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US ARMY MATERIEL COMMAND

METHODOLOGY INVESTIGATION

FINAL REPORT

IMPLEMENT REMOTE SENSING

By

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U.S. ARMY DUGWAY PROVING GROUND
DUGWAY, UTAH 84022-5000

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MEMORANDUM FOR Commander, U.S. Army Dugway Proving Ground, ATTN: STEDP-MT-M, Dugway, UT 84022-5000

SUBJECT: Methodology Investigation Final Report, Implement Remote Sensing, TECOM Project No. 7-CO-M91-DPD-005

1. Subject report is approved.

2. Point of contact at this headquarters is Mr. James Piro, AMSTE-TC-D, amstetcd@apg-9.apg.army.mil, DSN 298-2170.

FOR THE COMMANDER:

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The Dugway Proving Ground radar wind profiler, a ground-based 404.37 MHz Doppler radar, operated continuously through its FY91 evaluation period, providing 6-min and hourly wind profiles at 250 m intervals from 500 m to 10 km above ground level. Profiler performance was evaluated using a series of internal measures and through intercomparison with radiosonde-derived wind soundings. Results show profiler measurement precision comparable to that of radiosonde-derived wind data, but with greatly increased temporal resolution. Profiler spectra were examined during periods with strong wind shear, precipitation, and aircraft passage through the radar beams. These conditions caused no significant problems, although data quality was marginal or poor in strong convection or during very dry conditions (dew points below -35° C). A problem with antenna element degradation was discovered, and corrective action has been initiated. Automated quality control algorithms were developed for the 6-min profiler data, and formats were developed for inclusion of wind profiler data in test data reports. Shutdown procedures were also developed to eliminate profiler inter-

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19. ABSTRACT (Cont'd)

ference with search and rescue satellites.

Radar wind profiling is a promising remote sensing technology that offers significant advantages over existing balloon-based wind sounding methods. Once frequency allocation issues are resolved, radar wind profiling is expected to become the preferred method for obtaining ballistic wind data.

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FOREWORD

This project was partially funded by FY 91 Research, Development, Test, and Evaluation (RDTE) funds. The U.S. Army Test and Evaluation Command (TECOM), Atmospheric Sciences Division Dugway Meteorological Team provided the radiosonde flight data used in this report. Mr. Robert Feldman of the Dugway Meteorology Division prepared the satellite overpass software, and Mr. James Frese of the Dugway Test Data Division, Analytical Systems Branch wrote the data archival, quality control, and display software. Mrs. Susan Gross provided the clerical services to produce this report.

SECTION 1. SUMMARY

1.1 BACKGROUND

Dugway Proving Ground (DPG) has installed a wind profiling radar designed to provide continuous wind speed and direction profiles at 250-m intervals from 500 m to 10 km above ground level. The wind profiler is a ground-based phased-array radar that receives Doppler-shifted radio wave energy backscattered from patches of turbulence transported by wind across the radar beam pattern. Backscattered radar returns are characterized by their intensity (returned power), Doppler frequency shift, and spectral width. Each returned signal is also time-tagged. The time interval between transmission and reception, multiplied by the speed of light and divided by two (to account for the round trip out from and back to the antenna) identifies the radial distance (range) to the scattering layer. The length of the transmitted pulse defines the resolution with which range to the scattering layer can be resolved (range gate size). Measurements derived from beams of radiated energy oriented along five radial directions (vertical and 15° off vertical towards east, west, north, and south) are resolved into east-west and north-south wind components. These components are then converted into wind speed and direction profiles.

The wind profiling radar's primary function is to support DPG's materiel test mission. Copp's (1982) study of meteorological data "staleness" effects on field artillery accuracy showed that ballistic wind temporal and spatial variability is the largest source of meteorological error for artillery weapons. Wind component velocities often vary by as much as 50 percent between successive radiosonde flights, while temperature and density variations in excess of 5 percent are unusual. The need for improved elliptical probable error creates a need for improved temporal and spatial representativeness in wind profile measurements. The DPG radar wind profiler is ideally suited to address this requirement by providing continuous updates of the wind field. Also, unlike pilot balloon and radiosonde wind measurements, the profiler is designed for continuous, unattended operation and requires no expendable flight equipment. The DPG profiler is located 20 km west of the Ditto Technical Center between two major artillery ranges. Wind profiler data are also shared on an as available basis with the National Weather Service Forecast Office in Salt Lake City and the Meteorology Department at the University of Utah.

1.2 PROBLEM

The radar wind profiler is a new application of radar technology made possible by recent advances in high-speed data processing, low-noise amplifiers, and innovative antenna designs. While wind profilers exhibit considerable potential for supporting materiel test measurement requirements, system performance has not been thoroughly tested, and adequate data quality control and applications software has not been developed.

1.3 OBJECTIVES

The objectives of this study were to: (1) evaluate the performance of the DPG radar wind profiler, and (2) develop quality control and data presentation software relevant to DPG materiel test applications.

1.4 PROCEDURES

The performance of the DPG radar wind profiler was defined using a series of tests. The first test, designed to detect flaws in system design and installation, examined returned signals from each of the five radar beams for power, spectral width, and noise level. These test results were used to optimize the radar configuration for DPG test support requirements. The basic system performance tests were followed by: (1) an evaluation of returned signal spectra for errors and anomalies, and (2) intercomparison of profiler-derived winds with winds obtained from local radiosonde flight data.

As discussed in more detail in Section 1.5, the results of the profiler returned signal test suggested the need for development of an automated quality control algorithm to identify, flag, and remove anomalous radar returns from the data set as early as possible in the data processing procedure. This quality control algorithm was developed, tested, and implemented for continuous on-line operation.

The DPG radar wind profiler was delivered with software designed to archive wind profiles and display them in a wind barb format. While the wind barb format provides a convenient depicton of the time-height wind field history for weather analysis and forecasting applications, it is not appropriate for documenting wind profiles in a materiel test data record. Software was therefore developed to provide wind profiles in a tabular format compatible with test data format requirements. Because the DPG profiler operates at 404.37 MHz, interference with search and rescue satellites (SARSATs) operating at 407 MHz is possible. Consequently, satellite overpass prediction software was also developed to schedule transmitter shut-off whenever SARSATs pass within the profiler's beam envelope.

1.5 RESULTS

During the FY91 evaluation period the DPG radar wind profiler remained in operational status in excess of 95 percent of the time, providing continuous wind profile records 24 hrs per day, 7 days per week. A majority of the profiler's down time is attributable to communications faults. The only other significant down time occurred during power outages and antenna element repairs. The profiler experienced no electronics component failures during FY91.

Results of the initial radar performance parameter evaluation were encouraging. Beam-to-beam returned power, spectral width, and noise levels were acceptable and consistent. Some large random errors were observed, but the random error pattern was amenable to correction using automated quality control algorithms. However, after approximately 6 months of operation, groups of correlated error patterns began to appear in the data, particularly in the lower and upper range gates. These errors were traced to a gradual degradation in the antenna due to a manufacturing fault and moisture intrusion. Some antenna elements were replaced in April 1991 as a temporary fix. Additional repairs scheduled for November 1991 are expected to replace deficient antenna solder joints and provide better protection against moisture intrusion.

The automated quality control algorithm developed for the DPG radar wind profiler performs well in the absence of correlated errors. This algorithm is applied to each basic 6-min wind data set. Data passing the quality control algorithm are then used to produce a high quality 18-min averaged wind profile by taking a running average of three consecutive 6-min blocks. That is, the 18-min average is updated every 6 min by dropping the oldest 6-min data set and adding a new one. These data are continuously available on the DPG computer system for interested users. Profiler data collected within the past 48 h can also be selected and formatted for inclusion in a test day data report. Unfortunately, the logic used in the quality control algorithm cannot overcome the correlated errors that can occur because of antenna performance degradation. Manual intervention is still required to identify and remove correlated errors from the data set.

Satellite overpass prediction software obtained from a commercial vendor was adapted for use with the DPG profiler. Satellite positional data are updated weekly, and derived profiler shutoff times are entered into the profiler's operation schedule. The DPG profiler is programmed to shut down whenever a SARSAT is scheduled to pass within a conical envelope 35° above the horizon. Typically, ten shutdown periods of 12 to 20 minutes in duration occur during any 24-h period. Satellite overpass shutdown has not caused a significant adverse impact on profiler operations.

Wind data from the DPG radar wind profiler were compared with wind data from concurrent radiosonde flights taken at the Horizontal Grid and Ditto Radiosonde launch locations. The Horizontal Grid site is 1 km south of the wind profiler array, while the Ditto site is 20 km east of the profiler. Comparabilities as defined by Hoehne (1971) (i.e., root mean square differences) of the Horizontal Grid radiosonde versus profiler-derived winds were on the order of 1 m/s. Comparabilities of the Ditto radiosonde versus profiler winds ranged between 3 and 5 m/s. These inter-site comparability differences are due to site spatial separation and terrain effects. Biases on the order of 1 m/s were observed as a result of Granite Mountain wind shadow effects at the profiler site.

Atmospheric thermodynamic effects on profiler operation were also investigated. Atmospheric moisture enhances radar returns; useable radar returns are most likely to be received from portions of the atmosphere where the dew point exceeds -35 °C. The temperature gradient exhibits no apparent effect on the strength or quality of radar returns.

1.6 CONCLUSIONS

Radar wind profiling is a promising and reliable remote sensing technology. The advantages offered by the radar wind profiler include continuous unmanned operation and automated real-time data processing. Continuous operation provides wind profiles with a temporal resolution unattainable from balloon-borne wind measurements, and automated data processing makes the wind profiles available within several minutes following the data collection period. Also, the radar wind profiler can operate with minimal degradation in most weather conditions and requires no expendable flight equipment. One of the most important advantages of the radar wind profiler is that profiler operation requires no on-site personnel; an entire profiler network can be controlled by a single operator stationed at a centralized location. This unattended operation capability will increase in importance as the number of meteorological technicians available to perform balloon-borne measurements decreases at U.S. Army Test and Evaluation Command (TECOM) test centers.

Like any new technology, the radar wind profiler has its problems. A construction deficiency in the antenna of the DPG profiler created a series of correlated errors, occasionally defeating an automated quality control algorithm that otherwise works well. This antenna deficiency has been identified and corrective action is underway. The major problem with wind profiling radar technology is that these systems radiate considerable amounts of radio frequency energy and occupy significant bandwidth in already crowded radio frequency bands. National frequency management groups are working on a solution to the profiler frequency allocation problem.

1.7 RECOMMENDATIONS

Upon resolution of the frequency allocation issues, widespread application of radar wind profiling technology is expected throughout the world. This technology has significant potential for supporting the rapidly evolving atmospheric measurement requirements of the modern Army. Further development of profiler applications, to include profiler networks at major test facilities, mobile profilers for remote site measurements, and merging of passive radiometric temperature and humidity profiling with wind profiling is warranted. The National Weather Service is currently evaluating the radar wind profiler and supplementary remote sensing technologies for eventual replacement of balloon-borne atmospheric sounding systems. The Army should also continue to gain experience with and develop applications for these new remote sensing technologies. Otherwise, it risks remaining dependent upon costly, labor-intensive, obsolescent technologies for ballistic meteorological support.

SECTION 2. DETAILS OF THE INVESTIGATION

2.1 RADAR PERFORMANCE EVALUATION

The DPG radar wind profiler consists of four major subsystems: transmitter, antenna, receiver, and processor. The transmitter features solid-state electronics with a tube-based final amplifier designed to deliver 35 kW peak, 1.75 kW average pulsed radio frequency (RF) power to the antenna. The antenna subsystem consists of two arrays (x and y) of coaxial-collinear antenna elements, with the x array overlaying and at 90° to the y array. These arrays form and steer the beam through precise phasing of the energy radiating from each of the antenna elements. The superheterodyne receiver converts received RF energy to in-phase and quadrature signal components that are sent to the processor, which translates raw data into user output. Profiler output is sent via telephone modem to a profiler data handler (PDH) located in the Ditto Technical Center. A general description of profilers and their operation can be found in van de Kamp (1988) and Peterson (1988).

The DPG wind profiler is installed at a flat, open site 40° 12′ N, 113° 10′ W with the y axis antenna array oriented towards true north. Electronic beam steering provides antenna array polarization in the following sequence: (a) X+15 (15° tilt towards east), (b) X+00 (vertical beam from x antenna array), (c) Y+15 (15° tilt towards north), (d) X-15 (15° tilt towards the west), (e) Y+00 (vertical beam from the y antenna array), and (f) Y-15 (15° tilt towards the south).

DPG wind profiling radar operating parameters are set via modem from a terminal (the Keyboard Display Unit, KDU) in the Ditto Technical Center, and output data are sent via modem to the PDH located in the Ditto Weather Station. The profiler is normally configured to operate in the high resolution mode, providing 250-m range resolution for range gates from 500 to 9,250 m above ground level (AGL). Spectra from each range gate are subjected to windowing and tapering to minimize effects from the extreme wings of the the spectra. Antirange aliasing and ground clutter suppression algorithms have been activated. Maximum full scale radial velocities are set at 17.7 m/s for the vertical axis and 28.7 m/s for the off-vertical axes on each range gate. This velocity scaling was chosen as a compromise between the need to include maximum expected radial velocities within the spectrum range while retaining good velocity resolution. The radar is programmed to remain on each beam position for 1 min of data collection; the sequence through the entire set of beam positions requires 6 min.

The configuration of the DPG radar wind profiler with a six-beam position rotation pattern facilitates profiler performance evaluation. Direction orientation redundancy (east versus west, north versus south, and vertical x versus vertical y) permits comparisons between data sets obtained from paired sets of beam orientations, and the beam-to-beam measurement differences provide an excellent set of internal performance checks. Radar data available for intercomparison include hourly consensus orthogonal wind component averages (u, v, w) in meters per second, returned power along each beam radial direction (Px, Py, Pz) in decibels (dB), spectral width of the velocity signal (xw, yw, zw) in meters per second, and noise levels (xnl, ynl, znl) in decibels.

"Consensus" is a method devised by the National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS) to evaluate data quality for hourly groups of 6-min data (van de Kamp, 1988). The consensus algorithm examines the ten velocity estimates obtained during an hour for each range gate and determines the largest subset of values within ±5 m/s of each other. If the largest subset of consensus values is four or more, those velocity estimates are averaged to form the hourly averaged wind report. If the largest subset is less than four, no hourly consensus is formed. Consensus is an effective single-pass procedure for determining mean wind estimates from a sufficiently large (ie, hourly) data set. Because this procedure tends to smooth small scale perturbations and remove outliers from the data set, it is most suitable for defining the synoptic scale wind field. Consensus data are available for display and archival through the PDH.

Hourly consensus data were initially selected for profiler evaluation because of their availability through the PDH. A total of 160 hourly profiler consensus data sets were collected for analysis, and differences were calculated for paired consensus measurements averaged over all range gates. The computed differences were Δu, Δv, Δw, ΔPx, ΔPy, ΔPz, Δxw, Δyw, Δzw, Δxnl, Δynl, and Δznl. The means and standard deviations calculated for each set of computed differences were used with the Student's t test for N-1 degrees of freedom (Panofsky and Brier, 1965) to evaluate the null hypothesis that inter-beam differences (Δu, for example) are zero. Rejection of the null hypothesis leads to the alternative hypothesis that significant inter-beam differences exist. The results of the DPG profiler consensus data evaluation are presented in Table 1.

