W,B. Hanson Center
For Space Sciences

UT DALLAS
School of Natural Sciences
and Mathematics

Dynamo Currents in the Equatorial Ionosphere

Rod Heelis

U T Dallas

W,B. Hanson Center For Space Sciences

UT DALLAS School of Natural Sciences and Mathematics

Dynamo Currents in the Equatorial Ionosphere

OUTLINE

- Implications of a Quasi-Steady Description
- Applications to the Gravity Dynamo
- Applications to the F-Region Dynamo
- Applications to the E-Region Dynamo

Charged Particle Motions are Anisotropic

- Momentum equations relate the change in the particle velocity to the forces.

- It is usual to neglect the particle acceleration and the particle inertia by assuming a quasi steady state

For charged particles $\mathbf{V}_{\parallel} = \frac{\omega_B}{\upsilon}\frac{1}{eB}\mathbf{F}_{\parallel}$ $\mathbf{V}_{\wedge} = \frac{u/m}{u^2 + w_B^2}\left[\mathbf{F}_{\wedge} + \frac{w_B}{u}\mathbf{F}_{\wedge} \times \hat{\mathbf{b}}\right]$

IMPORTANT

In a steady state there is no specification of cause and effect.
We can only say ***what forces are in balance***.

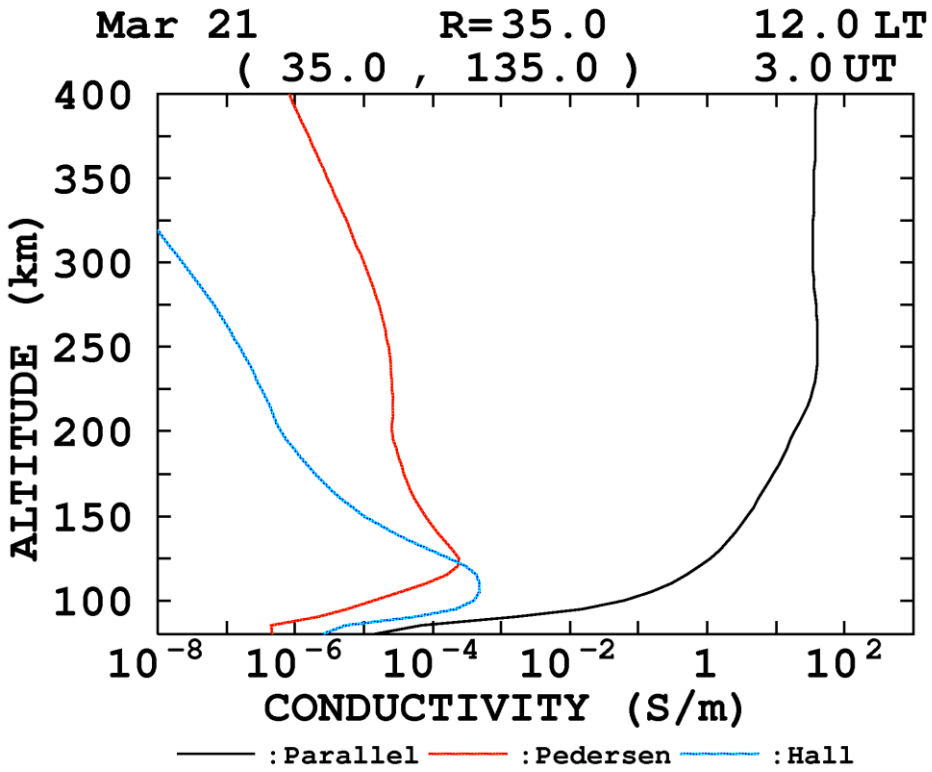
- It is most useful to specify the plasma motion in terms of ***a bulk motion*** of the plasma (ions and electrons) and ***a current density*** that specifies the perturbation velocity difference between the ions and electrons.

- The bulk flow of the plasma may be expressed as an equivalent electric field where $\vec{E} = -\vec{V} \times \vec{B}$

- In the ionosphere the JxB force generally balances the gravitational and collisional forces.

