

Exploring the Formation of Polar Cap Patches via Model-Based Lagrangian Coherent Structures in the Ionosphere

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The polar cap patch (PCP) is a few 100-km-scale ionospheric enhancement appearing at high-latitude upper atmosphere poleward of the auroral oval. The study of the PCP is of great interest because it is associated with ionospheric plasma density irregularities that can affect Global Navigation Satellite System (GNSS) service (Moen et al., 2013) by causing a rapid fluctuation in signal amplitude and phase, known as scintillation. For that reason, tracking patches in time-evolving plasma drifts is important. Coherent structures are features of a time-varying flow that persist in space and time, indicating transport and energy transfer processes. Lagrangian coherent structures (LCSs) are a frame-invariant structure defined by the locally maximum finite time Lyapunov exponent (FTLE) describing the maximum separation (or convergence) regions in the flow. Previous work indicates that LCSs are found in the ionosphere and more prominent at higher latitudes (Wang et al., 2018). A study of the geomagnetic storm on 17 March 2015 revealed that a necessary condition for the PCP formation is that storm enhanced density (SED) exist poleward of the ionospheric LCS (Wang et al. 2018; Ramirez et al., in preparation).

In this work, we apply the LCS technique to analyze other geomagnetic storms in the current solar cycle to investigate the formation of the PCP in model-based plasma drifts. To do this, the polar electric potential model Weimer 2005 (Weimer 2005) and 12th generation International Geomagnetic Reference Field (Thebault et al. 2015) are used to generate plasma drifts in the ionosphere. A 2D algorithm, Ionosphere-Thermosphere Algorithm for Lagrangian Coherent Structures (ITALCS), is used for computing the forward-time FTLE scalar fields in the ionospheric drift field to visualize the ionospheric LCSs. The PCP is traced backward in time to study its formation for each storm event.

For the storms on 26 September 2011 and 25 October 2011, the part of the SED poleward of the LCS ridge has the potential to become a polar cap patch in the future. This observation matches the conclusion of Wang et al. (2018) that the LCS ridge demarcates the poleward part of SED as possible source plasma for the formation of a polar cap patch.