IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 14, Issue 10 Ser. II (October 2020), PP 17-27
www.iosrjournals.org

Modified conversion of METCM meteorological message to METEO11 format

Karel Šilinger[1], Michal Šustr[1], Jan Ivan[1], Ladislav Potužák[1]
[1]*(Department of Fire Support/ University of Defence, Czech Republic)*

Abstract:*The paper presents a new procedure of converting a METCM meteorological message into the METEO11 format. The METEO11 format is necessary for a calculation of artillery firing data in some NATO countries. If these countries will operate in some multinational task forces and they will not be able to carry out their own comprehensive meteorological soundings, then other states may provide them meteorological messages. However, these meteorological messages will usually be in NATO standardized METB3 or METCM format. To ensure interoperability, it is therefore necessary to be able to convert these messages to the required METEO11 format.*
Background*: A major obstacle to the interoperability of some artillery with other NATO nations is so-called meteorological preparation. Some states use a non-standardized METEO11 meteorological message format, which follows from a non-standardized concept of firing tables and froma different model of a tabular (standard) atmosphere. The standardized meteorological message formats in NATO are mainly METCM, intended for computer processing, and METB3, used in manual calculations. Due to the existing armaments, the artillery of some states depends on the format of the meteorological message METEO11, which was standard in the armies of the former Eastern bloc.*
Materials and Methods*: The original conversion model basically simulated a comprehensivesounding of the atmosphere by a meteorological radiosonde. The new conversion model uses more accurate calculation methods, thanks to which data can be used in higher heights, which were inaccurate in the original model.*
Results*: The modified model of METCM meteorological message conversion to METEO11 format and its implementation into software.*
Conclusion:*A new and more accurate converting way of METCM meteorological message to the METEO11 format compared to its predecessor.*
Key Word*:Meteorological message; METEO11; METCM; METB3; Artillery.*

Date of Submission: 02-10-2020 Date of Acceptance: 16-10-2020

I. Introduction

METEO11 meteorological message uses the standard atmosphere model of prof. Ventcel (Russia), which is slightly different from the NATO model, established according to the International Civil Aviation Organization (ICAO) model and set out in STANAG 4044[1]. The differences between both standard atmosphere models (Table no. 1) represent different values, especially for relative humidity, air pressure and temperature gradient. The significance of the data in the METB3[2] and METCM[3] meteorological messages, compiled according to the ICAO atmosphere model and for use with firing tables according to STANAG 4119[4], is entirely different compared to the significance of the data in the METEO11[5] meteorological message. The system of artillery firing data calculationis also different.

Table no. 1: Selected differences between standard atmosphere models.

Data	Soviet model		ICAO model		The difference between ICAO and the soviet model
	Table value	Listed in units	Table value	Listed in units	
Ground air temperature	+15 °C	°C	+15 °C	K	0 °C
Ground air pressure	1 000 hPa (750 torr)	torr	1 013.25 hPa (760.002 torr)	mbar	13.25 hPa (10.002 torr)
Ground air density	1.206 $kg \cdot m^{-3}$	$kg \cdot m^{-3}$	1.225 $kg \cdot m^{-3}$	$kg \cdot m^{-3}$	0.019 $kg \cdot m^{-3}$
Temperature gradient	-0.006328 $°C \cdot m^{-1}$ (up to 9 300 m)	$°C \cdot m^{-1}$	-0.0065 $°C \cdot m^{-1}$ (up to 11 000 m)	$°C \cdot m^{-1}$	-0.000172 $°C \cdot m^{-1}$
Wind speed	-	$m \cdot s^{-1}$	-	kt	-
Wind direction	-	dc	-	mils	-

		(azimuth, 1 circle = 6000 dc)		(azimuth, 1 circle = 6400 mils)	
Relative air humidity	50 %	-	0 %	-	50 %

If artillery firing units, using METEO11 meteorological messages, operate in international combat formations and if comprehensive meteorological soundings are performed by a foreign state, then meteorological messages are distributed to all firing units exclusively in METB3 or METCM format. This is a significant and long-standing problem for the artillery of some NATO states. The solution to this problem is the ability to convert meteorological messages from METB3 and METCM format to METEO11 format with satisfactory accuracy. The conversion of the METB3 meteorological message to the METEO11 format is defined in the referenced paper[6]. In the past, the METCM conversion procedure was also defined in these referenced paper[7]. This recalculation has been further modified and its final form is presented to the professional public in this article.

In the past, the conversion of METCM meteorological message into METB3 format, which was dealt with by the Military Research Laboratory of the U. S. Army Naval Forces, was also resolved. The result of their research was implemented into software, that enabled this conversion. It is clear from the available final reports[8, 9, 10]that a number of assumptions and simplifications had to be made to define the mathematical apparatus and to set restrictive conditions for the use of recalculated messages, especially with larger changes in wind vector (direction). The research laboratory did not publish the conversion algorithm anywhere.

II. Conversion model

The conversion procedure according to paper[7] is based on the calculation of meteorological data at altitudes after 50 meters above the artillery meteorological station. The performed interpolations of meteorological data during the conversion, including differences between standard atmosphere models and conversions of physical quantities basically simulate meteorological comprehensive sounding by radiosonde, during which data seem to be obtained after 50 meters, and from which the mean values of meteorological data at medium heights of METEO11meteorological message are calculated.

The modified mathematical model of the conversion of the METCM meteorological message to the METEO11 format enables a more accurate determination of meteorological data, especially at higher standard heights of the METEO11 meteorological message, in comparison with the previous conversion procedure. The original mathematical model was limited to use only up to a standard height of 3000 meters in the METEO11 meteorological message and for wind changes from zone 00 to zone 07 by a maximum of 3200 miles. The new conversion model allows the use of converted meteorological data to calculate data for artillery fire without adjustment fire up to a standard height of 5,000 meters (and to calculate control shot firing data up to a standard height of 12 kilometers).

The METCM meteorological message is intended for computer processing, and the values of meteorological data are related only to the altitude ranges of individual zones. This principle of meteorological data allows, with the use of computer and ballistic models of calculations of artillery firing data, a more detailed inclusion of meteorological conditions in individual zones. However, the principle of mean values only for the height ranges of individual zones is completely unsatisfactory for manual calculations of artillery firing data. Therefore, to include meteorological conditions in the manual calculations of artillery firing data, the METEO11 and METB3 meteorological messages provide values that are "average" for all altitudes through which the ballistic curve passes. Different nature of the significance of meteorological data in the METCM message causes errors in the conversion of data of wind sounding – these errors do not arise when converting METB3meteorological message. Conversely, temperature sounding data is more accurate after the conversion of a METCM meteorological report, as the METCM meteorological message, like the METEO11 meteorological message, presents the results of temperature sounding in the form of virtual air temperature. The relative humidity is thus wholly eliminated during conversions. Only different tabular air temperatures resulting from different temperature gradients in individual models of the standard atmosphere are taken into account.

The mathematical model of conversion of the METCM meteorological message to the METEO11 format is defined for the conversions up to the standard height of 12000 meters in the METEO11 meteorological message and can be divided into these following steps:

1. Compilation of the METEO11 header and calculation of ground meteorological data;
2. Calculation of meteorological data in the mean heights of METCM individual zones;
3. Calculation of meteorological data for the altitudes in the METEO11 standard heights;
4. Calculation of mean values of meteorological data in METEO11 standard heights.

Compilation of the METEO11 header and calculation of ground meteorological data

The header and ground meteorological data are given in the METCM meteorological message similarly to the METB3 meteorological message. The only difference is the way in which the ground air pressure is stated. The air pressure at the station of the artillery meteorological station is given as a measured value of air pressure directly in millibars.

