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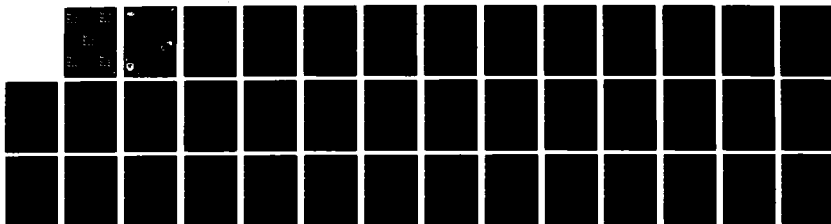   METEOROLOGICAL DATA ON FIELD.. (U) ARMY ELECTRONICS
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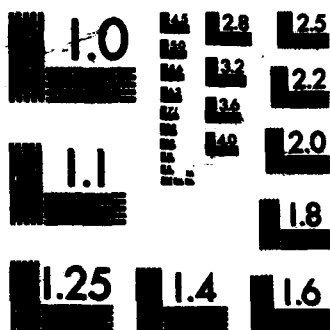
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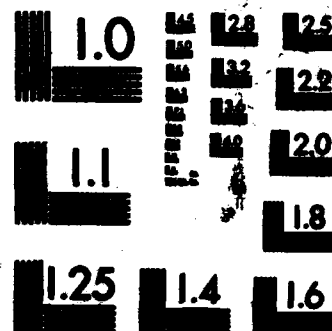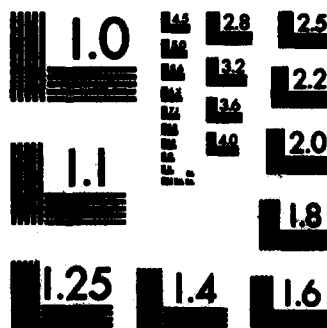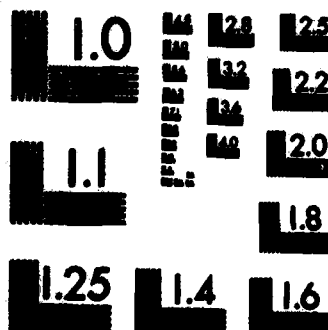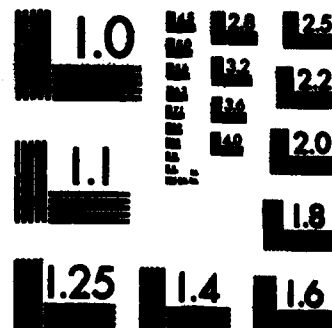
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IMPACT OF SPACIAL AND TEMPORAL FREQUENCY OF METEOROLOGICAL DATA ON FIELD ARTILLERY ACCURACY

AUGUST 1982

By

J. D. Copp

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ASL-TR-0113	2. GOVT ACCESSION NO. AD-A120 642	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) IMPACT OF SPACIAL AND TEMPORAL FREQUENCY OF METEOR- OLOGICAL DATA ON FIELD ARTILLERY ACCURACY		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. D. Copp		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Atmospheric Sciences Laboratory White Sands Missile Range, NM, 88002		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DA Task 1L162111AH71.F2
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Electronics Research and Development Command Adelphi, MD 20783		12. REPORT DATE August 1982
		13. NUMBER OF PAGES 38
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Elliptical probable errors
Space-time staleness
Met variability
Ballistic met parameters

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The effect of spacial and temporal frequency of radiosonde data on artillery accuracy is analyzed for the 8-in (short tube) and 155 mm (long tube) weapon systems. Range and deflection elliptical probable errors for hitting a stationary target are calculated for various firing scenarios using real meteorological data from central Europe. The individual errors due to variability and uncertainty in wind, temperature, and density measurements are also analyzed for several of the firing examples.

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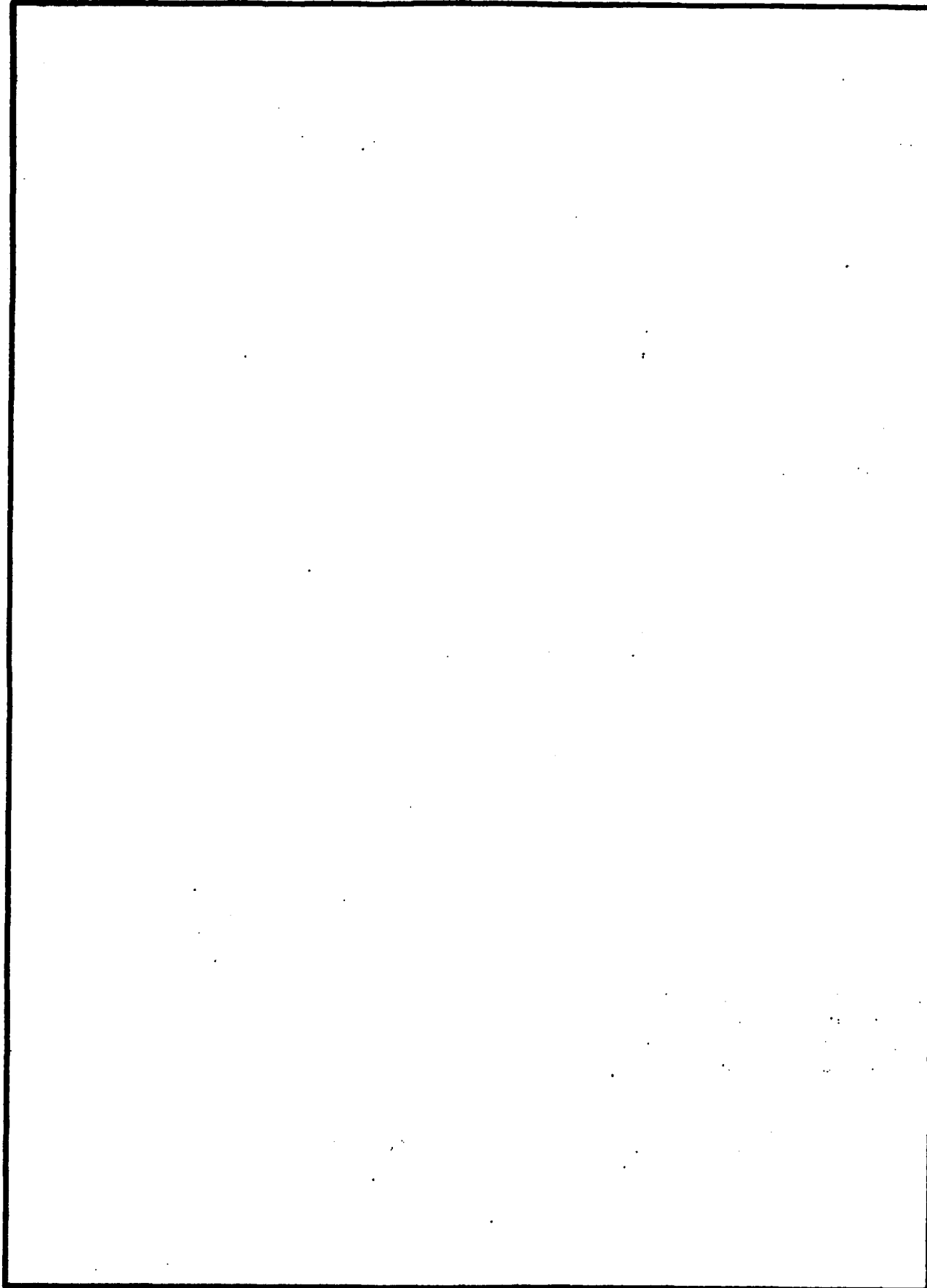
ACKNOWLEDGMENT

The author wishes to thank Dr. D. M. Swingle for developing the equations
which were used to generate the elliptical probable errors for this study.

