doi: 10.22564/rbgf.v11i2.1149

# TOTAL OZONE TRENDS IN THE SOUTHERN HEMISPHERE - AN UPDATE

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The largest variation of total ozone is the seasonal variation, which, at middle latitudes, can be as large as 30% decrease from spring to autumn. The next important variation is the Quasi-biennial oscillation which is irregular and can have a range of 0-10%. The long-term variation (decrease) is comparatively small, only about 2-3% from 1980 onwards up to 1987, after which a rising tendency is indicated, data inaccuracies notwithstanding. As a health hazard, the seasonal variation would be most dangerous, specially from spring to summer, during 10 AM to 3 PM.

**TENDÊNCIAS DO OZÔNIO TOTAL NO HEMISFÉRIO SUL - UMA ATUALIZAÇÃO** *A maior variação do ozônio total é a sazonal, a qual, em latitudes médias, pode alcançar uma queda de até 30% da primavera até o outono. A segunda variação mais importante é a oscilação Quasi-bienal, que é irregular e pode variar de 0-10%. A variação a longo prazo (queda) é comparativamente pequena, somente cerca de 2-3%, de 1980 até 1987, após o que foi indicada uma tendência de ascensão até o presente, apesar da inexatidão de dados. Como um risco à saúde, a variação sazonal é mais perigosa, especialmente da primavera ao verão, das 10 às 15 horas.*

## INTRODUCTION

The daily means of atmospheric total ozone, as measured by Dobson Spectrophotometers, show many types of variations. The day-to-day variations probably have periodicities of 5-15 days, but the variations are mostly irregular. During the last decade, the Antarctic ozone level in October seems to be abnormally low, giving rise to the popular term Antarctic Ozone hole (Farman et al., 1985; Chubachi and Kajiwara, 1986; Komhyr et al., 1986; Bojkov, 1986a,b). In this note, we examine the total ozone variations at several latitudes in the southern hemisphere. Results up to 1985 were reported in earlier publications (Sahai et al., 1982; Kane et al., 1984/85; Kane, 1988).

## SEASONAL CHANGES

The Dobson spectrophotometer data used here were obtained from "Ozone Data for the World", published by World Ozone Data Centre (WODC), Canada. Fig. 1 shows a plot of the monthly mean values at several locations. The top plot is for South Pole and Syowa in the Antarctic region. The most spectacular variation is the seasonal variation, with minima in October and maxima in December. Till 1983, the October minima were at about 250 D.U. However, since then, the October values have dropped considerably, to about 150 D.U. A similar pattern is seen at Syowa. At Buenos Aires (35°S), the minimum level was during Jan-April, but seems to have shifted to May-June during 1985-88 and there was a reduction of about 5% in this interval, but a recovery seems to have started thereafter. At still lower latitudes, viz. Cachoeira Paulista, Natal and Huancayo, the changes are smaller. The lower part of Fig.1 shows plots for some locations in the northern hemisphere at longitudes similar to South-American continent. Whereas the seasonal variation is very conspicuous, there are no striking long-term changes nor any similarity with the Antarctic ozone hole.

Fig. 2 shows a plot of the average seasonal variation at some locations. For northern hemisphere (left half), the seasonal variation has a maximum in about March (spring) and a minimum in about September (autumn). The amplitudes are large (range 100 D.U. or about 30%) at high latitudes and small (10-20%) at lower latitudes. For southern hemisphere (right half), the maxima are near October (again, local spring) and the minima are near March (local autumn). For middle and higher latitudes, the reduction from October to December could be as large as 20% and would have serious health implications, as discussed further. It should be noted that this is a truly seasonal variation which has nothing to do with the Antarctic ozone hole.

## YEAR-TO-YEAR VARIABILITY

To bring out variations of longer periods, the seasonal variation has to be eliminated. Usually, this is done by the anomaly method, i.e., by evaluating an average seasonal variation (e.g. the ones illustrated in Fig. 2) and subtracting these from the monthly values of each year. Since the annual wave may change amplitude from year to year, this method leaves undesirable residues. Instead, we prefer the method of running means over 12 consecutive monthly values, though, this way, amplitudes of periodicities near 1 year (2-3 years) get reduced. But this defect is compensated by the smoothness of the resulting values.

