First Observations of Simultaneous Inter-hemispheric Conjugate High-latitude Thermospheric Winds

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Abstract

We report the first observations of simultaneous high-latitude inter-hemispheric F-region neutral wind fields by combining 630 nm optical measurements from two scanning Doppler imagers (SDI) and three Fabry-Perot interferometers (FPI) for a period exceeding 5 hours. From the southern hemisphere, a SDI at Mawson and a FPI at Davis, both in Antarctica, were geomagnetically mapped onto the northern hemisphere. These data were combined in the northern hemisphere with a SDI at Longyearbyen, Svalbard, and two FPIs near Kiruna in Sweden and Sodankyla in Finland. Geomagnetic conditions were moderate and steady although the IMF Bz did change polarity several times. There was good agreement between the conjugate 630 nm optical intensities and wind vectors. All wind field vectors were overlaid onto the northern SuperDARN ion convection contours. The agreement between neutral and ion flow was remarkably good throughout the study interval, even down to meso-scale spatial size.

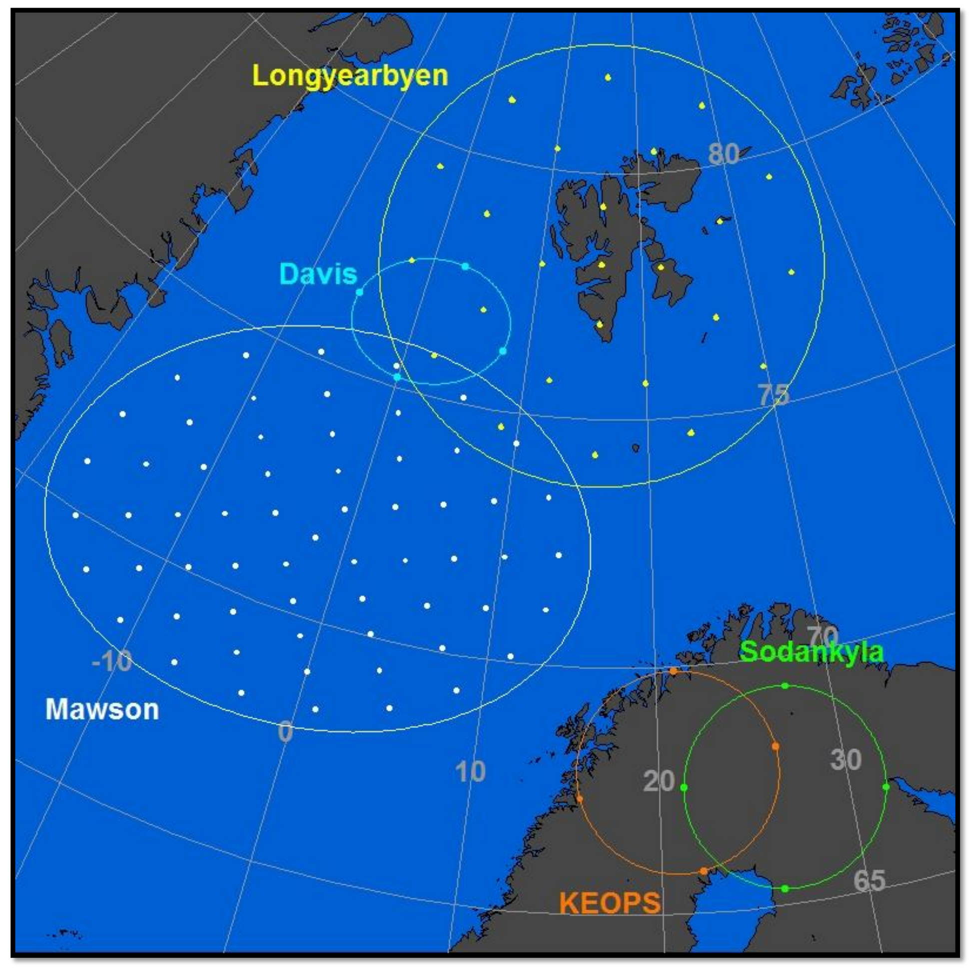

Figure 1: Map showing the geomagnetic conjugates of the Mawson SDI and Davis FPS fields-of-view, along with the Longyearbyen SDI, KEOPS FPI and Sodankyla FPI fields-of-view. Dots within the Mawson and Longyearbyen fields-of-view mark the centers of these instrument's viewing zones.

