Preface

The term "Space Weather" has reached a greater sense of public awareness in recent years. When used in the press, it usually refers to a large disturbance of the Earth's magnetic field called a (geo)magnetic storm, but the term actually applies to any phenomenon in the solar system that is caused by solar activity. The Sun is only now coming out of an extended period of inactivity and so when the chances of increased space weather effects at the Earth increase even slightly it is immediately reported in the press. Unfortunately most of these have proven to result in nothing significant at the Earth. The Dst index, the universal indicator of geomagnetic activity, has only dropped below -100 nT six times, and has not once dropped below -150 nT, since December 2006. In other words, so far in the current solar cycle there has been no geomagnetic activity that could be regarded as severe.

So why all the press interest in the possibility of severe space weather? Partly, it's because of its rarity in the current solar cycle. This may change in the next year or so as we reach the maximum in solar activity (what we call solar maximum), and it is worth noting that during the last solar cycle the most severe space weather events were caused in the declining stage of the cycle as the solar activity ramped back down towards solar minimum.

The other, and most important reason for the increased interest in space weather is because of the potential damaging effects that can result from it. We live in a technological age with nanotechnology and electromagnetic communication, and as we become more advanced our technology becomes smaller and more sophisticated. Electronic devices carry smaller electrical circuits, and so even minor variations in the magnetic environment could induce damaging currents, potentially short-circuiting or overloading these electric systems. Sudden magnetic variations can disrupt electromagnetic transmission, potentially damaging satellite and ground communications. Also are increased radiation effects in the high-altitude atmosphere, where increasing numbers of people travel on intercontinental flights. These hazards are already known to be potentially serious, and they will become more significant as our technology and traveling habits become more sophisticated.

Because of these hazards governments, the private sector, and now the general public are becoming more aware of space weather, and to how we can predict and mitigate its most severe cases.

What causes space weather? Or more precisely, what causes (geo)magnetic storms? Read any news report on the last predicted magnetic storm and you will probably find that they are caused by solar flares. This is not true, or rather not true most of the time. Flares are sources of great concentrations of energetic particles, and those particles can be magnetically guided to the Earth thereby causing a magnetic storm. Solar flares, however, are highly localized phenomena, and even if the particles are able to "fan-out" from their source regions, the Earth would need to well placed at the right time to receive the bulk of energetic particles arriving from a solar flare. While it would not be correct to say that this never happens, it is not what causes most magnetic storms. The real culprit is the coronal mass ejection.

Some of the better news outlets are beginning to mention coronal mass ejections (CMEs) more regularly when reporting on space weather, and while the phenomenon is gaining recognition it is still widely believed that solar flares cause magnetic storms. A CME is a large eruption of plasma and magnetic field from the Sun. It is much larger in size, and carries much more energy than the flare, and its interaction with the Earth's magnetic field is responsible for major space weather. It is also a physical mechanism for the removal of magnetic complexity and built-up magnetic energy from the Sun, and therefore plays an important role in solar evolution.

This Brief introduces the coronal mass ejection as the phenomenon responsible for magnetic storms at the Earth. We discuss the physics behind how CMEs interact with the Earth and the processes by which they build up energy at the Sun and erupt. We explore the history of CME observation, how we observe and track them, the physics behind their onset and evolution, and how they cause space weather.

The author published a larger and more detailed introduction to CMEs last year, called *Coronal Mass Ejections: An Introduction* (Springer, 2011). This Brief is mostly an abridged and updated version of that larger text, with an additional chapter (Chap. 5) dedicated to the latest developments that have occurred since the publication of that book. I have gone to great lengths, for example, to significantly reduce the mathematical content in this Brief, but a small amount does remain as in such a complex topic as CMEs it is unavoidable.

The purpose of this Brief is to introduce the concept of the CME to a non physics audience: to science students, scientists in fields other than space physics, or to the general public seeking to find out more about space weather. If there is a single message the reader should take away from this book it is this: The most severe space weather effects, (geo)magnetic storms, are not caused by solar flares. They are caused by coronal mass ejections. Therefore if one is interested in studying the causes of severe space weather it is the CME, and not the flare, that we should be investing our resources into. As this Brief shows, there is much that is not yet understood about this important and fascinating phenomenon.

Boulder, Colorado, USA Tim Howard

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Howard, T.
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