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Reconnection in the magnetosphere: a global simulator's view

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Gumics-4 global MHD model

Solar wind

Earth's dipole

Magnetosphere

MHD equations

mapped along dipole field lines

precipitation

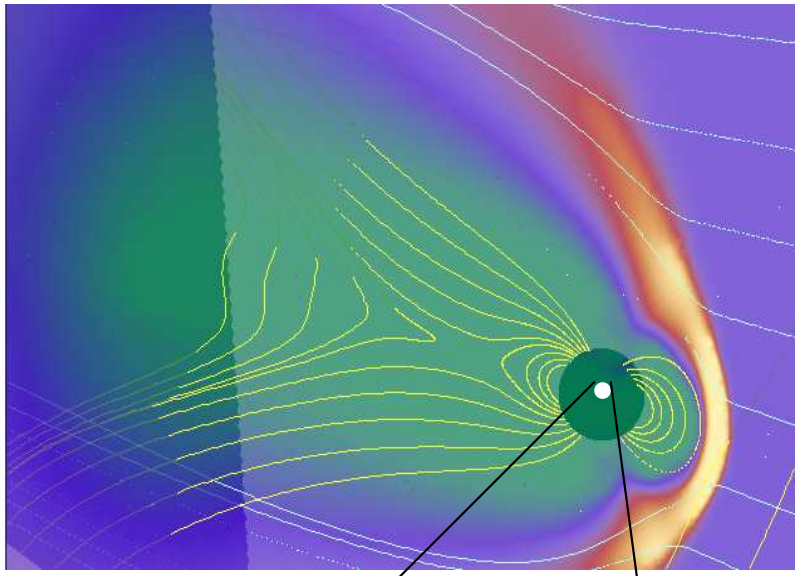
FAC

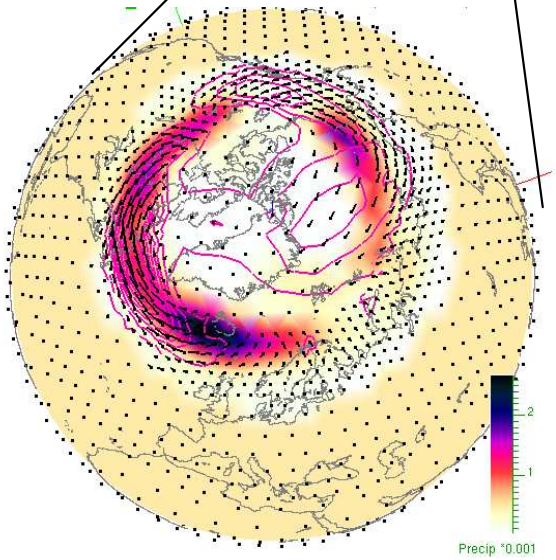
potential

Solar UV

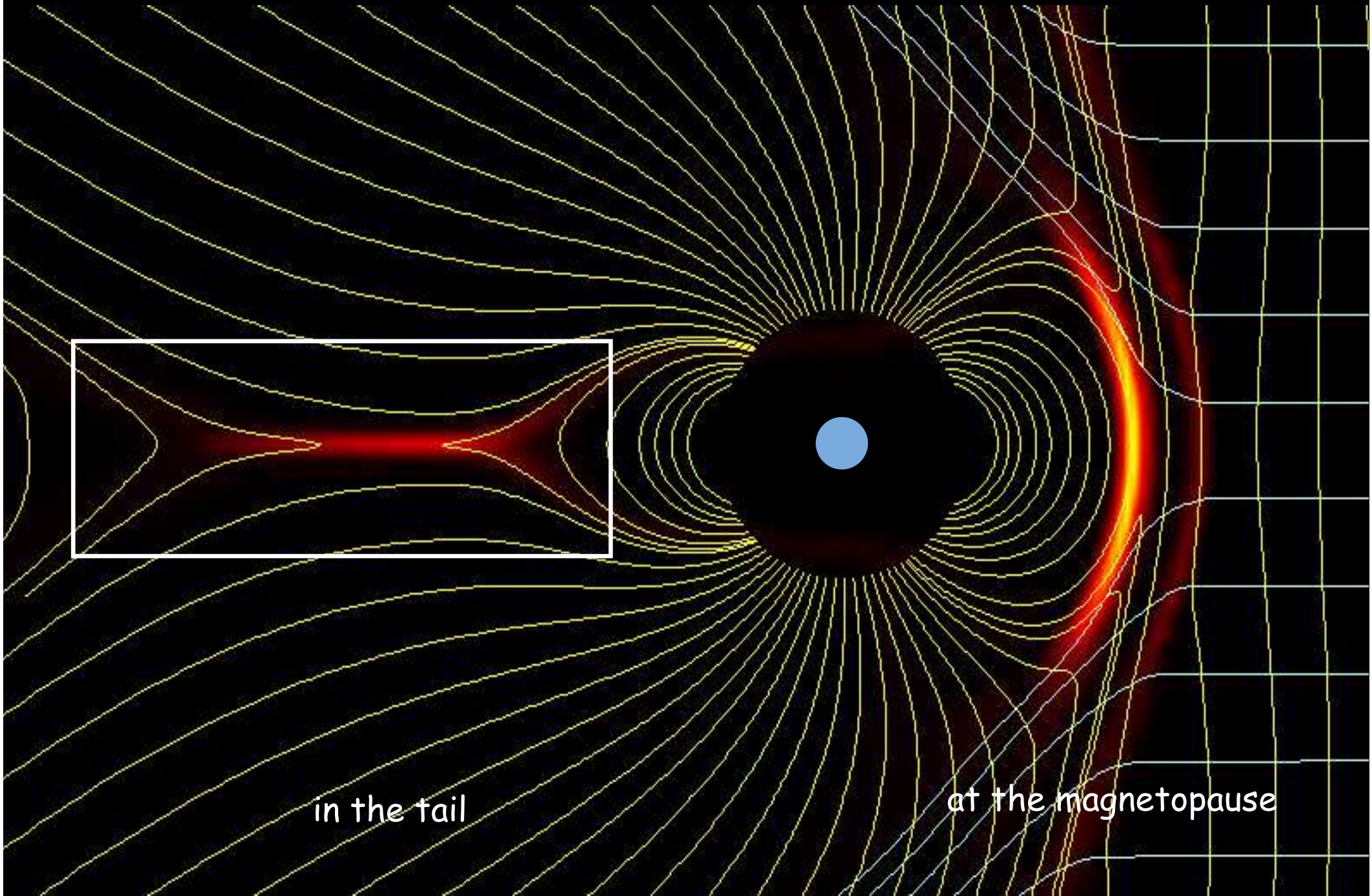
Ionosphere

electrostatic equations

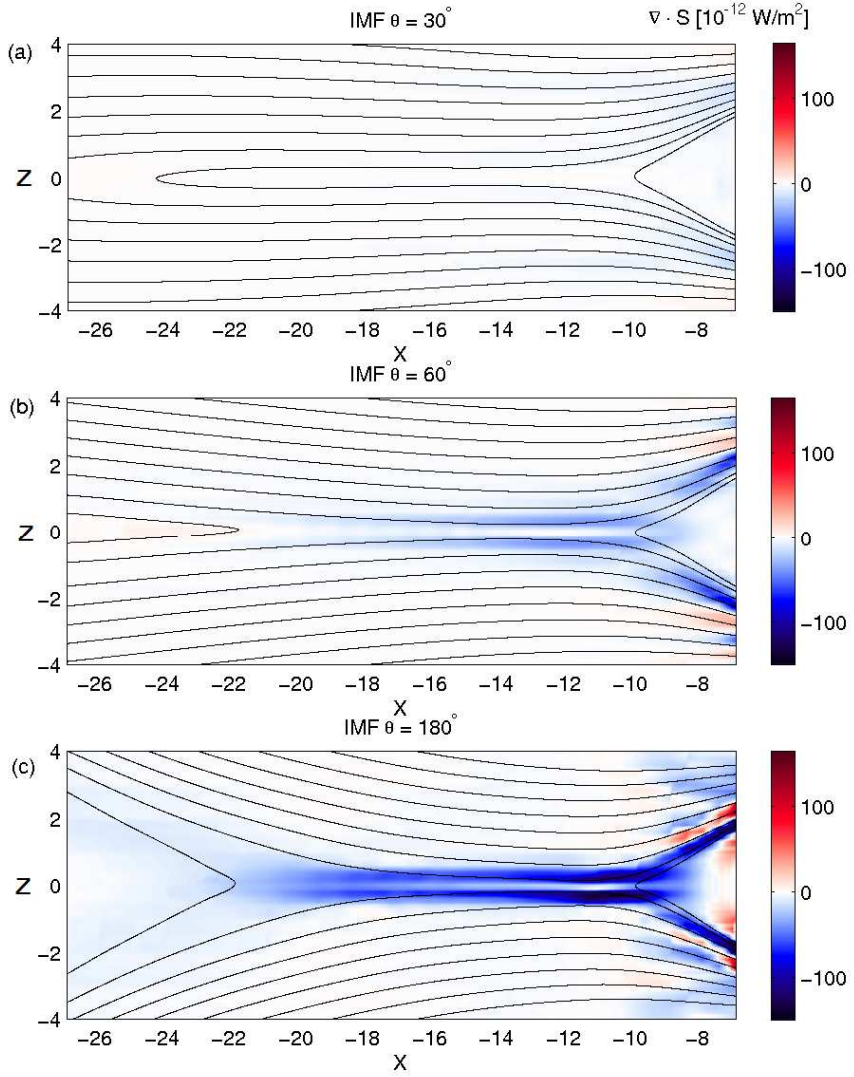




