Investigation of the response of the ionospheric current to upstream solar wind and magnetospheric activity: a neural network approach

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Introduction

It is well known that geomagnetic field disturbances can be generated at high latitudes due to strong ionospheric electrojet currents during substorms and geomagnetic storms. These large magnetic disturbances, usually accompanied by a large rate-of-change in the magnetic field dB/dt, will also produce geoelectric fields and geomagnetically induced currents (GIC). In order to study the variations of ionospheric currents (i.e., the Equivalent Ionospheric Currents (EICs) and the Spherical Elementary Current (SEC) amplitudes) and its response to upstream solar wind and the magnetospheric activities, we developed an ANN-SEC model based on the feedforward neural network to reproduce the ionospheric current obtained from the SEC technique. The conventional statistical analysis is incapable of providing a quantitative prediction and reproduction of the EICs and SEC amplitudes with relatively high accuracy due to the high nonlinearity of this system. Understanding how the upstream solar wind, the magnetospheric dynamics, and the Earth's ionosphere coupled with each other is essential. The data utilized are measured by multiple spacecraft and ground-based observations, and the target values of the ANN-SEC model are the ionospheric currents obtained from the SEC technique, including both components of the EICs and the SEC amplitudes. The input parameters include the locations of the measurements (longitude and latitude), solar wind parameters (e.g., solar wind velocity, magnetic field, dynamic pressure), and geomagnetic indices (e.g., AL, AU, AE, SYM-H, ASY-H). Based on the result of our ANN-SEC model, we found that our model is promising in predicting the Earth's ionospheric currents using the driving mechanism of the solar wind and the magnetosphere. Our model is designed to provide spatial and temporal reconstruction of the ionospheric currents whenever and wherever they are not directly available from the SEC current system.

Data investigation

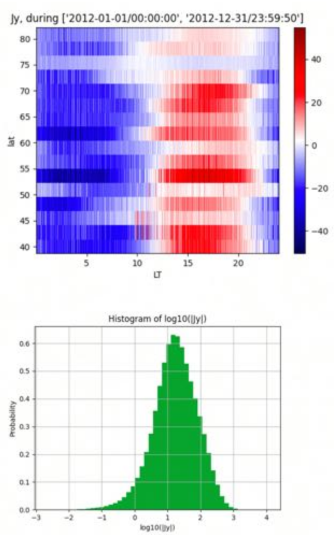


Figure 3. The upper plot shows the distribution of Jy component of EICs current during one year. The red color represents the eastward current and the blue color represents the westward current. The lower plot shows the histogram of EICs Jy component, which shows the mean value is between 10 and 10^2.

ii. Ionospheric current observations. Case study 1: substorm

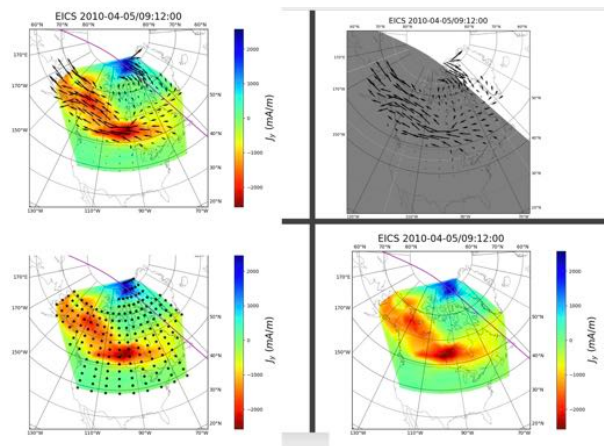


Figure 1. The event on 2010/04/05, the equivalent ionospheric currents (EICs) vectors are shown on the upper right panel. the other panels show the contour plots of the Jy component of EICs, which +y direction points towards eastward. The virtual measurement locations, which were derived from the ground magnetic field data, are distributed as the spots shown on the bottom left panel. This substorm event shows that the westward EICs were observed

iii. Ionospheric current observations. Case study 2: storm

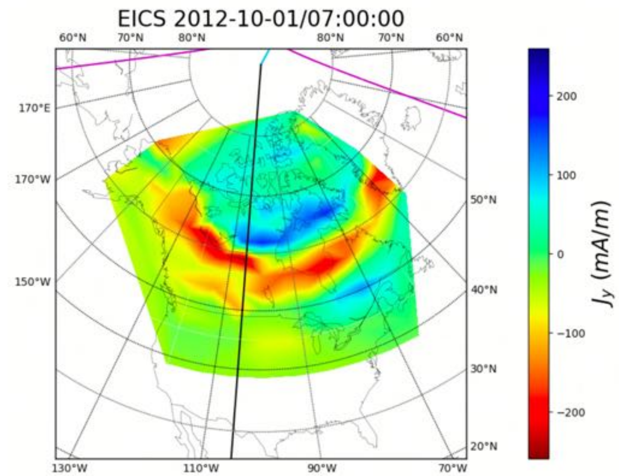


Figure 2. The event on 2012/10/01, the equivalent ionospheric currents (EICs) vectors are shown on the upper right panel. the other panels show the contour plots of the Jy component of EICs, which +y direction points towards eastward. The virtual measurement locations, which were derived from the ground magnetic field data, are distributed as the spots shown on the bottom left panel. This storm event shows that the westward EICs were observed. The purple line represents the dawn-dusk line, and the black-blue line represents the noon-midnight line (black: midnight; blue: noon).

iv. The variation of loss function of the training process

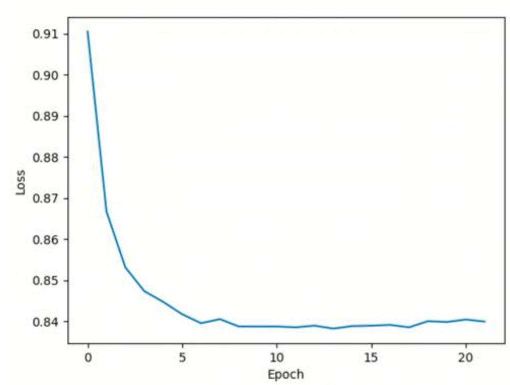
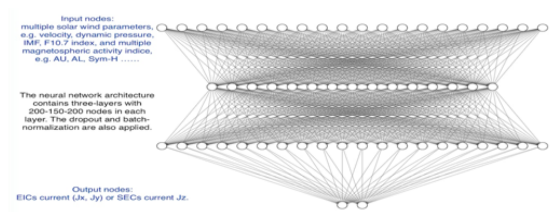


Figure 4. The plot shows the variation of the loss function with the epochs when training the neural network model.



v. Discussion and Conclusion

We used the neural network model to predict the EICs and SECs current of the ionosphere in order to investigate their response to the upstream solar wind and the magnetospheric activity indice. We studied the ionosphreic current by case studies and the initial statistical analysis. The neural network is well established to match the prediction project and has been started to train. Further comparsion between the model results and the observation will be made later, especially for the substorm and storm events.