Conversion of the METCM into the METEO-11

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Abstract—This article deals with a proposed method of conversion of the METCM meteorological message into the METEO-11 format. This method is designed for artillery of these armies that are using the METEO-11 meteorological message during a spare (manual) method of firing data calculation. The proposed method is based on the simulation of temperature and wind sounding by radiosonde from the values of the METCM meteorological message. Then the values of the METEO-11 meteorological message are calculated with using carried out simulation of temperature and wind sounding by radiosonde. The conversion of the METCM meteorological message into the METEO-11 format consists of the recalculating of the meteorological message header, recalculation of meteorological data in the METCM meteorological message onto the units used in the METEO-11 meteorological message, conversion of the ground meteorological data, conversion of the meteorological data from the particular zones used in METCM meteorological message into the needed heights above an artillery meteorological station used in the METEO-11 meteorological message and the calculation of the meteorological data average values in the individual layers of the METEO-11 meteorological message.

Keywords—Artillery; METCM meteorological message; METEO-11 meteorological message; conversion of meteorological message

I. Introduction

Twostandard types of meteorological messages are used in the North Atlantic Treaty Organisation (NATO) during the firing data calculation – METCM meteorological-computer message and the METBK meteorological-ballistic message [1, 2]. The METCM is used inautomated artillery fire control systems and the METB3 during spare (manual) methods of firing data calculation.

Artilleries of NATO armies have to be able to provide meteorological messages to each other. The compatibility in using of the same meteorological messages is currently achieved only in the automated mode – in using of the METCM. Some artillery of NATO armies still use the non-standardized format of the METEO-11 meteorological message in case of the classic (spare, manual) mode is used. The transition to the exclusive use of standard meteorological messages is not often possible (because of implemented weapon systems and their firing tables, due to the implemented firing data calculation methods, for economic reasons, etc.)[3 - 5].

If the artillery, uses the METEO-11, could not realize own comprehensive meteorological sounding of atmosphere for various reasons, some other artillery can provide the METCM for this artillery. If this artillery cannot carry out the firing data calculation with using of automated artillery fire control system, it has to be capable to transpose (convert) the METCM into the METEO-11 format. However, the algorithm of this conversion has not been defined yet [6 - 9].

The proposed method of conversion of the METCM into the METEO-11 format can be divided into three consecutive phases:

1.) header (baseline data) of the meteorological message recalculation;
2.) ground meteorological data conversion;
3.) meteorological data average values in the individual layers conversion.

II. Header of the Meteorological Message Recalculation

The header of the METCM consists of the following symbols:

METCMQ $L_AL_AL_AL_0L_0L_0$ $YYG_0G_0G_0G$ $hhhP_dP_dP_d$,

where: METCM is signification (type) for the meteorological message;
- Q is the designation of the earth octant;
- $L_AL_AL_A$ is the latitude of centre of the valid area in tens, unit and tenths of degree;
- $L_0L_0L_0$ is the longitude of centre of the valid area in tens, units and tenths of degree. The hundreds digits are leaving out for longitude 100-180° including.
- YY is the day of that month in which the time validity starts beginning;
- $G_0G_0G_0$ is the world time GMT of the time validity beginning in tens, units and tenths of hours. It is used the 24hours interval from 000 to 239;
- G is the time of meteorological message validity in hours. The time validity is determining in the interval from 1 to 8 hours. The number 9 designates the time validity of 12 hours;
- hhh is the altitude of the artillery meteorological station (AMS) in tens of meters;
- $P_dP_dP_d$ is the air pressure at the level of the AMS in

units of millibars. If the air pressure is more than 1000 millibars, thousands digits are leaving out [9].

The header of the METEO-11 consists of the following symbols (different countries can use different letters):

METEO-11CC-DDHHM-VVVV,

where: METEO-11 is signification (type) for the meteorological message;
CC is meteorological unit number which compiled the meteorological message;
DD is the day of the end of meteorological sounding;
HH is the hour of the end of meteorological sounding;
M are tens of time minutes of the end of meteorological sounding;
VVVV is the altitude of the AMS in meters[9].

