Mid-latitude effects of supersubstorms during storms: a case study

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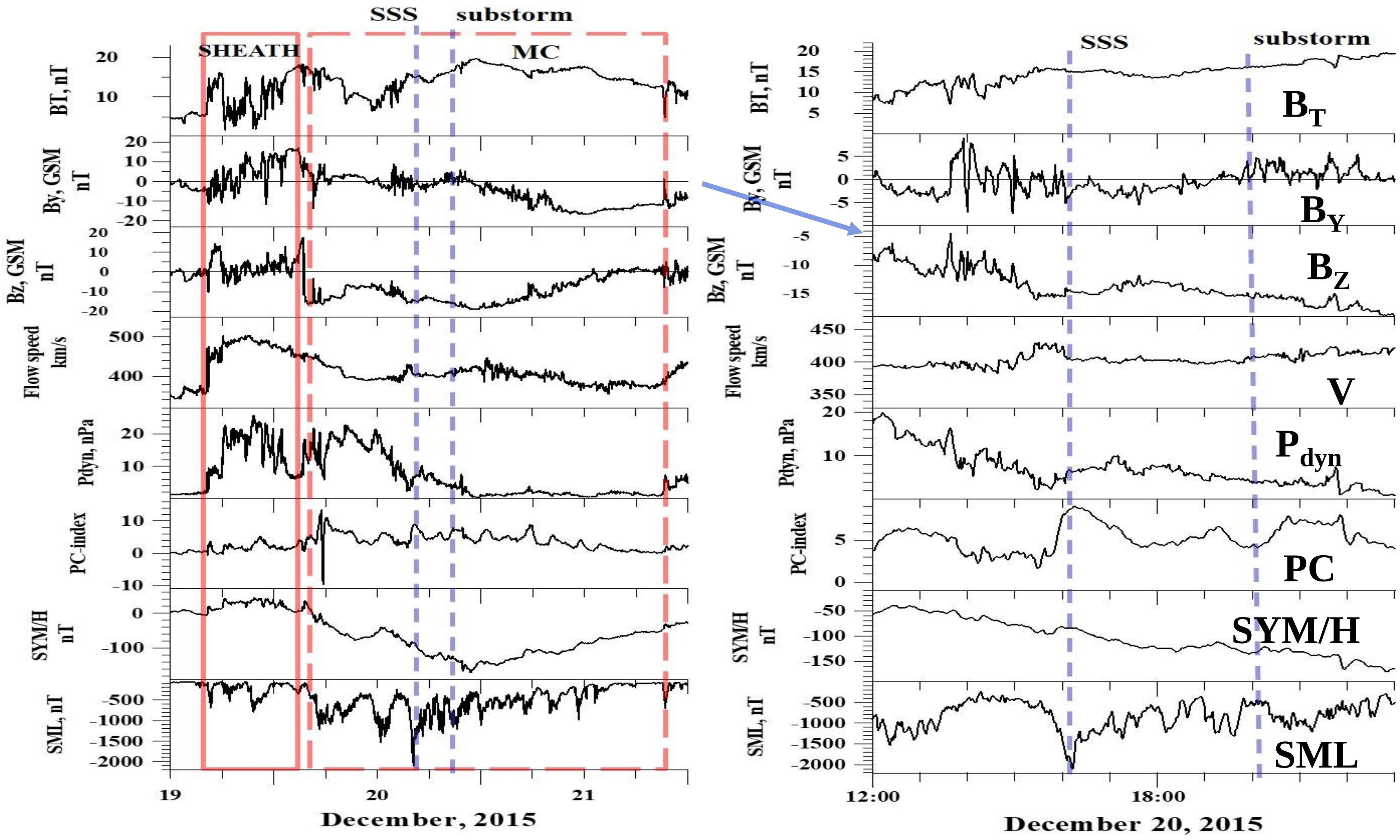
The aim of this work is to find possible mid-latitudes magnetic effects of supersubstorms (SSS) which were recently determined as very intense substorms with large negative values of SML index (≤ -2000 nT). We analyzed one intense substorms on 20 December 2015 at 16:05 UT during the magnetic storm, which was caused by magnetic cloud (MC). The ground-based mid- and low-latitudes substorms have been studied by the global magnetometer networks SuperMAG, INTERMAGNET and IMAGE data as the positive magnetic bays observed simultaneously with the negative bays at auroral latitudes. The SSS demonstrated the global development at auroral latitudes: the strongest disturbances were registered over Alaska, in the morning sector; but the westward electrojet was observed from the dusk side (IMAGE stations) to the dawn side (Alaska stations). Besides, SSS was accompanied by positive intensity bays at the subauroral latitudes (OUJ-TAR stations), but there were no significant positive magnetic bays at middle latitudes (PAG, SUA, IRT, NVS, PET stations). Moreover, we obtained the auroral oval location for this event using data from NOAA(POES) satellites. It was shown that the conversion latitude of the magnetic bay sign of the magnetic bay was about 7° CGLAT lower than the ones associated with usual substorms. The longitudinal expansion of the positive magnetic bays was much larger in case of the SSS. This study was supported by the RFBR (project number 20-55-18003_Bulg_a) and NSFB (project KP-06-Russia/15).

Solar wind and IMF conditions

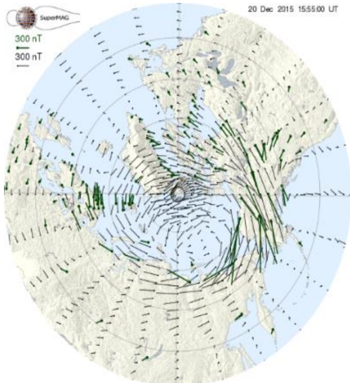


Magnetic storm 20 December 2015 (Dst ~ -180 нТл)

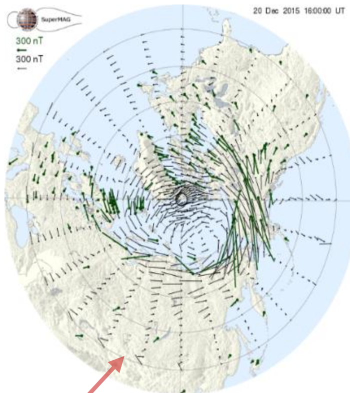
At the main phase of the storm was registered intense substorm: ~16:05 UT , (SML ~-2000 nT), supersubstorm (**SSS**).

