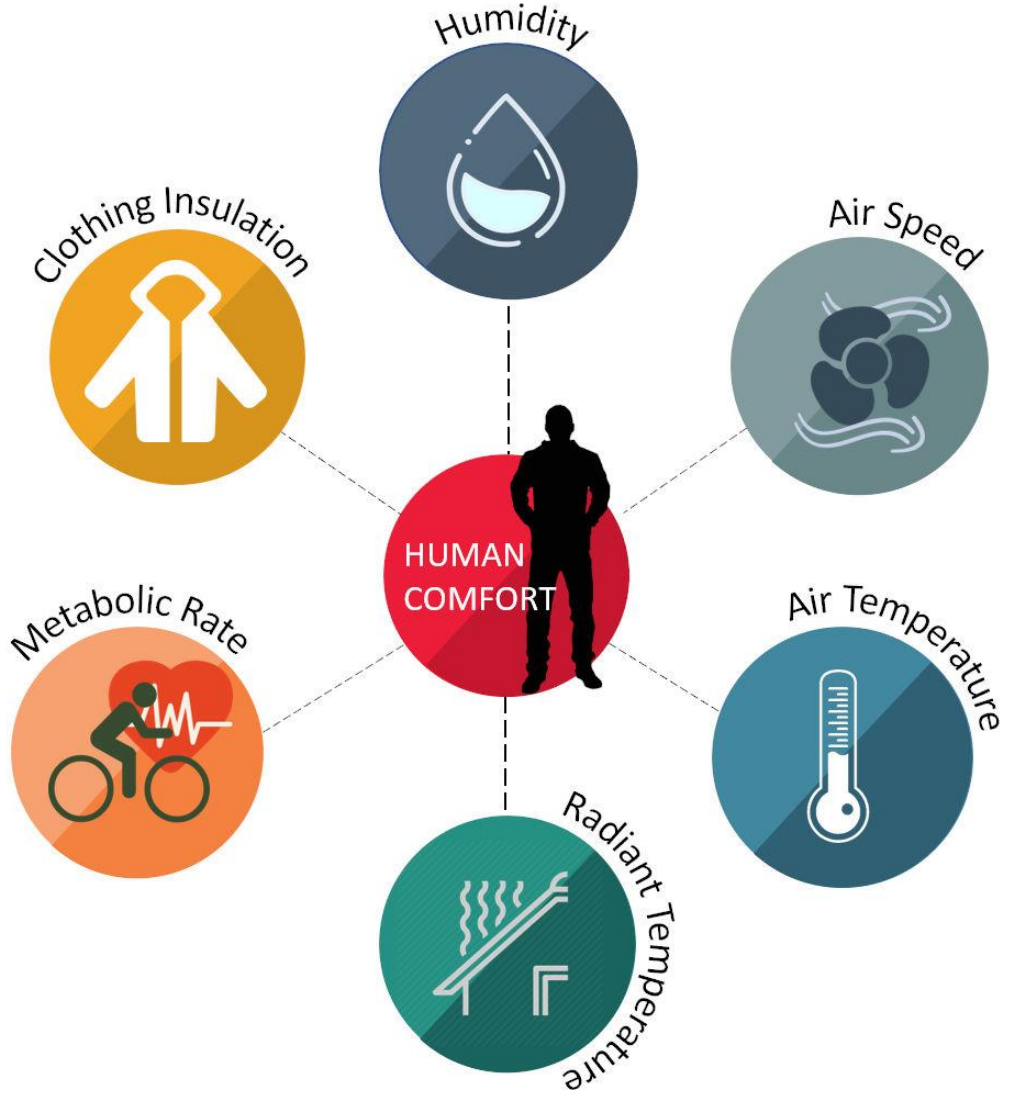
ÍNDICES DE CONFORTO BIOCLIMÁTICO: CONCEITOS E FERRAMENTAS

Marcelo Fragoso

CONCEITOS:

Conforto térmico



componente física ambiental | parâmetros biofísicos | aspetos individuais

CONCEITOS:

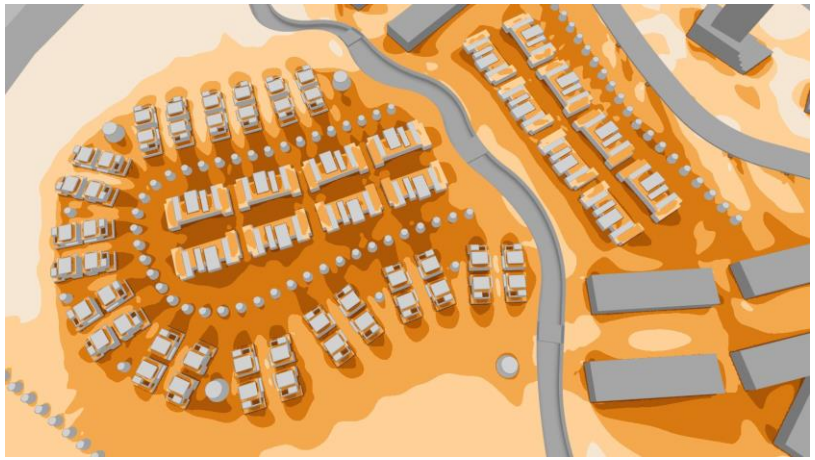
Conforto térmico

Índices bioclimáticos

Índices empíricos

- Wind chill (1945)
- Heat index (1979)
- …

Conforto/Stress térmico humano



- Índices racionais
  - PET (1987)
  - UTCI (2002)
  - …

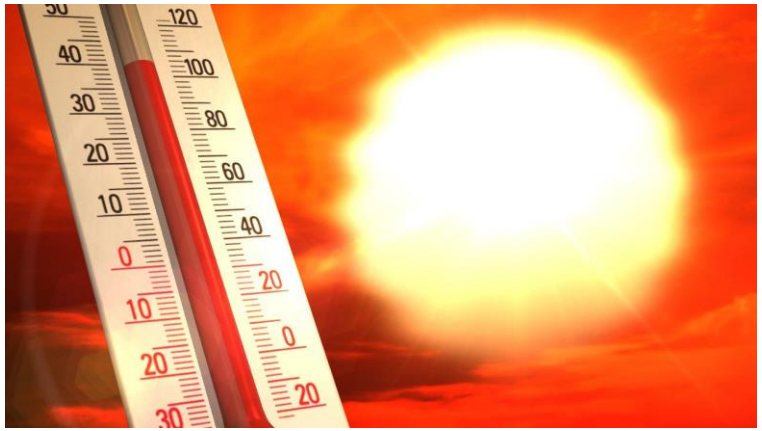
Conforto/Stress termo-fisiológico humano

CONCEITOS:

