Mausam, (1996), 47, 1, 53-58

551.510.534 : 551.511.3 : 551.543 (59)

Analysis of total ozone, potential vorticity and tropopause pressure over southeast Asia during winter

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(*Received 23 December 1994*)

सार — इस शोध-पत्र में संपूर्ण ओजोन और विभव भ्रमिलता का विश्लेषण और शीत काल (दिसम्बर, जनवरी, फरवरी) के दौरान 20°-50° उ०, 90°-160° पू० (दक्षिण-पूर्व एशिया) क्षेत्र पर क्षोभमंडलीय सीमा दाब का विश्लेषण भी किया गया है। यह अध्ययन तीन भिन्न अक्षांशीय पट्टियों 20°-30° उ०, 30°-40° उ० तथा,40°-50° उ० के लिए किया गया है। निम्न अक्षांशीय पट्टी में ओजोन के अधिकतम अक्षांशीय प्रवणता के कारण विभव भ्रमिलता तथा क्षोभमंडलीय सीमा तल के साथ भी उच्च सहसंबंध पाया गया है।

ABSTRACT. This article shows the analysis of total ozone and potential vorticity and also tropopause pressure during winter period (December, January and February) over the area 20°-50°N, 90°-160°E (southeast Asia). This is done for three different latitude bands 20°-30°N, 30°-40°N and 40°-50°N. Due to maximum latitudinal gradient of ozone in the lower latitudinal band, high correlation is found with potential vorticity and also with tropopause level.

Key words — Total ozone, Isentropic potential vorticity, Tropopause.

1. Introduction

The ozone mixing ratio and Ertel's potential vorticity (IPV) are both quasi-conservative tracers in the lower stratosphere (Leovy *et al.* 1985, Clough *et al.* 1985, Reiter 1972, Hartmann 1977, Danielsen 1968, Danielsen *et al.* 1987) and also increase with decreasing pressure upto 10 hPa. Thus, the transport of IPV is to be similar to that of ozone in the lower stratosphere. Herring (1966) showed that IPV is positively correlated with ozone mixing ratio over the longitude extent of North America, and in the stratosphere, the features in the profile of IPV and ozone mixing ratio were shown to be similar on the large scale by Danielsen (1968).

Later studies have confirmed that a strong positive correlation exists between IPV and ozone mixing ratio at all scales in the lower stratosphere. The evidence was discussed by Danielsen (1985).

The changes in the mixing ratio of ozone on isentropic surfaces are wholly contained in the stratosphere and advection of the tropopause along isentropic surfaces linking stratosphere and troposphere. This is equivalent to changing the depth of the stratosphere thus, clearly, altering the total amount of ozone in a vertical column. By looking at the correlation between the total ozone and IPV on an isentropic (θ) surface it is possible to discern how much of the variability in total ozone is contributed by variation in ozone mixing ratio on that surface. It is also possible to study the contribution to the variability in total ozone coming from changes near the tropopause by correlating total ozone directly with tropopause pressure.

In this article correlations between TOMS total ozone and IPV are calculated statistically at three different latitude bands (20°-30°N, 30°-40°N and 40°-50°N) in the region 90°-160°E, 20°-50°N and compared with the correlation with tropopause pressure.

2. Materials used

Daily gridded total ozone data have been supplied from the TOMS instrument on the Nimbus-7 satellite for the period from December 1982 to February 1983 in the region 90°-160°E and 20°-50°N. Wind speeds have been obtained from global analysis fields supplied by the European Centre for Medium Range Weather Forecasts (ECMWF), Reading. Values of tropopause level pressure have been taken from the radiosonde tropopause reports after quality control to remove spurious values.

3. Method of analysis

Statistical method has been used in this article. For each radiosonde station, the tropopause pressure and IPV values on various isentropic (θ) surfaces have been obtained for 0000 UTC on the first 20 days of each month. For each day total ozone has

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been interpolated from gridded TOMS data to the station positions.

TOMS measures near local noon and the nearest synoptic hour to the ozone measurements in the sector 90°-160°E is midnight UTC with a time displacement of 3-6 hours from the Nimbus-7 overpass. Meteorological data for 0000 UTC, therefore, has been used in this comparison. Daily gridded TOMS total ozone are supplied at intervals of 1° in latitude and 1.25° in longitude. Fleig *et al.* (1986) have reported that recent updates of ozone absorption cross-sections in the Huggins bands mean that the TOMS-gridded ozone values supplied for 1982-1983 should be increased by about 6%. This correction has been applied uniformly to the entire data set used here and, therefore, supposed not to affect statistical studies. Wind speeds have been obtained from global analyses supplied by the ECMWF, Reading. These analyses provide fields of zonal and meridional wind components, geopotential height and temperature on the 850, 700, 500, 300, 200 and 100 hPa surfaces. The data are available on a 2.5° × 2.5° latitude-longitude grid. For the results described here, the zonal and meridional wind components at 200 hPa surface at each grid point combined to give a vector wind.

