

# Variations of yearly mean values of effective heights for the ionospheric sporadic E-layer

V.F.Petrukhin, E.A.Ponomarev, V.D.Kokourov, \* and N.A.Sutyurin

Institute of Solar-Terrestrial Physics SB RAS. 664033 Irkutsk-33, p/b 4026.

Tel. (3952)-51-16-06, fax (3952)-51-16-75

E-mail: zdk@iszf.irk.ru

## Abstract

An analysis of the time variations of the yearly mean values of the sporadic Es-layer effective heights using the observations from Irkutsk (52.47° N, 104.41° E) spanning the time interval 1960-1996 show that sporadic EsC, EsL and EsF form within the 105-132 km region. Their time variations are similar to one another and have a typical period of about eight years. During 1967-1969 the sporadic EsCL layer underwent a decrease relative to the long-term mean level by about 20 km; for a long time afterwards (about 17 years) these values remained low and it was not until 1985-1987 that they recovered to the mean level.

In order to understand better the sporadic EsCL layer formation, we examined the statistical correlation between solar and magnetic activity for the period 1900-2000. Noteworthy is the fact that the correlation between solar and magnetic activity decreases drastically and becomes negative approximately during 1969-1987. That period of time showed the anomalous EsCL layer behavior. It was also noticed that the correlation between solar and magnetic activity has a different character for the rising and decreasing branches of solar activity, acquiring an anomalous character in cycle 20 and 21.

Key words. Solar activity, magnetic activity, ionospheric sporadic Es-layer.

## Introduction

To understand the processes and phenomena in the upper atmosphere and the cause-and-effect relationships between different regions of the atmosphere requires a detailed analysis of the atmospheric parameter variations for a long period. The state of the upper atmosphere undergoes a host of variations under the effect of solar activity, seasonal cycles, and geomagnetic activity, which makes such an analysis very difficult. A large body of observational data on the state of the upper atmosphere has been accumulated over the last several decades. This makes it possible to undertake an analysis of the long-term regime of upper-atmospheric conditions and investigate the upper atmosphere climate as well as opening up fresh opportunities to investigate a large number of phenomena and processes in the upper atmosphere that have previously been inaccessible for analysis. For example, this would imply studying the main regularities of the origin and development of sporadic ionization structures. Such investigations can be made for a long-time span, for different states of the Sun-Earth system (for different conditions of solar and magnetic activity, etc.). Long-term changes of upper-atmospheric parameters can be recorded and analyzed only over time intervals far exceeding the length of solar cycle. Currently existing observational data permit only preliminary investigations of the secular variations of upper-atmospheric parameters. This was stressed in papers [1,2].

## Statement of the problem

Occupying the space at 85-140 km altitude, the ionospheric E-region is formed in complicated conditions under the forcing of meteorological processes and tidal phenomena from below, a broad spectrum of solar electromagnetic and corpuscular radiation, and meteor fluxes from above. The regular ionospheric E-region and sporadic Es-layers of different types lie in this region of space.

The unconventional structure of the ionospheric E-region has always attracted the attention of physicists, who have sought to explain the causes for the sporadic features with increased electron density, and examined the stability of these structures and the influence exerted on them by regular winds, turbulent motions, etc. During 1930-2003, numerous investigations were made of the main spatial and temporal occurrence patterns of the sporadic layers, and a number of mechanisms and

theories were suggested to explain the formation of such features. No mechanism or theory that satisfactorily explains the occurrence of all different types of sporadic layers has been suggested. The climatology of the ionospheric Es-region remains virtually unexplored.

With the purpose of investigating the regularities of the various sporadic features and the climatology of the region of space in question, it seems appropriate to study the variations of some ionospheric layer parameters over a long time interval.

### Experimental data.

We have used for the analysis the long-year homogeneous data of vertical ionospheric radiosounding at observatory Irkutsk (52.47 N, 104.41 E) for 1960 – 1996. Before 1964 the observations were provided by the automatic ionospheric station 249 type (produced in UK), during 1964 – 1996 - by the panoramic ionosonde AIS produced in USSR.