Conforto térmico

Índices bioclimáticos

HI Heat index

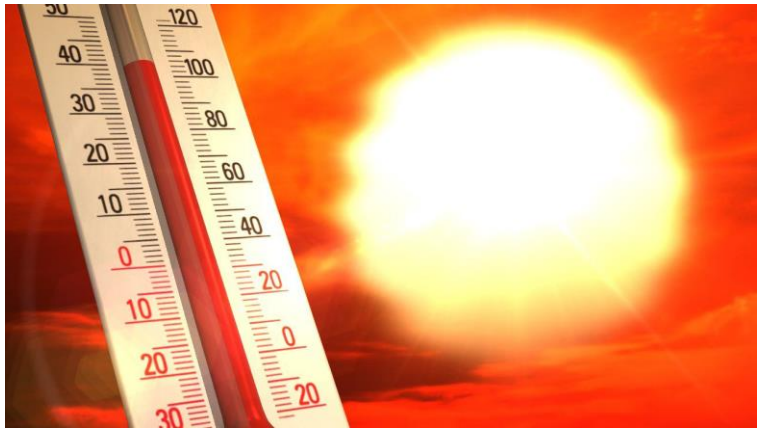


CONCEITOS:

Conforto térmico

Índices bioclimáticos

HI Heat index



ÍNDICE DE CALOR °F (°C)

O índice de calor é uma medida precisa de quão quente realmente se sente quando os efeitos da umidade são adicionados à alta temperatura.

Temperatura.	UMIDADE RELATIVA (%)												
	40	45	50	55	60	65	70	75	80	85	90	95	100
110	136												
(47)	(58)												
108	130	137											
(43)	(54)	(58)											
106	124	130	137							nbsp;			
(41)	(51)	(54)	(58)										
104	119	124	131	137									
(40)	(48)	(51)	(55)	(58)									
102	114	119	124	130	137								
(39)	(46)	(48)	(51)	(54)	(58)								
100	109	114	118	124	129	136							
(38)	(43)	(46)	(48)	(51)	(54)	(58)							
98	105	109	113	117	123	128	134						
(37)	(41)	(43)	(45)	(47)	(51)	(53)	(57)						
96	101	104	108	112	116	121	126	132					
(36)	(38)	(40)	(42)	(44)	(47)	(49)	(52)	(56)					
94	97	100	103	106	110	114	119	124	129	135			
(34)	(36)	(38)	(39)	(41)	(43)	(46)	(48)	(51)	(54)	(57)			
92	94	96	99	101	105	108	112	116	121	126	131		
(33)	(34)	(36)	(37)	(38)	(41)	(42)	(44)	(47)	(49)	(52)	(55)		
90	91	93	95	97	100	103	106	109	113	117	122	127	132
(32)	(33)	(34)	(35)	(36)	(38)	(39)	(41)	(43)	(45)	(47)	(50)	(53)	(56)
88	88	89	91	93	95	98	100	103	106	110	113	117	121
(31)	(31)	(32)	(33)	(34)	(35)	(37)	(38)	(39)	(41)	(43)	(45)	(47)	(49)
86	85	87	88	89	91	93	95	97	100	102	105	108	112
(30)	(29)	(31)	(31)	(32)	(33)	(34)	(35)	(36)	(38)	(39)	(41)	(42)	(44)
84	83	84	85	86	88	89	90	92	94	96	98	100	103
(29)	(28)	(29)	(29)	(30)	(31)	(32)	(32)	(33)	(34)	(36)	(37)	(38)	(39)
82	81	82	83	84	84	85	86	88	89	90	91	93	95
(28)	(27)	(28)	(28)	(29)	(29)	(29)	(30)	(31)	(32)	(32)	(33)	(34)	(35)
80	80	80	81	81	82	82	83	84	84	85	86	86	87
(27)	(27)	(27)	(27)	(27)	(28)	(28)	(28)	(29)	(29)	(29)	(30)	(30)	(31)

Categoria	Índice de calor	Possíveis distúrbios de calor para pessoas em grupos de alto risco
Perigo extremo	130°F ou mais (54°C ou mais)	É provável que ocorra insolação ou insolação.
Perigo	105 - 129°F (41 - 54°C)	Insolação, câibras musculares e/ou exaustão pelo calor são prováveis. Insolação possível com exposição prolongada e/ou atividade física.
Cuidado extremo	90 - 105°F (32 - 41°C)	Insolação, câibras musculares e/ou exaustão pelo calor são possíveis com exposição prolongada e/ou atividade física.
Cuidado	80 - 90°F (27 - 32°C)	Fadiga possível com exposição prolongada e/ou atividade física.

Fonte: https://www.weather.gov/ffc/hichart

CONCEITOS:

Conforto térmico

Índices bioclimáticos

HI Heat index

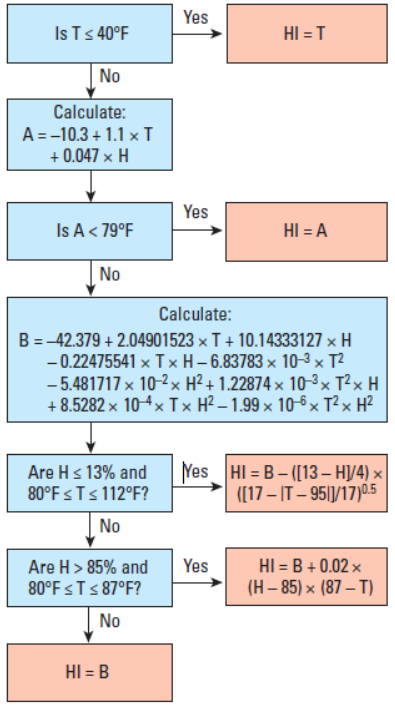


Figure 3. Algorithm used by the NWS online heat index (HI) calculator (NWS 2011) to determine heat index based on air temperature in degrees Fahrenheit (T) and relative humidity in percent (H).

FONTE: Anderson *et al.*, 2013)

Table 1. Heat index algorithms that have been used in environmental research.

