Magnetospheric Currents at Quiet Times

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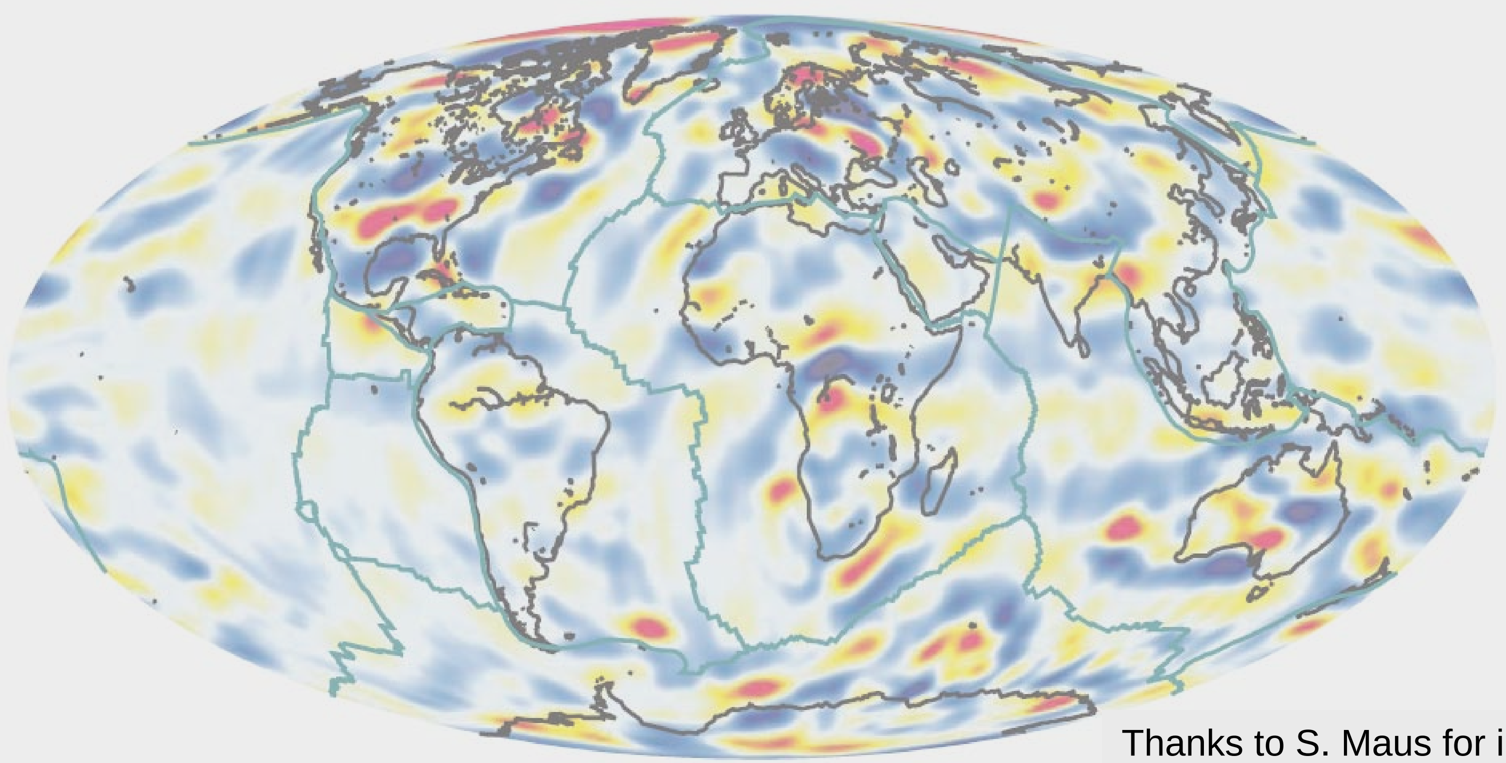
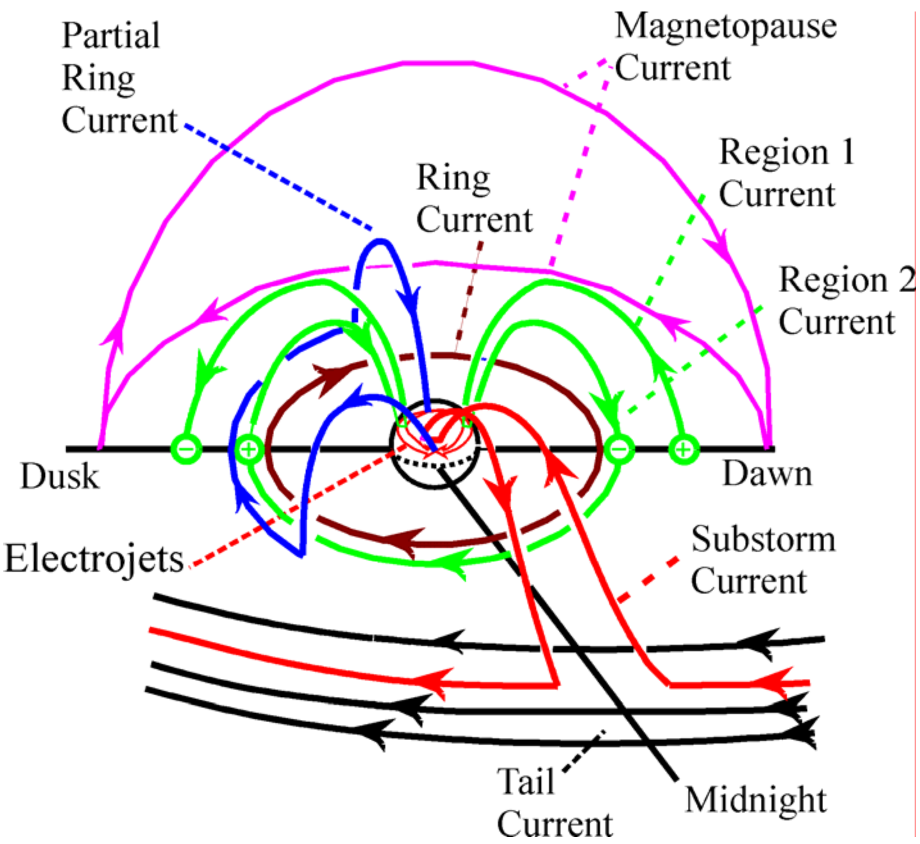


