Researchers share perspective on key elements of ozone layer recovery

December 14 2017, by Ellen Gray

A composite image of the Western hemisphere of the Earth. Credit: NASA

Each year, ozone-depleting compounds in the upper atmosphere destroy the protective ozone layer, and in particular above Antarctica. The ozone layer acts as Earth's sunscreen by absorbing harmful ultraviolet radiation from incoming sunlight that can cause skin cancer and damage plants, among other harmful effects to life on Earth. While these different compounds each release either reactive chlorine or bromine, the two active ozone-destroying ingredients, during a series of chemical reactions, the molecules have a range of different lifetimes in the atmosphere that can affect their ultimate impact on the ozone layer and its future recovery.

n a Perspective piece appearing in the Dec. 8 issue of *Science*, NASA researchers discuss the nuances that distinguish three categories of compounds and their impacts on upper atmospheric ozone: long-lasting and human-made compounds, short-lived and human-made compounds, and compounds that are short-lived and naturally emitted from the ocean. All of the long-lasting and some of the anthropogenic short-lived compounds are controlled by the Montreal Protocol in order to reduce their impact on ozone. The researchers find that long-lasting compounds still dominate the outlook for ozone recovery.

This discussion is part of an on-going scientific debate about the impact of short-lived ozone-depleting compounds that stay in the atmosphere for less than six months, whose human-produced emissions have risen. It is relevant to the work being done by the United Nations Environment Programme that administers the Montreal Protocol and its amendments, the seminal global agreement to ban and phase out ozone-destroying compounds. Currently only ozone-depleting substances with atmospheric lifetimes ranging from a year to over 100 years, are controlled because they linger in the atmosphere long enough to reach the upper atmosphere, called the stratosphere. Shorter-lived compounds are unregulated as their impacts are less significant.

"The Montreal Protocol has been a huge success," said atmospheric scientist Qing Liang at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and first author of the perspective. As a result of regulation by the Montreal Protocol, the levels of ozone-depleting chlorine and bromine stopped growing in the atmosphere in the mid-1990s, and have been decreasing at nearly the expected rate. The ozone layer is showing hints of healing.

Nevertheless, the long-lived controlled substances, the majority released before 1987, are projected to still comprise 56 percent of the total stratospheric chlorine and bromine in 2050, according to Liang and her colleagues' analysis. In contrast, at most only four percent of chlorine and bromine is expected to come from unregulated human produced ozone-depleting compounds. The remainder of the chlorine and bromine in 2050 will come from compounds naturally emitted by the ocean. But as ocean temperatures increase due to climate warming, their emission rates could potentially rise by 20 percent between 2010 and 2100. An additional source of natural ozone-depleting compounds are forest fires, both natural and human-set.

Scientists at NASA, the National Oceanic and Atmospheric Administration, as well as other international agencies constantly monitor the stratospheric ozone layer and the levels of ozone-depleting chemicals at Earth's surface.

Whether a substance reaches the stratosphere or not is the prime factor that dictates which category of compounds to worry about, said co-author Susan Strahan of NASA Goddard. The longer the lifetime of an ozone-depleting substance, the longer it will be around to make it to the stratosphere and destroy ozone. Short-lived substances, on the other hand, will have a minimal effect on delaying ozone recovery because they are more likely to degrade before reaching the stratosphere, she said.

One of these substances called dichloromethane has come under recent scrutiny because of its increasing emission rates over the last few years. It is a versatile substitute for many banned chemicals in industry. Dichloromethane breaks down in the atmosphere in about four months and its harmful degradation products are completely removed from the atmosphere within a few years of their emissions.

"Because of its very short-lived nature, and the unlikely scenario of the emissions sustaining a high growth rate, it's highly unlikely dichloromethane would have a major impact on the ozone layer," said Liang. Liang believes its emission rate will plateau once industries reach their carrying capacity based on economic demand.

In addition, industrial short-lived ozone-depleting substances emitted on land, often in the mid-latitudes, have four- to six-month journey to the stratosphere. This is slightly longer than their lifetimes and allows more time for them to be destroyed or washed out by rain before they arrive at the ozone layer, Liang said.

Short-lived bromine compounds naturally released from the ocean surface, however, have a more pronounced impact on ozone than their short-lived industrial cousins. Because they are released in large quantities from tropical oceans, they are rapidly lofted by tropical thunderstorms into the stratosphere within a month or two where they can destroy ozone for a larger portion of their lifetimes.

"The other major factor is climate change. As the tropical oceans warm, natural emissions of methyl bromine and other short-lived brominated species are going to increase," Strahan said. "And you can't turn that off. As the ocean gets warmer, the emissions increase continues."

Also of concern are the banned chemicals that continue to enter and accumulate in the atmosphere. One example is carbon tetrachloride, which is regulated by the Montreal Protocol and has a lifetime of 33 years in the atmosphere. While its production, use and destruction are accurately monitored and reported, it also forms as a by-product in the production lines of chloroform and dichloromethane. Because it is highly volatile, it has unintended emissions that leak into the atmosphere, Liang said. It likely isn't the only regulated ozone-depleting substance that sneaks out unaccounted for from the production line of other chemicals.

Liang and Strahan based their analysis on a combination of computer model simulations of the atmosphere and measurements of the concentrations of the ozone-depleting chemicals. NASA's Goddard Earth Observing System Version 5 (GEOS-5) model simulates the atmosphere in 3-D, which allows the research team to follow atmospheric gases from their sources on the ground through their journey to the upper atmosphere. The model is supported by observations from satellites, ground-based networks that measure ozone -depleting chemicals in the real world, and by observations from two decades of NASA aircraft field campaigns, including the most recent Airborne Tropical Tropopause Experiment (ATTREX) in 2013 and the Atmospheric Tomography (ATom) global atmospheric survey, which has made three deployments since 2016.

More information: Qing Liang et al. Concerns for ozone recovery, *Science* (2017). DOI: 10.1126/science.aaq0145

Provided by NASA's Goddard Space Flight Center