The recalculation of METCM header into the METEO-11 format will be carried out according to the following rules:

a) the label of the METEO-11 is always the same – „METEO-11“;
b) CC – this information is not possible to get from the METCM, as a result it must always be fill in manually;
c) DD – it corresponds to the YY data in the METCM;
d) HH – it corresponds to the first two symbols $\mathbf{G_0G_0}G_0$ in the METCM;
e) M – it corresponds to the third symbol $G_0G_0\mathbf{G_0}$ in the METCM. Tenths of an hour will be converted to the tens of minutes as follow:

$$M = G_0 \cdot \frac{6}{10}, \qquad (1)$$

f) VVVV – it corresponds to the hhh in the METCM. The altitude of AMS (hhh) will be multiplied by 10 for getting the altitude in meters:

$$VVVV = hhh \cdot 10 \qquad (2)$$

III. Ground Meteorological Data Conversion

The ground meteorological data are listed in the METCM in the line (zone) 00, which consists of the following symbols:

00dddFFFTTTTPPPP,

where: 00 shows the line in the meteorological message (zone code 00);
ddd is the wind direction – from which the wind vector is coming (from where the wind is blowing) – in tens of mils (in the METCM is usually used the division of the circle into the 6400 mils);
FFF is the wind speed in units of knots;
TTTT is the virtual air temperature in tenths of Kelvin degrees;
PPPP is the air pressure in units of millibars[9].

The ground meteorological data are shown in the METEO-11 by following symbols:

$B_0B_0B_0T_0T_0$,

where: $B_0B_0B_0$ is the change of the ground air pressure due to the tabular value in thealtitude of AMS;
T_0T_0 is the change of the virtual ground air temperature due to the tabular value in units of Celsia degrees[9].

The conversion of METCM ground meteorological data into the METEO-11 format will be carried out according to the following rules:

a) $B_0B_0B_0$ will be converted from PPPP indication of the zone 00 at first by determining the value of auxiliary change of the ground air pressure due to tabular value ($B_0B_0B_0'$) as follows:

$$B_0B_0B_0' = 0{,}750064 \cdot PPPP_{00} - 750\ , \qquad (3)$$

where: $PPPP_{00}$ is the air pressure in the 00 zone (in the AMS altitude).

Then the $B_0B_0B_0$ value will be determined by the follow relation:

$$B_0B_0B_0 = \begin{cases} (-1)\cdot B_0B_0B_0' + 500,\ pro B_0B_0B_0' < -0{,}5 \\ B_0B_0B_0',\ pro B_0B_0B_0' \geq -0{,}5 \end{cases}. \quad (4)$$

b) T_0T_0 will be converted from TTTT of zone 00 at first by determining the value of auxiliary change of the virtual ground air temperature due to tabular value (T_0T_0') as follows:

$$T_0T_0' = \left(\frac{TTTT_{00}}{10} - 273{,}15\right) - 15{,}9\ , \quad (5)$$

where: $TTTT_{00}$ is the virtual air temperature in the 00 zone (in the AMS altitude).

Then the T_0T_0 value will be determined by the follow relation:

$$T_0T_0 = \begin{cases} (-1)\cdot T_0T_0' + 50,\ pro\ T_0T_0' < -0{,}5 \\ T_0T_0',\ pro\ T_0T_0' \geq -0{,}5 \end{cases}. \quad (6)$$

IV. Meteorological Data Average Values in the Individual Layers Conversion

Meteorological data in the individual zones of the METCM are listed in the relevant lines of the meteorological message and they are expressed by the following symbols:

ZZdddFFFTTTTPPPP,

where: ZZ is the line number indicating the zone code (tableI);
ddd is the wind direction;
FFF is the wind speed in units of knots;
TTTT is the virtual air temperature in tenths of Kelvin degrees;
PPPP is the air pressure in units of millibars[9].

Virtual air temperature, wind direction and wind speed are expressed as average values of the appropriate zone in the

METCM. Therefore it was established an assumption – these meteorological data average values correspond to the meteorological data in the medium height of particular zones (table I). Hence the courses of the virtual air temperature, wind direction and wind speed are linear in the interval from the bottom to the upper boundary of the appropriate zone.

The air pressure in the individual heights above AMS is not consider during the firing data calculation (its effect is included in the virtual air temperature)[10]. Therefore the air pressure in the individual heights above AMS is not converted.

