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**Generation of Ballistic Meteorological Messages - Surface to
Surface (METB3s) from Computer Meteorological Messages
(METCMs)**

by James Cogan and David Sauter

ARL-TN-0550

July 2013

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14. ABSTRACT The armed forces of many North Atlantic Treaty Organization (NATO) members and other nations have used ballistic meteorological (MET) messages for surface to surface trajectories (METB3s) for many decades. It was developed before users had ready access to computers on the battlefield and is normally applied in a manual mode. The later computer MET message (METCM) came into use, as the name implies, after the advent of battlefield computers and continues to be widely used. Some newer artillery MET systems no longer generate METB3s since modern fire control systems use METCMs, and in some NATO nations, the more recent gridded MET message (METGM). Nevertheless, for certain applications and as a backup, there is a requirement to be able to produce a METB3 from a METCM generated locally or transmitted from another artillery MET system. This report briefly discusses a program that converts a METCM into a METB3, which can be applied to specific systems with appropriate modifications, and outlines a modified version for a handheld device. The program applies methods found in available field manuals and NATO publications. Some of the algorithms embodied in the program were extracted from a similar spreadsheet-based method developed at the Armament Research, Development and Engineering Center (ARDEC).					
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1. Introduction

The armed forces of many North Atlantic Treaty Organization (NATO) members and other nations have used ballistic meteorological (MET) message for surface to surface trajectories (METB3s) for many decades. It was developed before users had ready access to computers on the battlefield and is normally applied in a manual mode. The later computer MET message (METCM) came into use, as the name implies, after the advent of battlefield computers and continues to be widely used. Some newer artillery MET systems no longer generate METB3s since modern fire control systems use METCMs and, in some NATO nations, the more recent gridded MET message (METGM). Nevertheless for certain applications and as a backup, there is a requirement to be able to produce a METB3 from a METCM generated locally or transmitted from another artillery MET system.

This report briefly discusses a program that converts a METCM into a METB3, which can be applied to specific systems with appropriate modifications, and outlines a modified version for a handheld device. The program applies methods found in available field manuals and related NATO publications. Some of the algorithms embodied in the program were extracted from a similar spreadsheet-based method developed at the Armaments Research, Development, and Engineering Center (ARDEC). In addition, the report contains some samples of input and respective output messages.

2. Method

The METCM normally contains 32 data lines (zone or line 0 through 31), one for each message zone or layer. Except for the surface each line of MET data has mean values for the respective zones. The surface essentially repeats the values measured or generated by a numerical weather prediction (NWP) model for the surface. When a METCM is transmitted manually or when it is derived from radiosonde data, it may have fewer than 32 lines. The METB3 has 19 lines of data, but unlike the METCM each line above the surface (line or zone 0) contains a weighted mean of the mean values for that zone and all zones below not including zone 0. For example, the temperature for zone 5 is a weighted mean of the mean zone values for zones 1 through 5. The weighted mean value at line or zone 1 (0–200 m) is the zone value itself (weight of 1.00). Details on the METCM and METB3 may be found in Army field manuals (e.g., FM 3-09.15 (FM6-15)/MCWP 3-16.5, FM 6-16, and FM 6-40/MCWP 3-1.6.19) and NATO standardization agreements (e.g., STANAG 4061 and STANAG 4082) including information on message formats, variables, and required header data. The METGM is outside the scope of this report, but a description may be found in STANAG 6022.

The METCM and METB3 differ in some variables and formats. The METCM has wind speed in knots, wind direction in tens of mils, virtual temperature in tenths of K, and pressure in mb. The METB3 has weighted values as noted above for wind speed in knots, wind direction in hundreds of mils, sensible temperature in percent of the standard atmosphere value, and density in percent of standard. For temperature and density, round the percent of standard to the nearest tenth of a percent and multiply by 10, and for numbers ≥ 1000 subtract 1000 (e.g., 98.3 becomes 983 and 100.9 becomes 009). Table 1 shows a sample METCM for the first three lines with the relevant units, and table 2 has a sample for a METB3. Both samples were based on messages from Yuma Proving Ground (YPG) that were derived from a radiosonde sounding. More complete examples may be found in appendix A. Different versions of the input routine of the program briefly described in this report can read other formats such as the METCM produced by the Computer, Meteorological Data – Profiler (CMD-P), also found in appendix A.

