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Recent changes in stratospheric composition due to and despite the Montreal Protocol

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The Montreal Protocol appears to have been a great success. Networks have shown that total tropospheric organic chlorine peaked in 1993, followed by a decrease of 0.5-1 %/yr. Remote-sensing data revealed a peak in stratospheric chlorine in 1996-1997 followed by a decrease at rates close to -1%/yr. Given this, we expect stratospheric chlorine and bromine to continue to decrease and the ozone layer to 'recover' towards the middle/end of the century.

Despite this, there are a number of factors which could mean that the decrease in stratospheric halogens is not a smooth downward trajectory. Recent observations of stratospheric column HCl (the reservoir of stratospheric chlorine) showed an increase in the northern hemisphere (Mahieu et al., 2014) from around 2007 to 2011. However, through studies with an atmospheric 3-D chemical transport model, we could show that this increase in HCl was due to multi-year variability in the stratospheric circulation causing air in the NH lower stratosphere to become more aged (i.e. contain more HCl and less organic source gas) – i.e. the protocol is still on track.

In contrast, the protocol only controls the emissions of long-lived ODSs. So-called very short-lived substances (VSLS), with lifetimes less than about 6 months, are not considered. While many VSLS are natural, in Hossaini et al. (2015) we presented ground-based observations showing a rapid increase in the anthropogenic VSLS CH2Cl2. I will show model results which quantify the potential that these VSLS pose to stratospheric ozone, thereby delaying recovery. Through depleting ozone in the very low stratosphere, VSLS also exert a relatively large leverage on climate.

I will also present some results of 'World Avoided' experiments that reveal the state of the ozone layer if the Montreal Protocol had not been implemented. Under cold stratospheric cold conditions (as experienced in 2010/11) we would already be in an era of deep Arctic ozone holes (Chipperfield et al., 2015).