TABLE I. HEIGHTS INTERVALS OF INDIVIDUAL METCM ZONES

Zone code	Zone height above AMS [m]	Medium height of zone [m]	Zone code	Zone height above AMS [m]	Medium height of zone [m]
01	0 - 200	100	14	14 000 - 16 000	15 000
02	200 - 500	350	15	16 000 - 18 000	17 000
03	500 - 1 000	750	16	18 000 - 20 000	19 000
04	1 000 - 1 500	1 250	17	20 000 - 22 000	21 000
05	1 500 - 2 000	1 750	18	22 000 - 24 000	23 000
06	2 000 - 3 000	2 500	19	24 000 - 26 000	25 000
07	3 000 - 4 000	3 500	20	26 000 - 28 000	27 000
08	4 000 - 5 000	4 500	21	28 000 - 30 000	29 000
09	5 000 - 6 000	5 500	22	30 000 - 32 000	31 000
10	6 000 - 8 000	7 000	23	32 000 - 34 000	33 000
11	8 000 - 10 000	9 000	24	34 000 - 36 000	35 000
12	10 000 - 12 000	11 000	25	36 000 - 38 000	37 000
13	12 000 - 14 000	13 000	26	38 000 - 40 000	39 000

Meteorological data in the individual layers of the METEO-11 are expressed by the following symbols:

hhTTSSRR,

where:
- hh is the layer code;
- TT is the average change of virtual air temperature due to tabular value;
- SS is the average wind direction in hundreds of mils (in the METEO-11 is usually used the division of the circle into the 6000 mils);
- RR is the average wind speed in meters persecond[9].

The average change of virtual air temperature due to tabular value corresponds to the entire high interval from the AMS altitude up to the medium height of appropriate layer above AMS (table II).

The average wind direction and the average wind speed correspond to the entire high interval from the AMS altitude up to the upper boundary of appropriate layer above AMS (table II).

TABLE II. HEIGHTS INTERVALS OF INDIVIDUAL METEO-11 LAYERS

Zone code	Zone height above AMS [m]	Medium height of zone [m]	Zone code	Zone height above AMS [m]	Medium height of zone [m]
02	0 - 200	100	40	3 000 - 4 000	3 500
04	200 - 400	300	50	4 000 - 5 000	4 500
08	400 - 800	600	60	5 000 - 6 000	5 500
12	800 - 1 200	1 000	80	6 000 - 8 000	7 000
16	1 200 - 1 600	1 400	10	8 000 - 10 000	9 000
20	1 600 - 2 000	1 800	12	10 000 - 12 000	11 000
24	2 000 - 2 400	2 200	14	12 000 - 14 000	13 000
30	2 400 - 3 000	2 700	18	14 000 - 18 000	16 000

For each METEO-11 layer is need to calculate:

a) the average change of virtual air temperature due to tabular value in Celsius degrees (TT);
b) the average wind direction in hundreds of mils (SS);
c) the wind speed in meters per second (RR).

A. The Average Changes of Virtual Air Temperature due to Tabular Value (TT) Calculation

The average virtual air temperatures in the individual METCM zones ($TTTT_{ZZ}$) correspond to the virtual air temperature values in the medium heights of appropriate zones. The average virtual air temperatures in the individual METCM zones in tenths of Kelvin degrees ($TTTT_{ZZ}$) have to be converted to Celsius degrees as follow:

$$T_{(°C)_{ZZ}} = \frac{TTTT_{ZZ}}{10} - 273{,}15 \text{ , (7)}$$

where: $T_{(°C)_{ZZ}}$ is the virtual air temperature in the medium height of appropriate zone (ZZ) in Celsius degrees.

It is necessary to carry out a simulation (budgeting) of temperature (and also wind) sounding in the particular heights above AMS from the values established according to the (7) relation for calculation of the average changes of virtual air temperature (and also the average wind directions and the average wind speeds) in the individual METEO-11 layers – as if they were actually measured by radiosonde. The radiosonde sends the measured meteorological data at specified intervals after approximately 25-50 meters (depending on the speed of meteorological balloon ascent and on the used meteorological sets). The simulation (budgeting) of temperature and wind soundings can be carried out on the basis of linear interpolations of particular meteorological data in the appropriate heights above AMS from the meteorological data mentioned in the METCM. For these simulations it is sufficient to calculate the meteorological data at intervals of 50 m (in heights above AMS)[11 - 13].

