High-Latitude Topside Ionospheric Vertical Electron-Density Profile Changes in Response to Large Magnetic Storms

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Motivation

Radio Plasma Imager (RPI) magnetospheric measurements from IMAGE near-apogee over the polar cap during the great magnetic storm of 31 March 2001 revealed:

Large magnetospheric electron-density Ne enhancements (~ X 16)

Moderate magnetospheric magnetic-field magnitude |B| enhancements (~ X 2)

Highly correlated fluctuations in solar-wind and magnetospheric parameters (with 3 hour time lag) [Osherovich et al., JGR, 2007]

Above results based on *in-situ* RPI-stimulated plasma resonances IMAGE ~ 8 R_E radial distance above the northern polar cap

During the same storm, RPI field-aligned echoes indicated strongly enhanced polar-cap Ne profiles down to ~ 4 R_E radial distance [Tu et al., JGR, 2007]

Goal

Investigate Alouette/ISIS high-latitude topside-sounder data during large magnetic storms and attempt to relate Ne(h) changes to solar-wind parameters

Approach

125 large magnetic storms (minimum Dst < -100) were identified in the 1965 - 1985 interval when both solar-wind and Alouette/ISIS topside-sounder data were potentially available from the NASA/GSFC Space Physics Data Facility (SPDF)

http://spdf.gsfc.nasa.gov/

Many had > 100 high-latitude topside electron-density profiles Ne(h) or ionograms
10 storms were investigated
5 had Ne(h) in the northern hemisphere; 5 had Ne(h) in the southern hemisphere
Here we report on 4 northern hemisphere cases that also had good solar-wind data

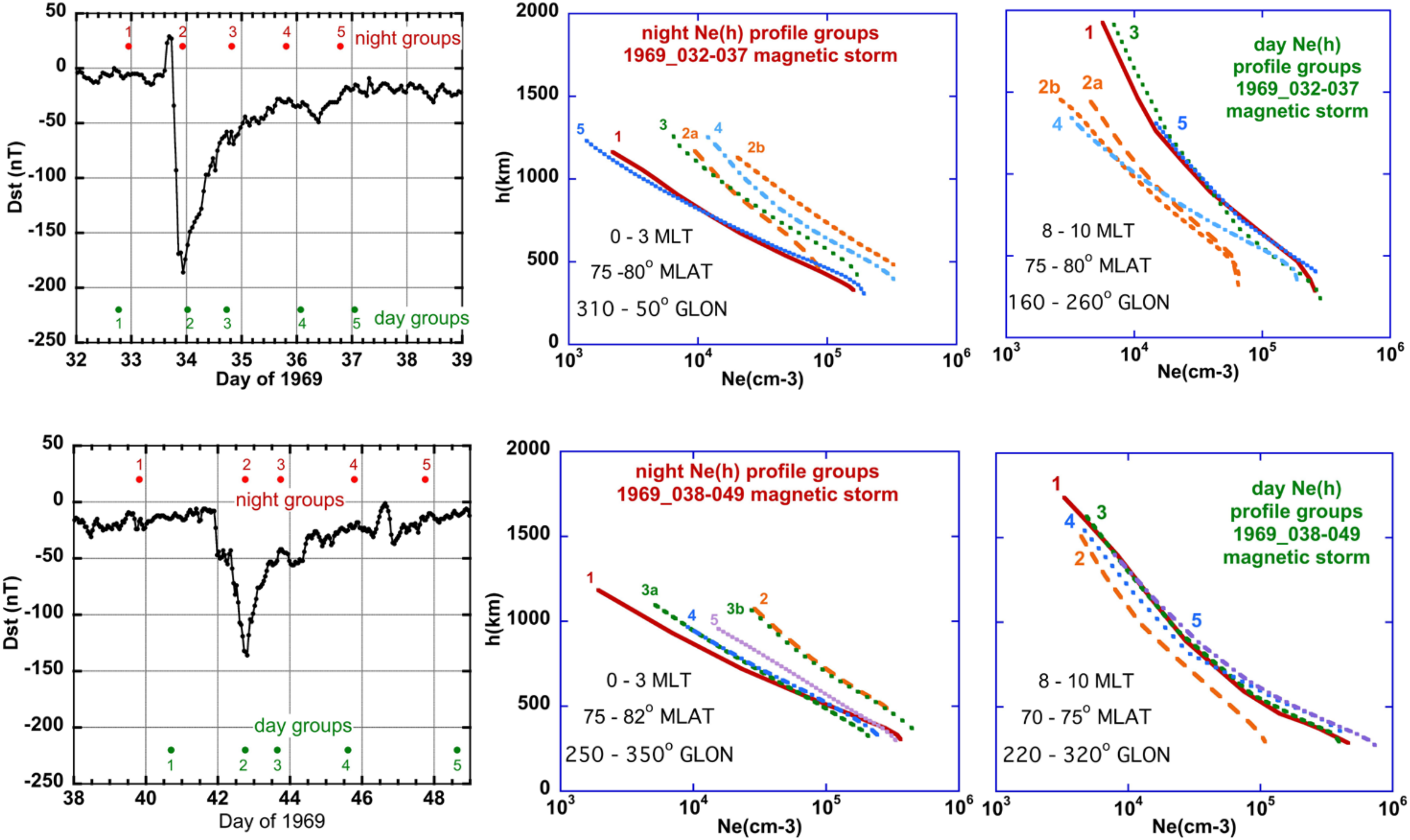
The large topside Ne(h) profile database allowed groups of profiles to be collected from the same small space/time region before, during and after each storm

