frontiers

Supplementary Material

Occurrence of heavy precipitation influenced by solar wind high-speed streams through vertical atmospheric coupling

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1 Supplementary data

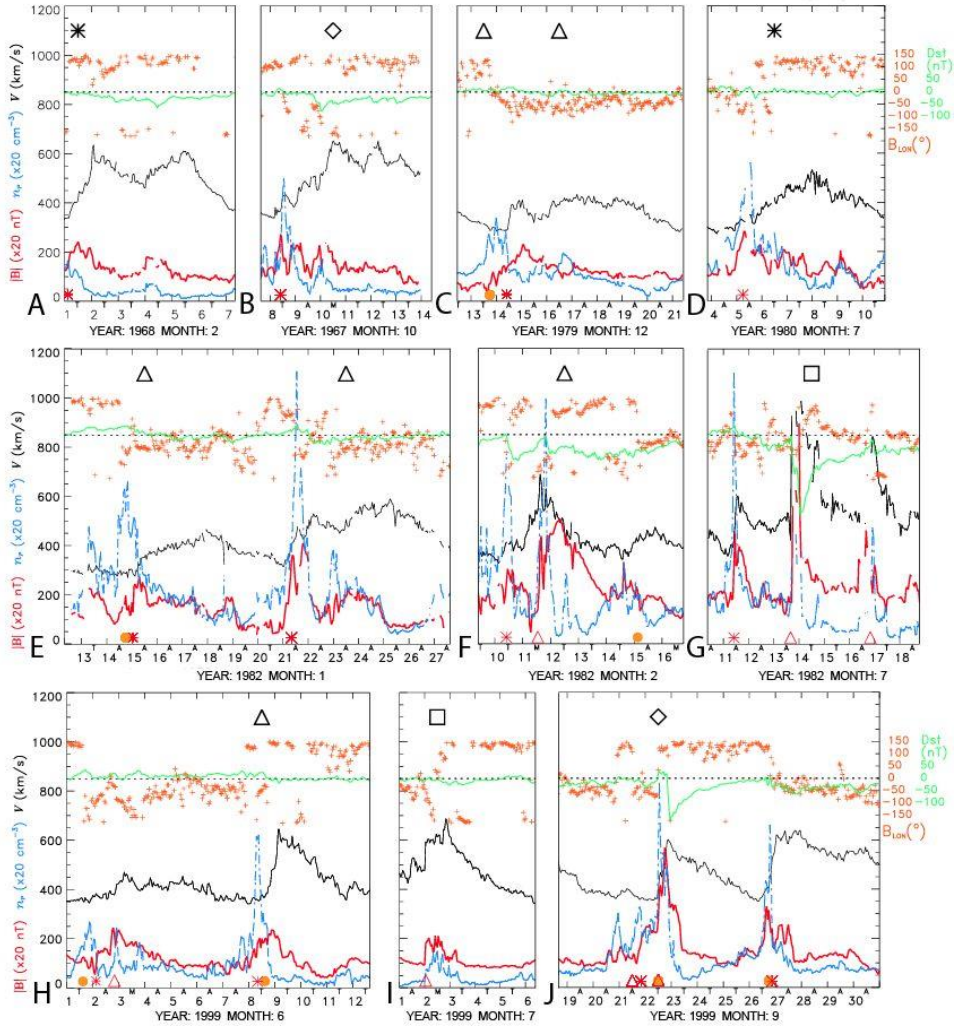
Figure 1 shows solar wind variables including the IMF direction longitude (orange crosses) and the *Dst* index (green line). The symbols on the time axis indicate the times of HSS/CIRs arrivals, impacts of ICMEs, and the IMF sector boundary/HCS crossings. Where available, the proxy magnetic field sectors (A: away, T: toward) are indicated below the time axis. Start dates of heavy rainfall events in Canada included in the SPE analysis are marked by black symbols at the top. These are examples of events that occurred following arrivals of HSS/HCS/CIRs (Figures 1A-E) but also impacts of strong ICMEs that caused severe geomagnetic storms (Figures 1F-G, 1J). Most of these cases are included in the Canadian Disaster Database as flood events (Figures 1A, 1C-D, 1G-J) with start dates of heavy rainfall events (some lasting for a few days) that lead to these floods also identified by browsing historical weather data (see, Section 2). For example, the B.C. government documents provide some details on the events in Figure 1C. On December 13, 1979, stations Victoria Highlands and Victoria Gonzales Hts recorded daily rates of 114 and 83.3 mm, respectively. While the start of this event preceded the CIR stream interface it coincided with the HDP ahead of the HCS. On July 6-7, 1980 (Figure 1D), torrential rain caused flooding and some landslides in Gaspésie Region in Quebec (Gaspé recorded 137.8 mm on July 6th). In January 15-16 and 23-24, 1982 (Figure 1E), heavy rainfall and flash floods occurred in the B.C. capital region Victoria. On February 12-14, 1982 (Figure 1F), the Lower Mainland, B.C., "experienced two days of snow, followed by heavy rain. A series of weather systems moved in from the southwest. Heavy rain caused flooded basements, landslides and following heavy snowfalls in the interior avalanches closed highways." On July 14-15, 1982 (Figure 1G), heavy rainfall occurred in Grande Prairie, AB. On June 8, 1999 (Figure 1H), White Rock, BC, experienced a sudden, intense storm with heavy rain that caused flash floods and mudslides. In July 1999 (Figure 1I), heavy snow and rain fell starting on July 2 caused flooding in Clearwater, AB. On September 22-23 (Figure 5J), Prince Edward Island experienced a severe rainstorm causing flash flooding damaging highways Eight highways and bridges. Heavy rainfall also occurred in Moncton, NB, caused by the remnants of tropical storm Harvey and Hurricane Gert.

