Total Ozone Observations at Syowa Station, Antarctica

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昭和基地におけるオゾン全量観測

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要旨: 昭和基地におけるオゾン全量観測は，1961年に第5次越冬隊によって開始された．その後はほかの気象要素とともにほぼ連続して実施されてきた．使用した測器はDobsonオゾン分光光度計である．

ここては，これまでのデータを使い昭和基地におけるオゾン全量の季節変化，観測開始以来の経年変化およびオゾン全量と上層の気温との関連を調べ，その概要を述べる．

季節変化は春から夏の初めにかけて最大となり，冬の初めに最小となる．

経年変化は1966年以来，ほぼ一定か，わずかな減少傾向を示す．

オゾン全量と上層の気温との関連は，10月から12月にかけての期間は特に密接で，この期間の平均気温の経年変化はオゾン全量の変化とまったく一致し，オゾン全量の多い年は気温も高く，オゾン全量が少ない年には気温も下降している．

Absrtact: The total ozone amount observations at Syowa Station (69°00′S, 39°35′E) have been carried out since 1961 by the members of the Japanese Antarctic Research Expedition using the Dobson ozone spectrophotometer.

This paper describes general results of annual and year-to-year variations of the total ozone amount, and some statistical relationships between the total ozone amount and the upper level temperature (at levels of 30, 50, 100, 200 and 500 mb).

The annual variation of the total ozone amount shows maximum value in spring (November) and minimum value in early winter (June-July).

The trend of the total ozone amount since 1966 is almost constant with a slight decrease

There is a high correlation between the total ozone amount and the air temperature at 50 and 100 mb levels in October and November

1. Introduction

The total ozone amount observations at Syowa Station have been carried out since 1961, except the period from 1962 to 1965 (because of the closure of Station) and in 1973 (in order to recover the instrument which needed adjustment). Recently these data have been critically reviewed and instrumental constants revised retrospectively to give

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near-homogeneous series These data were published by the JAPAN METEOROLOGICAL AGENCY as "Special volume of Antarctic Meteorological Data" (1978). This paper describes general results of annual and year-to-year variations of the total ozone amount, and relationships between the total ozone amount and the upper air temperature at Syowa Station

The total ozone amount means the integrated amount of ozone in a vertical column of air, extending from the earth's surface to the top of the atmosphere. The total ozone amount is expressed as the thickness in cm, if it would be concentrated into a uniform layer of pure gas under the condition of standard pressure and temperature.

The observations of the total ozone amount at Syowa Station were carried out with the Dobson ozone spectrophotometer using sunlight or moonlight. The total ozone amount is deduced from the measurement of the intensity of a suitable ultraviolet wavelength which came to the earth's surface passing through the ozone layer.

2. The Data of the Total Ozone Amount

As Syowa Station is located at high latitude, the observations using sunlight were made only in eight months of a year, from September to next April Therefore, the data using sunlight are not available from May to August. In 1969, the members of the 10th Japanese Antarctic Research Expedition tried to get the data during the dark season and carried out the observations with the focused image method using moonlight, and got precious data (ISHIDA *et al.*, 1971)

For the purpose of getting accurate data, the regular tests such as the test with a mercury lamp, the test with two lamps and the test with a standard lamp were made

Table 1 Monthly mean of the total ozone amount (m-atm-cm) and number of the data.

	1961	1966	1967	1968	1969	1970	1971	1972	1974	1975	1976
Jan	336(4)		317(27)		333(30)	322(15)				333(31)	319(21)
Feb		322(19)	314(12)		328(22)	319(16)	318(4)		329(13)	318(19)	324(17)
Mar	335(5)	332(27)	305(18)		302(24)	301(8)		289(13)	286(16)	298(3)	322(8)
Apr					308(2)		325(1)	278(1)			
May					298(1)						
June					276(3)						
July					284(3)						
Aug.					318(6)						
Sep	295(5)	322(22)			345(9)	295(18)	298(9)	276(3)	305(5)	292(6)	274(2)
Oct	332(10)	359(29)	381(14)	381(11)	308(22)	298(11)	330(5)	322(10)	352(23)	323(13)	285(26)
Nov	329(9)	398(29)	378(25)	439(27)	343(19)	377(15)	384(9)	382(10)	410(29)	394(24)	386(19)
Dec	356(10)	351(31)	355(21)	379(30)	346(22)	348(19)	315(16)	355(14)	382(30)	374(26)	343(28)

conform to "Manual for ozone observation", written in Japanese in accordance with the "Observer's handbook for the ozone spectrophotometer", Ann. IGY, Vol. 5 (DOBSON, 1957).

