Dayside NBZ heat focus group: to understand the enhanced heating during northward IMF in the dayside cusp ionosphere which is not measured by any indices.

The main ionosphere-thermosphere heating is frictional heating as a result of collisions between the ions and neutrals. The collisional heating rate is, [Vasyliūnas and Song, *JGR,* **110**, A02301 (2005)], $q = \nu_{in}\rho_i |\mathbf{V}-\mathbf{U}|^2$ where **V** and **U** are plasma and neutral wind velocities, respectively. The thermal energy is equally distributed between the plasma and neutrals. (*In the workshop, I mentioned definition of Joule heating. Let me repeat it here again. In our field, the Joule heating is defined as **J·E**. However, the electric field is frame reference dependent. There are two frames of reference: the plasma frame and neutral wind frame. One can show that the Joule heating, defined as a process to convert electromagnetic energy to thermal energy, should be the one in the plasma frame of reference. It is negligibly small. The Joule heating used in the M-I coupling, the one in the neutral wind frame of reference, is the frictional heating.*) If assuming a steady state, from the plasma momentum equation, one can derive, [Song et al., JGR, 106, 8149, 2001],

$$\nu_{in}\rho_i |\mathbf{V}-\mathbf{U}|^2 = \mathbf{J}^2/\sigma .$$

In other words, the Joule hating discussed in our field is the frictional heating but presented differently. The Poynting flux difference as used in our field is also the frictional heating in essence. But note a major difference: frictional heating depends on the velocity difference. When the plasma and neutrals move at the same speed, the heating diminishes. The heating is stronger when the plasma motion has just changed. When the neutrals are accelerated by the plasma, the heating decreases.

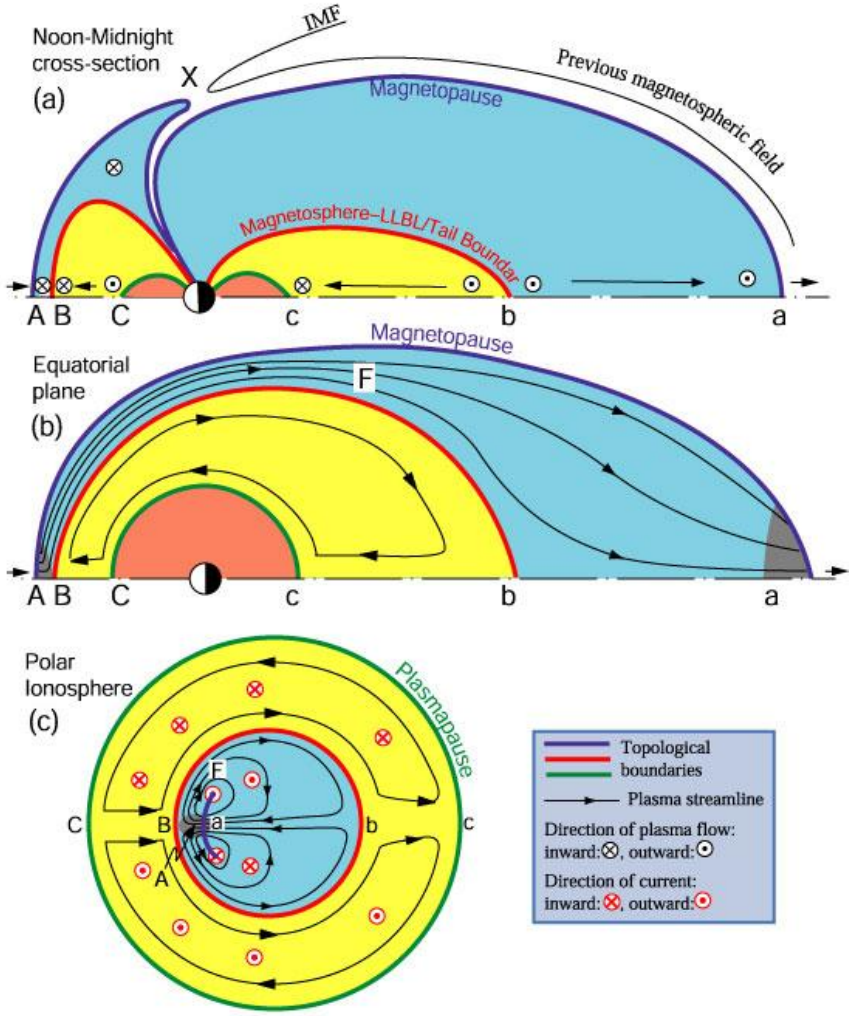
For the dayside heating for northward IMF discussed at the workshop, it is clear that to calculate the heating rate, one needs the velocity difference between the plasma and neutral wind speed, plus the local plasma density and collision frequency. These two quantities can be obtained from the AMIE and TIGCM models. The current and the electric field, two derived secondary quantities, are not essential, although they conventionally are considered essential.

The total heating can be derived by integrating the heating rate over height, area and time.

For the dayside NBZ heating, if the neutral wind speed does not change much during the time scale of interest, say, 2-3 hours [Song et al, *J. Geophys. Res*., **114**, A08213 (2009)], the heating is basically determined by the variation of the plasma velocity. The heating is strongest in places where plasma flow is strong and varies rapidly with the IMF variations.

According Song et al model of NBZ, the strongest flow occurs in the cusp region. Therefore, this is where most heating occurs. Attached below is the model [JGR, 104, 28361, 1999]. Please pay a special attention to panel c.

Also note that the region poleward of the cusp corresponds to the nightside distant tail region, shaded region of point "*a*" in panel b. This flux tube is formed from the expansion of the reconnected flux tube of the subsolar point "*A*" in panel b. Note that the expansion factor is $(r_{tail}/r_{subsolar})^4$. The fourth power is based on a dipole magnetic volume. If $r_{subsolar}$ is 10 Re and r_{tail} is 40 Re, the expansion factor is 256. In other words, the density would decreases by two orders or more from the equatorward of the cusp to the poleward of it. One would not be surprised that poleward cusp region appears to be empty. However, this region is on closed field lines. This was why I questioned to use the density as the single identifier for open/closed geometry, another issue we discussed at the workshop.


Noon-Midnight cross-section
(a)
IMF
X
Previous magnetospheric field
Magnetopause
Magnetosphere–LLBL/Tail Boundar
A B C c b a
Equatorial plane
(b)
Magnetopause
F
A B C c b a
Polar Ionosphere
(c)
Plasmapause
F
C B a b c
A
Topological boundaries
Plasma streamline
Direction of plasma flow: inward:⊗, outward:⊙
Direction of current: inward:⊗, outward:⊙