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NASA Airborne Doppler Lidar Program:

Data Characteristics of 1981 Wind Field Measurements

Technical Report No. 1

Prepared for George C. Marshall Space Flight Center Under Contract NAS8-34768

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R. W. Lee

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Abstract

The first flights of the NASA/Marshall airborne CO_2 Doppler lidar wind measuring system were made during the summer of 1981. Successful measurements of two-dimensional flow fields were made to ranges of 15 km from the aircraft track. This report examines the characteristics of the data obtained, and summarizes a study of various artifacts introduced into the data set by incomplete compensation for aircraft dynamics. Most of these artifacts can be corrected by post processing, which reduces velocity errors in the reconstructed flow fields to remarkably low levels.

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I. Introduction

As part of the NASA severe storms program NASA/Marshall has constructed an airborne lidar system designed to measure two-dimensional horizontal flow fields in the atmosphere. This system uses a pulsed coherent CO_2 laser operated much as a Doppler radar. Velocity components along the lidar beam are measured by observing the Doppler shifts in the signals returned from naturally-occurring aerosol scatterers. The beam is steerable within a forty-degree cone to the left of the aircraft; by taking measurements with the beam oriented in the two horizontal extremes of the cone (70 and 110 degrees to the left of the aircraft heading) two components of the horizontal flow field are sensed. From these two components it is possible to reconstruct the two orthogonal components of horizontal flow.

This complex system was assembled by a group of NASA personnel and contractors over a three-year period. The first data flights using the NASA/Ames CV990 aircraft were completed during the summer of 1981. Data was obtained in a variety of situations: boundary-layer and orographic flows were observed in California, Colorado, Oklahoma, Nevada and Montana, while flows in the vicinity of convective storms were observed at many levels in Montana during participation in the CCOPE experiment.

It is no simple matter to operate a Doppler radar using an aircraft as a platform. The velocity of the aircraft is high compared with the atmospheric velocities which must be measured. This motion of the measuring instrument must of course be removed from the measurement, a feat which can only be accomplished by very accurate knowledge of the platform velocity and all the relevant angles relating aircraft motion, attitude and instrument pointing.

This much is required for accurate measurement of the velocity component parallel to the lidar beam. To obtain horizontal flow vectors, a second component must be measured by steering the lidar beam as described above. During a measurement run a series of measurements is obtained at each observation angle. Each series consists of a grid of velocity component measurements typically separated in range and track by 300 m (the range gate width and the scanner period). The two grids of measurements are then superimposed and processed to extract the velocity vectors, just as vectors are derived in ground-based multiple Doppler measurements.

To make such interpretation possible the relative registration of the measurement points must be sufficiently well known - within a fraction of a grid spacing - to permit correlating the proper observations with each other, a requirement which places stringent limitations on the allowable errors in aircraft navigation and lidar beam pointing.

The flow-vector estimate produced by operations on the two component measurements can, at best, be only as good as the original radial velocity measurements. In fact, it is worse, since the poor geometry of the two measurements (with only a 40-deg included angle) triples the error in the vector component parallel to the aircraft track; such geometry mandates both very high accuracy on the part of the Doppler estimator and very high stability on the part of the lidar local oscillator and transmitter.

The state-of-the art in aircraft navigation and lidar systems is strained by such stringent accuracy requirements. Therefore the success of the 1981 field tests is all the more remarkable, and is a tribute to the efforts of all concerned.

While the program was a success in the sense that useful measurements of several types of flow fields were obtained, many of the measurements are clearly contaminated. The purpose of this report is to survey the problems present, to suggest corrections where corrections are possible, and to describe problems not now understood.

Most of the artifacts present in the data sets appear to stem from incomplete compensation for aircraft dynamics. Since the motion of the platform is so critical to these problems, Section II is devoted to examples of time-series plots of several important aircraft parameters: pitch, roll, velocity, etc. Examples of radial-velocity measurements and lidar pointing are also presented.

Section III uses "real-time" plots (obtainable on the aircraft in essentially real time for use in experiment management) to demonstrate the characteristic types of artifacts found in the raw data sets.

Section IV is devoted primarily to the major cause of these artifacts - incorrect interpretation of the aircraft drift angle. This

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section opens with time-series examples of the important parameters and their derivatives. The cause of the drift-angle problem is suggested, and the argument is reinforced by means of simulated uniform flow fields wherein artifical drift-angle errors have been introduced. A first-order correction is suggested and tested - first on a time series of mean radial velocity, and then upon actual flow fields. This correction removes about 75% of the largest source of error in the data.

Other sources of error are present, however, as discussed in Section V. Included in this category are correctable errors due to incorrect horizontal pointing information, uncorrectable errors in the elevation angle of the lidar beam, and errors due to lidar moding and local-oscillator drift which are not yet understood.

Section VI is devoted to examples of interesting flow fields observed during the 1981 program. These samples (corrected to first-order for drift-angle errors) demonstrate the potential of the system for investigating orographic flows, boundary layer flows during convection, gust-fronts in clear air, and clear-air flow in the vicinity of convective storms at mid- and upper-levels.

The detective work in unravelling the mysterious problems with these data sets is not yet complete. It is felt that a significant part of the remaining errors in the data is correctable, and techniques for such correction have been devised but not tested. Section VII discusses briefly this work in progress.

During investigation of this mass of field test data the author attained a certain degree of familiarity with it, and a good deal of software was written to allow examination of the data and testing of various correction algorithms. While this software was written strictly for internal use, it does constitute a complete set of software for processing the data from original tape to gridded flow fields. It was thought worthwhile to include the software in this report, not so that all of the software will be used as such, but rather to explain, in a definitive way, questions of treatment.

Appendix A lists the format of the raw data tapes, with some comments on problems in the data headers. Appendix B lists the software just mentioned, with enough description to orient the reader.

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II. Aircraft performance

As indicated in the introduction, aircraft dynamics are critical factors in the error budget of the data sets. The data acquisition system attempts to monitor the relevant aircraft parameters and to correct for platform motion and attitude. Correction is accomplished in two ways: the lidar scanner attempts to compensate for attitude changes, and the lidar second local oscillator attempts to compensate for velocity changes.

Section III will discuss the degree to which these corrections are successful. The intent of this section is to provide examples typical of platform motion during the field tests. The data set selected is run 10 of flight 19, a run at low altitude up the western side of the San Joaquin Valley in California. This run was selected because of its unusual length (about 40 minutes) and because the rather uniform wind field allows measurement errors to be easily seen.

Figure 1 shows ground speed as estimated by the inertial navigation system (INS) as a function of time over the 40-minute data collection period. The resolution of this measurement is 1 kt, and it is subject to errors due to INS drift. Since a fraction of this velocity of about cos(70 deg) must be removed from the measurement to correct for platform motion, it is clear that the ultimate accuracy of an individual Doppler measurement of radial velocity referenced to ground cannot exceed 0.17 m/s = 1 kt * cos(70).

The variation of altitude during the run is shown in figure 2. The aircraft normally flies at constant pressure altitude, to an accuracy of about 15 meters. Complications arise for the flow field measurement whenever the altitude is changed; at the longer ranges the delay between forward and aft measurements at the same point may be up to one minute, and if the altitude has changed the two measurements will reflect flows at two separate altitudes. This is significant in the boundary layer.

Figure 3 shows aircraft true heading during the run. The general trend of the plot reflects the aircraft course along the curving western edge of the San Joaquin Valley. The fine structure, amounting to about one degree peak-to-peak, reflects aircraft control-system stability in mild turbulence. The oscillations of a few degrees are aircraft responses to changing crosswind. True heading is obtained from the INS navigation unit with a resolution of 0.44 deg.

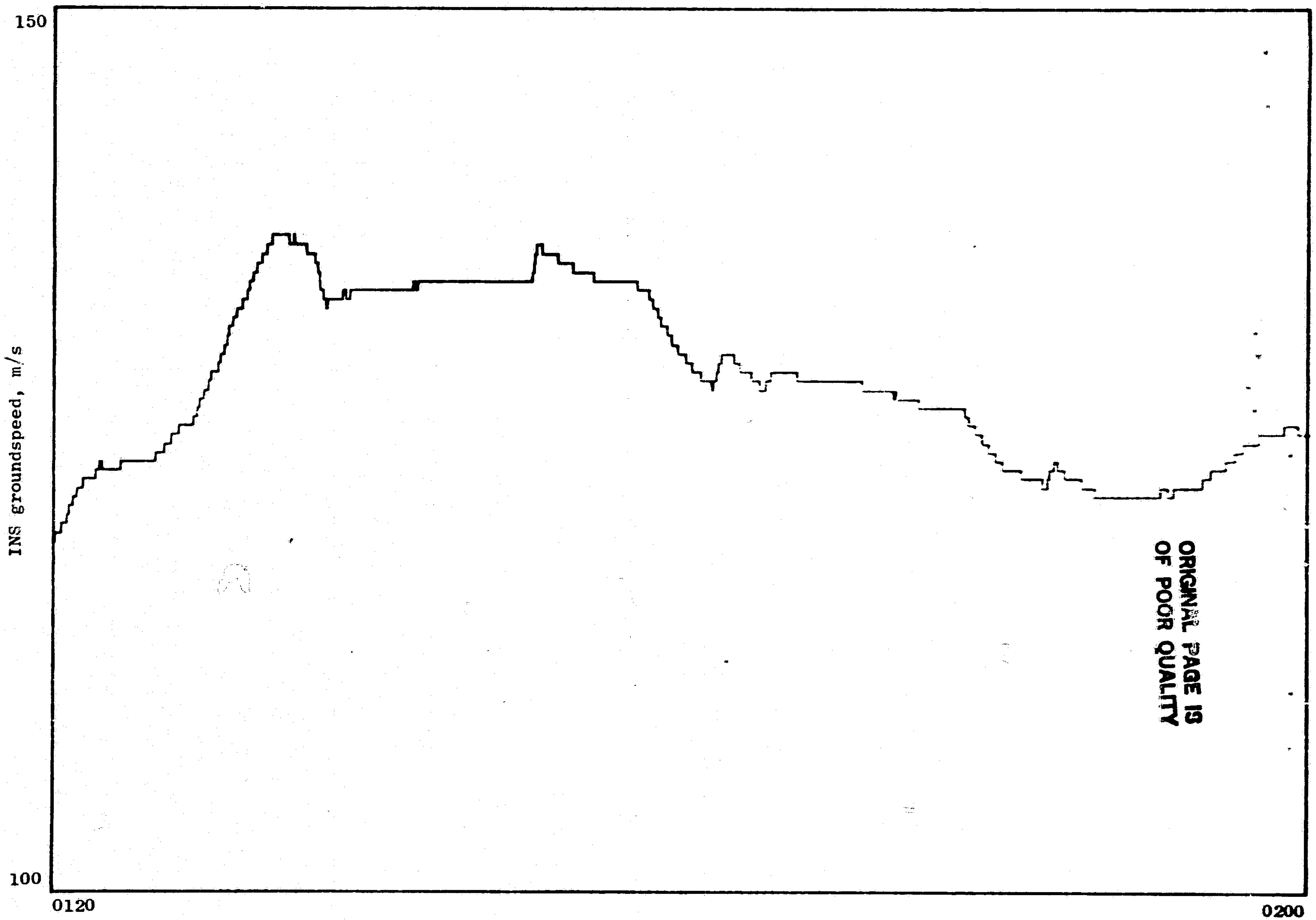

Figure 1 : Aircraft groundspeed

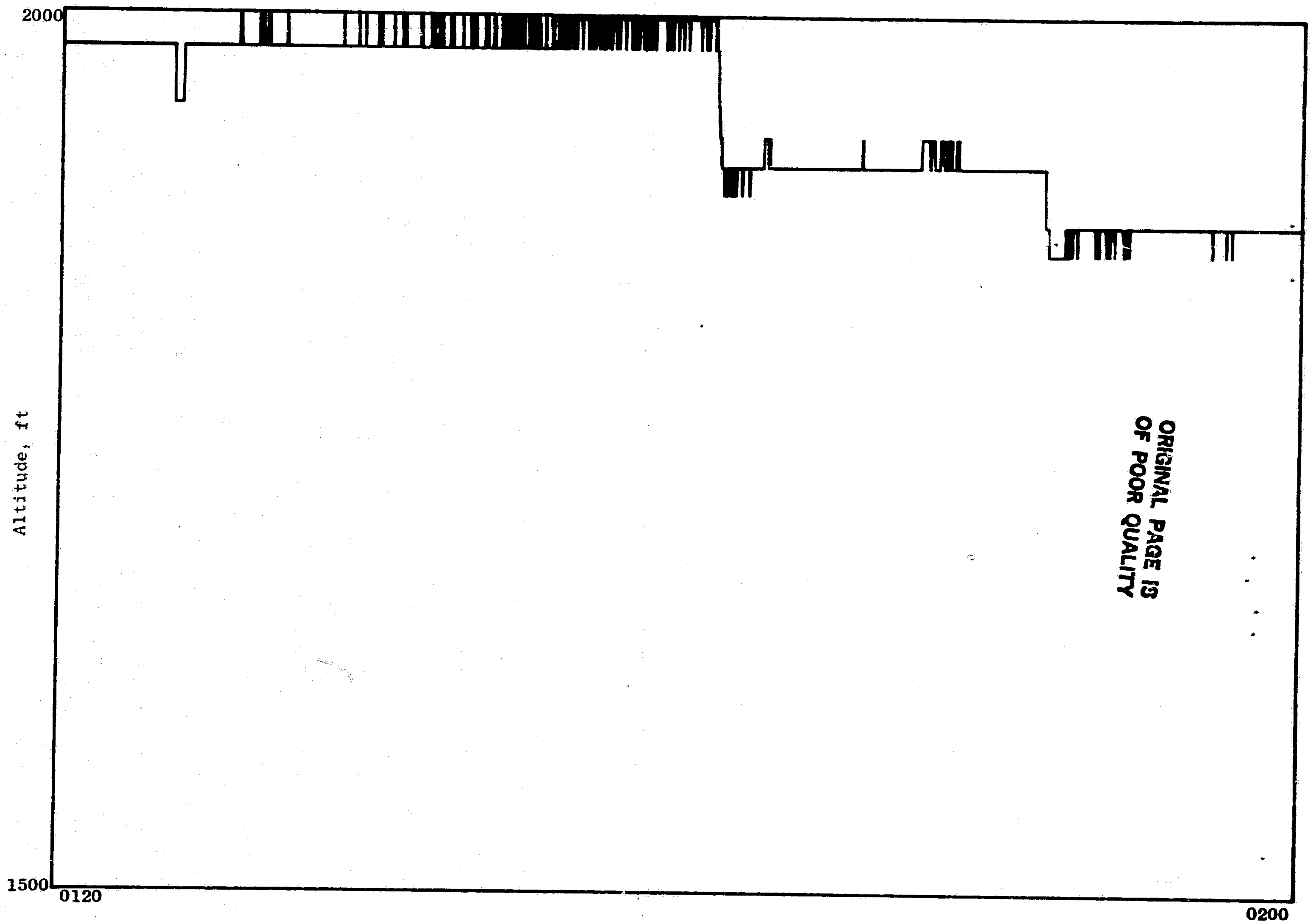

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Figure 2 : Aircraft altitude

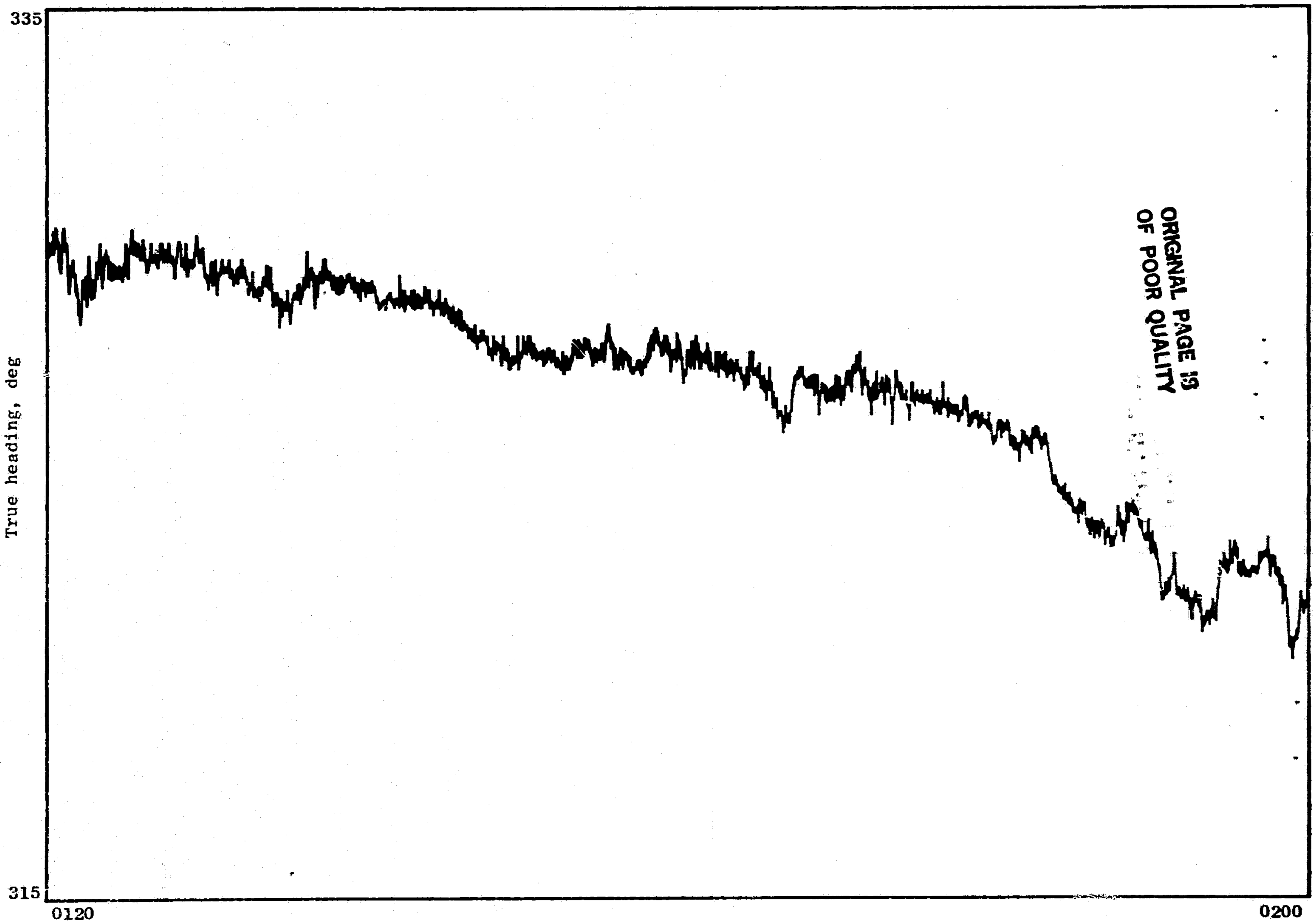

Figure 3: Aircraft true heading

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True airspeed is used by the data acquisition system only to estimate the probable Doppler shifts in the data (since the nominal Doppler shift is expected to be TAS*cos(70)). The form shown in figure 4 is quite similar to ground speed (figure 1), with a small offset due to a headwind.

The pitch of the CV990 aircraft is rather stable, as shown in figure 5, with transients on the order of 1 deg whenever altitude or airspeed is altered. Pitch is obtained from the INS unit with a resolution of 0.44 deg, and is used by the lidar scanner to hold the lidar beam in the horizontal plane. Aircraft roll, shown in figure 6, is used by the scanner in the same manner. Roll is subject to excursions on the order of degrees, often with a well-defined period.

Aircraft drift angle is critical to the correction for platform velocity. The plot shown in figure 7 exhibits a typical short-term variability of about 1 deg peak-to-peak, with larger variations where the flow field is complex. Drift angle often shows resonant oscillations related to the feedback characteristics of the aircraft control loops. Once again the resolution of this measurement is 0.44 deg.

Using knowledge of ground speed, airspeed, and drift angle the INS unit estimates the wind vector in the vicinity of the aircraft. Figures 8 and 9 show the magnitude and direction of this estimate for the run. While this measurement is not always reliable, it has been a useful comparison for the lidar measurements.

Examples of the raw lidar radial velocity measurements are shown in figures 10 and 11. The radial velocities have been averaged over 30 range gates. While these measurements cannot be compared directly with the INS wind estimates (since the INS estimate is a magnitude, and the lidar measurements are components), several features on the curves agree and demonstrate that the lidar system is measuring something related to the wind field. Note that the fine structure in the lidar measurements is on the order of 1 m/s.

The look-angles at which the forward and aft lidar measurements were taken are shown in figures 12 and 13. The form of the curves closely approximates the aircraft true heading (figure 3), with 70- and 110-deg offsets. The resolution of these angular measurements is 0.1 deg.

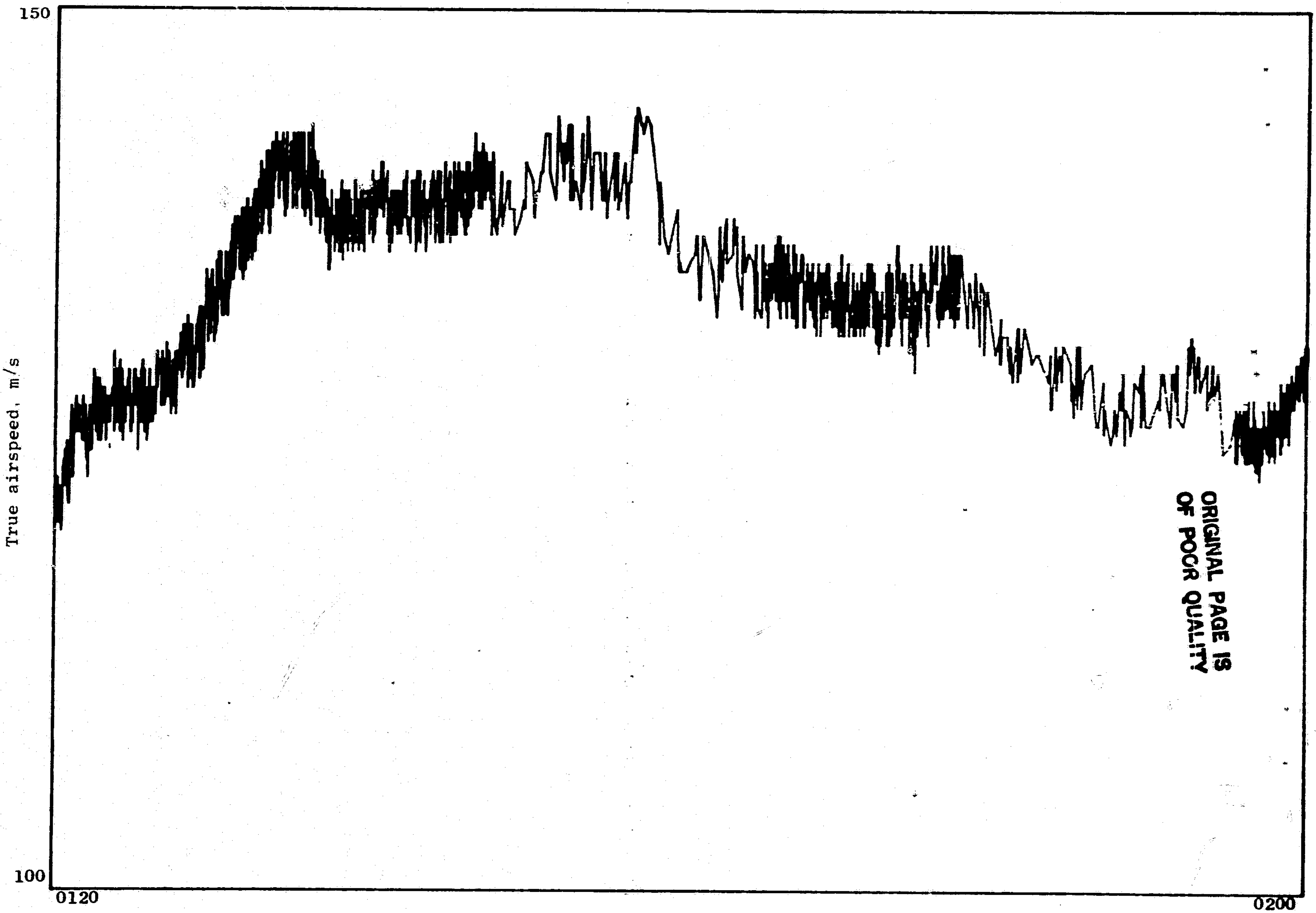

Figure 4: Aircraft true airspeed

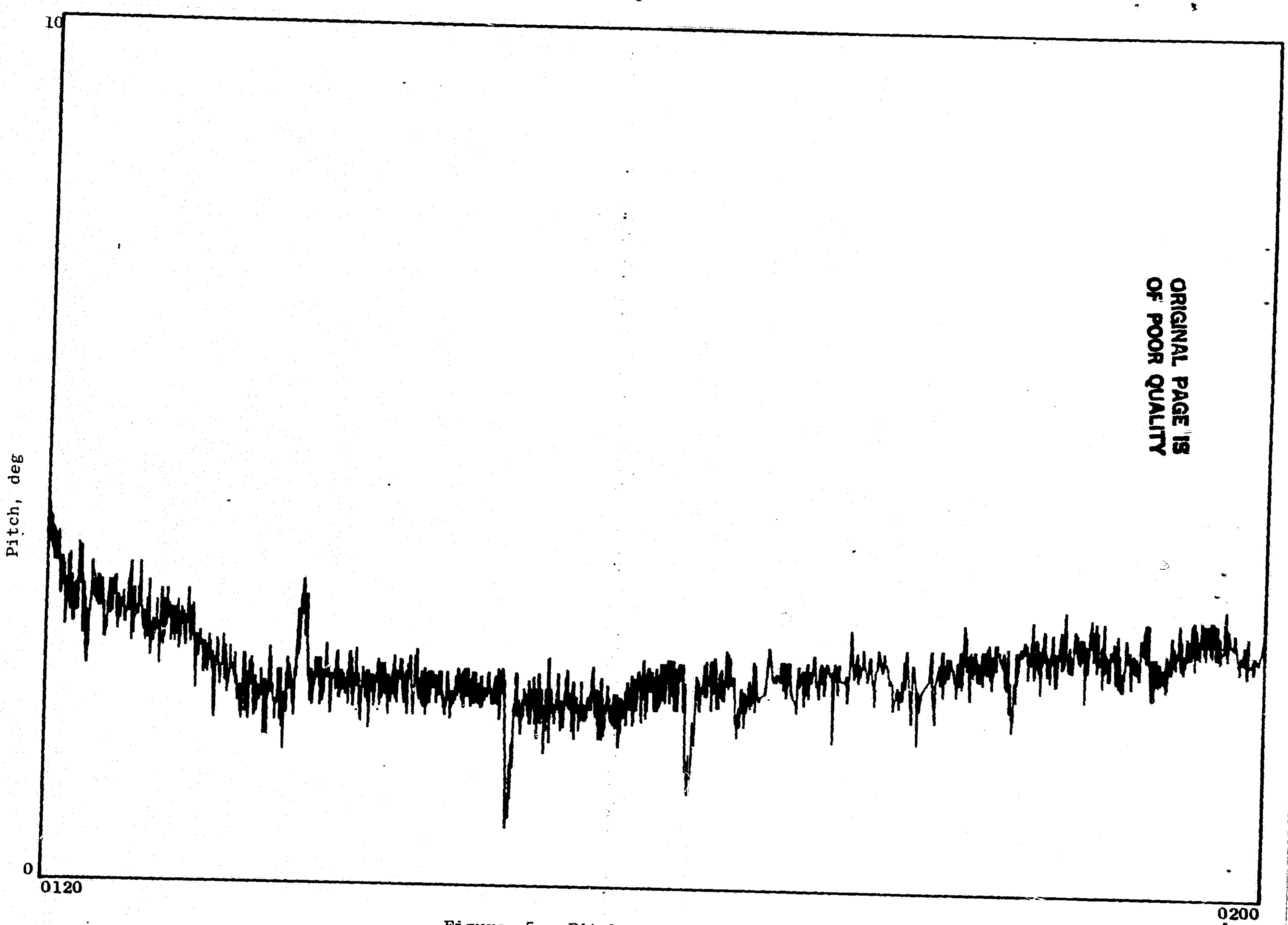

Figure 5: Pitch angle

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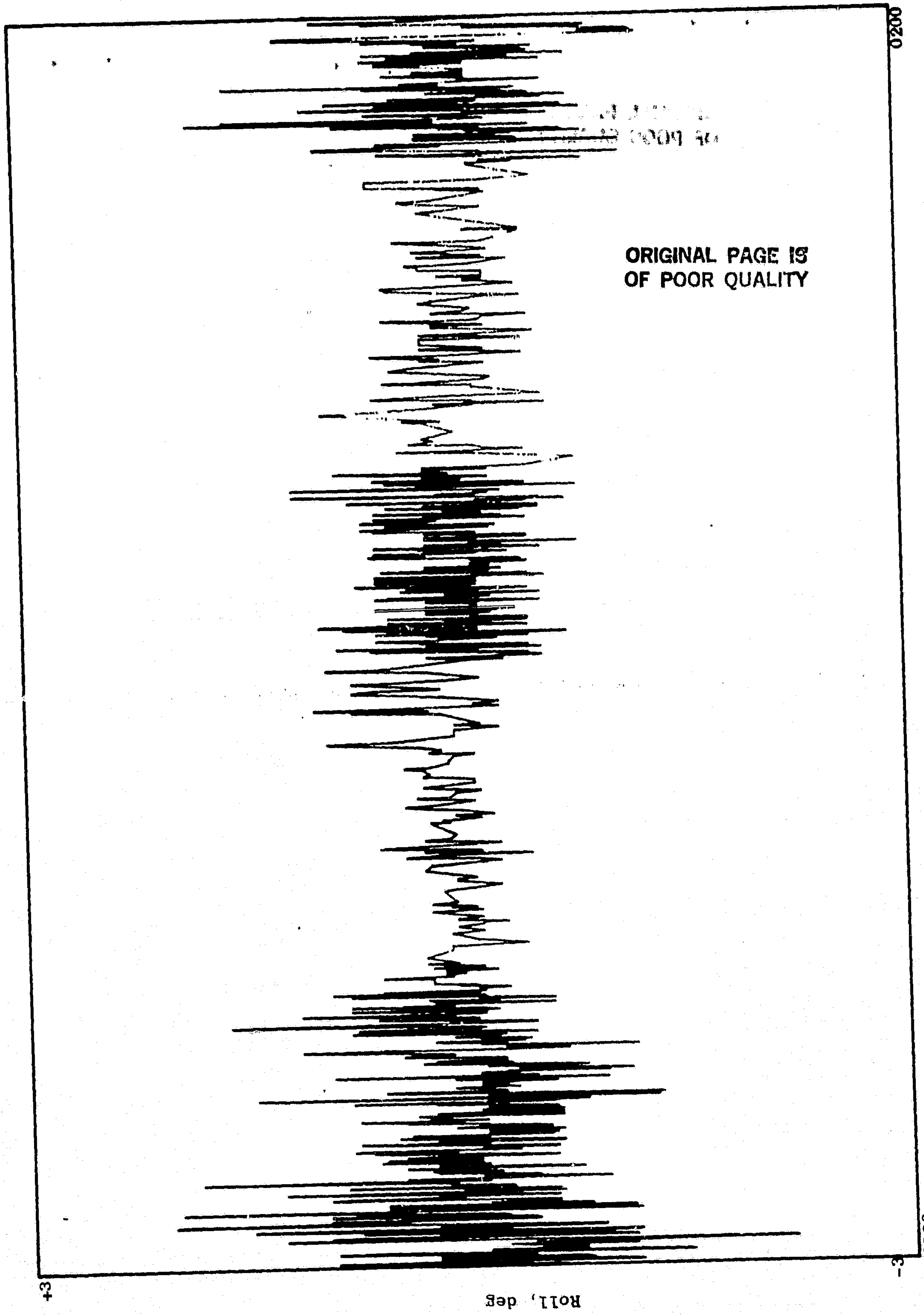

Figure 6 : Aircraft roll angle

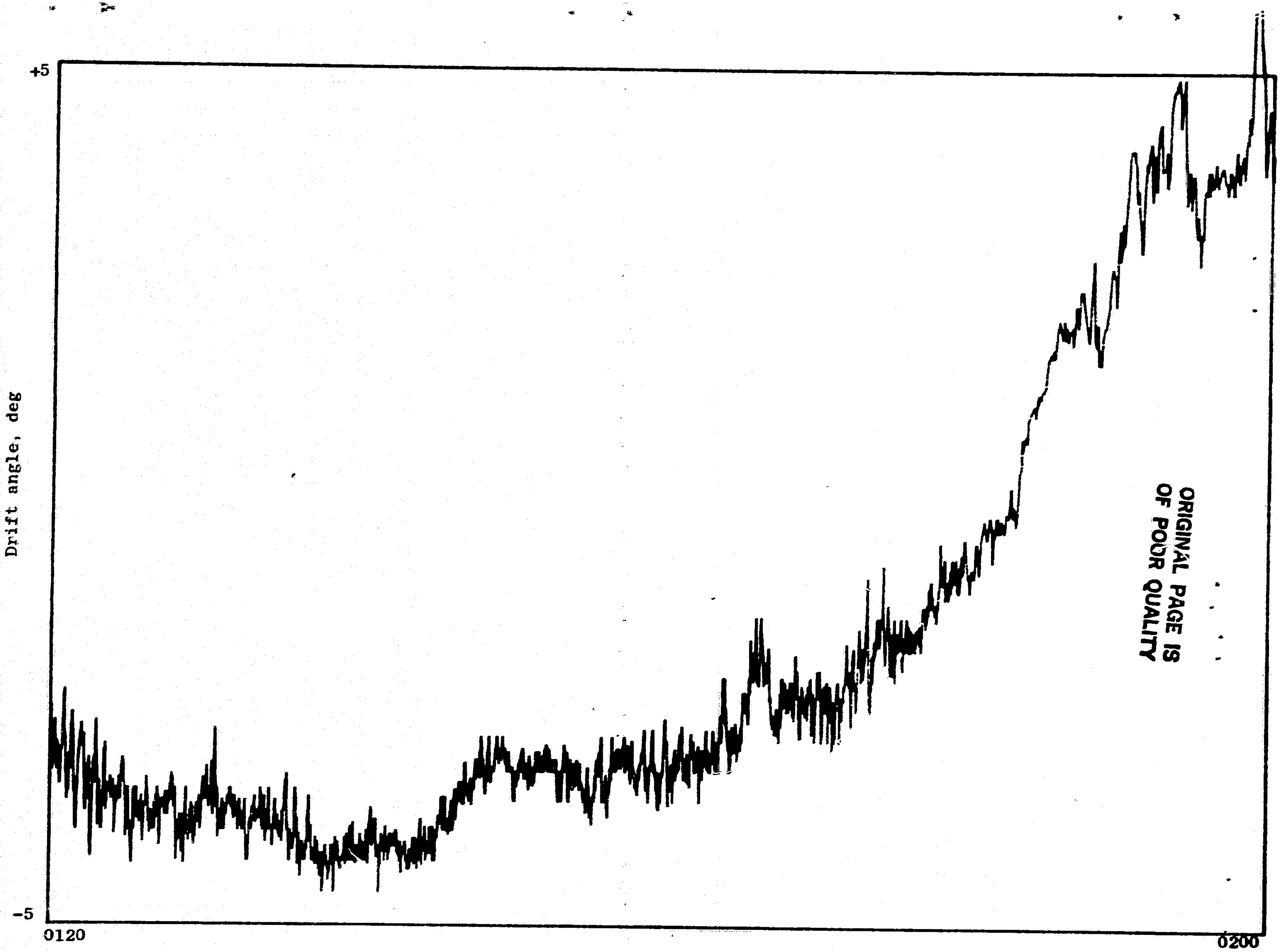

Figure 7: Aircraft drift angle

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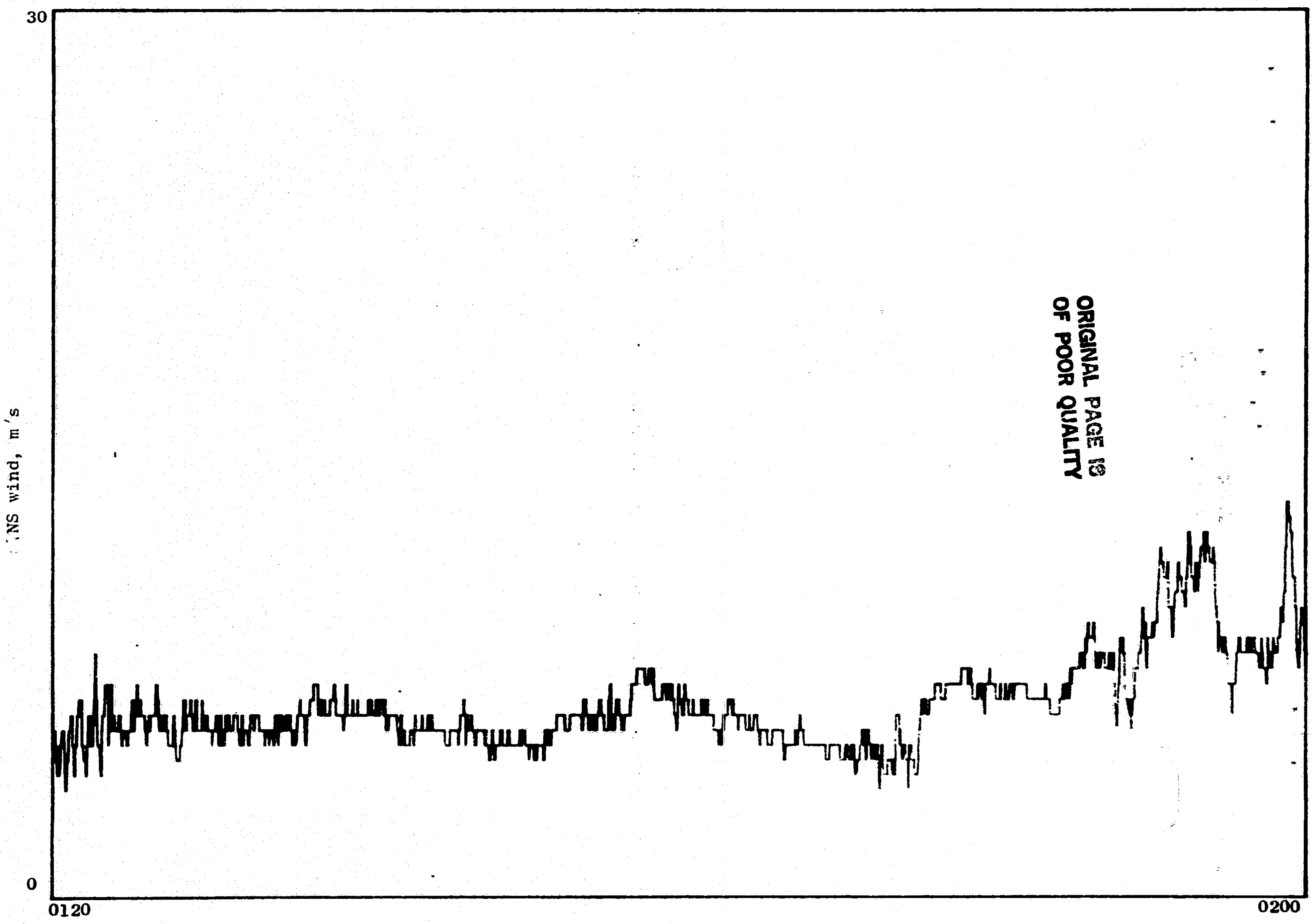

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Figure 8 : Aircraft INS wind magnitude

