Magnetospheric drivers for Ion upflow and outflow within quiet-time plasma sheet: MMS and DMSP observations

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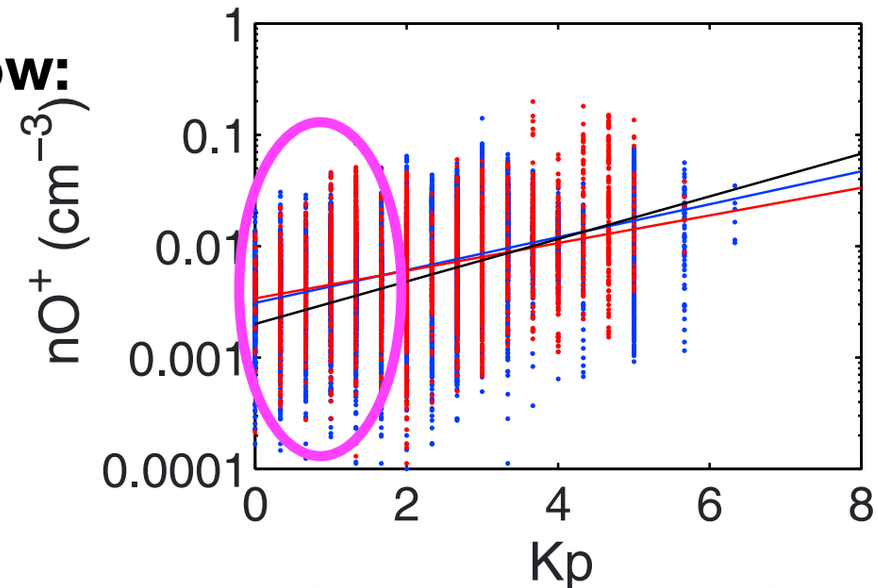
Levon A. Avanov, Robert J. Strangeway, Narges Ahmadi, Jacob Bortnik

Q: Large variation of O^+ density in the quiet-time plasma sheet, what causes it?

- **Two magnetospheric drivers for upflow and outflow:**
  - **(1) Soft electron (<~100 eV) precipitation**
  - **(2) Wave Poynting flux**
- **Two plasma regimes in quiet-time plasma sheet:**
  - **(1) Cold-dense plasma sheet (CDPS)**
  - **(2) Hot plasma sheet (HPS)**
- **The two drivers stronger in CDPS than HPS, leading to higher O^+ density?**

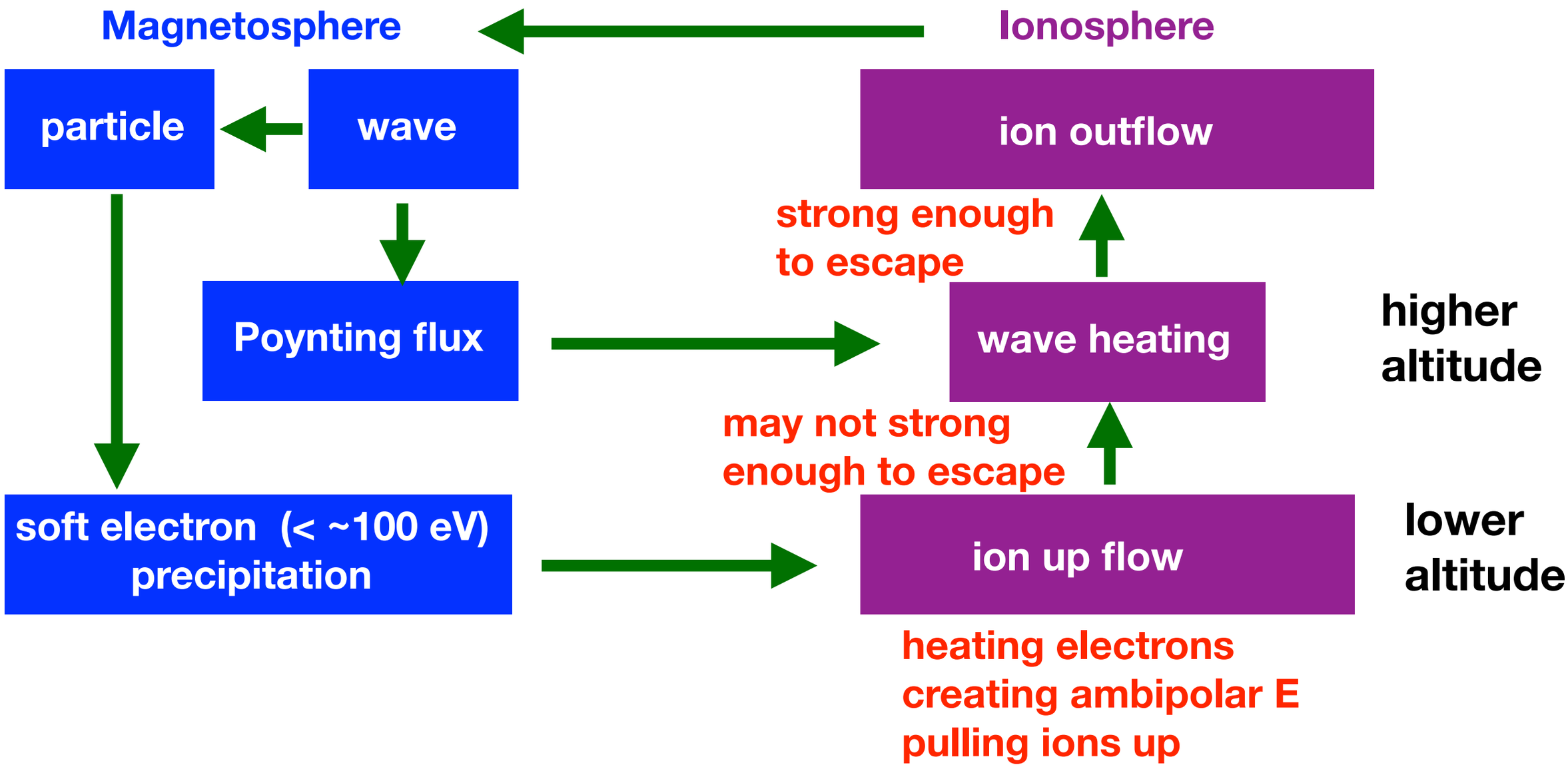
Cluster O^+ density



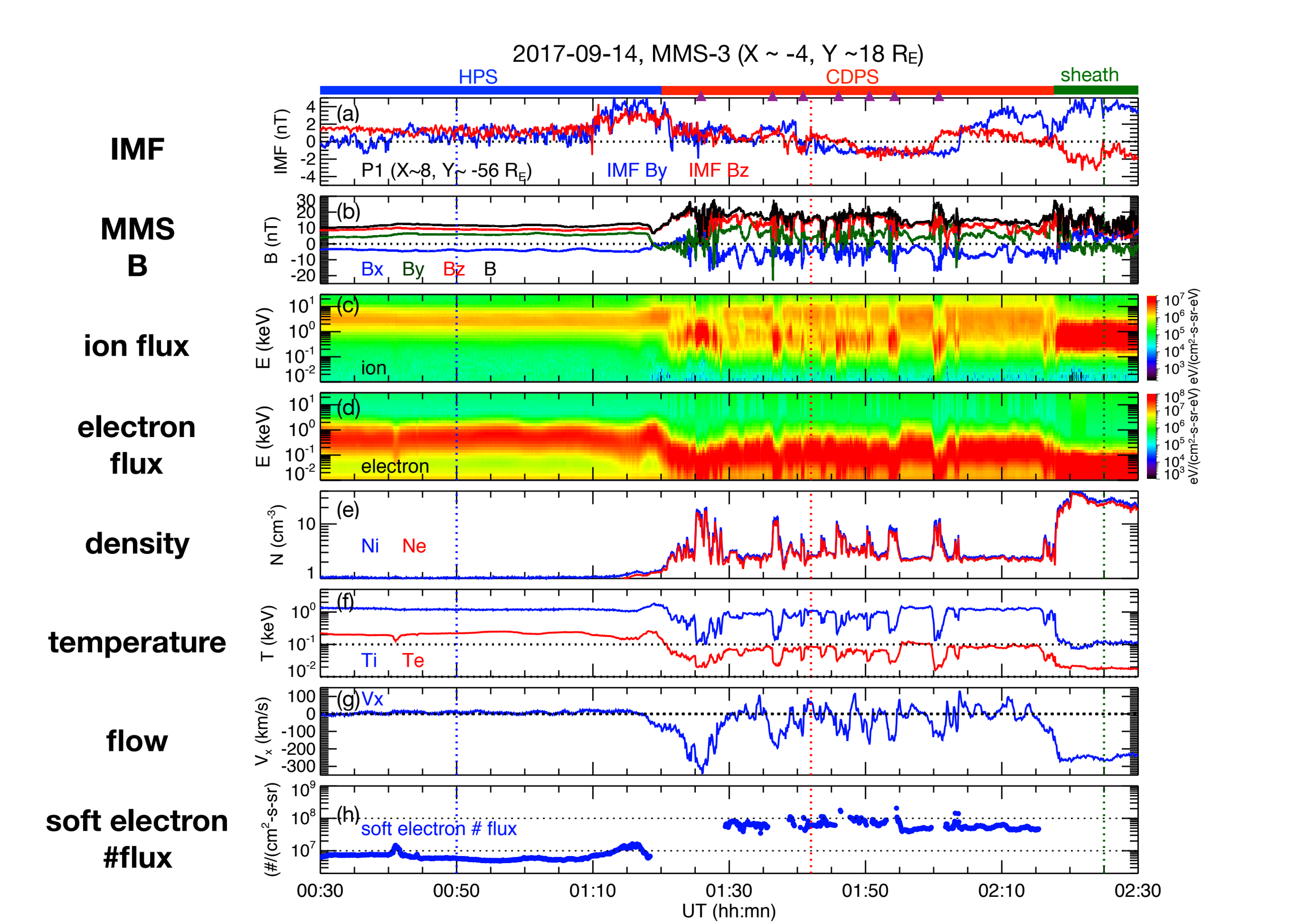
[Maggiolo et al., 2014]

Show MMS-DMSP conjunction events

magnetospheric drivers for O^+ upflow and outflow



based on [Strangeway et al., 2005]


2017-09-14, MMS-3 (X ~ -4, Y ~18 R_E)
HPS
CDPS
sheath
IMF
MMS B
ion flux
electron flux
density
temperature
flow
soft electron #flux
(a)
IMF (nT)
P1 (X~8, Y~ -56 R_E)
IMF By
IMF Bz
(b)
B (nT)
Bx
By
Bz
B
(c)
E (keV)
ion
(d)
electron
(e)
N (cm^-3)
Ni
Ne
(f)
T (keV)
Ti
Te
(g)
Vx
V_x (km/s)
(h)
soft electron # flux
(#/(cm^2-s-sr)
eV/(cm^2-s-sr-eV)
00:30
00:50
01:10
01:30
01:50
02:10
02:30
UT (hh:mn)

