Simultaneous Thermospheric Neutral Winds and Plasma Velocities

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Abstract

Simultaneous Fabry-Perot spectrometer, FPS, data from Davis (gg 68.6° S 78.0° E, magnetic 74.3° S 101.5° E) and Mawson (gg 67.6° S 62.9° E, magnetic 70.2° S 91.7° E) have been obtained on a number of occasions since 1997. Data from the two instruments can be combined to provide an average wind field in the region spanning approximately 10 degrees of geomagnetic latitude and longitude [1]. The two Fabry-Perot spectrometers are beneath the Swoya East SuperDARN radar beam. The Fabry-Perot spectrometers measure neutral wind and Swoya SuperDARN measures plasma velocities. Preliminary comparisons of these two quantities on 18 September 1998 are presented.

Thermospheric neutral wind field.

Mawson and Davis Fabry-Perot spectrometers, FPSs, are central fringe viewing instruments. They can measure line-of-sight winds using a number of emissions. Since the Davis instrument became operational in 1997 a number of campaigns have resulted in simultaneous observations of the thermospheric λ630 nm emission. The resultant eight line-of-sight wind measurements can be combined to provide a wind field which incorporates a mean and zonal and meridional gradients of the zonal and meridional wind. The uncertainties in the wind measurements are used to weight the measurements in a fitting procedure described in detail elsewhere [1].

The strength of this technique lies in determining wind gradients, as line-of-sight velocities can be misleading for both radars and FPSs [2]. Mawson and Davis are fortuitously situated such that thermospheric observations in magnetic cardinal point directions provide two independent and approximately orthogonal pairs of measurements of the neutral wind. Figure 1 shows line-of-sight wind measurements from Mawson and Davis, bold arrows, and a fitted thermospheric wind-field. Note the small wind measurement in the Davis magnetic east direction and the large fitted wind field almost perpendicular to the measurement.

The λ630 nm emission is predominately aurorally generated in the region of Davis and Mawson. The height of the emission will vary depending on the energy of incoming particles. However because the excited state has a relatively long lifetime at altitudes below 200 km the excited state is generally quenched by N_2. Hence, in most circumstances, the λ630 nm emission can be assumed to originate from a layer near 200-250 km. Davis, and less often Mawson, at times passes under the polar cap. The polar cap is exceptionally dark; emission intensities are very low. Measurements with low intensities usually have high errors but one such measurement will have little effect on the fitted wind field.

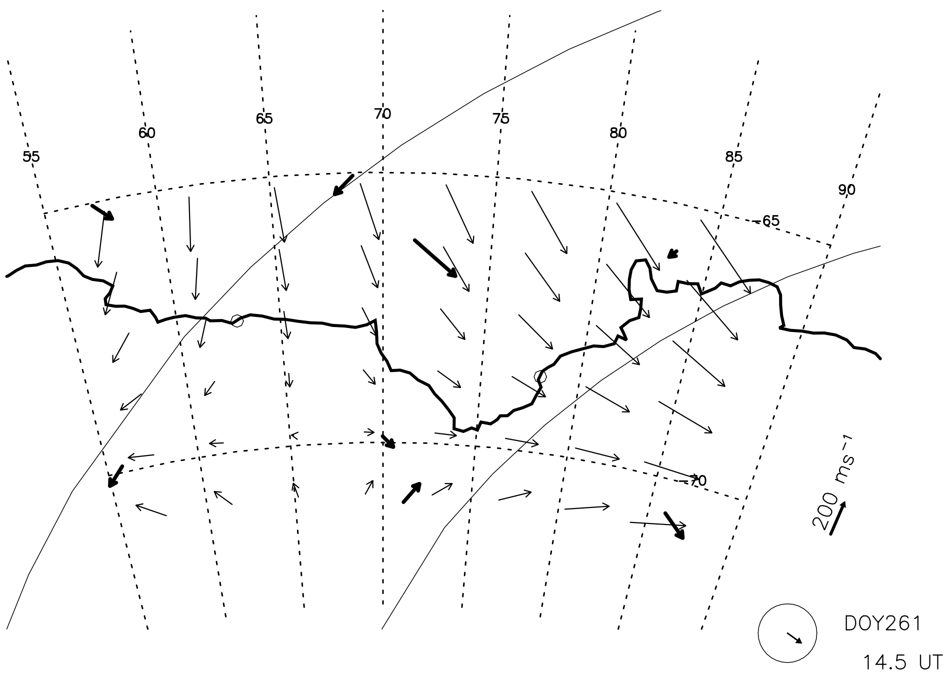

Figure 1: Measured line-of-sight thermospheric neutral winds (bold arrows) from two independent Fabry-Perot spectrometers at Mawson and Davis. The thin arrows are from a six parameter fit of the mean wind and zonal and meridional gradients of the zonal and meridional wind. In the fitting routine, measured values are weighted by their uncertainties. The two solid lines are magnetic latitude 70 and 75 S.

The weakness of the FPS experiment lies in the time resolution of the interferometers. It takes approximately 40 minutes to complete a sequence of measurements of the zenith, four cardinal points, and a calibration source. Half hourly samples in the four directions have been used to determine wind fields at hourly intervals which should be based on independent measurements. Modern sky-mapping interferometers are capable of time resolutions of ~10 minutes, e.g. [3].

