Rainfall structural modelling in urban hydrology

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RAINFALL STRUCTURAL MODELLING IN URBAN HYDROLOGY

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INTRODUCTION

The aim of work is to study the possibility of modelling a rainfall using an urban raingauge network.
This kind of network is quite new, but their existence will lead to a kind of modelling in which both space and time variations are taken into account. This will be helpfull for the simulation and the conception of drainage system, and even prediction of dangerous urban evolutions (case of the static rainfall over Nimes in France, 1988.)
These last cases are esentially due to stormy phenomena with important variations in time and space that must be handled through the local rainfall intensity : i (x,t) x representing the space, t the time.
Two kind of systems can be used to measure local rainfall intensity :

- The raingauge which provides the measure of i (t) in a specitif point of the urban area.
- The radar which provides the measure of i (x) at a time.

This last method is still in development, so this work is based on the analysis of the results obtained by two urban raingauge netwoks (LYON and BORDEAUX in FRANCE). (I)

1 - Method

Reestablishing continuity of the intensity from a limited number of measures (typically 30 for LYON and BORDEAUX networks) requires the detection of a king of regularity by the network. This means that the intensities obtained from the raingauges are to be structured, using a particular comparison technique between the signals of the different raingauges.
If it is impossible, the intensity measured by a raingange has no relationship even with neighbour raingauges. So we cannot transform local information into a global one.

1.1 Comparison technique

The similarity of the intensities $i_1(t)$ and $i_2(t)$ measured by two raingauges can be valued using :

$$A = \frac{\int_0^T i_1(t)\, i_2(t)\, dt}{\|i_1(t)\| \cdot \|i_2(t)\|}$$

where : $\|i(t)\| = \left| \int i(t)^2\, dt \right|^{1/2}$

T : duration of the rainfall

A = 1 means i (t) = i (t) at all times while A = O means no similarity between i (t) and i (t).

This first measure favours synchronicity of the two signals, so it is important to use another measure which takes into account the lag time between two signals : (II)

$$B(Z) = \frac{\int i_1(t) \times i_2(t - Z)\, dt}{\|i_1(t)\| \cdot \|i_2(t)\|}$$

the optimal lagtime Z * is obtained by B maximal.

1.2 Analysis Strategy

Several ways can be followed in order to obtain a structure of the set of signals. The choice of a particular method depends on rainfall models which can be used after. Two different ways are here explored.

1.2.1. Synchronous sets

From a particular point (j) of the set, the use of the measure A allows to create a set of rainganges whose signals are nearly identical. This choice is based on a lower limit A_{min} of the measure A.
The set of raingauges is, by this method, structured in subsets of synchronous signals. Each subset can then be considered to be associated with a particular rainfall phenomena and studied alone . Average intensity and space distribution of the maximun of intensity were studied as a first approach to inner group modelling.

1.2.2. Rainfall propagation, relationship between subsets

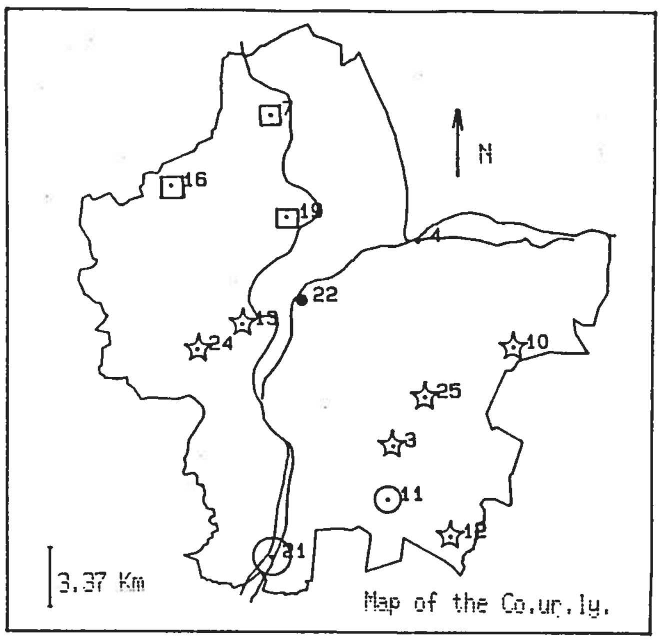
The use of the other measure B allows to value the time relation between the subsets, that is to say the propagation of the rainfall.
In order to determine the optimal lag time between subsets, the signals associated with the raingauge where the local intensity as maximal were used.