IMF

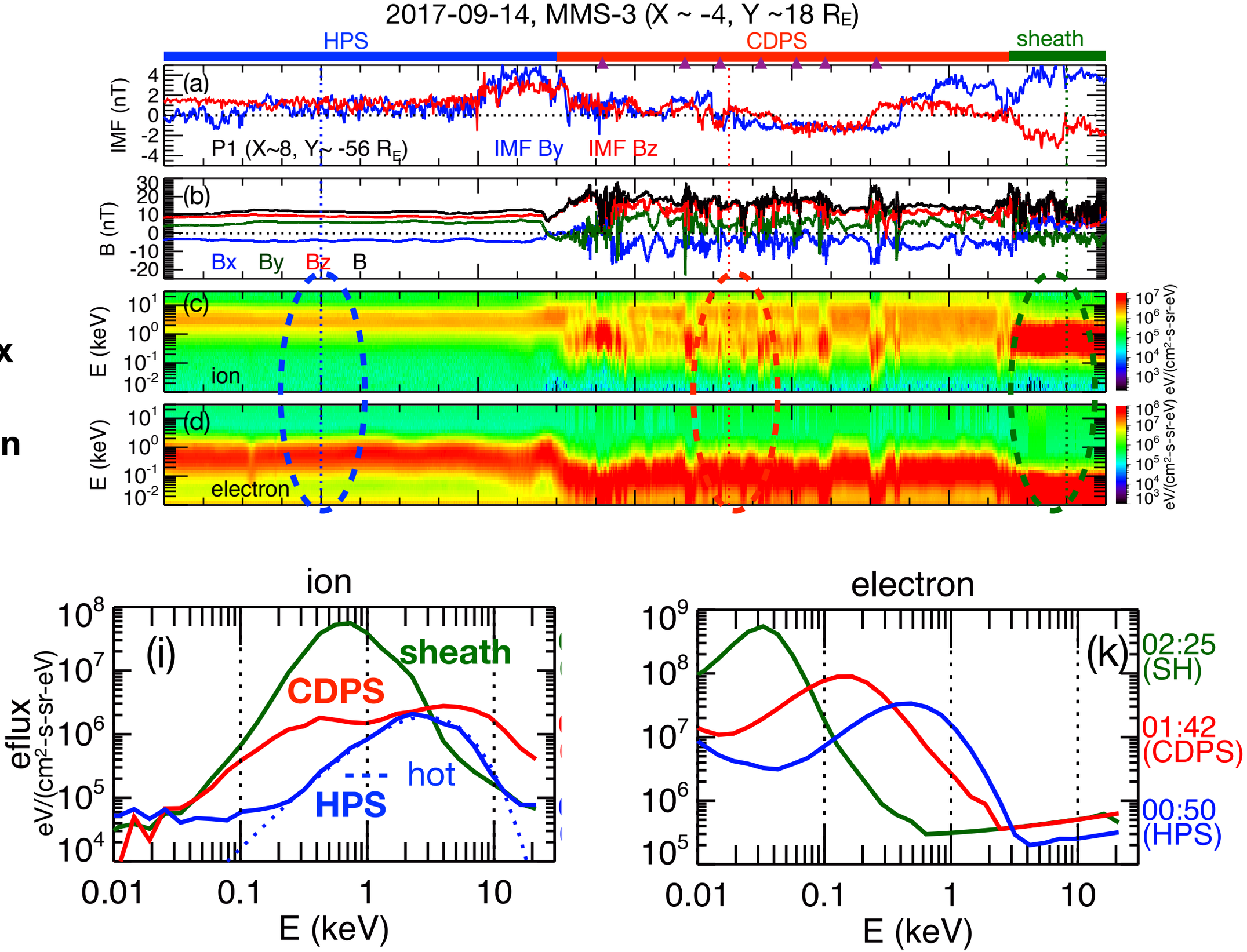
MMS B

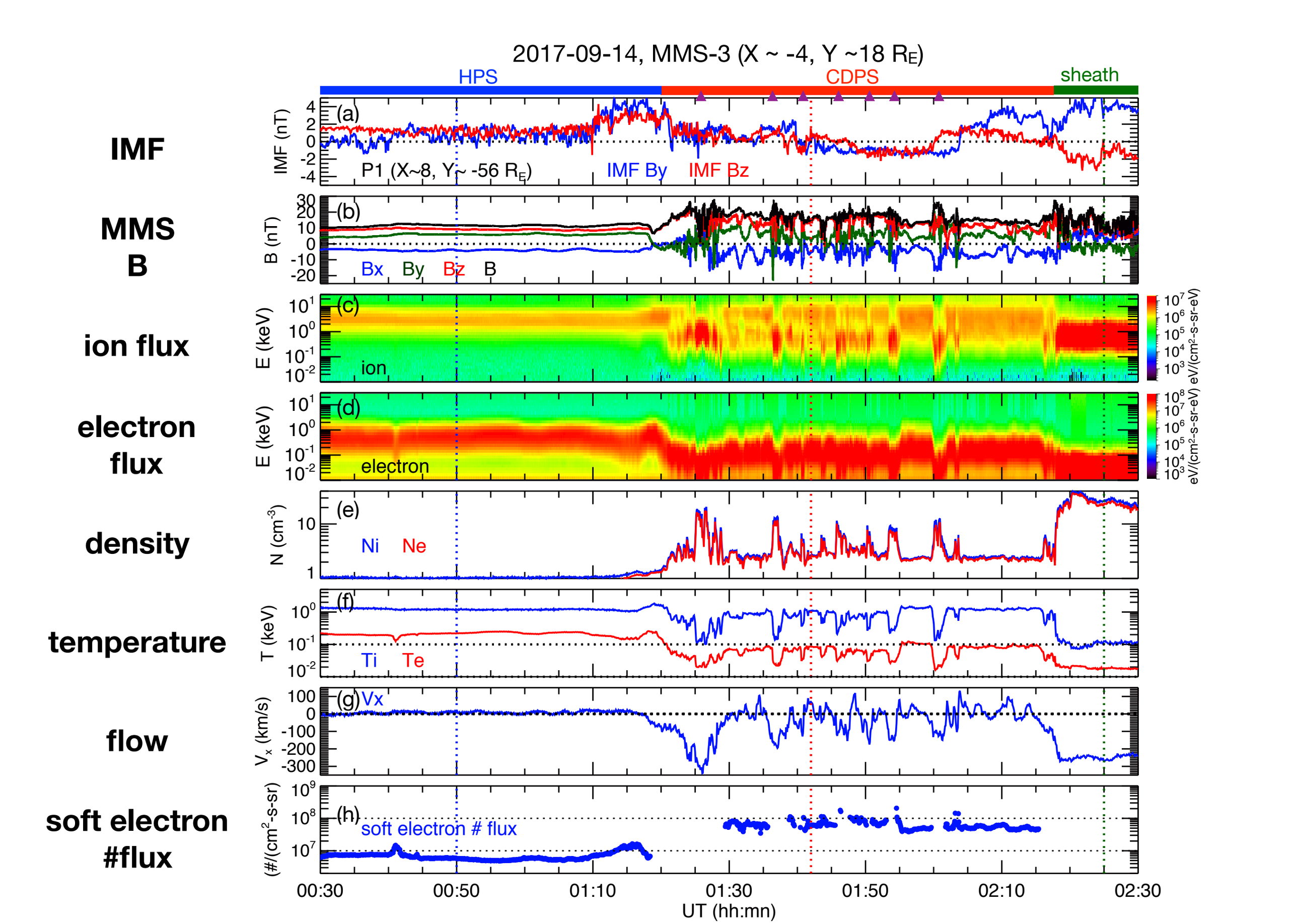
ion flux

electron flux

te

so

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IMF

MMS B

ion flux

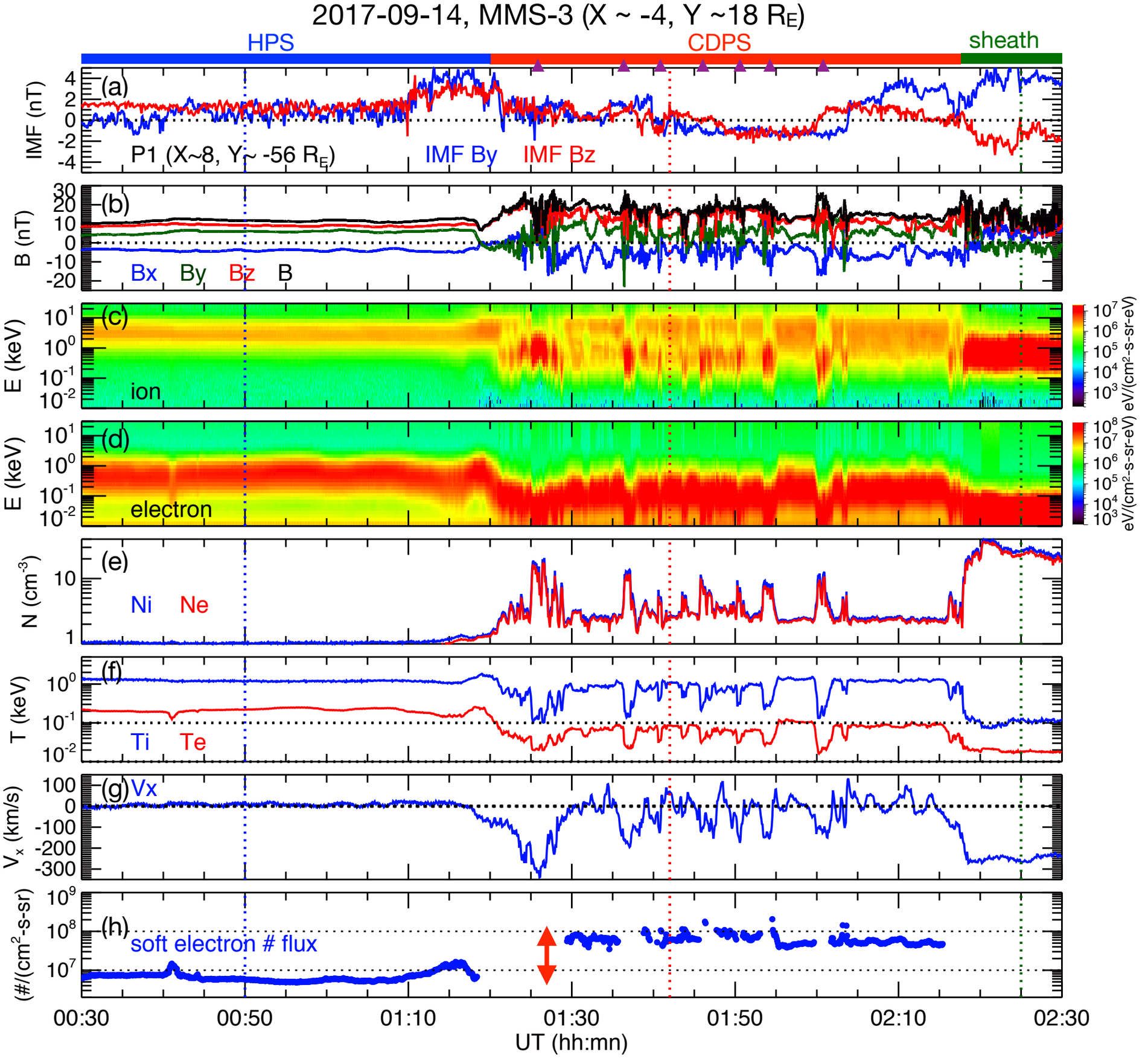
electron flux

density

temperature

flow

soft electron #flux



IMF

MMS B

ion flux

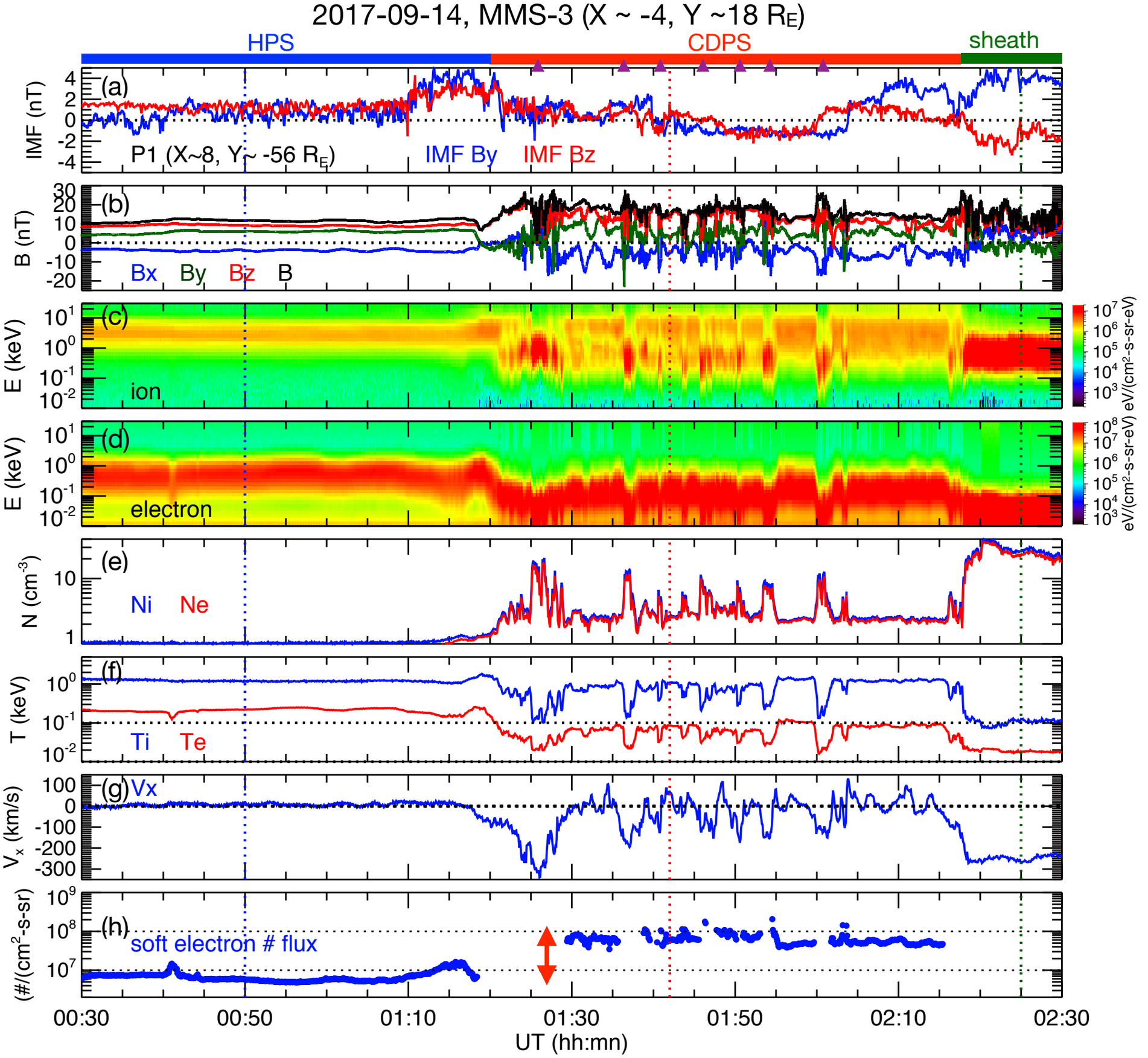
electron flux

density

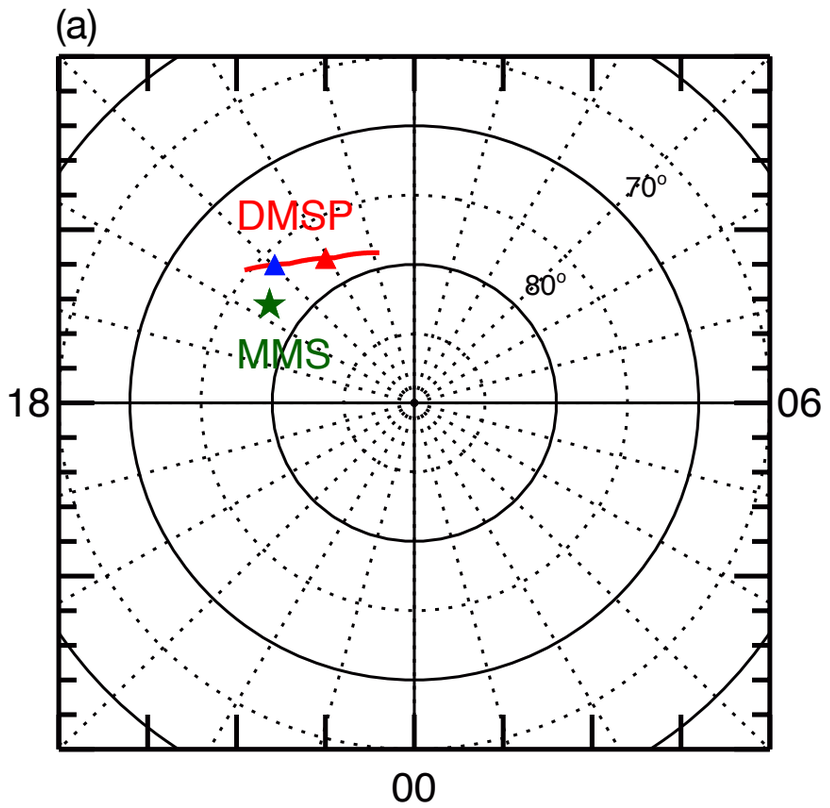
temperature

flow

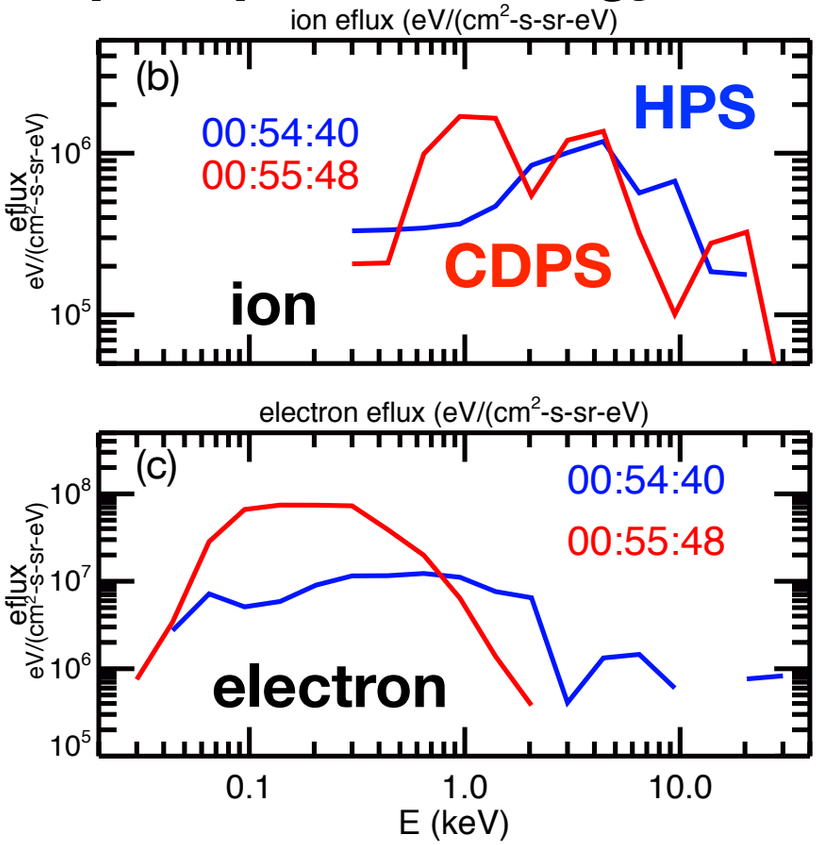
soft electron #flux

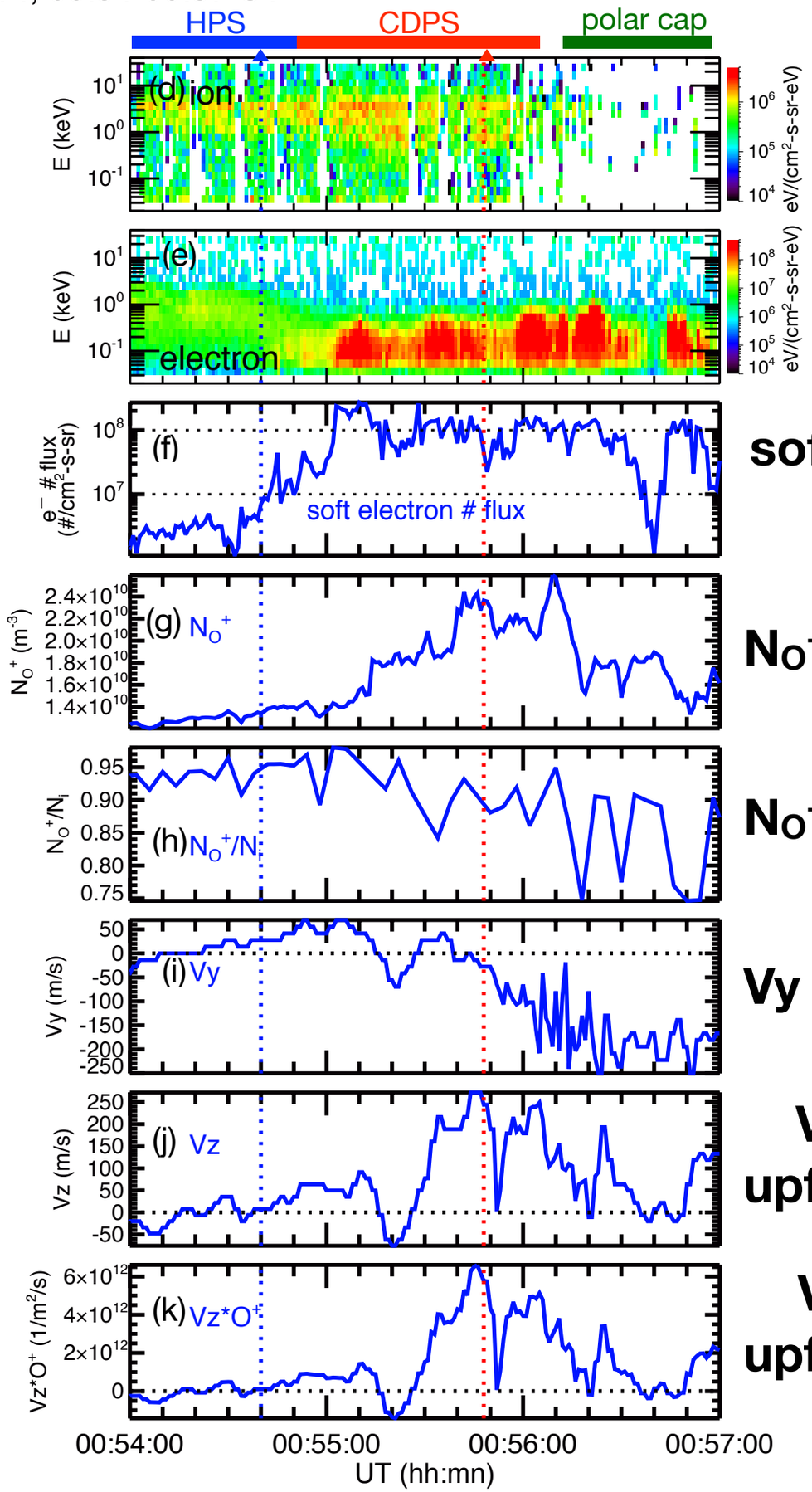


DMSP F18, N.H. pass
2017-09-14, 00:54-00:57 UT



precipitation energy flux





ion eflux

