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Regional study of the ionosphere quietness over Europe

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Abstract
Regional catalogues of the ionospherically disturbed and quiet days are developed on the basis of the analysis of vertical-incidence sounding data over European area during 1964-1990. This paper presents the results obtained by comparing and combining two regional catalogues of the ionospheric disturbed and quiet days into one definitive catalogue recommended for implementation in the PRIME oriented and other studies. According to the criteria applied to the *F* region peak parameters, only 10 to 20% days per year manifest quietness of acceptable level. Comparison of ionospherically quiet days with geomagnetically quiet periods during 1976-1988 shows coincidence of quiet days in both fields not more than 30% of times considered. Conventional practice of analysis of the ionosphere state by comparing it with the geomagnetic conditions should be forerun by specification of the proper ionospheric quiet and disturbed periods.

Key words *ionosphere – geomagnetic field – quiet and disturbed conditions*

At URSI-COST 238 (PRIME) Workshop on verification of the ionospheric models and maps at Roquetes, Spain, May 1992, no publications were presented on the criteria of definition of quiet days in the ionosphere (Hanbaba, 1993). Nevertheless, there is an urgent need to clear up the problem since most of available models and maps concern only the quiet conditions.

Specification of the said conditions in the ionosphere is often made by reference to available geomagnetically quiet or disturbed periods, though sometimes even for magnetic indices $Kp = 6.7$ the ionospheric behaviour seems to be quiet and *vice versa* during quiet magnetic conditions, when *Kp* indices from the last days do not exceed 1, the *F*2 region critical frequency f_0F2 shows irregular deviations from medians and also from the level before disturbance. Even the cross correlation coefficient between f_0F2, delta f_0F2 and *Kp* indices for different solar-geophysical state confirm that, although magnetic and ionospheric disturbances originate both during magnetospheric disturbance, their further development is rather different and is not correlated with each other (Stanislawska, 1993).

To which extent the available ionospheric models and maps are valid in the real ionosphere? What stratification should be made with the ionospheric data and which priorities should become convenient for their analysis? These and other issues require an immediate solution.

In response to that urgent need, work packages have been planned and cataloguing of the ionospherically quiet and disturbed days has been started in PRIME Project (Cooper *et al.*, 1993). In the year after the Roquetes meeting criteria have been defined and the first catalogues appeared for the ionospheric quiet and disturbed days. By the time of COST 238 Trieste meeting (October 1993) three verti-

Table I. Years and data/stations used of $f_0/M(3000)F2$ are marked with (+). UP: Uppsala; KL: Kaliningrad; JR: Juliusruh; SL: Slough; KV: Kiev; DB: Dourbes; PQ: Pruhonice; LN: Lannion; BH: Bekeschabe; PT: Poitiers; RO: Rome.

Years	Data/stations										
	UP F_0M3	KL F_0M3	JR F_0M3	SL F_0M3	KV F_0M3	DB F_0M3	PQ F_0M3	LN F_0M3	BH F_0M3	PT F_0M3	RO F_0M3
1964		+ +		+	+ +	+ +	+			+ +	+
1965	+ +	+ +		+	+ +	+ +	+			+ +	+
1966		+ +		+	+ +	+ +	+			+ +	+
1967	+ +	+ +		+ +	+ +	+ +	+			+ +	+ +
1968	+ +	+ +		+ +	+ +	+ +				+ +	+ +
1969	+ +	+ +		+ +	+ +	+ +				+ +	+ +
1970	+ +	+ +		+ +	+ +	+ +				+ +	+ +
1971	+ +	+ +		+ +	+ +	+ +		+ +		+ +	+ +
1972	+ +	+ +		+ +	+ +	+ +		+ +		+ +	
1973	+ +	+ +		+ +	+ +	+ +		+ +		+ +	
1974	+ +	+ +	+ +	+ +	+ +	+ +		+ +		+ +	
1975	+ +	+ +	+ +	+ +	+ +	+ +		+ +		+ +	
1976	+ +	+ +	+ +	+ +	+ +	+ +	+	+ +		+ +	+ +
1977	+ +	+ +	+ +	+ +	+ +	+ +	+	+ +		+ +	+ +
1978	+ +	+ +	+ +	+ +	+ +	+ +	+	+ +		+ +	+ +
1979	+ +	+ +	+ +	+ +	+ +	+ +	+	+ +		+ +	+ +
1980	+ +	+ +		+ +	+ +	+ +	+	+ +		+ +	+ +
1981	+ +	+ +	+ +	+ +		+ +	+	+ +		+ +	+ +
1982	+ +	+ +	+ +	+ +		+ +	+	+ +		+ +	+ +
1983	+ +	+ +	+ +	+ +	+ +	+ +	+	+ +		+ +	+ +
1984		+ +	+ +	+ +	+ +	+ +	+	+ +		+ +	+ +
1985	+ +	+ +	+ +	+ +	+ +	+ +		+ +		+ +	+ +
1986	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
1987	+ +	+ +	+ +	+ +	+ +	+ +		+ +		+ +	+ +
1988	+ +	+ +	+ +	+ +	+ +	+ +		+ +		+ +	+ +
1989	+ +	+ +	+ +	+ +				+ +		+ +	+

