Twenty Questions and Answers About the Ozone Layer: 2018 Update

Scientific Assessment of Ozone Depletion: 2018

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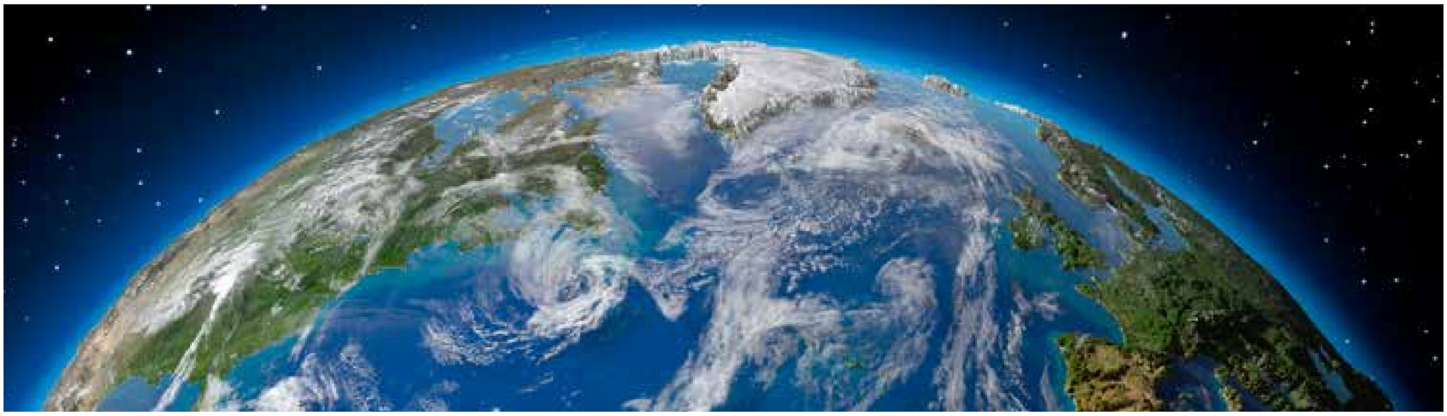

World Meteorological Organization
United Nations Environment Programme
National Oceanic and Atmospheric Administration
National Aeronautics and Space Administration
European Commission

Q16 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 provide evidence that surface ultraviolet radiation has increased in large geographic regions in response to ozone depletion.

The depletion of stratospheric ozone leads to an increase in solar ultraviolet radiation at Earth's surface. 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, which is invisible to the human eye. Long-term changes in UV-B radiation reaching the surface have been measured directly and can be estimated from total ozone changes.

Exposure to UV-B radiation can harm humans, other life forms, and materials (see Q2). Most of the effects of sunlight on the human body are caused by UV-B radiation. A principal effect is skin erythema, which leads to sunburn. Excess exposure may lead to skin cancer. Erythemal radiation is regularly reported to the public in many countries in the form of the *UV Index*. Long-term changes in surface UV-B radiation are important to study because of potential harmful effects as well as the relationship between excess UV-B radiation and ozone depletion.

Surface UV-B radiation. The amount of UV-B radiation reaching Earth's surface at a particular location depends in large part on the amount of total ozone at that location. Ozone molecules in the stratosphere and in the troposphere absorb UV-B radiation, thereby significantly reducing the amount that reaches Earth's surface (see Q2). If conditions occur that reduce the abundance of ozone molecules somewhere in the troposphere or stratosphere, total ozone is reduced and the amount of UV-B radiation reaching Earth's surface is increased proportionately. This relationship between total ozone and surface UV-B radiation has been confirmed at a variety of locations with direct measurements of both quantities.