CONTENTS

INTRODUCTION

The effects of wind, temperature, and density on a projectile are easy to understand. Acquiring the necessary meteorological (met) data so corrections can be applied before firing the projectile, however, is easier to talk about than to do. Often a weapon will be fired using a met message several hours old, or a projectile will be fired in a direction opposite to that which the radiosonde balloon was carried by the prevailing wind. Because the balloon and projectile will never be at the same place at the same time, the met message will always be stale. Also, no radiosonde and angular tracking system is completely free of measurement error. Thus we will always be firing a projectile using met data that is not entirely correct for the current time and location. The purpose of this study is to show in a statistical manner how range and deflection probable errors increase due to space-time staleness and to measurement uncertainty of the ballistic met message parameters. The probable errors generated for this study were attained using equations developed by Swingle* that describe the variability and measurement errors of the ballistic met message parameters.

DISCUSSION

There are four basic types of met error that will affect the range accuracy of a field artillery weapon. These errors are (1) time and space variability of ballistic wind, (2) measurement uncertainty of ballistic wind, (3) time and space variability of ballistic temperature and density, and (4) measurement uncertainty of ballistic temperature and density. Because of the relationship between temperature and density, as seen by the equation of state, it is necessary to compute the combined effect of their variations.

All of the above individual errors in the met data will be expressed as variances for the range and deflection components of trajectory. The sum of the range and deflection variances then can be converted to standard deviations and finally to elliptical probable errors of the range and deflection estimate. Expressing the total range and deflection variances in equation form:

$$X^2 = ST \cdot RWV + RWM + ST \cdot RTDV + RTDM \tag{1}$$

$$Y^2 = ST \cdot DWV + DWM \tag{2}$$

---

*Swingle, D. M., unpublished work, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 1979.

where

X^2 = total range variance (m^2)

Y^2 = total deflection variance (m^2)

ST = space-time staleness factor (min)

RWV = range impact variance due to wind variability (m^2/min)

RWM = range impact variance due to wind measurement error (m^2)

RTDV = range impact variance due to temperature and density variability (m^2/min)

RTDM = range impact variance due to temperature and density measurement error (m^2)

DWV = deflection impact variance due to wind variability (m^2/min)

DWM = deflection impact variance due to wind measurement error (m^2).

Note that the temperature and density contributions to the deflection component of error have been dropped since they are negligible compared to the wind effects.

Many studies[1][2][3] of wind variability in the last 30 years have focused on finding how the wind vector at a point varied in time or how the wind vector varied from point to point in space at the same instant in time. Studies[4][5] have also been conducted to relate wind temporal and spacial variability. The space-time relation of parameter variability is important to this study since we want to show how accuracy of the weapon system is affected by spacial as well as temporal staleness of the ballistic met message. Since a simple scaling factor is used to equate spacial and temporal variation, the spacial staleness of the met message due to the separation between the radiosonde and the projectile can be expressed as a staleness in time. The wind studies[5] at

[1]Lowenthal, M., and R. Bellucci, "Variability of Ballistic Winds," ECOM-3529, US Army Electronics Command, Fort Monmouth, NJ, 1970.

[2]Durst, C. S., "The Variation of Wind With Time and Distance," Geophysical Memoir No 93, UK Meteorological Office, 1954.

[3]"Exercise Summerwind in the Meppen Area (West Germany)," Met Working Paper No 1, NATO Report, 4-20 July 1966.

[4]"Report on Exercise Summerwind by Denmark and the Netherlands," Met Working Paper No 85, NATO Report, 1971.

[5]Arnold, A., and R. Bellucci, "Variability of Ballistic Meteorological Parameters," Tech Memo M-1913, US Army Signal Corps Engineering Laboratories, Fort Monmouth, NJ, 1957.

Meppen, West Germany, indicate an equivalence in ballistic wind variability between 1 h in time and 30 km in distance. This can be simplified to a 2-min time interval being equivalent to a spacial separation of 1 km. This scaling factor will certainly vary some from day to day and from location to location, but the value of the 2 min/km will be used for this study since it was obtained in the NATO area and is comparable in magnitude to the results found by others.[*]

We can now define the total space-time factor, used in equations (1) and (2) representing the total space and time age of the met information.

$$ST = 2 \cdot S + T \tag{3}$$

where

S = the separation of balloon and projectile when both are at the projectile's maximum trajectory ordinate (km)

T = the time interval between the measurement of the met data and the firing of the artillery weapon (min)

The factor 2 which multiplies S is the scaling factor in min/km that relates space to time variation. The variability in windspeed due to a separation of 1 km in space between points, then, is approximately equivalent to the variability during a 2-min time interval at a single point.

In the above expression, T is the time between measurement of the met parameter and the firing of the weapon by the artilleryman. The actual measurement of wind, temperature, and density is made throughout the layer from the ground up to whichever ballistic line the projectile will reach. Depending on the thickness of the layer, the balloon could take 10, 20 or more minutes to reach the altitude of the desired ballistic line. A question arises, then, as to which point in time we take as the time of measurement. For this study it was assumed that the measurement time occurs when the radiosonde balloon reaches the altitude that corresponds to the midpoint or maximum ordinate of the projectile trajectory. Factors contributing to the time staleness of the met data are time spent tracking the balloon above the ballistic line of interest, computation of the ballistic met message, lag before broadcast of the met message, and the lag between broadcast time and firing time.

A number of factors will affect the spacial staleness, S, in equation (3), also. These factors include relative position of met station and weapon,

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[*]Engebos, Bernard F., "A Least Squares Approach to Missing Meteorological Data," ASL-CR-82-0008-1, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 1982.

firing direction of the weapon, balloon ascent rate, ballistic line the projectile will reach, and often, most importantly, the speed and direction of the wind. Although spacial staleness is improved when the balloon path and projectile trajectory are close, space staleness can be quite large when the firing direction is opposite that of the mean wind and drift of the radiosonde.

A brief explanation concerning the calculation of terms in equations (1) and (2) is included to further clarify the text.

