Segmentation of Storm Enhanced Density (SED) by Boundary Flows Associated with Westward Drifting Partial Ring current

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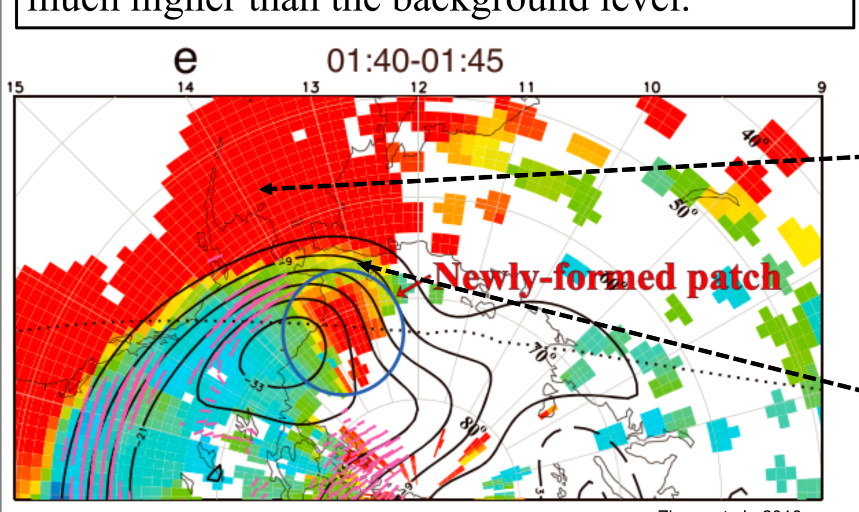
ABSTRACT

High-density plasma originated from dayside subauroral region can be transported into the high-latitude region and then segmented into smaller-scale **patches**. The segmentation mechanism is proposed to be related with temporal changes of IMF or transient reconnection. Using the GITM driven by two-way coupled BATSRUS and RCM model, a new segmentation mechanism is proposed. This mechanism works as follows: a strong boundary flow between the Region 1 and Region 2 FACs can develop while the shielding process develops in the inner magnetosphere. As the partial ring current drifts westward, the peak of the boundary flow also moves westward. This strong boundary flow raises the ion temperature through enhanced frictional heating, enhances the chemical recombination reaction rate and reduces the electron density. When this boundary flow crosses the SED plume, the plume will be segmented into patches. No external IMF variations or transient reconnections are required in this mechanism.

INTRODUCTION

Polar cap patches: F-region plasma density structures in the polar cap where the density is much higher than the background level.

The formation of patch needs a reservoir of high-density plasma and a segmentation mechanism.



Plasma reservoir: (1) Dense thermal plasma from the sunlit region (e.g. storm-enhanced density). (2) Plasma density increase in the cusp due to soft precipitation in the F region.

Segmentation: (1) Temporal changes in IMF Bz or By. (2) Flux Transfer Events (FTE) signatures in the ionosphere.

Motivation: Can and How partial ring current contribute to the segmentation?

