Total Lightning Measurements of Tropical Precipitating Systems

CAMEX Workshop

13-15 March 2002

Principal Investigator: Richard Blakeslee, **NASA/MSFC/NSSTC**

Co-Investigators: Douglas Mach, **Univ. of Alabama in Huntsville**

Monte Bateman, **USRA/NSSTC**

CAMEX-4 Electrical Measurements Research Objectives

Support overarching science objective

Observe and explain the structure of convection in tropical cyclones and hurricanes and how the strength and structure changes immediately before and after landfall.

CAMEX-4 Electrical Measurements Research Objectives

Specific questions pertaining to electrical conditions

- **Can lightning provide cues for intensification and storm track forecast (presence of lightning may indicate changes underway)?**
- **Can lightning serve as useful aid in identifying flood producing rainfall following landfall?**
- **How are kinematic/microphysical properties of electrically active clouds different from less active clouds (also land vs. ocean convection)?**
- **What are the electrical properties of precipitating bands in tropical convection and how do they relate to storm microphysics?**
- **Why are some rainbands more electrically active than others?**

Lightning Instrument Package (LIP)
NASA High Altitude ER-2

Instrumentation

- **Electric Field Mills (8)**
- **Conductivity Probe**

Measurements

- **Vector components of electric field (E_x, E_y, E_z)**
- **Aircraft Charge**
- **Air conductivity**
- **Lightning statistics (derived using field changes)**
- **Storm electric currents**
- **Storm charge structure**

Measurement Range / Accuracy

- **Electric Field : few V/m to hundreds's of kV/m 5 - 10%**
- **Conductivity : 10^{-13} to 10^{-11} mhos/m 5 - 10%**

Lightning Instrument Package (LIP) NASA Medium Altitude DC-8

Instrumentation

- **Electric Field Mills (6)**
- **High voltage “Stinger” (calibration of enhancement factors)**

Measurements

- **Vector components of electric field (E_x , E_y , E_z)**
- **Aircraft Charge**
- **Lightning statistics (from field changes, optical transients)**
- **Storm electric currents (when used with ER-2 measurements)**
- **Storm charge structure**

Measurement Range / Accuracy

- **Electric Field : <1 V/m to 10^6 V/m 10 - 20%**

LIP Campaign Summary

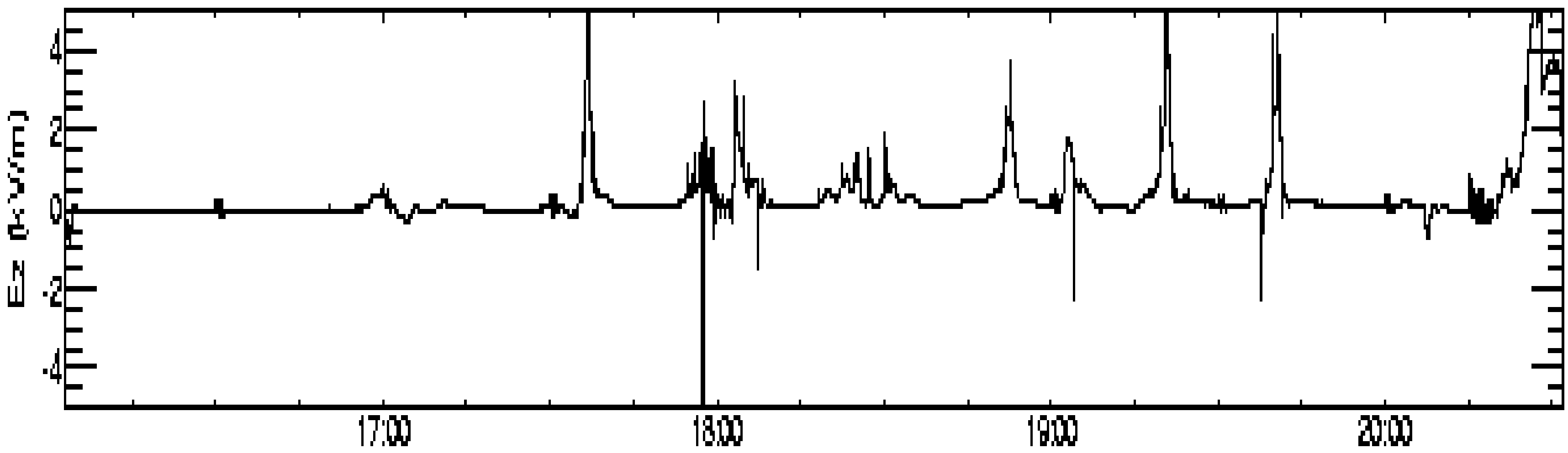
- Instrument performed well entire program.
- Several interesting thunderstorm flights acquired.
- Most Hurricane overflights showed only weakly electrified conditions.
- Preliminary electric field calibration done; will continue refining.
- Plan to integrate LIP electrical measurements with other sensors.

Summary of electrical activity

Date	Sortie ER-2	Sortie DC8	Description	Summary
18 Aug 2001	01-131,	10406	Overflight of Andros and FL Keys	Two small storms: 1830-1845 and 1910-1920
20 Aug 2001	01-132,	10407	Tropical Storm Chantal	Storms throughout (2000-2300)
25 Aug 2001		10408	Buoy overflight (central FL coast)	No thunderstorms
26 Aug 2001	01-133		Buoy overflight (central FL coast)	Weak (distant?) cells (1830-1915)
3 Sept 2001	01-134,	10409	Gulf storms	Two small storms: 1640-1650 and 1700-1715
6 Sept 2001		10410	Overflight FL and GA east coast	
7 Sept 2001	01-135,	10411	Stratiform precipitation over Gulf	Storms throughout (1700-2000)
9 Sept 2001	01-136,	10412	KAMP	Three storms 1645-1700, 1710-1740, and 1820-1850
10 Sept 2001	01-137,	10413	Hurricane Erin	Very weak electrification detected
15 Sept 2001		10414	Tropical Storm Gabrielle	
16 Sept 2001	01-138		Hurricane Gabrielle	One small storm: 2200-2220
19 Sept 2001	01-139,	10415	KAMP	Storms throughout (1700-2000)
22 Sept 2001	01-140,	10416	Tropical Storm Humberto	Two small storms: 1930-1945 and 2000-2215
23 Sept 2001	01-141,	10417	Hurricane Humberto	Very weak electrification detected
24 Sept 2001	01-142,	10418	Hurricane Humberto	Very weak electrification detected

Example of thunderstorm observations

ER-2 electric field observation of embedded convection on 7 Sept. 2001 **(i.e., 9-10 electrified storms overflown)**



