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ON THE RELATIONSHIP BETWEEN THE MONTHLY MEAN OF TOTAL OZONE AMOUNTS AND THE MONTHLY MEAN OF STRATOSPHERIC TEMPERATURE AT SYOWA STATION, ANTARCTICA

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Abstract: In this paper, we report the relationship between the monthly mean of total ozone amounts and the monthly mean of air temperature in the stratosphere for the period of 1961 to 1983 at Syowa Station (69°S, 40°E). There is a very good positive correlation between the total amount of ozone and the stratospheric temperature in October and November. The scatter diagrams and regression curves for each month are also described.

1. Introduction

The total ozone observation at Syowa Station (69°00′S, 39°35′E), Antarctica was started in 1961 by the members of the meteorological team of the 5th Japanese Antarctic Research Expedition (SEINO *et al.*, 1963), and it has been carried on with two interruptions, one is in the period from 1962 to 1965 when Syowa Station was closed, and the other is in 1973 because of overhaul of the Dobson spectrophotometer. As the main part of atmospheric ozone is located in the lower stratosphere, some meteorological variables in this level should have some relationship with the total amount of ozone. For example, SHIMIZU (1970) reported that the total amount of ozone and the temperature at the 100 mb level have a good correlation from September to November at Syowa Station. The summary and outline of these observations before 1976 at Syowa Station were given by SAKAI (1979). He reported a good correlation between the monthly mean of the lower stratospheric temperature and the monthly mean of the total amount of ozone for October and for November. However, he did not report the regression curves between the total ozone and the stratospheric temperature. As an extention of SAKAI (1979), the present paper reports the correlation coefficients between the monthly mean of the lower stratospheric temperature and the monthly mean of the total ozone amounts for each month and for standard pressure levels from 500 to 30 mb by the use of ozone data measured by Dobson spectrophotometer and aerological data before 1983. Moreover, the coefficients of the regression curves of each level for each month are calculated. By using these regression curves, it is possible to get the monthly mean of the total ozone amounts from air temperature in the stratosphere within the root mean square error of 20 Dobson Units (DU). The scatter diagrams are presented with the first order regression curves for each month and the second order regression curves for November.

2. Data

The monthly mean aerological data for each year at Syowa Station are obtained from "Antarctic Meteorological Data, Vol. 3 (1964), Vols. 7–24 (1969–1985)" published by Japan Meteorological Agency. After 1974, the aerological observations have been carried out two times (00Z and 12Z) a day at Syowa Station. The observation at 00Z was used in this paper. The total ozone amounts at Syowa Station are obtained from "Aerological Data of Japan (20-Year Period Averages, 1961–1980, of Atmospheric Ozone)" (JAPAN METEOROLOGICAL AGENCY (JMA), 1984). In this paper, only the monthly means of representative total ozone amounts are used.

3. Annual Variation of the Total Ozone Amounts and the Stratospheric Temperature

Figure 1 shows seasonal variation of the total ozone amounts. This is the same as that of SAKAI (1979) except for the use of ozone data of seven years from 1977 to 1983. In Fig. 1, the solid line shows the monthly mean over the period of 1961 to 1983, and the broken line shows SAKAI's result (monthly mean from 1961 to 1976). The values of the solid line are smaller than those of the broken line in October and in November. This indicates a decreasing tendency of Antarctic ozone (CHUBACHI, 1984; FARMAN *et al.*, 1985). Figure 2 shows the monthly mean of stratospheric temperature (50 mb) using the data from 1961 to 1983. In these two figures, the values from September to the next year March are presented. Only summertime data were used, because the number of total ozone observation from April to August is not enough (ISHIDA *et al.*,

