Q14: Do changes in the Sun and volcanic eruptions affect the ozone layer?

Yes, factors such as changes in solar radiation, as well as the formation of stratospheric particles after volcanic eruptions, do influence the ozone layer. However, neither factor can explain the average decreases observed in global total ozone over the last two decades. If large volcanic eruptions occur in the coming decades, ozone depletion will increase for several years after the eruption.

Changes in solar radiation and increases in stratospheric particles from volcanic eruptions both affect the abundance of stratospheric ozone, but they have not caused the long-term decreases observed in total ozone.

Solar changes. The formation of stratospheric ozone is initiated by ultraviolet (UV) radiation coming from the Sun (see ***Figure Q2-1***). As a result, an increase in the Sun's radiation output increases the amount of ozone in Earth's atmosphere. The Sun's radiation output and sunspot number vary over the well-known 11-year solar cycle. Observations over several solar cycles (since the 1960s) show that global total ozone levels vary by 1 to 2% between the maximum and minimum of a typical cycle. Changes in solar output at a wavelength of 10.7 cm, although much larger than changes in total solar output, are often used to show when periods of maximum and minimum total output occur (see ***Figure Q14-1***). Since 1978, the Sun's output has gone through maximum values around 1969, 1980, and 1991, and is currently near a maximum value in 2002.

Over the last two decades, average total ozone has decreased over the globe. Average values in recent years

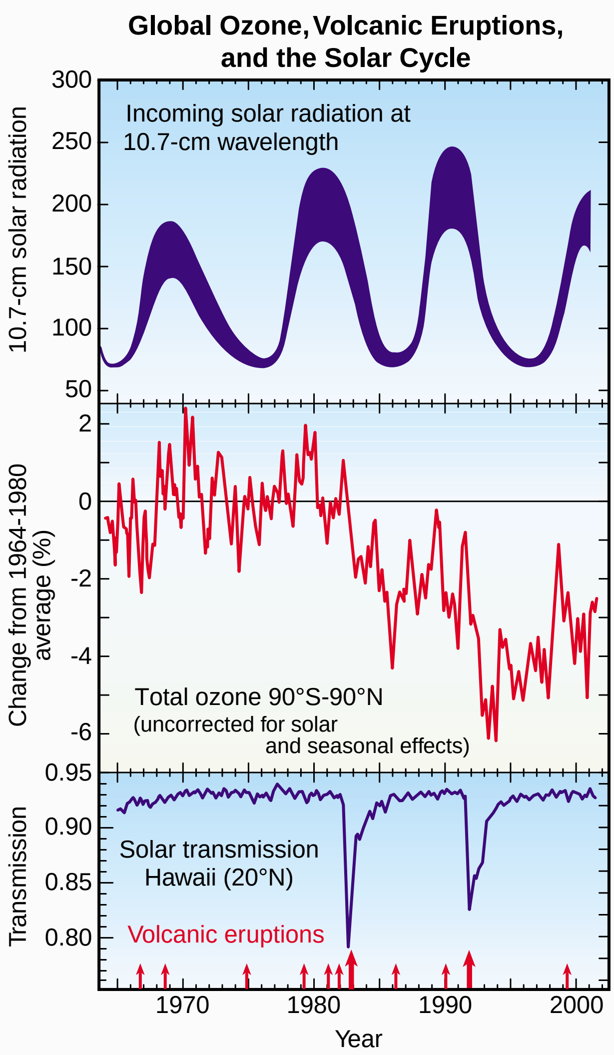

Figure Q14-1. Solar changes and volcanoes. Total ozone values have decreased beginning in the early 1980s (see middle panel). The ozone values shown have not been smoothed for solar and seasonal effects as they were in ***Figure Q13-1***. Incoming solar radiation, which produces ozone in the stratosphere, changes on a well-recognized 11-year cycle. Solar radiation at 10.7-cm wavelength is often used to show the times of maximum and minimum solar output (see top panel). A comparison of the top and middle panels indicates that the cyclic changes in solar output cannot account for the long-term decreases in ozone. Volcanic eruptions occurred frequently in the 1965 to 2002 period. The largest recent eruptions are El Chichón (1982) and Mt. Pinatubo (1991) (see large red arrows). Large volcanic eruptions are monitored by the decreases in solar transmission to Earth's surface that occur because new particles are formed in the stratosphere from volcanic sulfur emissions (see bottom panel). These particles increase ozone depletion but do not remain in the stratosphere for more than a few years. A comparison of the middle and bottom panels indicates that large volcanic eruptions also cannot account for the long-term decreases found in global total ozone.

show a 3-4% depletion from pre-1980 values (see ***Figure Q14-1***). The ozone values shown have not been smoothed for solar and seasonal effects as they were for ***Figure Q13-1***. Over the same period, changes in solar output show the expected 11-year cycle but do not show a decrease with time. For this reason, the long-term decreases in global ozone cannot result from changes in solar output alone. Most discussions of long-term ozone changes presented in this and previous international scientific assessments account for the influence of the 11-year solar cycle.

Past volcanoes. Large volcanic eruptions inject sulfur gases directly into the ozone layer, causing new sulfate particles to be formed. The particles initially form in the stratosphere above the volcano location and then spread globally as air is transported within the stratosphere. The presence of volcanic particles in the stratosphere is shown by observations of solar transmission through the atmosphere. When large amounts of particles are present in the stratosphere, transmission of solar radiation is reduced. The large eruptions of El Chichón (1982) and Mt. Pinatubo (1991) are recent examples of events that temporarily reduced transmission (see ***Figure Q14-1***).

Laboratory measurements and stratospheric observations have shown that chemical reactions on the surface of volcanically produced particles increase ozone destruction by increasing the amounts of the highly reactive chlorine gas, chlorine monoxide (ClO). Ozone depletion increases as a consequence of increased ClO. The most recent large eruption was that of Mt. Pinatubo, which resulted in up to a 10-fold increase in the number of particles available for surface reactions. Both El Chichón and Mt. Pinatubo reduced global ozone for a few years (see ***Figure Q14-1***). After a few years, the effect of volcanic particles diminishes as volcanically produced particles are gradually removed from the stratosphere by natural air circulation. Because of particle removal, the few large volcanic eruptions of the last two decades cannot account for the long-term decreases observed in ozone over the same period.

Future volcanoes. Observations and atmospheric models indicate that the record-low ozone levels observed in 1992-1993 resulted from the relatively large number of particles produced by the Mt. Pinatubo eruption, combined with the relatively large amounts of halogen gases present in the stratosphere in the 1990s. If the Mt. Pinatubo eruption had occurred before 1980, changes to global ozone would have been much smaller than observed in 1992-1993 because the abundance of halogen gases in the stratosphere was smaller. In the early decades of the 21^{st} century, the abundance of halogen gases will still be substantial in the global atmosphere (see ***Figure Q16-1***). If large volcanic eruptions occur in these early decades, ozone depletion will increase for several years. If an eruption larger than Mt. Pinatubo occurs then ozone losses could be larger than previously observed and persist longer. Only later in the 21^{st} century when halogen gas abundances have declined will the effect of volcanic eruptions on ozone be lessened.