cal-incidence sounding catalogues of the ionospheric Q/D days have been made available:

1) Gulyaeva PRIME catalogue of the 5 most disturbed days and the 10 quietest days per month during 1964-1989 based on criteria (Gulyaeva, 1993);

2) Stanislawska catalogue of European quiet days during 1966-1991 (Stanislawska, 1993);

3) Moraitis catalogue of D and Q days at one station – Athens – during 1966-1974 (Moraitis, 1993).

The list of stations used in (1) and (2) catalogues varies from year to year and comprises 4 to 10 stations in a particular month. f_0F2 and $M(3000)F2$ data were used in (1) and are presented in table I, f_0F2 data were analysed in (2) (table II), and f_0F2 data from Athens station were anal-

Table II. Years and data/stations used of f_0F2 are marked with (+). UP: Uppsala; KL: Kaliningrad; JR: Juliusruh; SL: Slough; KV: Kiev; DB: Dourbes; PQ: Pruhonice; LN: Lannion; PT: Poitiers, RO: Rome; SU: South Uist; SP: St. Peter Ording; SF: Sofia; LS: Lisbon; AT: Athens; GR: Garchy; GB: Gibilmanna.

Years	Data/stations																
	UP	KL	JR	SL	KV	DB	PQ	LN	PT	RO	SU	SP	SF	LS	AT	GB	GR
1966	+				+	+	+		+	+			+		+		
1967	+	+			+		+		+	+					+		
1967	+	+			+		+			+					+		
1968	+				+				+	+					+		
1969	+	+			+	+			+	+			+		+		
1970	+	+			+	+			+	+					+		
1971	+	+			+	+			+	+					+		
1972	+	+		+	+	+		+	+						+		+
1973	+	+		+	+	+		+	+						+		+
1974	+	+		+	+	+		+	+						+		+
1975	+		+	+	+			+									
1976	+		+		+	+		+							+		
1977	+		+		+			+		+							
1978	+	+	+	+	+	+		+	+	+							
1979	+	+	+	+	+	+		+	+	+							
1980	+	+	+	+	+	+				+							
1981	+	+	+	+	+	+		+		+							
1982	+	+	+		+			+	+	+							
1983	+	+		+		+			+	+					+	+	
1984	+	+							+							+	
1985	+	+				+					+					+	
1986	+	+				+		+		+	+					+	
1987	+	+		+		+							+	+		+	
1988	+	+		+		+							+	+		+	
1989	+	+		+		+					+	+		+		+	
1990	+		+					+	+	+	+	+		+		+	
1991	+								+	+						+	

ysed in (3). For analysis of data concerning different points of observation, the local catalogue is more suitable for each ionospheric station indicating 5 most disturbed days and 10 quiet days per month as is done with the planetary geomagnetic indices (Menvielle and Berthelier, 1991). An example of such a catalogue is presented in Gulyaeva (1993, 1994). However, in a more general sense, for justification of applicability of regional (and global) ionospheric models and maps in the present paper a combined regional catalogue has been compiled on the basis of the available European data bank (Hanbaba, 1993).

Separation of data concerning quiet and disturbed conditions is made by different criteria. Gulyaeva's approach is based on ranking the disturbance $Dm-$ and $Dm+$ indices of the negative and positive deviations of f_0F2 and MUF (3000) $F2$ from monthly median and their range Rm regarding monthly mean threshold (Gulyaeva, 1993). Stanislawska estimates ionospherically quiet days by two-fold comparison of deviations of f_0F2 from monthly median and the same deviation but applied to the diurnal smoothed variations of f_0F2 (Stanislawska, 1993). Four fixed thresholds defining degree of disturbance and quietness of f_0F2 regarding its regression on daily relative sunspot number were introduced by Moraitis (1993). Absolute average deviation of f_0F2 from the median less than 0.5 MHz was accepted as a measure of quietness by Radicella *et al.* (1993). The monthly median is taken as a reference level of quietness since it is widely used by available ionospheric models and maps. Other temporal filters, for example deviations from running means for solar rotation etc., are acceptable.

