Deliverable D3.7

Final report on the production of the climatology of the Carpathian Region

Contract number: OJEU 2010/S 110-166082
Deliverable: D3.7
Author: Dragan Mihic, Jonathan Spinoni, Tiberiu Antofie
Date: 21–06–2013
Version: final

Contents

1. Introduction

The Climate of the Carpathian Region (CARPATCLIM) project aims at improving the basis of climate data for the Carpathian Region for applied regional climatological studies such as a Climate Atlas or drought monitoring. One important step in this process is the calculation of a climatology for several meteorological parameters and climate indicators. This deliverable presents these parameters and indicators together with the methodology of their computation.

2. Climatological parameters and indicators

Generally, all the climatological parameters and indicators were computed from the daily gridded data, for each gridpoint, and for the period from 1961 to 2010. All calculated parameters/indicators are listed in Table 1. with information on their abbreviation, description, units and time frequency.

Table 1. List of parameters/indicators

No.	Indicator	Description	Units	Frequency
1.	TA_M	Average mean air temperature	^oC	Monthly
2.	TA_Y	Average mean air temperature	^oC	Yearly
3.	TMIN_M	Average minimum air temperature	^oC	Monthly
4.	TMIN_Y	Average minimum air temperature	^oC	Yearly
5.	TMAX_M	Average maximum air temperature	^oC	Monthly
6.	TMAX_Y	Average maximum air temperature	^oC	Yearly
7.	PREC_M	Accumulated total precipitation	mm	Monthly
8.	PREC_Y	Accumulated total precipitation	mm	Yearly
9.	WS10_M	Average 10m horizontal wind speed	m/s	Monthly
10.	WS2_M	Average 2m horizontal wind speed	m/s	Monthly
11.	SUN_M	Sunshine duration	hours	Monthly
12.	SUN_Y	Sunshine duration	hours	Yearly
13.	CC_M	Average cloud cover	tenths	Monthly
14.	RG_M	Global radiation	J/cm^2	Monthly
15.	RH_M	Average relative humidity	%	Monthly
16.	PV_M	Mean vapour pressure	hPa	Monthly
17.	PA_M	Mean surface air pressure	hPa	Monthly
18.	SNOW_M	Snow depth	cm	Monthly
19.	SWE_M	Snow water equvivalent	mm	Monthly
20.	FD_M	Number of frost days (Tmin < 0^oC)	days	Monthly
21.	PFD_M	Percentage of frost days (Tmin < 0^oC)	%	Monthly
22.	FD_Y	Number of frost days (Tmin < 0^oC)	days	Yearly