20.12.2015: SSS with onset ~16:05 UT

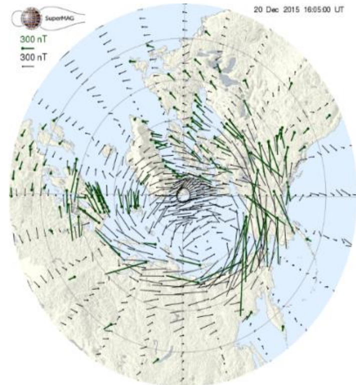
15:55



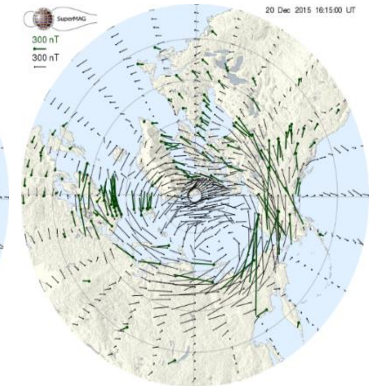
16:00



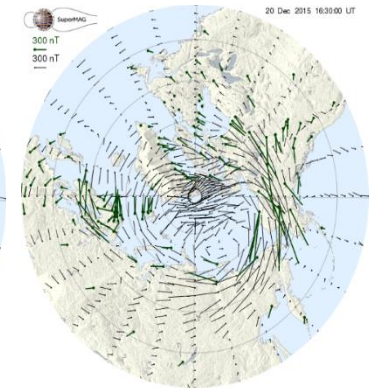
16:05



16:15

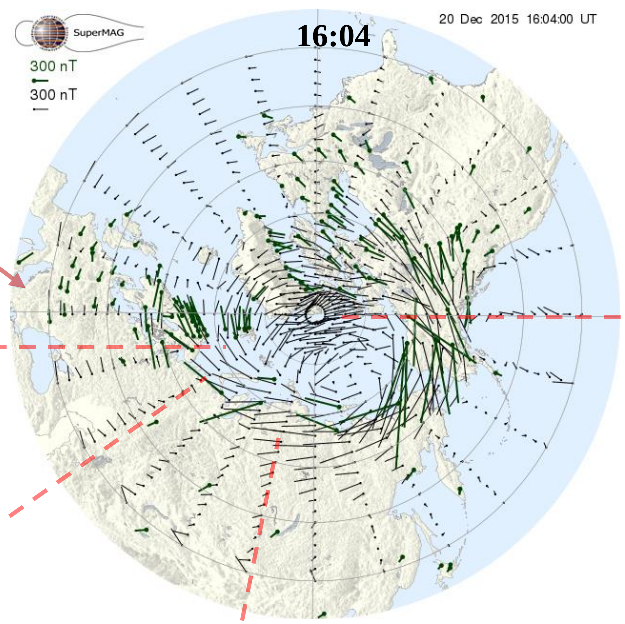


16:30



The pattern of distributions of magnetic field vectors at 15:55-16:30 UT, according *SuperMag data*

The westward auroral electrojet is rather wide in longitude- from the dawn to the dusk one;
the greatest disturbances were in the dawn sector (5-7 MLT), at Alaska stations.
The IMAGE chain was located in the dusk sector (~ 17-18 MLT)



