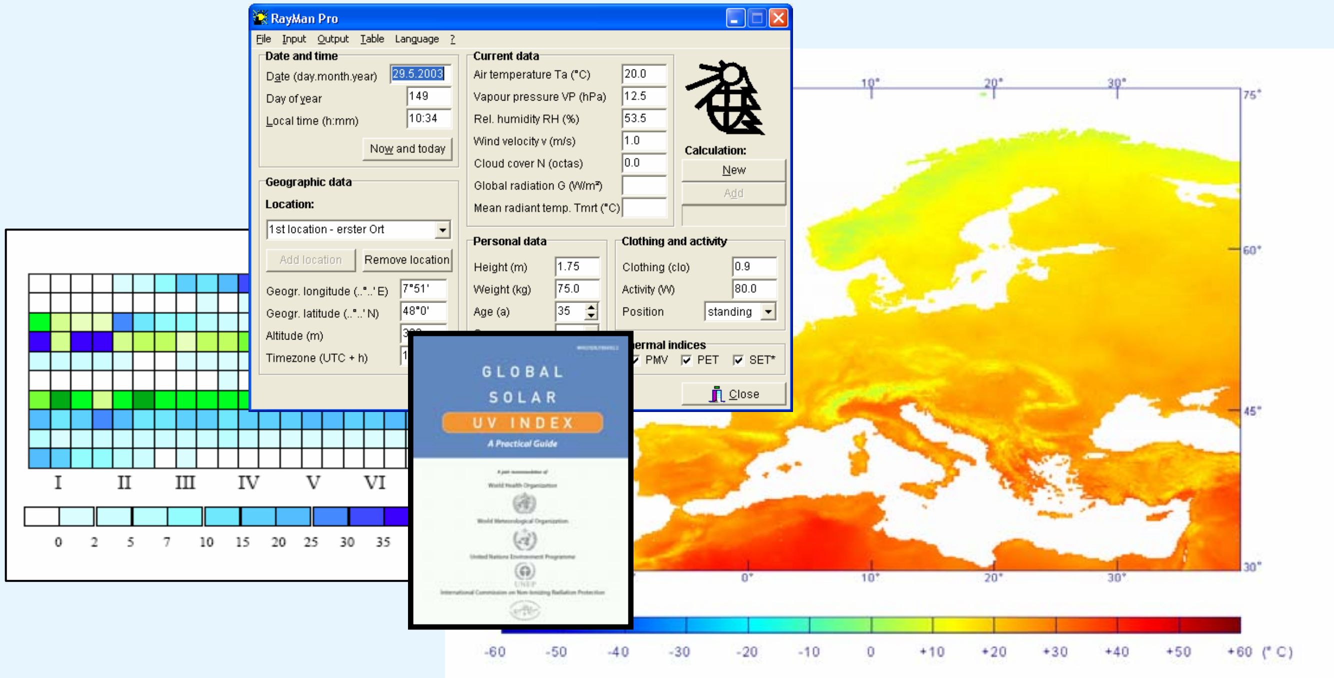
Importance of thermal comfort and bioclimate for tourism



Andreas Matzarakis and Maria Joao Alcoforado

Climate Change and Tourism, 7.-8. September 2007

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- Thermal comfort and energy balance
- Assessment methods and applications
  - PMV, PET, ...
  - Bioclimate maps and climate change
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- New way of including thermal comfort in tourism and recreation studies
- Conclusions

Atmospheric Environment

Thermal environment

- Air temperature
- Air humidity
- Wind speed
- Short and long wave radiation
- ....

■ ■ ■ others

thermal effective complex

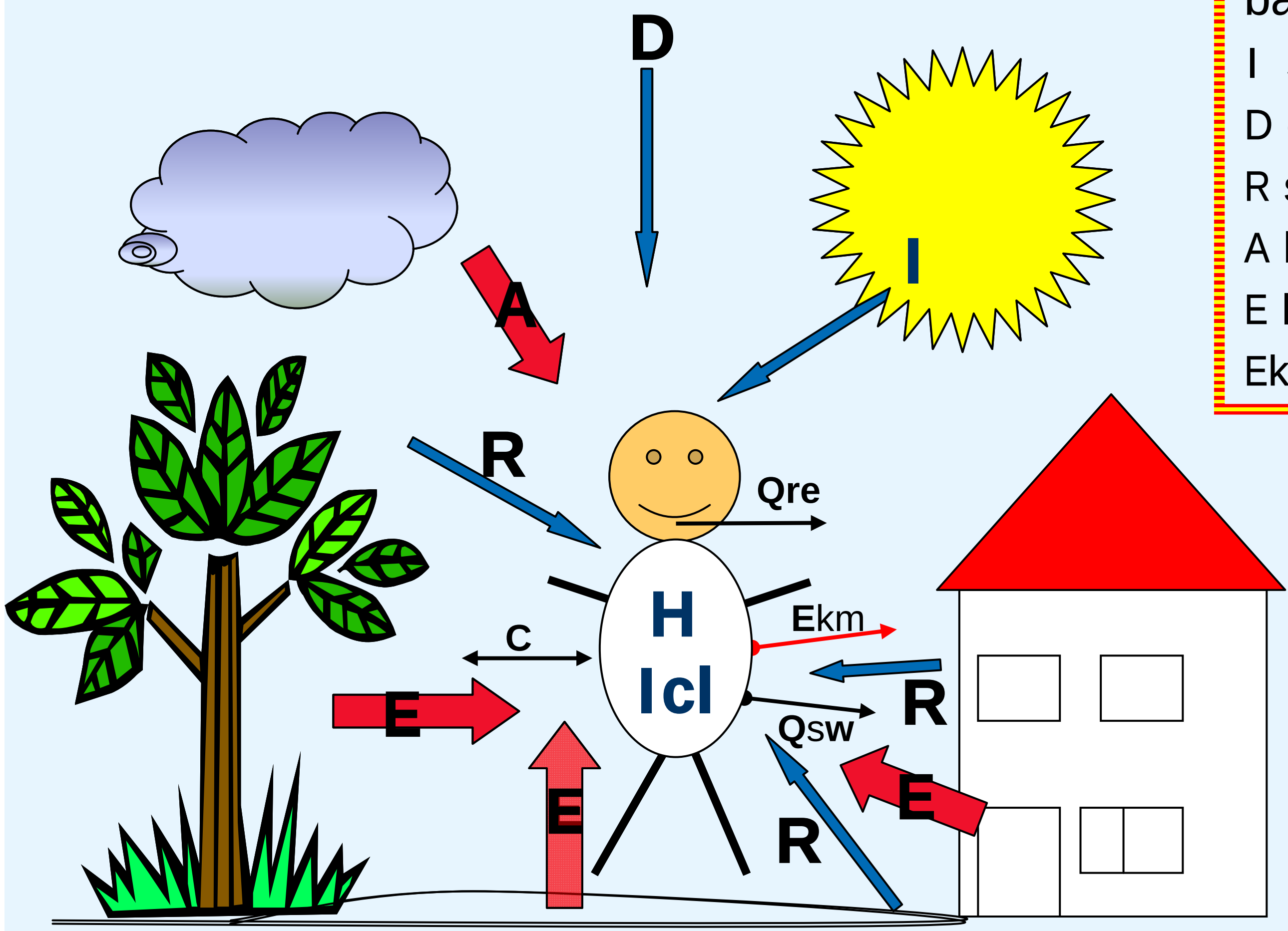
If one wants to assess the influence of climate on the human organism in the widest sense, it is necessary to evaluate the effects not only of a single parameter

but of all thermal components.

This leads us to the necessity of modelling the human heat balance.

