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CLIMATIC JUMP IN THE POLAR REGION (II): PRELIMINARY STUDY OF SEA SURFACE TEMPERATURE

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Abstract: By using the COADS (Comprehensive Ocean-Atmosphere Data Set) data, we have examined sea-surface temperature (SST). Although the region of analyses is limited, we may give the following conclusion: the SST in the mid latitudes of the Pacific and Atlantic Ocean abruptly increased around 1940; and they are rather larger than those in the other area, *i.e.* the high latitudes and eastern Atlantic Ocean, even though the SST in the central and eastern Pacific Ocean is deduced from the other investigators' results. Taking account of ROLL's result and our estimate of the random error, we may infer that the increase of SST is real, in spite of contamination of the effect due to the change of observing method, *i.e.* the "bucket method" or the "intake method".

1. Introduction

In our preceding papers (YAMAMOTO *et al.*, 1985, 1986, 1987), we detected the climatic jumps around the year 1950 in several climatic elements over Japan, and those of the sea-level pressure in the Northern Hemisphere around the years 1920 and 1950. In the other authors' papers, we can also find such a result that indicates abrupt changes occurred almost simultaneously and globally. These facts suggest that they associate with some abrupt change, *i.e.* the "jump", of the atmospheric general circulation. We can also find an abrupt change of several quantities expressed by the other elements of climatic system: for example, the extent of Arctic ice around the year 1920 (LAMB, 1972); and SST along the coast of the northeastern Japan (Fig. 1; KONDOH, 1986). BARNETT (1984) also showed the abrupt increase of SST in the central North Pacific Ocean, although it is partially due to the change of the SST observing method.

WHYSALL *et al.* (1987) indicated that the northeast trade winds in the equatorial Pacific Ocean suddenly increased in the 1940s (Fig. 2). Taking account of the above results and using the SST data from COADS, we will examine whether we can find the climatic jump of SST all over the global ocean or not.

2. SST Data Problem

BARNETT (1984) discussed the difference of the SST obtained from two observing

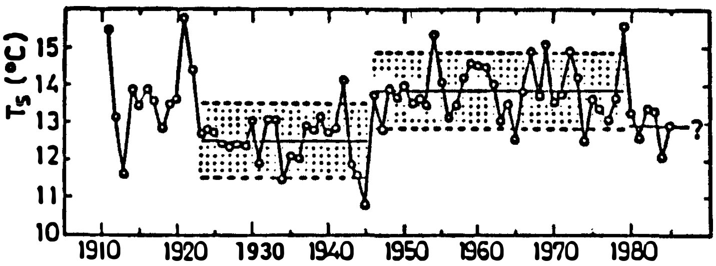

Fig. 1. Interannual variation of annual mean SST at Enoshima in Miyagi-ken located in northeast Japan (reproduced from KONDOH, *1986).*

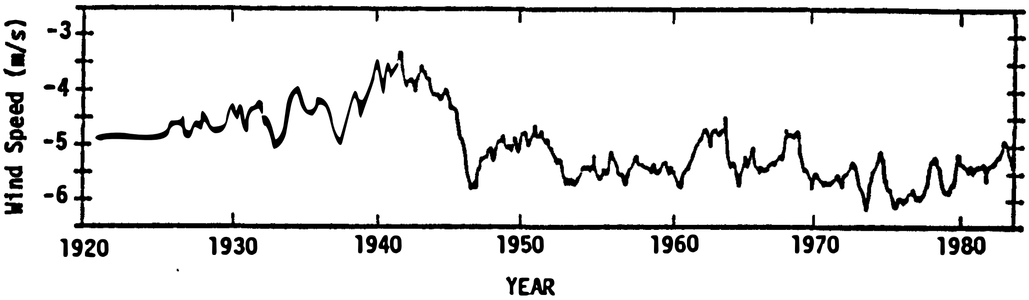

Fig. 2. Interannual variation of the northeast trade winds in the North Pacific Ocean; 12-month running mean zonal wind averaged over the region 5°–25°N, 150°E–130°W (reproduced from WHYSALL *et al., 1987).*

