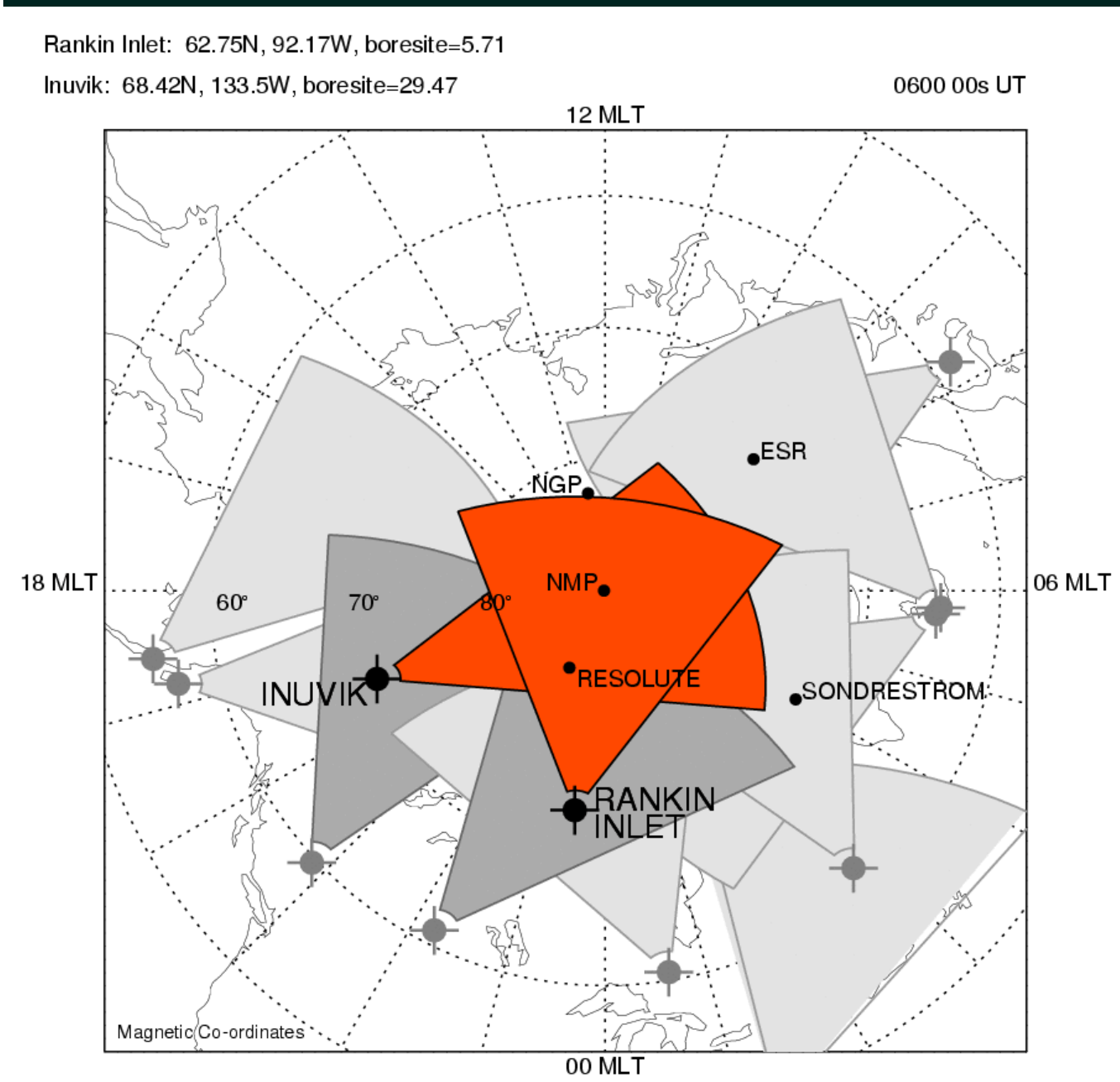
PHYSICS AND ENGINEERING PHYSICS

Polar Cap Dynamic Lobe Cell Structure from full 2-radar PolarDARN data

George Sofko, M. Watanabe, Xi Yan, J.-P. St. Maurice,
K.McWilliams, Sasha Koustov, G. Hussey, D. Andre

Institute of Space and Atmospheric Studies



Deployment of the two PolarDARN radars is complete. The results are so good that we would like to add a third PD radar on Baffin Island to give wider MLAT coverage.

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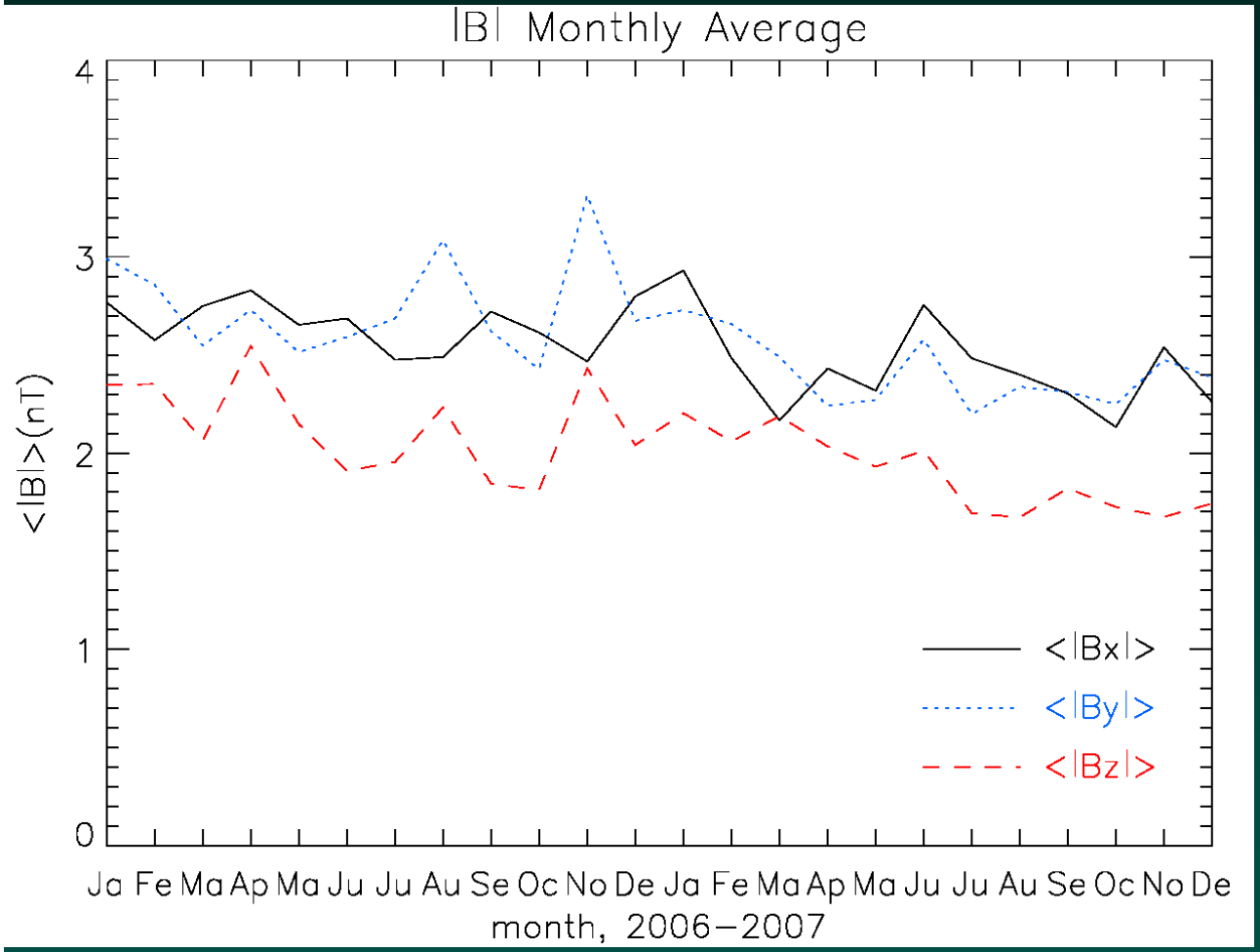
The Dynamic Polar Cap

- Substantial changes in convection take place between successive one-minute scans, so it is best to operate in one-minute scan mode.
- The inclusion of PolarDARN data shows considerable polar cap convection structure. This in turn leads to modified convection equatorward of the polar cap, because the spherical harmonic fitting must match that flow to the structured polar cap flows.
- Polar cap structure can be quite detailed during two main types of IMF conditions: By dominant and Bz+.

Comparison of 2-year IMF absolute values



The average in 2006 and 2007 of <|Bz|> is lower by 21.9% than that of <|By|>. By thus is expected to play an important role in rxn. And <|Bz-|> is 23.6% less than |By|!

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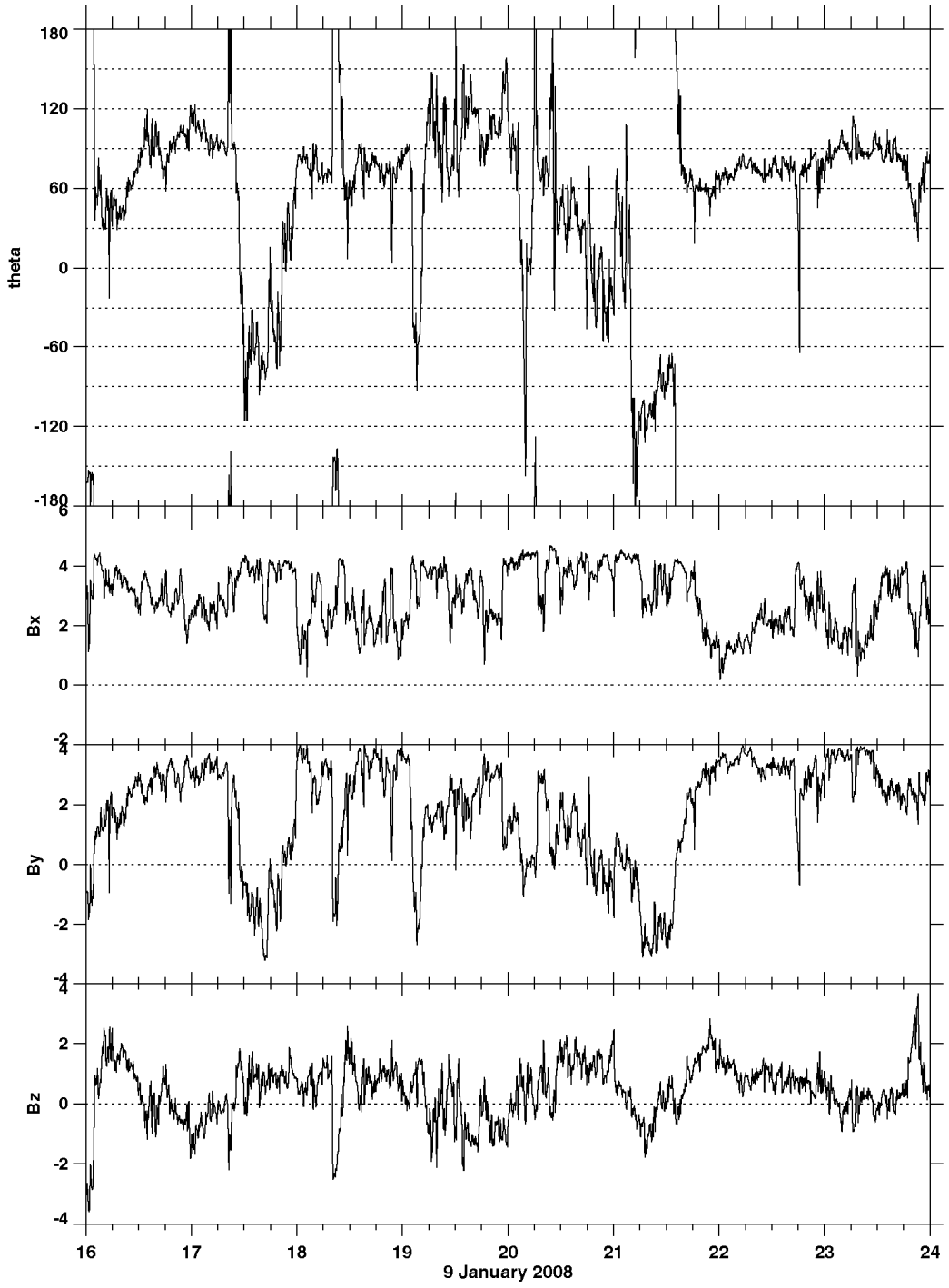

JANUARY 9, 2008

For Jan 09/08, the ACE data shows that By+ dominated from about 1800 – 2045 UT and again from 2135 – 2400 UT. Bz was weak and mostly +. The solar wind speed was about 530 km/s, (delay time from ACE to ionosphere was estimated to be about 54 min).

