Standardised Radon Index (SRI): a normalisation of radon data-sets in terms of standard normal variables.

THE UNIVERSITY OF NORTHAMPTON
School of Science and Technology

R G M Crockett and C P Holt

1. Data Analysis Group, School of Science and Technology, University of Northampton, NN2 6JD, UK.

Introduction

There is an increasing body of evidence which indicates that radon emissions from rocks, soils and groundwater can provide a diagnostic tool for some geophysical processes, e.g. tidal deformations and earthquakes. In this context, it is often informative to compare two radon data-sets, e.g. variations/anomalies in radon concentrations at different locations which might be responses to common stimuli. However, this can be complicated, e.g. by the use of different detectors, radon concentrations being orders of magnitude different or different nonlinear responses of radon emissions due to different rocks and soils.

As a means of investigating similarity of response to stimulus, we propose a Standardised Radon Index (SRI), adapted from Standardised Precipitation Index (SPI) methodologies under development at the University of Northampton.

We have piloted this on a previously analysed data-set containing simultaneous radon-anomalies temporally associated with the M5 Dudley earthquake of 22 September 2002.

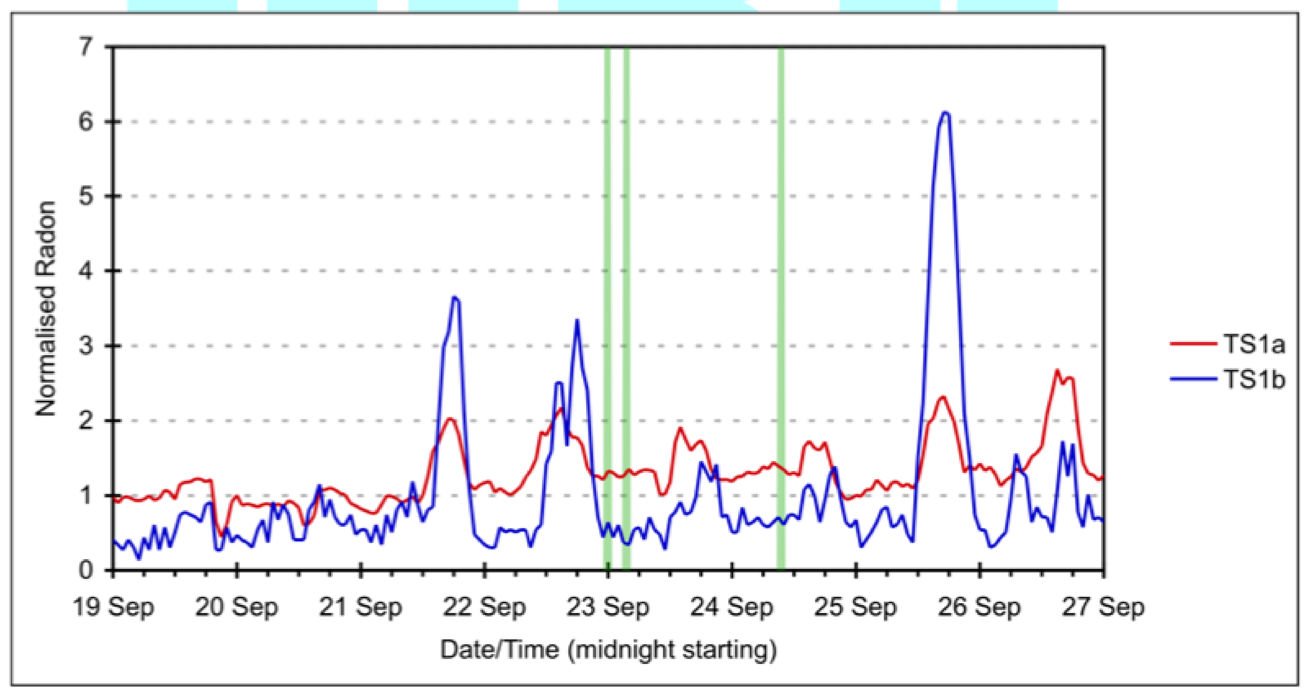

Fig 1. Simultaneous (normalised) radon anomalies. Earthquake timings are shown in green.