These groups were examined for storm-induced Ne(h) profile differences

These differences were compared with time-shifted solar-wind parameters

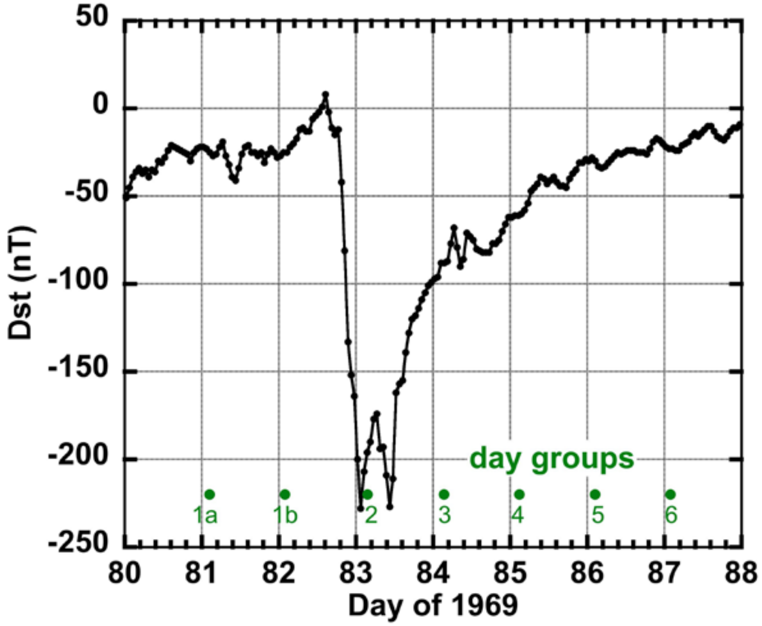
The estimated appropriate time shift of the solar-wind parameters was determined in the IES2015 companion paper by Osherovich & Fainberg (#47 in Session 9B)

