Auroral Model Validation – Boundary identification

Options for defining two auroral boundaries (equatorward and poleward)

Methods 1 and 3 are relatively simple in that they use a constant threshold value for defining the boundaries.

But the advantage of Method 2 is that different identified regions have physical meanings. It may help modelers (global MHD in particular) a physics basis of defining their boundaries where locating such boundaries is not trivial.

1. Hardy model

$J_{tot} > 10^7 / cm^2 / s / sr$ (16 energy channels from 50 eV to 20 keV – SSJ3).

J_{tot}: the directional integral flux

$J_{Etot} > (2 \sim 3)10^7 keV / cm^2 / s / sr$

J_{Etot}: the differential energy flux

Definition of J_{tot} and J_{Etot} can be found on page 4231of Hardy et al., 1985, JGR

Reference: Gussenhoven et al., 1981

Gussenhoven, M. S., D. A. Hardy, W. J. Burke (1981), DMSP/F2 electron observations of equatorward auroral boundaries and their relationship to magnetospheric electric fields, J. Geophys. Res., 86(A2), 768-778.

Hardy, D., M. Gussenhoven, and E. Holeman (1985), A Statistical Model of Auroral Electron Precipitation, J. Geophys. Res., 90(A5), 4229-4248.

2. JHU/APL boundary

For the dayside:
The equatorward boundary is the equatorward edge of identified closed regions (the equatorward edge of CPS); The poleward boundary is the transition between closed and open regions. The dayside analysis consists of region identifications (CPS, BPS, open-LLBL, LLBL, cusp, mantle, polar rain, void) which are then parsed to look for boundaries.

See Section 2.1 of Newell and Meng, 1992 and/or pages 3-4 of Wing et al., 2010 et al for details on these regions.

More references: Newell et al., 1991a and Newell et al., 1991b

For the nightside:
The nightside analysis is direct boundary identification.
Equatorward boundary is the equatorward-most of b1e, b2i, b2e
Poleward boundary is b5.

b1e, b1i (from Newell et al., 1996)

The algorithm moves from lower latitudes to higher, comparing the average of jip(E1, E2) (partial flux between E1 and E2) and jep(E1, E2) (ordinarily E1 and E2 are the two lowest channels) over the three previous spectra with the three succeeding spectra. An increase in jip by a factor of 2 marks the onset of the zero-energy boundary, which is separately determined for the two species. This jump is significant only if it also significantly exceeds the background counts obtained by averaging over several equatorward seconds. If jep rises to a value above 8.0 (or if jip reaches 6.5), a factor of only 1.6 jump is acceptable in determining the zero-energy boundary. If jep >8.25 (jip > 6.9), it is assumed that the boundary has been reached, even if no jump in the value of the fluxes is measured.

Special cases: The energy range considered (El to E2) in the partials depends on whether photoelectrons are present and whether the spacecraft is charged to -28 V. The former can be identified by a sharp drop-off in electron fluxes above 68 eV at latitudes below the auroral zone, the latter by a sharp cutoff above the 32 eV ion channel. In the absence of these effects the channels are set to the lowest available value, i.e., E1 = 32 and E2 = 47. If the spacecraft is charged to -28 V, the ion channels are set to E1 = 47 and E2 = 68. If photoelectrons are present (rare on the nightside), the next available "clean" channels are 100 and 145 eV, respectively. Finally, isolated noise can sometimes cause false positives, as by radiation belt (1118:30 UT in Plate 4). Thus a "checkble" routine performs a double-check by simply examining the next several seconds. If, in the next few seconds as the auroral oval is purportedly entered, a drop-off in fluxes is exhibited instead of a rise in fluxes, the identification of b1e is inaccurate, and the search resumes toward increasing latitudes.

b1e corresponds fairly well with the existing equatorward boundary introduced by Gussenhoven et al. [1981] and Hardy et al. [1981].

b5e, b5i

These boundaries are computed separately, but using the same procedure. An average jE for the previous 12 s is compared with jE for the succeeding 12s.