The observations using sunlight were made principally at noon, and if possible made at hours when the value of μ was equal to 2.5 (μ: the relative path-length of sunlight through the ozone layer) in the morning and in the afternoon. Taking the accuracy of the data into account, if the value of μ was greater than 3.5, the data were not adopted in this paper. The daily values of the total ozone amount were calculated by averaging all data obtained in a day. The monthly data were calculated by averaging daily values in a month.

Table 1 shows the monthly mean value and the number of the daily values.

3. Annual Variations of the Total Ozone Amount

Fig. 1 shows the annual variations of individual years. As mentioned in the foregoing paragraph, only 1969 provides all the data throughout a year. Patterns of the variations of the total ozone amount of most years look almost the same. The maximum values of the total ozone amount come to about 400 m-atm-cm in November of

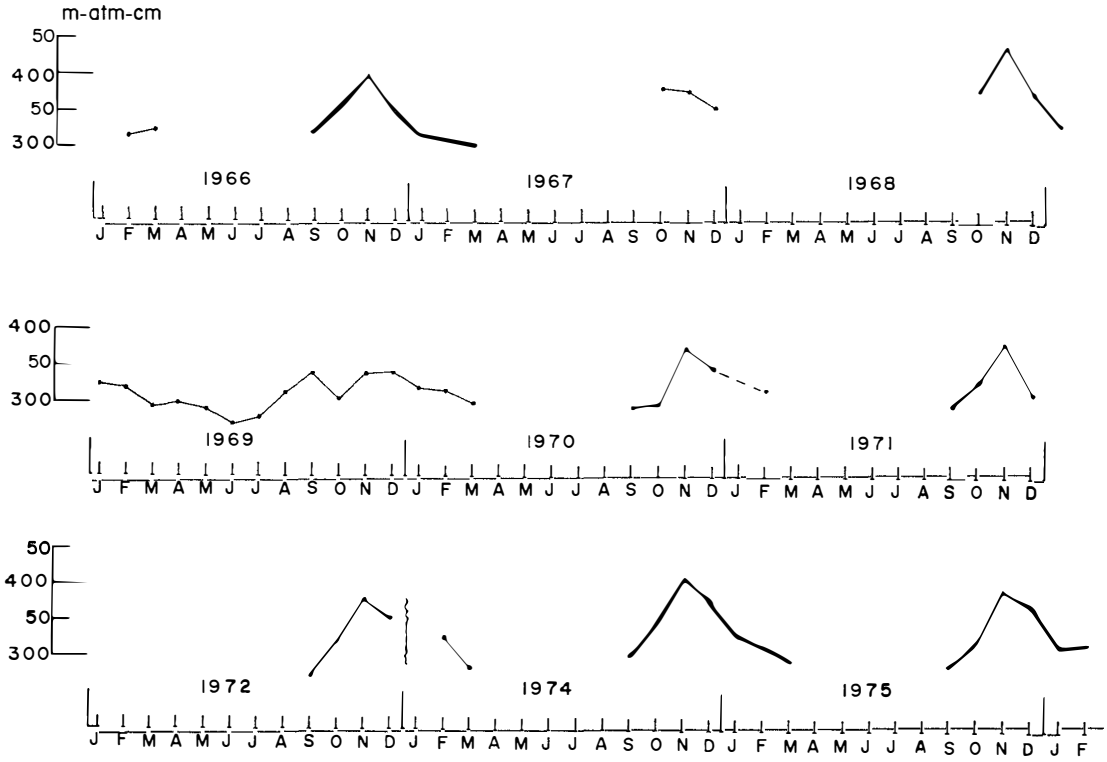

Fig 1. Annual variations of the total ozone amount for individual years

most years except 1967 and 1969.

The pattern of the total ozone amount variation from September to October in 1969 is different from that of the other years. The total ozone amount in this year had increased early in the season compared with normal year and came up to 345 m-atm-cm in September. This value was considerably larger than a normal value. In October the value came down to 308 m-atm-cm, considerably smaller than a normal value for October. Then it recovered to about 350 m-atm-cm in November and December, but it could not form a clear peak in November like normal year.

