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UPPER ATMOSPHERE DENSITY VARIATION INVESTIGATIONS BASED ON RUSSIAN SPACE SURVEILLANCE SYSTEM DATA

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ABSTRACT

The aims of the current upper atmospheric density investigations based on Russian Space Surveillance System(RSSS) data are described. The results obtained up to date indicate the real possibility of essential increasing (from 1.3 to 1.8 times) the low Earth orbit(LEO) space object(SO) motion prediction accuracy in the low and high level periods of the solar activity 11-year cycle. The data on the "PION" experiment carried out in 1992 are presented, during which the unique information for the further upper atmosphere investigations at the mean solar activity level had been collected.

1. INTRODUCTION

The dominant factor preventing from raising the accuracy of LEO motion prediction is inadequate knowledge on the upper atmospheric density behaviour. The atmospheric density estimation errors, when using the presently available empirical or semiempirical models (Refs. 1,2,3,4,5), account for about 10% for quiet periods and more than 30% during magnetic storms.

In the states of the former USSR the investigations of spatial-temporal regularities of the upper atmosphere density variations on the base of geoheliophysical and satellite drag data are conducted for several years. Coordination of these works and processing the experimental data are accomplished by SRC "Kosmos". TSAGI(Zhukovsky, Moscow region), Aviation Institute and TSSKB(Samara), Institute of Technical Mechanics (Dnepropetrovsk, Ukrain), TSNPO "Vympel"(Moscow) and other organizations are taking part in it as well.

The aims of this activity are the following:

raising the LEO prediction accuracy on the base of determination and forecasting the atmospheric density short-period fluctuations;

updating the error levels and improving the atmospheric density models used for orbital prediction;

determination of aerodynamic characterictics of simple shaped SO in natural conditions and comparing them with data of labouratory simulation at the vacuum aerodynamic installations.

To date the following basic results have been obtained (Refs. 6,8,9,10,12):

1. The atmospheric density short-period fluctuations determination and prediction technique at the heights 200 - 500 km based on RSSS's LEO drag and geoheliophysical data is developed and mastered by practice.

2. The atmospheric density variations are determined experimentally and the density model errors are estimated for low (30.11.85 - 24.02.86) and high (25.05.89 - 20.08.89) solar activities.

3. The potential possibilities of raising the accuracy of LEO SO motion prediction taking into account the atmospheric density short-period fluctuations are estimated. The accuracy may be raised at an average by 1.8 times, when using the a posteriori estimates of the atmospheric density fluctuations, and by 1.3 times, when using the predicted values of density variations.

4. The aerodynamic factors ratios were determined for the two pairs of passive standard satellites "PION".

The investigation results were put into practice during the process of tracking the orbital complex "Salyut-7"-"Cosmos-1686" at the last stage of flight(Ref. 12).

2. "PION" EXPERIMENT

The "PION" experiment conducted in 1992 is the further development of works on investigation of the upper atmosphere provided the medium level of solar activity. As well as in two previous cases (June and August 1989) the two passive standard satellites "PION-5" and "PION-6" were separated from spacecraft "RESURS-F" at the interval 1 day. The satellites were designed by the Samara Aviation Institute, the constructive characteristics of them being presented in Table 1. More detailed information concerning construction and aerodynamic characteristics of the satellites are given in (Ref. 11).

Name	Mass Kg	Diameter m	Covering material
PION-5	49.465945	0.3300	aluminium-magnesium alloy (AMG-6)
PION-6	49.433945	0.3300	plastiglass covered with nitroenamel

Table 1. Constructive characteristics of satellites "PION"

Name	PION-5	PION-6
Separation date	01.09.92	02.09.92
Separation time (UTC)	8.50	8.36
Separation velocity, m/s	0.1 - 0.4	0.1 - 0.4
Velocity vectors direction to RESURS direct axis, deg	15	15
Period, min	89.090	89.085
Inclination, deg	82.57	82.57
Apogee altitude, Km	249	247
Perigee altitude, Km	228	226
Reentry date	24.09.92	24.09.92
Reentry time	23.58	13.18
Number of orbital parameters updatings	94	56

Table 2. The "PION" separation and tracking data

The data on separation time and velocity vector, initial meanings of orbital parameters, reentry times and a number of parameters updating for the two "PIONs" are presented in Table 2.

