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Contents

Abstract

In order to make clear the effects of El Niño event in 1982–83 on the socio-economic impacts in Japan, climatic anomalies in summer of 1982 and in winter of 1982/83 were dealt with first. It was indicated that wet/cool (dry/hot) summers with active (weak) Baiu frontal activity are closely related to El Niño (anti-El Niño) over the equatorial Pacific. Temperature anomalies over West and Central Japan are highly correlated to the SST anomalies over the western Pacific. The cold (warm) winters are associated with anti-El Niño (El Niño) over the equatorial Pacific. Secondly, the socio-economic impacts were studied on the agricultural production, energy condition and water use. It was concluded that (i) damaged area and quantity of paddy field rice by abnormal cool summer was great in 1982 during the last 15 years, (ii) total energy demand, ratio of water power to purely domestic total energy product, increasing rate of petty electricity demand and water amount for domestic use showed minimum in 1982, and (iii) these common patterns with minimum in 1982 can be attributable to the low temperature in summer in 1982 and they recovered contrastly in 1983.

1. Introduction

Japan is a country of natural disasters. Almost in every year, we suffer from various kinds of natural disasters associated with abnormal weather conditions such as severe rainstorm during the Baiu season, drought during summer, typhoon in summer and autumn, and heavy snowfall during winter monsoon etc.

In the meantime, the rapid urbanization in most part of our country in recent years has been making the economic and social system of our country more sensitive and fragile even to the minor anomalous climatic conditions. For example, even a minor drought may sometimes cause a serious deficiency of water supply in the large cities.

The climatic anomalies related to El Niño 1982/83 raised a considerable impacts on the economics and human life in various parts of the world. In Japan, the impact of that

El Niño seems not to be remarkable compared to other countries, as described in the latter part of this paper. However, this does not imply that the climatic anomalies of each year and season over Japan are not influenced by El Niño events. Far from it, we will offer some apparent evidences that the climatic anomalies are totally closely connected with the ENSO in a broad sense.

In this paper, we review the climatic anomalies of summer and winter in the past 20 to 30 years and discuss their association with the ENSO. The impacts of these anomalous conditions to the economic and social activity in Japan are also preliminarily surveyed. Particular emphasis will also be made on the significance of the climatic anomalies related to the anti-El Niño events.

2. ENSO and Climatic Anomalies in Summer

In the summer (June, July, August) of 1982, we had abnormally long-lasting Baiu (Meiyü in China) season, which is a stationary polar-frontal activity over far east Asia. This active Baiu front persisted accompanied with the cooler than normal air mass to the north of it. Fig. 1 shows the air temperature and rainfall anomales from normal for July 1982. The wetter and cooler condition prevailed especially over the western and central Japan.

This wet and cool summer associated with active Baiu front is not a specific feature of 1982, but is a more general feature for the El Niño years. Table 1 and Table 2 evidently show that in the typical El Niño (warm SST over the eastern Pacific) years the rainfall amounts during Baiu season are larger than those in anti-El Niño (cool SST over the eastern Pacific) years and that the dates of withdrawal of Baiu season are far later than those in the anti-El Niño years.

Table 3 shows air temperature anomalies for summer and winter over the western, central and northern Japan for the last 9 El Niño years. The temperature anomalies for summer (July, August) are significantly below normal particularly over the western and central Japan. More precisely speaking, however, we may notice that the temperature anomalies and the SST anomalies over the eastern Pacific are not consistently correlated each other. For example, the

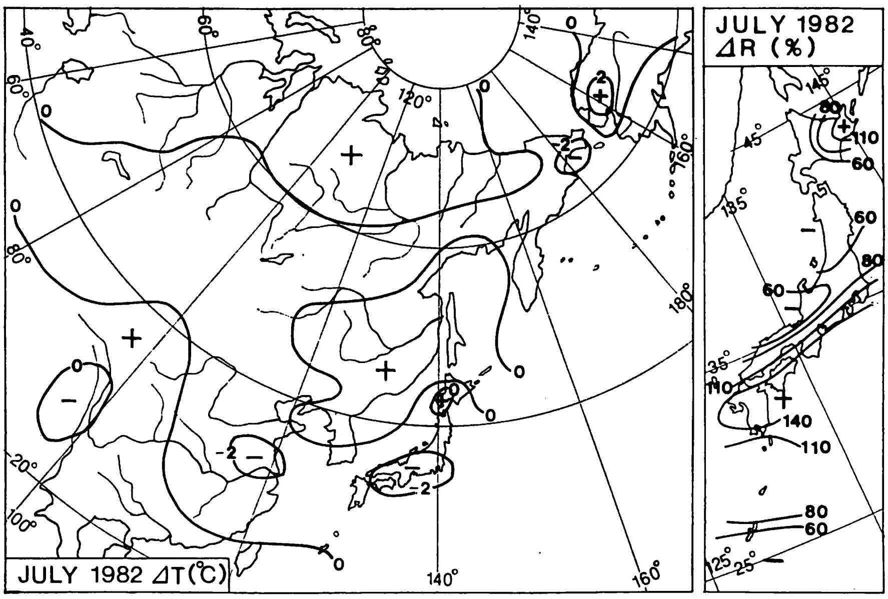

Fig. 1. Air temperature anomaly (ΔT) and rainfall anomaly (R) for July 1982.

