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Total ozone potential vorticity and tropopause pressure : A comparative analysis over south-east Asia

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सार - अक्तूबर 1982 से सितंबर 1983 तक की अवधि में टी.ओ.एम.एस. के आंकड़ों के आधार पर 20°-50° उ., 90°-160° पू., (दक्षिण-पूर्वी एशिया) तक के क्षेत्र में कुल ओज़ोन, विभव भ्रमिलता और क्षोभसीमा दाब का एक तुलनात्मक विश्लेषण किया गया है। इस अध्ययन में 20°-30° उ., 30°-40° उ. और 40°-50° उ. की तीन विभिन्न अक्षांश पट्टियों पर विचार किया गया है। शरद् ऋतु के अतिरिक्त सभी ऋतुओं में क्षोभ सीमा स्तर के निकट घनिष्ठ सहसंबंधों का पता चला है।

ABSTRACT. On the basis of TOMS data, a comparative analysis of total ozone. potential vorticity and tropopause pressure has been done over the area 20° – 50° N, 90° – 160° E (south-east Asia) for a period October 1982 to September 1983. The study has been done for three different latitude bands 20°–30° N, 30°–40° N and 40°–50° N. High correlations have been found near the tropopause level at all seasons except in autumn.

Key words – Total ozone, Potential vorticity and tropopause pressure.

1. Introduction

The total ozone depends on combined action between photochemical processes, that produce ozone in the upper stratosphere and atmospheric motions that transport ozone into the lower stratosphere where its photochemical life time is very long. The stratosphere can be divided into an upper layer where photochemical processes are much faster than advective processes and in which the ozone concentration is unaffected by transport and a lower layer where photochemical changes are very slow compared to the advection of ozone (Hartman and Garcia, 1979). Due to changes in ozone in the lower stratosphere the primary changes occur in total column ozone.

The correlation between total ozone and potential vorticity (*PV*) on a given θ surface (*i.e.* P_θ) shows the amount of variability in total ozone on that surface.

The discontinuity in *PV* (which separate stratospheric air and tropospheric air) is the tropopause (Reed, 1955; Shapiro, 1978, 1980; Shapiro *et al.*, 1982, Danielsen, 1968, 1985 and Danielsen *et al.*, 1987). This discontinuity separates high values of *PV* in the stratosphere from relatively low values in the troposphere. The surface $P_\theta \sim 1.6*10^{-6}$ K m^2 kg^{-1} s^{-1} is defined as the tropopause forming the boundary between large P_θ in the stratosphere and smaller ones in the troposphere. That reflects for the marked change in $d\theta/dp$ between the two regions, a consequence of P_θ being created by ozone heating in the upper stratosphere and destroyed at the ground.

The change in total ozone near tropopause may be studied by correlating total ozone directly with tropopause pressure.

In an earlier paper (Begum, 1996) an analysis of total ozone, potential vorticity and tropopause pressure was done only for winter. The present article describes the comparison of total ozone, potential vorticity and tropopause pressure throughout the year over south-east Asia (20°-50° N, 90°-160° E) at three different latitude bands (20°- 30° N, 30°-40° N and 40°-50° N).

2. Data used

Daily grided total ozone data for the area 90°-160° E and 20°-50° N were supplied from the TOMS instrument on the Nimbus-7 satellite for the period from October 1982 to September 1983. Zonal and meridional wind components were obtained from global analysis fields

