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JIMSPHERE WIND AND TURBULENCE EXCEEDANCE STATISTICS

by S. I. Adelfang and A. Court

Prepared by
LOCKHEED-CALIFORNIA COMPANY
Burbank, Calif.
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16. ABSTRACT

Exceedance statistics of winds and gusts observed over Cape Kennedy, Florida with Jimsphere balloon sensors are described. Gust profiles containing positive and negative departures, from smoothed profiles, in the wavelength ranges 100-2500, 100-1900, 100-860, and 100-460 meters were computed from 1578 profiles with four 41 weight digital high pass filters. For exceedance probabilities of 0.998 to 0.005, the distribution of gusts for 1578 profile parent population is closely approximated with a random sample of 25 profiles; the random sample underestimates the gust speed of the parent population for probabilities outside that range. Extreme values of the square root of gust speed are normally distributed. Gust speeds were found to increase with altitude slightly more rapidly than they decrease above the altitude of maximum gust speed. Monthly and annual exceedance probability distributions of normalized rms gust speeds in three altitude bands (2-7, 6-11, and 9-14 km) are log-normal. The rms gust speeds are largest in the 100-2500 wavelength band between 9 and 14 km in late winter and early spring. A study of monthly and annual exceedance probabilities and the number of occurrences per kilometer of level crossings with positive slope indicates significant variability with season, altitude and filter configuration. A decile sampling scheme is tested and an optimum approach is suggested for drawing a relatively small random sample that represents the characteristic extreme wind speeds and shears of a large parent population ~~of~~ of Jimsphere wind profiles.

17. KEY WORDS turbulence exceedance statistics wind profile gust speeds gust shape wind sensors	18. DISTRIBUTION STATEMENT

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FOREWORD

This study was conducted under NASA Contract NAS8-26661 with the Aerospace Environment Division, Aero-Astrodynamics Laboratory, Marshall Space Flight Center. Dr. George H. Fichtl was the technical monitor. The support for this study was made available by Mr. William McGowan of the NASA Office of Aeronautics and Space Technology. The results contained herein represent the first application of vertical detailed wind profile measurements in the development of environmental gust exceedance criteria for the design and operation of aeronautical and aerospace systems. Although the results of this study are valid only for Cape Kennedy, Florida, the techniques developed under this contract can be used to develop detailed wind profile gust exceedance models for other sites. If a sufficient number of sites are examined in the future, then the resulting models could be combined to form regional and perhaps global detailed wind profile gust exceedance models.

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Section 1

PURPOSE AND DATA

Certain characteristics of the winds between 2 and 14 km over Cape Kennedy, Florida, which are important in the design and operation of space vehicles launched from there, are examined in this report. These characteristics are chiefly the statistical distributions of strong winds and of gusts, defined as the differences between the actual wind speeds and those given by a smoothed profile. Smoothing was accomplished by four different filters which removed, respectively, fluctuations with wavelengths greater than 0.5, 1, 2, and 4 km in the vertical.

Data used came from a series of 2719 detailed wind profiles acquired by NASA-MSFC from 1 December 1964 to 29 June 1970 (Camp, 1971). The profiles were obtained from the tracking, by precision radar (FPS 16), of Jimsphere balloons. These balloons, 2 meters in diameter with roughened surface, were inflated to more than atmospheric pressure so as to rise at 4 to 5 meters per second. In the data reduction, balloon positions determined every 0.1 second are smoothed to provide mean positions at each 25-meter interval of ascent.

Differences in position between alternate 25-meter levels then indicate the mean wind for the corresponding 50-meter layer, and are reported as the wind at the 25-meter level in the middle of the 50-meter layer. Thus the basic data analyzed here were wind speeds and directions for 50-meter layers, overlapping by 25 meters. Even when the overlaps are eliminated, winds for successive 50-meter layers are not independent, because they are based on the smoothed balloon position at the common boundary. Only when at least 25 meters intervenes between two layers (i.e., winds reported for levels at least 75 meters apart) can two winds be considered as free from common errors. Thus the minimum distance for which wind shear can be computed is 75 meters.

After two years of development, the Jimsphere design was standardized in late 1964, and routine ascents were begun. By mid-May 1967, a total of 1,196 wind profiles had been obtained and listed on four magnetic tapes; this series is here called N-1. These data were studied intensively in two previous reports by the Lockheed-California Company: Adelfang, Ashburn, and Court (1968) and Adelfang, Court, Melvin, and Pazirandeh (1970); these two reports are here referred to as L-1 and L-2, respectively. The data were also used by others, notably Carlisle (1970), who found that of the 1,196 profiles, only 861 had complete data for each 25-meter level between 4 and 16 km. Similarly, Adelfang et al. (L-2) found that 16 of the listed profiles had no data, 11 others were exact duplicates of previous profiles, and many others were incomplete or suspect.

These and other problems led NASA-MSFC to re-examine the data, as well as other profiles obtained during those 31 months but not included in N-1. Duplicate and questionable profiles were eliminated, as were some from serial ascents at 1 and 2 hour intervals. Other profiles, not previously listed, were added, giving 1,215 profiles through May 1967 with another 1,504 for the next 37 months, for a total of 2,719 (Camp, 1971). However, the eight data tapes supplied by NASA-MSFC for this study contained only 1,941 profiles, and 47 of these were not used for the present study because of apparent non-standard format or erroneous data.

Thus 1,894 wind profiles spanning 67 months at Cape Kennedy were available for the present analysis, which had two parts, with different criteria. Gusts were to be studied in three altitude bands, 5 km thick, which were taken as 2-7, 6-11, and 9-14 km. Gusts were defined as departures from a smooth profile, obtained by filtering the original data. Such a filter required an additional 0.5 km of data below the first band and above the third one, so that reasonably complete data were needed from 1.5 to 14.5 km. Wind speeds and shears were studied over the entire profile, without smoothing or separation into altitude bands, from 4 to 14 km. To obtain wind shears over 3 km layers, however, data were needed from 1 to 14 km, requiring rejection of more profiles.

In addition, the gust study could use data from the entire period of Jimsphere observations, but the wind profile and shear study was intended to extend results obtained in the previous report (L-2), and hence rejected profiles already used. In addition, both studies rejected profiles with more than 11 missing data points (5 percent) in any of the three layers, 2-7, 6-11, and 9-14 km, or with more than two missing points between 1.5 and 2.0 km. After all these rejections, the gust study was based on 1578 profiles, the wind study on 844. Since all but 12 of the 844 profiles used in the wind study were included in the gust study, a total of 1590 distinct profiles were used herein. Details of the profile selection are illustrated in Figure 1.

These profiles were not evenly distributed through the year (Figure 2). In the original data base (N-1) used for L-1, the 1196 profiles were biased toward the windier winter months, with 57 percent in the six months November-April. The 900 profiles extracted from N-1 for L-2 still had 55 percent in winter. The new set (N-2) was still biased, with 52 percent in winter, but most of the profiles not listed in the basic data tapes were from the winter, leaving only 49 percent of the 1894 profiles in winter. Further screening increased the summer bias: wintertime profiles represented 47 percent of the 1578 gust data and 39 percent of the wind profile base.

In the present study, wind speeds and shears from these profiles were not used directly. For the gust study, they were first filtered and differences from such smoothed profiles were analyzed (Section 3). For the shear study, the profiles were coded according to the deciles represented by nine different characteristics, as discussed in the next section.

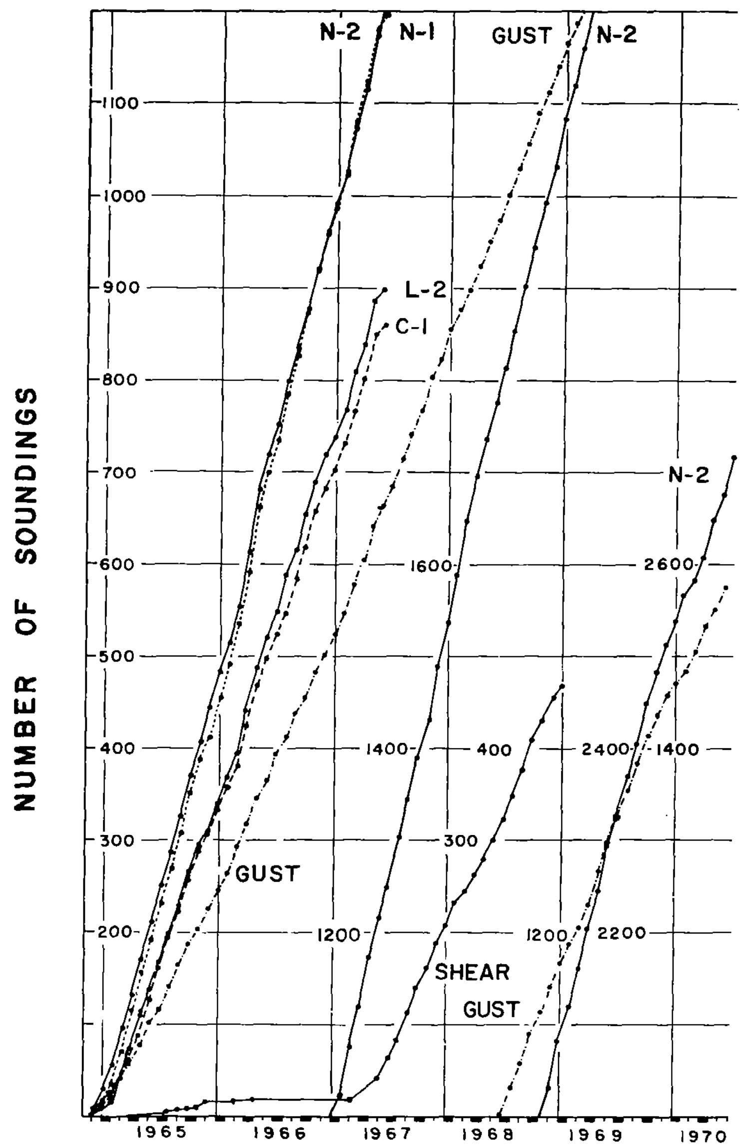

Figure 1. Cumulative Number of Jimsphere profiles over Cape Kennedy

N-1. NASA-MSFC data tape 1964-1967

C-1. Accepted by Carlisle (1970)

L-2. Accepted for previous study (L-2)

N-2. NASA-MSFC data tape 1964-1970

GUST. Used for gust studies herein

SHEAR. Used for shear studies herein

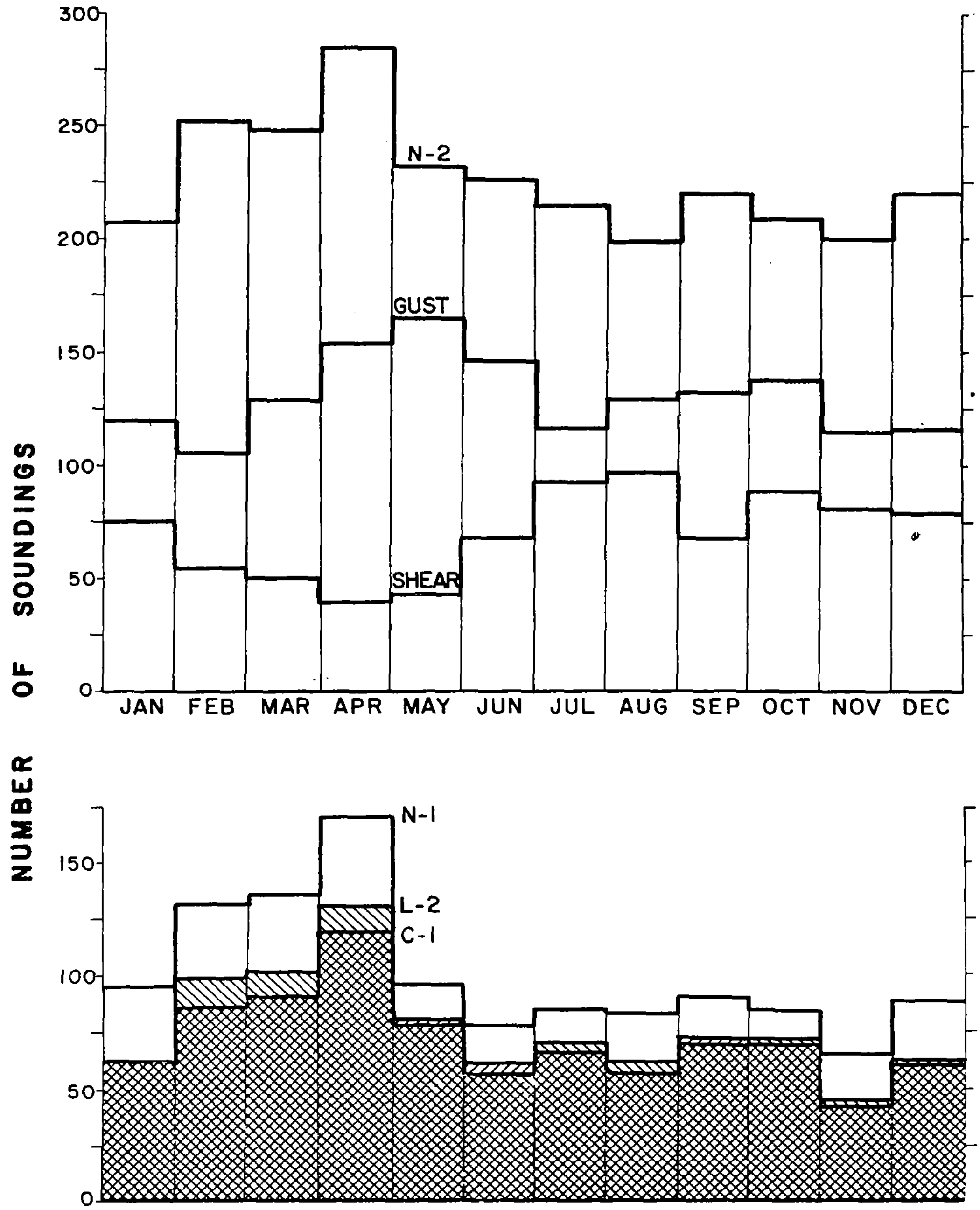

Figure 2. Monthly Distribution of Jimsphere Wind Profiles

N-1.	NASA-MSFC data tape 1964-1967
C-1.	Accepted by Carlisle (1970)
L-2.	Accepted for previous study (L-2)
N-2.	NASA-MSFC data tape 1964-1970
GUST.	Used for gust studies herein
SHEAR.	Used for shear studies herein

Section 2

DECILES

2.1 Decile Coding

Representative samples were obtained from a collection of wind profiles, in the previous report (L-2), by classifying the profiles according to a limited number of characteristics. These were the maximum scalar wind speed and the maximum wind shears through intervals of 100, 400, 1,000, and 3,000 meters. Although usually only the absolute value of wind shear is considered, for this purpose shears were termed "positive" or "negative" according to whether the scalar wind speed at the top of the layer was larger or smaller than that at the bottom.

The entire set of profiles was placed in rank order, separately according to the magnitude of each characteristic, and divided into deciles for each one. Each sounding was then coded according to the decile into which each of its nine characteristics fell with respect to the total sample. Thus a single profile might bear the code

1 6 9 2 3 1 4 1 6 .

