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PROBABILITIES OF ZERO WIND SHEAR PHENOMENA BASED ON RAWINSONDE DATA RECORDS

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ABSTRACT

The term zero wind shear is defined for the condition where winds aloft attain speeds of 36 m/sec or higher and persist through a vertical distance such that there is maintained a vector wind shear in the interval ±5 m/sec per kilometer between successive 1-kilometer levels.

Data are obtained from two RAWIN observations per day for five years from Santa Monica, California. Both data decks were edited, checked and serially completed before use. Results are presented as graphs of zero shear thickness versus peak wind speed, and as empirical probabilities of occurrence of zero wind shear conditions at altitudes above and below the mean height of the level of peak wind. Probabilities of total depth of zero wind shear are also presented.

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Lawrence E. Truppi*

*This report was prepared as a result of an investigation conducted under NASA Government Order No. H-66040 with the U. S. Weather Bureau, National Weather Records Center. The Technical Supervisor was Mr. W. W. Vaughan of the George C. Marshall Space Flight Center.

AEROSPACE ENVIRONMENT DIVISION
AERO-ASTRODYNAMICS LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

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SUMMARY

The term zero wind shear is defined for the condition where winds aloft attain speeds of 36 m/sec or higher and persist through a vertical distance such that there is maintained a vector wind shear in the interval ±5 m/sec per kilometer between successive 1-kilometer levels.

Data are obtained from two RAWIN observations per day for five years from Santa Monica, California. Both data decks were edited, checked and serially completed before use. Results are presented as graphs of zero shear thickness versus peak wind speed, and as empirical probabilities of occurrence of zero wind shear conditions at altitudes above and below the mean height of the level of peak wind. Probabilities of total depth of zero wind shear are also presented.

I. INTRODUCTION

This study is concerned with investigating the thickness of bluntness of vertical wind profiles in the atmosphere above and below the level of maximum speed. In an early study, Reiter [1] used the term "Layer of Maximum Wind" (LMW) to describe a condition of small vertical change of wind through the altitude of peak speed. He defined the depth of LMW as the layer in which wind speed differs by less than 10 percent from the mean wind of the LMW, or by about 20 percent from the peak speed. The mean wind of the LMW was defined as 90 percent of the peak speed. The LMW is defined here as a depth in the troposphere and/or stratosphere, from 3 km to 21 km, where a vector wind shear is maintained within the limits ±5 m/sec per kilometer above and below a level of peak wind speed of 36 m/sec or higher. This is a finer definition of LMW than Reiter's.

Reiter limited his LMW analysis to sounding with mean layer winds of 60 kt (31 m/sec) or higher and to depths up to 5 km so that jet stream profiles would not become obscured. His primary concern was to employ the LMW analysis to investigate jet stream phenomena both vertically and horizontally. This study was motivated by the need of design criteria for space vehicles that must penetrate the atmosphere during conditions of very high winds aloft. This analysis provides an investigation of the thickness of the LMW as represented by the wind profile bluntness.

As a space vehicle ascends and enters layers of the atmosphere where wind speed and direction change with altitude, an overturning moment will be produced. The response of a launch vehicle to wind can be compensated, to a large degree, by control system design, if the magnitudes of possible wind speed and direction changes with altitude (wind shear) are known during the design phase. Therefore, it is necessary* to estimate the vertical extent of the wind buildup that produces the shear, the bluntness of the wind profile that indicates the thickness of the LMW, and the vertical depth of wind decreases above the LMW.

Appreciation is extended to Mr. William W. Vaughan of the George C. Marshall Space Flight Center, who initiated this study and whose comments were invaluable in the preparation of this paper. Personnel of the National Weather Records Center prepared the necessary computations and graphs.

II. DATA

A. Sources

The basic RAWIN data recorded at 6- to 12-hour intervals are subject to a bias due to a decrease in the number of wind observations with increase in altitude. Court [2] discussed this bias with regard to its effect on means, standard deviations and correlation coefficients, and he noted consistent trends, rather than random fluctuations, for the means and standard deviations of wind components as the sample sizes are decreased. Charles [3], who also made a study of this bias, suggested that suitable estimates of missing wind data be used to augment observed data and so reduce the bias. Later, in a study at NWRC, these estimates were made at two locations, Cape Kennedy, Florida, and Santa Monica, California, as described by Essenwanger, et al. [4], and the results were so favorable that routine augmentation of RAWIN data was begun to form Deck 600 (these data are available on magnetic tape upon request to NASA - Marshall Space Flight Center, R-AERO-Y). In a report by Crutcher [5], soon to be published, examination of standardized moments indicates that the null hypothesis of normality of frequency distribution of maximum wind speeds need not be rejected. It had been known that basic RAWIN speed data might be non-Gaussian (non-normal) due to loss of observations with altitude, and this distortion would be most

*For an example of the application for data of the type described in this report, reference is made to the report "An Evaluation of a Switched-Integral Controller for Load Relief," Report # LMSC/HRECA036684, prepared by Lockheed Missiles and Space Co., Huntsville Research & Engineering Center, Huntsville, Alabama, under Task L-3, NAS8-11148 for Marshall Space Flight Center, 1965.

noticeable when investigating the upper and lower parts (mean ±3 standard deviations) of the wind frequency distribution. It now appears that such augmentation of basic RAWIN speed data can produce distributions approximating a normal frequency distribution. The assumption has been made for several years that upper winds are normally distributed in the bivariate sense. This assumption is supported by Brooks and Carruthers [6].

There also exists another uncertainty regarding basic RAWIN data. A number of authors, such as Tolefson [7] and Salmela [8], have elaborated on errors produced in wind velocity data as measured by operational RAWIN equipment of the various weather services. An attempt was made to correct all detectable measurement errors in the augmentation process that produced Deck 600, but the accuracy of RAWIN data always will be limited by the capability of the observing equipment.

These data were derived from RAWIN soundings made by the standard AN/GMD-1A sounding systems at Cape Kennedy, Florida, and Santa Monica, California, which were further processed by being serially completed (missing data inserted by interpolation, extrapolation, or use of data from nearby stations) by professional meteorologists. Two RAWIN observations per day for six years from Cape Kennedy and four RAWIN observations per day for five years from Santa Monica were available.

NWRC Deck 600 consists of upper wind data of speed in meters per second and direction in whole degrees from the surface up to 27 kilometers at 1 kilometer intervals. The serial completion process presents a unique upper wind record, since observations previously terminated by premature balloon bursts or limiting elevation angles are now completed to 27 kilometers. In addition, erroneous data were corrected from the original data records. This affords an opportunity to investigate upper wind phenomena unhampered by incomplete data, particularly when strong winds were present aloft. However, the basic data records still reflect average wind velocities over about 600 m intervals recorded at 1 km altitude intervals. Therefore, the smaller scale behavior of the wind profile is not recorded. For certain vehicle design and operational problems, this may be a significant contribution to the overall response.

An optimum upper wind data record would be one describing each wind profile by significant points, such as maxima, minima and inflection but, unfortunately, the present form of data recorded at specified altitudes will probably continue since RAWIN networks were designed to serve the needs of synoptic meteorology rather than research.

B. Processing and Computation

All RAWIN data were subjected to a checking program using electronic data processing equipment in addition to a visual check of each sounding as part of serial completion. If individual values of wind speed or direction fell outside predetermined limits, these were indicated and the original records re-examined.

The presence of an LMW was determined by examining the highest or peak speed reported in each RAWIN sounding. If the peak speed was 36 m/sec or higher, then 1-kilometer levels above and below the level reporting the peak speed were tested to determine if a vector wind shear in the interval ±5 m/sec existed between the level of peak speed and winds immediately above and below. If vector wind shear exceeded this criterion, the fact was noted and frequency of the event accumulated. If this criterion was satisfied, then the condition of zero shear was said to exist, and successive 1-kilometer levels above and below were tested to determine if reported winds maintained the same zero shear (LMW) condition. This process was continued until levels were found, above and below, which did not maintain zero shear condition. Frequencies of the various depths were accumulated for zero shear above and below the peak level as well as the total thickness, from the lowest level through the peak to the highest level. If two identical peak speeds were reported in a sounding, then each peak level was treated separately as if they had occurred on different soundings. In situations of multiple jet cores of different speeds, the lesser speeds maxima were counted only in their capability of maintaining zero shear conditions above or below the peak level.

