Radiation Protection Dosimetry
Vol. 24 No. 1/4 pp. 85–88 (1988)
Nuclear Technology Publishing

^{222}Rn IN THE ANTARCTIC PENINSULA DURING 1986

E. B. Pereira, A. W. Setzer and I. F. A. Cavalcanti
Instituto de Pesquisas Espaciais
C. Postal 515, 12201 S. J. Campos, S. P. Brazil

Abstract — ^{222}Rn was continuously measured at the Brazilian Antarctic Station (62°S, 58°W) during the year of 1986. Baseline radon concentration averaged 0.02 Bq.m^{-3} with surges peaking 0.4 Bq.m^{-3}. The data exhibited a characteristic periodicity of about 25 days and a strong positive association with short term fluctuations of atmospheric temperature. No seasonal variations of radon were observed. Interpretation of the radon surges with reference to synoptic charts and weather satellite pictures showed that the continental influence of radon at the Antarctic Peninsula is very small and comes only from the tip of the South American cone.

INTRODUCTION

Studies of long-range transport of gaseous and particulate trace components in the atmosphere are of major importance insofar as the effects of anthropogenetic contaminants are concerned. Classical methods deduced by air trajectory calculations may not always be applicable to these studies, particularly in remote areas or in areas with insufficient data coverage.

The use of ^{222}Rn as a tracer for these long-range transport studies has drawn the attention of a large number of authors$^{(1-4)}$. This is due to the fact that the 3.82 day half-life, the chemical inertness, and the well established continental origin for radon make it the best approach towards an ideal atmospheric tracer.

Owing to the almost negligible fraction of exposed surface, and also to the reduced human activities, the Antarctic region can be viewed as one of the most recommended sites for studies of long-range transport of atmospheric constituents, including the radioactive ones.

The Brazilian Antarctic Station 'Ferraz' was established at King George Island in the Antarctic Peninsula (62°05'S, 58°23.5'W) in 1984 (Figure 1). Since 1986 ^{222}Rn and long-life radon daughters are continuously measured throughout the year. This paper is the analysis of the first year of operation and corresponds to data acquired during the year of 1986.

INSTRUMENTS AND METHODS

^{222}Rn is measured by a novel design radon-gas collector$^{(5)}$ shown schematically in Figure 2.

The principle of operation is based on the well known technique of electrostatic collection of the decay products of radon onto metallic wires and plates. The collection chamber is a closed hemispheric plastic container which is internally coated with a conductive paint. A silicon surface barrier detector is placed at the spherical centre of this hemisphere. In order to collect the short-life radon daughter ions produced inside the chamber, a very strong electric field of the order of 6×10^4 V.m^{-1} is applied between the metallic sheet and the detector. Owing to the geometric configuration of the system this electric field is radial, which minimises the transit time of ions inside the chamber

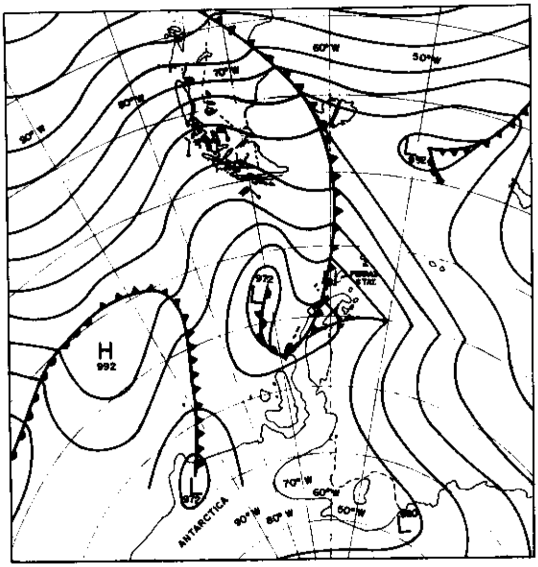

Figure 1. Location of the Brazilian Antartic Station. The weather synoptic analysis corresponds to the peak of maximum radon level of 1986 at Ferraz Station (62°05'S, 058°23.5'W). Isobars are drawn at 4 mb intervals; wind arrows indicate flow from the tip of South America to the Northern Antarctic Peninsula.

