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THE BRAZILIAN NETWORK OF STRATOSPHERIC OZONE MONITORS: OBSERVATIONS OF THE 1992 OZONE HOLE

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A network of spectrophotometers for ground based operation has recently been installed in South America (Brazil and Chile) to provide systematic total column ozone data. First results are described for some of these stations, including the 1992 observation of the Antarctic stratospheric ozone hole at Punta Arenas, Chile, and at the Brazilian Antarctic Station Comandante Ferraz.

A REDE BRASILEIRA DE MONITORES DE OZÔNIO ESTRATOSFÉRICO *Uma rede de espectrofotômetros, para operação de superfície, foi recentemente instalada na América do Sul (Brasil e Chile) com a finalidade de obter dados sistemáticos da coluna total de ozônio. Os primeiros resultados para algumas destas estações são descritos, inclusive a observação em 1992 do buraco de ozônio estratosférico em Punta Arenas, Chile, e na estação brasileira Comandante Ferraz.*

INTRODUCTION

Measurements of stratospheric ozone in Brazil, on a regular systematic basis, started in May 1974 with the installation of Dobson spectrophotometer nº 114 in Cachoeira Paulista (22.7°S, 45.0°W). By the end of 1978, another Dobson instrument, nº 93, was installed at Natal (5.8°S, 35.2°W), on a collaboration agreement with NOAA. Simultaneously, another international cooperation program started, in which INPE and NASA agreed to launch ozonesondes from Natal on a systematic basis in order to improve the equatorial data base for ozone profiles (Kirchhoff et al., 1981, 1983, 1991). All these activities are still continuing. Results for the two Dobson stations were described by Sahai et al. (1982) and Sahai et al. (1987).

The two Brazilian Dobson stations, together with the Peruvian station at Huancayo (12.0°S, 75.3°W) and the Argentinian one at Buenos Aires (34.5°S, 58.7°W), have been the only systematic total ozone observation stations in South America for many years. However, none of these stations were used for the trend analysis, reported in the most recent issue of the "Scientific Assessment of Ozone Depletion: 1991", on grounds that the data record is not long enough for trend analyses.

The number of Dobson stations in the Northern Hemisphere is overwhelmingly larger than the number of stations in the Southern Hemisphere. In their trends paper, Stolarski et al. (1992) use 33 Northern Hemisphere stations and only 6 Southern Hemisphere stations. There are not enough observatories in South America as well (only 4). For an approximately equivalent geographical area, Canada for example, has presently 9 total ozone stations; the United States has 8 stations, plus the Dobson Spectrophotometer used as the control standard; and the former Soviet Union had a total of 45 M83 stations operating systematically over its territory.

With the great success that the ozone work at Natal has achieved over recent years, more scientists became involved and it became clear that other ozone stations should be established over Brazilian territory. These would cover mostly low latitudes, where not much stratospheric ozone has been depleted over the last 15 years. However, as pointed out in the above mentioned ozone assessment report, ozone trends from TOMS data are statistically significant in all seasons south of about 25°S. No trends have been found, so far, for the equatorial regions. However, Stolarski et al. (1992) obtain a year-round trend at Samoa (14°S) of -1.2% and at Huancayo (12°S) of -0.5% per decade. In any case, reliable ground based stations in the Southern tropics could provide valuable information if the data are produced regularly over very long intervals (15-20 years). This is what is intended with the establishment of a Brazilian Stratospheric Ozone Network.

THE BRAZILIAN NETWORK

In addition to the two Dobson stations in Brazil, four new Brewer spectrophotometers have been installed, one of them in the Chilean city of Punta Arenas, in collaboration with the University of Magallanes. In addition, activities have been intense at the Brazilian Antarctic Station Comandante Ferraz

Figure 1. Map of South America showing the geographic location of the stratospheric ozone monitors in Brazil and Chile. The location of the Brazilian Antarctic station Comandante Ferraz is also shown.

Mapa da América do Sul que mostra a localização geográfica dos monitores de ozônio estratosférico no Brasil e no Chile. Mostra também a localização da Estação Antártica Brasileira Comandante Ferraz.