No.	Algorithm	Reference
1	NWS algorithm (Figure 3)	NWS 2011[a]
2	$HI_C = T_C - 1.0799e^{0.03755T_C}(1 - e^{0.0801(D_C - 14)})$	Schoen 2005[a]
3	$HI_F = T_F - 0.9971e^{0.02086T_F}(1 - e^{0.0445(D_F - 57.2)})$	Schoen 2005[a]
4	$HI_C = -1.3 + 0.92T_C + 2.2e_S$	Gaffen and Ross 1999; Steadman 1984[a]
5	$HI_F = -42.379 + 2.04901523T_F + 10.14333127H - 0.22475541T_FH - (6.83783 \times 10^{-3})T_F^2 - (5.481717 \times 10^{-2})H^2 + (1.22874 \times 10^{-3})T_F^2H + (8.5282 \times 10^{-4})T_FH^2 - (1.99 \times 10^{-6})T_F^2H^2$. Correction factor: $HI_F = T_F$ when $T_F \le 80°F$ or $H \le 40\%$	El Morjani et al. 2007[a]; Oka 2011
6	$HI_F = -42.379 + 2.04901523T_F + 10.14333127H - 0.22475541T_FH - (6.83783 \times 10^{-3})T_F^2 - (5.481717 \times 10^{-2})H^2 + (1.22874 \times 10^{-3})T_F^2H + (8.5282 \times 10^{-4})T_FH^2 - (1.99 \times 10^{-6})T_F^2H^2$. Correction factor: $HI_F = T_F$ when $T_F < 80°F$ or $H < 40\%$	Fandoeva et al. 2009[a]
7	$HI_F = -42.379 + 2.04901523T_F + 10.14333127H - 0.22475541T_FH - (6.83783 \times 10^{-3})T_F^2 - (5.481717 \times 10^{-2})H^2 + (1.22874 \times 10^{-3})T_F^2H + (8.5282 \times 10^{-4})T_FH^2 - (1.99 \times 10^{-6})T_F^2H^2$. Correction factor: $HI_F = T_F$ when $T_F \le 78.8°F$ or $H \le 39\%$	Di Cristo et al. 2007[a]; Rajib et al. 2011
8	$HI_F = -42.4 + 2.049T_F + 10.14H - 0.2248T_FH - (6.838 \times 10^{-3})T_F^2 - (5.482 \times 10^{-2})H^2 + (1.229 \times 10^{-3})T_F^2H + (8.528 \times 10^{-4})T_FH^2 - (1.99 \times 10^{-6})T_F^2H^2$. Correction factor: $HI_F = T_F$ when $T_F < 79°F$	Johnson and Long 2004[a]
9	$HI_F = 16.923 + 0.185212T_F + 5.37941H - 0.100254T_FH + (9.4169 \times 10^{-3})T_F^2 + (7.28898 \times 10^{-3})H^2 + (3.45372 \times 10^{-4})T_F^2H - (8.14971 \times 10^{-4})T_FH^2 + (1.02102 \times 10^{-5})T_F^2H^2 - (3.8646 \times 10^{-5})T_F^3 + (2.91583 \times 10^{-5})H^3 + (1.42721 \times 10^{-6})T_F^3H + (1.97483 \times 10^{-7})T_FH^3 - (2.18429 \times 10^{-8})T_F^3H^2 + (8.43296 \times 10^{-10})T_F^2H^3 - (4.81975 \times 10^{-11})T_F^3H^3 + 0.5$. Correction factor: $HI_F = T_F$ when $T_F < 75°F$	Robinson 2001[a]
10	$HI_C = -8.784695 + 1.61139411T_C + 2.338549H - 0.14611605T_CH - (1.2308094 \times 10^{-2})T_C^2 - (1.6424828 \times 10^{-2})H^2 + (2.211732 \times 10^{-3})T_C^2H + (7.2546 \times 10^{-4})T_CH^2 - (3.582 \times 10^{-6})T_C^2H^2$. Correction factor: $HI_C = T_C$ when $T_C \le 20°C$	Blazejczyk et al. 2012[a]
11	$HI_F = -42.4 + 2.05T_F + 10.1H - 0.255T_FH - (6.84 \times 10^{-3})T_F^2 - (5.48 \times 10^{-2})H^2 + (1.23 \times 10^{-3})T_F^2H + (8.53 \times 10^{-4})T_FH^2 - (1.99 \times 10^{-6})T_F^2H^2$. Correction factor: $HI_F = T_F$ when $T_F \le 80°F$ or $H \le 40\%$	Patricola and Cook 2010[a]
12	$HI_C = -2.719 + 0.994T_C + 0.016D_C^2$. Correction factor: $HI_C = T_C$ when $T_C < 25°C$	Smoyer-Tomic and Rainham 2001[a]
13	$HI_C = -2.653 + 0.994T_C + 0.0153D_C^2$	Analitis et al. 2008; Basara et al. 2010; Halonen et al. 2011a, 2011b; Kuchcik 2006; Mbanu et al. 2007; Michelozzi et al. 2007, 2009; O'Neill et al. 2003; Rich et al. 2008; Schneider et al. 2008; Zanobetti and Schwartz 2005[a], 2006
14	$HI_C = -2.719 + 0.994T_C + 0.016D_C^2$	Perry et al. 2011[a]
15	$HI_F = -42.379 + 2.049015T_F + 10.1433H - 0.2248T_FH - (6.83783 \times 10^{-3})T_F^2 - (5.4817 \times 10^{-2})H^2 + (1.229 \times 10^{-3})T_F^2H + (8.528 \times 10^{-4})T_FH^2 - (1.99 \times 10^{-6})T_F^2H^2$. Correction factor: $HI_F = T_F$ when $T_F < 57°F$	Tam et al. 2008[a]
16	$HI_F = -42.379 + 2.04901523T_F + 10.14333127H - 0.22475541T_FH - (6.83783 \times 10^{-3})T_F^2 - (5.481717 \times 10^{-2})H^2 + (1.22874 \times 10^{-3})T_F^2H + (8.5282 \times 10^{-4})T_FH^2 - (1.99 \times 10^{-6})T_F^2H^2$	Rothfusz 1990[a]
17	$HI_C = -8.7847 + 1.6114T_C - 0.012308T_C^2 + H[2.3385 - 0.14612T_C + (2.2117 \times 10^{-3})T_C^2] + H^2[-0.016425 + (7.2546 \times 10^{-4})T_C + (-3.582 \times 10^{-6})T_C^2]$	Fischer and Schär 2010[a]
18	$HI_C = T_C - 0.55 \times (1 - 0.001H)(T_C - 14.5)$	Costanzo et al. 2006[a]
19	$HI_C = 2.719 + 0.994T_C + 0.016D_C^2$	Smoyer 1998a[a], 1998b
20	$HI_F = T_F - \{[0.55 - 0.55(H/100)]T_F - 58\}$	Lajinian et al. 1997[a]
21	$HI_C = -2.653 + 0.994T_C + 0.368D_C^2$	Basara et al. 2010[a]; Vaneckova et al. 2011

Abbreviations: D_C, dew point temperature in degrees Celsius; D_F, dew point temperature in degrees Fahrenheit; e_S, water vapor pressure in kilopascals; H, humidity in percent; HI_C, heat index in degrees Celsius; HI_F, heat index in degrees Fahrenheit; T_C, air temperature in degrees Celsius; T_F, air temperature in degrees Fahrenheit.
[a]Earliest publication of the algorithm found through our research; in some but not all cases, this is the original source of the algorithm.

