Uses and Abuses of the Global Convection Mapping Software

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Abstract: The APL fitting technique is increasingly in use as a way to process a set of SuperDARN velocity measurements into a global convection map. The technique essentially fits all the available line-of-sight velocity information to an expansion of the electrostatic potential in terms of spherical harmonic functions. The procedure involves a median filtering of the raw velocity data from FITACF, a mapping to a global grid consisting of equal-area cells, and the assignment of uncertainties based on the spatio-temporal variability of the velocity. The radar velocities are supplemented with data from a statistical model before fitting. In this presentation we review the range of application of the technique. Some cautionary comments are in order. It must be remembered that the fitting solution represents the optimal solution for the global convection pattern. Other techniques, or even the fitting technique modified so as to preserve more local flavor, will generally be more suitable for determining an optimal local solution. The quality of the fitting should be apprised by several methods, including examination of the differences between the measured velocities and those implied by the fitting. In general, no more processing should be performed than is necessary to highlight the effect under study, and the research conclusions ought to be insensitive to reasonable variation of the fitting parameters.

Introduction:

The APL technique for estimating the global convection pattern on the basis of the SuperDARN velocity measurements was introduced by *Ruohoniemi and Baker* [1998]. The mathematical formalism had its antecedent in the work of *Ruohoniemi and Greenwald* [1996], who reduced six years of Goose Bay data to a statistical convection model. In essence, the technique fits an ensemble of line-of-sight velocity data to an expansion of the electrostatic potential in terms of spherical harmonic functions. The result is a map of the distribution of potential, from which fitted velocities can be derived. Here we shall refer to the technique as the APL potential fitter, or just the APL fitter.

The APL fitter is being used more widely. Recent studies of effects in convection include *Greenwald et al.* [1999], *Slinker et al.* [2000], *Yeoman et al.* [2000], and *Huang et al.* [2000]. In addition, the fitter is the basis for the generation of the real-time convection pattern and related products at the JHU/APL SuperDARN website (http://superdarn.jhuapl.edu/). *Shepherd and Ruohoniemi* [2000] have shown how the dependence of the fitter results on the statistical model contribution is almost eliminated when the coverage is extensive. The Appendix of that paper also describes some refinements of the original technique. As more SuperDARN radars come on line, the value of the global result provided by the APL fitter will certainly increase.

The mapping software had been distributed from APL to a number of SuperDARN institutions via Leicester University. The British Antarctic Survey has adapted the code to run on the Southern hemisphere radars. Several studies are proceeding that test the capabilities of the fitter. All in all, it seems a good time to briefly discuss the fitter in terms of what it can and cannot do, its sensitivity to the selection of fitting parameters, and the reliability of the fitter results. In this note, we will confine ourselves to providing a narrative. Figures that illustrate some of the points made here can be viewed in the Appendix containing viewgraph materials.

Discussion:

First of all, it must be remembered that the fitter finds a ‘best-fit’ estimate of the *global* convection pattern. That is, the fitter finds the solution for the global distribution of electrostatic potential that is most consistent with the entire ensemble of line-of-sight velocity measurements. The solution is optimal globally but not locally. One great merit of the global solution is that the velocities derived from it are automatically consistent with the divergence-free condition. This can be contrasted with the velocities obtained by directly merging line-of-sight velocity measurements within common-volume areas. The merged vector is optimal locally but the map of merged vectors is, in general, not consistent with a potential function as it will have finite divergence. This raises problems with the physical reality of the larger pattern. Ideally, the optimal global and local solutions coincide. Some dissatisfaction results when the fitter is used to estimate the local velocity vector but the result is inconsistent with the local velocity measurements. This is not unexpected but it is undesirable. One can appreciate that a trade-off has been made: the fitter ignores some local behavior in order to render a plausible global pattern.

The velocity vectors plotted on the maps are usually derived from the gradient of the potential function, that is, they are identically consistent with the global solution. These vectors may be inconsistent with the local velocity measurements for at least three reasons: i) the spatial filtering inherent in the fitting may eliminate local structure, ii) the errors associated with the measurements may cause the local feature to be suppressed in the fitting, and, iii) the local velocity may be inconsistent with a potential function. The maps can be plotted with velocity vectors that retain more of the local character. One option is to select 'true' vecs from the plotting menu. A true vec (or vector) is plotted using a measured line-of-sight velocity plus the transverse velocity component implied by the fitting result. The true vec is thus a hybrid possessing both local and global information. Another option is to fit only a local subset of velocity measurements. This prevents velocity data collected over other areas from affecting the local solution. Of course, the cost for this exercise is the loss of realism over the outlying areas. In general, one should choose the proper analysis for the problem under consideration. From this discussion it will be appreciated that using the global fitter uncritically to estimate local velocities on small spatial scales is inappropriate.

The values of a number of parameters have to be set before a fitting can be performed. For example, a user can adjust the order, L, of the spherical harmonic fitting and hence the spatial resolution. The data from the statistical convection model can be varied depending on the type of IMF that is presumed to be effective in the ionosphere. The low-latitude boundary of the convection zone needs to be specified. Most of the variable parameters can be set from the plotting menu. The results of the fitting are less sensitive to the selection of the fitting parameters as the amount of data increases. Furthermore, we have found it possible to examine the radar data themselves for information on the parameter values. For example, the low-latitude limit of the backscattering activity turns out to be a good proxy for the boundary of the convection zone. Examination of the radar velocity measurements often identifies which statistical convection pattern (ordered by IMF) is most suitable for selection of model data. The important point here is that *the effects under study should be stable against reasonable variation of the fitting parameters*.

We turn to consideration of the quality of a fit. At one level this can be posed as the question: how well does the fitting result reproduce its inputs? We refer to the difference between a line-of-sight velocity implied by the fitting and the associated measured line-of-sight velocity as the 'residual'. A velocity input has been fit successfully when the residual is less than the uncertainty. Statistically, the degree to which this condition is satisfied in a global fitting is expressed by a chi-squared factor. This is plotted on the map with other diagnostic information. The chi-squared factor should not much exceed 1.0. Values as large as 2.0 indicate that the line-of-sight velocities have not been reproduced to within their uncertainties. Often, this can be corrected by going to a higher fitting order. It might also be that the measurements are contaminated with 'bad' data that are not consistent with a potential function. By plotting the residuals, a user can identify problem data and take corrective steps. Even when the fit is good in a chi-squared sense, the result might be misleading, especially when data are sparse. The fitter might, for example, prefer to draw complicated structure to accommodate a few variable velocity points when the points themselves look dubious. It is advisable to refer back to the line-of-sight velocity data and merged vectors as much as possible. The idea is to *test the features of the convection under study for consistency with the basic measurements*.

Conclusion:

The APL fitter is a very useful tool for tackling problems in high-latitude convection that require a global view. However, it should be applied with some appreciation for its limitations. Chief among these is fact that it generates a best-fit global pattern that might not reproduce local behavior. We have seen that some local flavor can be recovered by plotting hybrid true vecs or by fitting only a local subset of the available velocity data. A number of fitting parameters can be adjusted and this makes for some subjectivity in the fitting result. The rule of thumb is that the effects under study in the convection patterns should be stable against reasonable variation of the fitting parameters. Fortunately, the radar data themselves are of considerable value for setting the values of some parameters. Finally, the goodness of the fit needs to be taken into account. The interpretation of the fitted patterns should be checked for consistency with the velocity inputs and merged results.

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