TABLE 1

Correlation coefficients and slopes for March

Latitude range (°)	Days	Tropopause press & Ozone correlations	Slope of tropopause	Correlation between ozone and IPV					Slope of IPV on ozone				
				310K	330K	350K	370K	390K	310K	330K	350K	370K	390K
20-30	1st–5th	0.49	2.33	0.25	0.59	0.71	0.67	0.56	0.00	0.05	0.01	0.08	0.07
	6th–10th	0.83	1.05	0.08	0.57	0.55	0.51	0.38	0.00	0.02	0.05	0.05	0.04
	11th–15th	0.39	1.37	0.10	0.18	0.49	0.59	0.70	0.00	0.01	0.04	0.05	0.05
	16th-20th	0.29	1.63	0.28	0.31	0.57	0.43	0.54	0.00	0.02	0.06	0.04	0.06
	1st-20	0.35	1.12	0.15	0.35	0.44	0.35	0.40	0.00	0.02	0.04	0.03	0.04
30-40	1st-5th	0.43	0.69	0.50	0.62	0.60	0.56	0.61	0.01	0.05	0.05	0.04	0.05
	6th-10th	0.61	0.76	0.59	0.68	0.43	0.50	0.47	0.02	0.05	0.02	0.03	0.03
	11th-15th	0.56	0.48	0.62	0.58	0.42	0.45	0.53	0.02	0.04	0.02	0.02	0.03
	16th-20th	0.31	0.38	0.35	0.50	0.43	0.46	0.55	0.02	0.04	0.02	0.03	0.06
	1st-20th	0.45	0.54	0.50	0.59	0.48	0.51	0.54	0.02	0.04	0.03	0.03	0.04
40-50	1st-5th	0.67	0.75	0.51	0.41	0.32	0.38	0.44	0.03	0.02	0.01	0.01	0.02
	6th-10th	0.48	0.78	0.40	0.27	0.28	0.30	0.46	0.02	0.01	0.01	0.01	0.03
	11th-15th	0.52	0.55	0.54	0.31	0.38	0.42	0.57	0.03	0.01	0.01	0.02	0.03
	16th-20th	0.59	0.63	0.52	0.17	0.35	0.33	0.51	0.03	0.01	0.01	0.01	0.03
	1st-20th	0.52	0.59	0.49	0.30	0.34	0.038	0.53	0.02	0.01	0.01	0.01	0.03

supplied by the European Center for Medium range Weather Forecasts (ECMWF), Reading. From the radiosonde tropopause reports the tropopause level pressure were collected after quality control to remove spurious value.

3. Method of analysis

Statistical method has been used throughout the analysis. The radiosonde stations have been used in this analysis divided into 3 groups according to their latitude 20°-30° N, 30°-40° N and 40°-50° N to see whether the correlations between total ozone and tropopause structure was latitude dependent. The tropopause pressure and potential vorticity values on various isentropic (θ) surfaces have been obtained for each radiosonde station for 0000 UTC on the first 20 days of each month to avoid the huge number of data set which could not be accommodated here. Each correlation coefficient (*r*) was calculated with 500 – 700 points but these are not independent because of spatial and temporal correlations within each ozone and isentropic potential vorticity (IPV) dataset. For each radiosonde station positions total ozone values has been interpolated from grided TOMS data for each day. Within the selected region for each radiosonde station, the tropopause pressure and IPV values on various isentropic surfaces have been calculated. Correlation coefficient have been calculated between total ozone and other parameters. Method of calculation for this analysis is same as it has already been described earlier for winter (Begum, 1996).

4. Result

Correlation coefficients between total ozone and both IPV and tropopause pressure on different isentropic surfaces were calculated statistically for each month. Seasonal variations of the results are as follows.

Winter

In this season due to the mean stratospheric circulation the total amount of ozone increases with the

