FRM4GHG 2.0
Fiducial Reference Measurements for Greenhouse Gases

Technical Note on HCHO retrieval from low-resolution spectrometers

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1 DOCUMENT CHANGE RECORD

Issue	Date	Item	Comment
V0.0	2023-09-15	-	Initial version
V0.1	2023-10-01		Submitted version

2 ACCESS LIST

This document is a deliverable "D2.4.1: HCHO retrieval from low-resolution spectrometers" – 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 formaldehyde (HCHO) retrieval strategy applied to the low-resolution spectrometer measurements performed within FRM4GHG 2.0. It shows the obtained HCHO time-series and how they perform compared to the HCHO products obtained with the high-resolution spectrometer network.

4 DOCUMENT STRUCTURE

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5 HCHO RETRIEVAL FROM LOW-RESOLUTION SPECTROMETERS

5.1 Measurement campaign at Sodankyla (2019)

A harmonized HCHO retrieval strategy has been developed in the past for the high-resolution (HR) spectrometers of the Network for Detection of Atmospheric Composition Change (NDACC) and used at all the NDACC sites and at some TCCON sites equipped with InSb detector (Vigouroux et al., 2018). In the FRM4GHG first project, we conducted a feasibility study to check if HCHO could also be measured with a decent precision using the low-resolution (LR) spectrometer Vertex70. The tests were performed at Sodankyla (Finland), allowing a comparison with the HCHO derived from the HR spectrometer measuring at the same site. These first retrievals obtained using the Vertex70 measurements were promising, with the best agreement found between the Vertex70 and HR HCHO columns when the same set of four micro-windows were used in both cases (see Fig.1). The variability is well reproduced by the Vertex70, however we observe a large low bias of about 45%. We performed also retrievals using the HR spectra degraded to the resolution of the Vertex70, and we can observe that the bias with the HR data is reduced to about 7%. Therefore, the negative bias of 45% does not seem to come from the resolution itself. However, this site is quite clean and therefore was not so optimum for HCHO. With these encouraging results, we proposed to optimize the settings during FRM4GHG2, with campaign measurements performed at Uccle (Belgium) and Kolkata (India).

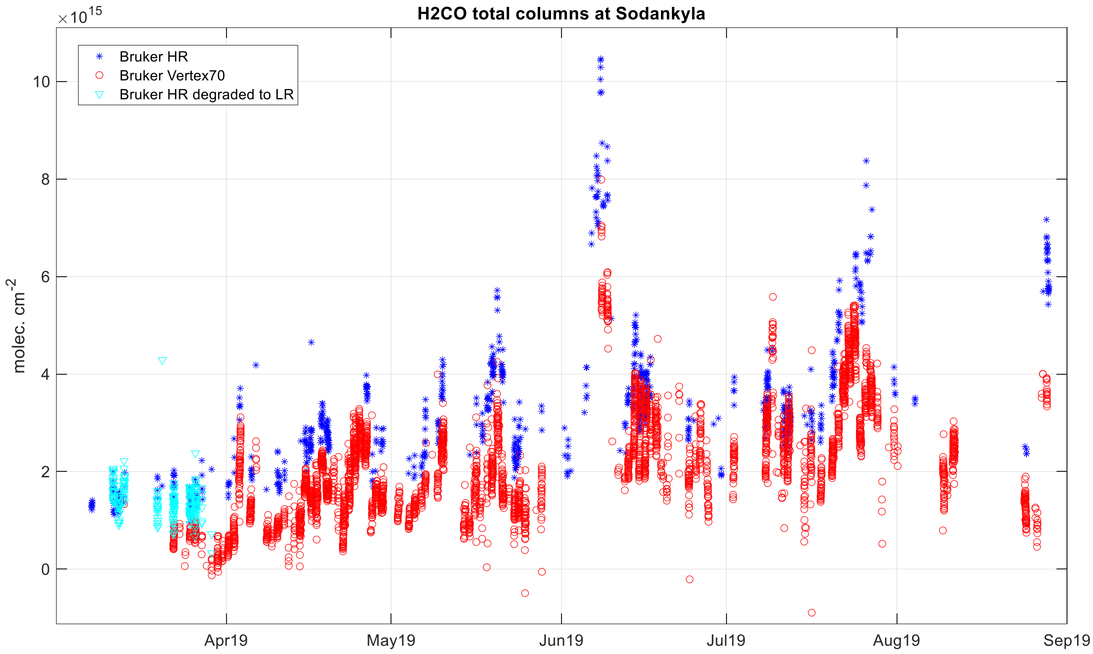

Figure 1: Formaldehyde (HCHO) total columns retrieved at Sodankyla from the HR (blue), HR spectra degraded to the Vertex70 resolution (light blue), and Vertex70 (red) measurements.

