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The Impact of New Estimates of Mixing Ratio and Flux-Based Halogen Scenarios on Ozone Evolution

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Introduction

• The evolution of ozone in the 21st century has been shown to be mainly impacted by the halogen emissions scenario and predicted changes in the circulation of the stratosphere.

• New estimates of mixing ratio and flux-based emission scenarios have been produced from the SPARC Lifetime Assessment 2013 (SPARC, 2013).

• Here we conduct simulations using the Goddard Earth Observing System Chemistry-Climate Model (GEOSCCM) with the new A1 2014 halogen scenario (Velders and Daniel, 2013) and compare to one using the previous A1 2010 scenario.

• For the A1 2014 scenario we conducted 2 simulations, one using the mixing ratio based scenario and second using flux-based emissions (SPARC, 2013) for 5 of the ozone depleting substances (ODS).

• Flux-based emissions were used for CFC-11 (F11), CFC-12 (F12), CFC-113 (F113), Methyl Chloroform (MCF), HCFC-22.

Model and Simulations

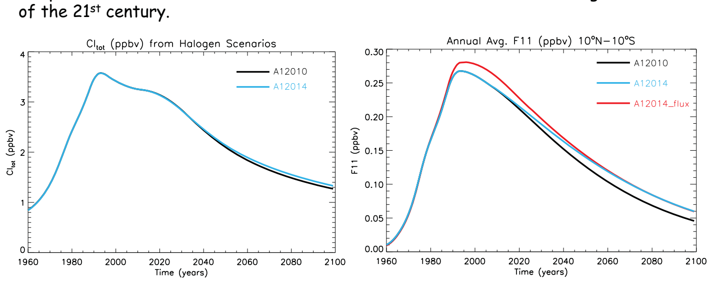
The Goddard Earth Observing System Chemistry-Climate Model (GEOSCCM) was used to conduct simulations of ozone response to 3 different halogen scenarios. GEOSCCM has included a number of improvements since CCMVal-2, including adding a realistic representation of Quasi-Biennial Oscillation and improvements related to the break up of the Antarctic polar vortex. The model was run at 2° x 2.5° (lat. x long.) horizontal resolution with 72 vertical layers up to 80 km.

Table 1. Model simulations used in this study.

Runs	Time Period	SST	GHG	Halogen
A12010	1960-2099	CESM1	RCP 6.0	A1 2010
A12014	1960-2099	CESM1	RCP 6.0	A1 2014
A12014_flux	1960-2099	Obs./CESM1	RCP 6.0	A1 2014 with 5 fluxes

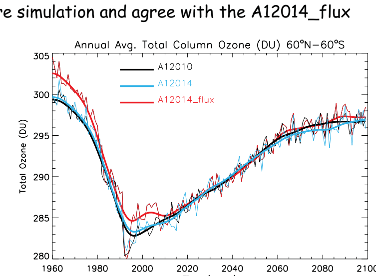
Halogen Scenarios

The left panel below shows the total Chlorine (ppbv) from the A12010 and A12014 scenarios. The slightly larger amounts of Chlorine in the second half of the 21st century is in good part due to the longer lifetime of F11 which leads to higher amounts remaining in the atmosphere longer (right panel). F11 concentrations are higher in the flux-based emissions simulation from around 1990 to the end of the 21st century compared to A12010 scenario and match well the A12014 scenario during the 2nd half of the 21st century.



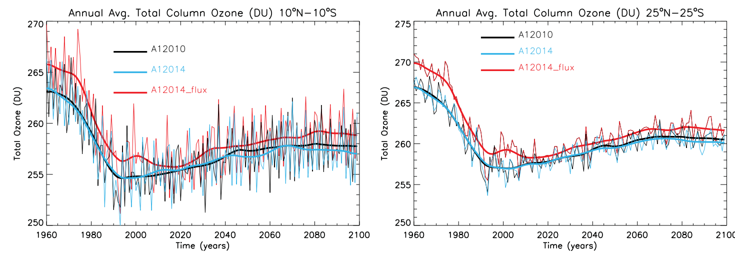
Quasi-Global Ozone Evolution

The 60°S-60°N annual average total column ozone evolution is shown below. A12010 and A12014 agree well throughout the entire simulation and agree with the A12014_flux simulation over the 21st century. The small difference over the past 50 years in A12014_flux simulation is from the use of observed rather than modeled SSTs. The impact of the Mt. Pinatubo eruption can be clearly seen in the large ozone loss from 1992-1994 in all 3 simulations. Observed sulfate surface area densities were used for the past time period.



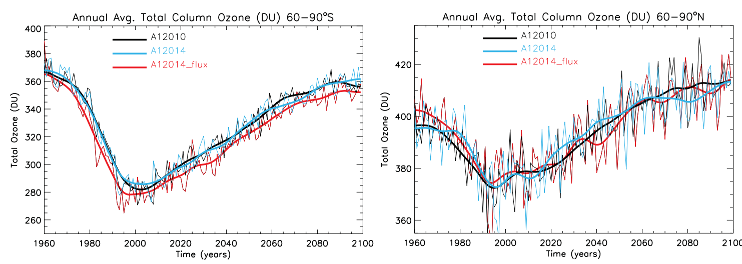
Tropical Ozone

The impact of the QBO on deep tropical (10°S-10°N) total column ozone can be seen below in the left panel causing significant interannual variability. However, averaging over the broader tropics (25°S-25°N, right panel) cancels out much of the QBO variability and what remains is largely driven by SST variability impacting the Brewer-Dobson Circulation. Little difference is seen between A12010 and A12014 mixing ratio halogen scenarios, however ozone is generally higher in the flux based emission scenario.



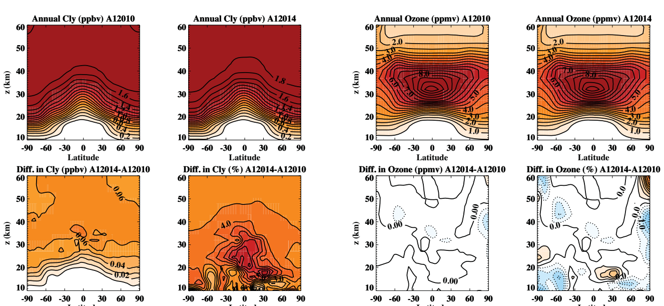
Polar Ozone

Again only small difference are seen between scenarios in polar total column ozone. Only significant differences are seen in the flux based emission scenario in the southern polar region where less ozone is simulated.



2050-2080 Cl_y and Ozone Differences

By the second half of the 21st century Cl_y is about 3-4% larger in the new A12014 scenario and while some decreases in ozone are present most are not significant and would likely require a large number of ensembles to detect a significant decrease in ozone.



Conclusions

• GEOSCCM shows very little difference in ozone evolution between the A12010 and A12014 halogen scenarios.

• In the deep tropics (10°S-10°N) the QBO has a pronounced impact on the interannual variability of the total column ozone, however the variability is largely canceled out over the wider tropics (25°S-25°N) and SST variability is the dominate driver.

• By 2050-2080 approximately 3-4% more Cl_y is present in the extratropics in the A12014 scenario compared to the A12010 scenario causing a relatively small ozone anomaly. Multiple-ensembles would be necessary to significantly discern this impact on ozone.

Acknowledgements

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References

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Velders, G. J. M. and Daniel, J. S.: Uncertainty analysis of projections of ozone-depleting substances: mixing ratios, EESC, ODPs, and GWPs, Atmos. Chem. Phys. Discuss., 13, 28017-28066, doi:10.5194/acpd-13-28017-2013, 2013.