Low Latitude Storm Time Ionospheric Electric Fields: Outstanding Questions

Bela G. Fejer

Center for Atmospheric and Space Science

Utah State University

Logan, Utah

CEDAR/GEM Meeting

Boulder

June 2013

Introduction

The low latitude ionosphere undergoes large and complex changes during and after periods of strong geomagnetic activity as a result of large departures of the electrodynamic plasma drifts and thermospheric winds from their quiet-time values. These storm-time perturbations cover a broad range of temporal and spatial scales.

Storm time low latitude ionospheric electric fields result mostly from the penetration of magnetospheric electric fields into the plasmasphere and from disturbance dynamo electric field driven by enhanced energy deposition into the high latitude ionosphere. However, they can also be driven by substorms and solar wind dynamic pressure changes.

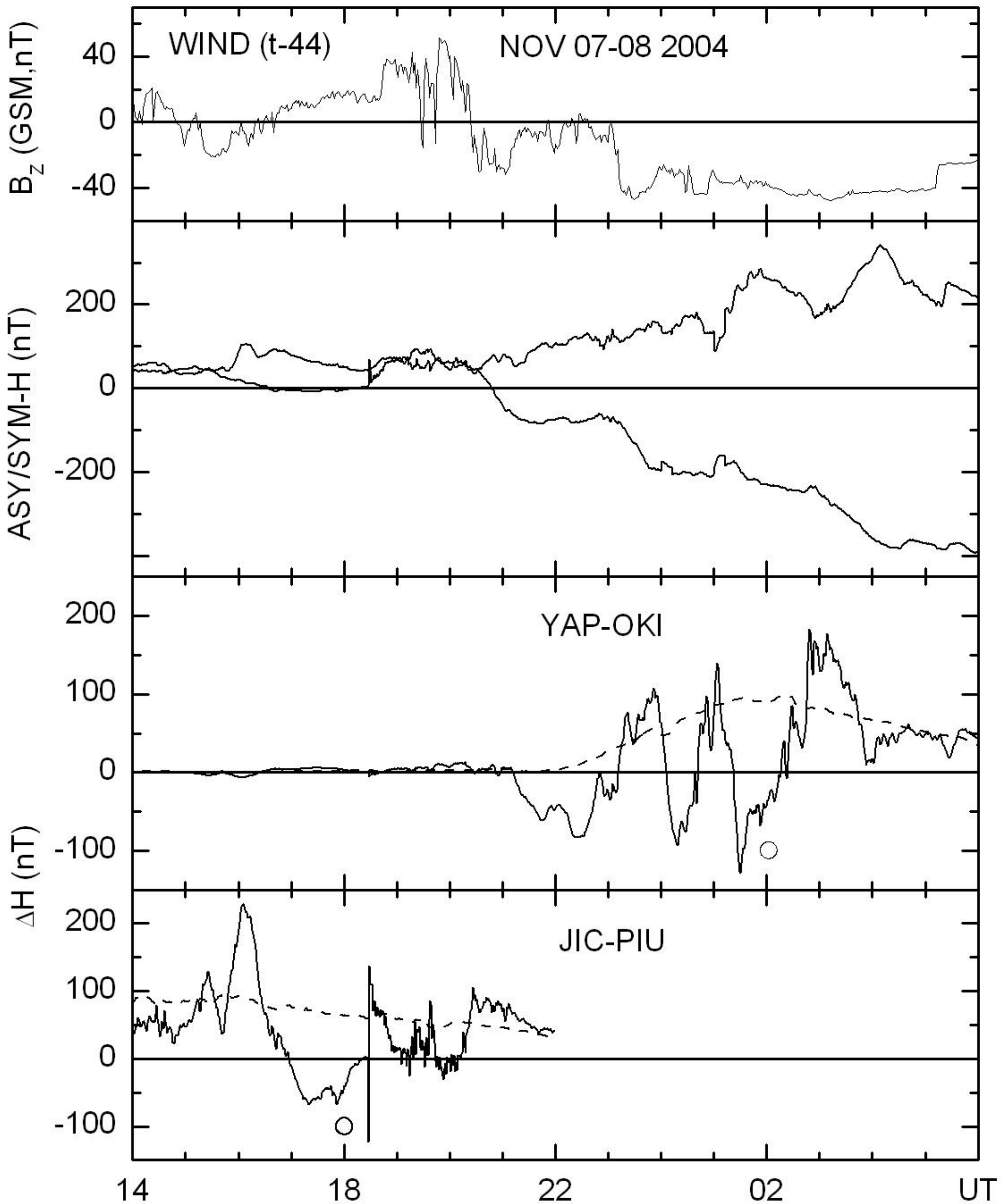
The understanding and accurate modeling and forecasting of low latitude storm time electric fields and their low latitude electrodynamic effects requires the proper specification of their solar wind, magnetospheric and high latitude ionospheric drivers, but also of season, solar flux, latitude and longitude dependent ionospheric parameters.