Thanks to S. Maus for image

Motivation



The primary challenge in mapping the lithospheric magnetic field by satellite is the *correction for external fields*.

While the influence of ionospheric currents can be almost entirely avoided by selecting quiet night time data (low latitudes) or tracks with low residual rms (polar latitudes), variable *contributions* from the magnetosphere *are always present* and are only partly removed by the usual Dst correction.

Maus, S., et al., (2002), First scalar magnetic anomaly map from CHAMP satellite data indicates weak lithospheric field, GRL, 29(14), 47-1-4.

Magnetospheric Currents

- Chapman-Ferraro current……..*Magnetopause current*
- Tail current………………………..*Double solenoid*
- Region 1 current………………….*High latitude edge of oval*
- Region 2 current………………….*Low latitude edge of oval*
- Westward electrojet…………….*Morning side Hall current*
- Eastward Electrojet…………….*Evening side Hall current*
- Cusp currents…………………….Divergence of ionospheric flows
- Ring current……………………..*Westward drift of positive ions*
- Partial ring current……………..*Ionosphere closure of ring current*
- Substorm current wedge………*Ionospheric closure of tail current*
- NBZ current……………………..Reconnection with northward Bz

Magnetopause Current

- The current is the boundary of the Earth's field
- In the north it circulates CCW (dawn-dusk) about the northern neutral point
- It produces a positive (northward) perturbation at Earth's equatorial surface
- It is controlled by the dynamic pressure of the solar wind

  $P_{dyn} = m_p n V^2$

  - m_p is mass of solar wind particles
  - n is their number density
  - V is velocity of solar wind