Its maximum speed was in the lowest decile, its greatest "positive" 100 m shear was in the sixth decile, its strongest "negative" 100 m shear in the ninth decile, etc.

Exactly the same decile coding procedure was used in the present study for the 844 profiles which met all criteria (Section 1) and had not been used for the previous study (L-2). Because 61 percent of these profiles were from the six "summer" months (May-October), while only 45 percent of the previous set were from the less windy summer season, the limits of the deciles, for all nine characteristics, were slightly lower in the present study than for the previous one (Table 1). The median of the maximum wind speeds of all profiles was 33.8 m/s in the previous study, 29.4 m/s in this one.

Table 1. DECILE LIMITS (m/SEC) FOR NINE CHARACTERISTICS OF SAMPLES OF 844 (A) AND 900 (B) JIMSPHERE WIND PROFILES OVER CAPE KENNEDY

DECILE:				1	2	3	4	5	6	7	8	9	X
LIMITS:			MIN	10	20	30	40	50	60	70	80	90	MAX
MAX WIND SPEED		A	5.7	12.4	16.5	19.9	23.9	29.4	34.3	41.5	46.9	55.5	79.3
		B	5.3	15.1	18.8	23.3	27.5	33.8	39.5	45.3	50.7	59.2	81.7
100m SHEAR	POS	A	1.6	2.5	2.8	3.0	3.2	3.5	3.8	4.2	4.6	5.5	10.1
		B	1.7	2.6	3.0	3.3	3.6	3.9	4.1	4.5	4.9	5.6	14.2
	NEG	A	1.7	2.4	2.7	2.9	3.2	3.5	3.8	4.2	4.8	5.7	10.5
		B	1.6	2.5	2.8	3.1	3.4	3.7	4.0	4.4	4.9	5.7	19.1
1 km SHEAR	POS	A	3.6	7.3	8.6	9.4	10.4	11.5	12.5	13.9	15.7	18.5	32.0
		B	3.7	7.8	9.1	10.2	11.5	12.3	13.5	15.0	17.0	19.7	48.0
	NEG	A	0.0	5.9	7.0	7.8	8.6	9.5	10.4	11.6	13.3	16.7	36.5
		B	2.3	6.0	7.1	8.0	8.9	9.9	11.0	12.3	14.2	17.4	33.5
400m SHEAR	POS	A	3.2	5.1	5.9	6.6	7.2	7.8	8.6	9.3	10.3	11.8	18.5
		B	2.8	5.6	6.5	7.2	7.8	8.4	9.3	10.1	11.1	12.6	24.1
	NEG	A	3.0	4.9	5.5	6.1	6.8	7.3	8.0	8.8	10.3	11.9	22.5
		B	3.1	4.8	5.5	6.4	6.9	7.7	8.5	9.5	10.7	12.7	20.0
3 km SHEAR	POS	A	4.3	9.8	11.8	14.1	15.8	17.8	20.0	21.7	24.8	29.2	50.4
		B	2.7	10.6	12.8	15.4	17.2	19.1	21.2	23.6	26.4	30.3	97.0
	NEG	A	0.0	2.0	5.9	7.3	8.4	9.6	10.9	12.4	14.4	17.7	41.9
		B	0.0	3.3	6.1	7.5	8.7	9.9	10.9	12.6	14.7	18.4	38.3

Over Cape Kennedy, the strongest wind speeds between 4 and 14 km always occur (in the present set of 844 soundings) above 9 km, and never in summer. All 84 maximum wind speeds in the uppermost decile (Table 2) occurred in winter and spring soundings, and only one as low as 9 km. The weakest maximum winds, on the other hand, were all in summer soundings, but occurred at all levels.

In the windiest month, March, the strongest winds of each sounding came at heights above 10 km, and none was in the lowest three deciles. In August, on the other hand, the strongest winds occurred at all altitudes, although only nine came between 6 and 10 km; in 82 of the 88 August soundings, the strongest winds were in the lowest four deciles.

Strong shears, especially "positive" shears, tend to occur in soundings with strong winds. For each of the 36 possible pairs of the nine characteristics, the number of profiles having the various deciles of the two characteristics was tabulated. Each 10 X 10 table was summarized by counting the number of cases in which both characteristics were above their medians, below their medians, etc. From these 2 X 2 tables, medial correlation coefficients were computed, as in the previous study. They are given in Table 3, together with those from the earlier sample (L-2, Table 3.4).

The coefficient of medial correlation, q, has a distribution which is approximately normal with variance $(1 - q^2)/n$. Thus adding and subtracting $2 \sqrt{1 - q^2/844}$ from the computed value of q provides a 95 percent confidence interval for the true correlation. For various sample values of q , this half-width of the 95 percent confidence interval is

sample coefficient:	.900	.700	.500	.300	.100
confidence interval: ±	.030	.049	.060	.065	.069

Thus any coefficient larger, in absolute value, than 0.07 differs significantly from zero.

Table 2. ALTITUDE IN WHICH STRONGEST WINDS OF EACH PROFILE FELL DURING EACH MONTH

In each cell, the figures indicate, for the months as arranged in table at right, the number of maximum winds occurring in the 1 km altitude layer and within indicated decile of all 844 profiles

FEB	MAR	APR
MAY	JUN	JUL
AUG	SEP	OCT
NOV	DEC	JAN

DECILE

LAYER	1			2			3			4			5			6			7			8			9			X		
13-14	.	.	.	.	.	.	.	.	.	.	.	.	.	1	3	2	1	4	1	.	7	2	3	12	2	3	6	5	4	1
	.	5	7	3	7	5	4	4	3	6	6	3	5	9	3	11	2	.	6	4	.	7	3	.	8	2	.	1	.	.
	9	6	1	12	3	2	4	5	2	4	7	5	.	6	5	.	2	9	.	1	9	.	1	1	.	.	1	.	.	.
	.	.	.	.	.	.	1	.	.	5	5	.	5	3	2	4	4	3	8	5	5	6	5	4	4	4	2	2	6	4
12-13	.	.	.	.	.	.	.	.	.	.	1	1	1	.	3	.	4	2	3	.	5	.	1	5	.	5	7	9	8	2
	.	4	2	1	3	6	1	5	2	1	5	3	5	2	.	3	3	.	4	.	.	3	.	.	8	1	.	2	.	.
	1	1	1	5	1	1	5	12	6	1	4	3	.	4	2	.	2	4	2	1	1	1	.	6	1	.	1	.	.	.
	.	.	.	.	.	.	.	.	.	1	.	1	1	1	1	5	3	.	3	5	4	4	2	4	6	3	5	3	4	4
11-12	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	1	1	1	1	1	4	4	4
	.	.	2	.	1	5	.	1	1	.	2	2	4	2	.	2	.	.	.	.	.	1	1	.	.	2	.	.	.	.
	4	.	.	1	3	.	3	5	.	2	2	3	1	3	2	1	1	1	.	.	1	.	.	.	.	.	1	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	3	.	1	2	.	2	3	1	.	4	1	1	1	.	3
10-11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	3	.	1	1	6	4	.
	.	3	.	.	.	.	1	.	.	.	.	.	1	1	.	1	1	.	.	.	.	1	.	.	1	.	.	.	.	.
	3	1	1	2	.	2	2	1	.	2	2	1	.	.	.	.	1	1	.	.	1	.	.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	1	.	1	1	.	.	.	.	3
9-10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	1	.	.
	.	1	2	.	1	.	.	1	1	.	2	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	1	.	1	.	.	.	3	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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8-9	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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	.	2	1	.	.	4	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	.	.	.	2	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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5-6	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	.	2	2	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	3	2	.	3	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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	.	1	1	.	2	1	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Table 3. MEDIAL CORRELATIONS BETWEEN PAIRS OF CHARACTERISTICS, for 844 profiles, chiefly 1967-1970, above diagonal, and for 900 profiles, chiefly 1965-1967, below diagonal

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
MAX WIND SPEED	(1)	---	.50	.40	.54	.29	.53	.31	.71	.01
MAX 100m SHEAR POS	(2)	.35	---	.39	.52	.25	.62	.33	.47	.05
MAX 100m SHEAR NEG	(3)	.41	.40	---	.37	.41	.35	.60	.39	.13
MAX 1 km SHEAR POS	(4)	.48	.39	.36	---	.34	.64	.34	.61	.10
MAX 1 km SHEAR NEG	(5)	.34	.24	.45	.37	---	.32	.54	.36	.28
MAX 400m SHEAR POS	(6)	.38	.51	.40	.60	.33	---	.39	.53	.09
MAX 400m SHEAR NEG	(7)	.32	.28	.60	.36	.55	.39	---	.31	.16
MAX 3 km SHEAR POS	(8)	.64	.32	.36	.60	.39	.43	.35	---	.12
MAX 3 km SHEAR NEG	(9)	.10	.13	.16	.16	.29	.18	.24	.23	---

On the whole, the medial correlations between characteristics in the present sample of 844 soundings show the same pattern as those for the 900 soundings studied previously. Correlations between maximum wind speeds and maximum positive wind shears are generally higher than those with maximum negative shears; the negative shears correlate somewhat among themselves, except for the 3 km negative shear, which has little relation to any of the other characteristics. For some purposes, wind profiles might be characterized by only their maximum wind speeds and maximum 3 km negative shears, without regard to the other characteristics.

2.2 Decile Sampling

While coding wind profiles according to the deciles of various characteristics permits various studies, as suggested in the previous section, the major purpose of the procedure is the drawing of a random sample. Such a sample is represented by a matrix, in which each row represents one of the characteristics and each column a decile. Soundings, drawn at random from the entire set, are accepted for the sample unless they cause one of the cells of this matrix to exceed some predetermined limit. In the previous study of 900 profiles, samples were constructed in this way with <u>at most</u> 2, 3, 4, or 5 entries per cell. Other samples were drawn to include <u>at least</u> 2, 3, 4, or 5 entries per cell, with the procedure terminated when this lower limit was attained or surpassed for each cell. That study also demonstrated the superiority of taking soundings at random over sampling them sequentially in time.

Although nine characteristics were coded according to deciles for each of the 844 wind profiles, only five were considered as primary, and the other four as supplementary. This same approach was used in the present study, but the lower and upper limits for numbers of entries per cell were changed to 3, 4, 5, 6, 7, and 8. Each of three randomizations of the 844 profiles was scanned 12 times, to select profiles which would have at most m in each decile, and then at least m. Results were very close to those obtained previously. When an upper limit is placed on the number per cell, the sample size was consistently 90 per cent of optimum (10 m); when a lower limit was used, sample size was roughly 13 m + 10, just as in the previous study. These relations are shown in Fig. 3, which is very similar to the corresponding figure in the previous report (L-2, Fig. 3.2).

Table 4 gives, for each of the three randomizations, the number (m) of profiles in each sample, and the total number of profiles scanned to obtain the sample. When at most m profiles per decile are desired, the entire set of profiles is scanned, and often almost the last one is accepted. For at least m profiles per decile, however, the procedure usually ends before 20m profiles have been examined. In this sense, therefore, the "at least m" procedure is more efficient, and presumably should be used in obtaining samples of 20 (for which m = 1) or more. For smaller samples, "at most 1" will give a fairly representative sample of nine soundings.

Whether larger grouping, e.g. quintiles instead of deciles, and fewer characteristics such as only maximum wind speed and maximum 3 km negative shear, would provide samples equally well has not been studied here, but may be worth investigation.

Table 4. NUMBER OF PROFILES USED (n) AND ORDINAL (N) OF LAST PROFILE USED IN COMPLETING DECILE MATRIX WITH AT LEAST m PROFILES PER CELL AND IN ATTEMPTING TO COMPLETE WITH AT MOST m PROFILES PER CELL, FROM THREE RANDOMIZATIONS OF 844 WIND PROFILES OVER CAPE KENNEDY

randomization	3	4	5	6	7	8
			at least m			
1	52/ 67	62/ 79	72/ 88	85/100	97/105	109/122
2	51/ 63	64/ 92	76/126	90/140	98/166	109/167
3	49/ 81	63/117	72/122	87/129	97/131	109/140
			at most m			
1	25/574	36/734	45/658	56/836	66/814	76/754
2	26/255	37/442	47/716	55/528	64/716	74/839
3	29/805	37/530	46/530	56/576	54/380	73/809

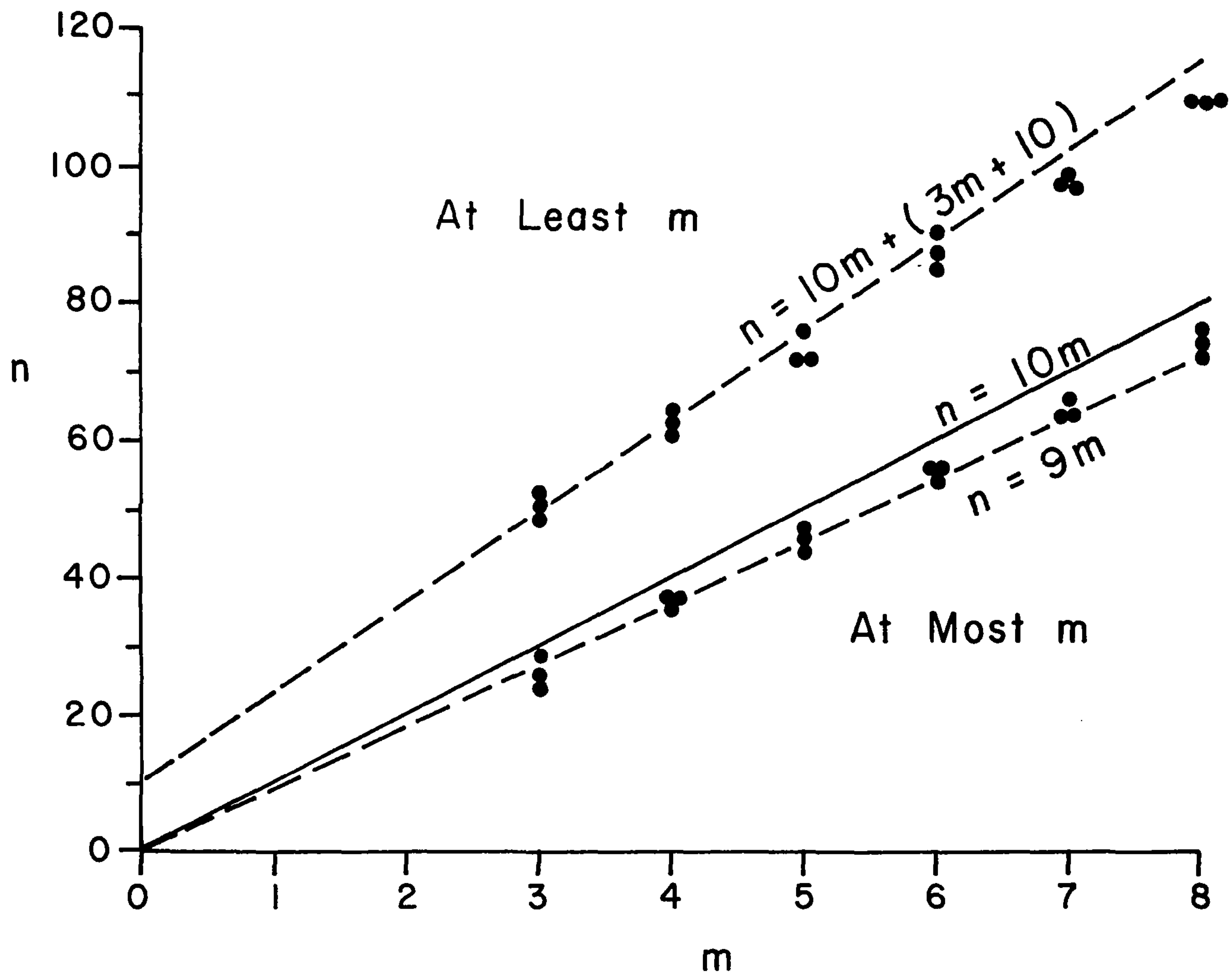


Figure 3. Number of Profiles Accepter (n) in Seeking at Least or at Most m Entries per Cell in Three Random Samplings; Diagonal Line Represents Optimum Number, if Each Cell has Exactly m Entries.

