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### The ozone layer and ozone depletion

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## The recovery of the ozone layer

The principal parameters that determine depletion of the stratospheric ozone layer and so are important for its recovery are:

- The chlorine and bromine concentrations in the layer now and in the future;
- The existence of particles in the stratosphere; and
- Stratospheric temperature

The Montreal Protocol seeks to reduce the first of these and has been successful in limiting the maximum Equivalent Effective Stratospheric Chlorine to 3.5 ppb. It has now fallen to about 3 ppb. This contrasts with a value of 9 ppb that would have existed now without the Montreal Protocol [1]. It is expected to fall below 2 ppb by the middle of the 21st century in response to much reduced emissions of Ozone Depleting Substances.

In the absence of other changes, this would reduce ozone depletion and, in the second half of this century, recurrence of the Antarctic ozone hole would cease.

Measurements since the 1990s [2] show that ozone levels in the stratosphere above populated regions of the earth stopped decreasing in 1994-1996.

Most ozone depletion occurs because particles in the stratosphere provide reactive surfaces that regenerate chlorine that has been released from CFCs but is held in the stratosphere in forms that are inactive (such as hydrogen chloride). Thus volcanoes that inject sulphuric acid mist into the stratosphere can profoundly affect ozone for a few years until the sulphuric acid falls out into the troposphere.

If the stratospheric temperature falls low enough, ice crystals will form, even in this comparatively dry region of the atmosphere. This is the reason that Polar Stratospheric Clouds can form during the winter over both Poles but particularly Antarctica. Ice crystal surfaces act in the same way as sulphuric acid mist to regenerate chlorine.

Stratospheric temperatures have been observed to have fallen over the past decades; this is because of the lower ozone levels. Furthermore, if the surface temperature of the earth and the temperature of the lower atmosphere rise in the future due to greenhouse gases, the temperature of the stratosphere will fall.

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### *The recovery of the ozone layer*

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These future changes in stratospheric temperatures will complicate the expectations for recovery of the ozone layer. Lower temperatures may result in more frequent stratospheric clouds and hence more intense Antarctic ozone holes or even an equivalent hole in the Arctic ozone layer. However, the extent to which these feedbacks in temperature will interact can only be estimated using models of the atmosphere. These show that recovery of the ozone layer may not be simply what we might have expected from the reduction in chlorine loading. Nevertheless, chlorine loading is the most important factor and is controlled under the Montreal Protocol.

#### **Sources:**

1. Prather M., P. Midgley, F.S. Rowland and R. Stolarski; The ozone layer: the road not taken, Nature, 381, 551-554, 1996.
2. Scientific Assessment of Ozone Depletion: 2014, World Meteorological Organization, Global Ozone Research and Monitoring Project Report No. 55, WMO, Geneva, 2014.