



## Ozone Hole Depletion over Brazilian Antarctic Station in the spring 2003/2004

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This paper was prepared for presentation at the 9<sup>th</sup> International Congress of the Brazilian Geophysical Society held in Salvador, Brazil, 11-14 September 2005.

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### Abstract

We present measurements of ozone and UV-B radiation made in Brazilian Antarctic Station on King George Island (62.1°S; 58.4°W), during 2003/2004 spring. A field campaign was organized to measure the ozone using a ground based Brewer spectrophotometer, filter photometers, and the vertical profile was obtained on several days using balloon-borne ECC ozonesondes. During this period the UV-B radiation were also measured daily with the Brewer spectrophotometer. 13 successful ozone soundings were obtained during September and October 2003 and 6 ozone soundings were launched during October of 2004. The comparison between 2003 and 2004 these soundings showed severe depletion of stratospheric ozone, mostly in the lower stratosphere, which reached a maximum on October 06 2003, with 60% the reduction on ozone concentration and 2004 the maximum depletion was on October 14, with reduction of the 40%. During 2003 the total ozone content varied considerably: between 121 Dobson Units (DU) on October 06 and 391.6 DU for November 03 and the occurrence the minimum total ozone was the 35 days showing 16 consecutive days. During 2004 the ozone depletion was present 22 days with 11 consecutive days. The comparison of the total ozone content measured by the ozonesondes with the total ozone Brewer spectrophotometer that operates from the ground has also been used during the campaign, giving a percentage difference of  $3.9 \pm 2.4\%$ .

In terms of the UV-B index, higher values were seen during 2003: on two occasions the Index passed the level of 9; which is larger than values observed on any campaign at the site. During the end of September and the beginning of October the index running mean reached 6, while during the 2004 equivalent period the higher value was about 6.8 and the running mean reached 3.3.

### Introduction

The Antarctic ozone hole is a phenomenon of strong ozone depletion in the Antarctic stratosphere [Stolarski *et al.*, 1986; Stolarski, 1988; Solomon, 1988, 1990]. The enhanced ozone destruction is a consequence of heterogeneous chemical reactions that occur in the

presence of a special type of aerosol, the polar stratospheric clouds, which act as if they enhance reaction rates that destroy ozone by reacting mainly with chlorine [Toon and Turco, 1991].

Ozone and UV-B variations have been studied in the Antarctic region during austral spring in the presence of the Antarctic Ozone Hole (Solomon *et al.*, 1986, 1988; Stolarski, 1988 ).

Ozone Hole extensions over the southern part of South America have been observed during several years in Punta Arenas, Chile (Bojkov *et al.*, 1995 ; Kirchhoff *et al.*, 1997 a,b,c ).

### Instrumentation

Total ozone , vertical profile and UV-B radiation were measurement using different techniques: launching ozonesondes on balloons is a well known technique ,(Kirchhoff *et al.*, 1991) of obtaining the vertical profile of ozone in the trop and stratosphere. A series of ozone profiles were obtained using the Electrochemical Concentration Cell (ECC). The technique has been used extensively in Antarctica and the measurement procedures and the accuracy and precision of the technique have been described before (Barnes *et al.*, 1985; Hilsenrath *et al.*, 1986; Kirchhoff *et al.*, 1997a,b,c) to document the vertical position of the ozone hole, which is not perceived by ozone integrating instruments (Dobson, Brewer, Toms).A series of ozone profiles were obtained using the Electrochemical Concentration Cell (ECC) sonde, launched on balloons. The sonde was used with a buffered 1% KI solution; all other procedures follow instructions of the manufacturer of the ZECC sonde. From the experience obtained in previous years, this set of procedures guarantees very good agreement in total ozone, compared to Brewer spectrophotometer values. The concentration of ozone is measured from the ground to heights of about 30-34 km.

The Mark IV Brewer spectrophotometer measured the total ozone (Direct Sun, DS and Zenith Sky, ZS), NO<sub>2</sub>, SO<sub>2</sub> and UV-B radiation . The spectrophotometer obtains ozone data by looking directly at the Sun( Brewer 1973, Brewer and Kerr, 1973).

