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Capabilities of software “Vector-M” for a diagnostics of the ionosphere state from auroral emissions images and plasma characteristics from the different orbits as a part of the system of control of space weather

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Abstract

In the paper are presented capabilities of software “Vector-M” for a diagnostics of the ionosphere state from auroral emissions images and plasma characteristics from the different orbits as a part of the system of control of space weather. The software “Vector-M“ is developed by the celestial mechanics and astrometry department of Tomsk State University in collaboration with Space Research Institute (Moscow) and Central Aerological Observatory of Russian Federal Service for Hydrometeorology and Environmental Monitoring. The software “Vector-M“ is intended for calculation of attendant geophysical and astronomical information for the centre of mass of the spacecraft and the space of observations in the experiment with auroral imager Aurovisor-VIS/MP in the orbit of the perspective Meteor-MP spacecraft.

1. Introduction

Online diagnostics of characteristics of the ionosphere (global and local) and their short term forecast subsystem are really fitted in the system of control of space weather parameters. Sources of data measurements of characteristics of the ionosphere consist of: the nets both of the ground radio, riometer, magnetometer instruments and optic imaging instruments located in polar north and south zones and in perspective on the different orbits of low-orbit and high-apogee spacecrafts and at the series of drone that are long time at the altitude more 15 km, and functioning of all these instruments needs to be synchronized. All information received from experiments should flow to data centre for processing, analysis, and visualization of global and local distributions of characteristics of the ionosphere. Significant contribution in this information will be bring direct small-scale data measurements of near-satellite plasma namely energetic characteristics of charge particles fluxes that precipitate to the ionosphere and go out from the ionosphere in 10 eV – 100 keV span, field aligned current along magnetic field lines base on small-scale gradients of magnetic and electric fields in ±5000 nT span, characteristics of VLF/ELF waves, and images of auroral emissions both small-scale visible (at perspective Meteor-MP and Probe spacecrafts and large-scale VUV auroral emissions [4] (in perspective Arctic-2 space project).

Energetic characteristic of charge particles can be compute from the auroral emissions intensity distributions in images both visible (at the night side of the ionosphere) [1, 5] and VUV (at the night and sunlit side of the ionosphere). Energy flux and mean energy of electrons and protons distributions are based for definition of altitude integrated Hall and Pedersen conductance distribution, and local N_e concentration in maximum of E-region of the ionosphere can be compute too [2]. Knowledge of local distribution of these characteristics is necessary to research the reason of delay and the failure of signals of orbital navigation systems and their phase and amplitude scintillations in time crossing of region of precipitation charge particles, field aligned currents and auroral structures when geomagnetic conditions change [3].

Auroral imagers Aurovisor-VIS/MP at perspective spacecraft Meteor-MP consist of three parallel imaging monochromatic channels tuned to oxygen emission λ630,0 nm, emission of 1NG system of N_2^+ λ427,8 nm, and Doppler shifted hydrogen line H_β of Balmer series accordingly that provide capability for control of electrons and protons precipitation contributions in excitation of auroral emissions [3]. 30° field of view angle of each channel provides presence

of magnetic field line projection in the images at according altitude of the emission. Axis of channels directed to nadir. Threshold response of every channel is <50 Rayleigh. The parallel monochromatic channels of auroral imager Laetitia tuned to emission λ630,0 nm and λ427,8 nm have field of view angle 30° too and similar threshold response. Direction of axis f.o.v. of channels of Laetitia depend on instantaneous position of Sun because axis (-Y) of Probe spacecraft see the Sun always. Simultaneous launch of Meteor-MP and Probe is expected to "create" the circle Sun synchronous orbits in near-by planes at different altitudes. Due to this quality there can be situations when both imagers will be "see" the same auroral structure from different position when spacecrafts will be cross the auroral oval. Stereoscopic observations and 2D images from different angle provide opportunity reconstruction 3D images of emissions and local N_e concentration accordingly [2].

2. Description of the software "Vector-M"

The purpose of "Vector-M" is calculation of the positions of the centre of mass of the spacecraft Meteor-MP, planning of geophysical experiments and also processing of geophysical data. The software is relevant for heights up to 60 R_E and for angles of inclination of the orbital plane both more and less than 90 degrees.

The software "Vector-M" is based on the high-precision numerical orbital model of the satellite. This model was developed by the staff of the celestial mechanics and astrometry department of Tomsk State University. The main tasks of the "Vector-M" are: 1) coordinate transformation, 2) tracing along the force lines of the geomagnetic field, 3) calculation of the conjugation matrices of images along the magnetic force lines, 4) calculation of the attendant geophysical and astronomical information for the centre of mass of the spacecraft Meteor-MP, 5) calculation of the forecast for specific situations of locations of several spacecrafts (in the different orbits) in space and over specific points on the Earth.

The initial data for the software "Vector-M" are: 1) spacecraft's initial orbital parameters, 2) geomagnetic field and atmosphere parameters, 3) the ephemeris of the Sun and Moon and the lunar phase angle, 4) the coordinates of the earth-based observation stations, 5) the orientation of the spacecraft data received on both the night and day sides of the orbit. The initial data of the auroral imager Aurovisor-VIS/MP and Laetitia are: the viewing angles of fields of the channels, the angles of optical axes of the channels with the construction axes of the spacecraft, the angles of input windows of the analyzer of charged particles.

The software "Vector-M" makes calculations of the positions of the centre of mass of the spacecrafts and its forecasting at specific times and time intervals by using the numerical model of the spacecraft motion. It is also possible to make calculations relative locations of the spacecrafts in space: 1) within certain values of the dipole latitude and MLT, 2) geographic and geomagnetic local time in the neighbourhood of magnetic force line and its footprint at the altitude of emission, 3) at the intersection of the concrete sectors of northern and southern auroral ovals, 4) at the flyby of the spacecraft over specific points on the Earth's surface (earth-based bright sources of light and points of location of the earth-based all-sky imagers and another diagnostic instruments), 5) on illumination (Sun, Moon).

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