CONCEITOS:

Conforto térmico

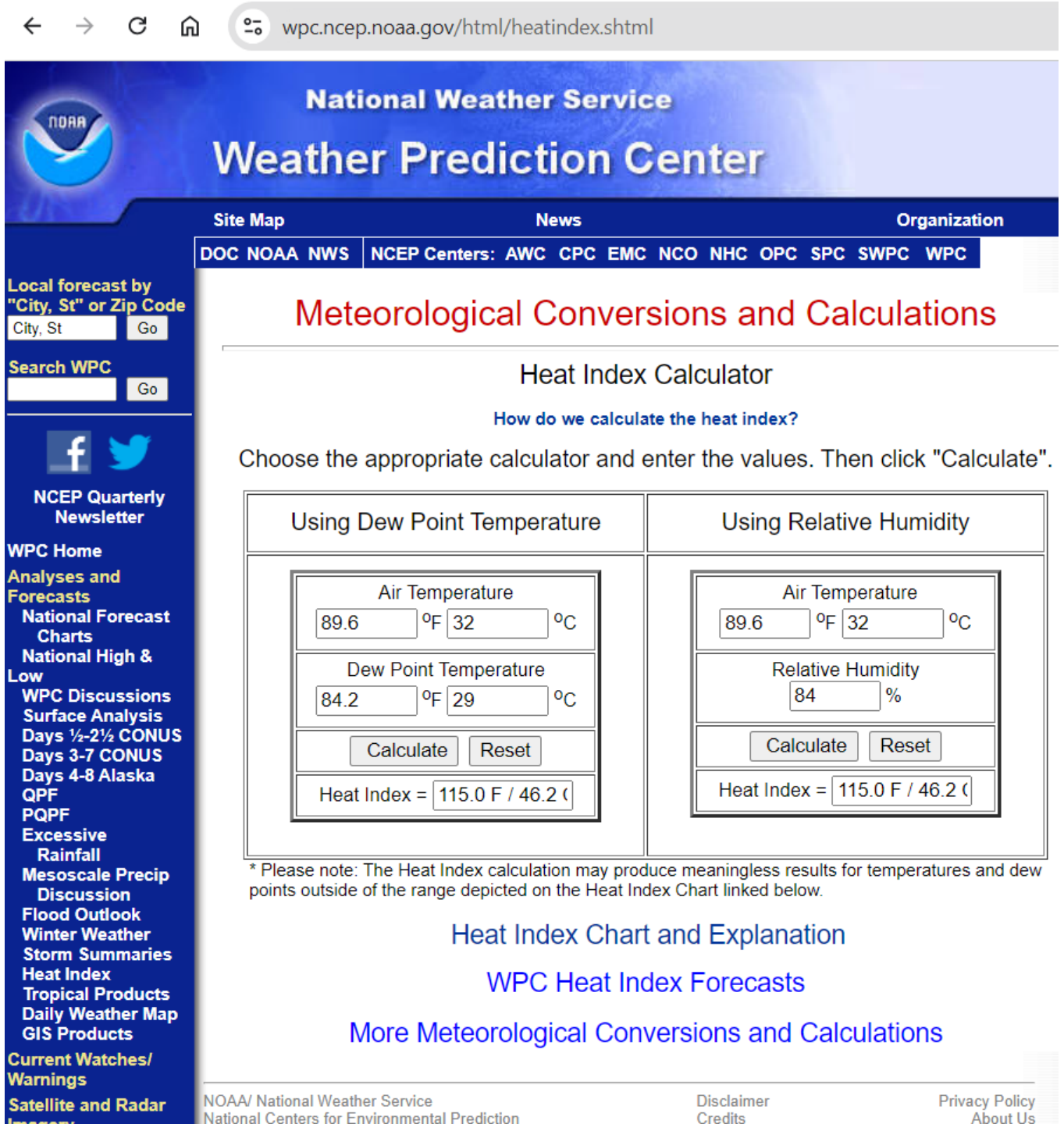
Índices bioclimáticos

HI Heat index

www.wpc.ncep.noaa.gov/html/heatindex.shtml

Programa para cálculo do HI em R, em acesso aberto, produzido por Brooke Anderson:

https://github.com/geanders/weathermetrics



CONCEITOS:

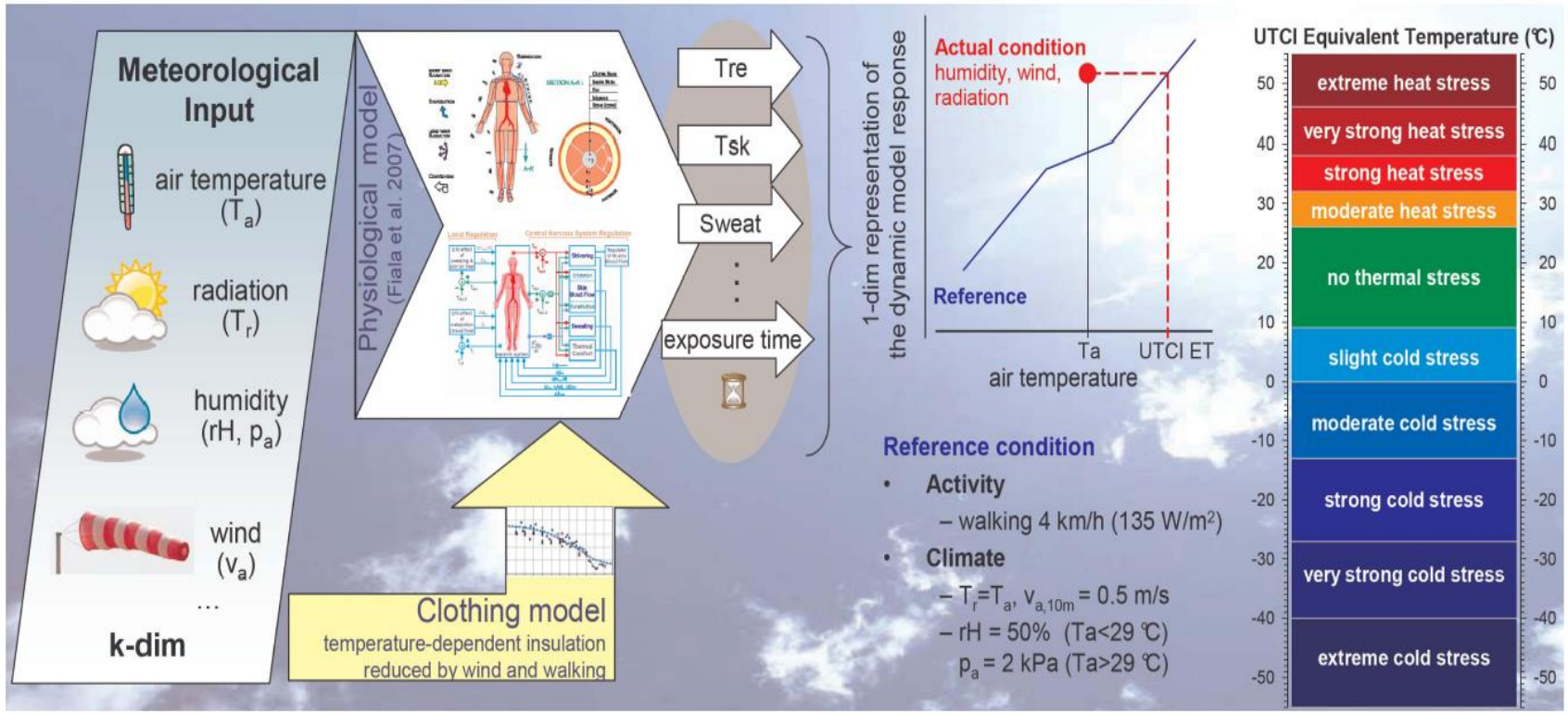
Conforto térmico

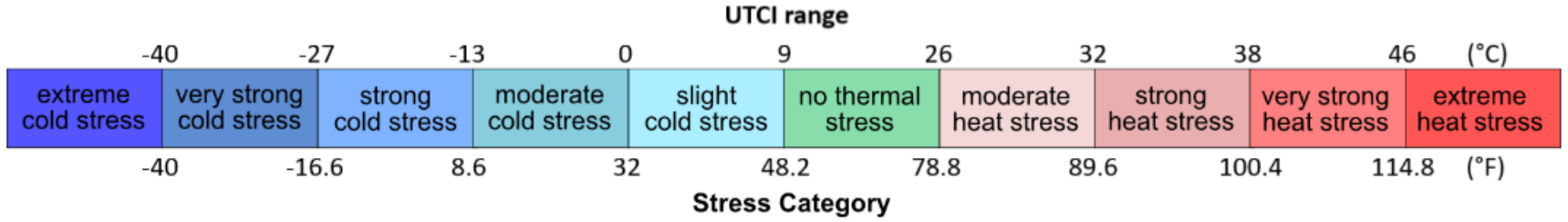
Índices bioclimáticos

HI Heat index

UTCI

extraído de http://www.utci.org/





CONCEITOS:

- Conforto térmico
- Índices bioclimáticos
- HI Heat index
- UTCI

https://www.utci.org/utci_calc.php

UTCI

Home | COST Action 730 | ISB Commission 6 | Contact

UTCI Calculator

Please note: The given polynomial approximation limits the application of this procedure to values of wind speed between 0.5 and 17 m/s!

Air temperature Ta ° Celsius

Δ Tmrt = Tmrt - Ta Kelvin

Water vapour pressure

hPa

Rel. humidity RH

%

Wind speed v in 10m m/s

submit reset

CONCEITOS:

Conforto térmico

Índices bioclimáticos

HI Heat index

UTCI

O UTCI pode ser calculado em http://www.utci.org/

ou usando o software **BioKlima** (gratuito):

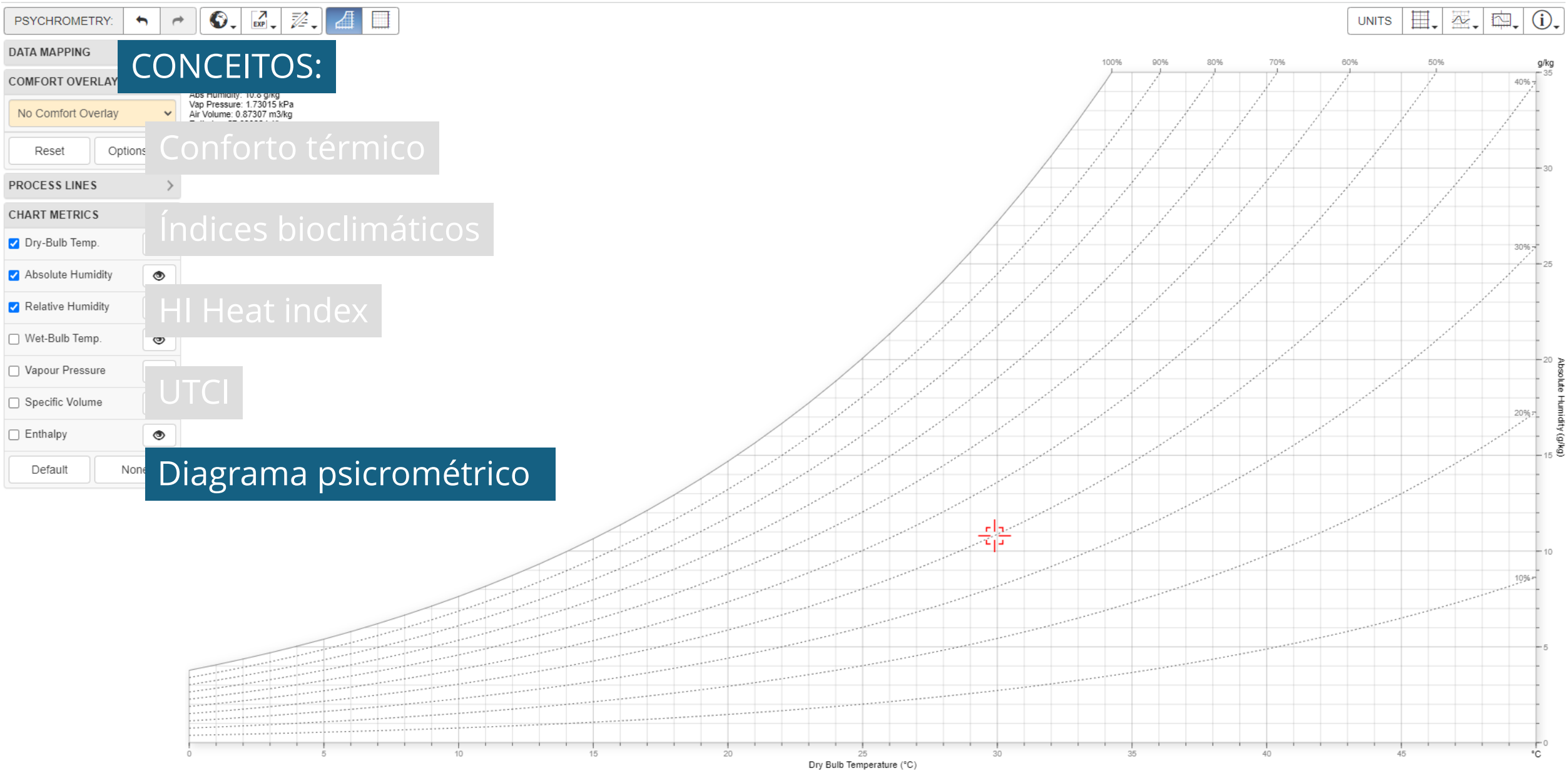
BioKlima - Universal tool for bioclimatic and thermophysiological studies

https://www.igipz.pan.pl/bioklima.html

(Department of Geoecology and Climatology, Inst. Geog. e Organização Espacial, Varsóvia, Polónia)

COPERNICUS:

Global, horário, desde 1979;
0.25° x 0.25° (ERA5)
https://cds.climate.copernicus.eu/cdsapp#!/dataset/derived-utci-historical?tab=overview


