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GROUND BASED MONITORING OF THE EARTH'S ENVIRONMENT AT NAGYCENK OBSERVATORY (NCK)

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Ground based observations of the "Széchenyi István" Geophysical Observatory of the Hungarian Academy of Sciences (Nagycenk) offer a unique opportunity for investigation of the complex processes of Earth's environment and of its effect on radio wave propagation. High temporal resolution recording of variations of the geomagnetic field, vertical incidence sounding of the ionosphere and observation of whistlers enable determination of plasma density profiles in the inner magnetosphere (plasmasphere) and their changes. Study of ionospheric processes and their effects in the upper atmosphere (thermosphere) is supported by a permanent GPS station. Both DC and AC fields of lightning discharges are also recorded in the Observatory. Measurement of the DC field is related to the atmospheric electric circuit, where the global thunderstorm activity is the generator and fine weather areas play the role of loading. Loading of the atmospheric electric field depends on rate of ionization, ionization being caused by galactic cosmic rays. However, galactic cosmic rays are modulated by solar activity. Similarly amplitude of Schumann resonances depend on thunderstorm activity and its distance from the recording site. Resonance frequencies occurring at wave-lengths approximating dimensions of the Earth-ionosphere wave-guide are affected by conductivity variations of the upper boundary of the cavity resonator and thus, by changes of thickness of the cavity resonator.

Keywords: atmospheric electricity; ionosphere; magnetosphere; Schumann resonances; space weather

1. Introduction

For a complex investigation of the Earth's environment by ground based observations, processes controlling space weather are considered. Space weather is formed by solar activity, and its effects are mediated directly (solar electromagnetic radiation), or indirectly by the interplanetary magnetic field and the solar wind, especially by irregularities (plasma clouds, corotating high speed plasma streams). Most responsive to space weather effects are the horizontal component of the geomagnetic field and the ionosphere, as a screen, on which events related to solar activity are shown. Detailed pictures are only obtained, if both temporal and spatial resolving power of the screen is sufficient. Nowadays, complex case histories are most promising, since investigations carried out using indices, or proxies minimized often substantial characteristics of the event. Complex studies enable omission of indices and proxies. However, in this case, on the one hand co-ordinated satellite and ground based observations are needed.

2. Method and data

The "Széchenyi István" Geophysical Observatory of the Hungarian Academy of Sciences was established for investigation of the Earth's electromagnetic field. At the beginning, variations of the two horizontal electric components (N-S, E-W) of the electromagnetic field were recorded from the commencement of the International Geophysical Year 1957–1958. This measurement, registration of the earth (telluric) currents is carried out since then up to the present. Recording of the three magnetic components began in 1960 using at that time standard La Cour type variometers. Nowadays, geomagnetic observations are operated in the framework of the INTERMAGNET organization and are carried out by a triaxial fluxgate magnetometer. In the nineteen fifties it was assumed that the vertical electric component of the electromagnetic field is the atmospheric electric field. Thus, registration of the atmospheric electric potential gradient began in 1961 and it is carried out since than up to the present.

In 1992 the observatory got an IPS-42 type ionosonde from the Hungarian Meteorological Service, where it was operated in the meteorological station Békéscsaba. It was necessary to build an antenna system and to reconstruct the ionosonde to enable it for digital recording. However, ionograms were usable only in the low frequency part. Now a new ionosonde constructed in the Space Research Center of the Polish Academy of Sciences is working in the Observatory.

In the latter years, observation activity has been extended by observation of the Schumann resonance frequencies, by recording of whistlers and operating a permanent GPS station.

This has already been a list. However, development of the Observatory's instrumentation was planned keeping in view the complex investigation of the Earth's electromagnetic field.

