Three-way validation of the Rankin Inlet PolarDARN radar velocity measurements

A. V. Koustov,1 J.-P. St.-Maurice,1 G. J. Sofko,1 D. Andre,1 J. W. MacDougall,2 M. R. Hairston,3 R. A. Fiori,1,4 and E. E. Kadochnikov1

Received 28 October 2008; revised 23 April 2009; accepted 28 April 2009; published 8 July 2009.

[1] The newly installed Rankin Inlet HF radar is very similar to other SuperDARN radars but uses a new type of antennae with its back lobe overlooking the auroral zone where ionospheric irregularities occur very frequently. Despite the fact that a special screen has been installed, there is a chance to receive echoes from the back/side lobe, which can affect the observed velocities. In this study, Rankin Inlet HF radar (RKN) velocities are compared with measurements from three independent instruments: the HF radar in Saskatoon, the CADI ionosonde at Resolute Bay, and drift meters on board DMSP satellites passing the RKN field of view. Although data spread and the degree of agreement vary from one comparison to another, the overall conclusion is that even if echoes are received from the back/side lobe, their effect is statistically insignificant. RKN velocities were found to be comparable to those inferred from other instrument outputs; the slope of the best fit line and the correlation coefficient can be as high as 0.7 and 0.8, respectively. The majority of inconsistencies are related to the difference in the spatial and temporal resolutions of the instruments involved in the comparison.


1. Introduction

[2] The SuperDARN network of HF radars was introduced to monitor the global-scale plasma convection pattern [Chisham et al., 2007] by measuring the Doppler velocity of echoes coming from the high-latitude F region (~300 km). It is believed that F region irregularities (responsible for the HF echoes) move with the bulk plasma flow and the Doppler velocity of echoes measured in each range gate is the cosine component of the \( E \times B \) plasma drift. To build a global-scale convection map, data from individual radars are either merged by considering two velocities at beam intersections (merge technique), or binned into a uniformly distributed grid and processed to fit a model distribution using a least squares minimization between the modeled and measured velocities (Potential Fit technique).

[3] The SuperDARN method assumes that each HF radar produces a high-quality measurement of the \( E \times B \) drift component in each range gate. The question of how accurately these measurements reflect the true plasma flow is not widely discussed. This lack of the discussion is certainly due to the fact that there are no instruments for routine comparisons with SuperDARN data. Incoherent scatter radars (ISRs) are believed to be a very good instruments for such a comparison; however, despite long run times over years, common data sets are limited [e.g., Ruohoniemi et al., 1987; Davies et al., 2000; Xu et al., 2001]. Similar difficulty exists for the SuperDARN data comparison with ion drift measurements performed on board the DMSP satellites [Drayton et al., 2005] and ground-based ionosondes [Grant et al., 1995].

[4] There are, however, reasons to be cautious about the SuperDARN velocity measurements. Among them are technical features of individual radars, including the possibility of echo reception from the antennae back/side lobe. Most of the SuperDARN radars have poleward-
oriented boresights and ionospheric echoes are not expected from the back lobe as irregularities at midlatitudes are much less frequent and less intense than they are at auroral zone latitudes. However, several SuperDARN radars such as the Stokkseyri, King Salmon, Syowa-East and Unwin radars, have azimuthally oriented boresights and these radars are more vulnerable to the effect of back lobe contamination as their back lobes overlook the auroral oval ionosphere. In addition, it has been known for years that strong ground scatter, which is characterized by low velocity, regularly comes from the back lobe [Milan et al., 1997]. Arnold et al. [2003] found that short-range Hanksalmi meteor echoes had velocity magnitudes a factor of 2 smaller than the expected neutral wind velocity measured by a concurrently operating MF radar. Back lobe signal contamination was suggested as the reason for discrepancy.