1) meridian IMAGE + HLP, BEL , SUA, PAG, TAM

MLT~ 17 -18 h

2) meridian AMD, MOS, ARS MLT~ 19 -21 h

3) meridian DIK, NVS, IRT

MLT~ 22 -23 h

4) Meridian Alaska + VIC, SIT , TUC, TEO

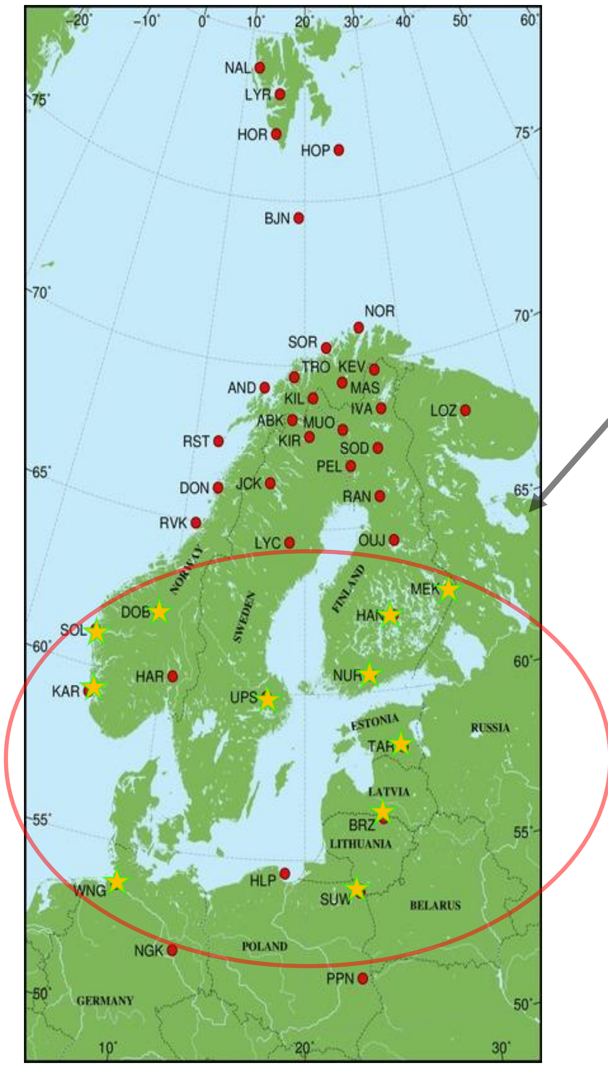
MLT~ 5 -7 h

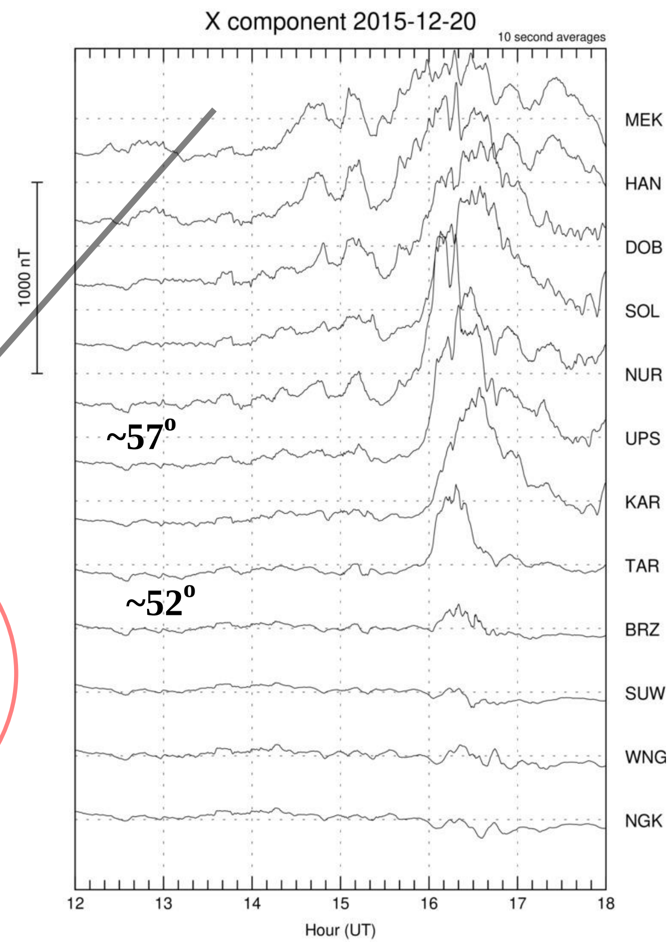
Mid-latitude positive bays were registered in the limited area

