Investigation into Alternative Statistical Auroral Oval Models, Stage I.

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1. Introduction

High latitude ionospheric modelling relies heavily upon a description of the auroral precipitation pattern (the auroral oval). On a global scale no theoretical model is available to describe the oval. Observationally a variety of satellites have made insitu particle observations and optically imaged the auroral emissions. The latter, not being a local observation, has its advantages; however, coverage and availability of images is exceedingly sparse and will remain so for the next few years. To date, data from particle detectors, primarily electrons, has been statistically binned to produce global statistical oval models. Such models have been extensively used as the auroral description for both thermospheric and ionospheric model studies.

The ionospheric modelers have concerns with such statistical models due to the lack of quantitative information as to how well they model the auroral oval. For only a very limited number of cases does the actual auroral oval appear as smooth as the statistical models. Furthermore, since the auroral oval can have discrete structures over a wide region which itself changes latitude from case to case, the average models smooth out sharp gradients in precipitation and underestimate the peak auroral intensities.

Several years ago while Dave Evans and Jan Sojka were at the fall AGU, these topics were discussed. Dave described data from the post noon sector which repeatedly showed a marked feature of a narrow intense auroral structure. Such a feature, since it has a variable latitude of occurrence, would be heavily smoothed out over a wide region of latitudes in the statistical auroral models. The sensitivity of auroral models to such well defined features has never been tested. Dave offered to make his data base and computer resources available for such a study. In the following section the first stage of this study is described. Mike Bowline spent four weeks during November-December 1986 at Boulder working with Dave Evans attempting to quantitatively define the statistical model sensitivity to different methods of binning the NOAA/TIROS data base.

2. Stage I Findings

For the benefit of future USU visits to NOAA in Boulder to work with Dave Evans, appendix 1 has been generated. This contains useful general information on how to use the NOAA computer system.

After becoming familiar with the data base, Mike Bowline and Dave Evans decided to concentrate this stage of the study on a subset of the data base. Specifically activity levels 7 and 3. These activity levels are defined in terms of the total energy flux (or power) into the ionosphere and are derived from Dave Evans auroral model. As described in the introduction the initial thinking was to try binning the auroral data with respect to the most intense auroral form in each satellite pass. This would hopefully produce stronger gradients and conserve the peak intensity at the cost of producing a relative latitude scale. Since the satellite passes lie approximately within 1/2 hour MLT slices, only orbits which reach magnetic latitudes greater than 80° were used for this study.

2.1. *Binning According to Peak Intensity in Each Partial Auroral Pass.*

Each partial auroral pass was analyzed to locate the latitude of the peak electron energy flux. Then using this location as the final reference latitude, all the other data were binned relative to it. The final reference latitude was made equal to the average latitude of the peak. This binning procedure was carried out for 48 different MLT sectors.

Unfortunately and somewhat surprisingly this procedure was not very useful. Figure 1*a* shows the 1800 and 0600 MLT bins and for contrast Figure 1*b* shows the corresponding data from Dave Evan's auroral model. Clearly this binning method produces an inferior auroral profile, and the situation is no better at other MLT's. The problems with this procedure are summarized as follows:

1. The resultant profiles have a rather unphysical triangular shaped latitudinal profile when plotted on a $\log_{10}$ scale. (Figure 1*a*)
2. The binning procedure generates significant auroral energy fluxes at low latitudes where it is never observed.
3. Equatorward boundary energy flux gradients were much too flat.
4. The profile is much more spread out than even the original auroral model (compare Figures 1*a* and 1*b*).
5. The source of the problem is that the peak intensity does not necessarily lie close to the center of the profile. It can be a very narrow feature lying almost anywhere in the oval latitudinal range.

2.2. *Binning According to the Center of Gravity in the Precipitation Energy Flux*

The next line of attack was to bin according to where the latitudinal profile center of gravity lay. This procedure overcomes the problem of very narrow intense features controlling the binning. Again the same data sets were analyzed and a binning made. Figure 2 shows the MLT cut corresponding to Figure 1 for this new binning. These profiles look better and indeed look similar to the original auroral model (compare with Figure 1*b*.) However problems still remain:

1. Still getting energy flux at low latitudes in region where is is not observed.

2. The profiles look too humpy, their shape still does not look like the observations; especially the observed strong equatorward gradients are not reproduced.
3. The binned data set looks somewhat similar to Dave's auroral model.
4. Binning according to either the peak or the center of gravity does not introduce improvements over the earlier auroral models. In fact this leads to erroneous artifacts.