2 - Exemples of studies for LYON

These two measures allows to describe structures varying from a single synchronous set to a structure where each raingauge is a subset with time relations between raingauges.

2.1. First example

Rainfall of the 15 July 1985; Duration 240 mm;
Time step 6 mm.
120mm/h : maximun intensity in point 19
13 points of measurement.



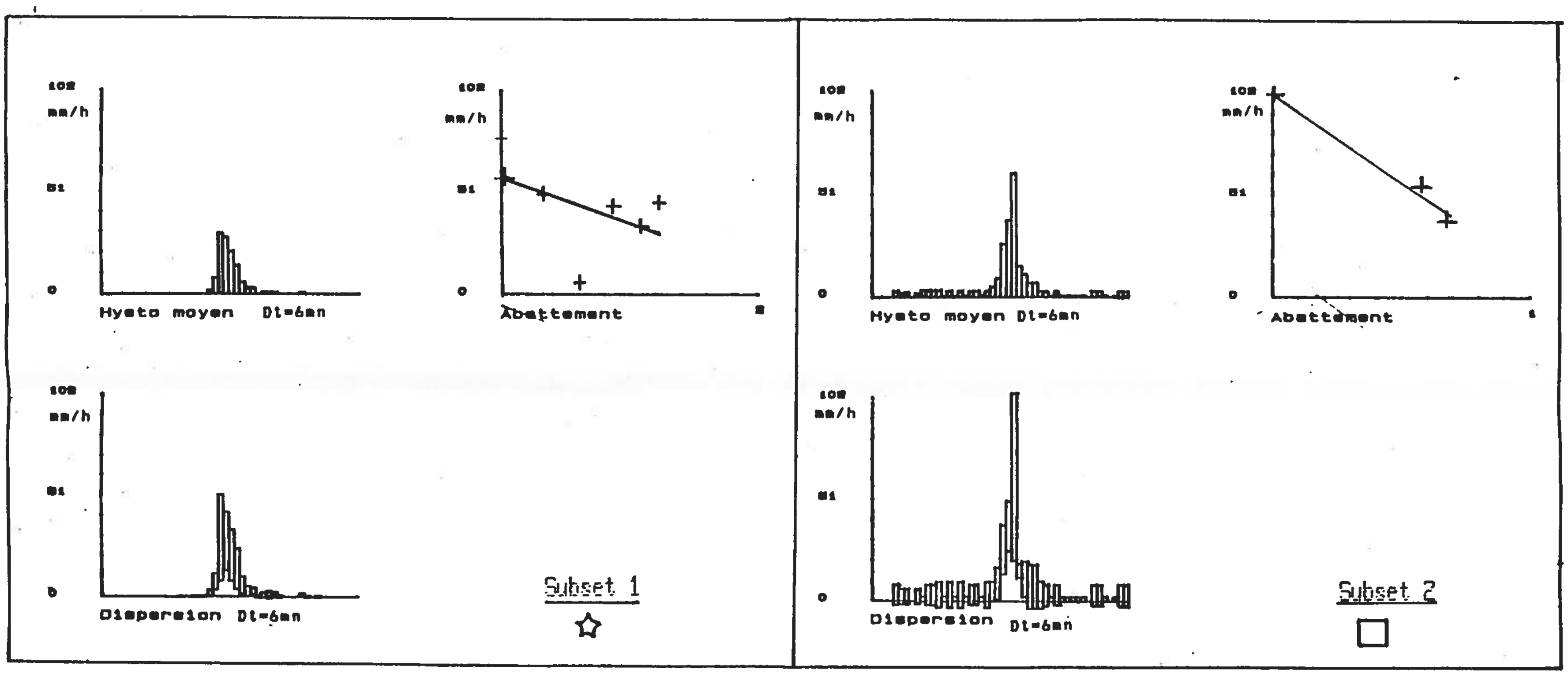
(1) Observed rainfall structured into four synchronous subsets.

