COSPAR Várna, 1975 jun 2
cikk leadva 75 jun
főszerkesztő (Rycroft) nem engedte megjelenni, mert ky egy „non-mode" index-et nem lehet integrálni!

I-IV.2.

CONNECTION BETWEEN THE TOTAL INTENSITY OF A GEOMAGNETIC STORM AND THE CORRESPONDING AIR-DENSITY FLUCTUATION

I. Almár[a], A. Horváth[b] and E. Illés-Almár[b]

[a] Satellite Geodetic Observatory, Budapest, Hungary

[b] Konkoly Observatory of the Hungarian Academy of Sciences, Budapest, Hungary

The equivalent duration of air-density fluctuations during a geomagnetic storm is proportional to the integral of the corresponding geomagnetic indices. The coefficient /β/ has been determined by the orbital-drag method in 58 cases. We have found that the farther the drag acts from the centre of the bulge, the larger β is, and the steeper its increase with height.

1. Introduction

Density fluctuations in the upper atmosphere during a geomagnetic storm are transient phenomena superimposed on a relatively slow variation of the "background" density (ρ_0) - at least at a fixed point with respect to the Sun. According to our suggestion, made at the 1970 COSPAR meeting [1], they can be considered as a kind of perturbation, and their total intensity is easily obtainable by integrating the curve of relative density variations during the storm. As the period curve of a satellite accumulates the drag effect of the geomagnetic activity, the observed total change of the orbital period from the beginning till the end of the storm, ΔP_{obs}, implies information on the strength of the phenomenon. The observed value may be directly compared with the corresponding theoretical one, ΔP_c obtained by a step-by-step orbital integration procedure. Using the exact area-to-mass ratio values and a perfect theory of the satellite's motion (geomagnetic effect included) $\Delta P_{obs} = \Delta P_c$. Their systematic deviation from each other is to be considered a sign of inadequacy of the theoretical model.

Such a direct comparison has been carried out in order to check our earlier conclusion that during geomagnetic storms the Jacchia-71 model needs an appropriate correction between 200 and 300 km [2]. Altogether 9 ΔP_{obs} values, measured during one geomagnetic storm in 1966, were selected. The results, given in Table 1, refer to heights below 300 km and on an average show a 28% excess in the total period change, during the

7 days of strong geomagnetic activity, as compared to theoretical values calculated in the Space Research Institute, Moscow. An indirect comparison with the Jacchia-71 model yields a similar 18% excess. A simple relation was used to transform equivalent durations [1] into

$$\gamma = \frac{\Delta P_{obs}}{\Delta P_{J71}} = \frac{D_{obs} + (b-a)}{D_{J71} + (b-a)} \qquad (1)$$

In Eq. (1)(b-a) is the duration of the storm. These results support our earlier conclusions.

The value of ΔP_{obs} in itself is obviously not a suitable parameter of the geomagnetic effect, because it depends on the time interval taken into consideration and on the area-to-mass ratio of the satellite. If ΔP is, however, devided by an integrated mean value of $\dot{P}_o$ (the acceleration in storm-time without the geomagnetic effect) we have the equivalent duration,

$$D = \frac{\int(\dot{P}-\dot{P}_o)dt}{\bar{\dot{P}}_o} = \frac{\Delta P}{\bar{\dot{P}}_o} - 1 = \frac{\int(\rho - \rho_o)dt}{\bar{\rho}_o}. \qquad (2)$$

D is practically independent of the factors mentioned above. If the density is proportional to the rate of decrease of the orbital period, $\dot{P}$, the equivalent duration characterizes the total intensity of the atmospheric response on excess geomagnetic heating during a storm at a given position in the atmosphere. Therefore D is related to a parameter L, characterizing the total strength of the geomagnetic phenomenon, e.g. $\int(a_p - a_{po})dt$ or $\int A_p dt$ or $\int(K_p - K_{po})dt$. We assume, for simplicity, a linear relation D = βL, where the coefficient β may be function of the position (height, geographic coordinates etc.) and of other parameters. In §.3 we shall give some results concerning the form of two β functions.

