Investigation of ion heating signatures observed by the CASSIOPE/e-POP satellite

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1. INTRODUCTION

The ionospheric ion upflow energization process involves multiple steps. The relative importance of wave-particle interaction in driving ion heating and the associated ion upflow process at its initial stage is unclear. Also, the wave-generation mechanism and the specific wave-interaction pattern leading to the ion heating are unresolved. Previous studies suggested that wave-ion-heating can happen as low as 520 km altitude(Frederick-Frost et al. 2007). Using data from the CASSIOPE/e-POP satellite, we show an intensive anisotropic ion heating event (up to 4.3 eV increase in perpendicular ion temperature within ~1 km narrow spatial region) associated with large ion upflow velocities (2.2 km/s), the so-called broadband extremely low frequency waves (BBELF) (Kintner et al. 1996) and highly structured FACs within an active auroral surge in the nightside auroral region at an altitude of 410 km. A statistical survey in the e-POP database reveals 22 additional potential wave-ion-heating events from March 2015 to April 2016, which will be the basis of future work.

2. e-POP instruments

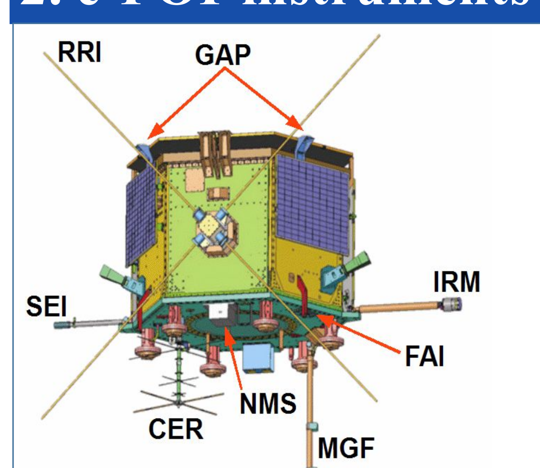


Figure 1. e-POP instruments on CASSIOPE satellite operating since September 2013 up to date in a polar orbit (325—1500 km). (Image from UofC e-POP team.)

Superthermal Electron Imager (SEI): Vertical ion velocity and ion temperature are derived from100 images per second low-energy 2-D ion distribution function (Knudsen et al. 2015).

Radio Receiver Instrument (RRI): 10 Hz –18 MHz radio wave electric field (10 Hz-30 kHz waves in our cases)