In 2006, the U of Saskatchewan (Canada) installed a new SuperDARN-class radar at Rankin Inlet (RKN), Nunavut (62.8°N, 266.9°E, MLAT = 73.2°). In 2007, a partner radar was installed at Inuvik, North West Territories (68.4°N, 226.5°E, MLAT = 71.2°). The pair is termed PolarDARN. The radars are located at high magnetic latitudes to monitor convection within the polar cap. For both these radars, the effect of the back/side lobe echo reception can be even more significant than for the azimuthally looking auroral zone radars. To mitigate this potential problem, a special screen was installed behind each radar antennae of the PolarDARN pair. Over the first year of the Rankin (RKN) radar operation obvious signatures of sidelobe effects have not been noticed, however, the question as to whether or not the effect is completely eliminated still remains.

This study compares RKN F region velocities with velocity measurements by three independent instruments, the SuperDARN Saskatoon (SAS) radar, the CADI ionosonde at Resolute Bay and ion-drift meters on board DMSP satellites, with the primary goal of validating the RKN radar data. The secondary goal of this three-way velocity comparison is to assess the degree of agreement between the outputs of these instruments as they are used for research in space physics. One month of continuous operation has been considered, October 2006; during this month reasonable amount of RKN data was collected and the coverage with other instruments was also significant.

2. Geometry of Observations

Figure 1 shows the geometry of observations. The fields of view (FoVs) of the SAS and RKN radars is shown for ranges of 405–3200 km and 405–2800 km, respectively. Range gate marks of 15, 25, 35, 45, and 55 are shown for ease of viewing. The dotted line indicates the footprints of DMSP F13 for day 275. For Day 280, actual DMSP measurements of the cross-track ion drift are shown.
avoid ground-scatter contamination cases) and spectral width was positive and less than 500 m/s, similar to Drayton et al. [2005].

[8] Also shown in Figure 1 is the location of the CADI ionosonde (diamond) at Resolute Bay, Nunavut, Canada (74.7°N, 265.0°E, MLAT = 83.5°). This is about 1350 km away from RKN (range gate 27 of beam 5). CADI estimates a convection vector (thick stick in Figure 1 as an example) by collecting signals from the scatterers in the F region near the zenith [e.g., Grant et al., 1995]. To have a credible comparison with CADI, the RKN velocity is evaluated for a comparable area; shading in Figure 1 reflects that part of the ionosphere over which the RKN velocity was estimated for the CADI-RKN comparison. More specifically, the RKN velocity was assumed to be the median value of the radar measurements for beams 4, 5 and 6 and range gates between 24 and 30. Since the RKN velocity is obtained roughly along one direction, the CADI vector was projected onto the direction of RKN beam 5.

[9] Finally, Figure 1 shows footprints of two DMSP satellite passes over the PolarDARN FoV. Two types of comparisons between RKN and DMSP data can be made: line-of-sight comparison and projection comparison. The footprints shown are convenient for the first type of the comparison. On Day 280 (7 October, ~2220 UT), satellite F13 crossed the RKN FoV passing the vicinity of Resolute Bay. One can directly compare the observed radar velocity (along the direction of shading) and the DMSP cross-track ion drift, vectors, similar to Drayton et al. [2005]. At the western part of the RKN FoV, the satellite path is almost aligned with RKN beam 0 (shading) and radar data in this beam can be directly compared with the along the track component of the ion drift. The DMSP footprint alignment with RKN beam 0 is much better for another satellite path, DMSP F13 on Day 275 (2 October, ~2330 UT). Consideration of the data for October 2006 showed, however, that the amount of joint RKN-DMSP points is not significant to draw a definitive conclusion. For this reason, we present in this study results of the projection comparison which may be performed in more central beams of the radar; here the full vector of the ion drift measured by DMSP was projected onto the direction of a closest radar beam, similar to Xu et al. [2008].

