We would like to thank Dr. Stegmann for the detailed comments and suggestions. We have replied to all comments and revised the manuscript. Please see the replies below. The original comments are in black italic font, and the replies to the comments are in blue normal font.

Journal: Geophysical Model Development

Year: 2022

Title: Introduction of the DISAMAR radiative transfer model: Determining Instrument Specifications and Analysing Methods for Atmospheric Retrieval (version 4.1.5)

Comments:

In the manuscript, the authors describe the so-called DISAMAR one-dimensional radiative transfer model.

The model is described by the authors as a polarized all-sky radiative transfer model, i.e. it is suitable for purely absorbing clear-sky atmospheres and atmospheres with scattering clouds.

The application focus of said model are satellite radiance retrievals, in particular for the TROPOMI instrument on board the european Sentinel-5p satellite.

Nevertheless, the authors list a suite of different available solvers and a range of additional model features that are not required for retrievals, such as irradiance computations.

It is emphasized by the authors that the primary advantage of their model is the seamless combination of all necessary features for satellite remote sensing in their model.

Comments on the Introduction:

- line 44: The assumption that the atmospheric input profile of the radiative transfer model is hydrostatic is of some importance. How does this approximation impact the DISAMAR retrieval results?

The hydrostatic assumption is only used when determining the altitude grid. The altitude grid may be slightly different if the input pressure, temperature profile are not hydrostatic. For the actual calculation of the number of molecules we use the pressure and temperature profile and the trace gas mixing ratio profile specified in the input configuration file.
In the revised manuscript we removed this sentence in the introduction and added the explanation of the conversion from pressure grid to altitude grid in Sect. 3.2.2 after the description of the pressure grid. The conversion from pressure grid to altitude grid is now described in Appendix C.

- line 47: Is a Lambertian reflectance the only surface reflectance type available? Does this limit the accuracy of the model over ocean surfaces where the Cox-Munk model is typically applied?

Yes, DISAMAR version 1.4.5 has only Lambertian surface reflectance available. Indeed, it means a limitation of DISAMAR to apply it over ocean surface or vegetation with strong BRDF. We may implement the Cox-Munk model if it is required by users.

- It would be advantageous to provide a list of other relevant radiative transfer models with similar purpose and complexity in comparison to DISAMAR.

Examples include the CRTM [1-3] and RTTOV [4].

Thank you for the suggestion. We included the references and revised the text in the introduction close to line 54. Text added:

Due to the time consuming line-by-line calculations, DISAMAR is not suitable for fast computations or application in numerical weather prediction (NWP) models. We would recommend RTTOV (Saunders et al., 2018) and CRTM (Lu et al., 2021, Karpowicz et al., 2022, Stegmann et al., 2022) as fast radiative transfer models for NWP applications. Actually DISAMAR has been used to benchmark RTTOV simulations in the UV/visible wavelength range.

Comments on Section 2:

- line 65: Please provide a short explanation on the purpose of the wavelength grid.

To improve the explanation in the previous version of the manuscript, the text has been revised close to line 67 in the revised manuscript.

Old version:

'This makes the integration more accurate than an equidistant grid with similar number of grid points. '

New version:

'This makes the integration over altitude, wavelength, or polar angle more accurate than the integration at an equidistant grid with a similar number of grid points.'

- lines 71 and 72: Please provide references for the application of the derivatives for optimal estimation and the application to the error covariance matrix, gain vectors, and averaging kernel.

We added Rodgers (2000) as reference, after line 75.

- line 73: The formal theory of evaluating the derivatives of a computer program is quite well developed [5].

Thank you for the reference. We have included it in the paper close to line 77.

In DISAMAR all derivatives are calculated in a semi-analytical manner although algorithmic differentiation can be used to evaluate the derivatives (Griewank and Walther, 2008).

Could you please elaborate whether your semi-analytical approach computes the forward-mode (tangent-linear) or reverse-mode (adjoint) derivative of your code output/ the radiance spectrum?

The semi-analytical approach computes the forward-mode derivatives of the radiance spectrum.

We have added this sentence in the paper. (add the sentence close to line 91)

Comments on Section 3:

- line 92: Are there any restrictions when using a tabulated ISRF? It is stated in Section 2 that the radiance wavelength grid is given on a set of Gaussian quadrature points. Are the tabulated values automatically interpolated onto the grid?

