Existence of Periodicity in Radon Concentrations and in the Large-Scale Circulation at Lower Altitudes' between 40 ø and 70 ø South

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Existence of Periodicity in Radon Concentrations and in the Large-Scale Circulation at Lower Altitudes between 40° and 70° South

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South of 40°S, the proportion of continental areas not covered by water (oceans or antarctic ice sheet) is very small. Thus, the atmospheric concentration of radon measured either in the middle of oceans or at stations on the antarctic continent is the result of the action of all phenomena able to change the large-scale circulation at low altiude. An analysis of the results obtained hour by hour for 2 years in three subantarctic or antarctic stations clearly shows for each of them a 28-day periodicity that cannot be found north of the fortieth parallel. The authors present a first interpretation of this phenomenon.

INTRODUCTION

Radon originates from the soil of continents, and its concentration in the lower layers of the atmosphere depends primarily on the atmospheric stability. Generally, the concentration decreases exponentially with altitude, i.e., from 50 to 100 pc/m³ at ground level to a few pc/m³ above 2 km [*Kirichenko*, 1962; *Ba Cuong et al.*, 1967; *Birot et al.*, 1968]. This distribution is generally valid over all large continental masses and is greatly altered only in two cases [*Servant*, 1964; *Fontan*, 1964]. First, in the presence of a temperature inversion, in the immediate vicinity of the ground, radon concentration may reach 5000 pc/m³; and, second, in winter-time, when the soil is flooded or frozen over vast areas, radon concentration may be less than 10 pc/m³.

If we measure radon concentration sufficiently far from a continent, the situation is quite different:

1. The measured concentration no longer depends on purely local meteorological conditions. Even in the Kerguelen Islands, whose

dimensions attain the order of 100 km, studies have shown that the radon that is produced locally is negligible and that no simple correlation may be established between radon concentration and local meteorological conditions [*Lambert and Polian*, 1965].

2. On the contrary, radon concentration depends essentially on the circulation pattern of the air masses from the continents to the measuring station. For example, a long transit time will result in lower concentration, owing to decay of radon (half-life 3.8 days). Further, vertical mixing can also alter the radon distribution considerably. Unusually high values of concentration may result from such particular synoptic situations as those which bring the low-level continental air very quickly, without dilution by mixing from upper air. It is clear, therefore, that the concentration of radon in the atmosphere, where it is measured far from continents, is diagnostic of large-scale atmospheric circulation.

ANTARCTIC AND SUBANTARCTIC MEASUREMENTS

Since the end of the International Geophysical Year, stations for measuring radon concentrations have been established at New Amster-

dam (37°50'S, 77°30'E), Crozet (46°20'S, 51°E), the Kerguelen Islands (49°30'S, 70°E), and Adélie Coast (Terre Adélie, 66°40'S, 140°E) (see Figure 1). The concentration is determined by simply measuring the short-lived decay products of radon.

Since 1967 these stations have been fitted with equipment carrying a large rotating air filter. Every other hour the part of the filter that has been collecting the aerosols is automatically switched over to an α scintillation counter. Through the measurement of α activity decay we can distinguish between the respective contributions of radon 222 and thoron 220. The utilization of this counter has enabled us to obtain the systematic identification of sharp radon concentration variations (independent of variations of thoron) and, consequently, of local meteorological conditions. The amplitude of variations justifies the neologism of 'radon storms' [Polian and Lambert, 1968]; in the example given in Figure 2, it is clear that radon concentration suddenly rises almost to the continental value of 10 pc/m³. In a few cases, these storms occurred nearly simultaneously in several stations.