The general characteristics of storm-time driven low latitude electric field perturbations are now reasonably well understood and reproduced by global convection models. However, there is still questions regarding their temporal and spatial variability.

Outstanding questions resulting from solar-wind and magnetospheric conditions include changes in the efficiency of prompt penetration electric fields for different solar wind structures (e.g., magnetic clouds and fast streams) and storm-phases, and the effects of IMBy, magnetospheric reconfiguration, substorms.

The response of low latitude ionospheric electric fields to these solar-wind and magnetospheric conditions and parameters will vary with season solar, cycle, and longitude.

The specification of low latitude storm-time electric fields requires initially the accurate removal of highly variable tidal and planetary wave driven electric fields.



WIND (t-44)
NOV 07-08 2004
B_Z (GSM,nT)
ASY/SYM-H (nT)
YAP-OKI
ΔH (nT)
JIC-PIU
14
18
22
02
UT

Solar wind – Magnetosphere Coupling Filters

Newell et al. (2007) derived a nearly universal solar-wind derived a nearly universal solar wind-magnetosphere coupling function

$$d\mathbf{F}_{MP/dt} = \mathrm{v}^{4/3} B_T^{2/3} \sin^{8/3}\left(\theta_c/2\right)$$

representing the rate magnetic flux is opened at the magnetopause which correlates best with 9 out of 10 indices of magnetospheric activity.

McPherron et al. (2013, in press) presented state-dependent linear prediction filters which transforms rectified linear solar wind electric field (VBs) to output functions such as AU and AL. This study shows strongest coupling to AU and AL at solar minimum and weakest at solar maximum.

Solar-Wind Low Latitude Electrodynamic Transfer Function

$$E(\theta,\phi,t) = \int_{-\infty}^{\infty} G(\theta,\phi,t)\Phi_0(t-\tau)d\tau \qquad (1)$$

E = Ionospheric electric field perturbation

Φ_o = Input signal (IEF, PCP, AE, etc.)

G = Green's function (physical content of the model which is dependent on magnetospheric and ionopheric parameters)

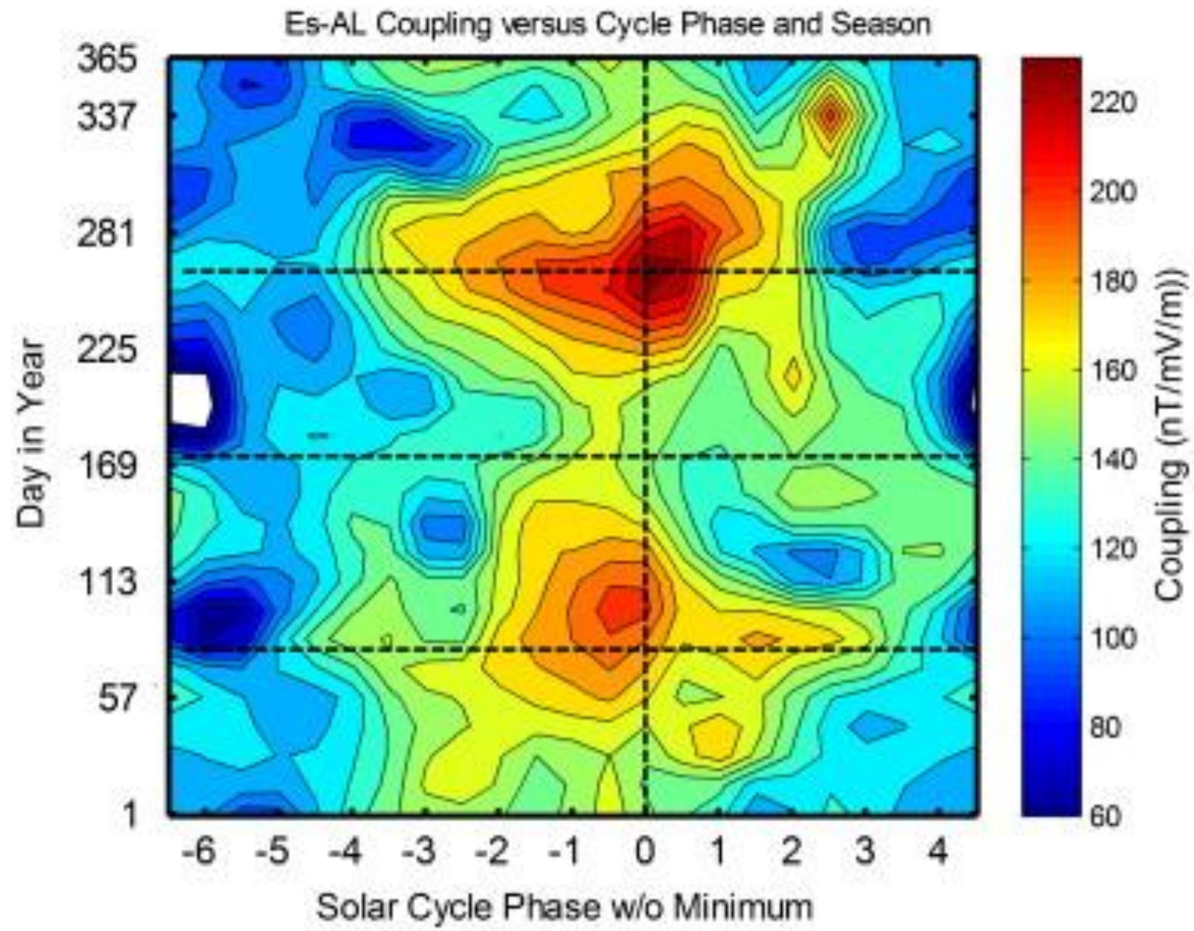
Integrating (1) by parts and assuming no source at -∞,