Table 1. Mean Baiu rainfall amounts for typical El Niño, anti-El Niño, and normal year (Asakura, 1985).

	Fukuoka	Osaka	Tokyo	Niigata	Sendai
El Niño	700 mm	457	322	262	248
anti-El Niño	329	288	173	247	171
Normal	509	377	255	270	246

Table 2. Mean date of withdrawal of Baiu for typical El Nino, anti-El Nino and normal years (Asakura, 1985).

	Fukuoka	Osaka	Tokyo
El Niño	July 21.4	22.3	25.0
anti-El Niño	13.0	12.1	12.6
Normal	18	17	18

extemely cooler condition appeared not in 1982 but in 1976, when the El Niño was minor compared to that in 1982. Kurihara (1985) presented an answer to this problem, by comparing the temperature anomalies over central Japan and the SST anomalies over the equatorial western Pacific as shown in Fig. 2. A high positive correlation between these two factors should be noted. Fig. 3 shows that the temperature anomalies over the most part of Japan are highly correlated with the SST anomalies over the western Pacific. This significant correlation may be interpreted meteorologically as a strong coupling between the convective activity over the Indonesian maritime continent and the western part of the subtropical high over the northern Pacific via the local Hadley circulation. The "qualitative" correlation as shown in Table 1, 2 and 3 may be resulted from the high negative correlation of the SST anomalies between the eastern and the western Pacific (Wyrtki, 1979). From this point of view, remarkably hot and dry summers of 1978, 81 and 84 were also closely associated with the major anti-El Niño condition of these years.

3. ENSO and Climatic Anomalies in Winter

1982/83 winter in Japan was relatively warm. Table 3 shows that the El Niño years are generally characterized as warmer than normal winters over Japan although there are some exceptional years. Fig. 4 shows that El Niño (anti-El Niño) winters

Table 3. Summer and winter mean temperature for El Niño years. (*) denotes minor El Niño year (Kurihara, 1985).

	Summer mean temp. (Jul., Aug.)			Winter mean temp. (Dec., Jan., Feb.)		
	west	central	north	west	central	north
1951*	−0.6	−0.2	1.1	−0.7	−0.4	−0.3
53*	0.0	−0.9	−0.5	1.3	0.7	0.4
57	−0.3	−0.4	−0.3	0.3	0.7	1.1
63*	0.2	0.2	0.0	0.2	0.3	0.7
65	0.2	−0.6	−0.8	0.2	0.2	0.2
69*	−0.1	−0.3	−0.5	−0.4	−0.5	−0.9
72	−0.7	−0.3	0.6	0.9	0.9	1.6
76*	−0.9	−1.5	−0.8	−1.5	−1.2	−1.8
82	−1.2	−1.0	0.4	0.3	0.7	0.8
Mean	−0.4	−0.6	−0.1	0.1	0.2	0.2

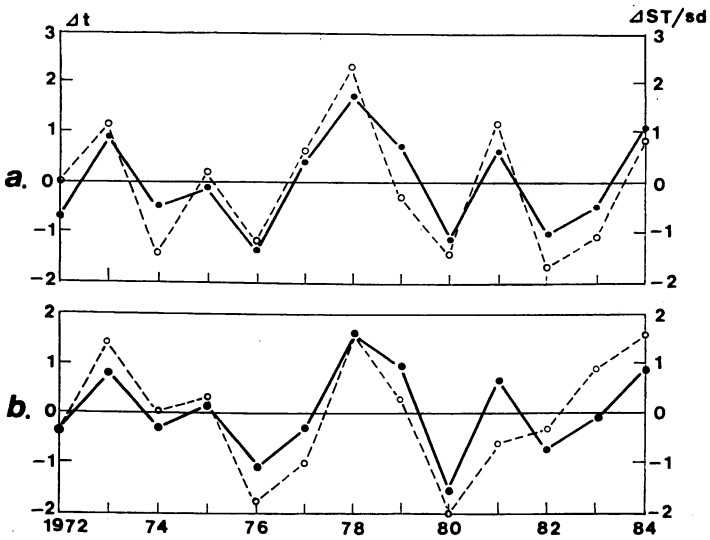

Fig. 2. Standardized anomaly of sea water temperature in the equatorial western Pacific (solid line) and (a) July and (b) August mean air temperature over central Japan (dashed line) (Kurihara, 1985).

