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How tail reconnection affects the asymmetric state of the magnetosphere in the LFM model

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EGU 2020

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IMF By induces north-south asymmetries

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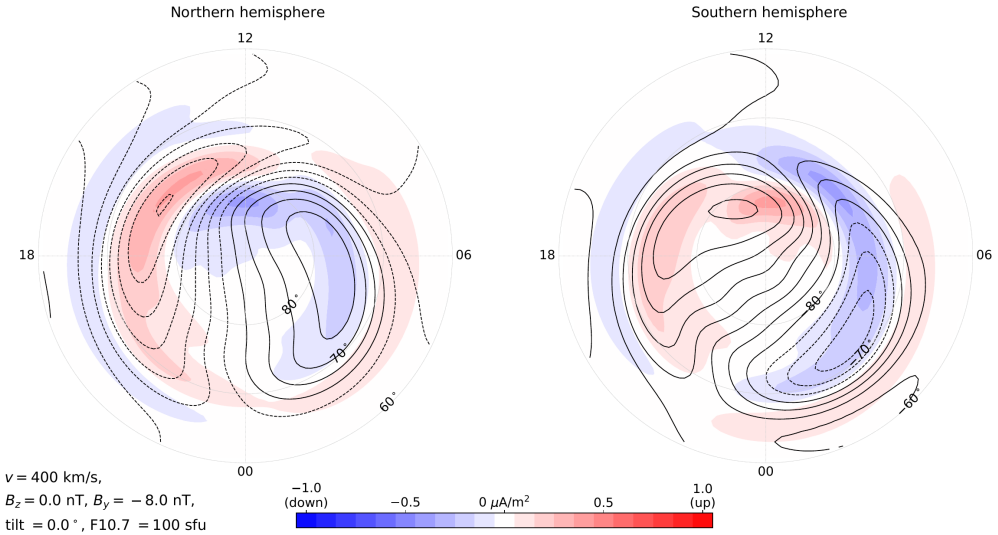
IMF B_y is a source of numerous asymmetric features in our magnetospheric system, e.g. north-south asymmetries in the aurora, the magnetospheric and ionospheric current systems and the plasma convection.

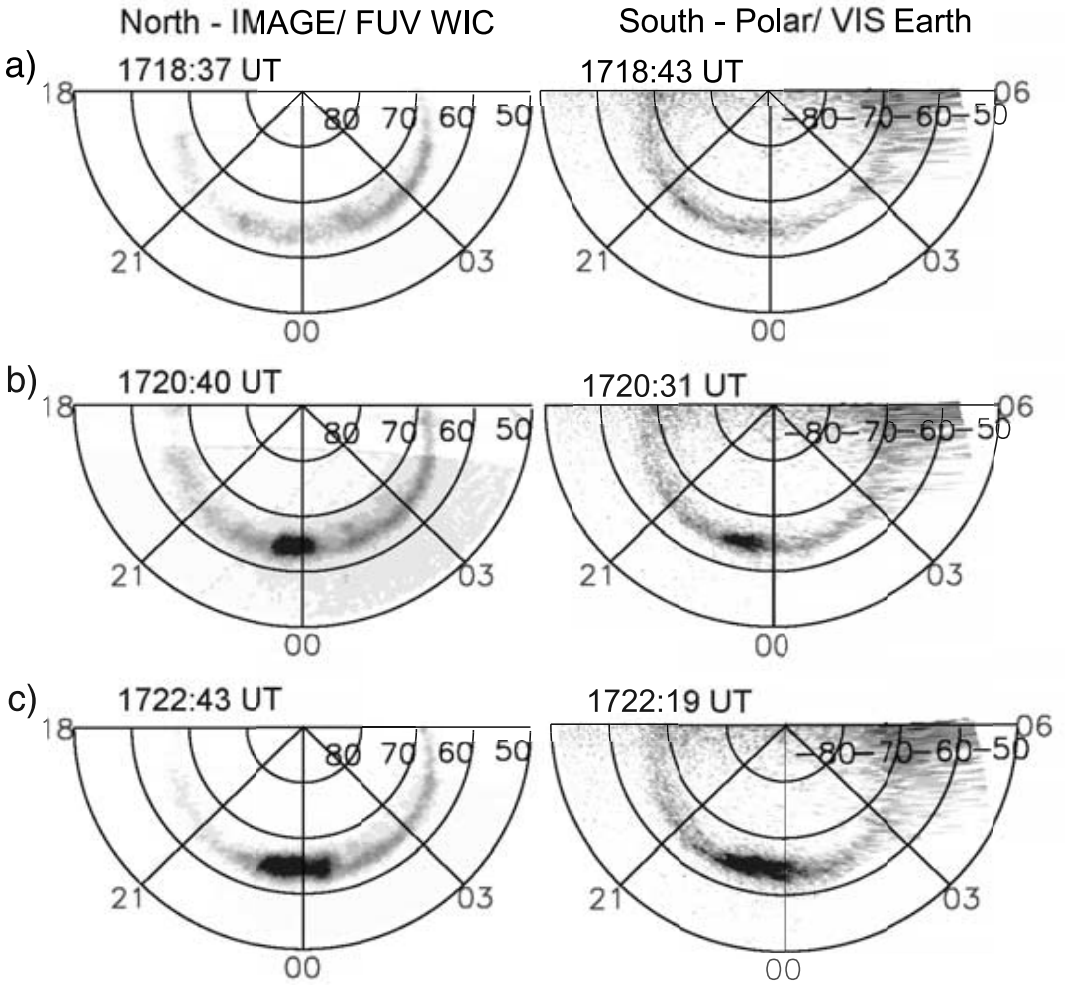
Field-aligned and divergence free currents from the AMPS model with IMF $B_y = -8$ nT



