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Atmospheric Measurement Techniques Discussions

Interactive comment on "A neural network radiative transfer model approach applied to TROPOMI's aerosol height algorithm" *by* S. Nanda et al.

Anonymous Referee #1

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TROPOMI aerosol layer height retrievals use the Disamar radiative transfer model, which performs line-by-line calculations and requires several minutes to retrieve aerosol layer height for a single sounding. This limits the yield of the aerosol layer height processor. The authors propose using artificial neural networks in place of Disamar. They train three neural networks, one for the reflectance and one each for the derivative of the reflectance with respect to aerosol layer height and aerosol optical thickness. The neural network models produced reflectance and Jacobian biases in the 1-3% range. Retrievals were performed for both synthetic and real data. For synthetic data, the neural network retrievals of aerosol height had a median difference of about 2 hPa compared to Disamar retrievals. For a real test case (forest fires in South-

ern California), retrieved aerosol height using the neural network was, on average, less than 50 meters, different from the Disamar value. The neural network retrievals were three orders of magnitude faster than line-by-line retrievals.

General Comments:

This work is novel and interesting. The proposed algorithm produces results that have comparable accuracy to line-by-line models while achieving three orders of magnitude speed-up in computational efficiency. This makes it possible to increase the throughput of TROPOMI aerosol retrievals and possibly enable operational retrievals for all pixels in each TROPOMI orbit. The computational speed-up also opens up the possibility of including more physics in the forward model.

The usage of three neural network models is an interesting idea. It takes advantage of the fact that correlations between input parameters and different forward model outputs are different.

The paper should be published, but only after the comments (see below) are dealt with.

Specific Comments:

Line 14, page 1: "eligible for retrieving aerosol layer height". Is this because of clouds? If this is the case, say so.

Lines 26-28, page 1: The previous sentence suggests that the method utilized line-by-line calculations to generate training data set. Do the authors mean that line-by-line calculations are not used in the "operational" retrieval that utilizes neural networks? The authors also need to say more to distinguish their method from that used by Chimot et al. and Loyola et al.

Line 33, page 1 – Line 1, page 2: It is not clear what the difference is from the existing neural network approaches. Is it that Optimal Estimation is used? "using artificial neural networks to improve the computational speed of RT calculations" is very vague and general; isn't that common to all neural network approaches?

Line 8, page 2: Add the following references:

Timofeyev et al., 1995; Sanghavi et al., 2012; Geddes & Bösch, 2015; Colosimo et al., 2016; Davis et al., 2017; Xu, et al., 2017; Zeng et al., 2018

Colosimo, S. F., V. Natraj, S. P. Sander, and J. Stutz (2016), A sensitivity study on the retrieval of aerosol vertical profiles using the oxygen A-band, Atmos. Meas. Tech., 9(4), 1889–1905, doi:10.5194/amt-9-1889-2016.

Davis, A. B., O. V. Kalashnikova, and D. J. Diner (2017), Aerosol layer height over water from O2 A-band: mono-angle hyperspectral and/or bispectral multi-angle observations, Preprint, doi:10.20944/preprints201710.0055.v1.

Geddes, A., and H. Bösch (2015), Tropospheric aerosol profile information from high-resolution oxygen A-band measurements from space, Atmos. Meas. Tech., 8(2), 859–874, doi:10.5194/amt-8-859-2015.

Sanghavi, S., J. V. Martonchik, J. Landgraf, and U. Platt (2012), Retrieval of aerosol optical depth and vertical distribution using O2 A- and B-band SCIAMACHY observations over Kanpur: A case study, Atmos. Meas. Tech., 5(5), 1099–1119, doi:10.5194/amt-5-1099-2012

Timofeyev, Y. M., A. V. Vasilyev, and V. V. Rozanov (1995), Information content of the spectral measurements of the 0.76 μm O2 outgoing radiation with respect to the vertical aerosol optical properties, Adv. Space Res., 16(10), 91–94, doi:10.1016/0273-1177(95)00385-R.

Xu, X., Wang, J., Wang, Y., Zeng, J., Torres, O., Yang, Y., et al. (2017). Passive remote sensing of altitude and optical depth of dust plumes using the oxygen A and B bands: First results from EPIC/DSCOVR at Lagrange-1 point, Geophys. Res. Lett., 44, 7544–7554, doi:10.1002/2017GL073939.