3. Saskatoon-Rankin HF Radar Velocities

[10] We first consider RKN and SAS joint observations. Ideally, one would want to compare data in individual range gates for the radars. Unfortunately, this is impossible as the SAS radar is located ~1500 km southwest of the RKN radar so that at typical ranges of common SAS-RKN echoes, the width of the SAS beam is of the order of 250 km while the width of the RKN radar beam is only ~100 km. For this reason, every SAS radar velocity measured in a certain gate was associated with several (typically 3 or 4, depending on the range and echo availability) RKN velocities measured at an appropriate range and in all beams whose centers were located within the selected gate of the SAS radar. To characterize the set of RKN velocities, the median value was selected for each range of the comparison.

[11] Selection of “common” gates is not enough for a proper comparison since the radar beams do not coincide ideally. In this study, we consider data only for those beams whose azimuthal difference is less than 10°. One can realize from Figure 1 that this is only possible in the most clockwise RKN radar beams so that the comparison is biased toward this portion of the FoV.

[12] There is also a difference in the timing of measurements, as we consider data collected during the standard scanning mode of operation. Although each radar scan starts at the beginning of every second minute (or every minute for the fast mode scanning), the SAS radar steers the beam clockwise while the RKN radar steers the beam counterclockwise. As a result, there is some time difference between measurements for almost coinciding beams, for example RKN beam 15 and SAS beam 8 as shown in Figure 1. Generally, the maximum time separation between the extreme beam positions could be as large as 2 min (or 1 min for the fast scan mode, the duration of a scan), but for the beam positions considered, the time separation is somewhat smaller. We consider this time separation to be insignificant as a large number of joint measurements are investigated and the impact of the effect should be greatly reduced.

[13] Two kinds of comparison have been performed. The first is the gate-by-gate comparison (with a caveat that the RKN data were actually for a set of gates, as explained above). The second comparison is performed at the uniformly distributed grid points in which the velocities are binned for the Potential Fit approach.

[14] To identify common RKN-SAS data in the gate-by-gate comparison, an algorithm has been developed that allowed one to find, for a given SAS gate, all RKN radar gates for which there were F region echoes (for ranges gates above 10) and the RKN beam azimuthal separation from the orientation of the SAS beam was less than 10°. Data for October 2006 were first searched manually to identify potential events, and then processed by a computer.

[15] One would generally expect enormous amounts of data to be collected as each radar measures velocity in many beam positions and at ~50 radar gates. In reality, because of imposed limitations on beam orientation and variable quality of propagation conditions, the common echo occurrence is not large. In October 2006, 3846 common points were found.
In the second approach, the RKN and SAS radar velocities at common grid points were selected; these are simultaneous measurements within the concept of the Potential Fit. The only restriction was that points correspond to radar beams that have azimuthal differences of less than $10^\circ$ and that RKN radar gates are above 10, to match the criteria for data selection in the first approach. Since data averaging over a number of radar gates is involved in the Potential Fit approach, the number of points for the second comparison is dramatically reduced; only 517 joint points were found for the same periods as in the first approach.

Figure 2a shows the RKN velocity versus the SAS velocity (first approach) in the form of a contour plot. Also shown is a line indicating the best linear fit to the data (dashed line). The contour lines in Figure 2 reflect the number of measurements in each location of the 2-D plot, with the top contour indicating the most frequently occurring outcome of the measurements. The bisector represents the line of ideal coincidence between the data. One can see that the majority of points are located around this line so that the overall agreement between the SAS and RKN data is reasonable. One can notice that the contours have “tongues” stretching along vertical and horizontal axes. These data correspond to RKN and SAS observations strongly affected by the ground scatter. These data should not have been passed the Potential Fit procedures and included into a comparison, but the currently existing SuperDARN software fails to reject them as the velocity magnitudes are $>50$ m/s which is well above the typical velocities of the ground-scattered echoes. Some aspects of this issue have been recently discussed by Ponomarenko et al. [2008].

In Figure 2a, there is significant number of points for which the polarity of echoes is opposite. For these points, the velocity magnitudes were not large. We found that the different polarities occurred in $\sim29\%$ of cases. For data with the same polarity, velocities differed in magnitude by a factor 2 or less in approximately 41% of cases.

