Penetration of high latitude ionospheric electric field to the equatorial region: a case study based on SuperDARN Data and the IMech model

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Outline

- Motivation

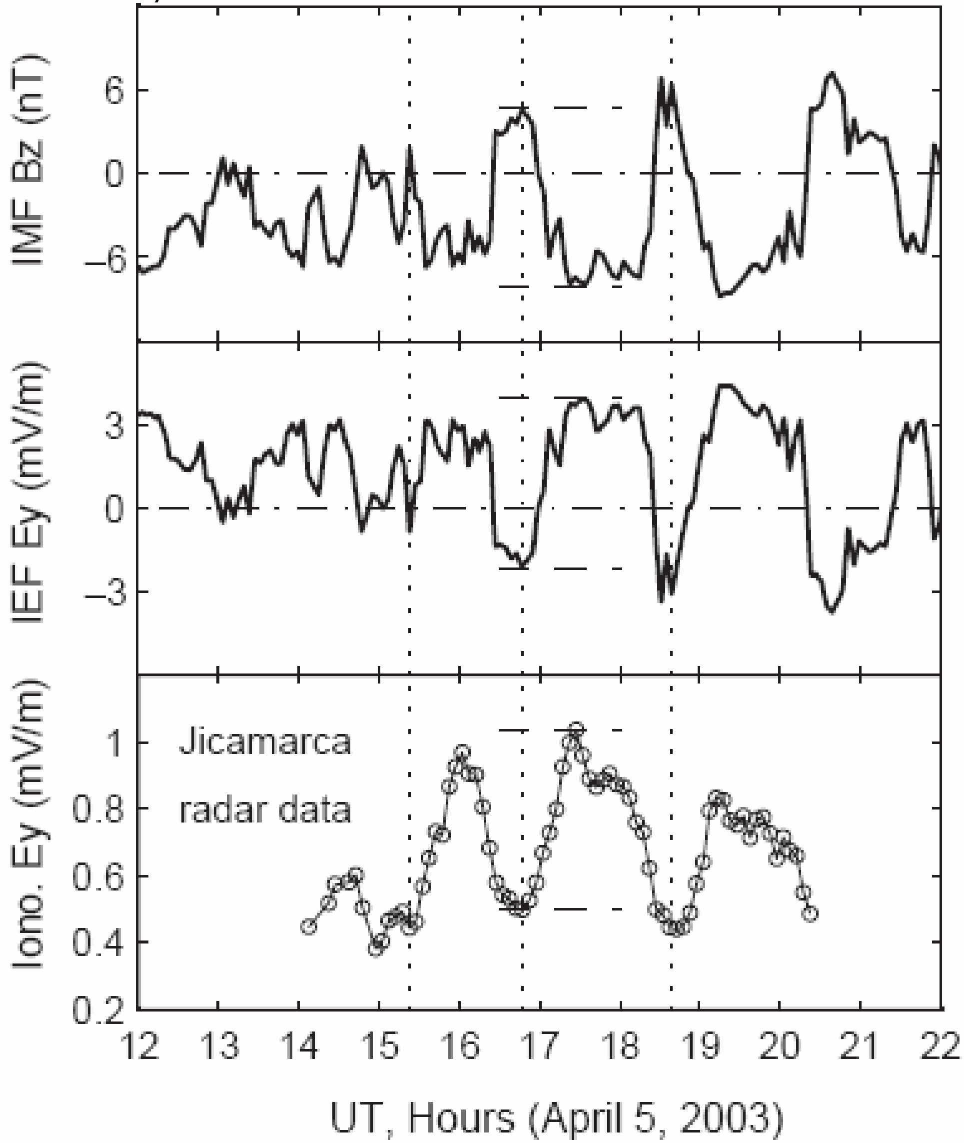
- The IMech model

- The 05 April 2003 event (IMech and SuperDARN)

- Summary

Motivation

Huang et al., *Penetration electric fields: Efficiency and characteristic time scale*, JASTP, **2007**.



Penetration electric fields are the electric fields of solar wind/magnetospheric origin observed equatorward of the shielding layer.

The shielding layer acts to shield regions equatorward of it from the magnetospheric convection electric field and is identified with the inner edge of the plasma sheet/ring current.

The low-latitude ionosphere may be shielded from the high-latitude electric field by the action of the region-2 field-aligned currents under geomagnetically quiet or steady conditions.

During active times, the solar wind/ magnetospheric electric fields can penetrate to the low- latitude ionosphere.

A new potential model for the ionosphere - 1

The correlation between the IMF B_z and the equatorial West-East electric field suggests that one should try to model the penetration of the electric field from the high latitude ionosphere to the equatorial ionosphere.

For this purpose we can make use of SuperDARN data and use its reconstruction of the northern and southern potential as input to a global model of the magnetosphere-ionosphere potential.

The model we have used has been developed at the Institute of Mechanics of the Bulgarian Academy of Sciences (Sofia). The model has been used in the past using as input the Papitashvili and Rich model.

Kartalev, M. D., M. J. Rycroft, V. O. Papitashvili, A quantitative model of the effect of global thunderstorms on the global distribution of ionospheric electrostatic potential, **J. Atmos. Solar Terr. Phys.,** 66, 1233-1240, **2004**.

Rycroft,M. J., M. D. Kartalev, V. O. Papitashvili, V. I. Keremidarska, On the effect of near-equatorial thunderstorms on the global distribution of ionospheric potential., **Adv. Space. Res.,** 35, 1450-1460, **2005**.

Kartalev, M.D. , M.J. Rycroft, M. Fuellekrug, V.O. Papitashvili, V.I. Keremidarska, A possible explanation for the dominant effect of South American thunderstorms on the Carnegie curve, **Journal of Atmospheric and Solar-Terrestrial Physics** 68, 457-468, **2006**.

A new potential model for the ionosphere - 2

Global model, describing the whole global ionospheric conductor including high, middle, low latitudes, and the equatorial region.

- It takes into account the mutual influence between magnetically conjugate points, but **without imposing the same potential at conjugate points**.

- It takes into account in a **self-consistent way** all **basic drivers** of the potential distribution:

  - ✓ Currents with solar wind and magnetosphere origin, acting over both – northern and southern polar regions

  - ✓ Dynamo effects of the thermal and gravitational tides in the thermosphere

  - ✓ Atmospheric electricity effects

A new potential model for the ionosphere - 3

The model starts with initial ionospheric potential distributions in the northern and southern hemisphere.

It then calculates the corresponding FAC distribution.