(62°S, 58°W), where, in 1992, the Antarctic ozone hole (Stolarski, 1988) was observed using balloon launched ozonesondes. The Brazilian ozone network is shown in Fig. 1, on a map of South America. Brazil is shown hatched; black dots indicate the ground based ozone monitors; the black square shows the geographic position of the Brazilian Antarctic station.

Table 1 shows the location of the stations and the starting date of each. Of the Brewer stations, Cuiabá has the longest data record so far, having started in 1990. Note that all four Brewers can also observe the SO_2 column in the atmosphere. The stations of Cuiabá and Natal have both seen the arrival and dissipation of the 1991 Pinatubo SO_2 cloud (Kirchhoff, 1993). For future research topics, the UV

Table 1. The Brazilian Stratospheric Ozone Network.
A Rede Brasileira de Monitores de Ozônio Estratosférico.

Monitor	Site	Observes	Start Date
Brewer* 056	Cuiabá 15.6°S, 56.1°W	O_3, SO_2, UV	Oct 90
Brewer 081	Sta. Maria 29.5°S, 53.5°W	O_3, SO_2	May 92
Brewer 073	Rio Branco 09.5°S, 67.5°W	O_3, SO_2, NO_2, UV	Oct 91
Brewer 068	Punta Arenas 52.5°S, 71.0°W	O_3, SO_2, NO_2, UV	Aug 92
Dobson** 114	Cachoeira 22.7°S, 45.0°W	O_3	1974
Dobson 093	Natal 05.8°S, 35.2°W	O_3	1978
Sondes	Com. Ferraz 62.1°S, 58.4°W	O_3	Apr-Oct 92

* Brewer Spectrophotometer. ** Dobson Spectrophotometer.

data provided by the Brewers have great potential.

It is unfortunate that the Rio Branco unit never produced a longer record of data. At first, the computer broke down because of strongly varying local electric energy supply, and then a lightning discharge (despite conventional protection) disabled the Rio Branco Brewer unit so badly that it was not reactivated yet.

RECENT RESULTS

As mentioned, the two Dobson stations have the longest record. We show in Fig. 2 the yearly averages from 1974 to 1992 (19 years) for Cachoeira Paulista. The overall average is 278.1 ± 7.4 Dobson units. The shaded area shows the domain of the standard deviation from the mean (± 7.4 Dobson units, DU). The averages over the last three years reached the upper limits of the expected deviation. Evidently, no apparent negative trend can be seen.

Fig. 3 shows the yearly averages for Natal, from 1978 to 1990 (13 years). The overall average is 276.1

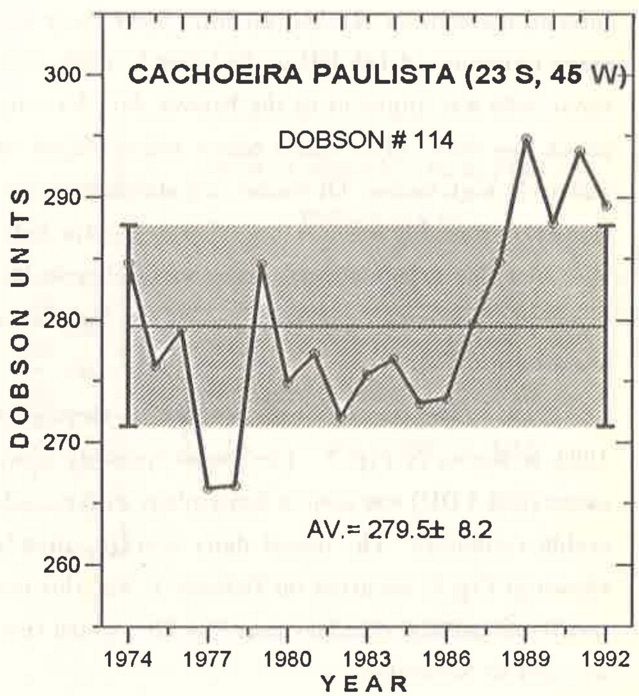

Figure 2. Total ozone yearly averages for the Cachoeira Paulista station from 1974 to 1992.

