BioClima Indexes

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نرم افزار Bioklima

محاسبه بعضی از شاخصهای زیست اقلیمی در تعیین آسایش حرارتی لازم است به واسطه حجم بالای اطلاعات و پیچیدگی محاسبات، استفاده از نرم افزارهای تخصصی به منظور صرفه جویی در وقت ، هزینه و نیروی انسانی اهمیت ویژه ای پیدا کرده است. **در صفحات بعدی بیش از ۵۰ شاخص بیوکلیمایی به تفصیل آورده شده است که امید است مورد استفاده پژوهشگران عزیز قرار گیرد. البته دوستان می توانند از طریق نرم افزار Bioklima هر کدام از شاخص‌های زیر را اجرا و نتایج آن را مورد استفاده قرار دهند.**

زهرایی

This is the full list of input data in BioKlima.

Abbreviation	Description	Unit	Default value
t	Air temperature	°C	
f	Relative humidity of air	%	
N	Cloudiness	%	
N8	Cloudiness	octants	
v	Wind speed (see note below the table)	m/s	
v10m	Wind speed at 10 m above ground	m/s	
p	Air pressure	hPa	1000
M	Metabolism	W/m2	135
Icl	Clothing insulation	clo	1 (can be calculated)
ac	Albedo of skin and/or clothing	%	31
sex	Sex (1=woman)	-	2 (man)
vprim	Man movement	m/s	1.1
ag	Albedo of ground	%	22
hour	Hour (without minutes; 0-23)	-	
min	Minutes (0-60)	-	0
month	Month (1-12)	-	
day	Day of month	-	
lat	Latitude (degrees.minutes)	-	
Kglob	Global solar radiation	W/m2	= Kdir + Kdif
Kdir	Direct solar radiation	W/m2	
Kdif	Diffuse solar radiation	W/m2	
Kref	Reflected solar radiation	W/m2	
Tg	Ground temperature	°C	can be calculated
Ts	Skin temperature	°C	32 (can be calculated)
e	Vapour pressure	hPa	can be calculated
hSl	Sun altitude	°	40 (can be calculated)
tmax	Maximum daily air temperature	°C	
tmin	Minimum daily air temperature	°C	
prec	Daily total of precipitation	mm	
snow	Snow cover	cm	
vis	Visibility	m	

If the value of wind speed (v) is smaller than 0.25 m/s, BioKlima will internally set it to 0.25. This reflects the fact that there is no such thing as perfectly windless weather.

Tek Equivalent temperature °C

Equivalent temperature (Tek, in °C) evaluates common influence on human organism of air temperature and air vapour pressure. Tek is defined as a temperature which the air would have (in constant air pressure) if all the vapour it contains was condensed. Tek is calculated as follows:

Tek = t + 1.5 e

The following scale evaluates thermal sensations of man:

below 18 °C	- cold
from 18 to 24	- cool
from 24 to 32	- slightly cool
from 32 to 44	- comfortable
from 44 to 56	- slightly sultry
above 56	- sultry

TE Effective temperature °C

Effective temperature (TE, in °C) evaluates common influence of air temperature, wind speed and relative humidity of air on man staying in the shadow. TE is calculated with the use of Missenard formulas as follows:

- at v <= 0.2 m/s

TE = t - 0.4 (t - 10) (1 - 0.01 f)

- at v > 0.2 m/s

TE = 37 - (37 - t) / {0.68 - 0.0014 f + [1 / (1.76 + 1.4 v^0.75)]} - 0.29 t (1 - 0.01 f)

The following scale evaluates thermal sensations of man:

below 1°C	- very cold
from 1 to 9	- cold
from 9 to 17	- cool
from 17 to 21	- fresh
from 21 to 23	- comfortable
from 23 to 27	- warm
above 27	- hot

TRE Radiative-effective temperature °C

Radiative-effective temperature (TRE, in °C) evaluates common influence of air temperature, wind speed, relative humidity of air and global solar radiation on man. TRE is calculated on the base of TE index as follows:

TRE = TE + [(1 - 0.01 ac) Kglob] [(0.0155 - 0.00025 TE) - (0.0043 - 0.00011 TE)]

The following scale is used for evaluation human's thermal sensations:

below 1°C - very cold
from 1 to 9 - cold
from 9 to 17 - cool
from 17 to 21 - fresh
from 21 to 23 - comfortable
from 23 to 27 - warm
above 27 - hot.

i Air entalphy kJ/kg

Air entalphy (i, kJ/kg) represents total heat content in air mass unit. i depends on air temperature (t, °C) and air vapour pressure (e, hPa) and is calculated as follows:

$$i = (0.24\ t + (0.622 / (755 - 0.75\ e)\ (0.46\ t + 595)\ 0.75\ e))\ 4.187$$

Brazol's scale is used to evaluate thermal sensations as follows:

below 10.5 kJ/kg	- frosty
from 10.5 to 14.6	- cold
from 14.6 to 25.1	- slightly cold
from 25.1 to 31.4	- cool
from 31.4 to 35.6	- pleasant cool
from 35.6 to 41.9	- comfortable
from 41.9 to 46.0	- pleasant warm
from 46.0 to 50.2	- very warm
from 50.2 to 80.0	- sweltery
from 80.0 to 108.9	- sweltery and sultry
from 108.9 to 130.0	- intolerably hot

above 130.0 - heat stroke

SB Bodman's weather severity index

Weather severity index (SB, dimensionless) is used for bioclimatic evaluation of weather conditions of winter half-year. SB is calculated basing on air temperature and wind speed according to Bodman's formula as follows:

$$SB = (1 - 0.04\ t)\ (1 + 0.272\ v)$$

Osokin's scale is used to evaluate winter weather severity:

- above 7 - extraordinary sever conditions
- from 5 to 7 - extremely sever conditions
- from 4 to 5 - very sever conditions
- from 3 to 4 - sever conditions
- from 2 to 3 - slightly sever conditions
- from 1 to 2 - less sever conditions
- below 1 - mild conditions

WCT Wind chill temperature °C

Wind Chill Index (WCI, in W/m2) qualifies thermal sensations of man in wintertime. It is especially useful at low and very low air temperature and at high wind speed. WCI values are not equal to the actual heat loss from the human organism. WCI is calculated according to ISO TR 11079 as follows:

WCI = (10 SQRT(v) + 10.45 - v) (33 - t) 1.163

Thermal sensations of man wearing clothing with insulation of 4 clo are assessed as follows:

above 2326.0	- extremely frost
from 1628.2 to 2326.0	- frosty
from 930.4 to 1628.2	- cold
from 581.5 to 930.4	- cool
from 232.6 to 581.5	- comfortable
from 116.3 to 232.6	- warm
from 58.3 to 116.3	- hot
below 58.3	- extremely hot

H Cooling power W/m2

Cooling power (H, in W/m2) is an index assessing thermal sensations of standing man wearing clothing adequate for particular seasons. It illustrates dry heat loss from the human body involved by air temperature and air motion. The values of H are not equal to the actual amount of heat loss. H index is calculated according to Hill's formulas as follows:

- at v <= 1 m/s:

H = (36.5 - t) (0.2 + 0.4 SQRT(v)) 41.868

- at v > 1 m/s:

H = (36.5 - t) (0.13 + 0.47 SQRT(v)) 41.868

Thermal sensations are assessed according to modified Petrovic-Kacvinski's scale:

above 2100	- extremely cold and windy
from 1680 to 2100	- very cold
from 1260 to 1680	- cold
from 840 to 1260	- cool
from 630 to 840	- slightly cool
from 420 to 630	- neutral
from 210 to 420	- hot
below 210	- very hot.

