Contribution of small-scale field variation to the high-latitude energy input estimation

Yanshi Huang[1]
Cheryl Y. Huang[2]
Yi-Jiun Su[2]

[1]COSMIAC, University of New Mexico, ABQ, NM
[2]AFRL, Space Vehicles Directorate, Kirtland AFB, NM

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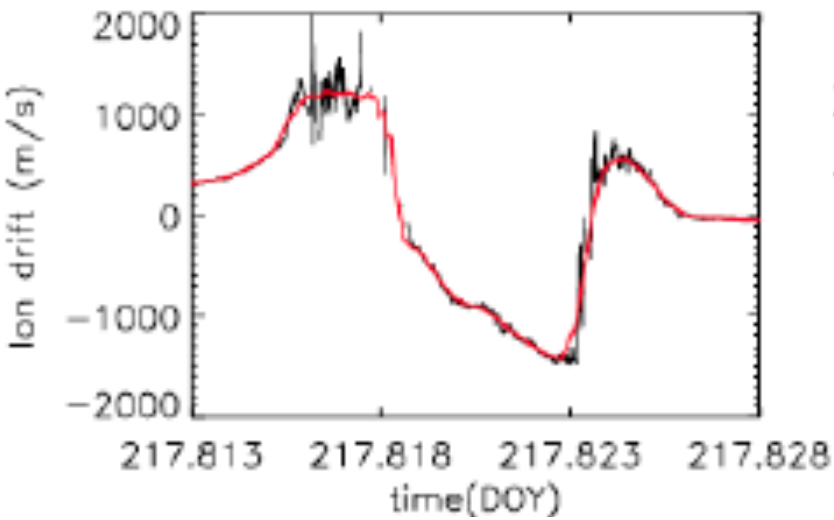
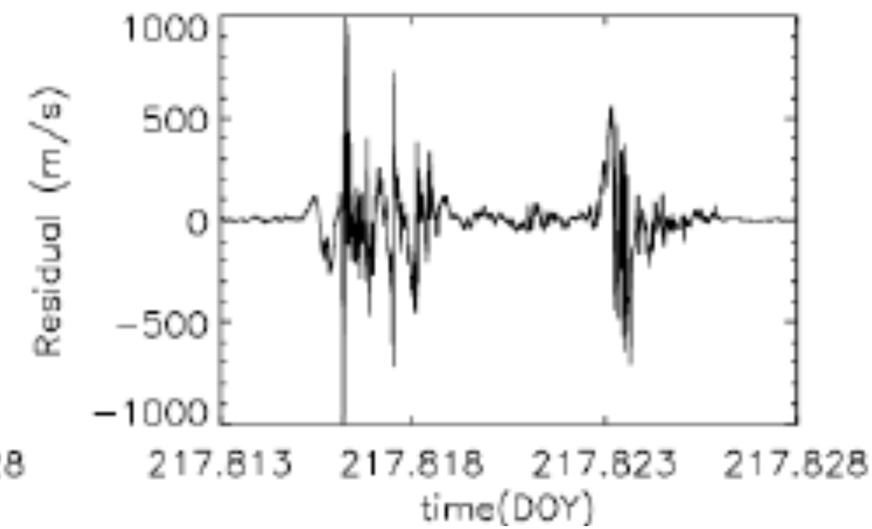
Calculating small-scale variations

- In reality, a field variation consists of a spectrum of various scales in time and space.
- The small-scale variation is obtained as the residual field between original data (1-sec DMSP F16 data) and the 5° latitude window averaged field.

