Comparison of SuperDARN observations with the ionospheric projection of the reconnection line as calculated through the Cooling model.

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Motivation

We have used the Cooling model for some case studies with northward IMF and dominant $B_{y,}$.

In such cases, we have met some problems when comparing the projection of the Cooling X-line with the probable location of the X-line inferred from SuperDARN maps.

Therefore, we considered this issue more closely.

Here we present a preliminary report on what we have found.

The Cooling model - 1

The Cooling model (2001) makes use of a Kobel and Fluckiger magnetopause model (1994) and propagates the IMF and solar wind plasma data through the magnetosheath by using the Spreiter *gas-dynamic* model (1966).

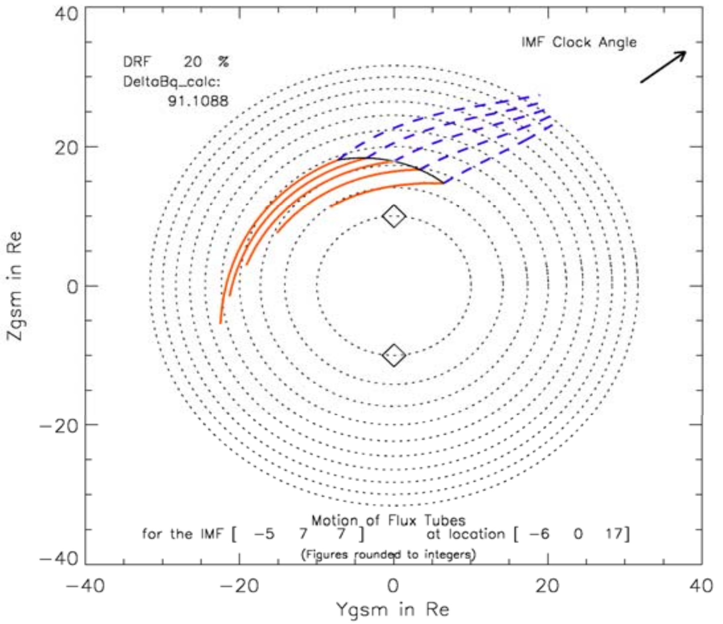
The Cooling model has been used to calculate the motion of reconnected flux tubes at the magnetopause (MP) (e.g. see Wild et al., 2007, and Fear et al., 2007).

The Cooling model allows to:

1) evaluate the probability of component merging – this reconnection test is generally fulfilled over a finite region of the magnetopause;

2) draw an X-line on the magnetopause, starting from a central point (which has to be chosen);

3) follow the motion of the reconnected magnetic flux tubes over the magnetopause.



The Cooling model - 2

Dotted circles are YZ projections of intersections (at 2 R_E intervals) of the MP with planes parallel to the YZ plane

The black line shows the YZ projection of a Cooling X-line.

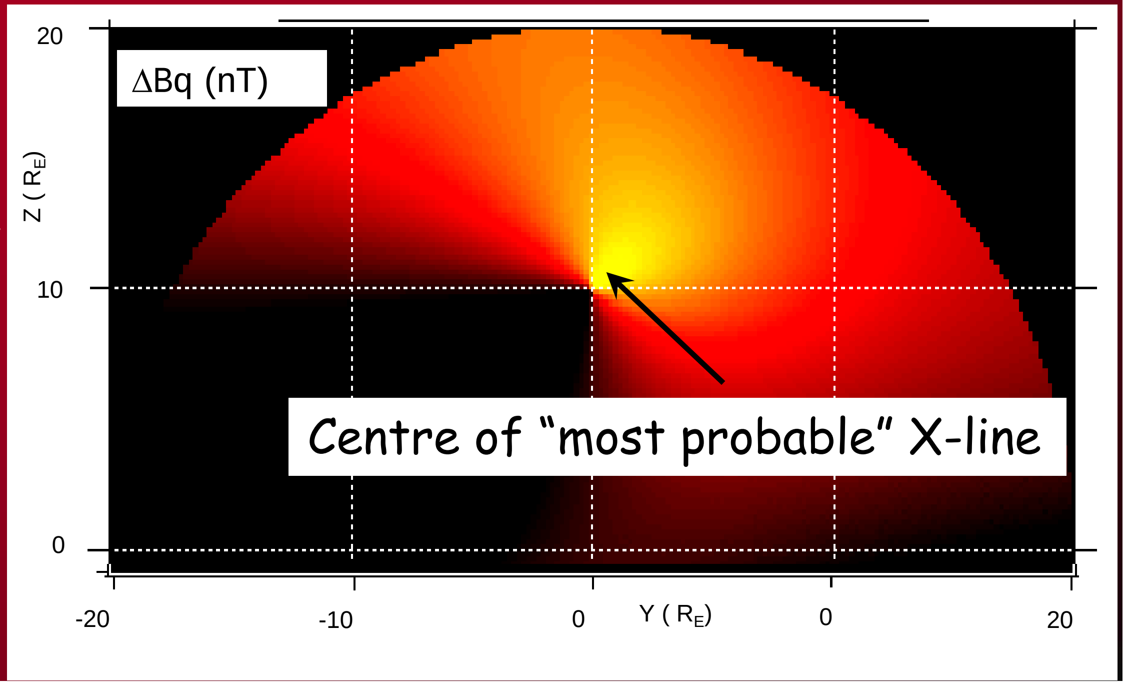
The red and blue lines indicate flux tube motion.

Bq is the field component tangential to the current sheet and parallel to $B_{MSH} - B_{MP}$.

ΔBq is the Bq jump across the magnetopause. Cooling suggests that reconnection can occur if ΔBq > 35 nT.

We assume that the probability of steady - state component reconnection should increase with ΔBq.

Therefore, we talk about "most probable" X-line meaning the one which is centred at the point of maximum ΔBq.



Comparing Cooling X-lines and SuperDARN maps

For the events we discuss hereafter we
- calculate various Cooling X-lines at the magnetopause,
- project them onto the high latitude ionosphere through the Tsyganenko 96 (T96) model,
- compare the projected X-line with the SuperDARN ionospheric convection maps obtained through the "Map Potential" software

For that purpose, we do the following:
- project each Cooling X-line onto the T96 magnetopause;
- project the T96 X-line onto the ionosphere.