Fluxgate Magnetometer (MGF): 160 Hz vector magnetic field data

Fast Auroral Imager (FAI): large-scale auroral emissions

3. Ion upflow without heating

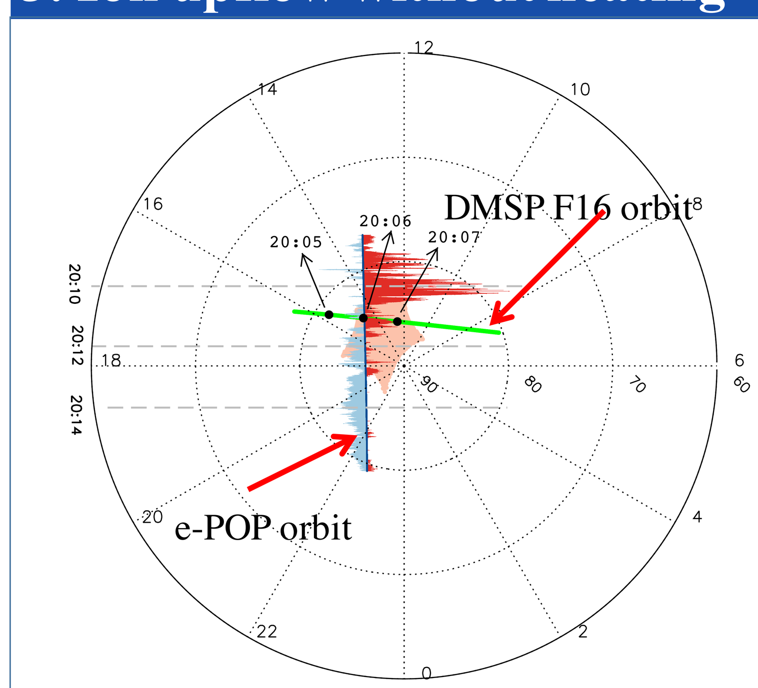


Figure 2. e-POP and DMSP F16 (green line) satellite orbits and measurements on 1 June 2014 in AACGM latitudes and MLT coordinate. The grey dashed lines indicate UT for points along e-POP orbit. The other three times represent the close conjunction times with DMSP F16 satellite. Red and blue lines represent upward and downward ion flow, respectively. The maximum ion velocity is 1.64 km/s. **(Shen et al., 2016, submitted)**

