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The Wisconsin Method of SCATT Wind Ambiguity Removal

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Summary

SCATT ambiguis vectors were removed by a simple method that made a streamline analysis of the highest probability vectors and then eliminated all vectors that disagreed with this analysis. Using standard methods for analyzing meteorological data it was found that large-scale (1° or larger) wind patterns could be extracted from the SCATT data. Smaller scale features required a more careful analysis of the wind field. It was our conclusion that the SCATT sensor could provide wind data of the highest resolution and quality known to meteorologists and oceanographers if ambiguity removal methods were employed.

The Wisconsin Wind Ambiguity Removal Method

1. Introduction

Our approach was to edit the NOSS vectors according to streamline analyses made from the high probability vectors. The philosophy was that the basic streamline patterns could be defined by using only the vectors with the highest probabilities in each group and then successive edits and re-analyses of the streamlines could produce finer details of the wind patterns. This was an iterative procedure that contained two basic steps: an objective streamline analysis, followed by an editor that removed all NOSS vectors which disagreed with the streamline analysis. These steps were repeated several times to converge on the wind field.

Obviously the highest probability vectors were not the best choices in all groups. For this reason we employed objective analysis techniques that were designed for making wind field analyses from noisy data. That is data that contained some bad or erroneous measurements which are typical of meteorological data. These techniques use averaging or smoothing functions to minimize the affects of bad observations. The details of the techniques used and their results are described in detail in the next two sections.

2. Description of the Method

The first step of the method was to rank all vectors in each cluster according to their probabilities. Then a streamline field was made using only the highest probability vectors from each cluster. These vectors were called our "First Choice" winds. Where all vectors contained equal probabilities, the clusters were ignored from the first analysis and no First Choice wind was assigned.

The "Barnes Low Pass Filter" technique (Barne, 1973) was used to make objective analyses of the U and V components of the wind field at uniformly spaced grid points. The method of Barnes filled each grid point with the average of all wind vectors weighted according to their distance from the grid point. An inverse exponential weighting function was used (Fig. 1).

The degree of detail contained in the analyzed wind field could be regulated by varying the resolution of the grid or grid point spacing, and the width of the weighting function. By using a high resolution grid and a narrow weighting function, the analyzed field could describe all of the measurements in detail. However, this was not desired because the analyzed field would contain all of the noise in the original data. By experimenting with different grid resolutions we found that a grid spacing of 1° latitude and longitude with the weighting function shown in Figure 1 produced streamline patterns that closely depicted most of the features of the wind field which we were trying to reproduce (see Figure 2). For our examination of the results, the objectively analyzed streamlines were plotted from the U and V component grids using the method described by Whittaker (1977).

The second step was to edit out all NOSS vectors that deviated substantially from the wind direction of the objectively analyzed field. The editing was done objectively by the computer. For the first pass we eliminated all vectors in excess of $\pm 45°$ from the analyzed wind direction.

For the second iteration our objective analysis was made on all of the vectors that passed the first iteration. The same grid spacing and weighting function was used. This new analysis was used to re-edit the NOSS field with a criteria of $\pm 20°$ in direction.

This method was initially carried through 5 iterations on the starter data set (Rev 825) but little change in the analysis field appeared after the second iteration. Experiments were tried with different editing criteria and 45°/20° criteria was chosen as an optimum match.

Actually the editing criteria had only a small influence on the resulting fields. The purpose of using a 45° criteria on the first pass was to eliminate most of the obviously wrong choices from the field and leave the fine tuning to a second pass. It was our experience that most of the streamline patterns were determined from the objective analysis of the highest probability vectors on the first pass. The second pass only changed minor details inside the initial patterns.

3. Results

a. General Performance

To judge the accuracy of our method on a gross statistical basis each ambiguity removed SCATT vector was compared to the direction of the "truth field" vector given with the data set. All vectors that were within ±20° of the truth vector were catagorized as "good choices" and vectors outside of this range were labelled as "bad choices." In addition, we had several vector groups from which no vector choices were made and these groups were catagorized as "no picks."

These statistics show that the method had a high rate of success. From 79.4 to 88.9% of the vectors chosen were correct choices. The number of bad choices were small, ranging from 4.3 to 9.6% of the total picks made.

A substantial number of "no-picks" were made, ranging from 6.4 to 11.8% of the groups. These groups were not included in the error column (Bad Picks) because sometimes no choice within ±20° of the truth vector were available.

We did not attempt to determine if each no pick group did indeed have a valid vector that our method missed.

Inside the Good and Bad Pick catagories we also listed the number of our First Choice winds that were present. It is apparent that the majority of Good Picks were high probability vectors (First Choice) to start with. The First Choice Good Picks ranged from 70.4 to 76.7% of the total vector groups examined while the First Choice winds that were Bad Picks were only 1.6 to 2.3% of the total. This re-affirms our faith in using the high probability vectors as a starting point.

b. The Locations of the Bad Picks

The Bad Picks were in either light wind areas or where sharp directional changes occurred. The subtropical highs and cols (deformation zones) were difficult to analyze with these data. However, these features have been difficult to analyze with all other meteorological data because of their variable wind directions and generally unorganized nature.

The objective analysis scheme used here tended to produce broad features by smoothing the input observations. Thus, where small scale directional changes were present, many of the Bad Picks or No Picks occurred because the method tended to emphasize larger scale features.

In a few areas of strong winds many No Picks occurred where there was a strong shear zone or area of sharp directional turning. This too was a result of the smoothing in the streamline analyses.

A detailed description of each case studied follows: The Starter Set, Rev 825 -- Because of the length of the orbit we were forced to break 825 into two sections and made separate analyses of each. The major problem encounter was on the lower part of the orbit where the westerly winds (blowing from west toward the east) changed to northeasterly winds (Fig. 2). This is a subtropical high area and the locations of the No Picks are indicated by arrows in the margins.

The upper part of the orbit contained westerly winds and a double low or cyclonic vortices (Fig. 3). These features were diagnosed in our streamline analysis, however, most of the No Picks and Bad Picks were around the double vortices. A few also occurred on the left side of the left track around the vortex at the top of the track.

The upper part was processed through five iterations as shown in Fig. 3. Little change can be seen between the second and fifth edited fields as previously mentioned.

From the streamline analyses made of these data we concluded that the major features of this orbit were resolved to a 1° resolution and the errors were minor points of these features.

• Case 1, Rev 1093--There were only two features of 1093: a low or cyclonic vortex on the upper left side, and a shear zone on the lower left side which may have been a cold front (Fig. 4). Our major problem was in the shear zone. Most of the Bad Picks and No Picks were in this area because of the inability of the streamline analysis to resolve a tight gradient in the wind field. However, the general features of this area were properly diagnosed by the analysis.

Other No Picks occurred east of the vortex on the right side also where the directional changes were large.

We feel that our analysis accurately handled this data set as it did the previous set.

• Case 2, Rev 1298--This case was broken into two parts as done for Rev 825. The upper section contained a large anticyclonic vortex with an edge of a cyclonic vortex on the fringe of the right track (Fig 5). Our analysis correctly dignosed this feature. A very small number of Bad Picks were made which were mainly on the right track (Fig 5).

The lower part contained a col (deformation) on the left track and part of a cyclonic vortex on the right track. Most of the Bad and No Picks occurred in and south west of the col area as indicated by the arrow (Fig 5).

Case 3, Rev 1140--This case contained a cyclonic vortex on the upper part of the right track and large complicated anticyclonic vortex (probably a subtropical high) on the southern part of the orbit (Fig 6). Our method found the cyclonic vortex on the upper part of the orbit but failed to diagnose it as a closed circulation. This was a result of having very few First Choice winds on the right side of the vortex. The resulting analysis produced a vortex which opened toward the east. Had other data been available to the east, such as a previous orbit, this error might not have been made.

The majority of Bad Picks and No Picks were made in the anticyclonic vortex to the south. Our analysis indicates that most of the major features of the pattern were correctly diagnosed. However, the finer points were poorly handled. The reason for this problem was obviously the quality of the First Choice winds.

In an attempt to improve the quality of our first guess field we change the criteria for selection of the First Choice winds. The criteria was upgraded from selecting just the highest probability vector in each group to require that this vector also have a probability greater than 1% of the other vectors in the group. This eliminated many of the groups with nearly equal probabilities. The resulting fields also are shown in Figure 6. It is apparent that this exercise did not improve the first guess field and made the streamline analysis worse.

Our conclusion was that our analysis could not be better than the high probability vectors and in areas where probabilities were nearly equal our analysis would be poor.

- Case 4, Rev 1183--The major feature of this case was a large anticyclonic vortex fully covered by the orbit. Our analysis correctly found this feature, however, the complicated pattern to the southwest was difficult to resolve. Many of the No Picks and Bad Picks occurred in this area (Fig 7).

Our analysis appeared to resolve the major features of this case with the errors mainly appearing in areas of sharp changes as discussed earlier.

- Case 5, Rev 1298--A vortex in the upper part of the orbit and a shear line on the lower section where westerly winds changed to northerly winds gave us our largest problems (Fig 8). As in the previous two cases, most of the Bad and No Picks occurred where the First Choice winds were scattered. However, the majority of this orbit was correctly diagnosed because of the large areas with strong winds of uniform direction that defined the large scale pattern.

- Case 6, Rev 1140--A similar large anticylonic vortex dominated this orbit with smaller features to the north (Fig. 9). Our analysis resolved the major features of this orbit as expected.

Most of the Bad and No Picks occurred on the outer edges of the swaths. It was obvious that the greatest difficulty occurred on these edges. The streamline program appeared to be good at finding areas where the First Choice winds were in agreement with each other and smoothly interpolating between these areas. However, on the edges of the swath the program had to extrapolate gradients because of the lack of bounding information. This increased the probability of making errors.

4. Vorticity and divergence fields

Vorticity and divergence analyses were made on Case 5 and 6 (Fig 10). The analyses made on our ambiguity removed SCATT fields tended to closely resemble the truth fields. This was encouraging and indicated that our method produced wind fields that were basically correct in their major features.

As a second measure of the quality of the analyses we made scatter plots of the divergence values for each 1° grid point as a function of the vorticity values (Fig 10). From the patterns shown it appeared that vorticity and divergences were mostly unrelated. This notion is given to the viewer because the maxima and minima of each pattern are found in different locations. But from Ekman boundary layer theory we would expect some convergence to occur with cyclonic vorticity. The scatter plots show that this is the case and the vorticity and divergence have some relationship. The correlation of the two on a grid point basis was approximately 0.5 to 0.6.

5. Spacial correlations

As another measure of the quality of the simulated SCATT wind fields the auto correlation functions were calculated for 3 cases, both the truth and analyzed fields (Fig 11). A fairly broad correlation was found for both types of data. The high correlations for close distances (less than 100 km) indicate that there were little changes between neighboring vectors. Thus, the 50 km sampling represented an "over kill" of information.

The width of the correlation is roughly comparable to the auto correlation of ship wind measurements (Fig 12). The ship and cloud correlation functions were made over the tropical Indian Ocean during the summer of 1979 (Wylie and Hinton, 1981). By comparing Figures 11 and 12 one can see that the cloud motion data have a broader correlation. This is not a surprise because cloud motions represent winds above the boundary layer and thus we did not expect to see many shear lines or other small scale features.

