PhD

Title and Author
A Generic Framework to Produce Probabilistic Rainfall Scearios Incorporating Climate Change. Application to Sustainable Urban Management Strategies.

Xavier Beuchat

Date of Completion

December 15, 2010 (Draft)

Website Link
http://library.epfl.ch/en/theses/?nr=4975

Abstract (~500 words)
The present work addresses the problematic of forecasting impacts of climate change on future rainfall regimes and their consequences on urban stormwater infrastructures. Researches carried out allowed to develop an integrated framework for producing high resolution probabilistic rainfall projections suitable for studying hydrological processes at the scale of urban drainage. Downscaling is at the core of the methodology as the predictions of the numerical General Circulation Models (GCMs) employed by the climate scientific community to model climate evolution are too coarse for hydrolog¬ical impact studies. The proposed downscaling approach respects the scales of the physical processes characterizing precipitations and consists in three steps: i) Daily rainfall series at the location of interest are downscaled from coarse-gridded monthly GCMs projections (scale of weather events); ii) The generated daily series are further downscaled to the hourly time-step (scale of storms dynamics); iii) Finally, hourly series are disaggregated to sub-hourly level (scale of raincells).
Daily downscaling is achieved by a statistical procedure, based on Generalized Linear Models (GLMs), seeking to relate large-scale atmospheric variables, corresponding to the scale of GCMs, to local daily rainfall series. The proposed methodology was assessed using three

contrasted situations in Switzerland (Geneva, Sion and Saäntis) and was shown to perform well in reproducing historical rainfall statistics (including extremes and inter-annual variability) in the present-day climate; furthermore, projec-tions were shown to be consistent with the simulations of physically-based dynamical models (i.e. Regional Climate Models). Projections for the second part of the 21th century indicates considerably drier summers, but no significant tendency toward more extreme events was detected except for Säntis. Finally, extensions of the methodology were presented allowing to downscale other atmospheric variables than rainfall.
Sub-daily rainfall downscaling is achieved using a stochastic hourly rainfall generator based on Poisson clusters model which aims at conceptualizing storm dynamics in a simple way. To provide sensible results such generators have to be fitted on historical rainfall statistics computed at different levels of temporal aggregation. In the present context, this raises a fundamental problem as the required fitting statistics at the sub-daily time-scale are not available for the future. Shortcomings of existing methods led us to develop a novel approach based on Multivariate Adaptive Regression Splines (MARS) which were so far seldom used in hydrology. The proposed MARS models are conditioned on climate and fit thus particularly well in the general downscaling framework. In addition, atmospheric predictors allow to account naturally for seasonal variations meaning that a single MARS model holds for the whole year, whereas existing models are specific to each month of the year and are therefore not robust against the seasonal changes that might induce global warming. The methodology was applied to generate hourly rainfall series from daily data simulated by the GLMs at Geneva for the end of the 21th century. Climate change was found to impact significantly summer storm dynamics: raincells are predicted to be shorter but more intense, and storms are projected to be less frequent. A frequency analysis made on the simulated hourly rainfall series revealed a significant increase of hourly rainfall return levels.
Hourly rainfall series are further disaggregated to the 10-minute level using a cascade-based model. Using case studies in the Geneva area, the performances of this sub-hourly rainfall disagreggator (in particular the reproduction of extreme values) were shown to be equivalent when fitted on statistics derived from the temporal levels 10-minute to 1-hour (sub-hourly fitting set), or from the 1-hour to 3-hour levels (supra-hourly fitting set). In consequence, the supra-hourly statistics of the hourly rainfall series generated by the stochastic Poisson clusters model can be used to fit the disagreg¬gator model in order to simulate 10-minute rainfall series.

Projections of 10-minute rainfall at Geneva for the end of the 21th century indicates an increase of extreme events intensities.
Uncertainties in the proposed downscaling procedure are dealt with using, whenever feasible, probabilistic models (i.e. GLMs, hourly rainfall generator, MARS model and sub-hourly disagreggator), and relying on a large number of General Circulation Models projections conditionned on various greenhouse gases emissions scenarios.
The present work concludes with a case study illustrating how the developed downscal¬ing methodology may be used to evaluate different strategies of sustainable stormwater management. The Industrial Zone of Plan-les-Ouates (ZIPLO) taken as example is a small urbanized area of Geneva. Urban drainage was characterized using a semi¬distributed rainfall–runoff model, and climate change (under the higher greenhouse gas emissions scenario) was shown to increase significantly the peak discharge flows at the ZIPLO outlet. Different sustainable stormwater options were then evaluated in order to limit the peak discharge flows under the joint scenario of climate change and projected urbanization increase.

SWITCH Deliverable Contribution
n.a.

Description of how PhD contributes to goals/objectives of deliverables
n.a.