Methane Emission from Rice Paddies

Haruo Tsuruta
(National Institute of Agro-Environmental Sciences)

1. Monitoring of atmospheric methane in Japan
2. Source inventory of atmospheric methane in Japan
3. Methane emission from rice paddies in Japan and The Thailand

atmospheric methane

global warming

atmospheric chemistry

troposphere

stratosphere

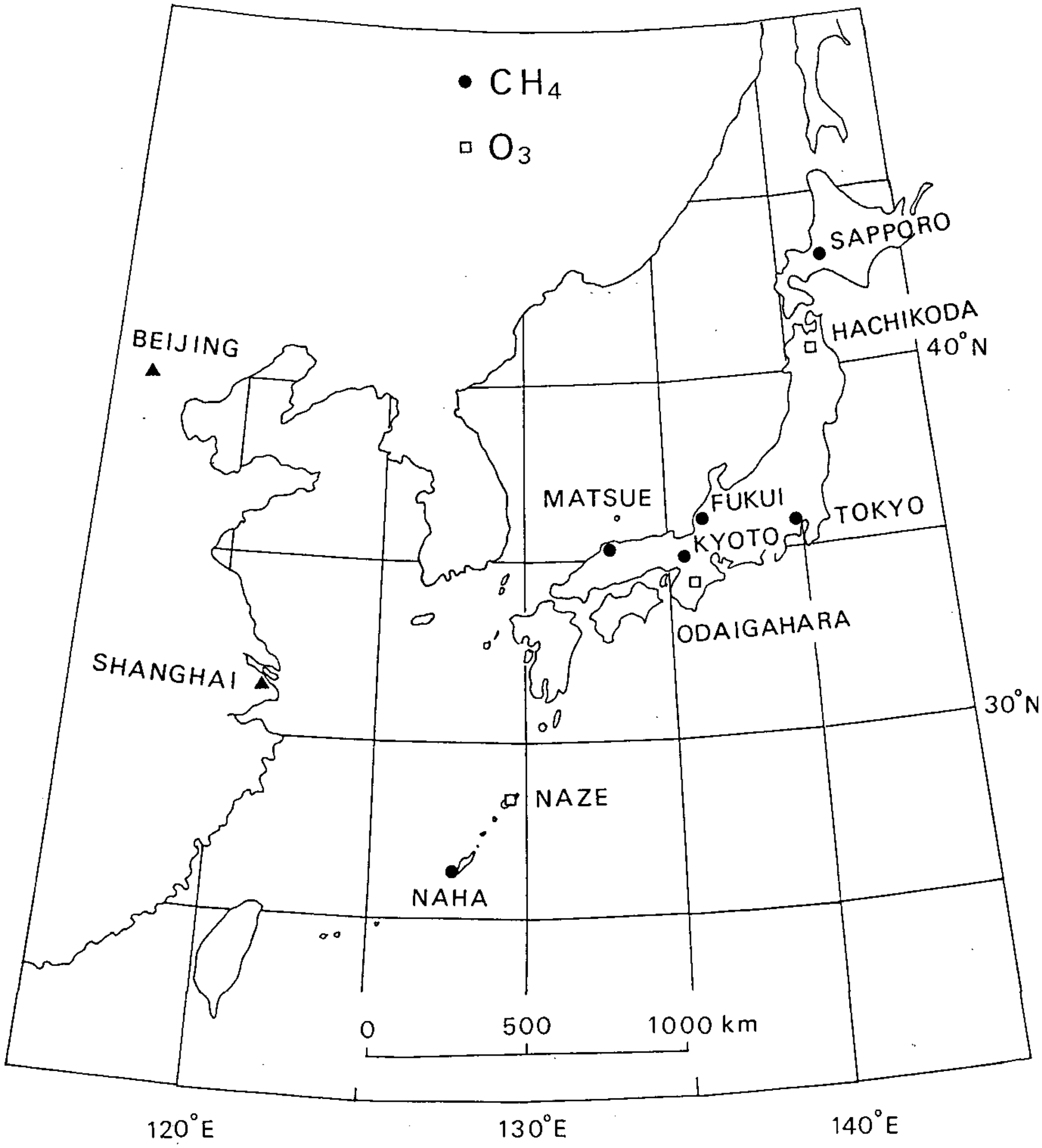
We can understand much better

atmospheric methane,

investigating from

both sides now.

- behavior of atmospheric methane in (remote / source) areas.
- Source inventory of atmospheric methane



● CH_4
□ O_3
SAPPORO
HACHIKODA
40°N
BEIJING
MATSUE
FUKUI
TOKYO
KYOTO
ODAIGAHARA
SHANGHAI
30°N
NAZE
NAHA
0
500
1000 km
120°E
130°E
140°E