Table 1. Variables and formats for the first 3 lines/zones of a sample METCM based on radiosonde data from YPG.

Zone height (m at top)	Line Number	Wind Direction (10s of mils)	Wind Speed (knots)	Temp (virtual) (0.1 K)	Pressure (mb)
Surface	00	533	005	2788	0989
200	01	566	011	2817	0977
500	02	014	009	2815	0948

Table 2. Variables and formats for the first 3 lines/zones of a sample METB3 based on radiosonde data from YPG. See text for format of percent of standard values.

Zone height (m at top)	Line Number	Wind Direction (100s of mils)	Wind Speed (knots)	Temperature (% std)	Density (% std)
Surface	00	53	05	968	009
200	01	57	11	980	996
500	02	63	09	983	992

Part of the primary method used to produce METB3s employed variations of some of the algorithms found in the spreadsheet method from ARDEC (Ray, 2013). It used the same type of calculation of METB3 zone values prior to weighting and an algorithm for extrapolating METCM levels above the highest line where the input has less than the full 32 METCM zones. Both methods also compute and weight the horizontal wind components and then convert them to wind speed and direction. As noted above, the standard METB3 message contains sensible temperature, but the METCM has virtual temperature. Normally the difference is small above the lowest zones and usually can be ignored for trajectory calculations. The method of this report uses the virtual temperatures of the METCM for the METB3. Also, it's more accurate to use virtual temperature to calculate density than sensible temperature, especially where they differ by more than a very small amount.

The program's data ingest routine reads a METCM starting at the surface or zone 0. If the METCM ends before the highest zone (line 31), the user has the option of having the ingest routine extrapolate from the last input data line through line 31. Following the spreadsheet's method, the extrapolation sets the wind speed and direction the same as at the METCM's uppermost zone. The percent of standard of temperature at the highest input zone is multiplied by the standard temperature values for the extrapolated zones. The same procedure gives the extrapolated pressures, that is, the percent of standard at the highest input zone is multiplied by the standard pressures.

The following process calculates the un-weighted zone values for the METB3 from the input METCM. For the data lines above the surface, the METCM zone values are taken as the values at the midpoints. For the surface and where the zone midpoints of both messages are the same (e.g., for zone 2, midpoint at 350 m), the values from the METCM are copied into the METB3. For those zone midpoints that differ from one another, the program takes the average of the values for the METCM zone midpoints immediately above and below the midpoint of the relevant METB3 zone. Wind speeds and directions from the METCM zones are converted into their respective horizontal components (u, v) before being converted into METB3 zone values. Figure 1 illustrates the relation between the message zones and the two ways of generating the METB3 midpoint values.