23.	PFD_Y	Percentage of frost days (Tmin < 0°C)	%	Yearly
24.	SD_M	Number of summer days (Tmax > 25°C)	days	Monthly
25.	PSD_M	Percentage of summer days (Tmax > 25°C)	%	Monthly
26.	SD_Y	Number of summer days (Tmax > 25°C)	days	Yearly
27.	PSD_Y	Percentage of summer days (Tmax > 25°C)	%	Yearly
28.	HD_M	Number of hot days (Tmax > 30°C)	days	Monthly
29.	PHD_M	Percentage of hot days (Tmax > 30°C)	%	Monthly
30.	HD_Y	Number of hot days (Tmax > 30°C)	days	Yearly
31.	PHD_Y	Percentage of hot days (Tmax > 30°C)	%	Yearly
32.	PAI	Palfai Drought Index	-	Yearly
33.	SPI-3	Standardized Precipitation Index – 3-months	-	Monthly
34.	SPI-6	Standardized Precipitation Index – 6-months	-	Monthly
35.	SPI-12	Standardized Precipitation Index – 12-months	-	Monthly
36.	SPEI-3	Stand. Prec. Evapotranspiration Index – 3-months	-	Monthly
37.	SPEI-6	Stand. Prec. Evapotranspiration Index – 6-months	-	Monthly
38.	SPEI-12	Stand. Prec. Evapotranspiration Index – 12-months	-	Monthly
39.	RDI-3	Reconnaissance Drought Index (3-months)	-	Monthly
40.	RDI-6	Reconnaissance Drought Index (6-months)	-	Monthly
41.	RDI-12	Reconnaissance Drought Index (12-months)	-	Monthly
42.	PDSI	Palmer Drought Severity Index	-	Monthly
43.	ID_M	Number of ice days (Tmax < 0°C)	days	Monthly
44.	PID_M	Percentage of ice days (Tmax < 0°C)	%	Monthly
45.	ID_Y	Number of ice days (Tmax < 0°C)	days	Yearly
46.	PID_Y	Percentage of ice days (Tmax < 0°C)	%	Yearly
47.	EHD_M	Number of extremely hot days (Tmax ≥ 35°C)	days	Monthly
48.	PEHD_M	Percentage of extremely hot days (Tmax ≥ 35°C)	%	Monthly
49.	EHD_Y	Number of extremely hot days (Tmax ≥ 35°C)	days	Yearly
50.	PEHD_Y	Percentage of extremely hot days (Tmax ≥ 35°C)	%	Yearly
51.	ECD_M	Number of severe cold days (Tmin < -10°C)	days	Monthly
52.	PECD_M	Percentage of severe cold days (Tmin < -10°C)	%	Monthly
53.	ECD_Y	Number of severe cold days (Tmin < -10°C)	days	Yearly
54.	PECD_Y	Percentage of severe cold days (Tmin < -10°C)	%	Yearly
55.	GSL_Y	Growing season length	days	Yearly
56.	WD_M	Number of wet days (RR ≥ 1 mm/day)	days	Monthly
57.	PWD_M	Percentage of wet days (RR ≥ 1 mm/day)	%	Monthly
58.	WD_Y	Number of wet days (RR ≥ 1 mm/day)	days	Yearly
59.	PWD_Y	Percentage of wet days (RR ≥ 1 mm/day)	%	Yearly
60.	EWD_M	Number of wet days with (RR > 20 mm/day)	days	Monthly
61.	PEWD_M	Percentage of wet days with (RR > 20 mm/day)	%	Monthly
62.	EWD_Y	Number of wet days with (RR > 20 mm/day)	days	Yearly
63.	PEWD_Y	Percentage of wet days with (RR > 20 mm/day)	%	Yearly
64.	M1DTOT_M	Maximum 1-day total rainfall	mm	Monthly
65.	M1DTOT_Y	Maximum 1-day total rainfall	mm	Yearly
66.	M5DTOT_M	Maximum 5-day total rainfall	mm	Monthly
67.	M5DTOT_Y	Maximum 5-day total rainfall	mm	Yearly
68.	ARI	Aridity index	-	Monthly

69.	MI	Moisture index	-	Monthly
70.	EI	Ellenberg index	C/mm	Yearly
71.	CDD6	Cooling degree days (summer)	^{o}C	Yearly
72.	HDD6	Heating degree days (winter)	^{o}C	Yearly
73.	GDD8	Growing degree days (extended summer)	^{o}C	Yearly
74.	PET	Potential evapotranspiration	-	Monthly

3. Methods of computation

3.1 Average mean air temperature

The daily average air temperature was calculated as the arithmetic mean of homogenized minimum and maximum daily air temperatures. The monthly average mean air temperature was computed by averaging the daily values of the average air temperature for the specific month. The annual average mean air temperature was computed by averaging 365 (or 366) daily average air temperatures.

3.2 Average minimum air temperature

The monthly average minimum air temperature was computed by averaging the daily values of the minimum air temperature for the specific month. The annual average minimum air temperature was computed by averaging 365 (or 366) daily minimum air temperatures.

3.3 Average maximum air temperature

The monthly average maximum air temperature was computed by averaging the daily values of the maximum air temperature for the specific month. The annual average maximum air temperature was computed by averaging 365 (or 366) daily values of maximum air temperatures.

3.4 Accumulated total precipitation

The monthly accumulated total precipitation was computed by cumulating the daily values of total precipitation for the specific month. The annual accumulated total precipitation was computed by cumulating the 12 monthly values of monthly accumulated total precipitation amount.