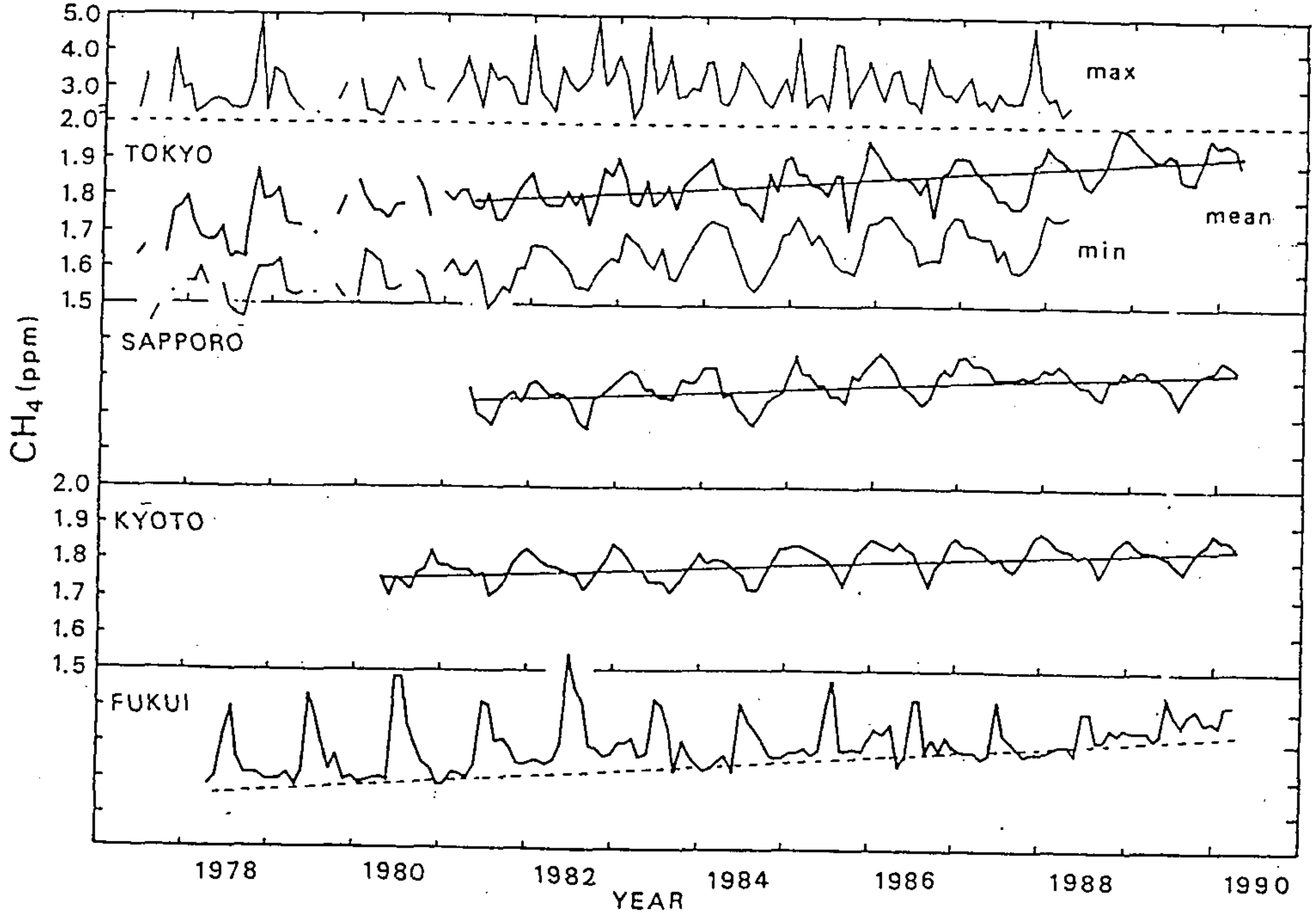


Fig. 1. Long-term trends and seasonal variations of monthly mean concentration of atmospheric methane at four stations (Tokyo, Sapporo, Kyoto, and Fukui) in Japan.

