Running the APL Map Potential Software with Southern Hemisphere SuperDARN data

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Abstract

The JHU/APL global convection mapping software is proving a useful tool, combining as it does SuperDARN line-of-sight velocity observations with the APL convection model to provide estimates of the polar ionospheric convection. As yet, the application of this software has been confined to the northern hemisphere. At BAS, the software has been modified to allow the production of southern hemisphere ionospheric convection maps using the southern hemisphere SuperDARN radars. This paper discusses the assumptions made in this adaptation and presents our early impressions of some of the potential uses and abuses of the software.

Introduction

The main focus of this paper is the promotion of discussion about the APL Global Convection Mapping/Map Potential Software. This software is becoming increasingly employed within the SuperDARN community and so a full understanding of its uses and limitations is essential.

This paper will discuss the implementation of the software to run with southern hemisphere SuperDARN data as well as three issues regarding the use of the software in both the northern and southern hemispheres: (1) The influence of the statistical model on the output; (2) The setting of the low latitude convection boundary; (3) The reproduction of mesoscale features. All these issues are discussed to some extent by *Ruohoniemi and Baker* [1998] and careful reading of this paper is encouraged.

The software was first developed at APL by *Ruohoniemi and Baker* [1998]. The software takes as its inputs all the available line-of-sight Doppler velocity data for a particular time interval from all the SuperDARN radars in the chosen hemisphere. A number of fit options need to be selected (e.g., the order of the spherical harmonic fit to be performed, and the spatial extent of the fit). The final input is a statistical convection model which provides data for the fit for regions not covered by the SuperDARN coverage. The statistical model presently used is the APL statistical model (*Ruohoniemi and Greenwald,* 1996) which is comprised of 24 different models (for 8 IMF directions and 3 IMF strengths).

The methodology is as follows: Firstly, all ground scatter and noise is removed form the line-of-sight data. The data are then gridded in to specific latitude/longitude bins. The data from all the radars are combined. The spatial gaps are filled with velocities from the statistical model. A best fit is then made to the data with a spherical harmonic expansion of a potential function.

The output is a potential map in spherical harmonic form. This potential map provides an estimate of the cross-polar cap potential as well as estimates of the convection flow vectors. Two types of vectors are typically used for visualising the flow patterns: (1) Fit vectors: These are velocity vectors which are evaluated from the estimated potential function. (2) True vectors: These are velocity vectors obtained by combining the measured line-of-sight velocity measurements with the transverse (to the line-of-sight direction) component of the Fit vectors.

Implementing the Software for the Southern Hemisphere

The southern hemisphere now boasts 6 operational SuperDARN radars. Their fields-of-view (in AACGM co-ordinates) are

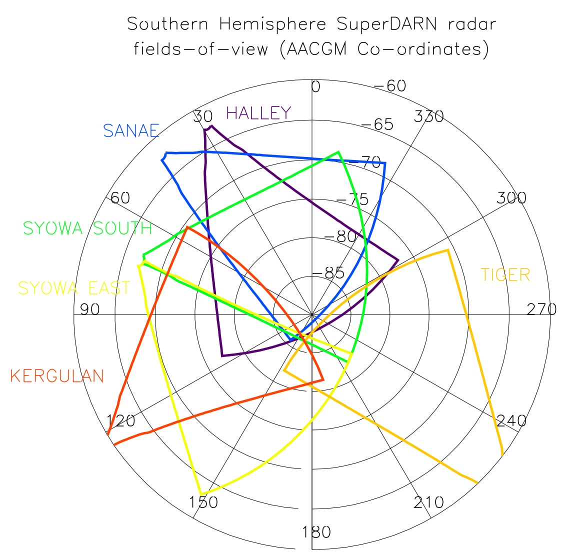

Figure 1 The Southern hemisphere SuperDARN radars.

presented in Figure 1. Although they do not provide the same level of coverage of the polar ionosphere as in the North, the coverage should often be adequate enough to produce estimates of the global convection picture by using the mapping software.

A number of alterations were made to the software in order for it to run for southern hemisphere data (contact GC for details). The graphical output is the same as for the northern hemisphere, the perspective being as if viewing from above the geomagnetic North pole. This allows easier comparisons with northern hemisphere maps. One possible improvement that could be made to the software would be the addition of a southern hemisphere statistical convection model. At the present time the software uses the northern hemisphere statistical model with the sense of IMF By reversed.