### Results and discussion

The 2003 measurement campaign started the sonde launchings in early September and finished in October, obtaining a total of 13 vertical ozone profiles. During this period the total column ozone were also measured daily with a Brewer spectrophotometer, but the Brewer was operational for August 01 through December 10. Over the

Brazilian Antarctic Station, the ozone hole condition started August 25 and lasted until October 15. During 2003 the total ozone content varied considerably: between 121 Dobson Units (DU) on October 06 and 391.6 DU for November 03 and the occurrence the minimum total ozone was the 35 days showing 16 consecutive days (September 19 to October 12). The minimum ozone value observed by Brewer and ozonesonde was 121 DU for October 06. During 2004 the ozone measurement by ozonesondes started October 8 and finished in October 19. The Brewer was operational for September 27 until March 05. The minimum ozone measured was 166 DU on October 13. The maximum ozone depletion of the 2003 campaign, a condition that was not surpassed others campaigns (1996, 1997, 1999, 2001 and 2004).

Figure1 shows the total ozone measured by spectrophotometer Brewer during September and October 2003 and 2004. Ozone depletion during 2004 was present 22 days with 11 consecutive days measured by TOMS. The hatched area represents the ozone hole condition in the September and October.

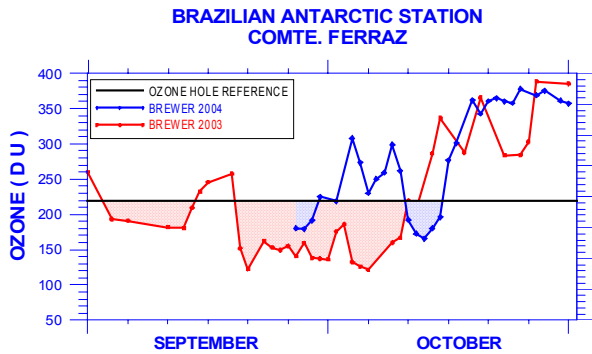


Figure1. Total ozone observed at Brazilian Antarctic Station measured by Spectrophotometer Brewer during 2003 and 2004. The profiles represents daily means of the ozone. The dark line is ozone hole reference. The red line represent measurements in the 2003 and the blue line represent 2004 period.

The vertical distribution of ozone was examined and 13 successful ozone soundings were obtained during September and October at 2003 and 6 ozone soundings were launched during October the 2004. The comparison between 2003 and 2004 these soundings showed severe depletion of stratospheric ozone, mostly in the lower stratosphere, which reached a maximum on October 06 2003, with 60% the reduction on ozone concentration and in the 2004 the maximum depletion was on October 14, with reduction of the 40%.

Figure2 shows the ozone and temperature profiles obtained using ozonesondes at the Brazilian Antarctic Station in 2003, during a severe ozone hole condition on October 6 (line A), and a "normal" profile (line B) on October 20, shown for comparison. The stratosphere temperature measurements shows an decrease of the 40% during the ozone depletion.

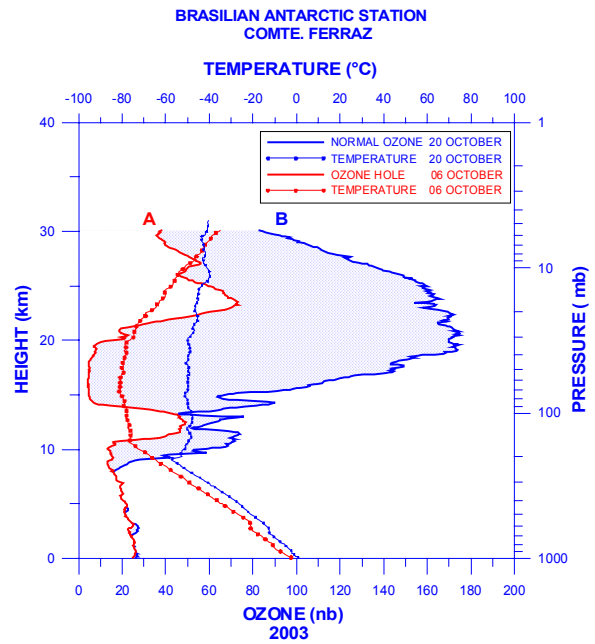


Figure2. Ozone and stratosphere temperature profiles, during a severe ozone hole condition (red line A), and a "normal" profile (blue line B). The stratosphere temperature variation is represented by dotted line.