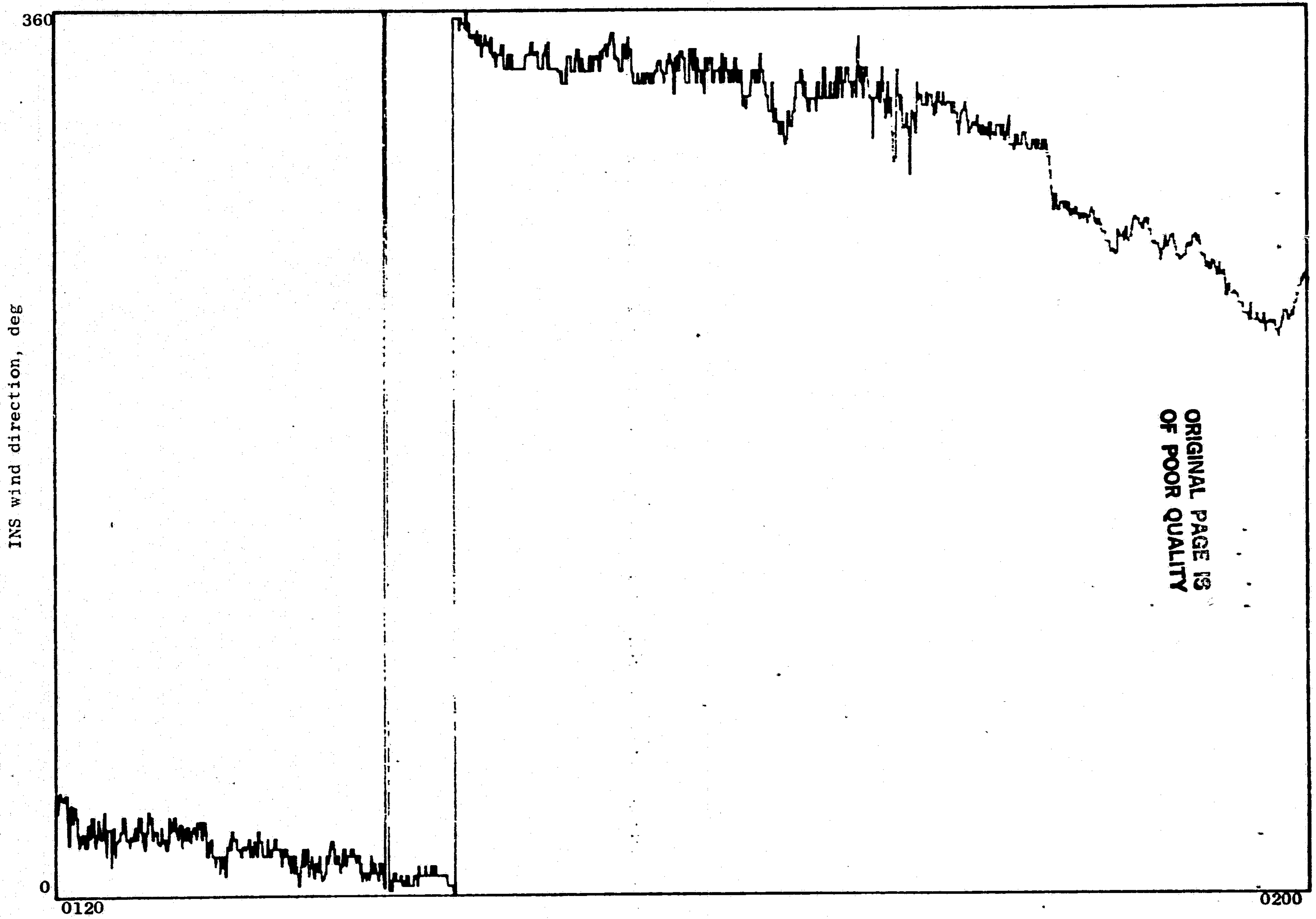

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Figure 9: Aircraft INS wind direction

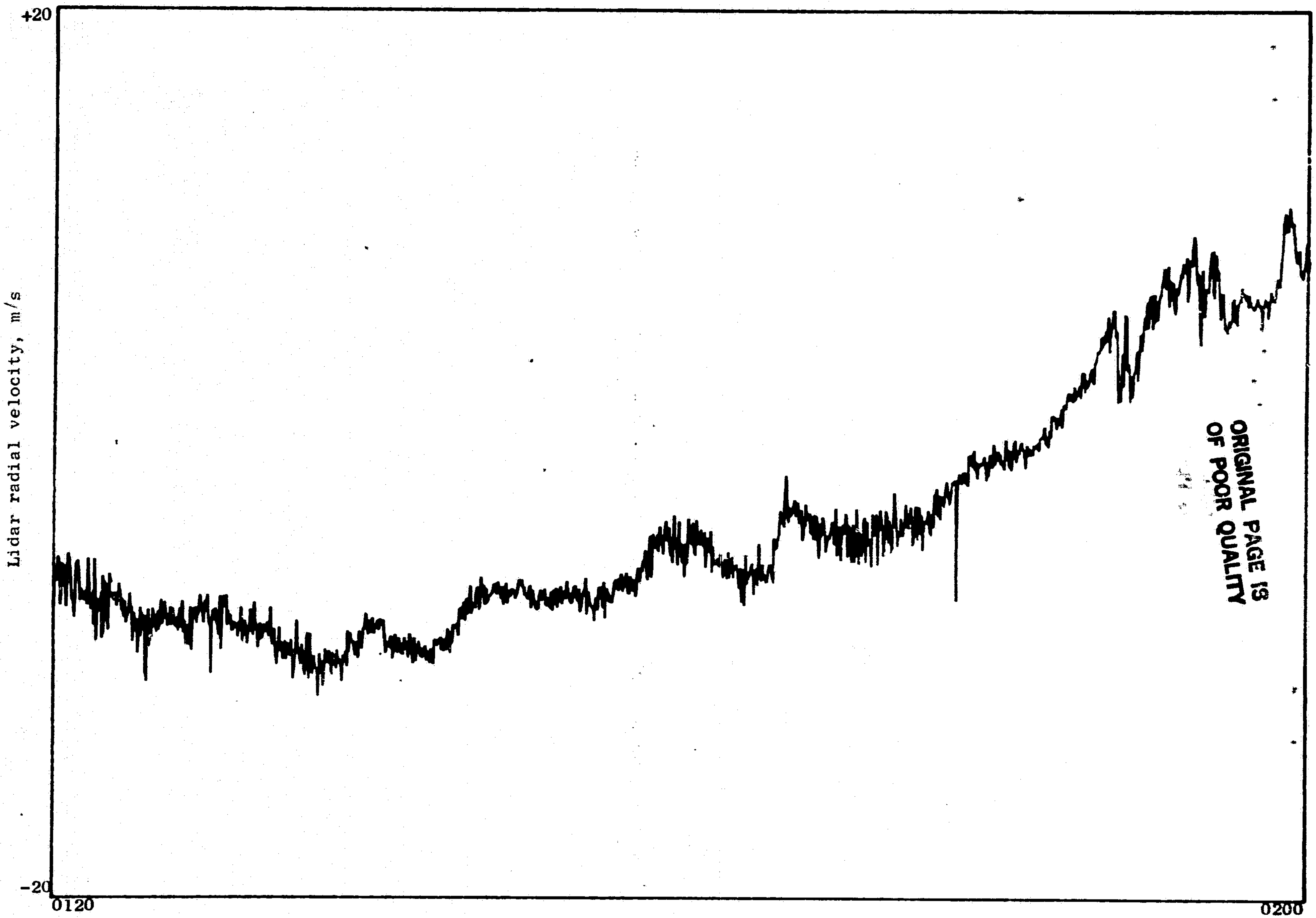

Figure 10: Forward radial velocity

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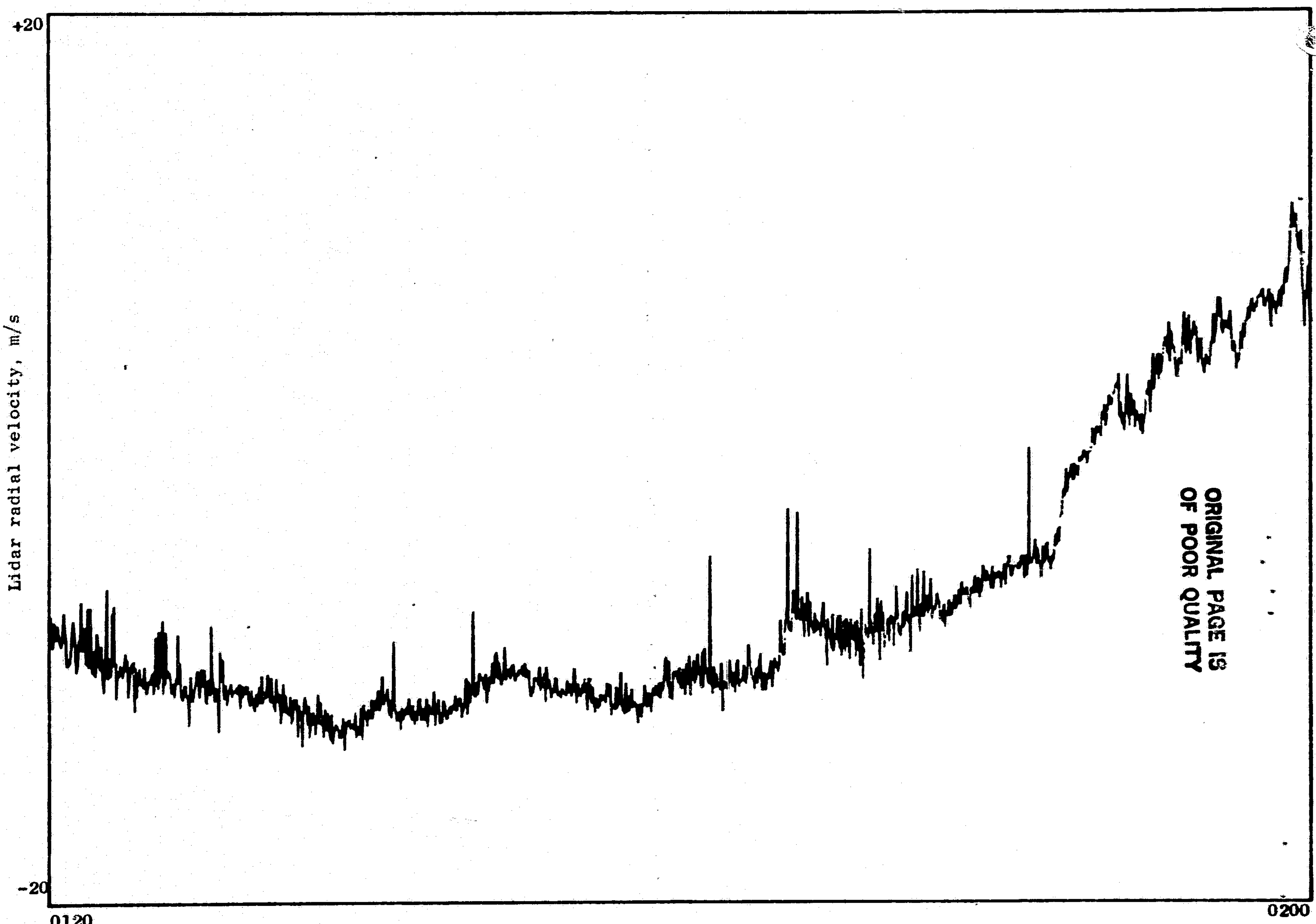

Figure 11: Aft radial velocity

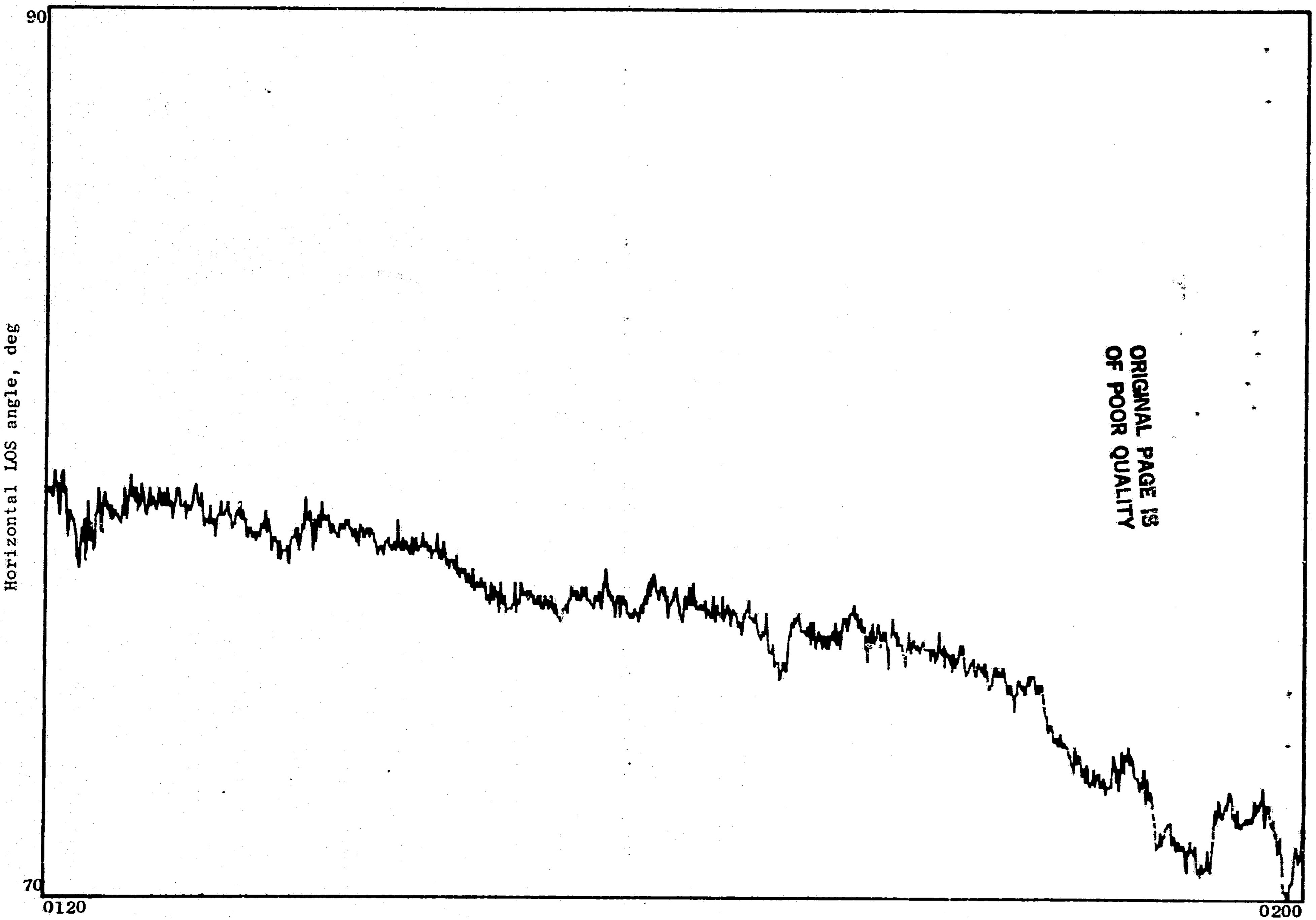

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Figure 12: Forward beam pointing angle

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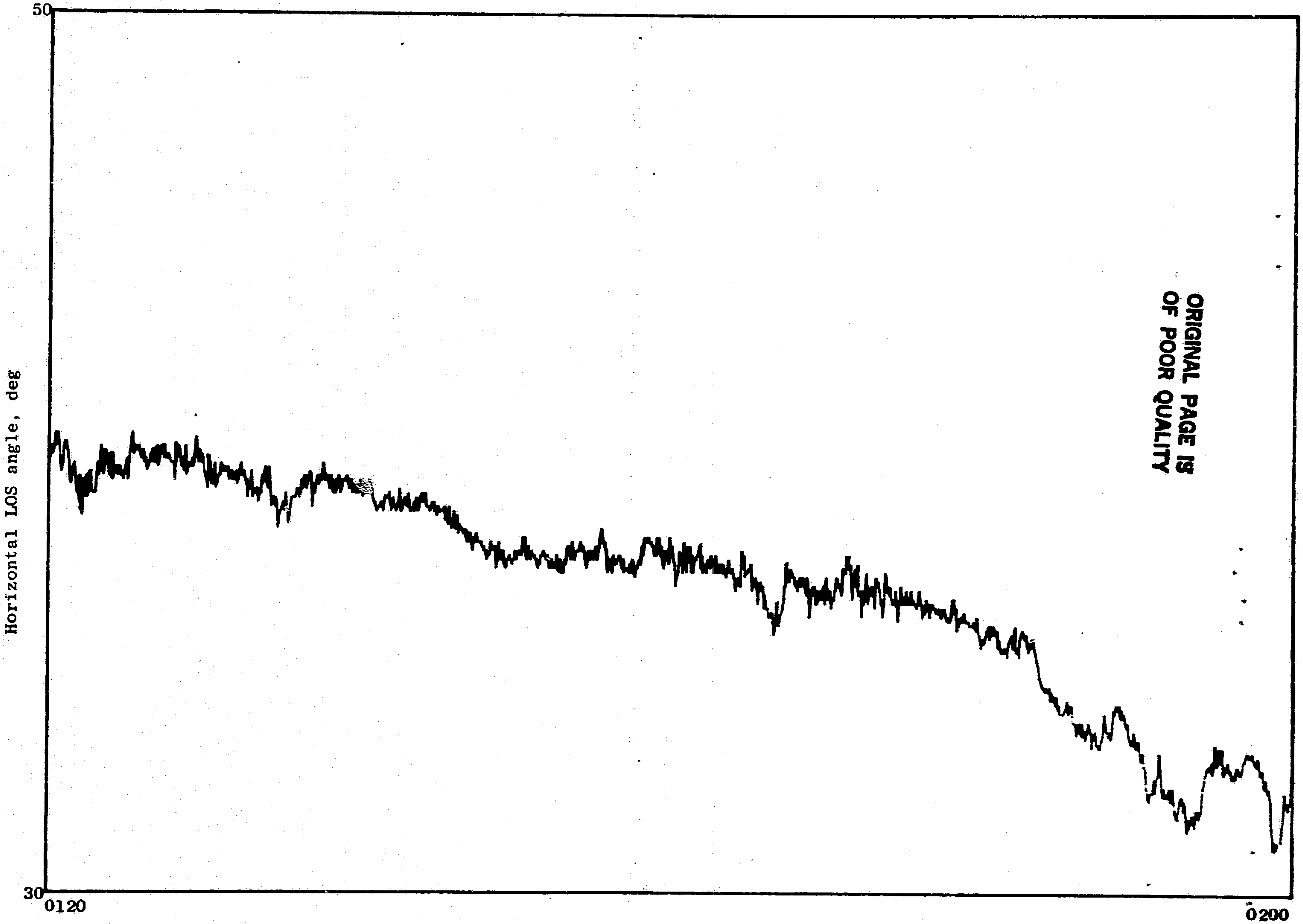

Figure 13: Aft beam pointing angle

It should be noted that the examples shown above are typical of flight in mild turbulence. At high altitudes aircraft parameters are sometimes maintained to tighter tolerances, while in more severe turbulence excursions can be markedly higher.

III. Raw data characteristics

The data acquisition software used during the 1981 flight program provided for "real-time" plots of horizontal flow fields. The plots were updated on a scan-by-scan basis to allow rapid feedback to the experimenters. This section uses six of these plots to illustrate the characteristics of the uncorrected data. The cases were chosen for their relatively uniform flow fields, which make data errors more visible.

Figure 14 illustrates a rather smooth flow field with few artifacts present. As such it is typical of the better measurements. The format is similar to that of the figures to follow: the flight track is at the bottom of the figure, left to right. The grid spacing of the measurements is roughly 300x300 m, with a nearest-neighbor criterion used to match forward and aft scan points. At longer ranges, corresponding to the top of the figure, useful returns were not obtained, as indicated by various letter codes.

Figure 15 is taken from earlier data on the same flight. The flow vectors are confused and difficult to interpret. One might infer that there is a complex flow pattern arising from convection present; in fact, errors to the extent of a few m/s are present in the vectors, and the pattern of the errors is not readily apparent. Near the top of the figure are a few "wild" measurements, often found at long ranges where the returns are weak. The apparent complexity of this measurement on a nearly uniform field should be a warning to interpreters of flow fields: make sure the data is significant before engaging in deep interpretation.

More obvious artifacts are present in the example shown in figure 16. There is a definite tendency for vectors to line up on the 70- and 110-deg radials at which lidar measurements were made. This triangular appearance of the data was one of the first characteristics noted on many of the early plots. Also seen in this figure, in addition to a few isolated "wild" measurements, is a row of uniform, strong vectors in the upper left. A rather frequent a result of multiple-mode interference in the laser system, they are easily rejected.

This same triangular effect takes on a different appearance when the flow is primarily parallel to the aircraft track, as in figure 17. Note

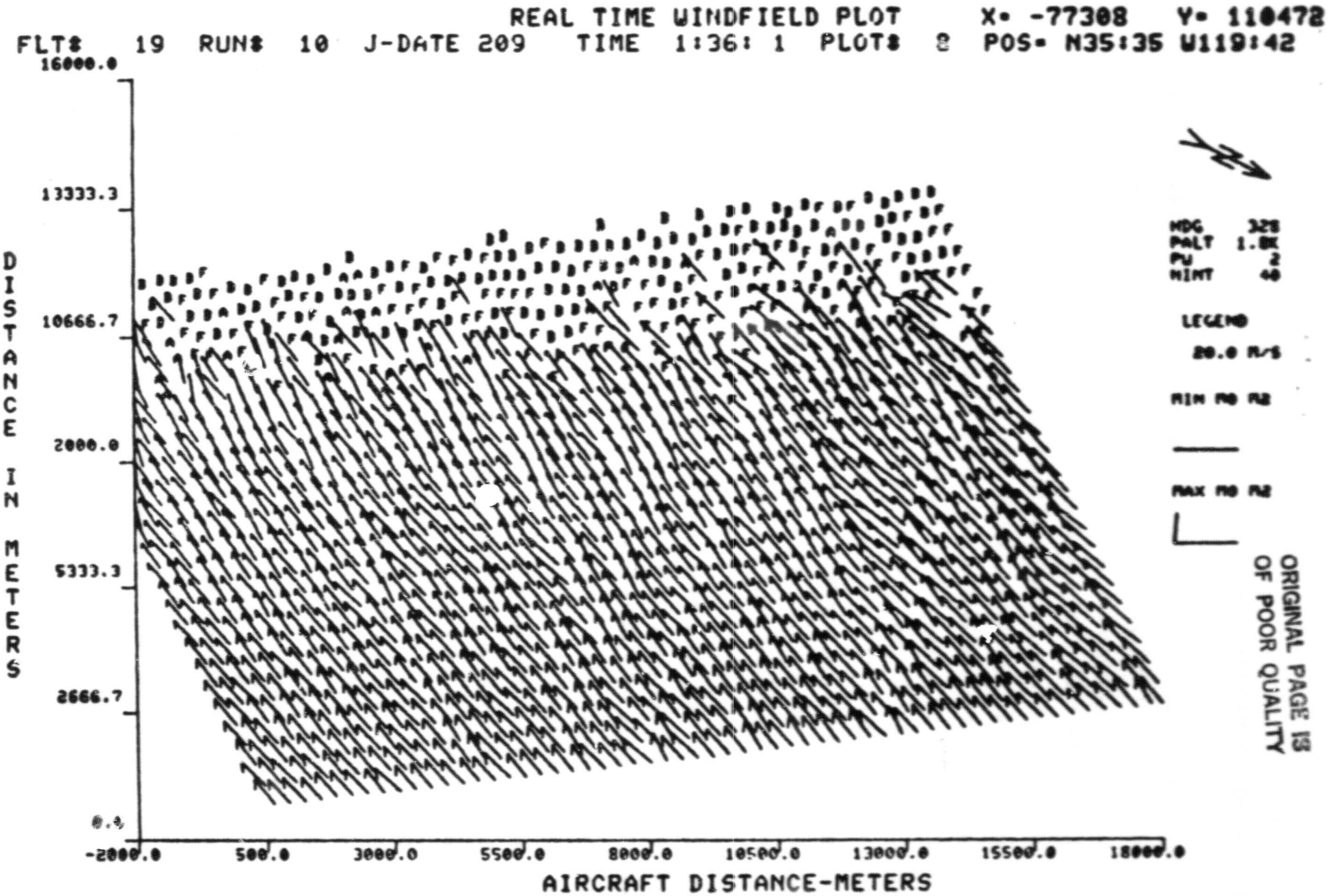

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Figure 14: Uncorrected smooth wind field

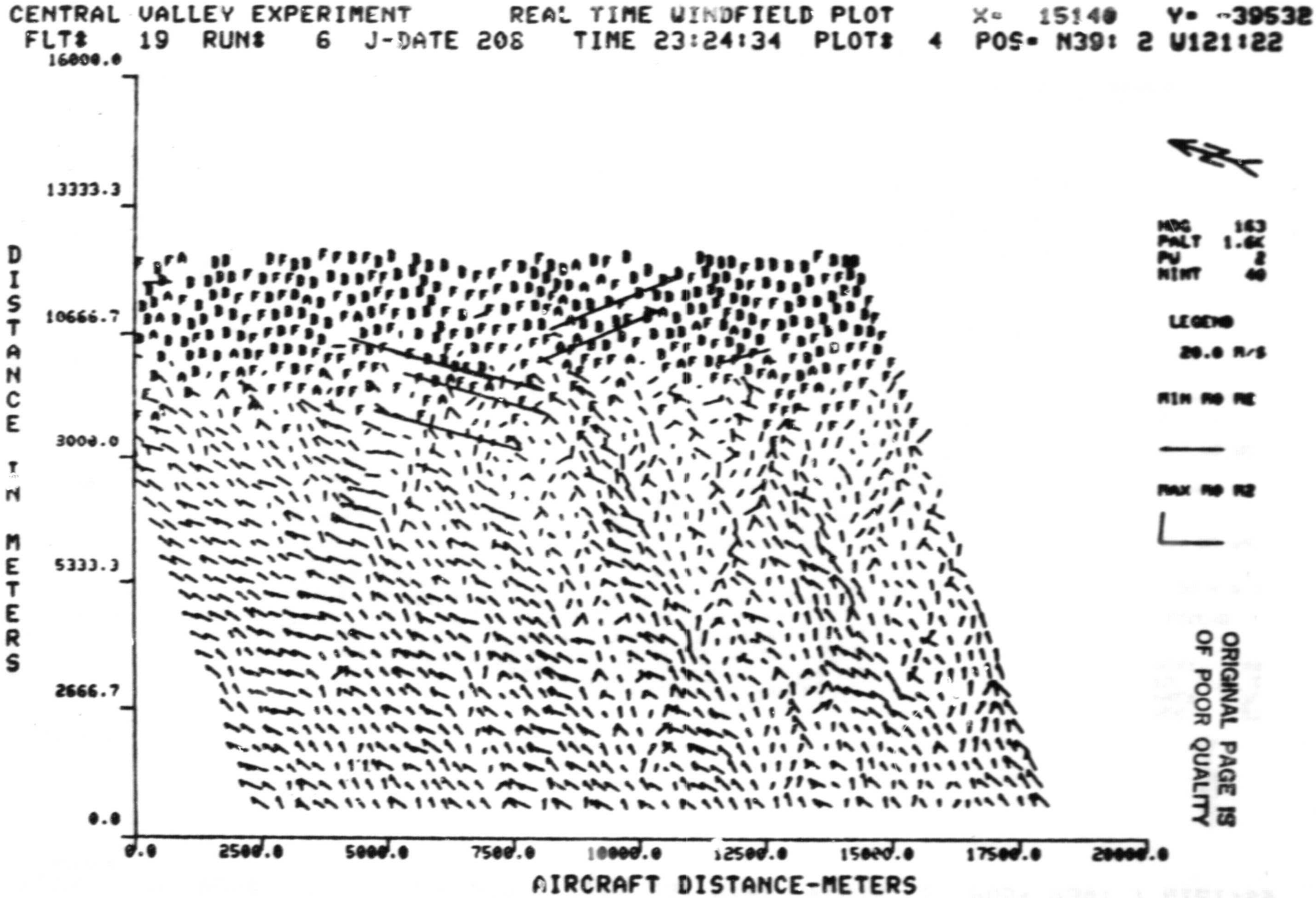

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Figure 15: Uncorrected contaminated wind field

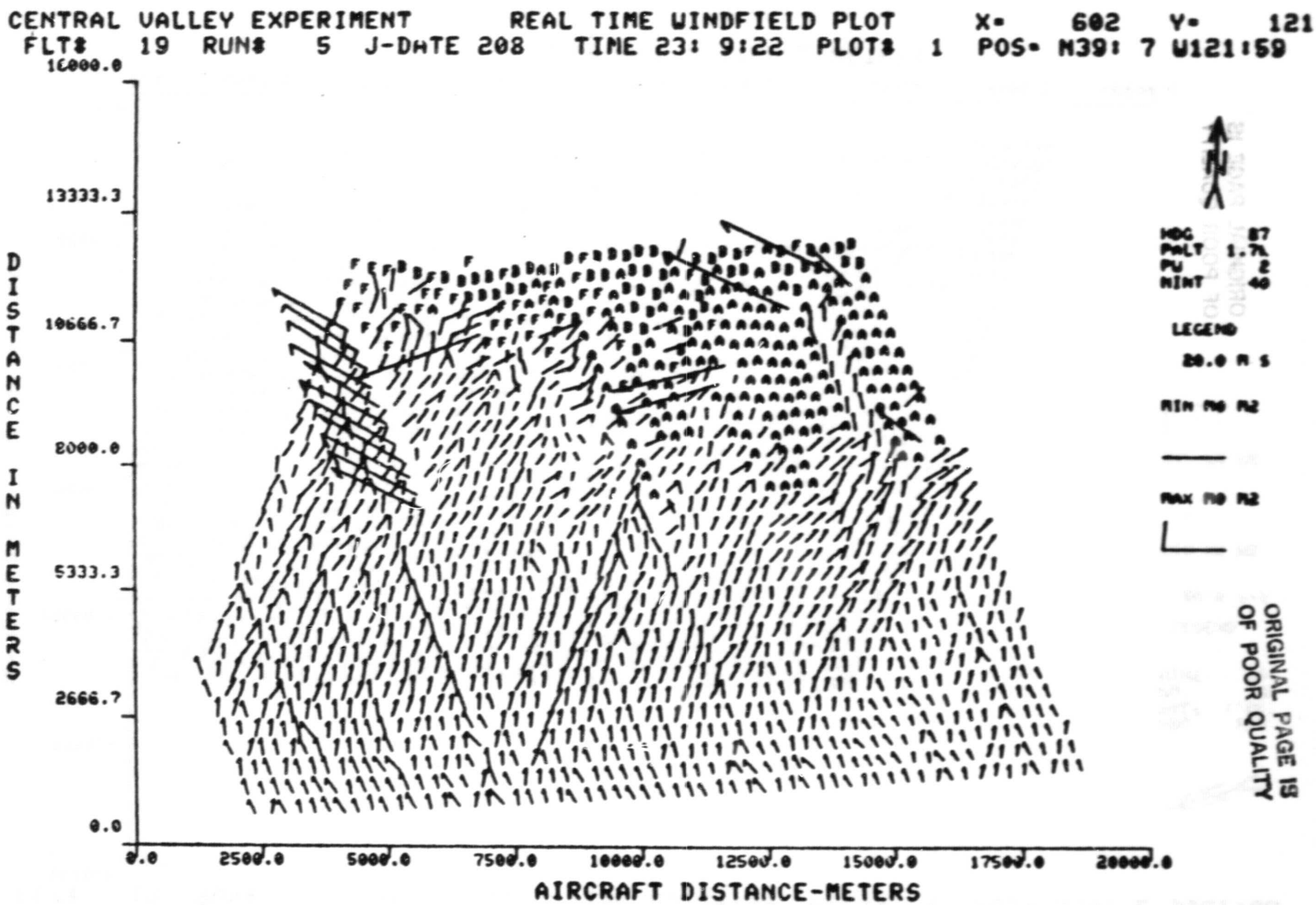

Figure 16: Wind field with diagonal errors

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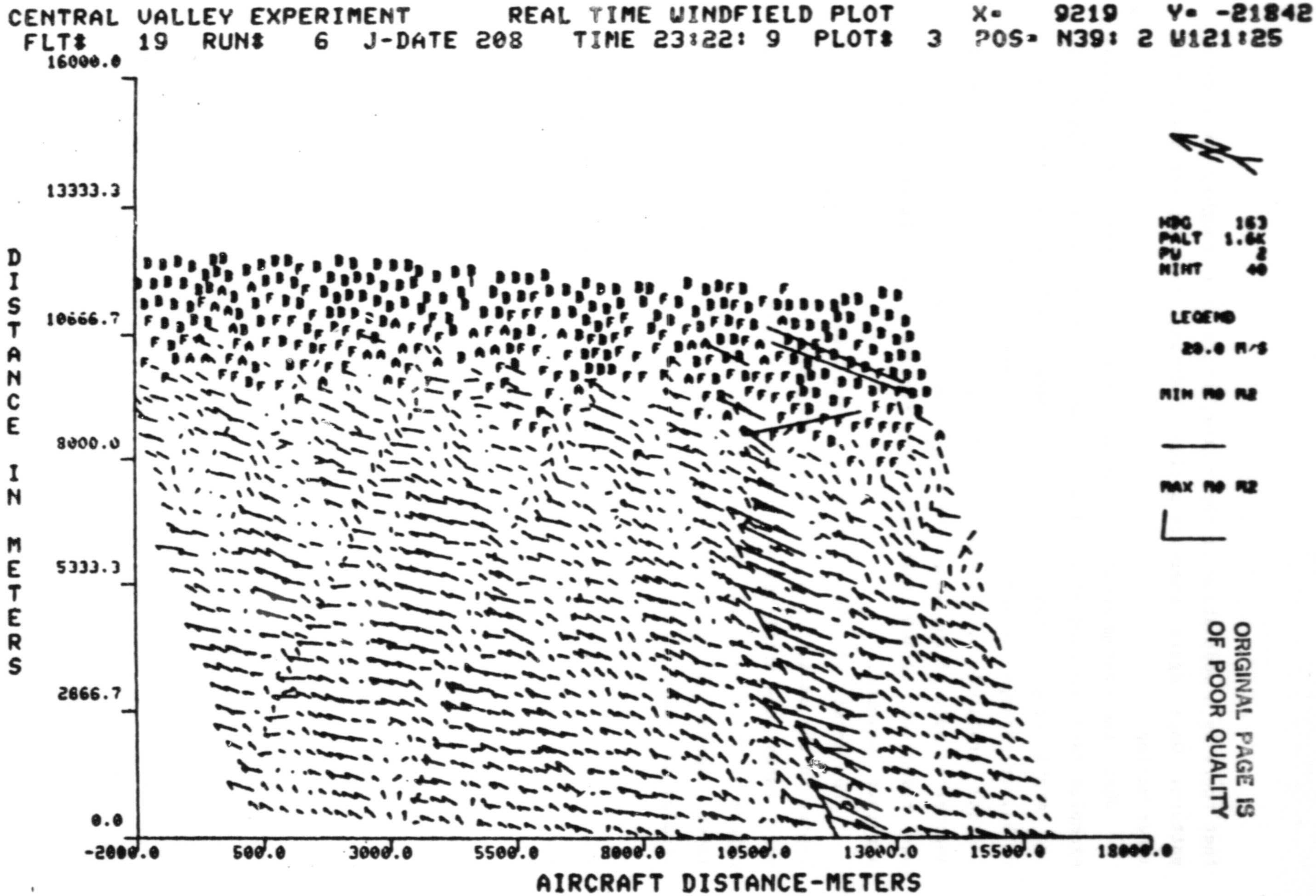

Figure 17: Wind field with longitudinal errors

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that there is a modulation of the vector length in a roughly triangular pattern. Once again there is a line of strong, constant vectors due to laser moding.

When the system errors are periodic the errors seen in the previous examples take the form of braiding of the flow vectors, as in figure 18. One might imagine that the flow is dominated by organized horizontal rolls, or perhaps influenced by canyon topography; but the effect is instead produced by aircraft dynamics, as discussed in Section IV. Another example of the same effect is shown in figure 19, where the data was taken at 12,400 feet and the structure is due almost entirely to aircraft dynamics.

The moral of this section is clear. Some very interesting effects appear in the data, but unfortunately they are instrumental in origin. In many cases the artifacts are so severe that they completely obscure the nature of the flow field. This is particularly true in the boundary layer, where the flow-field perturbations of interest in convection studies are quite small.