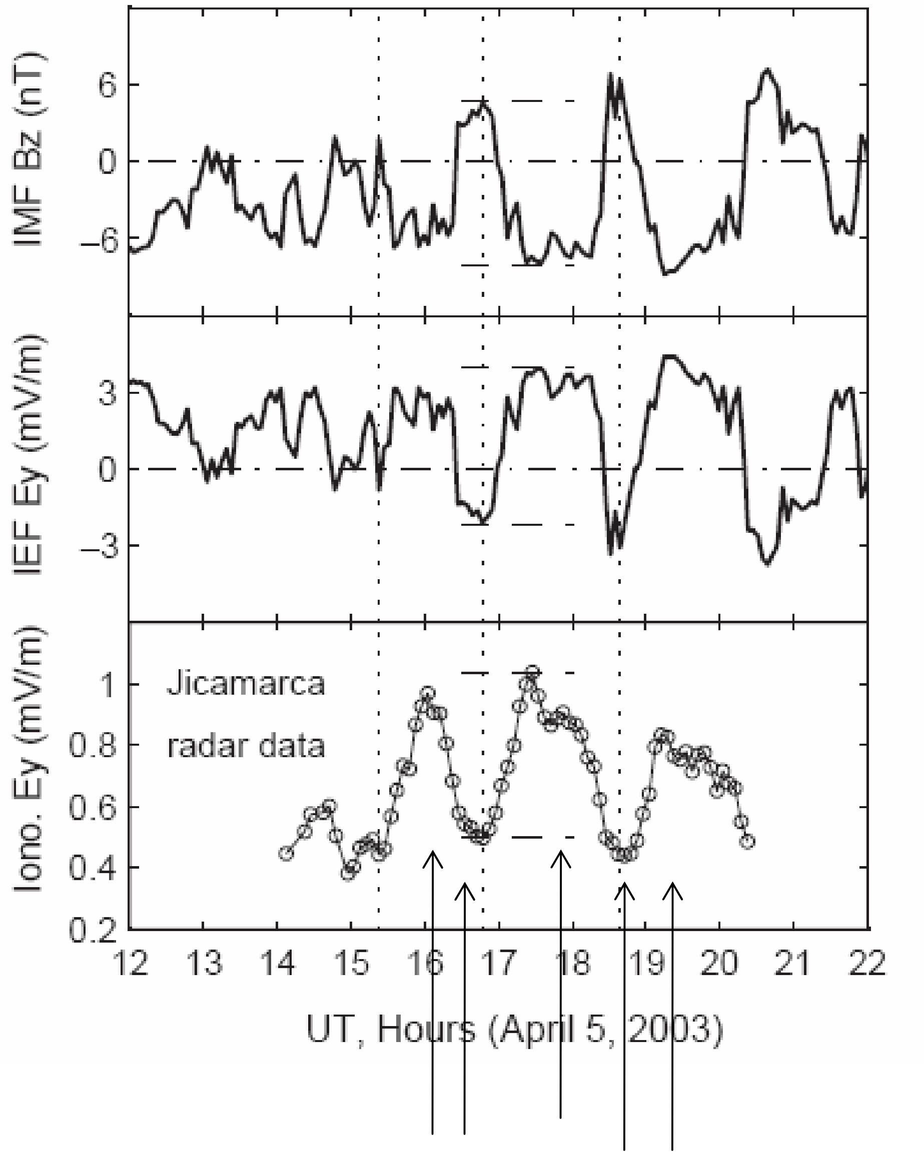
From such distribution it calculates a global distribution of FACs and potentials.

In so doing, the potentials may depart from the initial ones. If this happens, the FACs in each hemisphere are multiplied by appropriate factors.

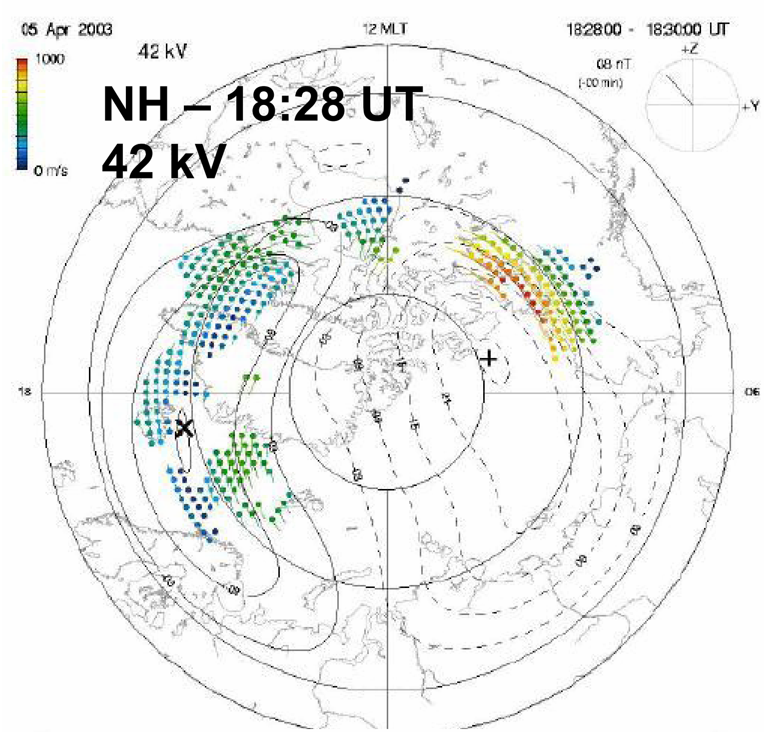
More iterations, if needed.

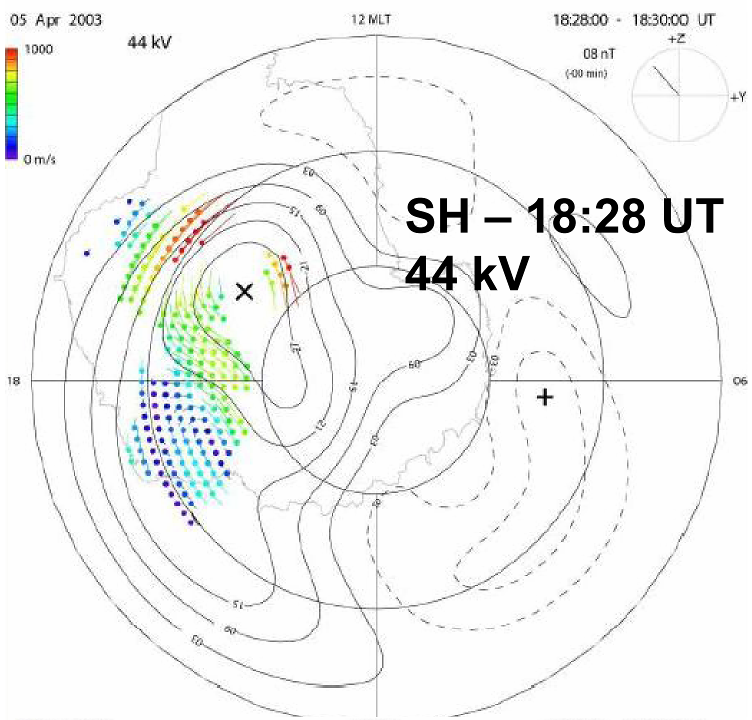
The model makes use of model ionospheric conductivities tuned to the solar conditions, using the sunspot number and $F_{10.7}$ solar radio flux taken from DXLC.com.
In our case we have:
F10.7 flux = 120
Sunspot number = 60

First step.
Calculate SuperDARN northern and southern hemisphere potential maps



Second step.
Run the model at the times of minimum and maximum E_{eq}.

