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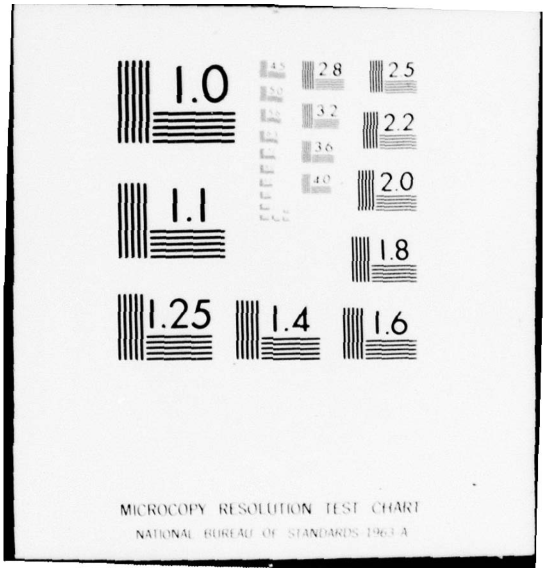

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FOR THE COMMANDER

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Dual Theodolite Pibals were taken concurrently with Combat Control Team mean effective wind calculations. Combat Control Team errors were analyzed within selected ranges of mean effective wind and it was found that error increases significantly with increasing wind speed. Errors resulting from mean direction measurement were found to be insignificant. Similarly, aircraft positioning errors resulting from short term temporal variations were found to be insignificant when compared to speed measurement errors. Two methods of

next page

20. approximating mean effective winds were introduced for the purpose of providing a check against the larger CCT errors. Each method was tested for accuracy against the Dyess wind data. Of the two, a very simple estimation technique derived by the British Meteorological office fit our data very well.

PREFACE

This report was initiated upon a request from the Commander, Detachment 16, 9th Weather Squadron, Lt Col James H. Wood. Impetus behind the request was the desire to investigate Combat Control Team (CCT) procedures for taking mean effective wind (MEW) observations in support of paradrop operation. These procedures, for the most part, are specified by MACR 3-3.

ACKNOWLEDGEMENTS

As is the case with most technical studies, the few pages contained within this report were preceeded by rather vigorous exercises in pre-planning, research, data accumulation and processing, and finally, report writing. Each of these tasks were supported by the selfless efforts of many individuals. Unfortunately the list is too long to include everyone. We do, however, wish to personally thank all involved, and to include the names of those individuals without whose support this report could not (and would not) have been written.

Thanks to the men and women of Det 16, 9WS who augmented the 6WS (MOB) pibal team and made possible the round-the-clock scheduling of data samples. A special thank you goes to Lt Col James Wood, 1Lt Sidney Theis, and MSgt Charles Tresser for their management efforts, long hours worked, and hospitality afforded. They made a difficult task pleasant.

Thanks to the participating members of the 1MAPS and 6WS (MOB) teams who diligently collected the data which made this study possible.

Thanks to Capt John Ernst, 7WW/DON, for his tireless efforts and assistance in guiding the field experiment.

Thanks to 1Lt Gerald Griggs who supplied us his personal dual theodolite program, and to 1Lt Charles R. "Bob" Posey II, who modified that program to fit our needs.

Finally, thanks to the 3WW staff for their suggestions and editing. And especially to Mrs. Diana LeBoeuf, A1C Robert Troastle, and A1C David Nelson for their typing, graphics and punch-card work.

TABLE OF CONTENTS

INTRODUCTION

This technical note documents a study to compare mean effective wind velocities from 6WS (MOB) dual theodolite pibal data with those obtained by MAC Combat Control Teams (CCT). Dual theodolite pibals were scheduled concurrently with CCT runs at three-hour intervals beginning at 0000 LST. Additional concurrent pibals were scheduled at 15-minute intervals twice daily from 0215-0300 and 1415-1500. Concurrent runs were also taken 10 and 30 minutes prior to all scheduled paradrop missions. The study was conducted between 28 March and 2 April 1977 at the Marrion Drop Center, Dyess AFB, Texas.

Prior to the study, it was decided that the 6WS (MOB) team would release 30-gram balloons separately from, but simultaneous to, the CCT 10-gram balloon releases. This was done so that independent results could be obtained without having the CCTs deviate from standard equipment or procedures. At all times, distance from the points of release (6WS and the CCT) was 1000 feet or less.

