THE SUDPLAN PROJECT: FACILITATING URBAN HYDROLOGICAL CLIMATE CHANGE IMPACT ASSESSMENT IN EUROPE

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ABSTRACT

The EU-project SUDPLAN (Sustainable Urban Development Planner for Climate Change Adaptation) aims at developing a web-based planning, prediction and training tool to support decisions in long term urban planning. This will help to assure population's health, comfort, safety and life quality as well as sustainability of investments in utilities and infrastructures within a changing climate. With its open nature and architectural design, SUDPLAN will contribute to a shared information space in Europe.

1 INTRODUCTION

Changes in the climate can potentially greatly impact urban hydrological processes and thus the functionality of e.g. sewer networks and waste-water treatment plants (WWTP). In Sweden the main issue is likely the anticipated changes in the precipitation pattern towards larger amounts during winter and possibly higher short-term intensities during summer. Also an increased temperature may have an impact, e.g. by changing the character of snow-melt processes in northern latitudes as well as causing an increased evapotranspiration that may partly offset an increased precipitation. In other parts of Europe, other types of changes and impacts are expected.

The EU-project SUDPLAN (Sustainable Urban Development Planner for Climate Change Adaptation) aims at developing a web-based planning, prediction and training tool to support decisions in long term urban planning. This will help to assure population's health, comfort, safety and life quality as well as sustainability of investments in utilities and infrastructures within a changing climate. With its open nature and architectural design, SUDPLAN will contribute to a shared information space in Europe.

The functionality of the SUDPLAN tool is centred around three so-called "common services" related to (*i*) intense, short-term rainfall for urban hydrology, (*ii*) rural hydrology and (*iii*) air quality. In the tool, results from Regional Climate Model (RCM) scenarios will made available with possibilities of further processing and downscaling to allow for local climate change impact assessment.

In this paper, the urban hydrological common service of SUDPLAN is described in some detail, together with some previous experience of the methods used.

2 CLIMATE MODELLING AND URBAN HYDROLOGY

The main tools to study climate mechanisms are Global Circulation Models (GCMs) that model the interactions between atmosphere, ocean and biosphere on a global scale. However, their outputs cannot be directly used in local area such as a city or a catchment area, mainly because of the coarse spatial resolution, incomplete understanding of sub-gridscale processes and limitations in computer power. Instead, Regional Climate Models (RCMs), nested in GCMs, show a better representation of local climatic situations by means of incorporating extra information such as orography at finer resolutions. Additionally, the RCMs themselves are also actively involved in development by taking innovative parameterizations, land-surface schemes and feedbacks into account (Kjellström *et al.*, 2006). In Europe there are several advanced RCMs available, for instance, RCA3 from Sweden, CNRM from France, KNMI from Holland and MPI from Germany. They are being driven by a number of GCMs and emission scenarios and they will be accessible through SUDPLAN.

The commonly available results from RCMs are generally on a 50×50 or 25×25 km grid and a daily time scale. These resolutions are however too low for urban hydrological applications, which generally require short-term precipitation intensities (5-10 min) at a very local scale (single km², essentially a point value). To assess future precipitation changes at these small scales, and generate data for effect studies, different approaches are required.

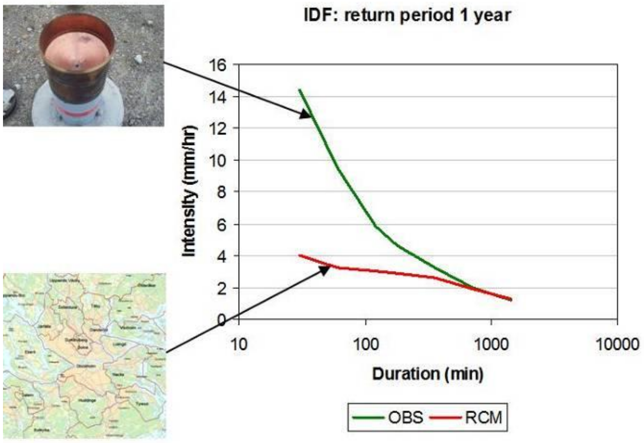

Figure 1. Principal IDF-curves from point observations (OBS) and RCM output (RCM)

Concerning the time scale, RCM results at close to the internal model time step may be retrieved and analysed. In this study, 30-min values are used, which is a time resolution reasonably close to the urban hydrological needs. However, due to the coarse spatial resolution of the RCM (and also possibly model bias), Intensity-Duration-Frequency (IDF) curves derived from RCM output at model grid scale are distinctly different from the IDF-curves derived from local observations, that are used in urban hydrological modelling (Figureure 1). Essentially extremes are underestimated, to a degree increasing with decreasing time scale. This is expected in light of the rainfall generating mechanisms. Point extremes are mainly generated by localised convective systems on sub-grid scales.