6. Conclusions and Recommendations

From this exercise we concluded that the highest probability vectors of the SCATT data set were good measurements of the wind field. For modelling uses and synoptic scale uses (1° or larger resolution analyses) ambiguity removal is not needed. Analyses can be directly made from the highest probability vectors that will satisfy all requirements.

For studies of shear zones and individual wind pattern features on any detail, some ambiguity removal is necessary. Our analysis failed to converge on small scale features. Thus, an ambiguity removal program will be necessary but it need not be done by totally automatic means. Our method could have been greatly improved by the injection of other data such as ship reports or by a man guessing at the nature and shape of the wind pattern in difficult areas. Given the ability of modern computing machines, this should be possible.

7. References

Barnes, S. L., 1973: Mesoscale objective map analysis using weighted time-series observations. NOAA tech. Memo ERL NSSL-62, 60 pp.

Whittaker, T. M., 1977: Automated streamline analysis. Mon. Wea. Rev., 6: 786-788.

Wylie, D. P., and B. B. Hinton, 1981: The feasibility of estimating large-scale surface wind fields for the summer MONEX using cloud motion and ship data. Bound. Layer Met., in Press.

Table 1: The Summary of the Total Numbers of Good and Bad Picks made from the Simulated SCATT Data sets.

		# Good Picks		# Bad Picks		No Picks
Case	Rev	1st Choices	all	1st Choices	all	
Ø	825	76.7%	83.5%	2.3%	5.9%	10.6%
1	1093	74.6%	83.2%	0.7%	6.2%	10.5%
2	1298	76.7%	87.6%	1.8%	6.0%	6.4%
3	1140	70.4%	79.4%	1.8%	9.6%	11.0%
4	1183	72.8%	81.5%	2.2%	7.1%	11.4%
5	1298	78.9%	88.9%	1.6%	4.3%	6.8%
6	1140	72.5%	82.9%	1.6%	5.3%	11.8%

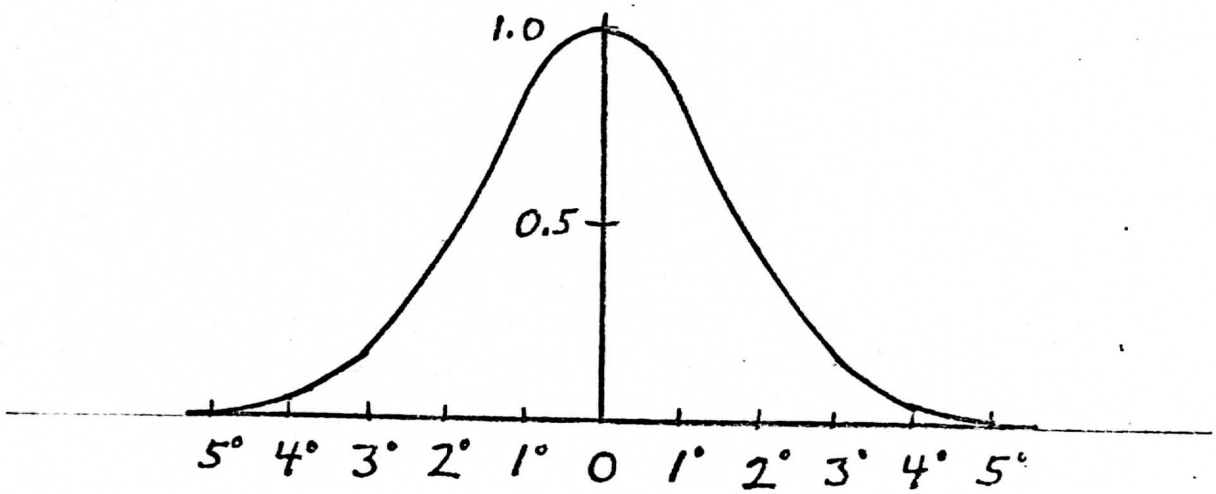


Figure 1: The weighting function used in the objective analysis program.

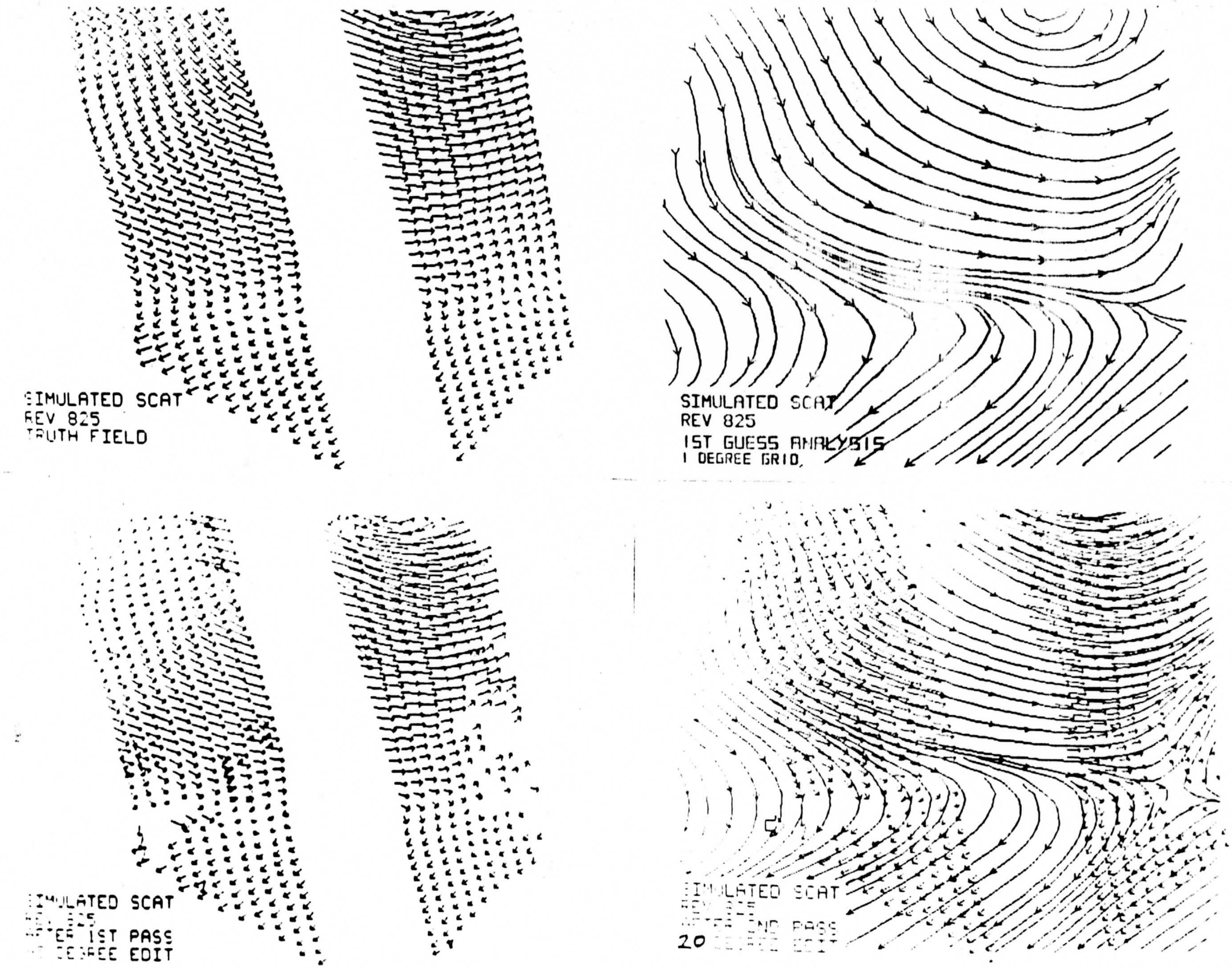


Figure 2: The starter data set Rev 825, lower half.

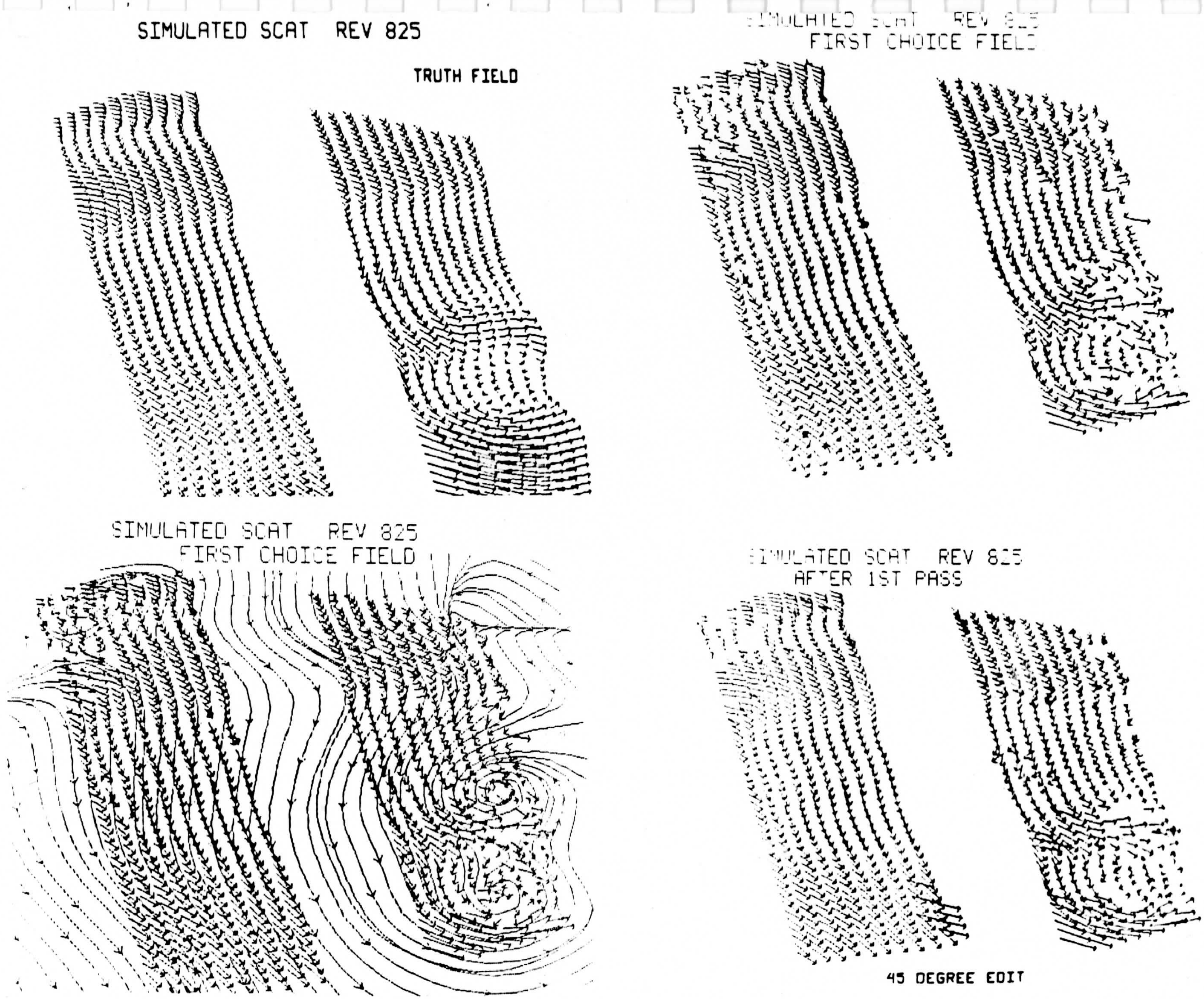


Figure 3: Rev 825 upper half.