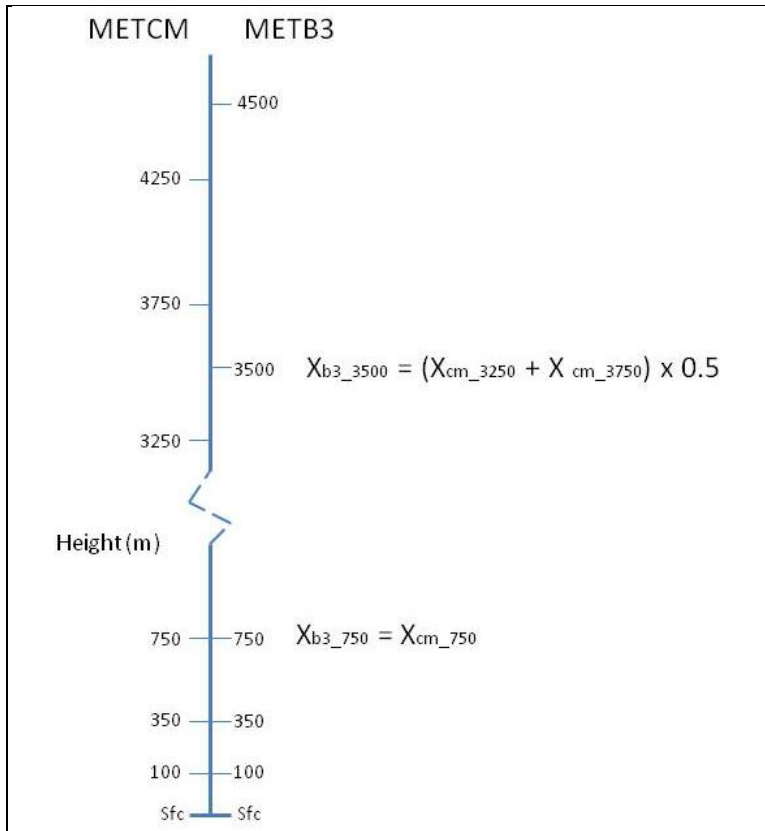


Figure 1. Illustration of the METCM and METB3 zone midpoint heights and the method of obtaining METB3 zone values from METCM zone values. X represents any variable and the subscripts (b3 for METB3 and cm for METCM) indicate the message type and midpoint. All heights are m above ground level (AGL).

An alternate method to the one described herein uses a process for computing METB3s similar to that employed for other types of data such as from radiosondes (Cogan and Jameson, 2004) or climatological tables (Cogan and Haines, 2013). This second method treats the METCM as it would any appropriate vertical profile, where above the surface the values at each line of the METCM are considered as data at the height of the midpoint of the zone. This method is nearly the same as the primary one except they differ with respect to obtaining the midpoint values for the individual METB3 zones prior to weighting.

Since the METCM does not have density it is computed from the virtual temperature and pressure for the heights of the zone midpoints. The ideal gas law equation modified for moisture via the use of virtual temperature is used to compute density (ρ):

$$\rho = P/RT_v \quad (1)$$

where P is pressure (mb), T_v is virtual temperature (K), and R is the gas constant for dry air. Density is in units of g/m^3 .

Using the form of the equation outlined in the FMs as modified by ARDEC, we use the value of the inverse of 1/R to obtain

$$\rho = 348.36764 P/T_v \quad (2)$$

The weighting procedure is the same for both the primary and alternate methods. Weighting tables were developed some years ago and may be found in FM 6-16 and STANAG 4061. Appendix B reproduces the weighting tables as extracted from STANAG 4061. The concept is not difficult, though the programming of the process is somewhat complicated. Here we reproduce a part of the temperature (T) weighting table as table 3. Note that since METCM input is T_v , for the METB3 computations and output $T = T_v$.

Table 3. Part of the table of temperature weighting factors for computing METB3 weighted zone values. Table B-1 has the complete set of weighting factors along with the supplement shown in table B-2.

Line	Zone				
	1	2	3	4	5
1	1.00				
2	0.27	0.73			
3	0.13	0.20	0.67		
4	0.08	0.12	0.25	0.55	
5	0.05	0.10	0.20	0.21	0.44

For zone 0 (surface), there is no weighting and the METB3 uses the METCM values as noted above directly or as input for calculation of, for example, temperature and density as percent of standard. Line 1 has a weight of 1.00 and therefore is not modified except for the conversion to percent standard, etc. Using the temperature weighting factors of table 3 to obtain the value for line 2 the temperature at zone 1 is multiplied by the zone 1 weighting factor for line 2 (0.27), which is added to the temperature at zone 2 multiplied by its weighting factor for line 2 (0.73). For example, if $T_{zone1} = 290K$ and $T_{zone2} = 288K$, then $T_{line2} = 290*0.27 + 288*0.73 = 288.54K$. This result is then converted to % standard (% relative to 285.9K), which comes to 100.92%. For this example, the line 2 value would appear as 009 using the format described above. A similar procedure is followed for density, which also is expressed as a percent of standard.

For wind speed and direction, the procedure is somewhat different. For the surface (line 0), the wind components are the same as in the METCM. For lines 1 and above, up through METB3 line 18 (16–18 km AGL), the wind components are computed as above from the METCM's wind components. The components are weighted using the table for wind (appendix B). The weighted values of u and v are then converted into wind speed (knots) and direction (hundreds of mils). The procedure does not compare wind speed and direction with a standard set of values.

