STATISTICS OF ONE-MINUTE RAIN RATE DISTRIBUTIONS IN JAPAN BASED ON AMeDAS ONE-HOUR RAIN RATE DATA

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1. Introduction

The effect of rain causes serious attenuation and depolarization of radio waves at frequencies above 10 GHz. Therefore, quantitative understanding of rainfall statistics for various locations on the earth as well as development of accurate prediction methods is indispensable for realizing reliable radio communication systems.

Almost all of the rain attenuation prediction methods presented so far, including the CCIR method, require one-minute rain rate data for certain time percentages such as 0.01% at the place concerned for calculation. However, availability of such one-minute rain rate data is strictly limited in general. On the other hand, one-hour rain rate data seems to be more easily obtainable because conventional weather observation stations collect weather data every hour. Moreover, the automated meteorological data acquisition system known as AMeDAS has been operated in Japan since 1976, and one-hour rain rate data for various locations in Japan have been obtained. Under such circumstances, a method for conversion of one-hour rain rate data to the equivalent one-minute rain rate distribution is considered very useful at present.

Recently, two conversion methods were presented independently in Japan, one by Hosoya(1) and the other by the authors(2). In this paper, first, we evaluate the prediction error of our method. Then, we present analytical results of the 0.01% rain rate for various locations in Japan based on our method using the AMeDAS data over 10 years.

2. AMeDAS rain data

AMeDAS is a system developed by the Japan Meteorological Agency for monitoring anomalous weather events such as locally produced storms and extremely heavy rains. More than 1300 robot observation stations are distributed all over Japan at a spacing of about 17 Km and have been operated since 1976. All kinds of meteorological data sampled every hour have been forwarded through telephone lines to the central station and recorded on MTs there. Tipping-bucket-type rain gauges (0.5 mm/tip) with a diameter of 20 cm are utilized in the system.

3. Proposed conversion method

3.1 Cumulative time distribution

In Refs.2 and 3, we compared year-to-year variations between the measured ten-minute rain rate reported(4) and various quantities reduced from one-hour rain rate data in Tokyo and Osaka. Based on the analysis, we proposed the following conversion formula given by:

$$R_{0.01} = a\,R_{5H}, \qquad R_{0.1} = b\,R_{10H}, \qquad (1)$$

where $R_{0.01}$ [$R_{0.1}$] is the one-minute rain rate for 0.01 [0.1] % of each year, and R_{5H} [R_{10H}] is the mean value of the largest five [ten] values (i.e., from top value to the fifth [tenth] value of the annual ranking). Based on examination using various measured data reported so far, the coefficients a and b in the formula are tentatively given by a=2.3 and b=0.96, the values of which seem optimum for the Japanese climate.

As for cumulative time distribution of the one-minute rain rate on a long-term statistical basis, it was identified by Hosoya[1] that a distribution introduced by Moupfouma[5] agrees well with actual data in Japan covering a wide range of time percentages. The cumulative time distribution, P(R) in terms of $R_{0.01}$ and $R_{0.1}$ is as follows:

$$P(R)= \frac{r}{R}\exp(-uR)\ x100, \qquad (\%) \qquad (2)$$

where $u= \frac{1}{R_{0.01}-R_{0.1}}\ \ln(\frac{10R_{0.1}}{R_{0.01}}), \qquad r= 10^{-4}R_{0.01}\ \exp(R_{0.01}u)$.

3.2 Prediction accuracy of the method

In this section, we examine the prediction accuracy of the proposed method. Limiting ourselves to measured cumulative time distributions of one-minute rain rate data for a period of more than three years, we find that data are available now for the following seven locations: Nagoya[1], Kashima[6], Tokyo[7], Hiroshima[8], Takahagi (near Hitachi), Yamaguchi and Naha. The latter three are our own data collected during long-term propagation experiments. Moreover, measured values of $R_{0.01}$ at 20 locations in Japan averaged over five years were also reported by Irie[9]. Therefore, 27 sets of data in all can be utilized for evaluation of prediction errors of the method.

On the other hand, predicted one-minute rain rate as a function of time percentage at a given location can be calculated using the AMeDAS data from 1976 to 1987 (12 years) through the following steps:

i) calculate R_{5H} and R_{10H} for each year,

ii) calculate the mean values of R_{5H} and R_{10H},

iii) estimate $R_{0.01}$ and $R_{0.1}$ by Eq. (1),

iv) estimate cumulative time distribution by Eq.(2)

Figure 1 shows the cumulative time distribution comparing measured data with predicted values at Naha, Nagoya and Hiroshima, which seem to represent some typical rain types in Japan. Figure 2 also shows a scattergram of one-minute rain rate between measured data at 27 locations (mentioned above) and predicted values. As can be seen from Figs. 1 and 2, the prediction accuracy of the method is mostly within 10 % for time percentages from 0.001 % to 0.1 %.