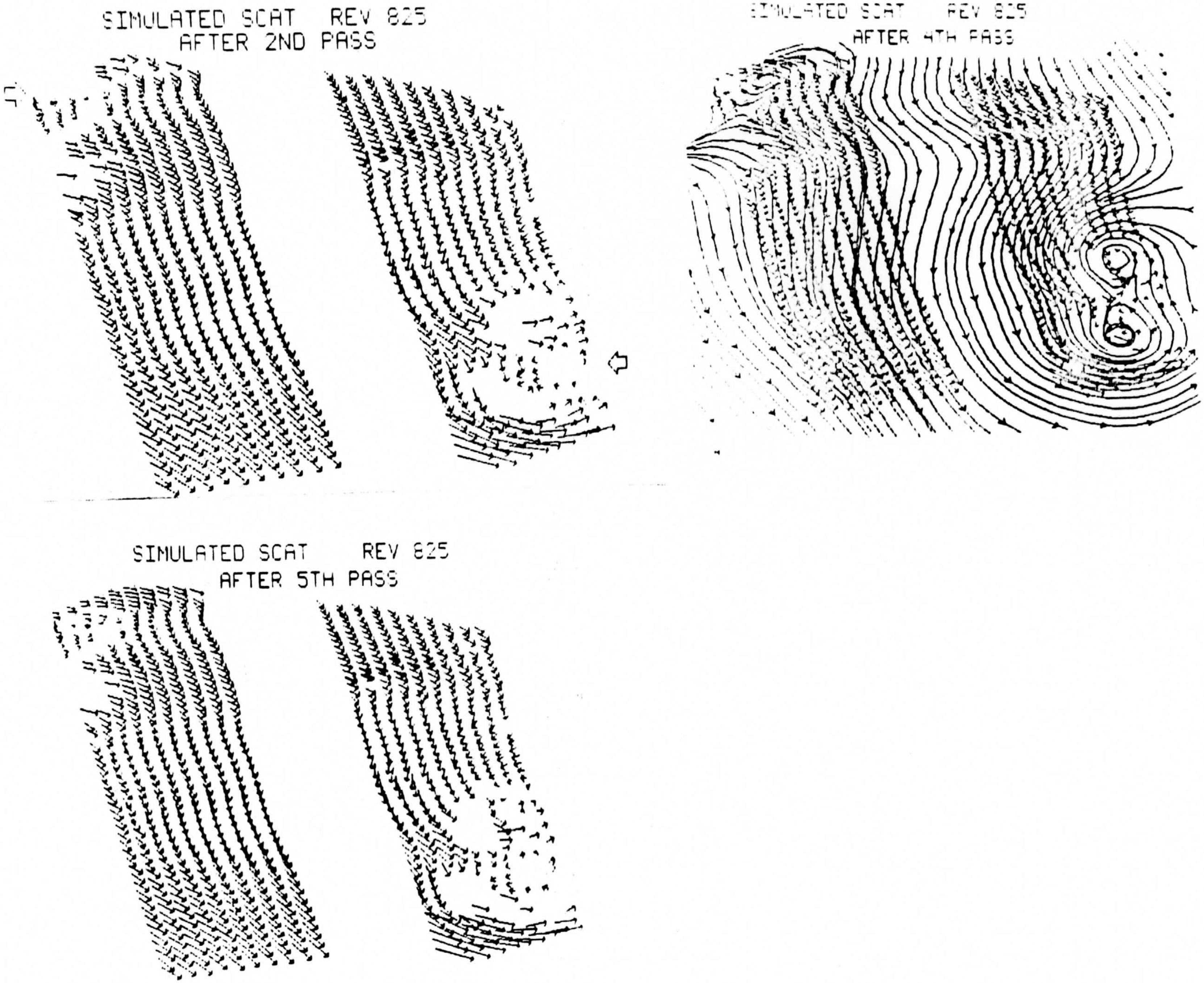


Figure 3 continued: Rev 825, upper half.

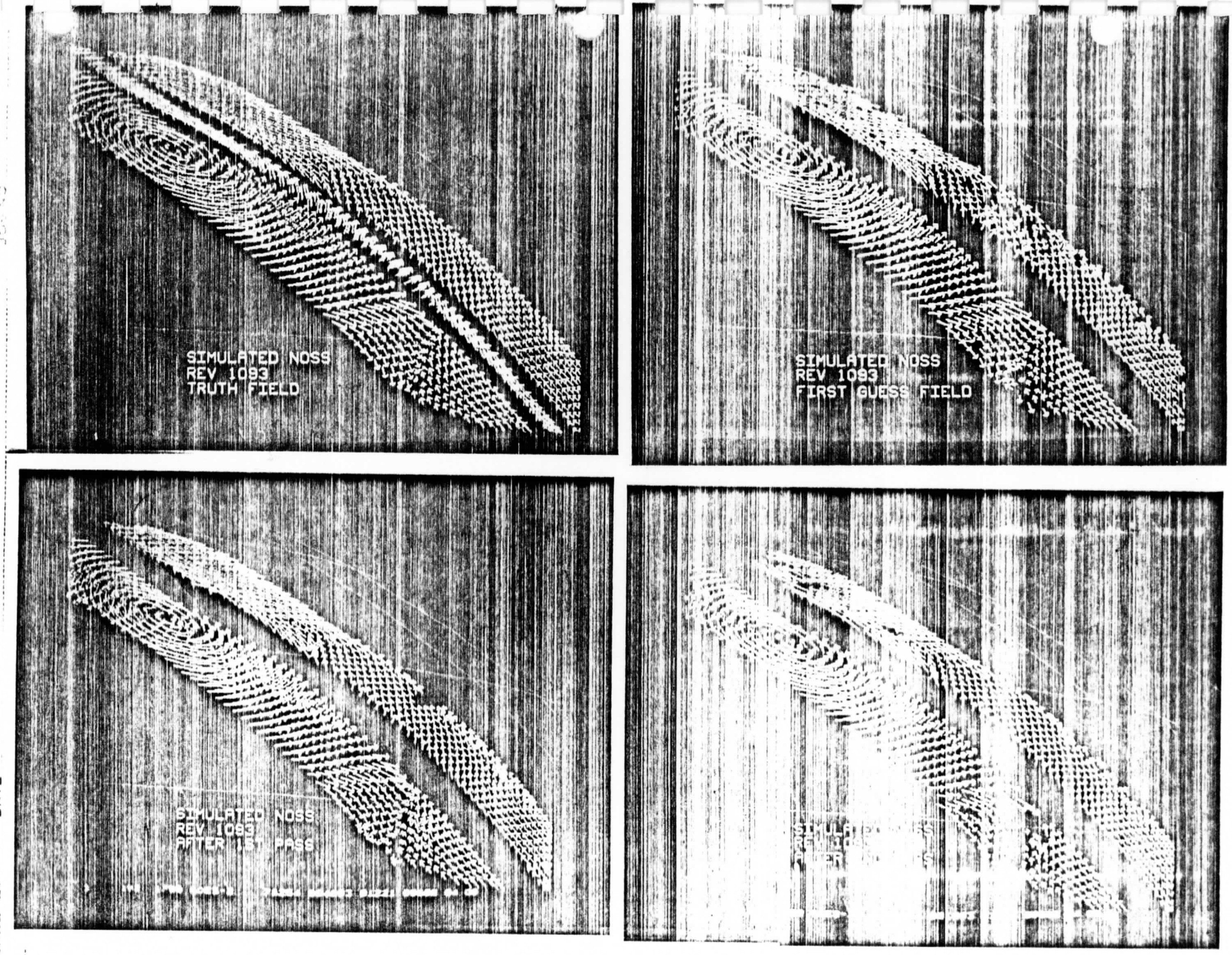


Figure 4: Case 1, Rev 1093.

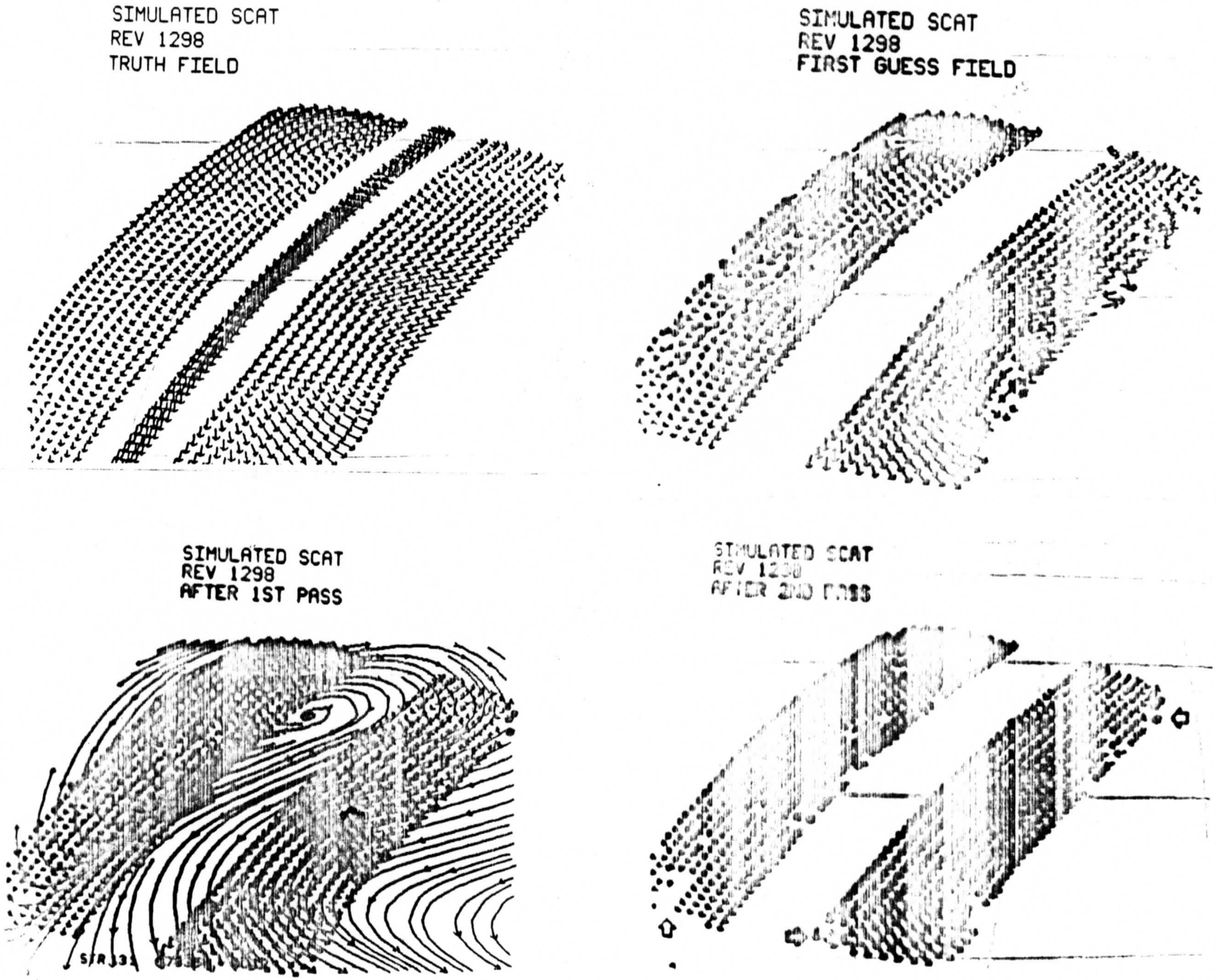


Figure 5: Case 2, Rev 1298, upper half.