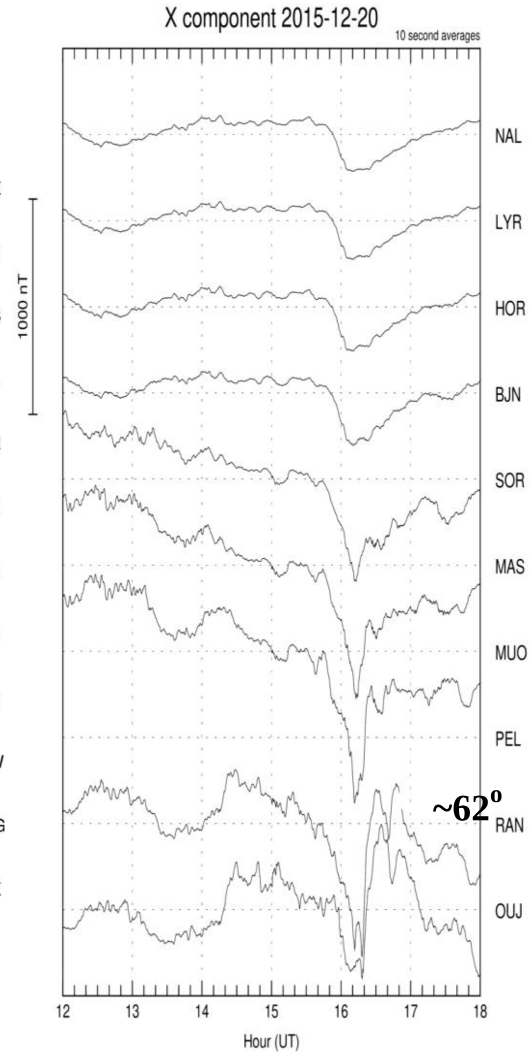
Map of the IMAGE magnetometer stations

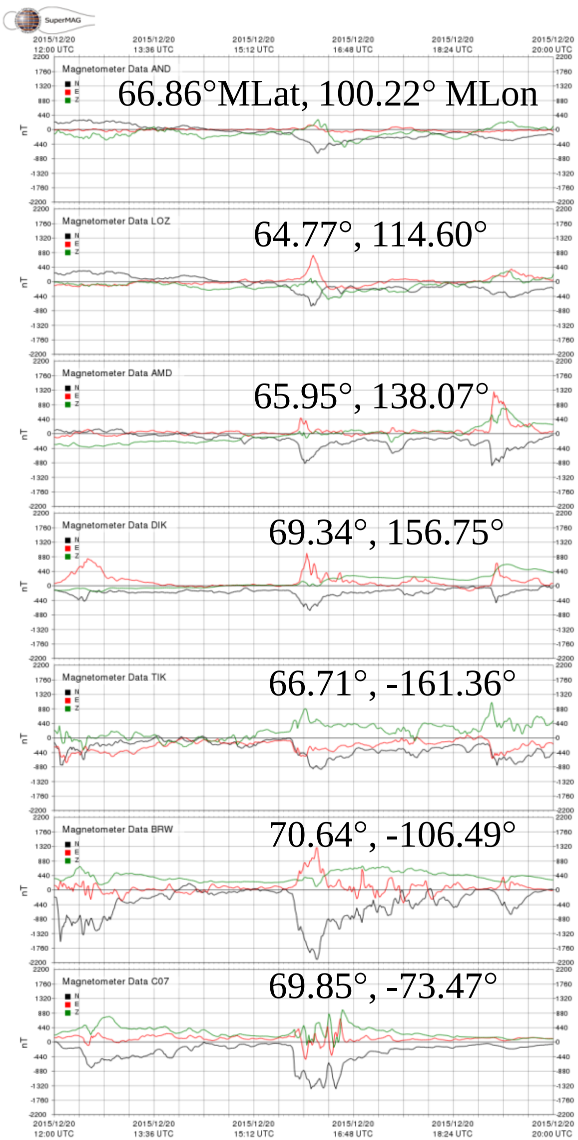
Auroral zone,
negative magnetics bays

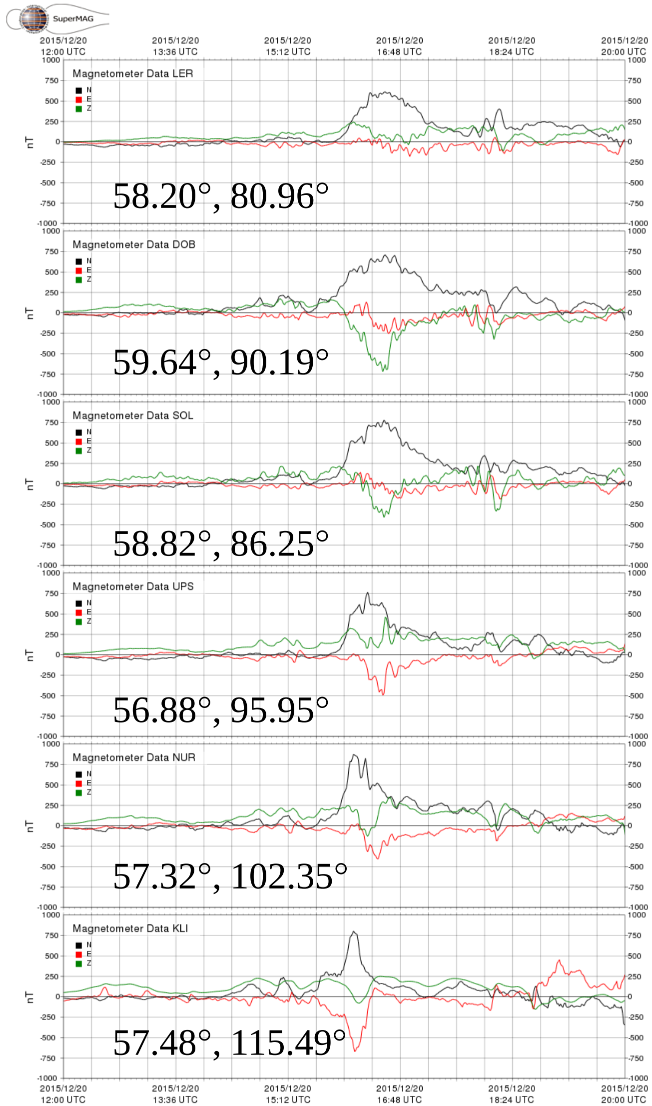
Sub-auroaral and mid latitudes,
positive bays



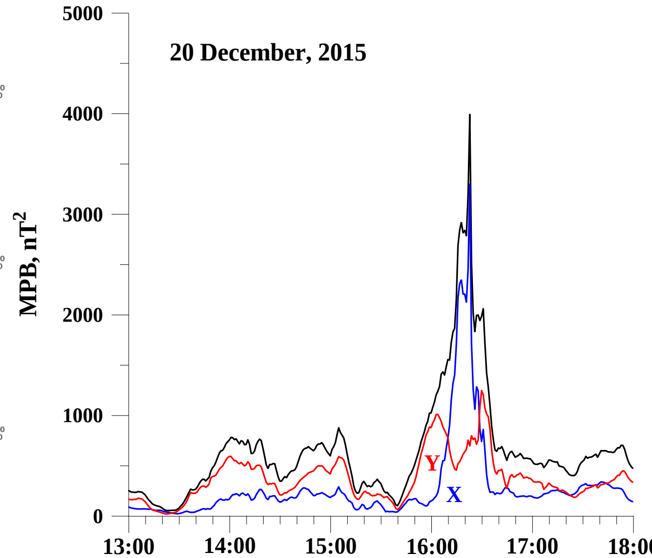








MPB index



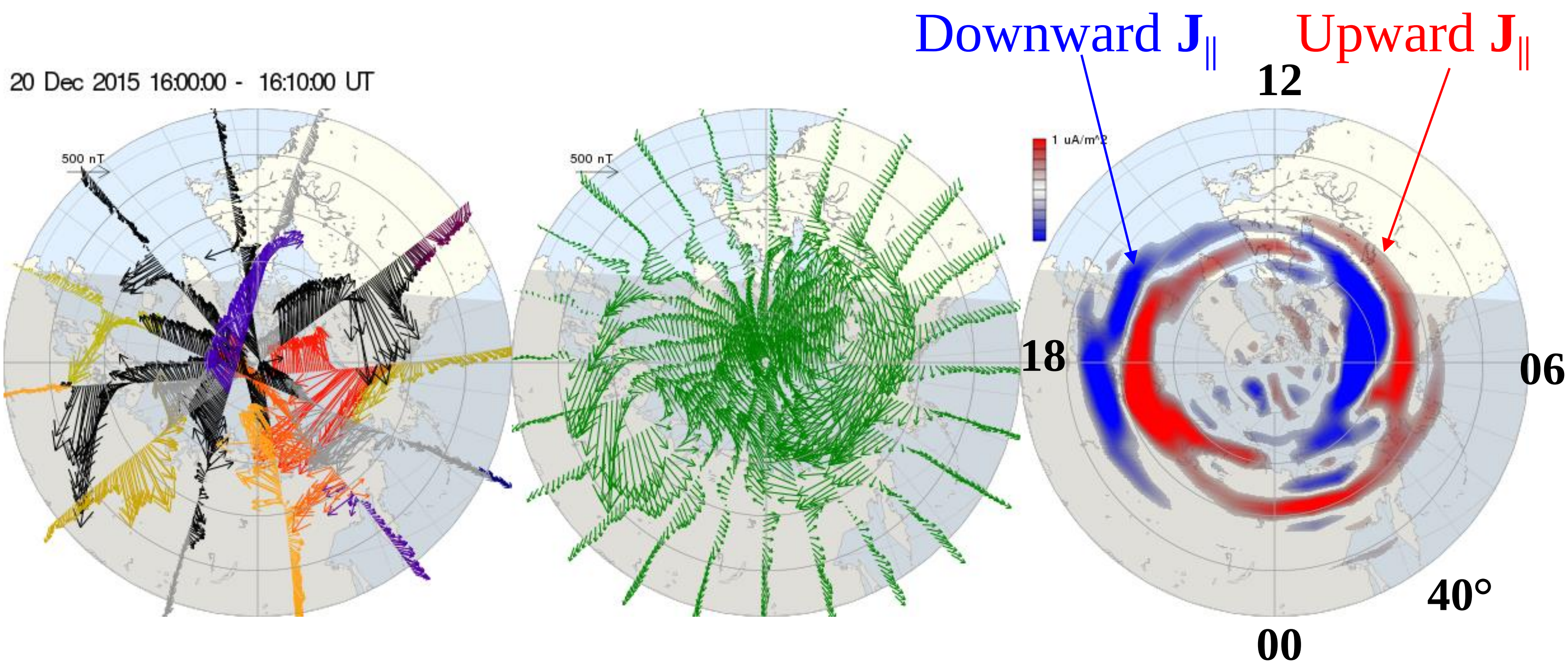
±(20 - 52°) MLat (Chu et al., 2015)

