Specification of Equatorial Ionospheric Irregularity Formation During the Main Phase of Strong Magnetic Storms

S. Basu[1], Su. Basu[2], E. MacKenzie[1], Cesar Valladares[1], C. Bridgwood[3]

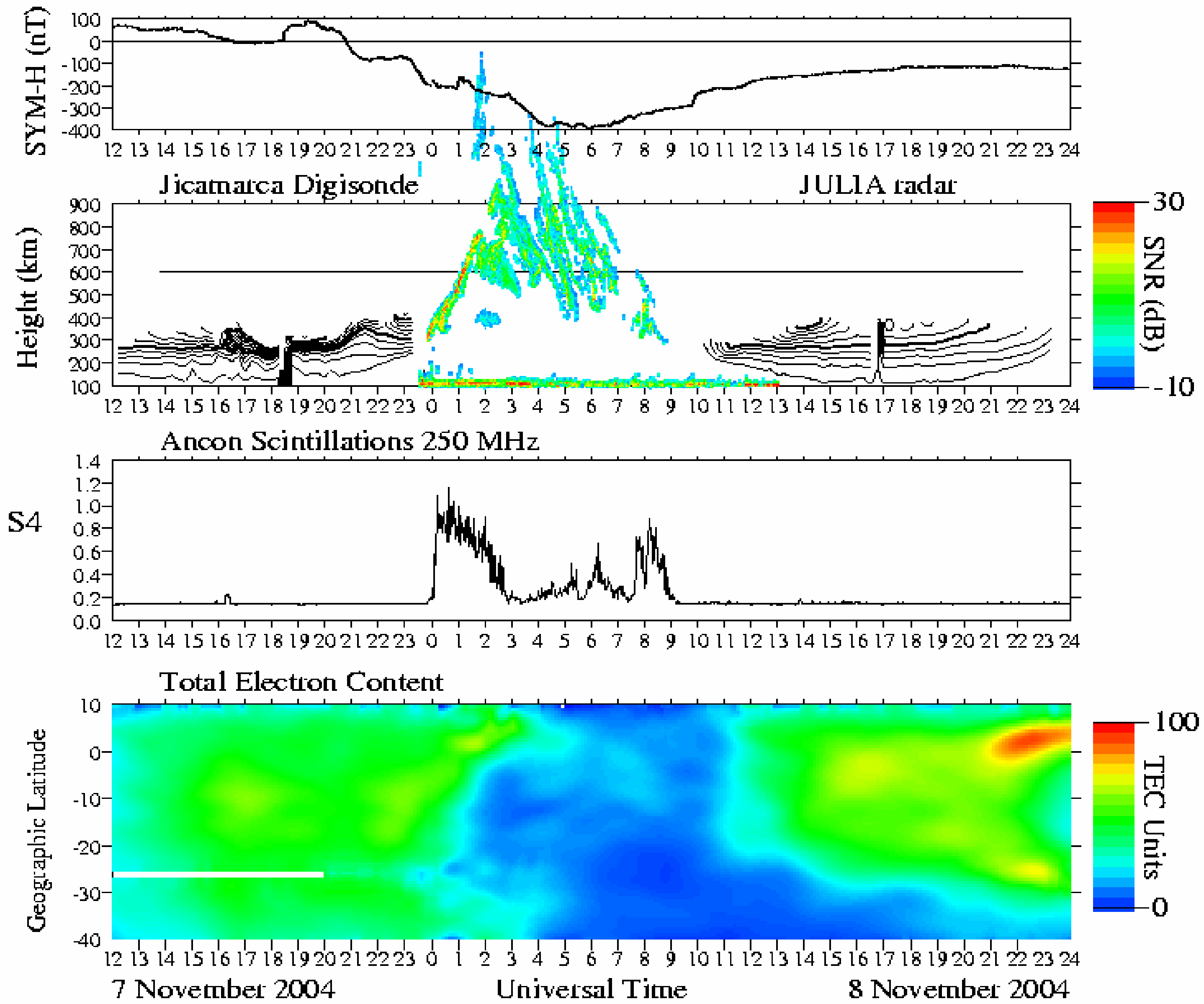
[1]Institute for Scientific Research, Boston College, Chestnut Hill, MA 02467; [2]Center for Space Physics, Boston University, Boston, MA; [3]AER Inc., Lexington, MA 03421.