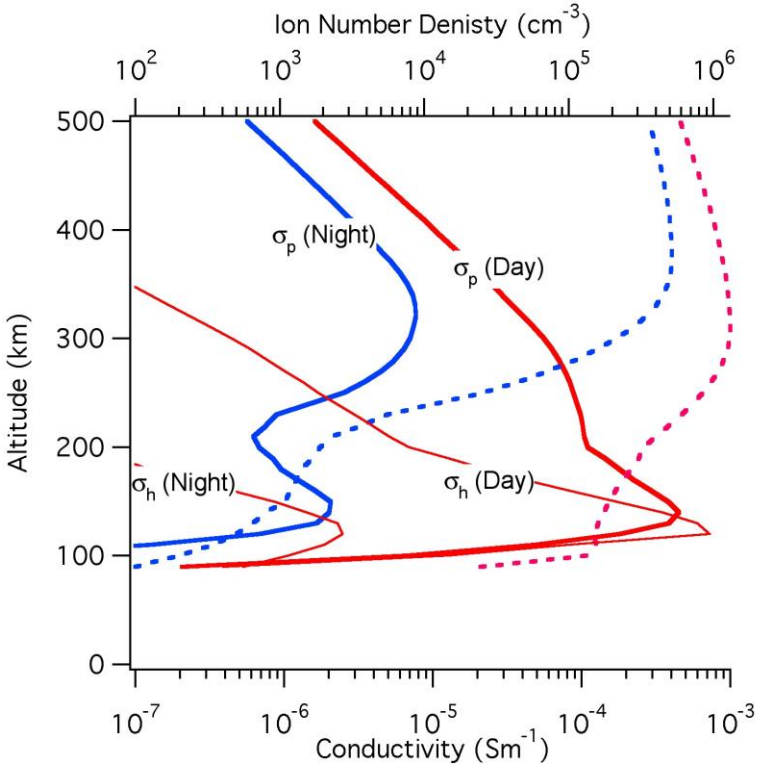
Ionospheric Conductivity

Specifies the current density driven by any force expressed as an equivalent electric force.



- Parallel Conductivity is very large
  - Magnetic field is almost an electric equipotential above 120 km.
  - **Plasma on a magnetic flux tube moves together.**
  - **Determine the motion anywhere on the flux tube, that is the motion everywhere**

Ionospheric Conductivity



- Hall conductivity exists in one layer
  - 100 km – 200 km (E region)
- Pedersen Conductivity exists in 2 layers
  - 120 km – 220 km (E region)
  - 200 km – 500 km (F region)

- E region conductivity dominates by day, substantially reduced at night.

- Pedersen conductivity in E and F regions is comparable at night

Middle and Low Latitude Current Systems

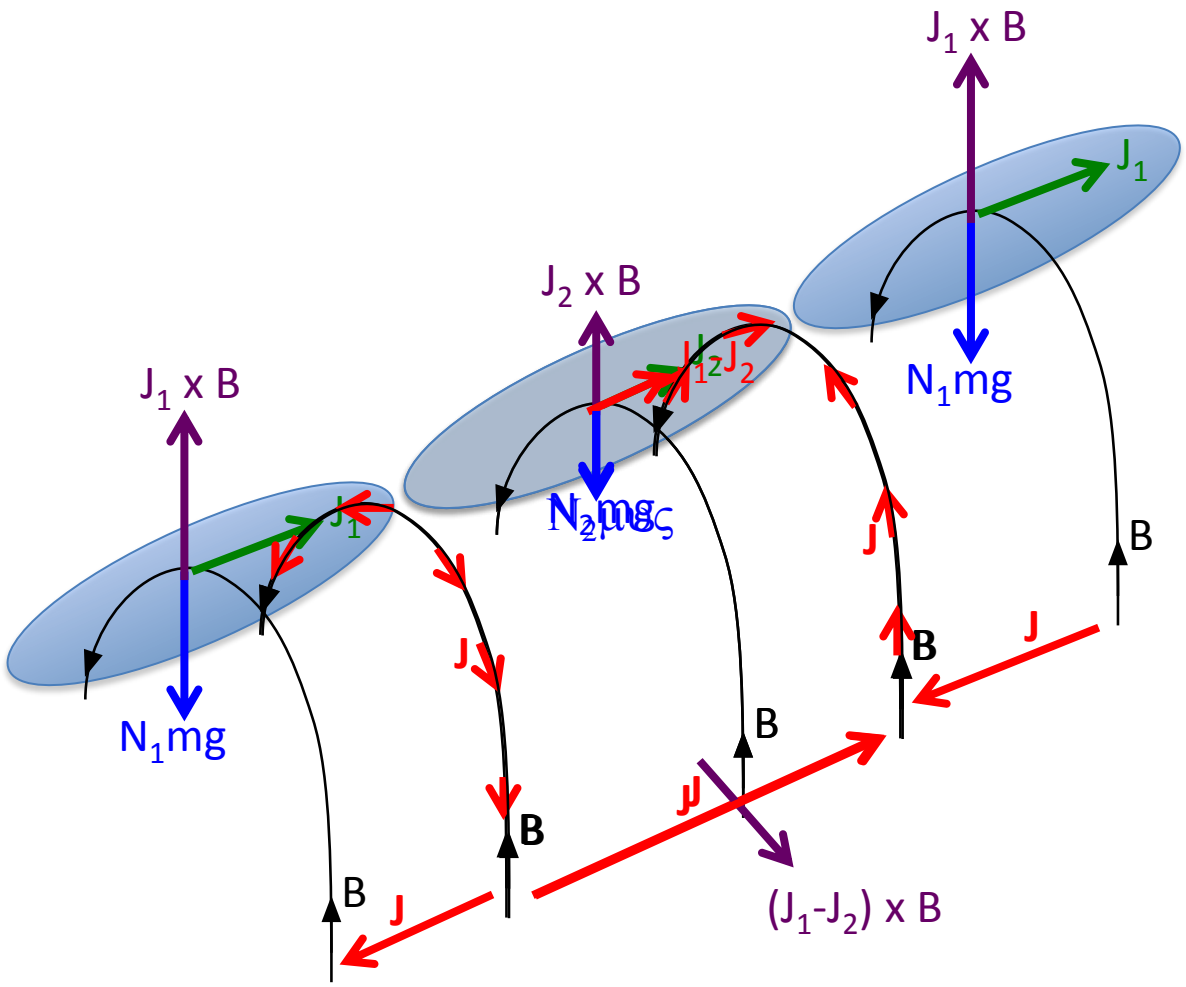
It is usual to consider currents originating from two sources

