

FRM4GHG 2.0

Fiducial Reference Measurements for Greenhouse Gases



Technical Note on enhanced retrieval products from TCCON spectra

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1 DOCUMENT CHANGE RECORD

Issue	Date	Item	Comment
V0.0	2024-12-05	-	Initial version

2 ACCESS LIST

This document is a deliverable “D2.3.2: TN on enhanced retrieval products from TCCON spectra – created for the project FRM4GHG 2.0 and will be submitted to ESA. The document can be downloaded from the project webpage <http://frm4ghg.aeronomie.be>.

3 PURPOSE

The document describes the strategies for retrieving CH₄ vertical information from ground-based FTS near-infrared spectra, CO partial column information and improved CO column retrievals, and N₂O tropospheric column information from standard TCCON spectra.

4 DOCUMENT STRUCTURE

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5 RESULTS

The column averaged dry air mole fraction of methane (XCH₄) is the standard product of the Total Carbon Column Observing Network (TCCON). The GGG code is the standard retrieval code which is used to perform profile scaling retrieval of methane column concentrations. These measurements are widely used to validate satellite based XCH₄ measurements as well as model estimates of XCH₄. However, partial column measurements are of high relevance for understanding the methane cycle as well as for the satellite validation and model evaluation. It is for this reason; that we have investigated a new method of retrieving CH₄ vertical information from ground-based near-infrared spectra which are the standard measurements performed at the TCCON sites. A SFIT4NIR retrieval strategy has been investigated based on the TCCON spectra measured in the near-infrared spectral region using the SFIT_v9.4.4 retrieval code. The strategy has been tested for measurements performed at one of our TCCON sites at Reunion Island. More detailed discussion can be found in Zhou et al., 2019. After further optimization, it has been applied for other sites.

The SFIT4NIR retrieval strategy for St. Denis data was able to get two degrees of freedom separating the partial column information into tropospheric column between 0 – 16.5 km and stratospheric column between 16.5 – 50 km. The systematic and random uncertainties of the tropospheric column are 3.1 % and 0.5 %, while those for the stratospheric column are 6.8 % and 3.3 %. The total column computed has the systematic uncertainties of 3.2 % and random uncertainties of 0.5 %.