o Long-term trends

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o Seasonal variations

summmer minimum and winter maximum

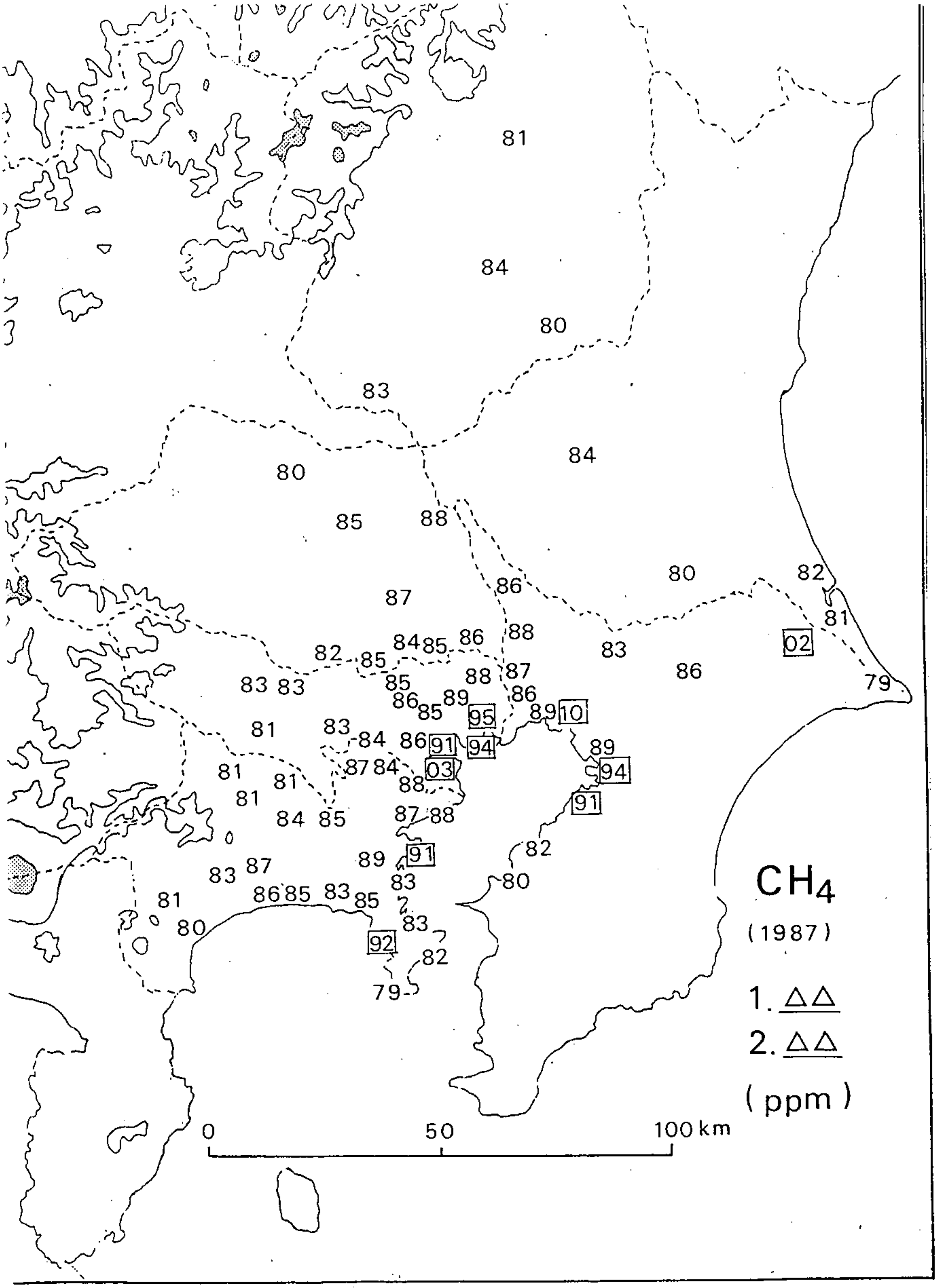
- two different air masses
- local sources

summer maximum

- rice paddies

no variation

o Diurnal variation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91
83 87
80
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81
86 85 83 85
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92
82
79
CH4
(1987)
1. ΔΔ
2. ΔΔ
(ppm)
0
50
100 km

