Downscaling of ERA-40-driven regional climate model precipitation

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INTRODUCTION

There is today a widespread consensus that global warming is a real threat to the future climate (IPCC, 2007). General Circulation Models (GCM) are used to predict the associated climate impacts on a global scale. However, not least in light of the recent strong medial focus on the climate change issue, the demand from society for assessments of the climate change impact on also regional and even local scales is rapidly increasing. This necessitates some form of downscaling of the GCM results from a resolution of typically ~3º down to much finer spatial grids, and even virtually point values if changes in local processes are to be assessed. There are today two main downscaling strategies: dynamical and statistical. The former implies that a Regional Climate Model (RCM) is nested inside the GCM to increase the spatial resolution (to typically ~0.5º); the latter is based on statistical relationships between GCM results and regional or local observations.

The main objective of this preliminary study is to assess the possibility to relate the result in terms of spatially averaged precipitation from an RCM grid box to point value observations from a nearby located precipitation gauge. The key issue is with which accuracy RCM results can be statistically downscaled to represent the precipitation process as manifested in a single point. The underlying motivation for the study is urban hydrological assessment, i.e. what is the expected impact of climate change in terms of flooding and other problems (e.g. pollution transport) in the storm drainage network of large cities. To be accurately described by computer models, this urban runoff process requires point value precipitation data, i.e. even the spatial resolution of RCM:s is far too coarse. Also the temporal resolution required for urban hydrological assessment is very high (~5-10 min), but recent RCM output is at least approaching these time scales.

DATA AND STUDY REGION

The regional climate model data consist of results from an RCM named RCA3, which stands for the third version of the Rossby Centre Atmospheric model (Kjellström et al., 2005). This model has been developed at the Swedish Meteorological and Hydrological Institute. The model domain covers Europe and is shown in Figure 1a. The spatial resolution of the results used here was 49×49 km and the time step 30 min. Data from grid boxes close to the observation stations (right) were used.

Precipitation observations from single gauges in three Swedish cities (Kalmar (1), Jönköping (2), Stockholm (3); Figure 1b), representing climate regions of both maritime and more inland character, were used. The observations were obtained by tipping-bucket gauges, recording the time when 0.2 mm had accumulated, and were aggregated to 30-min values to conform with the RCA3 output time step (Hernebring, 2006).

ROLE OF ERA-40

A general difficulty with GCM results, whether further downscaled or not, concerns their comparability with observations representing the present climate. As (1) climate exhibits low-frequency oscillations (on decadal time scales or even longer, e.g. NAO phases) and (2) GCM runs start from arbitrary initial conditions, it is not certain that GCM results in a given time period are “in phase” with the real climate. Averaging over several decades may reduce the problem, but to which degree is difficult to assess, as is the relative contributions from “model errors”

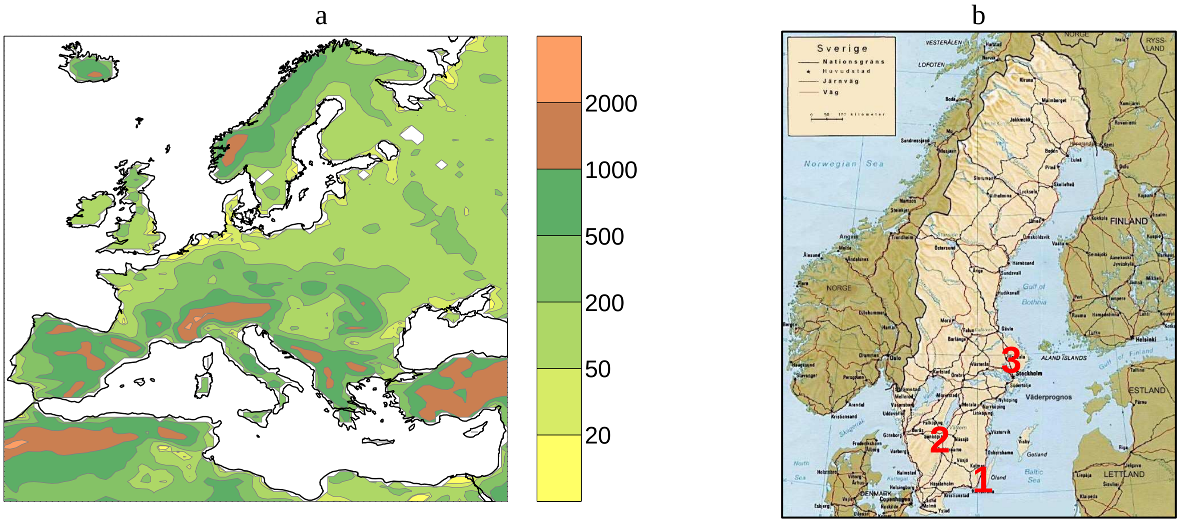

Figure 1. RCA3 domain (Europe; a) and location of gauges (Sweden; b).