Standardised Precipitation Index (SPI)

SPIs were first proposed by McKee *et al.* in 1993, and can be summarised as a normalisation of precipitation data in terms of standard normal random variables. In effect, variations in the data are presented in terms of abscissae of the standard normal distribution via an equiprobability mapping from the cumulative probability distribution of the data. Thus periods of the same relative drought (or anti-drought) in different precipitation regimes have the same SPI: the same SPI in different data-sets represents the same relative drought/anti-drought across different precipitation regimes.

The standard formalisation of SPIs, as proposed by McKee *et al.*, involves an equiprobability mapping between a gamma distribution, used to fit the data, and the standard normal distribution, from which SPIs are derived as abscissae. The equiprobability mapping can be eliminated where the precipitation data are (truncated) square-root or cube-root normally distributed, for example, and we have proposed a methodology which generalises a root-normal calculation of SPIs.

Standardised Radon Index (SRI)

Transferring the principal of SPIs to radon, where data-sets are generally lognormally distributed, is straightforward and does not require an equiprobability mapping. Simply, SRIs can be calculated directly from the logarithms of the data, taking care to express any zero-readings as an appropriately small fraction of the detector minimum threshold. Figure 2 compares SRIs to the normalised radon, as shown in Figure 1.

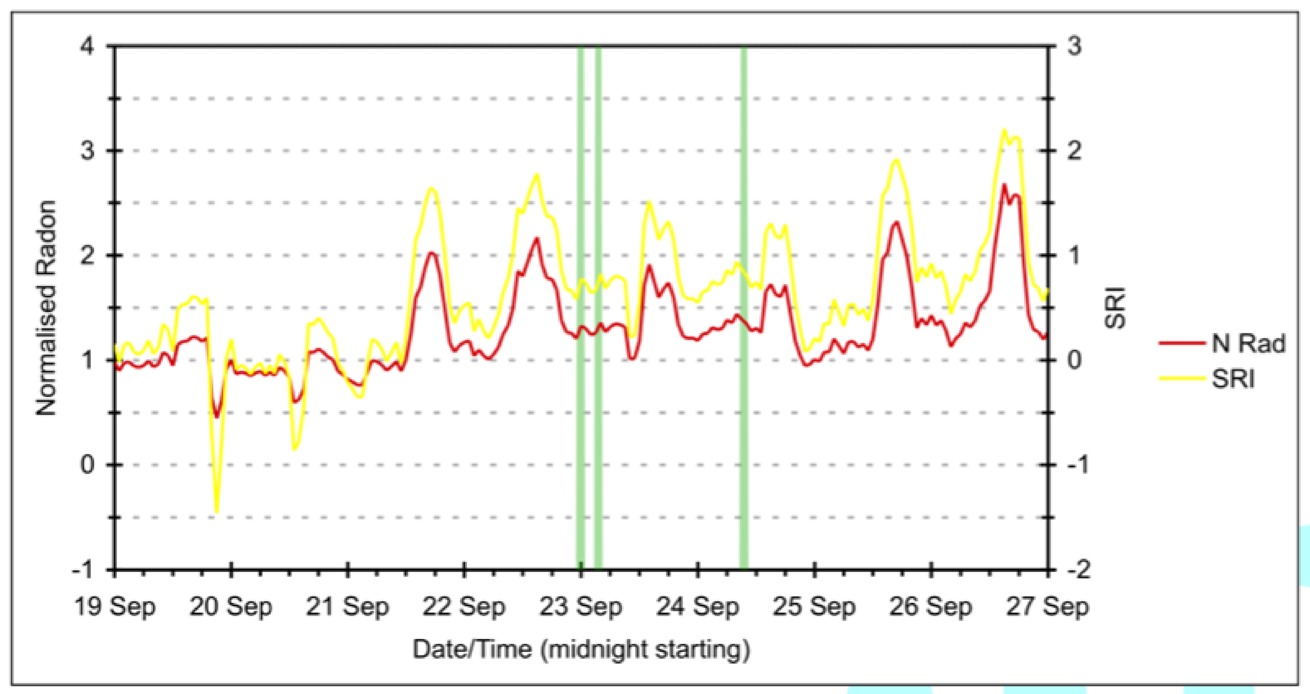

Fig 2a. TS1a, Normalised radon and SRI.