Médias anuais de ozônio total para a estação de Cachoeira Paulista de 1974 a 1992.

± 5.6 DU, and again the shaded area shows the standard deviation of the mean. As in the case for Cachoeira Paulista, Natal also shows, for 1989 and 1990, average values that are near the upper limit of the expected deviations. Again, no negative trend is apparent.

Fig. 4 shows the seasonal variation of both Dobson stations. As expected, these are very similar. Also shown are the standard deviations of the monthly means for Natal. The seasonal maxima occur in September - October and the minimum is seen in May, at both stations.

Fig. 5 shows the variability of the Brewer station at Punta Arenas for the month of November, 1992. The monthly average was 339.1 ± 15.8 DU. The vertical bars show the standard deviation. In contrast, the situation in October was quite different because of the appearance of the Antarctic ozone hole over Punta Arenas. This is shown in Fig. 6, where the total ozone column reached an impressive daily average minimum of 185 DU on October 5, 1992. The ozone hole was apparent in the Brewer data for only about one week, after which ozone values stayed at relatively high values. Of course, the standard deviation of the monthly mean is larger because of the hole, and does not reflect normal ozone variability in the layer, which is better characterized by the November variations of Fig. 5.

The longer period, from August to November 1992, is shown in Fig. 7. The lowest monthly mean ozone (306.1 DU) was seen in September, with considerable variability. The lowest daily average, already shown in Fig. 6, occurred on October 5, but this low recovered quickly to values near 360 DU, which then decayed in November.

Ozonesondes were launched from the Brazilian Antarctic Station Comandante Ferraz from March to November 1992. Kirchhoff and Marinho (1992) analysed tropospheric characteristics from these soundings. Figs. 8 and 9 show two cases where the ozone

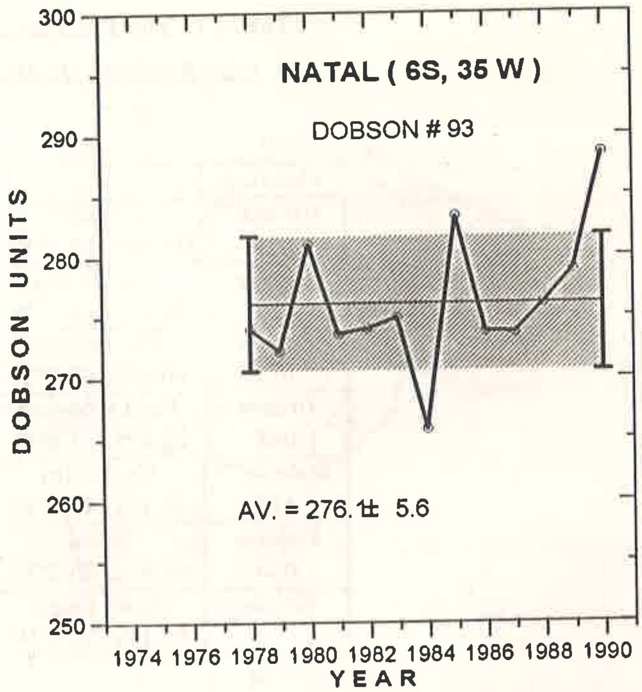

Figure 3. Total ozone yearly averages for the Natal station from 1978 to 1990.

Médias anuais de ozônio total para a estação de Natal de 1978 a 1990.