Fig. 2 shows the mean annual variation of the total ozone amount in the period from 1961 to 1976 In this figure, the numerals in brackets are the numbers of years for averaging.

As mentioned in the foregoing paragraph, the data in the dark season were obtained with the focused image method using moonlight only in 1969. The data in the other season were obtained using sunlight.

Judging from this figure, there is a considerable annual variation of the total ozone amount. The total ozone amount decreases slowly from January to May and comes to the minimum value of about 280 m-atm-cm in June. After that, the total ozone amount increases slowly toward September and increases rapidly during October along with the stratospheric warming at Syowa Station. The total ozone amount comes to the maximum value of about 400 m-atm-cm in November. After that, the total ozone amount decreases rapidly toward December and January.

Expressed in another way, the total ozone amount decreases slowly from the latter part of summer toward early winter and comes to the minimum value in early winter. With rising of the sun, the total ozone amount increases slowly toward spring and in-

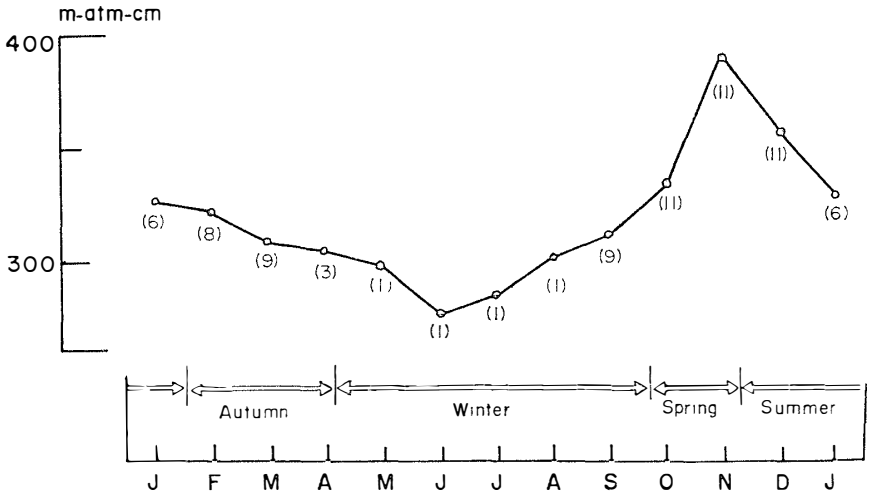

Fig 2 Annual variation of the total ozone amount (1961–1976).

creases rapidly from the latter part of spring toward summer and comes to the maximum value.

Though the data in winter are not enough in this paper, it can be said that the normal maximum value of the total ozone amount is about 400 m-atm-cm in November and the minimum value is about 280 m-atm-cm in early winter (June-July). Judging from the above data, yearly normal value of the total ozone amount is estimated to be 320–330 m-atm-cm. This value agrees with the value near Syowa Station which was got from the global ozone map (LONDON and KELLEY 1974; KIKUCHI, 1978).

4. Year-to-year Variation

Here are the data accumulated since 1961. But as mentioned in the foregoing paragraph, there are no data from 1962 to 1965 and 1973, and the data are poor for the dark season from April to August.

In this paragraph, general results of year-to-year variations are mentioned with the

