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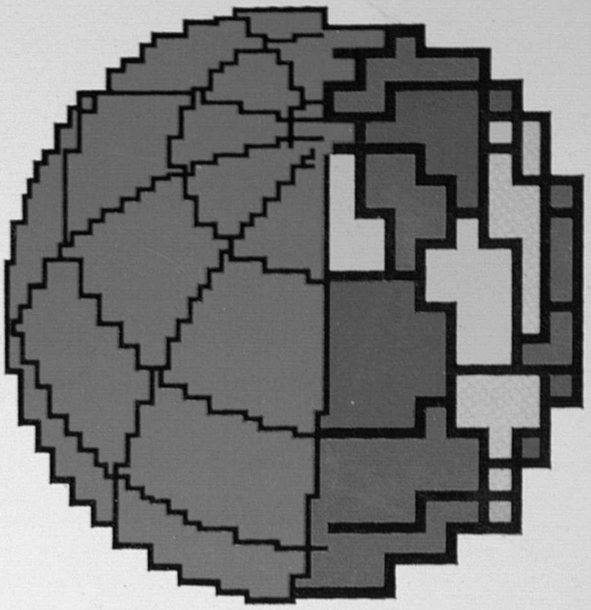

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Istituto Nazionale di Geofisica
Via di Villa Ricotti 42
00161 Roma

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ON POSSIBLE LONG-TERM TRENDS OF SOME IONOSPHERIC SPORADIC-E CHARACTERISTICS

P. Dominici (*) and B. Zolesi
Istituto Nazionale di Geofisica

Abstract

The values of the sporadic-E characteristics foEs and fbEs measured by the ionosonde station in Rome over the years 1949-1984 are analysed by means of the same method used by Baggaley (1984) for similar data from the New Zealandian stations of Christchurch and Rarotonga. The results seem to confirm the existence of some long-term trends in these sporadic E values, but further studies are necessary.

The measurement of ionospheric characteristics by systematic vertical radio sounding began several tens of years ago and now it is possible to study long series of data for many stations in the world-wide ionosonde network. In particular, it is now possible to search for long-term trends of ionospheric parameters, as is done in studies of the elements of the geomagnetic field.

Baggaley (1984; denoted here as BN) has published a short note on the long-term trends (period of about 35 years) of sporadic-E parameters measured by ionosondes at two stations in the southern hemisphere: Rarotonga (21.2° S, 200.3° E) in the subtropical region (year 1947-1980) and Christchurch (43.5° S, 172.5° E) in the temperate zone (year 1947-1983). The author concluded his analysis by suggesting that an investigation of these features in northern hemisphere data should be of considerable importance. Since we have studied intense sporadic-E observed at our station near Rome (41.9° N, 12.5° E) during the period 1948-1953 and (after a complete rearrangement of the station) from 1956 untill the present, it is possible to follow the suggestion of BN, using the same analysis method.

The parameters analyzed consist of hourly values of foEs and fbEs obtained at the Rome station. Roughly speaking, foEs is related to the peak Es ionization and fbEs is related to the Es ionization integrated over the total thickness of the Sporadic E layer. Hourly values from 00 to 04 hours of local time and foEs $\geq$ 4 MHz, fbEs $\geq$ 2 MHz, from 10 to 14 hours and foEs $\geq$ 5 MHz, fbEs $\geq$ 4 MHz, from 19 to 23 hours and foEs $\geq$ 4 MHz, fbEs $\geq$ 2 MHz have been considered as "morning", "daytime" and "evening" period, respectively. The monthly values of the occurrence frequency P (in percentage) for the occurrence of foEs and fbEs have been calculated for each local time interval (thus, the statistical set was typically of 150 values); the seasonal variation has been smoothed by a 12-month running mean.

(*) Present address - Dipartimento di Energetica dell'Università "La Sapienza", Roma.

The results are shown in Figures 1 and 2 for Rome and (by redrawing the original diagrams in BN) for Rarotonga and Christchurch. Following the analysis in BN we have also considered for Rome daytime values with foEs $\geq$ 4 MHz and fbEs $\geq$ 2 MHz and we have added (at the bottom) the 12 month running mean of the sunspot number (as a reference for solar activity) and (at the top) the mean critical frequency foE between 10 and 14 hours (as a reference for normal-E layer ionization). Since the internationally accepted scaling rules (Piggott and Rawer, 1972) for Es parameters were slightly different our fbEs values appear only from 1971. Moreover, before 1956 a complete rescaling of the data would have been necessary; as such, we have plotted only the available daytime values with foEs $\geq$ 5 MHz (which even at that time were scaled regularly in Rome).