2. Method of Analysis

Three kinds of data were used to derive 58 equivalent durations with the help of 30 different satellites and 14 storms from 1961 till 1972: a/ visual observations of artificial satellites carried out at Hungarian, Soviet, Roumanian, Finnish, French, British and Dutch tracking stations; b/ orbital elements given by prediction services like NASA GSFC,SAO, Appleton Laboratory; c/ air-density and $\dot{P}$ values published in the literature.

Special methods [3] were used giving us a possibility to improve considerably the time resolution of the period curves. From every pair of visually observed transits of a given satellite a mean value of the anomalistic period, P, was derived, (leaving all other orbital elements unchanged) by the PERLO orbital analysis programme. These values complemented succesfully the infrequent series of anomalistic periods given from time to time by the prediction services. The accuracy of the two kinds of data proved to be practically the same; no systematic deviation was found. The accuracy can be considerably improved if photographic observations are also available [4]. While deducing the equivalent duration values from the period curve, the effect of solar radiation pressure was also taken into consideration.

The other part of the equivalent durations comes from the integral of different density or $\dot{P}$ curves published by Jacchia

[5] and others. The six largest $\int(\rho - \rho_o)/\rho_o\, dt$ values given in a paper by Römer [6] were included as well.

On the other hand we tried to find a characteristic parameter of the total intensity of geomagnetic variations during a storm by integrating different geomagnetic indices. Two cases are of special interest because of the nearly linear relation between Δa_p and the corresponding density change $\Delta\rho$

$$L_1 = \int (a_p - a_{po})\, dt \quad \text{and} \quad L_2 = \int a_p\, dt. \qquad (3)$$

All L_1 and L_2 values were derived by the numerical integration of a_p curves. The results are given in Table 2, as well as other parameters characterizing the position where the drag-effect was most effective on the motion of the satellite. Circular and nearly circular orbits were omitted.

3. Results and conclusions

The correlation between the total intensity of the atmospheric (D_{obs}) and the geomagnetic (L) phenomena was investigated by plotting first the coefficient $\beta_1 = D_{obs}/L_1$ as a function of different parameters. β_1 proved to be independent of L_1, i.e. the linearity of the relation is a good approximation. If β_1 is plotted against the corresponding h_{ref} value (Fig.1 top section) the conclusion can be drawn that at 600-800 km β_1 is somewhat larger than below this height.

If instead of D_{obs} a theoretical equivalent duration D_{J71} is determined by integrating the density curves of the Jacchia-71 model, a similar quantity β_{1J} can be calculated. In accordance with our previous results[2] concerning the altitude dependence of D_{obs}/D_{J71} the increase with altitude of β_{1J} is significantly stronger than that of β_1.

Römer, on the other hand, comes to the conclusion that β_1 is constant and "this linearity proves that the upper atmosphere is a linear recipient" [6] . His study of β_1 is based on 89 events of a single satellite, and he neglects the variation of β_1 with height and position. The value $\beta_1 = 0.0128$, given in his paper, fits our observations only under special conditions (see Fig.1 and 2).

The middle and bottom sections of Fig. 1 show how the $\beta_1(h_{ref})$ function depends on the position of the satellite's perigee with respect to the centre of the bulge. Obviously the increase of β_1 with height is significant only outside the bulge. It means that there must be a noticeable difference between the in-bulge and outside-the-bulge values of β_1 at higher altitudes. The effect is demonstrated on Fig. 2, where β_1 is plotted as a function of ψ_B at different height intervals. Below 350 km β_1 is almost constant, but it increases steadily with the distance from the centre of the bulge, ψ_B, at higher altitudes. From Fig. 1 and 2 one can draw the preliminary conclusion that in case of geomagnetic storms, at least over 350 km, the total response of the upper atmosphere is smaller in the bulge than on the other side of the Earth.