The instruments at Mawson and Davis are part of a suite of instruments including all-sky auroral videos [4]. On the 18th Sept 1998 the Mawson imager was operational, unfortunately the Davis imager was not. By combining observations from the Mawson imager and intensity measurements from the FPS at Davis a good indication of the location of the visible auroral oval can be obtained.

Swoya East Radar Plasma Velocities

Figure 2 shows plasma velocities from the Swoya East beam. The data was obtained in 1998, prior to the establishment of the Kerguelen radar, so there is no overlapping data from a second radar. Vector velocities have been produced using the standard method for a single radar [5]. Approximate positions of Mawson and Davis stations are shown by the bold circles between 90 and 105º magnetic east longitude and 70 and 75º magnetic south latitude. In this case they are on the edge of the radar data. At some times the radar data cover more of the FPS fields-of-view, at other times there is little overlap of the radar and FPS sampling regions.

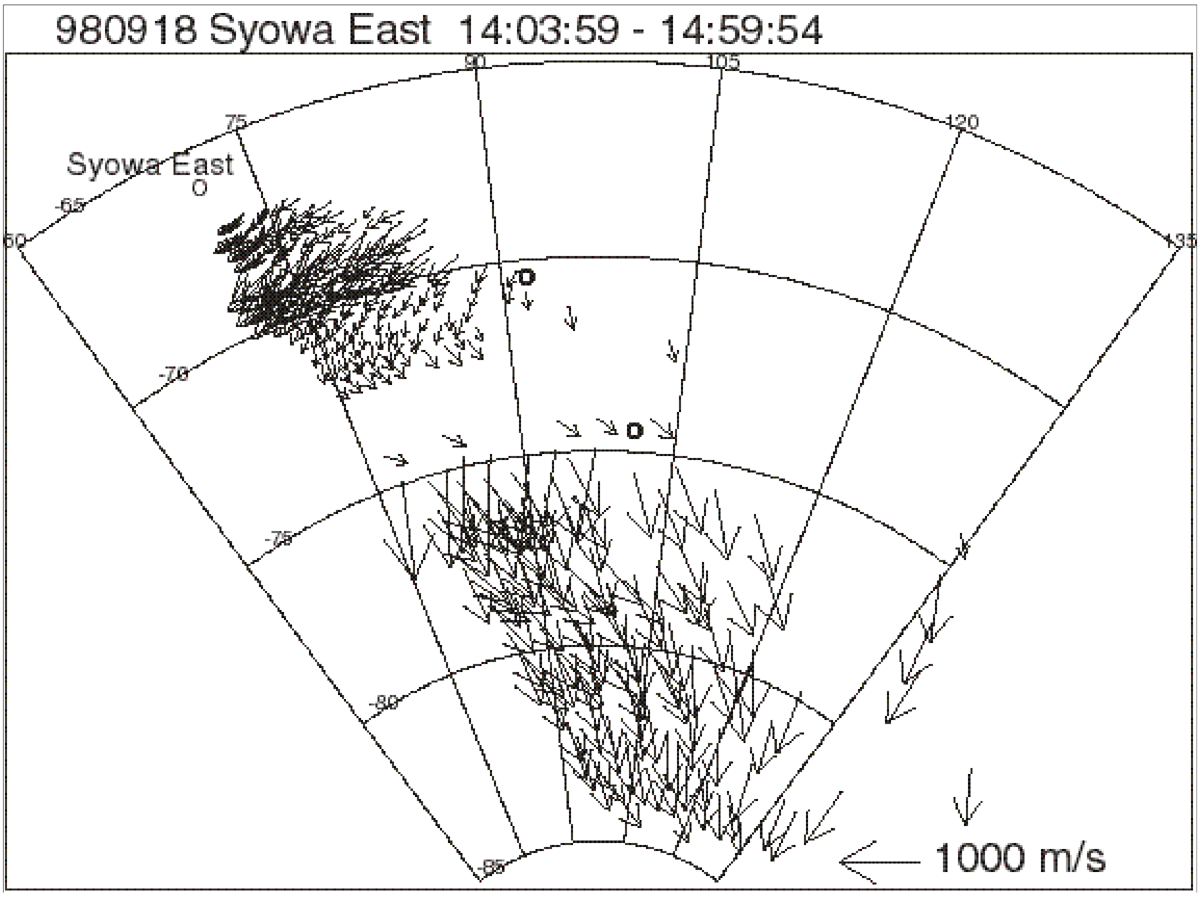

Figure 2: Syowa East SuperDARN radar averaged plasma velocities. The approximate positions of Mawson and Davis stations are shown by the bold circles between 90 and 105º magnetic east longitude and 70 and 75º magnetic south latitude, Davis is further south.

SuperDARN echoes, at the distances of Mawson and Davis from Swoya, are from F-region irregularities. The height of the echo is not precisely known but to a first approximation it is reasonable to expect that F-region radar echoes and the λ630 nm auroral emission are coming from similar heights.

The Swoya radar samples at two minute intervals. Two minute maps similar to figure 2 do not commonly have vectors over Mawson and Davis so some averaging would be required for useful comparisons. In view of the FPS time resolution hourly averages of SuperDARN data have been used in this instance. Radar averaging may need to be varied for different studies after consideration of echo spatial and temporal distributions.

