Prediction of Magnetic Substorms using a State Space Model

K. UNNIKRISHNAN [1,2]

[1] *Department of Physics, N S S Hindu College, Changanacherry, Kerala 686 102, India*

[2] *School of Pure and Applied Physics, Mahatma Gandhi University, Priyadarshini Hills, Kottayam, Kerala– 686 560, India*

Phone:+91-469-2604383, kaleekkalunni@gmail.com

Magnetic storms and substorms interconnect in a uniquely global manner the sun and the earth. Magnetosphere has a non linear behaviour due to the internal dynamics associated with loading and unloading related with storms and substorms.

Considering the solar wind-magnetosphere interaction to be a natural input-output system, its dynamical features can be reconstructed on the storm time scale by using the method of time delay embedding. The dusk to dawn electric filed $Ew=VBz$ is chosen as the input and the AL as the output. The reconstructed phase space is represented by the state vector

$$X(t)=[AL(t),\ldots\ldots,AL(t-(m_{out}-1)\,\tau_{out});\ Ew(t),\ldots\ldots,\ Ew(t-(m_{in}-1)\,\tau_{in})] \qquad (1)$$

where m_{out} and m_{in} are embedding dimensions of output and input time series, respectively. Similarly, τ_{out} and τ_{in} respectively represent the time delays for output and input time series. Using this technique, the AL value at the next time interval $AL(t+1)$ is expressed as

$$AL\ (t+1)= F[X(t)] \qquad (2)$$

where the functional F of the state vector $X(t)$ is obtained from the dynamical features of the reconstructed phase space. The local value of F is obtained by a Taylor expansion around $X(t)$ and the coefficients computed by fitting procedure using the evolution of the nearest neighbours of $X(t)$. When the Taylor expansion is limited to the linear term, this yields a local linear technique. The local linear technique can be used to make one-step and iterated predictions. In the present study, we have considered sufficient number of substorm events, to reconstruct the phase space, which is called the training set. For a given state outside the training set, similar states in the data set within the embedding space are identified as the nearest neighbours. Then the predictions are obtained by nearest neighbour technique, which assumes that the evolution of these nearest neighbours determines the evolution of the current states under consideration. Thus input-output state space models can effectively forecast space weather.

Key words: magnetic substorms, state space model, input-output system, solar wind-magnetosphere interaction

References

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