PSYCHROMETRY:
UNITS
DATA MAPPING
COMFORT OVERLAY
No Comfort Overlay
Reset
Options
PROCESS LINES
CHART METRICS
Dry-Bulb Temp.
Absolute Humidity
Relative Humidity
Wet-Bulb Temp.
Vapour Pressure
Specific Volume
Enthalpy
Default
Vap Pressure: 1.73015 kPa
Air Volume: 0.87307 m3/kg
100%
90%
80%
70%
60%
50%
g/kg
40%
30%
20%
10%
Absolute Humidity (g/kg)
Dry Bulb Temperature (°C)
°C
CONCEITOS:
Conforto térmico
Índices bioclimáticos
HI Heat index
UTCI
Diagrama psicrométrico

PSYCHROMETRY:

UNITS

DATA MAPPING

COMFORT OVERLAY

No Comfort Overlay

Reset | Options

PROCESS LINES

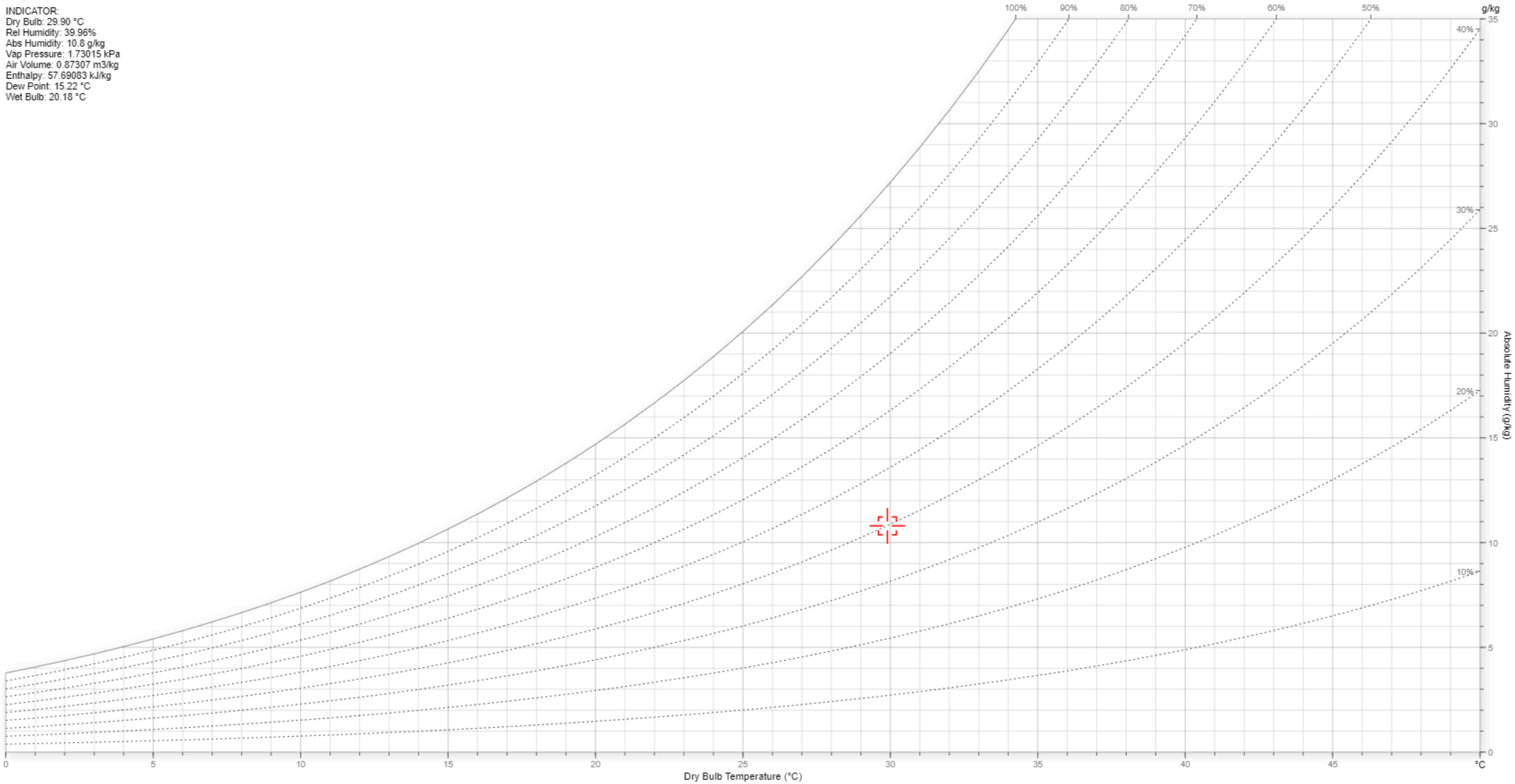
CHART METRICS

- [x] Dry-Bulb Temp.
- [x] Absolute Humidity
- [x] Relative Humidity
- [ ] Wet-Bulb Temp.
- [ ] Vapour Pressure
- [ ] Specific Volume
- [ ] Enthalpy

Default | None

Psychrometric Chart

INDICATOR:
Dry Bulb: 29.90 °C
Rel Humidity: 39.96%
Abs Humidity: 10.8 g/kg
Vap Pressure: 1.73015 kPa
Air Volume: 0.87307 m3/kg
Enthalpy: 57.69083 kJ/kg
Dew Point: 15.22 °C
Wet Bulb: 20.18 °C



