Q4 How is ozone measured in the atmosphere?

The amount of ozone in the atmosphere is measured by instruments on the ground and carried aloft on balloons, aircraft, and satellites. Some instruments measure ozone remotely over long distances by using ozone's unique optical absorption or emission properties. Other instruments measure ozone locally by continuously drawing air samples into a small detection chamber.

The abundance of ozone in the atmosphere is measured by a variety of techniques (see **Figure Q4-1**). The techniques make use of ozone's unique optical and chemical properties. There are two principal categories of measurement techniques: local and remote. Ozone measurements by these techniques have been essential in monitoring changes in the ozone layer and in developing our understanding of the processes that control ozone abundances.

Local measurements. Local measurements of the atmospheric abundance of ozone are those that require air to be drawn directly into an instrument. Once inside an instrument's detection chamber, the amount of ozone is determined by measuring the absorption of ultraviolet (UV) radiation or by the electrical current or light produced in a chemical reaction involving ozone. The latter approach is used in "ozonesondes", which are lightweight, ozone-measuring modules suitable for launching on small balloons. The balloons ascend up to altitudes of about 32 to 35 kilometers (km), high enough to measure ozone in the stratospheric ozone layer. Ozonesondes are launched regularly at many locations around the world. Local ozone-measuring instruments using optical or chemical detection schemes are also used on research aircraft to measure the distribution of ozone in the troposphere and lower stratosphere (up to altitudes of about 20 km). High-altitude research aircraft can reach the ozone layer at most locations over the globe and can reach furthest into the layer at high latitudes. Ozone measurements are also being made routinely on some commercial aircraft flights. Local measurements of the abundance of ozone at the surface are obtained at many thousands of sites over the globe, which provide hourly data critical for assessing and improving air quality throughout the world.

Remote measurements. Remote measurements of total ozone amounts and the altitude distributions of ozone are obtained by detecting ozone at large distances from the instrument. Most remote measurements of ozone rely on its unique absorption of UV radiation. Sources of UV radiation that can be used are sunlight (and reflected sunlight from the moon), lasers, and starlight. For example, satellite instruments use the absorption of solar UV radiation by the atmosphere or the absorption of sunlight scattered from the surface of Earth to measure ozone over nearly the entire globe on a daily basis. Lidar instruments, which measure backscattered laser light, are routinely deployed at ground sites and on research aircraft to detect ozone over a distance of many kilometers along the laser light path. A network of ground-based

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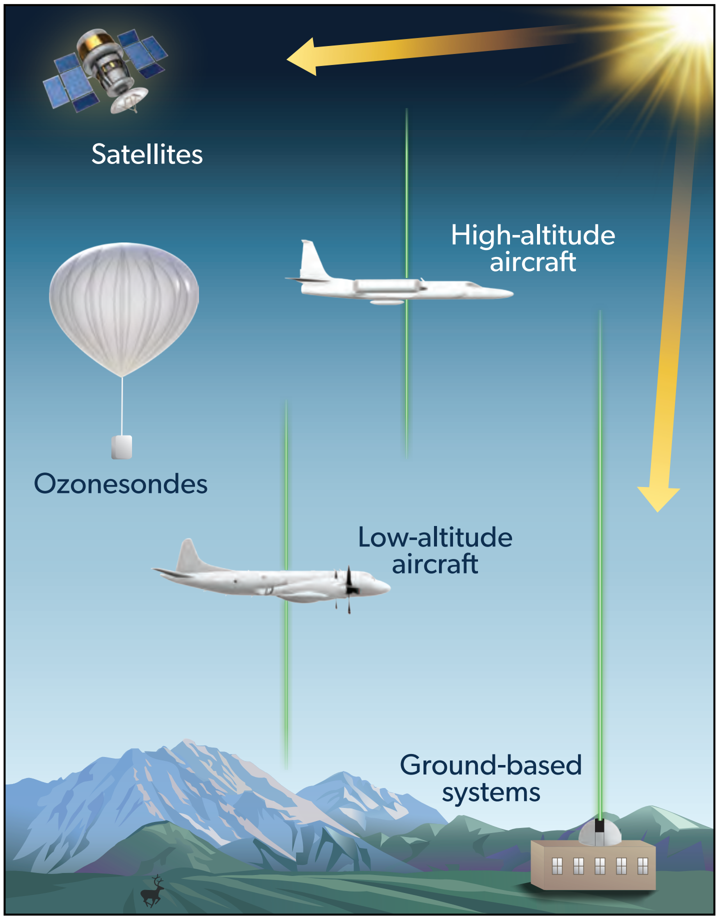