Frequencies of zero shear were grouped by observed peak speeds representing midpoints of class intervals of 10 m/sec as follows:

Peak Speed (m/sec)	Class Interval (m/sec)
40	36 - 45
50	46 - 55
60	56 - 65
70	66 - 75
80	76 - 85
90	86 - 95
100	96 - 105
106+	≧ 106

Also noted were the altitudes at which the peak speeds were reported. A mean height was determined for each of the eight speed groups as follows:

Peak Speed (m/sec)	Cape Kennedy (km)	Santa Monica (km)
40	12.3	11.1
50	12.0	10.8
60	11.8	10.8
70	11.7	10.6
80	11.6	10.6
90	11.6	10.0
100	11.4	-
106+	11.2	-

It is interesting to note that higher peak winds have lower mean altitudes than the lesser peak winds. This holds true for both Cape Kennedy and Santa Monica.

C. Presentation

Zero shear data are presented in summary tabular form as probability of occurrence of zero wind shear phenomena at or below the indicated altitude for levels higher than the peak level, as probability of zero wind shear phenomena at or above the indicated altitude for levels lower than the peak level, and as probability of occurrence at or less than the indicated total depths for specified peak speeds. Annual and four-seasonal probabilities were tabulated for each station.

Also, figures were prepared illustrating thicknesses of zero shear above, below, and through the level of peak wind at the 99th percentile level.

III. ANALYSIS

A. Graphical

Figures 1.1 through 1.5 and 2.1 through 2.5 show the variations of zero shear at the 99th percentile level versus peak speeds for the respective locations of Cape Kennedy, Florida, and Santa Monica, California. On an annual basis, Figures 1.1 and 2.1 and Table I illustrate the difference between the two stations. Upper winds at Cape Kennedy reached greater speeds than those observed at Santa Monica. The following table illustrates observed frequencies and percentage frequencies of peak wind speeds representing midpoints of class intervals of 10 m/sec.

TABLE I

Annual Frequencies and Percentage Frequencies of Peak Wind Speeds

Peak Speed	Cape Kennedy (1/56 - 12/61)		Santa Monica (1/56 - 12/60)	
(m/sec)	(F)	(%F)	(F)	(%F)
< 36	2326	53.1	4829	66.1
40	722	16.5	1450	19.9
50	595	13.6	588	8.1
60	408	9.3	265	3.6
70	184	4.2	132	1.8
80	97	2.2	32	0.4
90	37	0.8	4	0.1
100	8	0.2	0	0.0
106+	3	0.1	0	0.0
Total	4380		7300	

Values of zero shear thickness decrease with increasing values of peak wind. As speed at the peak level becomes greater, there is less chance of maintaining a vector shear of ±5 m/sec or less at a depth of 1-kilometer or more. For the three cases of peak wind speeds of 106+ m/sec at Cape Kennedy, there was no instance of zero shear being present. For the 100 m/sec speed group at Cape Kennedy with eight cases, there was no instance of zero shear being present. For the 100 m/sec speed group at Cape Kennedy with eight cases, there was no occurrence of zero shear below the LMW, but above there was an interpolated 99 percent probability of finding a depth of 1.2 kilometer or less. This illustrates* the asymmetry in the wind profile found around the level of peak speed, since in these eight cases the buildup of wind speed to the peak level caused a vector shear greater than ±5 m/sec per kilometer. At Cape Kennedy there appears to be a tendency for zero shear condition to be greatest above the peak level, while at Santa Monica the opposite is apparent, although the probability values for the two conditions are close, indicating a more symmetrical wind profile at the latter location.

Figures 1.2 and 2.2 illustrate variations of zero shear thickness versus peak speeds for the spring season (March, April and May) only, as indicated in Table II.

TABLE II

Spring Season Frequencies and Percentage Frequencies of Peak Wind Speeds

Peak Speed	Cape Kennedy (March, April, May) (1956 - 1961)		Santa Monica (March, April, May) (1956 - 1960)	
m/sec	(F)	(%F)	(F)	(%F)
< 36	326	29.5	1022	55.5
40	235	21.3	488	26.5
50	220	19.9	203	11.0
60	188	17.0	81	4.4
70	81	7.3	35	1.9
80	37	3.4	10	0.6
90	11	1.0	1	0.1
100	3	0.3	0	0.0
106+	3	0.3	0	0.0
Total	1104		1840	

*As revealed by conventional rawinsonde wind profile measurements.

These three months contain the highest winds observed at Cape Kennedy, with less shear above the peak level than below. Winds in the 80 m/sec speed group appear to be very narrow in vertical depth with strong shear above and below the peak level. Santa Monica data present a consistent plot indicating a regular decrease of zero shear depth with increasing wind speed. Unlike the Cape Kennedy curve, the greater shear appears above the peak level. At the 40 m/sec group, there is a 99 percent probability of finding total thickness of zero shear of 8.8 kilometers or less from the bottom to the top of the maximum wind layer.

Figures 1.3 and 2.3 present data observed during the summer months, June through August.

TABLE III

Summer Season Frequencies and Percentage Frequencies of Peak Wind Speeds

Peak Speed	Cape Kennedy (June, July, August) (1956 - 1961)		Santa Monica (June, July, August) (1956 - 1960)	
m/sec	(F)	(%F)	(F)	(%F)
< 36	1071	97.0	1667	90.6
40	30	2.7	146	7.9
50	3	0.3	17	0.9
60	0	0.0	10	0.6
Total	1104		1840	

The summer season (Table III) has more effect on upper wind speeds at Cape Kennedy than at Santa Monica. The few cases at Cape Kennedy in the 40 and 50 m/sec speed groups have very narrow wind profiles, but at Santa Monica a typical wind profile is apparent at 40 m/sec or less.

Figures 1.4 and 2.4 show upper wind conditions observed during the autumn season.

TABLE IV

Autumn Season Frequencies and Percentage Frequencies of Peak Wind Speeds

Peak Speed	Cape Kennedy (Sept., Oct., Nov.) (1956 - 1961)		Santa Monica (Sept., Oct., Nov.) (1956 - 1960)	
m/sec	(F)	(%F)	(F)	(%F)
< 36	770	70.5	1378	75.7
40	203	18.6	305	16.8
50	80	7.3	112	6.2
60	20	1.8	21	1.1
70	10	0.9	4	0.2
80	7	0.6	0	0.0
90	1	0.1	0	0.0
100	1	0.1	0	0.0
Total	1092		1820	

As the colder months (Table IV) of the year approach, stronger winds aloft become more frequent at Cape Kennedy than at Santa Monica. It is interesting to note the relatively large thickness at Cape Kennedy for speeds in the 40 m/sec group, as compared to the 40 m/sec speed group in the spring season.

Figure 1.5 and 2.5 complete the series of graphs, and along with Table V, they illustrate variations of peak speeds and zero shear thicknesses of the two stations in the winter season.

TABLE V

Winter Season Frequencies and Percentage Frequencies of Peak Wind Speeds

Peak Speed	Cape Kennedy (Dec., Jan., Feb.) (1956 - 1961)		Santa Monica (Dec., Jan., Feb.) (1956 - 1960)	
m/sec	(F)	(%F)	(F)	(%F)
< 36	159	14.7	762	42.3
40	254	23.5	511	28.4
50	292	27.0	256	14.2
60	200	18.5	153	8.5
70	93	8.6	93	5.2
80	53	4.9	22	1.2
90	25	2.4	3	0.2
100	4	0.4	0	0.0
Total	1080		1800	

Although the three spring months of March, April, and May contained the highest observed winds at Cape Kennedy, Table V reveals that the 50 m/sec speed group has the highest frequency of all observed upper winds in the winter season. These consistently high winds of the winter season, when plotted in Figure 1.5, reveal a pattern of thicknesses that varies according to wind speed group. In the 40 m/sec group at Cape Kennedy, a total of thickness of zero shear of 6.8 kilometers at the 99th percentile and an LMW profile with greater thickness below the peak level than above are indicated. However, at 60 m/sec, the LMW profile is almost symmetrical. At Santa Monica in the 40 m/sec speed group, the total thickness is almost the same as Cape Kennedy, but thicknesses above and below are very close indicating an almost symmetrical profile.

