information, objective weather type classes (Bissoli and Dittmann, 2001), are being analysed, and then measured radar rainfall from eight years (2002 – 2009) is classified into the weather type classes. Objective weather type classes are available for current weather and for all climate scenario simulations (Krahé et al., 2011). Thus, for each of the objective weather type classes, representative events measured by radar are available. For the future climate scenarios, a radar event is drawn randomly from the event set in the bucket for a weather type class.

Radar data were available from a C-band radar with a 1 x 1 km spatial resolution and a 5 minute time step. The quality of the data has been verified and corrected if necessary, and the radar measurements have been adjusted to rain gauge measurements (Jessen et al., 2009).

The objective weather type classes have been verified: the obtained objective weather type classes from the model data have been compared to those of the measurement period 1979 – 2000. The comparison showed a very strong similarity (Figure 3) with a correlation of more than 0.95.

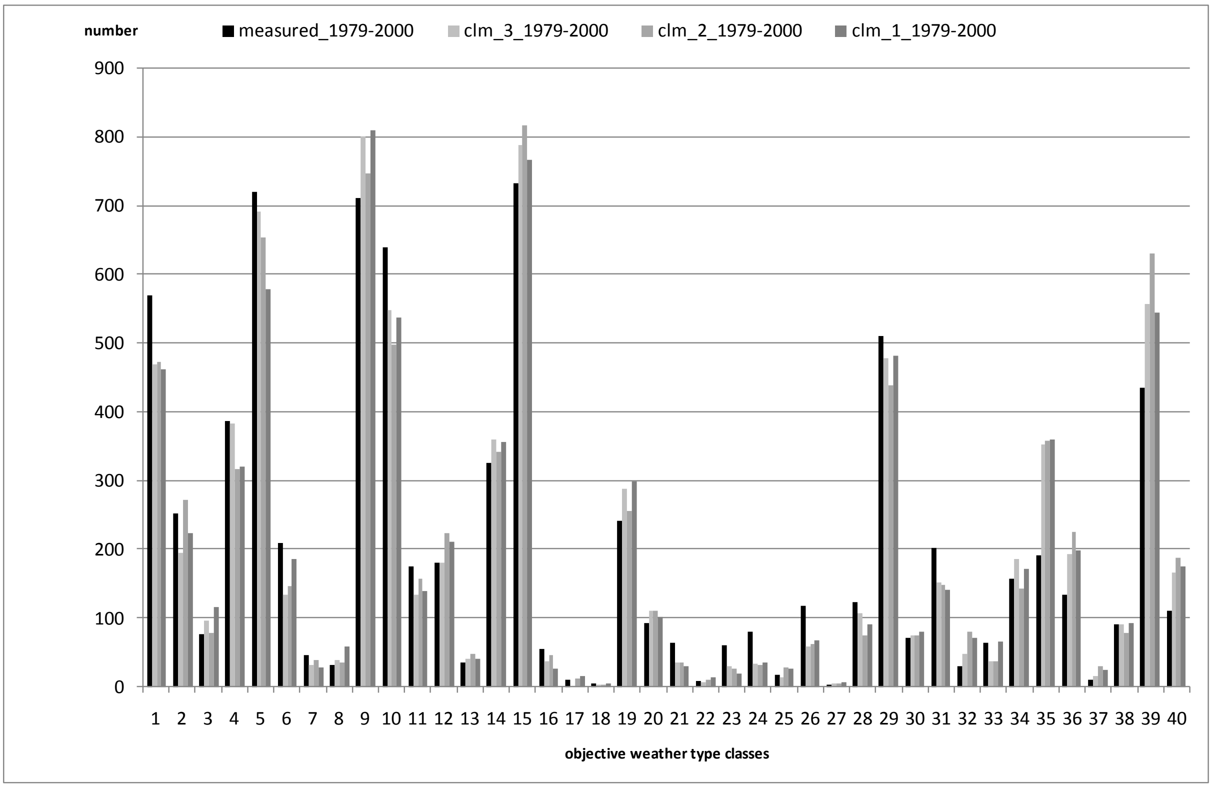

Figure 3. Number of occurrences of objective weather type classes for measured (black) and modelled (grey) data for 1979 – 2000

This approach in its pure realization proved to be not feasible because some important classes did not have enough representative events during the eight year observation period of the radar data.

Therefore, a hybrid approach has been developed, making use of the radar measurements as well as of the objective weather type classes, but selecting rainfall days as well on the basis of the modelled precipitation amount of that day. Results of this approach need to be further evaluated, also in the perspective of a realistic representation of extreme events.

CONCLUSIONS AND OUTLOOK

Time series data from regional climate models may not be qualified for direct use in impact models due to their low spatial and temporal resolution and due to systematic errors (bias). Therefore, such data need to be fitted to measurement data (bias correction) and to be rescaled using an appropriate downscaling approach in time and space.

With the example of data of the regional climate model CLM, a methodology based on the quantile mapping approach has been developed to modify precipitation time series for bias, differentiating for months and different quantiles. For extreme daily sums (beyond the 97% quantile), different methods are currently tested.

The precipitation downscaling uses radar rainfall data as well as informations from objective weather type classes. This methodology is also under further investigation at the current time.

The development of the two steps bias correction and downscaling has to be finalised in summer 2011 in order to produce a standardized and consistent precipitation data set for the users in *dynaklim* according to the individual requirements of their impact models.

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