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Effect of Antarctic ozone holes of 1988, 1989, and 1990 on lower latitudes of the southern hemisphere

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Abstract. The October depletions in the Antarctic ozone spread to lower latitudes in early November in 1988, in late November in 1989, and in late October in 1990. The depletions were 10–15% for latitudes up to 40°S and smaller thereafter, and almost negligible at 25°S and beyond. However, for the southern hemisphere, the normal seasonal changes at middle latitudes from October to December are much larger (about 20%). Also, there are superposed fluctuations of about 20% over a few (5–6) days.

1 Introduction

In an earlier paper (Kane, 1991), the extension of the Antarctic ozone hole of October 1987 (45% depletion) to lower latitudes in the South American region was reported. It was shown that while Buenos Aires probably had a depletion of about 10%, and Natal and Huancayo had a depletion of about 5%, a considerable part of these depletions could be due to a routine seasonal effect. The same was true for the Australian region (Atkinson *et al.*, 1989). In this note, results for the ozone holes of 1988, 1989, and 1990 are presented.

2 Data

All ozone data were obtained from "Ozone Data for the World" published by the Atmospheric Environment Service, Department of the Environment, Canada, in cooperation with the World Meteorological Organization (WMO).

3 Event of October 1988

Figure 1 illustrates the ozone hole of October 1988. In the top plot, the South pole daily ozone values (full lines) were available only from 13 October onwards. The hole was intense (225 DU) up to 25 October, had a sharp recovery up to 4 November, a renewed depression up to 7 November, followed by a final recovery up to 16 November. The ozone values at Syowa at 69°S (crosses), do not show an exactly similar pattern, probably because Syowa was in and out of the ozone hole edge. Plots for Buenos Aires (Argentina), Cachoeira Paulista and Natal (Brazil) and Huancayo (Peru) do not show any spectacular effects different from the general *seasonal* variation, represented by the triangles joined by thick lines. However, at Buenos Aires there were large fluctuations above and below the seasonal trend. In particular, the ozone level fell rather abruptly from 1 November to 6 November (10% in 6 days) and later again from 1 December to 6 December (10% in 5 days). These falls may represent ozone-poor air reaching lower latitudes in distinct parcels, with intervals of 10–20 days.

The plots for Australian longitudes show depletions below the seasonal trend level of about 10% at Hobart, about 5% at Melbourne, and smaller depletions at Perth and Brisbane. At Lauder (New Zealand) about 10% depletion is seen. Thus, the ozone hole seems to cause a 10–15% depletion for latitudes up to about 40°S and lesser depletions thereafter up to about 25°S, in agreement with the three-dimensional chemical transport model (Prather and Jaffe, 1990; Prather *et al.*, 1990). We also note that the extension of the Antarctic ozone depletion does not seem to be confined to the longitude range 0–30°W as claimed by Chandra and McPeters (1986).

It is interesting to note that these depressions are smaller in magnitude than the seasonal effect itself, which is of the order of 20% in 3 months October–December at 40°S. Also, wavy structures are superposed, wherein changes as large as 20% or more seem to occur within a matter of 5–6 days. These changes do not seem to be random. Many peaks are common to Hobart and Melbourne. The accuracies of these daily values are uncertain and may differ from place to place but errors of the order of 2–3% seem to be involved (Ozone Data for the World).

