SHORT CONTRIBUTION

The southern ozone hole as observed at Belgrano station

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RESUMEN

En el presente trabajo, se estudia el adelgazamiento de la capa de ozono considerando mediciones efectuadas en la Estacion Antártica Belgrano (78.0°S; 38.8°W).

Para estimar los valores mínimos de la densidad del ozono estratosférico, se utiliza la primera función de distribución para valores extremos de Gumbel. A partir de estos cálculos se predice el valor mínimo correspondiente a los meses de primavera de 1998. El resultado encontrado fue de (109 ± 15)DU. Este valor coincide muy bien con el valor obtenido en la Estación Belgrano el 2 de octubre de 1998.

ABSTRACT

The thinning of the stratosphere ozone layer in the Antarctic region is studied by considering ground-based observations at Belgrano Station (78.0°S; 38.8°W).

Gumbel's first distribution of extreme values is used to evaluate the highest depletion of the Southern ozone hole for the spring months of 1998.

According to the present study we predict that the expected largest yearly deviation of the ozone layer density during 1998 would be (109 ± 15)DU. This result agrees remarkably well with the measured value of 102 DU as obtained on October 2 of 1998 at Belgrano Station.

1. Introduction

The Antarctic atmosphere has peculiar characteristics and has a collateral control on the climate of our planet, it presents a very complicated geochemical equilibrium, involving not only gases but also aerosols, many of them proceeding from gas-vapor-particle changes.

Monitoring stratospheric chemistry in Antarctica has been the aim for the efforts of several countries, they have discovered the Ozone Depletion in the ozone layer which is the region of the stratosphere containing the bulk of atmospheric ozone. This effect is a consequence of destruction of O_3 through chemical reactions in the Antarctic stratosphere including chlorine catalitically. During the polar winter the Antarctic atmospheric circulation is comparatively isolated, due to the effect of the Polar Vortex (Kirchhoff and Pereira, 1992).

In the present paper, we use the theory of extreme value statistics and the Gumbel's first distribution to analyze the maximum depletion of the stratospheric ozone layer in the Antarctic region. Prior statistical articles have been published by Silbergleit (1996) and Siscoe (1976).

2. Methods

For a given maximum value, the probability that this value be less than m is called f (m, A, B). The probability that this value be grater than m is estimated by [1- f (m, A, B)]. The theory of extremes provides the expression of f (m, A, B) according to Gumbel (1954).

The first asymptotical function distribution of the extreme value of Gumbel is defined by:

$$f(m, A, B) = \exp[-\exp(-Am - B)] \qquad (1)$$

The constants A and B are obtained through the best fitting adjustment of the data. In preparing the data for plotting, we calculated the differences between the characteristic ozone level ($\sim$ 300 DU) and the ground-based observations (it is mentioned as AMD in Table 1). These values are ranked in ascending order and each data is assigned a probability according to Gringorten (1963):

$$P(i) = (i - 0.44)/6.12, \quad \text{with } i = 2, 3 \dots 6 \qquad (2)$$

The return periods T(m) were calculated by using the expressions:

$$T(m) = 1/[1 - f(m, A, B)] \qquad (3)$$

$$T'(m) = f(m, A, B)^{-1} = T(m)[T(m) - 1]^{-1} \qquad (4)$$

$T(m)$ shows the waited number of years required to detect one interval with extremes equal to or exceeding m, and, $T'(m)$ exhibits the expected number of intervals necessary to obtain one period with the extreme value less than m.

To predict the expected largest yearly deviation of the ozone density during the spring months of 1998, we introduced the value $T(m) = T'(m) = 7$ in Eqs. 3 and 4 respectively. We considered the data from the seven years between 1992 and 1998. The results obtained were $T(7) = 124$ DU and $T'(7) = 94$ DU.

Table 1. Data used in the present article.

Year	minimum ground-based observations	(AMD) largest yearly deviation from 300 DU(%)
14/10/92	95 DU	68.3
14/10/93	102 DU	66.0
23/9/95	125 DU	58.3
5/10/96	125 DU	58.3
4/10/97	120 DU	60.0
2/10/98	102 DU	60.0

3. Data Selection

To detect the ozone hole variations, we have used the daily records of a Brewer spectrophotometer as located at Belgrano Station (78.0°S; 38.8°W). To obtain the future development of the ozone abundance, the highest yearly ozone depletion were selected for the period from 1992 to 1997.

To analyze the observations we used as a reference the typical value of 300 DU, then, we calculated the differences between 300 DU and the ground-based observations.

