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ATMOSPHERIC DESCRIPTION FOR IDAHO FALLS B-757 RUN #9 on September 25, 1990

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VOLPE

CENTER

WAKE

VORTEX

ATMOSPHERIC DESCRIPTION FOR IDF B-757 RUN #9

1. INTRODUCTION

The Volpe National Transportation System Center (Volpe Center) has been developing data processing software for the meteorological tower and tethersonde data observed during the special wake vortex experiments conducted at Idaho Falls in 1990. In addition, the data have been analyzed by Volpe Center meteorological support personnel for the purpose of preparing "canonical cases" for study by wake vortex modelers. The following material is the first such case developed for a particularly strong and persistent up wind vortex from a B-757 flyby at 0818LST on 25 Sept, 1990. Data are provided in three forms: raw data, data smoothed in time and height, and best fit polynomials.

Except at the turbulent scale, the bulk characteristics of a local airmass change slowly relative to the lifecycle of a vortex pair from a single aircraft. Therefore, the dataset from this case taken over the space of a few minutes by the instrumented tower and a tethersonde less than a mile away should be reasonably representative of flyby #9 on Sept 25, 1990. In future experiments, we must further test and prove this hypothesis. However, in the present case, it seems like a reasonable working assumption without evidence to the contrary.

We manually smoothed the tethersonde data primarily in order to remove some of the effects of what appears to be significant observational noise associated with the sounding technique employed. The tethersonde balloon only developed for ten (10) seconds at each observation level in order to minimize the time of balloon flight and provide safe aircraft flybys. The smoothed data were then fit to fourth order polynomials which provided an analytical description of the profiles of wind, temperature, and derived parameters. This also removed more of the irregularities while preserving the larger scale vertical structure. Thus users of this dataset can choose from several optional forms of data.

It should be noted that we have presented the wind data in terms of the orthogonal components; u, which is positive west to east, and v, which is positive south to north, rather than in terms of direction and speed.

2. TECHNICAL DISCUSSION

2.1 RAW DATA

Tables 1 and 2 provide the original temperature vertical profiles from the meteorological tower and the tethersonde respectively, along with the derived parameters: u and v wind components, lapse rate, Brunt-Vaisalla frequency (B-V), and Richardson Number (Ri). These are also the data that are provided in the Volpe Center data processing and display system.

TABLE 1. UNSMOOTHED TOWER DATA FROM IDF B-757 RUN #9						
Height (ft)	Temp (C)	u (m/sec)	v (m/sec)	Lapse (C/100ft)	B-V Freq (sec-1)	Rich Num
6.25	8.4	-1.01	-1.62	XXXX	XXXX	XXXX
12.5	8.4	-1.27	-1.81	0.00	0.018	0.012
25	8.3	-1.24	-2.14	-0.80	IMAG.	-0.077
50	8.2	-1.42	-2.45	-0.40	IMAG.	-0.052
100	8.4	-2.10	-3.12	0.40	0.028	0.204
150	9.0	-3.20	-4.10	1.20	0.041	0.183
200	9.6	-3.28	-4.68	1.20	0.041	1.144

TABLE 2. UNSMOOTHED TETHERSONDE DATA FROM IDF B-757 RUN #9						
Height (ft)	Temp (C)	u (m/sec)	v (m/sec)	Lapse (C/100ft)	B-V Freq (sec-1)	Rich Num
112	8.3	-0.59	-3.03	XXXX	XXXX	XXXX
224	8.8	-2.22	-6.10	0.45	0.029	0.082
297	9.5	-1.70	-5.56	1.00	0.038	1.222
409	11.6	-1.51	-7.78	1.89	0.050	0.573
449	11.9	-1.23	-5.79	0.73	0.034	0.045
549	12.4	-0.90	-5.12	0.56	0.031	1.282
624	12.6	-2.04	-5.94	0.23	0.024	0.208

TABLE 3. SMOOTHED TOWER AND SONDE DATA FROM IDF B-757 RUN #9						
Height (ft)	Temp (C)	u (m/sec)	v (m/sec)	Lapse (C/100ft)	B-V Freq (sec-1)	Rich Num
6.25	8.4	-1.01	-1.62	XXXX	XXXX	XXXX
12.5	8.4	-1.27	-1.81	0.00	0.018	0.012
25	8.3	-1.24	-2.14	-0.80	IMAG.	-0.077
50	8.2	-1.42	-2.45	-0.40	IMAG.	-0.052
100	8.4	-2.10	-3.12	0.40	0.028	0.204
150	9.0	-3.20	-4.10	1.20	0.041	0.183
200	9.7	-2.86	-5.34	1.40	0.044	0.298
300	11.5	-2.6	-5.56	1.80	0.049	1.377
400	12.4	-1.57	-6.50	0.90	0.037	0.666
500	12.4	-1.80	-5.15	0.00	0.018	0.172
600	12.6	-2.02	-5.50	0.20	0.024	3.15

Note: The derived parameters (last three columns of each table) are centered on the layer bounded by the height of that row and the height of the row immediately preceding. The term "IMAG" is for imaginary B-V frequencies (unstable lapse rate cases).

The tower data are from three minutes averages at the heights shown. The tethsonde data from 0816 LST (the closest available in time) are from 10 second averages at each observation level.

Therefore, the tower data vary less with height and time than do the tethersonde data which have a larger noise component due, in part to the bobbing of the balloon during its flight. The Turbulence data available from the hot film anemometers is presented in Attachment C along with a description of the analysis of this data.

2.2 SMOOTHED TETHERSONDE DATA IN HEIGHT AND TIME

Because the tethersonde data were noisy, were not synchronized with the flybys, and were not taken simultaneously at all levels, it was determined that these data should be smoothed in height and time.
This was accomplished by plotting height vs. time cross-sections of temperature and wind components from the tower and tethersonde data, and then averaging data pairs from ascents and descents which were at nearly the same level. The tower data were not smoothed *per se.* However, they were averaged with the tethersonde data in the overlap region around 150 to 200 feet. The averaged data were then hand analyzed to give somewhat smoothed contours that would permit the extraction of data at any arbitrary time and height. Figures 1. and 1a. illustrate this process with the height vs. time cross-section of original wind speed (kts) from the morning of the 25th. Note that there are fewer data "bullseyes" and suspiciously tight gradients on Figure 1a, the smoothed chart. Table 3 gives the smoothed values of temperature, and u- and v-components for the heights shown, along with the derived parameters.

2.3 FITTING CURVES TO THE SMOOTH DATA

The smoothed profiles for Run #9 were then plotted and it was noted that there was probably still some unwanted noise in the data; therefore, each profile was fitted with polynomials of various orders, and 4th order functions seemed to do a reasonable job, especially for temperature. Figures 2 and 3 show the smoothed curves for temperature and u and v along with the polynomial fits and their equations. Note that the atmosphere was quite stable above about 50 feet as suggested by the strong temperature inversion in that region of the sounding. We will see large values of B-V and Ri in that region which would suggest that turbulence was probably suppressed above 50 feet.