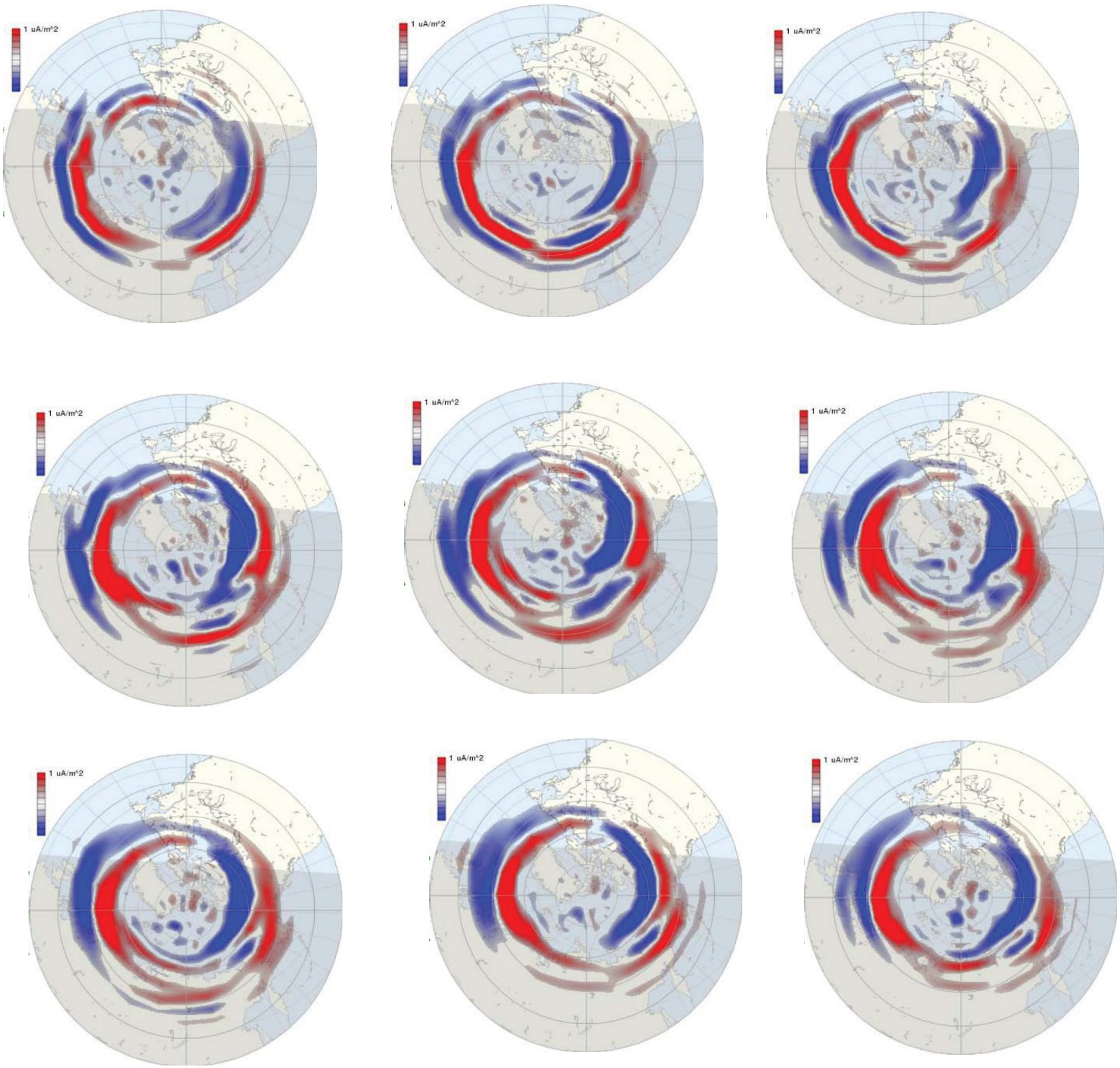
±45° (McPherron and Chu, 2017)

AMPERE

Active
Magnetospphere and
Planetary
Electrodynamics
Response
Experiment

$\delta\mathbf{B}$ Spherical harmonic fit: $\delta\mathbf{B}$ $\mathbf{J}_r$=rot $\delta\mathbf{B}$