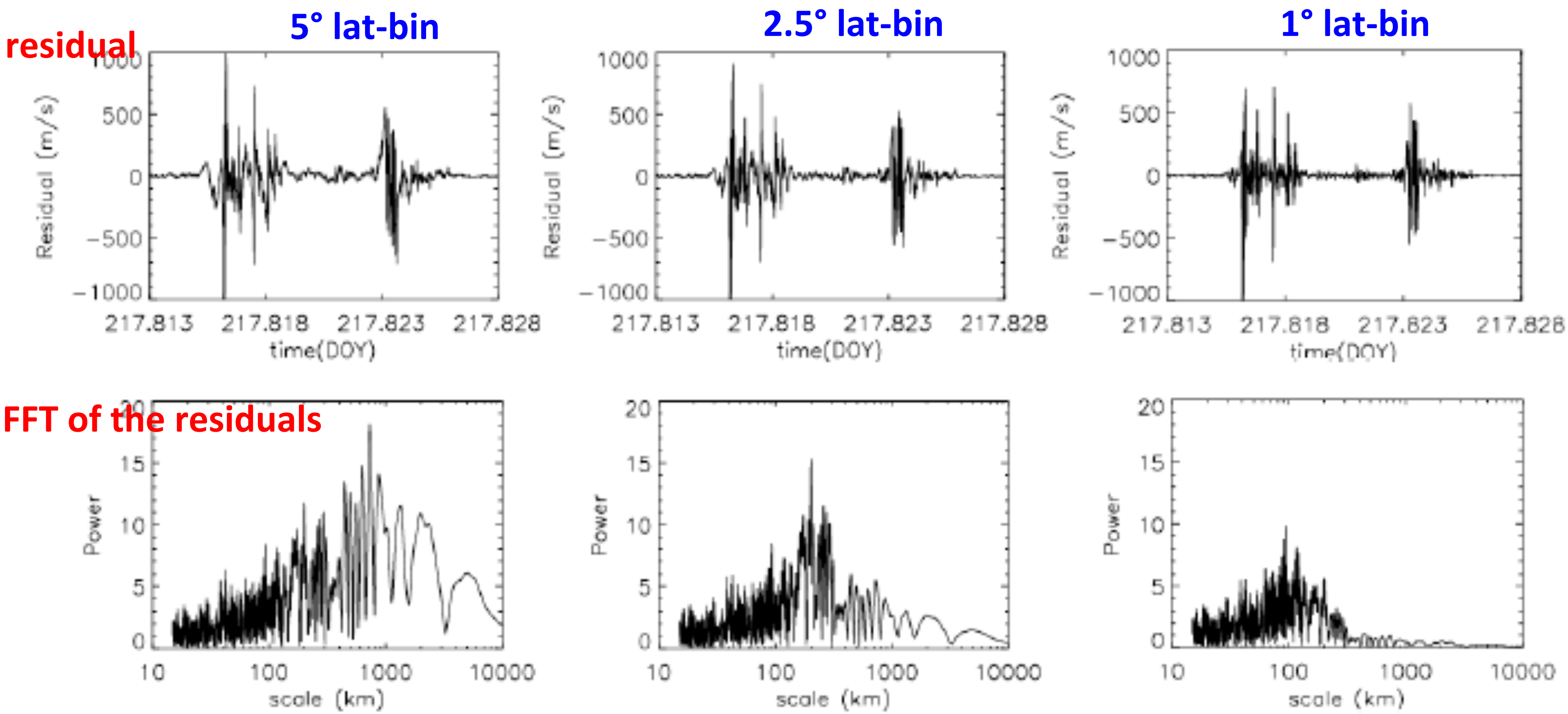


Horizontal component of ion drift velocity from DMSP F16
5-degree latitude average



Residual calculated as the difference between original data and the 5° latitude average

Different scale variations using various latitude bin sizes



- Various sizes of latitude bins (5°, 2.5° and 1°) are used to get different scales of field variations (~650km, ~330km, ~130km).
- Using a finer bin captures smaller structures in the field.

Small-scale E and B fields

E-field: $E = \underline{E_L} + \underline{E_S}$

Large-scale variation Small-scale variation

B-field: $\Delta B = \underline{\Delta B_L} + \underline{\Delta B_S}$

Large-scale variation Small-scale variation

Energy Dissipation: $JH = \sigma_P E^2 = \sigma_P \left(E_L^2 + \underline{2E_L E_S + E_S^2} \right)$
(Joule heating)