3.5 Average 10m horizontal wind speed

The daily average 10m horizontal wind speed was computed by averaging values of 10m horizontal wind speed from daily climatological measurements (depending on the countr measurements are taken at 7, 14 and 21 UTC, or at 0, 6, 12, and 18 UTC). The monthly average 10m horizontal wind speed was computed by averaging the daily values of the average 10m horizontal wind speed for the specific month.

2.6 Average 2 m horizontal wind speed

The daily average 2m horizontal wind speed was computed from the daily average 10 m horizontal wind speed by using the logarithmic wind profile model according to the following formula:

$$z_2(t) = \frac{\ln\left(\frac{2}{0.1}\right)}{\ln\ (10/0.1)} z_{10}\ (t)$$

where

$z_{10}(t)$: daily mean wind speed series at 10 m with roughness 0.1

$z_2(t)$: daily mean wind speed series at 2 m with roughness 0.1

The monthly average 2 m horizontal wind speed was computed by averaging the daily values of the average 2 m horizontal wind speed for the specific month.

3.7 Sunshine duration

The monthly sunshine duration was computed by cumulating the daily values of sunshine duration for the specific month. The annual sunshine duration was computed by cumulating the 12 monthly values of monthly sunshine duration.

3.8 Average cloud cover

The monthly average cloud cover was computed by averaging the daily values of the average cloud cover for the specific month.

3.9 Global radiation

The monthly global radiation was computed by cumulating the daily values of global radiation for the specific month.

3.10 Average relative humidity

The monthly average relative humidity was computed by averaging the daily values of the average relative humidity for the specific month.

3.11 Mean vapour pressure

The monthly mean vapour pressure was computed by averaging the daily values of the mean vapour pressure for the specific month.

3.12 Mean surface air pressure

The monthly mean surface air pressure was computed by averaging the daily values of the mean surface air pressure for the specific month.

3.13 Snow depth

The monthly value of snow depth was computed as the ratio of the sum of daily snow depths and the number of days with snow cover, for the specific month.

3.14 Snow water equivalent

The monthly value of snow water equivalent was computed by cumulating the daily values of snow water equivalent of newly fallen snow for the specific month.

3.15 Frost days

A frost day is defined as a day with minimum air temperature lower than 0 ^{o}C. Both number and percentage of frost days were computed. Monthly (annual) number of frost days was computed by counting the frost days for the specific month (year). Monthly (annual) percentage of frost days was computed by dividing the number of frost days with total number of days for the specific month (year).

3.16 Summer days

A Summer day is defined as a day with maximum air temperature higher than 25 ^{o}C. Both number and percentage of summer days were computed. Monthly (annual) number of summer days was computed by counting the summer days for the specific month (year). Monthly (annual) percentage of summer days was computed by dividing the number of summer days with total number of days for the specific month (year).

3.17 Hot days

A Hot day is defined as a day with maximum air temperature higher than 30 ^oC. Both number and percentage of hot days were computed. Monthly (annual) number of hot days was computed by counting the hot days for the specific month (year). Monthly (annual) percentage of hot days was computed by dividing the number of hot days with total number of days for the specific month (year).

3.18 Palfai Drought Index (PADI)

Inputs: Monthly precipitation P (mm) and monthly air temperature T_M (^oC); 50 years of data.

Base Value [^{o}C /mm]

$$PADI_0 = \frac{20\sum_{i=1}^{5} T_{M_i}}{10+\sum_{j=1}^{11}(P_j\omega_j)} \qquad \begin{cases} i = 1(Apr), \dots, 5(Aug) \\ j = 1(Oct), \dots, 11(Aug) \end{cases}$$

Monthly weights

$$\omega_j = \begin{cases} 0.1 & j = 1 \\ 0.4 & j = 2 \\ 0.5 & j = 3, \dots, 7 \\ 0.8 & j = 8 \\ 1.2 & j = 9 \\ 1.6 & j = 10 \\ 0.9 & j = 11 \end{cases}$$

PADI [^{o}C /mm]

$$\boxed{PADI = (PADI_0)K_1K_2K_3}$$

Temperature Correction

$$K_1 = \frac{T_{M_{JUN}}+T_{M_{JUL}}+T_{M_{AUG}}}{\overline{T_M}_{JUN}+\overline{T_M}_{JUL}+\overline{T_M}_{AUG}}$$

Above: mean temperatures of the considered year; below: 50-years mean values.