WBGT Wet bulb globe temperature °C

WBGT (Wet bulb globe temperature, in °C) is an index illustrating thermal and humid impacts on man. WBGT can be measured with the use of special equipment or calculated according to the following formula:

$$WBGT = 0.567\ t + 0.393\ e + 3.94$$

The following ranges of WBGT indicate several recommendations for outdoor activity:

WBGT:	Recommendation:
below 18°C	Unlimited
from 18°C to 24°C	Keep alert for possible increases in the index and for symptoms of heat stress
from 23°C to 28°C	Active excercise for unacclimatised persons should be curtailed.
from 28°C to 30°C	Active excercise for all but the well acclimatised should be curtailed.
above 30°C	All activity should be stopped

Humidex Humidex °C

Humidex (in °C) is a general heat stress index. It represents outdoor temperature felt by man in hot and humid environment. Humidex is calculated as follows:

Humidex = t + 0.5555 (e - 10)

According to Environment Canada, Humidex-related hazards are as follows:

Humidex (°C):	Danger category:	Heat syndrome:
below 30	Caution	Little discomfort, Fatigue possible with prolonged exposure and activity
from 30 to 40	Extreme caution	Some discomfort, heat stroke, heat exhaustion and heat cramps possible with prolonged exposure and activity
from 40 to 55	Danger	Great discomfort, avoid exercise. Heat cramps or heat exhaustion likely. Heat stroke possible with prolonged exposure and activity.
above 55	Extreme danger	Heat stroke imminent with continued exposure

* HSI Heat stress index %

Belding-Hatch's Heat Stress Index (HSI, in %) expresses the ratio of evaporation required for keeping heat equilibrium of an organism to maximal evaporation in actual environmental conditions. 390 W/m2 is a limit of evaporative heat loss and it is equal to water loss of 1 litre per hour. HSI is calculated as follows:

HSI = 100 Ereq / Emax

where:

Ereq = M + mQ + mC + mRes

Emax = k v^0.6 (56 - e)

k is 7.0 for clothed man (Icl >= 0.5) and 11.7 for nude man (Icl < 0.5).

There are the following physiological responses of an organism observed at particular HSI values:

below 0 - Slight cool stress

from 0 to +10 - Thermoneutral conditions

from more then 10 to 30 - Slight and moderate heat stress

from more then 30 to 70 - Intensive heat stress; health hazard for unacclimated persons

from more then 70 to 90 - Very intensive heat stress; water and minerals supply necessary

from more then 90 to 100 - Maximal heat stress tolerated by young, acclimated persons

above 100 - Hazard of an organism overheating; exposure time must be controlled.

* SWreq Sweating required   W/m2

Sweating Required (SWreq) is a principal thermophysiological index used in hot environments (ISO 7933). It express the sweat amount (and/or its heat equivalent) which must evaporate from the body for keeping heat equilibrium of an organism. SWreq index (in W/m2) is calculated from the human heat balance equation. 1 W/m2 is the heat equivalent of 1.47 gram of sweat evaporated from 1 m2 of skin surface during 1 hour (for an average man, 1 W/m2 is equal to 2.6 grams of sweat per 1 hour).

SWreq is calculated as follows:

SWreq = Ereq / (1.0 - 0.5 w^2)

where:

Ereq = M + mQ + mC + mRes
w = 0.002 for Ts < 22 °C
w = 1.0 for Ts > 36.5 °C
w = 1.031 / (37.5 - Ts) - 0.065 for Ts between 22 °C and 36.5 °C

According to ISO 7933 there are the following, limit values of SWreq are as follows:

Person:	acclimated		unacclimated	
Value:	warning	danger	warning	danger
SWreq (for M <= 70 W/m2)				
W/m2	200	300	100	150
g/hour	520	780	260	390
SWreq (for M > 70 W/m2)				
W/m2	300	400	200	250
g/hour	780	1040	520	650

## HR		Heart rate 1/s

Heart Rate (HR, in beats per minute) is one of the basic physiological indices. It expresses the number of heart beats per 1 minute. HR values depend on metabolism (M), air temperature (t) and air vapour pressure (e). Average HR for a man is of 70-72 beats per minute and for a woman - of 78-82 beats per minute. Higher HR values indicate greater load of circulatory system. HR of 90 beats per minute is a warning value. HR index is calculated according to Fuller-Brouh's formula as follows:

$$HR = 22.4 + 0.18\,M + 0.25\,(5\,t + 2.66\,e)$$

In some cases the message "normal" appears in the data table instead of a value. It means that HR doesn't depend on meteorological parameters and is displayed for HR < 60 beats per minute.

MHR Accepted level of physical activity W/m2

Maximal activity level (MHR, in W/m2) indicates the limit value of activity which does not provoke the rise of heart rate (HR) above 90 beats per minute in given meteorological conditions. MHR is calculated as follows:

$$MHR = [90 - 22.4 - 0.25 (5 t + 2.66 e)] / 0.18$$

SST Still shade temperature °C

Still Shade Temperature index (SST, in °C) can be used for preliminary evaluation of bioclimatic conditions. SST value is influenced by two factors. The first one relates to increase of air temperature caused by solar radiation (it is represented by cloudiness) and the second one - its decrease by wind speed. SST index takes also into account metabolic heat production. It is calculated according to Burton-Edholm's formula as follows:

SST = t + 0.42 (1 - 0.009 N) (100 - ac) 1 / (0.61 + 1.9 SQRT(v)) - 0.15673 M [1 - 1/ (0.61 + 1.9 SQRT(v))]

The following scale can be applied to assess thermal sensations in man:

below -7.5°C	- extremely cold
from -7.5 to 0.3	- very cold
from 0.3 to 2.0	- cold
from 2.0 to 5.2	- cool
from 5.2 to 11.3	- neutral
from 11.3 to 18.8	- warm
from 18.8 to 20.9	- hot
from 20.9 to 23.7	- very hot
above 23.7	- extremely hot

PMV Predicted mean vote

Predicted Mean Vote index (PMV) can be used in thermoneutral conditions (i.e. at ambient temperature of 18-25°C). PMV index was derived from Fanger's human heat balance equation. It takes into consideration activity level of man and clothing insulation. Thermal conditions can be assessed as follows:

PMV	Thermal conditions:
-3	- cold
-2	- cool
-1	- slightly cool
0	- thermoneutral
+1	- slightly warm
+2	- warm
+3	- hot

* STE Skin temperature equilibrating heat balance °C

STE index (Skin Temperature Equilibrating heat balance, in °C) is derived from the human heat balance equation for stationary conditions, i.e. taking into account mean (daily, monthly, yearly) values of meteorological parameters. Equilibrium of heat gains and losses is reached by changes of skin temperature. STE is calculated with the use of Blazejczyk's man-environment heat exchange model MENEX_2002. When calculating STE, the values of clothing insulation (Icl) and metabolism (M) are always taken equal to their default values (see 'Data options' dialog box).

The de Freitas scale is used for assessing predominated thermal sensations in man:

STE	Bioclimatic conditions:
below 21°C	- very cold
from 21 to 26	- cold
from 26 to 29	- cool
from 29 to 30.8	- slightly cool
from 30.8 to 32.2	- comfortable
from 32.2 to 33.3	- slightly warm
from 33.3 to 34.4	- warm
from 34.4 to 35.2	- hot
above 35.2	- very hot

* PSI Potential storage index W/m2

Potential Storage Index (PSI in W/m2) represents hypothetical value of net heat storage in man at constant skin temperature of 32°C and clothing insulation of 1 clo in given meteorological conditions. PSI is derived from the human heat balance equation for stationary conditions, i.e. taking into account mean (daily, monthly, yearly) values of meteorological parameters. Blazejczyk's man-environment heat exchange model MENEX_2002 is used for the calculations. When calculating PSI, the values of clothing insulation (Icl), mean skin temperature (Ts) and and metabolism (M) are always taken equal to their default values (see 'Data options' dialog box).