Section 3
GUSTS

3.1 Definition

In this study gusts are defined as positive or negative departures from a smooth wind profile. The departures are computed at 25 m intervals with Martin Graham cosine roll-off high pass digital filters composed of 41 weights. Properties of these filters and a practical methodology for their derivation are described by DeMandel and Krivo (1969). Four sets of gust profiles were computed using 1578 Jimsphere profiles in the altitude range from 2 to 14 km. Each set is composed of 757,440 departures which were computed for a particular high pass filter configuration. Characteristics of the four high pass filters used are summarized in Table 5.

Table 5. CHARACTERISTICS OF FOUR 41 WEIGHT HIGH PASS FILTERS USED TO COMPUTE DEPARTURES FROM SMOOTH JIMSPHERE WIND PROFILES

Cut-Off Wavelengths (m)		Termination Wavelengths (m)		rms Difference
Nominal (λ_c)	Effective (λ_c^*)	Nominal (λ_t)	Effective (λ_t^*)	
4000	2503	1000	1058	.040
2000	1922	667	782	.043
1000	858	500	542	.035
500	459	333	352	.033

Nominal cut-off and termination wavelengths, λ_c and λ_t, are used to describe the roll-off behavior of idealized high pass filters composed of an infinite number of weights. For wavelengths $\lambda > \lambda_c$ the ideal filter reduces the amplitude of wind speed fluctuations by more than 80 percent; for wavelengths $\lambda < \lambda_t$ amplitude reduction is less than 20 percent. In practice the use of digital filters having a finite set of weights results in deviations from the idealized filter roll-off and thus effective cut-off and termination wavelengths, λ_c^* and λ_t^*, are realized. The rms difference between the ideal and actual filter response is also given in Table 5. The filter weights comprise Appendix I. The reduction of low frequency variability with decreasing λ_c is illustrated in Figure 4 for a 5 km segment (9-14 km) of Jimsphere profile 8419 (22 January 1968, 0220 GMT). The rms gust speed, σ, is .90 m/sec for λ_c = 4 Km; in comparison σ is reduced to .68, .42, and .33 m/sec for λ_c = 2, 1, and 0.5 Km, respectively.

The gust profiles are composed of fluctuations with a wavelength range that results from the behavior of the transfer function of the total Jimsphere system for small wavelengths and the high pass filter for large wavelengths. For descriptive purposes, the wavelength range for the four types of gust profiles extends from a minimum of 100 m to a maximum given by λ_c^*.

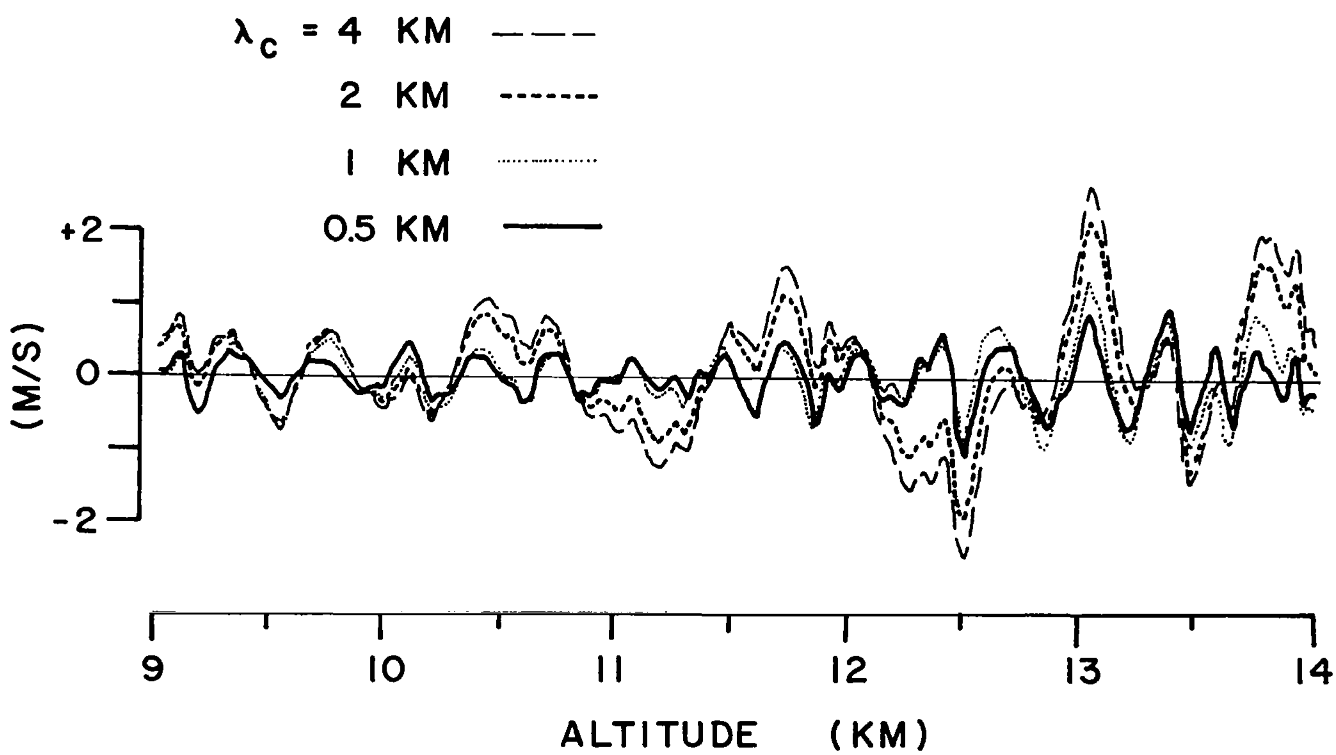


Figure 4. High Pass Filtered Jimsphere Profile (Test 8419 22 January 1968, 0220 GMT) for Nominal Cut-Off Wavelengths, λ_c, of 0.5 1, 2, and 4 km.

3.2 Gust Shape

The shapes of gusts, with respect to the smoothed (filtered) profiles, appear to be not quite symmetrical. Below the maximum speeds, wind speeds increase with height slightly more rapidly then they decrease above the level of maximum speed. This tentative conclusion was drawn from an analysis of gust speeds, defined as the wind speed departures from smoothed profiles. For each profile in each month, a tabulation was made of the number of cases in which the gust speed at a level exceeded that at the level immediately below. Thus, for each of the four filters, in each 5 km atmospheric layer (L,M,H), 200 gust speed differences were evaluated as positive or negative. In January, for example, the 125 soundings yielded 125 x 200 = 25,000 such differences, for each filter and layer.

In most of these month-layer-filter tabulations, less than half of the differences were positive, and in none of the few combinations with more than half the differences as positive was the excess significant. The results were considered as analogous to the outcomes of the tossing of a coin $N = 25{,}000$ or so times by each of 120 persons, of which 30 used nickels, 30 used dimes, 30 used quarters, and 30 used half-dollars; the coins correspond to the four filters. If the coins were true, the expected number of heads obtained by each person would be $N/2$, with a variance of $1/2 \times 1/2 \times N$, or a standard deviation of $0.5\ N^{1/2}$, which for $N = 25{,}000$ is 79.1.

In very many sets of 25,000 tosses of a true coin, some 68 percent would yield within 79 of 12,500 heads, or between 12,421 and 12,579, and 95 percent between 12,342 and 12,658 heads. For any one set of 25,000 tosses, a number of heads outside this latter range would lead to rejection, at the 5 percent level, of the hypothesis that the coin was actually true.

Table 6 shows, for each month-layer-filter combination, the departure from expected of the number of positive gust speed differences between successive levels both in actual value and in terms of standard deviations. The overwhelming majority of the departures are negative - - less than half of the

Table 6. DEPARTURE FROM EXPECTED VALUE OF THE NUMBER OF POSITIVE DIFFERENCES IN GUST SPEEDS BETWEEN SUCCESSIVE 25-m LEVELS, FOR EACH MONTH, FILTER, AND ALTITUDE LAYER. D. IS ACTUAL DIFFERENCE, R IS RELATIVE DIFFERENCE: i.e. D/S, WHERE S IS THE STANDARD DEVIATION

		LOW (2-7 KM)				MIDDLE (6-11 KM)				HIGH (9-14 KM)			
FILTER		0.5	1.0	2.0	4.0	0.5	1.0	2.0	4.0	0.5	1.0	2.0	4.0
JAN	D	-67	-226	-254	-277	-49	-154	-262	-261	28	-12	-196	-95
N = 25,000	R	0.85	2.86	3.22	3.51	0.62	1.95	3.32	3.30	0.35	0.15	2-48	1.20
FEB	D	-93	-182	-250	-246	-119	-101	-141	-182	-57	1	-38	-40
21,800	R	1.78	3.50	4.81	4.73	2.28	1.94	2.71	3.50	1.10	0.02	0.73	0.77
MAR	D	-168	-194	-171	-217	-65	-130	-260	-325	-113	-37	-11	13
26,800	R	2.90	3.34	2.95	3.74	1.12	2.24	4.48	5.60	1.95	0.64	0.19	0.22
APR	D	-107	-98	-175	-156	-114	-229	-343	-365	0	-19	-63	-75
32,200	R	1.70	1.56	2.78	2.48	1.81	3.63	5.44	5.79	0	0.30	1.00	1.19
MAY	D	15	-10	-125	-113	-127	-249	-344	-306	-199	-331	-265	-251
35,000	R	0.23	0.15	1.89	1.71	1.92	3.77	5.21	4.64	3.01	5.01	4.01	3.80
JUL	D	60	27	47	89	-79	-77	-112	-144	-82	-102	-162	-151
24,200	R	1.09	0.49	0.85	1.62	1.44	1.40	2.04	2.62	1.49	1.85	2.95	2.75
AUG	D	-53	-24	-41	-45	-63	-141	-227	-243	-27	-94	-92	-68
27,200	R	0.91	0.41	0.71	-.78	1.09	2.43	3.91	4.19	0.47	1.62	1.59	1.17
SEP	D	40	-14	-53	-45	-82	-97	-98	-175	-98	-79	-87	-69
27,200	R	0.67	0.24	0.91	0.78	1.41	1.67	1.69	3.02	1.69	1.36	1.50	1.19
OCT	D	-82	-186	-195	-176	-26	-164	-231	-291	93	-48	2	-17
29,200	R	1.37	3.10	3.25	2.93	0.43	2.73	3.85	4.85	1.55	0.80	0.03	0.28
NOV	D	20	27	7	-28	47	-51	-133	-182	101	85	-16	-1
23,800	R	0.36	0.49	0.13	0.51	0.85	0.93	2.42	3.31	1.84	1.55	0.29	0.02

differences are positive - - and many of them are significantly so. The fractions which differ by more than two standard deviations from the expected value were:

Filter:	0.5	1	2	4
High	.1	.1	.3	.2
Middle	.1	.5	.9	1.0
Low	.1	.4	.5	.5

Gusts around the high-frequency filter (0.5) were almost symmetrical, while those around the low-frequency filter (4) showed a pronounced tendency for fewer than half the differences to be positive.

3.3 Exceedance Probability of Gusts

If F(X) is the cumulative probability distribution of gusts, W ,[i.e., $F(X) = P(W \leq X)$] then the exceedance probability, $P(W > X)$, is $1 - F(X)$. The exceedance probabilities of gusts computed from four sets of 757,440 gusts observed in 1578 profiles between 2 and 14 km are represented by the curved lines Figure 5. The plotted points represent the exceedance probability for 12,000 gusts observed in a random sample of 25 profiles drawn from the parent population of 1578 profiles. This random sample composed of less than 1.6 percent of the data in the parent population closely follows the distribution of the parent population over a large range of probabilities except for a tendency to underestimate the extreme gusts. Since the exceedance probability of a normal distribution would be plotted as a straight line with slope proportional to the standard deviation of W , the curvature of observed exceedance distributions supports the conclusion that gusts defined as departures from smoothed Jimsphere wind speed profiles do not have a normal distribution. Similar deviations from normality have been observed in high altitude turbulence measured from aircraft. The core of Dutton's (1968) explanation for this behavior is the hypothesis of locally Gaussian patches of turbulence with variable intensity. When an analysis is performed on a set of data composed of these Gaussian patches, the resulting probability density distribution is larger near the origin and in the tails, and less in between