$$E(\theta,\phi,t) = \int_{-\infty}^{\infty} G_0(\theta,\phi,\tau)\frac{d\Phi(t-\tau)}{dt}d\tau$$

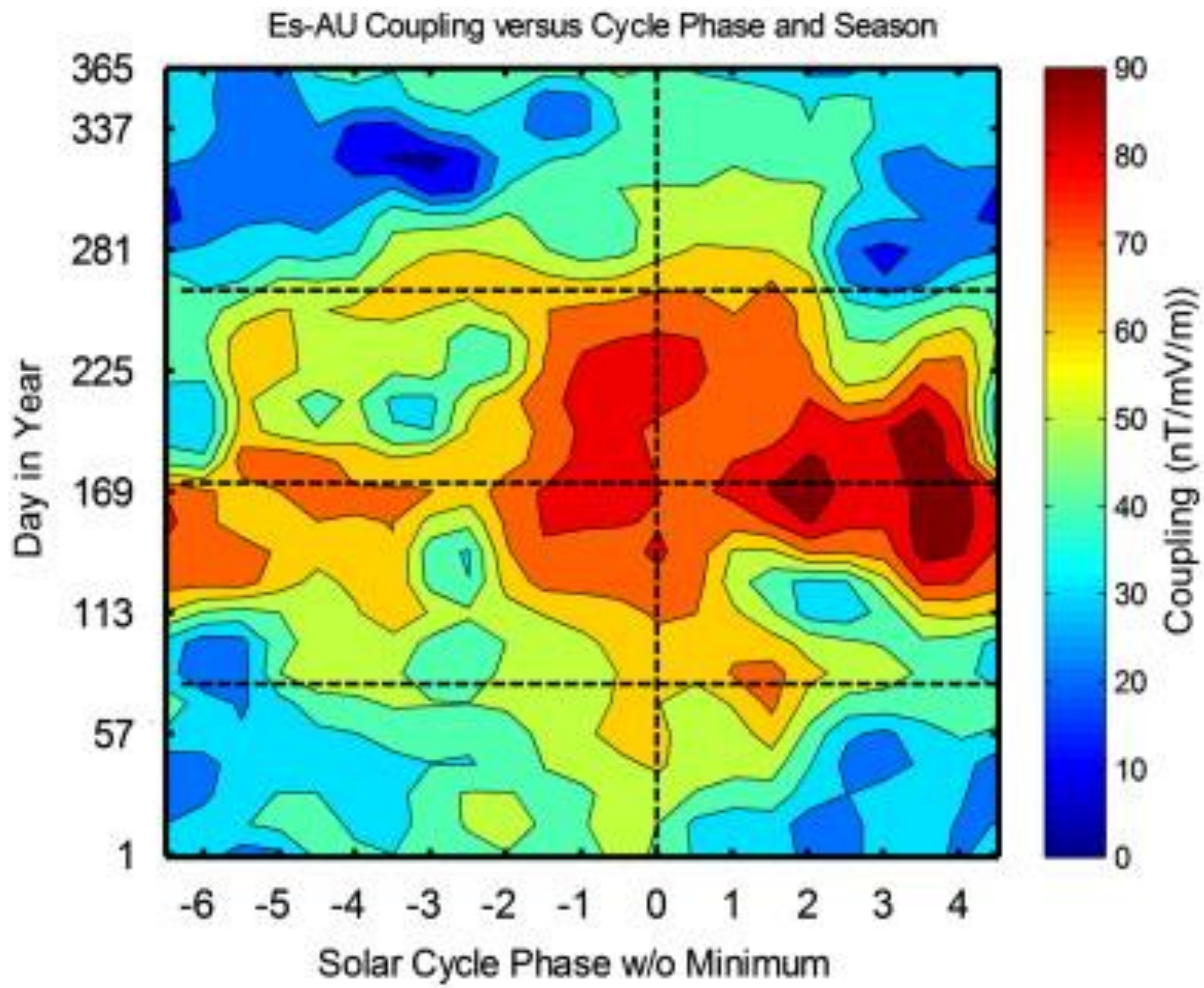
where $$G_0 = \int_{-\infty}^{t} G(\theta,\phi,\tau)d\tau$$

