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INFERRING CHANGE IN PROPERTIES OF SHORT-TERM RAINFALL CAUSEDE BY GLOBAL WARMING

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ABSTRACT

Many sediment-related disasters occur in Japan every year. Particularly in the last couple of decades, when the frequency of intense rainfall has increased, causing more severe sediment-related disasters. Changes of rainfall intensity due to climate change have very important implications for the occurrence of sediment-related disasters. Changes of rainfall properties should be inferred in order to prepare for the future occurrence of sediment-related disasters. However according to the IPCC, potential changes in the frequency of intense rainfall are still difficult to infer from global climate models. So this research is the analysis of past trends in the change of short-term rainfall properties performed to estimate the effects on sediment-related disasters of climate change caused by global warming. A statistical method (Gumbel Model) is applied to the analysis. Hourly and daily precipitation data for a period of about 100 years from all meteorological observatories in Japan are used. Future trends in the change of rainfall properties are inferred based on the results of the statistical analysis.

Key words: Global warming, Short term rainfall, Gumbel model, Sediment disaster

INTRODUCTION

The Third Assessment Report of the IPCC prepared in 2001 differs from previous reports by describing actions that are necessary to deal with global warming that it has shown to be a scientifically significant phenomenon (Ishikawa, 2002).
In order to evaluate the impacts of global warming on society and to either prevent or minimize its negative impacts in Japan, six programs have been established as part of the Global Warming Research Initiative enacted as an environmental project that is a priority concern of the Council for Science and Technology Policy, and concerned ministries and agencies are conducting cooperative research to resolve these problems. One of these programs, the Global Warming Impact and Risk Evaluation Research Program, is concerned with disaster prevention. This research division is carrying out the Study of Measures to Evaluate and Reduce the Risk of Sediment Disasters in Response to Global Warming as part of this program (NILIM, 2001).

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In order to evaluate the risk of sediment disasters under global warming, it is essential to estimate how hourly rainfall, daily rainfall, and other short term rainfall values will be changed by future warming. But present climatic models cannot predict short term rainfall quantities of this kind.

So this study is intended to statistically evaluate changes in short term rainfall quantities that are presumed to have a serious impact on changes in sediment disaster risk that accompany global warming based on data for the past century in order to estimate changes in rainfall properties on the assumption that changes identical to past changes in rainfall (yearly extreme value) will occur during the next century.

A method of preparing a scenario for the change of sediment disaster occurrence properties accompanying rainfall fluctuations was studied to propose a risk evaluation index based on this scenario for change.

SURVEY METHOD

In order to study trends in the change of extreme rainfall such as the annual extreme hourly rainfall and the annual extreme daily rainfall, a method based on a Gumbel model (Yamamoto, et al., 1996) was used to obtain the significance of long term change trends in short term rainfall (hourly rainfall, daily rainfall) during the past century in order to study a scenario of future change in rainfall properties with reference to the past changes clarified in this way.

COLLECTING DATA

The documents used for the study contained annual extreme hourly rainfall and annual extreme daily rainfall at meteorological observatories from 1901 to 2000. Annual extreme hourly rainfall data was collected from 8 locations and annual extreme daily rainfall from 42 locations in almost all parts of Japan. Figure 1 shows where these data were collected.

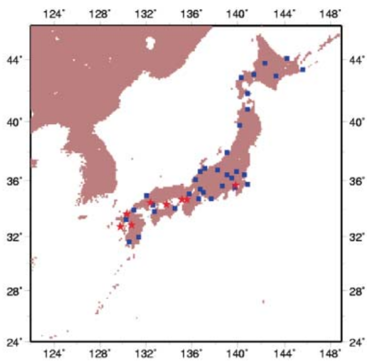


Fig.1 Data Collection Locations

*The symbol ★ indicates the meteorological observatories where the extreme hourly rainfalls were obtained

CHARACTERISTICS OF RAINFALL CHANGE

Trends in long term rainfall change were calculated based on the procedure in Figure 2.