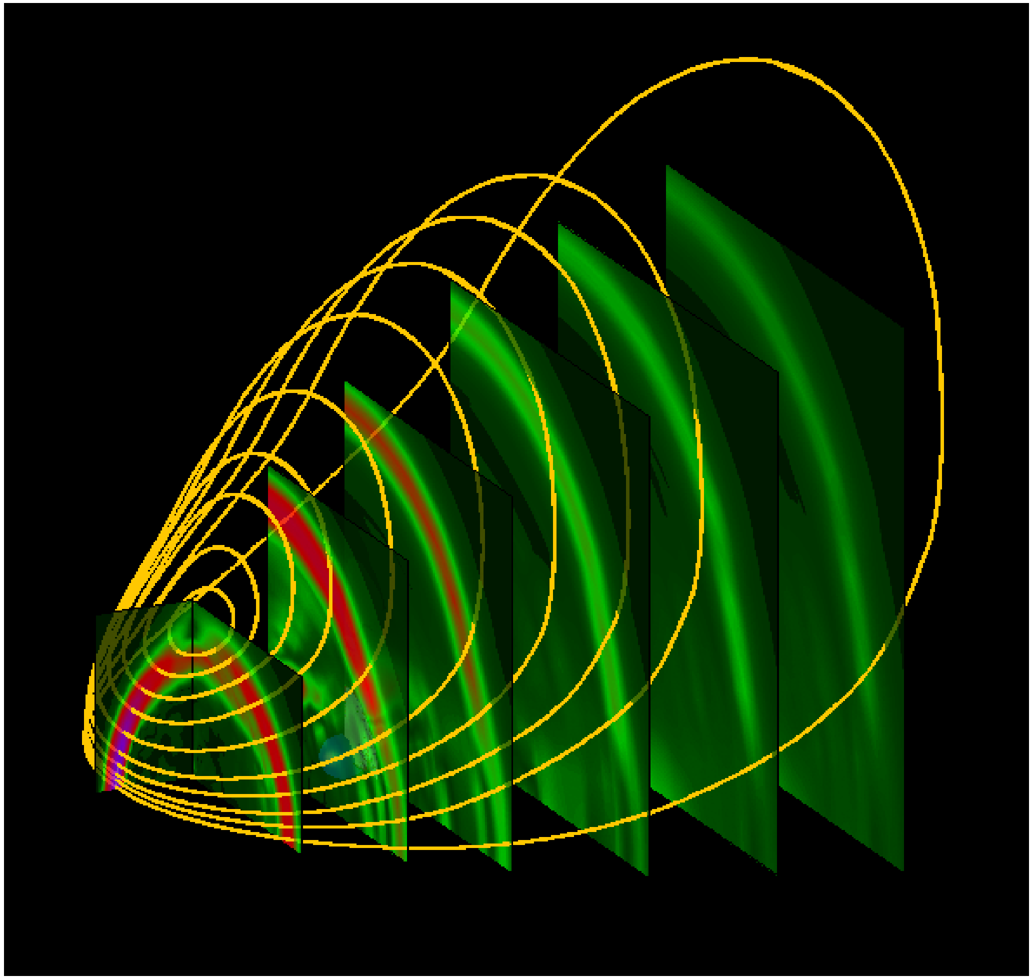
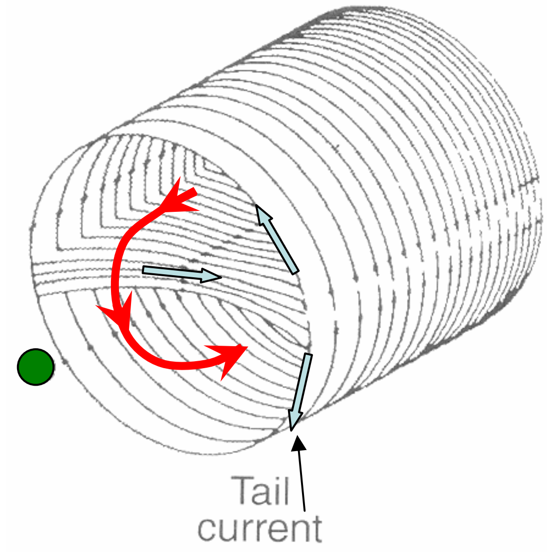
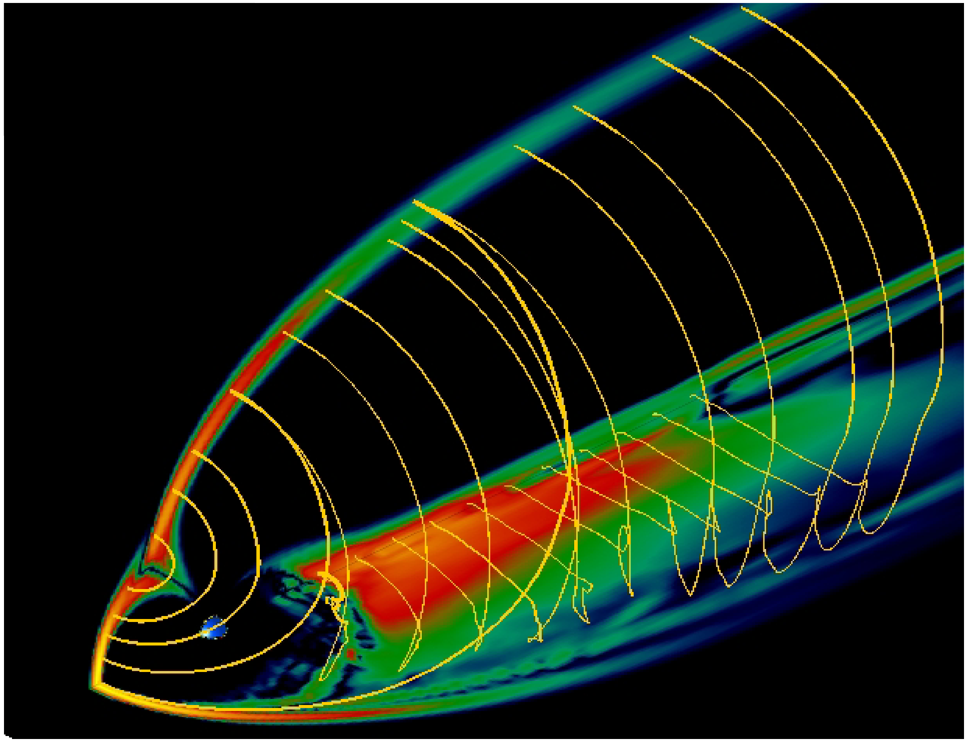


Image from Siscoe

Tail Current

- Tail current consists of two coils wound in opposite directions
- Current is produced by particle drifts inside cylinder and particle reflections at outer boundary
- Required by Ampere's law because antiparallel fields must be separated by current
- Produced by tangential drag
- Causes a negative perturbation at Earth's surface