Fig. 3 shows a plot of the 12-month running means plotted 6 months apart. The top plot (Row 1) shows sunspot cycles 19, 20, 21 and 22 and the vertical lines mark sunspot minima. Volcanic eruptions of Agung, Fuego and El Chichon are marked with triangles. Row 2 represents S. Pole ozone. Values for winter are generally missing and are manipulated as shown by the dashed lines in Fig. 1 (a). Hence the reliability is diminished. But, wavy structures indicating Quasi-biennial (QBO) and Quasi-triennial (QTO) oscillations are seen. The thick line represents 3-year running averages and shows about 10% decrease from 1968 to 1980, a further decrease of about 10-15% from 1980 to 1986, and a **steady level thereafter**. Relationship with sunspot cycle is obscured by these long-term changes at the South Pole.

Fig. 3, Row 3 shows plots for MacQuaire Island (54°S, 159°E). Surprisingly, apart from a QBO, the level was constant at about 340 D.U., except for the rise to about 360 D.U. in 1980 at the sunspot cycle maximum. Thus, no parallelism with S. Pole ozone is indicated. At Hobart (42°S, 147°E, Row 4), data for 1984-89 do not show any downtrend. At Aspendale-Melbourne (38°S, 145°E, Row 4), apart from a QBO, the level dropped by about 3% from 1964 to 1975, rose by about 3% in the next 2-3 years, showing a maximum around 1980 (sunspot maximum) and declined thereafter by about 3% up to 1989. At Buenos Aires (35°S, 58°W, Row 6), the pattern is roughly similar to that at Melbourne, except that from 1986 onwards, there is a generally **rising** tendency, so that the 1988 level is higher than that of 1970-74. At Brisbane (27°S, 153°E, Row 7), from a low level in 1961-62, the level rose by about 2-3% up to 1966 and thereafter, was within 1-2% of the same up to 1977.