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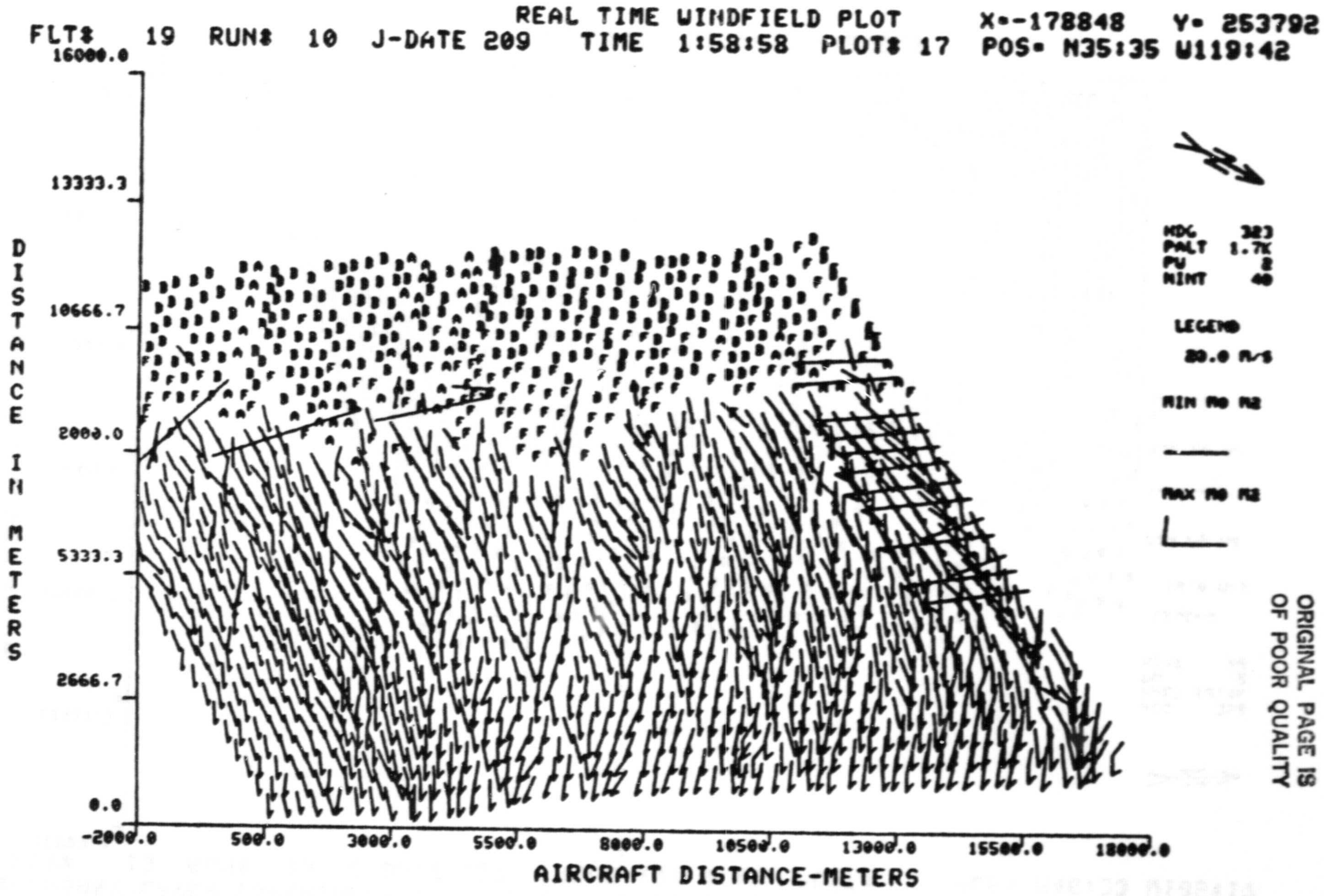

Figure 18: Wind field with braided errors

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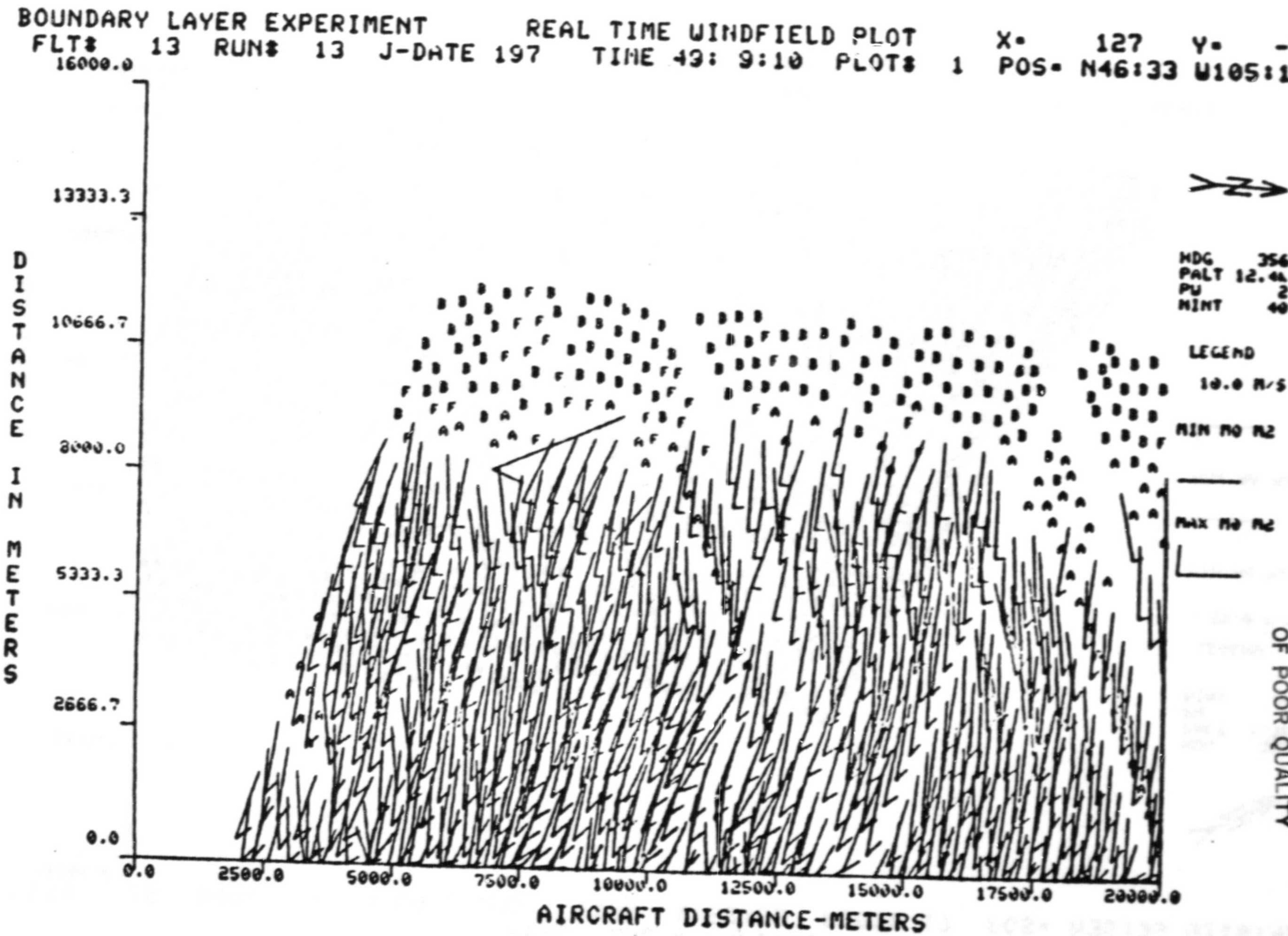

Figure 19: Wind field with braided errors

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IV. Drift angle correction

This section is devoted to an explanation of the most significant source of artifacts in the data, erroneous drift-angle information. To establish conventions for various angles, refer to figure 20. The body of the aircraft is aligned along the vector THDG (true heading), but the center-of-gravity of the aircraft is travelling along the vector TRK (track) relative to the ground. The two vectors do not coincide due to the assumed presence of a wind from the left; the difference between the two vectors is the drift angle, which in this case is positive. The direction of the lidar measurement is given by vector LOS (line-of-sight), and this angle is measured by angle SCAN with reference to THDG.

Note that the ground velocity is along vector TRK. It is the component of this velocity parallel to LOS which must be subtracted from the data measurements in order to reference the wind flow to the ground. Thus the angle between the laser measurement and the aircraft motion is SCAN+DRIFT. The angle SCAN is closely controlled and monitored by the lidar scanner; thus the angle DRIFT is crucial for proper application of the velocity correction.

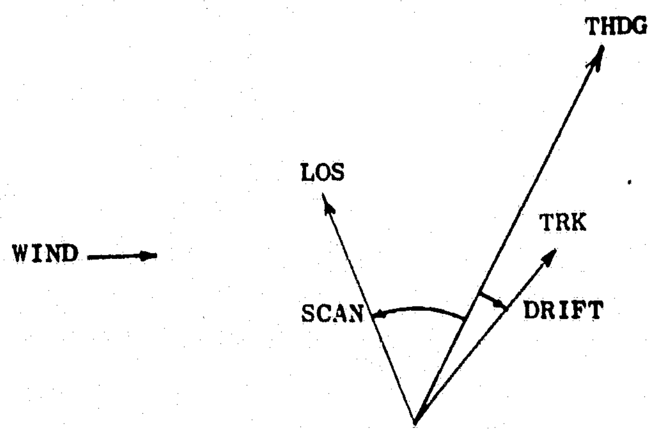

Figure 20: Lidar-aircraft geometry

With this in mind one can conclude that drift angle and aircraft ground speed are the critical parameters required for removal of the component due to aircraft motion. Three aspects of these two parameters can cause errors in this correction: resolution, accuracy, and time delay. Clearly if the resolution of the measurement is limited the correction will be correspondingly limited. Similarly, if there are errors in the measurement of drift angle or ground speed there will be errors in the correction. Finally, if the correction quantity is outdated when it is used there will be errors, provided that the quantity changes fast enough. The latter effect dominates errors in the data sets.

Figure 21 shows a 2-minute sample of raw radial-velocity measurements taken during a portion of run 10, flight 19. The two plots are for the forward and aft measurements, and 30 range gates have been averaged together. The wind field was relatively uniform. The most obvious features of the figure are excursions on the order of a few m/s which are correlated in the two plots. One can easily show that such large excursions in a mean velocity are unlikely: the velocities are averaged over 10-km in range, and show changes in the means of up to 4 m/s in 300-m of flight. This implies a shear of 0.01/s over 10 km, an order of magnitude higher than that typical of the turbulent boundary layer, in a situation which was relatively smooth. Further, rapid changes in the two measurements are not consistent with correlation between them, since the averaged regions diverge from the aircraft, and are separated by 7 km at 10-km range. We may safely conclude that most of the excursions in figure 21 are due to some form of measurement error.

A study of the continuity in range of individual lidar shots indicates that the Doppler estimation errors within each shot are quite low. The source of error is thus likely to lie in the correction of the measured velocities to ground-based coordinates. Therefore the next step is to investigate these suspect measurements. Figure 22 shows two such measurements for the same 2-min time period. The relationship between true heading and the "errors" of figure 21 is not apparent, but clearly drift angle is somehow correlated.

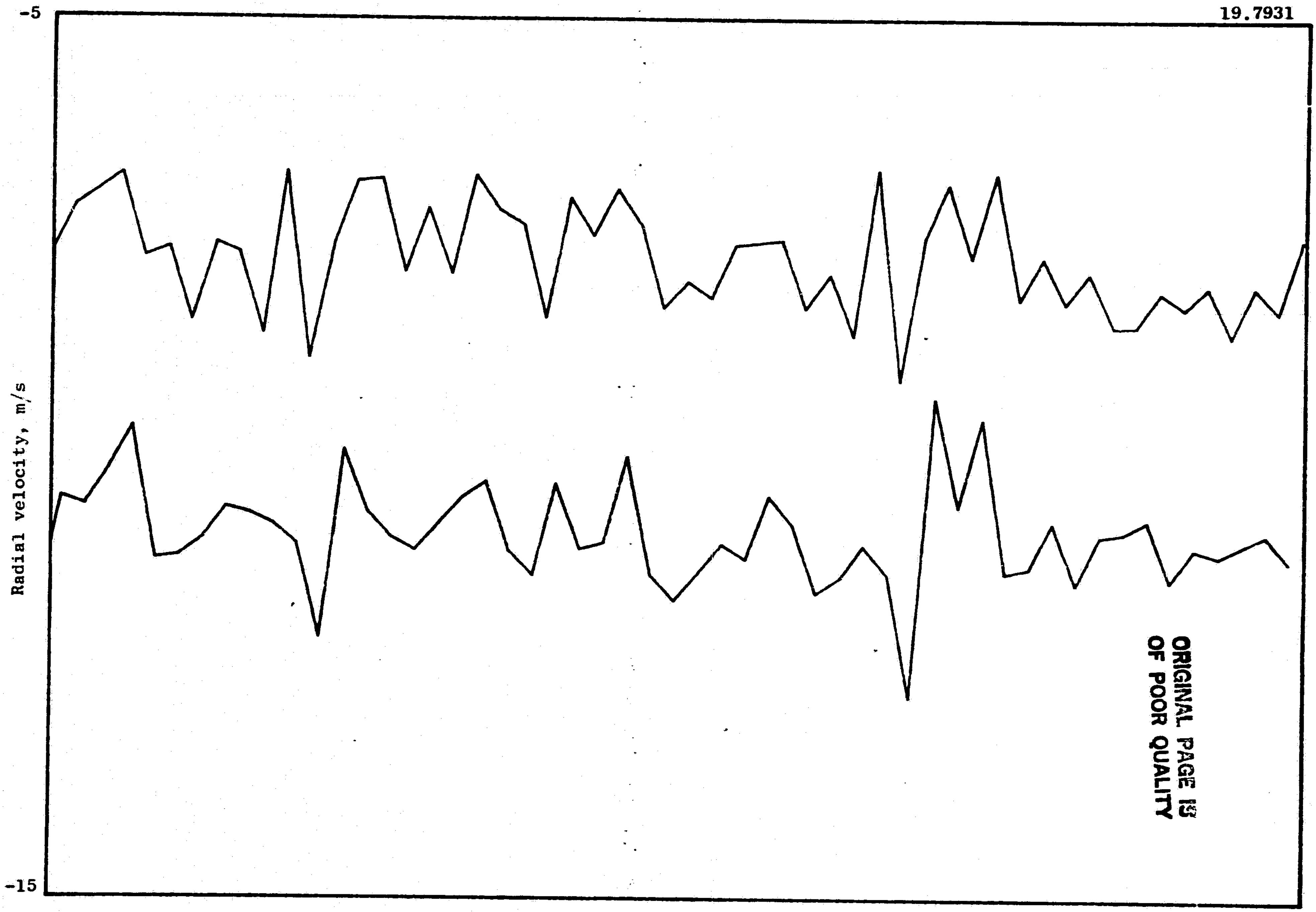

Figure 21: Uncorrected mean forward and aft lidar radial velocities

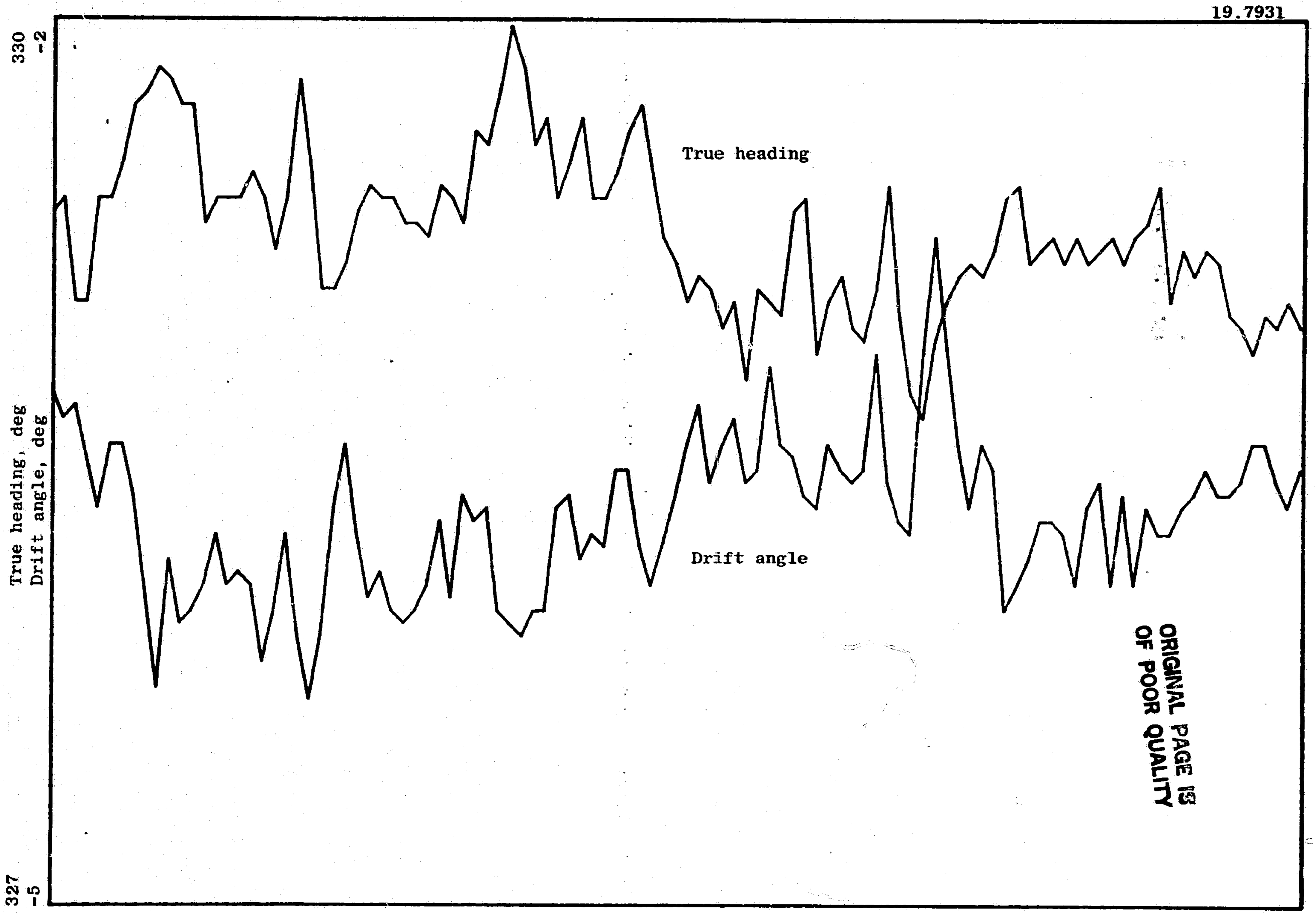

Figure 22: Aircraft true heading and drift angle

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Figures 23 and 24 plot the derivatives of true heading and the two line-of-sight angles of the forward and aft scans. These derivatives, which are estimated by taking 2-scan (approximately 2.2-sec) differences, are also somewhat correlated with the "errors" in figure 21.

Finally, figure 25 shows the 2-scan derivative of drift angle, plotted separately for the forward and aft scans. If this figure is held face to face with figure 21 a remarkable correlation will be observed. Not only is the correlation very accurate, but there is a time delay between the two figures amounting to about 2 seconds.

Obviously, since there is something remarkably similar between drift-angle changes and apparently erroneous mean radial velocity measurements, the next step was to find the connection. Simulation was used to ascertain the impact of oscillatory drift-angle errors upon derived wind fields, given a variation in radial velocity of a few m/s and differences in drift angle on the order of 1 deg. The results are shown in figures 26-28. In each case a uniform wind of 10 m/s was assumed, and an artificial sinusoidal perturbation in drift angle of about 0.3 deg was used in the model.

In the case of figure 26 the assumed constant wind field was normal to the aircraft track (along the bottom of the page in these three figures). The effect of the drift-angle perturbation is substantial, even though the perturbation was only 0.3 deg. When the wind field is parallel to the aircraft track as in figure 27 the appearance is quite different: a modulation of the vector length very much like that seen in figure 17. Finally, with the wind vector at 45 deg relative to the aircraft track the effect is a braiding of the flow vectors identical to that seen in figures 18 and 19.

To quantify this effect note that in terms of the geometry of figure 20 the magnitude of the velocity correction is GS*COS(SCAN+DRIFT). Assuming that the quantities GS (ground speed) and DRIFT are subject to errors (from whatever source) EGS and EDR, one can expand the expression and determine the errors in the correction term. The expansion contains three terms:

EDR * GS * SIN(SCAN+DRIFT)

EGS * SIN(SCAN+DRIFT)

EDR * EGS * COS(SCAN+DRIFT)

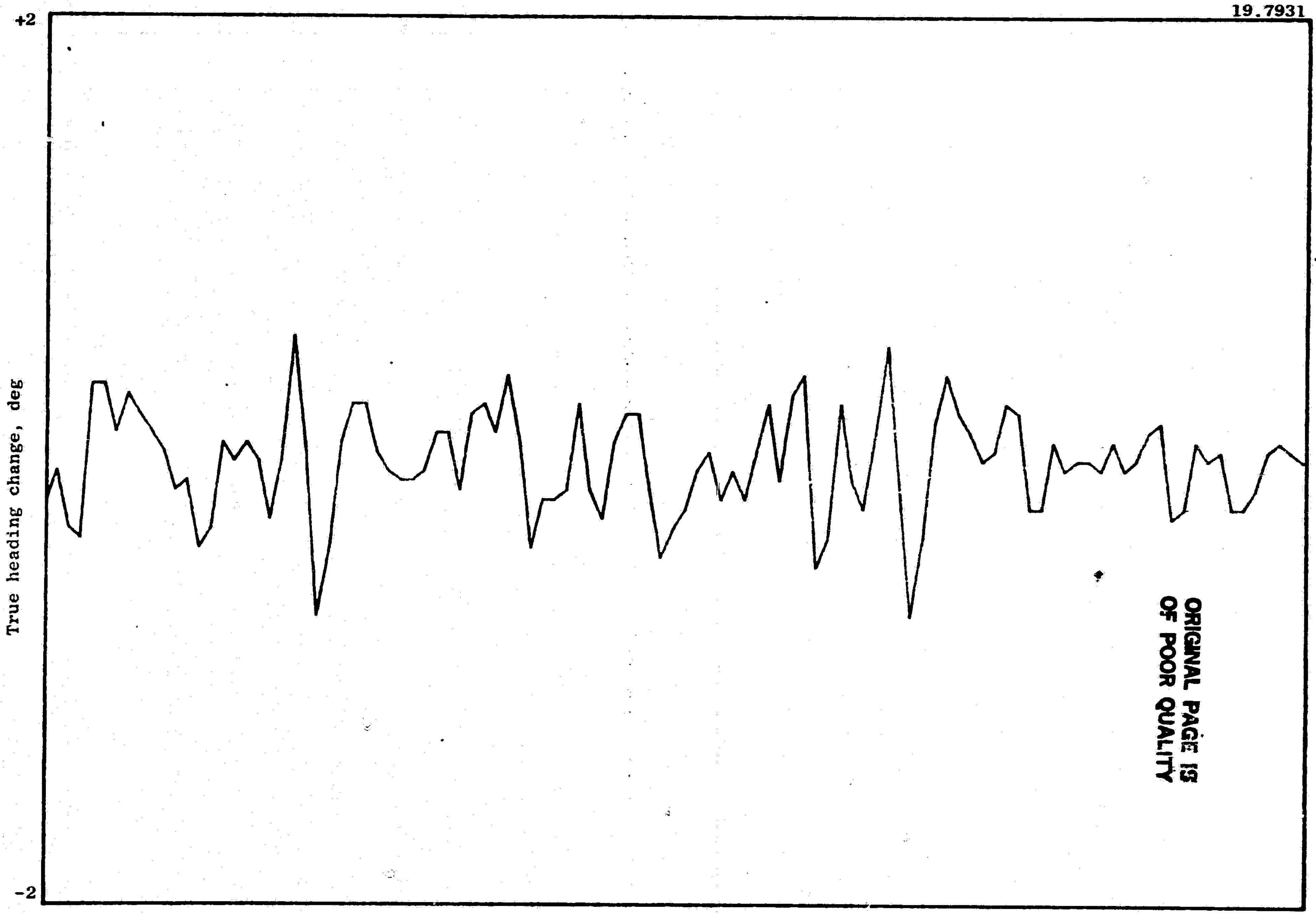

Figure 23: 2-lag differential true heading

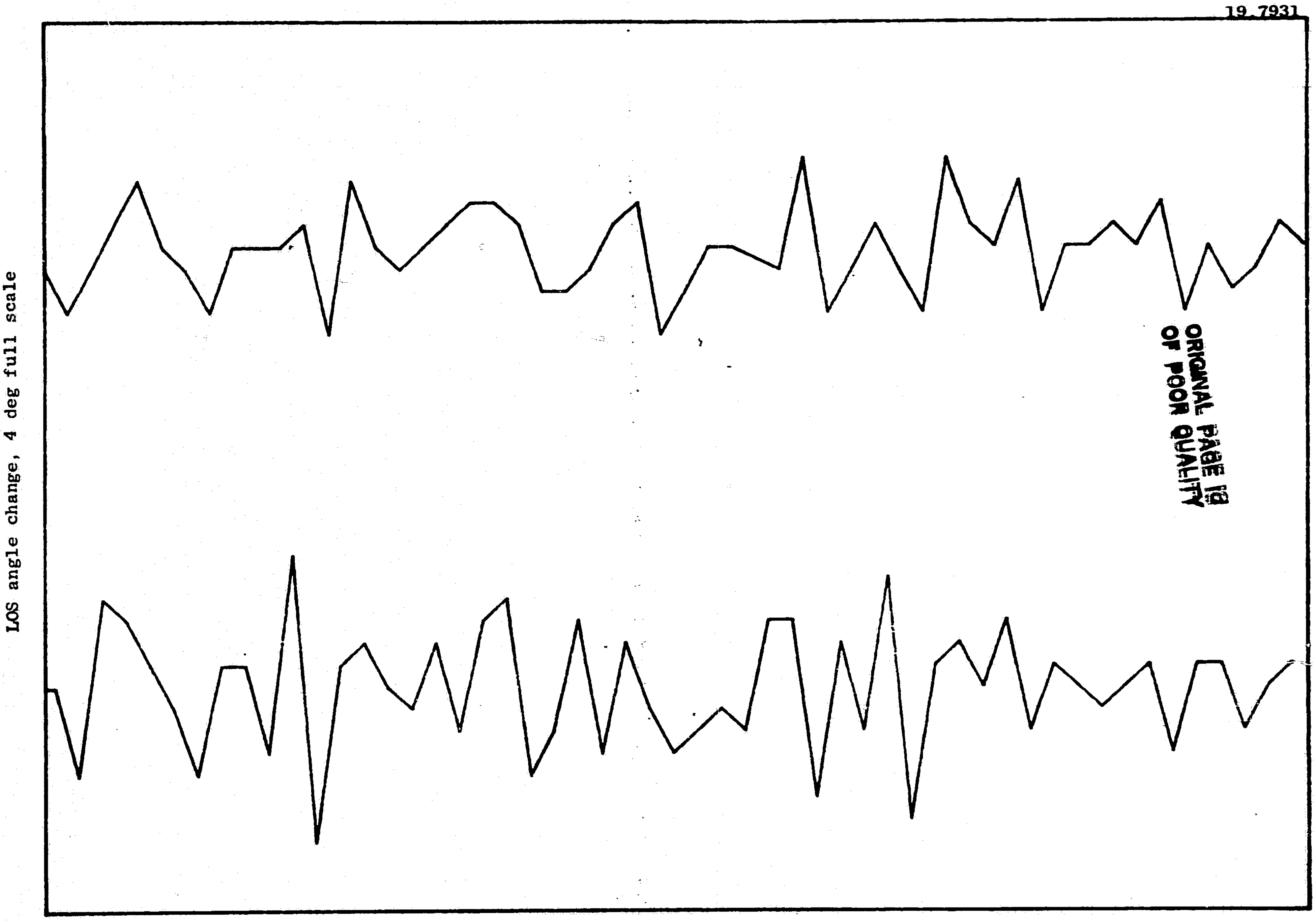

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Figure 24: Forward and aft differential line-of-sight angle

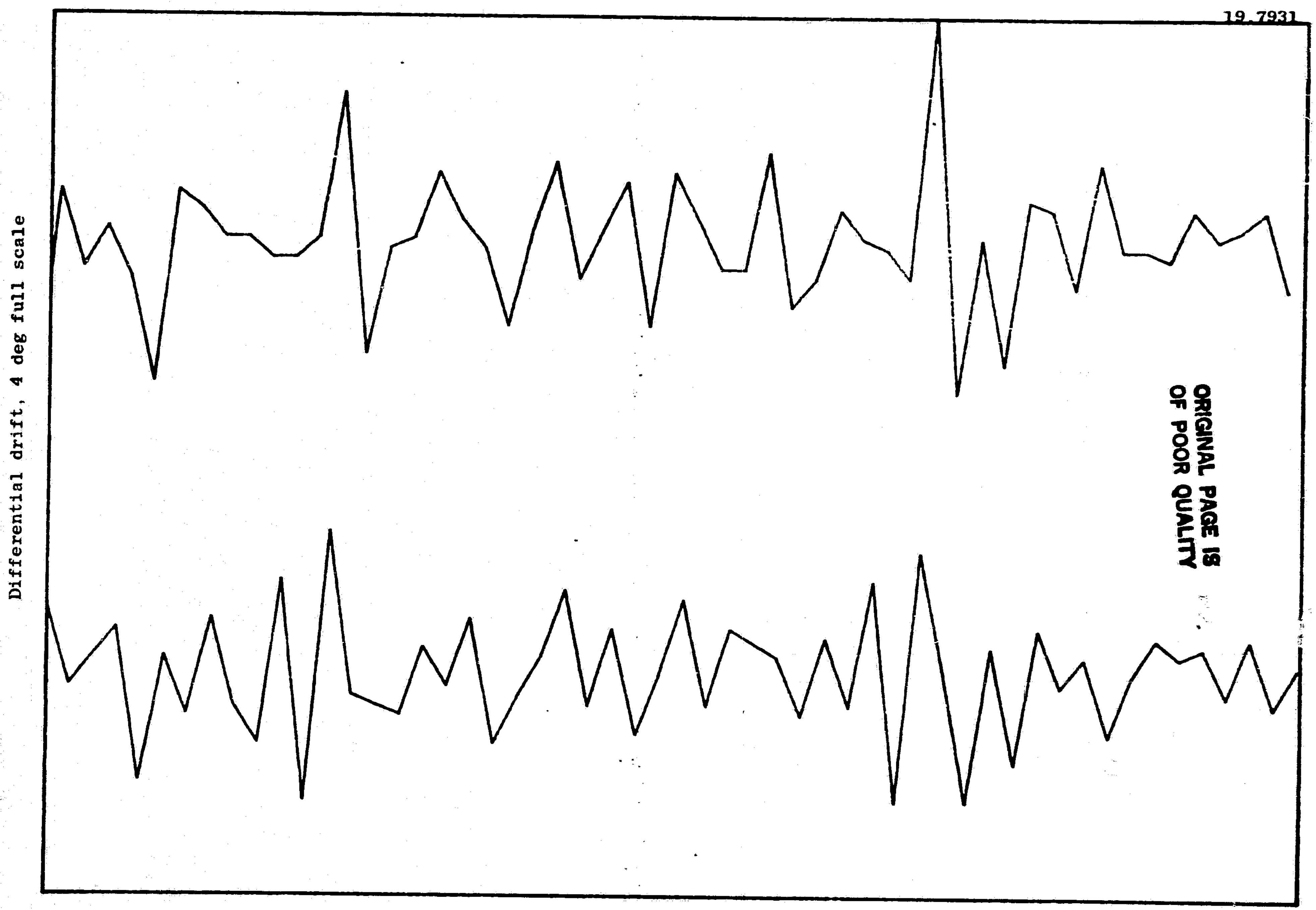

Figure 25 Forward and aft differential drift angle

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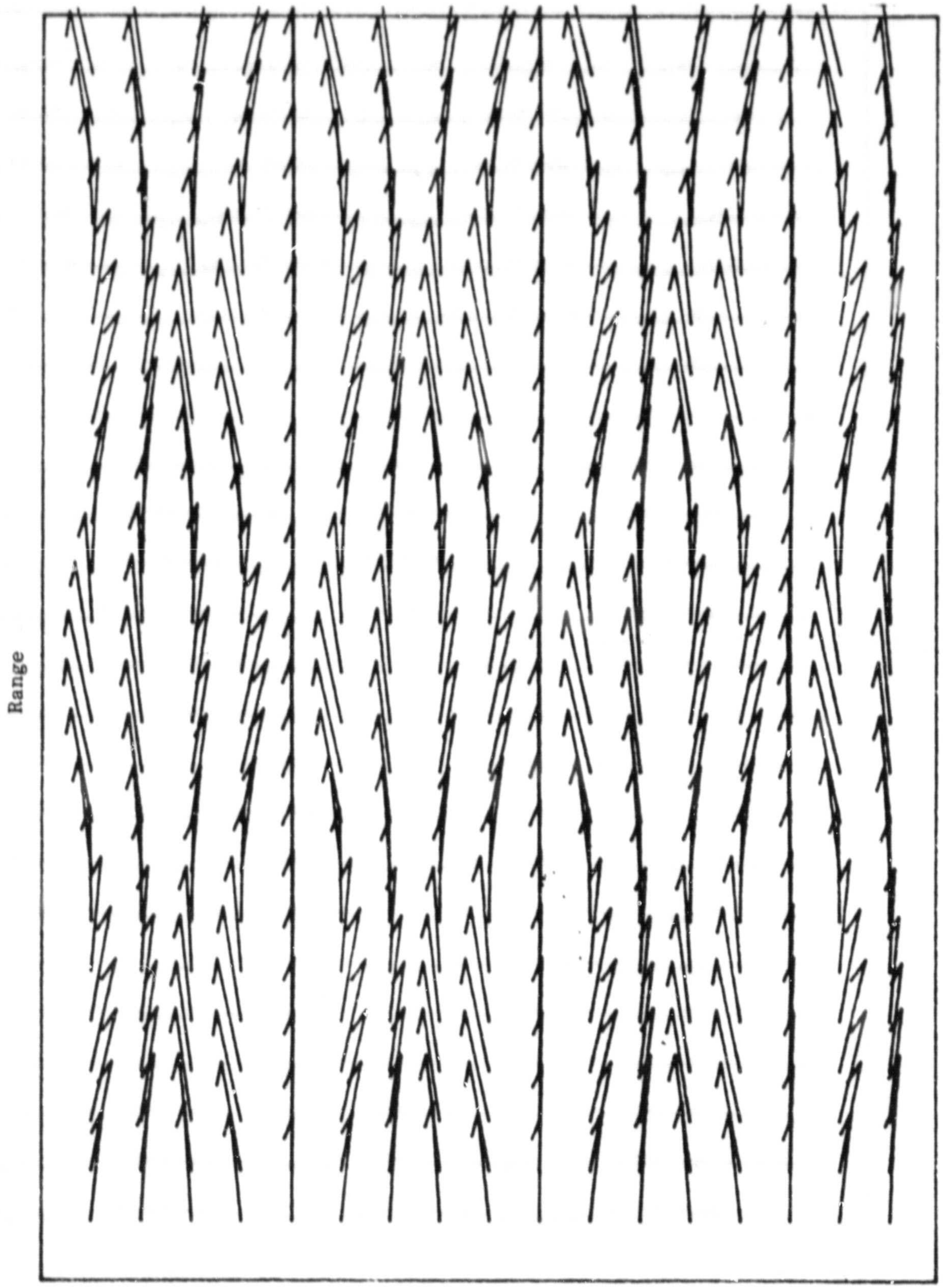

Figure 26: Simulated transverse flow

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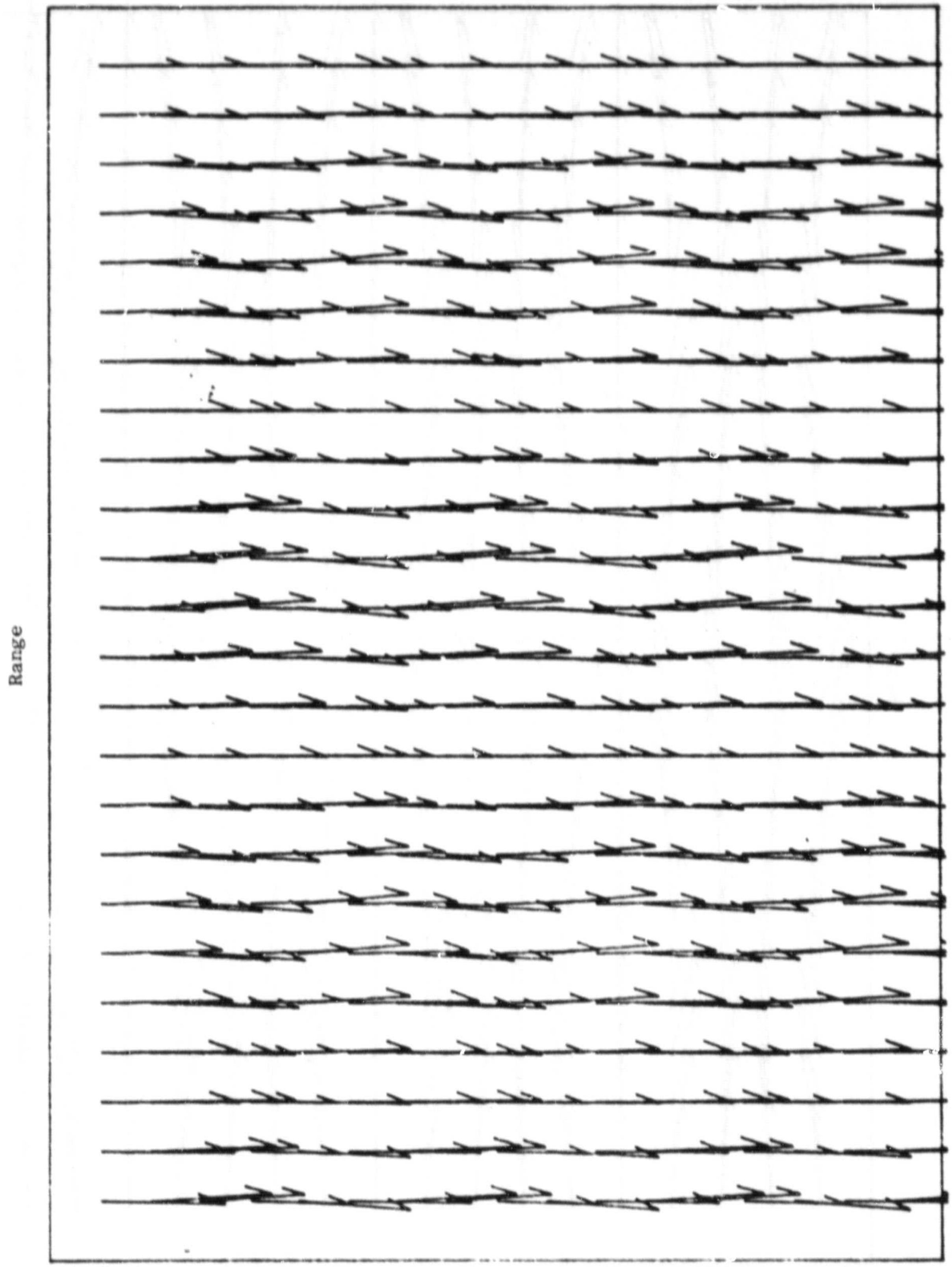

Figure 27: Simulated longitudinal flow

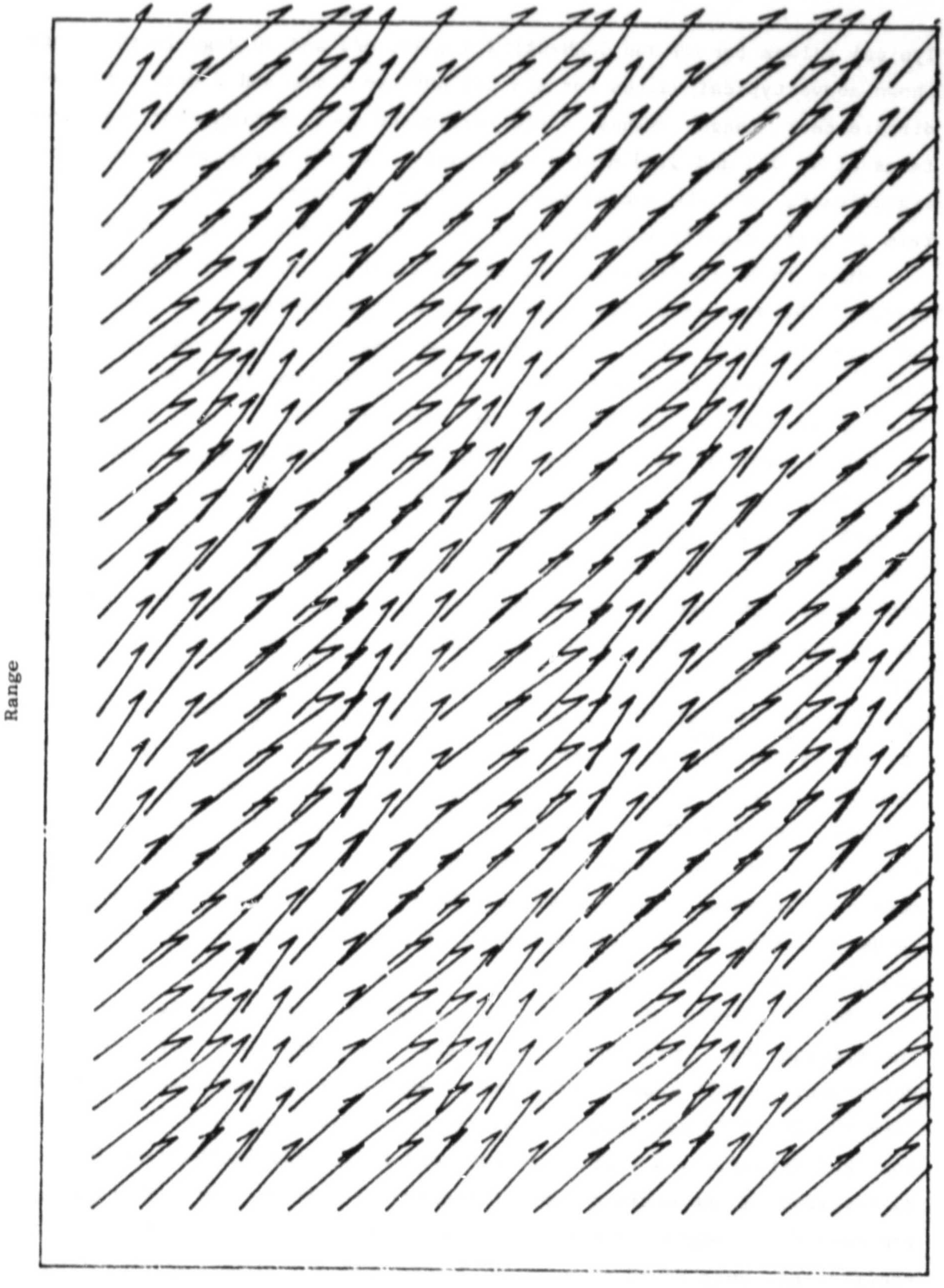

Figure 28: Simulated 45-deg flow

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Typical values for GS and SCAN+DRIFT are 130 m/s and 70 deg. In the plots shown above typical values for EGS and EDR are 1 m/s and 2 deg, for 2-sec differences; these values yield estimated contributions for the three terms of 4, 0.3 and 0.03 m/s, respectively. Clearly the cross term is not significant, and the second term is relatively small. However, the first term is quite significant, and produces errors of the proper magnitude.

With this confirmation of the critical factor a correction of the error can be attempted. Using the 2-lag drift difference as the error, and the geometry just described, the mean radial velocities can be corrected as shown in figure 29. The data is the same as shown in figure 21, but the variance has been reduced substantially.