2.3. *Binning According to the Equatorward Boundary*

Dave Evans suggested binning with respect to another distinguishing feature: the equatorward boundary. At almost all MLT's, this boundary is evident. Furthermore it is a very sharp gradient, readily identified in the data. Hence, Mike tried binning the passes relative to this location. Quite different results were obtained; Figure 3 shows the MLT corresponding to Figures 1 and 2 for activity level 7. The problems associated with the equatorward edge are all gone. However, several other problems surfaced:

1. The latitudinal profiles extend well into the polar cap.
2. Only about 10% of the activity level 7 data show energy flux at the 1 erg/cm^2 sec level in the polar cap. The remaining 90% show energy fluxes at the 0.01 erg/cm^2 s level. The model shows fluxes on the order of 0.1 erg/cm^2 s. In order to discriminate against the 10%, the data was rebinned using now a median rather than an average criterion to determine the energy flux in each latitudinal bin. Figure 4 shows the net result of this procedure. This looks quite encouraging.

Figures 5*a* and 5*b* contrast at all MLT's. This median binned model with the Spiro statistical oval (Spiro et al. 1982). The new median model has significantly more realistic equatorward boundary gradients. At present the median equatorward boundary procedure is almost as coarse as the original auroral models. The latitudinal averaging of earlier models has been replaced by an uncertainty in the reference equatorward boundary latitude and the polar regions discriminated against by using "median" averaging procedures. Both of these indicate a search for possible dependencies on other geophysical parameters may be useful.

3. Summary

It is evident that the 4th run has possibilities. The data ranging from 1 MLT to 8 MLT and from 13 to 20 MLT all show good systematic trends, which look a lot closer to a typical data pass (see Figure 5*a*.) Although not in detailed agreement with individual data, they are somewhat more representative than earlier statistical models.

The differences arise from the fact that the individual passes of a particular activity level show a variety of signatures, hence, they themselves do not appear to have a unique profile. Before more sophisticated statistical techniques can be applied to binning the data, a more detailed look at sorting the individual orbits with respect to other parameters should be considered. (ie., B_z north versus south may seperate the 10% of filled polar cap cases rather naturally).

Thus we would like to pursue working with Dave Evans on a subset of data (say activity level 7) and attempt some finer classification of the data:

1. Classify orbits with respect to B_z. [assume B_x and possibly B_y do not affect oval or polar cap.]
2. Try classification on D_{st}, ie., look and see if equatorward boundary latitude correlates with it.
3. In desperation try any other available parameters: K_p, A_e etc.

These studies would be aimed at sub-dividing the Activity 7 orbits into a few sets (perhaps 3-4). The final aim would be to see if the NOAA/TIROS data combined with the IMF or other parameters could produce a significantly improved auroral model.

Figure 1. Top panel shows a model of the northern hemisphere magnetospheric potential plus corotational potential contours for a northward IMF orientation of: $B_x = 0, B_y = 3\gamma, B_z = 6\gamma$. The contours are drawn at 5 kV intervals and presented in an MLT-magnetic latitude frame. Bottom panel shows a selection of ionospheric plasma convection trajectories for this IMF; each trajectory has tick marks at hourly convection intervals around the trajectory. The shading shows the region of sunward convection in the polar cap.

Figure 2. Identical to Figure 6 except that the northward IMF orientation is changed to: $B_x = 0, B_y = -3\gamma, B_z = 6\gamma$.