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ER-2 LIP Data Plots

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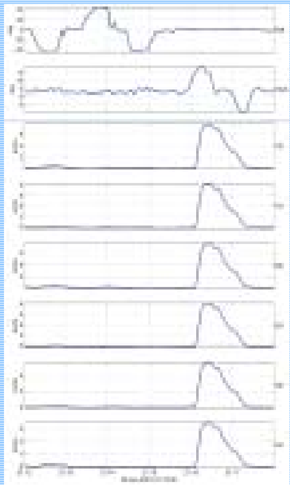
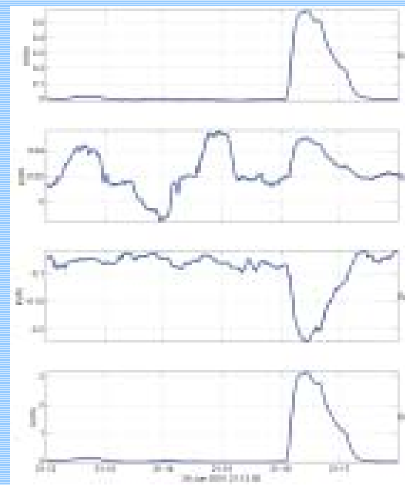
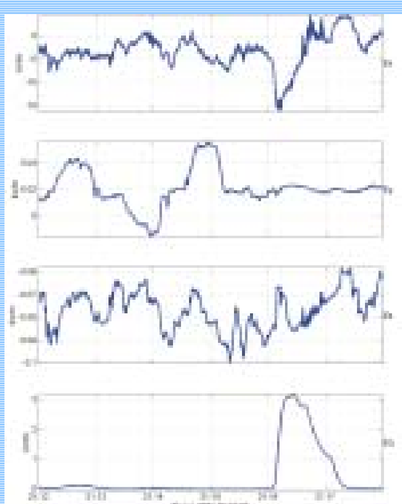
Calibration of an Airborne Field Mill Array



(A) Aircraft Roll/Pitch Data & Raw Electric Field Values showing the effect of aircraft charge and roll/pitch maneuvers on the fields at each mill.



(B) External Electric Field Values based on first guess of **M** matrix. Note that there is significant aircraft charge contamination of the external fields.



(C) **External Electric Field Values (& Aircraft Charge)** based on the third iteration of **M**. Note that the aircraft charge contamination has been greatly reduced.

- Each field mill output can be considered as a linear sum of the external electric field and field due to charge on the aircraft:

  $m_i = M_{xi}*E_x + M_{yi}*E_y + M_{zi}*E_z + M_{qi}*E_q$ (a)

- The set of equations (a) for all mills on an aircraft can be represented as a matrix equation:

  $\underline{m} = \mathbf{M}*\underline{E}$ (b)

  where $\underline{m}$ (mill outputs) & $\underline{E}$ (vector electric field and field due to charge on the aircraft) are vectors, and **M** is a 6x4 matrix

- To determine the electric field $\underline{E}$ from the mill outputs $\underline{m}$, we need the 4x6 matrix **C** which satisfies the equations:

  $\underline{E} = \mathbf{C}*\underline{m}$ (c)

  $\mathbf{C}*\mathbf{M} = \mathbf{I}$ (d)

  where **I** is the 4x4 identity matrix

- Although we need **C** to determine $\underline{E}$ from the mill outputs, $\underline{m}$, the unique properties of the M matrix drive our method
  - There is only one **M**, that satisfies (b) for all possible values of $\underline{E}$ and $\underline{m}$
  - In the process of determining **C** from **M**, we can manipulate the inverse to emphasize or de-emphasize individual mills in the determination of $\underline{E}$

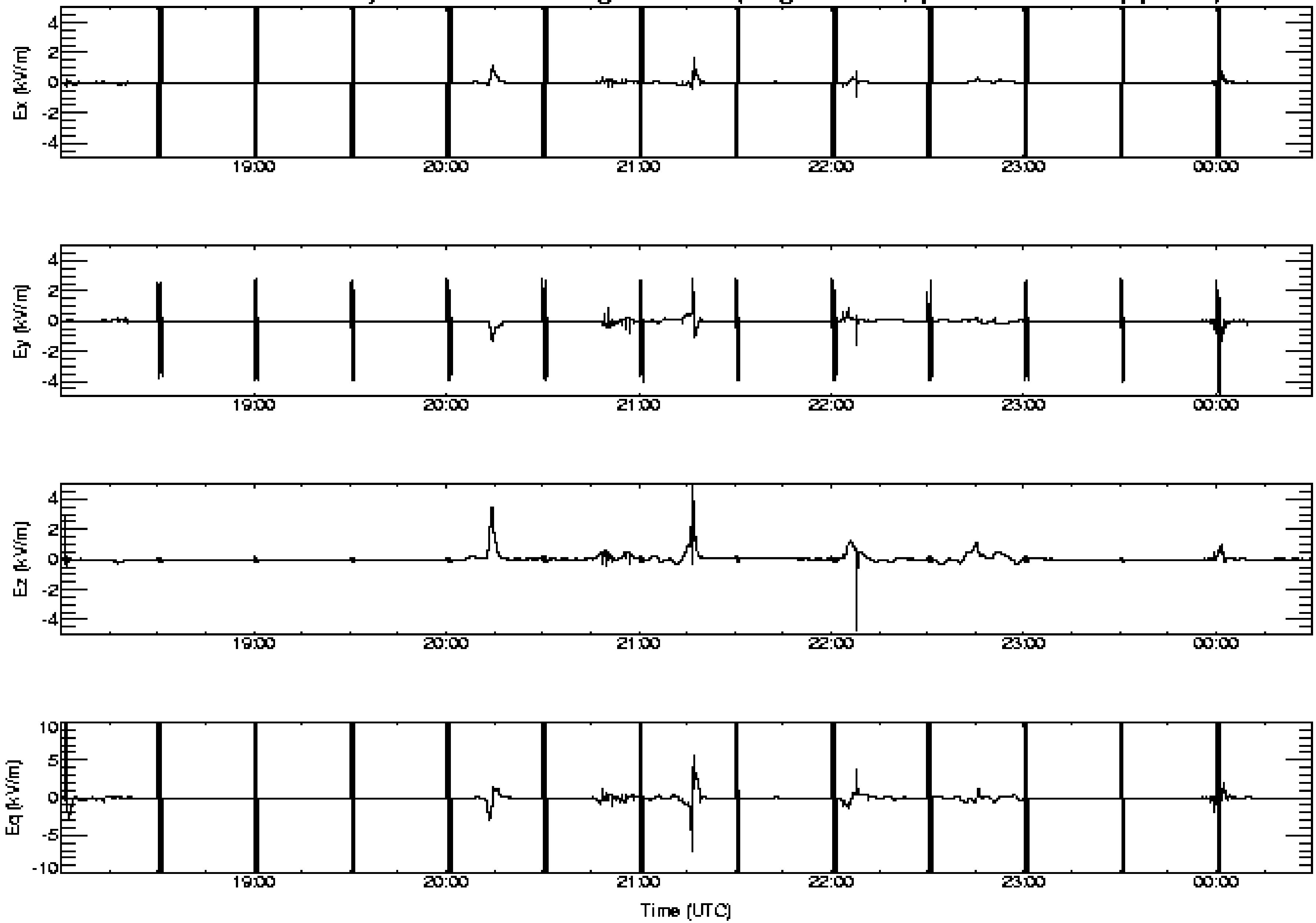
- To determine M, we follow a "cookbook" type procedure:

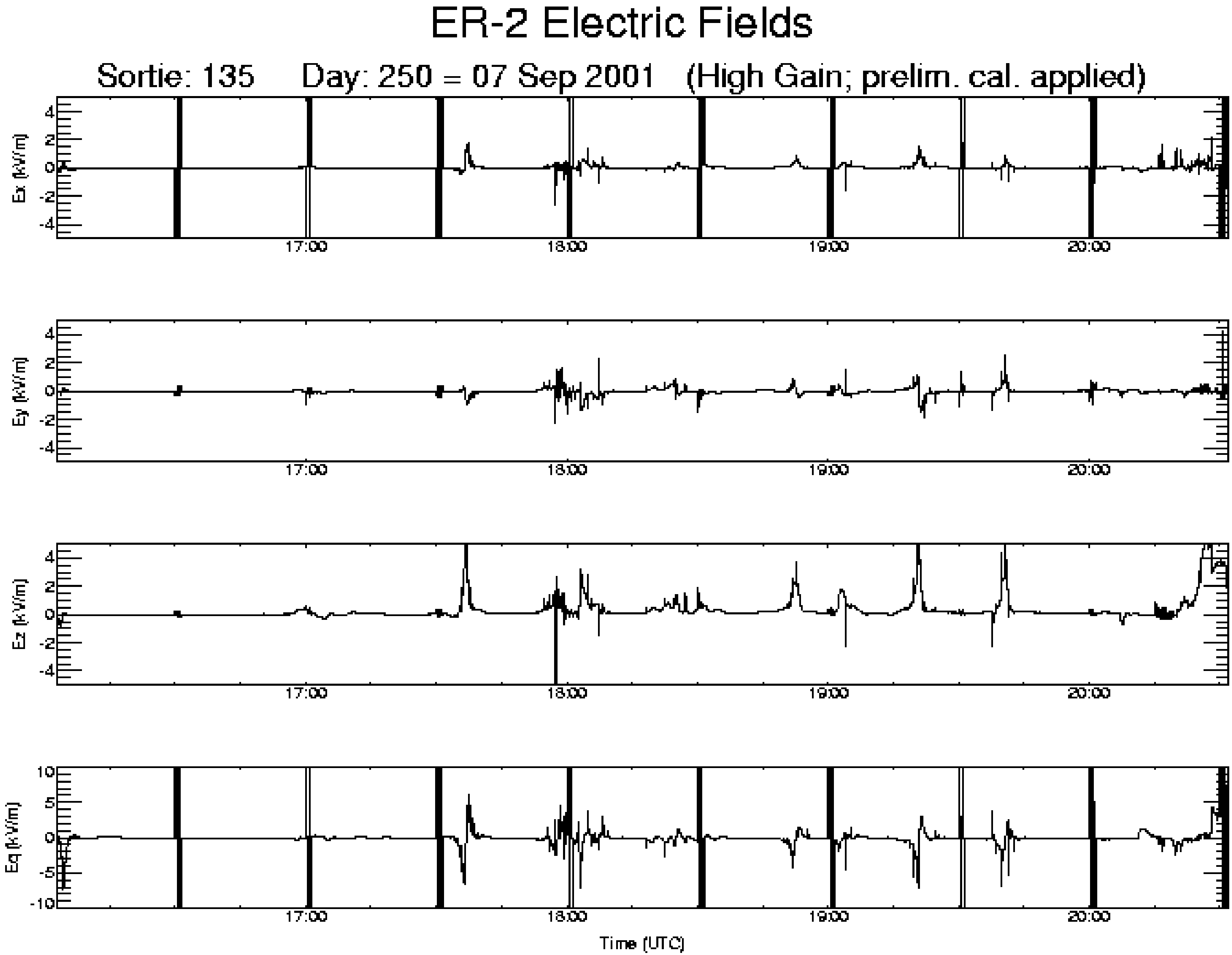
1) Estimate **M**
2) Determine **C** from **M**
3) Calculate the estimated $\underline{E}$ from **C** and $\underline{m}$
4) "Fix" $\underline{E}$ based on knowledge of flight conditions
5) Use "fixed" $\underline{E}$ and $\underline{m}$ to determine new **M**
6) Repeat
7) Final **M** scaling
8) Invert final **M** to produce **C**
9) Use equation (c) to determine $\underline{E}$ from **C**

Priority Days (first tier)

ER-2 Electric Fields

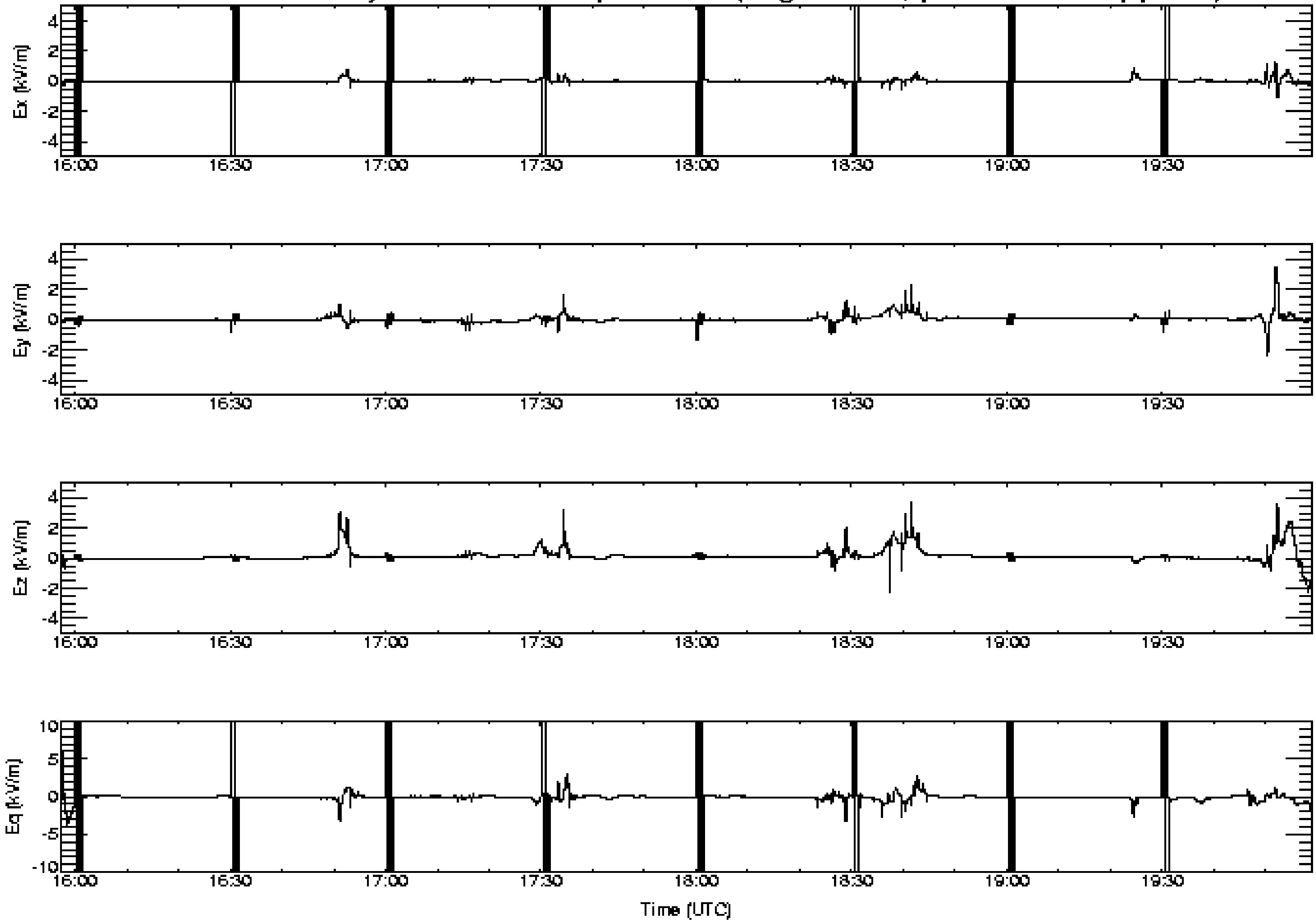
Sortie: 132 Day: 232 = 20 Aug 2001 (High Gain; prelim. cal. applied)