Due to the analogy of the procedure of compiling the header of the METEO11 meteorological messageand the calculation of ground meteorological data according to the METCM meteorological message with the procedure used to convert the meteorological report METB3 to METEO11 format[6], partial calculations are not given below.

The header of the meteorological message and the values of the ground meteorological dataare given in the first line of the report in the METCM report in the following format:

METCMQ $L_AL_AL_AL_0L_0L_0$ $YYG_0G_0G_0G$ $hhhP_dP_dP_d$

where the individual symbols represent:

METCM	marking of computer meteorological message;
Q	Earth's octantcode;
$L_AL_AL_A$	the latitude of the artillery meteorological station in tens, units and tenths of a degree;
$L_0L_0L_0$	longitude of the artillery meteorological station in tens, units and tenths of a degree (for longitudes greater than or equal to 100 °, hundreds of digits are omitted);
YY	the day of the month in which the meteorological message became valid;
$G_0G_0G_0$	World Time (GTM) of the beginning of the time validity of the meteorological message in tens, units and tenths of an hour;
G	the validity period of the message in hours, where the number 9 represents the validity period of 12 hours,
hhh	altitude of artillery meteorological station;
$P_dP_dP_d$	air pressure at the location of the artillery meteorological station expressed in hundreds, tens and units of millibars (if the pressure is greater than or equal to 1000 millibars, the digit thousand is omitted).

When calculating the change in ground air pressure with respect to the table value, the air pressure data in the METCM meteorological messagehas to be assessed. In the METEO11meteorological message, only the ground change in air pressure with respect to the table value is reported. To determine this value it is sufficient to evaluate whether the value of $P_dP_dP_d$ is greater than 500. If it is less, then the air pressure is logically greater than 1000 millibars;in this case, 1000 is added to the PdPdPd.

The values $L_AL_AL_A$ and $L_0L_0L_0$are used to calculate the meridian convergence (γ). Its value is added to or subtracted from the calculated values of the geographical azimuths of the wind in the standard height (SH) of METEO11meteorological message, thus obtaining the values of the wind directions.

Calculation of meteorological data in the mean heights of METCM individual zones

Meteorological data at individual heights above the artillery meteorological station are given in separate lines in the METCM meteorological message, which are written in the following format:

ZZdddFFFTTTPPPP

where the individual symbols represent:

ZZ	code designation of the line (zone) in the message;
ddd	the geographical azimuth of the wind direction (from which the wind blows) given in thousands, hundreds and tens of miles. Code 000 means no wind;
FFF	the mean wind speed in a particular zone, expressed in hundreds, tens and units of knots;
TTTT	the mean virtual air temperature in the hundreds, tens, units, and tenths of Kelvin in a particular zone;
PPPP	air pressure at the mean height of the particular zone, expressed in thousands, hundreds, tens and units of millibars.

The zone with the code designation "00" corresponds to the SH of the artillery meteorological station. From zone 00, the TTT data is used to calculate the ground change of the virtual air temperature in the METEO11meteorological message.

The calculation of changes in the virtual air temperature with respect to the tabular values in the mean heights of the individual zones of the METCM meteorological messagehas to be performed using the TTTT data in the individual lines of the meteorological message. Changes in virtual air temperatures with respect to the tabular values in GOST 4401-48 are obtained using tabular values and calculated correction factors for different models of the standard atmosphere according to the relations (1) to (19):

$$t_{100} = \frac{1}{10}\mathrm{TTTT}_{01} - 288.4172 - 0.0175 \quad (1)$$

where:

t_{100} is the change in virtual air temperature with respect to the table value at the height of 100 meters above the artillery meteorological station;

TTTT_{01} is the mean virtual air temperature for zone 01 in the METCM meteorological message.

$$t_{350} = \frac{1}{10}\mathrm{TTTT}_{02} - 286.8352 - 0.0602 \tag{2}$$

$$t_{750} = \frac{1}{10}\mathrm{TTTT}_{03} - 284.304 - 0.129 \tag{3}$$

$$t_{1250} = \frac{1}{10}\mathrm{TTTT}_{04} - 281.14 - 0.215 \tag{4}$$

$$t_{1750} = \frac{1}{10}\mathrm{TTTT}_{05} - 277.976 - 0.301 \tag{5}$$

$$t_{2250} = \frac{1}{10}\mathrm{TTTT}_{06} - 274.812 - 0.387 \tag{6}$$

$$t_{2750} = \frac{1}{10}\mathrm{TTTT}_{07} - 271.648 - 0.473 \tag{7}$$

$$t_{3250} = \frac{1}{10}\mathrm{TTTT}_{08} - 268.484 - 0.559 \tag{8}$$

$$t_{3750} = \frac{1}{10}\mathrm{TTTT}_{09} - 265.32 - 0.645 \tag{9}$$

$$t_{4250} = \frac{1}{10}\mathrm{TTTT}_{10} - 262.156 - 0.731 \tag{10}$$

$$t_{4750} = \frac{1}{10}\mathrm{TTTT}_{11} - 258.992 - 0.817 \tag{11}$$

$$t_{5500} = \frac{1}{10}\mathrm{TTTT}_{12} - 254.246 - 0.946 \tag{12}$$

$$t_{6500} = \frac{1}{10}\mathrm{TTTT}_{13} - 247.918 - 1.118 \tag{13}$$

$$t_{7500} = \frac{1}{10}\mathrm{TTTT}_{14} - 241.59 - 1.29 \tag{14}$$

$$t_{8500} = \frac{1}{10}\mathrm{TTTT}_{15} - 235.262 - 1.462 \tag{15}$$

$$t_{9500} = \frac{1}{10}\mathrm{TTTT}_{16} - 228.9809 - 1.68088 \tag{16}$$

$$t_{10500} = \frac{1}{10}\mathrm{TTTT}_{17} - 224.2937 - 3.49368 \tag{17}$$

$$t_{11500} = \frac{1}{10}\mathrm{TTTT}_{18} - 221.9505 - 4.40048 \tag{18}$$

$$t_{12500} = \frac{1}{10}\mathrm{TTTT}_{19} - 221.65 - 4.1 \tag{19}$$

Furthermore, wind speeds in the mean altitudes of the individual zones of the METCM meteorological message in meters per second w_{sv} are calculated. Wind speeds are calculated according to the relationship:

$$w_{sv} = 0.515 \cdot \mathrm{FFF}_{zz} \tag{20}$$

whereFFF_{zz} is the wind speed in knots, given in the ZZ zone in the METCM meteorological message.

Calculation of meteorological data for the altitudes in the METEO11 standard heights

From the meteorological data for the mean heights of the individual zones of the METCM meteorological message, the changes in the virtual air temperature with respect to the tabular values at the mean heights and azimuthsand wind speeds at the heights of the upper boundaries of the METEO11 meteorological message layers are calculated. The mathematical model of METCM conversion to METEO11 format assumes a linear course of meteorological values between the mean heights of individual zones of the METCM meteorological message, and therefore meteorological data in the middle heights and upper boundaries of the METEO11 meteorological message layers are gained by interpolations.