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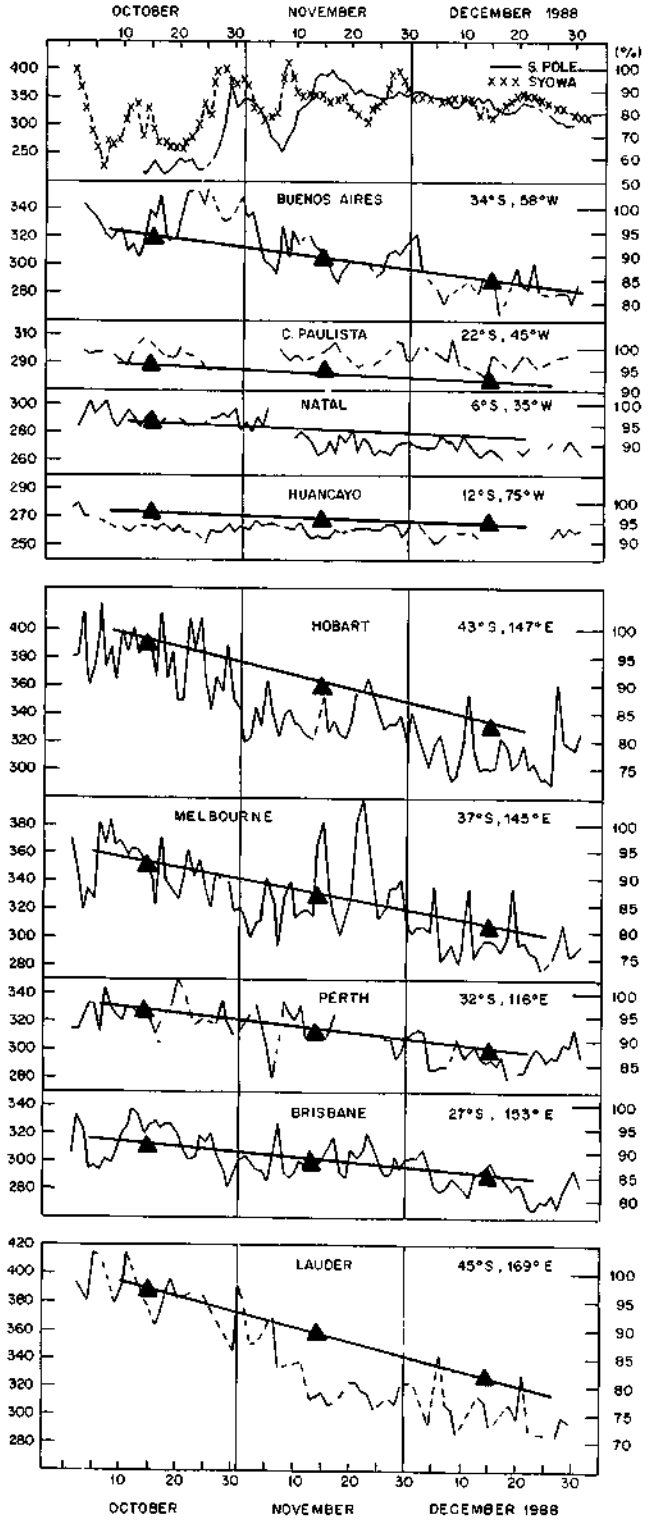

Fig. 1. Daily means of total ozone at South Pole and Syowa (*top plot*), and at locations in South America, Australia and New Zealand for October, November, and December 1988. *Triangles joined by thick lines* show seasonal trends

