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DOWNSCALING RAINFALL FOR A CHANGING CLIMATE

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INTRODUCTION

In the UK and many other developed countries, rain gauges have been widely installed and monitored for decades. Rainfall measurement has been playing a vital role in civil engineering for a number of applications, in terms of drainage design, flooding engineering, landslide engineering and so on. Unfortunately, most operating gauges can only provide daily rainfall measurements. Considering urban catchments with rapid response, precipitation data with finer scaled resolution (typically hourly series) is required for an efficient and cost-effective urban drainage design. Under such context, it is necessary to adopt a stochastic hydrological model which can statistically analyse available daily information so as to produce possible realisations of rainfall in an hourly scale.

SITE OF INTEREST

This project focuses on the area situated in Eastern England, including Suffolk, Norfolk and Cambridgeshire. The topography of this site can be characterised as relatively flat and plain compared to other parts in the UK, which means the rain and wind are more spatially uniform. There are eleven hourly based rainfall gauges (with the elevation ranging from 5 to 75m above mean sea level) operating across this area, and the historical observations can be tracked from British Atmospheric Data Centre. Figure 1 presents the geological distribution of these eleven hourly weather stations.

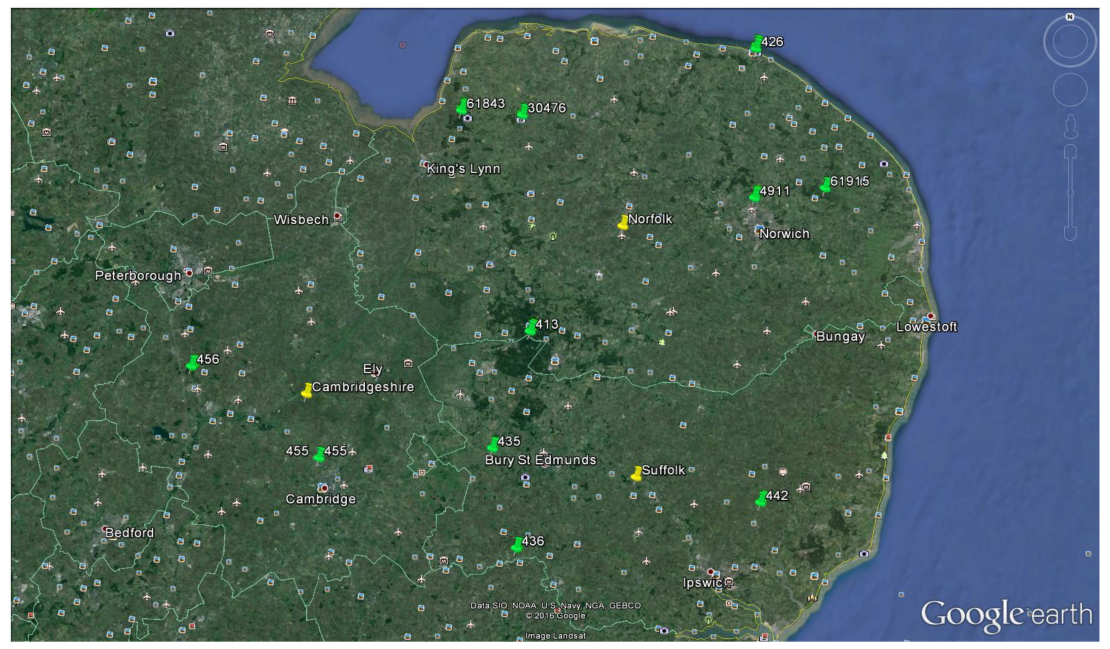

Figure 1: Site of Interest

RAINFALL GENERATION METHOD

The Bartlett-Lewis rectangular pulses model (BLRPM) was chosen due to its wide applicability and experience in calibrating and applying it to several climates. One of the theoretical structures of the BLRPM is the construction of a wet cluster/period. The characteristics of a given storm event, in terms of duration, intensity and occurrence interval, can be determined by the shape/dimension of wet cells. In order to appropriately reproduce storm events, multiple random variables are used to identify the characteristics of the rectangles. Figure 2 shows the underlying principals of the BLRPM, where