The two methods of obtaining mean effective winds (6WS and CCT) are discussed in Chapter 1. In this chapter we have documented pertinent equations so that they might be easily referenced for future studies of this nature. Chapter 2 discusses the analyses of CCT measurement errors. We attacked the statistics from several different vantage points in order to glean the most information from the rather limited data sample. Perhaps the most relevant findings are those associated with CCT speed measurement error. Chapter 3 discusses the impact of time lag between CCT measurement and actual drop time. Chapter 4 contains methods which might be used to approximate the mean effective winds using observed surface and flight level (1000 ft) observed winds. It is hoped that such approximations might lead to a routine method for spotting mean effective wind observations having a large error. Finally, Chapter 5 concludes this report.

CHAPTER 1

DATA REDUCTION

1. The Mean Effective Wind (MEW) is defined as the mean integrated wind through a given layer of the atmosphere. It is the vector wind which will result in an airborne parcel's displacement when the parcel ascends or descends through the layer. Mathematically this wind is defined as (5):

$$\mathrm{MEW} = \frac{1}{H}\int_{Z_1}^{Z_2} V(Z)\,dZ \qquad \text{Equation 1}$$

where H = Thickness of the layer
Z_1 = Base of layer
Z_2 = Top of layer

2. Combat Control Team procedures for computing the MEW from the surface to drop altitude require that the vertical and azimuth angles be read, from a hand-held Brunton compass, when the balloon theoretically reaches the drop altitude. The vertical angle at which the balloon is observed is then converted to a mean speed (based on the constant ascent rate tables given in MACR 3-3) and the azimuth angle is used directly as the mean direction (magnetic) through the layer.

3. Since it is possible to calculate height directly from dual theodolite readings, MEWs from 6WS (MOB) data were computed as follows:

a. Balloon heights were computed from dual theodolite data, using computer processing.

b. Using the computed heights, angular data from the balloon release site (Station A) were linearly interpolated between known levels to the drop height (1000 feet in most cases). 6WS (MOB) dual theodolite readings were taken every 20 seconds, consequently the interpolation to obtain the 1000 foot angular data was usually made between layers 200 feet thick or less. Examination of the data between the layer below 1000 feet and the layer above 1000 feet indicated that this method of interpolation was accurate.

c. Once the interpolated azimuth and elevation angles, ϕ and θ, respectively, were determined at station A, the MEW was computed as follows:

$$\left|\mathrm{MEW}\right| = \frac{.592}{T}\;\frac{H}{(\tan\theta)}\ (\mathrm{kts}) \qquad \text{Equation 2}$$

where

.592 is a conversion factor from feet per second to knots.

T = Time required for balloon to reach drop altitude, H (seconds).

H = Drop altitude height (feet).

θ = Elevation angle at time T (degrees).

4. Appendix I lists the individual mean effective winds observed by 6WS (MOB) (dual theodolite) and CCT members (Brunton Compass).

CHAPTER 2

DATA COMPARISON

1. Dual Theodolite Accuracy. For the purpose of this study, dual theodolite measurements are assumed accurate. The reason being that the time increments used to compute mean effective winds to 500 or more feet were generally in excess of 50 seconds. A study by Butler and Duncan (4), indicates that velocity errors from dual theodolite readings are less than one knot and six degrees for time increments of 50 or more seconds.

2. Significance Tests. All but one of the significance tests in this report are Student t tests. The one departure was a test which uses the general binomial probability equation. Student t tests were chosen because our study uses data samples of limited size and unknown population means. In this chapter we test the significance of the CCT errors (departures from the dual theodolite MEW). In chapter 4 we test the significance of the CCT error as compared to the errors generated using a simple estimation formula derived by the British Meteorological Office.

3. Average MEW 28 March-2 April. The average mean effective wind for the 72 dual theodolite pibals taken was 16.4 knots; this is mentioned because it indicates the strength of the winds during the period of the study. A similar study conducted by the AWS/Directorate of Aerospace Sciences, 1971 (1), utilized 83 pibals and obtained an average MEW of 11.6 knots. The relevance of the strong winds observed at Dyess will be discussed later.