The IMERG satellite-based precipitation data are available from June 2000. At the top in Figure 2, the maximum IMERG daily rates at any grid cell over Canada (solid purple line) and the number of IMERG grid cells over Canada with precipitation rates exceeding 50 mm (dotted line) are shown. During the maximum of solar cycle 23 in November2001 there were numerous ICMEs impacts, sometimes coincident with HSS/CIRs, causing intense geomagnetic storms. Figure 2A shows strong HSS/CIR/ICME impacts on November 5-6 and 24 closely followed by high-rate precipitation occurrence with peaks in daily IMERG precipitation maxima and the number of grid cell with precipitation rates > 50 mm/d. ICMEs on October 31 and November 19, as well as the HDP ahead of

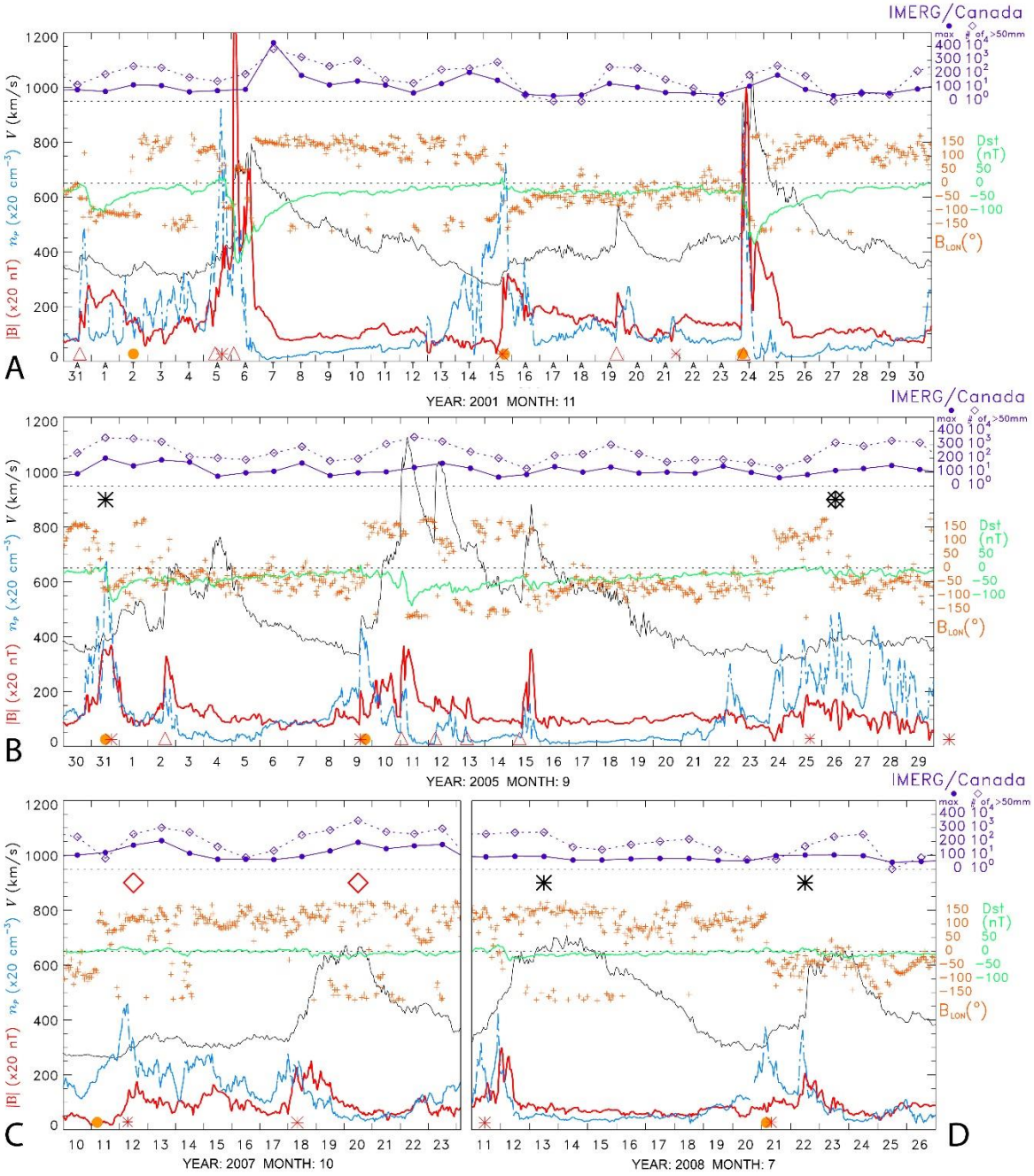
the HSS/CIR/HCS on November 15, are also associated with enhanced high-precipitation occurrence that was caused by a series of intensifying cyclones on the east and west coasts, and one over the central Canada. The B.C. documents mention only one minor flood event on November 19 that is associated with an ICME.

In August - September 2005 (Figure 2B) it was mainly the east coast that was affected by heavy rainfall events in Quebec and Newfoundland that closely followed arrivals of HSS/CIRs. Enhanced high-rate precipitation occurrence is also associated with a strong HSS/CIR on September 9 followed by a series of ICMEs. Figures 2C-D show cases of heavy rainfall events in New Brunswick and Quebec, respectively, as well as enhanced high-rate precipitation occurrence following HSS/CIRs.