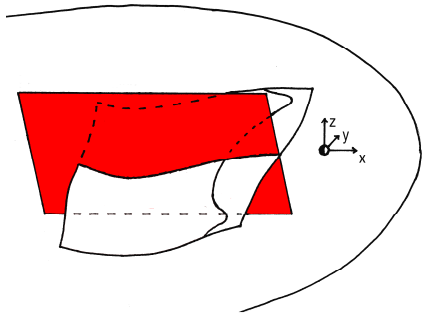
Reconnection sites in the magnetosphere



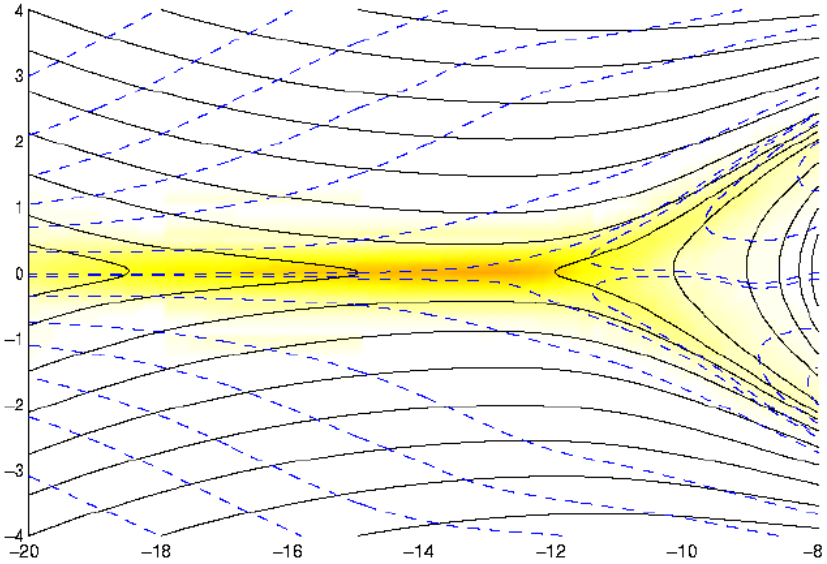
Tail reconnection on noon-midnight plane



Onset of reconnection as IMF turns southward



Magnetic field and plasma flow around the x-line



Energy conversion: div S, σ_{Ec} and P_{rec}

Energy conversion surface density σ_{Ec}

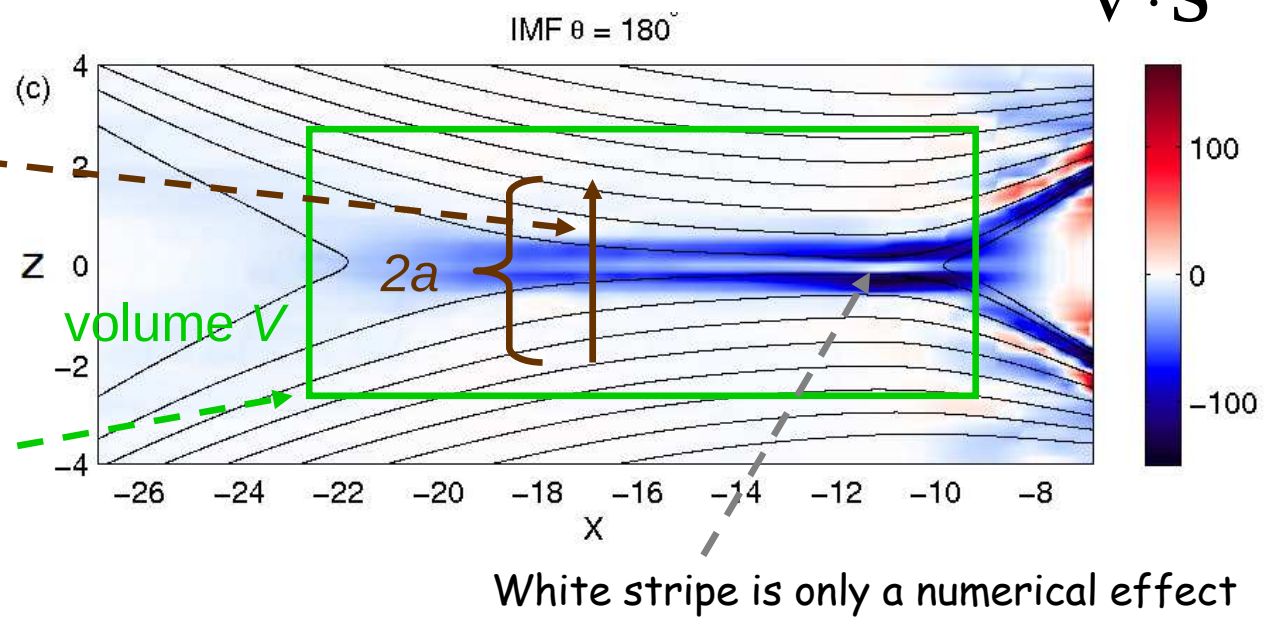
- used to localise energy conversion on the magnetopause
- can signify magnetic diffusion or plasma acceleration by **J**x**B** force.