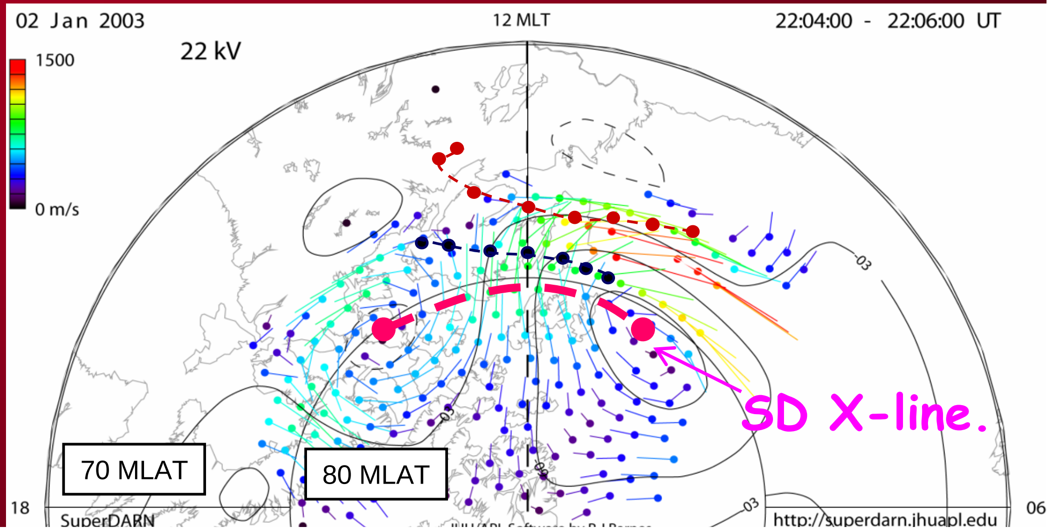
Other authors used the T96 for projecting the X-line from the magnetopause to the ionosphere and found that they had to use "ad hoc" values of the solar wind dynamic pressure (e.g. Phan et al., 2003, and Pinnock et al., 2003).

Here, for some events we do the same.

Moreover, for each event we show several X-line ionospheric projections :

1) the "most probable" one;

2) the one which best fits the SuperDARN global convection maps.



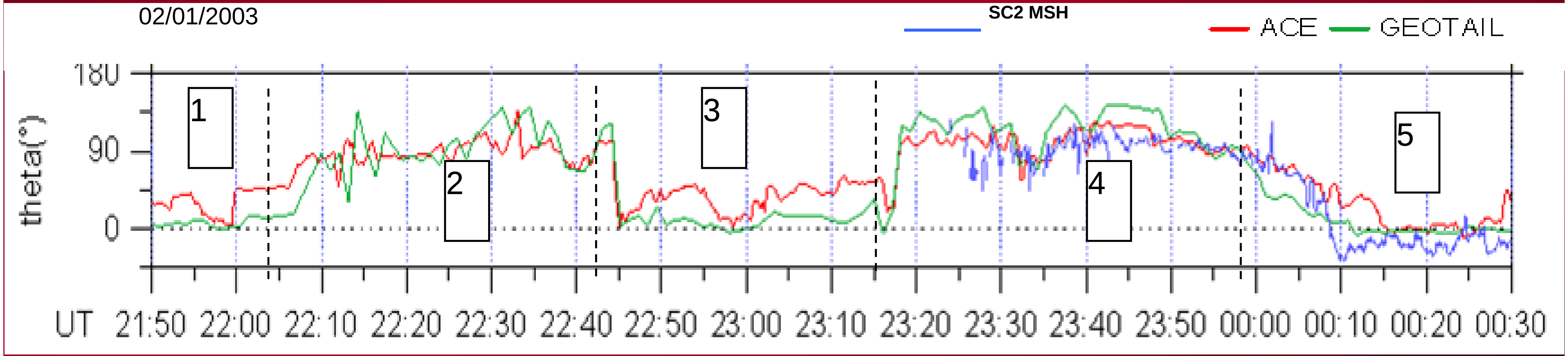
January 02, 2003, events

On this day we identified 5 intervals characterized by similar IMF conditions:

- periods 1, 3 → $B_y > 0$, $B_z > 0$ (here we show only period 1);

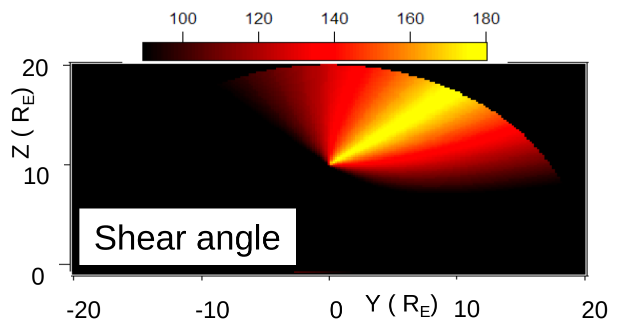
- periods 2 and 4 → dominant $B_y > 0$ (here we show only period 2);

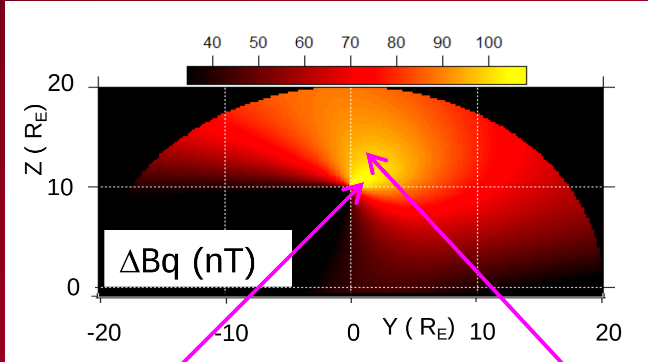
- period 5 → $B_y \approx 0$; $B_z > 0$.

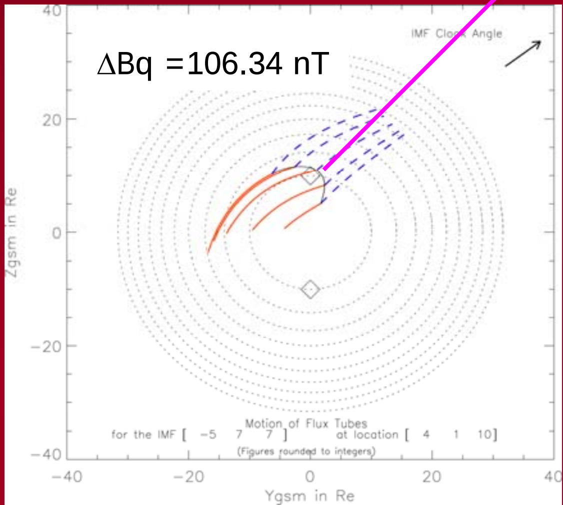


Clock angle at ACE (red), Geotail (green) and Cluster SC2 (blue) between 21:50 and 00:30 UT.