If β_{1J} values from the Jacchia-71 model are used for comparison, it is remarkable that below 350 km $(\beta_1 - \beta_{1J})$ is significantly positive in the bulge, but converges steadily to zero on the other side. It means that according to our observations the atmospheric response below 350 km is stronger around the bulge than the model suggests; there is a satisfactory agreement on the antibulge-side. It is interesting to note that according to

Römer the specific geomagnetic heating at night is about 30% larger than at noon - in qualitative agreement with our results at higher altitudes.

There is no obvious correlation between β_1 and ϕ, which is probably due to the fact that only few points are at higher latitudes. The local solar time LST ought to be also related to β_1, but it is less suited to this kind of investigation than ϕ_B.

Finally the same effect has been investigated using β_2 instead of β_1. A simple relation between the geomagnetic index A_p and the corresponding atmospheric density is published in [7]: $\rho = \rho_o(1 + \beta A_p)$. Using a_p instead of A_p and integrating both sides we have

$$D = \beta \int a_p \, dt = \beta_2 L_2 \tag{4}$$

where $\beta_2 = 0.003$ at 200 km and $\beta_2 = 0.015$ at 700 km. It can be seen on Fig. 3 that Eq. (4) represents a good fit if $\phi_B > 70^o$, but is completely wrong in the bulge where practically there is no altitude dependence.

There are, of course, further possibilities to check all kinds of model relations between an appropriate geomagnetic index and the corresponding density fluctuations. An attempt was already made earlier in connection with a model of Elyasberg and others [8] . We do not think, however, that the results of our investigations can be extrapolated to smaller geomagnetic disturbances, which might represent a different class of geophysical phenomena.

References

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[3] A. Horváth and E. Illés-Almár in: Observations of Artificial Satellites of the Earth, IX, 277 /Warsaw 1970/

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[8] I. Almár in: Observations of Artificial Satellites of the Earth, XIV, /Bucharest 1975/ in print

Table 1. Comparison of ΔP values

Ident	h_{ref} km	ΔP_{obs} 10^{-5} days	$\Delta P_{obs}/\Delta P_c$	$\Delta P_{obs}/\Delta P_{J71}$
65-011A	282	6.08	1.18	1.21
65-011B	284	8.70	1.76	1.21
65-052A	235	16.6	1.33	1.10
65-095A	226	25.5	1.16	1.23
65-095B	236	30.0	1.37	1.19
66-004A	267	12.15	1.18	1.26
66-036A	274	6.30	1.15	1.21
66-043A	220	25.8	1.25	1.04
66-061A	270	7.80	1.14	1.19
Mean	254.9	-	1.28	1.18