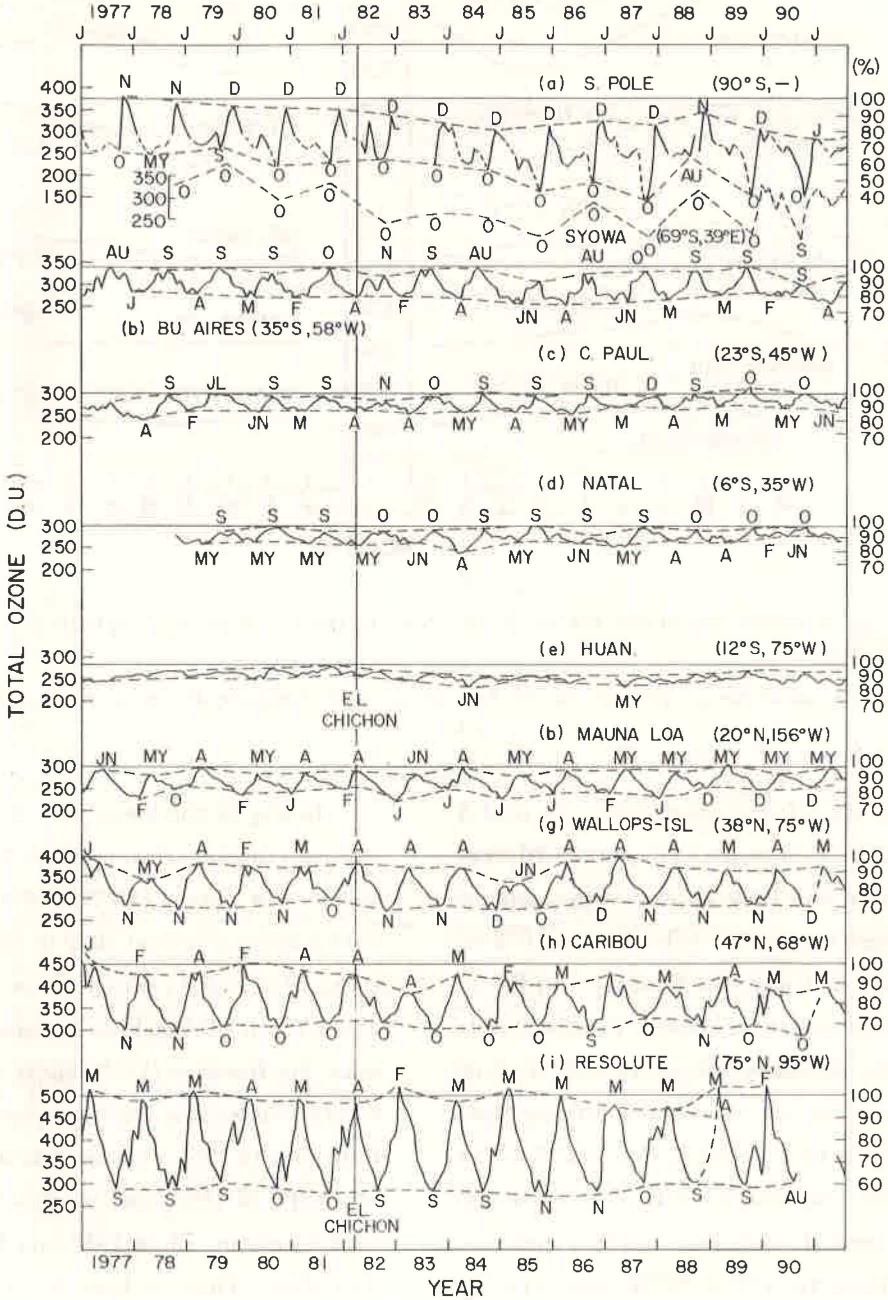


**Figure 1**. Montly mean values of total ozone at various locations.

*Valores médios mensais do ozônio total em vários locais.*

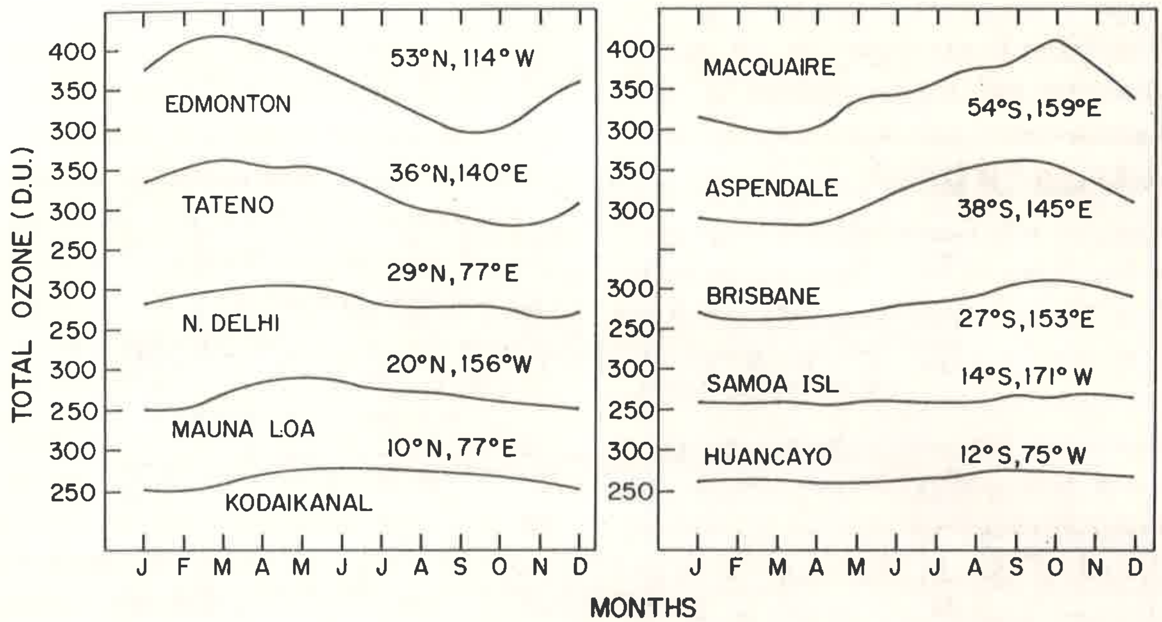


**Figure 2**. Average seasonal variations for some locations in the northern hemisphere (left half) and southern hemisphere (right half).

