Depletion of the global ozone layer by major volcanic eruptions

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Depletion of the stratospheric ozone layer, which protects the biosphere from harmful solar ultraviolet radiation, is known to be caused by certain human-produced, chlorine- and bromine-bearing molecules which enter the stratosphere and undergo chemical transformations to reactive species that attack ozone. The most effective of these chemical processes are heterogeneous, i.e., involve the presence of a surface to catalyze the reaction. Thus, the surface area presented by polar stratospheric cloud particles is the main reason that a major ozone hole forms in the springtime Antarctic stratosphere, where nitric acid and water ice clouds readily form in the cold winter stratosphere. However, it has been shown that the heterogeneous chemical processes are also efficient on the surfaces of sulfuric acid aerosol droplets under warmer temperatures in the global stratosphere. Under normal conditions the amount of sulfate aerosol in the stratosphere is very small. However, following a major explosive volcanic eruption, such as that of Mt. Pinatubo in 1991, sufficient sulfur dioxide is injected into the stratosphere, where it chemically converts to sulfuric acid vapor and condenses, to increase the mass of sulfate aerosol in the stratosphere by more than an order of magnitude. The ensuing increase in droplet surface area affects climate by backscattering sunlight and catalyzing additional ozone depletion by the pre-existing chlorine and bromine gases. Regulations on emissions of certain halogen precursor gases, related to the Montreal Protocol on substances that deplete the ozone layer, have been effective and total equivalent chlorine (a quantity which takes into account the ozone depletion efficiency of all the chlorine- and bromine-bearing gases) reached a maximum at the surface about 1994. Remote sensing of halogen gases suggests that they are also near a maximum in the stratosphere. The global ozone layer has ceased declining and the Antarctic ozone hole shows continued severe ozone loss. Thus, the stratosphere is near its most vulnerable state, in terms of chemical ozone-depletion potential. A major volcanic eruption during the next 10-15 years would result in global ozone reductions up to about 5% and bring the ozone depletion issue back into the spotlight. The importance of continued monitoring of ozone and ozone-depleting substances as well as the stratospheric burden of volcanic related sulfuric acid droplets is emphasized.