Changes in the virtual air temperature with respect to the tabular values in the SHs of the METEO11 meteorological message are calculated similarly to changes in the virtual air temperature with respect to the tabular values when converting the METB3 meteorological report to the METEO11 format[6]. The values of the changes of the virtual air temperature are determined according to equations (21) to (33).

$$\tau_{100} = t_{100},\ \ \tau_{5500} = t_{5500} \tag{21}$$

$$\tau_{300} = \frac{4}{5}(t_{350} - t_{100}) + t_{100} \tag{22}$$

$$\tau_{600} = \frac{5}{8}(t_{750} - t_{350}) + t_{350} \tag{23}$$

$$\tau_{1000} = \frac{1}{2}(t_{1250} - t_{750}) + t_{750} \tag{24}$$

$$\tau_{1400} = \frac{3}{10}(t_{1750} - t_{1250}) + t_{1250} \tag{25}$$

$$\tau_{1800} = \frac{1}{10}(t_{2250} - t_{1750}) + t_{1750} \tag{26}$$

$$\tau_{2200} = \frac{9}{10}(t_{2250} - t_{1750}) + t_{1750} \tag{27}$$

$$\tau_{2700} = \frac{9}{10}(t_{2750} - t_{2250}) + t_{2250} \tag{28}$$

$$\tau_{3500} = \frac{1}{2}(t_{3750} - t_{3250}) + t_{3250} \tag{29}$$
$$\tau_{4500} = \frac{1}{2}(t_{4750} - t_{4250}) + t_{4250} \tag{30}$$
$$\tau_{7000} = \frac{1}{2}(t_{7500} - t_{6500}) + t_{6500} \tag{31}$$
$$\tau_{9000} = \frac{1}{2}(t_{9500} - t_{8500}) + t_{8500} \tag{32}$$
$$\tau_{11000} = \frac{1}{2}(t_{11500} - t_{10500}) + t_{10500} \tag{33}$$

The wind directions at the heights of the upper boundaries of the layers of the METEO11 meteorological message are calculated according to equations (34) to (46).

$$s_{200} = \begin{cases} \frac{15}{16}\left[10\cdot DD_{01} - \frac{1}{6}(10\cdot DD_{01} - 10\cdot DD_{02})\right] + \gamma, \text{ for } DD_{02} < DD_{01} \wedge (DD_{01} - DD_{02}) < 320 \\ \frac{15}{16}\left\{10\cdot DD_{01} + \frac{1}{6}[10(DD_{02} + 640) - 10\cdot DD_{01}]\right\} + \gamma, \text{ for } DD_{02} < DD_{01} \wedge (DD_{02} - DD_{01}) < -320 \\ \frac{15}{16}\left\{10(DD_{01} + 640) - \frac{1}{6}[10(DD_{01} + 640) - 10\cdot DD_{02}]\right\} + \gamma, \text{ for } DD_{02} > DD_{01} \wedge (DD_{02} - DD_{01}) > 320 \\ \frac{15}{16}\left[10\cdot DD_{01} + \frac{1}{6}(10\cdot DD_{02} - 10\cdot DD_{01})\right] + \gamma, \text{ for } DD_{02} > DD_{01} \wedge (DD_{02} - DD_{01}) < 320 \\ \frac{150}{16}DD_{02} + \gamma, \text{ for } DD_{02} = DD_{01} \end{cases} \tag{34}$$

where:

DD_{01} is the geographical azimuth of the wind direction in tens of miles, given in the METCM meteorological message in the line 01;

DD_{02} the geographical azimuth of the wind direction in tens of miles, given in the METCM meteorological message in the line 02;

γ is the meridian convergence calculated for the latitude and longitude of the artillery meteorological station.

$$s_{400} = \begin{cases} \frac{15}{16}\left[10\cdot DD_{02} - \frac{1}{8}(10\cdot DD_{02} - 10\cdot DD_{03})\right] + \gamma, \text{ for } DD_{03} < DD_{02} \wedge (DD_{02} - DD_{03}) < 320 \\ \frac{15}{16}\left\{10\cdot DD_{02} + \frac{1}{8}[10(DD_{03} + 640) - 10\cdot DD_{02}]\right\} + \gamma, \text{ for } DD_{03} < DD_{02} \wedge (DD_{03} - DD_{02}) < -320 \\ \frac{15}{16}\left\{10(DD_{02} + 640) - \frac{1}{8}[10(DD_{02} + 640) - 10\cdot DD_{03}]\right\} + \gamma, \text{ for } DD_{03} > DD_{02} \wedge (DD_{03} - DD_{02}) > 320 \\ \frac{15}{16}\left[10\cdot DD_{02} + \frac{1}{8}(10\cdot DD_{03} - 10\cdot DD_{02})\right] + \gamma, \text{ for } DD_{03} > DD_{02} \wedge (DD_{03} - DD_{02}) < 320 \\ \frac{150}{16}DD_{03} + \gamma, \text{ for } DD_{03} = DD_{02} \end{cases} \tag{35}$$

$$s_{800} = \begin{cases} \frac{15}{16}\left[10\cdot DD_{03} - \frac{1}{10}(10\cdot DD_{03} - 10\cdot DD_{04})\right] + \gamma, \text{ for } DD_{04} < DD_{03} \wedge (DD_{03} - DD_{04}) < 320 \\ \frac{15}{16}\left\{10\cdot DD_{03} + \frac{1}{10}[10(DD_{04} + 640) - 10\cdot DD_{03}]\right\} + \gamma, \text{ for } DD_{04} < DD_{03} \wedge (DD_{04} - DD_{03}) < -320 \\ \frac{15}{16}\left\{10(DD_{03} + 640) - \frac{1}{10}[10(DD_{03} + 640) - 10\cdot DD_{04}]\right\} + \gamma, \text{ for } DD_{04} > DD_{03} \wedge (DD_{04} - DD_{03}) > 320 \\ \frac{15}{16}\left[10\cdot DD_{03} + \frac{1}{10}(10\cdot DD_{04} - 10\cdot DD_{03})\right] + \gamma, \text{ for } DD_{04} > DD_{03} \wedge (DD_{04} - DD_{03}) < 320 \\ \frac{150}{16}DD_{04} + \gamma, \text{ for } DD_{04} = DD_{03} \end{cases} \tag{36}$$

$$s_{1200} = \begin{cases} \frac{15}{16}\left[10\cdot DD_{03} - \frac{9}{10}(10\cdot DD_{03} - 10\cdot DD_{04})\right] + \gamma, \text{ for } DD_{04} < DD_{03} \wedge (DD_{03} - DD_{04}) < 320 \\ \frac{15}{16}\left\{10\cdot DD_{03} + \frac{9}{10}[10(DD_{04} + 640) - 10\cdot DD_{03}]\right\} + \gamma, \text{ for } DD_{04} < DD_{03} \wedge (DD_{04} - DD_{03}) < -320 \\ \frac{15}{16}\left\{10(DD_{03} + 640) - \frac{9}{10}[10(DD_{03} + 640) - 10\cdot DD_{04}]\right\} + \gamma, \text{ for } DD_{04} > DD_{03} \wedge (DD_{04} - DD_{03}) > 320 \\ \frac{15}{16}\left[10\cdot DD_{03} + \frac{9}{10}(10\cdot DD_{04} - 10\cdot DD_{03})\right] + \gamma, \text{ for } DD_{04} > DD_{03} \wedge (DD_{04} - DD_{03}) < 320 \\ \frac{150}{16}DD_{04} + \gamma, \text{ for } DD_{04} = DD_{03} \end{cases} \tag{37}$$

