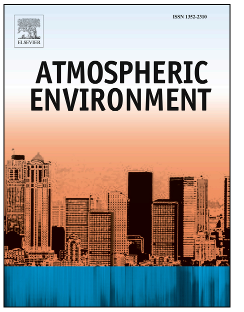
Accepted Manuscript



The Antarctic ozone depletion caused by Erebus volcano gas emissions

V.V. Zuev, N.E. Zueva, E.S. Savelieva, V.V. Gerasimov

PII: S1352-2310(15)30424-6

DOI: 10.1016/j.atmosenv.2015.10.005

Reference: AEA 14163

To appear in: *Atmospheric Environment*

Received Date: 4 June 2015

Revised Date: 1 October 2015

Accepted Date: 2 October 2015

The Antarctic ozone depletion caused by Erebus volcano gas emissions

V. V. Zuev [a, b, c], N. E. Zueva [a], E. S. Savelieva [a, *], V. V. Gerasimov [a, b]

[a] *Institute of Monitoring of Climatic and Ecological Systems of the Siberian Branch of the Russian Academy of Sciences, 10/3, Academichesky ave., 634055, Tomsk, Russia*
[b] *National Research Tomsk State University, 36, Lenina ave., 634050, Tomsk, Russia*
[c] *National Research Tomsk Polytechnic University, 30, Lenina ave., 634050, Tomsk, Russia*
* Corresponding author. *E-mail address:* ekat.savelieva@gmail.com (E. Savelieva). *Telephone:* (3822) 492–448.

E-mail address: vvzuev@imces.ru (V. V. Zuev), vzuev@list.ru (N. E. Zueva), gvvsnake@mail.ru (V. V. Gerasimov)

Heterogeneous chemical reactions releasing photochemically active molecular chlorine play a key role in Antarctic stratospheric ozone destruction, resulting in the Antarctic ozone hole. Hydrogen chloride (HCl) is one of the principal components in these reactions on the surfaces of polar stratospheric clouds (PSCs). PSCs form during polar nights at extremely low temperatures (lower than –78 °C) mainly on sulfuric acid (H_2SO_4) aerosols, acting as condensation nuclei and formed from sulfur dioxide (SO_2). However, the cause of HCl and H_2SO_4 high concentrations in the Antarctic stratosphere, leading to considerable springtime ozone depletion, is still not clear. Based on the NCEP/NCAR reanalysis data over the last 35 years and by using the NOAA HYSPLIT trajectory model, we show that Erebus volcano gas emissions (including HCl and SO_2) can reach the Antarctic stratosphere via high-latitude cyclones with the annual average probability $\overline{P}_{\text{ann.}}$ of at least ~ 0.235 (23.5%). Depending on Erebus activity, this corresponds to additional annual stratospheric HCl mass of 1.0 to 14.3 kilotons (kt) and SO_2 mass of 1.4 to 19.7 kt. Thus, Erebus volcano is the natural and powerful source of additional stratospheric HCl and SO_2, and hence, the cause of the Antarctic ozone depletion, together with man-made chlorofluorocarbons.

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

Abbreviations: VCD, vertical column density; PSCs, polar stratospheric clouds; CFCs, chlorofluorocarbons; UVB, ultraviolet B; DU, Dobson units; HCl, hydrogen chloride; Cl_2, molecular chlorine; Cl, chlorine atoms; ClO, chlorine monoxide radicals; $ClONO_2$, chlorine nitrate; SO_2, sulfur dioxide; H_2SO_4, sulfuric acid aerosols.

1. Introduction

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