B. Probability Tables

Probability tables have been prepared for each station which indicated the empirical probability of zero shear condition at or between the indicated altitude and the level of peak wind speed. Also presented is the probability of zero shear without regard to whether above or below the peak wind speed altitude level. The notation, <1, indicates the probability of the absence of zero wind shear for peak speeds of the indicated group.

These tables agree with a previous study [9] conducted by NASA involved in finding the maximum thickness of strong wind layers (LMW) at Cape Kennedy, Florida, and Santa Monica, California. They also emphasize the points previously made that the level of fastest speeds lowers with increasing speed, and that the faster the speed the narrower the layer. This is not unexpected. Reference should be made to the frequency of peak speed data given in Tables I through V relative to the statistical significance that may be placed in Figures 1.1 through 2.5.

The Annual Probability Table for Cape Kennedy (Table VI) indicates, for example, the following: (a) for peak winds in the 40 m/sec speed group, the mean altitude of occurrence was 13 km, (b) for 40 m/sec peak winds there was a 72.7 percent probability that no zero shear condition would exist for 1 kilometer above the level or a 67.2 percent chance that none would occur for 1 kilometer below, and (c) there was a 93.3, or less, chance of zero shear for 1 kilometer above the peak wind speed altitude. Also, for peak speeds in the 50 m/sec speed group and higher, the mean altitude of occurrence is 12 kilometers. Probability of finding total depth of zero shear condition for all peak speeds in a speed group regardless of altitude also are presented. Similar information is presented in Table VII for Santa Monica, California.

IV. CONCLUSIONS

With 4380 serially complete RAWIN soundings from Cape Kennedy and 7300 serially complete RAWIN soundings from Santa Monica, the data appear sufficient to estimate some characteristics of LMW phenomena related to the geographical locations of the two stations. Certainly the climatic regimes of the two places are different. Santa Monica has a climate typical of the west coast of continents with a characteristic dry summer and a rainy winter, while Cape Kennedy represents an east coast, semitropical regime with no distinct dry season.

This study indicates that the upper wind climatology of the two locations are different also. At Cape Kennedy Peak winds were reported higher than 85 m/sec in 48 soundings, but at Santa Monica only 4 cases were reported. In addition, the mean altitudes of peak winds were reported 1 kilometer lower at Santa Monica than Cape Kennedy. Using the zero wind shear criterion to determine vertical dimensions of LMW occurrences, it was found that LMW's were thinner, and therefore the wind shear greater, above and below the peak speed level at Cape Kennedy. Moreover, the LMW's were asymmetrical in vertical dimension with greater thickness below the peak level than above. At Santa Monica, the LMW was more symmetrical, and greater in total depth.

Serially complete RAWIN data, such as employed in the study, represent the best available source of upper air wind profile records. Raw RAWIN data, as reported from the field, make a poor base for investigations concerned with strong winds aloft due to the loss of both observations and accuracy in periods of very high winds aloft using the AN/GMD-1A sounding system, and any computations using such basic RAWIN data would suffer accordingly. However, even using the special serially complete RAWIN data, wind observations at 1-kilometer intervals can miss significant points in a wind profile, if they do not fall exactly on a level that was recorded. Also, the filled-in high and cases of the serially complete data probably represent the greatest error source. Perhaps RAWIN data recording maximum, minimum, and inflection points of the wind profile would be a better form of data for the purposes of this study.

The technique used in this study, that is, using a value of vector wind shear as a standard, facilitates machine processing of RAWIN data and enables large amount of data to be condensed in tabular form. This is a particular advantage when RAWIN data are to be investigated, since the data are voluminous and some criterion is needed to relate wind speeds, altitudes, and vertical thicknesses. It is believed this study indicates that the criterion of vector wind shear of ±5 m/sec per kilometer served to present valuable and significant information regarding wind variations around the peak speed level at Cape Kennedy, Florida and Santa Monica, California.

TABLE VI

Cape Kennedy, Florida
(1/56 - 12/61)

Zero Shear Probability

ANNUAL

Zero Shear		Peak Speed (m/sec)							
	Depth (km)	40	50	60	70	80	90	100	106+
Above Peak Wind	4		99.9						
	3	99.9	99.4						
	2	98.3	98.4	99.9	98.4				
	1	93.3	94.5	94.6	96.8	99.9	99.9	99.9	
	< 1	72.7	68.8	71.5	82.5	87.0	78.9	80.0	99.9
	Mean level (km) of peak wind speed - 13 for 40 m/sec. 12 for 50 through 106+ m/sec.								
Below Peak Wind	< 1	67.7	77.0	73.8	84.1	95.7	94.7	99.9	99.9
	1	95.7	92.9	94.6	98.4	99.9	99.9		
	2	93.7	97.3	99.2	99.9				
	3	96.2	99.4	99.9					
	4	99.6	99.9						
	5	99.8							
	6	99.9							
Without Reference to Peak Wind Level	Total Depth (km)								
	8	99.9							
	7	99.8							
	6	99.6							
	5	98.7	99.9						
	4	97.5	99.5	99.9					
	3	94.5	98.9	97.7	99.9				
	2	89.1	94.5	95.4	96.8				
	1	76.9	93.1	86.2	95.2	99.9	99.9	99.9	
	< 1	49.6	52.5	54.6	68.2	82.6	73.7	80.0	99.9

TABLE VII

Santa Monica, California
(1/56 - 12/60)

Zero Shear Probability

ANNUAL

Zero Shear		Peak Speed (m/sec)					
	Depth (km)	40	50	60	70	80	90
Above Peak Wind	6	99.9					
	5	99.1					
	4	98.3					
	3	98.0	99.9				
	2	96.9	95.9	99.9	99.9		
	1	89.7	89.1	95.4	95.5	99.9	99.9
	< 1	70.4	68.2	77.9	80.0	91.7	50.0
Mean level (km) of peak wind speed - 13 for 40 m/sec. 12 for 50 through 106+ m/sec.							
Below Peak Wind	< 1	58.2	74.4	81.4	93.3	75.0	99.9
	1	86.7	94.6	95.4	97.8	99.9	
	2	94.0	97.7	99.9	99.9		
	3	96.6	98.5				
	4	98.6	99.9				
	5	99.2					
	6	99.9					
Without Reference to Peak Wind Level	Total Depth (km)						
	10+	99.9					
	9	99.4					
	8	99.3					
	7	99.1					
	6	98.3					
	5	97.2					
	4	95.2	99.9				
	3	93.2	97.7	99.9	99.9		
	2	87.5	91.5	98.9	97.8		
	1	73.8	80.6	89.6	93.3	99.9	99.9
	< 1	41.3	49.6	61.6	75.5	66.7	50.0