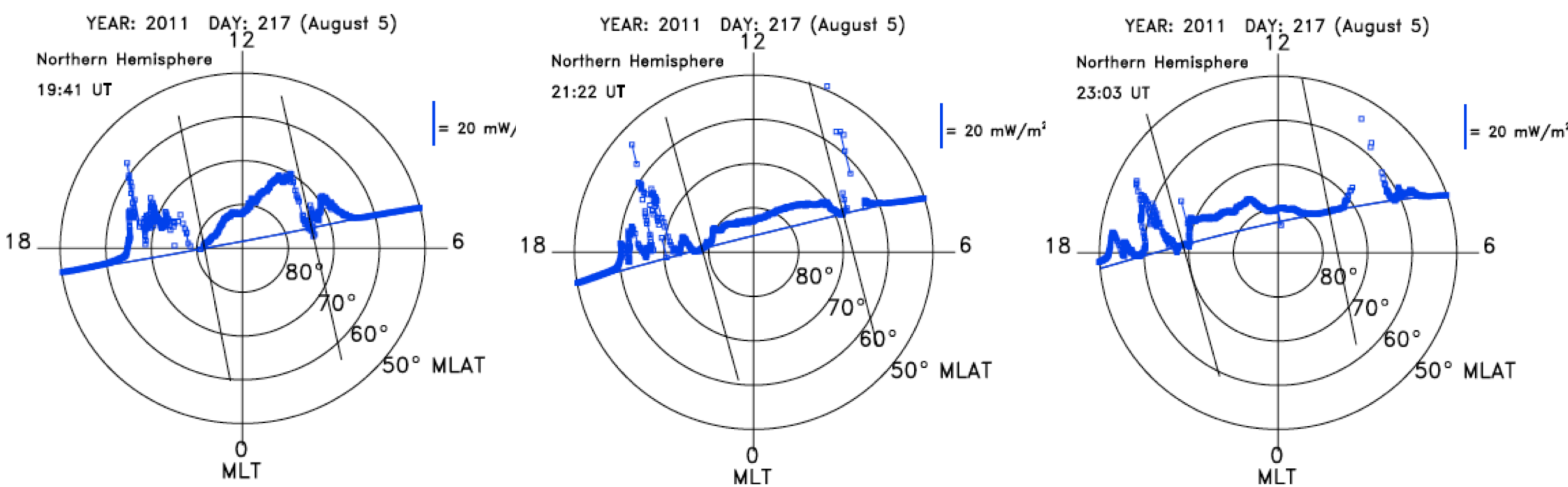
Small-scale E-field contribution to JH: $$\frac{2E_L E_S + E_S^2}{E^2}$$

Energy input: $PF = \frac{1}{\mu_0}\left(E \times \Delta B \right) = \frac{1}{\mu_0}\left(E_L \times \Delta B_L + \underline{E_L \times \Delta B_S + E_S \times \Delta B_L + E_S \times \Delta B_S} \right)$
(Poynting flux)

Small-scale E- and B-field contribution to PF: $$\frac{E_L \times \Delta B_S + E_S \times \Delta B_L + E_S \times \Delta B_S}{E \times \Delta B}$$

