Plasmasphere-Magnetosphere Interactions

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Plasmasphere–Magnetosphere Interactions

How Are Magnetospheric Processes Regulated By Plasmaspheric Dynamics?

5 Year Focus Group 2008-2012
Conveners: Jerry Goldstein, Joe Borovsky

• Examine Two-way coupling between PS-MS

• Plasmasphere dynamics are controlled by magnetospheric convection—driven by the solar wind and modified by internal coupling processes

• PS affects and controls many critical physical processes in the magnetosphere.
Plasmasphere–Magnetosphere Interactions
How Are Magnetospheric Processes Regulated By Plasmaspheric Dynamics?

WAVE-PARTICLE INTERACTIONS

I. How does the evolving global distribution of cold plasma govern the growth and propagation of waves, specifically those that control energetic particle distributions?

II. How do ambient plasma properties such as temperature, density, and composition influence wave particle interactions?
Plasmasphere–Magnetosphere Interactions

How Are Magnetospheric Processes Regulated By Plasmaspheric Dynamics?

PLUME DYNAMICS & RECIRCULATION

I. How is eroded plasmaspheric material transported throughout the magnetosphere, and how does it evolve?

II. How do plumes influence the reconnection process, and what are the implications for solar wind-magnetosphere coupling?
The Plasmasphere

IMAGE EUV

EUV He+ column abundance

He+ 15%

resonant scattering 30.4 nm
Global Magnetospheric Convection

global circulation pattern
driven when IMF $B_z < 0$ (southward)
Internal Coupling Processes

Large scale solar wind imposed electric field modified by internal coupling processes

Ring current pressure gradients drive Region-2 field aligned current system

Horizontal ionospheric closure current modifies the convection field

A. Shielding

B. SAPS / SAID
Convection + Corotation

Volland-Stern with Chen et al. [1975] Kp normalization

+ SAPS Goldstein et al., [2005] Kp normalization
Cycles of Erosion and Recovery

$\Delta t = 11.5$ hrs

Details of Plume Formation Depend on:

- time history of convection
- the initial plasma distribution

[e.g., Spasojevic et al., 2003; Goldstein and Sandel, 2005]
Formation of a Plume

18 Jun 2001 12:25:00 UT

IMF Bz

18 Jun
Repeated Cycles of Driving

Newly Formed Plume
resurgence of convection

Wrapped Plume
formed during previous convection interval

Dayside Azimuthal Irregularities
pervasive during disturbances

[Spasojevic et al., 2003]
Waves result from instabilities in ring current ion (EMIC) and electron (chorus) distributions.

The presence (EMIC, hiss) or absence (chorus) of cold plasma is a critical parameter controlling the global wave distribution.

Cold plasma also determines how the waves, once generated, can interact with radiation belt electrons.
EMIC waves thought to contribute to radiation belt losses

Only occurs in the plasmasphere and plume since the presence of cold plasma lowers the resonant energy for EMIC waves to a few MeV

Composition of cold plasma (H+, He+, O+) is critical in determining the frequency bands of wave generation

Also, determines wave propagation characteristics

Evolving composition of the cold plasma during storms is not well characterized
EMIC waves in inner mag: at dusk in regions of enhanced ne not necessarily at pp

Anderson et al., 1992

Fraser and Nguyen, 2001

Incomplete MLT coverage
EMIC Wave Global Distribution

Theoretical Prediction

Observations Suggest
EMIC Waves: Enhanced Growth Rate at Plasmapause

[Thorne and Horne, 1997]

Cold Plasma Density

Ray Path

Path Integrated Wave Gain

HOTRAY model

Ray starts here

Enhanced wave gain due to guiding

Ray confined to field-aligned propagation

Wave-normal angle
**EMIC Waves: Density Irregularities**

**[Spasojevic et al., 2003]**

*Filamentary guiding structures could lead to enhanced growth rates throughout plume*

*Fraser et al. [2005] reported observations of EMIC waves in broad regions of the plume for these same events*
Chorus has a duel role