Reconnection power P_{rec}

- dV defined to include only regions of negative div(S)
- Gives the total amount of magnetic energy converted to mechanical energy of plasma by reconnection

$$\sigma_{Ec} = \int_{-a}^{a} \nabla \cdot \mathbf{S}\, dl$$

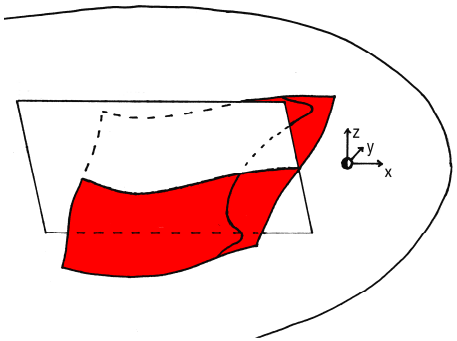
$$P_{rec} = -\iiint \nabla \cdot \mathbf{S}\, dV$$

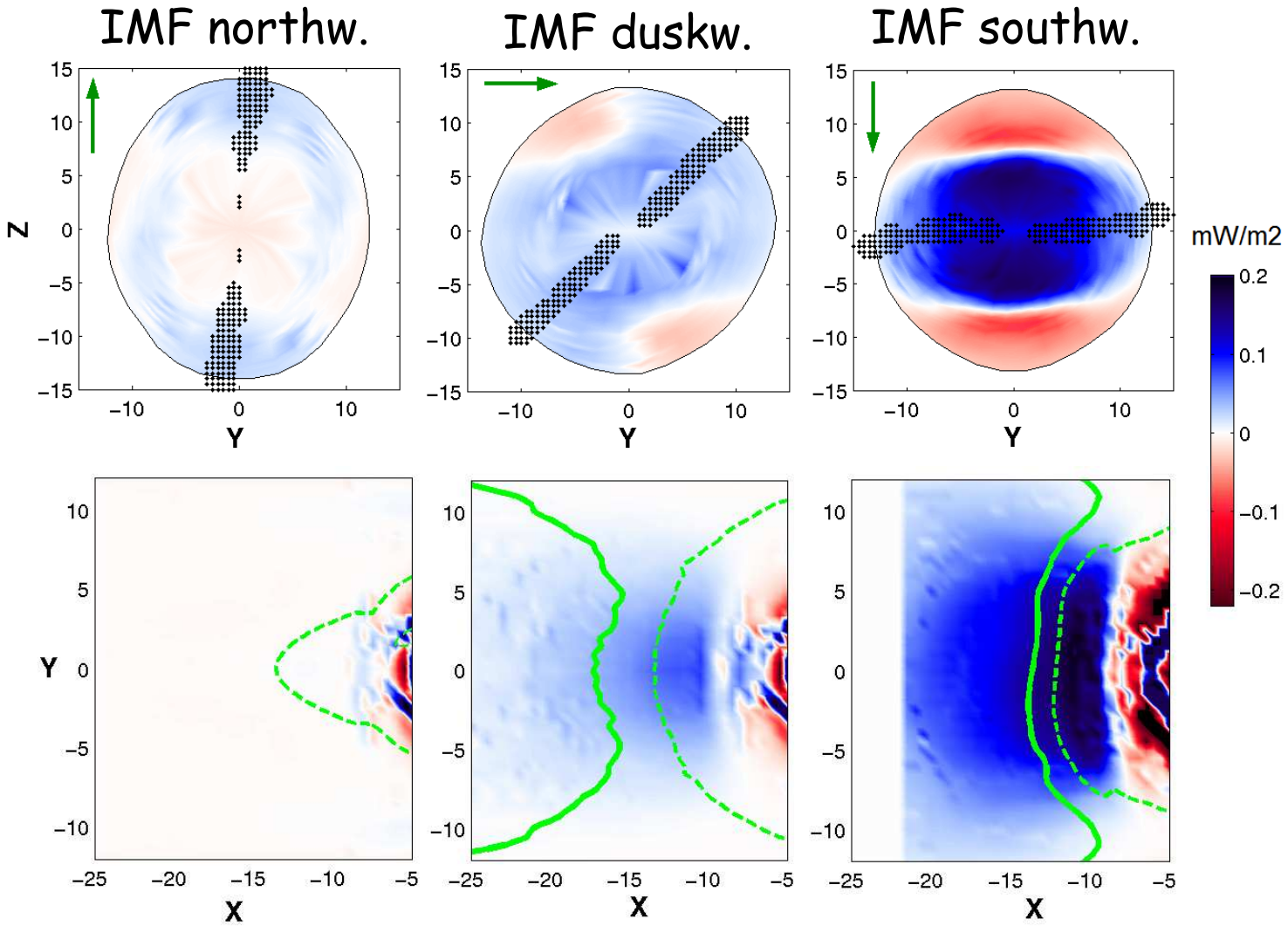


σ_{Ec} on magnetopause and tail current sheet

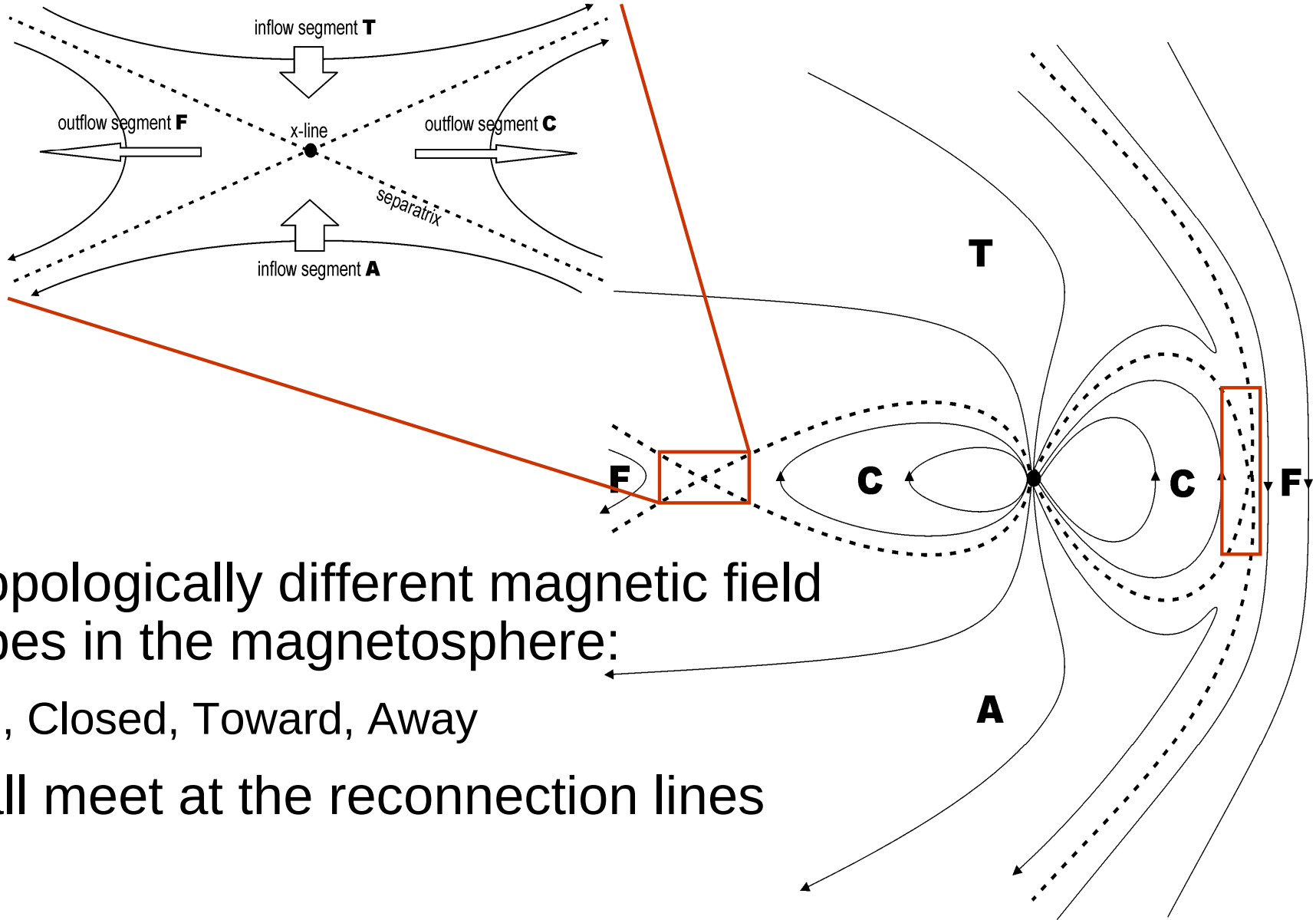
Similar appearance:

- Wide Ec region
- Ec of same order of magnitude
- X-line and flow reversal



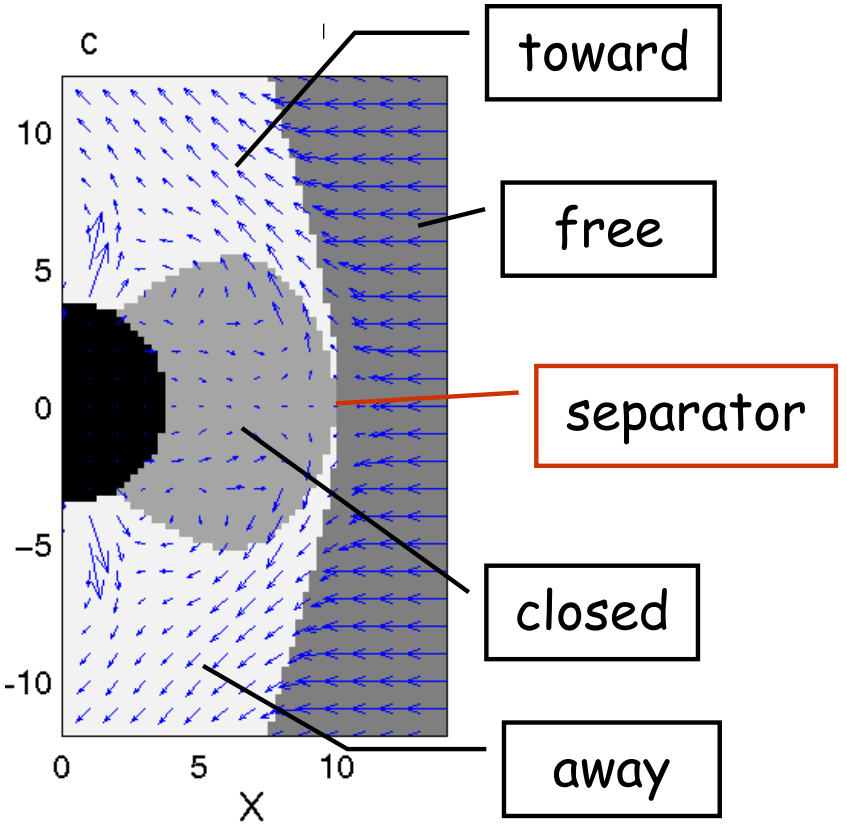


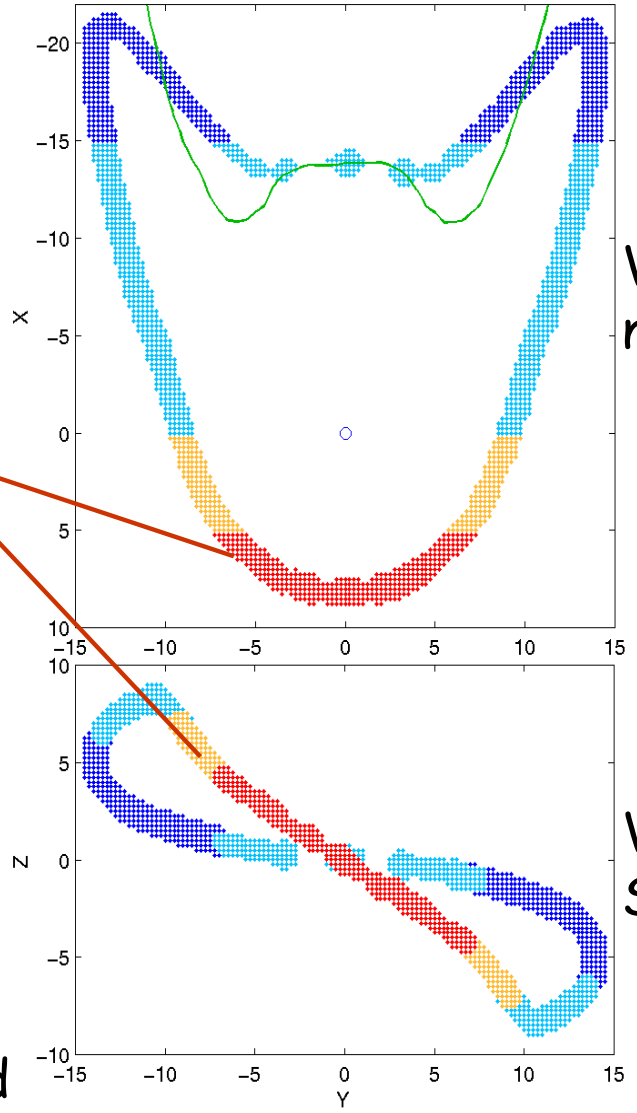
Reconnection line as topological separator



- Four topologically different magnetic field line types in the magnetosphere:
  - Free, Closed, Toward, Away
- They all meet at the reconnection lines