Fig 1. UNSMOOTHED WIND SPEED X-SECTION
9/25/90 IDF

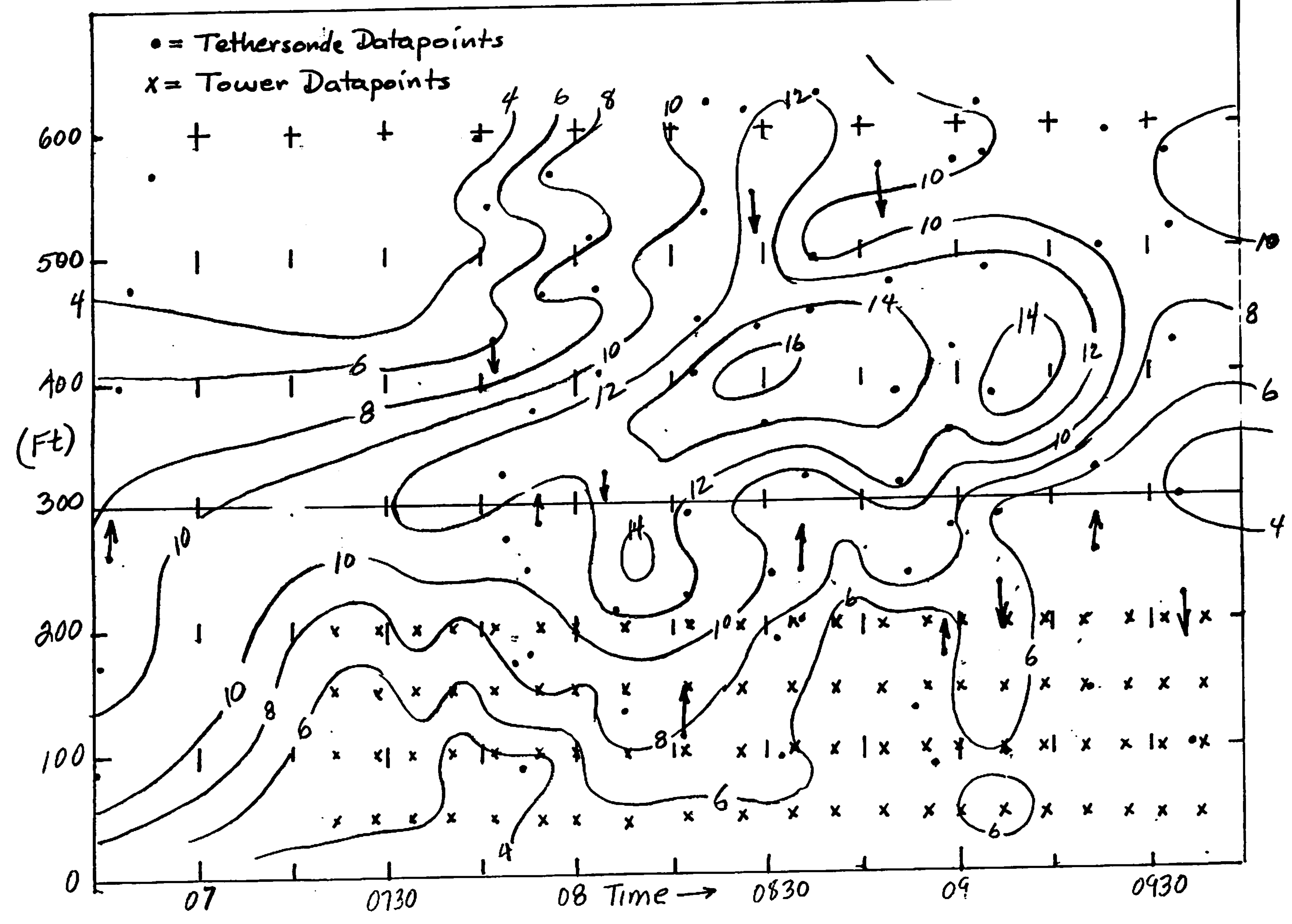


Fig 1a. Smoothed Wind Speeds 9/25/90

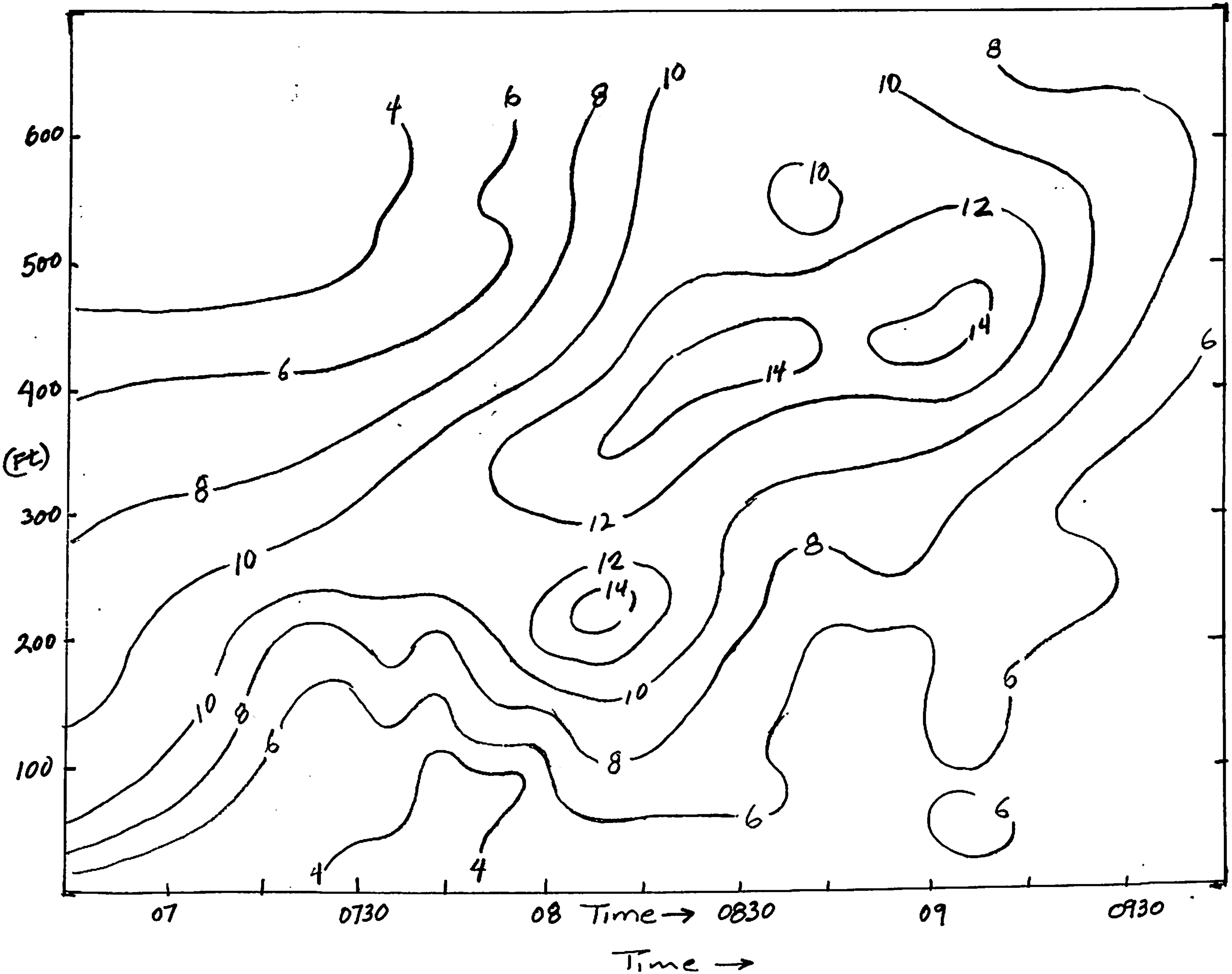


FIG. 2. TIME-SMOOTHED AND FITTED TEMPERATURE PROFILE FOR B-757 RUN#9

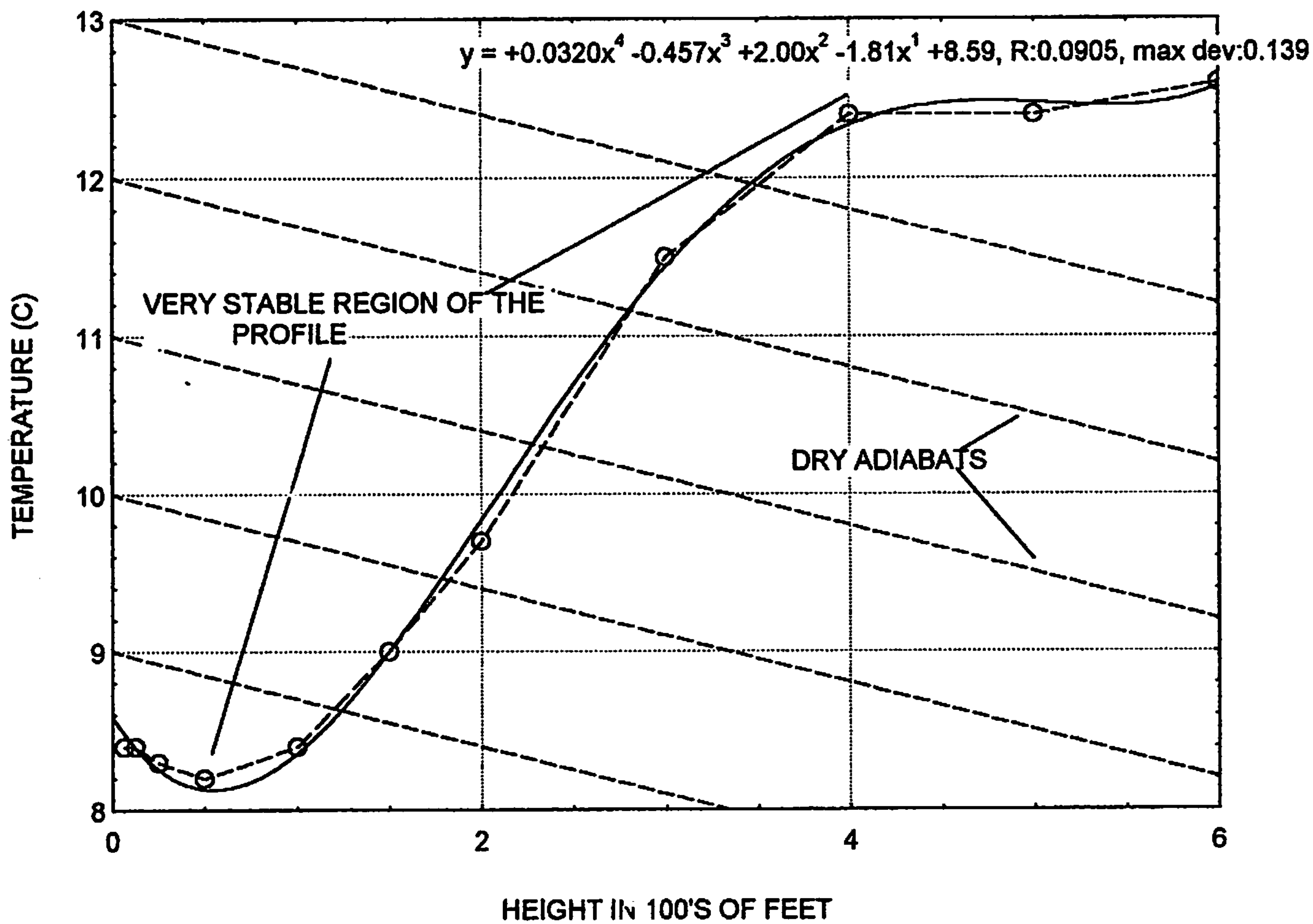
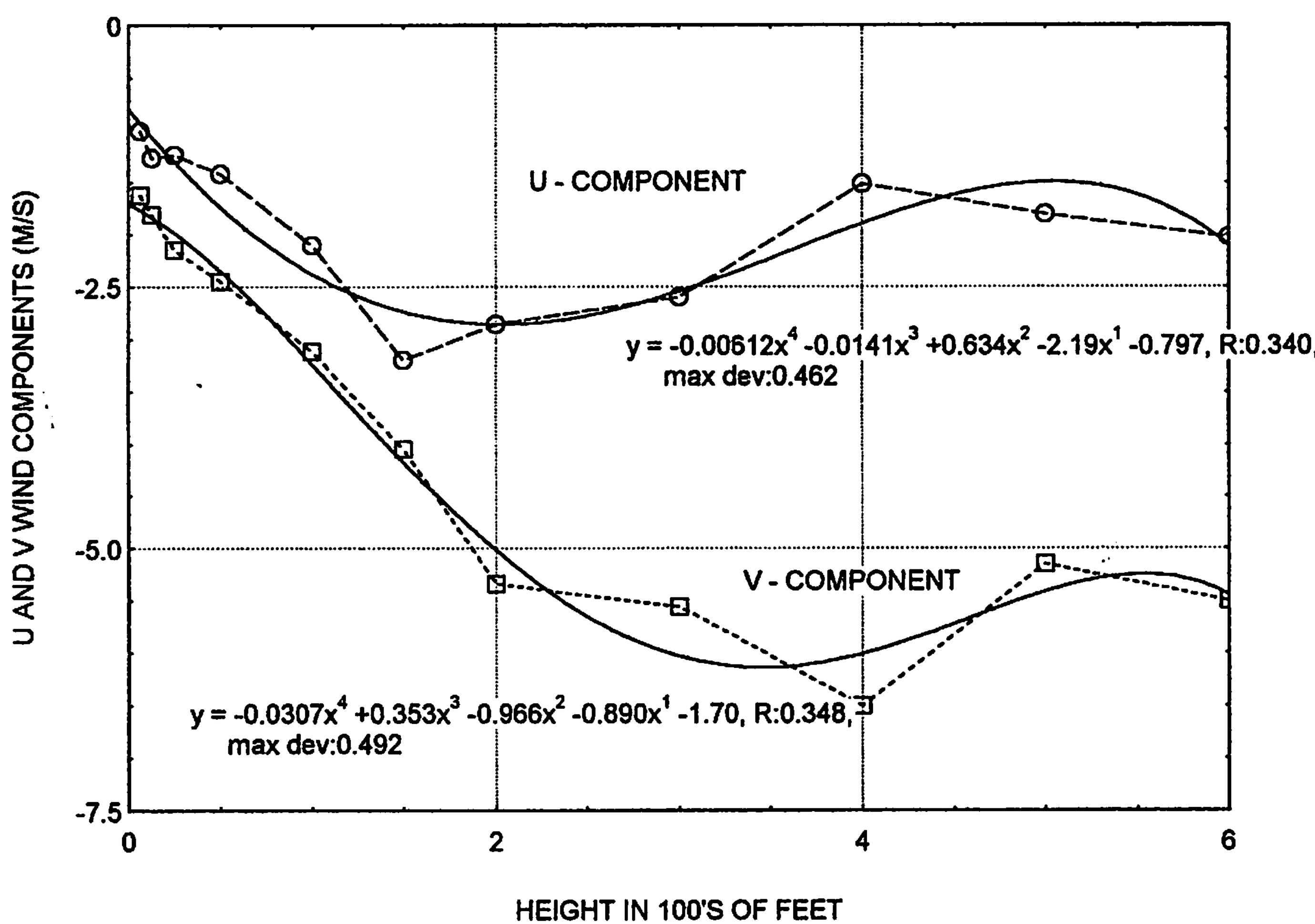


FIG. 3. TIME -SMOOTHED AND FITTED PROFILES OF U AND V FOR B-757 RUN #9



2.4 DERIVED PARAMETERS FROM THE FITTED DATA

Since we now have analytical versions of the profiles in the form of polynomials, it is possible to solve analytically for the derived parameters: lapse rate, B-V, and Ri. This was done and the results are shown in Attachment A as two figures and a table which are the output from a MATHCAD program. Also shown are the analytical expressions used in the computation. If the reader wishes to work with the equations, be aware that heights are in the 100's of feet (e.g., z = 5 corresponds to 500 ft), and there are some mixed units because winds are in m/sec. This required the correction term 930.25 in the expression for Ri.