Table 2. Observational data

Storm			Satellite							
MJD	L_1	L_2	Ident.	h_{ref} km	ϕ deg	LST hour	ϕ_B deg	D_{obs} day	β_1	β_2
37472	120	138	61-004A	716	-13	9.8	72	0.96	0.0080	0.0069
37507	114	134	61-004A	727	20	10.1	53	1.51	0.0132	0.0113
37601	157	170	61-004A	764	-29	10.6	48	2.31	0.0147	0.0135
38016	93	119	61-004A	650	35	15.3	62	1.24	0.0133	0.0104
38286	92	116	61-004A	456	-27	18.9	78	0.86	0.0094	0.0074
38294	215	244	61-004A	439	- 4	18.7	72	2.36	0.0109	0.0097
39369	275	371	58-001A	368	15	12.4	24	1.72	0.0062	0.0046
			59-001A	591	-29	11.7	53	2.20	0.0080	0.0059
			60-009A	1190	-42	7.7	97	2.90	0.0105	0.0078
			63-053A	703	11	14.7	13	4.94	0.0179	0.0133
			64-004A	1043	- 2	11.3	36	1.51	0.0055	0.0041
			64-076A	590	- 3	7.0	102	4.46	0.0162	0.0120
			65-011A	282	0	13.6	9	3.10	0.0112	0.0083
			65-011B	284	1	13.8	8	2.97	0.0108	0.0080
			65-011D	289	-26	17.0	59	1.60	0.0058	0.0043
			65-052A	235	21	15.3	26	2.05	0.0074	0.0055
			65-095A	226	24	13.7	12	2.65	0.0096	0.0071
			65-095B	236	34	13.4	23	2.38	0.0086	0.0064
			66-043A	220	5	23.9	146	1.61	0.0058	0.0043
			66-044A	302	25	11.7	28	1.70	0.0061	0.0046
			66-061A	270	8	2.7	161	3.12	0.0113	0.0084
39636	258	265	58-001A	361	25	17.7	57	0.67	0.0026	0.0025
			62-076F	251	-14	10.5	64	0.65	0.0032	0.0031
			63-043A	373	54	23.6	99	0.50	0.0019	0.0019
			63-053A	763	-20	16.2	51	1.80	0.0070	0.0068
			64-004A	1034	11	15.3	21	2.01	0.0078	0.0076
			64-076A	583	-60	10.8	89	2.86	0.0111	0.0108
			65-011D	300	50	15.0	32	0.89	0.0034	0.0034
			65-053F	586	54	20.7	79	4.46	0.0173	0.0168
			66-051B	184	-48	1.3	152	0.56	0.0022	0.0021
40018	194	244	61-001A	490	55	11.8	39	1.80	0.0093	0.0074
			63-053A	826	43	12.7	21	1.64	0.0084	0.0067
			64-004A	861	40	6.0	41	1.00	0.0051	0.0041
			64-076A	524	32	12.8	17	1.57	0.0081	0.0064
40161	304	339	60-014A	441	14	9.6	67	1.46	0.0048	0.0043
			63-053A	881	-23	19.2	75	2.13	0.0070	0.0063
			65-011D	284	-27	13.2	15	2.60	0.0085	0.0077
			68-066A	727	0	15.0	24	1.67	0.0055	0.0049
40356	222	262	58-001A	341	15	10.1	54	1.47	0.0066	0.0056
			60-014A	450	-27	12.9	46	1.32	0.0059	0.0050
			63-053A	896	24	16.7	40	2.33	0.0105	0.0089
			64-004A	655	12	8.3	82	2.71	0.0122	0.0103
			64-035A	357	27	13.4	8	2.33	0.0105	0.0089
			65-82LP	734	- 3	8.4	84	4.83	0.0217	0.0184
			66-044A	293	4	6.2	112	0.92	0.0041	0.0035
			66-070A	392	-44	7.4	107	2.02	0.0091	0.0077
			67-042A	496	-51	3.3	144	4.63	0.0208	0.0176
			68-066A	794	-35	15.7	58	2.32	0.0104	0.0088
40494	195	227	58-001A	329	- 3	5.4	129	1.37	0.0070	0.0060
			63-053A	1023	-49	0.0	121	1.00	0.0051	0.0044
			66-044A	305	31	23.6	135	1.63	0.0083	0.0072
			66-070A	405	81	0.6	100	1.06	0.0054	0.0047
40654	235	252	58-001A	290	31	5.0	130	0.50	0.0021	0.0020
			69-82DX	747	62	16.7	74	3.20	0.0136	0.0127
			69-110A	222	39	5.8	118	1.70	0.0072	0.0067
			70-004B	236	-80	2.1	92	1.46	0.0062	0.0058
41536	396	414	63-053A	926	8	5.5	123	8.60	0.0217	0.0207
			68-066A	806	18	21.8	108	7.02	0.0177	0.0169

Figure captions

Fig.1. The coefficient $\beta_1 = D_{obs}/L_1$ is plotted against the reference altitude. In the middle and bottom sections data are separated according to the distance ψ_B of the satellite's perigee from the centre of the bulge. Thin solid lines represent the β_1 value as given by Römer [6].

Fig.2. The coefficient $\beta_1 = D_{obs}/L_1$ is plotted against the distance ψ_B from the centre of the bulge for different height intervals. Thin solid lines represent the β_1 value as given by Römer [6].