One approach to deal with the mismatch in spatial resolution is the so-called Delta Change (DC) method (e.g. Hay *et al*., 2000). In this method, historical observations are modified in line with the expected consequences of the climate change. By comparing RCM output at the model grid scale for future periods with output for a historical reference period, future differences are calculated. These differences are normally absolute in the case of temperature (e.g. 2ºC warmer) and relative in the case of precipitation (e.g. 30% less precipitation) and calculated separately for each month (or season). Under the assumption that future changes at model grid scale are representative also for smaller scales, which is not certain but a necessary working hypothesis, historical point observations may be modified in line with the grid-scale differences obtained, to simulate future point precipitation.

3 URBAN HYDROLOGICAL COMMON SERVICES

The urban hydrological common service is intended to have three main functionalities. The first will be based on extreme value analysis of RCM output on 30-min time scale to estimated changes in short-term precipitation extremes and Intensity-Duration-Frequency (IDF) curves. In the second functionality, the possibility to upload historical continuous rainfall time series and have them rescaled in line with the expected climate change is given. Finally, a “storm generator” is foreseen, which essentially generates a design storm, representing today’s or future climate, with consistent inputs in selected locations.

3.1 Future changes in IDF curves and design storms

The IDF curve downscaling is based on extreme value analysis of annual rainfall maxima of different durations in RCM output using the Generalized Extreme Value (GEV) distribution, as outlined in e.g. Wern and German (2009). For each selected scenario, this analysis is applied to one reference and one future, user-specified 30-year time-series of 30-min values from the five model grid points surrounding the desired location. The relative difference between extreme intensities for short durations may in turn be used to re-scale local designs storms (Figure 2).

3.2 DC rescaling of high-resolution rainfall time series

The Delta Change method has been recently developed and applied on smaller, sub-daily time scales. Semadeni-Davies *et al*. (2008), in a joint study of the effects on urban drainage related to both climate change and increased urbanisation in Helsingborg, Sweden, used a version of the DC method with different factors for low and high rainfall intensities (drizzle and storm), respectively. The monthly DC factors were found to vary widely between a 50% decrease and a 500% increase for the period 2071-2100, implying that both season and intensity level need to be taken into account.

Olsson *et al.* (2009) further refined the approach by considering the entire frequency distribution of precipitation intensities. An application of the method in Kalmar, Sweden, indicated that in summer and autumn, the highest intensities will increase by 20-60% by year 2100, whereas low intensities remain stable or decrease (Figure 3). In winter and spring, generally all intensity levels increase similarly (Figure 3). Contrary to standard DC, this refined version makes it possible to transfer opposing trends to historical observations, such as higher maximum intensities but lower seasonal volume.

