



Interactive comment on “Influence of a component of solar irradiance on radon signals at 1 km depth, Gran Sasso, Italy” by G. Steinitz et al.

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Received and published: 3 March 2013

We thank the editor for the review and discussion as well as for the various specific points which were raised for discussion. Some of the main points of the discussion parallel those raised by reviewer #2 and the reader therefore the reader is also referred to our response to that review.

The Editor:

In my opinion the authors do not produce a convincing argument that environmentally related processes are not producing the observed periodic variations in radon. Given that their preferred alternative explanation is somewhat exotic it behoves them to be completely thorough in eliminating the possibility that these variations are simply an

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artefact of periodic changes in environmental conditions.

The eventual influence of environmental parameters relates primarily to temperature and pressure. Temperature is stable at the site and thus pressure is raised as a possible influencing factor. This point was also raised by reviewer #2. Below is our response. We performed a statistical evaluation (Kendall rank test) of the data presented Fig. 9. This data set is important as it refers to radon measurement with an alpha detector. We did a similar evaluation for further data sets of gamma radiation and pressure and thereby covering the full monitoring range. Radon time series in the natural environment often show variations which have similarities with those of environmental parameters – primarily pressure and temperature. This probably leads to ambiguity when analysis is performed in the time or in the frequency domain. The ambiguity is enhanced when short data sets are used or when the radon signal is relatively low (as in the case at LNGS). To overcome this difficulty we maintain that analysis in the combined frequency-time domain is of superior significance. This approach we presented in Figs. 11–12.

The Editor:

I found it troubling that the exact method used to present the diurnal radon (DR) signal was not specified in the text, apart from an unclear comment in the figure caption of Fig. 6 and ambiguous points on pages 1515–1516. DR appears to be produced by subtracting a long-pass filtered version of the radon time series from the data, producing a differential signal around zero as shown in Fig. 6. The explanation given for the data analysis would not produce such a zero-centred normalised dataset. The authors need to specify exactly what data processing was performed to produce the DR time series from the original data.

Response - The MD and DR signals were obtained by decomposition with sliding averages – as we did in previous works. We clarified this in the text and accordingly added explanations to Figs. 4, 5 & 6.

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The Editor:

Figure 3 demonstrates a degree of anti-correlation between radon signals and air pressure.

Response - Figure 3 shows both "correlation" and "anti-correlation". We maintain that such short intervals in the time domain are not indicative in the case of features with waveforms of comparable duration. We address the issue separately.

The Editor:

The scale of both temperature and RH have been enlarged so much that it is impossible to ascertain if there is a correlation with radon or not. This gives the reader the sense that the authors are not exhausting the investigation of potential environmental related processes on the radon modulations. A more detailed presentation of pressure related changes is given in Fig. 8, and this highlights the presence of short-term modulations which look similar to those seen in the raw radon signal, and which are also observed in the DR data.

Response - Temperature (Table 1) and RH are indeed stable and bear no relation to the variation in radon. The issue of the eventual relation to variation of pressure is dealt below, separately

The Editor:

The authors claim that the datasets 'show a different pattern', but they are only looking at the MD data, not the DR data. Furthermore, there are periods of apparent correlation in the datasets presented in Fig. 8 and the authors statement that they show a different pattern is not substantiated by an objective test.

Response - We extended the statistical analysis of the relations of pressure and radon in the time domain in Table 1 and in the frequency domain in Figure 10.

The Editor:

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The authors should determine time series for temperature, pressure and humidity using the same data processing approach used for the production of the DR time series, and present these data with appropriate scaling together with the radon data, to allow the reader to see for themselves that there isn't (or is) a correlation.

Response - Temperature and RH are stable at the site. We applied the same data processing procedures for radon and for pressure. We added

The Editor:

Furthermore, results from FFT studies of these environmental parameters should be presented in the text and discussed.

Response - For RH we have data only those shown in Fig. 3. Temperature is very stable for long time segments. We extended the FFT analysis and added information in Table 1.

The Editor:

Fig. 9 presents an analysis which is used to support the idea that pressure variations are uncoupled to radon signals, but the authors ignore the possibility that the radon pressure relationship may be non-linear, and therefore it may not necessarily produce a linear relationship even if there is a causal factor linking pressure and radon.

Response - We have no reason to assume that only radon (noble gas) concentration is driven non-linearly by pressure. As far as we are aware there is neither a theoretical basis nor experimental data supporting such a view.

The Editor:

An unexplained feature of figure 9 is the choice of data set; why was only data from days 193-235 used, and why is the variation in pressure so limited (up to 3-4 hPa) when in figure 8 the pressure varies by 25 hPa? The authors need to explain why they use data from different periods.

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Response - We extended the analysis of the pressure-radon relations by covering further time intervals. See separately.

The Editor:

Figures 12-16 seem to be redundant, these should be condensed into a single figure.

Response - We disagree – the figures show different characteristics. This is the first time that such an analysis of the radon system in the frequency-time domain is presented. Features highlighted by such an analysis occur also in other radon time series and therefore this case should serve as an example and reference. Figure 12 establishes, in the case of radon, in the frequency interval of up to 4 CPD the differing variation patterns at separate segments of the diurnal cycle. Figure 13 reconstructs the temporal variation of the signal at 1 CPD. Figure 14 shows that the pattern depicted in Figure 13 is composed of 24 systematic and continuous hourly variation patterns. Figure 15 demonstrates from the latter (Fig. 14) two pairs of time series which are separated by 12-hours and which exhibit inverse variation patterns. Figure 16 presents the overall pattern of the above features substantiating the 12 hour inverse pattern within the whole daily cycle. This pattern allows linking the phenomena to the rotation of Earth.

The Editor:

Overall I feel that the authors do not produce a compelling case for the role of solar irradiance in modulating radon signals.

Response - The radon phenomena at the site lack of a simple relation of with local environmental parameters, On the other hand they show a linkage with the rotation of Earth. This situation is the basis of our suggestion that a component of solar irradiance is influencing the radon signal. Raising this suggestion corresponds with recently raised similar considerations on radon systems in the geological environment and in simulation experiments.

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Interactive comment on Solid Earth Discuss., 4, 1511, 2012.

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