PROBABILITY OF BACKGROUND RADIATION ENHANCEMENT ACCOMPANIED WITH RAIN

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INTRODUCTION

It is well known that the background radiation level often enhances when a rain starts. However, this is well known only on its qualitative nature. Quantitative information has been poor. In order to obtain clues for making a numerical model of this correlation, we have concentrated efforts on analysing the relationship between the radiation enhancement at onset of a rain and the timelength of pre-rain dry period.

INSTRUMENTATION AND DATA

Most rain measuremnts in routine monitorings have been done by conventional "seesaw" rainmeters whose minimum detectable precipitation is 0.5 mm, and most rain analyses have been done on hourly data basis. However,such low-sensitivity rainmeters cannot detect start of a rain unless it is a considerably heavy shower. In addition, hourly data cannot reveal detail time variation.

Accordingly, we initiated a continuous rain measurement by use of a "raindrop counting" rainmeter which features much higher sensitivity(the minimum detectable precipitation of 0.00426 mm or precipitation rate of 0.2556 mm/h.) The measurement has been done simultaneously with that of gamma radiation level in an open field of NIRS since 1985. The latter has been measured by a scintillation monitor with a cylindrical NaI(Tl) detector(2"ϕ). The rainmeter was set near the ground surface while the scintillation monitor was set at 1.5 m above the ground. These detectors were installed about 3 m apart horizontally. Rain data have been printed out digitally every 1 minute, and radiation data have been plotted on a dot-printer chart. Although NIRS accommodates various accelerators and RI facilities, data have been collected only in periods with no artificial contribution. Data analyses were done for periods below:Mar.2,1985-Mar.28,1985; May30,1985- Sep.9,1985; Sep.10,1985-Nov.6,1985; Nov.7,1985-Feb.3, 1986;Feb.4,1986-Apr.1,1986;May20,1986-Jun.26,1986;Sep.10,1986-Nov. 6,1986;Nov.7,1986-Feb.3,1987.

ANALYSIS

We wanted to know how a pre-rain dry period should continue so that the radiation enhancement is accompanied with onset of a rain. Therefore, we have measured the timelength of no-rain period between the onset of a rain and the endpoint of its previous rain. If the enhancement was not accompanied with the onset,or if the enhancement was extremely indiscernible, such was excluded from our data. However, we had met a probelm that there was sometimes aftereffect of an ending rain because our rainmeter was highly sensitive to count even waterdrops falling from a funnel to which the waterdrops had been stuck after the rain had stopped. Such "pseudo" rains were found only among the rain data of 0.2556 mm/h(lowest recording level.) Therefore, we set a threshold of 0.5112 mm/h(second lowest recording level) to ignore all data below that level. In order to check sensitivity on the threshold, however, we have also analysed data corresponding to five other thresholds of 1.2780, 2.0, 5.0, 10.0 and 20.0 mm/h.

This "threshold method" has, however, the problem that there remains a possibility that small detached rains may be involved in the concerned no-rain period because "no rain" here depends on a given threshold. If there is such an internal rain, its onset may cause another radiation enhancement. In order to avoid such inconvenience, we set two conditions for a starting rain: (1) it should clear a given threshold, (2) it should be the first rain after the end of the previous one(ending rain of any magnitude.) However,internal rains below 0.5112 mm/h were ignored in any case. The radiation enhancement at onset of a rain will be referred as "event" hereafter. We got 115 events under the above conditions.

DISCUSSION

Fig.1 shows the ordering of the timelength of the no-rain period for six thresholds separately. It can be seen that every distribution is almost monotonous in which more events occur as the no-rain period becomes shorter. This figure implies that the enhancement is possible even just after the previous rain.

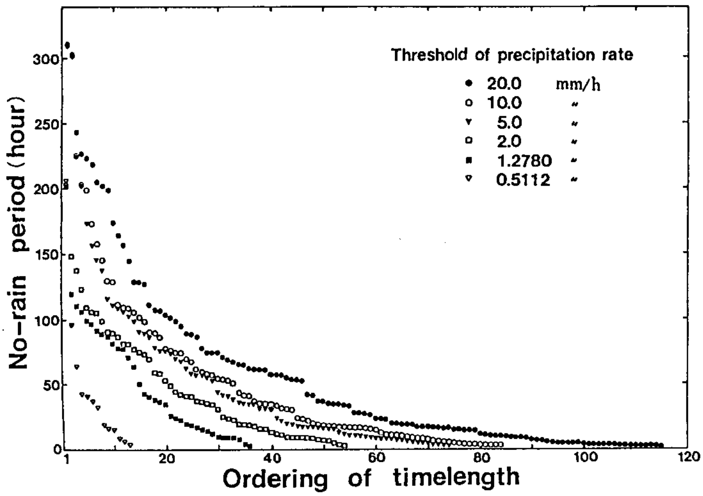

Fig.1 Occurrence of events in order of timelength of no-rain period. Seasonal difference is ignored, and data involve all seasons. Ordinate: timelength of no-rain period; Abscissa: ordering of the timelength.