2008 URSI General Assembly
Chicago, IL
11-16 August 2008

Scope of Presentation

- The response of the equatorial ionosphere at dusk to large magnetic storms during solar cycle 23 with Dst min ≤ -100 nT has been studied.
- We focus our attention on equatorial ionospheric irregularities that form during the prompt or, direct penetration (DP) phase of electric fields that cover the time interval between dDst/dt ≥ -50 nT/hr and Dst min.
- During the DP phase the penetration electric field is eastward during the daytime through dusk and westward at nighttime
- Equatorial irregularities in the dusk sector have been detected from scintillation measurements by the Air Force Research Laboratory’s global SCINDA (Scintillation Network Decision Aid) network and DMSP satellite in-situ measurements of equatorial plasma bubbles and bite-outs.
- We investigate if the longitude interval of equatorial ionospheric disturbances (scintillations, bubbles and bite-outs) can be specified from a knowledge of the Universal Time interval of the DP phase.

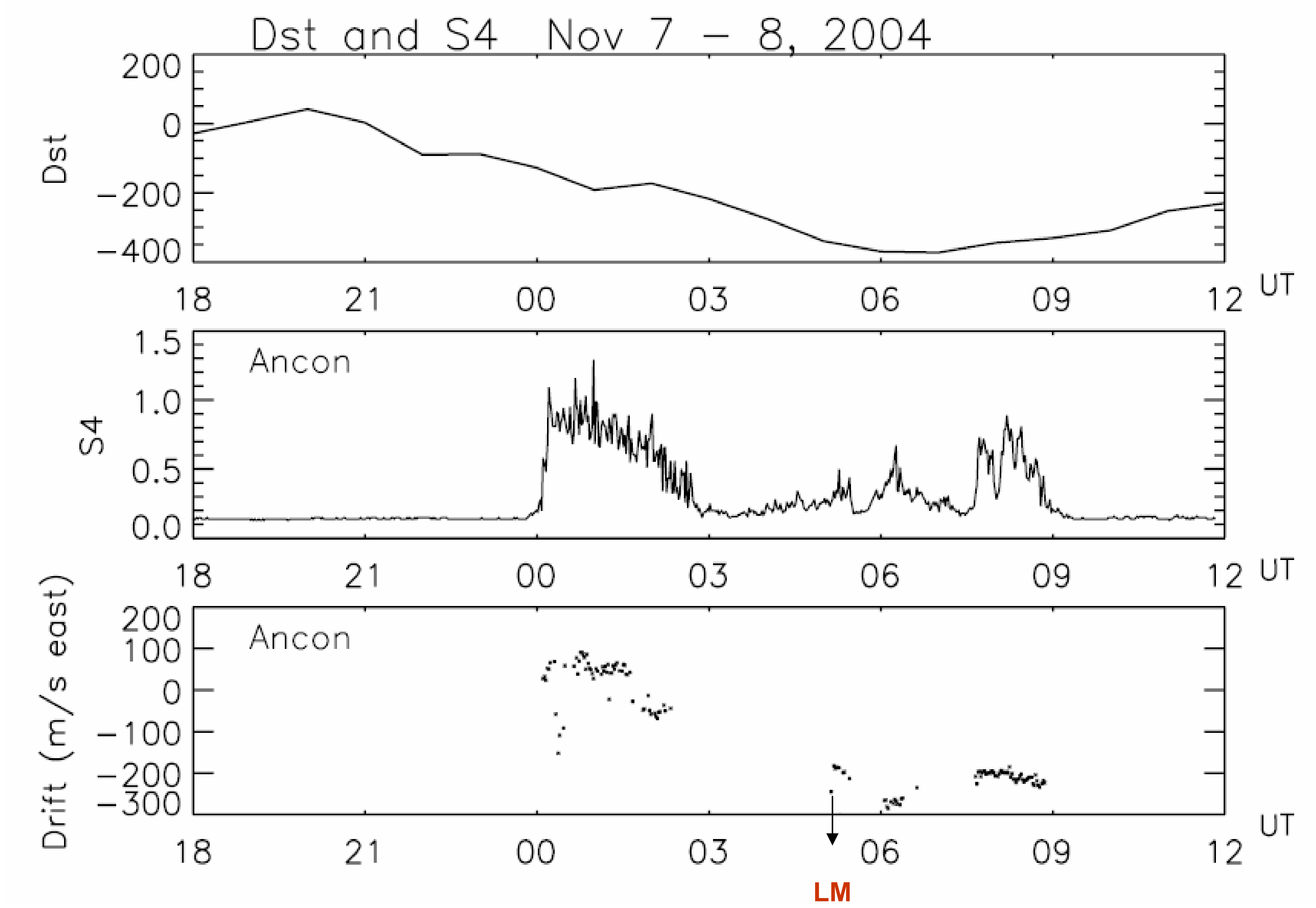
Great Magnetic Storm of 7-8 November 2004 and Formation of Irregularity Structures in the Peruvian Sector