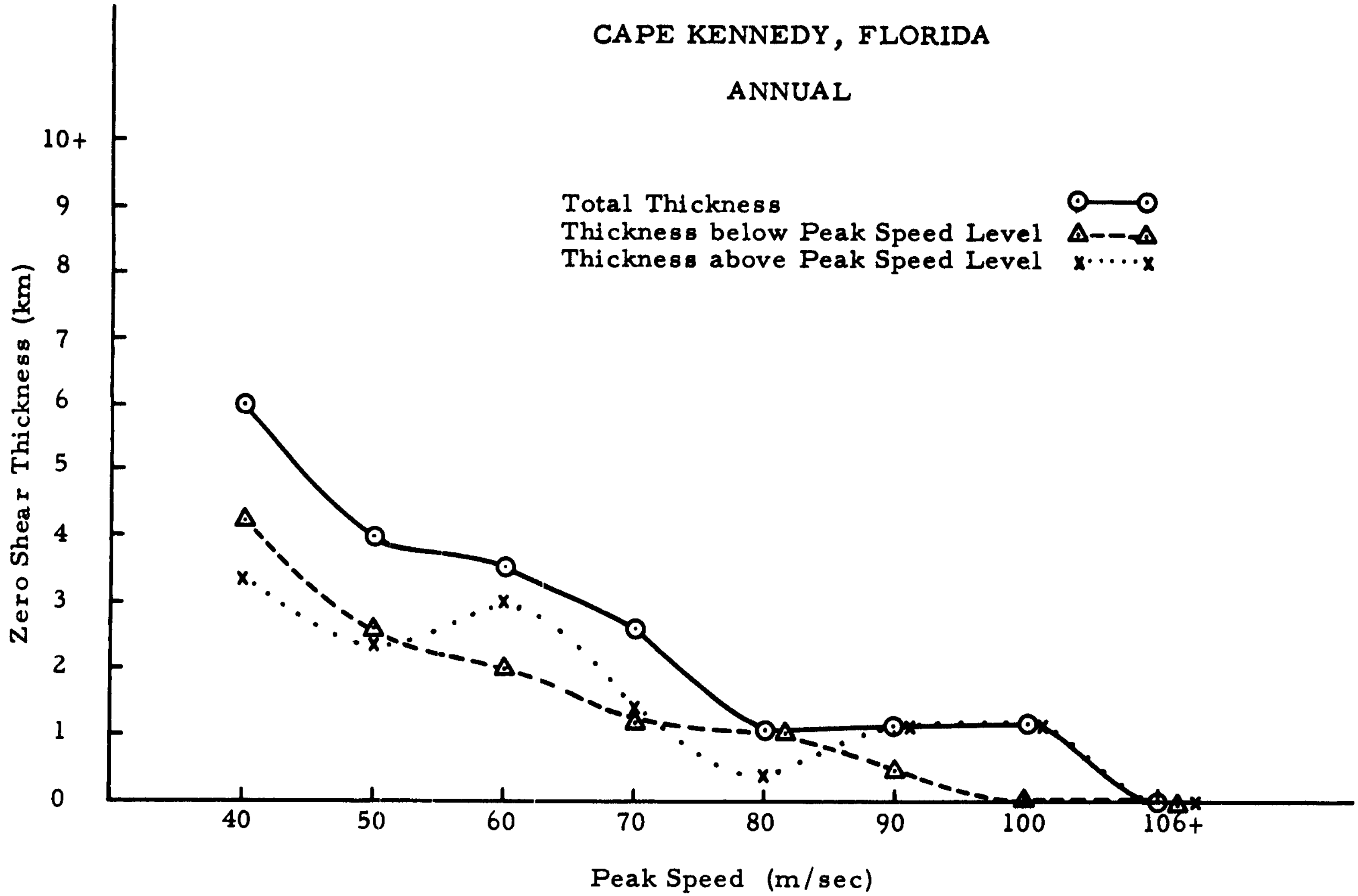

Figure 1.1 Envelopes of 99 percentile zero shear thickness for various peak speed groups

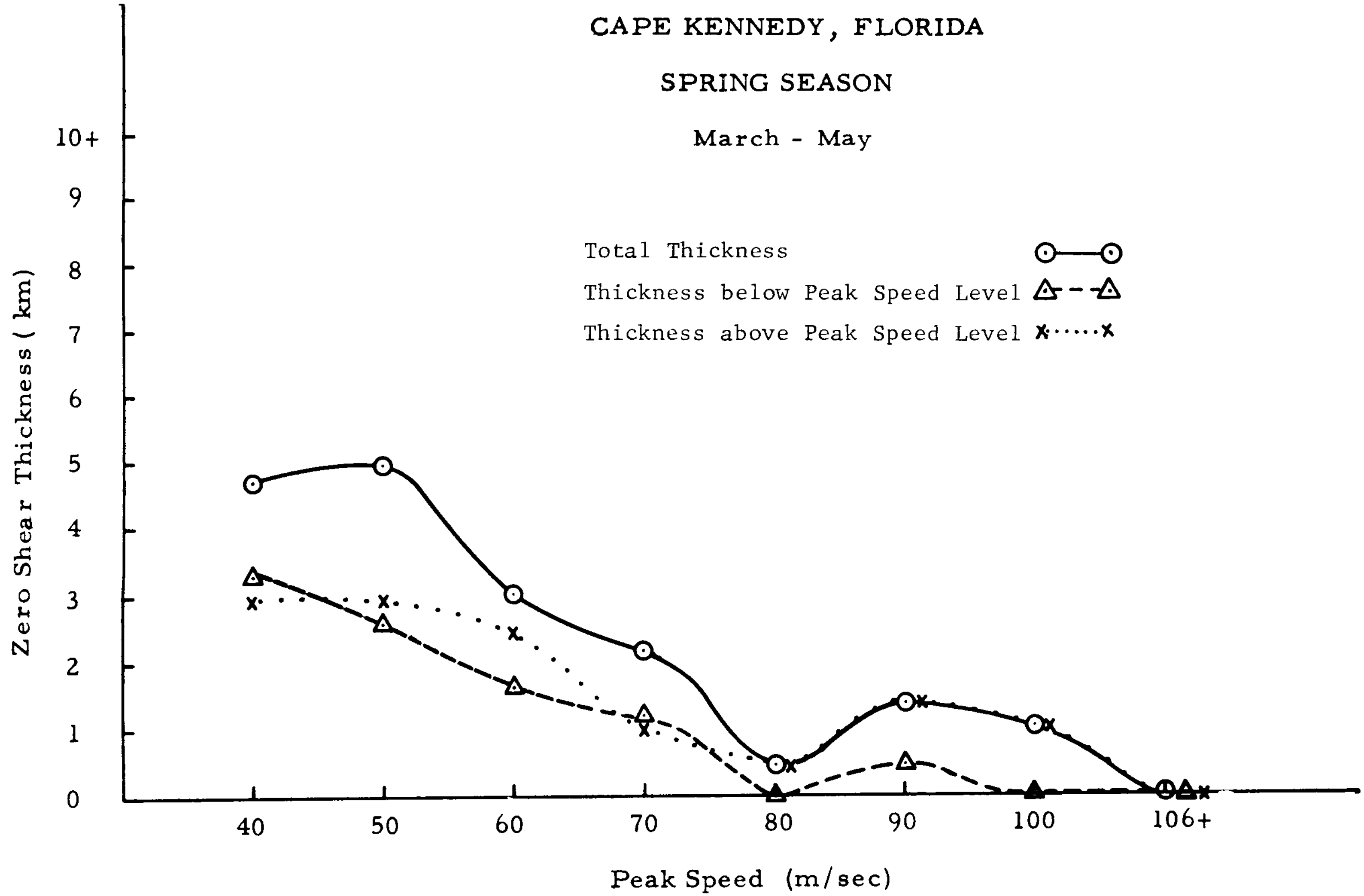

Figure 1.2 Envelopes of 99 percentile zero shear thickness for various peak speed groups

