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Comment on acp-2022-383

Seyed Omid Nabavi et al.

Author comment on "Spatio-temporal variation of radionuclide dispersion from nuclear power plant accidents using FLEXPART ensemble modeling" by Seyed Omid Nabavi et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-383-AC1, 2022

Dear Dr. Brioude and referee #1,

We would like to thank referee #1 for the careful review of our manuscript and the insightful comments. By responding to these comments and implementing respective changes directly into the text, we are confident that the manuscript will be significantly improved.

In the following, we list our response to all comments and highlight the changes implemented in the revised manuscript.

- I do not see any novelty neither in methods nor in results or discussion. I do not mean to degrade authors' great work, but I do not see this manuscript of relevance for publication in ACP.
- **The novelty of this paper lies in the application of the FLEXPART Langrangian model for radionuclide dispersion simulations to inter-compare the variability and quantify uncertainties using a broad ensemble of (re-)analyses, as well as forecasted meteorological input datasets.**
- **There are several works previously published in ACP using FLEXPART with a single meteorological dataset (Zhu et al., ACP 2020)(Sauvage et al., ACP 2017). In this study, we have designed a four-member ensemble that allows for the first time to inter-compare simulations produced by FLEXPART and FLEXPART coupled with the Weather Research and Forecasting model (FLEXPART-WRF) and capture the effect of downscaling on FLEXPART dispersion modelling. We evaluate the relative performance of forecast runs against three re-analysis runs (Table 1), both complementing and extending the approach (taking a reanalysis run as a reference run) by Leadbetter et al. (ACP, 2022).**
- **Our paper also expands upon previous studies published in ACP that focus on a fictitious case to quantify the impact risks. For instance, the study by Salminen-Paatero et al. (ACP, 2020) uses dispersion modeling results with the SILAM model to study due to hypothetical reactor accidents in Finland. Our methodology of continuous release allows us to uniquely estimate the probability of occurrence over each hour-of-day and month-of-the-year.**
- **In summary, our paper is not devoted to the model performance analysis in a**

specific real-world accident, but rather we aim to highlight and quantify the strong variability due to diurnal and seasonal meteorological variations stemming from the choice of re-analysis used for dispersion modelling. We capture the range of uncertainty through the iterative multi-day simulations, starting each day of the year, and the analysis of the resulting age spectrum of pollutants. Thus, our results will benefit the future development of early warning systems for both aerosol and gaseous pollutants and toxic substances that are subject to transport processes.

- **Finally, we illustrate for the first time how the use of different meteorological inputs causes differences due to planetary boundary layer height (PBLH) representation in Langrangian models. We also demonstrate how the low spatial resolution of meteorological inputs causes the omission of the sea and land breeze circulation effects on the PBLH and, as a result, the variability in radioactive tracer concentrations.**
- The authors write "Using an ensemble of meteorological inputs, this study primarily aims to investigate the seasonal and diurnal changes in the transport and surface concentration and deposition magnitude of radionuclides in the event of a potentially possible nuclear accident". I am very sensitive with radiological issues and I think they should be handled very carefully, because then can have a negative pshycholgical impact to the public. What is "potentially possible nuclear accident" supposed to mean? There is no explanation that could justify this. Why did the authors study this particular hypothetical release? Why did they not study, for example, a hypothetical release from an older reactor? For instance, several Balkan reactors (which I do not want to name, but one can easily google) from the Soviet-era have shown functionality problems during the last 10 years and could affect a more significant area (central Europe) where a larger population lives and reproduces.
- **While few new nuclear power plants are licensed in the Western world, and most Soviet-era stations are nearing the end-of-life decommissioning**, **several nuclear facilities are planned or proposed, and in the last few years are under construction or becoming operational in the Middle East/North Africa (MENA) region. The Barakah station is the latest NPP to become operational in a region with unique climatological conditions that were previously void of such developments and where the risk from radionuclide dispersion received little coverage in the literature, as opposed to Europe and the US.**
- **In that regard, we also address what levels of radionuclide concentrations and deposition may affect the populated areas of Qatar in the event of a nuclear accident, a matter of significant concern due to the geopolitical situation in the region. The particular location has been selected because Barakah is the first nuclear power plant in the region, and additional ones have been planned.**
- **It is beyond the scope of this study to designate the causes or estimate the probability of a nuclear accident. Information about the risks of nuclear accidents is not shared by the industry and governments but needs to be taken seriously. We simulate a fictitious accident at the severity level of the Fukushima disaster but note that our results are indicative and can be scaled for any magnitude of emission from a small leak or release of radionuclides from an INES7 accident.**
- **The following explanation will be added to the revised manuscript: We simulate a fictitious accident at the severity level of the Fukushima disaster to compare the simulations with those produced for this accident.**
- Usually, for the assessment of transport of radionuclides and the impact of meteorological fields in transport modelling, more sophisticated state-of-the-art databases are used. I would encourage the authors to use the ETEX (Nodop, K., Connolly, R., and Girardi, F.: The field campaigns of the European Tracer Experiment (ETEX): Overview and results, Atmos. Environ., 32, 4095–4108, 1998) and ETEX-2 (https://doi.org/10.1016/j.atmosenv.2008.07.027) experiments and repeat their assessment rather that a hypothetical release that may never happen or cause the

aforementioned problems (see previous comment).