The mean differences in the u, v, and w wind components presented in Table 1 are on the order of a few centimeters per second and do not differ from zero at the 95-percent confidence level. The relatively large standard deviations, due principally to a relatively few cases with large inter-beam radial velocity differences, illustrate the need for quality control algorithms to remove spurious radar returns before derived data are contaminated.

The statistically significant differences in radar return spectral widths (Δxw, Δyw, and Δzw) shown in Table 1 suggest the existence of differences in beam formation or response to scattering mechanisms along the various radial directions. A subsequent investigation of antenna beam patterns revealed that beam-to-beam differences exist, but these differences are not of sufficient magnitude to warrant corrective action.

Table 1. Sample Mean ($\bar{x}$), Standard Deviation (S_x), and Student's t Score (to) for DPG Profiler Paired Beam Consensus Data.[a]

	Beam Differences											
	Radial Velocity (m/s)			Returned Power (dB)			Spectral Width (m/s)			Noise Level (dB)		
Statistics	Δu	Δv	Δw	ΔPx	ΔPy	ΔPz	Δxw	Δyw	Δzw	Δxnl	Δynl	Δznl
$\bar{x}$	0.045	-0.040	-0.007	0.280	-0.275	[illegible].361	-0.032	0.135	0.122	0.036	-0.376	0.053
S_x	1.368	2.101	0.246	0.688	0.737	0.694	0.121	0.125	0.068	0.301	0.322	0.295
to	0.42	-0.24	-0.37	5.16	-4.72	-35.75	-3.37	13.66	22.47	-1.50	-14.76	2.27

[a]Note: A t score of ±1.96 or greater is significant at the 95 percent confidence level.

Table 1 shows that the differences in paired beam returned power (Px, Py, Pz) and noise level (nxl, nyl, nzl) are statistically significant at the 95-percent confidence level for all data pairs except the x axis noise level (xnl). These differences, which were found to be due to slight differences in antenna beam patterns, are not considered operationally significant except for the difference ΔPz in the vertical beam power level. The power returned from the vertical x beam is significantly lower than the y beam returned power, with a mean difference of nearly 2 dB. The x and y antenna arrays differ in that the x array elements are 2 to 3 cm further from the antenna ground plane than the y array elements. An antenna element ground plane distance of one-quarter wavelength is a major performance consideration. However, the physical limitations imposed by overlapping antenna arrays preclude both arrays from being at this optimum distance; the x array is apparently at the less advantageous distance from the groundplane. As a result of this finding, the radar was reconfigured to use only the vertical beam from the y-array (Y+00) for operational vertical wind measurements.

Review of the profiler data continued throughout FY91, and information gained during this process was used to develop automated quality control algorithms. The profiler data review included a detailed examination of errors in the reported data. If the profiler is operating properly, errors due to noise exceeding returned signal should exhibit a random pattern. Random errors can usually be distinguished from valid data and can often be removed using an automated quality control algorithm. Beginning in February 1991, patterns of "correlated" errors (i.e., errors that exhibited consistency in time or space) began to appear in the data. Correlated errors are more difficult to distinguish from valid data, especially using simple automated quality control algorithms that rely on temporal and spatial continuity checks. Figure 1 shows a profiler-generated height-versus-time wind diagram containing both correlated and uncorrelated patterns of invalid data. Virtually the entire wind field above 7 km above mean sea level (MSL) in this figure consists of invalid data, including some matched sets of wind barbs that represent correlated errors. Correlated error patterns also appear throughout the entire profile at 1240 Universal Coordinated Time (UTC). (Note that the data set in Figure 1 is among the poorest provided by the profiler during its entire period of operation.)

The DPG profiler's vendor returned in April 1991 to correct the problem that was causing the correlated errors. The increasing number of errors, particularly correlated errors, was found to be due to a manufacturing fault that caused antenna performance to degrade over time. Each antenna element consists of two strands of coaxial cable soldered to either side of a balun or line balance converter (much like a standard dipole antenna). Solder joints on some antenna elements failed due to vibration in high winds. Also, the fiberglass coverings over the elements are not watertight. Subsequent moisture seepage into an antenna element's balun capacitors and printed circuit boards produces changes in the dialectric constant, altering the element's impedance. The combined effects of manufacturing faults and moisture intrusion caused a number of elements to detune or fail over time. Examples of functional and malfunctional antenna element impedances versus frequency are shown in Figure 2. Manufacturer's specifications require an impedance loss of at least 14 dB centered near the profiler operating frequency (404.37 MHz) for an antenna element to function adequately.

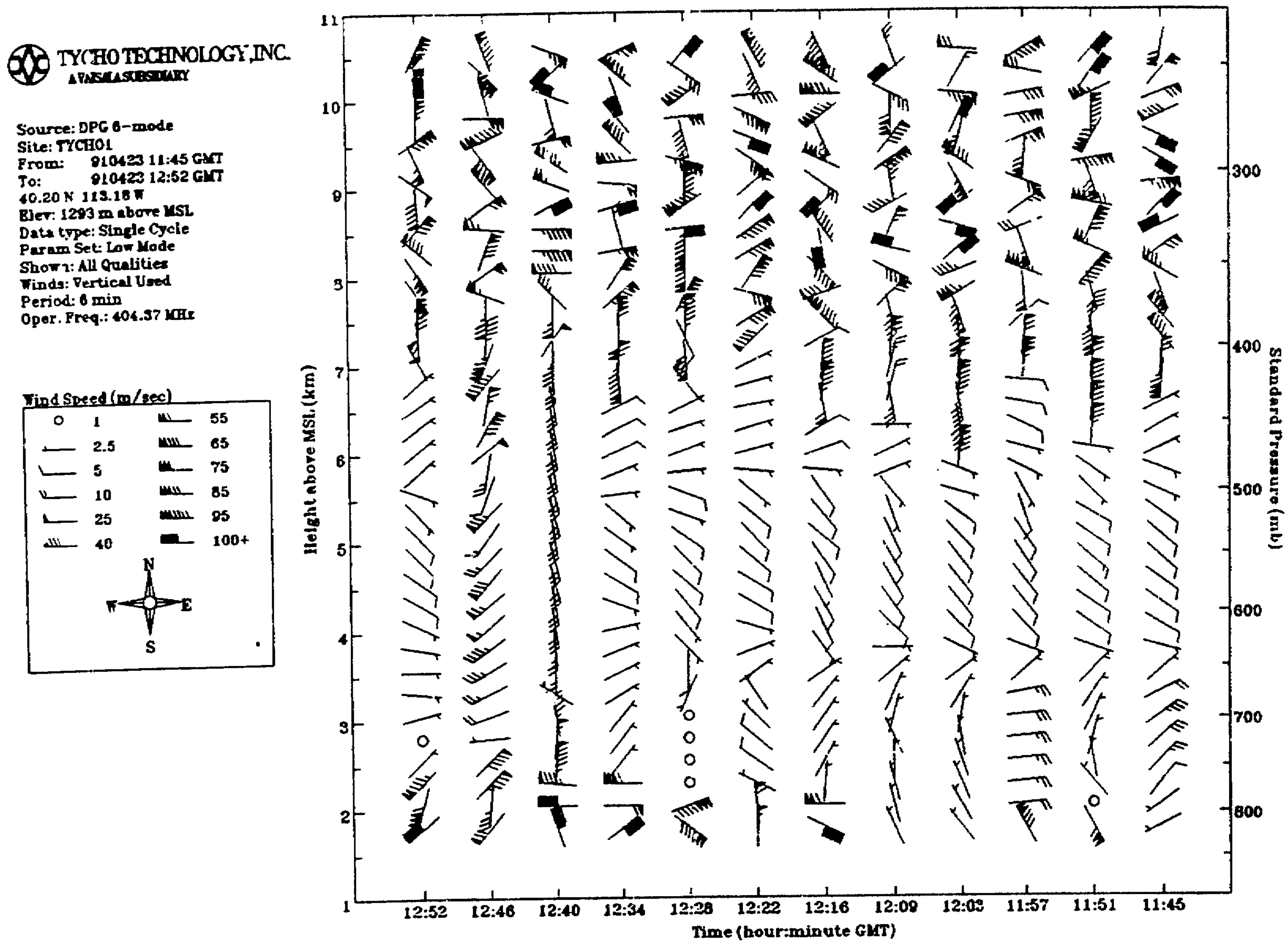

Figure 1. A Time versus Height Depiction of the Profiler-Generated Wind Field for 1145 to 1252 UTC on 23 April 1991. Data are Presented at 6-Min Intervals Illustrating the Presence of Correlated and Uncorrelated Errors. Note That Data in This Figure Have Not Been Passed Through a Quality Control Algorithm.

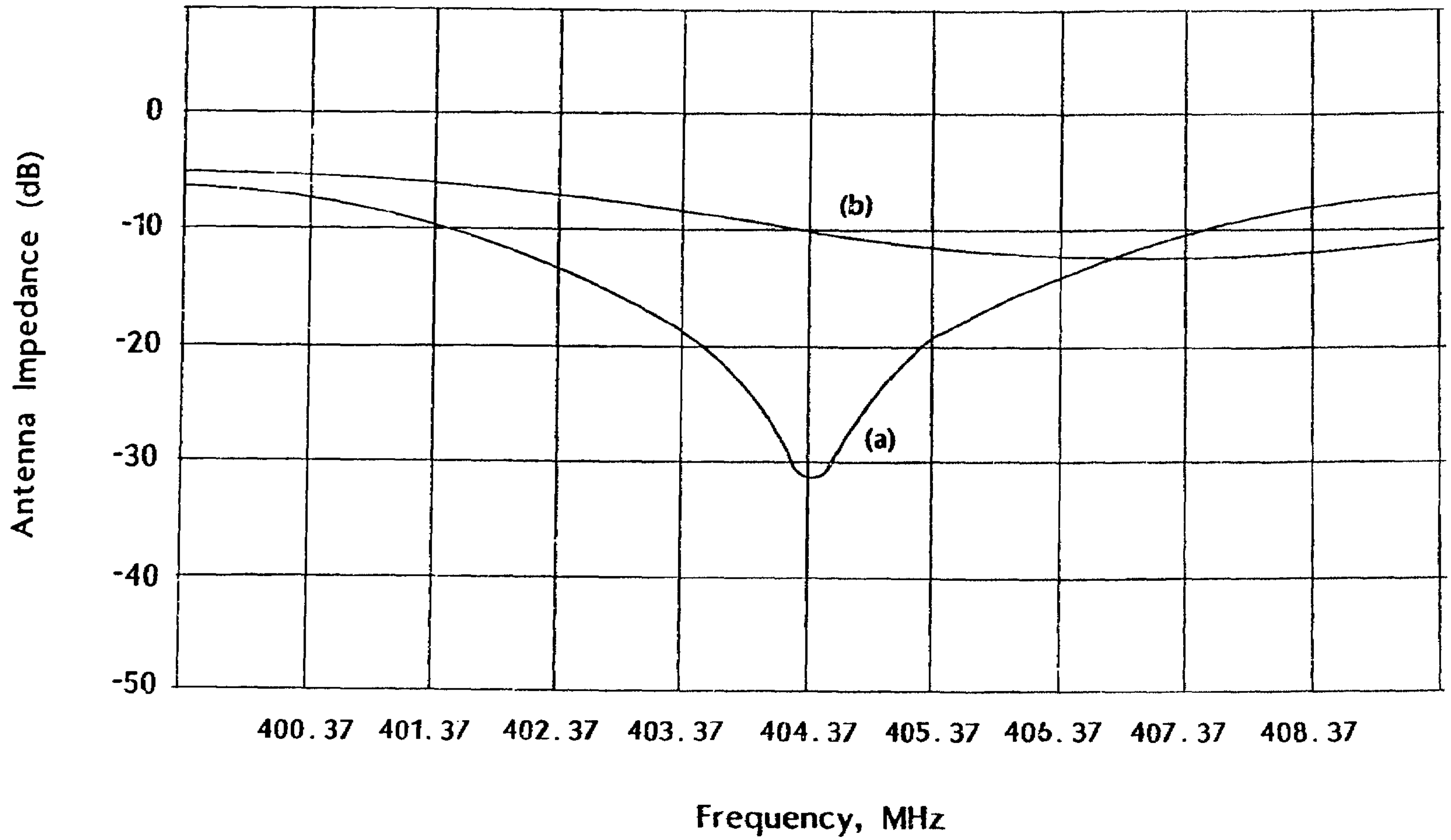

Figure 2. Antenna Impedance versus Frequency for (a) Functional and (b) Nonfunctional Antenna Elements.

The manufacturer replaced the malfunctioning antenna elements of the DPG wind profiler with new elements in April 1991, but the basic problems of moisture intrusion and inadequate solder joints remained. Gradual deterioration of profiler antenna performance again became evident in August 1991. Meanwhile, profiler maintenance was taken over by a new contractor, who reported progress in improving antenna element manufacturing procedures and the development of an epoxy coating for the fiberglass antenna element housings to retard moisture intrusion. Contractor technicians are expected to return in November 1991 for a thorough overhaul of the profiler antenna that is expected to resolve the antenna degradation problem.

2.2 ANALYSIS OF RANGE GATE SPECTRA

Radar wind profiler spectra plots illustrate the basic radar return information averaged over a 1-min period for each of the 36 range gates on a selected beam. Spectral information includes spectral shape, size, width, and location of the spectral peak. The spectra are auto-scaled so that a strong signal rises well above the noise level. When the signal is weak or absent, the background noise becomes a dominant feature on a spectrum plot. Each of the 36 spectrum plots visually depicts the signal to noise power ratio, returned power, spectral width, and Doppler velocity shift for returns from a range gate. Spectrum plots also list tabular full-scale velocity (FSV) information, which indicates the velocity (± m/s) corresponding to spectral full scale on the selected beam. Columns along the left side of each spectrum plot indicate range gate height in meters MSL and radial velocity (m/s). The signal to noise ratio (S/N) in decibels and maximum power in decibels before ground clutter removal (MAX) are provided in the column to the right of each spectrum plot. Figure 3 is typical plot of spectra for each of the 36 range gates on the DPG profiler's south beam. Range gate centroids are indicated by a vertical bar (see, for example, the vertical bar marked A on the 8th range gate in Figure 3). Alternating current (60 Hz) noise appears as sets of small spikes (B) symmetrical about the spectrum axis. Spectra for range gates 1 and 34-36 exhibit no signal peak because the total returned signal power was insufficient to emerge above the noise level. Another feature illustrated in Figure 3 is a case (range gate 30) where, for some unknown reason, the correct spectrum centroid was not selected.

Profiler spectra were examined during periods when events occurred that could cause erroneous radial wind velocity signal detection. These events included strong wind shear, precipitation, and passage of aircraft through the beam. Figures 4, 6, and 7 show examples of profiler spectra for each of these events. An example of spectra illustrating data loss due to a poorly formed beam in the lowest range gates because of profiler antenna deterioration is presented in Figure 8.

Figure 4 presents a strong wind shear case as indicated by the profiler spectra in range gates 8 through 12. The spectra for these range gates also exhibit considerable spectrum broadening, which is indicative of turbulent conditions that cause a wide range of radial velocities within the shear zone. Figure 5 illustrates the strong wind shear zone between 3 and 5 km MSL that caused this spectral broadening. The profiler handled this and other observed wind shear conditions extremely well, providing detail on shear and turbulence that is unavailable using balloon-based wind profiling systems.