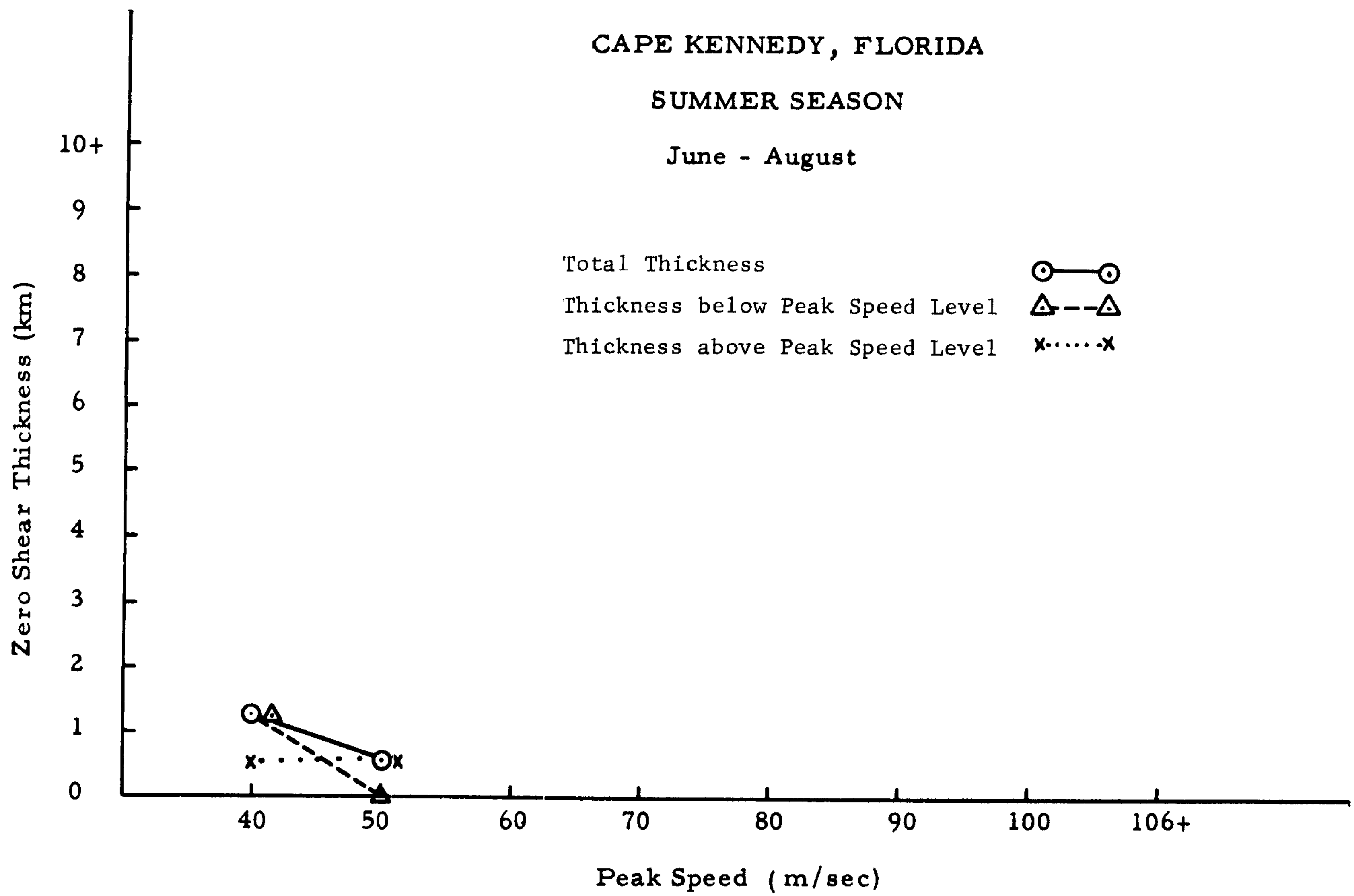

Figure 1.3 Envelopes of 99 percentile zero shear thickness for various peak speed groups

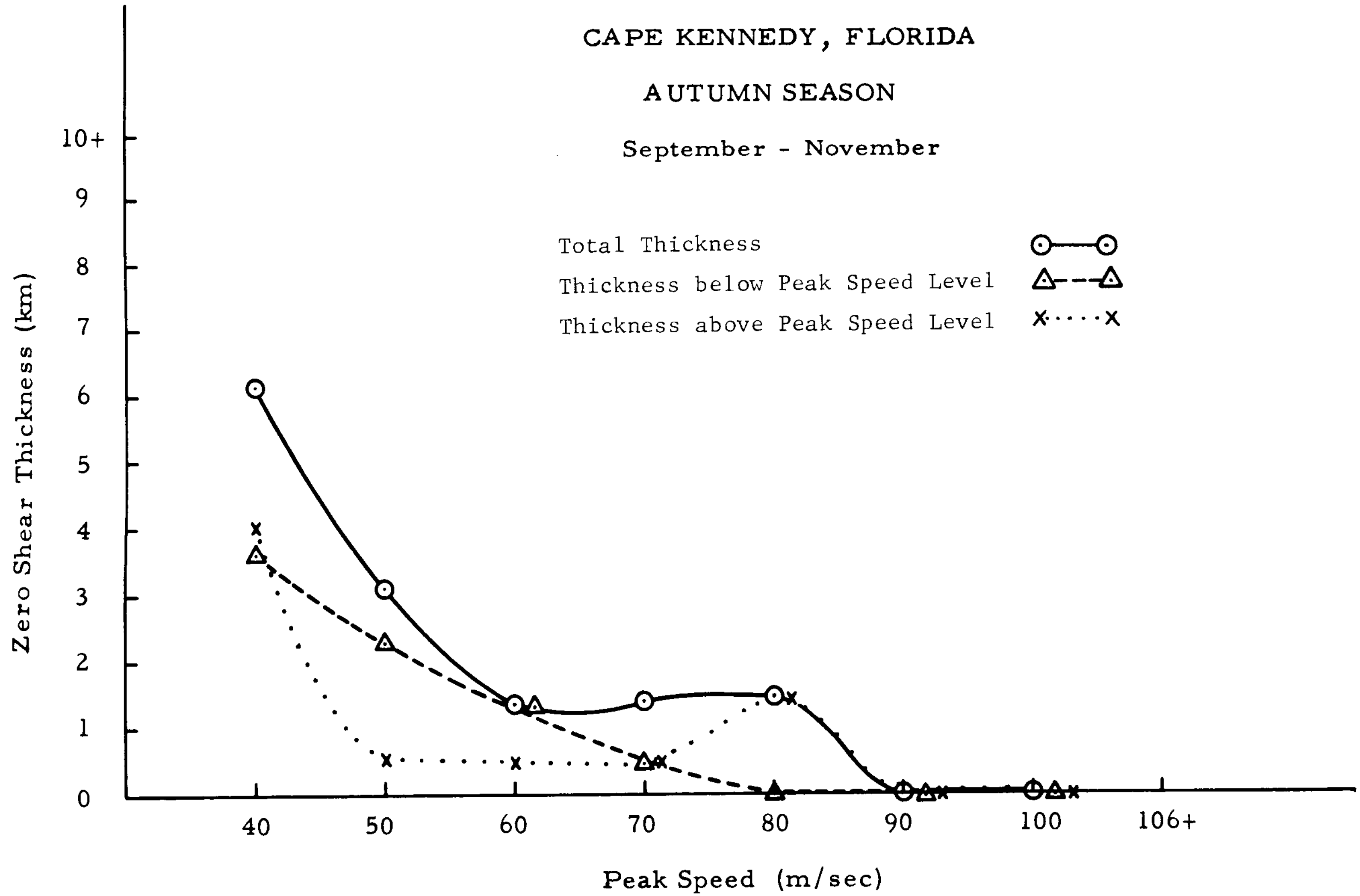

Figure 1.4 Envelopes of 99 percentile zero shear thickness for various peak speed groups