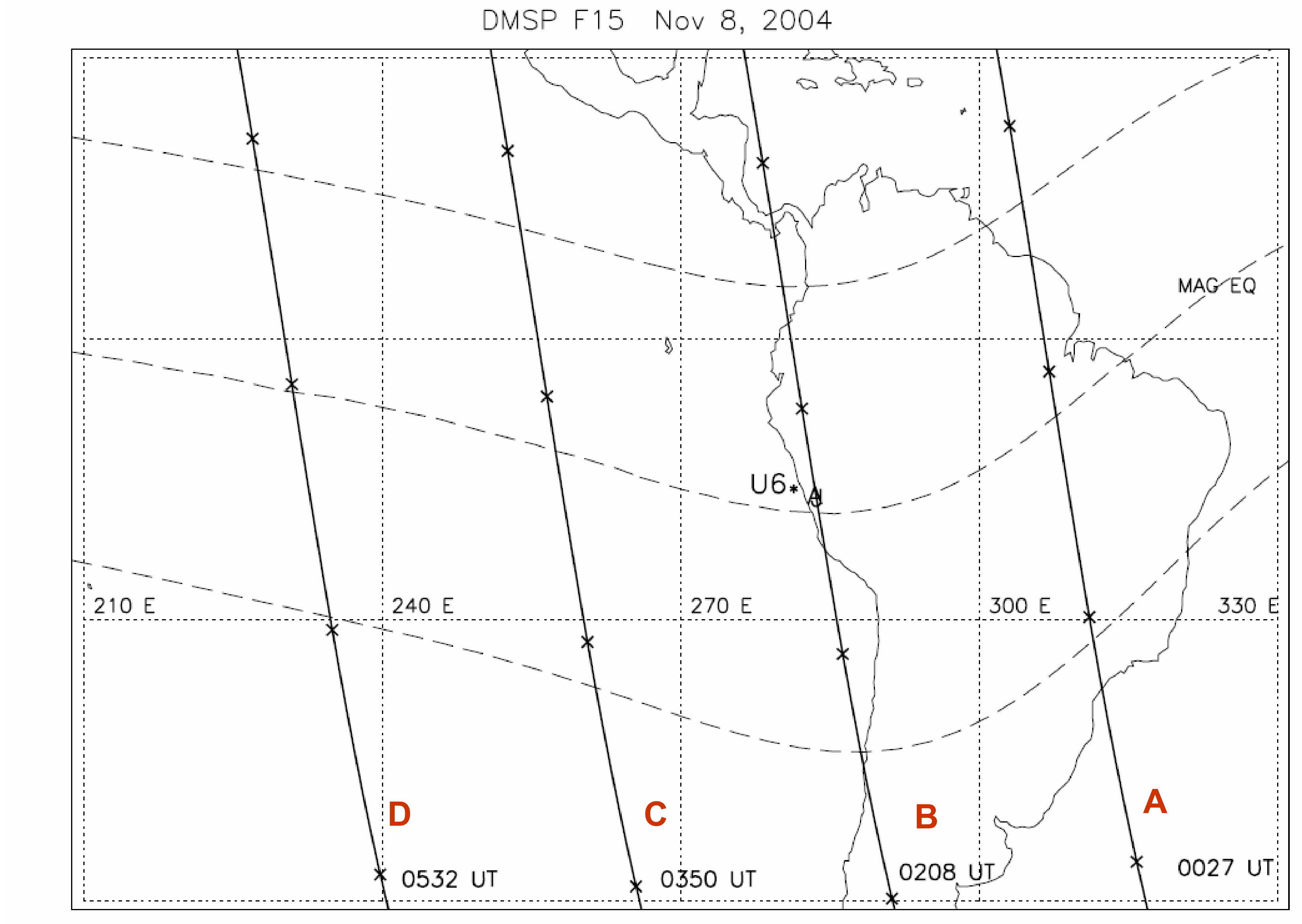
DP Phase:
00 – 06 UT
dDst/dt ≤ -50 nT/hr at 00 UT and Dst min at 06 UT