The Influence of the Statistical Model

Because a statistical model is being used in the mapping process we need to have some appreciation of the influence of this model on the final output. The statistical model is only used to fill in gaps where the data coverage is poor, and so the influence of the statistical model is obviously heavily dependent on the data coverage (this may be more of a problem in the southern hemisphere where the spatial data coverage is likely to be lower).

In order to study the influence of the statistical model on the output we have studied an interval with extensive data coverage in the northern hemisphere, and compared the output for different statistical model conditions. A 5-minute interval was studied during which the IMF was southward and of low magnitude. Using these statistical model conditions the estimated cross-polar cap potential was 55 kV. Figure 2 presents the fit vectors and potential pattern for this interval obtained using Bz+, 0<BT<4 statistical model conditions. The cross-polar cap potential estimate in this case was 39 kV. To compare with this, Figure 3 presents the fit vectors and potential pattern obtained using Bz-/By+, 6<BT<12 statistical model conditions. The cross-polar cap potential estimate in this case was 72 kV.

There are a number of interesting features apparent in comparing the vectors and potential patterns in Figures 2 and 3. Firstly, in the region of data coverage, the potential pattern and the fit vectors are remarkably similar. This provides us with a large amount of confidence in our results in these areas and suggests that the statistical model is having little influence in areas of large data coverage as we would expect. Conversely, in the region of no data coverage (the bulk of the afternoon convection cell), the estimated potential patterns are vastly different as they depend entirely on the statistical model conditions.

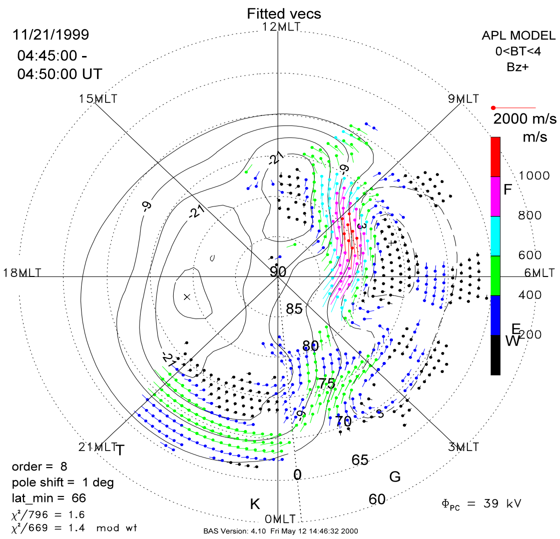

Figure 2 Output for a single scan using Bz+, 0<BT<4 statistical model.

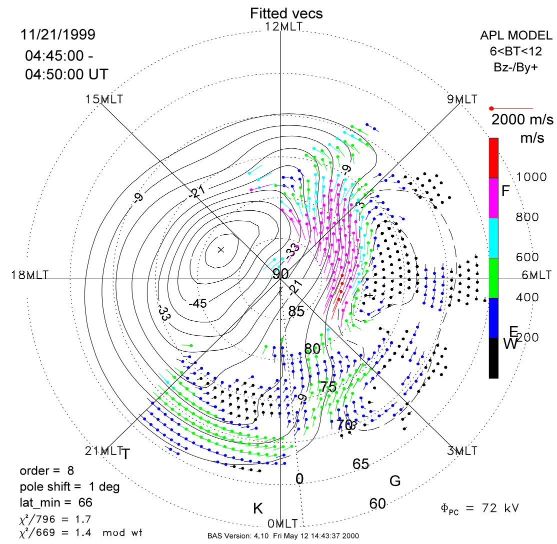

Figure 3 Output for a single scan using Bz-/By+, 6<BT<12 statistical model.

The fact that a large region of one of the convection cells is dominated by the statistical model results in the wildly different cross-polar cap potentials for different statistical model conditions. We would suggest that in this case the cross-polar cap estimate is unreliable, even when using the correct statistical model conditions that match the prevailing IMF conditions. Only when both cells have an acceptable amount of data coverage can the cross-polar cap potential be considered reliable and uninfluenced by the statistical model.

A method to determine the uncertainty in the cross-polar cap potential estimate based on factors like the % data coverage, the IMF variability etc. would provide an extremely useful tool for estimating the significance of the cross-polar cap potential values estimated in this way.