Data analysis of DMSP F16 data

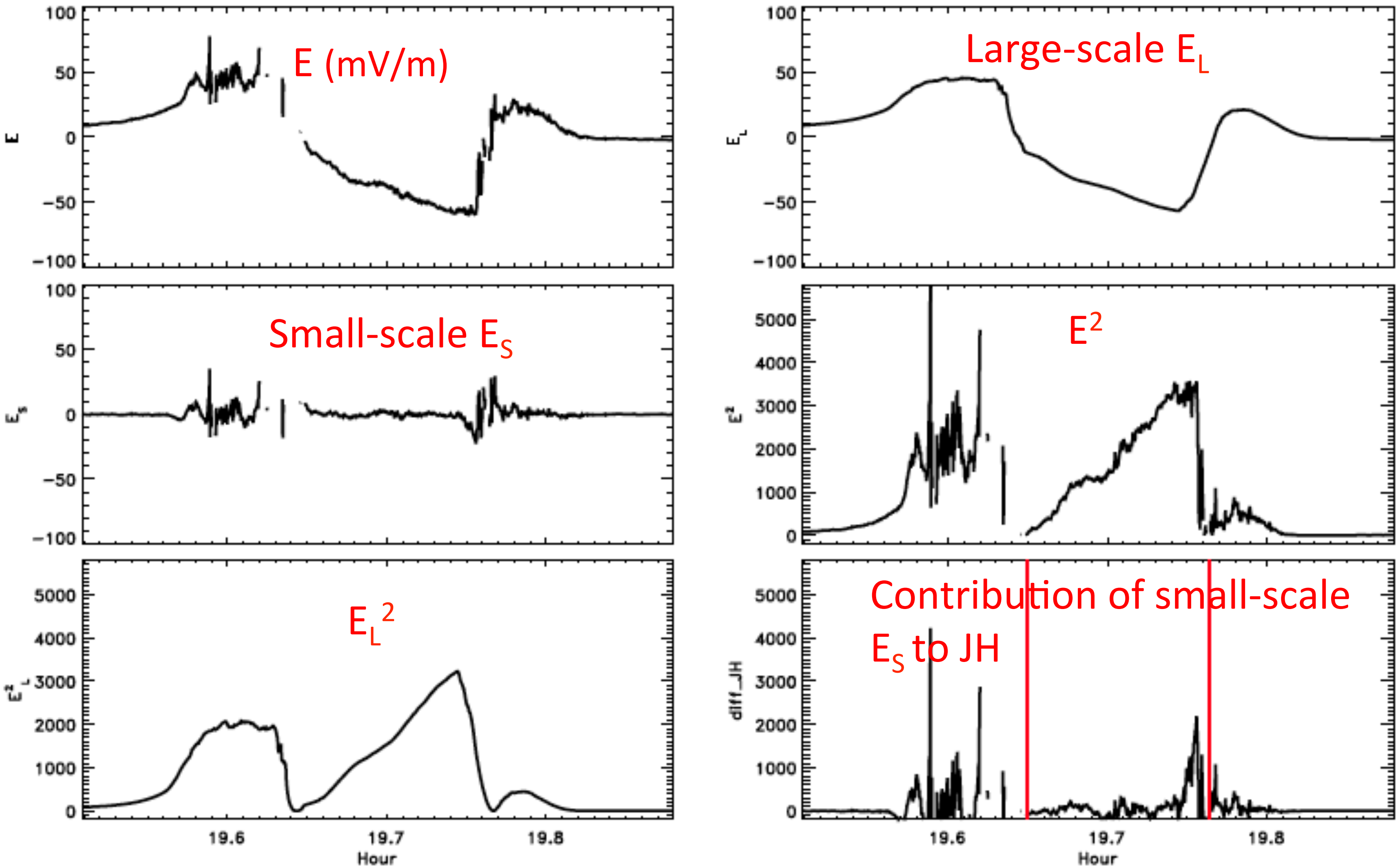
- 1-sec E-, B-field data from DMSP F16.
- During the August 2011 storm.
- Use various latitude window sizes (5°, 2.5°, 1°,…) to filter the small-scale variations in E- and B-field.
- The small-scale fields includes both spatial & temporal variations.
- Investigate the importance of small-scale fields in the estimation of Joule heating (JH)and Poynting flux (PF).



