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Echo state network によるサブストーム活動の確率モデル

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Probabilistic model of substorm activity based on an echo state network

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A substorm is one of fundamental physical phenomenon in the magnetosphere-ionosphere system. Since a substorm is a main cause of geomagnetic disturbances in the polar ionosphere which may affect electric infrastructure, many studies have attempted to predict the substorm onsets. However, those studies showed that the prediction of each individual substorm occurrence is highly difficult.

In this study, we hypothesize the difficulty in the prediction of a substorm onset is due to the stochastic nature of a substorm. In order to consider the stochastic occurrences of substorms, we represent the sequence of substorm onsets with a nonstationary Poisson process, which is a probabilistic model describing event time series. The occurrence rate of substorms is then modelled with an echo state network model. The echo state network is a kind of recurrent neural networks where the connections and weights between hidden state variables are fixed. We use solar wind data as inputs of the echo state network model.

After training the model with the solar wind data and a substorm event list for 11 years, we calculated the occurrence rate of substorms for artificial solar-wind conditions. The results show that the following well-known characteristics are reproduced with our model.

1. Substorm occurrences are mainly controlled by IMF Bz and solar-wind velocity.
2. Short-term variations of IMF Bz and solar-wind velocity are not likely to be effective for substorm occurrences. The occurrence rate is highly enhanced after a few hours of duration of high-speed solar wind with southward IMF.

In addition, the result suggests the followings.

3. The expected substorm occurrence rate is also highly controlled by solar wind density.
4. Substorm occurrences appear to be stochastic during a long duration of southward IMF.

These results show that the probabilistic model is effective for describing
substorm activity.