Research Interests

My research interests are in the space physics and geophysics. Particularly, I deal with ULF processes in magnetosphere and ionosphere, MHD waves and structures, geomagnetic pulsations, and ULF electromagnetic field noises possibly connected with lithospheric processes. The latter are inspired by recent achievements in a new science - Seismo-electromagnetics.

My current research topics

1. Surface waves in space

Geomagnetic pulsations (in the range 0.001-5 Hz) are observed both on the ground and in the Earth’s magnetosphere. In most cases they are considered to be a consequence of Field Line Resonances (FLR) generated along definite magnetic field lines forming standing wave structure in the Earth’s magnetosphere. FLR are shear Alfven waves initiated possibly by MHD cavity modes of the magnetosphere. The cavity modes of the magnetosphere are formed between the magnetopause and the plasmopause but they are rarely to be observed on the ground. Thus FLR excited by the magnetospheric modes, can propagate to the Earth ionosphere where an alternate Hall current is produced and its magnetic field is recorded on the Earth surface as geomagnetic pulsations.

Beside magnetospheric cavity modes, MHD surface waves can exist in the Earth’s environment. Their magnetic field is localised at any plasma and magnetic field discontinuities propagating along them. A well-known example of MHD surface waves is the Kelvin-Helmholtz instability which appears on the Earth’s magnetopause. MHD surface waves can also be observed within the magnetosphere, e.g. on the plasmopause. The propagation of MHD surface waves to the Earth surface is thus allowed. It was already shown that such a mechanism of wave energy flux to the
Earth’s surface works in the cleft/cusp region. Magnetometer data from IK-Bulgaria 1300 satellite have been used to illustrate this phenomenon.

There are also MHD surface wave eigenmodes of the Earth’s magnetosphere. Their propagation being supported by adjacent plasma boundaries, is similar to FLR, i.e. they form standing wave structures in the magnetosphere. These modes could be confused with FLR. It was shown that observed discrete spectra in the Pc5 pulsation range might be explained by MHD surface modes of the outer magnetosphere. Thus, many properties of the so-called non-FLR events can be explainable in terms of surface wave eigenmodes of the Earth’s magnetosphere.

**Recent publications**


**2. Magnetosphere-ionosphere interactions**

Magnetosphere-ionosphere interactions represent an essential link of the energy transfer from the solar wind to the Earth. Large-scale field-aligned currents (FAC) structures between the magnetosphere and the ionosphere and high energy particle fluxes are observed in the Earth’s ionosphere and atmosphere. They are intensified thus providing energy, mass and momentum input to the Earth. Variety of processes (magnetic storms, ULF waves, particle precipitation and energy gain, etc.) is generated that produces all external sources of geomagnetic variations on the Earth surface. Nowadays all these processes are in the focus of the Space Weather Programme.

ULF waves are one of the most pronounced entities of the magnetosphere-ionosphere system. Their wave characteristics are changing through the system and modifying thus carrying an information for the plasma properties of the region through which they pass. Therefore, they could be considered as suitable diagnostic tool of the dynamics of the Earth’s magnetosphere and plasmasphere (link).

**Theoretical findings**

ULF wave polarization properties in the Earth’s Hall ionosphere and its different responses (rotation and ellipticity) for Alfven and (fast) magnetosonic modes depending on the Hall region thickness are well studied (Nenovski, 1994, 2001). Well-known results for the rotation of the polarization plane of the MHD waves
(Dungey, 1963; Nishida, 1964; Hughes, 1974; Hughes and Southwood, 1976) are thus generalised. It was shown that the ionospheric effects on ULF waves upon the polarization of the (fast) magnetosonic waves are twofold. Besides the rotation of the polarization plane an ellipticity effect of the ionosphere is discovered. The latter is inherent to compressional MHD modes. Theoretically, the polarization changes can be expressed as a function of i) the ratio \( R \) of the Hall (\( \Sigma_{\text{Hall}} \)) and Pedersen (\( \Sigma_{\text{Pedersen}} \)) conductances in the Hall region and ii) a wave/magnetospheric parameter \( A_m \). The derived wave/magnetospheric parameter \( A_m \) depends on the wave frequency, the horizontal scale of the ULF waves, and the Hall-region thickness.

Using standard models (IRI 90 and MSIS 86) responses of magnetosonic waves to seasonal/diurnal ionospheric variations at high latitudes are illustrated for arbitrary, but reasonable values of the wave/magnetospheric parameter \( A_m \). It was found that the ellipticity effect reaches a maximum when the \( A_m \) wave parameter and the Hall, Pedersen coconductances change according to relationship \( \Sigma_{\text{Hall}}^2 = A_m^2 + \Sigma_{\text{Pedersen}}^2 \). The polarization ellipse rotation for the compressional MHD waves ranges between 0 and \( \pi/2 \). These findings are suggestive for another dissipative mechanism (non-resonant) of transformation of magnetosonic waves into Alfven modes in the ionosphere.