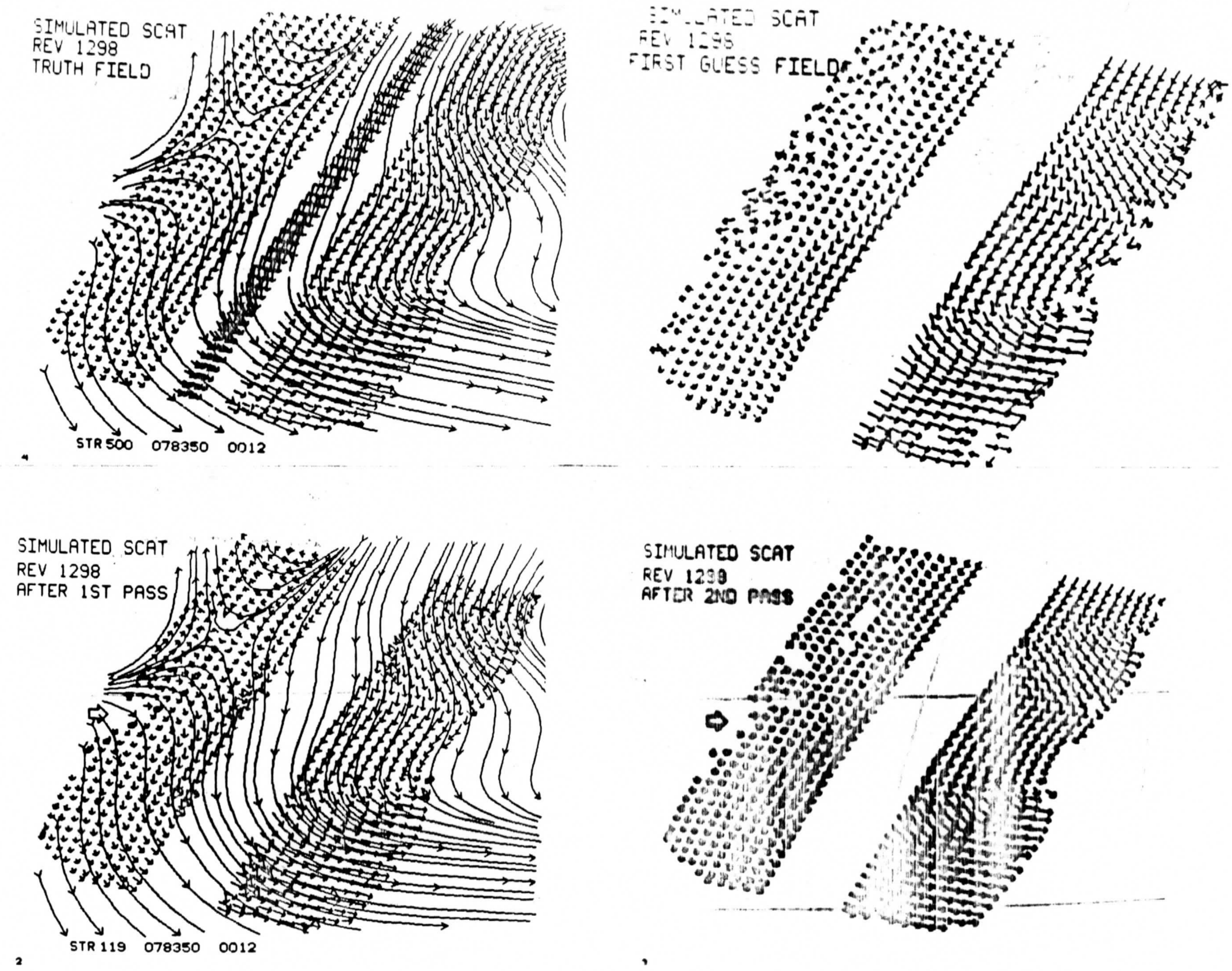


Figure 5 continued: Case 2, Rev 1298, lower half.

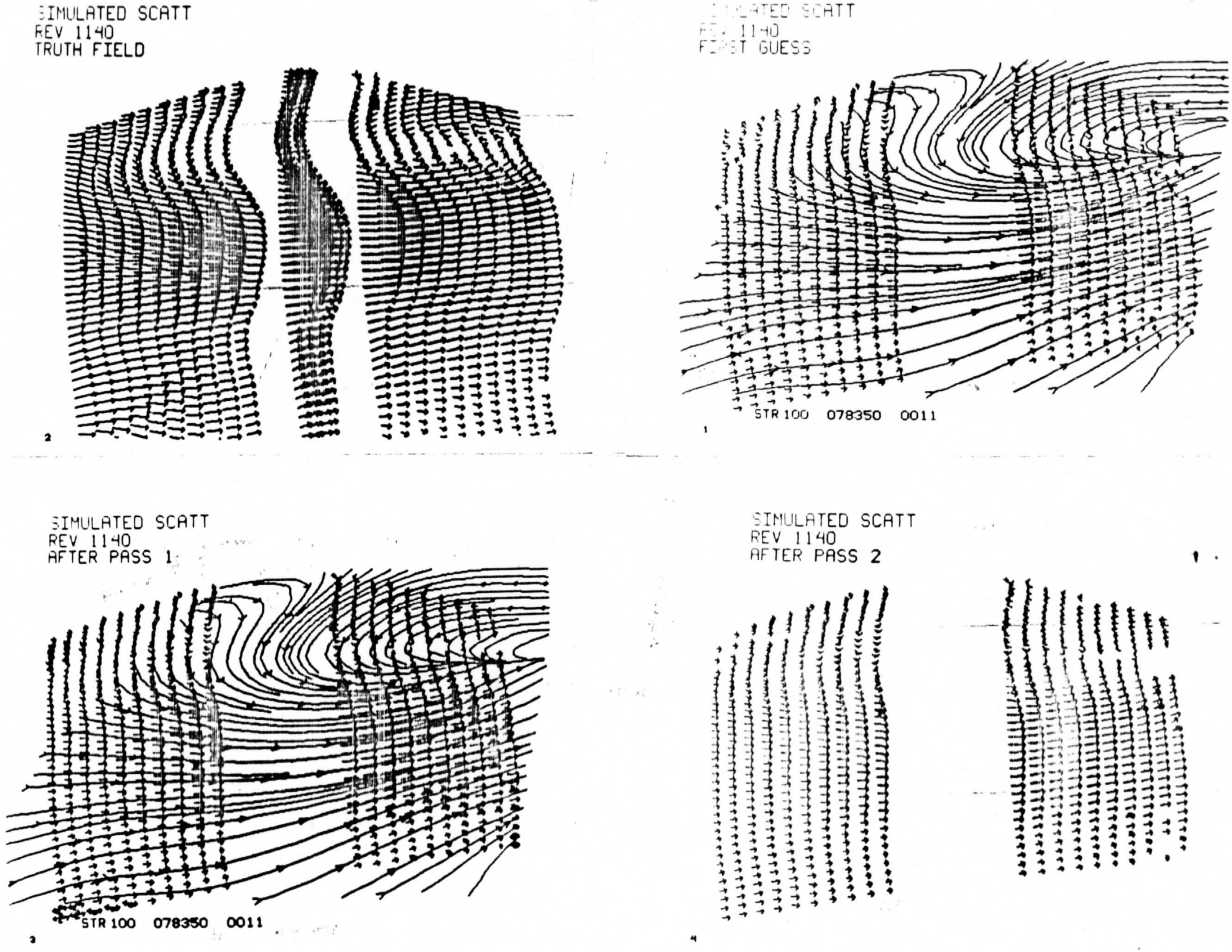


Figure 6: Case 3, Rev 1140 upper half.

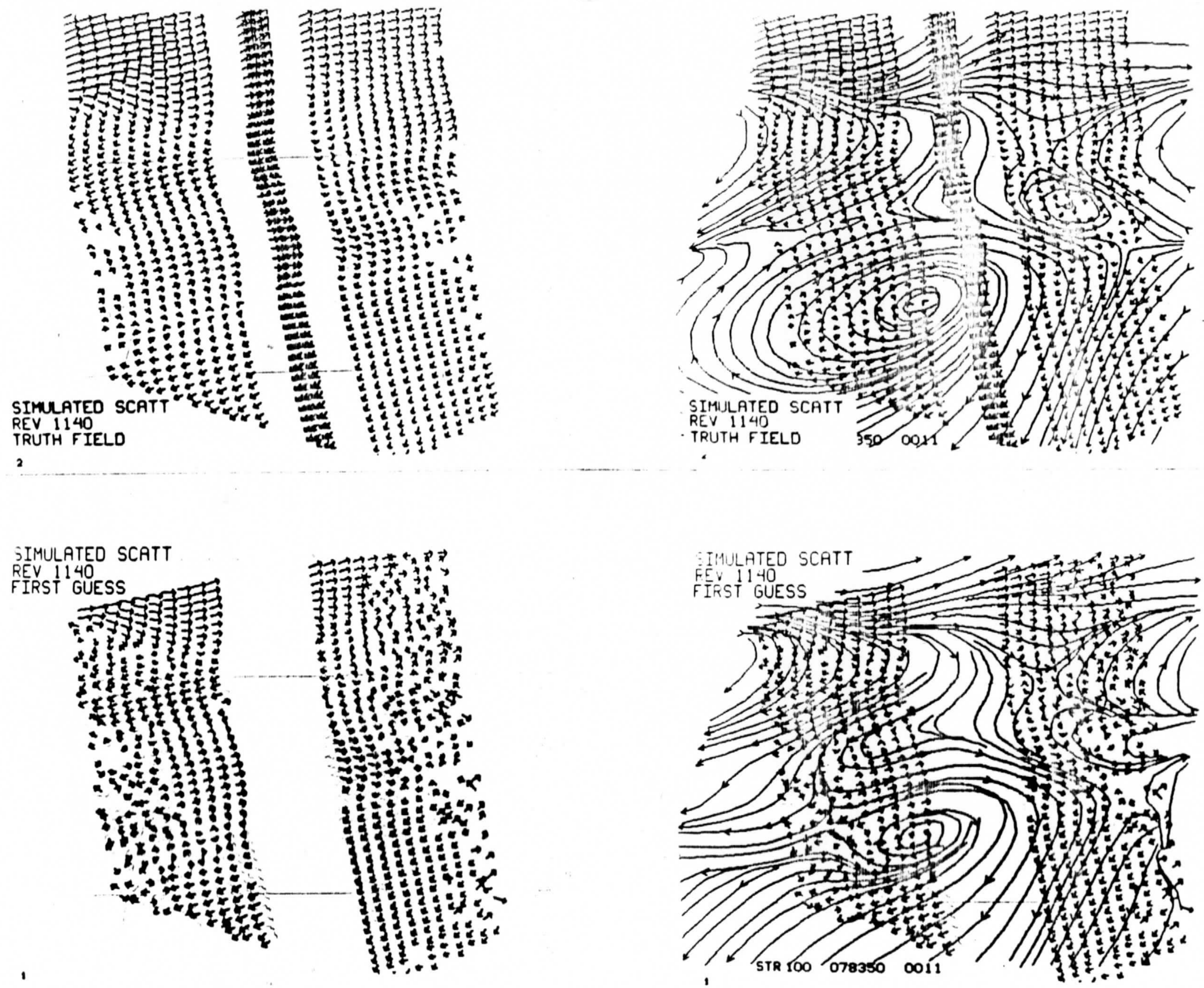


Figure 6 continued: Case 3, Rev 1140 lower half.

