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# TOTAL OZONE OBSERVATIONS AT PUNTA ARENAS, CHILE (53.2°S;70.9°W)

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**Abstract:** *During the recent decades there has been an increasing concern related to the ozone layer and to solar ultraviolet radiation UV-B (280-320 nm), reaching the surface of the earth. The Antarctic Ozone Hole is a phenomenon of strong ozone depletion in the Antarctic stratosphere; this is a consequence of heterogeneous chemical reactions and dynamic processes which enhance ozone losses by reactions with chlorine. Punta Arenas (53.2°S,70.9°W) is the southernmost city in Chile with a population of approximately 120.000. Due to its location, well within the area affected by the Antarctic Ozone Hole, systematics observations of ozone and UV-B with a Brewer spectrophotometer have been made in order to study the Antarctic Ozone Hole conditions. To analyze the behavior of the stratospheric ozone layer over Magallanes the reference AVE-CLI-TOMS minus twice the standard deviation of the reference mean (TOMS: 1978-1987, mean monthly – 2SD) was used. The number of days per year shows an interesting cycle of 8 to 10 years, but monthly variations did not show a significant decrease, especially during September-October period.*

**Keywords:** Antarctic Ozone Hole, Ultraviolet Radiation, Brewer Spectrophotometer

## Introduction

Antarctic stratospheric ozone loss has been regularly measured since the mid 1970s. During the spring time this dramatic reduction in the Antarctic stratosphere has been named the Antarctic Ozone Hole (AOH) (Chubachi, 1984; Farman *et al.*, 1985). The AOH has grown in intensity (minimum average measurements) and in the amount of area covered (WMO, 2003). Record ozone hole sizes close to 29 and 28 million km2 were observed, the size during 2011 was almost 24 million km2. In terms of the intensity of the AOH, considering the minimum measured at the Antarctic region in September- December period, it has been maintained under 100 DU values (http://toms.gsfc.nasa.gov, visited: Dec. 2012). This pronounced seasonal ozone loss results from heterogeneous chemical reactions (Solomon & Garcia, 1986) and dynamical processes (Prather *et al.*, 1990), which enhance ozone loss by reactions with chlorine and bromine (WMO, 2003).

Due to the dynamic conditions of the behavior of the Antarctic polar vortex, the AOH is not restricted to the Antarctic region. It also periodically affects lower latitudes during each spring. (Casiccia *et al.*, 2003, 2008).

Regions near the South Pole, such as Chilean and Argentina Patagonia and Tierra del Fuego Island are locations that are affected by the Antarctic Ozone Hole phenomenon (*e.g.* Pazmiño *et al.*, 2005; Casiccia *et al.*, 2003, 2008; Cede *et al.*, 2002). In order to study the influence of the AOH over the South Cone of America the Laboratory of Atmospheric Sciences of the University of Magallanes has installed a spectrophotometer Brewer to measure the total ozone column over Punta Arenas. Here we present the total ozone column measurements and a detailed analysis during the 2010-2011 period.

## Materials and Methods

### *Station*

Punta Arenas is the southernmost city in Chile with a population of approximately 110,000. Due to its location, well within the area affected by the Antarctic Ozone Hole

## Instrumentation

Total column ozone and UV-B radiation were measured with an automated Brewer spectrophotometer. In order to determine column ozone and $SO_2$ the Brewer utilizes 5 wavelengths with a resolution of 0.6 nm centered on 306.3, 310.0, 313.4, 316.7 and 319.9 nm. The instrument includes automatic wavelength calibration using an internal mercury discharge lamp, as well as a relative spectral intensity source from a quartz-halogen lamp.

## Results

In Figure 2, the dotted line shows the time series of the daily total ozone values for Punta Arenas obtained from the Brewer spectrophotometers from 1992 to 2009. The black solid line represents the running averages (n = 30) for the same period. The horizontal black line shows the threshold of the Antarctic Ozone Hole [Total Ozone = 220(DU)] for reference. The natural variation of column ozone for this latitude is observable, with minima in winter and maxima in spring. A simple linear fit from the daily ozone shows a slight increase from 1992 (red line).

