New Physical models for the multi-instrumental diagnostics of ionospheric modification, including irregularities and scintillations, based on high and low radio frequency observations

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The perturbations in the system Earth-Atmosphere-Ionosphere-Magnetosphere (EAIM) are characterized by the pronounced synergy between the ULF, VLF and HF processes which can be effectively detected and used for the ionosphere diagnostics based on corresponding international networks, providing GPS & GLONASS/TEC, VLF, LOFAR/HF and other data.

The following theoretical results will be important for the modeling TEC including irregularities and scintillations, revealing in TEC/GPS data. (i) The penetration into the ionosphere of electromagnetic signal from the ULF current source placed in the lower atmosphere/Earth is about one order more effective than electrostatic field from the stationary source; (ii) High electric field, (1-10) mV/m, could penetrate into ionospheric altitudes. At altitudes of order of 150 km, the corresponding perturbations of electron concentration are of order of few percent. (iii) To explain the observed effects in the ionosphere including large (dozens - hundred kms) plasma structures, the following development of the theory is necessary. (a) the electric-photochemistry model of the penetration of electric/electromagnetic field into/through the ionosphere should become self-consistent; (b) electromagnetic/atmospheric-gravity wave (AGW) channel of the coupling “atmosphere-ionospere” should adopt the synergetic approach: a set of “active lenses” placed in the lower atmosphere (with the heat instability, aerosols, electric field and AGW), mesosphere (with electric-heating-photochemistry instability), in the E region of the ionosphere (with electric-heating instability) andin the F region (with Perkins or Rayleigh-Taylor instability of plasma placed into gravity, electric and magnetic fields); (iv) developing the model with adequate boundary conditions at the ends of open or closed geomagnetic field lines (models of “Two Earths” and “One Earth”, respectively).

The models of the very important indication of the influences on the ionosphere from the powerful sources placed “above”, “below” and “inside” the ionosphere including extremely effective Space Weather diagnostic, namely effects based on VLF electromagnetic waves, both propagating in and radiated from or incident on (from the magnetospheric ducts) the WGEI is under development and will be discussed. The results of the new tensor impedance method for modelling propagation of electromagnetic beams (TIMEB) in multilayered gyrotropic waveguides and its applications to the VLF beams in the WGEI will be presented; the new and very promising, for the ionosperic diagnostics, model on the mode excitation in the WGEI will be demonstrated. In particular it will be shown that at the long enough propagation distance (of order of 1000 km, what is typical for the VLF experiments), the second mode of the WGEI would be more pronounced than the main one due to corresponding loss relation between the modes. The models of beam propagation and mode excitation by a given (current) source will be united properly. The possible applications of the combined TIMEB-mode method to the new satellite and ground experiments on VLF propagation will be discussed, such as, ongoing NASA VIPER (VLF Trans-Ionospheric Propagation Experiment Rocket) project (PI J. W. Bonnell, UC Berkeley, NASA Grant 80NSSC18K0782); Taranis project in the aspect of lightning-VLF connections; ground-based measurements on the basis of European VLF transmitter-receiver system and Ukrainian VLF receivers in the National Center for Control and Testing of Space Facilities of the State Agency of Ukraine.