Review 3: ***The authors discuss measurements observed in a network of sensors deployed in the North Eastern region of Spain, around the city of Balboa. In particular, they discuss how a weather event in the region, called Galerna (GL), typically characterized by strong winds, and precipitation affects readings of the Gamma Dose Rate (GDR) in their sensors. They divide their dataset into precipitation (P) and non precipitation (NP) data, as well as GL and non GL data and investigate differences between these segments. Supplementary they also investigate radon readings and look for correlations with the GDR. Finally they present two examples of GL events, one with precipitation and one without and show how the discussed effect, are realized in individual instances.***

Overall, the authors present their work in a clear and simple-to-understand language, the paper is well structured, and they use proper English. Their discussion of existing literature and their overall results agrees with the understanding that I have of the topic. The presented work is interesting and is relevant to the readers of sensors. I do agree with the content of the paper and the overall conclusion, but I don't believe that most of the data, as they are currently presented, actually support their claims. In order to study the impact of events that typically last a few hours and can occur at any time throughout the day, it is necessary to decouple the daily fluctuations from the event's impact. This has not been done here. I believe most observed effects, as presented, are statistical in nature and just happen to go the right way (and sometimes they also go the wrong way)! I believe that it is possible to correct the analysis (and figures) and find quantitative indicative results. I will provide suggestions on how to go about this for each of the relevant sections in the general comments section below. If for some reason the suggestions do not work out, or if the authors already tried this, they should talk about it in a "Discussions" section. To conclude, I strongly encourage the authors to address the flaws of the manuscript and continue pursuing a publication in this journal. I believe their work is interesting and having more results in this field of research is very valuable.

Many thanks for these words. We really appreciate these comments and for the following suggestions. We have implemented all of them in the new version of this article.

One final comment: There are a lot of small errors (wrong Figure and Section numbers, for example) in the script. A proper proofreading should have caught those. It is not a reviewer's job to proofread a paper, the authors should have done so themself.

We deeply regret it. We have tried to solve all of them in the new version of this manuscript

General comments:

Section 2.3: I don't think it is entirely clear that you have two alarm levels. One being active whenever there is rain, another (lower one) whenever there is no rain. Try to make this a bit clearer

We have modified the new version of the article to clarify this point. We have included the following information Lines 134-142 "It is essential to identify and understand the increase in GDR values. Using the recorded GDR values, two distinct alert thresholds are defined based on weather conditions: one for dry conditions and another for wet conditions. Due to the washout of the radon daughter, which are located in the soil when there is precipitation, the threshold of this situation has to be higher than the other. The GDR values for both scenarios follow a normal distribution, and given that the data consist of discrete values, we apply Currie's definition [12] to establish critical levels of GDR. The alert threshold for dry weather is activated in the absence of precipitation, while the wet weather threshold becomes active during precipitation events. These thresholds adjust dynamically depending on the presence or absence of rainfall, ensuring that variations in GDR are properly assessed according to prevailing weather conditions."

Also, I think the discussion of the alarm level here is cryptic. Maybe just give some examples and provide the false alarm rate. At k=1 you will have about 15.8% of backgrounds triggering an alarm (or roughly one false alarm every hour), at k=2 you have about 2.3% of backgrounds doing the same (or roughly a false alarm every 7 hours), k=3 about 0.1% of backgrounds (false alarm rate of 1 every 5 days). Please check my math. I personally would just state the false alarm rate for a few examples of k.

Thanks for your comment. We know that in other Networks the Alarm Levels are defined by static level and with K=3, but in some cases, small increases of GRD are not detected. For example, close to our Bilbao station there is an incinerator and in one case iodine plume was detected only with the increase of GDR in dry case. We could change the value of K, but we are comfortable with those levels.

Section 2.4: What is the average length of a GL event? Would be good to mention this. Is it a few minutes, hours, or days? Is the GL event starting randomly or is there a correlation with the day-time pattern? Where is the wind coming from? If it is coming from the Atlantic I would assume it brings in radon poor sea air...

We understand this comment and the suggestion. We have included more information about GL in the new version of this paper Lines 165-169 "[9] characterized the occurrence and development of this event, indicating that it occurs more frequently between May and June, and between noon and the late afternoon. More information about GL can be consulted in [9]."