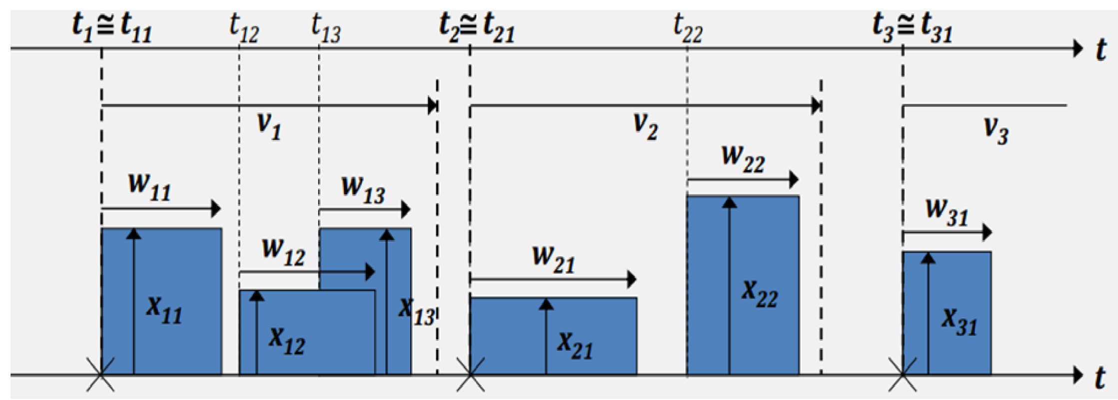

Figure 2: Rainfall Generation Method (Kossieris et al., 2015)

i. Storm origins t_i occur following a Poisson distribution
ii. Cell origins t_{ij} arrive following a Poisson distribution
iii. Cell arrivals terminate after a time v_i exponentially distributed
iv. Each cell has a duration w_{ij} exponentially distributed
v. Each cell has a uniform intensity X_{ij} with a user-specified distribution, noting that X_{ij} is typically assumed to have an exponential distribution with parameter $1/\mu_x$. As an alternative, X_{ij} can also be set as a gamma distribution with mean μ_x and standard deviation σ_x.

A linear adjusting procedure is then applied to the simulated series in order to preserve the daily totals. After that, an iteration procedure is also included in order to achieve an improved preservation of autocorrelations and skewness.

ACKNOWLEDGEMENTS

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RESULTS FROM THE SINGLE-SITE DISAGGREGATION

The validation of the calibrated BLRPM can only be examined by comparing rainfall statistics (e.g. mean, variance, skewness, lag-1 autocorrelation and proportion dry) due to the fact that this model aims to reproduce the statistics of the rainfall at the different site. In other words, it is not a forecasting model that would aim to exactly reproduce the intensities at different times of the day. The 1-, 6- and 12- hour observed and disaggregated statistics at master station 456 for 2015 are computed and compared. Overall, a close agreement is observed for most statistics.