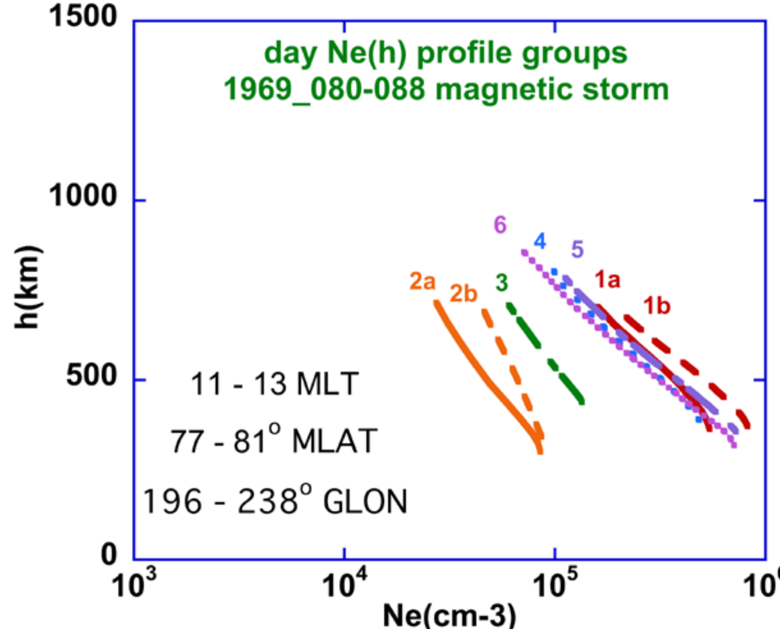
Dst & topside Ne(h) for Magnetic storms of 1969_32 – 39 (top) & 38 – 49 (bottom)



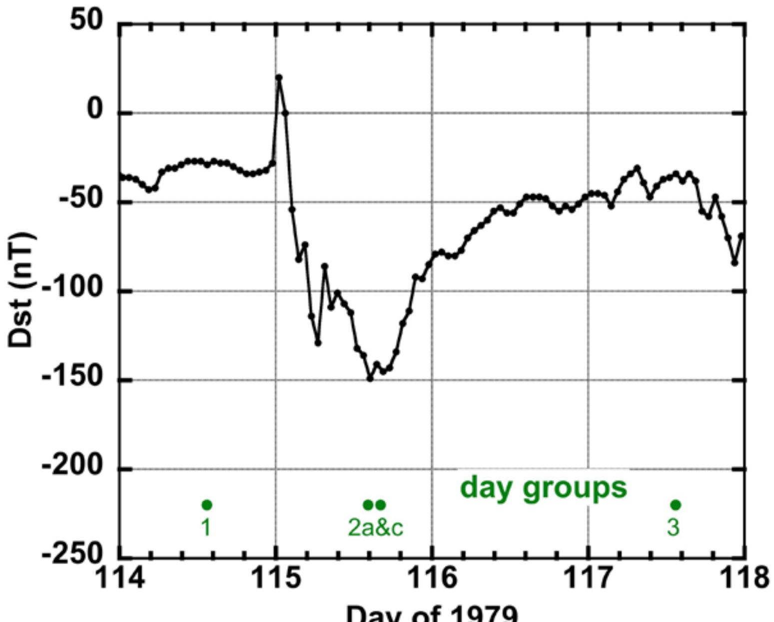
Above topside Ne(h) from manual-scaling of 35-mm film ionograms in the 1960s & 70s

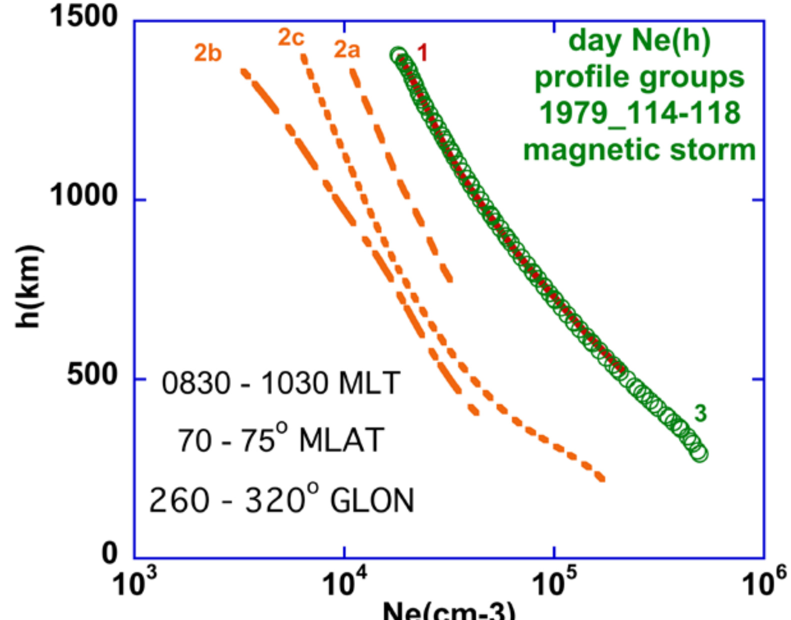
Dst & topside Ne(h) for Magnetic storms of 1969_080–088 (top) & 1979_114– 118 (bottom)





