## 2.1 RELATIONSHIPS BETWEEN CHANGES IN ANNUAL FREQUENCY OF HEAVY PRECIPITATION IN JAPAN AND ENSO

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### 1. INTRODUCTION

Climate changes in global scale such as the El Nino-Southern Oscillation (ENSO) and global warming have significant impacts on local and regional hydrological regimes, which affect ecological, social and economical system. A key parameter in basin water managements is the characteristic of local precipitation, and an accurate estimate of the climate-change impacts on the heavy precipitation is needed to prevent flood disasters in the future.

Climate changes due to global warming and ENSO impacts have been investigated mainly using global circulation and regional climate models (IPCC, 2001; IDAG, 2005). Some of their outputs are useful for mean local climate: the annual, seasonal precipitation, and typhoon track in monsoon Asia changes due to ENSO (Ropelewski and Halpert, 1987; Yonetani, 1992; Yumoto and Matsuura, 2003). However, the global models cannot capture the short-term and basin-scale precipitation accurately.

This study presents temporal, regional and statistical changes in the observed precipitation in Japan for a period from 1961 to 2002. We discuss relationships between ENSO, which is one of the global climate changes, and the local characteristics of annual precipitation, May-Oct. precipitation, and annual frequency of heavy precipitation events.

### 2. STATISTICAL DATA

Daily precipitation records during 42 years (1961-2002) at 125 observational stations of the Japan Meteorological Agency were used to analyze long-term changes in precipitation. Annual and seasonal precipitations in each station were evaluated by these data.

The annual frequency of heavy precipitation at each station was also analyzed. Heavy precipitation was defined as the partial duration series (PDS) composed of the 42 large 2-day precipitations in the 42 years at each station, considering the usefulness for the prevention of regional-scale flood disasters. That is to say, heavy precipitation is the 2-day precipitation exceeding threshold set to be the minimum one in the PDS at each station. These methods are often applied to flood prevention and water management (e.g. Weiss, 1977).

Almost all heavy precipitation occurs in summer season (May–Oct.) in Japan due to typhoon, Baiu-Changma-Meiyu and depression. We investigated whether the heavy precipitation occurrence was related to typhoon or not referring to the meteorological records published by JMA.

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### 3. CHARACTERISTICS OF CHANGES IN PRECIPITATION

The time series of the annual and the seasonal (May-Oct.) precipitation were analyzed with the Mann-Kendall trend test (Kendall, 1938). The slopes of the trends were calculated by the least square linear fitting.

Figures 1 and 2 show the trends of the annual precipitation and the seasonal precipitation, individually. The annual precipitations tend to increase in East Japan, and to decrease in Central and West Japan. The trend of the precipitation during May-Oct. is similar to that of the annual precipitation. The annual precipitation trends depend on the changes in the May-Oct. precipitation because the heavy precipitation occurs mainly in May-Oct. in Japan.