*Variações sazonais médias para alguns locais no hemifério norte (metade da esquerda) e hemisfério sul (metade da direita).*

Thereafter, there was a fall of about 5% in the next 5 years (up to 1982), which seems to have **steadily recuperated**, so that the 1989-90 level is the same as that of 1977. There is no solar cycle effect in 1979-80 (solar maximum). At Cachoeira Paulista also (23°S, 45°W, Row 8), a similar rising tendency is discernible from 1985 to 1989. At Santa Helena (16°S, 6°W, Row 9), the level was constant or **slightly rising** from 1978 to 1987. At Samoa Island (14°S, 171°W, Row 10), the level was constant from 1977 to 1984, fell by 2-3% in the next 3 years (up to 1987) and rose thereafter. At Huancayo (12°S, 75°W, Row 11), the level was almost constant from 1966 to 1982 (within ± 2%), fell sharply by about 5% up to 1985 and from 1987 onwards there is a **rising** tendency. At Natal (6°S, 35°W, Row 12), apart from a QBO, there was a steady level from 1980 to 1987 and a **rising trend** thereafter. At Mahe (5°S, 56°E, Row 13), after a high level in 1980, the level fell by about 2% by 1986 and **a rising trend** is seen thereafter.

In Fig. 3, the lower part shows plots for two locations (chosen arbitrarily) in the **northern** hemisphere. For Tateno (36°N, 140°E, Row 14), the level fell by about 2% from 1962 to 1965, remained steady up to 1979, rose by about 2% in 1982-83, fell back by about 2% in 1984 and has remained at that level up to date. For Resolute (74°N, 95°W, Row 15), apart from a very conspicuous QBO, the level rose by about 5% from 1960 to 1965, remained steady up to 1973, fell by about 5% in 1977, rose by about 2% in 1978-80, fell back by about 2% in 1982 and has remained steady thereafter. Thus, at least for these two locations in the northern hemisphere, there was no decrease connected with the Antarctic ozone hole.

All the trends illustrated above cannot be taken completely on their face value. The International Ozone Trends Panel Report (UNEP-WMO, 1989) had concluded that the Dobson data were not adequate to determine trends in tropics, subtropics or