Diurnal variations of trace gases and aerosol over the Sagami Bay

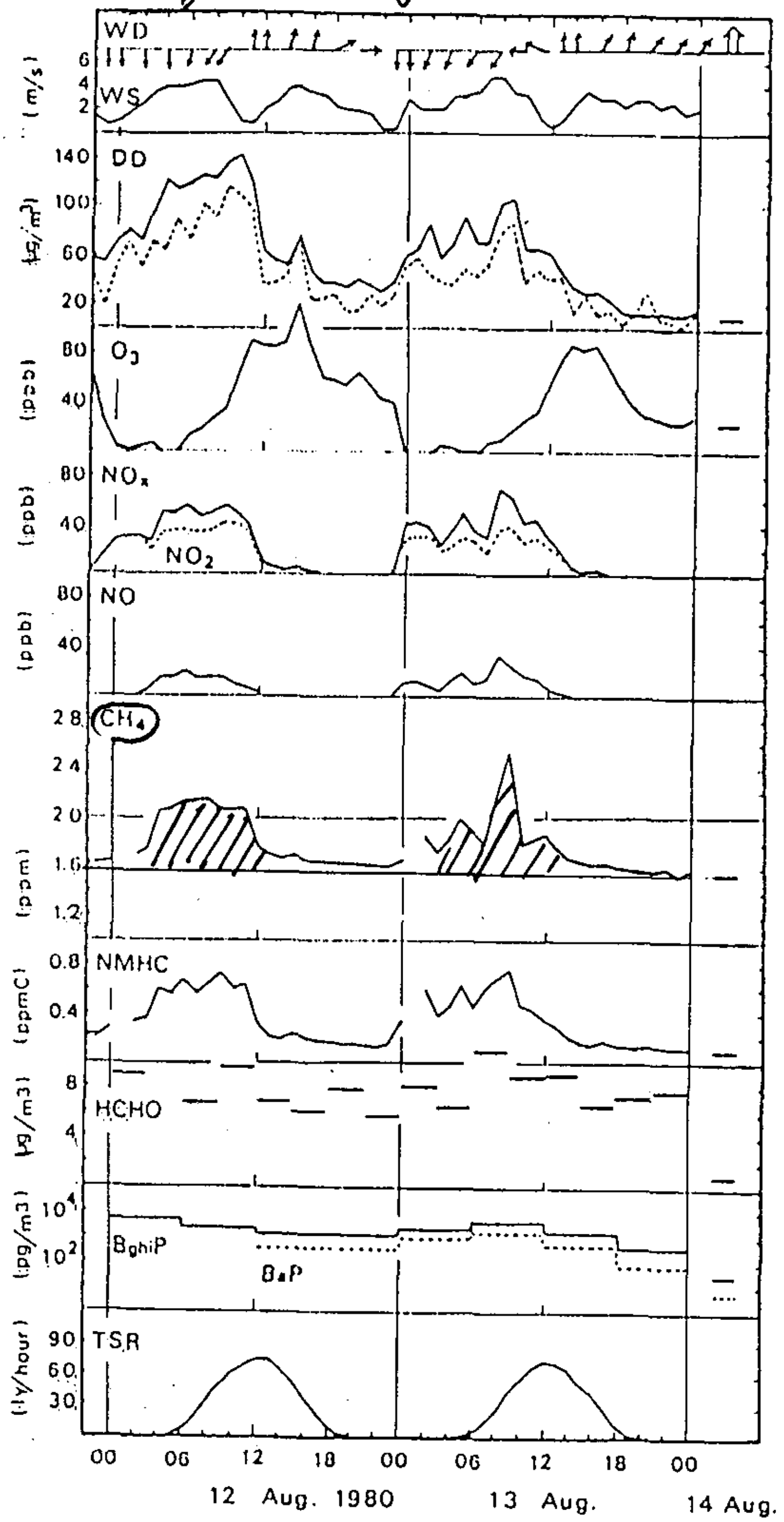

図4.3.1　第1次調査期間中のP点におけるガスの濃度の日変化。
（1980年8月12日～8月13日）

Estimate of methane emission in Japan (1990)

Sources	Annual emissions (Tg/year)
Rice paddies	0.150-0.300
Domestic animals	0.275
Landfills	0.068-0.427
Natural gas systems	0.061-0.096
Municipal refuse incinerators	0.025-0.034
Fossil fuel burning	0.005-0.010
automobills	0.004-0.150
Natural wetlands	0.007-0.020
Total	0.565-1.312

LONG-TERM TRENDS AND SEASONAL VARIATIONS OF ATMOSPHERIC METHANE IN JAPAN

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1. INTRODUCTION

Atmospheric methane is one of the greenhouse gases and plays an important role in atmospheric chemistry of both the troposphere and the stratosphere. Global sources of atmospheric methane have been estimated to be about 500 Tg-CH_4 and the annual emission rate from natural wetlands and rice paddies to the atmosphere has been supposed to be 20% of the global emission of methane, respectively [1,2]. In Japan, total emission of methane has been estimated to be about 1 Tg-CH_4 per year, and only 0.2% of the global emission [3]. 70% of the total emission in Japan has been estimated to be derived from rice paddies, domestic animals, and landfills with solid waste.

Atmospheric methane has been measured in remote area of the world, and the methane concentration in global average has increased at a rate of 0.9% per year [1,4]. Behavior of surface methane, however, has not been clear in the eastern part of Asia due to lack of data. In Japan, atmospheric methane has been measured continuously for these ten years at the air pollution monitoring network. In this report, we will show a brief summary on analyses of long-term trends and seasonal variations of atmospheric methane in Japan by using these data.

2. DATA SOURCE

Methane and non-methane hydrocarbon have been measured every ten minutes by a gas chromatograph equipped with a flame ionization detector at the stations in the air pollution monitoring network in Japan since 1980's. A number of stations for these two gases is now about 300, most of which are located in urban area. The data of one-hour average concentration of methane and non-methane hydrocarbon is stored in magnetic tape, as well as the other data such as sulphur dioxide, nitrogen oxides, and photochemical oxidant. The methane data, however, had not been analyzed because the national environmental quality standard for methane in ambient air is not determined. We have analyzed these data for the first time and have repoted in some papers [5,6].

3. RESULTS AND DISCUSSION

3.1. Long-term trend

An annual mean concentration of atmospheric methane was 1.83

KEY WORDS: atmospheric methane, long-term trends, seasonal variation, methane sources, rice paddy fields.