Büttner, 1938

Energy balance applied on human beeings



Components of the radiation balance

I solar radiation
D diffuse radiation
R shortwave reflected radiation
A longwave radiation of atmosp.
E longwave radiation of surfaces
Ekm longwave radiation human

H internal heat production
Icl clothing insulation
C convection
Qsw sweat evaporation
Qre heat flux respiration

nach G. Jendritzky

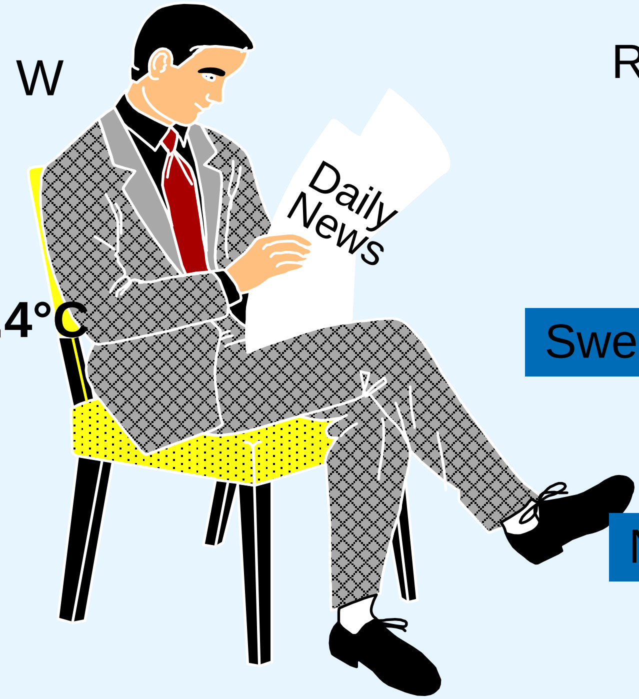
Heat balance (MEMI): Indoors

Activity: sitting, light work

$T_a = T_{mrt} = 21°C$, RH=50%, v=0.05m/s

Internal heat production: 156 W

Resp. heat loss: -11 W



Mean skin temperature: 34.4°C

Sweat evaporation: -12 W

Core temperature: 36.9°C

Convection: -48 W

Net radiation: -59 W

Body parameters: 1.80 m, 75 kg, 35 years, 1.0 clo

Heat Balance (MEMI): Summer

T_a = 30 °C, T_{mrt} = 60 °C, RH = 50%, v =1.0 m/s, PET = 43 °C

Internal heat production: 258 W

Mean skin temperature: 36.1 °C

Body core temperature: 37.5 °C

Skin wetness: 53 %

Water loss: 525 g/h

Respiratory heat loss: -27 W

Sweat evaporation: -317 W

Convection: -143 W

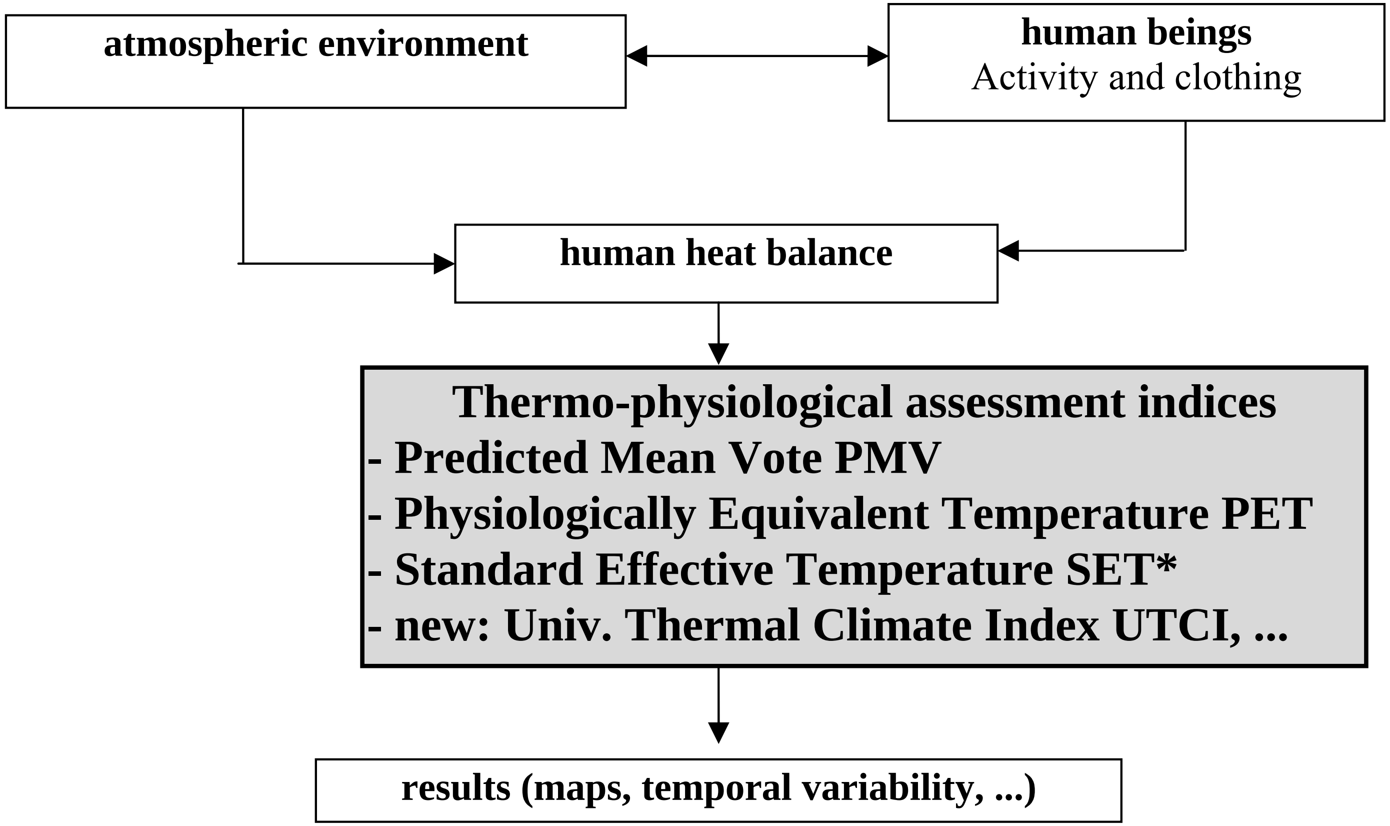
Net radiation: +240 W

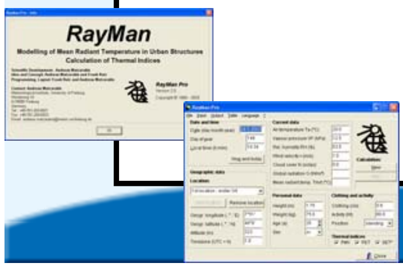
Body Parameters:1.80 m, 75 kg, 35 years, 0.5 clo, walking (4 km/h)

Assessment methods

- The climatic indices (ET, THI, etc) have deficits they do not include the effects of short and long wave radiation fluxes which are generally not included in climatic records
- Thermal indices have to be based on the energy balance of human body