Fig.3. The same as on Fig.2. for the coefficient $\beta_2 = D_{obs}/L_2$. Solid lines represent the β_2 function as given in [7].

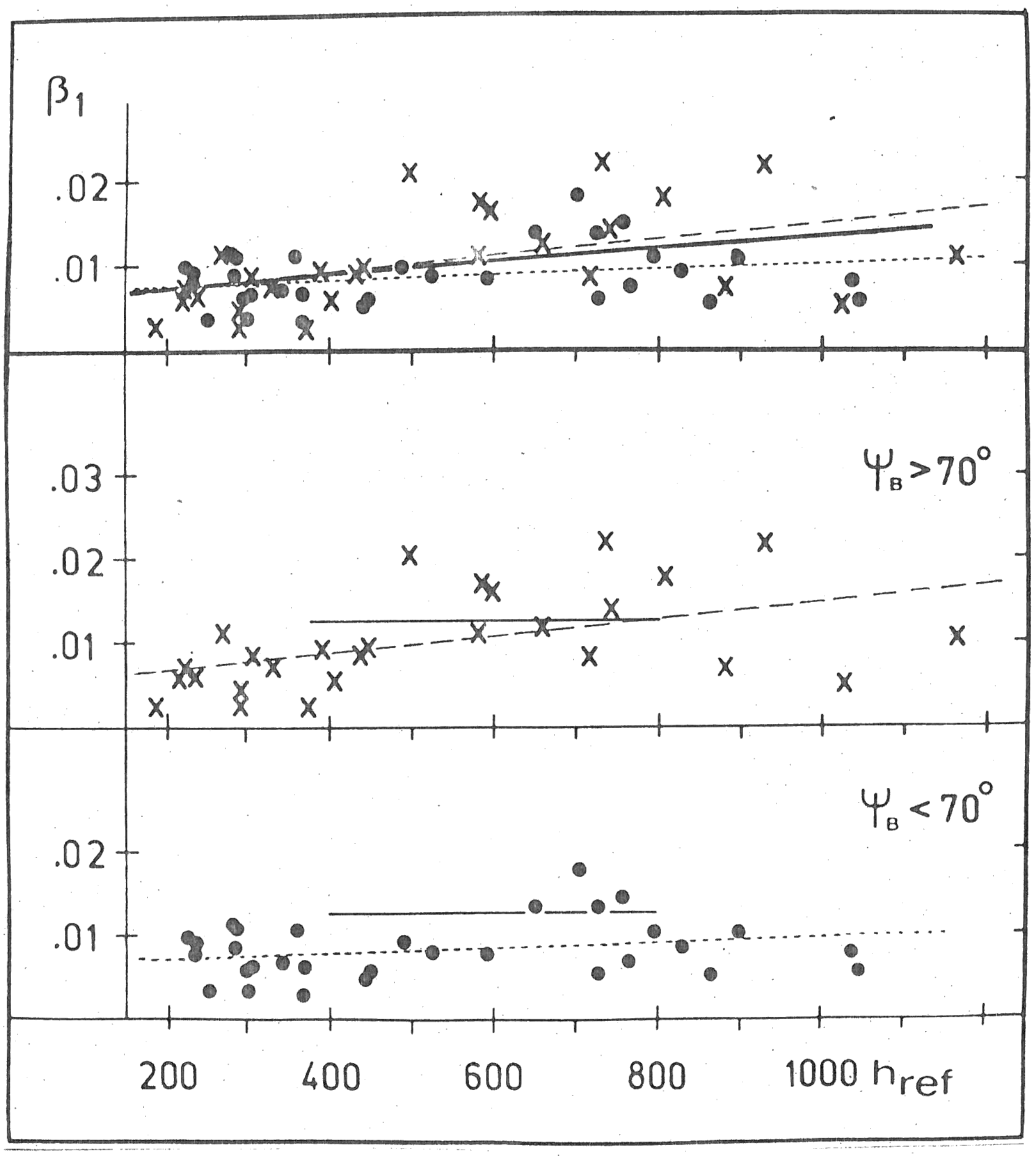

Fig. 1