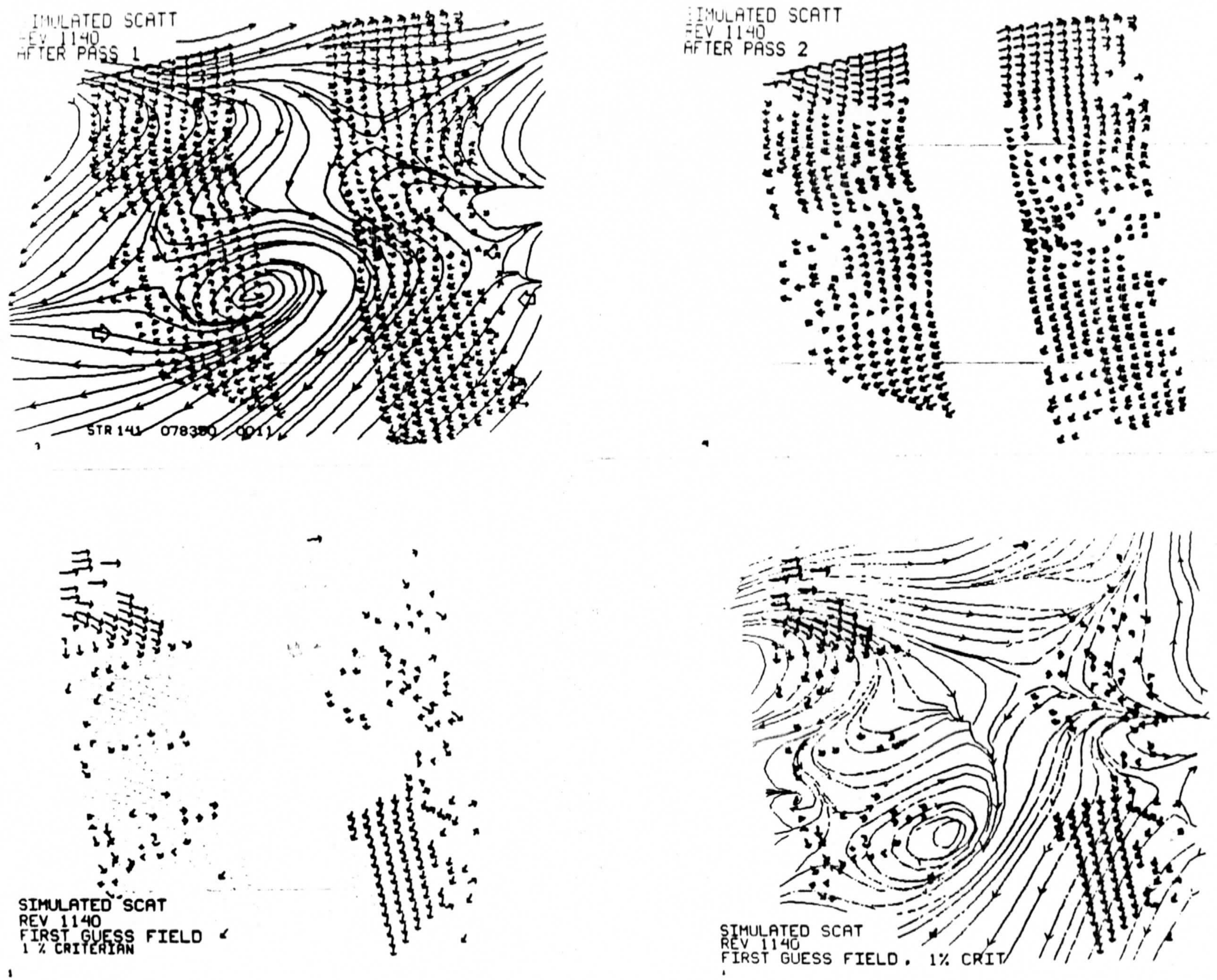


Figure 6 continued: Case 3, Rev 1140 lower half where the First Choice winds had probabilities >1% of the other vectors in their groups.