4. Ion upflow with heating

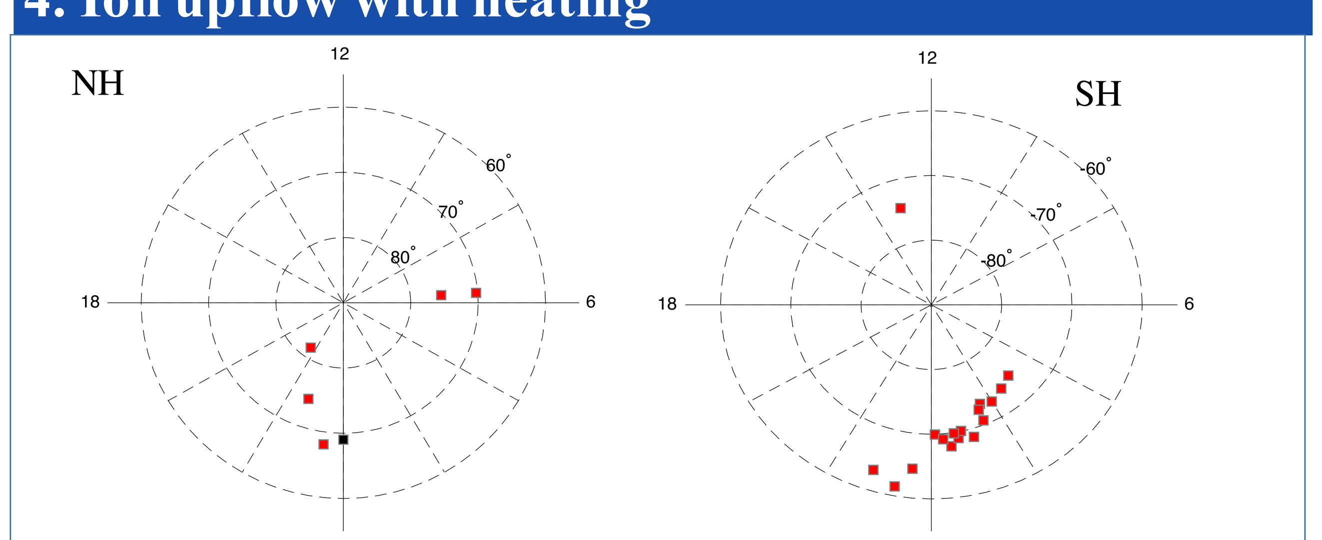
