Forecasting of Pc5 Geomagnetic Pulsations Observed in Space using Machine Learning Technique

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Introduction

- Pc5 geomagnetic pulsations are ultralow frequency (ULF) waves observed both in space and on the ground.
- They are created by processes within and outside the Earth's magnetosphere.
- Pc5 geomagnetic pulsations are capable of accelerating radiation belt electrons to high velocities which is harmful to satellites and astronauts.
- Therefore, forecasting of Pc5 waves observed in space is crucial to protecting technological systems and humans in space.
- Here, we developed a robust Feedforward Neural Network (FNN) model for forecasting of Pc5 geomagnetic pulsations observed in space utilizing solar and interplanetary parameters.

Data and Method

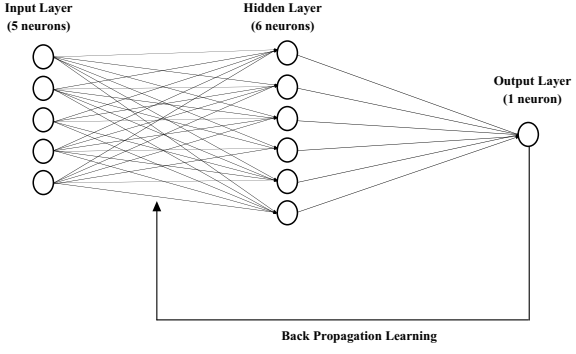

Figure 1. Architecture of FNN model utilized in the study. It consists of 1 input layer with 5 neurons, 1 hidden layer containing 6 neurons and an output layer containing 1 neuron representing forecast Pc5 geomagnetic pulsations. A back propagation learning algorithm was utilized.

- Denoised Pc5 geomagnetic pulsations were extracted from the toroidal component of the magnetic field time series retrieved from the **GOES-10** during solar cycle 23 and were utilized as the target in the model development.
- The model was trained using solar and interplanetary parameters retrieved from the OMNI Web database during solar cycle 23.
- The solar wind parameters retrieved from OMNI Web database include: Bz, solar wind speed, proton density, flow pressure and plasma beta.
- The data was carefully divided for effective training and validation of the model.
- The model was validated during various phases of the solar cycle to assess its performance.

Results

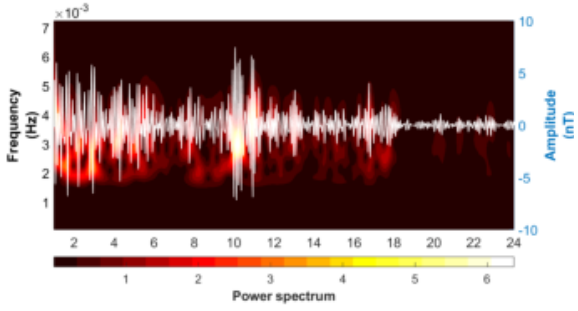

Figure 2. Extracted denoised Pc5 geomagnetic pulsation together with the wavelet spectrum on 31 October 2003, a geomagnetic active day. The frequency of the wave lies in the band of **1-7 mHz** which is a typical frequency band of Pc5 ULF waves. This validates our choice of target used in training the FNN model. Pc5 pulsations are prevalent on the dayside compared to the night side.

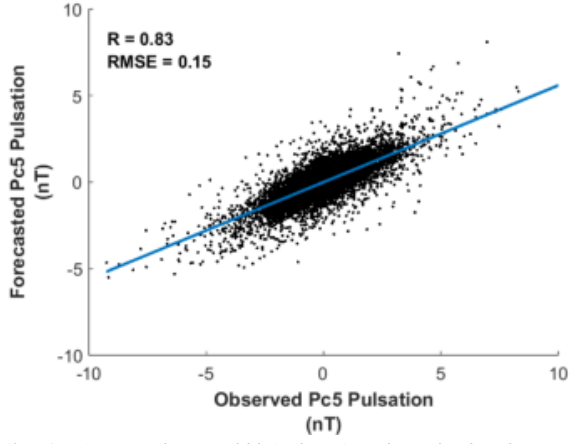

Figure 3. Performance of the FNN model during the maximum phase of the solar cycle (i.e. 2001). The FNN model forecasts the observed Pc5 waves with an accuracy of 83% and a RMSE of 0.15 nT was obtained during this year.

Conclusions

- Machine learning technique was utilized for effective forecast of Pc5 waves observed in space at geostationary orbits.
- The FNN model developed in the study showed good forecasting accuracy during various phases of the solar cycle.
- An average forecasting accuracy of 80% with an average RMSE of 0.12 nT was obtained during the various phases of the solar cycle.
- We recommend the infusion of machine learning techniques for studies of Pc5 waves in space. This is because of the ability of machine learning to generalize well.

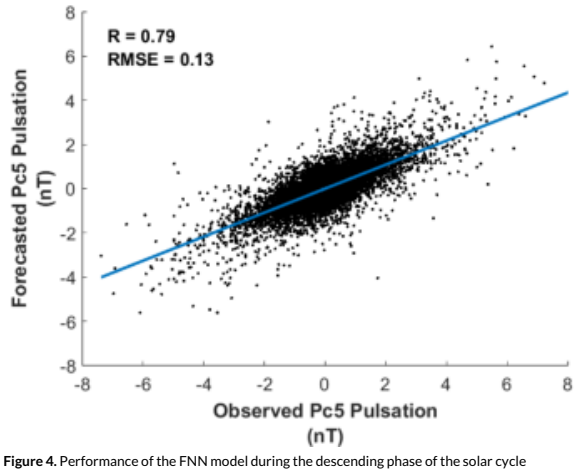

Figure 4. Performance of the FNN model during the descending phase of the solar cycle (i.e. 2005). The FNN model forecasts the observed Pc5 waves with an accuracy of 79% and a RMSE of 0.13 nT was obtained during this year.

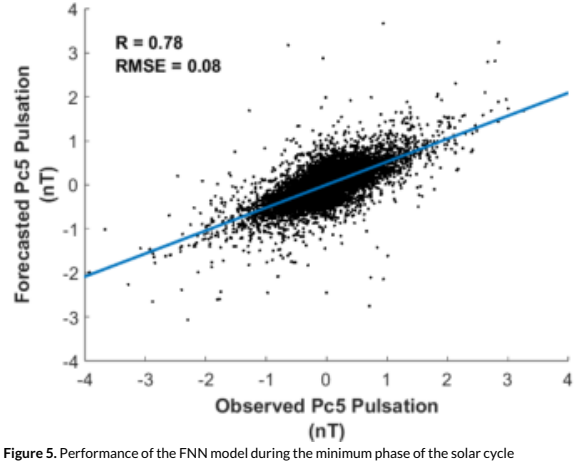

Figure 5. Performance of the FNN model during the minimum phase of the solar cycle (i.e. 2009). The FNN model forecasts the observed Pc5 waves with an accuracy of 78% and a RMSE of 0.08nT was obtained during this year.

Acknowledgements

We thank the hardworking operators of the GOES-10 satellite and the OMNI Web database for making the data available publicly for scientific use. The first author of this article acknowledges all members of the Space Environment Research Lab (SERL) that participated in the discussions leading to this article. Lastly, my special thanks goes to TICAD7 scholarship for supporting my study at the Egypt-Japan University of Science and Technology.

This work was supported by the TICAD7 Scholarship at E-JUST.

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