METHODS

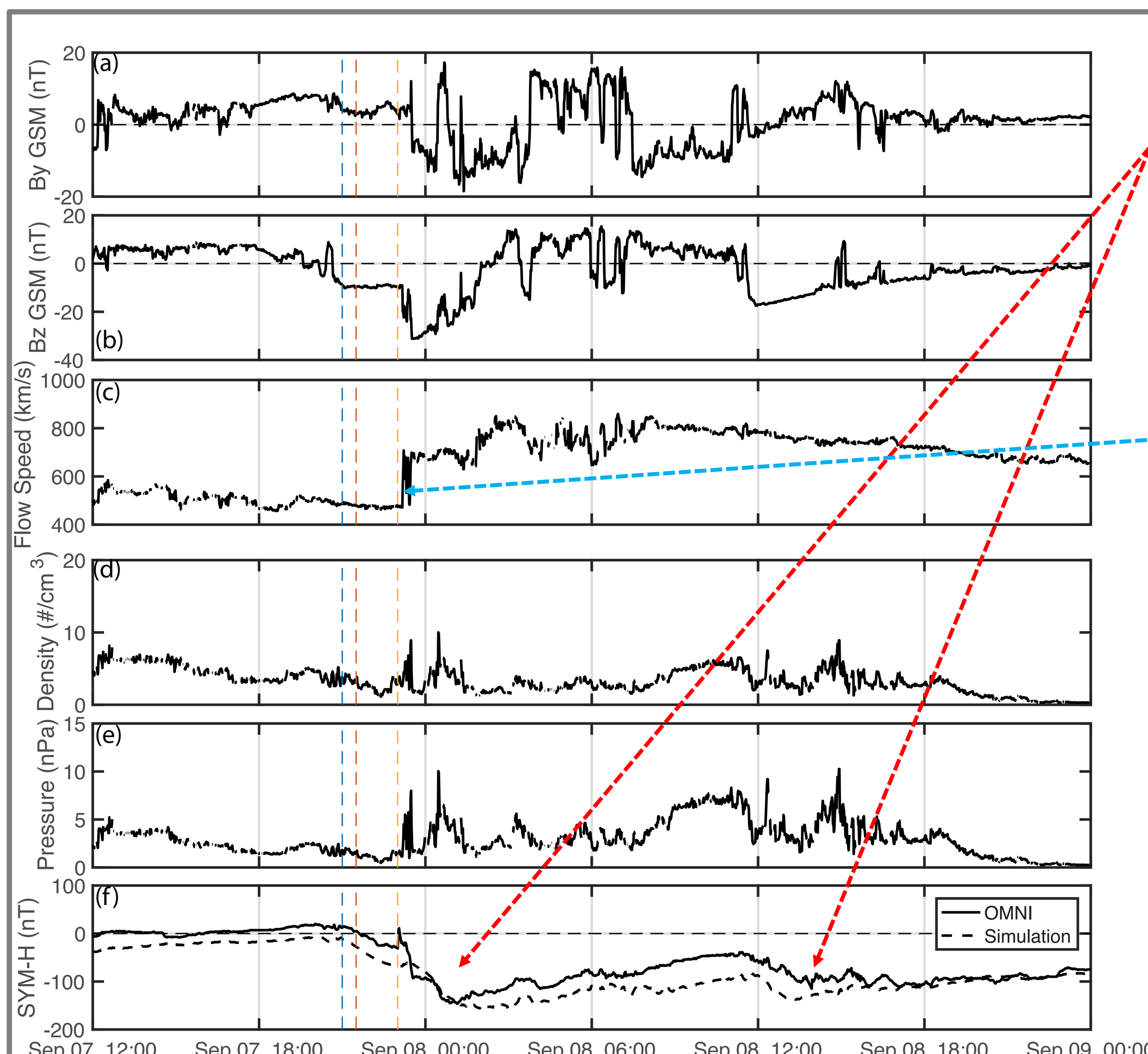
2-Way Coupled Rice Convection model (RCM) and Block-Adaptive-Tree-Solar Wind-Roe-Upwind-Scheme (BATSRUS) provides electric field and precipitation
\+
Flare Irradiance Spectral Model (FISM) provides solar radiation

Driver →

Global Ionosphere and Thermosphere Model (GITM)
Solves for:
6 Neutral & 5 Ion Species Ion and neutral density,
Velocity and temperature.
Flexible grid resolution.
Can have non-hydrostatic solutions.

The geomagnetic storm on Sep 7, 2017 was simulated to study the segmentation of SED plume into polar cap patches.