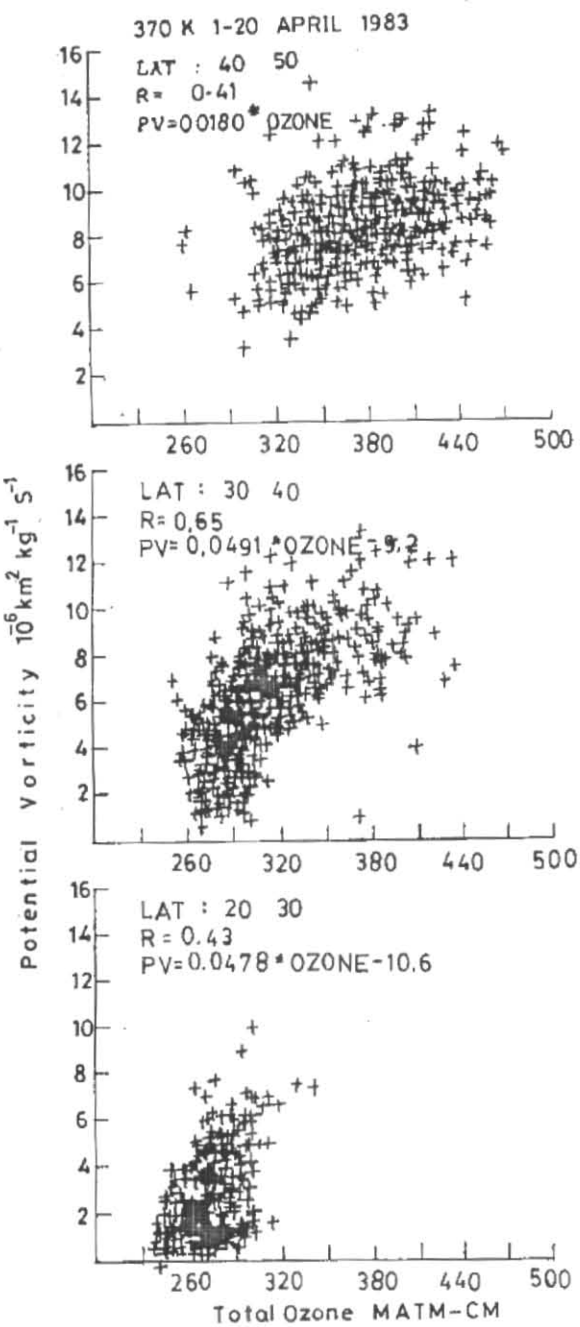

Fig. 1. Correlation coefficients between total ozone and potential vorticity at 370K for three different latitude bands in April 1983

increase of latitude. Higher correlations between total ozone and *PV* were found in February than in December and January but the features were same.

The correlation between total ozone and tropopause pressure gradually increased as the season proceeded in the low latitude band (20°-30° N) and also the slope of regression line of tropopause pressure on total ozone increased. In mid latitude band the mean tropopause pressure and total ozone values were much greater than at lower latitude due to the presence of subtropical jet stream (STJ) near 30° N. As the season was proceeded the correlations between total ozone and tropopause pressure increased but these were markedly lower than the maximum correlation coefficient found between total ozone and *PV* for each month.

For winter (DJF), the analysis of total ozone, isentropic potential vorticity and tropopause pressure has already been described (Begum, 1996) for different latitude bands.

Spring

In the low latitude band the daily range of total ozone was about the same in early spring as it was in winter. The gradient of total ozone was starting to decrease very slowly with the weakening of the STJ from March. But although a strong STJ was present, the correlation coefficient between ozone and IPV dropped unexpectedly in this month. A discrepancy has been observed in March, Because of this the March results were shown here especially to see whether there is any season behind. To study the representativeness of monthly mean value with respect to 5 days mean, a survey of 5 days period was also conducted for this month (Begum, 1989). The statistical results ore shown in Table 1.

In the low latitude band the range of correlation coefficients for the 5 days survey was high. On the whole, correlation coefficient for individual successive 5 days were higher than that for the whole month in this lalitude band.

The range of correlation coefficient for individual 5 day periods are smaller in mid latitude band (30°-40° N) than that was found in the low latitude band (20°-30° N). The correlation coefficient for the whole 20 days were similar to those for individual 5 days.

Although in the high latitude band the amount of total ozone increased with the increasing of latitude, for individual 5 days almost lower correlation coefficients were found than that was found in the mid latitude band. A high value of total ozone was found in this latitude band on 6-10th March which the lowered the correlation coefficients between total ozone and IPV. The variation of correlation coefficients were similar to that found in the mid latitude band and for the whole 20 days, the correlation coefficients were similar to those for individual 5 days in this latitude band.

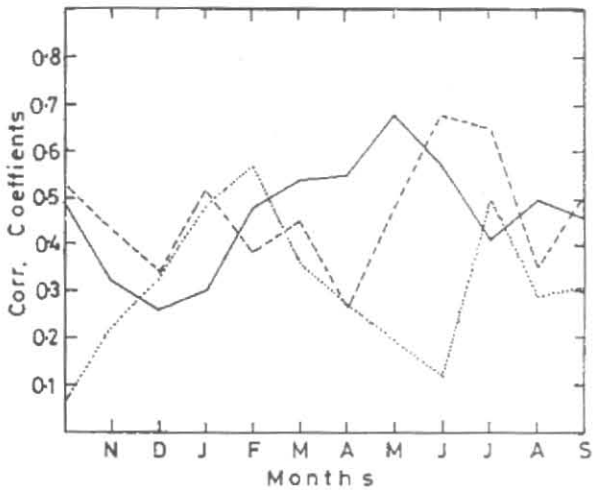

Fig. 2. Correlation coefficients between total ozone and tropopause pressure for each month. Dotted line : 20°-30° N; dashed line: 30°-40° N; solid line: 40°-50° N

The correlation coefficients between total ozone and tropopause pressure were lower than the correlation coefficient with IPV for the low and mid latitude band but in high latitude band it was slightly higher in this month.

