

We are grateful to the Reviewer for her/his detailed comments. All the comments are addressed below and highlighted in the revised paper.

Major comments:

It appears that the authors are not fully aware of other existing global models that have been used to simulate atmospheric Be-7. For example, at the beginning of the abstract (or similarly on P2, L50-51), it is stated that “Previously, modelling of the beryllium atmospheric transport was performed using simplified box-models or air back-tracing codes. While the ability of full atmospheric dynamics models to model beryllium transport was demonstrated earlier, no such ready-to-use model is currently available.” There has been a long history of simulating Be-7 using global models, e.g., Brost, R.A., J. Feichter, and M. Helmann, Three-dimensional simulation of ⁷Be in a global climate model, *JGR*, 96, 22,423-22,445, 1991 (<https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/91JD02283>). The authors mentioned a few modeling papers (sometimes not accurately; see below for example) but there are many more.

We thank the reviewer for these suggestions. We have extended the discussion and added more references: *lines 66-90*.

P2, L47-48: “A full 3D modelling of the production and transport of beryllium isotopes in the Earth’s atmosphere was performed earlier using the ECHAM5-HAM atmospheric model (Heikkilä et al., 2008a,b).” -- Heikkilä et al. (2008a) used a two-box model and did not use a 3-D model. Heikkilä et al. (2008b) used the production rates from Masarik and Beer (1999) and did not do a full 3-D modeling of the production of beryllium isotopes. P14, L273: Brattich et al. (2020) is not relevant to sudden stratospheric warming (SSW) events at all.

The sentence has been changed (*see line 81*).

We apologize for the typo with the wrong reference. The correct reference is Brattich et al., 2021, where the effect of SSW is discussed (*line 348*).

P3, L53-55: “while several models of different complexity and accuracy have been developed in the recent past to model transport and deposition of beryllium isotopes, most of them have been abandoned and not supported further and cannot be directly applied in new analysis works.” -- Which “several models”? Which ones were abandoned and not supported further? There are other existing global models (see point 1 above). Are

you saying that a global model of transport and deposition coupled with a Be-7 production model is needed? Was the CRAC:Be model coupled with SOCOL previously? More generally, it would help to list (in a table or schematic with references) the model components that already existed and those that this paper would like to develop or improve. The evaluation or performance of the original SOCOL model in simulating Be-10 also needs a bit of elaboration. While this paper focuses on Be-7, the same processes (except decay) control Be-7 and Be-10 in the troposphere.

We have changed this paragraph: *lines 103-123*.

Section 2.3: “beryllium is considered as a gas tracer” – This is confusing. As authors also stated, after production, Be-7 attaches to ambient aerosols. That’s why Be-7 has long been used as an aerosol tracer. Therefore it should be treated as an aerosol in the model. It should not be treated as “gas form” as also stated in the last sentence of this paragraph.

Gas and aerosol forms of beryllium isotopes have similar transport for non-volcanic conditions due to the small size of particles. We have revised part 4.3: *see lines 246-256*.

Section 2.3: How is convective transport represented in the model? How about turbulent mixing in the boundary layer? How realistic is the stratosphere-to-troposphere transport of Be-7 (or other tracers)?

We have added to the text: *lines 260-264*.

Different processes such as stratospheric mixing, stratosphere–troposphere exchange, tropospheric transport and deposition, are realistically modelled by the CCM SOCOL (e.g., Feinberg et al., 2019).

Evaluation of the STT of Be-7 is one of this manuscript aims. Judging from the results it seems realistic (*see fig.5, 9*).

Section 2.4: “tropospheric washout of gases is calculated by...” - Be-7 is an aerosol tracer.

section 2.4: “Deposition of beryllium isotopes is parameterized as a function of surface properties, solubility and reactivity of the considered species (Kerkweg et al., 2006). This scheme considers actual meteorological conditions, different surface types, and trace gas properties like solubility and reactivity. Since beryllium is transported like a gas in

the CCM SOCOL, the dry deposition scheme is like other gases in the model (e.g., Revell et al., 2018). Moist convection contributes significantly to transport of energy, momentum, water, and trace gases in global modelling.” - Again, Be-7 should be treated as aerosol (not gas) in both dry deposition and wet deposition parameterizations.

P8, L159-160: “Scavenging coefficients for gas-phase species are calculated based on Henry’s law equilibrium constants.” - If Be-7 is treated like a gas, it means Henry's law has been applied to Be-7 (actually an aerosol tracer) in the model, which does not make sense. Since scavenging is the largest Be-7 sink in the troposphere, more detailed description of the scavenging scheme is required here beyond simply citing the reference of Tost et al. (2010), for example, how large-scale (stratiform) vs. convective scavenging and in-cloud vs below-cloud scavenging are separately treated.

As we said before, gas and aerosol forms of beryllium isotopes have similar transport for non-volcanic conditions due to the small size of particles (e.g., Lal & Peters, 1967; Delaygue et al., 2015). However, for the dry- and wet-deposition schemes, we use Henry’s constants and reactivity of the sulphate aerosol (*lines 279-280*).

We add more explanation to the text: *lines 275-278*.