ER-2 Electric Fields
Sortie: 135 Day: 250 = 07 Sep 2001 (High Gain; prelim. cal. applied)
Ex (kV/m)
Ey (kV/m)
Ez (kV/m)
Eq (kV/m)
17:00
18:00
19:00
20:00
Time (UTC)

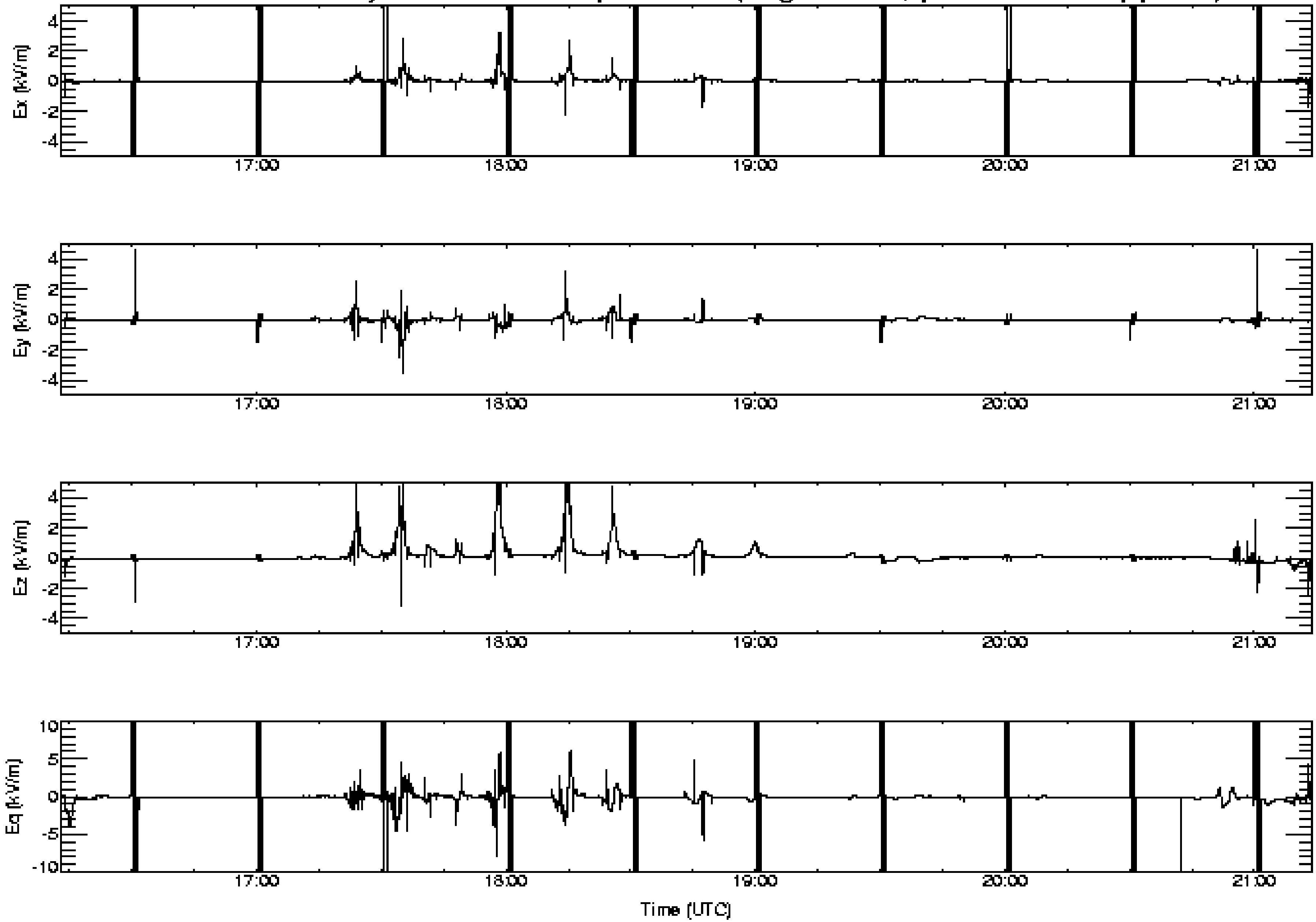
ER-2 Electric Fields

Sortie: 136 Day: 252 = 09 Sep 2001 (High Gain; prelim. cal. applied)

