AN "EQUIVALENT DURATION" TO CHARACTERIZE ATMOSPHERIC DISTURBANCES CONNECTED WITH GEOMAGNETIC STORMS

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1. Introduction

The response of the upper atmosphere to short-lived disturbances, usually connected with geomagnetic activity, has been thoroughly investigated by Jacchia [1], Roemer [2] and others. In addition to the parameters predominantly used up till now to describe the geomagnetic effect /time lag and amplitude of temperature fluctuations/ we suggest the introduction of a new quantity that would characterize the total reaction of the atmosphere independently of the actual profile of the variation. In cases, when normal conditions prevail in the atmosphere before and after a geomagnetic storm, the relative density-variation function may be integrated and the resulting area is closely connected with the total response of the atmosphere at a given altitude. A convenient measure of this parameter can be chosen in the form of an "equivalent duration" /D/, i.e. the length of time of a hypothetical disturbance having the same integrated area as the actual one, but giving rise to a constant 100% density increase for D days.

In so far the change of the orbital period of a satellite /$\dot{P}$/ is proportional to the air density at 0.5H above perigee [3], the density curve may be substituted by the /$\dot{P} - \dot{P}_0$/$\dot{P}_0^{-1}$ curve, where $\dot{P}_0$ is the period change without the geomagnetic effect. /If the atmospheric drag differs slightly before and after the disturbance, a medium value should be adopted as $\dot{P}_0$./ 2m

2. The calculation of D by means of the O-C method

Orbital elements with a time resolution of several hours are available only on rare occasions, therefore, we encountered difficulties in constructing adequate $\dot{P}/t/$ diagrams. It is an advantage, however, that the O-C technique can be introduced to determine D-values even without a high time resolution, or special observations during the geomagnetic storm at all. The O-C method needs observations at a fixed, preselected point of the satellite's real orbit, possibly once a day; e.g. the observation of different transits of a satellite through the topocentric celestial equator of the tracking station is a good fulfilment of the condition 4 . The computer programme PERLO serves for the elaboration of this kind of observation 5 . Its first part reduces, in three different ways, series of semiprecise visual observations accomplished near the topocentric celestial equator in order to find exact crossing times, i.e. when $\delta = 0$. All results are transformed to the reference latitude of a hypothetical tracking station and to perigee respectively by means of approximate orbital elements $/O_n/$.

In an undisturbed atmosphere, if $\dot{P}_o \approx$ const, obviously $2/O_n - C_n/ = n/n+1/\dot{P}_o$, where $C_n = O_o + n.P_o$ and $\underline{n}$ is the revolution number and P_o the initial period. If O_o and P_o has been correctly chosen, the $y = 2/O_n - C_n/$ values should be plotted versus $n/n+1/$ in order to find $\dot{P}_o$. It can be proved that after the appearance and disappearance of a short-lived density increase, even if the drag has the same effect again on the satellite's motion, the observed $\underline{y}$-values will be smaller than $n/n+1/\dot{P}_o$, and the difference, Δy, is a linear function of $\underline{n}$. In this case, plotting Δy as a function of $\underline{n}$, the result will be a straight line, the slope of which is equal to $2\dot{P}_o D$.

The second part of the PERLO programme calculates the variation of the quasi-nodal and the anomalistic period respectively. A graphically constructed $\dot{P}/t/$ curve serves to find appropriate time intervals when $\dot{P}_0 \approx$ const. The third part makes use of the results of the first and second to derive D-values in the suitably selected intervals by means of the method outlined above with the help of a least squares solution.

The equivalent duration obtained in this manner is obviously independent of the choice of the satellite and also of atmospheric models. D depends only on the strength of the disturbance and on the position of the satellite's perigee. In order to investigate the variation of D with the height alone, the diurnal effect should be eliminated using one of the atmospheric models. It is convenient to reduce the measured height, corresponding to the actual D-value, to a common $\psi = 90^o$ direction, using an approximate formula 6 , and Jacchia's model atmosphere 7

$$h_{\psi=90^o} = h - H.\ln/1 + 0.33\cos\psi/$$

where H is the scale height.

3. Preliminary numerical results

The PERLO programme has been first applied to determine equivalent durations connected with the geomagnetic event on 26 May 1967 at different altitudes. The observational material consisted of visual observations of 28 Soviet, English, French, Hungarian, Finnish, Rumanian and Polish tracking stations; their breakdown by satellites was as follows:

Table 1

	No. of transits	No. of positions
1963-43A	28	196
1964-76A	38	295
1965-11D	46	257

The time interval in question has been divided into sections of constant $\dot{P}_0$, and the corresponding mean accelerations determined by the O-C method. The variation of the orbital period caused by solar radiation pressure was negligable for every satellite. The results are given in Table 2.

Table 3 summarizes the final results for the geomagnetic storm of 26 May 1967, including two other D-values derived by integrating the published density and temperature curves respectively 8 , 9 .

Several geomagnetic disturbances of the years 1966-69 are now under examination with the aim of determining the equivalent duration at different altitudes and under different conditions of geomagnetic and solar activity.

