II-15

# ON THE PREDICTABILITY OF RAINFALL CHARACTERISTICS AT SMALL SPACE-TIME SCALES

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## INTRODUCTION

Typical urban catchment areas range in size from 1 to 2 km$^2$. In most of these catchments the overland flow time to gutter inlets is seldom longer than 1-10 minutes. The flow time in a drain pipe or sewer is usually between 1-5 minutes. This poses special requirements concerning the rainfall observations used in forecasting of runoff, in e.g., a computerized on-line total system management of the urban hydrological system. Here, a basic knowledge is needed of the smallest rainfall structures, i.e., individual convective cells. In turn, these cells with an areal extension of 2-3 km$^2$ (defined as the area within the spatial 0.7 correlation isoline assuming second-order stationarity; e.g., Niemczynowicz, 1984; Berndtsson, 1988) are highly dynamic and undergo different development stages during the course of a few minutes (Hobbs and Locatelli, 1978). Deterministic models for rainfall forecasting have in most cases used radar. However, radar still gives rather disappointing quantitative results for small-scale urban catchments compared to dense raingage networks with high time-resolution. Besides, most urban catchments are still not equipped by radar. Instead, urban rainfall is traditionally usually observed by raingages. Consequently, in order to extend the use of these raingages there are needs to develop methods for rainfall forecasting for the specific requirements of urban drainage and urban hydrological management. The objective of this paper is to discuss some possibilities to mathematically forecast the smallest space-time rainfall structures in terms of motion, shape, size, and intensity as observed at ground level. The basis for this discussion is observed minute rainfall at twelve raingages in the city of Lund, Sweden (see further Niemczynowicz, 1984). A complete statistical characterization of the rainfall field on these scales and subsequent real-time prediction experiences are described by Berndtsson et al. (1991) and Jinno et al. (1991).

## EXPERIMENTAL LAYOUT

Twelve raingages covered the main part of the city of Lund (25 km$^2$), Sweden, during a three-year observation period (1979-81; Niemczynowicz, 1984). The average distance between the gages was 1.3 km. The gages were of tipping-bucket type with 0.035 mm per tipping. The time resolution was set to 1 minute and all gages functioned automatically which also allowed for synchronous observations. Further details about the operation of the network and calibration procedures for the tipping-bucket gages are described by Niemczynowicz (1984). In total about 400 rainfall events were identified during the observation period (defined as separated by at least 15 minutes of no recordings and exceeding 3.3 mm/10 minutes).

## STATISTICAL PROPERTIES OF SMALL-SCALE SPACE-TIME RAINFALL VARIABILITY

The average speed of the rainfall cells over the observation network was estimated to 10.4 m/s. In turn this means that individual rainfall cells may pass over an average-sized urban catchment of length-scale 1.5 km during about 2-3 minutes and an average-sized city (length-scale of 5 km) during less than ten minutes. Obviously, for urban-scale real-time forecasting purposes, we will be interested in time scales of 1-10 minutes. Having identified the time scale (1-10 minutes) of main interest, the entire data base was used for a further statistical treatment (about 400 individual rainfall events during 3 years). To characterize a statistical measure of the rainfall area to be forecasted and how this area is likely to change depending on aggregation period and lag time, spatial correlation fields assuming second-order stationarity were calculated using the entire data base. Correlation coefficients were calculated by excluding aggregated data occurring as zero rainfall at both of the pairwise combined stations.

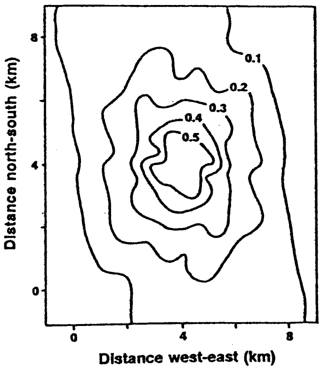

Figure 1. Example of spatial correlation fields assuming second-order stationarity for the total 1-minute series data (data observed during three years at twelve gages).

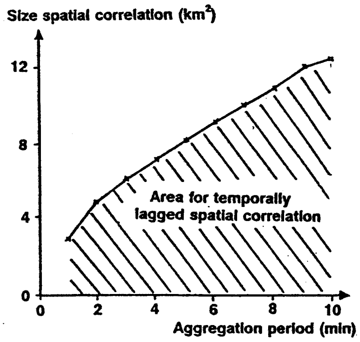

Figure 2. Size of spatial correlation fields within the 0.5 correlation isoline depending on aggregation period (c.f., Figure 1).

This was done in order to avoid an erroneous rise in correlation due to long dry periods which is obvious for minute observations (Berndtsson, 1987). Figure 1 shows an example of the spatial correlation field for time lag zero and the total 1-minute data series. It is seen that the correlation field is not isotropic. Instead, the correlation field is typically elongated in the NNW and SSE direction. This may be an influence of preferential storm paths (Niemczynowicz, 1984). The area within the 0.5 correlation isoline (this correlation level was arbitrarily chosen to represent an adequately statistical significance level) corresponds to about 2.9 km$^2$. Consequently, this area may on an average be possible to track in forecasting situations. However, in a forecasting situation the change and decay of spatial patterns in time will tend to decrease the possibility to track patterns or shapes. Figure 2 shows the size of the spatial correlation fields within the 0.5 correlation isoline depending on aggregation period (data observed during three years). It is seen that the correlation areas increase as the aggregation period increases. As the forecasting period increases we will probably have to increase also the aggregation period in order to have a possibility to forecast the rainfall area with reasonable accuracy due to the rapidly changing rainfall patterns. The full line in Figure 2 may be regarded as maximum areas on an average to be possible to detect. The striped area below the full line represents temporally lagged correlation areas which obviously are smaller compared to unlagged data. Figure 2 also indicates the necessary spatial resolution of the observation network for tracking rainfall patterns. If the distance between gages is greater than the diameter of the average-sized correlation field for a certain aggregation period in the figure, it is less probable to be able to forecast the actual rainfall field with any reasonable accuracy.

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