and thus reduces the chances of neutralisation. Atmospheric air is then pumped in through the chamber at a constant flow of 5 $l.min^{-1}$ by a membrane pump, after passing through a filter (Millipore type MF, 0.45 μm) and through a delay line in order to remove, respectively, particles and the short-lived radon isotopes ^{220}Rn and ^{219}Rn. The newly produced ^{218}Po and the ^{214}Po from the decay of radon will be promptly precipitated onto the active surface of the alpha particle detector and counted. The total collection efficiency is 58%. Counting rates within a selected energy range, can be readily converted to activity of radon per volume of sampled air by a simple multiplicative constant. Data are automatically acquired hourly and recorded onto a cassette tape as well as registered by a line printer.

The instrument background activity is about 0.001 $Bq.m^{-3}$ for a 24 h integration time, which is more than adequate to measure the small radon concentrations typically found in the Antarctica (~ 0.02 $Bq.m^{-3}$).

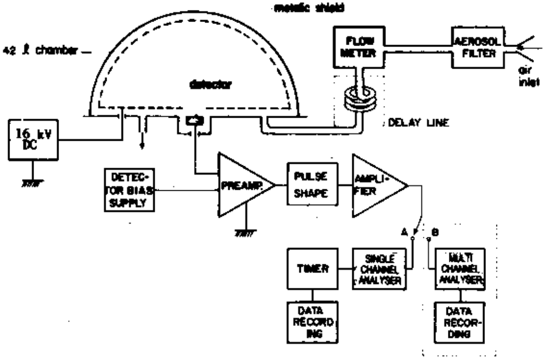

Figure 2. Function diagram of the radon measuring instrument. The option B after the amplifier is normally used during calibration.

EXPERIMENTAL RESULTS

The 5-day average activity of radon for the year 1986 at Ferraz is shown in Figure 3 along with the local atmospheric temperature. Distinctive features of these curves are the large surges of radon and its association with local atmospheric temperature increases. It was first thought that this effect was due to local melting of permafrost with a resulting surge of the radon trapped in the soil. However, a close look at some of these peaks showed that in some cases the atmospheric temperature peaks were below the melting point of ice and yet the peak of radon was clearly present. Actually, it stayed well below freezing on some of these occasions, particularly from day 72 to day 84 (−2°C to −8°C). Furthermore, on many occasions it was observed locally that although the temperature increased above the melting point it did so for a very short period (a few hours) and only by a very small amount (less than 0.5°C) thus possibly not allowing enough time for the thermal wave to remove the snow cover and melt the permafrost. In addition, the absence of a seasonal fluctuation of radon can be considered as strong evidence for the negligible local contribution for radon.

In view of these considerations we found no reason to assign a local source for the radon peaks in our experiment.

Fifteen major radon peaks selected from the background fluctuation of radon of 0.02 $Bq.m^{-3}$ were studied with reference to surface synoptic charts and weather satellite pictures. To do this we employed a more complete set of data composed of daily averaged radon, and arbitrarily established a line corresponding to three times the background fluctuation of radon. Then, we picked up only the surges above this line.

This analysis showed that all major surges undoubtedly occurred while synoptic systems were passing south of South America, more precisely, when the low pressure centre associated with these systems was located somewhere in the Drake Passage at about 70°W longitude. This situation causes a cyclonic wind circulation bringing oceanic air masses from the South Pacific Ocean directly to the Antarctic Peninsula after a short transit time over the tip of the South American cone. Furthermore, by performing the reverse analysis we observed that whenever the above synoptic situation occurred a radon increase was also present, although sometimes at such low intensity that it could barely be resolved from the background noise. This observation failed only once out of the 31 occurrences in 1986.