For each height (v) above AMS (after 50 meters) it necessary to calculate the appropriate changes of virtual air temperature due to tabular value (ΔT_v) according to (8) to (13):

- for v=50 m:

  at first it is needed to determine the virtual air temperature at the height of 50 m above AMS in Celsius degrees:

$$T_{50} = \frac{T_{(°C)_{00}} + T_{(°C)_{01}}}{2} \text{ ,(8)}$$

where: $T_{(°C)_{00}}$ is the virtual air temperature in the height of 50 m above AMS and it corresponds to T_0T_0' value,
$T_{(°C)_{01}}$ is the virtual air temperature in the medium height of the 01 zone (100 m) determined according to (7)

and then it can be calculated the change of virtual air temperature in the height of 50 m above AMS due to tabular value in Celsius degree (ΔT_{50}):

$$\Delta T_{50} = T_{50} - (15{,}9 - 0{,}006328 \cdot v), \text{ (9)}$$

- for v=100 m:

$$T_{100} = T_{(°C)_{01}} \text{ , (10)}$$

$$\Delta T_{100} = T_{100} - (15{,}9 - 0{,}006328 \cdot v), \text{ (11)}$$

- for v=150 m:

$$T_{150} = \left[T_{(°C)_{02}} - T_{100}\right] \cdot \frac{50}{v_{02} - (v - 50)} + T_{100} \text{ , (12)}$$

where v_{02} is the medium height of the METCM 02 zone ($v_{02} = 350$ m) – table I, (7)

$$\Delta T_{150} = T_{150} - (15{,}9 - 0{,}006328 \cdot v) \text{ , (13)}$$

Analogously it is needed to carry out the calculation of all changes of virtual air temperature in the heights after 50 m above AMS due to tabular value in Celsius degree – up to required height above AMS.

Then it will be calculated auxiliary average changes of virtual air temperature due to tabular value in the particular METEO-11 layers (TT_{hh}') according to (14) to (16):

$$TT_{02}' = \frac{\sum_{n=1}^{2} \Delta T_{50 \cdot n}}{2} \text{ , (14)}$$

where 50·n is the height (v) above AMS in meters,

$$TT_{04}' = \frac{\sum_{n=1}^{6} \Delta T_{50 \cdot n}}{6} \text{ , (15)}$$

$$TT_{08}' = \frac{\sum_{n=1}^{12} \Delta T_{50 \cdot n}}{12} \text{ , (16)}$$

etc.

The average changes of virtual air temperature due to tabular value in the particular METEO-11 layers (TT_{hh}) will be determined according to the follow relation:

$$TT_{hh} = \begin{cases} (-1) \cdot TT_{hh}' + 50, \ pro\ TT_{hh}' < -0{,}5 \\ TT_{hh}', \ pro\ TT_{hh}' \geq -0{,}5 \end{cases} \text{ ,(17)}$$

where hh is the code of the METEO-11 layer.

B. The Everage Wind Direction (SS) Calculation

The average wind directions in the individual METCM zones (ddd_{ZZ}) correspond to the wind directions in the medium heights of appropriate zones. The average wind directions in the medium heights of appropriate zones (ddd_{ZZ}) is needed to convert to mil (usually used in the METEO-11 – 6000 mils for one circle) as follow:

$$\alpha_{w(dc)_{ZZ}}' = ddd_{ZZ} \cdot 10 \cdot \frac{15}{16}, \text{ (18)}$$

where $\alpha_{w(dc)_{ZZ}}'$ is the wind direction in the medium height of appropriate zone (ZZ) in mils;
ddd_{ZZ} is the average wind direction in the appropriate zone (ZZ) in tens of mils.