3. SUMMARY

The Run #9 meteorological dataset has been prepared in three forms: raw data, manually smoothed and best fit polynomial. The users can therefore choose what they believe to be the best dataset for their purpose. No digital form of the smoothed or best fit data are available; however, the raw data can be obtained on a floppy disk from Volpe Center. For this first case, we hope to get user feedback as to what is the most usable form for future cases.

A map extracted from the NOAA Wake Vortex Technical Memorandum ERL ARL-199 is provided in Figure 4. The direction of flight of the aircraft is 300 degrees True North. The trajectories of the vortices are approximately perpendicular to the aircraft flight paths for the #9 flyby at 0818 LST on 25 Sept, 1990; these vortices are plotted in Figure 5.

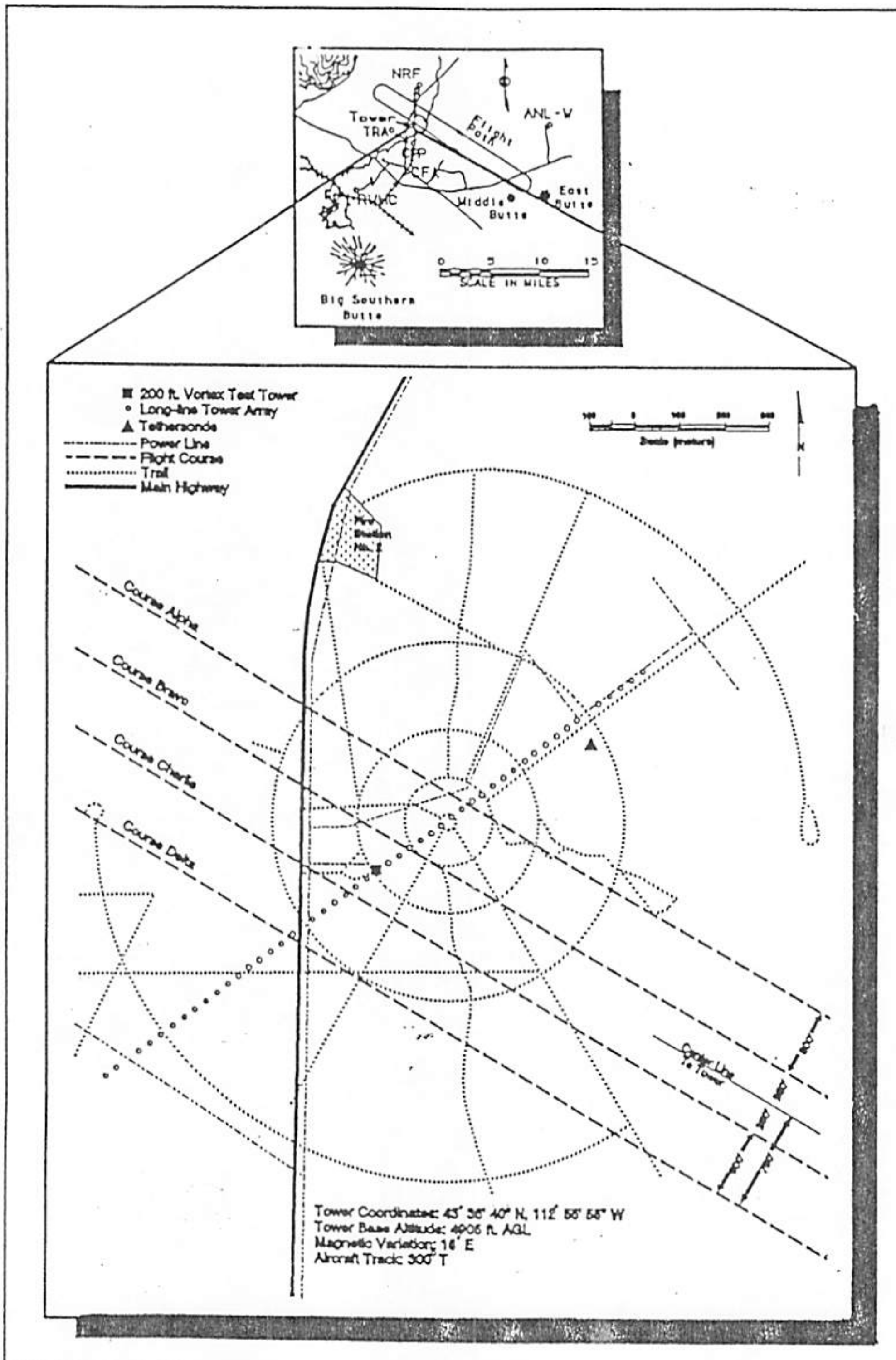


Figure 4. NOAA wake vortex test site and associated aircraft flight path in relation to various local landmarks on and near the INEL complex.

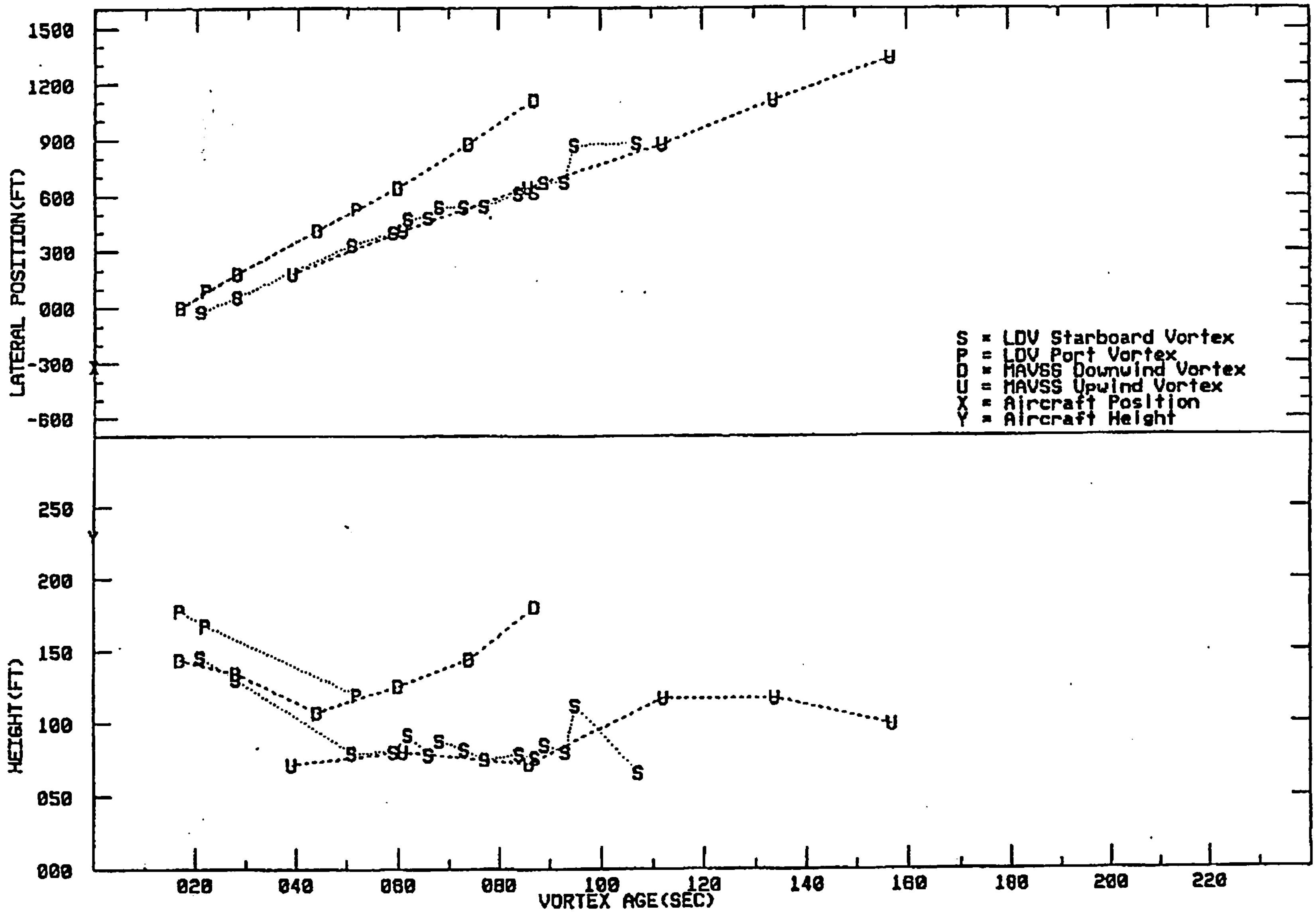


Figure 5. COMBINED LDV MAVSS VORTEX POSITIONS FOR RUN 009, A/C B757, 09/25/1990, 08:18:18

ATTACHMENT A

THIS PROGRAM, B757NO9, COMPUTES THE ANALYTICAL PROFILES OF TEMP LAPSE RATE, BRUNT-VAISALLA FREQUENCY, AND RICHARDSON NUMBER FROM FOURTH ORDER POLYNOMIAL CURVES OF U, V, AND T BASED ON TIME-SMOOTHED PROFILES TAKEN FROM HEIGHT VS. TIME PLOTS.