Filtering of small-scale E-field

(5° smoothing window)

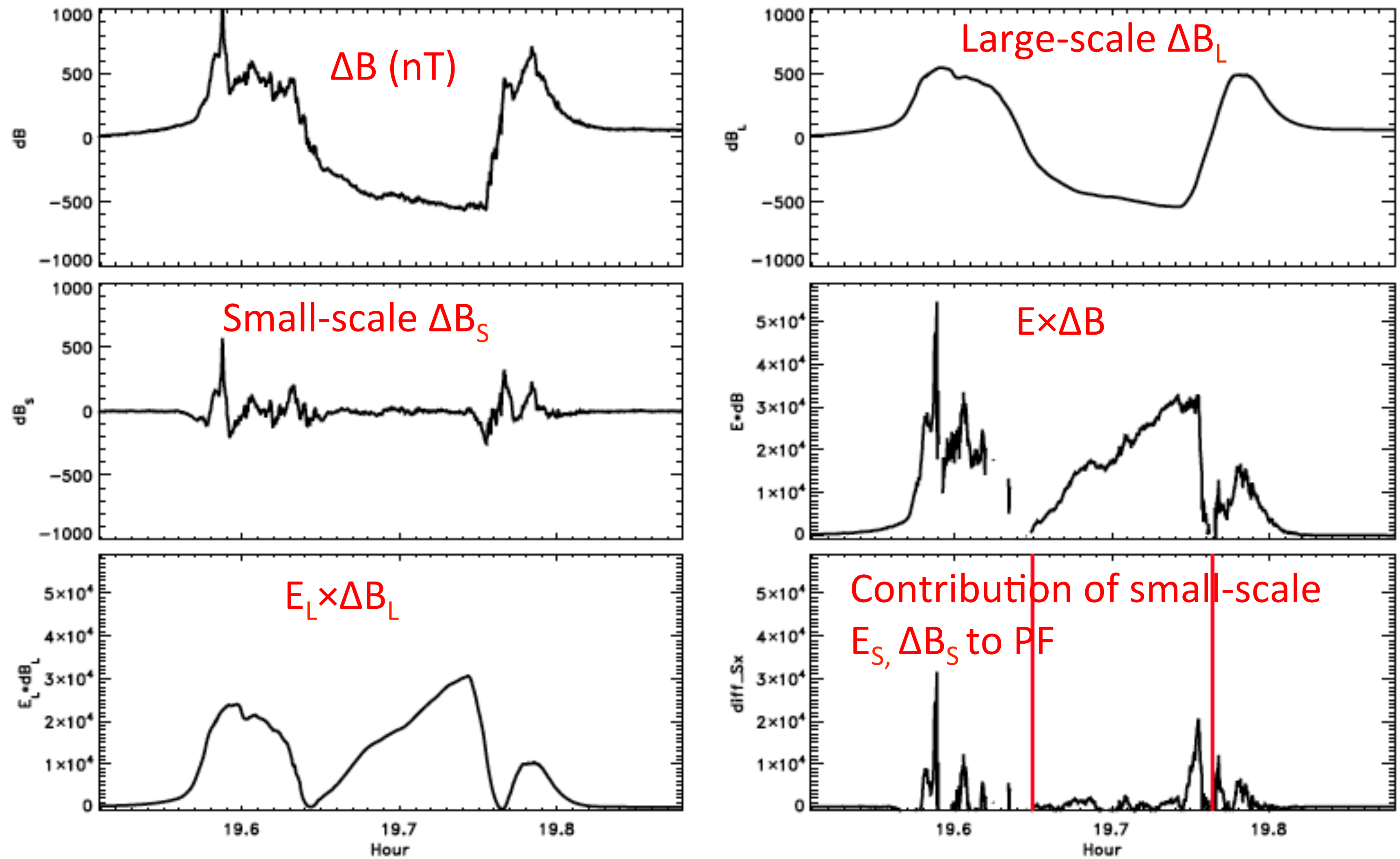
Aug 5, 2011 19:30 – 19:54 UT, F16



Filtering of small-scale B-field

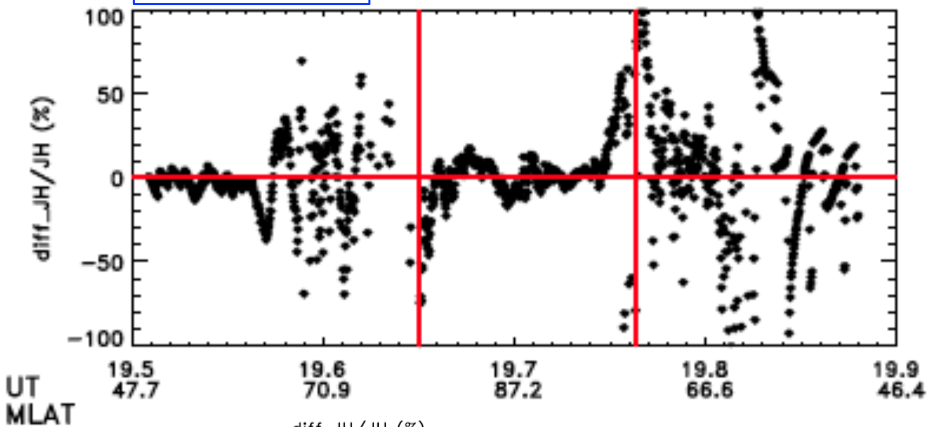
(5° smoothing window)

