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Interactive Comment

Interactive comment on "Near-infrared remote sensing of Los Angeles trace gas distributions from a mountaintop site" *by* D. Fu et al.

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Thank you for your comments suggesting revisions to our manuscript. We made changes to the text as suggested by you.

The reviewers' suggestions are in *italic*.

All of the revisions, which were made by following the suggestions from reviewers, are in **bold**.

Reviewer's suggestions:

This paper is very well written. The authors describe a very interesting novel setup for mapping of XCO2, XCH4 and XCO by using an FTIR spectrometer located on a *mountaintop. I recommend publication of this relevant contribution in AMT. Below I list a few comments concerning clarifications/extensions for consideration in the final publication in AMT. Spectrometer description: The metrology laser system seems not to be of the quadrature type, but instead uses a single laser channel. Is it possible to coadd interferograms?*

Re: It is not possible to co-add raw time-domain interferograms because in our laser metrology method, successive interferograms are not necessarily sampled on the same grid with respect to ZPD. It would be possible to co-add re-sampled and phase-corrected interferograms but there is no obvious advantage to this approach compared with our current method of co-adding spectra. We have not made any changes to the text to reflect the reviewer's comment.

Is the optical encoder information used for defining an absolute ZPD (zero path difference) reference or is the location of the center burst determined for coaligning interferograms before superposition?

Re: As discussed in section 4.1, CLARS-FTS determined ZPD from the location of the center burst. Each interferogram is resampled, phase-corrected and transformed individually. Interferograms are not co-added. We do not think it is necessary to add any additional explanatory text in the paper.

Is the scan operation mode of the spectrometer forward-backward or forward scan + fast return?.

Re: We added a sentence in **Page 8813 line 5** for adding discussion on this topic.

"The travel speed of the air-bearing slide is typically set to 0.3 cm s^{-1}. Interferograms are acquired in both forward and backward scans of the moving mirror".

In case of TCCON, it turned out that the presence of sampling ghosts (due to a systematic sampling position mismatch between even and odd laser sampling positions) is an important issue. Did you investigate these artifacts? Can you specify an upper *threshold for the ghost to parent ratio?.*

Re: The Bruker 125HR instruments which are employed in the TCCON network, use the laser zeros crossings to trigger interferogram samplings [Dohe et al., 2013]. This sampling method can cause spectral ghosts due to the effects of non-zero DC offset in the laser interferogram channel. CLARS-FTS used an interferogram sampling methodology (Section 2.2.3) that is different from the Bruker system and is insensitive to offset errors. Hence, we do not expect ghosts in the CLARS-FTS spectra. We have not added any text to the paper in response to the reviewer's comment.

Dohe, S., Sherlock V., Hase F., Gisi M., Robinson J., Sepúlveda E., Schneider M., and Blumenstock T. (2013), A method to correct sampling ghosts in historic near-infrared Fourier transform spectrometer (FTS) measurements, Atmospheric Measurement Techniques, 6(8), 1981–1992, 2013.

Learner, R.C.M., Thorne, A.P., and Brault J.W., Ghosts and artifacts in Fourier-transform spectrometry, Applied Optics, 35(16), 2947-2954, 1996.

I appreciate the careful and extensive characterisation of ILS (instrumental line shape) characteristics performed by the authors. There might be a single remaining issue: I wonder whether it can be safely assumed that the background intensity at each ground scene is uniform across the whole FOV (field of view) of the spectrometer? Otherwise the ILS might vary between ground scenes. A near infrared camera could be used to check whether surface albedo variation within the FOV is a non-negligible influencing factor.

Re: We agree that a target scene, whose surface albedo is not uniform across the FOV of the spectrometer, leads to distortion of rectangular function. Hence, it is critical to exam whether the target scene is uniform across FOV of a spectrometer. There is a near infrared camera co-aligned to the CLARS-FTS FOV. We used the following approaches to mitigate the impacts; (1) When selecting target sites in our measurement sequences, we tried to find out target sites with a generally uniform surface albedo

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across spectrometer FOV by using the images recorded by the NIR camera; (2) The images recorded by the near infrared camera enable us to incorporate the impacts of non-uniform scenes on the rectangular function for the spectral fits, if needed. However, this treatment is not included our operational algorithm since it is a time consuming processing. On the other hand, we applied post-screening that filtered out those scenes with poor spectral fitting quality. Hence, if there are any target scenes severely affected by the inhomogeneous surface albedo across the FOV, the post-screening reports abnormally large fitting residuals.