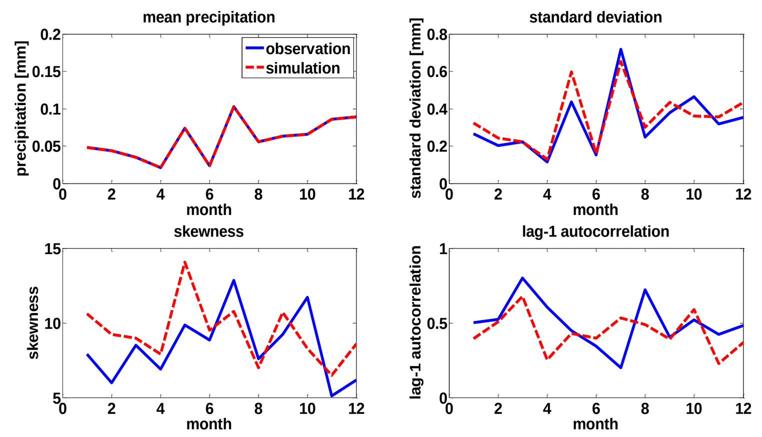


Figure 3: 1- hour Statistics

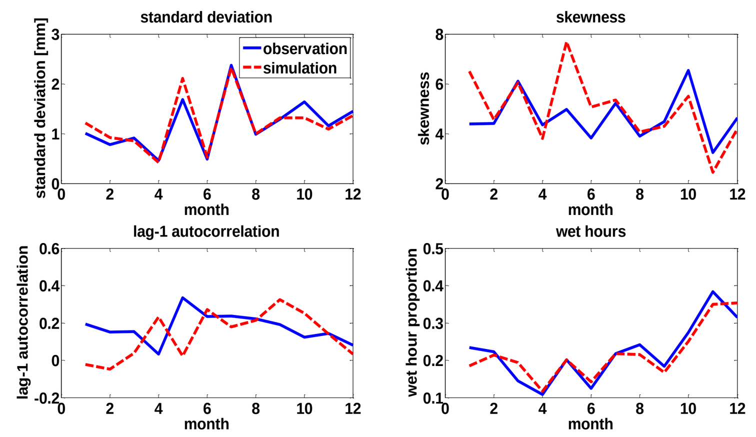


Figure 4: 6- hour Statistics

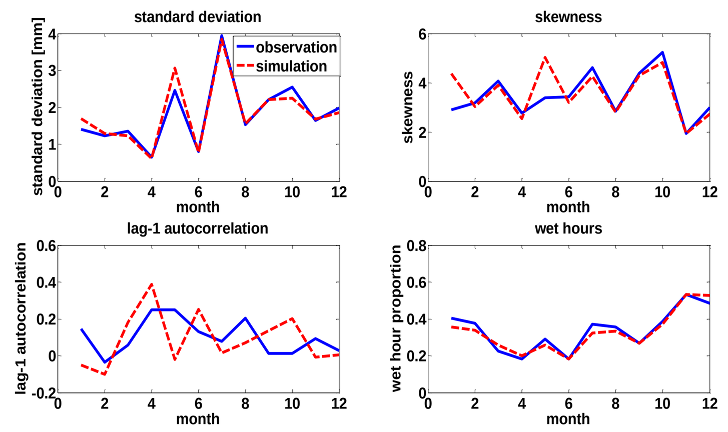
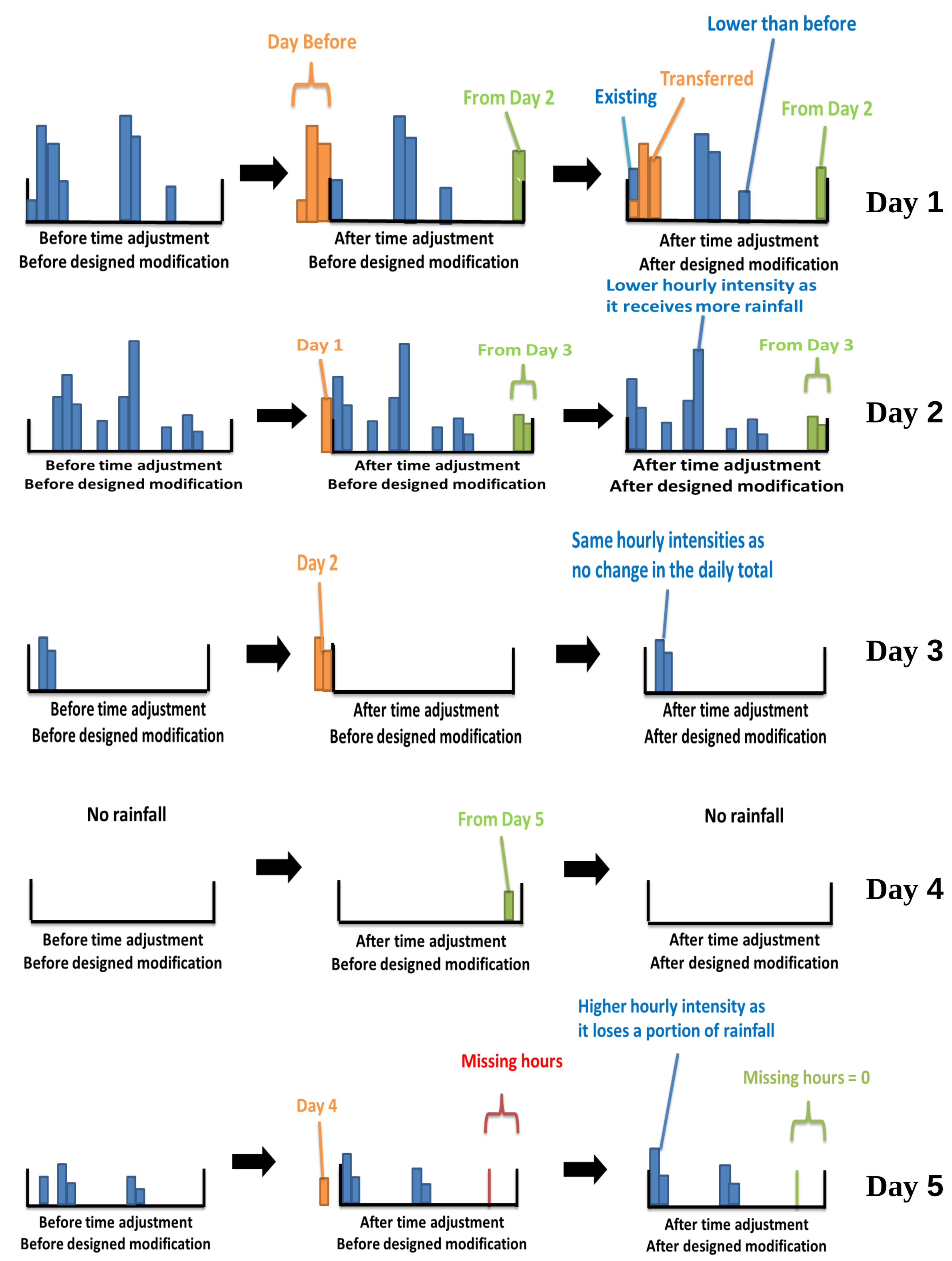


Figure 5: 12- hour Statistics

SPATIALISATION OF THE DISAGGREGATION MODEL

Based on the observed daily totals, a linear space adjustment is first applied to the hourly disaggregated profile at the master station so as to downscale the daily precipitation into hourly precipitation at each of the gauges across the interested area. Taking into account of storm advection, a time adjustment must be considered at each station as the whole site is of size of 130 * 90 km^2. After the application of time adjustments, a modification procedure must be applied to the time-shifted profile so as to preserve the observed daily totals. The algorithm of the modification can be illustrated by a five-day storm event as shown on the right, where x-axis is time and y-axis is rainfall intensity. For the case study from 22/07/2015 to 31/07/2015, a good match between the observed and simulated series was observed for the hourly spatial correlation between the master station and individual stations. Moreover, the timing of the maximum rainfall was satisfactorily reproduced at most satellite stations. Further improvement can be achieved by using a sub-hourly disaggregation model, which can simulate a finer scaled standard profile at the master station and also allows the time adjustments to be approximated to a finer level.



REFERENCES

Kossieris, P., Efstratiadis, A., Tsoukalas, I. and Koutsoyiannis, D. (2015) Assessing the performance of Bartlett-Lewis model on the simulation of Athens rainfall. In EGU General Assembly Conference Abstracts (Vol. 17, p. 8983).