

Time Evolution of the Substorm Current Wedge from Ground and Space-based Magnetic Fields

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Abstract: Over the past several years, intensive efforts have resulted in a significant improvement in the ground instrumentation for auroral studies in North America. A major part of this is due to the THEMIS ground program, both in the U.S. and in Canada. The THEMIS Ground-Based Observatory network has fielded 10 additional magnetometers in Canada and Alaska. Further THEMIS magnetometers are part of the GEONS outreach effort, found in the continental U.S. and Alaska. Athabasca University initiatives and collaborations have made yet further magnetometer data available, most notably from a new network of instruments in central Alberta. Several stations of the University of Tokyo STEP network remain operational, and some have been upgraded. There is finally a dense enough set of magnetic data that techniques based on forward modeling, and most relevant to the opportunity afforded by THEMIS, Automated Regional Modeling (ARM), can be reliably used. These techniques specify where net field-aligned current (FAC) and ionospheric electric current flow are located. In some cases the Pedersen system can also be included based on data. Even when it is not, it can be considered collocated with electrojet locations given by ARM. The extension into space of the FAC (net or Pedersen) allows comparison with the perturbations observed at THEMIS. We present results from an event on March 13, 2007, during which THEMIS in its early orbital configuration was over central North America, clear weather prevailed, and a substorm took place whose perturbations were ideally suited for inversion using ARM. At about 5 UT, activations were detected from the ground with magnetic perturbations also detected from THEMIS above the affected stations. The ground perturbations are very well represented by a three-dimensional substorm current wedge (SCW) system, and perturbations in space indicate radial propagation at a time when the electrojet was expanding poleward. Little longitudinal propagation of the SCW is suggested by the ground data.

Athabasca University Geophysical Observatory (AUGO)

A comprehensive observatory ideally located for THEMIS conjunctions

54.72 N, 246.7 E

CGM (2005)

62.0, 306.5

L=4.55

Founded 2002

(UCLA mag 1998)



AUGO's Instrumentation

1. UCLA Fluxgate
2. THEMIS GBO Camera
3. KEO NORSTAR Camera

Guest instruments from
STELAB:

1. Multispectral ASC
including H β
2. 64 Hz induction coil
3. proton spectrometer



Ground Magnetometry

In a Sun-to-Mud approach, we are in the mud...

EDMO UCLA magnetometer installed by Martin Connors (Tom Sawyer-like technique applied to astronomer Brian Martin) in December 2004



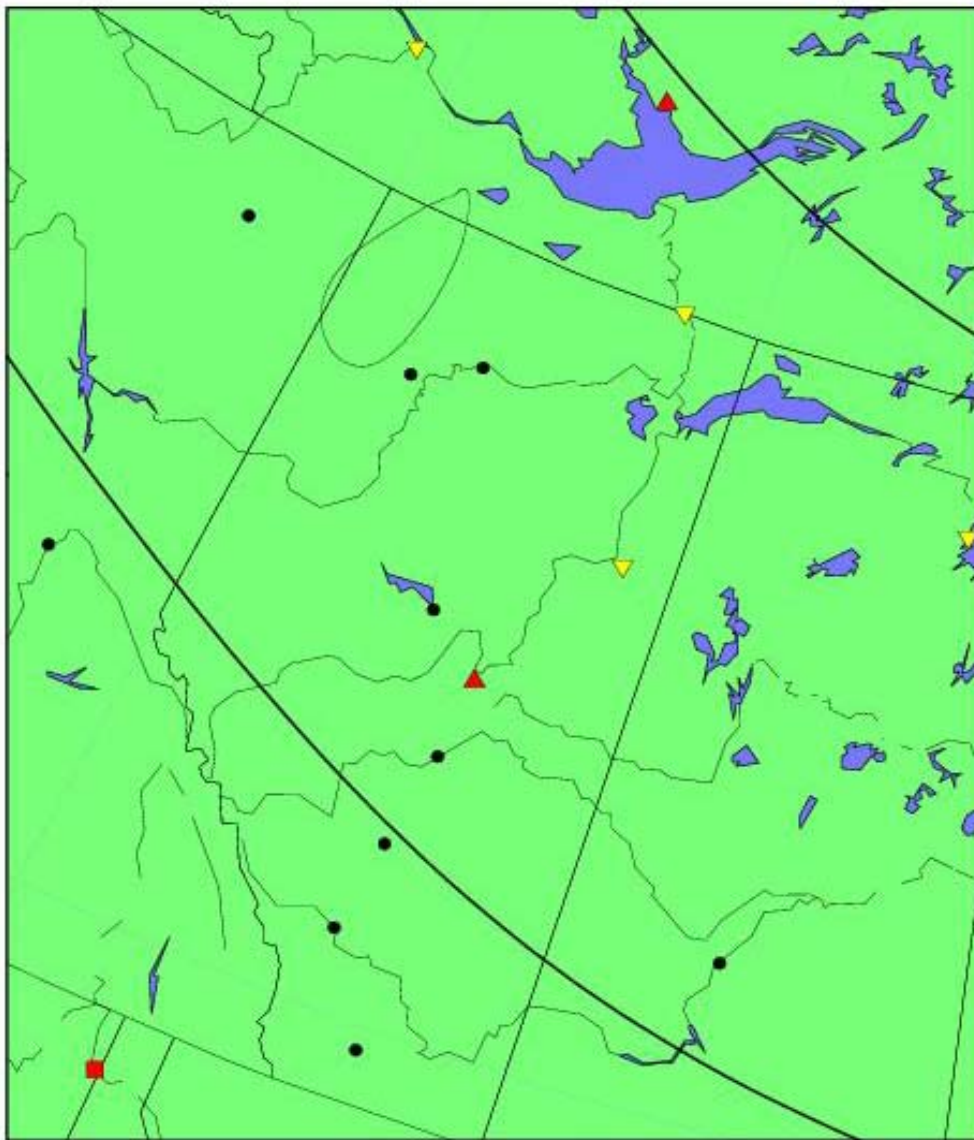
Often the locales are less agreeable than France (Kanji Hayashi in LaRonge, Canada, mid-October 2004) but intensive fieldwork by teams from Athabasca University, UCLA, University of Calgary, University of Tokyo, and Northern Lakes College has greatly expanded North America's magnetometer networks



