Solar Superstoms - a storm is a tea cup, or a global risk for society and economies?

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Abstract

Rarely occurring solar superstorms generate X-rays and solar radio bursts, accelerate solar particles to relativistic velocities and cause major perturbations to the solar wind. These environmental changes can cause detrimental effects to the electricity grid, satellites, avionics, air passengers, signals from satellite navigation systems, mobile telephones and more. They have consequently been identified as a risk to the world economy and society. This paper will review their impact on a variety of engineered systems and will identify ways to prepare for these low-probability but randomly occurring events.

Explosive eruptions of energy from the Sun that cause minor solar storms on Earth are relatively common events. In contrast, extremely large events (superstorms) occur very occasionally – perhaps once every century or two. Most superstorms miss the Earth, travelling harmlessly into space. Of those that do travel towards the Earth, only half interact with the Earth's environment and cause damage. Since the start of the space age, there has been no true solar superstorm and consequently our understanding is limited. There have, however, been a number of near misses and these have caused major technological damage, for example the 1989 collapse of part of the Canadian electricity grid. A superstorm which occurred in 1859, now referred to as the 'Carrington event' is the largest for which we have measurements; and even in this case the measurements are limited to perturbations of the geomagnetic field. An event in 1956 is the highest recorded for atmospheric radiation with August 1972, October 1989 and October 2003 the highest recorded radiation events measured on spacecraft. How often superstorms occur and whether the above are representative of the long term risk is not known and is the subject of important current research. The general consensus is that a solar superstorm is inevitable, a matter not of 'if' but 'when?'. One contemporary view is that a Carrington-level event will occur within a period of 250 years with a confidence of ~95% and within a period of 50 years with a confidence of ~50%, but these figures should be interpreted with considerable care.

Mitigation of solar superstorms necessitates a number of technology-specific approaches which boil down to engineering out as much risk as is reasonably possible, and then adopting operational strategies to deal with the residual risk. In order to achieve the latter, space and terrestrial sensors are required to monitor the storm progress from its early stages as enhanced activity on the Sun through to its impact on Earth. Forecasting a solar storm is a challenge, and contemporary techniques are unlikely to deliver actionable advice, but there are growing efforts to improve those techniques and test them against appropriate metrics. Irrespective of forecasting ability, space and terrestrial sensors of the Sun and the near space environment provide critical space situational awareness, an ability to undertake post-event analysis, and the infrastructure to improve our understanding of this environment.

This paper will explore a number of technologies and demonstrate that global society and economies are indeed vulnerable to a solar superstorm. In a 'perfect storm' a number of technologies will be simultaneously affected which will substantially exacerbate the risk. Mitigating and maintaining an awareness of the individual and linked risks over the long term is a challenge for government, for asset owners and for managers.

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