HEIGHT IN 100'S OF FEET $z := 0, 0.25 .. 6$

TEMPERATURE IN ^{0}C $T(z) := .0320 \cdot z^4 - 0.457 \cdot z^3 + 2 \cdot z^2 - 1.81 \cdot z + 8.59$

WIND COMPONENTS IN <u>M/SEC</u>

$u(z) := -.0061 \cdot z^4 - .0141 \cdot z^3 + .634 \cdot z^2 - 2.19 \cdot z - .797$

$v(z) := -.0307 \cdot z^4 + .353 \cdot z^3 - .966 \cdot z^2 - .890 \cdot z - 1.7$

TEMP LAPSE RATE IN ^{0}C/100FT $dTdz(z) := .128 \cdot z^3 - 1.371 \cdot z^2 + 4 \cdot z - 1.81$

VERTICAL WIND SHEAR IN UNITS OF M/SEC/100FT

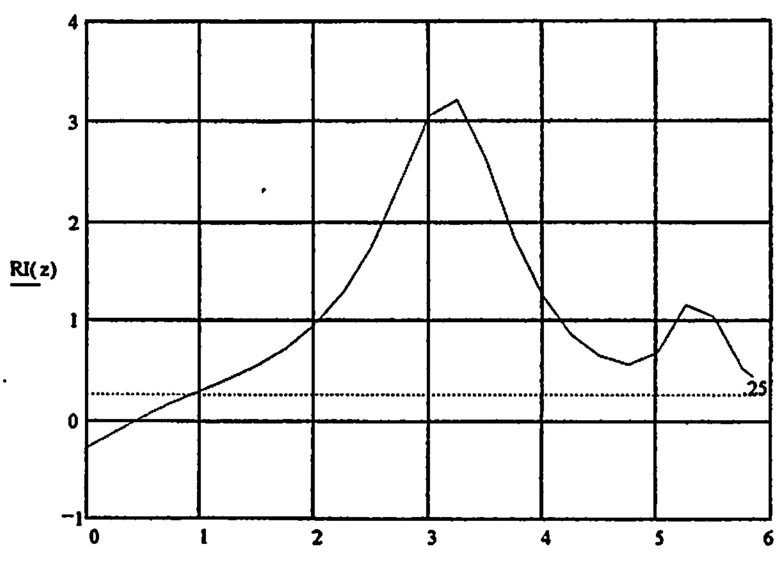
$dudz(z) := -244 \cdot 10^{(-4)} \cdot z^3 - 423 \cdot 10^{(-4)} \cdot z^2 + 1.268 \cdot z - 2.19$

$dvdz(z) := -.1228 \cdot z^3 + 1.059 \cdot z^2 - 1.932 \cdot z - .89$

BRUNT-VAISALLA FREQ. = $$BV(z) := \left[\left(\frac{0.32}{273.16 + T(z)} \right) \cdot (dTdz(z) + .299) \right]^{0.5}$$

RICHARDSON NO. = $$RI(z) := \left(\frac{BV(z)^2}{dudz(z)^2 + dvdz(z)^2} \right) \cdot 930.25$$

RICHARDSON NUMBER FOR B757 RUN #9

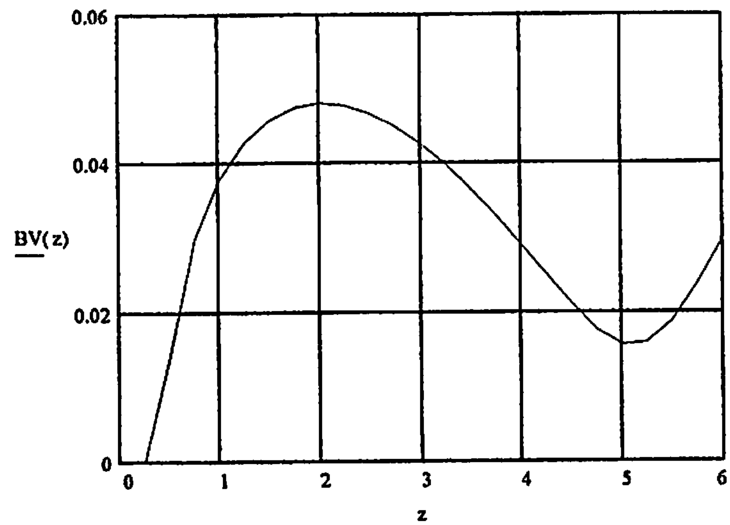


RICHARDSON NUMBER (DIMENSIONLESS). THE CRITICAL VALUE 0.25 IS INDICATED BY A DASHED LINE

HEIGHT IN 100'S OF FEET

BRUNT-VAISALLA FREQUENCY FOR B757 RUN #9

BRUNT-VAISALLA FREQUENCY (SEC^{-1})



HEIGHT IN 100'S OF FEET

THE FOLLOWING TABLE GIVES TEMPERATURE, U AND V WIND COMPONENTS, LAPSE RATE IN 0C/100FT, BRUNT-VAISALLA FREQUENCY IN SEC-1, AND RICHARDSON NUMBER AS A FUNCTION OF HEIGHT IN FEET FOR THE B757 RUN #9 CASE.

z·100	T(z)	u(z)	v(z)	dTdz(z)	BV(z)	RI(z)	z·100
0	8.59	-0.797	-1.7	-1.81	0.041i	-0.286	0
25	8.255	-1.305	-1.977	-0.894	0.026i	-0.12	25
50	8.13	-1.736	-2.344	-0.137	0.014	0.034	50
75	8.175	-2.091	-2.772	0.473	0.03	0.169	75
100	8.355	-2.373	-3.234	0.947	0.038	0.291	100
125	8.638	-2.586	-3.707	1.298	0.043	0.412	125
150	8.995	-2.734	-4.173	1.537	0.046	0.549	150
175	9.398	-2.821	-4.612	1.677	0.047	0.719	175
200	9.826	-2.851	-5.011	1.73	0.048	0.948	200
225	10.257	-2.832	-5.359	1.707	0.048	1.274	225
250	10.674	-2.768	-5.646	1.621	0.047	1.748	250
275	11.063	-2.667	-5.867	1.484	0.045	2.393	275
300	11.413	-2.536	-6.02	1.307	0.042	3.046	300
325	11.715	-2.382	-6.103	1.103	0.04	3.201	325
350	11.963	-2.215	-6.121	0.883	0.036	2.623	350
375	12.156	-2.044	-6.078	0.66	0.033	1.832	375
400	12.294	-1.877	-5.983	0.446	0.029	1.229	400
425	12.381	-1.725	-5.849	0.252	0.025	0.85	425
450	12.423	-1.6	-5.688	0.091	0.021	0.636	450
475	12.43	-1.511	-5.52	-0.025	0.018	0.556	475
500	12.415	-1.472	-5.362	-0.085	0.015	0.671	500
525	12.393	-1.494	-5.24	-0.076	0.016	1.151	525
550	12.384	-1.591	-5.179	0.013	0.019	1.03	550
575	12.408	-1.777	-5.206	0.195	0.024	0.522	575
600	12.49	-2.064	-5.355	0.482	0.03	0.305	600

ATTACHMENT B

A NOTE ON THE VOLPE CENTER METEOROLOGICAL DATA AND DISPLAY SYSTEM FOR IDAHO FALLS 1990

A NOTE ON THE VNTSC METEOROLOGICAL DATA AND DISPLAY SYSTEM FOR IDAHO FALLS 1990

1. INTRODUCTION

The purpose of this note is to describe the meteorological data and derived parameters taken during the 1990 wake vortex experiments which are available in a VNTSC data display package of software for the PC. The meteorological data are from the Idaho Falls (IDF) instrumented tower and tethersonde. The software also displays vortex lateral displacement, height and strength data vs. time for each of the aircraft runs; these will also be briefly discussed. This paper focuses on the substance of the meteorological data and is not intended to be a user's manual for the software.

Figures 1 and 2 are images of two of the screens available from the VNTSC display program. Each major element of these screens is described below.

2. SCREEN 1: VORTEX AND MET TOWER DATA

Figure 1 shows Screen 1 with vortex plots from B-757 runs 6 through 9 displayed along with corresponding vertical atmospheric profile data from the tower. Up to nine separate runs can be simultaneously displayed on this screen. The legend in the upper-right identifies the symbols used to distinguish the vortices (V1 is downwind and V2 is upwind) and the types of sensors used (lidar (LDV) or acoustic (MAV)).

2.1 LATERAL VORTEX DISPLACEMENT

The upper-left window shows plots of lateral displacement (ft) vs. time (sec) of the vortex pairs. When the paths are "upward", as in this figure, the vortices drift towards the tower and across the array of acoustic sounders; this is the desired configuration for a successful run, and data will generally be complete in the other two top windows. Note that the time axes are adjustable with a maximum range of 240 seconds.

2.2 VORTEX HEIGHT

The upper-center window shows traces of vortex height (ft) vs. time (sec).

2.3 VORTEX STRENGTH

The upper-right window in Fig. 1 displays vortex strength, defined as average circulation

(ft^2/sec) over a selected radius, vs time (sec). In the figure, the legend shows that a radius of 45 feet was selected for this display.

2.4 WIND SPEED PROFILE

The lower-right window displays the windspeed (three minute average in knots) vs. height (ft) from seven levels on the instrumented tower (6.25, 12.5, 25, 50, 100, 150, and 200 ft).

2.5 WIND DIRECTION PROFILE

The lower-center window displays the wind direction (deg. true) vs. height (ft) at the seven instrumented levels.

As a quality check, one can compare the wind speed normal to the flight path (derived from the speed and direction profiles) at the level of the vortex (seen on the height vs. time trace) with the lateral drift rate derived from the slope of the lateral displacement trace. In Figure 1, we can use Run #9 (yellow) to derive a lateral speed of V1 as approximately 10.5 ft/sec or 6.2 knots. On the height trace, V1 remains at about 80 to 100 ft.; therefore, we check the wind component at this level for consistency. From the wind direction profile, we see that the wind is from the NNE (about 25 to 30 deg.) which is nearly parallel to the acoustic array; therefore, the speed of 6 to 7 knots at 80 to 100 ft. is consistent with the lateral drift rate.

2.6 TEMPERATURE PROFILE

The lower-right window displays temperature (C) vs height (ft) at the defined seven levels from the instrumented tower.

3. SCREEN 2: METEOROLOGICAL DATA

Figure 2 displays wind and temperature data profiles from the tethersonde, plus the derived parameters: Dewpoint temperature, Richardson Number (Ri), Lapse Rate (LR), and Brunt-Vaisala Frequency (N). The tethersonde is a tethered balloon carrying an instrument package which was reeled up and down between altitudes of 100 and 800 ft and paused at several points to record data. These soundings were made frequently during the experimental flyby runs, but are not synchronized with them. Therefore, one must choose a sounding representative of a desired flyby on the basis of the date and time, not on the sounding number. Because the soundings are made on the basis of pressure, the values will not be recorded at the same geometric heights from sounding to sounding. It is possible to plot up to three soundings simultaneously, and one can turn any of the plotted parameters off and on using the screen controls. The ranges of the height and the plotted parameter scales can be changed using other screen controls.

3.1 MEASURED PARAMETERS

The software displays the following measured tethersonde parameters:

- o Air Temperature plotted in black (C)
- o Wind direction plotted in blue (deg. true)
- o Wind speed plotted in yellow (knots)
- o Wetbulb temperature (not displayed). This is defined as the temperature an air parcel would have if cooled adiabatically to saturation at constant pressure by evaporation of water into it, all latent heat being supplied by the parcel.
- o Dewpoint Temperature plotted in purple (C). This is actually calculated from the wetbulb information, and is defined as the temperature to which the air must be cooled at constant pressure and constant water-vapor content in order for saturation to occur.