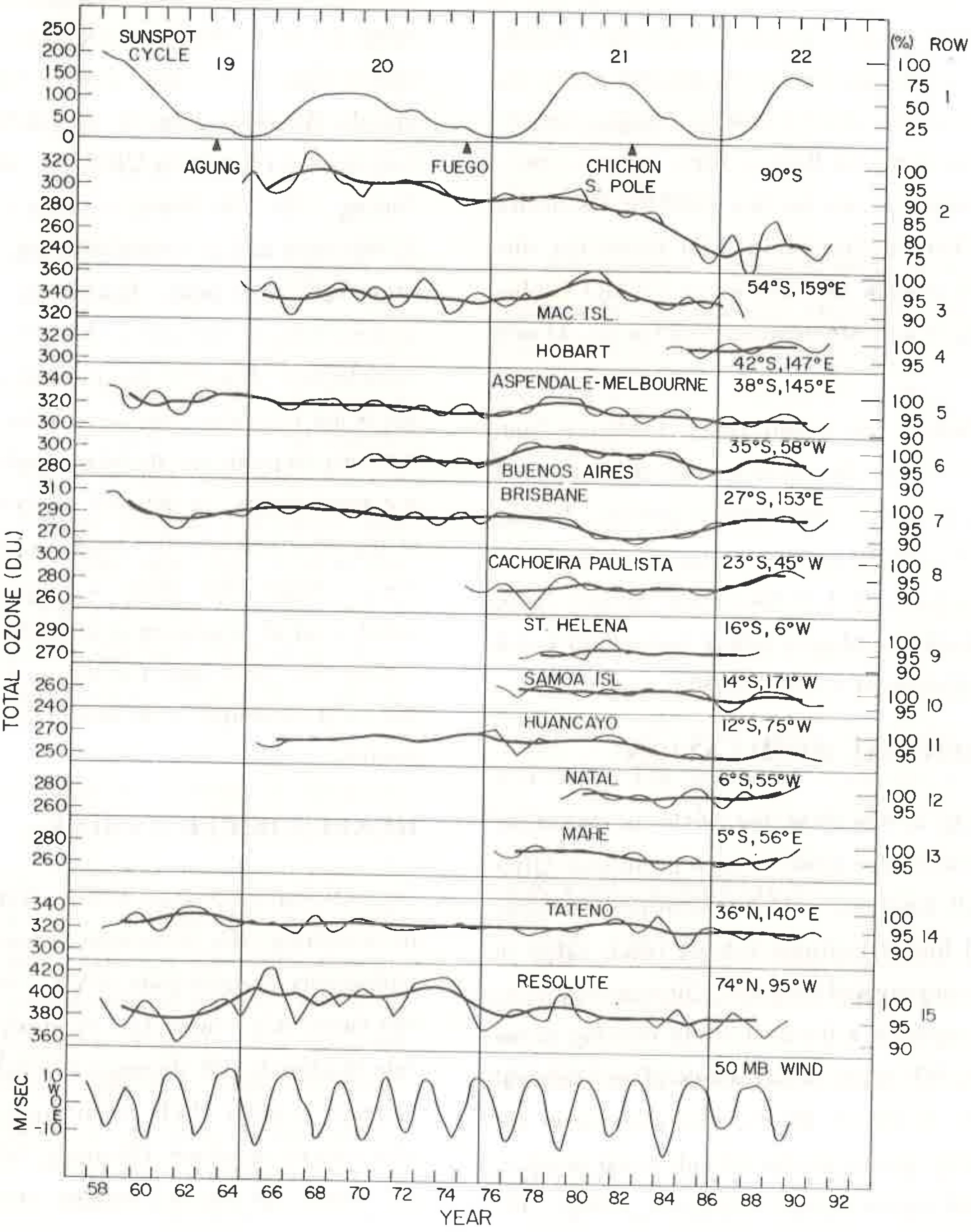


**Figure 3**. 12-monthly running means for sunspot (Row 1), for total ozone at various locations (Rows 1-15) and for 50 mb equatorial zonal wind (Row 16). Vertical lines mark sunspot minima. Thick lines are 3-year running averages.

*Médias corridas de 12 meses para número de manchas solares (linha 1) e para vento zonal equatorial de 50 mb (linha 16). Linhas verticais marcam o mínimo de manchas solares. Linhas grossas são médias corridas de 3 anos.*

Southern Hemisphere. Since then, Bojkov et al. (1988) made a comparison between ground-based and Total Ozone Mapping Spectrometer (TOMS) data on Nimbus 7 satellite and identified more than 20 stations having excess variability and another dozen having long-term drifts and/or sudden changes, e.g., erroneous rising trend for Buenos Aires, jump in early 1985 for Brisbane, jump in late 1980 for Cachoeira Paulista, a sharp decline in 1982 for Huancayo, discrepancies at Mauna Loa and so on (WMO Global Ozone Research and Monitoring Projects no. 24 and 25, 1991).

Nevertheless, the recent rising tendency from 1987 onwards at some locations may be at least partly genuine and should be investigated further. In any case, there seem to be no decreasing trends at lower latitudes. Using revised Dobson data, Bojkov et al. (1990) obtained for Mauna Loa a very small trend (-0.73 $\pm$ 0.52/decade) for 1958-1986.

## QUASI-BIENNIAL OSCILLATION

From Fig. 3, it is clear that, if the annual variation is eliminated, the residues show prominent QBO at almost all locations. The magnitudes (ranges) are larger at higher latitudes (about 10%). QBO in ozone has been reported long ago. Oltmans and London (1982) reported a detailed study relating ozone QBO with QBO in the zonal winds of the tropical stratosphere. In Fig. 3, the bottom plot shows 12-month running means of the 50 mb zonal wind in the equatorial region (Venne and Dartt, 1990). Oltmans and London (1982) reported that the QBO period decreased from about 27 months at the equator to about 24 months at mid-latitudes. Using TOMS data on Nimbus 7 satellite, Bowman (1989) reported global patterns of QBO in ozone and stated that at equator, QBO of ozone and zonal wind were well-correlated. In Fig. 3, Huancayo ozone does not show any worthwhile QBO. Bowman reported that large negative correlations extended to the poles in both winter hemispheres. For the South Pole station, besides the hole effect, some QBO effect can be seen, but it is very irregular (Garcia and Solomon, 1987). There seems to be no similarity between QBOs of Row 2 (South Pole ozone) and Row 15 (50 mb wind). Similarly, Resolute (Row 15, almost North Pole) ozone does show a prominent QBO, but also very irregular. During 1959-1980, Resolute ozone had 8 peaks, while 50 mb wind had 10 peaks! During 1981-85, Resolute ozone QBO was weak. Thus, away from the equator and specially at the poles, the QBO situation is very complicated. However, the purpose of the present paper is not to discuss the finer characteristics of QBO, but only to point out its large magnitude (10%) during some cycles. A detailed analysis of ozone QBO is reported recently by Zerefos et al. (1992) using revised ozone data, where a comparison with 50 mb zonal wind at Singapore is presented. Both Bowman (1989) and Gary and Dunkerton (1990) claim that the local seasonal cycle modulates the QBO considerably.

