WAVE PROCESSES, GLOBAL– AND LARGE–SCALE DISTURBANCES IN THE NEAR–EARTH PLASMA

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INTRODUCTION

Particular attention has been recently paid to physical processes originating in geospace from natural and anthropogenic sources of energy (see CEDAR and Space Weather Plan). Results from these investigations contributed enormously to understanding of how different geospheres are coupled, or, in other words, how the lithosphere, atmosphere, ionosphere, and magnetosphere exchange mass, momentum, energy, and information. This means that geospace is an open nonlinear system, and the mechanisms for coupling the above subsystems are studied insufficiently. The coupling processes include linear and nonlinear waves, and the aim of this study is to determine the apparent velocities of the perturbations, using observations, and to find out the types of waves responsible for perturbation propagation.

MODEL SPECIFICATIONS AND CALCULATIONS

Detailed calculations of energetics during disturbances on the sun, in the magnetosphere, ionosphere, atmosphere, and lithosphere have been made (Chernogor, 1998). The starting point for the development of the model is the following: the intensity of solar emissions in the ultraviolet, gamma ray, soft, and hard X-ray wavelengths, as well as solar wind characteristics under quiet and disturbed conditions. For the magnetosphere, the following parameters have been obtained: geomagnetic micropulsation energy, plasma thermal energy, nonthermal particle energy, geomagnetic storm power and energy, energy of the electric fields of magnetospheric origin. The energetics of the ionosphere is estimated taking into account the power and energy inputs from the sun, the plasma thermal particles, and the winds at ionospheric heights, electric currents, particle precipitation at high and middle latitudes. The energetics of the atmosphere is suggested to be determined by the balance between energy inputs and outputs, and by processes in the medium. The latter include thermal motion, the moving solar terminators, winds, large- and small-scale turbulence, atmospheric electricity, the entries of large space bodies into the atmosphere, *etc.* The energetics of seismic processes includes the potential and elastic energy in the lithosphere, the energy and power of volcanic processes and tsunami. The energetics of earthquake acoustic, electric, and magnetic effects on the near-earth environment is separately studied. Estimates of the energy of optical, radon, and other emissions produced by earthquakes are made. Particular attention is given to the energetics of such anthropogenic effects as explosions, space vehicle launches and re-entries into the earth's atmosphere, beams of particles and plasma, high-power radio transmissions, harmonics in the kHz range radiated by electrical power transmission lines, MHD generators, and meteotrons.

The estimates made suggest that energy deposition into the environment from various natural and anthropogenic processes can be significant. Energy estimates are just the first stage in estimating the detectability of the effects of a particular disturbance. Further, it is necessary to make comparisons between specific characteristics of the signal and noise (interference). These may include the energy or power of the process per unit volume. Because the process under study is spatially and time discrete, its specific characteristics relatively increase. Moreover, it is necessary to take into account that the source of energy, say a cyclone, may not cause significant ionospheric or magnetospheric disturbances, and the conversion factors can significantly differ depending on the nature of the energy of the disturbance, the coordinates and the timing of energy release, and the condition in the system and its subsystems, although it is sure enough that there are feedbacks in the near-earth system, which is sometimes called geospace sphere consisting of the well-known geospheres: the lithosphere, the atmosphere, the ionosphere, the magnetosphere, *etc.* On the other hand, the system, and, moreover, the subsystems, are open systems, and, therefore, a release of energy may be triggered. For instance, E-region heating by relatively low-energy HF amplitude-modulated waves changes the ionospheric (direct current) conductivity, which results in modulating the strength of high-energy electric currents in space. Particle precipitation from the magnetosphere triggered by a low-energy source can significantly change the energetics of the lower ionosphere ($\sim 50-100$ km) as well (Chernogor *et al.*, 1998).

The nomenclature of manifestations of the triggering mechanism may be continued. The variations in parameters of the near-earth medium caused by different disturbances in principle differ a little. To detect the display of a particular disturbance, the variations in parameters of the medium caused by different disturbances should undergo an in-depth examination by a cluster of independent methods, and mathematical models of the signal and interference should be developed. Only after this, the problem of disturbance detection can be set and practically solved.

MECHANISMS OF THE PERTURBATIONS TRANSFER AT LARGE– AND GLOBAL–SCALE DISTANCES

Possible causative mechanisms for the transfer of perturbation at large- and global-scale distances from a localized ionospheric disturbance have been analyzed in order to identify the role of various physical processes. Acoustic (infrasound) waves (Gossard and Hooke, 1975; Francis, 1975; Chernogor, 1997), MHD waves (Jacobs, 1970; Guglielmi and Pokhotelov, 1996; Kelley, 1989), slow MHD waves (Sorokin and Fedorovich, 1982), gyrotropic waves (Sorokin and Fedorovich, 1982; Sorokin, 1986; Sorokin, 1987), seismic waves (Pasechnik, 1970), as well as nonlinear waves (Whitman, 1974; Nonlinear waves, 1974; Scott, 1970; Lamb, 1980; Petviashvili and Pokhotelov, 1992; Guglielmi and Pokhotelov, 1996; Pokhotelov *et al.*, 1996; Gurevich, 1978) and structures are considered to be important processes in transferring perturbations from discrete disturbances to sites at global-scale distances. The data on observations of perturbations at global-scale distances from initial disturbances exhibit several groups of propagation speeds of $\sim 0.3-0.8$ km/s, $2-3$ km/s, $3-5$ km/s, and $10-100$ km/s. They correspond to different types of waves which we have analyzed in detail.

CONCLUSIONS

1. The lithosphere, atmosphere, ionosphere, and magnetosphere are a single open system. Energy is incoming into the system from the sun and space. The exchange of energy, matter, and governing influences takes place between the subsystems; feedbacks through the system appear at different directions.
2. Estimates of the energetics of the solar processes affecting the earth, as well as of the main processes in the lithosphere-atmosphere-ionosphere-magnetosphere system, are made.
3. Estimates of the energetics of a few processes linking the subsystems (disturbances in the geomagnetic and geoelectric fields, ionospheric electric currents, winds, turbulence, energetic particle fluxes, *etc.*) are made.
4. Perturbations in the near-earth medium are transferred via acoustic waves ($v \sim 0.3-0.7$ km/s), slow MHD waves ($v \sim 1-10$ km/s), seismic waves ($v \sim 3-8$ km/s), gyrotropic waves ($v \sim 10-8\times10^2$ km/s), and MHD waves ($v \sim 10^3$ km/s). The role of nonlinear waves is to be studied.

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