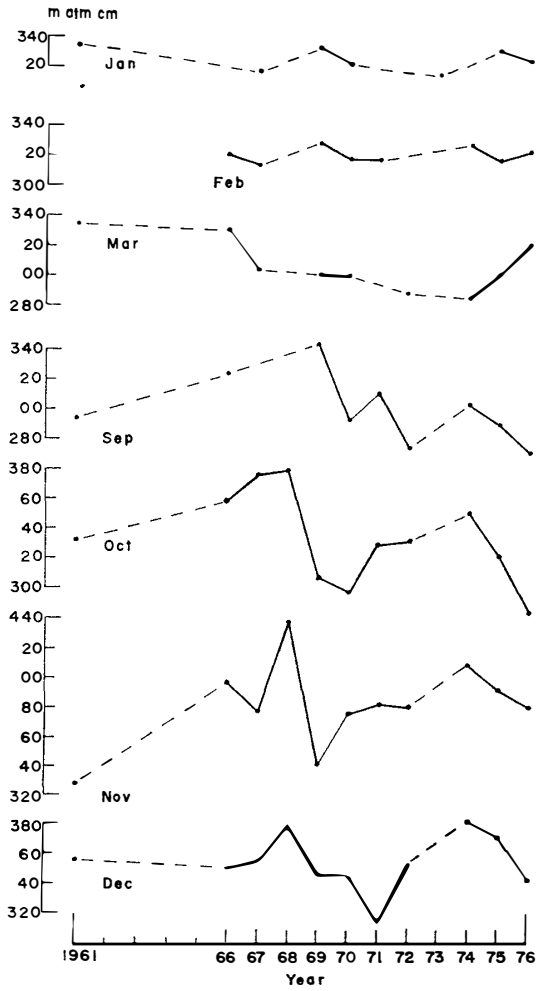

Fig. 3. Year-to-year variations of the total ozone amount for various months.

data observed only from September to March.

Fig. 3 shows year-to-year variations of the total ozone amount in various months. The variation of each month is as follows:

The variations of January and February are almost the same. The maximum and minimum values are 336 and 317 m-atm-cm for January and 329 and 314 m-atm-cm for February. The amplitudes of variations for those months are very small compared with the other months

As regards March, the total ozone amount was recorded 335 m-atm-cm in 1961, since then it was decreasing till 1974, after that the total ozone amount increased.

As regards September, the total ozone amount increased from 1961 to 1969. It came up to 345 m-atm-cm and recorded the maximum value for September, after that the total ozone amount decreased

As regards October, the total ozone amount increased from 1961 to 1968, and decreased rapidly toward 1970. After that, it increased slowly toward 1974, and then the total ozone amount decreased again.

As regards November, the total ozone amount increased from 1961 to 1968 similar to that of October. It was recorded 439 m-atm-cm in 1968 which is the largest monthly mean value of the total ozone amount since 1961. After that, it suddenly decreased to 343 m-atm-cm next year. Then, it increased again slowly toward 1974, after that the total ozone amount decreased.

As regards December, the total ozone amount remained nearly constant from 1961 to 1966, then it increased toward 1971. It kept increasing until 1974 when it began to decrease again.

The trends of the total ozone amount since 1961 are as follows:

The trends in January, February, November and December are almost constant, and those in March, September and October show a slight decrease. Take the above-mentioned fact into acount, the trend of the total ozone amount of yearly mean value is almost constant with a slight decrease

5. Relationships between the Total Ozone Amount and the Upper Level Air Temperature

There are several studies on the relationships between the total ozone amount and the other meteorological elements. In this paper, the relationships between the total ozone amount and the upper level (30, 50, 100, 200 and 500 mb) air temperature are described.

Table 2 shows correlation coefficients between the monthly mean total ozone amount and the monthly mean air temperature at each level during 1961–1976. The

Table 2. Correlation coefficients between the monthly mean total ozone amount and the monthly mean air temperature of each level (1961–1976).

	Jan.	Feb.	Mar.	Sep.	Oct.	Nov.	Dec.
30 mb	0.40	0.50	0.68	0.14	0.85	0.75	0.51
50 mb	0.47	0.33	0.81	0.20	0.94	0.89	0.56
100 mb	0.01	0.30	0.78	0.10	0.87	0.87	0.58
200 mb	0.36	0.35	0.20	0.10	0.56	0.55	0.30
500 mb	0.17	0.32	0.41	0.10	0.55	0.17	0.64

season that has a good correlation is early spring (from October to November) when the stratospheric warming occurs in a normal year. The levels that have a good correlation are 50 and 100 mb. In these levels, the ozone density shows maximum value (SHIMIZU, 1969) and the stratospheric warming occurs clearly.

Judging from these facts, it can be said that the rapid increase of the total ozone amount in early spring is closely related to the stratospheric warming in the latter part of winter.

