The following comments are for the authors' reference to improve the manuscript.

L73-74: “Even though conventional forward operators calculate the attenuated or corrected reflectivity, they do not trace the radar beam and its extinction through the cloud under study. A key aspect of SynRad is a ray tracing module that calculates the extinction of the transmitted (and reflected) radar signal due to interactions within the ash cloud.” Some of the forward radar operators you mentioned do not calculate the extinction of radar signal, but they output the specific attenuation coefficient of each radar gate. With this output, users can easily obtain the path attenuation (or extinction) by accumulating their effects.

Agreed. This point has been added to manuscript. The distinction is made between SynRad and other operators by highlighting that SynRad calculates extinction along the beam **online** while it can be calculated **offline** from the specific attenuation coefficients in the other operators.

We would also like to bring the authors' attention to a new forward radar operator recently published in GMD (Xie et al., GMD, 17, 5657–5688, 2024).

This reference has now been added (L71).

L128: Why is that the atmospheric refraction is totally neglected? A simple static 4/3RE effective radius model would significantly improve the accuracy of beam trajectory calculations. Such incorporation does not introduce complexity but improves the accuracy

It is indeed due to the introduction of complexity that we decided to neglect the effect of atmospheric refraction in the first version of SynRad. The way we staged the development of SynRad was to have a simple ray tracing module initially. With respect to the trajectory calculation, this involved treating the beam as single line rays (modelling the beam-axis) from the radar location to the model grid cell centre while neglecting atmospheric refraction and hence beam bending. The second stage (which we are currently working on) will be to include the effects of refraction as well as attenuation due to the atmosphere and thereafter beam broadening.

Currently, the way we trace rays are by considering the cell centre where the radar is located as the start point of a beam. The different rays are then obtained by considering each of the cell centres of the ATHAM output grid as the end points. By considering the ray as a straight line, we then divide this into equal ray sub-segments and then interpolate values from the (non-equidistant) grid cell centres to each of the sub-segment centres. The attenuation is then calculated using the Beer-Lambert law **along the beam direction**. If we were to implement the 4/3ERM now, we would obtain a new set of latitudes and longitudes for corresponding radar elevations and azimuths by applying the method, and values would need to be then interpolated from the model grid to this new lat-lon grid. We would then divide these rays into sub segments to calculate along the beam attenuation which probably wouldn’t be the attenuation experienced by the actual beam. In this way, the 4/3 ERM would be an inconvenient implementation currently and more importantly wouldn’t fit in with our current along-the-beam attenuation calculation module.

Instead, an along-the-beam model for ray propagation with beam bending like the TORE (TOtal Reflection) method (Zeng et al 2014) is planned to be implemented as the next step.

This would be better suited for our attenuation calculation as well. As the main purpose of the tool is to evaluate which radar frequency or combination of frequencies would be ideal for capturing the propagation of the entirety of an ash cloud, the attenuation due to ash along the ray path was a higher priority at this stage of the development of SynRad.

Zeng Y, Blahak U, Neuper M, Jerger D. 2014. Radar beam tracing methods based on atmospheric refractive index. J. Atmos. Ocean. Technol. 31:2650–2670

L130: Volcanic ash and hydrometeors are currently assumed as spheres. The non-sphericity effect has not been discussed at all. If dual-polarization capability is introduced, non-sphericity and orientation preference must be considered. Otherwise, the polarimetric radar variables will be zero.

This was answered in a previous comment from a reviewer and is repeated below:

Yes, the assumptions regarding sphericity would need to be re-evaluated in the case of introducing dual polarization. We would need to do a sensitivity study to investigate the importance of the different individual parameters for the polarimetric variables. Hopefully this might reveal dependencies that could be used to simplify relations or validate assumptions. We would need to look at the variability in density, shape and settling properties, especially of ice.

We have now included the following line in the manuscript as well (L 135).

This would also include considering non-sphericity and orientation preferences for the ash and hydrometeors.

L320: For the single gamma size distribution method. SynRad operator must perform fit for each radar gate, is it right? I wonder whether the volume densities of different size bins match gamma distribution so well for each radar gate. I suggest authors should validate this point.

We perform a fit to a gamma distribution using the initial concentrations to obtain a value for the three different parameters: $\nu_{ash}, N_{0,ash}, \lambda_{ash}$. Then for each radar gate/grid cell, we prescribe λ_{ash} and ν_{ash} to be fixed and calculate $N_{0,ash}$ from the prognostic ash concentration variables in each grid cell (using equation 22) and then calculate the ash number concentrations (assuming a gamma PSD). This does introduce an overestimation due to the tail of the gamma PSD. This discussion is shown in figure 4 and the corresponding text (L325-333).

4.2 While this paper presents the development and methodology of SynRad, validation against real observations has not been conducted or discussed. To strengthen the credibility of SynRad, at least one case study comparing simulation results with actual observations should be included. If there is difficulty, the missing comparison should be explained.

This manuscript is intended as an introduction of this model with the focus on concept, methodology and details. The magnitudes of the radar measurables and other results for the eruption presented in this manuscript are realistic and we feel that this gives sufficient confidence on the validity of this code. Additionally, since the Raikoke eruption was never observed with ground-based radars and never modelled before, this is the first time this eruption has been studied in such detail. We will be submitting a comparison with actual observations as a follow-on publication in due course where detailed comparisons with radar observations and with different radar frequencies will be presented for a known and well-studied/observed eruption. Including this here would be beyond the scope of this paper.

Report #1

Two technical corrections: in line 44, please add the citation for the Tongariro eruption paper (Crouch, J. F.; Pardo, N. & Miller, C. A.; Dual polarisation C-band weather radar imagery of the 6 August 2012 Te Maari Eruption, Mount Tongariro, New Zealand; J Volcanol Geotherm Res, Elsevier BV, 2014, 286, 415-436, doi: 10.1016/j.jvolgeores.2014.05.003)

Added (L45)

and in line 368 the last word should be 'are'.

Corrected