GEOMAGNETIC STORM ON SEP 7, 2017

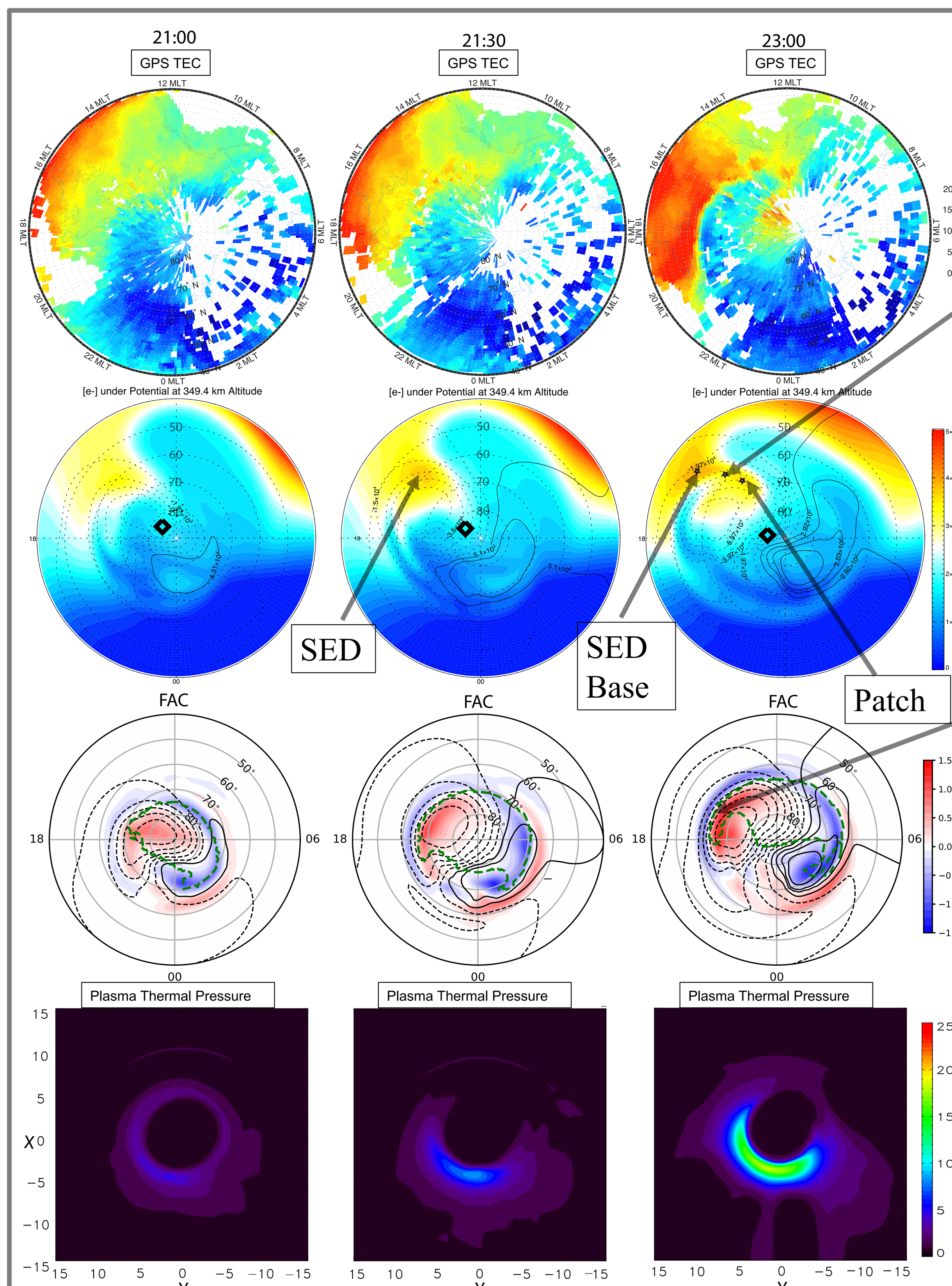


A double-dip storm. The SYM-H index reached ~-142 nT at the first dip and then ~-100 nT at the second dip.

A shock-ICME complex structure arrived with the shock enhanced IMF Bz reaching ~-30 nT.

Validation: Although there is a ~20 nT negative bias, the temporal variation of the simulated Dst is consistent with the SYM-H index.

SIMULATION RESULTS



Boundary Flow

SED occurred after the southward turning of IMF (expanded convection pattern).

