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Ozone depletion and climate change – a continuing challenge

Dr Marc von Hobe, from the German Forschungszentrum Jülich GmbH research centre, is coordinator of the EU-funded RECONCILE project. The project contributed to the first detection in 2011 of a hole in the ozone layer over the Arctic. Dr von Hobe believes more work needs to be done to control greenhouse gas emissions.

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Loss of sea ice, melting of the Greenland ice sheet, thawing permafrost … the Arctic is one of the regions where the effects of global climate change are most evident. High above the Arctic, in the stratosphere, another man-made environmental problem is still visible: the depletion of the ozone layer, the natural 'sunscreen of the earth' that protects life from too much ultraviolet (UV) radiation. In spring 2011, the most severe Arctic ozone loss on record was observed. At the same time, researchers were investigating remaining questions on polar ozone as part of the international project RECONCILE, funded by the European Union, that specifically addressed the links between ozone depletion and climate change.

The threat to the ozone layer posed by chlorofluorocarbons (CFCs) and other man-made chemicals became apparent to the general public in the 1980s, when scientists from the British Antarctic Survey reported an alarming thinning of the ozone layer over Antarctica in spring that became known as the 'ozone hole'. In 1987, only two years after this discovery was reported in the scientific literature, the Montreal Protocol on substances that deplete the ozone layer was signed. The agreement came into force in 1989, and the regulations have been tightened in several amendments to the original protocol since then.

From today's perspective, the swift political action taken in 1987 is remarkable: the basic concept of why and how an ozone hole is formed had only just been elucidated, and the sophisticated present-day computer models had not yet been developed. It was only about 20 years later that a modern climate model was used to show us the so-called ‘world avoided’, a simulation of what would have happened without the Montreal Protocol: rapidly increasing atmospheric chlorine levels would have led to ozone hole conditions not only in Antarctica but virtually all over the globe, and surface UV levels would have soared with severe impacts on ecosystems and human health. An interesting secondary finding of these ‘what would have happened if …’ simulations was the scale of the temperature rise due to the CFCs, which are not only a threat to the ozone layer but also powerful greenhouse gases: the Montreal Protocol has not only prevented a catastrophic destruction of the ozone layer, it is also the most effective piece of climate policy to date.

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The ozone layer above the Arctic on 2 April 2011. In the polar vortex, temperatures are cold and ozone is strongly depleted. As a result, surface UV levels in 2011 were significantly higher than in other years at northern high- and mid-latitudes in spring. Figure source: Forschungszentrum Jülich/Marc von Hobe; ozone and UV data: Ozone Monitoring Instrument (OMI); temperature data: European Centre for Medium-Range Weather Forecasts (ECMWF).

The ozone layer above the Arctic on 2 April 2011. In the polar vortex, temperatures are cold and ozone is strongly depleted. As a result, surface UV levels in 2011 were significantly higher than in other years at northern high- and mid-latitudes in spring. However, they are still moderate compared to the UV levels at lower latitudes, where ozone depletion could have a much greater impact on human health. Figure source: Forschungszentrum Jülich/Marc von Hobe; ozone and UV data: Ozone Monitoring Instrument (OMI); temperature data: European Centre for Medium-Range Weather Forecasts (ECMWF).

Even 25 years after the Montreal Protocol came into force, the Antarctic ozone hole is still a regular feature, recurring each austral spring, and it is not surprising that the reports of the first Arctic ozone hole in 2011 made some people question the success of the measures taken. However, CFCs are known to be extremely long-lasting in the atmosphere, and it was clear that their removal from the atmosphere and consequently the decline of chlorine levels and the recovery of the ozone layer would take time. The most recent estimates of the ozone recovery date range from 2050 to 2070. But CFC concentrations are slowly decreasing now, and one study carried out within RECONCILE has confirmed that the recovery of Antarctic ozone has indeed begun.

The 2011 record ozone loss in the Arctic does not contradict this trend. It was caused by a combination of an inhibited supply of ozone from lower latitudes and substantial chemical loss, both fostered by special meteorological conditions with an exceptionally cold and stable polar vortex (a stratospheric low pressure system). The relation between ozone loss and low temperatures is well known, and it raises the important question of the impact of climate change on stratospheric ozone. It is impossible to say if the conditions in 2011 were brought about by climate change. But climate change could favour similar conditions in future years: while increasing greenhouse gas emissions warm the Earth’s surface, the ozone layer sits ‘outside the greenhouse’ and might become considerably colder.

Over the past five years, new laboratory experiments, an aircraft campaign, the launching of ozone sondes (monitoring balloons) and satellite observations have been used in the framework of RECONCILE to improve our understanding of polar ozone loss, and in particular to quantify exactly how dependent essential processes, such as PSC (polar stratospheric cloud) formation and catalytic ozone chemistry, are on temperature change.

Improved parameters were developed and incorporated in a global chemistry climate model (CCM) to better predict the effects of climate change on polar ozone depletion. The improved model was tested against past observations.

In the Antarctic, where there is little variability from year to year and ozone loss is driven largely by the processes inside the polar vortex, the improved model led to a visibly better correlation between the climate model and reality. In the Arctic, the effect of the modified processes in the models is not so obvious, because the inter-annual variability of ozone depletion is very large. To fully understand this variability, which is closely related to patterns in planetary wave dynamics, remains an open challenge.

EU-funded research has played a key role in enabling us to better predict future scenarios, for example, how unchecked greenhouse gas emissions will affect climate and ozone. However, there are still many processes that are not very well understood, and our knowledge of the earth's climate system is far from perfect. Under Horizon 2020, more projects like RECONCILE are needed to make predictions even more reliable and robust, and to reduce the uncertainties surrounding the causes and consequences of climate change to a level that leaves no room for dispute. But even the most accurate climate models cannot by themselves avert the unpleasant scenarios that they may predict.

These scenarios can only be avoided by policymakers through their decisions and by all of us through our actions. When the Montreal Protocol was signed in 1987, only a blurred picture existed of the global catastrophe that was to be prevented. Today's climate models already give us a much clearer picture of the future we are headed for if we don't reduce greenhouse gas emissions. How clear does it need to be until we start to take effective action?

How CFCs make an ozone hole

In the second half of the 20th century, chlorofluorocarbons (CFCs) were widely used as refrigerants and spray can propellants and thus emitted into the atmosphere. These compounds are chemically very stable, which means that they can reach the stratosphere.

At altitudes above 15 to 20 km, the intense UV radiation transforms them into chlorine radicals that can destroy the ozone.

But with the current chlorine levels, the ozone loss is restricted to a few percent at most latitudes, because most of the chlorine radicals are readily turned into the less reactive inorganic compounds: hydrogen chloride (HCl) and chlorine nitrate (ClONO2).

However, conditions over the polar regions in winter favour a particularly devastating ozone destruction.

That's because of the combination of four factors: the cold air becomes isolated in a polar vortex, meaning that the reactive chlorine compounds cannot be diluted; HCl and ClONO2 react quickly to produce ozone-destroying radicals on cold aerosol surfaces and in polar stratospheric clouds (PSCs); sedimenting PSC particles remove nitrogen compounds that would otherwise turn the chlorine radicals back into ClONO2 and stop the ozone destruction chain; and catalytic cycles destroy ozone particularly fast at low temperatures and a large solar zenith angle.

This is why, at present day chlorine levels, such severe ozone destruction only occurs over the poles in winter.

More info

RECONCILE

World Meteorological Organization Assessment

The World Avoided