In conclusion the 5 days analyses gave values consistent with the 20 days analyses for latitude greater than 30° N, but gave significantly higher correlation for the low latitude band.

At low latitude band the range of *PV* increased from 350 to 370K. Fig.1 shows low correlation with total ozone in April. In mid latitude a high correlation was found at 330K and again at 390K. Although almost all PV's were stratospheric at 330K, the same correlation was observed in the high latitude band.

Very poor correlation coefficients were shown in Fig. 2 between total ozone and tropopause pressure at the two lower latitude bands. A higher correlation was found in the higher latitudinal band in April with the low slope of tropopause pressure on total ozone.

A similar distribution of ozone and IPV was observed at the low latitude hand at the end of spring *i.e.* in May but with lower correlation coefficients. The maximum correlation coefficient was at 330K in the mid and the high latitude bands.

The correlation coefficient between tropopause pressure and total ozone increased with the increase of latitude.

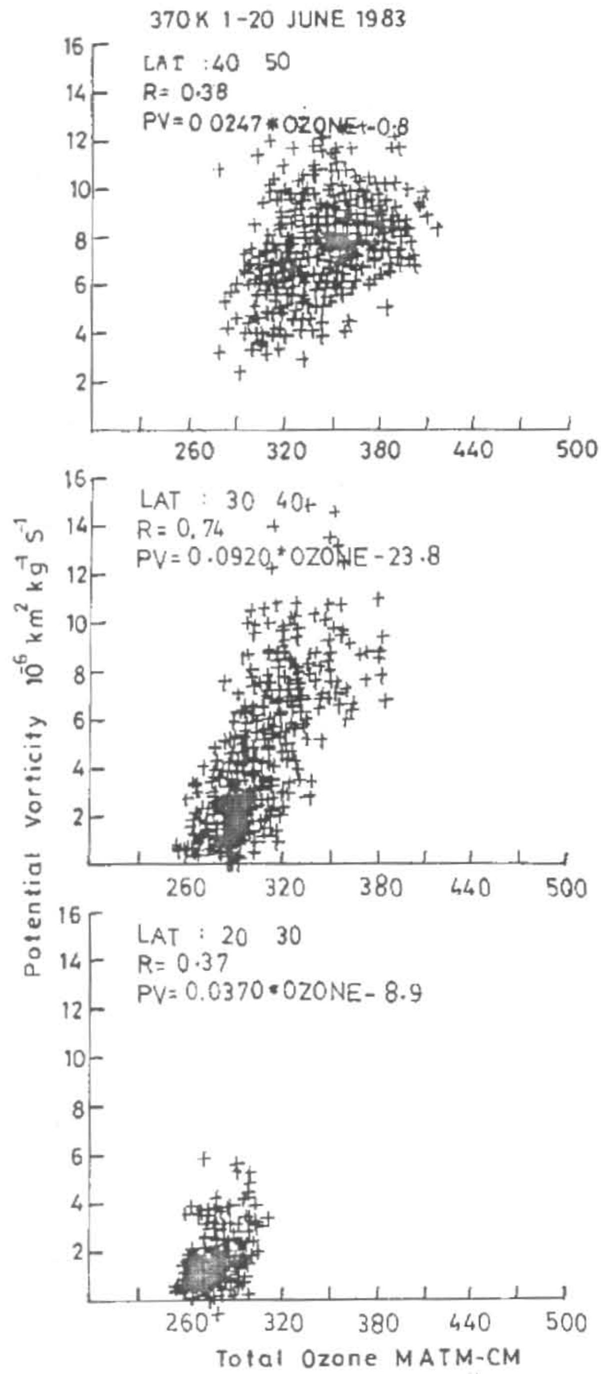

Fig. 3. Same as Fig. 1 for June 1983

Summer

The atmospheric meridional circulation ceases gradually from the beginning of summer (JJA) with the withdrawal of the winter monsoon. The total ozone value decreased and the STJ with lesser strength shifted towards