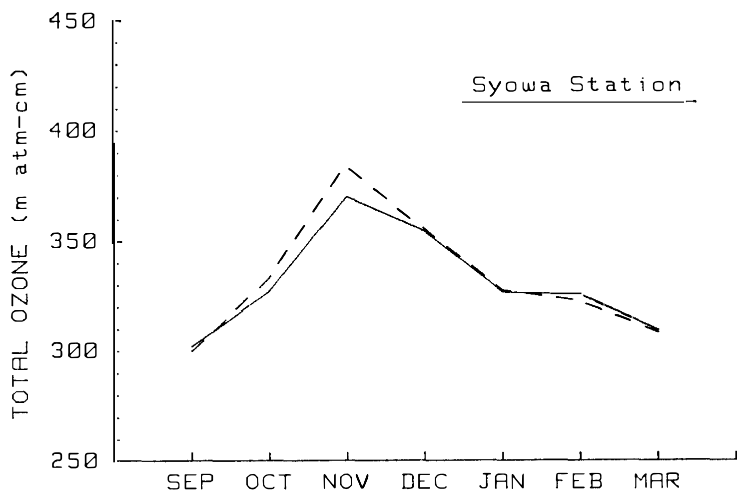

Fig. 1. Seasonal change of the monthly mean total amount of ozone at Syowa Station (69°00'S, 39°35'E). The solid line shows the monthly mean of 1961–1983 and the broken line shows that by SAKAI (1979) of 1961–1976.

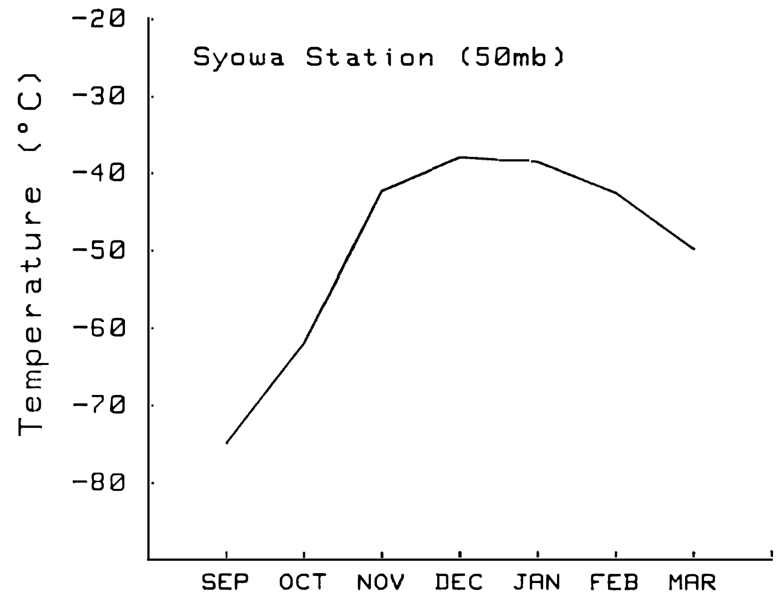

Fig. 2. Seasonal change of air temperature of the 50-mb level at Syowa Station (1961–1983).

1971; CHUBACHI, 1984). The total ozone increases from September to November and decreases from November to March.

4. Correlation Coefficient between the Monthly Mean of the Total Ozone and the Monthly Mean of the Upper Air Temperature

Table 1 gives the correlation coefficients for each month and each pressure level between the monthly mean of the total ozone amounts and the monthly mean of the stratospheric temperature at Syowa Station. It shows that the correlation coefficients are larger for October and for November while smaller for February and for September. In the lower stratosphere from the 175 to the 30 mb level, these correlation coefficients are positive; the higher the temperature, the larger the total ozone amounts. The correlation coefficients are larger than 0.9 on the 100 mb level for October and on the 70 and 100 mb levels for November. The value of the coefficient of the 100 mb level for January and of the 50 mb level for March are larger than 0.7. In December the

Table 1. The correlation coefficients between the monthly mean temperature and the monthly mean total ozone amounts for each level and for each month at Syowa Station (1961–1983).

mb	30	40	50	70	100	125	150	175	200	250	300	350	400	500
Sep.	+.10	+.28	+.28	+.38	+.42	+.48	+.36	+.16	+.12	+.02	−.05	−.10	−.12	−.12
Oct.	+.76	+.81	+.85	+.89	+.92	+.89	+.85	+.78	+.71	+.52	+.43	+.37	+.35	+.36
Nov.	+.65	+.81	+.89	+.93	+.92	+.87	+.79	+.72	+.67	+.60	+.49	+.36	+.28	+.22
Dec.	+.58	+.58	+.58	+.46	+.57	+.45	+.29	+.26	+.25	+.23	−.25	−.34	−.46	−.54
Jan.	+.61	+.61	+.62	+.65	+.71	+.67	+.51	+.37	+.31	+.33	−.28	−.41	−.46	−.59
Feb.	+.23	+.25	+.25	+.17	+.17	+.09	+.07	+.03	−.04	−.11	−.13	−.35	−.45	−.53
Mar.	+.60	+.69	+.72	+.66	+.64	+.62	+.58	+.52	+.42	+.14	+.26	+.25	+.19	+.17