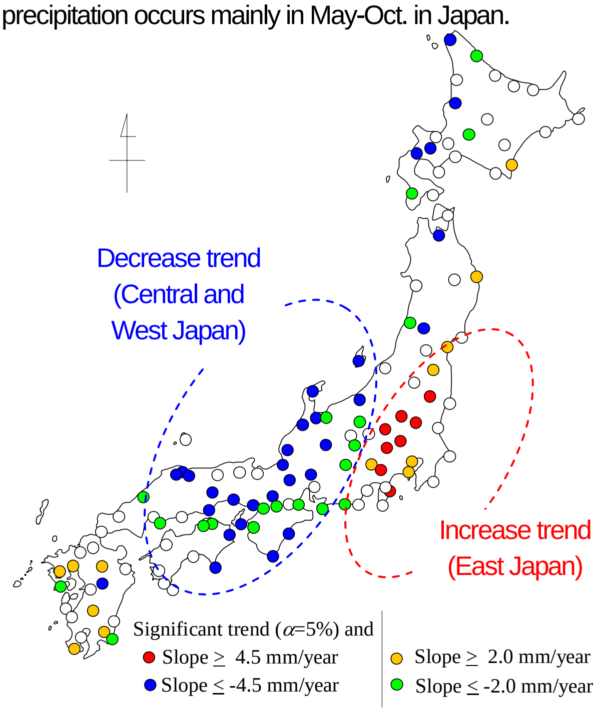



Fig. 1: Trend of annual precipitation

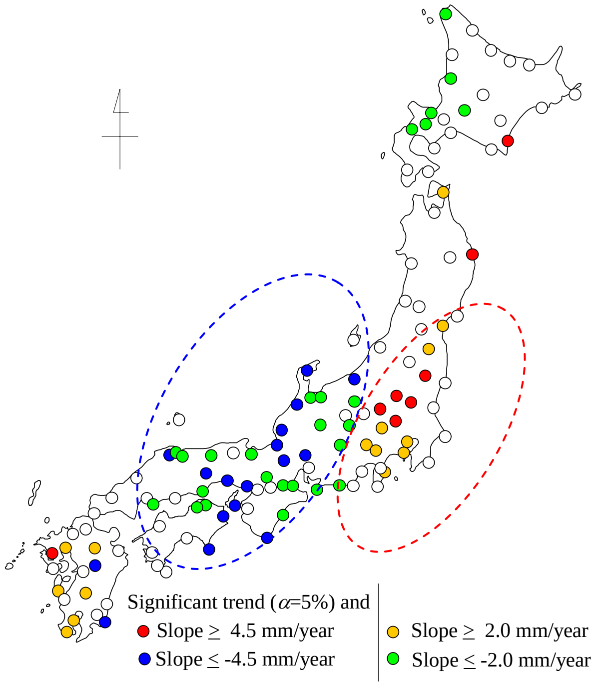



Fig. 2: Trend of May-Oct. precipitation

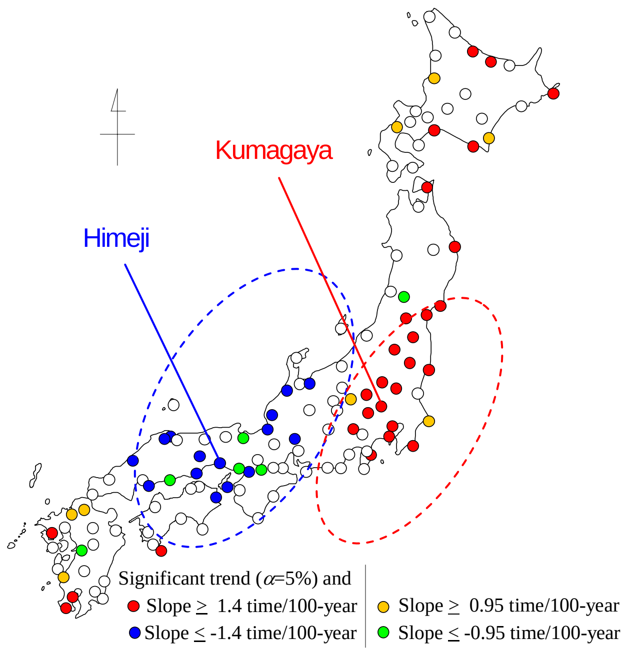



Fig. 3: Trend of heavy precipitation frequency

The annual frequency of the heavy precipitation was also analyzed, whose trend is shown in Fig. 3. The trend of the heavy precipitation frequency is similar to that of the annual and the May-Oct. precipitations.

Figure 4 indicates the time series of the annual precipitation and that of the residual precipitation which is the annual precipitation excluded the heavy precipitation in PDS at Kumagaya and Himeji stations. The annual precipitations in Kumagaya (Himeji) tend to the increase (decrease) significantly. However, the residual precipitation do not tend to increase or decrease. The large annual precipitation corresponds to the large precipitation in PDS. Consequently, the residual precipitations do not show the increase or the decrease trend in any station data in Japan. It is clarified that the trends of annual precipitation are mainly attributed to the results of the changes in the heavy precipitation frequency.