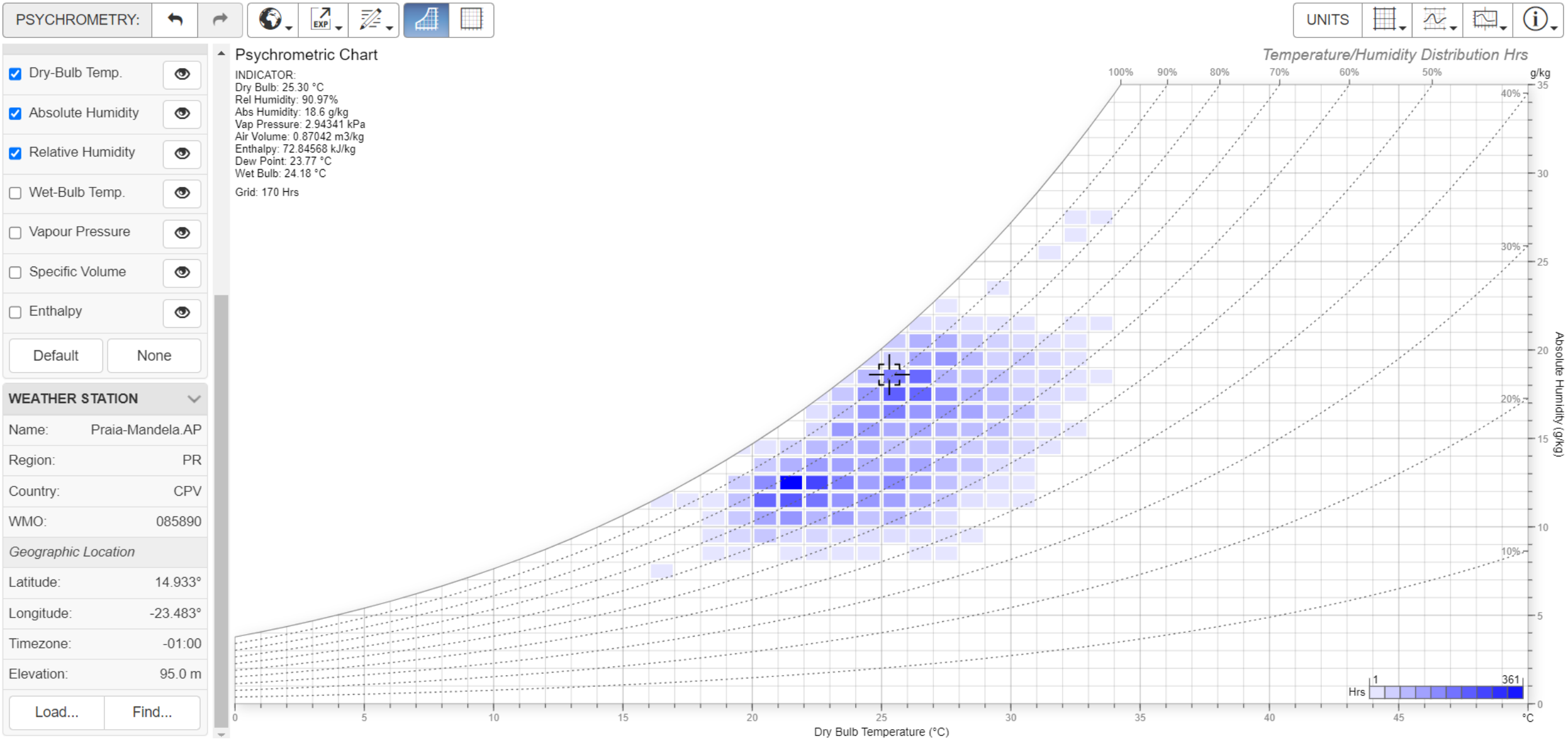
ATIVIDADES:

Psychrometric chart

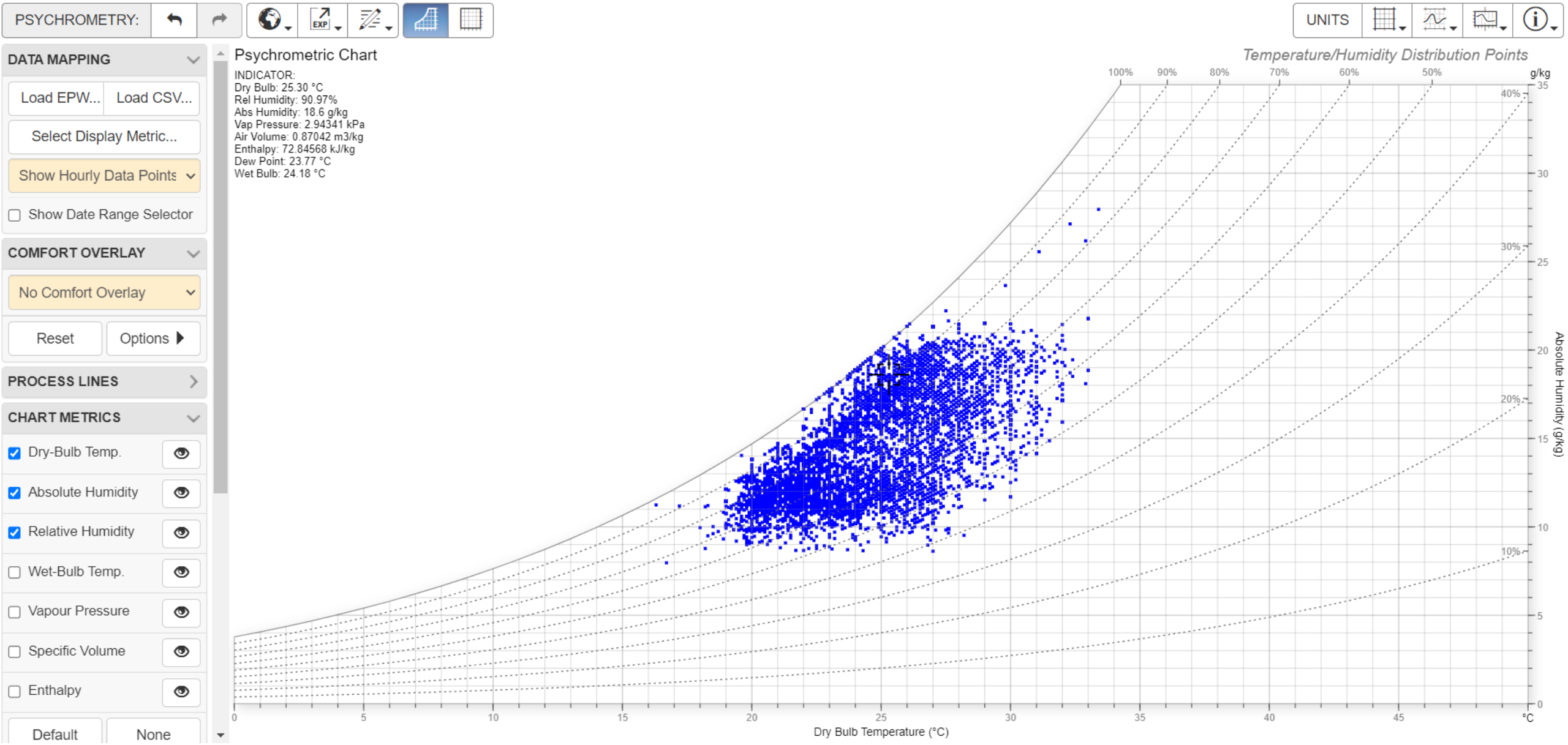
https://andrewmarsh.com/software/psychro-chart-web/