5.2 Measurement campaign at Uccle (2022)

A measurement campaign took place in 2022 at Uccle (Belgium) with two low-resolution spectrometers: a Vertex70 and an Invenio. The two LR spectrometers shared the same solar tracker with the active tracking using a camtracker option set to the Vertex70. A part of the incoming light from the solar tracker was fed into the Invenio using a set of two folding mirrors. The HCHO time-series obtained using the harmonized strategy for HR instruments are shown in Fig. 2. As can be seen, we unfortunately have only a few days with both instruments measuring simultaneously. However, we observe a high bias between the two data sets (Invenio is larger by a factor of about 2) and the Invenio HCHO columns show a higher dispersion: 15% of standard deviation for consecutive measurements taken within 30 minutes, while the Vertex70 shows only 5% of this standard deviation. This is most probably linked to the absence of the active tracking of the Invenio using a camtracker.

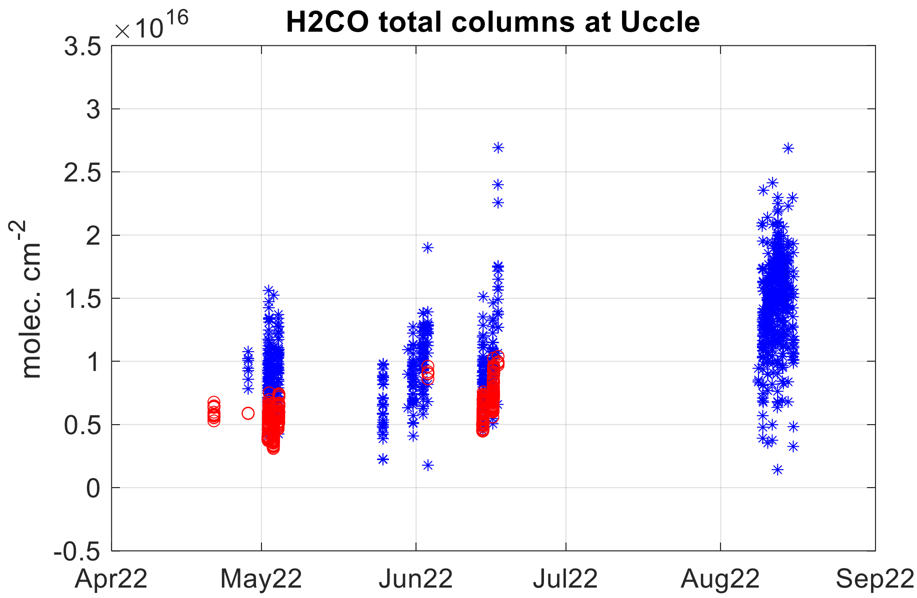

Figure 2: Formaldehyde (HCHO) total columns retrieved at Uccle from the Invenio (blue) and Vertex70 (red) measurements.

We do not have HR measurements at Uccle to compare with these two different LR time-series and conclude about the high bias (factor 2) between them. Therefore, we performed comparisons of these LR data sets with TROPOMI collocated data. We are indeed in charge of the TROPOMI HCHO validation using the HR NDACC network (+ few TCCON sites), as can be seen in Vigouroux et al. (2020) and in the updated ESA Quarterly Validation Reports (https://mpc-vdaf.tropomi.eu/). We provide in Fig. 3 the last update of this validation work (ESA report #19). We see that the TROPOMI bias with FTIR HR HCHO data is dependent on the HCHO levels: clean sites show a TROPOMI positive bias, and polluted sites a negative one.

