Magnetosphere is dynamic. This makes magnetic field mapping complicated.

1. Inductive electric fields => magnetic field-lines are not equipotential.
2. Delays exist between ionospheric and magnetospheric convection signatures due to wave propagation time.
3. Magnetic field topology can be very complicated due to dynamic effects (not mentioning IMF By/Bx effects)
   - Thin current sheets, stretched tails
   - Flux-ropes

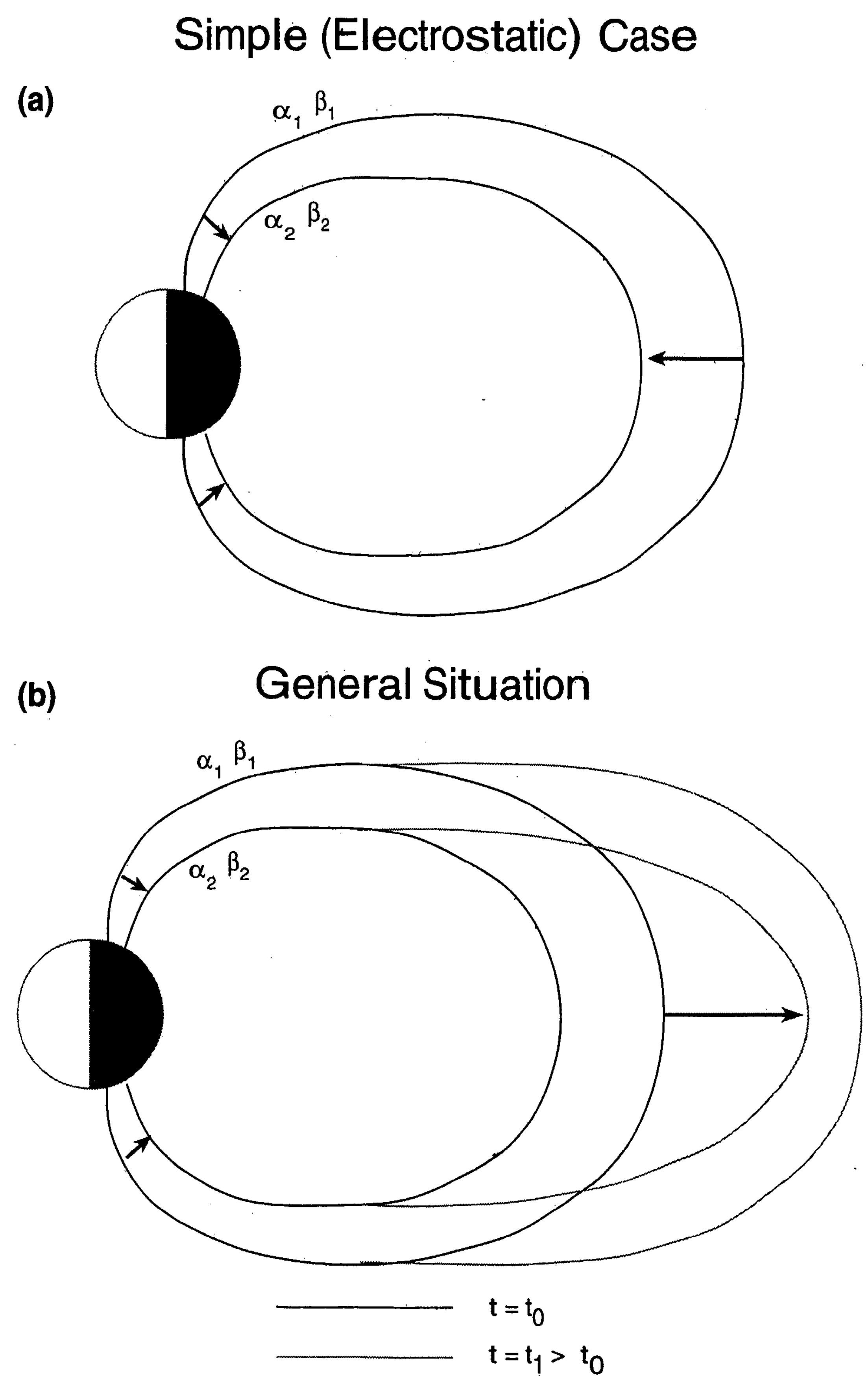
1) Magnetic field lines are not equipotential in ideal MHD, except in steady state:

$$\mathbf{E} \cdot \mathbf{B} = 0$$

$$\mathbf{B} \cdot \nabla \Phi = -\mathbf{B} \cdot \frac{\partial \mathbf{A}}{\partial t}$$

This means that, strictly speaking, earthward motion in the tail does not necessarily imply equatorward motion in the ionosphere.