Figure 2b shows the RKN velocity versus the SAS velocity for common grid points (second approach, as described above), again in the form of a contour plot. Also shown is a line of the best linear fit (dashed line). In this case, the agreement is much better. The “tongues” corresponding to the ground scatter contamination are almost disappeared and the line of the best linear fit is closer to the bisector of ideal correspondence. We estimate that the velocity differed in magnitude by a factor 2 or less in approximately 76% of cases and had different polarities in only 14% of cases.

4. Rankin Radar-CADI Ionosonde Comparison

Our second RKN comparison is with measurements made by the Resolute Bay CADI ionosonde. It should be noted that the quality of $E \times B$ estimates with ionosondes is an issue on its own [e.g., Koustov et al., 2007], and consideration of joint SuperDARN-CADI data is important for both instruments. Specifically Resolute Bay CADI convection measurements have been recently compared with concurrent DMSP data and agreement was found to be reasonable [Koustov et al., 2007]. This was certainly an encouraging circumstance at the beginning of the present work.

To make CADI-RKN comparison credible, some smoothing of both RKN and CADI data is needed. This is because CADI data are collected over a short interval of $\sim1.5$ s every 30 s while the RKN radar measures the velocity near the RES zenith (beam 5) over 7 s (or 3 s) roughly at the moment corresponding to the one third
mark of a 2 min (or 1 min) interval (beams ~5). Also, raw data showed more variability for CADI (for limited number of events in October 2006), and for this reason it has been decided to associate every RKN velocity (typically one number for every 2 min) with the median value of the CADI velocity over 5 values centered at the RKN time of measurement. This would mean that the time interval of the CADI measurement (5 × 30 = 150 s) covers the entire period during which the RKN radar reported one velocity value.

[22] Another issue is that CADI collects signals from the entire sky, although typically the strongest echoes are received at not more than ~20°–30° off the zenith. This means that spatial averaging of RKN data is needed because one radar gate spans only 45 km. To make collecting areas of the instruments comparable, we selected the RKN velocity as the median value of measurements in each scan over radar beams 4, 5 and 6 and range gates 24–30 (Rankin location corresponds to the range gate 27). The RKN collecting area is depicted in Figure 1, and one can see that the radar averaging is not excessively large.

[23] For October 2006, 3791 common points were found. This is significant because CADI had periods of poor signal (we considered only those measurements for which a sky map had at least 20 individual signals to process), there were periods of E region echo contamination and, finally, the RKN echo occurrence over RES is not great (we also restricted to cases for which more than 10 individual measurements existed for each scan).

[24] Figure 3 presents the RKN velocity versus the CADI velocity in the form of a contour plot with a best linear fit line (dashed line), a format similar to the one in Figure 2. The alignment with the bisector of ideal agreement is much better in this case. We estimate that the velocities differed in magnitude by a factor 2 or less in approximately 61% of cases and different polarities occurred in only 15% of cases.

5. Rankin Radar-DMSP Comparison

[25] Now we consider joint RKN-DMSP observations. The DMSP satellites are on a circular, polar orbit. They cross the RKN radar FoV in certain directions and at certain ranges, as illustrated in Figure 1. However, since the RKN radar echoes are infrequent at ranges greater than ~1200 km, not every pass is useful for comparison. To find common events, DMSP passes over the RKN FoV were identified with both satellite and radar data being of good quality, for every day in October 2006. Typically one-two passes were available per day. The manually selected events were then processed by a computer by making proper mapping of the DMSP trajectories and finding the true directions of the along-track and cross-track components of the ion drift. We used 4-s averages of the raw DMSP velocities. Only DMSP points having a quality tag of 1 (measurements are reliable) were considered [Drayton et al., 2005; Kihn et al., 2006].

