The Effects of Volcano-Induced Ozone Depletion on Short-lived Climate Forcing in the Arctic

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Photodissociation of oxygen maintains the stratopause ~50°C warmer than the tropopause. Photodissociation of ozone warms the lower stratosphere, preventing most of this high-energy DNA-damaging solar radiation from reaching the troposphere. Ozone depletion allows more UV energy to reach the lower troposphere causing photodissociation of anthropogenic ozone and nitrogen dioxide. UV energy also penetrates the ocean >10 m where it is absorbed more efficiently than infrared radiation that barely penetrates the surface. Manmade chlorofluorocarbons caused ozone depletion from 1965 to 1994 with slow recovery predicted over the next 50+ years. But the lowest levels of ozone followed the eruptions of Pinatubo (1991 VEI=6), Eyjafjallajökull (2010 VEI=4), and Grímsvötn (2011 VEI=4). Each of the relatively small, basaltic eruptions in Iceland caused more ozone depletion than the long-term effects of chlorofluorocarbons, although total ozone appears to return to pre-eruption levels within a decade.

Ozone depletion by 20% increases energy flux thru the lowermost troposphere by 0.7 W m-2 for overhead sun causing temperatures in the lower stratosphere to drop >2°C since 1958 in steps after the 3 largest volcanic eruptions: Agung 1963, El Chichón 1982, and Pinatubo. Temperatures at the surface increased primarily in the regions and at the times of the greatest observed ozone depletion.

The greatest warming observed was along the Western Antarctic Peninsula (65.4°S) where minimum temperatures rose 6.7°C from 1951 to 2003 while maximum temperatures remained relatively constant. Minimum total column ozone in September-October was 40-56% lower than in 1972 almost every year since 1987, strongly anti-correlated with observed minimum temperatures. Sea ice decreased 10%, 7 ice shelves separated, 87% of the glaciers retreated and the Antarctic Circumpolar Current warmed. Elsewhere under the ozone hole, warming of continental Antarctica was limited by the high albedo (0.86) of Antarctic snow and decreasing solar zenith angles at higher latitudes.

The second largest ozone depletion was in the Arctic at the times and places of greatest winter warming. Average ozone at four stations in Canada (43-59°N) compared to the 1961-1970 mean were 6% lower in December 2010 after the eruption of Eyjafjallajökull and 11% lower in December 2011 after the eruption of Grímsvötn. In 2012, ozone levels were still 10% lower in March and 7% lower in July. The regions and timing of this depletion are the regions and times of unusually warm temperatures and drought in North America during 2011-2012. The Dust Bowl droughts in 1934 and 1936 show a similar temporal relationship to a highly unusual sequence of five VEI=4-5 eruptions around the Pacific in 1931-1933.

Major increases in global pollution were from 1950-1970 while ozone-destroying tropospheric chlorine rose from 1970 to 1994, along with ocean heat content and mean temperature. Pollution does not seem to cause an increase in warming until ozone depletion allows more UV into the lower troposphere. Pollutants decrease surface solar radiation but also reduce Arctic-snow albedo.

Widespread observations imply that ozone depletion and associated photodissociation cause substantial warming. Several issues regarding the microphysics of absorption and radiation by greenhouse gases must be resolved before we can quantify their relative importance.

Index terms: Arctic region, Regional climate change, Climate change and variability, Volcano/climate interactions