Ionograms for profiles 1b, 2a, 2b, 3, and 6 illustrated on next slide





Topside Ne(h) from manual-scaling of digital ionograms from ISIS 1 (top) & ISIS 2 (bottom)

Selected ISIS-1 ionograms used to obtain Ne(h) profiles before, during & after magnetic storm of 1969 _082.8

Note echo changes between ionograms 2a & 2b (separated by 28 s)

Note appearance & disappearance of upper-hybrid resonance within ionogram 2a during ~ 4 s of fixed-frequency sounding at 1.95 MHz

Above indicates high spatial and/or temporal Ne gradients during Dst minimum

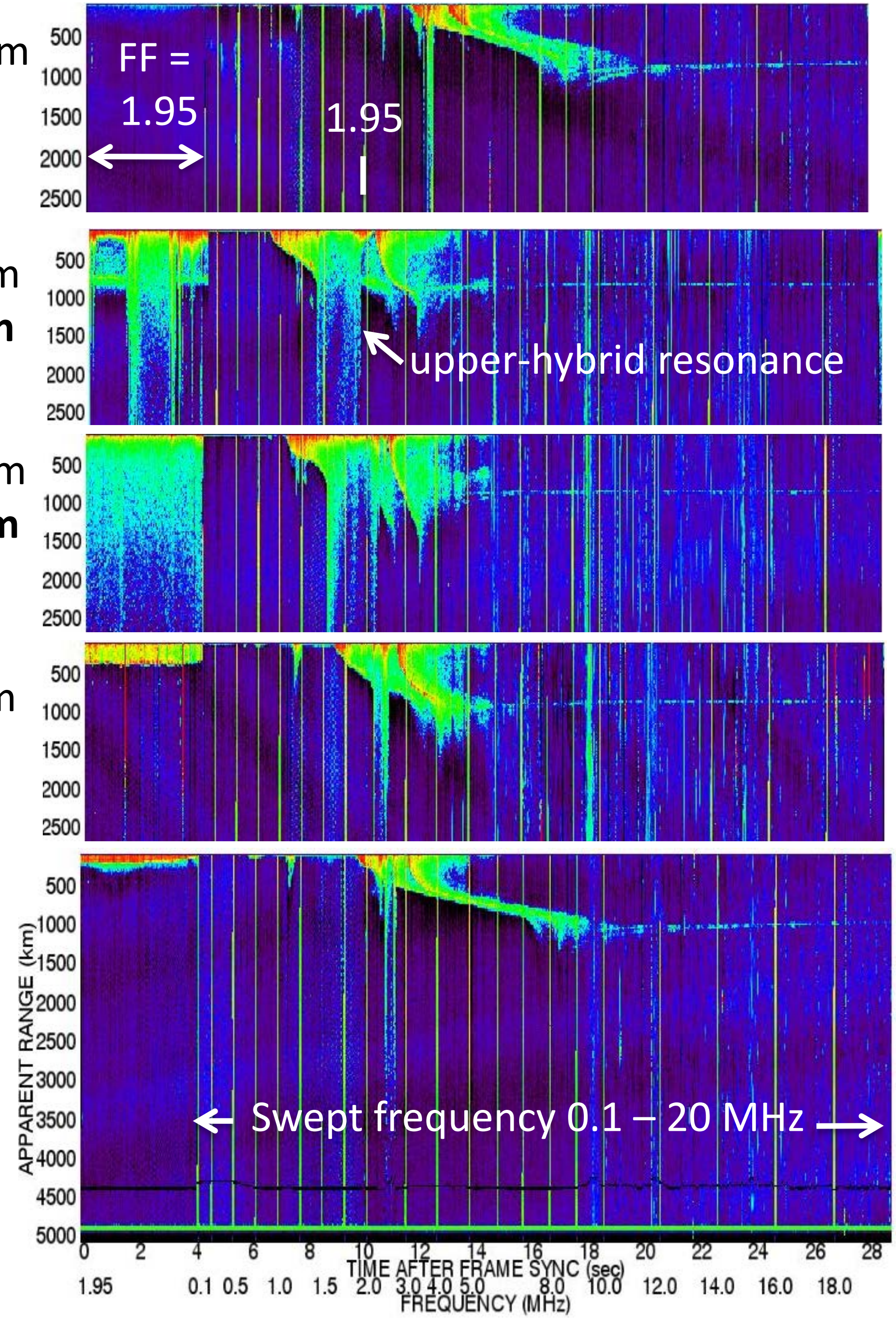
profile 1b ionogram
before storm
082_0228:15 UT