Figure 3 shows monthly mean Brewer spectrophotometer measurements compared with the reference values (TOMS data 1978-1987), plus and minus one standard deviation is indicated with the hatched areas for each year 2008 to 2011. The vertical error bars in the Fig. 3 show the standard deviation of each month. Every year the mean monthly measurements during spring and summer are lower than reference values and the standard deviations are larger during the months of September, October and November, due to the perturbations generated by the Antarctic Ozone Hole. Here we see clearly that the recent measurements (2011) are below the average of the September–December period, demonstrating the marked activity of the Antarctic Ozone Hole during that period over Punta Arenas.

In Figure 4 the behavior of the ozone column during two years in Punta Arenas is shown. Each point represents the mean for each day of the total ozone column obtained from the Brewer spectrophotometer in Punta Arenas in 2010 and 2011, the 220 DU line is shown for reference to the AOH condition. Conventionally, it is considered that there is an ozone hole when the ozone abundance is ≤ 220 Dobson units (DU) in a specific geographic place. The vertical hatched area indicates the high activity period of the AOH over Punta Arenas (and Magallanes region) from late August until end of November, and occasionally some activity of the AOH is observed over the south cone during December. For reference, hatched area in this figure show the mean values and their respective deviations of a non-AOH period (1978-1987).


**Figure 1.** Punta Arenas, Chile (53.2°S, 70.9°W).

## Discussion

Recent reports of the behavior of the ozone layer at high and middle latitudes of the Southern Hemisphere showing signs of recovery , but due to the large variability year-year is necessary to look for at least a decade of continuous increases, in order to affirm a global recovery to pre-80 values. Analysis of low ozone events can be an indicator of the recovery of the ozone layer. Figure 5 shows the number of events of low ozone in Punta Arenas. The criteria for defining an event of low ozone is that the ozone column (daily average) must be lower than the reference

**Table 1.** Brewer instruments at Punta Arenas

| Brewer – Punta Arenas | Institution | Period of observations |
|---|---|---|
| Brewer MKIV 068 | National Institute for Space Research (INPE-Brazil) | 1992-2000 |
| Brewer MKIII 180 | University of Magallanes | 2002 – Jun. 2006 |
| Brewer MKIV 124 | National Institute for Space Research (INPE-Brazil) | Aug. 2007-Nov. 2007 |
| Brewer MKIII 180 | University of Magallanes | Nov. 2007-today |

