We thank anonymous referee #1 for their helpful comments on this work. Below, original comments are in italics and our responses are in bold.

General comments:

Although the paper is generally well-structured, it does appear to jump around a bit when describing the various tests that were carried-out. For example, at the beginning of section 5 (P5378), it would be helpful to include a list of the types of tests (in addition to Table 3), or at least just mention that there are also tests considering temporally varying errors in the prior parameters. Another point that I found confusing was whether or not transport (and measurement) errors were added to the pseudo-observations, as the impact of these is mentioned later in section 5.2 (P5383).

We have added some text at the beginning of Section 5 to mention that a temporally-varying bias is considered for some of the tests. We have also added a sentence indicating which tests can be found in which subsection of Section 5. We did not add random noise to the pseudo observations in most of these tests, but did perform a subset of tests with noise added that yielded the same results as the tests with no noise. We have added some text to mention this.

Specific comments:

P5370, L20: please change this to: "Agricultural activities such as fertilizer application and animal waste management increase the substrate available for nitrification and denitrification pathways leading to enhanced…" as by writing that the reactions are enhanced suggests increased rates of reaction.

We have made this change.

P5371, L5-8: suggest that the authors also include reactive nitrogen substrate in this list, as it is one of the most important determinants of N2O emissions

We have made the addition to the list.

P5374, L8: by "loss frequencies" do the authors mean photolysis cross-sections or other, please clarify.

By loss frequencies we mean the loss due to both photolysis and reaction with $O(^1D)$. We have added some text to clarify this.

P5375, L23: by enforcing a minimum value of the posterior scaling parameters of zero implies that the fluxes cannot change sign in the inversion, i.e., a negative flux cannot become positive and vice-versa. Is this what the authors mean? In which case it is not quite correct that regions with a prior negative flux (e.g. over the ocean) cannot become more negative, but rather that they cannot become sources?

Correct—we thank the reviewer for catching that. We have updated the text to note that the assumption implies that the sign of the a priori N_2O flux is correct (i.e. net sinks will remain net sinks and vice versa).

P5375, L19: does the size of the state vector apply to the two-year inversion period? Given that the number of elements for the stratospheric loss parameters is 192, I would be presume so, but it would be helpful to state this here.
Yes. We have added some text to note that the state vector corresponds to the two-year inversion.

P5376, L6: could you please give the order of magnitude of the transport errors calculated? This would be interesting to know, especially in connection to the influence of the transport errors on the ability for the inversion to simultaneously optimize the emission and loss parameters.
The transport errors are quite small at the surface (0.2 ppb on average), but can be much larger aloft when calculated with respect to an aircraft's location (2-8 ppb on average). We have added some text to include this information.

P5378, L23: do you add any random noise to the pseudo-observations, and if so, was this consistent with the error characteristics of the observation error covariance matrix?
The tests presented here do not have random noise added to the pseudo observations, but we did do a subset of tests in which we added random noise (consistent with the observation error, which is the sum of measurement and model transport error) and got the same results as the tests with no random noise. We have added some text to note this at the beginning of Section 5.

P5378, section 5: by adding a spatially uniform error to the prior values of the scaling parameters, you are testing the ability of the inversion to correct a uniform bias, which effectively means one degree of freedom. However, it would be also a useful test to see how well random spatially distributed errors can be corrected.
We did perform a test in which we assimilated surface pseudo observations and applied a spatially-random emission bias of up to ±50%. The correction to the random bias was slight, and occurred mainly in the vicinity of sites with continuous observations. We opted not to include this test as the error reduction calculations give the same information. We have added a sentence to Section 5.4 mentioning this.

P5380, L1-5: did the authors examine how the correction to the biased a priori scaling factor varied from season to season? I would expect that there would be some dependency on season as well due to the seasonal variation stratosphere-to-troposphere (STT) mixing on the tropospheric mixing ratios of N2O. This would be useful information to include.
For the case of a uniform bias in emissions, the correction to the scaling factor has very little variation month-to-month. The only variability appears to be due to the temporal variability of emissions in the a priori database for ocean emissions.

P5382, L5-10: I think here it is important that the authors make a distinction between the lower and upper stratosphere. The vast majority of the loss of N2O occurs in the upper stratosphere, therefore, the influence of a bias in the loss will only be seen in the troposphere (where the nearly all the observations are made) after the time delay for transport from the upper stratosphere to the troposphere, which is long, i.e. 1-2 years. However, mixing from the lower stratosphere to the troposphere can occur on shorter timescales of weeks to months.

This is a good point. We have added some text to make the distinction that the timescale of mixing from the upper stratosphere to the troposphere is what drives the ability to correct the biased a priori values.

P5394, L1: although in the future, satellite retrievals of N2O may reach the precision and accuracy needed to help constrain N2O emissions, current retrievals and instruments are not at this level: the error on N2O retrieved from AIRS is about 7 ppb in the troposphere (for comparison, this is more than 3 times the inter-hemispheric gradient in N2O). At present, the AIRS satellite retrieved may be helpful in addition to ground-based observations for, e.g., establishing the vertical profile of N2O for the initial conditions but not in solving for surface emissions of N2O.
We agree with this statement and have expanded this point in the Conclusions.

Technical comments:

P5369, L8: replace "aboard" with "on-board", i.e., the adjective
We have made this change.

P5370, L13: 100-year
We have made this change.

P5370, L15: "those of any other ozone depleting substance"
We have made this change.

P5370, L16: replace "reactions" with "pathways" as nitrification and denitrification each involve a series of reactions
We have deleted "reactions".

P5375, L23: "…ocean regions with a net N2O uptake are not stronger sinks than in the prior…"
We have altered the text here to address the specific comment above.

P5377, L25: please put the phrase in brackets "(in general…)" after "lowermost stratosphere" to make the sentence easier to understand
We have made this change.