During the DP Phase (00 – 06 UT) Dusk Conditions prevailed in Peru; the enhanced eastward penetration electric fields across the terminator sets off plasma instabilities causing scintillations at Ancon and Julia radar backscatter at Jicamarca

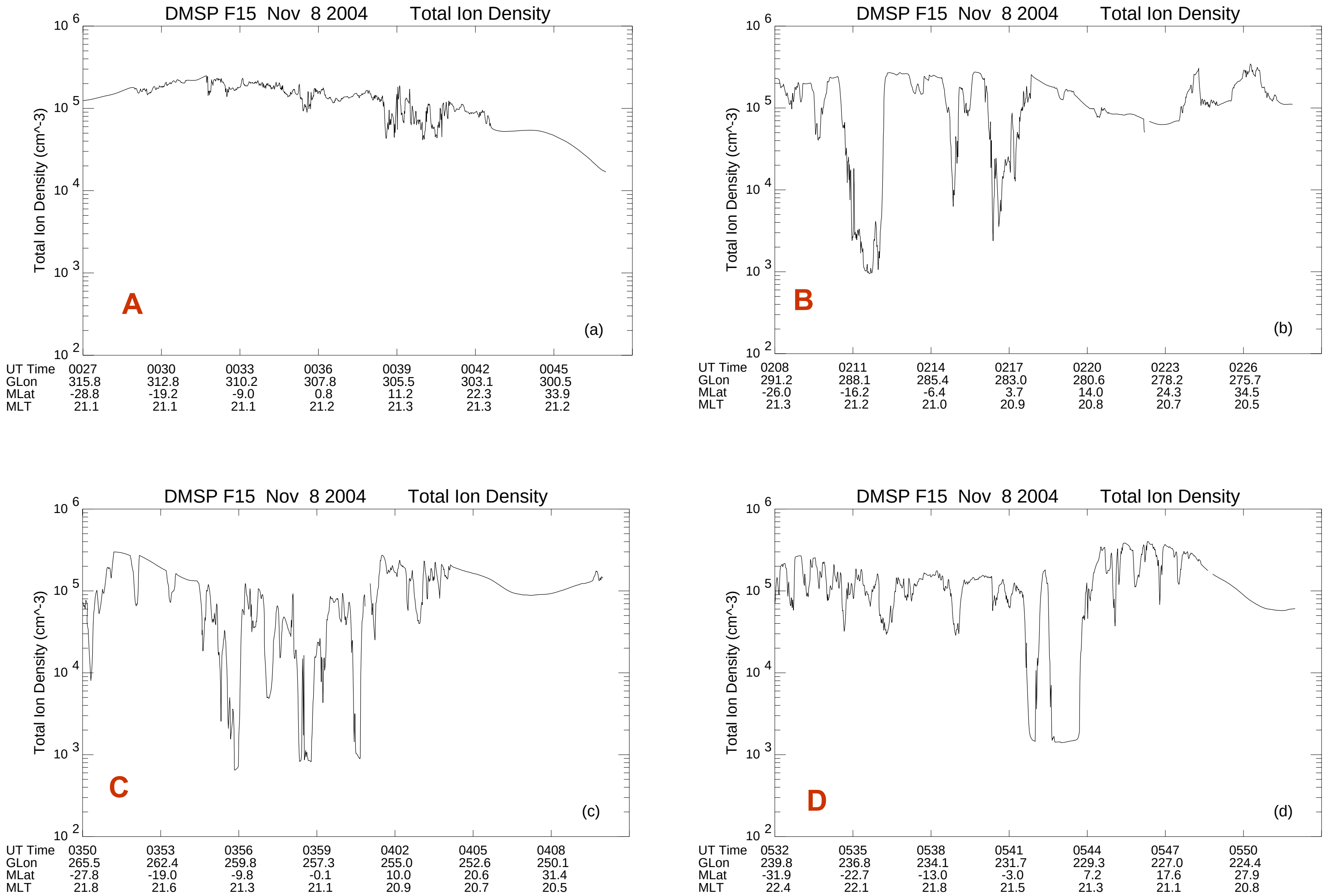
Spaced Receiver Scintillation Measurements Show Post-Midnight Westward Drifts During the Magnetic Storm of 7-8 November 2004