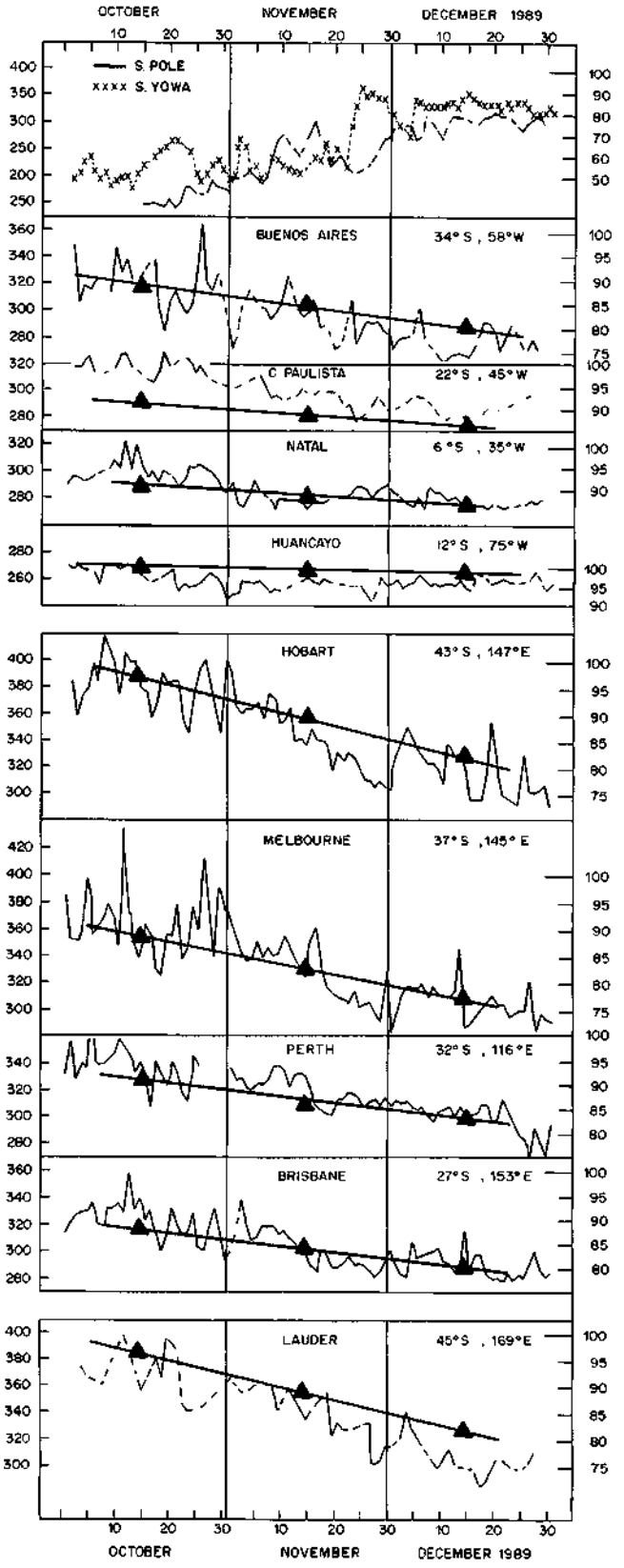

Fig. 2. Same as Fig. 1 for 1989

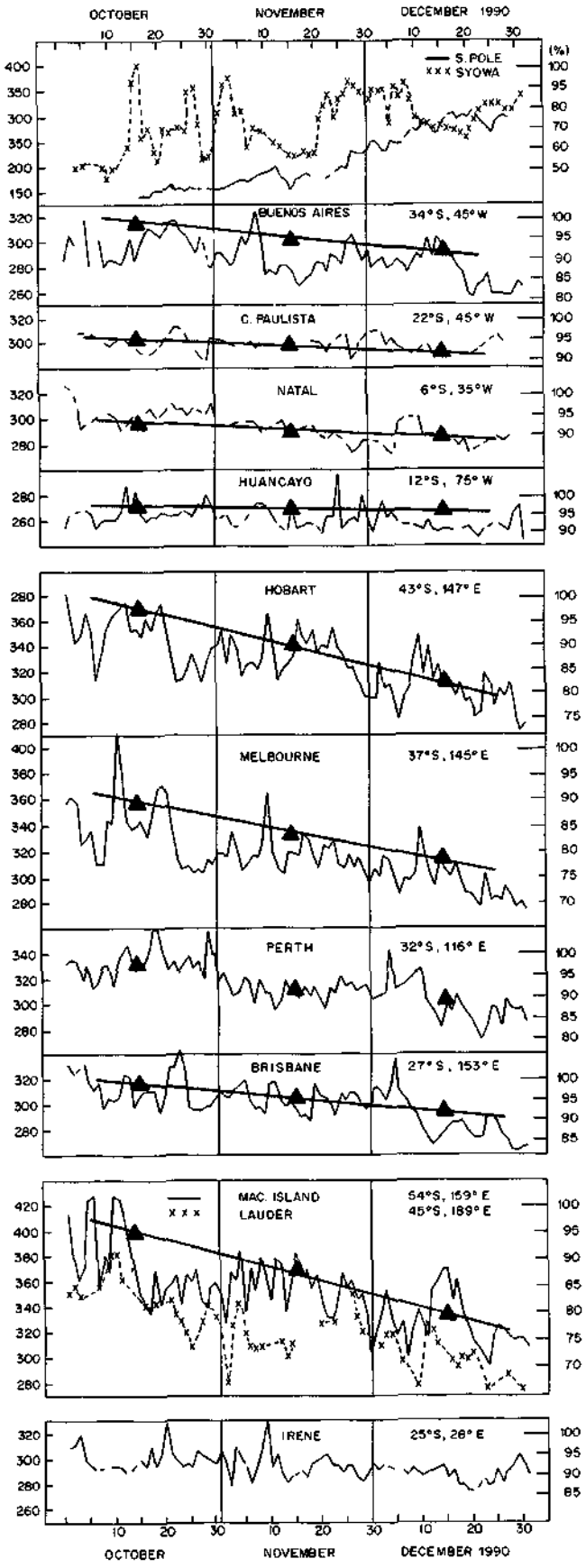

Fig. 3. Same as Fig. 1, and for Irene (South Africa) for 1990

To obtain statistical estimates, we subjected these series to maximum entropy spectral analysis (MESA), (Ulrych and Bishop, 1975). The Hobart and Melbourne daily mean series for October–December 1988 (92 days) showed periodicities in the 5–10 and 10–20 days range. Since MESA does not give amplitude estimates correctly (Kane and Trivedi, 1982), we used these periodicities for a multiple regression analysis (Bevington, 1969), and found that periodicities near $T = 7$ and 15 days were significant at a 2 sigma (a priori) level. These periodicities could be due to isolated parcels of air coming from the Antarctica at such intervals (Prather *et al.*, 1990). However, there is also a possibility that these may correspond to middle atmospheric *planetary* waves, viz. Rossby-gravity waves of periods 4–5 days of mode 0 (Lindzen and Matsuno, 1968), and Kelvin waves of periods 10–20 days of mode-1 (Holton and Lindzen, 1968). This needs further exploration.

4 Event of October 1989

Figure 2 illustrates the event of October 1989. As before, the South Pole ozone (full lines) had a depletion level of 150 DU in mid-October, which recovered steadily to 300 DU by the end of November. At Syowa (crosses), the ozone level showed a similar recovery but with a superposed wavy structure of period 5–10 days. In South America, there were no long-term spectacular decreases different from the seasonal trend. But many short-term fluctuations (5–10% in 5–6 days) occurred at Buenos Aires in all months, and hence they are probably not related to the Antarctic ozone hole. In the Australian region depletions (5–10%) were seen at Hobart, Melbourne and Lauder by the end of November, but changes at Perth and Brisbane were negligible.

5 Event of October 1990