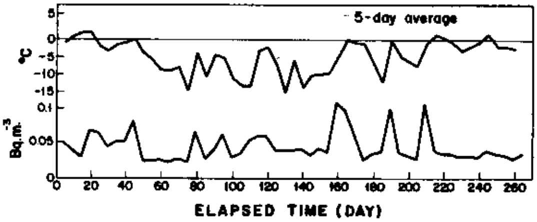

Figure 3. Plot of the 5-day average radon data versus temperature. The x-scale is time elapsed after the first day of the experiment 17 March 1986.

A closer look at the weather satellite pictures corresponding to the period from September 19 to October 1 (Figure 4), where one of the highest positive radon excursions occurred, exhibited a series of synoptic systems moving to the east near the Antarctic Peninsula.

The first system was very wide as seen in Figure 1. Its corresponding low pressure centre was located at 72°W longitude in the Drake Passage when the maximum radon occurred. The first radon surge was observed almost simultaneously with the arrival of the continental warmer air from lower latitudes. The following systems passed shortly after, while the air at Ferraz was still under the temperature influence of the first.

The very short duration of the radon surges (about 18 h) is an indication of a relatively close source for radon. A source further upwind would probably favour a larger degree of mixing and dilution causing a sluggish response for radon at Ferraz.

It seems that Ferraz is just at the border of what we called 'zone of continental influence'. This zone is established when winds associated with the frontal system moving east, reach the tip of the South American cone, and extend probably to the Weddell Sea or maybe even further to Queen Maud Land. When this zone is established, the air which was purely oceanic from the South Pacific Ocean becomes contaminated with continental air. It seems that this moment is felt exactly at the region of the South Shetland Islands where Ferraz is located.

If the above hypothesis is true we may conclude that the air at Ferraz is mostly of oceanic origin and its radon as well as all of its other continental trace gas load will be very low.

RADON ANOMALIES AND THE INDEX CYCLE

The time series of radon at Ferraz were studied with the maximum entropy method – MESA(6). MESA is a non-linear method of spectral estimates for the study of periodicities in time series which is considered superior to earlier methods.

The logarithm of the power spectral density versus period from the MESA program output applied to our radon data can be seen in Figure 5. Two characteristic peaks are resolved from the short period background, one of 19 days and one at 25 days which is by far the largest. No seasonal variations were observed by applying MESA for a larger range of periods.

Observations made by Lambert *et al*(7) as early as in 1970, show a characteristic periodicity of 28 days for radon measured at Terre Adelie (66°40'S, 140°E). This periodicity was explained in terms of fluctuations of the solar component of the cosmic rays without further considerations. Other studies(8,9) have demonstrated that periodicities of about 20 to 27 days at higher south latitudes are tied to the barotropic interchange of energy between lower latitudes and higher latitudes. Kidson defined an irregular index cycle of 20 to 30 days which is due to changes in the zonal wind flow with weak poleward transport of heat (negative index) and a blocking phase where the increased meridional flow strengthened the poleward heat transport (positive index). The strong association between temperature and radon concentrations in Figure 2 seems to be

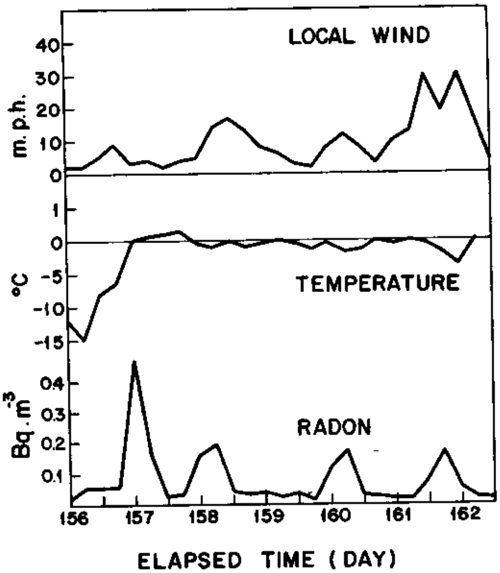

Figure 4. Plot of the 6-hour average radon, the local temperature, and the wind for the period corresponding to day 156 through 162 (19 Sept.-1 Oct.) when the highest radon surge occurred.