The output from this program is in a generalized format that has the variables and the structure of the METB3, but not the exact same format and header information as in the FMs. As suggested in appendix A, different users have somewhat different forms of the METB3 (e.g., Yuma

Proving Ground vs. FM 3-09.15 (FM6-15)/MCWP 3-16.5) as well as the formats of the input METCMs (Yuma vs. CMD-P vs. MMS-P, etc.). Modifications to the input and output routines can be made to accommodate different input and output formats, but the computation routines would not change. The program also may be revised so that it can run on a variety of processors including handheld or mobile computers.

3. Mobile Device Application

Earlier, the U.S. Army Research Laboratory (ARL) developed a capability to produce METCMs and METB3s directly from a surface MET observation and upper air wind vectors computed from the visual tracking and recording of pilot balloon (PIBAL) azimuth and elevation data measured at specific times after release. It consisted of an application that would run on a Windows Mobile based personal digital assistant (PDA) and also added the capability to compute a METB3 from the surface and PIBAL data. This application as described in Jameson and Sauter (2007) was tested, accepted, and fielded. A further capability was requested to convert a METCM that was already resident on the PDA or received from another system to a METB3 on the PDA. Consequently, the conversion software discussed in this report was re-hosted onto the PDA.

The requested METCM conversion utility also involved the receipt and transmission of MET messages to/from an Advanced Field Artillery Tactical Data System (AFATDS) via tactical radios. Thus, ARL teamed with ARDEC to develop the combined enhanced capability. ARDEC has extensive experience in the use of tactical communications to transmit and receive artillery-based information from the ruggedized PDA. Due to the concurrent development of the conversion and communications functionalities, it was decided to develop a version of the conversion routine as a dynamic link library (dll) for the PDA. This dll also would incorporate the existing PDA based capabilities and then be transitioned to ARDEC for integration with their current software package. As of the date of this report, an initial dll had transitioned to ARDEC, and was tested and integrated with their software. A formal testing and evaluation by the Marine Corps was slated for fall 2013. The dll is written in C++ and was developed using the Visual Studio 2008 Integrated Development Environment (IDE). The advantage of a dll implementation is that the library functions can be readily invoked via applications on other systems as well.

4. Summary of Results

The output from the program was tested against the ARDEC spreadsheet as well as output from YPG. Not surprisingly, the output using extrapolation matches that from the spreadsheet since both use the same basic algorithms for computing individual METB3 line values and weighted line values, as well as the same extrapolation algorithm. The only exception was the % density for lines ≥ 13 (midpoint at 11000 m). The ballistic standard for that line in the FM is slightly larger than that in the spreadsheet. When that one number was changed, the output METB3 from the two systems had the same values for all variables. Here we used the value found in the FM.

The METB3 output from YPG radiosonde data is slightly different. If the METB3 is computed directly from the radiosonde data, one would expect it to be somewhat different than if derived from the accompanying METCM. Unfortunately, the exact method of computing METB3s at YPG is not known since the software is proprietary and apparently no documentation is currently available. Appendix A contains a sample of METCM input and two resultant METB3s where one did not use extrapolation and other did. An additional example shows a METCM for YPG computed by a CMD-P and the consequent METB3. No extrapolation was needed since the METCM had all 32 zones.

The PDA dll implementation results were tested against the standalone version results for a number of cases, including a range of METCM lines from only line 0 to the maximum 32. The overwhelming majority of all of the output parameters matched exactly while a limited number differed by a value of ± 1 in the least significant digit. This is deemed to be the result of rounding errors between the different processors on the standalone and PDA implementations and is not a concern.

5. Conclusion

This report briefly describes a computer program for producing a ballistic MET message for surface to surface fires (METB3) using a METCM for input. Though at first developed independently, it later incorporated certain algorithms expressed in a spreadsheet developed at the Firing Tables and Ballistics Division in ARDEC. The program was developed for eventual use on a handheld or mobile device, where a CMD-P or similar MET system would not be available. Nevertheless, it can be applied to any system where a METB3 is not directly computed as part of the primary software package. The only required modifications to the program as it currently exists would be in the input and output routines plus revisions to enable it to run with different operating systems and devices. A variant of the program already can read METCMs from a CMD-P, so in some cases little or no change to the input section would be needed. The net result is software to compute a METB3 from a METCM that can be applied with minimal modification to many systems that can generate or receive a METCM.