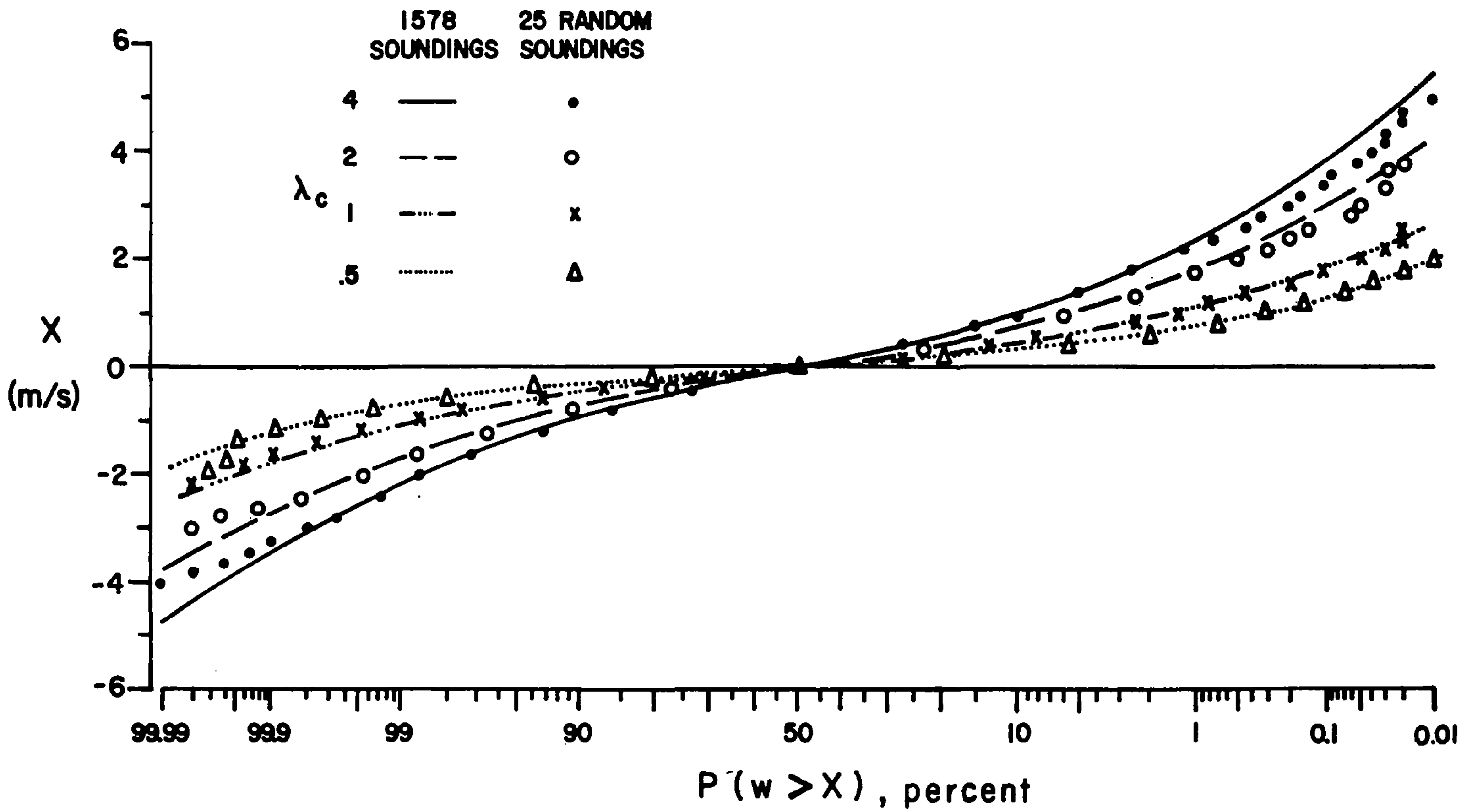


Figure 5. Exceedance Probability of Gust Speed

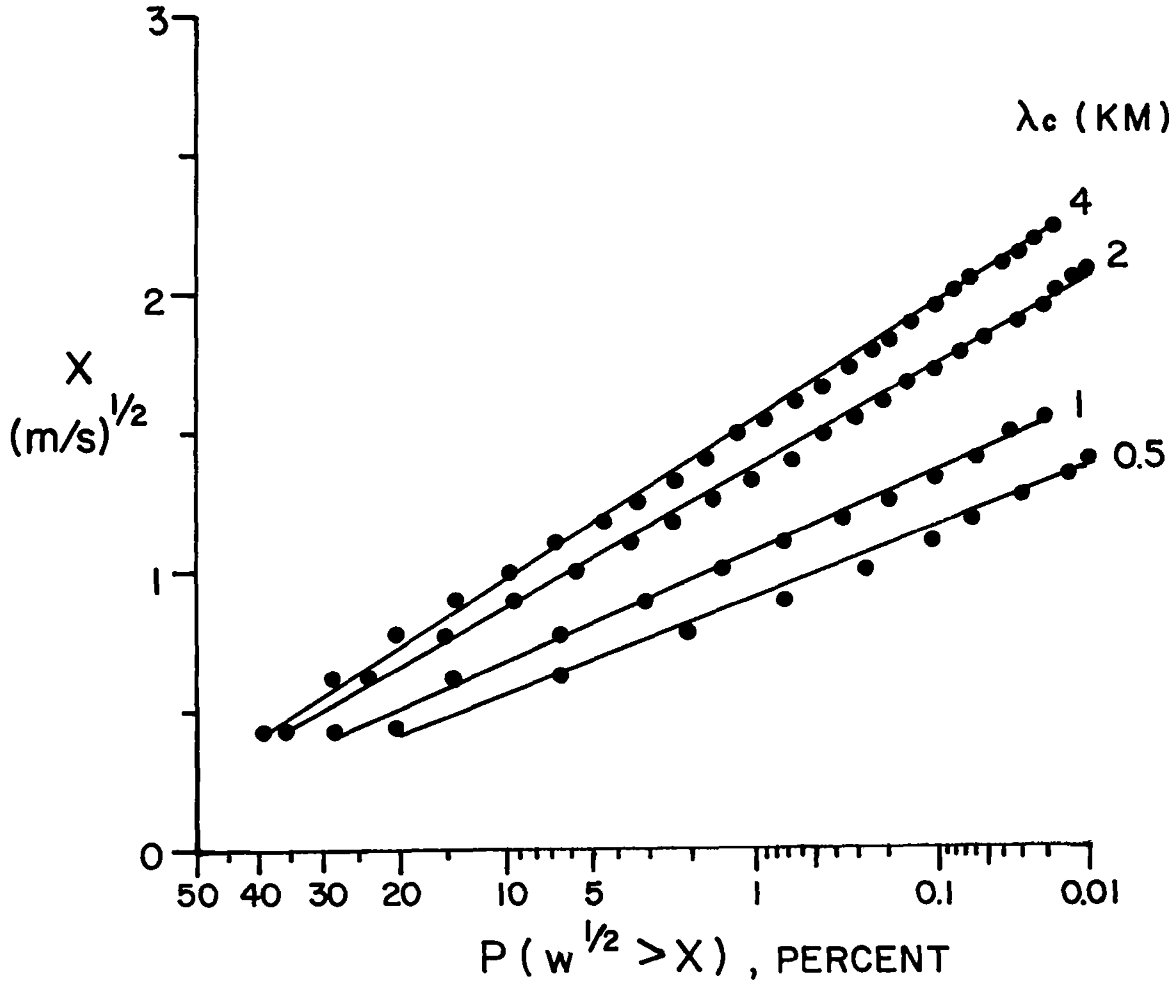


Figure 6. Exceedance Probability of the Square Root of Gust Speed

than the Gaussian distribution. This hypothesis, similarly unsupported by evidence which clearly indicates locally Gaussian patches, could be proposed to explain the gust speed distribution observed in Jimsphere wind profiles. Further study of individual Jimsphere wind profiles in narrow altitude bands could establish the validity of the locally Gaussian hypothesis for Jimsphere gust speeds.

As illustrated in Figure 6, the exceedance probability of large values of the square root of positive gust speed, P $(W^{1/2} > X)$, can be accurately represented by the exceedance probability of a normal variate. Table 7 gives the means (μ) and variances (σ^2) of normal distributions which can be used to estimate the exceedance probability of the square root of large Jimsphere gust speeds.

Table 7. μ AND σ^2 OF NORMAL VARIATE WITH EXCEEDANCE PROBABILITY EQUIVALENT TO OBSERVED EXCEEDANCE PROBABILITY OF THE SQUARE ROOT OF POSITIVE GUST SPEED.

λ_c (km)	.5	1	2	4
μ (m/sec)	.12	.18	.25	.26
σ^2 (m^2/sec)	.12	.15	.24	.31

3.4 Root Mean Square Gusts

For aero-astronautical applications information is needed concerning the probability that vehicle responses to wind inputs will exceed a given magnitude. According to the basic theory of Rice (1944-5) as described by Dutton (1968), the average number of exceedances with positive slope, $\overline{N}(y)$, of a linear response variable, y, to a stationary Gaussian forcing variable, x, is a function of the standard deviation, σ_x, of x of the form

$$\overline{N}(y) = N_o \int_0^\infty \exp -1/2 \, (y/A\sigma_x)^2 \, f(\sigma_x) \, d\sigma_x \tag{1}$$

where $f(\sigma_x)$ is the probability distribution of σ_x, N_o is the number of zero crossings with positive slope, and A is the ratio of output to input variance for a linear system.

In attempting to apply this theory by using available Jimsphere wind information to calculate response exceedances for ascending or descending vehicles it is necessary to establish whether the two essential elements which form the basis of the theory are satisfied: specifically are the gust speeds of a Jimsphere wind profile a realization of a stationary Gaussian process?

It could be argued that the Jimsphere gust speed fluctuations should have a tendency toward exhibiting the characteristics of a vertical sample of turbulence as the large wavelength deterministic component of the variability is progressively removed. But what is known about the vertical variation of turbulence? Available data indicate well-defined maxima near the ground and at the tropopause, near the level of maximum wind speed. Therefore, acceptance of this argument leads to the conclusion that, to some degree, profiles from Jimsphere soundings subjected to a high-pass filter should be non-stationary.

Certainly the stationarity of the input process is not aided by the fact that most ascending launch vehicles are accelerating through the atmosphere, thus introducing an artificial but real non-stationarity into the input. A previous study of 268 Jimsphere gust speed profiles (Adelfang, 1970) viewed in Saturn vehicle time coordinates, found the variance of gusts in the 12.2 to 16.3 km altitude band (corresponding to a Saturn flight time interval of 80 to 90 seconds) was more than six times larger than the variance observed in the 5.9 to 8.7 km band (60-70 sec). Since this artificial non-stationarity consists of a shift of wind input fluctuations to smaller wavelengths as the vehicle ascends, the increase of variance with altitude would be the same for altitude as for vehicle time coordinate systems.

For the study of the rms gust speed, σ, an attempt was made to reduce the non-stationarity by selecting for analysis three overlapping 5 km altitude bands centered at 4.5, 8.5, and 11.5 km.

As indicated in Section 3.3, for a large sample, only the extreme values of the square root of Jimsphere gust speeds can be represented by a Gaussian distribution. Otherwise, a Gaussian distribution would significantly underestimate the gust speeds at the extremes. However, it is not known whether an optimum decomposition of the data can be found to represent a narrow altitude or wavelength interval which is more closely Gaussian.

The variance, σ^2, of a particular 5 km gust sample is the mean square deviation from a smooth profile for the entire sounding. The smoothing is over a range of wavelengths limited at large wavelengths by an amount which depends upon the particular high pass filter used. Therefore, σ^2 is smaller, especially for λ_c small, than the variance about the mean wind for the entire layer, because this includes deviations contributed by large wavelengths.

To study the shape of observed annual and monthly exceedance probability distributions of σ for the three altitude bands a normalizing factor, σ_{50}, the median of σ, was chosen which in effect eliminates the variability of σ attributable to the filtering process. σ_{50} is a function of the filter cut-off frequency of the form

$$\sigma_{50} = m \ln \lambda_c + b \qquad (2)$$

for m and b in m/sec and λ_c in km.

Plots of the values of σ / σ_{50} , in Figures 7 and 8 show that the exceedance probability, $P (\sigma / \sigma_{50} > X)$, can be approximated by the exceedance probability of a log-normal distribution (straight lines) with parameter N. Thus X , the normalized σ for any exceedance probability, can be calculated by substitution of the unique value of N , given in the upper portion of the abscissa scale, in Figures 7 and 8, associated with that probability:

$$X \ (m/sec) = \exp \ (\alpha N) \tag{3}$$

The constants α, m , and b of equations 2 and 3 are given in Table 8 for each month and season. Both m and b increase with altitude and each is a minimum in late summer. The coefficient α increases with altitude in all months except July, when it is greatest in the 2-7 band; its maximum value is in January in the 6-11 and 9-14 bands, with a secondary maximum in June in the 9-14 band.

As described above a Jimsphere wind profile is composed of wind fluctuations that are attributable only in part to turbulence. Although the filtering process tends to emphasize turbulence as more of the large wavelength fluctuations are removed no specific attempt has been made in this study to completely isolate turbulence. Although a similar problem exists in the analysis of wind fluctuations viewed by aircraft in horizontal flight, another difficulty is related to the fact that a large proportion of horizontal flight time is an air containing small wind fluctuations that are of the order of the noise in the measurement system. For example, turbulence data comprised less than 3 percent of the flight time during the HICAT investigations of stratosphere turbulence (Crooks, et al, 1967, 1968). Although smooth air generally occurs less frequently near the ground the results obtained in the LO-LOCAT measurement program (Jones et al 1970) include only those measurements that were considered turbulent. Therefore, in attempting to compare exceedance probabilities of Jimsphere rms gusts with those obtained in the HICAT and LO-LOCAT programs within similar wavelength bands, it must be emphasized that the latter probabilities are conditional upon the existence of turbulence. The shape of the exceedance curves for rms gust speeds would change and the magnitude of the gusts for a given exceedance probability would be diminished

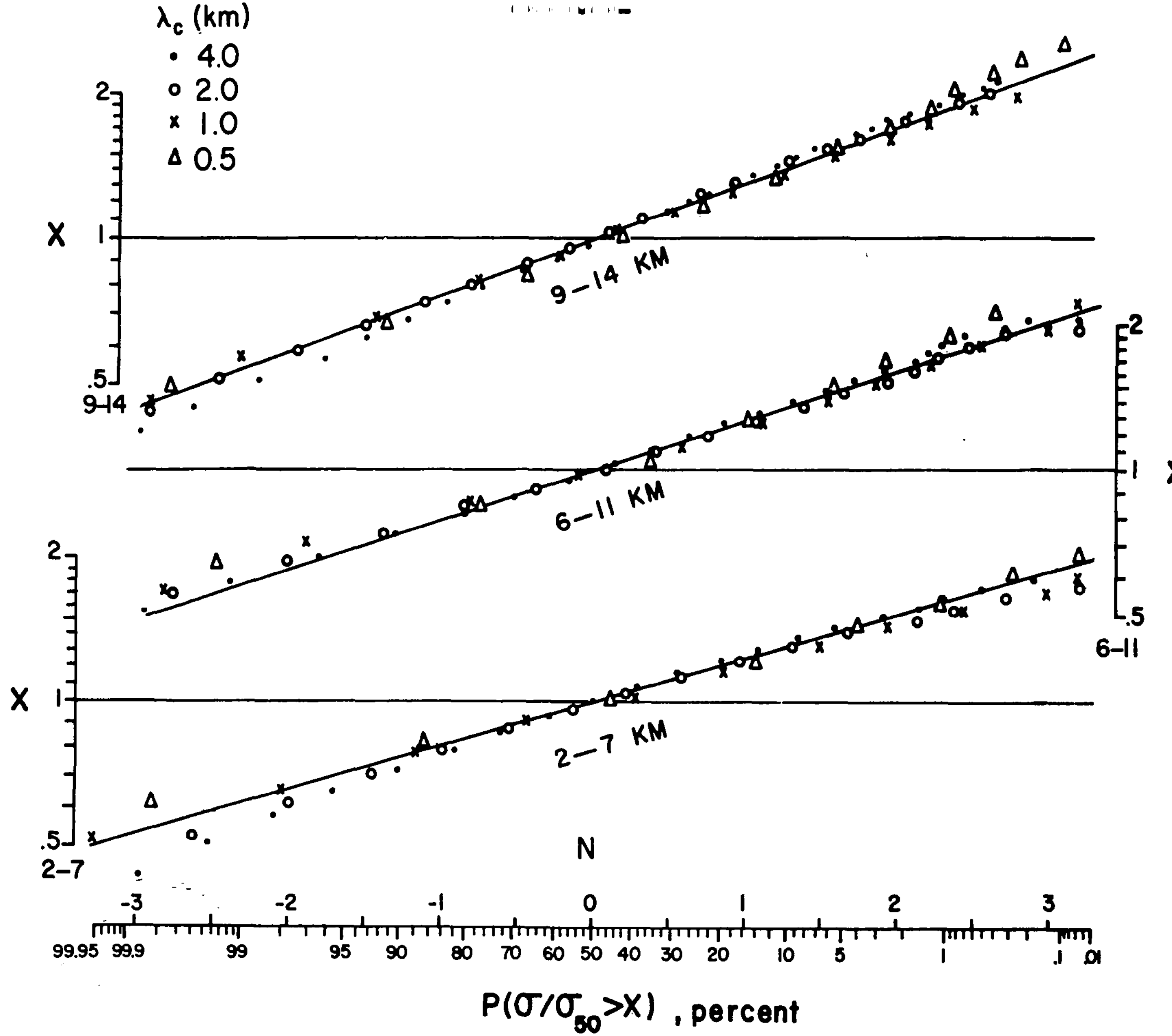


Figure 7. Annual Exceedance Probability of Normalized Root Mean Square Gust Speeds

