Supporting Information for "Relationship between cusp-region ion outflows and east-west magnetic field fluctuations in Southern and Northern Hemispheres"

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Introduction

In this study all ion and magnetic field observations made below 3800-km altitude are excluded from the analysis shown in Figures 3–6. For each of the four groups of orbits analyzed in sections 3.1 through 3.4, Figures S1–S4 show how including ion and B-field and ion measurements made below 3800-km altitude affects the correlation coefficient r between average upward ion flux and east-west B-field perturbations ΔB_{EW}, as a function of B-field frequency band in the spacecraft frame of reference. In the Supporting Information the correlation coefficient r refers to the correlation coefficient between average upward ion flux and east-west B-field perturbations, as a function of frequency band in the spacecraft frame of reference. For each of the four groups of orbits r is shown in panel c of Figures 3–6.

In summary, Figures S1–S4 in this Supporting Information show that when FAST observations are made at altitudes primarily above 3800 km (Orbit Groups 1 and 2, Figures S1 and S2), r coefficients are largely unchanged when we relax the restriction to observations made at altitudes at or above 3800 km. In contrast, when a large fraction of FAST observations are made at altitudes below 3800 km (Orbit Groups 3 and 4, Figures S3 and S4), r coefficients are largely reduced when we relax the restriction to observations made at altitudes at or above 3800 km.

Text S1.

Figure S1 shows analysis of the 33 NH cusp-region passes during September 23–26, 1998 (Group 1) presented in section 3.1. Figure S1a shows FAST altitude as a function of magnetic local time (MLT) for each Group 1 orbit. Thin lines indicate the availability of ΔB_{EW} measurements, while thick transparent lines indicate the observation of ion outflow. Both lines are restricted to the portion of the orbit for which FAST was between 60° and 87° magnetic latitude (MLat).

From Figure S1a it is apparent that all observed ion outflow occurs above 3800-km altitude, while ΔB_{EW} measurements are made both above and below 3800-km altitude. Relaxing the 3800-km altitude restriction for Group 1 orbits therefore provides no additional ion observations in the calculation of average ion flux for each Group 1 orbit, and a relatively small number of additional ΔB_{EW} measurements for the calculation of each ΔB_{EW} power spectral density (PSD). We therefore expect little or no difference between r coefficients calculated with the 3800-km altitude restriction (Figure S1b, reproduced from Figure 3c in the main article), and r coefficients calculated without the altitude restriction (Figure S1c).

Figure S1b (reproduced from Figure 3c in the main article), shows r coefficients calculated under the in Figure S1c, which are calculated with the 3800-km altitude relaxed As expected, there is little difference between r coefficients in Figure S1b (reproduced from Figure 3c in the main article), and r coefficients in Figure S1c, which are calculated with the 3800-km altitude relaxed.

Comparison of Figure S1b and Figure S1c indicates that the overall coefficients of r are in fact slightly higher when the additional B-field measurements from below 3800-km are included in the analysis of Group 1 orbits. In specific Figure S1c shows that the region for which $r \geq 0.9$ is somewhat larger than the $r \geq 0.9$ region in Figure S1b. The morphologies shown in each Figure are nevertheless largely the same.

Figure S2 shows, in a format identical to that of Figure S1, analysis of the 38 NH cusp-region passes between December 30, 1996 and January 7, 1997 (Group 2) presented in section 3.2. Figure S2a shows that, for Group 2 orbits, ion outflow occurs above 3800-km altitude, while ΔB_{EW} measurements are made both above and below 3800-km altitude.

Similar to the Group 1 orbits just discussed, relaxing the 3800-km altitude restriction for Group 2 orbits provides no additional ion observations in the calculation of average ion flux for each Group 2 orbit, while a relatively small number of ΔB_{EW} measurements are added to each ΔB_{EW} PSD calculation.

Thus, as with Group 1 orbits, there is little difference between r coefficients in Figure S2b (reproduced from Figure 4c in the main article), and r coefficients in Figure S2c, which are calculated with the 3800-km altitude relaxed. Comparison of Figures S2b and S2c indicates that r is almost unchanged when the additional B-field measurements from below 3800-km are included in the analysis of Group 2 orbits.

Figure S3 shows, in a format identical to that of Figure S1, analysis of the 32 SH cusp-region passes during January 8–15, 1999 (Group 3) presented in section 3.3. Figure S3a shows, for Group 3 orbits, the occurrence of ion outflow and measurements of ΔB_{EW} over altitudes between ~3100 km and apogee near 4150 km.

In contrast to Group 1 and Group 2 orbits, relaxing the 3800-km altitude restriction for Group 3 orbits provides many additional ion observations and ΔB_{EW} measurements in the calculation of average ion flux and ΔB_{EW} PSD, respectively, for several Group 3 orbits.

Comparison of the distribution of r coefficients in Figure S3b (reproduced from Figure 5c in the main article) with r coefficients in Figure S3c, which are calculated with the 3800-km altitude relaxed, reveals large differences. First, r coefficients in Figure S3c are nearly everywhere lower than corresponding r coefficients in Figure S3b. Second, r coefficients in Figure S3c decrease more rapidly with increasing frequency lower bound f_{bot} (or "start frequency," shown on the y axis) for $f_{\mathrm{bot}} \gtrsim 0.2$ Hz.