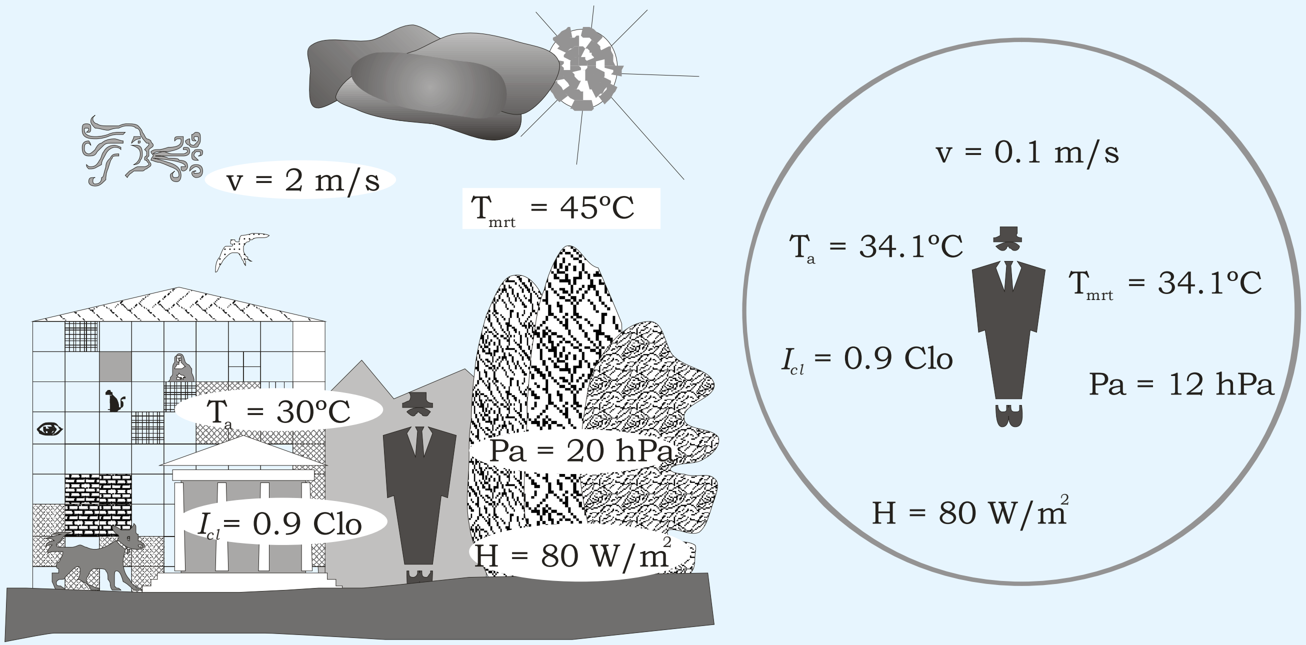
Human-Biometeorological Assessment of the Thermal Component of Different Climates





Physiologically Equivalent Temperature PET

basis: human energy balance model MEMI (*M*unich *E*nergy Balance *M*odel for *I*ndividuals**)**



Actual environment with PET = = 34.1°C and equivalent standard environment (Andrade, 2003)

Thermal indices (PMV, PET), Thermal perception, Physiological stresss

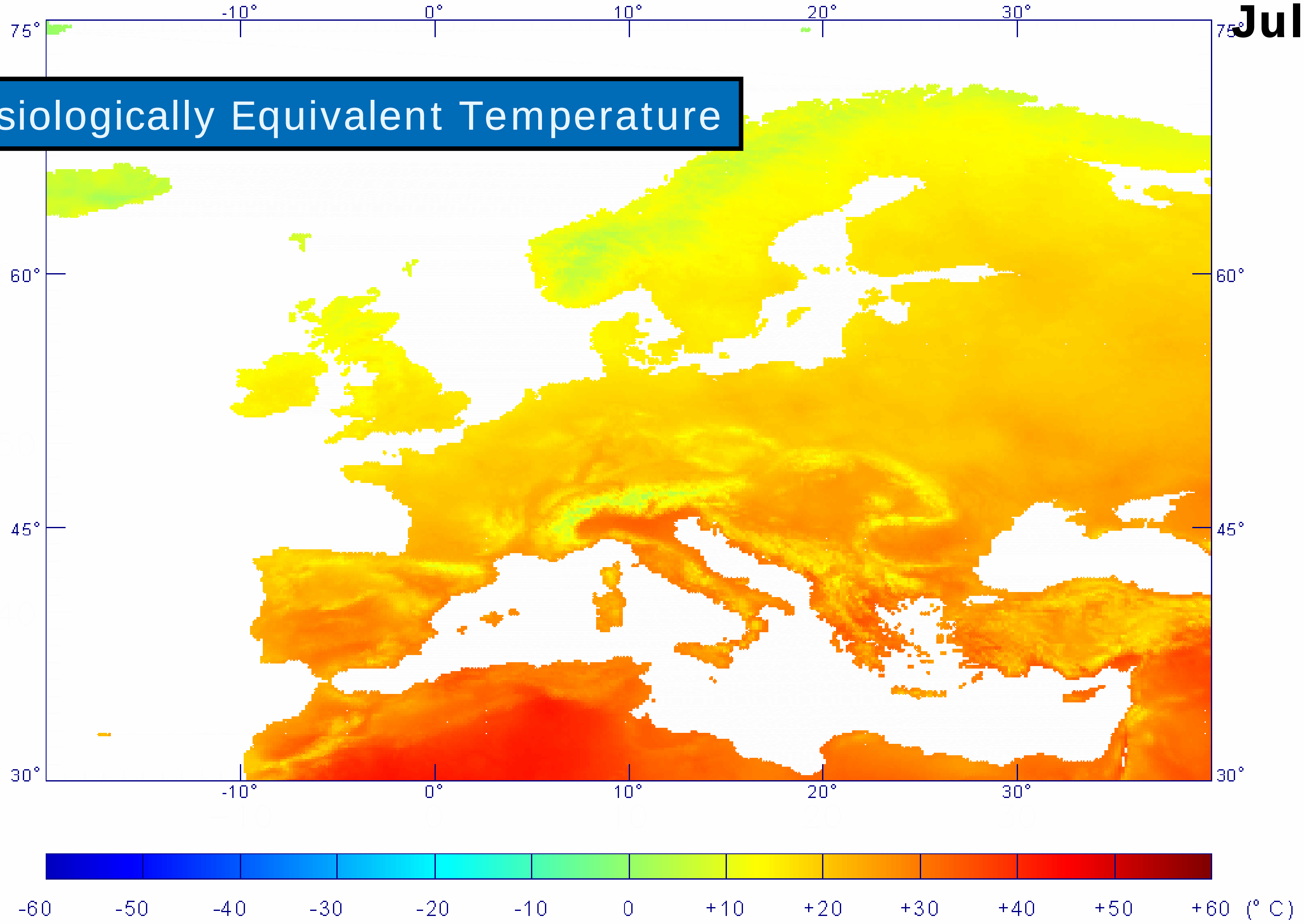
PMV	PET	Thermal Sensitivity	Grade of Physiological Stress
		very cold	extreme cold stress
-3,5	4 °C		
		cold	strong cold stress
-2,5	8 °C		
		cool	moderate cold stress
-1,5	13 °C		
		slightly cool	slight cold stress
-0,5	18 °C		
		neutral (comfortable)	*no thermal stress*
0,5	23 °C		
		slightly warm	slight heat stress
1,5	29 °C		
		warm	moderate heat stress
2,5	35 °C		
		hot	strong heat stress
3,5	41 °C		
		very hot	extreme heat stress

Threshold values of thermal indices PMV and PET

(Matzarakis and Mayer, 1996)

