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POLAR CAP PLASMA CONVECTION MEASUREMENTS AND THEIR RELEVANCE TO THE REAL-TIME MODELING OF THE HIGH LATITUDE IONOSPHERE

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Recent theoretical calculations of electron density profiles within the high latitude/polar cap ionosphere demonstrate that the diurnal foF2 variation observed at Thule, is controlled by the plasma convection pattern and the associated drift velocities. The model calculations for $B_z < 0$ and $B_z \approx 0$ show factor 2 to 3 differences in Nmax over Thule, supporting the stated importance of convection pattern and velocity measurements for the modelling of the high latitude ionosphere.

INTRODUCTION

The UT dependence of the winter polar cap ionosphere (Sato and Rourke, 1964, Buchau et al., 1985), the longitudinal variation in F-region densities in the nightside auroral zone (de la Beaujardiere et al., 1985) and the formation of the main F-layer trough are either entirely or to a large extent the result of large scale plasma convection across the polar cap. (Knudsen, 1974, Knudsen et al., 1977, Watkins, 1978, Sojka et al., 1981) and of the displacement of the geomagnetic and geographic poles (Sojka et al., 1979).

The existence of polar plasma convection has been inferred from electric field measurements from satellites (Caufman and Gurnett, 1982), or by directly measuring the convection with satellite-borne plasma drift measurements (Hanson and Heelis, 1975). Ground based high latitude plasma convection measurements have been conducted during the decade-long measuring campaign of the Chatenika Incoherent Scatter Radar - ISR (Foster, 1983) and looking northward by the Millstone Hill ISR (Evans et al., 1980). The large body of plasma convection data shows that in its simplest form the convection occurs in a two cell pattern. Models of this two cell convection pattern developed by Volland (1975) and improved by Heelis et al. (1982) have been used extensively to model the ionosphere under the influence of the convection (above references). Figure 1 from Heelis et al. (1982) shows the two cell configuration, with antisunward plasma flow across the polar cap, and sunward return flow along the morning and evening flanks of the auroral oval.

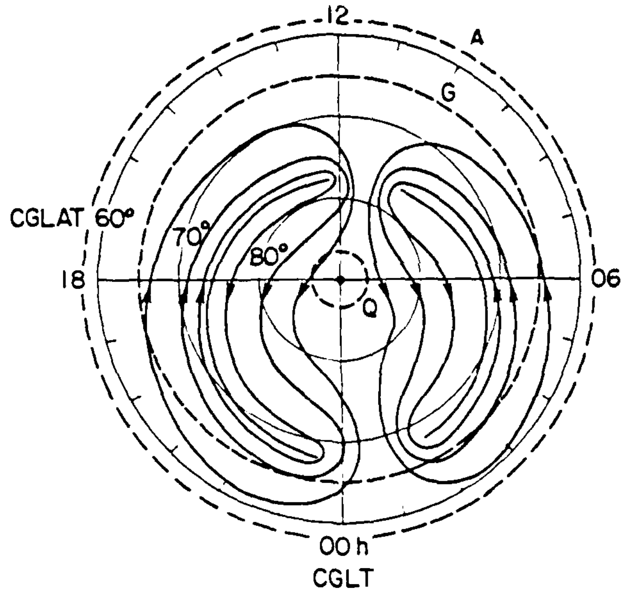


Figure 1. Polar Plasma Convection Pattern (Heelis et al., 1982) in CGL/CGLT coordinate system. The locations of the drift measuring stations Qaanaaq, Goose Bay and Argentia are indicated by dashed circles.

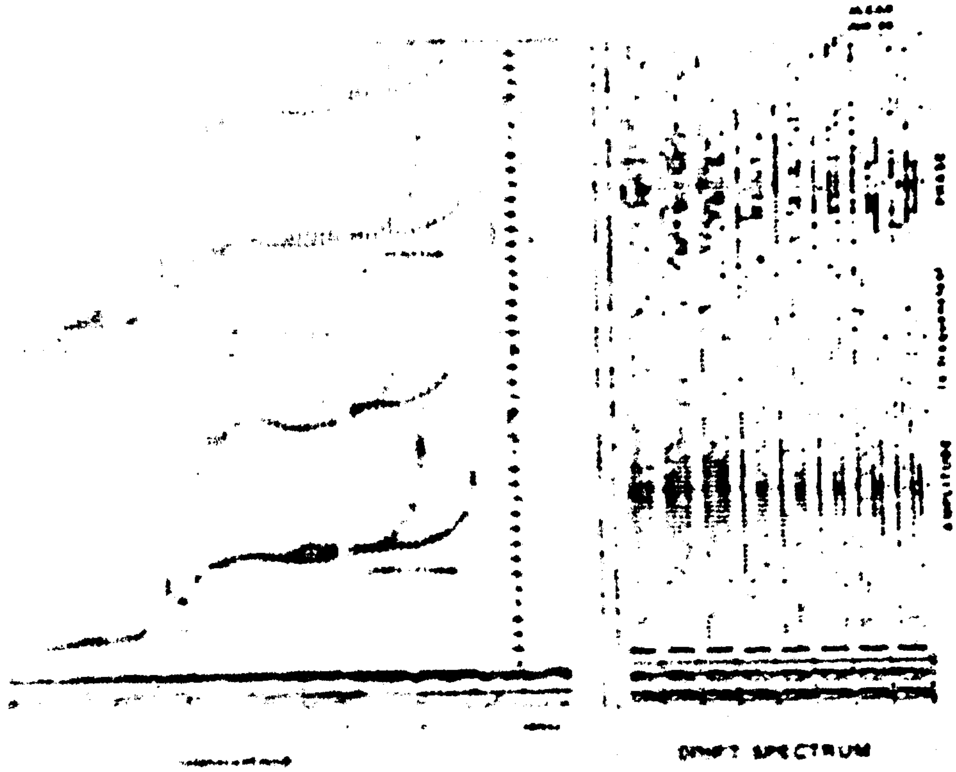
Past observations and modelling efforts have shown that knowledge of the convection pattern is a prerequisite for accurately modelling the ionosphere over the full high latitude region. The two cell pattern occurs most clearly when the Interplanetary Magnetic Field (IMF) has a southward component ($B_Z < 0$), while the exact flow geometry is controlled by B_y (Heelis 1984). For $B_Z > 0$, dusk to dawn polar cap electric fields have been measured, which cause sunward plasma flow across the central polar cap (Burke et al., 1979) and leads to an interpretation of the existence of a four cell convection pattern. Satellite magnetometer measurements (Zanetti et al., 1984) suggest a three or four cell pattern depending of the sign of B_y. Lassen (1979) interpreted the polar cap auroral arcs, observed during magnetically quiet periods, as being the result of a shear between a third central polar cap cell occuring either at the edge of the morning (when $B_y < 0$) or the evening cell (when $B_y > 0$). Recent analysis of DE2 data (Heppner and Maynard, 1987) indicates, that it is possible to explain the data for the full range of B_Z and B_y with a basic two cell pattern. For the $B_Z > 0$ condition this approach results in substantial distortion of the two cells, in order to explain sunward flow in the central polar cap, but the resulting pattern agrees with observations in other regions of the high latitude ionosphere.

