Real-time Solar Flare Probability Forecast Using Deep Neural Network: Deep Flare Net (DeFN)

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Solar flares are the largest explosive events in the Heliosphere. They affect the earth by X-ray and UV emissions, high energy particles, and magnetic storms, causing troubles of satellites and blackout in a large area. To avoid these problems, it is important to predict flares. The mechanism of solar flares is a long-standing puzzle in solar physics. The energy storage and triggering processes of flares are driven by the emergence of flux in the photosphere. The physical process of sunspot formation and flare eruption originating from dynamo action has been intensely studied by observation and theory. In particular, the amount of solar observation data, which is available in the near real time, has remarkably increased. However, it is still difficult to predict flares occurring even in the following 24 hr by human forecasting.

We developed a solar flare prediction model using a deep neural network (DNN), named Deep Flare Net (DeFN). The model can predict probabilities of the maximum class of flares occurring in the following 24 hr. From $3x10^5$ images during 2010-2015 taken by SDO, we detected active regions and calculated 79 features for each region, to which flare occurrence labels (X, M, C) were attached. We used features in our previous work (Nishizuka et al. 2017) and added novel features for operational prediction: coronal hot brightening at 131 A ($T=10^7$ K) and the histories of X-ray and 131 A emissions 1 and 2 hr before an image. We divided the database into two with a chronological split: the dataset in 2010-2014 for training and the one in 2015 for testing. Then, we applied DeFN model to give the output of probabilities for >=M-class flares and >=C-class flares. The model consists of deep multilayer neural network, formed by adapting skip connections and batch normalizations. It was trained to optimize the skill score, i.e., the true skill statistic (TSS), and we succeeded in predicting flares with TSS=0.80 for >=M-class flares and TSS=0.63 for >=C-class flares in an operational setting. Note that, in this DeFN model, the features are manually selected, and it is possible to analyze which features are effective for prediction.

In this talk, we would like to introduce our DeFN model and our activity to use it in a real-time forecasting operation. We will also discuss the flare triggering mechanisms by the comparison of the extracted solar features.

Keywords: solar flare, prediction, space weather, deep learning, X-ray emission, real-time operation

