The terrestrial magnetosphere under zero interplanetary magnetic field solar winds

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Motivation

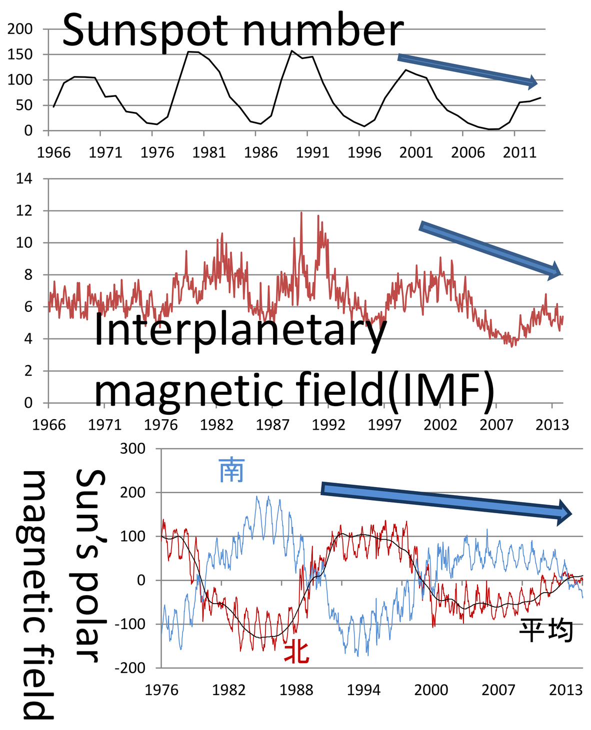
It is considered that during the Maunder Minimum period, the intensity of the solar wind magnetic field was very weak. This study focuses on the response of the terrestrial magnetosphere to near-zero magnetic field solar winds using global magnetohydrodynamics simulation.

The solar wind at the Maunder Minimum

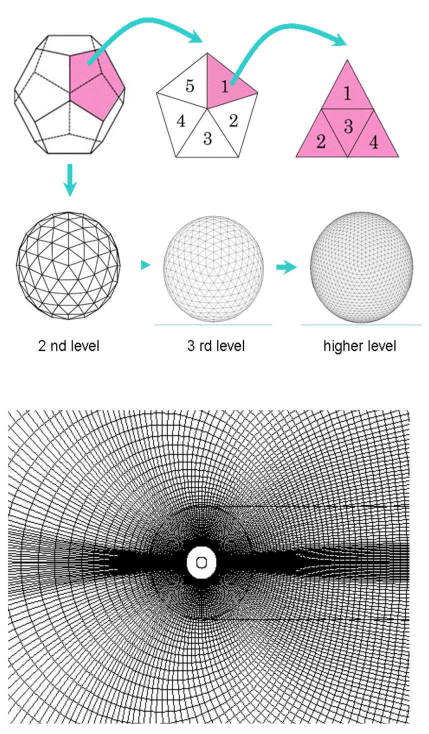
Cliver et al., [1998]
Calculated the solar wind velocity using the relationship between the aa index and the sunspot number V_{SW} ~ 340±50 km/s

Steinhilber et al., [2010]
They have reconstructed the interplanetary magnetic field (IMF) using the solar modulation potential derived from cosmogenic ^{10}Be radionuclide data B_{SW} ~ 2 nT

Wang and Sheeley [2009]
The Sun's polar magnetic field becomes weak with a decrease in the sunspot number, and the IMF becomes weak with the weakening of the Sun's polar magnetic field.



