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Towards Developing a Nowcasting Solar Flare Capability Using Subionospheric VLF Radio: Addressing the ICAO Call for Global Aviation

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Extended Abstract
Solar flares are often the first indicator of a sequence of space weather events that have the potential to impact societal technology. They are linked to processes which disrupt maritime mobile services, emergency responders, high-frequency (HF) communications, and the aviation industry. In this study we present a technique for analysing very low frequency (VLF) radiowave signals in order to achieve rapid, real-time detection of solar flares for nowcasting by space weather forecast centres, through changes in VLF radio signal propagation conditions [1]. We investigate the reliability of VLF phase and amplitude perturbations, during large solar flares, to determine the X-ray fluxes involved. We identify the most accurate parameterisation needed to develop nowcasting equations relating VLF phase perturbations with longwave X-ray fluxes (0.1-0.8 nm, XL), and show that other relationships involving VLF amplitude perturbations, and shortwave x-ray fluxes (0.05-0.4 nm, XS), are less reliable.

Amendment 78 to the International Civil Aviation Organization (ICAO) Annex 3 (application date November 2018) identifies solar flares and solar storms as potential hazards that affect communications, navigation, and could pose a radiation risk to aircraft crew and passengers. Because of this ICAO has released a Manual of Space Weather Information in Support of Air Navigation [2]. This manual indicates that early warning of solar flare driven HF radio blackout occurrence, duration and severity is a requirement for ICAO. Solar flares of X1 class are identified by ICAO as requiring a moderate space weather advisory of likely weak HF radio communication, while an X10 flare requires a severe advisory due to likely HF radio blackout conditions. Forecasting of solar flare occurrence is an outstanding problem. Predictive techoniques using morphological methods based on observed parameters have been developed but currently have low forecast skill scores, particularly for large, infrequent flares. In light of the difficulties in forecasting large solar flares it is imperative that a swift nowcast capability is developed, with the ability to rapidly detect and classify enhanced solar X-ray flux levels. Nowcasting of solar flares needs to identify when a flare has occurred, when it has reached a disruptive size, when it has peaked, how large the fluxes are at the peak, and how long the flare effects will last. Our VLF technique addresses these requirements.

In our presentation we demonstrate accurate nowcasting of the occurrence and magnitude of X-class flares, as reported in our recent paper [1]. We go on to show how the same techniques can be applied to smaller, much more common, M-class flares. We then contrast the long north-south path subionospheric VLF path previously used [1], with a long east-west VLF path. The later paths are generally easier to set up, and there are significant historic east-west VLF path observations available. Unfortunately, we find that the accuracy of the X-ray magnitude estimates from the east-west paths are considerably lower than for the original north-south path.

References

[1] George, H. E., Rodger, C. J., Clilverd, M. A., Cresswell-Moorcock, K., Brundell, J. B., & Thomson, N. R. (2019). Developing a Nowcasting Capability for X-Class Solar Flares Using VLF Radiowave Propagation Changes. *Space Weather*, 17, 1783– 1799. https://doi.org/10.1029/2019SW002297.
[2] ICAO (2019). Manual on Space Weather Information in Support of International Air Navigation, International Civil Aviation Organization Doc 10100, 2019. Available from: https://store.icao.int/en/manual-on-space-weather-information-in-support-of-international-air-navigation-doc-10100