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RESEARCH MEMORANDUM

THE EFFECT OF SAMPLE SIZE ON THE DETERMINATION OF MAXIMUM GUST VELOCITIES IN CLOUDS

By

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

The application of simple sampling procedures to gust data obtained from the P-61 thunderstorm flights at Orlando, Fla. indicates that the observed values of the maximum effective gust velocities are, on the average, functions of the record distance of cloud survey. The relationship determined for these data between the maximum effective gust velocity and record distance is sueful for making similar data gust velocity and record distance is useful for making similar data of smaller extent directly comparable.

INTRODUCTION

Flight investigations have yielded considerable data on the structure and intensity of atmospheric gusts. In the analysis of these data, an important problem for many purposes has been the determination of a relative measure of gust intensity for the atmospheric conditions investigated. For the flight investigations of cumulus-congestus and cumulo-nimbus clouds, a measure of gust intensity extensively used is the maximum effective gust velocity (reference 1). In the investigation of relations between gust and other meteorological variables for these data, it has been the practice, for lack of better information, to use the maximum effective gust velocity encountered on a flight as a measure of the true maximum gust velocity for the cloud surveyed. Inasmuch as this measure would appear to be dependent upon the completeness in time and space of the cloud survey, questions of sampling adequacy have arisen. In addition, questions have arisen concerning the validity of comparing these data with data obtained from other similar investigations.

Recent data obtained from the Thunderstorm Project at Orlando, Fla. have provided an apportunity for evaluating the sampling errors in the use of the observed value of the maximum effective gust velocity obtained from limited samples of data as a measure of the maximum for the cloud. An investigation was undertaken in an effort to measure the variations of observed maximum effective gust velocity and their relation to sample size. As a consequence, a simple procedure for adjusting the maximum effective gust velocities obtained from thunderstorm flight operations for differences in record distance was developed. This procedure removes the effects of differences in record distance between two sets of data and allows direct comparison of the gust velocities.

In view of the present interest in thunderstorm gust data, it is felt that these results would be of interest to the various agencies making use of these data.

ANALYSIS AND RESULTS

The atmospheric gust data obtained from the Thunderstorm Project at Orlando, Fla. during the summer of 1946 represent the most complete thunderstorm survey data available at this time. For each flight five P-61 airplanes were utilized to make simultaneous cloud traverses at five different altitudes and yielded an average record distance of 176 miles per flight. A summary of the operating conditions for these flight surveys is given in table I.

In an effort to obtain a measure of the variations of maximum effective gust velocity with sample size, these data were assumed to give complete cloud coverage and a simple random sampling procedure was utilized to obtain measurements of the maximum effective gust velocity for samples of various sizes. Comparison of the maximum effective gust velocities obtained in this manner provides an empirical measure of the accuracy of samples of various sizes.

Random samples of gust record covering 10.2, 20.4, 28.4, 45.5, and 96.5 miles of flight were selected from the data for each of the P-61 flights. The values of the maximum effective gust velocities for each of these samples given as $|U_e|_{10}$, $|U_e|_{20}$, $|U_e|_{28}$, $|U_e|_{45}$, and $|U_e|_{96}$ were used as estimates of the maximum effective gust velocity for the cloud. Table II gives a summary of the maximum effective gust velocity measured during all traverses of each flight and the values obtained by taking random samples of the indicated record distances from the data of each flight. Also shown are the ratios of the sample values of $|U_e|_{10}$, $|U_e|_{20}$, $|U_e|_{28}$, $|U_e|_{45}$, and $|U_e|_{96}$ to the actual measured values of $|U_e|_{max}$. For the purposes of this paper, this ratio will hereafter be referred to as the "efficiency ratio."

Figure 1 gives a graphical representation of the average relation between the efficiency ratio and the record distance. This curve was obtained by fitting a logarithmic curve through the five points determined from the samples. Also shown in figure 1 are the 67-percent and 95-percent confidence bands (reference 2) which indicate the expected limits of error of the average values of efficiency ratios based on samples of 28 records. The bands shown were derived from the standard deviations of table II by obtaining confidence intervals at the sample record distances of 10.2, 20.4, 28.4, 45.5, and 96.5 miles and fitting smooth curves through these points.