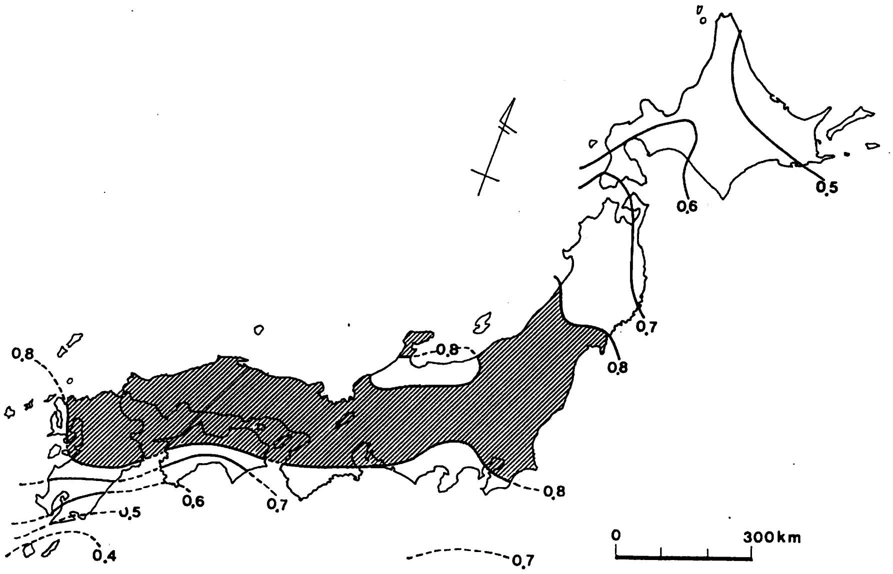

Fig. 3. Distribution of correlation coefficients between mean July sea water temperature (ST_{4-7}) averageg over 4 points from 4°N to 7°N (depth=20 m) and monthly mean July air temperatures at various stations in Japan for 1972-1982. Area with γ greater than 0.8 is hatched (Kurihara, 1984).

are well correlated with the higher (lower) than normal zonal indices over east Asia and also with the higher (lower) than normal air temperature anomalies over central Japan.

In contrast to 1982/83 winter, 1983/84 winter was the coldest winter during the past 40 years as shown in Fig. 4. In Tokyo we experienced 22 cm snow-depth and number of snowfall days was 10 days in February, which was more than 3 times of the normal value.

The mean 500 mb height and anomaly patterns for 83/84 winter (December, January, February) are shown in Fig. 5. A deep trough is located over Japan to the central north Pacific, which remains almost station-

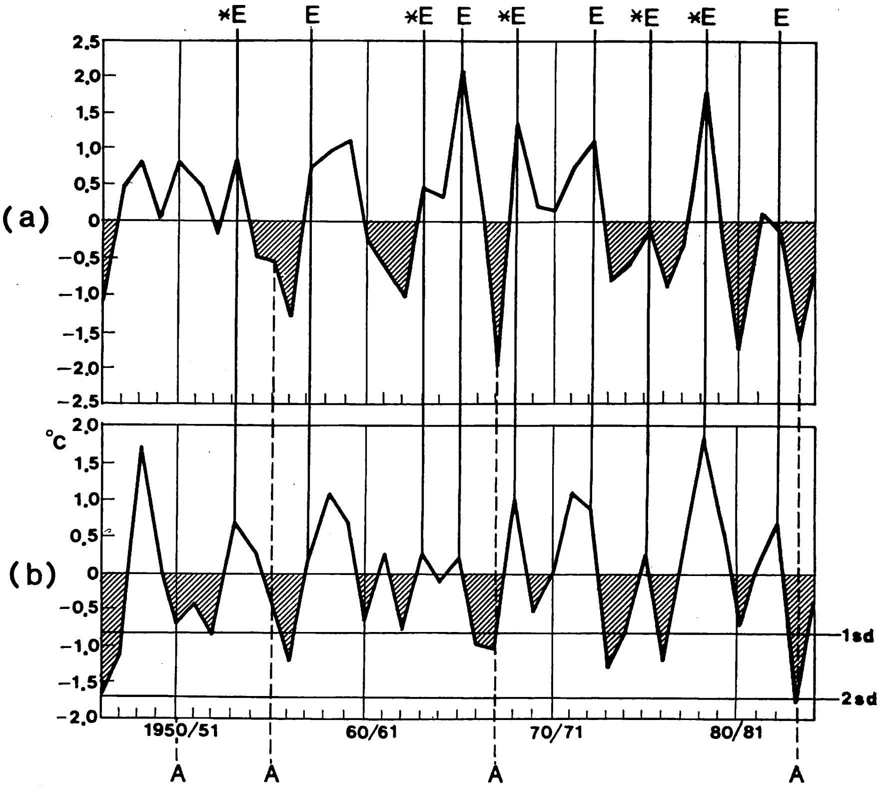

Fig. 4. Time series of winter (D-J-F) means of zonal index anomaly in east Asian mid latitudes and temperature anomaly in central Japan during the period from 1945/46 winter to 1983/84 winter.
a) Standardized zonal index (ZI) anomaly.
b) Temperature anomaly in central Japan. Anomaly is the average of five station data. Standard deviation is 0.8°C for the 30 year mean.
E and A denotes El Niño and Anti-El Niño year, respectively, and *E denotes the minor El Niño year (after Kurihara and Kawahara, 1985).

ary during the winter. The persistence of the large pressure difference between Siberia and the north Pacific sustained strong far-east monsoon. This pressure pattern attributes a strong meridional flow and southward shift of the westerlies over east Asia (Kurihara and Kawahara, 1985), as shown in the low zonal index (Fig. 4). Kurihara and Kawahara (1985) suggested that this severe cold winter over Japan may be directly connected with the intensified convective activities over the western Pacific via the local Hadley circulation. The severe cold winter of 83/84, therefore, correspond well with the typical anti-El Niño condition, where the SST anomalies over the western Pacific is extremely high.