$$s_{1600} = \begin{cases} \frac{15}{16}\left[10\cdot DD_{04} - \frac{7}{10}(10\cdot DD_{04} - 10\cdot DD_{05})\right] + \gamma, \text{ for } DD_{05} < DD_{04} \wedge (DD_{04} - DD_{05}) < 320 \\ \frac{15}{16}\left\{10\cdot DD_{04} + \frac{7}{10}[10(DD_{05} + 640) - 10\cdot DD_{04}]\right\} + \gamma, \text{ for } DD_{05} < DD_{04} \wedge (DD_{05} - DD_{04}) < -320 \\ \frac{15}{16}\left\{10(DD_{04} + 640) - \frac{7}{10}[10(DD_{04} + 640) - 10\cdot DD_{05}]\right\} + \gamma, \text{ for } DD_{05} > DD_{04} \wedge (DD_{05} - DD_{04}) > 320 \\ \frac{15}{16}\left[10\cdot DD_{04} + \frac{7}{10}(10\cdot DD_{05} - 10\cdot DD_{04})\right] + \gamma, \text{ for } DD_{05} > DD_{04} \wedge (DD_{05} - DD_{04}) < 320 \\ \frac{150}{16}DD_{05} + \gamma, \text{ for } DD_{05} = DD_{04} \end{cases} \tag{38}$$

$$s_{2000} = \begin{cases} \frac{15}{16}\left[10\cdot DD_{05} - \frac{1}{2}(10\cdot DD_{05} - 10\cdot DD_{06})\right] + \gamma, \text{ for } DD_{06} < DD_{05} \wedge (DD_{05} - DD_{06}) < 320 \\ \frac{15}{16}\left\{10\cdot DD_{05} + \frac{1}{2}[10(DD_{06} + 640) - 10\cdot DD_{05}]\right\} + \gamma, \text{ for } DD_{06} < DD_{05} \wedge (DD_{06} - DD_{05}) < -320 \\ \frac{15}{16}\left\{10(DD_{05} + 640) - \frac{1}{2}[10(DD_{05} + 640) - 10\cdot DD_{06}]\right\} + \gamma, \text{ for } DD_{06} > DD_{05} \wedge (DD_{06} - DD_{05}) > 320 \\ \frac{15}{16}\left[10\cdot DD_{05} + \frac{1}{2}(10\cdot DD_{06} - 10\cdot DD_{05})\right] + \gamma, \text{ for } DD_{06} > DD_{05} \wedge (DD_{06} - DD_{05}) < 320 \\ \frac{150}{16}DD_{06} + \gamma, \text{ for } DD_{06} = DD_{05} \end{cases} \tag{38}$$

$$s_{2400} = \begin{cases} \frac{15}{16}\left[10 \cdot DD_{06} - \frac{3}{10}(10 \cdot DD_{06} - 10 \cdot DD_{07})\right] + \gamma, \text{ for } DD_{07} < DD_{06} \wedge (DD_{06} - DD_{07}) < 320 \\ \frac{15}{16}\left\{10 \cdot DD_{06} + \frac{3}{10}[10(DD_{07} + 640) - 10 \cdot DD_{06}]\right\} + \gamma, \text{ for } DD_{07} < DD_{06} \wedge (DD_{07} - DD_{06}) < -320 \\ \frac{15}{16}\left\{10(DD_{06} + 640) - \frac{3}{10}[10(DD_{06} + 640) - 10 \cdot DD_{07}]\right\} + \gamma, \text{ for } DD_{07} > DD_{06} \wedge (DD_{07} - DD_{06}) > 320 \\ \frac{15}{16}\left[10 \cdot DD_{06} + \frac{3}{10}(10 \cdot DD_{07} - 10 \cdot DD_{06})\right] + \gamma, \text{ for } DD_{07} > DD_{06} \wedge (DD_{07} - DD_{06}) < 320 \\ \frac{150}{16} DD_{07} + \gamma, \text{ for } DD_{07} = DD_{06} \end{cases} \quad (39)$$

$$s_{3000} = \begin{cases} \frac{15}{16}\left[10 \cdot DD_{07} - \frac{1}{2}(10 \cdot DD_{07} - 10 \cdot DD_{08})\right] + \gamma, \text{ for } DD_{08} < DD_{07} \wedge (DD_{07} - DD_{08}) < 320 \\ \frac{15}{16}\left\{10 \cdot DD_{07} + \frac{1}{2}[10(DD_{08} + 640) - 10 \cdot DD_{07}]\right\} + \gamma, \text{ for } DD_{08} < DD_{07} \wedge (DD_{08} - DD_{07}) < -320 \\ \frac{15}{16}\left\{10(DD_{07} + 640) - \frac{1}{2}[10(DD_{07} + 640) - 10 \cdot DD_{08}]\right\} + \gamma, \text{ for } DD_{08} > DD_{07} \wedge (DD_{08} - DD_{07}) > 320 \\ \frac{15}{16}\left[10 \cdot DD_{07} + \frac{1}{2}(10 \cdot DD_{08} - 10 \cdot DD_{07})\right] + \gamma, \text{ for } DD_{08} > DD_{07} \wedge (DD_{08} - DD_{07}) < 320 \\ \frac{150}{16} DD_{08} + \gamma, \text{ for } DD_{08} = DD_{07} \end{cases} \quad (40)$$

$$s_{4000} = \begin{cases} \frac{15}{16}\left[10 \cdot DD_{09} - \frac{1}{2}(10 \cdot DD_{09} - 10 \cdot DD_{10})\right] + \gamma, \text{ for } DD_{10} < DD_{09} \wedge (DD_{09} - DD_{10}) < 320 \\ \frac{15}{16}\left\{10 \cdot DD_{09} + \frac{1}{2}[10(DD_{10} + 640) - 10 \cdot DD_{09}]\right\} + \gamma, \text{ for } DD_{10} < DD_{09} \wedge (DD_{10} - DD_{09}) < -320 \\ \frac{15}{16}\left\{10(DD_{09} + 640) - \frac{1}{2}[10(DD_{09} + 640) - 10 \cdot DD_{10}]\right\} + \gamma, \text{ for } DD_{10} > DD_{09} \wedge (DD_{10} - DD_{09}) > 320 \\ \frac{15}{16}\left[10 \cdot DD_{09} + \frac{1}{2}(10 \cdot DD_{10} - 10 \cdot DD_{09})\right] + \gamma, \text{ for } DD_{10} > DD_{09} \wedge (DD_{10} - DD_{09}) < 320 \\ \frac{150}{16} DD_{10} + \gamma, \text{ for } DD_{10} = DD_{09} \end{cases} \quad (41)$$

$$s_{5000} = \begin{cases} \frac{15}{16}\left[10 \cdot DD_{11} - \frac{1}{2}(10 \cdot DD_{11} - 10 \cdot DD_{12})\right] + \gamma, \text{ for } DD_{12} < DD_{11} \wedge (DD_{11} - DD_{12}) < 320 \\ \frac{15}{16}\left\{10 \cdot DD_{11} + \frac{1}{2}[10(DD_{12} + 640) - 10 \cdot DD_{11}]\right\} + \gamma, \text{ for } DD_{12} < DD_{11} \wedge (DD_{12} - DD_{11}) < -320 \\ \frac{15}{16}\left\{10(DD_{11} + 640) - \frac{1}{2}[10(DD_{11} + 640) - 10 \cdot DD_{12}]\right\} + \gamma, \text{ for } DD_{12} > DD_{11} \wedge (DD_{12} - DD_{11}) > 320 \\ \frac{15}{16}\left[10 \cdot DD_{11} + \frac{1}{2}(10 \cdot DD_{12} - 10 \cdot DD_{11})\right] + \gamma, \text{ for } DD_{12} > DD_{11} \wedge (DD_{12} - DD_{11}) < 320 \\ \frac{150}{16} DD_{12} + \gamma, \text{ for } DD_{12} = DD_{11} \end{cases} \quad (42)$$