AMPS model: *Laundal et al*. (2018)

Asymmetrically displaced substorm onset for IMF $B_y < 0$

November 15, 2001



Østgaard et al. (2004)

How the asymmetry is induced

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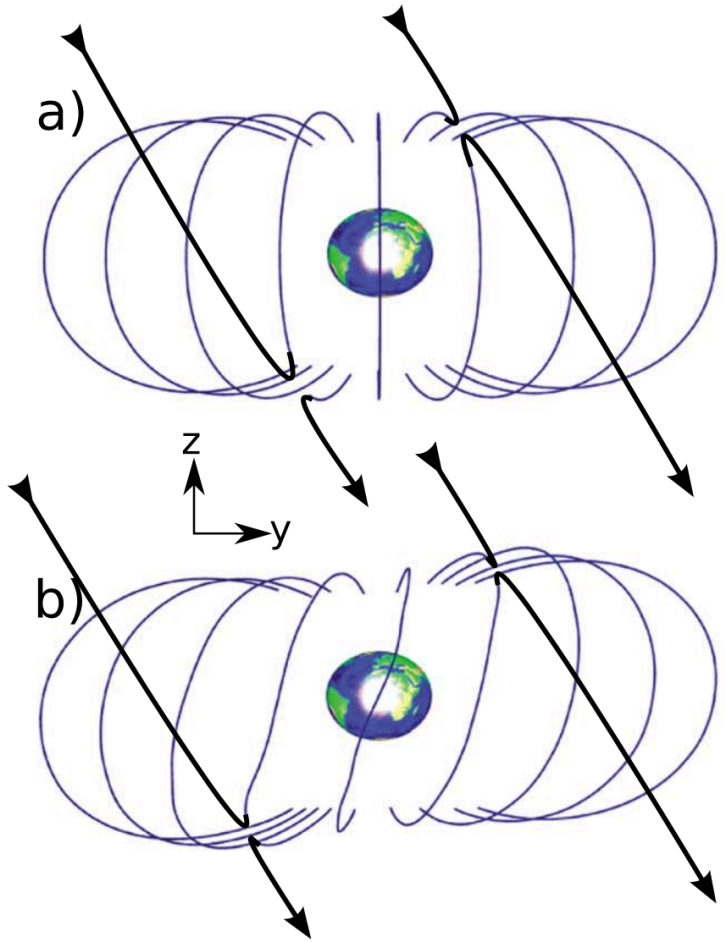
Dayside reconnection geometry when IMF $B_y > 0$



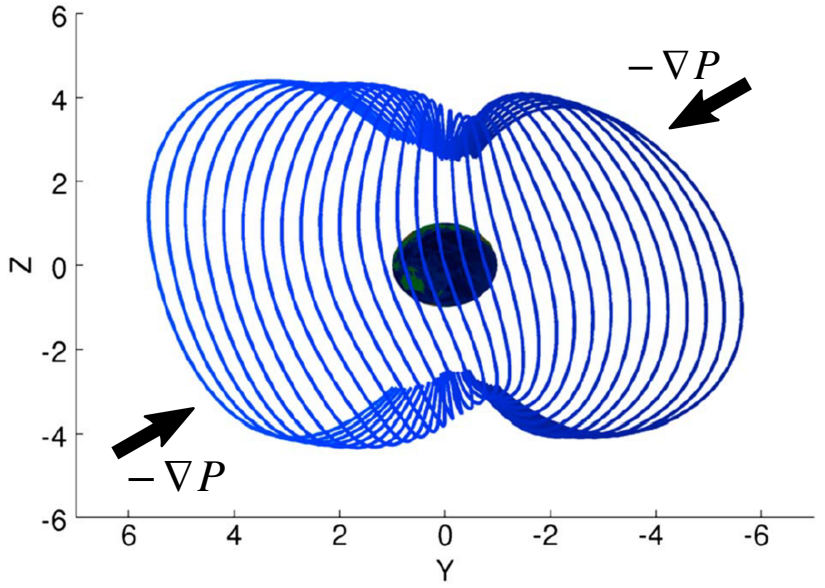
Tenfjord et al. (2015)

Magnetic flux from dayside reconnection is added asymmetrically to the two hemispheres due to magnetic tension

For IMF $B_y > 0$, the flux is added at dawn in NH and at dusk in SH

The resulting asymmetric pressure distribution induces asymmetries in the magnetosphere (*Khurana et al*., 1996; *Liou & Newell,* 2010; *Tenfjord et al*., 2015)

Closed nightside fieldlines at $L = 11\ R_E$, 25 minutes after IMF B_y were introduced in the MHD simulation



Tenfjord et al. (2015)

Timescales at geosynchronous orbit

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Response to IMF B_y polarity changes at geosynchronous orbit
(*Tenfjord et al.*, 2017, 2018)