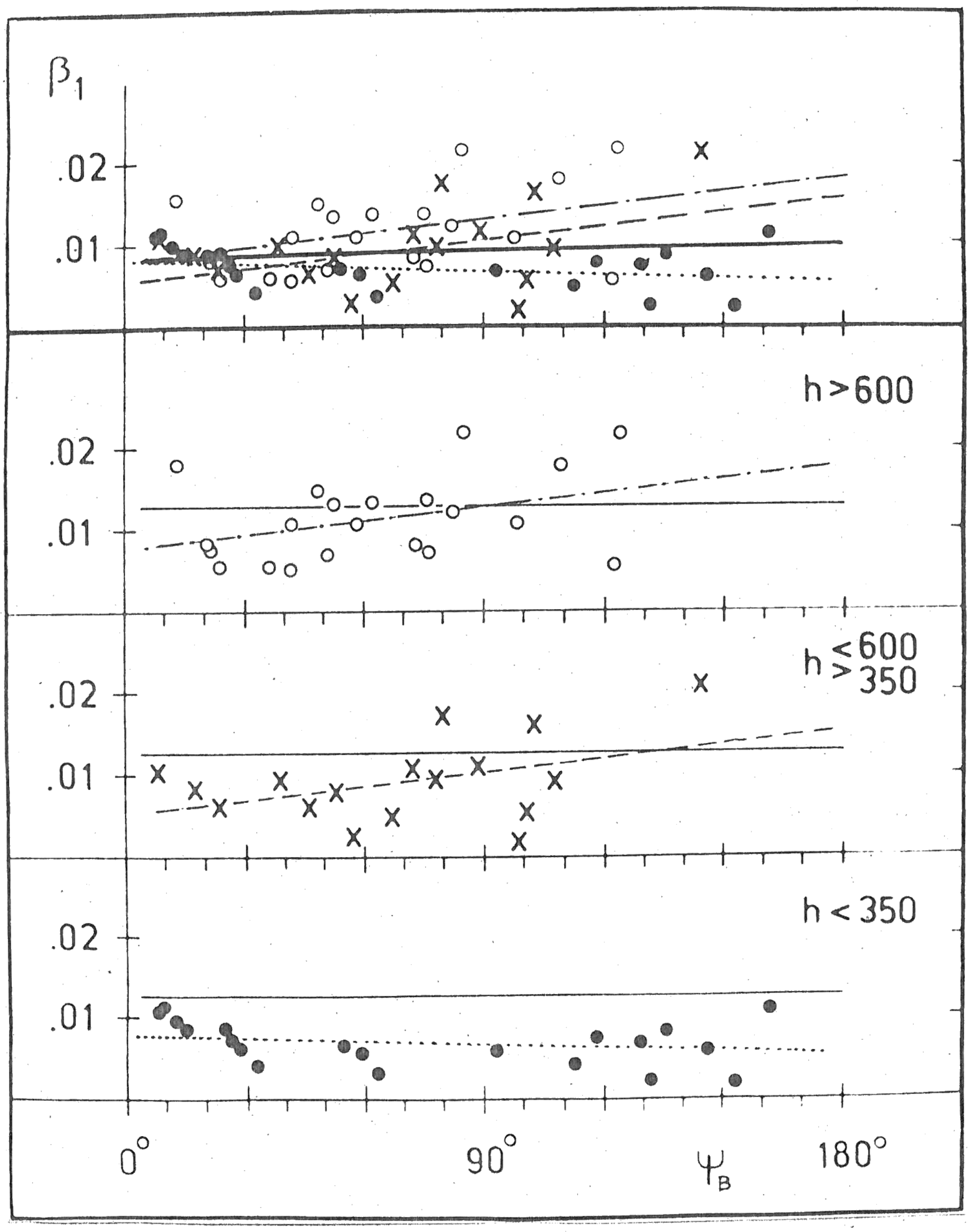

Fig. 2

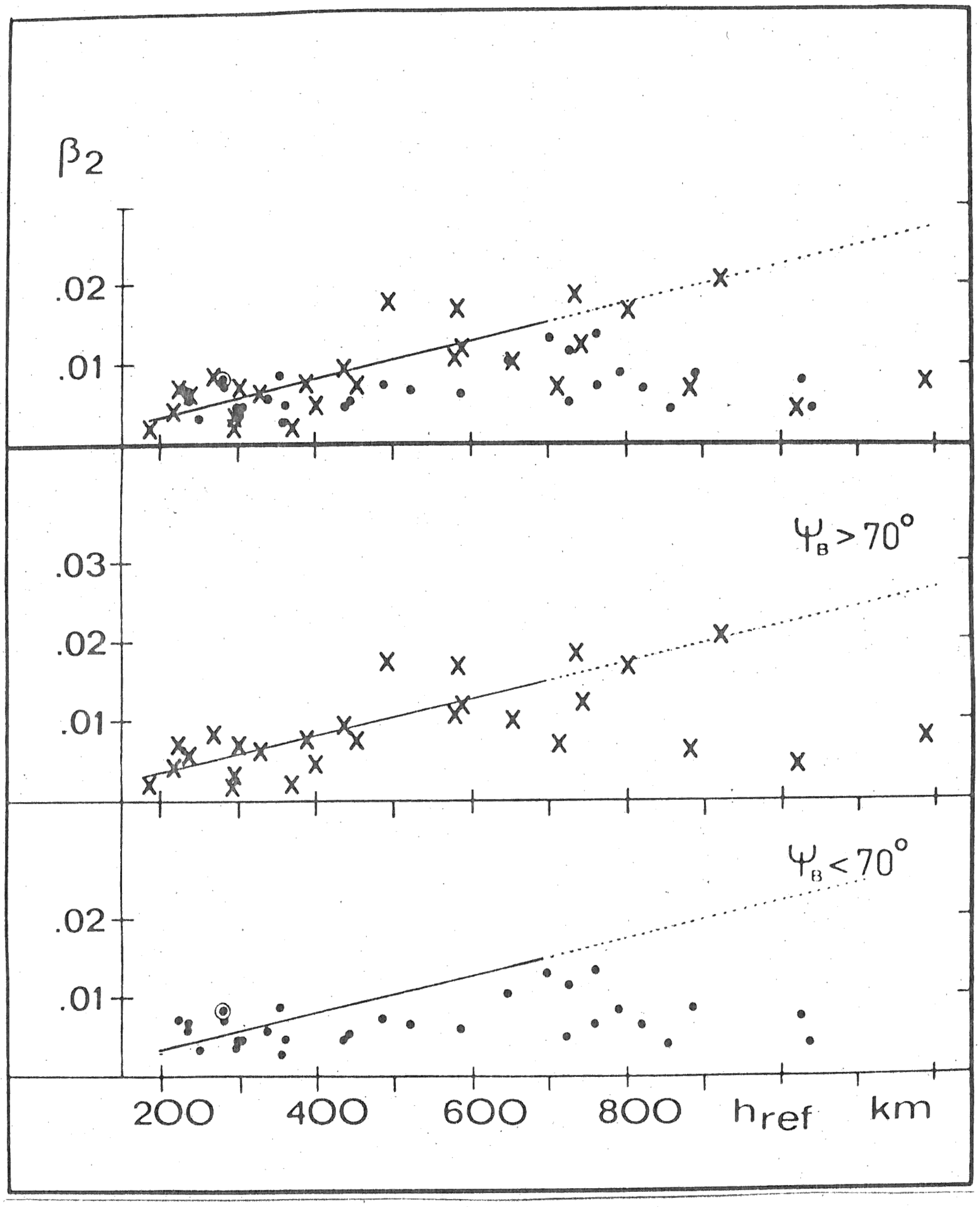

Fig. 3

I-IV - Joint Open Meeting of W.G.1 and W.G.4

UPPER ATMOSPHERE RESEARCH USING SATELLITE TRACKING AND DRAG OBSERVATIONS

I-IV.1. BARLIER F. (C.E.R.G.A., 8 bd Emile Zola, 06130 Grasse, France). Methods of Satellite Orbital Analysis Used for Atmospheric Studies Treatment of Data.