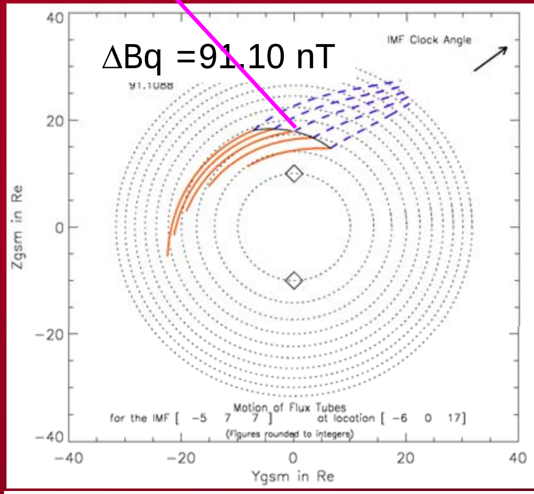
Period 1 (22:05 UT) IMF = (-5, 7.5, 7.5) nT
For period 3, which we do not show, we find similar results.





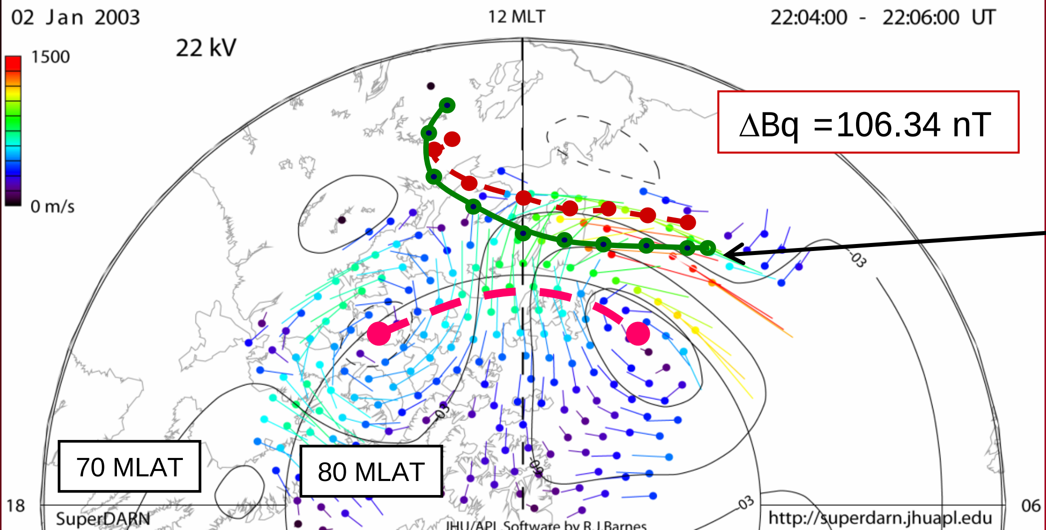


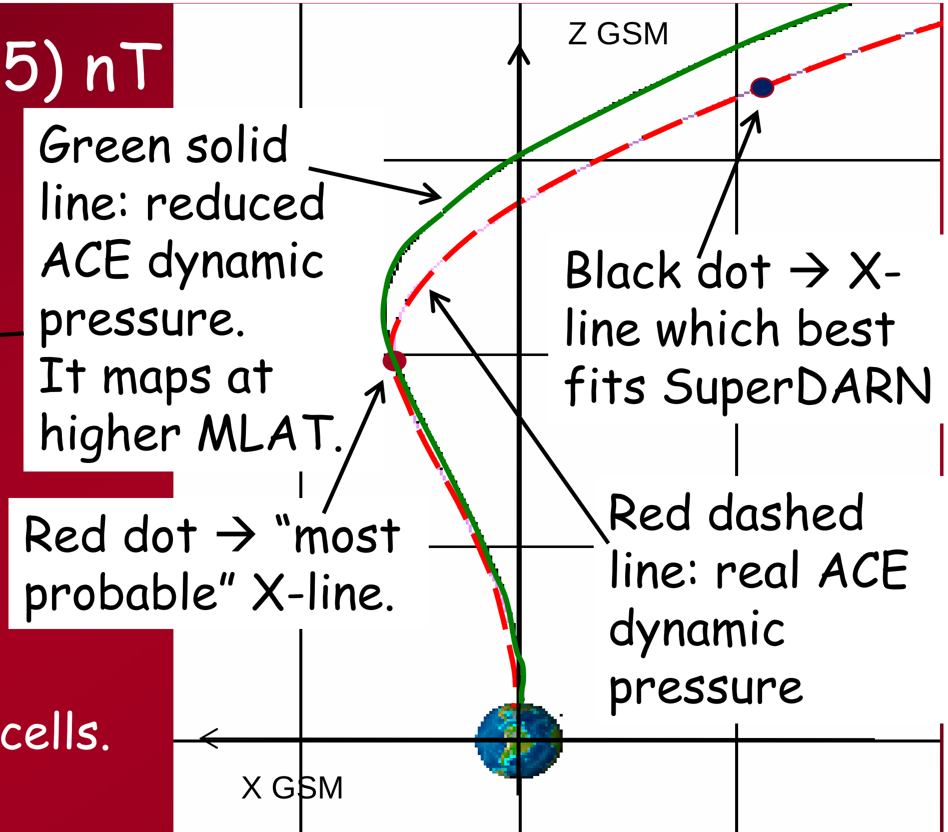
YZ projection of the "most probable" Cooling X-line.



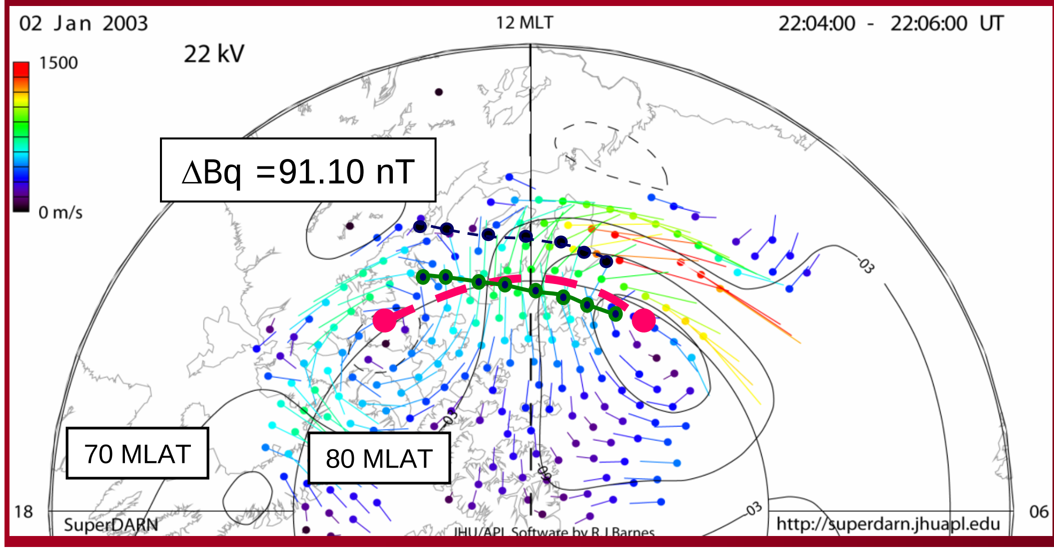
YZ projection of the Cooling X-line which best fits the SuperDARN map.