4. Ascent Rate of the 30-gram Balloon. The average ascent rate of 6WS pibals was 582.23 feet/min. This constitutes a considerable departure from the 750 feet/min. ascent rate published in the MACR 3-3 tables for 30-gram balloons. It was possible the 6WS balloons were not being weighted properly, but checks indicated the procedures were correct. If ascent rates observed by the Dyess study are accurate, this difference is significant in that a balloon assumed to be at a height of 1000 feet would only be at 776 feet. The MEW consequently, would be computed for a considerably lower altitude than that assumed. This may, or may not, result in a considerable wind speed error, depending upon the vertical profile of the wind. This is mentioned as the 10-gram balloon normally used by combat controllers is very difficult to keep sighted when the MEW exceeds 20 knots. A 30-gram balloon, being larger, would be more visible.

5. MEW Speed Errors. Errors were analyzed as CCT deviations from the 6WS (MOB) computed MEW. The following definitions apply to the given statistics:

$$\text{Mean Error} = \frac{1}{N}\sum_{i=1}^{N} \Delta V_i \qquad \text{Equation 3}$$

$$\text{Mean Error Magnitude} = \frac{1}{N}\sum_{i=1}^{N} |\Delta V_i| \qquad \text{Equation 4}$$

$$\text{R.M.S.E.} = \frac{1}{N}\sum_{i=1}^{N} \Delta V_i^{2} \qquad \text{Equation 5}$$

where: N = Number of MEW comparisons
ΔV = MEW (6WS) - MEW (CCT); (Direction and speed are compared independently)

It was noted earlier in this study that the greatest majority of speed errors took the form of combat controllers underestimating the mean effective wind. Furthermore, it was stated that CCT measurement error increased as the mean wind speeds increased. To illustrate this point, we have grouped our mean winds (as measured by dual theodolite) into 3 speed ranges. These speed ranges, $0<|MEW|\leq 13$ kts, $13<|MEW|<19.5$ kts and $|MEW|\geq 19.5$ kts, were chosen because each category contains a nearly equal distribution of pibals. A change in the middle range of only ± 1/2 kt would have increased the mid-range count by 10 pibals. This would have come as a loss of 5 pibals each to the low and highest speed ranges. Items a, b, and c below indicate CCT measurement errors in these speed ranges. In addition, items a, b, and c contain Student t tests for significance of the CCT error (8). The test hypothesis was that the CCT error would reduce to zero (i.e., equal the MEW) given an infinite number of pibals. As can be seen, the probability of this hypothesis fails at the 1 percent level of confidence ($t_{.01} \approx 2.8$). That is, the CCT errors are clearly not related to chance.

Item d below, contains an error assessment for all speed ranges and a quantification of the degree of CCT underestimation (positive error). Perhaps the most significant elements in item d are the two ratios which show that CCT underestimation occurred in 53 or 74% of all observations and accounted for 85% of all the errors. Regarding the former percentage, if the CCT errors were non-biased and normally distributed, there would be an equal likelihood of underestimation and overestimation of the MEW. That is, the probability should be .5 for making either a positive or negative error. However, if we substitute our number of positive errors into the general binomial probability equation (8), we find that the probability of achieving our error distribution is only 2.5×10^{-5}. Consequently, we must conclude that CCT errors are not normally distributed and that a positive bias exists. The reason for the bias is unknown.

a. MEW speed range $0<|MEW|\leq 13$ kts:

Mean Error Magnitude	1.9 kts
R.M.S.E.	2.6 kts
Number Observations	25
t(24)	3.58
P(CCT = MEW)	<.01

b. MEW speed range 13 kts $<|MEW|<19.5$ kts:

Mean Error Magnitude	3.1 kts
R.M.S.E.	3.7 kts
Number Observations	23
t(22)	3.92
P(CCT = MEW)	<.01

c. MEW speed range ≥ 19.5 kts:

Mean Error Magnitude	5.8 kts
R.M.S.E.	7.2 kts
Number Observations	24
t(23)	3.86
P(CCT = MEW)	<.01

d. All Wind Speeds.

Mean Error:	2.4 kts
Mean Error Magnitude:	3.6 kts
R.M.S.E.:	4.3 kts
Ratio: Positive error to mean magnitude (total) error:	0.85
Ratio: Number of observations with positive error to all observations:	0.74
Number of observations:	72
t(71)	7.1
P(CCT = MEW)	<.001

e. The above statistics indicate that wind speed affects CCT results. The following comments are offered.