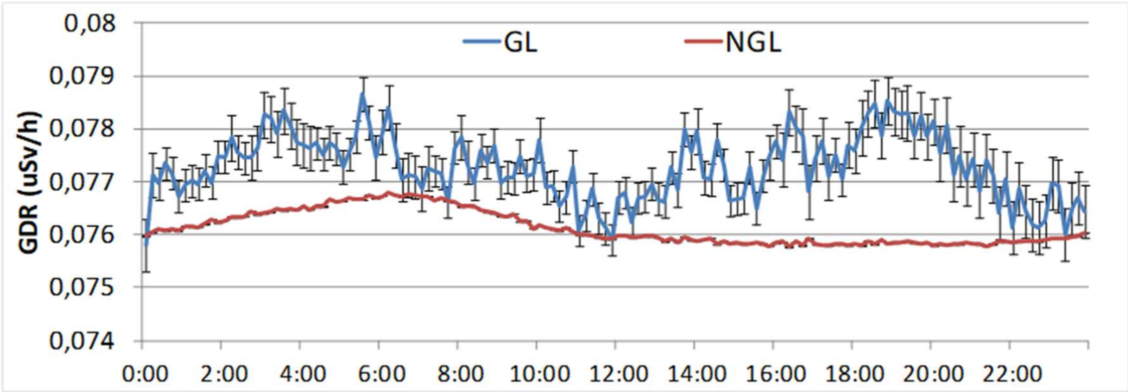
General comment on figures: Neither of these figures fits the current format: Unless the final article is two columns and wider, stack them on top of each other!

We have modified the figure accordingly.

Section 3.3. GDR influencing by radon concentrations: I believe you can't draw any meaningful conclusions here by simply looking at P and NP days. Rain events are typically very episodic and irregular, and not constant at all, particularly not over a full day. Rain events most of the time only last for a few hours at most, or vary a lot in intensity throughout rainy days. I suspect the differences between P and NP days are just statistical fluctuations: The differences between P and NP days are driven by a few rain events taking place at specific times (more events in the morning, vs more events in the afternoon). I would also suspect that the daily evolution of radon concentration changes with the seasons. So, there might have been more rain events during a specific season, where radon fluctuations are higher. All of this might affect the averages substantially and the conclusion P = more radon in the morning and less radon in the afternoon is just coincidental. The fact that the GDR doesn't considerably change in P compared to NP supports my assumption. A better way of analyzing the data would be to actually correct the radon concentrations by their daily fluctuations. For example average 2-4 days (no precipitation) before and after a rainy day and subtract the average concentration from the radon concentration during the rain event (same for GDR). Then you align all rain events with the onset of rain, or look at them one by one. You should see a spike in radon

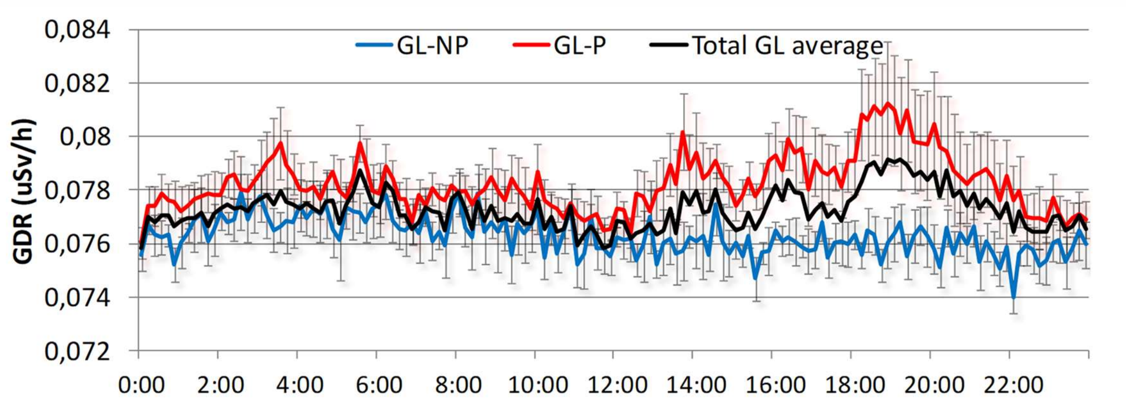
during the rain (and even stronger GDR), that decays back to baseline over a few hours after the rain event. Doing so you don't need to worry about P and NP, you will directly see what the impact of rain is.

