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Solid Earth Discussions

Interactive comment on "The Pollino 2012 seismic sequence: clues from continuous radon monitoring" *by* Antonio Piersanti et al.

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Interactive comment on "The Pollino 2012 seismic sequence: clues from continuous radon monitoring" by Antonio Piersanti et al. R. C. Tiwari (Referee)

COMMENT 1: This paper is well organized and presents in-depth analysis of 2 selected seismic events out of about 5000 events. The analysis of the experimental data has been done using two approaches namely phenomenological and a purely numerical analysis. The authors have successfully arrived at same or similar conclusions, however, micro-seismic events of magnitude less than 3 and radon emanation have not been considered. It cannot be ruled out that radon anomalies for such events may be indicators of impending massive earthquakes.

REPLY 1: We confirm that all our analyses involving seismicity (cross-correlation,

change point analysis and detection algorithm) employ ALL events recorded by ISIDe between December 2011 and October 2014 with epicentral distance from MMN less than or equal to 15 km (4,800 events), without any type of selection on magnitude value. Among other things, micro-seismic events (Mw<=3.0) represent 99% of those selected in this work.

COMMENT 2: Authors have considered daily average and 14 days moving average data to analyze the radon behaviour for 2 stations by different methods, indicates the efforts that have been put by authors to generate the data to understand the phenomenon. It is interesting to see a non accidental correlation between Radon concentrations and seismic moment release. I wish to appreciate the authors for their commendable job.

REPLY 2 We sincerely thank Dr. Tiwari for his appreciation

COMMENT 3: In general, the radon peaks showing variations in concentration for 2 SD (Standard Deviation) or more that 2 SD are considered to be anomaly due to seismic events, provided that the data is rectified for the false anomaly that may be due to influence of meteorological parameters (Pressure, Temperature, Rainfall etc). I do hope authors have taken care of this aspect. Radon anomalies of both types (rise/fall in radon concentration) are equally important.

REPLY 3: In the present work we tried to extend the standard "anomaly" analysis by means of a twofold investigative approach: a global correlation and cross correlation analysis and the detection algorithm. The former tries and assesses a not accidental relationship between radon emanation and seismic moment release time series as a whole, while the latter tries and overcomes the usual anomaly notion by means of a more complex and (hopefully!) powerful approach (see also figure 1R). The sense of empirical correction developed in this work is just to take into account (removal or at least reduction) of the bias of meteorological parameters (temperature, pressure and precipitation variations) on the radon measured concentration. The impact that

this correction has also on the cross-correlation analysis represents a good check of its usefulness for us. Presently our detection algorithm is structured only to issue an alarm for a positive variation in the trend of radon concentration (i.e. rise) that seems to be the actual important one for the present case study, but our next target is to include negative variations too.

COMMENT 5: Western side of study area has recorded more number of seismic events and of higher magnitude as compared to eastern side. Explain reasons?

REPLY 5: The regional seismotectonic framework of the Pollino area lies at the northern edge of the Calabrian subduction zone and represents quite a complex sector of remarkable geodynamic interest still not fully understood, as many studies showing different conclusions demonstrate (Bonini et al., 2011; Frepoli et al., 2011; Spina et al., 2011; Neri et al., 2012). The hypocenters relocalization of the 2010–2013 swarm that has revealed two main clusters, has been subject of a recent work (Totaro et al., 2015), but no indication came about the different number and magnitude distribution of seismic events recorded in the Western side of the area. The only reasonable explanation could lie in the Gutenberg-Richter law: two different clusters of values for magnitude and total number of localized earthquakes seem to suggest that two distinct structures of different dimensions have been activated.

COMMENT 6: Whether the meteorological observatory is located on site, or far from the radon monitoring site, if so how far from the site? Please clarify the situation for both monitors.