Method REPPU (REProduce Plasma Universe)code developed by T. Tanaka

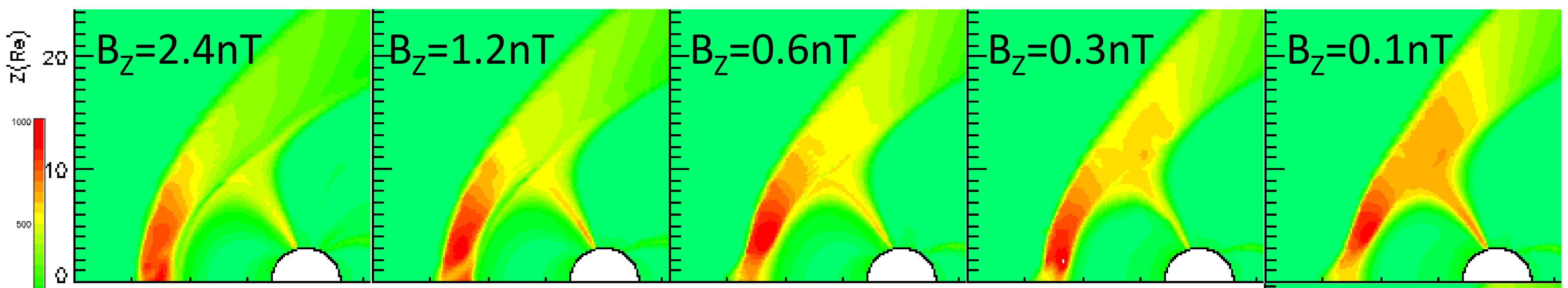


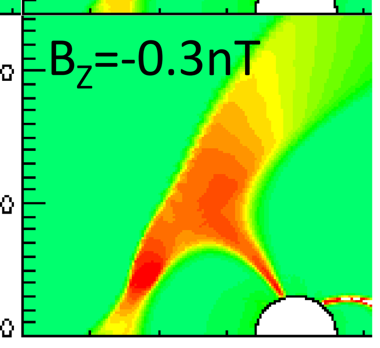
*Scheme : finite volume TVD scheme
*Grid system : The regular dodecahedron is divided into triangles
*mpi-omp hybrid parallel computing
*number of grids : level6 $(12\times5\times4^{6-1})\times240$
triangles : 61440
total number of grids : 30722
*inner boundary : 3.0Re
*outer boundary : -39Re → 200Re
*M-I Projection
Magnetosphere to Ionosphere : $J_{//}=\nabla\cdot(\Sigma\nabla\Phi)$
Ionosphere to magnetosphere : $\nabla\Phi=-\boldsymbol{v}\times\boldsymbol{B}$

Solar wind

	RUN1	RUN2	RUN3	RUN4	RUN5	RUN6
B_X	2.4 nT	1.2 nT	0.6 nT	0.3 nT	0.1 nT	0.3 nT
B_Y	-2.4 nT	-1.2 nT	-0.6 nT	-0.3 nT	-0.1 nT	-0.3 nT
B_Z	2.4 nT	1.2 nT	0.6 nT	0.3 nT	0.1 nT	-0.3 nT
Density	5 /cc					
Velocity	372 km/s					
Pressure	14.07 pPa					
Tempereture	1.0×10^6 K					