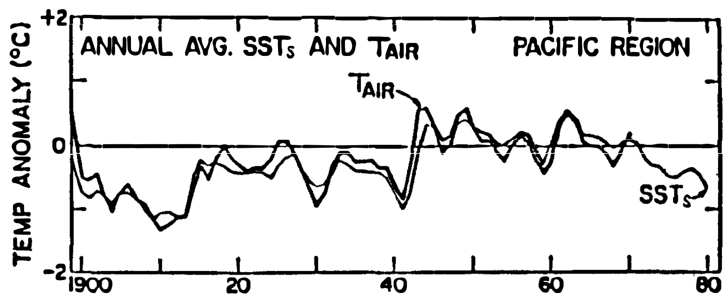

Fig. 3. Annual mean SST anomaly and surface air temperature anomaly in the central North Pacific Ocean (150°–180°W and 35°–50°N) (reproduced from BARNETT, *1984).*

methods, *i.e.* the bucket and intake methods: the former method was used mainly prior to the early 1940s, and after then the latter method largely replaced the former one. He concluded that the observed change of SST contains the bias as much as 30 to 50% by the observing methods. This systematic error of COADS SST is also discussed by FOLLAND *et al.* (1984) and JONES *et al.* (1986). However, taking into account the result of ROLL (1965) that "the average intake temperature is nearly 0.2°C higher than the bucket temperature", we can say that BARNETT's (1984) result (Fig. 3) indicates the abrupt change of the SST in the middle Northern Pacific Ocean around the year 1940. If, however, we take into consideration that the data set of COADS contains sparse regions and periods, we should estimate random error based on an appropriate method and criterion besides the systematic error due to the change of observing methods. In the next section we will show a method of estimating the random error.

3. Estimation of Random Error of SST

MOBLEY and PREISENDORFER (1985) showed that the random error of monthly mean SST averaged in the 4° latitude $\times$10° longitude area is inverse to square root of the number of days sampled in the area. However, it cannot apply in the case of a few number of sampling days. Here we will adopt another method for estimation of the random error of SST based on the structure function of the optimum interpolation method, as was employed by YAMAMOTO and HOSHIAI (1980).

We define an anomaly of observed data at an area i from the normal value by f_{io}, the value of the large-scale field by f_i, the systematic error by η_i and the random error by ε_i. The relation among these values is as follows:

$$f_{io}=f_i+\eta_i+\varepsilon_i\,. \tag{1}$$

For estimating the random error, we can use the following structure function of the sampled data

$$B_{ijo}=\overline{(f_{io}-f_{jo})^2}=\overline{(f_i-f_j+\varepsilon_i-\varepsilon_j+\eta_i-\eta_j)^2}\,, \tag{2}$$

which depends on the distance between two points i and j. Here we may assume that the systematic error η_i at i is equal to η_j at j, if the distance between i and j is small, even though the systematic error varies in time: $\eta_i=\eta_j$. Then, the relation (2) reduces to

$$B_{ijo}=\overline{(f_i-f_j)^2}+\overline{\varepsilon_i^2}+\overline{\varepsilon_j^2}=\overline{(f_i-f_j)^2}+2\varepsilon^2\,, \tag{3}$$

where we assume $\varepsilon^2=\overline{\varepsilon_i^2}=\overline{\varepsilon_j^2}$, and $\overline{f_i\varepsilon_i}=\overline{f_i\varepsilon_j}=0$. From the relation (3), we obtain

$$\lim_{j\to i} B_{ijo}=2\varepsilon^2\,. \tag{4}$$

Assuming that the logarithm of the structure function B_{ijo} linearly depends on the distance, we can obtain the value of B_{ijo} at the distance zero by extrapolation: *i.e.* $j\to i$. Thus, we can estimate the random error from the above relationship. By applying the above method in the region 40°–20°W with relatively abundant data for the 2°$\times$2° box, we estimated the random errors of monthly (January and July) data during the years 1876–1979 (104 years), as is shown in Table 1. The results suggest that more than 50% of the standard deviation is, in most cases, due to the random error, and that we must eliminate such random errors to detect the reliable signal and to estimate the systematic error. For eliminating the random error we will employ the simple moving (equally weighted) average method. Here we adopted 7-month sampling duration for averaging in order to retain the seasonal change. For spatial averaging we examined the longitudinal scale of the phenomena based on the monthly mean data, *i.e.* the variation of the structure function: at the distance of the half wavelength the structure function has a maximum (or inflection point) in the case without (or with) larger-scale phenomena. We assumed that a minimum scale in the east-west direction is twice the