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- STANAG 6022 (Edition 2), North Atlantic Treaty Organization – NATO Standardization Agency, *Adoption of a Standard Gridded Data Meteorological Message*, 2010, Brussels, Belgium, 36 pp.

Appendix A. Sample METCM Input from YPG and CMD-P and METB3 Output

Tables A-1 through A-5 include a sample of METCM type input from YPG and a METCM from a CMD-P along with output METB3 type data from the program. One of the YPG cases used extrapolation of the input METCM, the other did not. No extrapolation is needed for CMD-P METCMs since to date they have always had all 32 zones.

Table A-1. Input METCM produced from a radiosonde sounding from YPG dated 0800 MST on 11 FEB 2013. The GMT time (1430) indicates the approximate launch time of the radiosonde.

```

Computer Met Message For Flight: 13021108 Date: 02-11-13 Time: 0800 MST
  ID      Octant  Location  Date  Time  Duration  Station HGT MSL Pressure
          (GMT)   (Hours)   (10's M)   (MBS)
METCM    1      329 140   11    145     2       023     989
-----
      Zone      Line      Wind      Wind      Temp      Pressure
      Height    Number    Dir      Spd      (1/10 K)  (Millibars)
      (Meters)  10s/mils  Kts
=====
          SFC      00      533      005      2788      0989
          200      01      566      011      2817      0977
          500      02      014      009      2815      0948
         1000      03      630      006      2785      0903
         1500      04      593      005      2747      0849
         2000      05      559      007      2702      0797
         2500      06      599      005      2658      0748
         3000      07      612      003      2614      0701
         3500      08      477      008      2576      0656
         4000      09      487      017      2539      0614
         4500      10      502      022      2499      0574
         5000      11      507      028      2459      0535
         6000      12      468      049      2431      0482
         7000      13      436      062      2371      0418
         8000      14      445      058      2331      0362
         9000      15      467      061      2316      0312
        10000      16      451      060      2297      0269
        11000      17      473      069      2267      0232
        12000      18      464      075      2256      0199
        13000      19      445      080      2234      0171

```

Table A-2. Output METB3 derived from the YPG METCM of table A-1. The exact format of the METB3 may be different for other systems, but the variables and units are the same. No extrapolation was performed.

METB3 output

Date: 02-11-13

Time: 0800

Latitude: 32.90000

Longitude: 140.00000

Elevation: 23.00

Height (m)	Line	Wind Direction (100s of mils)	Wind Speed (kts)	Temperature (pcnt std)	Density (pcnt std)
0	0	53	05	967	009
200	1	57	11	980	996
500	2	63	09	983	993
1000	3	63	07	983	992
1500	4	61	06	982	992
2000	5	58	06	980	993
3000	6	60	05	974	995
4000	7	51	08	971	997
5000	8	51	15	966	998
6000	9	48	25	964	997
8000	10	45	40	964	993
10000	11	46	42	964	982
12000	12	46	48	964	975

Table A-3. Output METB3 derived from the YPG METCM of table A-1 where the message was extrapolated to the maximum METCM zone. The exact format of the METB3 may be different for other systems, but the variables and units are the same.

METB3 output

Date: 02-11-13

Time: 0800

Latitude: 32.90000

Longitude: 140.00000

Elevation: 23.00

Height (m)	Line	Wind Direction (100s of mils)	Wind Speed (kts)	Temperature (pcnt std)	Density (pcnt std)
0	0	53	05	967	009
200	1	57	11	980	996
500	2	63	09	983	993
1000	3	63	07	983	992
1500	4	61	06	982	992
2000	5	58	06	980	993
3000	6	60	05	974	995
4000	7	51	08	971	997
5000	8	51	15	966	998
6000	9	48	25	964	997
8000	10	45	40	964	993
10000	11	46	42	964	982
12000	12	46	48	964	975
14000	13	45	52	964	975
16000	14	45	54	964	977
18000	15	45	53	964	978

Table A-4. Input METCM from a CMD-P obtained at YPG dated 6 FEB 2013 at 2130 GMT.