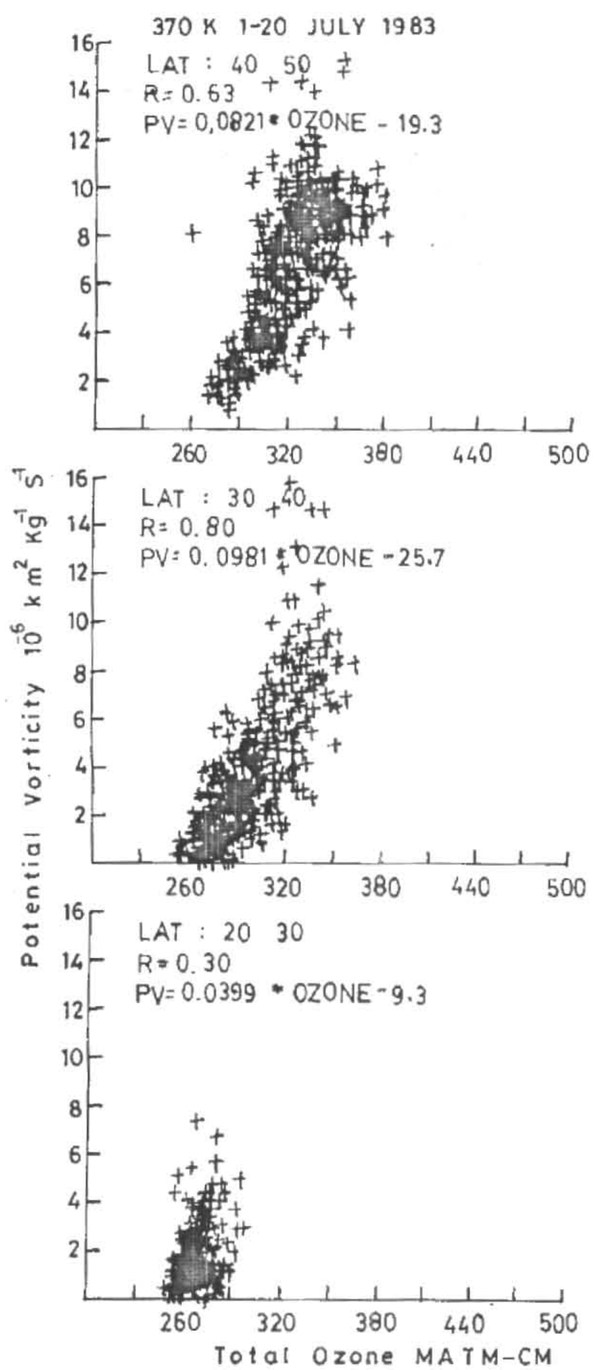

Fig. 4. Same as Fig. 3 for July 1983

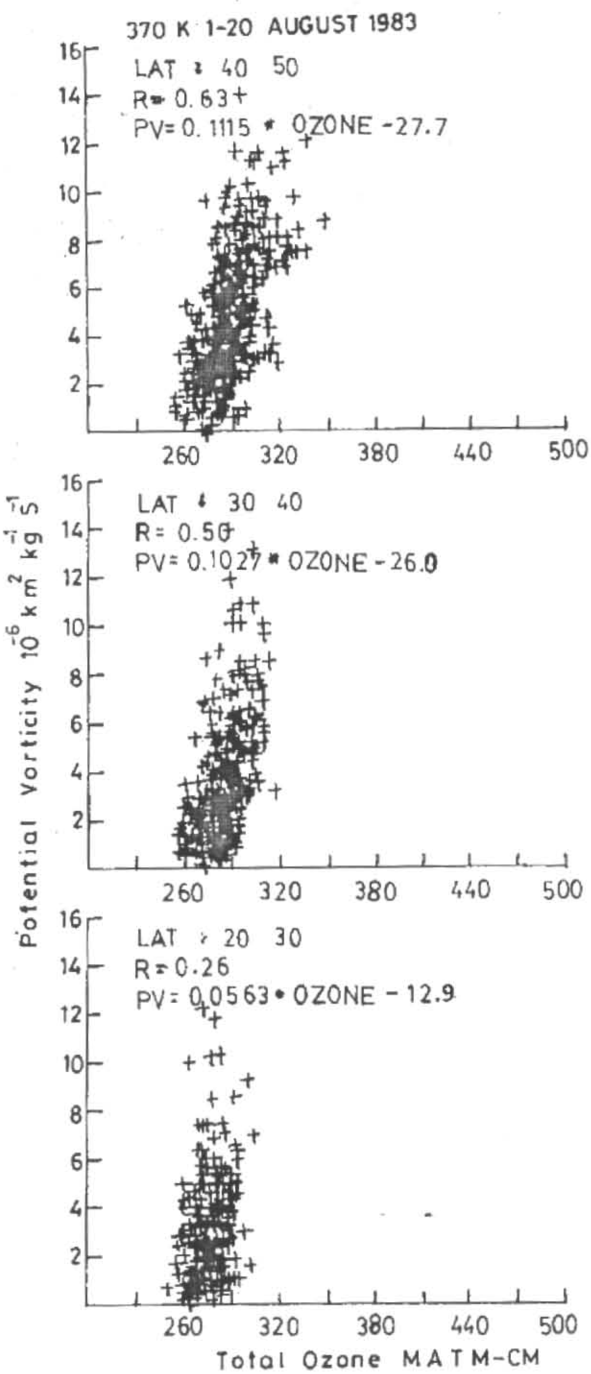

Fig. 5. Same as Fig.1 for August 1983

the north (Begum, 1993). With only 60 DU variation in total ozone and predominantly tropospheric IPV values the correlation coefficient between them was very low in the low latitude band at all θ surfaces (*e.g.* Figs. 3-5 for 370K). Very high correlation was found near tropopause in the mid latitude band where the range of *PV* was very

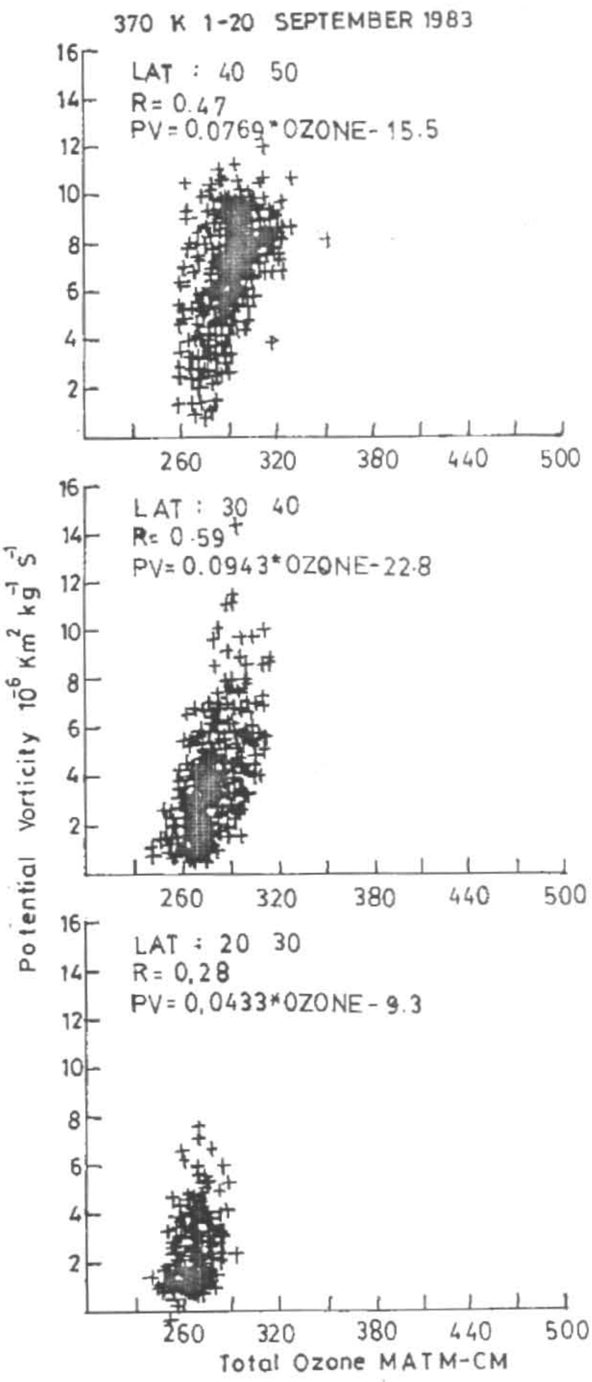

Fig. 6. Same as Fig. 1 for September 1983

high. In this season the correlation between total ozone and tropopause pressure was also high Fig.2. The correlation between total ozone both with IPV and tropopause pressure were found to be lower in the high latitude band than in the mid latitude band, In August the latitudinal gradient of total ozone was nearly flat. In high latitude band, higher correlation coefficients were found between total ozone and both IPV and tropopause pressure, compared to other latitude bands.