(1) There appear to be two likely reasons for the increase in CCT measurement error when the mean speeds increase. First, during high winds the balloon is extremely difficult to see with the naked eye after a short period of time. Second, with high mean winds (low elevation angles), small angular measurement errors result in large velocity errors. These reasons often show up coincidentally. They can, however, be unrelated. For example, the first may only be a balloon recognition problem, while the second can result from an irregular movement of the compass.

(2) It is not understood why the CCT derived-MEWs are lower than the actual MEWs; however, this tendency has two important ramifications:

(a) Insofar as the aircrew is concerned, the largest error in MEW observations would occur when the CCT reports the MEW in the 13-19.5 knot range. This is definitely within paradrop operational range. Further, if the error occurs at night, as did four out of the five soundings with errors greater than 10 knots, then the surface wind usually would have quieted (2). Consequently, the only indication of strong winds and possible error would be the aircraft doppler winds.

(b) If MEW underestimation is universal and not just a local problem, drop zone studies which are based on CCT measurements are likely to be affected. They will likely be over-optimistic in forecasting an expected frequency of favorable drop winds.

6. MEW Direction Error. In general, errors in direction were not significant. The mean error in direction was 6.0° with an R.M.S.E. of 8.0°. It was noted that CCT members most often reported winds to the nearest 10° and in some cases to the nearest 5°. Therefore, the error falls within the range of report. No significant direction bias was noted. Of the 72 soundings 12 were in error 10 degrees or more and three were in error 20 degrees or more.

7. Combined Effects of Speed and Direction Errors. The effect of speed and direction errors is additive to the displacement of the parcel away from the drop zone. Given a true mean effective wind (MEW_t) and an observed value (MEW_o); the resultant wind vector (V_r) that will act to displace the parcel away from the drop zone is given by:

$$V_r = \{(MEW_t)^2 + (MEW_o)^2 - 2\,(MEW_t)\,(MEW_o)\,\cos\delta\}^{\frac{1}{2}} \qquad \text{Equation 6}$$

where δ = azimuth error.

To obtain the final positioning error, multiply V_r by the time during which the parcel is acted upon by the mean wind and project that distance in the direction of δ. Note that this error is only the error caused from miscalculating the true MEW. Errors originating from improperly conceived parcel ballistics and parachute deployment characteristics are not considered in this note. Therefore, based upon our average error of 3.6 knots, a mean speed of 16.4 knots, and 6° direction error we find an average resultant vector of 3.9 knots. Assuming a 30-yard positioning error for each knot speed error (1), we find an average error of 117 yards. When the MEW speeds are greater than 19.5 knots, however, the average directional error was 7° and the average speed error 5.8 knots. Based upon a mean speed in the above range of 23 knots and a CCT underestimation of the winds, the resultant vector is 6.3 knots, thus yielding a 188-yard positioning error. In addition, assuming a normal distribution for this speed range, the R.M.S.E. indicates approximately 32 percent of errors may be expected to exceed 7.5 knots or 226 yards. In other words, high winds are likely to result in large MEW errors and correspondingly large paradrop displacement errors. An inspection of surface wind climatology for Dyess AFB reveals that this was not an extraordinarily windy period. As mentioned earlier, the average MEW for the period was 16.4 knots. The corresponding average surface wind was 7.5 knots and climatology tells us that surface winds for Dyess are 10 kts, 11 kts, 12 kts, 11 kts and 11 kts respectively for February, March, April, May and June. It appears, therefore, that large measurement errors should be expected at Dyess in the late winter and spring.