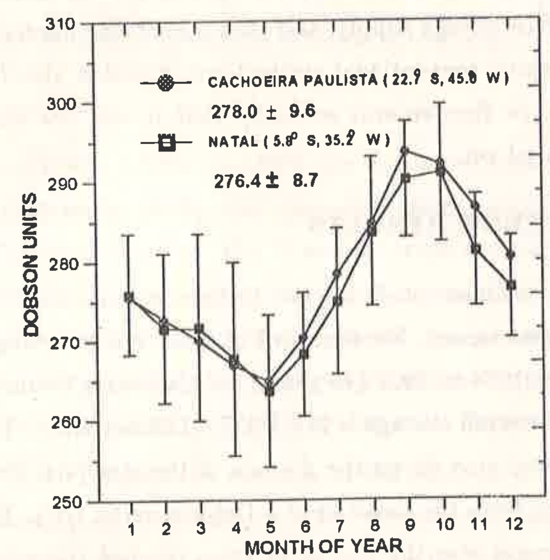

Figure 4. Seasonal variation of total ozone at Natal and CachoeiraPaulista(Dobson stations).

Variação sazonal de ozônio total em Natal e Cachoeira Paulista (estações Dobson).

hole condition over the station was quite severe. Fig. 8 shows the September 25 hole, while Fig. 9 shows the October 20 hole. Both figures show the ozone profile obtained from a sounding of September 15, used as a control layer, since it represents the normal (no ozone hole) profile over the station. The hatched areas in the figures represent the ozone that was destroyed between the normal and hole condition situations. Clearly, the stratospheric ozone destruction is severe in both cases, at all heights and, in the lower stratosphere close to 16 km, the ozone partial pressure nearly vanishes.

Fig. 10 shows satellite ozone data obtained from the TOMS (Total Ozone Mapping Spectrometer) instrument in October of 1992. The idea here is to show the variability of the satellite data in a given month. The standard deviations of the monthly means are about 15 DU, which is very similar to the variability shown by the Brewer instrument in Fig. 5.

Measurements in Santa Maria started in May 1992. The objective of setting up a station in Santa Maria was, of course, to be as close as possible to the Antarctic region. Any perturbation at lower latitudes, as a possible consequence of the Antarctic ozone hole, should show up first at this station. Evidently, the direct effect of a hole, as it is produced in Antarctica, is not expected at any Brazilian territory station. However, indirect effects, such as the result of export of ozone poor air masses from Antarctica to lower latitudes (Prather and Jaffe, 1990; Prather et al., 1990; Thompson, 1991), may be, or become, a secondary effect of yet unknown consequences. Since the ozone hole in Antarctica is still increasing in strength and size every year, one may speculate that such indirect effects may be seen in the future.

The October average at Santa Maria was lower than expected. Fig. 11 shows the Santa Maria monthly averages, where a simple interpolation between the September and November averages would produce a larger October value than the one actually

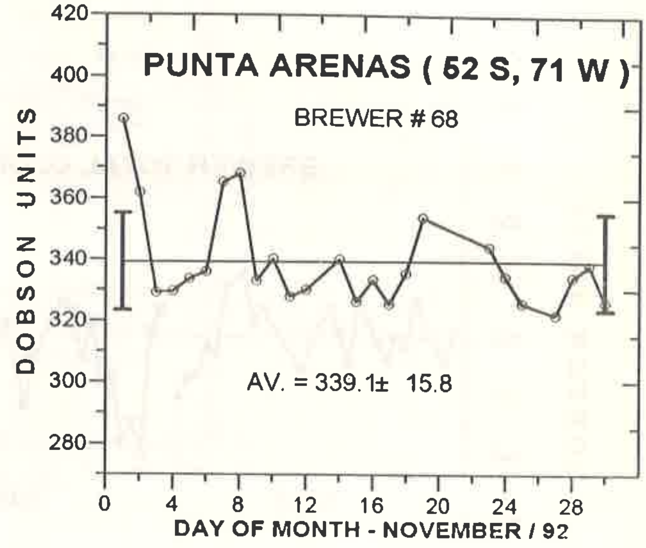

Figure 5. Total ozone daily average variations at the Punta Arenas Brewer station during November 1992.

Variações médias diurnas de ozônio total em Punta Arenas, medidas pela estação Brewer durante novembro de 1992.