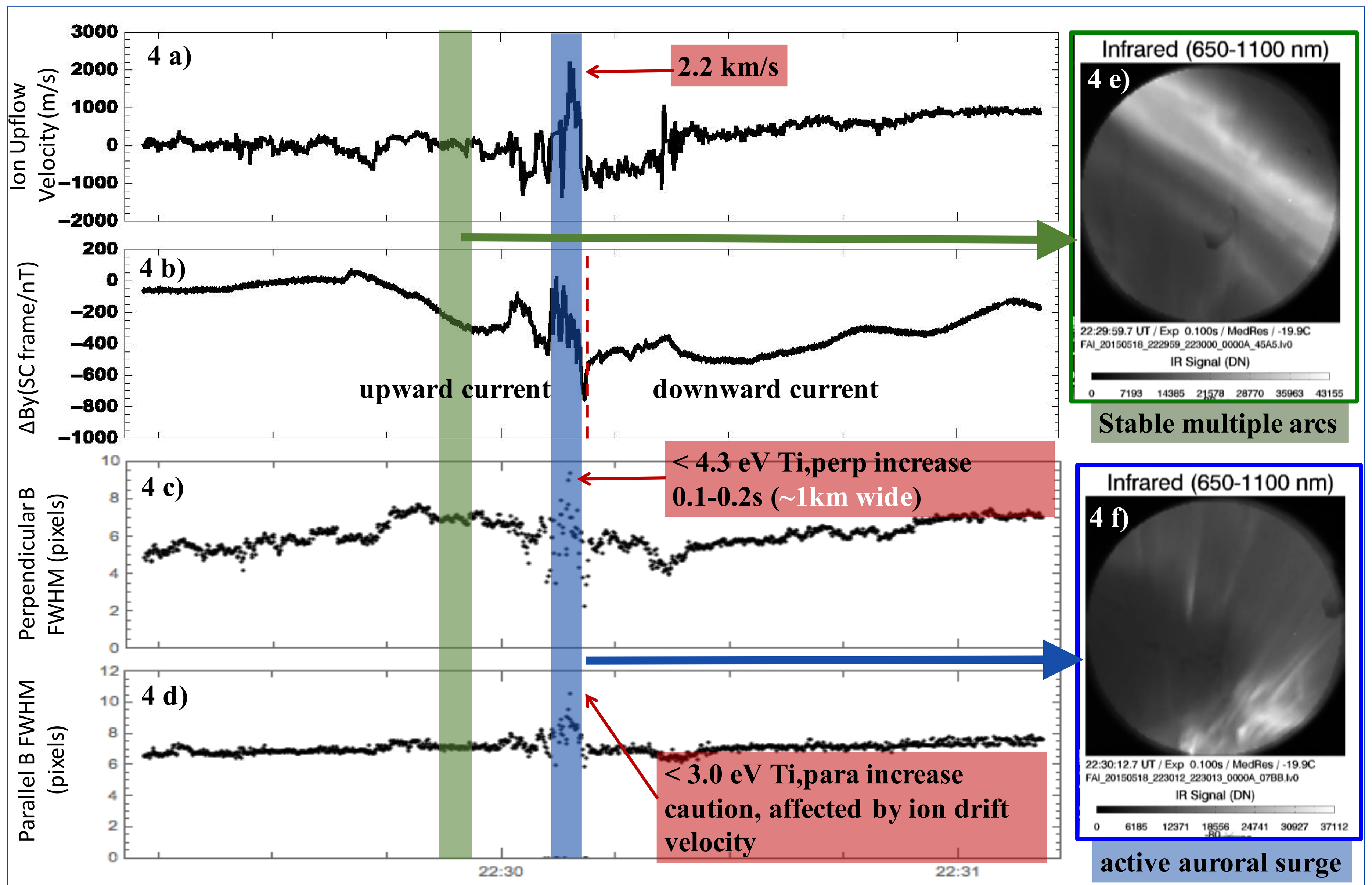
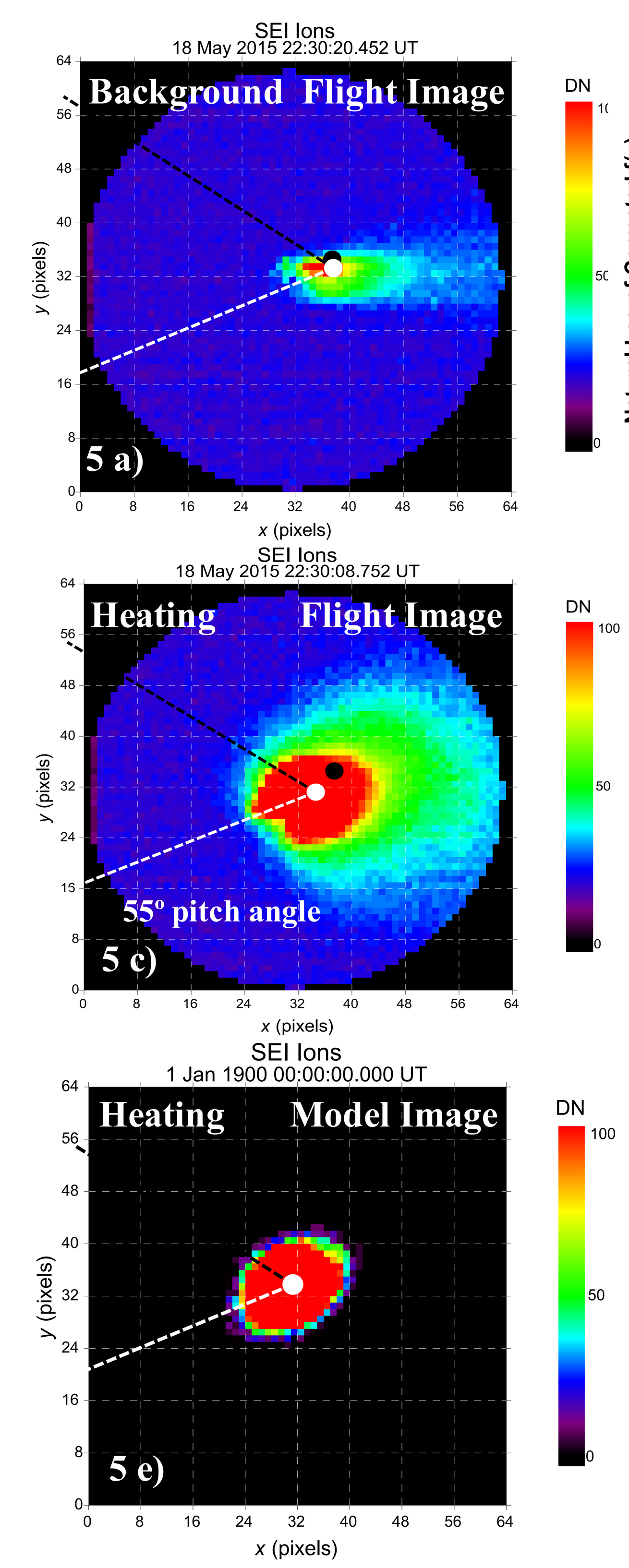