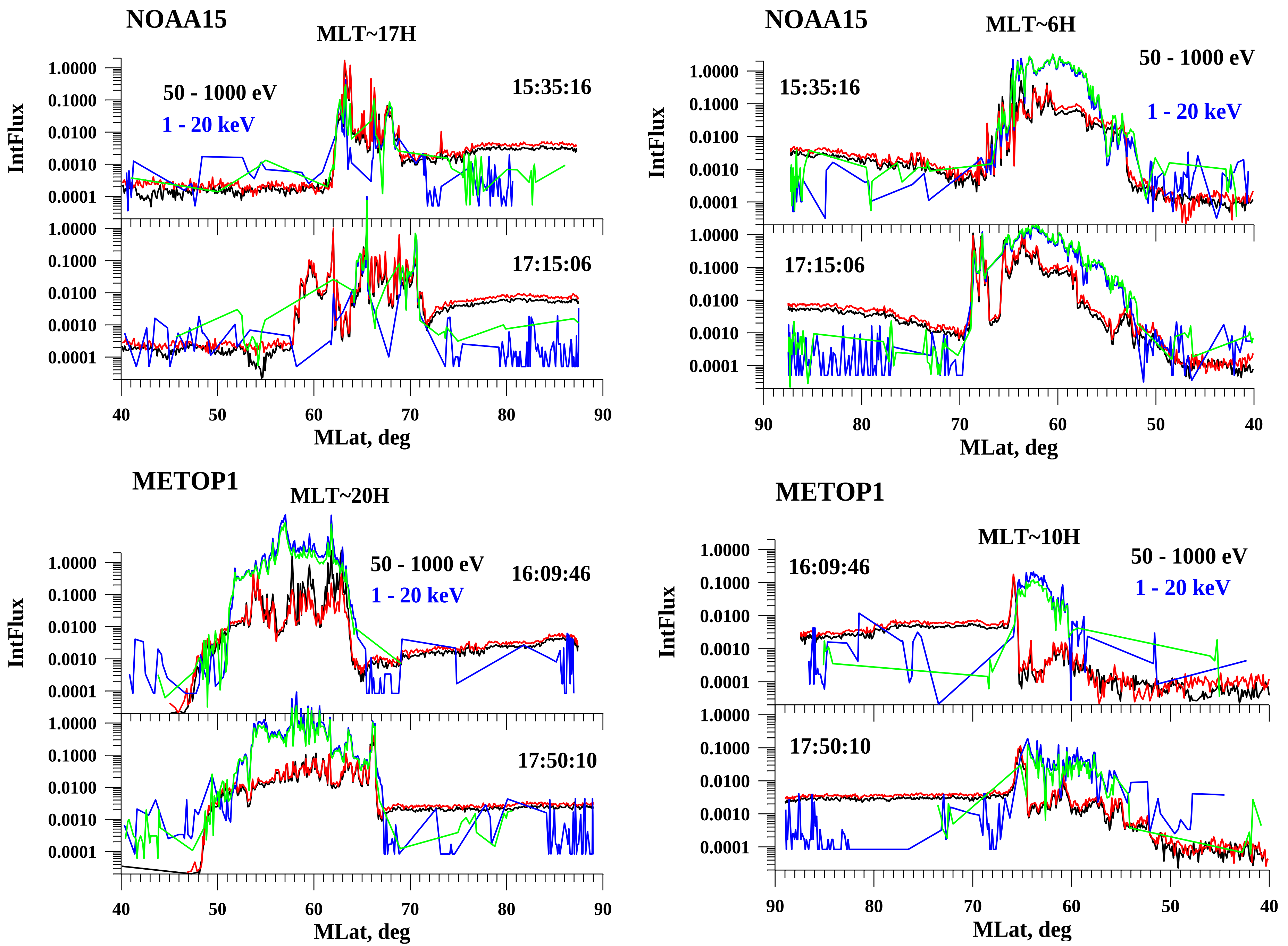


AMPERE

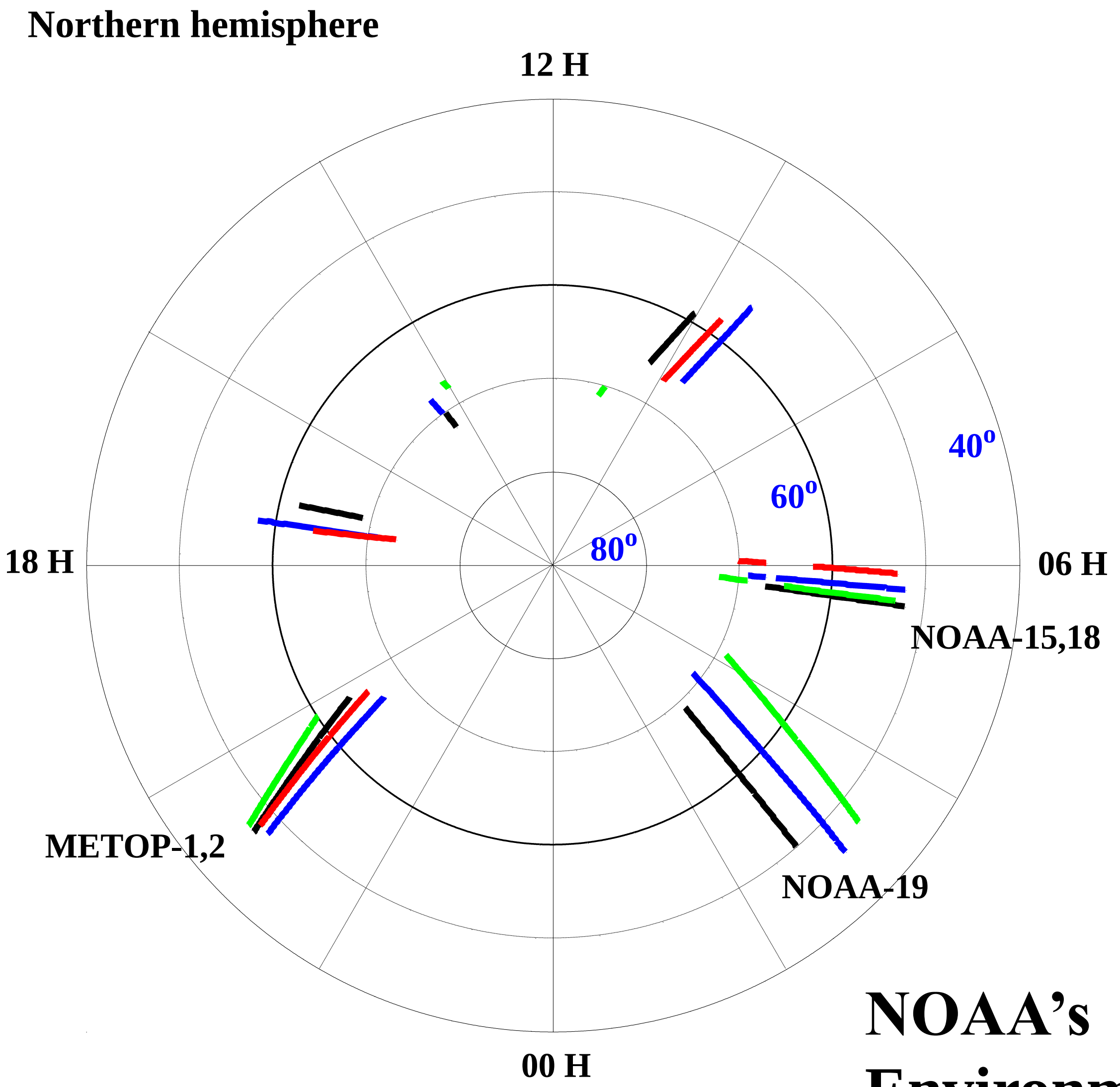
15:30 – 16:00

16:00 – 16:30

16:30 – 17:00



NOAA15
MLT~17H
50 - 1000 eV
1 - 20 keV
15:35:16
17:15:06
IntFlux
MLat, deg
NOAA15
MLT~6H
50 - 1000 eV
1 - 20 keV
15:35:16
17:15:06
IntFlux
MLat, deg
METOP1
MLT~20H
50 - 1000 eV
1 - 20 keV
16:09:46
17:50:10
IntFlux
MLat, deg
METOP1
MLT~10H
50 - 1000 eV
1 - 20 keV
16:09:46
17:50:10
IntFlux
MLat, deg