**Experimental evidences for ionospheric polarization effects**

These findings should be taken into account for the analysis of various polarization puzzles coming from the geomagnetic pulsations observations. Sunrise effects on the polarization of the Pc 3-4 pulsations (Saka et al., 1982), effects of transformation of pure compressional disturbance in the magnetosphere into transverse wave on ground (Lanzerotti and Tartaglia, 1972), etc, could be explained in the term of the ellipticity mechanism by the ionosphere.

Simultaneous measurements of the electric and magnetic field of ULF waves at ground and balloon heights have revealed polarizations of opposite handedness (Bering et al., 1995) (link). It is shown that the polarization of the magnetosonic wave penetration through a horizontally homogeneous high-latitude ionosphere continues further through the atmosphere and would result in different polarization states for the electric and magnetic fields. The opposite handedness of the Pc5 wave polarization recorded at the South Pole by measurements of the electric and magnetic field components (Bering et al. 1995) might be explained as a result of an influence of the ionosphere on the ULF waves of initially left-hand polarization. The southern ionosphere causes an additional right-hand polarization effect in the ionosphere/atmosphere produced mostly on the wave magnetic field.

**Recent publications**


**3. Field-Aligned Current (FAC) structures in the magnetosphere-ionosphere system**

Coupling mechanisms between the solar wind and the Earth’s magnetosphere result in an emergence of various plasma convective structures in the polar regions. Large-scale field-aligned currents (FAC) flowing along the magnetic field lines toward and away from the Earth are modeled using a non-linear (NL) zero-frequency MHD surface modes enhanced by the solar wind flow. The model is elaborated to yield quantitative relationship between the FAC densities and the solar wind parameters.

Coming nearer to the Earth the large-scale FAC are intensified and a *pattern formation* process can be initiated. The overall (large-scale) FAC structure (e.g. region 1 and 2) can be transformed into multiple FAC structures of smaller scale and inverse polarity. A threshold value to start such a structure transformation exists and it depends on the ‘thermal’ (or chaotic) properties of the FAC carriers (ions and electrons). The threshold value is equal to 0.3 mA/m² provided that the carrier (electron) temperature is 1000 K.

**Recent publications**


**4. ULF electrotelluric measurements**

Last three-decade studies of magnetic field variations in seismically active regions have revealed various anomalous electromagnetic (EM) phenomena related to processes preceding strong earthquakes. Anomalous EM phenomena emerged in wide frequency ranges - from ULF to IR radiation. Advantage of the ULF frequency range as compared with higher frequency field observations (ELF/VLF and so on) is a larger skin depth, that enables the electromagnetic emissions in this band reach the ground directly from an epicenter of forthcoming quake. IR radiation correlates with the Earth surface temperature anomalies that also emerge above the impending earthquake hypocentres. Electromagnetic noises and pulse-like signals enhance weeks- few hours before an impending earthquake. These findings are fruitful for seeking reliable EM precursors of dangerous earthquakes. All the seismic-related EM phenomena however have local character and require a network. Nevertheless, the mechanisms of occurrence of anomalous electromagnetic ULF emissions before earthquakes cannot be considered as well established.
Seismo-electromagnetism – a new science

Recently an apparatus for measurement of the DC and ULF electrotelluric field variations at the seismic station Krupnik (South-West Bulgaria) was put in operation (July 2003). The goal of such measurements is to establish their possible connection with seismic/tectonic processes in Bulgaria and neighbour countries. The Krupnik region represents an active fault system (of ~100 km long) that generates weak earthquakes (several times monthly). Anomalous ULF noise signals were observed. Our electrotelluric field measurements allow to observe so-called Seismic Electric Signals (SES) indicative for forthcoming earthquakes in the Central Balkan peninsula.

Recent publications


Projects

• Analysis of the ULF electro- and magnetotelluric observations related to seismic activity, GPI (Sofia)-SRI (Graz), 2005-2007
• Electromagnetic monitoring of regions with enhanced seismic activity, supported by Ministry of Education and Science (Bulgaria), No ES-1402/04.
• Analysis of ULF electromagnetic observations in Italy and Bulgaria related to magnetospheric and seismic activities, GPI (Sofia)-L’Aquila University (Italy), 2004-2006
• A study of ELF/ULF waves and field-aligned current systems by satellite and ground based measurements, SRI (Sofia)- IIG (Mumbai), 2004-2006;

• Advanced methods of analysis of the electromagnetic observations related to seismic activity, GPI (Sofia)- United Institute of Earth (Moscow), 2002-2005;

• Multi-point measurements of geomagnetic pulsations at mid-latitudes: interplanetary, magnetospheric and ionospheric effects, GPI (Sofia)- L’Aquila University (Italy), 2001-2003;