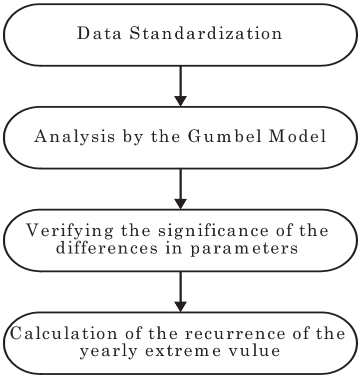


Fig.2 Analysis Procesure

Standardization of the data

If regional variation of rainfall is large, its effects can distort the results of the analysis, so the data was standardized based on equation (1).

$$X=(R-R_a)/S_r \quad \text{-----(1)}$$

Where:

X: standardized point rainfall (yearly extreme value)
Ra: averaged point rainfall (ditto)
Sr: standard diviation of point rainfall (ditto)
R: point rainfall (ditto)

Analysis by the Gumbel Model

In order to investigate the long-term change trends in annual extreme hourly rainfall, and annual extreme daily rainfall nationwide, long-term change trends were analyzed based on differences in the Gumbel Model parameter ξ , dividing the century from 1901 to 2000 into a first 50 years and a second 50 years. Equation (2) represents the Gumbel distribution and the parameters β and ξ were obtained from equation (4) and equation (5).

$$f(X)=\exp\left[-(\exp(X-\xi)/\beta)-(X-\xi)/\beta\right] \quad \text{-----(2)}$$

Where:

β : scale parameter
ξ : location parameter
β and ξ are obtained by the following equations.

$$\beta = S_X \bullet \mathrm{sqrt}(6)/\pi \quad \text{-----(3)}$$

$$\xi = X_a - \gamma B \quad \text{-----(4)}$$

Where:

γ : 0.57721
Xa: average of standardized point rainfall
Sx: standard diviation of standardized point rainfall

The results of the Gumbel Model parameter calculation of the annual extreme hourly rainfall and the annual extreme daily rainfall are shown in Table 1. Change of the Gumbel distribution of the annual extreme daily rainfall and the annual extreme houly rainfall are respectively shown in Figure 3 and Figure 4.

Table.1 Calculated Values of Gumbel Model Parameters (β, ξ)

		β	ξ
Annual extreme daily rainfall	First 50 years	0. 950	−0. 045
	Second 50 years	1. 044	0. 048
	Increase of ξ	—	0. 093
Annual extreme hourly rainfall	First 50 years	0. 968	−0. 247
	Second 50 years	0. 989	0. 270
	Increase of ξ	—	0. 517

*Number of observation locations: 8 (annual extreme hourly rainfall), 42 (annual extreme daily rainfall)

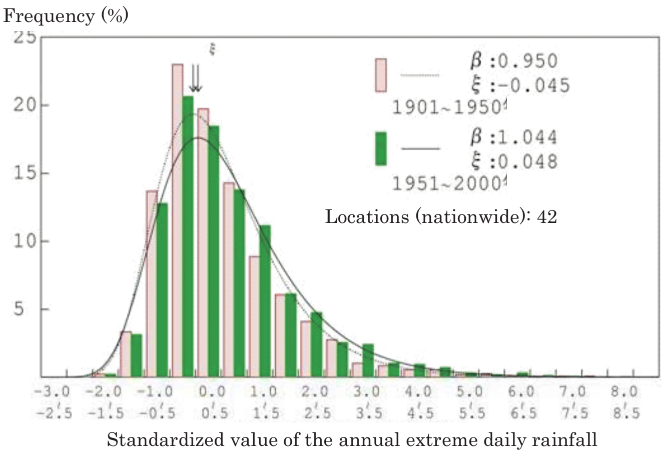


Fig.3 Change of Gumbel Distribution of annual extreme daily rainfall between the First 50 Years and Second 50 Years of 20 century
(Frequency of annual extreme values of daily rainfall and Gumbel distributions)

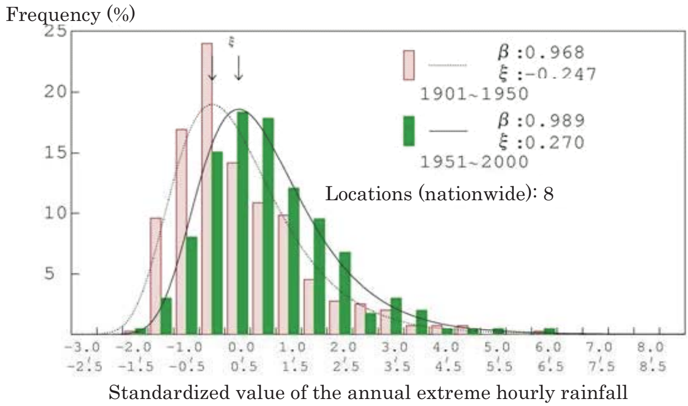
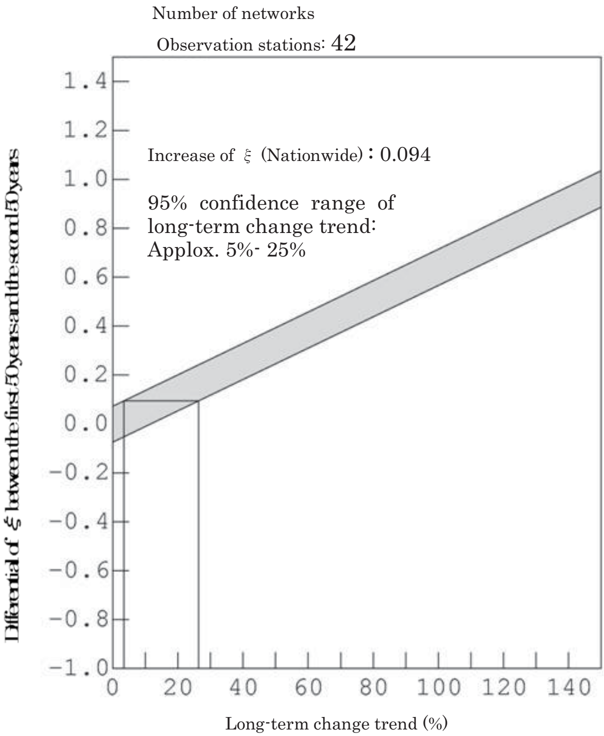


Fig.4 Change of Gumbel Distribution of annual extreme hourly rainfall
Between the First 50 Years and the Second 50 Years of 20 century
(Frequency of annual extreme values of hourly rainfall and Gumbel distributions)

Assessment of the significance of the difference in the parameter ξ

In order to assess the significance of change of ξ , a Monte Carlo simulation (100 (years) • observation stations • 1,000 occurrences) was performed to obtain the confidence limit. The significance was assessed by adding the long-term change trends (hypothesizing that the standard diviation of X rises k%) to each random number and the parameters (β , ξ) of dummy observed values with change trends were calculated to study the degree that the differential of ξ in the first 50 years and the second 50 years obtained from actual rainfall corresponds to long term change trends. Figure 5 shows the confidence limit by long term change trend of the differential of ξ obtained from values of the annual extreme daily rainfall. This figure shows that $\Delta\xi$ (differential of ξ in the first 50 years and the second 50 years of the twentieth century obtained from observed values) is significant at a 95% confidence limit within a range of long-term change trends from about 5% to about 25%. Figure 6 also shows the confidence limit by long term change trend of the differential of ξ obtained from values of the annual extreme hourly rainfall. Table 2 shows the confidence limit of the annual extreme hourly rainfall and annual extreme daily rainfall (standard diviation). As a result of the above analysis, it can be stated that when the first 50 years and the second 50 years of the twentieth century were compared, the increase of rainfall intensity of both the annual extreme hourly rainfall and annual extreme daily rainfall is significant.

Additionaly, in order to assess whether the difference of the long-term change trends on increase of annual extreme daily rainfall differs with regions within Japan. Therefore Japan was divided into two regions, northern Japan, which has snow fall in winter, and southern Japan, which seldom has snow fall (The difference of the long-term change trends on increase of annual extreme hourly rainfall were not assessed, because the number of data are not addequate).

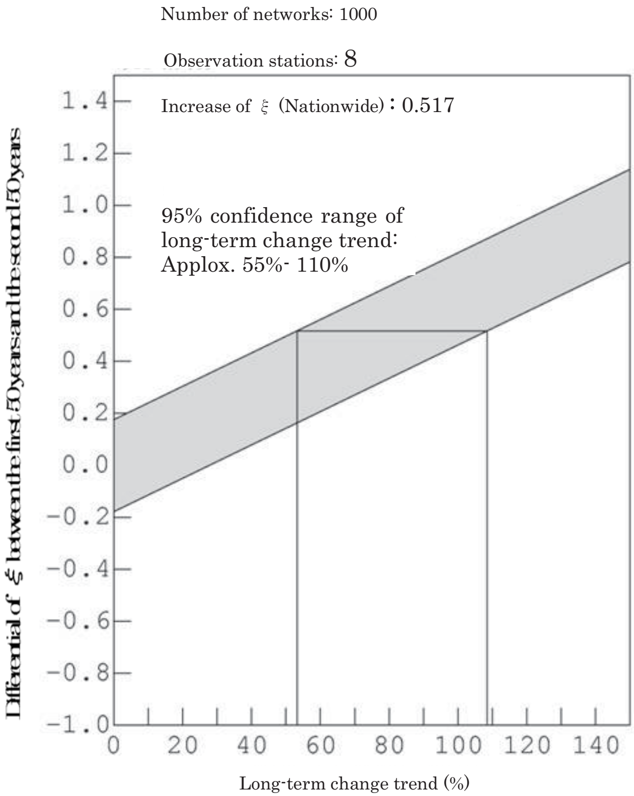


Dependence of ξ on the long-term change trend (daily rainfall).

