Penetration Electric Fields During Large Magnetic Storms

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Effect of Strong Penetration on Equatorial Ionosphere?
Equatorial Superfountain Effect

Figure from Mannucci et al., GRL, 2005
Effect of Strong Penetration on Equatorial Ionosphere

Ionospheric and plasmaspheric density structuring at mid latitudes during a large storm

Figure from [Foster et al., 2005]
Penetration E-fields in the Ionosphere

Figure courtesy of Rod Heelis

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Is it possible that during large magnetic storms, there is no shielding in the “traditional” sense?

How long can penetration E-fields last during large storms? How large can penetration E-fields get in the equatorial ionosphere?

Can simulated E-field possibly account for observations?

Numerical Model (RCM): solves

- adiabatic drift equations in the inner magnetosphere
- FAC via pressure gradients (Vasyliunas equation)
- Ionospheric current conservation equation

Two plasma populations:

- Hot (plasma sheet, ring current, keV H+, O+, e-)
- Cold ionospheric plasma (no transport)

Case study: November 9-10, 2004 magnetic storm
March 31, 2001 magnetic storm
How Southward Turning Affects RCM Inputs

- **Electromagnetic:**
  - It increases polar-cap potential
  - Magnetic flux in the tail lobes increases, tail field stretches

- **Plasma**
  - Southward IMF changes $PV^{5/3}$ in the middle and distant plasma sheet, but the change is highly uncertain due to lack of knowledge and understanding of how solar wind controls plasma sheet.
  
  Specifying ionospheric conductance model is another uncertainty affecting penetration E-fields.


  Magnetic field model: *Hilmer-Voigt* model had input parameters:
  - Estimate standoff distance from solar-wind $\rho V^2$.
  - Use observed ABI
  - Use measured $Dst$ ($SYM-H$).

  The principal parameters we need to specify are $PV^{5/3}$ and $TV^{2/3}$.

  Estimate $PV^{5/3}$ and $TV^{2/3}$ at 13 $R_E$ in the plasma sheet from plasma sheet statistics hold plasma boundary condition constant in time.

  or produce equatorial maps of $PV^{5/3}$ and $TV^{2/3}$, combine statistical models:
  - T01 magnetic field models.
November 7-11 2004 Magnetic Storm
November 7-11, 2004 Magnetic Storm RCM Simulation

PCP=109.1 kV  Dst=-108.8  UT=65:00:00

Figure courtesy of Bela Fejer
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Summary

Storm-time magnetospheric E-fields is a major factor in controlling transport of ionospheric plasmas at all latitudes. This includes penetration E-fields at low and mid latitudes as well as subauroral flow structures (both really combine).

Magnetosphere-ionosphere coupling electrodynamic processes

- Increase in the polar-cap potential
- Increase in the magnetic flux in the tail lobes, magnetotail stretching

will drive time-dependence of penetration E-field. The full role will not be understood without the role of neutral wind dynamo. There may be no shielding for hours in the usual sense during large (super) storms. Equatorial E(east-west) reaches up to 3 mV/m.

Although full self-consistent models of the magnetosphere and ionosphere are not available yet, the global picture of magnetospherically generated E-fields is consistent with the observed phenomena related to storm-time plasma transport in ionosphere.