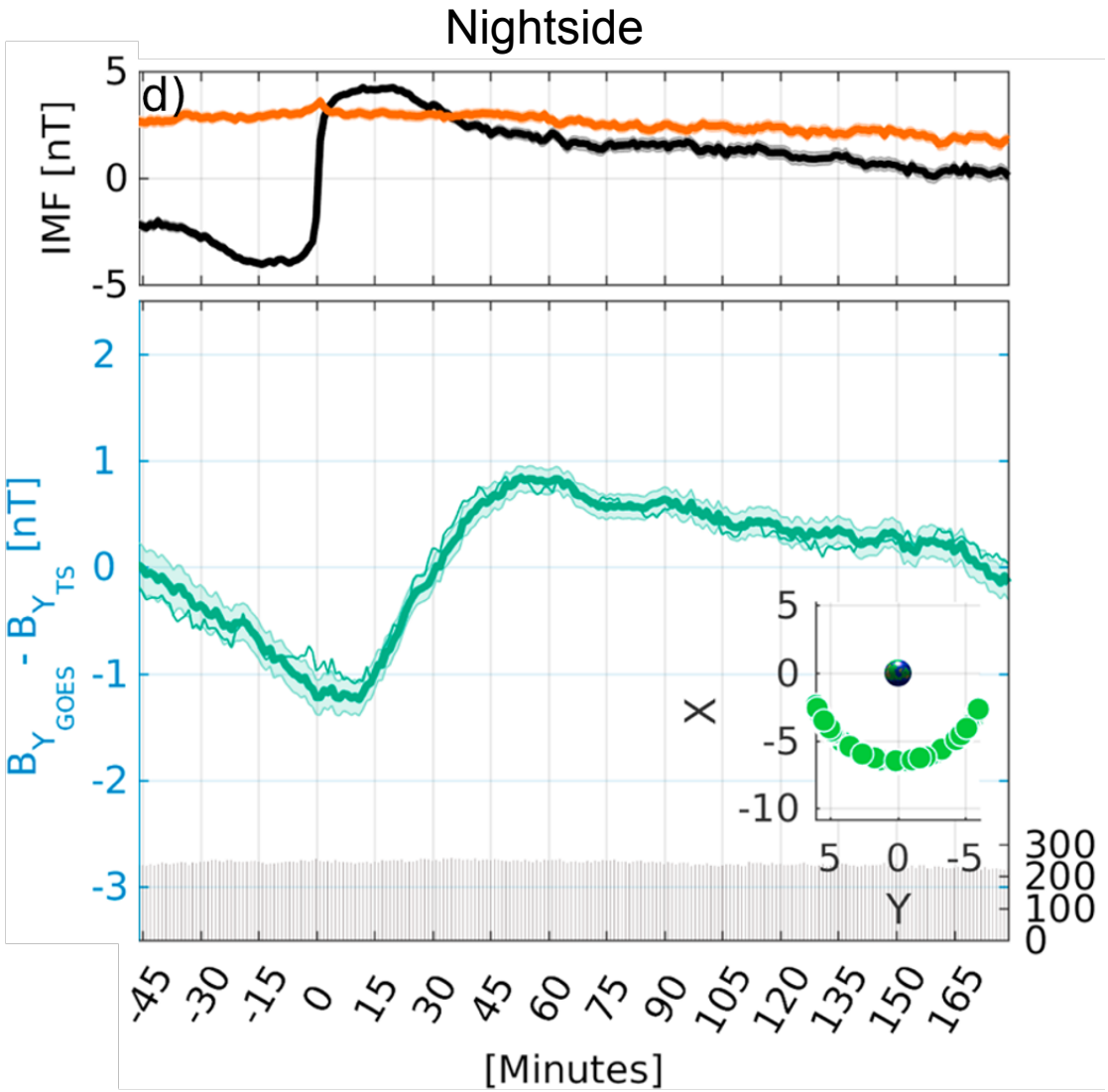
Response time < 15 min

Reconfiguration time < 50 min

Similar timescales

- For both IMF B_y polarity changes
- At the dayside and at the nightside
- For IMF $B_z < 0$ and $B_z > 0$

Confirm that asymmetries in the lobe pressure play a major role in inducing these asymmetries.



Tenfjord et al. (2018)

Reduced asymmetry during substorms

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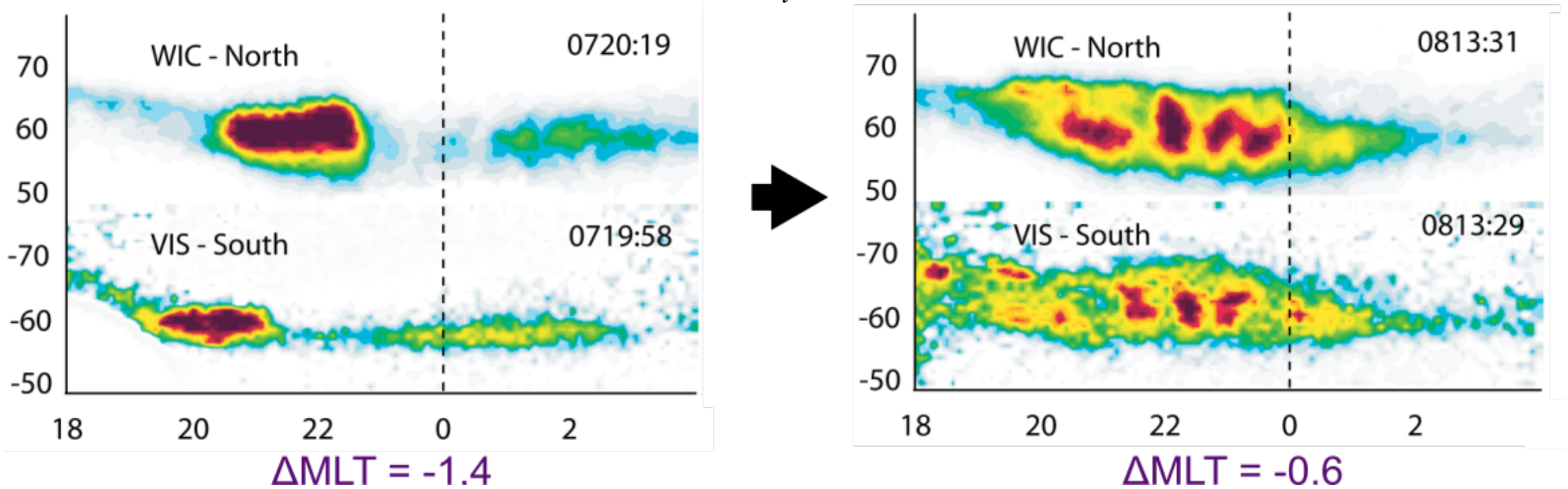
How do increased tail reconnection affect asymmetries?