"PIONs" stayed in orbit for 22-23 days. During this period the RSSS was keeping a close track of them, their orbital parameters and ballistic coefficients Kb being updated regularly. The last parameter Kb by its sense is a coefficient of agreement between the real SO drag and its calculated value rated with the use of the standard atmospheric density model (State Standard 25645.115-84) without taking into account variations correlated with geomagnetic perturbations indices. That is why for spherical-shaped satellites (including "PIONs") temporal change of Kb is correlated first of all with short-period atmospheric density fluctuations. The graphs illustrating Kb evolution for "PION-5" and "PION-6" are shown on Fig. 1.

It is worth to say that the developed technique of calculating the atmospheric density fluctuations uses not only data on standard satellites drag but also the joint orbital data of several tens of LEO SO with different altitudes and inclinations dwelling in orbit during the experiment. In the experiment of 1992 gathering the orbital data on LEO SO was carried out since the moment of primary planned launch of the spacecraft "RESURS-F" up to the date of "PIONs" reentry(22.05.92 - 25.09.92). The data on state and dynamics of geoheliophysical conditions during this period are presented on Fig. 2, where the changes of solar radio flux index F10.7 and of sum dayly value of geomagnetic activity index Kp are shown. The analysis of data mentioned above allows to assert that the considered period is characterized by mean level of solar 11-year cycle activity and by moderate level of geomagnetic perturbations.

During this period the information on 114 LEO SO was collected. Table 3 comprises the generalized characteristics on all these SO. Figs 3, 4 and 5 shows their perigee altitude, inclinations and mean values of Kb distributions. The total amount of orbital parameter vectors collected and used for the analysis equals 40585. The information gathered during this period(1992) is more represantative and exceeds in number the similar data obtained earlier. For example, in the case of the experiment in 1989 on the interval of 3.5 months only 25000 orbital parameters vectors of 62 SO were gathered. Taking this into account, as well as the fact that the preceeding similar experiments have been conducted at the periods of low and high levels of solar activity, there are every reason to assert that the information obtained in the last experiment is unique and essentially supplements the former one.

Processing and detailed analysis of the gathered information go on. The results will be published in the near future.

3. REFERENCES

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Fig. 1. Variations of Kb(PION-5, PION-6)