value of the coefficients around the 40 mb level is about 0.6. The correlation is not so good for September (the maximum value is 0.48 on 125 mb) and February (0.25 on 40 mb). These characteristics agree well with SAKAI's (1979) results. The level of the best correlation ascends from September (125 mb) to December (40 mb) and descends from February (40 mb) to March (50 mb). This variation may be due to the change of the maximum level of the ozone density. It should be noticed that the correlation in troposphere for summer months (December, January and February) is negative; with a rise of temperature, the value of total ozone becomes lower. The absolute value of the coefficients with the 500 mb temperature is larger than 0.5 for the months of December, January and February.

5. Scatter Diagrams for October and November

We can estimate the monthly mean of total ozone amounts from the data of monthly mean temperature using linear regression. The levels of the best correlation are shown in Table 2. Figures 3a and 3b show the scatter diagram between the temperature of these levels and the total ozone amounts for October (Fig. 3a) and for November (Fig. 3b) when the coefficients are larger than 0.9. The broken lines in these figures show linear regression lines (the coefficients are shown in Table 2). The root mean square error of these linear regression is 17 DU (October) and 11 DU (November), respectively. Moreover the coefficients of the regression lines on the 100 and 50 mb levels are presented in Table 3, because the aerological data on these surface are easy to get.

Table 2. Coefficients of correlation between total ozone amounts and isobaric air temperature at which the correlation coefficient is highest for each month over the period of 1961 to 1983, and coefficient of the simple and quadratic (November only) regression equations including R.M.S. of the errors.

	Best corr. level (mb)	Correlation coeff.	$\Omega = aT(°C)+b$		R.M.S. error	$y=cT(°C)^2+dT+E$		
			a	b		c	d	E
Sep.	125	0.48	11.97	1197	19			
Oct.	100	0.92	11.29	1087	17			
Nov.	70	0.93	6.75	680	11	−0.0822	−0.618	517
Dec.	40	0.584	6.80	604	14			
Jan.	100	0.71	8.03	662	11			
Feb.	40	0.254	2.21	418	10			
Mar.	50	0.72	5.33	573	12			

6. Scatter Diagrams Except for October and November

For January and March, the values of the best correlation are about 0.7 (Figs. 4c and 4e). For December, the value of the best correlation is about 0.6 (Fig. 4b). For September the value of the coefficients is 0.48 (Fig. 4a). In February the maximum value in the lower stratosphere is 0.25 (Fig. 4d), but for the month the value of coefficient on the 500 mb level is −0.53 (Fig. 5). The scatter diagrams for these months are

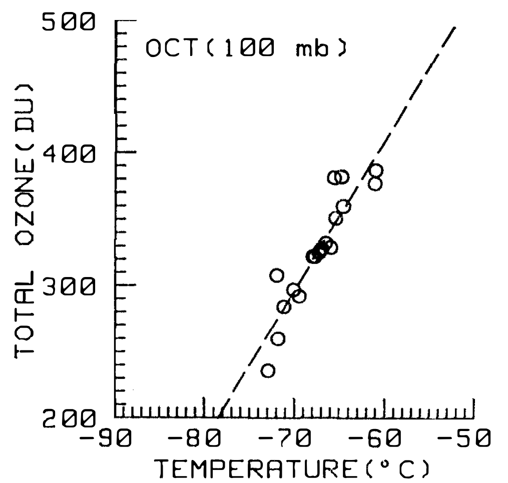

Fig. 3a. Scatter diagram of the monthly mean of the 100-mb temperature and the monthly mean total amount of ozone for October. The broken line shows the simple regression line at Syowa Station (1961–1983).

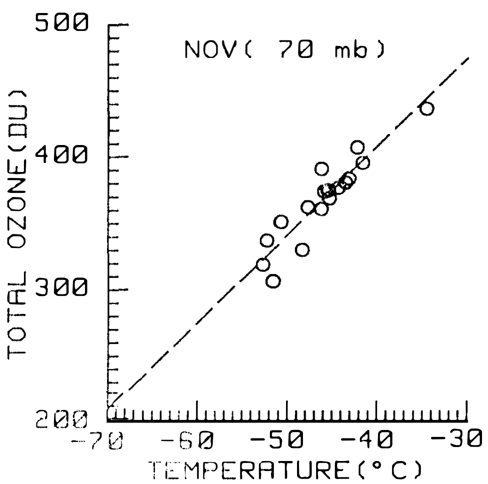

Fig. 3b. As in Fig. 3a except for 70-mb temperature for November.