The four field junction in the simulation



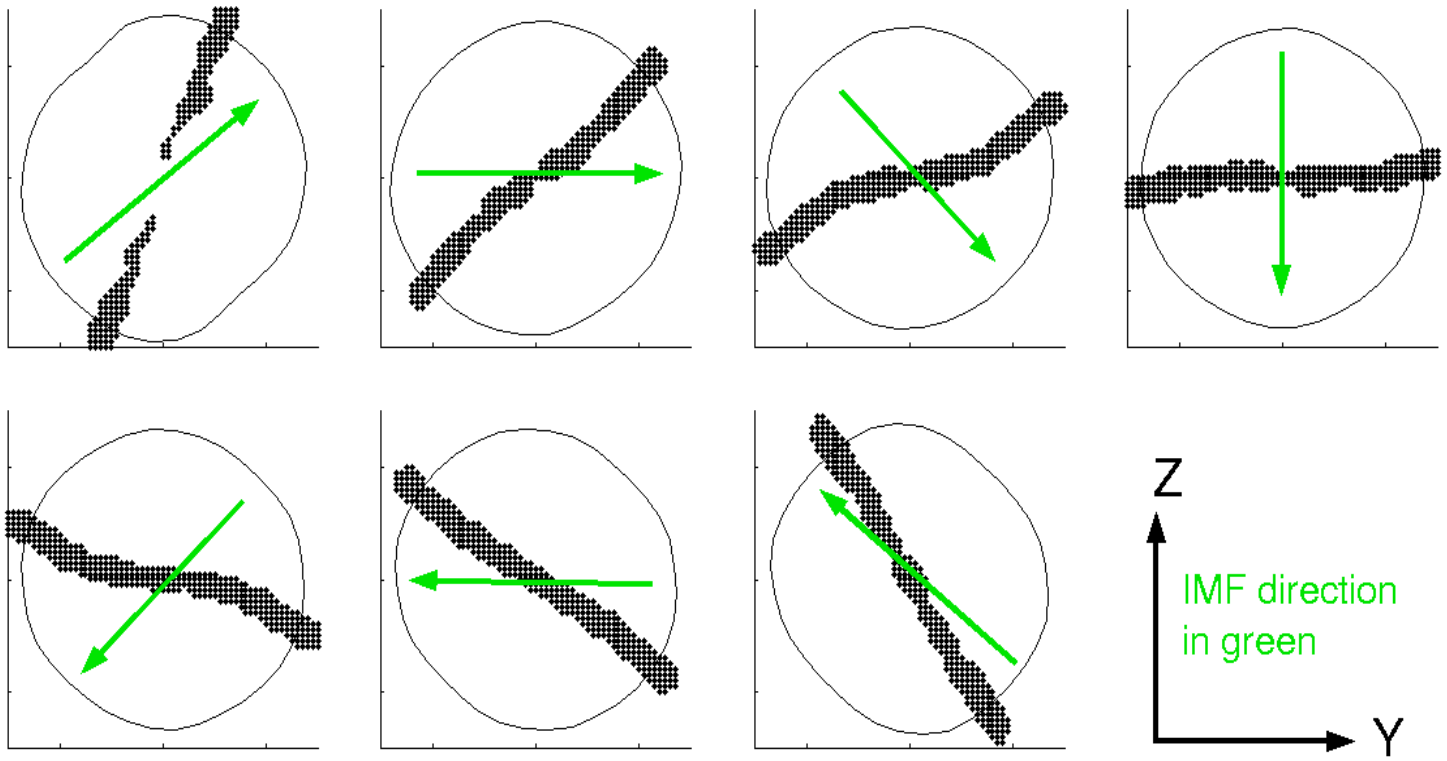


View from north

View from Sun

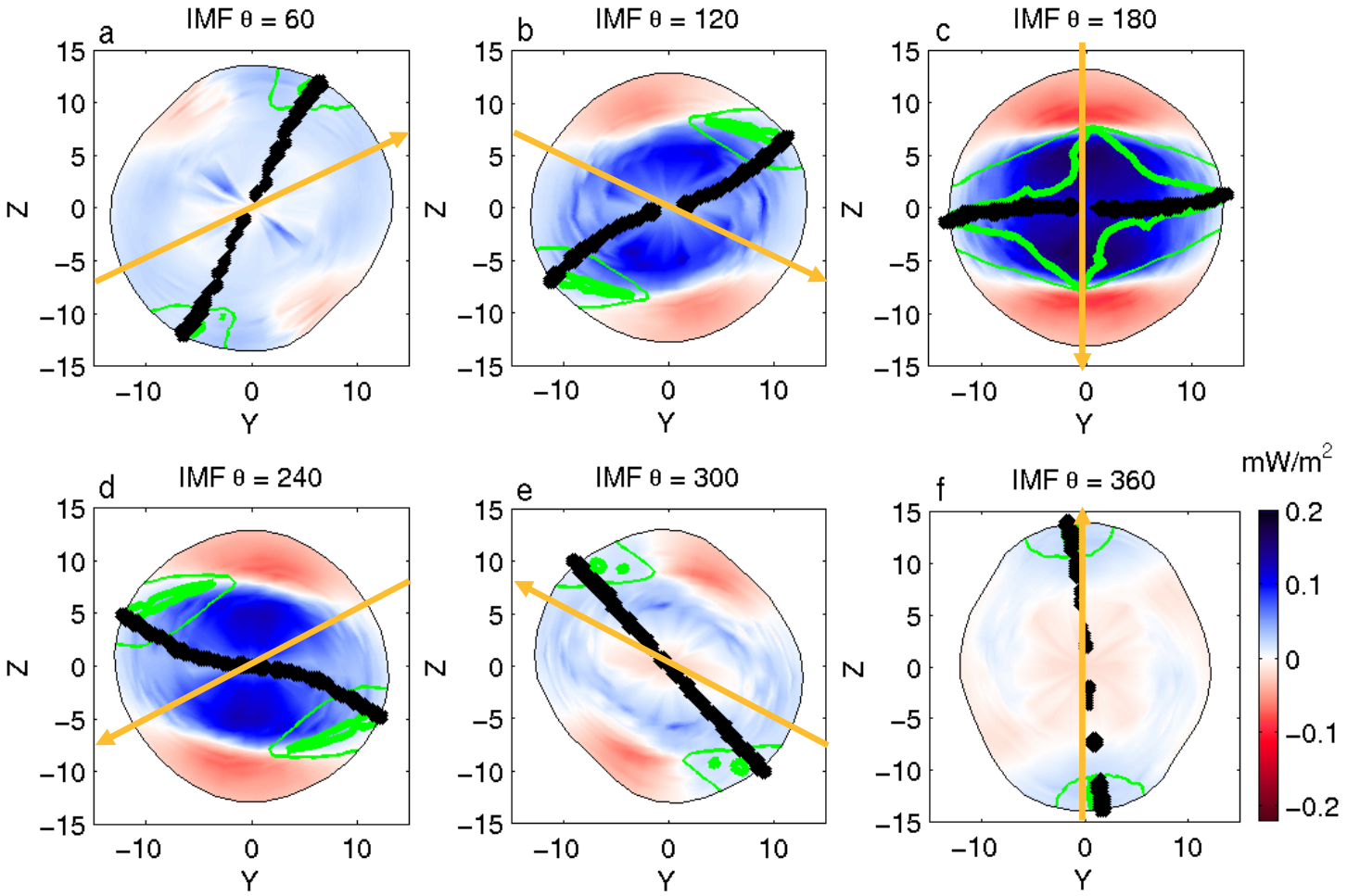
Separator loops around Earth
MP reconnection line part in red

FFJ on magnetopause under rotating IMF



- X-line clock angle is half of IMF clock angle.
- Consistent with component reconnection hypothesis.