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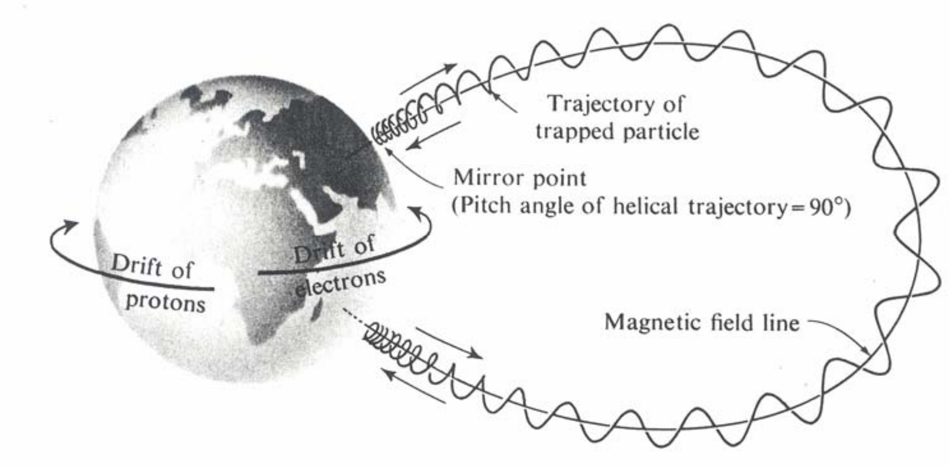
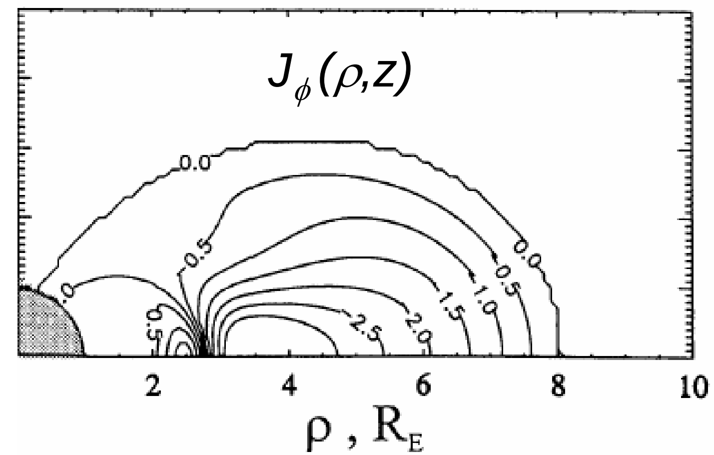
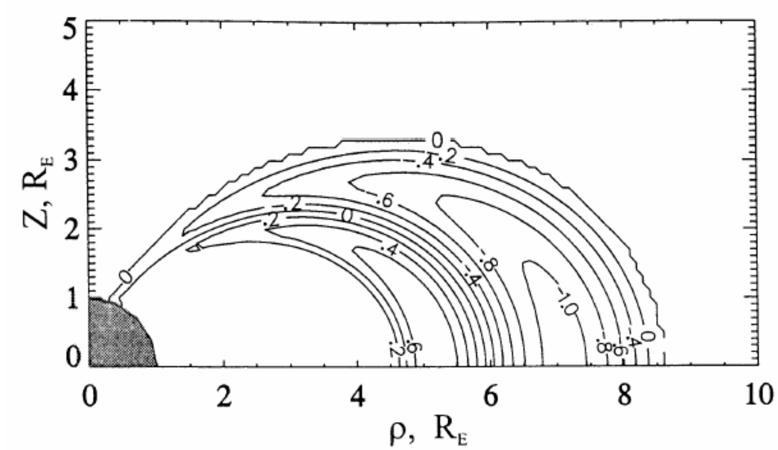
The Ring Current



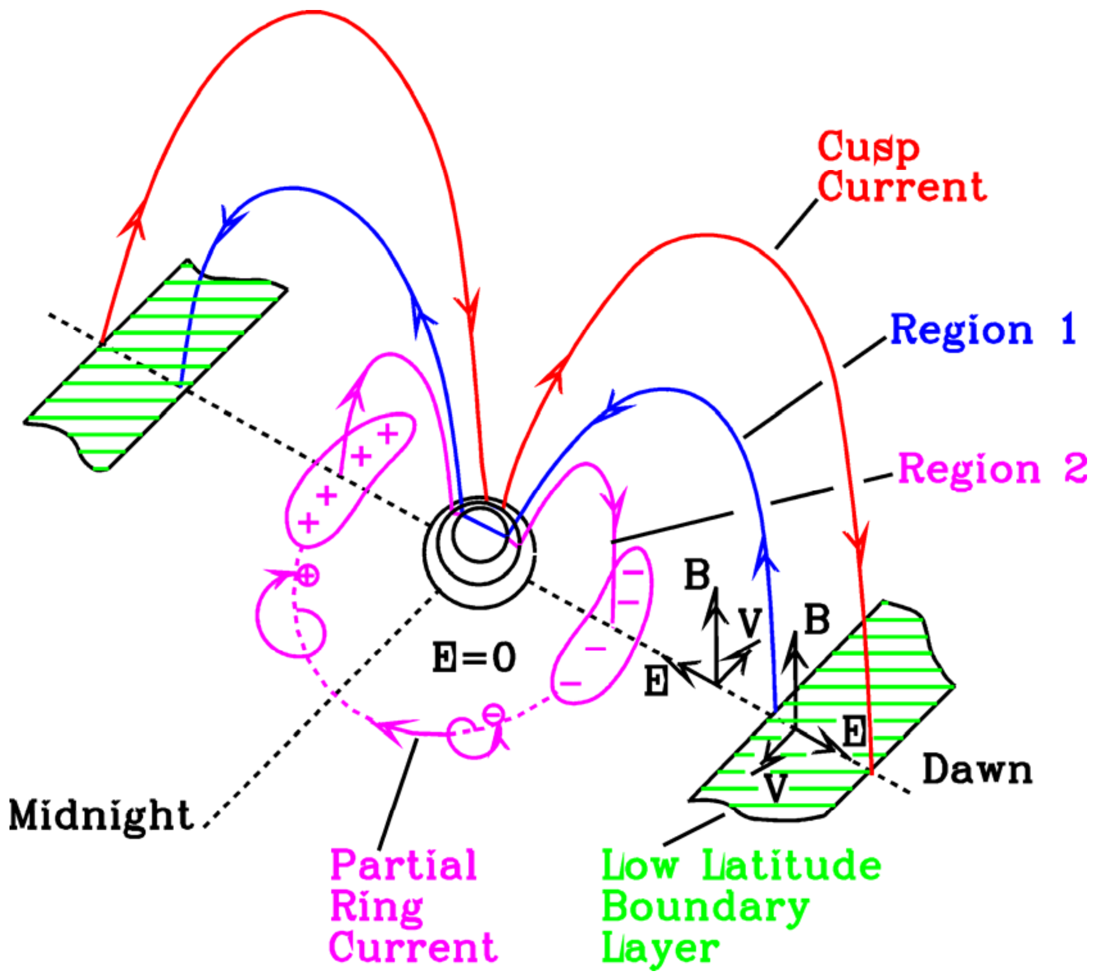




- Electrons are less energetic and quickly lost so ions dominate the ring current
- The inner edge of the ring current is eastward because of proton gyration
- Particles are injected from tail by convection
- They are trapped in circular orbits by a relaxation of convection
- They are lost by a variety of wave particle interactions