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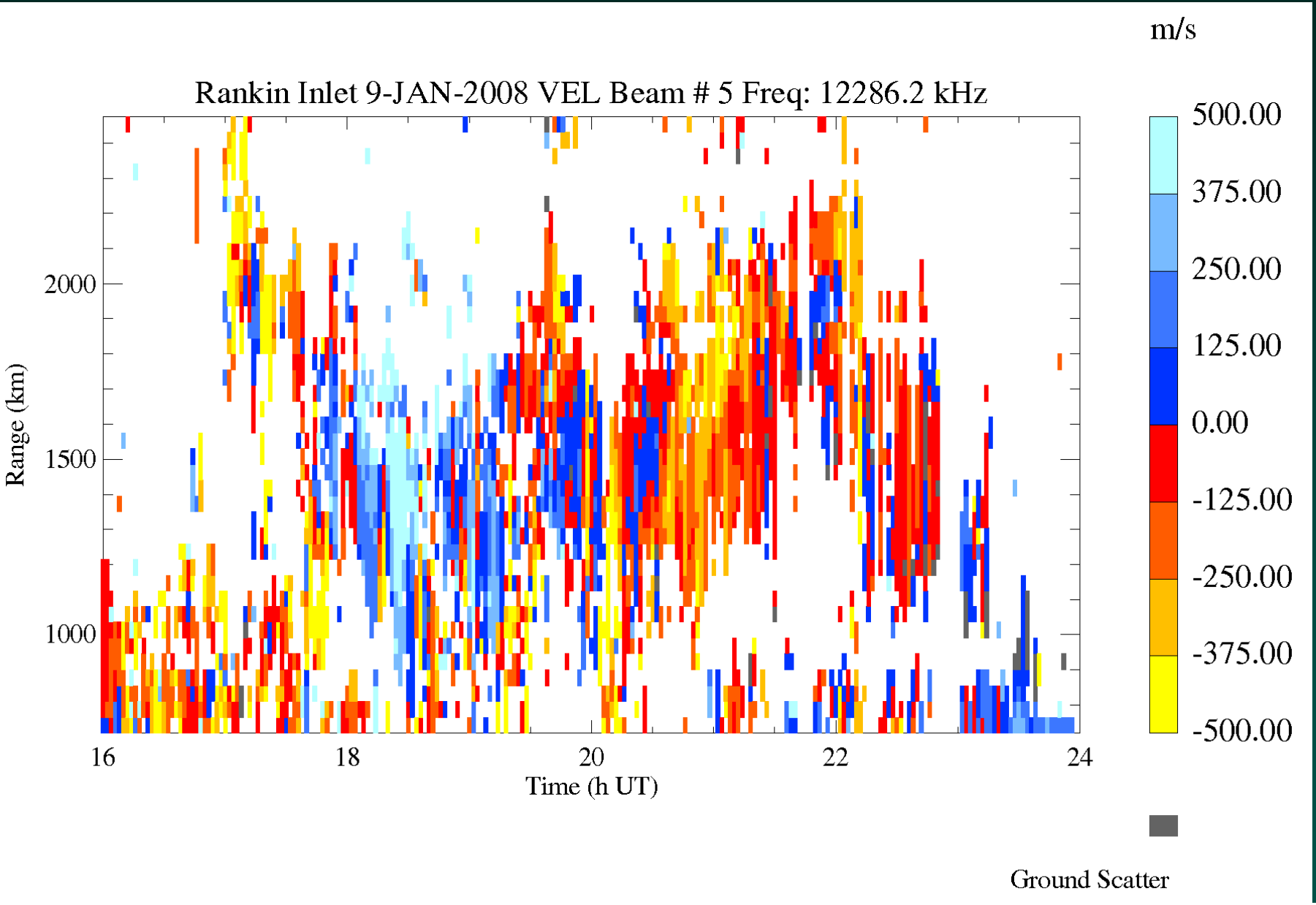
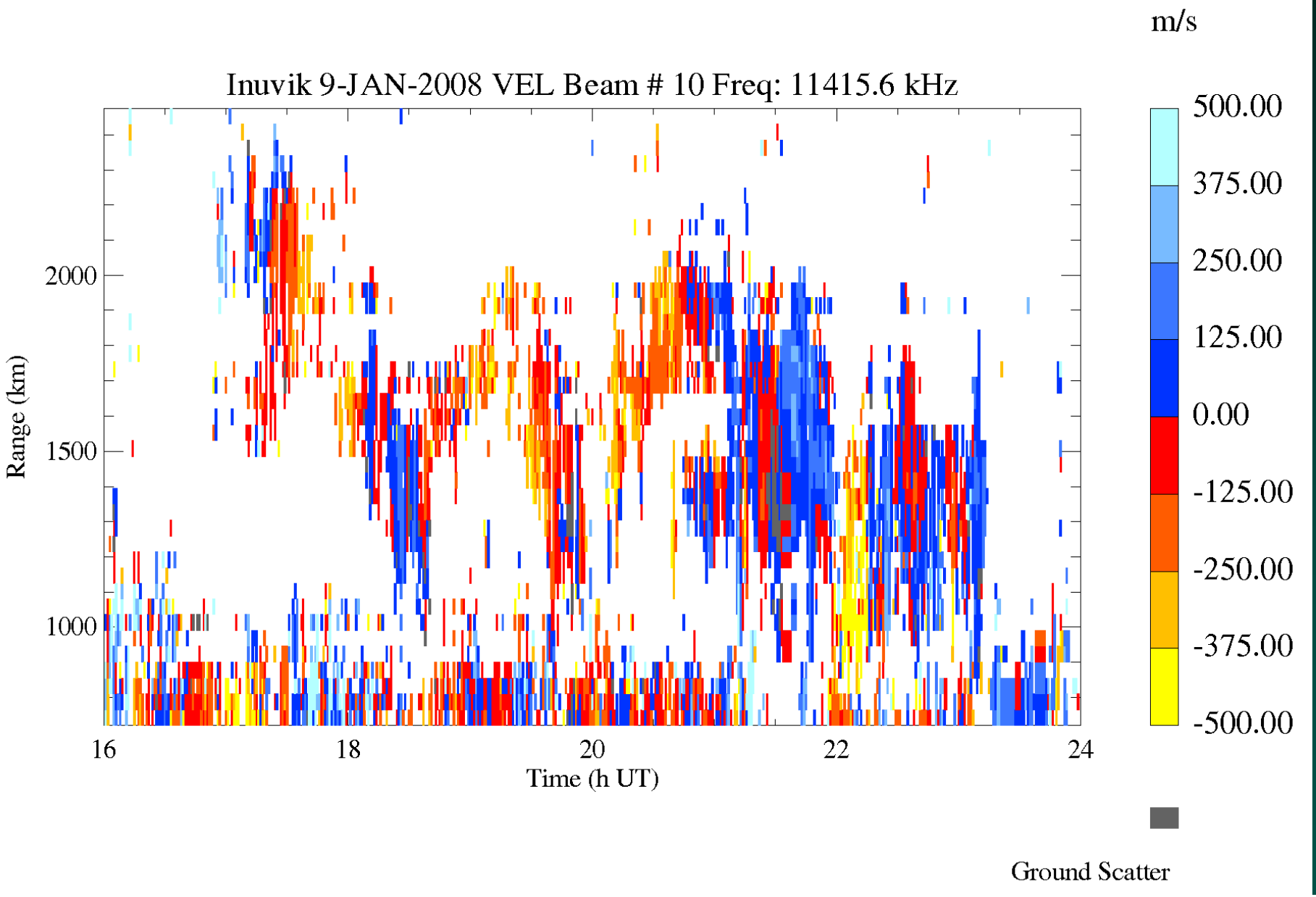
Jan 09/08 – Rankin Beam 5 velocities

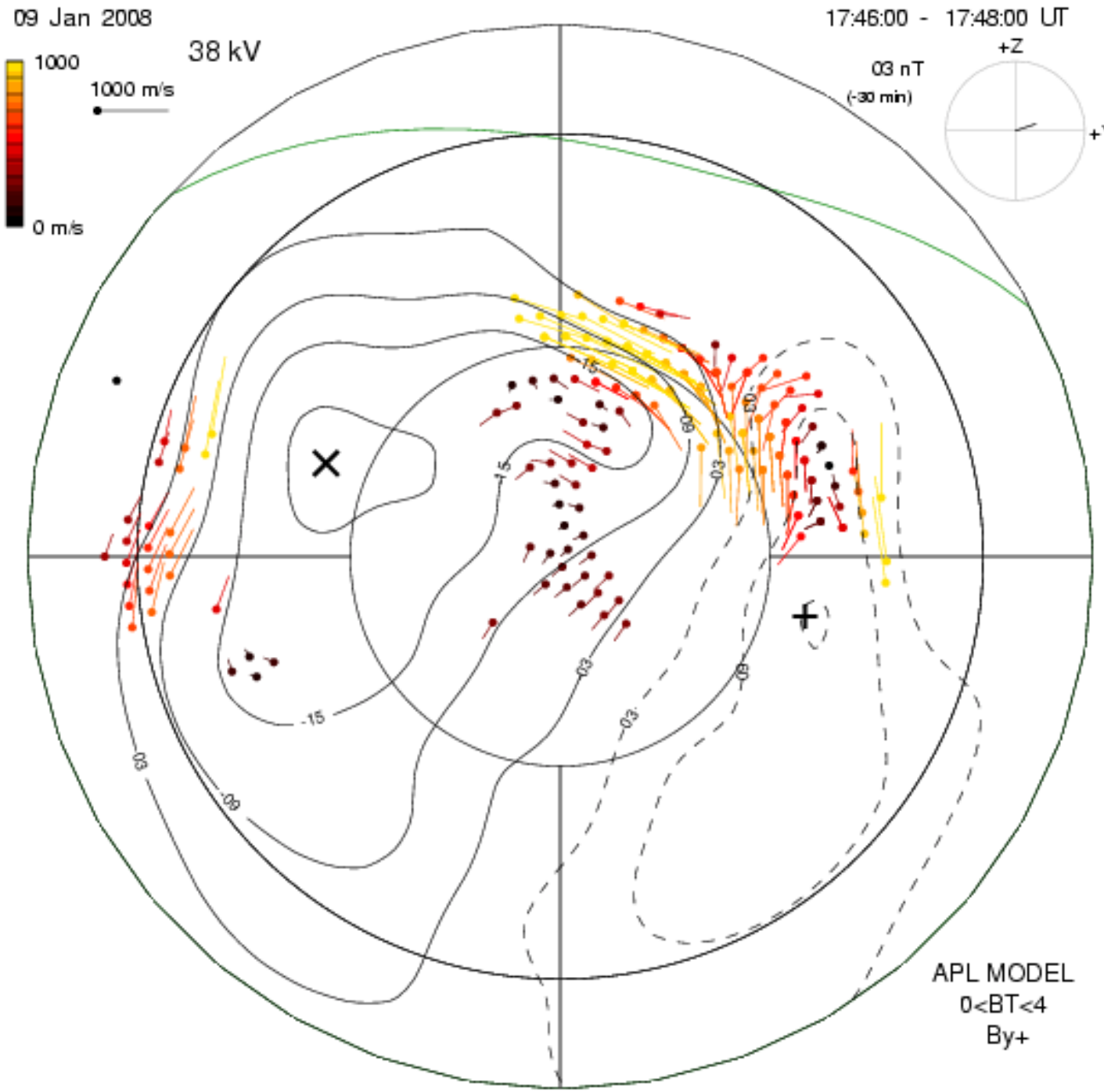


Jan. 09/08 – Inuvik Beam 10 velocities



Lobe Cell #1 – strong By+

- The first lobe cell is a clockwise cell that develops in the prenoon sector for strong By+ conditions, as expected.
- There is strong westward flow in the prenoon sector where the reconnection is occurring. That flow is not only due to Dungey-type rxn **but also to interchange rxn** of lobe to closed lines that results in closed-to-closed field line flow **equatorward of the OCFLB**.



During strong By+ conditions, a protrusion arm develops in the polar cap just before noon. This will develop into a clockwise (CWSE) lobe cell during the next 8 minutes.