Magnetopause, effect of IMF direction



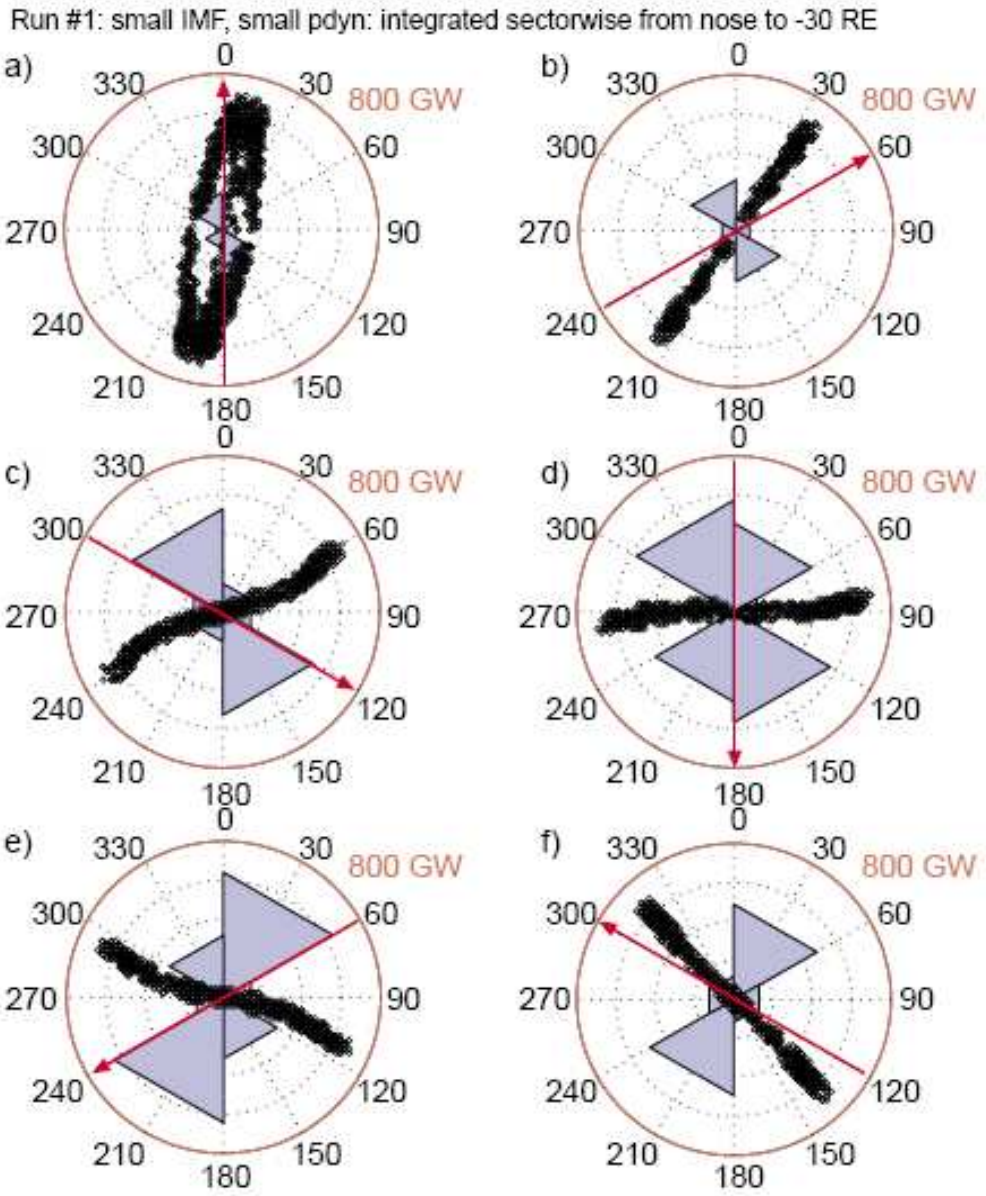
Shown: dayside magnetopause (x > 0)

Black: separator line
Green: antiparallel regions
Orange: IMF direction

Energy conversion surface density

- Separator line does not follow antiparallel regions
- Efficient energy conversion during southward IMF.

