

# Operations of Solar Flare Prediction Model Using Deep Neural Networks

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Solar flares are an origin of space weather phenomena, and it is important to predict solar flares more accurately. Especially, an automated prediction model in real-time operations, which can be used by even non-scientists and can give a better feedback from previous prediction experience, is expected. In our previous works, we developed an operational solar flare prediction model using deep neural networks, named Deep Flare Net (DeFN). DeFN can issue probabilistic forecasts of solar flares in two categories, such as  $\geq$ M-class and  $<$ M-class events or  $\geq$ C-class and  $<$ C-class events, occurring in the next 24 h after observations and the maximum class of flares occurring in the next 24 h. DeFN is set to run every 6 h and has been operated since January 2019.

The input database of solar observation images taken by the Solar Dynamic Observatory (SDO) is downloaded from the data archive operated by the Joint Science Operations Center (JSOC) of Stanford University. Active regions are automatically detected from magnetograms, and 79 features are extracted from each region nearly in real-time using multiwavelength observation data. Flare labels are attached to the feature database, then the database is standardized and input into DeFN for prediction. DeFN was pretrained using the datasets obtained from 2010 to 2015. The model was evaluated with the skill score of the true skill statistics (TSS) and achieved predictions with TSS = 0.80 for  $\geq$ M-class flares and TSS = 0.63 for  $\geq$ C-class flares.

For comparison, we evaluated the operationally forecast results from January 2019 to June 2020. We found that operational DeFN forecasts achieved TSS = 0.70 (0.84) for  $\geq$ C-class flares with the probability threshold of 50 (40) %, although there were very few M-class flares during this period and we should continue monitoring the results for a longer time. Here, we adopted a chronological split to divide the database into two for training and testing. The chronological split appears suitable for evaluating operational models. Furthermore, we proposed the use of time-series cross-validation.

In this talk, we would like to introduce our solar flare prediction model, Deep Flare Net, and the operational prediction results. We also would like to discuss the standard evaluation methods for operational forecasting models, such as the preparation of observation, training, and testing datasets, and the selection of verification metrics.

Keywords: solar flares, space weather forecasting, operational model, deep neural networks, verification