~15 – 18 UT

NOAA's Polar Orbiting Environmental Satellites (POES)

Discussion

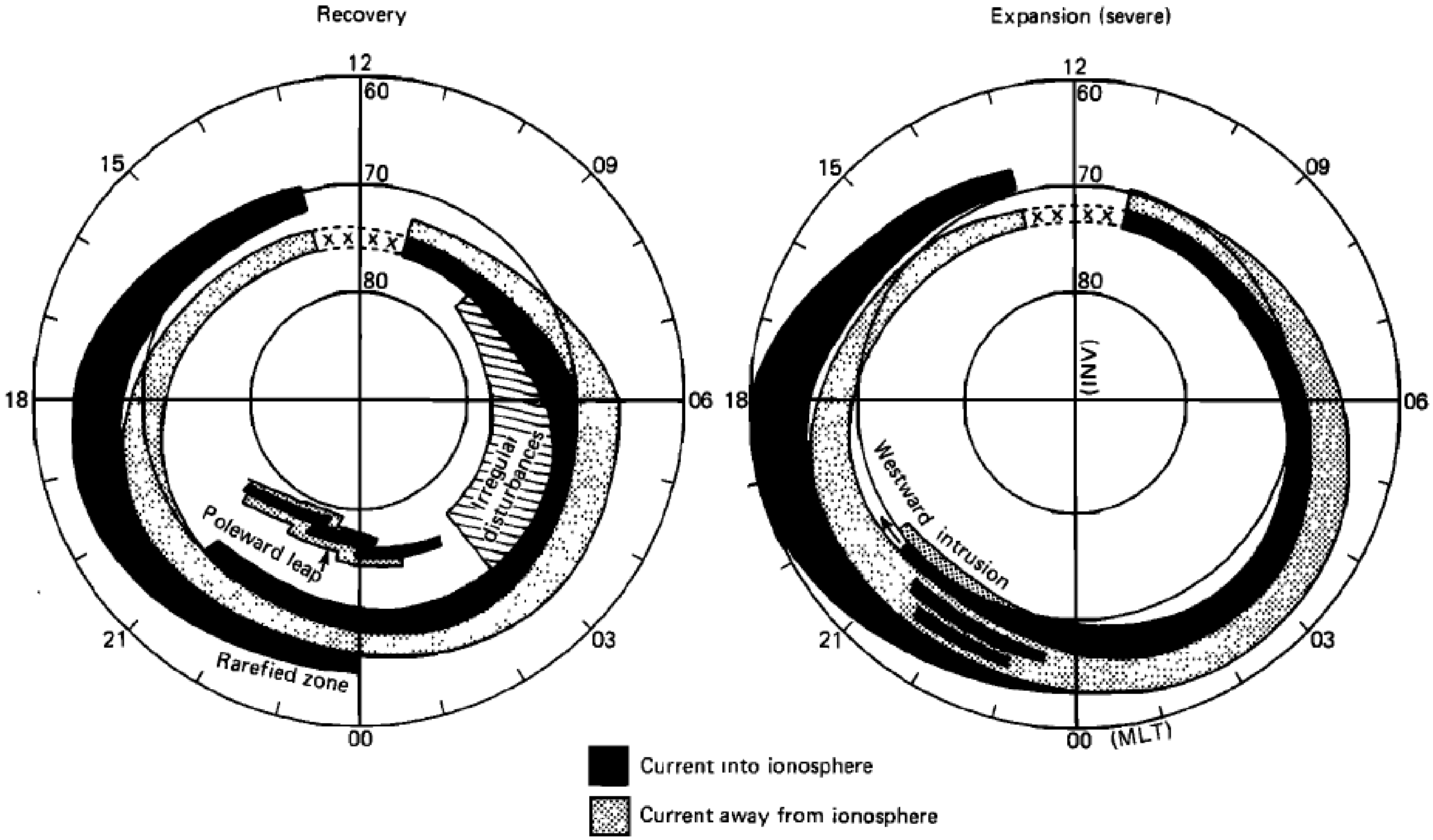
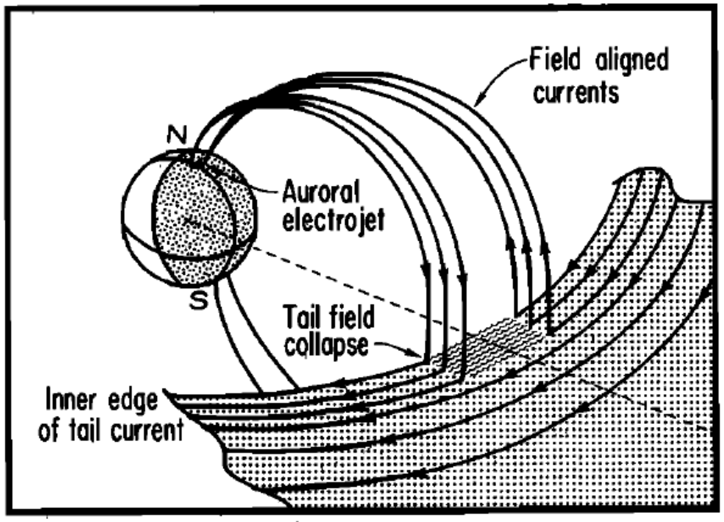


Fig. 15. Schematic diagram illustrating substorm-associated changes superimposed upon the basic distribution of field-aligned currents.

[T. Iijima and T.A. Potemra. Large-scale characteristics of field-aligned currents associated with substorms. JGR, V.83, No.A2, 1978]



[R.L. McPherron, C.T. Russell, M.P. Aubry. Satellite studies of magnetospheric substorms on August 15, 1968 9. Phenomenological model for substorms. JGR, V.78, No.16, 1973.]