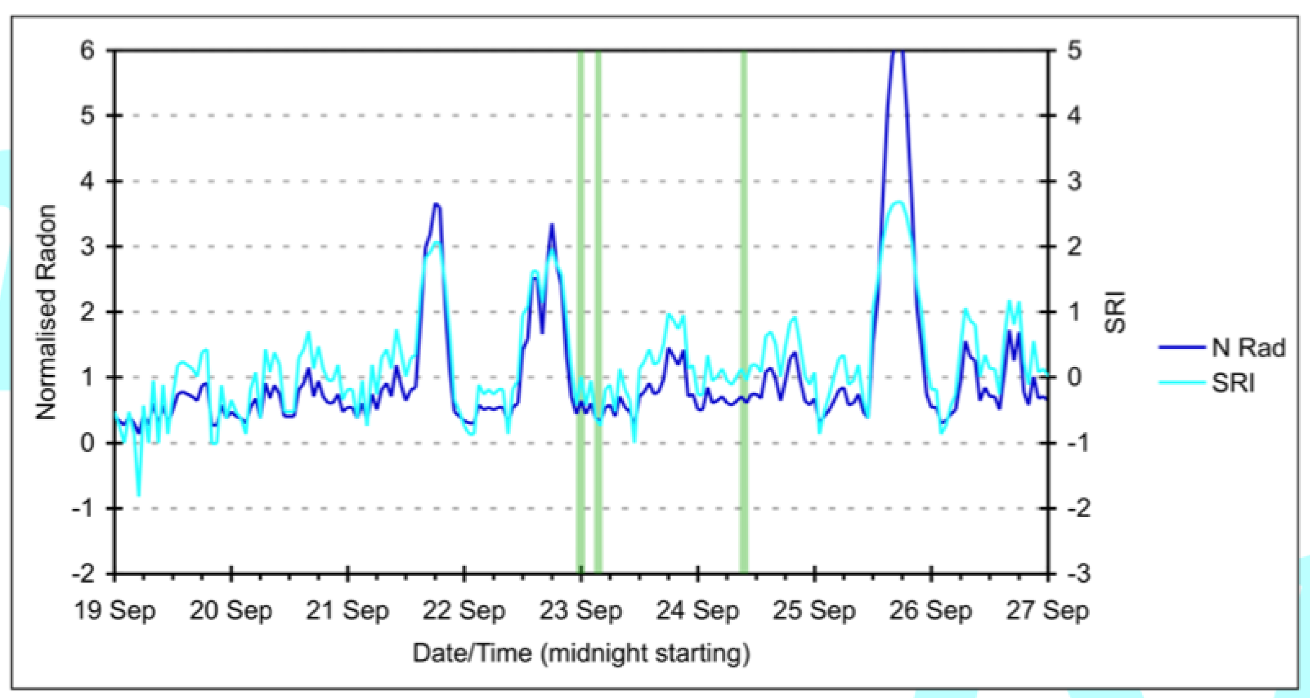

Fig 2b. TS1b, Normalised radon and SRI.

Results

Figure 2a shows that the SRIs for TS1a emphasise the relative peaks and troughs compared to the (normalised) radon data. Figure 2b shows that the SRIs for TS1a de-emphasise the relative peaks and troughs compared to the normalised radon data.

It is deduced from this difference that TS1b has a higher-amplitude response to the (earthquake) stimulus than TS1a. This is confirmed by the greater similarity of magnitudes of peaks and troughs in the SRI time-series compared to the (normalised) radon time-series. The two SRI time-series are shown in Figure 3.