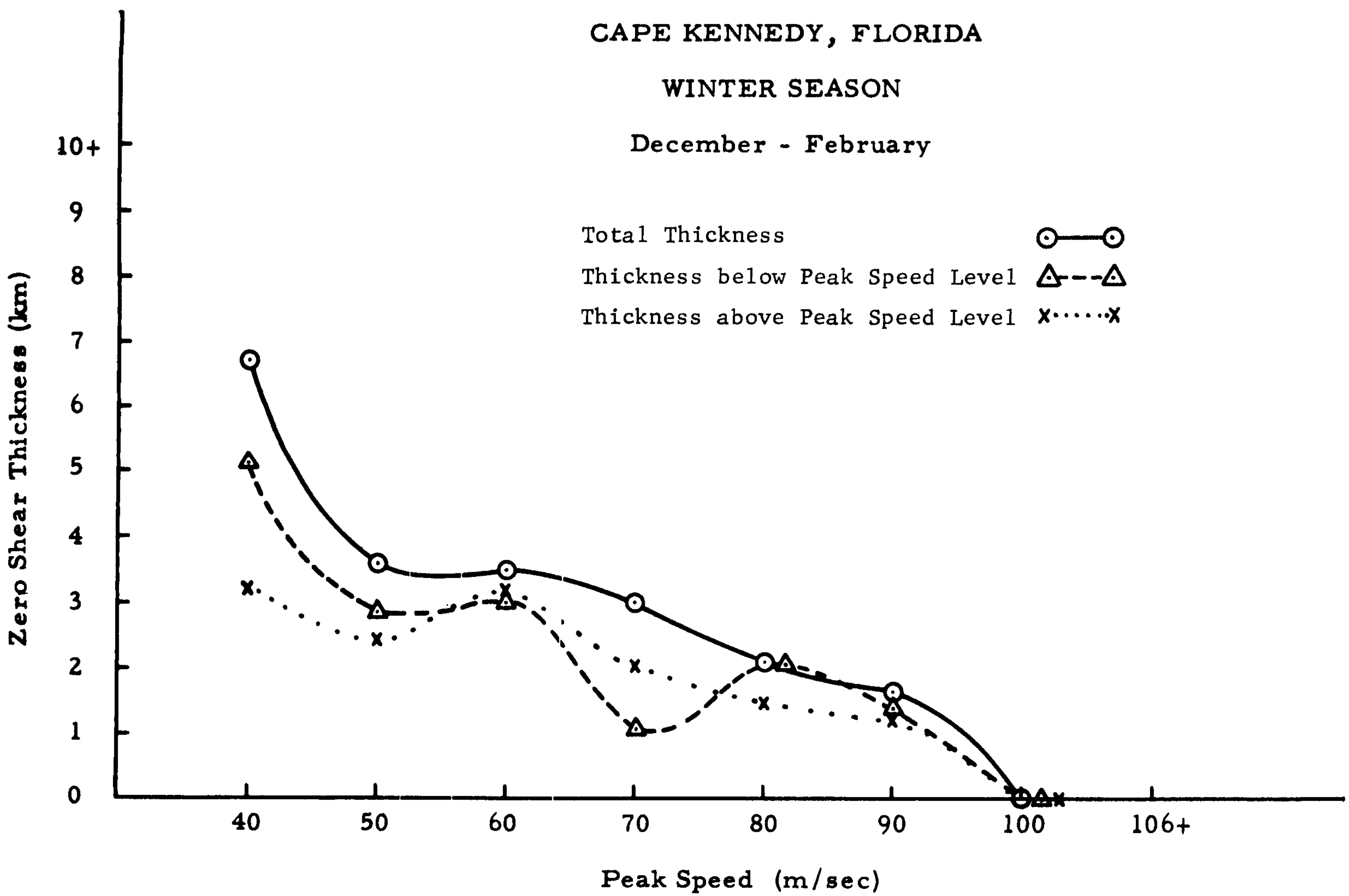

Figure 1.5 **Envelopes of 99 percentile zero shear thickness for various peak speed groups**

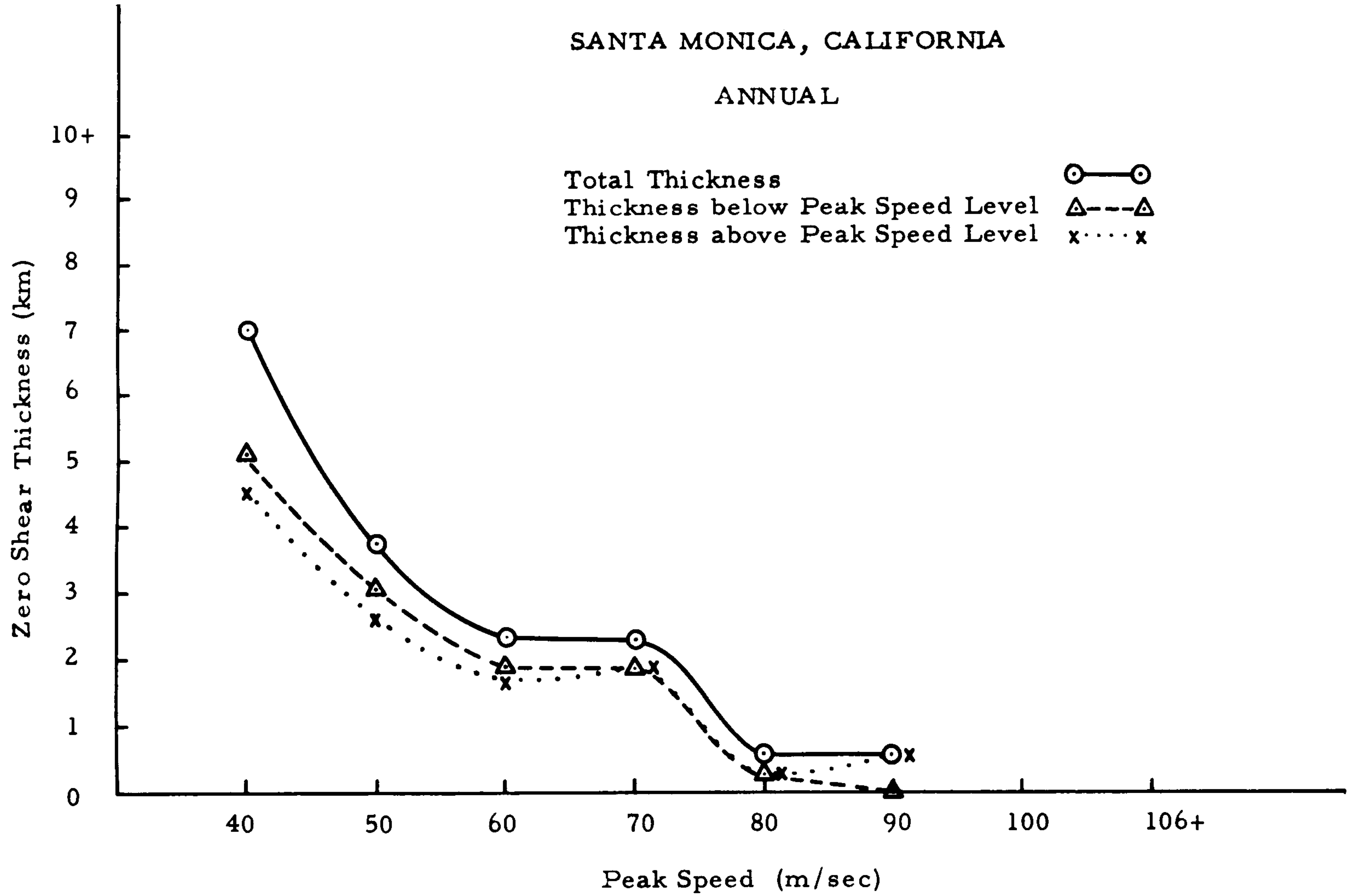

Figure 2.1 Envelopes of 99 percentile zero shear thickness for various peak speed groups