In this paper we describe a ground based coherent HF radar (digital ionosonde) technique, which allows continuous, relatively low cost measurement of the plasm convection at selected sites. Early observations (Reinisch et al., 1987) show good agreement between the measurements and the major features of the plasma convection. The analysis presented here indicates, that not only the major features, but also details such as shears and drift reversals in response to quiet magnetic conditions are observed. The measurements suggest that the continuous monitoring of the convection pattern with a ground based technique will be possible.

SPACED ANTENNA DOPPLER DRIFT TECHNIQUE

The drift technique, which has been developed for a digital ionosonde, the Digisonde (Bibl and Reinisch, 1978), is based on a technique using spectral analysis of ionospheric drift data, developed by Pfister (1974 a, b). This technique has been refined for automatic data processing (Dozois, 1983), and is an integrated capability of all modern Digisondes (Reinisch 1986).

The drift measurements are conducted using phase coherent pulse transmission on two HF frequencies, which are selected to sample desired heights in the F-region. These vertically transmitted HF waves illuminate a large area of several hundred kilometers diameter in the F-region; an array of 4 or 7 antennas (depending on the site) deployed in a 100 m baseline triangle receives the signals reflected from the ionosphere (the technique is equally applicable to E-region studies). The individual antennas of the receiving arrary are multiplexed at the pulse repetition rate (200 Hz). The time series received at each of the antennas is Fourier transformed in real time, resulting in four (or seven) complex spectra at the end of each measurement period.



[illegible] ionogram and drift measurements collected during a [illegible] data set is collected every five minutes.

[illegible] ionograms are taken in five minute intervals, [illegible] dynamic environment, while the time be- [illegible] eight drift measurements. Figure 2 shows [illegible] measurements. On the left is the representation of [illegible] information on Doppler/direction/ [illegible] frequency drift spectra. Frequencies se- [illegible] gates were set at 240/290 and 275/285 km, [illegible] fixed.

[illegible] spectrum, with zero Doppler indicated by [illegible] The spectra show two major peaks, one with [illegible] at positive Doppler, but shifting towards zero [illegible] spectra are determined for 20 seconds [illegible] Doppler range ± 32 × 0.05 Hz, or ± 1.6 Hz. [illegible] are typical for the measurements [illegible] shows the phase of each Doppler line; [illegible]

[illegible] spectra determines the angle of [illegible] energy. As a result of this analysis one [illegible] point, or source (Dozois, 1983), [illegible] radial velocity component of the moving [illegible] from all these sources super- [illegible] frequency is given by:

[illegible] source index)

[illegible] Figure 3 is an example of such a [illegible] antenna array's main lobe, a frequency de- [illegible] reflections (±45° half beam width). The [illegible] positive, the numbers negative [illegible] are the result of uniform motion of [illegible] velocity vector v which, in the least- [illegible] frequencies f_i measured at the source locations [illegible] is approximately to the east-north-east.

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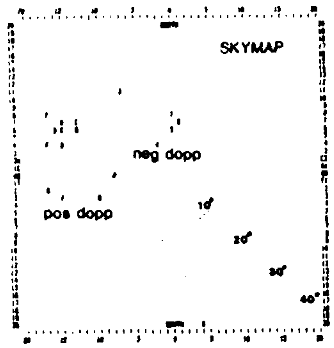
Cross-correlation P of complex Doppler spectrum F from 4 antennas:

$$P_{k\ell} = \sum_{j}\sum_{j'} F_{j\ell}\, F^{*}_{j'\ell}\, \exp -i\, \underline{k}\cdot[\underline{a}_j - \underline{a}_{j'}]$$

ℓ - spectral line
j - antenna
$\underline{a}$ - antenna position

yields angle of arrival of each reflected spectral line.



Least Squares Fit for Drift Velocity V:

$$\epsilon^2 = \frac{\sum_s w_s(\underline{V}\cdot\underline{B}_s - \frac{1}{2}\frac{\Delta f_s}{f}c)^2}{\sum_s w_s}$$

$\underline{B}_s$ - unit position vector of reflector s
Δf_s - Doppler frequency of reflector s
f - sounding frequency
w_s - weighting factor
c - speed of light in vacuo

Figure 3. Drift Skymap showing 12 sources with positive Doppler and 5 sources with negative Doppler.

As will be shown later, the size (or diameter) of the convection pattern and the actual convection velocities are important quantities in modeling the polar ionosphere. Three Digisonde equipped stations, namely Qaanaaq, Greenland (87° CGL), Goose Bay, Labrador (65° CGL) and Argentia, NAS, Newfoundland (57° CGL) provide a first step at defining these parameters, at least for a large part of the day. Their respective locations over a full day are indicated in Figure 1, by dashed circles marked Q (Qaanaaq), G (Goose Bay) and A (Argentia). The figure shows that for the conditions represented by this pattern, Qaanaaq is fully embedded in the anti-sunward flow in the central polar cap, while Goose Bay is under the influence of westward (sunward) flow before midnight, and observes eastward (sunward) flow after midnight. In the example chosen, Argentia would be outside the high latitude convection and would observe mid-latitude co-rotating plasma. Under more active conditions (in response to $B_Z << 0$), the convection pattern expands in diameter, bringing Argentia under its influence for part of the night, and extending the duration, during which Goose Bay observes sunward return flow. Figure 4 shows in a CG direction/CG local time diagram the approximate drift direction changes, which over a 24 hour day would be observed at Qaanaaq (top) and Goose Bay (bottom), assuming the convection pattern shown in Figure 1. The top graph shows the 360° rotation in 24 hours of the anti-sunward drift at Qaanaaq, while the bottom graph shows the westward drift before midnight and the transition to eastward flow through south at/or near midnight CGLT observed at Goose Bay. The coordinate system of Figure 4 has been chosen for the following discussion of the drift observations.