Comparison

At this point a preliminary study has been undertaken comparing data from seven hours on the 18th September, 1998. On this day Kp from 12 UT was 5^+ 4^+ 5 4^-, F10.7 was 124, B_y was stably positive, and B_z mostly negative. This is a magnetically active day, particularly when compared to days in 1997 [1].

The FPS neutral wind field plots and SuperDARN plasma velocities have been mapped using different co-ordinates and map projections. Using the station locations and magnetic latitude circles to orient and scale the FPS wind field to similar dimensions as that used for the radar, it can be seen, figure 3, that at 14.5 UT there was good agreement in the direction of the plasma and neutral wind velocities. Only the fitted FPS wind field has been shown, not the actual line-of-sight measurements. North and west of Mawson the winds are blowing generally magnetically westward, between Mawson and Davis the wind changes direction and magnetically south of Davis the wind is strongly magnetically southward. At this time the auroral video shows that the oval is on the northern horizon at Mawson, approximately at or north of 65° S.

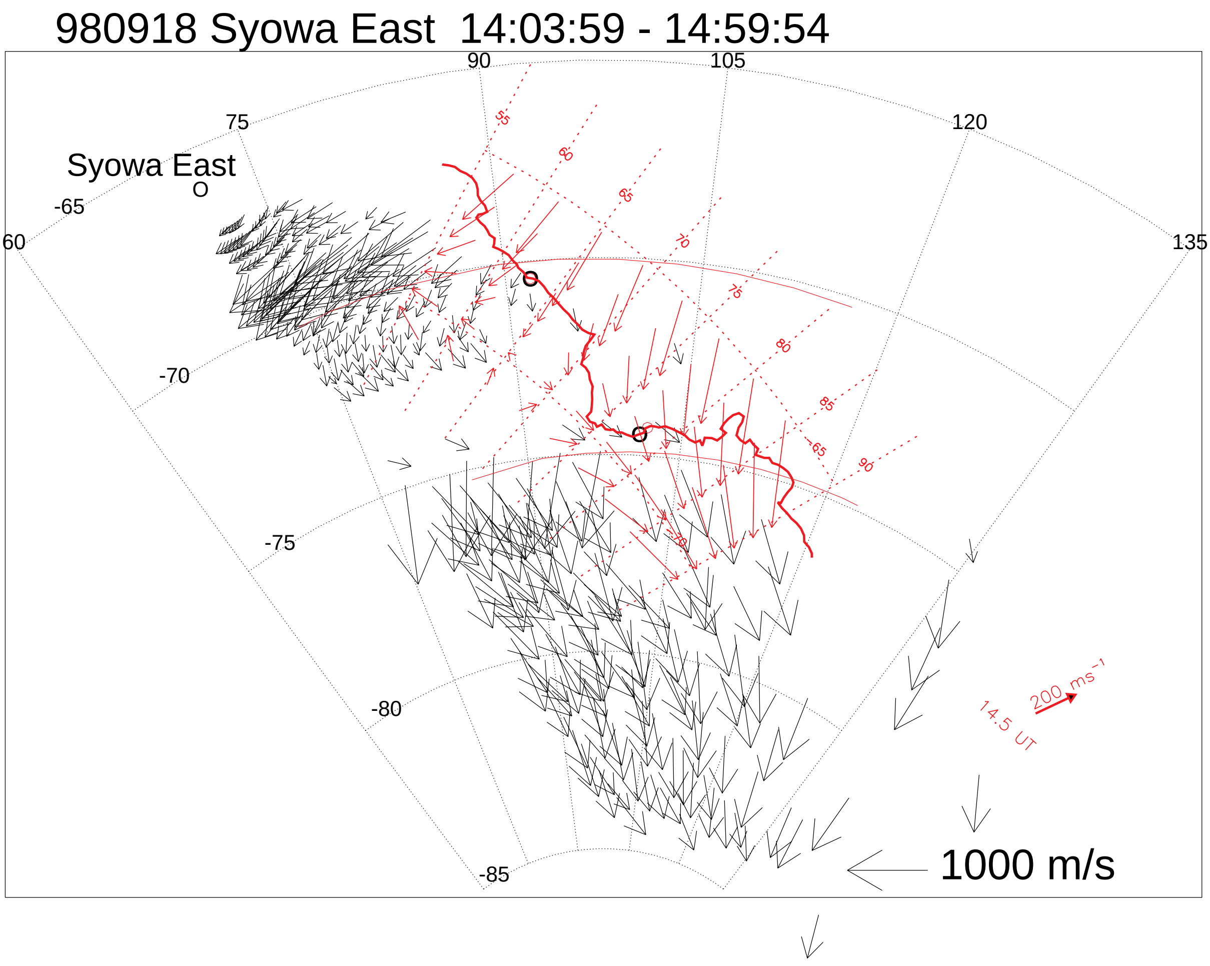

Figure 3: FPS neutral wind fields and scale arrows, red, compared with SuperDARN plasma velocities, black. The curvature in both fields is similar although magnitudes vary. Hourly average values are used for both plasma velocities and neutral winds. The time is 14.5 UT, covering the interval as shown on the plot.

Magnitudes of the plasma velocities and neutral winds are, however, significantly different. At 14.5 UT, figure 3, the plasma velocities are approximately five times that of the neutrals. At 20.5 UT plasma velocities are approximately twice that of the neutral wind. The density of ions and electrons and the ion-neutral collision frequency will influence the neutral wind plasma coupling and hence the plasma velocity, neutral wind velocity, ratio.