## HEALTH IMPLICATIONS

Atmospheric ozone serves a very useful purpose by absorbing solar ultraviolet radiation, specially the biologically harmful part (UVB, 190-330 nm), which can cause skin cancer and vegetation damage. As a rule of thumb, 1% decrease in ozone can cause 2% increase in solar UVB, resulting in 4% increase in skin cancer incidence (Mintzis, 1986). The effects are smaller at higher latitudes and smaller in winter as compared to summer, mainly because of lower solar elevations (Dahlback et al., 1989). Nevertheless, 5-10% decreases in ozone are expected to cause at least 10-20% increase in skin cancer, specially on Caucasian skins. Hence the ozone variations illustrated above would have the following implications for skin cancer incidence.

The seasonal variation is, by far, the largest ozone variation. In middle and high latitudes, ozone can decrease from spring to summer (and further up to autumn) by about 30% (Fig. 2). Since the solar elevation is also increasing from spring to summer, the UVB radiation would increase considerably and more than 50% increase in skin cancer incidence can be expected. This is a routine natural seasonal effect, not connected with long-term ozone depletions or the Antarctic ozone level. Hence, sunburns in summer are a permanent hazard. It was so in the past and is so at present and will remain so in the future.

If seasonal variations of ozone are ignored, the next largest effect is the QBO. As seen in Fig. 3, this oscillation is very irregular. The range can be anything from 0 to 10%. As such, in some years, the skin cancer incidence may be up to 20% larger than that in the previous and/or next year. This is also a natural variation, beyond human control. If ozone observations are quickly available (within months), the effect could be predicted and suitable warnings issued.

The long-term variation of ozone is comparatively small. Except in the Antarctic region and that too in October-November, the variations elsewhere have a solar cycle component of about 2%, again beyond human control. The residual long-term variations are not similar at different locations. Since the solar maximum of 1980, some locations have shown a 2-3% decrease up to 1986-87. Thereafter, some of these locations seem to indicate recovering tendencies. The Antarctic ozone hole is expected to be caused by CFC compounds (Anderson et al., 1989), mostly originating from human activities (sprays, etc.). It is assumed that the 2-3% decrease in lower latitudes in recent years is also due to CFC compounds and the Montreal agreement has recommended a complete ban on the production of these compounds. It is interesting to note, however, that the present low levels at some locations are roughly the same as in 1960-61, when CFC compounds were not important. Also, the recent ozone recovery in some locations indicates causes unrelated to CFC compounds. In any case, the 2-3% ozone decrease in the last decade could cause only about 8-12% increase in skin cancer incidence, much less than the effects due to natural seasonal variations and QBO, as mentioned above.

## CONCLUSIONS

Among the variations of total ozone, the largest seems to be the seasonal variation. At middle latitudes, the decrease can be as large as 30%, from spring to autumn. For deseasonalised values, the largest variation is the Quasi-biennial Oscillation, which could be 0-10%. The long-term variations are much smaller, only about 2-3%, except in the Antarctic region, where decreases as large as 20-30% have occurred since 1980 up to date. Since ozone decreases lead to solar UVB increases, which can cause skin cancer, the seasonal variation is a source of permanent danger, specially from spring to summer and during 10 AM to 3 PM, when sun is highest up in the sky. QBO is also a source of danger every 2-3 years.

## ACKNOWLEDGEMENTS

This work was partially supported by FNDCT Brazil under contract FINEP 5373 CT.

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Submetido em 09.03.93
Revisado em 06.05.93
Aceito em 07.05.93
Editor responsável V.W.J.H. Kirchhoff

| Palavras chave | Key words |
| --- | --- |
| Ozônio | Ozone |
| Tendências de ozônio | Ozone trends |
| Variações de ozônio | Ozone variations |