Modelling of spatio-temporal precipitation relevant for urban hydrology with focus on scales, extremes and climate change

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Time series of precipitation are necessary for assessment of urban hydrological systems. In a changed climate this is challenging as climate model output is not directly comparable to observations at the scales relevant for urban hydrology. The focus of this PhD thesis is downscaling of precipitation to spatio-temporal scales used in urban hydrology. It investigates several observational data products and identifies relevant scales where climate change and precipitation can be assessed for urban use. Precipitation is modelled at different scales using different stochastic techniques. A weather generator is used to produce an artificial spatio-temporal precipitation product that can be used both directly in large scale urban hydrological modelling and for derivation of extreme precipitation statistics relevant for urban hydrology. It is discussed why precipitation time series from a changed climate are nec-essay for assessment of urban hydrological systems under climate change. For this, a quantification of the tool “Three Points Approach” is introduced along with a municipal water balance approach. This is done to highlight why it is important to assess the performance of urban water structures for all possible weather and not only for extreme precipitation where problems are expected. Observational data is investigated at different spatio-temporal scales and rel-evant scales for assessment of climate change for urban application are iden-tified. Four different observational data sets of precipitation are compared and used to rank climate models with respect to performance metrics. The four different observational data sets themselves are compared at daily temporal scale with respect to climate indices for mean and extreme precipitation. Data density seems to be a crucial parameter for good representation of extreme precipitation and gridding lowers the peak levels of the extremes. Measurements from a tipping bucket rain gauge are investigated and modelled at the temporal scale of minutes using Markov chain models. The noise at this temporal scale is considerable and the model framework is not considered feasible for spatial application and inclusion of climate change. Correlated point measurements are compared to regional climate model output and the spatial correlation structure of extreme precipitation at the event level is assessed for both. Clearly, regional climate models have too long de-correlation lengths for sub-daily extreme precipitation besides having too low intensities. Especially the wrong spatial correlation structure is disturbing from an urban hydrological point of view as short-term extremes will cover too much ground if derived directly from bias corrected regional climate model output. A weather generator is introduced to statistically downscale precipitation to urban scales. The weather generator is fitted using data from a dense network of tipping bucket rain gauges. The weather generator is operated at hourly time step and generates output on a 2 km grid. The output from the weather generator performs very well when compared to observations both with respect to absolute intensities and spatial correlation of precipitation extremes at event level. Furthermore, the weather generator is able to produce an output with a realistic seasonal behaviour with most of the hourly extremes happening in summer and most of the daily extremes in fall. This behaviour is in good accordance with reality where short term extremes originate in convective precipitation cells that occur when it is very warm and longer term extremes originate in frontal systems that dominate the fall and winter seasons. The weather generator is perturbed with climate change signals derived from six different regional climate model runs. The regional climate model runs represent several emission scenarios, RCMs, GCMs and spatial model resolu-tion and result in six very different perturbation schemes. Even so, the resulting precipitation outputs have comparable extremes for comparable emission scenarios and the estimated change in extremes is in accordance with other studies for the area. The study furthermore shows that there is no simple scaling between moderate emission scenarios and high-end emission scenarios as the sub daily extremes seem to grow faster in magnitude than the daily and multi daily ones for the high-end scenarios. This study shows that spatio-temporal data products representing realistic precipitation in a changed climate can be produced at scales relevant for urban hydrology using stochastic weather generators. Good observational data for present conditions are however required as the correlation structures between different time series are important. If more sophisticated models are to be implemented at finer spatio-temporal scales models including physical behaviour describing precipitation movement and link it to synoptic scale weather are required. Alternatively, very high resolution regional climate models or simplifications hereof could be used for generation of data products at the desired scales.

General information
Publication status: Published
Organisations: Department of Environmental Engineering, Urban Water Engineering
Contributors: Sørup, H. J. D.
Number of pages: 53
Publication date: 2014

Publication information
Place of publication: Kgs. Lyngby
Publisher: DTU Environment
Original language: English
Electronic versions:
WWW version