Processing of ionograms and scaling E-sporadic were carried out in accordance with [3]. The annually averaged values were calculated as average for the complete calendar year.

We considered four types of Es.

- Type C (further EsC) – this type is a daytime phenomena, the radioecho usually is continuous with normal E-layer but later forms a clear cusp near f<sub>0</sub>E.
- Type L (further EsL) – usually is a daytime phenomena too and a flat low type Es, this forms below and is disconnected from the normal E-layer.
- Type F (further EsF) – a flat Es layer without increasing of height with increasing of frequency, this occurs only at night.
- Type CL (further EsCL) – this additional classification was used by authors for the observations when EsC and EsL existed at the same time. In case of EsCL f<sub>0</sub>Es, frequency of screening and virtual height are related to EsC. The similar definition was used in [4].

Other types of Es (for instance EsH) were rarely observed in Irkutsk and were not considered.

Table 1 shows the monthly mean number of Es types observed for 1960 – 1996.

Months	Es types			
	EsC	EsCL	EsL	EsF
1	65	13	70	124
2	64	8	59	58
3	108	7	53	35
4	155	10	50	33
5	342	21	49	86
6	394	23	57	96
7	386	22	64	111
8	347	20	56	137
9	226	31	88	134
10	169	32	109	164
11	82	16	104	131
12	77	17	72	134

### Results of analysis

EsC, EsL, EsF and EsCL types are commonly seen at mid-latitudes. Each type was analysed separately by calculating the yearly mean values of effective heights h'Es. It was found that the effective heights of the sporadic EsC, EsL and EsF vary within 105-132 km region with a typical period of about eight

years. The time variations of these values reveal a high similarity to one another. The time history of the values under discussion is plotted in Figs. 1 and 2.

A totally different picture is observed in the variations of yearly mean values of effective heights of sporadic EsCL formations (Fig. 2).

During 1967-1969 the average height for this sporadic layer type decreased relative to the mean level by about 20 km; for a long time afterwards (about 17 years) these values remained low, and it was not until 1985-1987 that they returned to the long-term mean level.

The search for any cause-and-effect relationships between solar and magnetic activity has been unsuccessful. For instance, Fig. 1 shows the time history of yearly mean values of Wolf numbers [5]. It is clearly seen that the average sporadic E heights are not correlated with solar activity, nor is there a direct correlation between Es heights and magnetic activity.

For the comparison of the features of the temporal variations for h'Es and other geophysical events we examined the statistical correlation between solar and magnetic activity for the period 1900-2000. For this purpose, the correlation coefficient between annually averaged Wolf numbers, W, and annually averaged values magnetic activity AA indices was determined for a time span of 11 years. The result obtained was assigned to the middle of this interval, which was then shifted by one year, the calculation being repeated, and so on. This calculation is shown in Fig. 3. The correlation coefficient between W and AA has - over a long time period - been high, and most importantly, had a positive value. However, in 1964 this coefficient starts to decrease rapidly until in 1969 it takes on a positive value and recovers to the long-term high level by 1987. A similar picture is also observed for the correlation of the solar emission flux at 2800 MHz frequency with the aforementioned AA indices.

Noteworthy is the fact that the anomalous EsCL layer behavior is observed in about the same years, when the correlation between solar and magnetic activity decreased dramatically and became negative.