1. The impact variance due to wind variability is found by multiplying the coefficient of ballistic wind variability* (Kn²/min) times the space-time factor (min) times the square of the unit effect of a range or deflection wind (m²/kn²). (Unit effects were obtained from the proper firing tables).'

2. The temperature and density variability term in equation (1) is found by multiplying the combined error per unit staleness due to temperature and density variability* (m²/min) times the space-time factor (min).

3. The combined variance due to temperature and density measurement uncertainty was computed using a lengthy equation* involving temperature and density random and bias measurement errors.

4. Impact variances due to wind measurement were calculated by multiplying the ballistic wind component measurement variance* (kn²) times the square of the unit effect of a range or deflection wind (m²/kn²).

These ballistic wind component measurement variances, for an AN/GMD-1 tracking system, were calculated by Swingle* for balloon ascent rates of 300 m/min, 400 m/min, and 500 m/min. This variance includes the error in balloon height measurement as well as balloon tracking error. There is quite a difference in these variances depending on balloon ascent rate and the ballistic line number. Table 1 lists these error variances for each balloon ascent rate. The major source of the error from the tracking system arises from angular errors because of ground reflections of the radiosonde signals. The tracking error is a function of balloon elevation angle and is less serious for a fast rising balloon than for a slower rising balloon.

With the appropriate information at hand, the total range and deflection impact variances given by equations (1) and (2) can now be calculated. Taking the square root of the variance yields the standard deviation, and multiplication by the constant factor* 1.1774 converts the standard deviation to the elliptical probable error of the range and deflection estimate. These range and deflection probable errors represent the 50 percent confidence limits for a population of projectiles fired at a fixed target. In other words, if a number of shells were fired at a target, 50 percent of the shells would land in an ellipse centered on the target with a major radius equal to

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*Swingle, D. M., unpublished work, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 1979.

'Firing Tables, FT 155-AM-1, 1972, FT 8-J-4, 1967, Department of the Army, Washington, DC.

TABLE 1. BALLISTIC WIND COMPONENT VARIANCE (Kn^2) FOR AN AN/GMD-1
          TRACKING SYSTEM

| Ballistic Line | Balloon Ascent Rates | | |
Number	300 m/min	400 m/min	500 m/min
1	.047	.071	.101
2	.010	.009	.009
3	.016	.011	.009
4	.033	.022	.017
5	.163	.052	.038
6	.804	.071	.051
7	3.505	.219	.092
8	2.685	.549	.132
9	145.239	.773	.137
10	184.254	1.979	.216
11	212.168	3.149	.274
12	258.732	4.113	.419
13	255.730	2.366	.515
14	193.627	1.125	.424
15	142.338	1.031	.301

the range probable error and with a minor radius equal to the deflection probable error. Again, it should be pointed out that these probable errors are only the result of variability and measurement uncertainty of the met parameters; they do not represent errors due to lack of correction for the meteorology, variations in muzzle velocity, variations in angle of departure, etc.

RESULTS

Real meteorological sounding data, from Munich, Germany, in the early spring of 1976, were used for the probable error calculations. In calculating the probable errors, the numbers of possible combinations of range, weapon, charge, and balloon ascent rate are enormous. This problem was reduced to a manageable size by considering only some of the larger error cases. Since the unit effects increase with range, the tests made were for long ranges and larger charges for the 155-mm and 8-in weapon systems. It was also assumed that the target and gun were at the same altitude. For each range, a low and high trajectory test was conducted, showing the increased error when firing to a higher maximum ordinate. To demonstrate the effects of windspeed on the errors, data for several days of high winds (1 Jan and 21 Jan), low wind (8

Feb), and a baseline test with no wind were generated. All examples assumed a balloon ascent rate of 400 m/min. All of these assumptions seem realistic for a battlefield situation. Table 2 shows the firing scenarios for the eleven cases in which errors were calculated.

TABLE 2. FIRING SCENARIOS FOR THE MET DATA FREQUENCY STUDY

Case	Date (1976)	Time (LST)	Weapon	Charge	Range (km)	Trajectory Max Ord (km)	Mean Wind (kn)	Ballistic Wind (kn)
1	21 Jan	1200	8 in	7	15	2.890	44.86	46.44
2	21 Jan	1200	8 in	7	15	7.544	62.77	73.04
3	21 Jan	1200	8 in	5	10	1.550	40.78	48.65
4	21 Jan	1200	8 in	5	10	4.919	52.64	58.82
5	21 Jan	1200	155 mm	8	16	3.056	45.21	52.14
6	21 Jan	1200	155 mm	8	15	8.648	64.86	70.97
7	21 Jan	1200	155 mm	6W	11	1.865	42.96	48.65
8	21 Jan	1200	155 mm	6W	11	5.306	54.35	62.97
9	Imaginary		8 in	7	12	1.445	0.00	0.00
10	8 Feb	1200	8 in	7	12	1.445	2.87	3.28
11	1 Jan	1200	8 in	7	12	1.445	44.12	46.25

For each test the time staleness was varied from 0 to 360 min and the spacial staleness was varied from 0 to 60 km. The smaller values of staleness, while not realistic to the battlefield, show the amount of minimum error due to measurement uncertainty. A complete array of the probable errors for the entire spacial and temporal range mentioned above is given in tables in appendix A for all the cases listed in table 2.

Figure 1 shows range probable error versus time staleness for a constant spacial staleness of 20 km for cases 1 through 8 listed in table 2. As one would expect the larger errors occur for the longer ranges and higher winds because unit effects increase with range, and wind variability increases with windspeed. The lines in this figure are nearly straight, as one might expect from the linear relationship of time (in the space-time factor) to range variance in equation (1). The slope of the probable error curve is slightly larger at the low age end of the graph than for the high end, but the difference is small. Obviously, the optimum age for met data so far as accuracy is concerned will be as small as possible, since fresher met data will be used and met parameter variability will be reduced. However, the information in the figure is useful since the graph does quantify the error as a function of time lag. Another interesting feature of this graph is that