Before further discussion of correction algorithms an explanation of the source of the drift-angle error is in order. The error arises not because the drift angle is in error, but because the drift angle used for velocity subtraction by the data acquisition system is not the current drift angle. The data gathering process is a complex one, depending upon the computer in the inertial navigation system, the computer in ADDAS (the CV990 data gathering system), and the computer in the lidar system. To take the case of drift angle in particular, it is first calculated by the INS system in what is termed the "slow" loop, updated at 0.9-sec intervals. This data is then output on the BCD bus at 0.9-1.0-sec intervals adding (on the average) an additional 0.48 sec to the delay. When this data is read by the lidar computer at the start of scanner motion it is about 1.38-sec old. By the time the scanner has moved to target position and the midpoint of the data sample has been reached another 0.84 sec has elapsed, for a total delay of 2.22 sec.

This 2.22-sec delay is nearly equal to 2 scan periods (2.2 sec on the average for this data set), and this explains why the 2-lag drift-angle difference correlates so well with the mean radial velocity "error". The 2.22-sec figure is a theoretical one, and must be confirmed for each situation. A routine is included in program FILED1 (see Appendix B) for finding the optimum 4-point transversal filter (or interpolator) for this drift-angle correction. For most of flight 19 the optimum filter coefficients were found to be 0.32, 0.56, 0.12 and -1.0, corresponding to a time lag of 2.42 sec.

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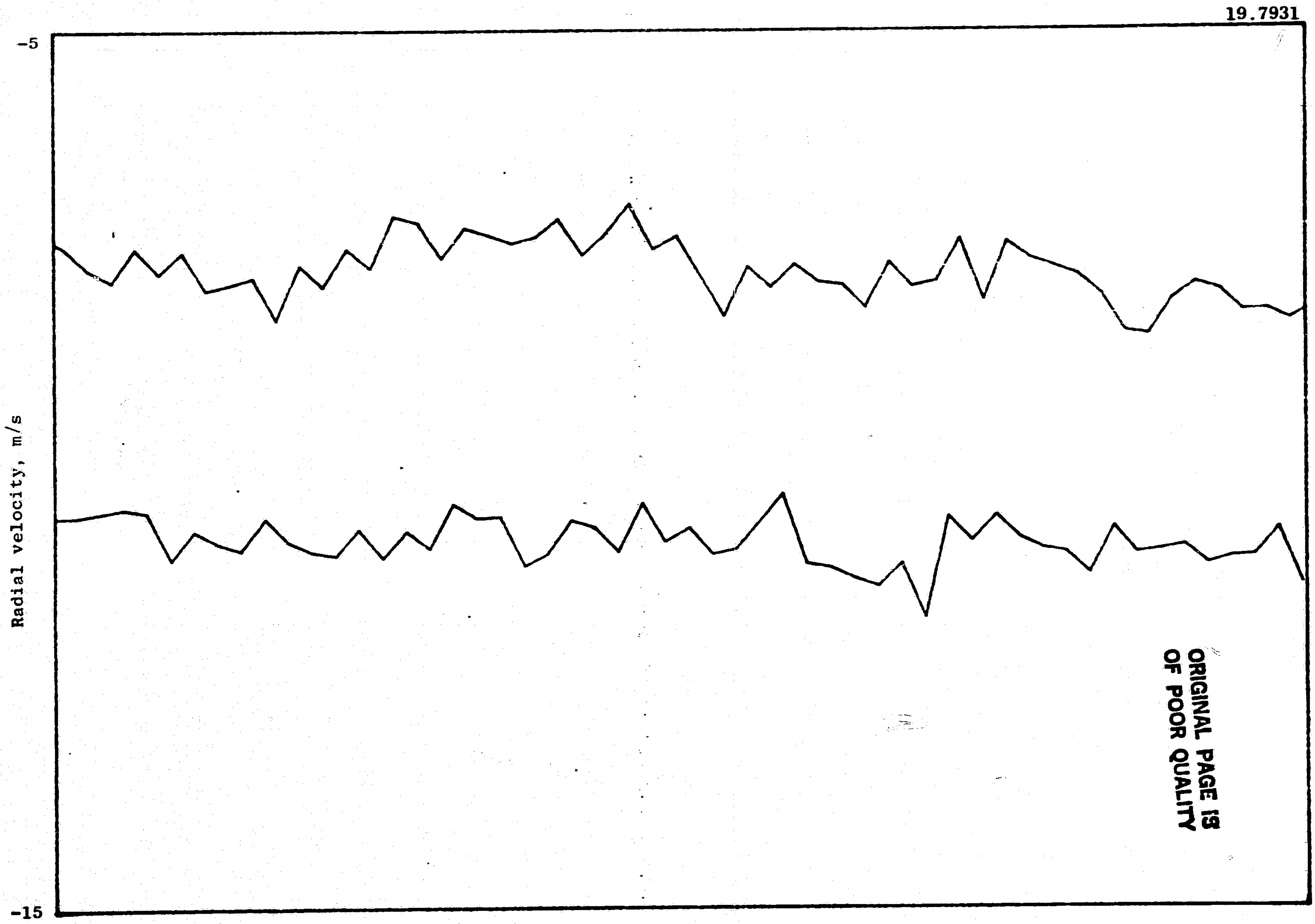

Figure 29: 2-lag corrected mean forward and aft lidar radial velocities

Using this optimal filter the data of figure 21 has been corrected to produce figure 30. The results are reasonably smooth, and definitely superior to the simple 2-lag result of figure 29. The wind field produced by the uncorrected data of figure 21 is shown in figure 31, and the corrected version is shown in figure 32. Considerable improvement is evident.

As an additional example another raw radial velocity data set is shown in figure 33. The velocity excursions are marked and regular, and appear to be due to an oscillation in the aircraft control system. Applying the optimal drift-angle correction to this data set produces figure 34. The comparable raw and corrected flow fields for these examples are shown in figures 35 and 36. The braided structure seen earlier is present in the former figure, but nearly gone in the latter.

As a final example a situation which exaggerates drift-angle effects is shown in figure 37. The aircraft began a slight turn midway through the example, producing artifacts consisting of counter-rotating flows in this uncorrected plot.

While drift-angle delays have been identified as the major contributor to the artifacts evident in the data sets, other effects are present as well, and the algorithm for correction discussed above is not completely satisfactory even for drift-angle correction. These additional considerations are discussed in the next section.

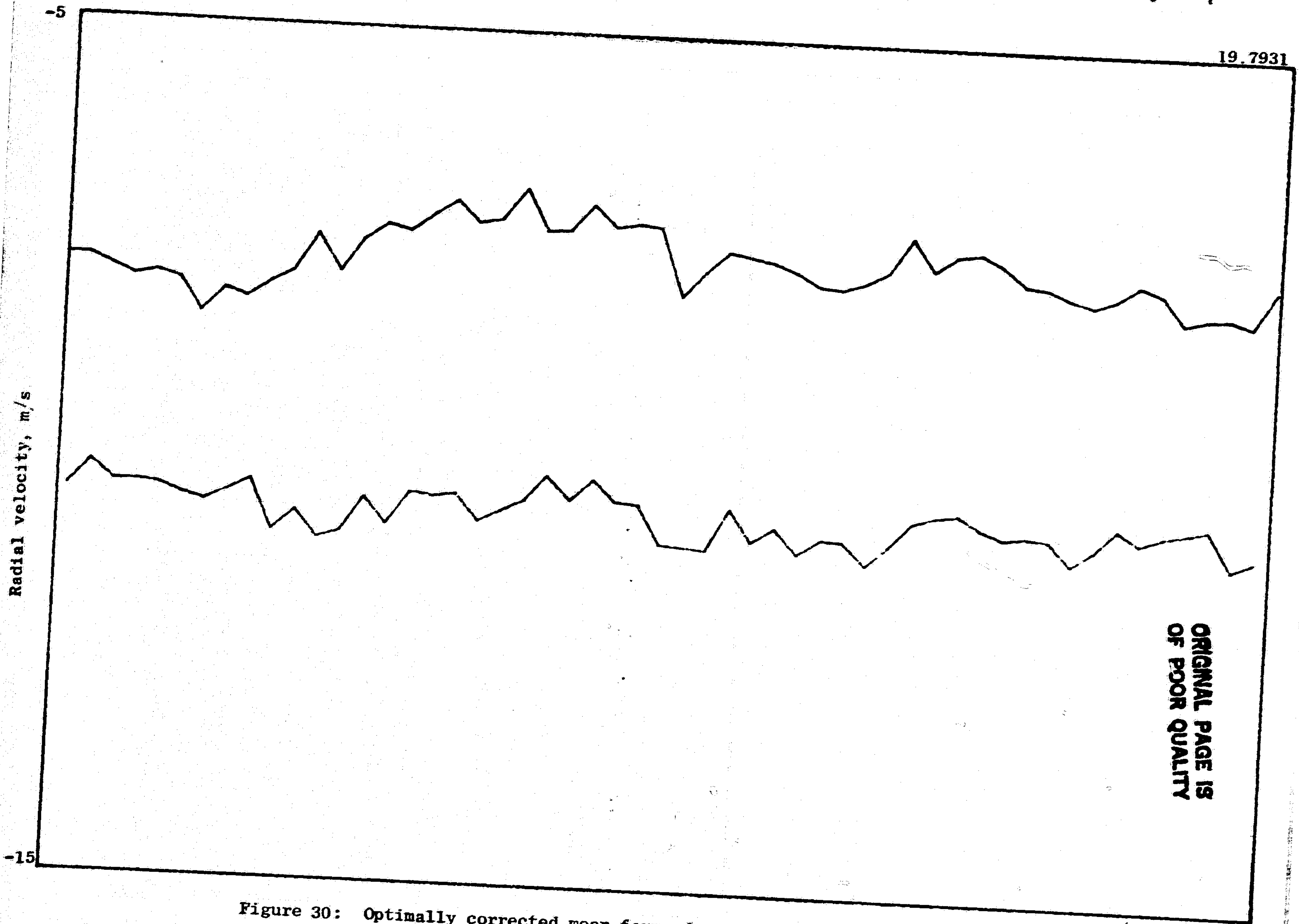

Figure 30: Optimally corrected mean forward and aft lidar radial velocities

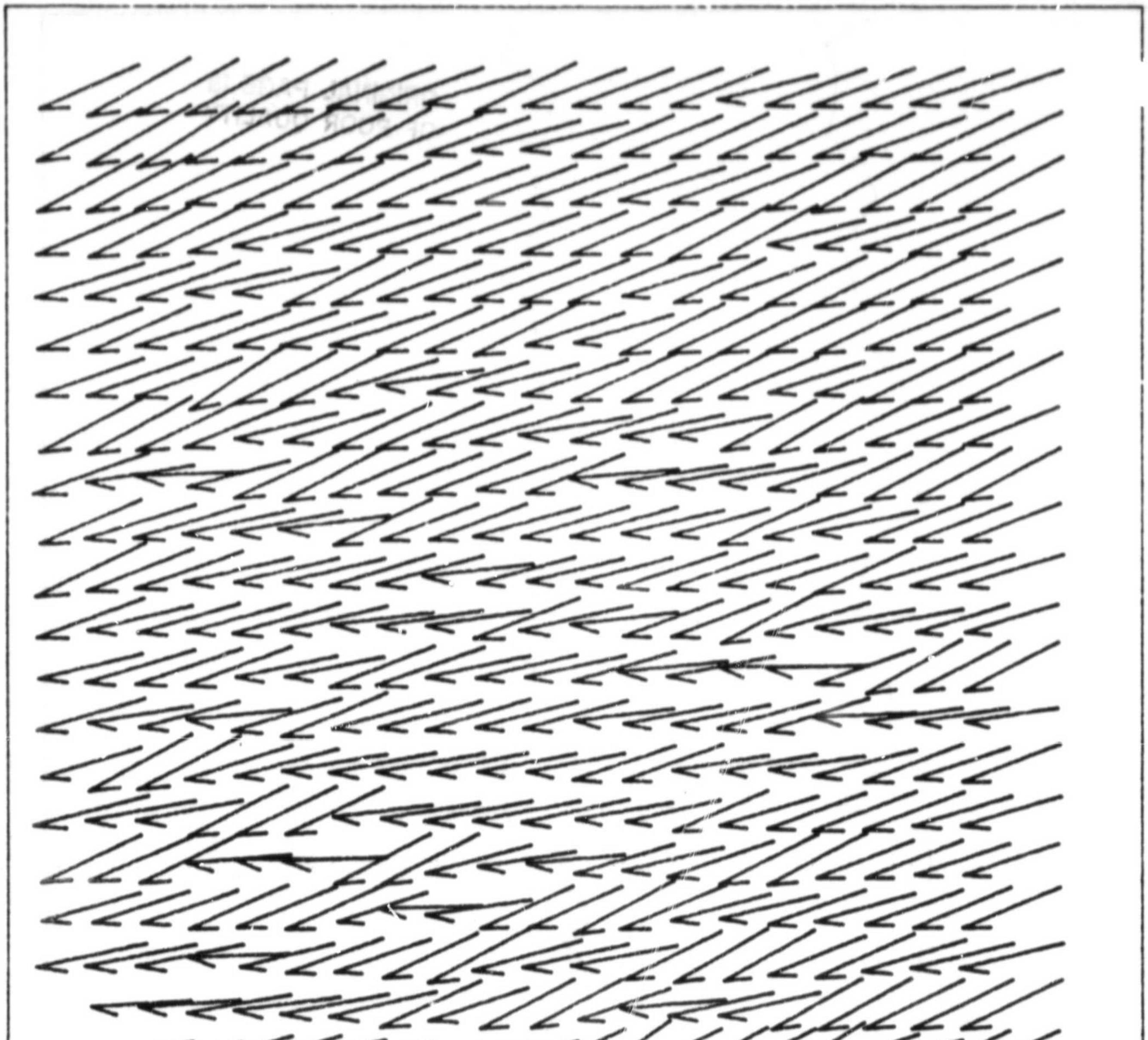

Figure 31: Uncorrected flow field (333-m grid)

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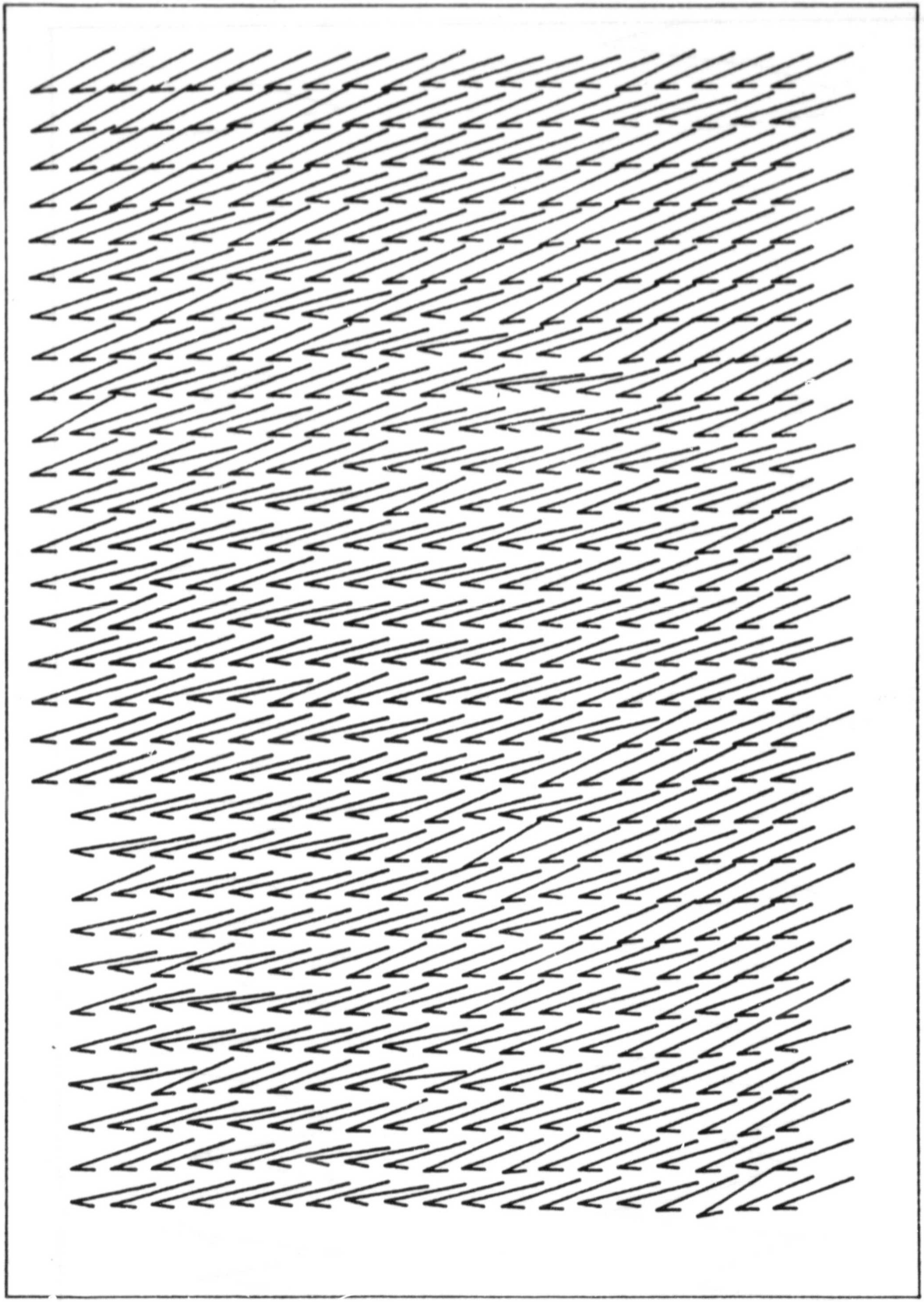

Figure 32: Corrected flow field

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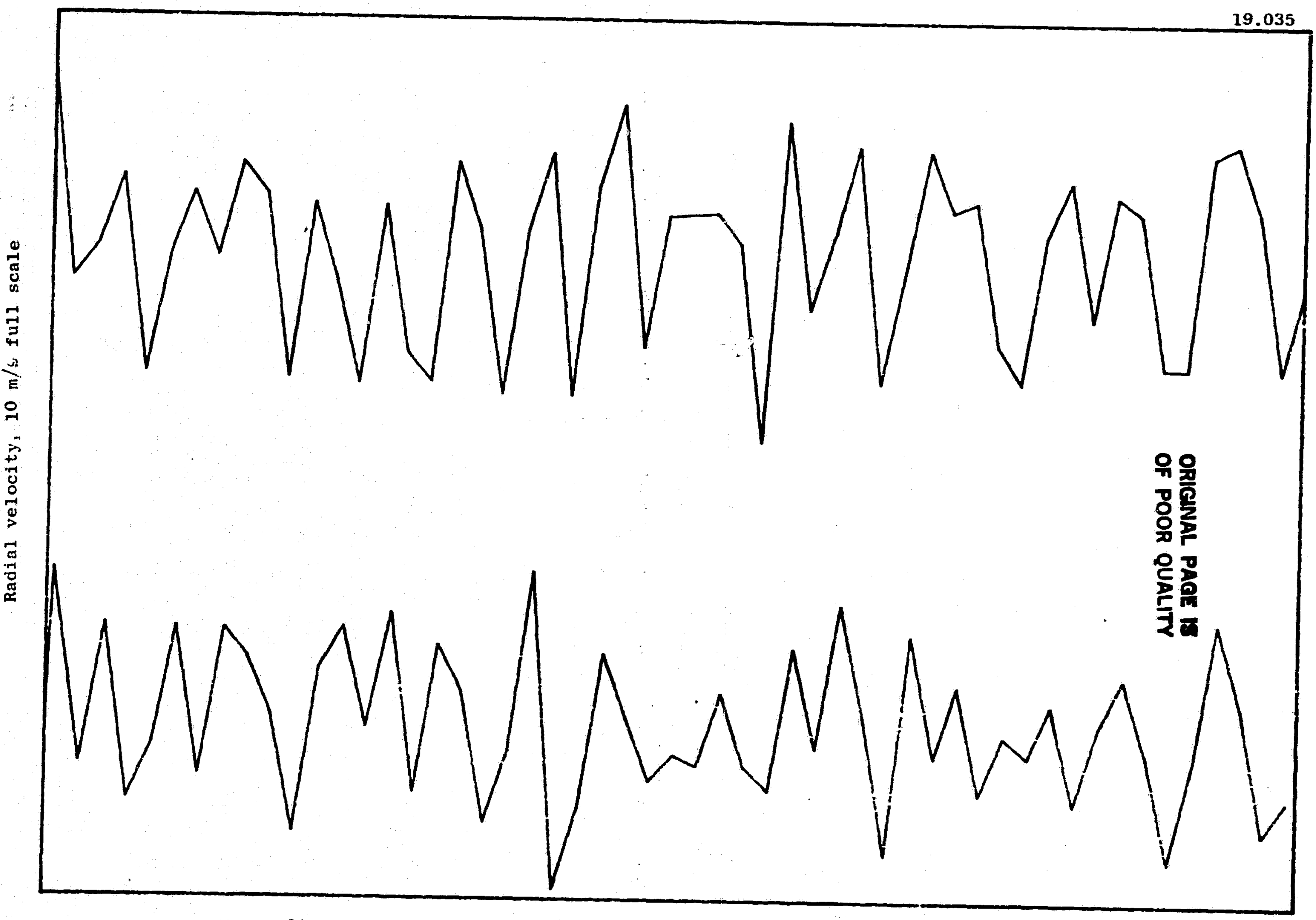

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Figure 33: Uncorrected mean forward and aft lidar radial velocities

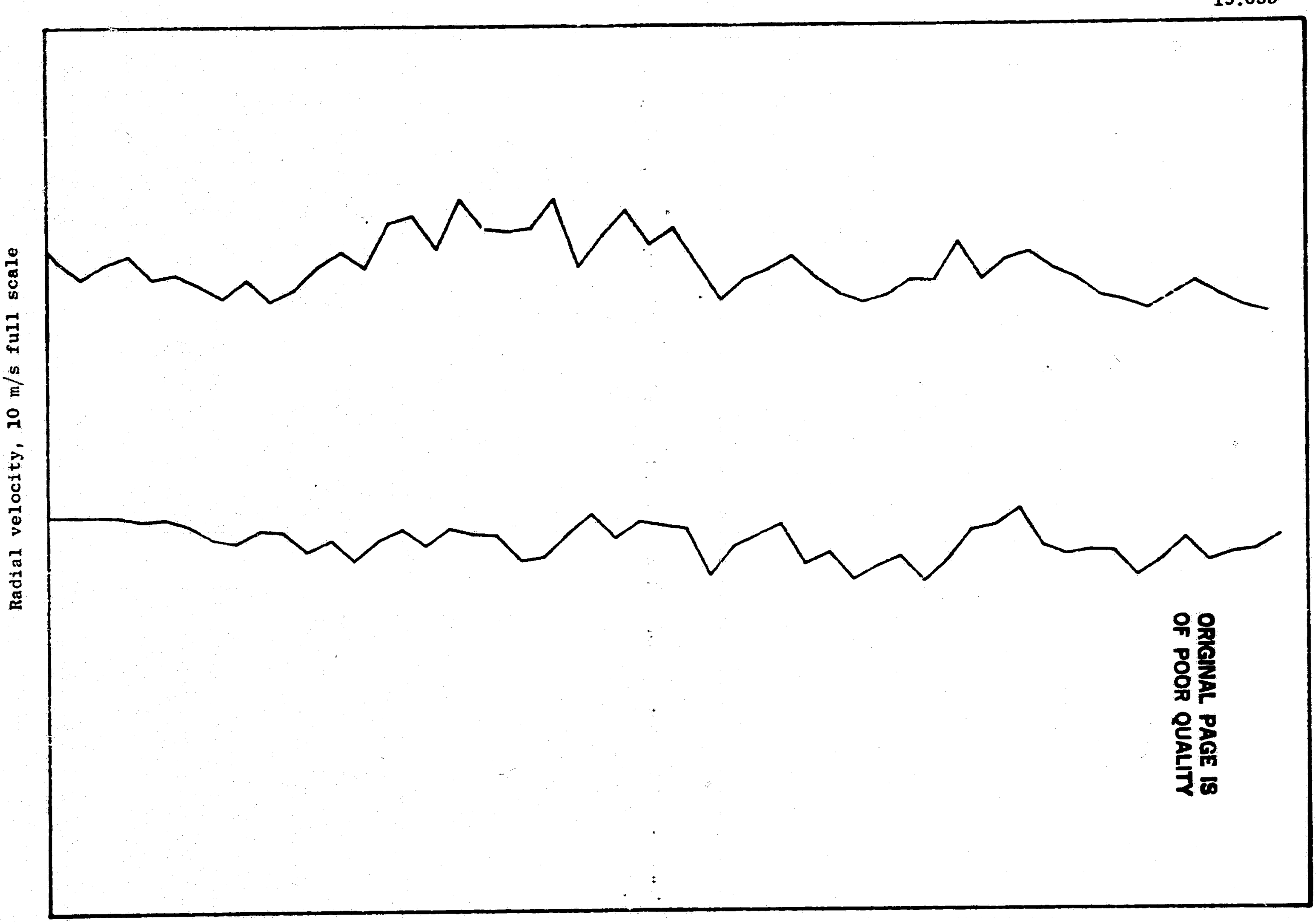
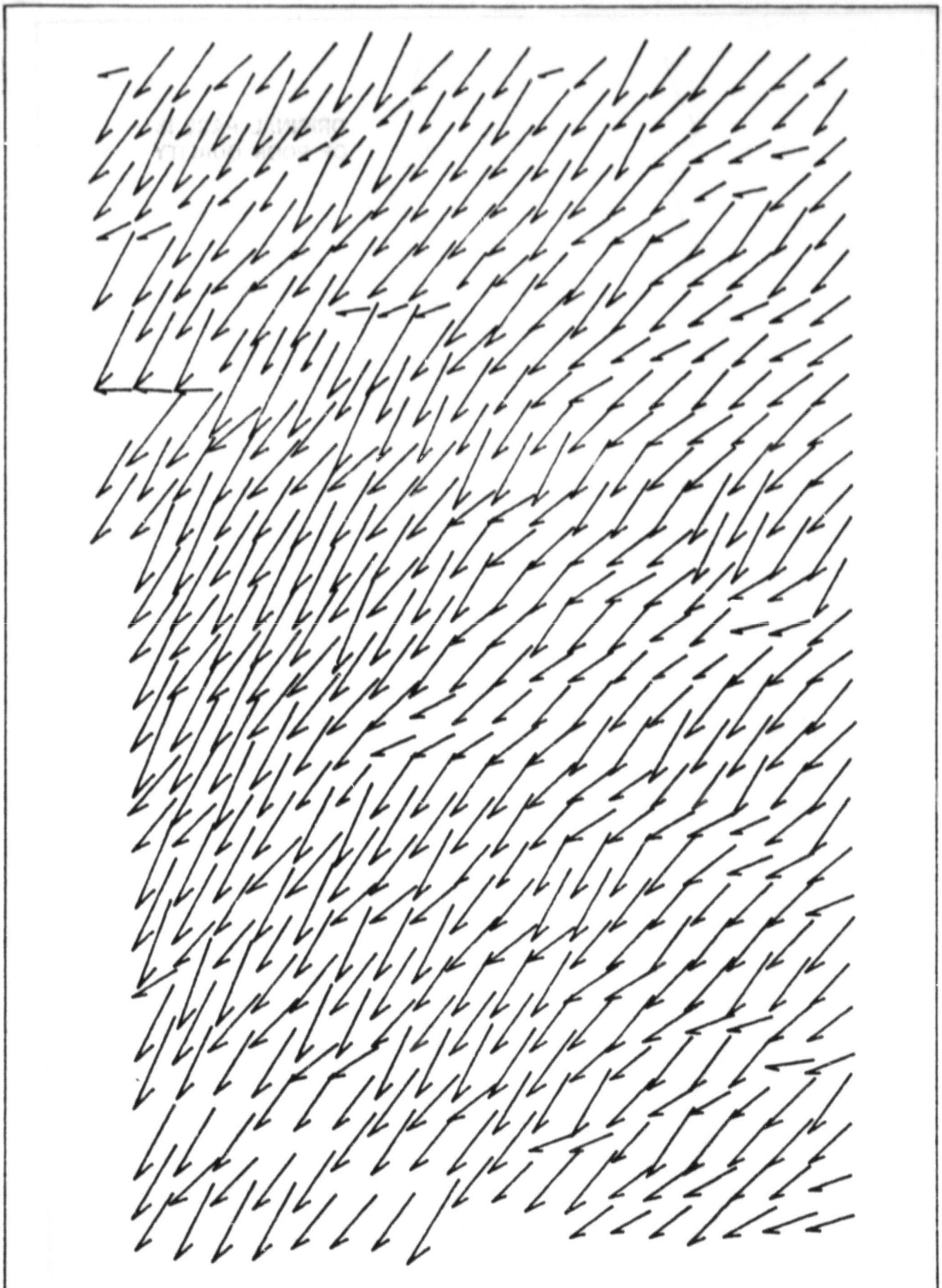


Figure 34: Corrected mean forward and aft lidar radial velocities



Range

Figure 35: Uncorrected flow field (333-m grid)

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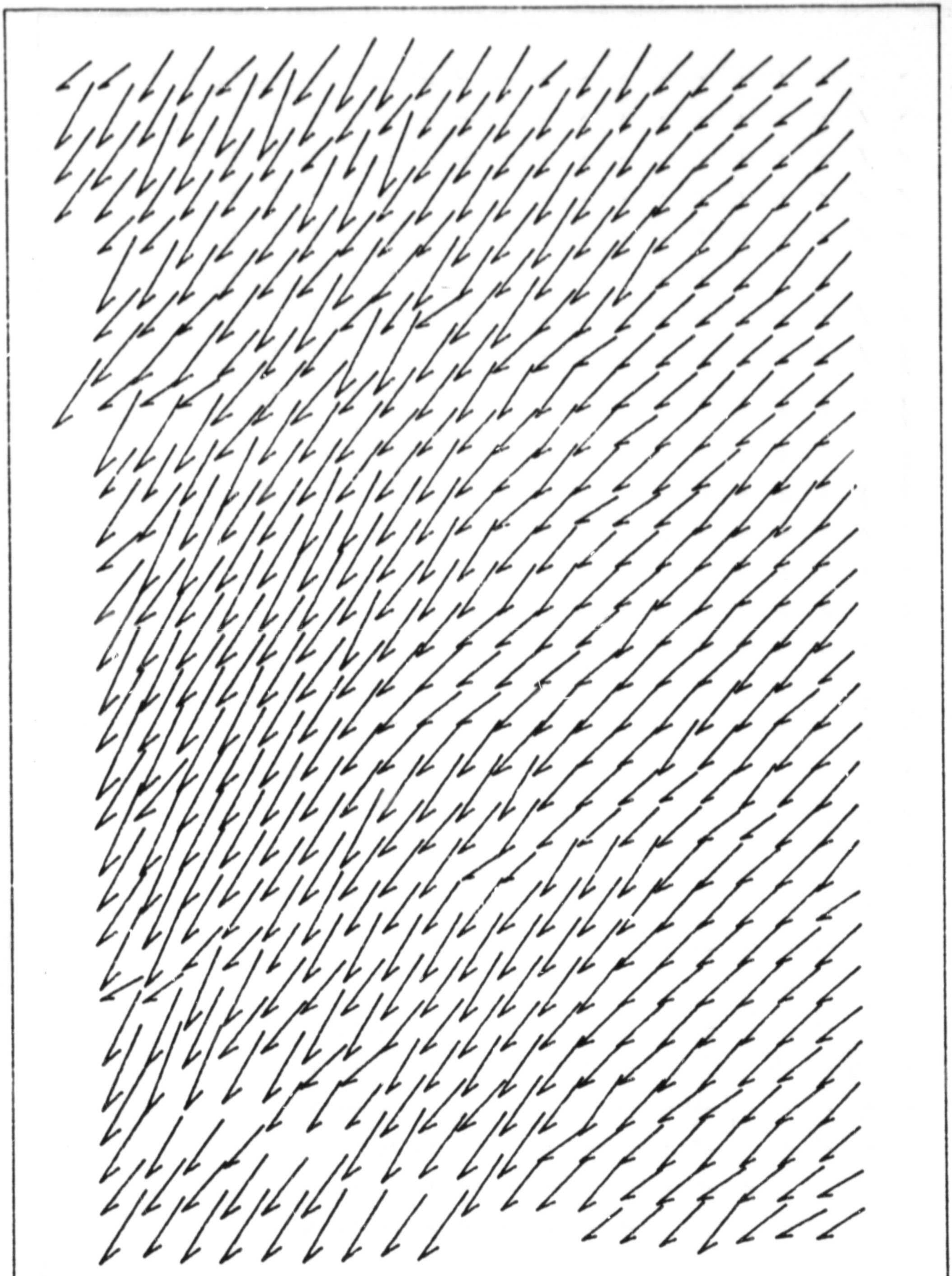

Figure 36: Corrected flow field

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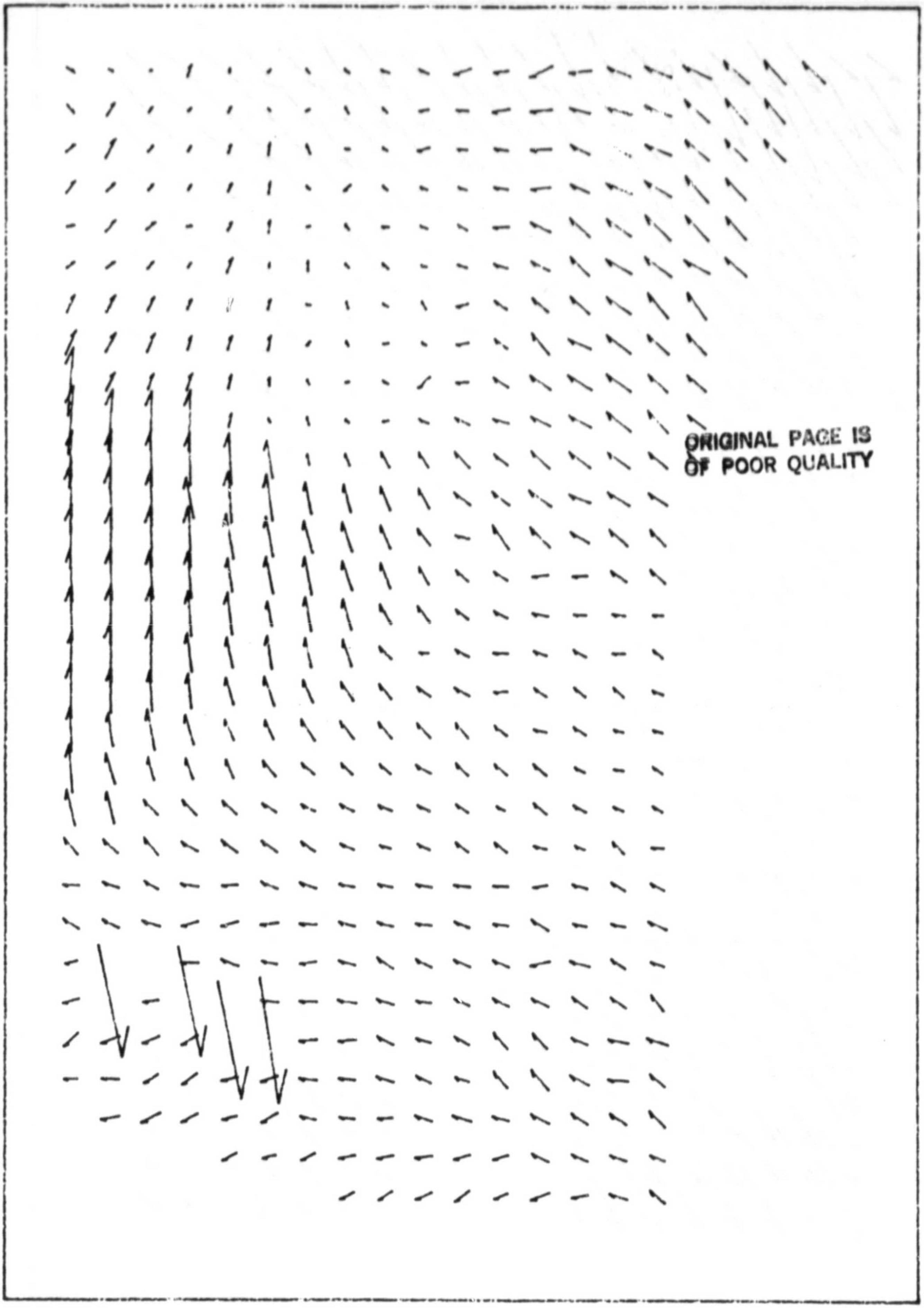

Range

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Figure 37: Flow field with errors due to aircraft turn

V. Other data errors

V.1 Errors due to delays in INS data

As mentioned in Section IV the correction for platform motion is also sensitive to delays in the INS ground-speed estimate. The error from this source is on the order of 0.3 m/s; though smaller than that due to the delay in drift angle it is still significant and should be taken into account.

The scanner control computer also relies upon INS attitude information in calculating the beam-pointing corrections required to compensate for roll and pitch. Errors due to the delayed angular information take the form of horizontal and vertical pointing errors on the order of 1 deg. The horizontal errors are easily corrected by interpolation of the INS estimates of true heading, with slight corrections from roll and pitch interpolations. Correction for the vertical errors is not possible. The magnitude of the errors may be estimated by interpolating the roll and pitch readouts, but the fact that the lidar beam did not travel in a horizontal plane cannot be changed. A 1-deg error in the vertical translates into a 175-m vertical displacement at 10-km range; this distance can be quite significant in the boundary layer. An example of this type of error (not included in the figures) is a case where the aircraft was flying about 100 m above the boundary layer in very smooth air; the measured wind field was very smooth with the exception of a few shots where the lidar beam dipped into the boundary layer. Since shear at the boundary-layer interface was strong the resulting flow field was discontinuous.

The problem of estimating and correcting for these data-delay errors is complicated by the fact that the lidar system does not operate at a constant duty cycle. The time between scans may vary substantially, depending upon the mode chosen by the operator. Thus the data set may contain a series of scans separated by 1.1 sec, with scans requiring over 2 sec interspersed. Correction formulas used thus far have assumed constant scan rates, and more complex algorithms must be developed to allow for the variable scan rate.

V.2 Hardware problems

Reference has been made above to a problem in the lidar system termed "moding". The laser is capable of oscillation in more than one mode, and when it does so the modes mix on the photodetector and create strong monochromatic signals. Such a case is evident in figure 17 as a row of strong, constant vectors. Data in such cases is lost, but it is not difficult to recognize this type of error.

Many of the low-level flights in California were near foothill regions. In several cases lidar returns from terrain were obtained, allowing checking of velocity correction (since ground returns should shown zero velocity). The actual location of the aircraft could be obtained very accurately from pictures taken periodically during the flights by a downward-looking camera. When terrain returns were compared with topographic maps it was discovered that there may be some fixed errors in the vertical elevations of the forward and aft beams. In particular, returns were obtained from the aft beam which indicated a bias of about -0.4 deg in that beam (that is, the beam tended to be below the horizontal). No terrain returns were obtained from the forward beam in situations where terrain was 1.0 deg above the horizontal, indicating a bias of 1.0 deg or more for the forward beam. Terrain returns have also suggested the possibility of a small bias error in lidar range.

Other hardware problems are suspected but less easily seen. There are cases in the data where velocity measurements appear to be accurate near the aircraft but deteriorate with range. Such cases are sometimes due to errors in the vertical pointing of the beam, but it appears possible that some are due to frequency modulation of the local-oscillator laser. This laser is the master-oscillator laser for the transmitter as well; as such, its frequency is by definition correct at the time of the pulse transmission, but if its frequency is not stable this relationship will deteriorate with time (or range). Strong mechanical vibrations associated with flight through turbulent air may excite such frequency drift. The extent to which this error source is significant is not known.

Evident in the data are yet other types of errors whose sources are not known. Fortunately most of these errors are large errors, and the editing software developed previously can effectively reduce their effects.

