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Multi-hour-ahead prediction of Dst index using nonlinear autoregressive models with exogenous variables

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Geomagnetic storms play an important role in the framework of space weather. Disturbance storm time index (Dst index) is a geomagnetic index that monitors the geomagnetic storm level. It is well known that the geomagnetic storms may damage critical equipment, such as communication satellites, power lines and GPS links. Therefore, modeling and prediction of the Dst index are important for both scientific and economic reasons.

Two kinds of approaches have been proposed to model the DST index. One way is to use simplified analogue physical models on the basis of physical principles. An alternative approach is to directly build statistical models on the basis of the measurements. In the latter approach, the linear and nonlinear autoregressive models with exogenous variables (ARX and NARX models) were mostly used to predict the Dst index.

In most statistical approaches, the variance of the Dst index was assumed to be constant, and the estimated mathematical expectation was used to be the prediction value of the Dst index. However, according to our computational analysis, we found that the Dst index is of time-varying variance, and the proper estimation of this time-varying variance will enhance the prediction performance.

If the geomagnetic field is taken as an input-output dynamics system, the Dst index and the solar wind parameters can be referred to as the output and input, respectively. To model this input-output dynamic system, we combined the generalized additive models for location, scale and shape (GAMLSS) with the NARX models to construct the models. By using the GAMLSS type NARX models, the mathematical expectation and variance of the Dst index can be predicted.

So far, most contributions focused on predicting the Dst index in an hour ahead. Because the geomagnetic storms are harmful to critical equipment and then should be forecasted as early as possible, the multi-hour-ahead prediction models are necessary for the Dst index. For this purpose, we investigated the performance of the GAMLSS type NARX models for multi-step-prediction of the Dst index.

Finally, the statistical results, including the coefficient of determination and the prediction mean squared error, are given to comprehensively illustrate the fitting and prediction performance of the models.

Keywords: Space weather, Dst index, prediction, nonlinear autoregressive models with exogenous variables