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range probable error does not vanish even if there is no time separation between measurement and firing. Part of this error is due to the 20 km of spacial staleness in this example; the remaining amount of error is due to the measurement uncertainty of wind, temperature, and density.
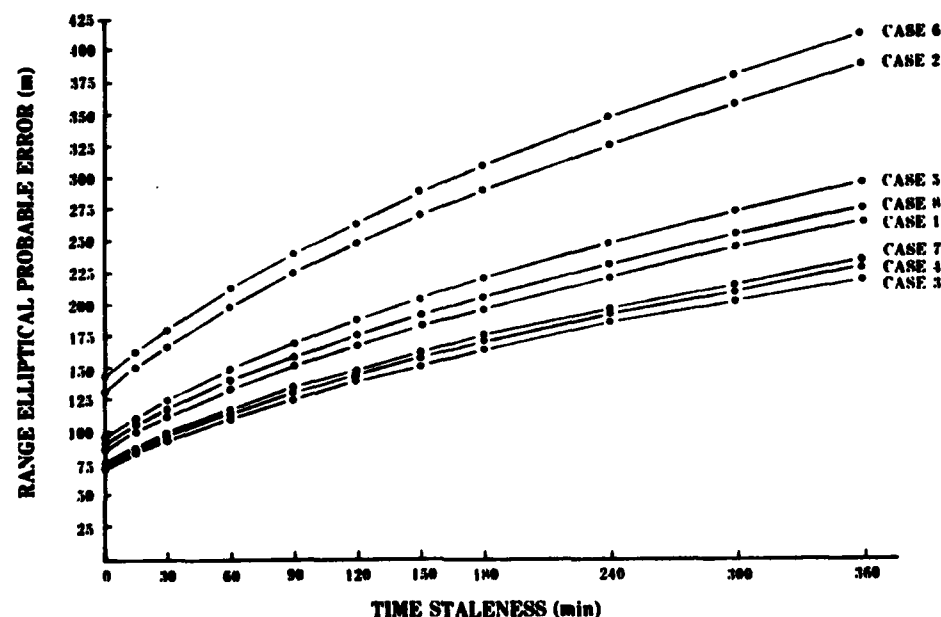
Figure 1.   Range elliptical probable error versus time staleness while the spacial staleness was fixed at 20 km (cases 1 through 8).

Figure 2 shows deflection probable error versus time staleness for cases 1 through 8 in table 2. Again a spacial separation of 20 km was used. These errors are not as large as the range errors nor do they increase quite as rapidly with increasing temporal staleness, but similar to range error they do increase in a nearly linear manner. The main reason these deflection errors are smaller than the corresponding range errors is that the unit effects for the crosswind component of wind are quite a bit less than for the range wind component. Recall, too, that temperature and density effects were small for the deflection component and, consequently, were neglected.

The effect of spacial staleness on range probable error is shown in figure 3. For these examples the time staleness was fixed at 2 h while the spacial staleness was varied. Similar to figure 1, and for reasons previously discussed, the error increases with range and windspeed. These error curves are quite linear, but the dependence of the error on space is a little weaker than the dependence on time as shown in figure 1. The main reason for the weaker dependence is that in the space and time scales of the battlefield, the variability of wind in time is usually greater than in space. Recall that a 2-min change in time is approximately equivalent to a 1 km change in space. A typical met spacial staleness is about 25 km and a typical time staleness from measurement to use is about 3 h. Using the above rule the staleness owing to met spacing is 2 min/km times 25 km or 50 min, while the staleness owing to time is 180 min.

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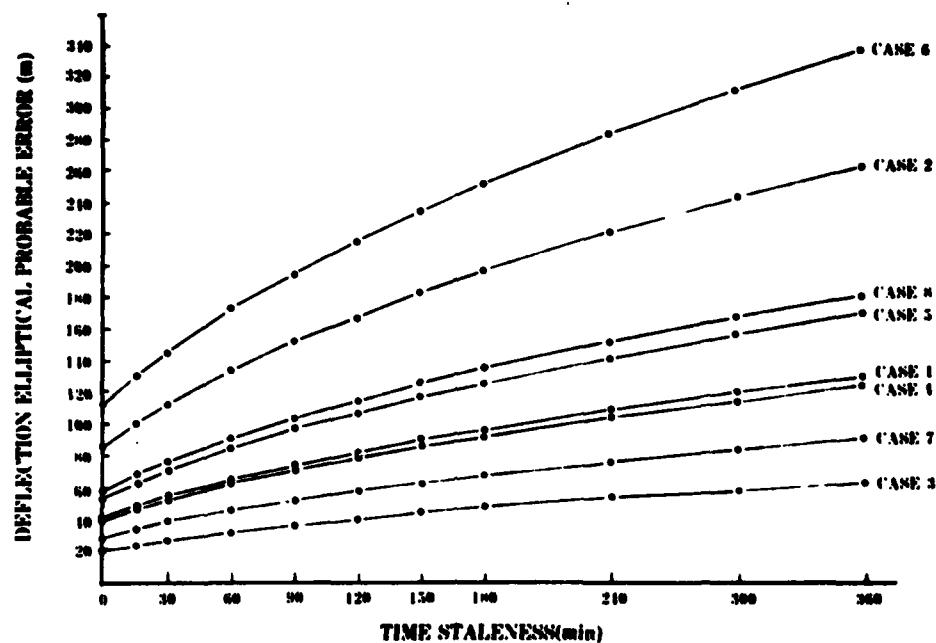
Figure 2. Deflection elliptical probable error versus time staleness while spacial staleness was fixed at 20 km (cases 1 through 8).
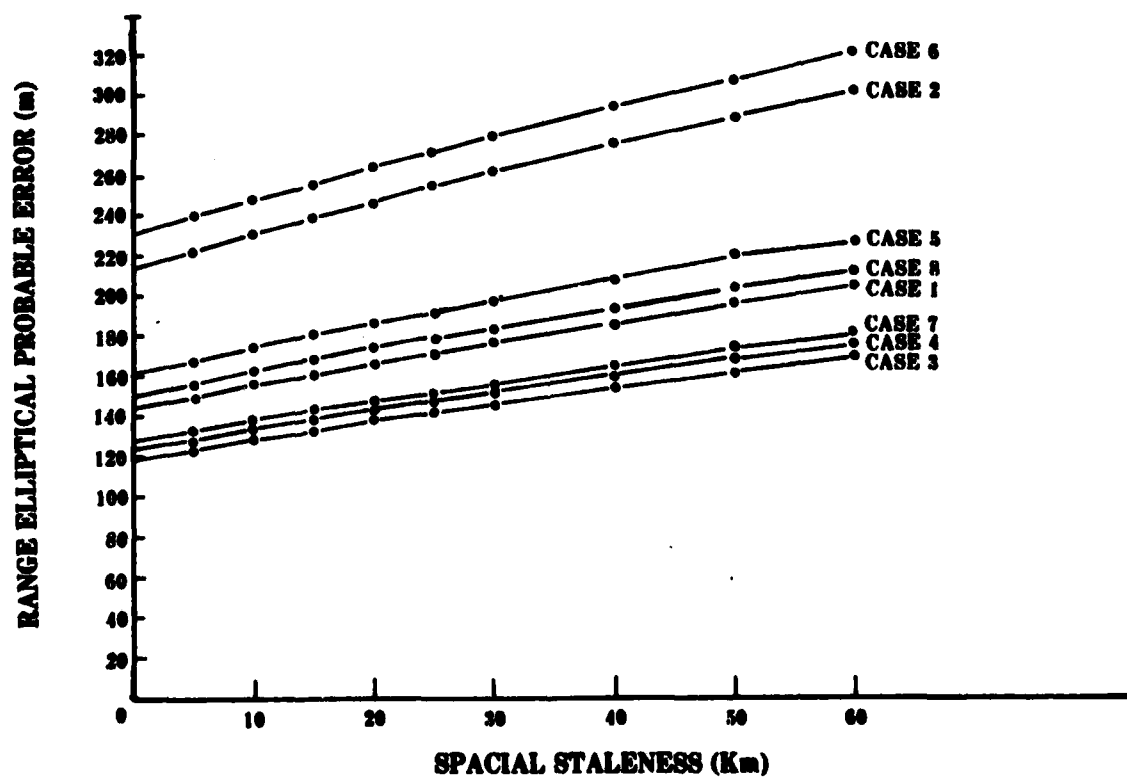
Figure 3. Range elliptical probable error versus spacial staleness while the time staleness was held at 2 h (cases 1 through 8).

