Auroral oval boundary observations by Meteor 3M satellite

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Abstract: The results of the observations of auroral oval boundaries by satellite METEOR 3M are presented. The satellite was lunched December 10, 2002 to the polar heliosynchronous orbit with the altitude of 1018 km and the inclination of 99.63°. The satellite mission includes the observations of the Earth’s resources, the control of the conditions in the near the Earth environment, meteorological and heliogeophysical parameters. The main goals of the mission are the forecast of the solar flare activity, control and prediction of the Earth’s radiation and the state of the Earth’s magnetic field, prediction of the conditions for the radio wave propagation, diagnostic and the control of the conditions in the magnetosphere and ionosphere. The electrostatic analyser MSGI-5EI is used for the analysis of the variations of the fluxes of auroral protons and electrons. It measures the electron and proton fluxes within the energy range from 0.1 to 10 keV in 50 energetic channels and the integral flux of electrons with energies > 40 keV. Determined by MSGI-5EI positions of the auroral oval boundaries are compared with the predictions of OVATION model. It is shown that due to auroral substorm activity the difference between observed and predicted by OVATION positions can exceed 5 degrees in latitude.

Key words: auroral oval, auroral satellite, OVATION model.

1. Introduction

Study of the main features of auroral substorm development requires constant monitoring of radiation and plasma near the Earth, determination of the position of the auroral oval and variations of fluxes of auroral particles, what is one of the main goals of the Meteor-3M No 1 satellite mission. Auroral oval boundaries move to the equator during substorm growth phase. Polar boundary move to the pole after substorm expansion phase onset forming the auroral bulge. OVATION model based on DMSP, POLAR and radar observations gives the position of auroral oval for concrete time intervals.

In this paper we describe the main features of satellite operation, present examples of particle measurements and results of the comparison of the predictions of OVATION model with the Meteor-3M No 1 measurements.

2. The features of the operation of the satellite METEOR 3M No 1

The satellite Meteor-3M No 1 mission includes study of the natural resources, the control of the environment conditions, the hydrometeorological and heliophysical testing. The satellite was lunched December 10, 2002 to the heliosynchronous orbit with the altitude 1018 km and the inclination 99.63° by the rocket “Zenit” from the Baikonur cosmodrome. Table 1 summarizes the main technical characteristics of the satellite.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Satellite mass</td>
<td>1250 kg</td>
</tr>
<tr>
<td>Altitude</td>
<td>1018 km</td>
</tr>
<tr>
<td>Inclination</td>
<td>99.63°</td>
</tr>
<tr>
<td>Launch date</td>
<td>December 10, 2002</td>
</tr>
</tbody>
</table>

3. Spectrometer MSGI-5EI

Measurements of auroral particle fluxes are made using the MSGI-5EI spectrometer [1]. The instrument includes the following sub-systems: high sensitive spectrometric module for low energy ion and proton measurements; high sensitive spectrometric module of low energy electron measurements; low sensitive spectrometric module for low energy electron measurements, and module for the measurements of integral flux of charged particles with the energies > 40 keV.

The detection of low energy particles, energy-charge separation is realized by two kinds of spectrometric modules representing the cylindrical electrostatic analyzers, secondary electron multipliers of the type VEU-6 (low sensitive module) or VEU-7 (high sensitive module), charge-sensitive amplifier and
Meridian Scanning Photometer and SuperDARN are used for model fitting. The DMSP particle precipitation data provides the “core” of OVATION. But DMSP temporal resolution is poor (about 50 minutes per updated position). The time resolution of Polar UVI (in the LBH-L filter used for this work) is typically one image every 1 min 30 s, but auroral images are available only for the northern hemisphere. Large data gaps occur daily, whenever Polar is not in position to observe the northern hemisphere polar regions. The Super Dual Auroral Radar Network consists of a collection of HF radars located in the Northern and Southern hemispheres, but its data are not used in all cases. University of Alaska, Fairbanks MSP (Meridian Scanning Photometer) data is high time resolution, but only works (1) in darkness, (2) under fair skies, (3) when the auroral oval is within a few degrees of Fairbanks. The verification of OVATION model requires using of data of auroral satellite which was not used in OVATION model.