Color contour : cusp pressure   Noon-midnight meridian plane



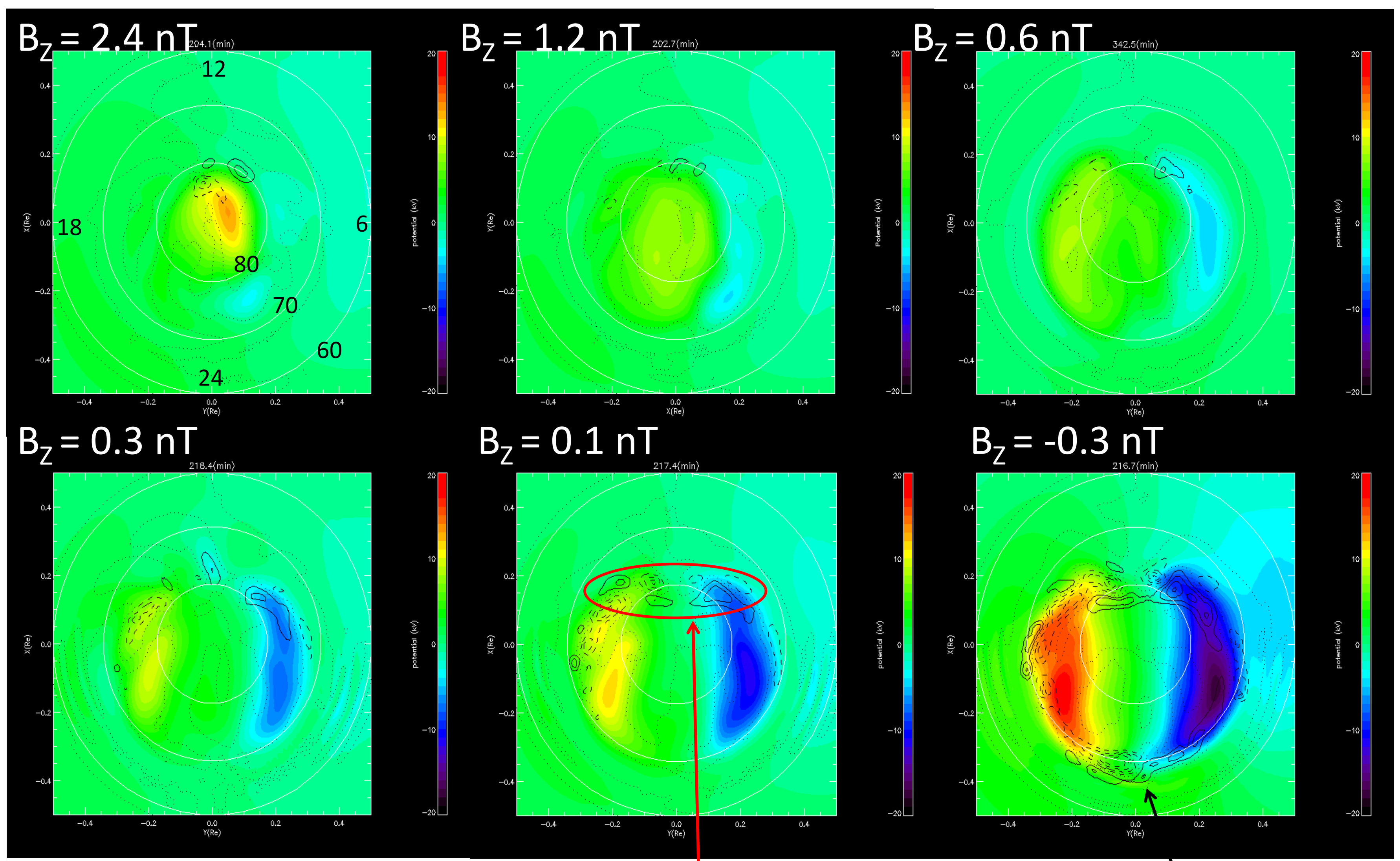


The cusp pressure increases with decreasing IMF intensity.

Dayside FACs become stronger.
Φ_{PC} also becomes stronger.