Precipitation Correction

$$K_2 = \sqrt[4]{\frac{2\overline{P_{min}}_{SUMMER}}{\min(P_{JUN},P_{JUL},P_{AUG})+\overline{P_{min}}_{SUMMER}}}$$

Above: the lowest value -over 50 yrs- of the summer precipitation cumulated values (sum of precipitation fallen in June, in July, and in August); below: the minimum precipitation value from the three summer months

Groundwater Correction

$$K_3 = \sqrt[n]{\frac{\bar{P}}{P_{36}}} \qquad n = \begin{cases} 3 & plains \\ 5 & hills/mountains \end{cases}$$

Above: Mean precipitation sum between Oct and Sep over 50-years; below: mean precipitation over the previous 36 months (considered year and 2 previous complete years).

Outputs: annual PADI values (only one per year)

Notes:

- If we compute 2005, we must use values from 2004 in $PADI_0$;
- Should the denominator exactly be equal to 0 in K_1, it is imposed K_1=1;

- Should $\overline{P_{min}}_{SUMMER} = 0$, it is imposed $\overline{P_{min}}_{SUMMER} = 1$;
- Should $\overline{P_{36}} = 0$, it is imposed $\overline{P_{36}} = 1$;
- We set up an elevation limit to 300*m* for “plains”;
- Approximately $0.30 < K_2 < 1.19$ and K_3 is designed to be close to 1;
- Should one input quantity for $PADI_0$ or corrections be missing or should one monthly precipitation value be missing in the previous 36 months, PADI cannot be calculated;

3.19 Standardized Precipitation Index (SPI)

Inputs: Monthly precipitation (P in mm).

Cumulated rainfall [mm] $x = x_i = \sum_{j=i-(r-1)}^{i} P_j$ *(r as in SPI-r calculated for month i)*

If we are looking for SPI-6 for September, n=6 and the accumulated rainfall will be the sum of the current month and 5 previous month, i.e. from May to September itself.

Gamma PDF $g(x) = \frac{1}{\beta^\alpha \Gamma(\alpha)} x^{\alpha-1} e^{-\frac{x}{\beta}}$ $\quad x > 0$

Gamma Function $\Gamma(\alpha) = \int_0^\infty y^{\alpha-1} e^{-y} dy$

Shape Parameter $\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right)$ $\quad \alpha > 0$

Scale Parameter $\beta = \frac{\bar{x}}{\alpha}$ $\quad \beta > 0$

A value $A = \ln(\bar{x}) - \frac{\sum_{i=1}^{n} \ln(x)}{n}$ $\quad \begin{cases} n = \text{ number of } x > 0 \text{ events} \\ m = \text{ number of } x = 0 \text{ events} \end{cases}$

Shape and scale parameters have been calculated with the maximum likelihood methodology.

Gamma CDF $G(x) = \int_0^x g(x)dx = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-\frac{x}{\beta}} dx$

t Parameter $t = \frac{x}{\beta}$

Incomplete Gamma Function $G(x) = \frac{1}{\Gamma(\alpha)} \int_0^x t^{\alpha-1} e^{-t} dt$

Since the Gamma function is undefined for x=0, G(x) must be transformed into:

Transformed Gamma CDF $H(x) = q + (1-q)G(x)$

Probability of "no rainfall" $q = \frac{m}{n}$

The transformed Gamma CDF H(x) must be transformed with equiprobability transformation to a standardized distribution Z with mean value 0 and standard deviation 1.