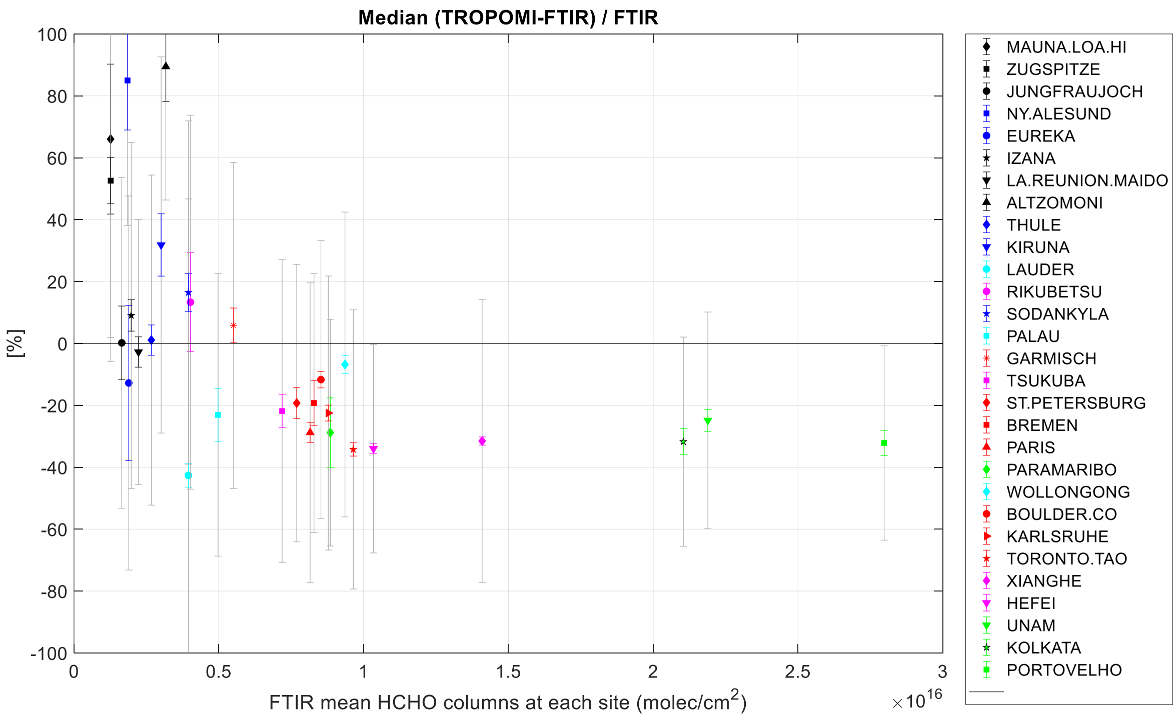

Figure 3: TROPOMI relative bias at each FTIR site, as a function of the HCHO mean levels at the site.

The comparisons of TROPOMI with the Vertex70 at Uccle are shown in Fig. 4. The median TROPOMI bias is -27%, which is roughly what is expected for the mean HCHO measured at this site with the Vertex (6.3E15 molec/cm^2) if we look at Fig. 3 for the other FTIR sites. The TROPOMI bias with the Invenio is more negative (-52%) and is too large compared to the bias obtained with the network. However, the number of coincidences is limited due to the short period of the campaign, especially for the Vertex70. We therefore extended our validation of LR HCHO columns using the results from a new campaign at Kolkata.