electron eflux

soft electron # flux

N_O^+

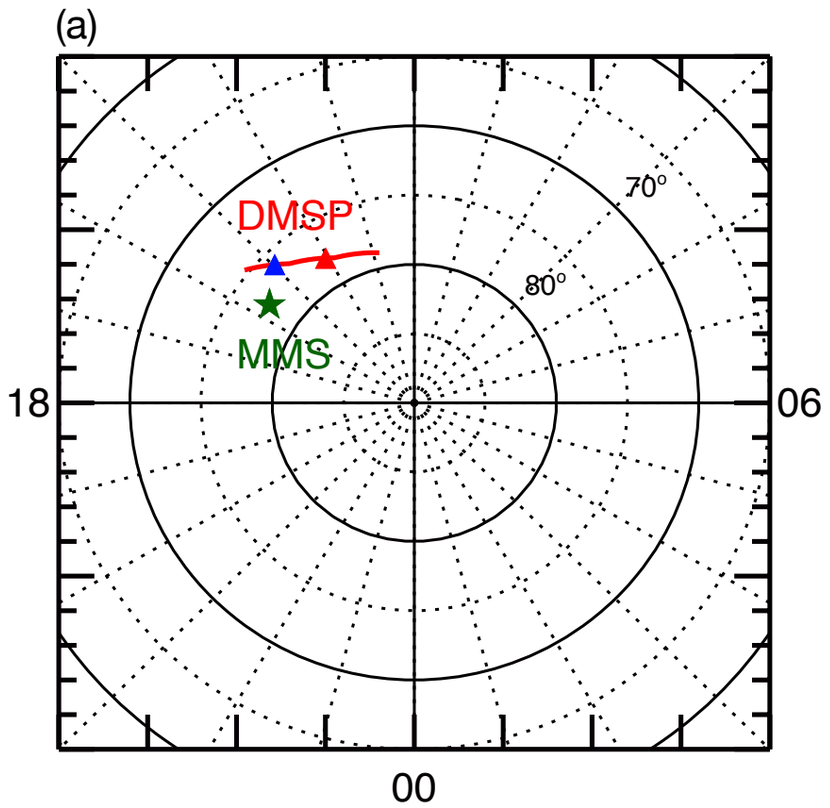
N_O^+/N

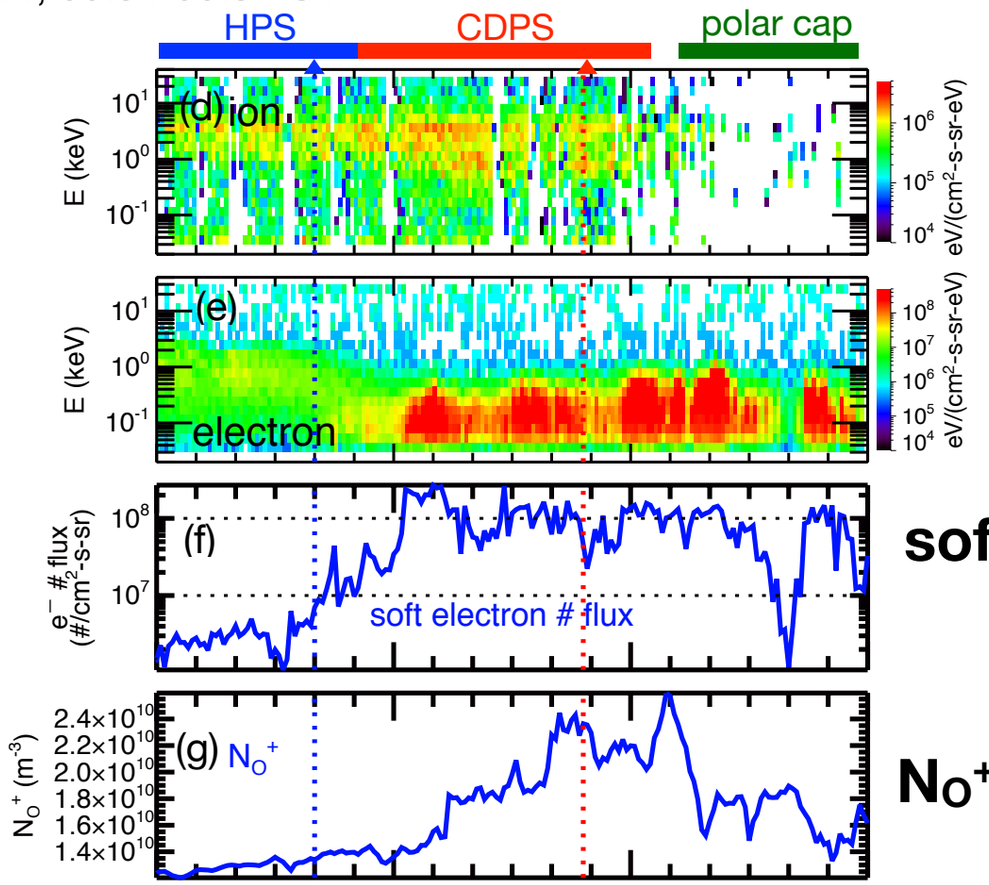
Vy

Vz upflow

$Vz \cdot N_O^+$ upflow flux

DMSP F18, N.H. pass
2017-09-14, 00:54-00:57 UT





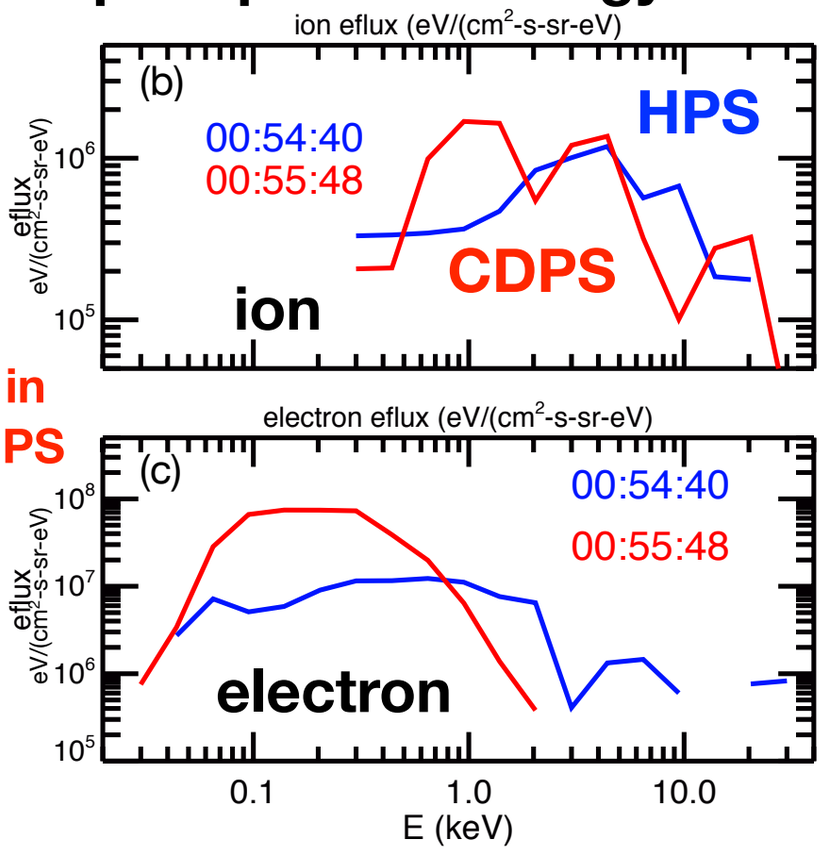
ion eflux

electron eflux

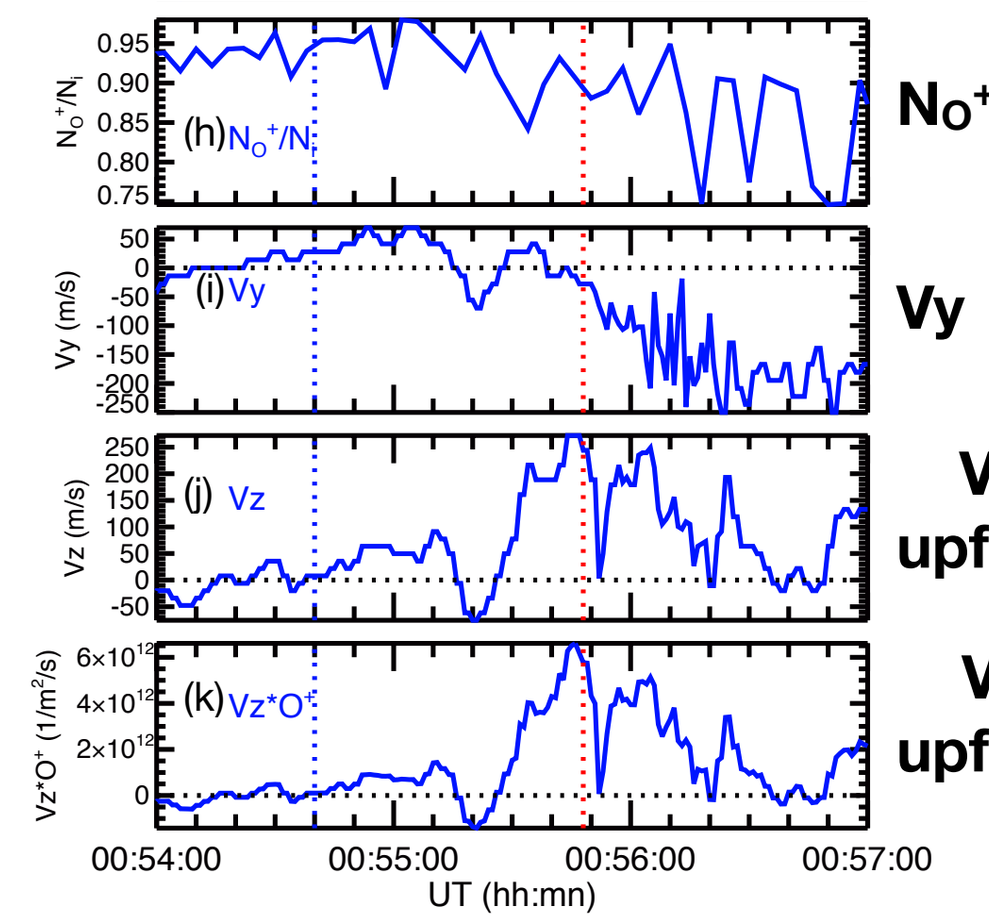
soft electron # flux

N_O^+

precipitation energy flux



larger soft electron precipitation in CDPS than HPS



N_O^+/N

Vy

Vz upflow

$Vz \cdot N_O^+$ upflow flux

DMSP F18, N.H. pass
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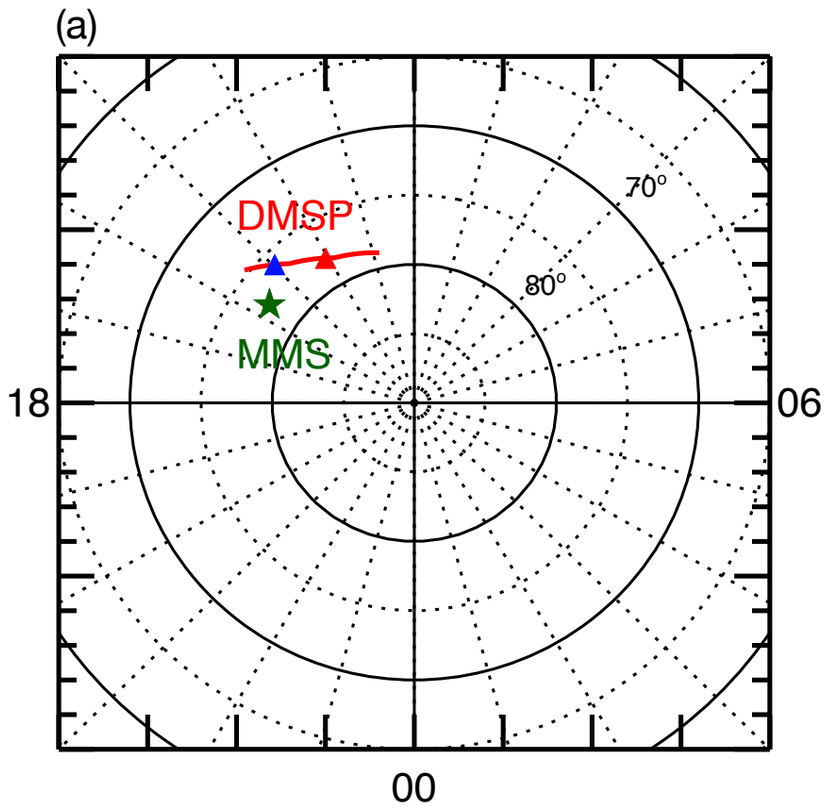
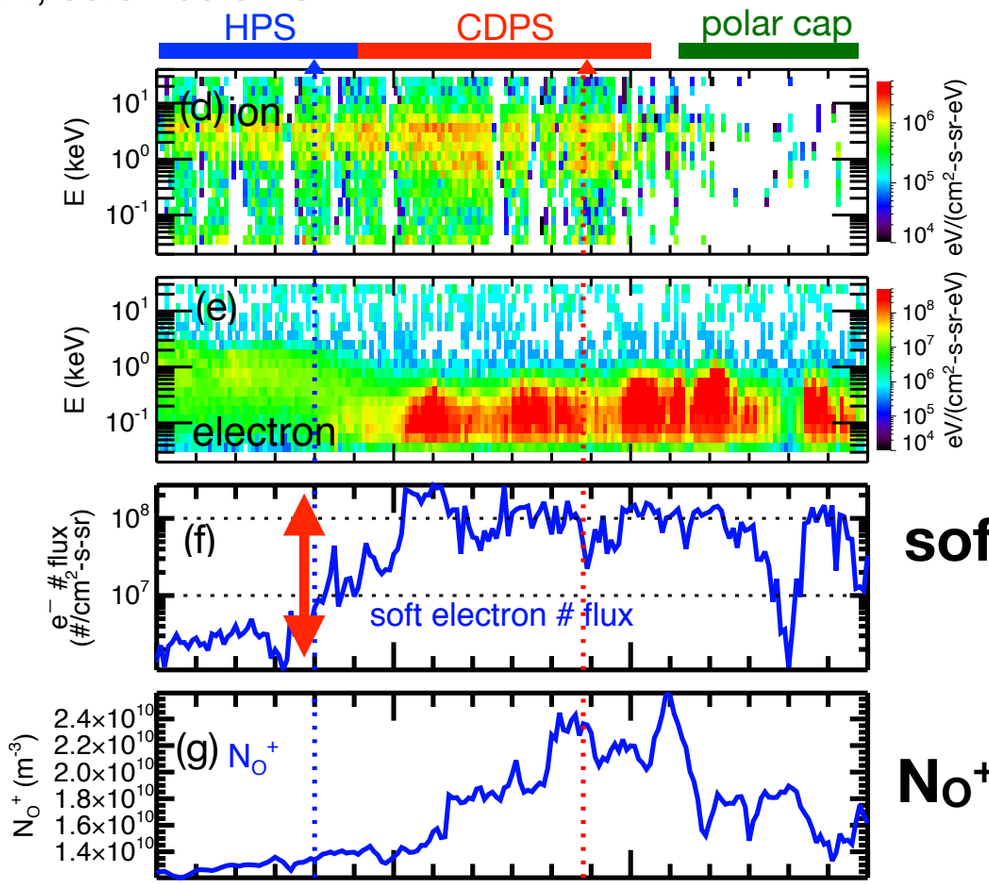