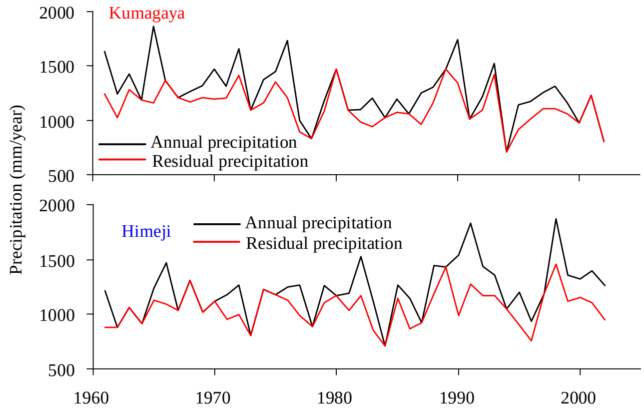



Fig. 4: Time series of precipitation

The causes of the trend of heavy precipitation frequency were discussed. Figure 5 shows the percentage of heavy precipitation frequency caused by typhoon in PDS. The regions of large percentage are located where the annual and seasonal precipitation trends are significant increase or decrease in Figs. 1 and 2. The regions of small percentage are found to be located in western Kyushu, where the heavy precipitation occurrence was mainly due to Baiu and/ or extra-tropical depression.

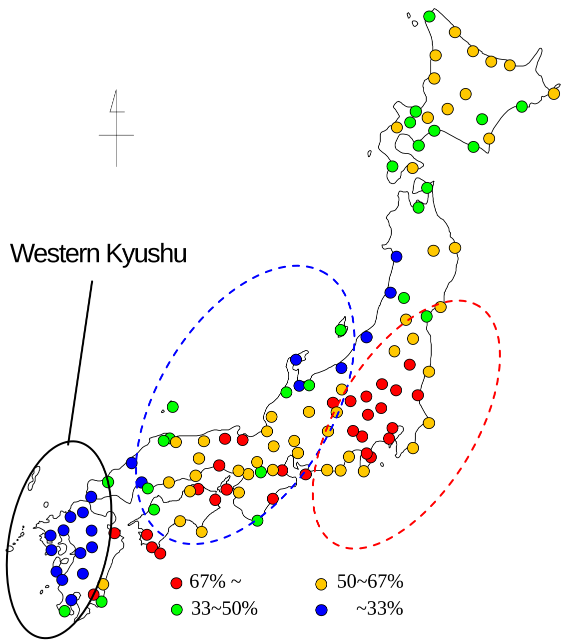



Fig. 5: Percentage of heavy precipitation caused by typhoon in PDS

Figures 6 and 7 show the trend of annual frequency of heavy precipitation due to typhoons and the others in PDS, individually. The heavy precipitation frequencies due to typhoons tend to increase in East Japan, and to decrease in Central and West Japan, and the frequencies due to Baiu and/ or extra-tropical depression have the increase trends in western Kyushu. These trends of the frequencies are also similar to those of the annual and the seasonal precipitations. We conclude that the precipitation changes in Japan are related to typhoons mainly.