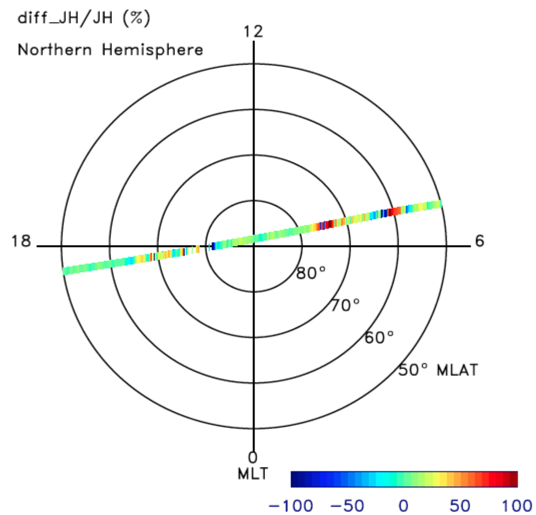
Aug 5, 2011 19:30 – 19:54 UT, F16



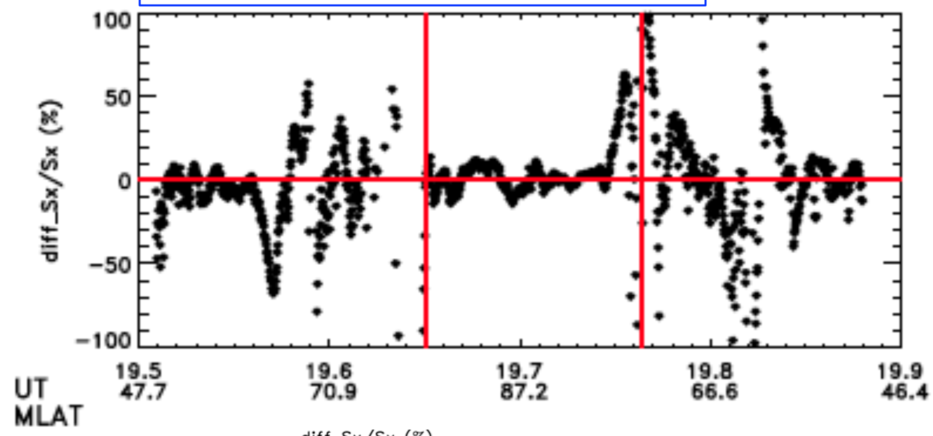
Contribution to total JH and PF

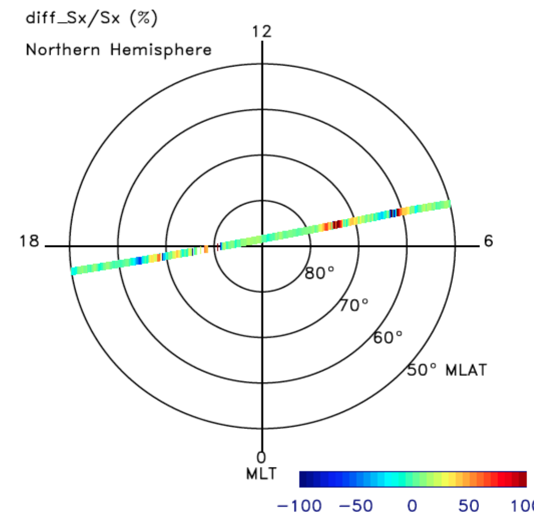
$$\frac{2E_L E_S + E_S^2}{E^2}$$



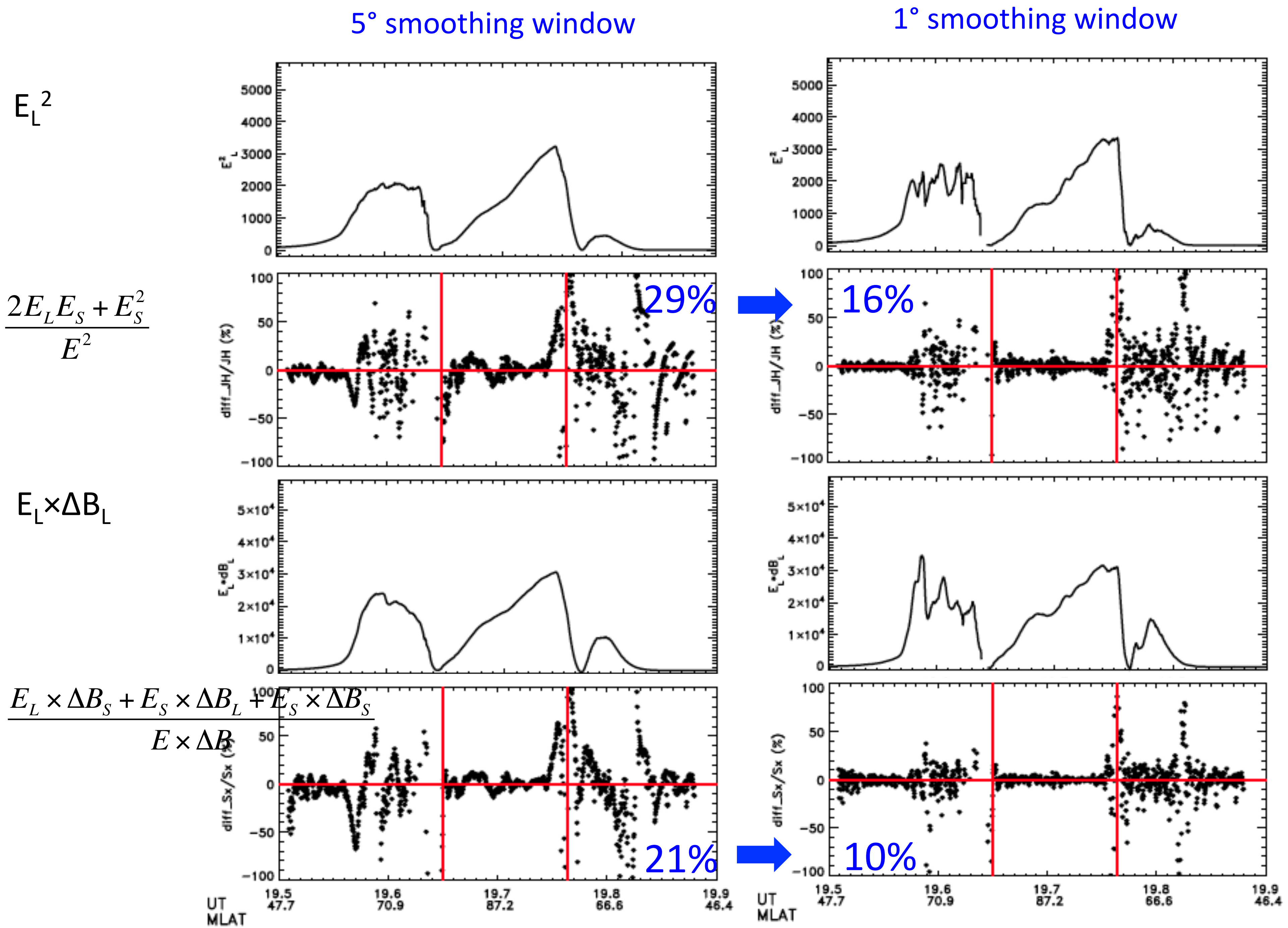


$$\frac{E_L \times \Delta B_S + E_S \times \Delta B_L + E_S \times \Delta B_S}{E \times \Delta B}$$





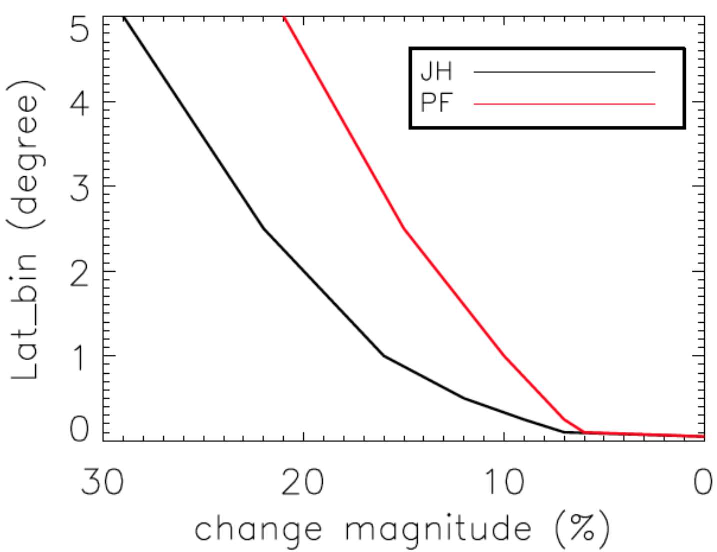
- The contribution of small-scale fields to JH and PF can be positive or negative.
- The average change ($\left|\frac{2E_L E_S + E_S^2}{E^2}\right|$, $\left|\frac{E_L \times \Delta B_S + E_S \times \Delta B_L + E_S \times \Delta B_S}{E \times \Delta B}\right|$) is 29% and 21%.


5° smoothing window
1° smoothing window
E_L^2
$\frac{2E_LE_S + E_S^2}{E^2}$
$E_L \times \Delta B_L$
$\frac{E_L \times \Delta B_S + E_S \times \Delta B_L + E_S \times \Delta B_S}{E \times \Delta B}$
29%
16%
21%
10%
E^2_L
diff_JH/JH (%)
E_L*dB_L
diff_Sx/Sx (%)
UT
MLAT
19.5 19.6 19.7 19.8 19.9
47.7 70.9 87.2 66.6 46.4