The de Freitas scale is used for assessing thermal sensations in man:

PSI (W/m2)	Sensations
below -281	- very cold
from -281 to -185	- cold
from -184 to -111	- cool
from -110 to -50	- slightly cool
from -49 to 16	- comfortable
from 17 to 83	- slightly warm
from 84 to 161	- warm
from 162 to 307	- hot
above 307	- very hot

* HL Heat load

Heat Load of an organism (HL, dimensionless) is calculated basing on net heat storage (mS), absorbed solar radiation (mR), and evaporative heat loss (mE), derived from Blazejczyk's man-environment heat exchange model MENEX_2002. HL is calculated as follows

- for mS < 0 W/m2 and mE >= -50 W/m2

HL = [{mS + 1000) / 1000]^[5 / (1 + mR)]

- for mS >= 0 W/m2 and mE >= -50 W/m2

HL = [(mS + 1000) / 1000]^[2 - 1 / (1 + mR)]

- for mS < 0 W/m2 and mE < -50 W/m2

HL = (mE / -50) [{mS + 1000) / 1000]^[5 / (1 + mR)]

- for mS >= 0 W/m2 and mE < -50 W/m2

HL = (mE / -50) [(mS + 1000) / 1000]^[2 - 1 / (1 + mR)]

Note that if mS is less than -1000 W/m2, BioKlima uses the value of -1000.

The intensity of heat load can be assessed as follows:

below 0.25	- extreme - cold stress
from 0.25 to 0.82	- great - cold stress
from 0.82 to 0.975	- slight - cool stress
from 0.975 to 1.025	- thermoneutral
from 1.025 to 1.18	- slight - warm stress
from 1.18 to 1.75	- great - hot stress
above 1.75	- extreme - hot stress

* mS Net heat storage W/m2

Net heat Storage (mS, in W/m2) is a principal index of the tendency and volume of the changes in heat contents in man. mS value is derived from the human heat balance model (Blazejczyk's MENEX_2002 model is used in this purpose). The general equation of the human heat balance has the following form:

mS = M + mQ + mE + mC + mRes,

where: M is metabolic heat production, mQ - radiation balance of man consisted of absorbed solar radiation (mR) and net long wave radiation exchange (mL), mE - evaporative heat loss, mC - heat exchange by convection, mRes - heat loss by respiration.

* SW Water loss g/hour

Water loss index (SW, in g/hour) is calculated based on the potential values of evaporative heat loss (Epot). Epot is derived from Blazejczyk's man-environment heat exchange model MENEX_2002 taking into accout 5% level of relative humidity of air (f):

SW = -2,6 Epot

where Epot is calculated the same way as mE but with e replaced by e'. e' is vapour pressure calculated using f always equal to 5%, regardless of the f value provided in the source data table.

Limit values of SW depend on human activity and subject acclimation levels as follows:

	Activity level	
	M <= 70 W/m2	M > 70 W/m2
acclimated subject:		
warning SW limit	520	780
hazardous SW limit	780	1040
non-acclimated subject:		
warning SW limit	260	520
hazardous SW limit	390	650

* DhRa / DhRna Dehydration risk

Dehydration risk is an effect of Water loss (SW). The water lost from the body can lead to dehydration. Depending on acclimation level of the subject, the risk related to dehydration depends on SW as follows:

Acclimated subject (DhRa):

No risk (NRa) SW < 780 g/hour

Dehydration warning (DWa) SW between 780 and -1040 g/hour

Dehydration hazard (DHa) SW > 1040 g/hour

Non-acclimated subject (DhRna):

No risk (NRna) SW < 520 g/hour

Dehydration warning (DWna) SW between 520 and 650 g/hour

Dehydration hazard (DHna) SW > 650 g/hour

* ECI   Expected clothing insulation clo

Expected Clothing Insulation index (ECI, in clo) is derived from Blazejczyk's man-environment heat exchange model MENEX_2002. ECI represents thermal insulation of clothing (in clo) which is necessary to balance heat gains and losses. ECI index can be used at air temperature < 20°C and both stationary and non-stationary conditions of heat exchange. When calculating ECI, the values of mean skin temperature (Ts) and metabolism (M) are always taken equal to their default values (see 'Data options' dialog box).

In some cases it is not possible to find clothing insulation that balances heat gain and losses. In such cases BioKlima returns -1 as the value of ECI.

Based on ECI values, thermal conditions can be assessed as follows:

below 0.30	- very warm
from 0.3 to 0.8	- warm
from 0.8 to 1.2	- neutral
from 1.2 to 2.0	- cool
from 2.0 to 3.0	- cold
from 3.0 to 4.0	- very cold
above 4.0	- arctic

This dialog box gives you the possibility to change information and defaults concerning input data and indices.

From the combo box on the top of the dialog box select the item you want to view and/or modify settings.

Below you can view and/or modify the following information:

· 'Name recognized by BioKlima' - will be displayed everywhere in lists of input data / indices and that will be used as column title;

· 'Description' - will be displayed everywhere where a data item description is displayed;
Note: do not use square brackets ('[' and ']') - use '{' and '}'; to enter the "degree" ('°') character type Alt+0176 on the numeric keypad;

· 'Default value' - will be used in calculations if a real value is not provided or cannot be calculated; you can leave this field empty which will indicate that there's no default value;

· 'Minimum' and 'Maximum' - these values will be used to determine if a value is 'Bad Data' (red cells in data tables).

· 'Calculation option' (only for indices) - specifies how the value of this index should be calculated during calculations; possible choices:

· 'Always re-calculate' - the value if this index is always recalculated;

· 'Try calculating; restore old value if not successful' - BioKlima will try to recalculate the value of the index but will leave the old value in case of failure;

· 'Calculate only if Lack of Data' - BioKlima will calculate this index only if it has not been calculated before for the given row;

· 'Never calculate' - this index is never calculated.

After making the changes you wish, click the 'Save' button - this will save changes done to the currently selected input datum or index. Closing the dialog box or selecting another data item without clicking 'Save' will not preserve the changes you made!

All data options are stored in the INI file.

* Mrt Mean radiant temperature °C

Mean radiant temperature (Mrt, in °C) is a value which characterises thermal impact of solar radiation and air temperature on man. Mrt represents a uniform surface temperature of an imaginary enclosure surrounding the person. Mrt is calculated as follows:

$$Mrt = [(Rprim + 0.5\ Lg + 0.5\ La) / (0.95\ 5.667\ 10^{-8})]^{0.25} - 273$$

where:

$$Lg = 5.5\ 10^{-8}\ (273 + Tg)^{4},$$
$$La = 5.5\ 10^{-8}\ (273 + t)^{4}\ [0.82 - 0.25\ 10^{(-0.094\ 0.75\ e)}],$$

*Rprim Solar radiation absorbed by nude man W/m2

Solar radiation absorbed by nude man (Rprim, in W/m2) can be calculated in several ways depending on solar radiation data. The MENEX_2002 model proposes SolDir, SolGlob and SolAlt models to calculate absorbed solar radiation.

In all formulas below, ac' = 1 - 0.01 ac, ac being the albedo of skin and / or clothing.