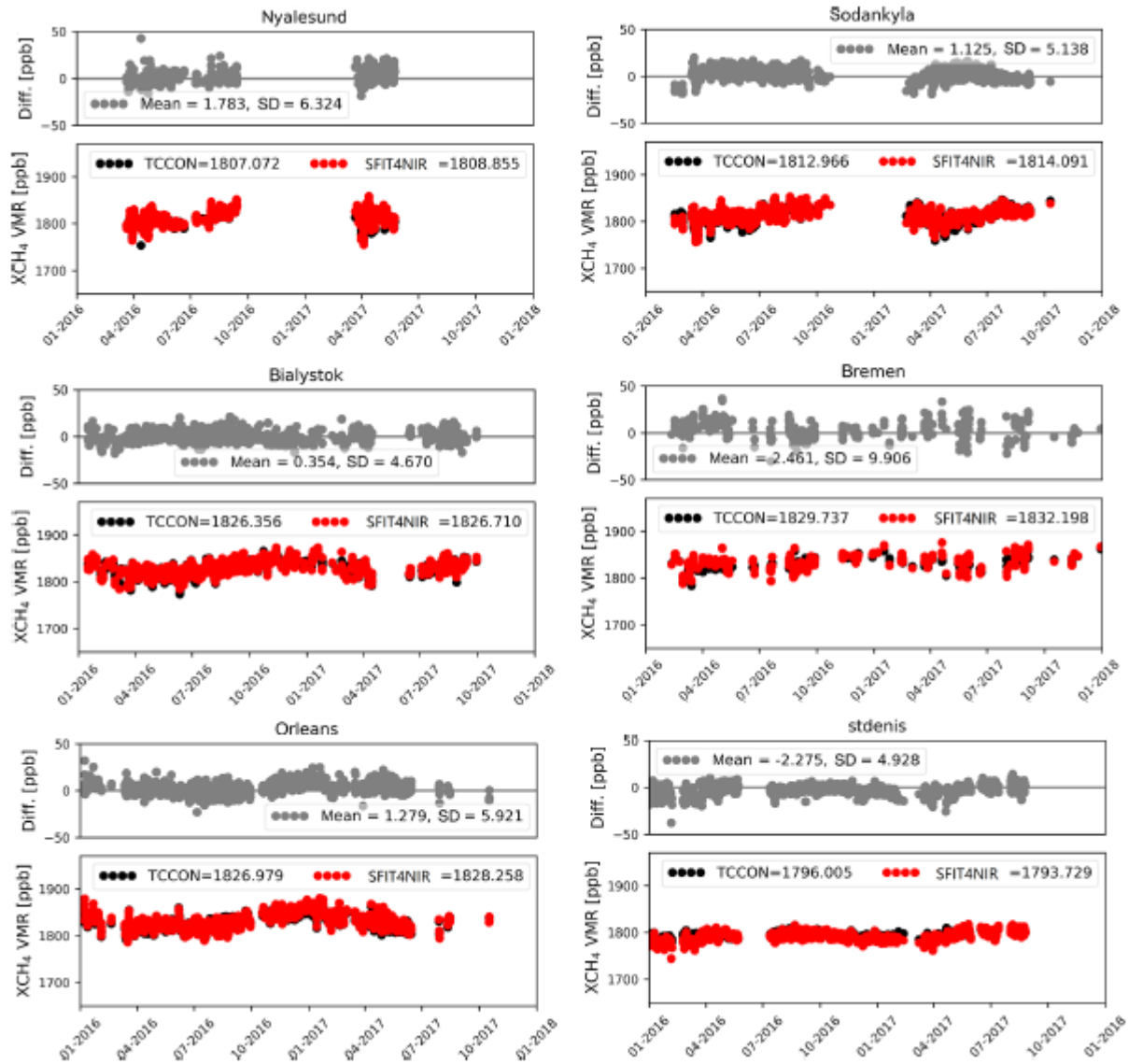


Figure 1: Time series of hourly mean of XCH₄ from SFTIR4NIR and TCCON retrievals and their differences at six sites during 2016 – 2017.

Figure 1 shows the time series of the hourly means of XCH₄ from SFTIR4NIR and TCCON retrievals and their differences performed in 2016 – 2017 period. The mean and standard deviation of the XCH₄ difference between SFTIR4NIR and TCCON at the six sites are in the range between -2.3 ppb (-0.14 %) and 2.5 ppb (0.15 %) and between 4.7 ppb (0.3 %) and 9.9 ppb (0.5 %). The standard deviation of the differences at all sites are within 0.5 %, which is consistent with the combined random uncertainties from SFTIR4NIR and TCCON retrievals. The systematic bias between the SFTIR4NIR and TCCON retrieved XCH₄ is much lower than 3.2 % indicating that the systematic uncertainty of the SFTIR4NIR total column from the spectroscopy is overestimated. Since the

systematic uncertainty of the TCCON XCH₄ retrievals is better than 0.2 %, it is inferred that the systematic uncertainty of the SFIT4NIR XCH₄ retrieval is within 0.35 %.

