Anonymous Referee #2

Major comments:

We thank the authors' great effort to improve their manuscript, by taking account of the referees' comments. It became clear that the authors focus on the physical causes of phenomena, rather than forecasts in this paper. They changed the title, and it became more suitable to the topic of this paper. However, if the authors focus on physics, it may be more suitable to use "Solar-Terrestrial Physics" (STP) for the title.

Thank you. We have added this to the title. Actually we think Solar-Terrestial Physics is the same as Space Weather since all things in solar terrestrial phenomena are interconnected and can influence space weather. We mention this now in the paper. At least this is true for interplanetary, magnetospheric and ionospheric phenomena. When we used the term "forecasts" we were meaning in the sense that one understands the physics well enough to predict events in the future. We have now used this term sparingly because we realize that people have different thoughts about what this means.

I agree with the authors' idea that the application of weather forecasting will help us improve the predictability of space weather. In the point of view of space weather forecasts, it is more important to show how much we can predict phenomena even if they are chaotic or which phenomena can be predicted. Recently, machine-learning techniques have been applied to solar flare predictions, and they succeeded in improving prediction accuracy a lot.

We are very happy to hear these positive results for machine learning techniques applied to solar flare predictions. Some of us have reviewed papers on machine learning associated results. The authors often exaggerate their successes. Of course we remain positive about this new technique. All we are trying to say is others should objectively assess the successes and failures. One should not assume that this new technique will be a panacea for the problem.

I also agree that prediction models should be evaluated by the third parties, but in the same operational settings. Recently, operational models have been compared in CCMC/NASA and other small benchmark workshops. I feel that there is no standard evaluation method discussed in our community and it is a problem.

We understand your comment. We have added a few sentences in the paper addressing this issue. All of our new additions to the paper are written in blue (as is this response).

"The best test for proving that workers in Space Weather understand all of the underlying physics and/or the machine learning algorithm is robust is to use the program on a new event and see how well it does. This should be done by independent researchers like the people at CCMC at the Goddard Space Research Center, Greenbelt Maryland and/or other related facilities."

I read through the revised parts in the text, colored in blue. I have additional comments on them, and I think that the current manuscript is still not enough for publication in NPG. I hope that my comments are useful for the authors to improve their manuscript.

Detailed comments:

1) [p.2, section 1.1, 1st para., line 1] The sentence “Space Weather is a new term for a topic that actually began over a century and a half ago.” is confusing. The term “space weather forecasting” first appeared in 1988 (Nagai 1988 JGR, Marubashi 1989 SSRv), and US national space weather program started in 1993. Please modify the sentence for readers to avoid misunderstanding.

Corrected as best we could. Please notice that we did not use the word “forecasting “ as you have mentioned above. This particular word has different meanings to different people and we have therefore avoided the useage here. We now say “Space Weather is a new term for a topic/science that began over a century and a half ago”. We hope that this is clearer now. Notice that after this statement we give concrete examples of Carrington, Maunder, Chree, Chapman, Bartels, Newton, etc. works that were published well before 1988. These works were all Space Weather science articles. We think the term “space weather” is just a new term describing of an old science.

Many of the young scientists don’t understand that there were major space weather works published well before they were born. They probably don’t remember or cite the papers that you mentioned. The people in the US think that the term was invented in the US. However the first coinage of the word is not so important. But it is important that young people realize that there were major contributions made to space weather science a long time ago.

2) [p.9, 2nd para, line 3-4] In the sentence “Only very few CMEs have speeds >2,000 km/s... (personal communications with referee, 2019)”, it is better to cite some references (e.g. Yashiro et al.).

Done. Thank you.

3) [p.16, 2nd para, line 3-4] Is it correctly “y is in the direction of the Earth’s south magnetic pole, (Omega x X)/|Omega x X|, where Omega is the angular velocity”?

Corrected. We have checked the statement in the paper and it is correct as it stands. We have added a phrase to help clarify things. To answer your question specifically, the x axis points towards the Sun. Omega is the direction of the south magnetic pole (which is close to the direction of the north rotational pole). So in the right hand system z = x x y. Z is in a direction close to the north rotational pole.