When a drop off of a factor 4 is located, a provisional b5 boundary is determined. Note that this algorithm emphasizes locating a sharp gradient in the flux levels.

Special cases: The net 30 s are double-checked (35s for electrons) to make sure the drop-off remains below auroral energy fluxes. If the log average jE has not dropped below about 9.7 for ions or 10.5 (logarithmic) for electrons. the search continues for the corresponding b5 boundary to take care of double oval.

For details, please see Newell et al.,1996.

For both dayside and nightside:
Newell et al., 2004

Newell, P. T., and Ching-I. Meng (1992), Mapping the dayside ionosphere to the magnetosphere according to particle precipitation characteristics, *Geophys. Res. Lett.*, 19(6), 609–612, doi:10.1029/92GL00404.

Wing, S., S. Ohtani, P. T. Newell, T. Higuchi, G. Ueno, and J. M. Weygand (2010), Dayside field-aligned current source regions , *J. Geophys. Res.* , 115 , A12215, doi:10.1029/2010JA015837.

Newell, P., Y. Feldstein, Y. Galperin, and C.-I. Meng (1996), Morphology of nightside precipitation, J. Geophys. Res., 101(A5), 10737-10748.

Gussenhoven, M., D. Hardy, and W. Burke (1981), DMSP/F2 Electron Observations of Equatorward Auroral Boundaries and Their Relationship to Magnetospheric Electric Fields, J. Geophys. Res., 86(A2), 768-778.

Hardy, D., W. Burke, M. Gussenhoven, N. Heinemann, and E. Holeman (1981), DMSP/F2 Electron Observations of Equatorward Auroral Boundaries and Their Relationship to the Solar Wind Velocity and the North-South Component of the Interplanetary Magnetic Field, J. Geophys. Res., 86(A12), 9961-9974.

Newell, P. T., S. Wing, C. I. Meng, and V. Sigillito (1991a), The auroral oval position, structure and intensity of precipitation from 1984 onwards: An automated on-line data base, J. Geophys. Res., 96(A4), 5877–5882, doi:10.1029/90JA02450.

Newell, P. T., W. J. Burke, E. R. Sanchez, C.-I. Meng, M. E. Greenspan, and C. R. Clauer (1991b), The low-latitude boundary layer and the boundary plasma sheet at low altitude: prenoon precipitation regions and convection reversal boundaries, J. Geophys. Res., 96(A12), 21,013–21,023, doi:10.1029/91JA01818.

Newell, P. T., J. M. Ruohoniemi, and C.-I. Meng (2004), Maps of precipitation by source region, binned by IMF, with inertial convection streamlines, J. Geophys. Res., 109, A10206, doi:10.1029/2004JA010499.

3. Redmon method

A threshold value of 10^4.5 (1/cm^2/sr/sr)

Used the highest nine energy channels of DMSP Special Sensor J4 (SSJ4) instrument, with energies between 1.39 and 30 keV, inclusive.

All candidate precipitation regions of time were identified where the spacecraft was above 58 degree magnetic latitude, and the smoothed number flux of precipitating particles exceeded the given threshold.

Page 3 of the paper Redmon et al., 2010

Redmon, R. J., W. K. Peterson, L. Andersson, E. A. Kihn, W. F. Denig, M. Hairston, and R. Coley (2010), Vertical thermal O^+ flows at 850 km in dynamic auroral boundary coordinates , *J. Geophys. Res.* , 115 , A00J08, doi:10.1029/2010JA015589.

Relating field-aligned currents to different auroral precipitation regions

See references below and references therein.

Wing, S., S. Ohtani, P. T. Newell, T. Higuchi, G. Ueno, and J. M. Weygand (2010), Dayside field-aligned current source regions , *J. Geophys. Res.* , 115 , A12215, doi:10.1029/2010JA015837.

Ohtani, S., S. Wing, P. T. Newell, and T. Higuchi (2010), Locations of night-side precipitation boundaries relative to R2 and R1 currents , *J. Geophys. Res.* , 115 , A10233, doi:10.1029/2010JA015444.