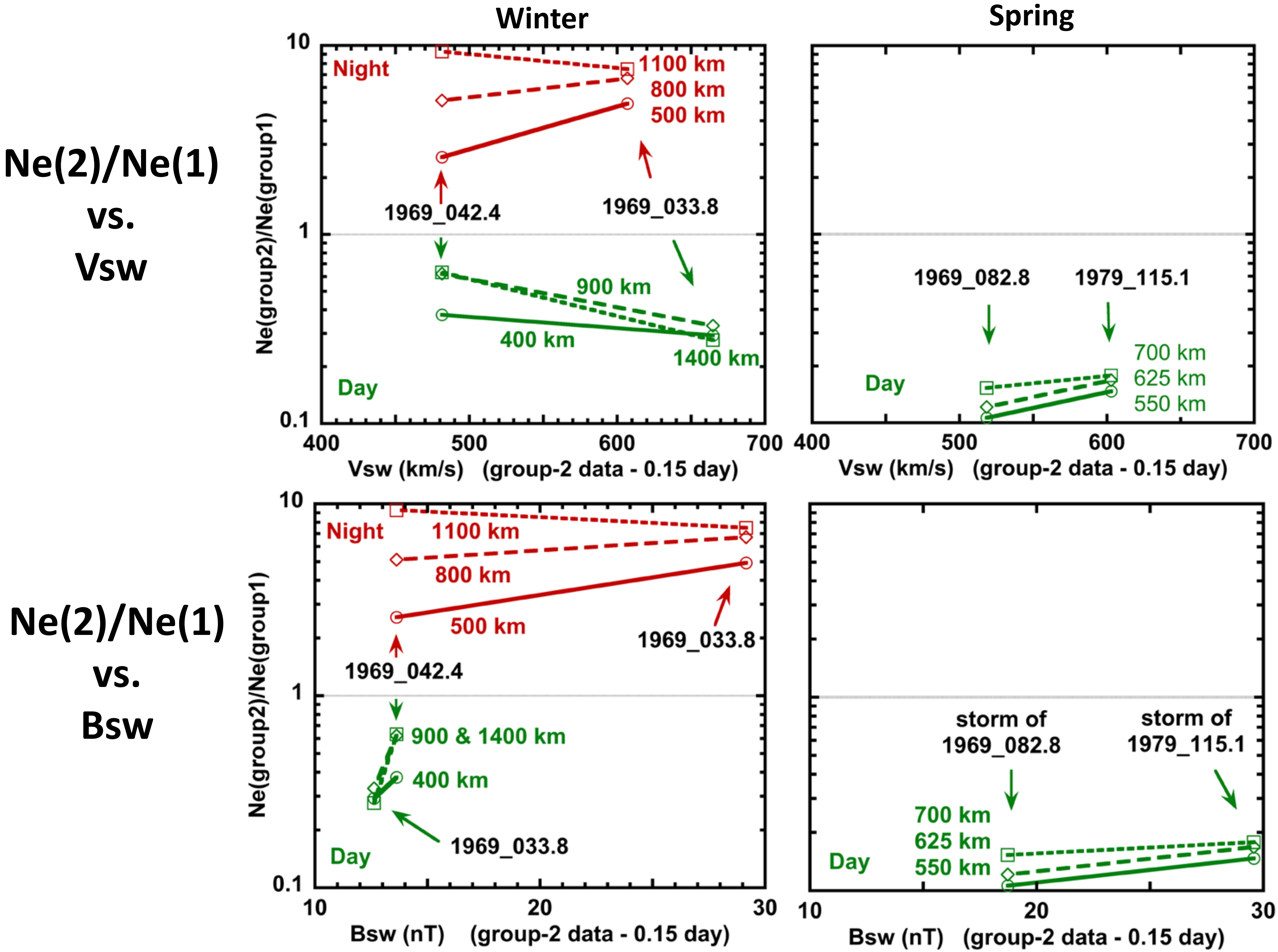
profile 2a ionogram
near Dst minimum
083_0340:33 UT