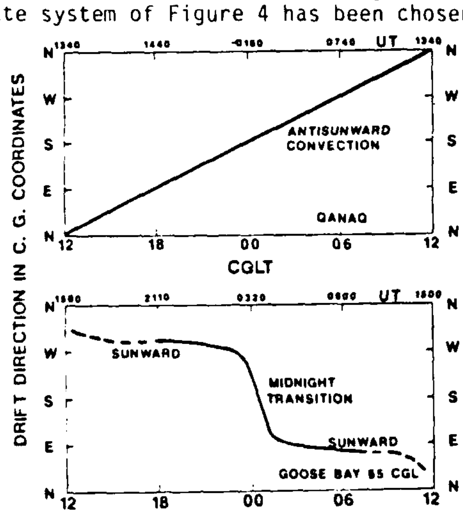


Figure 4. Expected diurnal change of the drift direction (assuming the convection shown in Figure 1) for Qaanaaq and Goose Bay in a CG direction and CG local time coordinate system.

DRIFT MEASUREMENTS

a. Thule - Magnetically Active Period, 1983/1984 Measurements

Several winter measurements campaigns were conducted by the Airborne Ionospheric Observatory, while on the ground at Thule AB, Greenland (86° CGL) to study the structure and dynamics of the polar cap ionosphere. During these measurements the antisunward convection of large non-auroral plasma patches was observed with an All Sky Imaging Photometer - ASIP, (Weber et al., 1984), and the UT dependence of the maximum electron densities in these patches was documented (Buchau et al., 1983). For the campaigns in December 1983, January/February 1984 and March 1985 a four-antenna array was deployed near the aircraft, to provide measurements of the plasma drift independent of the optical observations (the patches observable by the ASIP are generally absent in the 00-12 UT time window).

While the spaced antenna Doppler drift measurements were developed at the AFGL Goose Bay Ionospheric Observatory, the best evidence that this technique actually allows the measurement of plasma drifts was obtained from the initial central polar cap observations (winter 83/84). Figure 5 shows the drift results in the data format discussed in Figure 4, for measurements taken during four disturbed to moderately disturbed days between 30 January and 4 February 1984 (ΣK_p for 30, 31 Jan., 1, 2, 3, 4 Feb was 34, 29-, 23+, 22-, 23, 41+ respectively). The data show predominantely anti-sunward drift (the anti-sunward direction, rotating through 360° in 24 hours is indicated), corroborating coincident optical observation for 3/4 February 1984 (Weber et al., 1986), and earlier reports derived from optical data of antisunward plasma transport under disturbed conditions (Weber et. al., 1984). The observed velocities shown in the top panel of Figure 5 (median velocity and range) fluctuate between 150 and 900 msec^{-1}, well within range of previous satellite measurements and in general agreement with the optical observations. With the confidence in the technique gained from these measurements, permanent digital sounding capabilities were deployed at the Qaanaaq Geophysical Observatory of the Danish Meteorological Institute, in Northern Greenland (87° CGL), and at a suboval station (Argentia, Newfoundland, 58° CGL). With the AFGL Goose Bay Ionospheric Observatory (65° CGL) these station form a meridian chain along approximately 20° East CG Longitude.

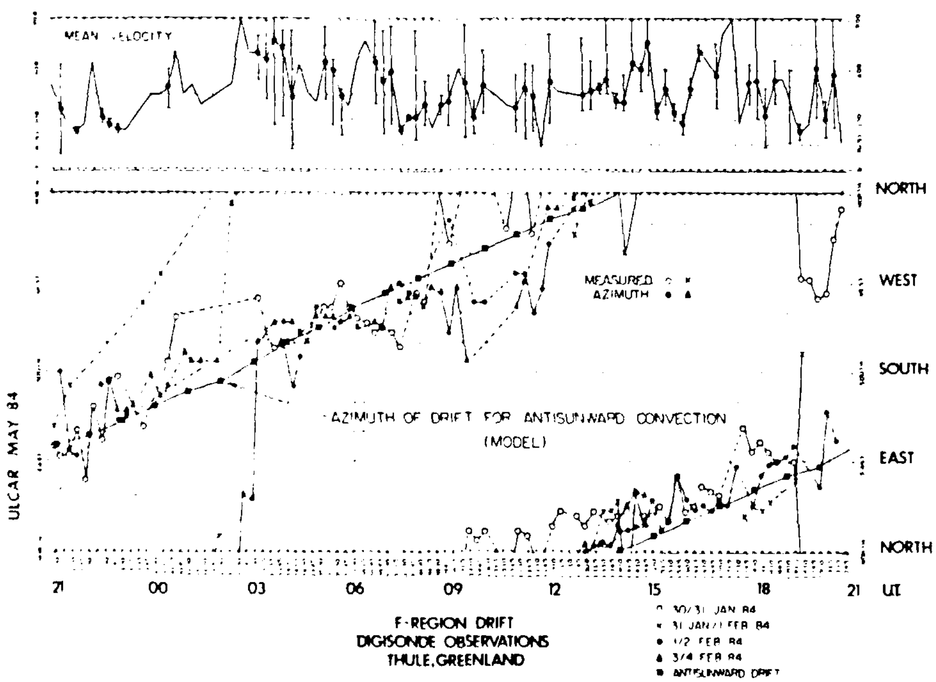


Figure 5. F-region drift direction (bottom) and velocity (top, showing mean velocity and range of observations) taken during four moderately disturbed days in Janurary and February 1984 at Thule AB, Greenland. The antisunward direction is indicated for reference.

b. Thule - Magnetically Quiet Period

The earlier polar cap campaigns had already established that sunaligned polar cap arcs, especially subvisual F-layer arcs, populate the polar cap under magnetically quiet conditions (Weber and

Buchau, 1981, Buchau et al., 1983). Reiff et al. (1978) had shown that current continuity at plasma flow shears requires upward (or downward) Birkeland currents, therefore producing (sub) visual signatures i.e. auroras in the region of upward currents. Conversely Lassen (1979) concluded that polar cap arcs should be plasma shear demarcation lines. The analysis of Sondrestrom ISR data in the context of ASIP arc observations has confirmed this hypothesis (Carlson et al., 1983).

