UK Space Environment Impacts Expert Group

Comments on US Space Weather Benchmarks: Solar Radio Bursts and Upper Atmosphere Expansion

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Introduction

This document consolidates comments from the UK Space Environment Impacts Expert Group (SEIEG, a group of independent UK space weather experts set up in 2010, with the encouragement of Cabinet Office, to provide advice to UK Government bodies seeking to mitigate the risks posed by space weather). It provides comments on the “Space Weather 1 Phase 1 Benchmarks” produced by the Space Weather Operations, Research, And Mitigation Subcommittee of the US National Science and Technology Council.

This document contains comments on the following aspects of the benchmarks and is as follows:

1. Solar Radio Bursts
2. Upper Atmosphere Expansion

1 Solar Radio Bursts

This section has a good focus on the mechanisms by which processes in the solar atmosphere generate several types of radio bursts that can penetrate Earth’s ionosphere (synchrotron and cyclotron maser emissions from energetic electrons; Langmuir waves from dense plasma in the corona/solar wind). These radio bursts can interfere with a vast range of radio technologies on Earth.

This focus on physical process is a good basis for developing benchmarks but is clearly at a preliminary stage, so the benchmarks presented in the document are largely based on a couple of observational papers. We encourage further progress towards physics-based benchmarks, in particular involving plasma theorists who can address these physical processes.

However, it would be very helpful to broaden the discussion of the benchmarks:

- To note how the physical processes relate to the radio burst labelling conventions used by the solar physics community (Type I etc). This would help to engage the solar physics community.
- Also to clarify the relationships between radio bursts and other solar phenomena including both coronal mass ejections and solar flares.
- To discuss what radio systems are at risk from the various types of radio bursts – and from which phase of a burst (where a burst varies in frequency). This would demonstrate to the wider community that there are important issues here. GNSS is obviously at risk as shown in many papers; interference with radars is also a long-standing issue. The UK studies (Cannon et al, 2013; Hapgood et al, 2016) have considered other important radio technologies

including WiFi and Short Range Device links, but concluded that their vulnerability from solar radio bursts is low. We would welcome an independent US opinion on this.

1.1 References

- Cannon, P, et al., (2013), Extreme space weather: impacts on engineered systems and infrastructure, Royal Academy of Engineering. http://www.raeng.org.uk/publications/reports/space-weather-full-report
- Hapgood, M, et al., (2016). Summary of space weather worst-case environments. Revised edition. RAL technical report, RAL-TR-2016-006. http://purl.org/net/epubs/work/25015281.

2 Upper Atmosphere Expansion

2.1 Overview

The introductory section, summarising what the risk is and how space weather can impact thermospheric neutral density and wind, and hence satellite drag, is good. Three main causes of atmospheric extension are listed: the impacts associated with geomagnetic storms and flares are well documented in the literature, but those related to extended periods of enhanced EUV, perhaps less so (see below).

2.2 Periods of enhanced EUV

We recommend that the discussion on enhanced EUV (starting line 755) is expanded. In particular:

- A discussion on why enhanced EUV over a few days occurs. Is this due to solar brightening, or a large active region generating a large number of X-class flares over a few days, or both?
- Line 767 – define what "a few days" is – 2, 3 or 4 days, or another value?
- The extreme observed value is assumed to be 390 sfu. When this value was observed, was this for one day, or was there enhanced EUV for several days around this time?
- Based on the answers to the above, is it reasonable to assume a daily maximum of 390 sfu applied over a few days? What is the theoretical justification for assuming the theoretical daily maximum is 500 sfu?

2.3 Benchmark development

Benchmarks are considered at three altitudes, 250 km, 450 km and 850 km, and are assessed on the basis of models, which is reasonable since there is an absence of upper atmospheric observations (a point that should perhaps be highlighted in the document, especially in respect of the targeted altitudes). However, a discussion of the suitability and accuracy of the models is required so users can understand the potential error in the benchmark figures:

- NRLMSISE-00 is used to assess the impact of enhanced EUV for a period of a few days. Similar models like JB2008 and DTM are available. Why were these not used?
- How accurate is NRLMSIS00? DTM2013 appears to perform better for neutral density – Bruinsma (2015), but does not estimate wind
- Given that these models are statistical, they cannot represent extremes because extremes are not included in the training data. Discuss the implications for the results.

The section on the impact on the thermosphere from geomagnetic storms is good but there should be more details on the physics-based model used for the assessment (was it TIEGCM or WAM?). How accurate is the model and what are its limitations? A particular point of discussion is how well the model components work at the large range of F10.7 used (eg the Weimar convection model).

Geomagnetic storms are considered only in respect of those driven by CMEs. Is it implicit that you regard storms driven by high-speed streams as of lesser impact? If so we recommend to make this explicit with a statement on why you exclude them. But if not, please add these storms to the discussion.

2.4 Benchmark presentation

The three scenarios (i.e. enhanced EUV, EUV from flares, geomagnetic storms) are presented in reverse order to importance, so perhaps reorder. We again recommend further detailed discussion.

2.5 Other specific comments

1. We recommend to highlight space debris more fully as a growing issue and hence linked to space weather via the impact of atmosphere on the debris.
2. In particular, we suggest to discuss the Kessler effect and the possibility that we are near a tipping point, so that debris avoidance is important if we are to avoid orbit denial. We recommend to highlight how the benchmark altitudes relate to the bands where debris is a real problem.
3. As with the ionosphere, extreme low values in the thermosphere (e.g. due to lack of solar activity) are perhaps as important as extreme high values. Statistical models may become invalid (e.g. overestimating drag leading to inaccurate forecasts of satellite locations). We need good models to deal with both high and low extremes of thermospheric parameters.
4. Separate the effects on low earth orbit into high inclination which experiences Joule heating and low inclination that does not. Joule heating is the largest uncertainty for polar orbits – and the enhanced risk of collision over the poles due to intersecting orbits.
5. Lines 755 onwards appear to make associations between EUV and F10.7 fluxes that might be at odds with the view of some in the field. Clearly they tend to follow one another (the document does state that, during bursts, the relative increase can be very different), but there is evidence that they do not follow each other as well as, say, UV and F10.7. We have space-based EUV measurements and should stress that we need to maintain them.
6. At the same location, a 390sfu daily figure might not be the most appropriate figure to infer as an 81 day mean.

2.6 References

- Bruinsma, Sean (2015) The DTM-2013 thermosphere model, J. Space Weather Space Clim. 5 A1 (2015). DOI: 10.1051/swsc/2015001