The wind pattern at 14.5 UT is maintained for the following hour although both the neutral wind and plasma velocity magnetically south of Davis decrease. Further plots of the SuperDARN plasma velocity FPS neutral wind comparison have been included as an appendix. Around 1545 UT the aurora to the north brightens and moves into the zenith at Mawson. At 16.5 UT a large eastward jet is seen in the plasma winds. The jet extends from approximately 70˚ to 77˚ magnetic south. This change in direction is not seen in the neutral winds until the following hour. It may be possible to better define the time taken for the jet to effect the neutral winds by returning to higher time resolution measurements not available for wind-field analysis.

At 18 UT both plasma and neutral velocities decrease as the region passes through the center of the evening circulation cell. The FPS implies larger neutral winds to the east of Davis. Plasma velocities at this time decrease south and east of Mawson and Davis. The direction of the plasma and neutral winds over Mawson are not in good agreement.

At times, such as 19.5 UT, SuperDARN echoes are only received from a small region. There is general agreement between the direction of the plasma velocity over Mawson and the neutral wind velocity, although the plasma velocity is approximately ten times larger than the neutral wind. At this time there is active aurora overhead Mawson although the poleward edge of the oval remains north of the Davis zenith.

By 20.5 UT both neutral winds and plasma velocities return to a smooth magnetically northward flow, consistent with a cross-polar jet. Magnetic midnight is at approximately 22 UT at Mawson, 21.5 UT at Davis. The plasma velocities are lower than earlier in the night. As mentioned above, the ratio of the amplitudes of the plasma to neutral winds is less, approximately 2.

Conclusions

On the night of 18 September, 1998, Swoya SuperDARN radar obtained plasma velocities over the region of Mawson and Davis enabling a preliminary comparison between plasma velocities and the neutral wind field determined from two FPSs at Mawson and Davis.

There is reasonable agreement between the directions of the neutral wind and plasma velocities. The ratio of the amplitude of the plasma to neutral velocity varies from approximately two to ten. This ratio will depend on the ion-neutral collision frequency and other ionospheric parameters.

Further studies could include determining the time taken for the neutral wind to change in response to a change in the plasma velocity.

Thermospheric neutral wind fields can only be obtained when the skies are clear at both Mawson and Davis. Appropriate FPS data were obtained on 9 nights in September, 1998; 2 nights in May 1999, and 4 nights in August, 1999. Further FPS campaigns are being run through 2000.

References

[1] **Greet P.A., Conde M.G., Dyson P.L., Innis J.L., Breed A.M., and Murphy D.J.** 1999 Thermospheric wind field over Mawson and Davis, Antarctica; simultaneous observations by two Fabry-Perot spectrometers of λ630 nm emission. *Journal of Atmospheric and Solar-Terrestrial Physics* **61:**1025–1045.

[2] **Freeman M.P., Ruohoniemi J.M., and Greenwald R.A.** 1991 The determination of time-stationary two-dimensional convection patterns with single-station radars. *Journal of Geophysical Research* **96:** 15735–15749.

[3] **Conde M. and Smith R.W.** 1998 Spatial structure in the thermospheric horizontal wind above Poker Flat, Alaska, during solar minimum. *Journal of Geophysical Research* **103:** 9449–9471.

[4] **Morris R.J., Monselesan D.P., and Klekociuk A.R.** 1995 Australian antarctic middle and upper atmospheric physics - a new direction. *Advances in Space Research* **16**: (5)151–(5)162.

[5] **Ruohoniemi J.M. and Baker K.B.** 1998 Large-scale imaging of high-latitude convection with a Super Dual Auroral Radar Network HF radar observations. *Journal of Geophysical Research* **103:** 20,797–20,811.