Setting the Low Latitude Convection Boundary

One of the major difficulties of using the global convection mapping software is the selection of the input parameters for the analysis. One of these parameters is the low-latitude convection boundary within which the spherical harmonic fitting of the data takes place. Obviously the true boundary location will give the most realistic potential variation. However, the location of this boundary will change with time and could potentially cover a wide range of latitudes. Here we will look at instances where this boundary position is set too low or too high and consider the implications.

Figure 4 presents the same data interval as shown in Figures 2 and 3 (in this case the correct statistical model conditions have been assumed for the prevailing IMF conditions). However, in this case the low-latitude convection boundary has been set too low (at 60 degrees). A couple of things are immediately obvious from the convection output. Firstly, the statistical model is providing more influence than necessary, especially at the lower latitudes, below the extent of the data coverage. The results therefore have a greater reliance on the statistical model. Secondly, this increased reliance on the statistical model at low latitudes has led to the introduction of some unrealistic, strange potential variations at low latitudes which have no basis in observation (e.g., the expansion of the morning convection cell towards noon at low latitudes).

Figure 5 presents the same data again but in this case the low-latitude convection

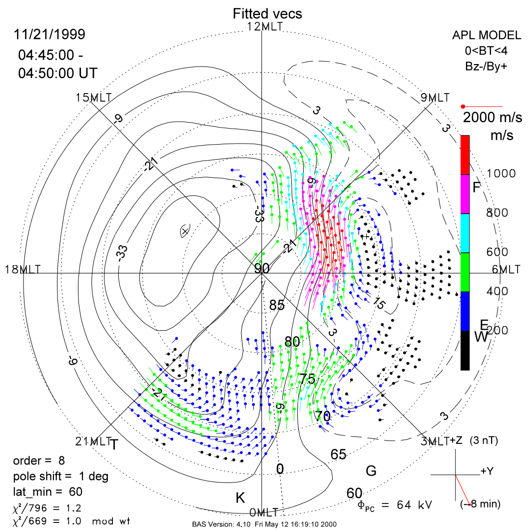

Figure 4 Example output where the low-latitude convection boundary is set too low at 60 degrees.

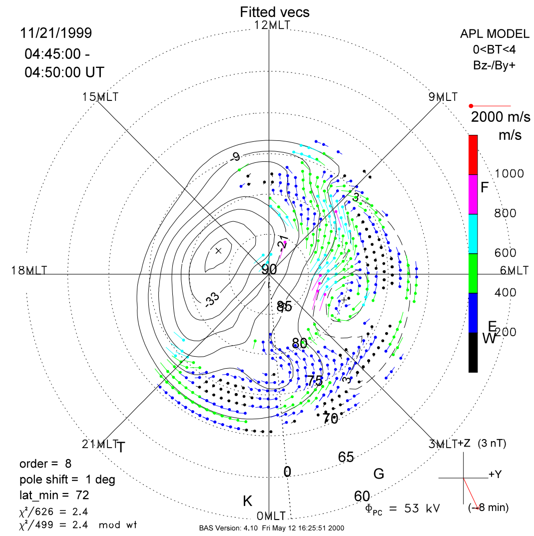

Figure 5 Example output where the low-latitude convection boundary is set too high at 72 degrees.

boundary has been set too high (at 72 degrees). Again, a number of things are immediately obvious from the convection output. Firstly, a large amount of data from lower latitudes has been lost (that below the low-latitude convection boundary) and hence the potential variation on this day will not be representative of all the data taken at this time. Secondly, the magnitudes of the flows in the throat region are significantly reduced. Furthermore, there is a much greater uncertainty in the fit as shown by an increase in the chi-squared parameter.

Obviously, selecting an optimum location for the low-latitude convection boundary is important. At present, it seems as if the best estimate of this boundary position can be taken as the low-latitude limit of the ionospheric backscatter, although some trial and error may be required to select the optimum position.

Reproduction of Mesoscale Features

Due to the amount of smoothing/averaging of the data that occurs in the gridding process and the constraint of the fit process it is important to test whether the global convection mapping process can reproduce mesoscale/small-scale features in the convection. This would highlight its usefulness in looking at local variations in the convection flow as well as the global picture.