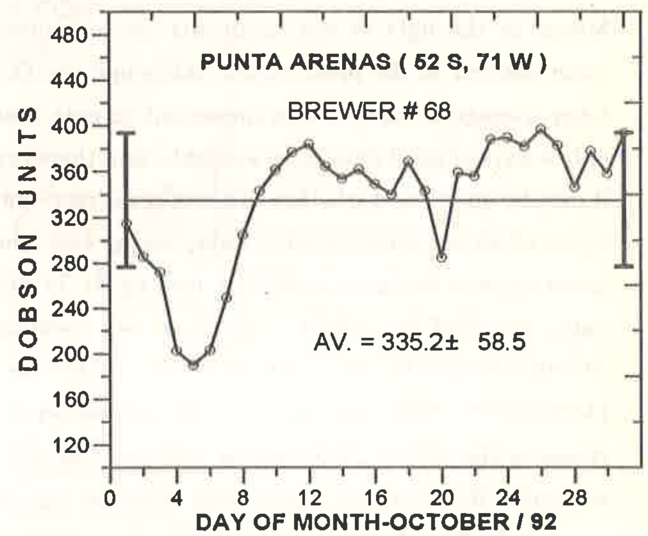

Figure 6. Total ozone daily average variations at the Punta Arenas Brewer station during October 1992.

Variações médias diárias de ozônio total na estação Brewer de Punta Arenas durante outubro de 1992.

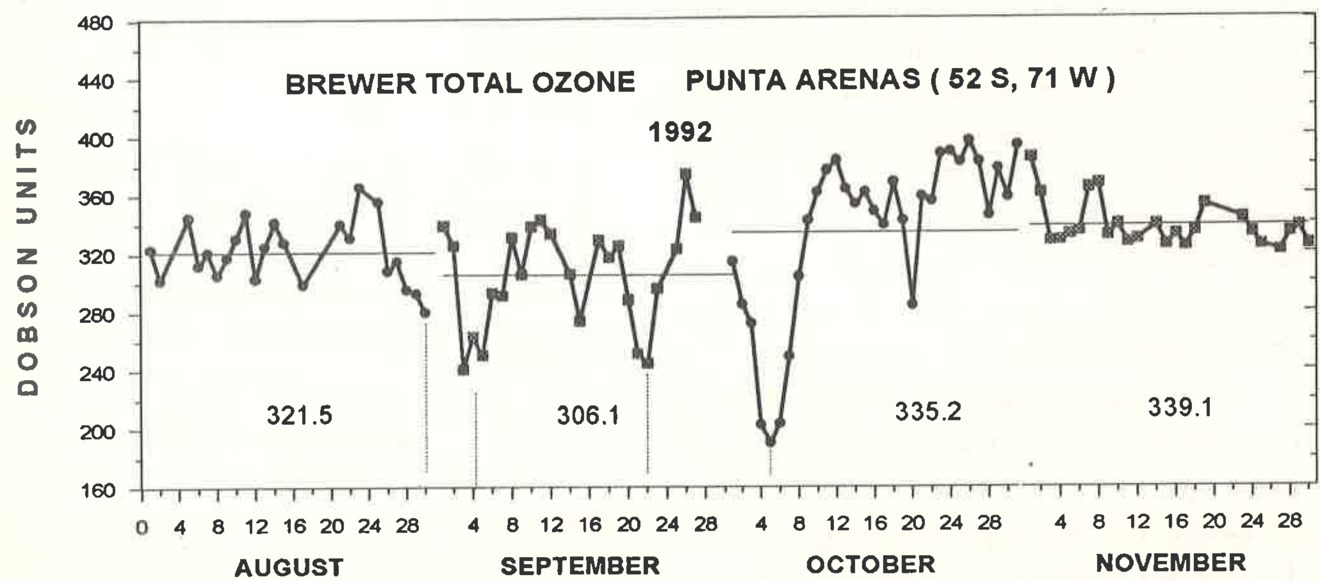

Figure 7. Monthly composite showing the evolution of the ozone hole at Punta Arenas in 1992.