and “phase errors”. Comparing GCM-driven RCM results with observations is therefore associated with large uncertainty and requires long time series, with seldom exist for short-term point precipitation observations. An alternative strategy, used in this experiment, is to drive the RCA3 model not by GCM results but by data from the ERA-40 reanalysis. ERA-40 data from 60 vertical levels with a horizontal resolution of 2º and temporal resolution of 6 h were interpolated to the RCA 3 grid and then used to specify the boundary conditions for an RCA3 run. Thus the model boundary conditions were “perfect” (within the accuracy of the ERA40 data set), which provides the most suitable RCA3 results for comparison with observations and reduces the need for long time periods. In this experiment, the time period used extends from the mid-80’s (when high-resolution observations started) to year 2000 (when the available ERA-40-driven RCA3 data ended), i.e. covering ~15 years.

DOWNSCALING METHODOLOGY

A simple stochastic scheme was formulated and tested for downscaling the RCA3 precipitation from a grid box to possible realisations of the precipitation in a point within the box (Figure 2). The method is based on not only total precipitation from the RCA3 model, but also on its two components: large-scale and convective precipitation (which when summed adds up to the total precipitation). For each of these components, a typical spatial coverage (% of grid box) needs to be estimated. For example, a typical convective cell may occupy 1/9=11% (=c_c) of the grid box. Thus the actual precipitation intensity is 9/1=9 times the grid box mean intensity and it has 11% probability of occurring in a certain point. A large-scale system (e.g. stratiform), on the other hand, may typically cover 89% (=c_l) of the grid box, i.e. with 89% probability producing precipitation with an intensity of 9/8=1.125 the grid box mean in a certain point (Figure 2). In this experiment the overall applicability of the simple scheme was assessed and the parameters c_c and c_l roughly optimised for the three Swedish cities.

It needs to be emphasized that this is a very first test with more or less arbitrarily selected parameter values. The results shown in the following should therefore be taken mainly as an indication of whether the suggested approach is at all able of generating a realistic result.

RESULTS

Figure 3 show some examples of results from the simple downscaling scheme. In the figures, blue represents properties of observed point rainfall time series, green represents time series of grid box rainfall averages and red represents simulated (downscaled) point rainfall. The results have averaged over 10 realizations from the stochastic scheme, to obtain stable estimates

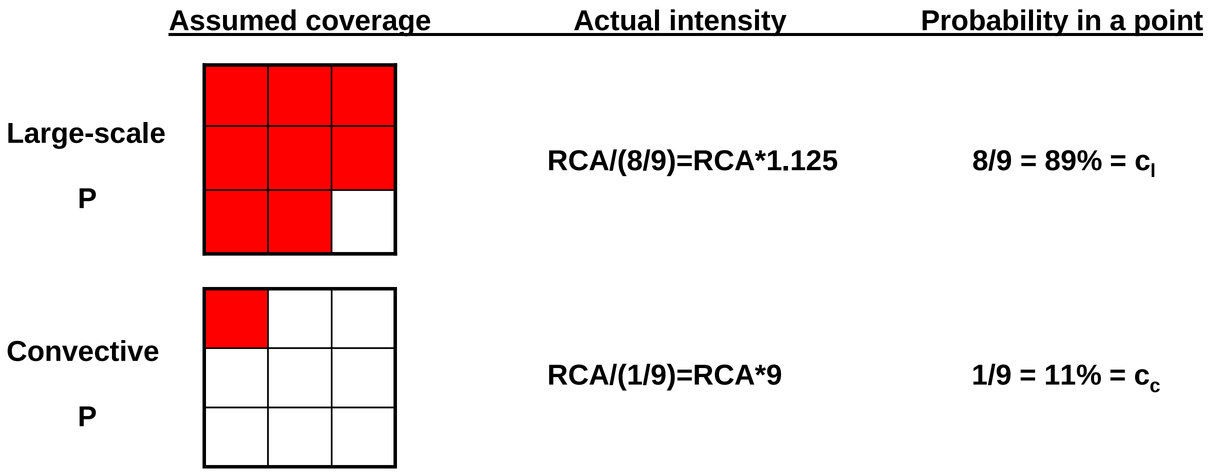

Figure 2. Schematic of the downscaling methodology.