- **We would like to thank you for your comment and the proposed references. Indeed, there are several studies assessing Langrangian dispersion models using controlled release experiments. As stated above, our aim is different and not directly comparable with ETEX. Repeating ETEX would not provide any information about the transport of nuclear tracers or other toxic substances in the Middle East. The current study is a contribution to the establishment of an early warning system in Qatar, being the first country in the region that is planning such a system. We feel that it is important for scientists in our field (and ACP) to reach out to this region, and not only focus on Europe.**
- **The analyses presented in this study are based on the median of numerous simulations (1460 simulation days or 35040 simulation hours at each point) to capture diurnal and seasonal variations throughout the year and uniquely capture the uncertainty from the input meteorology. Hence, we believe that our findings related to the seasonal and diurnal changes in the transport efficiency and the concentration and deposition of radionuclides and their spatial distribution are both timely for the region of interest and relevant for scientists and decision-makers for designing early warning systems and the preparedness for potential nuclear accidents.**
- - An alternative solution for publication might be to focus on the model developments they have done, correct the manuscript and submit to GMD. This would require a detailed validation of the results, which lacks here.
- **Other than section 3.3 which concerns developments and the performance analysis of FLEXPART/FLEXPART-WRF, the major part of this study is devoted to the topics outlined above. The main focus is on the seasonal and diurnal changes in the transport and deposition of radionuclides to the region of interest (and in Qatar, subsection 3.1). We further analyze the temporal and spatial distribution of radioactive materials, the distribution of radionuclides in relation to the population density, the synoptic patterns leading to the transport of dense radioactive plumes, and the sensitivity to atmospheric turbulence. We feel that these topics are suitable and aimed toward the subject matter and audience of ACP rather than GMD.**
- In line 175, the authors are talking about a nuclear accident, but then release particles for only 24h? During the 2 worst nuclear accidents (Chernobyl and Fukushima), emissions lasted much longer, which makesa the study completely un realistic.
- **Our study is not replicating previous accidents, rather we simulate emissions over 24-hours for each day over a full year period. This, along with aggregating statistically the median output, amounts to a continuous emission over a full year and allows us to gather meaningful representation of the seasonal and diurnal median changes in the distribution of radioactive materials basis (in total we emit over 365 days and simulate 1460 days). The diurnal variation in the radionuclide dispersion is also considered by stratifying the simulated concentrations (Figure 2) and deposition (Figure 3) corresponding to the hourly age of the lagrangian particles. We designed this analysis (along with those shown in Figures 4 and 5) to determine what time of the day and year is associated with the higher probability of the transport of dense radionuclide plumes from a hypothetical release in the Barakah nuclear plant to the study area. To the best of our knowledge, this is the first time that such a method is implemented, and we believe that it can be used to provide important information and guide the formulation of preparedness plans.**
- **We note that in terms of emission magnitude, to translate our findings for a case in which an event with different intensities would occur, one can simply linearly scale the reported concentration/deposition risk. A realistic accident could be simulated, when it occurs, by applying our methodology in an early warning context and scaling the source strength based on available**

information about the accident. Similarly, by essentially simulating continuous release over a full calendar year, we can probabilistically capture the eventualities irrespective of the length of the release. Our methodology follows other studies that did not set out to determine the source term but to investigate the spatio-temporal distribution of pollutants (due to the effect of atmospheric/modeling conditions). For instance, Leadbetter et al. (2022) used a hypothetical release of 1 PBq Cs137 equivalent over 6 h at an elevation of 50 m.

- Same paragraph later mentions that "... particles are initially distributed at height levels between 100 and 300 m above the ground level over the emission point". Since we have a nuclear accident and given our previous experience with nuclear accidents, one may expect emissions at higher altitudes (see paper from Stohl's group) depending of course if there was a thermal explosion (such as in Chernobyl) or a hydrogen explosion (such as in Fukushima). Hence, one understands that a sensitivity study is also required to examine what the impact of injection altitude would be on transport. I would expect large differences on transport between emissions that occurred at 300 m and at 3 km (such as those that were calculated for the 2 major nuclear accidents in 1986 and 2011).
- **In model sensitivity studies of the emission altitude (Evangeliou et al., ACP 2013; Table 1) we note that in the case of Chernobyl, other than the first few days when the graphite core was on fire (a deprecated design), the bulk of the emissions occurred at lower altitudes. Our study is indeed based on the paper by Stohl et al. (Figs. 4, 5) for the more recent and relevant example of Fukushima. We note that in that paper the inversion over three emission layers in altitude shows that for all practical purposes, the emissions were predominantly (almost 100% for Cs137) within the 0–50 m, and 50-300 m layers.**
- **Besides, carrying out sensitivity studies (in addition to what we have done for the turbulence schemes) causes a significant increase in the calculation load.**
- - Line 281: "Using conversion factors from Spiegelberg-Planer (2013), 131Iconc_seas_max (in a unit of Bq m-3) are converted to the maximum hourly doses from inhalation (in a unit of μSv)". This is not a proper dose-rate calculation. I would encourage the authors to calculate inhalation doses using the models presented in the WHO report for Fukushima that is the most recently updated: https://www.who.int/publications/i/item/9789241503662
- **Thank you for your suggestion. We agree with your comment and will soon recalculate the inhalation dose based on the suggested reference and add it to the revised manuscript**.

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