The period under investigation includes observations at Belgrano Station during the spring months from 1992 to 1997 (Fig. 1 shows its original site on the Filchner Ice Shelf in the Antarctic continent).
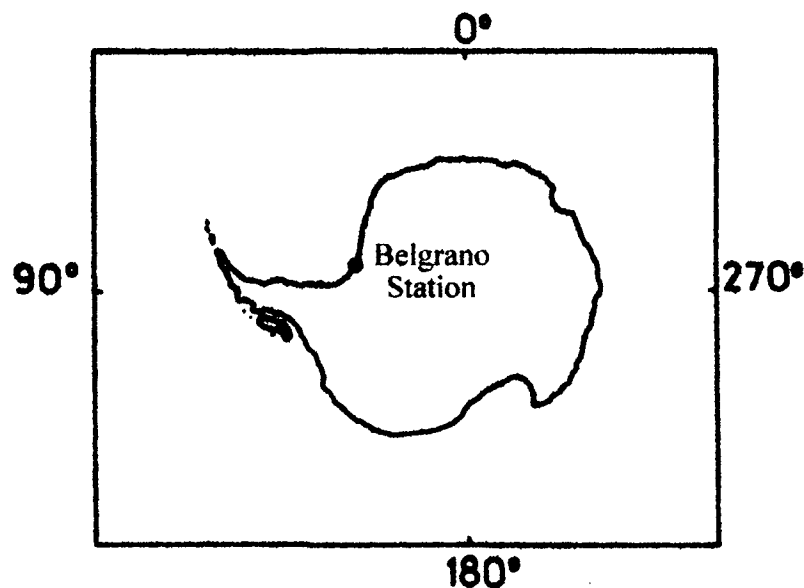

Fig. 1. Position of Belgrano Station on the Antarctic continent at its original site on the Filchner Ice Shelf.

4. Results and Conclusions

The constants considered in Eq. 1 were estimated by using the linear fit as it is plotted in Figure 2. It was constructed taken each ordinate equal to $-ln(-ln(P(i))$ and each abscissa equal to the AMD value. The constants obtained from the linear fit were, $A = 0.26 \pm 0.05$ and $B = -16 \pm 3$.

This study presents the development of the largest yearly deviations (to the characteristic ozone level of ~ 300 DU) of the ozone hole observed at Belgrano Station between 1992 and 1997. The greatest decrease of the ozone column density was detected on November 10th, 1992 and this value was equal to 95 DU, this is the 32% of the typical ozone column density. During 1995 and 1996 the diurnal ozone hole increased its density and in 1997 it decreased up to 120 DU.
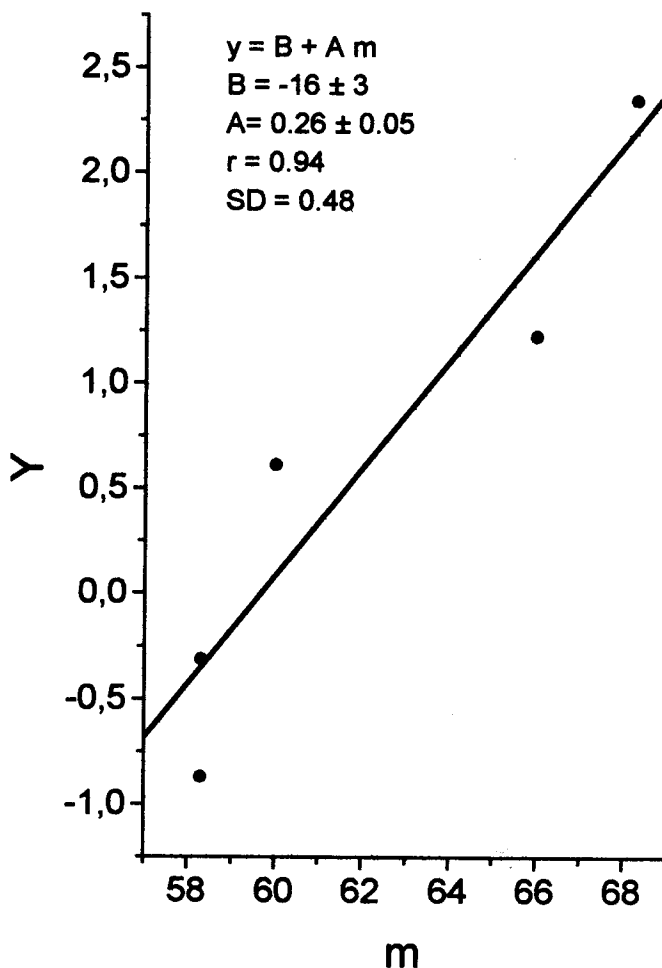

Fig. 2. Fitting adjustment obtained for the studied events using Gumbel's first distribution. The data recordings are obtained at Belgrano Station during the spring months. The differences between the characteristic ozone layer value and the observations are plotted by considering the ordinate values equal to -ln(-ln(P(i))).

We predict that the expected largest yearly deviation of the ozone layer density occurred during 1998 (as measured at Belgrano Station) would be in the interval defined by 94 DU and 124 DU. This result agrees remarkably well with the measured value of 102 DU as obtained on October 2 of 1998 at Belgrano Station.

Acknowledgements

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