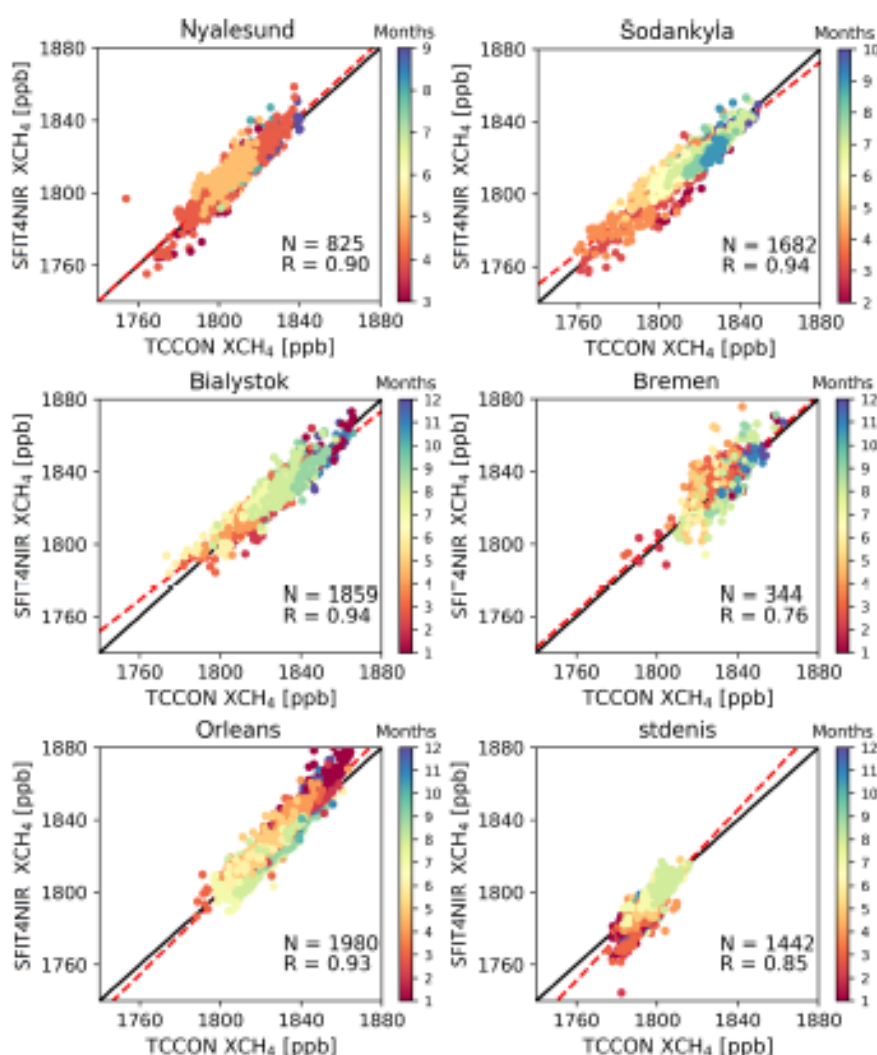


Figure 2: Scatter plot between SFIT4NIR and TCCON XCH₄ hourly retrievals at the six TCCON sites. The colours in the plots represents the measurement months. The black line is the one-to-one line and the dashed red line is the linear fit. N and R are the statistical parameters representing the number of measurements and the correlation coefficient.

Figure 2 shows the scatter plots of the XCH₄ retrievals from SFIT4NIR and TCCON at the six sites. The linear regression line is very close to the one-to-one line for all panels. The correlation coefficient is in the range between 0.76 and 0.94. No obvious seasonal variation is seen from Figure 1 and Figure 2.

6 VALIDATION OF THE RETRIEVAL RESULTS AGAINST COLLOCATED INDEPENDENT DATA

The AirCore is an atmospheric sampling system, which uses a long tube to sample air from the surrounding atmosphere and to preserve profiles of the trace gases of interest from the surface up to

the middle stratosphere (Kairon et al., 2010). Regular AirCore measurements have been carried out at Sodankylä since 2013. During the period of 2016 – 2017, seven AirCore profiles which are within 1 h of SFIT4NIR measurements are considered for the comparison with the remote sensing derived CH₄ products.

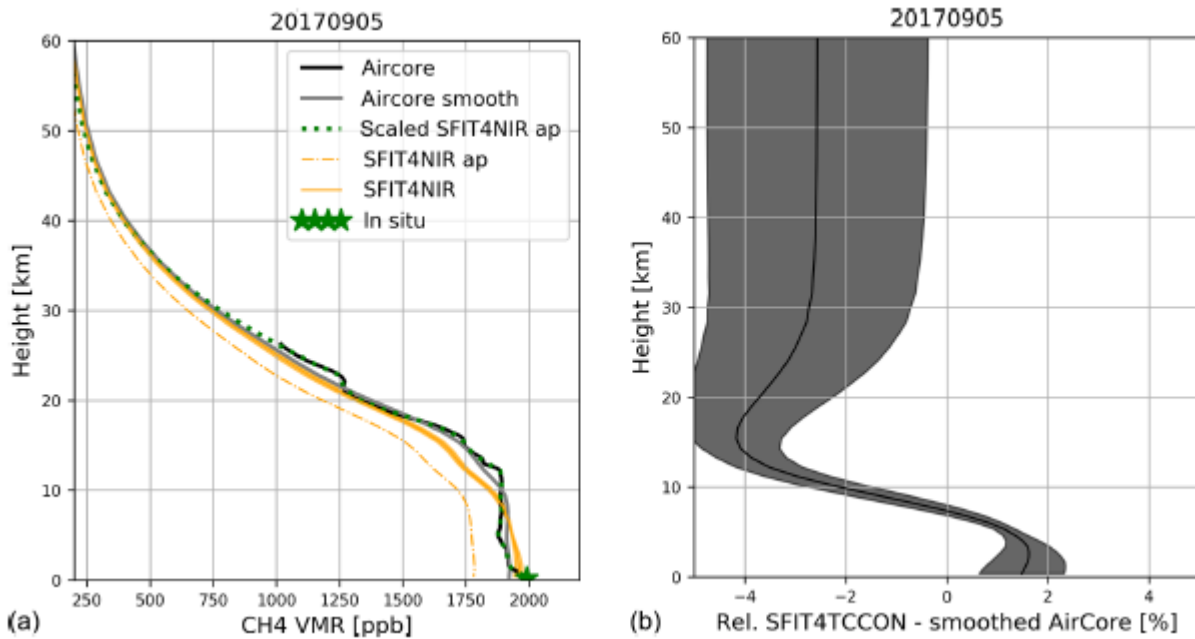


Figure 3: (a) The CH₄ profile from the AirCore measurements (solid black line) on 5th September 2017 along with the SFIT4NIR a priori (dash-dotted orange line) and retrieved (solid orange line) profiles. The grey line is the smoothed AirCore profile. (b) The mean (solid black line) and the standard deviation (shading) of the relative difference between the co-located SFIT4NIR retrieved profiles and the smoothed AirCore measurements.

