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Relative Factors of Ionospheric Plasma Irregularities Corresponding to Different Spread F Types over Hainan

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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 sending radio wave pulses of different frequencies (several MHz) and receiving the echoes. As radio waves of a specific frequency are reflected from a certain height in the ionosphere with a particular plasma density, these echoes create smooth, continuous traces that correspond to the plasma density profile of the ionospheric E, F1, and F2 regions.

The radio wave echoes by Ionospheric plasma disturbances/irregularities could show their characteristics in the plasma processes, corresponding to different Spread F (SF) types such as Frequency SF (FSF), Range SF (RSF), Branch SF (BSF), Mixed SF (MSF), Strong Range SF (SSF), and so on [1,2].

In the frequency-height figure called "ionogram" obtained by the ionosonde, the image features are associated with ionospheric features, corresponding to different physical mechanisms. As a result, researchers always conduct statistical studies on the different SF types. However, based on studies in the past, it was clear that the occurrences of different SF types had different variation features with local time, season, solar/magnetic activities, and other factors. By now, we don't have a well-accepted standard to describe the SF amplitude and detailed information. Recent advancements in machine learning have enabled the automatic identification of certain ionogram features [3].

In our work, we manually classified the SF types over Hainan (19.5° N, 109.1° E) from 2002-2016, building a new image set of 469,227 human-recorded ionograms including 38,226 Spread-F samples from one station over one solar cycle. On this basis we made a classification model. To validate our assumption, some models, such as VGG, ResNet, EfficientNet, and ViT, were utilized to execute classification on a picked image dataset contains 20,000 samples from each SF types and no SF(total 100,000 samples). In the dataset we random split 80% for training, 15% for validation and the rest 5% for test. After training, we found ResNet, EffientNet, ConvNet and MobileNet all have good performance (accuracy higher than 90%).

The classification model helps us to extract the features. Then we made a short-impending prediction model for the SF, and extracted parameters for the different types in the figure. Our ionogram generation method is proposed by combining a spatio-temporal ConvGRU model with a super-resolution EDSR model, based on image feature only. We use our classification model to check the predicted ionograms, such as with/without SF, SF features, and the ionospheric trace for background plasma density. We find the average accuracy for with/without SF (corresponding to plasma irregularities) is also over 90%

To learn more about the forming and developing processes of Ionospheric plasma irregularities, we also studied the relative factors such as the variations of Ionosphere bottom height as well as solar/magnetic activities with the data from 2002-2019. However, they don't show simple correlation, and we believe there are deep relationships inside our prediction processes.

References

[1] Piggott, W. R., & K. Rawer. (1972). URSI handbook of ionogram interpretation and reduction, Report UAG-23, 68-73, World Data Center A for Solar–Terrestrial Physics. https://www.researchgate.net/publication/252233278_URSI_Handbook_of_Ionogram_Interpretation_and_Reduction

[2] Booker, H. G., & Wells, H. W.. (1938). Scattering of radio waves in the F region of the ionosphere. Journal of Geophysical Research Atmospheres,43(3):249-256. doi: 10.1029/TE043i003p00249.

[3] Rao, Venkateswara, T., Sridhar, M., & Venkata Ratnam, D.. (2022). Auto-detection of sporadic E and Spread-F events from the digital ionograms. Advances in Space Research, 70, 1142-1152.doi: 10.1016/j.asr.2022.05.046.