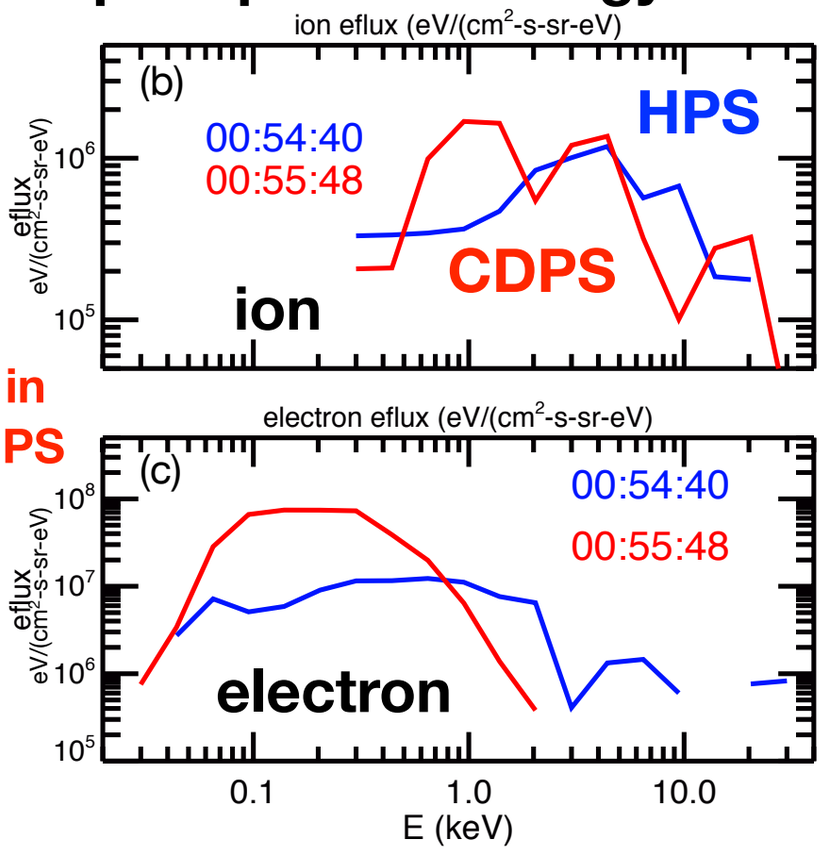
ion eflux

electron eflux

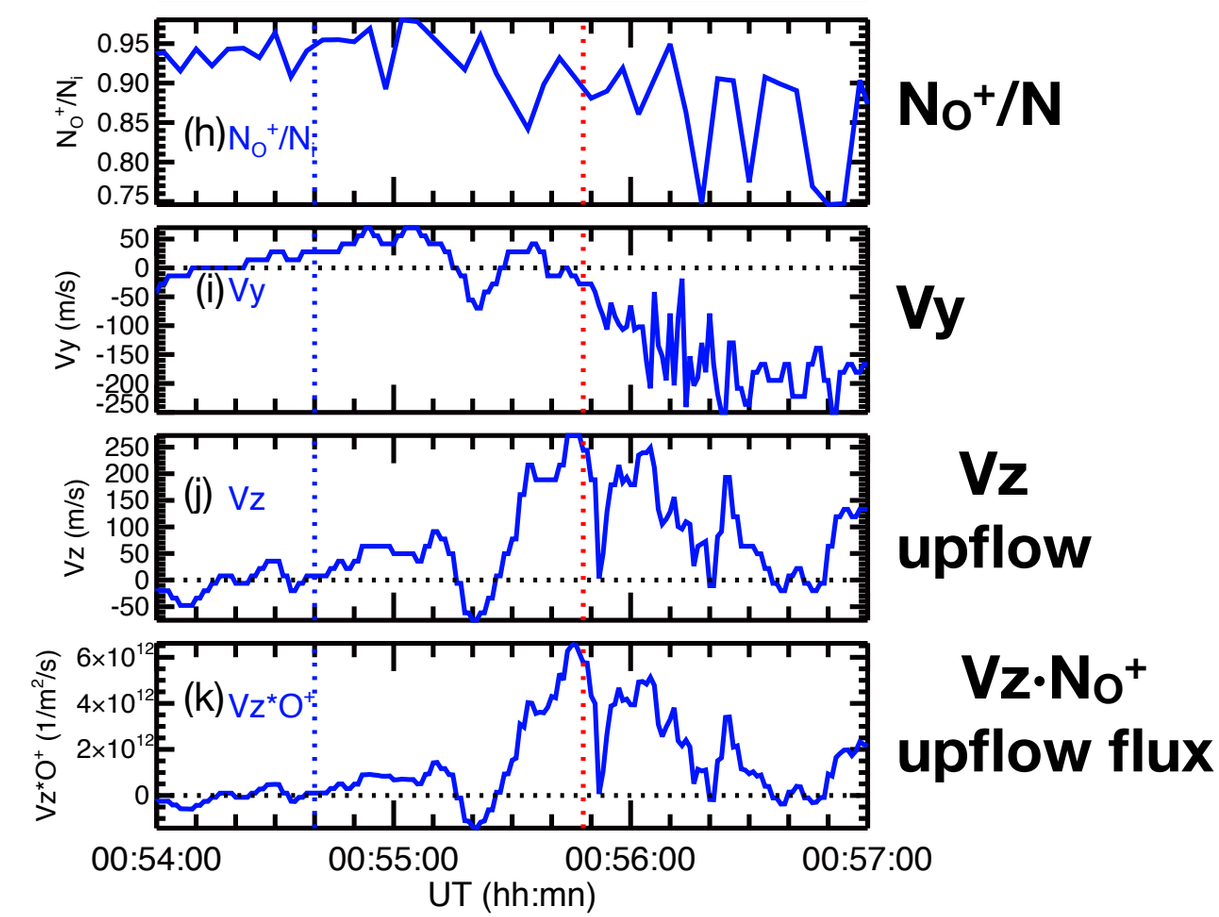
soft electron # flux

No+

precipitation energy flux



larger soft electron precipitation in CDPS than HPS



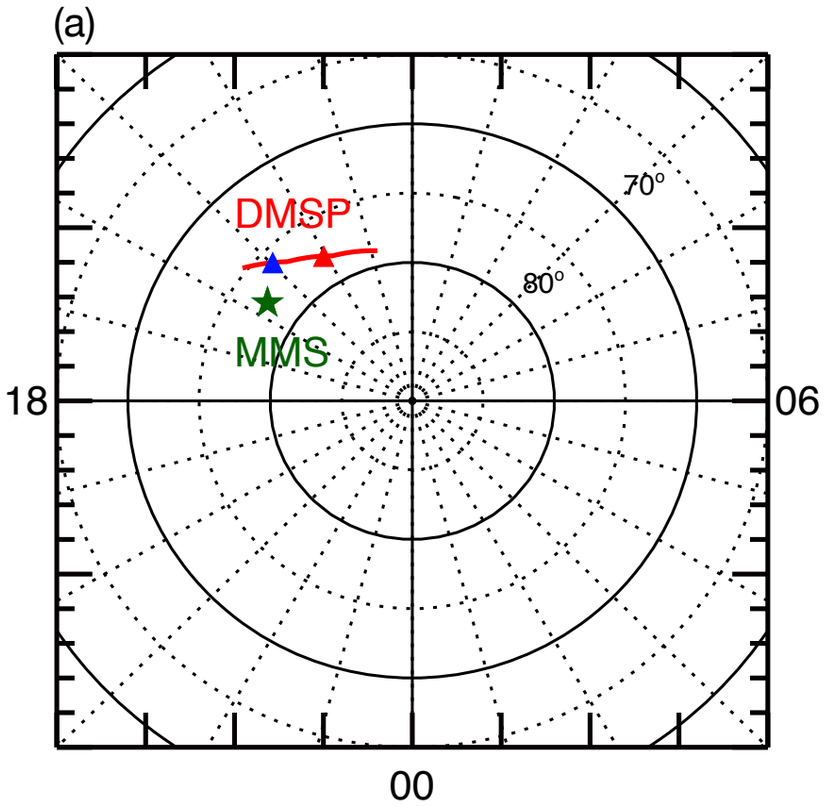
No+/N

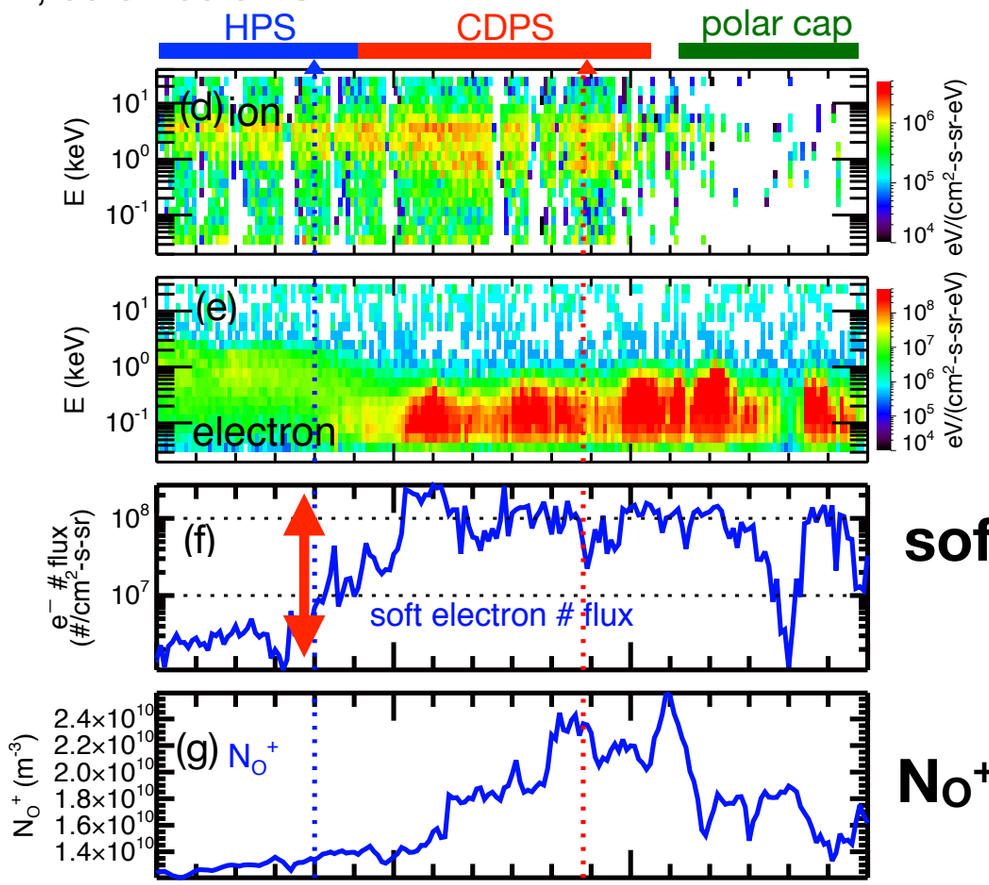
Vy

Vz upflow

Vz·No+ upflow flux

DMSP F18, N.H. pass
2017-09-14, 00:54-00:57 UT





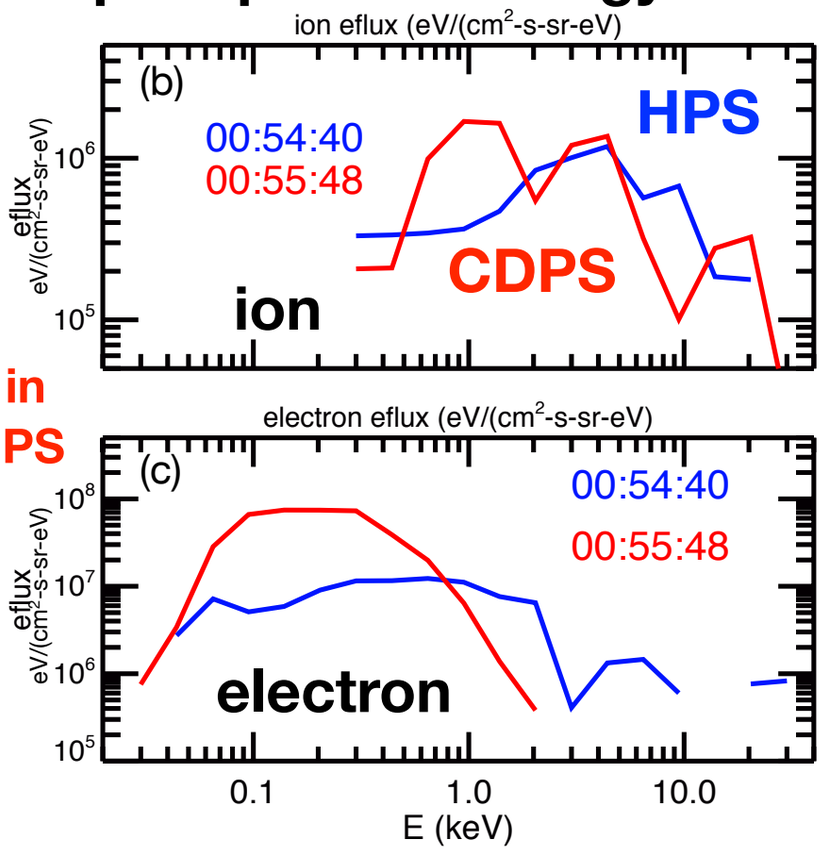
ion eflux

electron eflux

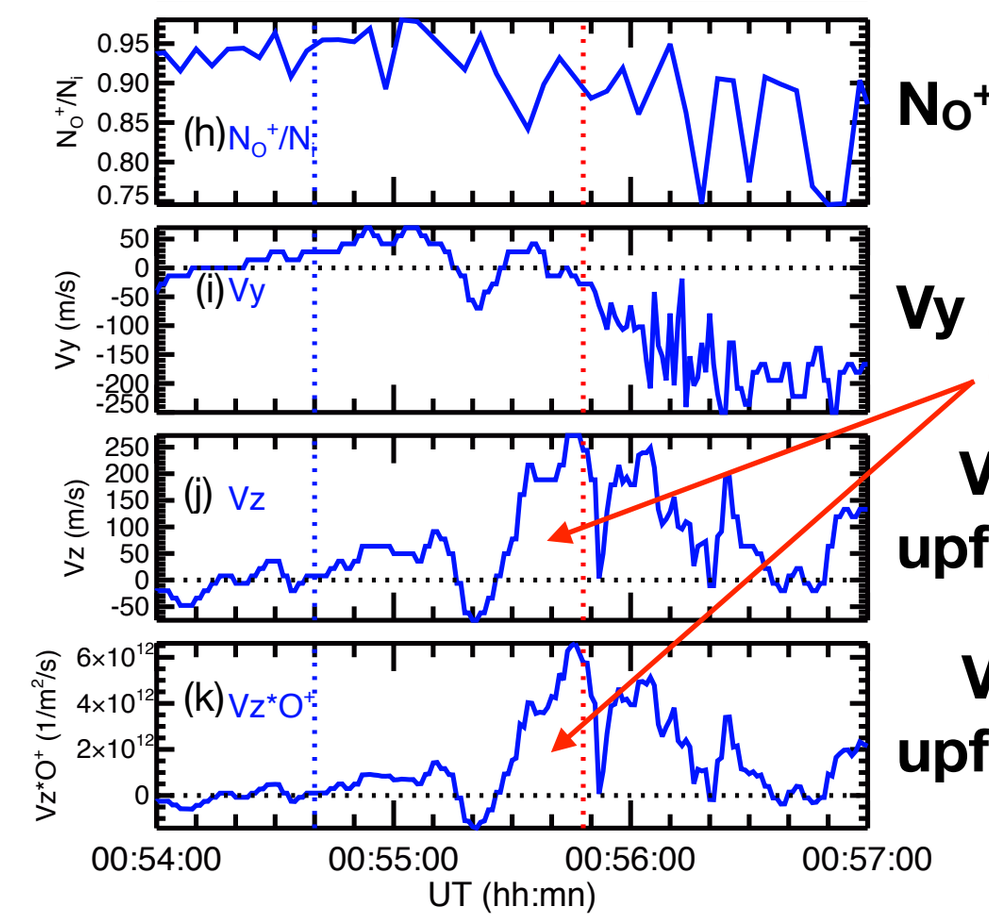
soft electron # flux

No+

precipitation energy flux



larger soft electron precipitation in CDPS than HPS



No+/N

Vy

larger upflow speed and O+ upflow flux in CDPS

Vz upflow

Vz·No+ upflow flux

$\delta \mathbf{B}_\perp$