VI. Windflow examples

This section presents examples of several types of flows observed during the 1981 flight tests. These examples have been corrected to first order for drift-angle and true-heading delays, but they have not been smoothed.

Figure 38 shows a very uniform flow observed above the boundary layer at 9000 ft. The deep boundary layer was just below the aircraft, and it is likely that the discontinuous measurements at the right-center in the figure are due to the lidar beam penetrating the boundary layer. The discontinuous measurements at the left-center of the figure may be due to laser moding, since they persist down to zero range.

Flow in the vicinity of a cumulus cloud is shown in figure 39. The regions in the figure with no measurements represent cloud regions not penetrated by the lidar. The velocity field is measured in the clear air around the cloud, and probably at the outer edge of the cloud itself. In some cases of this type regions at the sides of the cloud are not measured, since either the forward or the aft lidar returns were shadowed by the forward edges of the cloud.

Numerous examples of orographic flow modification are present in data taken in California at low levels. Figure 40 shows south-easterly flow impinging upon the foothills of the Sierra Nevada near Fresno. As the air mass rises against rising terrain the lidar sees flow progressively nearer the ground, where the flow is modified by the local topography. Figures 41 and 42 show flow diverging from the Carquinez Strait into the Sacramento-San Joaquin Delta. In figure 41 the southern portion of the flow exits from the strait at the lower right, forming eddies in the foothills in the upper part of the figure. In figure 42 the northern portion of the flow curls around a mountain forming the terminus of the strait.

Measurements were made in the San Gorgonio Pass region of southern California. At this point strongly divergent flow exits the narrow pass, offering opportunities for the operation of wind turbines. Figure 43 shows this strong flow entering at the lower right; weak confused flows are evident over foothills at the upper left. Figure 44 shows flow somewhat farther beyond the mouth of the pass, where complex patterns

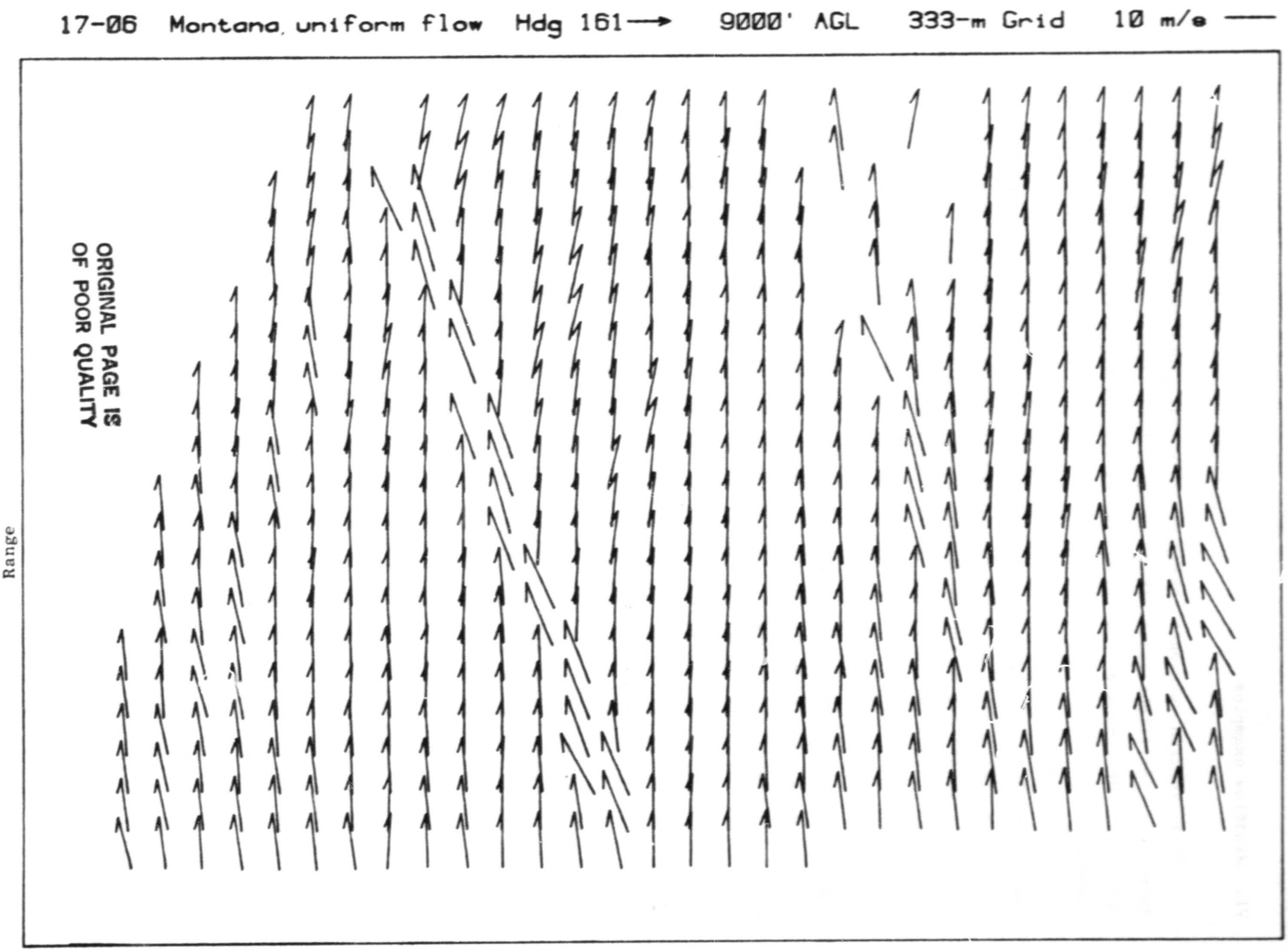


Figure 38: Uniform wind field

15-06 Montana anvil Hdg 183⟶ 12000' AGL 333-m Grid 10 m/s —

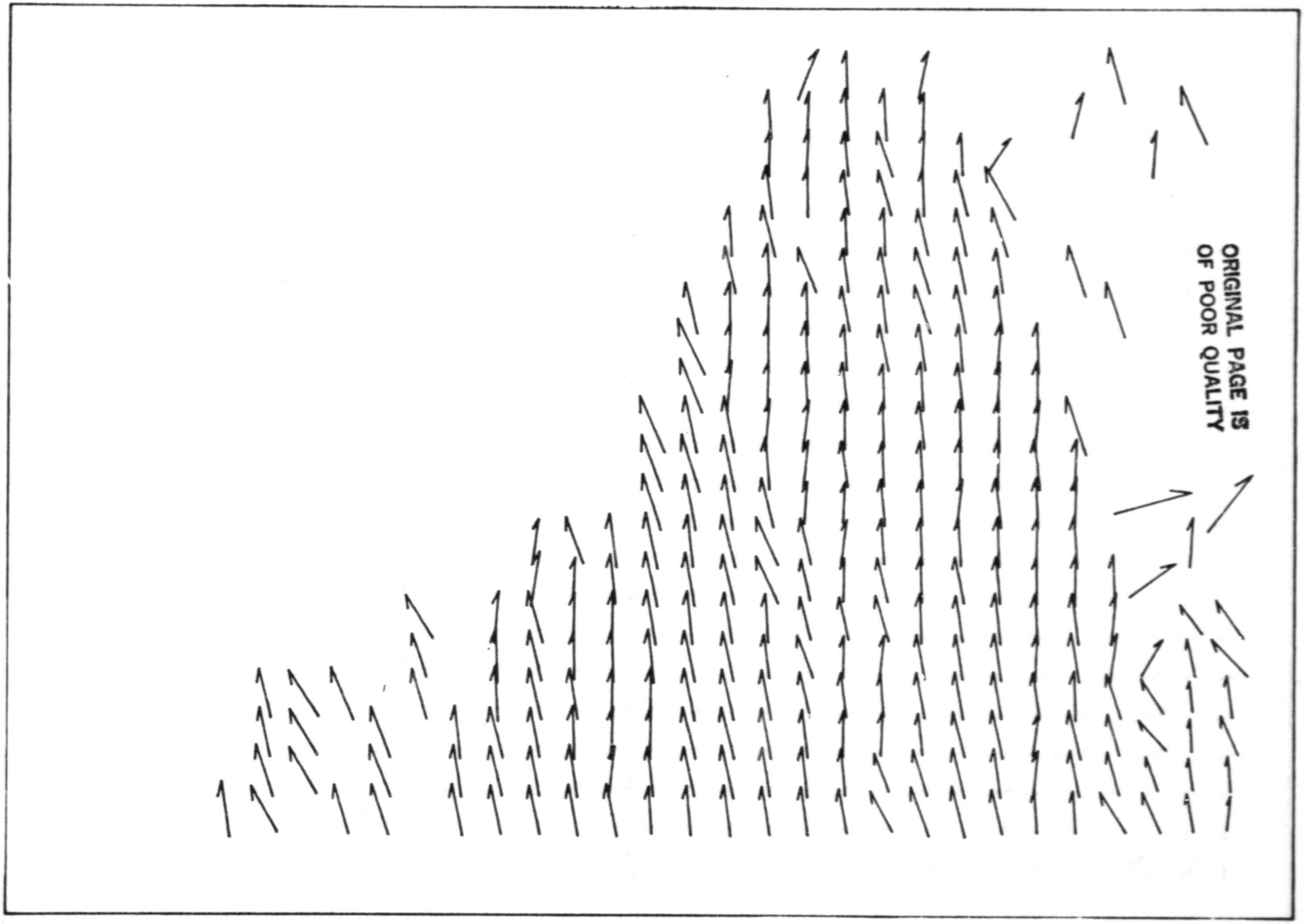
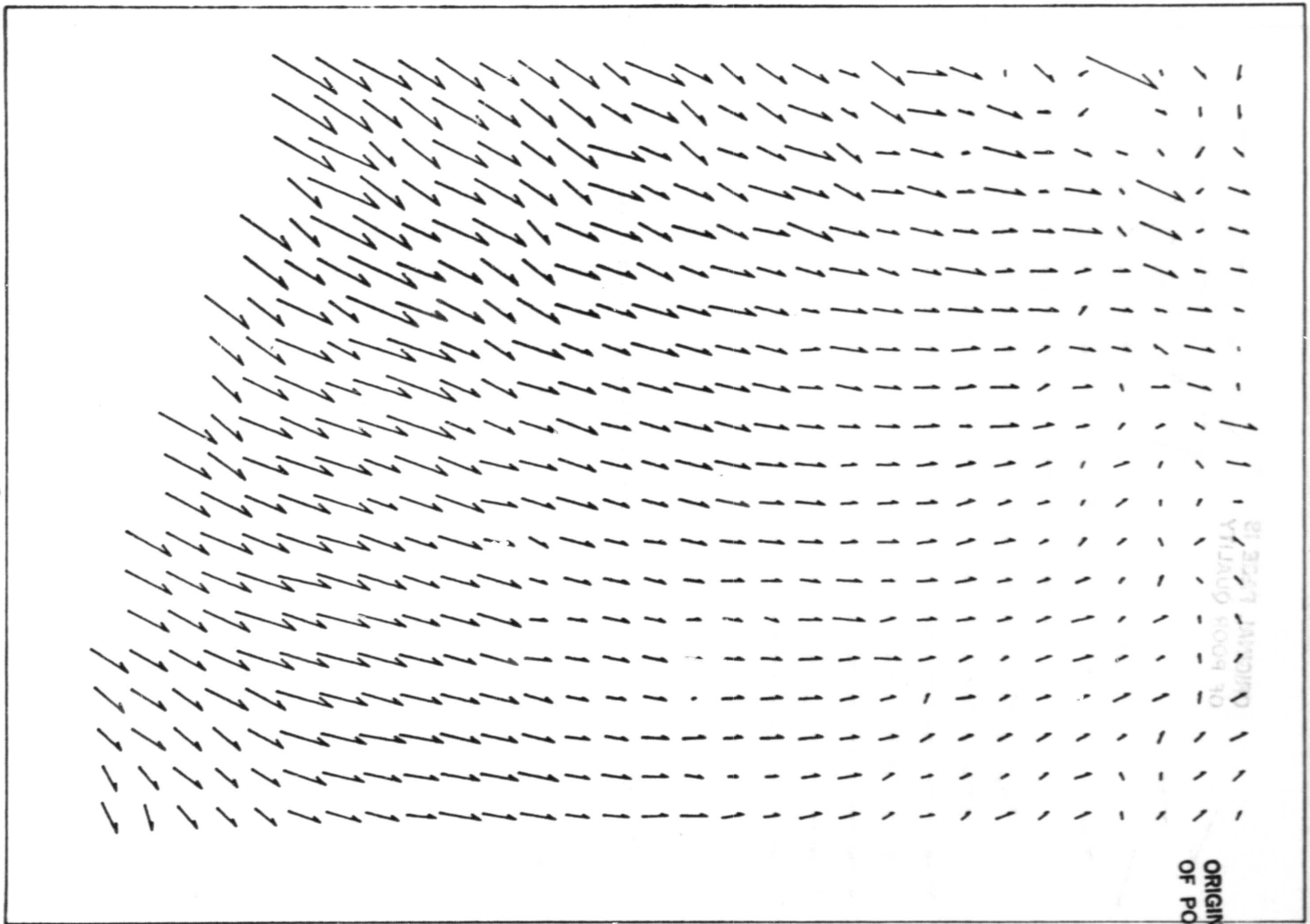


Figure 39: Flow adjacent to cloud turrets

19-03 Fresno Ca Hdg 132⟶ 1600' AGL 333-m Grid 10 m/s ——



Range

Figure 40: Valley flow near Sierra Nevada

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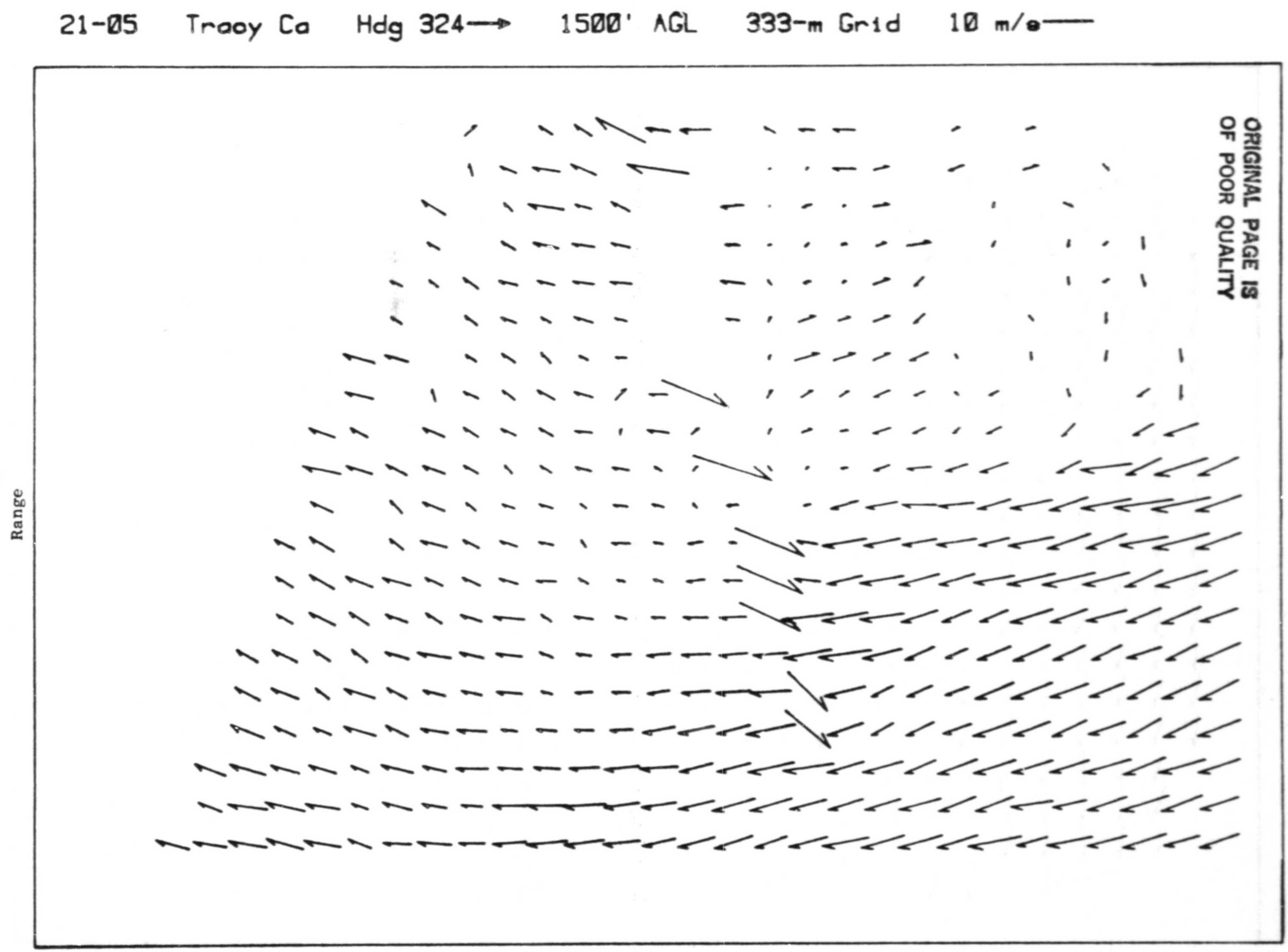

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Figure 41: Southerly flow from Carquinez Strait

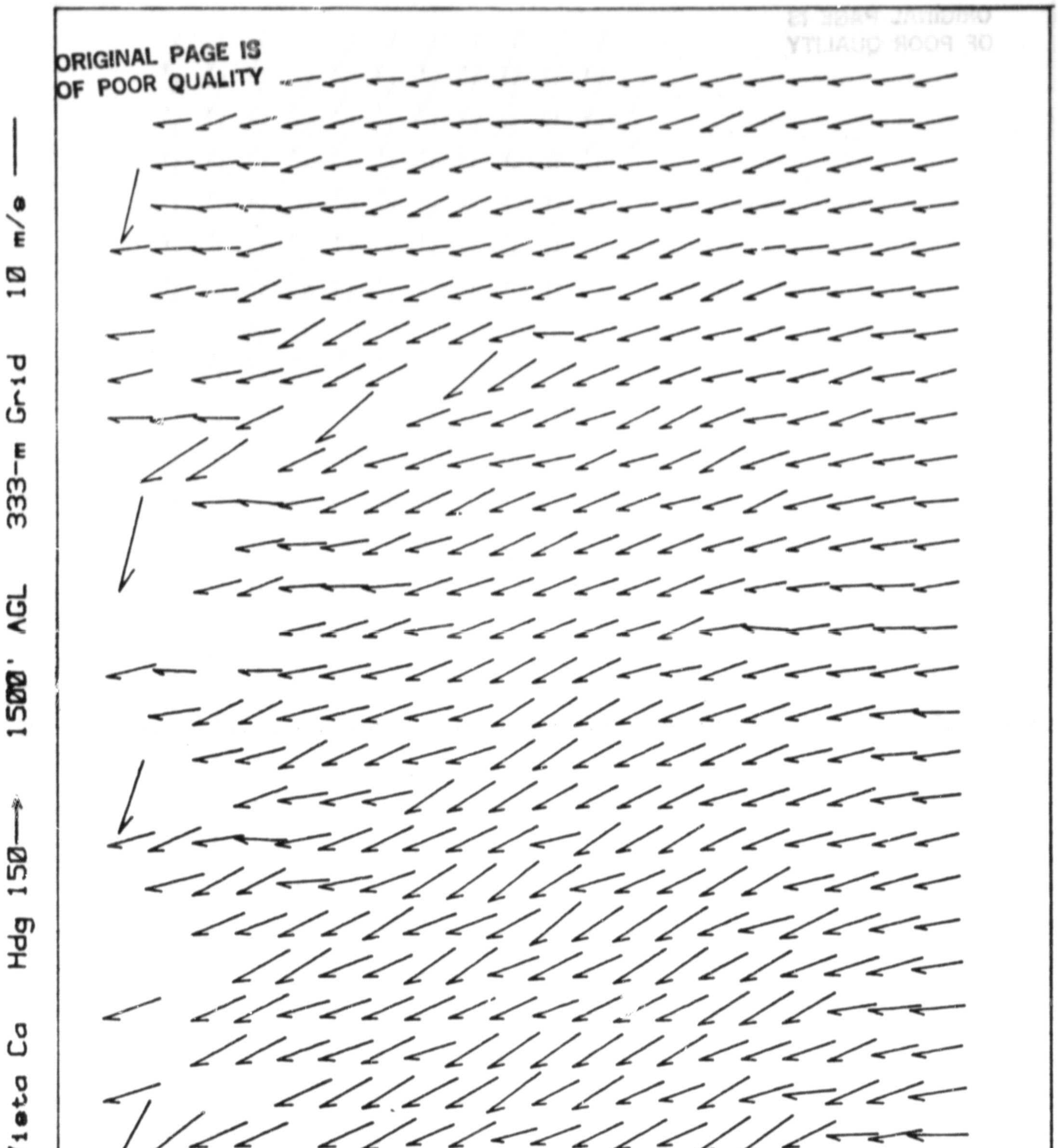

Figure 42: Northerly flow from Carquinez Strait

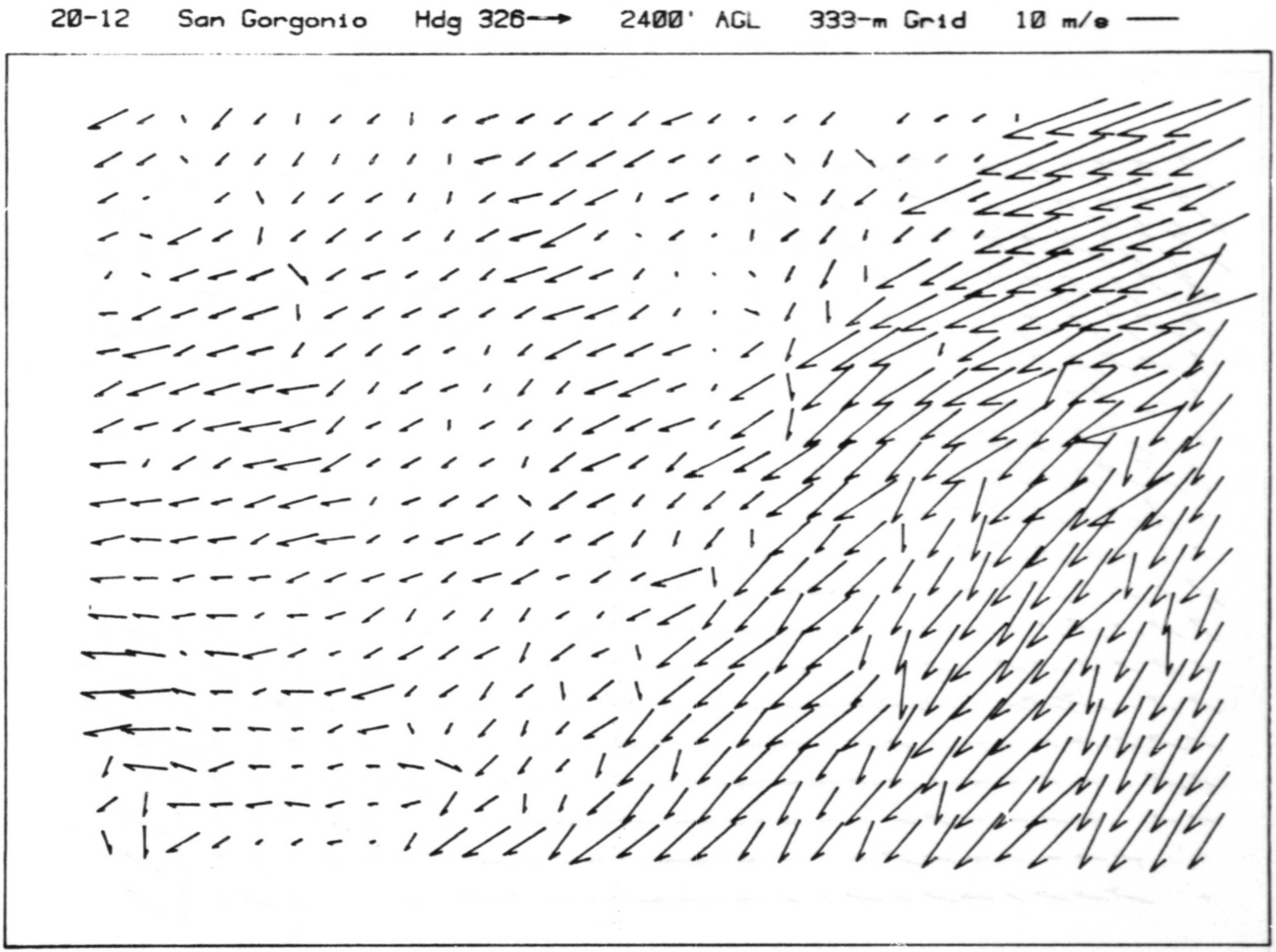

Figure 43: Exit flow from San Gorgonio Pass

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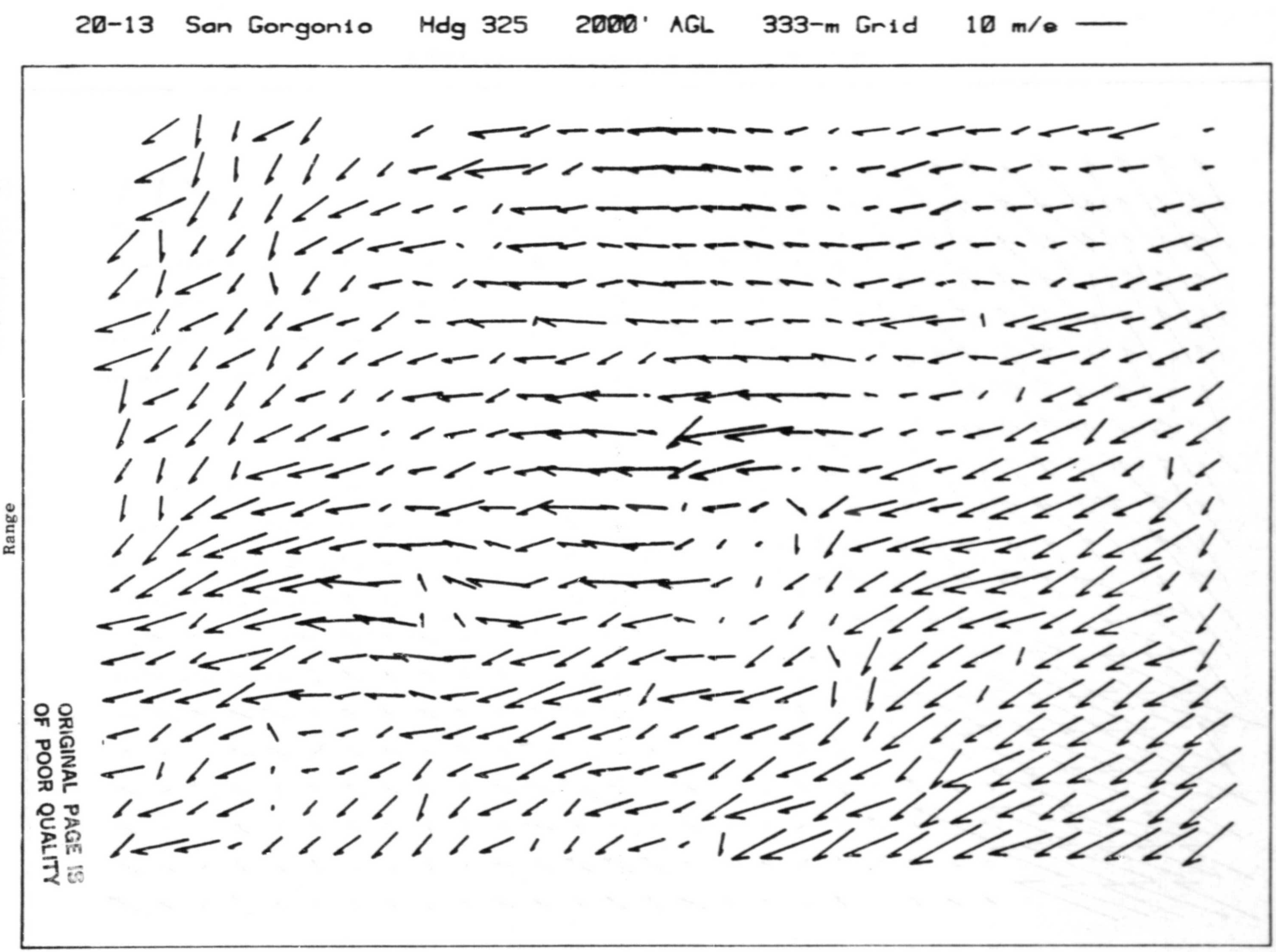

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Figure 44: Exit flow from San Gorgonio Pass

result from flow over terrain features (including a small hill at lower center).

Some of the most spectacular flows observed were at low levels beneath convective storms. Figure 45 shows at first sight an uninteresting flow field. The two disturbed areas are quite significant, however: they represent the horizontal signatures of areas of convection or outflow. A more dramatic example is shown in figure 46. A relatively uniform low-level flow is perturbed by an outflow descending from a convective structure at the upper left. The structure itself is not seen, as the lidar returns are apparently attenuated by cloud in that area.

Still stronger outflow - a true gust front - is shown in figure 47. The flow seen at the lower left is typical of a large area now shown in the figure, and may be taken as the unperturbed low-level flow. The strong flow crossing most of the figure is outflow from a convective structure of considerable size beyond the top of the figure. Similar merging of outflows with the low-level flow is shown in figures 48 and 49. Finally, in figure 50 a dramatic interaction between the outflow at the top of the figure and the low-level flow is apparent.

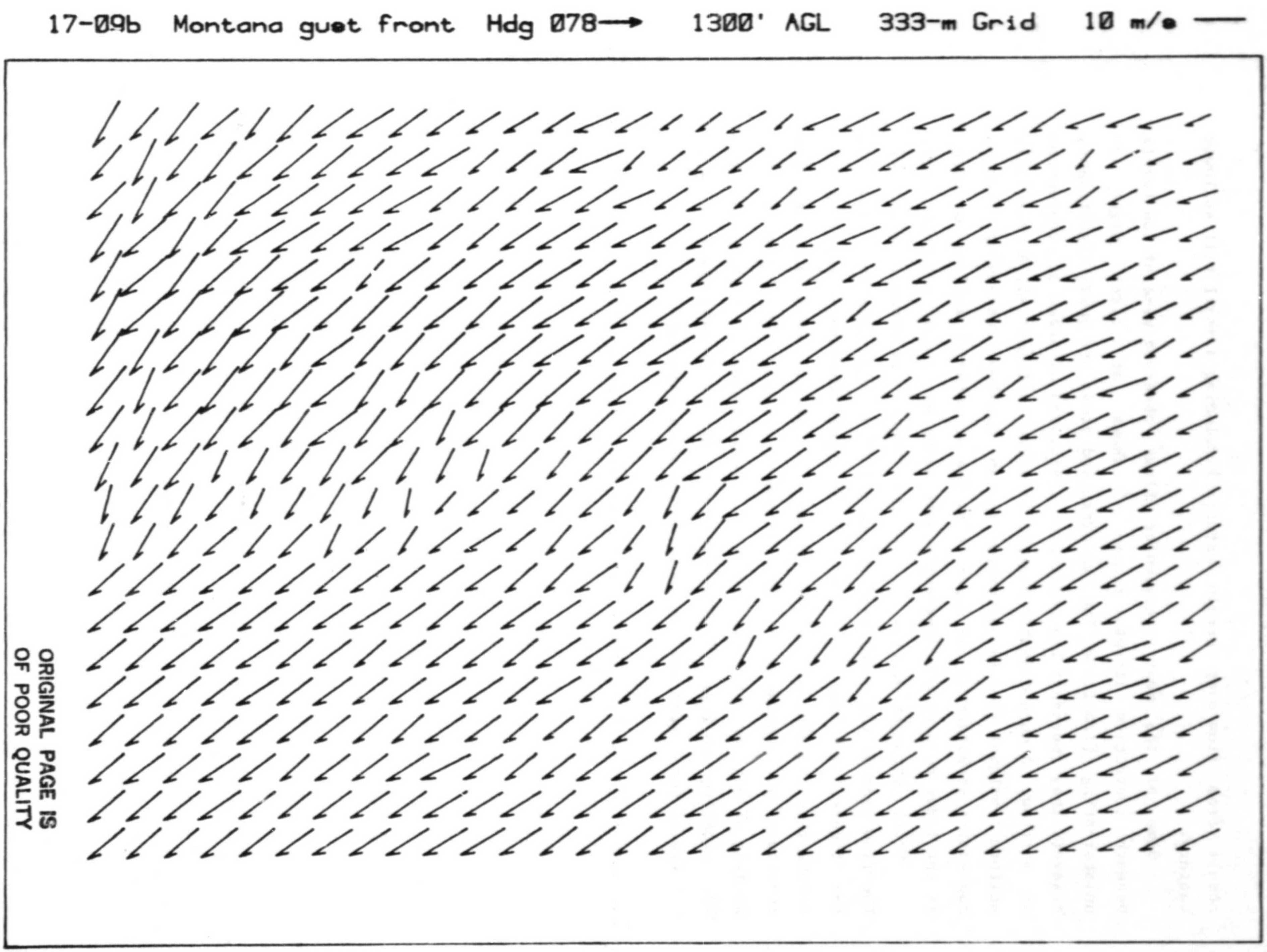

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Figure 45: Uniform flow with weak convection

17-Ø4 Montana gust front Hdg Ø84⟶ 1ØØØ' AGL 333-m Grid 1Ø m/s —

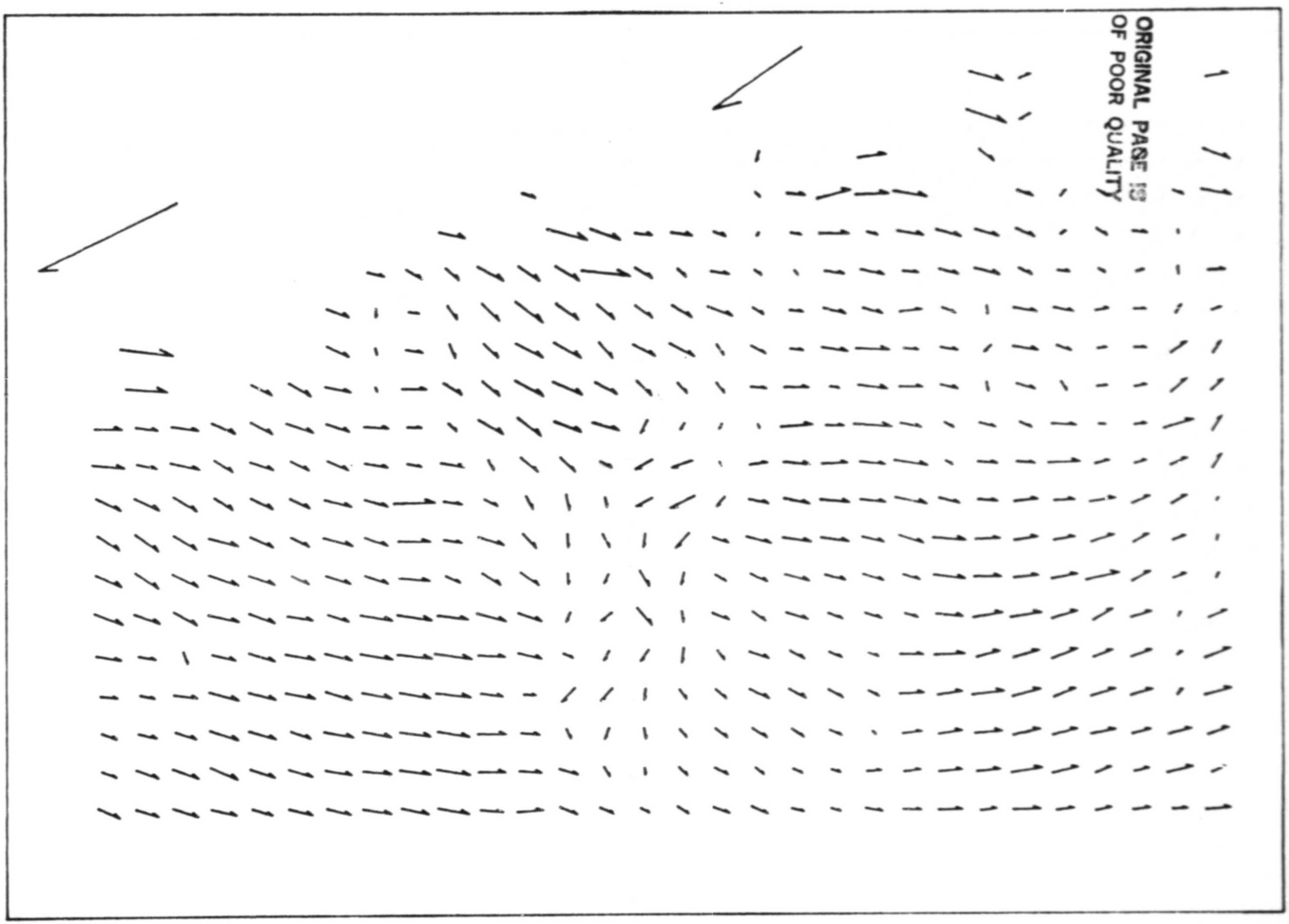

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Figure 46: Small gust front entering uniform flow

