AMT-2015-153: Butz et al., G3E.

Reply-to-reviewer 2

Thank you very much for very useful comments. Find reviewer comments in boldface and our point-by-point reply in regular font below. Suggested changes to the manuscript are italic face.

This paper presents a mission concept for a geosynchronous satellite sounder with the goal of constraining the sources and sinks of two major green house gases at a impressive spatial resolution. This high resolution will allow for the identification of points sources, such as power plants, for emission monitoring. It is unfortunate that the technique is limited to continental areas as ports and sea shipping routes are also of great interest.

The work presented in the paper presents an initial performance assessments for such a mission and is certainly within the scope of AMT. The methods and assumptions used in the assessment are clear and reproducible, although some minor clarifications would be helpful (addressed in the Specific comments section below). The interpretation of of the assessment results are thorough and well supported. The paper is appropriately structured and the title is fitting. Citations were used when appropriate and where of an appropriate number and quality.

However there are issues with the quality of language. The paper is of need of a thorough editing which would greatly improve the readability and clarity. I will highlight some of the issues in the Technical corrections section, however further review is still be necessary.

Specific comments

Only two error sources are examined in this work while no comments are made about other possible sources of error. It is important to at least address the relative contribution of other uncertainties such as forward model parameter errors (temperature profile, spectroscopy...) would have on the retrieval. If they are small compared to the measurement noise and backscatter that should be mentioned and if not, the impact of the uncertainties should be remarked upon in further detail. Also note that in the conclusion it is claimed that "retrieval algorithms can deliver XCO2 and XCH4 with accuracy in sub-percent range for the majority of cases". This seems to be an overstatement when no other sources of error are considered within this work.

Reviewer 1 raises a similar point. Overall, we decided to address noise and scattering related errors since (1) the noise assessment demonstrates the general capabilities of the mission concept and since (2) scattering induced errors are typically considered the largest – and most difficult to handle – source of error for solar backscatter greenhouse gas soundings. The latter has been shown for real observations from GOSAT [e.g. Guerlet et al., 2013]. Further, the introduction of the manuscript argues that it is these two error contributions that appear more challenging for a geostationary than for a low-Earth-orbit satellite since (1) the geostationary satellite is farther away from the target and since (2) viewing angles on the target are slant.

Addressing all possible sources of error is outside the scope of our study. However, we agree that our manuscript should discuss their existence and that there should be dedicated future efforts to address various other sources of error. Some findings for a low-Earth-orbit can be adapted for the geostationary satellite concept. A recent example might be our contribution on spectroscopy-induced errors for CH_4 remote sensing by Checa-Garcia et al., 2015.

We add information on other sources of error in the conclusion:

"*Our study does not assess the potential impact of error sources other than random radiometric noise and scattering induced errors. In particular, imperfect instrument performance will have a detrimental impact on retrieval accuracy. The spectrometers need to be accurately calibrated with respect to spectral and radiometric performance and with respect to the instrument spectral response function. Erroneous calibration or in-orbit degradation of the instrument will map into retrieval errors. Further, G3E's mission concept requires that the 4 spectrometers observe the same ground scene since information on particle scattering and gas absorption is simultaneously retrieved from all spectral bands. Therefore, deficiencies in the optical alignment or in the characterization of the spectrometers' spatial response can have a detrimental impact on retrieval quality largely depending on scene heterogeneity. Further errors might be caused by erroneous input parameters to the retrieval algorithm such as meteorological and topographical input driving the calculation of surface pressure which is assumed accurately known by our retrieval concept. Likewise spectroscopic parameters driving spectroscopic line shape models must be known with high accuracy to avoid that erroneous fitting of absorption lines causes spurious correlations among interfering absorbers (e.g. Checa-Garcia et al., 2015). GOSAT XCO_2 and XCH_4 retrievals have shown that an overall accuracy in the sub-percent range is achievable from LEO given proper instrument characterization, high-quality meteorological and topographic input, and careful assessment of the spectroscopic requirements [e.g. Dils et al., 2014].***"**

We do not agree that the statement that "retrieval algorithms can deliver XCO_2 and XCH_4 with accuracy in sub-percent range for the majority of cases" is an overstatement. The retrieval concept we use here is the one used for our retrievals from real GOSAT measurements which have been shown to perform well within the "sub-percent range" [e.g. Guerlet et al., 2013; Schepers et al., 2012]. The same concept has been successfully evaluated for future LEO missions such as S5 and S5P [e.g. Butz et al., 2012] and, it is the scientific baseline for the operational S5P processor. Here, we show that the G3E instrument in GEO orbit yields similar performance under similar conditions.

