Analysis of High-Latitude Ionospheric Processes During HSS and CME-Induced Geomagnetic Storms

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Publication date: 2016

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):

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Key Points

- Vertical electron content (VTEC) maps inferred from Greenliand GNSS stations are used for the first time to investigate differences in ionospheric disturbances caused by high-speed streams (HSS) and coronal mass ejections (CME).
- TEC mapping reveals pronounced negative storm phase and significantly decreased polar particle flux due to increased atmospheric heating.
- On the day following the HSS event (Nov, 4, 2016) a solar radio burst (SRB) caused anomalies in European and Greenlandic air navigation. We present our findings related to this rare event.

Observations and Mapping Technique

From the total number of 82 QMNET stations 16 were selected. This selection was based on their geographical location, elevation and distance to each other. The goal was to provide an even distribution along the coastline, which resulted in the best ITR coverage. The white disk in the right side panel of Fig A shows an example ITR provided for a given epoch.

The geostationary receivers are capable of tracking several observables, such as poleward auroral oval (PVO) and Polar and high-latitude auroral oval (PLAO) rings, using GPS data. The Global Ionospheric Maps (JPL GIM) to obtain VTEC values which then were merged (12). Fig A displays the ionospheric maps obtained from JPL GIM, which are selected from Marucchi et al. (1998). Fig B shows the time development of polar plasmasphere in a semi-circular region on the ZP1 VTEC map. The time interval between snapshots is 10 minutes.

Relative plasma drifts are of the order of 1000 km/s in the polar-cap region, which in theory requires at least 10-s sampling rate to detect. A wave such as a polar cap electron drift should be clearly visible electric field changes (Borovik et al. 2000).

CME-Induced Storm

An example for a larger CME-driven ionospheric storm is the 19 February 2016 high-speed stream disturbance, which had the largest impact on the disturbance storm-time (DST) index that year. The geomagnetic storm was the result of two powerful north-directed CMEs.

HSS-Induced Storm

An example for a larger HSS-driven storm is the 3 November 2016 geomagnetic storm following the next day by a CME, and an event very well described by Casey et al. (2000).

Fig A1 shows the schematic structure of a complex structure of the ionospheric storm. Fig A2 shows the simple ionospheric structure of the storm.

Results

Fig D displays results from Thule during the CME-driven 19 February 2014 storm. Thule is located deep in the polar region. Fig F displays the ionospheric mean profile showing 2 days of ionospheric vertical NmF2 distributions observed on 19 February 2014 (top) and on 20 February 2014 (bottom). The measured distribution shows large changes between both days. NmF2 is a proxy for the density of the ionosphere and it is related to the total electron content (TEC).

HSS-Induced Storm

For the first time we compared ionospheric effects of HSS and CME-driven storms at high-latitudes. There were similarities and also differences observed in the development of the storms. (1) Both storms resulted in a negative phase, which is indicated by an increase in TID-breaking down into patches and a decrease in patch formation in general throughout the Greenlandic sector. The negative phase development of the PCN index started to increase indicated energy input into the ionosphere. (2) The rate of PCN increase was different for the two types of storms. (3) The impact of the physical processes responsible for the negative phase has less pronounced impact on the Greenlandic sector.

We also investigated and assessed storm influences on airborne navigation at high-latitudes in order to determine the possible causes of the radio communication disturbances. This effort may lead us to a better understanding of the phenomenon and might help develop communication hardware that is more resistant to such effects.

Bibliography