In this study we compare the predictions of OVATION model with the results of Meteor-3M No 1 observations. This includes the determination of the geomagnetic coordinates and time of the oval boundary crossings by Meteor-3M No 1 satellite and simultaneously the position of auroral boundaries according to the OVATION model. After that we determine a difference in degrees between both geomagnetic latitudes. Fig. 1 shows precipitating electron fluxes observed by the METEOR-3M satellite January 1, 2003. Fig. 2 shows the auroral oval position provided by the OVATION model for the event January 9, 2003. The Meteor-3M crossings of auroral oval boundaries are shown by black squares, and the closest in time DMSP satellite trajectories are shown by white squares. “R” are the results of radar measurements used in the OVATION model. As it can be seen from Fig. 2, the auroral oval position provided by the OVATION model coincides very well with the Meteor-3M No 1 measurements for the event January 9, 2003. Nevertheless this coincidence is not observed for all events analyzed. Fig. 3 shows precipitating electron fluxes observed by the METEOR-3M satellite January 8, 2003 and Fig. 4 shows the auroral oval position provided by the OVATION model for this event. The discrepancy larger than 4° is observed.

To make a statistical analysis of discrepancies observed we separated all events analyzed in 6 sets according to the absolute value of the difference: from 0 to 1 degrees, from 1 to 2 degrees, from 2 to 3 degrees, from 3 to 4 degrees, from 4 to 5 degrees and larger than 5 degrees. Fig. 5 shows the results of produced analysis. Values on the ordinate axes show the number of analyzed events (in %). Upper part of the figure corresponds to the equatorial boundary of the oval; lower part corresponds to the polar boundary. It is possible to see that the model gives quite good predictions of auroral oval location in half of cases. Events with large discrepancy correspond to storm periods or to cases when the angular difference of DMSP and Meteor-3M trajectories is larger than 20° (in longitudes). Medium value of the discrepancy is 1.8° ± 1.3° for the equatorial boundary and 2.8° ± 2.5° for the polar boundary.

The average positions of polar and equatorial auroral boundaries are also determined. Equatorial boundary is located at 68° ± 4° near noon and 62° ± 6° near midnight. Polar boundary is located 77° ± 3° near noon and 70° ± 10° near midnight. These values are in agreement with existing models of auroral oval position [2, 5–9].
Fig. 1. Precipitating electron fluxes observed by the METEOR-3M satellite January 9, 2003

Fig. 2. Visualization of the results of the comparison of the OVATION model with Meteor-3M No 1 data for the January 9, 2003 event. Crossings of the Meteor-3M No 1 trajectories of the auroral oval are shown by black squares, white squares show nearly simultaneous crossings by one of the DMSP satellites. R are the results of radar measurements used in OVATION model

Fig. 3. Precipitating electron fluxes observed by the METEOR-3M satellite January 8, 2003

Fig. 4. Visualization of the results of the comparison of the OVATION model with Meteor-3M No 1 data for the January 8, 2003 event
5. Discussion and conclusions

The preliminary results presented here show the capability of the Meteor-3M No 1 satellite to verify and precise the auroral oval positions given by the OVATION model. We have found that the positions of the auroral oval boundaries, observed using the Meteor-3M precipitating particle flux measurements, generally coincide with these provided by the OVATION model. Nevertheless, for some events observed and modeled boundaries differ in a few degrees in geomagnetic latitude. It was found that this discrepancy increases with the angular distance between Meteor-3M No 1 and DMSP satellite used by the OVATION model as an input. We consider that the main reason of observed noncoincidence when the angular distance of DMSP and Meteor-3M No 1 satellite is small is the auroral boundary motions during magnetospheric substorms.

Acknowledgments

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References