Result

Color contour :Cross polar cap potential
Black line : Field-aligned current



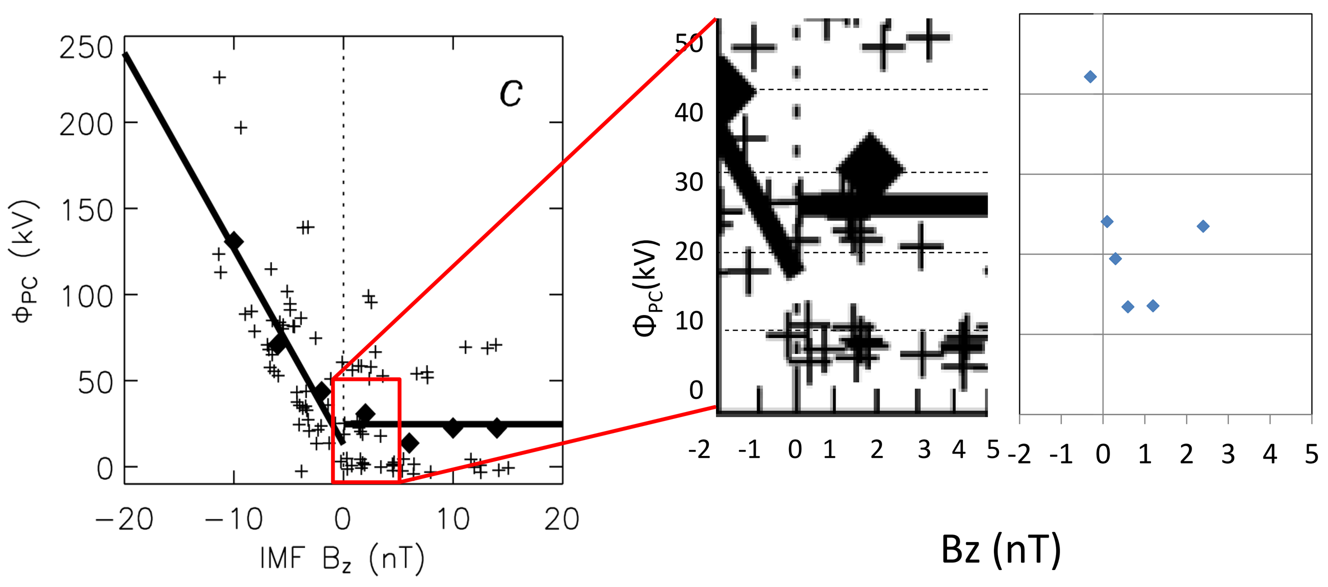
Solid line : upward FAC
Dotted line : downward FAC

Dayside FACs strengthen.

When the IMF directed southward, nightside FACs strengthen.

