Bioclimatic indexes for environmental applications

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Proposed systems for rating heat stress and strain (heat stress indices)

Year	Index	Author(s)
1905	Wet-bulb temperature (T_w)	Haldane[19]
1916	Katathermometer	Hill *et al.*[47]
1923	Effective temperature (ET)	Houghton & Yaglou[23]
1929	Equivalent temperature (T_{eq})	Dufton[48]
1932	Corrected effective temperature (CET)	Vernon & Warner[24]
1937	Operative temperature (OpT)	Winslow *et al.*[49]
1945	Thermal acceptance ratio (TAR)	Ionides *et al.*[50]
1945	Index of physiological effect (E_p)	Robinson *et al.*[51]
1946	Corrected effective temperature (CET)	Bedford[52]
1947	Predicted 4-h sweat rate (P4SR)	McArdel *et al.*[53]
1948	Resultant temperature (RT)	Missenard *et al.*[54]
1950	Craig index (I)	Craig[55]
1955	Heat stress index (HIS)	Belding & Hatch[7]
1957	Wet-bulg globe temperature (WBGT)	Yaglou & Minard[25]
1957	Oxford index (WD)	Lind & Hellon[34]
1957	Discomfort index (DI)	Thom[36]
1958	Thermal strain index (TSI)	Lee & Henschel[56]
1959	Discomfort index (DI)	Tennenbaum *et al.*[39]
1960	Cumulative discomfort index (CumDI)	Tennenbaum *et al.*[39]
1962	Index of thermal stress (ITS)	Givoni[58]
1966	Heat strain index (corrected) (HSI)	McKarns & Brief[59]
1966	Prediction of heart rate (HR)	Fuller & Brouha[60]
1967	Effective radiant field (ERF)	Gagge *et al.*[61]
1970	Predicted mean vote (PMV)	Fanger[9]
	Threshold limit value (TLV)	
1970	Prescriptive zone	Lind[62]
1971	New effective temperature (ET*)	Gagge *et al.*[63]
1971	Wet globe temperature (WGT)	Botsford[64]
1971	Humid operative temperature	Nishi & Gagge[65]
1972	Predicted body core temperature	Givoni & Goldman[66]
1972	Skin wettedness	Kerslake[67]
1973	Standard effective temperature (SET)	Gagge *et al.*[68]
1973	Predicted heart rate	Givoni & Goldman[69]
1978	Skin wettedness	Gonzales *et al.*[70]
1979	Fighter index of thermal stress (FITS)	Nunneley & Stribley[71]
1981	Effective heat strain index (EHSI)	Kamon & Ryan[72]
1982	Predicted sweat loss (m_{sw})	Shapiro *et al.*[73]
1985	Required sweating (SW_{req})	ISO 7933[74]
1986	Predicted mean vote (modified) (PMV*)	Gagge *et al.*[75]
1996	Cumulative heat strain index (CHSI)	Frank *et al.*[76]
1998	Physiological strain index (PSI)	Moran *et al.*[77]
1999	Modified discomfort index (MDI)	Moran *et al.*[78]
2001	Environmental stress index (ESI)	Moran *et al.*[79]
2005	Wet-bulb dry temperature (WBDT)	Wallace *et al.*[80]
2005	Relative humidity dry temperature (RHDT)	Wallace *et al.*[80]

Effective temperature [Missenard, 1955]:

$$ЭТ = t - 0,4(t - 10)(1 - f/100)$$

Equivalent-effective temperature [Aizenshtadt, 1987]:

$$ЭЭФ = t\left[1 - 0,003 * F\right] - 0,385V^{0,59}\left[\left(36,6 - t\right) + 0,622\left(V - 1\right)\right] +$$
$$\left[\left(0,0015V + 0.008\right)\left(36,6 - t\right) - 0,0167\right]F$$