Figure Q4-1. Ozone measurements. Ozone is measured throughout the atmosphere with instruments on the ground, aircraft, high-altitude balloons, and satellites. Some instruments measure ozone locally in sampled air and others measure ozone remotely a considerable distance away from the instrument. Instruments use optical techniques with either the Sun (direct, reflected, or scattered radiation) or lasers (green lines) as light sources; detect the thermal emissions from ozone and other atmospheric molecules (not shown); or use chemical reactions that are unique to ozone (ozonesonde). At many locations over the globe, regular measurements are made to monitor ozone amounts and their variations over time.

instruments measures ozone by detecting small changes in the amount of the Sun's UV radiation that reaches Earth's surface. Other instruments measure ozone using either its absorption of infrared, visible, or ultraviolet radiation or its emission of microwave or infrared radiation at different altitudes in the atmosphere, thereby obtaining information on the vertical distribution of ozone. Emission measurements have the advantage of providing remote ozone measurements at night, which is particularly valuable for sampling polar regions during winter, when there is continuous darkness.

Global Ozone Network

The first instrument for routinely monitoring total ozone was developed by Gordon M.B. Dobson in the United Kingdom in the 1920s. The instrument, called a Féry spectrometer, made its measurements by examining the wavelength spectrum of solar ultraviolet (UV) radiation (sunlight) using a photographic plate. A small network of instruments distributed around Europe allowed Dobson to make important discoveries about how total ozone varies with location and time. In the 1930s a new instrument was developed by Dobson, now called a Dobson spectrophotometer, which precisely measures the intensity of sunlight at two UV wavelengths: one that is strongly absorbed by ozone and one that is weakly absorbed. The difference in light intensity at the two wavelengths provides a measure of the total amount of ozone above the instrument location.

A global network of total ozone observing stations was established in 1957 as part of the International Geophysical Year. Today there are hundreds of sites located around the world ranging from South Pole, Antarctica (90°S) to Ellesmere Island, Canada (83°N) that routinely measure total ozone. The Brewer spectrophotometer was introduced into the global network starting in 1982. Whereas the original Dobson instrument measures atmospheric ozone based on observations of UV light at only two wavelengths, modern Dobson instruments as well as Brewer instruments use observations from multiple pairs of wavelengths. The accuracy of these observations is maintained by regular instrument calibrations and intercomparisons. At many of the stations, observations of total ozone are augmented by measurements of the vertical distribution of ozone obtained either from twilight measurements with Dobson or Brewer instruments, by routine launches of ozonesondes, or with the use of lidar instruments. Numerous stations also quantify the atmospheric abundances of a wide variety of related compounds, taking advantage of the unique optical properties of atmospheric gases.

Data from the network have been essential for understanding the effects of chlorofluorocarbons and other ozone-depleting substances on the global ozone layer, starting before the launch of space-based ozone-measuring instruments and continuing to the present day. Ground-based instruments with excellent long-term stability and accuracy are now routinely used to help calibrate space-based observations of total ozone as well as numerous other gases and physical quantities involved in ozone chemistry.

Keeping with the tradition of naming units after pioneering scientists, the unit of measure for total ozone is called the "Dobson unit" (see Q3).