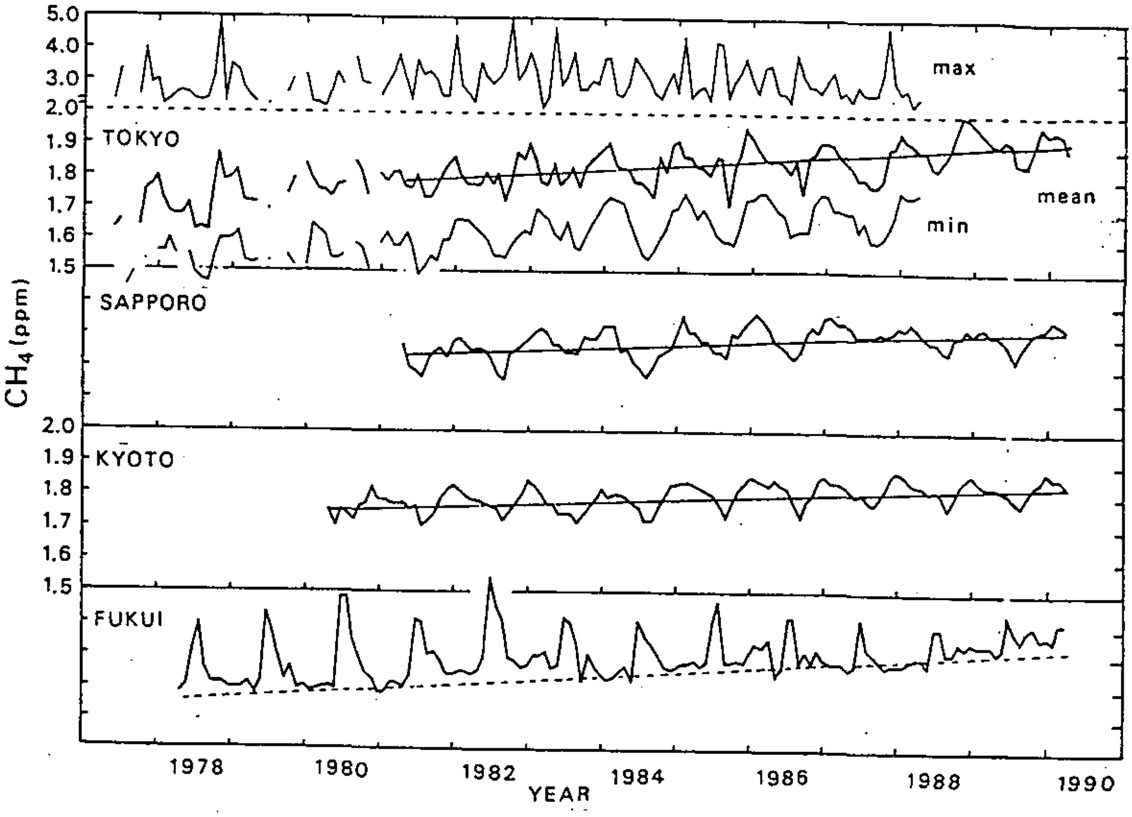

Fig. 1. Long-term trends and seasonal variations of monthly mean concentration of atmospheric methane at four stations (Tokyo, Sapporo, Kyoto, and Fukui) in Japan.

ppmv in 1989 averaging all the data in Japan, and it was slightly higher than the global average of 1.72 ppmv in 1989 [1].

Long-term trends of monthly mean methane concentration at the three stations located in the center of urban area of Tokyo, Kyoto, and Sapporo are shown in Fig.1. The methane concentration has clearly increased at a rate of 0.7% per year between 1981 and 1989, and which is lower than the global increasing rate. This suggests that the data may be influenced by local sources.

3.2. Seasonal variation

Summer minimum and winter maximum

The methane concentration at the three stations has clearly shown a seasonal variation with a summer minimum and a winter maximum as shown in Fig. 1. This seasonal cycle was also found at other monitoring stations located in urban area along the coast of the Pacific Ocean where the amount of methane emission to the atmosphere is very small [1]. At lower latitude in summer, methane concentration was lower and its duration was longer. These phenomena are caused by arrivals of maritime tropical air masses poor in methane to Japan Islands from the south. We have already observed in the ocean far south of Japan by research vessel that the methane concentration was drastically decreased after wind direction shifted from the north to the south [7]. This is consistent with a seasonal variation observed at Guam Island [8] located at lower latitude (13N) in the Pacific Ocean. The summer minimum of methane concentration is the same phenomenon as that of surface ozone concentration in rural Japan [9].

On the contrary, the other season except summer, Japan Islands are covered by continental air masses in which most of trace gases such as methane, ozone, nitrogen oxides are higher than in maritime air masses. The winter maximum was observed in December at the three stations, and much higher than the methane concentration in continental air masses. The reason is that atmospheric stability of the planetary boundary layer is strongest in December, and that many local sources of methane exist near the surface in urban area of Japan.

Methane concentration in remote world has shown a seasonal cycle with a summer minimum and a maximum from autumn to winter [1], and which is supposed to be mainly controlled by the reaction of methane with OH radical.

Summer maximum

The methane concentration at Fukui and Matsue located in the coast of the Sea of Japan, however, has shown a different seasonal cycle with a summer maximum as shown in Fig. 1. The summer maximum is attributed to the emission of methane to the atmosphere from rice paddy fields, because the station Fukui is surrounded by paddy fields. The methane flux from rice paddies to the atmosphere shows a seasonal variation with a summer maximum in California [10], Spain [11], and Japan [12], located in the mid-latitude of the northern hemisphere. The highest concentration was observed in June or July, but in August when surface temperature reaches maximum the methane concentration was slightly decreased, because maritime air masses poor in methane cover all over Japan usually from the latter half of July to August. The summer maximum has never been observed in remote stations of the world and will be characteristic of east Asia.

Since Japan has the large area of rice paddy fields mainly along the coast of the Sea of Japan, the emission rate of methane from rice paddies is about 20% of the total methane emission in Japan [3]. The methane concentration at an urban station 50km apart from the station Fukui, however, shows no summer maximum but shows a summer minimum as well as the three stations in urban area. Hence, an area where the methane concentration shows a summer maximum is not regional.

Methane concentration from autumn to spring was slightly changed at most of the stations located along the coast of the Sea of Japan, and was significantly different from that in the three stations. In this period, strong northwestery wind blows from northeastern Asia across the Sea of Japan to Japan Islands, and atmospheric stability of the boundary layer in the coastal area is very weak compared with that in summer and with that in the Kanto area. As a result, the seasonal variation does not show a winter maximum even if there are local sources.