Table 1. Sample standard deviation σ_0, random error ε, and their ratio of raw data of monthly mean SST of COADS in the 40°-20° W region.

	January			July		
	σ_0(°C)	ε(°C)	ε/σ_0	σ_0(°C)	ε(°C)	ε/σ_0
60°N～52°N	0.7	0.5	0.7	0.8	0.4	0.5
50°N～42°N	0.7	0.5	0.6	1.0	0.5	0.5
40°N～32°N	0.6	0.3	0.5	0.8	0.4	0.5
30°N～22°N	0.7	0.3	0.5	0.7	0.4	0.5
20°N～12°N	0.8	0.3	0.4	0.7	0.3	0.5
10°N～ 2°N	0.6	0.3	0.5	0.6	0.3	0.5

Table 2. Value of structure function at the maximum or inflection points of 7-month mean SST data of COADS in the 70°-20° W region. These values imply the half of the minimum scale in the east-west direction detected in these 7-month mean data. The unit is the longitudinal degree at each latitude.

Latitude	January	July
60°N～58°N	28	30
50°N～48°N	26	36
40°N～38°N	30	28
30°N～28°N	26	16
20°N～18°N	28	26

minimum value of the structure function at the maximum (or inflection) point (Table 2). These results agree with those of KENYON (1977) in the region 30°–40°N in the Pacific Ocean. From these results we averaged the data in the east-west direction over the range of 10° at lower latitudes than 40°N and that of 20° at higher latitudes than 40°N. Here we do not average the data in the latitudinal direction, since the above method for estimation of the scale cannot apply in its direction beacuse of the large gradient of the SST.

4. A Few Examples of SST in the Northern Mid Latitudes

At present we are in the preliminary stage of processing the voluminous data, and we will only show a few results of the analysis of SST in the regions a, b, c, and d indicated in Fig. 4. In the regions a and b located at the western part of the oceans we can see an abrupt change of the long-term mean value of January SST anomaly around the year 1940, even though the year-to-year variability is large (Fig. 5(a) and (b)), while in the other regions of the Atlantic Oceans, the abrupt change of SST around the year is rather smaller than in the regions a and b as can be seen in Fig. 5(c) and (d). To confirm the SST abrupt increase around the year 1940 in the central and eastern parts of the Northern Pacific shown by BARNETT (1984) and WRIGHT (1986), we are going to extend our analysis area.

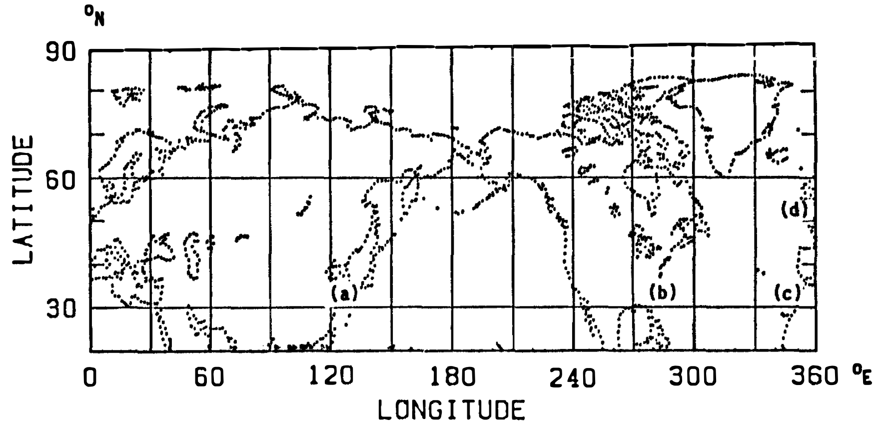

Fig. 4. *Location (2°×2° area) where year-to-year variation of January mean SST is given in the following figures, Fig. 5(a)–(d).*