Thank you very much for this suggestion. In order to establish the impact and difference between days with and without GL we have included Figure 6 in the new version of this article:



We have included the following information in the new version of this manuscript Lines 253-263 "In this section, 40 days of GL covering the period 2009 to 2018 are used as a reference, having all of them sufficient hourly GDR data available for analysis. Figure 6 shows the overall average daily GDR cycle in Bilbao without GL (NGL) and the GDR cycle under GL events (GL). On average, GDR values under GL are higher throughout the entire day. It is notable that both cycles exhibit high values during the night, followed by a decline to lower values. However, from midday onwards, GDR concentrations rise under GL events, with an increase from 12:00 hours until 20:00 hours, after which they begin to decrease. This increase coincides with the period established in [9] for the development of GL. Therefore, the GDR cycles in Bilbao reveals distinct daily patterns, suggesting a positive influence of GL formation in GDR levels during the afternoon, emphasizing the impact of atmospheric conditions on radiation levels throughout the day."

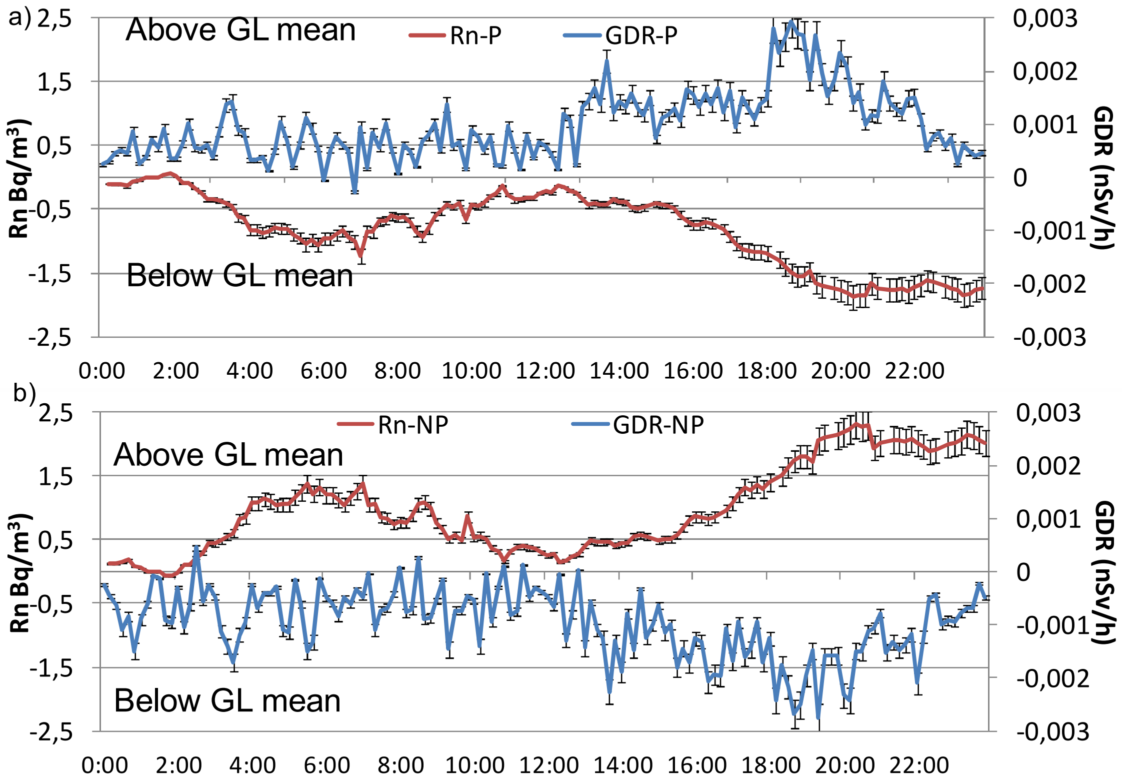
In addition, we have modified Figure 8 to investigate the impact of precipitation under GL events. We have applied the following methodology: Instead of considering days before and after the GL event, we have taken as reference the GDR daily cycle under GL event, and we have calculated the difference between this cycle and the two obtained with precipitation and without precipitation respectively.