In the top diagram, four general statistical properties of the time series are compared: (1) mean 30-min volume (mm), (2) standard deviation (mm), (3) mean non-zero 30-min volume (mm) and (4) probability of non-zero 30-min volume (-). In the bottom diagram, the results are expressed by so-called Intensity-Duration-Frequency (IDF) curves. This is a common way to describe the extreme values in a high-resolution rainfall time series. The x-axis represents the duration of a rainfall event (30 min to 1 day in this case) and the y-axis represents mean rainfall intensity (mm/hr) for each duration considered. Curves are typically constructed for different return periods (5 years in this case).

As expected, both in terms of general statistics and extreme values the time series of grid box averages (green) are substantially different from observed point series (blue). It rains more often but the extremes are lower in the grid box averages. The downscaled time series (red) overall surprisingly well reproduce the observations, both in terms of general statistics and extreme values. Some underestimation of the extremes is however apparent in Stockholm, which indicates that c_c needs to be reduced compared with the initial guess 11% used in this study.

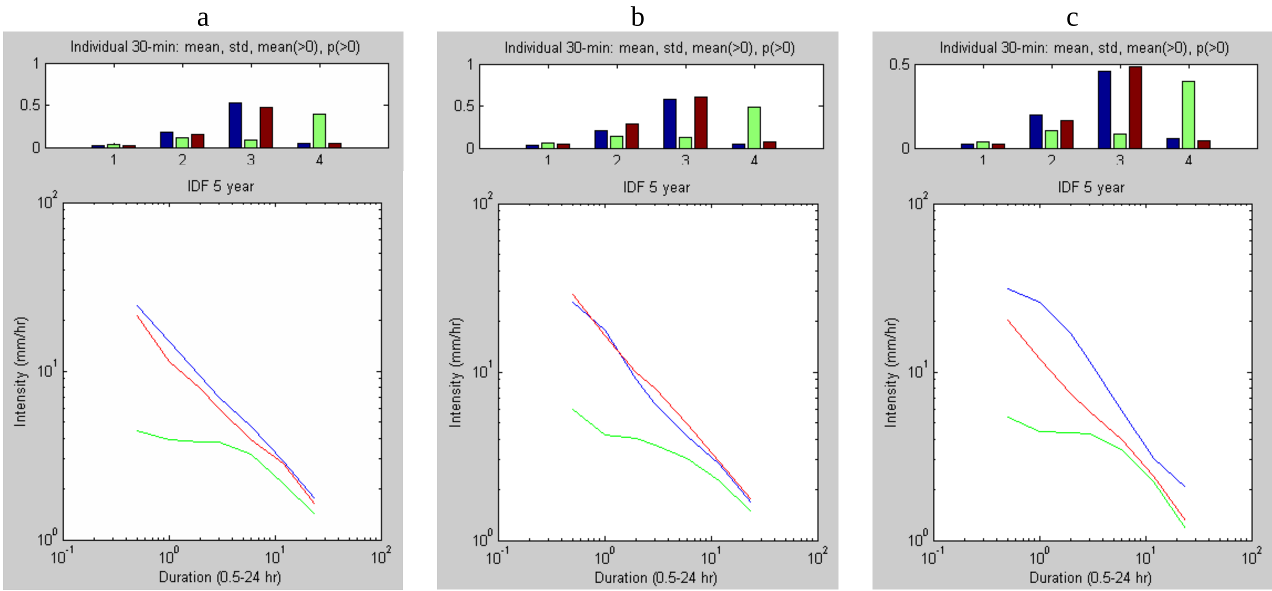

Figure 3. Examples of results from the downscaling method in Kalmar (a), Jönköping (b) and Stockholm (c).

CONCLUSIONS AND FUTURE WORK

From this preliminary evaluation, it appears possible to combine RCM precipitation output, separated into components representing convective and large-scale precipitation, with a simple stochastic scheme reflecting spatial coverage, to create reasonably accurate realisations of the associated point rainfall process. The downscaled point precipitation series compare well with observations both in terms of general descriptive statistics and extreme values. The results support the possibility to statistically relate RCM results to short-term point observations. One possible application discussed above is to use dynamically downscaled GCM output to assess future changes in point precipitation, which however will require a very careful treatment of the calibration for present climate. However, also other applications may be envisioned, e.g. simulating point precipitation properties in ungauged areas.

Future work will include the following activities: (1) optimisation of the coverage parameters (cc and cl) for the different cities, sensitivity testing, split sample calibration, (2) estimation of coverage not as fixed areas but as given by additional RCA3 output parameters, e.g. cloudiness, (3) evaluation and optimisation for not only ERA-40-driven RCA3 results but for GCM-driven RCA3 results representing present climate, (4) application of optimised downscaling scheme to GCM-driven RCA3 results representing future climate.

ACKNOWLEDGEMENTS

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