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Figure 4 is a graph of deflection probable error versus spacial staleness while the time lag was fixed at 2 h. The deflection probable errors are again less than the range probable errors. Also note that the slopes of the lines in figure 4 are not as large as those in figure 2 since met parameter variability in time is usually greater than in space.

To further access the effects of windspeed on probable error, several trials were conducted where ballistic windspeed ranged from moderate to an imaginary case with no wind while all other parameters, like range and quadrant elevation (QE), remained constant. The firing scenarios used were cases 9, 10, and 11 from table 2.

Figure 5 shows both the range and deflection probable error versus time staleness for a constant spacial staleness of 20 km. Again, errors increase with windspeed, the rate of error growth increases with speed, and errors do not disappear in the absence of wind since there is still a measurement uncertainty even when we have measured no wind. Also temperature and density contributions to the error are still left in the case of range probable error.

Figure 6 shows plots of probable error as a function of spacial staleness while the time lag was held at 2 h. The errors in this figure are linear with distance, and the size of the error is directly related to windspeed since all other met and firing conditions remain constant for these cases. Again the probable error rate of change in space is less than the change in time for the space and time scales in these examples.

Trying to separate the individual effects of wind, temperature, and density when viewing these graphs is quite difficult. To illustrate their effects, the individual range and deflection impact standard deviations as a function of space and time have been listed for cases 9 and 11 of table 2 in appendix A. Note that the errors due to measurement remain constant as time or space is varied. This occurs since the error is made at the time of measurement and does not depend on when the measured value is used. For a moderate ballistic wind, case 11, the errors due to met variability are dominant over the measurement errors with the range wind variability error being the largest. However, even with no wind as in case 9, the range wind variability is still the dominant error. This illustrates the importance of knowing the current wind no matter what its value. For these examples temperature and density variability and measurement errors were both important, but wind measurement error was quite small.

CONCLUSIONS

This study seems to reinforce what is already known: variability of ballistic wind is the largest source of met error for artillery weapons; but errors caused by temperature and density variation can make substantial contributions to the total error, especially when winds are light. The contribution to the total error because of wind measurement is highly dependent on balloon ascent rate and the ballistic zone to which measurements are made. Using a balloon with a 300 m/min ascent rate when making measurements above ballistic zone 8 can produce tremendous errors as seen by the measurement uncertainties listed in table 1. While the results of this study indicate what the optimum spacial and temporal frequency for obtaining met data is, as one would expect, as often as possible, the study is useful in quantifying errors that do exist. The user, then, can decide what trade-off is best for a particular battlefield situation.

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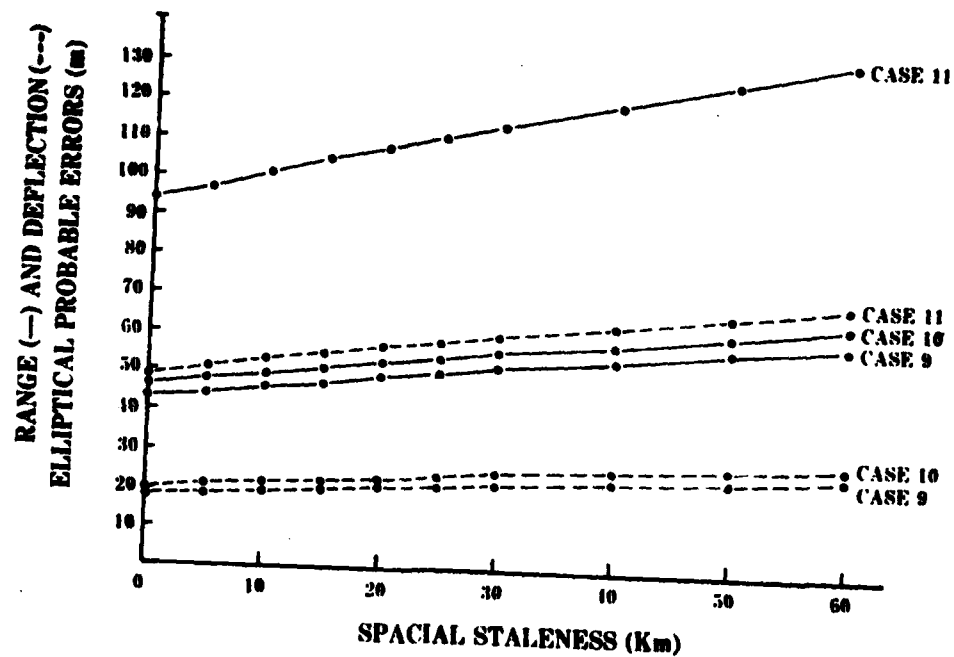
Figure 6. Range and deflection elliptical probable error versus spacial staleness while the time staleness was held at 2 h (cases 9 through 11).

REFERENCES

1. Lowenthal, M., and R. Bellucci, "Variability of Ballistic Winds," ECOM-3529, US Army Electronics Command, Fort Monmouth, NJ, 1970.

2. Durst, C. S., "The Variation of Wind with Time and Distance," Geophysical Memoir No 93, UK Meteorological Office, 1954.

3. "Exercise Summerwind in the Meppen Area (West Germany)," Met Working Paper No 1, NATO Report, 4-20 July 1966.

4. "Report on Exercise Summerwind by Denmark and the Netherlands," Met Working Paper No 85, NATO Report, 1971.

5. Arnold, A., and R. Bellucci, "Variability of Ballistic Meteorological Parameters," Tech Memo M-1913, US Army Signal Corps Engineering Laboratories, Fort Monmouth, NJ, 1957.

6. Engebos, Bernard F., "A Least Squares Approach to Missing Meteorological Data," ASL-CR-82-0008-1, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 1982.

7. Firing Tables, FT 155-AM-1, 1972, FT 8-J-4, 1967, Department of the Army, Washington, DC.

APPENDIX A

Tables A-1 through A-11 present range and deflection elliptical probable errors as a function of spacial and temporal staleness for all cases listed in table 2 in the text. Tables A-12 through A-15 present the individual range and deflection impact standard deviations as a function of space and time staleness for cases 9 and 11 in table 2 in the text.