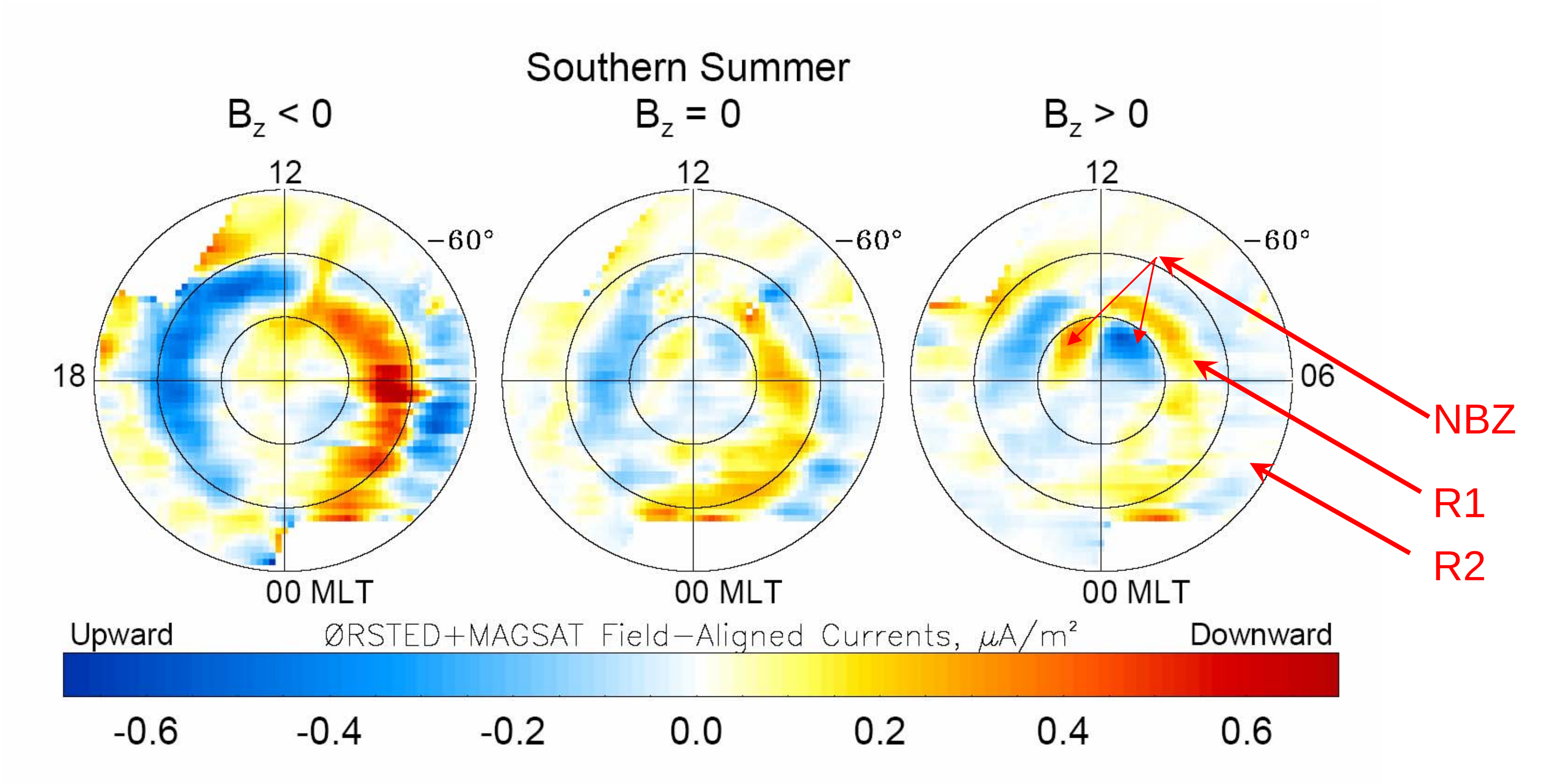
Region 1 & 2 Field-Aligned Current

- Tangential drag induces tailward motion in low latitude boundary layer (llbl)
- Pressure difference induces internal return flow
- There is a divergence of the electric field at inner edge of llbl that is mapped to the conducting ionosphere
- The mapped E field drives Pedersen current both poleward and equatorward
- Gradient and curvature drift separates charges producing a partial ring current and shielding electric field
- A divergence of the electric field at the dawn shielding layer requires upward field-aligned current
- The current is completed by particle drifts across midnight