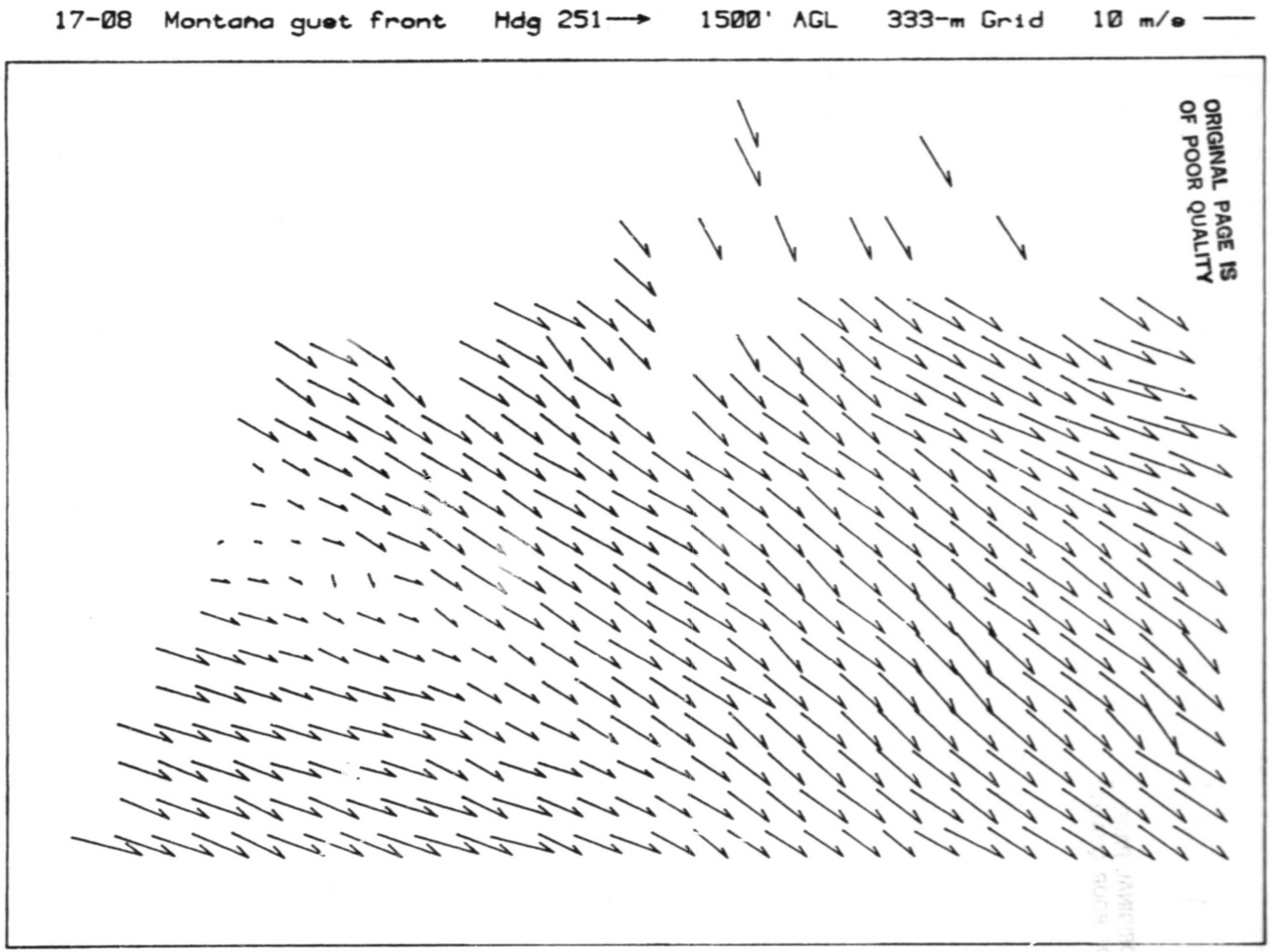

Figure 47: Gust-front interaction

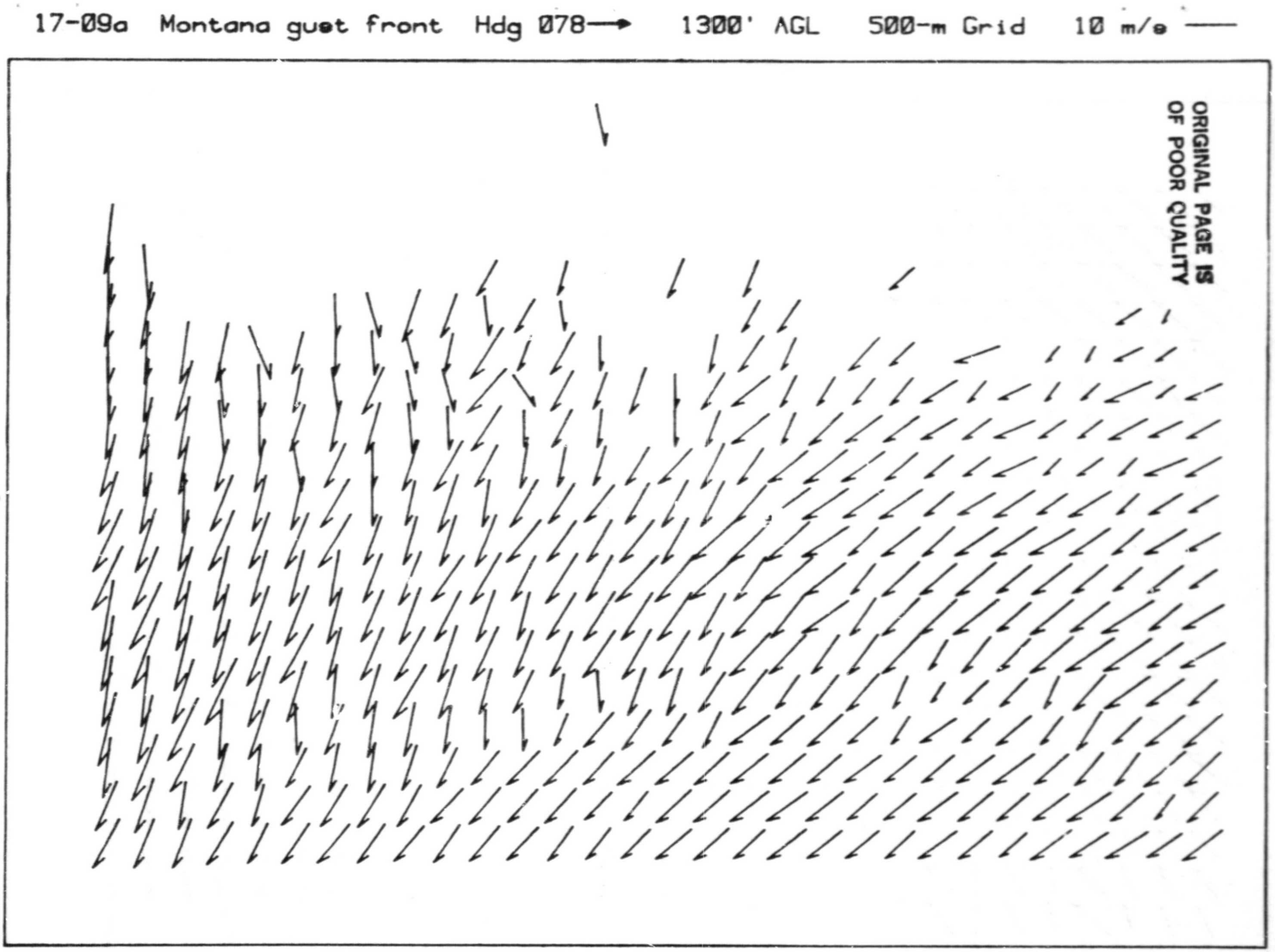

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Figure 48: Gust-front interaction

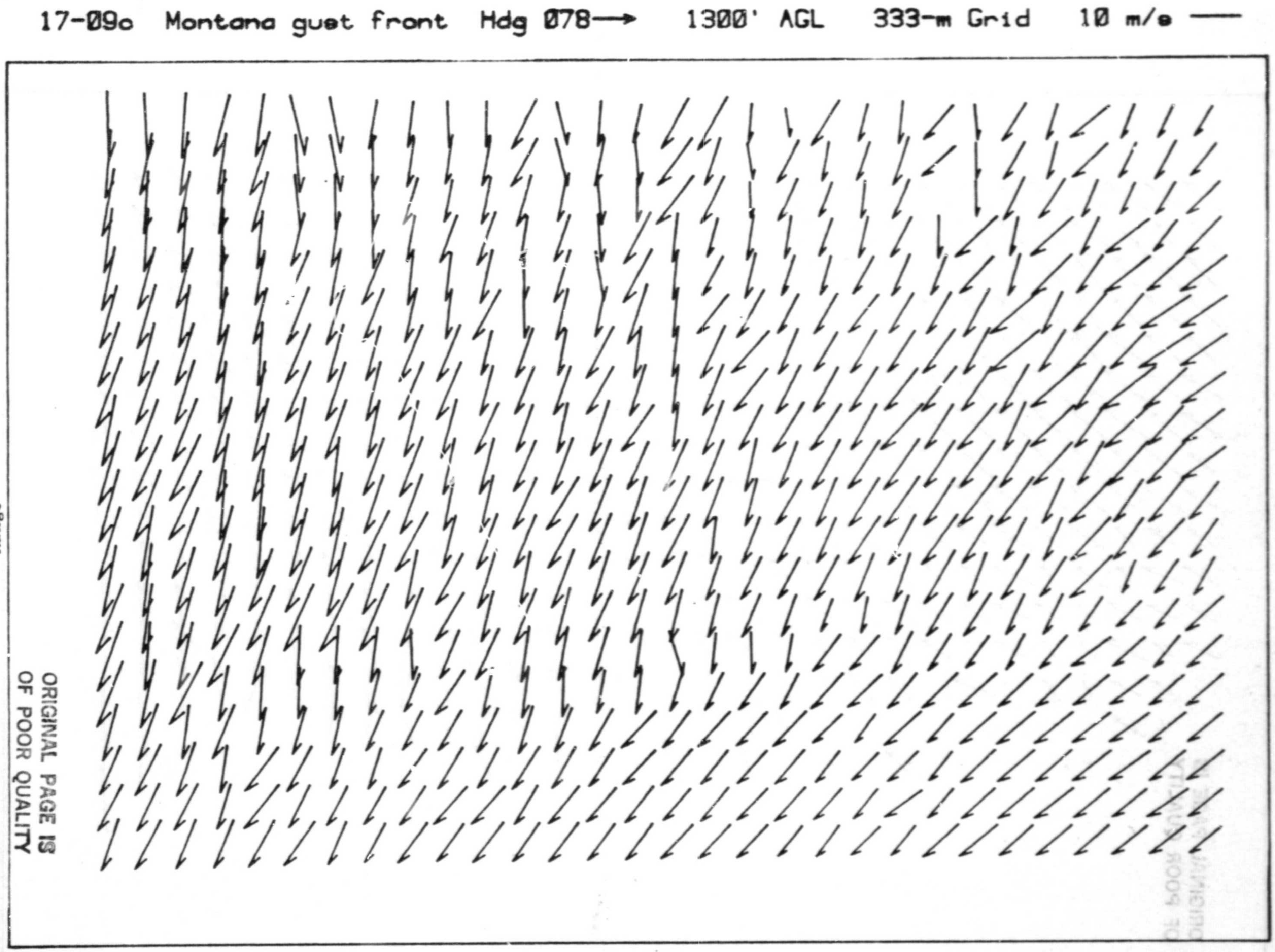

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Figure 49: Gust-front interaction

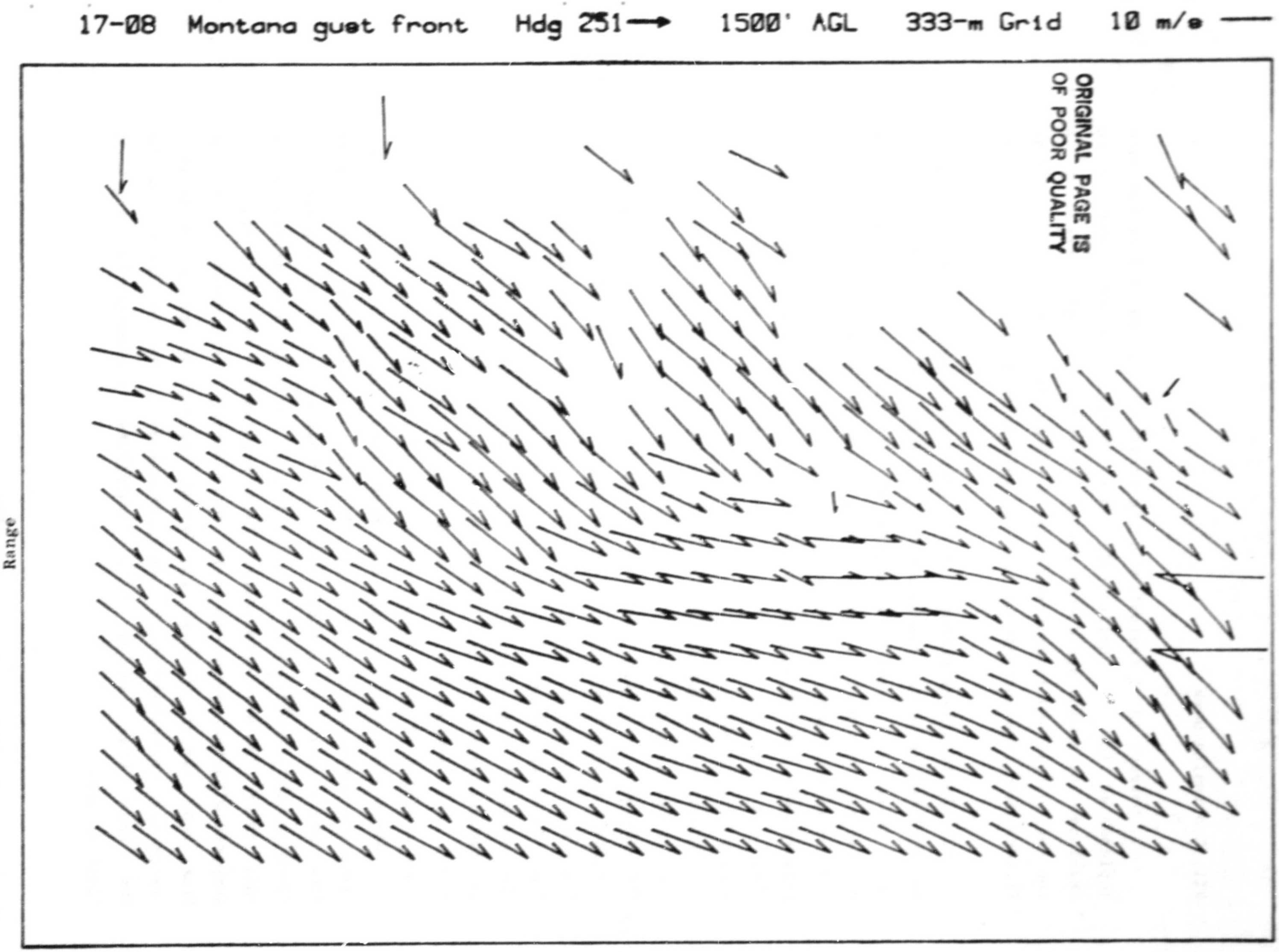

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Figure 50: Gust-front interaction

VII. Continuing work

1. Correction of navigation-delay errors. An optimal filter has been implemented for the drift-angle case. Similar filters need to be developed for ground-speed correction, line-of-sight angle correction in the horizontal, and line-of-sight angle estimation in the vertical. These filters must take into account the variable spacing of the scans in time.

2. Continuity-argument filter. After all known sources of error in the mean radial velocity measurements have been estimated and corrected for, there will remain a degree of uncertainty in the mean radial velocities. This will be due to errors in the INS estimates of attitude and velocity, and to the random nature of the delay between INS measurements and INS outputs. These errors are inherently unknowable, but they can for the most part be corrected by an argument involving windfield continuity.

Consider a time-series of mean radial-velocity measurements. Each item in the time series is an average over (for example) 10-km of range. The variance of each item will be due to that portion of the velocity fluctuation spectrum which is not averaged out by the 10-km integration. That is, the major part of the variance of the true time series will be due to spatial variations in the wind field on the order of several km. The observed time series will contain additional variance due to the unknown measurement errors just mentioned. Note that these measurement errors are independent from scan to scan. That is, this variance will cause addition of white noise to the true time series.

Since the variance of the true time series is due to very low frequency components (of long spatial scale), the true time series will fluctuate slowly and smoothly. This can be easily seen by noting that the 10-km velocity integrations from one scan to the next are separated by only about 300-m horizontally. This separation is quite small when compared with the several-km scales contributing to the variance of the true time series. Clearly the added variance due to the independent errors will contribute short-term fluctuations to the time series, while the true time series will contribute predominantly long-term fluctuations.

The solution to eliminating the error-contribution to the time series is obviously filtering. A low-pass filter will remove most of the contribution of the white errors, leaving most of the contribution of the true means. Note that this argument relies to a certain extent upon isotropy of the horizontal flow field, but only on scales smaller than 1 km. The most damage such an assumption could do to derived wind fields would be a reduction in the magnitude of 1-km and smaller flow features, and then the reduction would be suffered in only one dimension.

The errors of this approach can easily be evaluated with sample wind fields. It holds promise of reducing velocity errors to very low levels, a requirement for processing boundary-layer fields for convective studies.

3. Terrain returns. A careful examination of terrain returns will allow an independent check upon platform-velocity correction, since terrain would be expected to have zero velocity. Initial checks have shown terrain velocities on the order of 0-0.3 m/s. Terrain returns also have the potential for calibrating the lidar scanner both in elevation and azimuth.

4. Anomalous errors. Unexplained errors remain in the data sets. These errors probably are due to hardware problems such as local-oscillator drift. These errors may be correlated with aircraft accelerometer data. Whatever the cause investigation is warranted.

Appendix A: Magnetic tape format

The following is a description of the format of the raw data tapes. Comments on decoding the header parameters are included. The tape records contain 352 16-bit words, written in DEC format.

Word	Name	LSB	Comments
01	X	20 m	East distance
02	Y	20 m	North distance
03	LOSD	0.1 deg	Add 180 deg
04	STATUS	Coded	See Integraph 81-029
05	PULSE WIDTH	Coded	See Integraph 81-029
06	PS	Coded	Processor status
07-11	SPARES	NA	NA
12-299	DATA	-	See text
300	NFL	1	Flight number
301	IDAY	1	Day number - Julian
302	NRUN	1	Run number
303	TSEC	0.1 sec	Seconds 0-59.9
304	TMIN	1 min	Minutes past midnight Z
305	PALT	16.48 ft	Pressure altitude
306	PALT	?	Not significant
307	RALT	2 ft	Radar altitude
308	DFP	0.1 deg C	Dew/frost point
309	SATM	0.1 deg C	Static air temperature
310	IR-SUR	0.1 deg C	IR surface temperature
311	TAT	0.1 deg C	Total air temperature
312	LAT	0.1 min	Latitude
313	LAT	1 deg	Latitude
314	LON	0.1 min	Longitude
315	LON	1 deg	Longitude
316	TH	0.04395 deg	True heading
317	TAS	0.5144 m/s	True air speed
318	GS	0.0628 m/s	Ground speed actually used
319	DA	0.04395 deg	Drift angle

320	WS	0.05144 m/s	INS wind magnitude
321	WD	0.1 deg	INS wind direction
322	P	0.04395 deg	Pitch
323	R	0.04395 deg	Roll
324	THETA1	0.1 deg	Inner wedge positon
325	THETA2	0.1 deg	Outer wedge position
326	TTP	10 ms	Wedge time to position
327	SMT	?	Motor temperature
328	LOSE	0.1 deg	Scanner elevation
329	NINT	1	Pulses per integration
330	NLAG	1	Number of lags
331	TK	0.04395 deg	Track angle
332	LO	0.01 MHz	LO frequency
333	LOOFF	0.08 m/s	LO offset
334	GSSOURCE	1	GS source 0-2
335	GSD	0.0628 m/s	GS via Doppler radar
336	GSDA	0.0628 m/s	GS via Doppler/Addas
337	GSIA	0.0628 m/s	GS via INS/Addas
338-351	SPARES	NA	NA
352	CKSM	1	Checksum

Note that DA, P, and R are 0-359 deg. They should be converted to bipolar values by subtracting 8192 if greater than 4096. The same is true of LOSD and LOSE, from which 3600 should be subtracted if they are greater than 1800. See the comments in the program FCONVT in Appendix B for further conversion information.

The data contained in words 12-299 is composed of 96 sets of 3 measurements, corresponding to the 96 320-m range gates. The first word of each set is a logarithmic amplitude (LSB=0.184 dB). The second is a bipolar velocity (LSB=0.08 m/s). The third is a coded width estimate (0-15).

TSEC and TMIN are subject to complex errors in flight 13. TK is not independent but is derived from DA and TH.

Appendix B: Data reduction software

The following are brief descriptions of several programs developed during the course of the investigation of the data properties. While they constitute a complete set of data reduction software, it is not expected that they will be used as such. Rather, they may be of some use in helping to expain the techniques of data conversion, correction and evaluation. All programs are written in DEC RT-11 Fortran. The plotting routines require a Hewlett-Packard 7221A plotter.

1) Program FILED1. This program allows the user to examine raw data files on tape and to plot any item at any scale. Optimum coefficients for drift-angle correction can be determined for any data set length, based upon a 4-lag correction filter. It is also possible to plot certain differential quantities.

2) Program FTAPED. This program converts raw data files on tape to 568-word disk files. These disk files can also be examined, dumped or plotted.

3) Program FCONVT. This program operates on files produced by FTAPED and produces identical disk files as output with drift-angle corrections applied, X- and Y-coordinates corrected and added to the file, and mean powers and velocities computed. Plotting is also possible.

4) Program FEDIT. FEDIT operates on files produced by FCONVT and creates a file identical except for the addition of standard-deviation estimates for each velocity estimate.

5) Program FSMOTH. This program performs quadratic smoothing on files produced by FEDIT.

6) Program FGRID. FGRID produces gridded flow-field plots or files, operating on files created by FSMOTH. It can also produce gridded plots from files created by FEDIT, with nearest-neighbor algorithms used instead of interpolation.

7) Subroutines GRAPH1, SINV and MFSD. GRAPH1 is a plotting subroutine used by most of the above programs. It is designed to drive a Hewlett- Packard 7221A plotter. SINV and MFSD are used for matrix inversion in program FILED1.

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```
      PROGRAM FILED1
C     REVISED 10-22-81 FOR NEW DRIFT DEFINITION
      INTEGER*2 DBLK(4),ERROR(4),ARY(362),CODE,NWDS,ERRADR
      INTEGER*2 IRANGE(3),IWID(3),VELD(3),IDRIFT(4)
      REAL*4 AMP(3),VEL(3),WD(4),B1(3),A1(600),ATA(6),B(200)
      REAL*4 X1(3),DRIFT1(9)
      REAL*8 TIME,FLEFT
      BYTE A
      DATA DBLK/3RMT0,0,0,0/
      DATA ERROR/4*0/
      DATA WD/0.,1.,0.,-1./
      ERRADR=IADDR(ERROR)
      ICHAN=IGETC()
      IF(ICHAN.LT.0) STOP 'NO CHANNEL AVAILABLE'
      IF (LOOKUP(ICHAN,DBLK,0,-1).LT.0) STOP 'BAD LOOKUP'
      NRECD=0
      NSUM=103
      ZERO=-20.
      FULLS=20.
      FMULT=.00267
      SHIFT=0.
      ITAP13=0
      CON1=.04395
      NWDS=352
      FACTR=2.66
      LAST=1
      LAGV=3
      NRANGE=36

10    TYPE 905,NRECD
      ACCEPT *,I
      IF (I.EQ.0) GO TO 90       !READ AND TYPE HEADER
      IF (I.EQ.1) GO TO 100      !READ A RECORD
      IF (I.EQ.2) GO TO 200      !PRINT A RECORD
      IF (I.EQ.3) GO TO 300      !FORWARD SPACE
      IF (I.EQ.4) GO TO 400      !REWIND TAPE
      IF (I.EQ.5) GO TO 500      !BACKSPACE
      IF (I.EQ.6) GO TO 600      !PLOT ROUTINE
      IF (I.EQ.7) GO TO 700      !PLOT BOX
      IF (I.EQ.8) GO TO 800      !SET WEIGHTS AND SCALE
      IF (I.EQ.9) GO TO 350      !SPACE TO RECORD N
      IF (I.EQ.10) GO TO 801     !SET LAGV,NSUM
      IF (I.EQ.11) GO TO 750     !OPTIMUM COEFS
      IF (I.EQ.12) GO TO 802     !SET # RANGES
      IF (I.EQ.13) GO TO 803     !SET ITEM TO PLOT
      IF (I.EQ.14) GO TO 804     !SET PLOT TIME
      IF (I.EQ.15) GO TO 805     !SET FMULT,SHIFT
      IF (I.EQ.16) GO TO 806     !SET PLOT SCALE
      IF (I.EQ.17) GO TO 807     !SET ITAP13 - TIME CODE
      IF (I.EQ.18) GO TO 750     !PLOT OPTIMUM COEFS
      IF (I.EQ.19) GO TO 750     !TYPE OPTIMUM COEFS
      IF (I.EQ.99) GO TO 999     !EXIT FROM PROGRAM
      GO TO 10
```

ORIGINAL PAGE IS OF POOR QUALITY

```
90    ITEST=0                 !READ AND TYPE HEADER
      GO TO 105
100   ITEST=1
105   ERROR(1)=0
      ERROR(2)=0
      ICODE=ISPFNW(248,ICHAN,NWDS,ARY,ERRADR)
      NRECD=NRECD+1

      ARY(304)=ARY(304).AND.2047
      ARY(303)=ARY(303).AND.1023
      IT1=ARY(304)/60
      IT2=ARY(304)-60*IT1
      T3=ARY(303)/10.              !DECODE TIME
      IX=20*ARY(1)
      IY=20*ARY(2)            !X,Y POSITIONS
      N1=ARY(313)
      N2=ARY(312)/10          !LATITUDE
      IW1=-ARY(315)
      IW2=-ARY(314)/10        !LONGTITUDE
      IFLT=ARY(300)
      IRUN=ARY(302)           !FLIGHT AND RUN
      IALT=ARY(305)*16.4      !ALTITUDE
      FLOS=ARY(3)/10.+180.         !LINE OF SIGHT ANGLE
      THDG=ARY(316)*CON1      !TRUE HEADING
      DRIFT=ARY(319)*CON1     !DRIFT ANGLE
      IF (DRIFT.GT.180.) DRIFT=DRIFT-360
      FLOSE=ARY(328)/10.      !LOS ELEVATION
      PITCH=ARY(322)*CON1     !PITCH ANGLE
      ROLL=ARY(323)*CON1      !ROLL ANGLE
      IF (ROLL.GT.180.) ROLL=ROLL-360.
      TAS=ARY(317)*.5144      !TRUE AIRSPEED (M/S)
      GS=ARY(318)*.0628       !GROUND SPEED (M/S)
      WIND=ARY(320)*.05144         !INS WIND VELOCITY
      DIRN=ARY(321)/10.       !INS WIND DIRECTION
      IPROC=ARY(5)            !PROCESSOR STATUS
      ISTAT=ARY(4)            !MAJOR STATUS WORD
      ALOF=.01*ARY(332)       !LO FREQUENCY
      OFF=.08*ARY(333)        !LO CORRECTION, M/S
      GS1=.0628*ARY(335)      !DOPPLER GS VIA A/C
      GS2=.0628*ARY(336)      !DOPPLER VIA ADDAS
      GS3=.0628*ARY(337)      !INS GSPEED
      DRIFT2=CON1*(ARY(331)-ARY(316))     !TRACK-TRHDG

110   TYPE 901,IX,IY,N1,N2,IW1,IW2,IFLT,IRUN,IT1,IT2,T3,IALT
      TYPE 902,FLOS,THDG,DRIFT,FLOSE,PITCH,ROLL
      TYPE 903,TAS,GS,WIND,DIRN,IPROC,ISTAT
      TYPE 921,ALOF,OFF,GS1,GS2,GS3,DRIFT2
      TYPE *

      IF (ITEST.EQ.0) GO TO 410
      I3=NRANGE/3
      DO 150 I=1,I3           !PRINT NRANGE RANGE GATES
      DO 160 J=1,3
      IRANGE(J)=320*I+320*I3*J-3710
      I4=3*I3*J+3*I
```

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```
      AMP(J)=.184*ARY(I4-27)
      VEL(J)=.08*ARY(I4-26)
      IWID(J)=ARY(I4-25)
160   CONTINUE
150   TYPE 904,(IRANGE(K),AMP(K),VEL(K),IWID(K),K=1,3)
      TYPE *
      GO TO 410
200   PRINT 901,IX,IY,N1,N2,IW1,IW2,IFLT,IRUN,IT1,IT2,T3,IALT
      PRINT 902,FLOT,THDG,DRIFT,FCLOSE,PITCH,ROLL
      PRINT 903,TAS,GS,WIND,DIRN,IPROC,ISTAT
      PRINT *
      DO 250 I=1,12
      DO 260 J=1,3
      IRANGE(J)=320*I+3840*J-3710
      AMP(J)=.184*ARY(36*J+3*I-27)
      VEL(J)=.08*ARY(36*J+3*I-26)
      IWID(J)=ARY(36*J+3*I-25)
260   CONTINUE
250   PRINT 904,(IRANGE(K),AMP(K),VEL(K),IWID(K),K=1,3)
      PRINT *
      GO TO 10

300   TYPE 906
      ACCEPT *,N
      IF (N.EQ.0) GO TO 10
310   ERROR(1)=0
      ERROR(2)=0
      ICODE=ISPFNW(254,ICHAN,N,ARY,ERRADR)
      NRECD=NRECD+N
      GO TO 410

350   TYPE 917   !SPACE TO RECORD N
      ACCEPT *,N
      N=N-NRECD
      IF (N.GT.0) GO TO 310
      IF (N.EQ.0) GO TO 10
      N=-N
      GO TO 510

400   TYPE *,'REWIND TAPE'
      ERROR(1)=0
      ERROR(2)=0
      ICODE=ISPFNW(251,ICHAN,NWDS,ARY,ERRADR)
      NRECD=0
410   IF (ICODE.NE.0) TYPE *,'ICODE=',ICODE,ERROR(1),ERROR(2)
      GO TO 10

500   TYPE 907
      ACCEPT *,N
      IF (N.EQ.0) GO TO 10
510   ERROR(1)=0
      ERROR(2)=0
      ICODE=ISPFNW(253,ICHAN,N,ARY,ERRADR)
      NRECD=NRECD-N
      IF (NRECD.LT.0) NRECD=0
```

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```
      IF (ICODE.EQ.1) NRECD=0
      GO TO 410

600   TYPE 914          !EXECUTE PLOT
      ACCEPT *,MATCH        !MATCH THIS STATUS WORD (0=ANY)
      IF (MATCH.LT.0) GO TO 10

      XFACTR=2000./(XAXIS*60.)!PUNITS PER SECOND  YFACTR=1400./(FULLS-!
      A='p'
      TYPE 915,155          !START PLOTTER
      DO 650 I1=1,IRECDS

      ERROR(1)=0
      ERROR(2)=0
      ICODE=ISPFNW(248,ICHAN,NWDS,ARY,ERRADR)
      NRECD=NRECD+1

      ISUM=0                !SUM SEVERAL RANGES
      DO 610 K=16,NSUM,3
      ISUM=ISUM+ARY(K)
610   CONTINUE
      ARY(353)=ISUM

      ARY(303)=ARY(303).AND.1023
      ARY(304)=ARY(304).AND.2047    !MASK UNUSED BITS

      IF (ARY(319).GT.4096) ARY(319)=ARY(319)-8192
      IF (ARY(322).GT.4096) ARY(322)=ARY(322)-8192
      IF (ARY(323).GT.4096) ARY(323)=ARY(323)-8192
      IF (ARY(328).GT.1800) ARY(328)=ARY(328)-3600

      ARY(354)=ARY(335)-ARY(336)    !A/C DOPPLER-ADDAS DOPPLER
      ARY(355)=ARY(335)-ARY(337)    !A/C DOPPLER-ADDAS INS GS
      ARY(356)=ARY(336)-ARY(337)    !A/C ADDAS DOPPLER-ADDAS INS
      ARY(358)=ARY(ITEMD)-IDELY1    !AND ANY OTHER ITEM
      ARY(359)=ARY(ITEMD)-IDELY2
      ARY(360)=ARY(359)+ARY(358)
      IDELY2=IDELY1
      IDELY1=ARY(ITEMD)

      IDRIFT(4)=IDRIFT(3)
      IDRIFT(3)=IDRIFT(2)
      IDRIFT(2)=IDRIFT(1)
      IDRIFT(1)=ARY(331)-ARY(316)   !NEW DRIFT DEF'N - (ARY(319) IS OLD

      DDRIFT=0.             !WEIGHT DRIFT
      DO 630 I=1,4
      DDRIFT=DDRIFT+WD(I)*IDRIFT(I)
630   CONTINUE

      ARY(357)=FACTR*DDRIFT*ARY(318)/176.216+VELD(LAGV)

      VELD(5)=0.0
      VELD(4)=VELD(3)
      VELD(3)=VELD(2)
```

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```
      VELD(2)=VELD(1)
      VELD(1)=ARY(353)

      IF (MATCH.EQ.Ø) GOTO 64Ø
      IF ((ARY(4).AND.24).NE.MATCH) GOTO 65Ø
64Ø   TYPE 916
      TIME=6Ø.DØ*ARY(3Ø4)+.1DØ*ARY(3Ø3)

      IF (ITAP13.EQ.Ø) GO TO 647    !CODE TO FIX TAPE 13
      ISEC=ARY(3Ø3)/1Ø.
      IF (MOD(ISEC,1Ø).EQ.9) TIME=TIME-1.DØ
      IF (MOD(ISEC,1Ø).NE.Ø) GO TO 645
      IF (LAST.NE.Ø) TIME=TIME-1.DØ
      IF (LAST.NE.Ø) ISEC=ISEC-1
      LAST=Ø
      GO TO 646
645   LAST=1
646   CONTINUE
      IF (ISEC.LT.1Ø) TIME=TIME+6Ø.DØ

647   CONTINUE
      IF (TIME.LT.432ØØ.) TIME=TIME+864ØØ.
      X=XFACTR*(TIME-FLEFT)
      Y=(ARY(NITEM)*FMULT+SHIFT-ZERO)*YFACTR
      IF (X.GT.2ØØØ.) X=2ØØØ.
      IF (Y.GT.14ØØ.) Y=14ØØ.
      IF (Y.LT.Ø.) Y=Ø.
      IF (X.LT.Ø.) A='p'

      CALL GRAPH1(X,Y,A)
      A='q'
65Ø   CONTINUE
      TYPE 919,155   GO TO 1Ø

7ØØ   TYPE *,'OUTLINE BOX'
      TYPE 915,155
      CALL GRAPH1(Ø.,Ø.,'p')
      CALL GRAPH1(2ØØØ.,Ø.,'q')
      CALL GRAPH1(2ØØØ.,14ØØ.,'q'.
      CALL GRAPH1(Ø.,14ØØ.,'q')
      CALL GRAPH1(Ø.,Ø.,'q')
      TYPE 919,155
      GO TO 1Ø

75Ø   ICASE=I
      ITRIAL=Ø
      TYPE *,'FIND COEFS. FOR CODE (8,24):'
      ACCEPT *,MATCH
      IF (MATCH.LT.Ø) GO TO 1Ø
      TYPE *,'NUMBER OF SAMPLES:'
      ACCEPT *,NLSQ
      IF (ICASE.EQ.11) GO TO 754
      TYPE *,'NUMBER OF TRIALS'
      ACCEPT *,NTRIAL
      IF (ICASE.EQ.19) GOTO 754
```

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```
      TYPE *,'PLOT COEFFICIENT 1-4:'
      ACCEPT *,NCOEF
      A='p'
      TYPE 915,155   !TURN ON PLOTTER

754   N=-9
755   ERROR(1)=0
      ERROR(2)=0
      ICODE=ISPFNW(248,ICHAN,NWDS,ARY,ERRADR)
      NRECD=NRECD+1
      IF (ICODE.NE.0) GO TO 777
      IF (ARY(319).GT.4096) ARY(319)=ARY(319)-8192
      GS=.06279*ARY(318)  !M/S UNITS

      DRIFT1(9)=DRIFT1(8)
      DRIFT1(8)=DRIFT1(7)
      DRIFT1(7)=DRIFT1(6)
      DRIFT1(6)=DRIFT1(5)
      DRIFT1(5)=DRIFT1(4)
      DRIFT1(4)=DRIFT1(3)
      DRIFT1(3)=DRIFT1(2)
      DRIFT1(2)=DRIFT1(1)
      DRIFT1(1)=.04395*(ARY(331)-ARY(316))*GS*.01645    !M/S UNITS
C     ABOVE LINE REVISED FROM (ARY(319)) IN PARENS

      IVEL9=IVEL8
      IVEL8=IVEL7
      IVEL7=IVEL6
      IVEL6=IVEL5
      IVEL5=IVEL4
      IVEL4=IVEL3
      IVEL3=IVEL2
      IVEL2=IVEL1
      IVEL1=0
      DO 760 K=16,NSUM,3
      IVEL1=IVEL1+ARY(K)
760   CONTINUE        !.00267 M/S UNITS
      IF (N.LT.1) GO TO 775

      IF (MATCH.EQ.0) GO TO 765
      IF ((ARY(4).AND.24).NE.MATCH) GO TO 755
765   B(N)=.00267*(2*IVEL6-IVEL4-IVEL8)  !M/S UNITS
      DO 770 J=1,3
      N1=N+NLSQ*(J-1)
      A1(N1)=DRIFT1(J)-DRIFT1(J+1)-2.*DRIFT1(J+2)+2.*DRIFT1(J+3)
      A1(N1)=A1(N1)+DRIFT1(J+4)-DRIFT1(J+5)
770   CONTINUE

775   N=N+1
      NP1=NLSQ+1
      IF (N.LT.NP1) GO TO 755

      CALL GTPRD(A1,B,B1,NLSQ,3,1)
      CALL MATA(A1,ATA,NLSQ,3,0)
```

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```
      CALL SINV(ATA,3,.0001,IER)
      CALL MPRD(ATA,B1,X1,3,3,1,0,1)

      WD(1)=X1(1)
      WD(2)=X1(2)-X1(1)
      WD(3)=X1(3)-X1(2)
      WD(4)=-X1(3)
      ITRIAL=ITRIAL+1

777   IF (ICODE.NE.0) ITRIAL=NTRIAL
      IF (ICASE.EQ.11) GO TO 790     !CRT TYPEOUT
      IF (ICASE.EQ.19) GO TO 780     !PRINTOUT

      X=10.*ITRIAL
      Y=700.+WD(NCOEF)*350.
      IF (Y.GT.1400.) Y=1400.
      IF (Y.LT.0.) Y=0.
      CALL GRAPH1(X,Y,A)
      A='q'
      IF (ITRIAL.LT.NTRIAL) GO TO 754
      TYPE 919,155          !TURN OFF PLOTTER
      GO TO 10

780   IT1=ARY(304)/60
      IT2=ARY(304)-60*IT1
      T3=ARY(303)/10.
      PRINT 920,ITRIAL,NRECD,IT1,IT2,T3,WD
      IF (ITRIAL.LT.NTRIAL) GO TO 754
      GO TO 10
790   TYPE *,'WEIGHTING VECTOR=',X1
      TYPE *,'COEFFICIENTS=',WD

      GO TO 10

800   TYPE *,'WEIGHTING VECTOR (.3 1 0 -1)'
      ACCEPT *,WD
      TYPE *,'SCALE FACTOR (3)'
      ACCEPT *,FACTR
      GO TO 10

801   TYPE *,'VELOCITY LAG (3)'
      ACCEPT *,LAGV  TYPE *,'NSUM (103)'
      ACCEPT *,NSUM
      TYPE *,'ITEM TO DELAY'
      ACCEPT *,ITEMD
      GO TO 10

802   TYPE *,'NUMBER OF RANGES (36)'
      ACCEPT *,NRANGE
      GO TO 10

803   TYPE 908
      ACCEPT *,NITEM        !ITEM TO PLOT
      GO TO 10
```

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```
804   TYPE 911
      ACCEPT *,IHOUR,MINUTE    !LEFT EDGE INFO
      FLEFT=3600.D0*IHOUR+60.D0*MINUTE
      TYPE 912
      ACCEPT *,XAXIS       !FS IN MINUTES
      TYPE 913
      ACCEPT *,IRECDS           !# RECORDS TO PLOT
      GO TO 10

805   TYPE 910
      ACCEPT *,FMULT,SHIFT      !PLOT FACTOR
      GO TO 10

806   TYPE 909
      ACCEPT *,ZERO,FULLS !PLOT SCALE
      GO TO 10

807   TYPE *,'TAPE 13? (0,1)'
      ACCEPT *,ITAP13
      GO TO 10

901   FORMAT (1X,'X=',I6,'  Y=',I6,'  N',I2,':',I2,' W',
      1I3,':',I2,'  FLT ',I2,' RUN ',I3,'  TIME ',I2,
      1':',I2,':',F4.1,'  ALT ',I6)
902   FORMAT (1X,'LOS=',F6.1,'  THDG=',F5.1,'  DRIFT=',F5.2,
      1'  LOSE=',F5.1,'  PITCH=',F6.2,'  ROLL=',F6.2)
903   FORMAT (1X,'TAS=',F5.1,'  GSPD=',F5.1,'  WIND=',F5.1,
      1'  WDIR=',F5.1,'  PROC=',O6,'  STATUS=',O6)
904   FORMAT (1X,3(I5,F7.1,F6.1,I4,5X))
905   FORMAT (1X,'AT RECORD',I5,'   COMMAND: ',$)
906   FORMAT (1X,'SPACE FORWARD N RECORDS: ',$)
907   FORMAT (1X,'SPACE BACKWARD N RECORDS: ',$)
908   FORMAT (1X,'PLOT ITEM M: ',$)
909   FORMAT (1X,'ZERO AND FULL-SCALE FOR PLOT: ',$)
910   FORMAT (1X,'MULTIPLIER AND OFFSET: ',$)
911   FORMAT (1X,'LEFT EDGE HOUR, MINUTE: ',$)
912   FORMAT (1X,'FULL SCALE IN MINUTES: ',$)
913   FORMAT (1X,'NUMBER OF RECORDS: ',$)
914   FORMAT (1X,'PLOT CODE TO MATCH (0,8,24): ',$)
915   FORMAT (1X,A1,'.(',$)
916   FORMAT (1X,A1,$)
917   FORMAT (1X,'SPACE TO RECORD N: ',$)
918   FORMAT (1X,5A1,'}')
919   FORMAT (1X,'p}',A1,'.)')
920   FORMAT (1X,I4,I7,I5,':',I2,':',F4.1,4F10.4)
921   FORMAT (1X,'LO:',F6.2,'  OFFSET:',F6.1,'  GS:',3F6.1,
      1'  DRIFT: ',F5.2)

