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Prediction of the state of the Earth's magnetosphere using machine learning in SINP MSU Space Weather Analysis Center

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The state of the Earth's magnetosphere is characterized by both the level of geomagnetic field disturbances and the magnitude of the flux of relativistic and sub-relativistic electrons in the Earth's outer radiation belt (ERB). The Center for Space Weather Analysis of the Institute of Nuclear Physics, Moscow State University (SINP MSU) provides information on the current state of near-Earth space, as well as operational forecasts of variables describing this state - namely, of the geomagnetic indices (Dst and Kp) and of relativistic electron fluxes in the outer ERB. The forecasts are carried out using machine learning (ML) methods.

The changes in the parameters of the solar wind (SW) and interplanetary magnetic field (IMF) are responsible for both magnetic storms and variations of the fluxes of relativistic electrons of the outer ERB. So since the causes of changes in geomagnetic and radiation conditions in the near-Earth space are closely related to each other, the problems of predicting them are solved by similar methods.

The following operational forecasts, implemented using ML methods, operate at the portal of the Space Weather Analysis Center of SINP MSU (https://swx.sinp.msu.ru/):

- forecast of geomagnetic indices Dst [1, 2] and Kp [3];
- forecast of relativistic electron fluxes (E>2 MeV) of the Earth’s outer radiation belt in geostationary orbit [4,5];
- forecast of daily fluences of relativistic electrons (E>2 MeV) in geostationary orbit using the forecast of solar wind speed [6].

In all of the above forecasts, in addition to the predicted values themselves, the most important input parameters are the SW velocity, the magnitude and the vertical (z) component of the IMF, as well as sine and cosine with daily period. To predict the electron fluxes of the outer ERB, values of Kp and Dst are also required.

The most effective ML methods for solving these problems are artificial neural networks and gradient boosting over decision trees. In addition to the selection of optimal ML methods and the selection of their optimal parameters for each specific task, a very significant stage of processing is the selection of essential input features of the task.

In addition to directly predicting the value of geomagnetic indices, work is also underway to predict the level of geomagnetic field disturbance based on the Kp index using ML methods that carry out classification [7].

The tasks of studying and predicting the state of the magnetosphere are important from both fundamental and practical points of view [8].

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