Response to Dr. Felix Vogel

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We thank Dr. Vogel for a prompt and favorable review, and for the helpful questions he raised. Please find below our responses. Dr. Vogel's comments are in *blue italics*, our responses are in normal text. Portions of a response that refer to the main text are in "double quoted red".

Page 3 equation (1b) Please consider that the mass-balance for 14CO2 is only valid for d14C not D14C. The author discuss the issue of d13C corrections impacting D14C this confusion ca be avoided putting the mass balance for 14CO2 and then mentioning the assumptions made to arrive at a mass balance for D14C. e.g. https://journals.uair.arizona.edu/index.php/radiocarbon/article/downloadSuppFile/16347/212. *The impact of the approximation in (1b) seems negligible.*

Dr. Vogel is correct that strictly speaking the mass balance of $^{14}CO_2$ only yields an equation in terms of $\delta^{14}CO_2$, and certain assumptions must be made about the relative fractionation of $^{13}CO_2$ and $^{14}CO_2$ to arrive at our equation (1b) in terms of $\Delta^{14}CO_2$. We referred to these assumptions in the sentence immediately after equations (1), viz. "Δ_{atm} is the isotope signature of $^{14}CO_2$ in the atmosphere expressed in Δ notation, which includes corrections for mass dependent isotopic fractionation between reservoirs and radioactive decay between the times of sample collection and measurement, such that the quantity $\Delta^{14}CO_2$ is conserved in time." Since the (approximate) mass balance equation in terms of $\Delta^{14}CO_2$ has been covered in previous literature (e.g., Miller et al. (2012)), we did not re-derive it in the manuscript. Indeed, as Dr. Vogel says, the impact of those approximations on equation (1b) is small.

Page 16/17 conclusions The authors briefly discuss the potential impacts of model transport errors (investigated in section 4.3) and the added value of measurements of auxiliary species. Would you be able to advise on how much more model improvement is needed i.e. should this be an equally/less/more important part of developing the suggested future emission monitoring system?

While the need for model improvements is clear, Dr. Vogel's question is difficult to answer quantitatively within the present study. One of the two transport models we used for the "imperfect transport" OSSE, namely TM5 EI, was demonstrably biased (figures 2 and 3 in the manuscript), and therefore the difference between "NRC 5000 (EI)" and "Truth" in figure 11 is not an accurate measure of the error from a state-of-the-art unbiased transport model. Even our "better" transport model, TM5 EIC, had a noticeable bias in the vertical profile of SF_6 in figure 3. Therefore, at a minimum, transport models need to be improved until they agree with observed atmospheric gradients of passive tracers like SF_6 with reasonably well known sources. So to answer Dr. Vogel's question qualitatively, improving atmospheric transport models, especially over continental regions (which

are the primary sources of fossil fuel CO_2), needs to be as important as setting up an observational network to monitor future emissions.

References

Miller, J. B., Lehman, S. J., Montzka, S. a., Sweeney, C., Miller, B. R., Karion, A., Wolak, C., Dlugokencky, E. J., Southon, J., Turnbull, J. C., and Tans, P. P.: Linking emissions of fossil fuel CO_2 and other anthropogenic trace gases using atmospheric $^{14}CO_2$, Journal of Geophysical Research, 117, D08 302, doi:10.1029/2011JD017048, URL http://doi.wiley.com/10.1029/2011JD017048, 2012.