These analyses reveal that the seasonal variation of methane concentration in Japan is attributed to both the meteorological conditions and sources of methane, in regional and local scale. For meteorological conditions, methane concentration is affected by the global atmospheric circulation and the atmospheric stability in the planetary boundary layer. For methane sources, methane concentration is infulenced by regional sources such as continent and ocean, and by local or mesoscale sources such as urban-industrial area and rice paddy fields. Since the measurement of methane in the world has been performed only in remote area with no local sources, the measurement of methane in Japan has made clear the relationship between the sources and the concentration for the first time.

3.3. Diurnal Variation

Methane concentration in all the seasons was low in the daytime and high in the nighttime not only in urban-industrial stations but also in rural stations. This also indicates that main sources of atmospheric methane exist near the surface, because methane is almost non-reactive gas in ambient air. The diurnal variation of methane concentration is caused by that of the boundary layer, e.g., in the daytime the concnetration is low due to the increase of mixing height, and in the nighttime it is higher due to the decrease of mixing height.

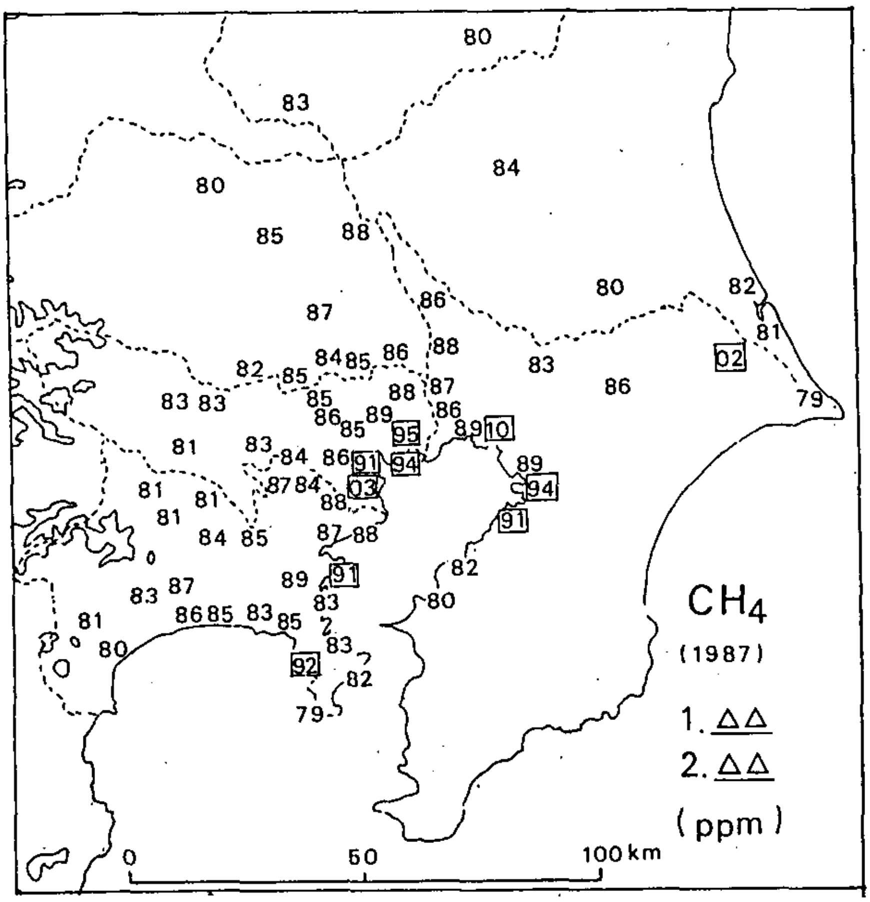

Fig. 2. Spatial distribution of annual mean concentration of atmospheric methane in the Tokyo metropolitan area. Numerical value means decimal part of its concentration. 88 means 1.88 ppmv. Only 02, 03 and 10 mean 2.02, 2.03 and 2.10 ppmv, respectively.

3.4. Spatial Distribution in the Tokyo Metropolitan Area

The annual mean concentration in the Tokyo metropolitan area was 1.85 ppmv in 1987, and higher than that of 1.80 ppmv in the surrounding area, as shown in Fig.2. The annual mean concentration was gradually higher as the monitoring station was located towards the center of the Tokyo metropolitan area, and was more than 1.90 ppmv at most of the stations located along the coast of Tokyo Bay. Maximum concentration was 2.10 ppmv, and this is supposed to be strongly infulenced by a local source such as landfills. These demonstrate that the Tokyo metropolitan area is a large areal source of atmospheric methane. The urban-industrial area and the coastal area have many local sources of anthropogenic origin such as landfills, refuse incinerators, automobills, deposit in the esturies and canals along the coast. Annual emission rate in the Tokyo metropolitan area is estimated from these data to be 10% of the total emission in Japan. In Osaka, the methane concentration in urban-industrial area is also higher than in rural area. Hence, urban and indusrial area in the world is supposed to be one of large areal sources of atmospheric methane.