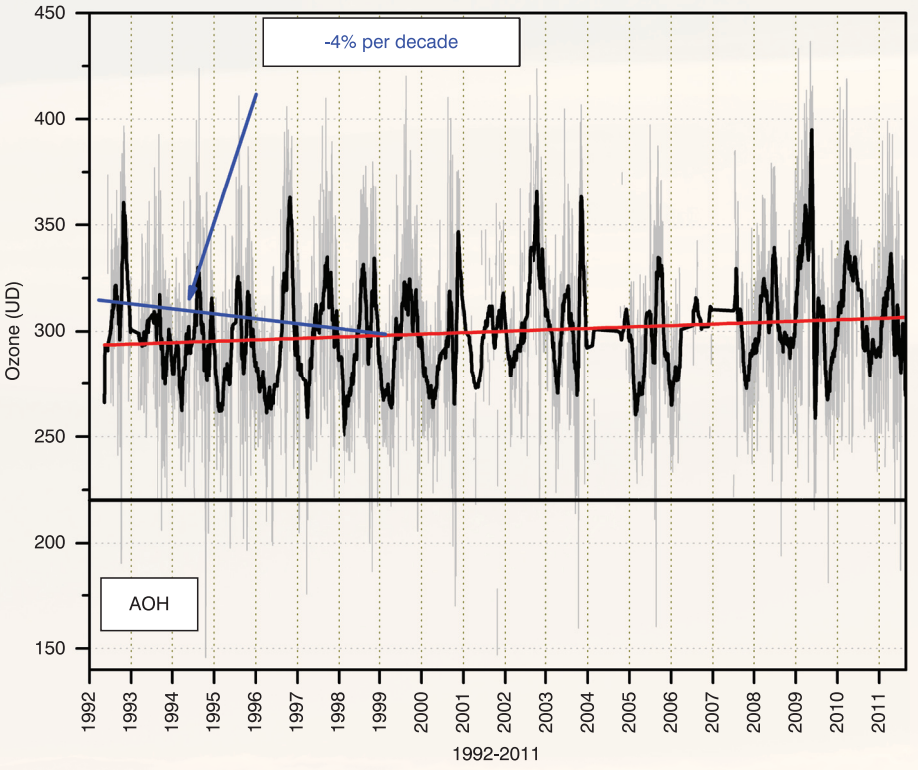


**Figure 2.** Total Ozone time series for Punta Arenas measured by Brewer instrument 1992-2011. Each dot represents the daily values, and the dark line represents a running average (n=30).

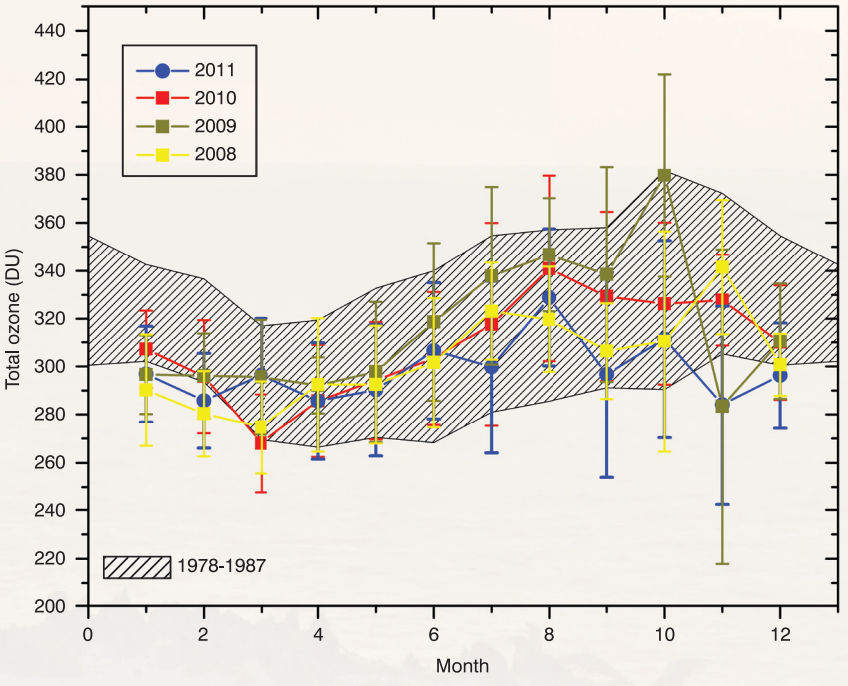


**Figure 3.** Ozone monthly averages and standard deviations for 2008-2011 period. The hatched area represents the reference average plus and minus the standard deviations.