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Then it will be compared the course of the wind direction. If the wind direction crosses the kilometre north direction (from left or right) the particular wind direction values must be adjusted. If the wind direction crosses the kilometre north direction from the left during a movement from one layer to the next (higher), the 60-00 value must be added to the $\alpha'_{w(dc)_{ZZ}}$value. If the wind direction crosses the kilometre north direction from the right during a movement from one layer to the next (higher), the $\alpha'_{w(dc)_{ZZ}}$ value must be deduced from the 60-00 value. By this way will be got all adjusted wind direction values in the individual METCM zones $\alpha_{w(dc)_{ZZ}}$ in units of mils. If the wind direction does not cross the kilometre north direction with increasing height above AMS, then the wind direction will be:

$$\alpha_{w(dc)_{ZZ}} = \alpha'_{w(dc)_{ZZ}} .(19)$$

For each height (v) above AMS it is necessary to calculate the wind directions (α_v) in hundreds of mils from the $\alpha_{w(dc)_{ZZ}}$ values according to (20) to (22):

$$\alpha_{50} = \frac{\alpha_{w(dc)_{00}} + \alpha_{w(dc)_{01}}}{2} \cdot 0{,}01 \ , \qquad (20)$$

$$\alpha_{100} = \alpha_{w(dc)_{01}} \cdot 0{,}01 \ ,(21)$$

$$\alpha_{150} = \left\{\left[\alpha_{w(dc)_{02}} - \alpha_{100}\right] \cdot \frac{50}{v_{02}-(v-50)} + \alpha_{100}\right\} \cdot 0{,}01 \ , (22)$$

etc.

Then auxiliary average wind directions (in hundreds of mils) in the particular METEO-11 layers (SS'_{hh}) will be calculated according to (23) to (24):

$$SS'_{02} = \frac{\sum_{n=1}^{4} \alpha_{50 \cdot n}}{4} \ , \qquad (23)$$

$$SS'_{04} = \frac{\sum_{n=1}^{8} \alpha_{50 \cdot n}}{8} \ , \quad (24)$$

etc.

The average wind directions in the particular METEO-11 layers (SS_{hh}) will be determined according to the follow relation:

$$SS_{hh} = \begin{cases} (-1) \cdot SS'_{hh} + 50, pro SS'_{hh} < -0{,}5 \\ SS'_{hh}, pro SS'_{hh} \geq -0{,}5 \end{cases} . \qquad (25)$$

C. *The Average Wind Speeds (RR) Calculation*

The average wind speeds in the individual METCM zones (FFF_{ZZ}) correspond to the wind speed values in the medium heights of appropriate zones. The wind speeds in the medium heights of appropriate zones in meters per second (FFF_{ZZ}) is needed to convert to meters per second as follow:

$$w_{(m \cdot s^{-1})_{ZZ}} = 0{,}51 \cdot FFF_{ZZ} \ , (26)$$

where $w_{(m \cdot s^{-1})_{ZZ}}$ is the wind speed in the medium height of appropriate zone (ZZ) in meters per second.

For each height (v) above AMS it is necessary to calculate the wind speeds (w_v) in meters per second from the $w_{(m \cdot s^{-1})_{ZZ}}$ values according to (27) to (29):

$$w_{50} = \frac{w_{(m \cdot s^{-1})_{00}} + w_{(m \cdot s^{-1})_{01}}}{2} \ , (27)$$

$$w_{100} = w_{(m \cdot s^{-1})_{01}} \ , (28)$$

$$w_{150} = \left[w_{(m \cdot s^{-1})_{02}} - w_{100}\right] \cdot \frac{50}{v_{02}-(v-50)} + w_{100} \ , (29)$$

etc.

Then the average wind speeds in the particular METEO-11 layers (RR_{hh}) (in meters per second) will be calculated according to (30) to (31):

$$RR_{02} = \frac{\sum_{n=1}^{4} w_{50 \cdot n}}{4} \ , \qquad (30)$$

$$RR_{04} = \frac{\sum_{n=1}^{8} w_{50 \cdot n}}{8} \ , \qquad (31)$$

etc.

V. Conclusion

The conversion of the METCM into the METEO-11 format is needed to be carried out by using the computer because the manual conversion is time-consuming and can leads to errors. It is advantageous to use the defined mathematical apparatus for the conversion in the own software application or to use it in some program – for example in the MS Excel.

Philosophy of the conversion of the METCM into the METEO-11 format can be also used to develop mathematical apparatuses for other conversions of meteorological messages (as METB3 into METEO-11 format or METCM into METB3 format) in the future.

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