Østgaard et al. (2011, 2018) and *Ohma et al*. (2018):

Reduced asymmetry during substorms

IMF $B_y < 0$



MHD model - setup

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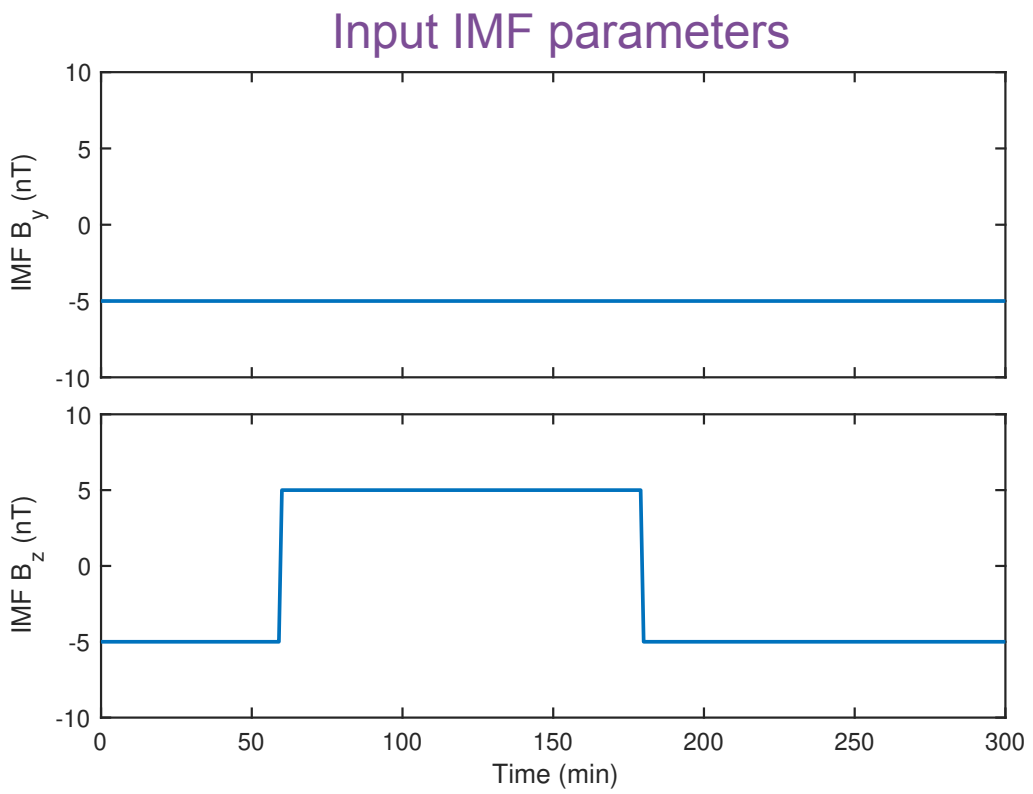

Run number at CCMC
Anders_Ohma_082219_1

To further investigate how enhanced tail reconnection affects the asymmetric state of the magnetosphere, we apply a global MHD model.

We use the LFM model, as LFM results most closely resemble “idealized substorm” (Gordeev et al., 2017)

Constant IMF $B_y = -5$ nT

IMF $|B_z| = 5$ nT

0 - 59 minutes: Southward IMF
60 - 179 minutes: Northward IMF
180 - 300 minutes: Southward IMF