July

Physiologically Equivalent Temperature

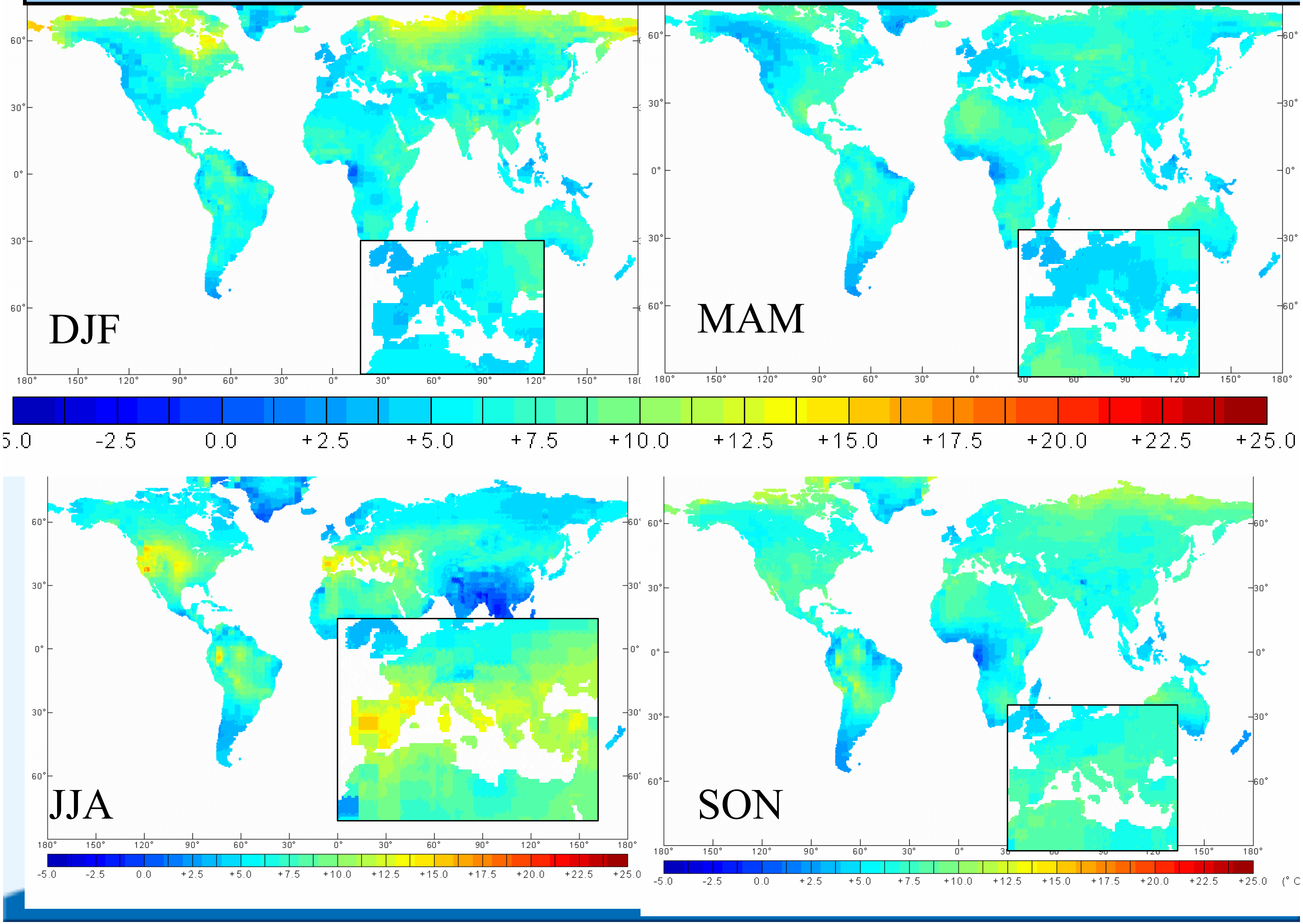


RayMan Pro

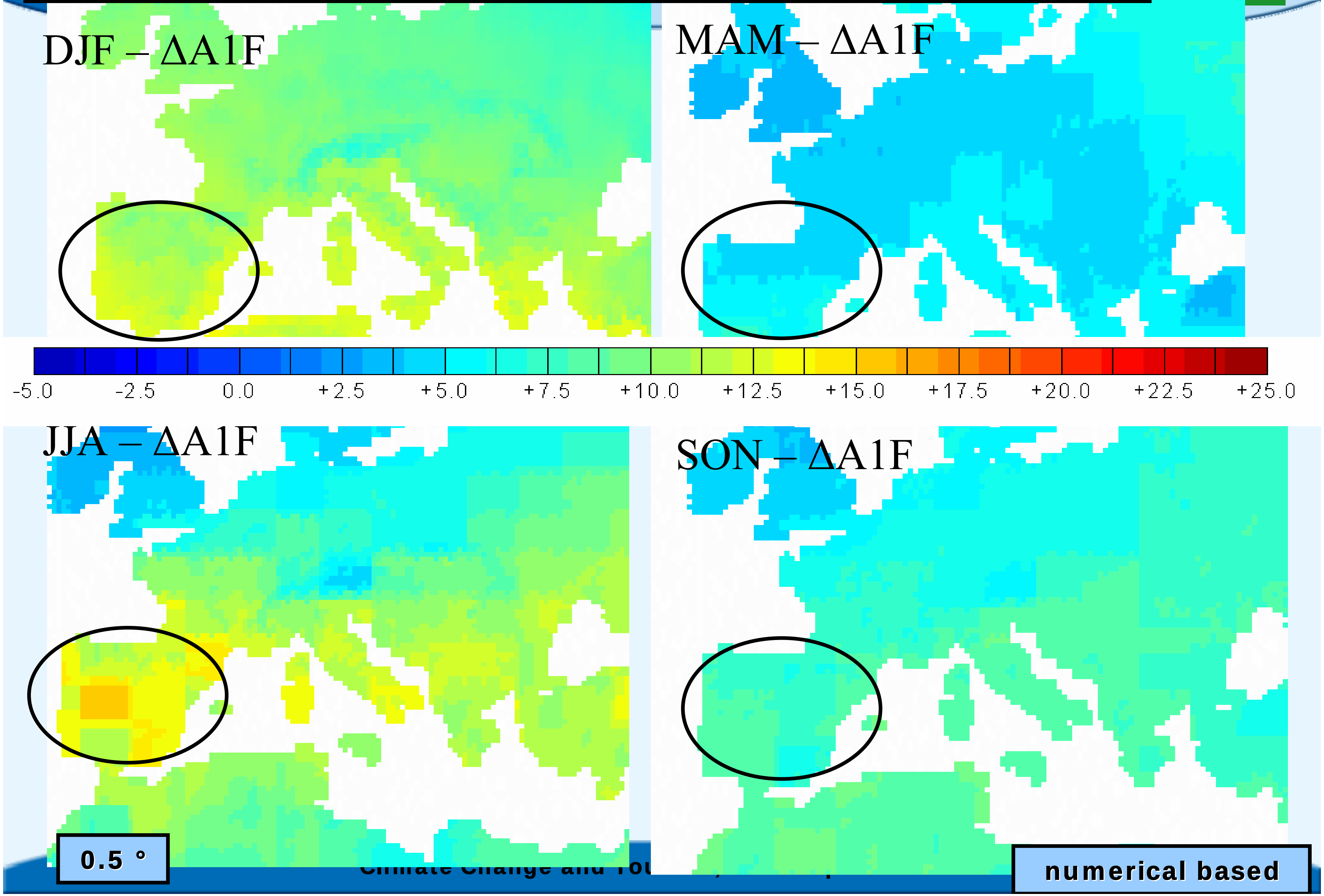
Climate model

Results: thermal

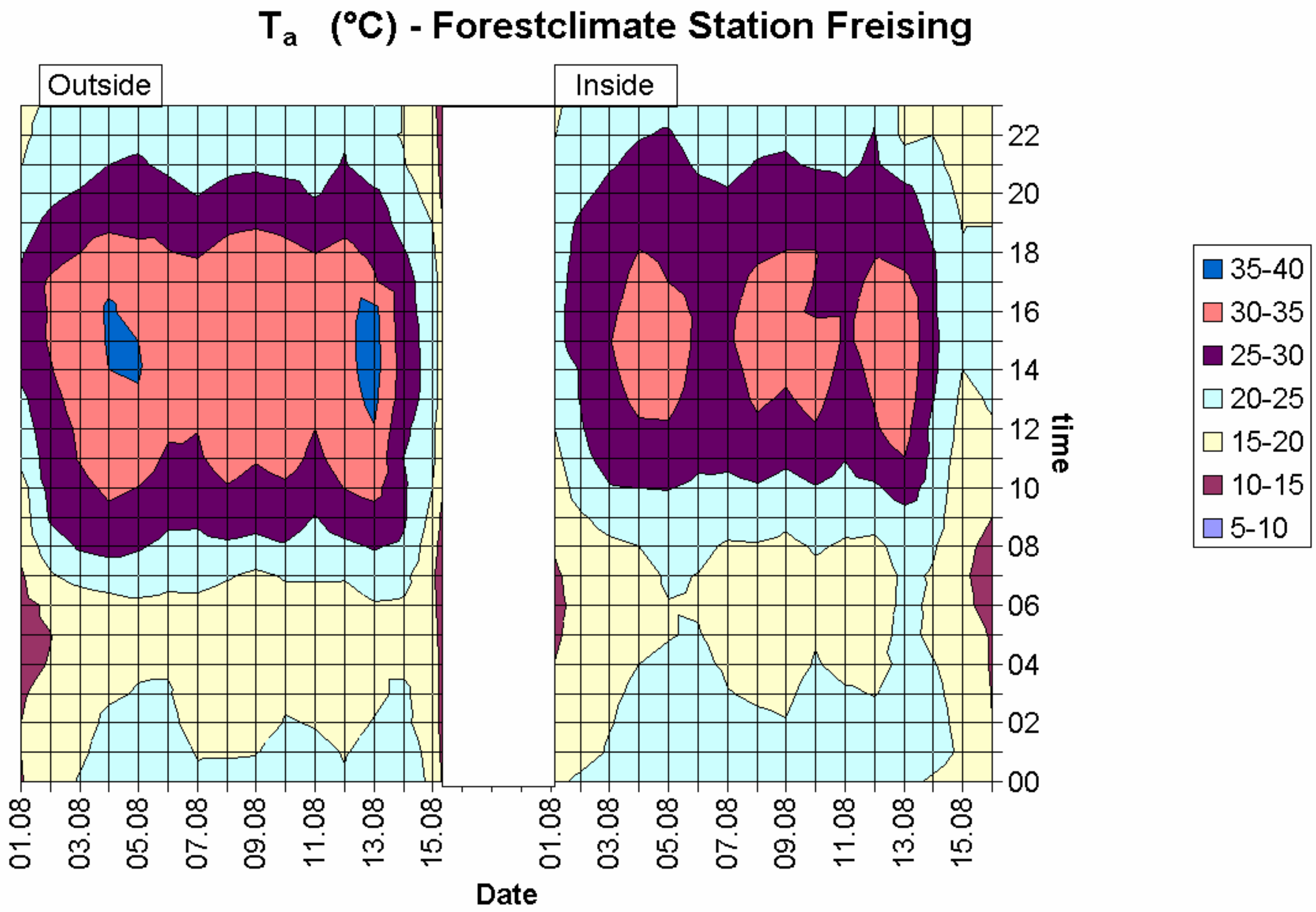
Seasonal PET ---- A1B (2070-2100) – Reference Period (1960-1990)



Seasonal PET (A1B (2070-2100) – Reference Period(1960-1990)



