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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "How severe Space Weather can disrupt global supply chains" *by* H. Schulte in den Bäumen et al.

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This paper is a very valuable contribution to understanding the economic impact of space weather. To the best of my knowledge, it is the first attempt to take that analysis beyond simple estimates based on partial or total loss of GDP over the period of disruption caused by space weather. In particular it highlights the issue of interconnectness – that an adverse impact on one sector of the economy and/or in one region of the world can have adverse impacts in other sectors or regions (because of trading links between sectors and regions). This is widely recognised as an important issue for space weather impacts, but has so far been poorly studied. Thus this is a welcome contribution to the literature.

However, there are problems with the present manuscript which I detail below – separately for economic issues and space weather issues. The key problem on the economic side is that the authors' description of their model is falls well below what is needed to engage the NHESS audience, most of whom are not expert in economics, but many of whom have good mathematical skills. The authors need to explain clearly both the mathematical tools that they use – and, very importantly, what is meaning and purpose behind their use of those tools. There are also a few other minor points on economic issues. On the space weather side there are several places where the authors' presentation of space weather phenomena and their impacts is either out-of-date or reflects commonplace mis-understandings (e.g. over-stating the space weather consequences of solar flares). This needs major revision as detailed below.

In summary, I commend the authors' work. They are seeking to address an important problem, well in scope of NHESS, and doing so with novel techniques. But they need to improve the presentation of both space weather and economic issues. I think this improvement is crucial to make a truly effective paper – and also to stimulate further work on the economic impact of space weather (which is certainly needed).

Economic issues

Page 4467, line 18. Your global transformer production figure is wildly implausible. Given a transformer lifetime of 50 years, it implies a global total of 250 large transformers installed worldwide. That's more like what is needed in one medium sized country. I suspect global production is much larger than you report.

Page 4467, lines 13-27. The figures that you cite for economic losses are of a similar size to GDP of the affected region over the cited period. Please indicate if these estimates simply based on total loss of GDP over the period of the grid outage, or do they include any more sophisticated analysis?

Page 4470. Some of the mathematical material is poorly presented, both in its terminology and in its purpose. Please clarify:

a) N is defined after it has been used twice, please reorder to define it first and then explain the purpose of the “N x 1” vectors y and x. My impression is that these are vectors with N elements (so the “x 1” is superfluous) and that each element represents demand or output of a particular sector. I may or may not be right. Whatever is the case, the purposes of y and x needs to be explained at a level appropriate for readers of NHESS.

b) Similarly the purposes of the IO matrices and the transactions matrix T need to be explained at an appropriate level. I assume that they describe the relationships between sectors, but this needs to be outlined in an explicit manner appropriate to the readership.

c) Also the purpose of the matrix product T1 needs to be explained. Does this pull out transactions internal to each sector?

d) Please also add some background to the National Accounting Identity – what are the assumptions underlying this equation? E.g. does it assume that the economy is initially in balance? Is the NAI linked to any particular approach to economics (e.g. neo-classical models, Keynesian, etc)?

Space weather issues:

Page 4464, Lines 17-18. It is very wrong to say that that the probability of an extreme geomagnetic storm is increased when sunspot numbers are maximal. The historical evidence is very clear that extreme events can occur at any phase of the 11-year cycle of sunspot numbers. For example, both the Carrington event of 1859 and the great storm of May 1921 occurred well away from maximum (as you note in line 1 of page 4467). Many experts, including myself, argue strongly that we must not be complacent about the risk of extreme storms even at solar minimum. The authors cite Ramesh’s 2010 paper in support of their argument - but that paper does not make any statements concerning extreme geomagnetic storms. This not surprising as Ramesh’s paper is focused on the solar cycle variations of CMEs over the period 1996 to 2010; it lacks

both the long-term data needed to assess rare extreme events and any specific data on geomagnetic storms.

Page 4465, Lines 12-15. This is a very confusing sentence that mixes up several aspects of space weather. I deal first with the increased entry of interplanetary plasma due to dayside reconnection – this is a key part of the causal chain driving geomagnetic storms. So it is not a similar effect to a geomagnetic storm; it is part of the storm. Secondly the impacts of solar flares and increased entry of energetic particles are very different to geomagnetic storms: increased ionisation in various parts of the atmosphere and increased radiation environments for satellites, aircraft and sometimes on the ground. The authors should not claim these are similar effects. The easiest solution is probably to remove this sentence, and perhaps replace with a short description of how dayside reconnection enables transport of magnetic flux and interplanetary plasma to the magnetotail eventually leading to further reconnection in that region.

Page 4465, line 28. I am not aware of damage to modern telecommunications cables from space weather – that risk has been retired with the switch from copper to optical fibre for long distance cables. But there is a risk of disruption to such cables due to space-weather-induced excess voltages in their power systems. Please could you review the current position on this as your reference pre-dates much of the recent deployment of optical fibres for long-distance telecommunications.

Page 4466, line 19-21. The studies of space weather signatures in polar ice records over past 450 years, as you reference via the Shea et al paper, are now discredited following the work of Wolff et al (2012) (DOI: 10.1029/2012GL051603). Please reformulate this sentence to focus on other papers that highlight the Carrington event, e.g. Cliver and Svalgaard, 2004 as you cite elsewhere.

Page 4466, lines 24-26. Several authors have re-interpreted the results of Tsurutani et al (2003) and derived much less extreme Dst values for the Carrington event, e.g. Siscoe et al (2006) (DOI: 10.1016/j.asr.2005.02.102) derived a value of -850 nT. Please reflect the range of views about the Carrington Dst in your text.

Page 4475, lines 15-18. There is a complete misunderstanding here about space weather impacts on the telecommunications sector. Solar flares can cause short-lived (minutes to an hour) interruptions of communications to aircraft and ships travelling through remote regions (in particular over the oceans out of sight of land). But that is their only significant impact and is generally well-mitigated. Solar flares have zero impact on the bulk of telecommunications. I suggest you reformulate this paragraph to remove reference to the telecommunication sector as a whole. A sector that would be worth study is civil aviation because it is vulnerable to a huge variety of space weather impacts and is a mainstay of the global economy.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 2, 4463, 2014.