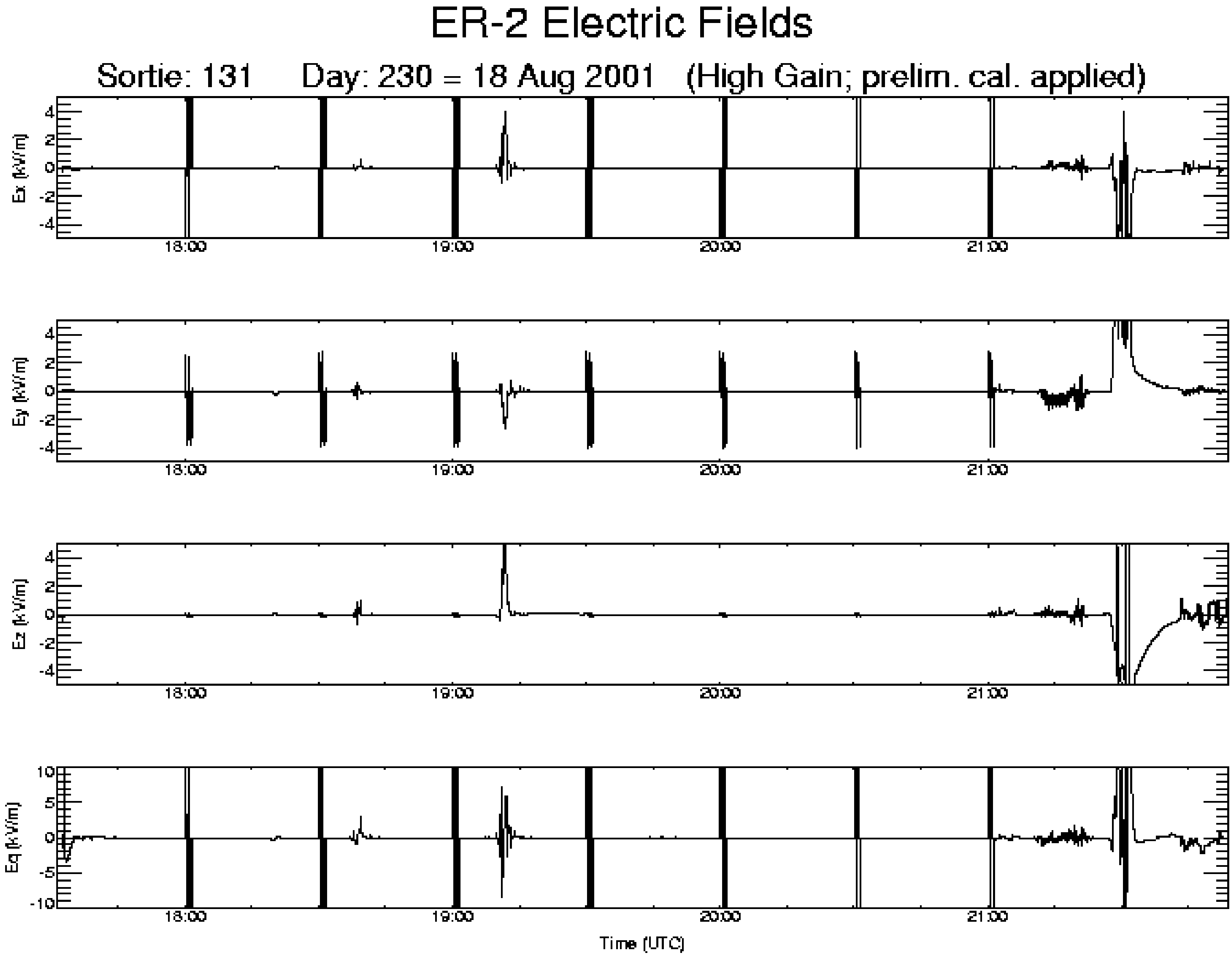


ER-2 Electric Fields

Sortie: 139 Day: 262 = 19 Sep 2001 (High Gain; prelim. cal. applied)



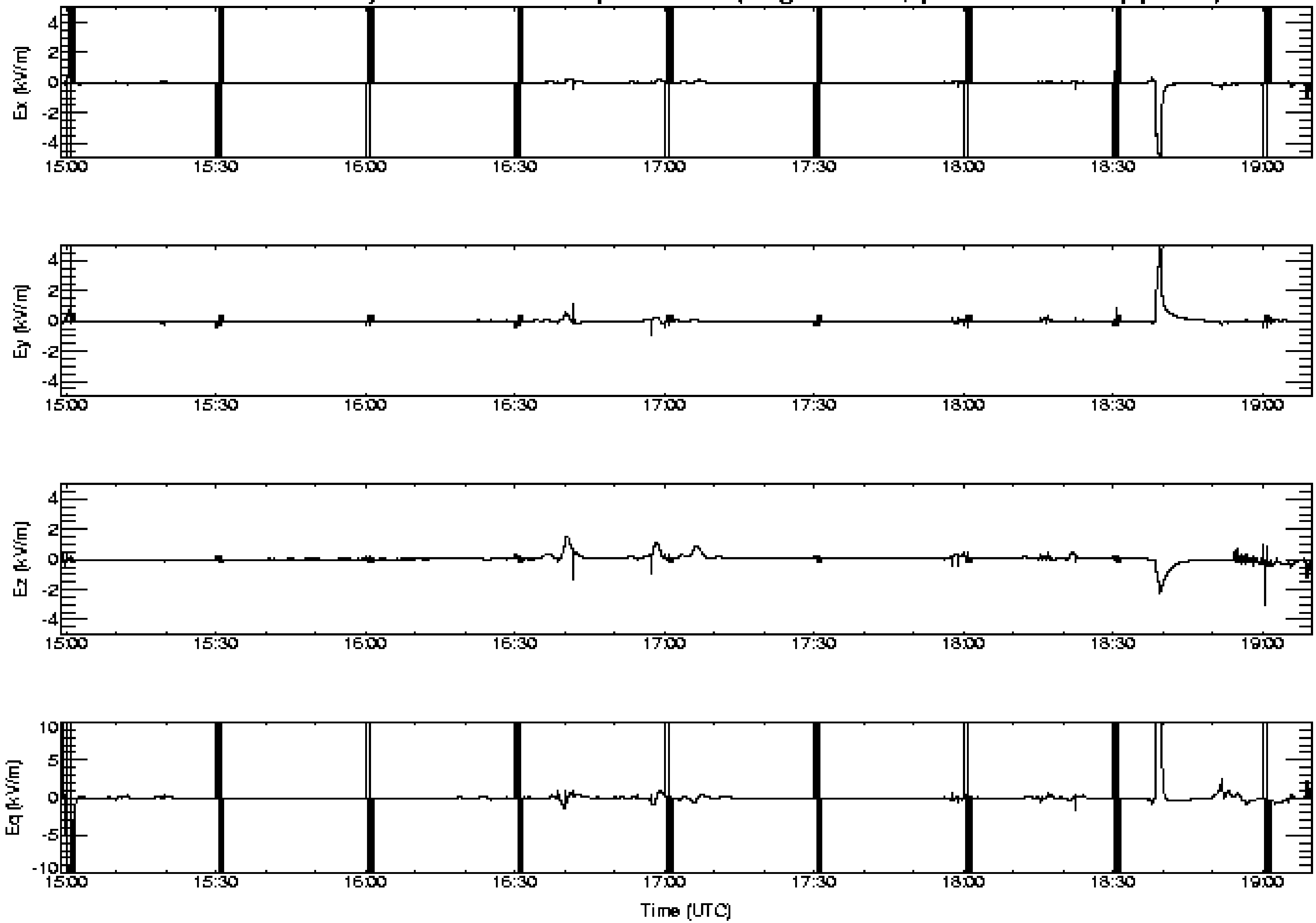
Priority Days (second tier)