We have included the following information in the new version of this article Lines 280-293 “Figure 8 displays the hourly evolution of GDR under GL events, considering pre-cipitation and without precipitation. Both daily cycles are compared with the overall average of GDR under GL events for the period 2009-2018. The figure shows that on GL with precipitation (P), daily GDR concentrations are higher than those on GL days without precipitation (NP). Similar values for P and NP events are registered at night and in the morning. While those obtained for NP days present similar values to the overall average, GDR for P days are slightly higher. Notably, after 12:00 hours, coinciding with the period in which [9] indicates the onset of GL development, the GDR on P days (red line) consistently exceeds both NP days (blue line) and the overall average (black line). This indicates a significant increase in the afternoon in GDR levels during GL events under precipitation, suggesting that precipitation may enhance the washout of radionuclides from the atmosphere, leading to elevated GDR levels. This evolution highlights that precipitation amplifies the effects of GL on GDR concentrations, particularly during critical periods of GL formation”

These figures clearly demonstrated that GL occur around midday or early afternoon, we considered that it was not necessary to establish a common start time for all episodes.

We have also performed the same analysis for radon concentrations, and we have compared GDR and radon differences under GL with precipitation and without precipitation. The following figure has been included in the new version of the paper. This figure helps to understand the relationship between both, GDR and radon, under GL with precipitation and without precipitation



Section 3.3: GDR evolution under GL with precipitation and non precipitation: study cases: First, the section number is wrong here, there already is a Section 3.3.

It has been changed

While the section is well written and I generally agree with what is said, it is a bit surprising to me to say that an increase in radon from GL leads to more false alarms, while obviously a much larger increase of radon in the night does not have the same effect. I suspect there is some other effect, maybe the strong winds during GL affect both radon readings and GDR, but one doesn't directly cause the other. I already mentioned this, but I also don't think the conclusion of radon going down during a GL event is correct looking at Figure 11. There are clearly visible upwards bumps in radon whenever GDR goes up. They just sit on a larger trend of declining radon values, typical during the afternoon hours? I think this section needs to be considerably reworked. While those two examples are interesting, I think a similar analysis as I suggested for the previous Section would be appropriate. Subtract the average radon and GDR levels measured over a few nearby days from the GL event values. Then align all GL events when they start (onset) and you see the "average" GL evolution as a function of time. Then draw conclusions from this.

To understand the relationship between both, GDR and radon, we have included the previous figure, which helps to understand the impact of radon concentrations on GDR. In section 3.4 we provide two examples of GL without precipitation and with precipitation. You are right, and there was a mistake in the way to describe the evolution of radon and GDR in the case of non precipitation. We have included the following information in the new version of this article (Lines 351-357) "During this increase in radon concentrations, GDR values remains in similar values, and only a very small increase is registered, reaching some of the GDR values the alarm level, and therefore, these occurrences should thus be classified as false alarms. However, they cannot be only associated with an increase in radon concentrations. The sudden increase in surface winds during the GL [9] can affect both radon and GDR concentrations, so, it is not possible to establish a direct relationship between them in this specific case."

Conclusion (Line 334): I don't understand this. Where do the authors show that GL and rain events are "accompanied by reductions in radon concentrations"? They show, at least to me, an "increase" in radon concentrations that slowly drops to baseline over the time of a few hours after the onset of the event, which is in line with literature.

Yes, you are right, and we have deleted this information in the new version of this article.

Author contribution, Acknowledgments and conflict of interest section: They have not properly been completed

You are right. It has been included in the new version of the manuscript.

Detailed comments:

Line 13: I would remove "automatic stations of"

It has been removed in the new version of this manuscript

Line 20: The present results point out THAT GDR values are OFTEN above the alarm levels when GL events are ON GOING? The current version of this phrase is not proper english.

We have removed this sentence and we have included the following one Line 21 “The present results indicate that GDR values frequently exceed alarm levels when GL are formed”

Line 24: “The results demonstrate that GL events are accompanied by an increase (GL without precipitation) and a reduction (GL with precipitation) in radon concentrations, and that GL with precipitation are associated with higher increases in GDR”. This is a pretty strong statement that would go against current literature, which says precipitation increases radon concentrations. I don’t believe the paper shows this, even the radon levels in Figure 11 (the only place this is discussed) seem to suggest an increase during GL events (although small and on the flank of a falling radon curve from the daily radon cycle).