2) In the Prospective noise performance section, the choice to use the same model to simulate and retrieved the concentrations should be discussed in further detail, particularly when in the particle loaded section the use of different models in the simulation and retrieval phases is emphasized.

For the random noise assessment, the choice of a consistent forward model for simulation and retrieval is logical, since we want to isolate the effect of random noise. If the forward model for simulation and retrieval was inconsistent, a forward model error would occur in addition to the noise error.

We add some explanation in Section 3:
"*A consistent setup is chosen to isolate the statistical noise error from other error sources. Section 4 introduces an additional forward model error by making the simulation and retrieval forward model inconsistent."*

3) Why choose to calculate aerosol optical particles use a Mie model with spherical shape of particles? More precisely, why spherical? What effect does the shape have on the optical thickness? How does this affect the assumption of hexagonal particle size in the retrieval model?

We are not entirely sure whether this comment refers to the simulation or the retrieval forward model. There might be a misunderstanding.

For the simulated measurements in section 4 (scattering-induced errors), we used a Mie model only for the (assumed spherical) aerosols, but a raytracing model for the (assumed hexagonal) cirrus particles. The particle optical properties are a composite of these contributions (weighted by optical thickness). Thus, they are not pure Mie-type properties but have non-spherical contributions.

For the retrievals in section 4, we assume a single Mie-type aerosol. It is on purpose, that the retrieval does not dispose of information on the cirrus particle type. Essentially, the point of section 4 is to assess what the retrieval error is when assuming an approximate particle scenario in the retrieval while facing a complicated (and therefore more realistic) scene for the simulated measurement. Thus, a significant contribution to the residual retrieval error shown in Figures 10, 11, 12, is caused by the fact that the Mie-assumption in the retrieval cannot entirely compensate for the scattering off non-spherical cirrus particles in the simulation.

See also the reply-to-reviewer 1 (first comment) and the changes to the manuscript suggested there.

Technical corrections

Thanks for the careful reading and for the corrections.

1) “Thereby” is mostly misused within the paper, it means ’by means of’ and is not a synonym for “thus”.

All “thereby” removed or replaced.

2) Page 6950, line 9 Rephrase “... including sampling of diurnal...”. Should be separate sentence.

Corrected.

3) Page 6950, line 26 Rephrase “... (MTG) satellites suggests making”. Instead of “suggests” perhaps use “makes possible” or “has the potential”

Corrected.

4) Page 6952 line 9 Change “ten km2” to “tens of km2”

Corrected.

5) Page 6952 lines 16 - 19 Sentence is too long and unbalanced. Consider separating for clarity.

Corrected.

6) Page 6953 lines 1 -3 “exploiting diurnal concentration cycles...” To do what? Needs clarification.

Actually, we think the meaning is clear and sufficiently illustrated by the example. Not changed.

7) Page 6953 line 7 Change “to support” to “of supporting”

Corrected.

8) Page 6953 line 19 Change “green house gases XCO2” to “green house gases of XCO2”

Really? Corrected.

9) Page 6954 line 7 Change “ which are in particular the . . .” to “which are the”

Corrected.

10) Page 6957 line 25 Change “to be traded” to “to be balanced”

Corrected.

11) Page 6960 line 10 Change “For our noise assessment here, this is of no relevance” to ”However this is not relevant for our noise assessment study.”

Corrected.

12) Page 6960 line 12 Change “ensemble here.” to “ensemble.”

Corrected.

13) Page 6960 line 18 Change “860 nm representative” to “860 nm as representative”

Corrected.

14) Page 6961 lines 13-14 Change “assessment here is consistent among the retrieval” to “assessment is consistent between the retrieval”

Corrected.

15) Page 6962 line 4 Change “identified a major” to “identified as a major”

Corrected.

16) Page 6963 line 6 Change “much alike” to “much like”

Corrected.

17) Page 6963 line 8 Change “extends from” to “extended from”

Corrected.

18) Page 6963 line 15 Change “particles scattering” to “particle scattering”

Corrected.

19) Page 6963 line 19 Change “Like for” to “As in”

Corrected.

20) Page 6966 line 8 Change “calculus” to “calculation”

Corrected.

21) Page 6967 line 7 Change “Beside” to “Besides”, or “In addition to”

Corrected.

22) Page 6967 line 18 Change “yields” to ”yield”

Corrected.

23) Page 6968 line 5 Change “performance the” to “performance for the”

Corrected.