SPI $SPI = Z = equiprob\ transform\ of\ H(x)\ into\ a\ std\ distrib$

Drought Magnitude $DM = \sum_{start}^{end} |SPI < 0| \quad \begin{cases} start: 1^{st}\ \ value\ of\ SPI < -1 \\ end: 1^{st}\ \ value\ when\ SPI\ is\ back\ to\ SPI > 0 \end{cases}$

<u>Outputs</u>: Monthly SPI-3, SPI-6, SPI-12.

3.20 Standardized Precipitation-Evapotranspiration Index (SPEI)

<u>Inputs</u>: Monthly precipitation (P in mm) and potential evapotranspiration (PET in mm).

Cumulated water balance [mm] $x = x_i = \sum_{j=i-(r-1)}^{i} (P - PET)_j$ *(SPEI-r for month i)*

If we are looking for SPEI-6 for September, n = 6 and the cumulated rainfall will be the sum of the current month and 5 previous month, i.e. from May to September itself.

We must shift the distribution to positive values, because x can be positive (P > PET), null (P = PET) or negative (P < PET). An $\varepsilon > 0$ is added in order to avoid 0 values also.

Shifted cumulated water balance [mm] $\gamma = x + |\min(x)| + \varepsilon \qquad \varepsilon > 0$

Gamma PDF $g(\gamma) = \frac{1}{\beta^\alpha \Gamma(\alpha)} x^{\alpha-1} e^{-\frac{\gamma}{\beta}} \qquad \gamma > 0$

Gamma Function $\Gamma(\alpha) = \int_0^\infty y^{\alpha-1} e^{-y} dy$

Shape Parameter $\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right) \qquad \alpha > 0$

Scale Parameter $\beta = \frac{\overline{\gamma}}{\alpha} \qquad \beta > 0$

A value $A = \ln(\bar{\gamma}) - \frac{\sum_{i=1}^{n} \ln(\gamma)}{n} \quad \begin{cases} n = \ number\ of\ \gamma > 0\ events \\ m = 0\ number\ of\ \gamma = 0\ events \end{cases}$

Shape and scale parameters have been calculated with maximum likelihood methodology.

Gamma CDF $G(\gamma) = \int_0^{\gamma} g(\gamma)d\gamma = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} \int_0^{\gamma} \gamma^{\alpha-1} e^{-\frac{\gamma}{\beta}} d\gamma$

t Parameter $t = \frac{\gamma}{\beta}$

Incomplete Gamma Function $G(\gamma) = \frac{1}{\Gamma(\alpha)} \int_0^{\gamma} t^{\alpha-1} e^{-t} dt$

$G(\gamma)$ must be transformed into to a standard distribution Z with mean value 0 and standard deviation 1.

SPEI $SPEI = Z = equiprob\ transform\ of\ G(\gamma)\ into\ a\ std\ distrib$

Outputs: Monthly SPEI–3, SPEI–6, SPEI–12.

3.21 Reconnaissance Drought Index (RDI)

Inputs: Monthly precipitation (P in mm) and monthly potential evapotranspiration (PET in mm)

Initial Value $a_K = \frac{\sum_{j=1}^{K} P_j}{\sum_{j=1}^{K} PET_j} \quad K = 3,6,12, \ldots$ *RDI-3, RDI-6, RDI-12, …*

If, e.g. K=3 (6, 12, ..), we need to cumulate the current month with 2 (5, 11, …) previous months.

Normalized RDI $RDI_N(K) = \frac{a_K}{\overline{a_K}} - 1 \quad \overline{a_K} = \text{longterm (50 years) mean value}$

The normalized RDI is comparable with FAO Aridity's Index.

Log-normal distribution $y_K = \ln(a_K)$ and $\overline{y_K} = \text{longterm (50 years) mean value}$

Standardized RDI $\boxed{RDI(K) = \frac{y_K - \overline{y_K}}{\widehat{\sigma_K}}} \quad \widehat{\sigma_K} = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (y_K - \overline{y_K})_i^{\ 2}}$

N is the number of months in the PET, and P records considered to build the RDI record. It can be compared with SPI and SPEI for the same number of cumulated months.