To calculate IPV, the absolute vorticity (on an isentropic surface), $\xi\theta$, and the stability of the atmosphere, $d\theta/dp$, were known. To calculate $\xi\theta$, northward and eastward wind components were, first, linearly interpolated with height at each grid point to the desired isentropic surface and then $\xi\theta$ was determined (as $dv/dx-du/dy$) at each radiosonde position. The ECMWF global analysis fields have sufficient horizontal resolution to determine $\xi\theta$, but lack the vertical resolution for determination of static stability ($d\theta/dp$). $d\theta/dp$ has, therefore, been calculated directly from radiosonde profiles after they had been smoothened to remove perturbations on height scales less than 1 km. The smoothening reduces contamination of the stability values by small scale gravity wave components, although any determination of $d\theta/dp$ relying only on single radiosonde profile cannot guarantee freedom from wave contamination. It is hoped that smoothening will have removed the worst of the contamination.

4. Results

The total variation of ozone in the low latitude band (20°-30°N) has been found to be around 90 DU at the beginning and increased slightly as the season proceeded. Below 330 K, *i.e.*, within the troposphere the variation of PV has also been very small and no relation with total ozone has been found on these surfaces. The variation of PV has increased gradually through the season for higher θ surfaces, giving good correlaltion with total ozone, although most of the PVs are tropospheric at 330 and 350 K. In December, the maximum correlation has been found at 350 K. Although the variation of PV is greater at 370 and 390 K than at lower levels, the correlation coefficients have been decreased. The same features have observed in January and February, but the maximum correlation coefficient has observed at 370 K in February. The slope of regression line of PV on total ozone has increased with increasing θ in December and January but in February, it decreased from 370 K, possibly because of decreasing correlation coefficient.

Due to Hadley circulation in winter the amount of total ozone has increased very rapidly with the increase of latitude. In the mid-latitude band (30°-40°N), the variation of total ozone is much higher (150DU) than at lower latitude. The variation of PV is around 4×10^{-6} $km^2kg^{-1}s^{-1}$ on the lower surfaces, but most of the PV values have remained tropospheric and have showed very poor correlations with total ozone in December. At 330 K the variation of PV has increased to around 10 units and almost all the values are stratospheric, give good correlation with total ozone, same as the next two levels (350 and 370 K). From 370 K, both the correlation coefficient and slope of the regression line have decreased. A greater variation of total ozone has been found in January (*i.e.,* around 180DU) in this latitudinal band and the correlation coefficients with PV are higher than in December.

From Figs. 1-3 it can be concluded that the rate of increase of total ozone variation for this latitudinal band is around 30DU per month in this period. The value of total ozone has increased at the same time as that of the gradient of ozone (Begum 1993). Almost all the PVs are tropospheric at 290 K, showing low correlation coefficient with total ozone. A higher correlaltion coefficient (0.62) has been found at 300 K although most PVs are tropospheric. The correlation coefficient has increased to 0.66 at 310 K but has decreased to 0.58 at 330 K, although the variation of PV is around 11 units and almost all the values are stratospheric. The correlation coefficient has increased slightly at higher θ surfaces. In this latitude band the maximum correlation (0.75) has been found between IPV and total ozone in January at 330 K. Due to the mean stratospheric circulation, the total amount of ozone increases with the increasing of latitude in

