



The World Already Avoided: Quantifying the Ozone Benefits Achieved by the Montreal Protocol

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Chlorine and bromine-containing ozone-depleting substances (ODSs) are controlled by the 1987 Montreal Protocol. In consequence, atmospheric equivalent chlorine peaked in 1993 and has been declining slowly since then. Consistent with this, models project a gradual increase in stratospheric ozone with the Antarctic Ozone Hole expected to disappear by ~ 2050 . However, we show that by 2014 the Montreal Protocol has already achieved significant benefits for the ozone layer. Using an off-line 3-D atmospheric chemistry model, we demonstrate that much larger ozone depletion than observed has been avoided by the protocol, with benefits for surface UV and climate. A deep Arctic Ozone Hole, with column values < 120 DU, would have occurred given the meteorological conditions in 2011. The Antarctic Ozone Hole would have grown in size by 40% by 2013, with enhanced loss at subpolar latitudes. The ozone decline over northern hemisphere middle latitudes would have continued, more than doubling to $\sim 15\%$ by 2013.