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Interactive comment on "Sensitivity of simulated CO₂ concentration to regridding of global fossil fuel CO₂ emissions" *by* X. Zhang et al.

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The manuscript "Sensitivity of simulated CO2 concentration to regridding of global fossile fuel CO2 emissions" by X. Zhang et al. presents an analysis of the impact of the misplacement of fossil fuel emissions to eater gridcells when regridding from a fine-scale grid to a coarse-scale grid on simulated atmospheric CO2. The authors compare two different reridding methods: a 'traditional' method where the emissions on the fine-scale grid are simply aggregated on the coarse grid and a 'reshuffling' method where emissions on the fine grid are displaced to the nearest coarse land gridcell in case the fine grid cell lies in a coarse water grid cell. The authors highlight this dynamical in-

consistency as a potential problem for atmospheric CO2 inversions. The reshuffling of emissions is indeed an interesting approach and worthwhile to follow up but there are several problems with the current manuscript. The authors claim that this reshuffling of the emissions ensures dynamical consistent results. However, it is not clear what they mean by 'dynamical consistent'. I assure this refers to the different vertical mixing and boundary layer behavior over land and water grid cells and that land fossil emissions in a coarse grid water grid cell would be advected differently than in a coarse grid land grid land grid cell. This needs to be discussed in the paper. We thank the referee very much for the comments. We agree that more discussion is needed to clarify the "dynamical consistency". We note that Referee 1 made a similar comment. For this purpose, we have modified text in the "Abstract" and "Introduction" sections.

In the "Abstract" section, we have made the following modifications: "Regridding of fossil fuel CO2 emissions (FFCO2) from fine to coarse grids to enable atmospheric transport simulations can give rise to mismatches between the emissions and simulated atmospheric dynamics which differ over land or water. For example, emissions originally emanating from the land are emitted from a gridcell for which the vertical mixing reflects the roughness and/or surface energy exchange of an ocean surface. We test this potential "dynamical inconsistency" by examining simulated global atmospheric CO2 concentration driven by two different approaches to regridding fossil fuel CO2 emissions."

We also added more explanation and modified the paragraph in the "Introduction" section as:

"Transport models typically distinguish the surface characteristics of a model gridcell in broad classes such as land versus water or urban versus rural. These classifications are important to both the emissions of FFCO2 and atmospheric transport above and/or downwind of particular gridcells. For example, modeled atmospheric transport processes such as mixing with the planetary boundary layer, convection, synoptic flow, and even general circulation are influenced by the gridcell surface characteristics (e.g.

surface roughness or energy budget). Global tracer transport models usually discretize surface gridcells at a lower resolution than those of fossil fuel CO2 emission data products produced in recent years and, thus, the emissions need to be aggregated to the coarser model resolution. In this process, the transport model gridcells with less than 50% land geography are usually designated as water gridcells. Emissions present on the finer FFCO2 grid, resident within the coarser model water grid cell are thereby mixed into the atmosphere according to vertical mixing processes characteristics of ocean or lake transport dynamics."

On the same topic, it is not clear how the meteorological driving fields from MERRA are treated. If the MERRA data have to be regridded as well to match the PCTM grid, then there is the same problem with the treatment of meteorological field if data from a fine grid land cell ends up in a coarse grid sea cell or vice versa. This may not be a problem in this particular case if the MERRA met forcing is already on the PCTM grid but it is certainly a problem for many other atmospheric transport and inversion systems. In fact this may actually be a much more important bias and is not limited to CO2. The MERRA meteorological data and the PCTM have exactly the same resolution. But the major problem with this study is that it is only half way done. Since the authors claim that this is potentially an important problem for atmospheric CO2 inversion the questions are now: What is the impact on the estimated surface fluxes when using the reshuffling method in atmospheric CO2 inversions? And how do we know that this results in more accurate flux estimates? It needs to be shown that this different way of regridding really results into different flux fields. But the second question is probably even more important because the reshuffling process may create artificial biases and shifts potential natural sinks/sources from water to land gridcells as the overall carbon budget needs to be balanced. So this reshuffling regridding may just move a bias from a dynamical transport process to balancing bias. The reviewer raises several points here which we need to separate. First the study is incomplete because we have not considered the impact on atmospheric inversions. This is true. Of course most studies are incomplete; our task here is to note the magnitude of an effect. We also note

that atmospheric inversions are not the only purpose for simulations of fossil fuel-like tracers; many studies in atmospheric chemistry have the same need and consequently the same problem. But the study also does do something of direct use for an inversion. The fossil fuel is part of the prior flux. So in an atmospheric inversion this term represents a systematic uncertainty in the mapping of fossil fuel flux into the prior mismatches (prior simulation of concentration – observations). We see that the effect is widespread and large compared to the measurement uncertainty usually used. This is enough to demonstrate significance for an inversion.

The second point is whether the reshuffling simply transfers errors from one place to another. The comment has some merit. For example reshuffling emissions away from an oceanic gridpoint may leave a station in that grid cell further from emissions than it really should be. This is possible of course. We can only investigate this by separating the transport and relocation effects by using an on-line model as suggested in another comment. We don't agree though that this could introduce land-ocean biases. Fixed fossil sources are almost entirely land-based. Putting them in ocean gridpoints seems far more likely to introduce land-ocean biases as the inversion tries to correct a poorly transported signal from the wrong environment. And finally it is not clear how fossil emissions from planes and ships should be treated. These data are available now as well on resolutions higher than typical transport models. How are they accounted for in such a reshuffling process? We have not addressed this problem yet. Airborne emissions are unlikely to be strongly impacted by this problem since the differences in atmospheric physics between land and ocean decrease once above the boundary layer. While emissions from shipping do potentially suffer from this problem the fraction subject to misallocation will be small so the total problem is a small fraction of a small fraction.

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