The Thule drift data taken on 9/10 December 1983 cover a nine-hour period at the end of a 27 hour long quiet period (9 December $\Sigma K_p = 5+$), during which subvisual and visual arcs typical for quiet periods were observed, occupying major parts of the sky and drifting from dawn to dusk from 1900 to 2300 UT on 9 December 1983. The concurrent drift measurements are shown in Figure 6, lower half. The drift direction oscillates wildly throughout the three magnetically quite three-hour periods at the beginning of the data sample (K_p is indicated below the abscissa), suggesting the transit of several shear boundaries through the station zenith. As magnetic activity increases, the convection direction becomes more orderly, with a general direction of 30^o to 45^o towards later times from due antisunward. The drift velocities are low (150 - 300 msec^{-1}) during the quiet period, and increase somewhat (150 - 600 msec^{-1}) during the disturbed period.

Also of significance here is the first comparison of drift data with Interplanetary Magentic Field (IMF) data, shown in the top half of Figure 6. The large fluctuations in drift direction, indicating the presence of shears, and the arc observations occur during times when $B_z > 0$, $B_y \approx 0$, and $B_x >> 0$. As B_x decreases and B_y increases with still (strongly) positive B_z, the plasma drift becomes more orderly, but skewed by 60^o to 90^o towards later times from straight antisunward. For the steady $B_z < 0$ conditons from 11 to 21 UT, the flow is steady antisunward (skewed 30^o to later times). As B_z becomes positive again after 21 UT, shears start to dominate again. No clear effects of B_y and B_x on the drift direction (under $B_z < 0$ conditions) can be derived from this short measurement.

Since for the drift analysis the convection is assumed to be uniform across the sky map, which clearly is not the case during the 9 hour period of arc observation, the resulting drift directions and velocities are not meaningful but merely give an indication of the existence of shears. A preliminary attempt to separate skymaps into regions within and on either side of arcs, using ASIP images as a guide, shows evidence of shears. The detailed discussion of this analysis is beyond the scope of this paper.

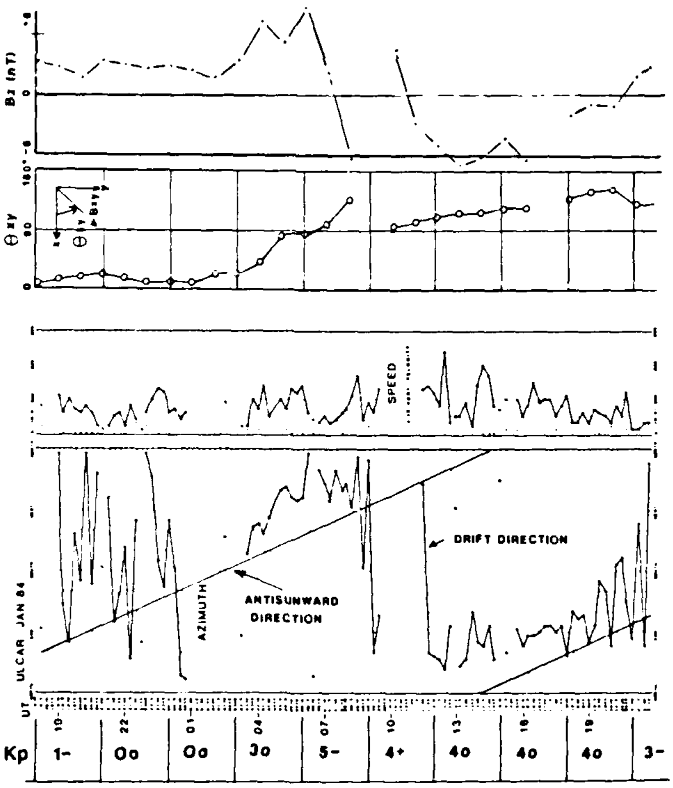


Figure 6. First comparison of F-region drift measurements, taken on 9/10 December 1983 at Thule, and interplanetary magnetic field (IMF) data (for discussion see text). Also shown are the K_p values for the measurement period.

c. Qaanaaq - First Extended Drift Measurements

Drift measurements until early 1986 had been made by mannually selecting frequencies and setting sampling gates, therefore requiring around the clock manning of the Digisonde. Since 1986 this procedure has been automated for all Digisonde 256 stations. The automation is based on the ARTIST trace identification software for the Digisonde (Reinisch and Huang, 1982, Reinisch et al, 1982) residing in an IBM AT microcomputer, which is part of the Digisonde 256. The automatic drift program also resides in the ARTIST computer (a report on this important advance is in preparation). After completing the O-trace identification the program automatically selects appropriate frequencies and sets the gates. Throughout each measurement (between two ionograms) the gates automatically follow the changes of the echo height using a two-gate scheme.

The data (Figure 7) cover a continuous period of almost 6 days of drift measurements, from 29 October to 3 November 1986. A cursory inspection suggests at least for the first four days steady antinsunward drift direction. However, clear deviations are seen for the period 15 - 18 UT on 29 October, and 12 - 16 UT on 1 November. Substantial direction oscillations similar to those discussed in section b and suggesting the presence of shears/arcs are observed, starting 17 UT on 1 November under quiet conditions, continuing more or less unabated through the end of the measurement.