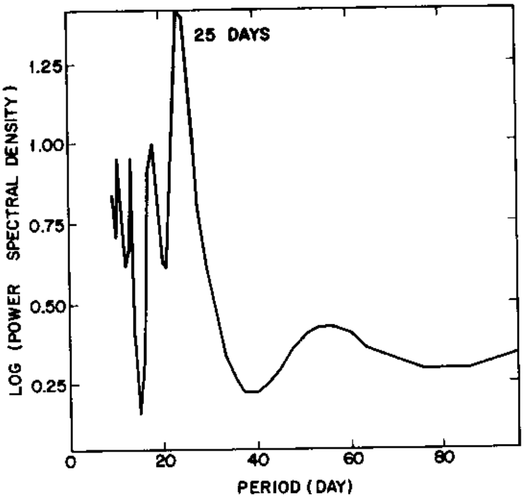

Figure 5. Plot of the logarithm of the power spectral density versus period in days, obtained by applying the maximum entropy spectral analyis (MESA) method in the daily averaged radon data. The periodicity of 25 days can be clearly seen.

quite consistent with the positive index defined by Kidson.

CONCLUSIONS

Radon kept an almost constant baseline average concentration of about 0.02 Bq.m^{-3} all year round, with peaks of up to 0.4 Bq.m^{-3} always corresponding to an increase of local atmospheric temperature. Other local meteorological parameters such as humidity, pressure, and wind, did not correlate well with radon.

The study of weather satellite pictures and synoptic charts revealed that the radon observed at Ferraz comes from the tip of the South American continent during the passage of frontal systems moving east in the Drake Passage.

A characteristic periodicity of about 25 days was resolved from the radon time series by applying a very efficient computational method for spectral estimates (MESA).

ACKNOWLEDGEMENTS

We appreciate the assistance of N.B. Trivedi in the application of the MESA program to our experimental data.

This work was partially supported by CIRM-PROANTAR, grants nos 9586 and 9503.

REFERENCES

1. Lambert, G., Polian, G., Sanak, J., Ardouin, B., Buissan, A., Jegou, A. and LeRoulley, J. C. *Cycle du Radon et de ses Descendants: Application à l'Étude des Échanges Troposphere-Stratosphere.* Ann. Geophys. **38** (4), 497-531 (1982).
2. Whittlestone, S. *Radon Measurements as an Aid to the Interpretation of Atmospheric Monitoring.* J. Atmos. Chem. **3**, 187-201 (1985).
3. Polian, G., Lambert, G., Ardouin, B. and Jegou A. *Long-range Transport of Continental Radon in Subantarctic and Antarctic Areas.* Tellus **38** (b), 178-189 (1986).
4. Pereira, E. B., Nordemann, D. J. R. and Vasconcellos, M. B. A. *Atmospheric Radon Measurements in the Antarctic Peninsula: A Preliminary Report.* An. Acad. Brasil. Cienc. **58**, 182-186 (1986).
5. Pereira, E. B., Nordemann, D. J. R., Takashima, A. M., Dutra, L. S. V. and Mantelli Neto, S. L. *Um Sistema para Monitoração do Radônio e seus Produtos de Decaimento na Atmosfera.* Rev. Brasil. Geofis. **2** (2), 59-64 (1984).
6. Kane, R. P. and Trivedi, N. B. *Effects of Linear Trends and Mean Value on Maximum Entropy Spectral Analysis.* Proc. Indian Acad. Sci. **95** (2), 201-208 (1986).
7. Lambert, G., Polian, G. and Taupin, D. *Existence of Periodicity in Radon Concentration and in the Large-scale Circulation at Lower Altitudes between 40° and 70° South.* J. Geophys. Res. **75** (12), 2341-2345 (1970).
8. Webster, P. J. and Keller, J. L. *Strong Long-period Tropospheric and Stratospheric Rhythm in the Southern Hemisphere.* Nature **248**, 212-213 (1974).
9. Kidson, J. W. *Index Cycles in the Southern Hemisphere during the Global Weather Experiment.* Monthly Weather Rev. **114**, 1654-1663 (1966).