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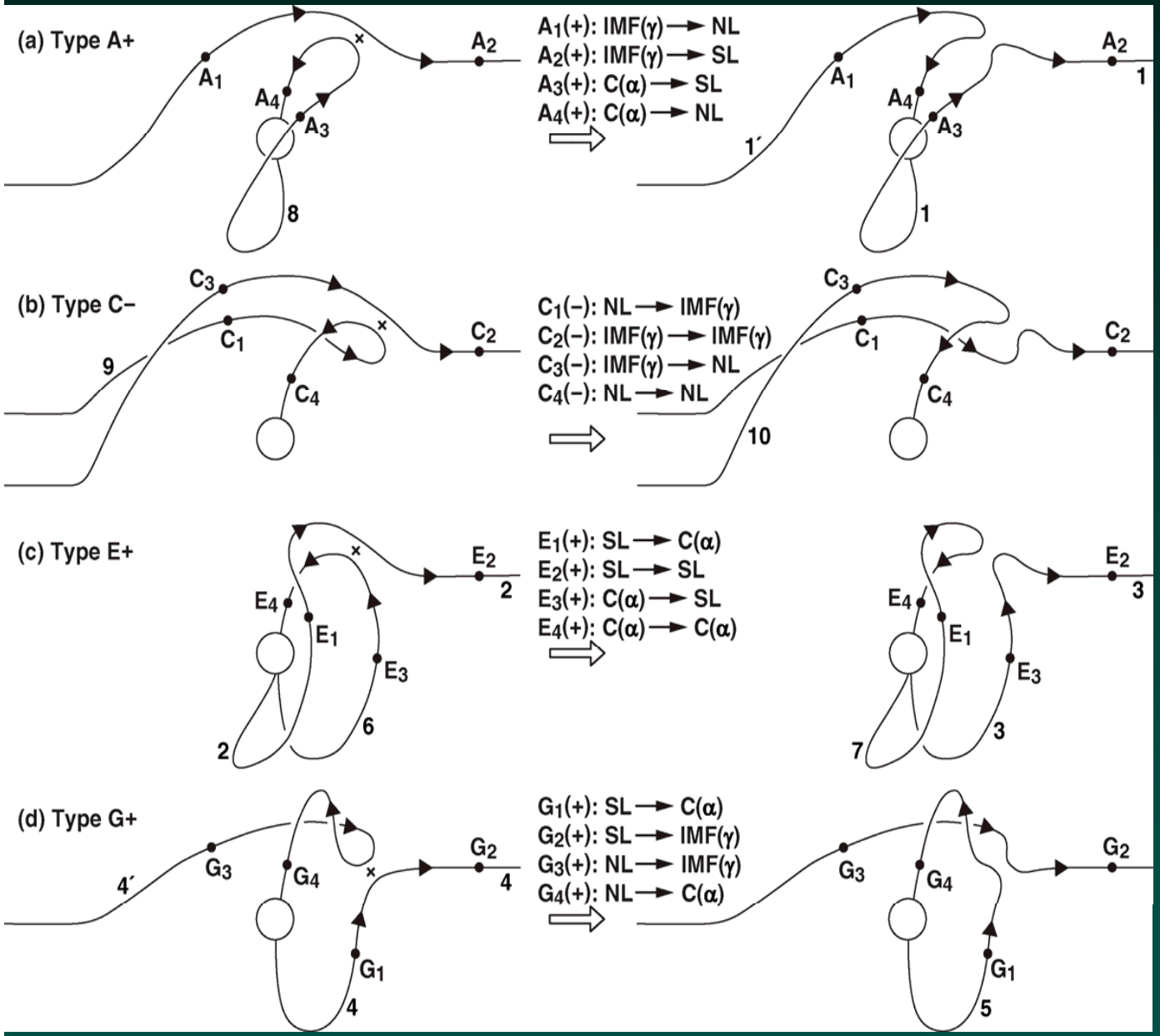
NH Reconnection during By+ IMF



Types A+ (IMF to closed) and G+ (north lobe to south lobe) are Dungey-type rxn, and are the driving types behind the 2-cell convection pattern.

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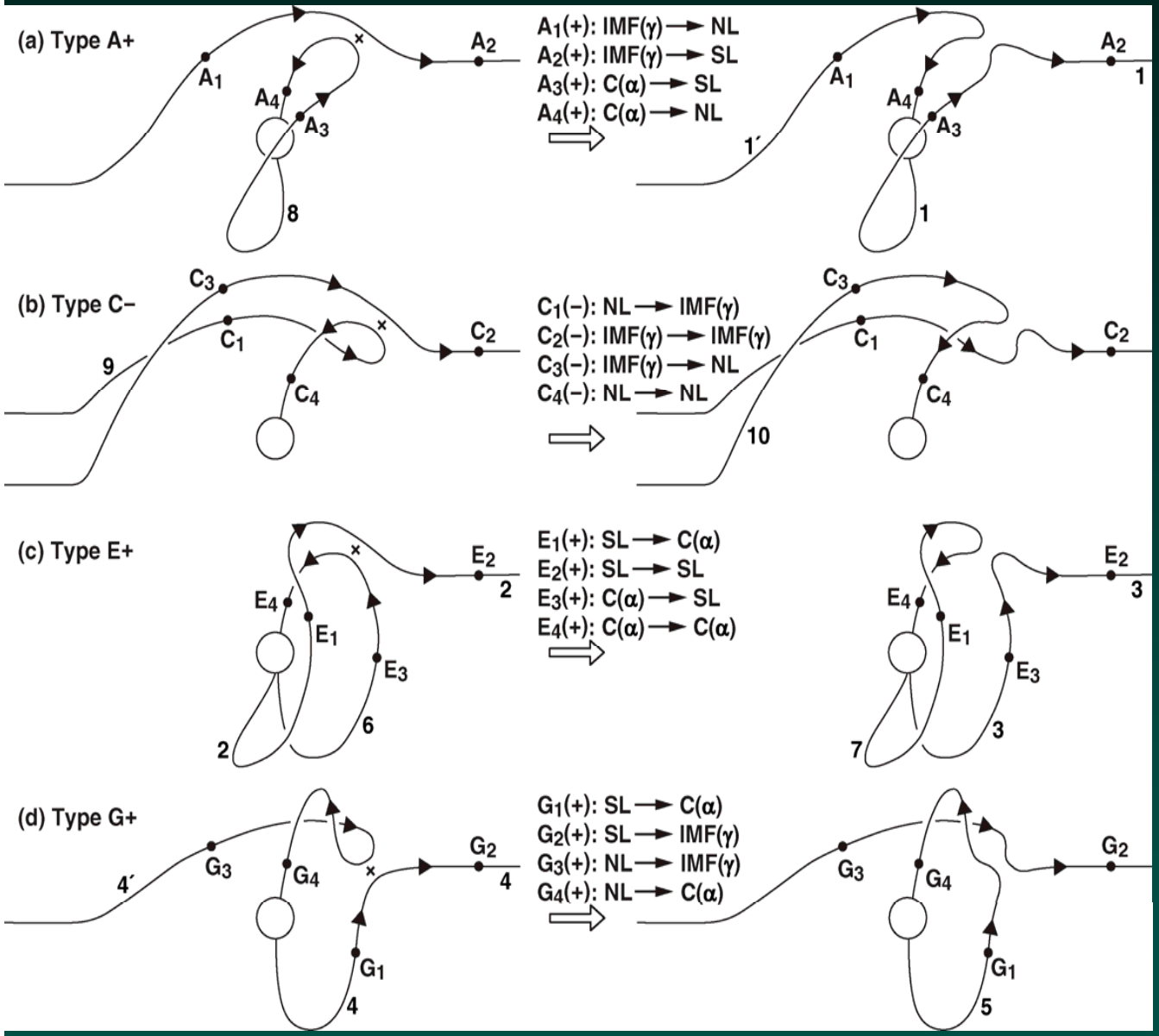
Interchange reconnection – convection effects



Types E and C are called "Interchange Rxn": the 2 "after" field lines are interchanged from the 2 "before" lines. Type E+ rxn drives closed-to-closed flows (see E_4), while type C- rxn drives open-to-open flows (see C_4).

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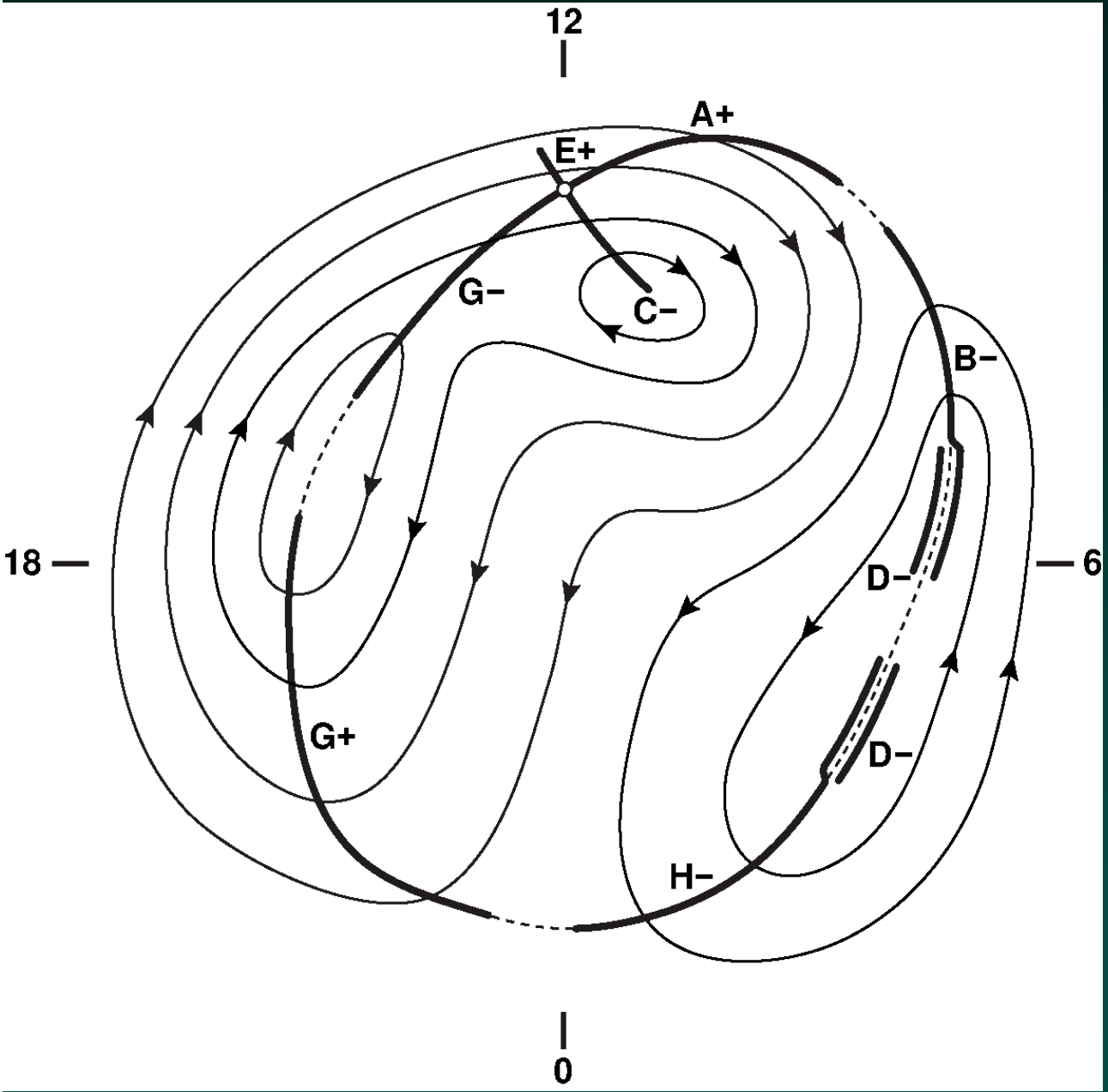

Type E+ interchange reconnection (lobe-closed) can drive the closed-to-closed flows equatorward of the normal OCFLB, while Type C- (IMF-lobe interchange rxn) can drive the open-to-open lobe cell flows poleward *of the OCFLB. The OCFLB itself results from Dungey rxn types A+ and G-.*

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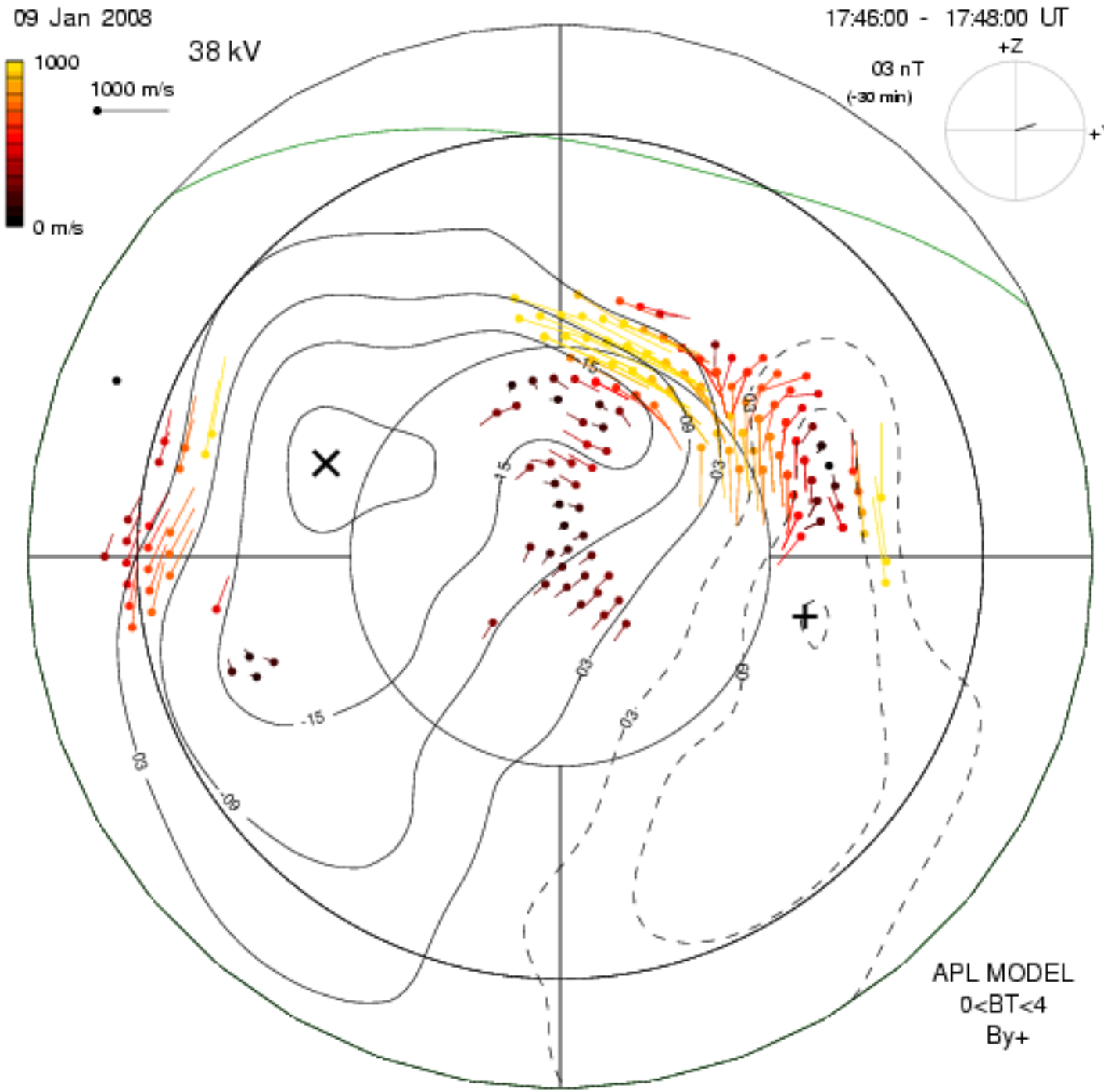