Energy transfer through magnetopause

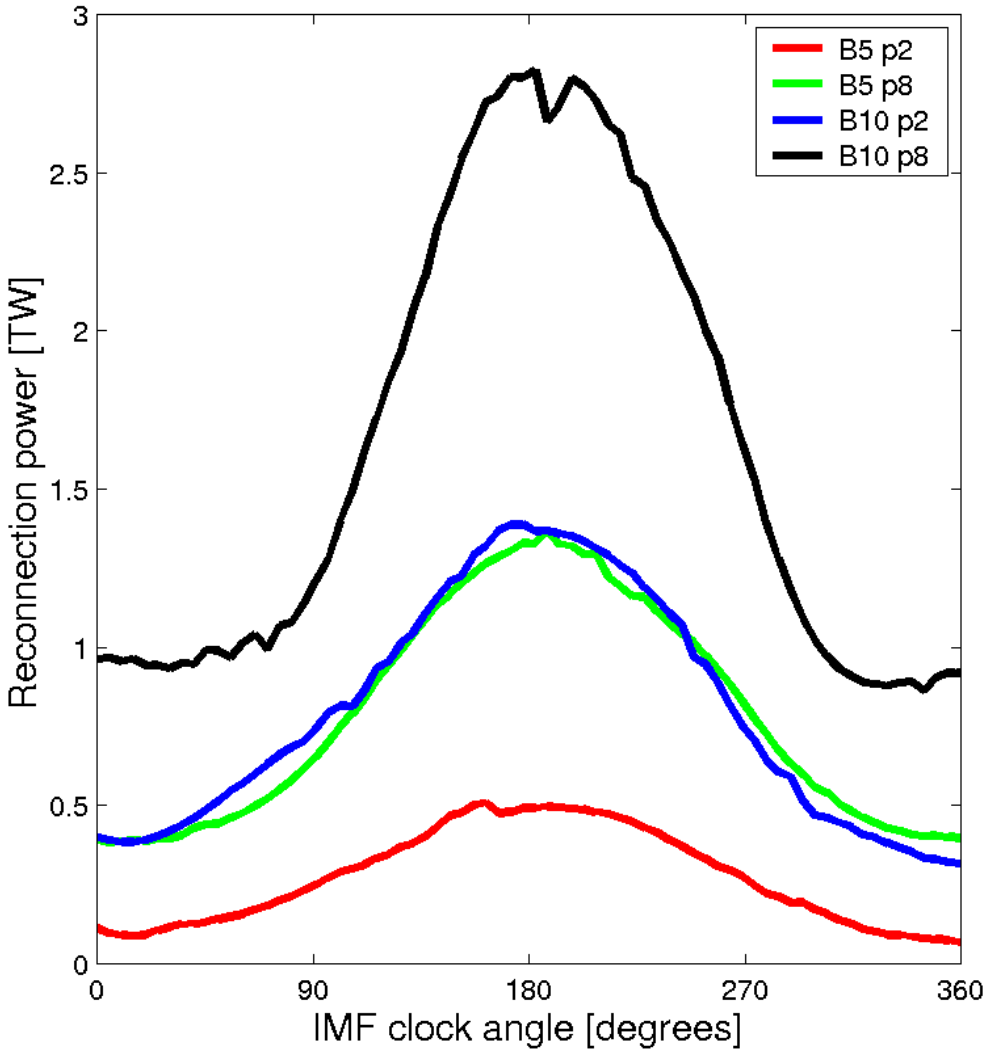


- Energy flows into magnetosphere mainly in sectors perpendicular to reconnection line.
  - Main component is Poynting flux
  - Consistent with Dungey-type field line convection

Blue = in
Red = out

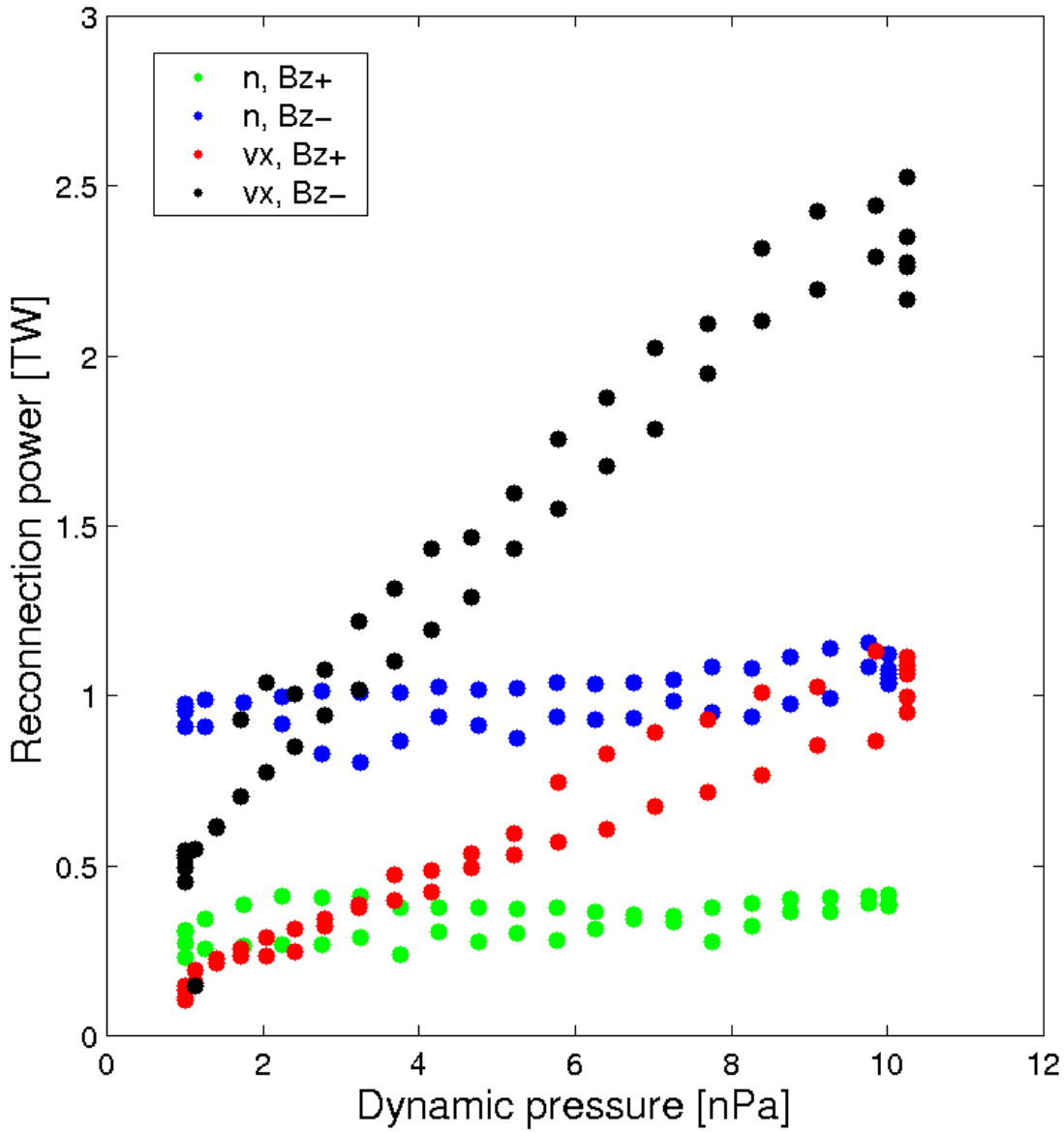
P_{rec} on the magnetopause: rotating IMF