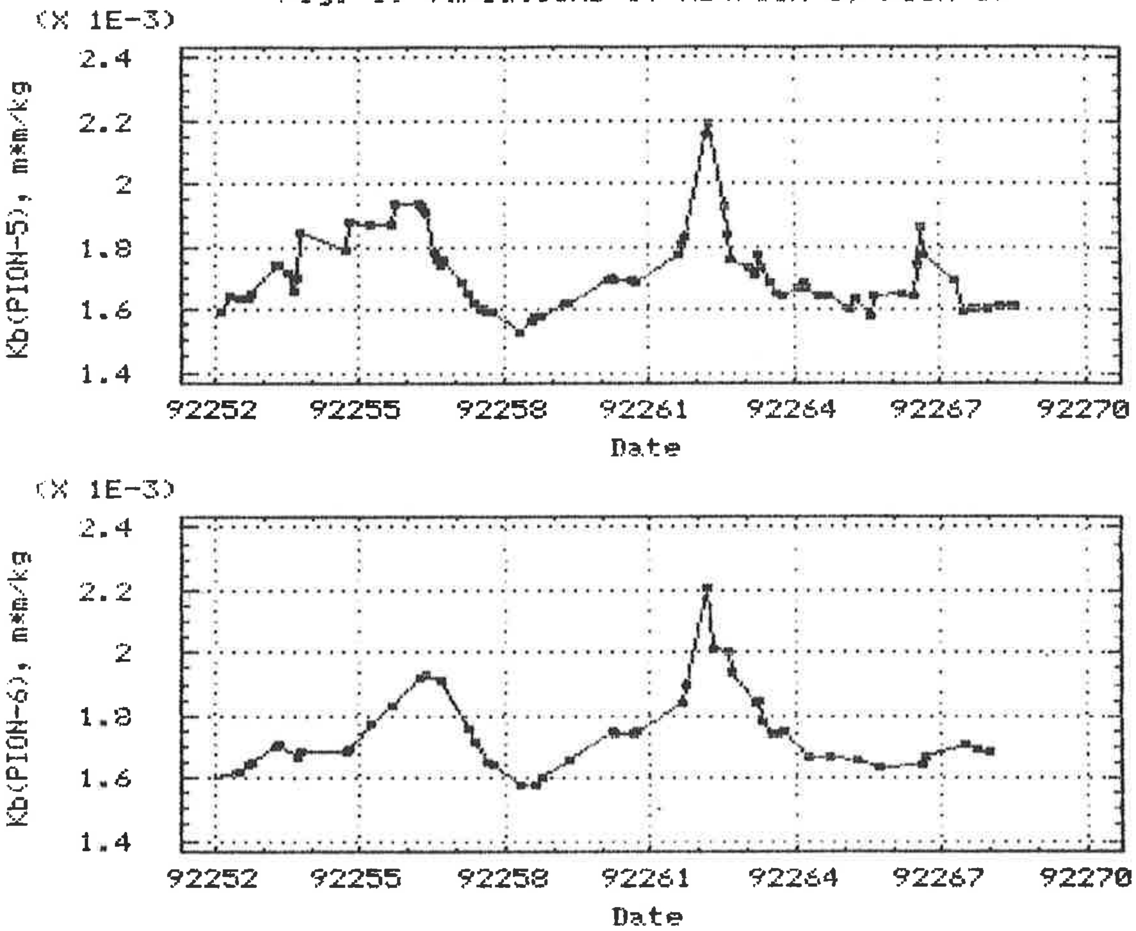
