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Long-term variations of ionospheric parameters as a basis for the study of the upper-atmospheric climate

V.D. Kokourov *, G.V. Vergasova, E.S. Kazimirovsky

Institute of Solar-Terrestrial Physics, Russian Academy of Sciences, Post Box 4026, Irkutsk 664033, Russia

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Abstract

The challenge of climate is treated as a problem not only of statistical dynamics of the ground-level atmosphere but also of electrodynamics, with due regard for all atmospheric regions—from the troposphere to the boundary with the Earth's magnetosphere. Long-term series of uniform measurements of the parameters of the thermosphere/ionosphere system make possible suggesting some climatic characteristics for the upper atmosphere. We present the results derived from analyzing the data of vertical-incidence ionospheric radio sounding (1948–1996) and the horizontal wind velocity measurements in the lower thermosphere/ionosphere (1976–1996) from observatory Irkutsk, East Siberia (52°N, 105°E). The analysis revealed long-term variations of such parameters as the minimum reflection frequency (fmin), the F-region virtual height (h′F), the critical frequency (foF2), the electron density dispersion (N) (spread-F parameter), the occurrence frequency of different types of sporadic ionospheric features, the virtual height of these sporadic layers, and the prevailing wind velocity in the height range 80–100 km. The association of climatic characteristics of the upper atmosphere with solar and geomagnetic activity, and the evolution of large-scale variations of the parameters under investigation are discussed.

Keywords: Climate; Upper atmosphere; Ionospheric parameters; Climatic characteristics; Long-term variations; Solar and geomagnetic activity

1. Introduction

The problem of interaction troposphere–stratosphere–mesosphere–ionosphere is topical at present because the new experimental evidences of a genuine link between meteorological processes in the lower atmosphere and ionosphere open the perspective for creating the self-regulating physical model of the reciprocal influence of the near-Earth space environment and the weather-producing processes. The investigation of the long-term variations of the main upper atmosphere and ionosphere parameters are especially important.

2. The topic formulation

The analysis and synthesis of the observational results during last decades allow us to study the state of the upper atmosphere during many years, i.e. the upper atmosphere (~80–500 km) climate. Using as the basement the experience of the climatic studies for the near-Earth lower atmosphere and the terms and methods of the "classical" meteorology, one may describe the long-term variations of the upper atmosphere main parameters in terms of climatic characteristics and climatic norms. Moreover, some events and processes not analyzed before in the upper atmosphere and ionosphere could be investigated. For instance, some data exist about the so called "sporadic" ionized structures and about large-scale features of the upper atmosphere dynamical regime. Perhaps the major achievement in recent years was the finding that the Earth's atmosphere and ionosphere form a coupled system

* Corresponding author. Tel.: +7 3952 511606; fax: +7 3952 511675.
E-mail address: zdk@iszf.irk.ru (V.D. Kokourov).

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in which influences that originate at one height or region can have profound influences elsewhere in the system. The long-term ionosphere data-series are actively used to derive the long-term changes (trends) in the numerous parameters—the electron concentration in the ionosphere F2 peak, the height of this peak, the dynamical regime of the ionosphere, the radio wave absorption in the ionosphere, and so on. These long-term changes sometimes could be connected with "Global Warming" in the lower atmosphere, with the decreasing of the Total Ozone Content, with anthropogenic atmospheric pollution, etc. But the upper atmosphere climate still is a challenge for the future research on the base of data from stations worldwide, the data well organized in a consistent format.

It is clear, that the long-term changes can be reliably derived only for lengthy time intervals, much longer than several solar activity 11-year cycles. At present only preliminary results could be considered (Rishbeth, 1997; Kokourov, 2003). The analyses of the basic astronomical, geophysical and meteorological factors controlling and forming the upper atmosphere climate are undoubtedly required.

It is well known that the term "climate" is used for the description of atmospheric state during many years, weather conditions of a place or area and typical variations and changeability (Monin and Shishkov, 1979; Herman and Goldberg, 1978; Drozdov et al., 1989). Nevertheless there were and are a lot of different definitions for this term—general, detailed and specific for the concrete tasks. But last few years the problem of climate is considered as the physical and mathematical problem of the atmospheric statistical dynamics taking into account the interaction of the atmosphere with oceans and continents. Therefore, the climate is the statistical ensemble of states which the system "continents-Ocean-atmosphere" passes during decades. The weather is the concrete, instant state of this system.

We think that for the creation of the Whole Atmosphere Climate Model it is expedient to take into consideration not only hydrodynamics but atmosphere electrodynamics too and not only lower near-Earth atmosphere but the upper atmosphere as well. The representative sets of the necessary parameters are required including the usual meteorological lower atmosphere parameters but in addition—the main structural parameters of the thermosphere/ionosphere system and the upper atmosphere dynamics. The search of parameters which could be considered as the climatologic characteristics for upper atmosphere is in process.

The aim of this paper is the analysis of the ionosphere observational database for Irkutsk (52°N, 105°E), mainly for 1960–1996, but sometimes even for 1948–1996. We have analyzed the long-term variations, response to the solar activity variations, geomagnetic storms and solar flares. The results for the normal and anomaly conditions could be used for the upper atmosphere climate study.

3. Results

3.1. The parameter

The minimal frequency of radio waves reflected from the ionosphere measured by standard vertical-incidence sounding (fmin) is usually considered as a qualitative measure of the so called "nondeviative" radio wave absorption in the ionosphere. Unfortunately this parameter is dependent on the radar instrumental characteristics and radio-noise level.

For the minimization and compensation of the instrumental errors we often and successfully used for the geophysical analysis another parameter—**dfmin**, i.e. the difference between the daily mean and daily median fmin values. Absorption was measured in area E of an ionosphere method A1 widely used in average breathes. The method consists in registration of amplitude of the reflected radio signal at vertical sounding on variable frequency. As the parameter describing absorption, the minimal frequency fmin since which on ionograma, a reflected signal is used. But the size of this parameter is influenced with characteristics ionosonde. Therefore for indemnification of instrument errors of measurements we used values dfmin, designed for each separate day on all to 24 h of the day as a difference between daily average value fmin and a daily median for all periods of supervision 1983–1991. Daily distribution of the minimal frequency of reflection differs positive asymmetry, average arithmetic is usually more than probable value, and dfmin—the factor of asymmetry (Panovsky and Brayer, 1972)—precisely enough compensates errors of measurement. In the spent calculations of a difference of two sizes (daily average value and a daily median), the difference "a mistake of measurement a minus a mistake of measurement" is simultaneously calculated. But the used size keeps the basic laws of change fmin as qualitative characteristic of absorption.

We have analyzed the temporal variations of dfmin for lengthy period and it was shown that this parameter, directly depending on the electron concentration and effective particles collision frequency in the ionosphere, responds to the stratospheric warmings and geomagnetic storms. It could be used as an indicator of stratosphere-lower thermosphere interaction and atmospheric planetary waves generation (Vergasova and Kazimirovsky, 1995; Vergasova et al., 1995; Kokourov et al., 2003a). For example, Fig. 1 shows the correlative functions between dfmin and indexes of geomagnetic activity (planetary index Ap) and solar activity (radio flux on the frequency 2800 MHz, F10, 7). At calculation of correlation functions depending on size of phase shift ô, the importance was defined by criterion Fisher (Panovsky and Brayer, 1972). This size depends on length of initial lines. Here results with the importance by Fisher criterion 0.95 are submitted. We may consider fmin as a useful climatic characteristics of the upper atmosphere.