Forecasting SEP Events with Solar Radio Bursts

Julliann Coffey[1]

Mentors: Lisa Winter[2] and Rick Quinn[2]

[1]Colorado School of Mines, Golden CO

LASP, Boulder CO

[2]Atmospheric and Environmental Research (AER)

Solar Energetic Particle (SEP) events from the Sun occur when particles associated with solar bursts like CMEs and flares are propelled into space. These events can cause substantial damage to objects in their paths, like satellites, by penetrating into them and causing radiation. A past study devised a method of forecasting the occurrence of an SEP event using properties of the type II and type III radio bursts measured from WIND/WAVES (Winter & Ledbetter 2015). This study analyzed 27 SEP events from 2010 to 2013. We now present an analysis of type II and type III bursts in solar cycle 23, associated with the 63 SEP events from 2000-2003. Parameters including the peak flux of type II bursts, integral flux of type II and II bursts, and the duration of type III bursts are used to create a radio index. This index is used to predict whether or not an SEP event will occur. Cycle 23 was more active than cycle 24, with significantly more radio bursts and SEP events. Our results show that the radio index successfully predicts the occurrence of SEPs for the events in the more active solar cycle 23. We also find that, in general, the higher the radio index the higher the peak proton flux will be following the burst.

Introduction

The proton data used to identify SEP events was acquired from the GOES-08 and GOES-11 satellites. After finding all the SEP events from 2000 to 2003, data from the WIND/WAVES satellite were used to observe the radio bursts. First, the data were cleaned so that the bursts were visible with clear structures. Then, the data were used to measure four parameters: type II peak, type II integral flux, type III integral flux, and type III duration. After all the new parameters were measured, the principal component analysis of these four parameters was used to create radio indices for each SEP event. The radio index is used to determine the probability of an SEP event occurring following type II and type III bursts.

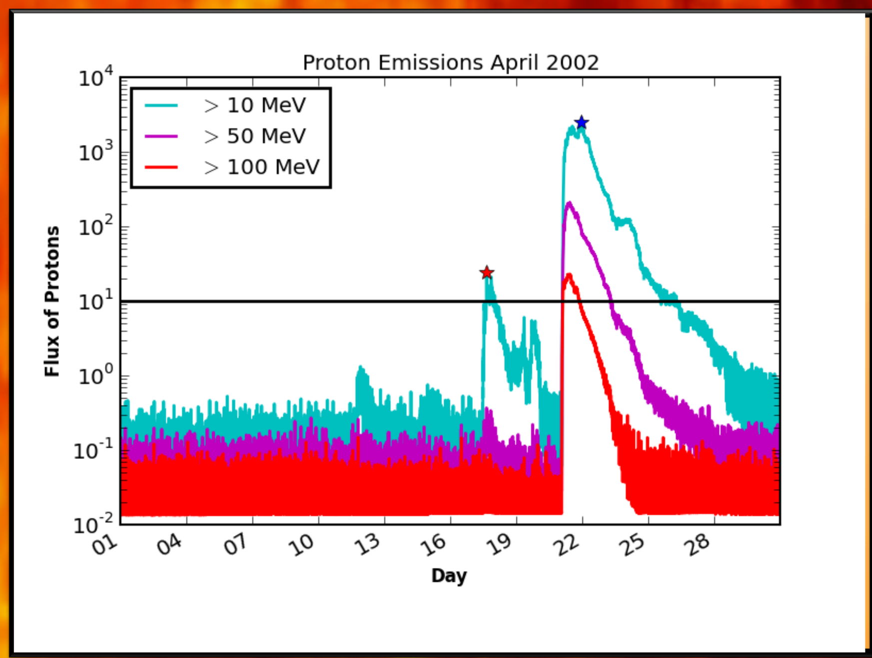
Data Acquisition

Wind-Waves (below) was the satellite used to measure the solar radio bursts. We looked at observations from the Radio Receiver Bands 1 and 2 (RAD1 and RAD2).

GOES (above) was the satellite used to measure the proton data (specifically GOES-08 and GOES-11). The proton data were used to determine when the SEP events occurred during the period of the study – 2000 to 2003. Solar cycle 23 was a very active cycle and therefore had many more SEP events and bursts than solar cycle 24.

