

Interactive comment on “Continental-scale enrichment of atmospheric $^{14}\text{CO}_2$ from the nuclear power industry: potential impact on the estimation of fossil fuel-derived CO_2 ” by H. D. Graven and N. Gruber

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Dear Felix,

We appreciate your interest in our paper and your input, which will improve the presentation of our work. We would like to address here one issue you raised on the influence of model resolution and model type to the interpretation of our results.

Our main interest is in the aggregate effect of multiple nuclear sites in producing steady-state, continental-scale gradients of $\Delta^{14}\text{C}$ and how such large-scale gradients can in-

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terfere with the estimation of fossil fuel CO_2 . We are also interested in the change in $\Delta^{14}\text{C}$ gradients from nuclear and fossil influences over the time period 1985-2005, and so we examined trends in annual mean results for specific sites. We chose to pursue an Eulerian approach in order to efficiently compute annual mean $\Delta^{14}\text{C}$ gradients arising from more than 200 nuclear sites over 21 years at the spatial scales that typically separate “polluted” and “background” observation sites (200-4000 km). This approach also allowed us to efficiently compute mean $\Delta^{14}\text{C}$ gradients arising from fossil fuel combustion, which is necessary to compare nuclear and fossil influences on $\Delta^{14}\text{C}$.

In each Northern Hemisphere region with a high density of population and nuclear energy production, significant $\Delta^{14}\text{C}$ gradients were produced by ^{14}C emissions from nuclear sites, and these gradients extended more than 700 km (approx. 3 grid cells) away from nuclear sites in some places. This spatial scale is sufficiently resolved by the coarse Eulerian model we used, 100-200 km in midlatitude regions, so our conclusions are not limited by our model or model resolution.

When examining specific locations, the results of Eulerian modeling with point sources such as the ^{14}C emissions from discrete nuclear sites are sensitive to model resolution and grid location. Point sources will be homogenized over the local grid cell; therefore, ^{14}C concentration will be underestimated near the nuclear site and overestimated far from the nuclear site within the local grid cell. This effect is not important for our assessment of the potential bias at Sable Island, Lutjewad, Schauinsland, Ryori and Gosan, however, since there were no nuclear sites present in the grid cells containing these sites. For the hilltop site of Schauinsland, 1250m ASL, we sampled the model at higher altitude (above the 3rd model level) so the potential bias shown in Figure 4 at Schauinsland is smaller than in the surface grid cell which does contain 4 nuclear sites. For Cape May, 2 nuclear sites with PWRs or BWRs are present in the grid cell containing this site. Therefore, the potential bias estimated in our model for Cape May may be too high.

Our objective in this paper was to point out the continental-scale effect and provide a

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first estimate of its magnitude. Since the issue of nuclear influences on $\Delta^{14}\text{C}$ is relevant to the spatiotemporal domains traditionally associated with both Eulerian approaches (large-scale, multiple sources, steady-state) and Lagrangian approaches (small-scale, individual sources, events), our estimates can be improved by work that addresses both domains. We encourage others to apply our ^{14}C emission estimates in models that bridge local and continental scales by using higher resolution, receptor-oriented or hybridized Lagrangian-Eulerian models, and are therefore likely to give better estimates of the total potential bias (local and continental) caused by nuclear ^{14}C emissions for specific locations.

We are grateful that you have raised this issue. We will revise our presentation to clarify further the limitations of the modeling approach we have taken, and place more emphasis on the result that significant, time-varying potential biases are likely to be present at continental scales and less emphasis on the quantitative results from our model. We will also implement other recommendations made in your comment.

Thank you and best regards,

Heather Graven and Nicolas Gruber

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