

***Interactive comment on* “Space Weather Forecasting: What We Know Now and What Are the Current and Future Challenges?” by Bruce T. Tsurutani et al.**

Anonymous Referee #1

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The manuscript “Space Weather Forecasting: What we know now and what are the current and future challenges” submitted to NPG, 2019, by Tsurutani et al., represents overall an excellent summary of the physics background of geomagnetic storms and substorms, solar energetic particle fluxes, enhanced energetic magnetospheric electron fluxes and radiation belt formation, as well as ionospheric TEC changes. The focus is placed on the physics of the different space processes and the interplanetary causes and solar origins.

It is very understandable that a summary on space weather cannot easily cover all aspects (incl. the glossary), ranging from new solar observations from SDO, 3D CME

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modelling results based on STEREO observations, new heliospheric imaging results for ICMEs also from STEREO, CME/ICME kinematics and new projects (e.g., FLARECAST, HESPERIA, AFFECTS, HELCATS, etc. and also other US and int. projects). However, before publication I suggest to state this in the paper and to add ref. about ongoing projects and literature covering those issues. I am not pointing out special references because they are easy to find through the internet or by browsing the Space Weather Journals of AGU and Int. Journal on Space Weather and Climate. I suggest adding clarifications of the focus and limitations of the paper at the beginning and end of the manuscript, see also the specific comments below. I also suggest to name some books on space weather (e.g., Hanslmeier: The Sun and space weather; Koskinen: The physics of space storms, etc.). Eventually even the title maybe modified to these suggestions to be more specific.

I further suggest adding more specific details on how new missions (PSP, SO) will help answer the addressed questions, or if it is not possible, to leave it out.

With these modifications the paper will certainly be a very good overview on space weather processes, written in a clear way.

Minor comments:

1) p.1, l.11: Since also the solar wind speed plays a role because of $E=-v \times B_z$, I suggest to add the word “major” at the beginning, i.e., “Major geomagnetic storms are caused by ...”. Or some similar clarification.

2) Same p., l.17: I suggest adding a sentence on SEPs because the topic start a little abrupt.

3) p.2, l.35: I suggest removing the word “old” by a more elegant sentence stating an evolution of space weather from solar terrestrial research over the years, or something similar. Several space missions over the last decades have made significant progress in terms of interdisciplinary research (SOHO, Cluster, ACE, STEREO, etc.) between

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the solar, magnetospheric, ionospheric disciplines and space physics in general. And the new data have led to fundamental new insights into solar storms (e.g., CME 3D structure and propagation to Earth).

4) p. 3, l. 70: I suggest adding “that occur more frequent during . . .”.

5) Same p., next lines: I suggest to rephrase “ We will explain to solar scientists . . .”. There are also solar scientists knowledgeable of space physics.

6) p.6, 1st par.: I suggest to not completely neglect the role of v solar wind here. I see it is addressed later on.

7) P.7, l.180: IASCO has observed by now far more than 10.000 CMEs, but only about 5% are faster than 700 km/s in the plane of sky. Only a very few have speeds of >2.000 km/s and these are coming preferential from coronal regions above enhanced photospheric fields, so that higher field strengths and compression effects are pronounced. That means only a subset of CMEs produces strong fields in ip space. Please add some clarifications.

8) p.8, 2nd par.: Results from STEREO observations are missing here. It is also pointed out that new missions will provide new insights, but do they really do for these research topics? And if so, how?

9) p.11, l. 268-272: There are results that relate MC magnetic field structures back to their solar source regions. I suggest including a few sentences.

10) Same p., next par.: Again, how do PSP and SO help specifically?

11) p.17, l.414: Only “intensities that some MC fields do”. Many MCs have weaker fields.

12) Same p., l.422: “having said”?

13) p.18, caption Fig.7: I suggest to write: “A large coronal hole at the . . .”

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- 14) p.19, l.442-444: LASCO C2 is also included.
- 15) p.21, l.480: How will these missions be useful? Be specific.
- 16) p.23, l.533: same as 15).
- 17) p.32, l.724: “stronger”
- 18) same p., l.727: wording of sentence
- 19) p.35, l.805-812: I missed some results from STEREO in this context.
- 20) Same p., 816-824: I suggest including here some sentences on the established drag modelling for CME propagation in the heliosphere.
- 21) p.37, l.865: “have shown”
- 22) p.38, l. 887: wording of sentence
- 23) p.39, caption Fig.18: I suggest adding clarifying text about the shock creation.
- 24) p.42, l.962: I suggest removing the word “poor”. Either there is connection or not.
- 25) p.50, l.1100: Why is the magnetic profile unlike those of other ICMEs? Please explain.
- 26) p.53, caption Fig.29: Please add the date.
- 27) p.54, l.1196: Please explain what the averaging time for Bz was to avoid averaging out negative time intervals.
- 28) p.55, l. 1225: What is meant by a solar filament in this context? Please explain.
- 29) p.31, caption Fig. 31: Please add the year.
- 30) p.57, l.1257-1260: I suggest elaborating things not addressed a little bit, see major comments.
- 31) Same p., next par.: I suggest adding the role of V, also for CME arrival time predic-

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tions.

32) p.58, first 2 lines: But what about forecasting with ENLIL?

33) Same p., last par.: I suggest adding drag modelling here.

34) p. 59, last lines: I suggest to add some more concluding remarks and references to books on space weather, including recently established forecast models and new projects.

35) p.60, l. 1338: wording of sentence

36) p.67, l. 1530: I suggest adding a statement on GNSS.

37) P.75, l. 1746: Solar activity includes many other phenomena, e.g., CMEs, jets, etc. but here only flares are addressed.

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