The number of events involved between zero and an arbitrary time in this figure was divided by the number of all events which covered the whole period. Such a quotient can be considered to be the "Probability of the event which occurs by the given time after the end of the previous rain." It is essentially a time-integrated probability, and the time in this case does not mean the no-rain period but means, in effect, the maximum waiting time for the event. As the denominator of the quatient does not involve rains with indiscernible events, though such are rare, the quotient may commit a slight overestimation.

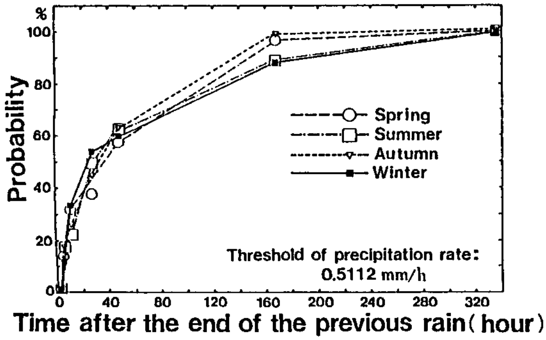

Fig.2 Seasonal dependence of the time-integrated probability for the threshold of 0.5112 mm/h. The probability of each season is plotted against the time after the end of the previous rain.

Fig.2 exemplifies how the time-integrated probability depends on seasons. As no significant difference can be seen among the four groups, this figure implies that we need not separate data according to seasons. Fig.3 demonstrates how the time-integrated probability is sensitive to a value of threshold. We can see that the probability does not depend on the threshold seriously though there is a systematic dependence on the time after the end of the previous rain. Therefore, we can consider that the time is the only significant variable among parameters considered.

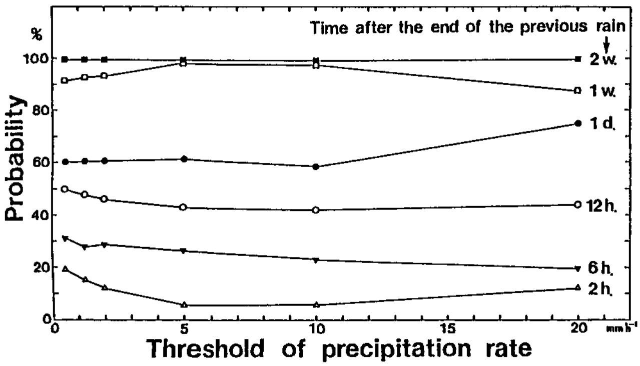

Fig.3 Sensitivity check of the time-integrated probability on the threshold. The probability is plotted for six time after the end of each previous rain separately. Seasonal difference is ignored, and data involve all seasons.

The number of events in all seasons was 115. However, owing to the feature of Fig.3, there will be no inconvenience if we combine data of the six thresholds. We could get 375 events by the combination, and we could smooth out the data effectively.

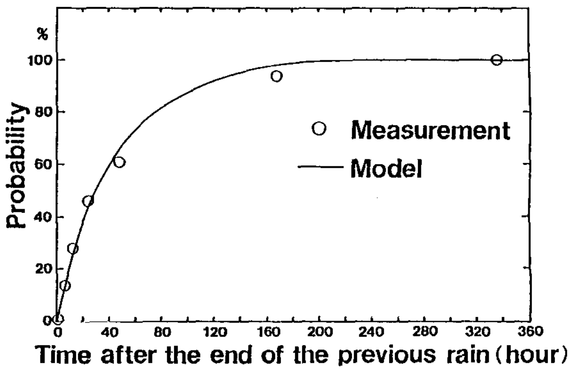

Fig.4 Comparison between the time-integrated probability derived from data(circles) and that of a model(solid line.) Ordinate: time-integrated probability of radiation enhancement accompanied with onset of a rain; Abscissa: time after the end of the previous rain.

Fig.4 shows the time-integrated probability derived from the 375 cases. The solid line represents a model expressed by a simple formula as

$$P = 1 - \exp(- kt) \qquad (1)$$

where P is the time-integrated probability, t is time after the end of the previous rain in unit of hour, and k is a constant. The k was estimated to be 0.023 by best-curve-fitting. It is apparent that the model well approximates the data.

The enhancement of the background radiation with a rain will be due to an increased deposition of natural radon daughters on the ground. When a rain occurs, it will scavenge more or less the airborne radioactivity leading to the radiation enhancement, only the degree of its prominence will depend on the amount of the deposition. Therefore, it will be natural to consider that the time-integrated amount of the deposition is in proportion to the formula(1). As the formula(1) is similar to the form of radiation strength which comes from a self-absorbing source, we can derive, by analogy, "effective half life" of the airborne radioactivity. The half life was calculated to be about 1.3 days.

Such a half life characterises the loss of radioactivity from air column above a local ground. It will depend on radon emanation from the ground, nuclear disintegration of radon and its daughters, vertical and horizontal air transport, and rain frequency. The half life will vary from one to another locality. More detail analysis will be done later.

CONCLUSION

The occurrence of radiation enhancement at onset of a rain is a function of timelength of no-rain period prior to the rain. It can be expressed well in terms of time-integrated probability as the formula(1). The seasonal dependence will be of no significance. The effective half life of natural airborne radioactivity in air column will be about 1.3 days though it may depend on locality.