Figure 3 shows that the monthly mean radon concentration is also subject to variations; in this example the variation shows a marked seasonal character. In subantarctic stations, the concentration doubles during the winter months, when the atmospheric circulation is more rapid.
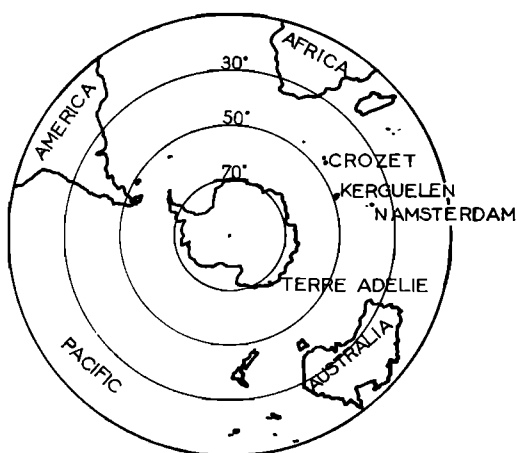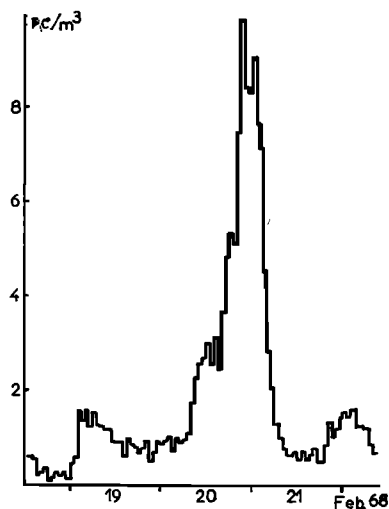

Fig. 2. Example of a 'radonic storm' at Adélie Coast.

For Adélie Coast, however, this increase for winter months is hardly visible. On the contrary, in Adélie Coast for the summer months of December and January, radon concentration increases threefold, up to the Crozet figure; this fact reveals the importance of the penetration into the antarctic continent of northern air masses, probably originating from the southern part of the American continent. (A south African or Australian origin would imply a very unlikely direct meridian transfer.)

CYCLIC VARIATION OF RADON CONCENTRATION

A thorough study of the radon recordings in any of our stations, with the exception of New Amsterdam, shows a cyclic nature of the observed values with a period of about one month.

To specify this phenomenon, the recordings were analyzed by two methods, the periodogram and the Fourier transform. In the periodogram method, the a priori assumption of the existence of an n-day period is made. The analyzed period is split into series of n days. Then the mean values for the 1st, 2nd, ⋯, nth days are worked out. A similar calculation is made for each possible period between 1 and 70 days. This method has the drawbacks of being insensitive and of delivering simultaneously multiples of the fundamental period. The Fourier
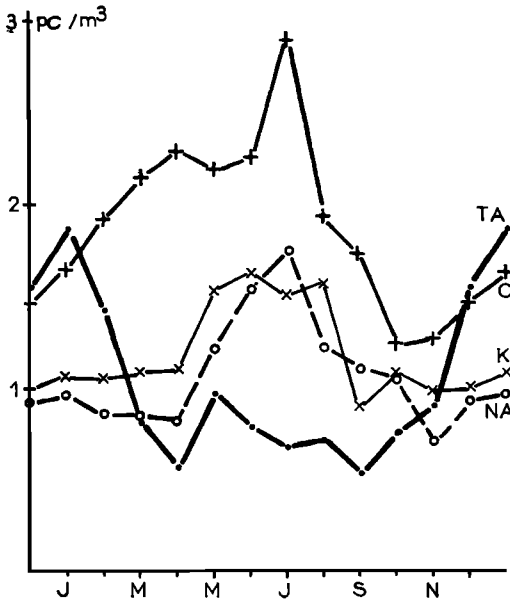

Fig. 1. Map of the Austral French stations in the antarctic area (Crozet, Kerguelen Islands, New Amsterdam, Adélie Coast).

Fig. 3. Monthly mean radon concentrations
(1967–1969); *NA*, New Amsterdam; *C*, Crozet;
K, Kerguelen; *TA*, Terre Adélie (Adélie Coast)

transform method is a classical, well-known
tool. It is very sensitive, but it has the dis-
advantage of being perturbed by the splitting
of the time interval under study.