DISCUSSION

The relation between the average efficiency ratio and record distance shown in figure 1 indicates that the sample size or record distance is an important consideration in the accuracy of estimates of the maximum effective gust velocity in a cloud. On the basis of the assumption that 176 miles of record distance yields an accurate measure of the effective gust velocity in the cloud, it is indicated that the efficiency ratio is approximately 66 percent at a record distance of 10 miles and increases to 75 percent at 20 miles, 85 percent at 50 miles, and roughly 92 percent at 100 miles. It appears, therefore, that samples of small size yield maximum effective gust velocities that are considerably below the maximum in the cloud. As an example, for samples of 30 miles, the efficiency ratio obtained from figure 1 equals 79 percent. The average value of $|U_e|_{max}$ observed, therefore, would be only 79 percent of the actual value.

The relation between efficiency ratio and record distance shown in figure 1 can be used to "blow-up" values of $|U_e|_{max}$ obtained from flights similar to the P-61 flights and of shorter record distance. The 176 record miles of the P-61 flight is used as a standard and data of shorter record distance can be made comparable by obtaining the blown-up or equivalent values of $|U_e|_{max}$. These values are, in effect, the estimated maximum values that would have been encountered had the record distance been 176 miles. Although estimated values obtained by this method give no assurance of being the actual maximum for the cloud, they should, on the average, yield reliable estimates. The use of 176 miles of record distance as a standard is an arbitrary assumption dictated by the limitations of available data. When more extensive data become available, the present procedures can be applied to a new standard.

Consideration of the efficiency ratios in table II indicates that considerable variation exists in the values obtained for the individual flights for each sample size. The extent of these variations provides a measure of the consistency of the sample values of $|U_e|_{max}$. Analysis of these data indicates that the use of the relation of figure 1 would yield values of $|U_e|_{max}$ that are, on the average, in error by ±25 percent for the sample size of 10 miles and ±10 percent for the sample size of 96 miles. It would therefore appear that estimates of the maximum effective gust velocity for a given cloud based on the maximums observed in samples of the present extent can be expected, on the average, to be in error by a considerable amount. Furthermore, the amount of average error appears to be a function of the size of the sample, decreasing with increasing sample size.

Although individual blown-up estimates of $|U_e|_{max}$ may be in error by a considerable amount, these errors may be considered largely random and estimates of average values of $|U_e|_{max}$ for a large number of flights, say 20 or more, are judged to be highly reliable. The 67- and 95-percent confidence bands for the average efficiency ratios based on 28 P-61 flights, which number of flights corresponds to the extent of the XC-35 airplane flight investigations (reference 3), are shown in figure 1. For flights of average record distance of 30 miles, the 95-percent confidence limits indicate a spread of about ±6 percent, about the mean value of 79 percent. It is also noted in figure 1 that the width of the confidence band increases as the record distance decreases. At a record distance of 10 miles, the width of the 95-percent confidence band is greater than 16 percent and increases rapidly with decreasing record distance. It is therefore felt that samples below 10 record miles would generally yield poor results. In addition, the width of the confidence interval will generally decrease with larger number of record flights as the confidence interval is inversely related to the square root of the number of flights.

As the XC-35 flights were made under the same general operating conditions as the P-61 flights, the results of the present analysis would appear applicable. Table I gives a summary of the operating conditions for the XC-35 flights. The major differences between the two sets of flights were the number and types of airplanes used. While the XC-35 airplane made successive traverses through the cloud at different altitudes, the five P-61 airplanes made a more extensive cloud survey by making simultaneous cloud traverses at 5000-foot intervals in a vertical section of the cloud. As a result, the XC-35 investigations yielded an average record distance of 27 miles per flight as compared with 176 record miles per flight for the P-61 investigation.

On the basis of the assumption that the operating conditions of these two sets of flights were essentially similar, the results of the present analysis were applied to the XC-35 data. The relation of figure 1 was used to obtain the efficiency ratios and the blown-up values of $|U_e|_{max}$ for each XC-35 flight. Table III gives a summary of the observed values of $|U_e|_{max}$, record distance, efficiency ratio, and blown-up or computed values of $|U_e|_{max}$ for each of 28 selected XC-35 flights. These flights represent all the flights through strong convective clouds for which more than 10 record miles of data were available. The values of $U_{e\ max}$ obtained in this manner are, on the average, about 30 percent higher than those actually measured and average 28.4 feet per second as compared to an average measured value of 21.9 feet per second. The use of the 95-percent confidence band of figure 1 at a record distance of 27.4 miles indicates that the average value of $|U_e|_{max}$ can be expected to be within ±2 feet per second of the actual value.