TABLE A-1. RANGE AND DEFLECTION ELLIPTICAL PROBABLE ERRORS (METERS)

WEAPON M110A1 HOWITZER

TIME STALENESS(MIN) SPACE STALENESS(KM)		WARHEAD M106		RANGE(KM) 15.000		QE(MILS) 551.7		CHARGE 7		MAX ORDINATE (KM) 2.890		
		0	15	30	60	90	120	150	180	240	300	360
0	R	13	53	73	103	126	145	162	178	205	229	251
	D	3	25	35	50	61	71	79	86	100	111	122
5	R	44	67	84	111	133	151	167	182	209	233	254
	D	21	32	41	54	64	73	81	89	102	113	124
10	R	60	79	94	119	139	157	173	187	213	236	258
	D	29	38	46	58	68	76	84	91	104	115	125
15	R	73	89	103	126	145	162	178	192	217	240	261
	D	35	43	50	61	71	79	86	93	106	117	127
20	R	84	99	111	133	151	167	182	196	221	244	264
	D	41	48	54	64	73	81	89	95	108	119	129
25	R	94	107	119	139	157	173	187	201	225	247	268
	D	46	52	58	68	76	84	91	98	110	120	130
30	R	103	115	126	145	162	178	192	205	229	251	271
	D	50	56	61	71	79	86	93	100	111	122	132
40	R	119	129	139	157	173	187	201	213	236	258	277
	D	58	63	68	76	84	91	98	104	115	125	135
50	R	133	142	151	167	182	196	209	221	244	264	283
	D	64	69	73	81	89	95	102	108	119	129	138
60	R	145	154	162	178	192	205	217	229	251	271	289
	D	71	75	79	86	93	100	106	111	122	132	141

WEAPON

BALL_WIND(KT) 46.44   WD MSMT VNC(KT^2) .071   AK(M/MIN) 400

NO BOMBLETS

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TABLE A-2. RANGE AND DEFLECTION ELLIPTICAL PROBABLE ERRORS (METERS)

WEAPON M110A1 HOWITZER

TIME STALENESS(MIN) / SPACE STALENESS(KM)		WARHEAD M106		RANGE(KM) 15.000		QE(MILS) 1060.2		CHARGE 7		MAX ORDINATE (KM) 7.544		
		0	15	30	60	90	120	150	180	240	300	360
0	R	40	85	113	155	188	216	240	263	303	338	369
	D	24	56	75	104	126	145	162	177	204	227	249
5	R	73	105	129	167	198	224	248	270	309	343	375
	D	48	70	86	112	133	151	167	182	203	231	252
10	R	95	121	143	178	207	232	256	277	315	349	379
	D	63	81	95	119	139	156	172	186	212	235	256
15	R	113	136	155	188	216	240	263	283	321	354	384
	D	75	91	104	126	145	162	177	191	216	238	259
20	R	129	149	167	198	224	248	270	290	326	359	389
	D	86	100	112	133	151	167	182	195	220	242	262
25	R	143	161	178	207	232	256	277	296	332	364	394
	D	95	108	119	139	156	172	186	199	224	245	265
30	R	155	172	188	216	240	263	283	303	339	369	399
	D	104	116	126	145	162	177	191	204	227	249	269
40	R	178	193	207	232	256	277	296	315	349	379	409
	D	119	130	139	156	172	186	199	212	235	256	275
50	R	198	211	224	248	270	290	309	326	359	389	417
	D	133	142	151	167	182	195	208	220	242	262	281
60	R	216	228	240	263	283	303	321	338	369	399	426
	D	145	154	162	177	191	204	216	227	249	269	287

WEAPON

BALL. WIND(KT) 73.04   WD MSMT VNC(KT^2) 1.979   AR(M/MIN) 400

NO BOMBLETS

TABLE A-3. RANGE AND DEFLECTION ELLIPTICAL PROBABLE ERRORS (METERS)

WEAPON
M110A1 HOWITZER

		WARHEAD M106		RANGE(KM) 10.000		QE(MILS) 512.4		CHARGE 5		MAX ORDINATE (KM) 1.550		
TIME STALENESS(MIN) / SPACE STALENESS(KM)		0	15	30	60	90	120	150	130	240	300	360
0	R	6	43	60	85	104	120	134	147	170	190	209
	D	1	12	17	24	29	34	38	41	48	53	59
5	R	35	55	70	92	110	125	139	151	174	193	211
	D	10	15	20	26	31	35	39	43	49	54	59
10	R	49	65	70	98	115	130	143	155	177	196	214
	D	14	18	22	28	32	36	40	44	50	55	60
15	R	60	74	85	104	120	134	147	159	180	199	217
	D	17	21	24	29	34	38	41	45	51	56	61
20	R	70	82	92	110	125	139	151	163	184	202	219
	D	20	23	26	31	35	39	43	46	52	57	62
25	R	78	89	98	115	130	143	155	166	187	205	222
	D	22	25	28	32	36	40	44	47	53	58	62
30	R	85	95	104	120	134	147	159	170	190	208	225
	D	24	27	29	34	38	41	45	48	53	58	63
40	R	98	107	115	130	143	155	166	177	196	214	230
	D	28	30	32	36	40	44	47	50	55	60	65
50	R	110	118	125	139	151	163	174	184	202	219	235
	D	31	33	35	39	43	46	49	52	57	62	66
60	R	120	128	134	147	159	170	180	190	208	225	240
	D	34	36	38	41	45	48	51	53	58	63	68

BALL. WIND(KT)   WD MSMT UNC(KT^2)   AK(M/MIN)
48.65   052   400
                 NO BOMBLETS

WEAPON

TABLE A-4. RANGE AND DEFLECTION ELLIPTICAL PROBABLE ERRORS (METERS)

WEAPON M110A1 HOWITZER		WARHEAD M106	RANGE (KM) 10.000			UE(MILS) 1078.4		CHARGE 5		MAX ORDINATE (KM) 4.919		
TIME STALENESS(MIN) SPACE STALENESS(KM)		0	15	30	60	90	120	150	180	240	300	360
0	R	13	46	64	89	109	126	140	154	177	198	217
	D	7	25	34	48	59	68	75	83	95	106	117
5	R	38	59	73	96	115	131	145	158	181	201	220
	D	21	31	39	52	62	70	78	85	97	108	118
10	R	53	69	82	103	120	136	149	162	185	205	223
	D	28	37	44	55	65	73	80	87	99	110	120
15	R	64	78	89	109	126	140	154	166	188	208	226
	D	34	42	48	59	68	75	83	89	101	112	121
20	R	73	86	96	115	131	145	158	170	192	211	229
	D	39	46	52	62	70	78	85	91	103	113	123
25	R	82	93	103	120	136	149	162	174	195	214	232
	D	44	50	55	65	73	80	87	93	105	115	124
30	R	89	100	109	126	140	154	166	177	198	217	234
	D	48	54	59	68	75	83	89	95	106	117	126
40	R	103	112	120	136	149	162	174	185	205	223	240
	D	55	60	65	73	80	87	93	99	110	120	129
50	R	115	123	131	145	158	170	181	192	211	229	245
	D	62	66	70	78	85	91	97	103	113	123	132
60	R	126	133	140	154	166	177	188	198	217	234	251
	D	68	72	75	83	89	95	101	106	117	126	135