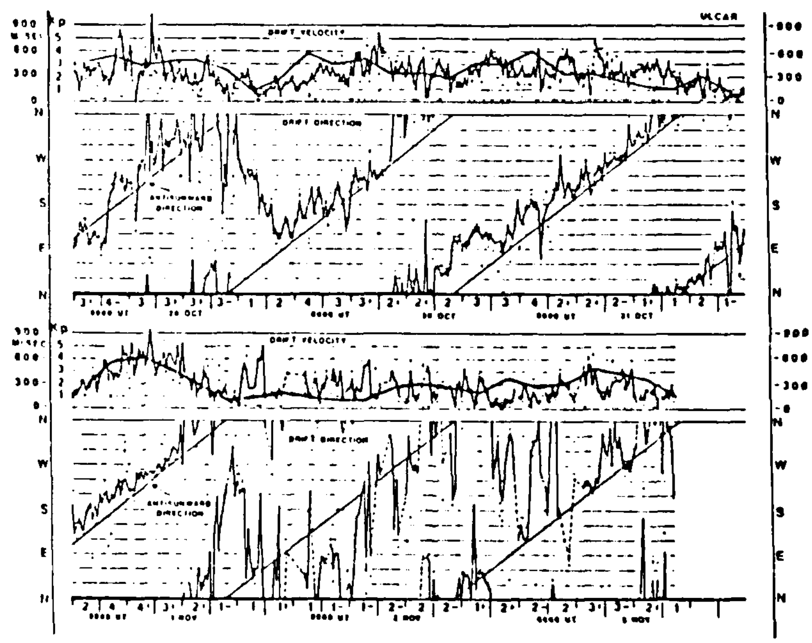


Figure 7. Continuous F-region drift measurements taken at Qaanaaq, Greenland, from 28 October 1986 (21 UT) to 3 November 1986 (15 UT). K_p values are shown between corresponding 3 hour tickmarks. Superimposed on the presentation of the drift velocity is for comparison an analog representation of the K_p time variation.

Along the time axis (abscissa) we have indicated the respective K_p values. A comparison shows that during the more disturbed periods ($K_p > 3$) on 29 October and early 30 October, antisunward convection at velocities greater than 300 msec^{-1} exists. This active period is interrupted by a 3 hour quiet period, ($K_p = 1$) during which the drift turns sunward, in agreement with the previously discussed satellite observation for $B_z > 0$. A second quiet period following a disturbed period with steady antisunward drift started at 12 UT on 1 November 1986 (K_p = 1-). Again rather stable sunward drift is observed. From here to the end of the measurements the magnetic activity remained generally quiet and clear evidence of shears was observed throughout, even though a short period of moderate activity (K_p = 3+, 3-) within this quiet period tended to show a somewhat more antisunward organization of the drift. The only puzzling observations are those taken on 31 October 1986, where inspite of extended rather quiet magnetic conditions the drift is consistently antisunward.

The (horizontal) drift velocities are shown above the respective drift direction panels. Superimposed is the variation of K_p as a function of time in analog presentation (continuous line). While the correlation between drift velocity and K_p is far from convincing, there is evidence, that higher K_p values correlate with higher velocites and lower K_p values with lover velocities (e.g. 21 UT on 31 October to 15 UT on 1 November). The correlation breaks down during the extended period of shear observation (2nd half of 1 November, and all of 2/3 November 1986).

d. Qaanaaq - Drift Measurements Under Sunlit Conditions

A limited set of drift measurements taken at Qaanaaq under fully sunlit conditions corroborates the observations in darkness. Drift measurements conducted at Qaanaaq on 29/30/31 July 1986 (data not presented here) show consistent antisunward convection with velocities between 150 to 450 $msec^{-1}$ for the prevailing moderately active conditions (ΣK_p = 26-, 20, 20+, respectively, or $K_p > 2$). For measurements taken under magnetically quiet conditions, in full sunlight on 8 April 1986 (Figure 8), with K_p = 1-, 1+, 1+, 2+ for the period of measurements (00 to 12 UT on 8 April 1986 or 22 to 09 CGLT) the convection is initially sunward, as expected for quiet or (inferred) $B_z > 0$ conditions. As magnetic activity increases through K_p = 1+ to 2+, the drift direction turns antisunward, skewed to later times by 30^o to 60^o.

It is clear from the set of Qaanaaq observations discussed so far, that K_p is at best a coarse ordering parameter of the drift observations, especially since $B_z > 0$ does not necessarily correspond to quiet magnetic conditions, as Figure 6 indicates, where a jump from B_z = +3 nT to + 6 nT corresponds to a change in K_p from 0_o to 3_o, contrary to expectation of continued quiet conditions.

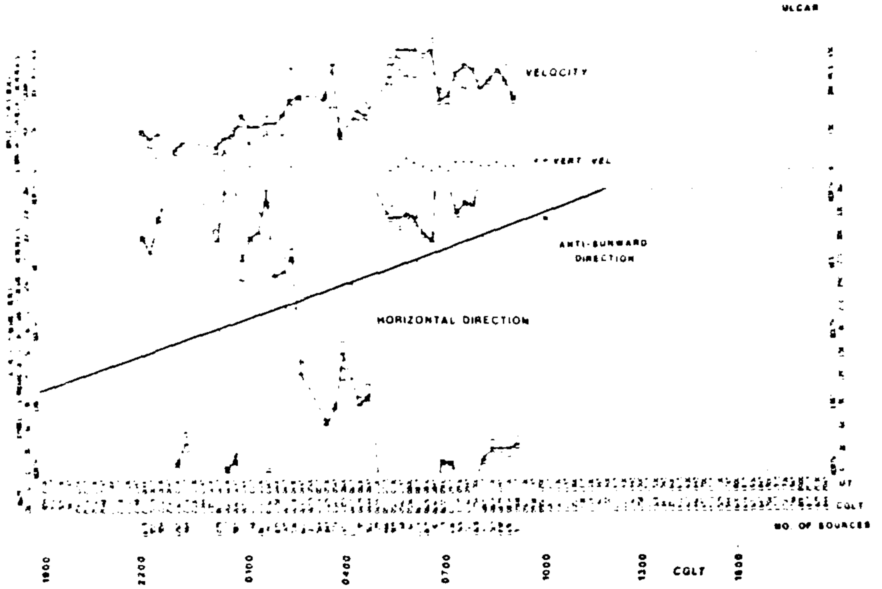


Figure 8. F-region drift observations from Qaanaaq, Greenland, take on 7/8 April 1986 taken under magnetically quiet conditions.

e. Goose Bay, Labrador Observations

As Figures 1 and 4 indicate, Goose Bay for the selected average convection pattern is under the influence of the sunward return plasma flow for ± six hours around CG midnight, with westerly flow expected prior to and easterly flow past midnight. At other times Goose Bay is under the influence of corotating plasma, measuring the lower drift velocities of the mid latitude ionosphere (Kent and Wright, 1968).