The north-to-south polarity change “triggers” a loading-unloading cycle

MHD model - results

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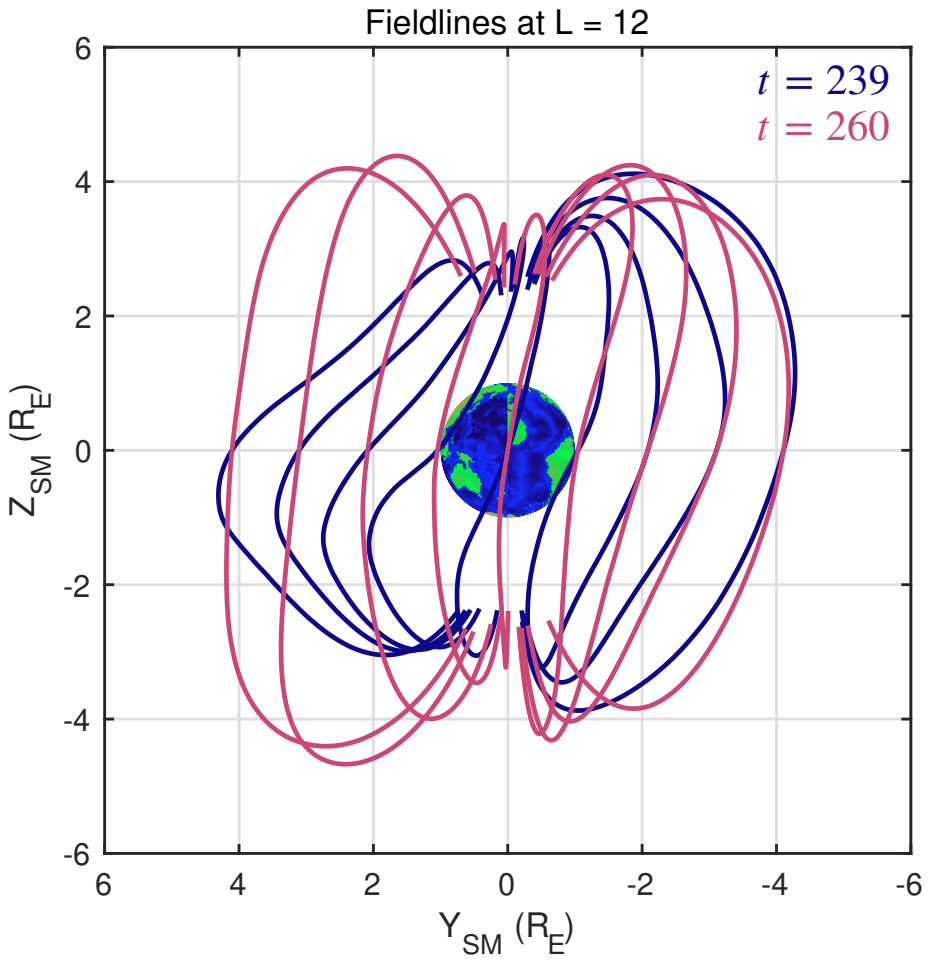
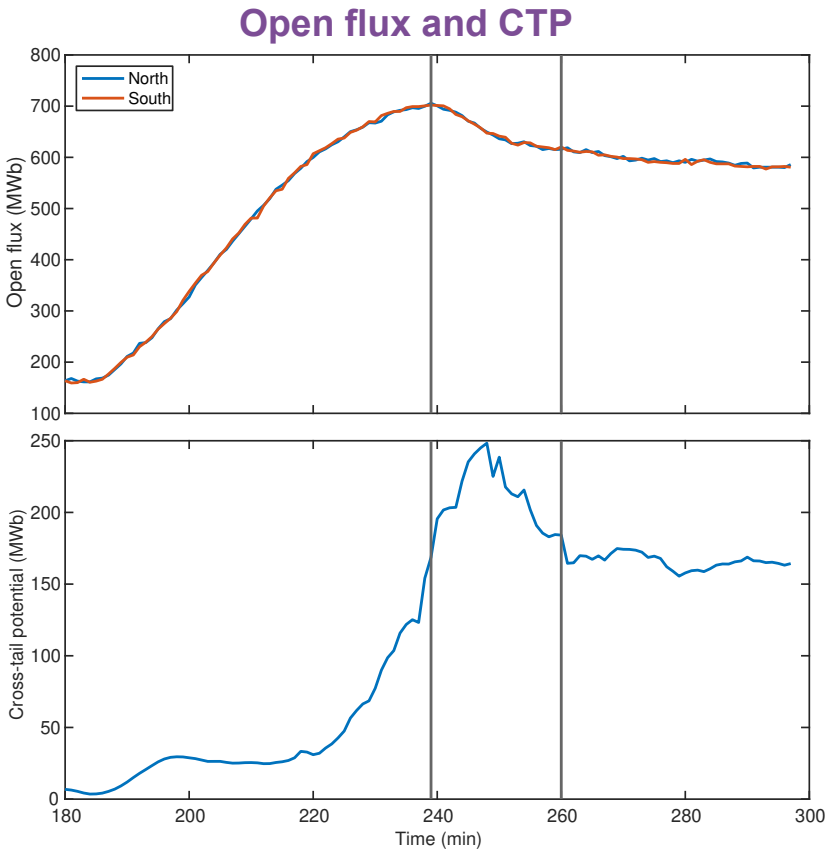


Closed field lines at the nightside are more symmetric after the increase in tail reconnection

Consider the time interval 180 - 300 minutes
The amount of open flux increases in the interval 180 - 239 min ("growth" phase)
"Onset" at t = 239 min
The amount of open flux decreases in the interval 239 - 260 min ("Expansion" phase)
The CTP also maximises in the period 239 - 260 min, implying enhanced tail reconnection
The magnetic field lines are more symmetric after the unloading have occurred



Cross-tail potential (CTP) quantifies earthward flux transport in the closed magnetotail.

We have used:

