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Interactive comment on "Parameterizing the instrumental spectral response function and its changes by a Super-Gaussian and its derivatives" *by* Steffen Beirle et al.

Anonymous Referee #1

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This manuscript proposed a novel method, the Super Gaussian, to parameterize the ISRF in DOAS trace gas retrievals. This method shows promising results when fitting the solar irradiances of GOME-2 and OMI. Because the on-orbit ISRF change is relatively small, it is possible to linearize the response of spectrum to ISRF changes when the "true" value is at the vicinity of the *a priori*. This study also demonstrates the effectiveness of this linearization using GOME-2 irradiance/radiance data. Overall, I think this manuscript is a valuable contribution to the community and recommend publication in AMT.

TROPOMI was briefly discussed in this manuscript. The vast data volume of this near future mission makes the ISRF fitting linearization especially appealing. Although no

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Discussion paper

actual spectra were shown, the Super Gaussian was fitted to the slit function stimulus (SFS) data with good agreement. However, the SWIR channel of TROPOMI was not mentioned at all. I suggest add discussion on the SWIR channel for completeness and concerns brought up in the following two paragraphs.

In section 2.2.4, the pseudo absorber (PA) was derived based on the assumption that trace gas absorptions are small (low optical depth). However, the NIR and SWIR bands of TROPOMI are characterized by high optical depths of O_2, H_2O and CH_4 and even saturation under higher air mass. The solar Fraunhofer lines are also much weaker than the atmospheric absorption. Including derivations under optically thick conditions will certainly benefit this work and make it more applicable for TROPOMI.

In addition, the spectral resolution of SWIR band is considerably higher than the other bands (0.25 nm), which marginally resolves individual lines, and it is possible to see the "floor" between lines (e.g., Fig. 1 in http://www.atmos-meas-tech.net/9/5423/2016/amt-9-5423-2016.pdf). This implies that the tails of ISRF may be important in determining the fitting residual. Although Super Gaussian did well in capturing the sharpened/broadened top of ISRF, it would be interesting to discuss about the tails.

Minor comments:

Overall: "residual", instead of "residue", should be used to describe the data and model difference.

Page 4, line 13: The reference (Nadarajah, 2005) should appear at line 11, after "is given by".

Page 5, lines 10-12: I suggest write out the equation more explicitly for clarity and mathematical rigor. Something like

$$\mathrm{P}(\mathrm{p},\lambda) = P(p*,\lambda) + \Delta p \left.\frac{\partial P(p,\lambda)}{\partial p}\right|_{p*} + \mathcal{O}(2).$$

And then state that to simplify, define

$$\partial_p P = \left.\frac{\partial P(p,\lambda)}{\partial p}\right|_{p*}$$

Page 5, lines 13-14: There are actually analytical expressions for the partial derivatives of Super Gaussian with respect to w and k. As these are crucial parts of the following RCS and PA construction, I suggest provide these formulas.

Page 6, line 15: I suspect that $\Delta p \partial_p \tilde{\sigma}$ should be $\Delta p \partial_p S$.

Page 6, line 19: First, is it necessary to define optical depth as negative? Second, even ignoring the I_0 effect, this equation no longer holds beyond the optically thin limit, for example in the O_2 A band. See previous comment.

Page 9, line 3: OMI has UV1 and UV2 bands. The UV1 resolution is about 0.6 nm.

Figure 7: How could the linearized RCS fit have progressively lower RMS than the non-linear Super Gaussian fit?

Page 13, line 23: Without both $\hat{\sigma}_w$ and $\hat{\sigma}_k$?

Page 17, line 29: Same as Page 6, line 15.

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