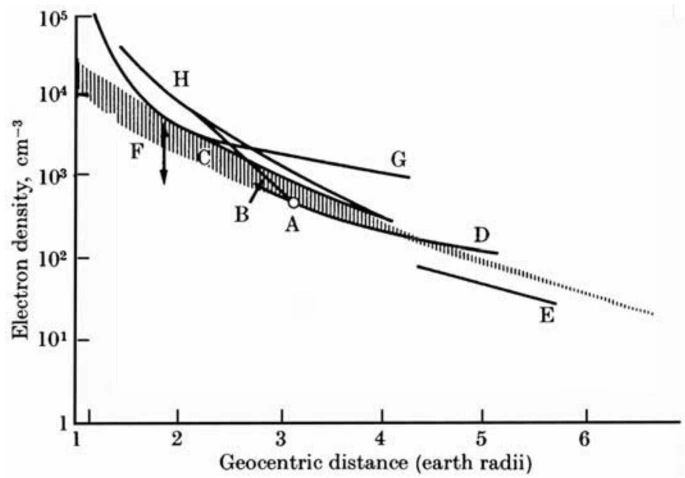

Fig. 1. Electron density distirubiton as a function of geocentric distance according to whistler studies obtained by several authors (Carpenter and Smith 1964)

3. Discussion

For plasma diagnostics, which is carried out related to space weather and ionospheric effects, either direct plasma (particle) measurement, or plasma waves can be used. Instrumentation of the Observatory enables application of both methods. Vertical incidence sounding of the ionosphere makes possible determination of electron density profiles. Filling and change of the plasma density in the plasmasphere (inner magnetosphere) is controlled by the plasma density in the F region. Thus, F region plasma density affects phenomena taking place in the plasmasphere. This phenomena are propagation of whistlers, audiofrequency electromagnetic waves emitted by lightning discharges and propagating along magnetic field lines (Ferencz et al. 2001). Propagation is promoted by ducts, waveguides of slightly increased electron density developing around field lines. Processing of whistler records enables determination of plasma density distribution as a function of altitude in the equatorial plane mainly by night and early morning (Fig. 1).

Another phenomena affected by F region plasma density are the field line resonance (FLR) type geomagnetic pulsations (in the period band of 5–45 s). These are toroidal oscillations of field lines, which are generated by so called upstream (UW) waves and their period is proportional to the length of the field line, as well as to the plasma density. Considering FLR type pulsations as a result of a resonant system, period and amplitude of this system at a given geomagnetic latitude depend on the plasma density in the plasmasphere. As the source of plasma in the inner magnetosphere is the F region of the ionosphere, period of FLR type pulsations depend on the electron density in the F region. Thus, a relation between the FLR period and f_oF2 (maximum electron density of the F region and maximum electron density in the ionosphere) was assumed and shown (Fig. 2). Distribution of plasma density in the plasmasphere can be determined by FLR type geomagnetic pulsations (Fig. 3).

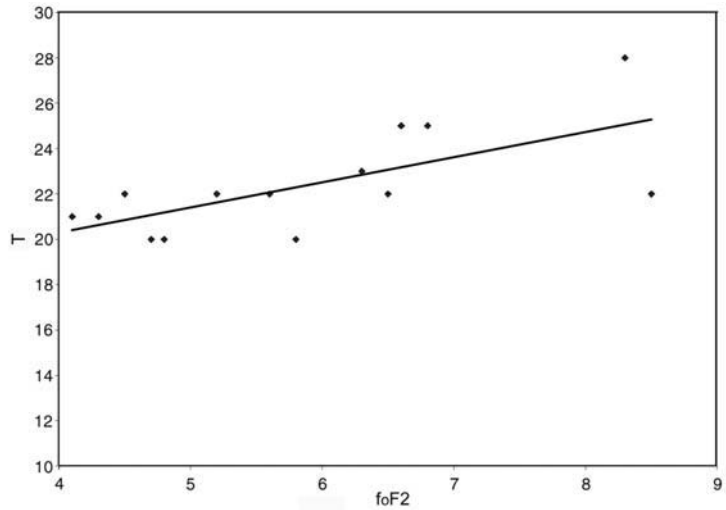

Fig. 2. Variation of the field line resonance (FLR) type geomagnetic pulsations with f_oF2 (maximum electron density in the F region (Bencze and Verő 2007a, 2007b)