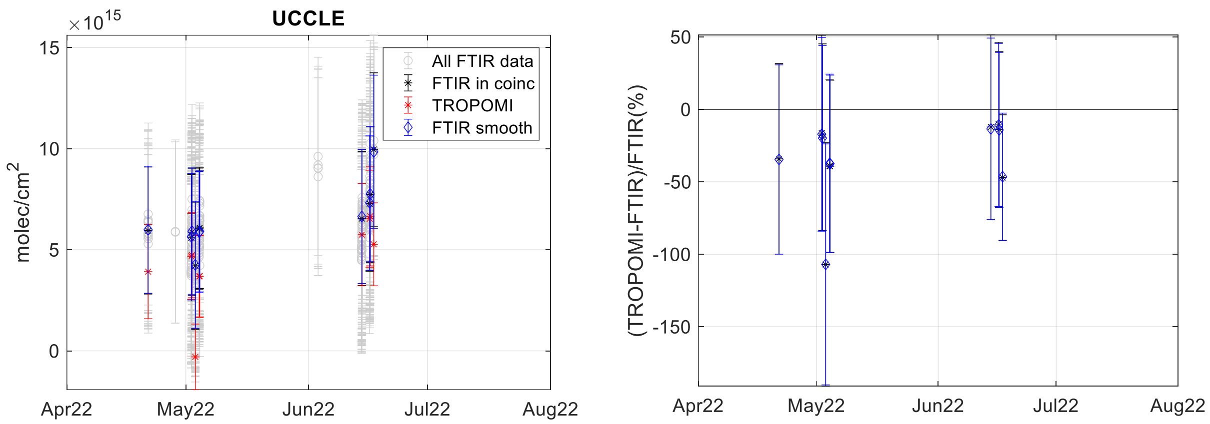

Figure 4: TROPOMI and Vertex70 (FTIR) HCHO total columns at Uccle (left), and TROPOMI and Vertex70 relative difference.

5.3 Measurement campaign at Kolkata (2023)

The time-series of HCHO columns obtained from the Vertex70 at Kolkata (India) and its comparison with TROPOMI are shown in Fig. 5.

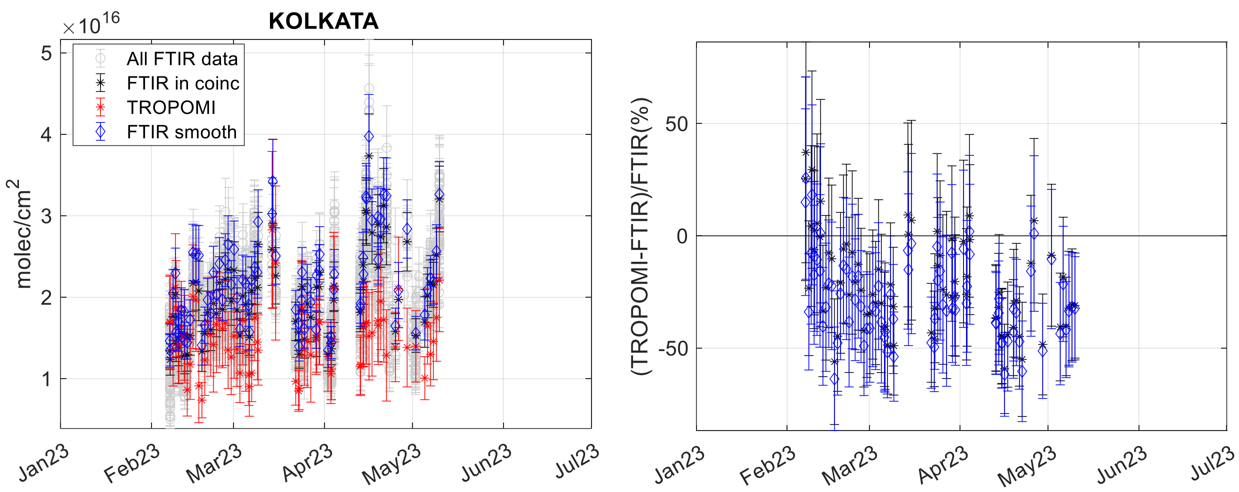

Figure 5: TROPOMI and Vertex70 (FTIR) HCHO total columns at Kolkata (left), and TROPOMI and Vertex70 relative difference.

The negative TROPOMI bias is -32%, which is what is expected in the FTIR network for the HCHO levels at that site (2.1E16 molec/cm^2). The Kolkata site is included now in the operational validation of TROPOMI and is shown in Fig. 3. The higher dispersion (lower precision) of the Vertex70 compared to HR is not so much an issue for the TROPOMI validation because the standard deviation in the differences with TROPOMI is dominated by the random uncertainty of TROPOMI. This is illustrated in Fig. 6, where the scatter plot of TROPMI and the HCHO FTIR data at all sites is shown. The black stars corresponding to Kolkata measurements show a comparable dispersion as for the other polluted sites.