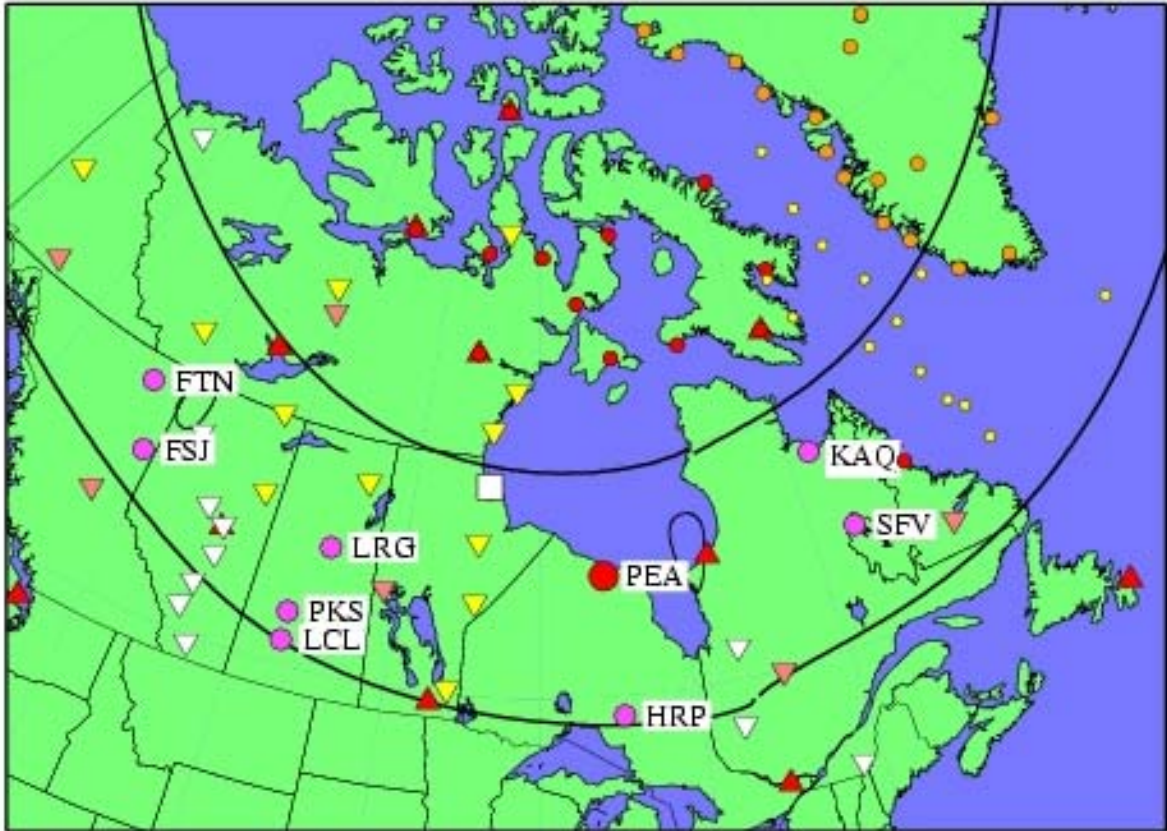


AUTUMN

Athabasca University THEMIS UCLA Magnetometer Network

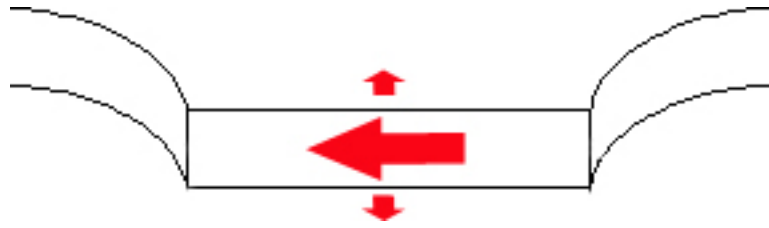


STEP Forward 2007–2008

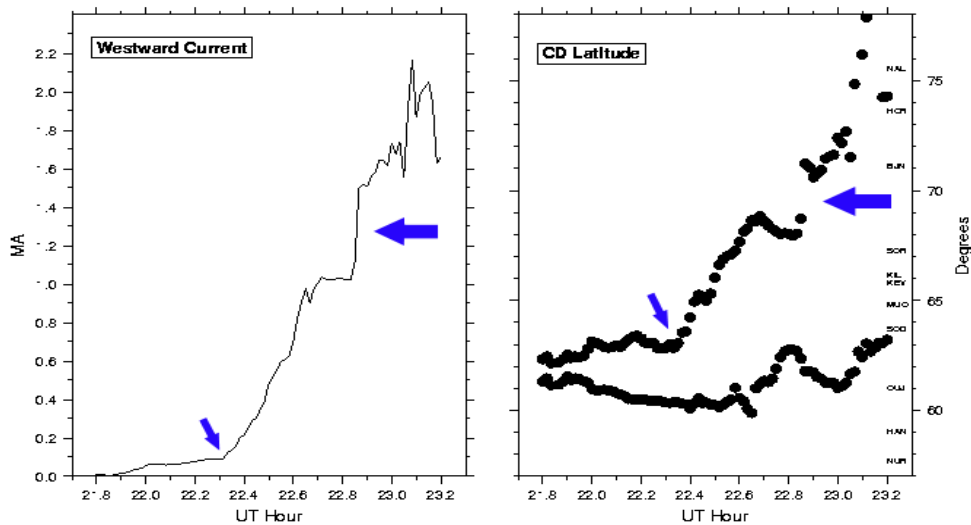


Athabasca University has assisted or runs 16 sites in Canada (white triangles = AUTUMN and purple dots = STEP in Western Canada). Most data available through UCLA, STEP website, or on request. PEA, KAQ, SFV hoped for soon. New Polaris sites (not shown) on E. Coast of Hudson Bay installed in 2007. Some GBOs not shown.

