INTRODUCTION

Geospace effects of high-speed solar wind streams

Geospace can be defined as the region of near-Earth space dominated by the Earth’s, rather than the Sun’s, magnetic field. The terrestrial magnetosphere forms a cavity in the interplanetary medium that partially shields our planet from cosmic rays, solar energetic protons and numerous other phenomena potentially harmful to terrestrial life and technological systems. The solar wind, in which the magnetosphere is immersed, is structured on many scales and is generally hard to predict; high-speed solar wind streams (HSS), which have their origins in the outflow from coronal holes, form a large-scale repeatable driver for Earth’s magnetosphere and the parts of geospace coupled to it (e.g. Denton et al. 2009).

It is the role of this repeatable driver, and the responses in the various regions of geospace, that is the focus of this special issue.

HSS are interesting not only owing to their recurrent nature, but also owing to their wide-ranging effects in the geospace environment. Though they tend to produce relatively small geomagnetic storm disturbances they are the major contributor to adverse space weather during the declining phase of the solar cycle. However, in some cases, they can drive responses as severe as those during large storms near solar maximum. Thus, HSS provide the opportunity to study repeatable activity that is not only at the most extreme end of magnetospheric responses to solar wind driving, but spans a range of response levels. The effects of these HSS are seen across geospace, from large-scale magnetospheric current systems (Liemohn et al. 2010) to the radiation belts (Morley et al. 2010) and the thermosphere (Mlynczak et al. 2010). A number of key results are presented by the papers in this special issue showing both the progress being made in this field of study, and the importance of these solar phenomena to both space and atmospheric sciences. The papers in this issue all address the topics discussed at the second HSS and Geospace Interactions (HSS-GI) workshop, held over 6–11th September 2009 at Hilltop, University of Cumbria in Ambleside, UK. A number of the topics worked on at the workshop were identified as salient questions during the first workshop in 2007 and are detailed in Denton et al. (2008).

As the high-speed solar wind flows out from the Sun it catches up with slow solar wind, forming a compression region (also known as a co-rotating interaction region (CIR)) in the interplanetary medium. As the plasma is frozen-in to the...
magnetic field the streams do not mix, but instead a stream interface (SI) is formed. The properties of the solar wind plasma and interplanetary magnetic field on either side of the SI also differ. The fast solar wind is hotter, more tenuous and has a distinctive Alfvénic wave-like structure (e.g. Tsurutani et al. 2006). The role of these Alfvénic fluctuations in the transfer of mass and energy to the magnetosphere and ionosphere is studied by Ilie et al. (2010) using coupled numerical models. Liemohn et al. (2010) present statistical data-model comparisons of storm-time ring current development for driving by both CIR and interplanetary coronal mass ejections (iCME). The overall response of the ring current to the storm drivers is found to be similar, though the relative contributions of different magnetospheric current systems may differ by driver.

The effects on the radiation belts are studied using the global positioning system (GPS) constellation by Morley et al. (2010) and a consistent rapid dropout in the electron counts is reported. These losses may be largely driven by magnetopause shadowing at larger radial distances, with wave-particle interactions playing an important role at smaller radial distances. A proxy approach to understanding the roles of loss and acceleration in the radiation belts is presented by MacDonald et al. (2010). They use in situ plasma measurements and quasi-linear theory to infer wave growth and present global distributions of inferred whistler- and electromagnetic ion cyclotron (EMIC)-mode wave activity at geosynchronous orbit during high-speed streams and other storms; post-storm radiation-belt electron fluxes are lowest for the storms exhibiting the most EMIC activity and less whistler-wave activity in the recovery phase. Pilipenko et al. (2010) use multi-instrument observations to study the excitation of ultra-low frequency oscillations in Earth’s magnetic field. They show that high-speed streams can produce effective Pc5 excitation and conclude that global Pc5 pulsations could be a more efficient driver for radiation belt electrons than the more commonly observed Alfvénic Pc5 pulsations.

Both CIR- and iCME-driven storms can produce large-scale enhancements in ionization over the north magnetic pole into the nightside ionosphere. Using networks of GPS receivers and tomographic inversion, the dynamics of the ionospheric ‘tongue-of-ionization’ are shown by Pokhotelov et al. (2010) to be controlled by the orientation of the interplanetary magnetic field; they suggest that most CIR-driven events may not produce a persistent tongue of ionization owing to the oscillatory behaviour of the interplanetary magnetic field during such events. The system-wide coupling from Sun to atmosphere is highlighted by Mlynczak et al. (2010), who report short-term periodicities in the radiative cooling of the Earth’s thermosphere by monitoring of nitric oxide emissions; the cooling is shown to arise not from solar ultraviolet radiation, but from coupling of the solar wind to the thermosphere.

The assembled papers present a snapshot of current research into the effects of stream interaction regions, and their attendant HSS, on geospace. While both space weather and its effects remain difficult to predict, progress in understanding the effects of this most repeatable of solar wind phenomena enhances both our basic understanding of the Sun–Earth system and our ability to predict the geospace response to solar variability.

Thanks are due to the organizing committee led by Michael Denton, without whom this workshop would not have been possible. The committee members were: Michael Denton, Jill Greenwood

and Jo Denton (Lancaster University), Joe Borovsky (Los Alamos National Laboratory), Steven Morley (University of Newcastle and Los Alamos National Laboratory), Martin Mlynczak (NASA Langley), and Craig Rodger (University of Otago).

Steven K. Morley
Space Science and Applications,
Los Alamos National Laboratory,
Los Alamos, NM, USA
E-mail address: smorley@lanl.gov

References


