Conjugate Space-based and Ground-based Observations of Energetic Electrons during Substorms
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Abstract
The visible aurora is an indicator of ionization caused by precipitating charged particles from the magnetosphere. Sudden brightening of the nightside auroral arcs are observed during the expansion phase of substorms. The electrons responsible for the aurora are mostly thought to originate from within the plasmasheet. Recent observations made using Poker Flat Incoherent Scatter Radar (PFISR) during the poleward expansion of an auroral substorm indicate precipitation of energetic electrons greater than 300 keV. Magnetically conjugate THEMIS measurements confirm changes in the plasmasheet thickness during this period. Our observations suggest that there is more to be understood of the link between magnetotail dynamics and energetic electron precipitation during substorms. Understanding this link may open up novel and potentially invaluable ways of diagnosing the magnetosphere from the ground.

Magnetic Substorms
Magnetospheric substorms are episodic release of magnetic energy stored in the geomagnetic tail extracted from the solar wind. The evolution of a substorm can be categorized into three separate phases.

Growth phase: Energy is transferred from the solar wind to the Earth’s magnetosphere.
Expansion phase: The energy stored in the magnetotail is unloaded through the process of magnetic reconnection.
Recovery phase: Magnetosphere returns to its quiet state.

Figure 1: Schematic of the magnetosphere during the three different substorm phases along with the corresponding auroral oval observed in the Northern hemisphere. The auroral oval is aligned with the equatorial plane. [1] The three auroral oval images were obtained with the IMAGE WIC Instrument.

Auroral arcs, including substorm auroral forms, are produced by precipitating 1-10 keV electrons. These electrons are accelerated by field-aligned potential structures. The acceleration region is located between about 1 to 3 Earth Radii (RE) in altitude.

It has been long known that variations in the flux of energetic particle occur in the near-Earth magnetotail during substorms. The energetic particle flux is seen to vary by more than two orders of magnitude in the near-Earth magnetotail.

The present study explores the possibility of using ground-based measurements in conjunction with data from satellites to understand the different magnetospheric physics that we can uncover during substorms.

Energetic electron measurements from ground & space

Figure 2: Substorm event on 26 March 2008 at ~11:46 UT where transient patches of ionization were observed at 70 km altitude. The top panel shows the all sky white light images of the substorm aurora and the bottom panel shows the plasma density pattern observed during the substorm expansion phase.

Figure 3: During the expansion phase of the substorm, the cross-tail current in the near-Earth region intensifies (11:22 UT to 11:46 UT, Figure 4). This causes the magnetic field to assume a more stretched configuration. At the onset of the expansion phase (at 11:46 UT, Figure 4), a portion of this enhanced current is diverted into the ionosphere through the substorm current wedge, and the magnetic field recovers to a more dipolar configuration.

Near-Earth magnetotail acceleration
The magnetic field configuration (as well as the net magnetic field intensity) before and after the substorm is similar, however, there is a marked increase in the energetic particle flux. This suggests some nonadiabatic process of acceleration must be at work.

This flux increase observed by THEMIS D satellite in the near-Earth magnetotail during substorms represent locally accelerated particles, unlike those accelerated by the field aligned potential structures in the auroral acceleration regions. These particles are thought to be regularly energized to hundreds of keV by inductive electric fields during the current sheet disruptions.

Conclusions
The similarity in the average electron density seen in Figure 4 b) during the substorm growth and expansion phase (11:22 UT to 12:30 UT) suggests that these energetic particles can be observed from the ground using radar systems such as PFISR.

The possibility of detecting energetic electrons originating from the near-Earth magnetotail from ground observations during substorms opens up a new remote sensing diagnostics of the magnetosphere during substorms.

Future Work
- Identifying more conjugate energetic electron measurements
- Identifying specific magnetospheric physics within the data obtained
- Exploring the prevalence of these energetic electrons during substorms
- Expanding the study using data from other ground-based instruments

References

Figure 4 a) shows the average ionization measured per altitude, along the RADAR beam. The figure shows a particular substorm event observed on 26 March 2008.

Figure 4 b) shows the average ionization measured per altitude, along the RADAR beam. The data follows a trend that is very similar to the electron energy flux measured by THEMIS D satellite during the same time period. c) The magnetic field configuration (as well as the net magnetic field intensity) before and after the substorm is similar, however, there is a marked increase in the energetic particle flux. This suggests some nonadiabatic process of acceleration must be at work.

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