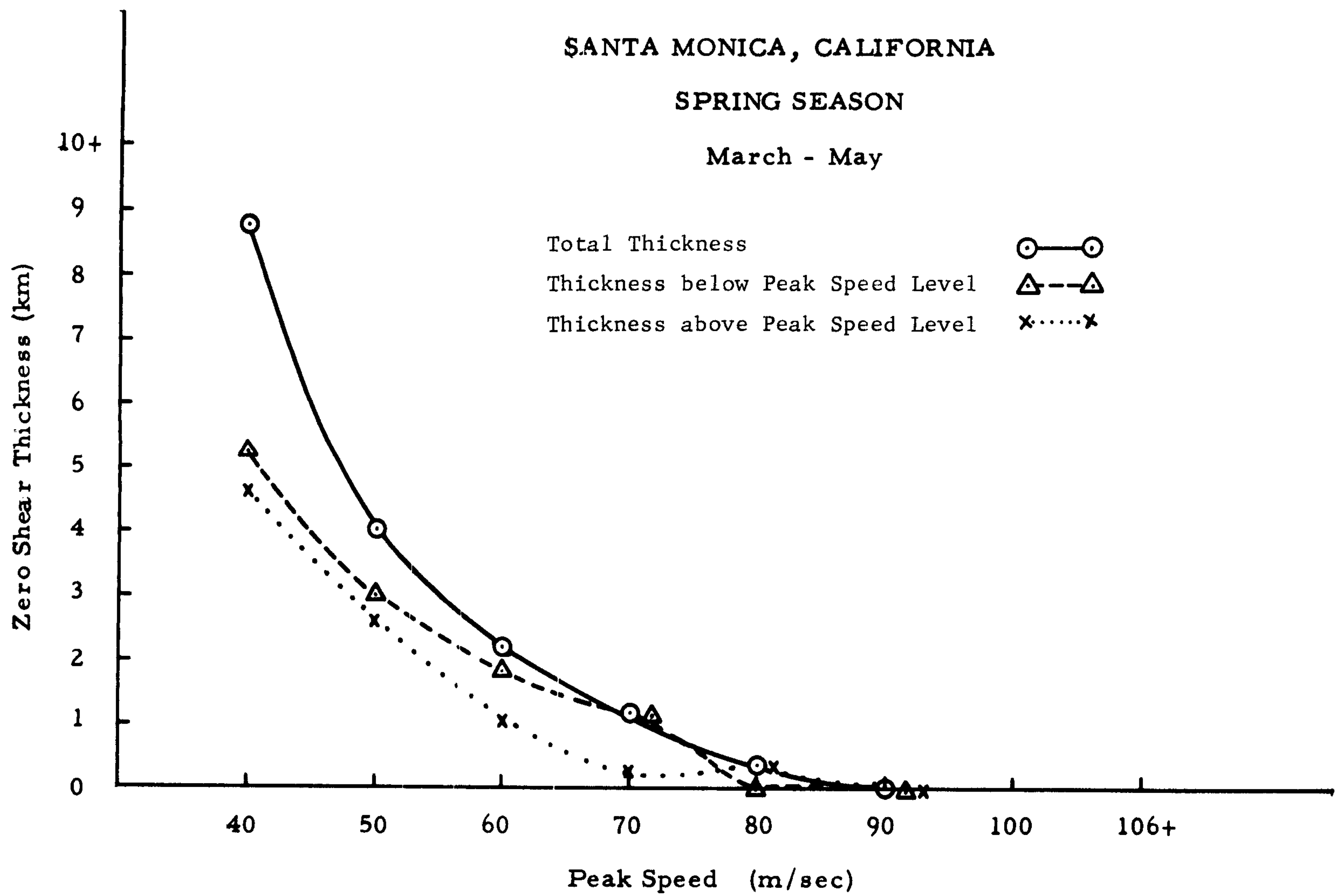

Figure 2.2 Envelopes of 99 percentile zero shear thickness for various peak speed groups

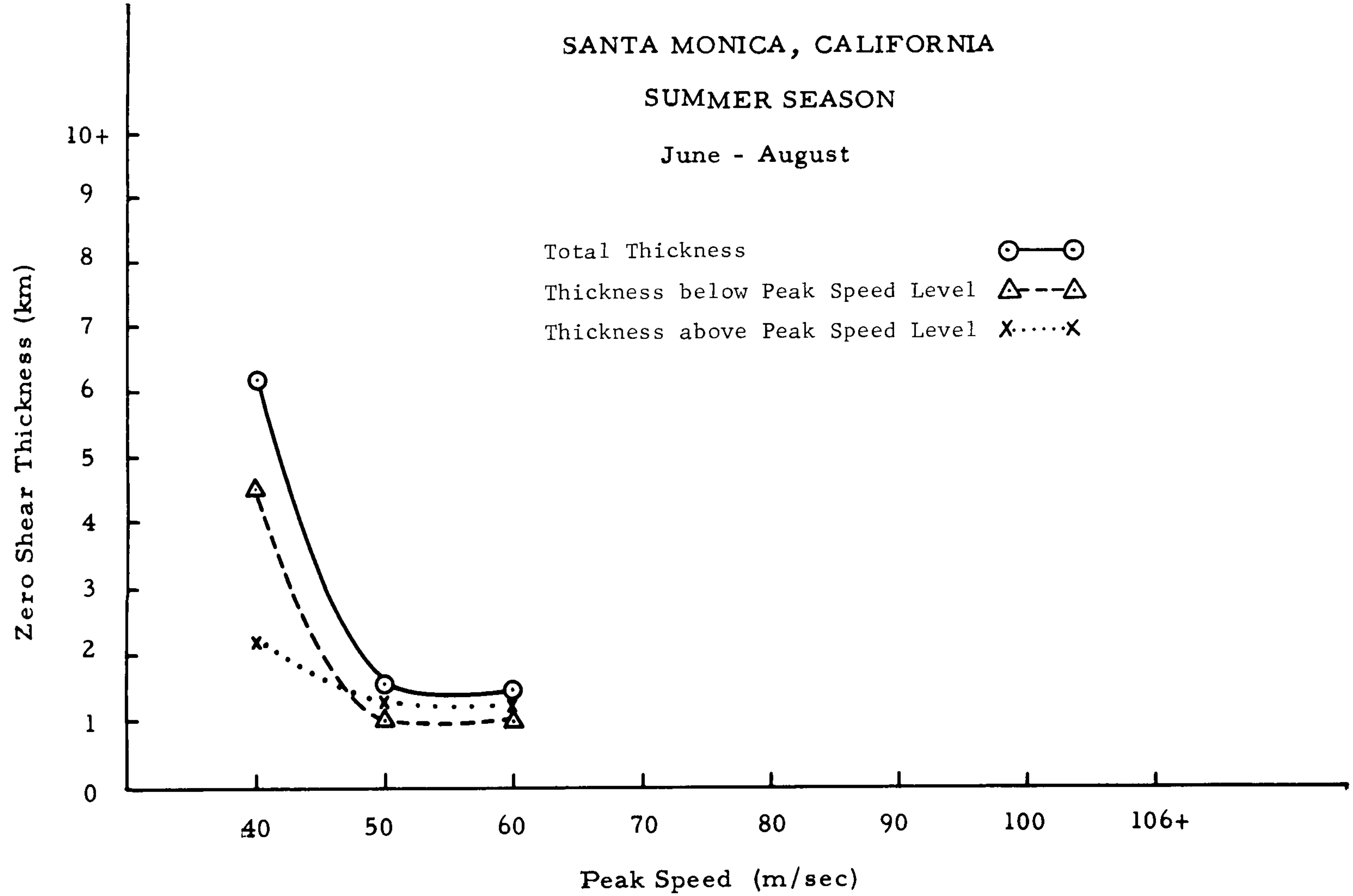

Figure 2.3 Envelopes of 99 percentile zero shear thickness for various peak speed groups

