

III. STRATOSPHERIC OZONE DEPLETION

Q11: How severe is the depletion of the Antarctic ozone layer?

Severe depletion of the Antarctic ozone layer was first observed in the early 1980s. Antarctic ozone depletion is seasonal, occurring primarily in late winter and spring (August–November). Peak depletion occurs in October when ozone is often completely destroyed over a range of altitudes, reducing overhead total ozone by as much as two-thirds at some locations. This severe depletion creates the “ozone hole” in images of Antarctic total ozone made from space. In most years the maximum area of the ozone hole usually exceeds the size of the Antarctic continent.

The severe depletion of Antarctic ozone known as the “ozone hole” was first observed in the early 1980s. The depletion is attributable to chemical destruction by reactive halogen gases, which increased in the stratosphere in the latter half of the 20th century (see Q16). Conditions in the Antarctic winter stratosphere are highly suitable for ozone depletion because of (1) the long periods of extremely low temperatures, which promote PSC formation and removal; (2) the abundance of reactive halogen gases, which chemically destroy ozone; and (3) the isolation of stratospheric air during the winter, which allows time for chemical destruction to occur (see Q10). The severity of Antarctic ozone depletion can be seen using images of total ozone from space, ozone altitude profiles, and long-term average values of polar total ozone.

Antarctic ozone hole. The most widely used images of Antarctic ozone depletion are those from space-based measurements of total ozone. Satellite images made during Antarctic winter and spring show a large region centered near the South Pole in which total ozone is highly depleted (see *Figure Q11-1*). This region has come to be called the “ozone hole” because of the near-circular contours of low ozone values in the images. The area of the ozone hole has reached 25 million square kilometers (about 10 million square miles) in recent years, which is nearly twice the area of the Antarctic continent. Minimum values of total ozone inside the ozone hole have fallen as low as 100 Dobson units (DU) compared with normal springtime values of about 300 DU (see Q4). The mass of ozone destroyed over the Antarctic each season has reached an estimated 80 megatons, which is about 3% of the global ozone mass (1 megaton = 1 billion kilograms = 2.2 billion pounds).

Altitude profiles of Antarctic ozone. Ozone within the “ozone hole” is also measured using balloonborne instruments (see Q5). Balloon measurements show changes within the ozone layer, the vertical region that contains the highest ozone abundances in the stratosphere. At geographic locations where the lowest total ozone values occur in ozone hole images, balloon measurements show that the

chemical destruction of ozone is complete over a vertical region of several kilometers. *Figure Q11-2* shows an example of such depletion with balloon measurements

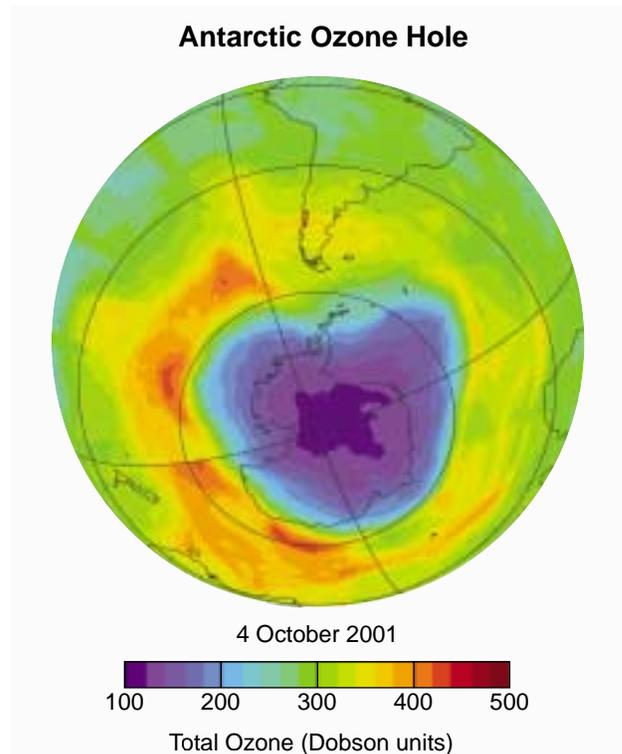


Figure Q11-1. Antarctic “ozone hole.” Total ozone values are shown for high southern latitudes as measured by a satellite instrument. The dark regions over the Antarctic continent show the severe ozone depletion now found in every spring. Minimum values of total ozone inside the ozone hole are close to 100 Dobson units (DU) compared with normal springtime values of about 300 DU (see Q4). In late spring or early summer (November–December) the ozone hole disappears as ozone-depleted air is displaced and diluted by ozone-rich air from outside the ozone hole.

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made over South Pole, Antarctica, on 2 October 2001. The altitude region of total depletion (14-20 kilometers) in the profile corresponds to the region of lowest winter temperatures and highest ClO abundances. The average South Pole ozone profiles for the decades 1962-1971 and 1992-2001 (see *Figure Q11-2*) show how reactive halogen gases have changed the ozone layer. In the 1960s, the ozone layer is clearly evident in the October average profile. In the 1990s, minimum average values in the center of the layer have fallen by 90% from the earlier values.

Long-term total ozone changes. Low winter temperatures and isolated conditions occur each year in the Antarctic stratosphere. As a result, significant spring ozone depletion has been observed every year since the early 1980s. In prior years, the amounts of reactive halogen gases in the stratosphere were insufficient to cause significant depletion. Satellite observations can be used to examine the average total ozone abundances in both polar regions for the last three decades (see *Figure Q12-1*). In the Antarctic, average values decreased steadily through the 1980s and 1990s, reaching minimum values that were 37%

less than in pre-ozone-hole years (1970-1982). The year-to-year changes in the average values reflect variations in the meteorological conditions, which affect the extent of low polar temperatures and the transport of air into and out of the Antarctic winter stratosphere. However, essentially all of the ozone depletion in the Antarctic in most years is attributable to chemical loss from reactive halogen gases.

Restoring ozone in spring. The depletion of Antarctic ozone occurs primarily in the late winter/spring season. In spring, temperatures in the lower polar stratosphere eventually warm, thereby ending PSC formation and the most effective chemical cycles that destroy ozone (see *Q10*). The transport of air between the polar stratosphere and lower latitudes also increases during this time, ending winter isolation. This allows ozone-rich air to be transported to polar regions, displacing air in which ozone has been severely depleted. This displaced air is diluted at lower latitudes with more abundant ozone-rich air. As a result, the ozone hole disappears by December and Antarctic ozone amounts remain near normal until the next winter season.

Figure Q11-2. Arctic and Antarctic ozone distribution.

The stratospheric ozone layer resides between about 10 and 50 kilometers (6 to 31 miles) above Earth's surface over the globe. Long-term observations of the ozone layer from small balloons allow the winter Antarctic and Arctic regions to be compared. In the Antarctic at the South Pole, halogen gases have destroyed ozone in the ozone layer beginning in the 1980s. Before that period, the ozone layer was clearly present as shown here using average ozone values from balloon observations made between 1962 and 1971. In more recent years, as shown here for 2 October 2001, ozone is destroyed completely between 14 and 20 kilometers (8 to 12 miles) in the Antarctic in spring. Average October values in the ozone layer now are reduced by 90% from pre-1980 values. The Arctic ozone layer is still present in spring as shown by the average March profile obtained over Finland between 1988 and 1997. However, March Arctic ozone values in some years are often below normal average values as shown here for 30 March 1996. In such years, winter minimum temperatures are generally below PSC formation temperatures for long periods. (Ozone abundances are shown here with the unit "milli-Pascals" (mPa), which is a measure of absolute pressure (100 million mPa = atmospheric sea-level pressure).)