UNCLASSIFIED

To: AFATDS

```

+-----MET CM-----+
| Location: 7 66669 36 40617 0240 11 |
| Latitude (deg): 32.871264 |
| Longitude (deg): -114.149975 |
| Day: 06 |
| Time: 21.5 |
| Duration (hours): 0 |
| Station Height (10's m): 024 |
| MDP Pressure (mb): 0986 |
+-----+-----+-----+-----+-----+
| Line | Wind Direction | Wind Speed | Air Temp | Pressure |
| Number | (10s mils) | (knots) | (K) | (mb) |
+-----+-----+-----+-----+-----+
| 00 | 505 | 007 | 292.3 | 0986 |
+-----+-----+-----+-----+-----+
| 01 | 507 | 008 | 291.6 | 0975 |
+-----+-----+-----+-----+-----+
| 02 | 511 | 009 | 289.4 | 0946 |
+-----+-----+-----+-----+-----+
| 03 | 519 | 008 | 286.0 | 0902 |
+-----+-----+-----+-----+-----+
| 04 | 513 | 006 | 282.6 | 0850 |
+-----+-----+-----+-----+-----+
| 05 | 540 | 006 | 279.2 | 0800 |
+-----+-----+-----+-----+-----+
| 06 | 546 | 009 | 276.4 | 0752 |
+-----+-----+-----+-----+-----+
| 07 | 534 | 014 | 273.7 | 0707 |
+-----+-----+-----+-----+-----+
| 08 | 520 | 018 | 270.6 | 0664 |
+-----+-----+-----+-----+-----+
| 09 | 515 | 022 | 267.1 | 0623 |
+-----+-----+-----+-----+-----+
| 10 | 518 | 024 | 263.5 | 0584 |
+-----+-----+-----+-----+-----+
| 11 | 519 | 027 | 260.0 | 0547 |
+-----+-----+-----+-----+-----+
| 12 | 508 | 031 | 254.3 | 0495 |
+-----+-----+-----+-----+-----+
| 13 | 497 | 036 | 246.0 | 0432 |
+-----+-----+-----+-----+-----+
| 14 | 494 | 042 | 237.7 | 0375 |
+-----+-----+-----+-----+-----+
| 15 | 487 | 050 | 231.0 | 0324 |
+-----+-----+-----+-----+-----+
| 16 | 485 | 060 | 226.8 | 0279 |
+-----+-----+-----+-----+-----+
| 17 | 483 | 068 | 225.0 | 0240 |
+-----+-----+-----+-----+-----+

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18	480	073	223.8	0206	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
19	473	074	221.9	0177	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
20	465	072	218.8	0151	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
21	459	068	214.4	0129	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
22	455	063	210.3	0110	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
23	452	056	207.0	0093	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
24	450	047	204.5	0079	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
25	444	037	203.8	0067	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
26	430	027	206.8	0057	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
27	420	015	208.1	0044	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
28	475	008	207.1	0032	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
29	478	015	210.6	0023	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
30	473	027	217.9	0017	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+
31	471	039	225.5	0012	
+-----+	+-----+	+-----+	+-----+	+-----+	+-----+

Table A-5. Output METB3 derived from the METCM of A-4.

METB3 output

Date: 06

Time: 21.5

Latitude: 32.87126

Longitude: -114.14998

Elevation: 24.00

Height (m)	Line	Wind Direction (100s of mils)	Wind Speed (kts)	Temperature (pcnt std)	Density (pcnt std)
0	0	50	07	014	959
200	1	51	08	014	960
500	2	51	09	013	961
1000	3	52	08	011	963
1500	4	51	07	010	964
2000	5	53	07	010	965
3000	6	53	10	011	965
4000	7	52	15	012	965
5000	8	52	18	011	966
6000	9	51	22	010	967
8000	10	50	30	010	972