- Gravity (Rayleigh Taylor Instability)
- Neutral Air Motions (Dynamo)
- Currents flow in closed loops and are distributed through regions connected by the magnetic field.
  - Redistribution of current density is controlled by $\nabla \bullet \vec{J} = 0$
- Current Density dependent on total electron (ion) density
- Equipotential Magnetic Field Lines make Bulk Plasma Flow identify a magnetic flux tube.
- Express the electric field in an Earth - Sationary frame as the gradient of a scalar potential

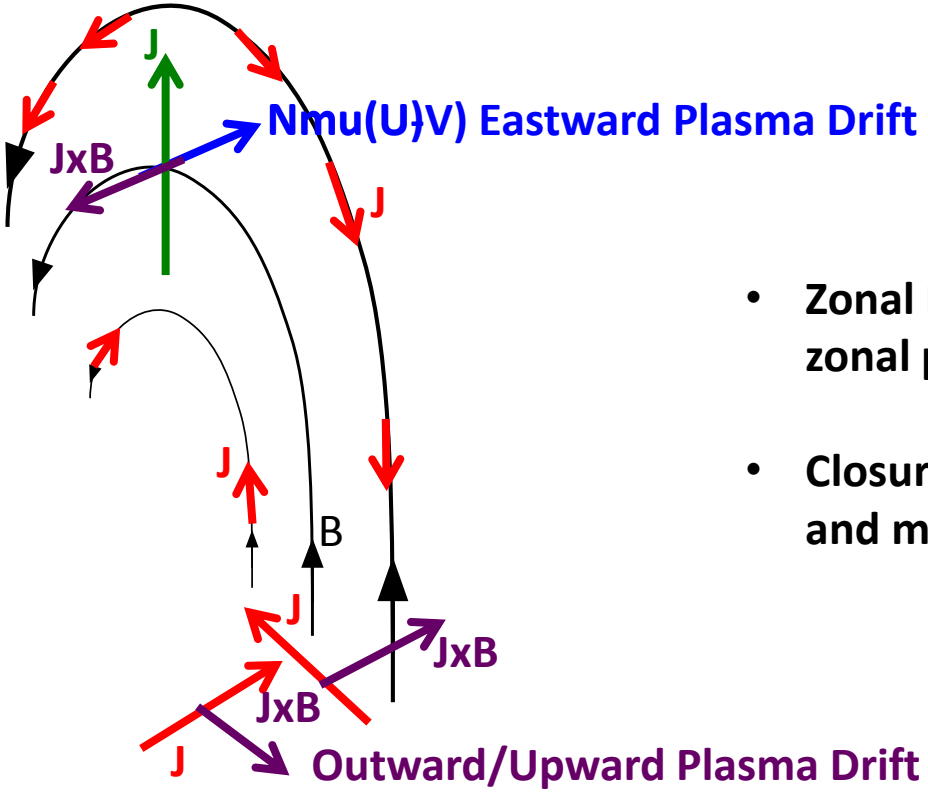
$$\int_{other\ end}^{one\ end} \nabla_\perp \vec{J}^{\perp}\Big|_{driver} ds - \int_{other\ end}^{one\ end} \nabla_\perp \left(\tilde{\sigma}_\perp \nabla_\perp \Phi\right) ds = \vec{0}^{\|end}_{one} - \vec{J}^{\|end}_{other}$$