ER-2 Electric Fields
Sortie: 131 Day: 230 = 18 Aug 2001 (High Gain; prelim. cal. applied)
Ex (kV/m)
Ey (kV/m)
Ez (kV/m)
Eq (kV/m)
18:00
19:00
20:00
21:00
Time (UTC)

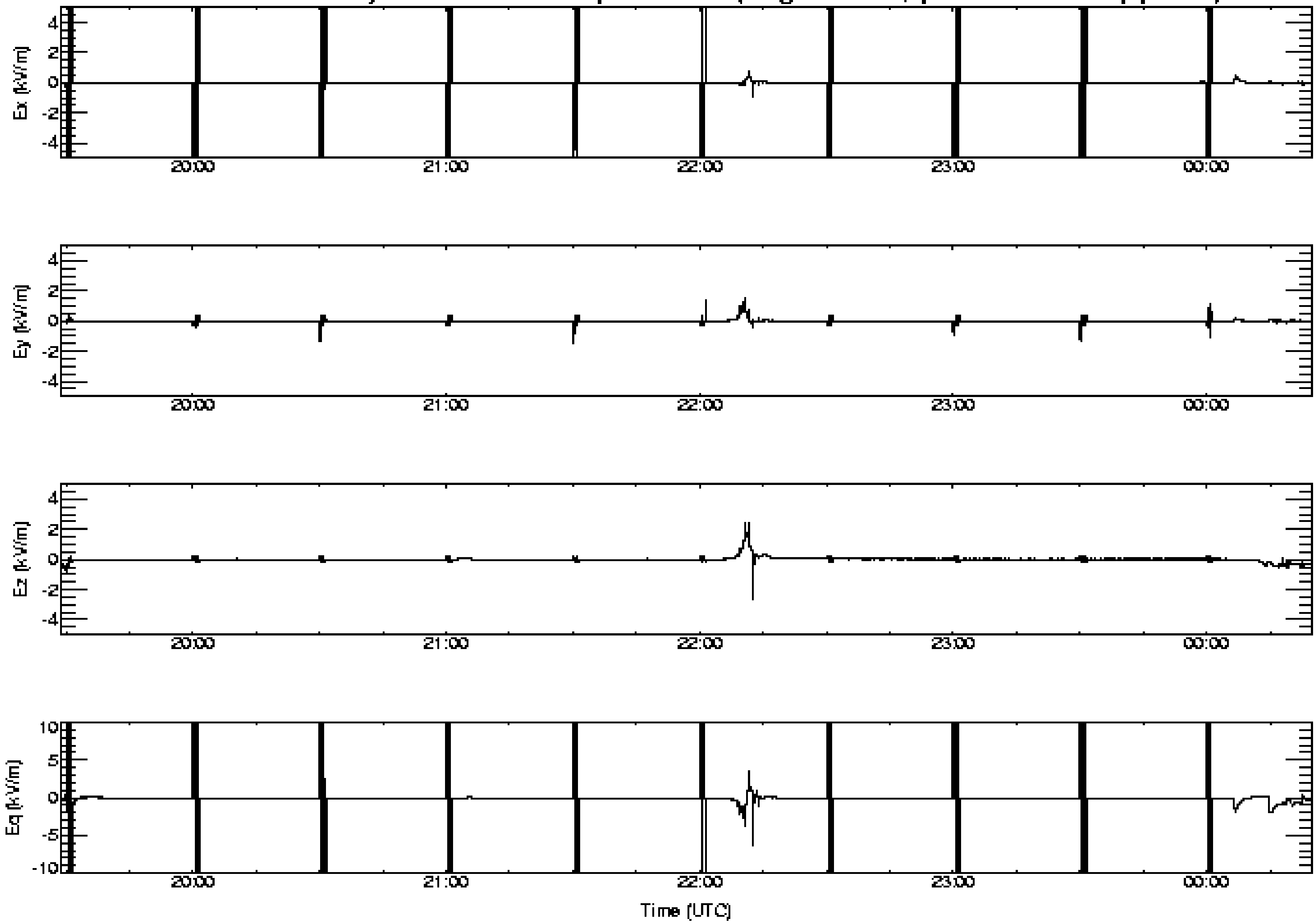
ER-2 Electric Fields

Sortie: 134 Day: 246 = 03 Sep 2001 (High Gain; prelim. cal. applied)