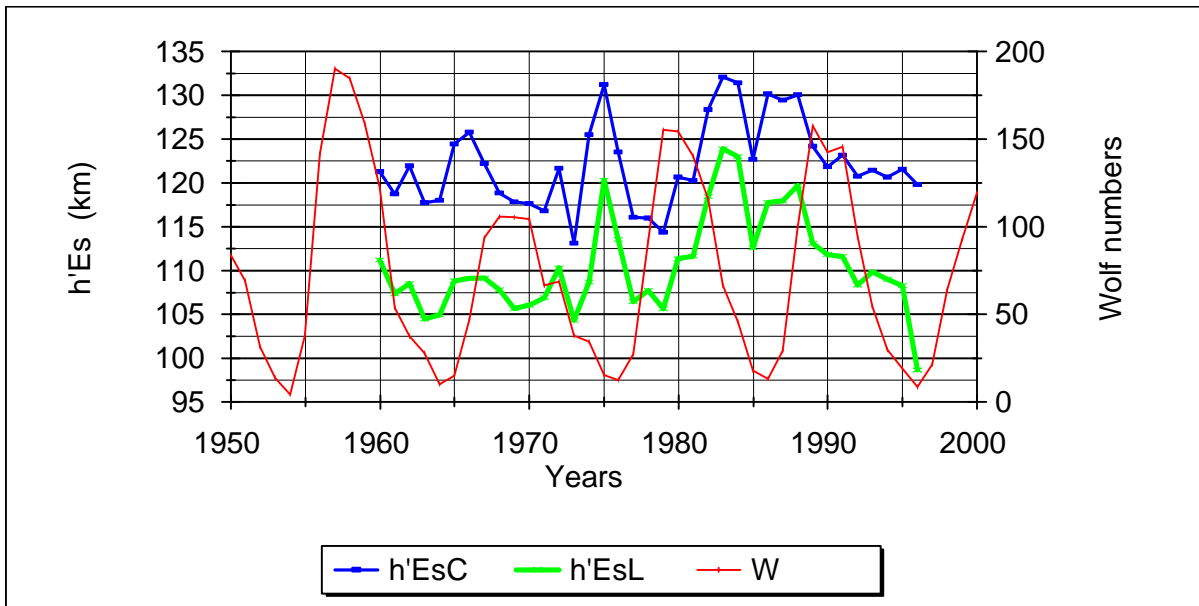
## Discussion and conclusions

The large-scale time variations of average effective heights of the sporadic "C", "L" and "F" layers have a high degree of similarity, with a typical period of eight years.

The average effective height of the sporadic Es-layer of the "CL" type has a peculiar and very complicated time variation. This has been compared with the statistical correlation between the values of W and AA. The large-scale variations in the average effective sporadic E layer heights and the correlation between solar and geomagnetic activity demands further investigation.

