Q3 How is total ozone distributed over the globe?

The distribution of total ozone over Earth varies with geographic location and on daily and seasonal timescales. These variations are caused by large-scale movements of stratospheric and tropospheric air and the chemical production and destruction of ozone. Total ozone is generally lowest at the equator and highest in midlatitude and polar regions.

Total ozone. The total column of ozone at any location on the globe is defined as the sum of all the ozone in the atmosphere directly above that location. Most ozone resides in the stratospheric ozone layer and a small percentage (about 5 to 10%) is distributed throughout the troposphere (see Q1). Total column ozone values are usually reported in *Dobson units* denoted as "DU." Typical values vary between 200 and 500 DU over the globe, with a global average abundance of about 300 DU (see **Figure Q3-1**). The ozone molecules required for total ozone to be 300 DU would form a layer of pure ozone gas at Earth's surface having a thickness of only 3 millimeters (0.12 inches) (see Q1), which is about the height of a stack of 2 common coins, if these molecules could be isolated and compressed. It is remarkable that a layer of pure ozone only 3 millimeters thick protects life on Earth's surface from most of the harmful UV radiation emitted by the Sun (see Q2).

Global distribution. Total ozone varies strongly with latitude over the globe, with the largest values occurring at middle and high latitudes during most of the year (see Figure Q3-1). This distribution is the result of the large-scale circulation of air in the stratosphere that slowly transports ozone-rich air from high altitudes in the tropics, where ozone production from solar ultraviolet radiation is largest, toward the poles. Ozone accumulates at middle and high latitudes, increasing the vertical extent of the ozone layer and, at the same time, total ozone. The total column of ozone is generally smallest in the tropics for all seasons. An exception since the mid-1980s is the region of low values of ozone over Antarctica during spring in the Southern Hemisphere, a phenomenon known as the Antarctic ozone hole (dark blue, Figure Q3-1; also see Q10 and Q11).

Seasonal distribution. Total ozone also varies with season, as shown in Figure Q3-1 using two-week averages of ozone taken from satellite observations acquired in 2021. March and September plots represent the early spring and autumn seasons in the Northern and Southern Hemispheres, respectively. June and December plots similarly represent the early summer and winter seasons. During spring, total ozone exhibits maximums at latitudes poleward of about 45° N in the Northern Hemisphere and between 45° and 60° S in the Southern Hemisphere. These spring maximums are a result of increased transport of ozone from its source region in the tropics toward high latitudes during late autumn and winter. This poleward ozone transport is much weaker during the summer and early autumn periods and is weaker overall in the Southern Hemisphere.

This natural seasonal cycle can be observed clearly in the Northern Hemisphere as shown in Figure Q3-1, with increasing values in Arctic total ozone during winter, a clear maximum in spring, and decreasing values from summer to autumn. In the Antarctic, however, a pronounced minimum in total ozone is observed during spring. The minimum is known as the "ozone hole", which is caused by the widespread chemical depletion of ozone in spring by pollutants known as ozone-depleting substances (see Q5 and Q10). In the late 1970s, before the ozone hole appeared each year, much higher ozone values than those currently observed were found in the Antarctic spring (see Q10). Currently, the lowest values of total ozone across the globe and all seasons are found during early spring in the Antarctic, as shown in Figure Q3-1 for 2021. After spring, these low values disappear from total ozone maps as polar air mixes with lower-latitude air containing much higher amounts of ozone.

In the tropics, the change in total ozone through the progression of the seasons is much smaller than at higher latitudes. This feature is present because seasonal changes in both sunlight and ozone transport are much smaller in the tropics compared to higher latitudes.

The abundance of ozone is larger at midlatitudes in the Northern Hemisphere (NH) than the Southern Hemisphere (SH), for all four seasons in the respective hemispheres. The thinner ozone layer at SH midlatitudes compared to NH midlatitudes is due to several factors: differences in the large-scale circulation of the two hemispheres that preceded the development of the ozone hole as well as larger abundances of tropospheric ozone in the NH compared to the SH that is caused by more pollution in the more heavily populated NH. Dilution of ozone-depleted air from the Antarctic ozone hole region starting in the 1980s further increases the hemispheric difference in total ozone. This hemispheric total ozone difference results in higher levels of UV light reaching the surface in the SH compared to the NH (see Q16).

Natural variations. Total ozone varies strongly with latitude and longitude, as seen within the seasonal plots in Figure Q3-1. These patterns come about for two reasons. First, atmospheric winds transport air between regions of the stratosphere that have high ozone values and those that have low ozone values. Tropospheric weather systems can temporarily alter the vertical extent of the ozone layer in a region, and thereby change total ozone. The regular nature of these air motions, in some cases associated with geographical features (oceans and mountains), in turn causes recurring patterns in the distribution of total ozone. Second, ozone variations occur as a result of changes in the balance of chemical production and loss processes. This balance is very sensitive to the amount of solar UV radiation (see Q2) reaching the various parts of the atmosphere.