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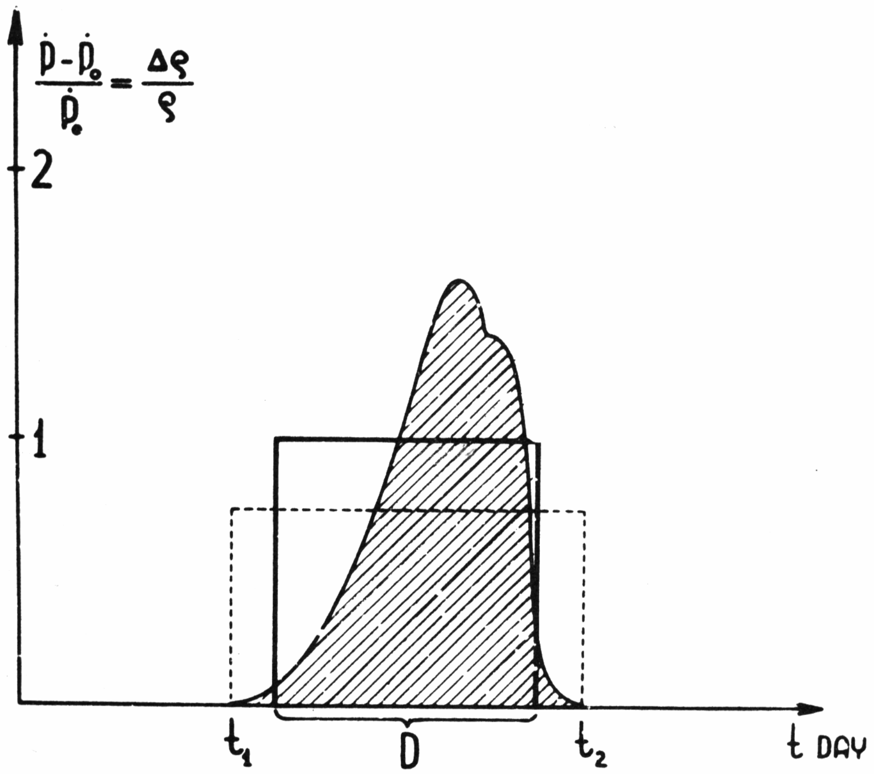
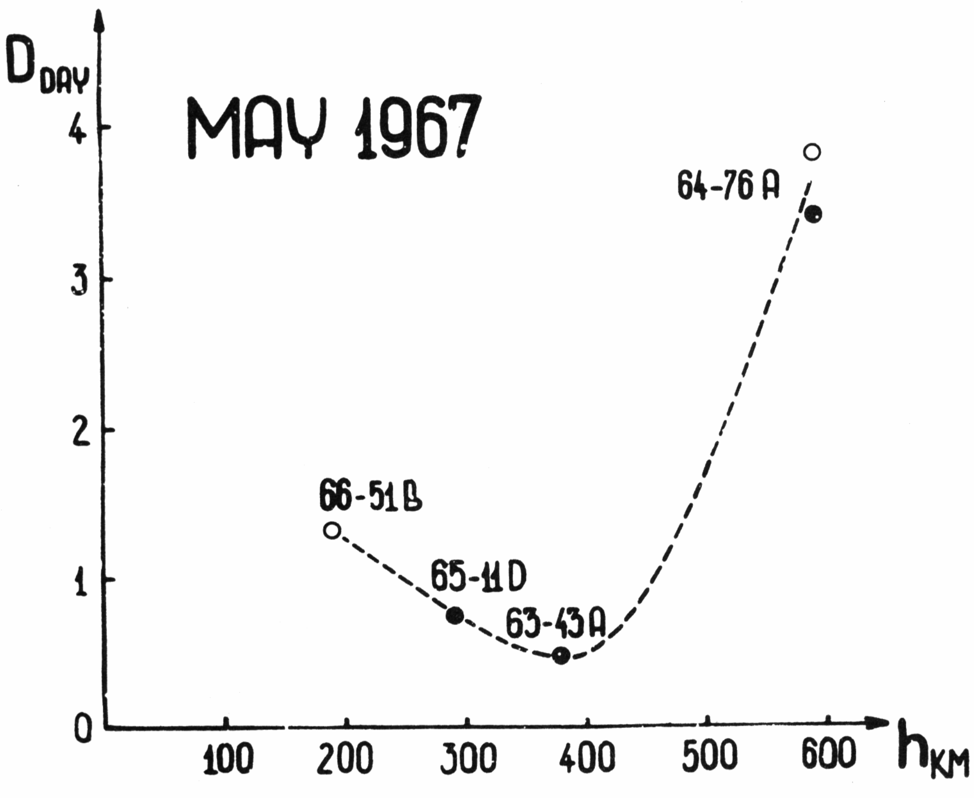