Acknowledgements

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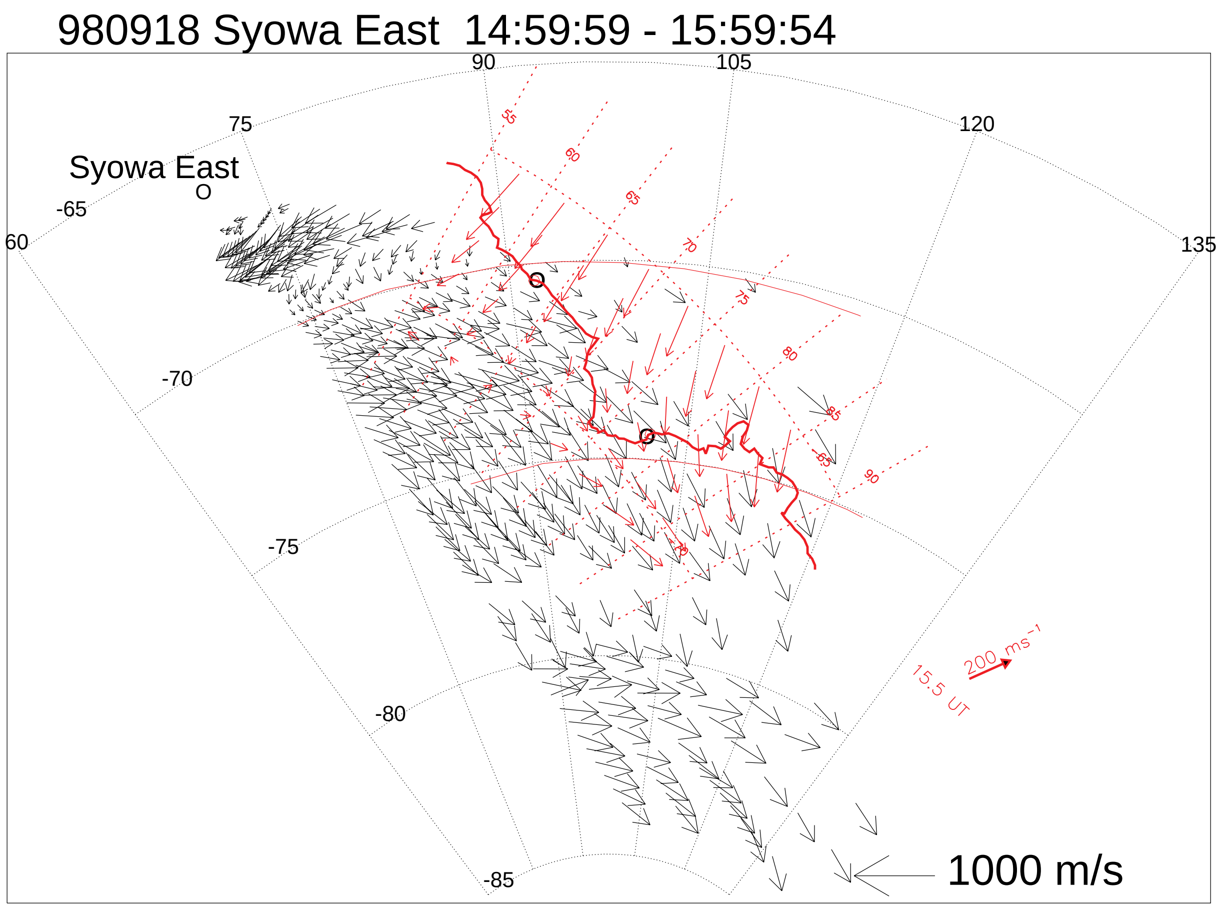
Appendix 1

