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# *Interactive comment on* "$N_2O$ changes from the Last Glacial Maximum to the preindustrial – Part I: Quantitative reconstruction of terrestrial and marine emissions using $N_2O$ stable isotopes in ice cores" *by* Hubertus Fischer et al.

**Anonymous Referee #1**

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This manuscript by Fischer et al. presents N2O gas observations including isotopes in ice cores from the Last Glacial Maximum to preindustrial. They build upon previous work using a Monte Carlo two-box model to interpret the data and estimate changes to terrestrial and marine emissions. The authors conclude that both terrestrial and marine emissions must have increased over the deglaciation, with the terrestrial contribution likely to be about a factor of 2 larger than marine, and discuss uncertainties. A more robust result from the analysis is the temporal dynamics that indicate two sharp increases in terrestrial emissions at the beginning of the B/A and end of the YD, while



marine emissions are driven by longer millennial fluctuations that appear to be linked to North Atlantic climate/AMOC.

Overall I find this to be an excellent study that gives new quantitative insights to N2O emissions over the last 28,000 years. The simple box model is a simple but suitable framework to estimate N2O emissions. However, I have a couple of issues regarding the model estimates that should be addressed before I would recommend publication.

Major Comment: Uncertainty of total terrestrial vs. marine emission increases over the deglaciation

In the abstract, the uncertainty levels on the deglacial increase of N2O emissions are small at 0.3 Tg N yr-1, which gives the impression that there is a high degree of certainty on the relative contribution of terrestrial and marine emissions, which is one of the most important results of this study. After reading the discussion in the text, this seems much more uncertain. For example on page 20, lines 1-2: "... the deglacial increase in terrestrial and marine emissions depends on the assumed initial ratio of terrestrial to marine N2O emissions...". This implies that the contribution of terrestrial vs. marine emissions over the deglaciation is determined from a modern model estimate that could have been much different in LGM conditions and thus introduces large uncertainties. My guess is that the temporal dynamics of the model fit to the observations prevent a large deviation from this imposed initial assumption, which could be more clearly described.

In any case, the selection of the uncertainty levels ($\pm$0.3 Tg N yr-1) should be specifically discussed. I guess it comes from the uncertainty in anomalies which is only described in one sentence in the caption of Figure 7, and thus I do not fully understand. It yields an uncertainty level of 0 at the LGM, i.e. assumes that the imposed initial condition based on a modern model is also correct in the LGM as I understand it. I would have thought the uncertainty should be at its largest levels during the LGM and deglaciation since there is additional uncertainty regarding how end-member isotopic values may have changed. In Figure 6, the low-biased and high-biased marine fraction sensitivity simulations suggest much higher uncertainties in emissions that seems more realistic since this is a key assumption/uncertainty driving the model estimate.

Minor comments:

Page 1, line 17: "show" should be something like "estimate" or "suggest" since that number is a model prediction, not an observation

Page 8, lines 30-32: "varied between -34 and +2 ‰ for the global terrestrial emissions and between +4 and +10 ‰ for global marine emissions"

What are the actual best-fit isotopic end-member values used in the model simulations? Given these wide ranges, I am curious how many plausible scenarios exist that can still explain the observations. Since the presented emission change scenarios are mostly consistent, I assume the range if values in the "accepted runs calculated by the Monte Carlo atmospheric two-box model" is quite narrow. Is that correct? In general, I wonder how useful the isotopic constraint is given these large ranges of end-member values.

Page 19, lines 17-18: "However, the temporal evolution of relative changes in land marine N2O emissions remains similar".

This is where I get a bit confused. Figure 6b shows large differences in the relative marine emissions for the different marine fraction scenarios. I would say that a scenario that remains near peak deglacial levels across the Holocene (high-biased fm) has a different temporal evolution to one that drops back to LGM values during the Holocene (low-biased fm), even if the smaller wiggles correspond.

Discussion: Previous work by Schilt et al., 2014 suggested an equal contribution from terrestrial and marine increases over the deglaciation, whereas this study suggest a larger contribution from terrestrial emissions relative to marine. What part of the data and/or model analysis differed in this study that led to this change?

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