[26] To compare DMSP and RKN data, the radar l-o-s velocity and the projection of the DMSP vector onto an appropriate radar beam for measurements in close vicinity of an appropriate radar gate were considered. The maximum temporal difference and the spatial separation between a radar gate and a DMSP measurement were selected to be 2 min and 55 km, respectively, consistent with comparisons by Xu et al. [2008] and comparable with the criteria adopted for CADI-RKN comparison of the previous section. In addition, since DMSP measurements have ~30 km resolution, the satellite data were averaged over all points that satisfied the above criteria to be close, both spatially and temporally, to a specific radar gate/measurement. Overall 187 joint points were found.

[27] Figure 4 presents results of the comparison in the form of a contour plot. The dashed line indicates the best linear fit to the data. For this plot, the DMSP velocities were decreased by 11% to take into account the effect of E × B magnitude decrease with the height. One can certainly recognize clear stretching of the contours along the bisector of ideal agreement. Overall, the RKN observations underestimate the DMSP magnitudes. We found that the velocity differed in magnitude by a factor 2 or less in approximately 58% of
cases and different velocity polarities occurred in 14% of cases.

6. Discussion and Conclusions

All three comparisons showed that the RKN velocity is statistically consistent with measurements of each of the complementary instruments. There were seldom occasions (~15% of cases) when the velocities were of opposite polarity; some of these cases may be interpreted as back lobe contamination of an ionospheric signal. However, overall one can conclude that the echo reception from the side/back lobe, the main concern after the RKN radar started operation, is not a significant effect influencing the quality of the RKN data supplied for the production of global convection maps.

The contour lines for the comparisons presented in Figures 2–4 exhibit linear trends with variable spread and degree of alignment with the bisector. To give a quantitative sense of the quality of the RKN data supplied for the production of global convection maps.

The contour lines for the comparisons presented in Figures 2–4 exhibit linear trends with variable spread and degree of alignment with the bisector. To give a quantitative sense of the quality of the RKN velocity and the velocity measured by a complimentary instrument we applied linear fit lines to the data, see dashed lines in Figures 2–4. Table 1 gives parameters of the fits. Table 1 also gives the standard deviation of points from the best fit linear line to characterize the data spread. We also report that typical errors of measurements were ~10–50 m/s for the SuperDARN radars, ~50–100 m/s for the CADI, and ~30–100 m/s for the DMSP satellites. These errors were computed as the standard deviation of individual measurements constituting a specific velocity used for comparison. The error of individual measurements was somewhat smaller.

Table 1. Parameters of the Linear Fit for Various Comparisons

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Slope</th>
<th>Intercept (m/s)</th>
<th>Correlation Coefficient</th>
<th>Standard Deviation (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAS radar gate</td>
<td>0.46</td>
<td>−25.1</td>
<td>0.50</td>
<td>154.6</td>
</tr>
<tr>
<td>SAS radar grid</td>
<td>0.69</td>
<td>−3.6</td>
<td>0.77</td>
<td>122.0</td>
</tr>
<tr>
<td>CADI</td>
<td>0.68</td>
<td>−20.6</td>
<td>0.84</td>
<td>126.5</td>
</tr>
<tr>
<td>DMSP</td>
<td>0.59</td>
<td>−8.5</td>
<td>0.68</td>
<td>123.3</td>
</tr>
</tbody>
</table>

One can conclude that the agreement is the best for the RKN comparisons with CADI and SAS grid velocities, both in terms of the line slope and correlation coefficient. We note that these two data sets were smoothed more than others, and this suggests that perhaps individual anomalous points affect the fit lines in a significant way. The overall look of Figures 2–4 gives a much better impression than some of the above inferred parameters of the linear fit. Importantly, for all comparisons presented, the number of points with significant inconsistencies is not large enough to be seriously concerned. Occasional strong inconsistencies can happen for the auroral zone radars as well [e.g., Xu et al., 2001; Xu, 2003]. Investigation of each individual event of poor agreement to find out the exact cause of discrepancy is a lengthy procedure that often does not provide a definite conclusion.