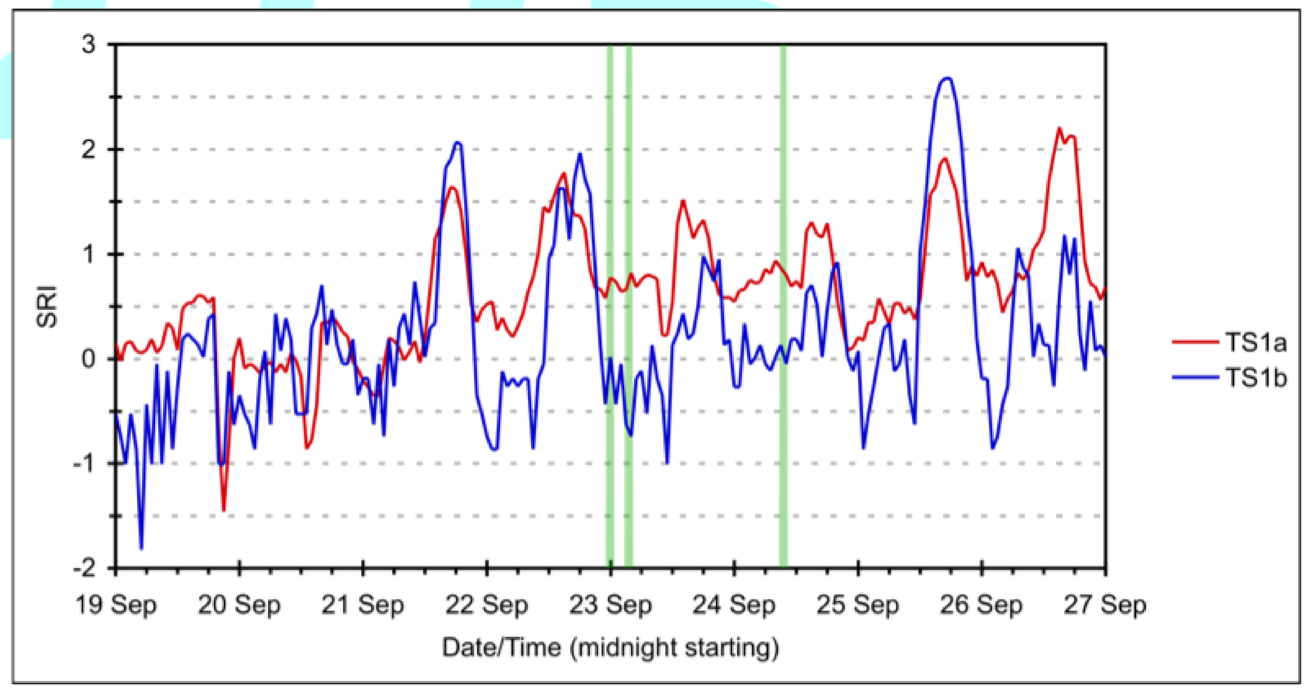

Fig 3. Simultaneous radon time-series presented as SRIs.

Discussion

The time-series shown in all the figures show a set of simultaneous anomalies occurring at the time of the M5 Dudley earthquake of 23:53, 22 September 2002 and its two significant aftershocks. This is one of two periods of such anomalies in this data-set, the other also corresponds temporally to an earthquake (Crockett *et al.* 2006).

In previous investigations, we have applied moving averages to reduce the effects of drift/mismatch in sampling times (for same sampling period), and also techniques such as Empirical Mode Decomposition (EMD) to de-noise time-series and reduce the effects of different detector responses. However, none of these account for different nonlinear radon responses to similar or common stimuli as do the SRIs we propose.

As is clear from Figure 3 (SRIs), a simultaneous dip ~48 hours before the earthquake is revealed more clearly, as an equal-probability response, than in Figure 1 (normalised radon).

This is also revealed in Figure 4, which presents each time-series in terms of cumulative probability of occurrence of a given radon reading.