A typical example of Goose Bay drift measurements are the data from 14/15 January 1983 (Figure 9), taken under moderately disturbed conditions (ΣK_p = 16+ and 28+ for 14 and 15 January, respectively). The convection in the pre-midnight sector is consistent and towards the west (sunward). The convection switches towards the east, moving smoothly through the expected southerly direction. A valid measurement indicating a quick switch back to westerly drift at 02 AST interrupts the smooth transition towards easterly flow. It should be noted that the velocities are considerably lower than those observed in the polar cap, with premidnight velocities measured at 250 $msec^{-1}$, and past midnight velocities at 100 $msec^{-1}$.

A substantial data set (38 full or partial days) collected between 1981 and 1985 during the development of the drift technique is not of the same quality and consistency as the polar cap data set. This is due to a.) manual data collection, b.) interference with the F-layer measurements by blanketing Es during magnetically disturbed periods, and c.) lack of solid echoes under low foF2 (trough) conditions, coinciding with quiet magnetic activity and small oval and convection-pattern diameter. But throughout the measurement set, consistent *premidnight westward/postmidnight eastward* drift direction is observed. Short 15 minutes to one hour drift reversals are however not uncommon, especially in the post-midnight sector. The drift velocities shown in Figure 9 are typical for the higher velocities observed in the full data set, however these higher velocities may be observed after midnight, as well as before. Low velocities (< 50 $msec^{-1}$) are more routinely observed, and are more typical for times away from midnight. A thorough analysis of the data in the context of available IMF data is planned, focusing specifically on the exact time of midnight switch, the relation of shortlived drift reversal to IMF conditions, and the daily duration of measurements of distinct convection conditions. This latter measurement may provide information on the diameter of the convection pattern.

f. Argentia NAS, Newfoundland, Observations

Our southernmost measurements have been taken at Argentia NAS (57° CGL). Here a Digisonde 256 has been operated to support the East Coast OTH-B Radar and AWS, unattended since summer of 1985 with occasional visits by a local engineer for data tape changes or to reset the ARTIST computer after a power outage. The Digisonde is controlled remotely via a dial-up telephone capability, and drift measurements in the automatic mode can also be innitiated and supervised remotely.

Under quiet and moderate magnetic conditions, Argentia is likely to remain under the influence of the corrotating ionosphere, at or south of the plasma pause (Figure 1). For low magnetic activity (ΣK_p < 25), observed drift directions to date do not exhibit any recognizable patterns. Measured velocities are in the 50 to 150 $msec^{-1}$ range. Figure 10, however provides evidence that for the magnetically active period of 9 to 12 February 1986 the diameter of the convection pattern expands to bring Argentia into the area of sunward return flow. For this station, magnetic midnight occurs at 04 UT.

For each of the 3 hour periods marked on the time axes of the three panels, the K_p values are as follows:

9/10 February panel, starting at 18 UT: 5+, 4o, 3+, 2o, 1o, 2o, 1o, 2-
10/11 February panel, starting at 18 UT: 3o, 3+, 2+, 3-, 2-, 3-, 4o, 5-
11/12 February panel, starting at 18 UT: 4-, 4+, 4+, 3+, (ending 06 UT)

An inspection of Figure 10 in the context of the listed magnetic activity shows evidence for sunward (westward) drift at 75 to 150 $msec^{-1}$ prior to local magnetic midnight, with occasional velocity increases to 300 $msec^{-1}$ for $K_p > 4$. The data on 10/11 February show for less active conditions ($2 < K_p < 4-$) a switch between sunward (westward) and eastward flow prior to magnetic midnight, suggestive of a sequence of contractions and expansions of the convection patttern, alternatingly shifting the convection pattern or the co-rotating plasma over the station. With regard to post-midnight data, the 11 February measurements show steady sunward (eastward) flow with velocities between 75 and 150 m sec^{-1} for enhanced activity, while the morning data on 10 February show low speeds (~ 50 m sec^{-1}) and less well organized drift direction under quiet condition.

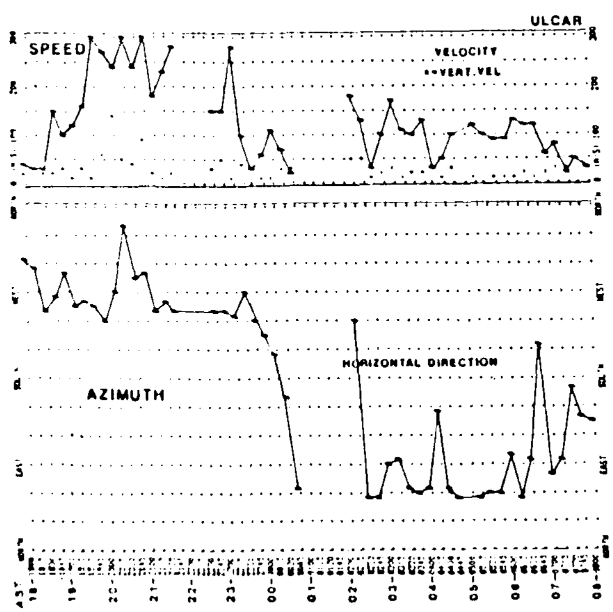


Figure 9. F-region drift observations at Goose Bay on 14/15 Janurary 1983 show the expected switch of the sunward convection return flow from westward to eastward near midnight.