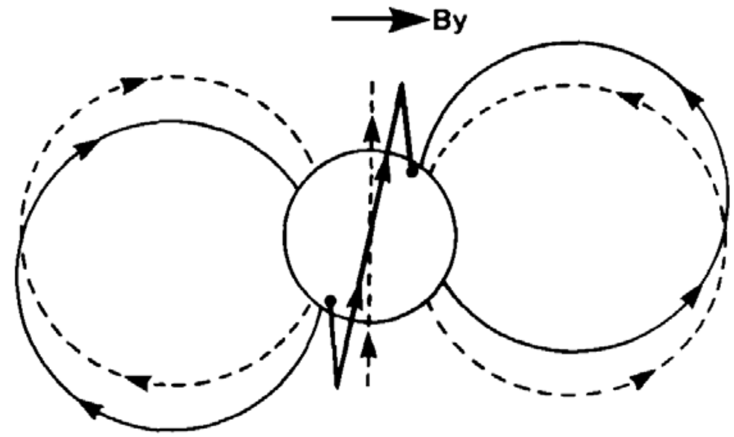
Northward Bz (NBZ) Current

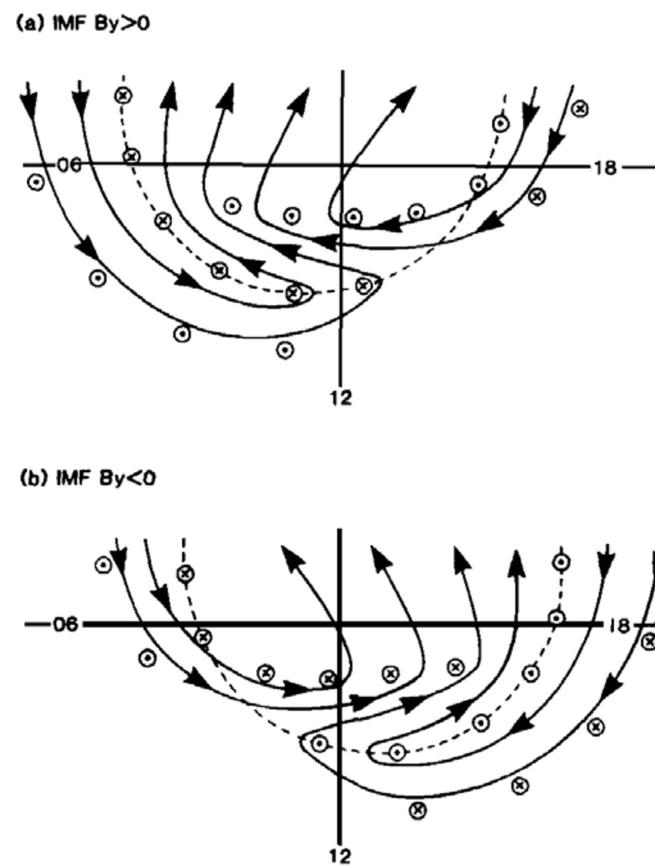
- A southern hemisphere statistical study of polar orbiting magnetometer data for IMF Bz both northward and southward
- Finds six different regions of field-aligned current
- Low latitude currents are R1 & R2 systems
- For Bz north the dayside polar cap is filled with current into the ionosphere on dusk side and out on the dawn side



Cusp Currents

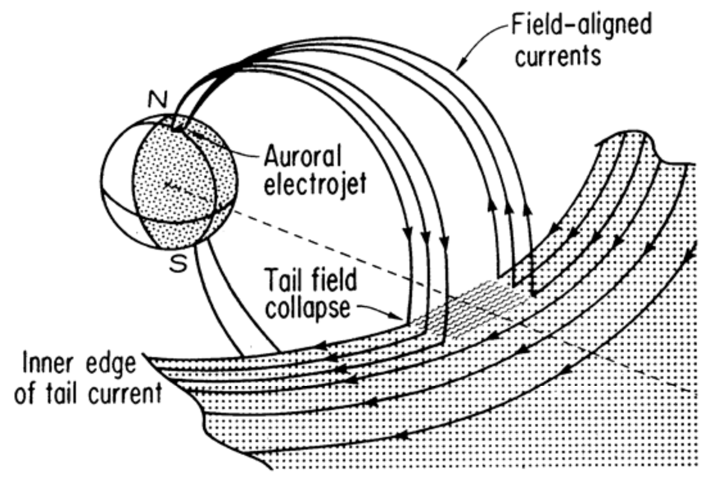
- Magnetic reconnection allows a fraction of the IMF to enter the magnetosphere
- Penetrating By adds to Earth's field distorting field lines and moving their foot points
- Convection patterns and their associated FAC (R1 & R2) are distorted producing multiple sheets in the polar cusp
- A strong IMF By with Bz>0 will produce both cusp currents and NBZ

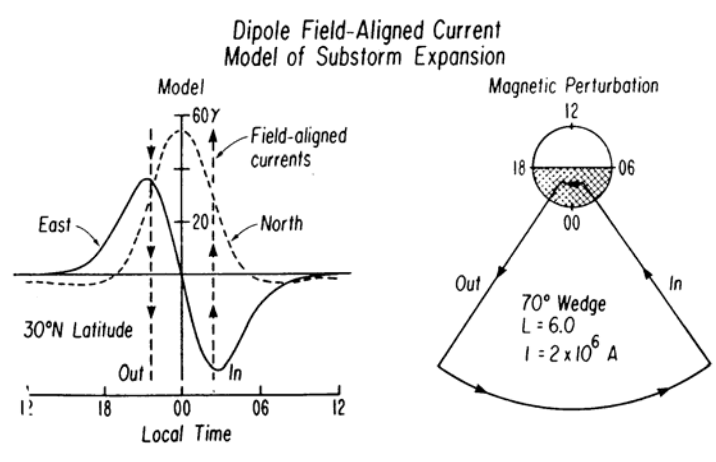




MAGNETIC EFFECTS OF A SUBSTORM CURRENT WEDGE

- Transverse currents in the magnetosphere are diverted along field lines to the ionosphere
- Viewed from above north pole the projection of the current system has a wedge shape
- Midlatitude stations are primarily affected by field-aligned currents and the equatorial closure (an equivalent eastward current)
- The local time profile of H component is symmetric with respect to the central meridian of wedge
- The D component is asymmetric with respect to center of wedge



