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# 1 The Antarctic ozone depletion caused by Erebus volcano gas emissions

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9 Heterogeneous chemical reactions releasing photochemically active molecular chlorine play a  
10 key role in Antarctic stratospheric ozone destruction, resulting in the Antarctic ozone hole.  
11 Hydrogen chloride (HCl) is one of the principal components in these reactions on the surfaces  
12 of polar stratospheric clouds (PSCs). PSCs form during polar nights at extremely low  
13 temperatures (lower than  $-78^{\circ}\text{C}$ ) mainly on sulfuric acid ( $\text{H}_2\text{SO}_4$ ) aerosols, acting as  
14 condensation nuclei and formed from sulfur dioxide ( $\text{SO}_2$ ). However, the cause of HCl and  
15  $\text{H}_2\text{SO}_4$  high concentrations in the Antarctic stratosphere, leading to considerable springtime  
16 ozone depletion, is still not clear. Based on the NCEP/NCAR reanalysis data over the last 35  
17 years and by using the NOAA HYSPLIT trajectory model, we show that Erebus volcano gas  
18 emissions (including HCl and  $\text{SO}_2$ ) can reach the Antarctic stratosphere via high-latitude  
19 cyclones with the annual average probability  $\bar{P}_{\text{ann}}$  of at least  $\sim 0.235$  (23.5%). Depending on  
20 Erebus activity, this corresponds to additional annual stratospheric HCl mass of 1.0 to 14.3  
21 kilotons (kt) and  $\text{SO}_2$  mass of 1.4 to 19.7 kt. Thus, Erebus volcano is the natural and powerful  
22 source of additional stratospheric HCl and  $\text{SO}_2$ , and hence, the cause of the Antarctic ozone  
23 depletion, together with man-made chlorofluorocarbons.

24 *Keywords:* springtime ozone depletion, Erebus volcano, polar vortex, high-latitude cyclones,  
25 hydrogen chloride, sulfur dioxide.

26 *Abbreviations:* VCD, vertical column density; PSCs, polar stratospheric clouds; CFCs,  
27 chlorofluorocarbons; UVB, ultraviolet B; DU, Dobson units; HCl, hydrogen chloride;  $\text{Cl}_2$ ,  
28 molecular chlorine; Cl, chlorine atoms; ClO, chlorine monoxide radicals; ClONO<sub>2</sub>, chlorine  
29 nitrate;  $\text{SO}_2$ , sulfur dioxide;  $\text{H}_2\text{SO}_4$ , sulfuric acid aerosols.

## 30 1. Introduction

31 The ozone layer is known to absorb the bulk of solar ultraviolet B (UVB) rays, i.e. only a  
32 small part of UVB reaches the Earth's surface, and therefore, it protects Earth's biological systems  
33 from this dangerous radiation (Stolarski et al., 1992; Zerefos et al., 1997). However, this layer is  
34 depleted due to various reasons, especially over Antarctica. Based on ozone observations in 1982 at  
35 Syowa station ( $69^{\circ}00' \text{S}$ ,  $39^{\circ}35' \text{E}$ ) in Antarctica, Chubachi (1984) revealed the smallest value of  
36 total ozone since 1966. Soon after, based on the Halley Bay station ( $75^{\circ}35' \text{S}$ ,  $26^{\circ}34' \text{W}$ ) data,  
37 Farman et al. (1985) revealed a smooth decrease since 1972 and a considerable depletion in the  
38 early 1980's in the total ozone also over Antarctica. The ozone depletion was attributed to man-  
39 made chlorofluorocarbons (CFCs) and the region, wherein the total ozone value is less than 220  
40 Dobson Units (DU), was called later the "ozone hole". For more than twenty years the springtime

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