For the data here examined the comments in BN were: (i) large fluctuations occur with time in both parameters; (ii) except for daytime fbEs, the data Christchurch and Rarotonga exhibit no coherent pattern between the two stations; (iii) marked trends are present in the data, with foEs decreasing and fbEs increasing, for both stations, for all diurnal periods and in all seasons; (iv) the daytime fbEs occurrence shows strong solar cycle control particularly at Rarotonga; (v) no similar trend occurs for foE; (vi) the observed trends are substantial, in the sense that they are not related to experimental conditions such as overall sensitivity of the ionosondes, enviromental noise and interferences, and scaling techniques.

Our data exhibit features consistent with points (i) and (ii), above. Concerning point (iii), our impression is that the Rome data also exhibit similar long-term trends, but with an opposite sense over the years; i.e., foEs and fbEs occurrences increase rather than decrease from the late 1940's to the present. However, we have some doubts about the homogeneity of our data, because we do not agree completely about the indipendence of such data from the characteristics of the ionosondes.

In Rome in January 1958 an home-made ionosonde (derived from the well-known C-2 ionosonde) was replaced by a more efficient Union Radio ionosonde, which in turn was replaced in November 1979 by a Digisonde 128. We think that the very strong increases in the occurence frequency of foEs, which appear to be centered on 1958 and 1980, are due to greater sensitivity gained by changing ionosondes at these times. In addition, in the change to the Digisonde, the apparent gain also changed because of the recording method (printing) of the ionograms, with its intrinsically larger dynamical range, compared to the previous normal photographic recording. Indeed, in our experience, we have found that by increasing the transmitter power and/or the receiver gain that is by increasing the overall sensitivity of the sounder, foEs present occurrence increases (more for the "f/l" type of Es we frequently observe at our station than for "c" type) and fbEs present occurrence decreases (always). We believe that evidence of such as "ionosonde-dependence" of the Es frequencies is also evident in the diagrams displayed in BN around the time of ionosonde replacement in July 1956 at both Christchurch and Rarotonga.

We discuss in the following only the period 1959-1978 (inclusive), which has reasonably homogeneous data from all three stations for a significantly long time. We have performed a linear regression analysis, between the monthly percentage of occurrence P and the number of the months of the period considered, whose results are displayed in Table 1.

It appears that: a) the long-term trend is very small for evening and morning foEs and fbEs data, probably within the errors if they could be evaluated; b) the same conclusions holds for daytime/foEs $\geq$ 5 MHz data of Christchurch and Rome; c) a marked trend, but with opposite sign, exists for daytime/foEs $\geq$ 5 MHz of Rarotonga (decreasing) and daytime/foEs $\geq$ 4 MHz of Rome (increasing) (a similar correlation with opposite phase appear to occur as well in the monthly data); d) the daytime fbEs data definitly show an in phase solar control for the three stations.

In conclusion, our results from Rome data agree with those of Baggaley regarding the existence of long-term trends for the occurrence probability of ionospheric foEs and fbEs, but less marked and with a less general character than in New Zealand.

To explain these observe trends and their particularities from opposite hemisphere is a quite difficult and complicated matter. In principle, on the basis of the above results many hypothesis are equally probable. For instance, the marked decrease for ”intense” daytime sporadic-E ionization at a subtropical station Rarotonga and for ”moderate” ionization at middle latitude station and the opposite sign of these trends in the northern and southern hemispheres, if real, suggest both the ”equatorial” (i.e. aeronomic) generation of the ionization and its enhancement by (seasonal) solar photoionization. However, the analysis used here and in BN as a first approach to the ptoblem, is incapable of giving a clear answer to this. Because different ”sporadic-E” exist, statistical analyses on hourly values regarding at least the two or three more frequent among the standard ”types” at each station are necessary. We think also that these analyses should be performed on parameters which are certainly not dependent, or at least very little dependent, on observational facts or/and are intrinsically more significant: for instance, (foEs-foE) and (fbEs-foE), as in a recent and very detailed analysis carried out by Piggott (1984).