$$\mathrm{CTP} = -\sum_{-15}^{+15} (\mathbf{v} \times \mathbf{B})_y \Delta y$$

at $X = -12\,R_E$

MHD model - evolution at a fixed location

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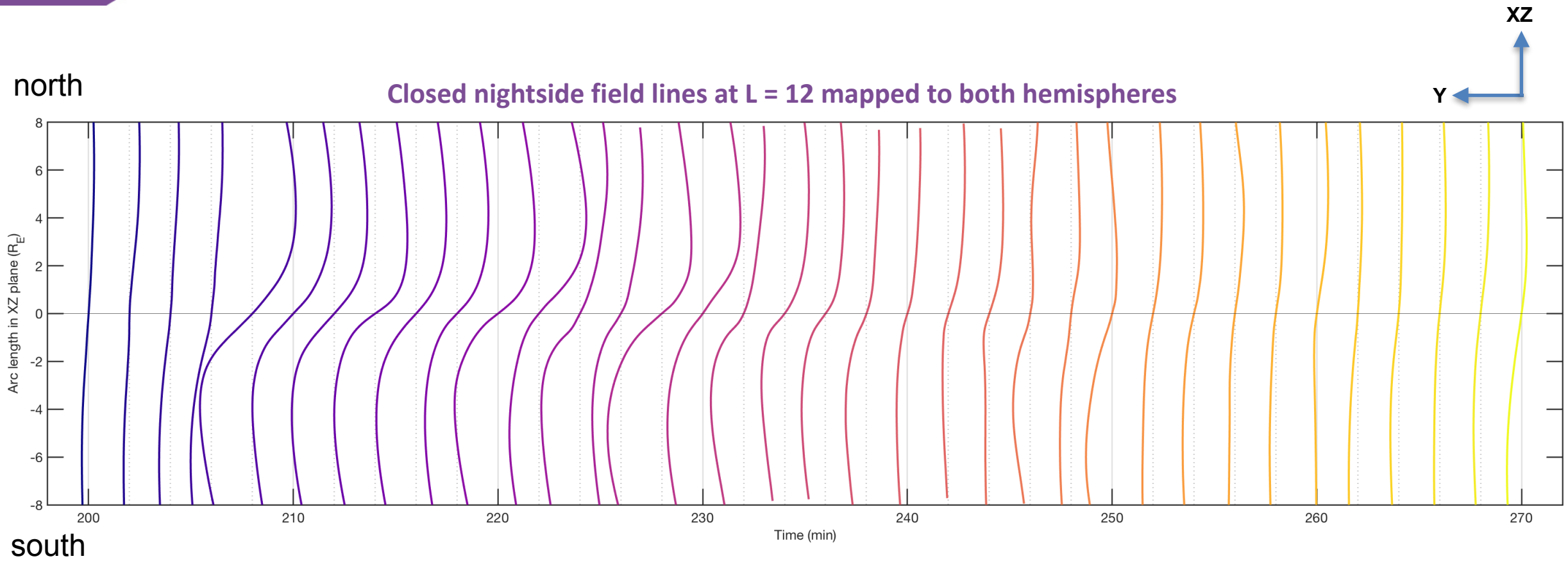

Mapping the field line located at $X = -12\,R_E$, $Y = 0\,R_E$, $Z = 0\,R_E$ to both hemispheres for every second time step.
Most asymmetric in the time interval 208 - 230 min, then reduced asymmetry
Near symmetric for > 250 min

MHD model - a closer look

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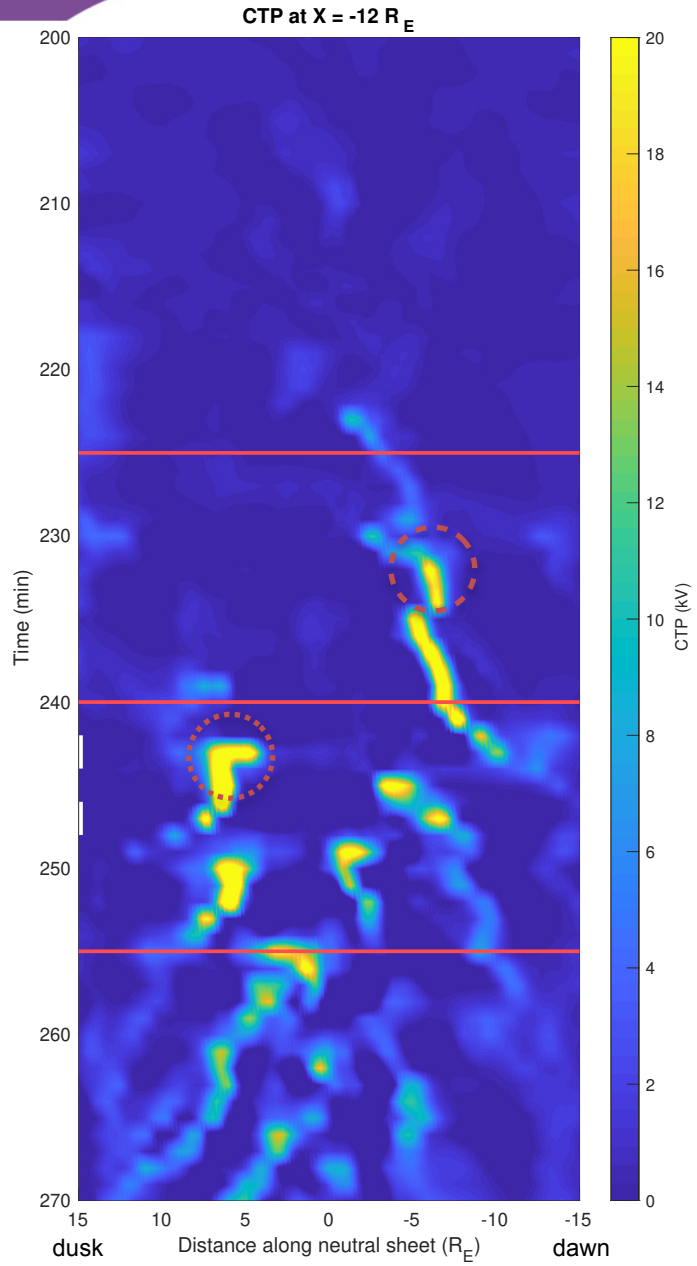


Figure of CTP shows several regions with enhanced earthward transport of flux, implying enhanced tail reconnection