4. ENSO and Natural Disasters in Japan

As shown in Sections 2 and 3, ENSO is related as a whole with wet/cool or dry/hot summers and warm or cold winters over Japan. From the viewpoint of natural disasters, the wet summer with the active Baiu front is very serious, since the active front frequently embeds severe rainstorms in it.

Since the forecasting of these rainstorms are still very difficult, they sometimes cause severe damages in the people's life. Figure 6 shows year-to year changes of some parameters of the natural disasters during the

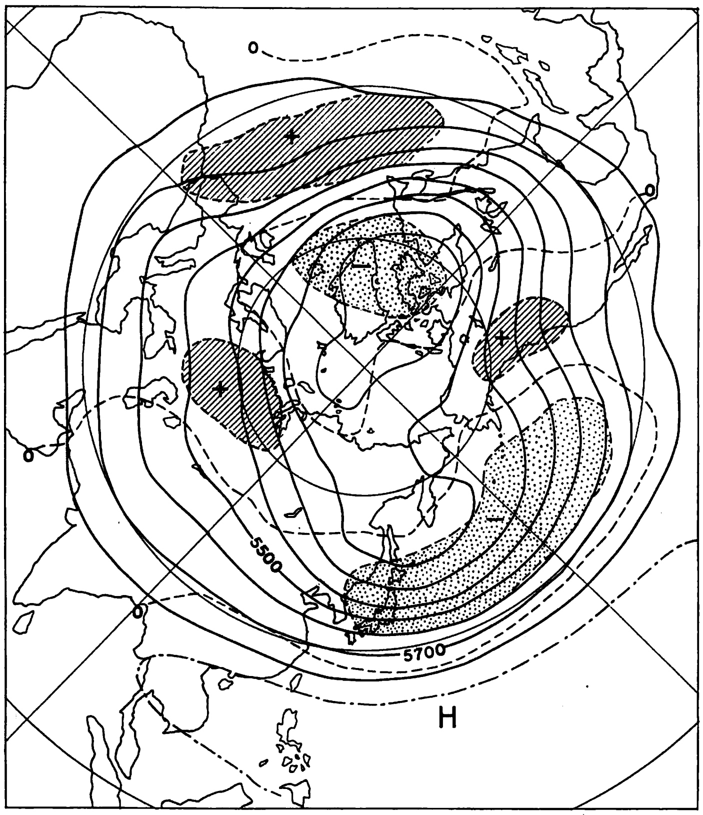

Fig. 5. Winter (D-J-F) mean 500 mb geopotential height and anomalies from 1951–1980 mean, winter 1983/84.
Contour interval is 100 gpm for geopotential height (solid line) except for 5850 gpm contour (dash-dotted line), and 50 gpm for anomaly (dashed line, Shaded>50 gpm, Dotted<−50 gpm) (Kurihara and Kawahara, 1985).

past 11 years. Number of destroyed houses, the damage of buildings and structures and the natural disaster relief expenditure show the maxima in 1972 and 76, when El Niño ocurred. These maxima are mostly attributed to the severe rainstorms during the Baiu season, which may be connected with El Niño as noted in Section 2.

5. Agricultural Production in 1982 and 1983

The most important agricultural production in Japan is paddy field rice. In order to analyze the production of paddy field rice together with upland rice and wheat, year to year changes of the yield and damages of paddy field rice (Table 4), upland rice (Table 5) and wheat and barley (Table 6) are presented first. The values were taken from "Statistical Yearbook of Ministry of Agriculture and Forestry, Japan". Here, ratio of damage in the tables show the total damaged quantity by abnormal weather, diseases and insects to normal production. Normal production was calculated by multiplying normal yield per 10 ares by planted area of each year. Normal yield per 10 ares refers to the yield per 10 ares calculated basing on the trend of production in the past years, taking into consideration the improvement of cultivation methods and the diversion of planted districts, and assuming that weather condition and occurrence of damages are equal to these of normal years.

During the 15 years from 1969 to 1983, the best harvest of paddy field rice appeared in 1978 and the worst in 1980, as far as ratio of damages is concerned. Yield

