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# Comment on angeo-2021-23

Anonymous Referee #2

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Referee comment on "Heavy rainfall, floods, and flash floods influenced by high-speed solar wind coupling to the magnetosphere–ionosphere–atmosphere system" by Paul Prikryl et al., Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2021-23-RC2, 2021

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Review of "Heavy rainfall, floods and flash floods in the context of solar wind coupling to the magnetosphere-ionosphere-atmosphere system" by Prikryl, Rusin, Prikryl, Stastny, Turna an Zelenakova

The paper contains interesting observations of weather related to solar wind conditions, but they have nothing to with sector boundary/heliospheric current sheet crossings. The body of the paper shows that extreme weather is associated with HSSs and that part of the paper should be emphasized. It seems that the authors do not realize that Alfven waves in HSSs cause substantial energy input into the Earth's auroral zones. The physics of the coupling between the solar wind-magnetosphere-ionosphere during HSSs is not discussed or at least not discussed correctly. There has been a research book containing tens of articles and tens of articles separately on this topic which the authors are apparently unaware of. The discussion of the intensity of high speed streams is a bit incorrect.

The paper needs a major rewrite to address the above problems. I will try to indicate where and how and give some references for the authors to follow. The authors need to do a bit of reading before attempting to rewrite the paper.

**Major Comments**

Almost all of the solar, interplanetary and magnetospheric results presented in this paper are not new. These previous findings should be referenced in an introductory paragraph or paragraphs so the reader is not misled when reading through the rest of the text.

The discovery that coronal holes were the source of high speed solar wind streams was

made in 1973 and was published in Sol. Phys. 23, 123, 1973. This paper should be quoted

High speed streams have a more or less constant speed of ~750 to 800 km/s. The authors seem to be unaware of this fact. See Science, 268, 1030, 1995; JGR, 111, A07S01, 2006. doi:10,1029/2005JA011273; JGRSP, 123, 2018. https://doi.org/10.1002/2017JA024203.

So why do HSSs detected at 1 AU sometimes have peak speeds less than 750 to 800 km/s? The solar wind emanating from the center of the CH has the speed of 750 to 800 km/s. However the solar wind expands at greater than 1/r2 which is called "super radial expansion". Detection of the HSS at Earth does not always cross the center or main body of the CH, thus the speed can be less than this maximum. This is shown and discussed in pp.99-119 in "Midlatitude Ionospheric Dynamics and Disturbances", vol 181 AGU press, 2008 (fig 3). 10.1029/181GM11; JASTP 73, 164, 2011 doi:10.1016/j.jastp.2010.04.003 and AG, 29, 839-849, 2011 doi:10.5194/angeo-29-839-.2011 (see schematic). Thus the profile of your HSS events have a rise to their maximum speed and then a tapering down. If the HSS event does not reach a peak speed of 750 to 800 km/s, then the spacecraft is just catching the edges of the superradial expanded part of the HSS. The HSS does not have variable speeds as your writeup seems to indicate. Please correct this throughout the paper.

There are many different interplanetary high plasma density features besides CIRs that can be found adjacent to CIRs. In your superposed epoch you are detecting all of them. For a schematic of these features, please see JGR, 100, 21717, 1995 and the paper starting on p 1 in *Recurrent Magnetic Storms: Corotating Solar wind Streams,* AGU monograph 167, 2006. One particular feature is the high density heliospheric plasma sheet (HPS) which will be mentioned again later.

CIRs were discovered in GRL, 3, 3, 137-141, 1976. This should be cited in the Introduction Section. CIRs are compressive regions caused by the fast wind interacting with upstream slow solar wind and therefore have magnetic field strengths higher than in the quiet solar wind. They have highly varying Bz components which can cause magnetic reconnection (see and quote PRL, 6, 47, 1961 for the solar wind energy coupling mechanism: magnetic reconnection and the JGR 1995 paper and references for Bz variations). However because of the strongly varying Bz within the CIR, the magnetic storms they cause are not particularly strong (see the above JGR 1995 paper).

The HSSs which are the main focus of your paper have embedded interplanetary Alfven waves within them. Through magnetic reconnection associated with the southward component waves with northward dayside magnetopause magnetic fields, strong auroral zone activity is caused. This was first reported in PSS, 35, 405-412, 1987. The resultant geomagnetic activity is called HILDCAAs, an acronym that is commonly used now in the literature. An entire AGU special issue was devoted to HSSs: "*Recurrent Magnetic Storms: Corotating Solar Wind Streams*", vol 167, AGU press, 2006. 10.1029/167GM03 following an AGU Chapman meeting in 2005. This book should be quoted. It was first pointed out by the JGR 1995 paper that HSSs put more energy into the magnetosphere

over 4 days than a ICME storm does. This feature of HSSs/HILDCAAs was verified by articles within the 2006 AGU book: https://doi.org/10.1029/167GM24, and https://doi.org/10.1029/167GM11. THIS is the energy input into the magnetosphere and not the sector boundary/heliospheric current sheet. Or probably CIR magnetic storms.

HSSs detected at Earth during the solar declining phase and solar minimum are well known. Please cite JGR 1995, JASTP, 121, 24-31, 2014, JGRSP, 119, 2675-2690, 2014. Doi:10.1002/2013JA019646.

