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The role of Erebus volcano in enhancing Antarctic ozone hole

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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 (H2SO4) aerosols, acting as condensation nuclei and formed from sulfur dioxide (SO_2).

We revealed that HCl vertical column density over the Arrival Heights station in Antarctica is considerably higher than that observed over other Earth's regions including Arctic one, whereas $ClONO_2$ is distributed homogeneously enough in the Earth's stratosphere. Moreover, we also revealed that concentration of H2SO4 aerosols formed from SO_2 is higher in the Antarctic stratosphere in comparison with that in the Arctic one. These facts cannot be explained by only the Brewer–Dobson circulation and are indicative of a volcanogenic source of HCl and SO_2 within the Antarctic continent.

Erebus volcano (77°32′ S, 167°09′ E, summit elevation 3794 m) located on Ross Island, Ross Sea, is known to be the only burning volcano in Antarctica and one of the most active volcanoes on the Earth. Erebus volcano is noted for its persistent and permanent gas and aerosol emissions mostly occurring via lava lake degassing. Erebus volcano eruptions are of the Strombolian type, which volcanic ejecta and gases are known to reach heights of 1–2 km above the volcano summit and, therefore, cannot directly reach the stratosphere.

Erebus volcano gas emissions can ascend to the Antarctic stratosphere via high-latitude cyclones which are coupled to the stratospheric polar vortex in cold seasons. Due to the asymmetry of the Antarctic continent relative to the geographic pole, the cyclones, moving along the west coast with meridional component of velocity, penetrate deep into the western Antarctic seas, including the Ross Sea. 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 of at least ~ 0.235 (23.5%). According to various measurement data, the masses of HCl and SO_2 emitted annually by Erebus volcano vary from 4.1 to 60.9 kilotons (kt) and from 6.0 to 83.9 kt, respectively. Taking into account the annual average probability 0.235, we obtain that the annual HCl and SO_2 masses, reaching the Antarctic stratosphere via high-latitude cyclones vary from 1.0 to 14.3 kt and from 1.4 to 19.7 kt, respectively, depending on Erebus volcanic activity. Note that in the early 1980s, the extremely high Erebus activity was synchronous with an increase of the springtime ozone hole area.

Reference: Zuev, V.V., Zueva, N.E., Savelieva, E.S., and Gerasimov, V.V.: The Antarctic ozone depletion caused by Erebus volcano gas emissions, Atmos. Environ., 122, 393–399, doi:10.1016/j.atmosenv.2015.10.005, 2015. (http://www.sciencedirect.com/science/article/pii/S1352231015304246)