Figure 3 illustrates the event of October 1990. The South Pole ozone had a low level of 150 DU in October, which recovered steadily to 300 DU by early December. In contrast, Syowa ozone showed violent fluctuations, indicating a pulsating vortex edge over Syowa. At Buenos Aires, 5–10% depletions below the seasonal trend were seen. At Hobart and Melbourne large depletions were also seen in late October, i.e. within a few days of the development of the Antarctic ozone hole. This depletion was also seen at Macquire Island (54°S, 159°E). Thus in this event the Antarctic ozone hole seems to have spread rather quickly to lower latitudes. Here again there are violent short-term fluctuations at Hobart and Melbourne with periods of 5–10 days, and many common peaks.

For South Africa data were available for Pretoria (15°S, 28°E) and Irene (25°S, 28°E), but those for Pretoria were very scarce. For Irene the bottom plot in Fig. 3 shows only short-term oscillations. Since no previous data are available we have no estimate of the seasonal trend, but no depletion related to the Antarctic ozone hole is discernible.

6 Conclusions

For the events of 1988, 1989 and 1990 the October depletions and subsequent recoveries in November for South Pole are sometimes very different from those of Syowa. Their extensions to lower latitudes are also different, being in late October for 1990, late November for 1989, and early November for 1988. The depletions are 10–15% for latitudes up to 40°S and smaller thereafter, being negligible at 25°S. By comparison the seasonal effects themselves are larger, 20% from October to December, and there are also superposed short-term fluctuations as large as 20% within 5–6 days. These could be due to intermittent dislocation of ozone-poor air parcels from the Antarctic region, but some effect due to middle atmosphere planetary waves is likely.

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