As a matter of interest, the application of the present method indicates that if as complete surveys had been made in the vicinity of Langley Field, Va., as were made in Florida, the average maximum effective gust velocity would have been greater by about 17 percent than the average value of 24.3 feet per second obtained for the Florida storms.

CONCLUSIONS

1. The value of the maximum effective gust velocity obtained from sample surveys of cumulo-nimbus flights is, on the average, a function of the sample size or record distance of cloud survey. This relation would appear of use in adjusting data from similar investigations for differences in record distance, thereby making direct comparison proper.

2. The accuracy of estimates of the maximum effective gust velocity for a given cloud based on the maximum velocity observed during a survey flight is, on the average, a function of the record

distance of cloud survey. Within the scope of the data presented, estimates of the average maximum effective gust velocity for a large number of flights, say 20 or more, appear highly reliable.

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REFERENCES

1. Rhode, Richard V.: Gust Loads on Airplanes. SAE Jour., vol. 40, no. 3, March 1937, pp. 81-88.

2. Deming, W. Edwards: Statistical Adjustment of Data. John Wiley & Sons, Inc., 1943, pp. 168-171.

3. Moskovitz, A. I.: XC-35 Gust Research Project - Analysis of Gust Measurements. NACA RB No. L4D22, 1944.

TABLE I

SUMMARY OF OPERATING CONDITIONS
FOR XC-35 AND P-61 AIRPLANE THUNDERSTORM FLIGHTS

Operating conditions	P-61	XC-35
Locality of tests	Orlando, Fla.	Langley Field, Va.
Number of airplanes	5	1
Number of flights	38	28
Average number of traverses per flight	12.8	8.6
Average record time per flight, minutes	59	12.2
Average indicated airspeed, mph	180	135
Average record distance, miles	176	27.4
Season and year	Summer 1946	Spring and summer 1941, 1942
Time of day	Afternoon	Afternoon
Survey plan	Simultaneous storm cloud surveys at 5000-foot intervals from 6000 to 26,000 feet.	Successive storm cloud surveys at altitudes up to 30,000 feet.

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TABLE II

SUMMARY OF MAXIMUM EFFECTIVE GUST VELOCITIES FOR P-61 FLIGHTS AND VALUES OBTAINED BY SAMPLES OF 10, 20, 28, 45, AND 96 RECORD MILES