$\delta \mathbf{B}_\perp$ **spectrum (5 mHz - 10 Hz)**

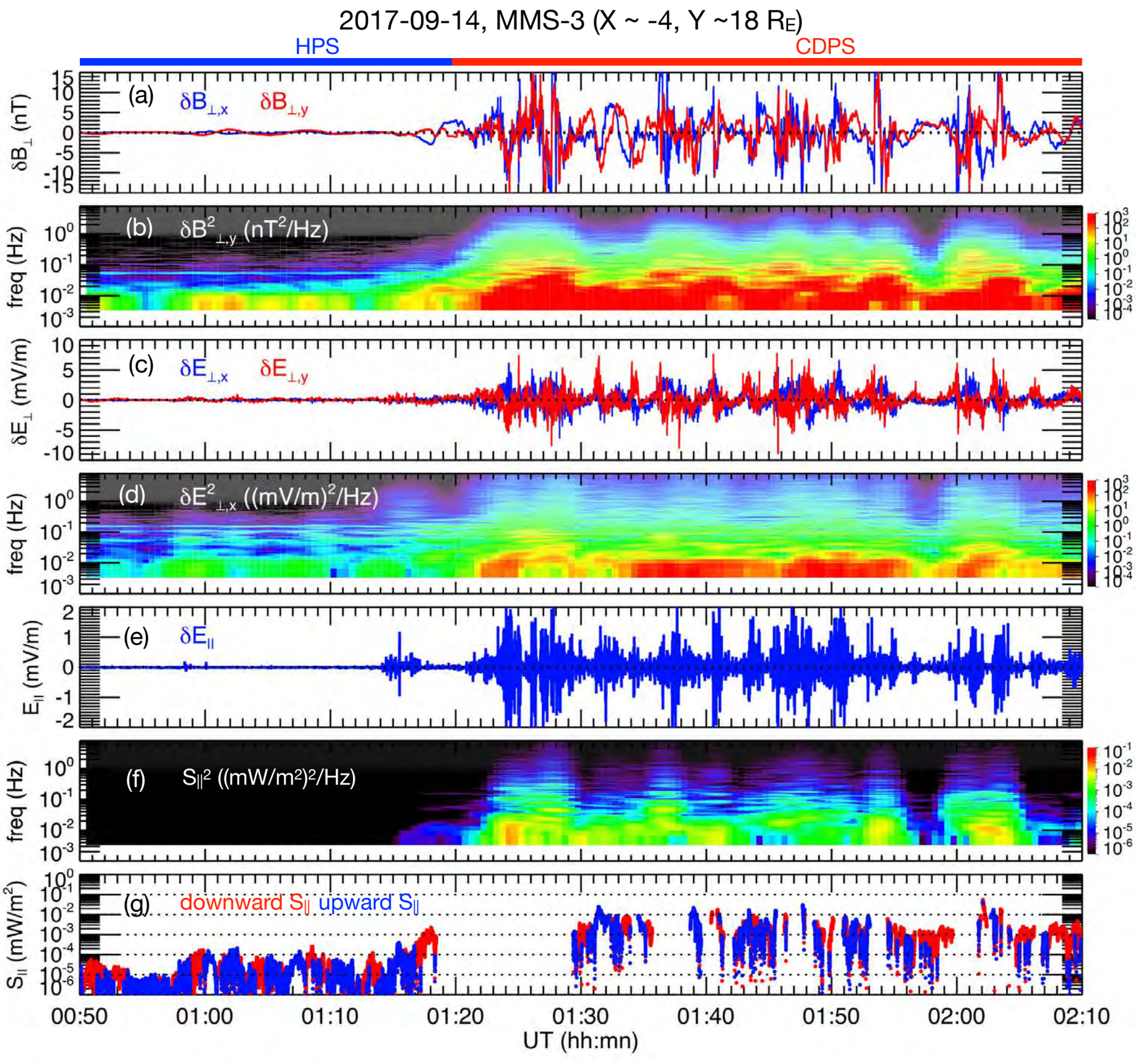
$\delta \mathbf{E}_\perp$

$\delta \mathbf{E}_\perp$ **spectrum (5 mHz - 10 Hz)**

$\delta \mathbf{E}_\parallel$

$\mathbf{S}_\parallel$ **spectrum (5 mHz - 10 Hz)**

$\mathbf{S}_\parallel$



$\delta \mathbf{B}_\perp$

$\delta \mathbf{B}_\perp$ **spectrum**
(5 mHz - 10 Hz)

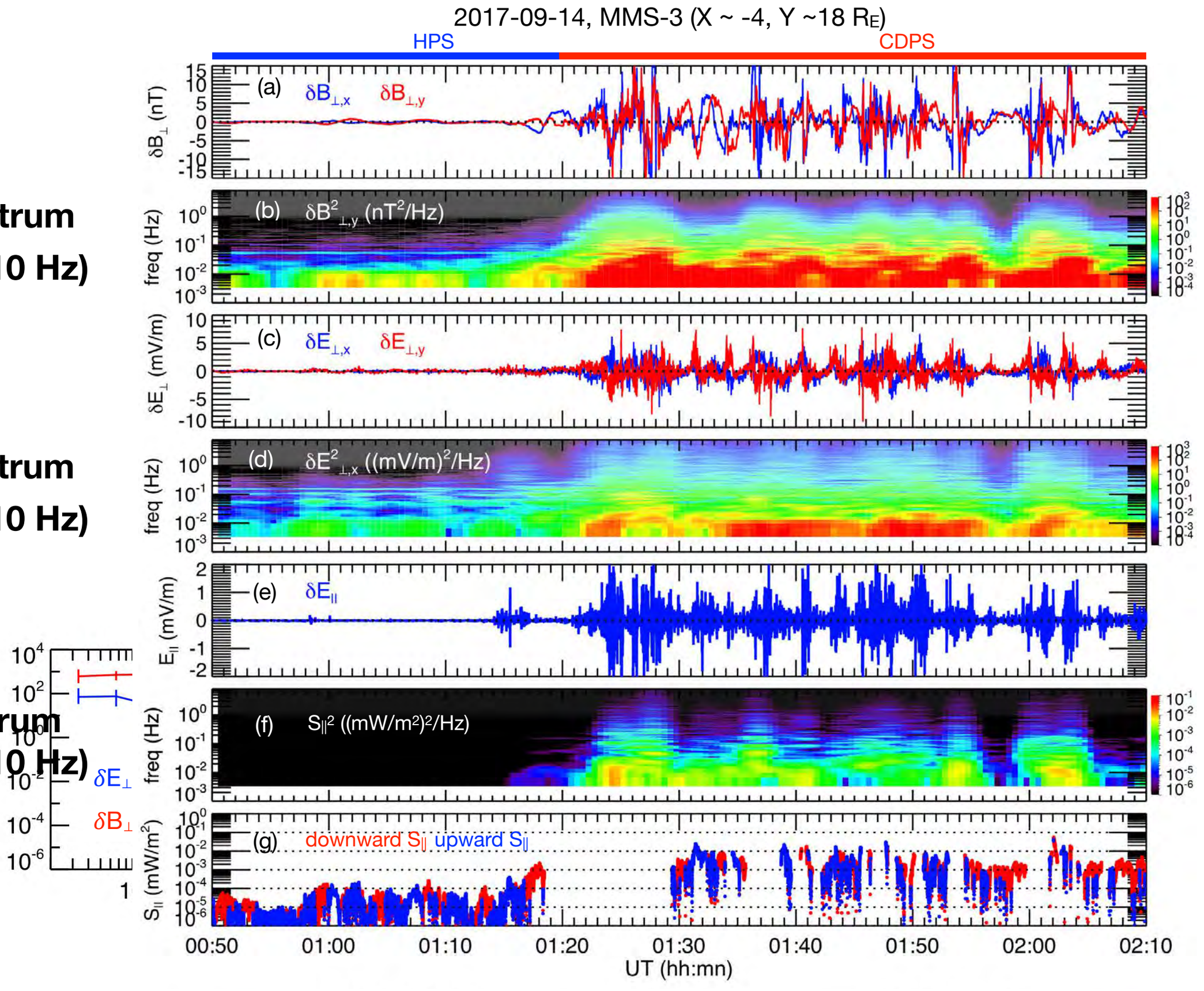
$\delta \mathbf{E}_\perp$

$\delta \mathbf{E}_\perp$ **spectrum**
(5 mHz - 10 Hz)

$\delta \mathbf{E}_\parallel$

$S_\parallel$ spectrum
(5 mHz - 10 Hz)

$S_\parallel$



$\delta \mathbf{B}_\perp$

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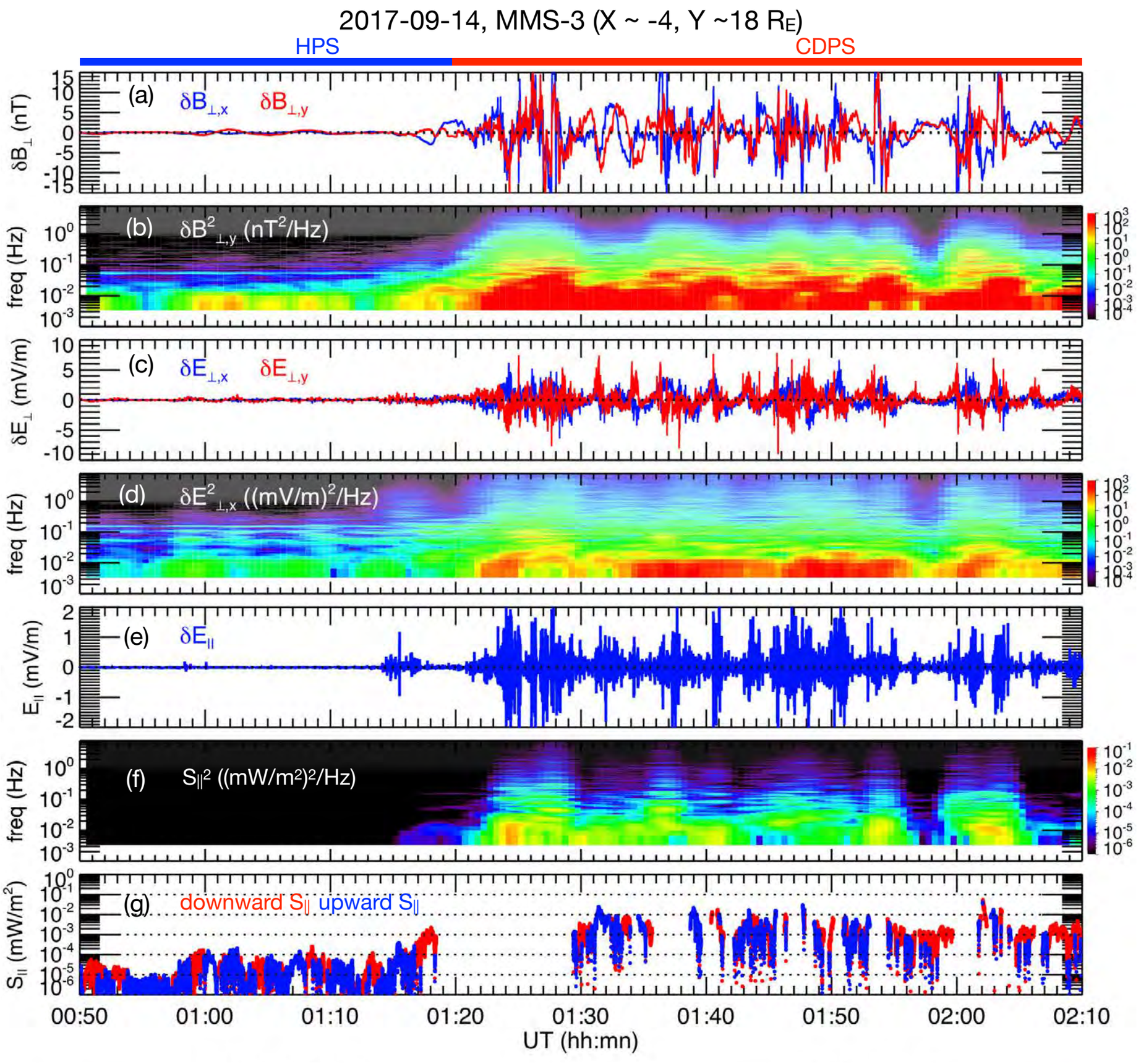
$\delta \mathbf{E}_\perp$