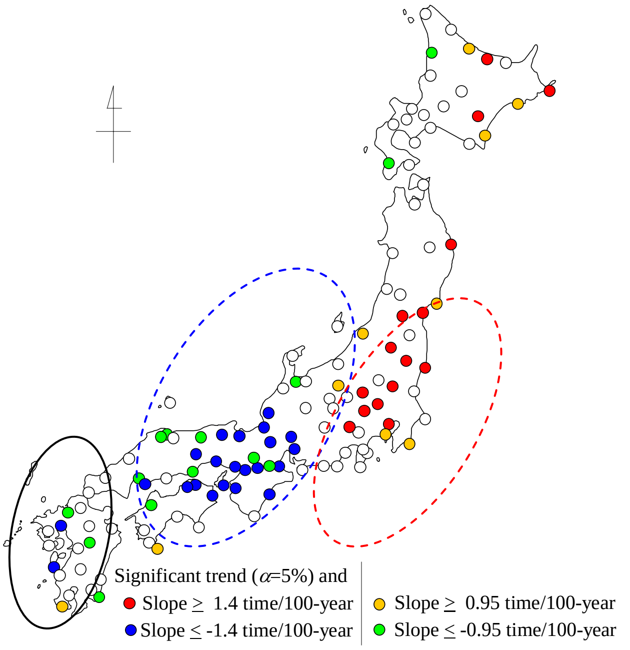



Fig. 6: Trend of annual frequency of heavy precipitation due to typhoons

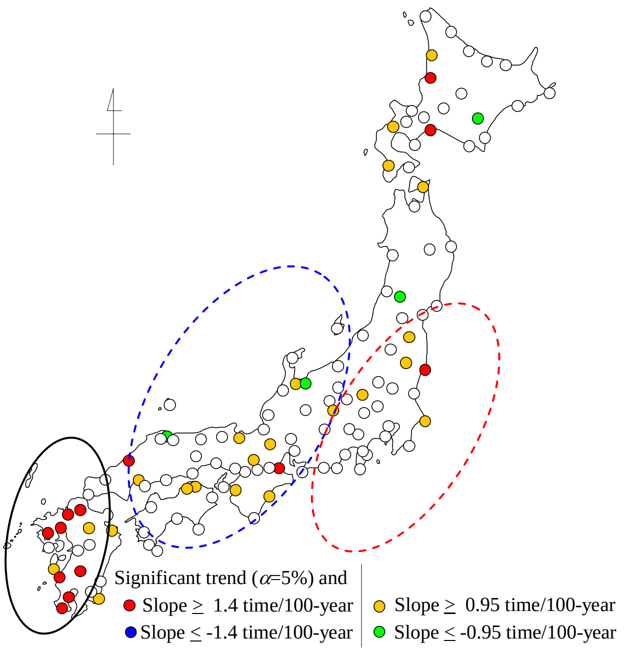



Fig. 7: Trend of annual frequency of heavy precipitation due to the others

## 4. RELATIONSHIPS BETWEEN ENSO AND PRECIPITAION IN JAPAN

To investigate the cause of the trends, the relationship between ENSO and heavy precipitation frequency was discussed using the sea surface temperatures (SSTs) in Nino 3 (4N-4S, 150W-90W), 4 (4N-4S, 160E-150W) and West (14N-EQ, 130E-150E), as shown in Fig. 8. Correlation between SSTs in Nino 3 and that in Nino 4 is positive, but SSTs in Nino West correlates inversely to the others.

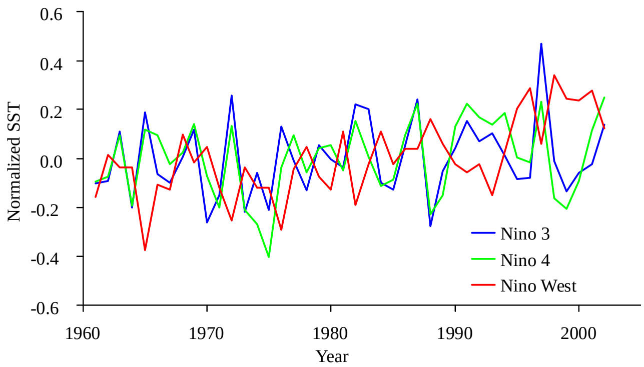



Fig. 8: Time series of SSTs in Nino 3, 4 and West

The singular value decomposition (SVD) analysis (Wallace *et. al*., 1992) was carried out. First, the data in the SVD analysis are constructed of the annual amount of the precipitation (*A*) and the average of sea surface temperatures (SSTs) in Nino 3, 4 and West regions during May-Oct. in each year (*B*). The correlation coefficient between the expansion coefficient for the annual precipitation and that for SSTs is very small. This result is similar to many previous studies (e.g. Kawamura *et al*., 2001).

