Abstract

At the NOAA Space Weather Prediction Center (NOAA/SWPC) forecasts are issued for solar radiation storms, which consist of mainly energetic protons. These events can be hazardous to astronauts and passengers & crew on polar flights, and they can damage satellite electronics. We present the current SWPC proton event forecast skill, assessed over two decades in the time period from 1997 through 2017.

Introduction

- Coronal Mass Ejections (CMEs) are large eruptions of plasma and magnetic field from the Sun. As they propagate, they can develop a shock in front of them.
- Often ions can get swept up in these shocks and protons can be accelerated to much higher energies.
- Once the CMEs become magnetically connected to Earth protons can stream along the field lines to Earth, where they are observed as a proton event (Bain et al. 2016)\(^1\).
- In some cases protons can arrive at Earth in tens of minutes after the CME eruptions, making them a challenge to forecast.

SWPC Forecast Products

- The SWPC Solar Radiation Storm S-scale (Fig. 1), is used to categorize proton events.
- SWPC forecast warnings are issued for 10 MeV protons reaching a threshold of 10 protons/sr/cm\(^2\)/s and for 100 MeV protons reaching a threshold of 1 proton/sr/cm\(^2\)/s.
- We analyzed SWPC 10 MeV forecast warnings between 1997 and 2017 in order to determine the SWPC forecast skill.

Forecast Lead Time

- Lead time is defined as the amount of time between the forecast warning issue time and the event onset time.
- Hits have positive lead times while misses have negative lead times.
- In Fig 4 you can see that despite the difficulty in forecasting these events, SWPC still has large lead times.
- An example of a long lead time is shown in Fig. 5.

Forecast Metrics

<table>
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<tr>
<th>Table 1: Forecast metrics</th>
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<tbody>
<tr>
<td><strong>True Positive (TP)</strong></td>
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<tr>
<td><strong>False Negative (FN)</strong></td>
</tr>
<tr>
<td><strong>False Positive (FP)</strong></td>
</tr>
<tr>
<td><strong>Warning was issued before alert [Hit]</strong></td>
</tr>
<tr>
<td><strong>Warning wasn’t issued or issued after alert [Miss]</strong></td>
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<tr>
<td><strong>Warning issued without alert [False Alarm]</strong></td>
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\[
\text{Probability of Detection} = \frac{TP}{(TP + FN)} \quad \text{False Alarm Ratio} = \frac{FP}{(TP + FP)}
\]

Fig. 2: Forecast outcomes from 1997 through 2017

- The forecast skill has improved between solar cycles 23 and 24 as less SEP events were missed, Fig. 2.
- Fig. 3 shows the POD and the FAR forecast metrics.
- In 2016 the FAR looks high, however this results from a single false alarm that year.

Fig. 3: Forecast POD and FAR from 1997 through 2017

Conclusions

SWPC forecasts are improving over time likely due to improved solar observations. In between solar cycles 23 and 24 the Probability of Detection has improved from 71% to 98% and the Critical Success Index (CSI) has improved from 0.58 to 0.70.

POD, FAR, CSI

<table>
<thead>
<tr>
<th>Solar Cycle 23</th>
<th>POD</th>
<th>FAR</th>
<th>CSI</th>
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<tr>
<td>0.71</td>
<td>0.18</td>
<td>0.58</td>
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\[
CSI = \frac{TP}{TP + FN + FP}
\]

Ref: (1) Bain et al (2016) 2016ApJ...825...1B apj, 825, 1
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