4. One-minute rain rate in Japan predicted using AMeDAS data

4.1 Software for the analysis

The first-stage data base storing AMeDAS original data was created in a CPU (FACOM M380S). Total memory of the first-stage data base required about 650 MB. The key to access the data base is "location number" and "date of observation". The software program enables easy extension of the created data base when new data are provided in the future. The following second-stage data base was also created covering all locations of AMeDAS local stations:

i) Total amount of rainfall for average year or month,

ii) Cumulative time distribution of one-hour rain rate

iii) Cumulative time distribution of one-minute rain rate

iv) Year-to-year variations of the above-mentioned annual statistics

4.2 Analytical result

Figure 3 shows a map of the 0.01 % one-minute rain rate $R_{0.01}$ in Japan predicted using the AMeDAS data. This kind of map has already been presented by Morita based on statistics of annual rainfall[10]. The map presented here, however, must be more accurately up-dated and spatially detailed because AMeDAS data includes more detailed information on variability of time and space than other data available now. It is also possible to determine more detailed statistics at any place depicted by a square in Fig. 3. Figure 4 shows, as an example, a cumulative time distribution in an average year in Tokyo by a solid line. The figure also shows other curves, considering the factor of safety as a parameter of MTBF (mean time between failure). The concept of the MTBF for propagation prediction was introduced in Ref.2. As for the MTBF in this case, the words "time" and "failure" are equivalent to "number of years" and "occurrence of year in which actual rain rate exceeds predicted value," respectively. Therefore, the curve corresponding to the MTBF of n in Fig. 4 shows that annual rain rate exceeds the curve once in n+1 years on an average. This means that, although the mean value of $R_{0.01}$ in Tokyo is 52 mm/H (MTBF=1), if we set $R_{0.01}$ at 83mm/H (MTBF=10), it is expected that a year in which actual rain rate exceeds the value (=83 mm/H for 0.01 % of time) probably does not occur within ten consecutive years.

5. Conclusion

We presented a simple method of converting one-hour rain rate data to one-minute rain rate statistics and examined its accuracy. From the examination using all available data in Japan, we determined that the accuracy of the method presented here is mostly within 10 %. Then we presented a map of the 0.01 % one-minute rain rate in Japan based on AMeDAS data. Since the method presented here has been successfully applied to various locations in Japan, it can be expected to be applicable with or without modifications to regions of the world where one-minute rain rate data are not yet available.

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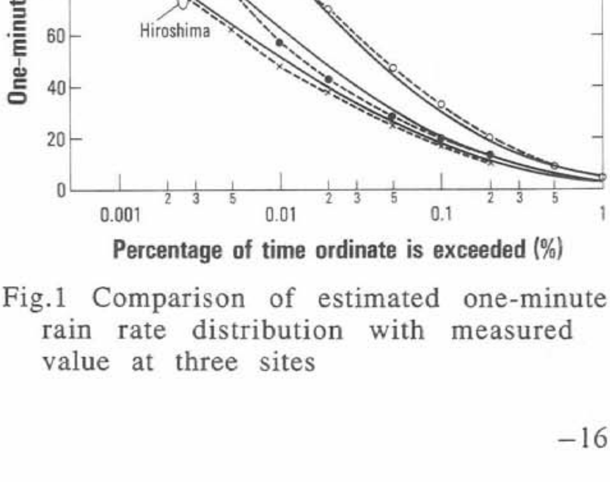

Fig.1 Comparison of estimated one-minute rain rate distribution with measured value at three sites

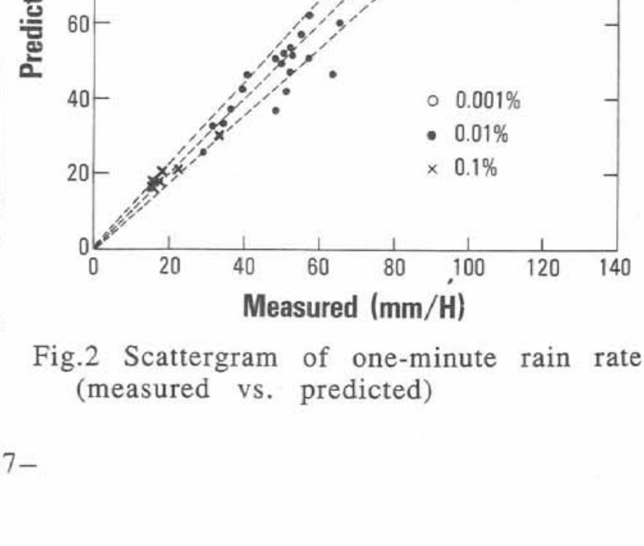

Fig.2 Scattergram of one-minute rain rate (measured vs. predicted)

