



Classification/prediction of Spread F by Digisonde with Machine Learning

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The ionosonde is an ionospheric radar that uses high-frequency (HF) radio waves to remotely sense the ionosphere. It measures the local ionospheric plasma density profile by transmitting radio wave pulses at various frequencies (typically several MHz) and receiving the echoes. These echoes, reflected from specific heights in the ionosphere with particular plasma densities, form smooth, continuous traces corresponding to the plasma density profiles of the ionospheric E, F1, and F2 regions. Ionospheric plasma disturbances and irregularities can modulate these echoes, revealing characteristics associated with different types of Spread F (SF) phenomena, such as Frequency Spread F (FSF), Range Spread F (RSF), Branch Spread F (BSF), Mixed Spread F (MSF), and Strong Range Spread F (SSF). Since 2002, we have operated a DPS-4 digital ionosonde (Digisonde), which was later upgraded to the DPS-4D model.

In our work, we trained the machine learning models base on our dataset of SF types over Hainan (19.5°N, 109.1°E) from 2002-2016, which contains about 469,227 human-recorded ionograms including 38,226 Spread-F samples from one station over one solar cycle. After training, we found ResNet, EffientNet, ConvNet and MobileNet all have good performance (accuracy higher than 90%), and we made tools of auto-SF-classification for further active learning. Through this, we have already applied the tools into ionograms from other ionosondes.

We also made ionogram prediction, proposing a method combining a spatio-temporal ConvGRU model with a super-resolution EDSR model. In this work we conducted noise simulation and data augmentation. However, we considered the Generative Adversarial Network (GAN) could better catch the F region features in the prediction, and also made the experiments.