N95- 10685

303918

MANIFESTATION OF QUASI-BIENNIAL OSCILLATION IN OZONE VERTICAL DISTRIBUTION

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ABSTRACT

The quasi-biennial oscillations (QBO) in ozone and temperature vertical distributions are studied on the basis of ozonesonde data of 21 stations. Maximum QBO amplitudes in ozone are noted in the 16-20 km layer over Resolute (75N), Aspendale (38S) and in the northern mid-latitude band, but in the 20-24 km layer in the northern subtropical band. In the upper layers the QBO effect is less evident. In the tropospheric layer it is difficult to note the QBO-related effect in all the groups of the data. In all the layers where the QBO effect is noted the positive deviations precede, but the negative deviations follow the time of the maximum of the easterly equatorial wind at 50 mb level. No essential differences in phase or amplitude characteristics of the ozone QBO were noted for the Aspendale data compared with that for the Northern Hemisphere data. The QBO-effect is not noted in the temperature data in the mid-latitudes. Above Resolute and in subtropics the ozone and temperature effects are roughly in phase each with other, except in the 28-32 km layer over subtropics, where they are opposite each to other.

1. INTRODUCTION

There are a lot of studies of the quasi-biennial oscillation (QBO) in total ozone (see e.g. Angell and Korshover, 1983; Hasebe, 1983; Bojkov, 1987; Bowman, 1989, Gruzdev and Mokhov, 1992, and references therein). Less studies deal with the QBO in ozone vertical distribution. Analyzing ozonesonde data, Wilcox et al (1977) calculated the amplitude and phase of 29-month ozone oscillation. Angell and Korshover (1978) analyzed Umkehr data and have noticed the ozone QBO in the 32-46 layer over Australia. Later they (1983) also detected the QBO-related signal both in Umkehr and ozonesonde data for temperate latitudes of the Northern Hemisphere (NH). Bojkov (1987) analysed ozonesonde and Umkehr data of several European stations and has found that the ozone QBO appears in all layers from the ozone maximum up to 28-30 km. Ling and London (1986) have demonstrated the ozone QBO in the 20-27 km layer using satellite (BUV) measurements. Finally, analyzing satellite (SAGE II) measurements, Zawodny and McCormick (1991) have shown the QBO in stratospheric ozone on a global scale.

2. DATA BASE AND METHOD OF ANALYSIS

The present paper deals with the QBO in ozone and temperature vertical distributions derived from ozone soundings. Ozonesonde data of 21 stations for variable periods from 1969-1990 were obtained from archives "Ozone Data for the World". The ozone contents and layer-mean temperature were calculated in seven 4 km-thick layers centered at 6, 10, 14, 18, 22, 26, and 30 km. Then monthly-means were calculated and the long-term annual means for each station were eliminated. The resulting deviations were smoothed by three-month running averaging. The stations were grouped in two latitude bands of the NH (the subtropical band, 10-40N, and the mid-latitude band, 40-60N). Two stations were considered separately: one subpolar station, Resolute (75N), in the NH, and another subtropical station, Aspendale (38S), in the Southern Hemisphere (SH). For these four groups the average QBO deviations are calculated, which are determined as averages of deseasonelysed ozone series around key-0 month, anchored at the months when maxima of easterly equatorial stratospheric wind at 50 mb level were observed.