An explanation of the disagreement between instruments is unique for each comparison, although there are several common reasons. These include the somewhat different spatial and temporal resolutions of the instruments, despite our efforts to minimize the differences. Effects of temporal variations have been clearly seen for the RKN-CADI comparison when CADI showed fast changes of the convection azimuth. Effects of different spatial coverage are very likely responsible for the majority of RKN-SAS differences. As mentioned earlier, one SAS velocity was compared with RKN velocity in several neighboring beams. The overall allowed beam separation of ~10° seems to be small, but one has to keep in mind that the RKN-SAS comparison was done for the prenoon and early afternoon observations (i.e., close to the throat region), for which the flows can experience strong rotations which is very unfavorable for the comparison.

Some velocity differences can be attributed to the specifics of an individual pair of instruments. For the case of the RKN-SAS-gate comparison, besides the above mentioned difference in the azimuthal size of radar gates, an important issue is proper locating of the echo region. As HF radio waves enter the ionosphere, their group speed becomes less than the speed of light (assumed in the standard SuperDARN algorithm) so that the range of the measurements can be overestimated. For
short-range echoes (the RKN radar), the effect is not significant, but for far ranges of >2000 km (the SAS radar) the accumulated error can be expected as large as 200–300 km. There is also a problem in mapping of the echoes because the height of scatter is unknown [Yeoman et al., 2008]. Yeoman et al. [2008] reported the differences of several radar gates between the true location of echoes due to scatter from artificially produced irregularities (whose location is known) for the Pikkvibaer radar and the mapped echo locations. Because of these effects, one cannot expect great agreement if the convection is not spatially uniform (which is the case for the throat region). Another possible effect is significant lateral refraction of radar waves which might be especially important for the SAS radar whose beams have to go through the highly structured auroral zone ionosphere. We attempted to put more (and then less) stringent conditions on the misalignment of the beams but found no significant difference in the obtained diagrams compared to the one presented in Figures 2a and 2b. We also performed a comparison by considering shorter SAS ranges (this also has been done for RKN-CADI comparison), and the results obtained were close to what we are reporting here. Certainly for the events considered, there were periods of better agreement; unfortunately, attempts to find out the reasons for breaking good agreement were unsuccessful.

[33] For the RKN-CADI comparison, there is a concern over the RKN and CADI overlap area. Even though the RKN data were evaluated over an area deemed to be comparable to the CADI collection area, the overlap is not ideal. Analysis of CADI echo arrival diagrams shows that echoes are often seen in only part of the sky, while the radar echo might be coming from the other corner of what is expected to be the “common” area. In addition, short periods were identified for which RKN echoes were very likely contaminated with the ground scatter as purely ground scatter echoes were detected in close vicinity of the considered gates. Some of these periods were easy to detect and remove from the statistics by making a line plot of both velocities and checking the radar quick-look plots. In many cases this was not possible as the signatures of the ground scatter contamination were not clear. We have to mention that this effect might well be in effect for the RKN-SAS radar comparison as a similar scrutiny was not performed for that comparison. This effect could also partially explain why the RKN-SAS data set showed worse agreement than the RKN-CADI set.

[34] For both the RKN-SAS and RKN-CADI comparisons the velocity data were obtained by sounding the ionosphere with HF radio waves. One would think that the RKN-SAS comparison would show better agreement than the RKN-CADI comparison because similar methods of measurements have been used for the first comparison and radar frequencies are closer. This is not the case for our data sets. Certainly, data were obtained during different periods and perhaps reflect different geophysical conditions, but the amount of data is significant and one expects that this factor is not important. Perhaps part of the explanation is that the data were smoothed more for the RKN-CADI comparison and not so much the RKN-SAS comparison. It well might be, however, that the data reflect a simple fact that as HF measurements are performed at larger and larger ranges, the echo locations become displaced more and more from the assumed ones and this gives progressively larger differences if the flow pattern is strongly inhomogeneous.