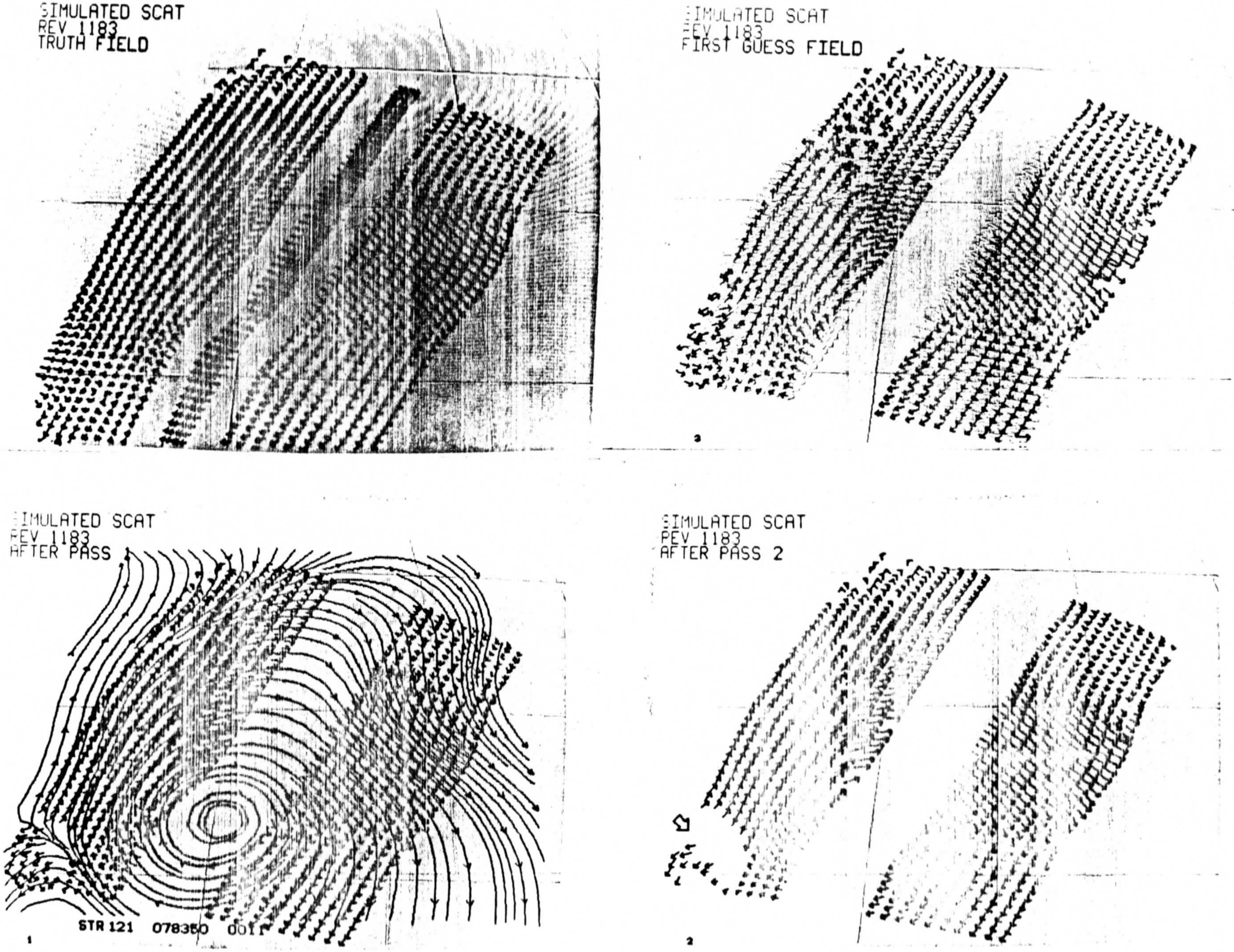


Figure 7: Case 4, Rev 1183 upper half

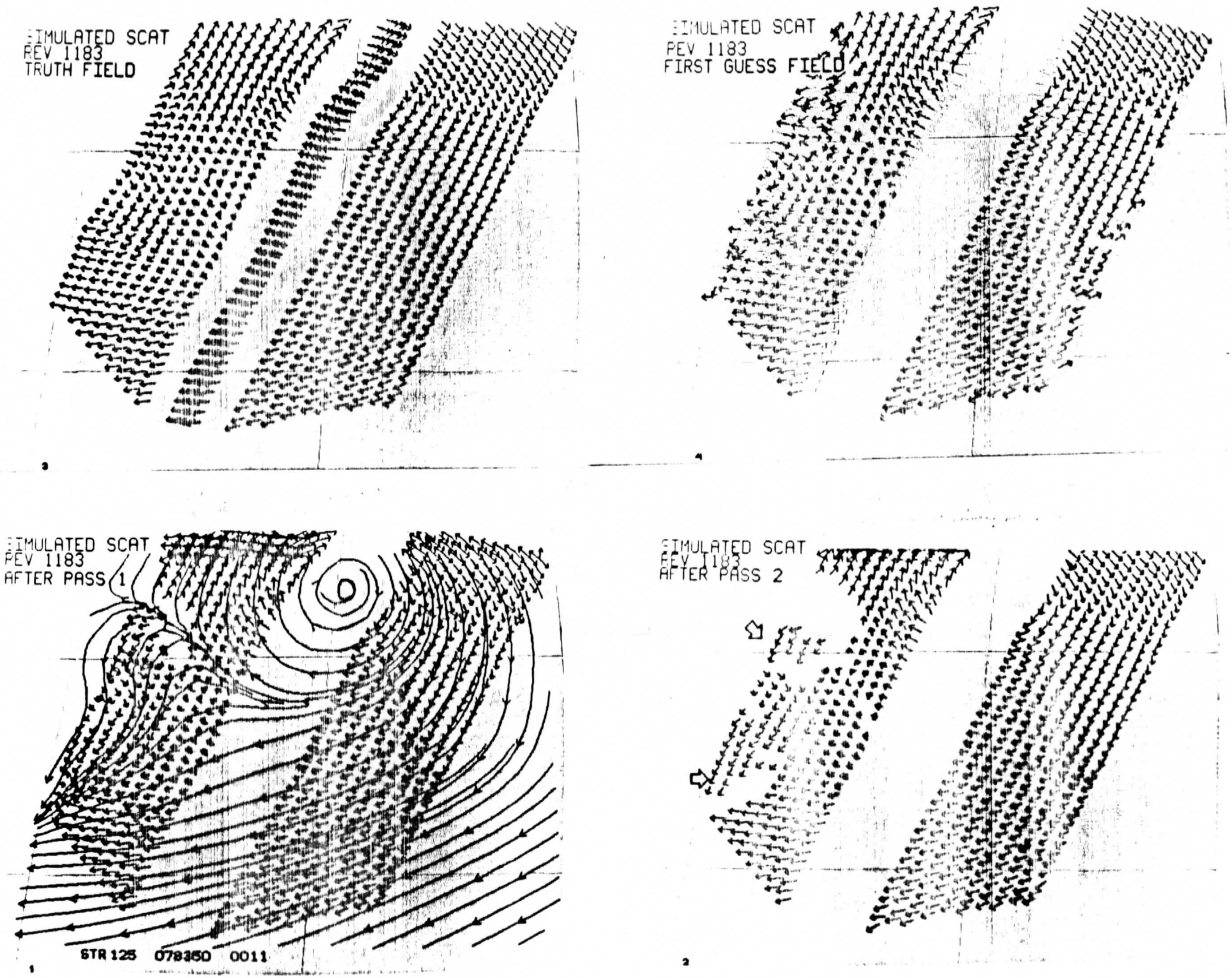


Figure 7 continued: Case 4, Rev 1183 lower half, Upper

Lower

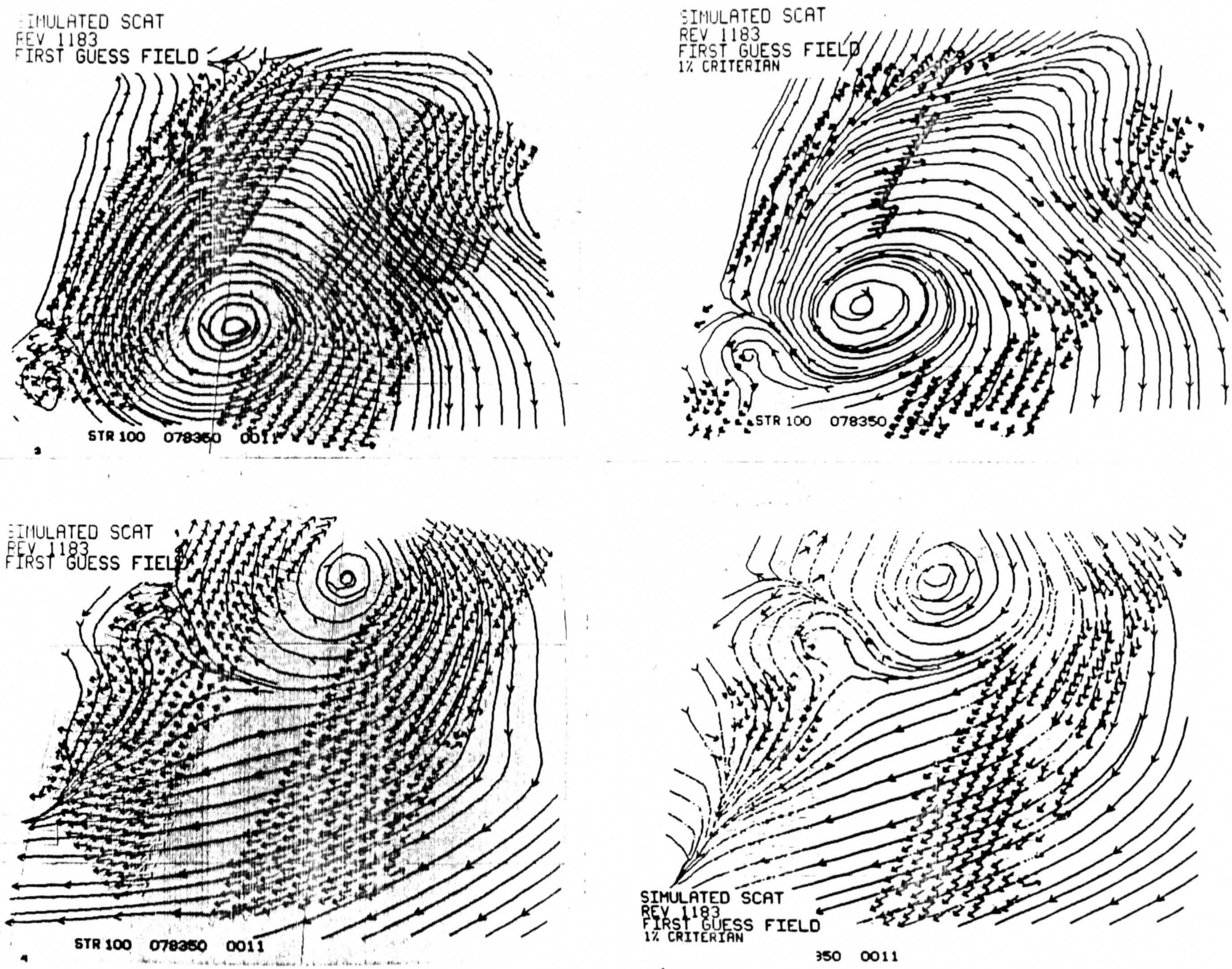


Figure 7: Continued

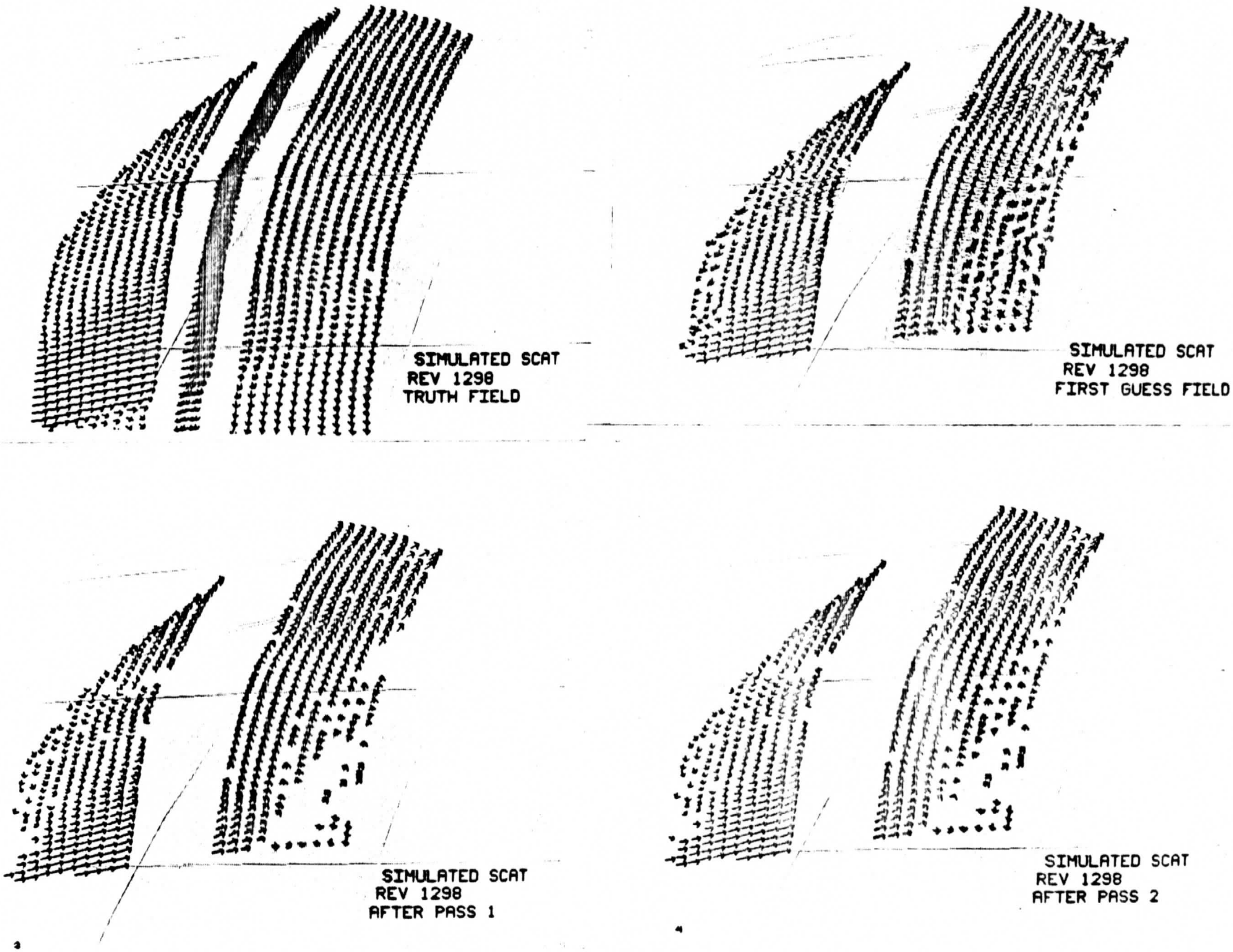


Figure 8: Case 5, Rev 1298 upper half