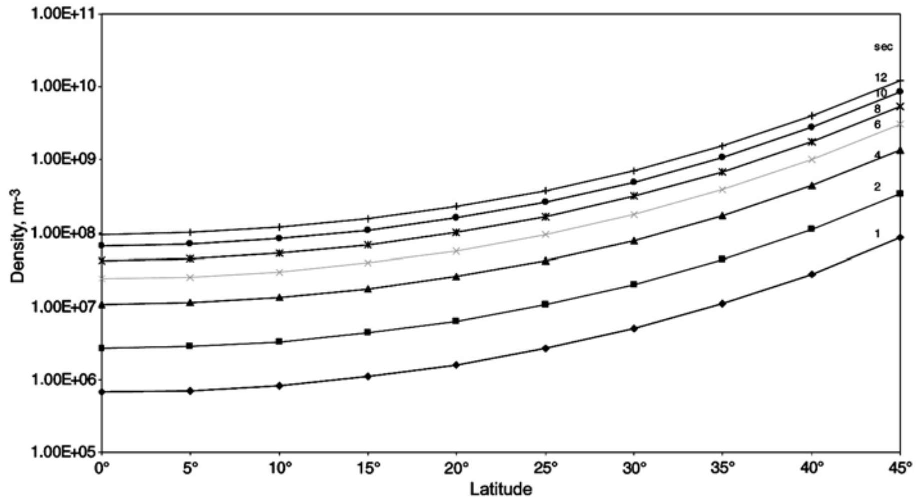

Fig. 3. Change of the electron density along the field line corresponding to $L = 1.9$ in the plasmasphere derived from FLR type geomagnetic pulsations (Bencze and Verő 2007a)

Recently, several studies have been published devoted to the spatial distribution of plasma density in the plasmasphere. These studies are based partly only on satellite measurements, partly both on satellite measurements and FLF type pulsations, and refer almost without exception to L values larger than 2 (Bencze and Verő 2007a, 2007b, Berube et al. 2006, Dent et al. 2006, Denton et al. 2006, Vellante and Förster 2006). For determination of spatial plasma density distribution in the plasmasphere, period of FLR type pulsations at the given place, intensity of the geomagnetic field along the field line corresponding to that place and length of this

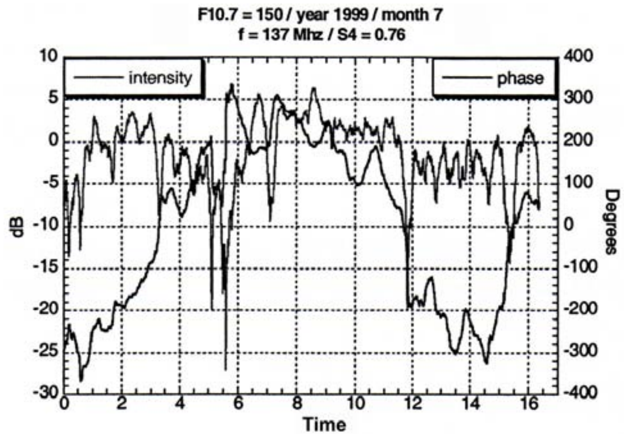

Fig. 4. Amplitude and phase fluctuations (scintillation) of VHF radio waves (Béniguel et al. 2004)

field line are necessary. In case of the period either measured values can be used, or a relation establishing change of the period due to variation of f_oF2 (Fig. 2). Calculations of the spatial plasma density distribution have been carried out related to the field line corresponding to the L value of the Observatory ($L = 1.89$). As at $L < 2$ the geomagnetic field can be approximated by an Earth-centered dipole, equations (field intensity as a function of distance from the Earth's center and geomagnetic latitude, as well as differential change of the length of the field line due to change of the L value and geomagnetic latitude) are obtained enabling determination of plasma density distribution along a field line (Fig. 3). At $L < 2$ values the distortion of the geomagnetic field can be neglected (Berube et al. 2006). Polarization of FLR type pulsations is determined by the ratio of the height integrated Hall conductivity to the height integrated Pedersen conductivity; that is, it depends also on the state of the ionosphere (Nishida 1978, Itonaga and Kitamura 1988, 1995).

GPS measurements and the total electron content (TEC) deduced from them supply additional informations on ionospheric processes. TEC observations enable recording of plasma scintillations (Béniguel et al. 2004). These scintillations are related to ionospheric irregularities, which may be due to electron density fluctuations in the F region (spread-F) or in the E region (sporadic E) affecting radio wave propagation (Fig. 4).