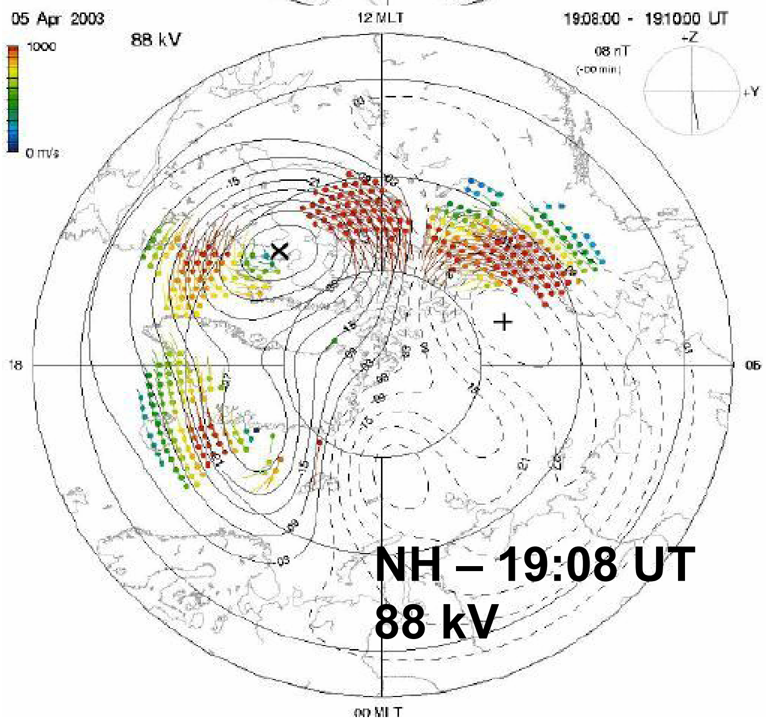


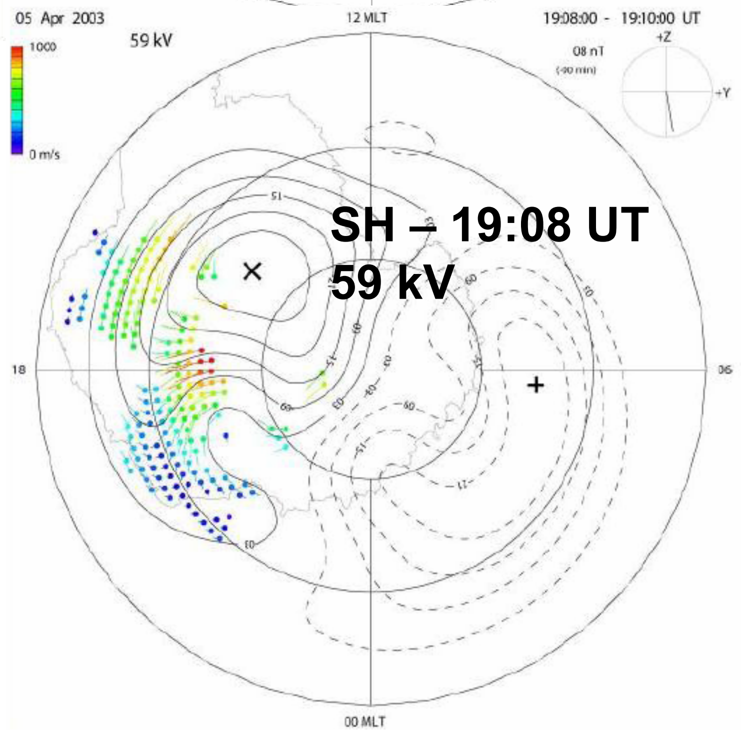


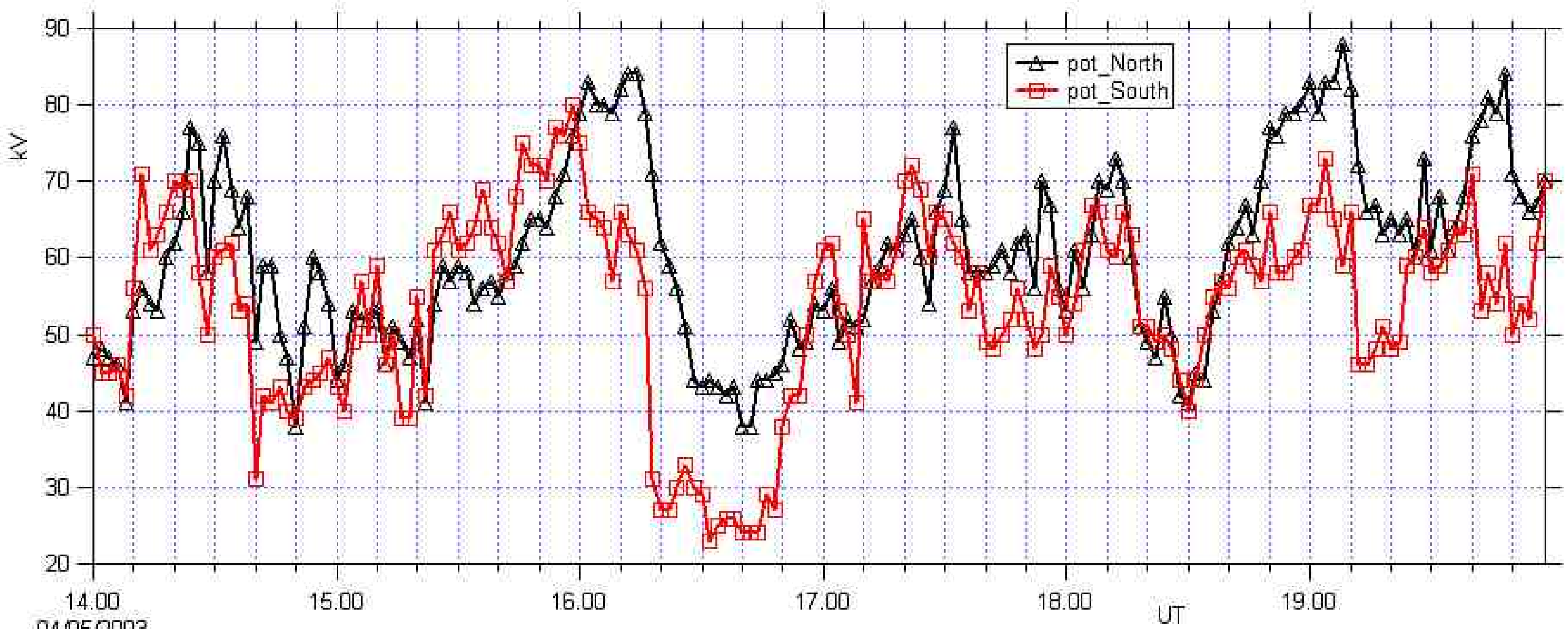
Northward IMF

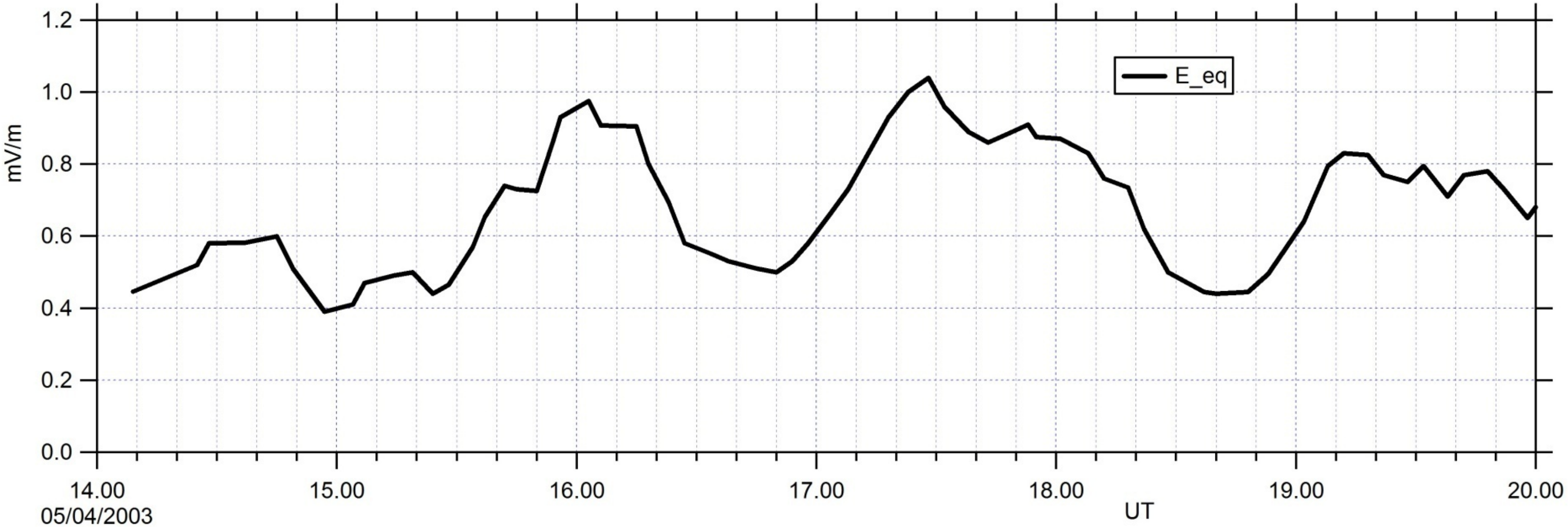
To propagate the IMF to the ionosphere we used the same time shift as Huang et al. (2207).