[35] The RKN-DMSP comparison showed results close to those for the SuperDARN auroral zone radars [Drayton et al., 2005; Xu et al., 2008]. The reasons for disagreement have been discussed in detail by Drayton et al. [2005] and we refer the reader to that paper. Here we would like to mention one very important effect which was overlooked in past discussions. When HF radar waves are scattered by ionospheric irregularities, the standard SuperDARN software assumes that scattering occurs in vacuum. For the real situation in the ionosphere, the measured Doppler velocity is a product of true velocity and the index of refraction n so that $v_{\text{measured}} = v_{\text{true}} \cdot n$ [e.g., Ginzburg, 1970, p. 422]. Since $n$ is less than 1, depending on ionospheric conditions, this may account for 10–20% of the reported RKN velocity underestimation of the $E \times B$ magnitude measured by DMSPs (currently, a paper making detailed estimations of the effect is in preparation).

[36] Finally, we would like to mention that although our comparisons do not show significant back/side lobe contamination for ionospheric signals, the question of whether this is true for the ground scatter signals requires special investigation. Our preliminary analysis of RKN ground scatter data shows that such signals typically occur simultaneously with ionospheric scatter at roughly double the ionospheric echo range. This fact strongly suggests that the ground scattered signals are coming from the front side because the ionospheric echoes are received from the front side of the antenna. In addition, a limited analysis of the elevation angle data does not show obvious interferometer evidence for echo reception from the back as reported by Milan et al. [1997]. We are planning to perform a full-scale analysis of the ground scatter echoes in the near future.

[37] Results obtained in this study can be summarized as follows:

1. Rankin Inlet HF radar velocities are statistically comparable to those measured concurrently by three independent instruments: the Saskatoon HF radar, the Resolute Bay CADI ionosonde and in situ drift meters on board DMSP satellites. Comparisons were performed for one month of operation, October 2006. Good agreement
between Rankin Inlet radar velocities and measurements by other instruments indicate that the back/sidelobe contamination for the radar is not an issue, as far as velocity measurements are concerned.

[39] 2. The best (worst) agreement has been found for the Rankin-CADI and Rankin-Saskatoon grid (Rankin-Saskatoon gate) comparisons. In all comparisons, Rankin velocities were somewhat smaller than those measured by a complimentary instrument. Typical slopes of the linear fit line to Rankin-complementary instrument data were \( 0.8 \). Spreads of the data around the line of the best linear fit (as characterized by the standard deviation) were of \( 0.7–0.8 \). Spreads of the data around the line of the best linear fit (as characterized by the standard deviation) were of the order of \( 100 \) m/s. Significant differences in the velocity magnitudes (by a factor of 2 and more) were found in 25–40% of cases and the velocity polarity in \( 15% \) of cases.

[40] 3. The occasional strong inconsistencies between measured velocities can be related to several reasons out of which the most likely one is the difference in the spatial and temporal resolutions of the instruments.

[41] Acknowledgments. This work has been supported by NSERC (Canada) and CSA (Canada) grants to operate the Saskatoon and Rankin HF radars to G.J.S. and Resolute CADI instruments to J.W.M. The research was supported by the Discovery grants to A.V.K., G.J.S., and J.-P.St.-M. Constructive criticism of both referees is appreciated.

References


Xu, L. (2003), SuperDARN-derived plasma convection: Comparison with other data and application to field-aligned current measurements, PhD thesis, Univ. of Saskatchewan, Saskatoon, Canada.


D. Andre, E. E. Kadochnikov, A. V. Kouostov, G. J. Sofko, and J.-P. St.-Maurice, ISAS, University of Saskatchewan, Saskatoon, SK S7N 5E2, Canada.

R. A. Fiori, Geomagnetic Laboratory, Natural Resources Canada, Ottawa, ON K1A 0Y3, Canada.

M. R. Hairston, William B. Hanson Center for Space Sciences, University of Texas at Dallas, Richardson, TX 75083-0688, USA.

J. W. MacDougall, Department of Electrical Engineering, University of Western Ontario, London, ON N6A 5B9, Canada.