We have modified the information provided. Lines 24-27 “The results demonstrate that GL event with precipitation is a meteorological scenario that can be associated with false alarm. The present analysis provides a distinct contrast in radon behavior under the same meteorological event in case of being developed with precipitation or without precipitation.”

Line 64: Dot missing

It has been added in the new version of this manuscript.

Line 118: Set of double brackets, use — for example to go around this.

It has been modified in the new version of this manuscript “observations, such as temperature (◦C) and precipitation (mm)”

Section 2.2: What meteorological data was collected? Temperature, Relative humidity, atmospheric pressure, solar irradiation, wind direction and speed and rain. How was rainfall (precipitation) measured?

It has been modified in the new version of this manuscript “precipitation (mm)”

Line 124: I don't understand that sentence, maybe rephrase this as: "The Bilbao radiological station is a BAI9100 manufactured by Berthold". I don't understand why “trademark” would be important?

You are totally right. This information has been deleted in the new version of this manuscript

Line 125: What does the BAI9100 measure, what sensors are used, how does it calculate GDR? Alpha concentration, beta concentration, radon, iodine, GDR. For alpha, beta and radon ZnS plastic scintillator, for iodine NaI detector, and for GDR Proportional Counter.

We have modified the information about BAI9100 in the new version of the manuscript “The Bilbao radiological station is equipped with a BAI9100, which measures alpha and beta particle concentrations, iodine, radon, and gamma dose rate (GDR). Alpha, beta, and radon are detected using a ZnS plastic scintillator, iodine is measured with a NaI detector, and GDR is monitored with a proportional counter"

Line 125: What is the "between other" doing here? Are you trying to say something along the lines of "it measures many things, but GDR is reported based on a proportional counter, and radon measurements are derived with the ABPD-Compensation and Measurement principle."

We have modified this information in the new version of the manuscript "The Bilbao radiological station is equipped with a BAI9100, which measures alpha and beta particle concentrations, iodine, radon, and gamma dose rate (GDR). Alpha, beta, and radon are detected using a ZnS plastic scintillator, iodine is measured with a NaI detector, and GDR is monitored with a proportional counter."

Line 135: "This level represents the value from which a signal measured by the instrument should be analyzed in detail to determine its origin". This phrase doesn't make any sense to me. I think it can just be removed.

It has been removed in the new version of this manuscript

Line 142: "a the" -> "the"

It has been changed in the new version of this manuscript

Line 146: No need to capitalize "Alarm Levels".

It has been changed in the new version of the article

Line 146 The paragraph talks about low and high confidence levels ("such as" meaning it is an example) but then doesn't specify "the" alarm levels that were used on the system. How exactly is the alarm level set? Also a "confidence level" is the wrong word here, use threshold or simply alarm level. Confidence level describes how certain you are that something is happening or not, so for example if a signal is very high you are more confident it is not background.

We understand your doubts about this information. We have modified this information in the new version of this manuscript "The procedure is the following: Each time that a GDR measurement is recorded, it is checked whether there is a record of precipitation or not. Based on this, the recorded value is compared to the corresponding alarm level. If the GDR value exceeds the alarm level, an automatic notification is triggered. Proportional counters are affected by storms, fog, voltage fluctuations, nearby construction activities, and other factors. For this reason, this procedure must be well-defined, as setting the alarm threshold too high could allow critical alerts to be missed, while setting it too low would trigger continuous alerts, diminishing their significance. Below, you can find the table with the alarm levels defined from 2009 to 2019 for wet and dry conditions. We include this table in article because we think it is relevant.

YEAR	Dry conditions (uSv/h)	Wet conditions(uSv/h)
2009	0,0841	0,0941
2010	0,0839	0,0930
2011	0,0830	0,0920
2012	0,0825	0,0914
2013	0,0828	0,0913
2014	0,0815	0,0900
2015	0,0839	0,0949
2016	0,0838	0,0913
2017	0,0829	0,0927
2018	0,0825	0,0904

Line 153: I don't understand this control. Does it say at least 75% of the duration of a given GL event needs to be covert by radiation data? Were there recent outages or why would an event not be covert? What happened in July that there is no GL event surviving the threshold? How many GL events were there in total before the cut?

