Institute for Space Weather Sciences Colloquium

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Dr. Seth Garland, Air Force Institute of Technology (AFIT)

Analysis of Coronal Magnetic Field Parameters during X- and M-Class Solar Flares

Using Non-Linear Force Free Field (NLFFF) extrapolation, 3D magnetic fields were modeled from the 12-minute cadence Helioseismic and Magnetic Imager (HMI) photospheric vector magnetograms, spanning a time period of one hour before through one hour after the start of 18 X-class flares and 12 M-class flares. Several magnetic field parameters were calculated from the modeled fields directly – as well as from the power spectrum of surface maps generated by summing the fields along the vertical axis – for two different regions: areas with photospheric $B_z \geq 300$ G (Active Region – AR) and areas above the photosphere with the magnitude of the non-potential field (B_{NP}) greater than 3 standard deviations above $\overline{|B_{NP}|}$ of the AR field and either the twist number ($|T_w|$) ≥ 1 turn or the shear angle (Ψ) $\geq 80°$ (Non-Potential Region – NPR). Superposed epoch plots of the magnetic field parameters were analyzed to investigate the evolution of the coronal field during the solar flare events and discern consistent trends across all solar flare events in the dataset, as well as across subsets of flare events categorized by their magnetic and sunspot classifications. The relationship between different flare properties and the magnetic field parameters was quantitatively described by the Spearman ranking correlation coefficient, r_s. The parameters that showed the most consistent and discernable trends amongst the flare events, particularly for the hour leading up to the eruption, were the total unsigned flux (ϕ), free magnetic energy (E_{Free}), total unsigned magnetic twist (τ_{Tot}), and total unsigned free magnetic twist (ρ_{Tot}). Strong to very strong correlations – $|r_s| \in [0.6, 0.79]$ and $|r_s| \in [0.8, 1.0]$, respectively – were found between the magnetic field parameters and the following flare properties: peak X-ray flux, duration, rise time, decay time, impulsiveness, and integrated flux. The findings of this study indicate that magnetic field parameters calculated from the modeled coronal magnetic field have greater predictive capability than what has been found from only using photospheric data.

Dr. Seth Garland graduated from the University of Virginia (BS, Meteorology, 2016) and the Air Force Institute of Technology (AFIT) (MS, Applied Physics/Space Physics, 2021; PhD, Applied Physics with focus in Solar Physics, 2023). As a Weather Officer in the Air Force, his first assignment was at the 17th Operational Weather Squadron at Hickam AFB in Hawai'i where he provided forecasts for several military and non-military installations across the Pacific arena. Following that assignment, he applied for and completed the Space Physics PhD program at AFIT. Currently he is Assistant Professor of Space Physics in the Department of Engineering Physics at the AFIT.