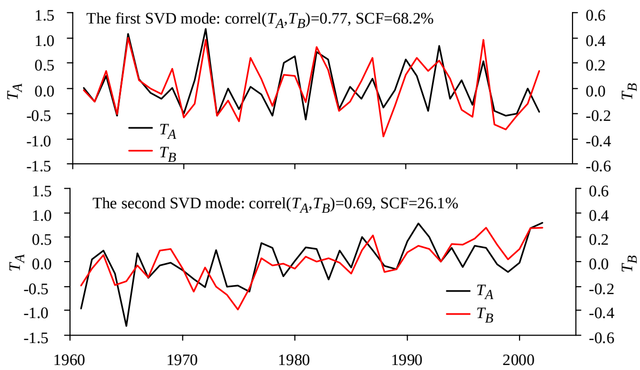



Fig. 9: Expansion coefficient

The data sets of the annual frequency of the heavy precipitations (*A*) and SSTs (*B*) were used. Figure 9 shows the correspondence of the expansion coefficients in the first and second SVD mode. The change in the expansion coefficient for the annual frequency of the heavy precipitations ($T_A$) agrees with that for SSTs ($T_B$). The expansion coefficient for SSTs in the first SVD mode, which accounts for 68.2% of the squared covariance fraction (SCF), indicates the periodical changes of ENSO. The expansion coefficient for SSTs in the second SVD mode, which accounts for 26.1% of SCF, shows the trend of SSTs.

Figure 10 indicates the results of the spectrum analysis for the expansion coefficients in the first SVD mode. The peak of power spectrums for $T_A$ and $T_B$ occurred at 3.6-year period. In the cross-power spectrum, the 3.6-year period is obviously detected.

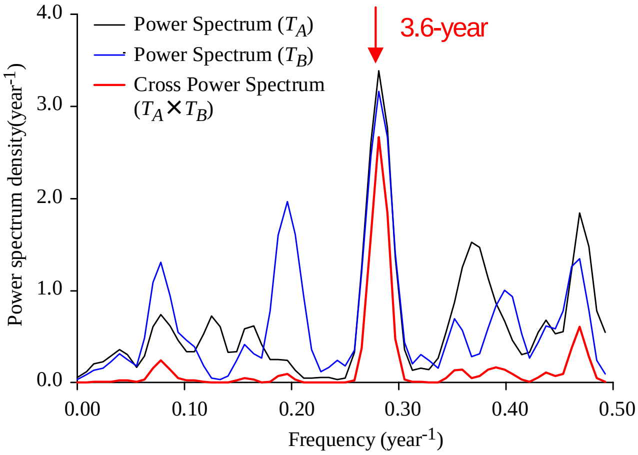


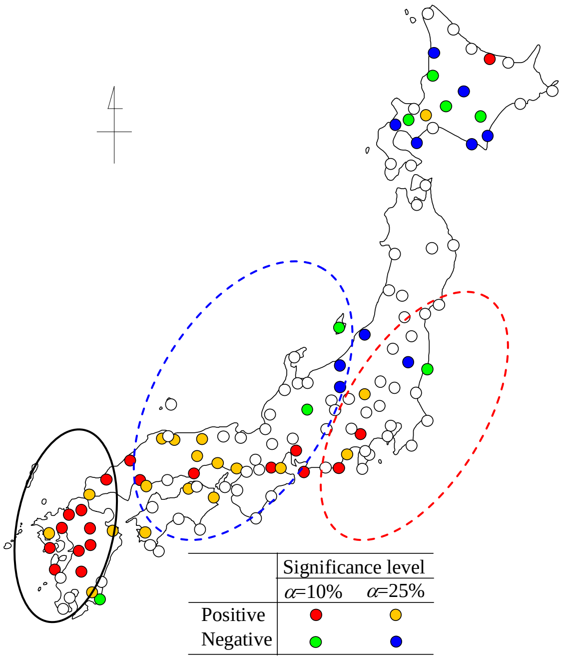

Fig. 10: Results of the spectrum analysis for the expansion coefficients

Figure 11 shows the heterogeneous correlation maps. In the first SVD mode, the positive correlations are found to be located in western Kyushu. The heavy precipitation due to Baiu and/ or extra-tropical depression changes with 3.6 year period, and is similar to ENSO. In the second SVD mode, the correlation coefficients between the annual frequency of the heavy precipitations and the expansion coefficient for SSTs tend to be positive in East Japan and to be negative in Central and West Japan. The distribution of positive (negative) correlation corresponds to that of the increase (decrease) trend of the annual frequency of the heavy precipitations. It is revealed that the changes in the heavy precipitation in Japan are related to ENSO.