Outputs: monthly RDI-3, RDI-6, … over the whole period encompassed by P and PET records.

Notes:

- If $\sum_{j=1}^{K} P_j = 0$ it is converted into $\sum_{j=1}^{K} P_j = 1$, otherwise $\ln(a_K)$ cannot be computed;
- If $\sum_{j=1}^{K} PET_j = 0$ it is converted into $\sum_{j=1}^{K} PET_j = K$, otherwise a_K cannot be computed;
- If both $\sum_{j=1}^{K} P_j = 0$ and $\sum_{j=1}^{K} PET_j = 0$, it is imposed $a_K = 1$;

3.22 Ice days (days without defrost)

An ice day is defined as a day with maximum air temperature lower than 0 ^{o}C. Both number and percentage of ice days were computed. Monthly (annual) number of ice days was computed by counting the ice days for the specific month (year). Monthly (annual) percentage of ice days was computed by dividing the number of ice days with total number of days for the specific month (year).

3.23 Extremely hot days

An extremely hot day is defined as a day with maximum air temperature higher than or equal 35 ^{o}C. Both number and percentage of extremely hot days were computed. Monthly (annual) number of extremely hot days was computed by counting the extremely hot days for the specific month (year). Monthly (annual) percentage of extremely hot days was computed by dividing the number of extremely hot days with total number of days for the specific month (year).

3.24 Severe cold days

A severe cold day is defined as a day with minimum air temperature lower than –10 ^{o}C. Both number and percentage of severe cold days were computed. Monthly (annual) number of severe cold days was computed by counting the severe cold days for the specific month (year). Monthly (annual) percentage of severe cold days was computed by dividing the number of severe cold days with total number of days for the specific month (year).

3.25 Growing season length

The Growing season length is the annual count of days between the first span of at least six days with a daily mean temperature higher than 5 ^{o}C and the first span after July 1st of six days with a daily mean temperature lower than 5 ^{o}C.

3.26 Wet days

A wet day is defined as a day with minimum 1 mm of total daily precipitation. Monthly (annual) number of wet days was computed by counting the wet days for the specific month (year).

3.27 Extremely wet days

An extremely wet day is defined as a day with more than 20 mm of total daily precipitation. Monthly (annual) number of extremely wet days was computed by counting the extremely wet days for the specific month (year).

3.28 Greatest 1-day total rainfall

Maximum daily precipitation amount, for a specific month (year).

3.29 Greatest 5-day total rainfall

Maximum precipitation amount for the 5-day period, calculated from a moving window with one day step, for a specific month (year).

3.30 Aridity index

Aridity index is defined as the ratio between monthly precipitation sum and monthly potential evapotranspiration.
If PET is null, it is imposed PET = 1 mm in order to avoid division by zero.

3.31 Moisture index

Moisture index is defined as the ratio between monthly water balance and monthly potential evapotranspiration. The monthly water balance is the difference between monthly precipitation sum and monthly potential evapotranspiration.
If PET is null, it is imposed PET = 1mm in order to avoid division by zero.

3.32 Ellenberg index

Ellenberg index (Ellenberg's Climate Quotient) is defined as the ratio between the mean air temperature of July and annual precipitation sum, for the specific year and multiplied by 1,000.

3.33 Cooling degree days (summer)[1]

$T_b = 22°\mathrm{C}$

$$CDD_i = 0 \qquad if \quad T_b \geq TX$$

$$CDD_i = \frac{TX - T_b}{4} \qquad if \quad TM \leq T_b < TX$$

$$CDD_i = \frac{TX - T_b}{2} - \frac{T_b - TN}{4} \qquad if \quad TN \leq T_b < TM$$

$$CDD_i = TM - T_b \qquad if \quad T_b < TN$$

$$CDD = \sum_{i=1}^{365} CDD_i$$

3.34 Heating degree days (winter)[2]

$T_b = 15.5°\mathrm{C}$

$$HDD_i = T_b - TM \qquad if \quad T_b \geq TX$$

$$HDD_i = \frac{T_b - TN}{2} - \frac{TX - T_b}{4} \qquad if \quad TM \leq T_b < TX$$