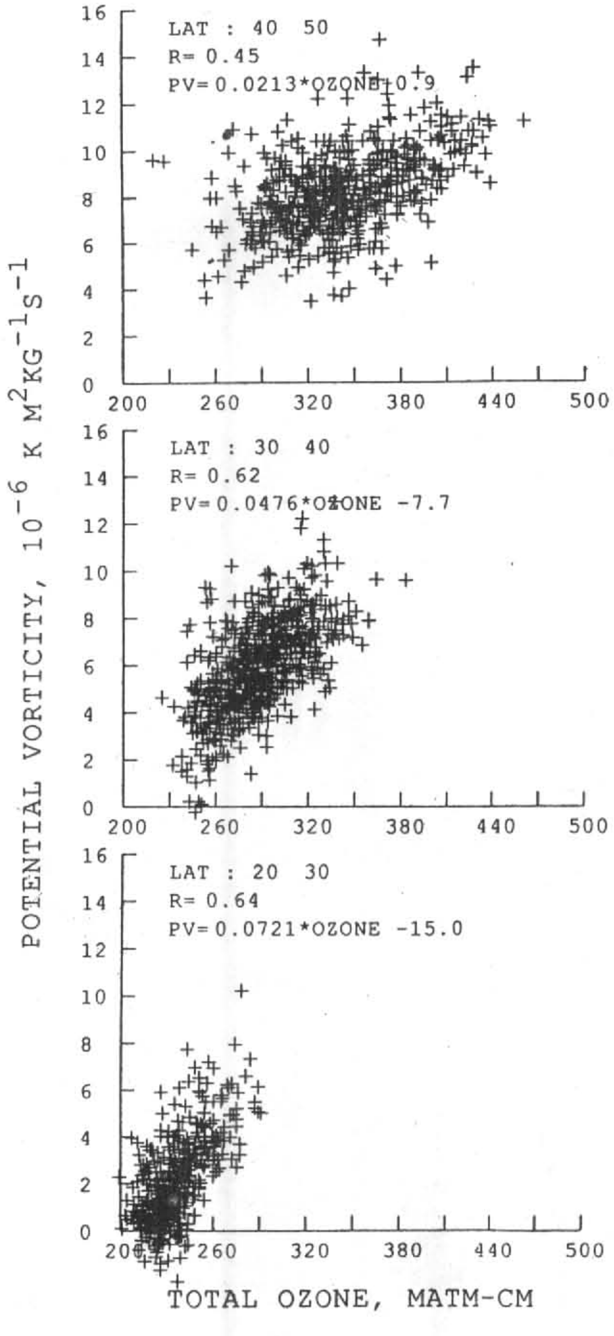

Fig. 1. Correlation coefficients between total ozone and PV at 370 K for three different latitude bands in December 1982

this period. The variation of PV, in December, in the next latitude band (40°-50°N) is around 5 units at 300 K and gives low correlation with total ozone. The variation of PV has increased with height as the surfaces from 330 K upwards are wholly stratospheric. In January, the variation of PV and total ozone has been found higher than in December and shown the same features but with higher correlation coeficients. The maximum value of total ozone is found in February. Higher correlation coefficients have been found in February than in December and January but the features are same.

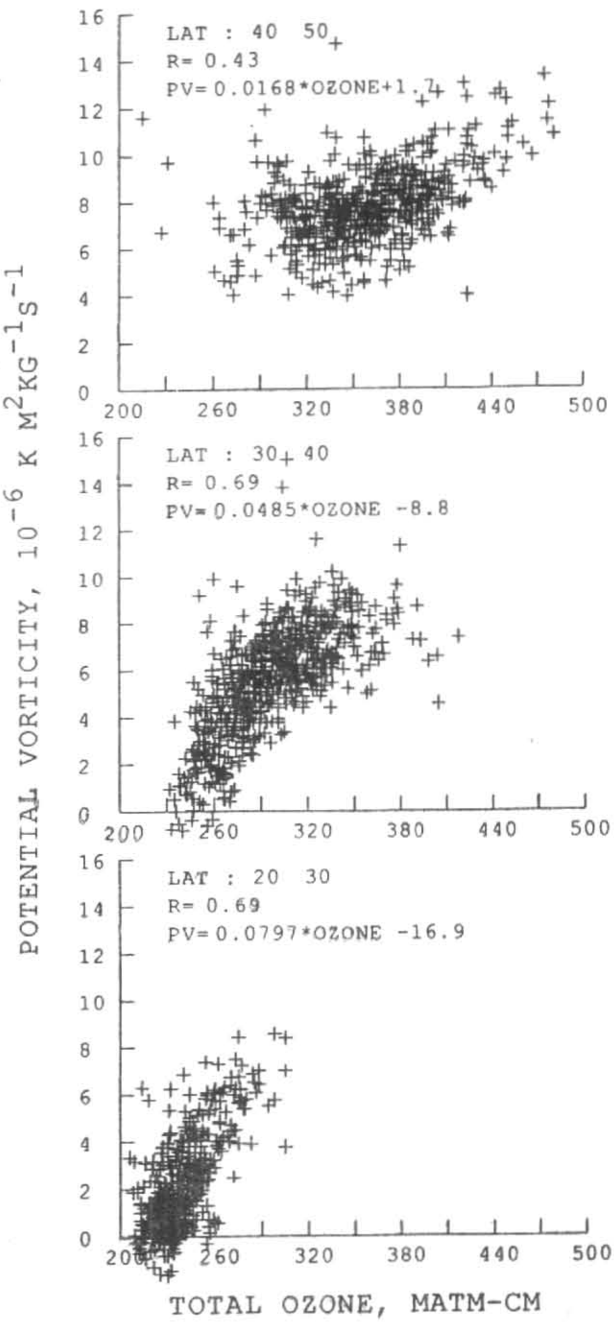

Fig. 2. Same as Fig. 1, for January 1983

The highest correlations are found near the tropopause and also at 390 K.