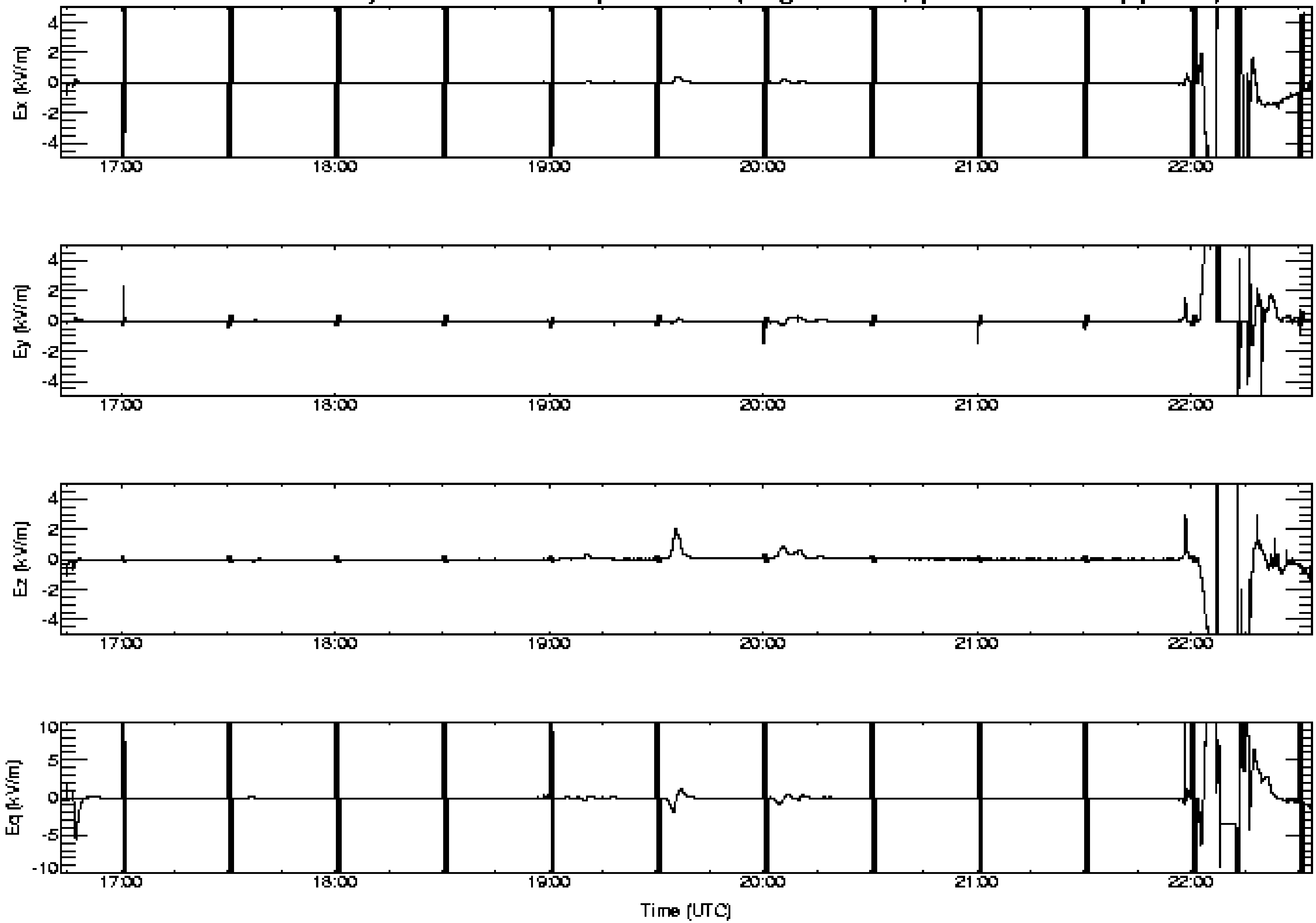
ER-2 Electric Fields

Sortie: 138 Day: 259 = 16 Sep 2001 (High Gain; prelim. cal. applied)



ER-2 Electric Fields

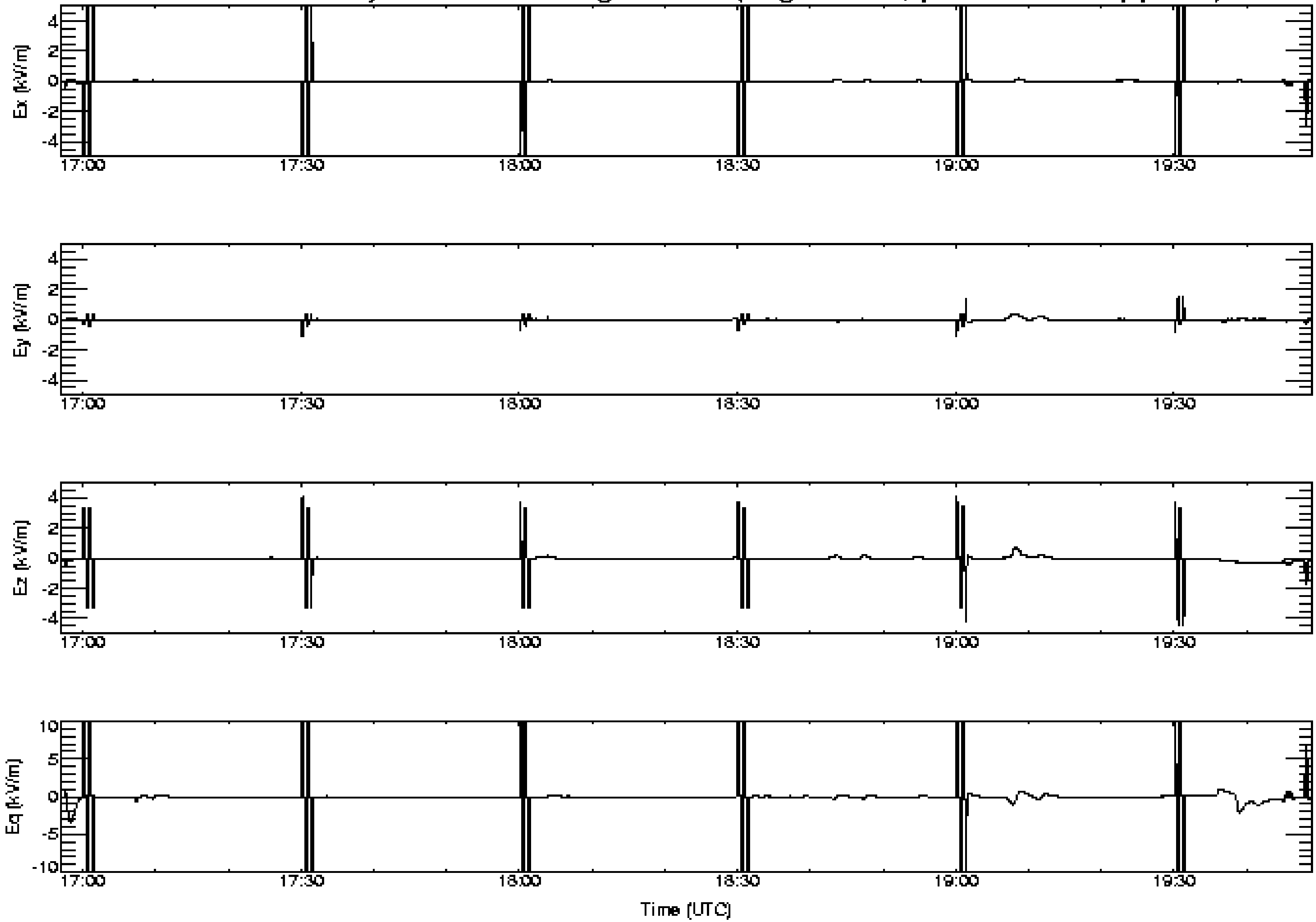
Sortie: 140 Day: 265 = 22 Sep 2001 (High Gain; prelim. cal. applied)