BALL. WIND(KT) WD MSMT VNC(KT^2) AR(M/MIN)
58.82 .549 400
NO BOMBLETS

WEAPON

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TABLE A-5. RANGE AND DEFLECTION ELLIPTICAL PROBABLE ERRORS (METERS)

WEAPON M109A1 HOWITZER WARHEAD M107 RANGE(KM) 16.000 QE(MILS) 518.6 CHARGE 8 MAX ORDINATE (KM) 3.056

TIME STALENESS(MIN) SPACE STALENESS(KM)		0	15	30	60	90	120	150	180	240	300	360
0	R	21	61	84	116	141	163	182	199	229	256	281
	D	6	33	46	65	80	92	103	112	130	145	159
5	R	51	77	96	125	149	169	188	204	234	260	284
	D	27	42	53	70	84	96	106	116	133	148	161
10	R	69	90	106	134	156	176	193	210	239	265	288
	D	38	50	60	75	88	99	109	119	135	150	163
15	R	84	101	116	141	163	182	199	215	243	269	292
	D	46	56	65	80	92	103	112	121	138	152	165
20	R	96	111	125	149	169	188	204	220	248	273	296
	D	53	62	70	84	96	106	113	124	140	155	168
25	R	106	121	134	156	176	193	210	225	252	277	299
	D	60	68	75	88	99	109	119	127	143	157	170
30	R	116	129	141	163	182	199	215	229	256	281	303
	D	65	73	80	92	103	112	121	130	145	159	172
40	R	134	145	156	176	193	210	225	239	265	288	310
	D	75	82	88	99	109	119	127	135	150	163	176
50	R	149	160	169	188	204	220	234	248	273	296	317
	D	84	90	96	106	116	124	133	140	155	168	180
60	R	163	173	182	199	215	229	243	256	281	303	324
	D	92	97	103	112	121	130	138	145	157	172	184

BALL. WIND(KT) 52.14   WD MSMT UNC(KT^2) .219   AR(M/MIN) 400

NO BOMBLETS

WEAPON

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TABLE A-7. RANGE AND DEFLECTION ELLIPTICAL PROBABLE ERRORS (METERS)

WEAPON: M109A1 HOWITZER

Parameters: WARHEAD M107 | RANGE(KM) 11.000 | QE(MILS) 526.8 | CHARGE 6 | MAX ORDINATE (KM) 1.865

TIME STALENESS (MIN)		WARHEAD M107	RANGE(KM) 11.000			QE(MILS) 526.8			CHARGE 6	MAX ORDINATE (KM) 1.865		
SPACE STALENESS (KM)		0	15	30	60	90	120	150	180	240	300	360
0	R	7	46	65	91	111	129	144	157	182	203	223
	D	2	17	25	35	43	49	55	60	69	78	85
5	R	38	59	74	98	117	134	148	162	186	207	226
	D	14	22	28	38	45	51	57	62	71	79	86
10	R	53	70	83	105	123	139	153	166	189	210	229
	D	20	27	32	40	47	53	58	63	72	80	87
15	R	65	79	91	111	129	144	157	170	193	213	232
	D	25	30	35	43	49	55	60	65	74	81	88
20	R	74	87	98	117	134	148	162	174	196	216	235
	D	28	33	38	45	51	57	62	66	75	83	90
25	R	83	95	105	123	139	153	166	178	200	219	238
	D	32	36	40	47	53	58	63	68	76	84	91
30	R	91	102	111	129	144	157	170	182	203	223	240
	D	35	39	43	49	55	60	65	69	78	85	92
40	R	105	114	123	139	153	166	178	189	210	229	246
	D	40	44	47	53	58	63	68	72	80	87	94
50	R	117	126	134	148	162	174	186	196	216	235	252
	D	45	48	51	57	62	66	71	75	83	90	96
60	R	129	136	144	157	170	182	193	203	223	240	257
	D	49	52	55	60	65	69	74	78	85	92	98

BALL. WIND(KT) 40.65   WD MSMT VNC(KT^2) .052   AR(M/MIN) 400

WEAPON   NO BOMBLETS

TABLE A-8. RANGE AND DEFLECTION ELLIPTICAL PROBABLE ERRORS (METERS)

WEAPON: M109A1 HOWITZER

TIME STALENESS(MIN)	R/D	WARHEAD M107		RANGE(KM) 11.000		QE(MILS) 1049.7		CHARGE 6		MAX ORDINATE (KM) 5.306		
SPACE STALENESS(KM)		0	15	30	60	90	120	150	180	240	300	360
0	R	19	56	78	108	132	152	169	185	214	239	262
	D	11	37	50	70	86	99	111	121	140	156	171
5	R	47	71	89	117	139	158	175	190	218	243	265
	D	31	46	58	76	90	103	114	124	142	158	173
10	R	64	83	99	124	145	164	180	195	223	247	269
	D	42	54	64	81	95	107	118	127	145	161	175
15	R	78	94	108	132	152	169	185	200	227	250	272
	D	50	61	70	86	99	111	121	131	148	164	178
20	R	89	104	117	139	158	175	190	205	231	254	276
	D	58	68	76	90	103	114	124	134	151	166	180
25	R	99	112	124	145	164	180	195	209	235	258	279
	D	64	73	81	95	107	118	127	137	153	168	182
30	R	108	121	132	152	169	185	200	214	239	262	282
	D	70	77	86	99	111	121	131	140	156	171	184
40	R	124	135	145	164	180	195	209	223	247	269	289
	D	81	88	95	107	118	127	137	145	161	175	189
50	R	139	149	158	175	190	205	218	231	254	276	296
	D	90	97	103	114	124	134	142	151	166	180	193
60	R	152	161	169	185	200	214	227	239	262	282	302
	D	99	105	111	121	131	140	148	156	171	184	197

BALL. WIND(KT) 62.97 WD MSMT VNC(KT^2) .773 AK(M/MIN) 400

NO BOMBLETS

WEAPON

TABLE A-9. RANGE AND DEFLECTION ELLIPTICAL PROBABLE ERRORS (METERS)