Introduction

The dominant forces which drive the high-latitude thermospheric neutral atmosphere are ion drag (due to collisions with ions moving under the influence of the high-latitude electric field mapped down from the magnetosphere) and the pressure gradient due to solar heating on the dayside. The large-scale pattern of high-latitude ionospheric circulation is primarily driven by the solar wind through magnetic reconnection of the interplanetary magnetic field (IMF) with Earth's geomagnetic field. Hence, the magnitude and direction of the IMF Bz and By components play a key role in ionospheric and thermospheric circulation at high latitudes.

Due to the inter-hemispheric large-scale symmetry of the geomagnetic field, it is reasonable to expect that many phenomena should be hemispherically conjugate.

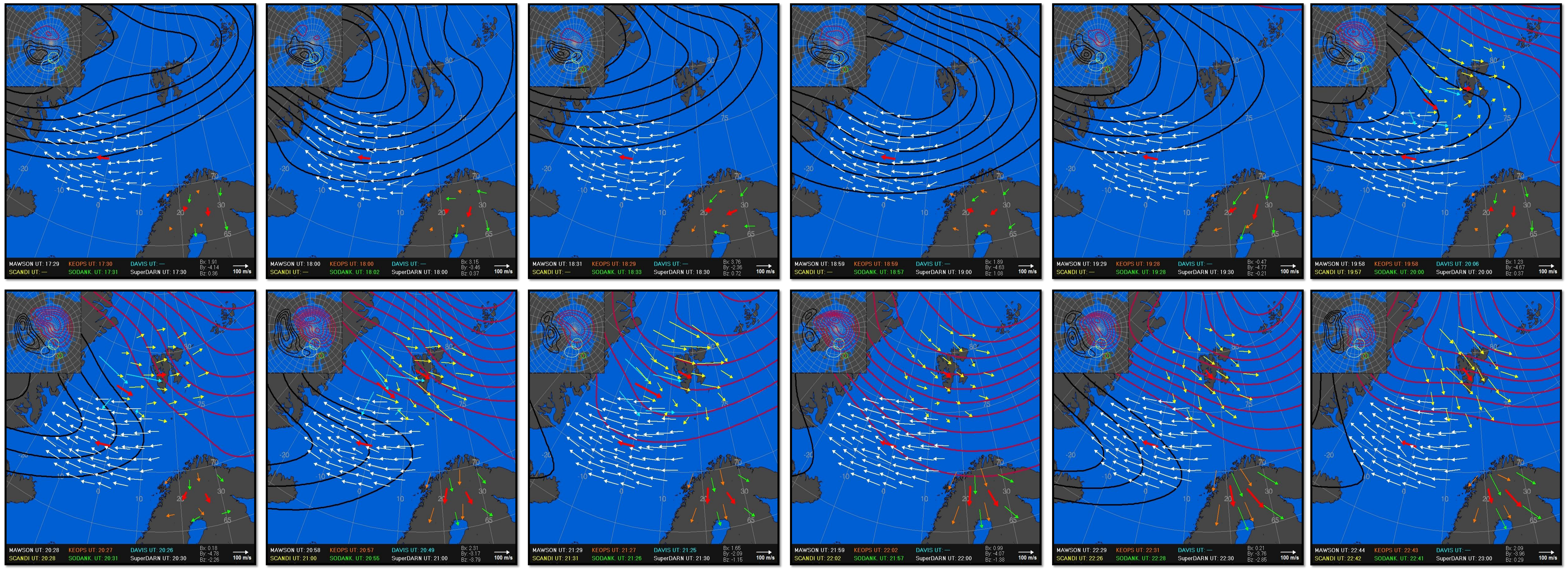

Figure 2: 630 nm thermospheric wind vectors in half hour increments from 17:30 to 23:00 UT on 3 October 2008. All wind vectors are centred on their projected geographic location. The larger red vectors represent the mean wind flow for each instrument. Each FPI wind vector is produced from 2 orthogonal line-of-sight components, and the resulting wind vectors were computed by taking combinations of these line-of-sight measurements (north+east, north+west, south+east, south+west) and are plotted at the approximate midpoint of the line-of-sight directions. Contour lines show the northern-hemisphere electric potentials from SuperDARN at 3 kV increments (black lines represent the dusk convection cell, red lines the dawn cell). The observation times for each instrument are indicated in the bottom panel of each figure, along with the IMF components and the vector wind scale. Inset in the top-left corner of each figure is an overview of the northern hemisphere high-latitude electric potentials derived from SuperDARN at 6 kV contour increments.