Un- or weakly electrified cases

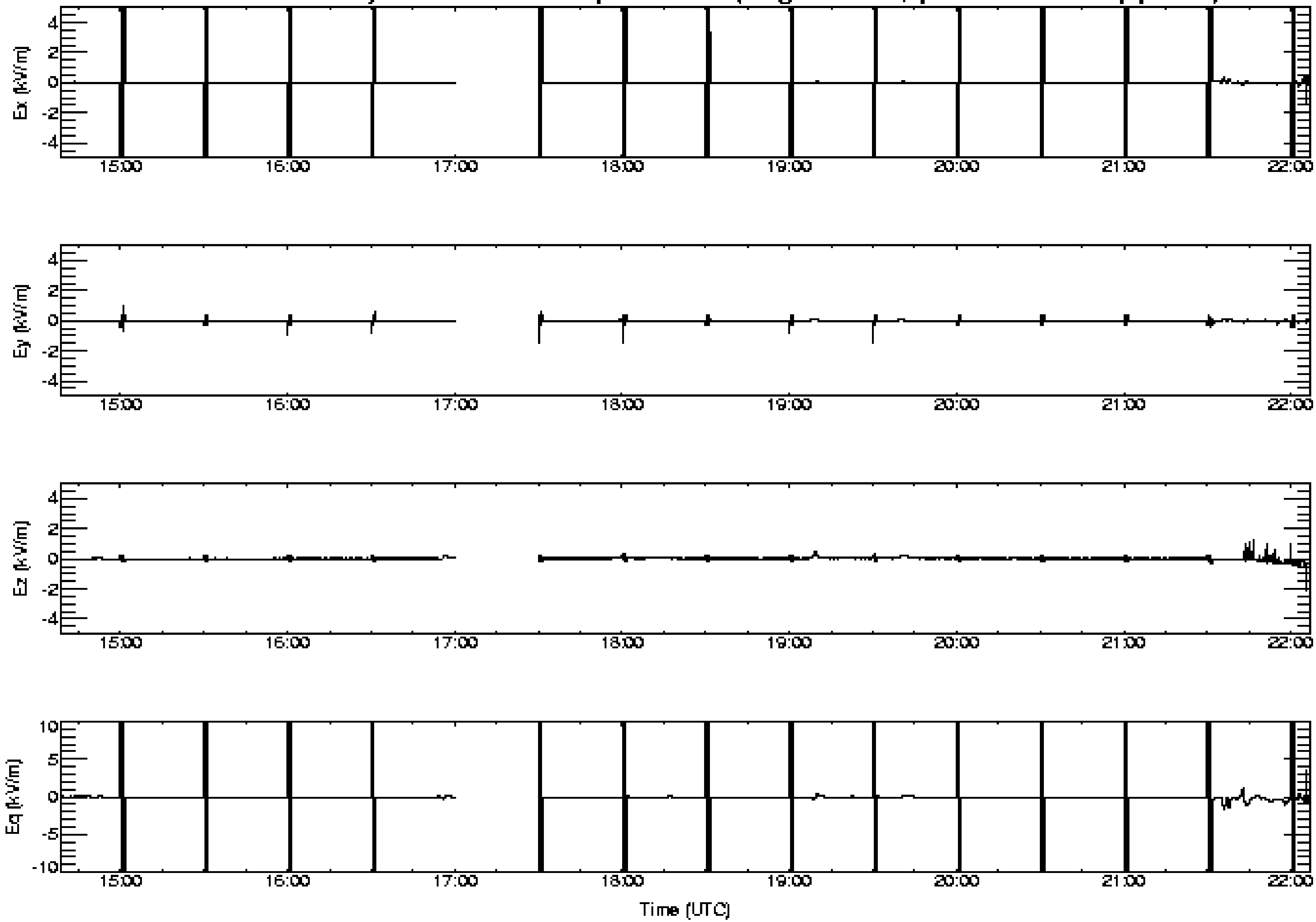
ER-2 Electric Fields

Sortie: 133 Day: 238 = 26 Aug 2001 (High Gain; prelim. cal. applied)



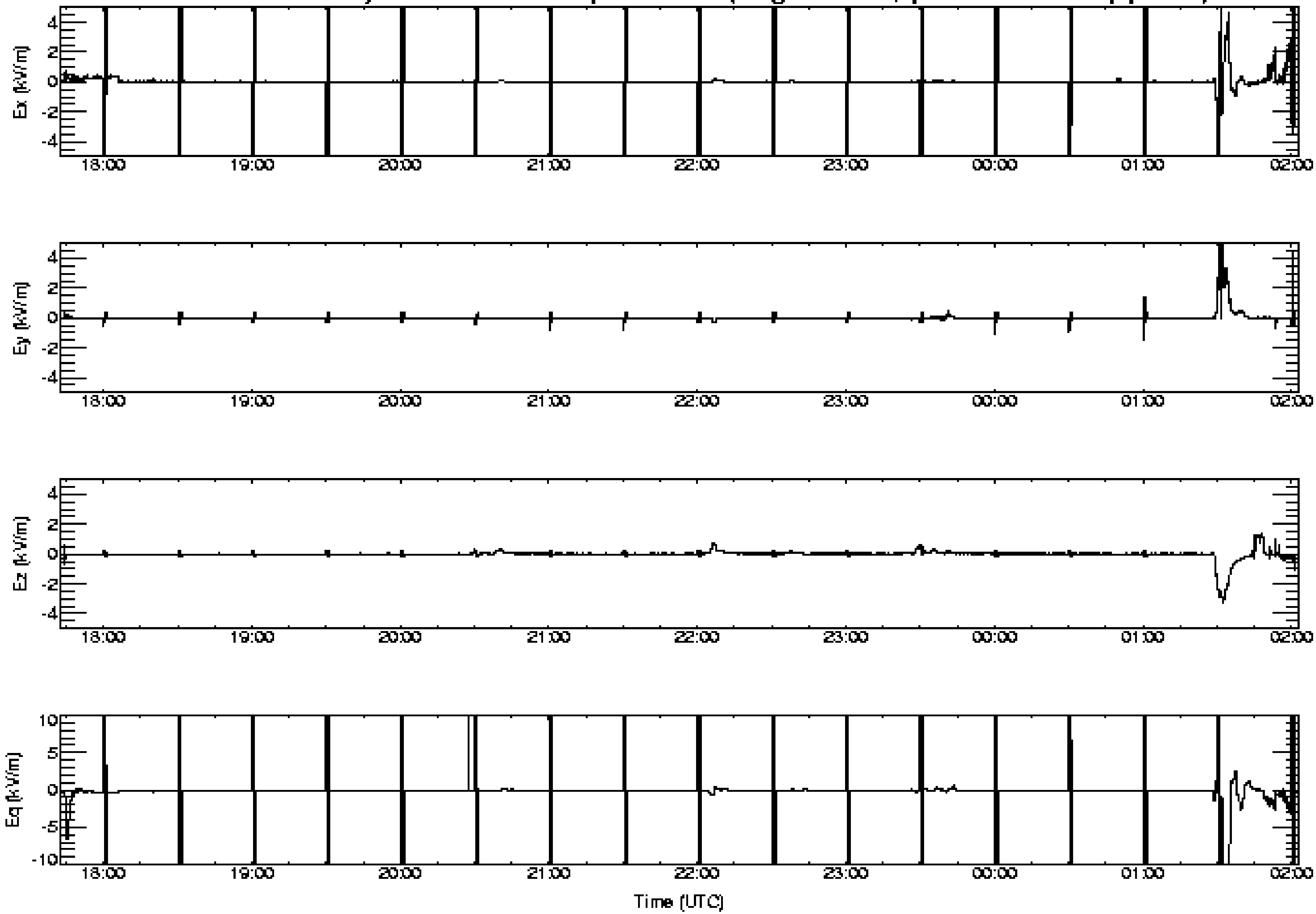
ER-2 Electric Fields

Sortie: 137 Day: 253 = 10 Sep 2001 (High Gain; prelim. cal. applied)



ER-2 Electric Fields

Sortie: 141   Day: 266 = 23 Sep 2001   (High Gain; prelim. cal. applied)



ER-2 Electric Fields

Sortie: 142 Day: 267 = 24 Sep 2001 (High Gain; prelim. cal. applied)