IMF B_Z - Φ_{PC}

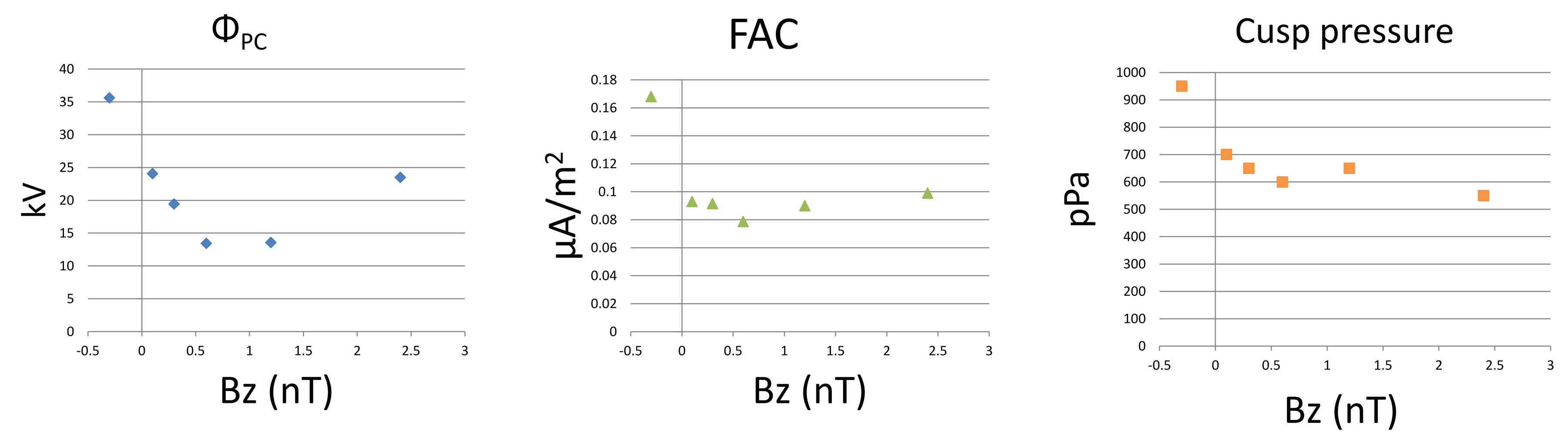
Observation



Simulation

[Milan et al., 2004]
+ : Observational data ◆ : Binned ±2nT,Φ_{PC}
Solid line (B_Z > 0) : average of Φ_{PC} for northward IMF
Solid line (B_Z < 0) : least mean square of Φ_{PC} for southward IMF

Φ_{PC}, FACs and the cusp pressure become stronger when the IMF becomes weaker.

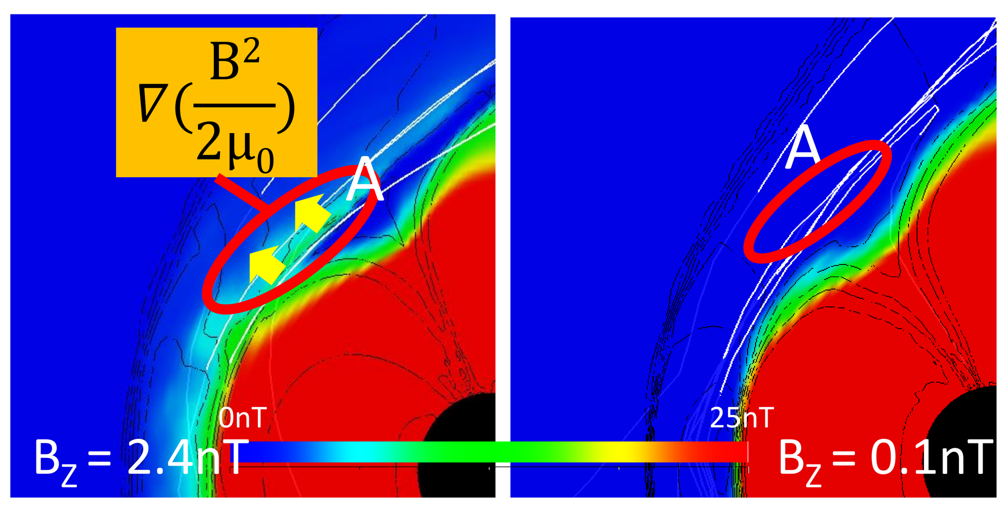


Discussion

1. High magnetic pressure region A diminishes with decreasing IMF intensity. Plasmas can easily intrude into the cusp.
2. The cusp pressure and the pressure gradient become stronger.
3. Diamagnetic currents become stronger.

