Predictions for solar flares activity in solar cycle 25

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Abstract: A forecast for the evolution of solar cycle 25 in terms of solar flares activity is presented. The forecast is derived from an existing phenomenological model based on the coupling of an internal solar component and a planetary component. In addition to sufficient temporal resolution, the predictions are characterized by features which both differentiate the model from other methods for space climate prediction and make it falsifiable.

A forecast for the next solar cycle (“C25”) is presented, as derived from the model for long-term solar evolution in [1]. Although flares are not the most common observable in solar cycle predictions, here they are deemed useful because of being more solid and impactful events than sunspots, and also because of the promising agreement of the model with the observations of the last four cycles.

Hereby, “flares” will refer to solar flares of X-ray flux intensity classes ≥M1.0. Flares belonging to C25 are defined as coming from active regions belonging to C25, according to their standard definition.

Figure 1 shows the predicted temporal evolution of C25 in terms of counts of flares. Some points about the prediction are discussed explicitly. For completeness, the model and the subsequent derivation of the forecast are overviewed briefly (details on the development of the model are deferred to the original article). The discussion closes with some clarifying remarks.

With some clarifications later below, here are certain explicit predictions resulting from Figure 1:

Onset: Taking uncertainties into account (see below), the first date with a flare count larger than 1 falls roughly between October 2019 and June 2021. The exact count exceeds 1 in late March 2020, so the weeks following it are proposed as the most probable onset window.

Amplitude: The maximum amplitude is expected to be around 40 flares per 80 days, corresponding to the first peak in the histogram.

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Evolution: The general activity will follow that of the plotted distribution, i.e. it will be rather low, spread out, and marked by two distinct ranges. More specifically, it will increase until roughly the beginning of year 2023 and subsequently decrease until a cease around mid-2025; a distinct second period of activity will follow, along roughly the second part of the plotted histogram.

Duration: With the currently available data, the start of cycle 26 is placed around 2032, making C25 about 12 years long. However, the predictions can be updated more precisely right after the start of C25.

Overall intensity: Comparable to that of cycle 24.

Comparison to historical sunspot minima: In terms of sunspots, C25 will be similar to the two historical “local minima”, cycles 6 and 14. (This is the only prediction related to sunspots.)

The prediction is derived from the model described in [1], which is fully quantitative, although only phenomenological so far as it arose from statistical analysis (using [2]).

For the four cycles with fully recorded solar flares, it was observed empirically that the flare count tends to increase towards the dates of heliocentric alignment of the planets Jupiter and Saturn and decrease towards the dates of their quadrature. Furthermore, the peak of each cycle’s activity is “dragged” further away from the alignment date as we proceed from 21 to 24. These observations seem compatible with the coupling of two quasi-periodic components: An internal solar one, presumably of magnetic origin, and a component related to the relative ecliptic motion of the two planets.
Starting from the empirical observations, it is assumed that the “planetary component” will be strongest around the *dates of the alignments* and spanning roughly the range between the quadratures; and that the “internal component” will be strongest around the *temporal middle of each cycle* (with cycles’ start and end defined by the appearance of flares) and spanning roughly somewhat less than 11 years.

If these assumptions are seen as describing the mean and two-standard-deviations of Gaussian distributions, they permit the extraction of two functions by fitting the data of cycle 21 (see [1]). Importantly, the assumption about the timing of the means permits the temporal extension of the model: The two extracted functions are unambiguously copied along the time range of cycles 21-24, by centering the “internal components” on the dates of the cycles’ temporal middles, and the “Jupiter-Saturn components” on the dates of the two planets’ alignments. Subsequently, their common areas are assumed to quantify the coupling of the two components; these areas are proposed to describe the long-term solar activity in terms of flares and provide results in good agreement with the observations (Figure 2). *By continuing this repetition of the distributions over the coming years, centered on the specified dates, the predictions for C25 are provided.*

In Figure 1 the distributions are plotted as solid curve for the internal and dashed for the planetary components, with their common areas comprising the binned histogram. Figure 2 is taken from [1] and shows the results of the model along with the observations for the previous cycles, and the extension over the next years (the data come from the NOAA SMS and GOES satellites [3]).

![Figure 2. Observations and model predictions for solar flares activity in cycles 21-25 as a function of time: Observed number of flares (black) overlaid with the model distributions (purple). The two types of Gaussian components centered on the respective dates are also shown, highlighted after 2010. (The time range starts on 1976/06/30.)](image-url)
As is apparent, the dates of temporal middles for cycles 24 and 25 have to be estimated in order to time their internal components. These dates were calculated from the difference between the solar cycle duration and the two planets’ half synodic period; on average, this difference increases by 396 days between consecutive cycles. This enabled the estimation of the middle of cycle 24, and then 25, from the known middle of 23. (After the actual start of C25 the calculation can be updated.)

This approximate, yet well-defined, determination carries an associated systematic uncertainty; the uncertainty was calculated from the comparison of this method against the actual temporal middles for cycles 22 and 23. Another source of uncertainty is the data binning choices; both systematic and statistical uncertainties are applied in quadrature on the resulting prediction.

It is notable that the time range of C25 is characterized by the presence of two planetary components. In the four fully recorded cycles this has occurred only towards the end of 24; in its second common area, weaker flares activity indeed showed up anew, after it had ceased completely. It is then reasonably expected that also during C25 the activity will follow both common areas, probably with lower intensity in the second one.

Finally, the model cannot be extended to times before cycle 21, since accurate records of flares are needed for the calculation of the temporal middles of the related activity. However, a coarse extension can use the sunspots activity instead. In that case the above-mentioned “double overlap” appears in cycles 6 (Dalton minimum) and 14 (Gleissberg minimum); this led to the prediction that sunspots will now also reach a “local minimum”.

Planetary influence might seem like an unlikely factor of solar activity modulation, but it is one of the few conceivable permanent factors which could perturb solar activity either spatially or temporally. The distinct features of the present forecast differentiate its base model from other space climate prediction methods, in addition to making it falsifiable.

References
[1] E. Petrakou, “A deterministic model for forecasting long-term solar activity”. JASTP, 176, 51 (2018)
[2] R. Brun, F. Rademakers, “ROOT - an object oriented data analysis framework”. NIMPR, 389, 81 (1997)
[3] Archive of the Space Weather Prediction Center, USA National Oceanic and Atmospheric Administration. http://www.swpc.noaa.gov