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Comment on acp-2021-232

Eric Ray (Referee)

Referee comment on "The impact of sulfur hexafluoride (SF_6) sinks on age of air climatologies and trends" by Sheena Loeffel et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-232-RC1, 2021

This paper explores the effects of SF6 loss on the mean age values and trends derived from SF6 model output and observations. The conclusion, that SF6 loss can reverse the sign of the mean age trend over recent decades compared to mean age from a tracer without loss, is important in helping us understand the long running discrepancy between modeled and measured trends. The explanation is actually incredibly straightforward, that the higher the concentration of a species in the atmosphere, the more absolute loss will occur and therefore the bias will grow over time. It's kind of hard to believe none of us studying this topic hadn't thought of this possibility before, but there you go. Nice work by the authors of this paper to recognize the importance of SF6 loss and quantify the effect.

There are still outstanding issues, the trend in CO2 derived mean age is one of them and the SF6 lifetime derived in the EMAC model is another since it seems to be higher than other recent estimates. Nevertheless, this paper is an important step forward in our understanding of mean ages derived from observations and how models can be used to help put them in context. My main comments described below revolve around how best to use this information to help us make the observationally derived SF6 mean ages more accurate. It doesn't make sense to cast the measurements aside when it comes to mean age estimates so we need to be careful to frame the current understanding in a more inclusive way.

I do recommend this paper be published with consideration of the comments below.

Main comments

- It would be really nice to see a plot of latitude vs. altitude trend differences between REF(WS, SF6) and REF(NS, SF6). I realize you've focused the trend analysis on the locations of the Engel et al. papers in the 4-6 year mean age range, and that's important to see. But at what mean age does the trend discrepancy emerge from the uncertainty to become significant? How does this vary with location? You hint at it in Figure 1 where the NS and WS profiles diverge but it would be good to see more. I think this is important for the community to know what age ranges we can reliably use SF6 as a mean age tracer. For instance, in my 2014 paper I showed mean age trends at four altitude ranges and in the bottom layer, where mean ages were 2-3 years, the SF6 measurement trends agreed within uncertainties with the modeled mean age trends. Is this expected based on your work?

- As a corollary to your findings, couldn't a correction to SF6 mixing ratios be made in the calculation of mean age to account for loss? This would be similar to the way CO2 is adjusted for production from CH4 oxidation before calculating mean age. This correction would have to vary with time and location, which you could derive from the differences between your REF(NS, SF6) run and the MIPAS data.

Specific comments

Line 6: I would add 'in the NH extratropical middle stratosphere' after 'positive trend'. Or something similar to give some reference to the Ploeger et al. (2015) and Stiller et al. (2017) hemispheric shift effect on the age trends that you mention in the introduction. Also, in Ray et al. (2014) I showed that the balloon age trends are negative in the lower

extratropical stratosphere.

Figure 1: It seems like you could do a better job of averaging model data to match the March 2000 balloon profile location. This balloon flight was clearly in the vortex as shown in Figs. 2 and 3 in Ray et al., 2017 with equivalent latitudes from 68-75N. By averaging model locations at all longitudes and latitudes as low as 60N you are mixing locations in and out of the vortex. It's relevant to the lifetime estimates to see how the polar vortex model and measurement profiles compare since this is the region most impacted by the SF6 loss.

Line 130: 'approximately' is misspelled, change 'turned out to be' to 'are'

Line 199: 'definition of Braesicke…'

Figure S4: No y-axis labeling.

Figure S5: In the caption you state 'Values averaged over the region 30-50N and 2007-2010'. I think the 30-50N part is not needed here since these are latitude vs altitude plots.