CHAPTER 3

EFFECTS OF SHORT TERM TEMPORAL VARIATIONS IN WIND SPEED

To answer the question of "How representative is a MEW that was observed ten minutes prior to drop time?", two one-hour blocks were scheduled each day (0215-0300 and 1415-1500) with runs at 15-minute intervals in each block. We also used data from MEWs taken at 20-minute intervals preceding paradrops. The variability factor may then be expressed as variations for soundings separated by 20 minutes or less.

a. The average MEW for all soundings with a data $t \leq 20$ minutes was 16.2 knots. This differs from the total mean speed by less than 1 knot and is felt representative of the entire data base. The average short-term variability was found to be 1.7 knots with an R.M.S.E. of 2.1 knots. This compares favorably with the theoretical R.M.S.E. of 1.8 knots obtained using the formula R.M.S.E. = $(1.5 + 0.1\ \text{MEW}) \times (t)^{\frac{1}{2}}$ (1). Consequently, we used this formula to compute an R.M.S.E. for a ten-minute interval (time of final pibal run taken prior to paradrop) and found an R.M.S.E. of 1.3 knots. If we consider the total variance in MEW to be the sum of the variances due to observational error and short term wind variation (1) we have:

$$\text{R.M.S.E. (All speeds)} = \left((3.6)^2 + (1.3)^2\right)^{\frac{1}{2}} = 3.8 \text{ knots}$$

$$\text{R.M.S.E. } (V \geq 19.5 \text{ knots}) = \left((7.2)^2 + (1.3)^2\right)^{\frac{1}{2}} = 7.3 \text{ knots}$$

Using these values in equation 6, we find the resultant positioning vector increases slightly to 4.07 knots (122 yards) and 7.62 knots (229 yards). This represents an increased drop positioning error of five yards for all wind speeds and three yards for speeds greater than 19.5 knots. Thus, errors in estimating mean effective wind have a much larger impact upon positioning errors than do the short-term variations in the wind.

CHAPTER 4

MEAN EFFECTIVE WIND APPROXIMATIONS

1. It is felt that regardless of how much training is given CCT members, or how closely the CCT members try to follow proper procedures, errors are likely to be made in their MEW computations. Reasons are numerous but might stem from any combination of the following:

a. Inability to visually "fix" on the balloon during high wind conditions because of the large distance of the balloon from the observer.

b. Inability to visually "fix" on the balloon during high wind conditions because the observer is being buffeted by gusts.

c. Errors made in the haste of combat or exercise conditions.

d. Non-standard ascent rates caused by changes in the length of the measuring string, grossly non-standard temperature lapse rates or irregularly shaped balloons.

2. No matter what the source of error, it would be beneficial to have a method of estimating whether or not the CCT derived MEW is accurate. Consequently, we examined two previously prepared studies for approximating the mean effective wind (6, 7). Both studies yield an estimation of the MEW based on observed surface and 1000 ft winds. When we tested the estimation techniques, we were unable to calculate as many 1000 ft winds as we were MEWs. The reason is near the end of the field experiment, one of the theodolites blew over in a gust of wind. In order to salvage the remainder of the project, we resourcefully procured an engineer's transit theodolite. Unfortunately, the new piece of equipment was not designed to track an ascending balloon and was not nearly as usable as a meteorological theodolite. Consequently, only a few angles were measured by the engineering theodolite during each release. (This was done to make possible accurate ascent rate calculations). The MEWs were then computed using single theodolite angular data, but, with dual theodolite ascent rates. The procedure gave no problems insofar as MEW computations are concerned, but unfortunately made determination of the 1000 ft wind most often impossible.

3. Methods.

a. The British Meteorological Office Study. An 18 month study showed that MEWs up to 1200 ft could be often estimated by adding two-thirds of the 1000 ft wind to one-third of the surface wind (6). The British Study also recommended subtracting 9 degrees from the 1000 ft wind to obtain mean direction. Since 1000 ft winds are generally obtainable from aircraft instrumentation, and surface winds are known, the method is ideal for providing a simple and practical check. All that remains is to determine if it would be a reliable check for the CCTs to use against their balloon measured MEWs. This has been accomplished by inserting the 1000 ft winds obtained by dual theodolite readings and surface winds into the approximation formula. The results are listed below:

(1)

MEW Speed Range	Number Observations	Estimation Formula R. M. S. E.	CCT R. M. S. E.
0<|MEW|<13 kts	20	2.2 kts	2.6 kts
13<|MEW|<19.5 kts	21	3.3 kts	3.7 kts
|MEW|>19.5 kts	21	4.6 kts	7.2 kts
All Speeds	62	3.5 kts	4.3 kts
Mean Error Magnitude:	2.6 kts		