3. RESULTS OF ANALYSIS

Fig.1 shows the mean ozone deviations around the key-0 month in

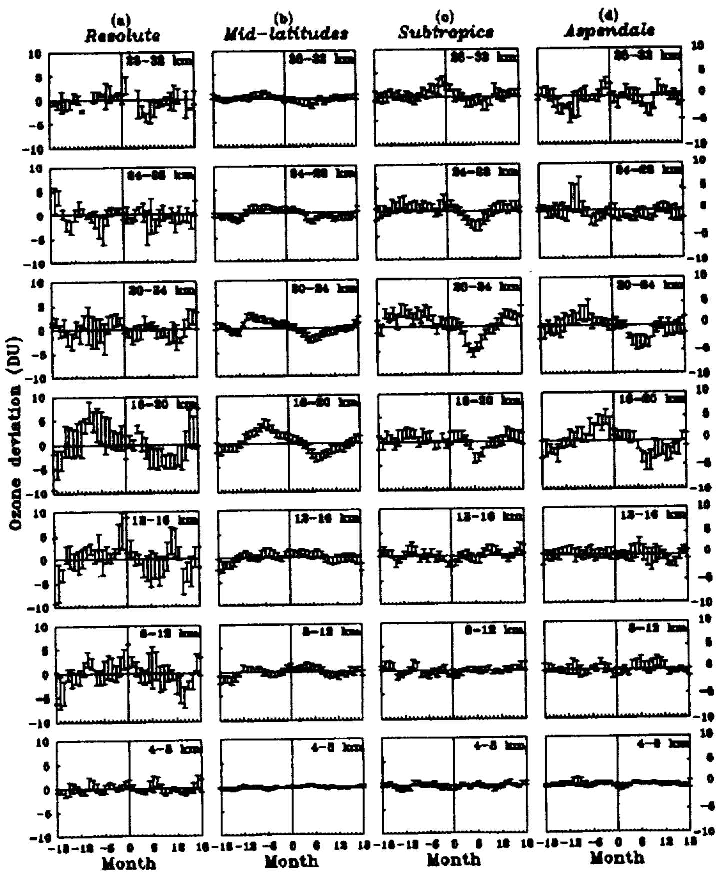

Fig.1. Mean ozone deviations around key-0 month, when maxima of easterly equatorial wind at 50 mb were observed, in layers (from top to bottom) 28-32, 24-28, 20-24, 16-20, 12-16, 8-12, and 4-8 km above (a) Resolute, (b) mid-latitude band, (c) subtropical band, and (d) Aspendale. Vertical segments denote standard deviations.

different layers above Resolute, the NH middle latitudes, NH subtropics and Aspendale. The quasi-biennial effect is most evident in the layers near the maximum ozone concentration level for all the four latitudinal groups of data (in the 16-20 km layer for Resolute and in the two middle layers, 16-20 and 20-24 km, for the three other groups). There the amplitudes of the ozone deviations approach (for the mid-latitude and subtropical bands) and exceed (for Resolute and Aspendale) 3 DU per 4-km thick layer. Note that the height of the maximum deviation decreases with latitude. In the 24-28 km layer, the effect is small (at the mid-latitudes and subtropics) or not evident (above Resolute and Aspendale; above Resolute the effect is not also evident in the lower, 20-24 km, layer). In the upper, 28-32 km, layer the QBO effect is evident in the mid-latitude and subtropical bands. There is also some evidence of the QBO effect in this layer above Resolute and Aspendale. This is surprising because in the lower, 24-28 km, layer the effect is not evident above these stations. In layers lower 16 km the QBO-related effect is not noted in all the groups of the data, although there is a large positive deviation approaching 5 DU near 0-month in the Resolute data (smaller deviation is also seen in the 8-12 km layer). In all the layers where the QBO is noted, for all the four groups of data, the positive deviations precede, but the negative deviations follow the time of the maximum of the easterly equatorial stratospheric wind at 50 mb. Note that there are no essential differences in phase or amplitude of the ozone deviation