Zeng, Z.-C., V. Natraj, F. Xu, T. J. Pongetti, R.-L. Shia, E. A. Kort, et al. (2018), Constraining aerosol vertical profile in the boundary layer using hyperspectral measure-

ments of oxygen absorption, Geophys. Res. Lett., 45, doi:10.1029/2018GL079286.

Line 24-26, page 4: “The polarized . . . 760 nm”.

1. First order scattering also has a polarization effect. Presumably, the authors mean that they ONLY compute the first order polarization. If so, please state that.

2. What is "small"? < 5%? < 1%? This statement is potentially untrue. If true, values for how small is small must be given, with proof. In the continuum and in weak lines, the second order effects might be large.

Lines 27-28, page 4: There is a contradiction here. If the exclusion is not advised, the effect cannot be small. The authors should simply state that they ignored this for computational reasons. Besides, the whole point of using neural networks is to speed up calculations. Why not use them for speeding up Raman calculations too, or at least use lookup tables for Raman effects?

Lines 29-30, page 4: “From preliminary . . . significantly”.

Quantify this statement, and ideally provide a figure to illustrate the effects.

Lines 30-31, page 4: Although it is true that retrievals are typically performed under "cloud free" conditions, optically thin cirrus clouds need to be accounted for since they are almost always present.

Lines 1-8, page 5: What are the effects of these approximations on the retrieved results? It seems that many of these simplifications are not needed because of the use of neural networks. Also, if only single scattering is used, calculation of ANY phase function is trivial and not time consuming. Considering the fact that the authors aim to produce an operational retrieval algorithm, these simplifications seem unwarranted and restrictive.

Table 2, page 8: What does "varied" mean for the aerosol layer thickness? Is the aerosol layer thickness part of the feature vector? If not, how is it handled?

Line 8, page 8: “a choice of 500,000 Disamar generated spectra”

How are these spectra generated? It is not clear how the choice is made.

Lines 20-22, page 9:

Need more quantitative error information, like for the derivative with respect to tau. Also, what does continuum (3d) mean?

Lines 23-24, page 9: “these parts . . . cross sections”

Why do low oxygen absorption cross sections lead to low aerosol information content?

Technical Comments:

Line 19, page 1: correlative -> correlated

Line 20, page 1: Hasekamp and Butz (2008) -> (Hasekamp and Butz, 2008)

Line 19, page 4: in -> on

Line 25, page 5: an -> a

Line 17, page 7: differentiation which -> differentiation, which

Line 2, page 8: selected TROPOMI -> selected to represent TROPOMI

Line 6, page 8: an -> and

Line 7, page 8: isn’t a -> is no

Line 14, page 8: legible -> physical

Line 12, page 9: were trained -> was trained

Line 18, page 9: to -> of

Line 20, page 9: remove “more than”

Line 23, page 9: at -> in

Line 24, page 9: with respect -> compared

Line 16, page 10: less than -> by less than; remove “approximately”

Line 23, page 10: less than -> less by

Line 29, page 10: were -> was

Table 3 caption, page 11: an -> and

Line 13, page 11: agreements, they primarily departed in the -> agreement, they primarily differed for the

Line 16, page 11: departure, different -> bias, differing

Line 17, page 11: departure -> bias

Table 4 caption, page 11: disamar -> Disamar

Figure 1 caption, page 14: available -> shown

Figure 2 caption, page 15: A schematic -> Schematic

Figure 4, page 17: need x axis label for (a), x and y axis labels for (b), correct x and y axis labels for (c), y axis label for (d), correct y axis label for (d)

Figure 5 caption, page 18: A histogram -> Histogram; plotting -> plotted

Figure 6 caption, page 19: A histogram -> Histogram

Figure 7 caption, page 20: A MODIS-> MODIS; remove “the” before “ocean”; remove “either”; cloud mask, or by a land-sea mask -> cloud mask or land-sea mask

Figure 8 caption, page 21: represents the difference -> Difference

Figure 9 caption, page 21: Figre (a) directly compares retrieved aerosol layer heights from the two methods. Figure (b) provides a histogram of the difference between these retrieved heights from Disamar and NN. The difference is defined as zaer(Disamar) -

zaer(NN). Figure (c) compares these differences with TROPOMI's operational absorbing aerosol index product (x axis). -> (a) Retrieved aerosol layer heights from the two methods; (b) Histogram of the difference between retrieved heights from Disamar and NN. The difference is defined as zaer(Disamar) - zaer(NN); (c) Differences compared to TROPOMI's operational absorbing aerosol index product (x axis).

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