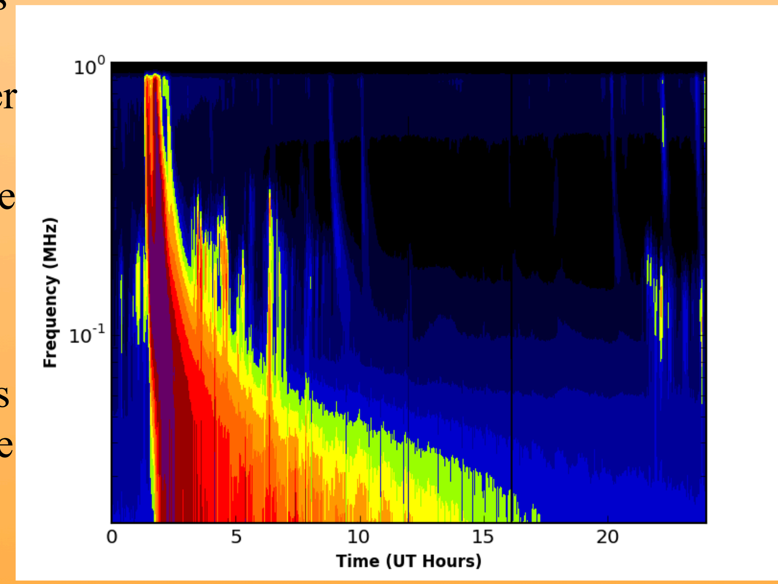
Parameters Measured

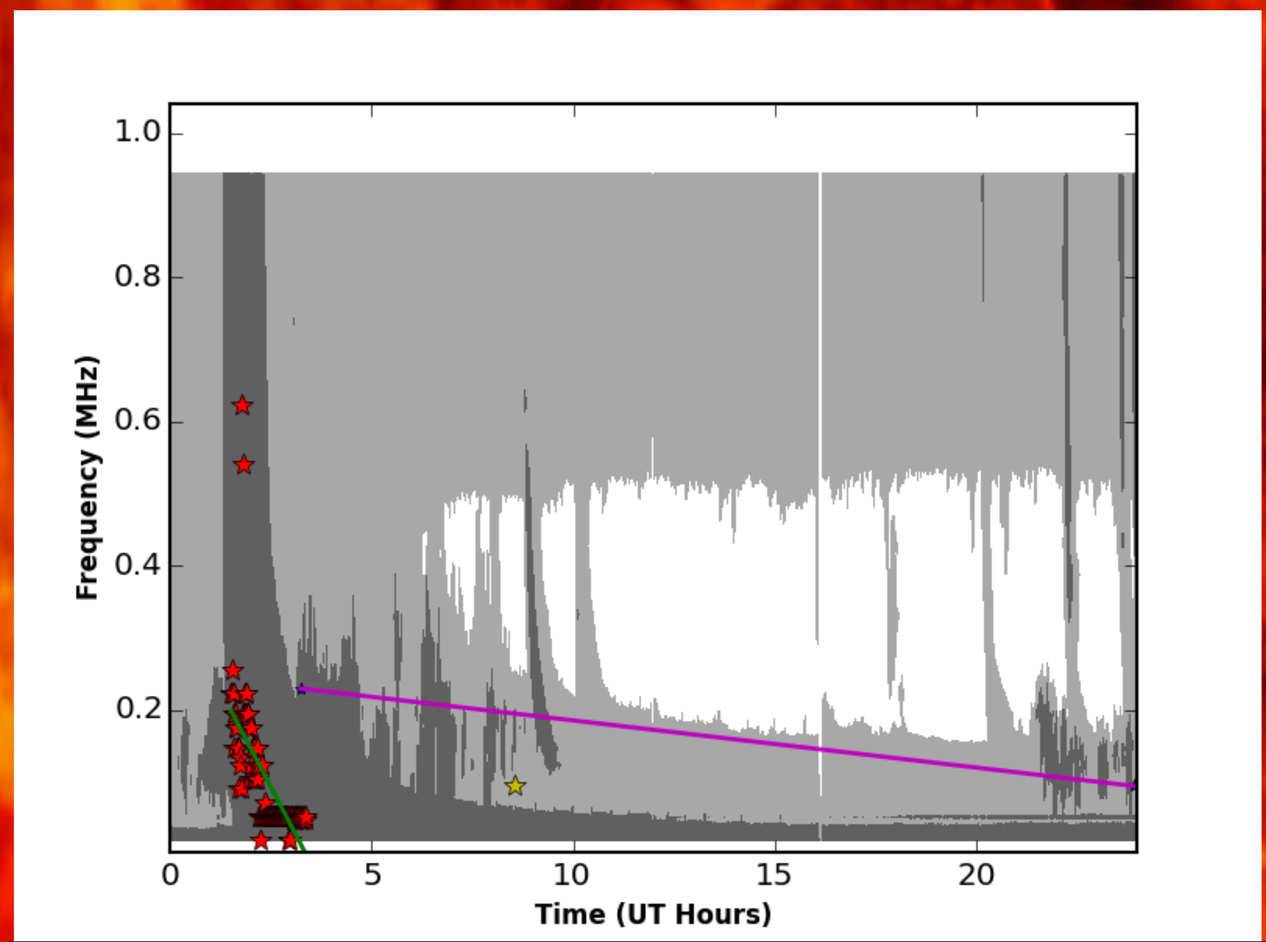
- Type II Flux Peak
- Type II Integral
- Type III Integral
- Type III Duration