Forests and Air Temperature during heat waves



Data: Bavarian Agency of Forestry. Freising – Munich

Adaptation

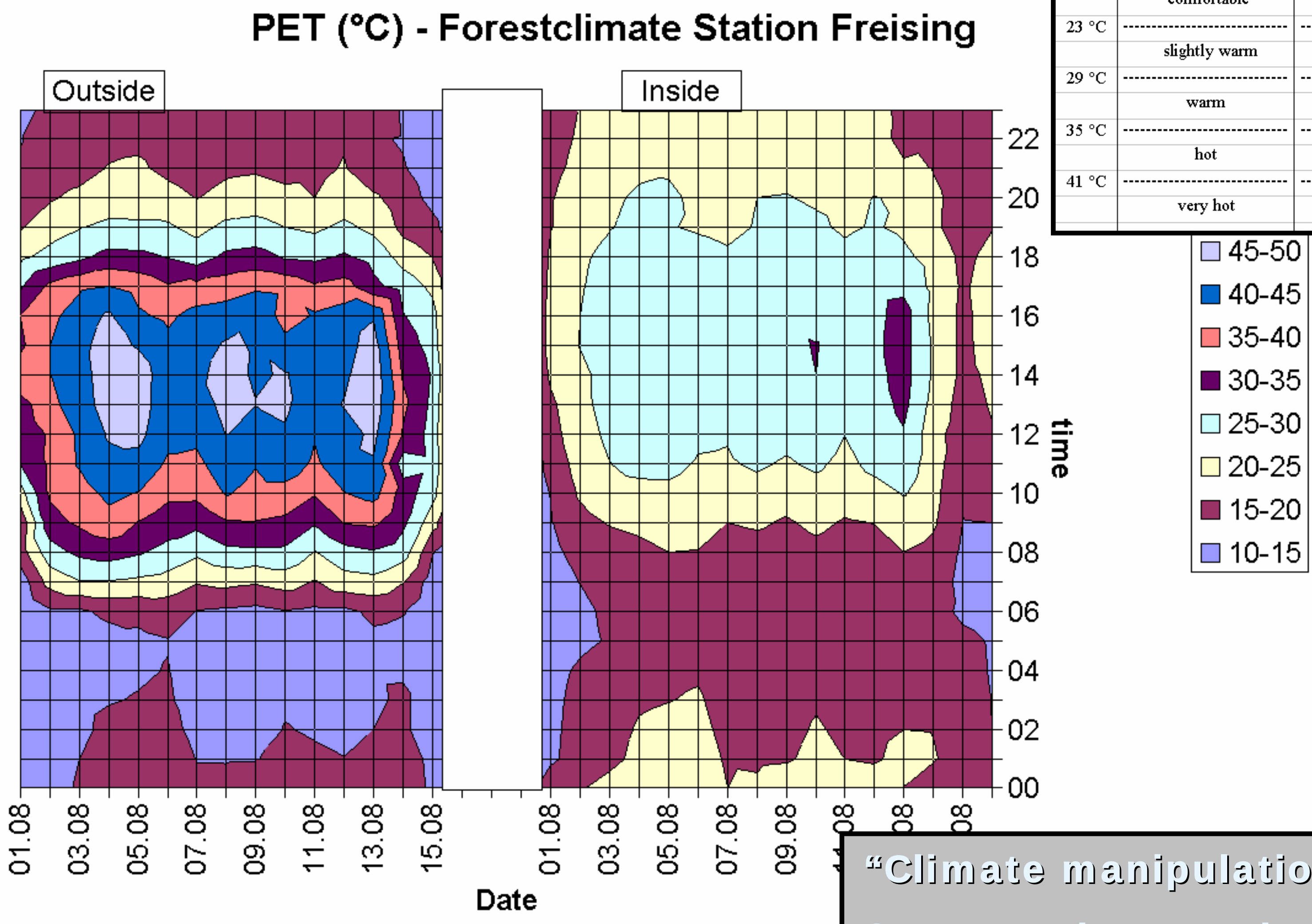
ALBERT-LUDWIGS-UNIVERSITÄT FREIBURG

Met

Faculty of Forest and E

Forests and Bioclimate

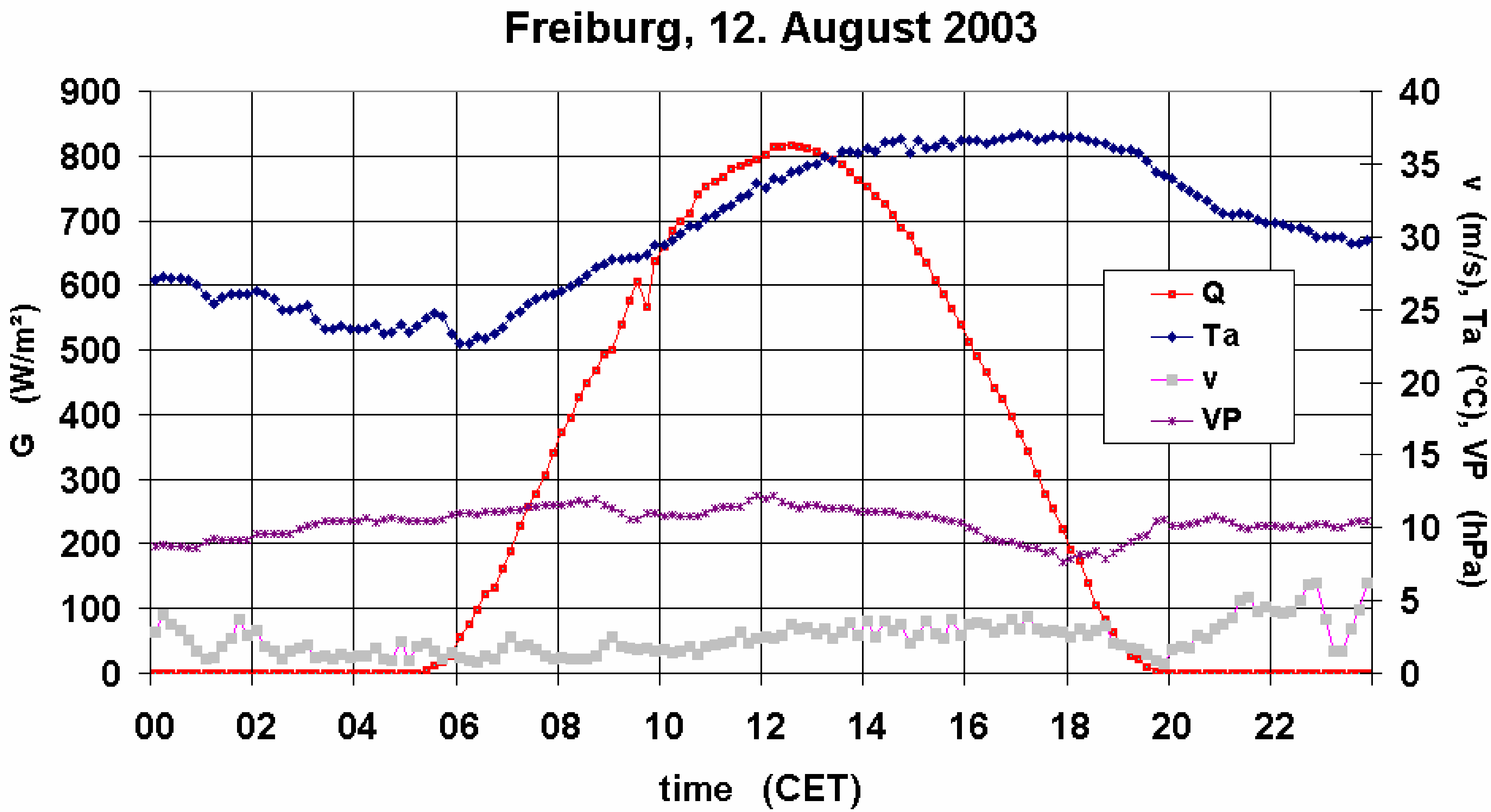
PET	Thermal Sensivity	Grade of Physiologic Stress
	very cold	extreme cold stress