4. CONCLUSIONS

The data of atmospheric methane measured at stations in the air pollution monitoring network in Japan since 1980's, was analyzed for the first time. The conclusions are as follows.
(1) The annual mean concentration of methane in Japan was 1.83 ppmv in 1989, which was slightly higher than the global average of 1.72 ppmv.
(2) The methane concentration at three monitoring stations located in the center of urban area of Tokyo, Kyoto, and Sapporo has increased at a rate of 0.7% per year between 1981 and 1990. This increasing rate was slightly lower than the value of 0.9% per year in the global average concentration.
(3) Atmospheric methane measured at urban stations located in the coastal area of the Pacific Ocean has shown a clear seasonal variation with a winter maximum and with a summer minimum. The winter maximum is caused by the strongest atmospheric stability of the boundary layer in winter and by existence of many local sources of methane near the surface in urban-industrial area. The summer minimum is attributed to arrivals of maritime tropical air masses poor in methane to Japan Islands from the south in summer.
(4) At monitoring stations surrounded by rice paddy fields, the methane concentrarion has shown a summer maximum due to large methane emissions from rice paddies to the atmosphere.
(5) Methane concentration in all the seasons was low in the daytime and high in the nighttime, not only in urban area but also in rural area.
(6) Monitoring data demonstrated that the Tokyo metropolitan area is a large areal source of atmospheric methane and its emission rate is estimated to be 10% of the total emission of methane in Japan.

REFERENCES

1) Watson, R. T.; Rodhe, H.; Oeschger, H.; Siegenthaler, U.: In Climatic Change, Houghton, J. T.; Jenkins, G.J.; Ephraums, J.J.(Eds.): Cambridge University Press, 1990; pp 1-40.
2) Cicerone, R.; Oremland, R.: Global Biogeochem. Cycles, 1988, 2, 299-327.
3) Japan Environment Agency: Report of Emission Inventory for Methane and Nitrous Oxide, Japan Environmental Sanitation Center, 1990.
4) Blake, D. R.; Rowland, F.S.: Science, 1988, 239, 1129-1131.
5) Tsuruta, H.: Chemical Industry, 1990, 40, 572-578. (in Japanese)
6) Tsuruta, H.: In Proceedings of the 10th International Symposium of Environmental Biogeochemistry, 1991. (to be published)
7) Tsuruta, H.: Special Report on the Photochemical Air Pollution in the Southern Part of the Kanto Area, Yokohama Research Institute of Environmental Sciences, 1983. (in Japanese)
8) Steele, L. P.; Fraser, P. J.; Rasmussen, R. A.; Khalil, M. A. K.; Konway, T. J.; Crawford, A. J.; Gammon, R. H.; Masarie, K. A.; Thoning, K. W.: J. Atmos. Chem., 1987, 5, 125-171.
9) Tsuruta, H.; Shinya, K.; Mizoguchi, T.; Ogawa, T.: In Ozone in the Atmosphere, Bojkov, R. D.;Fabian, P.(eds.): Deepak Publishing, 1990; 433-436.
10) Cicerone, R. J.; Shetter, J. D.; Delwiche, C. C.: J. Geophys. Res., 1983, 88, 11022-11024.
11) Seiler, W.; Holzaphel-Pschorn, A.; Conrad, R.; Scharffe, D.: J. Atmos. Chem., 1984, 1, 241-268.
12) Yagi, K.; Minami, K.: Soil Sci. Plant Nutr., 1990, 36, 599-610.

JAPAN-CHINA SYMPOSIUM ON AIR POLLUTION

The 4th Japan-China Symposium of JCSTEA Series

EXTENDED ABSTRACTS

NOVEMBER 28—30, 1991
TOKYO, JAPAN

JAPAN-CHINA SCIENCE AND TECHNOLOGY EXCHANGE ASSOCIATION

THE CHINESE ACADEMY OF SCIENCES

Table 1.2 Estimated Sources and Sinks of Methane (IPCC, 1990)

	Annual Release (Tg CH_4)	Range (Tg CH_4)
Source		
Natural Wetlands (bogs, swamps, tundra, etc)	115	100 - 200
Rice Paddies	110	25 - 170
Enteric Fermentation (animals)	80	65 - 100
Gas Drilling, venting, transmission	45	25 - 50
Biomass Burning	40	20 - 80
Termites	40	10 - 100
Landfills	40	20 - 70
Coal Mining	35	19 - 50
Oceans	10	5 - 20
Freshwaters	5	1 - 25
CH_4 Hydrate Destabilization	5	0 - 100
Sink		
Removal by soils	30	15 - 45
Reaction with OH in the atmosphere	500	400 - 600
Atmospheric Increase	44	40 - 48

Soils may represent a removal mechanism for CH_4. The magnitude of this sink has been estimated (this assessment)

1.3.3.1 Natural wetlands

Significant progress has been made in quantifying the

B-2 Clarification of the Sources and Emissions of CH4 and N2O

(FY 1990 - 1992)

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2. Japan Environment Agency

The National Institute for Environmental Studies: H. Bandow, S. Sakamaki, Y. Yokouchi, Y. Nojiri, N. Takamura, A. Otsuki, S. Hashimoto, N. Yoshida

3. Ministry of Agriculture, Forestry and Fisheries

National Institute of Agro-Environmental Sciences: H. Tsuruta, K. Kanda, K. Yagi, I. Nouchi, T. Hosono, N. Owa

4. National Institute of Animal Industry: M. Shibata, F. Terada, M. Kurihara, T. Nishida

5. National Grassland Research Institute: K. Yamamoto, T. Kimura, T. Shibuya

6. Ministry of International Trade and Industry

National Research Institute for Pollution and Resources: K. Kitabayashi, M. Hayashi, N. Kido, H. Moritomi, Y. Suzuki, T. Isei, K. Mizuno