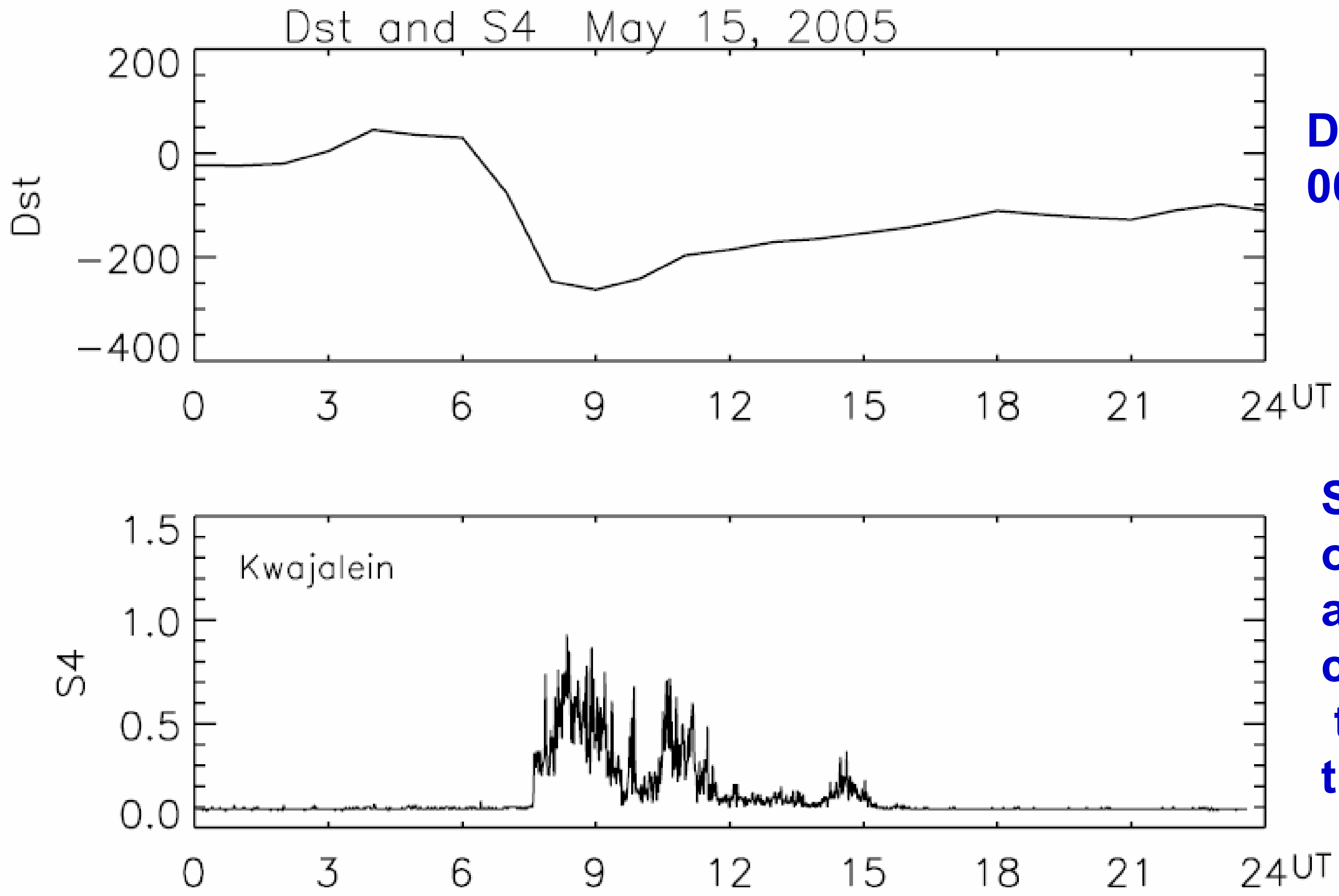
DMSP Orbits Detected Plasma Bubbles *ONLY* Over 230 – 300 E Where Dusk Prevailed During the DP Phase (00 – 06 UT)