Effect of different lat bin size

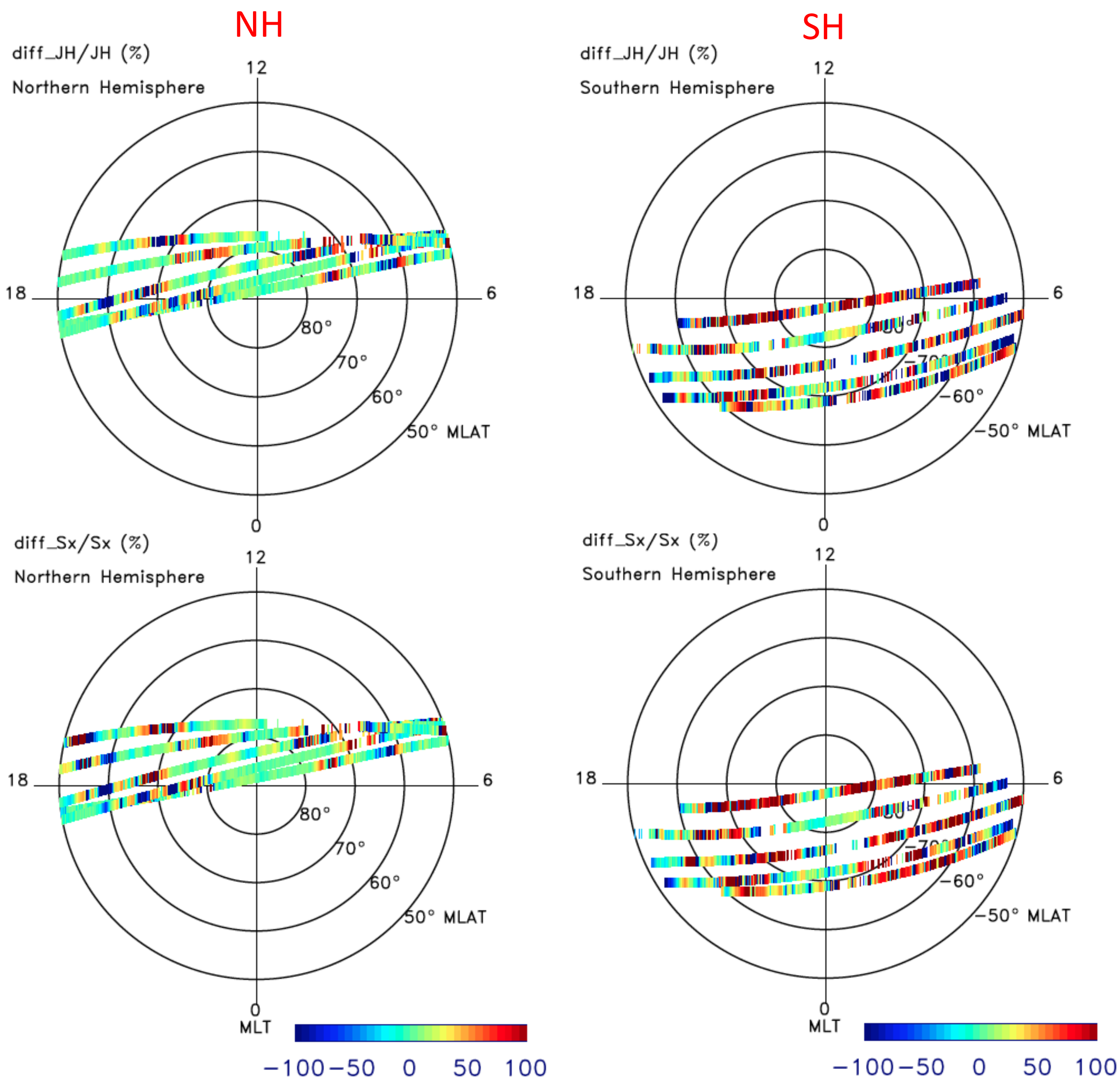
Mean magnitude of change from 19:30 – 19:54 UT, Aug 5, 2011 (F16)

Lat window size	JH (%)	PF (%)
5° (~650km)	29%	21%
2.5° (~330km)	22%	15%
1° (~130km)	16%	10%
0.5° (~65km)	12%	8%
0.25° (~33km)	9%	7%
0.1° (~13km)	7%	6%
0.05° (~7km)	0%	0%



- Finer bin size can capture more small-scale variations.
- The contribution of small-scale fields (< 100 km) to the JH and PF estimation are not negligible.

Aug 2011 storm main phase (F16)



Contribution from small-scale variation to JH (%)

Average change ~ 57%

Contribution from small-scale variation To PF (%)

Average change ~ 65%

Summary

- The electric and magnetic fields at high-latitude regions fluctuate on a variety of spatial and temporal scales.
- Various latitude bins (5°, 2.5°, 1°,…) are used to filter the small-scale variation in DMASP F16 E- and B-field during the main phase of Aug 2011 storm.
- The contribution of small-scale fields (≤650 km) can either increase or decrease the estimation of total JH/PF, by more than 100%.
- During this storm main phase, the global average of the change are 57% and 65% for JH/PF with or without small-scale fields (≤650 km) .

➢ It's important to have high resolution grids (sub-grid) to account for small-scale variation when describing the total high-latitude energy input during storm events.

➢ The geoeffective scale size is unknown, and further study is needed to see their effects on the IT system.