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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Evidence for the effectiveness of the Montreal Protocol to protect the ozone layer" *by* J. A. Mäder et al.

Anonymous Referee #1

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The authors apply two regression models to global total column ozone data. One of the regression models uses EESC as an explanatory variable, the other uses a variant of EESC that linearly extrapolates the increasing EESC of the 1980s and 1990s into the future. The authors show that the former model better fits the observed variations of total ozone than the latter. They stipulate that this demonstrates the effectiveness of the Montreal Protocol.

I think this is a nice study using only relatively simple tools to arrive at the conclusion. I have no doubts about the validity of the mathematics employed here. The topic is appropiate for ACP. The article is well structured, of appropriate length, and language is generally used correctly except for a few minor corrections noted below. I suggest to cite a few additional references, see below.

In criticism of the method, one could argue that in adopting an alternative EESC loading that just keeps increasing linearly since the 1980s, the bar is set quite low for proving the effectiveness of the Montreal Protocol. According to the authors, EESC would be around 4.4 ppbv in 2008 under a linear-growth scenario. The actual EESC loading in 2008 was near 3 ppbv (see comment below on the validity of the scenario). It is perhaps not surprising that the additional 46% of EESC would have a discernible impact on ozone. A more ambitious measure of success of the Montreal Protocol would involve complemening the existing two scenarios with a third one assuming constant EESC since the late 1990s. Chlorine has only decreased by about 0.3 to 0.4 ppbv since the peak, giving a difference in 2008 of around 10% since the peak. Of course, it's a matter of choice which test is adopted here. I think it would make for a better paper if the above test was also performed (although this may be asking for too much for a simple revision of the paper). The authors should consider referring to the papers on the "World avoided" that look at how chlorine could have developed and what would have happened to ozone without the Montreal Protocol (Prather et al., 1996; Velders et al., 2008, Morgenstern et al., 2008; Newman et al., 2009).

I do not understand where the reference EESC scenario comes from. The authors do not explain how they define EESC. According to WMO (2007), total chlorine at the surface was 3.6 ppbv in 1996 (2000: 3.5 ppbv, 2004: 3.4 ppbv). In the stratosphere, total chlorine peaked in around 1999 at around 3.4 ppbv (figure 1-10 of WMO, 2007). A popular definition of EESC is total chlorine + 60 times total bromine. Bromine peaked in the late 1990s at around 20 pptv. This gives a maximum EESC loading of 4.6 ppbv. This is nearly 1.4 ppbv more than the reference scenario adopted here, and the peak may also be later than shown here. If EESC is correct up to an erroneous scaling factor, the conclusions reached here remain valid.

As a minor caveat, I do not understand why the LT scenario is not equal to the observed EESC from the 1950s to 1970s (figure 1). The difference may not be big, but is unnecessary in the context of the paper and clearly not attributable to the Montreal

ACPD

10, C6729–C6732, 2010

Protocol. I would make the two scenarios equal until about 1990.

Minor comments:

P19907, l20: Please state the definition of EESC used here.

P19909, l10: Please add more recent references, e.g., SPARC CCMVal (2010).

P. 1912, eq. 3: This equation can do with more explanation and motivation, both for the shape of the expression and for the origins of the numerical parameters.

P19013, l5: Replace “Totally” with “In total,”.

P19013, l13: Please explain more clearly how you define equivalent latitude. Usually, it is the area enclosed by a PV contour on an isentropic surface, mapped onto the latitude that encloses the same area. This does not involve any vertical integration. Did you average the equivalent latitudes at different levels, weighted with the amount of climatological ozone enclosed?

Actually, arguably the dynamical variable most directly linked to vortex dynamics and associated ozone depletion is the Eliassen-Palm flux. Did you consider using this instead of EL?

P19013, l15 ff: Too much “it is known” in this sentence.

P19015 l23: Replace “whereas” with “because”.

P19015 l25: I suggest breaking up this sentence: ”This justifies. . .”.

P19017 l3: Insert “human” before “population”.

P19017 l13: Replace “largely” with “widely”.

P19017 l16: Insert newer references (e.g., SPARC CCMVal, 2010; Austin et al., 2010a and 2010b) here.

P19017, l21: Insert “for” before “a sound interpretation”.

ACPD

10, C6729–C6732, 2010

P19018, l3: Capitalize the “Montreal Protocol for the Protection of the Ozone Layer” as it is a name.

References:

Austin, J., et al., The decline and recovery of total column ozone using a multi-model time series analysis, J. Geophys. Res., in press, 2010a.

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Morgenstern, O., et al., The world avoided by the Montreal Protocol, *Geophys. Res. Lett.*, 35, L16811, 2008.

Newman, P. A., et al., What would have happened to the ozone layer if chlorofluorocarbons (CFCs) had not been regulated?, *Atmos. Chem. Phys.*, 9, 2113–2128, 2009.

Prather, M. J, et al., The ozone layer: The road not taken, *Nature*, 381, 551-554, 1996.

SPARC CCMVal, SPARC Report on the Evaluation of Chemistry-Climate Models, V. Eyring, T. G. Shepherd, D. W. Waugh (Eds.), SPARC Report No. 5, WCRP-132, WMO/TD-No. 1526, http://www.atmosp.physics.utoronto.ca/SPARC, 2010.

Velders, G. J. M., et al., The importance of the Montreal Protocol in protecting climate, *Proc. Natl. Acad. Sci.*, 104, 12, 4814–4819, 2007.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 19005, 2010.