Because of different techniques of classification criteria only negative choice was made below by comparing the regional catalogues (1) and (2). This means that disturbed days from catalogue (1) and quiet days from catalogue (2) are compared. The amount of comparable data is reduced because a coincidence of stations and time in both catalogues is lacking. The results presented in table III show a small disagreement in spite of the quietness criterion taken into account.

Table III. Percentage disagreement between quiet days (Q) from Stanislawska catalogue (2) and disturbed days (D) from Gulyaeva catalogue (1).

Station name	Code	Q	D	%
Dourbes	DB	439	78	18
Juliusruh	JR	434	32	7
Kaliningrad	KL	1071	170	16
Kiev	KV	874	72	8
Lannion	LN	444	46	10
Pruhonice	PQ	57	1	2
Poitiers	PT	506	102	20
Roma	RO	634	59	9 –
Slough	SL	198	23	12
Uppsala	UP	1213	178	15

Though the criteria for definition of the ionosphere disturbance and quietness are different in the above sources, the technique of sum of current ranks (Gulyaeva, 1993) allows to combine results in one presentation. To this end, the results obtained by Stanislawska (1993), have been expressed in percentage ($P\%$) of the quiet days regarding the number of stations used for checking the coincidence of Q-days in a particular month. Note that the former catalogue (2) presented only the number of stations with coincident Q-days and implicitly the list of quiet days at considered stations; however, the stations are widely separated from each other to give the highest sensitivity of quietness within the respective region.

Now when $P\%$ indicates daily degree of PRIME regional quietness (100% – for Q-day occurring at all stations analysed, 0% – for D-day), the following formula is applied to bring these percentage values to Dm indices dimensions of the type (1):

$$Dm = 1 + 0.02 * (100 - P\%)$$

Extending the technique of sum of current ranks to include four rows of data ($Dm-$, $Dm+$, Rm and Dm above), a combined PRIME vertical-incidence sounding catalogue of Q and D days is produced (*). It slightly differs from the former Gulyaeva catalogue (1), however most of former Q- and D-days are reconfirmed by including the 4th row of the Dm indices. Catalogue (3) is not used similar to (2) in combined presentation. Instead, it is left for verification of our combined catalogue by completely independent criteria and data of

(*) Regional and local catalogues of disturbed and quiet days in the European area are available on floppy disk asking for it to «Annali di Geofisica».

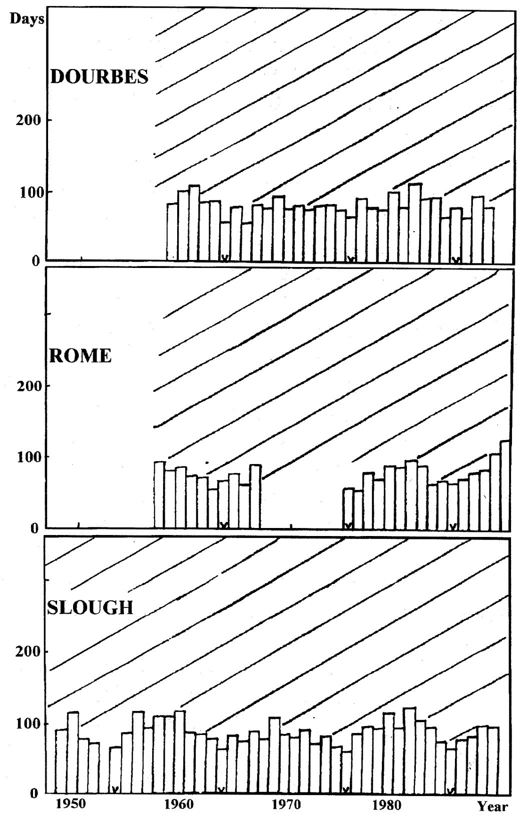

Fig. 1

Athens which were not among the input data for selections (1). Any other sources of the ionosphere information could serve for comparison and verification of our catalogue.

As a result of the mentioned studies the ionosphere proved to be really quiet not more than 20% time per year when the daily data of observation fit nearby the monthly median conditions. This is illustrated in fig. 1 where variation of quiet periods for every year (pixels) depends on the phase of solar cycle, while the dashed area presents the disturbed conditions in the ionosphere which occurred on a long-term scale of observations at Dourbes, Rome and Slough. The above results are based solely on analysis of the local F region peak parameters (Gulyaeva, 1993).