$$s_{6000} = \begin{cases} \frac{15}{16}\left[10 \cdot DD_{12} - \frac{1}{2}(10 \cdot DD_{12} - 10 \cdot DD_{13})\right] + \gamma, \text{ for } DD_{13} < DD_{12} \wedge (DD_{12} - DD_{13}) < 320 \\ \frac{15}{16}\left\{10 \cdot DD_{12} + \frac{1}{2}[10(DD_{13} + 640) - 10 \cdot DD_{12}]\right\} + \gamma, \text{ for } DD_{13} < DD_{12} \wedge (DD_{13} - DD_{12}) < -320 \\ \frac{15}{16}\left\{10(DD_{12} + 640) - \frac{1}{2}[10(DD_{12} + 640) - 10 \cdot DD_{13}]\right\} + \gamma, \text{ for } DD_{13} > DD_{12} \wedge (DD_{13} - DD_{12}) > 320 \\ \frac{15}{16}\left[10 \cdot DD_{12} + \frac{1}{2}(10 \cdot DD_{13} - 10 \cdot DD_{12})\right] + \gamma, \text{ for } DD_{13} > DD_{12} \wedge (DD_{13} - DD_{12}) < 320 \\ \frac{150}{16} DD_{13} + \gamma, \text{ for } DD_{13} = DD_{12} \end{cases} \quad (43)$$

$$s_{8000} = \begin{cases} \frac{15}{16}\left[10 \cdot DD_{14} - \frac{1}{2}(10 \cdot DD_{14} - 10 \cdot DD_{15})\right] + \gamma, \text{ for } DD_{15} < DD_{14} \wedge (DD_{14} - DD_{15}) < 320 \\ \frac{15}{16}\left\{10 \cdot DD_{14} + \frac{1}{2}[10(DD_{15} + 640) - 10 \cdot DD_{14}]\right\} + \gamma, \text{ for } DD_{15} < DD_{14} \wedge (DD_{15} - DD_{14}) < -320 \\ \frac{15}{16}\left\{10(DD_{14} + 640) - \frac{1}{2}[10(DD_{14} + 640) - 10 \cdot DD_{15}]\right\} + \gamma, \text{ for } DD_{15} > DD_{14} \wedge (DD_{15} - DD_{14}) > 320 \\ \frac{15}{16}\left[10 \cdot DD_{14} + \frac{1}{2}(10 \cdot DD_{15} - 10 \cdot DD_{14})\right] + \gamma, \text{ for } DD_{15} > DD_{14} \wedge (DD_{15} - DD_{14}) < 320 \\ \frac{150}{16} DD_{15} + \gamma, \text{ for } DD_{15} = DD_{14} \end{cases} \quad (44)$$

$$s_{10000} = \begin{cases} \frac{15}{16}\left[10 \cdot DD_{16} - \frac{1}{2}(10 \cdot DD_{16} - 10 \cdot DD_{17})\right] + \gamma, \text{ for } DD_{17} < DD_{16} \wedge (DD_{16} - DD_{17}) < 320 \\ \frac{15}{16}\left\{10 \cdot DD_{16} + \frac{1}{2}[10(DD_{17} + 640) - 10 \cdot DD_{16}]\right\} + \gamma, \text{ for } DD_{17} < DD_{16} \wedge (DD_{17} - DD_{16}) < -320 \\ \frac{15}{16}\left\{10(DD_{16} + 640) - \frac{1}{2}[10(DD_{16} + 640) - 10 \cdot DD_{17}]\right\} + \gamma, \text{ for } DD_{17} > DD_{16} \wedge (DD_{17} - DD_{16}) > 320 \\ \frac{15}{16}\left[10 \cdot DD_{16} + \frac{1}{2}(10 \cdot DD_{17} - 10 \cdot DD_{16})\right] + \gamma, \text{ for } DD_{17} > DD_{16} \wedge (DD_{17} - DD_{16}) < 320 \\ \frac{150}{16} DD_{17} + \gamma, \text{ for } DD_{17} = DD_{16} \end{cases} \quad (45)$$

$$s_{12000} = \begin{cases} \frac{15}{16}\left[10 \cdot DD_{18} - \frac{1}{2}(10 \cdot DD_{18} - 10 \cdot DD_{19})\right] + \gamma, \text{ for } DD_{19} < DD_{18} \wedge (DD_{18} - DD_{19}) < 320 \\ \frac{15}{16}\left\{10 \cdot DD_{18} + \frac{1}{2}[10(DD_{19} + 640) - 10 \cdot DD_{18}]\right\} + \gamma, \text{ for } DD_{19} < DD_{18} \wedge (DD_{19} - DD_{18}) < -320 \\ \frac{15}{16}\left\{10(DD_{18} + 640) - \frac{1}{2}[10(DD_{18} + 640) - 10 \cdot DD_{19}]\right\} + \gamma, \text{ for } DD_{19} > DD_{18} \wedge (DD_{19} - DD_{18}) > 320 \\ \frac{15}{16}\left[10 \cdot DD_{18} + \frac{1}{2}(10 \cdot DD_{19} - 10 \cdot DD_{18})\right] + \gamma, \text{ for } DD_{19} > DD_{18} \wedge (DD_{19} - DD_{18}) < 320 \\ \frac{150}{16} DD_{19} + \gamma, \text{ for } DD_{19} = DD_{18} \end{cases} \quad (46)$$

The calculated wind azimuths values according to equations (35) to (46) are further analyzed if they are in the range (0; 6000⟩. If any value is greater than 6000, 6000 is subtracted from it. If any value is less than or equal to zero, then add 6000 to it.

The values of wind speed (at the height of the upper boundery of the SH in the METEO11meteorological message) are determined according to equations (47) to (60).

$$r_{200} = \frac{2}{5}(w_{350} - w_{100}) + w_{100} \quad (47)$$

$$r_{400} = \frac{1}{8}(w_{750} - w_{350}) + w_{350} \quad (48)$$
$$r_{800} = \frac{1}{10}(w_{1250} - w_{750}) + w_{750} \quad (49)$$
$$r_{1200} = \frac{9}{10}(w_{1250} - w_{750}) + w_{750} \quad (50)$$
$$r_{1600} = \frac{7}{10}(w_{1750} - w_{1250}) + w_{1250} \quad (51)$$
$$r_{2000} = \frac{1}{2}(w_{2250} - w_{1750}) + w_{1750} \quad (52)$$
$$r_{2400} = \frac{3}{10}(w_{2750} - w_{2250}) + w_{2250} \quad (53)$$
$$r_{3000} = \frac{1}{2}(w_{3250} - w_{2750}) + w_{2750} \quad (54)$$
$$r_{4000} = \frac{1}{2}(w_{4250} - w_{3750}) + w_{3750} \quad (55)$$
$$r_{5000} = \frac{1}{3}(w_{5500} - w_{4750}) + w_{4750} \quad (56)$$
$$r_{6000} = \frac{1}{2}(w_{6500} - w_{5500}) + w_{5500} \quad (57)$$
$$r_{8000} = \frac{1}{2}(w_{8500} - w_{7500}) + w_{7500} \quad (58)$$
$$r_{10000} = \frac{1}{2}(w_{10500} - w_{9500}) + w_{9500} \quad (59)$$
$$r_{12000} = \frac{1}{2}(w_{12500} - w_{11500}) + w_{11500} \quad (60)$$

Calculation of mean values of meteorological data in METEO11 standard heights

The mean changes of the virtual air temperature with respect to the tabular values in the SH of the METEO11 meteorological message are calculated according to equations (61) to (74).

$$TT'_{02} = \tau_{100} \quad (61)$$
$$TT'_{04} = \frac{1}{3}\left(TT'_{02} + 2 \cdot \tau_{300}\right) \quad (62)$$
$$TT'_{08} = \frac{1}{2}\left(TT'_{04} + \tau_{600}\right) \quad (63)$$
$$TT'_{12} = \frac{1}{3}\left(2 \cdot TT'_{08} + \tau_{1000}\right) \quad (64)$$
$$TT'_{16} = \frac{1}{4}\left(3 \cdot TT'_{12} + \tau_{1400}\right) \quad (65)$$
$$TT'_{20} = \frac{1}{5}\left(4 \cdot TT'_{16} + \tau_{1800}\right) \quad (66)$$
$$TT'_{24} = \frac{1}{6}\left(5 \cdot TT'_{20} + \tau_{2200}\right) \quad (67)$$
$$TT'_{30} = \frac{1}{5}\left(4 \cdot TT'_{24} + \tau_{2700}\right) \quad (68)$$
$$TT'_{40} = \frac{1}{4}\left(3 \cdot TT'_{30} + \tau_{3500}\right) \quad (69)$$
$$TT'_{50} = \frac{1}{5}\left(4 \cdot TT'_{40} + \tau_{4500}\right) \quad (70)$$
$$TT'_{60} = \frac{1}{6}\left(5 \cdot TT'_{50} + \tau_{5500}\right) \quad (71)$$
$$TT'_{80} = \frac{1}{4}\left(3 \cdot TT'_{60} + \tau_{7000}\right) \quad (72)$$
$$TT'_{100} = \frac{1}{5}\left(4 \cdot TT'_{80} + \tau_{9000}\right) \quad (73)$$
$$TT'_{120} = \frac{1}{6}\left(5 \cdot TT'_{10} + \tau_{11000}\right) \quad (74)$$

The mean wind azimuths in the SHs of the METEO11 meteorological message calculated according to the data in the METCM meteorological message represent the least accurate recalculated data. The conversion of the METB3 meteorological message[6] is based on the values of the geographical azimuths of the wind, which are related to the altitude range from the artillery meteorological station to the upper boundary of the relevant layer. In the case of the METCM meteorological messega, this information is given only for the altitude range of the particular zone (from its lower limit to the upper limit).

During the design of the mathematical model of the conversion of the METCM meteorological message to the METEO11 format, a variant of the calculation was tested, in which the wind direction (after conversion from geographical azimuth) was gradually decomposed into x and y components within the Cartesian coordinate system. To calculate the coordinate differences, the horizontal distances (reached by the meteorological radiosonde when ascent through the atmosphere) were determined. For the calculations of these distances, the time required to overcome the height difference of two adjacent SHs in the METEO11meteorological message was derived.

Due to the absence of time data in the METCM meteorological message, a constant value of the meteorological balloon ascent rate of 6.2 m·s^{-1}was used in the calculations, which was obtained by analyzing available messages of measured meteorological data from the MARWIN MW32 set. Then, uniform accelerations (decelerations) of the wind in the respective altitude ranges were calculated. The decomposition of the wind vector into the x and y components was performed using data of wind speeds at individual altitudes, the derived time and the calculated uniform accelerations or decelerations.

To calculate the mean wind direction in the relevant SH, all corresponding coordinate differences were summed to obtain the x and y components of the mean wind direction vector in the particularSH of theMETEO11meteorological message. From these coordinate differences, the mean wind direction was then determined in the relevant SHof the METEO11 meteorological message. However, with this approach, it was possible to obtain medium wind directions in individual SHs of the METEO11 meteorological message, which differed from the actual directions by up to 5 units. The calculations were not refined even by adjusting the average balloon ascent rate. It was gradually changed by a tenth in the interval from 5 m·s^{-1}to 6.5 m·s^{-1}. Higher accuracy in the calculations of the mean wind direction was obtained by applying an analogous approach to the calculations of the mean wind speeds in the SHs of the METEO11 meteorological message, while it was necessary to take into account the fluctuations of wind from one side to the other. The mean wind directions in the SHs of the METEO11 meteorological message are therefore calculated according to equations (75) to (88) within the modified mathematical model of the conversion of the METCM meteorological message to the METEO11 format.

$$D_{02} = s_{200} \tag{75}$$

where:

D_{02} is the mean wind direction in the SH 200 meters in the METEO11 meteorological message;

s_{200} wind direction calculated according to the relation(34).

$$D_{04} = \begin{cases} D_{02} + 6000 - \frac{1}{2}(D_{02} + 6000 - s_{400}), \text{ for } D_{02} < s_{400} \wedge (s_{400} - D_{02}) > 3000 \\ D_{02} + \frac{1}{2}(s_{400} + 6000 - D_{02}), \text{ for } D_{02} > s_{400} \wedge (s_{400} - D_{02}) < -3000 \\ D_{02} + \frac{1}{2}(s_{400} - D_{02}), \text{ for } D_{02} < s_{400} \wedge (s_{400} - D_{02}) < 3000 \\ D_{02} - \frac{1}{2}(D_{02} - s_{400}), \text{ for } D_{02} > s_{400} \wedge (D_{02} - s_{400}) < 3000 \\ s_{400}, \text{ for } s_{400} = D_{02} \end{cases} \tag{76}$$

where:

D_{04} is the mean wind direction in the SH400 meters in the METEO11 meteorological message;

s_{400} wind direction calculated according to the relation(35).

The calculated value of the mean wind direction indicator in the SH must be evaluated immediately (before its further use) whether it is in the interval (0; 6000⟩. If it is greater than 6000, 6000 is subtracted from it. If it is less than or equal to zero, then is added 6000.

$$D_{08} = \begin{cases} D_{04} + 6000 - \frac{1}{2}(D_{04} + 6000 - s_{800}), \text{ for } D_{04} < s_{800} \wedge (s_{800} - D_{04}) > 3000 \\ D_{04} + \frac{1}{2}(s_{800} + 6000 - D_{04}), \text{ for } D_{04} > s_{800} \wedge (s_{800} - D_{04}) < -3000 \\ D_{04} + \frac{1}{2}(s_{800} - D_{04}), \text{ for } D_{04} < s_{800} \wedge (s_{800} - D_{04}) < 3000 \\ D_{04} - \frac{1}{2}(D_{04} - s_{800}), \text{ for } D_{04} > s_{800} \wedge (D_{04} - s_{800}) < 3000 \\ s_{800}, \text{ for } s_{800} = D_{04} \end{cases} \tag{77}$$

$$D_{12} = \begin{cases} D_{08} + 6000 - \frac{1}{3}(D_{08} + 6000 - s_{1200}), \text{ for } D_{08} < s_{1200} \wedge (s_{1200} - D_{08}) > 3000 \\ D_{08} + \frac{1}{3}(s_{1200} + 6000 - D_{08}), \text{ for } D_{08} > s_{1200} \wedge (s_{1200} - D_{08}) < -3000 \\ D_{08} + \frac{1}{3}(s_{1200} - D_{08}), \text{ for } D_{08} < s_{1200} \wedge (s_{1200} - D_{08}) < 3000 \\ D_{08} - \frac{1}{3}(D_{08} - s_{1200}), \text{ for } D_{08} > s_{1200} \wedge (D_{08} - s_{1200}) < 3000 \\ s_{1200}, \text{ for } s_{1200} = D_{08} \end{cases} \tag{78}$$

$$D_{16}=\begin{cases} D_{12}+6000-\frac{1}{4}(D_{12}+6000-s_{1600}), & \text{for } D_{12}<s_{1600}\wedge(s_{1600}-D_{12})>3000 \\ D_{12}+\frac{1}{4}(s_{1600}+6000-D_{12}), & \text{for } D_{12}>s_{1600}\wedge(s_{1600}-D_{12})<-3000 \\ D_{12}+\frac{1}{4}(s_{1600}-D_{12}), & \text{for } D_{12}<s_{1600}\ \wedge\ (s_{1600}-D_{12})<3000 \\ D_{12}-\frac{1}{4}(D_{12}-s_{1600}), & \text{for } D_{12}>s_{1600}\ \wedge\ (D_{12}-s_{1600})<3000 \\ s_{1600}, & \text{for } s_{1600}=D_{12} \end{cases} \tag{79}$$

$$D_{20}=\begin{cases} D_{16}+6000-\frac{1}{5}(D_{16}+6000-s_{2000}), & \text{for } D_{16}<s_{2000}\wedge(s_{2000}-D_{16})>3000 \\ D_{16}+\frac{1}{5}(s_{2000}+6000-D_{16}), & \text{for } D_{16}>s_{2000}\wedge(s_{2000}-D_{16})<-3000 \\ D_{16}+\frac{1}{5}(s_{2000}-D_{16}), & \text{for } D_{16}<s_{2000}\ \wedge\ (s_{2000}-D_{16})<3000 \\ D_{16}-\frac{1}{5}(D_{16}-s_{2000}), & \text{for } D_{16}>s_{2000}\ \wedge\ (D_{16}-s_{2000})<3000 \\ s_{2000}, & \text{for } s_{2000}=D_{16} \end{cases} \tag{80}$$

$$D_{24}=\begin{cases} D_{20}+6000-\frac{1}{6}(D_{20}+6000-s_{2400}), & \text{for } D_{20}<s_{2400}\wedge(s_{2400}-D_{20})>3000 \\ D_{20}+\frac{1}{6}(s_{2400}+6000-D_{20}), & \text{for } D_{20}>s_{2400}\wedge(s_{2400}-D_{20})<-3000 \\ D_{20}+\frac{1}{6}(s_{2400}-D_{20}), & \text{for } D_{20}<s_{2400}\ \wedge\ (s_{2400}-D_{20})<3000 \\ D_{20}-\frac{1}{6}(D_{20}-s_{2400}), & \text{for } D_{20}>s_{2400}\ \wedge\ (D_{20}-s_{2400})<3000 \\ s_{2400}, & \text{for } s_{2400}=D_{20} \end{cases} \tag{81}$$

$$D_{30}=\begin{cases} D_{20}+6000-\frac{1}{5}(D_{20}+6000-s_{3000}), & \text{for } D_{20}<s_{3000}\wedge(s_{3000}-D_{20})>3000 \\ D_{20}+\frac{1}{5}(s_{3000}+6000-D_{20}), & \text{for } D_{20}>s_{3000}\wedge(s_{3000}-D_{20})<-3000 \\ D_{20}+\frac{1}{5}(s_{3000}-D_{20}), & \text{for } D_{20}<s_{3000}\ \wedge\ (s_{3000}-D_{20})<3000 \\ D_{20}-\frac{1}{5}(D_{20}-s_{3000}), & \text{for } D_{20}>s_{3000}\ \wedge\ (D_{20}-s_{3000})<3000 \\ s_{3000}, & \text{for } s_{3000}=D_{20} \end{cases} \tag{82}$$

$$D_{40}=\begin{cases} D_{30}+6000-\frac{1}{4}(D_{30}+6000-s_{4000}), & \text{for } D_{30}<s_{4000}\wedge(s_{4000}-D_{30})>3000 \\ D_{30}+\frac{1}{4}(s_{4000}+6000-D_{30}), & \text{for } D_{30}>s_{4000}\wedge(s_{4000}-D_{30})<-3000 \\ D_{30}+\frac{1}{4}(s_{4000}-D_{30}), & \text{for } D_{30}<s_{4000}\ \wedge\ (s_{4000}-D_{30})<3000 \\ D_{30}-\frac{1}{4}(D_{30}-s_{4000}), & \text{for } D_{30}>s_{4000}\ \wedge\ (D_{30}-s_{4000})<3000 \\ s_{4000}, & \text{for } s_{4000}=D_{30} \end{cases} \tag{83}$$

$$D_{50}=\begin{cases} D_{40}+6000-\frac{1}{5}(D_{40}+6000-s_{5000}), & \text{for } D_{40}<s_{5000}\wedge(s_{5000}-D_{40})>3000 \\ D_{40}+\frac{1}{5}(s_{5000}+6000-D_{40}), & \text{for } D_{40}>s_{5000}\wedge(s_{5000}-D_{40})<-3000 \\ D_{40}+\frac{1}{5}(s_{5000}-D_{40}), & \text{for } D_{40}<s_{5000}\ \wedge\ (s_{5000}-D_{40})<3000 \\ D_{40}-\frac{1}{5}(D_{40}-s_{5000}), & \text{for } D_{40}>s_{5000}\ \wedge\ (D_{40}-s_{5000})<3000 \\ s_{5000}, & \text{for } s_{5000}=D_{40} \end{cases} \tag{84}$$

$$D_{60}=\begin{cases} D_{50}+6000-\frac{1}{6}(D_{50}+6000-s_{6000}), & \text{for } D_{50}<s_{6000}\wedge(s_{6000}-D_{50})>3000 \\ D_{50}+\frac{1}{6}(s_{6000}+6000-D_{50}), & \text{for } D_{50}>s_{6000}\wedge(s_{6000}-D_{50})<-3000 \\ D_{50}+\frac{1}{6}(s_{6000}-D_{50}), & \text{for } D_{50}<s_{6000}\ \wedge\ (s_{6000}-D_{50})<3000 \\ D_{50}-\frac{1}{6}(D_{50}-s_{6000}), & \text{for } D_{50}>s_{6000}\ \wedge\ (D_{50}-s_{6000})<3000 \\ s_{6000}, & \text{for } s_{6000}=D_{50} \end{cases} \tag{85}$$

$$D_{80} = \begin{cases} D_{60} + 6000 - \frac{1}{4}(D_{60} + 6000 - s_{8000}), \text{ for } D_{60} < s_{8000} \wedge (s_{8000} - D_{60}) > 3000 \\ D_{60} + \frac{1}{4}(s_{8000} + 6000 - D_{60}), \text{ for } D_{60} > s_{8000} \wedge (s_{8000} - D_{60}) < -3000 \\ D_{60} + \frac{1}{4}(s_{8000} - D_{60}), \text{ for } D_{60} < s_{8000} \wedge (s_{8000} - D_{60}) < 3000 \\ D_{60} - \frac{1}{4}(D_{60} - s_{8000}), \text{ for } D_{60} > s_{8000} \wedge (D_{60} - s_{8000}) < 3000 \\ s_{8000}, \text{ for } s_{8000} = D_{60} \end{cases} \quad (86)$$

$$D_{100} = \begin{cases} D_{80} + 6000 - \frac{1}{5}(D_{80} + 6000 - s_{10000}), \text{ for } D_{80} < s_{10000} \wedge (s_{10000} - D_{80}) > 3000 \\ D_{80} + \frac{1}{5}(s_{10000} + 6000 - D_{80}), \text{ for } D_{80} > s_{10000} \wedge (s_{10000} - D_{80}) < -3000 \\ D_{80} + \frac{1}{5}(s_{10000} - D_{80}), \text{ for } D_{80} < s_{10000} \wedge (s_{10000} - D_{80}) < 3000 \\ D_{80} - \frac{1}{5}(D_{80} - s_{10000}), \text{ for } D_{80} > s_{10000} \wedge (D_{80} - s_{10000}) < 3000 \\ s_{10000}, \text{ for } s_{10000} = D_{80} \end{cases} \quad (87)$$

$$D_{120} = \begin{cases} D_{100} + 6000 - \frac{1}{6}(D_{100} + 6000 - s_{12000}), \text{ for } D_{100} < s_{12000} \wedge (s_{12000} - D_{100}) > 3000 \\ D_{100} + \frac{1}{6}(s_{12000} + 6000 - D_{100}), \text{ for } D_{100} > s_{12000} \wedge (s_{12000} - D_{100}) < -3000 \\ D_{100} + \frac{1}{6}(s_{12000} - D_{100}), \text{ for } D_{100} < s_{12000} \wedge (s_{12000} - D_{100}) < 3000 \\ D_{100} - \frac{1}{6}(D_{100} - s_{12000}), \text{ for } D_{100} > s_{12000} \wedge (D_{100} - s_{12000}) < 3000 \\ s_{12000}, \text{ for } s_{12000} = D_{100} \end{cases} \quad (88)$$