Example of a proton plot showing an SEP event (flux > 10sfu). We looked at three energy levels (>10MeV, >50MeV, and >100MeV) to observe differences. We then looked at radio bursts from the same events.

We selected forty one of the sixty three SEP events to analyze. To clean the gaps in the data set, a liner interpolation was performed that drew a line between measured points and filled in all the missing points between with data that fit the line's equation. Duration of type III bursts was measured before the flux dropped below four times the background level.





We first found the maximum peak of the type III bursts and stepped through time to find local maxima (red stars) until their flux dropped by 15% of the original peak. A line was then fit to these points (green) and integrated along within four frequency bins. The type II burst were harder to identify through code because the bright type III bursts. Instead, we drew lines through the visually inspected type II burst and integrated along this line (purple). The peak of the type II burst was identified by finding the peak along this line (yellow star). Future studies should measure the type II burst more accurately and similarly to the type III.

Results

Proton Data Average Fluxes (sfu)

Cycle 23 – All SEP events	Cycle 23 – SEP events with type II burst	Cycle 32 – SEP events without type II bursts	Cycle 24 – All SEP events
2246.10	2674.68	2460.31	823.77

Type III Burst Duration

	Cycle 23	Cycle 24
Average(min)	26.08	15.50
Median(min)	22.00	13.00
Standard Deviation(min)	29.71	11.80

Type II Burst Peak

	Cycle 23	Cycle 24
Log of Average (sfu)	2.42	4.52
Log of Median (sfu)	2.11	2.95
Log of Standard Deviation (sfu)	0.59	4.85

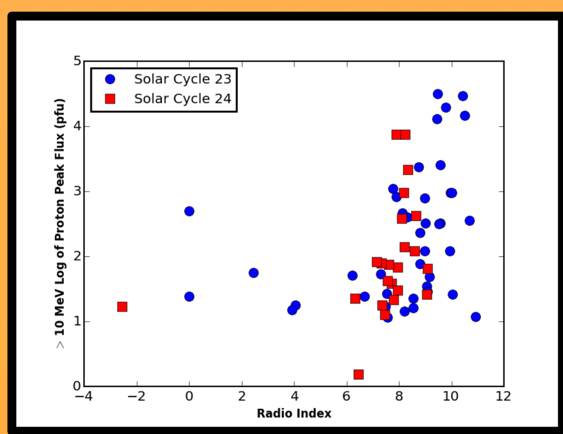
Type II Burst Integral

	Cycle 23	Cycle 24
Log of Average (sfu)	5.33	5.00
Median (sfu)	5.08	3.57
Log of Standard Deviation (sfu)	1.13	4.84

Type III Burst Integral

	Cycle 24
Log of Average (sfu)	7.53
Log of Median (sfu)	8.00
Log of Standard Deviation (sfu)	1.76

Our results show that overall, a more active solar cycle produces longer and brighter bursts. The plot of the radio indices with the proton flux peaks (below) shows that the high radio indices would be able to forecast SEP events from the bursts observed for both solar cycles 23 and 24. Additionally, we see that the higher the radio index is, the higher the peak flux it will produce.



Acknowledgments

This work was funded by NSF and the University of Colorado at Boulder as part of the LASP 2015 REU Program in Solar and Space Physics.

NASA Wind-Waves. Type II and IV Burst Lists. http://www-lep.gsfc.nasa.gov/waves/data_products.html.

NOAA SWPC. Solar Proton Events Affecting the Earth Environment. http://www.swpc.noaa.gov/ftpdir/indices/SPE.txt.