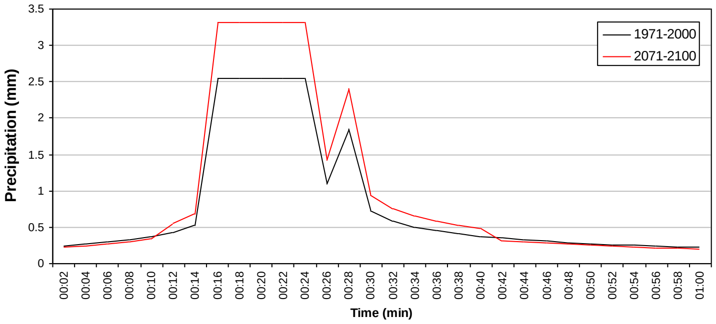

Figure 2. Examples of original (black) and re-scaled (red) design storms

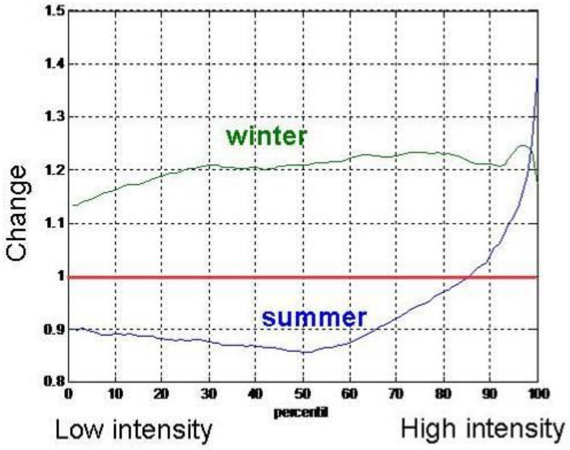

Figure 3. Example of future changes in the frequency distribution of rainfall intensities for Swedish conditions. The red horizontal line indicates no change

As in the case of IDF downscaling, in SUDPLAN the analysis will be applied to one reference and one future 30-year time-series of 30-min values from the five model grid points surrounding the desired location. The resulting changes will then be applied to an observed rainfall time series uploaded by the user.

3.3 Storm generator with climate change impact

The intention in this service is to simulate the passage of a rainstorm over an urban catchment and generate consistent time-series in selected locations. The generator is based on the concept of a design storm, i.e. an idealised time-series of rainfall intensity during an intense event. In the generator, such a design storm is first defined for the centre of the rainstorm. Then transfer functions are used to create consistent design storms in selected surrounding locations. This transfer includes time lagging and a reduction of the peak intensity. The transfer functions should be designed to match the typical shape and extension of intense rainstorms, as found empirically (e.g. Niemczynowicz, 1984).

For climate change impact assessment, the peak intensity may be changed to reflect the estimated future properties of intense rainfall. This requires an IDF analysis as described in section 3.1.

4 CONCLUDING REMARKS

As discussed above, the possibilities of performing urban hydrological climate change impact assessment are substantially limited by the difficulties involved in the generation of suitable rainfall input, representing a high resolution in both time and space. These difficulties involve both the acquisition of high-resolution climate model output and the implementation of re-scaling methods such as Delta Change.

In the SUDPLAN project, an automated system for rainfall input generation will be developed, significantly facilitating urban hydrological climate change impact assessment in Europe. Besides the provision of tailor-made inputs, based on uploaded data representing present climate, the system will allow users to examine future expected climate changes on both local, regional and continental scales through a user-friendly graphical interface.

The development and testing of the first, limited prototype of the SUDPLAN system is currently (autumn 2010) ongoing and it is scheduled to be functional by the end of 2010. The final product is to be delivered by the end of 2012. For more information on the project and its progress, please visit http://www.smhi.se/sudplan.

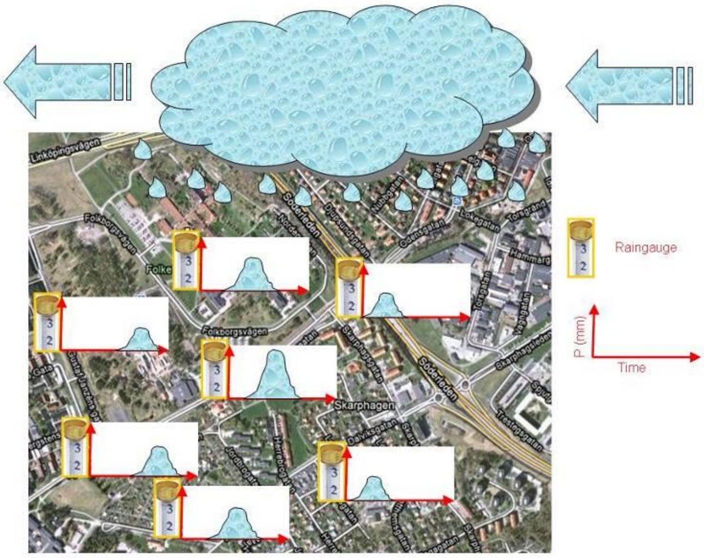

Figure 4. Schematic of the storm generator, simulating the passage of a storm over a catchment and generating consistent time series in selected locations

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