7. Ministry of Construction

Public Works Research Institute: T. Kyosai, M. Mizuochi

Project Leader: K. Minami

Ministry of Agriculture, Forestry and Fisheries

National Institute of Agro-Environmental Sciences

Nearly more than ten years have passed since the first evidence for an

Rice paddy areas in the world. (×10^6 ha)

表 2.6.3 世界の水田面積（×10^6ha）

	1935	1950	1960	1970	1980	1985	(%)
Asia	82.0	87.6	110.9	122.3	128.4	130.0	(89.7)
S America	1.2	2.3	3.9	5.7	7.3	6.1	(4.2)
Africa	1.9	2.9	2.9	4.0	4.9	5.5	(3.7)
N/C America	0.5	1.0	1.3	1.4	2.1	1.9	(1.3)
USSR	0.1	nd	0.1	0.4	0.6	0.7	(0.5)
Europe	0.2	0.3	0.4	0.4	0.4	0.4	(0.3)
Oceania	-	-	-	0.1	0.1	0.1	(0.1)
World	86.0	94.2	119.5	134.2	143.7	144.7	

Methane flux from rice paddies depends on

soil types
(degradatable organic carbon)
fertilizer treatment
soil temperature
water management

⋮

The methane emission rate from rice paddy fields in the IPCC report was estimated by using the data of methane flux in the temperate regions by a linear extrapolation of soil temperature.

Measurements of methane flux from rice paddies in the world

表1．世界各地で実測された水田からのメタンフラックスの実測値

Location	Daily average (g/m^2·day)	Flooding period (days)	Season total (g/m^2)	
California	0.25	100	25	Cicerone *et al.*(1983)
Spain	0.10	120	12	Seiler *et al.*(1984)
Italy	0.10–0.68	130	12–77	Schütz *et al.*(1989)
Japan				Yagi & Minami(1990,91)
peat soil	0.39	115	45	
gley soil	0.07–0.37	110	8–43	
andosol	<0.01–0.10	130	<1–13	
China(Hangzhou)				Schütz *et al.*(1990)
single rice	0.19	75–95	14–18	
early rice	0.69	80–140	55–97	
late rice	0.44	120–150	53–66	
Texas	0.06–0.21	80	5–16	Sass *et al.*(1990)
China(Tuzu)	1.39	120	167	Khalil *et al.*(1991)
India	0.04–0.46	60	2–28	Parashar *et al.*(1991)
Thailand				~~This~~ our study (NIAES)
Suphan Buri	0.47–0.77	97–109	51–75	
Khlong Luang	0.09	83	7	
Chai Nat	0.04	94	4	

Methane Emission from Paddy Fields in the Central Plain of Thailand

The concentration of atmospheric methane (CH_4) has been increasing at a rate of about 1% per year. Methane is one of the greenhouse gases; as well as CO_2, N_2O, and CFCs, which absorb the infrared radiation from the earth's surface, causing a possible elevation of the global temperature.

Although the leading cause of the rapid increase in atmospheric CH_4 has not yet been identified, it is generally considered that paddy fields may be an important source of atmospheric CH_4 among a wide variety of sources, taking into account the recent increase in the harvest area in the world. There is, however, a substantial lack of field data for CH_4 emission from paddy fields in tropical countries where about 70% of the world paddy area is located.

Against this background, we have conducted field measurements of CH_4 flux from paddy fields to the atmosphere in the central plain of Thailand. During the dry season in 1991, we performed the first series of measurements at the Rice Experiment Stations of Khlong Luang and Suphan Buri once a month at each site by using a closed chamber method. These two sites are located in the alluvial lowlands of the Chao Phraya river. The soil in Khlong Luang is an acid sulfate soil characterized by a low pH and high concentration of sulfate.

Methane flux from paddy fields in the central plain of Thailand showed marked seasonal variations. The flux increased with the growth of rice plants and the decrease in the redox potential of soil. The average and the maximum values of the flux at Khlong Luang were 3.8 and 9.4 mg CH_4/m^2 hr, respectively. These values were significantly lower than those at Suphan Buri, 19.5 and 46.6 mg CH_4/m^2hr. The CH_4 emission rates at these two sites were in the range of the values recorded in the temperate zone such as in California, southern Europe, and Japan, in spite of the relatively high soil temperature in the paddy fields of Thailand. It was assumed that the low contents of readily decomposable organic matter in the paddy soils were the major factor limiting the CH_4 flux from the Thai paddy fields. In addition, the low methanogenic activities in the acid sulfate soils led to a significant decrease of CH_4 flux from the paddy field in Khlong Luang. Total emission rates during one cultivation period were estimated to be 8 and 42 gCH_4/m^2 at Khlong Luang and Suphan Buri, respectively.

Field measurement of methane flux from paddy field by closed chamber method

Current estimates of CH_4 emission rates from paddy fieldds in the tropical region have been made by a simple correction of the soil temperature based on the field data of the temperate region, without considering the poor quality and quantity of organic matter in the tropical soils. Our results, therefore, strongly suggest that the emission rates of CH_4 from paddy fields in the tropics have been overestimated, and that we need more precise and extensive studies in various areas of the tropical countries.

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Japan ISSN 0915-7476

Newsletter

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Fruit cultivation in dry area of Syria
(Photo by H. Gocho)

Vol.2, No.4
October 1991

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