Figure S4 shows, in a format identical to that of Figure S1, analysis of the 29 SH cusp-region passes between May 24 and June 5 in 1998 (Group 4) presented in section 3.4. Figure S4a shows, for Group 4 orbits, the occurrence of ion outflow and measurements of ΔB_{EW} over altitudes between $\sim$3200 km and apogee near 4150 km.

As with Group 3 orbits, relaxing the 3800-km altitude restriction for Group 4 orbits provides many additional ion observations and ΔB_{EW} measurements in the calculation of average ion flux and ΔB_{EW} PSD, respectively, for several Group 4 orbits.

Comparison of the distribution of r coefficients in Figure S4b (reproduced from Figure 6c in the main article) with r coefficients in Figure S4c, which are calculated with the 3800-km altitude relaxed, reveals very large differences. In particular the range of f_{bot} values for which r is highest ($r \gtrsim 0.85$) in Figure S4b correspond to $r \lesssim 0.5$ in Figure S4c. The r coefficients in Figure S4c are nearly everywhere lower than corresponding r coefficients in Figure S4b. The r coefficients in Figure S4c for $f_{\mathrm{bot}} \gtrsim 2$ Hz, while universally less than 0.7, are in many places higher than corresponding values in Figure S4b.

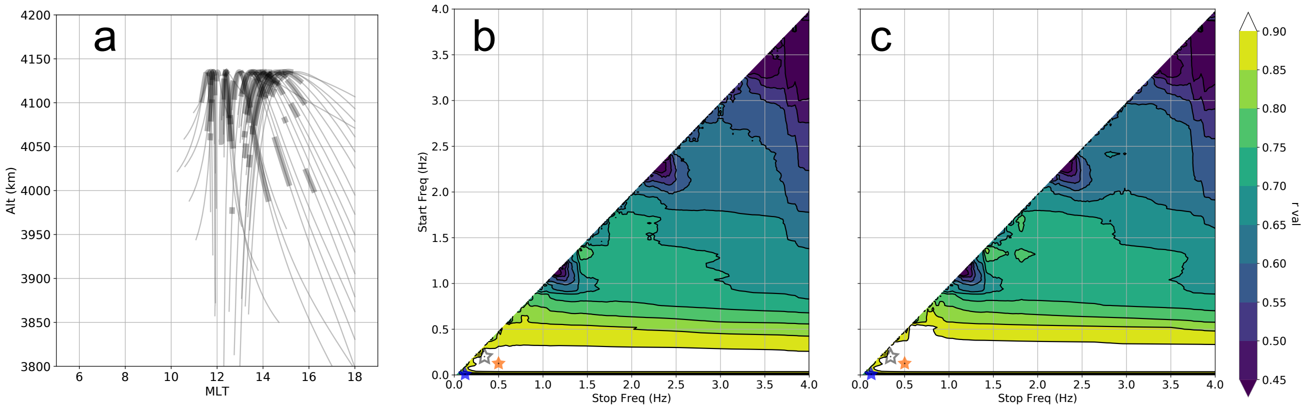

Figure S1. FAST local time and altitude coverage for 33 NH cusp-region passes during September 23–26, 1998, and comparison of correlation coefficient r when calculated with and without the 3800-km altitude restriction. (a) FAST magnetic local time (MLT) as a function of altitude for each orbit. Thin lines indicate the availability of ΔB_{EW} measurements; thick transparent lines indicate observation of ion outflow. (b) Correlation coefficient r calculated from measurements made at or above 3800-km altitude. (c) Correlation coefficient r calculated from all observations, without the 3800-km altitude restriction. The colorbar scale at right applies to panels b and c. Panel b is reproduced from Figure 3c in the main article. In panel b the S05 DC and AC frequency bands as well as highest-correlation frequency band are respectively indicated by blue, orange, and transparent black stars. These three frequency bands are also indicated on panel c for reference. As in the main article, all measurements are restricted to those made within dayside MLTs and over 60–87° magnetic latitude (MLat).