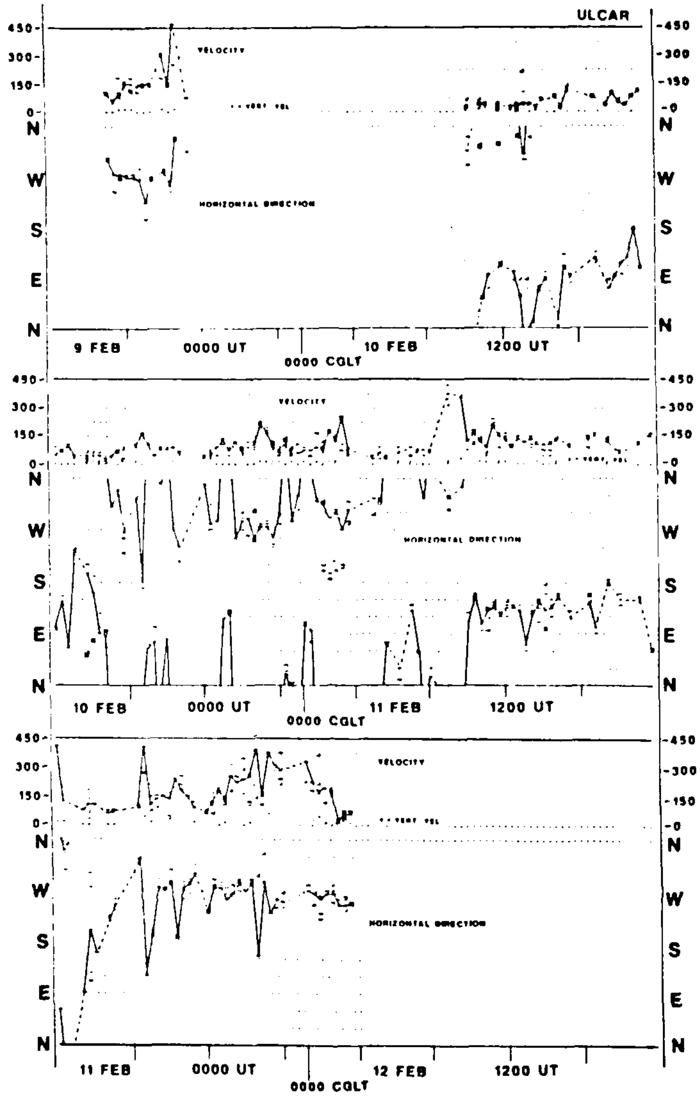


Figure 10. F-region drift observations at Argentia, Newfoundland on 9-12 February 1986 during moderately disturbed conditions.

DISCUSSION OF DRIFT MEASUREMENTS

A newly developed ground based technique to measure plasma drift at high latitudes has produced data, which essentially agree with previous observations from satellites, and from incoherent scatter radars:

a. In the central polar cap we find antisunward convection for $B_z < 0$, or for $K_p > 3$.
b. During quiet conditions, especially when following an active period, sunward convection is observed in the polar cap.
c. For extended quiet periods and $B_z > 0$, shear conditions typical for the sunaligned polar cap arcs are observed.
d. At oval/suboval latitudes we observe sunward flow (westerly before midnight and easterly after midnight), under magretically disturbed conditions.
e. Argentia (57° CGL), and to some extent also Goose Bay (65° CGL) show random switches from westerly to easterly and back under more moderate ($K_p < 2$) conditions, suggesting, that the station(s) move alternatingly under the influence of convecting or co-rotating plasmas.

Important parameters of the plasma convection, namely the antisunward convection velocity and the approximate diameter of the convection pattern can be estimated for at least part of the day.

DRIFT MEASUREMENTS AND MODELING OF THE HIGH LATITUDE IONOSPHERE

The importance of polar convection measurements lies in the relation of the convection pattern and the convection velocities (magnitude and direction) to the condition of the Interplanetary Magnetic Field (IMF), which controls the polar cap potential Φ_{pc}, through the solar wind-magnetospheric energy coupling function ε (Akasofu, 1981, 1984, Reiff et al., 1981). Ionospheric modeling has shown that polar cap and auroral oval ionization and the development of the F-layer trough to the south of the oval are controlled (location and intensity) by the magnitude of the polar cap potential, and therefore related to the polar cap convection velocities. We expect that future studies will lead to the development of either ε (IMF) or Φ_{pc} (IMF) dependent high latitude ionospheric models which can, in the absence of measurements for either parameter, be driven by polar cap plasma convection measurements.

As an example, we have investigated the effects of B_z on the electron densities in the central polar cap. Using solar production for the time dependent modeling of the ionization buildup (and decay) within a flux tube (for details see Anderson et al., 1987, this volume) as it travels along a trajectory described by a B_z dependent convection model (Heelis, 1984), the time history of the maximum electron density (N max) in flux tubes which cross Thule at selected times has been computed. The effects due to particle precipitation have been neglected, since the contribution to Nmax by the cusp precipitation is small (~2.4×10^4 cm^{-3}) due to the high cusp traversing velocities of between 500 to 1000 msec^{-1}, (Knudsen et al., 1977).

Figure 11 shows the trajectories of the flux tubes which cross over Thule at 1400 CGLT (■) and 2000 CGLT (▲), in a CGL/CGLT coordinate system for $B_z < 0$ and $B_z \approx 0$ condition, respectively. Other trajectories are also shown, but are not discussed further. The location of the flux tubes are indicated in Δt = 30 min increments; the starting point of each trajectory is six hours before the time of crossing over Thule. The figure illustrates the large difference in convection pattern diameter and in the convection velocities (ν is proportional to the distance between half hour marks) for the two selected B_z conditions. Of special importance is the exposure of the relevant flux tubes to solar UV. The relation of the flux tube trajectories to the terminator for December is shown in Figure 12. For $B_z < 0$, the flux tubes arriving at Thule at 1400 and 2000 CGLT, spend at least 4.5 hours in sunlight, much of that time at solar zenith angels of < 80°. Due to the high convection velocities, it takes the flux tubes only between 15 and 30 minutes to reach Thule, after crossing the terminator into darkness, a time short compared to the recombination time of the F-layer ionization. In contrast, for $B_z \approx 0$, the respective flux tubes experience sunlight for only 1.5 to 3.5 hours, and only with solar zenith angles of > 85°. As a consequence of the low convection velocities, it takes the flux tubes between 45 minutes and 1.5 hours to move from the terminator to Thule. Figure 13 shows the results of the modeling of the ionization time histories, as the flux tubes travel along the respective trajectories. The results indicate a difference of a factor 3 (2) in N max for ionization observed at Thule at 14 (20) CGLT, for the two considered conditions, $B_z = 0$ and $B_z < 0$, respectively.