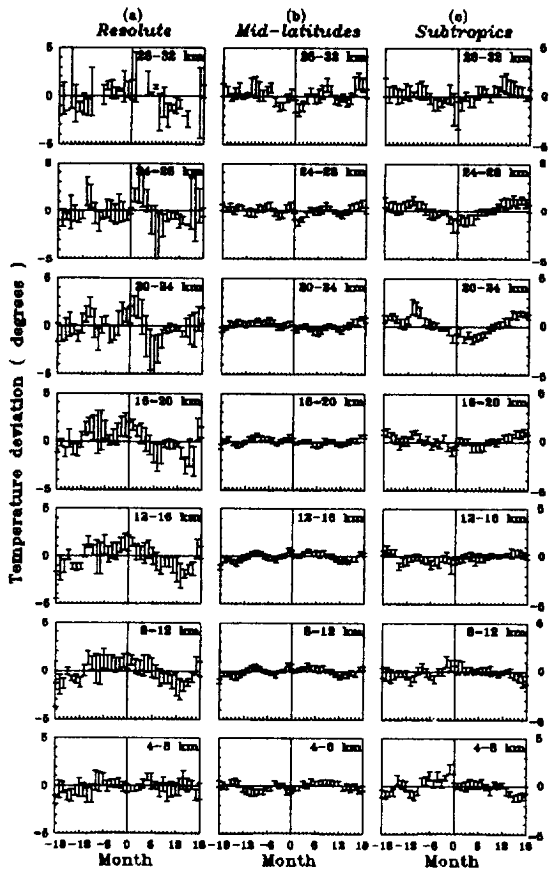

Fig.2. As in Fig.1a,b,c but mean temperature deviations.

between the SH station (Aspendale) and the NH data.

Fig.2 shows the similar deviations of temperature above Resolute, the NH middle latitudes, and NH subtropics (there are no accompanying temperature data for Aspendale). The QBO-related effect in temperature is absent in midlatitudes in all the layers. Above the subtropics it is clearly seen in the stratosphere. At the high NH latitudes (Resolute) the temperature deviations are noted in the two lower-stratospheric, 12-16 and 16-20 km, layers, and, perhaps, also in the 20-24 and 8-12 km layers. In the upper, 28-32 km, layer the negative temperature deviations can only be noted at the time after the 0-month.

The QBO-related ozone and temperature deviations are roughly in phase above Resolute in all the layers where these are seen simultaneously. Above subtropics the ozone and temperature deviations are roughly in phase in the 20-24 km layer, with some phase shift however, but have opposite phases in the 28-32 km layer. In the intermediate, 24-28 km, layer they are roughly $\pi/2$ out of phase.

4. DISCUSSION

The ozone QBO in the equatorial stratosphere is well known to be the result of the QBO-induced meridional circulation, so that downward (upward) motion during the westerly (easterly) phase of the equatorial stratospheric zonal wind results in the ozone increase (decrease) in the lower and middle stratosphere above the equator (Reed, 1964; Ling and London, 1986). The return branches of the QBO-induced circulation in the tropics have the opposite vertical direction to that at the equator (Reed, 1964), thus resulting in the opposite ozone anomalies in the tropics compared with the anomaly above the equator.

To explain the extratropical QBO, several possible mechanisms have been proposed. First, it may be due to advection of the upper-stratosphere equatorial ozone anomaly (which is of opposite sign to the lower-stratosphere anomaly) by the meridional stratospheric circulation (Holton, 1989). Another mechanism is the transport of the tropical ozone anomaly to higher latitudes by the climatological mean and eddy circulation (Gray and Pyle, 1989). Holton and Tan (1980, 1982) suggested that the zonal wind QBO modulates extratropical planetary wave activity in winters. Such mechanism could effect ozone not only in middle but also in high latitudes.

Fig.1 shows the ozone QBO in extratropical latitudes. The results obtained are in qualitative agreement with the results overviewed in Introduction and with some results of model considerations by Ling and London (1986) and Gray and Pyle (1989). The QBOs in all the four latitudinal groups in Fig.1 are out of phase with the equatorial QBO in total ozone shown by Bowman (1989), and, therefore, they should be in phase with the tropical ozone QBO. The mechanism of the extratropical QBO in Fig.1 cannot be point out here, because this question needs more careful and detailed consideration.

The decrease of the height of the maximum QBO effect in Fig.1 with latitude can be understood, if one takes into account that the maximum in ozone vertical distribution decreases with latitude. QBO-related vertical or/and horizontal motions should cause the largest ozone variations in the domain of large vertical or/and horizontal ozone gradients, i.e. below the maximum in ozone mixing ratio profile. The latitudinal decrease of height of the maximum ozone QBO has also been noted by Zawodny and McCormick (1991).

Small or absent QBO-related effects in the upper panels in Fig.1 agree well with the results of analysis by Zawodny and McCormick (1991) and with the theoretical consideration by Ling and London (1986). Ozone-temperature phase relationship above subtropics is in qualitative agreement with the Ling and London (1986) results.

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