Another physical mechanism has been proposed to replace any sector boundary/heliospheric current sheet magnetospheric effects. This is the heliospheric plasma sheet (HPS). This is the high density plasma located in the slow solar wind just ahead of the CIR and collocated with the HCS (see the schematics in the 1995 and 2006 papers). The ram pressure compressing the magnetosphere from HPS impingement cause the precipitation of relativistic electrons creating heating in the thermosphere, perhaps launching gravity waves. This data proof and scenario is given in JGRSP, 121, doi:10.1002/2016JA022499. This alternate scenario should be mentioned whereever the Wilcox et al 1973 scenario is mentioned. This mechanism is far more concrete than the sector boundary crossing scenario. The deposition energy of the relativistic electrons is actually calculated whereas the HCS crossings have not been.

Paragraph starting on line 36. The other mechanism for the Wilcox et al 1973, 1974 tropospheric vorticity observations should be mentioned here with equal weight. I will mention later that perhaps BOTH the Wilcox et al and the HPS impingement mechanism discussions should be reduced or deleted? There is a better mechanism which explains energy input during HSSs.

Line 44. "Prikryl et al. (2009a) confirmed the "Wilcox effect"" may be an incorrect statement. The weather may instead be due to CIR storms or HSS/HILDCAA effects. This should be corrected/addressed here. In fact the bulk of the paper has to do with HSSs and therefore the Wilcox effect discussion seems to be superfluous.

Line 50. Here you say that flash floods follow HSSs? Which is it, SBs/HCSs, heliospheric plasma sheet impingements, CIR storms or HSSs? HPS impingements were hypothesized to cause AGWs as well. This paragraph needs to be modified. Again the paper focusses on HSSs and NOT on the HCS crossings.

Line 73. Polar coronal holes. A good reference is GRL, 21, 1105-1108, 1994. https://doi.org/10.1029/94GL01065. "Can extend to low heliographic latitudes" see the JGR 1995 paper. A good reference here.

Line 109. "ICMEs" needs a reference. I suggest JGR, 86, A8, 6673-6684, 1981 for the

magnetic cloud and JGR, 93, A8, 8519-8533, 1988 for "driver gas" and upstream shock/sheath. A more correct phrase would be "ICMEs and their upstream sheaths". Sheaths have been shown to be equally as effective as magnetic clouds for causing magnetic storms: JGRSP, 124, 3926-3948, 2019. https://doi.org/10.1029/2018JA026425 and references therein.

Line 116 to 120. This is all related to the HSS and has nothing to do with the Wilcox effect. Delete reference to the Wilcox et al effect throughout the paper?

Line 134. Again this is all related to the HSS/HILDCAA. Delete Wilcox effect reference?

Line 159-160. Please see previous discussion of HSSs and CHs. For this case the spacecraft is not sensing the HSS coming from the center of the CH. It is catching the edge of the HSS.

Line 161-162. Be careful here. You are probably detecting the HPS as well.

Line 173. Polar coronal holes and their HSSs have been known to persist for years. Please see and quote JGR 87, A9, 7389-7404, 1982 and JGR, 100, A11, 21717-21733, 1995 here. This interval 1973-1975 was a record interval for HSSs impacting the Earth's magnetosphere. Such an occurrence has not happened again. After this paper, you might want to look at this period for extreme weather?

Line 194. A recurrence period of 27 days is not a new finding. See previous references.

Lines 204 to 206. HSSs have their sources at CHs, but CIRs are due to the HSSs interacting with slow solar wind plasmas in the interplanetary medium. This has been modeled by the paper starting on p. 51, in *Coll. Shocks Helio: Rev. Curr. Res*. AGU press, vol 35, Wash DC, 1985. The 7 to 9 day period may not have to do with CHs being separated on the Sun. It is also possible that you may be detecting the wavy edges of a single polar coronal hole. So be careful in your statement.

Line 208. One should add the reference AG, 29, 839-849, 2011 here. Please note that during solar minimum an all time minimum in geomagnetic activity occurred due to the low HSS velocities at Earth. An interesting question for you is did you see a minimum in extreme weather at this time? Maybe another paper?

Lines 211-214. This is somewhat of a repeat of the above paper?

Line 233. I disagree that "the results are similar to the "Wilcox effect". These are HSS or CIR storm effects which occur much later in time. Please revise this discussion.

Line 272. 750 km/s is NOT an "exceptionally fast HSS" as discussed before. Please revise discussion associated with Figure 11.

Lines 274-275. "moderate geomagnetic storms". Yes that is all CIRs cause. Only ICMEs or their upstream sheaths trigger superintense storms. See previous references.

Line 281. I would not call 650 km/s a "strong HSS".

Line 289. This is most likely associated with a HILDCAA.

Line 324. "a very strong and structured HSS"??

Line 410. HSSs generally do not cause geomagnetic storms. See the 2006 paper. Please double check.

Line 427. "While the HSS was weakening". This is almost certainly a spatial effect rather than a temporal effect. The Sun is rotating and the CH rigidly rotates with it (see the 1982 paper for rigid rotation). So you are detecting the superradial expansion part of the HSS.

Lines 452-455. Here you need to mention HILDCAAs and auroral zone auroral activity associated with HSSs. This is what is causing your weather effects and not sector boundaries/HCSs, HPSs or CIR magnetic storms in my opinion. Thus the discussion and conclusions of the paper needs to be revised substantially.