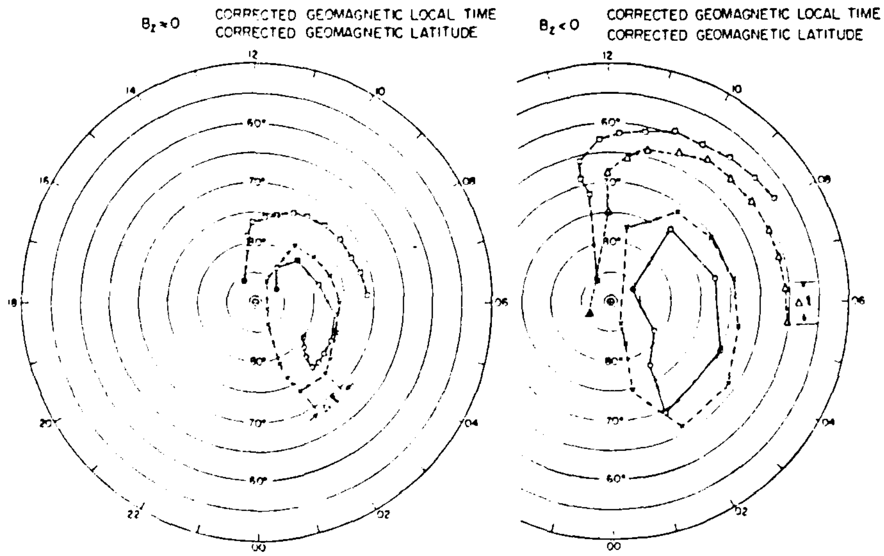


Figure 11. Convection trajectories for flux tubes crossing Thule at 02 CGLT (X), 08 CGLT (○), 14 CGLT (□) and 20 CGLT (△), for $B_z < 0$ and $B_z \approx 0$ conditions, in CGL/CGLT coordindates (Δt = 30 min). The 20 CGLT trajectory has not been shown in the left diagram, for clarity, since it follows closely the 14 CGLT trajectory.

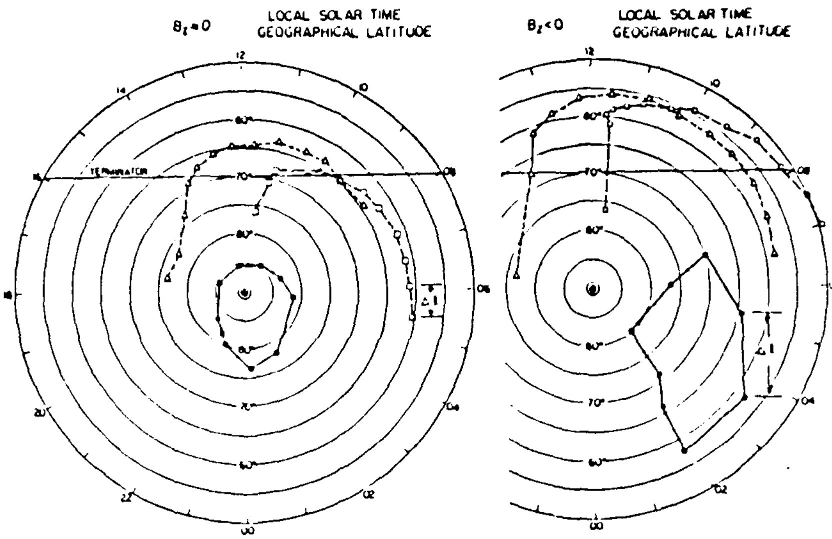


Figure 12. The same convection trajectories as in Figure 11, here in geographic latitude, local solar time coordinates. Also shown is the terminator (χ = 90^0).

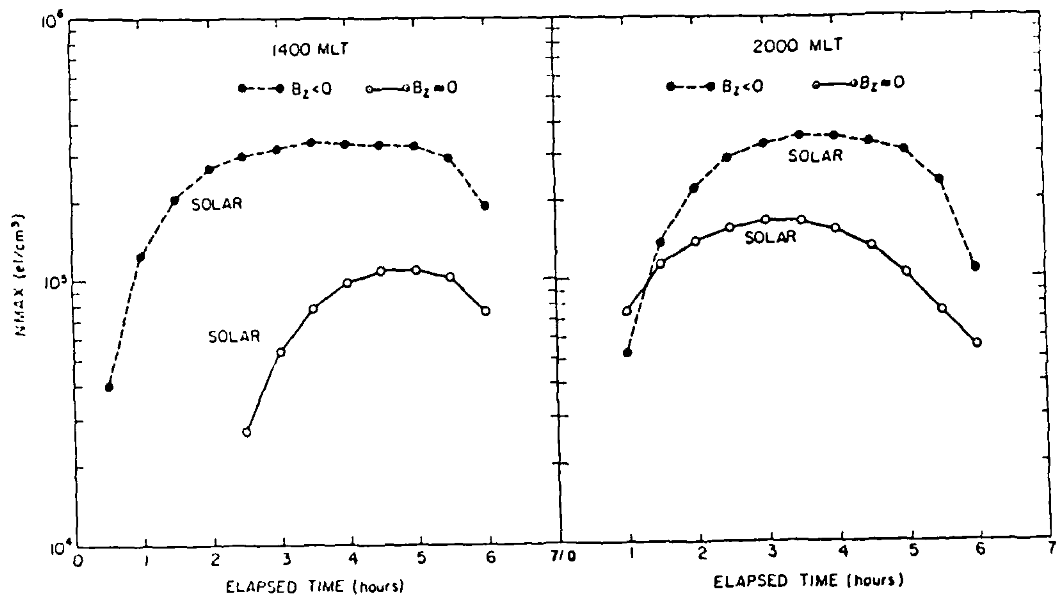


Figure 13. Calculated Nmax values along convection trajectories crossing Thule at 14 and 20 CGLT.

CONCLUSION

It has been shown, that a chain of Digisondes, using a newly developed automatic drift capability, is able to measure important parameters of the polar convection patern, such as magnitude and direction of the polar cap convection and the approximate diameter of the convection pattern. The importance of this new technique is that it permits affordable, continuous plasma drift measurements. With well considered additions to the current chain, these measurements can provide sufficient information to lead to real time definition/monitoring of the polar convection pattern, or could as a minimum provide the time dependence and spatial extension for the sporadic, but large scale transpolar satellite drift measurements.

The dependence of the polar cap, oval and trough F-layers on the magnitude and structure of the polar cap potential has been well established through modeling (see discussion in the introduction). Since the drift velocity in the polar cap is directly related to the polar cap electric field (polar cap potential), this quantity is considered a likely candidate for a driver of future physical or empirical high latitude ionosphere models. A model study sketched out in this paper shows, that for different B_Z conditions ($B_Z < 0$ and $B_Z \approx 0$), the drastically different convection patterns and velocities (Heelis, 1982) result in substantial differences in the plasma densities in the polar cap. This is in good agreement with observations. We will persue the outlined strategy in the hope to find in the polar cap plasma drift a new, measureable parameter to drive future high latitude ionosphere models.

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