We have added a statement to the paper on **Page 8820 line 5** addressing this point.

"Target site selection was guided by imagery from the NIR camera to ensure an uniform surface albedo across the spectrometer FOV. Supplement Table 1 lists the target coordinates, measurement mode, and descriptions of targets in a typical measurement sequence."

Equation 7 does not represent the solar spectrum but just a single solar line.

Re: We revised **Page 8823 line 22-27**:

"The monochromatic atmospheric absorption spectrum is then multiplied by a synthetic solar spectrum (I) which is represented by the following equation

$$I_{i,j} = S_j e^{-X_{i,j}^2/\sqrt{D_j^4+X_{i,j}^2 Y_j^2}} \quad (7)$$

where, i is the index of the monochromatic wavelength grid, j is the index of the empirical solar spectral lines, $S_j, X_{i,j}, Y_j$, and D_j are the line center optical thickness, the frequency difference from line center, 1/e-folding width and Doppler width in the empirical solar line list, respectively.".

I have problems to understand the rationale of the CLARS-FTS retrieval (or I misinterpret the description of the procedure): I believe to understand the description of the modifications performed on the radiative transfer calculation within GFIT: in comparison

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to the standard ground-based solar-absorption observation the scattered path section connecting the ground scene location with the observer is taken into account. Probably the model atmosphere assumes homogeneity in horizontal direction. Therefore, note that any e.g. CO2 enhancement just below the observer altitude on the mountaintop gives a much stronger spectral effect in comparison to a CO2 partial column enhancement of the same size just above the observer elevation. This does not harmonize well with the approach of scaling the a-priori profile (if the scaling is performed at all model levels). In my opinion, a valid retrieval scheme would require in a first step the analysis of a spectralon observation (for determining the scaling factor for the a-priori profile above the observer altitude). In a second step, a ground-scene observation is analysed. In this step, the previous scaling factor for the profile part above the observer remains unchanged, the scaling is only performed on model levels below the observer. This analysis suggests a certain type of observing pattern: the observations should alternate between spectralon observations and scans of several ground scenes. If one finally would challenge the assumption of horizontal homogeneity for the lowest levels near the ground scene, then the exploitation of the recorded spectra would become a very demanding task which calls for either assimilation schemes using a transport model of high spatial resolution or tomographic retrieval techniques or a combination of both approaches.

Re: The approach suggested by the reviewer is one that is employed in our analysis. The measurement sequence (Supplemental Material Table 1) of CLARS-FTS is alternating between Spectralon (SVO mode) and scans of ground target scenes (LABS mode). To estimate the enhancements of column-averaged volume mixing ratio of greenhouse gases, XGHG$_{enhancement}$, below CLARS site, we would use the following equation

XGHG$_{enhancement}$=XGHG$_{LABS}$-XGHG$_{SVO}$

where, subscripts of LABS and SVO indicate the measurements modes. This approach is effectively identical to the suggested approach. The coming manuscript(s) of

CLARS-FTS data analysis will apply the above equation for the estimation of XGHG emissions from LA basin.

When designed the measurement sequence, we planned to retrieve one-dimensional spatial gradient of XGHG over LA basin by using a set of CLARS-FTS. e.g., combining the measurements over T17, T18, T19, T20 and Spectralon over CLARS site allows us to retrieve the gradient of XGHG within the "urban dome" from inland towards ocean coast (Supplemental Material Figure 1). However, neither the tomographic retrieval algorithm nor the model tool over regional scale has been setup for CLARS-FTS data analysis. We will implement this capability for CLARS-FTS data analysis in the future.

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 8807, 2013.

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