$$HDD_i = \frac{T_b - TN}{4} \qquad if \quad TN \leq T_b < TM$$

$$HDD_i = 0 \qquad if \quad T_b < TN$$

$$HDD = \sum_{i=1}^{365} HDD_i$$

2.35 Growing degree days (extended summer)[3]

$T_b = 5.5°\mathrm{C}$

$$GDD_i = TM - T_b \qquad if \quad T_b < TM$$

$$GDD_i = 0 \qquad if \quad T_b \geq TM$$

$$GDD = \sum_{i=1}^{365} GDD_i$$

Note: Inputs for the degree days indicators are mean (T_M), minimum (T_N) and maximum T_X) daily temperatures (in degrees Celcius).

[1] Summer, from April 1st to September 30th.
[2] Winter, from October 1st to March 31st.
[3] Extended summer, from March 1st to October 31st.

3.36 Potential evapotranspiration

Inputs: Mean temperature (T_M, in ^oC, for all 12 months), Latitude (ϕ in radians)

PET [mm] $$\mathrm{PET}^* = \begin{cases} 0 & T_M < 0°C \\ 16\left(10\frac{T_M}{I}\right)^a & 0°C \le T_M < 26.5°C \\ -416.85 + 32.24(T_M) - 0.43(T_M)^2 & T_M \ge 26.5°C \end{cases}$$

Exponential a coefficient $a = 6.75(10^{-7})I^3 - 7.71(10^{-5})I^2 + 0.49239$

Annual Heat Index [^{o}C] $I = \sum_{j=1}^{12} i_j$

Monthly Heat Index [^{o}C] $i_j = \left(\frac{T_{M_j}}{5}\right)^{1.514}$

Adjusted PET [mm] $\mathrm{PET} = \left(\frac{\vartheta h}{360}\right)\mathrm{PET}^*$ ϑ = days (in that month)

Daylight [hours] $h = \frac{2\omega_{ss}}{15}$

Sunset hour angle [degrees] $\omega_{ss} = arccos\left(-tan(\phi)tan(\delta)\right)$

Solar Declination [radians] $\delta = \left(\frac{\pi}{180}\right)(23.45)sin\left(\frac{2\pi(284+d_n)}{365}\right)$

Julian day (15th) $d_n = 1(01\,Jan), \ldots, 365(31\,Dec)$ (Use the 15th of each month)

Outputs: monthly PET (Carpathians 1961–2010)

Annex: Self-calibrated Palmer Drought Severity Index methodology

REFERENCES

European Climate Assessment & Dataset (ECA&D), December 2012. EUMETNET/ECSN optional programme, Algorithm Theoretical Basis Document (ATBD), version 10.6

Guidelines on Analysis of extremes in a changing climate in support of informed decisions for adaptation. Climate Data and Monitoring, WCDMP-No. 72

Loukas A., Vasiliades L., 2004: Probabilistic analysis of drought spatiotemporal characteristics in Thessaly region, Greece. Natural Hazards and Earth System Sciences, 4, 719-73

McKee T.B., Doesken N.J., Kleist J., 1993: The relationship of drought frequency and duration to time scales. Eighth Conference on Applied Climatology, Anaheim, California

Tsakiris, G. and Vangelis, H., 2005: Establishing a Drought Index incorporating evapotranspiration. European Water, 9-10: 3-11.

Vicente-Serrano S. M., Begueria S., Lopez-Moreno J. I., 2009: A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index. Journal of Climate, doi: 10.1175/2009JCLI2909.1

Willmott C. J., Rowe C. M., Mintz Y., 1985: Climatology of the terrestrial seasonal water cycle. Journal of climatology, Vol. 5, 589-606

http://www.atikovizig.hu/projektx/dmcsee/ThePalfaiDroughtIndex_PaDI_Summary.pdf