The SolDir model is used when direct, diffuse and reflected solar radiation fluxes are all known. Depending on Sun altitude (hSl) absorbed solar radiation is calculated as follows:

- for hSl <= 5°:

Rprim = 1.4 ac' [Kdir exp (-0.51 + 0.368 hSl) + (Kdif + Kref) (0.0013 + 0.033 LN(hSl))]

- or for hSl > 5°:

Rprim = 1.4 ac' [Kdir (18.816 / hSl - 0.235) + (Kdif + Kref) (0.0013 + 0.033 LN(hSl))]

The SolGlob model assesses absorbed solar radiation based on global solar radiation. This model is used if the SolDir model cannot be used in a particular case due to lack of data. The equations have various forms depending on Sun altitude and on Kt coefficient:

- for hSl <= 12°:

Rprim = ac' (0.0014 Kglob^2 + 0.476 Kglob - 3.8)

- for hSl > 12° and Kt <= 0.8:

Rprim = 0.2467 ac' Kglob^0.9763

- for hSl > 12° and Kt between 0.8 and 1.05:

Rprim = 3.6922 ac' Kglob^0.5842

- for hSl > 12° and Kt between 1.05 and 1.2:

Rprim = 43.426 ac' Kglob^0.2326

- for hSl > 12° and Kt greater than 1.2:

Rprim = 8.9281 ac' Kglob^0.4861

where Kt is calculated as follows:

Kt = Kglob / (-0.0015 hSl^3 + 0.1796 hSl^2 + 9.6375 hSl - 11.9)

The SolAlt model is used when only cloudiness is known and neither SolDir nor SolGlob models cannot be used due to lack of data. :

- for hSl <= 4°:

Rprim = 1.4 ac' (1.388 + 0.215 hSl)^2

- for hSl > 4° and N <= 20%:

$$Rprim = 1.4\ ac'\ (-100.428 + 73.981\ LN(hSl))$$

- for hSl > 4° and N = 21-50%:

$$Rprim = 1.4\ ac'\ EXP(5.383 - 16.072 / hSl)$$

- for hSl > 4° and N = 51-80%:

$$Rprim = 1.4\ ac'\ EXP(5.012 - 11.805 / hSl)$$

- for hSl > 4° and N > 80% :

$$Rprim = ac'\ 0.9506\ hSl^{1.039}$$

The SolVis model is used if the albedo of skin and / or clothing is not known but the visibility (vis, in m) is known. In this model the absorbed solar radiation is assessed as follows:

- for vis < 5000 m

$$Rprim = 0.815\ hSl + 16.504$$

- for vis between 5000 m and 20000 m

$$Rprim = 23.216\ EXP(0.0268\ hSl)$$

- for vis between 20000 m and 30000 m

$$Rprim = 45.368\ EXP(0.0144\ hSl)$$

- for vis > 30000 m

$$Rprim = 22.626\ EXP(0.02674\ hSl)$$

When Mean radiant temperature (Mrt, in °C) is your input data of radiation flux, Rprim is calculated as follows:

$$Rprim = \{[5.39\ 10^{-8}\ (273 + Mrt)^4] - [5.39\ 10^{-8}\ (273 + t)^4]\}$$

and all the other formulas are disregarded.

Iclp Insulation predicted clo

Insulation predicted index (Iclp, in clo) defines approximated, predicted value of thermal insulation of clothing which is necessary to keep thermal comfort in man. Iclp index is derived from Burton & Edholm equation of total insulation of clothing and surrounded air layer as follows:

$$Iclp = \{0.082\ [91.4 - (1.8\ t + 32)]\} / (0.01724\ M) - 1 / [0.61 + 1.9\ SQRT(v)]$$

Based on Iclp values thermal conditions can be assessed as follows:

below 0.30 - very warm

from 0.3 to 0.8 - warm

from 0.8 to 1.2 - neutral

from 1.2 to 2.0 - cool

from 2.0 to 3.0 - cold

from 3.0 to 4.0 - very cold

* mR Absorbed solar radiation W/m2

Absorbed solar Radiation (mR, in W/m2) is one of the principal components of the human heat balance outdoors. It is additional source of heat in man. mR is calculated as follows:

mR = Rprim Irc

where Irc is coefficient reducing heat transfer due to clothing:

Irc = hc d' / [hc d' + hc d + 0.056 t + 4.48]
hc = 0.013 p - 0.04 t - 0.503
d = SQRT(v + vprim)
d' = 0.53 / {Icl [1 - 0.27 EXP(0.4 LN(vcor + vprim))]}
vcor = v if v >= 0.2
vcor = 0.2 if v < 0.2

mC   Turbulent exchange of sensible heat W/m2

Turbulent exchange of sensible heat (convection - mC) is expressed in W/m2. Its intensity depends on temperature difference between skin and surroundings as well as on air velocity and its heat content and density. mC is calculated as follows

$$mC = hc\ d\ Irc\ (t - Ts)$$

where Irc is coefficient reducing heat transfer due to clothing:

$$Irc = hc\ d' / [hc\ d' + hc\ d + 0.056\ t + 4.48]$$
$$hc = 0.013\ p - 0.04\ t - 0.503$$
$$d = SQRT(v + vprim)$$
$$d' = 0.53 / \{Icl\ [1 - 0.27\ EXP(0.4\ LN(vcor + vprim))]\}$$
$$vcor = v \text{ if } v >= 0.2$$
$$vcor = 0.2 \text{ if } v < 0.2$$

mE Turbulent exchange of latent heat W/m2

Turbulent exchange of latent heat (evaporation - mE) is expressed in W/m2. Its intensity depends on the difference of vapour pressure in the open air and on the body surface as well as on skin wettedness and air motion, its heat content and density. Evaporation depends also on sweat glands efficiency which is at females of about 30% lower then at males. mE intensity is a base for assessing actual water loss from an organism (SW). mE is calculated as follows:

mE = he d w Ie (e - esk) - 0.42 (M - 58.0) + 5.04

where:

he = t (6 10^-5 t - 2 10^-5 p + 0.011) + 0.02 p - 0.773

esk = EXP(0.058 * Ts + 2.003)

Ie = hc d' / [hc (d + d')]

hc = 0.013 p - 0.04 t - 0.503

d = SQRT(v + vprim)

d' = 0.53 / {Icl [1 - 0.27 EXP(0.4 LN(vcor + vprim))]}

vcor = v if v >= 0.2

vcor = 0.2 if v < 0.2

w = 0.002 for Ts < 22 °C

w = 1.0 for Ts > 36.5 °C

w = 1.031 / (37.5 - Ts) - 0.065 for Ts between 22 °C and 36.5 °C

mL Heat exchange by long-wave radiation W/m2

Heat exchange by long-wave radiation (radiation - mL) is expressed in W/m2. Resultant mL value is a difference between long wave radiation reaching human body and its amount emitted by the body. It depends on temperature difference between body surface and surrounding. mL is calculated as follows:

$mL = (0.5\, Lg + 0.5\, La - Ls)\, Irc$

where:

$Lg = 5.5 \cdot 10^{-8} (273 + Tg)^4$,
$La = 5.5 \cdot 10^{-8} (273 + t)^4 [0.82 - 0.25 \cdot 10^{(-0.094 \cdot 0.75\, e)}]$,
$Ls = 5.39 \cdot 10^{-8} (273 + Ts)^4$,

$Irc = hc\, d' / [hc\, d' + hc\, d + 0.056 * t + 4.48]$
$hc = 0.013\, p - 0.04\, t - 0.503$
$d = SQRT(v + vprim)$
$d' = 0.53 / \{Icl\, [1 - 0.27\, EXP(0.4\, LN(vcor + vprim))]\}$
$vcor = v$ if $v >= 0.2$
$vcor = 0.2$ if $v < 0.2$

mRes Respiratory heat loss W/m2

Respiratory heat loss (mRes) consists of heat loss due to heating and vapour saturation of the air contacted with human mouth. It is expressed in W/m2 and depends on the differences in temperature and vapour pressure between expired air and surrounding. mRes is calculated as follows:

$$mRes = M\,[0.0014\,(t - 35) + 0.0173\,(0.1\,e - 5.624)]$$

* mQ   Radiation balance of man   W/m2

Radiation balance of man (mQ, in W/m2) consists of absorbed solar radiation (mR) and net long wave radiation exchange (mL). mQ is calculated as follows:

mQ = mL + mR

* Ts Mean skin temperature   °C

Mean skin temperature (Ts, in °C) can be taken from direct measurements. However, if you don't have measured values of Ts BioKlima will calculate it based on the following parameters: air temperature (t), wind speed (v), mean radiant temperature (Mrt), relative air humidity (f), clothing insulation (Icl) and metabolism (M):

$$Ts = (26.4 + 0.02138\,Mrt + 0.2095\,t - 0.0185\,f - 0.009\,v) + 0.6\,(Icl - 1) + 0.00128\,M$$