Automated Forward Modelling (AFM)



For meridian data, AFM adjusts current and borders. This is called Automated Meridian Modelling (AMM) and nominally uses only the X and Z ground perturbations.



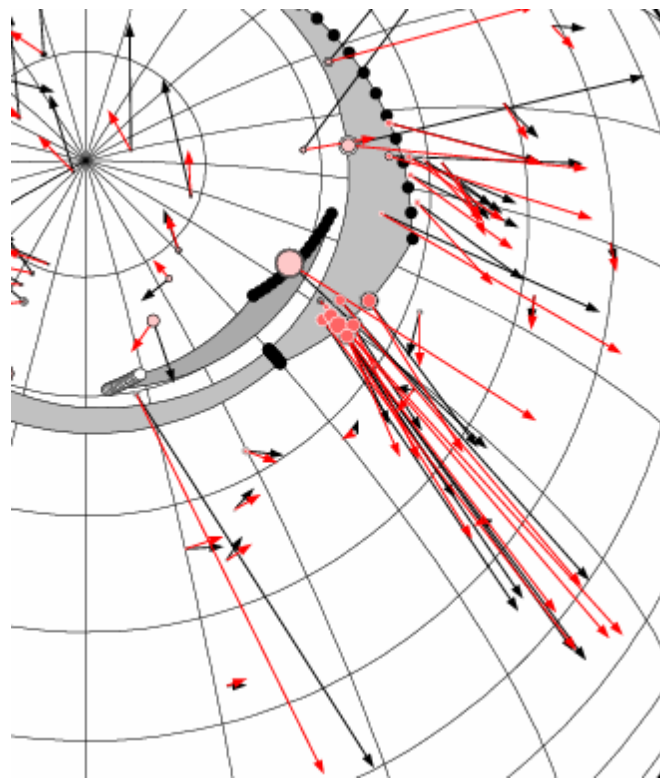
The method is however, much more general and can include field-aligned currents in realistic 3-d configurations. Midlatitude perturbations can be included as can a Dst-like parameter.

Array Interpretation from a distributed region is more difficult, complicated by problems of nonuniqueness. In a region such as North America, this is referred to as Automated Regional Modelling (ARM).

On the ground, one detects primarily the magnetic effects of the Hall currents associated with the auroral oval electric field

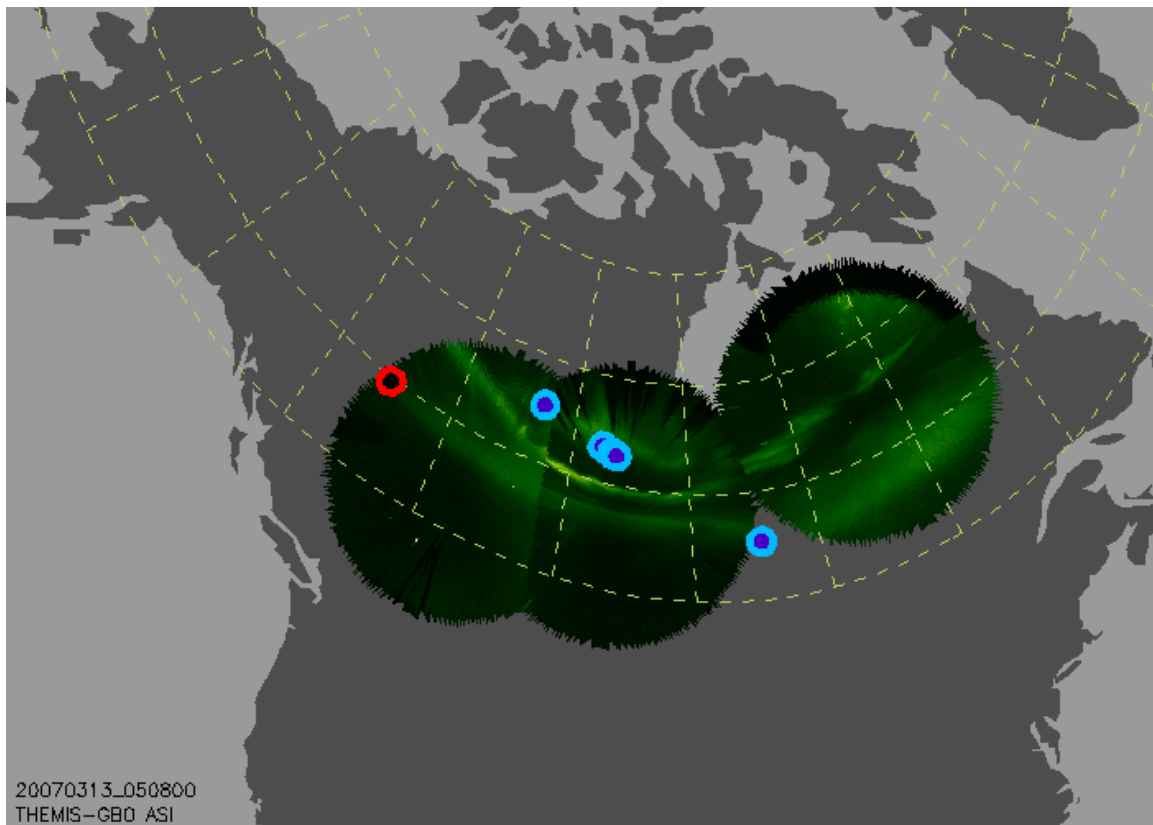
FAC effects CAN however also be detected from the ground.

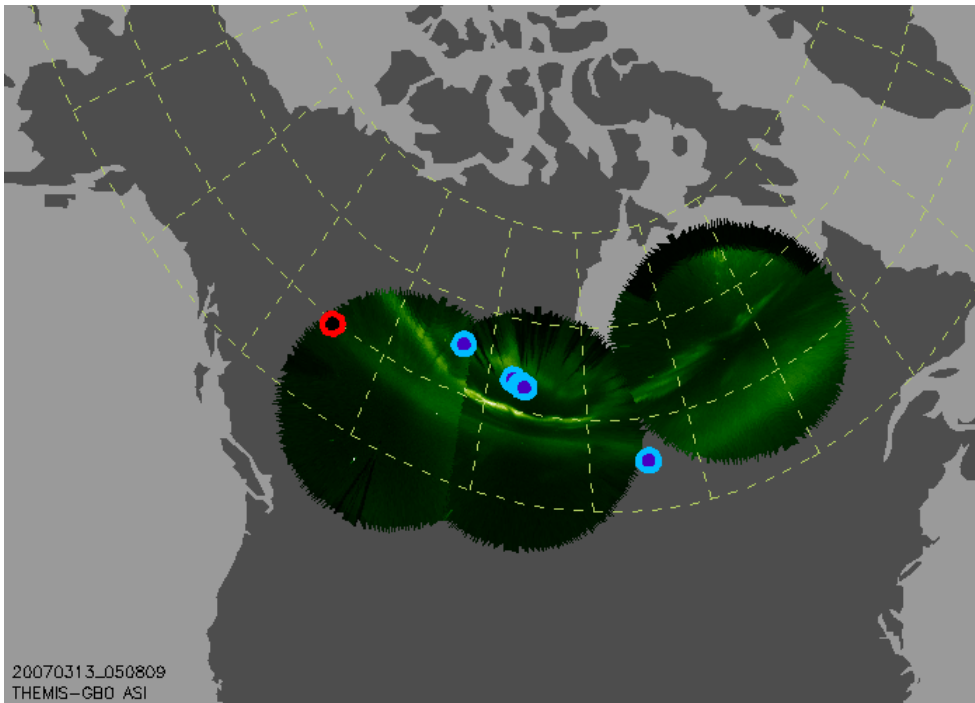
The figure shows a detailed model of the auroral oval on a global scale.



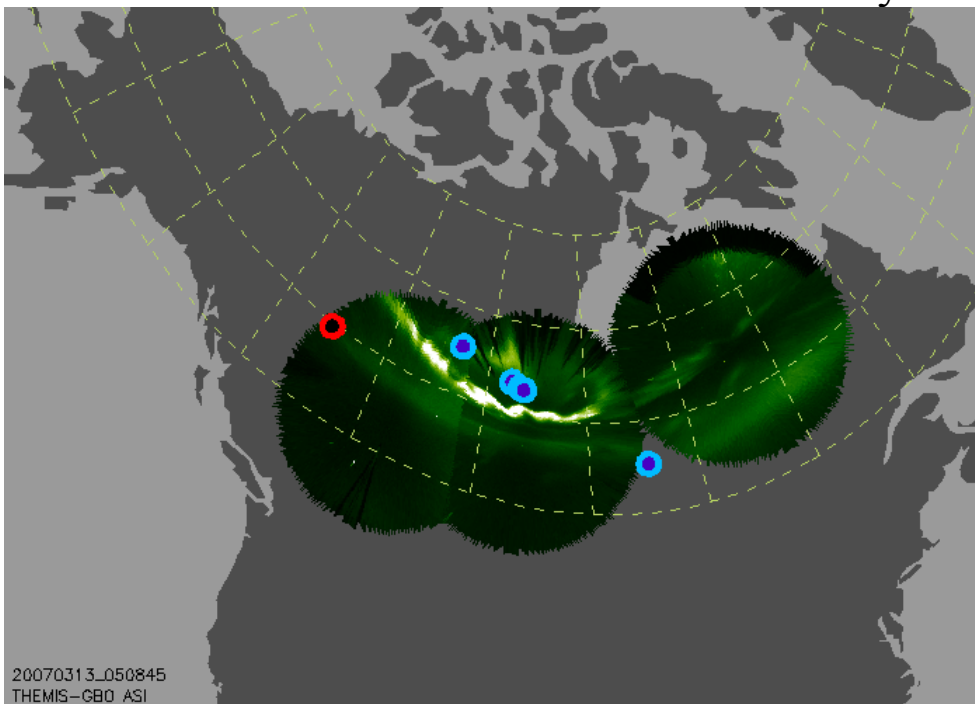
March 13, 2007 THEMIS Conjunction Event

Activations took place between 05:00 and 06:00 UT on March 13 2007, with several THEMIS satellites deployed in a line over central Canada with its THEMIS GBO cameras and many magnetometers. At 05:08:00 there was not much sign of activation. The cameras have 3s cadence.





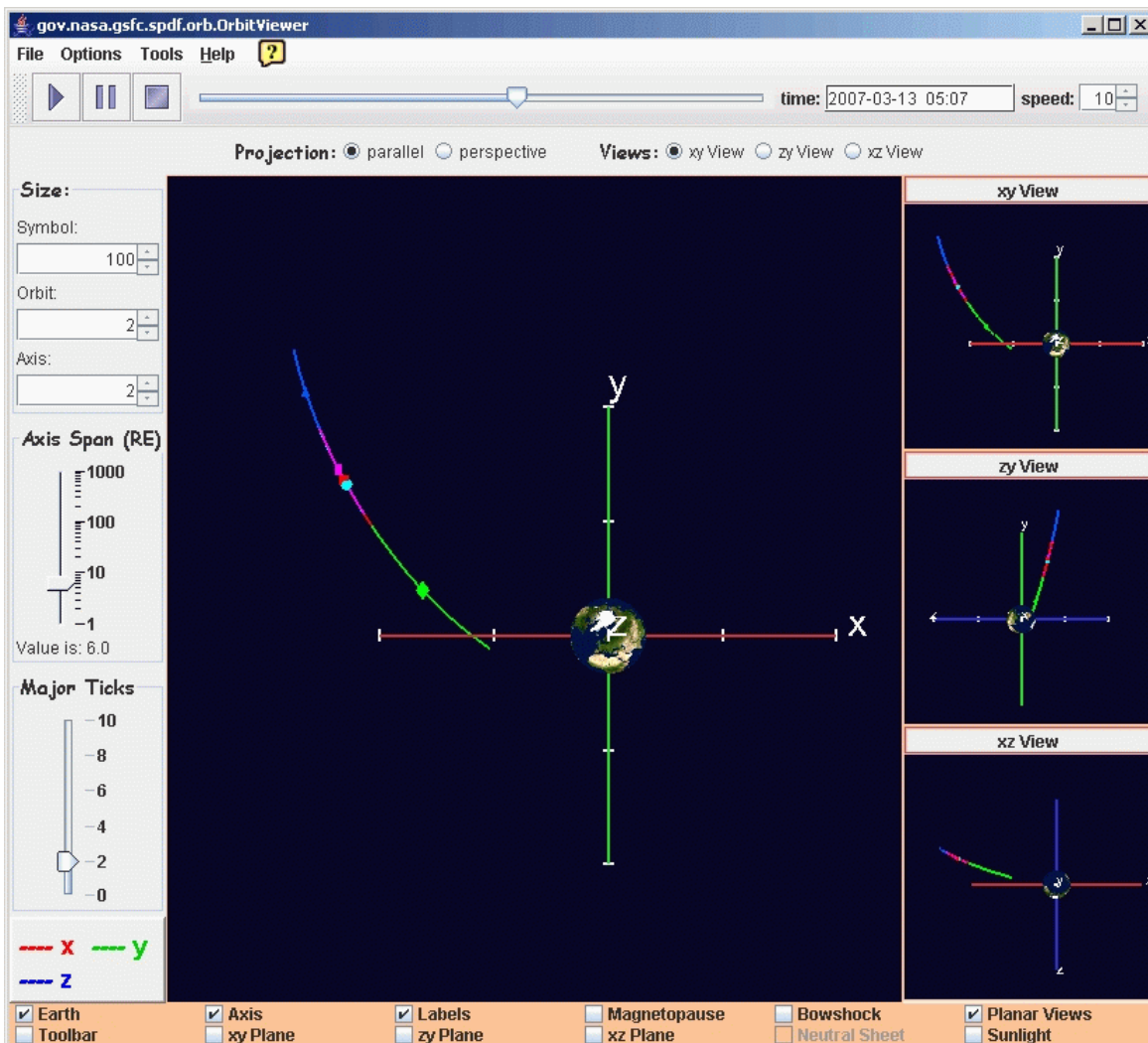
At 05:08:09 the activation was well under way.



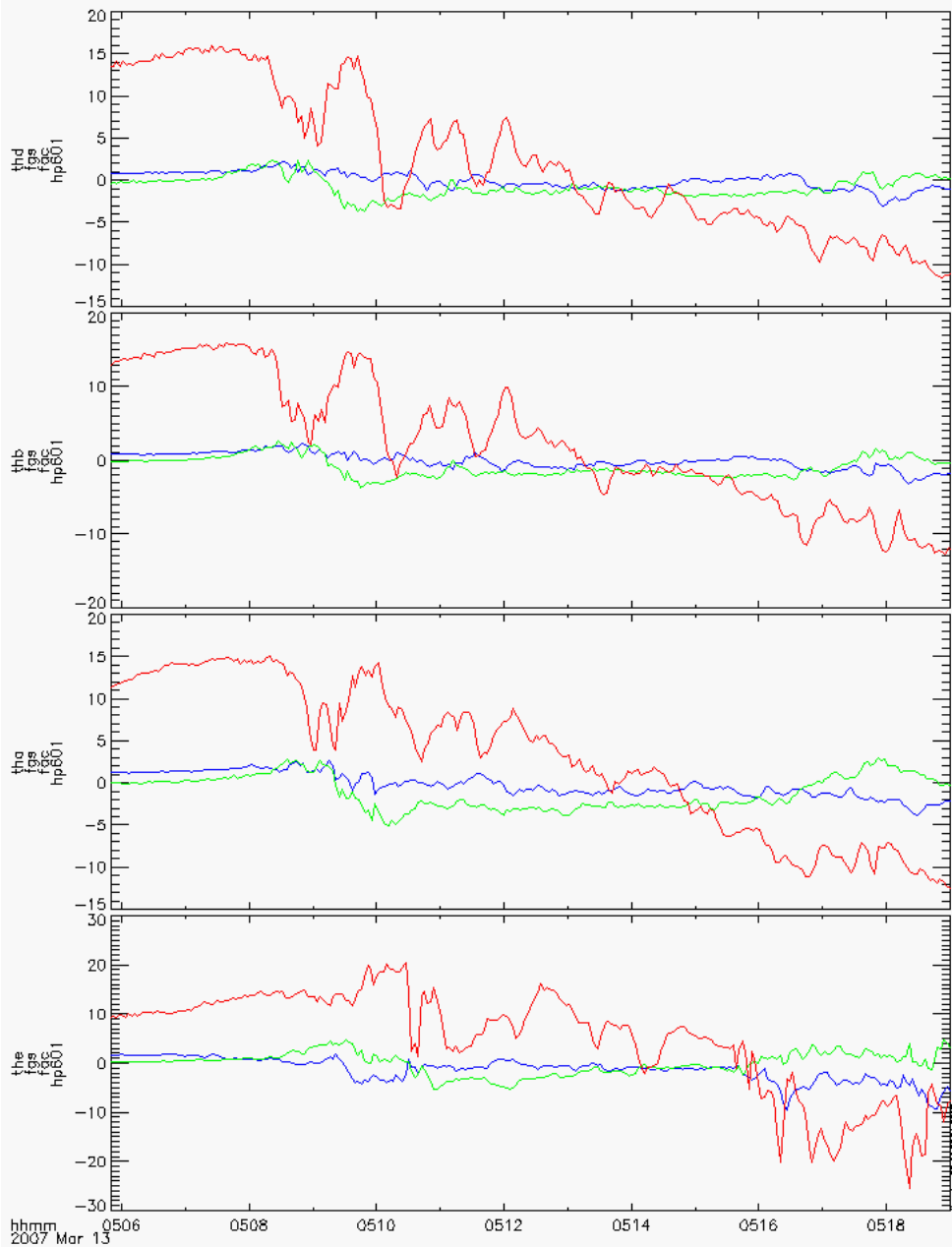
At 05:08:45 extensive vortical development had already taken place. The GBO network is a remarkable tool for identifying optical onset time and development of auroral features. More details will be presented at AGU by Donovan et al.

Magnetic Signatures

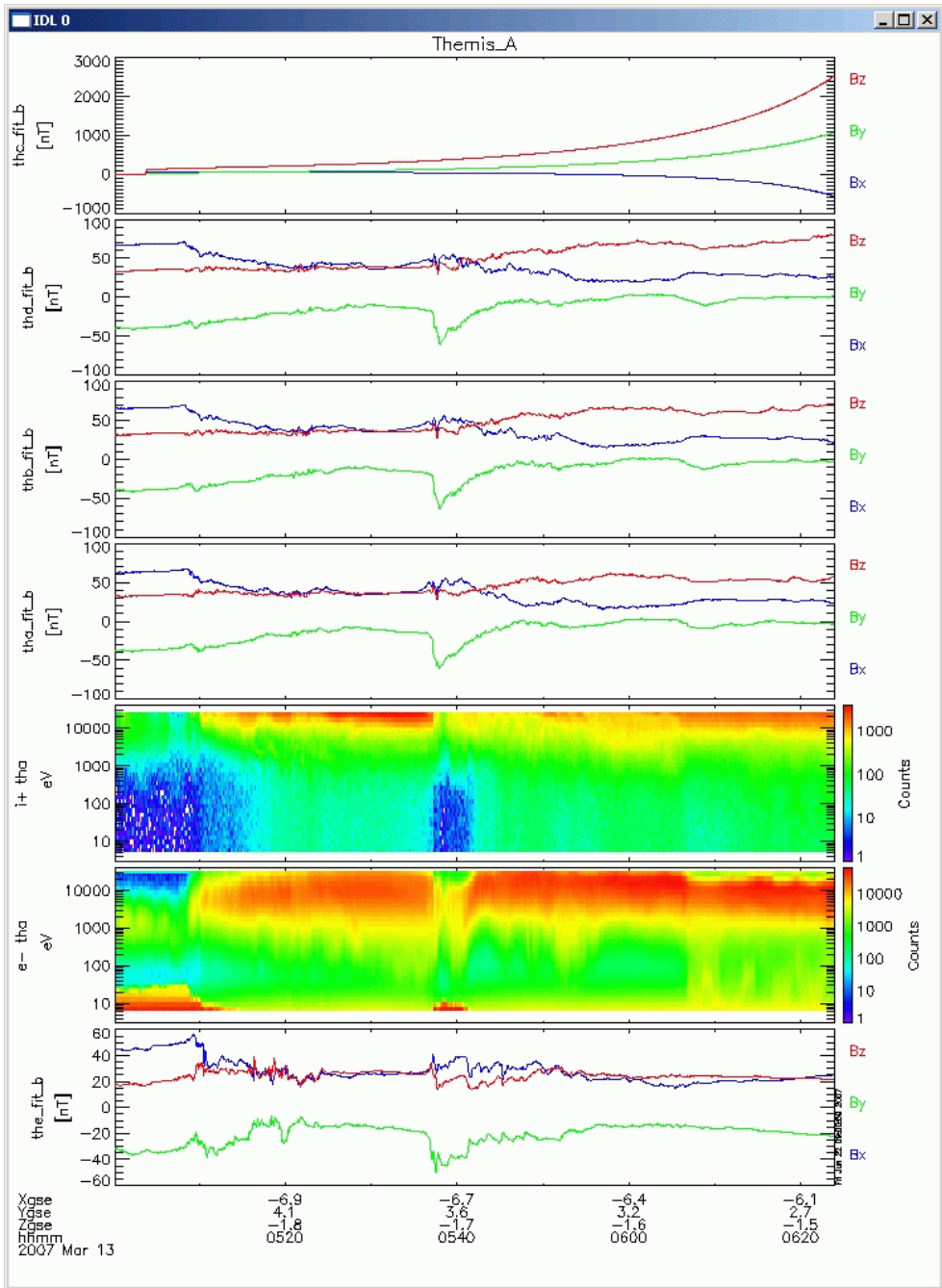
The magnetic signatures both in space and on the ground from the optically very bright 05:08:09 onset were modest. However they do show radial propagation outward.



Positions of spacecraft on Mar 13 2007 near 5:08 UT onset time. Scale is marked at $4 R_e$ intervals and dots are THEMIS C, D, B, A, and E, from lower right in main plot.



Radial and/or westward propagation of disturbance near 05:08 onset using field-aligned magnetic perturbations. X (blu) is toward Earth, Z (red) is along the field and Y (grn) westward.



Overview including second onset at 05:36.
 This onset appears suddenly at the location
 of the D, B, A, and E spacecraft.

Automated Regional Modelling preliminary results are based on local magnetic perturbations baselined with respect to March 18.

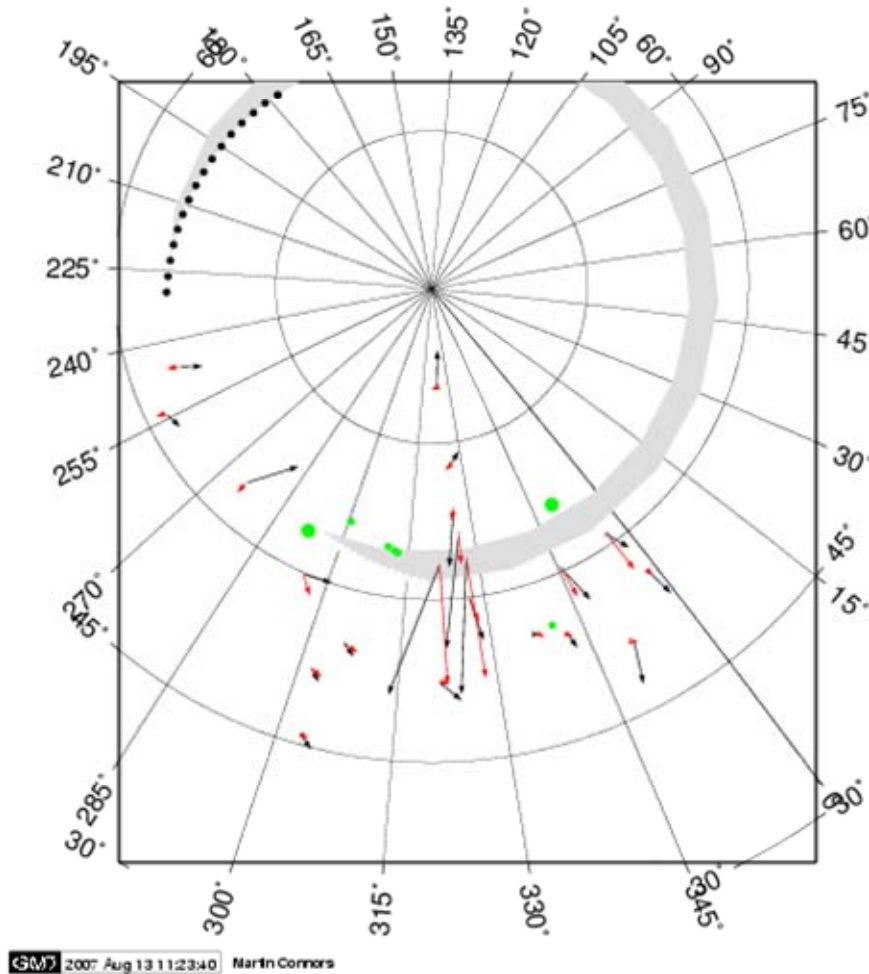
In all model runs, the electrojet was constrained to be in a substorm-current-wedge configuration, with downward field-aligned current (FAC) to the east, ionospheric current flow westward, and upward FAC to the west.

In the latter stages of the onset, this represented the magnetic perturbations at auroral and subauroral latitudes very well.

In the present model run Pedersen (north-south) currents and FAC sheets are not included, although the model can include them.

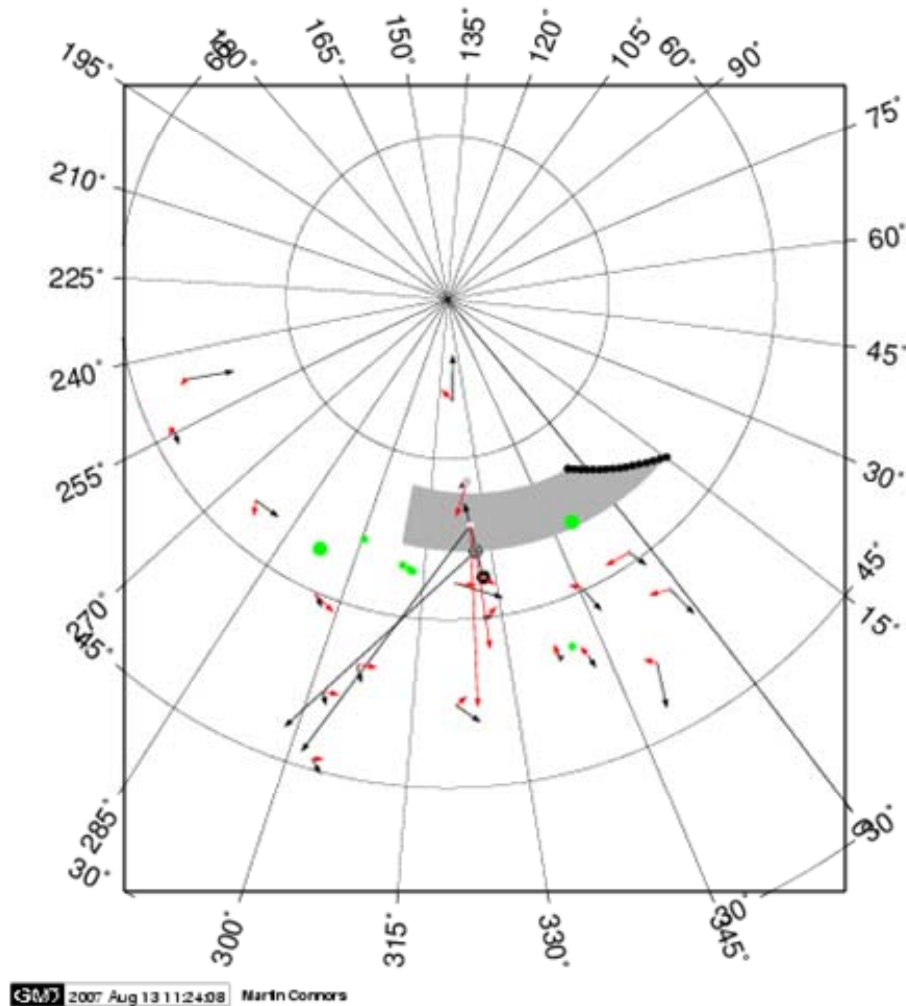
Model results are in red, observations in black.

file: eventmrq.10aug07
March 13 2007 5.341528 UT



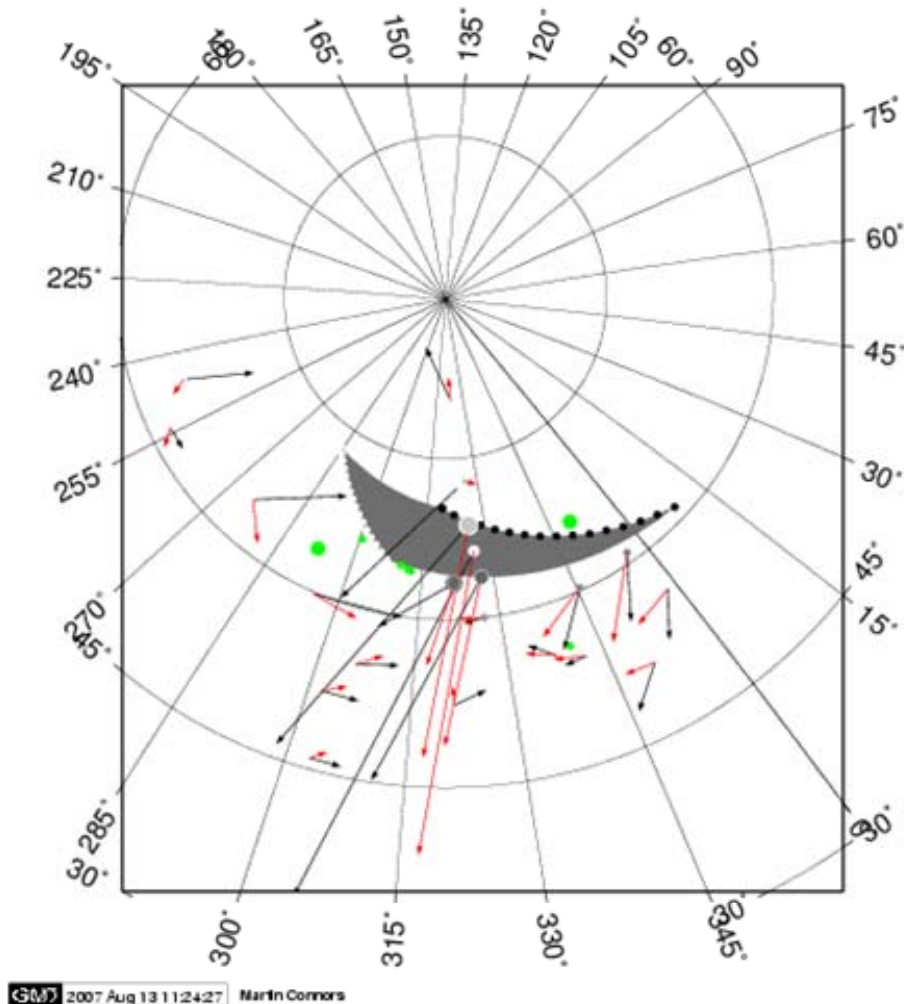
At 05:19.5 UT, after the initial onset, there is no indication of a narrow substorm current wedge. Perturbations in eastern North America are mainly southward. The eastward extension of the electrojet is poorly constrained and not indicative of reality.

file: eventmrq.10aug07
March 13 2007 5.624862 UT



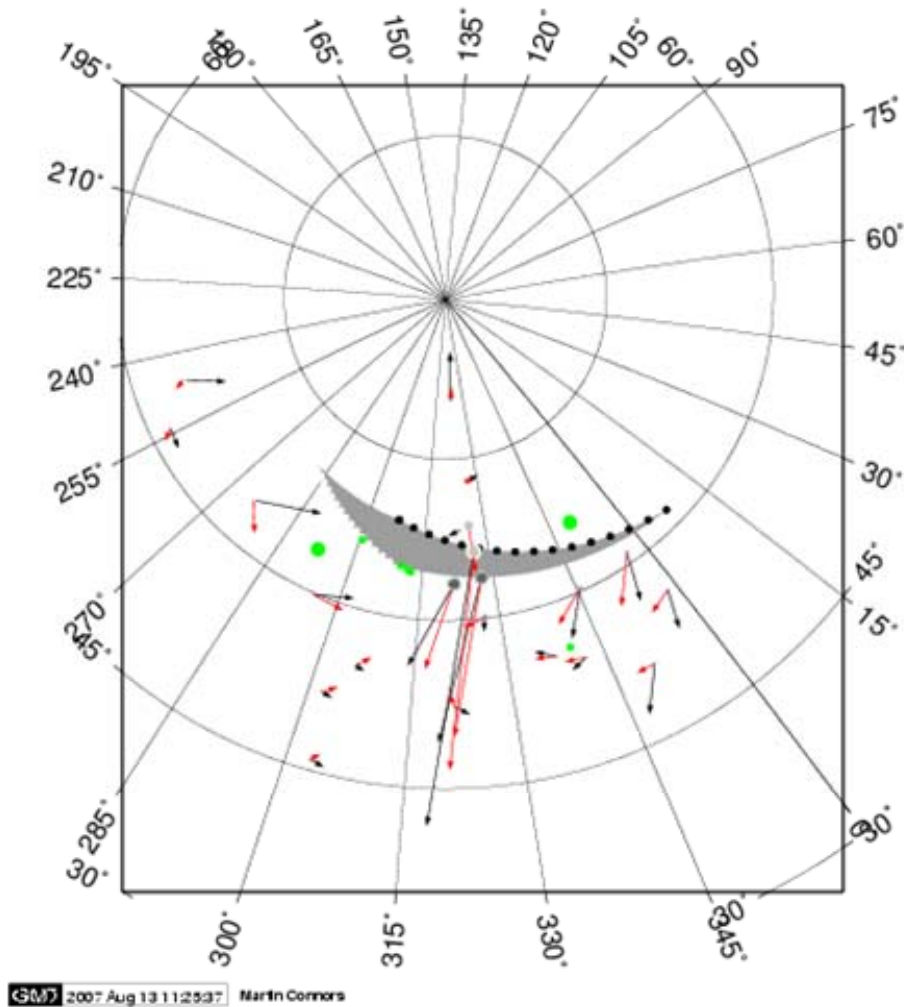
A feature of the 05:36 onset (here shown at 05:37.5) is large westward perturbations in the auroral zone. These are not explained by the current simple SCW model. At this time, perturbations in eastern North America (NA) do not suggest a downward FAC there.

file: eventmrq.10aug07
March 13 2007 5.824861 UT



By 05:49.5 (13 minutes after onset), the SCW is well formed. Note westward perturbations under the downward FAC over eastern NA, eastward ones over western NA, and auroral zone currents comparable to those of the FAC. Westward perturbations on the ground and eastward ones at the spacecraft have died off.

file: eventmrq.10aug07
March 13 2007 6.558194 UT



Nearly an hour after onset (6:33.5 UT), the same basic SCW pattern prevails but the intensity of currents has decreased.

Conclusions

- Within a month of launch, THEMIS already had a conjunction over North America in which optical and ground magnetic results could be compared with spacecraft data.
- In addition to an enhanced network of ground instruments, we have a new tool, Automated Regional Modelling, providing a simple view of current systems and explaining many aspects of ground perturbations.
- A simple SCW model explains many of the ground perturbations and should help studies of mapping to THEMIS.

Acknowledgements

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