With G_0=0 for τ<0.

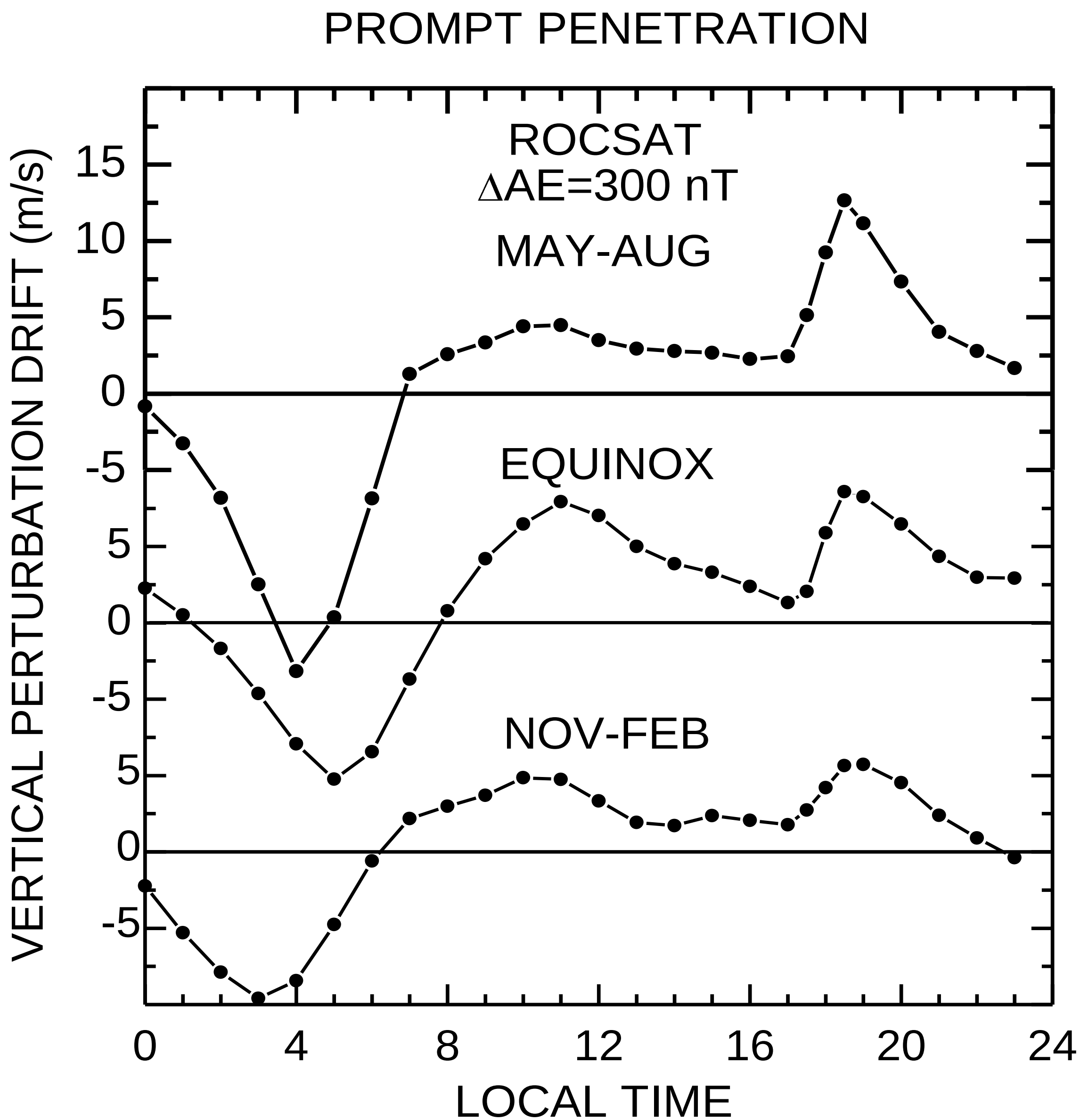
Seasonal and Solar Cycle Effects and Longitudinal Effects