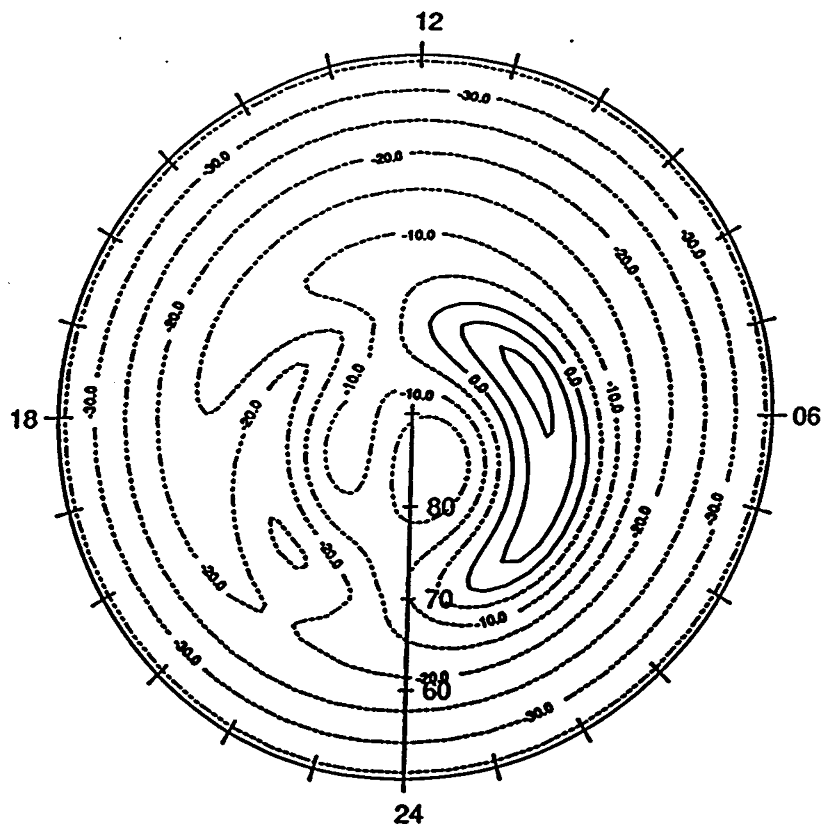

Figure 1a

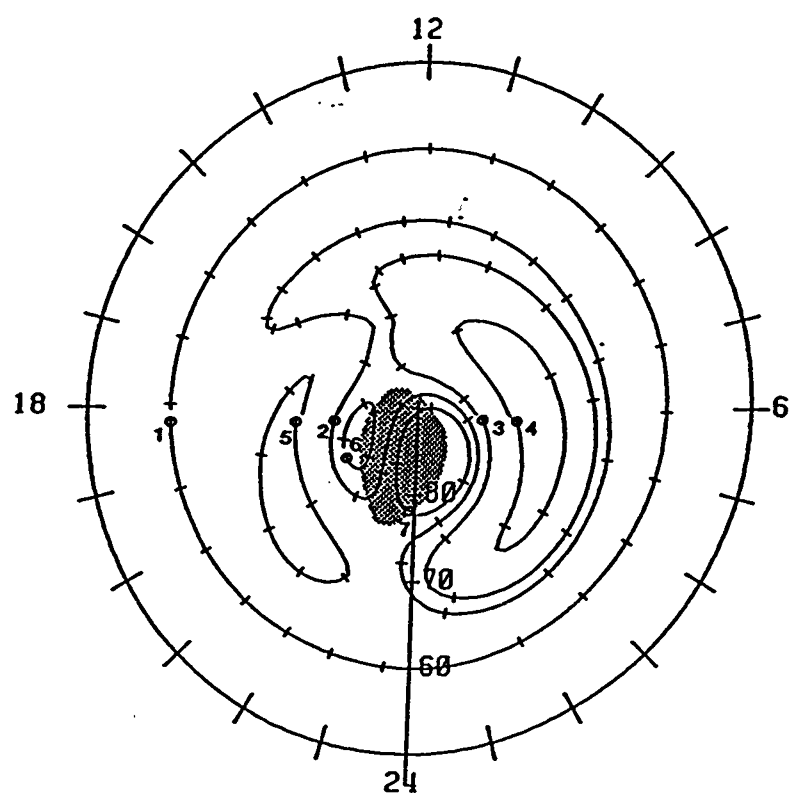

Figure 1b