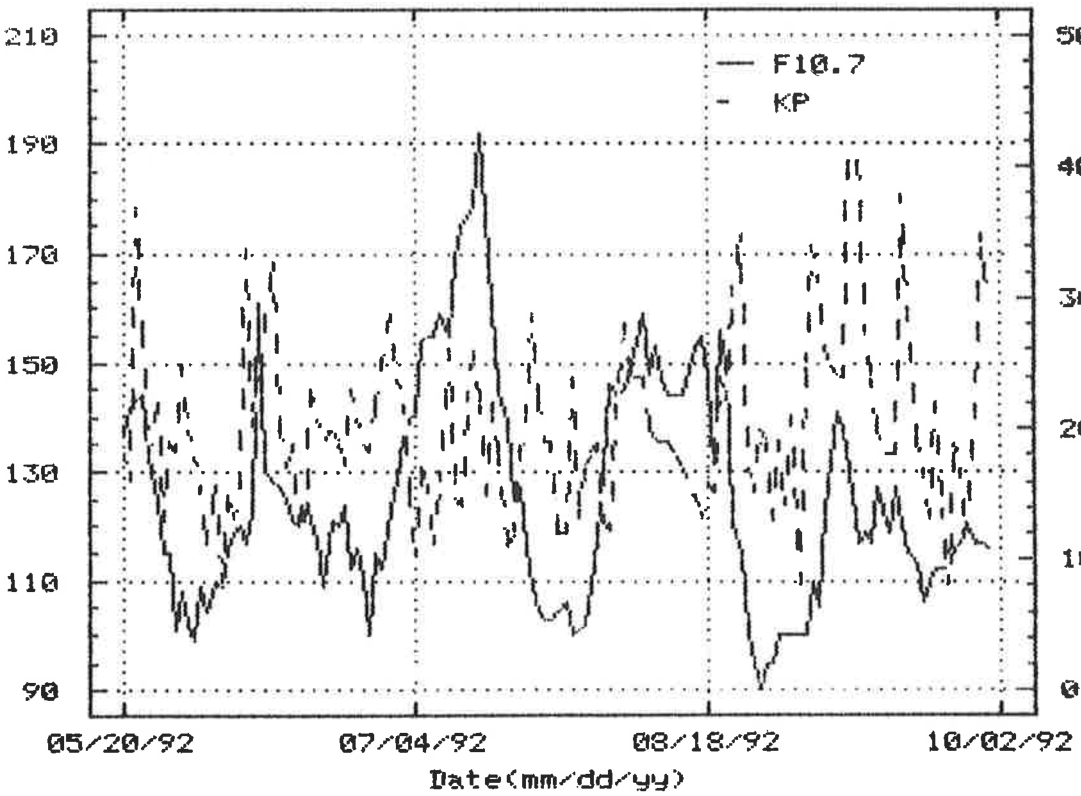