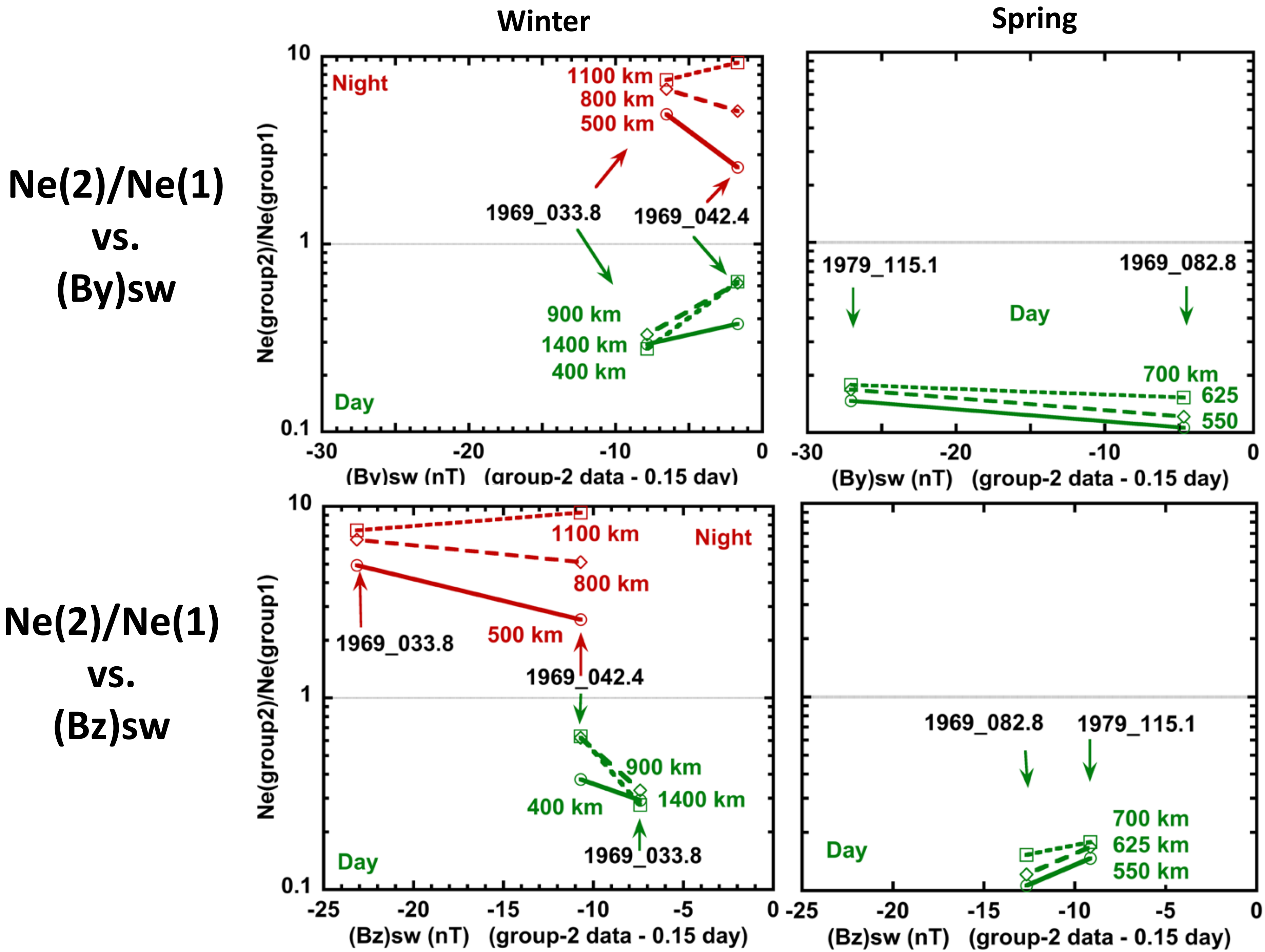
profile 2b ionogram
near Dst minimum
083_0341:01 UT