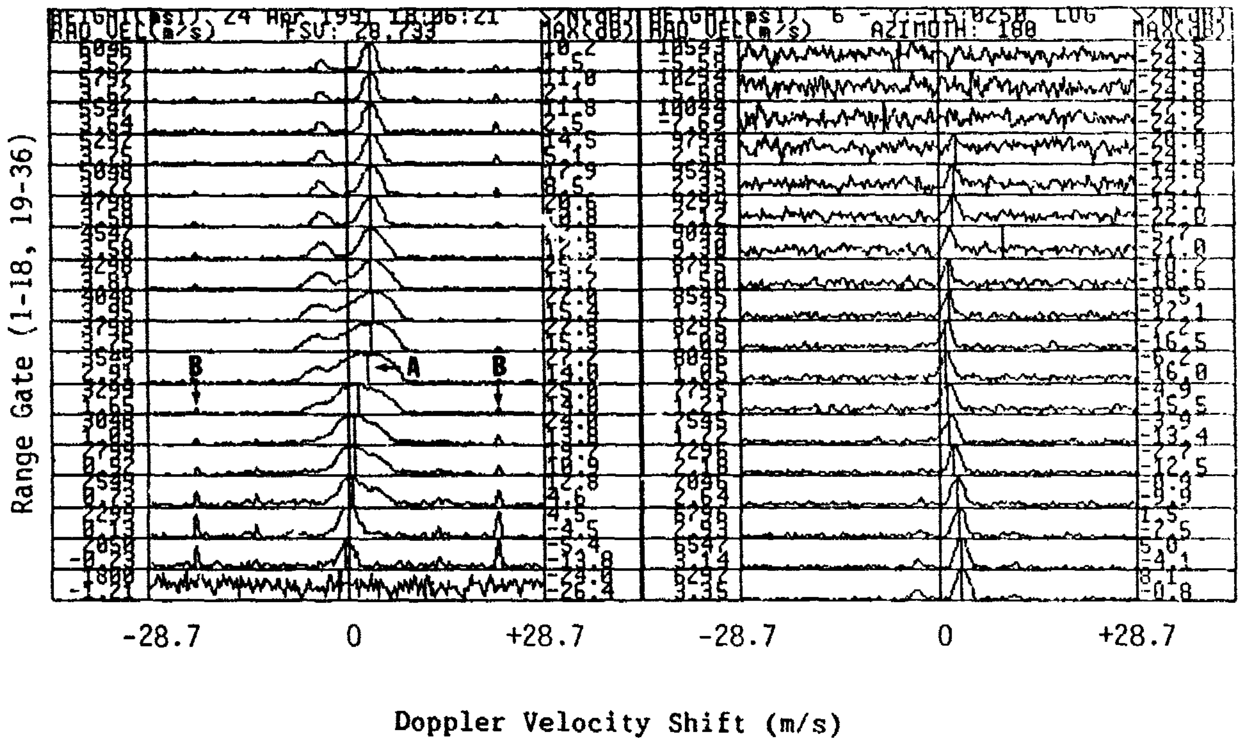

Figure 3. Spectra for the 36 Range Gates of the Y-15 (south) Beam of the DPG Profiler, 24 April 1991, 1806:21 UTC. A Vertical Bar Through the Spectral Peak on Each Range Gate Defines the Radial Velocity Along the Beam. The Noise Level Exceeds Signal on Range Gates 1 and 34-36.

Radars used for clear air wind profiling operate on a different scattering principle than the one used by weather radars. Weather radars, which typically operate at wavelengths of 3 to 10 cm, derive range-to-target information from "incoherent" scattering by the randomly distributed water droplets in clouds and precipitation. In contrast, Doppler radar wind profilers depend upon backscatter from the "coherent" spatial structure of dialectric constant fluctuations in the atmosphere. Incoherent backscatter varies inversely with the fourth power of wavelength (Gossard and Strauch, 1983), making incoherent backscatter only 0.03 percent as efficient for a 74-cm wind profiling radar as for a 10-cm weather radar. As a result, the DPG profiler is relatively insensitive to reflections from precipitation, but will respond to the presence of a rain shaft and the net downward vertical motion of the precipitation in it. Also, as shown by Figure 6, precipitation often causes spectral broadening due to the raindrop velocity distribution and accompanying atmospheric motions.

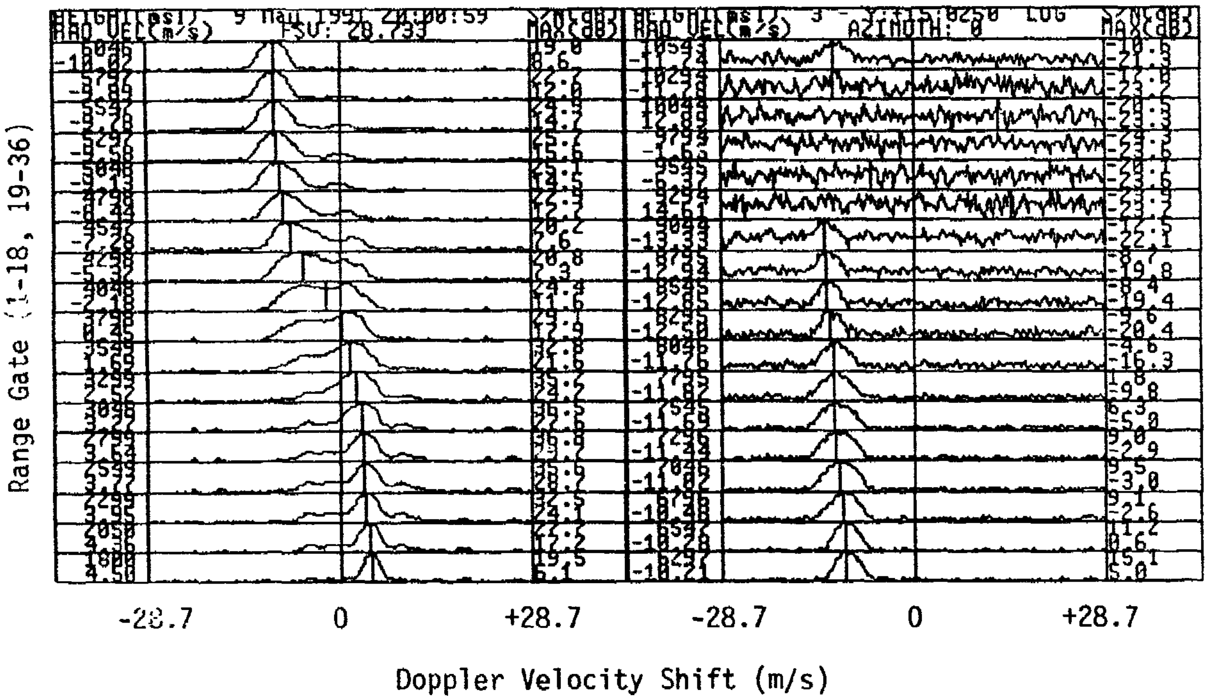

Figure 4. Spectra for the 36 Range Gates of the Y+15 (north) Beam of the DPG Profiler, 9 May 1991, 2000:59 UTC. High Wind Shear is Indicated in Range Gates 8-12. Spectrum Broadening is Also Evident in These Range Gates.

Although the profiler generally provides good velocity profiles in steady, uniform precipitation, strong convective motions (with or without precipitation) create problems because the spatial scales of these motions can be the same order of magnitude as the profiler's range resolution and beam separation distances. Profiler data reduction algorithms are based on the assumption that radar returns from each beam come from a homogeneous atmosphere. If one or more beams are sampling within a convective updraft while others are sampling within a downdraft, the assumption of inter-beam wind field homogeneity is violated and erroneous reports occur. It may be possible to define these adverse operating conditions by computing a vertical velocity from the four off-vertical beam measurements and comparing results with the vertical velocity measurements. However, the feasibility of this approach remains to be determined.

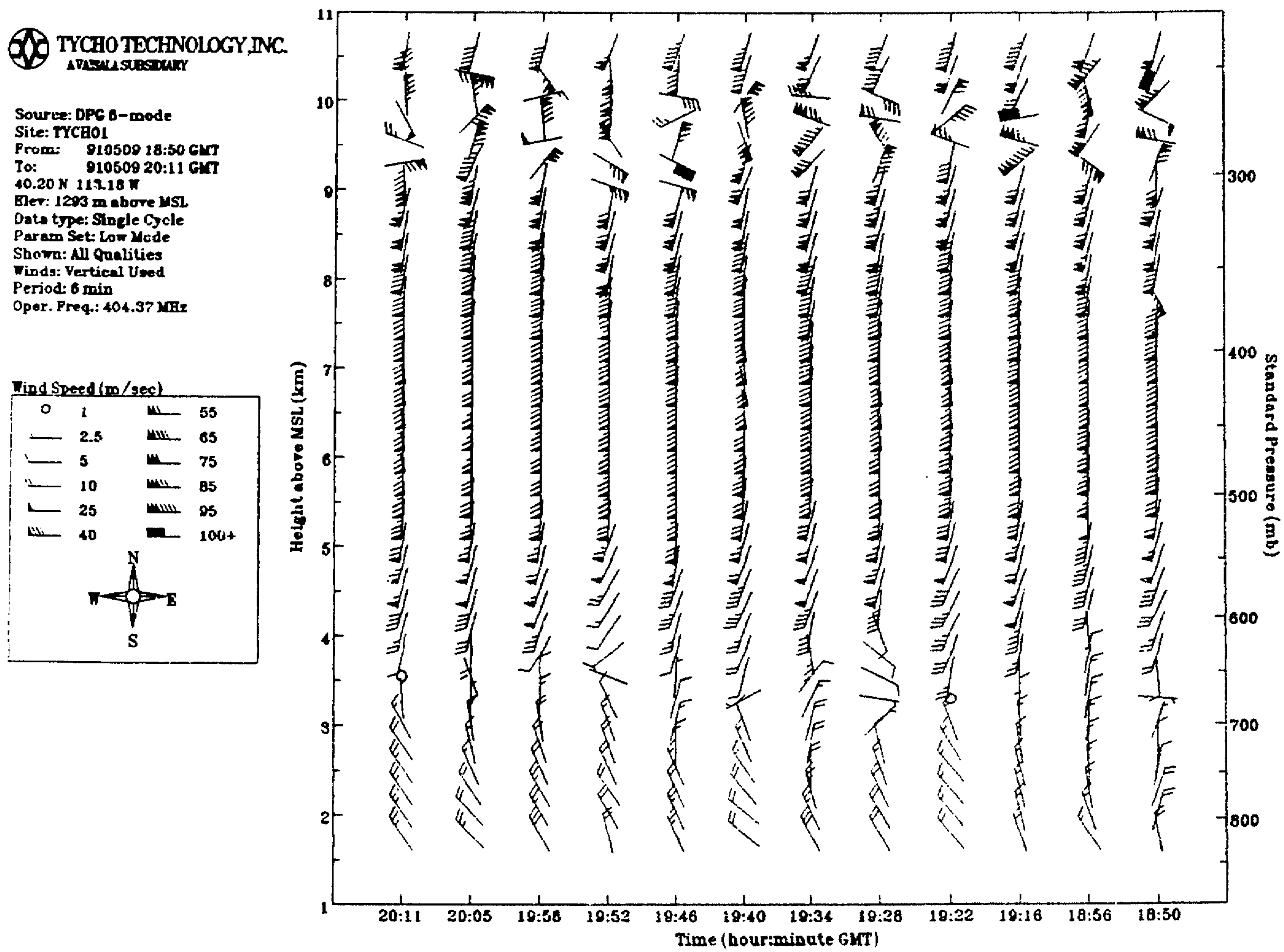

Figure 5. Time-Height Diagram for DPG Radar Wind Profiler, 9 May 1991, Illustrating Detail of Wind Field in 6-min Time Intervals from 1850 to 2011 UTC. Note That the Data Presented in This Figure Have Not Passed Through Quality Control Algorithms.

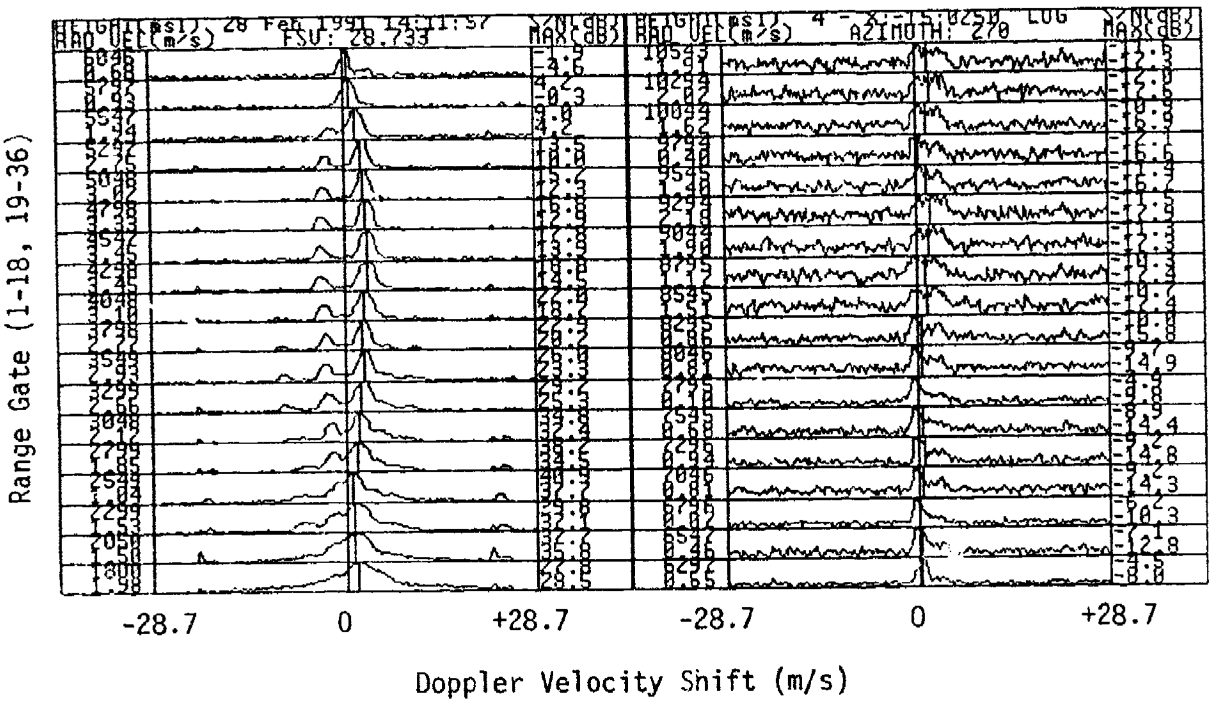

Figure 6. Spectra for the 36 Range Gates of the X-15 (west) Beam of the DPG Profiler, 28 February 1991, 1411:57 UTC. Precipitation Caused Spectral Broadening in the Lower 8 Range Gates, But Did Not Interfere with Selection of Spectrum Centroids.

RF energy reflected from solid surfaces will appear as a signal to the profiler. Ground clutter removal algorithms can be activated to eliminate returns from stationary objects, although the DPG profiler suffers few problems with spurious reflecting surfaces due largely to its location at a remote site in flat, open terrain. However, aircraft occasionally pass through one or more of the radar beams and cause anomalies in the spectra for affected range gates, as illustrated in Figure 7. These events are infrequent and cause few problems with profiler operation.