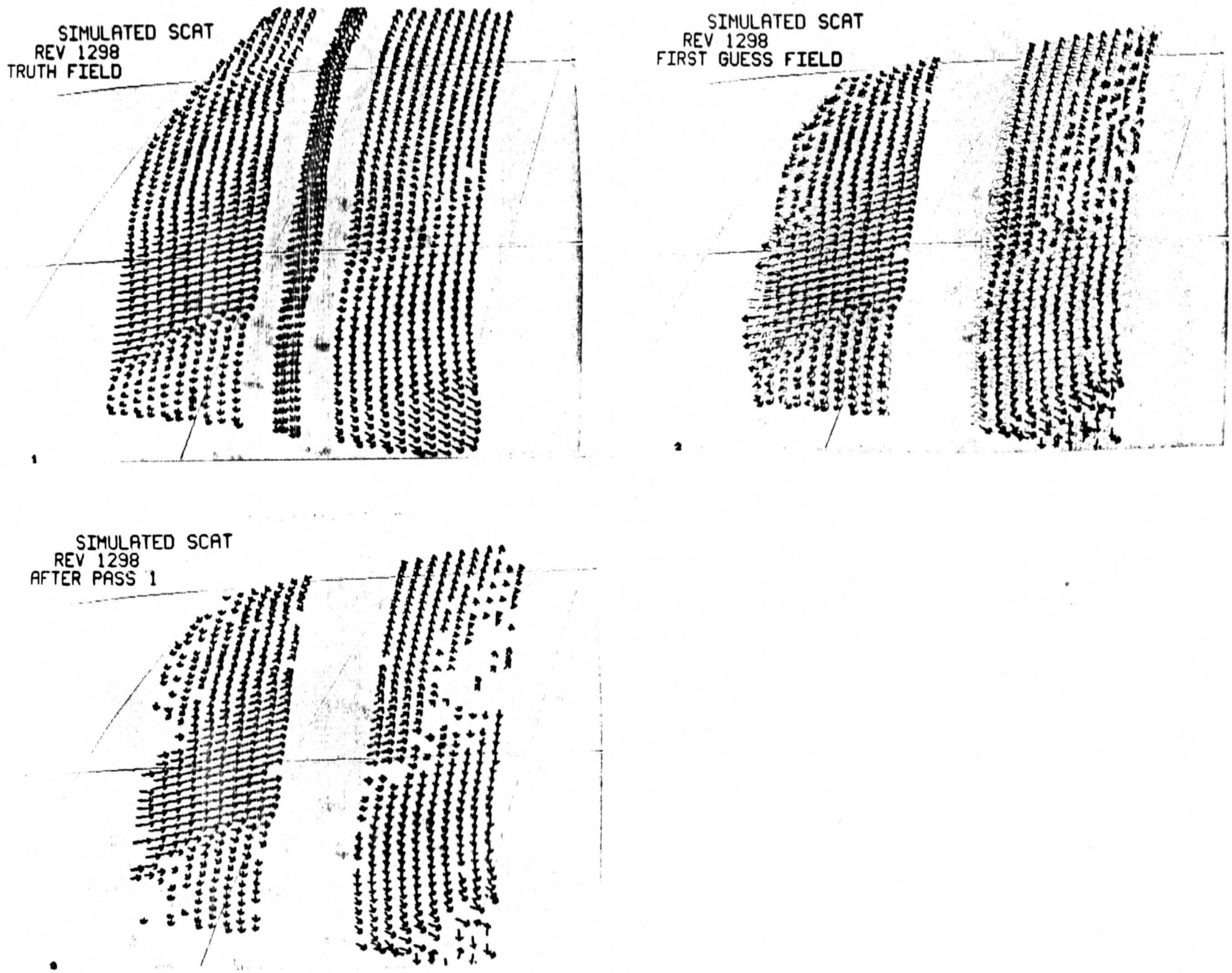


Figure 8 continued: Case 5, Rev 1298 lower half.

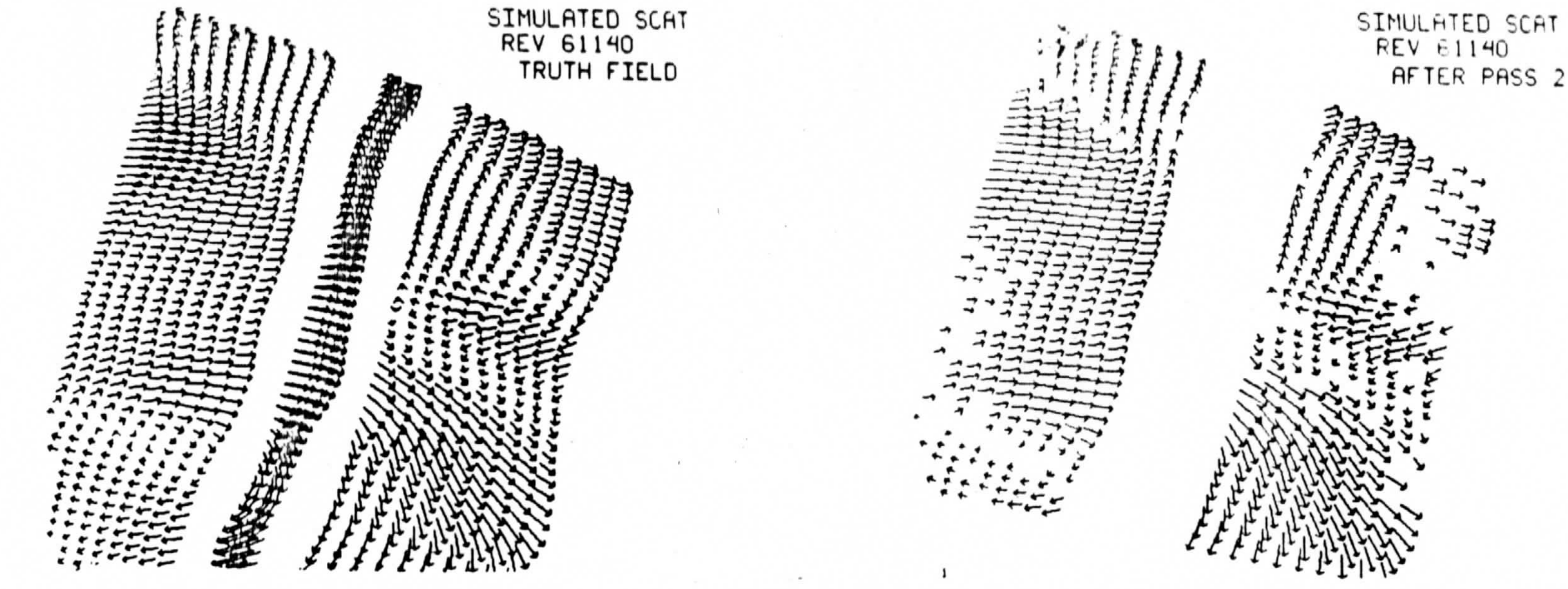


Figure 9: Case 6, Rev 1140 upper half.

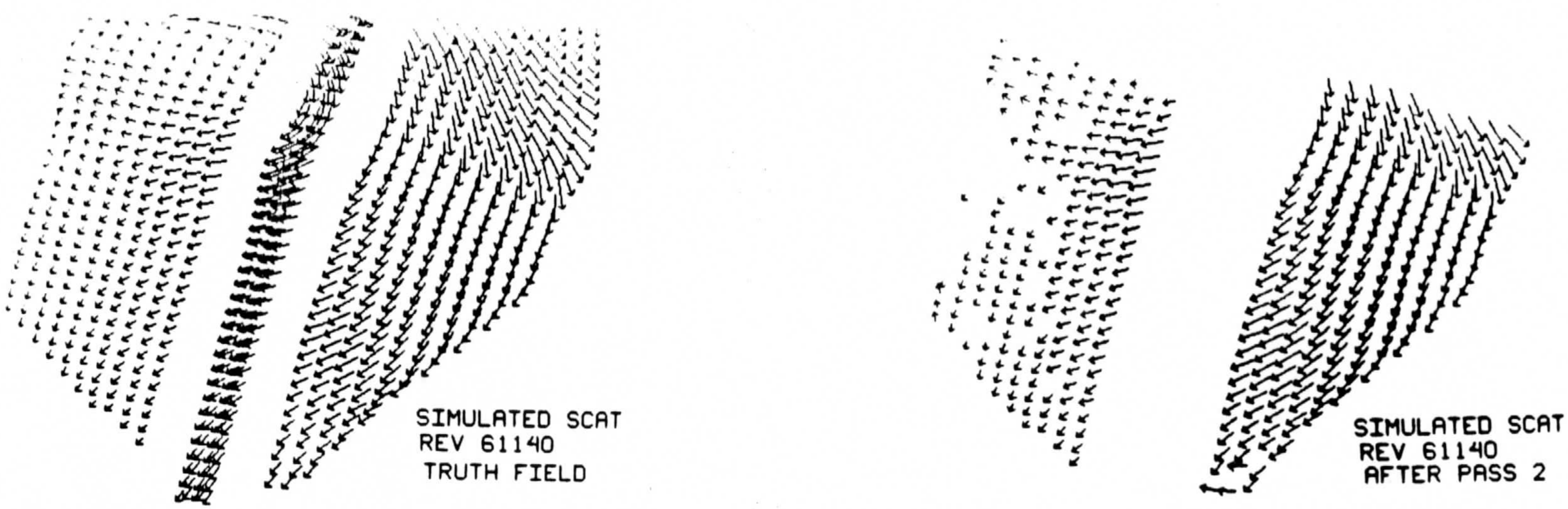
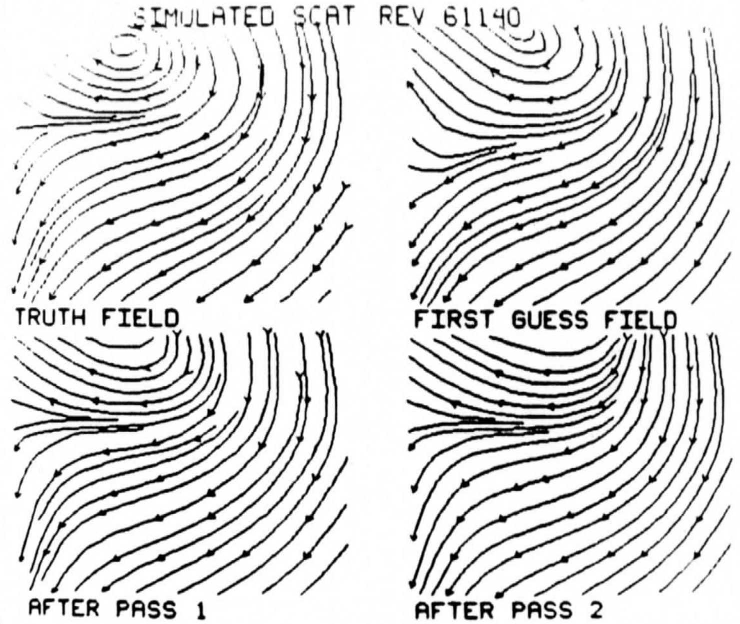
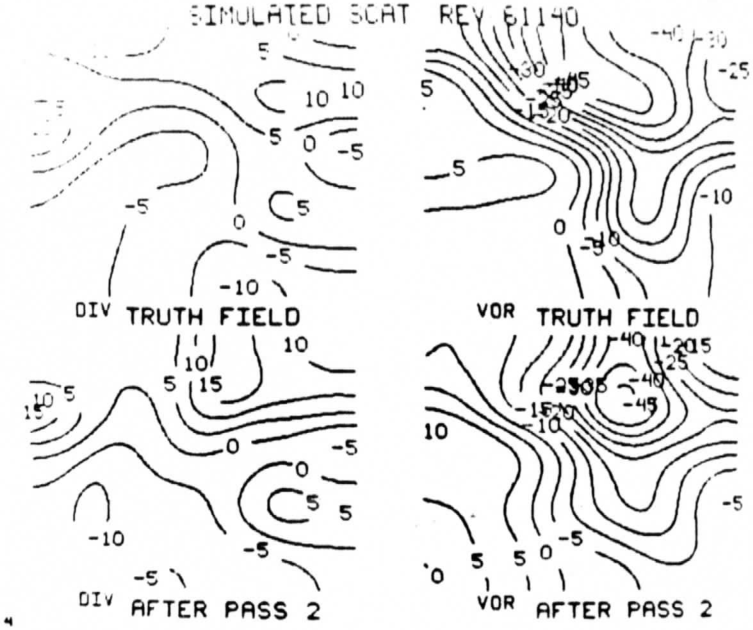
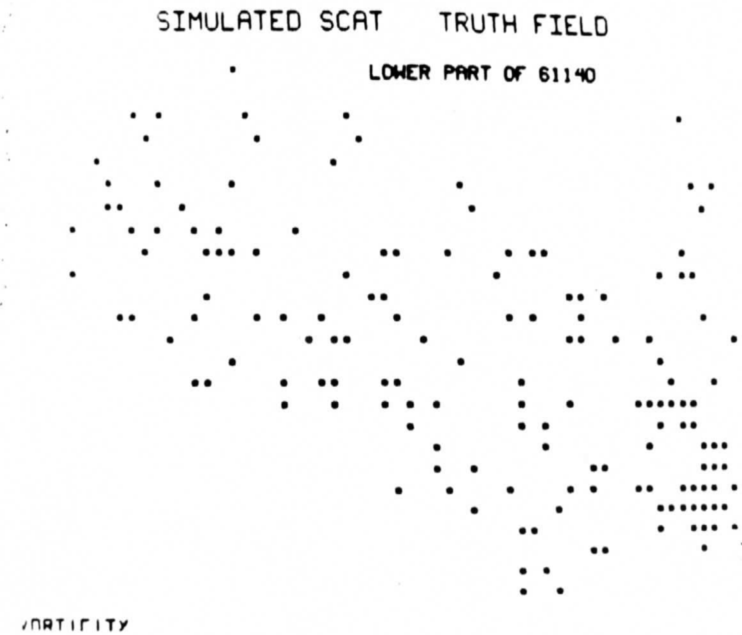


