Occurrence characteristics of subauroral rapid plasma flows observed by the SuperDARN Hokkaido East HF radar

Hiroki NAGANO, Nozomu NISHITANI, and Tomoaki HORI
(Nagoya Univ. STEL)
SAPS (Sub-Auroral Polarization Stream) \cite{Foster2002}

Westward rapid plasma flow occurs in subauroral region.

Because ExB drift of ion lead to SAPS, it may be observed as a large electric field and is called Sub-Auroral Electric Field (SAEF) \cite{Karlsson1998}.

Generation mechanism of SAPS

Anderson et al. (1993)

Pederson conductivity $\Sigma_p$ is large in electron precipitation region, and small $\Sigma_p$ in trough.

Large electric field is generated in order to flow the Region2 ionospheric current.
SAPS (Sub-Auroral Polarization Stream) \cite{Foster2002}

Westward rapid plasma flow occurs in subauroral region.

Because ExB drift of ion lead to SAPS, it may be observed as a large electric field and is called Sub-Auroral Electric Field (SAEF). \cite{Karlsson1998}

**Generation mechanism of SAPS**

Anderson et al. (1993)

Pederson conductivity $\Sigma_P$ is large in electron precipitation region, and small $\Sigma_P$ in trough.

Large electric field is generated in order to flow the Region 2 ionospheric current.

Fig.2. Anderson et al. (1993)
Westward rapid plasma flow occurs in subauroral region. Because $\text{ExB}$ drift of ion lead to SAPS, it may be observed as a large electric field and is called Sub-Auroral Electric Field (SAEF). Karlsson et al. (1998)

**Generation mechanism of SAPS**

Anderson et al. (1993)

Pederson conductivity $\Sigma_P$ is large in electron precipitation region, and small $\Sigma_P$ in trough. Large electric field is generated in order to flow the Region 2 ionospheric current.

Fig.2. Anderson et al. (1993)
SAPS (Sub-Auroral Polarization Stream) Foster and Burke. (2002)
Westward rapid plasma flow occurs in subauroral region.

**Previous works**
- As occurring MLT progress, the speed becomes slow, and SAPS shifts to lower latitudes. Foster and Vo. (2002)
- Positions of SAPS are highly correlated with Dst index. Kataoka et al. (2009)

There are still some open questions to be answered.
→ We conduct a statistical study on SAPS using the Hokkaido East HF radar data for about 8 years.

Fig. 3. Relation MLAT and velocity of SAPS against MLT Foster and Vo (2002).
SAPS (Sub-Auroral Polarization Stream)\(^\text{Foster and Burke (2002)}\)
Westward rapid plasma flow occurs in subauroral region.

**Previous works**

- As occurring MLT progress, the speed becomes slow, and SAPS shifts to lower latitudes. \(^\text{Foster and Vo (2002)}\)
- Positions of SAPS are highly correlated with Dst index. \(^\text{Kataoka et al. (2009)}\)

There are still some open questions to be answered.

→ We conduct a statistical study on SAPS using the Hokkaido East HF radar data for about 8 years.

\[\text{Fig. 4. Latitude dependence by Dst index} \]
\(^\text{Kataoka et al. (2009)}\)
Q. The slower speed limit of SAPS.
The slower speed limit of SAPS have not been defined so far. Because previous works used only (very) fast flows for the statistics.

Flow of this study

1. Checking the events of westward flows including the SAPS by using a wide range of background conditions.
   - Westward speed  $\geq 10.0 \text{ m/s MLAT } 40^\circ\text{ to } 70^\circ$
2. To distinguish subauroral region from auroral oval at that time.
3. Get the data of flow speed and MLAT, SYM-H every 30 minutes.
4. Investigating correlation between flow speed and MLAT-Dst dependence.

Positions of SAPS $\rightarrow$ Depends on Dst index
The flows whose positions depend on Dst $\rightarrow$ SAPS

Fig.4. Latitude dependence by Dst index  Kataoka et al. (2009)
Hokkaido East HF radar

This radar can observe the region of lower latitude than any other SuperDARN radars.

- MLAT: 36.46°, MLON: -145.34°
- Frequency 8~20 MHz

It measures Bragg scattering due to irregularity of electron density in the ionosphere. Considering the Doppler effect, we estimate Doppler velocity from obtained data.

Fig. 5. Picture and LOS of the Hokkaido East HF radar.
1. Checking the events of westward flows including the SAPS.
2. To distinguish subauroral region from auroral oval at that time.
3. Get the data of flow speed and MLAT, SYM-H every 30 minutes.

Fig 6. Precipitating flux obtained from TED on NOAA satellite, and LOS speed obtained from the Hokkaido HF radar. (2012/07/15)

Precipitating flux form TED >10⁰ mW/m²
Auroral Oval <10⁰ mW/m²
Subauroral region NOAA-19 foot print
1400 UT-1430 UT

Fig 7. Data of 2012/07/15 (from top) Doppler velocity, LOS velocity, IMF Bz, AL index and SYM-H.
Fig. 8. Dst index and occurred position for each MLT with Wang’s formulas.
Two populations, along the curve and not along the empirical curves by Wang+ 2008.

Fig.8. Dst index and occurred position of each MLT with Wang’s formulas.
Two populations, along and not along Wang’s curve (Wang et al., 2008).

Separate by the velocity. Threshold between 50 m/s and 300 m/s, every 50 m/s, has been applied.

Fig. 8. Dst index and occurred position of each MLT with Wang’s formulas.
Fig. 9. The Results separated by speed (22-1 MLT)
The result of the threshold is 150-200 m/s, which separate two groups roughly.
Statistical test

For each MLT bin, we separated all events into the two groups faster/slower than a velocity threshold. Then, we examined the percentage of the faster events that satisfy the latitude threshold. The latitude threshold is determined by Foster and Vo [2002] for Kp=7. The faster event percentage was evaluated with various velocity thresholds.

The percentage reaches asymptotically ~80-100%, when the threshold is ~150-200 m/s.

Table 1. The latitude threshold

<table>
<thead>
<tr>
<th>MLT [h]</th>
<th>13-16</th>
<th>16-19</th>
<th>19-22</th>
<th>22-1</th>
<th>1-4</th>
<th>4-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLAT[°]</td>
<td>61</td>
<td>58</td>
<td>55</td>
<td>54</td>
<td>52</td>
<td>50</td>
</tr>
</tbody>
</table>
The difference of relationship between MLAT and MLT for each Dst index is easily identifiable by applying threshold of > 200 m/s.

Q. The slower limit of SAPS.

→The slower limit of SAPS is 150-200 m/s.
Q. The slower limit of SAPS.
We classified westward flows by their velocity.
Faster flow than 150-200 m/s → As Dst decreases, their positions toward lower latitude.
Slower flow than 150-200 m/s → Their positions are not dependent on Dst index.
→ The lowest limit of SAPS speed is ~150-200 m/s.
• The slower flows are mid latitude F region echo (Fukao et al., 1988).
• This result gives a minimum electric field which generates SAPS.
→ A minimum electric field is 6-8 mV/m
• This electric field contribute to investigate mechanism of Feedback instability.

Future Work
• To confirm whether SAPS is generated when minimum electric field. And checking the situation at that time.
→ Investigating factor of generating SAPS.