$t = 231$: Increase at dawn

$t = 242$: Increase at dusk

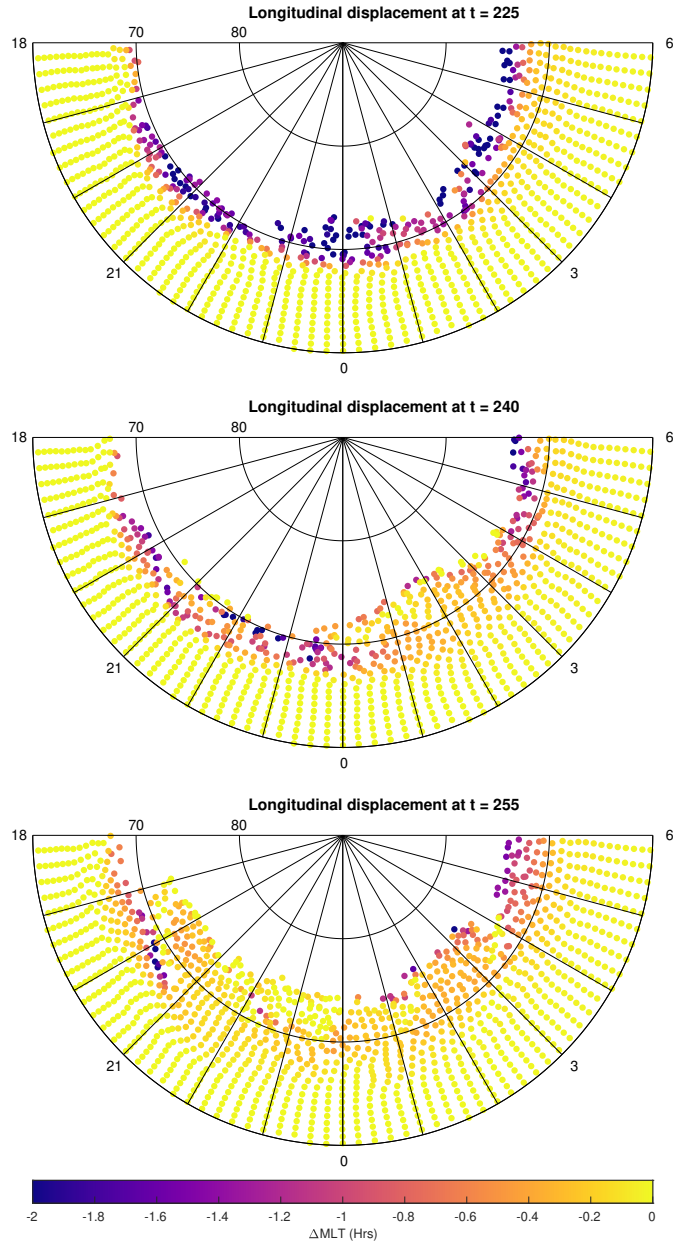
Figures of longitudinal displacement show large displacement in all MLT sectors before nightside reconnection sets in.

Reduced asymmetry at dawn following the increase at $t = 131$

Reduced asymmetry at dusk following the increase at $t = 242$

Consistent with the auroral observations, reduced asymmetry when tail reconnection increases.

Grid mapped from SH to NH to yield displacement



MHD model - cross-section of the magnetotail

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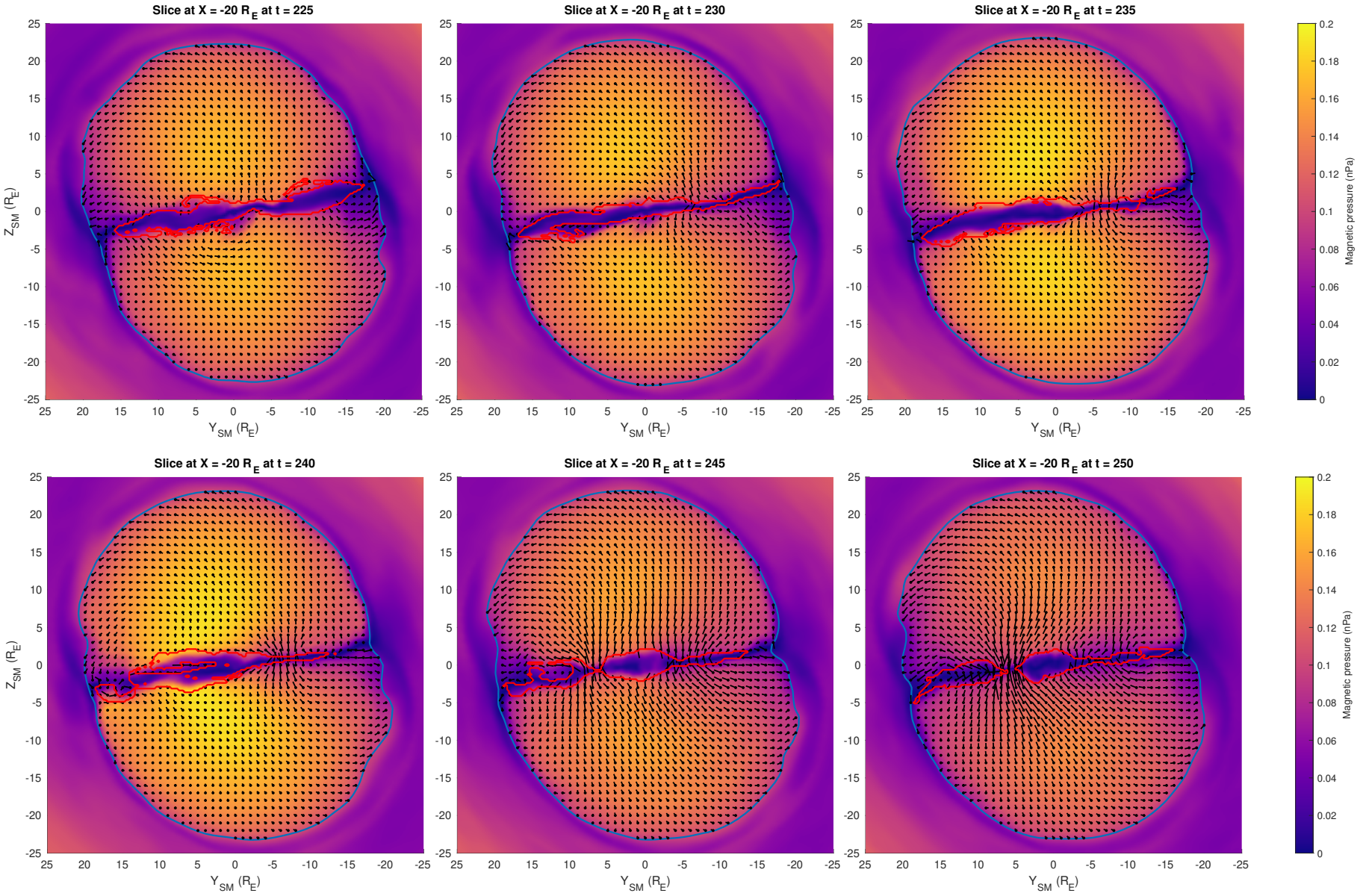