Period 1 (22:05 UT) IMF = (-5, 7.5, 7.5) nT





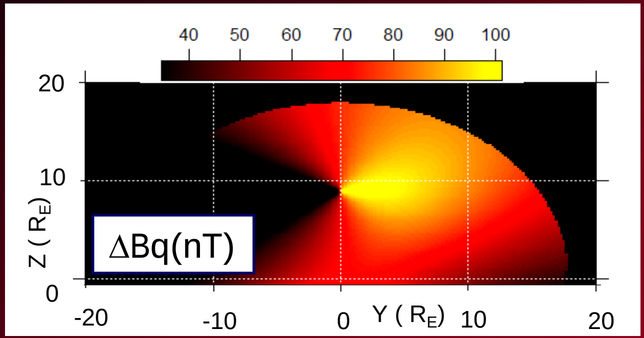
The pink line shows the probable lobe merging line connecting the foci of the dawn and dusk reverse cells. The projection of the "most probable" X-line falls equatorward of the two lobe cells.



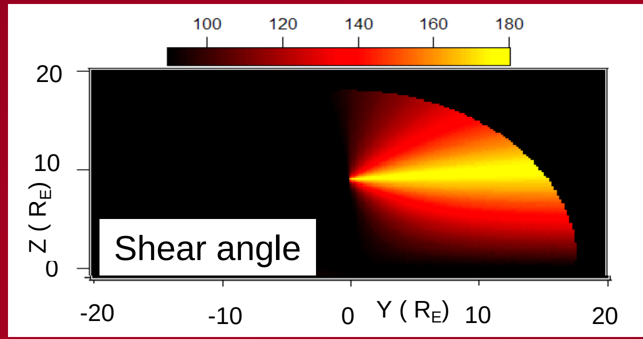
We can build a Cooling X-line which projects closer (3° roughly) to the SuperDARN line, but we have to move it far tailwards

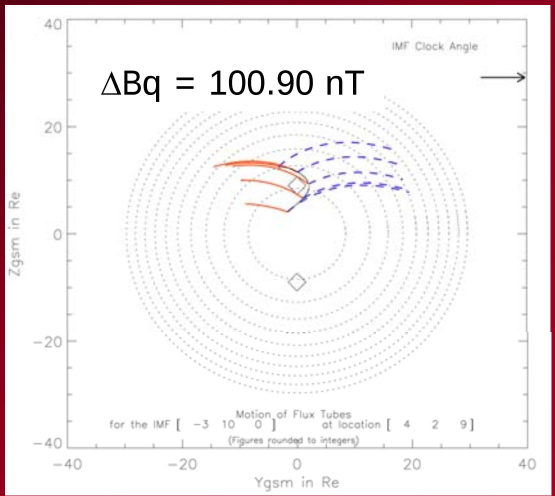
This same Cooling X-line projects at the SuperDARN line, if we reduce the ACE dynamic pressure.

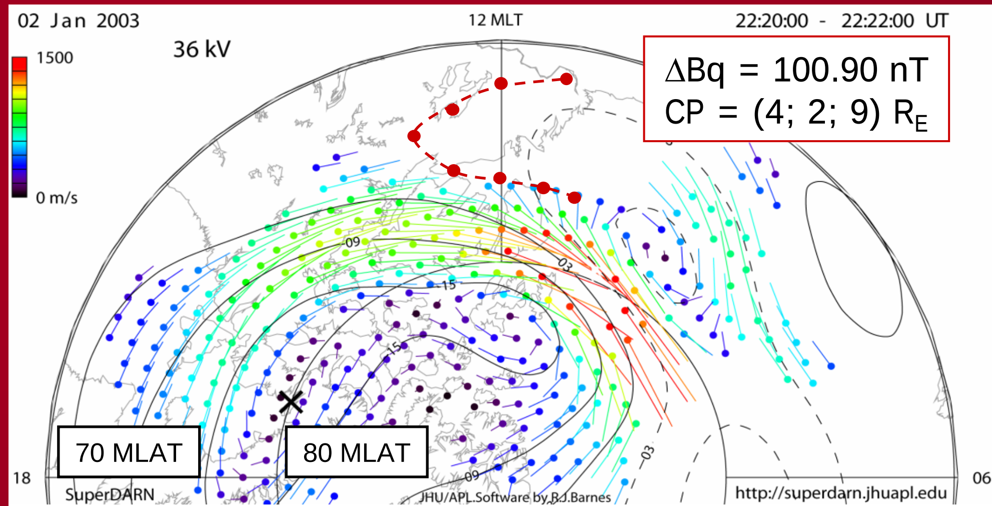
Period 2 (22:20 UT) IMF = (-3, 10, 0) nT



For period 4, which we do not show, we find similar results.





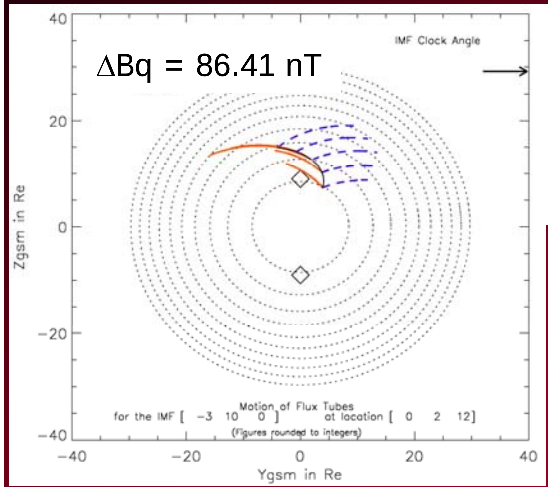


The red line is the ionospheric projection of the X-line overlaid on the corresponding 2-min SuperDARN convection map.

The ionospheric convection is characterized by a large clockwise dusk cell (due to $B_y > 0$) extending to the pre-noon sector.