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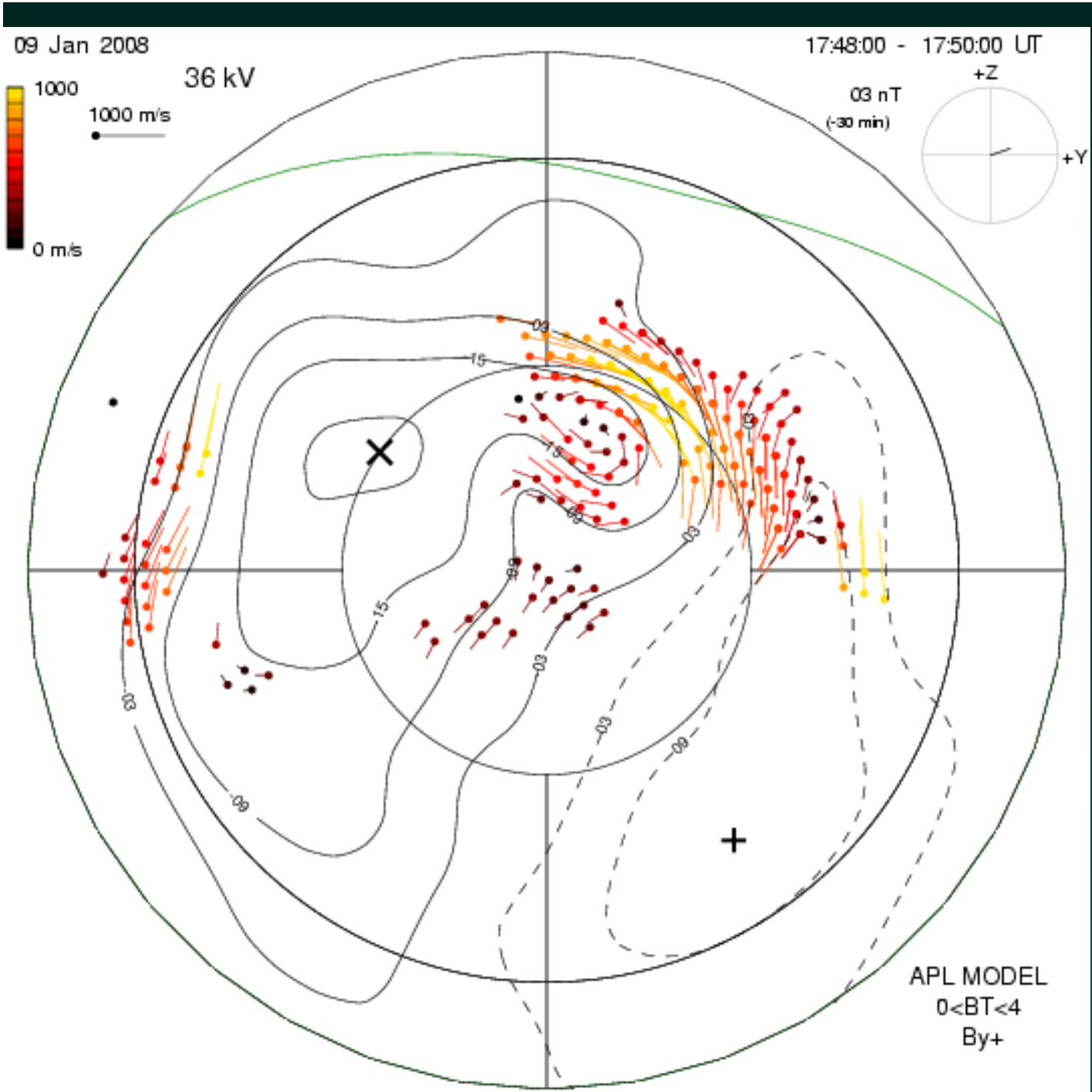

The CWSE cell is starting to close. The strong westward rxn flow ends just above 80 deg MLAT – it seems clear that the OCFLB is at the poleward edge of that flow.

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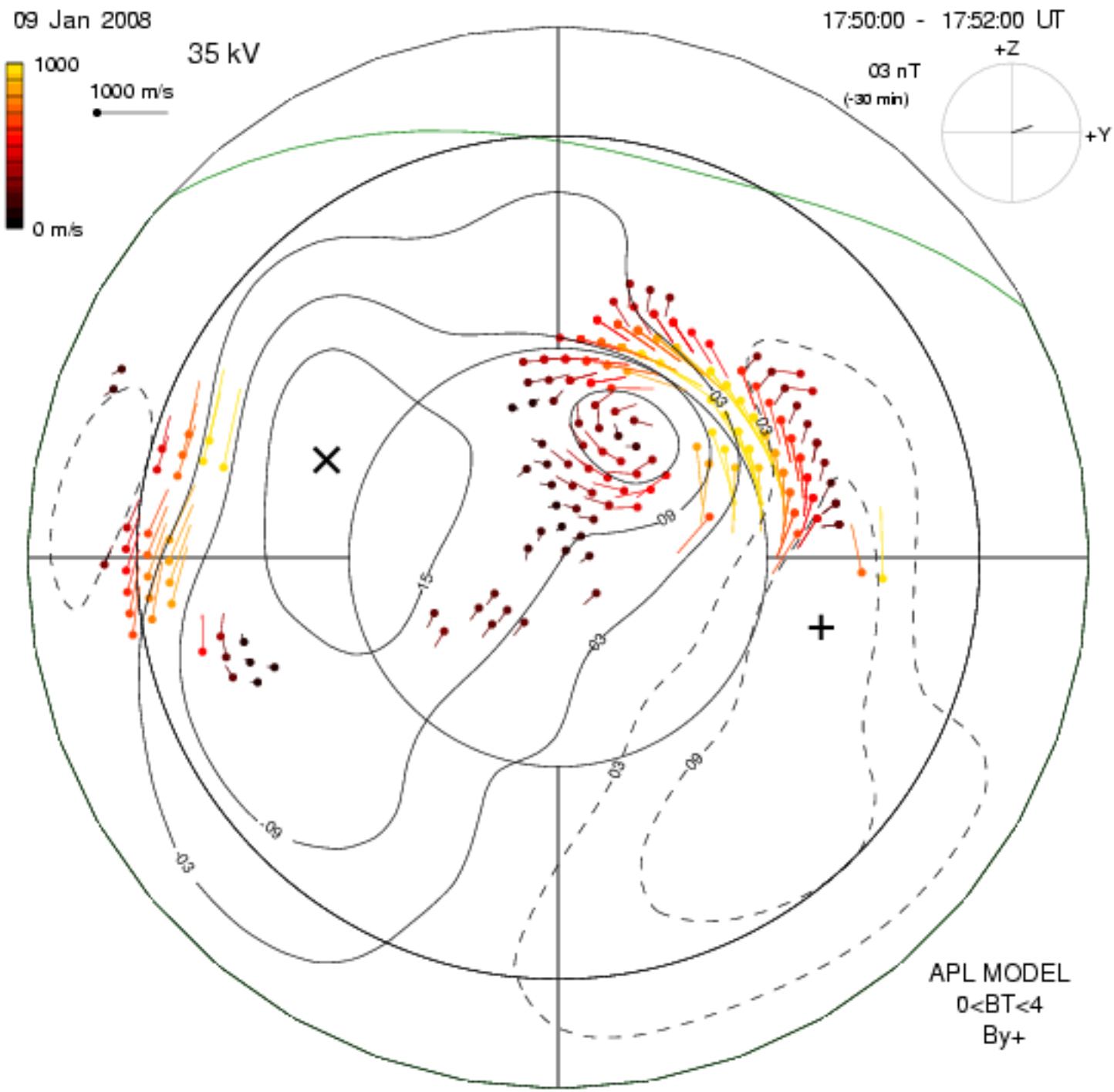

Note that the lobe cell central streamline is rather small – only about 4° MLAT. The small-scale resolution (45 km) is ideal for studying the details of such structures.

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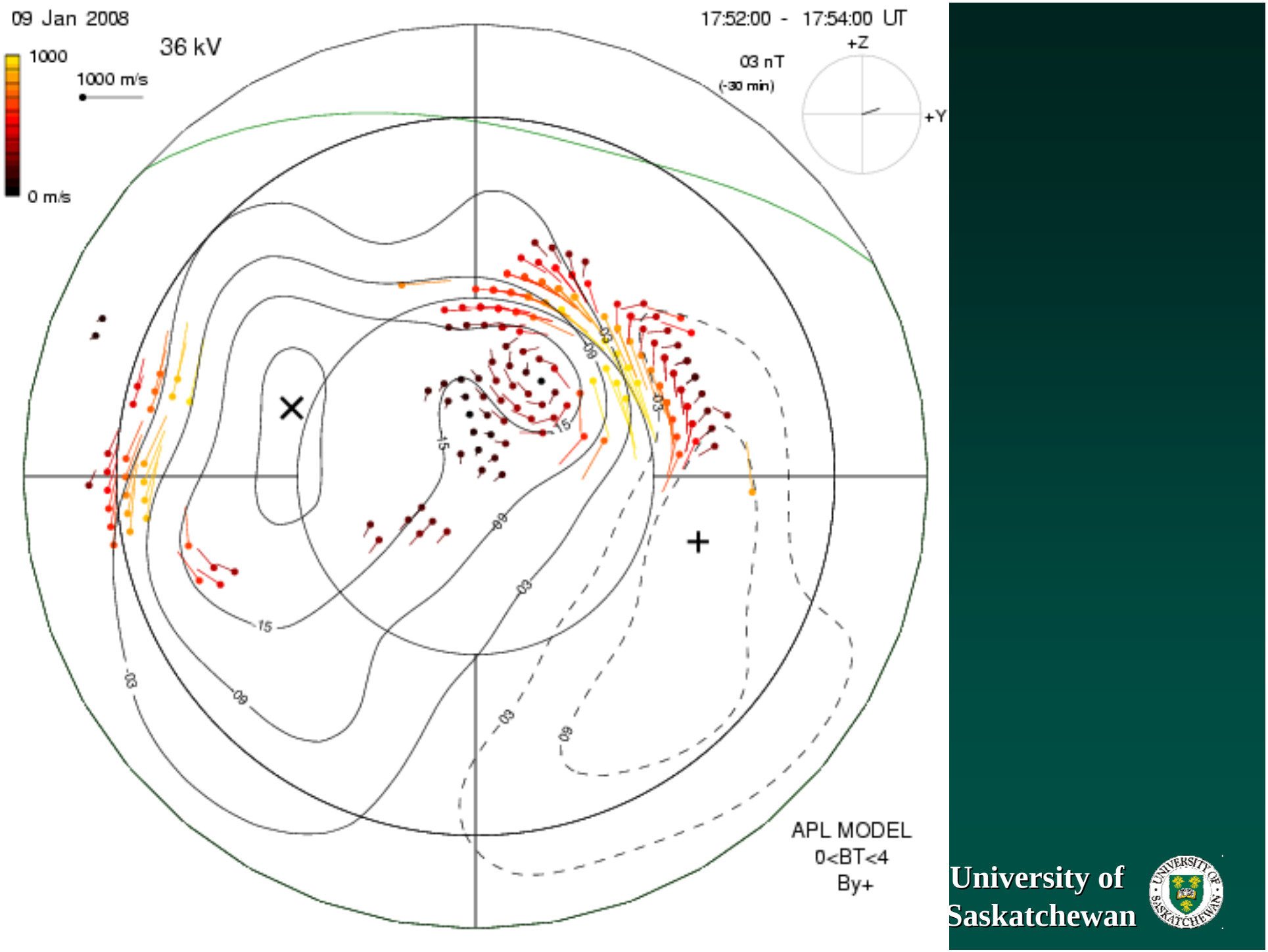
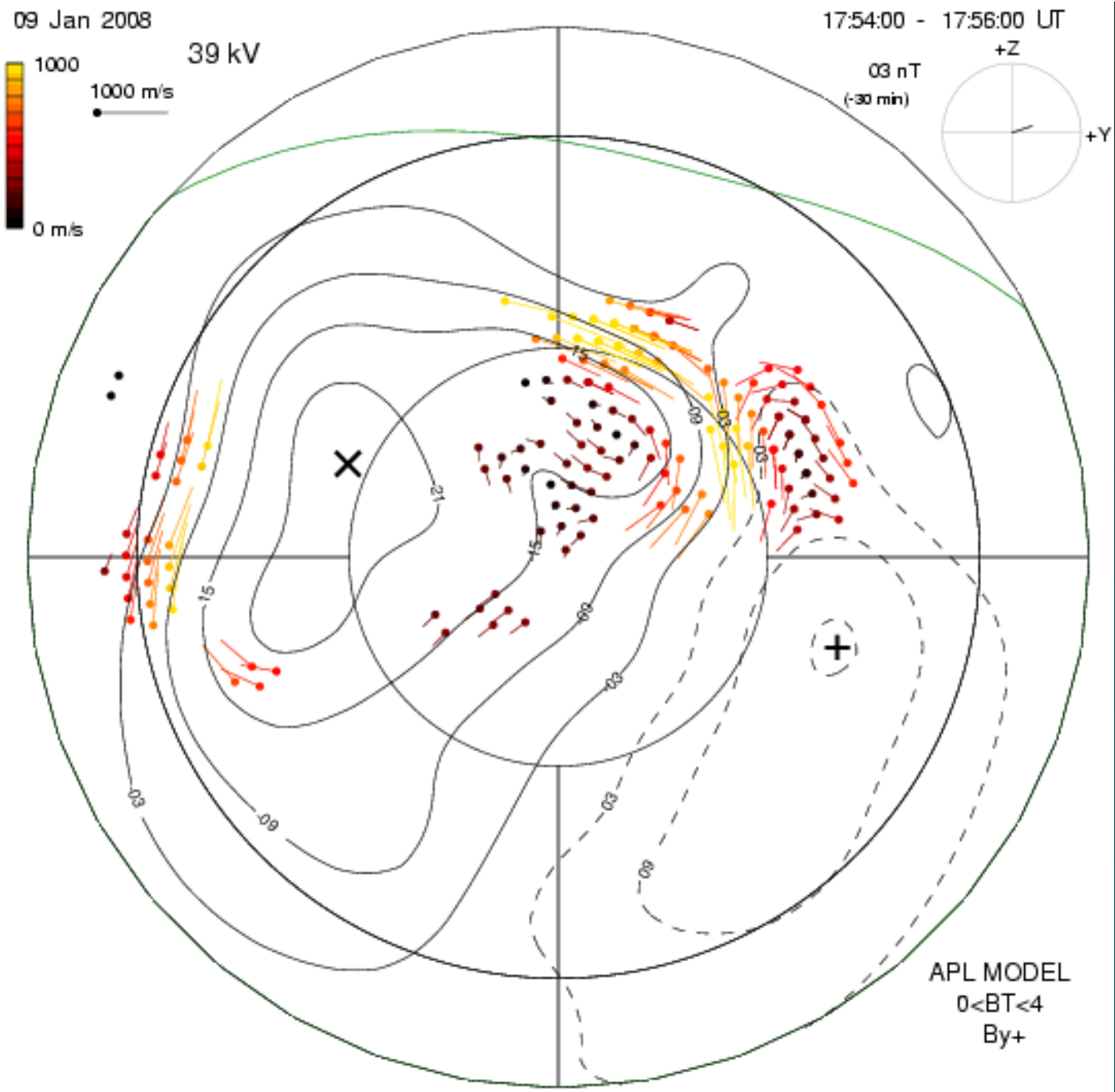

