Author response

We thank the reviewer for taking the time to evaluate the manuscript thoroughly and for giving the valuable comments that helped to improve the method and the manuscript. Below we answer the comments in detail, our response is marked in green and changes to the text in blue. Some larger changes are not repeated in detail here, but we refer to the relevant places in the updated manuscript as detailed as possible.

Review of SCIAMACHY nominal mode NO

The paper "Retrieval of nitric oxide in the mesosphere from SCIAMACHY nominal limb spectra" by Stefan Bender et al. describes a new mesospheric SCIAMACHY NO data product, the retrieval algorithm of which is largely based on the MLT mode NO retrievals. Preliminary results, along with the effects of a priori information, are also discussed. The paper is well written, flows logically, and is on a subject matter that would be of interest to an AMT reader. As well, the new NO data product will be of great interest to the mesospheric community as there are very few mesospheric NO data sets currently available (especially in the middle mesosphere where this data set yields the best results). I would recommend the paper for publication after one major issue and a number of more minor issues (listed below) are properly addressed.

Major issue

It is highly unlikely that using a constant correction factor (0.5) to the a priori values will be a solution to the overcorrection for all SCIAMACHY retrievals. Especially when considering the reason given–that the SNOE mission was during an epoch of high solar activity, since the SCIAMACHY mission spans almost an entire solar cycle. Also, NO peak densities are known to vary by much more than a factor of 2 throughout an 11-year solar cycle. I would highly recommend varying this scale factor based on known NO variation throughout a solar cycle and make it dependent on either Ap or AE index values.

The factor 0.5 was purely empirical. We agree that scaling it according to solar conditions is a viable option. To account for varying solar conditions (very low around 2008–2009, moderate 2010–2012), we tried several approaches. But one should keep in mind that the NOEM model itself already includes solar variations in terms of the Kp index and the ($\log_{10}$ of the) f10.7 radio flux. One option we considered, was to scale according to f10.7 with respect to the mean of the SNOE period (around 150 from 1998 to 2000). This resulted in a factor of about 0.5 at the beginning of the SCIAMACHY MLT measurements and higher values at the end, but overall the results were not satisfying. We therefore extended the retrieval algorithm to simultaneously fit this additional scale factor for the a priori values. This also accounts for longitudinal variability during one day and for variations on shorter time scales which are not fully captured by the models themselves. We have updated the manuscript Sect. 3.2 with the improved method (page 4 lines 28–30 and page 5 lines 1–10), the results section (pages 10–12) and the conclusions (page 14

lines 9–14) with our new findings.

Minor and/or technical issues

Title: Title has ”nitric oxide”, whereas P1L1 and P1L16 have ”nitric monoxide”. Suggest only using nitric oxide.
We changed the text to use “nitric oxide” throughout the manuscript.

Abstract: Try to reduce the number of times you begin a sentence with ”we”.
The abstract was rephrased to account for that.

P1L7: what does NOEM stand for?
NOEM stands for “Nitric Oxide Empirical Model”. We spelled it out here and in the a priori description section.

P1L8: Would ”realistic” be more accurate than ”meaningful”?
We replaced “meaningful” by “plausible”.

P1L10: What is meant by ”misidentification”?
We replaced it by “incorrect attribution”.

P2LL2-3: I would suggest something like ”...to about 91 km, they do not sample the lower thermosphere where peak NO densities are typically located, above $\sim$ 100 km (...”
We incorporated this suggestion into the manuscript.

P2L4: ”the whole” should be ”all”
Changed.

P2L14: Although there is no paper dedicated solely to SMR NO retrievals, it might be good to also cite Pérot et al., AMT, 2013 which also describes the SMR NO data.
We added a reference to this publication.

P2L15: I recommend mentioning that the ACE-FTS NO was validated by Kerzenmacher et al., 2008, as the study doesn't greatly discuss the retrieval algorithm. Also, the way the paragraph is structured could lead people to think that ACE observes emissions, when it is solar occultation.
The text was changed accordingly. We also changed the order of the instruments introduction, putting the limb instruments first and then ACE-FTS, mentioning explicitly that it measures solar occultations. We refer to page 2 lines 14–18 in the updated manuscript.

P2L20: Conclusions are given in Section 5.
Added to the text.

P3L1: It would be beneficial to mention that NO gamma band emission is fluorescent scattering, hence only dayside. (It could also be mentioned at line 11 of this page)
We added "fluorescent emission" in both mentioned places, page 3 lines 5–6 and 13 in the updated manuscript.

P3LL8-9: "we fit the measured NO gamma bands spectra to modelled spectra (..."
Changed.

P3LL30-31: It seems like you're describing solar occultation measurements. I would assume that the forward model would calculate emissivity along the line of sight (not extinction, as you just mentioned that for these transitions the atmosphere is optically thin), and from the top of the atmosphere to the tangent point (not from the sun)?
The emission is attenuated by ozone and air absorption and scattering in the same spectral range. This happens along both the line of sight from the retrieval grid cell to the satellite and from the sun to the grid cell. The text was intended to mention this ozone and air absorption. We rewrote the corresponding paragraph to be clearer in this respect. See page 4 lines 3–4 in the updated manuscript.