Upper and lower limit of the differential
between the 95% confidence limits for the first 50 years and for the second 50 years.

Fig.5 Confidence Limit by Long-term Change Trend of the Differential of ξ obtained from values of annual extreme daily rainfall. (Confidence limit 95%)

The Gumbel Model parameter, ξ, was calculated based on the same method as above. The significance of change of ξ were also assessed for the annual extreme daily rainfall. But, there were no significances of change of ξ. One of the main reasons for it is thought the numbers of data which were able to have been collected from a region were very few.



Dependence of ξ on the long-term change trend (hourly rainfall).

Upper and lower limit of the differential
between the 95% confidence limits for the first 50 years and for the second 50 years.

Fig.6 Confidence Limit by Long-term Change Trend of the Differential of ξ
obtained from values of annual extreme hourly rainfall
(Confidence limit 95%)

Table.2 Confidence Limit of Rainfall Fluctuation (Standard diviation)

	Lower Limit	Upper Limit
Annual Extreme Daily Rainfall	Approx. 5%/ 100yrs	Approx. 25%/ 100 yrs
Annual Extreme Hourly Rainfall	Approx. 55%/ 100 yrs	Approx. 110%/ 100 yrs

Table 3 shows the 100 year recurrence of the yearly extreme value during each period obtained using the Gumbel model parameters for the first 50 years and for the second 50 years of the twentieth century obtained above, hypothesizing that the probability of the occurrence of the annual extreme hourly rainfall and daily rainfall can be stipulated by the Gumbel distribution.

Table.3 Change of the 100-year Recurrence During the First 50 Years and the Second 50 Years

	First 50 yrs (a)	Second 50 yrs (b)	(b/a) %
Annual Extreme Dailly Rainfall	274mm	319mm	Approx. 120%
Annual Extreme Hourly Rainfall	89mm	106mm	Approx. 120%

Proposal of a scenario of change in rainfall characteristics

It is clear that the average air temperature in Japan increased by 1°C during the past century (Ishikawa et al., 2002). The results of the above study show that the yearly extreme value of the short term rainfall in this period changed greatly. But it is not known whether or not the yearly extreme value of the short term rainfall will increase in the same way as the globe continues to warm in the future. So a scenario of the change of the 100 year recurrence rainfall characteristics 100 years in the future was prepared using the parameters of the second 50 years (1951 to 2000), hypothesizing that rainfall will fluctuate during the next century in the same way that it did in the past century. The results are shown in Table 4.

Table.4 Hypothetical Rainfall Fluctuation and Resulting 100-year Recurrence After 100 Years

	Rate of Increase of rainfall fractuation		100-year recurrence (100 years from now)
Annual Extreme Daily Rainfall	Lower limit	Applox. 5%/ 100 yrs	322mm (rise of applox. 10%)
	Upper limit	Applox. 25%/ 100 yrs	334mm (rise of applox. 15%)
Annual Extreme Daily Rainfall	Lower limit	Applox. 55%/ 100 yrs	115mm (slite rise)
	Upper limit	Applox. 110%/ 100 yrs	124mm (rise of applox. 5%)

Note: It is hypothesized that the percentage increase in rainfall fluctuation will be identical to that during the past century. And the figures in ( ) represent the percentage increase of the present 100-year recurrence (last 50 years of the twentieth century) 100 years from now.

CONCLUSION

This analysis is based on limited data, but it clearly shows that the annual extreme hourly rainfall and daily rainfall have risen in the past century. And although it is premised on the unreliable hypothesis that rainfall fluctuations will be identical to those during the past century regardless of the degree of the future rise in temperatures, a scenario of approximate change in rainfall properties was prepared to evaluate sediment disaster risk under global warming.

BIBLIOGRAPHY

Ishikawa, H et al. (2002): Natural disaster science, J.JSNDS 21-2 91-22 (in Japanese)
Natinal Inastitute for Land and Infrastructure Management (2001): Project research, Study of technology to deal with global warming, http://www.nilim.go.jp/ (in Japanese)
Yamamoto, R et al.(1996): Detection of long term change trends of extreme rainfall phenomena, Proc. of the Autumn Meeting of the Meteorological Society of Japan (in Japanese)