The determination of the global air density has been one of the first applications of the satellite orbital analysis. Now these methods are known very well and a synthetic presentation will be given. Many results have been obtained with great success and a lot of data is available allowing statistical treatments of data and developments of empirical model. The principle of these treatments of data will be reviewed. The validity of data and results deduced from the satellite orbital analysis will be discussed.

The following two papers are to be combined in one presentation.

I-IV.2a. ALMÁR I. (Institute of Geodesy, Földmérési Intézet, 1051. Budapest Guszev u.19, Hungary). On the Determination of the Total Intensity of Density Changes in the Upper Atmosphere During Geomagnetic Storms.

The total intensity of the atmospheric variation during a geomagnetic storm may be characterized either by an "equivalent duration" value, being independent from the choice of the satellite, or by the total change of the orbital period of a satellite during the storm. The latter must always be compared with a corresponding theoretical value determined by a step-by-step numerical integration procedure including an atmospheric model. The ratio of the related ΔP values is a new, independent from the choice of the satellite, easily obtainable coefficient which can be used to correct the formulae of the geomagnetic effect in different atmospheric models. The advantages and disadvantages of the new parameter with respect to the equivalent duration as well as their relationship has been investigated. Theoretical ΔP values have been calculated, using a Soviet model of the upper atmosphere, belonging to the observed total changes in the orbital period of different satellites during 4 geomagnetic storms.

I-IV.2b. (22 37) ALMÁR I. (Institute of Geodesy, Földmérési Intézet, 1051. Budapest Guszev u.19., Hungary). HORVÁTH A. and ILLÉS-ALMÁR E. (Konkoly Observatory, Budapest 114 Pf.67, Hungary). Investigation of Model-Relations of the Geomagnetic Effect By Means of Equivalent Durations.

It has been proved that equivalent duration values are suitable to the determination of the form and the parameters of model-relations defining the atmospheric geomagnetic effect. These relations connect one of the geomagnetic indices and the corresponding density fluctuations. About 70 equivalent duration values belonging to 22 different geomagnetic storms from 1962 to 1972 have been used in the investigation. The equivalent duration values were plotted against parameters - derived by the integration of geomagnetic indices on the days in question - characterizing the total energy of the given geomagnetic storm.

I-IV.3. SEHNAL L. (Astronomical Institute, Ondřejov, Czechoslovakia). The Rotational Speed of the Upper Atmosphere from Orbital Inclinations of INTERCOSMOS Satellites.

The velocity of the rotation of the atmosphere is computed from secular changes of the inclination of the orbits of INTERCOSMOS satellites, the elements of which are expressed as polynomials. After numerical integration of the formula for the change of the inclination, the theoretical curves are compared to the observed values. Good results are obtained from the data of satellites INTERCOSMOS 3, 5 and 9.

I-IV.4. SCHUCHARDT K., BLUM P. (Institut für Astrophysik und extraterrestrische Forschung, Universität Bonn, 53 Bonn, F.R.G.). The Diurnally Averaged Rotation of the Exosphere Deduced From Satellite Data.

The only known method that allows the determination of the diurnally averaged rotation of the thermosphere is the analysis of the time variation of the inclination of satellite orbits. Previous investigations have deduced a linear decrease of the rotation rate of the thermosphere starting with an angular velocity of 1.4 times the angular velocity of the Earth at heights of 375 km down to 0.7 at 500 km. The theoretical explanation of such a velocity profile is difficult. The problem was reanalysed with data from Explorer 24 extending over a period of 4 years. The satellite's perigee height was

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PROGRAM/ABSTRACTS