Figure 3 shows the mean and the standard deviation of the relative differences between the co-located SFIT4NIR retrievals and the smoothed AirCore profiles. The bias is about +1.5 % in the lower and the middle troposphere, between +1 and -4 % in the upper troposphere and lower stratosphere region, and about -2.5 % in the middle and upper stratosphere.

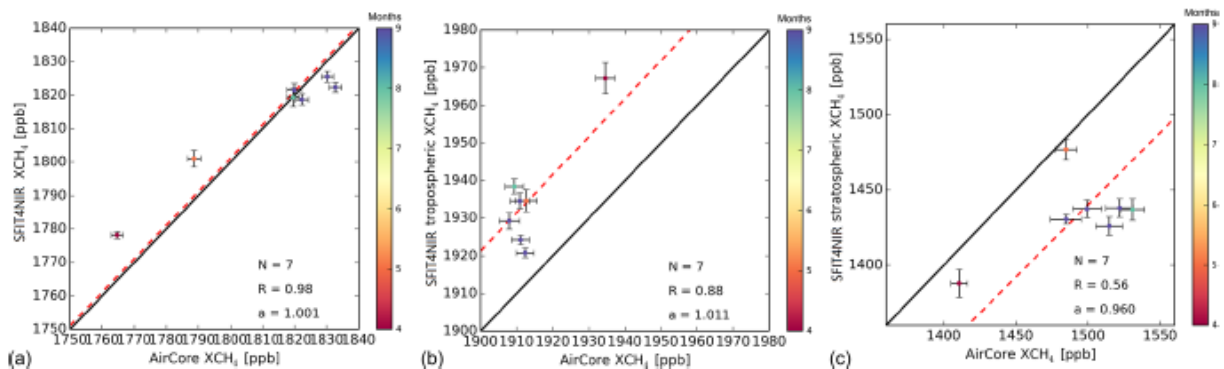


Figure 4: (a) Scatter plot of XCH₄ between the SFIT4NIR and the AirCore measurements for the whole atmosphere, (b) for the tropospheric and (c) for the stratospheric components. N is the number of co-located measurements, R is the correlation coefficient, and a is the slope.

Figure 4 shows the scatter plots of XCH₄ between the co-located SFIT4NIR retrievals and the AirCore measurements for the whole atmosphere, and for the tropospheric and stratospheric components. The error bars are the random uncertainties of the SFIT4NIR retrievals and the AirCore measurements. The random uncertainty of the AirCore profile is assumed to be about 0.1 % between the surface and its maximum measurement altitude and it is about 2 % above the maximum measurement altitude. The slope of the regression line in the whole atmosphere indicates that there is almost no systematic difference between the SFIT4NIR and the AirCore XCH₄, which is consistent with the result in the comparison between SFTIR4NIR and TCCON XCH₄ measurements. The tropospheric XCH₄ from the SFTIR4NIR is about 1.1 +/- 0.4 % larger than the AirCore measurements and the SFIT4NIR stratospheric XCH₄ is about 4.0 +/- 2.0% less than the AirCore measurements. These differences are within the SFIT4NIR retrievals and AirCore measurements are within the systematic uncertainties of the SFIT4NIR partial columns in the troposphere and stratosphere, and it is inferred that the systematic uncertainties of the SFIT4NIR partial column mainly comes from the uncertainty of the spectroscopy.

7 APPLICABLE DOCUMENTS

Statement of Work: Fiducial Reference Measurements for Ground-Based IR Greenhouse Gas Observations (FRM4GHG 2.0)
Prepared by: EOP-GMQ, Reference: ESA-EOPG-EOPGMQ-SOW-21

8 REFERENCE DOCUMENTS

Zhou, M., Langerock, B., Sha, M. K., Kumps, N., Hermans, C., Petri, C., Warneke, T., Chen, H., Metzger, J.-M., Kivi, R., Heikkinen, P., Ramonet, M., and De Mazière, M.: Retrieval of atmospheric CH₄ vertical information from ground-based FTS near-infrared spectra, *Atmos. Meas. Tech.*, 12, 6125–6141, <https://doi.org/10.5194/amt-12-6125-2019>, 2019.

Karion, A., Sweeney, C., Tans, P., and Newberger, T.: AirCore: An innovative atmospheric sampling system, *J. Atmos. Ocean. Tech.*, 27, 1839–1853, <https://doi.org/10.1175/2010JTECHA1448.1>, 2010.