* STI Subjective temperature index °C

Subjective Temperature (STI, in °C) is an index that illustrates the thermal stimuli subjectively felt by a man and caused by the ambient environment before the activation of the adaptation processes. The STI depends both on ambient conditions (temperature, solar radiation, wind, humidity) and on the man-environment heat exchange. Thus STI indicates thermal load formed in the air layer surrounding the outer layer of clothing. Thermal impacts of environment are expressed by mean radiant temperature (Mrt). Physiological response of an organism is represented by net heat storage (mS). STI is calculated as follows:

- for $mS < 0$:

$$STI = Mrt - \{[|mS|^{0.75} / (0.95\ 5.667\ 10^{-8}) + 273^{4}]^{0.25} - 273\}$$

- for $mS >= 0$:

$$STI = Mrt + \{[|mS|^{0.75} / (0.95\ 5.667\ 10^{-8}) + 273^{4}]^{0.25} - 273\}$$

The following ranges of STI represent various thermal sensations in man:

below -38.0°C	- extremely cold
from -38,0 to -20.0	- very cold
from -38.0 to -0.5	- cold
from -0.4 to 22.5	- cool
from 22.5 to 32.0	- comfortable
from 32.0 to 46.0	- warm
from 46.0 to 55.0	- hot
from 55.0 to 70.0	- very hot
above 70.0	- sweltering

* PhS Physiological strain in man

Physiological Strain index (PhS, dimensionless) indicates which physiological processes adapt human organism to given outdoor conditions. PhS is calculated as follows:

PhS = mC / mE

At PhS of 0.75 up to 1.5 only a slight response of thermoregulatory system is observed.

Cold physiological strain occurs at PhS greater than 1.5 and is manifested by: decrease in skin temperature, reduction of peripheral blood flow, increase in blood pressure, increase in thermal insulation of skin tissue and/or shivering.

Hot physiological strain occurs at PhS less than 0.75 and it leads to: increase in peripheral blood flow and decrease in blood pressure, increase in heart rate, intensive sweating and dehydration, temporal changes in skin temperature (from very high during warming of the skin to low during sweating phase).

The following scale of physiological strain intensity is applied:

below 0.0	- extreme hot strain
from 0.00 to 0.24	- great hot strain
from 0.25 to 0.74	- moderate hot strain
from 0.75 to 1.50	- thermoneutral (slight strain)
from 1.51 to 4.00	- moderate cold strain
from 4.01 to 8.00	- great cold strain
above 8.00	- extreme cold strain

* PST Physiological subjective temperature°C

Physiological Subjective Temperature (°C) represents subjective feeling of thermal environment by man. Thermal sensations in humans are an effect of signals from cold and/or warm receptors in the skin and in the nervous system. Thermal impacts of the environment are expressed by mean radiant temperature surrounded skin surface (iMrt, see Mrt). Actual ambient conditions influence the intensity of heat exchange between human body and the atmosphere and the basic level of net heat storage (see mS). The signals from temperature receptors activate physiological reactions of an organism to keep homeothermy. In the cold, skin receptors register actual skin temperature that is influenced by ambient conditions. In the warm, intensive sweat evaporation lead to cooling of the skin surface (0.066 °C for each 1 W/m2 of evaporation) and thermal receptors register a new, lower skin temperature (Tsk*, see Ts). Intensive adaptation processes are supported and regulated by thermal receptors in the nervous system and the resultant level of net heat storage (SR) is formed.

Physiological Subjective Temperature illustrates the level of thermal stimuli that form around the skin surface after 15-20 minutes of intensive adaptation processes. PST is calculated as follows:

- for SR < 0:

$$PST = iMrt - \{[|SR|^{0.75} / (0.95\ 5.667\ 10^{-8}) + 273^4]^{0.25} - 273\}$$

- for SR >= 0:

$$PST = iMrt + \{[|SR|^{0.75} / (0.95\ 5.667\ 10^{-8}) + 273^4]^{0.25} - 273\}$$

The resultant value of net heat storage (SR = M + mQ* + mE* + mC* + mRes) is calculated taking into consideration Tsk* value that is an effect of a cooling of the skin surface due to intensive sweat evaporation. The particular heat exchange components are calculated as follows:

$$mQ^* = mR + mL^*$$
$$mL^* = (0.5\ Lg + 0.5\ La - Ls^*)\ Irc$$
$$Ls^* = 0.95\ 5.667\ 10^{-8}\ (273+Tsk^*)^4$$
$$mE^* = he\ d\ (ie - esk^*)\ w^*\ Ie - [0.42\ (M - 58) - 5.04]$$
$$mC^* = hc\ (iMrt - Tsk)\ Irc$$
$$ie = 6.112\ 10^{[7.5\ iMrt / (237.7 + iMrt)]}\ (f / 100)$$
$$esk^* = EXP(0.058\ Tsk^* + 2.003)$$

w* = 0.002 for Tsk* < 22 °C
w* = 1.0 for Tsk* > 36.5 °C
w* = 1.031 / (37.5 - Tsk*) - 0.065 for Tsk* between 22 °C and 36.5 °C

where iMrt is the inner (i.e. under clothing) mean radiant temperature:

iMrt = {[mR + (0.5 Lg + 0.5 La) Irc + 0.5 Ls*] / (0.95 5.667 10^-8)}^0.25 - 273

and where the remaining components (e.g. Lg, he, d) are calculated as in formulas for mL, mE and mC.

The following ranges of PST represent various thermal sensations in man:

below -36.0 °C - frosty
from -36.0 to -16.1 - very cold
from -16.0 to 4.0 - cold
from 4.1 to 14.0- cool
from 14.1 to 24.0 - comfortable
from 24.1 to 34.0 - warm
from 34.1 to 44.0 - hot
from 44.1 to 54.0 - very hot
above 54.0 - sweltering

* Oc_W / Oc_HOvercooling risk

During prolonged stay at extreme ambient conditions physiological processes of thermoregulation can be insufficient to keep homeothermy. According to Hardy (1965) warning level of overcooling is noted at Tc of about 31°C and hypothermia risk occurs when Tc falls to about 25°C. That correspond to changes in body heat content of 1800 kJ and 3600 kJ, respectively.

Overcooling Warning (Oc_W) is a time (in min) that lead to great decrease in body heat content and significant decrease in body temperature. Oc_W is calculated as follows:

- for SR < 0 W/m2:

Oc_W = [(1800000 - 1.6 1200 |mS|) / (1.6 |SR|)] / 60

Hypothermia Risk (Oc_H) is a time (in min) that due to great decrease in body heat content fatal hypothermia can occur. Oc_H is calculated as follows:

- for SR < 0 W/m2:

Oc_H = 2 [(1800000 - 1.6 1200 |mS|) / (1.6 |SR|)] / 60

For both Oc_W and Oc_H, when SR >= 0, there is no overcooling risk and hence no time limit.

SR is the resultant value of net heat storage. In actual ambient environment, the physiological and physical processes continuously fluctuate to keep the equilibrium between heat gains and heat losses. The most intensive adaptation occurs during first 15-20 minutes after the sudden change of environment. The Resultant net heat storage (SR) represents the level of heat exchange after this adaptation time.

