Low-altitude ion heating with downflowing and upflowing ions

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1. Introduction

Mechanisms and their relative importance in driving O⁺ ion heating and ion upflow in the topside ionosphere have not been fully resolved yet. The objectives of this study are:

• To test whether wave-ion heating contributes significantly to the ion energization process at 300 -700 km altitudes, where previous studies assume that frictional heating or Joule heating dominates.

• To create statistics of low-altitude ion heating and ion flow observations with wave and plasma measurements, since no statistics exists except sporadic sounding rocket observations.

• To study fine structures of and correlations between field-aligned flow velocity, ion heating and field-aligned currents (FACs) with up to 10-ms temporal resolution (~80 m spatial resolution) low-energy (~100 eV) ion measurements.

We use one-year recordings of simultaneous ion, magnetic field, wave electric field and optical data from the e-POP satellite for this study.

2. Methodology

Figure 1. e-POP instruments on the CASSIOPE satellite operating since September 2013 in a nearly polar orbit (325-1500 km). Data obtained between March 2015 and March 2016 are used for this study.

• Superthermal Particle Imager (SEI): Vertical ion velocity and ion temperature are derived from 100-image-per-second low-energy 2-D ion distribution functions [Knudsen et al. 2015].

The ion upflow velocity (along B) is:

\[ v = n - (eV \times B) / (eB) \]

The ion temperature data can be estimated by the width of the ion distribution function (FWHM) [Shen et al. 2016].

• Ion Mass Spectrometer (IRM): 100-image-per-second 2-D ion distribution functions and ion composition in the energy range 0-100 eV/Q.

• Radio Receiver Instrument (RRI): up to 30 kHz radio wave electric fields (10 Hz – 18 MHz dynamic range available).

• Fluxgate Magnetometer (MFG): 160 Hz vector magnetic field.

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

3. Results

Example 1: Nightside Aurora

Figure 2. A typical SEI flight image.

Kp: 5+ Altitude: 410 km MLAT: -73.2° MLT 6:58h O+ dominates SEI and MFG perspectives

<table>
<thead>
<tr>
<th>Ion energy</th>
<th>0.3-3.0 eV TIpacer increase</th>
<th>3.0-0.3 eV TIpacer increase</th>
<th>SEI and MFG perspectives</th>
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<tbody>
<tr>
<td>Time</td>
<td>0.2s (~3 km wide)</td>
<td>0.2s (~3 km wide)</td>
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<td>Current</td>
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<td>Downward current</td>
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<td>3.0 eV TIpacer increase</td>
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4. Conclusions

1. 24 low-energy ion heating events from several different instruments provide convincing statistics and complementary views of the low-altitude ion energization process and its relation with field-aligned flows and FACs.

2. Transverse ion heating can be intense (up to 4.5 eV), very narrow (~2 km across B), is more likely in the downward current region, and is associated with BBELF waves between 330-730 km altitudes. This suggests that significant wave-ion heating should be included in relevant models at low altitudes.

3. The minimum altitude of strong wave-ion heating (~350 km) is lower than reported in the literature [Whalen et al. 1978].

4. Contrary to what would be expected from mirror-force acceleration of heated ions, the majority of these heating events (17 out of 24) are associated with core ion downflow rather than upflow. Unknown processes are involved.

5. References


6. Acknowledgement

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