$\delta \mathbf{E}_\perp$ **spectrum (5 mHz - 10 Hz)**

$\delta \mathbf{E}_\parallel$

$\mathbf{S}_\parallel$ **spectrum (5 mHz - 10 Hz)**

$\mathbf{S}_\parallel$



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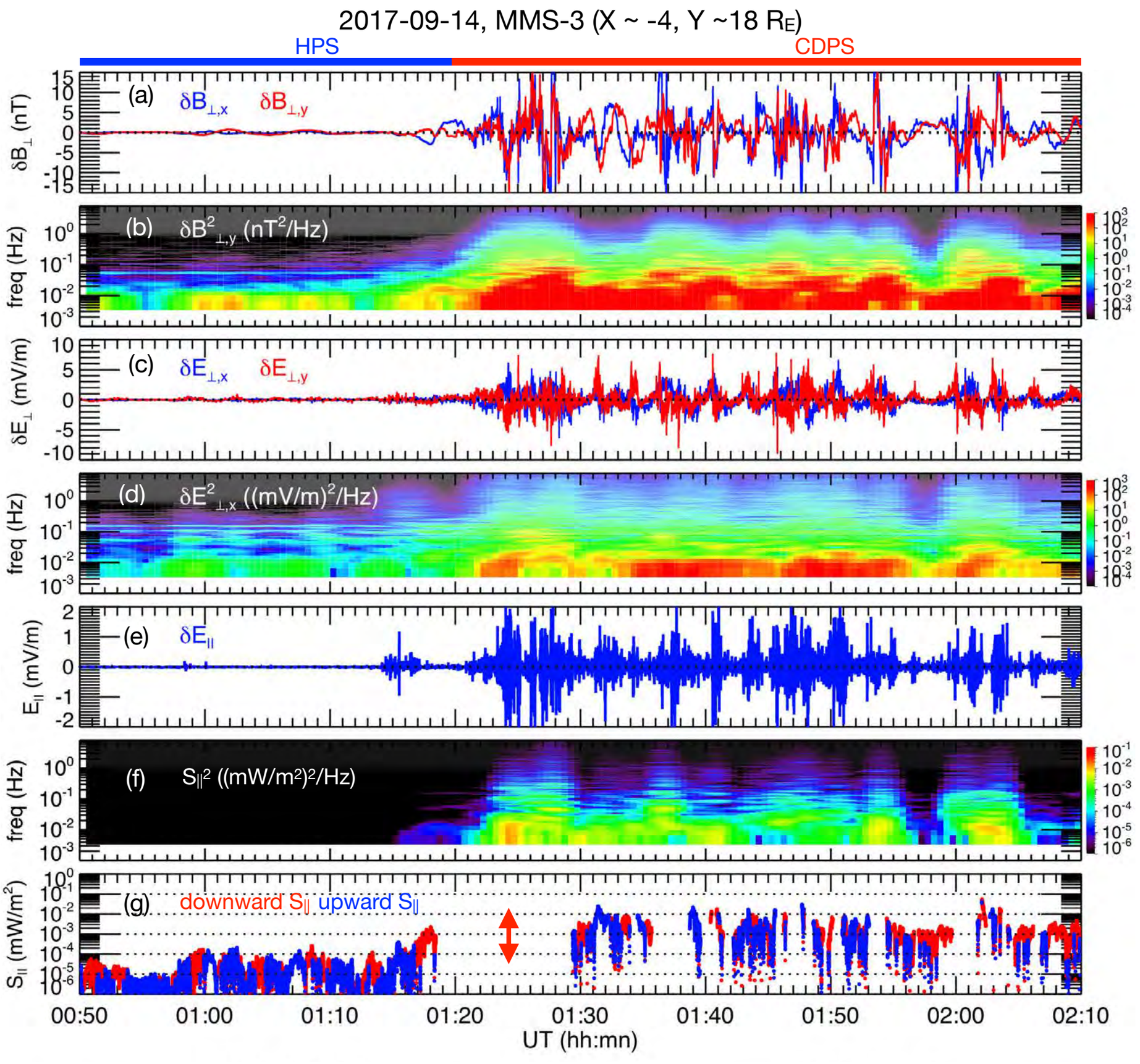
$\mathbf{S}_\parallel$ **spectrum (5 mHz - 10 Hz)**

$\mathbf{S}_\parallel$



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$\delta \mathbf{B}_\perp$ **spectrum (5 mHz - 10 Hz)**

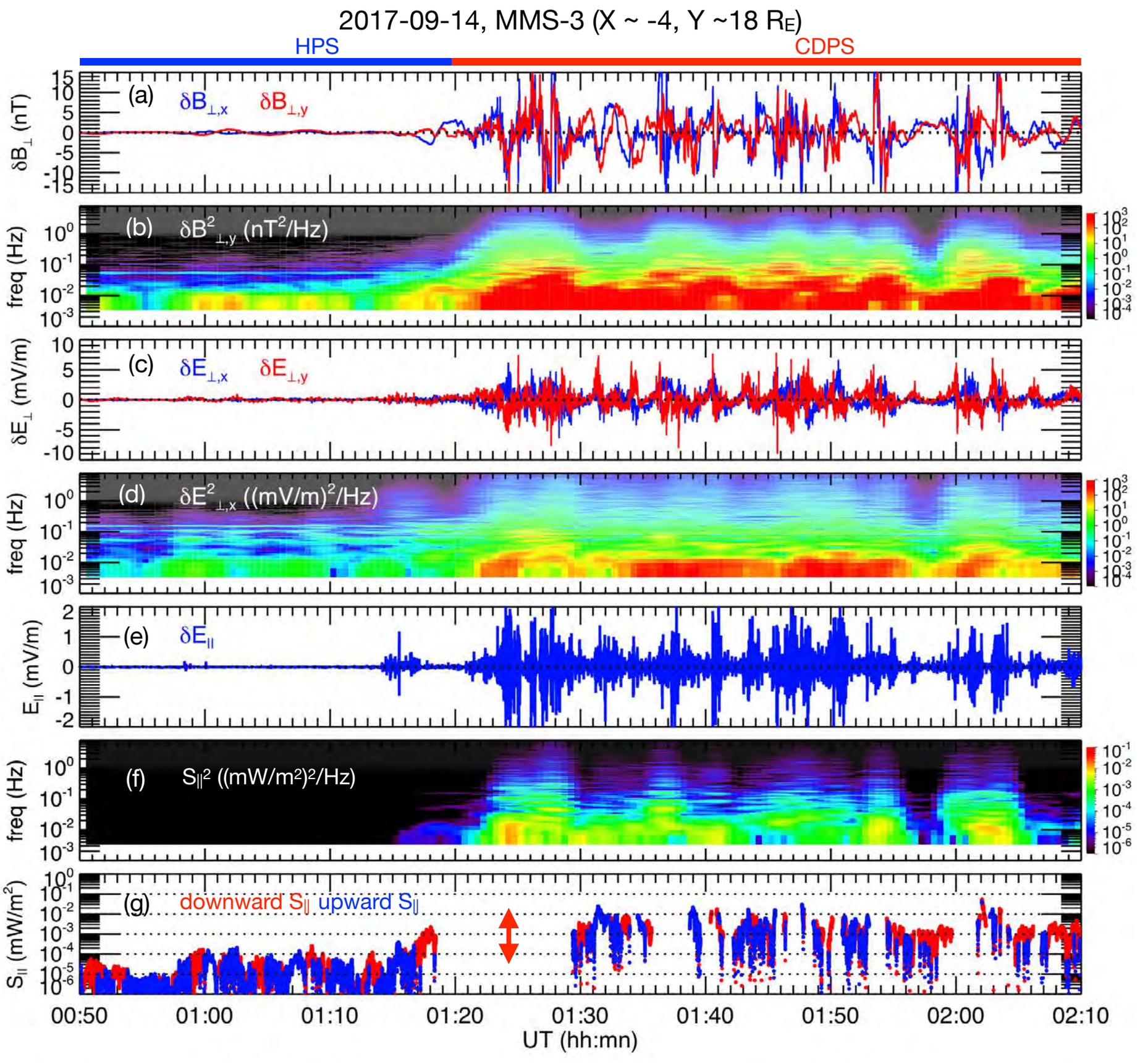
$\delta \mathbf{E}_\perp$

$\delta \mathbf{E}_\perp$ **spectrum (5 mHz - 10 Hz)**

$\delta \mathbf{E}_\parallel$

$\mathbf{S}_\parallel$ **spectrum (5 mHz - 10 Hz)**

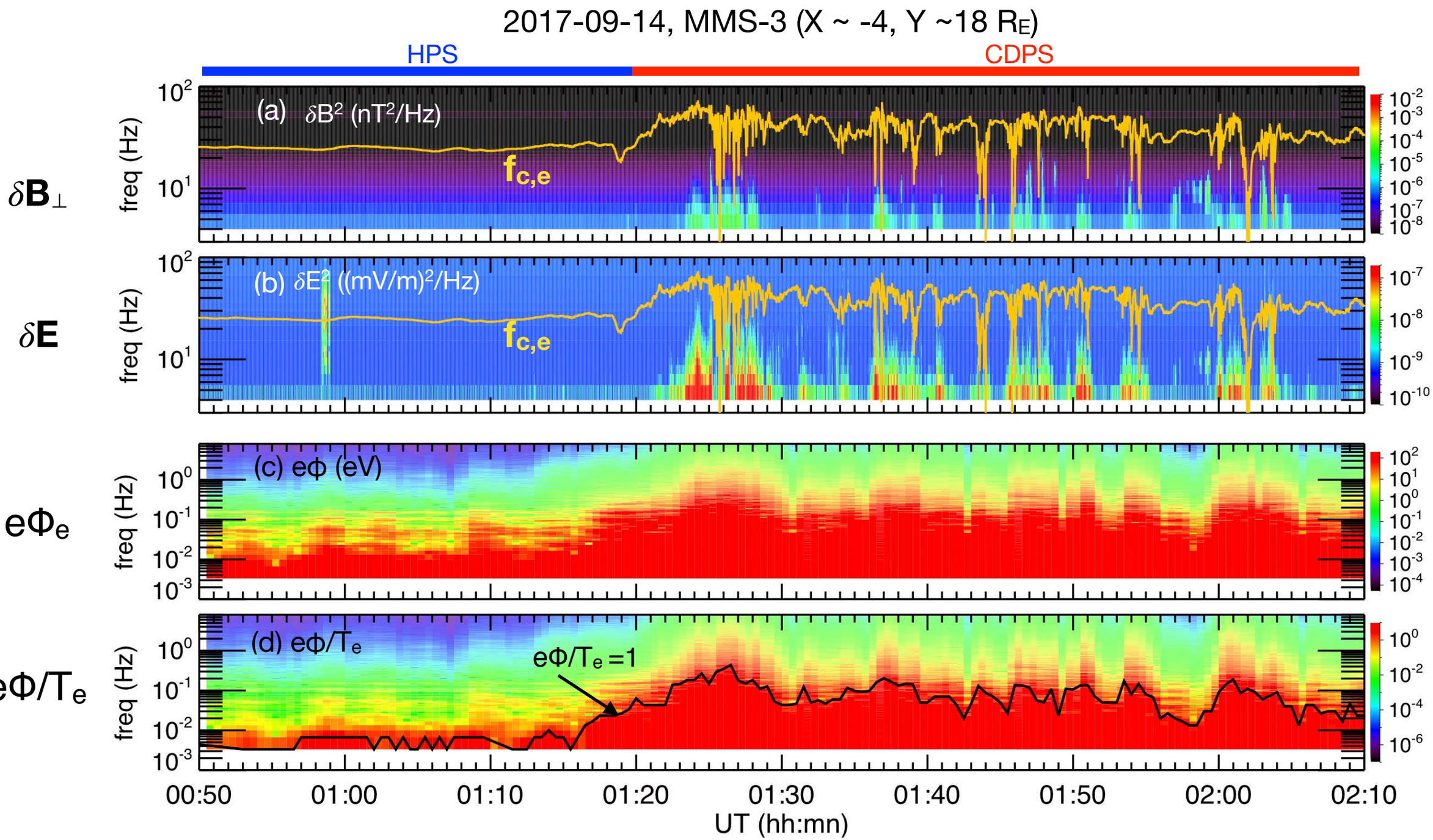
$\mathbf{S}_\parallel$



- **No ECH and whister-mode chorus waves to scatter soft electrons**
- **Consider kinetic Alfvén wave (KAW) for soft electron precipitation**
  electron pitch-angle change due to resonant with $E_{||}$ of KAW

$\Phi_{||} = E_{||}/k_{||} \sim E_{\perp}/k_{\perp} \sim E_{\perp}/(\omega/V_{flow})$

pitch angle change $\Delta\alpha/\alpha_{LC} \sim \sqrt{(e\Phi/T_e)}$ (1 if strong diffusion)