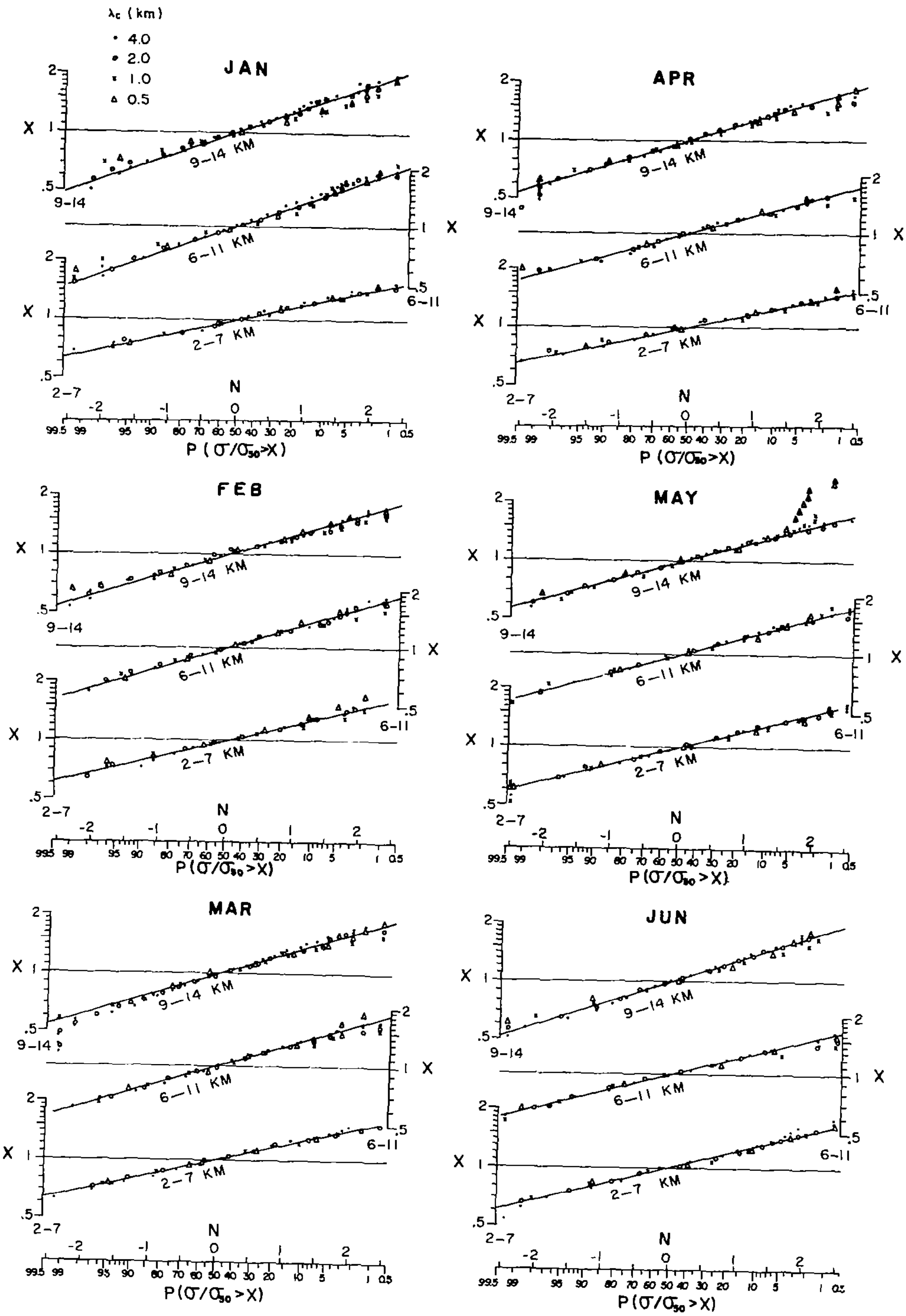


Figure 8. Monthly Exceedance Probability of Normalized Root Mean Square Gust Speeds

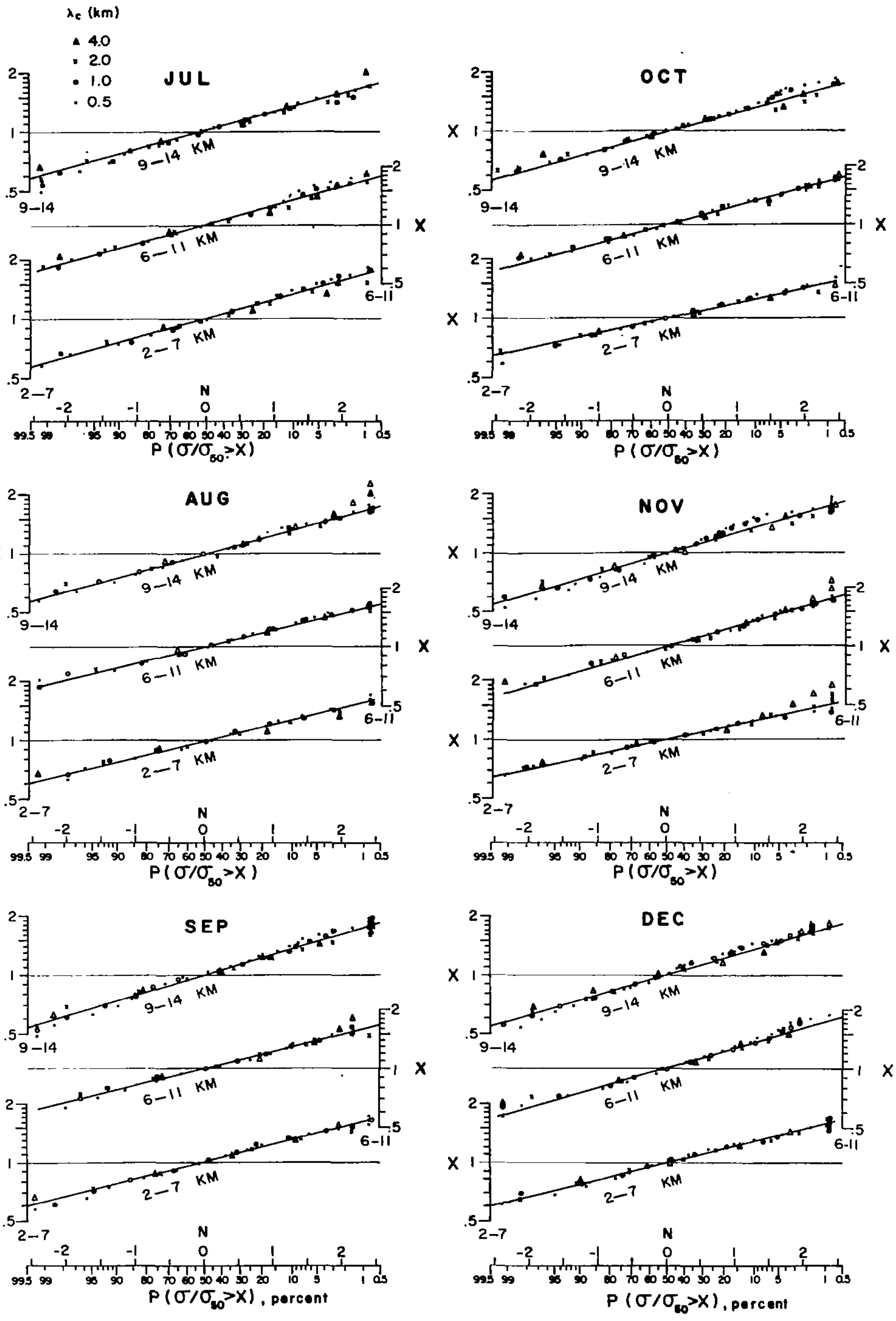


Figure 8. (Continued)

Table 8. α, m, AND b OF EQUATIONS 2 AND 3 AND THE NUMBER OF PROFILES USED, n.

		α			m(m/sec)			b(m/sec)		
Month	n	2-7	6-11	9-14	2-7	6-11	9-14	2-7	6-11	9-14
JAN	121	.18	.28	.28	.27	.24	.33	.44	.41	.55
FEB	106	.19	.24	.24	.25	.23	.32	.43	.44	.58
MAR	130	.18	.23	.24	.26	.23	.34	.43	.41	.56
APR	155	.17	.22	.25	.24	.23	.34	.42	.37	.53
MAY	166	.20	.22	.22	.23	.23	.33	.40	.39	.51
JUN	147	.20	.20	.26	.20	.21	.26	.38	.37	.42
JUL	118	.22	.22	.22	.18	.19	.24	.34	.34	.38
AUG	130	.21	.21	.23	.16	.19	.24	.33	.34	.37
SEP	133	.19	.20	.24	.18	.19	.23	.35	.35	.39
OCT	139	.17	.23	.22	.22	.22	.26	.38	.37	.42
NOV	116	.17	.23	.24	.25	.23	.28	.43	.38	.46
DEC	117	.20	.24	.24	.24	.23	.31	.40	.37	.49
Annual	1578	.21	.24	.26	.22	.22	.29	.39	.39	.47

if the measurements which failed to indicate turbulence are included.

The comparison of rms gust exceedance probabilities as illustrated in Figure 9 is subject to modification when a re-analysis of the data in the other programs is completed which includes all rms gust data.

3.5 Level Crossing Distributions

A Jimsphere gust speed profile consists of positive and negative departures from a smoothed profile. The 401 departures at intervals of 25 m in a particular 5 km segment (2-7, 6-11, or 9-14 km) for a particular filter configuration (λ_c = 0.5, 1, 2, or 4 km) for each Jimsphere profile comprise the basic data for this study of positive slope level crossing exceedance probability and occurrences per kilometer.

Positive slope level crossings at intervals of 0.1 m/sec were counted between successive 25 m gust values that increased with altitude. N(X), the number of crossings with positive slope of level X was calculated for, all the profiles in each month, and for all profiles.

The annual and monthly exceedance probabilities of positive slope level crossings, $P(\Gamma > X)$, are illustrated in Figures 10 (annual) and 11 (monthly). The curved lines were drawn to fit the original plotted points exactly. All the data show that, a Gaussian distribution (straight line) would under-estimate X for extreme probabilities, X increases as λ_c increases, and X is largest in the 9-14 band. A strong assymmetric tendency is observed in January, April, May, and December, in the 9-14 km band for λ_c = 4 km, when extreme positive gusts are 20 to 50 percent larger than extreme negative gusts.

The number of positive level crossings with positive slope per kilometer, N(X)/d, is illustrated in Figures 12 (annual) and 13 (monthly). For $X > 0.5$ m/sec, N(X)/d increases as λ_c increases, is largest in the 9-14 km band, and is smallest in July and August.

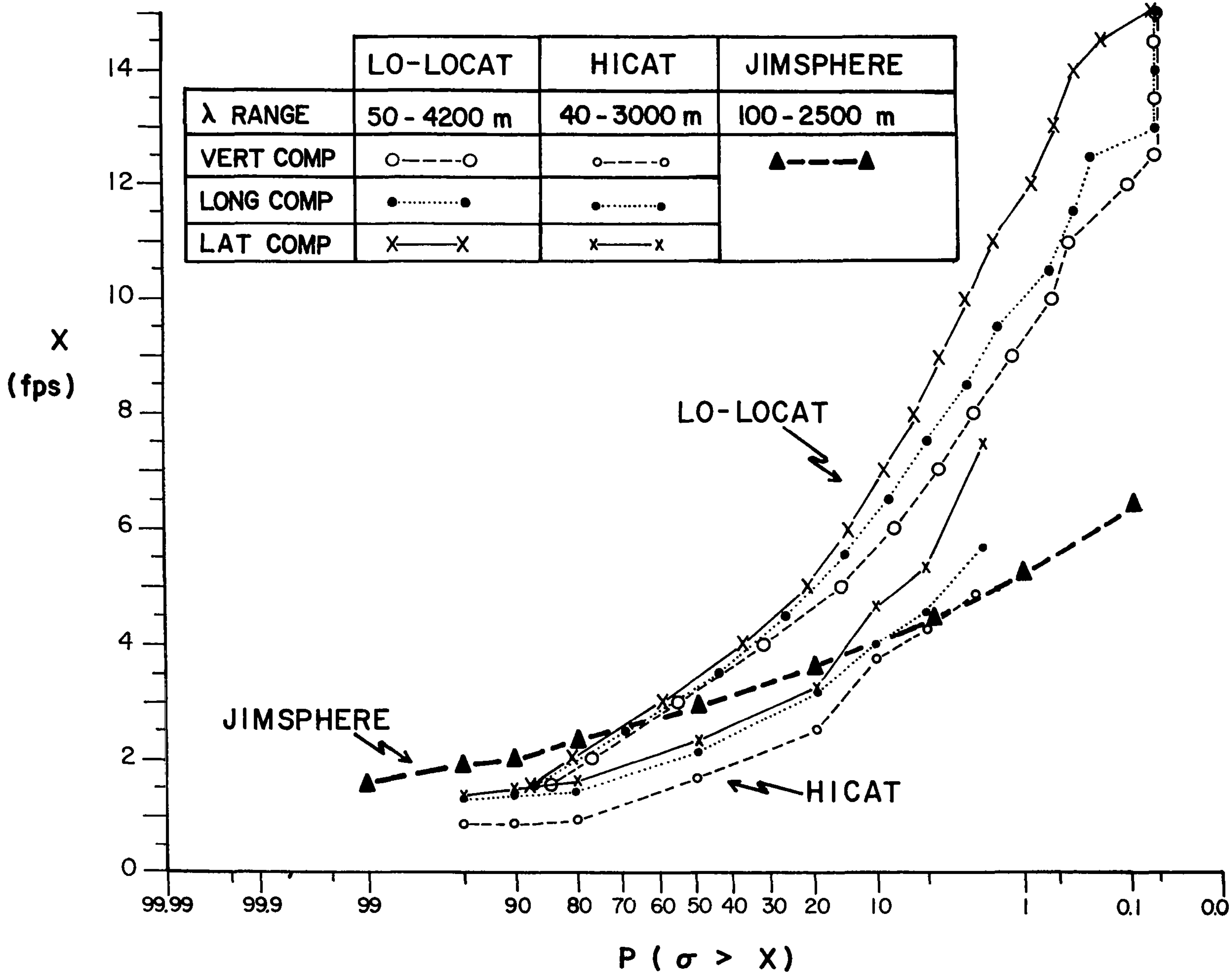


Figure 9. Comparison of Annual Exceedance Probability of RMS Gust Speed Obtained from Jimsphere Profiles between 9 and 14 km with Results Obtained from Aircraft in Horizontal Flight