Figure 3. Locations of identified ion heating intervals observed by the SEI instrument in MLAT-MLT coordinate. Red boxes indicate BBELF waves associate with ion heating. The black box means no BBELF signature. The majority of the events are located near the nightside auroral region in the southern hemisphere.



Kp: 5+ Altitude: 410km MLAT: -73.2º MLT 1.6h O+ dominates

Figure 4. Summary plot of the ion heating case on May 18, 2015. The heating region associated with intensive auroral surge (4f) is indicated in the blue background while the green background indicates where FAI saw stable multiple auroral arcs (4e). Panel 4a shows the ion upflow velocity profile. The maximum velocity is 2.2 km/s. Panel 4b displays magnetic field perturbation By (east) component in the spacecraft frame. Negative gradient regions suggest upward currents. Positive gradient regions suggest downward currents. Panels 4c&4d show the perpendicular and parallel to magnetic field Full Width at Half Maximum (FWHM) values, indicating ion temperatures.



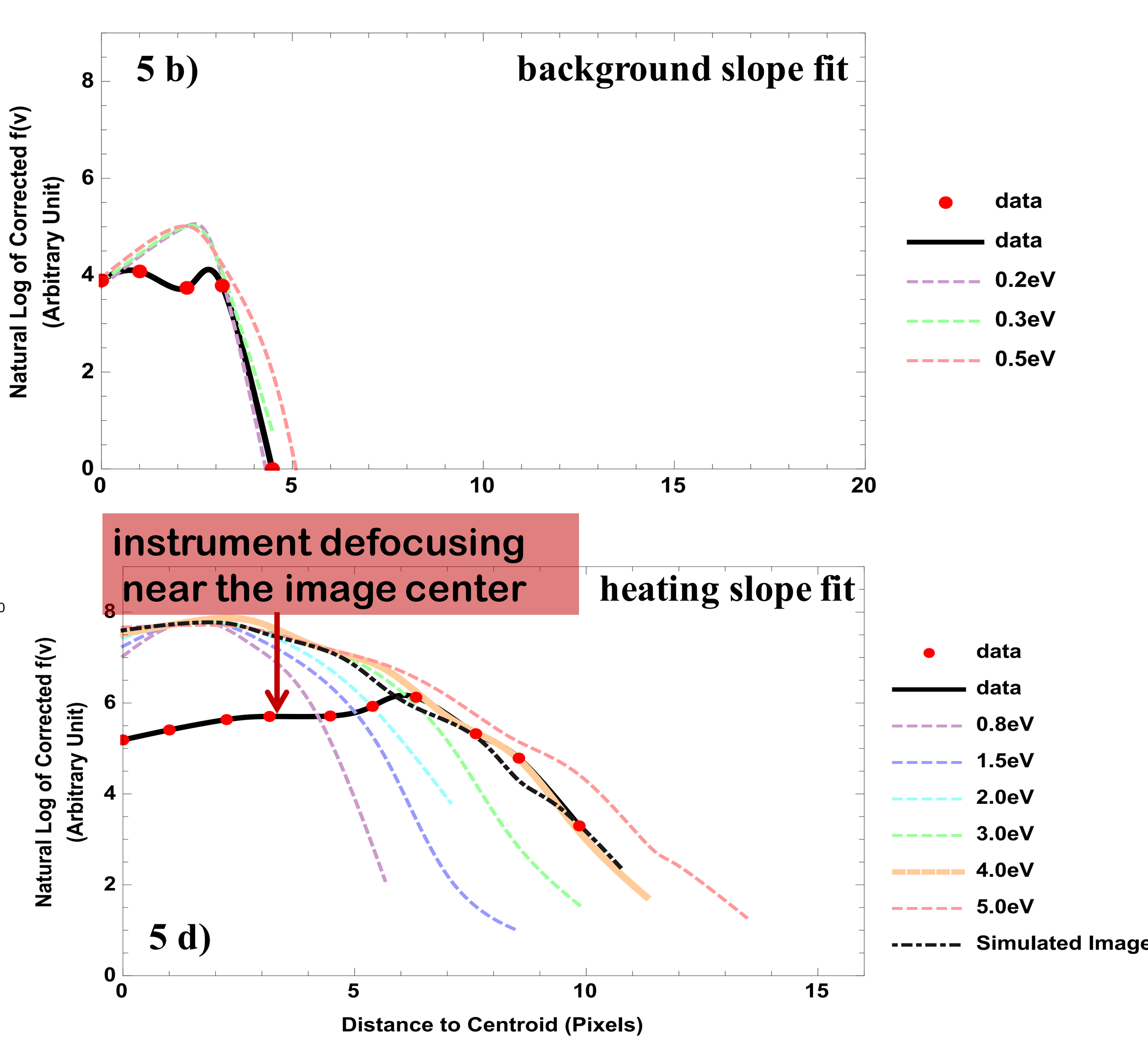


Table 1. Parameters for Monte-Carlo charged particle ray tracing simulation adapted to the SEI instrument