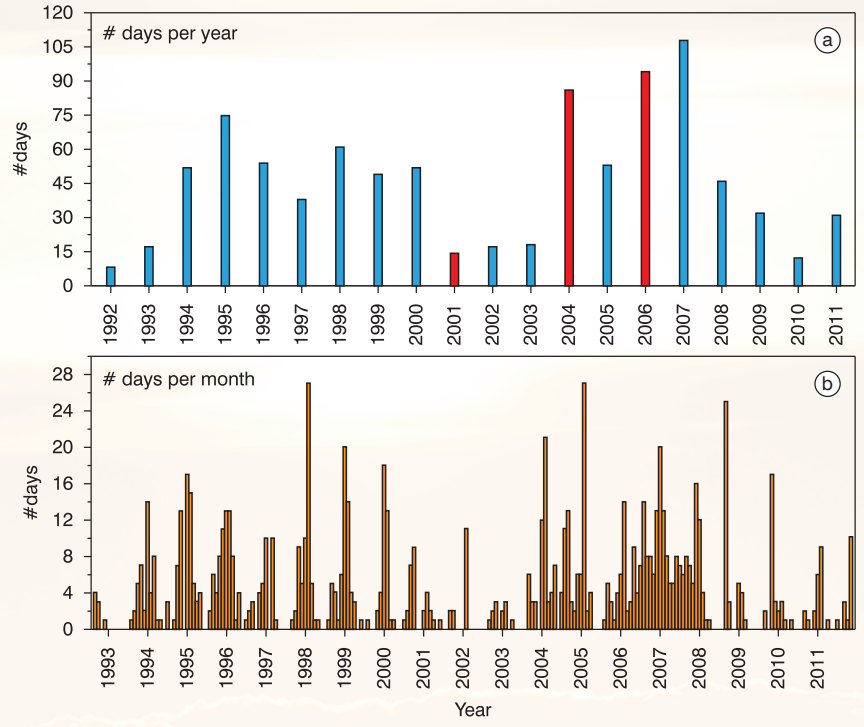


**Figure 4.** Total Ozone observed at Punta Arenas measured by Brewer instrument during 2010 and 2011. The hatched area represents the AVE-CLIM-TOMS reference average plus and minus one standard deviation.

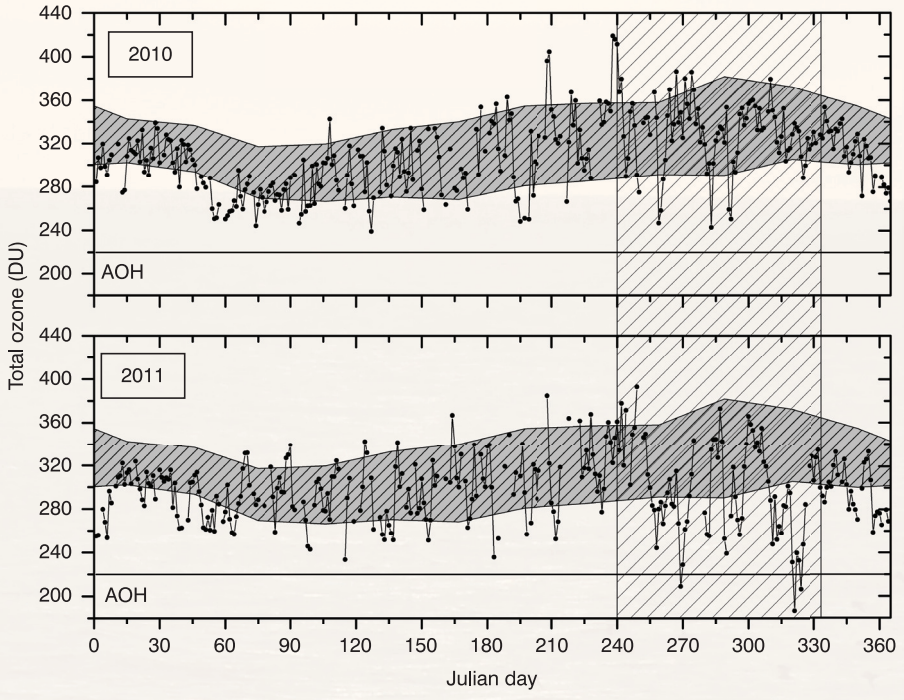


**Figure 5.** Number of days under the climatological average minus two standard deviations.

AVE-CLI-TOMS minus twice the standard deviation of the mean (mean monthly – 2SD, Casiccia *et al*., 2008). The number of days per year is shown in Figure 4 (a) and (b) are the number of days per month. The period 1994-1999 was the period when a significant number of low ozone days were observed each year. Between 2001 and 2003 there were fewer significant days with low ozone events, it could show a possible recuperation of the ozone over the latitude of Punta Arenas. However, during 2004 the number of days began to increase again. After 2008 the number of events of ozone depletion declines gradually but in 2011 increases again. From this data we can make the following question: has the recovery of the ozone layer in the middle southern latitudes been interrupted? The answer to this question will have to wait for some years until much more data is collected.

## Conclusion

A temporal series of total ozone column observations (1992-2011) was obtained. The data indicates that South Cone of the South American region is regularly under the influence of the Antarctic Ozone Hole during springtime. From Brewer ozone data measurements during the last 2 years, a significant number of days that were under the climatological average were detected. The data shows that it is still premature to discuss a recovery of the ozone layer in these latitudes.

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