The similar results averaged over the whole European area are given in fig. 2. Curve 1 – the number of the ionospherically quiet days with catalogue by Gulyaeva (1), curve 2 – the same with Stanislawska's catalogue (2) when the number of coincident quiet days at least at T stations occurred (data of $T+2$ stations are checked for a particular month), curve 3 – the number of regional Q-days which are simultaneously quiet in both catalogues. The last number of Q-days is appreciably less than in each of the two catalogues separately. Combining the different values of quietness and disturbances in the ionosphere, including such phenomena as the sporadic E layer appearance, F-spread, etc. the number of quiet days obtained could only be reduced.

Last but not least we are to compare the ionospherically quiet and disturbed periods with similar periods in the geomagnetic field since both fields can be treated as sen-

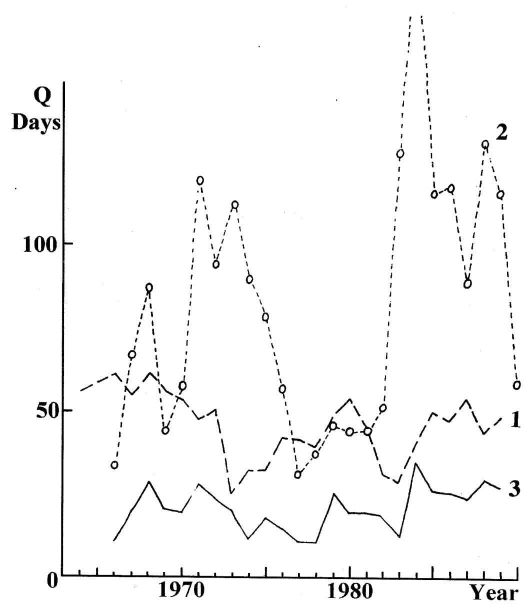

Fig. 2.

Table IV. Ionospherically quiet days coinciding with part of the 7 days geomagnetically quiet periods during 1976-1988. (a) Gulyaeva's catalogue; (b) Stanislawska's catalogue.

		(a)	(b)
1976	May		12,18
	July	19,20	18,19
	Aug.	11,12,19	12,13,15,18,19
	Oct.	21	21
	Nov.	4	5,6
1977	June	7	4
	Nov.	21,22,23,	19
1978	July	29,31	
	Dec.		6
1980	Jan.	18,23	
	Mar.	11,13,15,16,17	8,11,13,15,17,18
1985	June		13,14
	Aug.		3,4,5,7,9
1986	Jan.	14	11,12,14,19
	May	12,13,14,15	9,10,11,12,13,14,15
	July	6,7,12,13,20	4,5,12
	Dec.	9	3,4,7,8,9
1987	Apr.		29,30
	May	15,20,21	1,2,4,5,6,20
	Dec.	30	27,28,30
1988	Jan.	28,29	28,29
	Mar.		20,22,23,24
	Sept.	10	4,10
	Nov.	19.	19,22,23,24,25

sors of processes on the Sun, in the interplanetary media and on the Earth. Such a comparison of the ionospheric quiet days, according to the criteria by Gulyaeva and Stanislawska with the prolonged 7-days and longer geomagnetic quiet periods listed in catalogue (Joselyn, 1990), is presented in table IV. Depending on the criteria applied, we have 225 geomagnetic quiet days due to Joselyn catalogue as compared with the ionospheric quiet days: total 39 Q-days by Gulyaeva, 71 Q-days by Stanislawska and 21 coincident days in all the sources. Again we can state that only 10 to 30% of days both geophysical fields reveal quietness simultaneously. Hence, conventional practice of analysis of the ionospheric data by comparing these with the geomagnetic field state needs preliminary filtering out of the ionospherically proper quiet and disturbed periods.

Convenience of analysis of data for the European region is due to coincidence of the local times with universal time which allows to avoid affecting the ionospheric state by sunlight. The same makes straightforward relation of the ionospheric indices of disturbances with the geomagnetic planetary indices. Transition to other areas of the Earth and to the planetary ionosphere disturbance analysis requires to be more careful to avoid influence of local factors.

The potential value of ionospherically disturbed and quiet days catalogue enables to carry out a comparison of extreme ionospheric characteristics values with magnetic disturbance and Westerbork TID occurrence data (Spoelstra, 1993) by catalogue comparisons as a forerunner to (1) quantifying and mapping directly or indirectly the quiet ionosphere and (2) developing a forecasting capability through the establishment of regression relationships of ionospheric deviation from this base state as a function of the values of some readily predictable disturbance index. The above results can be taken as a most useful initial step.

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