Additional causes of UV changes. The actual amount of UV-B radiation reaching Earth's surface at a specific location and time depends on a number of factors in addition to total ozone. The primary additional factor is the position of the Sun in the sky, which changes with daily and seasonal cycles. Other factors include local cloudiness, the altitude of the location, the amount of ice or snow cover, and the amounts of atmospheric particles (aerosols) in the atmosphere above the location. Changes in clouds and aerosols are partially related to air pollution and greenhouse gas emissions from human activities. Measurements indicate that both increases and decreases in UV radiation at certain locations have resulted from variations in one or more of these factors. Estimating the impact of changes in these factors is complex. For example, an increase in cloud cover usually results in a reduction of UV radiation below the clouds and could at the same time increase UV radiation at a location in the mountains above the clouds.

Long-term surface UV changes. Long-term changes in UV-B radiation have been estimated from statistical analyses of measurements made with special UV monitoring instruments at several surface locations since about 1990. For example, as a consequence of Antarctic ozone depletion, the average UV-B measured at the South Pole during spring between 1991 and 2017 was 55–85% larger than estimated for the years 1963–1980. In addition, satellite observations of ozone changes have been used to estimate changes in surface UV-B radiation that have occurred over the past four decades. With satellite observations, the UV-B radiation changes can be separately attributed to changes in ozone and clouds (see **Figure Q16-1**). The results show that erythemal radiation has increased by an average of 3% between 1979 and 2008 over a wide range of latitudes outside the tropics (see lower panel of Figure Q16-1). The largest percentage increases have occurred at high polar latitudes in both hemispheres, where the largest annual decreases in total ozone are observed (see Figure Q12-1). Over this time period the UV increases due to ozone depletion are partially offset by changes in cloudiness or by increased air pollution, primarily in the high latitudes of the Southern Hemisphere (see top panel in Figure Q16-1). Without changes in cloudiness, the increases in erythemal radiation at these latitudes would have reached a maximum close to 9%. The smallest changes in erythemal UV have been in the tropics, where long-term changes in total ozone are smallest. There are indications of a decline in surface UV-B at a few surface monitoring stations in the Northern Hemisphere since 1994, a period coincident with the rise in global total ozone (see Figure Q12-1). However, the observed decrease in UV-B is also affected by changes in cloud cover and air pollution over this time period and therefore cannot be fully linked to the recovery of the ozone layer.