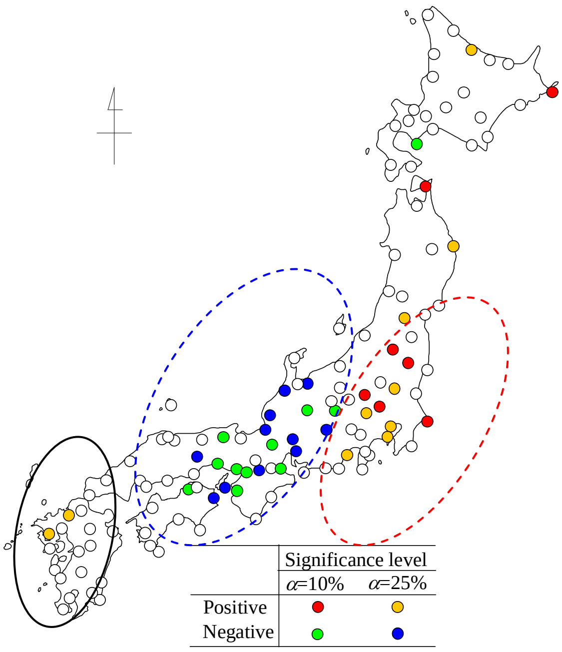
## 5. SUMMARY

This study describes temporal and regional changes in precipitation in Japan for a period from 1961 to 2002. Relationships between the ENSO and the trends of annual frequency of heavy precipitation events are also discussed.

The trends of annual frequencies of heavy precipitations were analyzed with the Mann-Kendall trend test. The annual frequencies tend to increase in East Japan, and to decrease in Central and West Japan. The trend of the heavy precipitation frequency was similar to those of the annual and the seasonal precipitations. It is clarified that the trend of annual precipitation is mainly the results of the changes in the heavy precipitation frequency.




(a) 1st SVD mode




(b) 2nd SVD mode

Fig. 11: Heterogeneous correlation map

To investigate the cause of the trends, the SVD analysis was carried out. The data in the SVD analysis were the annual frequency of the heavy precipitations and SST in the El Nino regions. The change in the expansion coefficient for the annual frequency of the heavy precipitations agreed with that for SSTs. The expansion coefficient for SSTs in the first SVD mode indicated the periodical changes of ENSO, and the one in the second

SVD mode shows the trend of SSTs. The distribution of positive (negative) correlation corresponded to that of the increase (decrease) trend of the annual frequency of the heavy precipitations. The results indicated that the precipitation changes due to typhoons in Japan are related to ENSO.

**Reference**


IPCC, 2001: *Climate Change 2001*: *The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Dai, X., Maskell, K. and Johnson, C.A. eds., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA..

IDAG, 2005: Review Article: Detecting and Attributing External Influences on the Climate System: A Review of Recent Advances, *J. Climate*, **18**, 1291-1314.

Kawamura, A., Eguchi, S. and Jinno, K., 2001: Correlation between Southern Oscillation and Monthly Precipitation in Fukuoka, *J. Hydrau., Coast. Environ., JSCE,* No.691/II-57, 153-158 (in Japanese).

Kendall, M.G., 1938: A new measure of rank correlation, *Biometrika*, **30**, 81-93.

Ropelewski, C.F. and Halpert, M.S., 1987: Global and regional scale precipitation patterns associated with the El Nino/Southern Oscillation, *Mon. Wea. Rev.*, **115**, 1606-1626.

Yonetani, T., 1992: Discontinuous Changes of Precipitation in Japan after 1900 Detected by the Lepage Test, *J. Meteor. Soc. Japan*, **70**(1), pp. 95-104.

Yumoto, M. and Matsuura, T., 2003: Interdecadal variability of tropical cyclone activity in the western North Pacific, *J. Meteor. Soc. Japan*, **81**, 1069-1086.

Wallace, J.M., Smith, C. and Bretherton, C.S., 1992: Singular value decomposition of wintertime sea surface temperature and 500-mb height anomalies, *J. Climate*., **5**, 562-576.

Weiss, G., 1977 :Shot Noise Models for the Generation of Synthetic Streamflow Data, *Water Resour. Res.*, **13**(1), pp.101-108.