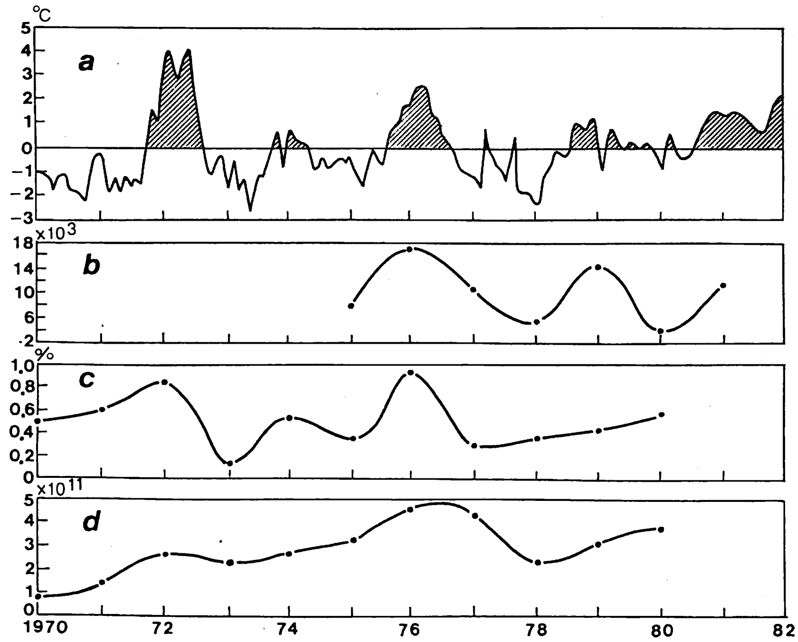

Fig. 6. Time series of a) SST anomalies over the equatorial eastern Pacific (110°W), b) number of completely and halfly destroyed houses by flood, c) damage of buildings and structures by natural disasters, and d) natural disaster relief expenditure for each year. Units are a) °C, c) percent of GNP, d) yen (Asakura, 1985).

Table 4. Paddy field rice yield and damages, 1969–1983.

	Yield	Ratio of damage*	Damage by abnormal weather		Note
			Area	Quantity	
1969	435 kg/10a	10.2%	1,201.0×10³ha	709.3×10³t	
1970	442	9.2	1,173.0	375.9	
1971	411	15.2	2,032.0	1,090.0	Bad harvest (cool summer) in N-Japan
1972	456	7.3	722.9	358.5	
1973	470	6.6	544.2	275.3	Good harvest (warm summer)
1974	455	9.3	736.6	308.6	
1975	481	6.4	898.5	298.0	Good harvest (warm late-summer)
1976	427	16.6	1,963.0	1,321.0	Bad harvest in N- and Central Japan
1977	478	5.9	517.2	213.9	
1978	499	5.6	664.2	294.6	Best harvest (warm summer) in N-Japan
1979	482	7.1	976.8	420.4	
1980	412	22.0	1,992.0	1,603.0	Bad harvest (cool summer), closely related to SST over equatorial W-Pacific
1981	453	13.0	1,504.0	956.3	Cool summer
1982	458	13.5	1,792.0	896.9	Cool summer
1983	459	12.3	1,646.0	711.5	Cool summer in N-Japan, but warm summer in SW-Japan
Average	459	10.9	1,229.2	855.6	

* Ratio of total damaged quantity by abnormal weather, diseases and insects to normal production.

Table 5. Upland rice yield and damages, 1969-1983.

	Yield	Ratio of damage*	Damage by abnormal weather	
			Area	Quantity
1969	203 kg/10a	14.8%	54.7×10^3ha	23.5×10^3t
1970	184	28.6	66.9	42.4
1971	153	38.9	74.9	46.2
1972	210	16.5	36.4	14.3
1973	145	47.4	42.8	44.3
1974	225	11.8	19.0	6.0
1975	179	32.2	32.1	26.0
1976	194	24.3	23.6	13.3
1977	218	13.3	14.4	5.8
1978	135	53.4	26.8	33.1
1979	207	20.2	12.3	9.4
1980	215	16.3	16.3	5.7
1981	202	21.5	17.6	9.7
1982	212	17.7	21.6	6.5
1983	216	16.2	14.8	5.8

Table 6. Wheat and barley yield and damages, 1969-1983.

	Yield	Ratio of damage*	Damage by abnormal weather		Note
			Area	Quantity	
1969	265 kg/10a	15.8%	185.8×10^3ha	102.3×10^3t	Warm winter
1970	207	38.8	194.8	183.1	
1971	265	18.1	100.5	64.2	
1972	250	23.1	93.0	60.0	
1973	270	18.7	47.5	32.5	
1974	280	16.2	49.5	33.5	Cold, snowy winter
1975	269	18.3	54.8	34.6	
1976	250	27.6	68.7	58.3	
1977	275	20.2	53.2	42.4	
1978	327	7.7	40.0	21.0	
1979	363	5.3	37.5	18.6	Abnormally warm winter
1980	305	14.5	120.0	72.7	
1981	262	32.8	174.1	215.8	Heavy snow, cold winter
1982	326	16.5	151.4	106.8	
1983	303	24.8	161.9	160.0	Cold winter

was the worst in 1971, but the second worst in 1980, but the difference is small. Indeed, damaged quantity by abnormal weather was the largest, $1{,}603\times10^3$ t, in 1980.

Looking at the values in 1982 and 1983, yield is just on the average of the 15 years' period. But it is worthy to note that the ratio of damage and the damage by abnormal weather show sharp increase during the last four years. In particular, damaged area and quantity by abnormal weather were large since 1980. As has been shown in column of Note in Table 4, cool summer prevailed in these four years. Especially cool summer conditions were serious in North Japan. In 1983, North Japan was suffered by cool summer damage, but Southwest Japan was warm and this resulted in slightly reduced damage as compared with 1982.

Upland rice shows different secular change to that of paddy field rice as given in Table 5. Area of the damage by abnormal weather is 1-2% of that of the paddy field rice, so that the details are not dealt with here.

Wheat and barley yield per unit area shows no particular values in 1982 and 1983, but damaged area and quantity became larger since 1981. Although they are not the worst case during the last 15 years, but they were relatively worse in 1982 and 1983. They were about three times greater than the averages of the period, 1971-1980.