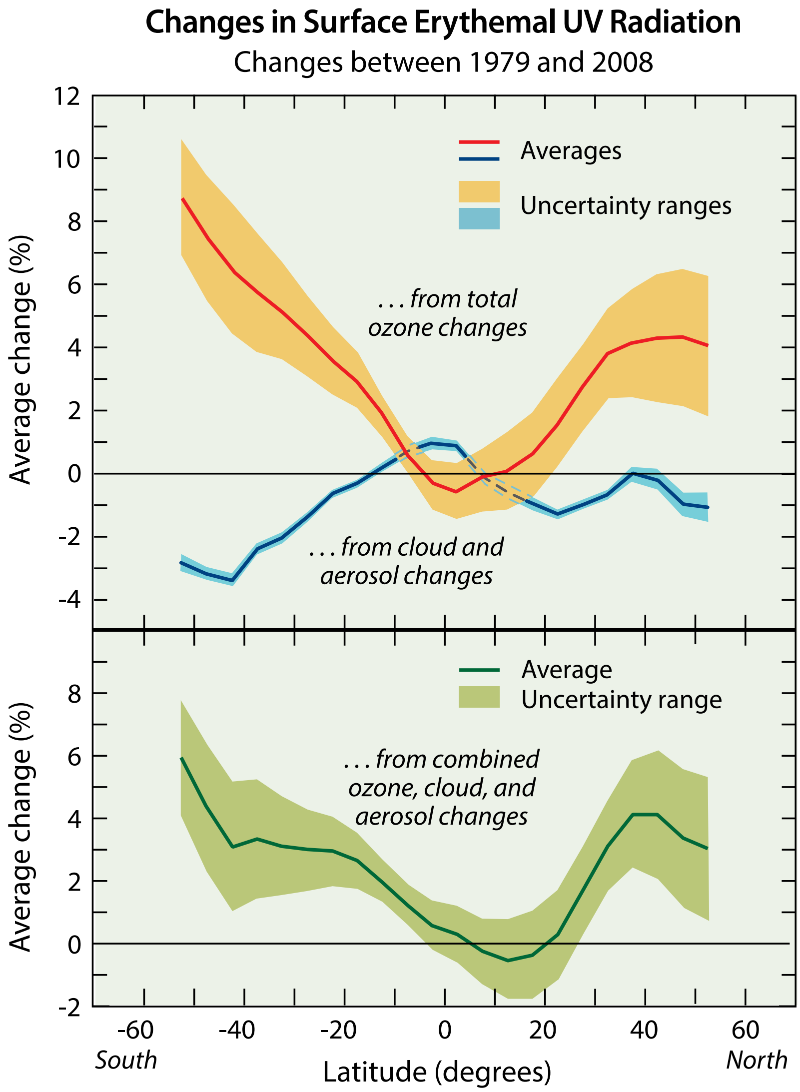

Figure Q16-1. Long-term changes in surface erythemal radiation. Solar ultraviolet (UV) radiation at Earth's surface increased over much of the globe between 1979 and 2008, a time of global ozone depletion (see Figure Q12-1). Erythemal radiation, which can lead to sunburn, is a component of surface UV radiation that is harmful to humans and other life forms. Surface erythemal radiation responds to changes in total ozone as well as to variations in clouds and aerosols. Satellite observations have been used to estimate the long-term changes of erythemal radiation due to changes in ozone, clouds, and aerosols, which are small particles in the atmosphere, such as those produced by human pollution. These estimates show that erythemal radiation at Earth's surface increased over much of the globe over the period 1979 to 2008, particularly at midlatitudes in both hemispheres (bottom panel). The increases in the Southern Hemisphere would have been larger without the offsetting changes due to clouds and aerosols (upper panel). The smallest estimated changes in erythemal radiation are in the tropics because observed total ozone changes over this period are smallest in this region (see Figure Q12-1).

UV Index changes. The UV Index is a measure of the erythemal radiation that occurs at a particular surface location and time. The index is used internationally to increase public awareness about the detrimental effects of UV on human health and to guide the need for personal protective measures. The maximum daily UV Index varies with location and season, as shown for three sites in **Figure Q16-2**. The UV Index increases when moving from high to low latitudes and is highest in summer when the midday Sun is closest to overhead. For example, UV Index values in San Diego, California, at 32°N, are generally higher than those in Barrow, Alaska, at 71°N. At all latitudes, UV Index values increase in mountainous areas and over snow- or ice-covered regions. The UV Index is zero during periods of continuous darkness in winter at high-latitude locations.

The UV Index over Antarctica has increased dramatically due to ozone depletion, as illustrated in Figure Q16-2. Normal index values for Palmer, Antarctica, at 64°S in spring were estimated from satellite measurements made during the period 1978–1980, before the appearance of the ozone hole over Antarctica. For example, since 1990, the severe and persistent ozone depletion that occurred in late winter/early spring over Antarctica increased the average UV Index well above normal values for several months. During times of large ozone depletion, the spring UV Index measured in Palmer, Antarctica, equals or exceeds spring and summer values measured in San Diego, California, which is located at a much lower latitude (32°N).

UV changes and human health. Over the past several decades, depletion of the stratospheric ozone layer together with societal changes in lifestyle have increased UV-B radiation exposure for many people. Increased exposure has adverse health effects, primarily associated with eye and skin disorders. UV radiation is a recognized risk factor for some types of eye cataracts. For the skin, the most common threat is skin cancer. Over the past decades, the incidence of several types of skin tumors has risen significantly among people of all skin types. Skin cancer in humans occurs long after exposure to UV radiation that causes sunburn. With current Montreal Protocol provisions, projections of additional skin cancer cases associated with ozone depletion are largest in the early to middle decades of the 21st century and represent a significant global health issue. Since it is projected that the recovery of the global ozone layer to 1980 values will not occur until the middle of this century (see Figure Q20-2), ozone depletion will continue to contribute to adverse health effects over the coming decades. An important human health benefit of UV-B radiation exposure is the production of vitamin D, which plays a significant role in bone metabolism and the immune system. Human exposure to solar UV-B radiation requires a careful balance to maintain adequate vitamin D levels while minimizing long-term risks of skin and eye disorders now and well into the future.