Figure 9 Case 6, Rev 1140 lower half.







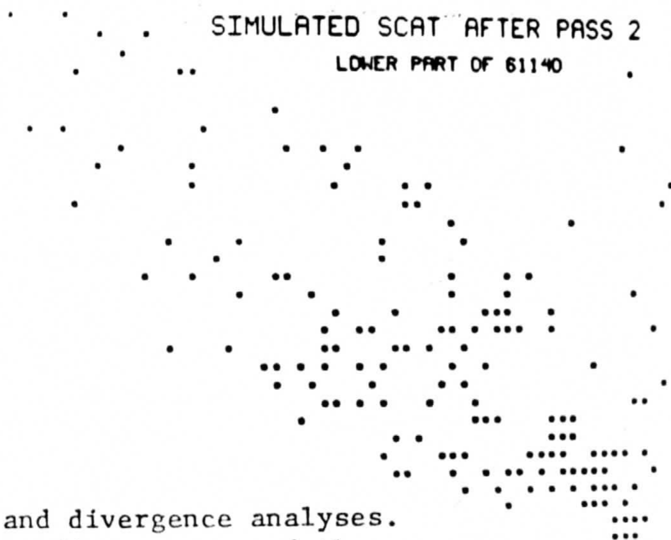


Figure 10: Example vorticity and divergence analyses. The left panels are divergences and the right panels are vorticites. The top row was made from the truth field while the bottom was made from the edited vectors. The scatter plots of divergence (ordinate) vs. vorticity (abscissa) are from the truth field on the left and the edited data on the right.

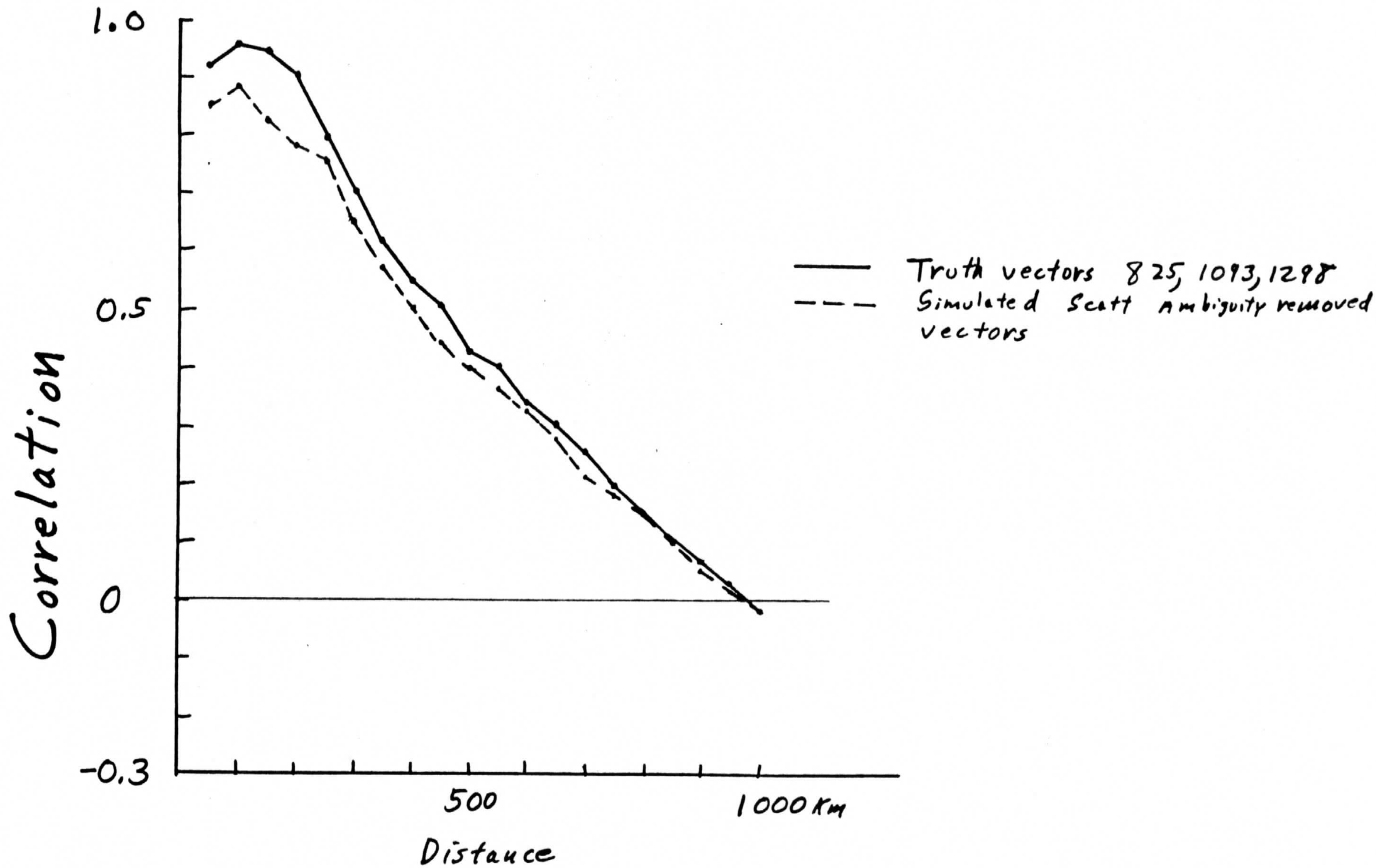


Figure 11: The auto correlations of the truth and edited SCATT vectors.

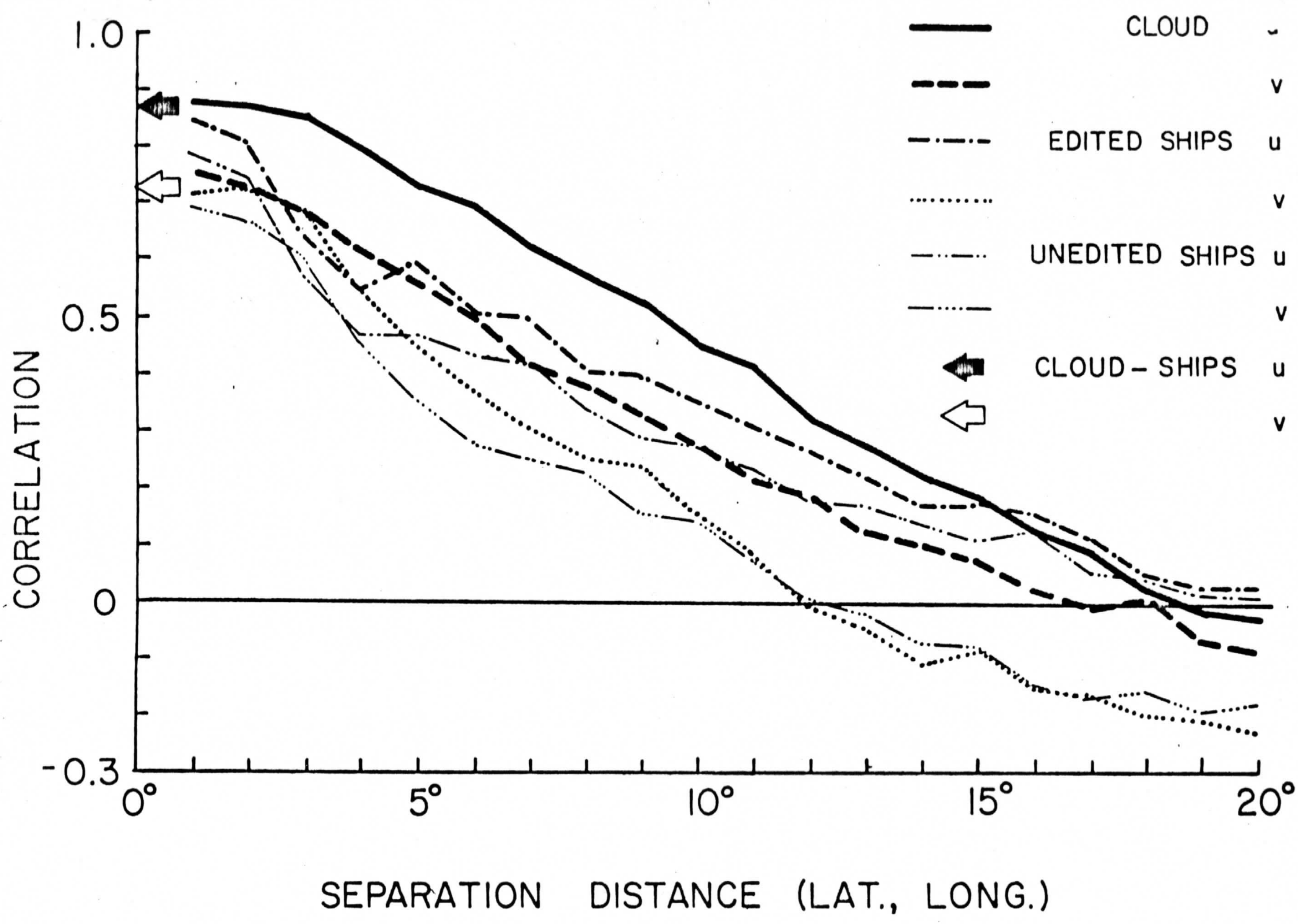


Figure 12: The auto correlations of cloud motion vectors and ship reports in the Indian Ocean for the months of May, June, and July, 1979. Taken from Wylie and Hinton (1981).