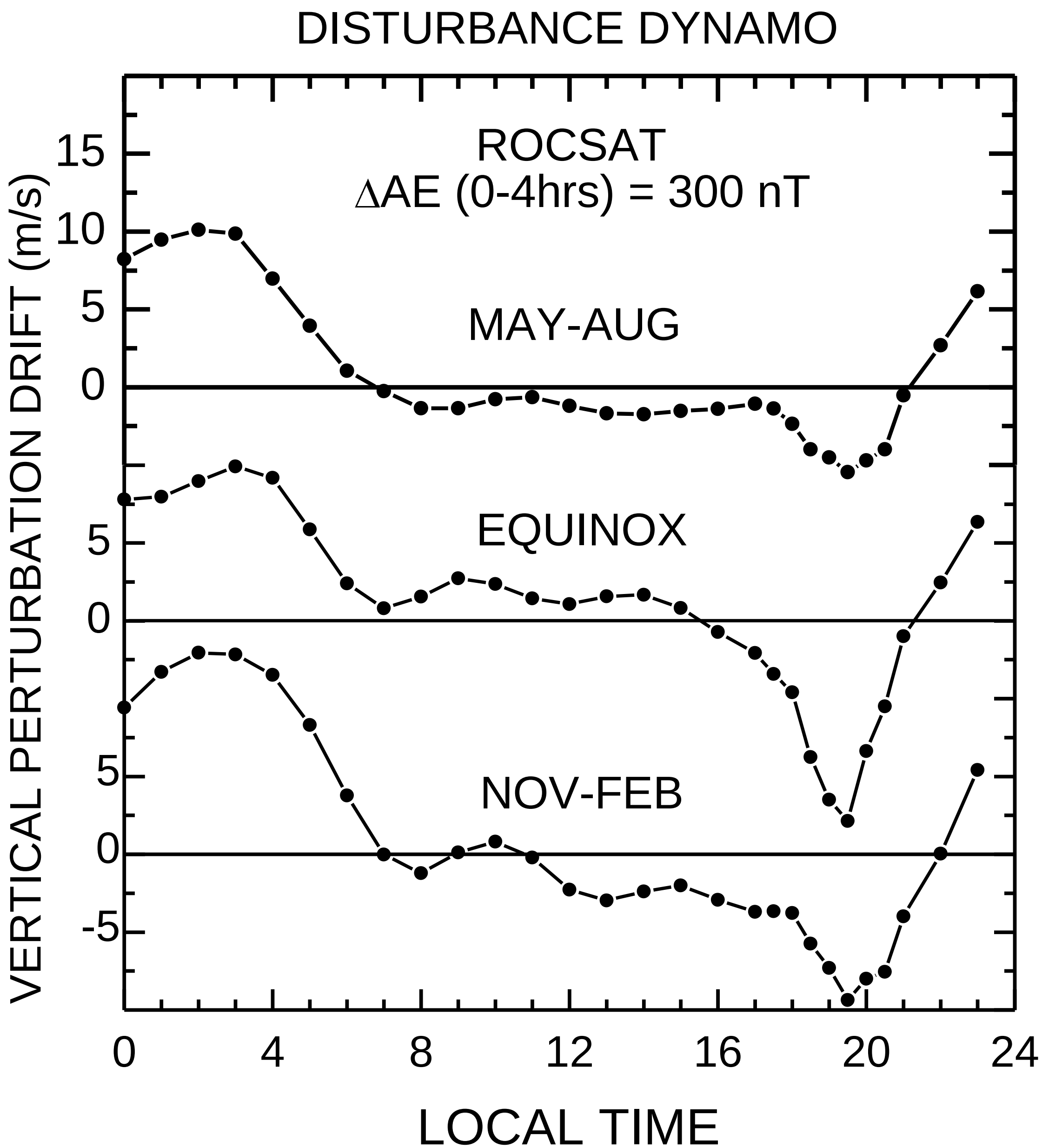