- $P_{rec} = P_0 + P_1 \sin^4(\theta/2)$
  - during northward IMF, P_0 from behind the cusps
  - during southward IMF, P_0+P_1 from low latitudes
  - delay of 5-10 minutes
- Increase of IMF or SW speed increases P_{rec} regardless of clock angle.

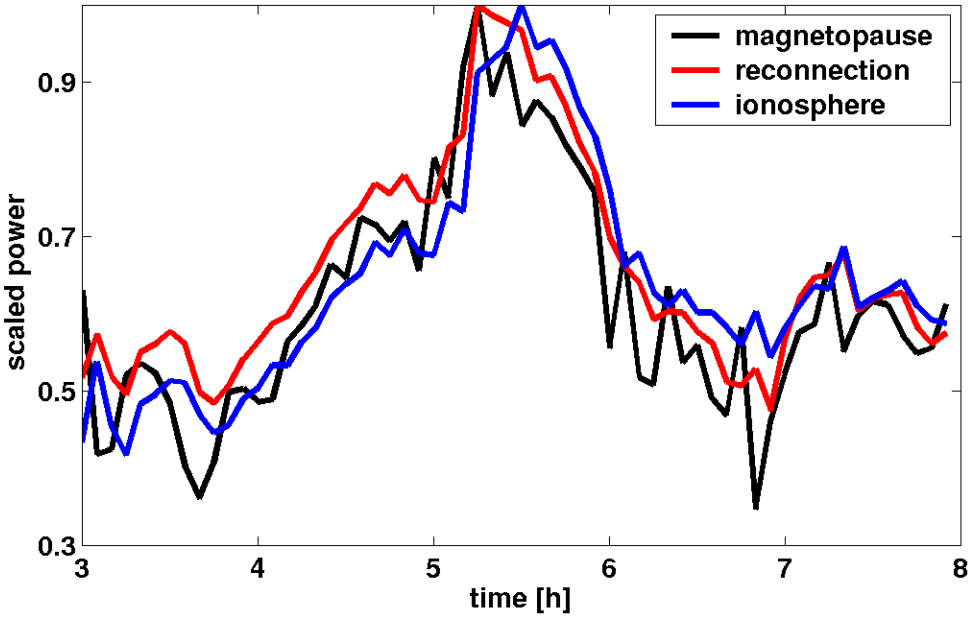


P_{rec} on the m'pause: changing SW pressure

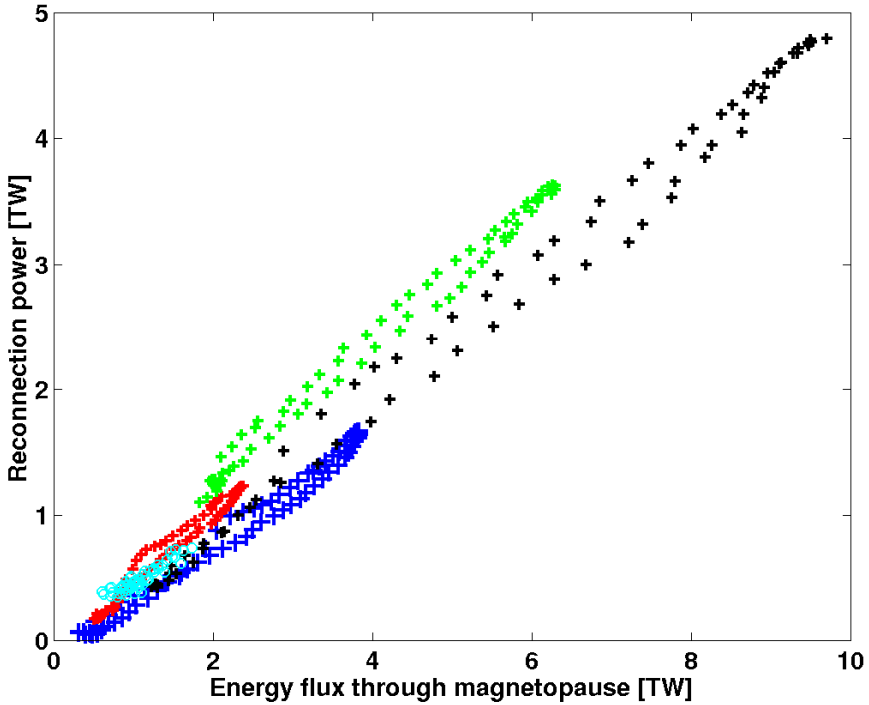
- SW density has almost no effect on total reconnection power
  - when density increases, σ_{Ec} concentrates in a smaller area on the nose.
- SW velocity has a strong effect
  - during both southern and northern IMF
  - $P_{rec} \sim v^2$



P_{rec} in the tail: following MP forcing



- Tail reconnection **transforms** about half of all energy coming in through the magnetopause



Conclusions (1/2)

1. Reconnection in Gumics-4 most closely resembles Sweet-Parker merging.
   - Energy conversion region wider than diffusion region?
2. Magnetopause reconnection in the simulation is consistent with the component merging model:
   - The separator line is continuous and crosses the subsolar point for other than northward IMF orientations
   - Sink of Poynting flux in the subsolar region between the cusps.
3. Total reconnection power is controlled by IMF clock angle, IMF magnitude and solar wind velocity
   - Solar wind density changes the distribution of σ_{Ec} on the magnetopause, but the effect on P_{rec} is negligible.
   - Velocity has a very strong effect.

Conclusions (2/2)

4. Reconnection controls energy and mass transfer through the magnetopause:
   - Energy transferred in sectors perpendicular to the reconnection line
   - Mass transferred in sectors along the reconnection line
   - Magnetopause reconnection power and energy transfer have similar (but not identical) dependence on solar wind parameters.
5. Tail reconnection is directly driven by energy flow from the magnetopause.

Further information & contact

- Rekonnektio Maan magnetosfäärissä - Reconnection in Earth’s Magnetosphere, PhD thesis, available from author:
- tiera.laitinen@irfu.se