The mean wind speeds in the SHs of the METEO11 meteorological message are calculated according to equations (89) to (102).

$$WW_{02} = r_{200} \quad (89)$$
$$WW_{04} = \frac{1}{2}(WW_{02} + r_{400}) \quad (90)$$
$$WW_{08} = \frac{1}{2}(WW_{04} + r_{800}) \quad (91)$$
$$WW_{12} = \frac{1}{3}(2 \cdot WW_{08} + r_{1200}) \quad (92)$$
$$WW_{16} = \frac{1}{4}(3 \cdot WW_{12} + r_{1600}) \quad (93)$$
$$WW_{20} = \frac{1}{5}(4 \cdot WW_{16} + r_{2000}) \quad (94)$$
$$WW_{24} = \frac{1}{6}(5 \cdot WW_{20} + r_{2400}) \quad (95)$$
$$WW_{30} = \frac{1}{5}(4 \cdot WW_{24} + r_{3000}) \quad (96)$$
$$WW_{40} = \frac{1}{4}(3 \cdot WW_{30} + r_{4000}) \quad (97)$$
$$WW_{50} = \frac{1}{5}(4 \cdot WW_{40} + r_{5000}) \quad (98)$$
$$WW_{60} = \frac{1}{6}(5 \cdot WW_{50} + r_{6000}) \quad (99)$$
$$WW_{80} = \frac{1}{4}(3 \cdot WW_{60} + r_{8000}) \quad (100)$$
$$WW_{100} = \frac{1}{5}(4 \cdot WW_{80} + r_{10000}) \quad (101)$$
$$WW_{120} = \frac{1}{6}(5 \cdot WW_{10} + r_{12000}) \quad (102)$$

The mean wind speeds in each SH of the METEO11 meteorological message calculated according to equations (89) to (102) are rounded to whole units.

Software implementation of the conversion model

The mathematical model of the METCM conversions into the METEO11 was implemented into a new software.This software was named as METCM & METB3 toMETEO11 (figure no. 1) and besides the conversions of the METCM meteorological messages format allows the METB3 meteorological messageconversions into the METEO11 format.

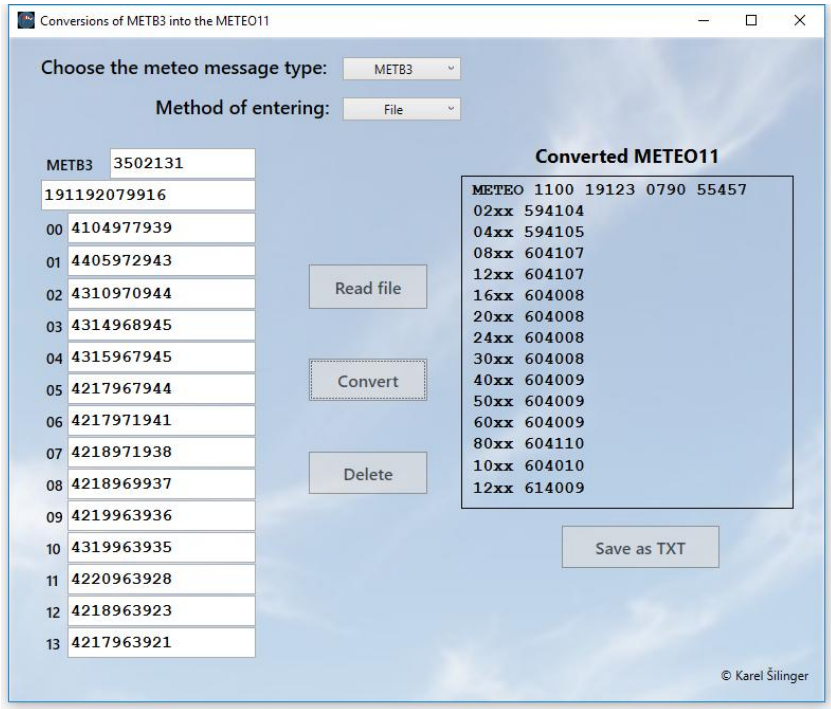

Figure no. 1: METCM & METB3 toMETEO11 software

III. Conclusion

The modified mathematical model of the conversion of the METCM meteorological message to the METEO11 format allows, compared to the original version of the conversion, the calculation of the mean values of meteorological data at all standard heighs, which are commonly used in the calculation of artillery firing data. Conducting surprising artillery fire without adjusting fire or firing a control shot is thus possible based on the calculation of artillery firing data, including meteorological conditions from converted meteorological messages METEO11 from the METCM.

References

[1]. NATO STANDARDIZATION AGENCY. *Adoption of a Standard Atmosphere.* STANAG 4044 Ed. 2. Brusel: 1969. 9 p.
[2]. NATO STANDARDIZATION AGENCY. *Adoption of a Standard Ballistic Meteorological Message*. STANAG 4061 Ed. 4. Brusel: 1969. 25 p.
[3]. NATO STANDARDIZATION AGENCY. *Adoption of a Standard Artillery Computer Meteorological Message*. STANAG 4082 Ed. 3. Brusel: 1969. 11 p.
[4]. NATO STANDARDIZATION AGENCY. *Adoption of a Standard Cannon Artillery Firing Table Format*. STANAG 4119 Ed. 2. Brusel: 2007.
[5]. MO ČR. *Hydrometeorologická příprava dělostřelectva.* Děl-6-9. Praha: 2015. 166 p.
[6]. Šilinger, K. & Blaha, M. 2017, "Conversions of METB3 meteorological messages into the METEO11 format", *ICMT 2017 - 6th International Conference on Military Technologies*, pp. 278-284.
[7]. Blaha, M. & Šilinger, K. 2015, "Setting a method of determination of "fire for effect" firing data and conversion of the METCM into the METEO-11", *International Journal of Circuits, Systems and Signal Processing*, vol. 9, pp. 306-313.
[8]. Jameson, C. T., Sauter, D. *Addendum to a PDA-based Backup System for Generating Marine Corps Artillery Meteorological MEssages*. ARL-TN-279. U.S. Army Research Laboratory: 2007, 22 p.
[9]. Cogan, L. J., Haines, P. A. METCM-based Messages from Climatological Data. ARL-TN-0528. U.S. Army Research Laboratory: 2013, 22 p.
[10]. Jameson, C. T., Sauter, D. *Generating of Ballistic Meteorological Message – Surface to Surface (METB3s) from Computer Meteorological Messages (METCMs).* ARL-TN-0550 U.S. Army Research Laboratory: 2013, 28 p.

Karel Šilinger, et. al. "Modified conversion of METCM meteorological message to METEO11 format." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 14(10), (2020): pp 17-27.