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The ozone layer and ozone depletion

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Climate change and ozone depletion

The atmospheric concentrations of the key greenhouse gas (GHGs), CO₂, CH₄ and N₂O, have been increasing since pre-industrial times and their possible impact on the climate is continuing to be studied [1, 2]. Although it may appear to contradict the intuitive view of the greenhouse effect, when the atmospheric concentration of CO₂ increases, the stratosphere actually cools. This favours the formation of Polar Stratospheric Clouds (PSCs) which strongly accelerate polar ozone depletion by catalytic effects that are now well understood [3].

Principle of the mechanism leading to a cooling of the stratosphere

The physics of radiation transfer within the atmosphere is relatively well known and obeys classic laws for absorption and emission of radiation by molecules. This makes it possible to measure, with a good degree of confidence, the greenhouse effect due to CO₂ of anthropogenic origin to be about 1.5 W/m² (of radiative energy redirected toward the earth's surface). This effect is the result of the budget of radiation emitted and absorbed by CO₂, integrated over the height of the atmosphere. However, the study of the radiative budget for the different layers of the atmosphere shows that, in the case of the stratosphere, more energy is emitted toward space than absorbed by the GHGs present at that altitude. This means that this region of the atmosphere will undergo cooling with the increase of CO₂ concentration.

Implications for stratospheric ozone depletion

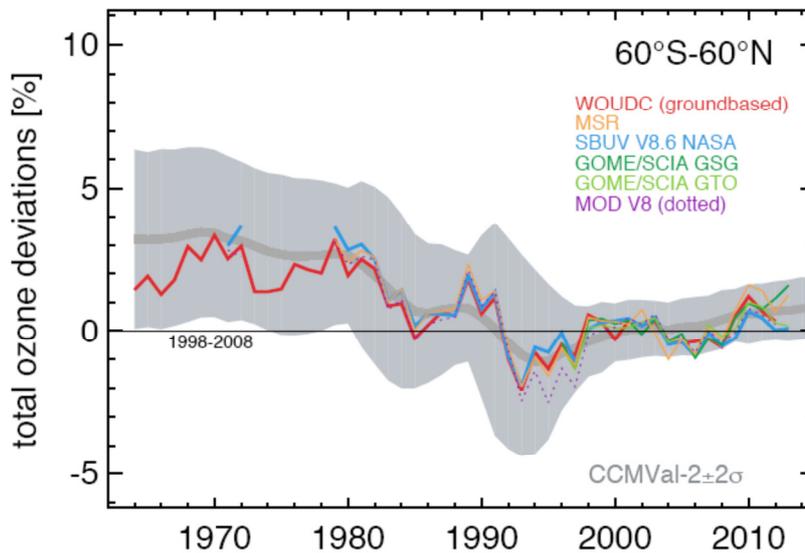
The key variable controlling ozone depletion is stratospheric chlorine loading. It has been shown that, as a result of the Montreal Protocol and its amendments, stratospheric chlorine loading is now decreasing [4, 5]. As a consequence, ozone abundances in the extrapolar regions, 60°S-60°N, have not further declined in recent years [6].

Mid latitude: between 60°N and 60°S (non polar regions)

In this area, which covers the major part of the earth, observations are showing a stabilization of the average concentration of ozone in the layer. Ozone abundances in the Northern Hemisphere midlatitude lowermost stratosphere (12-15 km) show a strong decrease between 1979 and the mid-1990s, followed by an overall increase from 1996 to 2004, giving no net long-term decrease at this level. This lowermost stratosphere ozone change contributed significantly to the column ozone change during the last decade. Southern Hemisphere observations show a smaller increase in the 12-15 km altitude range since the mid-1990s. (See figure below).

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Total column ozone annual mean anomalies for different data sets. Anomalies are with respect to the 1998 to 2008 mean of each individual data set. Coloured lines give observed results for the data sets. Grey line and grey range give multi-model mean and ± 2 standard deviation range of annual mean anomalies [6].

In the Antarctic

The Antarctic is the polar region of the southern hemisphere where the ozone hole develops every year from about mid-August to the end of the year, with a maximum depletion reached generally in mid-October. Air masses are isolated within a stratospheric vortex caused by circulating winds that are driven by large temperature differences between outside and inside the Antarctic area.

Temperatures within the stratospheric Antarctic vortex are well under the threshold of formation of PSCs, which means that further cooling is not likely to change the frequency of their formation to a large extent. There is expected to be less influence of climate change on stratospheric ozone recovery here than in the northern hemisphere [5, 6].

In the Arctic

The Arctic has different topography from the Antarctic, consequently temperatures are higher there and air masses travel in a more complex way, leading to the formation of an unstable Arctic vortex. In those conditions, no ozone hole develops in the Arctic but temporary ozone changes may develop, generally from January to March, if the vortex persists then.

The contribution of this polar ozone depletion to midlatitude ozone depletion is substantial; estimated to be about one-third in the Northern Hemisphere but this has been taken into account in the changes noted above.

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