999   CALL CLOSEC(ICHAN)
      STOP 'EXIT 99'
      END
```

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```
      PROGRAM FTAPED

C     REVISED 10-27-81
C     TURNS MAGTAPE FILES INTO DISK FILES
C     CAN ALSO EXAMINE/PLOT TAPE DATA

      INTEGER*2 DBLK(4),ERROR(4),ARY(354),CODE,NWDS,ERRADR
      INTEGER*2 IRANGE(3),IWID(3)
      REAL*4 AMP(3),VEL(3)
      REAL*8 TIME,FLEFT
      BYTE A,FILSPC(11)
      DATA DBLK/3RMTØ,Ø,Ø,Ø/
      DATA ERROR/4*Ø/
      ERRADR=IADDR(ERROR)
      ICHAN=IGETC()
      IF(ICHAN.LT.Ø) STOP 'NO CHANNEL AVAILABLE'
      IF (LOOKUP(ICHAN,DBLK,Ø,-1).LT.Ø) STOP 'BAD LOOKUP'
      NRECD=Ø
      FULLS=2Ø.
      ZERO=-2Ø.
      LAST=1
      CON1=.Ø4395
      FMULT=CON1
      SHIFT=Ø.
      NWDS=352
      NRANGE=36

1Ø    TYPE 9Ø5,NRECD
      ACCEPT *,I
      IF (I.EQ.Ø) GO TO 9Ø      !READ AND TYPE HEADER
      IF (I.EQ.1) GO TO 1ØØ     !READ A RECORD
      IF (I.EQ.2) GO TO 2ØØ     !PRINT A RECORD
      IF (I.EQ.3) GO TO 3ØØ     !FORWARD SPACE
      IF (I.EQ.4) GO TO 4ØØ     !REWIND TAPE
      IF (I.EQ.5) GO TO 5ØØ     !BACKSPACE
      IF (I.EQ.6) GO TO 6ØØ     !PLOT ROUTINE
      IF (I.EQ.7) GO TO 7ØØ     !PLOT BOX
      IF (I.EQ.8) GO TO 45Ø     !CREATE A FILE
      IF (I.EQ.9) GO TO 35Ø     !SPACE TO RECORD N
      IF (I.EQ.12) GO TO 8Ø2    !SET # RANGES
      IF (I.EQ.13) GO TO 8Ø3    !SET ITEM TO PLOT
      IF (I.EQ.14) GO TO 8Ø4    !SET PLOT TIME
      IF (I.EQ.15) GO TO 8Ø5    !SET FMULT,SHIFT
      IF (I.EQ.16) GO TO 8Ø6    !SET PLOT SCALE
      IF (I.EQ.17) GO TO 8Ø7    !SET TAPE I13 - TIME CODE
      IF (I.EQ.99) GO TO 999    !EXIT FROM PROGRAM
      GO TO 1Ø

9Ø    ITEST=Ø                  !READ AND TYPE HEADER
      GO TO 1Ø5
1ØØ   ITEST=1
1Ø5   ERROR(1)=Ø
      ERROR(2)=Ø
      ICODE=ISPFNW(248,ICHAN,NWDS,ARY,ERRADR)
      NRECD=NRECD+1
```

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```
      IT1=ARY(304)/60
      IT2=ARY(304)-60*IT1
      T3=ARY(303)/10.           !DECODE TIME
      IX=20*ARY(1)
      IY=20*ARY(2)          !X,Y POSITIONS
      N1=ARY(313)
      N2=ARY(312)/10        !LATITUDE
      IW1=-ARY(315)
      IW2=-ARY(314)/10      !LONGTITUDE
      IFLT=ARY(300)
      IRUN=ARY(302)         !FLIGHT AND RUN
      IALT=ARY(305)*1.64    !ALTITUDE
      FLOS=ARY(3)/10.+180.      !LINE OF SIGHT ANGLE
      THDG=ARY(316)*CON1    !TRUE HEADING
      DRIFT=ARY(319)*CON1   !DRIFT ANGLE
      IF (DRIFT.GT.180.) DRIFT=DRIFT-360
      FLOSE=ARY(328)/10.    !LOS ELEVATION
      PITCH=ARY(322)*CON1   !PITCH ANGLE
      ROLL=ARY(323)*CON1    !ROLL ANGLE
      IF (ROLL.GT.180.) ROLL=ROLL-360.
      TAS=ARY(317)*.5144    !TRUE AIRSPEED (M/S)
      GS=ARY(318)*.0628     !GROUND SPEED (M/S)
      WIND=ARY(320)*.05144      !INS WIND VELOCITY
      DIRN=ARY(321)/10.     !INS WIND DIRECTION
      IPROC=ARY(5)          !PROCESSOR STATUS
      ISTAT=ARY(4)          !MAJOR STATUS WORD
      ALOF=.01*ARY(332)     !LO FREQUENCY
      OFF=.08*ARY(333)      !LO CORRECTION, M/S
      GS1=.0628*ARY(335)    !DOPPLER GS VIA A/C
      GS2=.0628*ARY(336)    !DOPPLER VIA ADDAS
      GS3=.0628*ARY(337)    !INS GSPEED
      DRIFT2=CON1*(ARY(331)-ARY(316))     !TRACK-TRHDG

110   TYPE 901,IX,IY,N1,N2,IW1,IW2,IFLT,IRUN,IT1,IT2,T3,IALT
      TYPE 902,FLOS,THDG,DRIFT,FLOSE,PITCH,ROLL
      TYPE 903,TAS,GS,WIND,DIRN,IPROC,ISTAT
      TYPE 921,ALOF,OFF,GS1,GS2,GS3,DRIFT2
      TYPE *

      IF (ITEST.EQ.0) GO TO 410
      I3=NRANGE/3
      DO 150 I=1,I3         !PRINT NRANGE RANGE GATES
      DO 160 J=1,3
      IRANGE(J)=320*I+320*I3*J-3710
      I4=3*I3*J+3*I
      AMP(J)=.184*ARY(I4-27)
      VEL(J)=.08*ARY(I4-26)
      IWID(J)=ARY(I4-25)
160   CONTINUE
150   TYPE 904,(IRANGE(K),AMP(K),VEL(K),IWID(K),K=1,3)
      TYPE *
      GO TO 410
200   PRINT 901,IX,IY,N1,N2,IW1,IW2,IFLT,IRUN,IT1,IT2,T3,IALT
      PRINT 902,FLOT,THDG,DRIFT,FCLOSE,PITCH,ROLL
```

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```
      PRINT 903,TAS,GS,WIND,DIRN,IPROC,ISTAT
      PRINT 921,ALOF,OFF,GS1,GS2,GS3,DRIFT2
      PRINT *
      DO 250 I=1,12
      DO 260 J=1,3
      IRANGE(J)=320*I+3840*J-3710
      AMP(J)=.184*ARY(36*J+3*I-27)
      VEL(J)=.08*ARY(36*J+3*I-26)
      IWID(J)=ARY(36*J+3*I-25)
260   CONTINUE
250   PRINT 904,(IRANGE(K),AMP(K),VEL(K),IWID(K),K=1,3)
      PRINT *
      GO TO 10

300   TYPE 906
      ACCEPT *,N
      IF (N.EQ.0) GO TO 10
310   ERROR(1)=0
      ERROR(2)=0
      ICODE=ISPFNW(254,ICHAN,N,ARY,ERRADR)
      NRECD=NRECD+N
      GO TO 410

350   TYPE 917  !SPACE TO RECORD N
      ACCEPT *,N
      N=N-NRECD
      IF (N.GT.0) GO TO 310
      IF (N.EQ.0) GO TO 10
      N=-N
      GO TO 510

400   TYPE *,'REWIND TAPE'
      ERROR(1)=0
      ERROR(2)=0
      ICODE=ISPFNW(251,ICHAN,NWDS,ARY,ERRADR)
      NRECD=0
410   IF (ICODE.NE.0) TYPE *,'ICODE=',ICODE,ERROR(1),ERROR(2)
      GO TO 10

450   TYPE 451  !CREATE A NEW FILE
451   FORMAT (1X,'CREATE FILE DL0:',$)
      ACCEPT 452,(FILSPC(I),I=1,10)
452   FORMAT (10A1)
      IF (FILSPC(1).EQ.0) GO TO 450
      FILSPC(11)=0
      TYPE 453
453   FORMAT (1X,'NUMBER OF SCANS: ',$)
      ACCEPT *,NRECDS
      IF (NRECDS.LE.0) GO TO 10
      NBLOCK=1.394*FLOAT(NRECDS)+1
      TYPE *,'NBLOCK:',NBLOCK
      OPEN (UNIT=8,NAME=FILSPC,RECORDSIZE=177,TYPE='NEW',
      1ERR=460,FORM='UNFORMATTED',INITIALSIZE=NBLOCK)

      DO 455 I=1,NRECDS
```

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```
      ERROR(1)=0
      ERROR(2)=0
      ICODE=ISPFNW(248,ICHAN,352,ARY,ERRADR)
      NRECD=NRECD+1
      IF (ICODE.NE.0) GO TO 480

      ARY(353)=NRECD-1
      ARY(354)=0
      WRITE (8) ARY
455   CONTINUE

456   CLOSE (UNIT=8)
      GO TO 10


460   TYPE *,'ERROR UPON OPENING'
      GO TO 10

480   TYPE *,'READ NON-STANDARD TAPE RECORD'
      GO TO 456

500   TYPE 907
      ACCEPT *,N
      IF (N.EQ.0) GO TO 10
510   ERROR(1)=0
      ERROR(2)=0
      ICODE=ISPFNW(253,ICHAN,N,ARY,ERRADR)
      NRECD=NRECD-N
      IF (NRECD.LT.0) NRECD=0
      IF (ICODE.EQ.1) NRECD=0
      GO TO 410

600   TYPE 914          !EXECUTE PLOT
      ACCEPT *,MATCH         !MATCH THIS STATUS WORD (0=ANY)
      IF (MATCH.LT.0) GO TO 10

      XFACTR=2000./(XAXIS*60.)!PUNITS PER SECOND   YFACTR=1400./(FULLS-ZERO)
      A='p'
      TYPE 915,155           !START PLOTTER
      DO 650 I1=1,IRECDS

      ERROR(1)=0
      ERROR(2)=0
      ICODE=ISPFNW(248,ICHAN,NWDS,ARY,ERRADR)
      NRECD=NRECD+1

      IF (ARY(319).GT.4096) ARY(319)=ARY(319)-8192
      IF (ARY(322).GT.4096) ARY(322)=ARY(322)-8192
      IF (ARY(323).GT.4096) ARY(323)=ARY(323)-8192
      IF (ARY(328).GT.1800) ARY(328)=ARY(328)-3600

      IF (MATCH.EQ.0) GOTO 640
      IF ((ARY(4).AND.24).NE.MATCH) GOTO 650
640   TYPE 916
```

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```
      TIME=60.D0*ARY(304)+.1D0*ARY(303)

      IF (ITAP13.EQ.0) GO TO 647     !CODE TO FIX TAPE 13
      ISEC=ARY(303)/10.
      IF (MOD(ISEC,10).EQ.9) TIME=TIME-1.D0
      IF (MOD(ISEC,10).NE.0) GO TO 645
      IF (LAST.NE.0) TIME=TIME-1.D0
      IF (LAST.NE.0) ISEC=ISEC-1
      LAST=0
      GO TO 646
645   LAST=1
646   CONTINUE
      IF (ISEC.LT.10) TIME=TIME+60.D0

647   CONTINUE
      IF (TIME.LT.43200.) TIME=TIME+86400.
      X=XFACTR*(TIME-FLEFT)
      Y=(ARY(NITEM)*FMULT+SHIFT-ZERO)*YFACTR
      IF (X.GT.2000.) X=2000.
      IF (Y.GT.1400.) Y=1400.
      IF (Y.LT.0.) Y=0.
      IF (X.LT.0.) A='p'

      CALL GRAPH1(X,Y,A)
      A='q'
650   CONTINUE
      TYPE 919,155   GO TO 10

700   TYPE *,'OUTLINE BOX'
      TYPE 915,155
      CALL GRAPH1(0.,0.,'p')
      CALL GRAPH1(2000.,0.,'q')
      CALL GRAPH1(2000.,1400.,'q')
      CALL GRAPH1(0.,1400.,'q')
      CALL GRAPH1(0.,0.,'q')
      TYPE 919,155
      GO TO 10

802   TYPE *,'NUMBER OF RANGES (36)'
      ACCEPT *,NRANGE
      GO TO 10

803   TYPE 908
      ACCEPT *,NITEM       !ITEM TO PLOT
      GO TO 10

804   TYPE 911
      ACCEPT *,IHOUR,MINUTE     !LEFT EDGE INFO
      FLEFT=3600.D0*IHOUR+60.D0*MINUTE
      TYPE 912
      ACCEPT *,XAXIS       !FS IN MINUTES
      TYPE 913
      ACCEPT *,IRECDS          !# RECORDS TO PLOT
      GO TO 10
```

```
805   TYPE 910
      ACCEPT *,FMULT,SHIFT      !PLOT FACTOR
      GO TO 10

806   TYPE 909
      ACCEPT *,ZERO,FULLS !PLOT SCALE
      GO TO 10

807   TYPE *,'TAPE 13? (0,1)'
      ACCEPT *,ITAP13
      GO TO 10

901   FORMAT (1X,'X=',I6,'  Y=',I6,'  N',I2,':',I2,' W',
      1I3,':',I2,'  FLT ',I2,' RUN ',I3,'  TIME ',I2,
      1':',I2,':',F4.1,'  ALT ',I5,'0')
902   FORMAT (1X,'LOS=',F6.1,'  THDG=',F5.1,'  DRIFT=',F5.2,
      1'  LOSE=',F5.1,'  PITCH=',F6.2,'  ROLL=',F6.2)
903   FORMAT (1X,'TAS=',F5.1,'  GSPD=',F5.1,'  WIND=',F5.1,
      1'  WDIR=',F5.1,'  PROC=',O6,'  STATUS=',O6)
904   FORMAT (1X,3(I5,F7.1,F6.1,I4,5X))
905   FORMAT (1X,'AT RECORD',I5,'   COMMAND: ',$)
906   FORMAT (1X,'SPACE FORWARD N RECORDS: ',$)
907   FORMAT (1X,'SPACE BACKWARD N RECORDS: ',$)
908   FORMAT (1X,'PLOT ITEM M: ',$)
909   FORMAT (1X,'ZERO AND FULL-SCALE FOR PLOT: ',$)
910   FORMAT (1X,'MULTIPLIER AND OFFSET: ',$)
911   FORMAT (1X,'LEFT EDGE HOUR, MINUTE: ',$)
912   FORMAT (1X,'FULL SCALE IN MINUTES: ',$)
913   FORMAT (1X,'NUMBER OF RECORDS: ',$)
914   FORMAT (1X,'PLOT CODE TO MATCH (0,8,24): ',$)
915   FORMAT (1X,A1,'.(',$)
916   FORMAT (1X,A1,$)
917   FORMAT (1X,'SPACE TO RECORD N: ',$)
918   FORMAT (1X,5A1,'}')
919   FORMAT (1X,'p}',A1,'.)')
920   FORMAT (1X,I4,I7,I5,':',I2,':',F4.1,4F10.4)
921   FORMAT (1X,'LO:',F6.2,'  OFFSET:',F6.1,'  GS:',3F6.1,
      1'  DRIFT: ',F5.2)

999   CALL CLOSEC(ICHAN)
      STOP 'EXIT 99'
      END
```

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```
      PROGRAM FCONVT
C
C     REVISED 10-29-81, 11-5,16-81, 4-13-82
C     OPERATES ON FTAPED FILES (177 WORD RECORDS)
C     TO PRODUCE .RAW FILES (568 WORD RECORDS)
C
C     CAN ALSO EXAMINE 568-WORD RECORDS AND PLOT THEM
C
      INTEGER*2 HEADER(56),DATA(12,90)
      INTEGER*2 RAW(354),RAW1(354),RAW2(354),RAW3(354)
      REAL*8 TIME,FLEFT
      REAL*4 COEF1,COEF2,COEF3,COEF4
      BYTE A,FILSPC(11)
      ITAP13=0
      FULLS=20.
      ZERO=-20.
      LAST=1
      FMULT=.01
      SHIFT=0.
      MRANGE=1
      NRANGE=36
      COEF1=0.32     !DRIFT CORRECTION COEFFICIENTS
      COEF2=0.56
      COEF3=0.12
      COEF4=-1.0

10    TYPE 905,NRECD
      ACCEPT *,I
      IF (I.EQ.0) GO TO 90        !READ AND TYPE HEADER
      IF (I.EQ.1) GO TO 100       !READ A RECORD
      IF (I.EQ.2) GO TO 200       !PRINT RECORD JUST READ
      IF (I.EQ.4) GO TO 300       !REWIND FILE
      IF (I.EQ.6) GO TO 600       !PLOT ROUTINE
      IF (I.EQ.7) GO TO 700       !PLOT BOX
      IF (I.EQ.8) GO TO 400       !CREATE A NEW FILE
      IF (I.EQ.9) GO TO 350       !SPACE TO RECORD N
      IF (I.EQ.10) GO TO 750      !OPEN READ FILE
      IF (I.EQ.11) GO TO 770      !CLOSE READ FILE
      IF (I.EQ.12) GO TO 802      !SET # RANGES
      IF (I.EQ.13) GO TO 803      !SET ITEM TO PLOT
      IF (I.EQ.14) GO TO 804      !SET PLOT TIME
      IF (I.EQ.15) GO TO 805      !SET FMULT,SHIFT
      IF (I.EQ.16) GO TO 806      !SET PLOT SCALE
      IF (I.EQ.17) GO TO 807      !SET TAPE I13 - TIME CODE
      IF (I.EQ.18) GO TO 808      !SET COEFFICIENTS
      IF (I.EQ.99) GO TO 999      !EXIT FROM PROGRAM
      GO TO 10

90    ITEST=0                !READ AND TYPE HEADER
      GO TO 105
100   ITEST=1
105   READ (8,ERR=670,END=660) HEADER,DATA
      NRECD=NRECD+1

      IT1=HEADER(4)/60
```

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```
      IT2=HEADER(4)-60*IT1
      T3=HEADER(5)/10.     !DECODE TIME
      IX=2*HEADER(6)
      IY=2*HEADER(7)       !X,Y POSITIONS
      N1=HEADER(8)
      N2=HEADER(9)/10           !LATITUDE
      IW1=HEADER(10)
      IW2=HEADER(11)/10    !LONGTITUDE
      IFLT=HEADER(2)
      IRUN=HEADER(3)       !FLIGHT AND RUN
      IALT=HEADER(12)*2    !ALTITUDE
      FLOS=HEADER(31)/10.  !LINE OF SIGHT ANGLE
      THDG=HEADER(26)*.04395    !TRUE HEADING
      DRIFT=HEADER(27)*.04395   !DRIFT ANGLE
      FLOSE=HEADER(32)/10.      !LOS ELEVATION
      PITCH=HEADER(29)*.04395   !PITCH ANGLE
      ROLL=HEADER(30)*.04395    !ROLL ANGLE
      TAS=HEADER(20)/100.  !TRUE AIRSPEED (M/S)
      GS=HEADER(42)/100.   !GROUND SPEED (M/S)
      WIND=HEADER(43)/100.      !INS WIND VELOCITY
      DIRN=HEADER(44)/10.  !INS WIND DIRECTION
      IPROC=HEADER(19)     !PROCESSOR STATUS
      ISTAT=HEADER(18)     !MAJOR STATUS WORD
      ALOF=HEADER(33)/100.      !LO FREQUENCY
      OFF=HEADER(34)/100.  !LO CORRECTION, M/S
      GS1=HEADER(21)/100.  !DOPPLER GS VIA A/C
      GS2=HEADER(22)/100.  !DOPPLER VIA ADDAS
      GS3=HEADER(23)/100.  !INS GSPEED
      DRIFT2=.04395*(HEADER(28)-HEADER(26))    !TRACK-TRHDG
      FLOSA=HEADER(46)/10.      !ACTUAL L.O.S.
      POWER=HEADER(36)/100.     !MEAN NOISE POWER
      VAVG=HEADER(41)/100.      !MEAN VELOCITY
      VCOR=HEADER(40)/100.      !VELOCITY CORRECTION

110   TYPE 901,IX,IY,N1,N2,IW1,IW2,IFLT,IRUN,IT1,IT2,T3,IALT
      TYPE 902,FLOS,THDG,DRIFT,FLOSE,PITCH,ROLL
      TYPE 903,TAS,GS,WIND,DIRN,IPROC,ISTAT
      TYPE 921,ALOF,OFF,GS1,GS2,GS3,DRIFT2
      TYPE 922,FLOSA,POWER,VAVG,VCOR,HEADER(1)
      TYPE *

      IF (ITEST.NE.2) GO TO 111
      PRINT 901,IX,IY,N1,N2,IW1,IW2,IFLT,IRUN,IT1,IT2,T3,IALT
      PRINT 902,FLOS,THDG,DRIFT,FLOSE,PITCH,ROLL
      PRINT 903,TAS,GS,WIND,DIRN,IPROC,ISTAT
      PRINT 921,ALOF,OFF,GS1,GS2,GS3,DRIFT2
      PRINT 922,FLOSA,POWER,VAVG,VCOR,HEADER(1)
      PRINT *

111   IF (ITEST.EQ.0) GO TO 10
      DO 150 J=MRANGE,NRANGE          !PRINT NRANGE RANGE GATES
      IRANGE=320*J+32.
      AMP=.01*DATA(1,J)
      VEL=.01*DATA(2,J)
      IWID=DATA(3,J)
```

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```
      IX=2.*DATA(4,J)
      IY=2.*DATA(5,J)
      V1=.01*DATA(7,J)
      V2=.01*DATA(8,J)
      V3=.01*DATA(9,J)
      V4=.01*DATA(10,J)
      V5=.01*DATA(11,J)
      SIG=.01*DATA(6,J)         !EDITING STD DEVN
      SIG2=.01*DATA(12,J)       !SMOOTH STD DEVN
      IF (ITEST.NE.2) GO TO 150
      PRINT 904,IRANGE,AMP,VEL,IWID,IX,IY,SIG,V1,V2,V3,V4,V5,SIG2
150   TYPE 904,IRANGE,AMP,VEL,IWID,IX,IY,SIG,V1,V2,V3,V4,V5,SIG2
      TYPE *
      IF (ITEST.EQ.2) PRINT *
      IF (ITEST.EQ.2) REWIND 6
      GO TO 10

200   ITEST=2          !PRINT RECORD
      GO TO 105

350   TYPE 917  !SPACE TO RECORD N
      ACCEPT *,N
      IF (N.LT.1) GO TO 350
      IF (N.GT.MAXRCD) GO TO 350
      IF (N.EQ.NRECD) GO TO 10
      IF (N.GT.NRECD) GO TO 360
      N1=NRECD-N
      DO 355 J=1,N1
355   BACKSPACE 8
      GO TO 370
360   N1=N-NRECD
      DO 365 J=1,N1
365   READ (8,ERR=670,END=660)
370   NRECD=N
      GO TO 10

300   TYPE *,'REWIND FILE'
      REWIND 8
      NRECD=1
      GO TO 10

400   TYPE 401  !CREATE A NEW FILE
401   FORMAT (1X,'CREATE FILE DL0:',$)
      ACCEPT 402,(FILSPC(I),I=1,10)
402   FORMAT (10A1)
      IF (FILSPC(1).EQ.0) GO TO 400
      FILSPC(11)=0
      TYPE 403
403   FORMAT (1X,'NUMBER OF SCANS: ',$)
      ACCEPT *,NRECDS
      IF (NRECDS.LE.0) GO TO 10
      NBLOCK=4.473*FLOAT(NRECDS)+1
      TYPE *,'NBLOCK:',NBLOCK
      OPEN (UNIT=9,NAME=FILSPC,RECORDSIZE=568,TYPE='NEW',
     1ERR=460,FORM='UNFORMATTED',INITIALSIZE=NBLOCK)
```

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```
      TYPE 404
404   FORMAT (1X,'INPUT FILE: DLØ:',$)
      ACCEPT 402,(FILSPC(I),I=1,1Ø)
      FILSPC(11)=Ø
      OPEN (UNIT=8,NAME=FILSPC,RECORDSIZE=177,TYPE='OLD',
     1ERR=47Ø,FORM='UNFORMATTED',READONLY)

      READ (8,ERR=48Ø,END=465) RAW1
      READ (8,ERR=48Ø,END=465) RAW2
      READ (8,ERR=48Ø,END=465) RAW3

      DO 455 I=1,NRECDS

      DO 41Ø J=1,354
      RAW(J)=RAW1(J)
      RAW1(J)=RAW2(J)
41Ø   RAW2(J)=RAW3(J)

      READ (8,ERR=48Ø,END=465) RAW3

C     CONVERSION GOES HERE

      HEADER(1)=RAW(353)          !RECORD #
      HEADER(2)=RAW(3ØØ)          !FLIGHT #
      HEADER(3)=RAW(3Ø2)          !RUN #
      HEADER(4)=RAW(3Ø4)          !TIME, MIN
      HEADER(5)=RAW(3Ø3)          !TIME, .1 SEC
      HEADER(6)=RAW(1)            !XØ, 2Ø M
      HEADER(7)=RAW(2)            !YØ, 2Ø M
      HEADER(8)=RAW(313)          !LAT, DEG
      HEADER(9)=RAW(312)          !LAT, .1 MIN
      HEADER(1Ø)=-RAW(315)             !LONG, DEG
      HEADER(11)=-RAW(314)             !LONG, .1 MIN
      IF (IABS(RAW(3Ø5)).GT.3ØØØ.) RAW(3Ø5)=Ø
      HEADER(12)=8.2357*RAW(3Ø5)       !PALT, 2 FT
      HEADER(13)=RAW(3Ø7)         !RALT, 2 FT
      HEADER(14)=RAW(3Ø8)         !DEW PT, .1 DEG
      HEADER(15)=RAW(3Ø9)         !TEMP, .1 DEG
      HEADER(16)=RAW(31Ø)         !IR TEMP, .1 DEG
      HEADER(17)=RAW(311)         !TOT AIR T, .1 DEG
      HEADER(18)=RAW(4)           !STATUS WORD
      HEADER(19)=RAW(6)           !PROCESSOR STATUS
      HEADER(2Ø)=51.44*RAW(317)        !TAS, .Ø1 M/S
      IF (IABS(RAW(335)).GT.45ØØ) RAW(335)=Ø
      HEADER(21)=6.28*RAW(335) !GS-DOPPLER, .Ø1 M/S
      IF (IABS(RAW(336)).GT.45ØØ) RAW(336)=Ø
      HEADER(22)=6.28*RAW(336) !GS-DOP/ADDAS, .Ø1 M/S
      IF (IABS(RAW(337)).GT.45ØØ) RAW(337)=Ø
      HEADER(23)=6.28*RAW(337) !GS-INS/ADDAS, .Ø1 M/S
      HEADER(24)=RAW(324)         !WEDGE (I), .1 DEG
      HEADER(25)=RAW(325)         !WEDGE (O), .1 DEG
      HEADER(26)=RAW(316)         !THDG, .Ø4395 DEG
      HEADER(27)=RAW(319)         !DRIFT, .Ø4395 DEG
      HEADER(28)=RAW(331)         !TRACK, .Ø4395 DEG
```

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      HEADER(29)=RAW(322)        !PITCH, .04395 DEG
      HEADER(30)=RAW(323)        !ROLL, .04395 DEG
      HEADER(31)=RAW(3)+1800          !LOS DIRN, .1 DEG
      HEADER(32)=RAW(328)        !LOS ELEV, .1 DEG
      HEADER(33)=RAW(332)        !L.O., .01 MHZ
      HEADER(34)=8*RAW(333)           !L.O. OFST, .01 M/S
      HEADER(35)=RAW(306)        !PALT, FINE
      HEADER(36)=0               !MEAN POWER, .01 DB
      HEADER(37)=0               !DRIFT CORN, .01 M/S
      HEADER(38)=0               !SMOTH CORN, .01 M/S
      HEADER(39)=0               !BAD SCAN FLAG
      HEADER(40)=0               !V CORN ADDED, .01 M/S
      HEADER(41)=0               !MEAN V, .01 M/S
      HEADER(42)=6.28*RAW(318)   !GS USED, .01 M/S
      HEADER(43)=5.144*RAW(320)       !INS WIND, .01 M/S
      HEADER(44)=RAW(321)        !INS DIRN, .1 DEG
      HEADER(45)=RAW(326)        !TIME TO POSN, .01 SEC
      HEADER(46)=0               !ACTUAL LOS DIRN, .1 DEG
      HEADER(47)=0               !SPARES FOLLOW
      HEADER(48)=0
      HEADER(49)=0
      HEADER(50)=0
      HEADER(51)=0
      HEADER(52)=0
      HEADER(53)=0
      HEADER(54)=0
      HEADER(55)=0
      HEADER(56)=0

      IF (HEADER(27).GT.4096) HEADER(27)=HEADER(27)-8192
      IF (HEADER(29).GT.4096) HEADER(29)=HEADER(29)-8192
      IF (HEADER(30).GT.4096) HEADER(30)=HEADER(30)-8192
      IF (HEADER(31).GT.1800) HEADER(31)=HEADER(31)-3600
      IF (HEADER(32).GT.1800) HEADER(32)=HEADER(32)-3600

      POWER=0.
      VEL=0.
      DO 415 J=1,20
      POWER=POWER+FLOAT(RAW(3*J+219))*18.4
      VEL=VEL+FLOAT(RAW(3*J+13))*8.
415   CONTINUE
      POWER=POWER/20.
      IF (ABS(POWER).GT.20000.) POWER=20000.
      IF (ABS(VEL).GT.160000.) VEL=0.
      HEADER(36)=POWER
      HEADER(41)=(VEL/20.)

      ALOS=.1*FLOAT(RAW(3))+180.     !LOS DIRECTION, DEG
      THDGC=FLOAT(RAW1(316)-RAW(316))     !THDG CHANGE, .04395 DEG
      IF(THDGC.GT.4096.) THDGC=THDGC-8192.
      IF(THDGC.LT.-4096.) THDGC=THDGC+8192.
      ALOS=ALOS+.75*.04395*THDGC     !ACTUAL LOS DIRN, DEG
      CCOS=16.*COS(ALOS/57.2958)     !Y INCREMENT PER RANGE, 20 M
      CSIN=16.*SIN(ALOS/57.2958)     !X INCREMENT PER RANGE, 20 M
      X0=.1*CSIN+FLOAT(RAW(1)) !X FOR J=0
```

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      Y0=.1*CCOS+FLOAT(RAW(2)) !Y FOR J=0
      HEADER(46)=10.*ALOS

      V1=COEF1*FLOAT(RAW3(319))      !DRIFT CORRECTION
      V2=COEF2*FLOAT(RAW2(319))
      V3=COEF3*FLOAT(RAW1(319))
      V4=COEF4*FLOAT(RAW(319))
      VCORN=FLOAT(HEADER(42))/1383. !CORRECTION TO ADD TO V, .01 M/S
      VCORN=VCORN*(V1+V2+V3+V4)
      IF (ABS(VCORN).GT.2000.) VCORN=0.  !CORRECT IOVFL
      ICORN=VCORN
      HEADER(37)=ICORN
      HEADER(40)=ICORN
      HEADER(41)=HEADER(41)+ICORN

      DO 420 J=1,12
      DO 420 K=1,90
420   DATA(J,K)=0

      DO 430 J=1,90
      TEMP=18.4*FLOAT(RAW(3*J+9))!AMP, .01 DB
      IF (ABS(TEMP).GT.20000.) TEMP=20000.
      DATA(1,J)=TEMP
      TEMP=8.*RAW(3*J+10)+ICORN      !VEL, .01 M/S
      IF (ABS(TEMP).GT.8000.) TEMP=0.
      DATA(2,J)=TEMP
      DATA(3,J)=RAW(3*J+11)          !WIDTH, CODED
      DATA(4,J)=X0+J*CSIN       !EAST DISTANCE
      DATA(5,J)=Y0+J*CCOS       !NORTH DISTANCE
430   CONTINUE

      WRITE (9,ERR=490) HEADER,DATA

455   CONTINUE

456   CLOSE (UNIT=8,ERR=485)
      CLOSE (UNIT=9,ERR=485)
      GO TO 10

460   TYPE *,'ERROR IN OPENING OUTPUT FILE'
      GO TO 10

465   TYPE *,'END OF FILE'
      GO TO 456

470   TYPE *,'ERROR IN OPENING INPUT FILE'
      GO TO 456

480   TYPE *,'READ ERROR'
      GO TO 456

485   TYPE *,'CLOSURE ERROR'
      GO TO 10

490   TYPE *,'WRITE ERROR'
```

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```
      GO TO 456

600   TYPE 914          !EXECUTE PLOT
      ACCEPT *,MATCH         !MATCH THIS STATUS WORD (Ø=ANY)
      IF (MATCH.LT.Ø) GO TO 1Ø

      XFACTR=2ØØØ./(XAXIS*6Ø.)!PUNITS PER SECOND    YFACTR=14ØØ./(FULLS
      A='p'
      TYPE 915,155           !START PLOTTER
      DO 65Ø I1=1,IRECDS

      READ (8,END=66Ø,ERR=67Ø) HEADER,DATA
      NRECD=NRECD+1

      IF (MATCH.EQ.Ø) GOTO 64Ø
      IF ((HEADER(18).AND.24).NE.MATCH) GOTO 65Ø
64Ø   TYPE 916
      TIME=6Ø.DØ*HEADER(4)+.1DØ*HEADER(5)

      IF (ITAP13.EQ.Ø) GO TO 647     !CODE TO FIX TAPE 13
      ISEC=.1*HEADER(5)
      IF (MOD(ISEC,1Ø).EQ.9) TIME=TIME-1.DØ
      IF (MOD(ISEC,1Ø).NE.Ø) GO TO 645
      IF (LAST.NE.Ø) TIME=TIME-1.DØ
      IF (LAST.NE.Ø) ISEC=ISEC-1
      LAST=Ø
      GO TO 646
645   LAST=1
646   CONTINUE
      IF (ISEC.LT.1Ø) TIME=TIME+6Ø.DØ

647   CONTINUE
      IF (TIME.LT.432ØØ.) TIME=TIME+864ØØ.
      X=XFACTR*(TIME-FLEFT)
      Y=(HEADER(NITEM)*FMULT+SHIFT-ZERO)*YFACTR
      IF (X.GT.2ØØØ.) X=2ØØØ.
      IF (Y.GT.14ØØ.) Y=14ØØ.
      IF (Y.LT.Ø.) Y=Ø.
      IF (X.LT.Ø.) A='p'

      CALL GRAPH1(X,Y,A)
      A='q'
65Ø   CONTINUE
      TYPE 919,155   GO TO 1Ø

66Ø   TYPE *,'END OF FILE'
      GO TO 1Ø

67Ø   TYPE *,'READ ERROR'
      GO TO 1Ø

7ØØ   TYPE *,'OUTLINE BOX'
      TYPE 915,155
      CALL GRAPH1(Ø.,Ø.,'p')
      CALL GRAPH1(2ØØØ.,Ø.,'q')
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      CALL GRAPH1(2000.,1400.,'q')
      CALL GRAPH1(0.,1400.,'q')
      CALL GRAPH1(0.,0.,'q')
      TYPE 919,155
      GO TO 10

750   TYPE 751
751   FORMAT(1X,'OPEN FOR READING FILE DL0:',$)
      ACCEPT 752,(FILSPC(I),I=1,10)
752   FORMAT(10A1)
      IF (FILSPC(1).EQ.0) GO TO 750
      FILSPC(11)=0
      TYPE *,'TOTAL RECORDS:'
      ACCEPT *,MAXRCD
      OPEN(UNIT=8,NAME=FILSPC,RECORDSIZE=568,TYPE='OLD',
      1ERR=760,FORM='UNFORMATTED',READONLY)
      NRECD=1
      GO TO 10

760   TYPE *,'CANNOT OPEN FILE'
      GO TO 10

770   CLOSE (UNIT=8,ERR=780)
      TYPE *,'CLOSE FILE'
      GO TO 10
780   TYPE *,'CANNOT CLOSE FILE'
      GO TO 10

802   TYPE *,'FIRST AND LAST RANGE'
      ACCEPT *,MRANGE,NRANGE
      GO TO 10

803   TYPE 908
      ACCEPT *,NITEM        !ITEM TO PLOT
      GO TO 10

804   TYPE 911
      ACCEPT *,IHOUR,MINUTE     !LEFT EDGE INFO
      FLEFT=3600.D0*IHOUR+60.D0*MINUTE
      TYPE 912
      ACCEPT *,XAXIS        !FS IN MINUTES
      TYPE 913
      ACCEPT *,IRECDS           !# RECORDS TO PLOT
      GO TO 10

805   TYPE 910
      ACCEPT *,FMULT,SHIFT      !PLOT FACTOR
      GO TO 10

806   TYPE 909
      ACCEPT *,ZERO,FULLS !PLOT SCALE
      GO TO 10

807   TYPE *,'TAPE 13? (0,1)'
      ACCEPT *,ITAP13
```

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      GO TO 10

808   TYPE *,'COEFFICIENTS 1-4 (.32, .56, .12, -1.0):'
      ACCEPT *,COEF1,COEF2,COEF3,COEF4
      GO TO 10

901   FORMAT (1X,'X=',I6,'0 Y=',I6,'0 N',I2,':',I2,' W',
     1I3,':',I2,'  FLT ',I2,' RUN ',I3,'  TIME ',I2,
     1':',I2,':',F4.1,'  ALT ',I6)
902   FORMAT (1X,'LOS=',F6.1,'  THDG=',F5.1,'  DRIFT=',F5.2,
     1'  LOSE=',F5.1,'  PITCH=',F6.2,'  ROLL=',F6.2)
903   FORMAT (1X,'TAS=',F5.1,'  GSPD=',F5.1,'  WIND=',F5.1,
     1'  WDIR=',F5.1,'  PROC=',O6,'  STATUS=',O6)
904   FORMAT (1X,I5,F6.1,F6.1,I3,I6,'0',I6,'0',F6.2,' ',6F6.2)
905   FORMAT (1X,'AT RECORD',I5,'   COMMAND: ',$)
906   FORMAT (1X,'SPACE FORWARD N RECORDS: ',$)
907   FORMAT (1X,'SPACE BACKWARD N RECORDS: ',$)
908   FORMAT (1X,'PLOT ITEM M: ',$)
909   FORMAT (1X,'ZERO AND FULL-SCALE FOR PLOT: ',$)
910   FORMAT (1X,'MULTIPLIER AND OFFSET: ',$)
911   FORMAT (1X,'LEFT EDGE HOUR, MINUTE: ',$)
912   FORMAT (1X,'FULL SCALE IN MINUTES: ',$)
913   FORMAT (1X,'NUMBER OF RECORDS: ',$)
914   FORMAT (1X,'PLOT CODE TO MATCH (0,8,24): ',$)
915   FORMAT (1X,A1,'.(',$)
916   FORMAT (1X,A1,$)
917   FORMAT (1X,'SPACE TO RECORD N: ',$)
918   FORMAT (1X,5A1,'}')
919   FORMAT (1X,'p}',A1,'.)')
920   FORMAT (1X,I4,I7,I5,':',I2,':',F4.1,4F10.4)
921   FORMAT (1X,'LO:',F6.2,'  OFFSET:',F6.1,'  GS:',3F6.1,
     1'  DRIFT: ',F5.2)
922   FORMAT (1X,'LOSA=',F6.1,' POWER=',F6.1,' VAVG=',F6.2,
     1' VCOR=',F6.2,' RECORD=',I5)
999   CALL CLOSEC(ICHAN)
      STOP 'EXIT 99'
      END
```

```
      PROGRAM FEDIT
C     EDIT FILES CREATED BY FCNVT
C     REVISED 10-30-81 AND 11-5-81

      INTEGER*2 H1(56),H2(56),H3(56),H4(56),H5(56),
      1D1(12,90),D2(12,90),D3(12,90),D4(12,90),D5(12,90)
      BYTE INPFIL(11),OUTFIL(11)

      K=0        !RING BUFFER INDEX
      TYPE 101
101   FORMAT(1X,'INPUT FILE DL0:',$)
      ACCEPT 102,(INPFIL(I),I=1,10)
102   FORMAT(10A1)
      INPFIL(11)=0
      OPEN (UNIT=8,NAME=INPFIL,RECORDSIZE=568,TYPE='OLD',
      1ERR=900,FORM='UNFORMATTED',READONLY)

104   TYPE 105
105   FORMAT(1X,'NUMBER OF RECORDS: ',$)
      ACCEPT *,NRECDS
      IF (NRECDS.LT.0) GOTO 104
      NBLK=4.473*NRECDS+1
      TYPE *,'NBLK=',NBLK
      TYPE 110
110   FORMAT(1X,'OUTPUT FILE DL0:',$)
      ACCEPT 102,(OUTFIL(I),I=1,10)
      OUTFIL(11)=0
      OPEN (UNIT=9,NAME=OUTFIL,RECORDSIZE=568,TYPE='NEW',
      1ERR=910,FORM='UNFORMATTED',INITIALSIZE=NBLK)

      READ (8,ERR=920,END=800) H1,D1
      CALL FEDIT1(D1,H1(36))
      READ (8,ERR=920,END=800) H2,D2
      CALL FEDIT1(D2,H2(36))
      READ (8,ERR=920,END=800) H3,D3
      CALL FEDIT1(D3,H3(36))
      READ (8,ERR=920,END=800) H4,D4
      CALL FEDIT1(D4,H4(36))

200   K=K+1
      IF (K.GT.5) K=1
      GOTO (210,220,230,240,250) K
      STOP 'ILLEGAL K'

210   READ (8,ERR=920,END=800) H5,D5
      CALL FEDIT1(D5,H5(36))
      CALL FEDIT2(D1,D3,D5)
      WRITE (9,ERR=940) H3,D3
      GOTO 200

220   READ (8,ERR=920,END=800) H1,D1
      CALL FEDIT1(D1,H1(36))
      CALL FEDIT2(D2,D4,D1)
      WRITE (9,ERR=940) H4,D4
```