The most persistent problem with the DPG profiler has been the gradual degradation of antenna performance as the antenna elements deteriorate. One consequence of this deterioration is that the beam is poorly formed in the lower range gates, causing broad and distorted spectra that are occasionally bimodal. As a result, the radial velocities measured in the range gates below 1000 m AGL often contain errors. Figure 8 shows examples of distorted spectra in the lowest range gates due to antenna element deterioration. Note that a majority of the spectra in Figure 8 represent valid data. As discussed above, the November 1991 antenna repair is expected to fix the antenna deterioration problem.

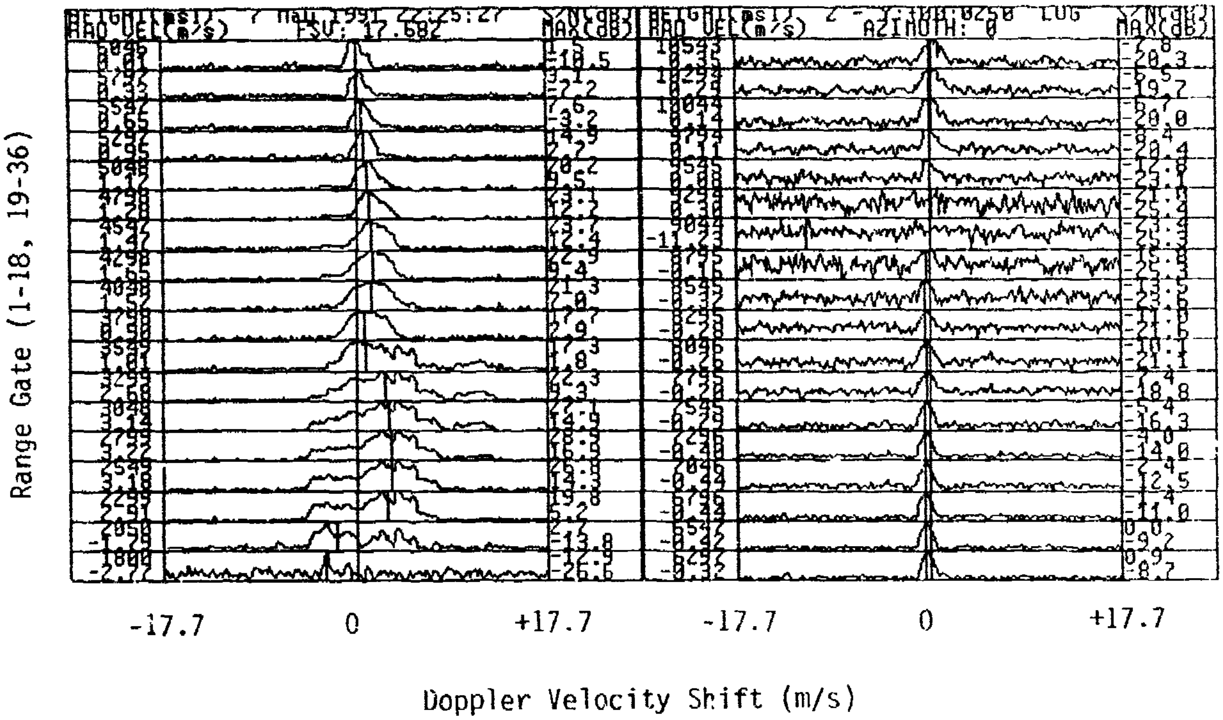

Figure 7. Spectra for the 36 Range Gates of the Y+00 (vertical) Beam of the DPG Profiler, 7 May 1991, 2225:27 UTC. Low-Flying Aircraft Passing Over the Profiler Caused Distorted Spectral Returns on Range Gates 2 through 8. Erroneous Spectral Peaks Occurred on Range Gates 2 through 7 as a Consequence of this Event.

Examination of the velocity spectra provided useful insights for the development of an automated quality control algorithm to eliminate spurious radar returns before they become embedded in the data set. These insights led to the development of some simple criteria based on spectral width and the arithmetic difference between returned signal power and noise power. First, radial velocity returns are usually broader than noise spikes because of velocity changes that occur within the sampling volume during a 1-min averaging period. Second, a broad spectrum can indicate a problem, but can also indicate the presence of turbulence or precipitation. These observations led to the following criteria for the spectral width of radial wind data:

(1) If the vertical velocity spectral width is 0.2 m/s or less, flag the data as questionable.

(2) If the off-vertical radial velocity spectral width is 0.24 m/s or less, flag the data as questionable.

(3) If the off-vertical radial velocity spectral width exceeds 2.5 m/s, flag the data as questionable.

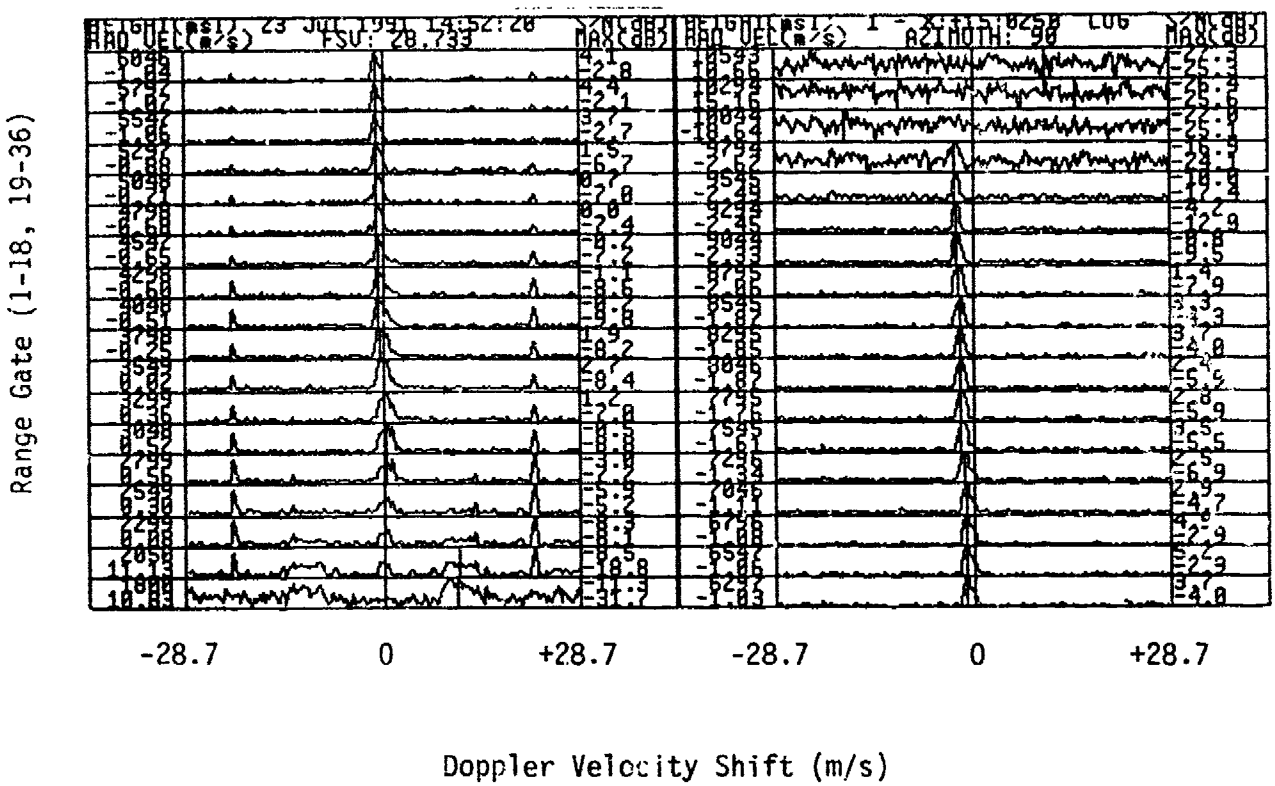

Figure 8. Spectra for the 36 Range Gates of the X+15 (east) Beam of the DPG Profiler, 23 July 1991, 1452:20 UTC. Anomalous Spectra Appear in the Two Lowest Range Gates, Causing Errors in the Measured Radial Velocities.

The signal-to-noise power differential (SND) is the arithmetic difference in decibels between the reported radial velocity signal and the mean background noise. If the signal and noise power are of nearly the same magnitude, separation of the signal spectral peak from the background noise becomes uncertain. After comparing profiler data quality with SND, the following rules were defined:

(1) If the vertical beam SND is less than or equal to 4.0, flag the data as questionable.

(2) If the off-vertical radial beam SND is less than or equal to 3.0, flag the data as questionable.

The initial data quality check for velocity spectral width and SND is based on the flag count. If any of the spectral width or SND flags are set, the associated radial velocity data are not used for wind component computations.

2.3 DEVELOPMENT OF QUALITY CONTROL ALGORITHMS

The first step in the development of a quality control procedure is to define the use for which the data are intended. The NOAA Environmental Research Laboratory (ERL) consensus algorithm, which is designed to generate smoothed winds for regional flow patterns, is not suitable for tracking local wind and wind shear conditions. Also, the other NOAA profiler quality control procedures utilize only the derived wind component data (see Brewster, 1989). It was therefore necessary to develop a quality control procedure designed for DPG test support applications.

As a general rule, it is most useful to apply quality control as close to the actual measurements as possible so that errors are removed before they can be included in smoothing or consensus algorithms. Consequently, an automated set of quality control algorithms was developed for use with all data points obtained from each range gate during each 6-min measurement cycle. This set includes the spectral width and SND checks described above, followed by intercomparisons of wind components prior to their conversion into wind speed and direction profiles. If paired measurements of a wind component do not agree within specified limits, the data points then undergo temporal and near-neighbor consistency checks. Temporal consistency checks include comparison of each new data point with the previous data point obtained for the same range gate. Near-neighbor consistency checks include comparison of each new data point with data points above and/or below it, as available. An advantage of this quality control procedure is that it uses only simple single-pass intercomparisons so that it can operate in real time (i.e., on line).

Following the examination of data points for the SND and spectral width criteria, the initial quality control checks are made using the two sets of vertical velocity data points (both obtained from the Y+00 beam) within a 6-min cycle. It is important to obtain a correct vertical velocity estimate ($\bar{w}$) because this estimate is subsequently used to determine the horizontal (u and v) wind components. If one vertical velocity component fails one of the SND or spectral width criteria, the remaining data point must pass temporal or near neighbor consistency tests to be accepted. If the two vertical velocity data points pass the SND and spectral width criteria and are consistent with each other ($|w_1-w_2| < 0.5$ m/s), they are averaged to obtain $\bar{w}$. Otherwise, these data points are subjected to temporal and near neighbor consistency checks. If neither pass the consistency tests, a vertical velocity estimate of zero ($\bar{w}$ = 0.0) is used for horizontal wind component computations. Figure 9(a) depicts the vertical wind consistency check process in block diagram format.

The off-axis radial wind velocity measurements that pass the SND and spectral width checks are used with $\bar{w}$ to compute the u and v wind components. If one of the paired measurements of a u or v wind component fails one of the SND or spectral width criteria, the remaining component measurement must pass temporal or near-neighbor consistency checks to be accepted. If the paired measurements of the same wind component differ by no more than 2.0 m/s, they are considered to be consistent and their average is used as the best estimate of that component in the quality controlled data set. If the paired measurements of the same component are inconsistent ($|u_1-u_2| > 2.0$ m/s, for example), these measurements are subjected to temporal and near-neighbor consistency checks. If neither passes the consistency checks, wind component data from this range gate are considered unacceptable and are not used to compute wind speed and direction for the quality controlled data set. The horizontal wind consistency check process is schematically depicted in Figure 9(b).

2.4 PROFILER-RADIOSONDE DATA INTERCOMPARISON

Paired sets of DPG radiosonde and radar wind profiler data were collected for use in an intercomparison of the wind measurements derived from these instruments and to evaluate the effects of temperature lapse rate and moisture on profiler performance. The radiosonde data used in the intercomparison were obtained from test support radiosonde flights made at either the Horizontal Grid Command Post (CP) site, approximately 1 km south of the profiler array, or the Ditto Radiosonde Site, 20 km east of the profiler array.

Radiosondes are expendable balloon-borne, battery-powered instrument packages that contain a thermistor for temperature measurements, a hygristor for humidity measurements, a pressure sensor, electronics for data collection from the sensors, and a radio frequency link for transmission to a ground station receiver. DPG used a WL8000 Loran-based position finding system to track each instrument package during its ascent; wind profiles are derived from time and position information received during the radiosonde flight. Wind measurement uncertainties from Loran network data are a function of Loran station geometry, but are typically on the order of ± 0.5 m/s in the western United States (Passi and Morel, 1987).

The wind profiler data used for intercomparison with radiosonde winds were the basic tabulated data provided by the PDH before the quality control algorithm is applied. As discussed above, two data sets (east-vertical-north and west-vertical-south) of reduced data were available every 6 min. The reduced east or west and north or south wind components were paired with comparable wind data obtained from radiosonde flights released within 15 min of the time of the profile. Basic profiler data, without smoothing and as free as possible from gross errors without passing through the quality control algorithms were chosen for intercomparison to obtain the clearest picture of profiler-radiosonde comparability.

Radiosonde basic wind data are reported at 1-min intervals rather than at constant height intervals. Consequently, reported wind data height levels vary from one flight to another as a function of the balloon ascent rate (nominally 300 m/min). It was therefore impossible to obtain radiosonde wind data corresponding to each of the standard profiler range gates. As an alternative, one radiosonde height level was selected within each of four intervals defined as near surface (750 to 1250 m AGL), upper boundary layer (1500 to 2250 m AGL), lower troposphere (2500 to 3750 m AGL), and mid-troposphere (4000 to 6000 m AGL). Each radiosonde wind report selected was within 100 m of the corresponding profiler wind height level.