Flight number	$\|U_e\|_{max}$ (fps)	Samples of indicated record distance									
		10 miles		20 miles		28 miles		45 miles		96 miles	
		$\|U_e\|_{10}$ (fps)	Efficiency ratio	$\|U_e\|_{20}$ (fps)	Efficiency ratio	$\|U_e\|_{28}$ (fps)	Efficiency ratio	$\|U_e\|_{45}$ (fps)	Efficiency ratio	$\|U_e\|_{96}$ (fps)	Efficiency ratio
1	20.7	16.3	0.787	17.8	0.860	17.4	0.838	20.7	1.000	18.5	.894
2	21.0	9.2	.438	15.7	.747	13.4	.638	21.0	1.000	21.0	1.000
3	14.3	8.4	.587	12.8	.895	12.8	.895	12.5	.874	11.6	.811
4	28.6	11.9	.416	19.8	.692	28.3	.990	21.4	.748	28.3	.990
5	25.5	25.5	1.000	14.0	.549	22.7	.890	22.7	.890	25.5	1.000
6	25.2	18.4	.730	25.2	1.000	16.3	.647	18.9	.750	25.2	1.000
7	28.4	15.0	.528	15.4	.542	28.4	1.000	28.4	1.000	28.4	1.000
8	31.6	18.3	.579	24.8	.785	24.8	.785	21.1	.668	24.8	.785
9	17.1	14.9	.871	17.1	1.000	17.1	1.000	17.1	1.000	17.1	1.000
10	23.1	11.9	.515	17.6	.762	19.6	.848	23.1	1.000	19.6	.848
11	23.4	23.4	1.000	17.6	.752	14.2	.607	23.4	1.000	20.2	.863
12	31.0	19.9	.642	15.2	.490	26.6	.858	22.2	.716	26.6	.858
13	23.5	11.8	.502	19.7	.838	23.5	1.000	23.5	1.000	23.5	1.000
14	26.3	20.4	.776	13.3	.506	12.0	.456	16.5	.627	21.4	.814
15	16.9	14.0	.828	14.0	.828	16.9	1.000	15.0	.888	15.0	.888
16	20.8	16.8	.808	19.8	.952	18.6	.894	18.0	.865	19.9	.957
17	22.1	21.8	.986	13.7	.620	18.7	.846	16.2	.733	21.8	.986
18	21.3	12.6	.592	18.9	.887	19.3	.906	20.2	.948	21.3	1.000
19	24.7	24.7	1.000	18.8	.761	24.7	1.000	24.7	1.000	24.7	1.000
20	24.8	15.0	.605	18.9	.762	18.9	.762	17.8	.718	21.0	.847
21	38.2	24.5	.641	22.4	.586	29.3	.767	28.3	.741	29.3	.767
22	24.3	14.2	.584	19.0	.782	24.3	1.000	20.9	.860	20.9	.860
23	19.0	11.4	.600	15.3	.805	15.3	.805	11.2	.589	19.0	1.000
24	27.3	15.6	.571	27.3	1.000	19.3	.707	27.3	1.000	23.9	.875
25	24.2	17.1	.707	24.2	1.000	15.7	.649	18.8	.777	24.2	1.000
26	35.5	29.5	.831	18.8	.530	28.6	.806	22.9	.645	32.2	.933
27	31.5	13.8	.438	29.2	.927	17.0	.540	14.8	.470	14.8	.470
28	27.8	8.7	.313	13.2	.475	14.8	.532	19.3	.694	18.1	.651
29	17.5	13.4	.766	15.2	.869	15.2	.869	17.5	1.000	17.5	1.000
30	21.7	20.6	.949	13.2	.608	15.0	.691	21.7	1.000	21.5	.991
31	20.3	10.0	.493	15.3	.754	20.3	1.000	16.6	.818	20.3	1.000
32	17.9	6.0	.335	6.9	.385	11.8	.659	17.9	1.000	17.9	1.000
33	31.0	10.7	.345	19.3	.623	20.9	.674	19.1	.616	27.9	.900
34	20.1	11.5	.572	14.0	.697	16.2	.806	20.1	1.000	20.1	1.000
35	21.6	11.7	.542	20.5	.949	20.2	.935	20.2	.935	20.5	.949
36	25.2	20.1	.798	22.6	.897	20.6	.817	25.2	1.000	22.6	.897
37	19.7	18.8	.954	18.8	.954	19.7	1.000	19.7	1.000	19.7	1.000
38	30.3	12.2	.403	18.7	.617	20.7	.683	19.9	.657	19.9	.657
Average	24.30	15.79	.659	18.00	.755	19.45	.811	20.15	.848	21.7	.908
Standard deviation			.199		.167		.152		.155		.118

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TABLE III

SUMMARY OF MEASURED AND COMPUTED VALUES OF $|U_e|_{max}$ FOR XC-35 FLIGHTS

Flight number	$\|U_e\|_{max}$ measured (fps)	Record distance (miles)	Efficiency ratio	$\|U_e\|_{max}$ computed (fps)
5	16.2	48.2	0.845	19.2
6	11.4	19.8	.750	15.2
7	28.2	42.1	.830	34.0
8	21.6	17.6	.730	29.6
9	18.0	49.5	.850	21.2
10	24.5	12.4	.695	35.3
11	34.0	62.1	.875	38.9
12	28.9	43.9	.835	34.6
13	22.0	11.3	.690	31.9
14	25.7	15.8	.720	35.7
15	31.1	24.5	.770	40.4
16	15.9	10.8	.685	23.2
18	17.9	21.2	.755	23.7
19	14.1	26.3	.780	18.1
20	23.4	31.1	.795	29.4
21	16.7	22.5	.760	22.0
23	13.3	24.8	.770	17.3
24	21.0	15.3	.720	29.2
25	18.6	12.2	.700	26.6
26	13.2	12.8	.700	18.9
27	25.1	20.5	.750	33.5
28	18.4	23.4	.765	24.1
29	18.5	20.7	.755	24.5
30	18.0	18.0	.735	24.5
31	19.3	63.7	.875	22.1
33	34.5	24.5	.770	44.8
34	37.6	46.8	.840	44.8
35	26.0	25.2	.775	33.5
Mean	21.9	27.4	.769	28.4