Acknowledgement

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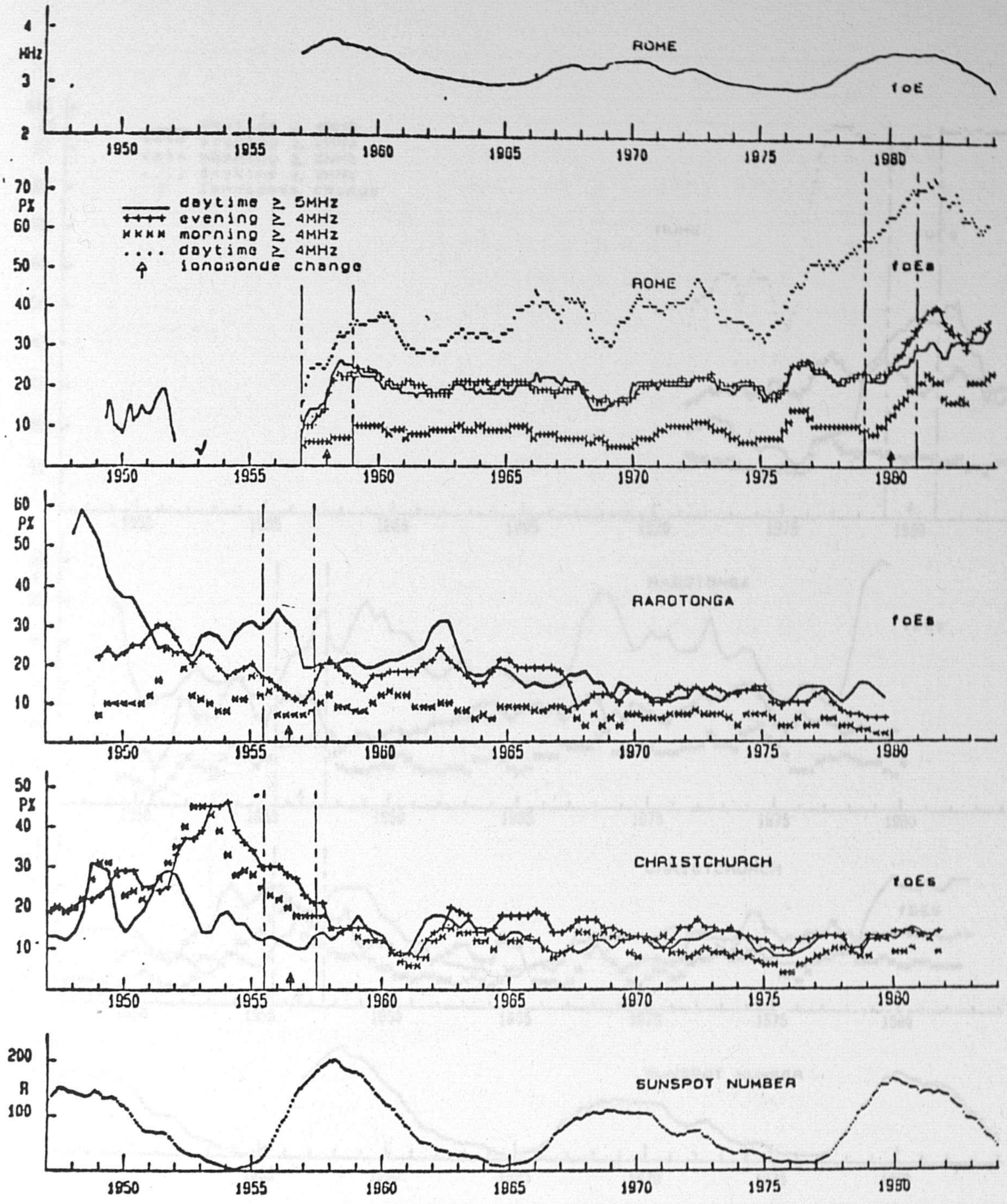

Fig.1. 12-month running mean of monthly sunspot number R, monthly occurrence (percentage) P of foEs exceeding the quoted value during the quoted period for Christchurch, Rarotonga and Rome, and monthly daytime foE for Rome.