09 Jan 2008
36 kV
1000
1000 m/s
0 m/s
17:52:00 - 17:54:00 UT
+Z
03 nT
(-30 min)
+Y
15
09
03
APL MODEL
0<BT<4
By+
University of
Saskatchewan



The lobe cell ends the way it began – with a convection reversal (CR) in the protrusion arm just poleward of the strong (yellow) flows marking the post-RXN region.

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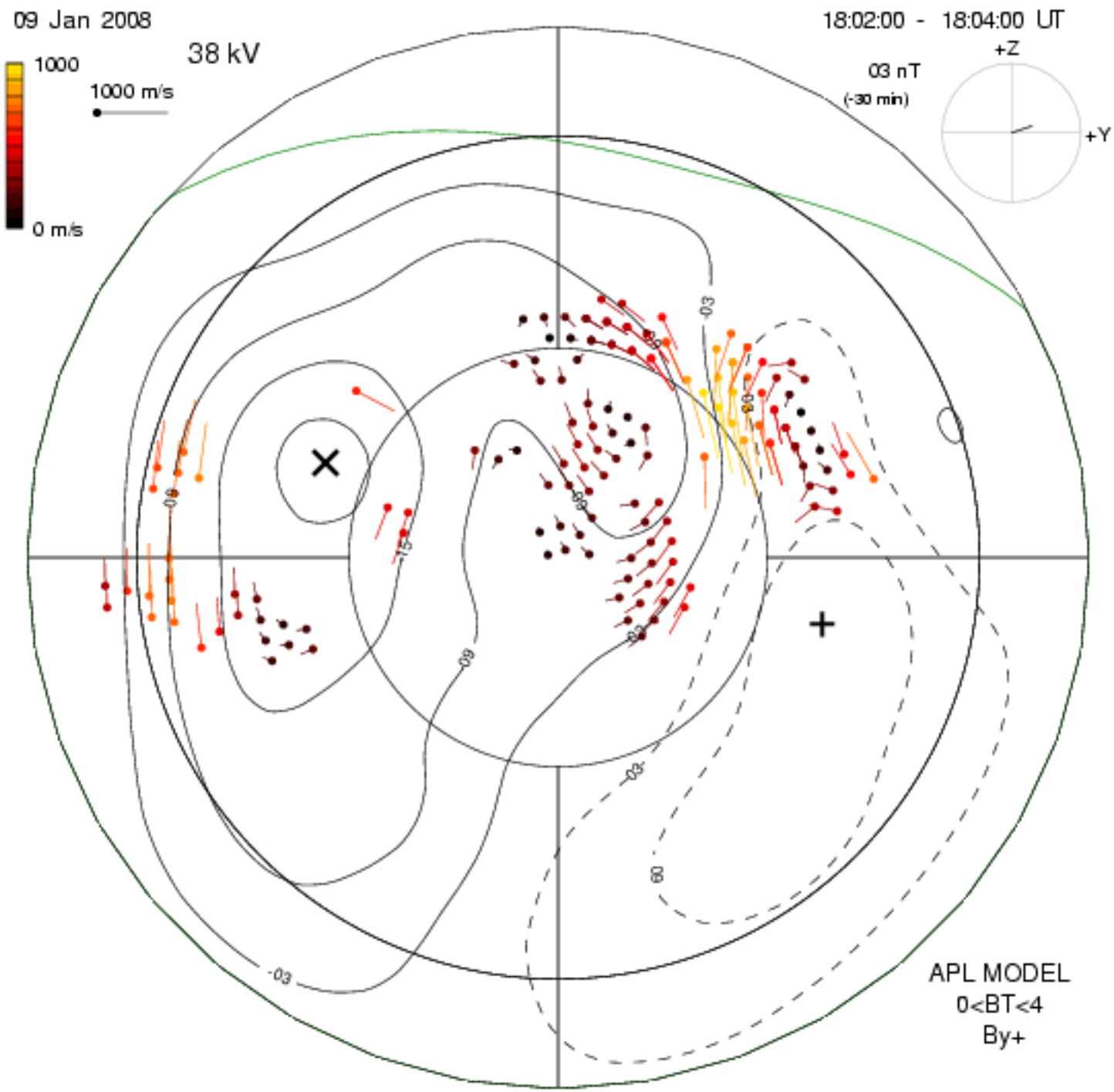
Lobe Cell #2

- This lobe cell illustrates a feature of relevance to studies of the cross-polar cap potential.
- The dusk-side minimum VMIN (X) can jump across to the focus of the lobe cell, located well within the polar cap. One must be careful not to use this value for studies of the cross-cap potential drop $V_{MAX} - V_{MIN}$.



Lobe cell #2 develops shortly after #1. This time, watch the voltage min X .

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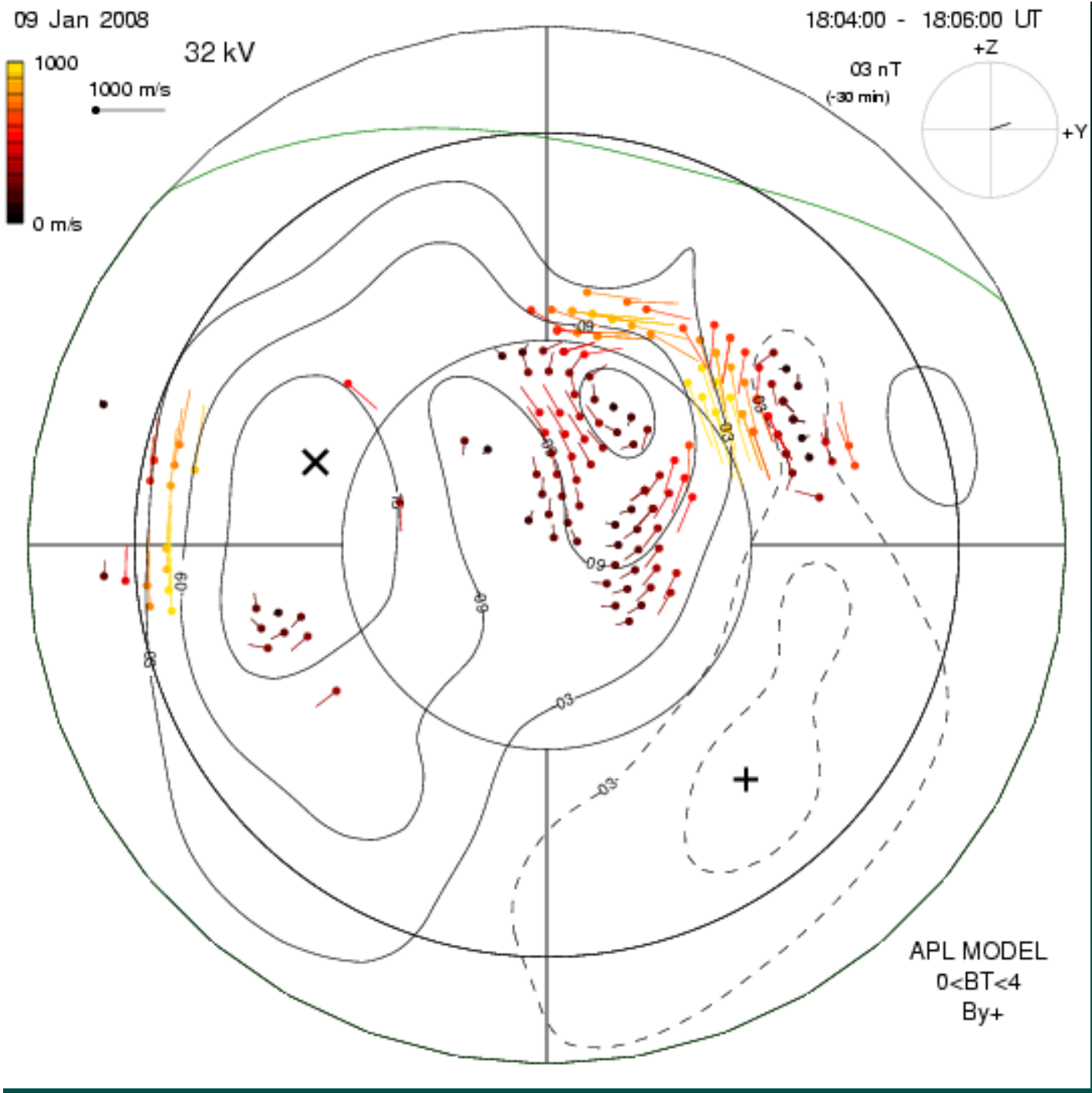

The central lobe cell streamline is again small. Sunward flow in the center of the polar cap is clear. Does the wavelike structure of near-noon flowlines indicate MPause waves?