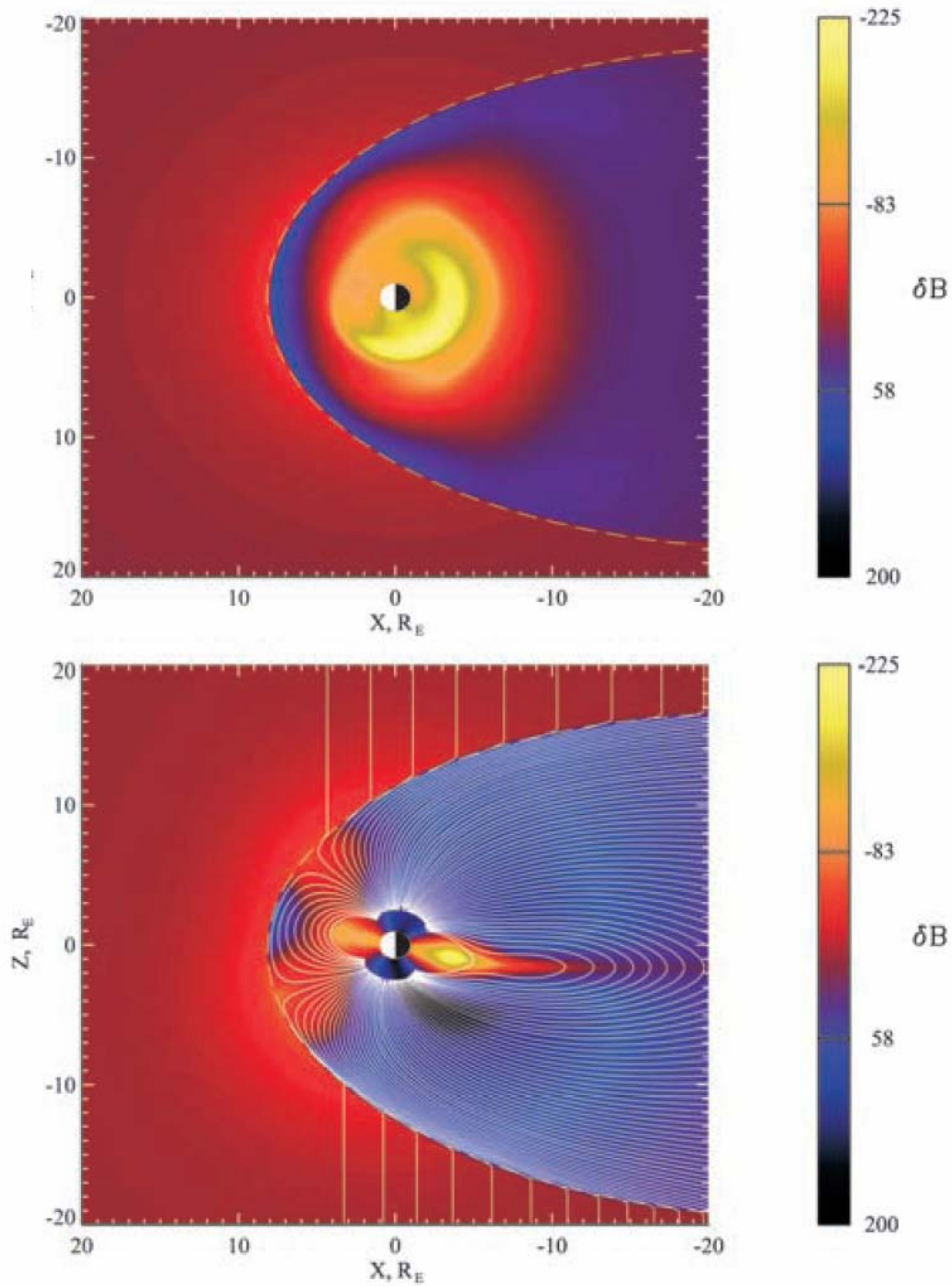


Deviation of B_{tot} from Dipole and Field Lines

(Tsyganenko, N.A., *107*(A8), 2002)

$$\begin{aligned}
\mathbf{B}_{\rm mod} = \mathbf{B}_{CF} &+ \left[t_1^{(0)} + t_1^{(1)}(P_d/P_{d0})^{\alpha_1} + t_1^{(2)}G_1 + t_1^{(3)}Dst^*\right] \\
\cdot\mathbf{B}_{T1} &+ \left[t_2^{(0)} + t_2^{(1)}(P_d/P_{d0})^{\alpha_2} + t_2^{(2)}G_1 + t_2^{(3)}Dst^*\right] \\
\cdot\mathbf{B}_{T2} &+ \left[s^{(0)} + s^{(1)}Dst^* + s^{(2)}(P_d/P_{d0})^{1/2}\right] \\
\cdot\mathbf{B}_{\rm SRC} &+ \left[p^{(0)} + p^{(1)}Dst^* + p^{(2)}(P_d/P_{d0})^{1/2}\right] \\
\cdot\mathbf{B}_{\rm PRC} &+ \left[b_1^{(10)} + b_1^{(11)}G_2\right]\mathbf{B}_{R1}^{(1)} + \left[b_1^{(20)} + b_1^{(21)}G_2\right] \\
\cdot\mathbf{B}_{R1}^{(2)} &+ \left[b_2^{(10)} + b_2^{(11)}G_2\right]\mathbf{B}_{R2}^{(1)} + \left[b_2^{(20)} + b_2^{(21)}G_2\right] \\
\cdot\mathbf{B}_{R2}^{(2)} &+ \left[\varepsilon_0 + \varepsilon_1 \sin^2\frac{\theta}{2}\right]\mathbf{B}_{\perp}^{\rm IMF}.
\end{aligned}$$