Only ten radiosonde flights were conducted for test support purposes from the Horizontal Grid CP site during the profiler-radiosonde intercomparison period, and not all of these cases provided suitable wind data for all levels. The resulting profiler-radiosonde u and v wind component differences are presented in Figures 10 and 11, respectively. Figures of merit used in the intercomparison were the mean difference (bias), root-mean-square difference (comparability), and standard deviation of the differences (precision). These

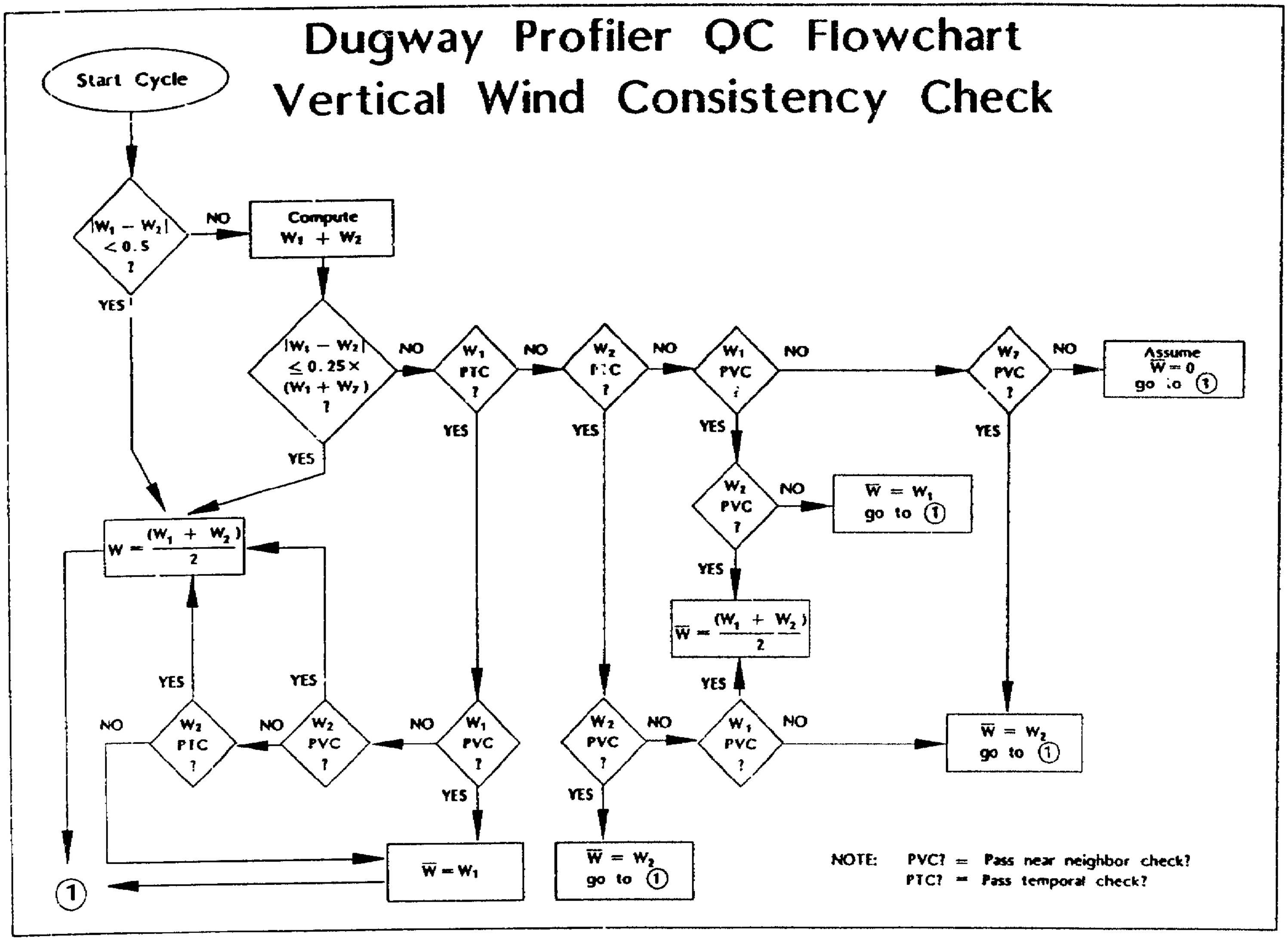

Figure 9(a). DPG Profiler Real-Time Quality Control Flowchart Illustrating the Vertical Wind Consistency Check Process.

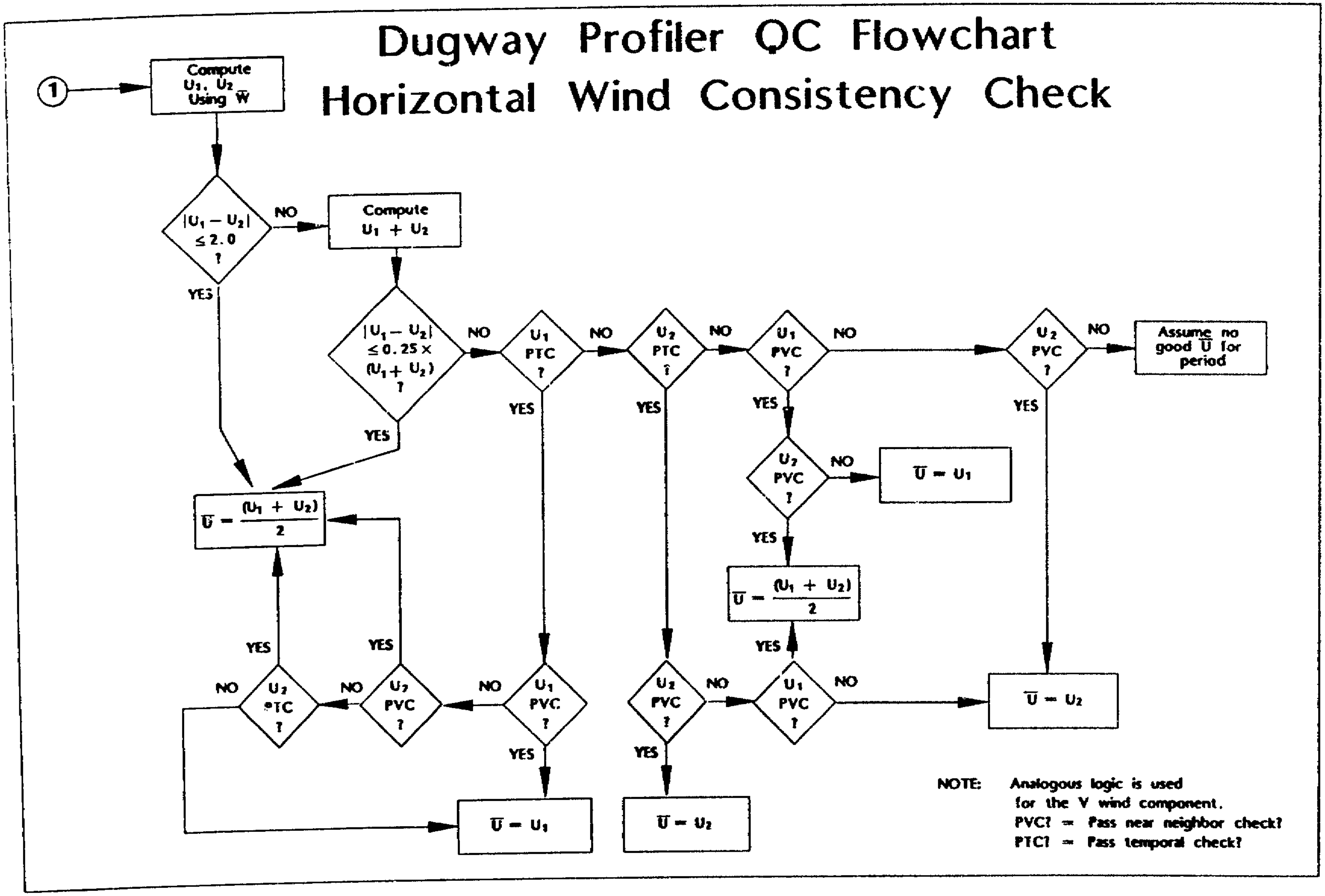

Figure 9(b). DPG Profiler Real-Time Quality Control Flowchart Illustrating the Horizontal Wind Consistency Check Process.

figures of merit are summarized in Table 2 for each height interval. With the exception of the mid-troposphere u (east-west) wind component, Table 2 shows biases of less than 0.5 m/s for both the u and v components with no consistent directional bias that could be indicative of antenna beam misorientation. Also, the comparabilities and precisions on the order of 1 m/s for all wind components except the mid-troposphere u are consistent with the accuracies expected from dissimilar wind measurement systems. These results are well within the 2.5 m/s wind component standard deviations reported by Weber and Wuertz (1990) following their extensive profiler/radiosonde intercomparison program. As shown by Figure 10, the mid-troposphere u-component bias of +1.66 m/s and accompanying large comparability and precision scores are largely attributable to a single data point that, in the small available sample size, dominates the figure of merit scores. The source of this singular discrepancy is not known. Although obtained with a small sample size, the intercomparison results suggest that the profiler beams are reasonably well oriented and that the DPG profiler is capable of obtaining data comparable to DPG radiosonde flight wind data.

Table 2. Bias, Comparability, and Precision for Profiler versus Horizontal Grid Radiosonde-Derived u and v Wind Components.

Layer	Wind Component	Bias[a] (m/s)	Comparability (m/s)	Precision (m/s)
Near Surface	u	+0.24	0.89	0.85
	v	-0.02	0.91	0.91
Upper Boundary	u	-0.19	0.74	0.71
	v	-0.45	0.99	0.88
Lower Troposphere	u	+0.08	0.82	0.82
	v	-0.28	1.17	1.14
Mid Troposphere	u	+1.66	3.91	3.54
	v	+0.32	1.16	1.11

[a] A positive bias indicates that, on average, the profiler wind component exceeds the radiosonde wind component.

A much larger data set consisting of 55 cases was available for profiler-radiosonde intercomparisons using data obtained from the Ditto radiosonde launch site. The results of profiler-radiosonde differences for u and v wind components are shown in Figures 12 and 13, respectively. The figures of merit for this data set are listed in Table 3. The bias in the u (east-west) component approaches -1 m/s for the near-surface and upper boundary layer regions, but decreases to -0.13 m/s in the mid-troposphere. The v component biases exhibit no similar consistency or trend. A likely explanation for the height variation of the u component bias is the influence of Granite Mountain, which is located 10 km west-southwest of the profiler site. Granite Mountain features a north-south oriented ridgeline rising 700 m above the local terrain. Using only the westerly through southwesterly flows that place the profiler site in the lee of Granite Mountain, the near-surface u component bias increases to -1.4 m/s. Thus, Granite Mountain apparently converts some energy from the mean flow within the first few kilometers of the surface into eddy energy. Granite Mountain eddy effects on near-surface micrometeorological data at a test grid near the profiler site have been previously observed by White et al. (1986).

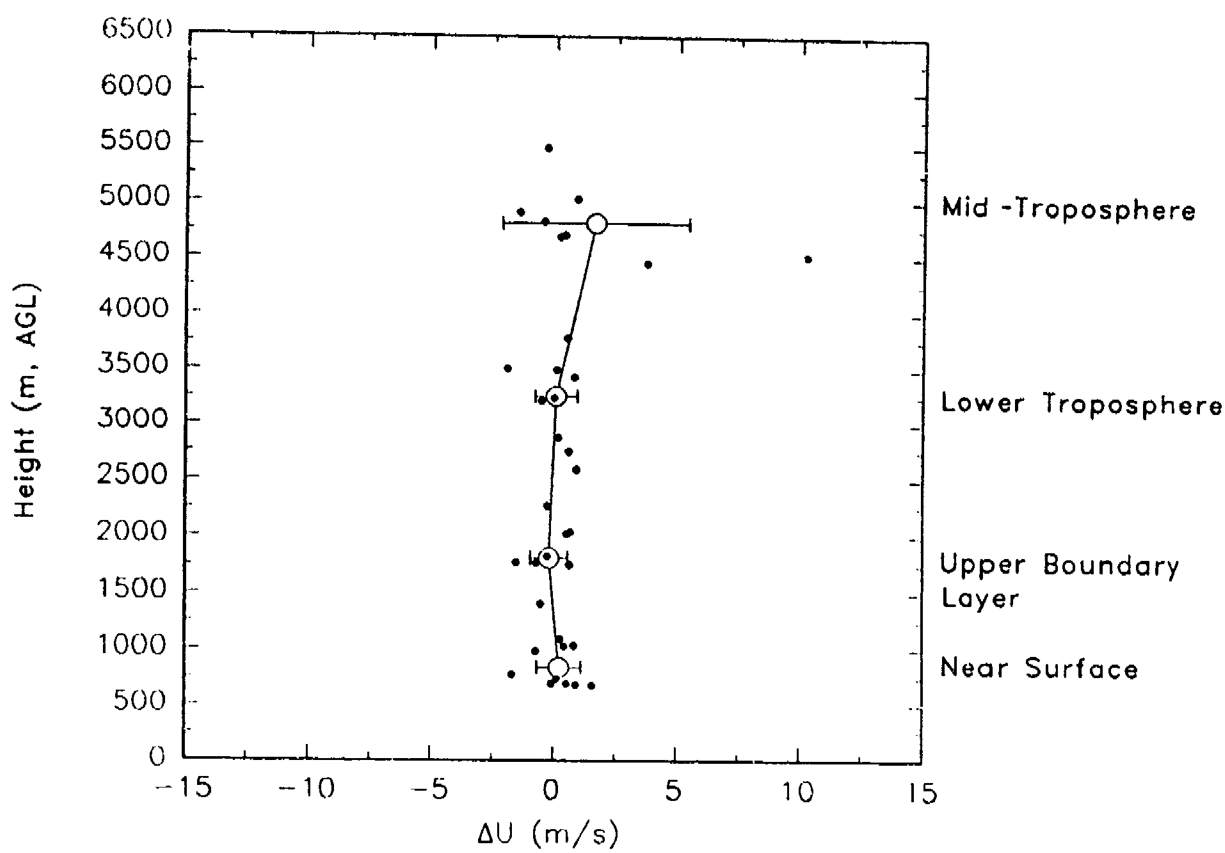

Figure 10. Differences Between the u-Component Profiler and Radiosonde Winds for Selected Near Surface, Upper Boundary Layer, Lower Troposphere, and Mid-Troposphere Data Points Using Horizontal Grid Radiosonde Data. Each Open Circle and Error Bar Indicates the Mean Plus and Minus One Standard Deviaton for a Data Point Cluster.

Table 3 shows that the comparabilities and precisions calculated for the Ditto radiosonde versus profiler wind component data are on the order of 3 to 5 m/s, in contrast to 1 m/s for the Horizontal Grid radiosonde versus profiler results presented in Table 2. The differences in these figures of merit between the two sites are consistent for both the u and v components and at all height levels. This indicates the magnitude of spatial differences in winds between the two sites. An examination of some individual cases revealed that improved figure of merit scores could have been achieved using levels above or below the levels selected for comparison. Weather systems propagate along isentropic surfaces, and these surfaces are usually tilted at some acute angle to the ground. Consequently, differences in measurements made at constant heights, but at significant separation distances, can be due to sampling in different portions of a weather system's wind profile. Local terrain effects also influence these scores.

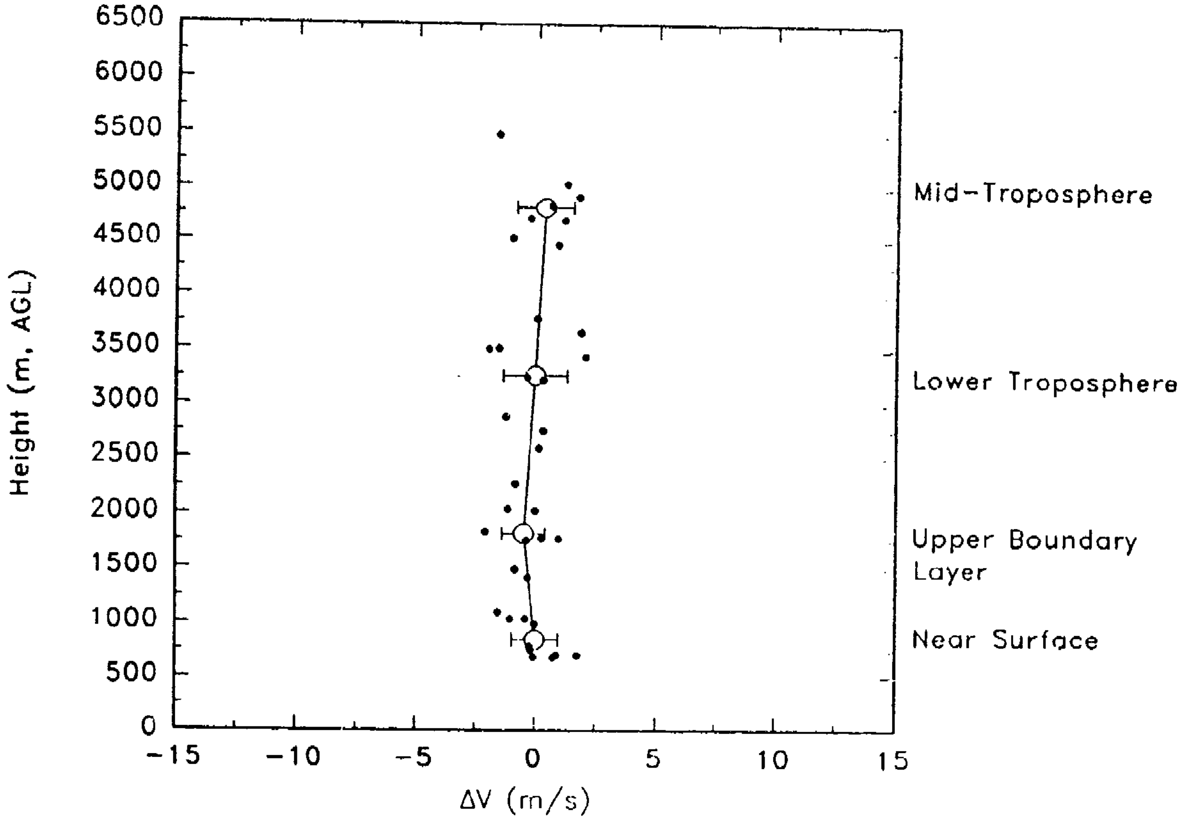

Figure 11. Differences Between the v-Component Profiler and Radiosonde Winds for Selected Near Surface, Upper Boundary Layer, Lower Troposphere, and Mid-Troposphere Data Points Using Horizontal Grid Radiosonde Data. Each Open Circle and Error Bar Indicates the Mean Plus and Minus One Standard Deviation for a Data Point Cluster.