The resultant value of net heat storage (SR = M + mQ* + mE* + mC* + mRes) is calculated taking into consideration Tsk* value that is an effect of a cooling of skin surface due to intensive sweat evaporation. The particular heat exchange components are calculated as follows:

mQ*= mR + mL*
mL*= (0.5 Lg + 0.5 La - Ls*) Irc
Ls*= 0.95 5.667 10^-8 (273+Tsk*)^4
mE*= he d (ie - esk*) w* Ie - [0.42 (M - 58) - 5.04]
mC*= hc (iMrt - Tsk) Irc
ie = 6.112 10^[7.5 iMrt / (237.7 + iMrt)] (f / 100)
esk* = EXP(0.058 Tsk* + 2.003)

w* = 0.002 for Tsk* < 22 °C
w* = 1.0 for Tsk* > 36.5 °C
w* = 1.031 / (37.5 - Tsk*) - 0.065 for Tsk* between 22 °C and 36.5 °C

where iMrt is the inner (i.e. under clothing) mean radiant temperature:

iMrt = {[mR + (0.5 Lg + 0.5 La) Irc + 0.5 Ls*] / (0.95 5.667 10^-8)}^0.25 - 273

and where the remaining components (e.g. Lg, he, d) are calculated as in formulas for mL, mE and mC.

* Oh_W / Oh_H Overheating risk

During prolonged stay at extreme ambient conditions physiological processes of thermoregulation can be insufficient to keep homeothermy. According to Hardy (1965) at core temperature (Tc) of about 40°C (that correspond to heat accumulation of about 900 kJ) thermoregulation disorders are observed and at Tc of 43°C (change in body heat content of +1800 kJ) hyperthermia and heat stroke arises.

Overheating Warning (Oh_W) is a time (in min) that lead to great increase in body heat content and significant increase in body temperature. Oh_W is calculated as follows:

- for SR >= 0 W/m2:

Oh_W = [(900000 - 1.6 1200 |mS|) / (1.6 |SR|)] / 60

Hyperthermia Risk (Oh_H) is a time (in min) that due to great increase in body heat content hyperthermia can occur. (Oh_H) is calculated as follows:

- for SR >= 0 W/m2:

Oh_H = 2 [(900000 - 1.6 1200 |mS|) / (1.6 |SR|)] / 60

For both Oc_W and Oc_H, when SR < 0, there is no overheating risk and hence no time limit.

SR is the resultant value of net heat storage. In actual ambient environment, the physiological and physical processes continuously fluctuate to keep the equilibrium between heat gains and heat losses. The most intensive adaptation occurs during first 15-20 minutes after the sudden change of environment. The Resultant net heat storage (SR) represents the level of heat exchange after this adaptation time.

The resultant value of net heat storage (SR = M + mQ* + mE* + mC* + mRes) is calculated taking into consideration Tsk* value that is an effect of a cooling of skin surface due to intensive sweat evaporation. The particular heat exchange components are calculated as follows:

mQ*= mR + mL*
mL*= (0.5 Lg + 0.5 La - Ls*) Irc
Ls*= 0.95 5.667 10^-8 (273+Tsk*)^4
mE*= he d (ie - esk*) w* Ie - [0.42 (M - 58) - 5.04]
mC*= hc (iMrt - Tsk) Irc
ie = 6.112 10^[7.5 iMrt / (237.7 + iMrt)] (f / 100)
esk* = EXP(0.058 Tsk* + 2.003)

w* = 0.002 for Tsk* < 22 °C
w* = 1.0 for Tsk* > 36.5 °C
w* = 1.031 / (37.5 - Tsk*) - 0.065 for Tsk* between 22 °C and 36.5 °C

where iMrt is the inner (i.e. under clothing) mean radiant temperature:
iMrt = {[mR + (0.5 Lg + 0.5 La) Irc + 0.5 Ls*] / (0.95 5.667 10^-8)}^0.25 - 273

and where the remaining components (e.g. Lg, he, d) are calculated as in formulas for mL, mE and mC.

* UTCI Universal thermal climate index °C

The UTCI is defined as the air temperature (t) of the reference condition causing the same physiological response as the actual condition. Thus, UTCI is the air temperature which would produce under reference conditions the same thermal strain as in the actual thermal environment. The multi-node Fiala model of the human heat balance was applied to assess physiological response of an organism.

Both meteorological and non-meteorological (metabolic rate and thermal resistance of clothing) reference conditions were defined:

- Wind speed (v) of 0.5 m/s at 10 m height (approximately 0.3 m/s at 1.1 m).
- Mean radiant temperature (Mrt) equal to air temperature.
- Vapour pressure (e) that represent relative humidity of 50%; at high air temperatures (29ºC) the reference humidity was taken constant at 20 hPa.
- Representative activity (M) of a person walking with a speed of 4 km/h (vprim = 1.1 m/s). This provides a metabolic rate of 135 W m-2.

The adjustment of clothing insulation is a powerful behavioral response to changing climatic conditions. The overall intrinsic clothing insulation (Icl) is a function of the ambient air temperature.

The UTCI is calculated as polynomial regression function up to 6th order of: t, v10m, e and Mrt-t. If v10m is absent, it is estimated from the regular wind speed: v10m = v / 0.667.

The UTCI was developed in the frame of European research co-operation programme COST Action 730 (2005-2009)

UTCI is categorized in terms of thermal stress in man as follows:

UTCI range (°C)	Stress Category	Physiological responses
above +46	extreme heat stress	Increase in rectal temperature (Tre) time gradient. Steep decrease in total net heat loss.Averaged sweat rate >650 g/h, steep increase.
+38 to +46	very strong heat stress	Core to skin temperature gradient < 1K (at 30 min).Increase in Tre at 30 min.
+32 to +38	strong heat stress	Dynamic Thermal Sensation (DTS) at 120 min >+2.Averaged sweat rate > 200 g/h. Increase in Tre at 120 min.Latent heat loss >40 W at 30 min. Instantaneous change in skin temperature > 0 K/min.
+26 to +32	moderate heat stress	Change of slopes in sweat rate, Tre and skin temperature: mean (Tskm), face (Tskfc), hand (Tskhn).Occurrence of sweating at 30 min. Steep increase in skin wettedness.
+9 to +26	no thermal stress	Averaged sweat rate > 100 g/h. DTS at 120 min < 1. DTS between -0.5 and +0.5 (averaged value).Latent heat loss >40 W, averaged over time.Plateau in Tre time gradient.
+9 to 0	slight cold stress	DTS at 120 min < -1.Local minimum of Tskhn (use gloves).
0 to -13	moderate cold stress	DTS at 120 min < -2. Skin blood flow at 120 min lower than at 30 min (vasoconstriction).Averaged Tskfc < 15°C (pain).Decrease in Tskhn. Tre time gradient < 0 K/h.30 min face skin temperature < 15°C (pain). Tmsk time gradient < -1 K/h (for reference).
-13 to -27	strong cold stress	Averaged Tskfc < 7°C (numbness). Tre time gradient < -0.1 K/h.Tre decreases from 30 to 120 min.Increase in core to skin temperature gradient.
-27 to -40	very strong cold stress	120 min Tskfc < 0°C (frostbite).Steeper decrease in Tre.30 min Tskfc < 7°C (numbness). Occurrence of shivering. Tre time gradient < -0.2 K/h.Averaged Tskfc < 0°C (frostbite).120 min Tskfc < -5°C (high risk of frostbite).
below -40	extreme cold stress	Tre time gradient < -0.3 K/h.30 min Tskfc < 0°C (frostbite).

According to the Glossary of Terms for Thermal Physiology (2003) the UTCI values between 18 and 26 C may comply closely with the definition of the "thermal comfort zone".