In the course of this analysis, the following
three precautions were taken:

First, the duration of each time span to be
analyzed was limited to 6 months so as to limit
the effect of possible stochastic shifts. However,
the results remain essentially unaffected when
the analyzed interval lasts longer than a year.
Moreover, these 6-month intervals have only a
3-month shift between them. Eventually, the
calculations were worked out again after a
shift of a few days in order to check that the
results did not show any casual trend.

Second, the complete calculations were made
not only on the original data but also on such
data as had been multiplied by a Gaussian
function, to eliminate edge effects. They were
also worked out again for such data as had
been corrected for the mean of the interval
starting 15 days before and ending 15 days after
the measurements, to cancel the aforementioned
seasonal effects.

Third, a similar calculation was undertaken

on purely stochastic data that had the same
mean value, distribution, and failure intervals
as the observed data. Thus, the splitting effects
due to possible failures are identical.

Figure 4 shows the curves obtained by the
two methods at the Crozet station from March
25 to October 16, 1968, from the original data,
the corrected data, and the stochastic figures.
Figure 5 sums up the results obtained by the
Fourier transform in four of the favorable
cases for data corrected for the mean seasonal
effect in the stations of Kerguelen Islands and
Adélie Coast. Several periods appear on the dia-
gram for the Kerguelen, Crozet, and Adélie
Coast stations. In most cases the main peak cor-
responds to a period of 28 days. This result
clearly appears in Figure 6, which shows the
frequency of appearance of each period during
the duration of our study (2.5 years). The 28-
day period is dominant and is associated with
the values corresponding to the second and
fourth harmonics. Beyond 28 days, no signifi-
cant period can be found. At the New Amster-
dam station, no periodicity is apparent.

Thus, it may be concluded that, in the antarc-
tic and subantarctic regions, the radon concen-
tration in the atmosphere and, hence, the large
scale atmospheric circulation, present cyclic
variations with a period of 27 to 28 days. Never-
theless, the following two remarks should be
made: (1) A first analysis does tend to show
that other scalar parameters of the atmosphere
present a similar cyclic nature. Such is the case
for the barometric pressure at the Kerguelen
Islands; and (2) Although the cyclic character
is well established for most 6-month intervals,
it may happen that it completely vanishes at
one of these stations. Conversely, it may appear
on occasion at New Amsterdam.

INTERPRETATION

If the existence of a 27- to 28-day period is
an experimentally established fact, the interpre-
tation that we may venture is at present only
a hypothesis. One cannot fail to be struck by
the similarity between this period and the
recurrence period (also 27 to 28 days) of the
solar component of cosmic rays, revealed by the
same periodogram method as used here, and
attributed to the rotation of subequatorial zones
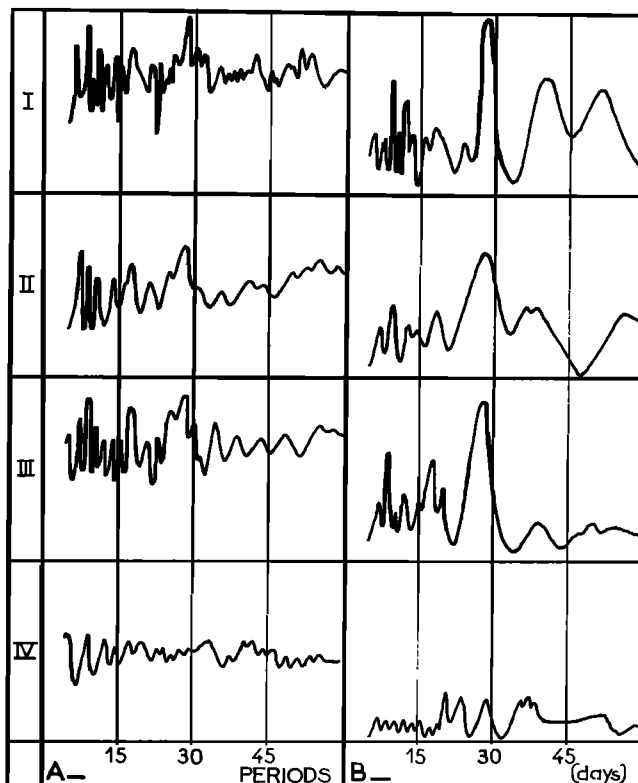on the surface of the sun. This interpretation