4 °C		
	cold	strong cold stress
8 °C		
	cool	moderate cold stress
13 °C		
	slightly cool	slight cold stress
18 °C		
	comfortable	no thermal stress
23 °C		
	slightly warm	slight heat stress
29 °C		
	warm	moderate heat stress
35 °C		
	hot	strong heat stress
41 °C		
	very hot	extreme heat stress



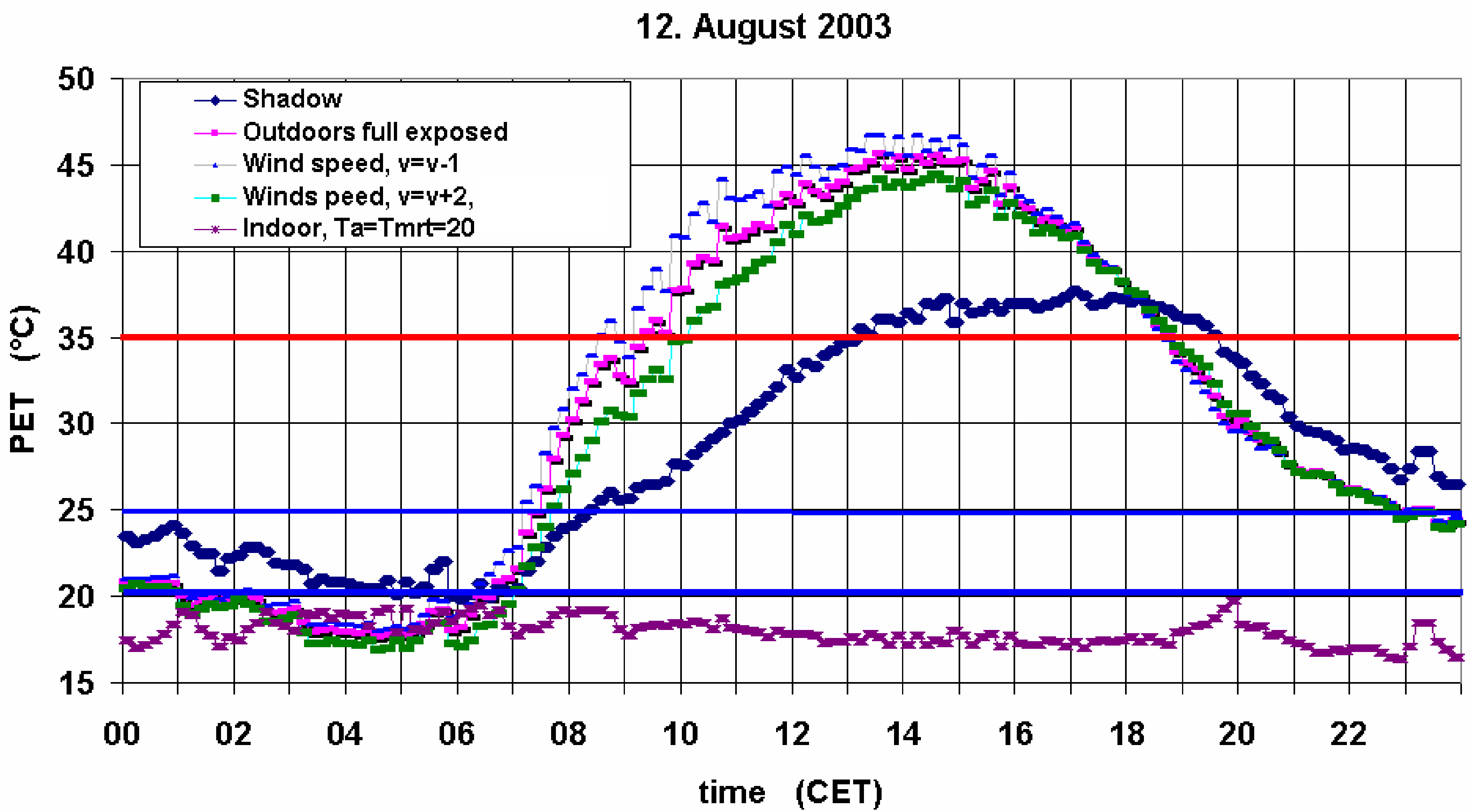
"Climate manipulation":