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```
      GOTO 200

230   READ (8,ERR=920,END=800) H2,D2
      CALL FEDIT1(D2,H2(36))
      CALL FEDIT2(D3,D5,D2)
      WRITE (9,ERR=940) H5,D5
      GOTO 200

240   READ (8,ERR=920,END=800) H3,D3
      CALL FEDIT1(D3,H3(36))
      CALL FEDIT2(D4,D1,D3)
      WRITE (9,ERR=940) H1,D1
      GOTO 200

250   READ (8,ERR=920,END=800) H4,D4
      CALL FEDIT1(D4,H4(36))
      CALL FEDIT2(D5,D2,D4)
      WRITE (9,ERR=940) H2,D2
      GOTO 200

800   CLOSE (UNIT=8,ERR=930)
      CLOSE (UNIT=9,ERR=930)
      STOP 'COMPLETED'

900   TYPE *,'ERROR OPENING INPUT FILE'
      GO TO 800

910   TYPE *,'ERROR OPENING OUTPUT FILE'
      GO TO 800

920   TYPE *,'READ ERROR'
      GO TO 800

930   STOP 'CLOSURE ERROR'

940   TYPE *,'WRITE ERROR'
      GO TO 800

      END
```

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```
      SUBROUTINE FEDIT1(D,MSNR)

C     LOAD ESTIMATES OF SIGMA INTO D
C     REVISED 11-Ø1-81 AND 11-5-81

      INTEGER*2 D(12,9Ø),SIGMA(6Ø),MSNR,SNR

      DATA SIGMA/3157,1571,1Ø39,771,6Ø9,499,42Ø,36Ø,313,
     1275,244,218,196,177,161,147,134,123,113,1Ø5,97,9Ø,
     184,78,73,68,64,6Ø,57,54,51,48,45,43,41,39,37,35,33,
     132,31,29,28,27,26,25,24,23,22,21,2Ø,2Ø,19,18,18,17,
     116,16,15,15/  !1-SIGMA VEL ERROR PER .2 DB SNR

      DO 2ØØ I=1,9Ø  !I IS RANGE INDEX

      SNR=(D(1,I)-MSNR+2ØØ)/2Ø
      IF (SNR.LT.1) SNR=1
      IF (SNR.GT.6Ø) SNR=6Ø
      D(6,I)=SIGMA(SNR)
2ØØ   CONTINUE

      RETURN

      END
```

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```
      SUBROUTINE FEDIT2(E1,E2,E3)

C     PERFORM MAIN EDITING FUNCTION
C     REVISED 11-01-81 AND 11-05-81

      INTEGER*2 E1(12,90),E2(12,90),E3(12,90),V(9),SIGMA,
     1VEL,S(9),V1(9),VMEAN

      DO 200 IRANGE=1,89   !I IS RANGE INDEX

      VEL=E2(2,IRANGE)     !V,S OF CENTRAL ELEMENT
      SIGMA=E2(6,IRANGE)   !CHECK FOR SMALL SIGMA (NO EDIT)
      IF (SIGMA.LT.40) GOTO 200

      IF (IRANGE.GT.1) GO TO 50

      DO 20 J=1,3          !1ST RANGE IS SPECIAL CASE
      JP3=J+3
      JP6=J+6
      V1(J)=E1(2,J)
      S(J)=E1(6,J)
      V1(JP3)=E2(2,J)
      S(JP3)=E2(6,J)
      V1(JP6)=E3(2,J)
      S(JP6)=E3(6,J)
20    CONTINUE
      GO TO 100

50    IM1=IRANGE-1
      V1(1)=E1(2,IM1)
      S(1)=E1(6,IM1)
      V1(2)=E2(2,IM1)
      S(2)=E2(6,IM1)
      V1(3)=E3(2,IM1)
      S(3)=E3(6,IM1)

      IM=IM1+1
      V1(4)=E1(2,IM)
      S(4)=E1(6,IM)
      V1(5)=E2(2,IM)
      S(5)=E2(6,IM)
      V1(6)=E3(2,IM)
      S(6)=E3(6,IM)

      IP1=IM+1
      V1(7)=E1(2,IP1)
      S(7)=E1(6,IP1)
      V1(8)=E2(2,IP1)
      S(8)=E2(6,IP1)
      V1(9)=E3(2,IP1)
      S(9)=E3(6,IP1)

100   ITHR=300          !3 M/S THRESHOLD FOR USE

105   K=0
```

```
      DO 110 J=1,9
      IF (S(J).GT.ITHR) GOTO 110
      K=K+1
      V(K)=V1(J)
110   CONTINUE
      IF (K.GT.0) GOTO 120
      ITHR=ITHR*2
      IF (ITHR.GT.1200) GOTO 200
      GOTO 105          !TRY AGAIN IF K=0

120   M=1               !SORT V'S THAT PASSED TEST
      IF (K.LT.5) GOTO 170      !NO SORT REQUIRED
      KM1=K-1
      DO 150 J1=1,KM1
      DO 140 J=1,KM1
      IF (V(J).LT.V(J+1)) GOTO 140
      ITEMP=V(J)
      V(J)=V(J+1)
      V(J+1)=ITEMP
140   CONTINUE          !CAN CONDENSE THIS ROUTINE
150   CONTINUE

      MIN=10000 !MINIMIZE V(J)-V(J+3)
      KM3=K-3
      DO 160 J=1,KM3
      ISUM=V(J)-V(J+3)
      IF (ISUM.GT.MIN) GOTO 160
      MIN=ISUM
      M=J
160   CONTINUE

170   IF (K.GT.4) K=4      !FIND MEAN OF MOST LIKELY V'S
      SUM=0.
      MPKM1=M+K-1
      DO 180 J=M,MPKM1
      SUM=SUM+FLOAT(V(J))
180   CONTINUE
      VMEAN=SUM/FLOAT(K)

      IDIFF=IABS(VMEAN-VEL)
      IF (IDIFF.LT.400) GOTO 200
      IF (IDIFF.LT.2*SIGMA) GOTO 200
      E2(7,IRANGE)=E2(6,IRANGE)     !SAVE FIRST ESTIMATE
      E2(6,IRANGE)=IDIFF-200

200   CONTINUE

      RETURN

      END
```

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```
      PROGRAM FSMOTH
C     SMOOTH FILES CREATED BY FEDIT
C     REVISED 11-2-81 AND 11-5-81

      INTEGER*2 H1(56),H2(56),H3(56),H4(56),H5(56),H6(56),H7(56),
     1H8(56),H9(56),D1(12,90),D2(12,90),D3(12,90),D4(12,90),
     1D5(12,90),D6(12,90),D7(12,90),D8(12,90),D9(12,90)
      BYTE INPFIL(11),OUTFIL(11)

      K=0         !RING BUFFER INDEX
      K1=0
      TYPE 101
101   FORMAT(1X,'INPUT FILE DL0:',$)
      ACCEPT 102,(INPFIL(I),I=1,10)
102   FORMAT(10A1)
      INPFIL(11)=0
      OPEN (UNIT=8,NAME=INPFIL,RECORDSIZE=568,TYPE='OLD',
     1ERR=900,FORM='UNFORMATTED',READONLY)

104   TYPE 105
105   FORMAT(1X,'NUMBER OF RECORDS: ',$)
      ACCEPT *,NRECDS
      IF (NRECDS.LT.0) GO TO 104
      NBLK=4.473*NRECDS+1
      TYPE *,'NBLK=',NBLK
      TYPE 110
110   FORMAT(1X,'OUTPUT FILE DL0:',$)
      ACCEPT 102,(OUTFIL(I),I=1,10)
      OUTFIL(11)=0
      OPEN (UNIT=9,NAME=OUTFIL,RECORDSIZE=568,TYPE='NEW',
     1ERR=910,FORM='UNFORMATTED',INITIALSIZE=NBLK)

      READ (8,ERR=920,END=800) H1,D1
      READ (8,ERR=920,END=800) H2,D2
      READ (8,ERR=920,END=800) H3,D3
      READ (8,ERR=920,END=800) H4,D4
      READ (8,ERR=920,END=800) H5,D5
      READ (8,ERR=920,END=800) H6,D6
      READ (8,ERR=920,END=800) H7,D7
      READ (8,ERR=920,END=800) H8,D8

200   K=K+1
      K1=K1+1
      TYPE *,'SCAN IN PROCESS:',K1
      IF (K.GT.9) K=1
      GO TO (210,220,230,240,250,260,270,280,290) K
      STOP 'ILLEGAL K'

210   READ (8,ERR=920,END=800) H9,D9
      CALL FSMOT1(D1,D3,D5,D7,D9)
      WRITE (9,ERR=940) H5,D5
      GO TO 200

220   READ (8,ERR=920,END=800) H1,D1
```


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      CALL FSMOT1(D2,D4,D6,D8,D1)
      WRITE (9,ERR=940) H6,D6
      GO TO 200

230   READ (8,ERR=920,END=800) H2,D2
      CALL FSMOT1(D3,D5,D7,D9,D2)
      WRITE (9,ERR=940) H7,D7
      GO TO 200

240   READ (8,ERR=920,END=800) H3,D3
      CALL FSMOT1(D4,D6,D8,D1,D3)
      WRITE (9,ERR=940) H8,D8
      GO TO 200

250   READ (8,ERR=920,END=800) H4,D4
      CALL FSMOT1(D5,D7,D9,D2,D4)
      WRITE (9,ERR=940) H9,D9
      GO TO 200

260   READ (8,ERR=920,END=800) H5,D5
      CALL FSMOT1(D6,D8,D1,D3,D5)
      WRITE (9,ERR=940) H1,D1
      GO TO 200

270   READ (8,ERR=920,END=800) H6,D6
      CALL FSMOT1(D7,D9,D2,D4,D6)
      WRITE (9,ERR=940) H2,D2
      GO TO 200

280   READ (8,ERR=920,END=800) H7,D7
      CALL FSMOT1(D8,D1,D3,D5,D7)
      WRITE (9,ERR=940) H3,D3
      GO TO 200

290   READ (8,ERR=920,END=800) H8,D8
      CALL FSMOT1(D9,D2,D4,D6,D8)
      WRITE (9,ERR=940) H4,D4
      GO TO 200

800   CLOSE (UNIT=8,ERR=930)
      CLOSE (UNIT=9,ERR=930)
      STOP 'COMPLETED'

900   TYPE *,'ERROR OPENING INPUT FILE'
      GO TO 800

910   TYPE *,'ERROR OPENING OUTPUT FILE'
      GO TO 800

920   TYPE *,'READ ERROR'
      GO TO 800

930   STOP 'CLOSURE ERROR'

940   TYPE *,'WRITE ERROR'
      GOTO 800
      END
```

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```
      SUBROUTINE FSMOT1(D1,D2,D3,D4,D5)

C     PERFORMS SMOOTHING ON ONE SCAN FROM FSMOTH
C     REVISED 03-NOV-81 AND 05-NOV-81

      INTEGER*2 D1(12,90),D2(12,90),D3(12,90),D4(12,90),D5(12,90)
      REAL*4 B(25),B1(25),B2(5),G(25,5),G1(25,5),G2(25),G4(15),
     1C1(5),R(25),W(25),X0,Y0,DX,DY,SUM,S1,S2,T1,T2,T3,STDEV

      INTEGER*2 IN(5,5)     !POINTER TO SYMMETRIC MATRIX G4
      DATA IN/1,2,4,7,11,2,3,5,8,12,4,5,6,
     19,13,7,8,9,10,14,11,12,13,14,15/

      T1=10000.              !THRESHOLDS
      T2=2.5
      T3=1.0
      IER=0

      DO 800 IRANGE=1,87

      IF (IRANGE.GT.3) GO TO 40
      IF (IRANGE.EQ.3) GO TO 30
      I1=1
      I2=5
      IF (IRANGE.EQ.2) GO TO 20

10    ITEST=11          !RANGE=1, LOAD SPECIAL G2
      DATA G2/.7,.6,.5,.3,.2,.9,.8,.6,.5,.4,.95,.9,
     1.7,.6,.5,.9,.8,.6,.5,.4,.7,.6,.5,.3,.2/
      GO TO 100

20    ITEST=12          !RANGE=2, LOAD SPECIAL G2
      DATA G2/.6,.7,.6,.5,.3,.8,.9,.8,.6,.5,.9,.95,
     1.9,.7,.6,.8,.9,.8,.6,.5,.6,.7,.6,.5,.3/
      GO TO 100

30    ITEST=13          !RANGE=3, LOAD NORMAL G2
      DATA G2/.5,.6,.7,.6,.5,.6,.8,.9,.8,.6,.7,.9,
     1.95,.9,.7,.6,.8,.9,.8,.6,.5,.6,.7,.6,.5/

40    I1=IRANGE-2            !SET UP RANGE OF INDEX
      I2=IRANGE+2            !FOR NORMAL RANGES

100   X0=D3(4,IRANGE)              !X,Y OF RELEVANT ELEMENT
      Y0=D3(5,IRANGE)

      DO 200 I=I1,I2         !LOAD G,B AND W MATRICES

      J1=I-I1+1         !SET UP INDICES
      J2=J1+5
      J3=J2+5
      J4=J3+5
      J5=J4+5

      B(J1)=D1(2,I)/100.   !B IS RAW VELOCITIES
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      B(J2)=D2(2,I)/100.
      B(J3)=D3(2,I)/100.
      B(J4)=D4(2,I)/100.
      B(J5)=D5(2,I)/100.

      W(J1)=100./D1(6,I)  !W IS 1/STD DEVNS
      W(J2)=100./D2(6,I)
      W(J3)=100./D3(6,I)
      W(J4)=100./D4(6,I)
      W(J5)=100./D5(6,I)

      DX=D1(4,I)-X0       !FIRST POINT
      DY=D1(5,I)-Y0
      G(J1,1)=DX**2
      G(J1,2)=DX
      G(J1,3)=DY**2
      G(J1,4)=DY
      G(J1,5)=1.

      DX=D2(4,I)-X0       !SECOND POINT
      DY=D2(5,I)-Y0
      G(J2,1)=DX**2
      G(J2,2)=DX
      G(J2,3)=DY**2
      G(J2,4)=DY
      G(J2,5)=1.

      DX=D3(4,I)-X0       !THIRD POINT
      DY=D3(5,I)-Y0
      G(J3,1)=DX**2
      G(J3,2)=DX
      G(J3,3)=DY**2
      G(J3,4)=DY
      G(J3,5)=1.

      DX=D4(4,I)-X0       !FOURTH POINT
      DY=D4(5,I)-Y0
      G(J4,1)=DX**2
      G(J4,2)=DX
      G(J4,3)=DY**2
      G(J4,4)=DY
      G(J4,5)=1.

      DX=D5(4,I)-X0       !FIFTH POINT
      DY=D5(5,I)-Y0
      G(J5,1)=DX**2
      G(J5,2)=DX
      G(J5,3)=DY**2
      G(J5,4)=DY
      G(J5,5)=1.

200   CONTINUE

      IF (W(ITEST).GT.T3) W(ITEST)=W(ITEST)*T2
```

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210   SUM=Ø.                    !SUM WEIGHTS
      DO 22Ø I=1,25
220   SUM=SUM+W(I)

      IF (SUM.LT.T1) GO TO 3ØØ  !EXIT IF THRESHOLD NOT REACHED

      DO 23Ø I=1,25
230   W(I)=W(I)*G2(I)           !CONVOLVE WEIGHTS
      GO TO 21Ø

300   CONTINUE

      DO 31Ø I=1,25             !WEIGHT LSQ PROBLEM WITH W
      B1(I)=B(I)*W(I)
      DO 31Ø    J=1,5
310   G1(I,J)=G(I,J)*W(I)

      DO 32Ø I=1,5              !REPLACES GTPRD
      SUM=Ø.
      DO 315 J=1,25
315   SUM=SUM+G1(J,I)*B1(J)
320   B2(I)=SUM

      L=Ø                       !G4 IS G1T*G1
      DO 33Ø J=1,5                   !THIS ROUTINE REPLACES MATA
      DO 33Ø I=1,J
      L=L+1
      SUM=Ø.
      DO 325 K=1,25
325   SUM=SUM+G1(K,I)*G1(K,J)
330   G4(L)=SUM

      CALL SINV(G4,5,.ØØØ1,IER)     !G4 IS INVERTED

      DO 36Ø I=1,5                   !REPLACES MPRD
      SUM=Ø.
      DO 355 J=1,5
355   SUM=SUM+G4(IN(I,J))*B2(J)
360   C1(I)=SUM

      DO 55Ø I=1,5
      J=I+6                !OUTPUT COEFFICIENTS
      COEF=C1(I)*1ØØØØ.
      IF (I.EQ.5) COEF=COEF/1ØØ.     !VEL * 1.Ø
      IF (COEF.GT.32767.) COEF=32767.
      IF (COEF.LT.-32767.) COEF=-32767.
550   D3(J,IRANGE)=COEF

      SUM=Ø.                    !FIND MEAN-SQ ERROR IN SOLUTION
      DO 61Ø I=1,25
      SUM1=-B1(I)
      DO 6Ø5 J=1,5
605   SUM1=SUM1+G1(I,J)*C1(J)   !G1*C1=RESULTANT VECTOR R
610   SUM=SUM+SUM1**2
```

```
      S1=Ø.                            !FIND COV MATRIX DIAG SUM
      S2=Ø.
      DO 62Ø I=1,4
      S1=S1+ABS(G4((I*(I+1))/2))
62Ø   S2=S2+ABS(C1(I))       !SURFACE VARIATION
      S1=S1+ABS(G4(15))

      STDEV=SQRT(.2*S1*SUM+2Ø.*S2*S2)
      STDEV=STDEV*1ØØ.
      IF (STDEV.GT.32767.) STDEV=32767.
      D3(12,IRANGE)=STDEV

8ØØ   CONTINUE

      RETURN

      END
```

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```
      PROGRAM FGRID

C     REDUCE FILES FROM FSMOTH TO GRIDPOINTS
C     REVISED NOV 9-11 81

      INTEGER*2 H1(56),H2(56),H3(56),H4(56),H5(56),
     1D1(12,90),D2(12,90),D3(12,90),D4(12,90),D5(12,90)
      INTEGER*2 OUT(30,20,10),SOURCE,PAVG
      REAL*4 Z(2,4)
      BYTE INPFIL(11),OUTFIL(11)

      COMMON OUT,X0,Y0,UCON,VCON,Z,RES,IFLAG,IFORD,
     1SOURCE,PAVG,ALOS,SCALE,ITHRSH,MRANGE,NRANGE

      NRECD=0
50    TYPE 52,NRECD                 !COMMAND DECODER
52    FORMAT (1X,'AT RECORD',I6,'    COMMAND: ',$)
      ACCEPT *,ICOMD
      IF (ICOMD.LT.1) GOTO 50
      IF (ICOMD.GT.7) GOTO 50             !ILLEGAL COMMANDS
      GOTO (100,300,500,600,400,800,700) ICOMD
      STOP 'ILLEGAL COMMAND'

100   K=0               !RING BUFFER INDEX
      K1=0              !EXECUTE GRIDDING OPERATION
      TYPE 150
150   FORMAT(1X,'NUMBER OF SCANS:',$)
      ACCEPT *,NUMSCN
      TYPE 152
152   FORMAT(1X,'STARTING X0,Y0 - METERS: ',$)
      ACCEPT *,X0,Y0
      X0=X0/20.                    ! **COMMAND LIST**
      Y0=Y0/20.
      TYPE 153
153   FORMAT(1X,'INITIAL AND FINAL RANGE (1-30): ',$)
      ACCEPT *,MRANGE,NRANGE
      TYPE 154                     ! 1 - EXECUTE GRIDDING
154   FORMAT(1X,'AZIMUTH, DEG: ',$)          ! 2 - OPEN INPUT FILE
      ACCEPT *,THETA                    ! 3 - SPACE TO RECORD N
      UCON=SIN(THETA/57.2958)                ! 4 - DRAW BOX
      VCON=COS(THETA/57.2958)                ! 5 - CLOSE INPUT FILE
      TYPE 156                     ! 6 - WRITE OUTPUT FILE
156   FORMAT(1X,'RESOLUTION, METERS: ',$)      ! 7 - STOP PROGRAM
      ACCEPT *,RES
      RES=RES/20.
      TYPE 158
158   FORMAT(1X,'PLOT? (0,1): ',$)          !0 => NO PLOT
      ACCEPT *,IFLAG
      TYPE 159
159   FORMAT(1X,'SMOOTHED DATA? (0 OR 1):',$) !1=>SMOOTHED DATA
      ACCEPT *,SOURCE
      IF (IFLAG.LT.1) GOTO 170 !PLOTTER NEEDED?

      TYPE 162                !SET UP PLOTTER PARMS
162   FORMAT(1X,'M/S PER INCH OF VECTOR: ',$)
```

```
      ACCEPT *,SCALE
      TYPE 164
164   FORMAT (1X,'ERROR THRESHOLD (M/S): ',$)
      ACCEPT *,THRESH
      ITHRSH=THRESH*100.
      TYPE 168,155
168   FORMAT(1X,A1,'.(',$)                     !TURN ON PLOTTER

170   READ (8,ERR=920,END=800) H1,D1
      READ (8,ERR=920,END=800) H2,D2
      READ (8,ERR=920,END=800) H3,D3
      READ (8,ERR=920,END=800) H4,D4
      NRECD=NRECD+4

      DO 180 I1=1,30                  !ZERO OUTPUT MATRIX
      DO 180 I2=1,20
      DO 180 I3=1,10
180   OUT(I1,I2,I3)=0

200   K=K+1                           !MAIN LOOP RETURN
      IF (K.GT.5) K=1
      K1=K1+1
      IF (K1.GT.NUMSCN) GOTO 800
      GOTO (210,220,230,240,250) K
      STOP 'ILLEGAL K'

210   READ (8,ERR=920,END=800) H5,D5
      NRECD=NRECD+1
      IFORD=H3(18)                    !STATUS WORD
      PAVG=H3(36)                     !MEAN POWER
      ALOS=H3(46)                     !LOS ANGLE
      CALL FGRID1(D1,D3,D5)
      GOTO 200

220   READ (8,ERR=920,END=800) H1,D1
      NRECD=NRECD+1
      IFORD=H4(18)
      PAVG=H4(36)
      ALOS=H4(46)
      CALL FGRID1(D2,D4,D1)
      GOTO 200

230   READ (8,ERR=920,END=800) H2,D2
      NRECD=NRECD+1
      IFORD=H5(18)
      PAVG=H5(36)
      ALOS=H5(46)
      CALL FGRID1(D3,D5,D2)
      GOTO 200

240   READ (8,ERR=920,END=800) H3,D3
      NRECD=NRECD+1
      IFORD=H1(18)
      PAVG=H1(36)
      ALOS=H1(46)
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      CALL FGRID1(D4,D1,D3)
      GOTO 200

250   READ (8,ERR=920,END=800) H4,D4
      NRECD=NRECD+1
      IFORD=H2(18)
      PAVG=H2(36)
      ALOS=H2(46)
      CALL FGRID1(D5,D2,D4)
      GOTO 200

300   TYPE 301               !COMMAND 2 - OPEN FILE
301   FORMAT(1X,'INPUT FILE DL0:',$)
      ACCEPT 302,(INPFIL(I),I=1,10)
302   FORMAT(10A1)
      INPFIL(11)=0
      OPEN (UNIT=8,NAME=INPFIL,RECORDSIZE=568,TYPE='OLD',
     1ERR=900,FORM='UNFORMATTED',READONLY)
      GOTO 50

400   CLOSE (UNIT=8,ERR=930)          !COMMAND 5 - CLOSE FILE
      TYPE *,'CLOSE INPUT FILE'
      GOTO 50

500   TYPE 502
502   FORMAT (1X,'SPACE TO RECORD N: ',$)
      ACCEPT *,NRECD1
      IF (NRECD1.EQ.NRECD) GOTO 50
      IF (NRECD1.LT.1) GOTO 50
      IF (NRECD1.LT.NRECD) GOTO 550 !BACKSPACE
      NUMSPC=NRECD1-NRECD
      DO 520 N=1,NUMSPC
      READ (8,ERR=920,END=800) H1,D1
      NRECD=NRECD+1
520   CONTINUE
      GOTO 50

550   NUMSPC=NRECD-NRECD1        !BACKSPACE REQD
      DO 570 N=1,NUMSPC
      BACKSPACE 8
      NRECD=NRECD-1
570   CONTINUE
      GOTO 50

600   TYPE *,'OUTLINE BOX'
      TYPE 168,155
      CALL GRAPH1(0.,0.,'p')
      CALL GRAPH1(2000.,0.,'q')
      CALL GRAPH1(2000.,1400.,'q')
      CALL GRAPH1(0.,1400.,'q')
      CALL GRAPH1(0.,0.,'q')
      TYPE 822,155
      GOTO 50

700   STOP 'COMPLETED'
```

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800  IF (IFLAG.LT.1) GOTO 820 !PLOTTER ACTIVE?
     TYPE 822,155
822  FORMAT(1X,'p}',A1,'.)')        !TURN OFF PLOTTER
     IFLAG=0

820  TYPE 801               !WRITE OUTPUT FILE IF REQD
801  FORMAT(1X,'WRITE OUTPUT FILE? (0,1): ',$)
     ACCEPT *,IWRITE
     IF (IWRITE.NE.1) GOTO 850     !NO FILE WRITTEN
     TYPE 802
802  FORMAT(1X,'OUTPUT FILENAME DL0:',$)
     ACCEPT 302,(OUTFIL(I),I=1,10)
     OUTFIL(11)=0
     OPEN (UNIT=9,NAME=OUTFIL,RECORDSIZE=3000,TYPE='NEW',
     1ERR=910,FORM='UNFORMATTED',INITIALSIZE=25)
     WRITE (9,ERR=940) OUT
     CLOSE (UNIT=9,ERR=930)
     GOTO 50

850  TYPE 851
851  FORMAT(1X,'PRINT RESULTS (0,1)? ',$)
     ACCEPT *,IWRITE
     IF (IWRITE.NE.1) GOTO 50 !NO PRINT RESULTS
     TYPE 855
855  FORMAT(1X,'ITEM (1-10): ',$)
     ACCEPT *,NITEM
     TYPE *,'UI,UF,VI,VF (PRINT LIMITS):'
     ACCEPT *,IUI,IUF,IVI,IVF

     DO 870 IU=IUI,IUF
     PRINT 860,(OUT(IU,IV,NITEM),IV=IVI,IVF)
860  FORMAT(1X,20I6)
870  CONTINUE
     PRINT *
     PRINT *
     GOTO 50

900  TYPE *,'ERROR OPENING INPUT FILE'
     GO TO 50

910  TYPE *,'ERROR OPENING OUTPUT FILE'
     GO TO 820

920  TYPE *,'READ ERROR'
     GO TO 800

930  TYPE *,'CLOSURE ERROR'
     GOTO 50

940  TYPE *,'WRITE ERROR'
     GO TO 50

     END
```

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```
      SUBROUTINE FGRID1(D1,D2,D3)

C     REDUCE TO GRIDPOINTS DATA FROM FGRID
C     REVISED NOV 9-11 81

      INTEGER*2 D1(12,90),D2(12,90),D3(12,90),OUT(30,20,10),
     1SOURCE,PAVG
      REAL*4 Z(2,4)

      COMMON OUT,X0,Y0,UCON,VCON,Z,RES,IFLAG,
     1IFORD,SOURCE,PAVG,ALOS,SCALE,ITHRSH,MRANGE,NRANGE
      COMMON /LOOP/X,Y

      IFD=0                          !FORWARD SCAN?
      IF((IFORD.AND.24).EQ.24) IFD=5

      DO 800 IRANGE=MRANGE,NRANGE    !MAIN RANGE LOOP

      IM=IRANGE-1                    !TRANSFORM X,Y TO U,V
      IP=IRANGE+1                    !AT CORNERS OF 3X3 REGION
      CALL FGRID2(D1(4,IM),D1(5,IM),1)
      CALL FGRID2(D1(4,IP),D1(5,IP),2)
      CALL FGRID2(D3(4,IM),D3(5,IM),3)
      CALL FGRID2(D3(4,IP),D3(5,IP),4)

      UMIN=AMIN1(Z(1,1),Z(1,2),Z(1,3),Z(1,4)) !FIND EXTREMES OF U,V
      UMAX=AMAX1(Z(1,1),Z(1,2),Z(1,3),Z(1,4))
      VMIN=AMIN1(Z(2,1),Z(2,2),Z(2,3),Z(2,4))
      VMAX=AMAX1(Z(2,1),Z(2,2),Z(2,3),Z(2,4))

      IF (UMIN.LT.1.) UMIN=1.        !CHECK LEGAL LIMITS
      IF (VMIN.LT.1.) VMIN=1.
      IF (UMAX.LT.1.) GOTO 800
      IF (VMAX.LT.1.) GOTO 800

      IU1=UMIN                 !SET LIMITS OF POSSIBLE GRID PTS
      IV1=VMIN
      IU2=UMAX+1.
      IV2=VMAX+1.
      IF (IU2.GT.30) IU2=30
      IF (IV2.GT.20) IV2=20
      IF (IU1.GT.30) GOTO 800        !IGNORE IF OUT OF RANGE
      IF (IV1.GT.20) GOTO 800

      DO 700 IU=IU1,IU2              !GRIDPOINT LOOP
      DO 700 IV=IV1,IV2

      X=X0+(IU*UCON-IV*VCON)*RES     !GRID POINTS TO X-Y COORDS
      Y=Y0+(IU*VCON+IV*UCON)*RES

      DMIN=FGRID3(D2(4,IRANGE),D2(5,IRANGE))

      DO 300 I=IM,IP
      DIST=FGRID3(D1(4,I),D1(5,I))
      IF (DIST.LT.DMIN) GOTO 700     !SKIP GRIDPOINT IF ANOTHER
```

```
      DIST=FGRID3(D2(4,I),D2(5,I))  !MEASUREMENT IS CLOSER
      IF (DIST.LT.DMIN) GOTO 700
      DIST=FGRID3(D3(4,I),D3(5,I))
      IF (DIST.LT.DMIN) GOTO 700

300   CONTINUE  !IF THIS POINT IS REACHED THE POINT AT
C               !D2(IRANGE) IS CLOSEST TO GRIDPOINT IU,IV

      OUT(IU,IV,1+IFD)=D2(1,IRANGE)-PAVG !AMP-NOISE
      OUT(IU,IV,3+IFD)=D2(3,IRANGE)      !WIDTH  OUT(IU,IV,5+IFD)=ALO!
      IF (SOURCE.GT.0) GOTO 400          !GOTO 400 IF SMOOTHED
      OUT(IU,IV,2+IFD)=D2(2,IRANGE)      !RAW VELOCITY
      OUT(IU,IV,4+IFD)=D2(6,IRANGE)      !EDIT SIGMA
      GOTO 500                      !EXIT TO PLOT TEST

400   DX=X-D2(4,IRANGE)             !X,Y DIFFERENCES
      DY=Y-D2(5,IRANGE)
      VEL=DX*(D2(8,IRANGE)+DX*D2(7,IRANGE))    !QUADRATIC SURFACE
      VEL=VEL+DY*(D2(10,IRANGE)+DY*D2(9,IRANGE))
      OUT(IU,IV,2+IFD)=.01*VEL+D2(11,IRANGE)  !SMOOTHED VELOCITY
      OUT(IU,IV,4+IFD)=D2(12,IRANGE)          !SMOOTHED SIGMA

500   IF (IFLAG.LT.1) GOTO 700      !GOTO 700 IF NO PLOT,
      IF(OUT(IU,IV,4).EQ.0) GOTO 700          !OR IF EITHER SIGMA
      IF(OUT(IU,IV,9).EQ.0) GOTO 700          !IS ZERO,
      IF(OUT(IU,IV,4).GT.ITHRSH) GOTO 700     !OR IF AFT OR FORWARD
      IF(OUT(IU,IV,9).GT.ITHRSH) GOTO 700     !SCANS FAILS TEST

      ALP=OUT(IU,IV,5)/572.958      !LOOK ANGLES
      BET=OUT(IU,IV,10)/572.958
      V1=OUT(IU,IV,2)/100.               !AND RADIAL VELOCITIES
      V2=OUT(IU,IV,7)/100.
      SINBMA=SIN(BET-ALP)
      XX=(V1*COS(BET)-V2*COS(ALP))/SINBMA     !X,Y FOR PHI=90 DEG
      YY=(V2*SIN(ALP)-V1*SIN(BET))/SINBMA
      UU=YY*VCON+XX*UCON            !U,V COORDS IN M/S
      VV=YY*UCON-XX*VCON

      DX=100.*UU/SCALE              !VECTOR HALF-LENGTHS
      DY=100.*VV/SCALE
      IF (ABS(DX).GT.400.) GOTO 700      !EXIT IF VECTOR TOO LONG
      IF (ABS(DY).GT.400.) GOTO 700
      X=60.*IU+100.-DX              !ORIGIN OF VECTOR
      Y=60.*IV+100.-DY
      CALL GRAPH1(X,Y,'p')               !MOVE TO ORIGIN
      X=X+2.*DX
      Y=Y+2.*DY
      CALL GRAPH1(X,Y,'q')               !PLOT BODY OF VECTOR
      X=X-.5*DX-.2*DY
      Y=Y-.5*DY+.2*DX
      CALL GRAPH1(X,Y,'q')               !PLOT BARB

700   CONTINUE

800   CONTINUE
      RETURN
      END
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```
      SUBROUTINE FGRID2(X,Y,I)

C     TRANSFORM X,Y COORDINATES INTO U,V COORDINATES
C     REVISED 9-NOV-81

      INTEGER*2 OUT(30,20,10),SOURCE,PAVG,X,Y
      REAL*4 Z(2,4)
      COMMON OUT,X0,Y0,UCON,VCON,Z,RES,IFLAG,IFORD,
     1SOURCE,PAVG,ALOS,SCALE,ITHRSH

      Z(1,I)=((X-X0)*UCON+(Y-Y0)*VCON)/RES
      Z(2,I)=((Y-Y0)*UCON-(X-X0)*VCON)/RES
      RETURN

      END




      REAL FUNCTION FGRID3(X1,Y1)

C     CALCULATES SQUARE-DISTANCE TO X,Y
C     CREATED 10-NOV-81

      INTEGER*2 X1,Y1
      COMMON /LOOP/X,Y

      FGRID3=(X1-X)**2+(Y1-Y)**2
      RETURN
      END
```

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```
      SUBROUTINE GRAPH1(X,Y,A)
      BYTE OUT(5),A
      IF (X.GT.32767.) X=32767.
      IF (Y.GT.32767.) Y=32767.
      IF (X.LT.Ø.) X=Ø.
      IF (Y.LT.Ø.) Y=Ø.
      IX1=X/1Ø24
      IX2=X/16-64*IX1
      IX3=X-16*IX2-1Ø24*IX1
      IY1=Y/4Ø96
      IY2=Y/64-64*IY1
      OUT(1)=224+IX1
      OUT(2)=128+IX2
      IF (OUT(2).LT.16Ø) OUT(2)=OUT(2)+64
      OUT(3)=128+IY1+4*IX3
      IF (OUT(3).LT.16Ø) OUT(3)=OUT(3)+64
      OUT(4)=128+IY2
      IF (OUT(4).LT.16Ø) OUT(4)=OUT(4)+64
      OUT(5)=(128.+Y-64.*IY2-4Ø96.*IY1)
      IF (OUT(5).LT.16Ø) OUT(5)=OUT(5)+64
      TYPE 95Ø,A,OUT
95Ø   FORMAT (1X,6A1,'}')
      RETURN

      END
```

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```
      SUBROUTINE SINV(A,N,EPS,IER)
      DIMENSION A(1)
      REAL*8 DIN,WORK
      CALL MFSD(A,N,EPS,IER)
      IF(IER) 9,1,1
1     IPIV=N*(N+1)/2
      IND=IPIV
      DO 6 I=1,N
      DIN=1.0D0/DBLE(A(IPIV))
      A(IPIV)=DIN
      MIN=N
      KEND=I-1
      LANF=N-KEND
      IF(KEND) 5,5,2
2     J=IND
      DO 4 K=1,KEND
      WORK=0.0D0
      MIN=MIN-1
      LHOR=IPIV
      LVER=J
      DO 3 L=LANF,MIN
      LVER=LVER+1
      LHOR=LHOR+L
3     WORK=WORK+DBLE(A(LVER)*A(LHOR))
      A(J)=-WORK*DIN
4     J=J-MIN
5     IPIV=IPIV-MIN
      IND=IND-1
6     CONTINUE
      DO 8 I=1,N
      IPIV=IPIV+I
      J=IPIV
      DO 8 K=I,N
      WORK=0.0D0
      LHOR=J
      DO 7 L=K,N
      LVER=LHOR+K-I
      WORK=WORK+DBLE(A(LHOR)*A(LVER))
7     LHOR=LHOR+L
      A(J)=WORK
8     J=J+K
9     RETURN
      END
```

```
      SUBROUTINE MFSD(A,N,EPS,IER)
      DIMENSION A(1)
      REAL*8 DPIV,DSUM
      IF (N-1) 12,1,1
1     IER=Ø
      KPIV=Ø
      DO 11 K=1,N
      KPIV=KPIV+K
      IND=KPIV
      LEND=K-1
      TOL=ABS(EPS*A(KPIV))
      DO 11 I=K,N
      DSUM=Ø.ØDØ
      IF(LEND) 2,4,2
2     DO 3 L=1,LEND
      LANF=KPIV-L
      LIND=IND-L
3     DSUM=DSUM+DBLE(A(LANF)*A(LIND))
4     DSUM=DBLE(A(IND))-DSUM
      IF(I-K) 1Ø,5,1Ø
5     IF(SNGL(DSUM)-TOL) 6,6,9
6     IF(DSUM) 12,12,7
7     IF(IER) 8,8,9
8     IER=K-1
9     DPIV=DSQRT(DSUM)
      A(KPIV)=DPIV
      DPIV=1.ØDØ/DPIV
      GO TO 11
1Ø    A(IND)=DSUM*DPIV
11    IND=IND+I
      RETURN
12    IER=-1
      RETURN
      END
```

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