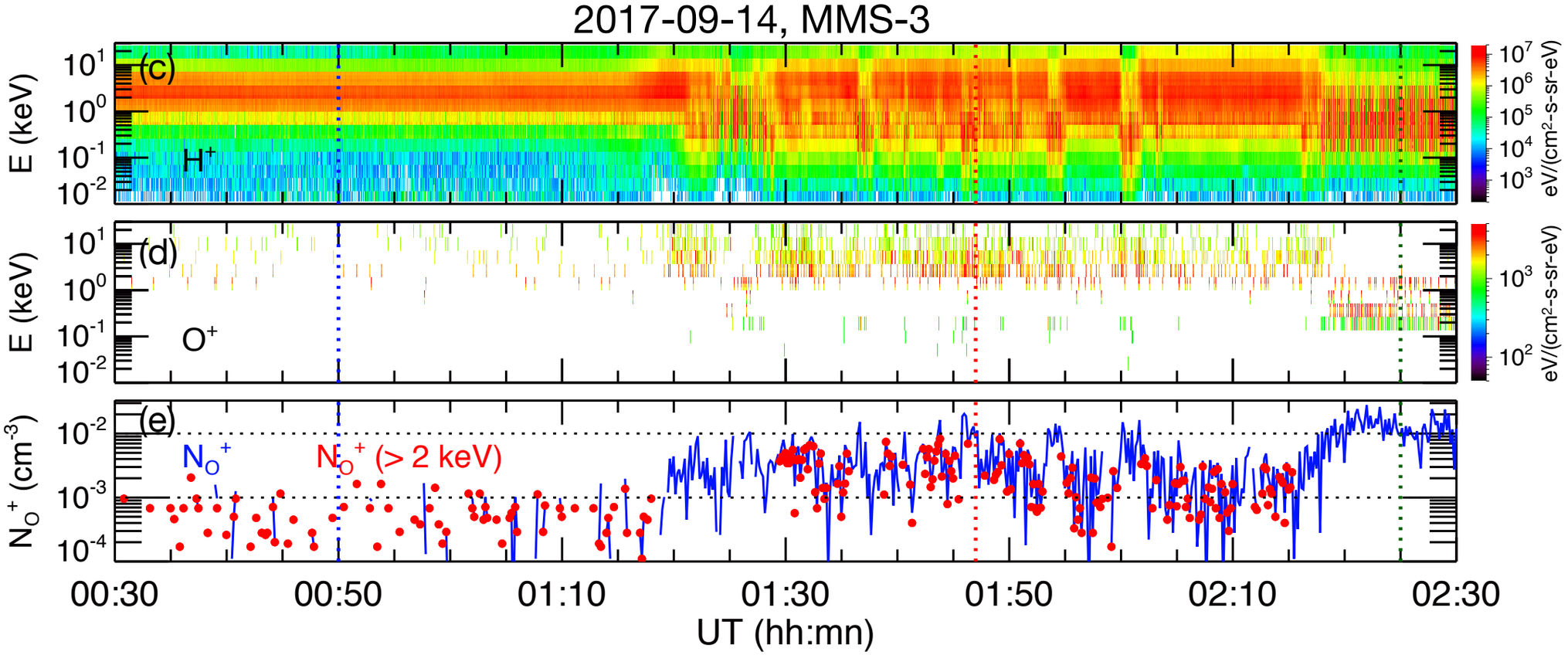
H⁺ eflux

O⁺ eflux

No⁺

MMS-2 counts

MMS-3 counts



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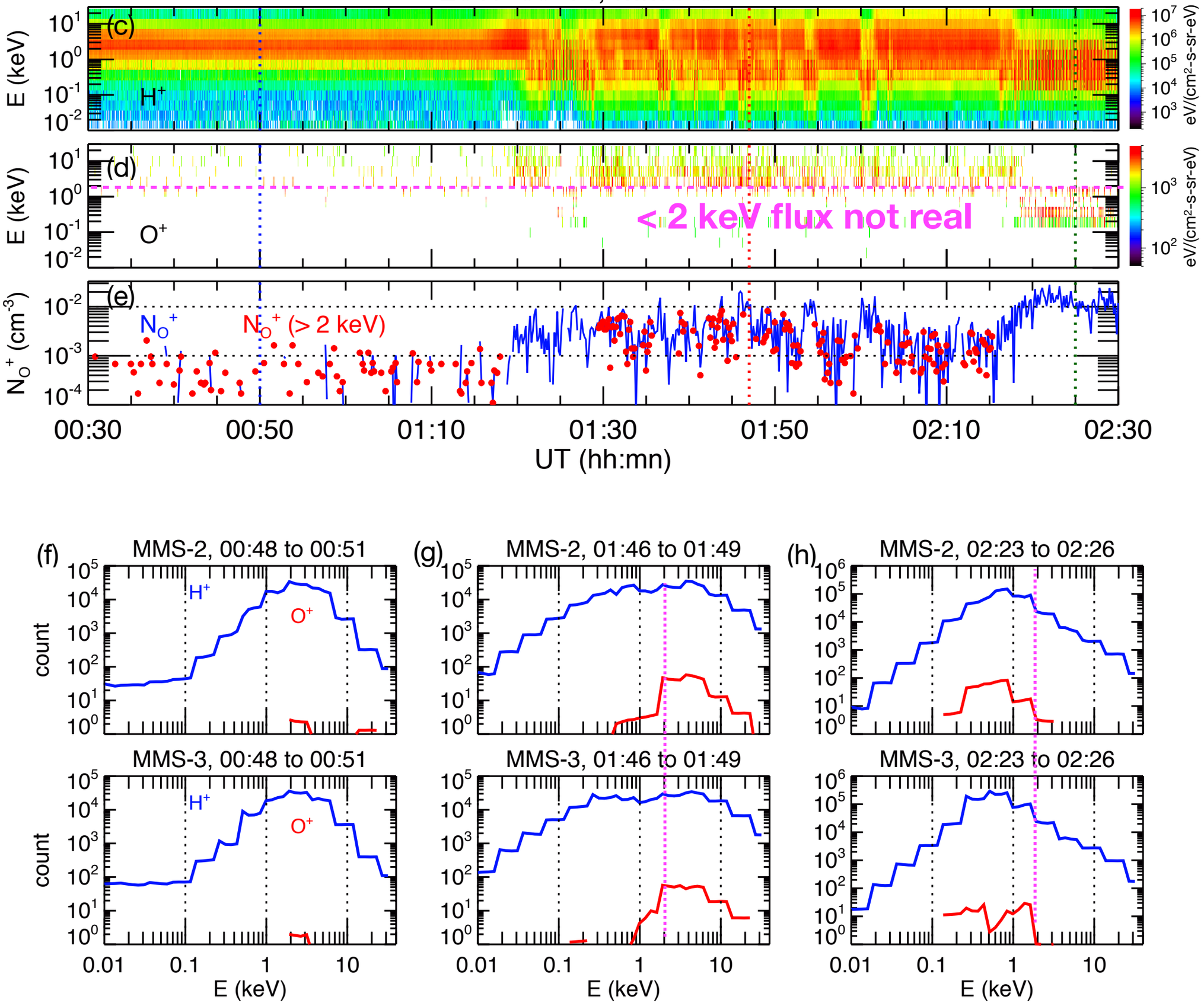
No⁺

MMS-2 counts

MMS-3 counts



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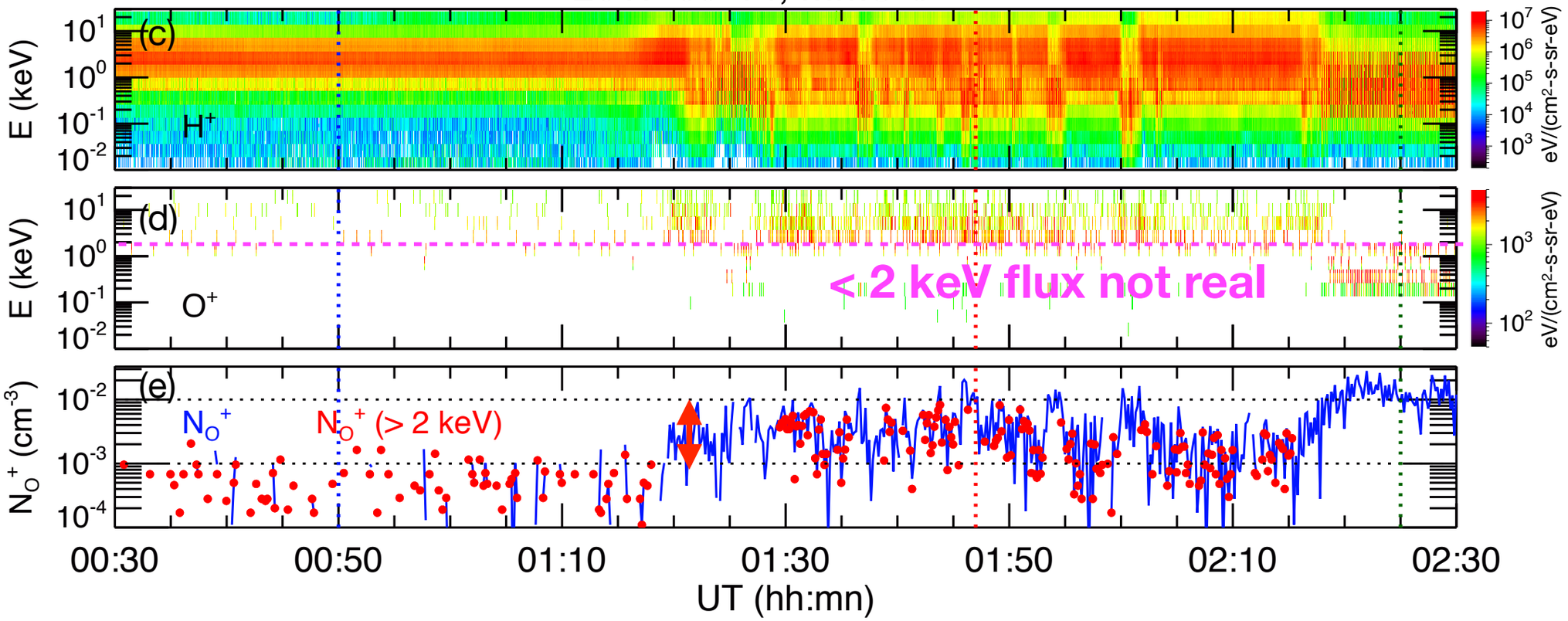
O⁺ eflux

No⁺

MMS-2 counts

MMS-3 counts



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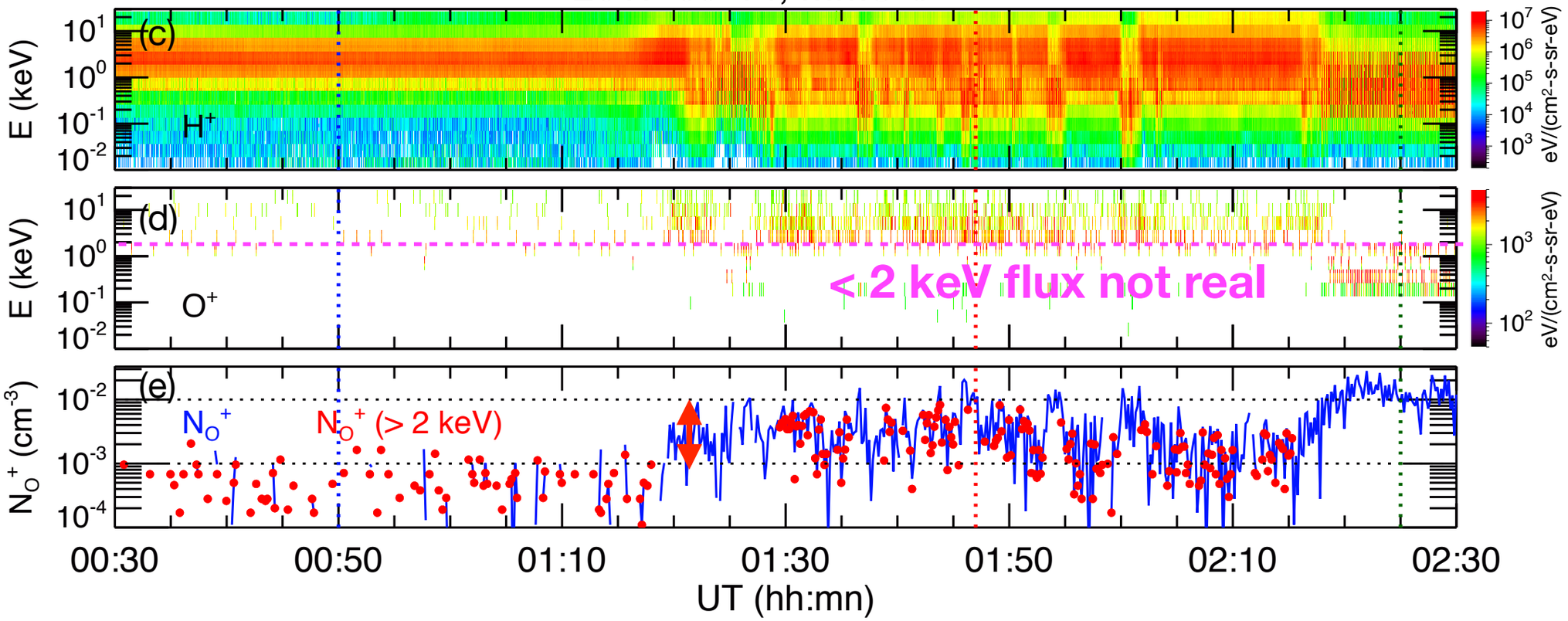
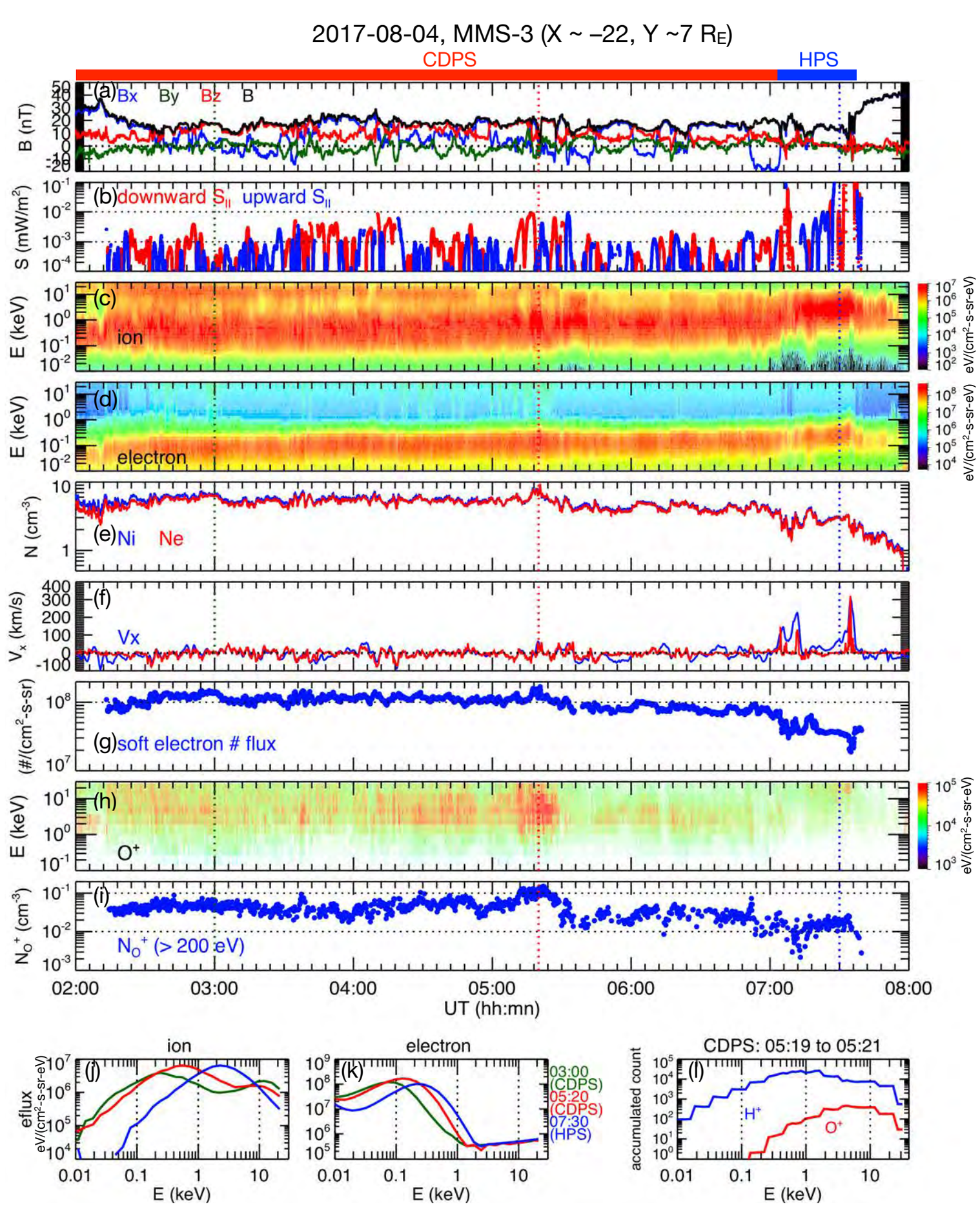
No⁺