Fig. 2. Solar and geomagnetic activities



Internat. designation	Inclin deg	Perigee KM	Apogee KM	K6 M*M/Kg	Orbital elements
1977 057001	97.3	397	406	0.0059	927
1992 051002	63.0	175	266	0.0038	24
1992 016001	67.2	188	369	0.0029	80
1981 003001	82.9	424	1734	0.0045	70
1967 043002	84.9	394	437	0.0074	1249
1970 025247	97.9	439	498	0.0217	29
1969 084002	81.2	467	531	0.0037	181
1965 038002	97.8	459	543	0.0120	241
1991 027002	28.4	378	392	0.0028	177
1973 080002	81.2	349	370	0.0057	1409
1981 081001	65.1	925	989	0.0002	190
1972 011001	81.1	450	474	0.0041	187
1963 024001	58.2	427	445	0.0051	183
1971 003003	81.1	439	496	0.0110	26
1968 019002	81.2	354	380	0.0048	1432
1990 104018	82.5	454	479	0.1350	213
1990 104019	82.5	463	492	0.1200	255
1991 076002	63.4	230	271	0.0041	91
1992 044002	27.4	194	349	0.0026	92
1990 078001	82.9	421	1915	0.0039	77
1967 011001	39.9	557	1090	0.0290	144
1968 091024	72.1	376	417	0.0470	64
1975 027001	114.9	831	852	0.0005	199
1990 104017	82.5	480	512	0.0990	292
1976 022001	82.9	395	1611	0.0039	79
1975 076001	81.2	385	403	0.0063	1449
1973 078003	28.8	320	888	0.0073	428
1990 104021	82.5	466	503	0.1200	280
1977 061001	81.1	398	420	0.0064	1066
1992 050003	62.3	197	557	0.0075	147
1978 026028	99.0	747	1010	0.0094	72
1990 005001	98.7	838	853	0.0002	144
1990 005002	98.6	795	809	0.0007	149
1984 068001	50.7	252	639	0.0035	953
1986 017147	51.6	383	417	0.0110	407
1986 017149	51.6	389	398	0.0048	230
1990 043010	89.8	438	490	0.0570	288
1990 075001	64.9	412	414	0.0010	995
1976 066043	65.8	303	318	0.0014	46
1984 123001	99.1	844	870	0.0009	231
1988 089001	99.0	853	887	0.0020	191
1987 012002	31.0	436	516	0.0067	162
1965 082354	32.2	421	439	0.0100	139
1987 090001	97.8	345	952	0.0067	229
1984 011005	28.1	265	833	0.0007	171
1990 104001	82.5	487	518	0.0036	83
1990 104002	82.5	509	541	0.0027	81
1985 021004	108.4	445	465	0.0045	178
1990 105002	98.9	364	397	0.0470	144
1987 101001	66.1	702	765	0.0010	633
1987 052001	65.0	915	991	0.0002	616
1979 017008	97.8	323	333	0.0044	560
1991 021001	65.9	424	455	0.0036	1215
1991 021002	65.8	306	320	0.0054	347
1991 017002	68.0	426	587	0.0041	182
1991 005001	64.9	412	418	0.0004	1249
1986 017136	51.6	309	321	0.0049	285
1986 017137	51.6	360	380	0.0045	908
1992 024001	82.1	245	255	0.0011	79
1976 024001	81.2	425	434	0.0067	563
1990 028001	94.1	424	570	0.0055	163
1983 111001	82.9	419	1803	0.0071	78
1965 082113	31.8	419	436	0.0210	207
1992 051001	63.0	183	333	0.0046	205
1992 056004	82.6	248	252	0.0030	56
1972 058058	99.3	426	500	0.0500	350
1990 015002	43.1	202	215	0.0035	11
1990 104022	82.5	465	502	0.1300	281
1992 025001	69.9	229	310	0.0009	202
1972 058070	98.4	385	436	0.0230	575
1966 013001	34.0	498	2492	0.0220	86
1989 026001	47.7	270	272	0.0043	231
1988 099001	97.9	312	998	0.0030	1564
1992 048004	82.3	235	341	0.0039	284
1986 017162	51.6	222	289	0.0100	27
1990 104024	82.5	482	510	0.1200	274
1986 019259	99.6	477	510	0.1300	284
1989 100001	73.5	450	473	0.0034	187
1992 018001	64.8	239	292	0.0021	1213
1983 046001	82.9	265	597	0.0056	1390
1991 072001	74.0	284	538	0.0036	1212
1992 040003	82.3	191	531	0.0091	106
1992 040002	82.3	202	340	0.0066	47
1992 048002	62.3	209	340	0.0096	42
1977 065006	29.0	439	940	0.0120	271
1990 005003	98.6	792	804	0.0007	135
1979 067002	81.2	410	435	0.0068	1295
1986 017140	51.6	358	380	0.0025	904
1986 017131	51.6	235	248	0.0036	47
1975 052079	99.7	387	403	0.1600	7
1979 017056	97.8	439	452	0.0013	129
1986 017001	51.6	383	440	0.0026	1120
1986 062001	64.9	920	996	0.0003	857
1992 007002	97.6	440	548	0.0073	267
1986 002008	74.0	1478	1516	0.0000	166
1986 073001	98.5	806	830	0.0015	175
1986 017154	51.6	397	407	0.0096	64
1986 017155	51.6	408	419	0.0040	11
1986 017156	51.6	405	41	0.0210	51
1986 017134	51.6	249	262	0.0036	78
1992 045002	62.8	206	317	0.0063	55
1986 017153	51.6	405	41	0.0039	52
1987 012007	30.8	400	470	0.0066	240
1987 017129	51.6	289	303	0.0033	247
1987 017132	51.6	273	290	0.0035	154
1986 017133	51.6	274	290	0.0034	162
1991 024001	72.6	332	339	0.0056	1378
1991 062006	31.2	434	660	0.0260	69
1971 015022	65.7	408	660	0.0560	62
1961 013002	28.9	371	526	0.0410	96
1990 104020	82.5	489	512	0.0002	86
1992 056003	82.5	228	249	0.0015	94
1990 104023	82.5	480	508	0.1000	267
1983 079005	74.0	791	805	0.0002	160
TOTAL ***					40585