Table 3. Coefficients of simple regression lines between total ozone and temperature (°C) on 50 and 100 mb isobalic surface at Syowa Station (1961–1983) (total ozone = aT + b).

	100 mb			50 mb		
	(Total ozone) = aT(°C) + b		R.M.S. error	(Total ozone) = aT(°C) + b		R.M.S. error
	a	b		a	b	
Sep.	7.68	883.	19	2.32	476.	20
Oct.	11.29	1087.	17	5.67	675.	22
Nov.	6.31	690.	13	7.32	677.	14
Dec.	7.26	630.	14	6.88	645.	14
Jan.	8.02	661.	11	7.16	604.	12
Feb.	2.21	421.	11	2.54	433.	11
Mar.	6.93	644.	12	5.61	587.	11

shown in Figs. 4a–4e. Regression lines are shown by the broken lines in each figure. In spite of the correlation coefficients for these months being not so large as those for October and for November, the root mean square errors of these regressions are within 15 DU except September.

7. Second Order Regression Curves for November

Figure 6 shows the second order regression curve for November. The coefficients are shown in Table 2. Needless to say, this curve of the second order regression expresses original data better than the curve of the first order.

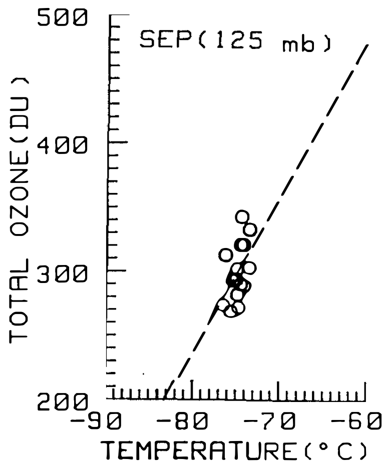

Fig. 4a. Scatter diagram of the monthly mean of 125-mb temperature and the monthly mean of total amount of ozone for September.

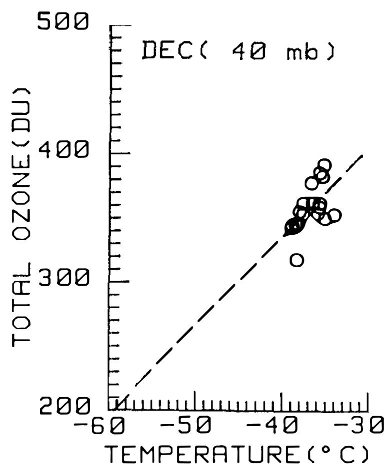

Fig. 4b. As in Fig. 4a except for 40-mb temperature for December.

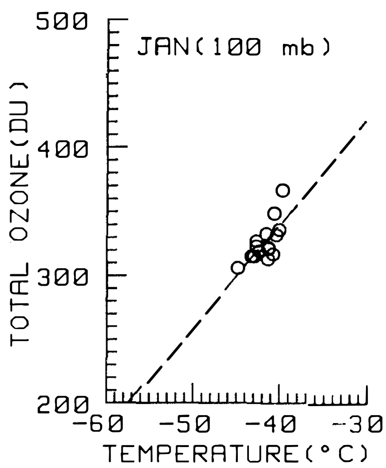

Fig. 4c. As in Fig. 4a except for 100-mb temperature for January.

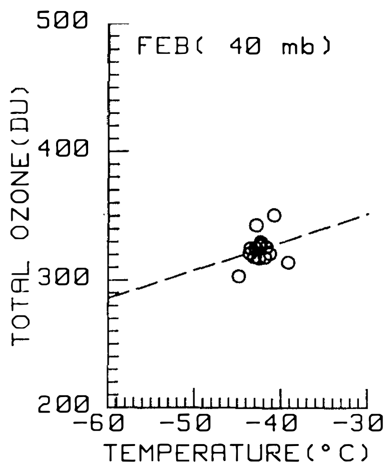

Fig. 4d. As in Fig. 4a except for 40-mb temperature for February.