10000	11	49	36	010	974
12000	12	49	43	010	969
14000	13	48	46	010	971
16000	14	48	46	010	974
18000	15	48	44	010	976

Appendix B. Weighting Tables from STANAG 4061

Tables B-1 through B-4 show the weighting tables for temperature, density, and wind as published in FM 6-16. The table numbers on the charts are those used in FM 6-16. Also included are the definition of standard atmosphere and the atmospheric structure of various meteorological messages from FM 3-09.15 (FM6-15)/MCWP 3-16.5 (table B-5). The standard atmosphere definition is that of the International Civil Aviation Organization (ICAO).

Table B-1. Weighting factors for temperature. See text for method of use. This table has zero values for weighting factors above line 9.

Table 2-7. Temperature Weighting Factors (Type 3 Message) (Surface-to-Surface Trajectories)

Line No.	Zone No.										
	1	2	3	4	5	6	7	8	9	10-15	
1	1.00										
2	0.27	.73									
3	0.13	.20	.67								
4	0.08	.12	.25	.55							
5	0.05	.10	.20	.21	.44						
6	0.04	.04	.09	.11	.13	.59					
7	0.02	.04	.07	.09	.11	.26	.41				
8	0.01	.03	.05	.04	.10	.19	.23	.35			
9 to 15	0.01	.01	.02	.03	.03	.09	.13	.24	.44		0.00

Table B-2. Supplemental temperature weighting factors for lines 10–15 from STANAG (4061). They were not used in the current program or in the ARDEC spreadsheet. However, they could be added using a modification to the one temperature weighting parameter file (as verified with test cases) without modifying the program.

Line No. - Ligne No.	STANDARD HEIGHT ABOVE MDP HAUTEUR AU-DESSUS DU MDP (M)	ZONE NO. - ZONE NO.														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		0 to 200	200 to 500	500 to 1000	1000 to 1500	1500 to 2000	2000 to 3000	3000 to 4000	4000 to 5000	5000 to 6000	6000 to 8000	8000 to 10000	10000 to 12000	12000 to 14000	14000 to 16000	16000 to 18000
10	8000	0.01	0.01	0.03	0.04	0.05	0.09	0.10	0.11	0.14	0.42					
11	10000	-0.04	-0.01	-0.02	-0.01	0.02	0.08	0.08	0.06	0.09	0.20	0.55				
12	12000	-0.01	-0.01	-0.02	-0.01	0.00	0.06	0.06	0.06	0.06	0.14	0.19	0.48			
13	14000	-0.02	-0.07	-0.08	-0.02	-0.01	0.05	0.03	0.07	0.09	0.16	0.11	0.19	0.50		
14	16000	-0.02	-0.02	-0.03	-0.02	-0.01	0.03	0.04	0.03	0.02	0.11	0.17	0.14	0.15	0.41	
15	18000	0.00	0.00	-0.03	-0.02	0.00	0.05	0.05	0.05	0.03	0.08	0.04	0.13	0.05	0.18	0.39

Table B-3. Weighting factors for density.

Table 2-5. Density Weighting Factors (Type 3 Messages)

Line No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.00														
2	.43	.57													
3	.22	.31	.47												
4	.15	.21	.32	.32											
5	.11	.17	.25	.22	.25										
6	.08	.11	.17	.17	.15	.32									
7	.06	.08	.14	.13	.12	.22	.25								
8	.05	.06	.11	.11	.10	.19	.17	.21							
9	.04	.06	.09	.09	.08	.17	.15	.14	.18						
10	.03	.04	.07	.07	.07	.13	.12	.11	.11	.25					
11	.01	.03	.05	.05	.06	.12	.11	.09	.09	.16	.23				
12	.02	.03	.05	.05	.05	.11	.10	.09	.08	.14	.12	.16			
13	.02	.02	.04	.05	.05	.11	.09	.09	.08	.14	.10	.09	.12		
14	.02	.03	.05	.05	.05	.10	.09	.08	.07	.13	.11	.08	.06	.08	
15	.02	.04	.05	.05	.05	.10	.09	.08	.07	.12	.09	.08	.05	.05	.06

Table B-4. Weighting factors for wind. These factors are used to weight the wind components (u, v).

Table 2-9. Wind Weighting Factors (Type 3 Message)