Table 3. Characteristics of LEO SO

Fig. 3. Perigee altitude distribution

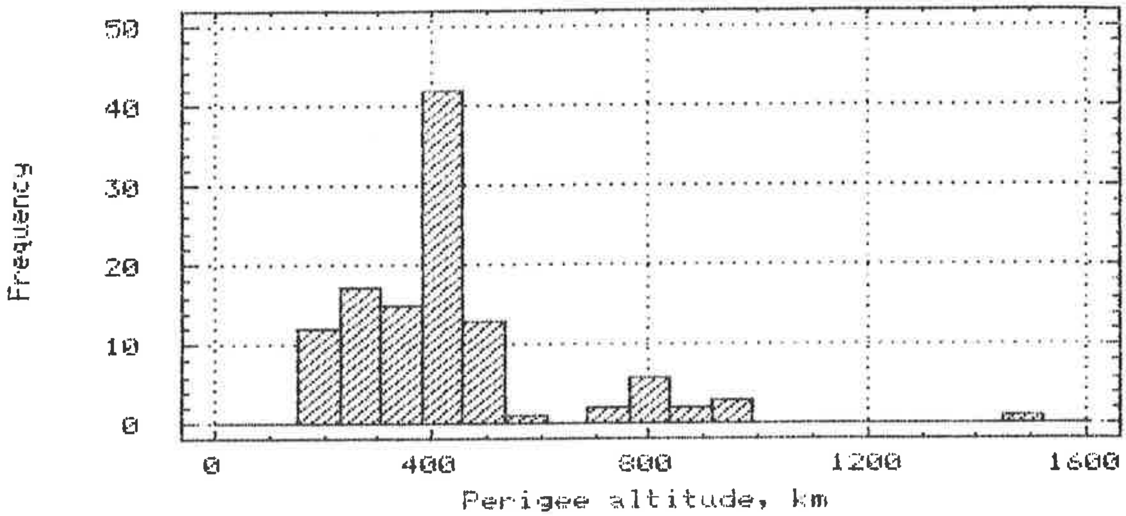


Fig. 4 Inclination distribution

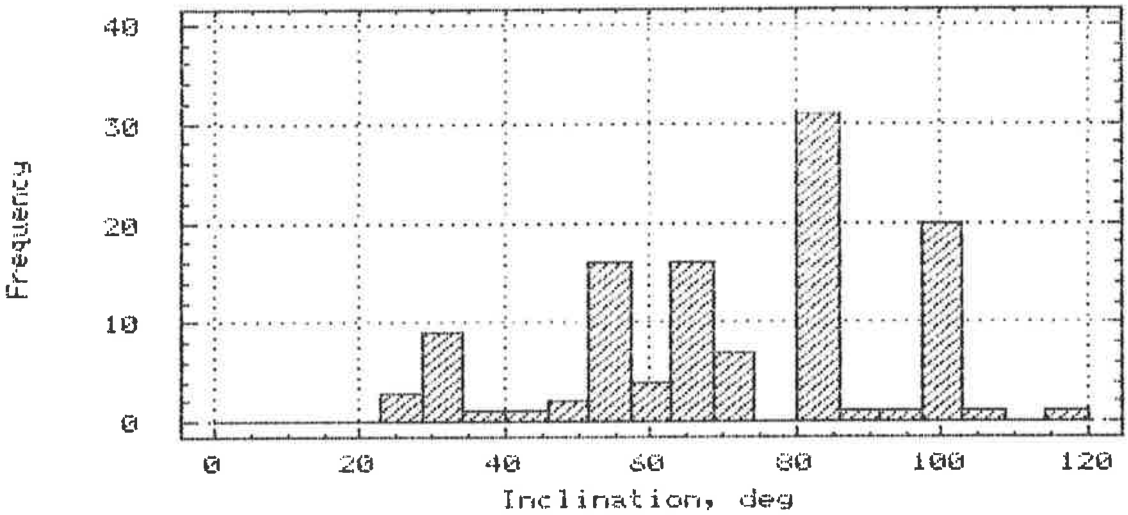


Fig. 5. Kb-distribution