Southward IMF



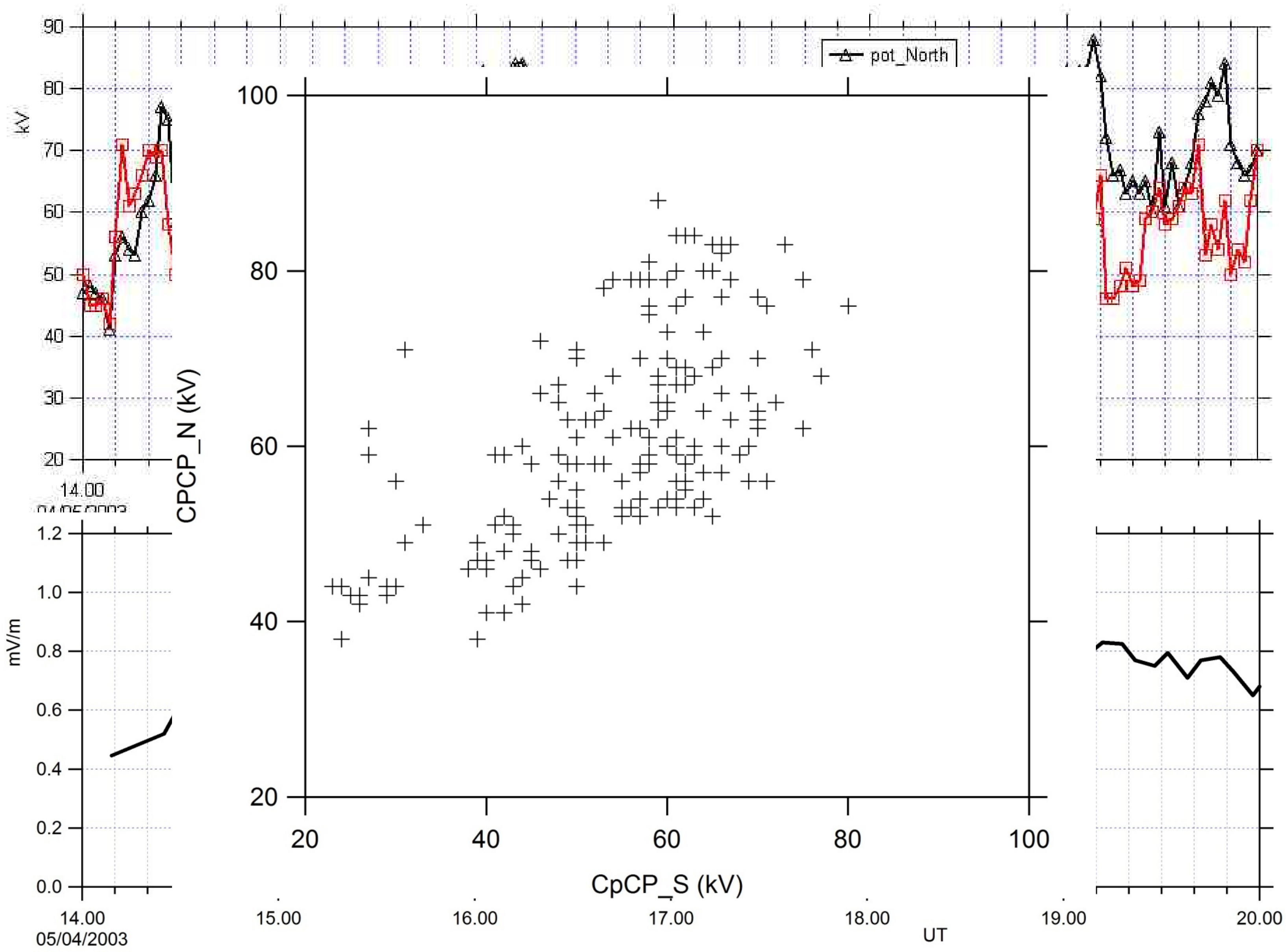






Higher equatorial E in general corresponds to higher CPCP.

Lower equatorial E in general corresponds to lower high latitude CPCP.