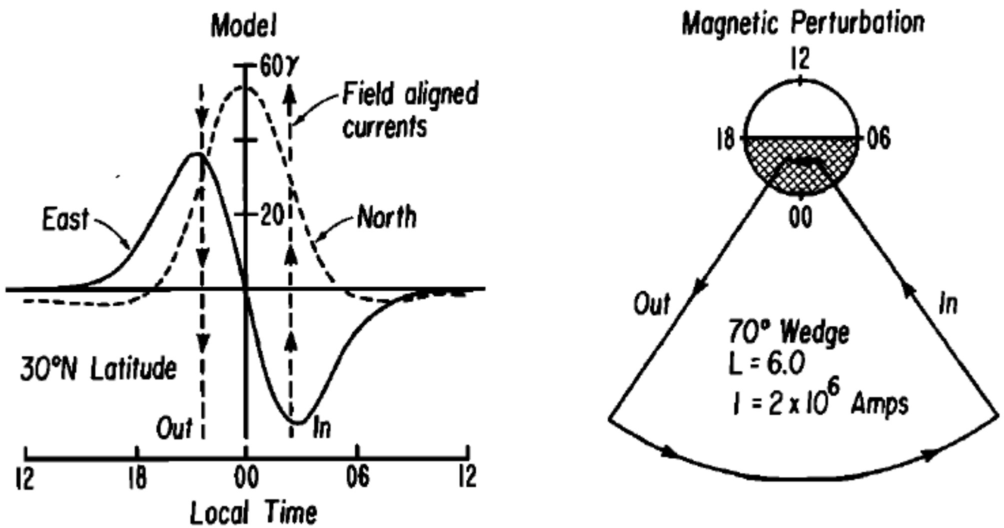


Fig. 9. A simple line current model in a dipole field of the expansion phase current system described in Figures 7 and 8. The right panel summarizes the model parameters, and the left panel the calculated midlatitude magnetic signature.

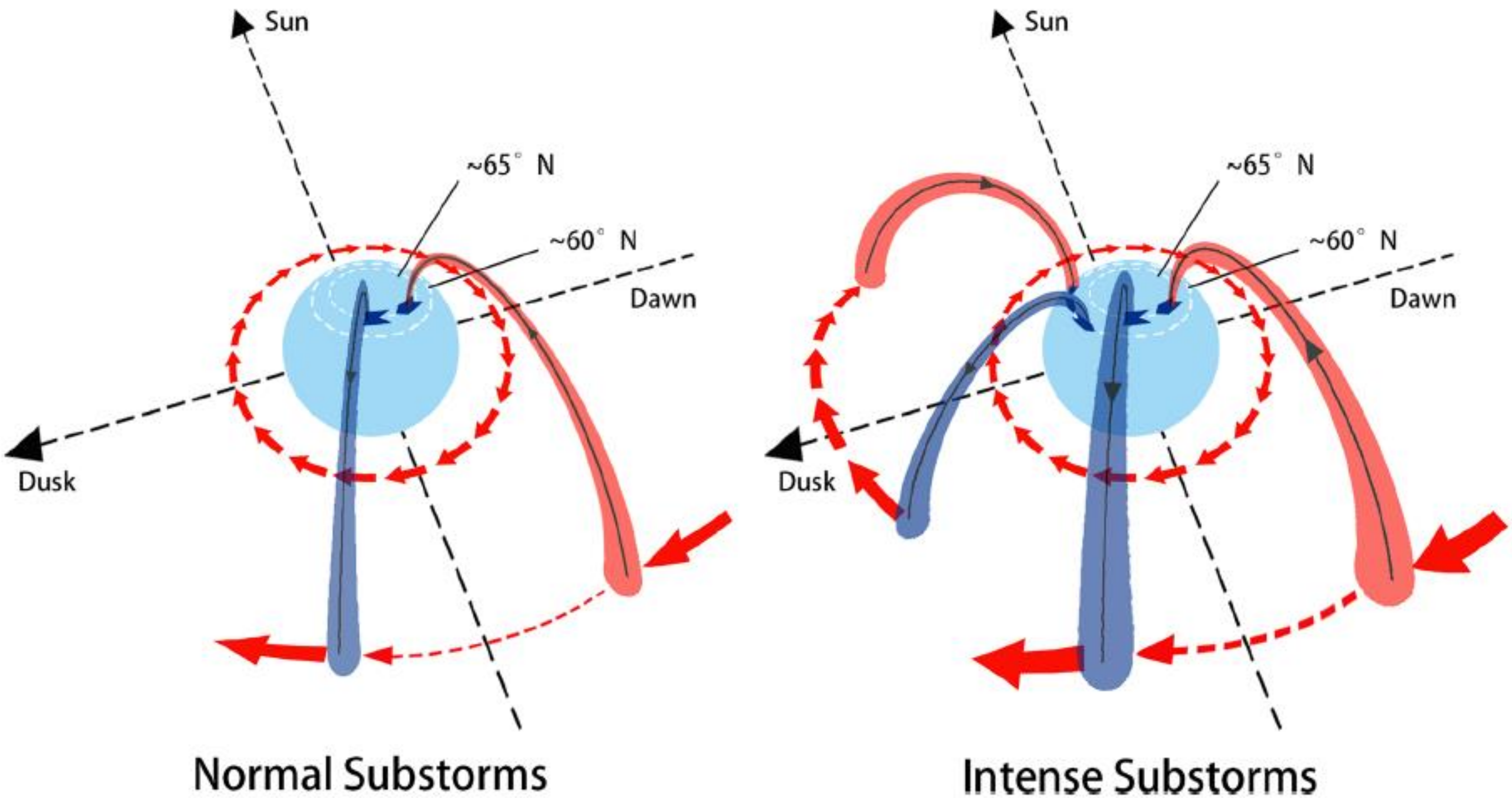


Figure 6. Substorm current wedges for modest substorms and intense substorms. Left panel shows the substorm current wedge during modest substorms. Right panel shows the substorm current wedge and the additional current wedge during intense substorms. The red arrows stand for the magnetospheric currents (e.g., ring current or cross-tail current sheet).

[H. Fu, C. Yue, Q.-G. Zong, X.-Z. Zhou, S. Fu. Statistical characteristics of substorms with different intensity. JGR: Space Physics, V. 126, e2021JA029318, 2021.]

Conclusions

The development of the supersubstorm on 20 December 2015 was analyzed using data from the global magnetometer networks SuperMAG, AMPERE data and data from NOAA(POES) satellites.

Good agreement was obtained for the development of disturbances according to different data sets.

The magnetic effects of supersubstorm give some evidence for the existence of partial ring current in the magnetosphere.

High values of MPB index during the supersubstorm development can be caused by a shift to the equator of the characteristic latitudes in the magnetosphere-ionosphere system.