(2) Significance. To test if a significant difference existed between the CCT measurements and the British estimates, we performed a Student t test on the 62 pairs of errors (3). In doing so, we employed the null hypothesis, or that no real difference would exist given a large number of error pairs. The mechanics of the test involved subtracting the magnitude of each estimation formula error from the magnitude of the corresponding CCT error. We then entered the Student t formula with the mean and standard deviation of the error differences. We found a mean difference of 1.039, a standard deviation of 3.436 and a value of t equal to 2.38. This means there is less than a 3% chance the null hypothesis is true. We therefore conclude that there is a significant difference in the two methods and that the British estimation technique performed better than the CCT (8). It is also

interesting that for our data, the estimation formulas did out-perform the CCT measured MEWs in every speed range. Additionally, unlike the CCT measurements, the estimation technique showed no apparent tendency for overestimating or underestimating the true MEW. Whereas CCT measurements had a 74% positive error ratio (underestimation) our computations with the estimation technique resulted in an overall positive ratio of only 55%.

(3) Usefulness as a check against CCT error. Since MAC must be ready to conduct paradrop operations on a global basis, it must be acknowledged that the estimation formula might not prove accurate during different times of the year, or at different locations. However, when analyzed with the data on hand, it worked well. Moreover, computation is relatively easy and quick. After a short explanation, our office staff was able to make the computations, in less than 30 seconds, without the aid of pencil and paper.

b. The Martin Study. A second borrowed estimation technique was extracted from a study by Martin et al, using the instrumented 1400+ ft television towers at Oklahoma City OK and Cedar Hill TX (7). The derived MEW approximation equations were best fit curves to the tower data. The tower data, in turn, were obtained from several wind instruments located at various levels on the tower. The regression equations (approximation formulas) were of the form $MEW = a_o + a_1V_6 + a_2V_{1050}$. Separate equations were derived for four time frames during the day, and for different months of the year. Our test data were verified against April equations which was the closest month listed to the Dyess data. The results were not as favorable as the British Method and are listed below.

(1)

MEW Speed Range	Number of Observations	Estimation Formula R. M. S. E.	CCT R. M. S. E.
$0<\lvert MEW\rvert<13$ kts	20	5.2 kts	7.2 kts
$13<\lvert MEW\rvert<19.5$ kts	21	5.1 kts	3.7 kts
$\lvert MEW\rvert\geq 19.5$ kts	21	3.0 kts	2.6 kts
All Speeds	62	4.5 kts	4.3 kts

Mean Error Magnitude: 3.3 kts

(2) Significance and Usefulness. The mean error magnitude of 3.3 kts is 27% greater than the British method. The R.M.S.E.s were greater than the British method through all ranges of speed, and greater than the CCTs for all ranges but the highest speed. Because of this, and the difficulty of having to use more than one set of approximation equations, this method was deemed not as suitable to CCT operations as the British method.

c. Direction Estimation. As a method of estimating mean direction, we tested the British method of subtracting 9 degrees from the 1000 ft wind. We also tested the closeness of the 1000 ft wind direction to the mean direction. We found that using straight 1000 ft wind directions gave the best results for wind speeds greater than 13 kts. The results follow:

(1)

MEW Speed Range	Number of Observations	1000 ft Wind Direction R.M.S.E.	1000 ft Wind Dir Minus 9 Degrees R.M.S.E.
$0<\lvert MEW\rvert<13$ kts	21	26.8°	25.5°
$13<\lvert MEW\rvert<19.5$ kts	21	1.7°	8.8°
$\lvert MEW\rvert\geq 19.5$ kts	20	1.9°	8.6°
All speeds	62	15.7°	16.5°

(2) Significance. As can be seen, for speeds greater than 13 kts, MEWs were estimated nearly as accurately using the 1000 ft wind direction as when measured by dual theodolite pibal. For light winds (MEWs less than 13 kts), directions were quite variable, hence the 1000 ft direction did not closely approximate the mean.