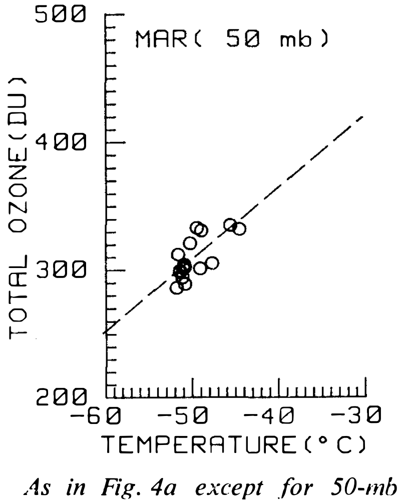

Fig. 4e. As in Fig. 4a except for 50-mb temperature for March.

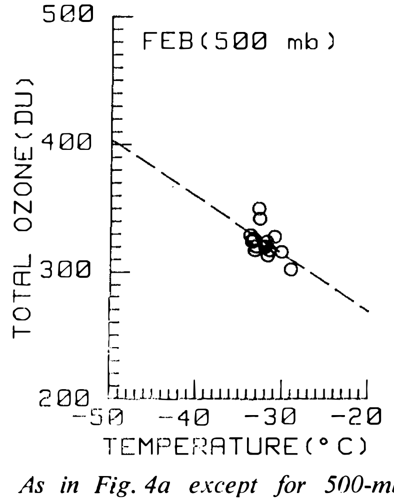

Fig. 5. As in Fig. 4a except for 500-mb temperature for February.

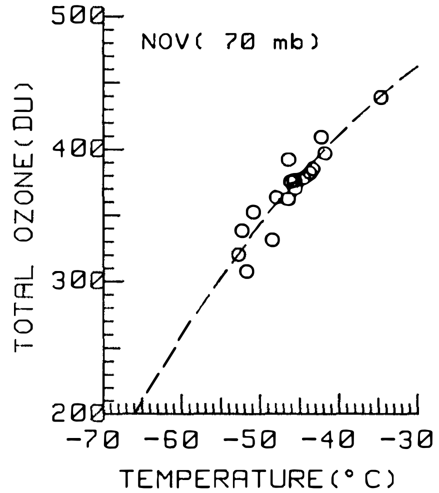

Fig. 6. As in Fig. 3b except for the broken line showing the second order regression curve.

8. Discussion

The very good positive correlation in October and November between the total ozone amounts and the stratospheric temperature at Syowa Station is remarkable. This good correlation should be closely related to the stratospheric warming which is considered to be associated with the increase of total ozone amounts. The sudden increase of total ozone amounts is reported at other Antarctic ozone stations (DOBSON, 1966). The poor correlation in September may have come from the insufficient data of total ozone amounts. The upper atmosphere observation by radiosonde has been carried out on almost all days at Syowa Station. However, the total ozone observation at Syowa Station is started usually from mid September and is not carried out in bad weather. So, the number of days of the total ozone observation in September (shown in Table 4) is not enough for mentioning "monthly mean" in most of the years. On the other hand, the low correlation in February is due to the small standard deviation of both stratospheric temperature and total ozone amounts. For December, January and March, the values of the correlation coefficients are from about 0.6 to about 0.7. For December, January and February, the negative correlation coefficients larger than 0.5 are observed. In these summer months, the stratospheric warmings hardly occur. This may be related to the wave activity of medium scale disturbance as SCHOEBERL and KRUEGER (1983) reported.

Table 4. Number of the days when total ozone amount observations are available in September at Syowa Station (1961–1983) (after JMA, 1984).

Year	1961	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83
Number of observation days	5	23	–	–	9	18	9	3	–	5	6	2	6	8	18	12	9	18	11

9. Summary

The relationship of the stratospheric temperature and the total ozone amounts was discussed on monthly mean basis.

1) The each month, the lower stratospheric temperature and the total ozone amounts show the positive correlation.

2) In October and November, these correlations are extremely good (larger than 0.9).

3) In December, January and March, the correlation coefficients are from about 0.6 to about 0.7. (In December, January and February, negative high correlation coefficients of about 0.5 are observed on the 500 mb level.)

4) We can estimate the monthly mean total amount of ozone within the root mean square error of 20 DU from the stratospheric temperature data by the use of the regression.

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