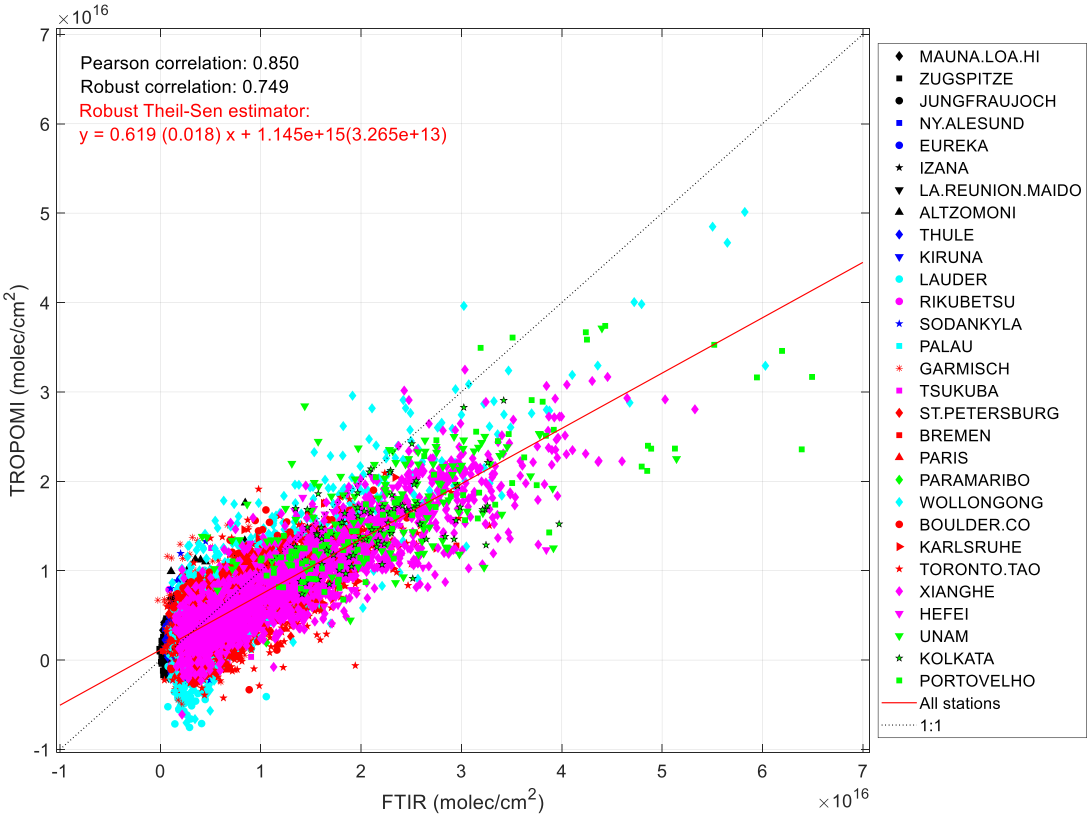

Figure 6: TROPOMI and Vertex70 (FTIR) HCHO total columns scatter plot for the FTIR network, including Kolkata (black stars).

5.4 Conclusions and perspectives

The harmonized HCHO retrieval strategy obtained for the HR FTIR network (Vigouroux et al. 2018) seems to be well-suited for the LR spectrometer (Vertex70). The HCHO columns measured by the Vertex70 have an enough precision to be useful for satellite validation. The biases obtained between TROPOMI and Vertex70 (Uccle, Kolkata) are in agreement with the biases obtained between TROPOMI and the HR FTIR network.

However, the only campaign where a HR and LR spectrometers were monitoring simultaneously (Sodankyla, 2019) shows a bias of about 45% between the retrieved HCHO columns. It would be necessary to make another campaign of LR measurements at another HR measuring site (preferably polluted), such as to understand this bias. If the bias still remains then check if it is due to the instrument LR itself or if the retrieval settings are less suitable for LR. On the other hand, if the bias is no longer present, then possibly the LR instrument set-up at Sodankyla was problematic and the cause of the bias.

6 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

7 REFERENCE DOCUMENTS

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