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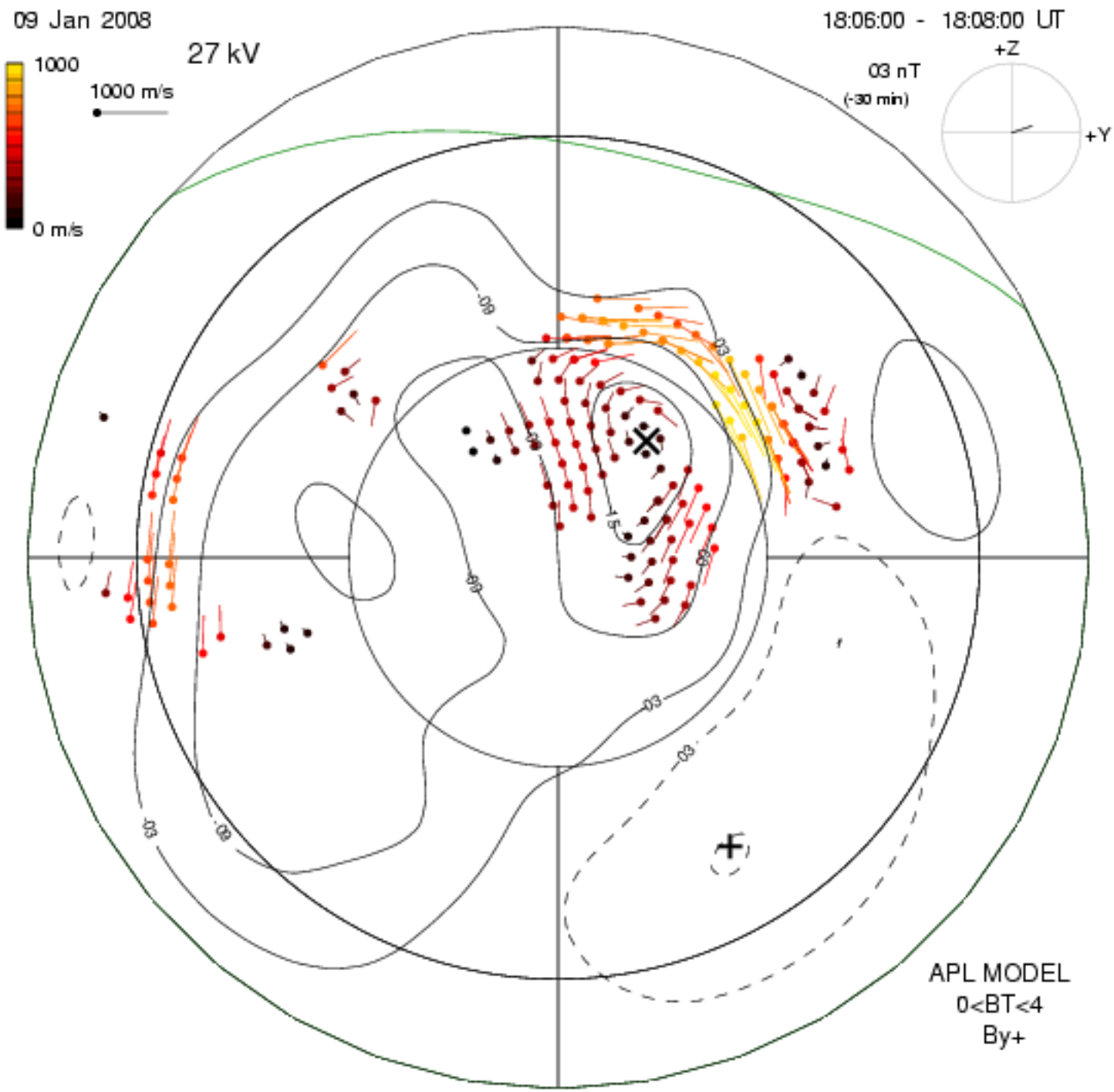

Note how the voltage min X has moved to the center of the lobe cell. Again note clear sunward flow in the polar cap, and the wavelike structure of noon-sector flowlines.

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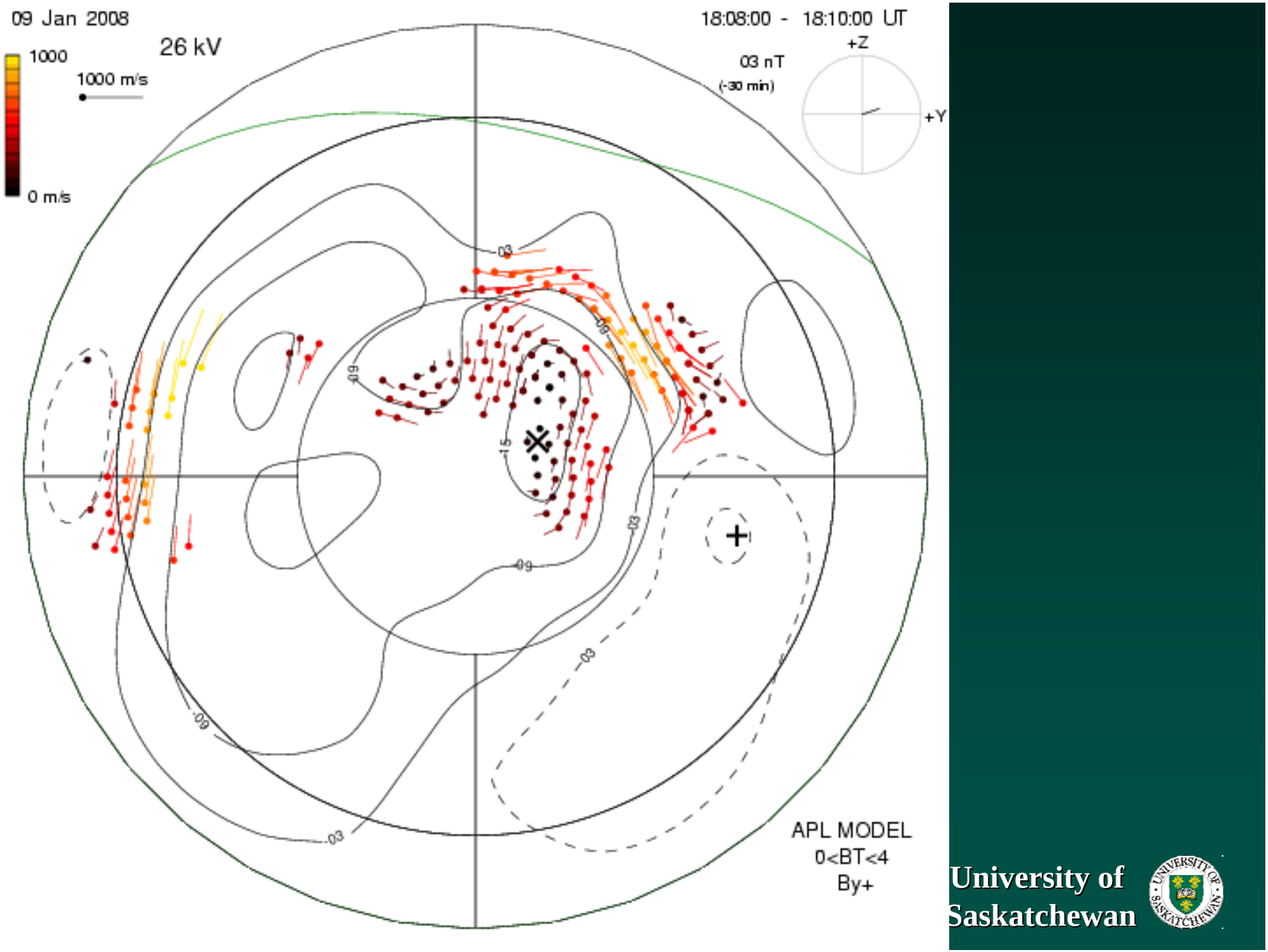
09 Jan 2008
26 kV
1000
1000 m/s
0 m/s
18:08:00 - 18:10:00 UT
+Z
03 nT
(-30 min)
+Y
03
09
15
03
09
03
09
03
APL MODEL
0<BT<4
By+
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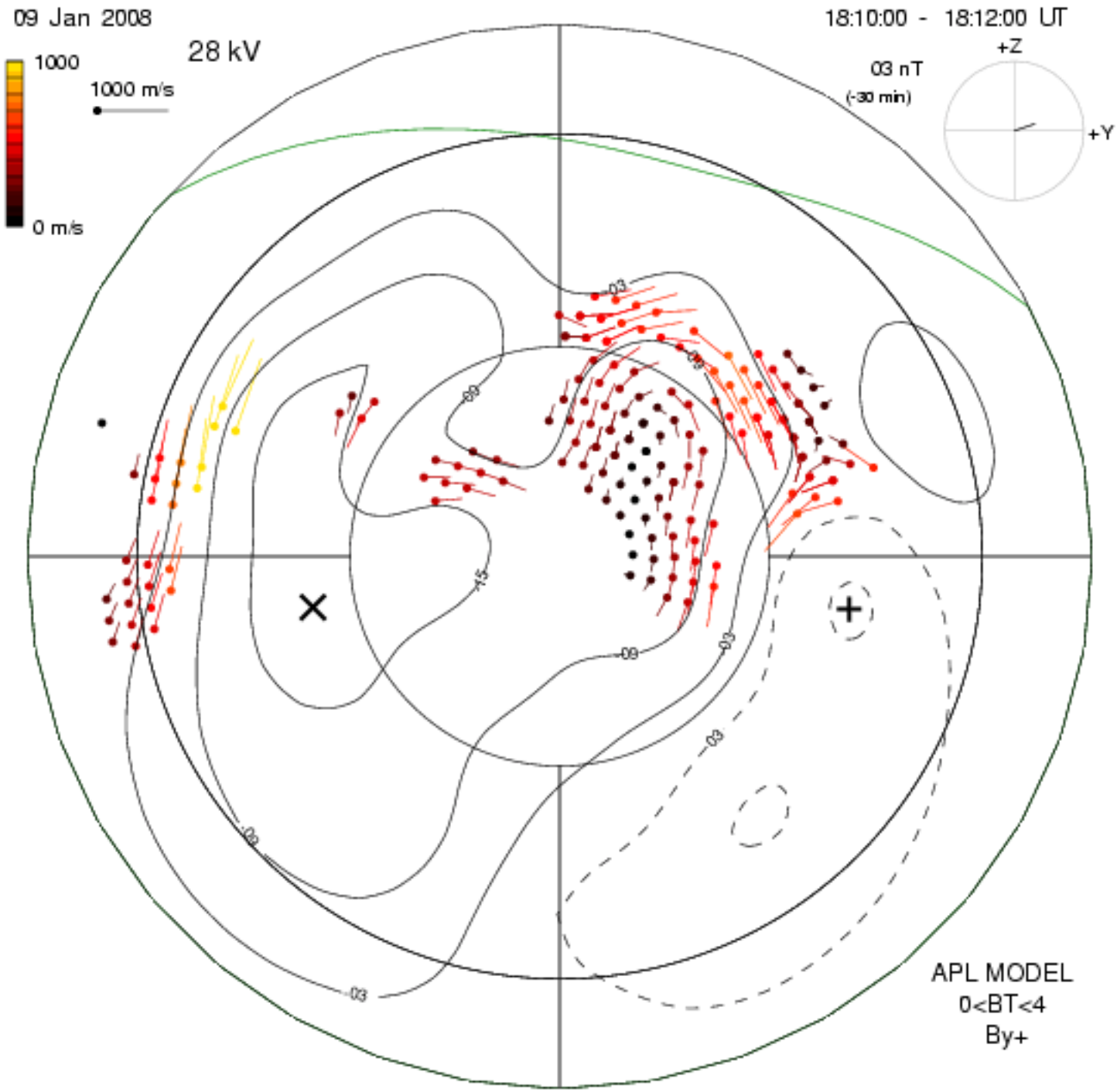
Saskatchewan



The lobe cell ends but the sunward flow and the wavelike structure of flowlines remains, even into the area of the polar cap itself. Note that VMIN X is back near dusk.

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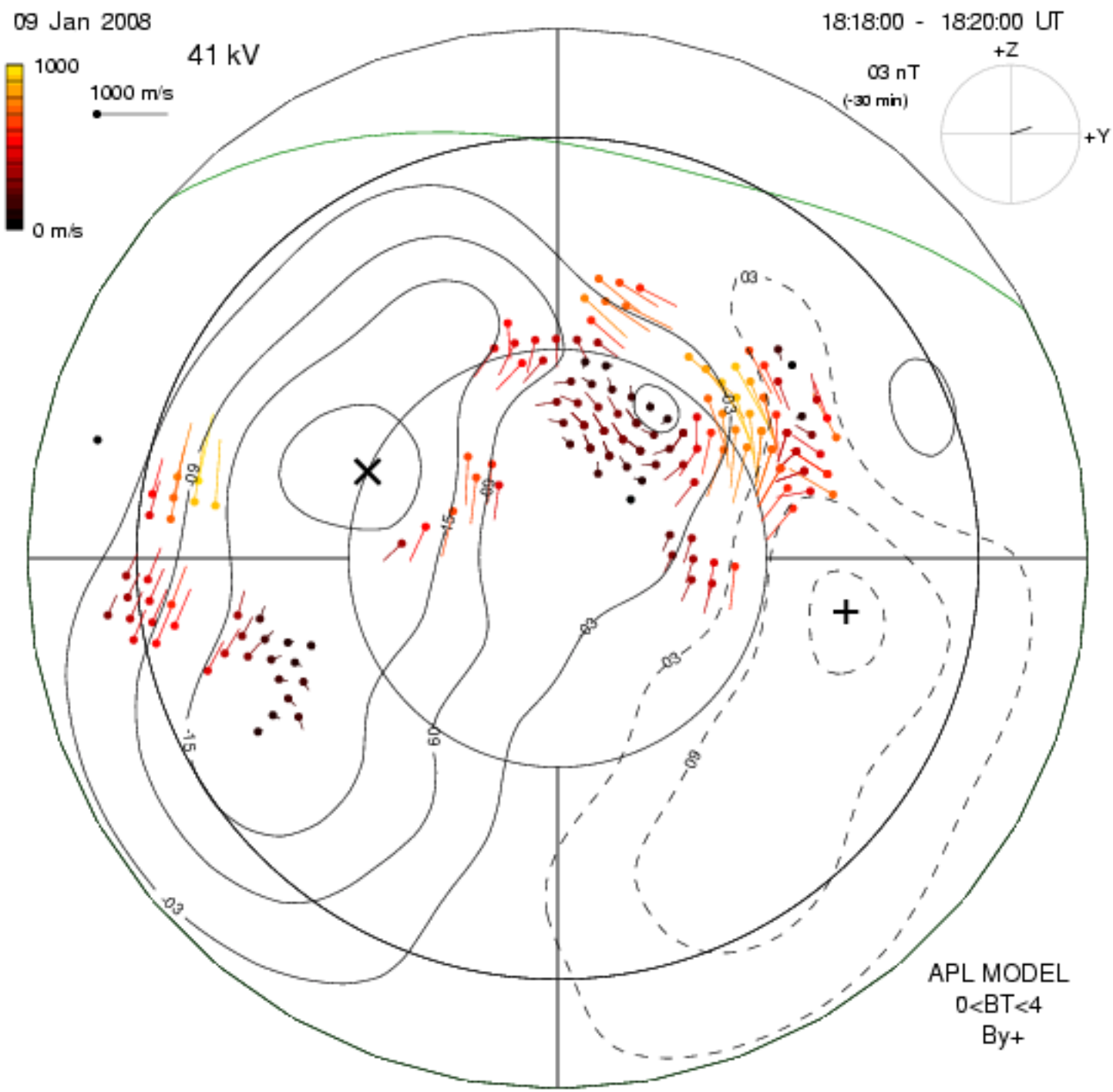
Complex Lobe Cell Structure #3

- During a period in which By is rapidly changing from near zero values while Bz is weakly +, the flows in general decrease in magnitude and the lobe cell evolution becomes more complex.
- This time, there is evidence of evolution from a single CWSE cell to **TWO** lobe cells – both CWSE and C-CLWE cells – and finally to a C-CWSE cell only, as the IMF By changes to minus sense. These are perhaps the first observations of such a transformation, which is consistent with reconnection expectations.
- There is a continuation of the wavelike structure of the flowlines.