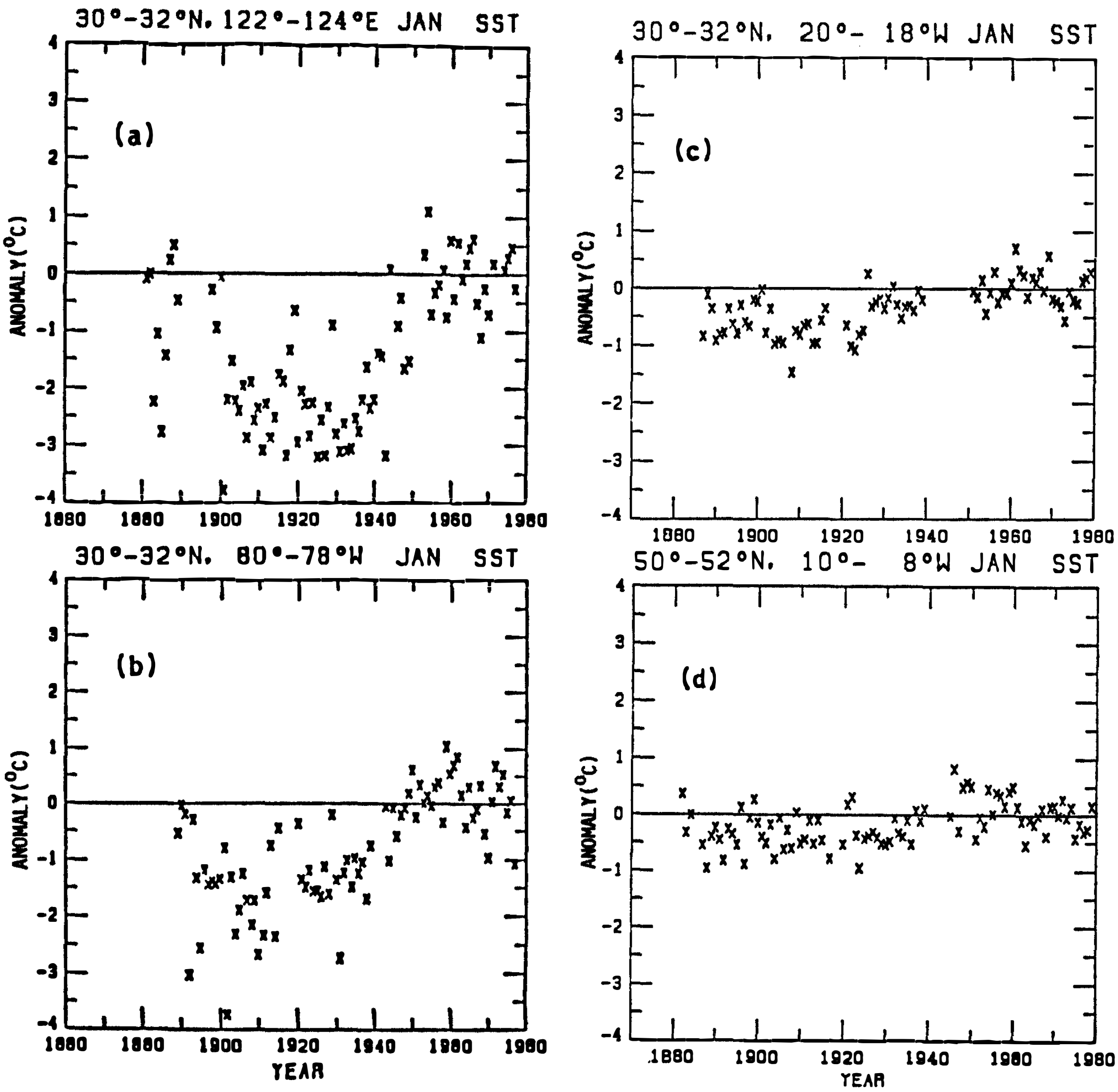

Fig. 5. *Monthly mean anomaly of January SST averaged over the 2°×2° area specified in Fig. 4: (a) 30°–32°N and 122°–124°E; (b) 30°–32°N and 80°–78°W; (c) 30°–32°N and 20°–18°W; (d) 50°–52°N and 10°–8°W.*