UTCI - Universal thermal climate index

UTCI range (°C)	Stress Category	Physiological responses
above +46	extreme heat stress	Increase in rectal temperature (Tre) time gradient. Steep decrease in total net heat loss. Averaged sweat rate >650 g/h, steep increase.
+38 to +46	very strong heat stress	Core to skin temperature gradient < 1K (at 30 min). Increase in Tre at 30 min.
+32 to +38	strong heat stress	Dynamic Thermal Sensation (DTS) at 120 min >+2. Averaged sweat rate > 200 g/h. Increase in Tre at 120 min. Latent heat loss >40 W at 30 min. Instantaneous change in skin temperature > 0 K/min.
+26 to +32	moderate heat stress	Change of slopes in sweat rate, Tre and skin temperature: mean (Tskm), face (Tskfc), hand (Tskhn). Occurrence of sweating at 30 min. Steep increase in skin wettedness.
+9 to +26	no thermal stress	Averaged sweat rate > 100 g/h. DTS at 120 min < 1. DTS between -0.5 and +0.5 (averaged value). Latent heat loss >40 W, averaged over time. Plateau in Tre time gradient.
+9 to 0	slight cold stress	DTS at 120 min < -1. Local minimum of Tskhn (use gloves).
0 to -13	moderate cold stress	DTS at 120 min < -2. Skin blood flow at 120 min lower than at 30 min (vasoconstriction). Averaged Tskfc < 15°C (pain). Decrease in Tskhn. Tre time gradient < 0 K/h. 30 min face skin temperature < 15°C (pain). Tmsk time gradient < -1 K/h (for reference).
-13 to -27	strong cold stress	Averaged Tskfc < 7°C (numbness). Tre time gradient < -0.1 K/h. Tre decreases from 30 to 120 min. Increase in core to skin temperature gradient.
-27 to -40	very strong cold stress	120 min Tskfc < 0°C (frostbite). Steeper decrease in Tre. 30 min Tskfc < 7°C (numbness). Occurrence of shivering. Tre time gradient < -0.2 K/h. Averaged Tskfc < 0°C (frostbite). 120 min Tskfc < -5°C (high risk of frostbite).
below -40	extreme cold stress	Tre time gradient < -0.3 K/h. 30 min Tskfc < 0°C (frostbite).

According to the Glossary of Terms for Thermal Physiology (2003) the UTCI values between 18 and 26ںC may comply closely with the definition of the "thermal comfort zone".

pC Approximated convective heat loss W/m2

Approximated (with an error smaller than 10%) values of convective heat loss (pC, in W/m2) are calculated with the use of simplified equations according to Blazejczyk's man-environment heat exchange model MENEX_2002. Air temperature, wind speed and cloudiness are parameters necessary for the calculations.

$$pC = -138.04 + 0.051 N + 4.738 t - 18.265 v$$

pL Approximated radiative heat loss W/m2

Approximated (with an error smaller than 10%) values of radiative heat loss (pL, in W/m2) are calculated with the use of simplified equations according to Blazejczyk's man-environment heat exchange model MENEX_2002. Air temperature, wind speed and cloudiness are parameters necessary for the calculations.

$$pL = -47.78 + 0.0465\,N + 0.916\,t + 0.6054\,v$$

pE   Approximated evaporative heat loss W/m2

Approximated (with an error smaller than 20%) values of evaporative heat loss (pE, in W/m2) are calculated with the use of simplified equations according to Blazejczyk's man-environment heat exchange model MENEX_2002. Air temperature is the only parameter necessary for the calculations.

pE = 1 / (-0.02742 + 0.000708 t)

pRes Approximated respiratory heat loss W/m2

Approximated (with an error smaller than 10%) values of respiratory heat loss (pRes, in W/m2) are calculated with the use of simplified equations according to Blazejczyk's man-environment heat exchange model MENEX_2002. Air temperature is the only parameter necessary for the calculations.

pRes = -18.485 + 0.292 t

pPhS Approximated physiological strain in man

Approximated (with an error smaller than 10%) values of physiological strain index (pPhS, dimensionless) are calculated with the use of simplified equations according to Blazejczyk's man-environment heat exchange model MENEX_2002. Air temperature is the only parameter necessary for the calculations.

pPhS = (2.12513 - 0.058018 t)^2

The following scale of physiological strain intensity is applied:

below 0.0	- extreme hot strain
from 0.00 to 0.24	- great hot strain
from 0.25 to 0.74	- moderate hot strain
from 0.75 to 1.50	- thermoneutral (slight strain)
from 1.51 to 4.00	- moderate cold strain
from 4.01 to 8.00	- great cold strain
above 8.00	- extreme cold strain

pHSI Approximated heat stress index %

Approximated (with an error smaller than 15%) values of heat stress index (pHSI, in %) are calculated with the use of simplified equations according to Blazejczyk's man-environment heat exchange model MENEX_2002. Approximated value of physiological strain index is the only parameter necessary for the calculations.

pHSI = 18.6058 - 24.7164 LN(pPhS)

There are the following physiological responses of an organism observed at particular HSI values:
below 0 - Slight cool stress
from 0 to +10 - Thermoneutral conditions
from more then 10 to 30- Slight and moderate heat stress from more then 30 to 70- Intensive heat stress; health hazard for unacclimated persons
from more then 70 to 90 - Very intensive heat stress; water and minerals supply necessa
from more then 90 to 100 - Maximal heat stress tolerated by young, acclimated persons

above 100 - Hazard of an organism overheating; exposure time must be controlled.

pSTI Approximated subjective temperature index °C

Approximated (with an error smaller than 15%) values of subjective temperature (pSTI, in °C) are calculated with the use of simplified equations according to Blazejczyk's man-environment heat exchange model MENEX_2002. Air temperature, wind speed and Sun altitude are parameters necessary for the calculations.

pSTI = 1.13 + 0.1964 hSl + 1.29 t - 0.626 v

The following ranges of pSTI represent various thermal sensations in man:

below -38.0°C	- extremely cold
from -38,0 to -20.0	- very cold
from -38.0 to -0.5	- cold
from -0.4 to 22.5	- cool
from 22.5 to 32.0	- comfortable
from 32.0 to 46.0	- warm
from 46.0 to 55.0	- hot
from 55.0 to 70.0	- very hot
above 70.0	- sweltering

pHL   Approximated heat load of an organism

Approximated (with an error smaller than 15%) values of heat load (pHL, dimensionless) are calculated with the use of simplified equations according to Blazejczyk's man-environment heat exchange model MENEX_2002. Air temperature, wind speed and Sun altitude are parameters necessary for the calculations.

pHL = 3.28 10^-20 [273 + (1.13 + 0.1964 hSl + 1.29 t - 0.625 v)]^7.88

The intensity of heat load can be assessed as follows:

below 0.25	- extreme - cold stress
from 0.25 to 0.82	- great - cold stress
from 0.82 to 0.975	- slight - cool stress
from 0.975 to 1.025	- thermoneutral
from 1.025 to 1.18	- slight - warm stress
from 1.18 to 1.75	- great - hot stress
above 1.75	- extreme - hot stress

W_Prec   Rainy weather class index

W_Prec (previously named PrecIdx) represents class of weather (see Weather) related to daily total of precipitation. 1 mm of precipitation is a limit value for rainy day.

W_Prec:	Class of weather:
0	not rainy day
1	rainy day

W_Snow   Snowy weather class index

W_Snow (previously named SnowIdx) represents class of weather (see Weather) related to snow cover. 10 cm of snow depth is a limit value for snowy day.