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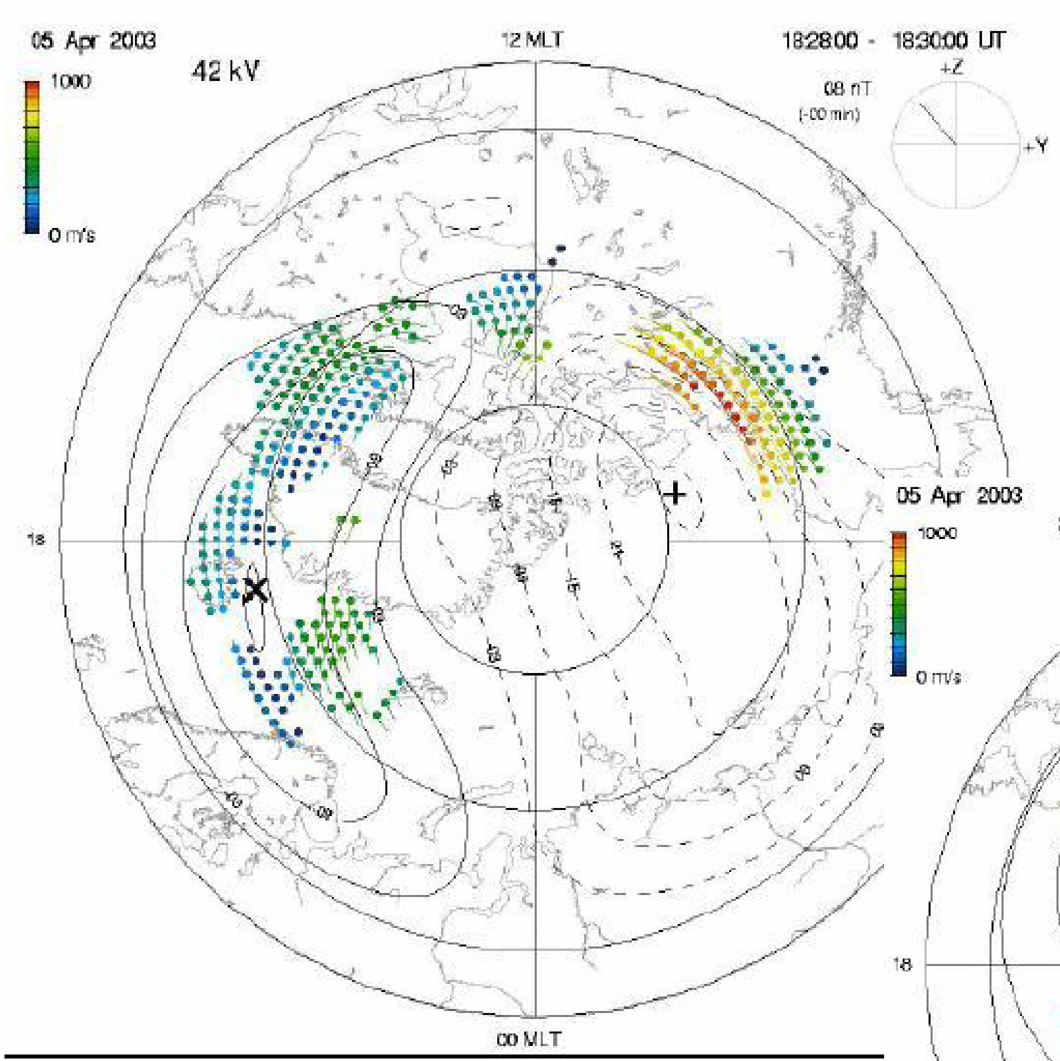
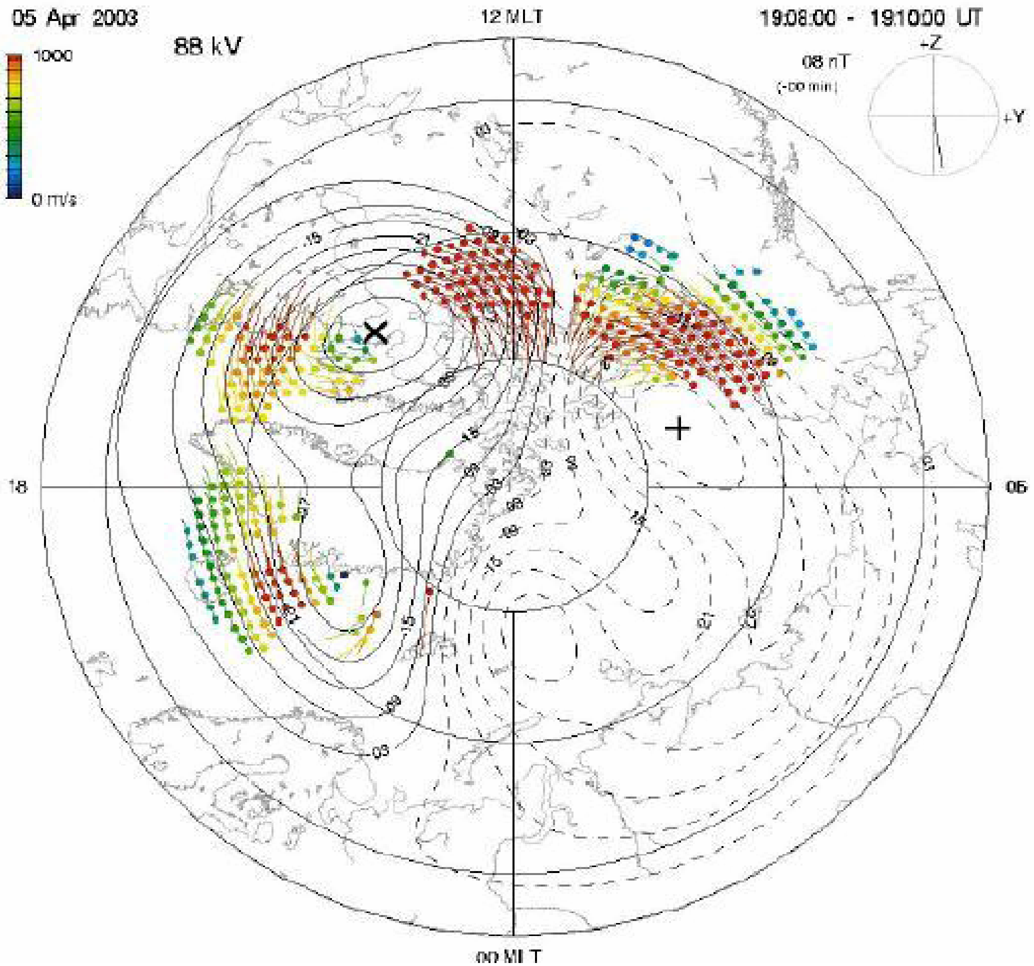
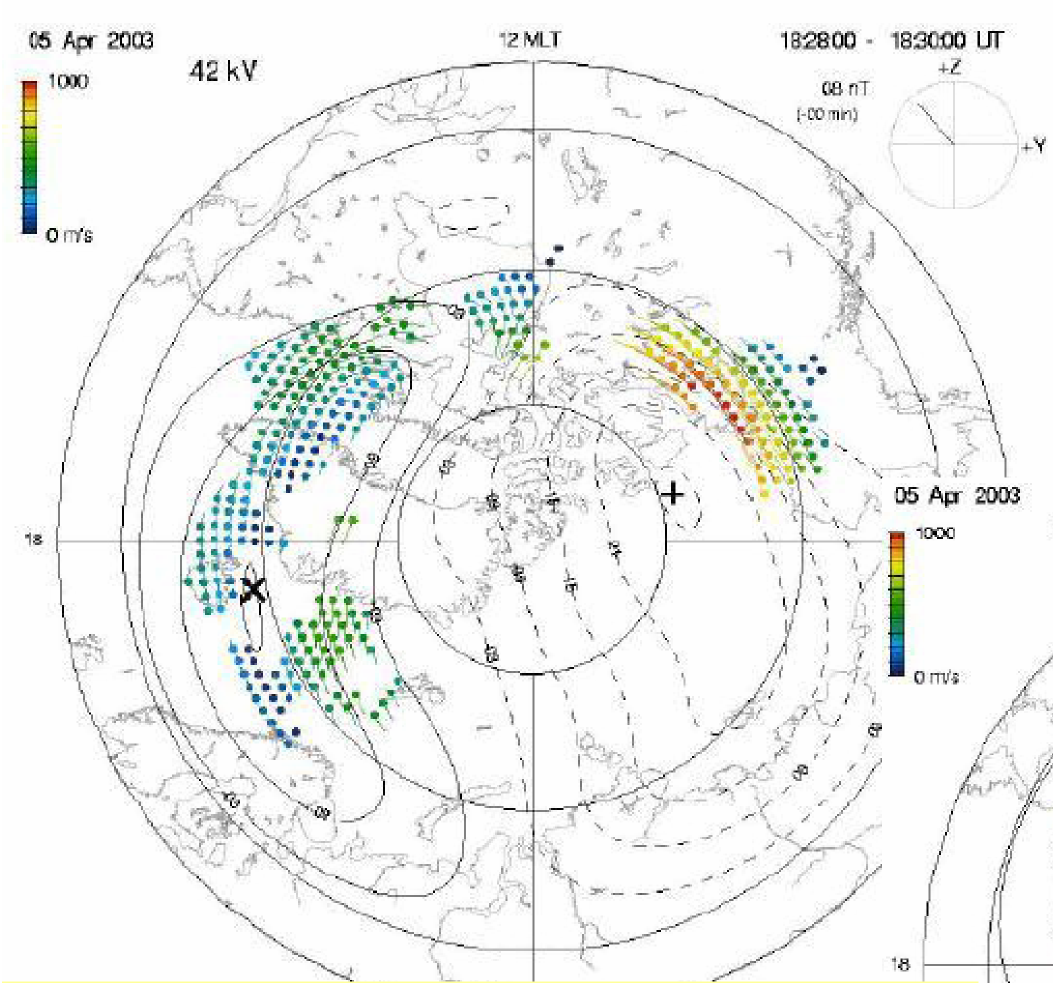


Starting from the SuperDARN potential values in both hemispheres, the global potential for the whole ionosphere has been calculated at 16:02, 16:30, 17.30, 18.30 and at 19:08 UT.