- * Subset 1 with A_{min} = .6 (6 points)
- □ Subset 2 with A_{min} = .6 (3 points)
- o Subset 3 with A_{min} = .5 (2points)
- . Subset 4 (1point)

relation between subsets.

1 — 2 with B = .95 four Z = 24 mn

(2) For the first two subsets, average rainfall, quality of the representation with this average rainfall (dispersion) and spatial distribution of the peak intensities ;

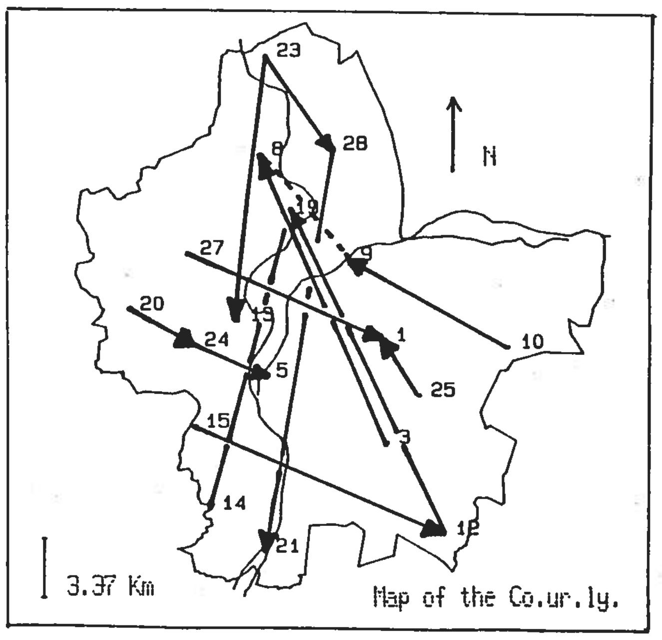


2.2 Second example :

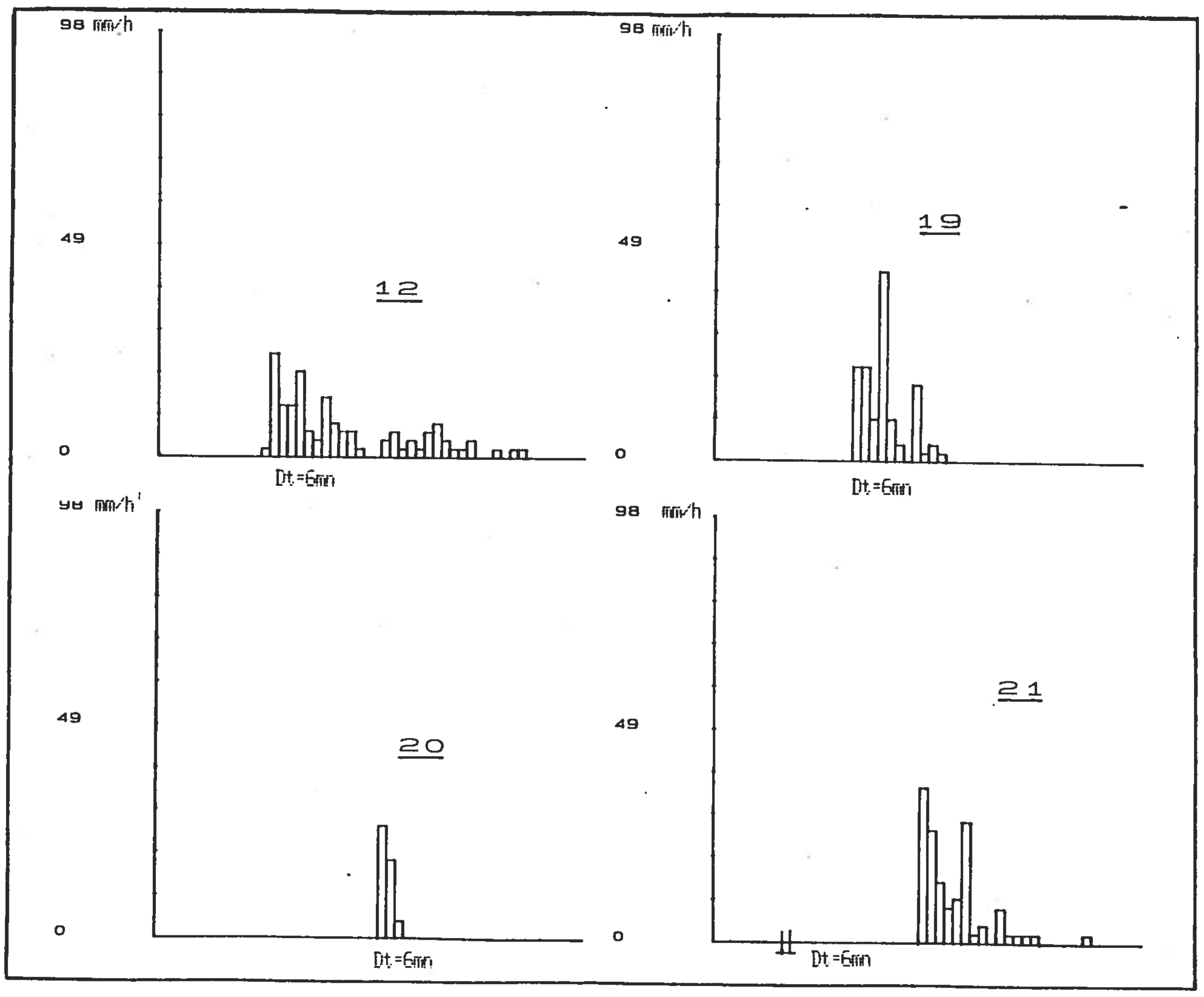
Rainfall of the 3 July 1986; examination of the similarity on a duration of 50 steps of time 6 mn ; 18 points of measurements; 98mm/h, maximun of intensity in point 9.

No significant synchronous sets due to important lag times between points which optimize B.

Point	point	lag-time	B
1	25	-18.00	.7520
3	8	54.00	.8959
5	24	-12.00	.9233
8	9	.00	.9328
9	8	.00	.9328
10	9	96.00	.8219
12	19	18.00	.8028
13	23	-54.00	.7532
14	19	-66.00	.8872
15	12	78.00	.7668
19	14	66.00	.8872
20	24	6.00	.8723
21	28	-36.00	.8173
23	28	18.00	.8637
24	5	12.00	.9233
25	1	18.00	.7520



Four types of signal ; a rainfall or several rainfalls ?



CONCLUSION

This kind of study prooved the efficiency of the urban raingauges networks examined. The relations between the different raingauges are well established. But the results are not equivalent for LYON and BORDEAUX. BORDEAUX (30 raingages over 300 Km^2) is characterised by rainfall phenomena described as a single moving subset and the information is generally sufficiently precise to establish an inner-set description.

In LYON (30 rainganges over 600 Km^2) the raingauge network allows to establish the existence of several subsets with small inter-relation. But the impossible analysis of the subsets structure is due to a lack of information. The increase of the number of raingauges or the use of a radar-would given precise informations ; the raingauge network must be conceived in order to be adapted to the territory of storms and not only to the area of the storm sewer network.

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