As a quality check, one can compare the measured parameters from the sounder with those from the tower for nearly coincident date/times. For example, the legend in the upper-left indicates that this sounding is from 25 Sept 1990 at 0816 and 31 seconds. This corresponds closely with Run #9 on Figure 1. We see that the wind direction (the far left curve) is about 15 deg at 120ft, and about 20 deg at just over 200ft. These are slightly more northerly than from the tower data, but are reasonably consistent considering the instrumentation used and the typical problems encountered in performing field measurements. The wind speed in the overlap range (the yellow curve second from left) matches up quite well with the tower values (6 vs.7 knots at around 100 ft, and a virtual match of 12 knots at 200 ft.).

3.2 DERIVED PARAMETERS

All derived parameters depend on centered finite differences of measured parameters; therefore, they are plotted at the midpoints of the layers bounded by each pair of measurement levels.

3.2.1 Richardson Number (Ri)

Ri is plotted in white in three selectable scale ranges. Ri is defined as follows:

$$Ri = (g / T_m) (\Delta T / \Delta z + \lambda) / (\Delta \underline{u} / \Delta z)^2$$

where: T_m = vertical mean temperature in a layer (K)
g = acceleration of gravity (32 ft/sec^2)
T = temperature (K or C)
z = the vertical coordinate (ft)
Δ indicates a finite vertical difference of the particular parameter,
λ = the negative of the dry adiabatic lapse rate (0.3 deg. C/100ft),
$\underline{u}$ = vector wind speed (ft/sec)

Ri is commonly used as a bulk atmospheric parameter to indicate the possible presence of turbulence in a layer and/or to classify an airmass as to its turbulence potential. Observations have shown that a value of Ri = 0.25 is often a critical threshold such that for Ri < 0.25, there can be a relatively sudden onset of turbulence (wind shear dominating atmospheric stability), and for Ri > 0.25, laminar flow will tend to prevail. Very small or negative values of Ri strongly suggest turbulence in a layer, while the opposite is true for positive values larger than 0.25

3.2.2 Temperature Lapse Rate

The lapse rate (LR) of temperature alone (plotted in brown) can also be used to classify the turbulence potential of a layer. In particular, the U.S. Nuclear Regulatory Commission has identified the following six potentially useful lapse rate classes for specifying diffusion conditions in the atmospheric boundary layer:

A. Most unstable:	LR < -0.58 C/100ft
B. Moderately Unstable:	-0.58 ≤ LR < -0.52 C/100ft
C. Unstable:	-0.52 ≤ LR < -0.46 C/100ft
D. Neutral:	-0.46 ≤ LR < -0.15 C/100ft
E. Stable	-0.15 ≤ LR < 0.46 C/100ft
F. Most stable	LR ≥ 0.46 C/100ft

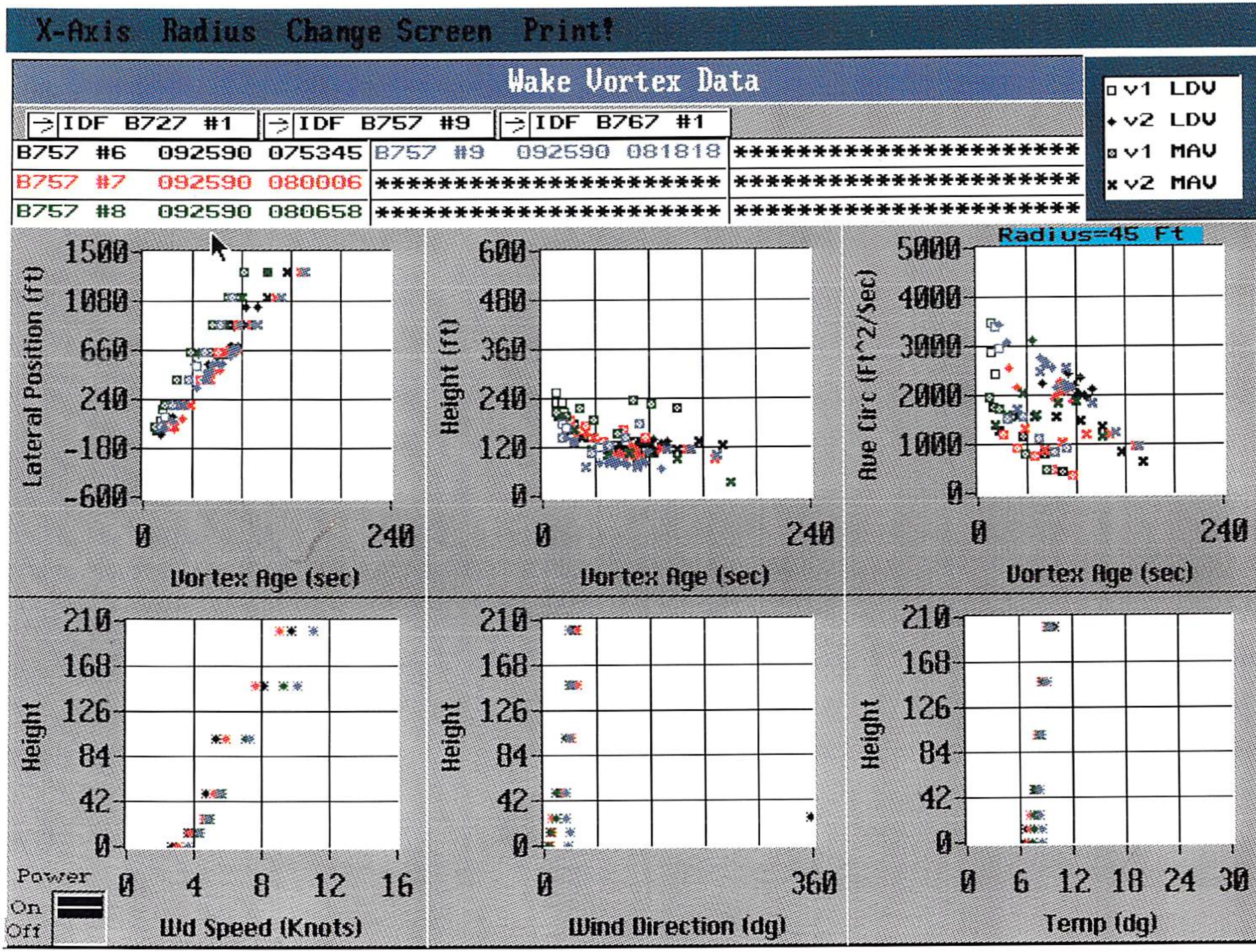
In particular, using these classes, we might assume that turbulence is very likely for classes A - C, and probable for class D, especially in the presence of even moderate wind shear and/or flow over rough terrain.

3.2.3 Brunt-Vaisalla Frequency (N)

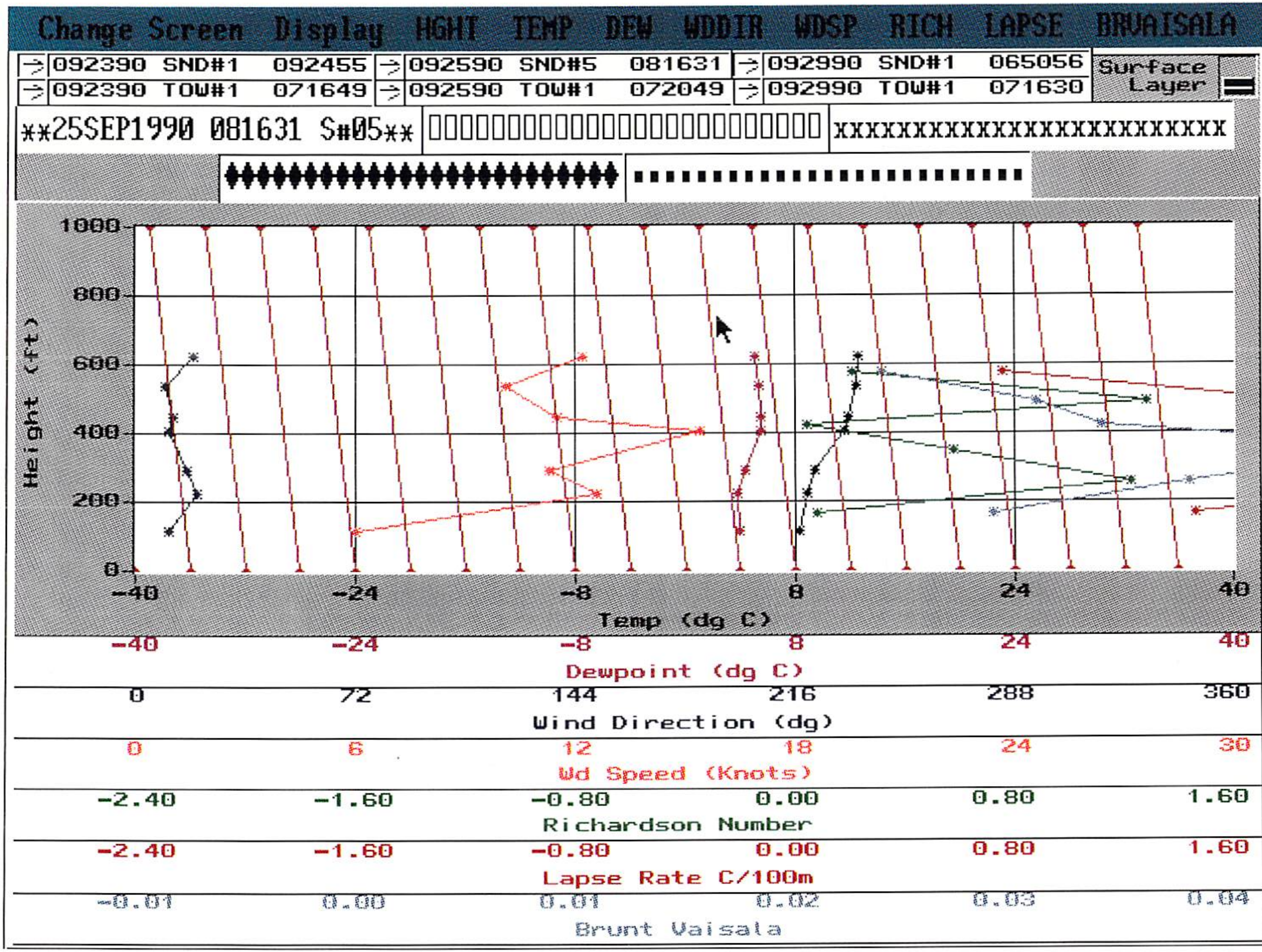
The Brunt-Vaisalla frequency (or buoyancy frequency) is the frequency of oscillation of a parcel of air that has been subjected to a vertical perturbation. N is defined as:

$$N = ((g/T_m)(\Delta T / \Delta z + \lambda))^{1/2}$$

In neutral conditions, $N = 0$, no accelerating force exists, and the displaced parcel will be in equilibrium with its environment. In stable conditions, $N > 0$, and the parcel oscillates about its original level with a period of $\tau = 2\pi / N$. In unstable conditions N is imaginary and represents an exponentially growing displacement with time. N can be seen in the numerator of Ri, and is used in Greene's analysis (1986) to characterize vortex decay as a function of atmospheric stability.



