

Precursors for flare forecasting

Solar events period	Method	Features	Reference
September, 2017 (AR 12673)	Hybrid Lasso	<ul style="list-style-type: none"> Falconer's l_{WLSG} wls_g_blos/value_int Heliographic longitude of SHARP centroid long_hg Heliographic latitude of SHARP centroid lat_hg Binary flag for occurrence of .1 flare in previous 24 hr flare_past Accumulated GOES flare peak magnitudes in previous 24 hr flare_index_past Total length of all MPILs mpil_blos/tot_length Multifractal structure function inertial range index sfunction_blos/zq Total unsigned flux around all MPILs mpil_blos/tot-usflux Schrijver's R (log10 form) r_value_blos_logr Sum of the horizontal magnetic gradient gs_slf/g_s Ising energy (calculated pixel-by-pixel) ising_energy_blos/ising_energy Maximum length of a single MPIL mpil_blos/max_length Multifractal generalized correlation dimension spectrum mf_spectrum_blos/dq Ising energy (calculated using Beff flux partitions) ising_energy_part_blos/ising_energy_part Separation distance lead. and follow. polarity subgroups gs_slf/slf Fractal dimension frdim_blos/frdim Total of all separate MPIL ratios of $I/h(\text{ncr})_{\text{min}}$ decay_index_blos/tot_I_over_hmin Ratio of MPIL $I/h(\text{ncr})_{\text{min}}$ (for longest MPIL) decay_index_blos/maxI_over_hmin $I/h(\text{ncr})_{\text{min}}$ decay_index_blos/max_I_over_hmin Ratio of MPIL $I/h(\text{ncr})_{\text{min}}$ (for MPIL having lowest $h(\text{ncr})_{\text{min}}$) decay_index_blos/I_over_minhmin: Effective connected magnetic field strength Beff beff_blos/beff Fourier power spectral index alpha_exp_fft_blos/alpha Continuous wavelet transform power spectral index alphaexp_cwt_blos/alpha 	Benvenuto et al. (2020)

Precursors for flare forecasting

Historical archive from 2012 September 14 to 2016 April 30	Hybrid Lasso	<ul style="list-style-type: none"> • $sfunction_blo s/zq$, • $sharp_kw/snetjzpp/total$, • $sharp_kw/ushz/stddev$, • $decay_index_br/maxl_over_hmin$, • $helicity_energy_bvec/$ • $abs_tot_dedt_in$, • $wlsg_br/value_int$ • topological parameter D 	Cicogna et al. (2021)
August, 2017 (AR 12671)	Feed Forward Neural network	<ul style="list-style-type: none"> • Falconer's WL_{SG} $wlsg_blo s/value_int$ • Heliographic longitude of SHARP centroid $long_hg$ • Heliographic latitude of SHARP centroid lat_hg • Binary flag for occurrence of .1 flare in previous 24 hr $flare_past$ • Accumulated GOES flare peak magnitudes in previous 24 hr $flare_index_past$ • Total length of all MPILs $mpil_blo s/tot_length$ • Multifractal structure function inertial range index $sfunction_blo s/zq$ • Total unsigned flux around all MPILs $mpil_blo s/tot-usflux$ • Schrijver's R (log10 form) $r_value_blo s_logr$ • Sum of the horizontal magnetic gradient gs_slf/g_s • Ising energy (calculated pixel-by-pixel) $ising_energy_blo s/ising_energy$ • Maximum length of a single MPIL $mpil_blo s/max_length$ • Multifractal generalized correlation dimension spectrum $mf_spectrum_blo s/dq$ • Ising energy (calculated using Beff flux partitions) $ising_energy_part_blo s/ising_energy_part$ • Separation distance lead. and follow. polarity subgroups gs_slf/slf • Fractal dimension $frdim_blo s/frdim$ • Total of all separate MPIL ratios of $I/h(ocr)min$ $decay_index_blo s/tot_I_over_hmin$ • Ratio of MPIL $I/h(ocr)min$ (for longest MPIL) $decay_index_blo s/maxl_over_hmin$ • $I/h(ocr)min$ $decay_index_blo s/max_I_over_hmin$ 	Guastavino et al. (2022)

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		<ul style="list-style-type: none">• Ratio of MPIL $I/h(\text{ncr})_{\text{min}}$ (for MPIL having lowest $h(\text{ncr})_{\text{min}}$) $\text{decay_index_blo}/I_{\text{over_minhmin}}$:• Effective connected magnetic field strength $B_{\text{eff}} \text{ beff_blo}/B_{\text{eff}}$• Fourier power spectral index $\alpha_{\text{exp_fft_blo}}/\alpha$• Continuous wavelet transform power spectral index $\alpha_{\text{exp cwt blo}}/\alpha$	
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References:

Benvenuto, F., Campi, C., Massone, A. M., & Piana, M. (2020), *Machine learning as a flaring storm warning machine: Was a warning machine for the 2017 September solar flaring storm possible?*, *The Astrophysical Journal Letters*, 904(1), L7.

Cicogna, D., Berrilli, F., Calchetti, D., Del Moro, D., Giovannelli, L., Benvenuto, F., Campi C., Guastavino S. & Piana, M. (2021), *Flare-forecasting algorithms based on high-gradient polarity inversion lines in active regions*, *The Astrophysical Journal*, 915(1), 38.

Guastavino, S., Piana, M. and Benvenuto, F. (2022), *Bad and Good Errors: Value-Weighted Skill Scores in Deep Ensemble Learning*, *IEEE Transactions on Neural Networks and Learning Systems*, , doi: 10.1109/TNNLS.2022.3186068.