There is a good understanding of how chemistry and air motions work together to cause the observed large-scale features in total ozone, such as those seen in Figure Q3-1. Ozone changes are routinely monitored by a large group of scientists using satellite, airborne, and ground-based instruments. The continued analyses of these observations provide an important long-term basis to quantify the contribution of human activities to ozone depletion.

Global Satellite Maps of Total Ozone in 2021

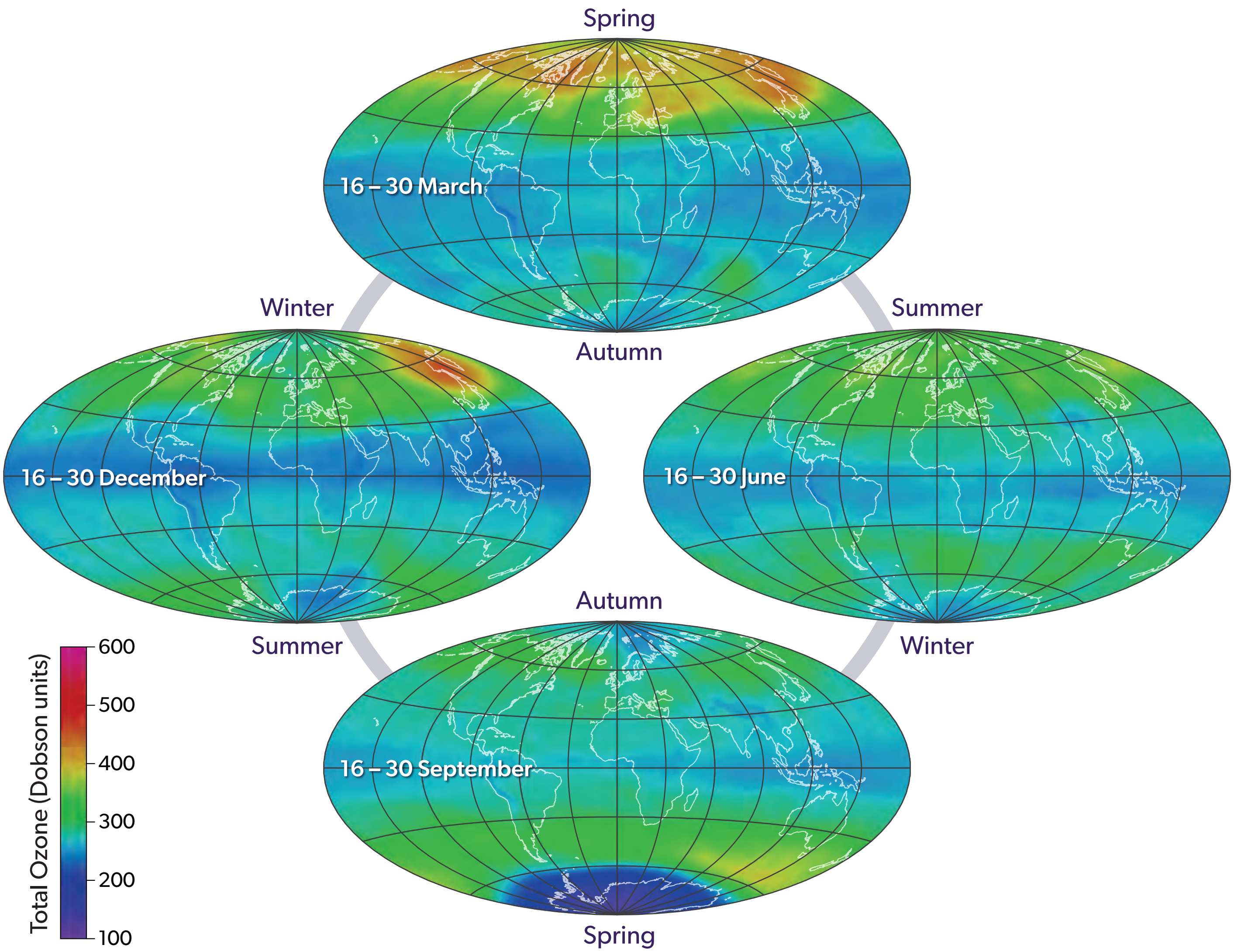

Figure Q3-1. Total ozone. Total column ozone at any location on the globe is defined as the sum of all the ozone molecules in the atmosphere directly above that location. Total ozone varies with latitude, longitude, and season, with the largest values at high latitudes and the lowest values usually found in tropical regions. The variations are demonstrated here with two-week averages of total ozone in 2021 as measured with a satellite instrument. Total ozone shows little variation in the tropics (20°N–20°S latitudes) over all seasons. Total ozone outside of the tropics varies more strongly with time on a daily to seasonal basis as ozone-rich air is moved from the tropics and accumulates at higher latitudes, with more ozone being transported in winter. The low total ozone values over Antarctica shown here in September constitute the "ozone hole" in 2021. Since the mid-1980s, the ozone hole in late winter/early spring represents the lowest values of total ozone that occur over all seasons and latitudes (see Q10).