X-Axis Radius Change Screen Print!
Wake Vortex Data
IDF B727 #1
IDF B757 #9
IDF B767 #1
B757 #6 092590 075345
B757 #7 092590 080006
B757 #8 092590 080658
B757 #9 092590 081818
v1 LDV
v2 LDV
v1 MAV
v2 MAV
Radius=45 Ft
Lateral Position (ft)
Vortex Age (sec)
Height (ft)
Ave Circ (Ft^2/Sec)
Height
Wd Speed (Knots)
Wind Direction (dg)
Temp (dg)
Power
On
Off


Change Screen Display HGHT TEMP DEW WDDIR WDSP RICH LAPSE BRVAISALA
092390 SND#1 092455
092390 TOW#1 071649
092590 SND#5 081631
092590 TOW#1 072049
092990 SND#1 065056
092990 TOW#1 071630
Surface Layer
25SEP1990 081631 S#05
Height (ft)
1000
800
600
400
200
0
-40
-24
-8
8
24
40
Temp (dg C)
Dewpoint (dg C)
0
72
144
216
288
360
Wind Direction (dg)
0
6
12
18
24
30
Wd Speed (Knots)
-2.40
-1.60
-0.80
0.00
0.80
1.60
Richardson Number
Lapse Rate C/100m
-0.01
0.00
0.01
0.02
0.03
0.04
Brunt Vaisala

ATTACHMENT C

WIND AND TURBULENCE FROM TOWER HOT-FILM ANEMOMETERS

During the first three Idaho Falls test days, the Volpe Center recorded wind speed data at 4000 Hz from the hot-film anemometers located at tower positions 110, 120, 130, 140, 150, 160 and 170 feet. The data were analyzed in three ways:

1) Stripcharts were made of the first 7.5 seconds of data. The plot for B-757 Run 9 is attached.

2) The mean speed and standard deviation were calculated for the first five seconds of the run (well before any vortices had reached the tower). The following results were obtained for Run 9:

Height (ft)	110	120	130	140	150	160	170
Mean Speed (ft/s)	8.4	9.6	8.0	10.1	10.6	12.2	13.1
Std Dev. Speed (ft/s)	0.57	0.70	0.70	0.67	0.62	0.54	0.46

Note that there seem to be sensor biases of about one ft/s in the mean speeds. The turbulence appears to be somewhat less at the top two locations.

3) The first four seconds of the run were processed with an FFT to obtain the power spectral density (PSD). The power spectral amplitude (square root of PSD) was plotted against frequency or eddy wavelength (using the mean speed to convert from frequency to wavelength). The spectral plots as a function of frequency and wavelength for B-757 Run 9 are attached.

The hot-film anemometers measure the wind speed in the plane perpendicular to their axis which was oriented parallel to the aircraft flight path in order to measure the vortex tangential velocity. Since the mean wind away from the vortices is horizontal, the mean wind speed is a measure of the crosswind with respect to the aircraft path and the standard deviation of the wind speed represents the crosswind component of the turbulence.

HIGH-SPEED IDAHO FALLS TOWER DATA: B-757 RUN # 9 9/25/1990 8:18:19

DATA RATE = 100 HZ VERTICAL TICKS: 1 SECONDS OVERLAPPING SCALES 0 TO 60 FT/SEC, 10 FT/SEC OFFSET

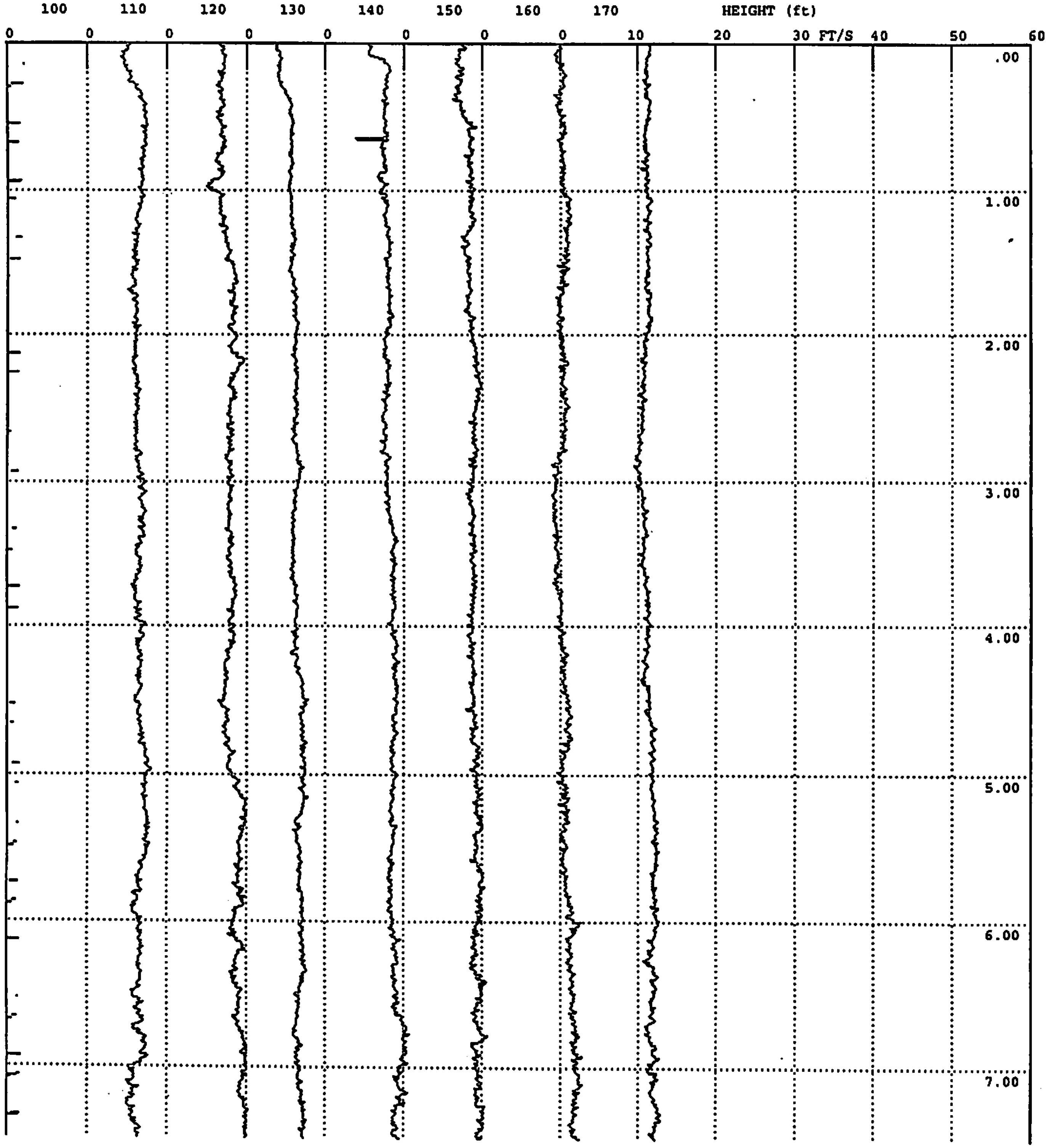
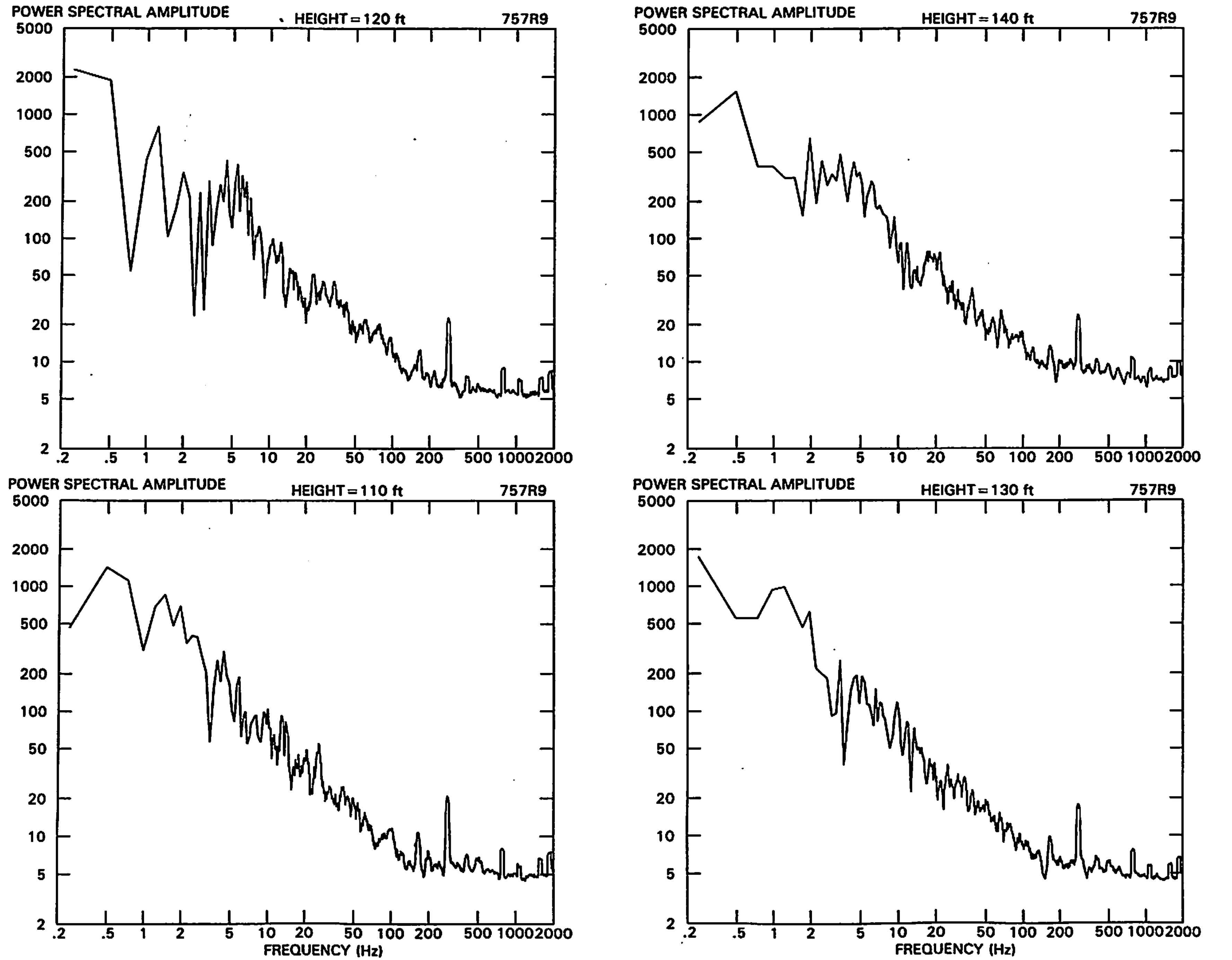
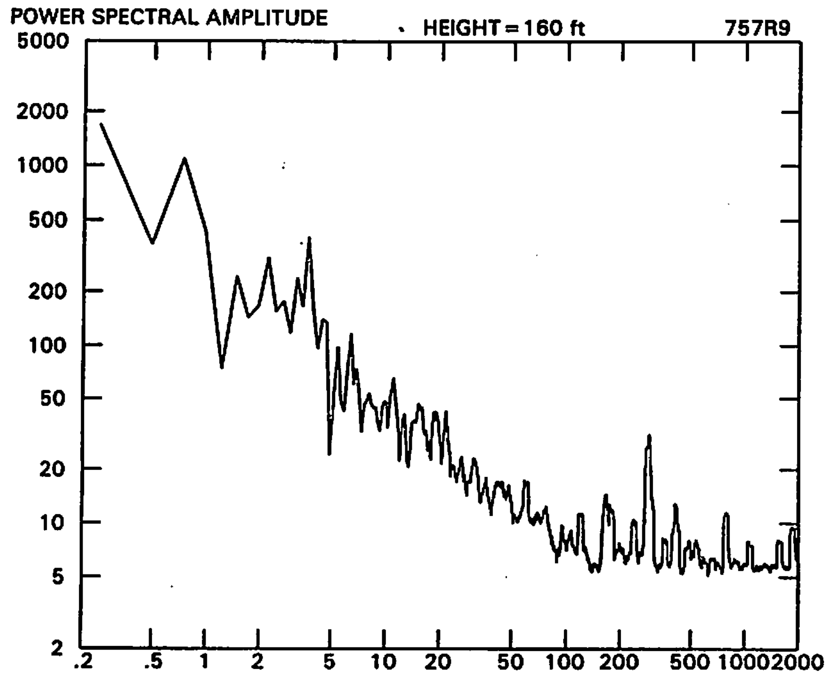
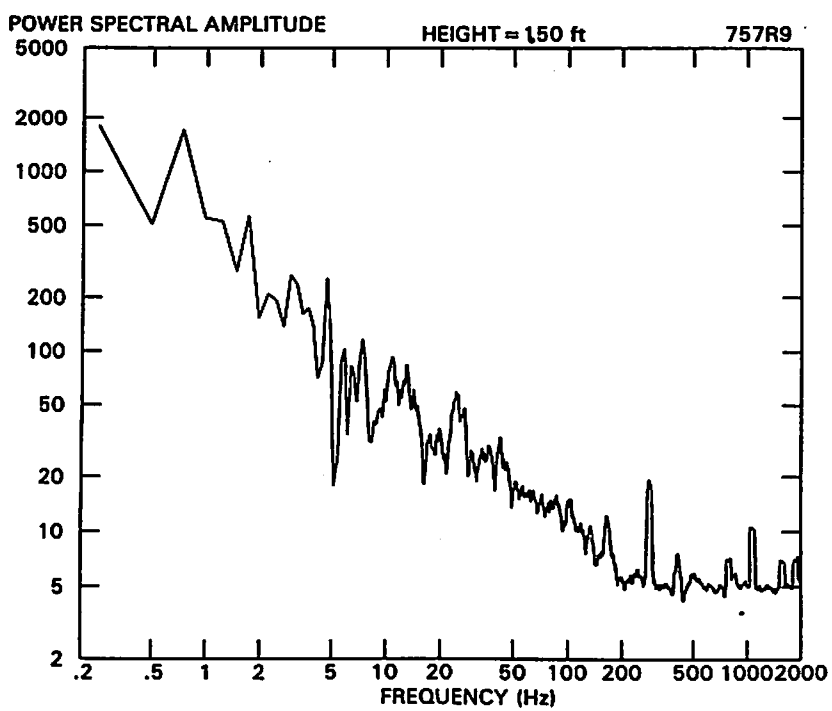
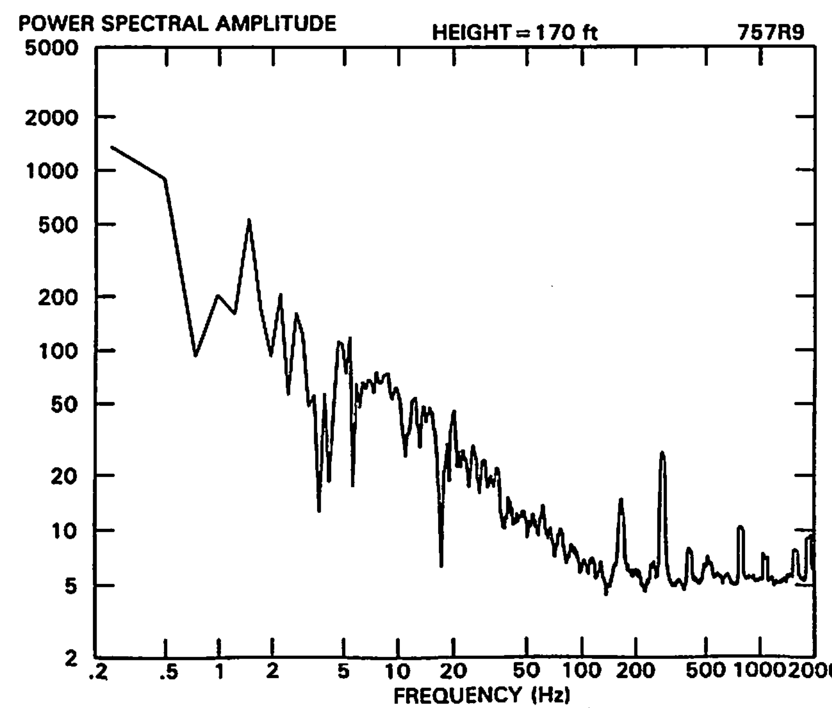


