

V. IMPLICATIONS OF OZONE DEPLETION

Q17: Does depletion of the ozone layer increase ground-level ultraviolet radiation?

Yes, ultraviolet radiation at Earth's surface increases as the amount of overhead total ozone decreases, because ozone absorbs ultraviolet radiation from the Sun. Measurements by ground-based instruments and estimates made using satellite data have confirmed that surface ultraviolet radiation has increased in regions where ozone depletion is observed.

The depletion of stratospheric ozone leads to an increase in surface ultraviolet radiation. The increase occurs primarily in the ultraviolet-B (UV-B) component of the Sun's radiation. UV-B is defined as radiation in the wavelength range of 280 to 315 nanometers. Changes in UV-B at the surface have been observed directly and can be estimated from ozone changes.

Surface UV-B radiation. The amount of ultraviolet radiation reaching Earth's surface depends in large part on the amount of ozone in the atmosphere. Ozone molecules in the stratosphere absorb UV-B radiation, thereby significantly reducing the amount of this radiation that reaches Earth's surface (see *Q3*). If total ozone amounts are reduced in the stratosphere, then the amount of UV radiation reaching Earth's surface generally increases. This relationship between total ozone and surface UV radiation has been studied at a variety of locations with direct measurements of both ozone and UV. The actual amount of UV reaching a location depends on a large number of additional factors, including the position of the Sun in the sky, cloudiness, and air pollution. In general, surface UV at a particular location on Earth changes throughout the day and with season as the Sun's position in the sky changes.

Long-term surface UV changes. Satellite observations of long-term global ozone changes can be used to estimate changes in global surface UV that have occurred over the past two decades. These changes are of interest because UV radiation can cause harm to humans and other life forms (see *Q3*). The amount of UV that produces an "erythema" or sunburning response in humans is often separately evaluated. UV-B radiation is a large component of sunburning UV. Long-term changes in sunburning UV at a location can be estimated from the changes in total ozone at that location. The results show that average sunburning UV has increased by up to a few percent per decade between 1979 and 1992 over a wide range of latitudes (see *Figure Q17-1*). The largest increases are found at high polar latitudes in both hemispheres. As expected, the increases occur where decreases in total ozone are observed to be the largest (see *Figure Q13-1*). The smallest changes in sunburning UV are in the tropics,

where long-term total ozone changes are smallest.

UV Index changes. The "UV Index" is a measure of daily surface UV levels that is relevant to the effects of UV on human skin. The UV Index is used internationally to increase public awareness about the detrimental effects of UV on human health and to guide the need for protective measures. The Index is essentially a measure of erythema radiation, of which UV-B is a principal component. The daily maximum UV Index varies with location and season, as shown for three locations in *Figure Q17-2*. The highest daily values generally occur at the lowest latitudes (tropics) and in summer when the midday Sun is closest to overhead. Values in San Diego, California, for example, normally are larger year round than those found in Barrow, Alaska, which is at a higher latitude. At a given latitude, UV Index values increase in mountainous regions. Winter and fall values become zero in periods of continuous darkness at high-latitude locations.

An illustrative example of how polar ozone depletion increases the maximum daily UV Index is shown in *Figure Q17-2*. Normal UV Index values for Palmer, Antarctica, in spring were estimated from satellite measurements made during the period 1978-1983, before the appearance of the "ozone hole" over Antarctica (see red dotted line). In the last decade (1991-2001) severe and persistent ozone depletion in spring has increased the UV Index well above normal values for several months (see thick red line). Now spring UV Index values in Palmer (64°S) sometimes equal or exceed normal values measured in San Diego (32°N) in spring.

Other causes of long-term UV changes. The intensity of surface UV-B may also change as a result of other human activities or climate change. Long-term changes in cloudiness, aerosols, pollution, and snow or ice cover will cause long-term changes in surface UV-B. At some ground sites, measurements indicate that long-term changes in UV-B have resulted from changes in one or more of these factors. The impact of some of the changes can be complex. For example, a change in cloud cover usually results in a reduction of UV-B radiation below the cloud layer, but can increase radiation above the layer (in mountainous regions).

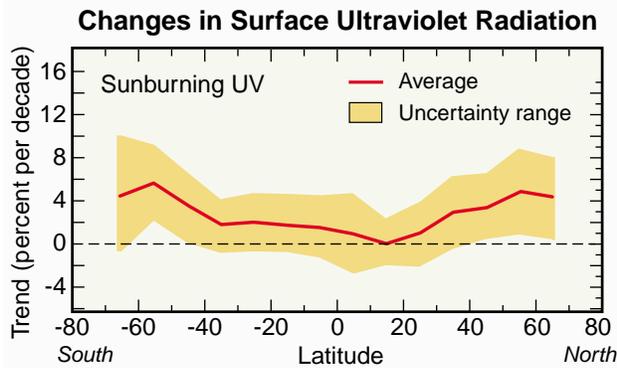


Figure Q17-1. Changes in surface UV radiation. Ultraviolet (UV) radiation at Earth’s surface that causes sunburning has increased over the globe between 1979 and 1992. Also known as “erythemal radiation,” sunburning UV is harmful to humans and other life forms. The increase shown here is estimated from observed decreases in ozone and the relationship between ozone and surface UV established at some surface locations. The changes in ultraviolet radiation in the tropics are estimated to be the smallest because observed changes in tropical ozone have been the smallest.

UV changes and skin cancer. Skin cancer cases in humans increase with the amount of sunburning UV reaching Earth’s surface. Atmospheric scientists working together with health professionals can estimate how skin cancer cases will change in the future. The estimates are based on knowing how sunburning UV increases as total ozone is depleted and how total ozone depletion changes with effective stratospheric chlorine (see Q16). Estimates of future excess skin cancer cases are shown in **Figure Q15-1** using future estimates of effective chlorine based on the 1992 Montreal Protocol provisions. The cases are those that would occur in a population with the UV sensitivity and age distribution such as that of the United States. The cases counted are those in *excess* of the number that occurred in 1980 before ozone depletion was observed (about 2000 per million population). The case estimates include the fact that skin cancer in humans occurs long after the exposure to sunburning UV. The results show that, with current Protocol provisions, excess skin cancer cases are predicted to increase in the early to middle decades of the 21st century. By century’s end, with the expected decreases in halogen source gas emissions, the number of excess cases is predicted to return close to 1980 values. Without the provisions of the Protocol, excess skin cancer cases would be expected to increase unchecked throughout the century.

Figure Q17-2. Changes in UV Index. The maximum daily UV Index is a measure of peak sunburning UV that occurs during the day at a particular location. UV-B, which is absorbed by ozone, is an important component of sunburning UV. The UV Index varies with latitude and season as the Sun’s path through the local sky changes. The highest values of the maximum daily UV Index occur in the tropics where the midday Sun is highest throughout the year and where total ozone values are lowest. For comparison, the figure shows that the UV Index is higher in San Diego than in Barrow throughout the year. Index values are zero at high latitudes when darkness is continuous. The effect of ozone depletion on the Index is demonstrated by comparing the Palmer and San Diego data in the figure. Normal values estimated for Palmer are shown for the 1978-1983 period before the “ozone hole” occurred each season (see red dotted line). In the last decade (1991-2001), Antarctic ozone depletion has led to an increase in the maximum UV Index value at Palmer throughout spring (see yellow shaded region). Values at Palmer now sometimes equal or exceed those measured in spring in San Diego, which is located at a much lower latitude.