**Pitch Angle Scattering:** precipitive losses of MeV electrons

**Energy diffusion:** acceleration of seed ring current electrons to MeV energies

Acceleration most efficient in region of low plasma- to gyro-frequency ratio

[Chorus Observations at L=2.5 during the Halloween Storm](Horne et al., 2005; Spasojevic and Inan, 2005)
Chorus Observations at Low $L$

Waves observed at $L=2.5$ in 2003

Chorus: 51% of days
Hiss: 58% of days

Chorus / Chorus & Hiss
Hiss Only

Palmer Station $L=2.5$
Average Emission Spectrogram 2003
Waves and the Plasmapause Location

Plasmapause at Palmer’s Longitude

- Hiss Observed
- Chorus Observed

Palmer Local Time

MLT=6, Kp=5+

CA92
$L_{pp} = 3.25$

EUV
$L_{pp} = 2.5$

Indicates chorus is present at low $L$ more often than previously expected

PP at Palmer’s $L$ when chorus observed

PP at lower $L$ that predicted by CA92
Plume Dynamics and Recirculation
Estimate Plasmaspheric Losses

Calculate Total He$^+$ Losses

- Images take 1 orbit apart, near apogee, calibrated
- Masked out the shadow of the Earth, and $r < 1.5$ and $r > 5.5$

Number of He$^+$ Ions for Each Event

<table>
<thead>
<tr>
<th>Event</th>
<th>He$^+$ Lost</th>
<th>min $Dst$</th>
</tr>
</thead>
<tbody>
<tr>
<td>02 Jun</td>
<td>20.4%</td>
<td>-24</td>
</tr>
<tr>
<td>26 Jun</td>
<td>26.3%</td>
<td>-16</td>
</tr>
<tr>
<td>28 May</td>
<td>31.9%</td>
<td>-39</td>
</tr>
<tr>
<td>08 May</td>
<td>32.1%</td>
<td>-53</td>
</tr>
<tr>
<td>18 Jun</td>
<td>42.0%</td>
<td>-57 nT</td>
</tr>
</tbody>
</table>

Δ$t$ = 14 hrs

[Spasojevic, 2003]
50 - 100 tons of material are removed from the plasmasphere during these moderate disturbance events.

For each event, the variation is on the order of tens of tons depending on the He\(^+\) to H\(^+\) ratio used.

[Spasojevic, 2003]
Plume Material Extends to the Magnetopause

Electron Density, cm$^{-3}$

ISEE 1

[Chen and Moore, 2006]

[Carpenter et al., 1993]
Outflow towards the magnetopause

Also quasi-trapped during periods of reduced convection
Plasmaspheric Material at the Reconnection Magnetopause

Geosynchronous observations of plume material transported through the reconnection site and mixing with magnetosheath plasma

[Su et al., 2001]
Plumes Weaken Solar Wind-Magnetosphere Coupling

[ Borovskv and Denton, 2006 ]

1963–2003 OMNI2 data set & geomagnetic indices

Indices are lower for a given solar wind driving when plumes are present

Weakened solar wind-magnetosphere coupling caused by the plumes. ~10% effect
Ionospheric Signature of Plumes

Consistency between Storm Enhance Density (SED) and plasmaspheric plumes

[Foster et al., 2002]
AMIE potential patterns overlayed on ionospheric TEC

Consistency between AMIE flows and the TEC signature

Suggests that ionospheric footprint of plume is carried over polar cap

[Su et al., 2001]

[Foster et al., 2004]
Plume Material Over the Polar Cap

High altitude observations by Polar of plasmaspheric plume material over the polar cap

Observations of this type were relatively rare

What happens to the majority of the plume material? Heating?

[Su et al., 2001]
Elphic et al. [1997] used numerical modeling to track the transport of the plasmaspheric ions and estimate the contribution to the plasma sheet.

Weimer electric fields and T89c

Concluded that plasmaspheric ions could increase the average density of the plasma sheet by a factor of 10 or more.

Inconsistent with plasma sheet ion density and composition measurements

Are vast majority of plasmaspheric ions drained down the magnetotail before the field line reconnects?
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