IMPROVEMENT IN CLIMATE FORCING FROM MONTREAL PROTOCOL GASES

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Abstract: This year of 2007, an important milestone for CO_2 measurements, marks the 30th anniversary of the beginning of nitrous oxide (N_2O) and chlorofluorocarbons (CFCs) measurements by NOAA ESRL scientists at the Mauna Loa Observatory (Fig. 1). The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, which effectively controls emissions of the CFCs, halons, halocarbon solvents, hydro-CFCs or HCFCs, and methyl bromide, was a landmark international agreement that not only controlled the emissions of halocarbons that contributed to the Antarctic Ozone Hole, but had the additional benefit of reducing the emissions of potent greenhouse gases. The CO_2 equivalent reduction in emissions of the Montreal Protocol gases is ~ 8 Gt CO_2-eq yr^{-1} (2.2 Gt C-eq yr^{-1}) between 1990 and 2010. This is four times larger than the reduction in greenhouse gas emissions targeted in the first commitment period of the Kyoto Protocol, which includes CO_2, CH_4, N_2O, SF_6, hydrofluorocarbons or HFCs, and perfluorocarbons or PFCs. Over the past couple of years, the atmospheric concentrations of two key halocarbon gases (CFC-12 and halon-1211) have leveled off in the atmosphere. It is important to continue to monitor non-CO_2 greenhouse gases (includes Montreal Protocol Gases, HFCs, CH_4, N_2O, and PFCs) in the future, because reducing emissions of these gases may prove to be less difficult in the short term than reducing CO_2 emissions, which will involve major changes in our energy use and the economy.

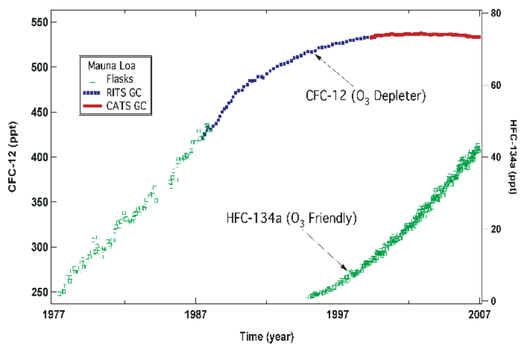


Fig. 1 Atmospheric trends of two important greenhouse gases, CFC-12 and HFC-134a at Mauna Loa Observatory. The halocarbon flask program was started in 1977 by Walt Komhyr and Thayne Thompson. Alan Yoshniaga was the key person responsible for 30 year time series of flasks and in situ halocarbon measurements at Mauna Loa.

Introduction: *Velders et al.* [2007] found that there were significant reductions in greenhouse gas emissions as a result of the Montreal Protocol when compared to Kyoto Protocol. The authors looked at the future emissions scenarios after the publication of the *Molina and Rowland* [1974] paper (MR74), future emission scenarios with no Montreal Protocol ratified in 1987 (NMP87), and the 2004 conditions under the Montreal Protocol (Baseline). Ignoring huge improvements the greenhouse gas emissions in the scenarios proposed after MR74 and NMP87 in Fig. 2, the Montreal Protocol under Baseline conditions reduced the climate forcing of ozone-depleting substances (ODS) in CO_2 equivalent of ~8 Gt CO_2-eq yr^{-1}, which is 4 times greater than the first commitment period of the Kyoto Protocol (2 Gt CO_2-eq yr^{-1}).

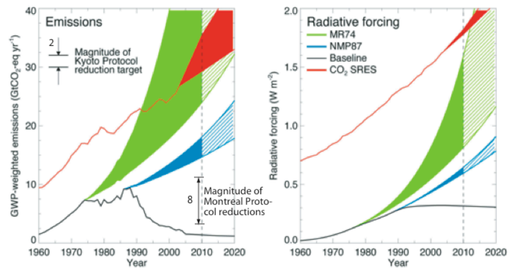


Fig. 2 Emissions and Radiative forcing for Kyoto Protocol (CO_2) and Montreal Protocol (ODS) up to 2010 (*Velders et al.* 2007).

Experimental: There are four basic gas chromatographs (GC) systems used by NOAA/ESRL scientists to measure ODS (Fig. 3). OTTO, LEAPS, CATS GCs use electron capture detection-gas chromatography (ECD-GC), and the MS-GC uses mass selective detector-gas chromatography. Flask pairs are collected typically twice a week at over 10 sites worldwide, the CATS GCs sample the air once an hour at Pt. Barrow, Alaska; Niwot Ridge, Colorado; Mauna Loa; American Samoa; and South Pole.

Fig. 3 Current NOAA/ESRL GC systems, Low Electrophilic Attachment Potential (LEAPS), GC-MS, and OTTO for analysis of flask samples in Boulder, Colorado (ESRL), and the in situ Chromatograph for Atmospheric Trace Species (CATS) at five baseline observatories (Mauna Loa GC pictured here).

Method: The Baseline scenario for the *Velders et al.* [2007] paper are obtained from the World Meteorological Organization's (WMO) Ozone Assessment and the Intergovernmental Panel for Climate Change (IPCC), which include the past (ground based network, ice core and firn) and current observations of the ODS from NOAA/ESRL and our colleagues from the mainly NASA supported Advanced Global Atmospheric Gas Experiment (AGAGE).

Our thirty years of measurements of N_2O and the major CFCs (11 and 12) are shown in Fig. 4 for the hemispheric and global mean mixing ratios.