Autumn

The jet related to the strength of the tropospheric Hadley circulation and the gradient of ozone occurred as a result of the transport of ozone poleward in the winter stratosphere. From the beginning of this season the latitudinal gradients of total ozone increased slowly due to the retreat of the monsoon The correlation between total ozone and IPV was found to be low in the low latitude band (*e.g.*, Fig. 6). In the mid latitude band high correlation was found near the tropopause as the season proceeded, where the variation of *PV* was high, but in November high correlation was observed at higher surfaces (*i.e.* above tropopause). In the high latitude band, the range of total ozone increased as the season proceeded. The maximum correlation between total ozone and IPV was found at higher surface but in November the values were comparatively low. In autumn the correlation coefficients were lower than those observed in summer.

Very low correlation was seen between total ozone and tropopause pressure at low latitude during this season, but at higher latitude band tropopause pressure increased gradually as the season proceeded. In this season the maximum correlation between total ozone and tropopause pressure was found in the mid latitude band rather than other two latitude bands.

5. Discussion of the results

On the whole, for almost all months the correlation coefficient between total ozone and IPV was higher than that with tropopause pressure, except in July in the mid latitude band and in spring in the higher latitude band.

In the low latitude band, a much greater spread of tropopause pressures was found in winter due to the Hadley circulation. In this season, lower tropopause pressures were found equator ward of the jet, and higher tropopause pressure poleward of the jet than was the case in summer. In the lower stratosphere, a greater spread of IPV was also observed and most of them were tropospheric. In summer, charts for both total ozone and IPV were largely featureless in low latitude band, resulting in weak correlation (except in July with tropopause pressure) due to the suppression of the Hadley cell.

The troposphere warms rapidly in spring in the midlatitude band due to absorption of solar radiation by elevated surface, High values of correlation coefficients were found between tropopause pressure and total ozone in early March because the spread of total ozone values was greater than at the end of the month. IPV also showed high correlation with total ozone in early March near the tropopause. As the north-east monsoon weakened in April, the total ozone values decreased and the STJ also weakened. The decrease of ozone is caused by vertical motion in the troposphere and lower stratosphere associated with the Tibetan anticyclone of summer. Reiter and Gao (1982) proposed that a considerable amount of upper tropospheric air is entrained into the lower stratosphere, during early spring *i.e.* above the stability tropopause, although it retains low tropospheric ozone and IPV. This is consistent with the present observation where correlation coefficients with IPV exceed greatly those with tropopause pressure in spring.

The maximum value of the correlation coefficient of total ozone with IPV was smaller from August to December than in other months. During summer the total ozone decreased while the tropopause pressure changed little. According to Schubert and Munteanu (1988) high correlations are due to barotropic disturbances in this season. The least latitudinal gradient of ozone was found in autumn (Begum, 1993) (consistent with Bowman and Krueger, 1985). The lowest layers of the stratosphere are depleted in ozone in this season (Dutsch, 1978), so total ozone is less sensitive to ozone concentration there than it is in spring. Hence lower correlations are to be expected and were observed.

In the high latitude band minimum spread of tropopause pressures was found in winter rather than in summer. High correlation coefficients were seen near the tropopause level at all seasons except in autumn In the midlatitude band the correlation coefficients between ozone and IPV were greater than that observed in the high latitude band. One possible explanation of this is that the latitudinal gradient of ozone was greater in the midlatitude band because of strong STJ but it is also possible that there was greater variability in ozone-mixing ratio above 100 hPa in the high latitude band.

The winter feature is linked to the extension Hadley circulation and STJ as discussed in the article (Begum, 1996). The summer features of the mid latitude band are similar to those of the high latitude band, caused by distortions of the tropopause by mid latitude weather system.

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