4) [p.20, section 3.2.1, 1st para. & Fig. 7, caption] Correctly, “the Soft X-ray Telescope (SXT)” onboard Yohkoh.

Corrected. Thank you.

5) [p.47, 1st para, line 2 and Fig. 22] It is hard to see the characters in Fig. 22 (c)-(d). Please cite the reference of this figure in the caption.

Done.

6) [p.47, 1st para, the last two sentences] It is better to remove the sentence “this solar flare example is... no transfer of energy to interplanetary space and then to the

magnetosphere.", because there is no evidence to show no energy transfer to the interplanetary space and the magnetosphere.

Okay, corrected. We have deleted the second sentence and have replaced it by another. The reason for stating this is to make magnetospheric scientists realize that not everything in space weather is transferred from the Sun to the Earth through ICMEs or high speed streams. That was the main intent of the sentence.

7) [p.47, 2nd para, line 1-2] The sentence "Some future space weather problems are to understand if the solar flare photon energy spectrum varies often" is misleading. Previous observations have shown that the energy spectra of solar flares differ in time and events. It is due to particle acceleration in flares, and the problem has been challenged by lots of solar physicists. I also recommend to use the term "solar energy spectrum" rather than "photon spectrum".

Okay, corrected. This has been reworded. One of us put this into the paper as a reaction to a solar physicist who strongly said at a meeting in reaction to a talk (about 10 years ago) "the solar flare spectrum does not vary!". The person's name is H. Hudson.

Actually this same person reacted somewhat violently to our review talk probably primarily because we were talking a little about solar physics (his topic and not ours). But in hindsight we thought then (and still do now), that there was nothing incorrect in what we said.

We apologize for reacting too strongly to a misstatement given by a solar physicist. This has been corrected.

We now mention that the challenge for solar physicists will be to "predict" the spectrum given the conditions in proximity to the flare site. This of course may be very difficult to do, but this is the theme of the whole paper: challenges for the future. Our point is if one can "predict it" you may understand the underlying physics. This is what we mean by the words "predict" or "forecast".

By the way we have been influenced by another famous solar physicist. After one talk when one of us explained the useage of the term Interplanetary CME, she came up to the speaker and thanked him for explaining the term. She had no idea why we were using this. This person was Shadia Habal. Again we have gone to some lengths to explain this term. We figured that if some solar people did not understand it, the person in the street would not at all. Thus our detailed explanation.

8) [p.48, line 1-2] The sentence "Solar flare data... would be useful to understand the details of flare spectral differences but solar physicists need to explain what the causes are" is also strange to solar physicists. The mechanisms of thermal and nonthermal emissions are qualitatively understood. For space weather forecasting, it is more important to predict X-ray/UV emissions from solar flares quantitatively. In addition, the solar energy spectrum is not observed by SORCE and TIMED, but by RHESSI and EVE/SDO.

Corrected. Thank you.

9) [p.62, Final comments, 1st para, line 7-10] “Meng et al. (2019b) have tested ...indices were used.” In this sentence, “Meng et al.” is not accepted now. What are the names of the two well-known ionospheric codes to predict TEC? The representation “not so good” is subjective, and the evaluation method is not explained at all. It is better to remove this sentence.

Deleted. These sentences have been removed.

The Meng et al. paper has just been resubmitted a third time will all questions addressed adequately. It should be accepted soon. We had looked for a quote in the paper for what “not so good” meant but there was none. The reason why this is not well stated in the paper is because the results were somewhat of a shock to the referees (and the authors).

10) [p.63, 3rd para] Who are the “atmospheric weather forecasters”? NOAA? Please cite references. As for the idea of ensemble forecast, it has already been included in machine-learning algorithms. So, it is useful mainly for scientists using models of physics-based numerical simulations.

Thank you. Corrected. We have added some references.

Concerning machine learning algorithms, we are saying something different. Even if different algorithms train on the same data and use ensemble forecasting they may get different results. Thus ~25 of these codes could be used and the results averaged. We did not change the wording for this part of the paper.