Table 3. Bias, Comparability, and Precision for Profiler versus Ditto Radiosonde-Derived u and v Wind Components.

Layer	Wind Component	Bias[a] (m/s)	Comparability (m/s)	Precision (m/s)
Near Surface	u	-0.97	3.50	3.36
	v	-0.09	5.05	5.05
Upper Boundary	u	-0.92	4.83	4.74
	v	+0.20	4.74	4.74
Lower Troposphere	u	-0.66	3.70	3.64
	v	-0.61	3.51	3.46
Mid Troposphere	u	-0.13	2.80	2.80
	v	+0.30	3.45	3.44

[a] A positive bias indicates that, on average, the profiler wind component exceeds the radiosonde wind component.

The effects of moisture and temperature lapse rate on profiler performance were also examined. These effects were quantified in terms of returned power in decibels versus dew point or lapse rate obtained from concurrent radiosonde flights. Radar returned power also decreases as a function of range to target, but this effect was eliminated as a variable by selecting only data from height levels near the 400 mb level (approximately 7 km MSL) for use in the analysis. The 400 mb level was chosen for evaluation because operationally significant variations in data quality often appear in profiler data sets near this level. In addition to returned power, an assessment was made of profiler data quality; each data point was subjectively determined to be of good or poor quality based on spectral width and near-neighbor consistency checks. Profiler returned power is compared with moisture and temperature lapse in Figures 14 and 15, respectively. Figure 14 illustrates a weak positive correlation between returned power and dew point. This result is consistent with the fact that turbulent eddies containing moisture are relatively strong reflectors of radio wave energy. It is also apparent that the number of "good" clear air radar returns, based on an analysis of wind data quality, diminishes sharply as the dew point falls below -35 °C. Figure 15 shows no discernable effect between temperature lapse rate and returned power or data quality.

2.5 DEVELOPMENT OF PROFILER DATA DISPLAYS

The PDH came from the vendor with software to generate time-height wind diagrams and tabular reports. Examples of these reports are shown in Figures 16 and 17. Figure 16 is a time-height diagram illustrating hourly consensus wind barbs displayed in the standard meteorological convention. The occasional missing data (the absence of a reported wind barb) and erroneous wind reports (wind barbs that grossly deviate from the established flow) typically appear on the vendor-supplied display. The tabular display in Figure 17 lists an hour of consensus data. While useful to the DPG weather forecaster, the data shown in Figures 16 and 17 have not been passed through the DPG profiler quality control algorithms and are not in a format appropriate for test reports. Consequently, a new 48-h data base was created on the DPG computer system to include the most recent 48 h of wind profiles. Data older that 48-h must be retrieved from 8-mm tape data archives. The 48-h data base consists of 18-min averages constructed from successive 6-min profiler data records that have been passed through the automated quality control algorithms. Software was developed to access and review these data and print user-selected records in a format suitable for publication.

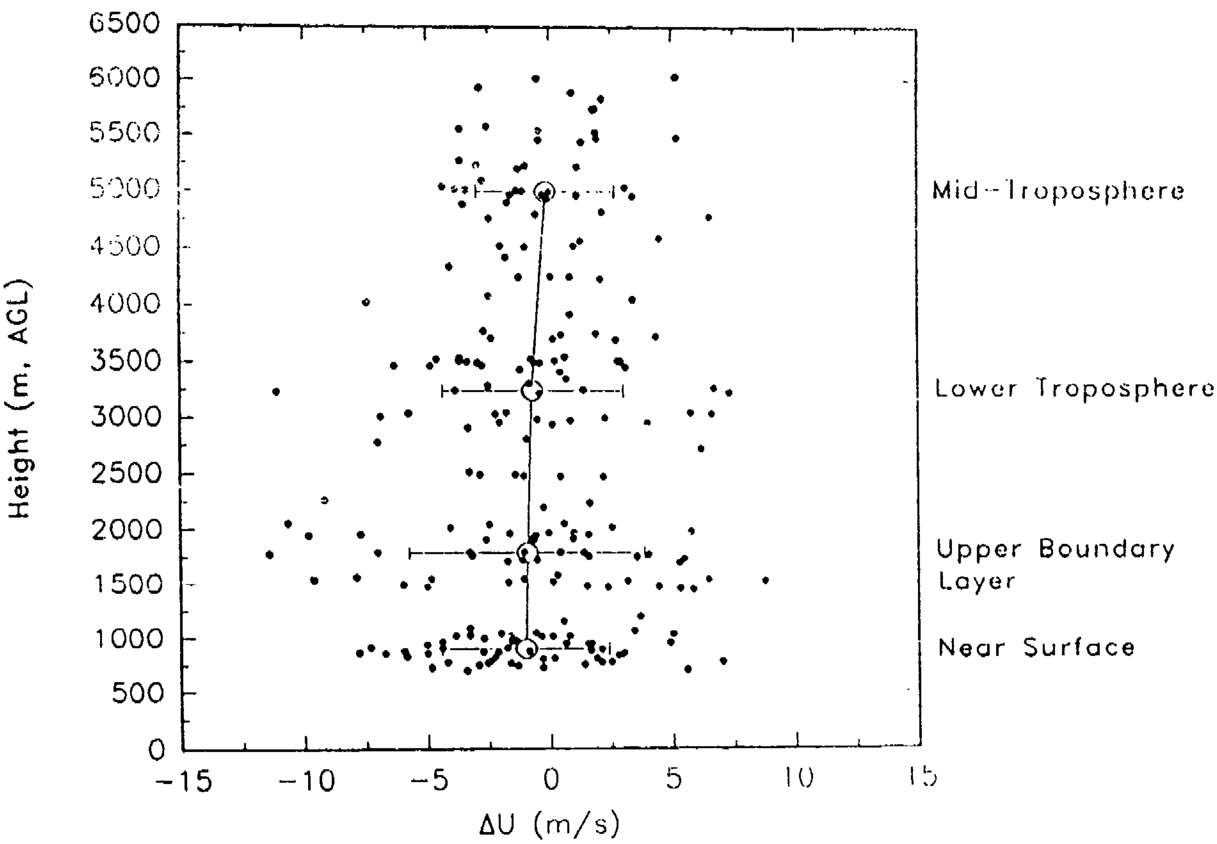

Figure 12. Differences Between the u-Component Profiler and Radiosonde Winds for Selected Near Surface, Upper Boundary Layer, Lower Troposphere, and Mid-Troposphere Data Points Using Ditto Radiosonde Data. Each Open Circle and Error Bar Indicates the Mean Plus and Minus One Standard Deviation for a Data Point Cluster.

An 18-min data averaging time was selected as a compromise between the need for frequent wind profile updates and the need to average a sufficient number of data points to produce a valid, representative wind profile. Hourly averaging is too long an interval for wind profile updating because significant changes (trends) in the wind field frequently occur on time scales of an hour or less. This is particularly true within the atmospheric boundary layer, under convective conditions, in the presence of precipitation, or during frontal passages. On the other hand, a single 6-min profile can often be too short in duration to be representative of wind conditions and may contain a significant amount of data that fail the quality control procedures. An 18-min running mean updated every 6 min appears to be a reasonable compromise that produces current, valid, and representative wind profile data.

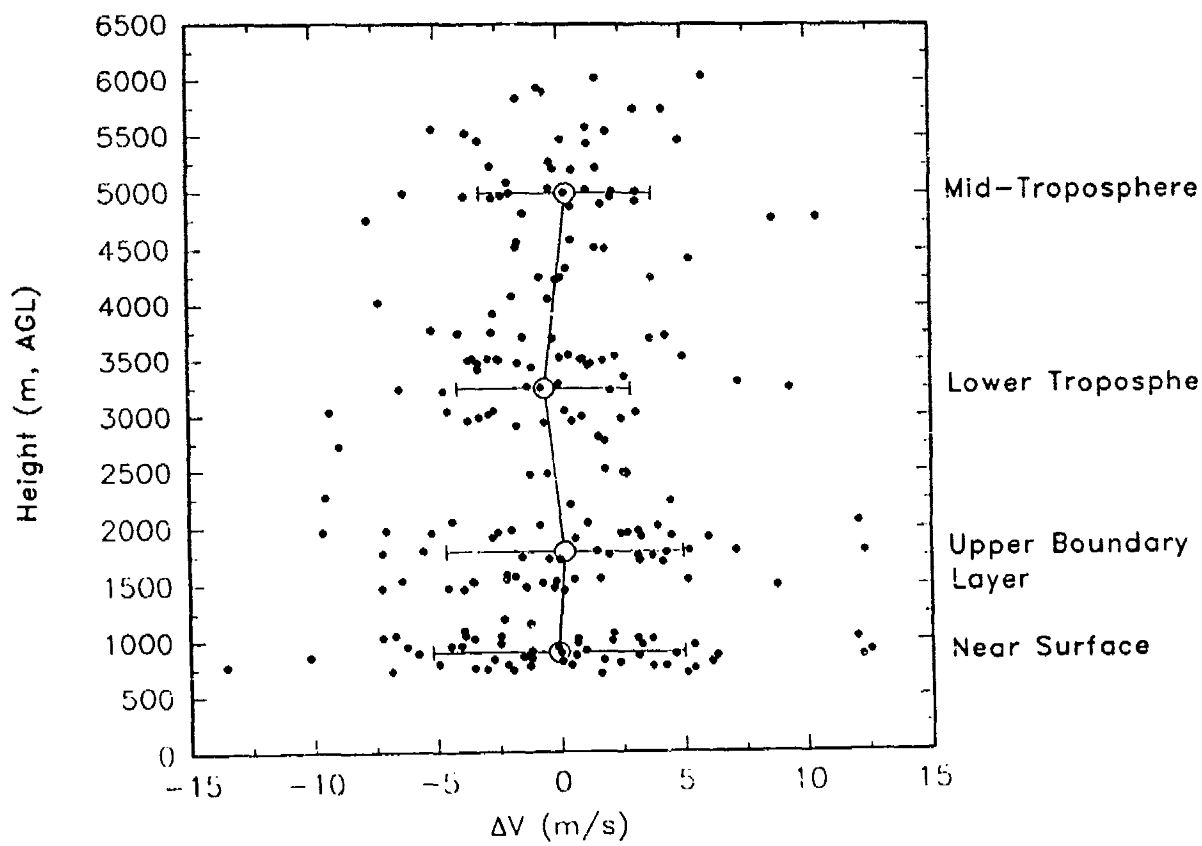

Figure 13. Differences Between the v-Component Profiler and Radiosonde Winds for Selected Near Surface, Upper Boundary Layer, Lower Troposphere, and Mid-Troposphere Data Points Using Ditto Radiosonde Data. Each Open Circle and Error Bar Indicates the Mean Plus and Minus One Standard Deviation for a Data Point Cluster.

To access the 48-h archive of profiler data, a user must have the capability to log on to the DPG computer system in the Ditto Computer Center. The symbolic command PFEXAM provides the user with the date and time for each 18-min record available in the 48-h data base. The user can select records of interest, such as those most closely corresponding to the previous day's artillery firing times. With time information in hand, the user then enters the symbolic command PFREPORT to generate a set of profiler data records in test report format. To produce the data in this format, the user selects: (a) the number of records to be presented (1 to 4); date and time of the record, as obtained from PFEXAM; (b) the tabular header information to include test name, date, and azimuth of fire; and (c) the range of profiler data heights to be included in the report. As many records as desired can be selected in groups of 1 to 4 per pass through the program. Figure 18 shows a set of profiler data records generated using PFREPORT.

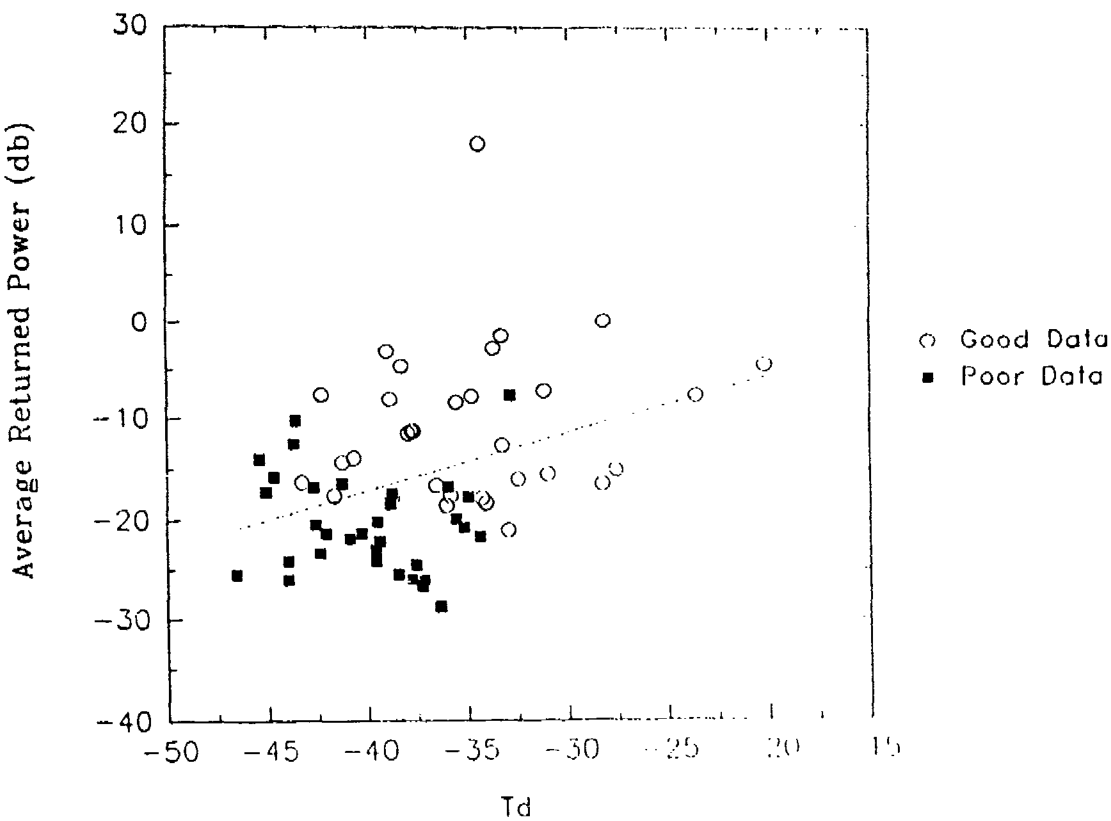

Figure 14. Atmospheric Dew Point (T_d, °C) versus Profiler Returned Power. Black Dots Denote Poor Data Quality and White Dots Denote Good Data Quality.