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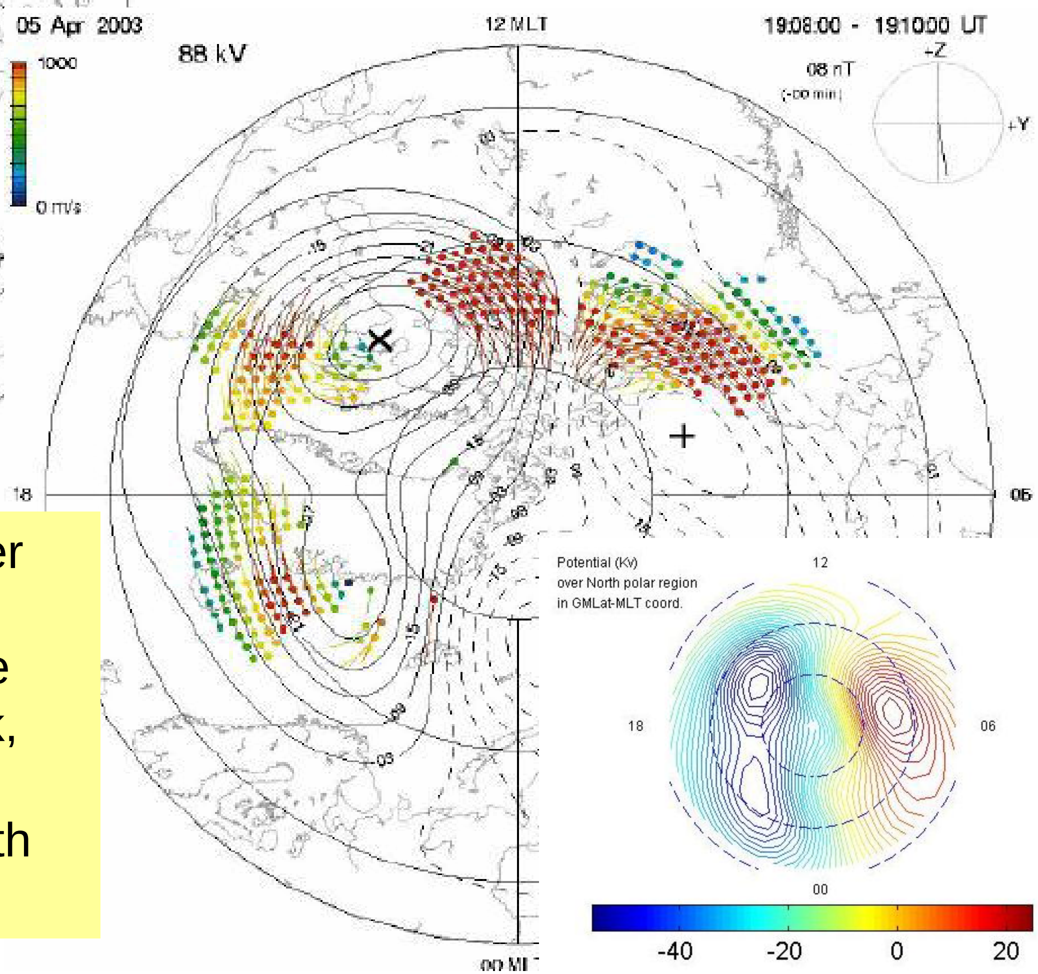
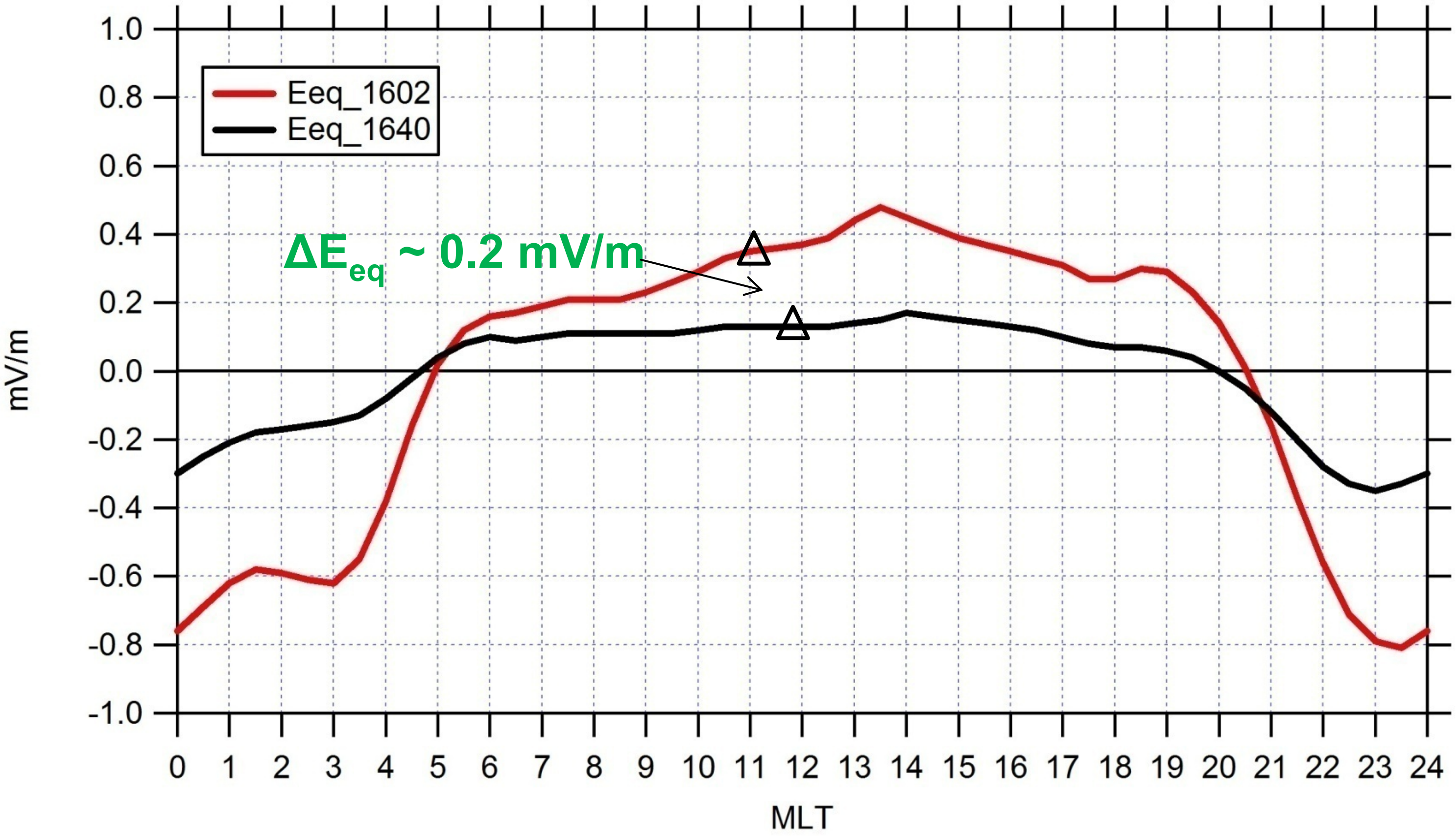
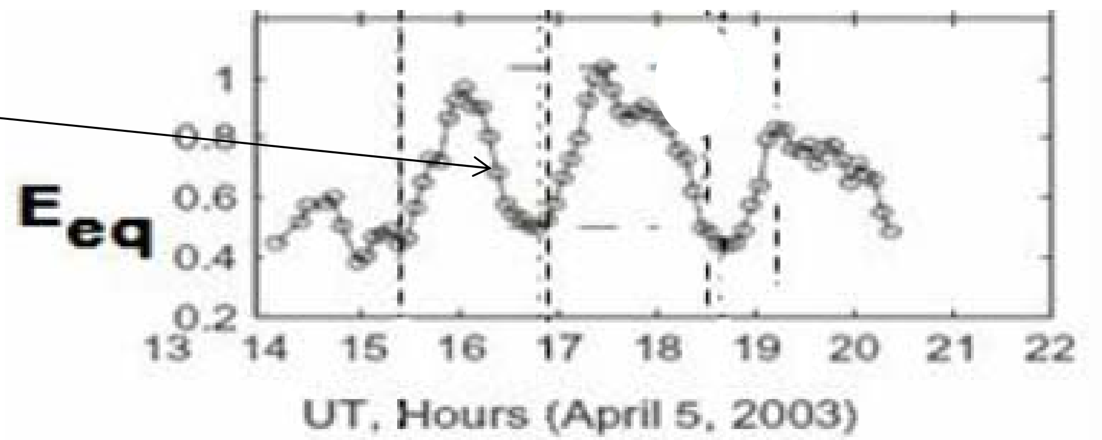
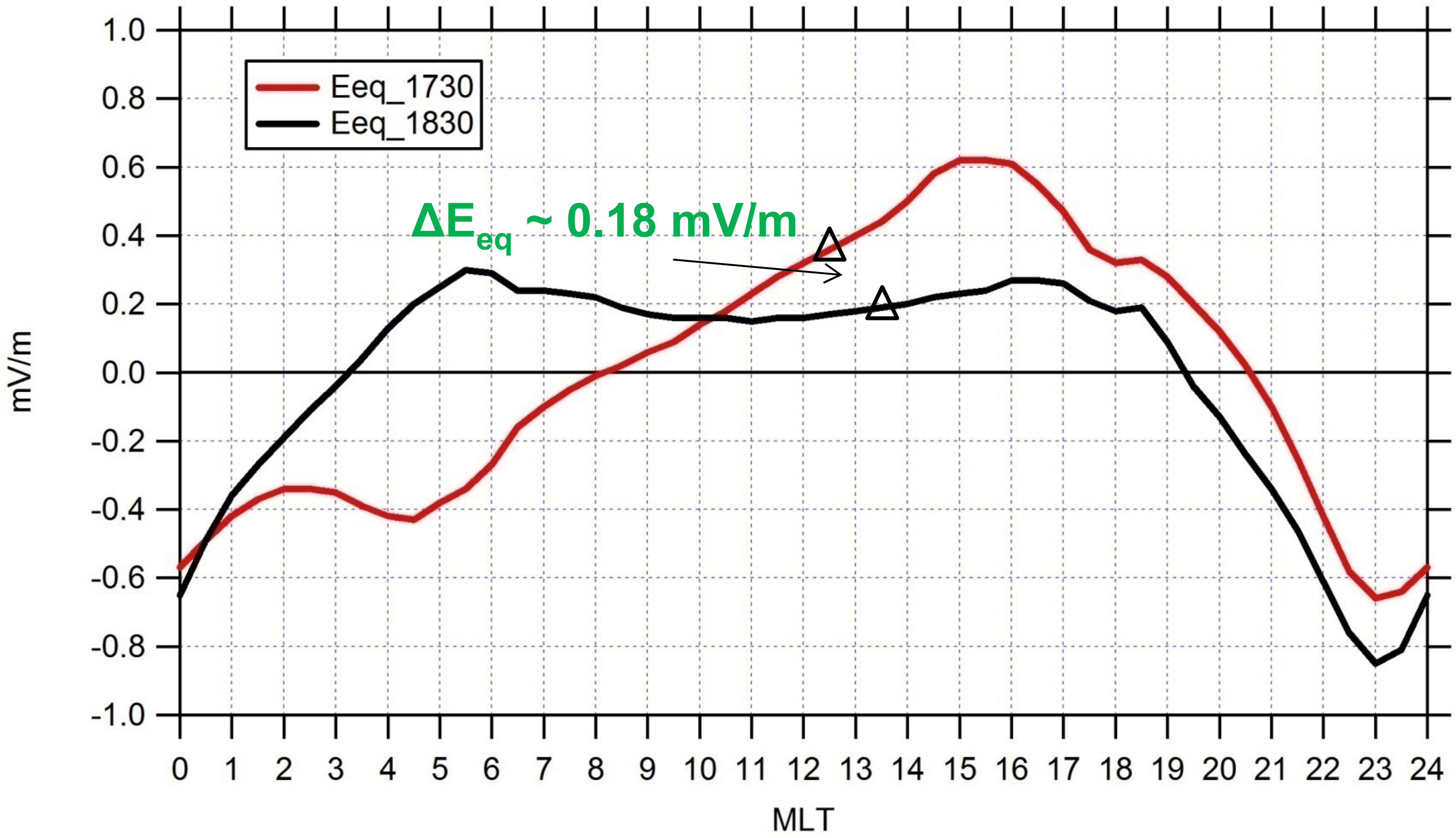