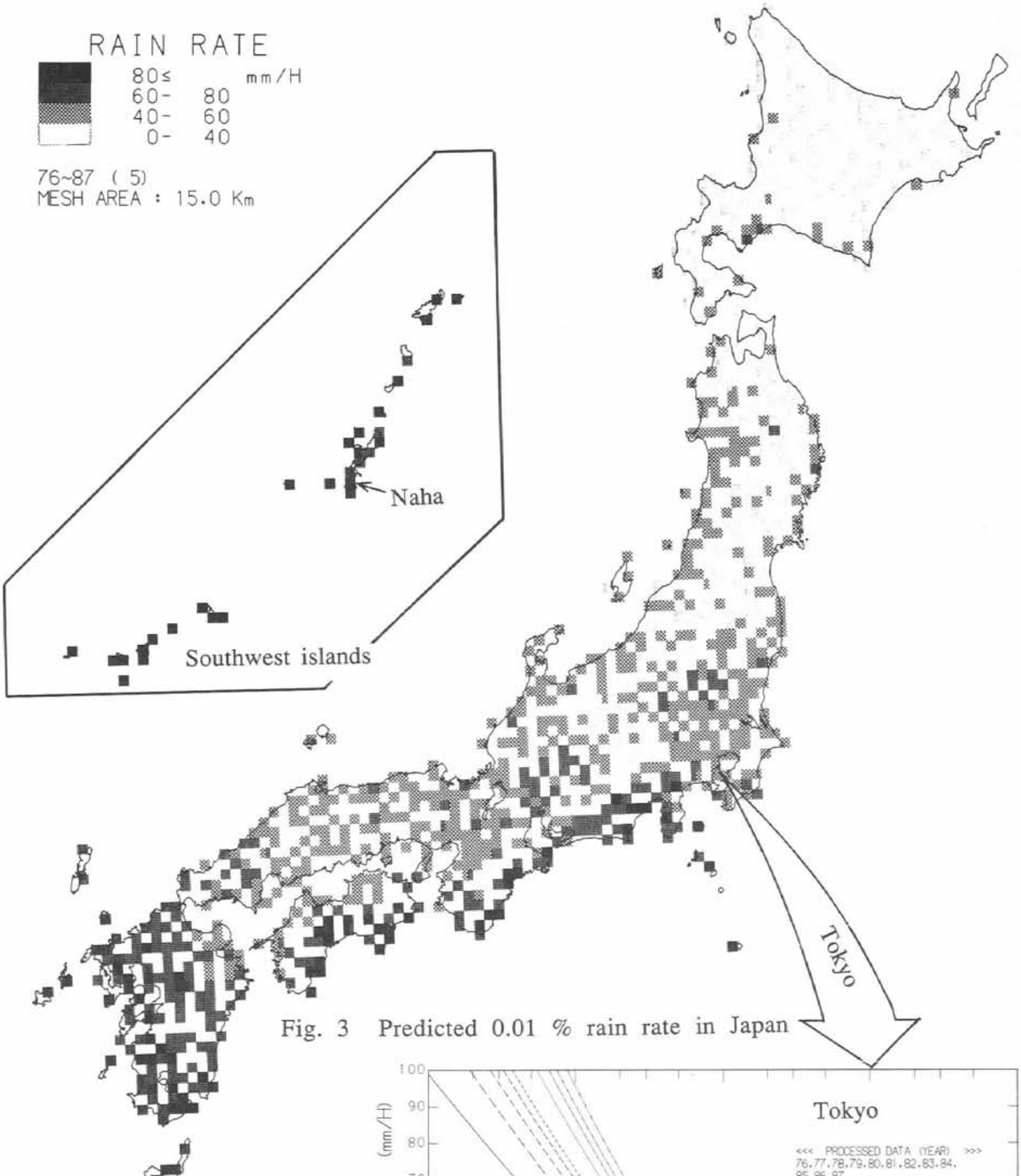

Fig. 3 Predicted 0.01 % rain rate in Japan

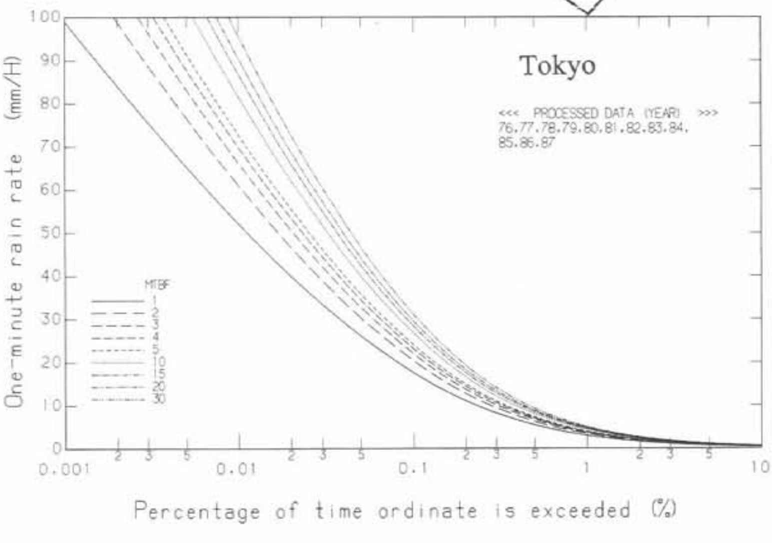

Fig. 4 Predicted one-minute rain rate in Tokyo for various MTBFs