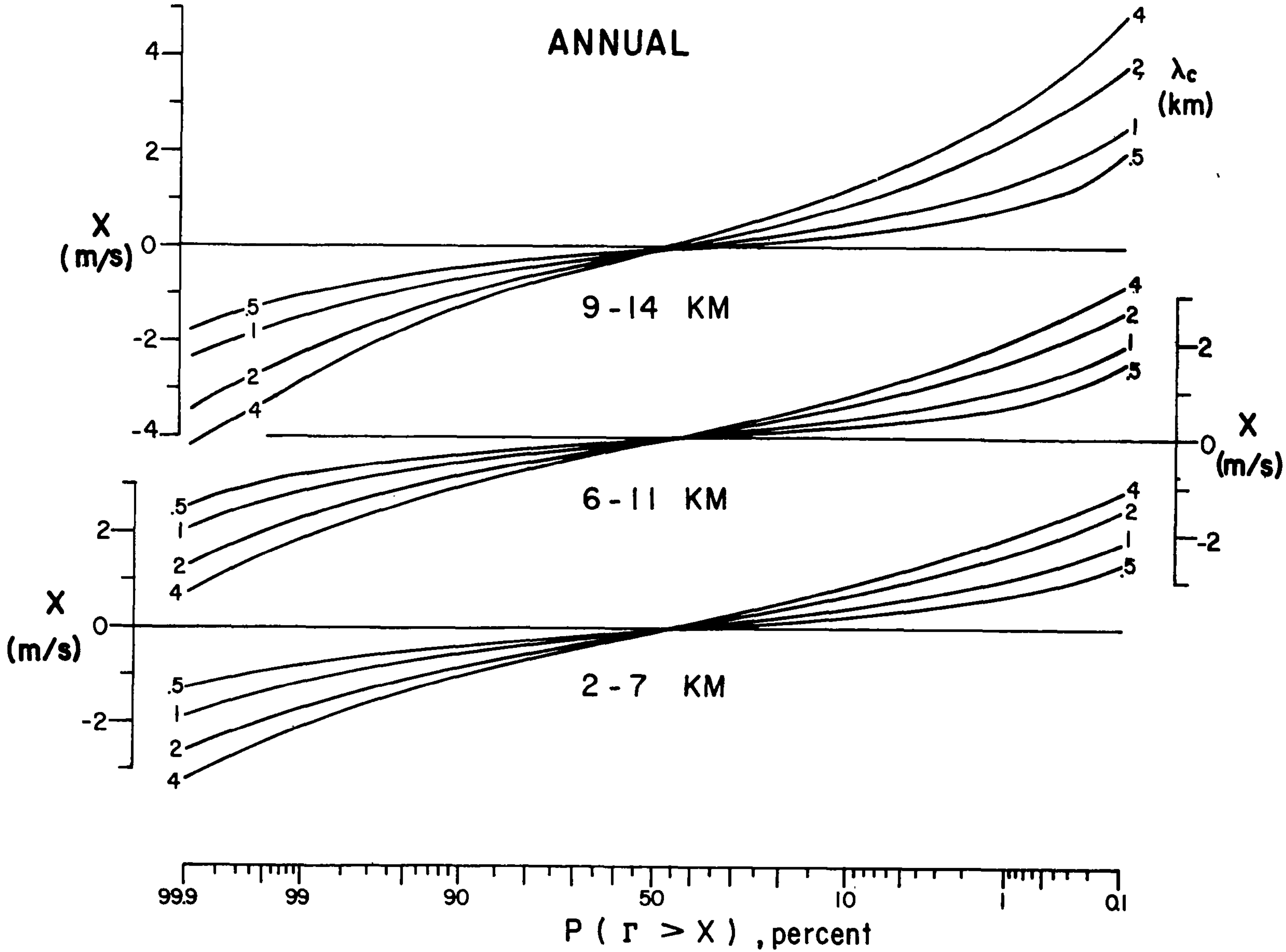


Figure 10. Annual Exceedance Probability of Level Crossings with Positive Slope

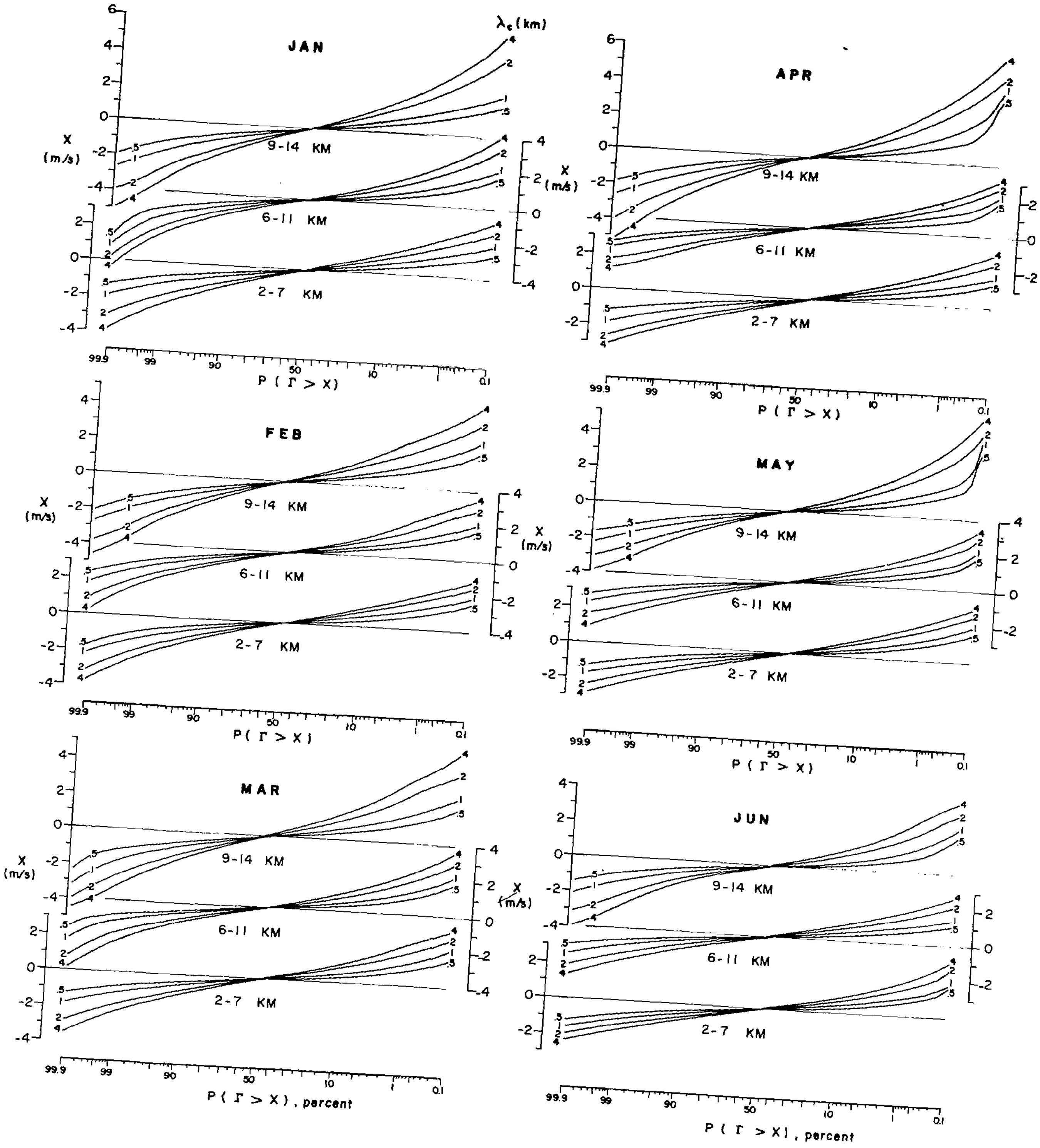


Figure 11. Monthly Exceedance Probability of Level Crossings with Positive Slope

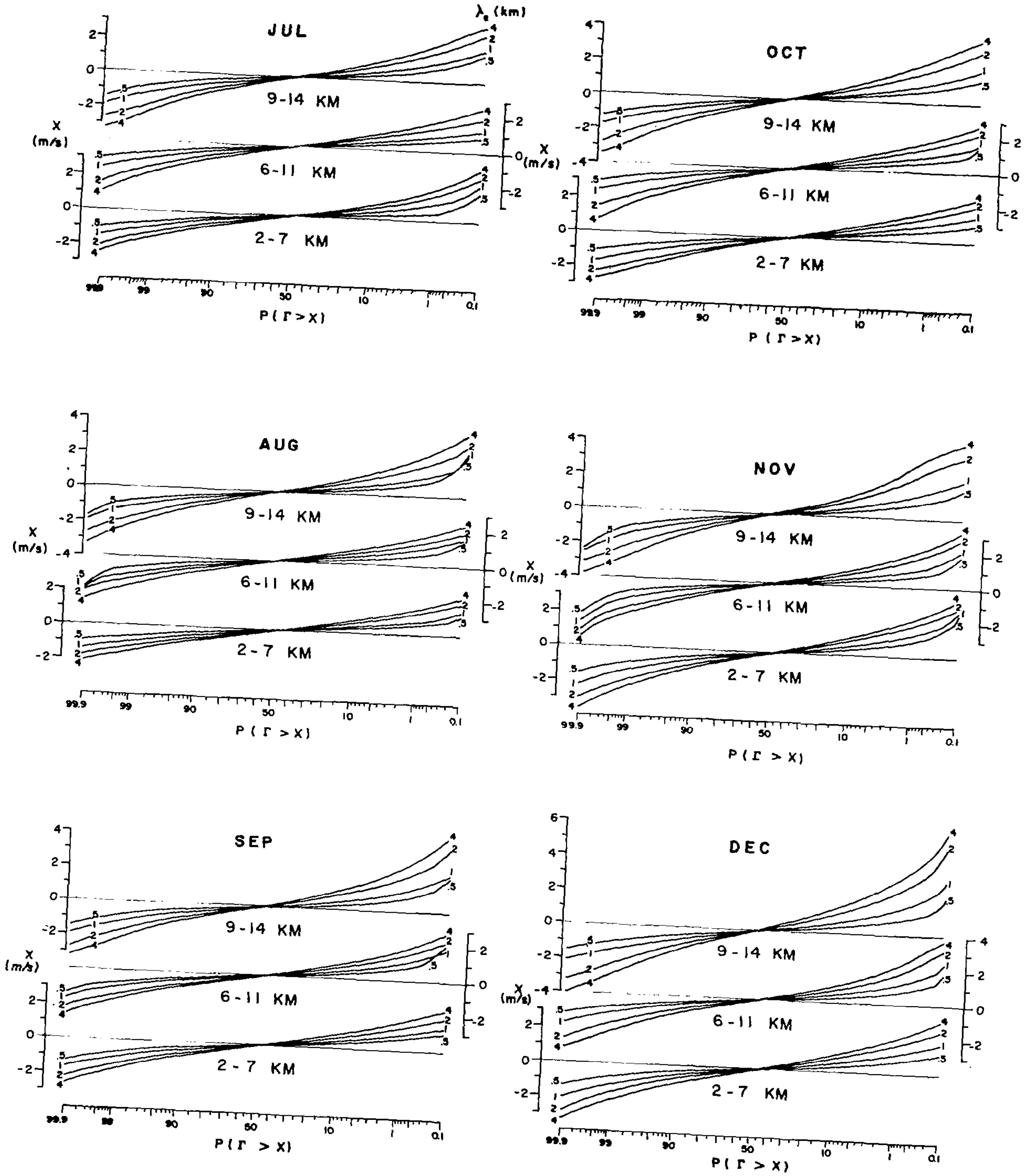


Figure 11. (Continued)

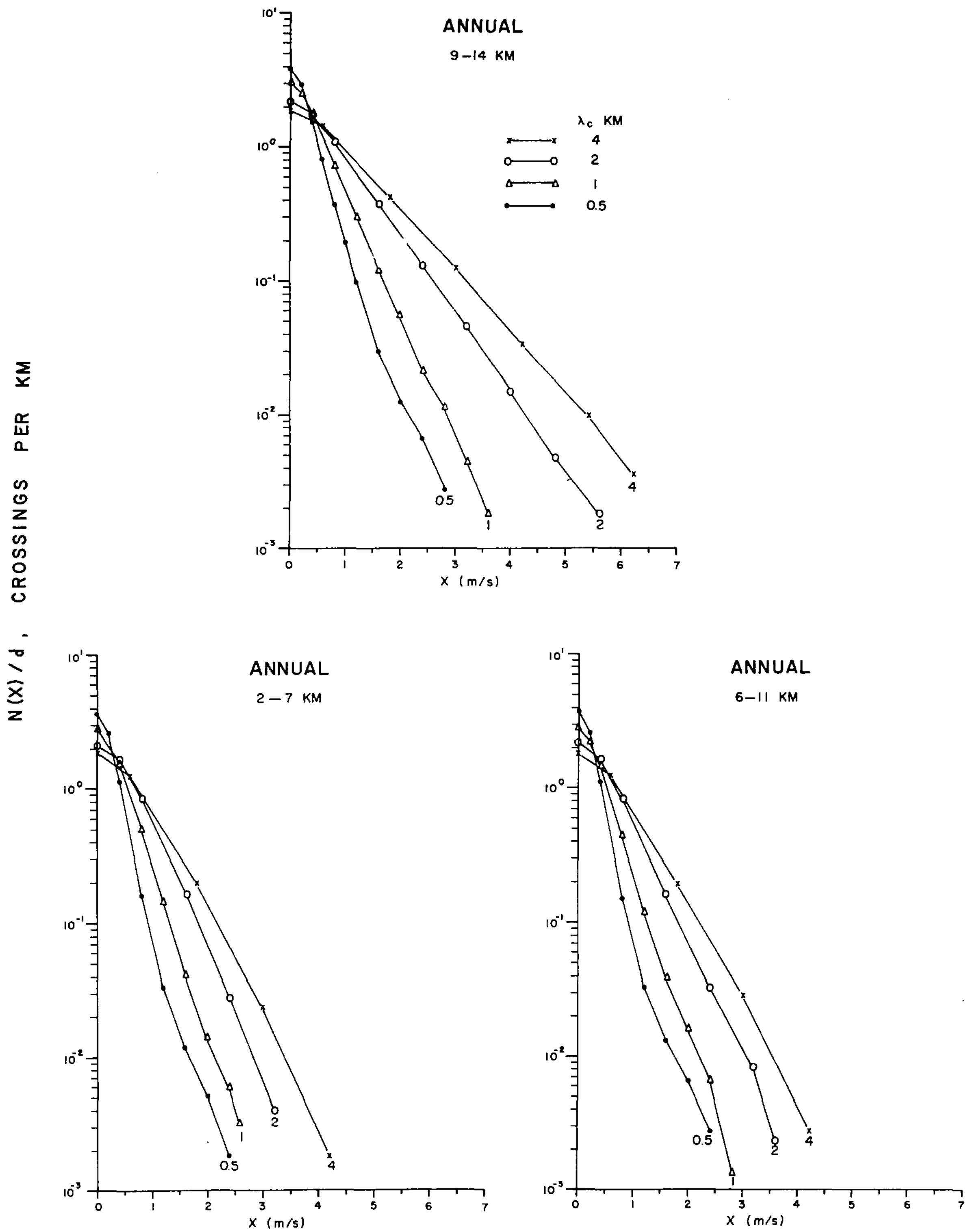


Figure 12. Annual Number of Positive Level Crossings with Positive Slope per Kilometer Observed in 1578 Jimsphere Profiles