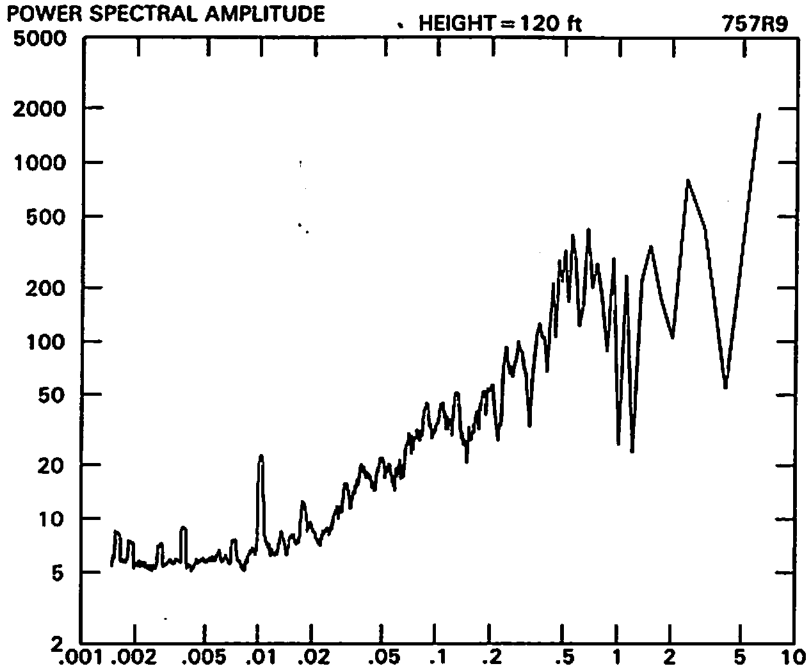
FIGURE 4. 1 HIGH RESOLUTION ANEMOMETER DATA RUN 9 B-757

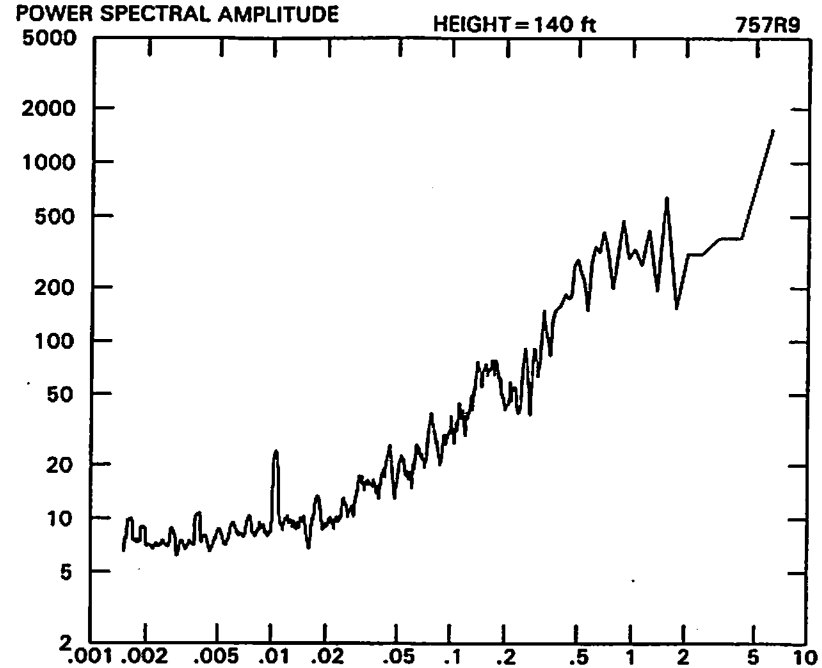

POWER SPECTRAL AMPLITUDE
HEIGHT = 120 ft
757R9
POWER SPECTRAL AMPLITUDE
HEIGHT = 140 ft
757R9
POWER SPECTRAL AMPLITUDE
HEIGHT = 110 ft
757R9
POWER SPECTRAL AMPLITUDE
HEIGHT = 130 ft
757R9
5000
2000
1000
500
200
100
50
20
10
5
2
.2
.5
1
2
5
10
20
50
100
200
500
1000
2000
FREQUENCY (Hz)