CHAPTER 5

CONCLUSIONS

1. During this study, 72 dual theodolite pibals were compared with CCT mean effective wind measurements. Resultant data were viewed from several different approaches to help us better understand the nature of the procedural errors which might result from CCT observational methods. The data were also helpful in determining the accuracy of the two previously prepared objective MEW estimation techniques. The following points summarize our findings.

a. The most significant error made by the CCT was in measurement of speed. During this study the preponderance of the speed error resulted from an underestimation of the true mean effective wind. Recall that we assumed the dual theodolite data correct. If so, the systematic underestimation of the mean wind can presumably result in aircrews performing drops into what they feel are suitable winds, when in actuality the winds are marginal or beyond limits.

b. Errors in measuring the mean direction were found to be within the limits of reported values and are considered negligible. Similarly, temporal changes in the wind speed were found most often to have little effect on the displacement of the dropped parcel.

c. Two approximation techniques were presented. Of the techniques, the British method fit the Dyess wind speed data quite well. Mean direction was best approximated for speeds above 13 kts directly from the 1000 ft wind direction.

2. Whether the results of this study are applicable to other times of the year, or different locations, is open to question. The data sample is relatively small and time-compressed. However, despite the size and time limitations, this study agrees quite closely (where comparison is possible) with the findings of the AWS Special Study of 1971 (1). As a consequence, our findings that CCT error increases, with increasing wind speed suggest relevance to different times and locations. Finally, since errors made during high wind situations are potentially large, further research appears needed to develop methods of providing systematic checks for CCT observations. The mean effective wind approximations provided, indicate such checks are likely to exist.

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Appendix I
OBSERVED MEAN EFFECTIVE WINDS

DATE/ LOCAL TIME	6WS (DUAL THEODOLITE) *DIR/SPD	COMBAT CONTROL TEAM (BRUNTON COMPASS) **DIR/SPD
28/1900	222/19.5	210/15
1921	223/18.1	220/14
2030	238/28.9	220/15
2112	246/31.1	240/18
2217	268/24.0	260/13
29/0000	294/21.2	290/21
0215	313/11.0	300/09
0245	314/7.7	310/05
0300	308/6.8	310/06
0600	142/6.7	120/06
0900	107/9.5	100/10
1200	210/14.2	200/13
1415	223/23.5	215/19
1430	226/28.2	210/30
1445	237/24.2	235/23
1500	254/25.1	225/13
1800	261/26.9	245/27
2030	347/11.0	320/12
2050	004/6.5	350/07
30/0025	012/11.4	350/13
0215	344/16.6	330/11
0230	340/16.9	330/13
0245	339/14.5	330/11
30/0300	334/12.9	330/11
0605	357/12.6	350/12
0846	359/6.4	360/10
0906	023/4.3	010/08
0921	027/7.2	010/15
1201	029/9.8	020/11
1415	038/8.5	030/05
1430	057/8.0	037/08
1445	042/5.8	005/08
1500	-	025/07
1800	040/10.8	030/13
1830	045/11.2	030/11
1850	047/12.5	040/13
1940	082/12.7	070/12
2000	085/11.8	070/12
2030	-	070/12
2120	104/15.7	090/13
31/0001	116/16.6	100/14
0215	111/20.1	090/13
0230	107/18.9	100/15
0245	103/19.3	090/16

DATE/ LOCAL TIME	6WS (DUAL THEODOLITE) *DIR/SPD	COMBAT CONTROL TEAM (BRUNTON COMPASS) **DIR/SPD
0300	097/20.3	090/16
0600	090/17.8	080/21
31/0902	085/14.6	070/14
1201	104/14.7	100/11
1415	112/12.7	100/07
1430	115/15.4	110/10
1445	120/14.0	105/19
1500	121/16.4	110/07
1800	132/20.1	120/14
2040	140/14.7	130/13
2056	139/16.3	120/16
2150	142/14.3	130/13
2315	150/19.1	130/18
2350	151/19.6	140/23
01/0001	153/20.0	130/19
0215	169/28.7	160/18
0230	173/28.1	160/19
0245	173/26.7	170/18
0300	172/23.4	160/15
0900	208/18.3	190/16
1200	-	-
1415	-	-
1430	-	-
1445	207/18.3	195/23
1500	213/19.8	190/13
01/1800	205/21.6	200/19
2100	-	-
02/0000	292/24.6	280/19
0215	304/20.7	270/20
0230	307/19.7	280/21
0245	303/18.7	300/18
0600	297/15.5	280/16
0900	292/13.0	280/10
1200	321/5.7	285/05

* 6WS (MOB) Observed True Direction

** CCT Observed Magnetic Direction