5. Summary and Concluding Remarks

In our previous paper (YAMAMOTO *et al.*, 1987), we inferred the "climatic jump" of the atmospheric general circulation. In order to ascertain whether such an abrupt change occurred globally or not, and to consider its cause, we should make further analyses of the global data of the climatic system.

In this sense it is very interesting to estimate the long-term variation of SST all over the global ocean from the COADS, even though we should pay attention to their systematic and random errors.

In the present work we employed a method of averaging the data in time and space to eliminate the random errors. Though WRIGHT (1986) discussed it, more reliable estimation of the systematic error should be made. In this work we showed an apparent increase of SST around the year 1940 in the mid latitudes of the western Pacific and Atlantic, although the area of the analysis and of the data available are limited in the present step. Further studies are needed for the definitive discussion and conclusion on the global distribution of SST change around the year 1940. Also, it is another interesting problem to examine the global change of long-term mean SST before and after the year 1920 when the abrupt change of the climatic elements in the atmosphere are found in our previous work.

References

BARNETT, T. P. (1984): Long term trends in surface temperature over the oceans. Mon. Weather Rev., **112**, 303–312.

FOLLAND, C. K., PARKER, D. E. and KATES, F. E. (1984): Worldwide marine temperature fluctuation 1856–1981. Nature, **310**, 670–673.

JONES, P. D., WIGLEY, T. M. L. and WRIGHT, P. B. (1986): Global temperature variations between 1861–1984. Nature, **322**, 430–435.

KENYON, K. E. (1977): A large-scale longitudinal variation in surface temperature in the North Pacific. J. Phys. Oceanogr., **7**, 256–263.

KONDOH, J. (1986): Climatic jump in the sea-surface temperature at Enoshima in Miyagi-ken. Presented at the Spring General Assembly of the Meteorological Society of Japan.

LAMB, H. H. (1972): Climate; Present, Past and Future, Vol. 1. London, Methuen, 595 p.

MOBLEY, C. D. and PREISENDORFER, R. W. (1985): Statistical analysis of historical climate data sets. J. Climate Appl. Meteorol., **26**, 525–528.

ROLL, H. U. (1965): Physics of the Marine Atmosphere. New York, Academic Press, 426 p.

WHYSALL, K. D. B., COOPER, N. S. and BIGG, G. R. (1987): Long term changes in the tropical Pacific surface wind field. Nature, **327**, 216–219.

WRIGHT, P. (1986): Problems in the use of ship observations for the study of interdecadal climate changes. Mon. Weather Rev., **114**, 1028–1034.

YAMAMOTO, R. and HOSHIAI, M. (1980): Fluctuations of the Northern Hemisphere mean surface air temperature during recent 100 years, estimated by optimum interpolation. J. Meteorol. Soc. Jpn., **58**, 187–193.

YAMAMOTO, R., IWASHIMA, T., SANGA, N. K. and HOSHIAI, M. (1985): Climatic jump; A hypothesis in climatic diagnosis. J. Meteorol. Soc. Jpn., **63**, 1157–1160.

YAMAMOTO, R., IWASHIMA, T., SANGA, N. K. and HOSHIAI, M. (1986): An analysis of climatic jump. J. Meteorol. Soc. Jpn., **64**, 273-281.

YAMAMOTO, R., IWASHIMA, T. and HOSHIAI, M. (1987): Climatic jump in the polar region (I). Proc. NIPR Symp. Polar Meteorol. Glaciol., **1**, 91–102.

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