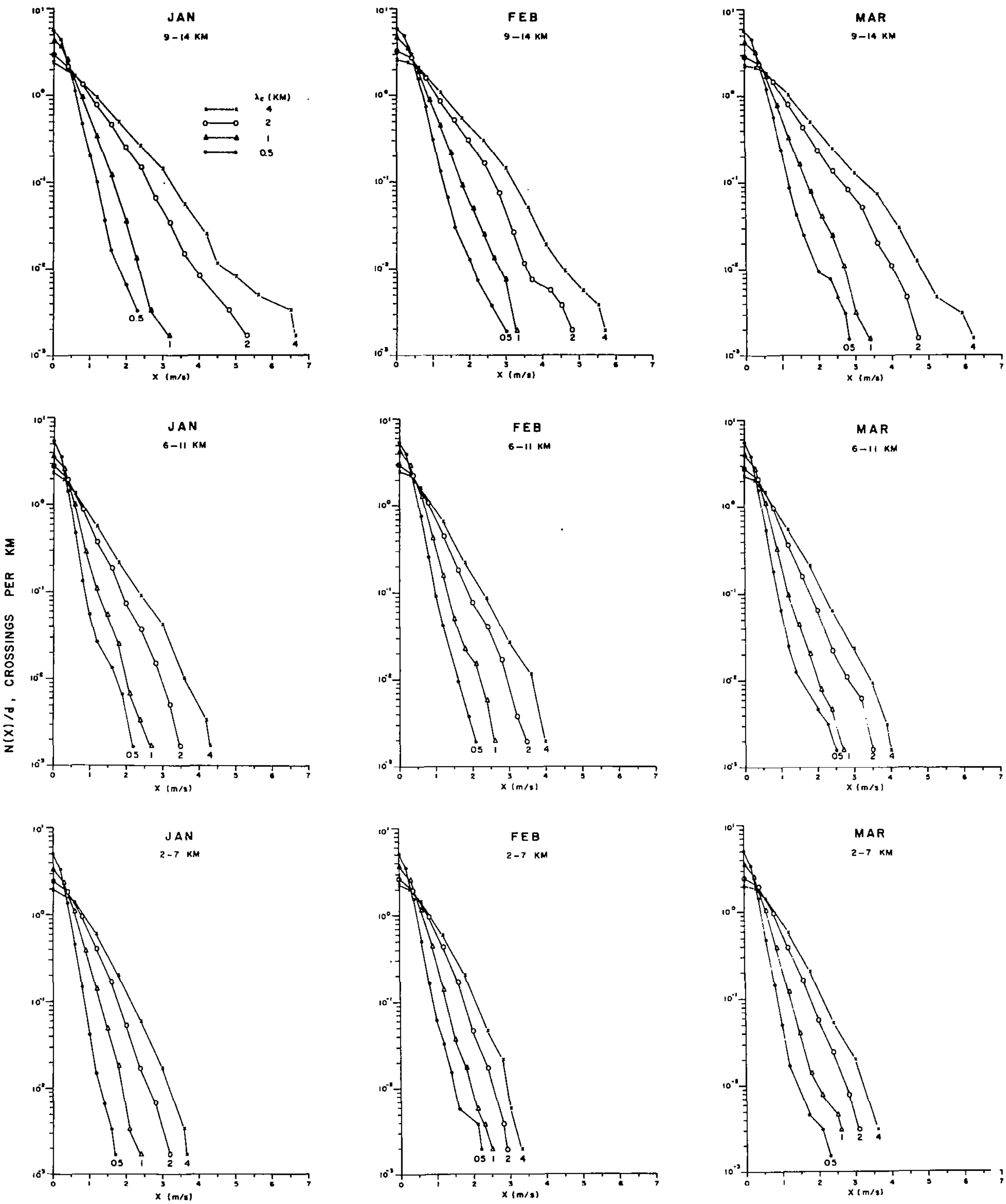


Figure 13. Monthly Number of Positive Level Crossings with Positive Slope per Kilometer

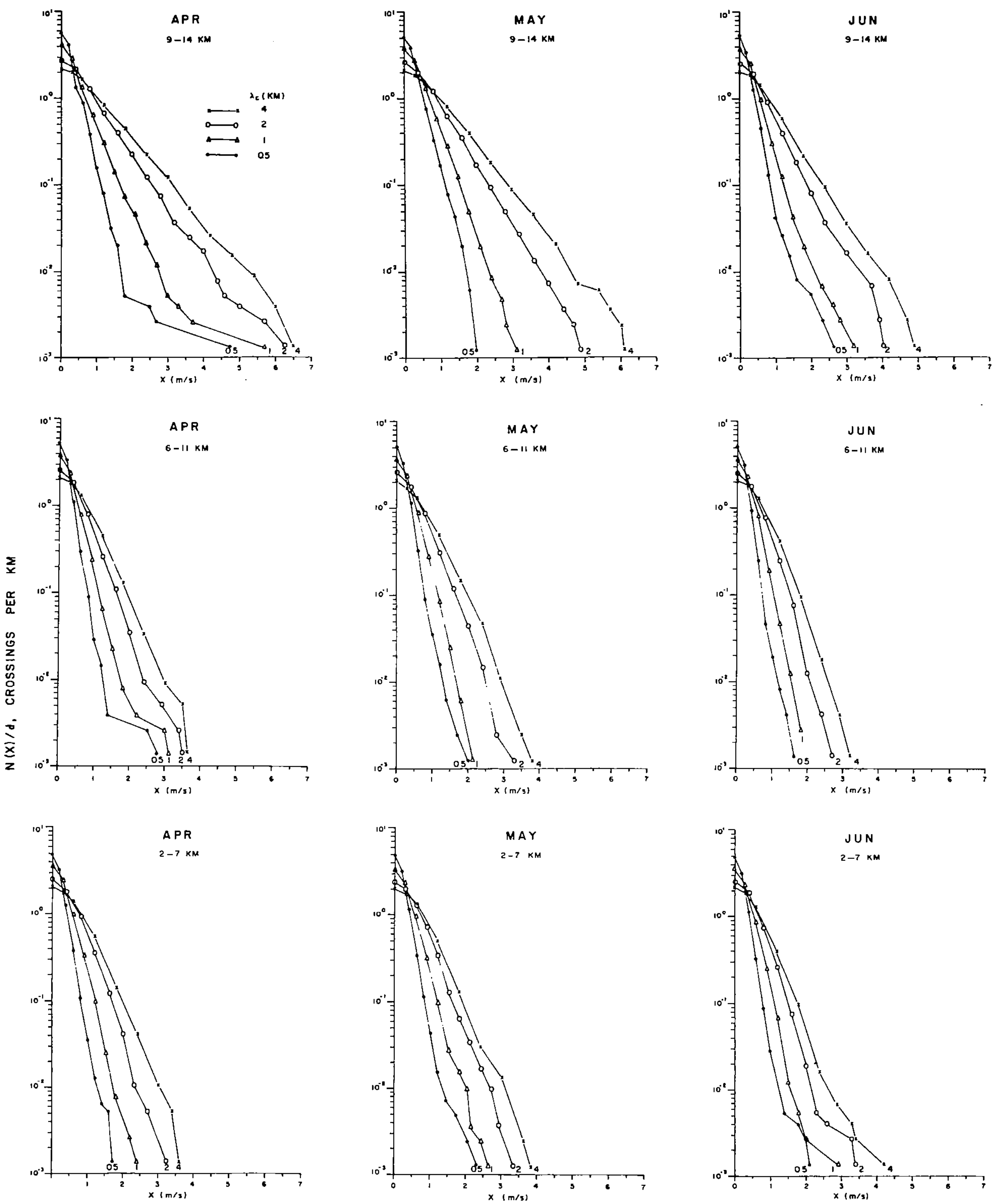


Figure 13. (Continued)

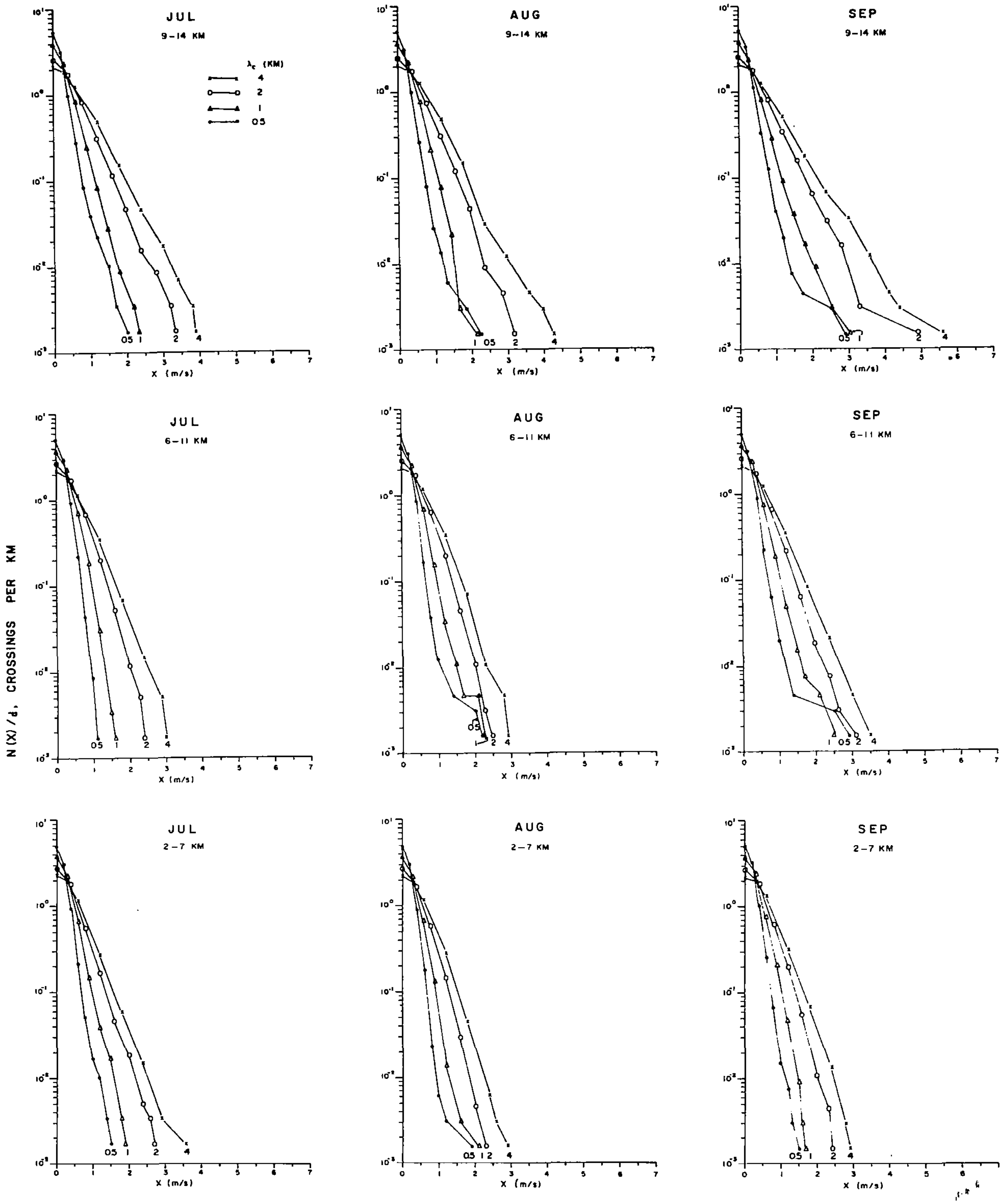


Figure 13. (Continued)

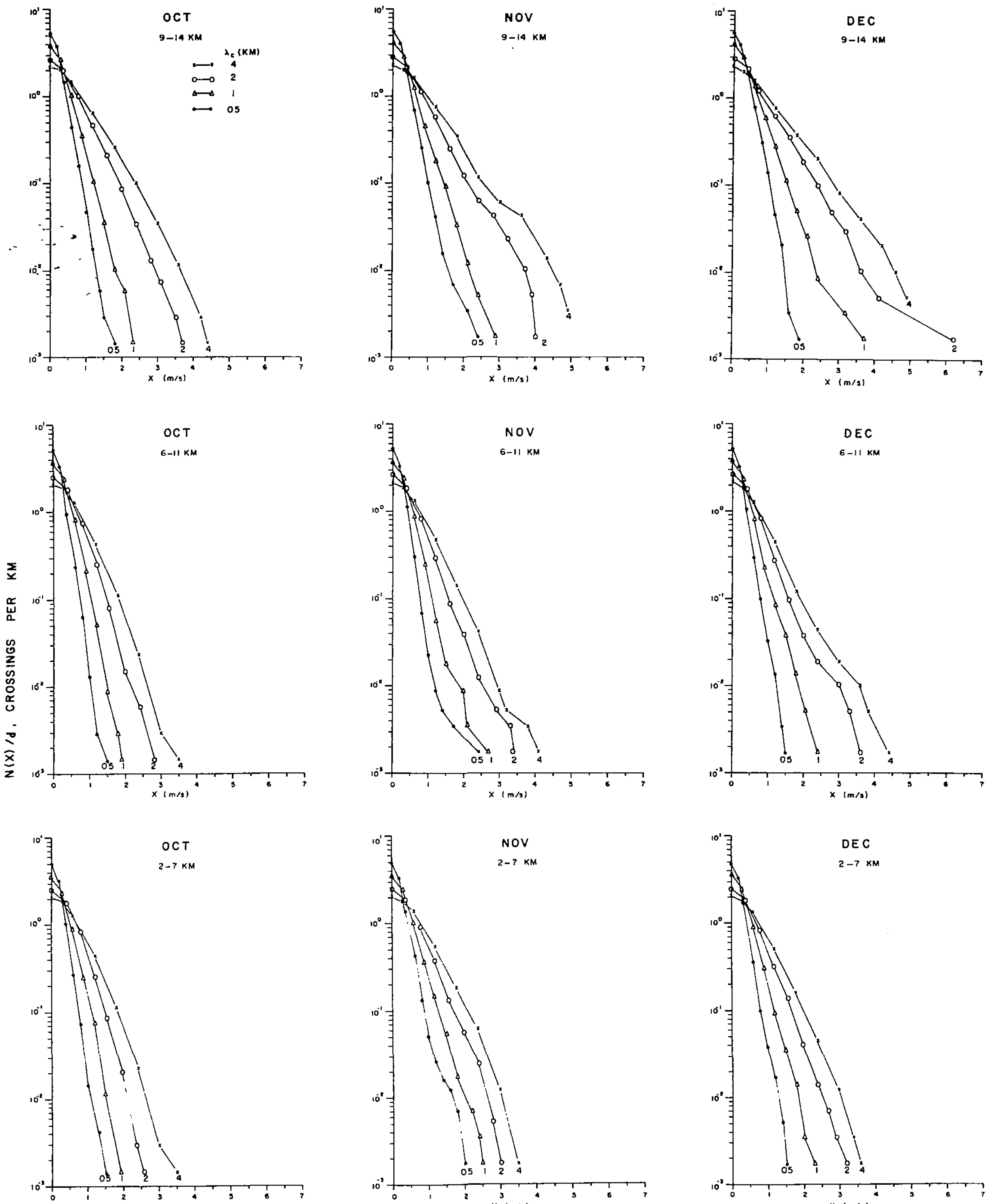


Figure 13. (Continued)

3.6 Application

The principle aim in the development of aircraft design criteria with respect to gust loads is to provide an objective technique for establishing an adequate, yet not excessively high, level of strength for aircraft structures. The development of design criteria based on representation of atmospheric turbulence as a stationary random process which can be analyzed by power spectral methods led to the requirement for measurements of turbulence in the atmosphere. Various research programs employing instruments and aircraft in horizontal flight have provided useful data for the development of design criteria. Since aircraft spend a significant portion of their operating lifetime in ascent or descent when the variations of horizontal wind speed with altitude are effectively sensed as gusts, it is appropriate to provide an analysis of the Jimsphere data which can be used to determine whether the established critical gusts are not unconservative for the ascent and descent operating modes.