Many thanks for this question

- Yes, there is a need to have 75 % of 10-min GDR data to consider a GL event in the present analysis. Therefore, GL events with less than 75 % of the data available, are not considered in the analysis.
- In July there were GL events with percentage of data available less than 75 %, so they were discarded in the present analysis

Line 169: I don't understand this formula for the mean standard deviation? I also never heard of the "mean standard deviation", and I can't really find much online either.

Sorry, there is a mistake. We have modified this information in the new version of this manuscript "We have calculated the standard error of the mean, which is calculated $Sx/N^{1/2}$ This value provides a measure of how precisely the sample mean estimates the true population mean. Unlike the standard deviation, which measures the dispersion of individual values around the mean, the standard error reflects the uncertainty in the estimate of the mean.

Line 173: No url here, add a proper reference at the end of the document

We have removed it in the new version of the document.

Figure 4: So much wasted space between the bars. This should be more of a continuous distribution (histograms), and maybe use overlapping histograms for the second panel (I

would need to see how it looks to decide if it is better), such as done here: https://i.pinimg.com/originals/41/67/03/416703cacdc80a61b25891e59c3efec4.jpg

Same for figure 5!

Sorry but we do not agree with this suggestion, we consider that this way of presenting these results is appropriated.

Line 206: what is "N", do you mean "P"?

We regret this mistake. You are right.

Line 207 - 210: Discuss averages or medians instead of "peak ranges" and "frequencies in the higher values and lower values". I am pretty sure average(P) > average(NP) for all seasons. And yes probably we also have average(summer) < average (any other season). Maybe add them into a table?

We have included this information in the new version of this article: "The seasonal GDR values with and without precipitation show higher concentrations during precipitation events across all seasons. In both meteorological scenarios, the highest average values are reached in winter (0.0769 ± 0,0002 µSv and 0.0765 ± 0,0001 µSv/h, for precipitation and without precipitation, respectively), while the lowest values are observed in summer (0.0754 ± 0,0002 µSv and 0.0751 ± 0,0001 µSv/h, respectively)"

Line 212: This is phrased a bit unfortunately. Precipitations moves airborne radionuclides closer to the ground. Using remove here might raise questions why the rate increases in a GDR sensor, when it is gone. Our understanding is that radioisotopes are attached to droplets in the cloud and the rain brings it to the ground, leading to an increase in GDR. There is another, albeit less noticeable effect; the water on the ground creates a sort of blanket that prevents radon outgassing from the ground, which reduces the GDR slightly.

We have modified the sentence in the new version of this article: Line XX: "These results demonstrate the significant influence of precipitation on GDR concentrations, primarily due to the washout effect, where rain brings airborne radionuclides closer to the ground, leading to increased GDR levels during and shortly after rainfall events. Additionally, the accumulation of water on the ground can slightly reduce radon outgassing, tempering the increase in GDR."

Line 214: I would have suspected that radon has a harder time moving from the ground to the atmosphere in winter (particular with snow), but I would assume that similar to rain, snow would trap some radioisotopes, but as it take a while for it to melt, retains them for longer. Not sure if there is a lot of snow in this area; It would be interesting to cross check if higher GDR's are correlated with snow days?

Many thanks for this suggestion. We understand this question, and it would be great to carry out this comparison. However, we do not have data of snow days. It can be an interesting analysis in the future.

Line 224: While I agree with this being likely true, I don't know if it can easily be derived from Figure 6. It seems to be driven by two outlier events in February and March, while the rest seems to be pretty consistent with the average + spread in GDR. This is in line with my main concern with this article; It is hard to draw conclusions on ~hour long events by simply looking at daily averages!

We understand the doubts. For this reason we have include the standard error of the mean in each figure.

Figure 6: I think it would be good to add "error bars" to this figure showing the standard deviations for the daily average or the range for the X's percentile (with X=90% or whatever the authors deem valuable).

We understand the doubts. For this reason we have include the standard error of the mean in each figure.