Fig. 4 shows year-to-year variations in the mean October-November-December value of the total ozone amount and the air temperature at each level. In this season, the total ozone amount shows larger value than in the other season. A noticeable fea-

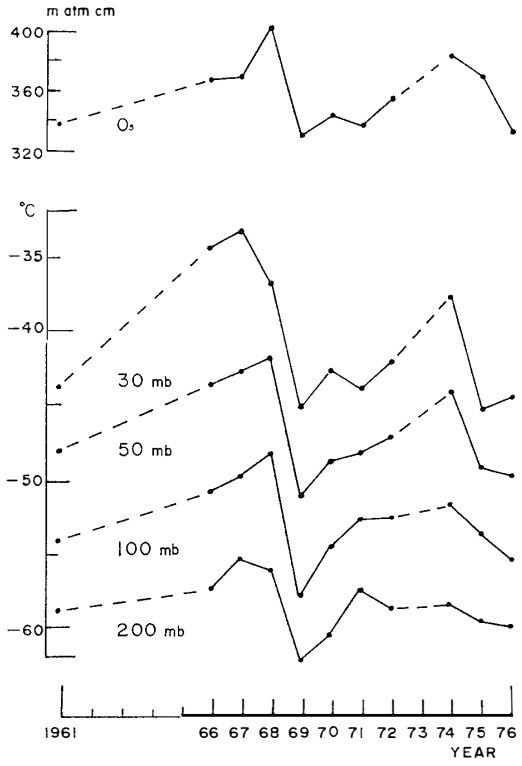

Fig 4. Year-to-year variations of the total ozone amount and air temperature at 30, 50, 100 and 200 mb levels in the mean October-November-December values.

ture of this figure is that the total ozone amount has a clear peak in 1968, a clear trough in 1969 and a peak in 1974, and that the trend of the air temperature at each level agrees completely with that of the total ozone amount.

The variations of the air temperature at upper levels in connection with that of the total ozone amount are as follows:

There is a first peak in 1968 at 50 and 100 mb levels at the same time with that of the total ozone amount, but in 1967 a first peak appears at 30 and 200 mb levels. Fall of the air temperature from 1968 to 1969 completely agrees with that of the total ozone amount and forms a clear trough over all levels. Rise of the air temperature from 1969 to 1974 completely coincides with that of the total ozone amount and forms a clear peak except for 200 mb level. Rise of the air temperature at 200 mb level stopped in 1971, after that it fell slowly toward 1976. A second fall of the air temperature from 1974 to 1976 agrees also with that of the total ozone amount.

Both the decrease of the total ozone amount and the fall of the air temperature at upper levels occur rapidly within a few years. So it seems like a falling.

On the contrary, both the increase of the total ozone amount and the rise of the air temperature at upper levels occur slowly in a period of about 5 years.

Judging from the above data, it is supposed that the air temperature at the upper levels especially above 100 mb in spring is considerably controled by the total ozone amount.

6. Conclusions

In this paper, the observations of the total ozone amount at Syowa Station were reviewed, and the results were summarized as follows:

1) The annual variation of the total ozone amount shows maximum value in spring and minimum value in early winter.

2) The trend of the total ozone amount at Syowa Station is almost constant with a slight decrease.

3) The air temperature at upper levels in spring and early summer is closely connected with the total ozone amount.

Regarding 3), discussions were made only with the data of the monthly means, and so just the general results were described in this paper. Further analyses and discussions in detail are desired in the next stage.

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References

DOBSON, G M B. (1957). Observer's handbook for the ozone spectrophotometer Ann IGY, **5**, 46–87.

JAPAN METEOROLOGICAL AGENCY (1970): Ozon Kansoku Shishin (Mannual of ozone observation)

JAPAN METEOROLOGICAL AGENCY (1978)· Data of total amount of ozone. Antarct. Meteorol Data, Spec. Vol , 79–115.

ISHIDA, K., SUZUKI, T. and SAKAI, S. (1971): Syowa Kiti ni okeru 1969-nen no ozon zenryô kansoku (Total ozone observations at Syowa Station, Antarctica in 1969). Nankyoku Shiryô (Antarct Rec), **39**, 32–38.

KIKUCHI, N. (1978). Sekai no ozon zenryô bunpu ni tsuite (Distribution of global total amount of ozone). Kôsôkishôdai Ihô (J. Aerol. Obs. Tateno), **39**, 60–66.

LONDON, J. and KELLEY, J (1974)· Global trends in total atmospheric ozone Science, **184**, 987–989.

SHIMIZU, M. (1969). Vertical ozone distribution at Syowa Station, Antarctica in 1966. JARE Sci., Rep , Ser. B, **1**, 38 p.

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