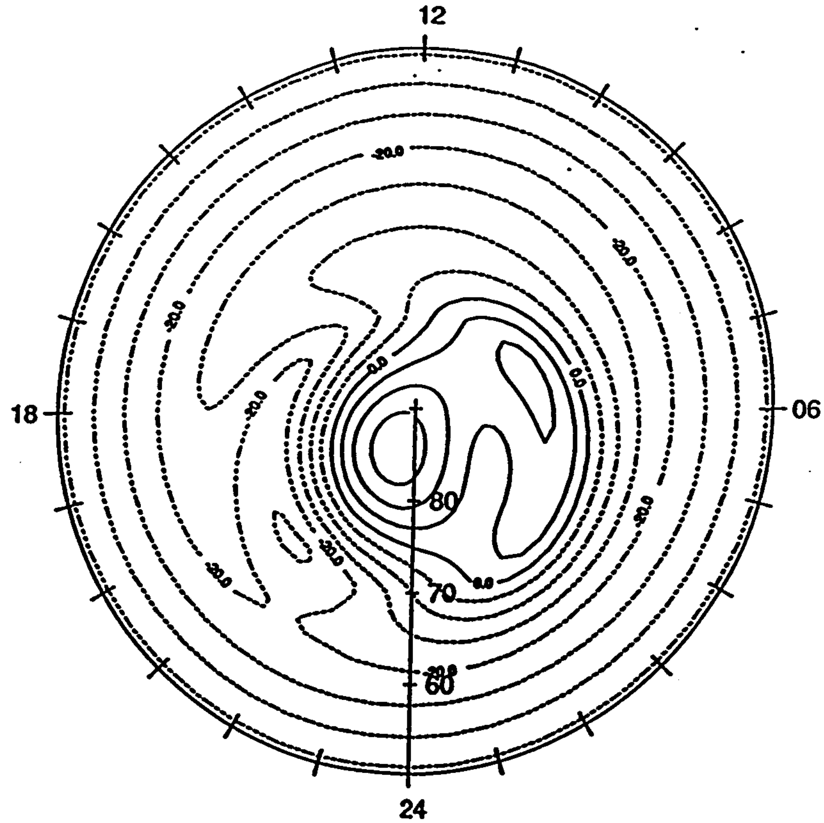

Figure 2a

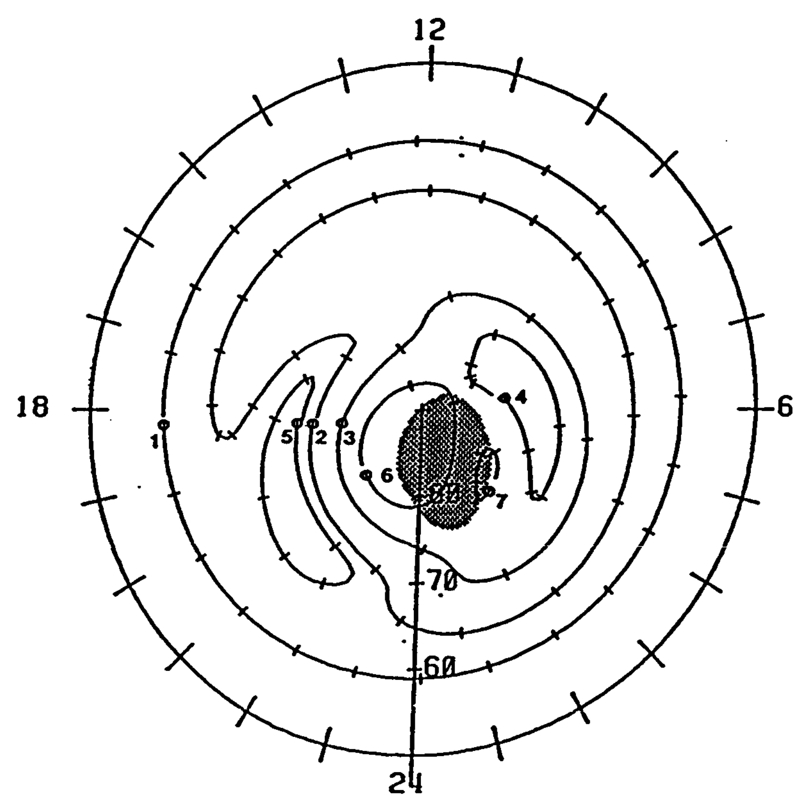

Figure 2b