The Tracking of Patchy Aurora and its Correlation to Co-rotation Convection Drift

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Objectives

This study aims to determine the following:

- the characteristic drift motion of patchy aurora observed in the late morning sector
- the correlation between patchy drift motion and $E \times B$ drift motion
- can ground based cameras be used as a means of determining local Ionospheric conditions?

Introduction

When the Interplanetary Magnetic Field (IMF) is Southward it creates magnetic reconnection in the Earth's magnetosphere. The open magnetic field is then dragged antisunward with the solar wind where it will reconnect deep in the magnetotail. The dragged magnetic field compresses the magnetic field within the magnetotail and causes the magnetic field within it to reconnect. This reconnection allows energetic electrons trapped in the Earth's plasmasphere to stream directly into the upper Ionosphere where it will interact to create aurora.

The dragging of the open magnetic field creates a potential difference across the polar cap as the plasma along the magnetic field is forced to move with it to conserve magnetic flux. The potential difference created by this process produces electric fields across the polar cap. Furthermore, the closed magnetic field in the nightside becomes compressed while the dayside magnetic field decompresses driving horizontal electric fields that create a two cell convection electrojet. This process driven by reconnections from the IMF is known as the Dungey cycle. These resultant electrojets, combined with the magnetic field, create plasma convection in the upper ionosphere.

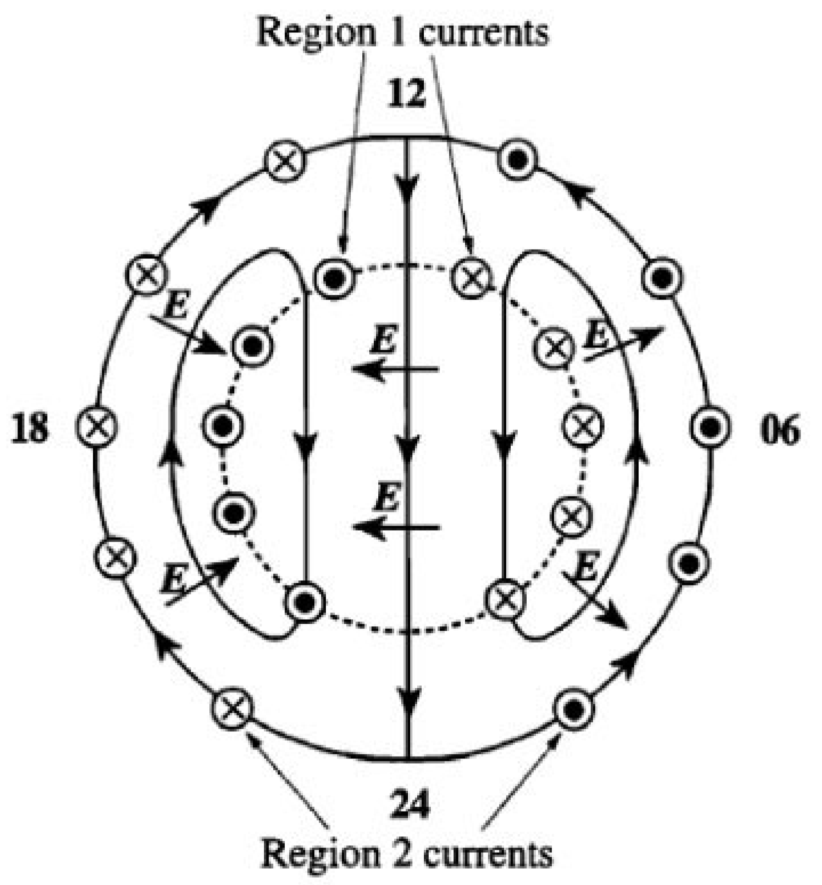

Figure: Figure taken from Cowley [6] depicting the flows produced by the Dungey cycle on a noon-midnight diagram. Dotted refers to magnetic field lines pointing into the ionosphere, and crosses refer to magnetic field lines pointing out of the ionosphere.