There is no restriction when using a tabulated ISRF. In fact we have used tabulated GOME-2 and TROPOMI ISRFs. The tabulated ISRF values are interpolated onto the wavelength grid.

We have revised the text close to line 97.

"During the convolution, the wavelength grid of the ISRF is interpolated to a high resolution wavelength grid (see Sect. 3.2.1)."

- line 106: How does the line-by-line absorption model impact the calculation time of DISAMAR?

The DISAMAR forward model is relatively slow.

Does DISAMAR include faster absorption models when calculation time is a constraint?

There is no faster absorption model in DISAMAR. DISAMAR has been used to train a neural network for aerosol layer height retrieval to improve the speed of the retrieval algorithm.

- line 140: Please explain how the pressure levels are translated into altitude levels. Are you using the hypsometric equation?

We use the Hydrostatic equation to convert pressure level to altitude levels. The complete formulas are added in Appendix C (Conversion from pressure grid to altitude grid) in the revised manuscript. We refer to the formulas in Appendix C close to line 155.

- line 185: There are different adding-doubling initialization schemes [6] and this is known as the infinitesimal generator initialization.

Thank you for the reference (*Wiscombe, 1976)*, of which we are aware. The choice of initialization schemes has been discussed by De Haan et al. (1987) in the description of the polarized Doubling-Adding algorithm. In the Doubling-Adding code two orders of scattering are used to initialize the doubling scheme. De Haan et al. (1987) did not use the so-called diamond method, because it was doubtful if the diamond method was better than the two-orders-of-scattering method. Also the diamond method was not tested for polarized light in Wiscombe (1976).

DISAMAR uses single scattering instead of two orders of scattering to initialize the doubling scheme, because of speed.

- I have not checked equations (19) to (26) for correctness.

We think they are correct, because we have checked the semi-analytical derivatives using the numerical perturbation method.

- line 335: If the Layer-Based Orders of Scattering method is fast for optically thin clouds, wouldn't it provide some advantages to initialize the Adding-Doubling solver with a LABOS solution, since it spends a lot of computation time doubling a small initial layer?

Thank you for the suggestion. We only use single scattering to initialize the adding-doubling solver, because it is faster than two orders of scattering that is used in the Doubling Adding method (de Haan et al., 1987; Stammes et al., 1989).

- Is the LABOS method related to the Successive Order of Scattering approximation? If so, what are the characteristic differences?

The principle is the same between LABOS and Successive Order of Scattering approximation. It was explained in manuscript in lines 331-335.

"Here one order of scattering represents scattering by an atmospheric layer. This differs from the classical method of successive orders of scattering where the scattering element is a volume-element of the atmosphere instead of a layer (Lenoble et al., 2007; Min and Duan, 2004). In the adding method one deals with matrix-matrix multiplications, whereas in LABOS one deals with matrix-vector multiplications. However, in LABOS the calculations have to be repeated for the different orders of scattering. "

References:

[1] C. H. Lu, Q. Liu, S. Wei, B. T. Johnson, C. Dang et al. (2021): The Aerosol Module in the Community Radiative Transfer Model (v2.2 and v2.3): accounting for aerosol transmittance effects on the radiance observation operator. Geosci. Model Dev., 15, 1317–1329.

[2] B. M. Karpowicz, P. G. Stegmann, B. T. Johnson, H. W. Christopherson et al. (2022): pyCRTM: At python interface for the community radiative transfer model. J. Quant. Spec. Rad. Trans. 288.

[3] P. G. Stegmann, B. T. Johnson, I. Moradi, B. Karpowicz, W. McCarty (2022): A deep learning approach to fast radiative transfer. J. Quant. Spec. Rad. Trans. 280.

[4] R. Saunders, J. Hocking, E. Turner, P. Rayer, D. Rundle, P. Brunel, et al. (2018): An update on the RTTOV fast radiative transfer model (currently at version 12). Geosci. Model Dev., 11, 2717–2737

[5] A. Griewank, A. Walther: Evaluating Derivatives, Principles and Techniques of Algorithmic Differentiation. Society for Industrial and Applied Mathematics; 2nd edition (November 6, 2008)

[6] Wiscombe, W. J., 1976. On initialization, error and flux conservation in the doubling method. J. Quant. Spectrosc. Radiat. Transfer 16, 637-658.