Total ozone measured by Brewer was compared with the ozonesonde height integrals, in the figure 3a and 3b. The largest differences are in the range of less than 10%; the average difference is of the order of 3.0 % with a standard deviation of 2.4 %. The good comparison of the Brewer spectrophotometer with the sounding's total ozone column values is a sign that the independent measurement techniques were performed adequately.

It can be seen that 80% of the soundings were made under Ozone Hole conditions, as defined by an ozone total content of less than 220 Dobson units (DU).

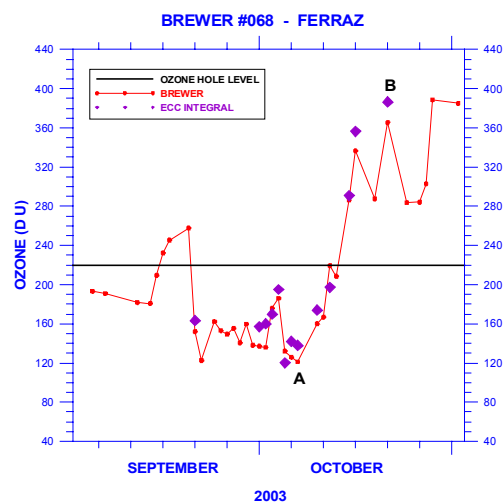


Figure 3a. Time variation of total ozone, and the days with ozonesondes launches during September and October 2003. A and B show the days of the profiles shown in the figure 2.

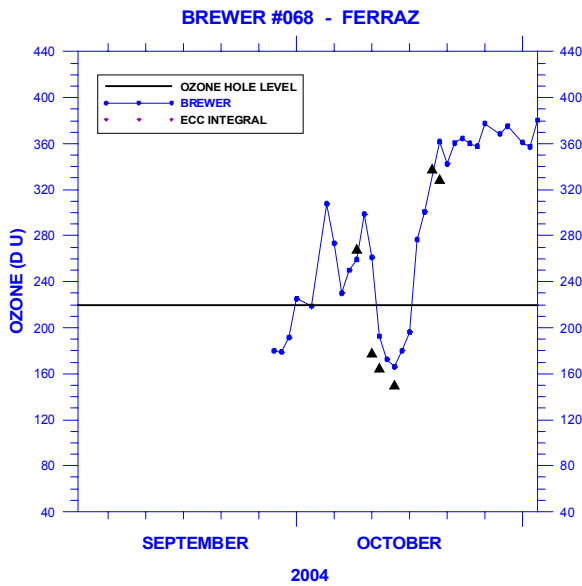


Figure 3b. Time variation of total ozone, and the days with ozonesondes launches during 2004 spring.

The comparison of the vertical profile ozone obtained on several days during 2003/2004 spring showed severe depletion of stratospheric ozone, mostly in the lower stratosphere, which reached a maximum on October 06 2003, with 60% the reduction on ozone concentration and in the 2004 the maximum depletion was on October 13, with reduction of the 40%.

The evolution of the ozone partial pressures at different heights can be seen in the figure4a and figure 4b. The ozone concentrations are lowest in the lower stratosphere, at heights of 15-17 km.

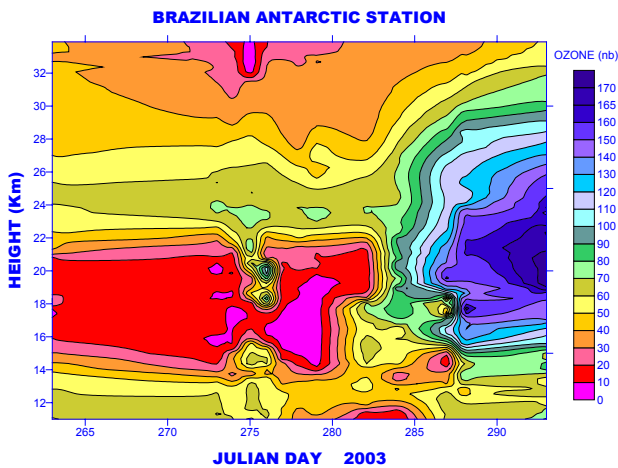


Figure 4(a). Evolution of the ozone partial pressures at different heights in the stratosphere, obtained by ozonesondes during 2003 spring.