Hourly plots comparing SuperDARN plasma velocities and FPS neutral winds for 15.5 UT, 16.5 UT, 17.5 UT, 18.5 UT, 19.5 UT, and 20.5 UT follow. As in Figure 3 FPS neutral wind fields and scale arrows are red and SuperDARN plasma velocities, black. Refer to text in Comparison section for discussion.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Syowa East
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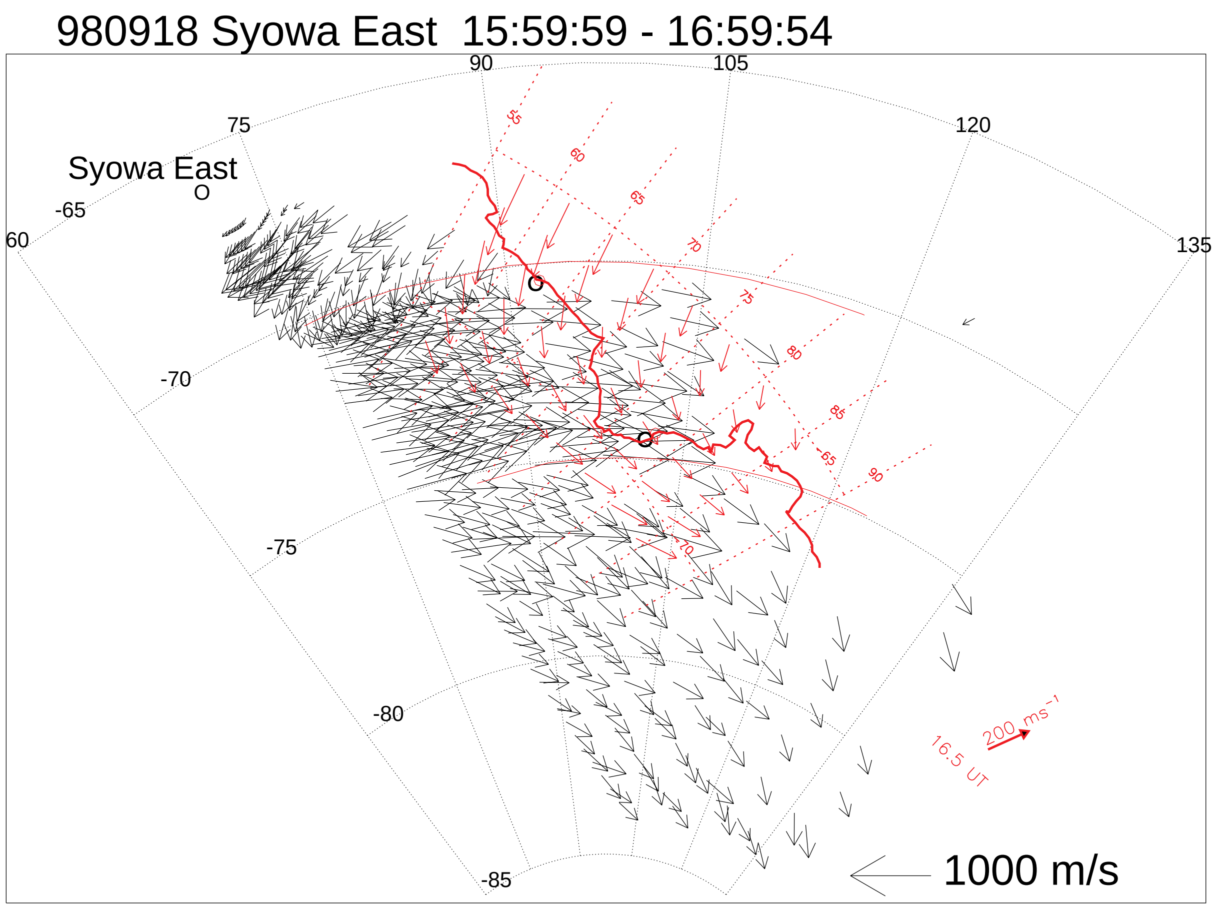
15.5 UT
200 ms⁻¹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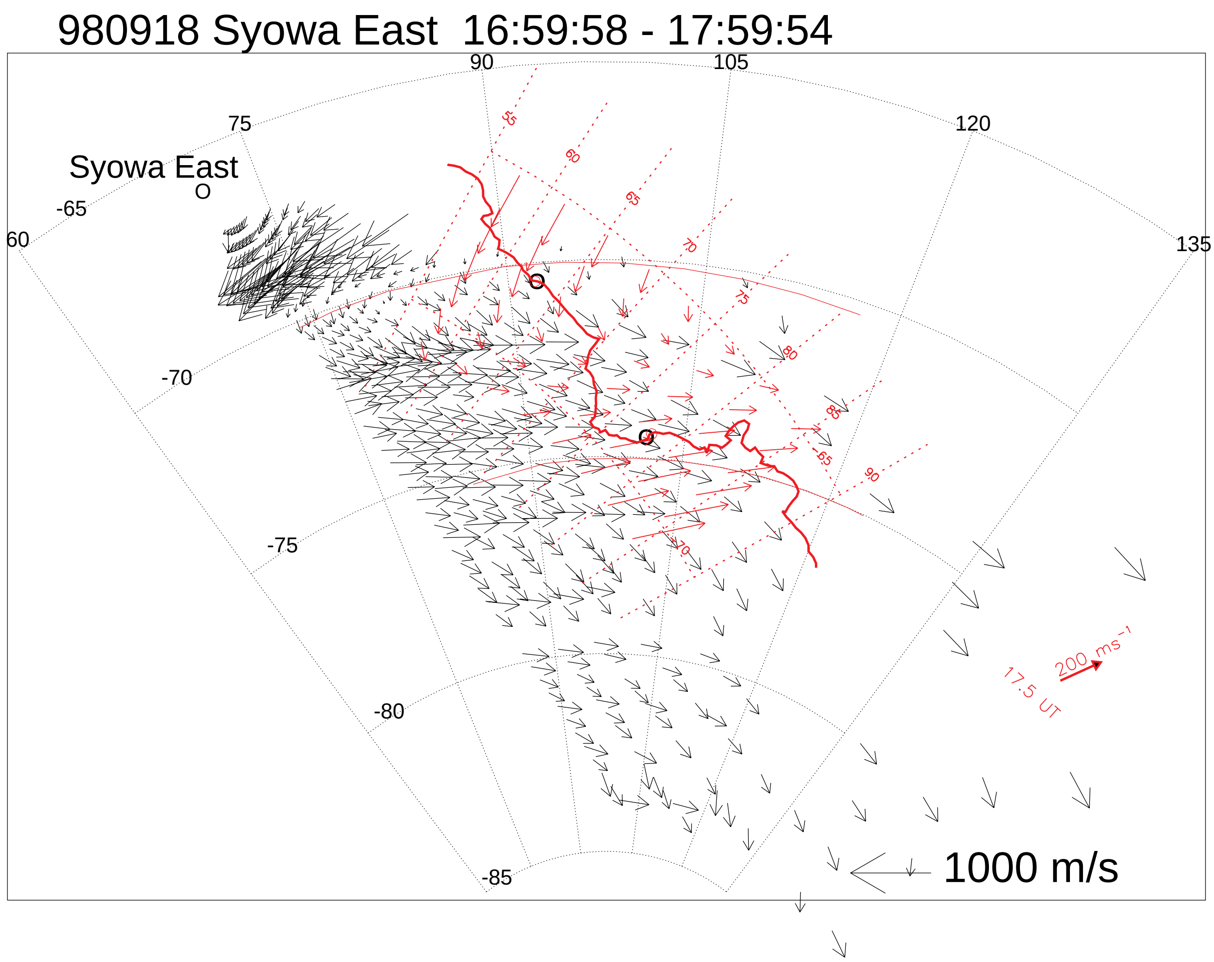
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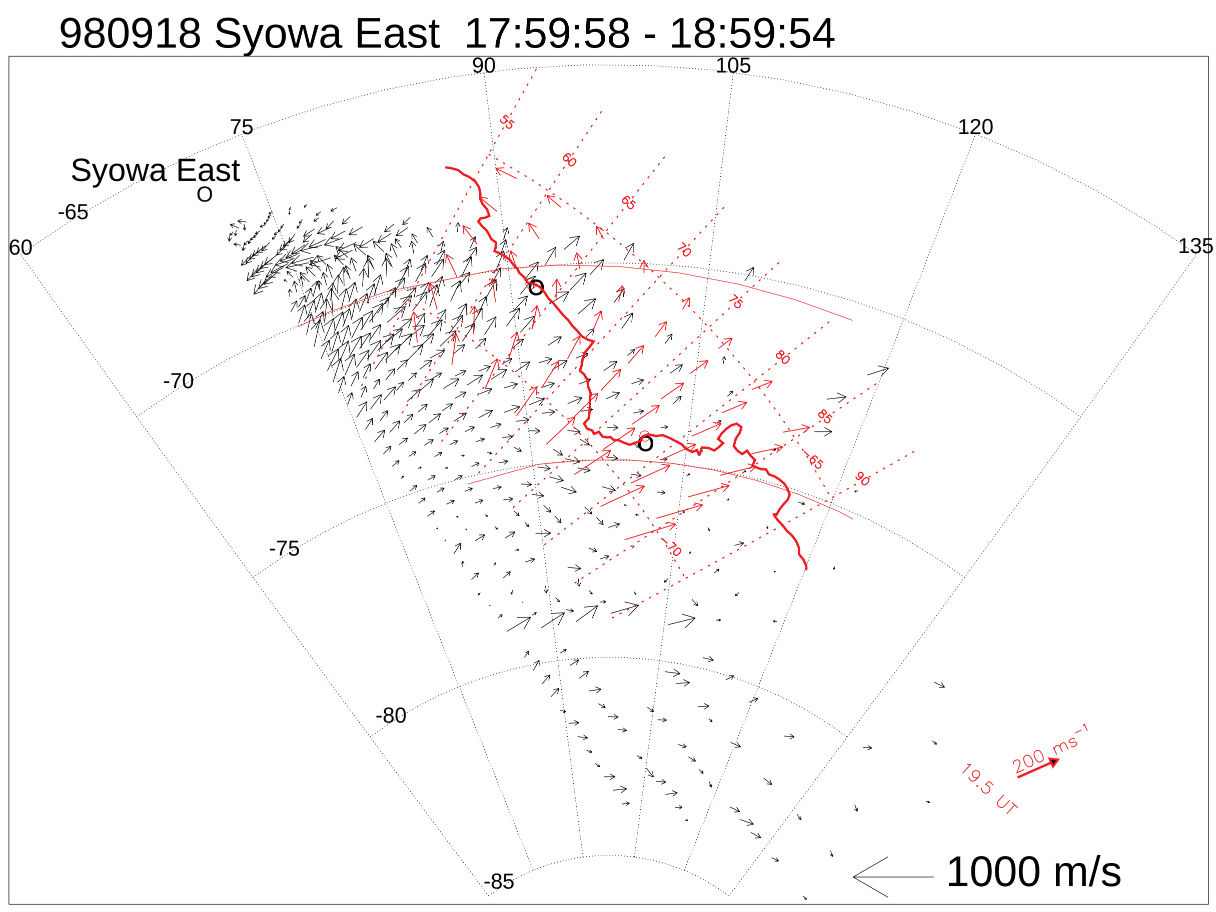
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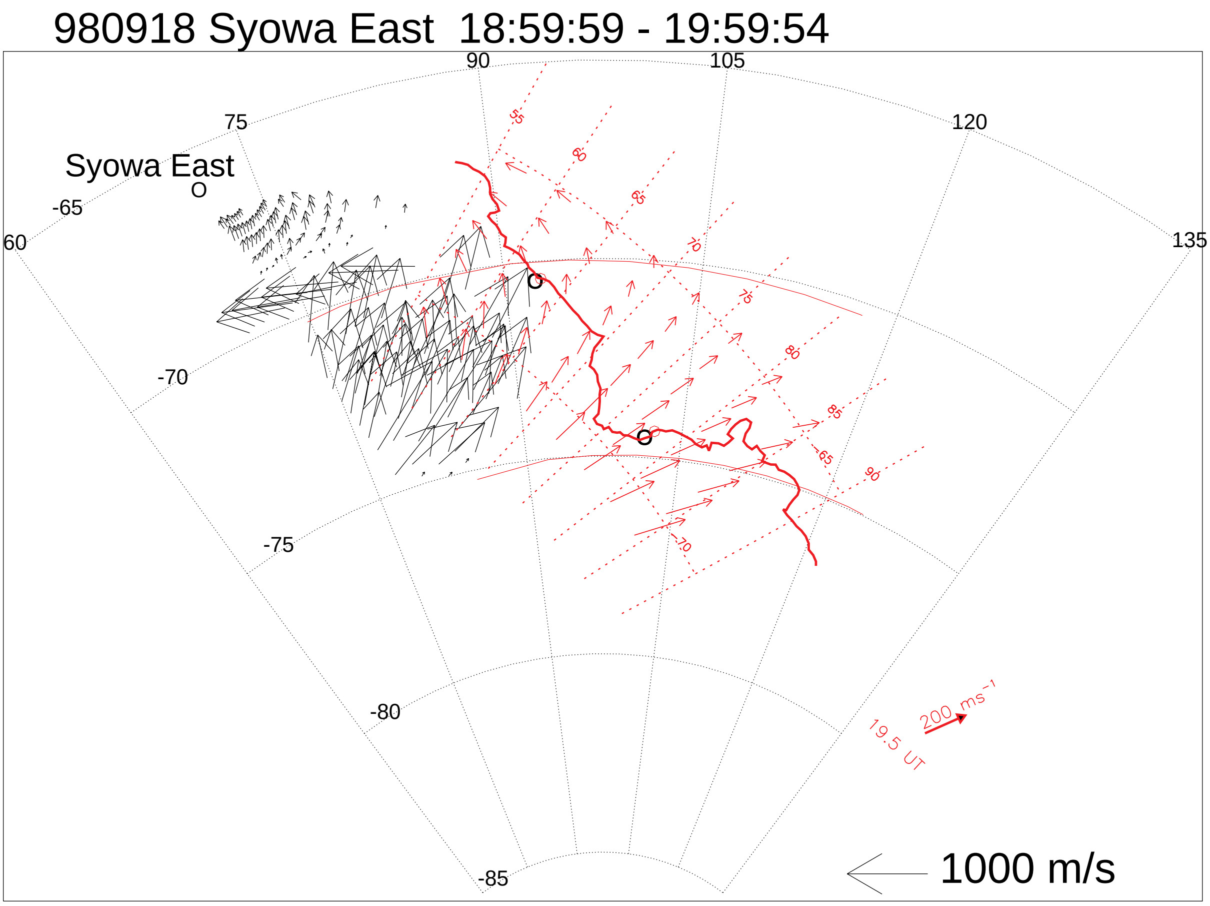