Instrumentation

The study makes use of digitized images taken at Poker Flat Research Range (PFRR) at Poker Flat, AK. These images were taken in a 512 x 512 pixel format, and in some cases 1024 x 1024 pixel, using a 180 degree FOV attributing a resolution of about 700m per pixel (340m for the secondary format). These images were taken at 12.5 s intervals leading to a max velocity of 28 km/s between images, and a minimum velocity of 56 m/s between images. For the case of the 1024 x 1024 format a cadence of 1 second was used leading to a max velocity resolution of 350 km/s and a minimum velocity resolution of 340 m/s between consecutive frames.

The data will also make use of another instrument located at PFRR, the Poker Flat Incoherent Scatter Radar (PFISR), which estimates the plasma drift velocities in the ionosphere. These estimates are integrated across a subsection of the sky above PFRR over one minute or three minute intervals.

Methods

The study will use optical flow techniques and Convolutional Neural Networks (CNN) in order to determine the magnitude of the velocity of the patches. This process takes the input data, in our case an array of image values, and passes a filter of desired dimensions over the image. The size and components of the filter may be altered depending on the desired output of the CNN. After the filter is swept across the image the resulting output, known as a convolutional layer, holds a a smaller subset of points referred to as neurons. Each of these neurons provides information about the corresponding area that is determined based on whether or not the neuron was activated or unactivated. This machine learning technique can be applied in various ways in order to determine where in the frame edges of auroral features are, as well as which parts of the frame contain a patch or no auroral activity. The study aims to determine both the motion of the central point of the patches and the motion of the blobs form. These data points can be correlated to the estimated plasma drift velocities integrated by PFISR.

Important Correlation

Should there be a strong correlation between the estimated plasma drift velocites as integrated by PFISR and the drift velocity of the observed patches by the all-sky camera, then ground based cameras may be used as method of determining the plasma drift velocity in the ionosphere. This would allow for portable instrumentation where the resolution is dependant on the camera and lens used. As a result, this correlation would allow for determining plasma drift in the ionosphere at locations where instruments such as PFISR or AMISR have not been previously installed.