According to a study by Uchijima (1986), variation of rice yield is closely related to the variation of air temperature in the summer season. Growth of paddy field rice is particularly sensitive to air temperature during heading phase and cool summer damage is a recurrent phenomenon in North Japan.

In Table 7, the mean anomalies of air temperature in July and August and the yield of paddy field rice for each District in Japan are listed for 1978 (the best year), 1980 (bad year), 1982 and 1983.

Even though there are some local differences, the status for the whole Japan as has been shown in Table 4 is also generally true for the District status.

6. Energy Demand in 1982 and 1983

In this part of study, energy demand is first dealt with in relation to socio-economic condition such as population and gross national product and secondly to air temperature condition.

Population of Japan is increasing, but its increasing rate is decreasing markedly since 1981 as shown at the bottom of Fig. 7. Also, gross national product shows steady increase during the period 1970-1983. From these two figures, it is indicated that the increasing rate of the socio-economic conditions in Japan were always positive and roughly linear, although the increasing rate of population is lowering in a strict sense.

Total energy demand of Japan is shown in the middle of Fig. 7. It is clealy seen that the total energy demand was increased untill 1979, but was not increasing after the year 1980. In other words, it fluctuates at the same level since the second half of 1970's. Among them, 1982 was minimum.

Ratio of water power to the purely domestic total energy product for 1970-1983 shows sharp increase in the first half of 1970's, but slow increase after the middle of 1970's. It is also striking that there are small fluctuations. Since 1980, fluctuations are small, but it is quite interesting to note that 1982 was minmum.

After the oil crisis, we are considering again water power electricity as purely domestic energy, clean energy, and energy

Table 7. Air temperature anomaly and rice yield in Japan in 1978, 1982 and 1983.

	1978		1980		1982		1983	
	Air temp.	Yield	Air temp.	Yield	Air temp.	Yield	Air temp.	Yield
Hokkido	+2.6°C	536 kg/10a	−1.7°C	385 kg/10a	+0.8	501 kg/10a	−0.5	355 kg/10a
Tohoku	+2.2	560	−2.5	410	−2.5	508	−1.0	522
Chubu	+1.9	498	−1.5	454	−1.0	463	0.0	474
Kyushu	+1.1	476	−1.3	404	−1.0	446	+0.7	452
Okinawa	−3.4	276	−2.6	255	−3.2	288	−2.9	270

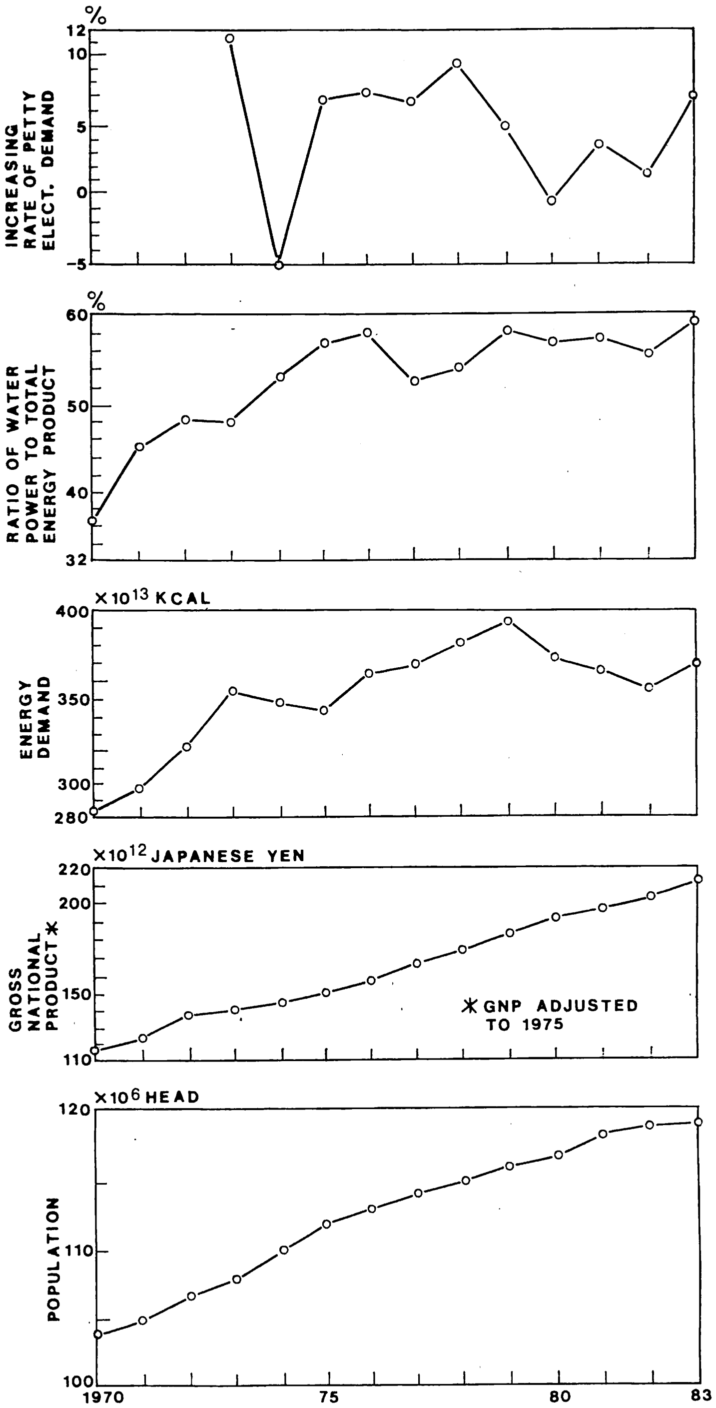

Fig. 7. Population, gross national product, total energy demand, ratio of water power to purely domestic total energy product and increasing rate of petty electricity demand in Japan, 1970-1983.