DYNAMO EQUATION

GRAVITY DYNAMO



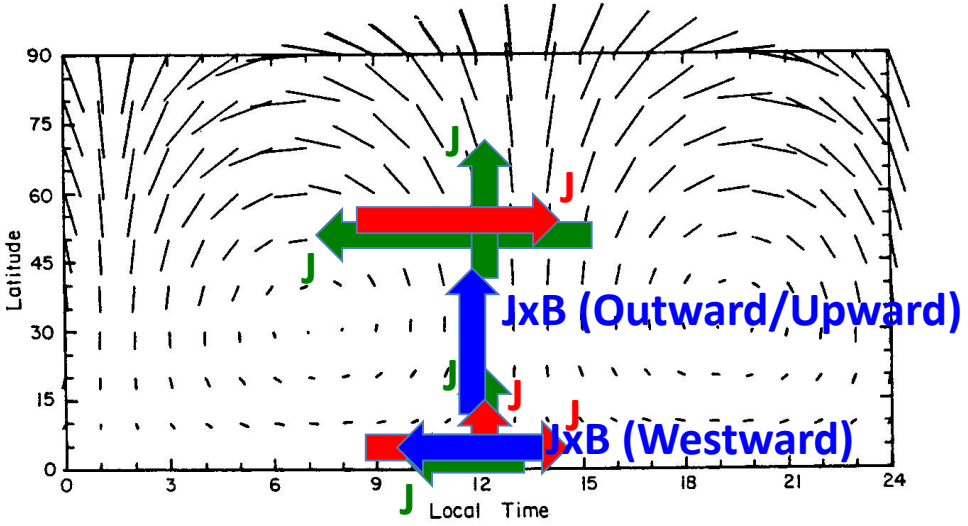
F-REGION DYNAMO

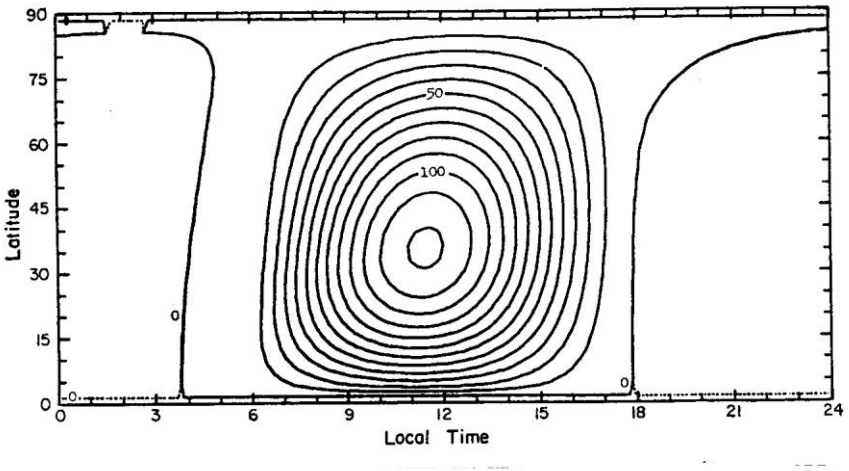


- **Zonal F-region wind produces zonal plasma drift**
- **Closure current produces zonal and meridional plasma drifts.**

E-REGION DYNAMO

- Treat E region as a layer with wind independent of altitude.
- E-region density has peak near local noon and large gradients near sunrise and sunset.





Tarpley, Planet. Space Sci., *18*, 1091, 1970

- **Current circulates anticlockwise**
- **Plasma drifts outward/upward during daytime**
- **Plasma drifts westward during daytime**
- **Plasma drifts inward/downward during nighttime**
- **Plasma drifts eastward during nighttime**

SUMMARY

- **Electric fields and bulk plasma drifts are self consistent in the F region**
  - **But one does not produce the other.**
- **In steady state bulk plasma moves to create a force balance.**
  - **JxB force balances the mechanical force**
- **Motions can be readily related to the current paths in the plasma**
- **Many current paths are possible and all exist in proportion to the equivalent circuit resistance.**

GRAVITY DYNAMO