통계적 기법을 이용한 국지성집중호우의 이동경로 분석

Rainstorm Tracking Using Statistical Analysis Method

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Abstract

Although the rainstorm causes local damage on large scale, it is difficult to predict the movement of the rainstorm exactly. In order to reduce the rainstorm damage of the rainstorm, it is necessary to analyze the path of the rainstorm using various statistical methods. In addition, efficient time interval of rainfall observation for the analysis of the rainstorm movement can be derived by applying various statistical methods to rainfall data. In this study, the rainstorm tracking using statistical method is performed for various types of rainfall data. For the tracking of the rainstorm, the methods of temporal distribution, inclined plane equations, and cross correlation were applied for various types of data including electromagnetic rainfall gauge data and AWS data. The speed and direction of each method were compared with those of real rainfall movement. In addition, the effective time interval of rainfall observation for the analysis of the rainstorm movement was also investigated for the selected time intervals 10, 20, 30, 40, 50, and 60 minutes. As a result, the absolute relative errors of the method of inclined plane equations are smaller than those of other methods in case of electromagnetic rainfall gauges data. The absolute relative errors of the method of cross correlation are smaller than those of other methods in case of AWS data. The absolute relative errors of 30 minutes or less than 30 minutes are smaller than those of other time intervals.

Key words: Tacking of the rainstorm, Temporal distribution, Inclined plane equations, Cross Correlation, Effective time interval

1. Introduction

The rainfall becomes heavy under the influence of north pacific high pressure during rainy season. Especially, about 85 % of the annual precipitation occurs during rainy season. The damage of the rainstorm has been shown rapid increase recently. Generally, the rainstorm is expressed as heavy rainfall in small catchment like 10~20 ㎞ with the short duration. The amount of the rainstorm is over 30 mm/hr or 100 mm/day. Recently, the damages occurred by the rainstorm are associated with injuries and property damages directly. Therefore, the tracking of the rainstorm is a critical issue to decrease these damages. In this study, the research about the rainstorm tracking is accomplished by using statistical methods, in accordance with rainfall data type.

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2. Rainstorm Tracking Methods

The statistical analysis of the moments describing the geometric characteristics of the hyetograph has been proposed by Yen and Chow(1977, 1980). The rainstorm is defined as the period of nonzero rainfall. The total amount of the rainstorm is denoted by depth D, in inches and millimeters, and is equal to the sum of the depth at each time interval through the rainfall duration. The duration of the rainstorm, t_d, is defined as the interval time between the beginning and the end of a nonzero rainfall. To express the temporal distribution of the rainfall, the hyetograph is nondimensionalized by using rainfall depth D and rainfall duration t_d. If a rainfall has concentrated in the first half of the rainstorm duration, the geometrical parameter of hyetograph a^o is smaller than 0.5. However, a^o is larger than 0.5 in opposite that a rainfall has concentrated in the latter half of the rainstorm duration.

The speed and direction of the rainstorm can be calculated by the method proposed by Diskin(1987, 1990). The equation of an inclined plane in the x, y, t space is formed as

$$ax + by + c = t \tag{1}$$

in which, a, b and c are the parameters of the equation. The values of these parameters can be calculated by solving the three simultaneous equations obtained from the data of three stations. The speed and direction of the rainstorm is calculated by the inverse of this value. The equations of an inclined plane appropriate for a set of N(>3) stations in x, y, t space are determined by the differences between the observed arrival time T and the estimated value t from Eq. (1). The coordinates of the stations are the location of the stations relative to arbitrary x and y axes, and the arrival time at the stations.

It assumed that there are n rainfall gauges continuously recorded during the rainstorm. y_{jt} is the rainstorm amount recorded in time interval $(t-1, t]$ at gauge j and the rainstorm duration N is determined by the time lapse between the beginning of the rainstorm, which is determined as any non-zero reading of a rainfall gauges, and the end of the rainstorm, when all rainfall gauges observes no rainfall. The relative coordinates of gauges j and k are determined as $U_{jk} = u_j - u_k$ and $V_{jk} = v_j - v_k$. Using the assumption of the spatial stationarity, the lag τ cross correlation between gauge j and k is considered as a function of only τ, U_{jk} and V_{jk}. Using cross correlation as the measure of association, the lag-τ cross correlation between rainfall data at point j and at point j' is greater than lag-τ cross correlation between rainfall data at point j and other point in the (u, v) plane. The displacement (U_τ, V_τ) becomes the coordinates of the maximum of the lag-τ correlation. Then, estimates of s and θ are derived from the locations of the maximum non-zero lag correlation.

3. Application

3.1 Description of data

Two types of data, electromagnetic rainfall gauges and AWS(Automatic Weather System), are utilized for the tracking of the rainstorm. The rainfall data sets of 25 electromagnetic rainfall gauges are utilized for the tracking of the rainstorm because of the balance of the observed rainfall data. The locations of electromagnetic rainfall gauges in Seoul are shown in Fig. 1. The locations of 26 AWS stations in Seoul are shown as Fig. 2.