security. The total water power electricity in Japan is, however, decreasing during the last 30 years gradually and it is almost constant in the last 10 years with small fluctuation. On the other hand, the purely domestic total energy product shows sharp decrease since 1955 and quite slow derease during the last 10 years. In recent years, it is 5-6% of the total energy supply. Therefore, ratio of water power to purely domestic total energy product increases during the period, but its actual value is small. For these reasons, the small fluctuation in the recent years can not be analysed and we cannot safely say, that the minimum of 1982 was caused by certain meteorological evidences.

Increasing rate of petty electricity demand shows rather great interannual change as shown in an upper part of Fig. 7. If we see the last five years, 1980 was the second minimum. These patterns of secular change also appear in the increasing rates of light demand and electricity demand for industry, although the figures are omitted due to the space. The reason for these minimums is attributed to the prolonged (cool) rainy season in early summer and cool summer, which reduced demand strikingly. This is because that lowering of petty electricity demand is caused by the reduced working hours of cooler equipment at homes and by the lowering production activity of the small industries.

The increasing rates of total electricity demand in Japan were +0.5 in 1981, −0.2 in 1982, +6.0 in 1983 and +1.4 in 1984. The fluctuation of these rates can be therefore attributable to cool summer in 1982 and particularly warm summer in Southwest Japan and cold winter in 1983.

7. Water for Domestic Use

In order to analyse water consumption in

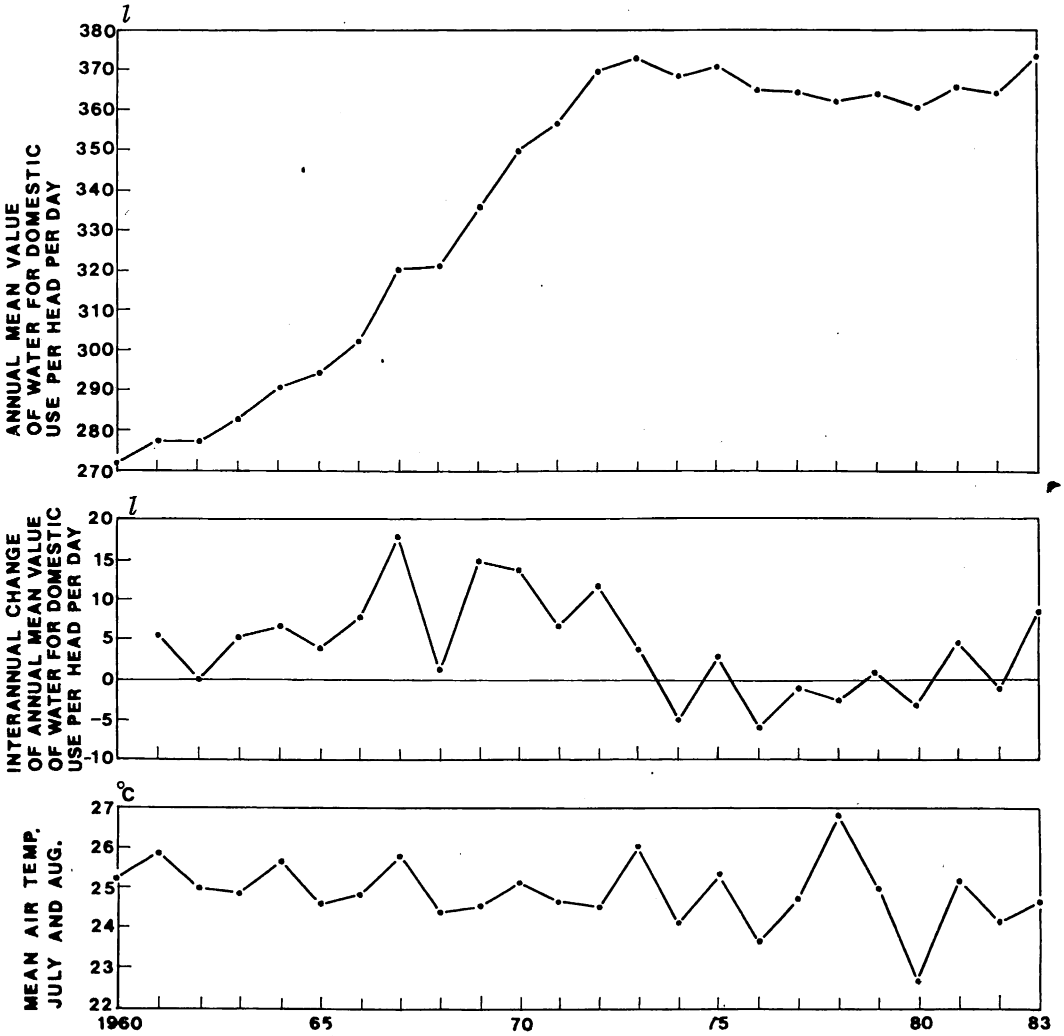

Fig. 8. Mean air temperature in July and August and interannual change and annual mean of water for domestic use per head per day in Japan, 1960–1983.