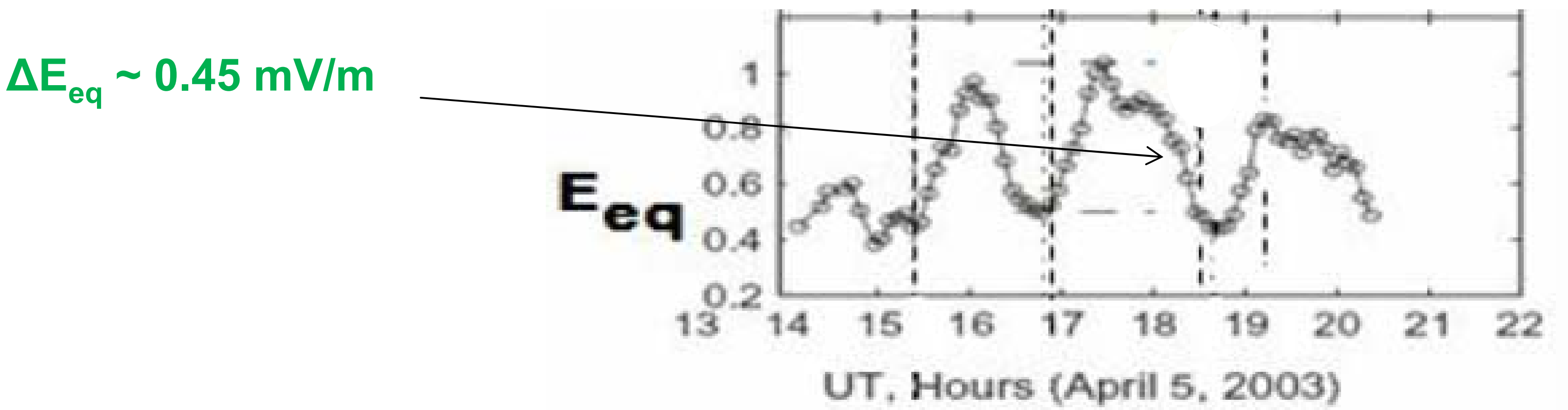
Such calculations have been made under various conditions as regards the field aligned conductivity in order to check the stability of the results. As a further check, the final potential distributions in both hemispheres were visually compared with the initial SuperDARN potential maps.