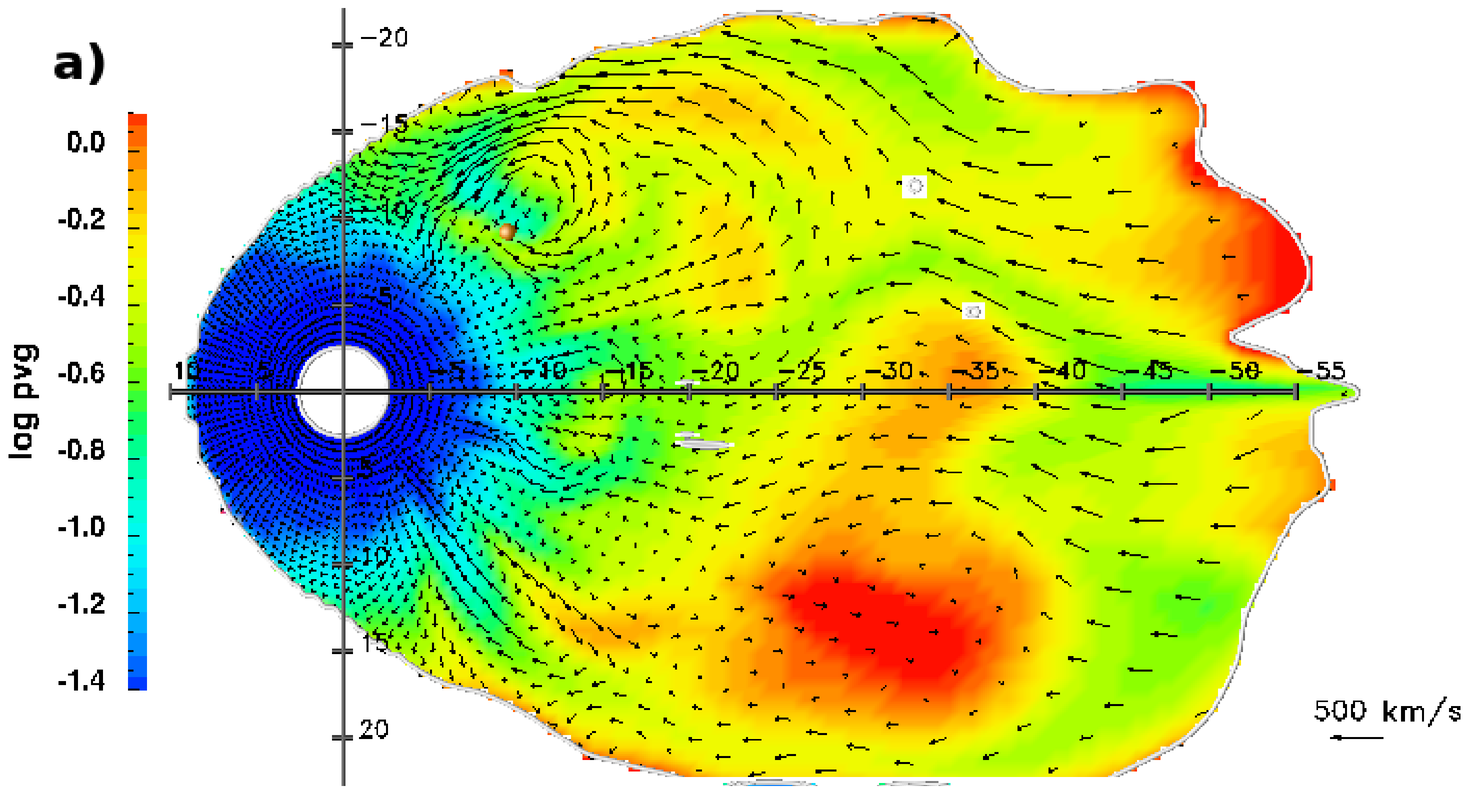
Quasi-stationarity maybe a good assumption for the inner magnetosphere, but one has to be cautious in the tail (e.g. during substorms, high-speed flows, etc.)