Part of the electromagnetic signal emitted by lightning discharges propagates in the Earth-ionosphere wave-guide. The wave-guide becomes a cavity resonator at wave-lengths of the signal, that are commensurable with dimensions of the wave-guide (Schumann resonance frequencies, first three modes of the resonance: 8, 14, 21 Hz) (Sátori 1996). Losses in the cavity resonator, consequently magnitude of the resonance frequencies are related to the electric conductivity of the upper boundary of the wave guide, that is, to the conductivity in the lower ionosphere. As conductivity depends on electron density, it is determined by ionization, which is produced by galactic cosmic rays. However, the flux of cosmic ray particles is modulated by irregularities (plasma clouds, high speed corotating plasma streams), occurrence of

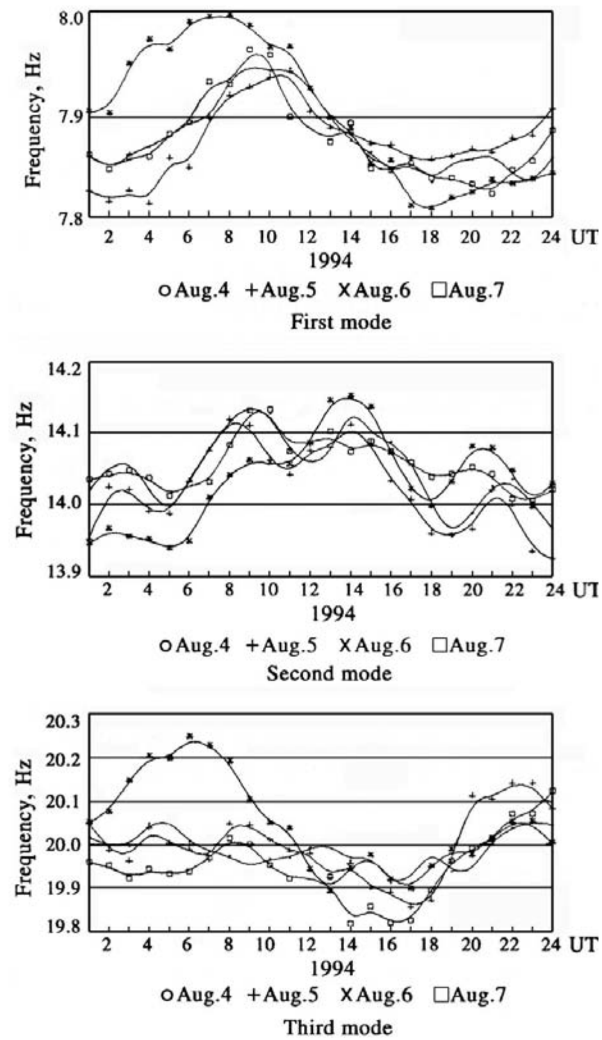

Fig. 5. Diurnal variations of the first three modes of Schumann resonances recorded in Nagycenk Observatory (Sátori 1996)

which changes with solar activity (Fig. 5). Thus, changes of the resonance frequencies may indicate space weather characteristics.

Registration of characteristics (e.g. potential gradient) of the atmospheric electric field is also connected with space weather phenomena being dependent on ionization in the lower atmosphere. Thus, magnitude of the atmospheric electric potential gradient is a function of galactic cosmic ray flux just as the resonance frequencies of the Earth-ionosphere cavity resonator. Increase of solar activity in the 20th century reduced the galactic cosmic ray flux by increased occurrence of plasma clouds resulting in decreased ionization and reduced potential gradient (Fig. 6) (Märcz and Harrison 2003).

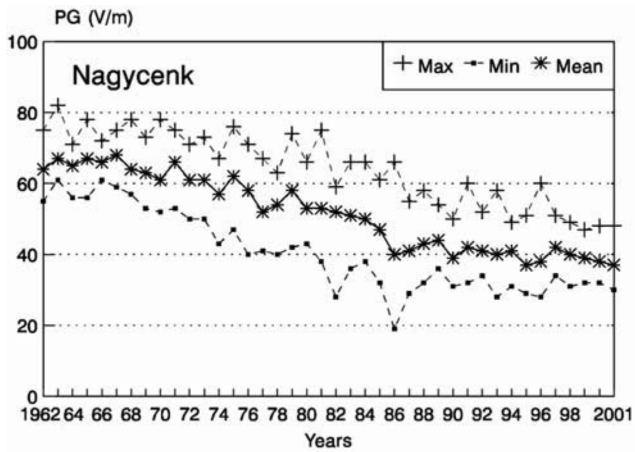

Fig. 6. Long-term change of the atmospheric electric potential gradient measured in the Nagycenk Observatory (Märcz and Harrison 2003)

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