V_ram	7353 m/s	Ne	10000cm-3
V_vertical	2000m/s	sensor bias	-5.3 V
Vz	0m/s	Bx	-10279.5nT
T_perp	**4.3eV**	By	39396.8nT
T_para	**1.5eV**	Bz	10838.9nT
composition	O+		

Figure 5. Flight images (integrated to 10 images per second) simulation using a Monte-Carlo charged particle ray tracing simulation tool adapted to the SEI instrument. The slopes of the ion distribution functions in 55º pitch angle are fitted with different Maxwellian temperatures. Panels 5a&5b display the quiet time background image with the slope fitting indicating 0.2 eV background ion temperature. Panels 5c&5d show the most intense heating image and slope fitting result. Panel 5e displays the matched simulating image with the parameters shown in Table 1. The calibrated parallel ion temperature is 1.5 eV.

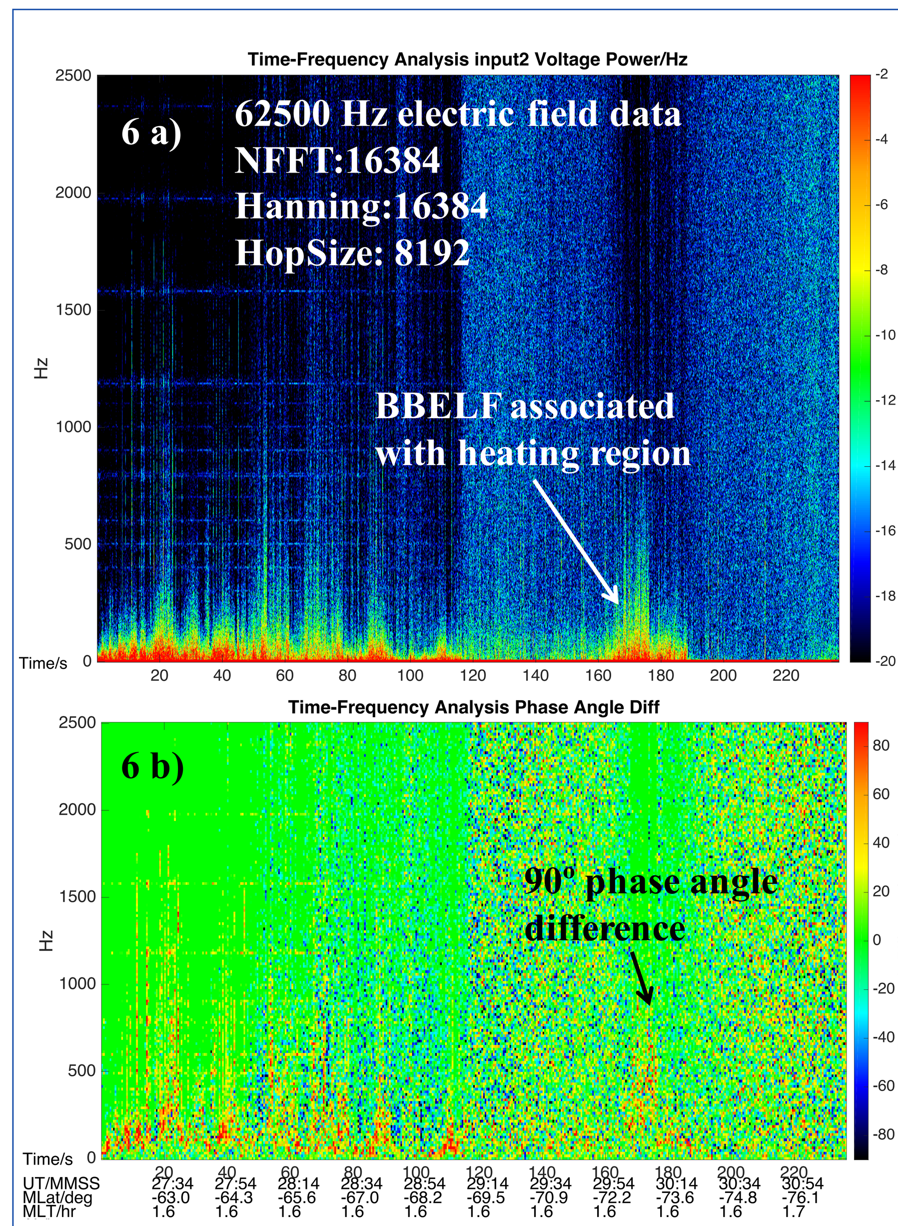


Figure 6. Panel 6a shows the power spectrogram for the RRI (cross-dipole mode) electric field measurements in the frequency range from 10 to 2500 Hz. The SEI-observed ion heating region is indicated by the arrow showing clear signature of BBELF wave emissions. Panel 6b displays the phase angle difference between the orthogonal double dipoles. In the higher frequency part of BBELF emission region, the phase difference is approaching 90º.

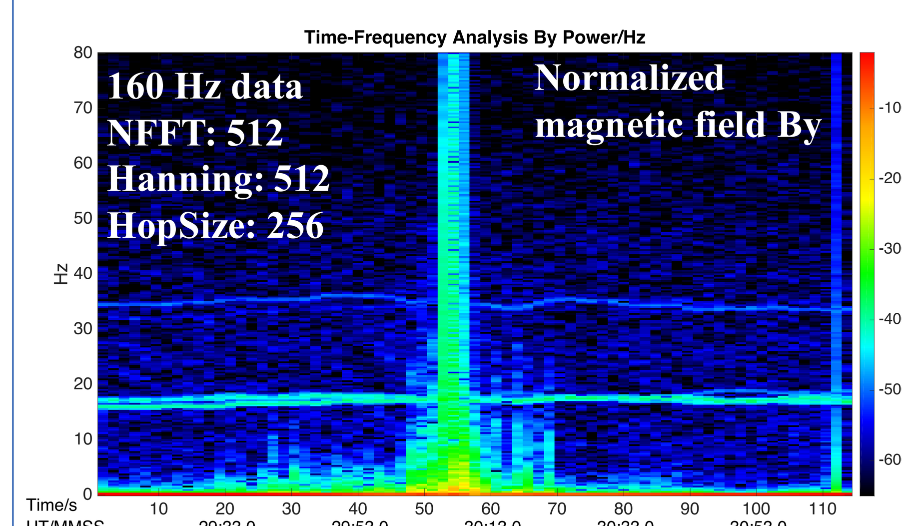