Creates a better microclimate

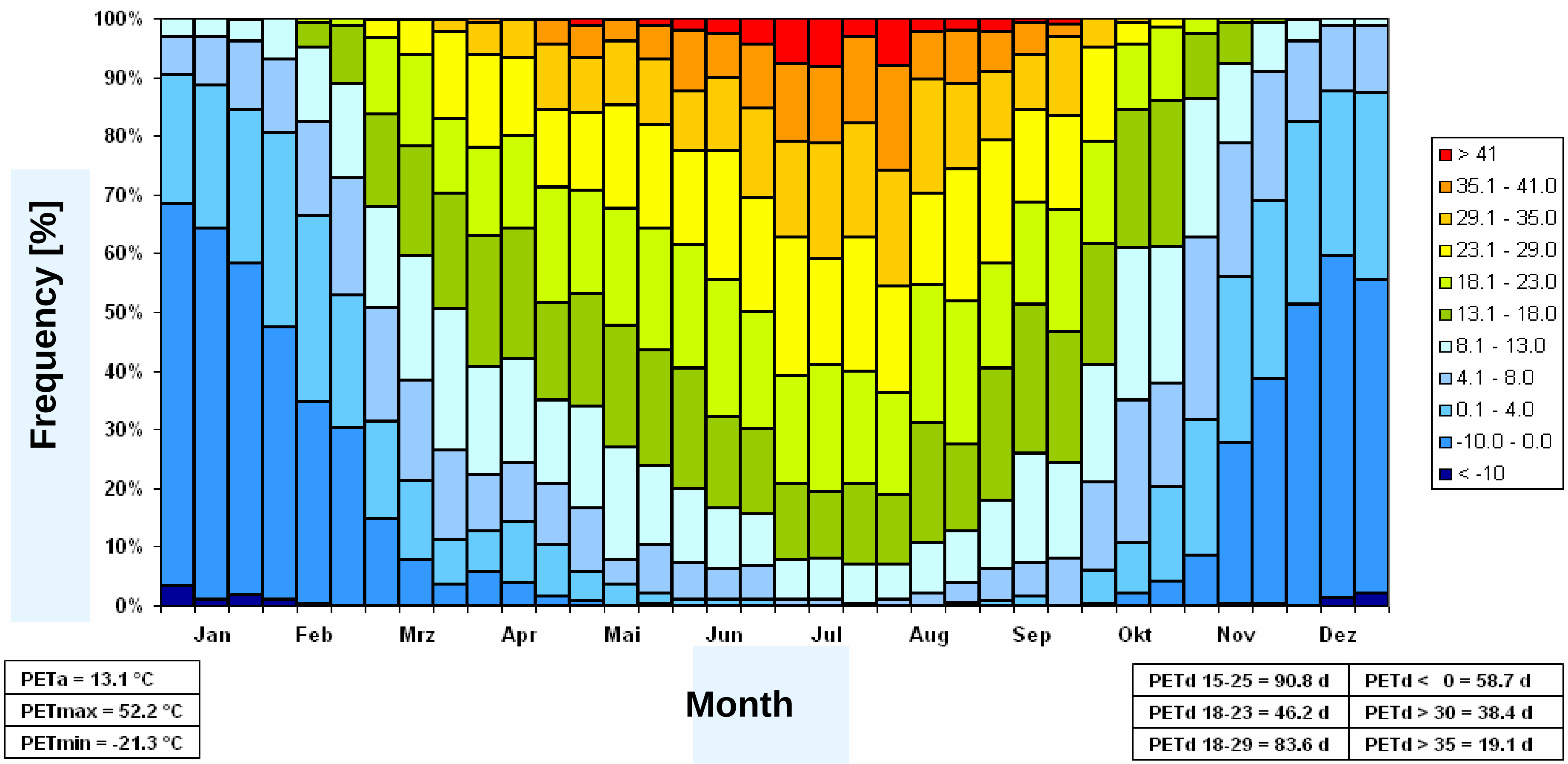
Perfect day


Freiburg, 12. August 2003
G (W/m²)
v (m/s), Ta (°C), VP (hPa)
time (CET)
Q
Ta
v
VP
900
800
700
600
500
400
300
200
100
0
40
35
30
25
20
15
10
5
0
00
02
04
06
08
10
12
14
16
18
20
22

Perfect day and bioclimate



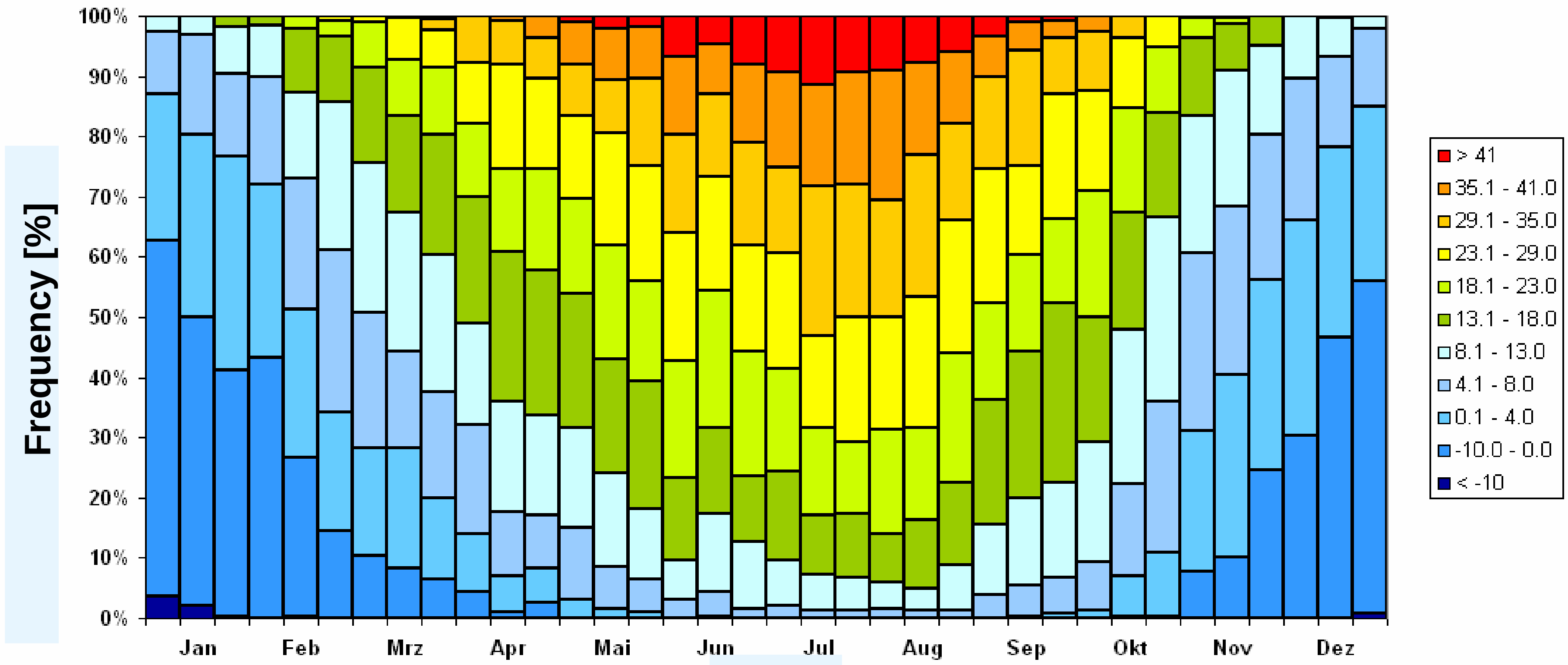
PET, Freiburg 1961-1990



PETa = 13.1 °C
PETmax = 52.2 °C
PETmin = -21.3 °C

PETd 15-25 = 90.8 d	PETd < 0 = 58.7 d
PETd 18-23 = 46.2 d	PETd > 30 = 38.4 d
PETd 18-29 = 83.6 d	PETd > 35 = 19.1 d