DMSP Ion Density Data Exhibit Plasma Bubbles in Four Successive Orbits Where Dusk Conditions Prevailed During the DP Phase of the Storm



Impact of 15 May 2005 Magnetic Storm Over the Pacific Sector

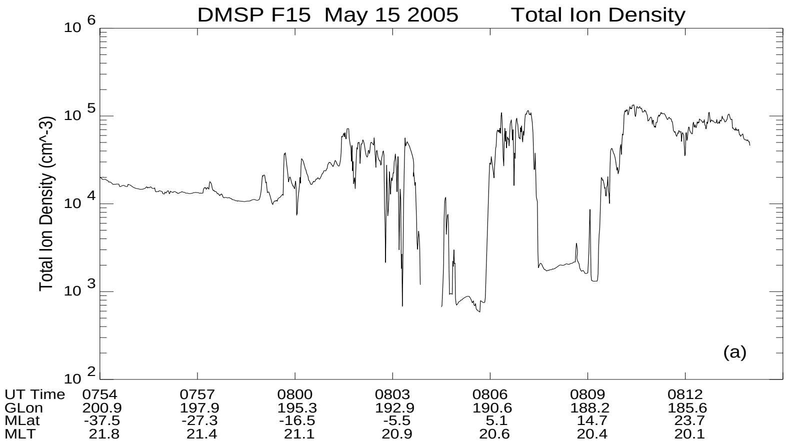


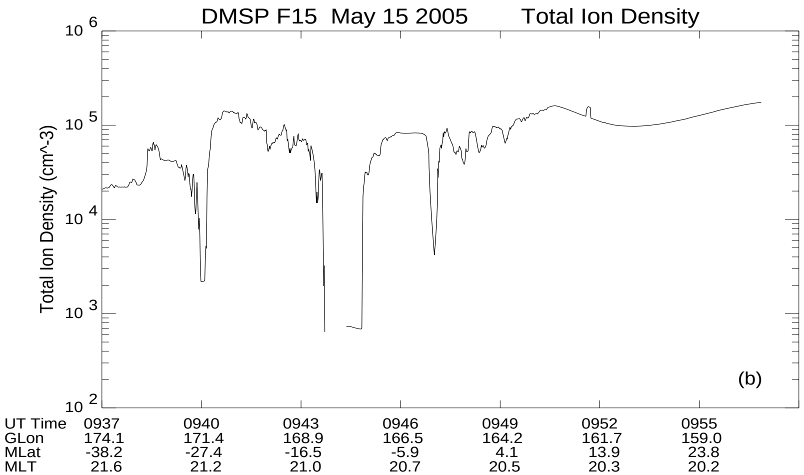
DP Phase: 06 UT – 09 UT

Scintillation onset at Kwaj at 1920 LT corresponds to dusk over the DP phase

LT=UT+11 Hours

DMSP Detected Plasma Bubbles ONLY in the Pacific where Dusk Conditions Prevailed During the DP Phase of 15 May 2005 Storm