The rainstorm events for the tracking are selected as the rainstorm events having amount above 80 ㎜/day of rainfall observed by Korea Meteorological Administration. The duration of rainstorm event is determined by continuous nonzero rainfall. The analyzed events are shown in Table 1. In addition, the effective time interval of rainfall observation for the analysis of the rainstorm movement was also investigated for the selected time intervals 10, 20, 30, 40, 50, and 60 minutes.

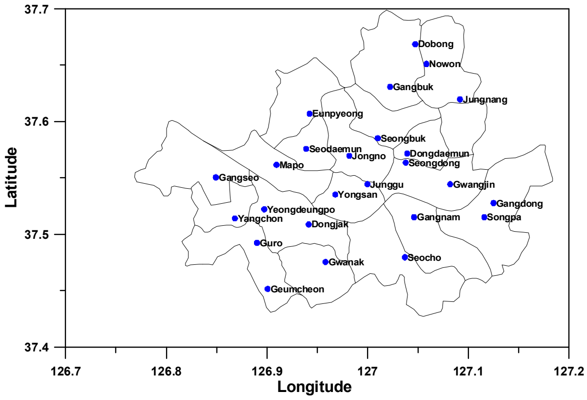

Figure 1 The locations of Electromagnetic rainfall gauges in Seoul

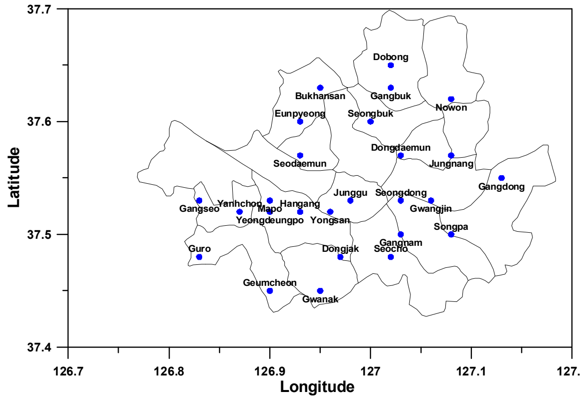

Figure 2 The locations of AWS stations in Seoul

Table 1 The selected rainstorm events

Event	Duration	Characteristics	Data state
August 25, 2000	00:00 ~ 13:00	Typhoon	Electromagnetic / AWS
August 28, 2000	00:00 ~ 08:00	Rainfall front	Electromagnetic
August 31, 2000	12:00 ~ 23:00	Typhoon	Electromagnetic / AWS
July 14 ~ 15, 2001	21:00 ~ 08:00	Rainfall front	Electromagnetic / AWS
August 13, 2001	08:00 ~ 13:00	Rainfall front	Electromagnetic
August 4, 2002	04:00 ~ 11:00	Rainfall front	Electromagnetic / AWS
August 31 ~ September 1, 2002	11:00 ~ 05:00	Typhoon	Electromagnetic / AWS
August 19 ~ 20, 2003	20:00 ~ 11:00	Rainfall front	Electromagnetic / AWS
August 24, 2003	08:00 ~ 23:00	Rainfall front	Electromagnetic / AWS
September 18, 2003	10:00 ~ 16:00	Rainfall front	Electromagnetic / AWS

3.2 Results

The accuracy between the real direction and the computed direction of the rainstorm is estimated by computing the absolute relative degree. The absolute relative degree is expressed as

$$D_E = \left| D_m - D_s \right| \tag{2}$$

in which, D_E is the absolute relative degree, D_s is a real direction(degree) of the rainstorm and D_m is computed direction(degree) using analysis methods. The real direction of the rainstorm is regarded as the path of rainfall center in every hour. The absolute relative degree by all methods and by all time intervals are shown in Table 2.

Table 2 The absolute relative error by methods and by time intervals

Data	Electromagnetic rainfall gauges					
Method	Temporal distribution		Inclined plane equations		Cross correlation	
Time	60 min.		60 min.		60 min.	
All	73.88		64.46		93.01	
Typhoon	106.26		59.76		80.82	
Front	59.99		66.46		98.22	
Data	AWS					
Method	Temporal distribution					
Time	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
All	68.90	49.33	56.36	60.65	56.13	85.79
Typhoon	66.00	71.67	29.57	66.73	50.82	58.59
Front	70.64	35.92	72.42	56.99	59.31	102.09
Data	AWS					
Method	Inclined plane equations					
Time	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
All	100.05	89.93	83.41	97.76	94.71	96.99
Typhoon	80.50	54.96	56.96	72.15	97.77	95.26
Front	111.77	110.91	99.28	97.13	92.87	98.01
Data	AWS					
Method	Cross correlation					
Time	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.
All	68.04	82.50	44.04	50.52	68.65	58.08
Typhoon	91.79	102.31	65.33	67.78	84.79	84.29
Front	53.79	70.61	31.26	40.16	58.97	42.35

4. Conclusion

The absolute relative errors of the method of inclined plane equations are smaller than those of other methods in case of electromagnetic rainfall gauges data. The absolute relative errors of the method of cross correlation are smaller than those of other methods in AWS data. The absolute relative errors of time intervals such as 30 minutes or less than 30 minutes are smaller than those of other time intervals.

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