Apparent temperature [Steadmen,1994] (Australia):

$$AT = t + 0,33e - 0,70V - 4$$

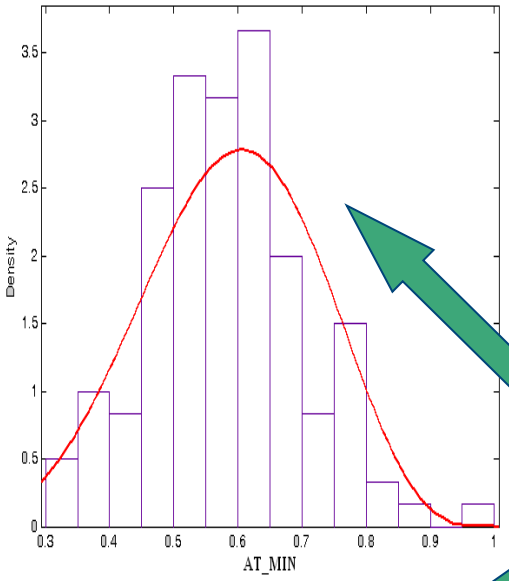
Heat Index, (USA):

$$HI = -42,379 + 2,04901523t + 10,14333127f - 0,22475541t * f -$$
$$0,00683783t^2 - 0,05481717f^2 + 0,00122874t^2 + 0,00085282T * f^2$$
$$- 0,00000199t^2 f, (8)$$

Variables for HIS (Heat Stress Index)
[Jill D.Watts, L.S.Kalkstein, 2004]

- ***Maximum and Minimum Apparent Temperature***
- ***Mean Cloud Cover*** (average hourly cloud cover from 10AM to 6PM).
- ***Cooling Degree Hours*** (sum of hourly degrees over 18.3 degrees apparent temperature for 24 hour period).
- ***Consecutive Day Count***, since the same oppressive weather for several consecutive days increases human health risks (day counted when mean daily apparent temperature is at least 1 standard deviation above the mean).

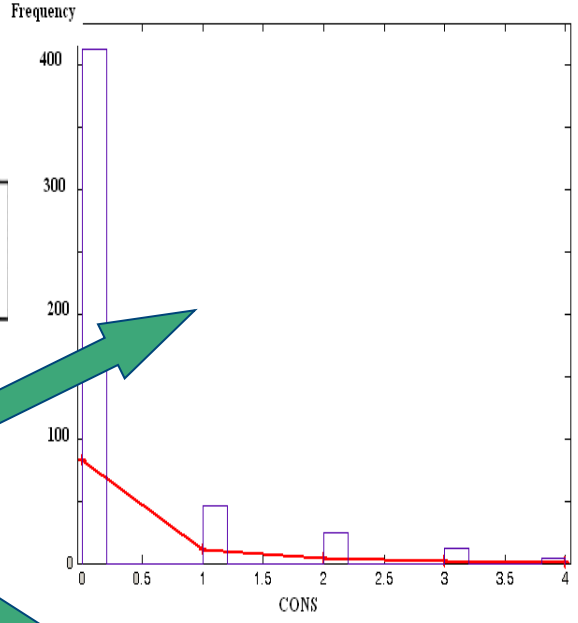
The steps necessary to create HIS:



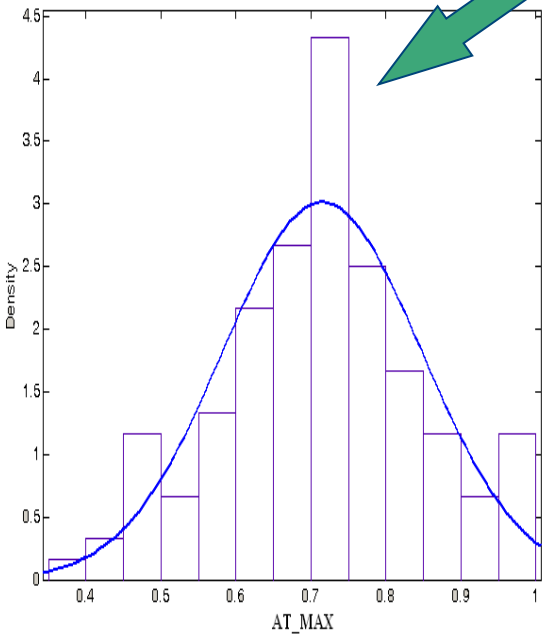
Run Steadman's AT algorithm hourly

Determine ATMAX and ATMIN

Calculate CCMEAN, CDD, and CONS



Fit distribution to each variable

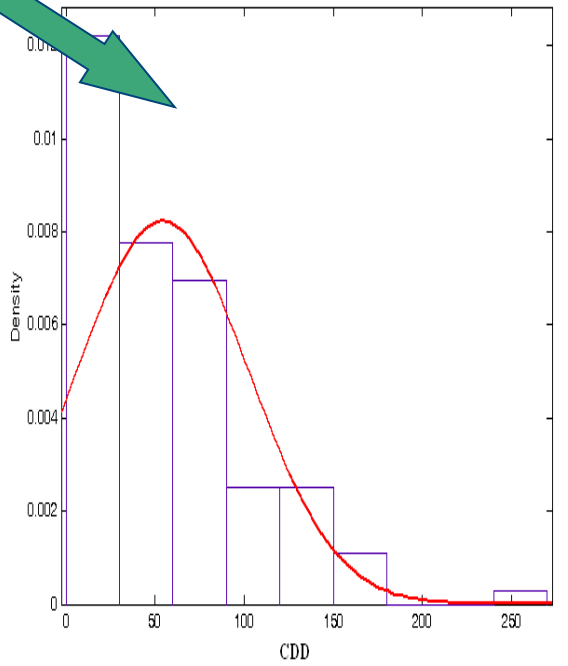


Determine daily value under distribution curve for each variable

Sum daily values for each variable

Fit distribution to summed values

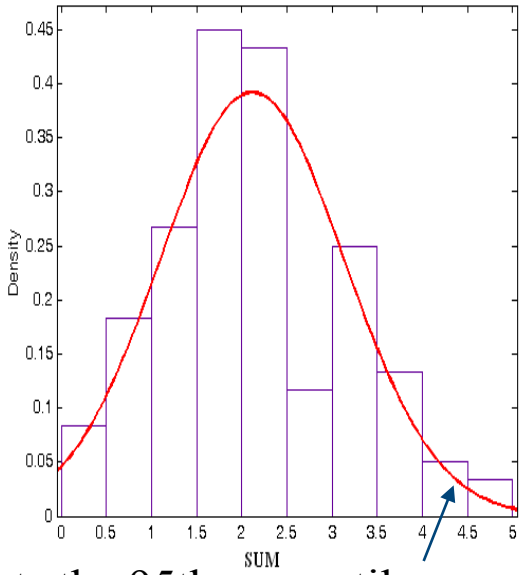
Determine each day's location under the curve



Method: Summation of Variables.
This is an example using Moscow on July 28, 2010.

Sum = At max +At min + CDD + Cons Day+ (1-CC mean)

Variable	Data	Persentage
AT_MAX	42.2 ºC	0.990
AT_MIN	32.2 ºC	0.999
CDD	178 ºC	0.92
CCMEAN	3.46	0.44
Cons_day	1	0.81
	SUM	4.29



4.29 represents the 95th percentile

The final HSI value is expressed as a percentile. Summing the percentiles for the five variables yields a final distribution and a final percentile. In this case, the HSI for Moscow for July 28, 2010 is 9.5 (converted from the 95th percentile).

The daily HIS value ranges:

9.6-10.0 EXTREME
9.0-9.5 HIGH
7.0-8.9 MODERATE
4.0-6.9 LOW
0.0-3.9 NONE

Forecast capabilities:

Spatial distribution of first-order weather stations throughout European Russia

Thanks for attention!