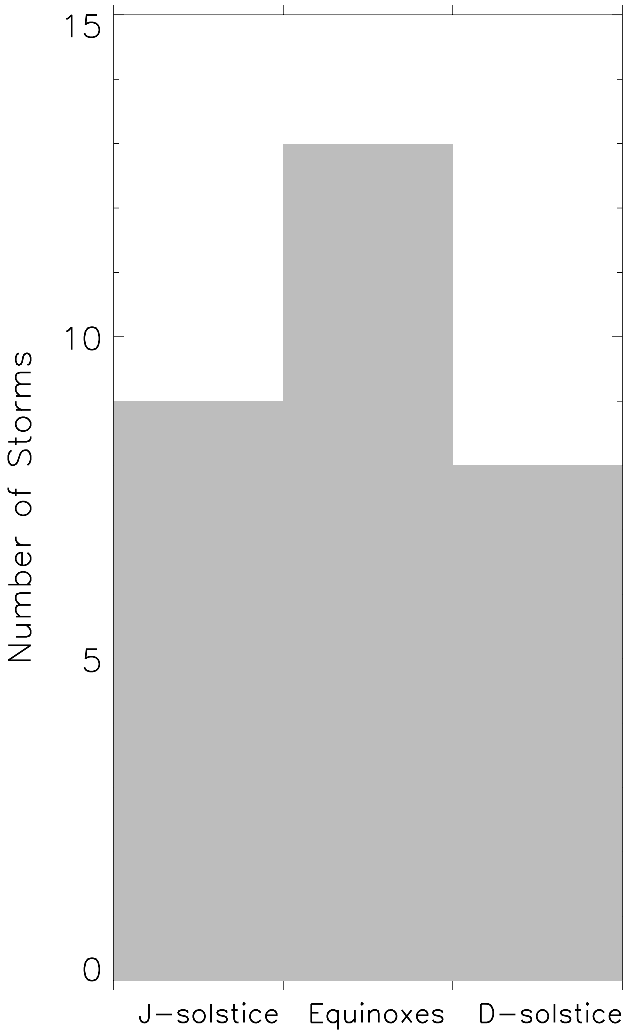




DP Phase (06-09 UT) corresponds to dusk in the Pacific sector

DMSP detected plasma bubbles in the Pacific at longitudes where dusk conditions prevailed during the DP phase of the storm

Seasonal Variation of Magnetic Storms During Solar Cycle 23



The semi-annual variation of geomagnetic activity is caused by the semi-annual variation in the effective southward IMF. It arises because the interplanetary field is ordered in the solar equatorial coordinate system , whereas the interaction with the magnetosphere is controlled by a magnetospheric system (Russell and McPherron, JGR, 1971).

In addition, the seasonal variation of ionospheric conductivity impacts the M-I coupling (Nakano et al., JGR, 2002; Akinari, JGR, 1999).

Note that the statistics is based on only 30 intense magnetic storms

Specification of the Longitude of Equatorial Scintillation from a Knowledge of the DP Phase of Intense Magnetic Storms