Line 227: I don't see a single event in Figure 6 that has 0.0923 uSv/h? Maybe cross check this number.

Yes, there was a mistake.

Figure 7: I think it would be good to show the X percentile (X=90% or something) bands around each of these lines (with some level of transparency for better visibility).

We understand the doubts. For this reason we have include the standard error of the mean in each figure.

There is no Figure 8: I think the numbering is off.

You are right, and we regret the mistake. The number of the figures has been changed accordingly.

Line 248: Better title would be "Impact of radon concentrations on GDR". "influencing" here is grammatically not correct.

It has been changed in the new version of this manuscript

Line 265: Again, while "removing from the atmosphere" is technically correct, I think it is a bad way of phrasing it for this context! They are TRANSPORTED with the rain from higher up in the atmosphere (mostly from the cloud forming regions) close to the surface.

We agree with you, and it has been changed in the new version of this paper.

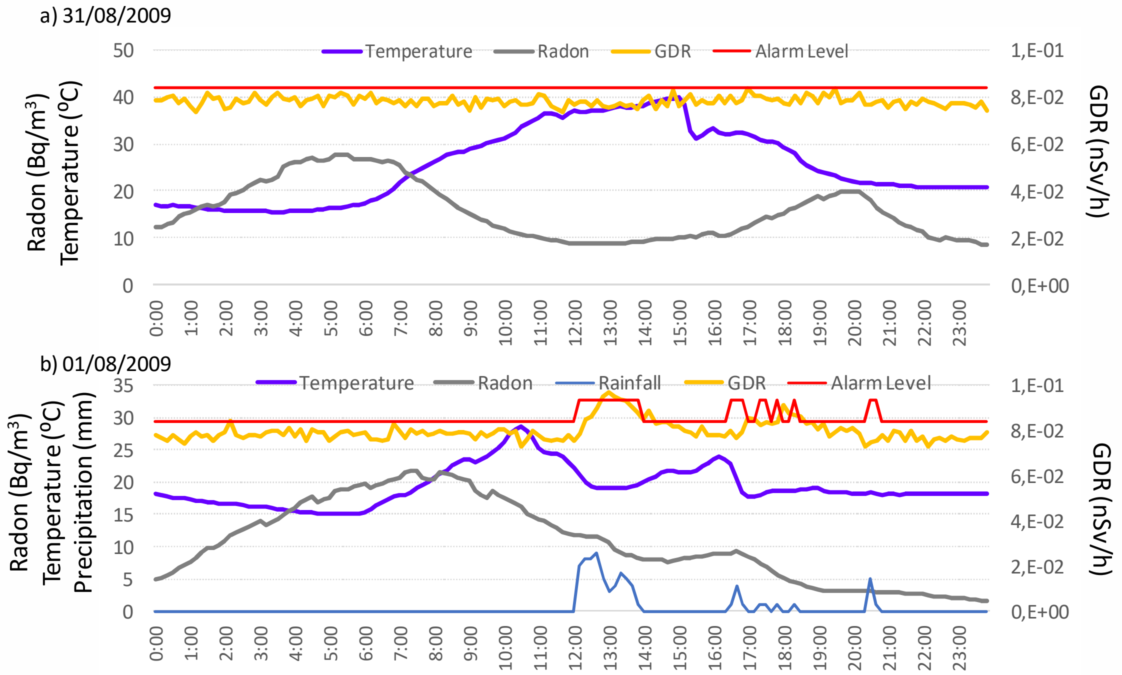
Figure 9: Also here some sort of percentile bands around the central lines would be useful to better judge the variability.

We understand the doubts. For this reason we have include the standard error of the mean in each figure.

Line 306: Figure number missing

It has been changed in the new version of this article

Figure 11: Radon is green in the plot but gray in the legend. In general, I think Figure 11 and Figure 10 are a bit overloaded. It would be good to have an axis for radon as well. You could add one more "radon" axis on the right, or just split them up into 3 separate plots with a common time axis.



Also why does the alarm threshold increase during rain? The authors never talk about this mechanism.

Information about the alarm threshold has been included in the new version of this manuscript.

317: temporarily reducing? I think you mean "increasing"? Again, it is only a displacement, not really a removal.

It has been changed in the new version of this manuscript