Composto mensal que mostra a evolução do buraco de ozônio em Punta Arenas em 1992.

observed. The low October average observed at Santa Maria, in the light of the comments above, caused some concern in the press media. Although the October average is correct, it is important to note that only 4 days of good data were available, and therefore it may be questioned whether this average is representative of all the other October days. In any case, the situation was further checked by looking at TOMS data, provided by NASA. Fig. 11 shows monthly TOMS averages for the locations (30°S, 50°W), and (40°S, 65°W). It is clear that there is an October decrease in the 30°S TOMS data as well, but the effect is small. However, no sign of any decrease can be seen at 40°S, indicating that the October decrease was apparently very local.

It would be interesting to find out if this October decrease will be repeated in 1993, which would indicate an indirect process of decrease associated to the Antarctic depletion. Special plans are underway

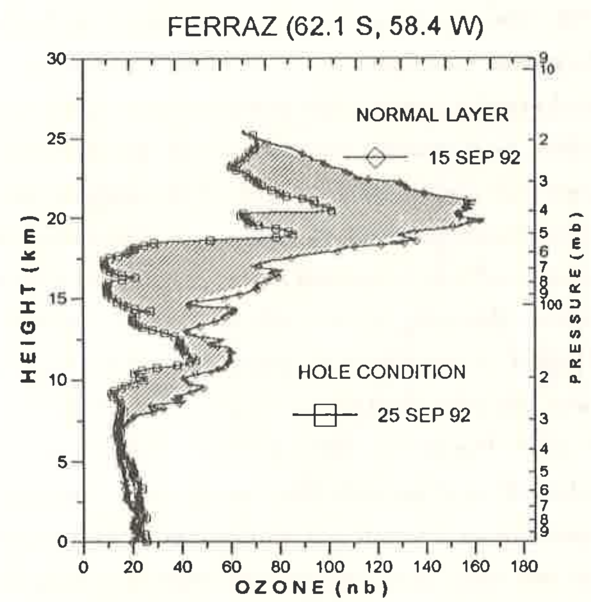

Figure 8. Ozone hole condition observed at the Brazilian Antarctic station Comandante Ferraz on September 25, 1992, using ozonesondes.

Condição do "buraco de ozônio" observado na Estação Antártica Brasileira Comandante Ferraz em 25 de setembro, 1992, usando sondas de ozônio.

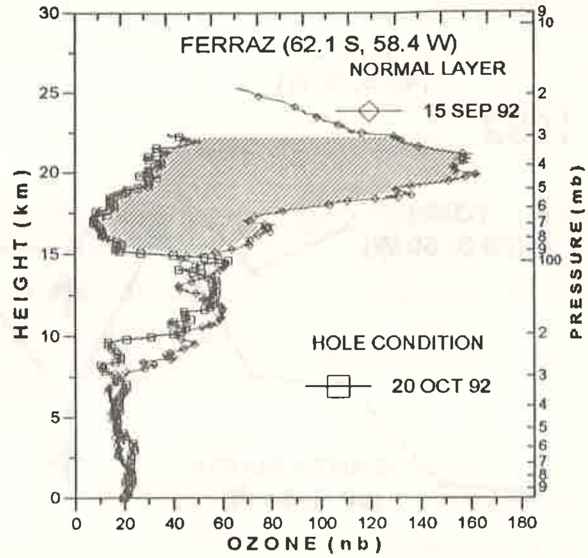

Figure 9. Ozone hole condition observed at the Brazilian Antarctic station Comandante Ferraz on October 20, 1992, using ozonesondes.

Condição do "buraco de ozônio" observado na Estação Antártica Brasileira Comandante Ferraz em 20 de outubro, 1992, usando sondas de ozônio.