W_Snow:	Class of weather:
0	no snow cover
1	snowy day

* W_Sens Thermal sensation weather type index

W_Sens (previously named ThermSens) represents type of weather (see Weather) related to thermal sensations in man. STI or pSTI (if STI cannot be calculated) values (in °C) are the base for evaluation of thermal sensations weather type as follows:

STI or pSTI:	W_Sens:	Type of weather:
below -38.0°C	-3	very cold
from -38.0 to -0.5	-2	cold
from -0.5 to 22.5	-1	cool
from 22.5 to 32.0	0	comfortable
from 32.0 to 46.0	1	warm
from 46.0 to 55.0	2	hot
above 55.0	3	very hot

* W_Rad Radiation stymuli weather subtype index

W_Rad (previously named Radiation) represents subtype of weather (see Weather) related to the intensity of radiation stimuli. Rprim values (in W/m2) are the base for evaluation of radiation stimuli as follows:

Rprim:	W_Rad:	Weather subtype:
below 75	1	weak radiative stimuli
from 75 to 150	2	moderate radiative stimuli
above 150	3	strong radiative stimuli

* W_Strain Physiological strain weather subtype index

W_Strain (previously named Strain) represents subtype of weather (see Weather) related to the type of physiological strain in man. PhS or pPhS (if PhS cannot be calculated) values are the base for evaluation of physiological strain as follows:

PhS or pPhS:	W_Strain:	Strain type:
from 0.75 to 1.50	0 (T)	thermoneutral
above 1.5	1 (C)	cold strain
below 0.75	2 (H)	hot strain

* W_Sult Intensity of sultriness weather subtype index

W_Sult (previously named Sultriness) represents subtype of weather (see Weather) related to the intensity of thermal-and-hygric load in man. HSI or pHSI (if HSI cannot be calculated) values (in %) are the base for evaluation of sultriness as follows:

HSI or pHSI:	W_Sult:	Intensity of thermal-and-hygric load:
below 30	0	non-sultry
from 30 to 70	1	moderate sultry
above 70	2	strong sultry

dt Daily temperature amplitude °C

Daily temperature amplitude (dt, in °C) illustrates daily contrasts of thermal stimuli. dt is calculated as follows:

dt = tmax - tmin

Intensity of thermal stimuli can be assessed as follows:

below 4.0 °C - neutral

from 4.0 to 7.9 - mild

from 8.0 to 11.9- severe

above 12.0 - very severe

W_TAmp Temperature amplitude weather class index

W_TAmp (previously named TempAmplit) is a daily thermal contrast index and represents weather class (see Weather) related to the daily temperature amplitude (dt).

Daily thermal contrasts are represented by the following dt values:

W_TAmp:	dt (°C):	Thermal contrast:
0	below 8	small
1	above 8	great

Weather Weather classification

The Weather index is a special index of composite nature: it is composed of values of seven other indices concatenated together to form a textual representation. The Weather classification consists of three levels: weather type (the first component of the index), subtype (the three middle components) and class (the last three components).

Weather characteristic	Weather type	Weather subtype			Weather class		
Source index	W_Sens	W_Rad	W_Strain	W_Sult	W_TAmp	W_Prec	W_Snow
Componentposition	1	2	3	4	5	6	7
Possible values	-3-2-10123	123	HTC	012	01	01	01

For example, the value 1_2H0_110 means: warm weather with moderate radiation stimuli, with hot physiological strain without sultriness. There are stimulated daily thermal contrasts and precipitation but there is no snow cover.

Weather types

The principal information dealing with the weather type are the thermal sensations experienced by a person walking outdoors with the speed of 4 km/hour. Thermal sensations are evaluated based using values of the W_Sens index as follows:

Value:	Description of weather type:
-3	- very cold
-2	- cold
-1	- cool
0	- comfortable
1	- warm
2	- hot
3	- very hot

Weather subtypes

The second component in the weather classification system defines the intensity of solar radiation stimuli. In this purpose the value of the W_Rad index is applied:

Value:	Radiation stimuli:
1	- weak
2	- moderate
3	- strong

The third component of weather characteristic is the kind of physiological strain. The W_Strain index is used to summarize physiological strain as follows:

Value:	Physiological strain
H	- hot strain
T	- thermoneutral
C	- cold strain

The fourth weather feature is the sultriness intensity, estimated using the W_Sult index:

Value:	Sultriness intensity:
0	- non sultry
1	- moderate
2	- great

Weather classes
The daily amplitude of air temperature illustrates the range of temperature fluctuations and gains importance if the recreation lasts for multiple hours. The W_TAmp index is used to assess its impact on the overall weather conditions:

Value:	Daily thermal contrasts:
0	- neutral
1	- stimulated

Daily totals of precipitation (see W_Prec) are applied in the weather classification as follows:

Value:	Precipitation:
0	- no rain
1	- rainy day

Finally, the snow cover (see W_Snow) is very important for winter tourism:

Value:	Snow conditions:
0	- no snow
1	- snowy day

WSI_xx Weather suitability index

The Weather Suitability Index (WSI) evaluates usefulness of various weather conditions (see Weather) for different forms of recreation and tourism. The most common forms are: sun baths (staying in the sunny place - WSI_SB), air baths (staying in the shaded place - WSI_AB), mild recreational activity (e.g. walking, light plays, shopping - WSI_MR), intensive recreation and summer tourism (e.g. football, biking, climbing, jogging etc. - WSI_AR), ski tourism (WSI_ST).

The usefulness of each individual weather situation for different forms of recreation and tourism was analyzed and every class of weather was evaluated using one of the following Weather Suitability Index values (WSI): 0 - unsuitable, 1 - suitable with limitations, 3 - suitable without limitations.

As an example, the following table contains several examples of WSI values for the most frequent weather conditions in the temperate climatic zone:

As an example, the following table contains several examples of WSI values for the most frequent weather conditions in the temperate climatic zone:

Weather type	Weather subtype			Weather class			WSI for:				
W_Sens	W_Rad	W_Strain	W_Sult	W_TAmp	W_Prec	W_Snow	SB	AB	MR	AR	ST
-2	1	C	0	0	0	0	0	0	1	3	0
-1	1	C	0	0	0	0	0	0	1	3	0
-1	1	C	0	0	0	1	0	0	1	3	3
-1	1	C	0	0	1	0	0	0	1	1	0
-1	2	C	0	0	1	0	0	0	1	1	0
-1	2	C	0	1	0	0	0	1	3	3	0
-1	2	C	0	1	1	0	0	1	1	1	0
0	2	T	0	0	0	0	3	3	3	3	0
0	2	T	0	0	1	0	1	1	1	1	0
0	2	T	0	1	0	0	3	3	3	3	0
1	2	H	0	1	0	0	3	3	3	1	0
1	2	H	1	1	0	0	1	1	1	0	0
1	2	T	1	1	1	0	1	1	1	0	0
1	3	H	0	1	0	0	3	3	1	1	0
1	3	H	1	1	0	0	1	1	0	0	0
2	2	H	1	1	0	1	1	1	0	0	0
2	2	H	2	0	0	0	0	0	0	0	0

Because of its nature (and the nature of the Weather index), WSI is not calculated with a mathematical formula but using a lookup table. Such a table contains the WSI_XX values corresponding to every realistic Weather classification. To simplify managing this information, the lookup table is loaded from a disk file named WSI.INI located in the same folder as the BioKlima.exe file. WSI.INI should be a text file containing 12 data columns and a single header row (obligatory but ignored by the program). Every row should contain the specification of a weather condition (first 7 columns, in the same order as in the Weather index; W_Strain values can be encoded either as digits or letters) and its corresponding WSI_XX index values (5 subsequent columns, in the following order: SB, AB, MR, AR, ST). Columns can be separated using any separator. Rows that don't follow this format will be ignored. The following is a sample section of the WSI.INI file:

```
ThermSens;Radiation;Strain;Sultriness;TempAmplit;PrecIdx;SnowIdx;SB;AB;MR;AR;ST

-3;1;1;0;0;0;0;0;0;0;0;0
0;1;2;1;0;0;1;1;3;1;1;1
2;3;1;0;0;0;0;3;3;1;0;0
```

Please note that if no valid row is present in the WSI.INI file for a particular weather condition, the calculated WSI_XX index value will be Lack Of Data.