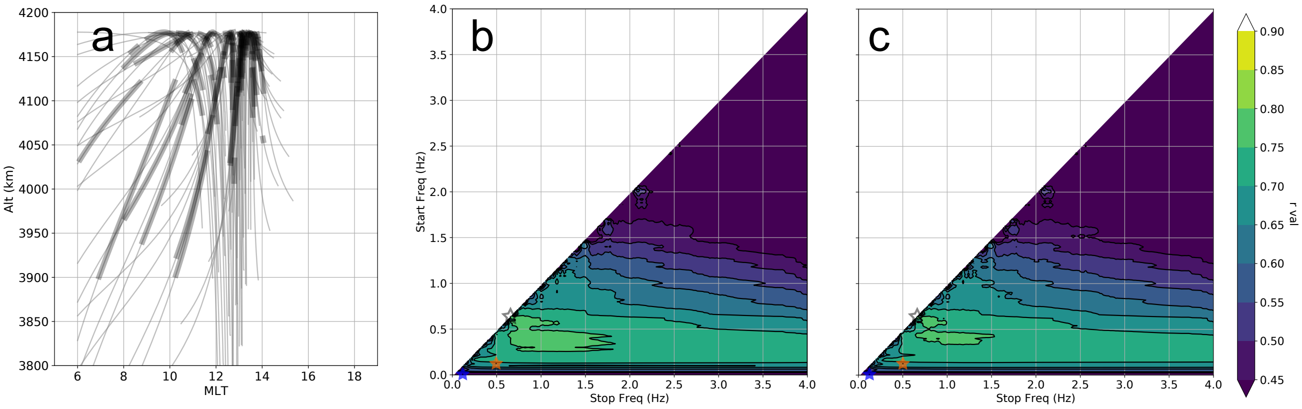

Figure S2. Comparison of the frequency-band analysis for 38 NH cusp-region passes between December 30, 1996 and January 7, 1997, in the same format as Figure S1. Panel b corresponds to Figure 4c in the main article. All measurements are restricted to dayside MLTs and to 60–87° MLat.

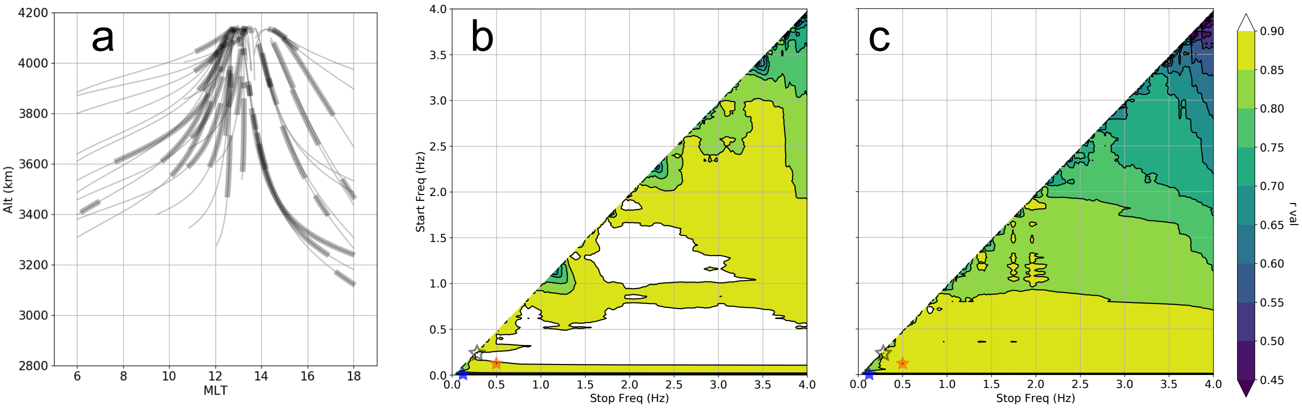

Figure S3. Comparison of the frequency-band analysis for 32 SH cusp-region passes during January 8–15, 1999, in the same format as Figure S1. Panel b corresponds to Figure 5c in the main article. All measurements are restricted to dayside MLTs and to -87° through -60° MLat.

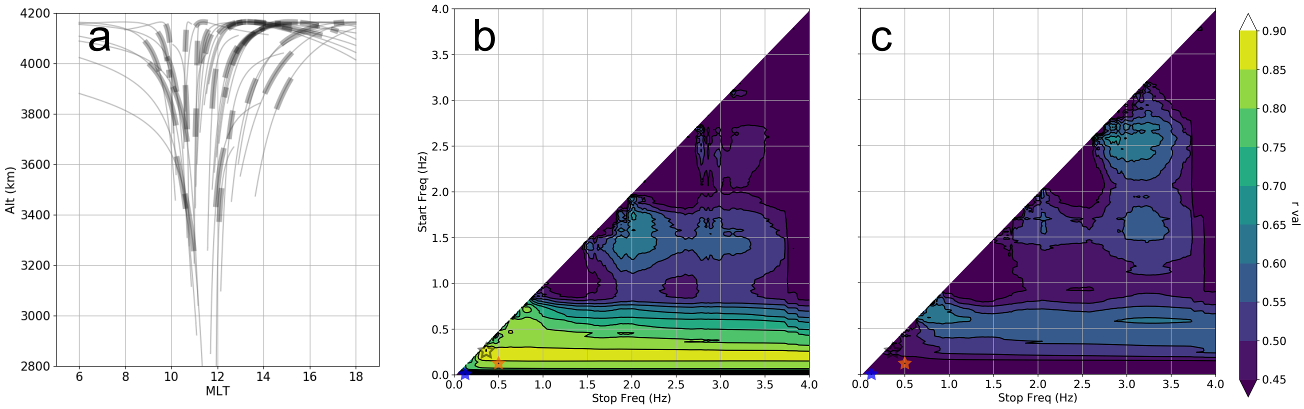

Figure S4. Comparison of the frequency-band analysis for 29 SH cusp-region passes between May 24 and June 5 in 1998, in the same format as Figure S1. Panel b corresponds to Figure 6c in the main article. All measurements are restricted to dayside MLTs and to -87° through -60° MLat.