Comparing Sources of the Storm-Time Ring Current O+

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Motivation

• There are two sources for the O+ in the nightside plasma sheet: the dayside cusp and the nightside aurora.
  – Cusp outflow convects over the polar cap into the lobe, and enters the plasma sheet through reconnection
  – Nightside aurora has direct access to the plasma sheet.
• From the Dessler/Parker/Sckopke relationship, the strength of the ring current is proportional to the total energy carried by ions in the ring current region.
• Thus the source that contributes the most to the ring current is the source that contributes the most to the energy density.

Here we address: Which of these sources (cusp vs. nightside aurora) is more important for populating the storm-time ring current by determining which contributes the most to the energy density?
The energy gain of an ionospheric ion depends on where it encounters the plasma sheet. The behavior depends on the particle gyroradius, compared to the curvature of the neutral sheet.

- If an ion reaches the plasma sheet close to the earth, it remains field aligned/bouncing, and does not gain much energy. These ions form the warm plasma cloak (<1 keV population).
- If the ion reaches the plasma sheet further down the tail, it is scattered and heated/accelerated, becoming part of the hot isotropic plasma sheet (>1 keV population).

From Moore et al., 2005 (Particle code of D. Delcourt)
Kistler et al., 2010, showed that during storm times, a strong cusp source is evident as mono-energetic beams observed over the polar cap and in the lobe.
Cusp-origin beams isotropize, becoming part of hot plasma sheet

1) In the southern lobe and plasma sheet, the tailward streaming cusp O+ is evident.

2) In the northern plasma sheet, the distribution is more isotropic – the cusp source has isotropized.

The beams are coming into the plasma sheet from the southern lobe, and isotropizing when they cross the neutral sheet. **Cusp outflow clearly contributes to the hot plasma sheet.**
During the main phase orbit, the field lines are very stretched. Van Allen Probes-B is sampling high latitude field lines in the PSBL.

Kistler et al. 2015, JGR, submitted
Main Phase Orbit

Oxygen Flux

0-30°
Earthward

75-105°

150-180°
Tailward

O+ HOPE and RBSPICE
3 PA ranges

- PSBL shows high fluxes of <1 keV field-aligned (tailward) O+ flow.
- Field aligned fluxes show energy dispersed features. Could be combination of:
  - Time dispersion – short term source, and then lower energies take longer to arrive
  - Spatial dispersion – Field line convects as ions moves up the field line, so lower energies are observed at inner field lines.
- A strong “ring current population” is observed at energies > 1keV seen at all pitch angles in the inbound pass. Does the outflow cause this?

<table>
<thead>
<tr>
<th>Energy (eV)</th>
<th>O+ V (km/s)</th>
<th>Dist. (Re)</th>
<th>O+ time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>24.60</td>
<td>6</td>
<td>25.93</td>
</tr>
<tr>
<td>100</td>
<td>34.79</td>
<td>6</td>
<td>18.34</td>
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<tr>
<td>200</td>
<td>49.19</td>
<td>6</td>
<td>12.97</td>
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<tr>
<td>500</td>
<td>77.78</td>
<td>6</td>
<td>8.20</td>
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<tr>
<td>1000</td>
<td>110.00</td>
<td>6</td>
<td>5.80</td>
</tr>
</tbody>
</table>
The main increase in the near-earth 1<E<60 keV plasma sheet O+ occurs in the pre-main phase orbit.

The association of this increase with the increase in solar wind dynamic pressure and the relatively isotropic distribution indicates that this population entered the plasma sheet further down the tail and is likely from the cusp.
- Increase in differential flux towards lower L-values
- Sharp open/closed drift path boundary, almost independent of L at ~50 keV
- Inward adiabatic convection (f vs μ conserved) from L=6 to L=3.0 brings the enhanced O+ into the ring current region.
Formation of Ring Current

- In differential flux units, the flux increases as the O+ moves inward. There is a strong auroral contribution at low energies.

- In phase space density, we see constant f at constant μ – inward adiabatic transport.

- The energy density is dominated by 10-50 keV particles at all L’s, due to sharp cut-off at 50 keV from the open/closed boundary.

- The population that dominates the energy density, and therefore the ring current, at L=3.5 (50 keV) is at 20 keV at L=6.

- The low energy (<1 keV) auroral contribution to the energy density is negligible.
Conclusions

• This event clearly shows that there is an increase in the O+ flux in the plasma sheet during the pre-storm orbit, and it is the inward convection of that plasma that populates the storm-time ring current.

• The source of this O+ is likely the cusp, as cusp outflow is known to increase with increased dynamic pressure. AE, which correlates with auroral outflow, remained low pre-storm.

• The hot O+ in the plasma sheet remains relatively constant for a long time ~12 hours. This indicates a steady stream of outflow from the cusp, similar to what was observed in the Cluster events.

• While there is strong auroral outflow during the main phase, it remains at low energies (<1 keV), and so does not contribute significantly to the energy density in the inner magnetosphere.

• Thus, in this case, direct auroral outflow is not able to get isotropized/heated fast enough to directly impact the ring current population.
• As with the O+, the main increase in the near-earth 1<E<60 keV plasma sheet H+ occurs in the pre-main phase orbit.
• In the main phase orbit, the H+ has decreased from the previous orbit after the long period of outflow.
 Formation of H+ Ring Current

- Same picture for H+ is observed.
- In differential flux units, the flux increases as the H+ moves inward. There is a strong auroral contribution at low energies.
- In phase space density, we see constant f at constant μ – inward adiabatic transport.
- More energy density comes from >60 keV – the RBSPICE contribution is more significant.
- The population that dominates the energy density, and therefore the ring current, at L=3.5 (50 keV) is at 20 keV at L=6.
- The low energy auroral contribution to the energy density is negligible.