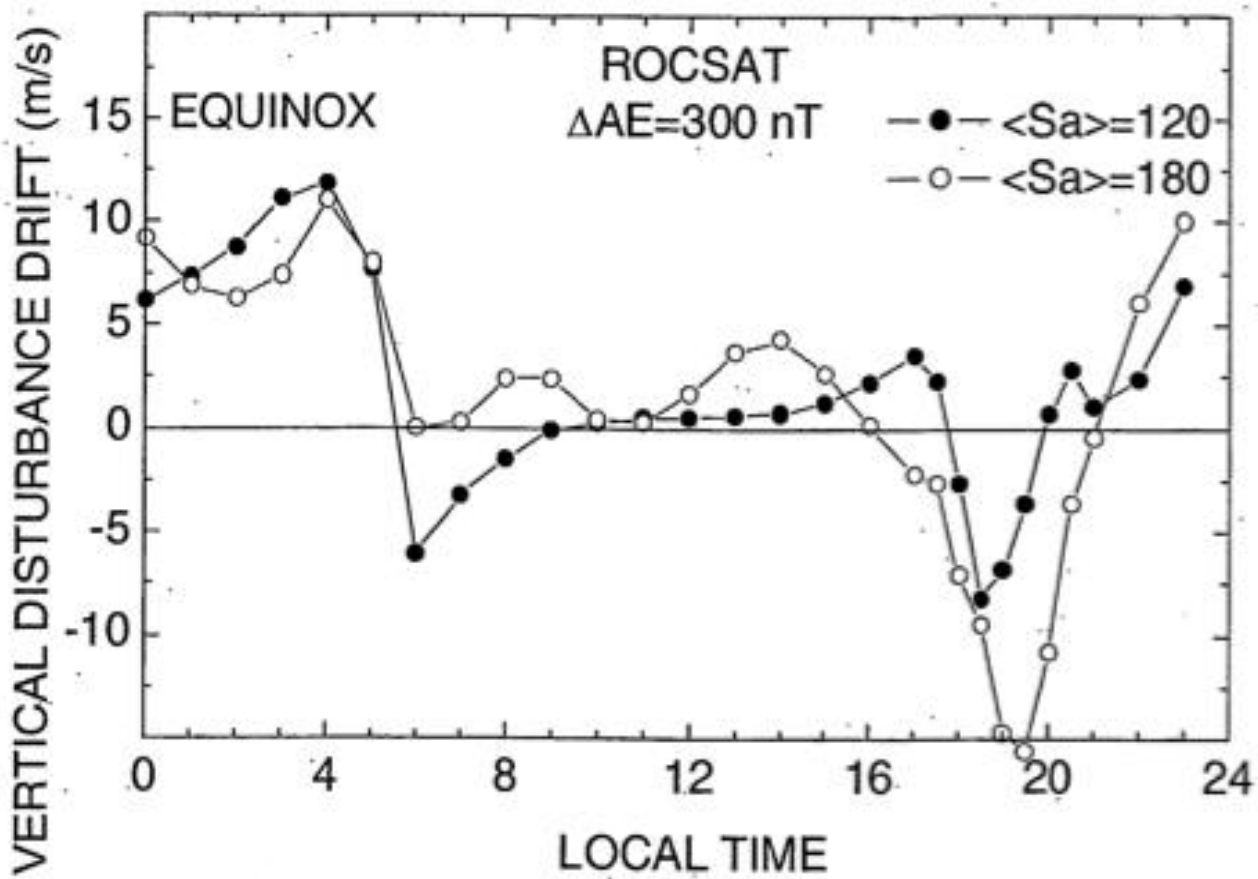
McPherron et al. (JASTP, in press)



