






## Machine Learning Classification Difficulties of VLF Amplitude Variations Around the Terminator

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Previously, very low frequency (VLF) ionospheric amplitude data was employed in various machine learning (ML) classification efforts (Arnaud, Kolarski, 2023; Arnaut et al., 2023; Arnaut et al., 2024), where the problem was defined as a binary classification task, determining whether a given data point in the test dataset was anomalous (e.g., solar flare events, instrument errors, nighttime signals, outliers) or a normal daytime signal. In a multiclass classification problem, each class must be clearly defined to prevent overlap and minimize the risk of false positives and/or false negatives. The analysis for this brief communication displays that the challenges in classifying nighttime versus daytime VLF amplitude signals occur at the terminator, a transitional zone between daytime-nighttime and nighttime-daytime signals. The majority of false positives and/or false negatives occur in this zone. Possible strategies for enhancing predictive power in this area may include statistical techniques such as cluster analysis or other methods that can be employed post-classification to further augment the overall efficacy of the approach.

### References

- Arnaud, F. & Kolarski, A., 2023. Machine learning approach for distinguishing daytime and nighttime ionospheric conditions on VLF signals related to solar flares during 2011. In XX Serbian Astronomical Conference, 16-20 October 2023, Belgrade, Serbia. Book of Abstracts, Astronomical Observatory of Belgrade and Faculty of Mathematics, pp. 79
- Arnaud, F., Kolarski, A. and Srećković, V.A., 2023. Random forest classification and ionospheric response to solar flares: Analysis and validation. *Universe*, 9(10), p.436.
- Arnaud, F., Kolarski, A. and Srećković, V.A., 2024. Machine Learning Classification Workflow and Datasets for Ionospheric VLF Data Exclusion. *Data*, 9(1), p.17.