



## Radio observations as input for the ESPERTA model to forecast moderate-to-extreme solar proton events

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The ESPERTA (Empirical model for Solar Proton Event Real Time Alert) proton event forecast tool was developed (Laurenza et al., 2009) to predict solar proton events (SPEs) with peak intensity  $> 10$  pfu (i.e., eS1 events, where S1 refer to minor storms on the NOAA Solar Radiation Storms scale), by using three input parameters for e M2 SXR flares: the heliographic longitude, the soft X-ray (SXR) fluence and the  $\sim 1$  MHz radio fluence as indicator of particle escape as well as a measure of flare size (which is usually ascribed solely to the SXR fluence). The evaluation of ESPERTA provided a Probability of Detection (POD) of 62% for all the  $>10$  MeV events, from 1995 to 2014 (Alberti et al., 2017), with a false alarm rate (FAR) of 39% and a median (minimum) warning time of  $\sim 4.8$  (0.4) h. Moreover, the radio fluence was found to be a more efficient parameter in distinguishing between the SEP associated events from the not associated ones. In addition, the ESPERTA model was modified to predict only  $> 100$  pfu (i.e., eS2 events, moderate to extreme) proton events, which produce both biological and space operations impacts and increased effects on HF propagation in the polar regions. The obtained verification measures are the following: POD of 75% (41/55) and a FAR of 24% (13/54) for the 1995–2014 interval with a median (minimum) warning time of  $\sim 1.7$  ( $\sim 0.2$ ) h based on predictions made at the time of the S1 threshold crossing. Finally, results showed that the median radio fluence for flares associated with eS2 events is generally increased of about one order of magnitude with respect to those associated with S1 events.

1. M. Laurenza, E. W. Cliver, J. Hewitt, M. Storini, A. G. Ling, C. C. Balch, M. L. Kaiser (2009), A technique for short-term warning of solar energetic particle events based on flare location, flare size, and evidence of particle escape, *Space Weather*, 7, S04008, doi:10.1029/2007SW000379.

2. T. Alberti, M. Laurenza, E. W. Cliver, M. Storini, G. Consolini, F. Lepreti, Solar activity from 2006–2014 and short-term forecasts of solar proton events using the ESPERTA model, *The Astrophysical Journal*, Volume 838, Issue 1, article id. 59, 11 pp., 2017.