A new look at the nightside convection system for oblique northward interplanetary magnetic field

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Introduction

It is known that for prolonged periods of oblique northward interplanetary magnetic field (IMF), there appears an ionospheric convection system on the nightside that is controlled by the Y component (B_Y) of the IMF. For $B_Y < 0$, the convection is clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere when viewed from above the northern ionosphere. The convection direction reverses for $B_Y > 0$. Milan et al. (2005) proposed a qualitative model of this convection system. The addition of the B_Y component to the tail skews the northern and southern lobe field lines with respect to each other. When Dungey-type reconnection occurs in the tail, the newly closed skewed field lines shrink and drive the above-mentioned convection in the ionosphere. Recently, Tanaka et al. (2023) proposed a different view of the convection system upon the basis of quantitative magnetohydrodynamic numerical simulations. In their model, the convective processes in the tail are very complex. The global convection system consists of an in-front interchange cycle (coupling of IMF-lobe reconnection and lobe-closed reconnection) and an off-front Dungey cycle, and the two cycles are intimately connected. The latter Dungey cycle manifests the B_Y-controlled convection system. The simulation by Tanaka et al. (2023) indicates that the open/closed (O/C) boundary has a polar cap constriction or a plasma sheet protrusion on the evening side before midnight for $B_Y < 0$ in the Northern Hemisphere, which is schematically shown in Figure 1. This characteristic is detectable by observations as an ionospheric signature of the above-mentioned processes. The purpose of this study is the observational verification of the simulation results. For this end, we first try to find satellite observations that match this feature.

Method

We use Defense Meteorological Satellite Program (DMSP) data. In order to find satellite data that match the phenomenon, we take four steps. Firstly, we determine the appropriate satellite orbit based on the polar cap shape obtained from global simulations. The Northern Hemisphere O/C boundary exhibits a constriction of the polar cap or a protrusion of the plasma sheet on the evening side before midnight for $B_Y < 0$ and after midnight for $B_Y > 0$, as depicted in Figure 1. We call the poleward protrusion of the plasma sheet a “tongue.” It was found that the orbit of the DMSP F16 satellite was more suitable (15–05 MLT in the Northern Hemisphere, and 03– 17 MLT in the Southern Hemisphere). Secondly, we searched for the satellite data from F16 that matched the phenomenon. The tongue of closed flux (shown in figure 1) means that there will be an ion precipitation zone in the polar cap. Thirdly, we examined IMF conditions to check B_Z and B_Y direction, and also we surveyed simultaneously observed aurora images for further confirmation. Finally, we determined the direction of convection based on the drift meter on board the satellite. Since the B_Y effects are antisymmetric between north and south and between dawn and dusk, the four patterns in table 1 are expected.

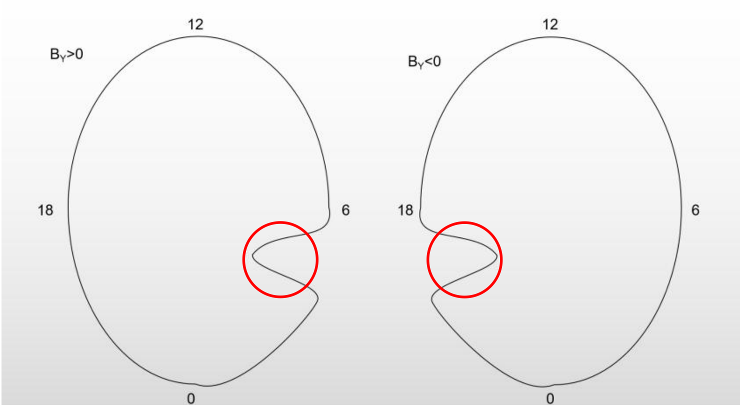

Figure 1.The Northern Hemisphere O/C boundary for $B_Y > 0$(left) and for $B_Y < 0$(right), viewed from above the Earth. The red circle indicates what we call the tongue in this paper.

Table 1. Four patterns expected from simulation

IMF	Northern Hemisphere	Southern Hemisphere
$B_Y > 0$	Tongue on dawnside Duskward convection	Tongue on duskside Dawnward convection
$B_Y < 0$	Tongue on duskside Dawnward convection	Tongue on dawnside Duskward convection

In the presentation, we show preliminary results of our analysis. One example is around 1000 UT on November 30, 2014. The IMF was $B_Z > 0$ and $B_Y < 0$. The F16 satellite observed ion precipitation within the polar cap in the postmidnight sector in the Southern Hemisphere. The associated convection was duskward and was consistent with simulation features.

Reference

Milan, S. E., et al. (2005). Formation and motion of a transpolar arc in response to dayside and nightside reconnection. *Journal of Geophysical Research*, *110*(A1). https://doi.org/10.1029/2004ja010835

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