In addition to report data, current 18-min averaged profiler data are available to any user who has access to the DPG computer system by typing the symbolic command CUROBS. The CUROBS display provides the most recent 18-min profiler wind observation available, with updates every 6 min as the profiler completes a 6-min update cycle. The sample of CUROBS profiler data in Figure 19 shows that CUROBS contains more detailed wind information than presented in the PFREPORT format. For each reporting level, this information includes the number of 6-min data points that passed the automated quality control algorithm for each wind component (3 indicates that all passed, 0 indicates that none passed). The next three columns contain the u, v, and w wind components obtained from the data that passed the quality control algorithms, and the two columns to the right list the wind speeds and directions derived from these components. The column at the far right is the vertical wind shear, which is calculated for each level using the winds above and below that level. The CUROBS wind and shear data provide the user with the ability to monitor current wind and shear conditions near major DPG artillery ranges.

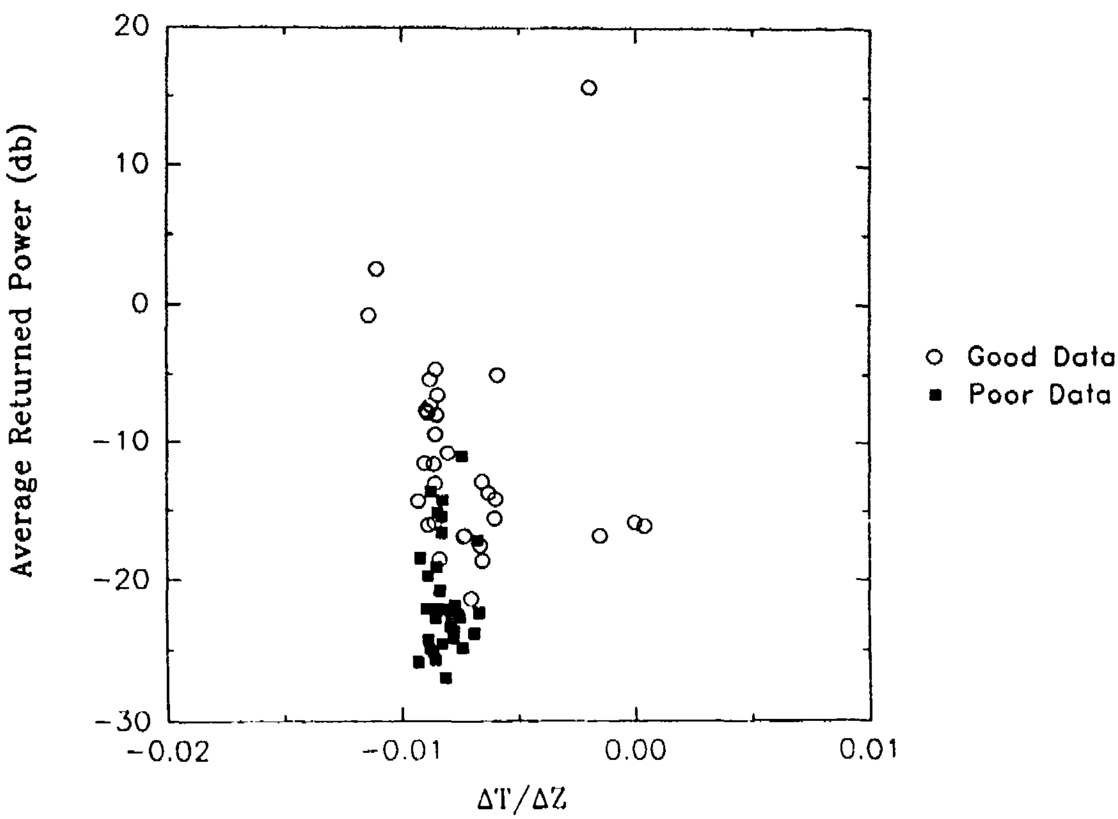

Figure 15. Temperature Lapse Rate (ΔT/ΔZ, °C/m) versus Profiler Returned Power. Black Dots Denote Poor Data Quality, and White Dots Denote Good Data Quality.

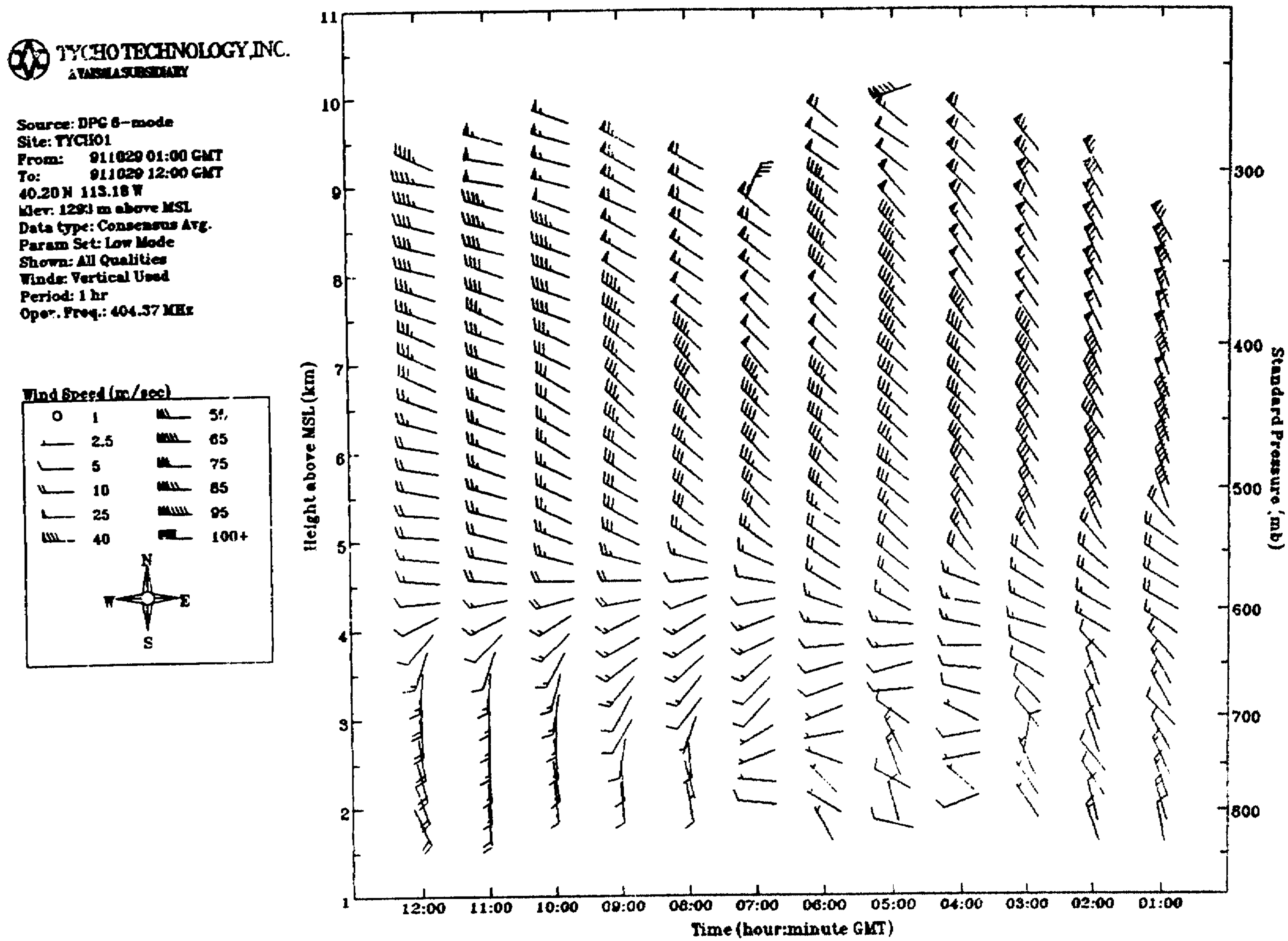

Figure 16. A Time versus Height Depiction of the Profiler-Generated Hourly Consensus Wind Field for 0100 to 1200 UTC on 29 October 1991 Using 250 m Range Gate Data. Blank Wind Barb Positions (at Various Locations Above 9 km MSL for all Hours) are Indicative of Range Gates Where Consensus Was not Achieved. Erroneous Wind Barbs at the Top of the 0500 and 0700 UTC Profiles Indicate Consensus on Erroneous Data.

TYCHO TECHNOLOGY, INC.
A VAISALA SUBSIDIARY

Source: DPG 6-mode
Site: TYCHO1
Time: 911029 12:00 GMT
40.20 N 113.18 W
Elev: 1293 m above MSL
Data type: Consensus Avg.
Param Set: Low Mode
Shown: All Qualities
Winds: Vertical Used
Period: 1 hr
Oper. Freq.: 404.37 MHz
Pulse Rep. Pd.: 100.0 us
First Gate: 507 m
Vertical Res.: 250 m
Gate Spacing: 250 m

GATE	HORIZONTAL WIND		WIND COMPONENTS			RADIAL VELOCITIES			SPECTRAL WIDTH			RETURNED POWER		
HEIGHT (m)	SPEED (m/s)	DIRECTION (deg N)	U (m/s)	V (m/s)	W (m/s)	XP (m/s)	YP (m/s)	V (m/s)	XP (m/s)	YP (m/s)	V (m/s)	XP (dB)	YP (dB)	V (dB)
1800	10.13	156.1	-4.10	9.26	-0.95	0.147	-3.312	-0.947	0.64	1.13	0.42	-19.1	-15.2	-18.1
2050	9.66	158.7	-3.52	9.01	-0.98	-0.034	-3.278	-0.979	0.65	0.78	0.41	-5.4	-2.0	-3.7
2300	9.63	167.3	-2.12	9.40	-1.00	-0.419	-3.399	-1.001	0.59	0.76	0.37	6.2	7.9	7.1
2550	9.59	172.3	-1.29	9.50	-1.01	-0.642	-3.435	-1.010	0.49	0.54	0.34	13.5	14.6	14.0
2800	9.39	175.9	-0.68	9.37	-1.00	-0.793	-3.394	-1.003	0.43	0.48	0.32	16.6	17.5	17.2
3050	8.98	180.3	0.04	8.98	-0.98	-0.961	-3.275	-0.984	0.42	0.46	0.32	17.0	17.8	17.8
3300	8.22	186.9	0.99	8.16	-0.93	-1.152	-3.009	-0.928	0.41	0.55	0.34	16.4	17.0	17.1
3550	6.85	197.7	2.08	6.53	-0.85	-1.357	-2.508	-0.847	0.46	0.73	0.36	15.4	15.7	16.0
3800	5.33	218.8	3.34	4.16	-0.81	-1.648	-1.859	-0.811	0.59	0.78	0.37	14.2	14.3	14.7
4050	5.16	246.7	4.74	2.04	-0.82	-2.017	-1.319	-0.819	0.59	0.67	0.33	12.7	12.4	13.3
4300	6.01	264.9	5.99	0.53	-0.82	-2.347	-0.934	-0.825	0.47	0.54	0.27	10.9	9.5	11.6
4550	7.04	273.6	7.02	-0.44	-0.81	-2.602	-0.671	-0.812	0.37	0.70	0.25	8.7	6.0	9.4
4800	7.99	274.7	7.96	-0.66	-0.79	-2.824	-0.593	-0.790	0.37	0.54	0.28	6.4	2.8	7.0
5050	8.87	275.4	8.83	-0.84	-0.78	-3.034	-0.533	-0.776	0.36	0.42	0.28	3.8	-0.5	4.4
5300	9.56	274.3	9.53	-0.72	-0.74	-3.186	-0.532	-0.744	0.34	0.62	0.29	1.1	-3.7	1.9
5550	10.03	278.1	9.93	-1.41	-0.70	-3.249	-0.313	-0.703	0.37	0.93	0.32	-1.1	-5.7	0.1
5800	10.20	278.1	10.10	-1.43	-0.59	-3.181	-0.195	-0.586	0.41	0.96	0.38	-2.0	-5.6	-1.4
6050	10.77	279.4	10.63	-1.76	-0.46	-3.190	0.017	-0.455	0.47	0.76	0.42	-2.0	-4.9	-1.9
6300	11.84	283.9	11.49	-2.85	-0.43	-3.386	0.325	-0.427	0.52	0.81	0.44	-2.5	-4.9	-2.2
6550	13.28	290.8	12.41	-4.71	-0.42	-3.618	0.814	-0.420	0.55	1.24	0.46	-4.0	-5.8	-3.6
6800	14.69	294.3	13.39	-6.05	-0.41	-3.860	1.172	-0.408	0.56	0.80	0.46	-5.9	-6.7	-5.7
7050	16.26	296.1	14.60	-7.16	-0.39	-4.154	1.478	-0.389	0.56	0.99	0.52	-7.3	-7.5	-7.1
7300	18.16	293.6	16.64	-7.27	-0.37	-4.667	1.523	-0.372	2.07	0.87	0.53	-7.9	-8.5	-7.7
7550	17.78	291.6	16.54	-6.53	-0.32	-4.585	1.386	-0.316	0.58	1.39	0.53	-9.1	-9.8	-8.7
7800	18.63	290.2	17.48	-6.44	-0.24	-4.761	1.431	-0.244	0.58	1.01	0.56	-10.7	-11.2	-10.3
8050	19.08	285.2	18.41	-5.00	-0.18	-4.940	1.119	-0.182	0.60	1.31	0.56	-12.4	-12.4	-12.1
8300	19.03	284.3	18.44	-4.71	-0.19	-4.951	1.040	-0.185	0.60	0.93	0.56	-14.9	-15.0	-14.0
8550	19.43	287.4	18.54	-5.80	-0.22	-5.016	1.283	-0.224	0.66	1.05	0.57	-17.1	-15.7	-16.3
8800	21.64	284.6	20.95	-5.44	-0.04	-5.461	1.309	-0.041	0.78	1.43	0.60	-17.4	-16.2	-16.0
9050	23.14	281.5	22.67	-4.61	-0.04	-5.906	1.157	-0.039	0.77	0.93	0.58	-17.7	-17.9	-16.4
9300	21.55	294.0	19.69	-8.75	-1.03	-6.091	1.270	-1.030	0.70	0.89	0.54	-21.4	-19.4	-21.2
9550	//////	//////	//////	//////	//////	-16.680	//////	4.602	0.49	//////	0.17	-26.4	//////	-26.3
9800	//////	//////	//////	//////	//////	//////	5.626	5.198	//////	0.69	0.13	//////	-23.7	-27.5
10050	//////	//////	//////	//////	//////	//////	//////	-5.225	//////	//////	0.09	//////	//////	-28.6
10300	//////	//////	//////	//////	//////	//////	1.013	//////	//////	2.04	//////	//////	-18.2	//////
10550	//////	//////	//////	//////	//////	//////	//////	-5.093	//////	//////	0.33	//////	//////	-26.1

Figure 17. A Tabular Presentation of Profiler Generated Hourly consensus wind Profiles for 29 October 1991, 1200 UTC Using 250 m Range Gate Data. Entries With the Solidus Indicate Range Gates Where Consensus Was Not Achieved.