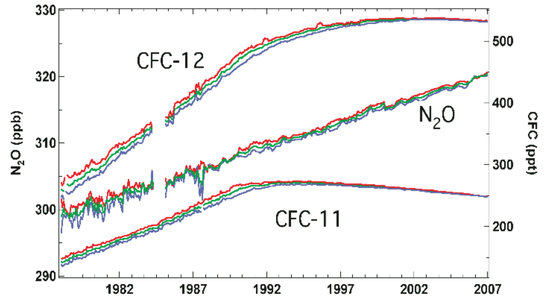


Fig. 4 Major Greenhouse Gases, CFCs and N_2O, mean mixing ratios for northern hemisphere (red), global (green), and southern hemisphere (blue).

This year, 2007, also is the fifteenth anniversary for many of the HCFCs measurement from our GC-MS flask project (Fig. 5). Our program has expanded to include other climate trace gases.

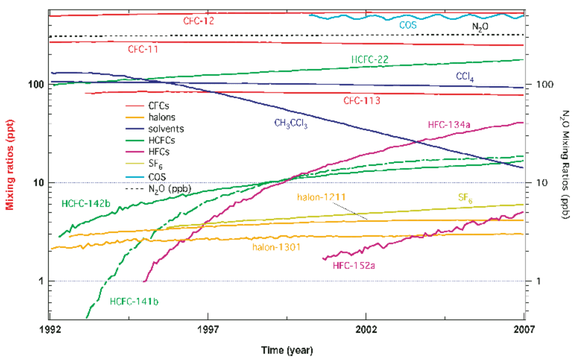
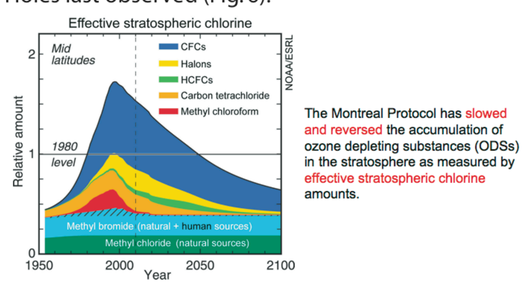


Fig. 5 Semi-log plot of mixing ratios of major and minor greenhouse gases measured versus time by NOAA/ESRL scientists.

Using NOAA/ESRL data from Figs. 4 and 5, ice firn measurements, destruction rates of halocarbons, mean age of the air in the stratosphere, and consumption restrictions imposed by the Montreal Protocol, it is possible to show past, current, and future effective stratospheric chlorine (ESCl includes both chlorine and bromine x 60) where 1980 is the reference year (unity) for no Antarctic Ozone Holes last observed (Fig. 6).



The Montreal Protocol has slowed and reversed the accumulation of ozone depleting substances (ODSs) in the stratosphere as measured by effective stratospheric chlorine amounts.

Fig. 6 Time history of effective stratospheric chlorine from NOAA/ESRL.

It will take until 2050 for the atmosphere to cleanse the ESCl back down to levels of the reference period. With this plot, it is possible to generate a scenario for the baseline for the radiative forcing of the ODS.

Conclusions: Climate forcing from ODS would be significantly worse today than without the Molina and Rowland [1974] paper and the Montreal Protocol and its subsequent amendments (Fig. 2). There is probably another 1.4 Gt CO_2-eq yr^{-1} in savings from ODS after 2010 (Fig. 7, Velders et al. 2007). Eliminating emissions of HCFCs sooner and completely eliminating HFC-23, a powerful GWP by product of HCFC-22 production (another 0.3 Gt CO_2-eq yr^{-1}), also could help too. Currently, developing countries can continue to manufacture and increase HCFC levels up to 2015, but afterwards their consumption must remain at those 2015 levels until they are completely phased-out by 2040. HFC-134a, an ozone friendly compound used now in mobile air conditioning, has a global warming potential (GWP is defined with a 100 years time horizon where CO_2 GWP=1) almost an order of magnitude less (1430) GWP than CFC-12 (10,900 times greater than CO_2), which it replaced. Substitution of HFC-134a with HFC-152a (GWP=124) and shorter-lived future fluorocarbon refrigerants may reduce the average refrigerant GWP another order of magnitude or greater (another 0.44 Gt CO_2-eq yr^{-1}). If policymakers take action on the suggestions of Velders et al. [2007], almost another Kyoto Protocol reduction of 2 Gt CO_2-eq yr^{-1} is gained. With tight science budgets for the future that have other uncertainties in the other categories for climate forcing (soot, aerosols, ice cover, cloud cover, etc.), the scientific community must continue to measure the atmospheric distributions and trends of all of the non-CO_2 greenhouse gases, because reducing their emissions may buy us more time to address the larger question of reducing CO_2 emissions.

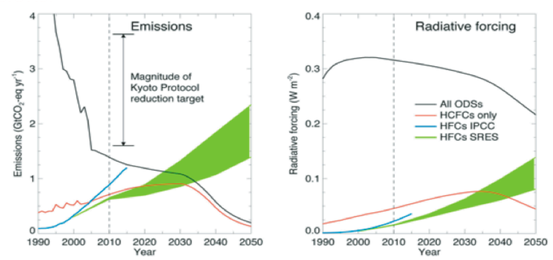


Fig. 7 Emissions and Radiative forcing for Kyoto Protocol (CO2), Montreal Pro tocol (ODS), HCFCs, and HFCs after 2010 (Velders et al. 2007).

References:

Molina, M.J., and F.S. Rowland, Stratospheric sink for chlorofluoromethanes: Chlorine atom catalyzed destruction of ozone, *Nature, 249,* 810-814, 1974.

Velders, G. J. M. , S. O. Andersen, J. S. Daniel, D. W. Fahey, and M. McFarland, The importance of the Montreal Protocol in protecting climate, *Proc. Nat. Acad Sci., 104 (12)*, 4814–4819, 2007