1.1 Supplementary Figures



Supplementary Figure 1. The OMNI solar wind *V* (solid black line), *B* (red), n_p (broken light blue line, with the y-axis scales shown on the left. The magnetic field direction longitude (orange crosses) and the *Dst* index (green line) with the y-axis shown on the right. The symbols at the time axis indicate CIR (∗), ICME (Δ), HCS (●), and the proxy magnetic field sector (A: away, T: toward). The symbols at the top mark the starting days of heavy-rainfall-induced floods in Canada (Δ BC; □ AB/SK/MB; ∗ ON/QC; ◊ NB/NS/PEI/NL).



Supplementary Figure 2. The maximum IMERG daily rates (solid purple line), the number of grid cells over Canada with precipitation rates exceeding 50 mm (dotted purple line), The OMNI solar wind *V* (solid black line), *B* (red), n_p (broken light blue line, with the y-axis scales shown on the left. The magnetic field direction longitude (orange crosses) and the *Dst* index (green line) with the y-axis shown on the right. The symbols at the time axis indicate CIR (∗), ICME (Δ), HCS (●), and the proxy magnetic field sector (A: away, T: toward). The symbols at the top mark the starting days of heavy-rainfall-induced floods in Canada (Δ BC; □ AB/SK/MB; ∗ ON/QC; ◊ NB/NS/PEI/NL; ◊ NB storms).