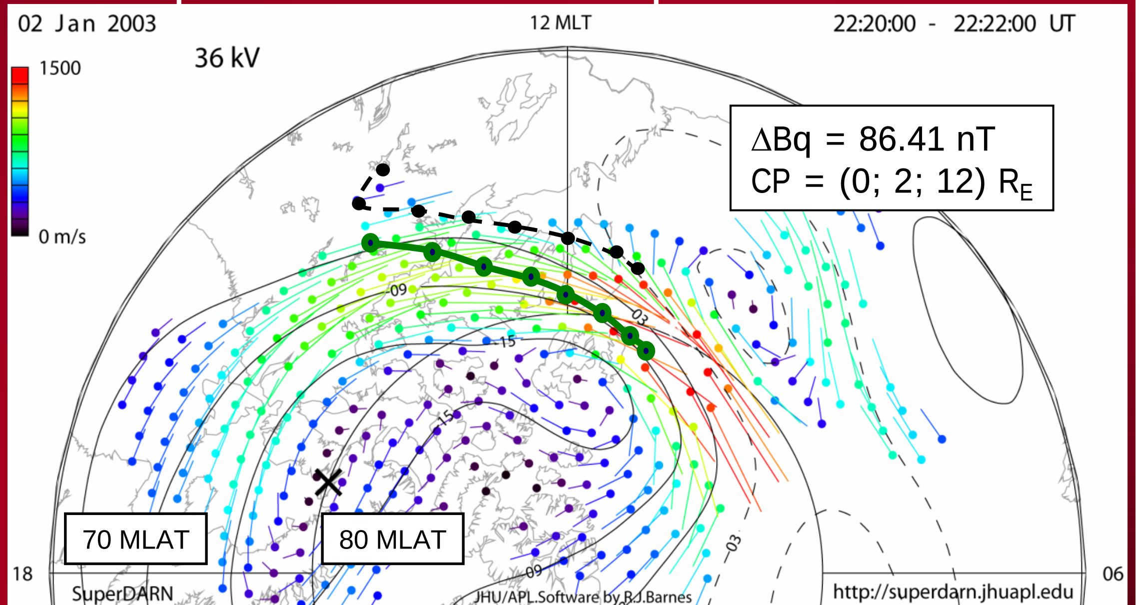
This line corresponds to the maximum of ΔBq and totally disagrees with the SuperDARN convection pattern, as its higher latitude part should yield equatorward convection, which is clearly not observed.

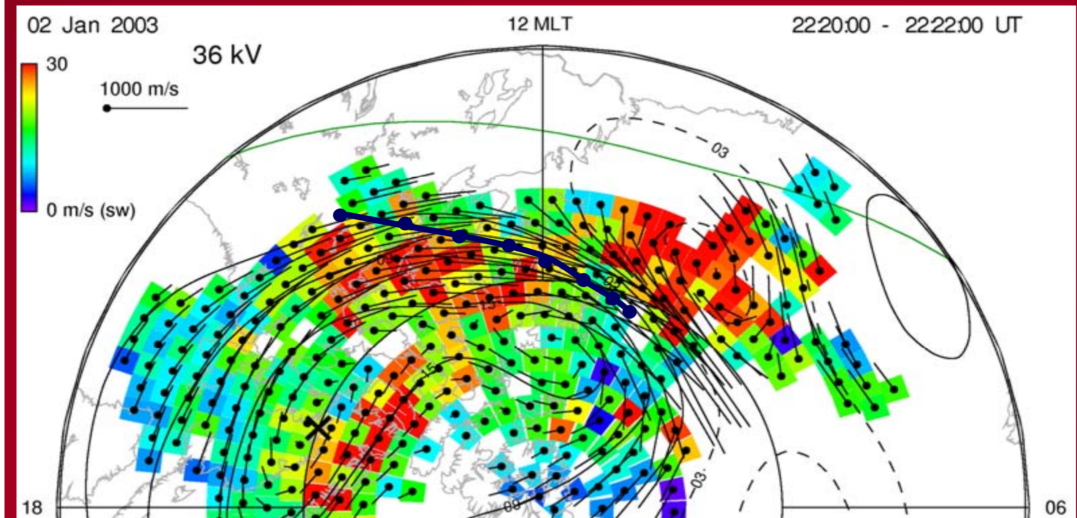
Period 2 (22:20 UT) IMF = (-3, 10, 0) nT



X-line which best fits the SuperDARN convection map.

The Cooling black X-line projects roughly 3° equatorward than expected from the SuperDARN convection pattern.

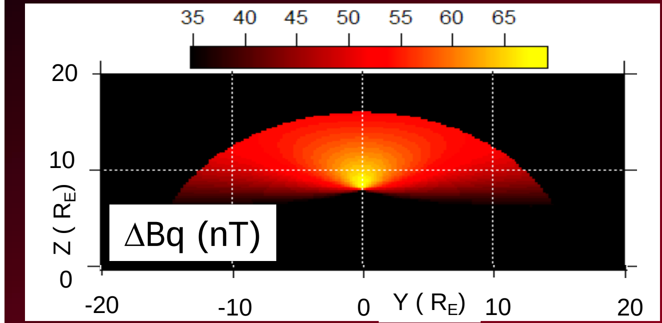




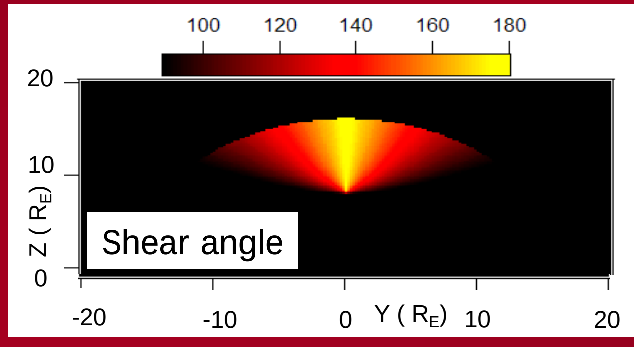
By decreasing the dynamic pressure, we obtain the green X-line projection, which roughly agrees with the SuperDARN map.