MMS-2 counts

MMS-3 counts




2017-08-04, MMS-3 (X ~ –22, Y ~7 R_E)
CDPS
HPS
(a) Bx By Bz B
B (nT)
(b) downward S_|| upward S_||
S (mW/m^2)
(c) ion
E (keV)
eV/(cm^2-s-sr-eV)
(d) electron
E (keV)
eV/(cm^2-s-sr-eV)
(e) Ni Ne
N (cm^-3)
(f) Vx
V_x (km/s)
(g) soft electron # flux
(#/(cm^2-s-sr)
(h) O+
E (keV)
eV/(cm^2-s-sr-eV)
(i) N_O+ (> 200 eV)
N_O+ (cm^-3)
02:00
03:00
04:00
05:00
06:00
07:00
08:00
UT (hh:mn)
ion
(j)
eflux
eV/(cm^2-s-sr-eV)
E (keV)
electron
(k)
03:00 (CDPS)
05:20 (CDPS)
07:30 (HPS)
E (keV)
CDPS: 05:19 to 05:21
(l)
accumulated count
H+
O+
E (keV)

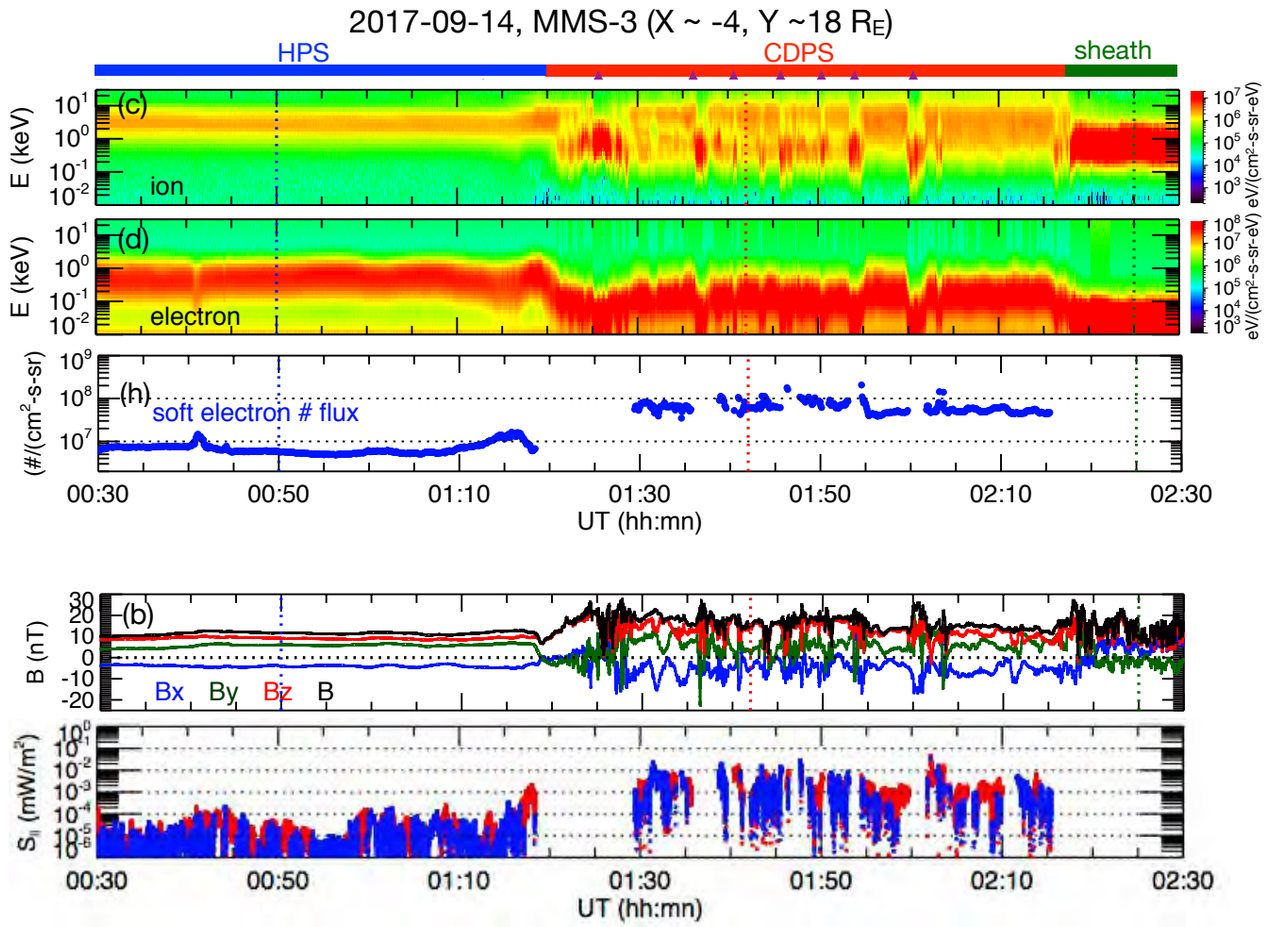
cold-dense plasma sheet

more soft electron

stronger wave

enhanced Poynting flux

enhanced soft electron precipitation



cold-dense plasma sheet

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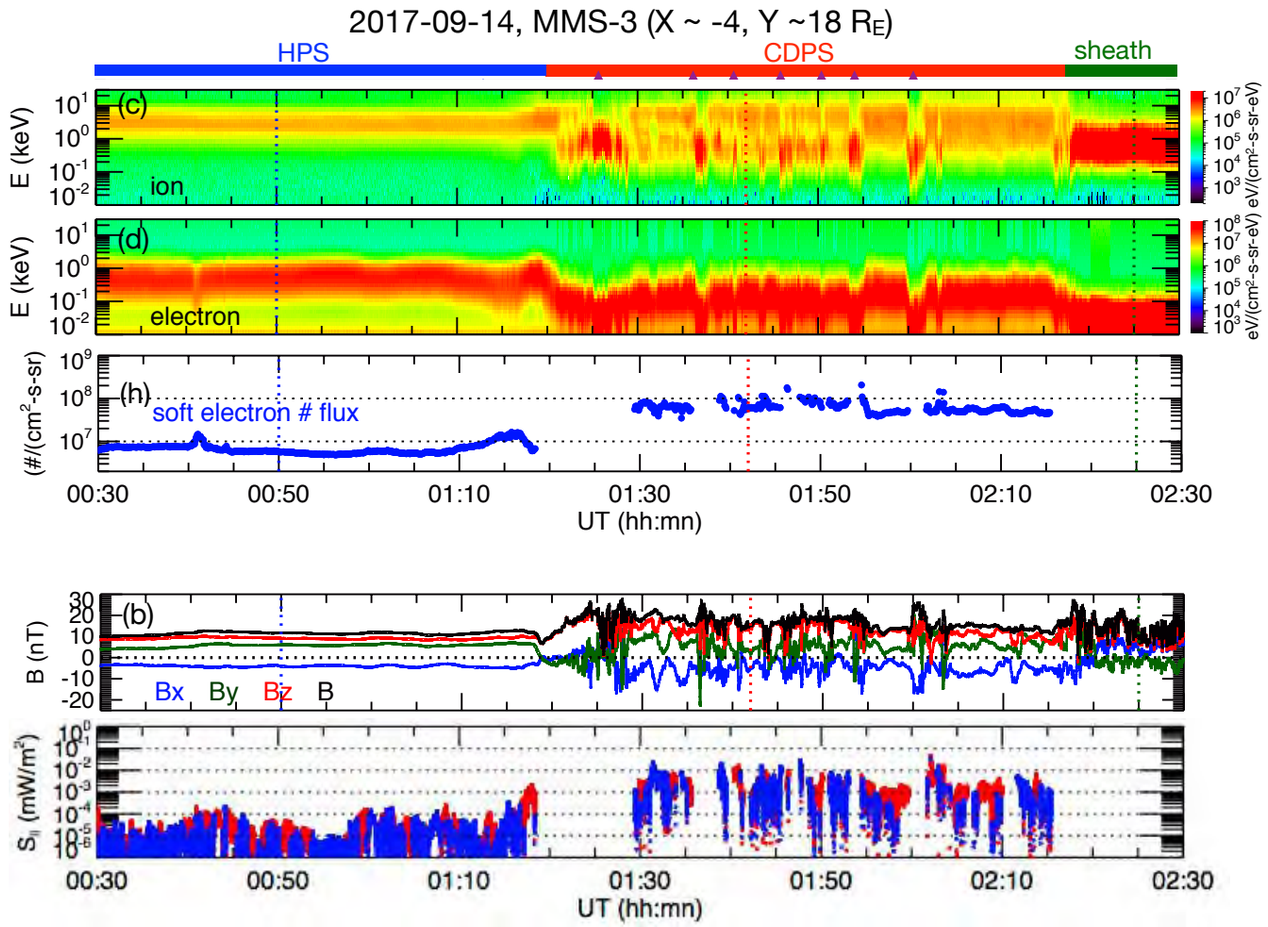
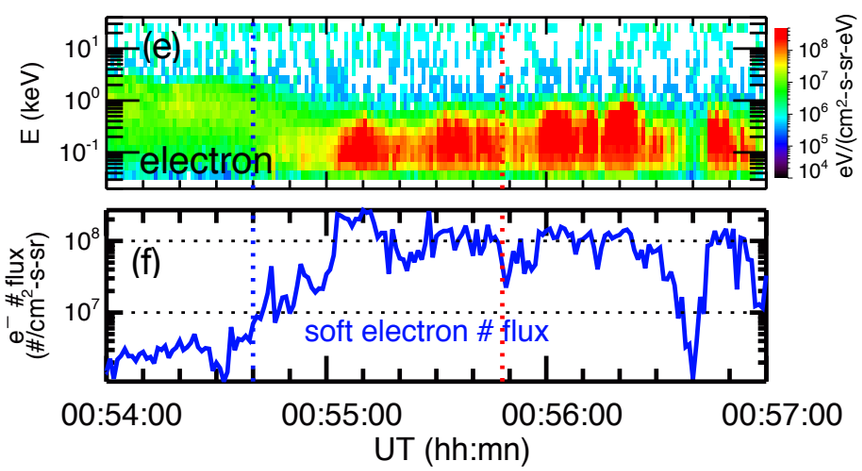
enhanced soft electron precipitation





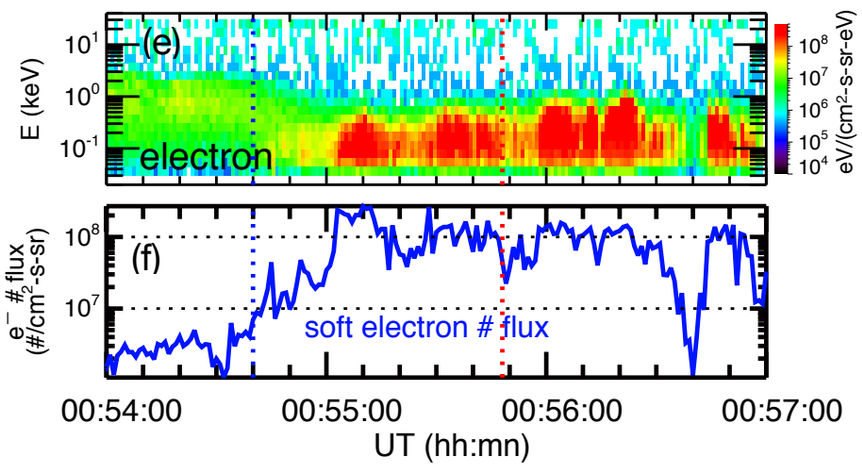
cold-dense plasma sheet

more soft electron

stronger wave

enhanced Poynting flux

enhanced soft electron precipitation



cold-dense plasma sheet

Ionosphere

more soft electron

stronger wave

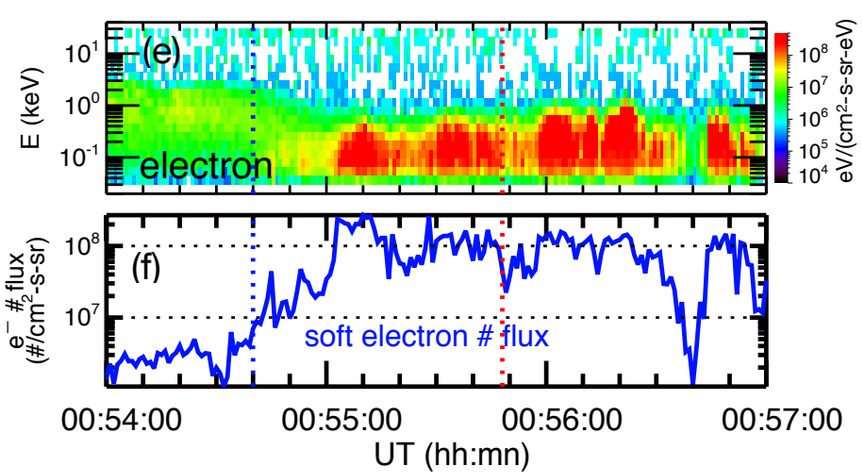
ion outflow

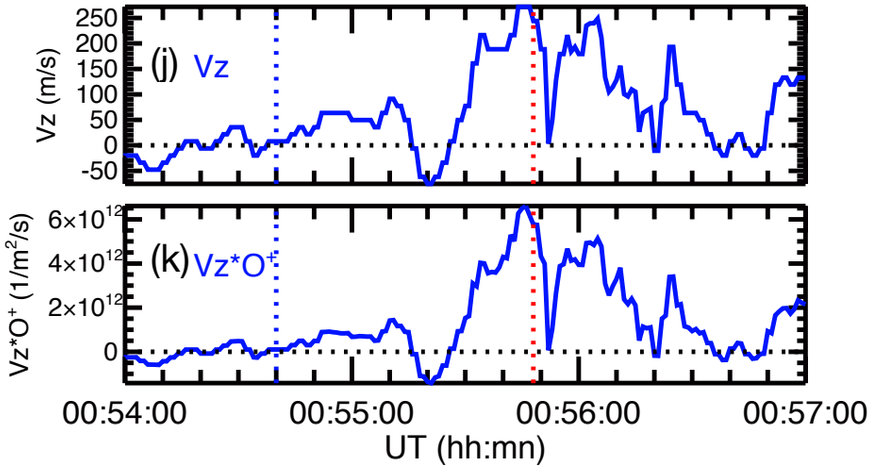
enhanced Poynting flux

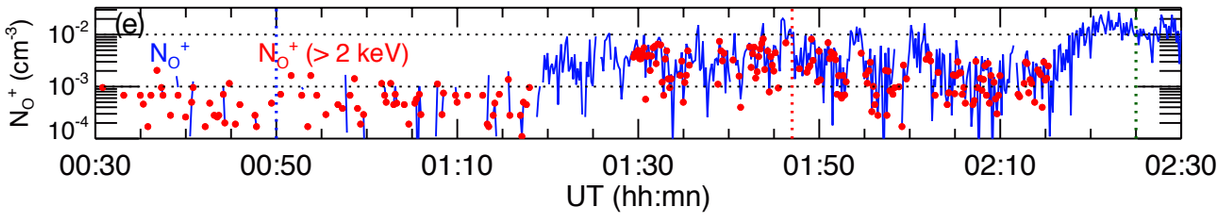
wave heating

enhanced soft electron precipitation

ion up flow







N_O^+ a factor of ~10 higher in CDPS than HPS

cold-dense plasma sheet ← **Ionosphere**

more soft electron ← **stronger wave**

stronger wave → **enhanced Poynting flux**

enhanced Poynting flux → **wave heating**

wave heating → **ion outflow**

enhanced soft electron precipitation

ion up flow