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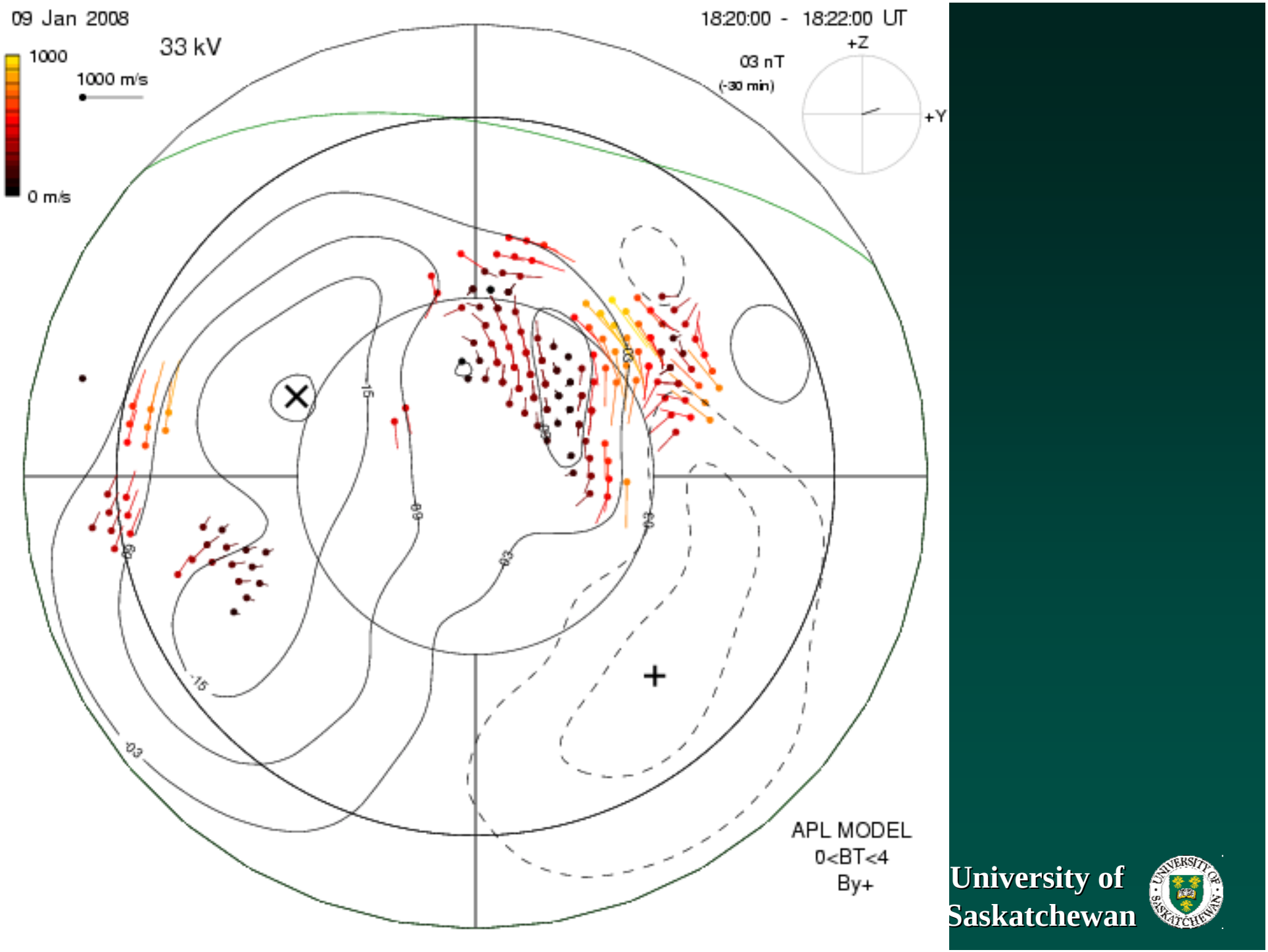
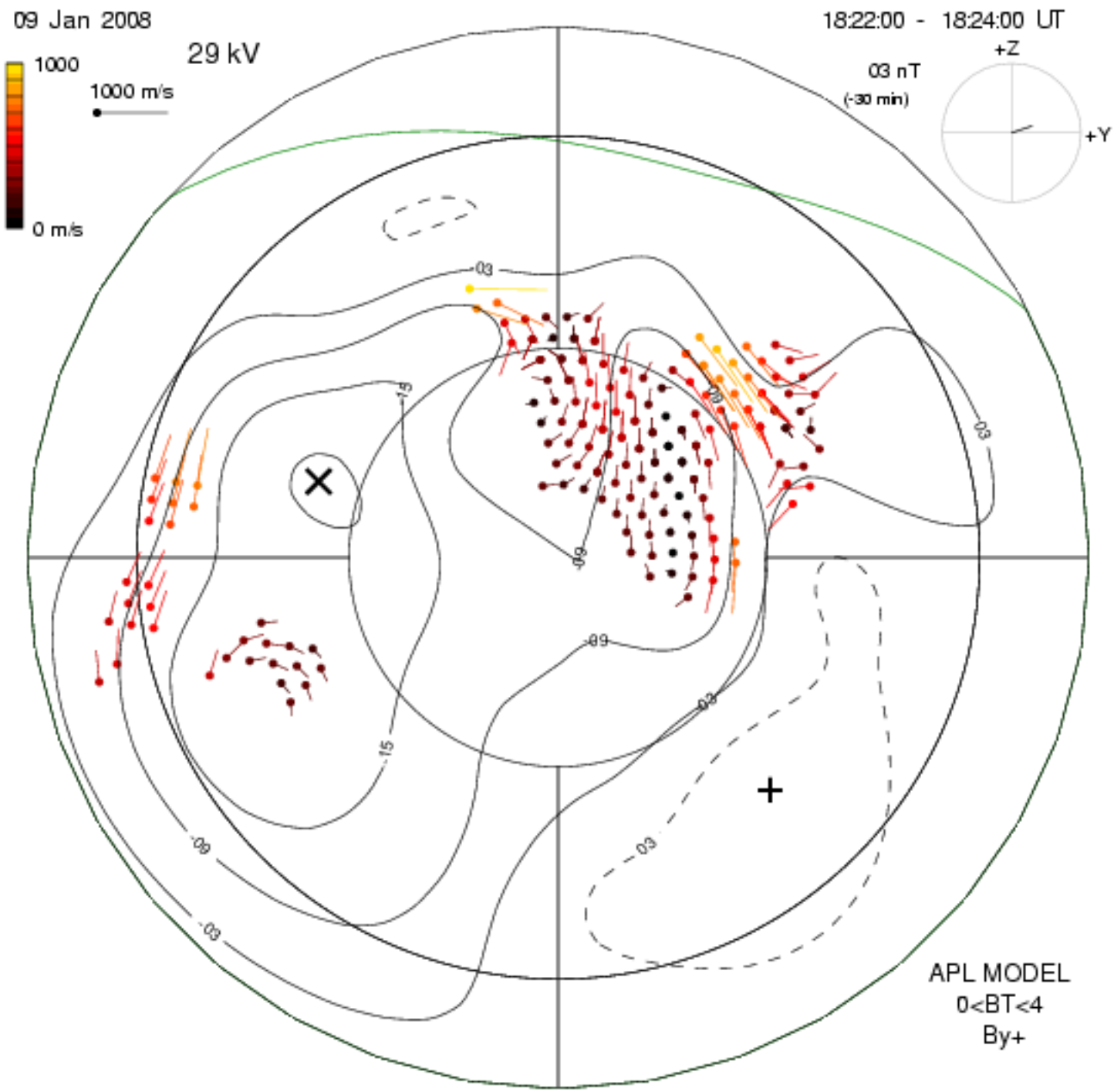

09 Jan 2008
33 kV
1000
1000 m/s
0 m/s
18:20:00 - 18:22:00 UT
+Z
03 nT
(-30 min)
+Y
APL MODEL
0<BT<4
By+
University of
Saskatchewan



There is now evidence of the prenoon CWSE lobe cell and the onset of a C-CWSE cell in the noon-postnoon sector, with clear sunward flow between the two cells.

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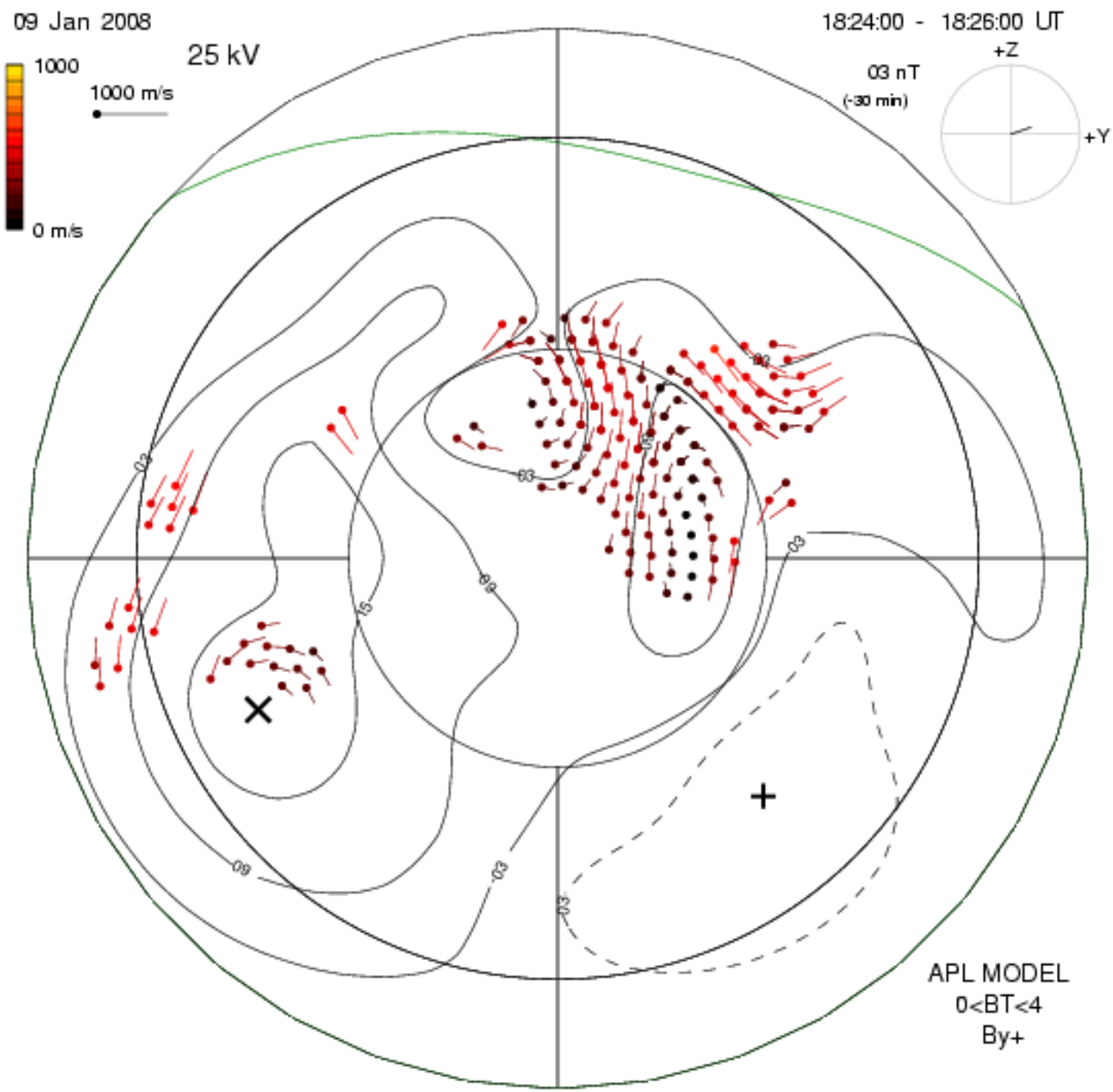

