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Why did the Carrington storm recover very rapidly?

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Intense geomagnetic storms are accompanied by rapid recovery, as represented by a quick increase of the Dst index after its minimum. As far as the geomagnetic storms that we have observed since the early 20th century, the more intense storms experienced the more rapid recovery. The Carrington event on 2 September 1859 also experienced an extremely rapid recovery (>1000 nT/h at Bombay, India; >300 nT/h with 1-hour average data). At least three major processes that occur in the Earth's inner magnetosphere are proposed to explain such rapid recovery: (1) the neutralization of energetic O^+ ions through charge exchange, (2) flow-out of energetic ions to the interplanetary field, and (3) loss of energetic ions into the atmosphere through pitch-angle scattering due to interactions with electromagnetic ion cyclotron (EMIC) waves. In addition, a sudden increase in the solar wind dynamic pressure around the storm maximum could cause a quicker recovery.

In this talk, we focus on intense magnetic storms with the Dst minimum smaller than -200 nT for which solar wind data are available. We first examine whether the rapid recovery can be explained by an ion flow-out effect associated with sudden changes of solar wind density, by modifying the empirical Burton's equation. We also estimate the amount of energetic O^+ ions, the spatial extent of EMIC wave active regions, and the increase rate of the solar wind dynamic pressure that could be required to reproduce the storm rapid recovery. In addition, we discuss how quickly the geomagnetic field could change during the recovery of an extremely intense storm such as the Carrington event.

Keywords: The Carrington event, Geomagnetically induced currents (GICs), Ring current, Magnetopause current, Interplanetary shocks, Coronal mass ejections (CMEs)