WEAPON M110A1 HOWITZER

		WARHEAD M106		RANGE(KM) 12.000		QE(MILS) 360.1		CHARGE 7		MAX ORDINATE (KM) 1.445	
TIME STALENESS(MIN)											
SPACE STALENESS(KM)	0	15	30	60	90	120	150	180	240	300	360
0	R	13	19	24	32	38	43	47	52	59	66	72
	D	1	6	9	13	16	18	20	22	25	28	31
5	R	17	23	27	34	39	44	49	53	60	67	73
	D	5	8	10	14	16	19	21	23	26	29	31
10	R	21	26	29	36	41	46	50	54	61	68	74
	D	7	10	12	15	17	19	21	23	26	29	32
15	R	24	28	32	38	43	47	52	56	63	69	75
	D	9	11	13	16	18	20	22	24	27	30	32
20	R	27	31	34	39	44	49	53	57	64	70	76
	D	10	12	14	16	19	21	23	24	27	30	33
25	R	29	33	36	41	46	50	54	58	65	71	77
	D	12	13	15	17	19	21	23	25	28	31	33
30	R	32	35	38	43	47	52	56	59	66	72	77
	D	13	14	16	18	20	22	24	25	28	31	33
40	R	36	39	41	46	50	54	58	61	68	74	79
	D	15	16	17	19	21	23	25	26	29	32	34
50	R	39	42	44	49	53	57	60	64	70	76	81
	D	16	18	19	21	23	24	26	27	30	33	35
60	R	43	45	47	52	56	59	63	66	72	77	83
	D	18	19	20	22	24	25	27	28	31	33	36

WEAPON

BALL. WIND(KT)   WD MSMT UNC(KT^2)   AR(M/MIN)
0.00   .022   400

NO BOMBLETS

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TABLE A-11. RANGE AND DEFLECTION ELLIPTICAL PROBABLE ERRORS (METERS)

WEAPON M110A1 HOWITZER	WARHEAD M106		RANGE(KM) 12.000		QE(MILS) 360.1		CHARGE 7		MAX ORDINATE (KM) 1.445		
	0	15	30	60	90	120	150	180	240	300	360
TIME STALENESS(MIN) SPACE STALENESS(KM)											
0 R	13	35	48	67	81	94	105	114	132	147	161
D	1	17	25	35	42	49	55	60	69	77	85
5 R	30	44	55	72	86	97	108	117	135	150	163
D	14	22	28	37	45	51	57	62	71	79	86
10 R	40	52	61	77	90	101	111	120	137	152	166
D	20	26	32	40	47	53	58	63	72	80	87
15 R	48	58	67	81	94	105	114	123	140	154	160
D	25	30	35	42	49	55	60	65	73	81	88
20 R	55	64	72	86	97	108	117	126	142	157	170
D	28	33	37	45	51	57	62	66	75	82	89
25 R	61	70	77	90	101	111	120	129	145	159	172
D	32	36	40	47	53	58	63	68	76	84	91
30 R	67	74	81	94	105	114	123	132	147	161	174
D	35	39	42	49	55	60	65	69	77	85	92
40 R	77	84	90	101	111	120	129	137	152	166	178
D	40	44	47	53	58	63	68	72	80	87	94
50 R	86	92	97	108	117	126	135	142	157	170	182
D	45	48	51	57	62	66	71	75	82	89	96
60 R	94	99	105	114	123	132	140	147	161	174	186
D	49	52	55	60	65	69	73	77	85	92	99

WEAPON

BALL. WIND(KT) 46.25   WD MSMT UNC(KT^2) .022   AIR(M/MIN) 400

NO BOMBLETS

TABLE A-12. IMPACT RANGE AND DEFLECTION STANDARD DEVIATIONS (METERS)

WEAPON M110A1 HOWITZER	WARHEAD M106		RANGE(KM) 12.000		QE(MILS) 360.1		CHARGE 7		MAX ORDINATE (KM) 1.445		
TIME STALENESS(MIN)	0	15	30	60	90	120	150	180	240	300	360
RG WD VRBLTY	16	19	21	25	29	32	35	38	42	47	51
RG WD MSMT	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
RG TD VRBLTY	12	14	16	19	22	24	26	28	32	35	38
RG TD MSMT	11	11	11	11	11	11	11	11	11	11	11
DFL WD VRBLTY	9	10	12	14	16	18	19	21	23	26	28
DFL WD MSMT	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91

BALL. WIND(KT) 0.00   SPACIAL STALENESS(KM) 20.00   AK(M/MIN) 400

WEAPON
NO BOMBLETS

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TABLE A-13. IMPACT RANGE AND DEFLECTION STANDARD DEVIATIONS (METERS)

WEAPON M110A1 HOWITZER	WARHEAD M106	RANGE(KM) 12.000	QE(MILS) 360.1	CHARGE 7	MAX ORDINATE (KM) 1.445
TIME STALENESS(MIN)	0 15 30	60 90 120	150 180	240 300 360	
RG WD VRBLTY	44 51 58	69 79 88	96 103	116 128 139	
RG WD MSMT	1.66 1.56 1.66	1.66 1.66 1.66	1.66 1.66	1.66 1.66 1.66	
RG TD VRBLTY	12 14 16	19 22 24	26 28	32 35 38	
RG TD MSMT	11 11 11	11 11 11	11 11	11 11 11	
DFL WD VRBLTY	24 28 32	38 43 48	52 56	64 70 76	
DFL WD MSMT	.91 .91 .91	.91 .91 .91	.91 .91	.91 .91 .91	

BALL. WIND(KT)   SPACIAL STALENESS(KM)   AK(M/MIN)
46.25   20.00   400

WEAPON
NO BOMBLETS

TABLE A-14. IMPACT RANGE AND DEFLECTION STANDARD DEVIATIONS (METERS)

WEAPON M110A1 HOWITZER	WARHEAD M106		RANGE(KM) 12.000		QE(MILS) 360.1		CHARGE 7		MAX ORDINATE (KM) 1.445	
SPACE STALENESS(KM)	0	5	10	15	20	25	30	40	50	60
RG WD VRBLTY	28	29	30	31	32	33	34	36	38	39
RG WD MSMT	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
RG TD VRBLTY	21	22	22	23	24	25	25	27	28	29
RG TD MSMT	11	11	11	11	11	11	11	11	11	11
DFL WD VRBLTY	15	16	16	17	18	18	19	20	21	21
DFL WD MSMT	.91	.91	.91	.91	.91	.91	.91	.91	.91	.91

BALL. WIND(KT) 0.00   TIME STALENESS(MIN) 120   AK(M/MIN) 400

WEAPON
NO BOMBLETS

TABLE A-15. IMPACT RANGE AND DEFLECTION STANDARD DEVIATIONS (METERS)

WEAPON M110A1 HOWITZER	WARHEAD M106		RANGE(KM) 12.000		DE(MILS) 360.1		CHARGE 7		MAX ORDINATE (KM) 1.445	
SPACE STALENESS(KM)	0	5	10	15	20	30	40	50	60	
RG WD VRBLTY	76	79	82	85	88	93	98	103	108	
RG WD MSMT	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	
RG TD VRBLTY	21	22	22	23	24	25	27	28	29	
RG TD MSMT	11	11	11	11	11	11	11	11	11	
DFL WD VRBLTY	42	43	45	47	48	51	54	56	59	
DFL WD MSMT	.91	.91	.91	.91	.91	.91	.91	.91	.91	

BALL. WIND(KT) 46.25   TIME STALENESS(MIN) 120   AK(M/MIN) 400

WEAPON
NO BOMBLETS

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