REPLY 6: The two radon stations MMN and MMNG installed in the Pollino area acquire simultaneously radon concentration data and local temperature values by means of a specific sensor co-located with the radon one. As explained in the manuscript, all other meteorological parameters daily values (external temperature, pressure, precipitation) employed in this work are obtained as short term (12-24h) weather forecast by an Italian weather forecasting site (http://www.ilmeteo.it/).

COMMENT 7: Authors are requested to explain reasons for the following: a) During summer season, Radon concentration is more pronounced. Why? b) Radon concentration decreases with increase in rainfall. Why? c) Can you elaborate further on your claim with explanation that 'the discontinuity in the radon increase is likely to be associated with a major rainfall that occurred just after the 5.2 magnitude earthquake'?

REPLY 7: a) The reason of this behaviour of radon concentration during summer is likely to be complex and not related to a single cause as different results from previous analyses carried on in different setting indicate. It is likely that precipitation could also play a role, being summer rain much lighter than winter one could be ascribable to minor precipitation events, considering that rain clearly inhibits radon emanation forming a sort of seal into the first layers of soil (see Figures 2 and 3). Incidentally also Oh, Y. and Kim, G. (2015) have recently observed that radon activity was on average higher during the summer than during the winter. b) The answer to the second question raised is closely connected with the point above and actually it has been subject to particular attention in the manuscript. c) The sense of this claim is that we believe that the severe rain event occurred just after the 5.2 magnitude earthquake has influenced a radon increase having a quasi-linear trend starting from the beginning of October (therefore almost a month before the mainshock). In Fig. 5c, where raw radon concentration (yellow dots) is reported together with daily averaged rainfall it is clear this trend from September to the end of November 2012 with the only exception, exactly, of the week after the 35 mm H2O peak of rain.

COMMENT 8: It is very interesting observation recorded by authors that: For the seismic event of magnitude 4.3, radon concentration gets restored to normal value after 7 days of the event. For the seismic event of magnitude 5.2, radon concentrations continue to increase for more than 30 days after the event. Can you explain the possible reasons?

REPLY 8 The actual physical mechanisms leading to radon emanation anomalies during earthquakes preparation are far from well assessed yet but they are likely to be

connected to the dynamics of fluids taking place in rocks undergoing rapid and dramatic changes of their internal state. While not quantitatively constrained yet, nevertheless it is reasonable to assume that the time needed to recover from this perturbed state (and thus to return to background radon level) is proportional to the overall energy involved in the seismogenic processes and hence to the magnitude of the impending earthquake.

COMMENT 9: Typo-graphical suggestions

REPLY 9: We corrected as suggested.

Oh, Y. and Kim, G. A radon-thoron isotope pair as a reliable earthquake precursor. Sci. Rep. 5, 13084; doi: 10.1038/srep13084 (2015).

Please also note the supplement to this comment:
http://www.solid-earth-discuss.net/se-2016-72/se-2016-72-AC1-supplement.pdf

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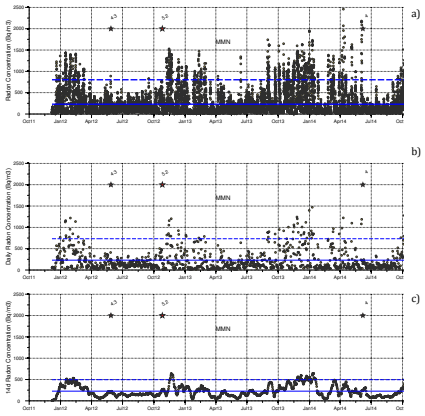

Figure1R: MMN radon concentration (yellow dots) in (Bq/m^3)/115 min (a), daily average (b), 14-days moving average (c) from January 2012 to October 2014. Red stars represent the occurrences of the main earthquakes of the sequence. Blue solid and dashed lines represent mean value and 2SD, respectively. a), b) and c) show how the "anomaly" concept may depend from different sampling times of moving average employed.

Fig. 1. See supplement for original size