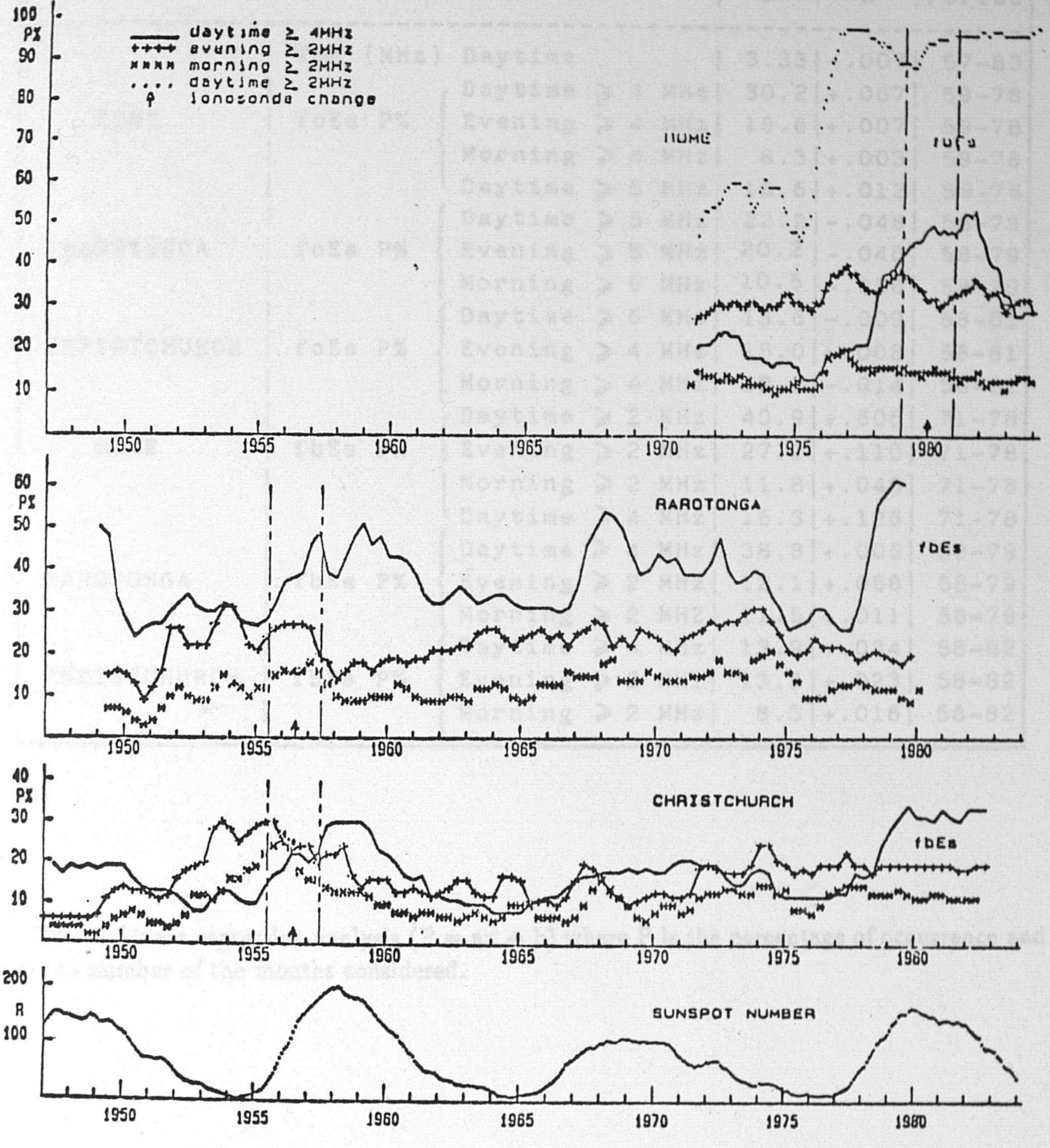

Fig.2. 12-month running mean of monthly sunspot number R, monthly occurrence (percentage) P of fbEs exceeding the quoted value during the quoted period for Christchurch, Rarotonga and Rome.

STATION			b	a	Period
ROME	foE (MHz)	Daytime	3.33	-.007	57-83
	foEs P%	Daytime ≥ 4 MHz	30.2	+.067	59-78
		Evening ≥ 4 MHz	19.6	+.007	59-78
		Morning ≥ 4 MHz	8.3	+.003	59-78
		Daytime ≥ 5 MHz	18.6	+.012	59-78
RAROTONGA	foEs P%	Daytime ≥ 5 MHz	22.2	-.048	58-79
		Evening ≥ 5 MHz	20.2	-.046	58-79
		Morning ≥ 5 MHz	10.5	-.026	58-79
CHRISTCHURCH	foEs P%	Daytime ≥ 5 MHz	13.6	-.009	58-81
		Evening ≥ 4 MHz	15.0	-.008	58-81
		Morning ≥ 4 MHz	12.2	-.014	58-81
ROME	fbEs P%	Daytime ≥ 2 MHz	40.9	+.606	71-78
		Evening ≥ 2 MHz	27.2	+.110	71-78
		Morning ≥ 2 MHz	11.8	+.048	71-78
		Daytime ≥ 4 MHz	15.3	+.126	71-78
RAROTONGA	fbEs P%	Daytime ≥ 4 MHz	38.8	+.005	58-79
		Evening ≥ 2 MHz	12.1	+.058	58-79
		Morning ≥ 2 MHZ	11.5	+.011	58-79
CHRISTCHURCH	fbEs P%	Daytime ≥ 4 MHz	13.9	+.034	58-82
		Evening ≥ 2 MHz	13.3	+.023	58-82
		Morning ≥ 2 MHz	8.3	+.016	58-82

Tab. 1 Linear regression analysis ($P = ax + b$) where P is the percentage of occurrence and x is the number of the months considered.