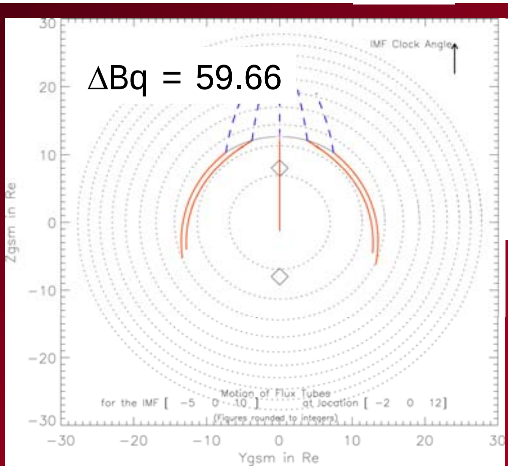
Same convection map with spectral width

Period 5 (00:20 UT) IMF = (-5, 0, 10) nT

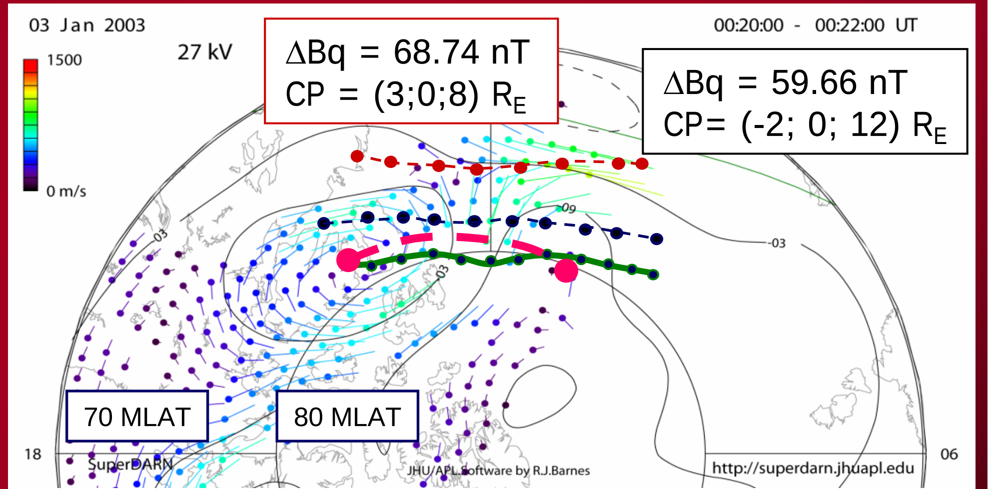


ΔBq parameter and magnetic shear angle at the MP according to the Cooling model.





Cooling X-lines which best fits the convection map



A dusk counter-clockwise lobe cell is seen.

The red line corresponds to the maximum of ΔBq.

This projection disagrees with the SuperDARN convection patterns (pink line) because clearly falls equatorward of the two lobe cells observed.

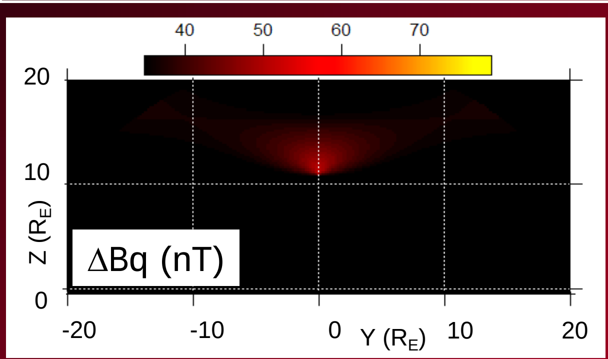
The black line is the ionospheric projection of X-line which best fits the SuperDARN convection maps.

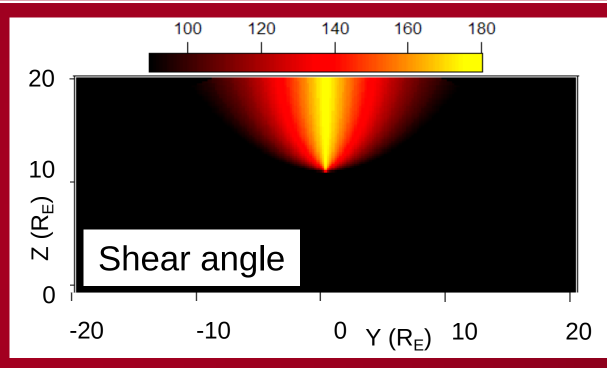
This projection falls roughly 2° equatorward than expected from the SuperDARN convection pattern.

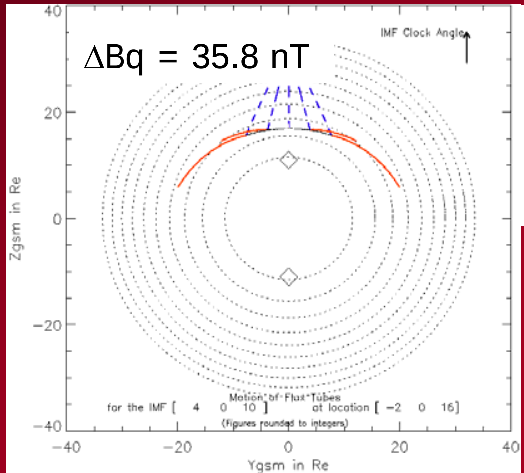
By decreasing the dynamic pressure, we obtain the green X-line projection, which roughly agrees with the SuperDARN map.

December 03, 2001 event: 09:16 UT IMF = (4, 0, 10) nT

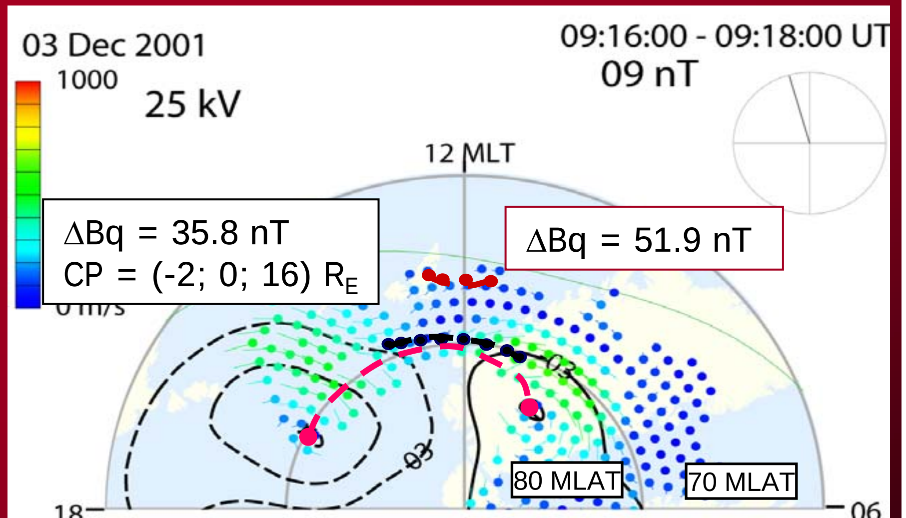
This event is taken from a period for which Marcucci et al. (2008) described the occurrence of dual lobe reconnection based on SuperDARN and Cluster data.