profile 3 ionogram
early recovery
084_0313:23 UT

profile 6 ionogram
after storm
087_0151:29 UT




Winter
Spring
Ne(2)/Ne(1)
vs.
Vsw
Ne(2)/Ne(1)
vs.
Bsw
Ne(group2)/Ne(group1)
Night
1100 km
800 km
500 km
1969_042.4
1969_033.8
900 km
400 km
1400 km
Day
1969_082.8
1979_115.1
700 km
625 km
550 km
Vsw (km/s) (group-2 data - 0.15 day)
Bsw (nT) (group-2 data - 0.15 day)
900 & 1400 km
storm of
1969_082.8
storm of
1979_115.1


Winter
Spring
Ne(2)/Ne(1) vs. (By)sw
Ne(2)/Ne(1) vs. (Bz)sw
Ne(group2)/Ne(group1)
Night
1100 km
800 km
500 km
1969_033.8
1969_042.4
900 km
1400 km
400 km
Day
(By)sw (nT) (group-2 data - 0.15 day)
1979_115.1
1969_082.8
700 km
625
550
(Bz)sw (nT) (group-2 data - 0.15 day)
700 km
625 km
550 km

Summary

- Northern-hemisphere topside Ne(h) profiles analyzed for 4 large magnetic storms
- Ne profiles compared in similar spatial regions before, during, and after storm
- Large storm-induced Ne increases (decreases) observed during night (day)
- Winter nighttime increases at 1100 km approached a factor of 10
- Spring daytime decreases at 550 km approached a factor of 1/10
- Large spatial and/or temporal Ne gradients observed during Dst minimum
- Ne storm-induced changes compared with solar-wind v, B, By, & Bz time shifted by 0.15 day from Ne profile #2 time in each case [Osherovich & Fainberg IES2015 #47]
- Ne changes during winter night increased with increasing v, B, –By, and –Bz
- Ne changes during winter day increased only with increasing v, and –By
- Ne changes during spring day increased only with increasing –Bz

- **Thus in these storms, with good background control,**
    - **–Bz appears to be the most important parameter in spring daytime**
    - **v and –By are the important parameters in winter daytime**
    - **and v, B, –By, and –Bz during winter night**

Illustration of obtaining Ne profile from topside ionogram

Scale X-trace ionospheric reflection from ionogram (a)

Use inversion program [Jackson, IEEE, 1969] to obtain Ne(h) (b)

Use Ne(h) to calculate O-trace ionospheric reflection and compare with scaled O trace to check inversion procedure (c)

ISIS 2 OTT digital ionogram1974_259 1322:22 UT