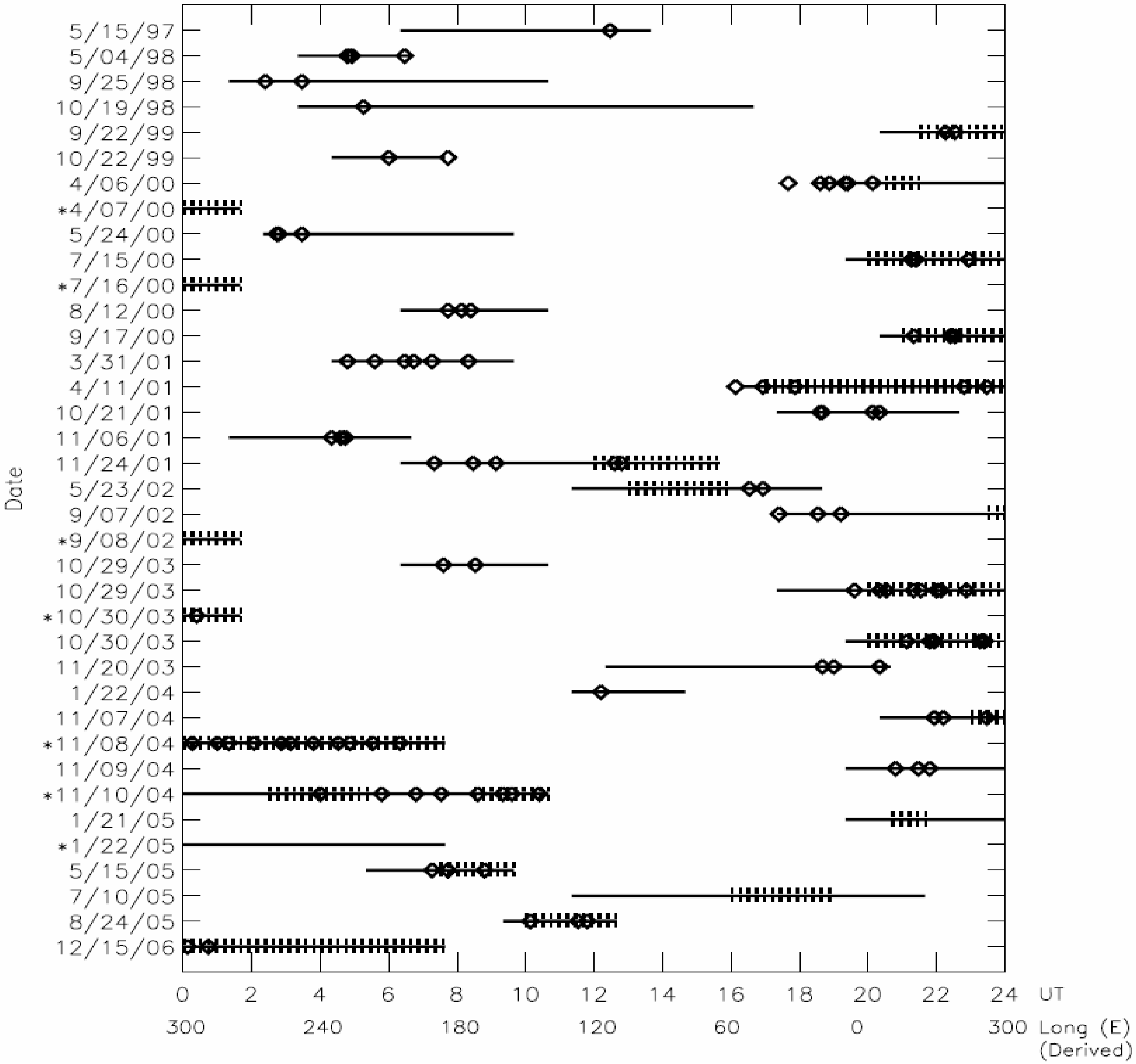
- Select storms with Dst min ≤ -100 nT and dDst/dt ≥ -50 nT/hr
- Determine the onset of storm, UT_1 when dDst/dt ≥ -50 nT/hr
- Determine UT min when Dst min is attained
- Consider the onset of Equatorial Scintillation to vary between 1920 LT [(20-0.66) h] and 2040 LT [(20 + 0.66) h]
- Obtain the longitude of ionospheric scintillation corresponding to the onset of DP Phase as:

  $\lambda_1 = [19.33 – UT_1] \times 15$
- Obtain the longitude of ionospheric scintillation corresponding to the end of DP Phase as:

  $\lambda_2 = [20.66 – UT\ min] \times 15$

Longitude interval of ionospheric scintillation is: $\lambda_2 - \lambda_1$

Statistics of the Response of the Equatorial Ionosphere to 30 Intense Magnetic Storms During Solar Cycle 23



Geophysical Implications

- During the DP phase of intense magnetic storms the penetration electric field remains eastward over the dayside through the dusk

- The dayside eastward penetration electric field is enhanced near sunset where the conductivity gradient maximizes

- The enhanced eastward electric field at the terminator uplifts the ionosphere and sets off the Rayleigh-Taylor instability to cause scintillations and plasma bubbles

- Therefore, the longitude interval of the dusk sector corresponding to the UT interval of the DP phase specifies the longitude interval of scintillations and plasma bubbles

Conclusions

- We have established that for large magnetic storms with Dst min ≤ -100 nT and dDst/dt ≥ -50 nT/hr,

  - Scintillations and plasma bubbles in the equatorial ionosphere occur only over the longitude interval where dusk conditions are encountered during the storm onset, UT_1, when dDst/dt ≥ -50 nT/hr and UT minimum, when Dst attains its minimum value.

  - The ordered excitation of equatorial scintillation during intense storms have not been reported before. This algorithm will be implemented in AFRL's SCINDA system to specify scintillation during intense magnetic storms.