Observations

F-region thermospheric neutral winds were derived from two SDIs, at Mawson station, Antarctica (mag. 70.4° S, 90.5° E), and at Longyearbyen on Svalbard island (mag. 75.4° N, 111.7° E), and from three FPIs, at Davis in Antarctica (mag. 74.7° S,100.5° E), near Kiruna - KEOPS - in Sweden (mag. 64.9° N, 103.0° E) and Sodankyla in Finland (mag. 64.1° N, 107.2° E). The southern hemisphere data were geomagnetically mapped onto the northern hemisphere using the IGRF/DGRF geomagnetic field model. The conjugates of the fields-of-view of each instrument are shown in Figure 1, and the derived thermospheric neutral winds (at half-hour intervals) are shown in Figure 2, along with the SuperDARN electric potential contours. The IMF components as measured by the ACE satellite (and delayed by 48 minutes to account for propagation delay) are shown in Figure 3. Ap varied between 9-15 nT during the study interval, and between 12-22 nT during the six hours preceding the interval.

Overall, the agreement between ion and neutral motion was remarkably good, taking into account the smoothing effect of the neutral winds. Even details concerning the transition between the dusk and dawn ion convection cells were well reproduced in the neutral wind field. Figure 4 shows the median correlation between optical intensity and wind components measured by the Mawson and Longyearbyen SDIs as a function of (projected) viewing-zone separation (with 1440 zone pairs). The meridional wind correlation was reasonably constant with zone separation, however the zonal wind correlation decreased rapidly to near-zero with increasing separation. Optical intensity decreased monotonically with zone separation, clearly indicating some conjugate relationship.

