NOTES AND CORRESPONDENCE

**A Statistical Analysis of the Extreme Events:
Long-Term Trend of Heavy Daily Precipitation****By Tatsuya Iwashima and Ryozauro Yamamoto***Climate Physics Laboratory, Department of Geophysics, Faculty of Science, Kyoto University,
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One of the most important and interesting issues associated with the global warming is the long-term trend of the extreme events (Houghton *et al.*, 1992). Our concern in the present work is the question of whether the occurrence of extremely heavy precipitation would have any long-term trend in the past several decades, accompanying the notable increase of the greenhouse gases.

The results of the numerical experiment with the use of GCM concerning the CO₂ doubling problem show that the frequency of intense convective precipitation increases, but that of intense large-scale (non-convective) precipitation decreases (Noda and Tokioka, 1989). This suggests some enhancement of heavy convective precipitation amount. Gordon *et al.* (1992) have also presented such a result from a numerical experiment, that the extreme daily precipitation intensity increases under the CO₂ doubling condition. Although the simulations in GCMs of precipitation processes are still crude, it is of interest to detect any evidence of a long-term trend in the frequency of heavy precipitation.

With the use of a conventional statistical method on observational data, it is difficult to detect any long-term variability of daily precipitation intensity: This is because the frequency of phenomena is temporally not high and it is spatially much smaller than the density of an observational network of precipitation. Here, our attention is directed to the occurrence time of heavy precipitation.

55 JMA OBS. STATIONS

Fig. 1. Location of the 55 JMA observational stations where the three largest daily precipitation amounts for the recent 100 years are recorded and are used in the present work.

JMA OBS. STATIONS

Fig. 2. Location of the station where any of the three largest daily precipitation amounts is recorded during every two decades. The symbols in the figure denote the first, second and third largest DPA as indicated by numbers 1, 2, 3, etc.

Fig. 3. Number of stations in the 55 JMA observational stations for every two-decade during the period 1890–1990 that recorded the three largest DPA throughout the period. The solid line is obtained by a least-squares method.

Fig. 4. Same as Fig. 3, but for every decade.

A statistical analysis is made for the appearance year of extreme daily precipitation at each station. The years of the three largest daily precipitation amounts (hereafter, DPA is used for abbreviation) during the past 100 years for each of the 55 observational stations of Japan Meteorological Agency (Fig. 1) are picked out. In the present work we will use all the data of the three largest DPA in the "Climatic Table by Stations" published by JMA (1990): From a preliminary analysis of the five largest DPA data before 1978 by Yonetani (1981), we have confirmed that the result for the three largest DPA qualitatively agrees well with that for the four or five largest DPA.

The observational stations which recorded any of three largest DPA in each two-decade are indicated in Fig. 2: The stations with the largest DPA are distributed rather homogeneously. The fact indicates that the increasing of frequency of the extreme DPA occurs widely over the entire area, and is not biased in a certain small area. The fre-

Fig. 5. Location of the 14 stations over the contiguous United States.

Fig. 6. The same as Fig. 3, except for 14 stations over the contiguous United States for every decade between 1916 and 1985; the three largest extremes for each month throughout the term are used.

quency of the year for all the 55 stations in each two-decade is shown in Fig. 3, where the frequency is referred in terms of percentage to the total number of 165. The frequency-of-appearance year of extremely heavy daily precipitation clearly shows a long-term increase. This increase is statistically significant: The chi-square test rejects the null hypothesis that there is not temporal variation of the frequency, because the χ^2 value of 11.06 is in the 5% critical region of the test. A linear regression of the frequency shows a variation from about 12% in the 20-year interval around the 1900s to 28% around the 1980s. Further, in order to examine decade-to-decade variation of the frequency of the largest DPA, we made a similar analysis for the statistical duration of one decade (Fig. 4). In comparison with the case of two-decade data (Fig. 3), the decade-to-decade variation is rather large. It is statistically significant with $\chi^2 = 22.45$ for 5% critical level; From a linear regression of the frequency we obtain a trend from 6% in the 1890s to 14% in

the 1980s.

A similar statistical analysis is made for the observational data during the past 70 years at 14 stations in the contiguous United States (Fig. 5; Weather Disc Assoc., 1990). Since the number of stations with daily data available to the present authors is much smaller than that in the case of Japan data, the appearance years of the three largest DPA for each month are picked out for each decade.

Figure 6 illustrates the results of the USA case. A long-term trend of the increase can also be seen: since $\chi^2=23.3$ the variation is statistically significant for the 5 % critical level. A linear regression line fitted to the above data shows an increase from about 10 % around the 1920s to about 19 % around the 1980s.

The results presented here evidently indicate an inter-decadal variation of precipitation in terms of a heavy daily amount. This inter-decadal variation or increasing trend of frequency of the extreme DPA may be due to several causes, besides the effects of CO₂ increasing, such as the urbanization and the frequency of a typhoon hitting or approaching Japan. Although the data are not yet adequate, we may assume, from our results of the extreme DPA and the result on the long term variation of the typhoon hitting frequency in the JMA report (1993), that the increasing of frequency of the extreme DPA is hardly affected by the urbanization and the typhoon-activity at most stations. Besides these factors, we should closely examine the influence of the increased greenhouse gases on the long-term variation of precipitation: our questions of great interest are whether the variation of frequency of the extreme DPA is related to global warming,

and what causes and mechanisms its increasing trend can be attributed to.

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日最大降水量極値の長期変動

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