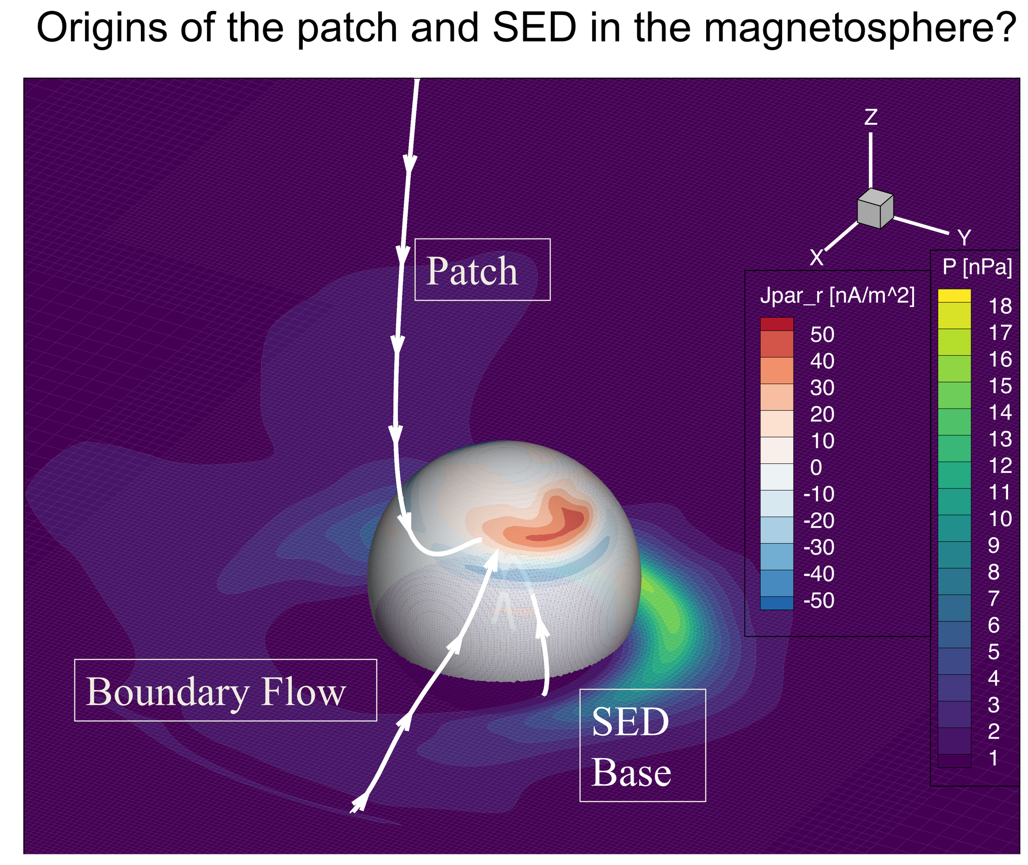
Enhanced boundary flows segmented SED plume into patches at 2300 UT.

Boundary Flow

Region 2 FACs near 15 MLT enhanced corresponding to the west drifted partial ring currents. Closure of region 1 and 2 FACs led to large boundary flow.

Partial ring currents drifted westward when the storm developed.

Origins of the patch and SED in the magnetosphere?

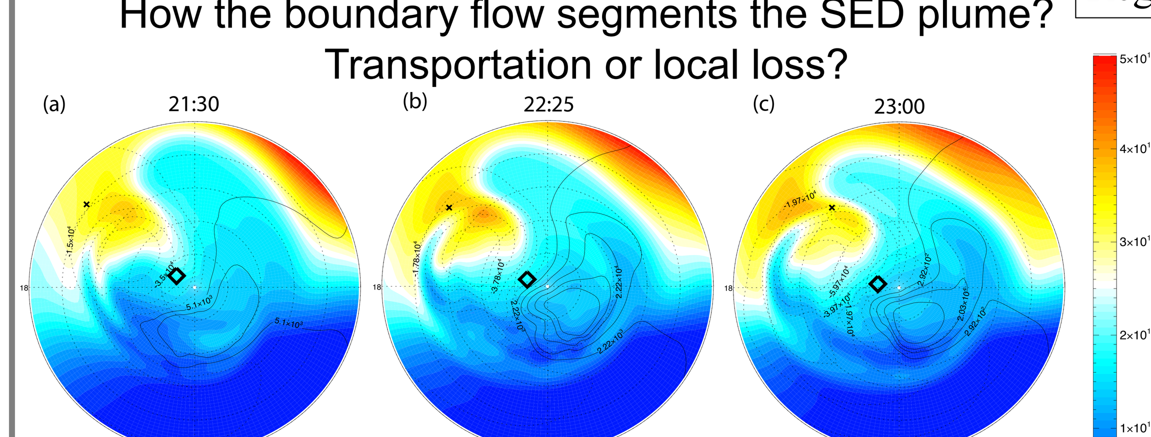


Polar cap patch: On open magnetic field lines and connected to the solar wind, showing that its poleward movement due to the magnetospheric convection driven by the southward IMF.