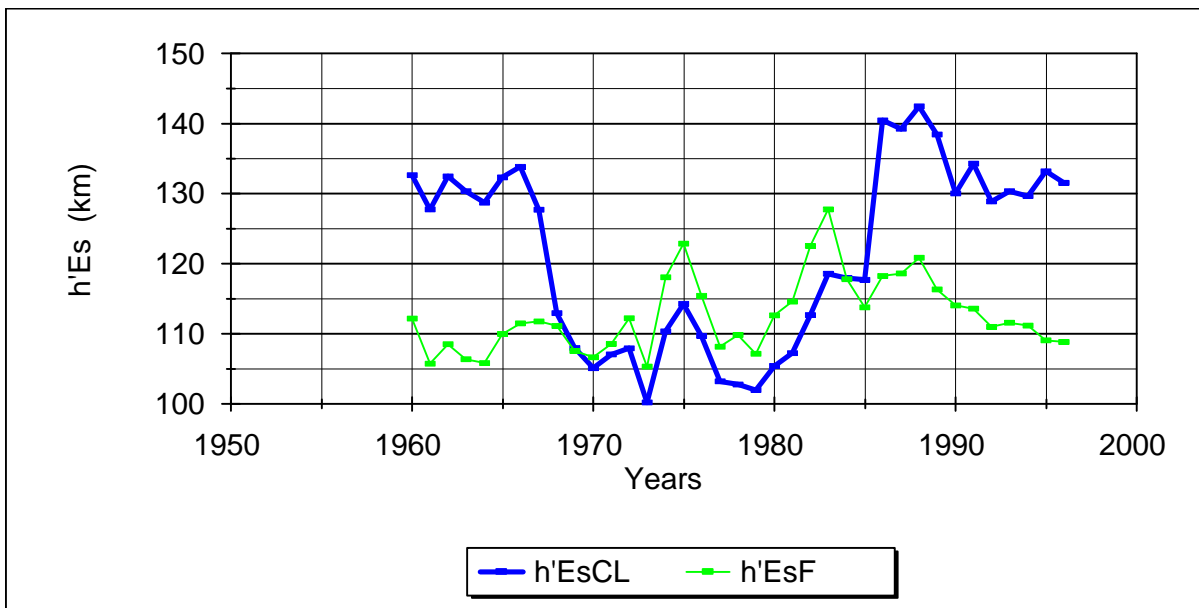
## References

1. Rishbeth H. Long-term changes in the ionosphere. In *Adv. Space Res.* 1997. Vol.20, No.11, pp. 2149-2155.
2. Kokourov V.D. Homogeneous series of observations in solar-terrestrial physics. In "Issledovaniya po geomagnetizmu, aeronomii i fizike Solntsa". Moscow: Nauka, 1998. v.109, pt. 1, pp.8-12 (in Russian).
3. Wright J.W., Knecht R.W. and Davis K. *Manual on Ionospheric Vertical Soundings for the International Geophysical Year.* 1956. National Bureau of Standards Boulder, Colorado, USA.
4. Akachurin A.D., Zikov E.J., Makarov N.A., Minullin R.G., Portnjgin J.A. Influence of semidiurnal inflow on variations of height sporadic E layer. In *Geomagnetizm i aeronomiya*, 1996. v.36, ? 3, pp 132-139
5. Solar-Geophysical Data prompt reports. NOAA, 2001, ? 678 - Part 1.



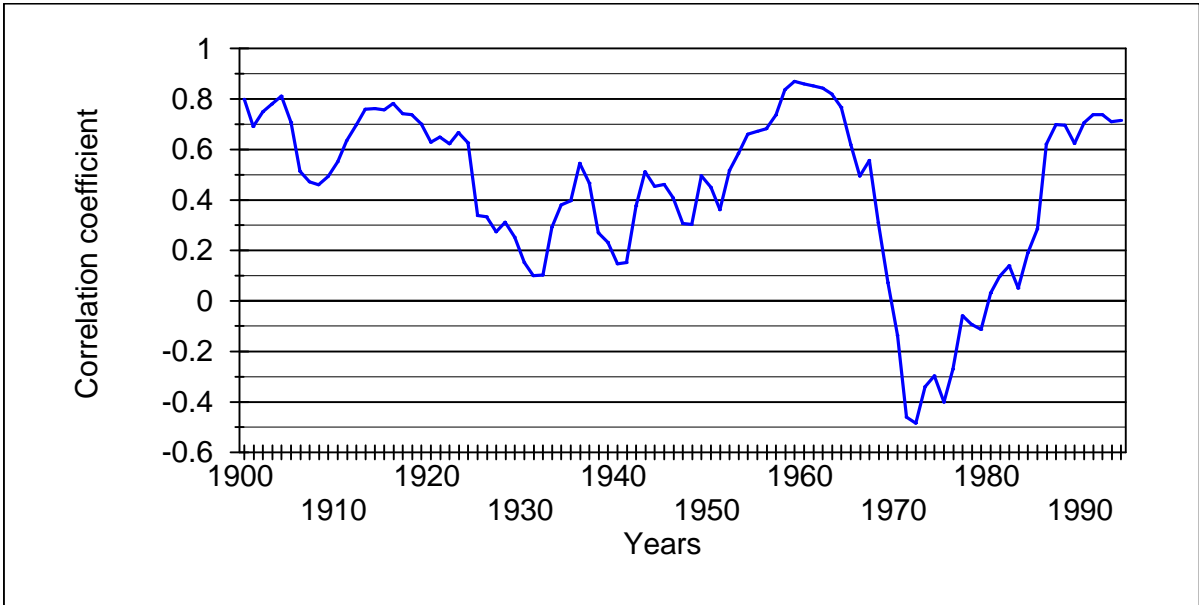
**Figure 1**

Variations of yearly mean values of effective heights of sporadic EsC and EsL formations, and of yearly mean values of Wolf numbers.



**Figure 2**

Variations of yearly mean values of effective heights of sporadic EsF and EsCL formations.



**Figure 3**

Correlation between solar and magnetic activity over the period 1900-2000.