As the season has proceeded in the low latitude band (20°-30°N) the correlatlion between total ozone and tropopause pressure gradually has increased. Both the mean tropopause pressure and total ozone values are much greater in the mid-latitude band than at lower latitude due to the presence of the STJ near 30°N. The correlation between the two variables has increased as the season proceeded but are markedly lower than the maximum

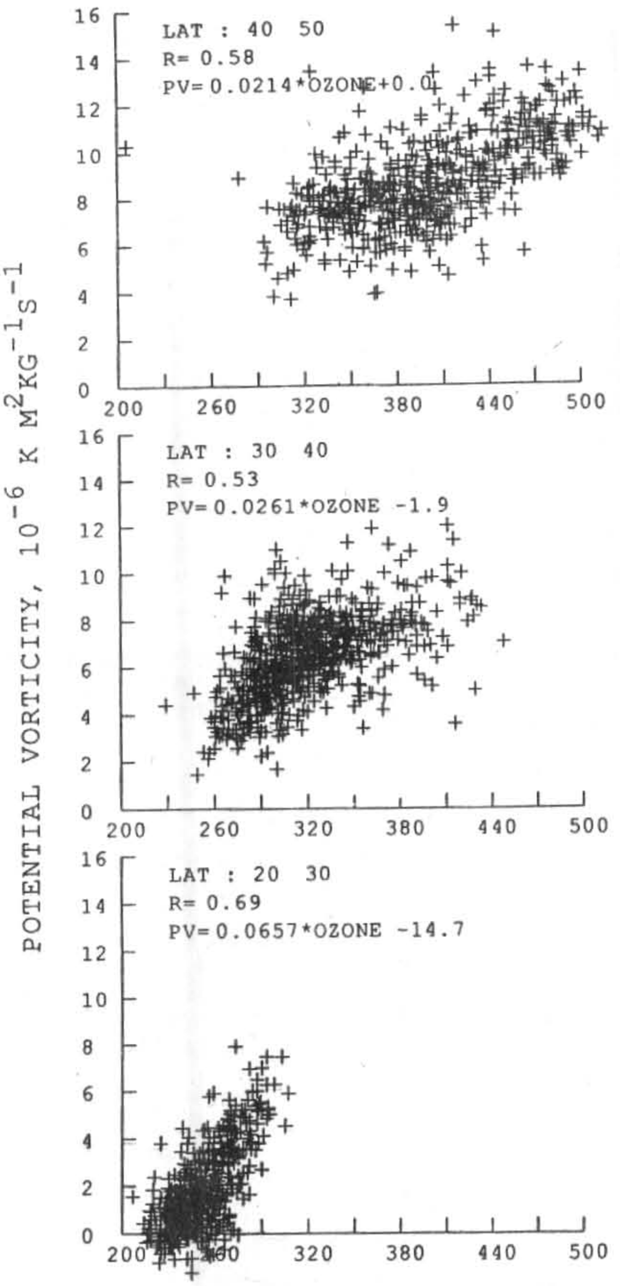

Fig. 3. Same as Fig. 1, for February 1983

correlation coefficients found between total ozone and PV for each month.

5. Discussions of the results

The maximum correlation between total ozone and IPV are much higher than those with tropopause pressure at all latitude bands. In winter, due to Hadley circulation, a much greater spread of tropopause pressure was found in the low latitude band. During this period lower tropopause pressures were found equatorward of the jet and higher tropopause pressure poleward of the jet. In the lower stratosphere, a greater spread of IPV was also observed. On the θ surfaces analysed, most of the IPV values were tropospheric, but the few stratospheric values poleward of the subtropical jet stream (STJ) gave good correlation with total ozone.

In winter, the STJ was strongest with high correlation during this season coinciding with the maximum latitudinal gradient of ozone (Begum 1993).

In the high latitude band the minimum spread of tropopause pressure was found in winter. High correlation coefficients were seen near the tropopause level. The correlation coefficients with IPV were greater in the mid latitude band than in the high latitude band. One possible explanation of this is that the latitudinal gradient of ozone was greater in the mid latitude band because of the strong STJ, but it is also possible that there was greater variability in the ozone mixing ratio above 100 hPa in the high latitude band. High values of 'r' were also observed at the 390 K surface in this band. This may indicate enhanced variability of ozone near the peak of the concentration profile (18-20 km). Radiosonde data were not avialable above 100 hPa and so it was not possible to investigate the spread of IPV values encountered near the peak of the ozone layer.

The feature of the low latitude band is very similar to that of the mid-latitude band and is linked to the extensive Hadley circulation and STJ.

Acknowledgements

The author expresses her grateful thanks to Dr. A. J. Fleig, Dr. A. J. Krueger, the TOMS experiment team, and the World Data Centre-A, Greenbelt, Maryland for supplying TOMS data and the staff of the European Centre for Medium Range Weather Forecasts for supplying meteorological data.

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