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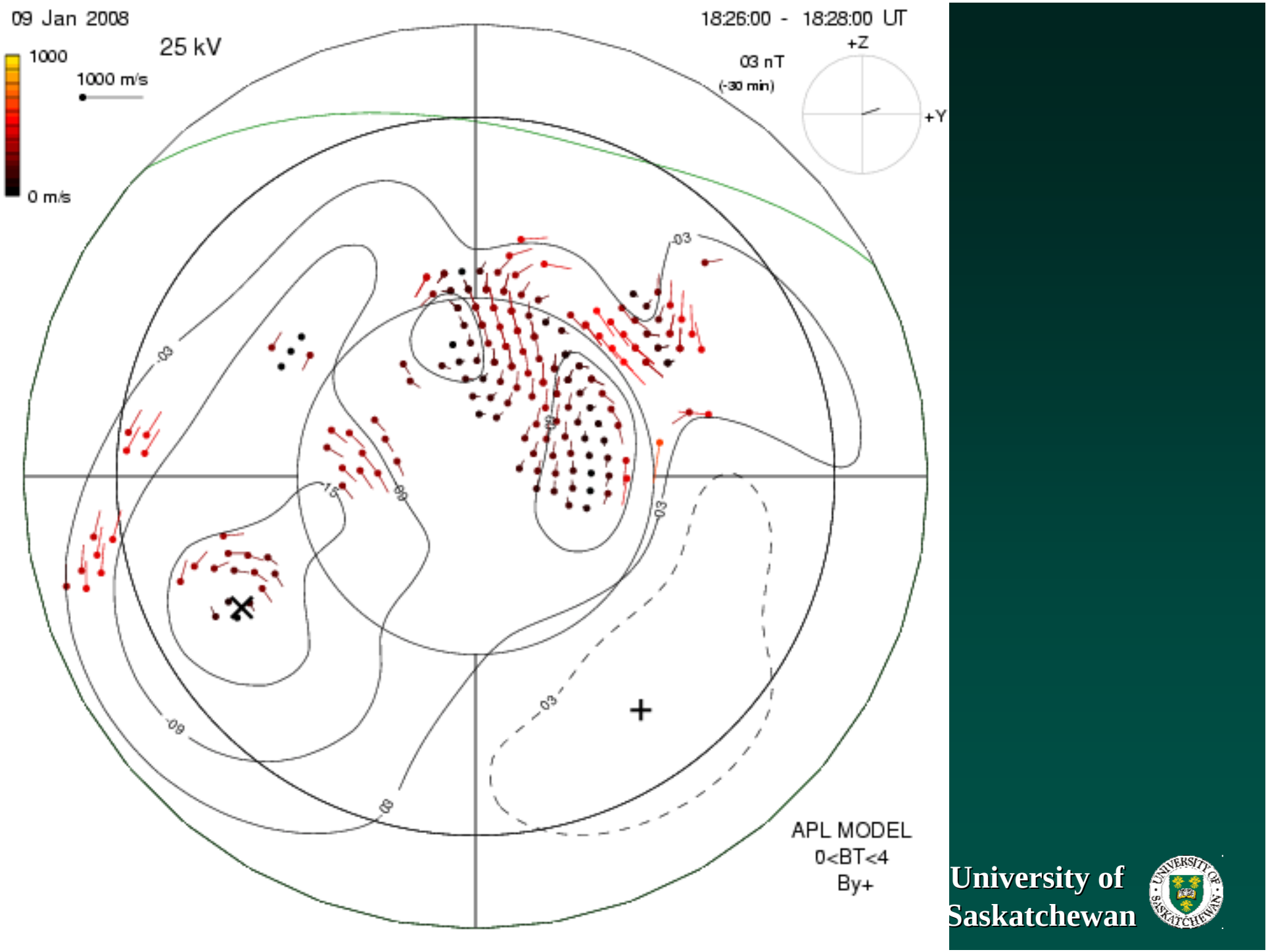
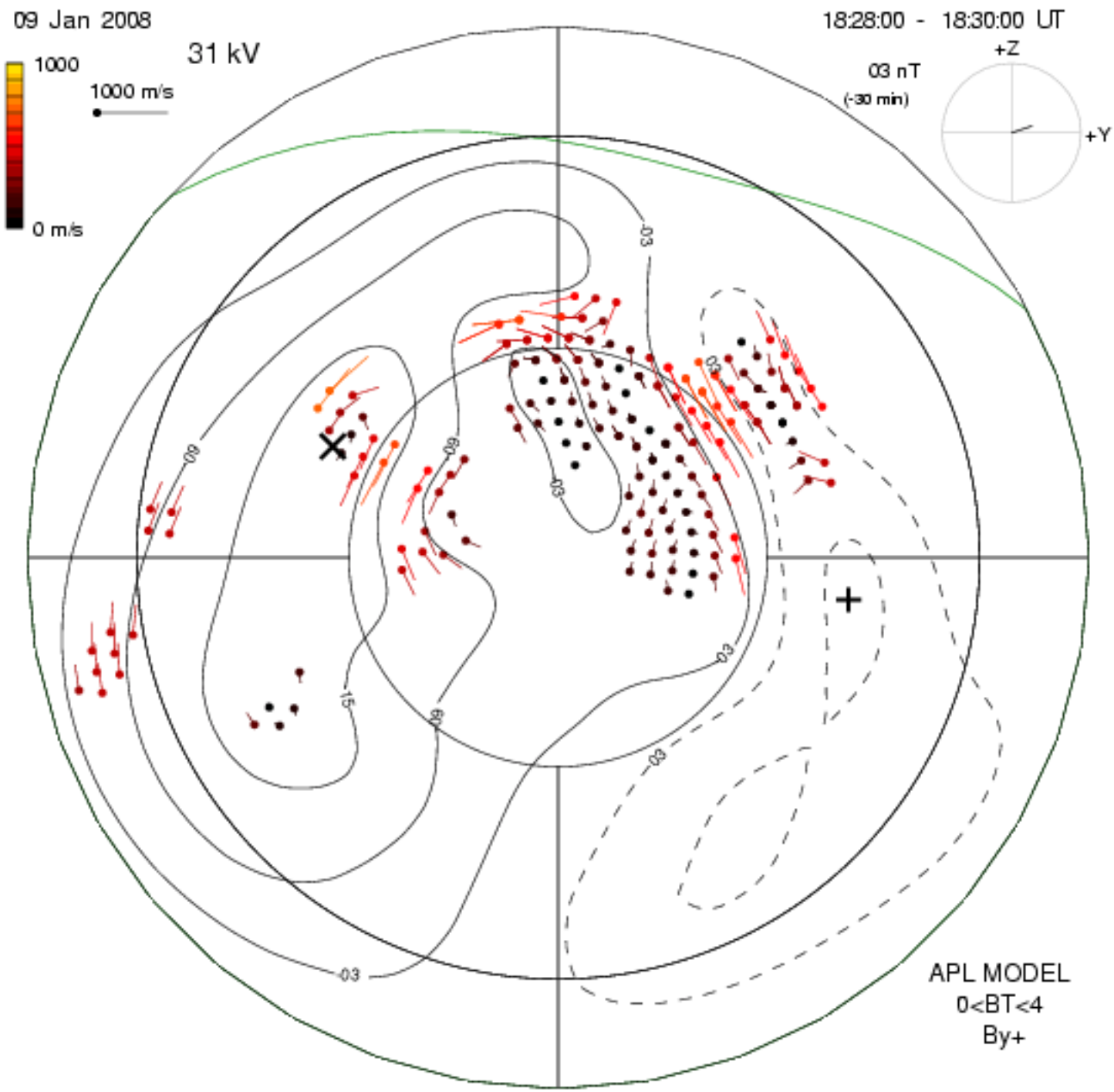

09 Jan 2008
25 kV
1000
1000 m/s
0 m/s
18:26:00 - 18:28:00 UT
+Z
03 nT
(-30 min)
+Y
03
09
15
09
03
03
09
APL MODEL
0<BT<4
By+
University of
Saskatchewan



Only the C-CWSE cell remains. Note the eastward flow sunward of the lobe cell. Both the cell sense and eastward flow are consistent with the change to By- IMF.

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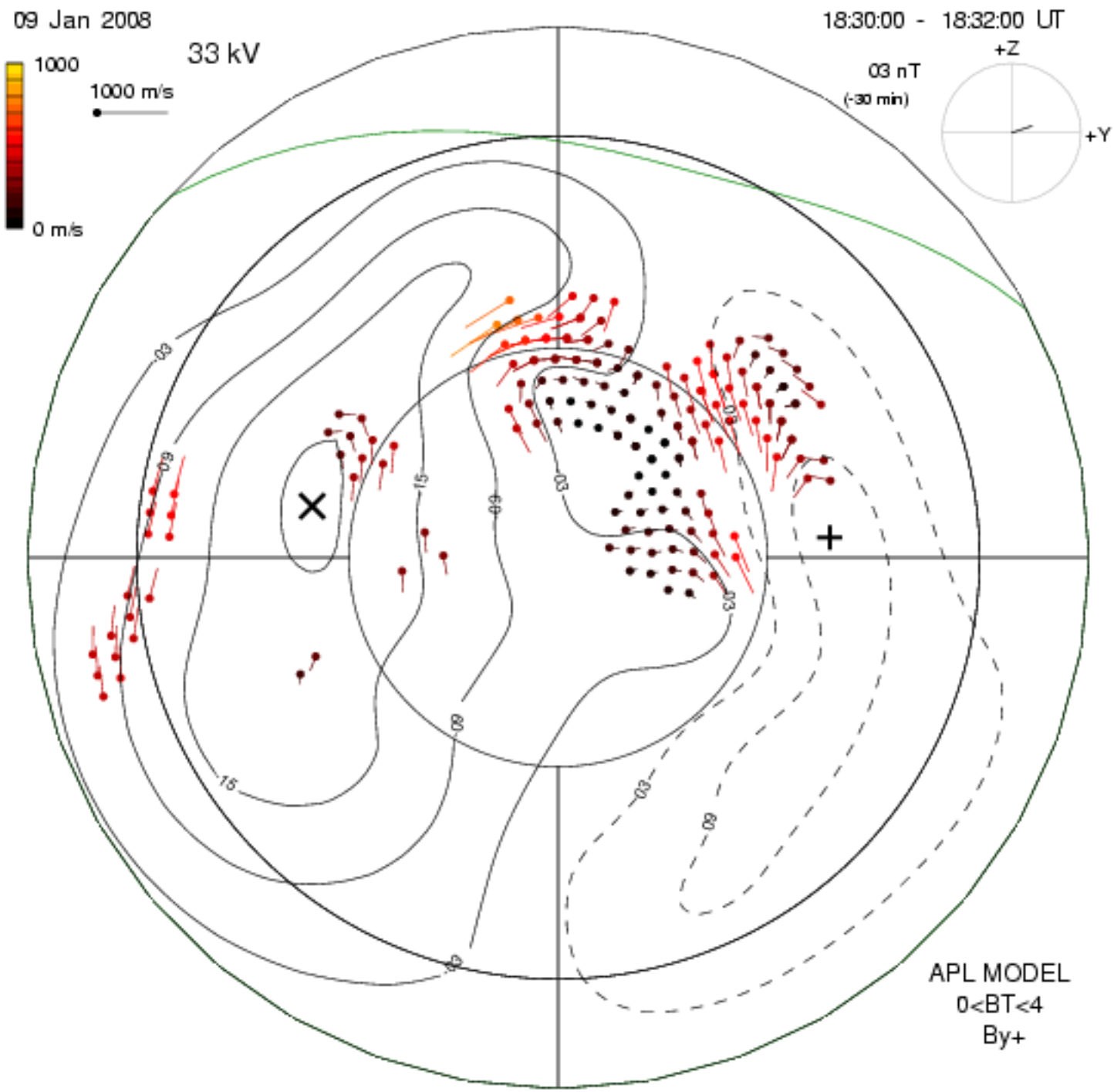

By 1830, the lobe cell structure has gone, ending the rapid 12-minute evolution from single CWSE cell to double cells to a single C-CWSE cell. The polar cap is DYNAMIC!

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Conclusions

- The polar cap is dynamic and shows quite structured flows during Bz+ and By-dominant conditions. The rapid lobe cell evolution on Jan. 09/08 indicates the great sensitivity of the polar cap and adjacent high latitude convection to the solar wind magnitude and direction.
- There is some evidence of strong wavelike activity in the convection patterns near noon, possibly indicating a link to pressure waves/surface waves near the magnetopause.
- The polar cap sensitivity to IMF is an important space weather feature that shows considerable potential for the study of solar variability effects upon climate change (see Scafetta and West, Phys. Today, March 2008)
- Since reconnection leads to different polar cap convection patterns in the two hemispheres, the development of PolarDARN South radars should be strongly considered.

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