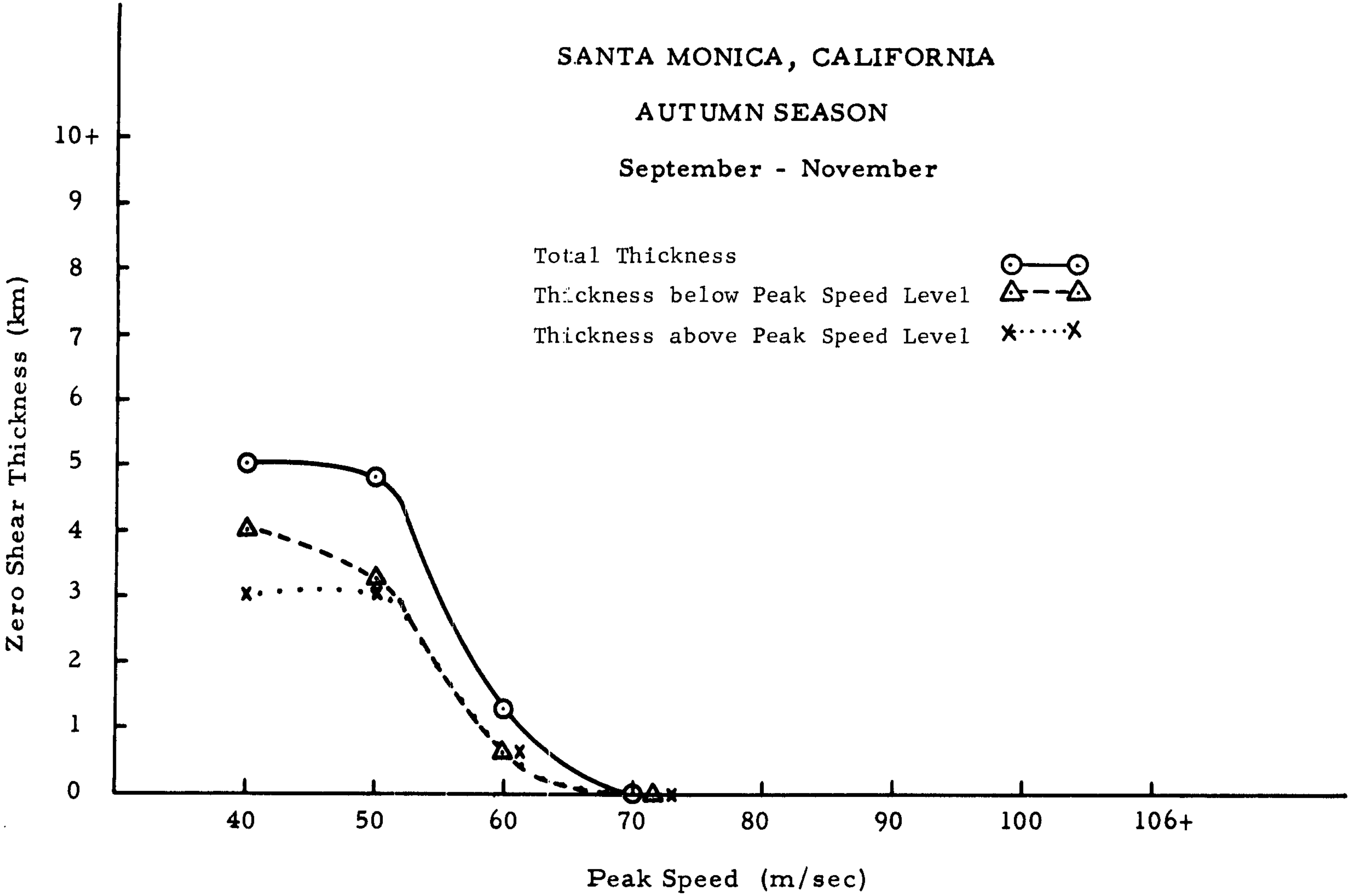

Figure 2.4 Envelopes of 99 percentile zero shear thickness for various peak speed groups

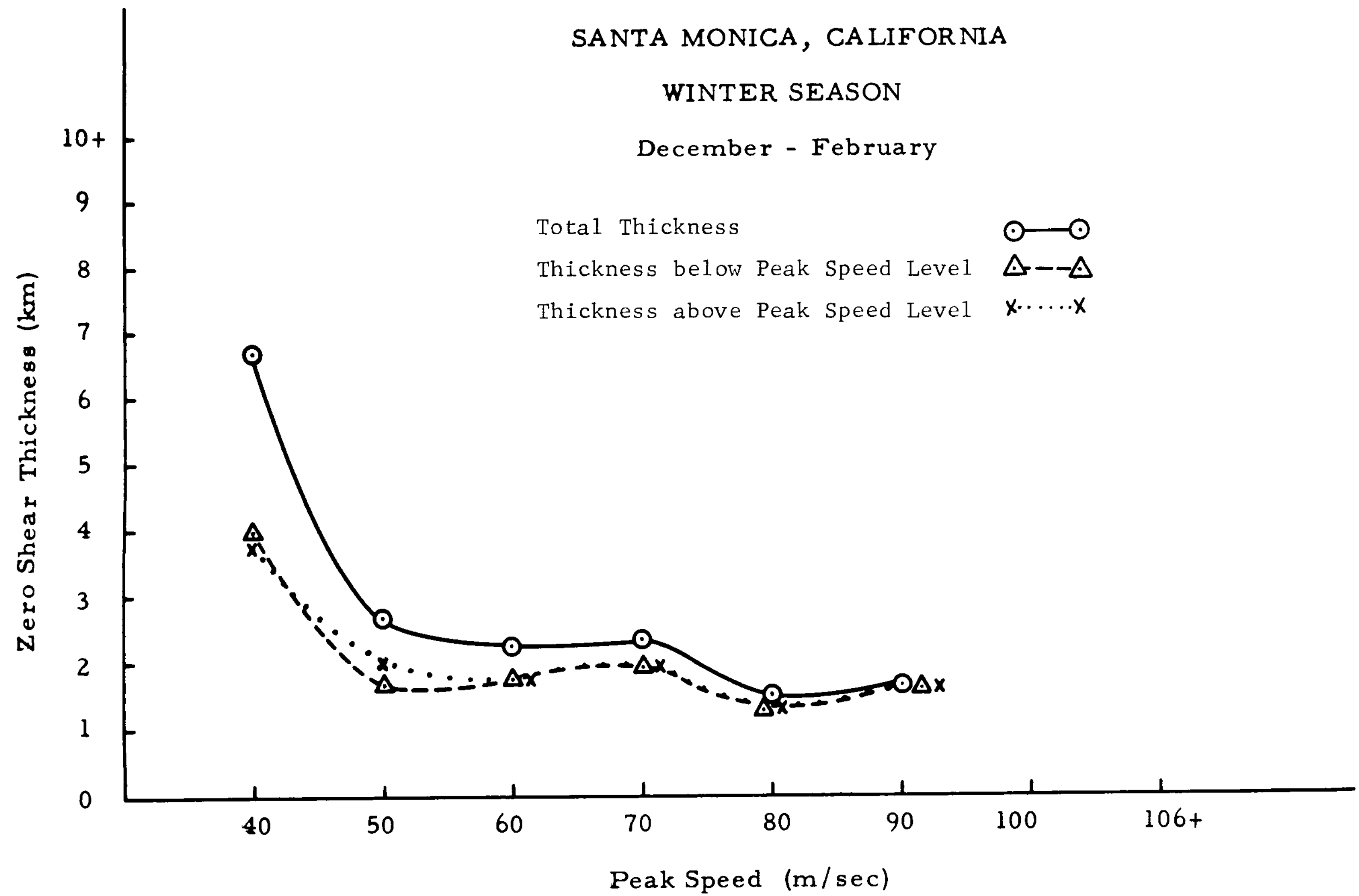

Figure 2.5 Envelopes of 99 percentile zero shear thickness for various peak speed groups

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By Lawrence E. Truppi

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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ABSTRACT

The term zero wind shear is defined for the condition where winds aloft attain speeds of 36 m/sec or higher and persist through a vertical distance such that there is maintained a vector wind shear in the interval ±5 m/sec per kilometer between successive 1-kilometer levels.

Data are obtained from two RAWIN observations per day for six years from Cape Kennedy, Florida and four RAWIN observations per day for five years from Santa Monica, California. Both data decks were edited, checked and serially completed before use. Results are presented as graphs of zero shear thickness versus peak wind speed, and as empirical probabilities of occurrence of zero wind shear conditions at altitudes above and below the mean height of the level of peak wind. Probabilities of total depth of zero wind shear are also presented.

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SUMMARY

The term zero wind shear is defined for the condition where winds aloft attain speeds of 36 m/sec or higher and persist through a vertical distance such that there is maintained a vector wind shear in the interval ±5 m/sec per kilometer between successive 1-kilometer levels.

Data are obtained from two RAWIN observations per day for six years from Cape Kennedy, Florida and four RAWIN observations per day for five years from Santa Monica, California. Both data decks were edited, checked and serially completed before use. Results are presented as graphs of zero shear thickness versus peak wind speed, and as empirical probabilities of occurrence of zero wind shear conditions at altitudes above and below the mean height of the level of peak wind. Probabilities of total depth of zero wind shear are also presented.

I. INTRODUCTION

This stud is concerned with investigating the thickness of bluntness of vertical wind profiles in the atmosphere above and below the level of maximum speed. In an early study, Reiter [1] used the term "Layer of Maximum Wind" (LMW) to describe a condition of small vertical change of wind through the altitude of peak speed. He defined the depth of LMW as the layer in which wind speed differs by less than 10 percent from the mean wind of the LMW, or by about 20 percent from the peak speed. The mean wind of the LMW was defined as 90 percent of the peak speed. The LMW is defined here as a depth in the troposphere and/or stratosphere, from 3 km to 21 km, where a vector wind shear is maintained within the limits ±5 m/sec per kilometer above and below a level of peak wind speed of 36 m/sec or higher. This is a finer definition of LMW than Reiter's.

Reiter limited his LMW analysis to sounding with mean layer winds of 60 kt (31 m/sec) or higher and to depths up to 5 km so that jet stream profiles would not become obscured. His primary concern was to employ the LMW analysis to investigate jet stream phenomena both vertically and horizontally. This study was motivated by the need of design criteria for space vehicles that must penetrate the atmosphere during conditions of very high winds aloft. This analysis provides an investigation of the thickness of the LMW as represented by the wind profile bluntness.