P4L19: remove "again".
Done.

Eq. 2: Sorry, I've never seen this notation before. I assume that, $\|Kx - y\|^2_{S_y^{-1}}$ is the same as $(Kx - y)^T S_y^{-1}(Kx - y)$?
Yes this is correct. This notation is used in a variety of publications regarding retrieval algorithms. We added the following footnote to the text (page 5):
In this notation the subscript matrix acts like a metric for the norm: $\|\vec{x}\|^2_M = \vec{x}^T \mathbf{M} \vec{x}$.

P5LL8-9: The NO peak height is *typically* between 100-110 km. The Odin measurements show that it can be lower in mid-winter.
We added the word "typically" to the mentioned sentence.

P5LL14-15: Please define NOEM and SNOE.
We spelled out NOEM and SNOE (Student Nitric Oxide Explorer) in the updated version of the manuscript in the mentioned place.

P6LL11-12: It would be better as "...fitted NO slant column densities from the (0, 2) band..." the way it's currently worded seems to imply that you're showing NO (0, 2) slant column densities, which is not the same as NO.
We changed the wording as suggested.

Figure 1: Is there a reason why only slant column densities from (0, 2) are being shown? If it's because it has the greatest S/N, maybe that should be mentioned in the text. Also, in the titles for the number density plots, "NO02+14+15" is a bit distracting. It could

just be "NO", or something like, "NO all bands average".
We chose the (0, 2) gamma band because it has the largest signal to noise ratio. A comparison to the other bands can be found in our earlier publication describing the MLT retrieval. Thus, we did not find it necessary to replicate those figures here. We have, however, changed the first paragraph of Sect. 4.1 to motivate our choice better (page 6 lines 19–24 the updated manuscript). We also removed the NO gamma band notation "02+14+15" in the figure title, it now states "NO" as suggested.

P7LL7-10: This point doesn't seem important, consider removing.
Removed.

P8L1: "...number densities without a priori..."
Changed.

P8LL17-18: Even though it only gives a rough qualitative look, please briefly describe the results in a sentence or two.
We added the following discussion to the paragraph and changed the first sentence slightly because most of the points were already mentioned in the paragraph above. (page 10 lines 1–7 in the updated manuscript):
"... gives only a rough qualitative look at the differences when using the different a priori models. When compared to using no a priori (Fig. 3), we find that below 90 km the NOEM a priori (left panel of Fig. 5) results in much lower differences in the northern hemisphere, but apparently large negative differences in the southern hemisphere. Using the regression model as prior input (right panel of Fig. 5), a similar north–south gradient appears, having slightly larger positive differences at northern latitudes and smaller negative differences in the southern hemisphere compared to the NOEM a priori. In both cases the number densities are closer to the full MLT retrieval results than without a priori. Note, however, that the above comparison shows only a single orbit. To assess..."

Figure 6: I'm not sure what the values "(490, 1680, 509)" are referring to, but they don't appear to be necessary (especially in the legends).
We removed the numbers from the figures, they were intended to indicate the number of averaged profiles within each latitude bin.

P10L3: should be "(dark orange and dark purple)".
Changed.

P11L3: "dark purple"
Changed.

Section 4.4: Please discuss how the values for the sample orbits compare to typical retrievals. Are they average, are they better or worse?
With respect to resolution, the selected orbits are typical examples in places with direct measurements. To clarify we added the following paragraph to the end of Sect. 4.4 (page

14 lines 1–2 in the updated manuscript):
In terms of resolution, the above orbits are typical examples. For all retrievals the averaging kernels are similar in all regions where measurements are available, i.e., between $\approx 80°$S and $\approx 75°$N in northern winter and vice versa in northern summer.

P13LL13-12: ACE-FTS measures NO in the same altitude range. Even though it's solar occultation, there should still be hundreds, if not thousands, of coincident measurements between SCIAMACHY and ACE NO. It is not necessarily recommended that you do the comparisons here, but it should be done in the future (and at least mentioned here).
Yes and we compared some of the SCIAMACHY MLT data already to the ACE-FTS product. Comparing it to the nominal data is certainly planned for the future. However, as far as the authors know, the ACE-FTS NO data is currently being re-processed. And also in view of the now updated SCIAMACHY nominal NO retrieval, the full data set has not yet been reprocessed. We added the following sentences to the relevant paragraph of the conclusions (page 14 lines 17–19):
ACE-FTS, although measuring solar occultation, delivers NO data in the same altitude range. Comparisons are planned for the future after the full SCIAMACHY nominal mode data are processed and also the ACE-FTS data have been re-processed.

P14L1: "The ten years of daily measurements allow for the study of NO..."
We changed the original expression to "... enable to investigate ... ".

Figure 3:

Figure 5: