What Radar Scientists need to know about Ground Magnetic Data

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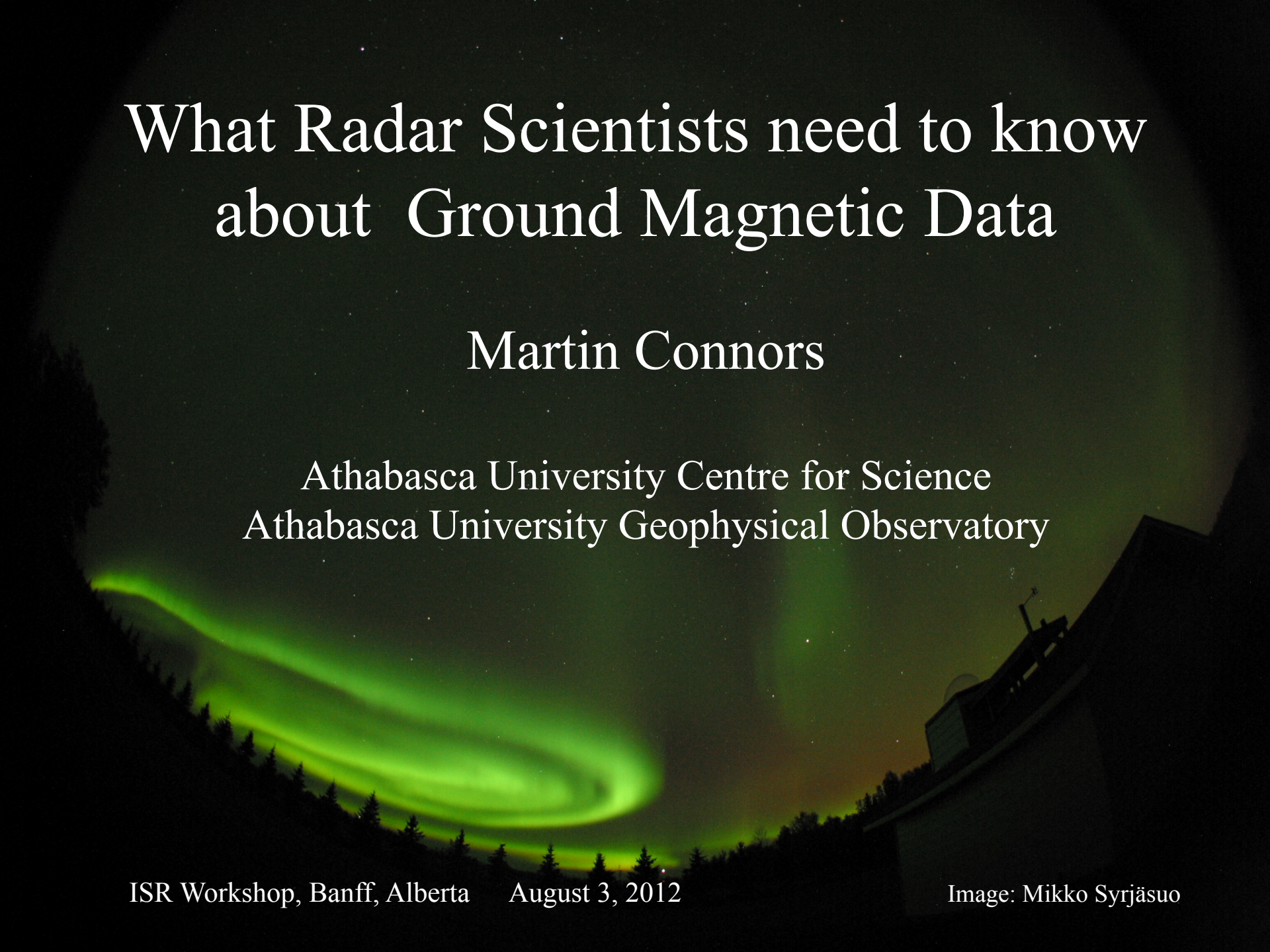


ISR Workshop, Banff, Alberta August 3, 2012

Image: Mikko Syrjäsuo

Basic Points

Ground Magnetic perturbations arise mainly from current systems in the ionosphere and above, and their image currents

In principle (Fukushima theorem) one cannot distinguish effects of field-aligned currents (FAC) from those of ionospheric current systems (Alfven-Chapman debate)

However, from spacecraft experiments, we know what FAC look like

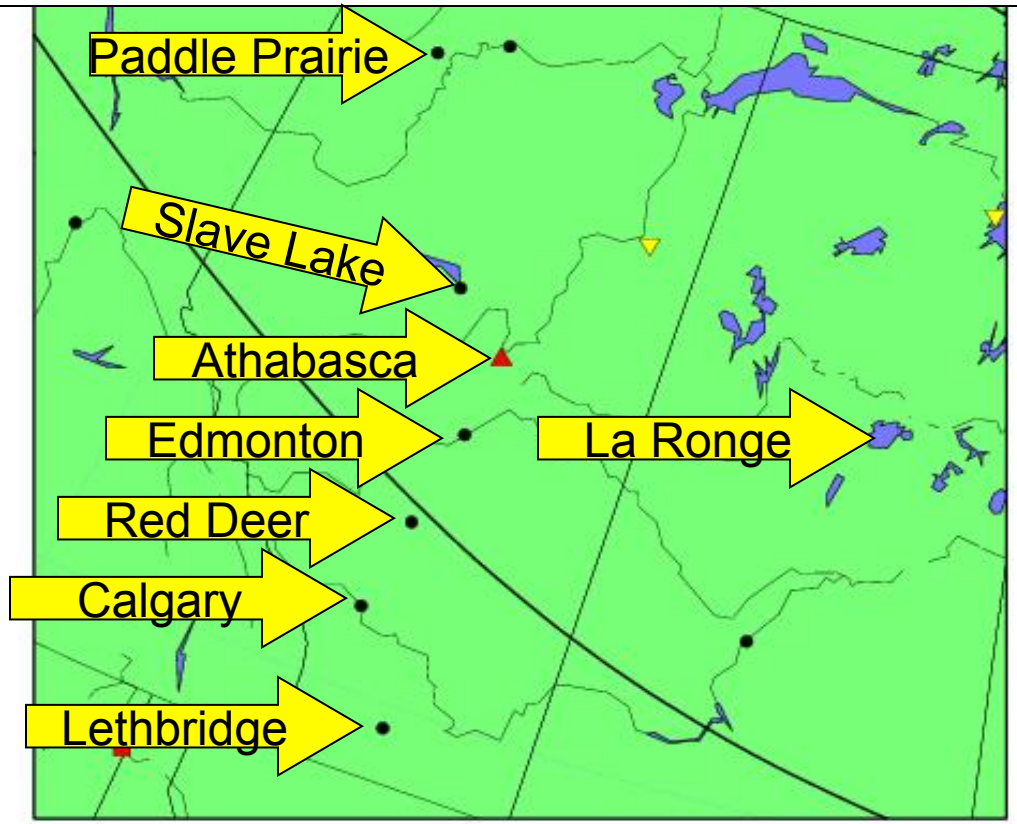
The 1973 McPherron substorm current wedge (SCW) system is a suitable simple model for three-dimensional current systems from magnetosphere to ionosphere

A computer can adjust SCW parameters to find the physical characteristics if enough ground magnetic data is available as input

The technique used for inversion is referred to as Automated Regional Modelling (ARM).

AUTUMN

Athabasca University THEMIS UCLA Magnetometer Network

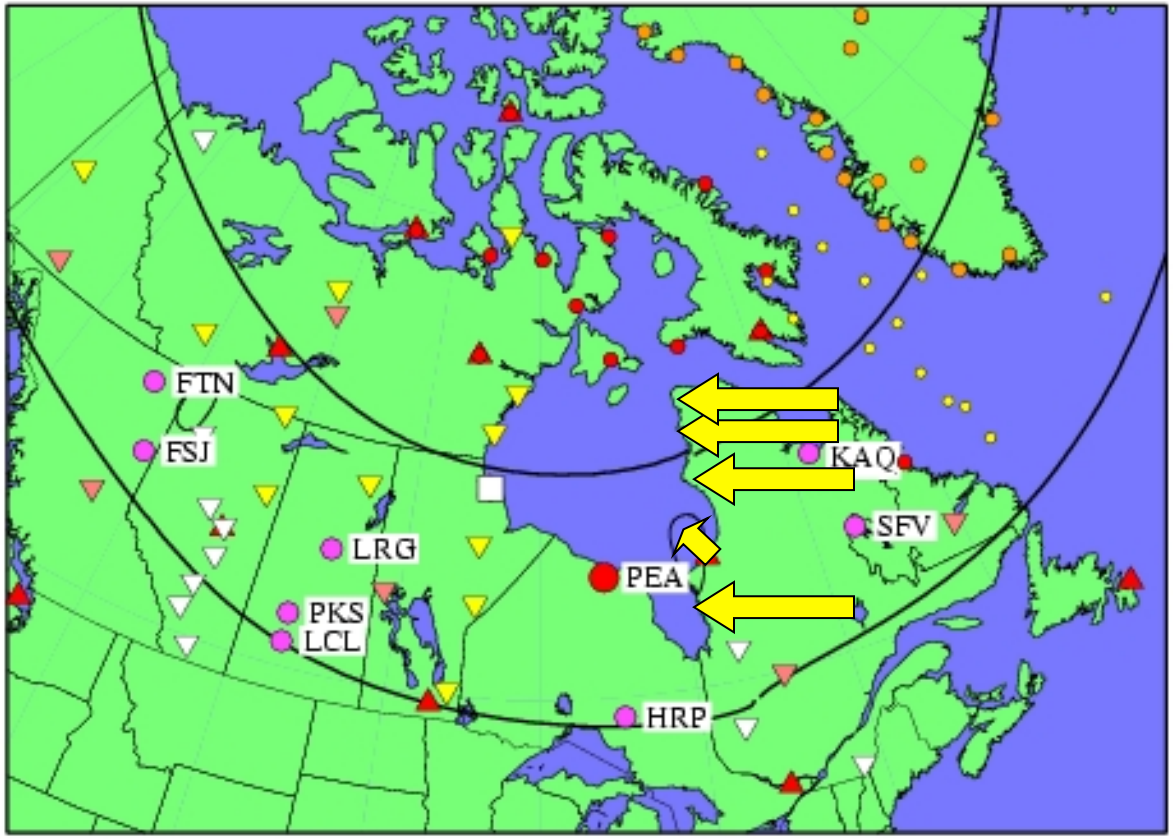


Sites installed fully and data (2 Hz) since Oct 4, 2005

Inuvik 2006

La Ronge 2008

STEP Forward 2007–2008



Athabasca University has assisted or runs 16 sites in Canada (white triangles and purple dots in Western Canada). Most data available through UCLA, STEP website, or on request. PEA, KAQ, SFV hoped for soon. New Polaris sites on E. Coast of Hudson Bay installed in 2007.

Some GBOs not shown.

UCLA Magnetometers

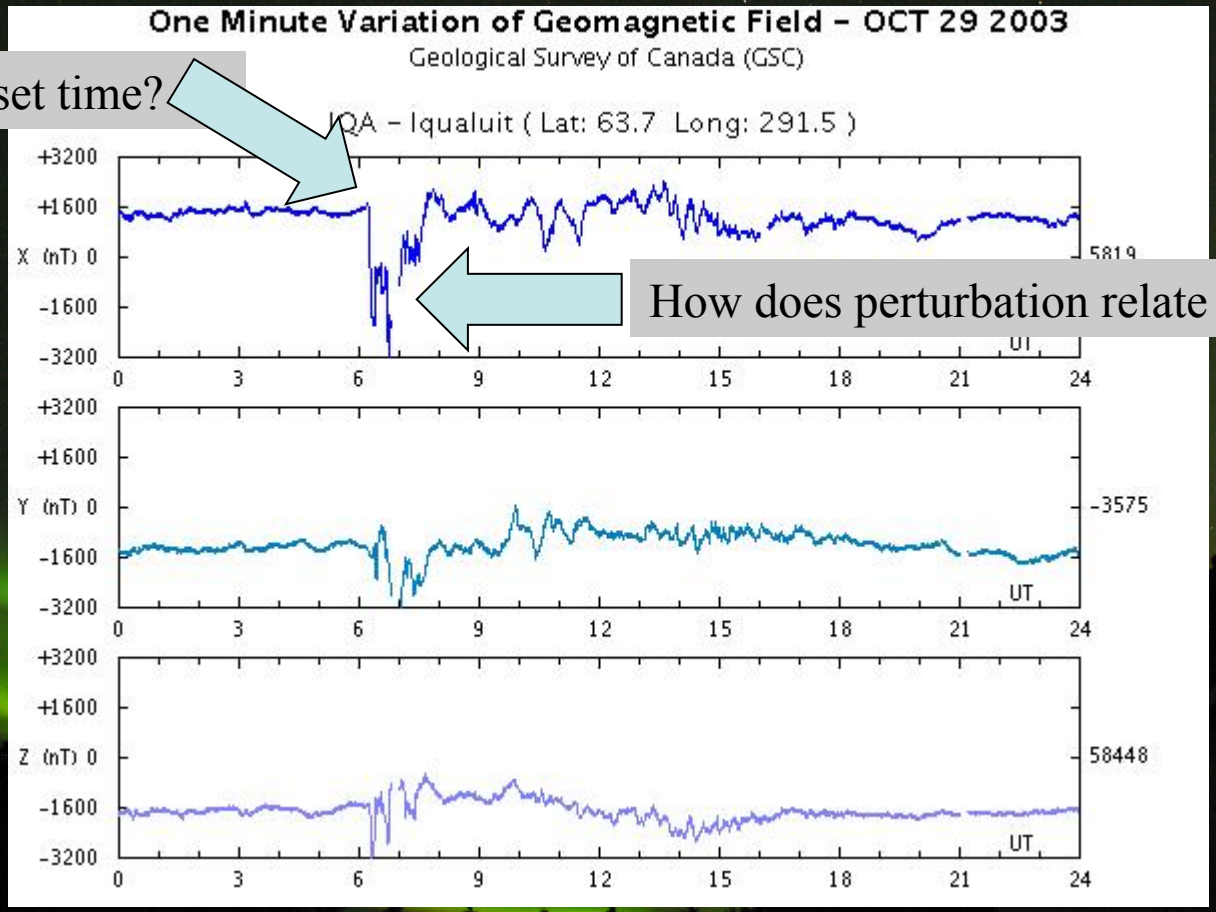
In a Sun-to-Mud approach, we are in the mud…

EDMO UCLA magnetometer installed by Brian Martin in December 2004

What can ground magnetic data tell us?

A single magnetogram tells little in fact and can be misleading

What was real onset time?

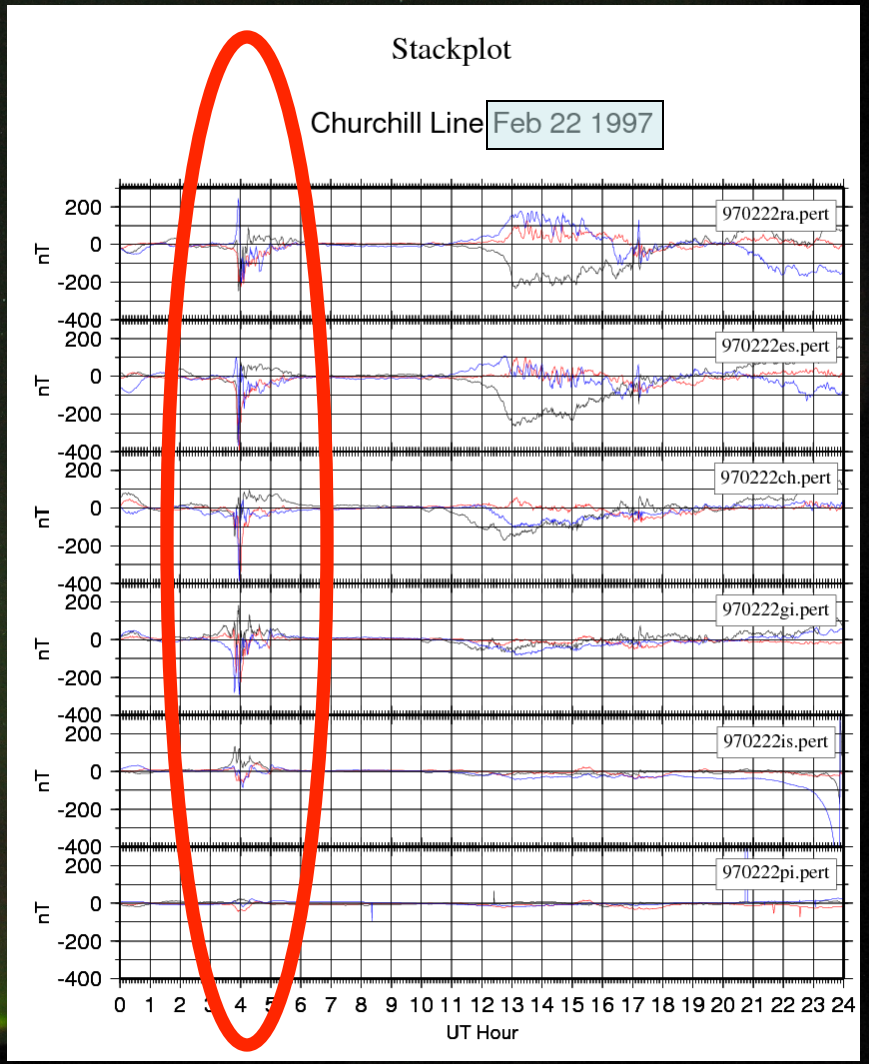


How does perturbation relate to current?

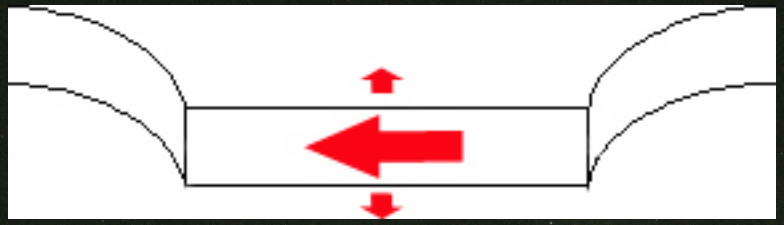
What can *more* ground magnetic data tell us?

Even multipoint measurements from a meridian chain are difficult to interpret, needing…

"geomagic"…



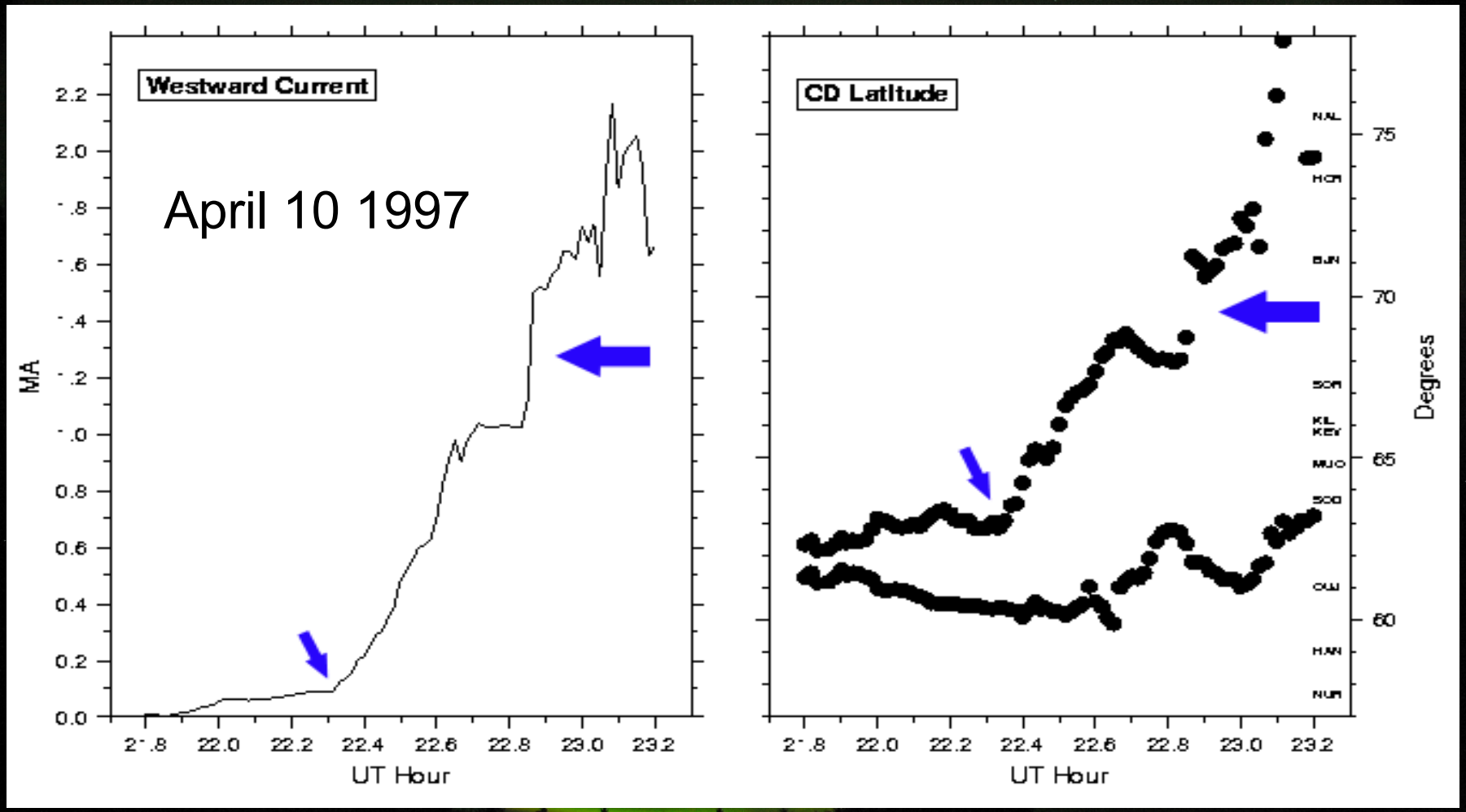
Automated Forward Modelling (AFM) can help.



For meridian data, AFM adjusts current and borders

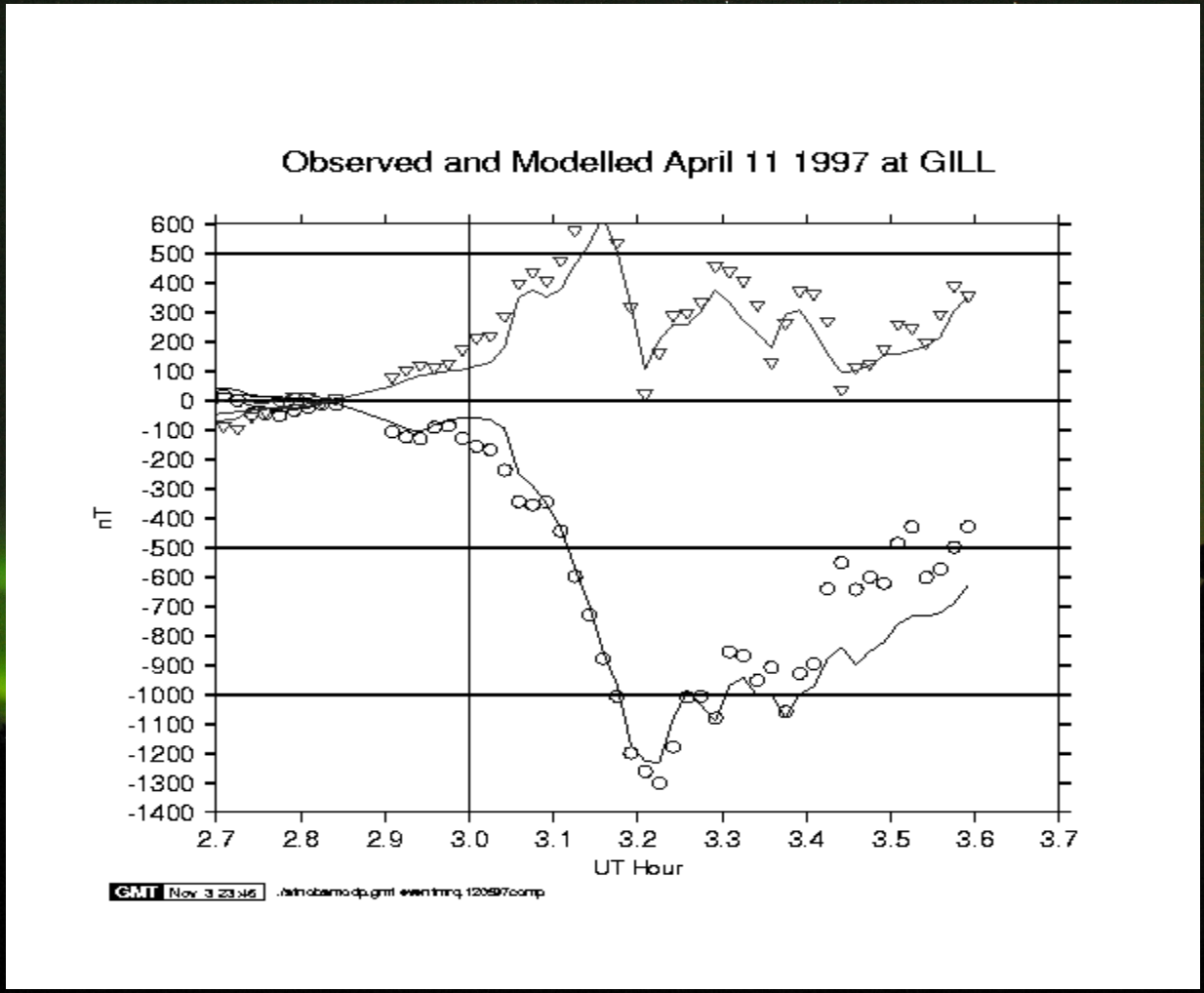
The method is however, much more general and includes field-aligned currents in realistic 3-d configurations. Midlatitude perturbations can be included as can a D_{st}-like parameter.

Inversion tells us more by giving simple parameters extracted from several ground stations

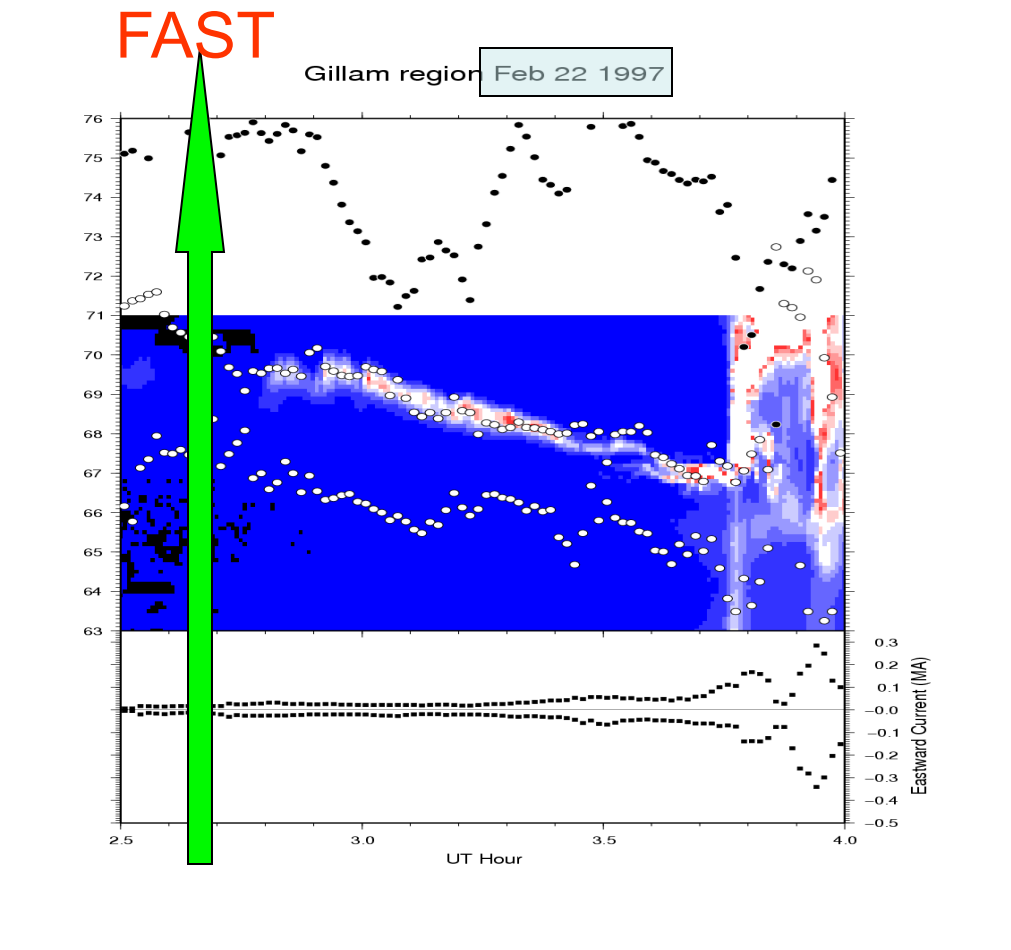


Ability to match input data is best near stations (and should always be verified to check results). We can also check relation to other data.

Note: different event and stations

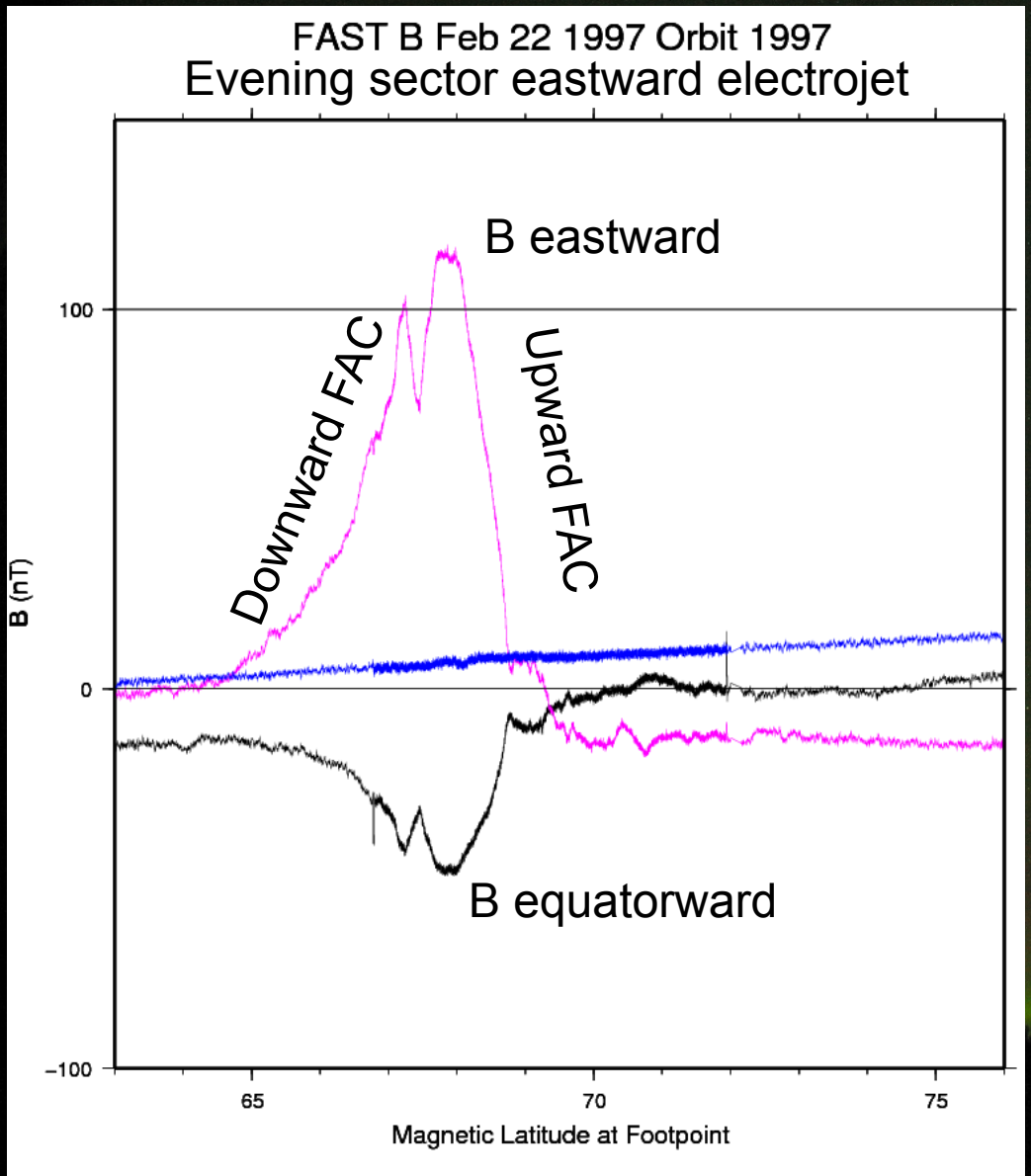


Independent confirmation: Comparison of optical borders from meridian scanning photometer and inversion results for growth phase (Feb 22 1997); also confirmed by FAST FAC detections



Two electrojet model results are shown superposed on 557.7 nm optical meridian scan data from Gillam. The growth phase arc is poleward of the evening sector eastward electrojet. Note that the method is sensitive to initial conditions

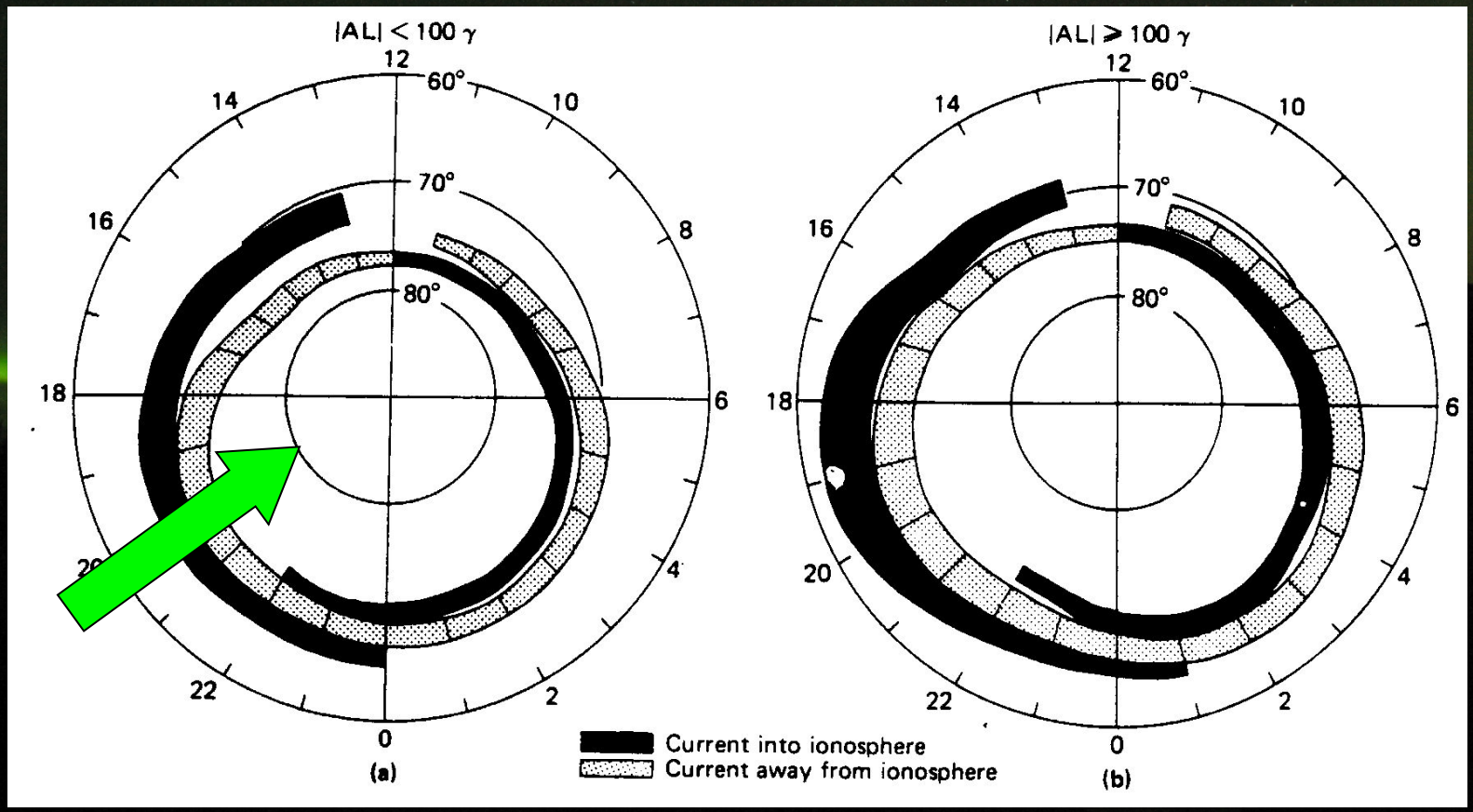
Spacecraft and the Auroral Oval



Spacecraft crossing the auroral oval respond primarily to the solenoidal current system comprised of field-aligned currents at its poleward and equatorward borders.

Ground magnetometers respond to elongated electrojets (often Hall currents).

Low-Altitude Satellites view near-Earth FACs. The above example is consistent with results from statistical studies (Iijima and Potemra) with evening sector upward FAC poleward of downward FAC.

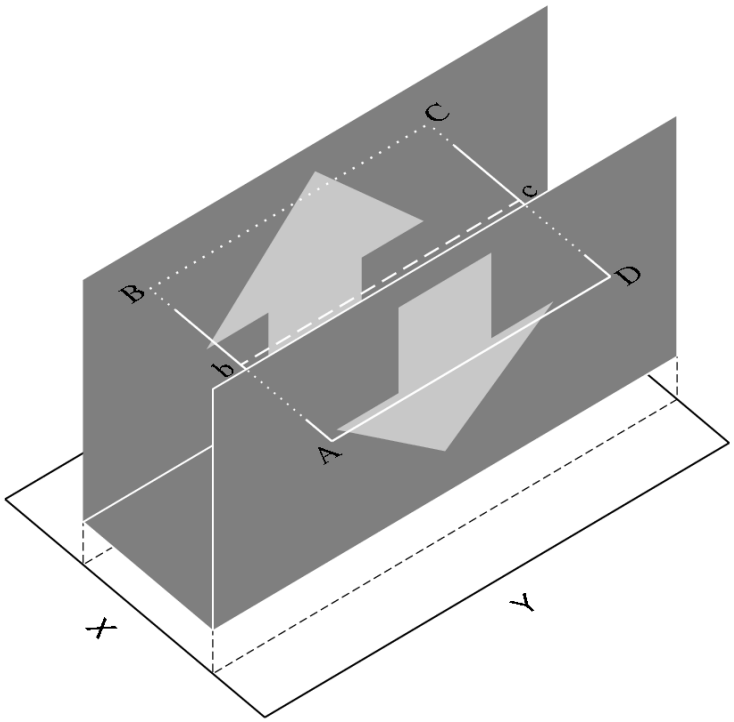


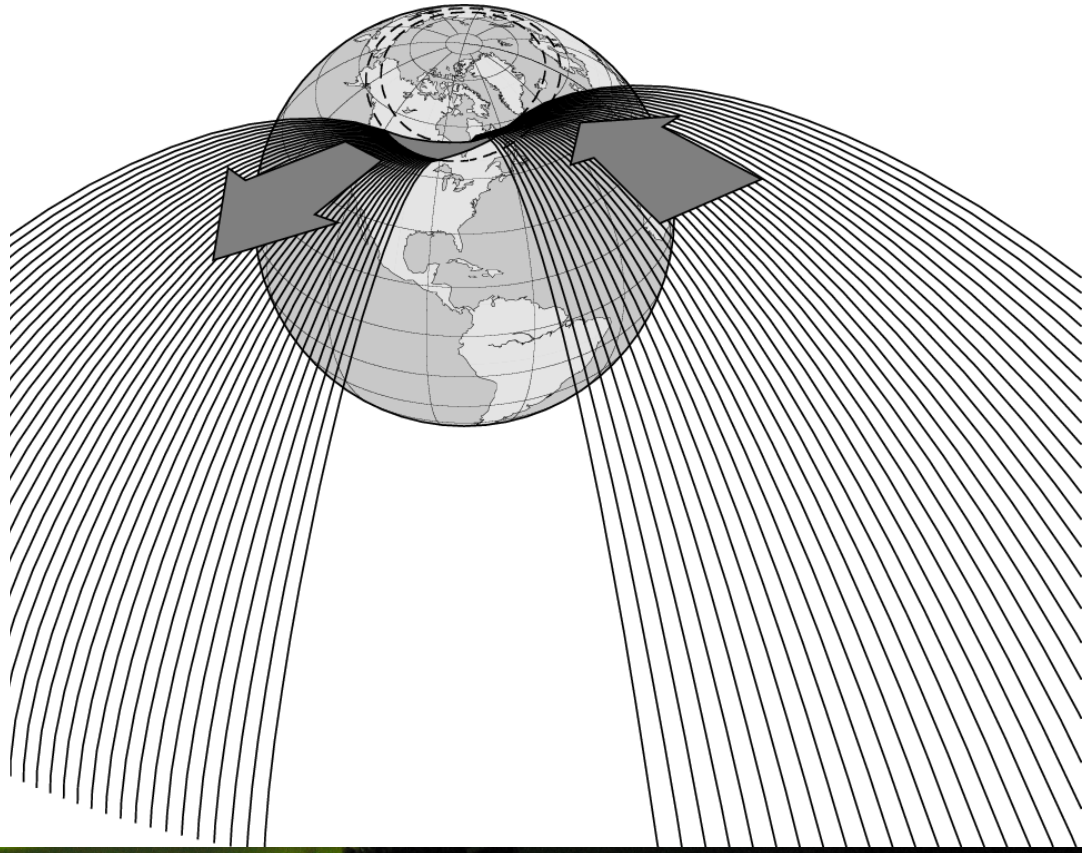
How to hide a magnetic field

http://www.bugman123.com/Physics/index.html

Hiding in Plain Sight

The electric currents that cause auroras are often set up so as to cancel magnetic effects (left)

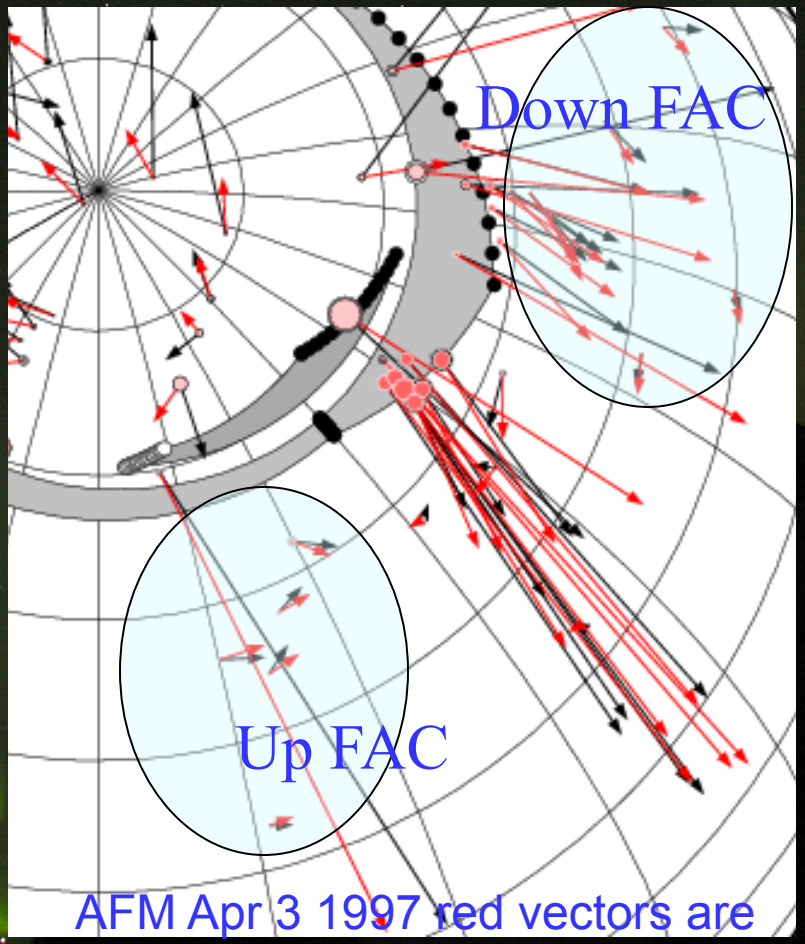




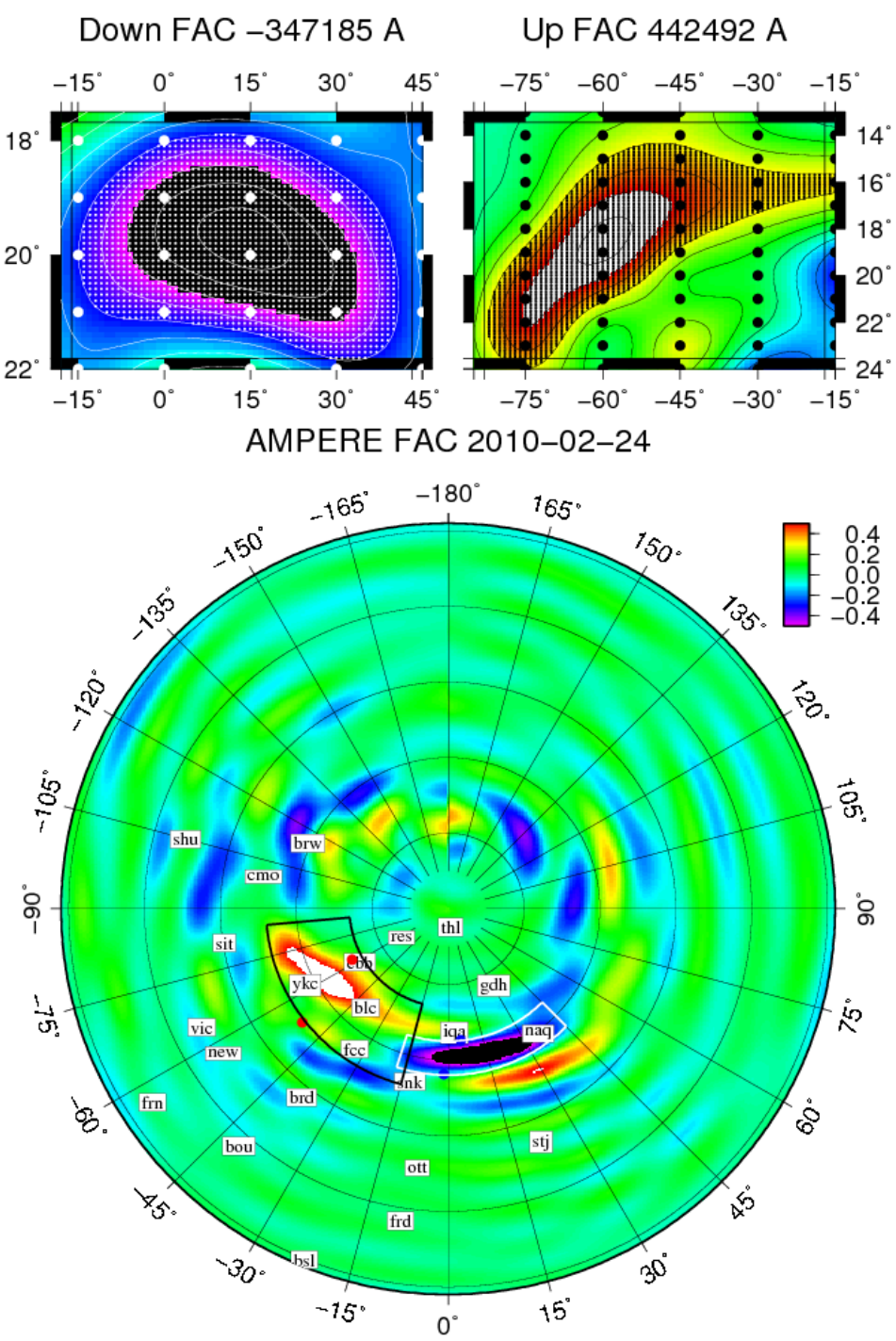
Even in the type of current system known to exist during aurora events (right) we cannot be sure that some systems of the “hidden kind” are not present, based on ground data

Array Interpretation from a distributed region is difficult, complicated by problems of nonuniqueness. An inversion procedure is needed.

- On the ground, one detects primarily the magnetic effects of the Hall currents associated with the auroral oval electric field
- FAC effects CAN be observed from the ground



AFM Apr 3 1997 red vectors are model, black observed



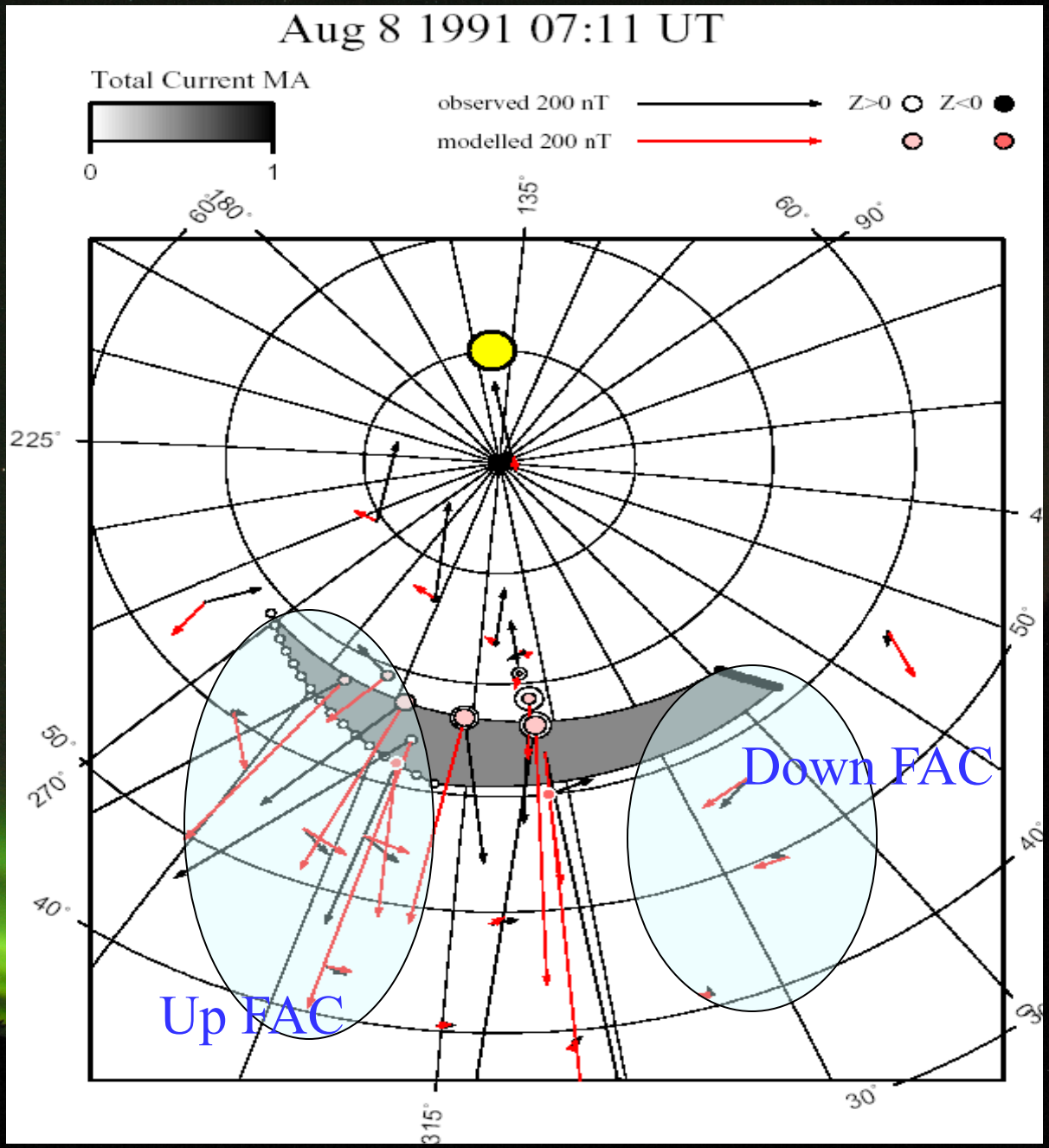
Best way to see FAC

The (not very commercially successful) Iridium satellite phone network has about 70 satellites continually overhead to provide service.

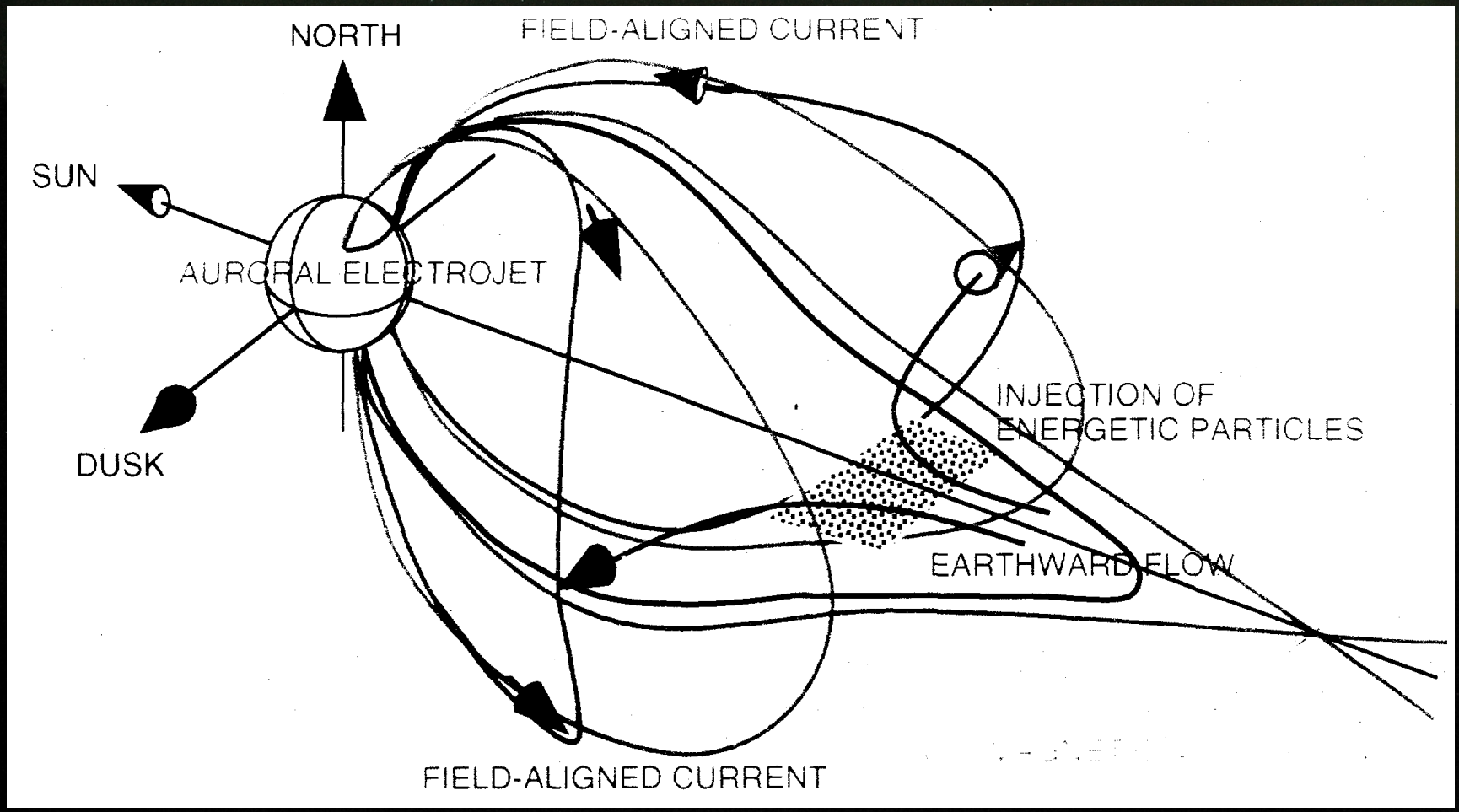
They measure magnetic field continuously. From this we can get (Ampere's Law) the current flowing along field lines.

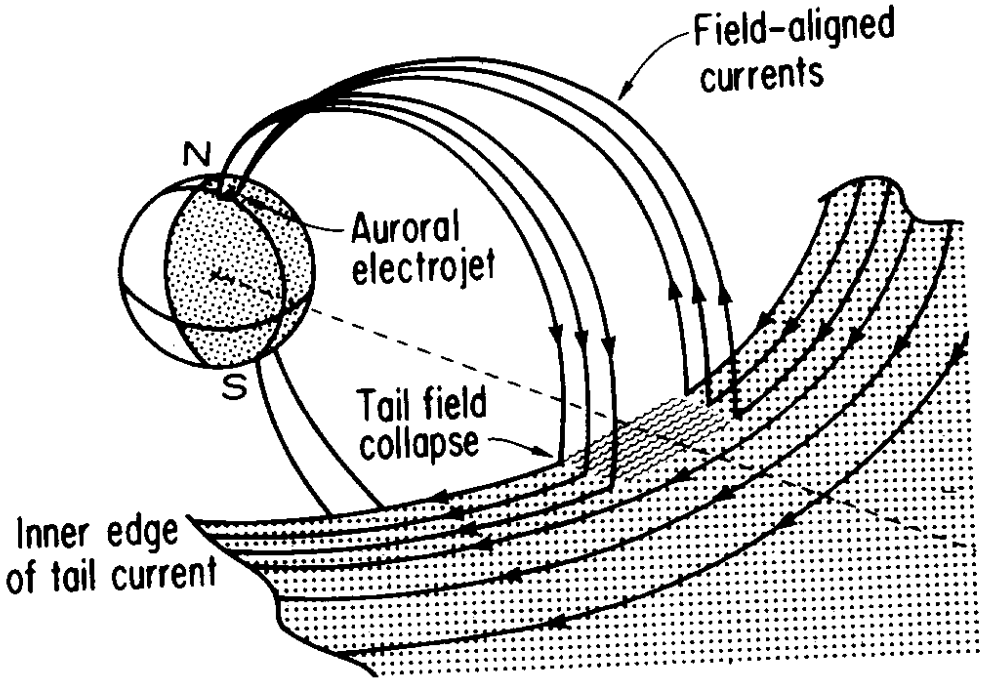
So far this actually matches up very well with what my ground data indicates, an important verification of my method.

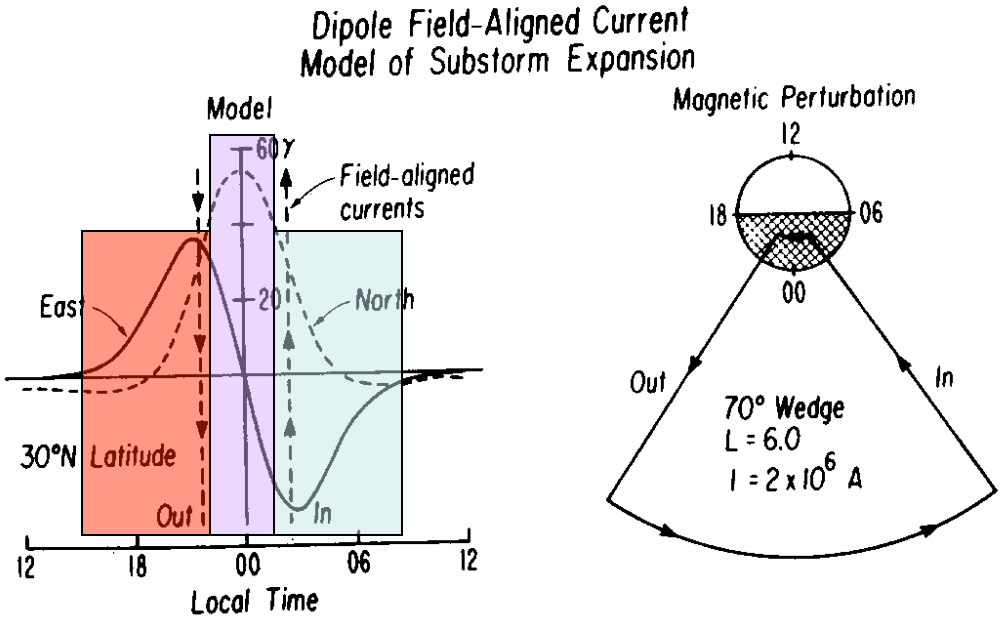
A simpler example, showing electrojet (southward) and subauroral perturbations due to FAC



These results due to near-Earth currents (net FAC and electrojet) are consistent with the Substorm Current Wedge (SCW) view of McPherron, Russell and Aubry 1973 (here as shown by Birn and Hesse, preprint 1998)







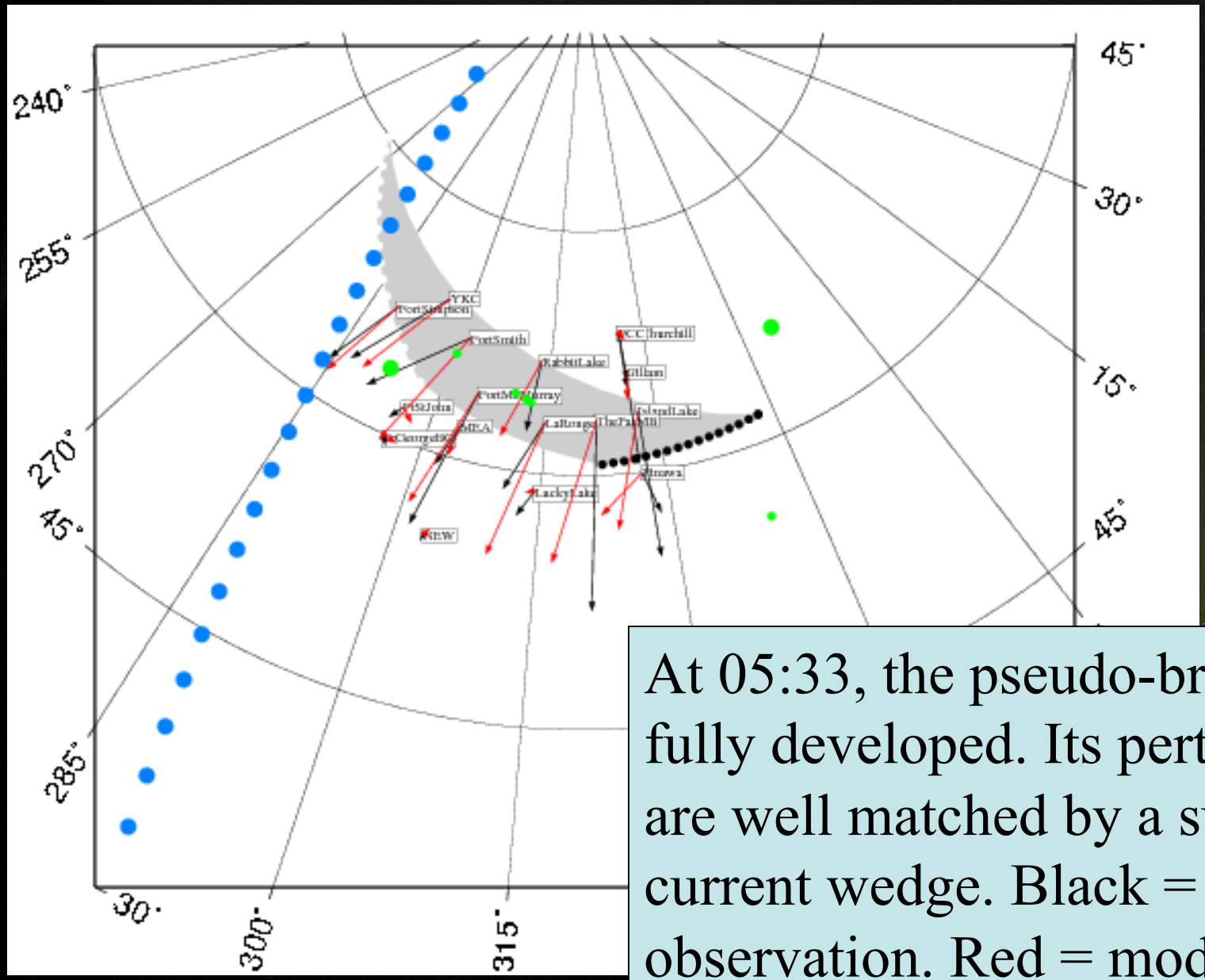
Magnetic Effect of SCW

1) Downward field-aligned current (FAC) in east –Y subauroral

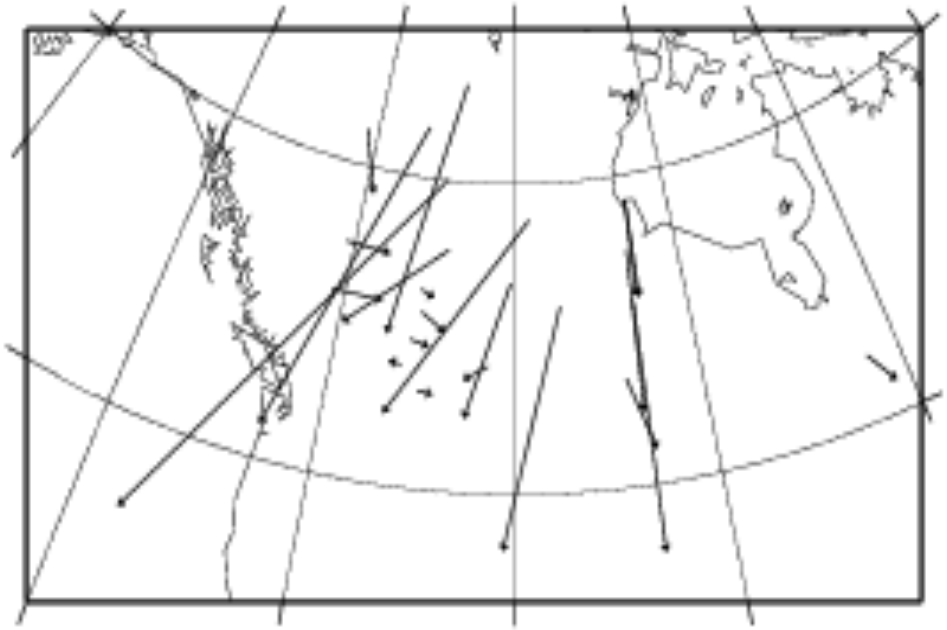
2) Ionospheric westward flow –X auroral, +X subauroral

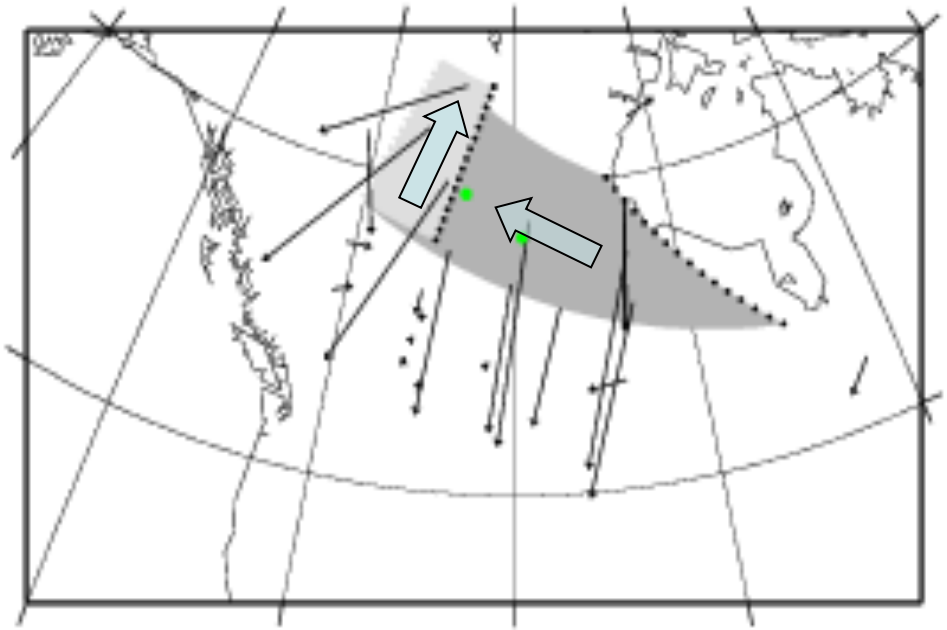
3) Upward FAC in west +Y subauroral

Details of closure unknown; width 70°



At 05:33, the pseudo-breakup is fully developed. Its perturbations are well matched by a substorm current wedge. Black = observation. Red = model.

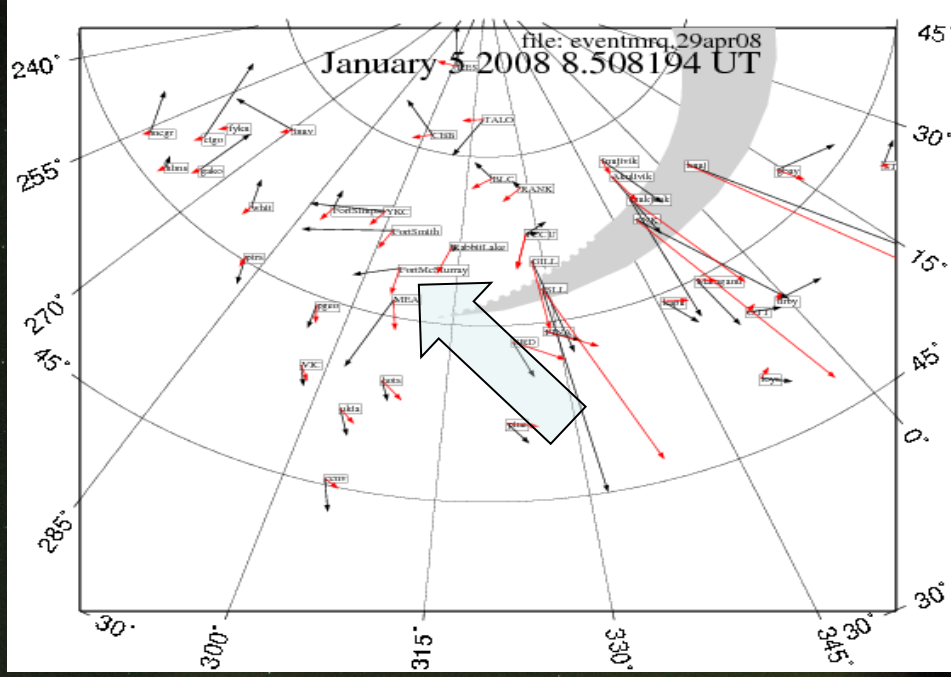


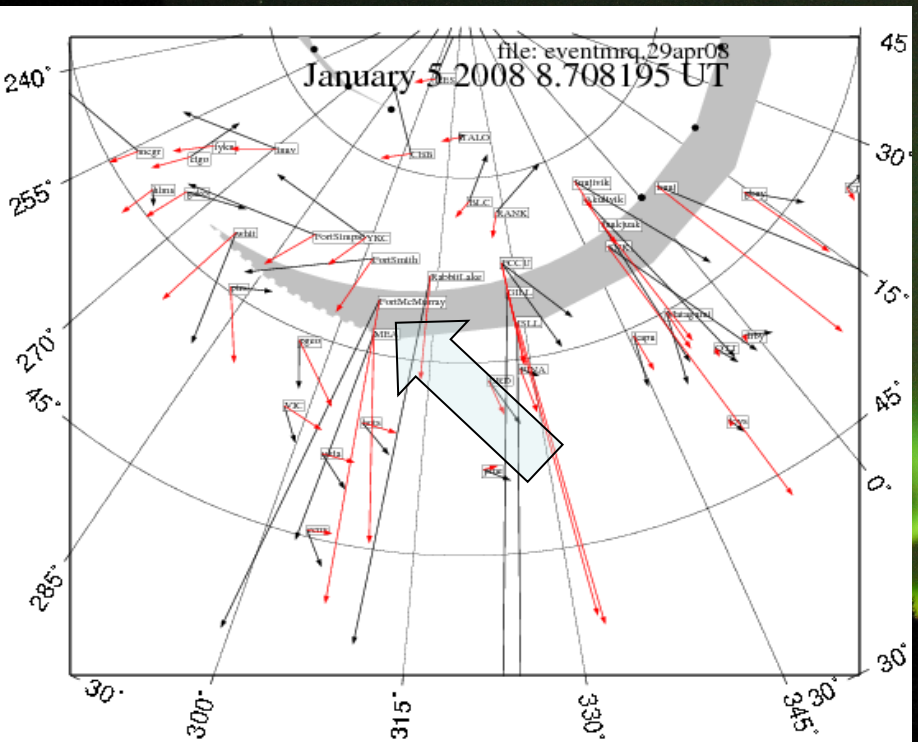


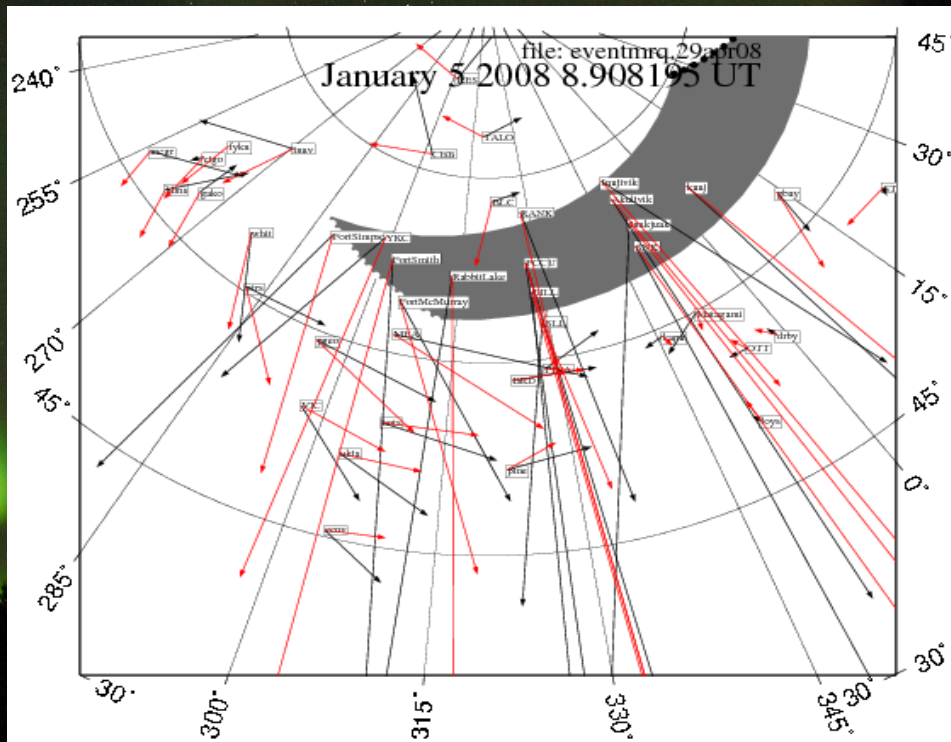
The top panel shows observations shortly after 0507 onset, the bottom panel shows model results and current systems. To reproduce the *westward* ground perturbations observed, a surge current system with poleward current flow needs to be added to the electrojet model.

This effect would be even more pronounced at 0536.

Time evolution is shown here for 48 minutes. At 8.1 UT a local onset has taken place, growing in strength at 8.3 UT. Surge westward perturbations west of wedge at 8.5 UT, full onset in this region by 8.7 UT. Stengthens and expands poleward at 8.9 UT. Black is data, red model results.



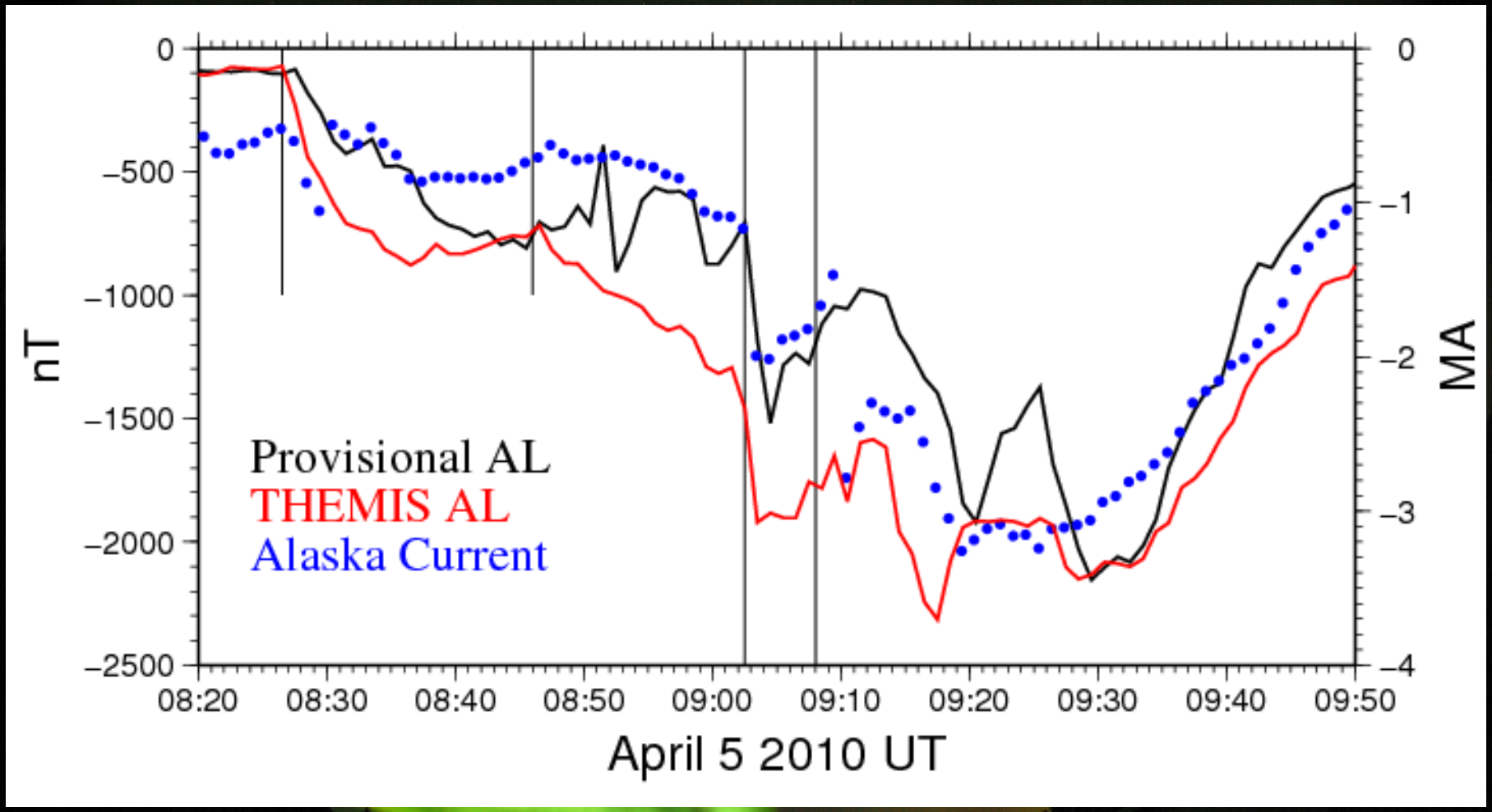




Conclusions about January 5 2008 Temporal SCW model

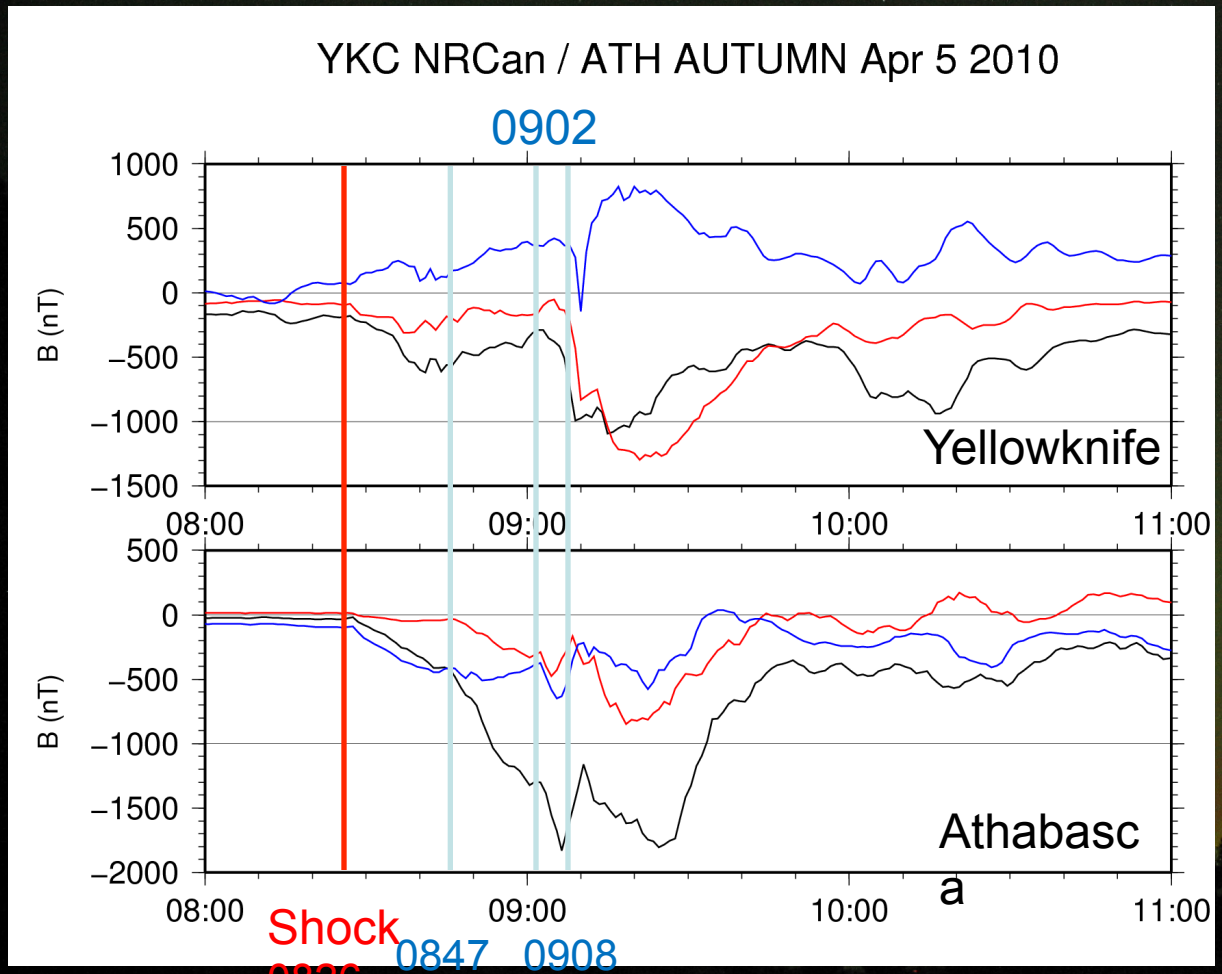
- There was substantial westward motion of the western part of the SCW current system
- This resulted in perturbations in the auroral zone, successively further west
- This resulted in subauroral perturbations that could be modelled well
- Perturbations were seen at THEMIS at the time the SCW expanded past the spacecraft

Indices – a cautionary tale



THEMIS AL indicates onsets better than Provisional AL. Current in the Alaska meridian is calculated using N-S GI Chain, shows 0908 onset best with 3 MA of current in a reasonable SCW

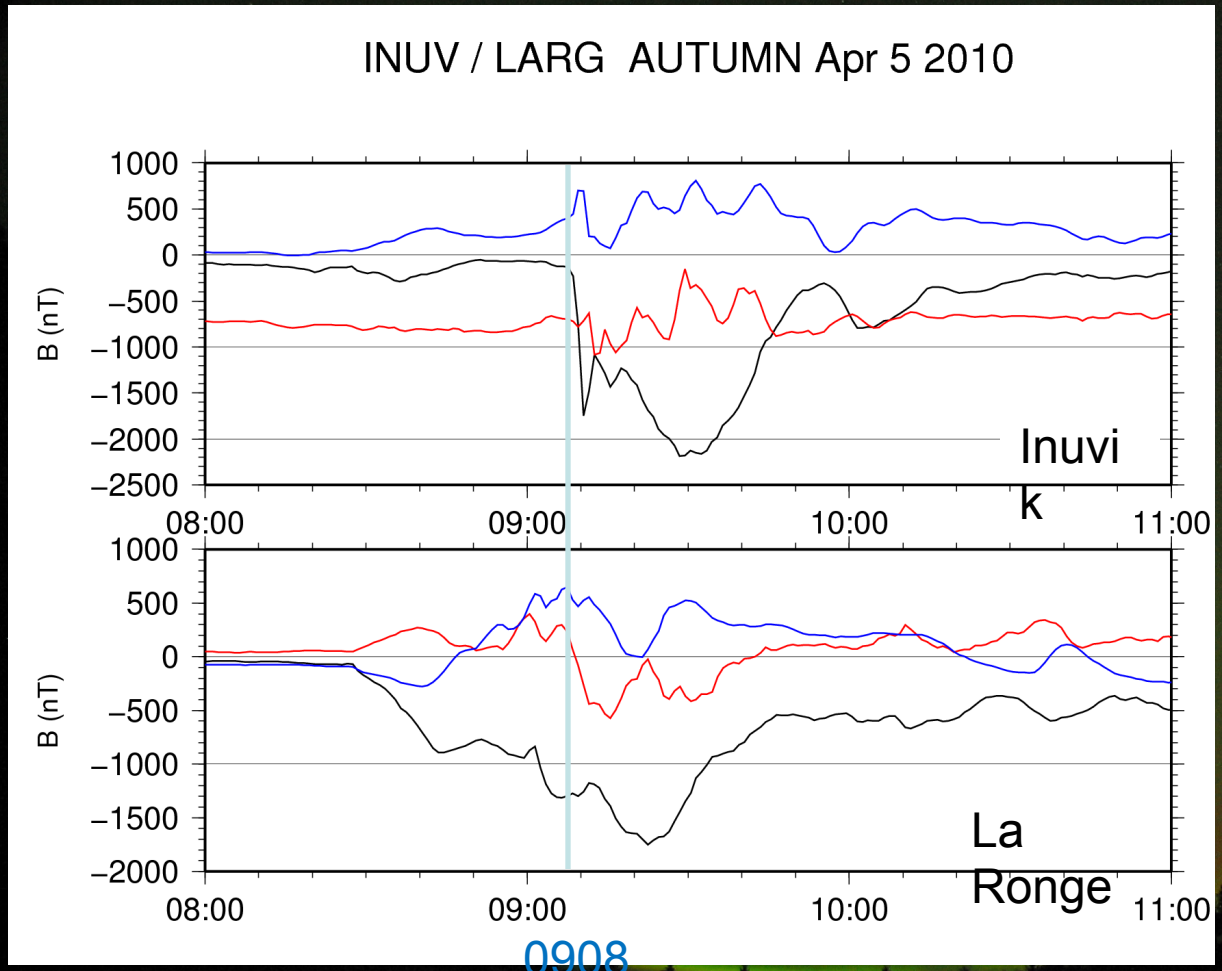
Yellowknife/Athabasca



Initial disturbance south of Yellowknife strengthening at 0826
Double onset at 0902/0908 becoming centered well south of Yellowknife (+Z, blue).
Origin of –Y (red) not clear at YKC.

Initial disturbance initially well north of Athabasca
Second onset still north but closer
Negative Y (red) at subauroral means downward FAC sector

Inuvik/Laronge



Inuvik did not see much of the initial disturbance

Sharp onset at 0908

Ps 6 like oscillations (Y,Z)

Laronge similar to Athabasca but smaller Z ca 8:30 places current not too far north

Potential Relation to Radar Data

- The electrodynamic variable best determined by magnetometers is electric current
- Some types of radars give flow velocity which is a close proxy for the electric field
- The current and field are related through the conductivity, in some cases radars give parameters from which this computed
- Magnetometers can *complement* radar to give a fuller picture of electrodynamics