980918 Syowa East 18:59:59 - 19:59:54
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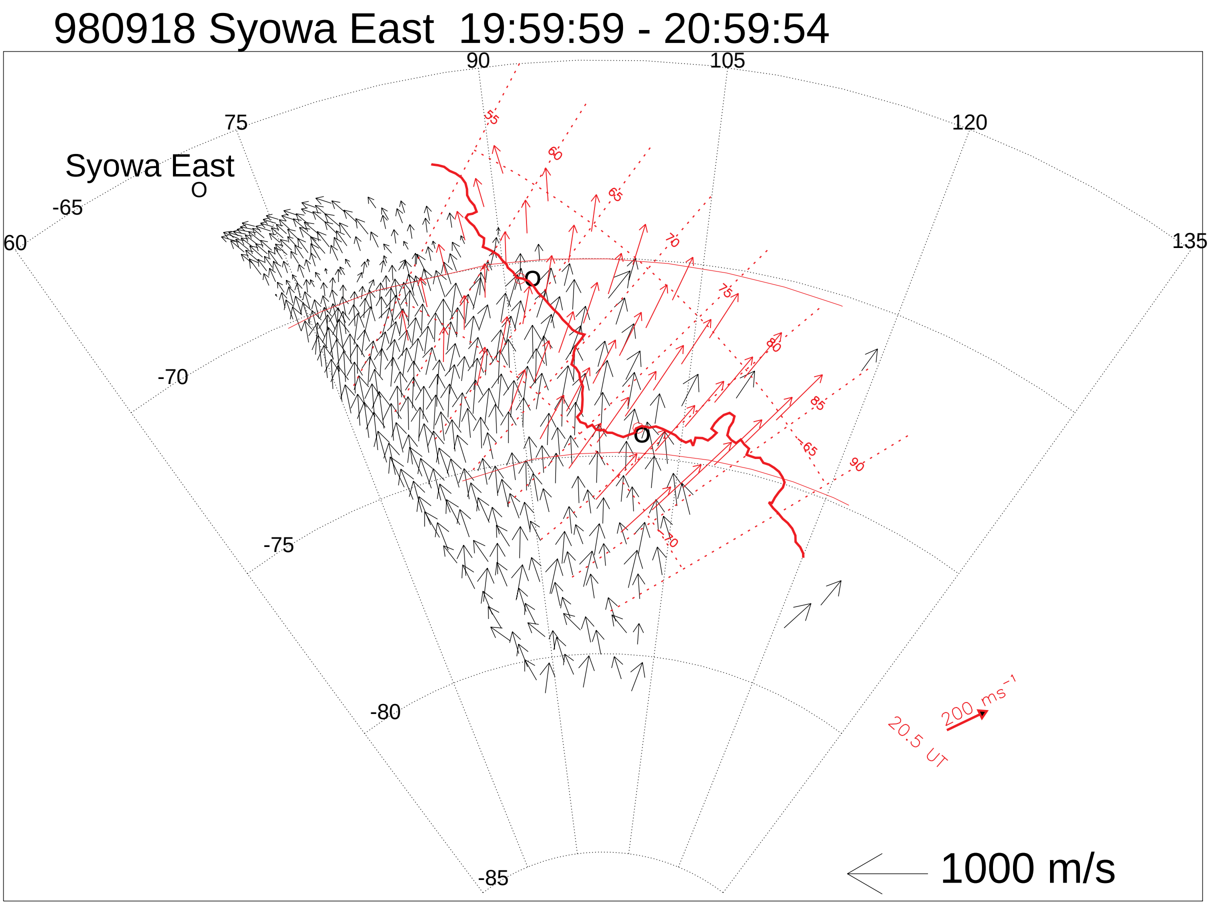

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200 ms⁻¹
20.5 UT
1000 m/s