relation to weather conditions amount of water for domestic use, in other words residential use, is dealt with in this part of our report. Water for domestic use is water for drinking, cooking, toilet, washing, bath etc. consumed at private homes and water used for general activities in cities such as at bureaus, offices, shops and other public facilities. Amount of water for domestic use has been increased in Japan strikingly from the second half of 1950,s. The areas with water supply in cities reached more than 90% in 1978 and 91.5% in 1980. The total amount was about 109×10^8 m^3. in 1980 (Editorial Committee, Mizushigen no Subete, 1984). Its increasing rate from year to year is about 3% during recent years.

Annual mean of water for domestic use per head per day since 1960 is then dealt with. It increased gradually until 1973, but it decreased with greater fluctuation after the year 1974 as shown in Fig. 8. It is interesting to note, however, that the period of El Niño from 1982 to 1983 shows the same pattern to those of the water power product and the electricity demand during the period 1980–1983 as mentioned above. Namely, it shows minimum in 1980 and second minimum in 1982 during the last five years. As has been shown, damage on the paddy field rice yield by abnormal weather shows the maximum in 1980 and the second maximum in 1982, which is just reverse to the change of water amount for domestic use.

As given in Fig. 8, the year to year change of the annual mean of water for domestic use in Japan is closely related to the air temperature; in particular the air temperature in July plus August. Mean air temperatures in Sapporo, Sendai, Tokyo, Osaka, and Fukuoka in July and August were 22.7°C in 1980, 25.2°C in 1981, 24.1°C in 1992 and 24.7°C in 1983.

In Table 8, seven cities were selected to show the relationship between air temperature anomalies in July and August maximum amount of water for domestic use in 1980, 1982 and 1983. According to this table, it is clealy seen that the amount of water used was smaller in Nagoya and Fukuoka in 1982 than in 1980. In 1983, they were relatively large in each cities. Therefore, it should be noticed that the amount in 1982 was second minimum as a country's average as shown in Fig. 8, but the conditions were more striking in some cities in 1982: Air temperature in summer was low and accordingly, the amount of water for domestic use was small.

8. Conclusion

It may be summarized that wet/cool (dry/hot) summers with active (weak) Baiu frontal activity are closely related to El Niño

Table 8. (A) Average air temperature anomaly in July and August and (B) maximum amount of water for domestic use in seven cities in 1980, 1982 and 1983.

Cities	1980		1982		1983	
	(A)	(B)	(A)	(B)	(A)	(B)
Sapporo	−1.6°C	345 l/head/day	+0.9°C	360 l/head/day	−0.5°C	366 l/head/day
Sendai	−2.9	413	−1.0	424	−1.1	444
Niigata	−1.7	512	−0.2	613	−0.2	756
Nagoya	−1.3	513	−1.5	510	+0.5	534
Fukuoka	−2.3	386	−1.1	368	+0.5	403
Nagasaki	−1.3	355	−1.1	390	−0.1	377
Kagoshima	−0.5	406	−0.5	427	+0.5	448

(anti-El Niño) over the equatorial Pacific. Temperature anomalies over western and central Japan are highly correlated with the SST anomalies over the *western* Pacific.

It is also suggested that cold (warm) winters are associated with anti-El Niño (El Niño) over the equatorial Pacific. 1983/84 severely cold winter was directly connected with the enhanced anti-El Niño condition over the weastern Pacific.

The damage by the natural disasters seems to increase in the El Niño years mostly because of severe rainstorms associated with the active Baiu front.

The socio-economic impacts of El Niño year in 1982-1983 were analysed for agricultural production, energy condition and water use taking some examples. The results obtained are summarized as follows: (1) Damaged area and quantity of paddy field rice by abnormal cool summer was great (No. 4 and No. 5 ranking respectively) in 1982 during the last 15 years. In 1983, it recovered. (2) Total energy demand in Japan shows minimum in 1982 since 1976 and becomes larger. (3) Ratio of water power to purely domestic total energy product shows also minimum in 1982. (4) Increasing rate of petty electricity demand was minimum in 1982 and increased in 1983. (5) Water amount for domestic use was also small in 1982 and large in 1983. (6) The patterns mentioned above were therefore same. These are attributable to the low temperature in summer in 1982. Most of them show the minimum in 1980, due to the largest negative anomaly of air temperature and the second minimum in 1982, but in some cases, the lowest in 1982. In 1983, contrastly, they recovered.

The present paper was presented at the UNEP/WMO/NCAR workshop on "world-wide climate anomalies of 1982-83 and their economic and societal impacts" convened in Lugano, Switzerland, on November 11-13, 1985.

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