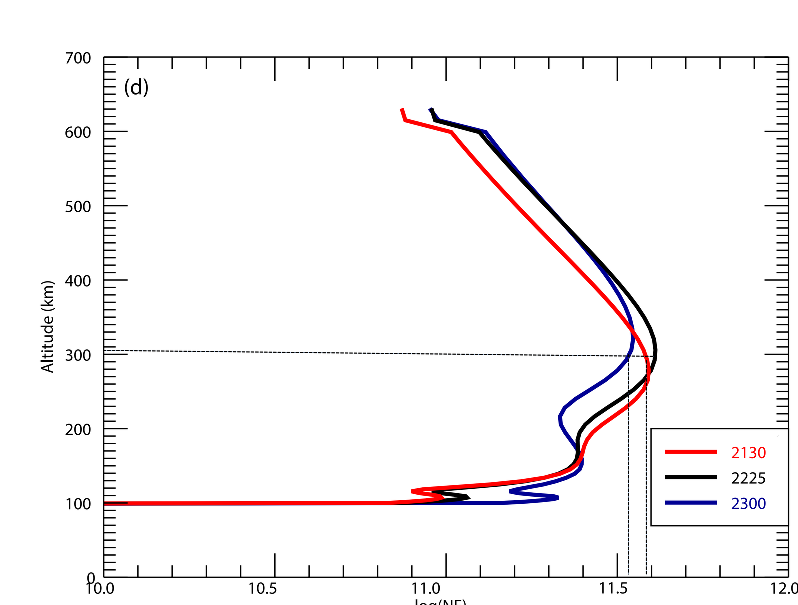
SED base: On the inner edge of the partial ring current, where the under-shielded electric field was responsible for the SED lifting and TEC grow.

The boundary flow region: Mapped to the outer boundary of the partial ring current (poleward boundary of Region 2 FACs in the ionosphere). This proves that the segmentation was due to the boundary flows located between the Region 1 and Region 2 FACs.

How the boundary flow segments the SED plume? Transportation or local loss?



The plasma parcel at the center of the boundary flow at 2300 UT was traced backward in time to 2130 UT to identify its source region.



Two different phases are found: Growing phase between 2130 and 2225 UT, decaying phase between 2225 and 2300 UT.

Growing phase: Plasma was lifted to higher altitudes. The lifting was found to be mainly due to projection of the northward convection flows in the vertical direction.

Decaying phase: The velocity difference between ion and neutral increased from 100 m/s to 600 m/s, the T_i increased from 1400 to 1700 K. The charge exchange rate between O^+ and N_2 increased. The production rate of NO^+ thus increased $1.88*10^7$ m^{-3} s^{-1}. The total NO^+ conversion during the decaying phase (~35 min) is $4*10^{10} m^{-3}$. NO^+ and e^- rapidly recombined and the electron density loss should also be $4*10^{10}$ m^{-3}, which matches the amount of electron lost in the model output. This simple calculation confirms that the enhanced chemical reaction within the enhanced boundary flows led to the electron density decrease and the segmentation of the SED plume into patches.

CONCLUSION

A new segmentation mechanism of SED plume into polar cap patches is proposed. The simulation results are validated with the comparison with the GPS TEC observations and SYM-H index.

When the center of the partial ring current drifts westward due to the gradient and curvature drifts, these large boundary flows also move westward from the night side to the day side. When they encounter the SED plume, the plume is segmented into patches, which later move further into the polar cap.

- **Enhanced boundary flows between Region-1 and Region-2 FACs segment SED plume into patches.**
- **Localized plasma loss due to enhanced frictional heating within boundary flows.**
- **During this process, no IMF variations or transient reconnections are required.**

References:
Zhang, Q.-H., et al. (2016), Polar cap patch transportation beyond the classic scenario, J. Geophys. Res. Space Physics, 121, 9063–9074.
Wang, Z., Zou, S., et al (2019). manuscript submitted for GRL.

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