Cross-section of the magnetosphere showing magnetic pressure and plasma convection.

Blue contour indicate the magnetopause using the technique outlined in *Peng et al.* (2010)

Red contour indicate the open-closed boundary, determined by field line tracing

General increase in lobe pressure until $t = 240$

Local decrease at dawn when tail reconnection starts here ($t = 235$ and $t = 240$)

Global decrease when tail reconnection starts at dusk ($t = 245$ and $t = 250$)

Summary

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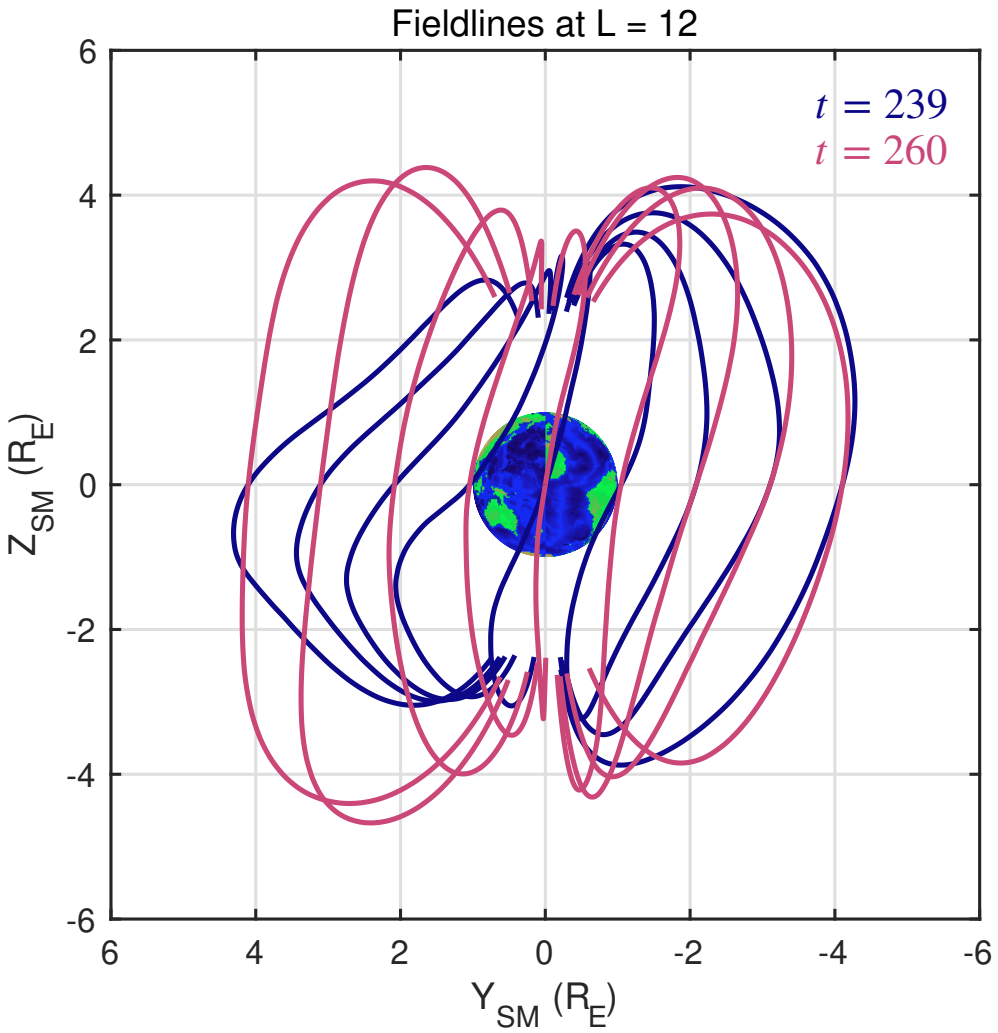
- LFM run with constant IMF $B_y = -5$ nT
- Following the southward turning of the IMF, the lobe pressure and the north-south asymmetry of the field lines increase
- The simulation clearly shows reduced asymmetry when tail reconnection sets in
- The reduction occurs first at dawn, then at dusk, which is consistent with the location of the reconnection region in the tail
- The regions of reduction also coincide with regions where the lobe flux is reduced

- The model is consistent with auroral observations, which show reduced asymmetry during substorms
- The reduced asymmetry is likely a result of changes in the force balance in the tail caused by the commencement of tail reconnection, and possibly directly related to the decrease of lobe pressure



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