Cooling XL which best fits the SuperDARN convection map



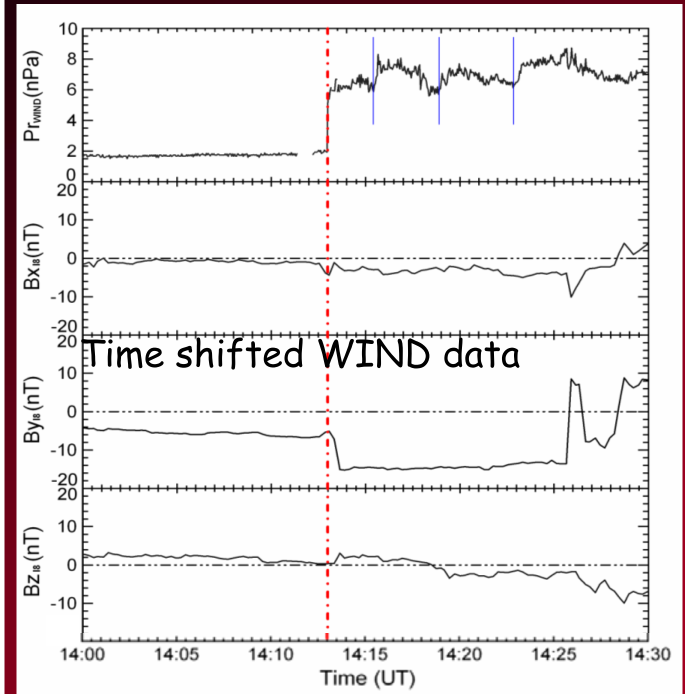
The ionospheric convection is dominated by two reverse lobe cells.

The red line is the ionospheric projection of the XL corresponding to maximum ΔBq, this projection falls equatorward of both lobe cells.

The black line is the ionospheric projection of the best XL.

The Cooling black XL projects roughly at the same latitude as the XL calculated for this time by Marcucci et al. and shown by the pink dashed line.

January 06, 1998 event



The top panel shows an increase of the dynamic pressure from 2 to 6 nPa, due to a Sudden Impulse (SI) observed by WIND close to L1.

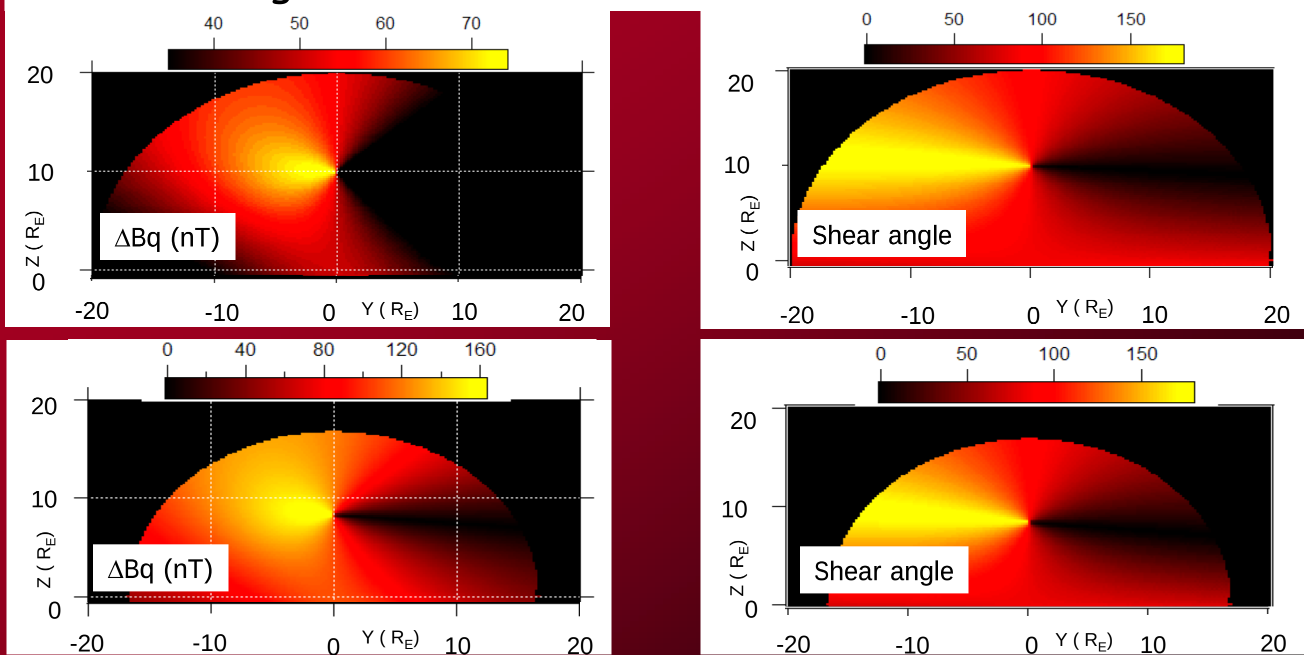
Across the SI B_y jumps from –7 to –15 nT.

The SI induces a reconfiguration of the ionospheric convection, which is seen by SuperDARN at 14:16 UT (Coco et al., 2008).

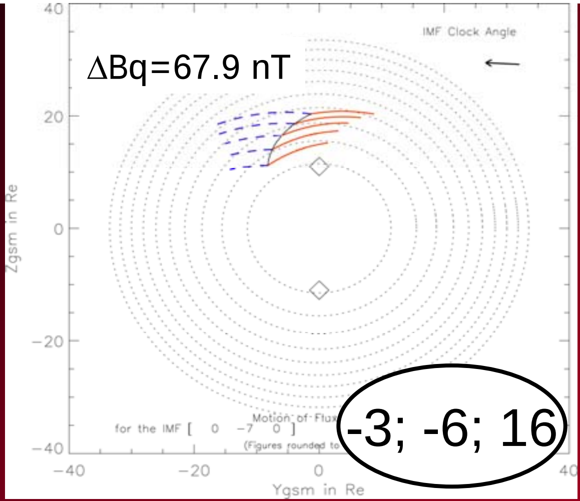
ΔBq parameter and magnetic shear angle at the MP according to the Cooling model.

Before the SI (14:14 UT)
IMF = (-0.5, -7, 0.5) nT

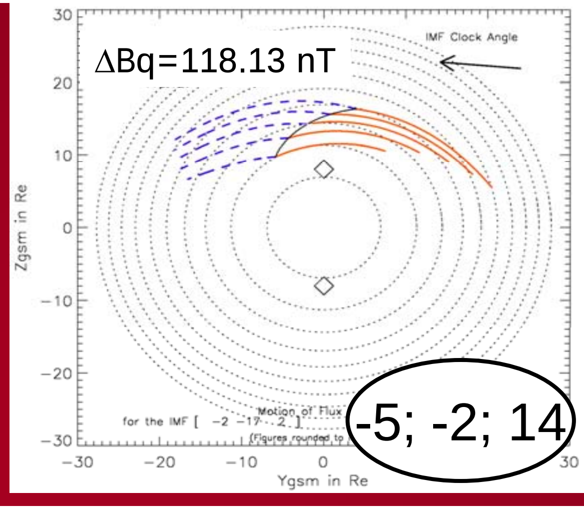
After the SI (14:18 UT)
IMF = (-2, -15, 2) nT