Line No.	Zone No.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.00														
2	.20	.80													
3	.09	.19	.72												
4	.06	.12	.26	.56											
5	.04	.08	.15	.20	.53										
6	.03	.05	.08	.09	.12	.63									
7	.02	.03	.07	.07	.08	.20	.53								
8	.02	.02	.06	.06	.06	.14	.19	.45							
9	.02	.02	.05	.05	.05	.12	.13	.20	.36						
10	.01	.02	.02	.04	.03	.07	.08	.09	.09	.55					
11	.00	.00	.01	.04	.03	.08	.08	.09	.09	.20	.38				
12	.00	.01	.01	.02	.04	.07	.07	.07	.08	.17	.16	.30			
13	.00	.01	.01	.01	.03	.07	.07	.07	.07	.15	.14	.13	.24		
14	.00	.01	.01	.01	.02	.07	.07	.07	.07	.13	.13	.13	.10	.18	
15	.00	.01	.01	.01	.02	.07	.07	.07	.07	.12	.12	.11	.10	.08	.14

Table B-5. Atmospheric structure of MET messages from FM 3-09.15 (FM6-15)/MCWP 3-16.5. The second and third columns (labeled COMPUTER for METCM and BALLISTIC for METB3) are relevant to this report.

HEIGHT (meters)	LINE (ZONE) NUMBERS					
	COMPUTER	BALLISTIC	TARGET ACQUISITION	SOUND RANGING	FALLOUT	
SURFACE	0	0	0	0	0	
50	1	1	1	1		
100			2			
200			3			
300	2	2	4	2		
400			5			
500			6			
600	3	3	7	3		
700			8			
800			9	4		
900			10			
1,000	4	4	11	1		
1,100			12			
1,200			13			
1,300			14			
1,400			15			
1,500			16			
1,600	5	5	17			
1,700			18			
1,800			19			
1,900			20			
2,000	21					
2,100	6	6	22	2		
2,200			23			
2,300			24			
2,400			25			
2,500			26			
2,600			27			
3,000	7					
3,500	8					
4,000	9				7	
4,500	10					
5,000	11				8	3
6,000	12					
7,000	13				10	4
8,000	14					
9,000	15				11	5
10,000	16					
11,000	17	12	6			
12,000	18			12		
13,000	19	13	7			
14,000	20			13		
15,000	21	14	8			
16,000	22					
18,000	24					
19,000	25					
20,000	26		10			

30,000					15	

Standard Atmosphere as defined in FM 3-09.15 (FM6-15)/MCWP 3-16.5:

“When computing trajectories, ordnance ballisticians use the International Civil Aviation Organization (ICAO) standard atmosphere. This standard atmosphere is the basis for all data of the ballistic solution as well as a point of departure for ballistic MET corrections. The ICAO atmosphere at sea level is described as follows:

- Dry air.
- No wind.
- Surface temperature of 15 Celsius degrees with a decrease, or lapse rate, of -6.5 Celsius degrees per 1,000 meters up to a height of 11,000 meters and a constant temperature of -56.5 Celsius degrees between 11,000 and 25,000 meters.
- Surface pressure of 1,013.25 millibars, decreasing with height.
- Surface density of 1,225 grams per cubic meter (gm/m^3), decreasing with height.”

List of Symbols, Abbreviations, and Acronyms

AFATDS	Advanced Field Artillery Tactical Data System
AGL	above ground level
ARDEC	Armaments Research, Development, and Engineering Center
ARL	U.S. Army Research Laboratory
CMD-P	Computer, Meteorological Data – Profiler
dll	dynamic link library
ICAO	International Civil Aviation Organization
IDE	Integrated Development Environment
MET	meteorological
METB3	ballistic MET message for surface to surface trajectories
METCM	computer MET message
METGM	gridded MET message
NATO	North Atlantic Treaty Organization
NWP	numerical weather prediction
PDA	personal digital assistant
PIBAL	pilot balloon
YPG	Yuma Proving Ground

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