Development of radiation belt forecast model based on the recurrent neural network

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The relativistic/sub-relativistic electron flux variations often cause serious damage to the satellites operating in space through the dielectric charging. In order to forecast flux variations of these hazardous electrons, various forecast methods have been developed, based on physical-based simulations and empirical models for the high energy electrons. As a method with physics-based simulations, the SUSANOO, which operates a code-coupling simulation of the heliosphere and radiation belts, provides MeV electron flux variations for the next couple of days. As those employing the empirical modeling, the linear prediction filter (LPF) and the auto-regressive moving average (ARMA) have been commonly used for the forecast of MeV electrons at geosynchronous earth orbit (GEO). Recently, machine learning techniques have widely been used for the space weather forecast, for example, ionospheric variations, the flare prediction, etc. In this study, we have developed a new system for predicting the variability of radiation belt electron fluxes based on a regression neural network model using a network called LSTM (Long Short Term Memory) as the hidden layer. As training data, we used solar wind data and high energy electron flux data from the High Energy Electron Probe (HEP) and the Ultra High Energy Electron Probe (XEP) observed at different L-values in the outer bands. The developed model outputs the time variability of the radiation band electron flux in the range of several hundred keV to several MeV at L values 4, 5, and 6 using the radiation band electron flux and solar wind data of the previous day as input parameters. After constructing the network, a random search method was used to search for hyperparameters, and a combination of hyperparameters with high prediction accuracy was derived. The developed system was used for prediction calculations, and it was found that using solar wind velocity, IMF-Bz, and radiation belt electron flux of the previous day as inputs for three days, the prediction accuracy was higher than that of previous studies. The dependence of the prediction accuracy on energy and L-value was also examined. We also compared the accuracy of the prediction when the flux increases and decreases, and found that the prediction accuracy is particularly low when the flux decreases. Based on the above discussion, in order to improve the prediction accuracy in the future, it will be necessary to add solar wind parameters such as solar wind density, which is not included in the current model and is considered to be the cause of the decrease in the flux outside the outer bands, to the input data. Furthermore, with a view to constructing a real-time space weather forecast, we have developed an automatic prediction system of radiation belt electron flux developed using quasi-real-time data of solar wind and arrows. As a result of the test operation, it was found that the system can robustly predict the variability even when the observed data is missing, and the Prediction Error is 0.84, which means that the system can achieve high prediction accuracy, and it is expected to be a useful model for future space weather forecasting. In order to improve the accuracy of automatic prediction in the future, it is necessary to use the prediction value obtained on the day before the missing day, instead of using the value on the day before the missing day when processing the missing observation value.

Keywords: Space Weather Forecast, radiation belts, Arase, Machine Learning