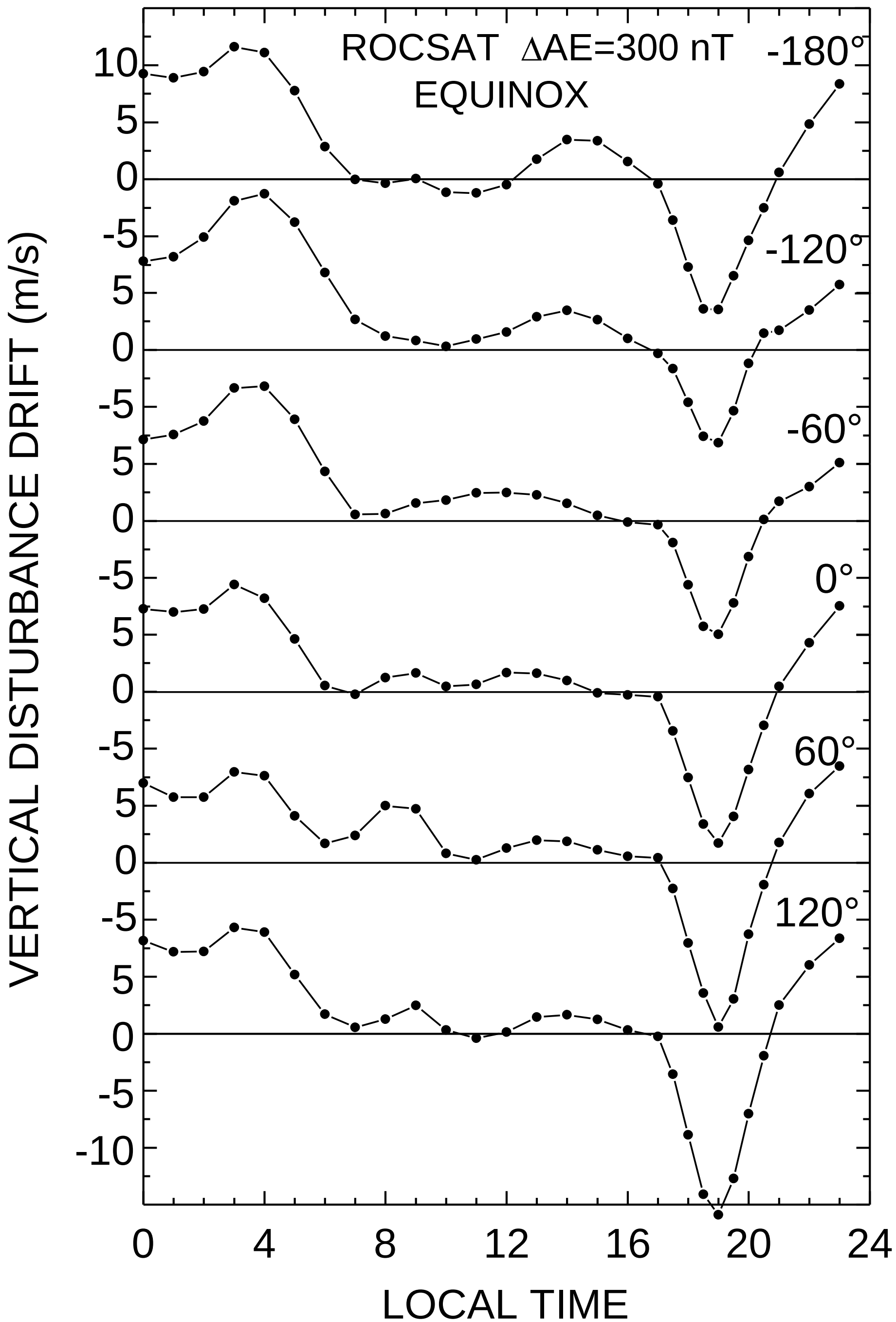
McPherron et al. (JASTP, in press)


PROMPT PENETRATION
ROCSAT
ΔAE=300 nT
MAY-AUG
EQUINOX
NOV-FEB
VERTICAL PERTURBATION DRIFT (m/s)
LOCAL TIME
15
10
5
0
-5
5
0
-5
5
0
-5
0
4
8
12
16
20
24


DISTURBANCE DYNAMO
ROCSAT
ΔAE (0-4hrs) = 300 nT
MAY-AUG
EQUINOX
NOV-FEB
VERTICAL PERTURBATION DRIFT (m/s)
15
10
5
0
5
0
5
0
-5
0
4
8
12
16
20
24
LOCAL TIME



ROCSAT
EQUINOX
ΔAE=300 nT
<Sa>=120
<Sa>=180
VERTICAL DISTURBANCE DRIFT (m/s)
15
10
5
0
-5
-10
0
4
8
12
16
20
24
LOCAL TIME