Figure 6 presents a comparison of the results of the mapping with MERGE velocity vectors during a quasi-steady IMF/solar wind interval during which the local flow pattern around noon was characterised by an unusual S-bend mesoscale flow pattern. It is immediately clear from the analysis that a high order of spherical harmonic fit is required in order to reproduce in any way this mesoscale feature (in Figure 6 a fit order of 12 is used). However, the fit vectors/potential contours do not reproduce the exaggerated nature of the feature. This is especially clear when looking at the merged vectors with a large equatorward component at noon. The equatorward component is not reproduced in either the fit vectors or the potential contours. However, the true vectors do reproduce this equatorward flow component and provide a much better picture of the convection flow in this region. Reflecting more of the line-of-sight velocity input, the true vectors do in general provide a better estimate of local convection flow characteristics. However, it must be highlighted that a high order fit is

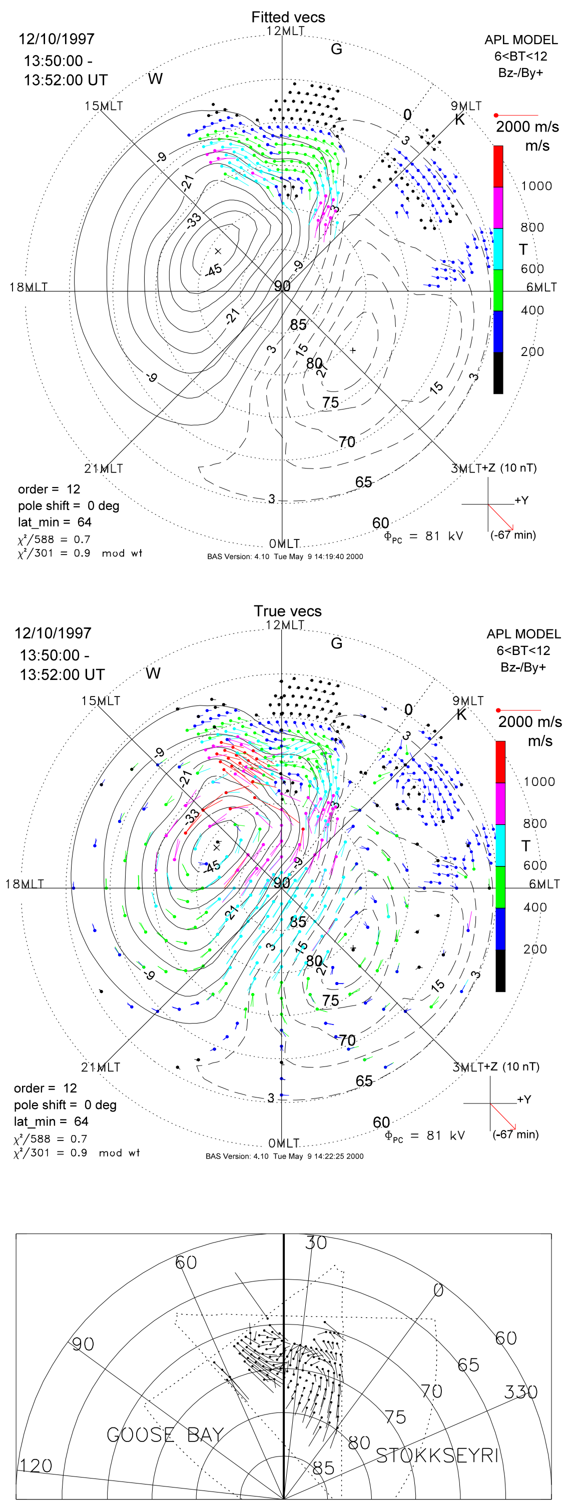

Figure 6 Fit, True and Merged vectors showing the reproduction of a mesoscale feature in the convection flow.

required to reproduce local mesoscale features.

Summary

This paper has discussed the uses and limitations of the APL global convection mapping software. It is now possible to perform this mapping in both the southern and northern hemispheres. We have a growing understanding of the uses and limitations of the software, although, as the examples in this paper show, caution must still be exercised when performing the analysis so as to achieve reliable results.

This software should prove an excellent analysis tool for future studies, especially for studies where extensive data coverage is available (reducing the dependence on the statistical model). In time, inter-hemispheric comparisons may provide considerable insight into the differences between northern and southern hemisphere convection.

References

Ruohoniemi, J. M. and K. B. Baker, Large-scale imaging of high-latitude convection with Super Dual Auroral Radar Network HF radar observations, *J. Geophys. Res.*, *103*, 20,797-20,811, 1998.

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