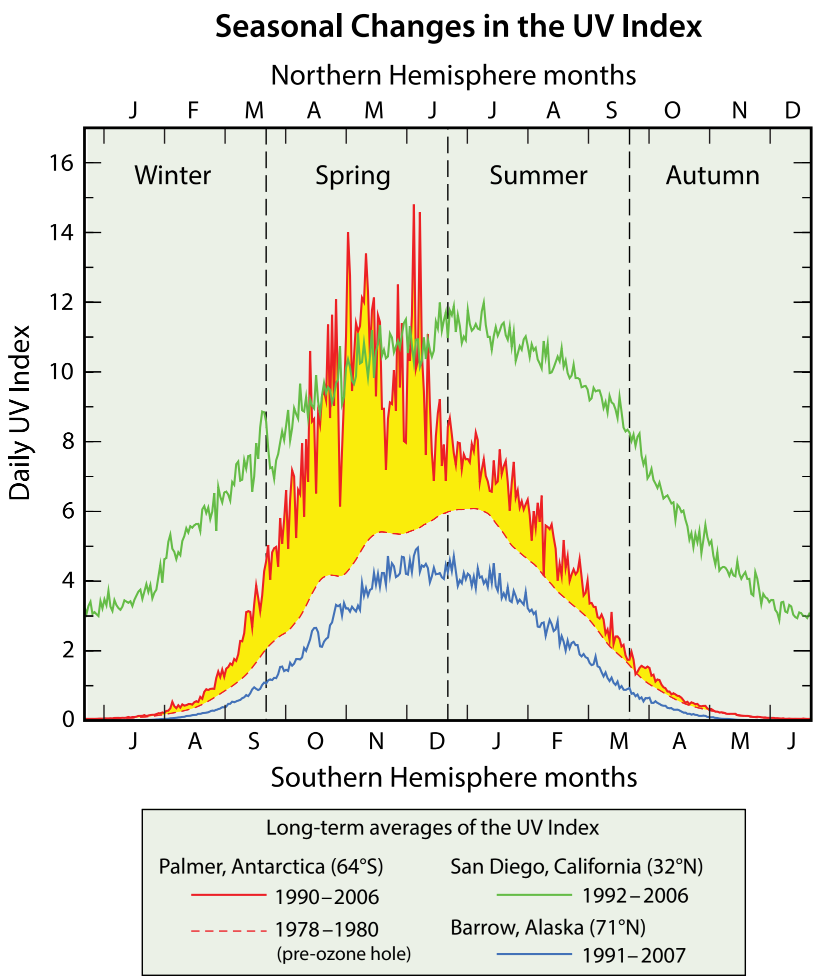

Figure Q16-2. Long-term changes in the UV Index. The UV Index is a measure of the erythemal radiation that reaches the surface at a particular time and location. Sunburn in humans is caused by erythemal radiation. The UV Index varies with total ozone above a location, as well as the Sun's midday position in the local sky, which depends on latitude and season. The highest values of the UV Index occur in the tropics, where the midday Sun is highest throughout the year and where total ozone values are low (see Figure Q3-1). The lowest average UV Index values occur at high latitudes. The figure shows daily maximum UV Index values at three locations. Values are higher throughout the year in San Diego, a low-latitude location, than in Barrow, a high-latitude location. UV Index values are zero at high latitudes in winter when darkness is continuous. Measurements at Palmer, Antarctica, demonstrate the effect of Antarctic ozone depletion. Normal values estimated for Palmer are shown for 1978–1980, a period before the appearance of the ozone hole (red dashed line). In the period 1990–2006, Antarctic ozone depletion increased the UV Index at Palmer throughout spring and into summer (yellow shaded region). For these years, springtime values of the UV Index at Palmer equaled or exceeded those measured in spring and summer in San Diego, which is located at a much lower latitude.