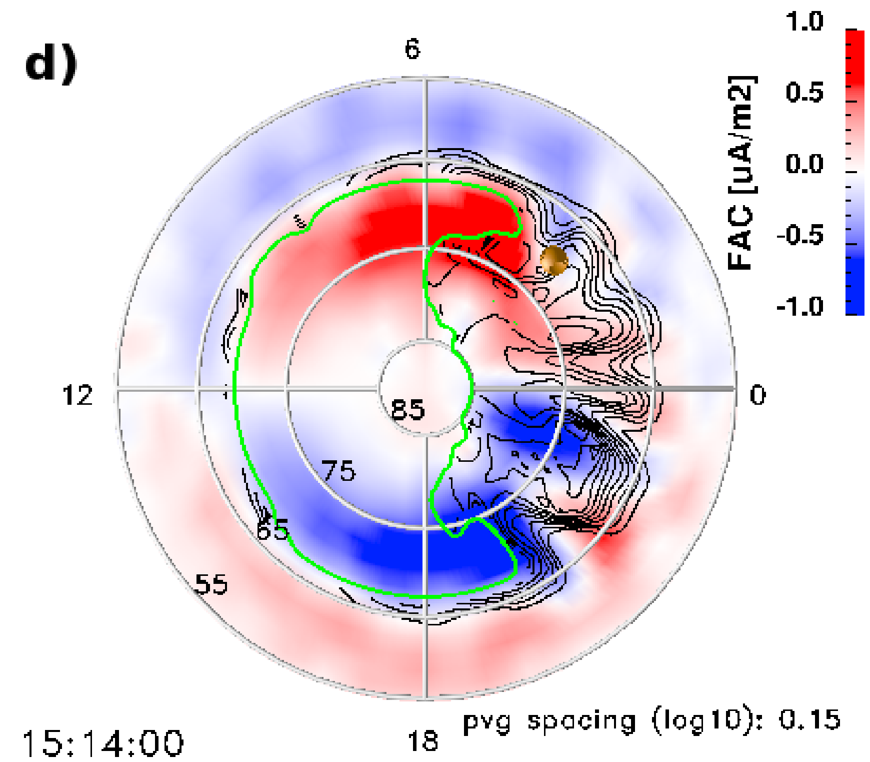


Hesse, Birn, & Hoffman, JGR, (1997)

2) Ionospheric response is delayed due to Alfven travel time.

Pembroke et al, submitted to JGR, (2011)