Fig. 4.   Crozet: April 4–August 21, 1968; *A*, periodogram; *B*, Fourier transform; I, original data; II, multiplied by a Gaussian function; III, correction of seasonal variations; IV, stochastic data.
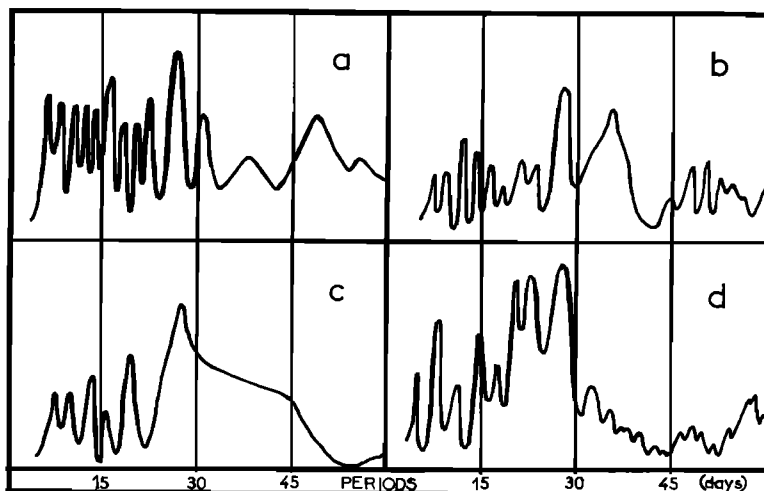

Fig. 5.   Fourier transform corrected for the mean seasonal effect: *a*, Adélie Coast, second half of 1967; *b*, Adélie Coast, second half of 1968; *c*, Kerguelen, first of 1967; *d*, Kerguelen, first half of 1968.
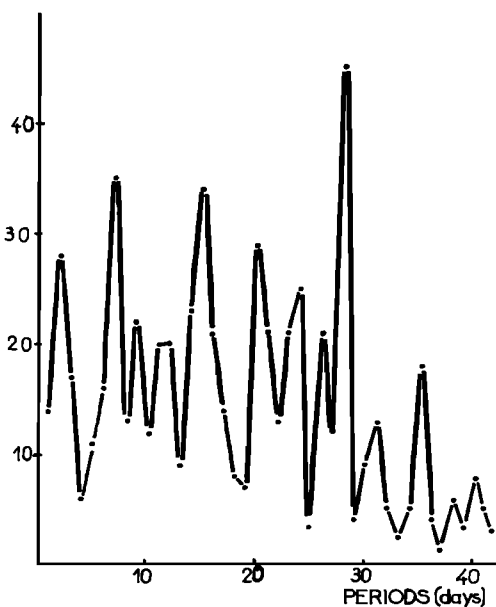
Fig. 6. Curve of frequency of appearance at different periods (for all data, Kerguelen, Crozet, Adélie Coast).

assumes that the corpuscular radiation (which constitutes only a very small part of the energy yielded by the sun) can, nevertheless, influence the general circulation even at a low altitude. No satisfactory model has yet been generated to explain such an influence. However, a similar hypothesis has been formulated by several geophysicists, including *Lambert et al.* [1965, 1966], to explain the cyclic variations, of an 11-year period, in lead 210 distribution in antarctic snow. *Mustel* [1968] has also presented a complete theory that is aimed at explaining the correlations he observed between the major solar flares and the distribution of barometric pressures at low altitudes.

These major flares have an energy that is very much higher than that of recurrent phenomena. Any action of these recurrent phenomena on atmospheric circulation could be explained only if the solar particles triggered a more complex mechanism than that put forward by Mustel.

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