Data Sample

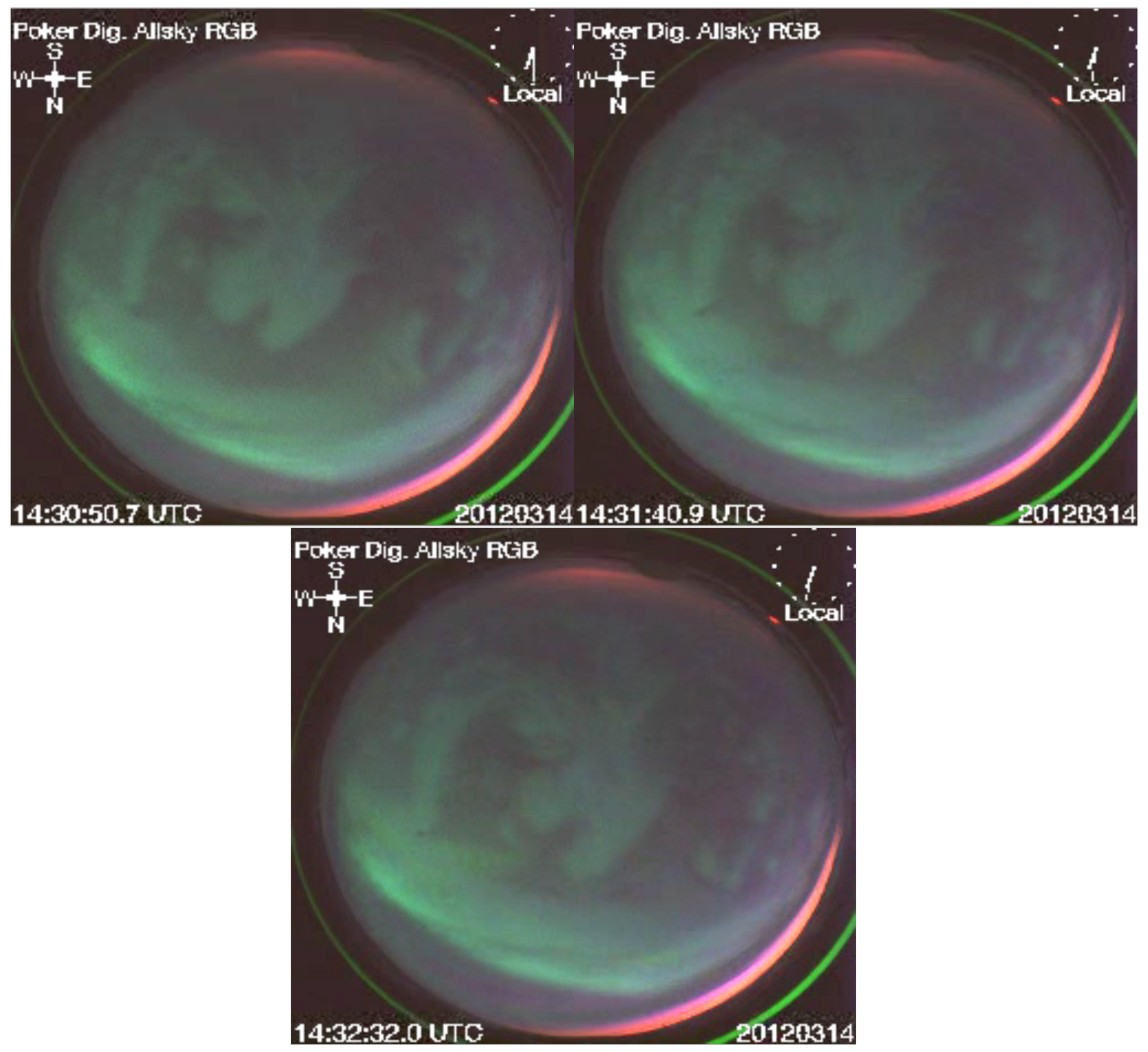

Figure: Patchy aurora captured by an all-sky camera stationed at PFRR on 03/12/14 with UTC time stamps on the bottom left to indicate time between images. As can be seen in the successive frames, a well defined patch drifts across the zenith of the camera view. The compass at the top left confirms the Eastward movement of the patch which is consistent with $E \times B$ convection drift.

Significance

In a cold plasma, such as the plasma found in the inner and outer regions of the plasmasphere as observed by the Ogo satellites[1][2], the thermal motion of the ions can be effectively neglected, and the ions can interact with electrons to cause gyrations at low frequencies. This interaction causes an EMIC wave to form within the ring current around the Earth. However, the ion population in this region creates an instability within the EMIC wave that results in a growth of the wave. This growth in turn drives pitch angle scattering of the cold plasma into the loss cone and producing auroral features in the ionosphere. The cold plasma contained within the plasmasphere is trapped on the closed magnetosphere, and as a result is subject to electric fields resulting from the Dungey cycle, thus giving way to convection drift.

The motion of patchy aurora has been observed to drift in a manner that is similar to convection drift, however the explicit details of their motion have yet to be fully understood. Once the particles enter the ionosphere and interact the product we see will be directly influenced on the conditions of the interaction. The study aims to determine if these forms drift convectively, meaning that the motion of the particles is directly influenced by the magnetic field that the particles flow in on, and the horizontal electric fields produced by the drifting of the magnetic field as a part of the Dungey cycle. While the electrojets formed by the cycle have been observed, auroral forms have not yet been determined to form in response to this cycle. Should the patchy auroral forms drift separate to this, then the forms are being influenced by other factors that have yet to be determined.

Significance

Further, the techniques applied in this study can be used in determining the generation mechanism for black auroral forms. Black aurora, which is the well defined absence of auroral emissions within diffuse or other auroral types, has been observed in a variety of differing flavours. These forms appear in a currently unpredictable manner and subject for debate about their underlying creation mechanism. A recent study done by Fritz et al [5] characterized new black auroral features that had not previously been observed, differing from the commonly used definition. The study lacked further data on the forms, data that could be accompanied by information such as the $E \times B$ drift in the ionosphere. Given that these structures are not as easily determined to appear as other auroral features, the planning of in situ measurements via rocket missions cannot currently be done in a reliable manner. Methods such as determining the conditions using ground based observations would greatly impact the studies done on these auroral features.

Additional Information

Previous studies done on this topic by Yang [3] and Scourfield [4] determined a correlation for a period of time, however the correlation dissipated as solar wind activity increased. These studies used data sets from THEMIS images and SuperDARN, and CCD images and STARE, respectively. These data sets have a lower spatial resolution than PFISR and the all sky images taken at PFFR.

References

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