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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Simulating the integrated $\Delta^{14}CO_2$ signature from anthropogenic emissions over Western Europe" *by* D. Bozhinova et al.

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Summary: In this study Bozhinova et al. present an advanced modelling framework for CO2 and 14CO2 including crops, which are used as natural integrators for D14C signals. The different components of the model are thoroughly described as well as the methodology used to derive D14C. The assumptions made are clearly pointed out and the different components/model outputs are then evaluated against existing dataset of CO2 concentrations, CO2 fluxes and integrated samples of 14CO2. The comparison uses well-established statistical tools and the interpretation of the differences is sound. The influence of the two most important components of the local 14CO2 offset i.e. depletion due to fossil fuel CO2 and addition of 14CO2 are extensively discussed.

This study also suggest a simplistic approach to derive CO2ff fluxes from local 14CO2 concentration measurements, before discussing the implications of their findings. The paper is well-structured and of good quality, however, there are a few significant points that should be clarified.

General comments:

1. This study should address the limitations of using only 6 month of (summer) data in greater detail. The fossil fuel CO2 emissions, especially in large urban areas increase substantially during winter (cold) month. The local and large-scale CO2ff gradients can be expected to be significantly different then. The different atmospheric conditions (e.g. more synoptic, rather than daily variations of trace gas concentrations) can also alter the results of a model-data comparison. Referencing e.g. "summer" in the title and a short discussion could help clarify this.

2. Given the high spatial and temporal resolution of the modelling framework the limitations of using a parameterized emission estimate of nuclear power plant 14CO2, can cause several problems (Vogel et al. 2013, Radiocarbon, doi:10.2458/azu_js_rc.55.16347) This study, unfortunately, does not account for the large uncertainty of the parameterization as reported by Graven and Gruber (2011) and thus likely underestimates the uncertainty this term contributes to the uncertainty of D14C. This study, furthermore, assumes a constant annual emission of 14CO2. Although, the 14C is produced relatively constant over time, its release can often be intermittent and linked to maintenance work e.g. Vogel et al. and references therein. If no higher resolution emission data can be retrieved it seems crucial to use the uncertainty range provided by Graven and Gruber (2011) to estimate the uncertainty of the d14Cnuclear term.

3. The methodology presented in Section 3.4, which derives CO2ff fluxes from mere concentrations could be misleading. Given that this section uses only synthetic data finding a good relationship between concentration and fluxes, when accounting for the

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"footprint" (=5x5 pixel average) seems straightforward. The fit should even be better when the real footprint is used for calculating the flux average instead the 5x5pixel mask. The concentration is afterall the convolution of footprint and flux. It is, however, unclear to me how this method could improve our understanding of fluxes, as deriving fluxes from concentrations does usually not work in the real world, but often requires more complex models than a linear fit.

Overall the modelling framework presented here has a great potential to help better understand atmospheric D14C and the ability to use D14C data to derive fossil fuel CO2 fluxes. Comparing different potential sampling strategies and techniques will be crucial to develop monitoring schemes to quantify fossil fuel CO2 emissions from atmospheric observations. After addressing the general comments this study will most definitely be a valuable addition to this field and a suitable contribution to ACP.

Specific comments:

Title: Please consider adding a reference to the limited time of the simulation here.

P30613 - line 2-5

Giving an estimate of the typical uncertainty at this scale would help the reader to appreciate which precision the top-down method has to achieve to be useful to improve the bottom-up estimates.

P30614 - line 1-4

Please add "and upper troposphere", as a notable amount of 14C is produced there es well. Tropospheric 14CO2 also tends to be transported to lower levels more quickly.

P30619 - line 25

Please add the information about the spatial resolution of the used meteorological data here.

P30620 line 24-26

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The biospheric flux model uses different meteorological data than the atmospheric transport model. Do you have an estimate of the differences of important variables (T, wind, solar radiation, ...) of those two meteorological datasets?

P30621 - line 18-26

See general comment 2. The production of 14C might be continuous, the release likely has both constant and large intermittent components. (Vogel et al. 2013, Radiocarbon, doi:10.2458/azu_js_rc.55.16347 and references therein)

P30624 - line 10 and Figure 2.d

The information that Jungfraujoch is used as Dbg is substantial. Please consider removing the parenthesis. Given the small addition of co2ff and 14co2nuc at JFJ, an agreement of the data from JFJ and a model driven by Dbg from JFJ is rather to be expected.

P30625 - line24 following and Figure 2 and Table 1.

The mismatch of D14C is quite large and an explanation seems hard. The Van der Laan et al. 2010 (VDL10) data seems to agree significantly better, although its seasonality is also determined by a 14C calibration. The model has a bias of 8.82permil to the 14C data from Lutjewad presented here. The mean bias to the hourly VDL10 data seems to be fairly consistent i.e. -2.31ppm CO2ff, which translates to roughly 6permil-7permil. Do you have a comparison of the D14C data used to calibrated VDL10 and the samples used in this study?

Section 3.4. See general comments 3.

P30630 - line 15-16

Please add a reference. According to (Pregger and Friedrich 2009, Environmental Pollution, doi:10.1016/j.envpol.2008.09.027) and others, a significant amount of emissions are emitted above 300m.

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P30630 line 22-24

See general comment 2. Please reconsider the "safe assumption" of constant 14CO2 emission from nuclear power plants or add citations of respective literature to back this assumption.

30631 - line 2-3

Please address that using plants for monitoring 14CO2 will be limited to summer month (in Europe) and can thus only be complementary to other techniques.

Figure 3 - caption

Please change "contrubution" to "contribution"

Figures general

Please add a, b, c to subfigures to identify them

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