ROCSAT ΔAE=300 nT
EQUINOX
-180°
-120°
-60°
0°
60°
120°
VERTICAL DISTURBANCE DRIFT (m/s)
LOCAL TIME
0
4
8
12
16
20
24
10
5
0
-5
-10

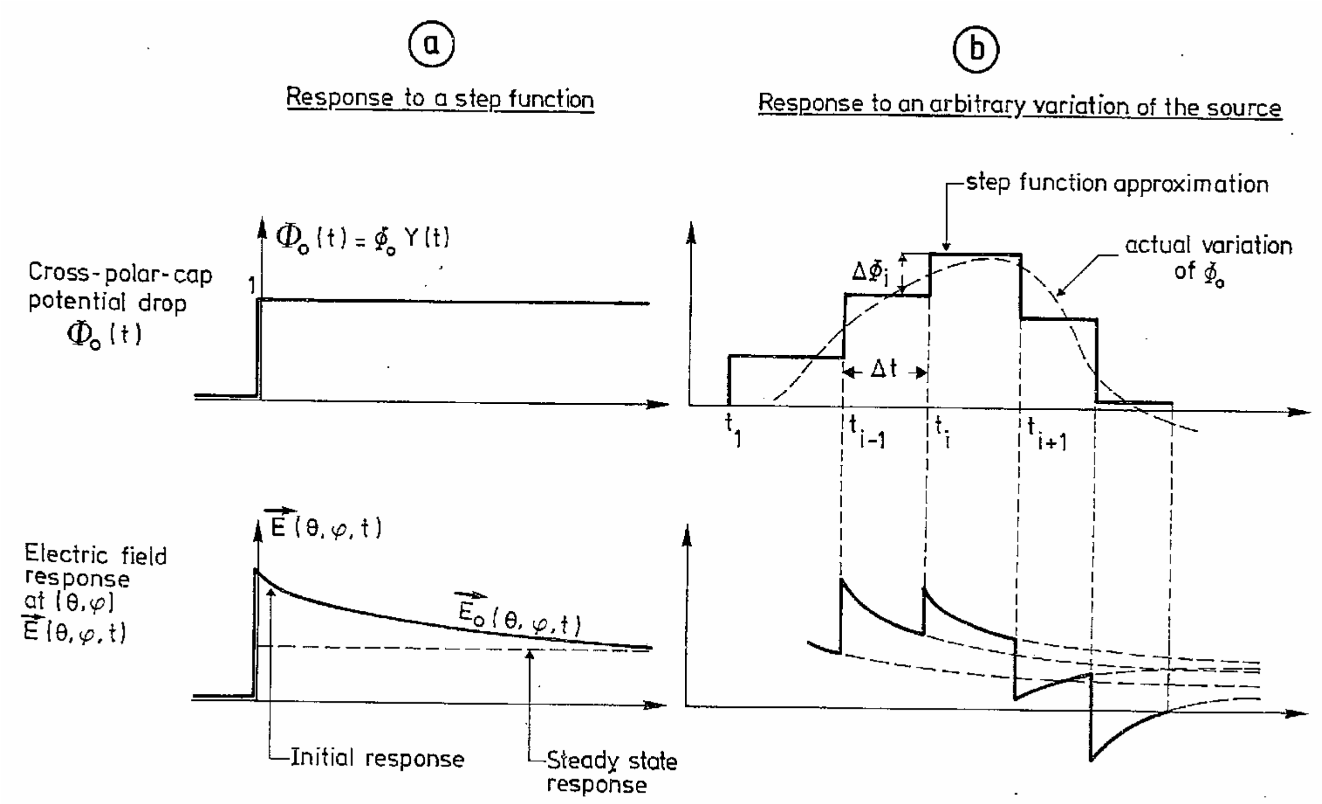
Summary

The major difficulty for experimental studies of these electric fields is the very limited current database of reliable GLOBAL ionospheric plasma drift and electric field measurements.

Future satellite observations (e.g. SWARM) and more extensive complementary magnetospheric and ionospheric global modeling studies and the use of recently developed solar wind-high latitude ionospheric transfer functions should provide considerable new information on low latitude storm electric field and their important ionospheric effects and result in the development of much more accurate predictive ionospheric models.

Taking $$\Phi_0(t) = \sum_{i=1}^{N} \Delta\Phi_i H(t - t_i)$$

Then: $$E(\theta, \phi, t) = \sum_{i=1}^{N} \Delta\Phi_i G_0(\theta, \varphi, t - t_i)$$



Senior and Blanc (1987)