Figure 7. The power spectrogram for the MGF (160 Hz) magnetic field By component measurements (normalized) in the frequency range from 0 to 80 Hz. There are large perturbations up to 80 Hz in the heating region.

5. CONCLUSIONS

1. We found in total 23 ion heating intervals (17 orbits) when ion temperatures perpendicular to the magnetic field are larger than 0.4 eV. Most of the events show presence of BBELF waves.
2. We show an intensive narrow (~1km/s) anisotropic ion heating (up to 4.3 eV) event within the active nightside auroral surge at an altitude of 410 km in the southern hemisphere associated with large ion upflow velocities (2.2 km/s), highly variable FACs and strong BBELF waves.
3. The ion temperature measurements are validated by a Monte-Carlo charged particle ray tracing simulation adapted to the SEI instrument.
4. The BBELF consists of electromagnetic waves in the lower frequency (<80 Hz) part and electrostatic waves at higher frequencies.

6. REFERENCES

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[3] Frederick-Frost, K. M., K. A. Lynch, P. M. Kintner, E. Klatt, D. Lorentzen, J. Moen, Y. Ogawa, and M. Widholm (2007), SERSIO: Svalbard EISCAT rocket study of ion outflows, J. Geophys. Res., 112(A8), doi: 10.1029/2006JA011942, A08307.

7. ACKNOWLEDGEMENT

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