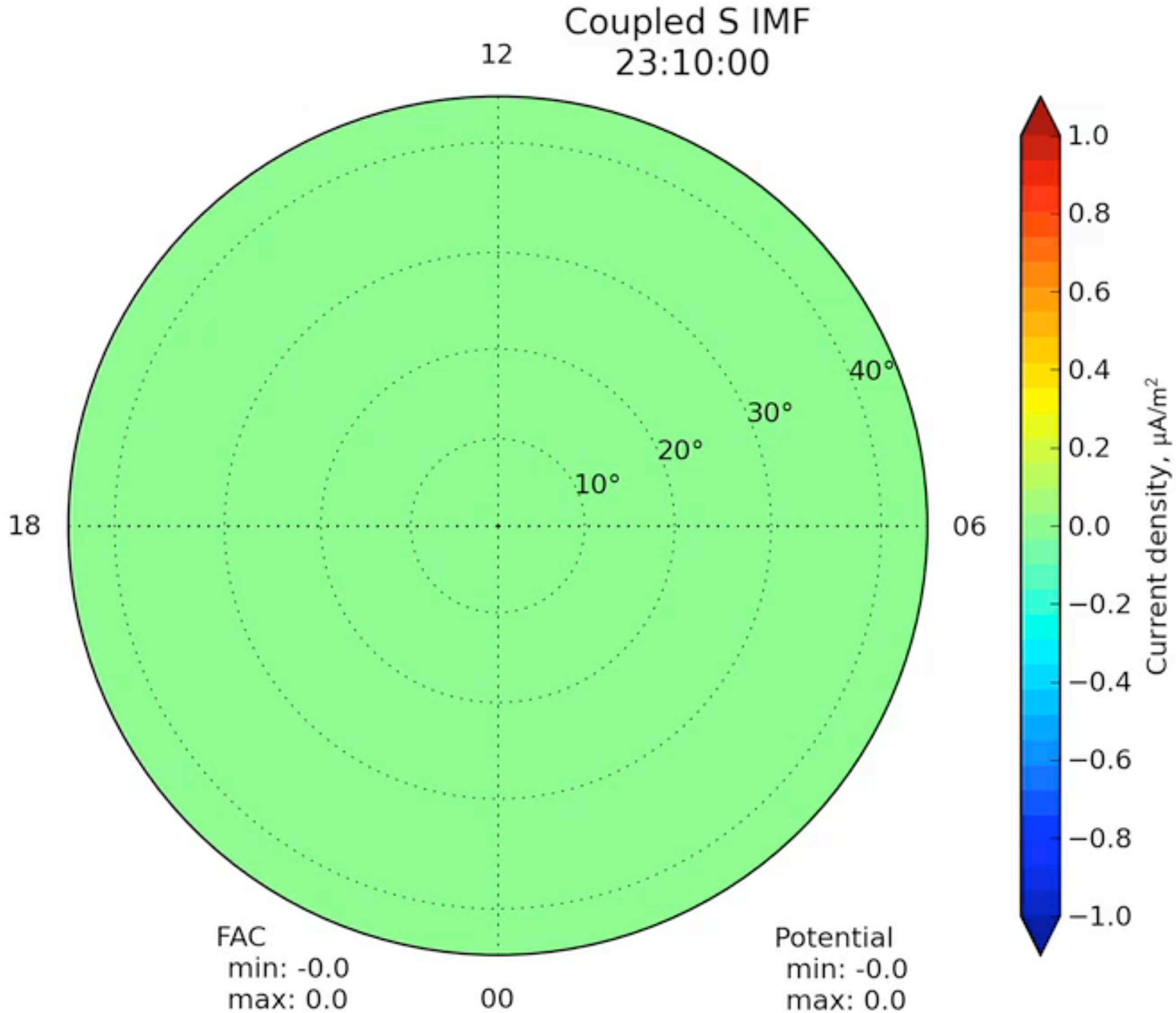




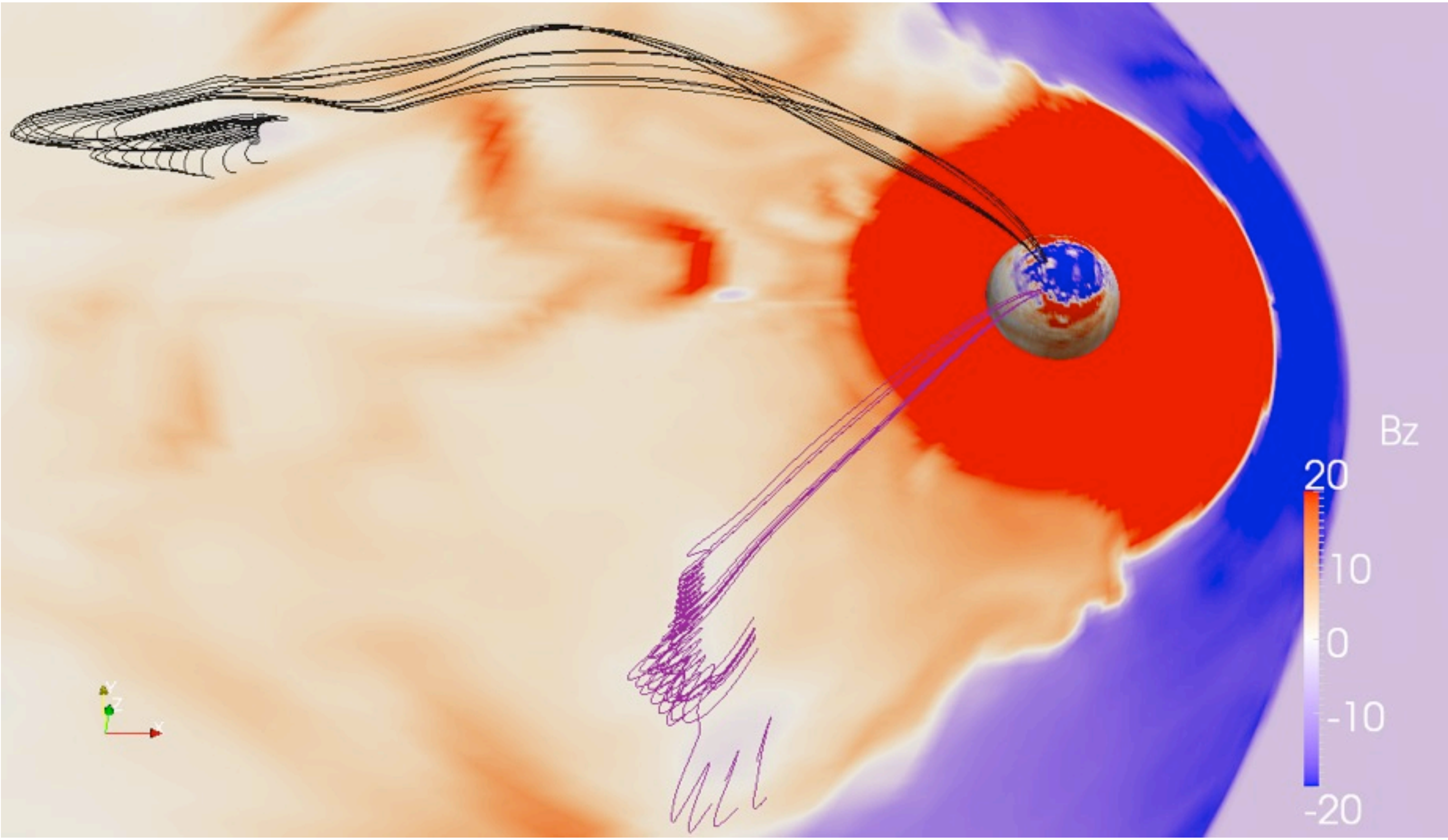
Flux-tube entropy and velocity field in an LFM-RCM simulation.