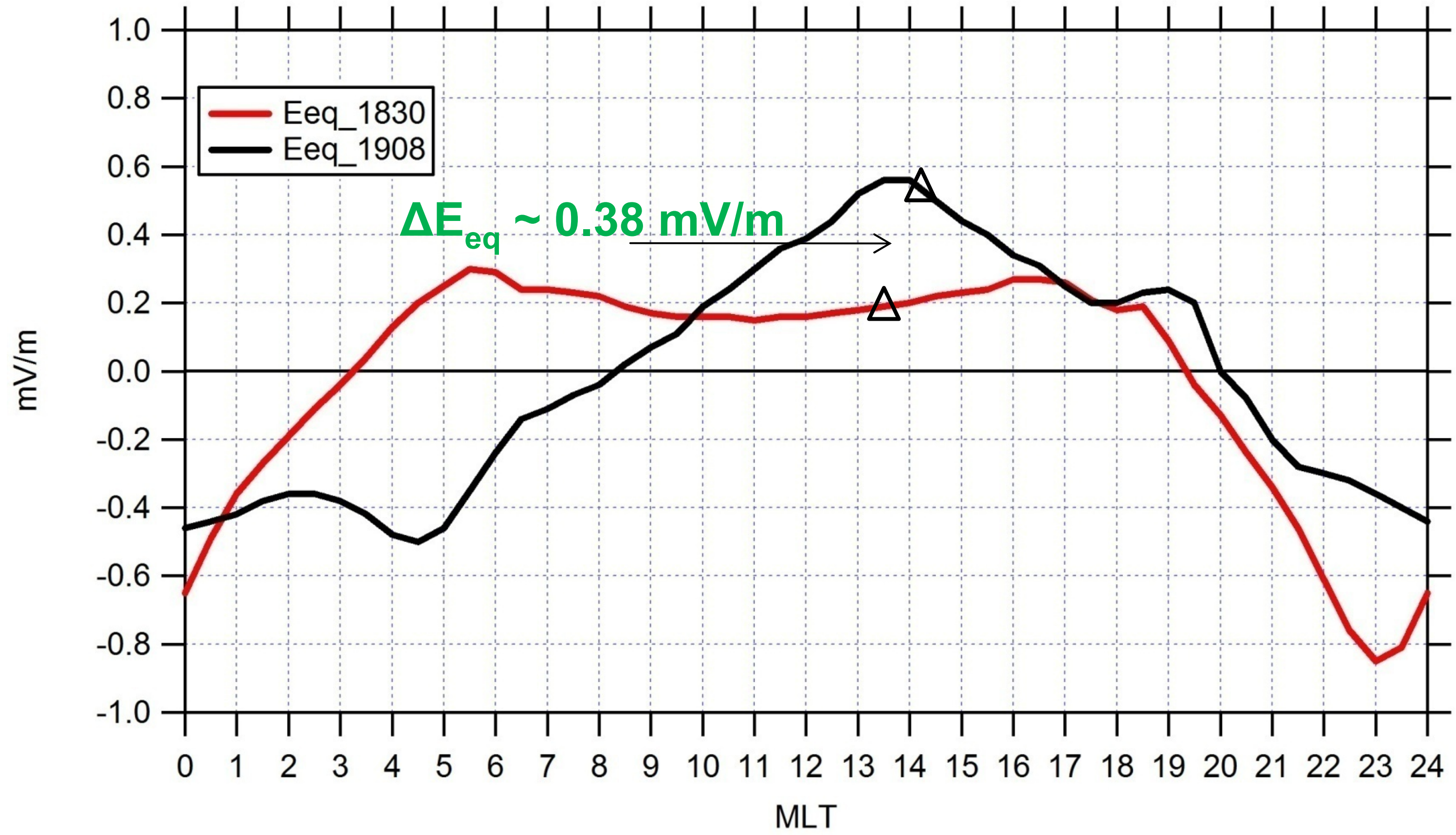


ΔE_eq ~ 0.45 mV/m

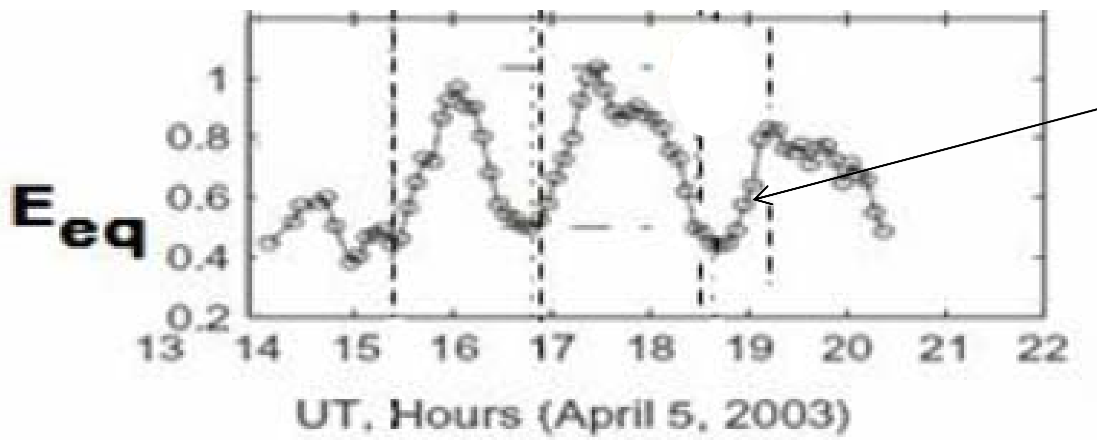



Eeq_1730
Eeq_1830
ΔE_{eq} ~ 0.18 mV/m
mV/m
MLT
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


ΔE_{eq} ~ 0.45 mV/m
E_{eq}
1
0.8
0.6
0.4
0.2
13 14 15 16 17 18 19 20 21 22
UT, Hours (April 5, 2003)



Eeq_1830
Eeq_1908
ΔEeq ~ 0.38 mV/m
mV/m
MLT



Eeq
UT, Hours (April 5, 2003)

ΔE$_{eq}$ ~ 0.4 mV/m

Summary and conclusions

We have used the IMech global model for a case study of penetration electric field (5 April 2003 event).

The model includes both hemispheres and permits inter-hemispheric currents, but does not force the potentials at conjugate points to be equal.

The model may take into account different forcing phenomena: field aligned currents; other current of magnetospheric origin (like those, generated by ring current); currents from the atmospheric electricity

High latitude SuperDARN data have been used as inputs to the model.

The E_y observed at Jicamarca and the modelled West-East ionospheric electric field at the equator show a reasonable agreement.

Thank you