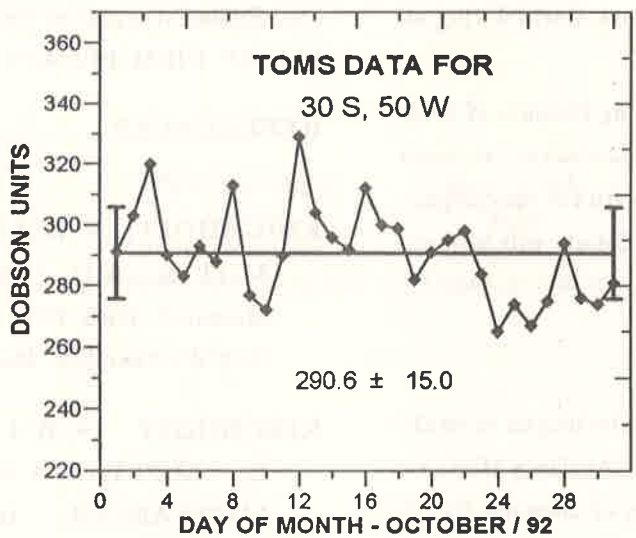

Figure 10. Daily average total ozone values computed from TOMS data (provided by NASA) for 30°S, 50°W during October 1992.

Valores médios diários de ozônio total, obtidos a partir de dados TOMS (cedidos pela NASA) para 30°S, 50°W durante outubro de 1992.

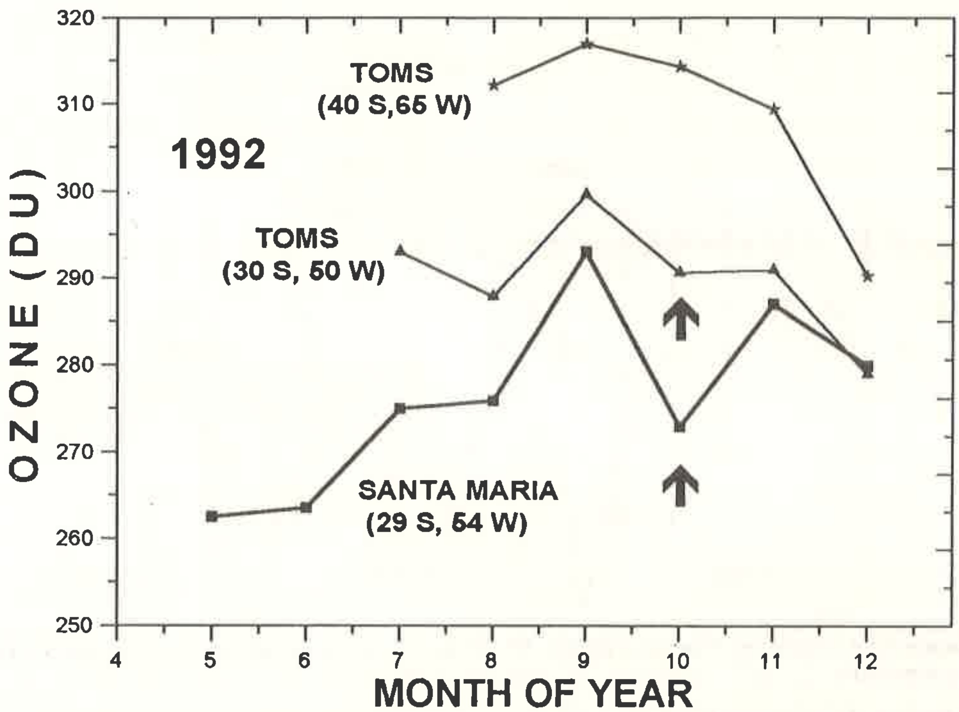

Figure 11. Brewer and TOMS monthly average data for Santa Maria and 30°S, 50°W. TOMS data for 40°S, 65°W are also shown. The arrows point to a relative October decrease.

Médias mensais para a estação Brewer e dados TOMS para Santa Maria e 30° S, 50° W. São mostradas também as médias para 40° S, 65° W. As setas apontam para o decréscimo relativo de outubro.

to monitor the ozone layer at Santa Maria during all days of October 93.

Note added in proof: Again, during October of 1993, an ozone decrease of about 20% was observed at Santa Maria. Observations were made with two spectrophotometers and ozonesoundings. Details will be published elsewhere.

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Monitores de ozônio	Ozone monitors