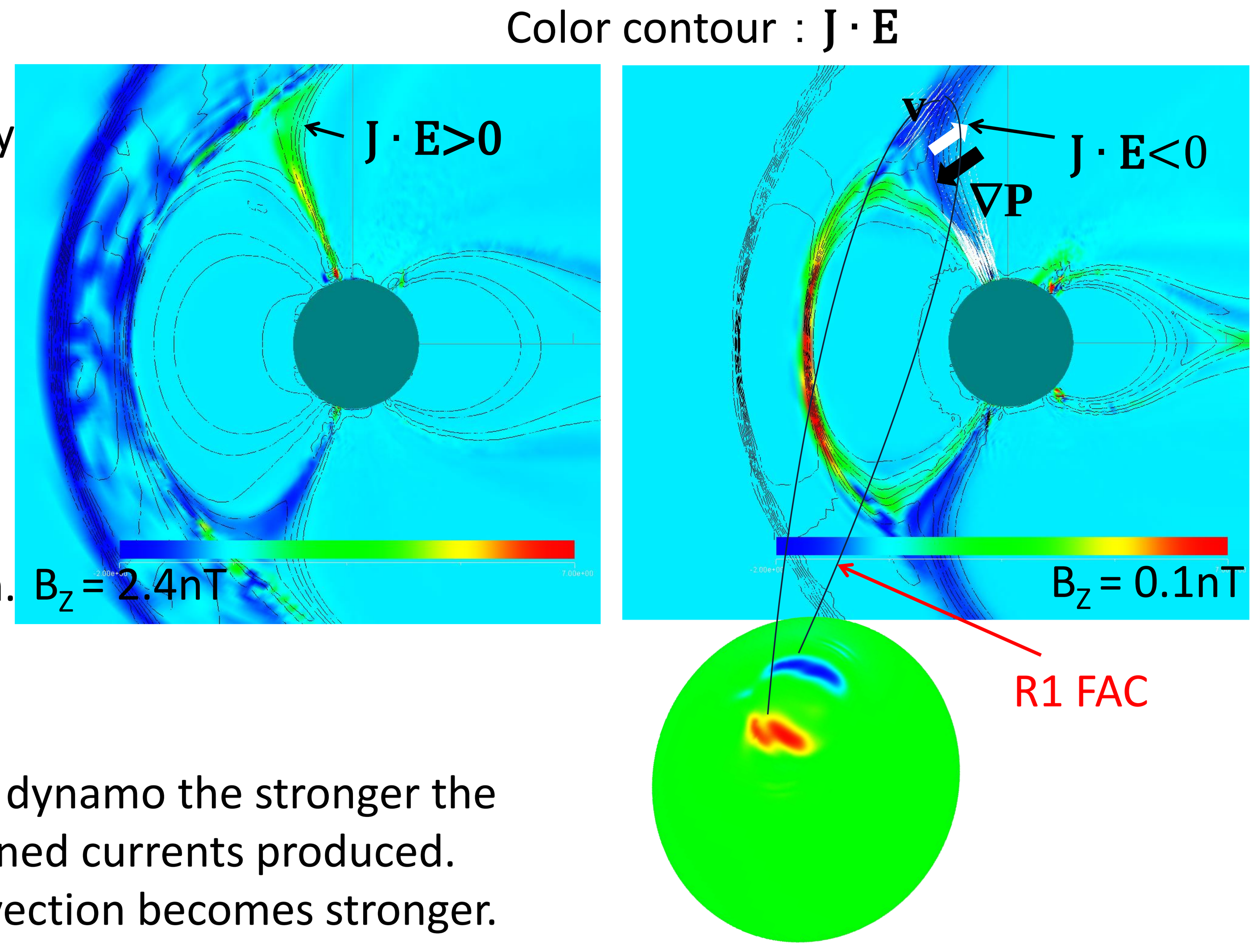
$$J=\frac{\mathbf{B}\times\nabla P}{B^2}$$

Color contour : $|\mathbf{B}|$



Color contour : $\mathbf{J}\cdot\mathbf{E}$

4. At the high latitude boundary of the cusp, plasmas move against the Lorentz force.
5. That opposing motion makes a dynamo region.



$\mathbf{J}\cdot\mathbf{E}<0$

6. The stronger the dynamo the stronger the dayside field aligned currents produced.
7. Ionospheric convection becomes stronger.

Conclusion

・It is found that the FACs and the cross polar cap potential in the ionosphere increase with decreasing IMF intensity.
・At the same time the pressure of the cusp increases in the magnetosphere.
・At the boundary between the magnetosheath and the cusp region, the magnetic pressure is weak when the IMF is weak. So, the weak shielding from the magnetosheath plasma entry leads to an increase of the cusp pressure.
・Increasing of the cusp pressure produces a dynamo region near the high-latitude boundary region. The stronger the dynamo, the stronger the FACs and convection.
・The result mentioned above is different from Dungey-'s reconnection picture(1961) and Axford and Hines' viscous interaction picture (1961).

Future work

To compare simulation results with observations of high latitude ionospheric convection derived from superDARN data.