Suppose that exceedance of a critical gust speed level, X, is associated with an aircraft structural limit load. Assuming a symmetric distribution of exceedances, which is valid for engineering applications, the expected number of exceedances per kilometer with positive and negative slope, $N^*(X)/D$, of X is obtained by doubling the expected number with positive slope, $N(X)/D$. The value of $N^*(X)/D$ for large values of X can be estimated by fitting an exponential function to the data given in Figures 12 and 13 of the previous section. For this analysis, the 2-7 altitude band is used because it is the most representative of conditions for turbojet aircraft in commercial operations which are at an average altitude of 3.8 to 5.3 km during ascent or descent to or from a cruise altitude of 9.6 km (Hunter, 1968). Based on a least squares fit for $X > 1$ m/sec to the annual exceedance data in the 2-7 km altitude band for a high pass filter cut-off wavelength of 4 km (Figure 12) we obtain

$$\frac{N(X)}{D} = 6.95 \text{ EXP } (-1.94X) \qquad (4)$$

thus

$$\frac{N*(X)}{D} = 13.9 \text{ EXP } (-1.94X) \tag{5}$$

where

X is in m/sec and N*(X)/D is the expected number of exceedances per kilometer.

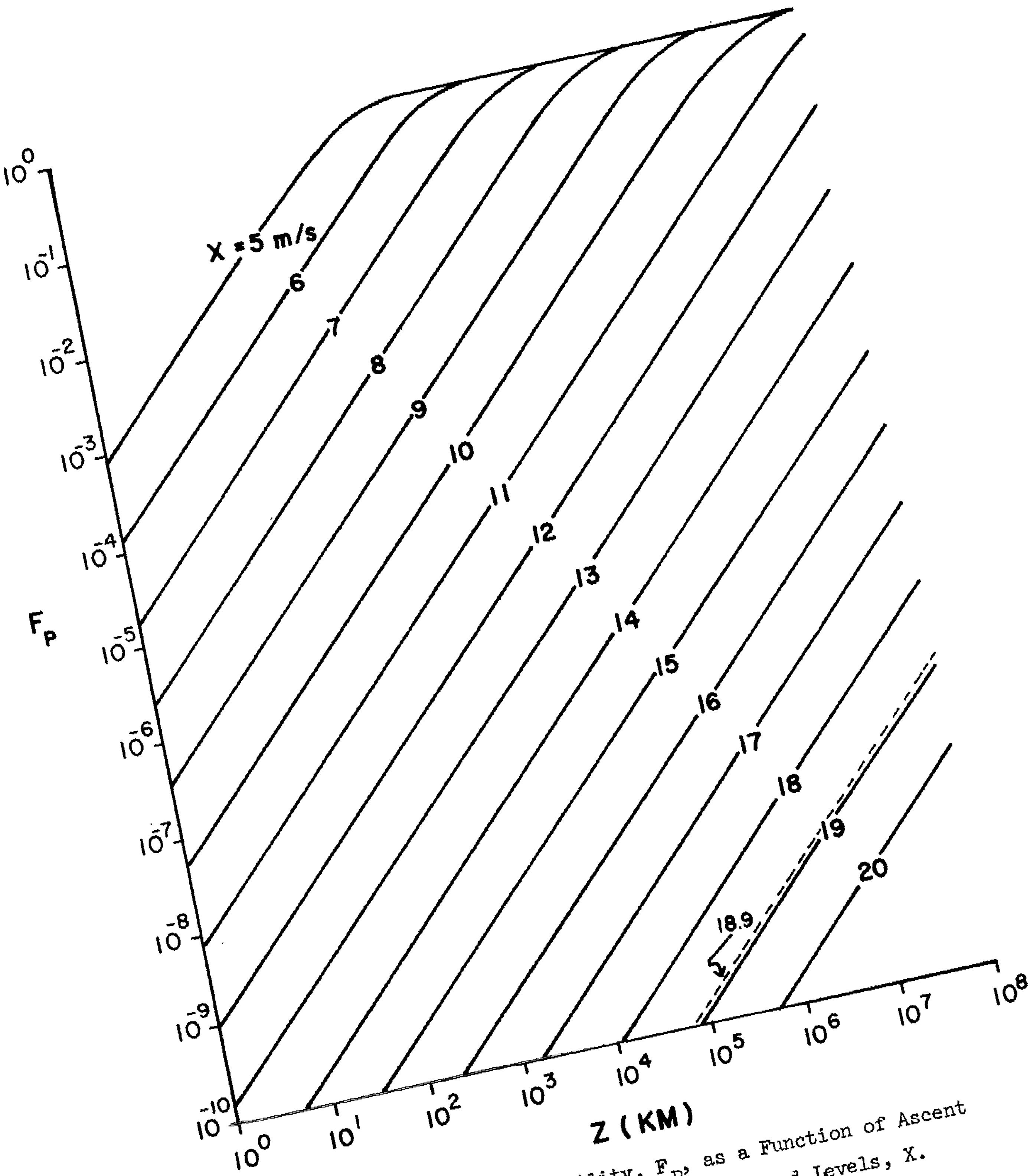
Assuming that successive exceedances of X are independent events, then the limit load failure probability, F_P, in a vertical distance Z can be estimated with an equation of the form given by Lin (1967) for a Poisson process;

$$F_P = 1 - \text{EXP}(-\lambda Z) \tag{6}$$

where λ is the expected limit load failure rate which is equivalent to N*(X)/D exceedances per kilometer.

A set of curves representing F_P as a function of Z for 1 m/sec increments of X derived from Equation 6 is illustrated in Figure 14. The dashed curve is for X = 18.9 m/xec (62 ft/sec) which has been established by Hoblit et al (1966) for the design of new aircraft on a limit load basis in the mission analysis approach.

It is of interest to determine F_P for this value of X for a typical aircraft. According to the data given by Hunter (1968) the time spent in the ascent-descent modes by three four-engined turbojet aircraft during two years of commercial operation is 31 percent of the total operating time. Assuming a total operational lifetime of 50,000 hours for such an aircraft, we obtain an ascent-descent time of 15,500 hours. Thus, for a typical ascent-descent velocity of 35 km/hr the lifetime ascent-descent distance, Z, is 5.4×10^5 km. As illustrated in Figure 14 for X = 18.9 m/sec and Z = 5.4×10^5 km F_P is 9×10^{-10}. For either smaller ascent distances (shorter operating lifetime) or larger critical gusts F_P is smaller than 9×10^{-10}; if the operating time is doubled (i.e., 100,000 hours) F_P is also doubled but remains small (1.8×10^{-9}). It would appear from these results that the criterion established by Hoblit, et al (1966) for the design of new aircraft are adequate for aircraft



...Load Failure Probability, F_P, as a Function of Ascent ... Critical Gust Speed Levels, X.

that experience effective gusts in ascent or descent attributable to wind speed shear. However, it should be pointed out that the validity of equation 5 for large values of X has not yet been established. Exceedance curves for turbulence observed in horizontal aircraft flights have shown a tendency to flatten out for large values of X. Therefore, the exceedance rates for large values of X would be underestimated by a function fitted to the data for small values of X. If future analyses of large samples of Jimsphere data indicate a similar tendency toward flatness the values of F_P given herein would have to be increased.

Section 4

CONCLUDING REMARKS AND RECOMMENDATIONS

4.1 Profile Sampling

It is suggested from the results described in Section 2 that a decile coding scheme can be used to obtain a relatively small random sample of Jimsphere soundings which accurately represent the characteristic extremes of maximum wind speed and shear. It is recommended that further investigations be performed to determine whether larger groupings such as quintiles instead of deciles, and fewer characteristics, such as maximum wind speed and maximum 3 km negative shear can provide samples equally well. Additional testing of the coding scheme should also be performed with Jimsphere data obtained at other locations to establish a basis for general application.

4.2 Jimsphere Gust Studies

The results described in Section 3 provide a description of the statistical characteristics of high pass filtered Jimsphere profiles for specific wavelength and altitude bands observed at Cape Kennedy, Florida. The ultimate objective of these studies is to develop techniques for predicting the response statistics of descending or ascending vehicles from input wind statistics. Based on existing theory and application it is possible to predict linear response statistics for stationary-Gaussian wind inputs. Tests of the theory for aircraft in horizontal flight indicate that observed extreme aircraft responses to known non-Gaussian inputs are underestimated (Dutton 1968). As indicated in Section 3 wind speed fluctuations in Jimsphere high pass filtered profiles are neither stationary or Gaussian. It is suggested that future studies of Jimsphere gust profiles be performed to determine whether an optimum decomposition or transformation of Jimsphere data can be derived which reduces the non-stationarity. In addition, the effects of non-Gaussian wind inputs should be studied by comparison of observed and predicted response statistics for various wind inputs. A similar study should also be performed to establish the statistical characteristics of gusts at the Western Test Range.

SECTION 5

REFERENCES

Adelfang, S. I., 1970: Analysis of Jimsphere Wind Profiles Viewed in the Flight Time Domain of a Saturn Vehicle. J. Spacecraft Rockets, Vol. 4, No. 9, pp. 1146 - 1149.

Adelfang, S. I., E. V. Ashburn and A. Court, 1968: A Study of Jimsphere Wing Profiles as Related to Space Vehicle Design and Operations. NASA Contractor Report CR 1204.

Adelfang, S. I., A. Court, C. A. Melvin and M. Pazirandeh, 1970: A Further Study of Jimsphere Wind Profiles as Related to Space Vehicle Design and Operations. NASA Contractor Report CR 1640.

Camp, D. W., 1971: NASA Marshall Space Flight Center's FPS-16 Radar Jimsphere Wind Profile Program. Bull. Amer. Meteor. Soc., Vol. 52, No. 4 pp 253-254

Carlisle, C. H., 1970: A Statistical Sampling Procedure for Jimsphere Winds Aloft Population. NASA Contractor Report CR-61324.

Crooks, W. M., F. M. Hoblit, D. T. Prophet, et al, 1967: Project HICAT. An Investigation of High Altitude Clear Air Turbulence. Air Force Flight Dynamics Laboratory Technical Report AFFDL-TR-67-123.

Crooks, W. M., F. M. Hoblit, F. A. Mitchell, et al, 1968: Project HICAT. High Altitude Clear Air Turbulence Measurements and Meteorological Correlations. Air Force Flight Dynamics Laboratory Technical Report AFFDL-TR-68-127.

De Mandel, R. E., and S. J. Krivo, 1969: Selecting Digital Filters for Application to Detailed Wind Profiles, NASA Contractor Report CR-61325.

Dutton, J. A., 1968: Broadening Horizons in Prediction of the Effects of Atmospheric Turbulence on Aeronautical Systems. In AIAA 5th Annual Meeting and Technical Display; AIAA Paper No. 68-1065.

Hoblit, F. M., N. Paul, J. D. Shelton, and F. E. Ashford, 1966: Development of a Power Spectral Gust Design Procedure for Civil Aircraft. FAA-ADS-53, Federal Aviation Agency, Washington, D.C., AD 651152

Hunter, P.A., 1968: An Analysis of VGH Data from One Type of Four Engine Turbojet Transport Airplane during Commercial Operations. NASA Technical Note TN D-4330.

Rice, S. O., 1944-45: Mathematical Analysis of Random Noise. Bell System Technical Journal, Vol. 23, pp 282-332, Vol. 24, pp 46-156.

Ryan, R. S., J. R. Scoggins and A. King, 1967: Use of Wind Shears in the Design of Aerospace Vehicles. AIAA J. 4, 1526-1532.

SECTION 6

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41 weight digital high pass filters; $\Delta Z = 25$ m;

λ_c = nominal cut-off wavelength

	γ_c (km)			
Altitude	0.5	1	2	4
Z	+ .87512054	+ .92623766	+ .95586332	+ .96839642
Z-ΔZ, Z+ΔZ	- .12162338	- .07303903	- .04392972	- .03155245
Z-2ΔZ, Z+2ΔZ	- .11216848	- .07089655	- .04331287	- .03136958
"	- .09741817	- .06741575	- .04229801	- .03106644
"	- .07876010	- .06272725	- .04090472	- .03064560
"	- .05790561	- .05700501	- .03915965	- .03011052
Z-nΔZ, Z+nΔZ	- .03669478	- .05045819	- .03709588	- .02946558
"	- .01689240	- .04332148	- .03475212	- .02871611
"	0	- .03584414	- .03217173	- .02786816
"	+ .01289268	- .02827883	- .02940167	- .02692863
"	+ .02120019	- .02087046	- .02649132	- .02590500
"	+ .02486875	- .01384573	- .02349130	- .02480548
"	+ .02433821	- .00740394	- .02045236	- .02363866
"	+ .02044731	- .00170944	- .01742410	- .02241360
"	+ .01429765	+ .00311390	- .01445392	- .02113970
"	+ .00709645	+ .00698608	- .01158603	- .01982652
"	0	+ .00987193	- .00886051	- .01848385
"	- .00602204	+ .01177992	- .00631247	- .01712141
"	- .01028542	+ .01275882	- .00397164	- .01574888
"	- .01244319	+ .01289260	- .00186164	- .01437576
Z-20ΔZ, Z+20ΔZ	- .01248795	+ .01229372	0	- .01301129

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