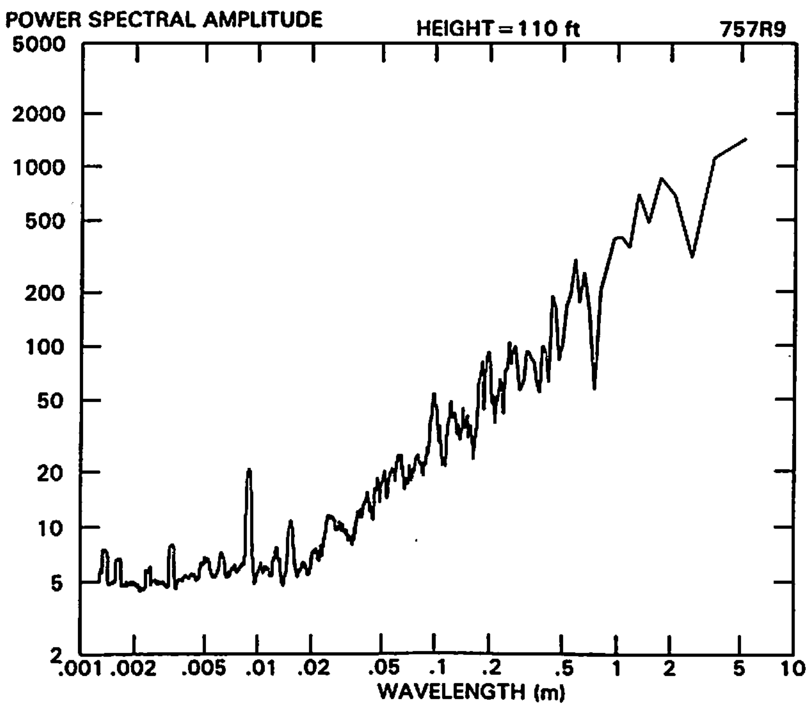

POWER SPECTRAL AMPLITUDE
HEIGHT = 160 ft
757R9
5000
2000
1000
500
200
100
50
20
10
5
2
.2
.5
1
2
5
10
20
50
100
200
500
1000
2000

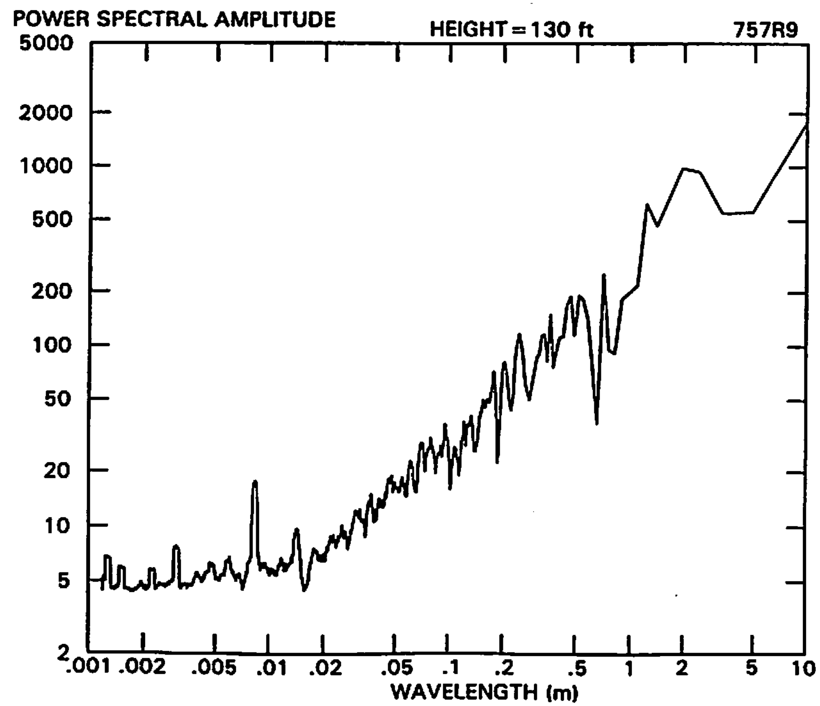

POWER SPECTRAL AMPLITUDE
HEIGHT = 150 ft
757R9
5000
2000
1000
500
200
100
50
20
10
5
2
.2
.5
1
2
5
10
20
50
100
200
500
1000
2000
FREQUENCY (Hz)

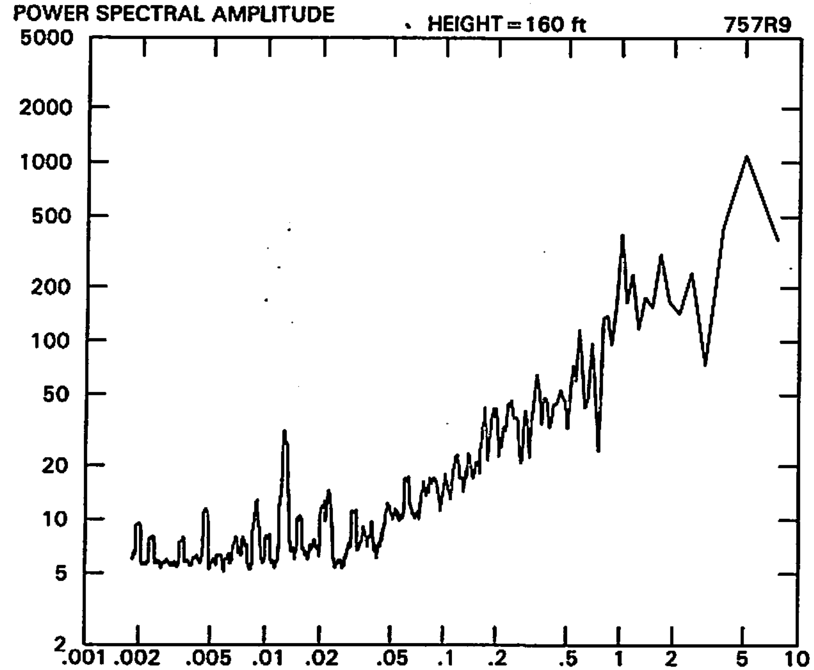

POWER SPECTRAL AMPLITUDE
HEIGHT = 170 ft
757R9
5000
2000
1000
500
200
100
50
20
10
5
2
.2
.5
1
2
5
10
20
50
100
200
500
1000
2000
FREQUENCY (Hz)

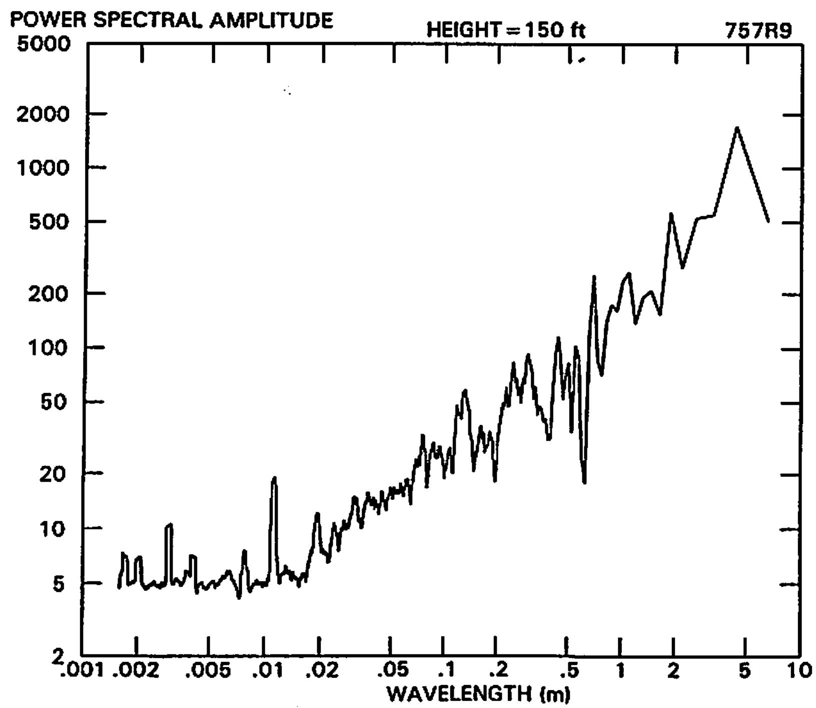

POWER SPECTRAL AMPLITUDE
HEIGHT = 120 ft
757R9
5000
2000
1000
500
200
100
50
20
10
5
2
.001 .002 .005 .01 .02 .05 .1 .2 .5 1 2 5 10

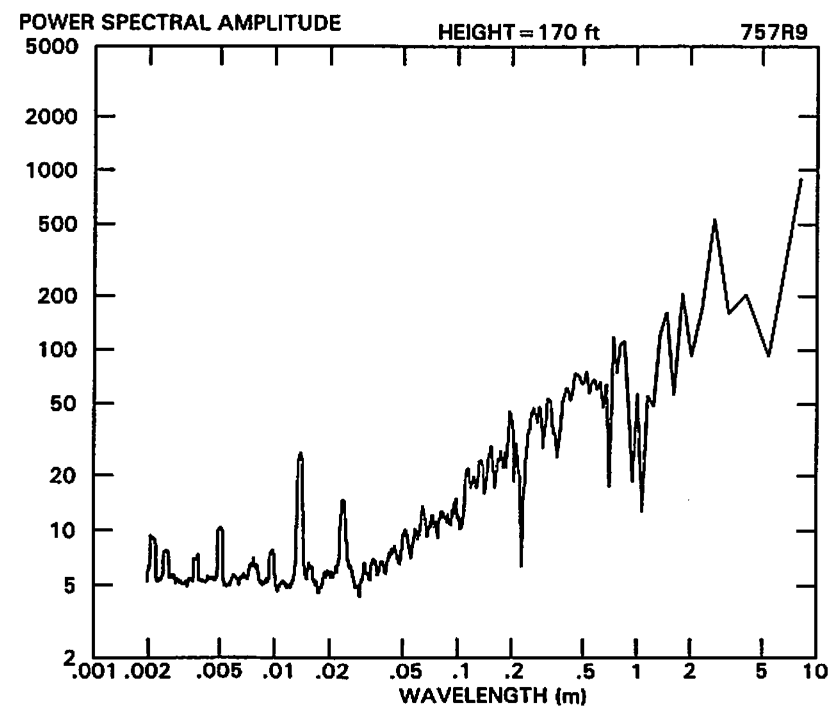

POWER SPECTRAL AMPLITUDE
HEIGHT = 140 ft
757R9
5000
2000
1000
500
200
100
50
20
10
5
2
.001 .002 .005 .01 .02 .05 .1 .2 .5 1 2 5 10


POWER SPECTRAL AMPLITUDE
HEIGHT = 110 ft
757R9
5000
2000
1000
500
200
100
50
20
10
5
2
.001 .002 .005 .01 .02 .05 .1 .2 .5 1 2 5 10
WAVELENGTH (m)


POWER SPECTRAL AMPLITUDE
HEIGHT = 130 ft
757R9
5000
2000
1000
500
200
100
50
20
10
5
2
.001 .002 .005 .01 .02 .05 .1 .2 .5 1 2 5 10
WAVELENGTH (m)


POWER SPECTRAL AMPLITUDE
HEIGHT = 160 ft
757R9
5000
2000
1000
500
200
100
50
20
10
5
2
.001 .002 .005 .01 .02 .05 .1 .2 .5 1 2 5 10


POWER SPECTRAL AMPLITUDE
HEIGHT = 150 ft
757R9
5000
2000
1000
500
200
100
50
20
10
5
2
.001 .002 .005 .01 .02 .05 .1 .2 .5 1 2 5 10
WAVELENGTH (m)


POWER SPECTRAL AMPLITUDE
HEIGHT = 170 ft
757R9
5000
2000
1000
500
200
100
50
20
10
5
2
.001 .002 .005 .01 .02 .05 .1 .2 .5 1 2 5 10
WAVELENGTH (m)

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