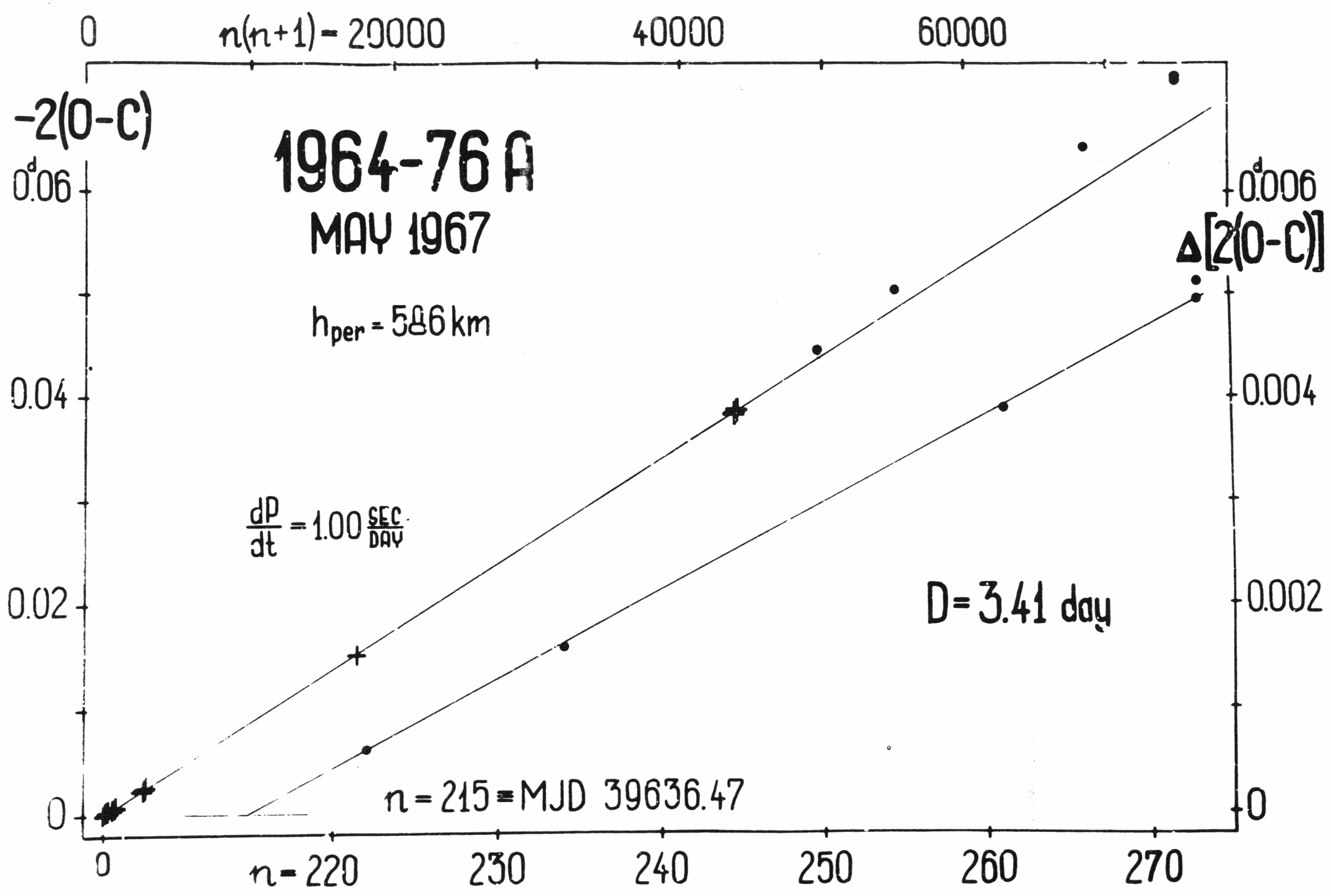
$\frac{\dot{P}-\dot{P}_0}{\dot{P}_0} = \frac{\Delta\rho}{\rho}$
2
1
t_1
D
t_2
t DAY

FIG.1



D_{DAY}
MAY 1967
4
3
2
1
0
64-76 A
66-51 B
65-11 D
63-43 A
100
200
300
400
500
600
h_{KM}

FIG.3



0
n(n+1) - 20000
40000
60000
-2(O-C)
0.06
0.04
0.02
0
1964-76 A
MAY 1967
h_{per} = 586 km
$\frac{dP}{dt} = 1.00 \frac{SEC}{DAY}$
D = 3.41 day
n = 215 ≡ MJD 39636.47
0.006
Δ[2(O-C)]
0.004
0.002
0
0
n - 220
230
240
250
260
270

FIG. 2

Table 2

	MJD	$\dot{P}_o x10^6$	MJD	$\dot{P}_o x10^6$	MJD	$\dot{P}_o x10^6$	MJD	$\dot{P}_o x10^6$	MJD	$\dot{P}_o x10^6$
1963-43A			39633-36:	1.28	39637-41:	1.15	39644-52:	0.73		
1964-76A			39620-36:	11.88	39637-41:	12.09	39642-50:	5.38	39656-69:	2.83
1965-11D	39614-28:	6.36	39630-36:	9.04	39637-41:	10.57				

Table 3

	h /km/		D /day/
1963-43A	380		0.50
1964-76A	586		3.41
		9	3.87
1965-11D	290		0.75
1966-51B	191	8	1.33