Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2019-356-AC2, 2020

Geoscientific Model Development Discussions

Interactive comment on "PAMTRA 1.0: A Passive and Active Microwave radiative TRAnsfer tool for simulating radiometer and radar measurements of the cloudy atmosphere" *by* Mario Mech et al.

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Received and published: 26 June 2020

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Anonymous reviewer 1

We thank the reviewer very much for her/his very useful comments and suggestions on the manuscript, and thereby the possibility to further improve it. In the following we will address the more detailed minor comments and list the changes we made in the manuscript. The technical corrections will be addressed afterwards. Text that has been revised or that has been added to the manuscript is written in italic letters.

Minor comments

1) I think more information are needed about the limitations of the model. I have noticed for examples the following points. What are the limitations due to the "column independent approximation" (P5 L12). What is the maximum range for the elevation angle? Would it be possible to quantify "strong scattering" (P5, L14) and "strong precipitation . . . large radar footprint" (P6, L26).

To address these points, subsection 2.1 has been revised. It now reads: *For the passive part, the one dimensional, polarized, and monochromatic vector RT equation for an azimuthally symmetric scattering media in a plane-parallel atmosphere applying the independent column approximation is solved using the RT4 code of Evans and Stephens (1995). 3D effects can not be modeled but horizontal inhomogeneity can be taken into account by the independent column approximation by realistically describing atmospheric variations along the path (Meunier et al. 2013). The assumption of a plane-parallel geometry is sufficient for most RT problems in the microwave spectral range with the exception of strongly scattering precipitation situations where the radiation does not originate within the instruments field of view (Battaglia and Tanelli,* *2011).*

The simulation of the passive radiative transfer at high frequencies for very strong scattering might require that the number of angles to describe the scattering matrix has to be increased. This number is fixed to 16 at the moment in PAMTRA, which is sufficient for most of the applications the model has been applied for so far. For future versions we will give the user the opportunity to adapt this variable, as it is already implemented in the solver backend RT4.

In respect to multiple scattering, we have to stress out again, that PAMTRA is not able to simulate multiple scattering. Whether multiple scattering occurs and whether it needs to be considered for specific situation depends on many different parameters like: considered frequency, beam width, observing geometry, particles, and particle size distribution present, etc.. This is described in more detail by the studies referred to in the manuscript (i.e., Matrosov and Battaglia (2009); Battaglia and Tanelli (2011)).

The radar simulator section has therefore been extended.

Currently, the simulation of multiple-scattering effects is not implemented in PAMTRA. Multiple-scattering generally increases with the amount of scatterers, with larger measurement volume, and with increasing radar frequency (Battaglia et al., 2010). For satellite radars, such as CloudSat, multiple scattering effects have to be accounted for in case of heavy precipitation events (Matrosov and Battaglia, 2009). Due to the smaller measurement volume of common ground-based cloud radars, multiple scattering can be usually be neglected for this application.

2) Sect. 2.1: What are the atmospheric input ? (temperature, pressure, humidity, trace gas profiles ?). I think that the radiative transfer equation solved by RT4

should be written. It is the core of PAMTRA for passive observations and it will help to better understand the model simplifications.

The module to solve the radiative transfer RT4 requires as input profiles of temperature and gaseous absorption at the specified frequency, and if present, profiles of the scattering properties of the hydrometeors for the same frequency. These are calculated (apart from the temperature) by appropriate methods as described in the manuscript. In addition, the type of the surface reflection and emissivity of the surface is needed by RT4. As minimum atmospheric input, PAMTRA needs profiles of temperature and pressure on a height grid. All other values can be either zero or are automatically set to reasonable default values. For these cases a warning is raised.

In our opinion the inclusion of the RT equation does not help the reader or potential user of the model. Including the equation would result in a lengthy explanation of the single terms and contributions which is beyond the scope of this manuscript. To help the interested reader to gain further understanding into the equations behind, we point to the formulation in a more detailed publication by Evans and Stephens (1993, Eq. 2.22) and in Evans and Stephens (1995, Eq.1). Furthermore, we extended the text by describing in more detailed what the assumptions and simplifications of the model are. The whole subsection 2.1 has been completely reformulated-

To make these points more clear in the manuscript, the subsection on the passive radiative transfer has been adapted in addition to what has been mentioned in the answer to comment 1.

The RT equation is described by the formulation in Eq. 2.22 by Evans and Stephens (1993) or Eq. 1 in Evans and Stephens (1995). It is solved numerically by the doubling and adding method which is formulated and described in detail by several textbooks *(i.e., Liou, 2002, p. 290). RT4 requires as input the vertical profiles of temperature and gaseous absorption coefficients and a lower and upper boundary condition. If hydrometeors are present, the profiles of the single scattering properties are required as well. Since a plane-parallel geometry with isotropic thermal emission is considered and all the particles are assumed to be azimuthally random oriented and mirror-symmetric, the radiation fluxes are also isotropic in azimuth. This symmetry in azimuth implies that the third and fourth Stokes components are zero and the RT problem simplifies to the first two components. RT4 does not make use of the Rayleigh-Jeans approximation which relates the Planck function linearly to the brightness temperature is widely used on the microwave regions.*

3) Sect. 2.2: The pulse width is not discussed for radar simulations. Is-it a model parameter? I think it will have an effect on the spectral width and on the measurement vertical resolution? Is the latter computed? (I did not see any description of it in the manuscript)

PAMTRA only provides a relatively simple 1D radar simulator, so no beam geometry etc. is considered. Of course, the pulse width affects the vertical resolution. In the model this resolution is defined by the user and his choice of the vertical grid in the atmospheric input. This treatment is reasonable because pulse width and vertical resolution are not strictly tied when pulse compression is used.

In the manuscript we have added at the end of the first paragraph in radar simulator description: *The vertical resolution of the simulated full radar Doppler spectrum is determined by the vertical resolution of the input profiles.*

Technical corrections:

P7L21: ".. dynamical and instrument effects such as attenuation . . .". Atmospheric attenuation is not "dynamics" nor "instrument". The sentence should be rephrased.

The sentence has been re-phrased to:

In reality, the idealized $\eta_v(v)$ spectrum is affected by attenuation, kinematic broadening, vertical air motion, and radar noise (Doviak and Zrnic, 1993).

P8, L15: To my knowledge, N2 does not have resonant lines in the microwave domain but it contributes to the continuum absorption. This contribution is included in a dry continuum term in Liebe together with a contribution from O2. This should be corrected.

The reviewer is right. This was wrong in the manuscript. We re-phrased the sentence to state it in a correct manner.

Absorption by atmospheric gases in the microwave range can be separated into contributions by resonant line absorption (i.e., H2O, O2, and O3) and the water vapor and dry continuum.

P13, Fig.2: What are the spatial coverage and resolution of the maps?

We changed the figures so that meridians and parallels are included. Given that the ECMWF IFS cycle 41r2 has a resolution of 0.1° this shows that the resolution is 6 to 7 km. The spatial coverage is approx. 950 km in North-South direction and 800 and 950 km in Northern and Southern part, respectively.

We added to the manuscript: *...cycle 41r2 with a 0.1° grid (6 to 7 km) ...*

P18,L10: correct [3] in “up to [3]km”

Corrected

P18L22: correct "model" in "Rosenkranz 98 m odel"

Corrected

Fig.6 caption: correct “denotes” in “The white line denote . . .”

Corrected