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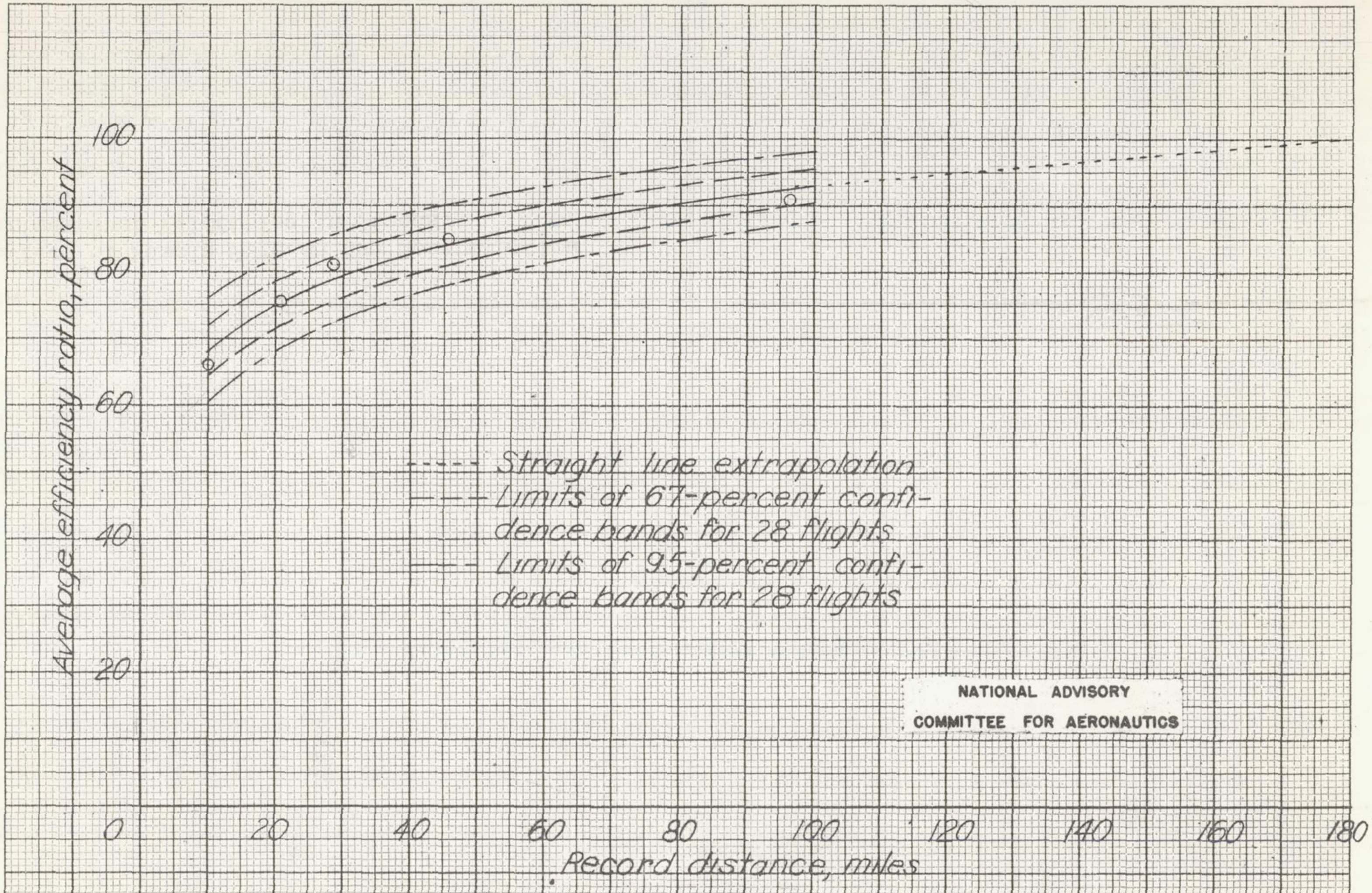

Figure 1. - Relation between average efficiency ratio and record distance for 38 flights of Thunderstorm Project