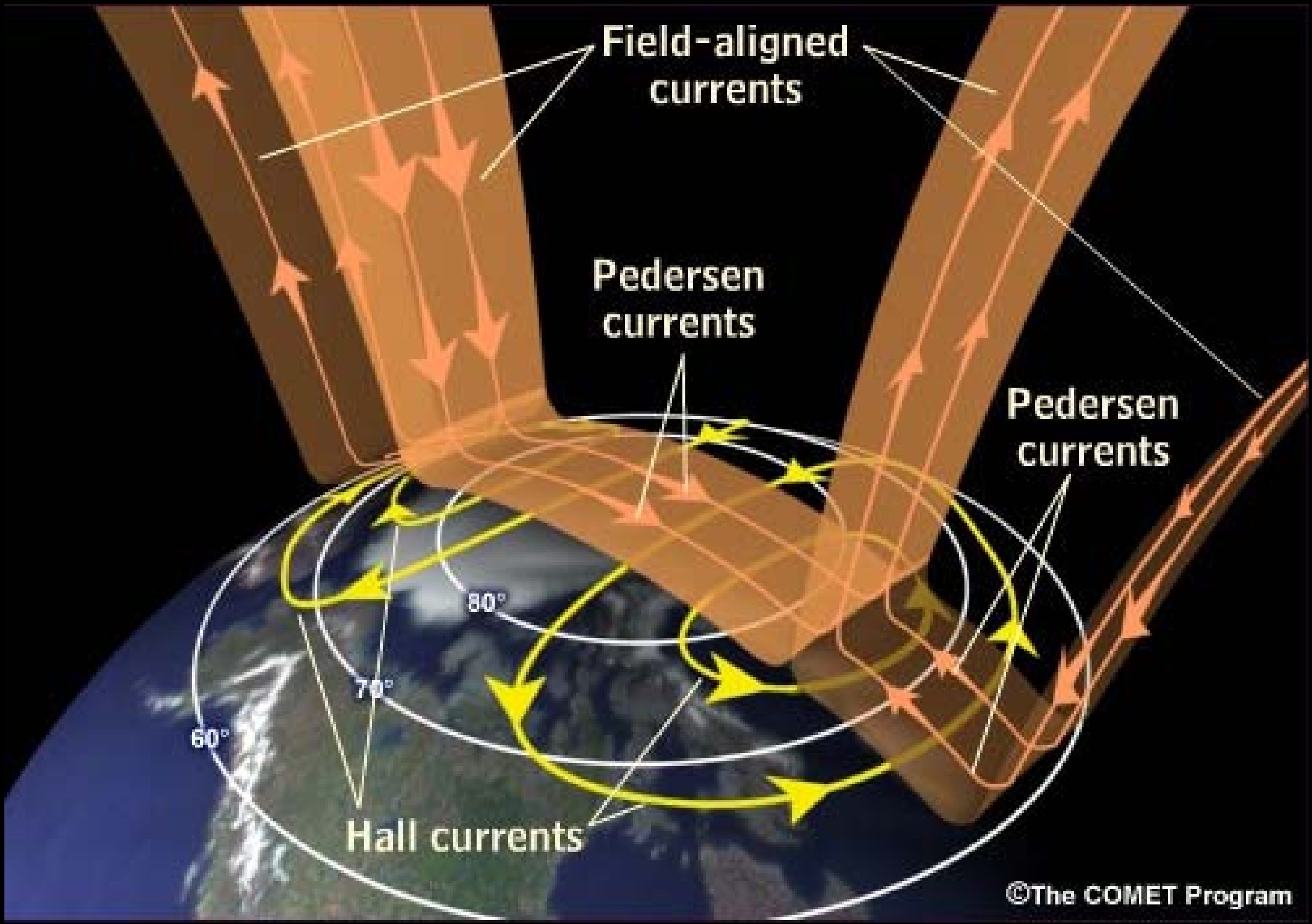
- Use 24 coefficients and 18 nonlinear parameters. Fit data
- Depressions in field magnitude are shown by red and yellow. Enhancements are shown by blue and black.
- Note the PRC is rotated towards dusk
- At bottom field lines are inflated and drawn out into the tail



Conclusions

- International quiet days will have NBZ current, cusp currents, possible effects due to changes in dynamic pressure, and decay of ring current
- Quiet days may include weak substorm current wedges
- Ring current persists for many days because of periodic injections that don’t completely decay before the next
- The locations of FAC are hard to predict because of IMF B_y effects and transient response times
- There is no time in which external currents completely vanish
- The most recent model has an average external field magnitude of 33 nT and an rms fitting error of 14 nT

The End!


Field-aligned currents
Pedersen currents
Pedersen currents
80°
70°
60°
Hall currents
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