A detailed description of the interactive wet-deposition scheme has been presented and discussed by Tost et al. (2006, 2007, 2010).

The parameterization is based on the model generated available liquid water in clouds (cloud water content) and below cloud (precipitating water) and uptake/release from droplets, which depends on the concentration and solubility of the considered species.

P12, L218: a) if SPE-produced Be-7 is hardly detectable in the background, please explain why it is still necessary or interesting to study the transport of SPE-produced beryllium; b) The reason for differences in seasonal transport is not given. Is it because of the seasonal minimum of stratosphere-to-troposphere transport in fall? L221: what’s the faster removal mechanism in winter?

a) Because of the much softer energy spectrum, SEPs produce ^7Be at shallower atmospheric depths and higher latitudes than GCR do. The SPE-related ^7Be signal is indeed unobservable for the recent decades, however, a factor of ~ 100 stronger SPEs are known to appear in the past (e.g., 775 AD, 994 AD) which have a clear signature in ^{10}Be

records in polar ice cores. A proper model of beryllium transport/deposition is needed for an accurate analysis of such events. We have revised the Introduction to make it clearer.

- b) As far as we know this question has not been fully addressed earlier. Moreover, as our modelling shows, the effect of a SEP event on the near-ground beryllium concentrations slightly depends on the season, because of the different patterns of the large-scale dynamics. During Summer-Autumn, the low tropopause and decreased static stability of the troposphere permit a more direct coupling with the upper atmosphere opening a path for the input of the polar stratospheric beryllium to lower levels. In contrast, in Winter-Spring, the tropopause rises, and intense radiative cooling stratifies the lower troposphere closing this route.

What's Be-7 residence time against deposition in this model, as compared to those in other models (e.g., Brost et al. 1991; Koch et al., 1996, <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/96JD01176>)? Simulated surface Be-7 concentrations are sensitive to wet/dry deposition.

The decrease of ^7Be isotope concentration is nearly perfectly exponential with $t_{7\text{Be}} = 72 \pm 3$ days, which includes both decay and removal. Thus, the ^7Be isotope is fully removed from the atmosphere, mostly due to decay, within several months.

More comments:

11) The text uses the word “beryllium isotopes” a lot but the paper mainly deals with Be-7 (and occasionally Be-10). Can you just say Be-7 (or Be-10)?

Done

12) Abstract: “An interactive deposition scheme was applied including both wet and dry depositions” - I don't think you applied a single deposition scheme that include both wet and dry deposition. L10: you actually presented results for 2002 (Fig.8), so it's not a spinup year. By “lateral deposition”, do you mean surface deposition? “including a perfect reproduction of the annual cycle” – I don't think it's perfect (see Fig.8). Please avoid using the word “perfect” in the text.

Thanks for the corrections. See *Line 18 and line 401*.

13) “Comparison with the real data of ^7Be concentration in the near-ground air fully validates the model and its high accuracy.” – Comparison

with surface Be-7 observations from a limited number of locations does not fully validate the model. Again, I suggest the authors look up current literatures especially those on global modeling of Be-7, where information on global data sets of surface Be-7 concentrations, deposition fluxes, and/or high-altitude observations are available.

Eventually, we aim at the modelling of radionuclides deposition in Greenland and Antarctic ice sheets. Therefore we are focused mostly on high-latitude regions and annual time scales. The Introduction has been revised to explain this.

14) P2, L40-41 (also see P6, L126): “these models cannot be applied for the short-living ^7Be isotope, whose half-life time is shorter than the typical atmospheric transport time” – Typical transport timescale in the troposphere is only ~hours to days.

We apologize for the typo. This sentence is revised.

15) P5, Figure 1: It is interesting to compare the production rates of Be-7 produced by GCR and SPE (even though they differ by magnitudes). However, these two panels use different units, making it hard to compare. Could you represent the production rates by SPE in “rates” instead of total production?

We have revised the plot and its description. Since the duration of a strong SPE is several hours, up to a day, we compare it with the daily production of beryllium by GCR. The use of production rate for an SPE makes little sense since it can vary by many orders of magnitude within short times.

16) Figure 9: specify in caption which two stations and their locations (latitude/longitude). Y-Title should be "Deposition ($\text{Bq}/\text{m}^2/\text{TIME}$)" since each quarter may contain different hours.

We added to plot $\text{Bq}/\text{m}^2/3\text{months}$ and created new *Table 1* (List of stations whose data were used for the present study.).

17) P14, L277-279: Why and how?

Gas and aerosol forms of beryllium isotopes have similar transport for non-volcanic conditions due to the small size of particles (e.g., Lal & Peters, 1967; Delaygue et al., 2015). After a strong volcanic eruption, the size distribution can be shifted to larger values. So, if in this time period we have an essential difference between the model and the measurements

we may suggest that it happens due to the model using ^7Be as a gas tracer. Using the AERONET we see no aerosols anomalies for that time.

18) P15, L321-322: “The modelled beryllium distribution is also in general agreement with earlier computations based on a similar approach.” -- Which earlier work?

We have added this sentence. *Line 406.*