WIND PROFILE DATA

TEST PROGRAM: TMDBCE DATE: 12-AUG-1991

LOCATION: WEST VERTICAL GRID AZIMUTH OF FIRE: 0.(DEG)

TIME(UTC)	16:31		16:37		16:43		16:49	
HEIGHT AGL (M)	WIND DIR (DEG)	WIND SPEED (M/S)	WIND DIR (DEG)	WIND SPEED (M/S)	WIND DIR (DEG)	WIND SPEED (M/S)	WIND DIR (DEG)	WIND SPEED (M/S)
5000	329	6.8	328	6.5	332	6.1	332	5.7
4750	327	8.1	327	8.1	332	7.8	336	7.5
4500	325	8.6	327	8.8	331	8.6	336	8.5
4250	322	8.3	324	8.5	328	8.6	332	8.5
4000	319	7.3	321	7.6	326	7.5	332	7.5
3750	324	6.3	327	6.6	330	6.6	334	6.7
3500	330	5.7	334	6.0	334	6.1	336	6.1
3250	330	5.1	335	5.4	333	5.7	332	5.7
3000	316	4.0	314	4.4	319	4.9	332	5.2
2750	339	2.0	314	1.8	310	2.7	304	3.0
2500	232	1.0	228	1.2	233	1.4	226	3.1
2250	219	3.6	220	3.8	223	5.0	221	4.7
2000	188	2.2	189	2.5	210	4.1	215	6.2
1750	203	4.8	194	4.9	206	6.5	193	6.6
1500	200	4.8	187	4.9	201	6.5	190	6.8
1250	199	4.8	184	4.8	199	6.4	189	6.8
1000	198	5.5	187	5.1	198	6.8	189	7.1
750	196	5.6	192	4.8	208	7.5	209	7.1
500	195	5.7	202	4.5	193	5.2	218	7.6

Figure 18. DPG Radar Wind Profiler 18-min Averaged Data for Theatre Missile Defense Bulk Chemical Experiment Trials, 12 August 1991, 1631-1649 UTC in Test Report Format.

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$ curobs
                      31-JUL-1991 22:43:50     31-JUL-1991 23:02:02
  HT     NR. VALID       AVERAGED WIND          WIND SPEED(M/S)     VECTOR HORIZ.
 AGL   6-MIN PERIODS     COMPONENTS(M/S)       AND DIRECTION(DEG)    WIND SHEAR
 (M)     U   V   W        U     V     W            WS     HD         (1/SEC)
-----------------------------------------------------------------------------------
9250     3   3   3      -9.4  -9.8  -0.3          13.5   224
9000     3   3   3      -9.2 -12.1  -0.2          15.2   217          0.0061
8750     3   3   3      -8.8 -12.8  -0.5          15.5   215          0.0033
8500     3   3   3      -7.8 -11.3  -0.4          13.7   215          0.0031
8250     3   3   3      -7.8 -11.6  -0.2          14.0   214          0.0013
8000     3   3   3      -7.2 -11.6  -0.1          13.7   212          0.0018
7750     3   3   3      -7.0 -11.9   0.1          13.8   210          0.0019
7500     3   3   3      -6.6 -12.3   0.2          14.0   208          0.0017
7250     3   3   3      -7.2 -12.8   0.2          14.6   209          0.0040
7000     3   3   3      -5.0 -13.6   0.3          14.5   200          0.0038
6750     3   3   3      -5.6 -13.8   0.6          14.9   202          0.0020
6500     3   3   3      -6.1 -13.5   0.7          14.8   204          0.0016
6250     3   3   3      -6.2 -14.3   0.7          15.6   203          0.0065
6000     3   3   3      -6.6 -16.7   0.9          18.0   202          0.0030
5750     3   3   3      -7.2 -15.5   1.0          17.0   205          0.0091
5500     3   3   3      -7.9 -12.4   0.9          14.7   212          0.0106
5250     3   3   3      -7.5 -10.2   0.6          12.6   216          0.0039
5000     3   3   3      -6.7 -10.8   0.5          12.7   212          0.0033
4750     3   3   3      -6.8 -11.7   0.4          13.5   210          0.0008
4500     3   3   3      -7.0 -11.0   0.5          13.1   212          0.0015
4250     3   3   3      -7.6 -11.7   0.7          13.9   213          0.0022
4000     3   3   3      -7.3 -12.1   0.9          14.1   211          0.0019
3750     3   3   3      -6.7 -11.9   0.9          13.7   209          0.0026
3500     3   3   3      -6.3 -11.3   0.9          12.9   209          0.0039
3250     3   3   3      -5.0 -11.1   0.7          12.1   204          0.0040
3000     2   3   3      -4.5 -12.1   0.6          12.9   200          0.0130
2750     3   3   3       0.4  -7.5  -0.2           7.5   177          0.0186
2500     3   3   3       1.9  -5.4  -0.4           5.7   161          0.0035
2250     2   3   3       2.1  -6.8   0.2           7.1   163          0.0035
2000     3   2   3       3.1  -6.6    .2           7.3   155          0.0036
1750     3   3   3       0.4  -6.2   0.1           6.2   176          0.0057
1500     3   3   3       0.8  -5.0  -0.1           5.0   171          0.0044
1250     3   3   3      -1.3  -4.8   0.0           4.9   195          0.0058
1000     2   3   3      -2.1  -5.1   0.1           5.5   202          0.0036
 750     2   2   3       0.4  -4.2   0.4           4.3   174
 500     0   1   3
$ pof
```

Figure 19. Current Profiler 18-min Averaged Wind Observations for 31 July 1991, 2243:50-2302:02 UTC Obtained by Executing the Symbolic Command CUROBS.

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SECTION 3. APPENDICES

APPENDIX A

METHODOLOGY INVESTIGATION PROPOSAL AND DIRECTIVE

DEPARTMENT OF THE ARMY
U. S. ARMY DUGWAY PROVING GROUND
DUGWAY, UTAH 84022-5000

REPLY TO
ATTENTION OF:

STEDP-MT-A (70)

20 MAR 1991

MEMORANDUM FOR Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TC, Aberdeen Proving Ground, MD 21005-5005

SUBJECT: FY91 D628 TECOM Test Technology Development and Test Process Improvement Obligation Plan and Request for Reprogramming Action

1. Reference memo, HQ TECOM, AMSTE-TC, 5 Mar 91, Subject: FY91 D628 TECOM Test Technology Program Performance.

2. The FY91 Test Process Improvement obligation plan and requested reprogramming is listed at enclosure 1.

3. The FY91 Test Process Improvement and Test Technology Development obligation plans are at enclosure 2.

4. Point of contact for this action is Mr. R. K. Dumbauld, DSN 789-5416 or Ms. Virginia Murray, DSN 789-5418, stedpmta@dugway-emh1.army.mil.

FOR THE COMMANDER:

2 Encl

Dean R. Ertwine
DEAN R. ERTWINE
LTC, CM
Director, Materiel Test

-AT (Perry Pederson)

14 MAR 91

FY91 METHODOLOGY OBLIGATION PLAN ($ K)

AS OF 9 MAR 91

TRMS NO.	TITLE	ORIGINAL FUNDING	REVISED FUNDING	CHANGE	BALANCE 03/09/91	OBLIGATION PLAN MAR	APR	MAY	JUN	JUL	AUG	SEP
7-CO-M91-DPD-001	QUICK REACTION	34	34	0	33	3	5	5	5	5	5	5
7-CO-M91-DPD-002	TECH COMMITTEE	8	8	0	4	0	1	1	1	1		
7-CO-M91-DPD-003	CHEM LAB AUTO & DATA	40	40	0	30	1.5	6	4.5	4.5	4.5	4.5	4.5
7-CO-M91-DPD-004	BIO CHALLENGES	48	52	4	29	5	7	6	6	3	2	0
7-CO-M91-DPD-005	IMPL REMOTE SENSING	12	22	10	9	2	1	2	1	1	1	1
7-CO-M91-DPD-006	REAL TIME ANAL	36	30	-6	26	2	2	3	5	5	5	4
7-CO-M91-DPD-007	AEROSOL PENETRATION	15	12	-3	9	3	1.5	1.5	1.5	1.5	0	0
7-CO-M91-DPD-008	ENV MONITORING PROG	20	20	0	18	4	3	3	4	2	1.5	0.5
7-CO-M91-DPD-009	AI FOR DATA ACQUIS	46	46	0	46	30	4	4	4	4	0	0
7-CO-M91-DPD-010	PROTECTION FACTOR	10	10	0	8	2	2	2	1	1	0	0
7-CO-M91-DPD-011	SURFACE SAMPLING	35	30	-5	28	1.5	3	3	4.5	6	6	4
TOTALS		304	304	0	240	54	35.5	35	37.5	34	25	19

Perry

DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005-5055

REPLY TO
ATTENTION OF

AMSTE-TC (70-10p)

23 MAY 1991

MEMORANDUM FOR Commander, U.S. Army Dugway Proving Ground, ATTN: STEDP-MT-A, Dugway, UT 84022-5202

SUBJECT: Amendment 3 to Test Execution Directive, Test Technology Development, Test Process Improvement, and Artificial Intelligence Programs

1. Reference memo, HQ TECOM, AMSTE-TC-D, 25 Oct 90, subject: Test Execution Directive, Test Technology Development and Test Process Improvement Programs.

2. This memo, with list of investigations at encl 1, amends reference 1, Test Technology Development Program.

3. Point of contact at this headquarters is Ms. Cynthia McMullen, AMSTE-TC, amstetcd@apg-9.apg.army.mil, DSN 298-7878/7881.

FOR THE COMMANDER:

Frederick D. Mabanta

Encl

FREDERICK D. MABANTA
Chief, Technology Development Division
Directorate for Technology

CF: STEDP-MT-AT

	DUGWAY PROVING GROUND	INITIAL FUNDING	REVISED FUNDING	AMEND #1
CO-M91-DPD-001	FY91 Quic!- Reaction Methodology	34.0	25.5	-8.5
/-CO-M91-DPD-002	FY91 Technical Committee Support	8.0	8.0	0.0
7-CO-M91-DPD-003	Chem Lab Auto. and Data Comm.-Rout. Anal	40.0	40.0	0.0
7-CO-M91-DPD-004	Biological Challenges	48.0	48.0	0.0
7-CO-M91-DPD-005	Implement Remote Sensing	12.0	17.0	5.0
7-CO-M91-DPD-006	Real-Time Analysis of Vapors	36.0	31.0	-5.0
7-CO-M91-DPD-007	Aerosol Penetration of Fabrics	15.0	15.0	0.0
7-CO-M91-DPD-008	Environmental Monitoring Program	20.0	27.5	7.5
7-CO-M91-DPD-009	AI for Data Acquisition Sys. Evaluation	46.0	46.0	0.0
7-CO-M91-DPD-010	Protection Factor Testing Standardizatio	10.0	10.0	0.0
7-CO-M91-DPD-011	Surface Sampling for Residual Contact Ha	35.0	10.0	-25.0
		----	----	---
	TOTAL DPG PROGRAM	304.0	278.0	-26.0

TEST CENTER: DPG

	FUNDING $(K)						
	PRIOR	FY91	FY92	FY93	FY94	FY95	FY96	FY97
PRIMARY MISSION AREA SUPPORTED: NBC		F12						

TITLE: Implementation of Remote Sensing Technology

BACKGROUND: New remote sensing instruments (scintillometers and radar wind profiler) will be arriving at DPG in FY 90-91. These instruments are "state of the art" and require testing before they are deployed on field test projects.

PROBLEM: DPG personnel have no experience operating the new remote sensing equipment, and definitive studies of the precision or operational comparability of these instruments have not been performed. Before using these instruments for test support, DPG must acquire operating experience and establish operational limitations.

OBJECTIVE: Perform intercomparison tests and develop operating procedures for new remote sensing instrumentation.

TEST CENTER: DPG

	FUNDING $(K)						
	PRIOR	FY91	FY92	FY93	FY94	FY95	FY96	FY97
PRIMARY MISSION AREA SUPPORTED: NBC		F15						

TITLE: Aerosol Penetration of Fabrics

BACKGROUND: To date the U.S. Army has no established methods for the evaluation of aerosol penetration of fabric swatches. There have been several studies funded by the Army that recommended various test fixtures and techniques, but no standardized methods exist. Requirements, however, do exist to assess the aerosol penetration of fabrics.

PROBLEM: Developmental fabrics are being selected for use by the Army without proper assessment of their ability to inhibit aerosol particle penetration. The hazards posed by percutaneously active aerosolized particles have been recognized as potentially incapacitating to soldiers. Methodology for evaluation of filter efficiency of candidate materials must be standardized.

OBJECTIVE: The goal of this methodology is to compile information on existing technologies related to testing fabrics for penetration of aerosol particles. After the applicable elements have been contacted, a DPG sponsored seminar will take place to coordinate the selection of test methods and instrumentation for the implementation of fabric penetration testing.

1111-7-11

DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005-5055

REPLY TO ATTENTION OF

AMSTE-TC-D (70-10p) 16 AUG 1990

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: FY91 RDTE Methodology and RDI Programs

1. The FY91 Methodology and RDI programs have been prioritized using a weighted combination of evaluations from the Test Centers (FY91 MIND submissions), as well as input from HQ TECOM Directorates for Test and Assessment and Technology. The resulting priority lists which represent the interests of the command are enclosed.

2. Test Centers are requested to use these lists to make necessary changes in the execution of their respective programs where applicable.

3. Point of contact at this headquarters is Mr. James Piro, AMSTE-TC-D, amstetcd@apg-emh4.apg.army.mil, AUTOVON 298-2170/3677.

FOR THE COMMANDER:

Encl

For Kenneth Belliot
FREDERICK D. MABANTA
C, Technology Development Div
Directorate for Technology

DISTRIBUTION:
Cdr, USAAVNDTA, ATTN: STEBG-MP-P
Cdr, CRTC, ATTN: STECR-MT-T
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Cdr, USAEPG, ATTN: STEEP-MO-M
Cdr, JPG, ATTN: STEJP-TD-D
Cdr, WSMR, ATTN: STEWS-PL
Cdr, YPG, ATTN: STEYP-MT-I
Cdr, MICOM, ATTN: AMSMI-RD-TE-M

	DUGWAY PROVING GROUND	INITIAL FUNDING
7-CO-M91-DPD-001	FY91 Quick Reaction Methodology	34.0
7-CO-M91-DPD-002	FY91 Technical Committee Support	8.0
7-CO-M91-DPD-003	Chem Lab Auto. and Data Comm.-Rout. Anal.	40.0
7-CO-M91-DPD-004	Biological Challenges	48.0
7-CO-M91-DPD-005	Implement Remote Sensing	12.0
7-CO-M91-DPD-006	Environmental Monitoring Program	20.0
7-CO-M91-DPD-007	AI for Data Acquisition Sys. Evaluation	46.0
7-CO-M91-DPD-008	Protection Factor Testing Standardization	10.0
7-CO-M91-DPD-009	Real-Time Analysis of Vapors	36.0
7-CO-M91-DPD-010	Aerosol Penetration of Fabrics	15.0
7-CO-M91-DPD-011	Surface Sampling for Residual Contact Hazards	35.0

	TOTAL DPG PROGRAM	304.0

APPENDIX B

REFERENCES

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