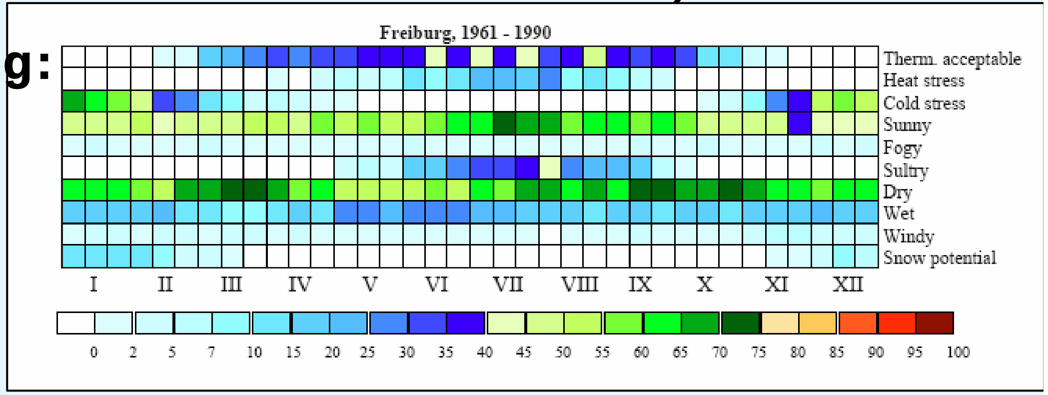
PET, Freiburg 2021-2050



PETa = 14.4 °C
PETmax = 53.7 °C
PETmin = -17.6 °C

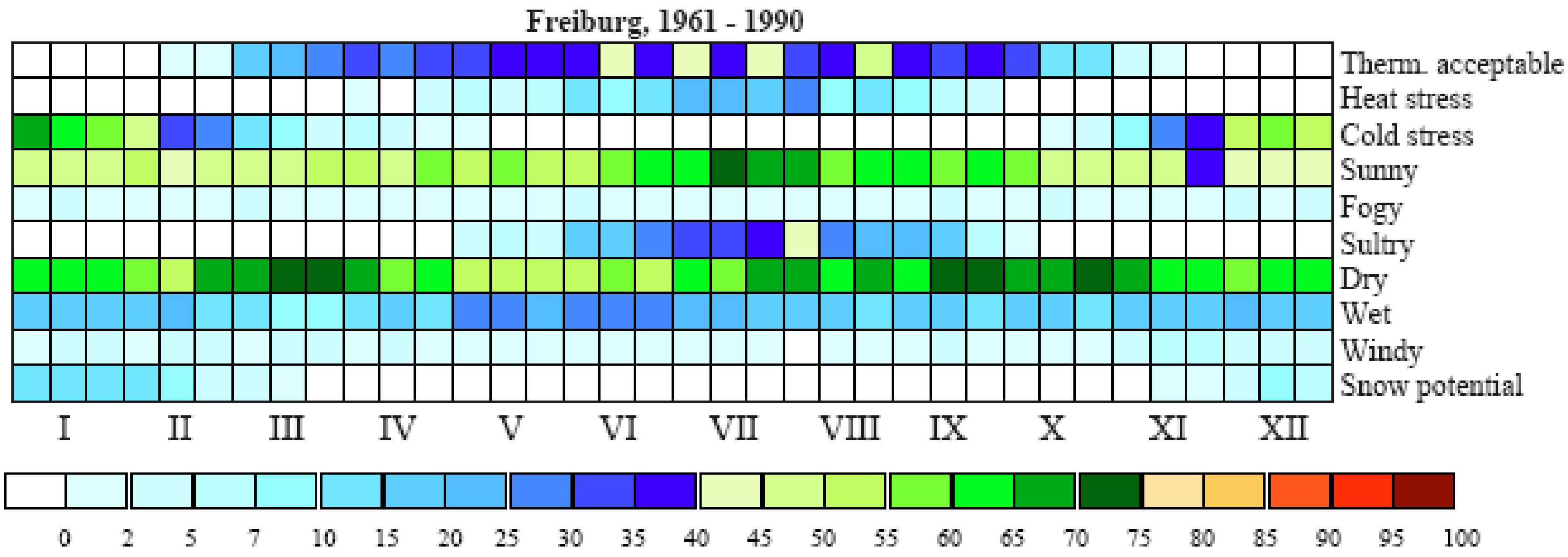
PETd 15-25 = 81.9 d	PETd < 0 = 44.8 d
PETd 18-23 = 40.4 d	PETd > 30 = 49.7 d
PETd 18-29 = 78.8 d	PETd > 35 = 26.8 d

CTIS (Climate-Tourism-Information-Scheme)

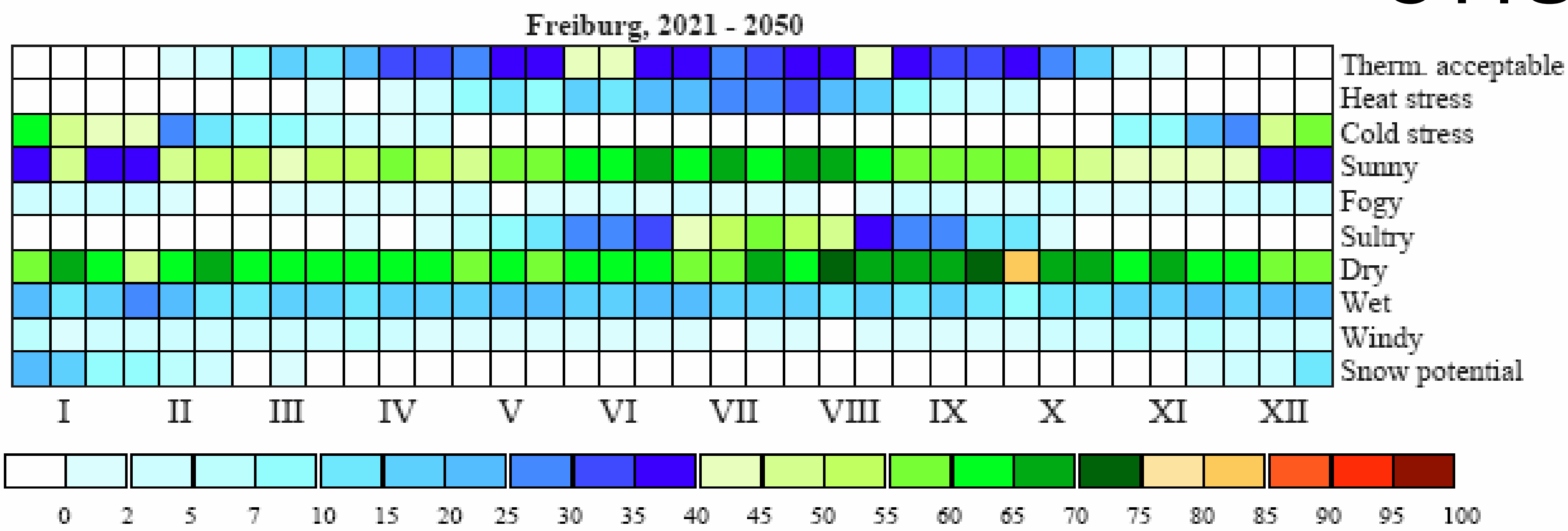


Threshold values for Freiburg:

- Thermal acceptability (PET 18 °C and 29 °C)
- Heat stress (PET > 35 °C),
- Cold stress (PET < 8 °C),
- Sunny (< 5 octa),
- Fog (based on rel. humidity > 93 %),
- Sultriness (based on vapour pressure > 18 hPa),
- Dry day (precipitation < 1 mm),
- Wet day (precipitation > 5 mm),
- Windy (> 8 m/s)


Freiburg, 1961 - 1990
Therm. acceptable
Heat stress
Cold stress
Sunny
Fogy
Sultry
Dry
Wet
Windy
Snow potential
I II III IV V VI VII VIII IX X XI XII
0 2 5 7 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

CTIS


Freiburg, 2021 - 2050
Therm. acceptable
Heat stress
Cold stress
Sunny
Fogy
Sultry
Dry
Wet
Windy
Snow potential
I II III IV V VI VII VIII IX X XI XII
0 2 5 7 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

Conclusions

- *To assess human comfort it is indispensable to* ***take into account the whole thermal environment*** *and not only temperature*
- *The thermal indices* ***based on the energy balance of the human being*** *are a good means to compute human thermal comfort*
- *And as a great part of tourists seek particular weather conditions, the use of thermal indices can be very* ***useful for tourists and stakeholders***
- *Moreover,* ***future situations can be simulated*** *based on different scenarios*

Studies will progress based on

- Interdisciplinarity
- Common and understandable language - end users