Field-aligned currents and entropy contours in the ionosphere concurrent with the magnetospheric plot.

Low-entropy fast flow channels (~BBFs) are expected to produce a pair of field-aligned currents due to velocity shear. However, entropy contours mapped into the ionosphere do not exactly match with the ionospheric currents because of propagation time delay.

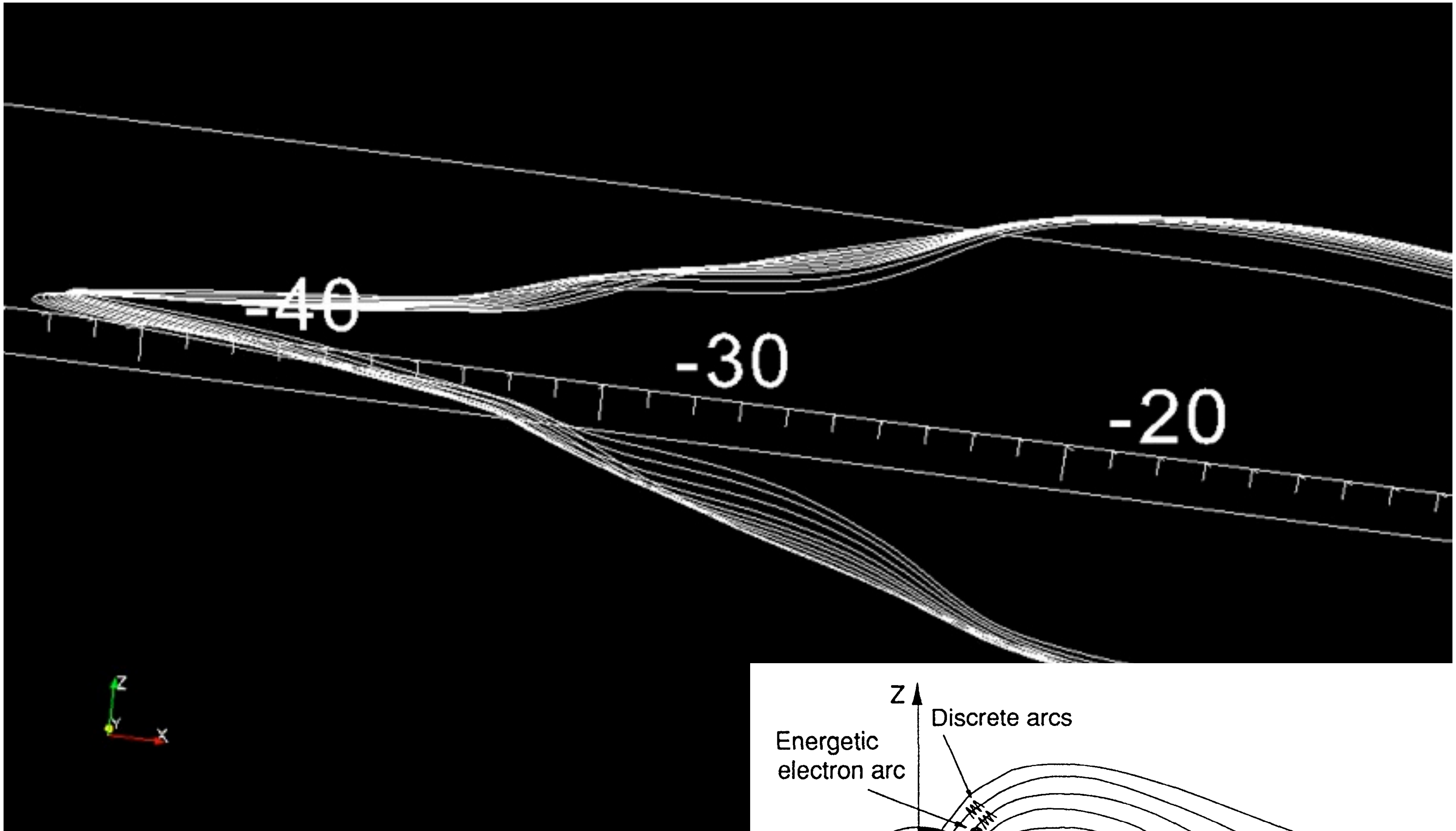

Coupled S IMF
23:10:00
12
18
06
00
10°
20°
30°
40°
FAC
min: -0.0
max: 0.0
Potential
min: -0.0
max: 0.0
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
Current density, μA/m2

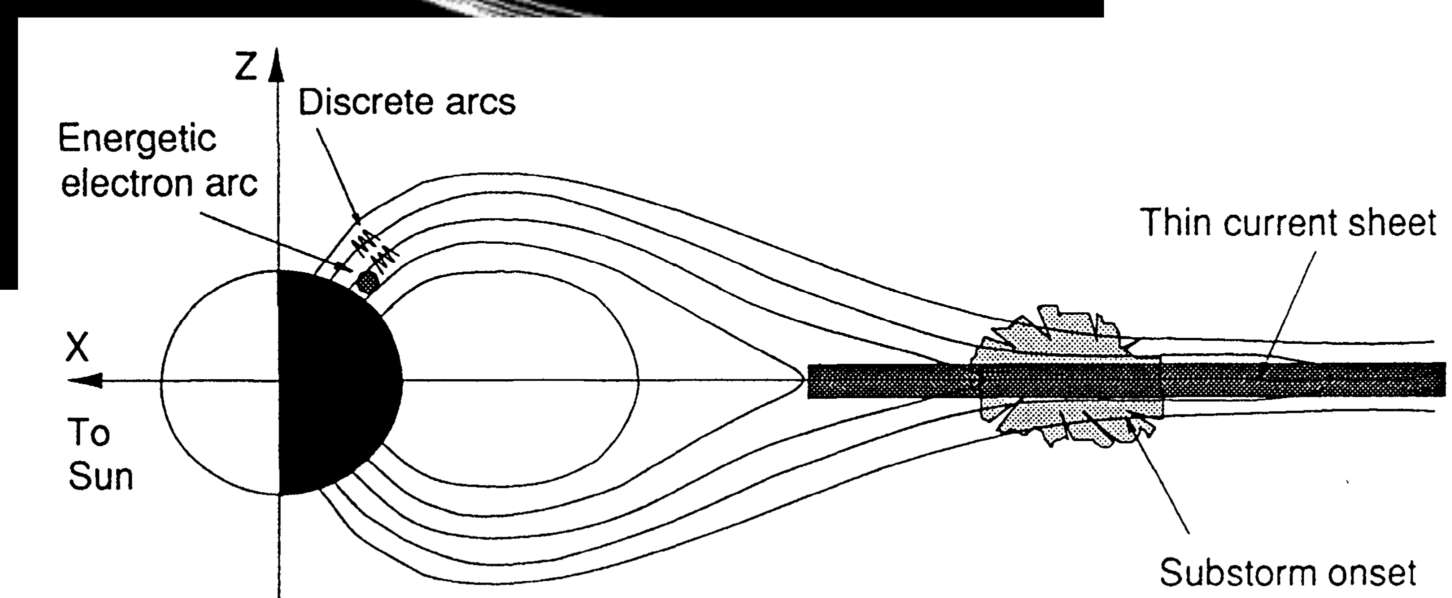
3) Magnetospheric (nightside) field topology is complicated.



Flux ropes make mapping non-obvious.

3) Magnetospheric (nightside) field topology is complicated (cont.)





Sergeev et al., 1996

Thin current sheets make mapping non-obvious. Not normally included in empirical magnetic field models.