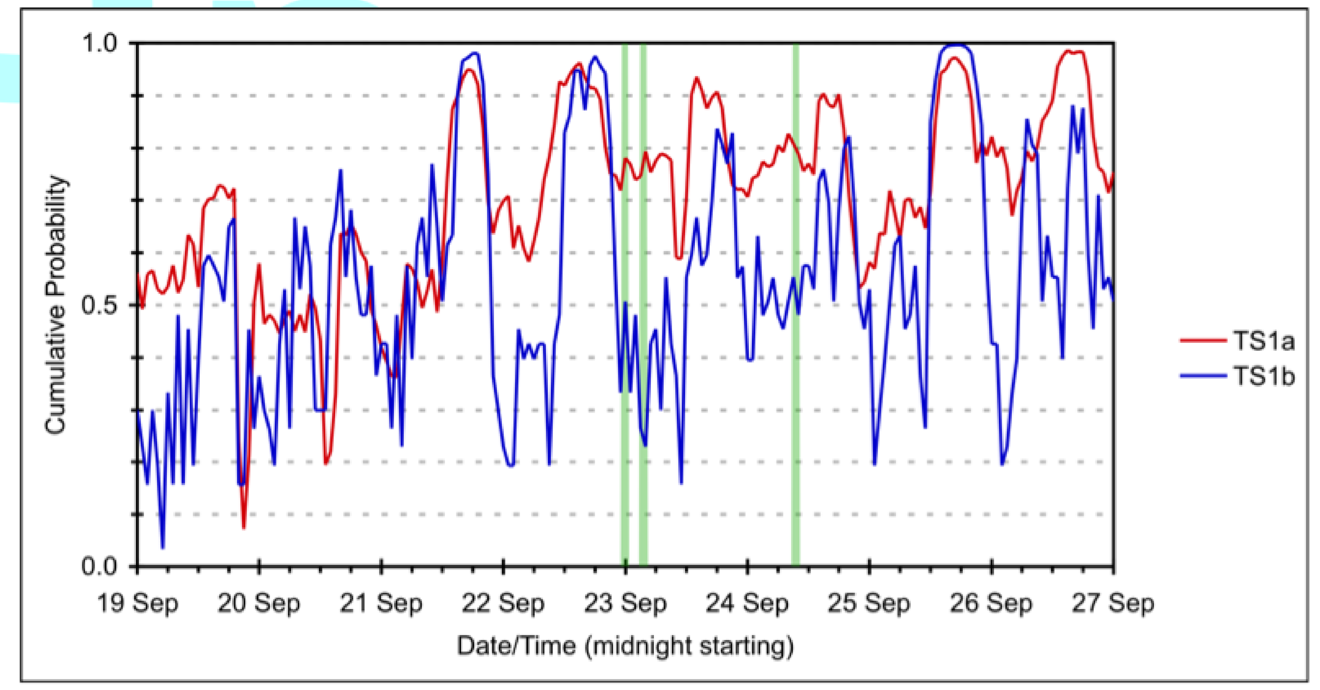

Fig 4. Simultaneous radon time-series presented as cumulative probabilities.

Conclusion

In presenting a radon time-series in terms of SRIs, it is possible to compare features and anomalies in terms of probability, thus accounting for some of the different nonlinearities of response of different rocks and soils (and different detectors).

SRIs, for lognormally-distributed data-sets, are easy to calculate: for non lognormally distributed data-sets, other transformations and equiprobability mappings afford routes of calculation.

Acknowledgement

The authors gratefully acknowledge members of the University of Northampton Radon Research Group for the collection of the data and also DEFRA (UK) for funding the research under which the 2002 data were collected.

References

1. McKee T B, Doesken N J and Kleist J (1993). The relationship of drought frequency and duration to time scales. Preprints, 8th Conference on Applied Climatology, pp. 179–184. January 17–22, Anaheim, California.
2. Crockett R G M, Gillmore G K, Phillips P S, Denman A R, Groves-Kirkby C J (2006). Radon Anomalies Preceding Earthquakes Which Occurred in the UK, in Summer and Autumn 2002. *Science of The Total Environment*, 364, 138-148.
3. Crockett R G M, Gillmore G K (2009). Spectral-Decomposition Methods for the Identification of Radon Anomalies Temporally Associated With Earthquakes Occurring in the UK in 2002 & 2008. EGU GA (and NHESS in review)