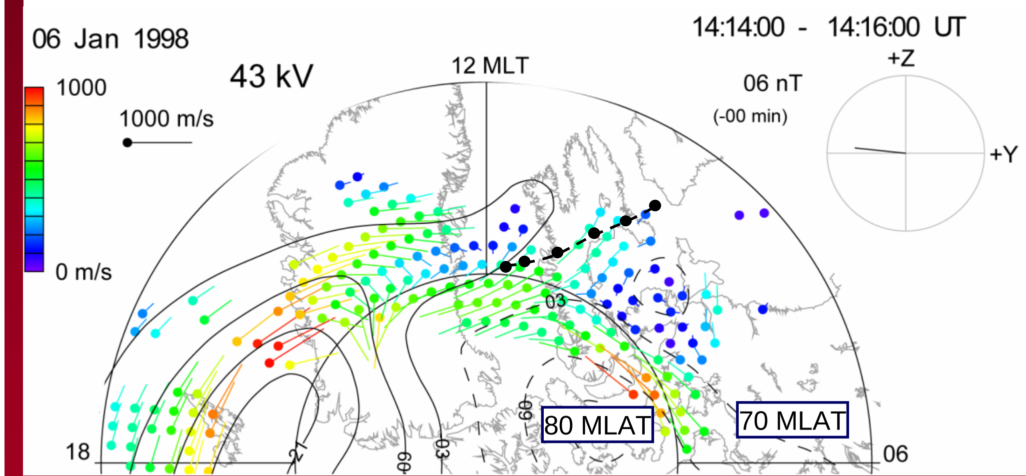
Cooling X-lines for the **pre-SI** conditions.



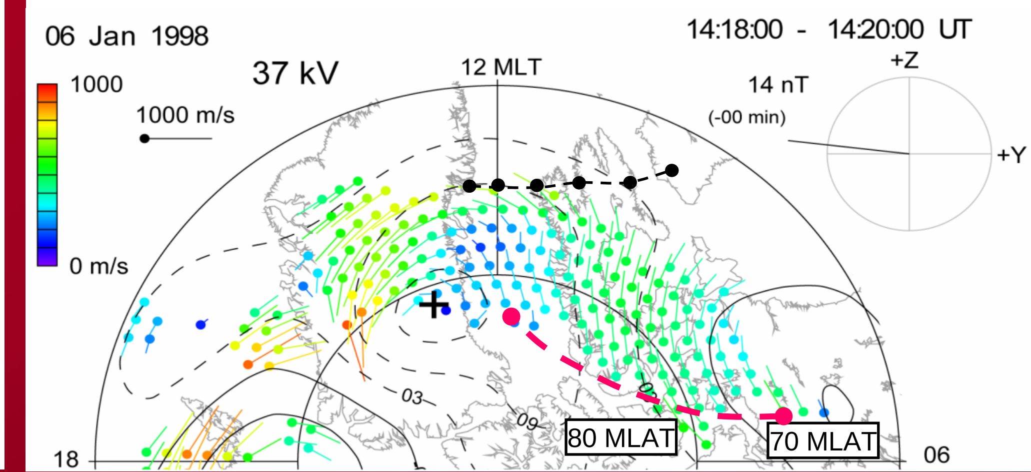
Cooling X-lines for the **post-SI** conditions.



Before the SI a clockwise dusk cell and a counter-clockwise dawn cell are observed.



After the SI a clear sunward flow is set up in the dawn quadrant and a counter-clockwise lobe cell appears with focus at 13 MLT and 81° MLAT.



The black lines are the ionospheric projections of the Cooling X-lines.

Before the SI, the projected X-line is compatible with the SuperDARN convection map.

After the SI, the projected X-line is totally incompatible with the convection map.

The pink line shows the lobe merging line proposed by Coco et al. to explain the dawn sunward flow.

Discussion and conclusions -1

In general, the ionospheric projection of the Cooling X-line obtained for the highest value of the Cooling ΔBq parameter (ΔBq_{max}) does not match the position of the X-line in the ionosphere as inferred from the SuperDARN convection maps.

In periods 1 and 3 of January 02, 2003 (with northward IMF and large B_y), in order to reconcile the Cooling X-line with the X-line inferred from SuperDARN maps, we had to move the X-line projection northward. A good match was obtained only by a combination of two operations:
- decreasing the solar wind dynamic pressure by a factor 2,
- moving the Cooling X-line tailward, to X=-6 R_E (probably too far tailwards).

-Similarly, in period 2 and 4 of January 02, 2003 (with dominating B_y) the Cooling X-line and the SuperDARN maps could be reconciled by decreasing the solar wind dynamic pressure by a factor 2 and by moving the Cooling X-line tailward to X= 0 R_E.

To this regard, we recall that Phan et al. (2003) discussed a case of lobe reconnection for which they had problems in reconciling "in situ" Cluster observations with Image observations. Contrary to our cases, they had to move their T96 projection equatorward. For that purpose, they doubled the solar wind dynamic pressure.

In period 5 (02/01/2003) and in the December 03, 2001, event (with northward IMF and B_y=0) the Cooling X-line can be reconciled with the X-line inferred from the SuperDARN maps by moving the centre of the Cooling X-line 2 tailward of the "most probable" reconnection point to X=-2 R_E (changing the dynamic pressure improves the agreement, but is not essential).

Discussion and conclusions - 2

In the January 06, 1998, 1414 UT event (B_z = 0 and B_y = -6 nT) the projection of the "most probable" X-line roughly matches the SuperDARN map (no need to act on the dynamic pressure).

In the January 06, 1998, 1418 UT event (B_z = 2 nT and B_y = -17 nT) the projection of the "most probable" X-line could not be reconciled with the SuperDARN map.

In this study we considered northward IMF and By dominated cases, i.e. we did not consider events in which the X-line was expected to be located near the subsolar point. Therefore, it is useful to recall that Feinrich et al. (2001) and Russel et al. (2001) also studied the projection to the ionosphere of reconnection X-lines and found that the T96 model performs worse than MHD models near the cusp.

Our results seem to support this view, as in several cases we had to modify the value of the solar ind dynamic pressure, while in three cases no agreement could be reached between the projected X-line and SuperDARN maps.

However, we also observed cases in which the Cooling X-line was in the cusp region and SuperDARN maps and the predictions of the Cooling and T96 models could be reasonably reconciled.

Final remarks.
The cases for which no agreement was reached or it was necessary to modify the solar wind dynamic pressure all had large values of B_y.
Something has to be done with the cusp region. To this regard, we notice that neither the Cooling model nor the Tsyganenko model includes a realistic shape of the magnetopause in the cusp region.

thank you