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Comment on amt-2021-15

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Referee comment on "Slit homogenizer introduced performance gain analysis based on the Sentinel-5/UVNS spectrometer" by Timon Hummel et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-15-RC1, 2021

The paper by Hummel et al on the “Slit homogenizer introduced performance gain analysis based on Sentinel-5/UVNS spectrometer” provides a detailed modelling of the S5 Instrument Spectral Response Function (ISRF) change in shape, wavelength position, and Full Width Half Maximum (FWHM) due to radiometrically in-homogenous scene observations, and even in the presence of a one-dimensional slit-homogenizing optical element in the path (SH).

The remaining distortions and observed shifts are the result of the still not completely homogeneous SH exit radiance field convolved with the detector sampling and the point-spread function of the combined collimator, grating and imager assembly.

The work presents an analytical model for the ISRF difference (error) in case of inhomogeneous with respect to homogenous observations and based on modelling the slit-homogeniser, collimator astigmatism, and the diffraction grating as separate components.

The results will be of high relevance to the future Sentinel-5 mission on-board EUMETSATs EPS-SG platforms, scheduled for launch in 2023, with three platforms measuring atmospheric composition, ozone, pollution and methane up to the 2040s, with hyperspectral measurements ranging from the UV to the short-wave infrared. The product quality is significantly depending on the accurate knowledge of the ISRF for a number of constitutions, in particular for the line-absorbers.

The authors find significant remaining ISRF distortions in particular in the presence of comatic aberrations of the collimator. But given that the SH has been added to this type of instruments for the first time in order to address the significant issue of ISRF distortions observed for previous missions like OMI and TropOMI/S5p, the remaining error budget on the ISRF is still significant, even for only moderately inhomogeneous scenes.

The paper is well written and the findings are significant and suited for publication in AMT. I can therefore recommend its publication providing the authors can address the following more general comments on the overall conclusion of the paper.

On the conclusion on the impact on S5

While the authors make a thorough case for their findings, they seem to refrain from drawing relevant conclusions.

The authors state at the end of section 4 that the "discrepancy in the [ISRF] values is quite significant" and that "we believe that depending on the mission parameters, this effect should be taken into account for the assessment of the ISRF stability and consequently the performance of the SH".

But then in the next sentence they state: "We also conclude, that for the Sentinel-5/UVNS instrument the impact of this effect is of second-order and doesn't degrade the performance of the SH significantly". This important conclusion is however stated without any further motivation or evidence. It also seems contradictory to the previous sentence.

In contrast, the error budget from tables 1 to 3 should be discussed in view of the S5 ISRF requirements error budget, which is intimately linked to the Sentinel-5 product requirements and quality.

In this respect, the nature of the S5-ESA scene should be discussed. Is this scene referring to the type 2 non-uniform scene as defined by the S5 system requirements document (Appendix A)? While this is meant to represent a realistic scene with in-homogeneities representing a more averaged land situation, the still moderate and more randomly distributed signal variations result in quite uniform smeared out signal conditions in along-track direction (averaged over the 7km across-track footprint of S5). So the 75% scene presented her seems to be a more realistic case for typical non-uniform scenes, with sharp surface type transitions (city or desert to vegetation, or land to water). The latter seems never to meet the 2% ISRF shape error budget of the S5 SRD not even for a normally distributed PSF.

I think it is important for the scope of the paper to discuss the findings in the specific context of the S5 mission, since the latter may turn out to remain the only mission with that specific type of one-dimensional slit-homogenizer. In this respect, it would be very interesting to understand, how likely it is going to be that the S5 collimator will show comatic aberrations at a level simulated in this work, and by this leading to significant ISRF errors.

Specific comments:

- I think it would be interesting to also add the expected ISRF error for an optics without SH to the results (tables) presented in Section 4, if that would be possible. Since this would provide the reference with respect to the currently flying push-broom missions.
- The reasoning for making the case for slit-homogenizations, as presented in the context of future missions with even higher spatial resolution like CO2M (Section 3, line 195ff), is a bit confusing. Although I understand, what the authors intend here. The relevance for CO2M is not in terms of CO2 emission inhomogeneities, but again, as for the other missions, in terms of radiances variation. The latter is in the extreme cases governed by clouds and surface and not dominated by atmospheric constituents. Especially the variation of CO2 emission is at times at the sub percent level to the background, therefore not contributing to radiance scene homogeneities. However, underlying variations in surface reflection (e.g. transitions of cities to rural land and lakes) may cause significant ISRF distortions without proper slit-homogenizations, which then, in turn would affect the very high accuracies needed to quantify the elevated CO2 emission plume concentrations. So in this respect NO2 emissions may provide a better example of a single point variations, although even there I would assume that the largest effect on NO2 retrieval accuracies due to ISRF distortions is still originating from surface variations or cloud edges.

Editorial comments:

Section 1, line 34ff: I would add here the linear detector array spectrometer with scanning mirrors like GOME-1/2 and SCIA have a large IFOV in along-track direction and a box-cart like PSF. You could also mention GOME-2 [Munro et al., 2016] in this respect.

Section 2.1, line 106. Shouldn't this reference be to Fig. 3b and not a?

Section 2.2, line 128: missing space.