Deep Flare Net Extended to 4-Class Solar Flare Prediction

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We developed a 4-class solar flare prediction model by extending Deep Flare Net (DeFN), which is an operational model to predict flares using a deep neural network. The solar flares are classified by GOES classes (X, M, C, etc.), and, the larger amount of flare X-rays increases the ionization of ionospheric D-layer, results in greater absorption of the radio signals. The model can forecast the flare occurrence probabilities of 4 classes of flares and predict the maximum classes of flares that occur in the following 24 h after observation images. From $4x10^5$ observation images taken during 2010-2017 by Solar Dynamic Observatory, we automatically detected sunspots and calculated 79 features for each region, to which flare occurrence labels of X-, M-, and C-class were attached. We adopted the features used in Nishizuka et al. (2017) and (2018), where we added ones from database in 2016-2017: for example, line-of sight/vector magnetogram in the photosphere, coronal hot brightening at 131 A (T~10^5 K) and the X-ray and 131 A intensity data 1 and 2 h before an image. For operational evaluation, we divided the database into two for training and testing: the dataset in 2010-2015 for training and the one in 2016-2017 for testing. The DeFN model consists of deep multilayer neural networks, formed by adapting skip connections, batch normalizations and weighted cross entropy. To statistically predict flares, the DeFN model was trained to optimize the skill score, i.e., the Gandin Murphy-Gerrity score (GMGS). As a result, we succeeded in predicting flares with GMGS=0.63 for 4-class flares including X, M, C and non-flares. Furthermore, we also developed a system to visualize the impact on the HF radio communication, based on our flare prediction results.

Keywords: Solar Flare Prediction, Space Weater Forecasting, Deep Learning , Soft X-ray Emission, Operational System, HF radio communications