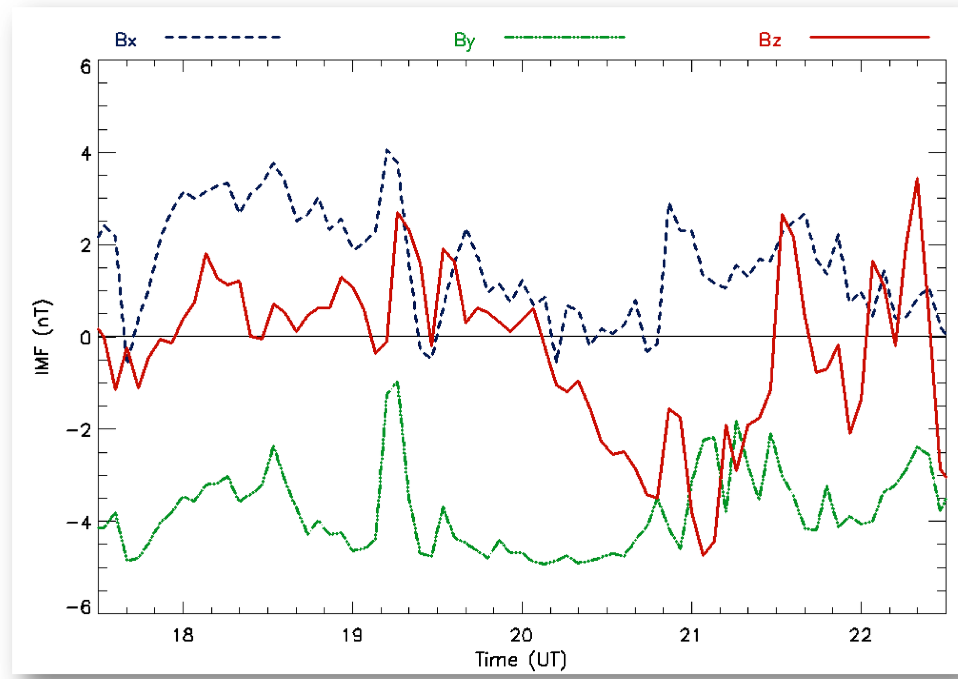

Figure 3: IMF components (delayed by 48 minutes) during the study interval on 3 October 2008.

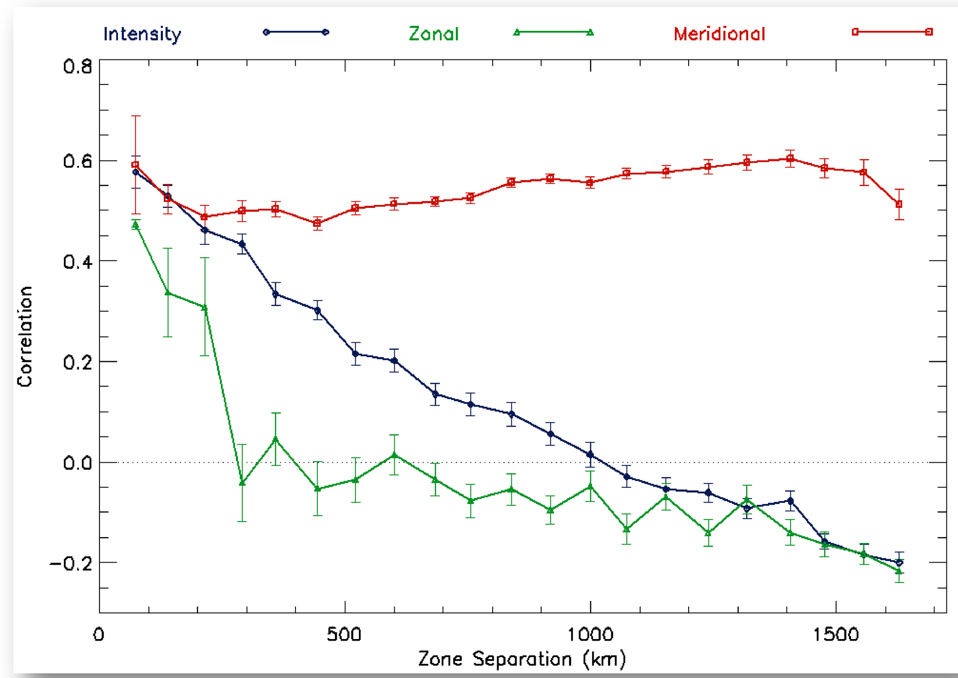

Figure 4: Correlation between the Mawson and Longyearbyen SDI estimates of emission intensity, zonal and meridional wind components, plotted as a function of the distance between the (projected) Mawson viewing zones and the Longyearbyen viewing zones, for times between 20:00 and 22:30 UT.

Conclusion

Thermospheric wind data from 2 southern, and 3 northern, hemisphere optical instruments have been geomagnetically mapped onto the northern hemisphere ion convection contours for a 5 hour period during moderate and steady-state geomagnetic activity. There was remarkable agreement between the inter-hemispheric wind fields, and the northern hemisphere ion convection pattern, even down to meso-scale spatial size. These data demonstrate that for moderate and steady-state geomagnetic activity, thermospheric wind circulation can be inter-hemispheric conjugate, following the ion convection despite changes in IMF Bz polarity. This result also suggests that for moderate and steady-state geomagnetic activity, the neutral wind velocity can be taken as a (smoothed) proxy for ion velocity where plasma drift data is unavailable, at least in the dusk sector. This is advantageous since FPI data are routinely recorded on a nightly basis, when electron densities are lower and therefore when radar backscatter is generally poorer.