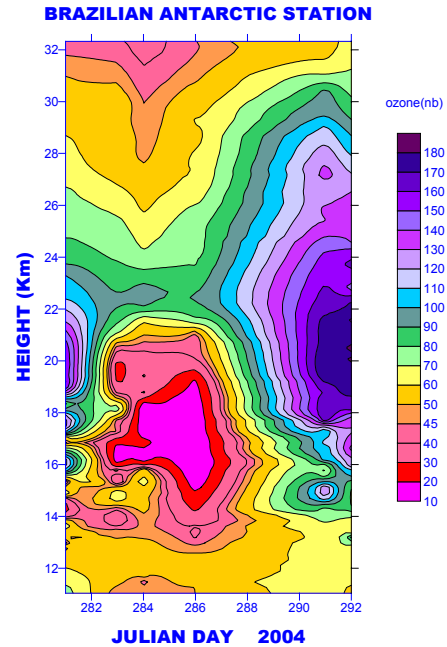


Figure 4b. Evolution of the ozone partial pressures at different heights in the stratosphere, obtained by ozonesondes for October 2004 (b).

In terms of the UV-B index, higher values were seen during 2003: on two occasions the Index passed the level of 9; which is larger than values observed on any previous campaign at the site. During September and October, the index mean was 6, while during the 2004 equivalent period the value was about 3.3 and the larger value was 6.8 on . Clearly part of this must be attributed to the presence or not of the ozone hole over the site, which appeared many days in September and beginning of October in 2003, whereas in 2004 it appeared few days.

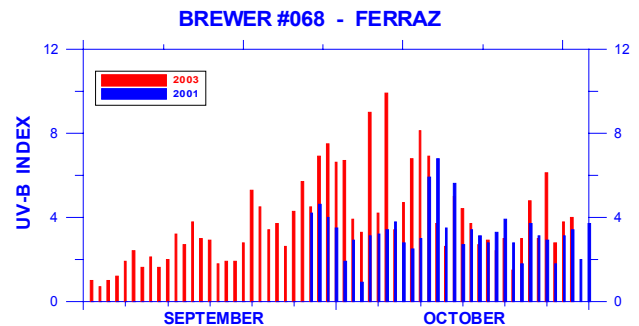


Figure 5. Comparison of the UV-B index measured by Brewer spectrophotometer , for 2003/2004.

## Conclusions

Ozone measurements have been made at the Brazilian Antarctic Station Comandante Ferraz, during 2003/2004 spring, using the ozone sounding technique and the Mark IV Brewer spectrophotometer. During about half the observation time, the ozone hole was clearly developed, and interesting ozone hole profiles have been observed. The comparison between 2003 and 2004 these soundings showed severe depletion of stratospheric ozone, mostly in the lower stratosphere, which reached a maximum on October 06 2003, with 60% the reduction on ozone concentration and in the 2004 the maximum depletion was on October 13, with reduction of the 40%. The ozone concentrations are lowest in the lower stratosphere, at heights of 15-17 km and the average height of minimum ozone is  $16.9 \pm 1.0$  Km. In terms of the UV-B index, higher values were seen during 2003: on two occasions the Index passed the level of 9; which is larger than values observed on any previous campaign at the site. During September and October, the index mean was 6, while during the 2004 equivalent period the value was about 3.3 and the larger value was 6.8 on .

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## Acknowledgments

We are grateful to the technical team, especially José R. Chagas, Luiz Manguiera and Armando Hadano. Tania Brito and Carmen Arroyo had leading roles in the administration of the program. This work was jointly sponsored by the Brazilian Research Council, of the Ministry of Science and Technology, and the Ministry of the Environment, through the Antarctic Program, CNPq/PROANTAR/MMA, and the Fundação de Amparo à Pesquisa do Estado de S.Paulo, FAPESP. Logistical support was provided by Secretaria Interministerial para os Recursos do Mar, SECIRM.