https://climate.onebuilding.org/

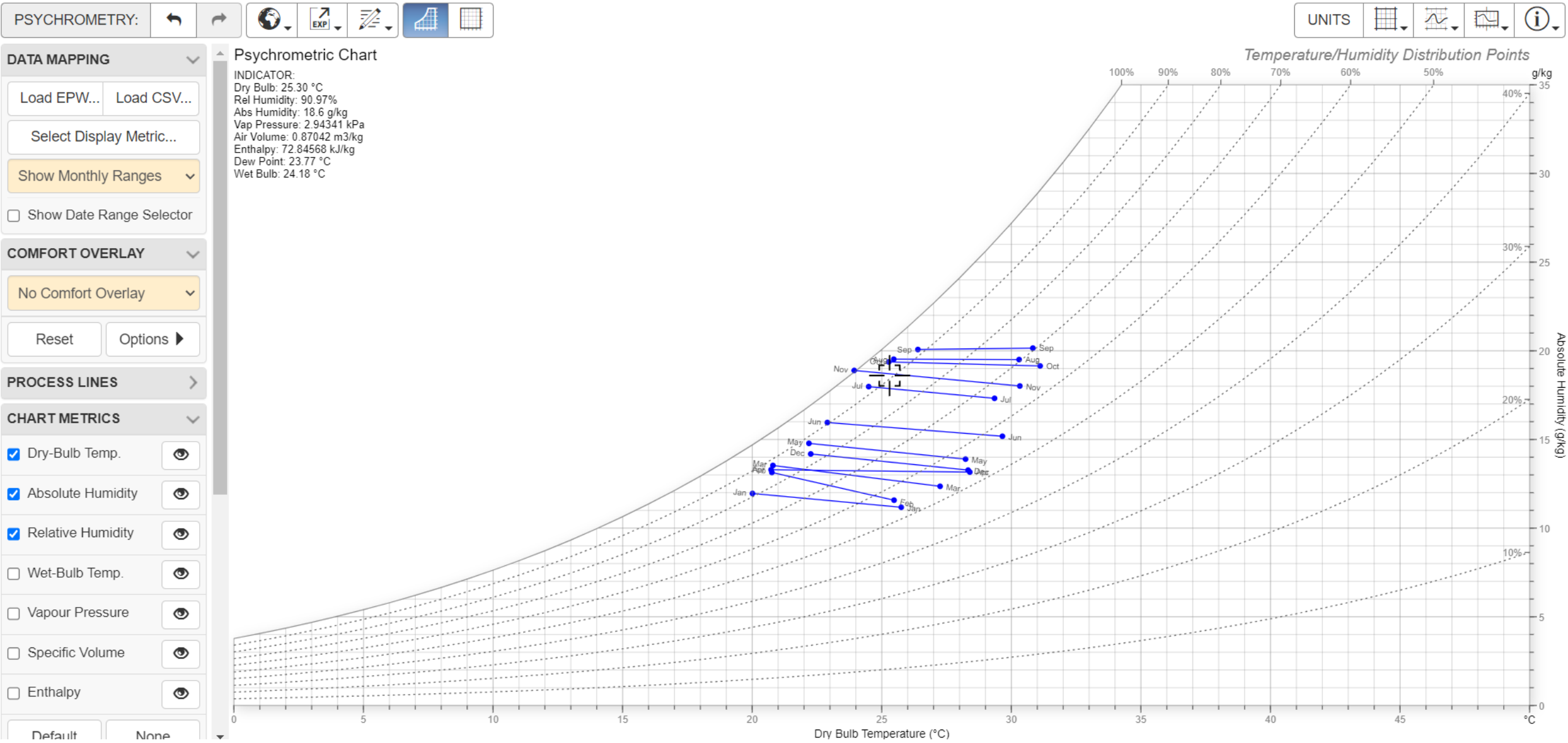
PRAIA – AEROPORTO (2009-2023) – CLIMA BWh – **frequência CT (nºmédio horas/ano)**



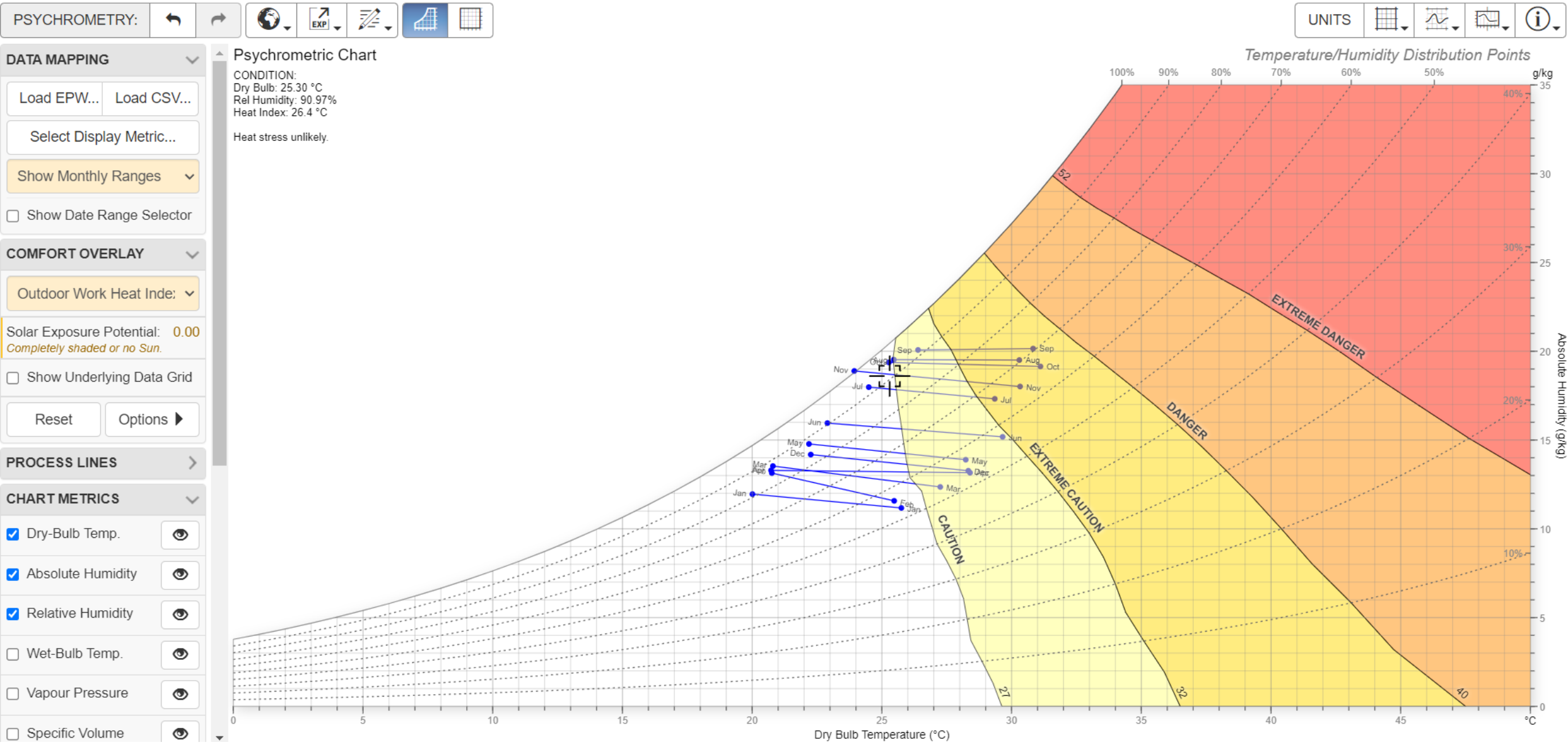
PRAIA – AEROPORTO (2009-2023) – CLIMA BWh – **frequência CT (observações horárias)**



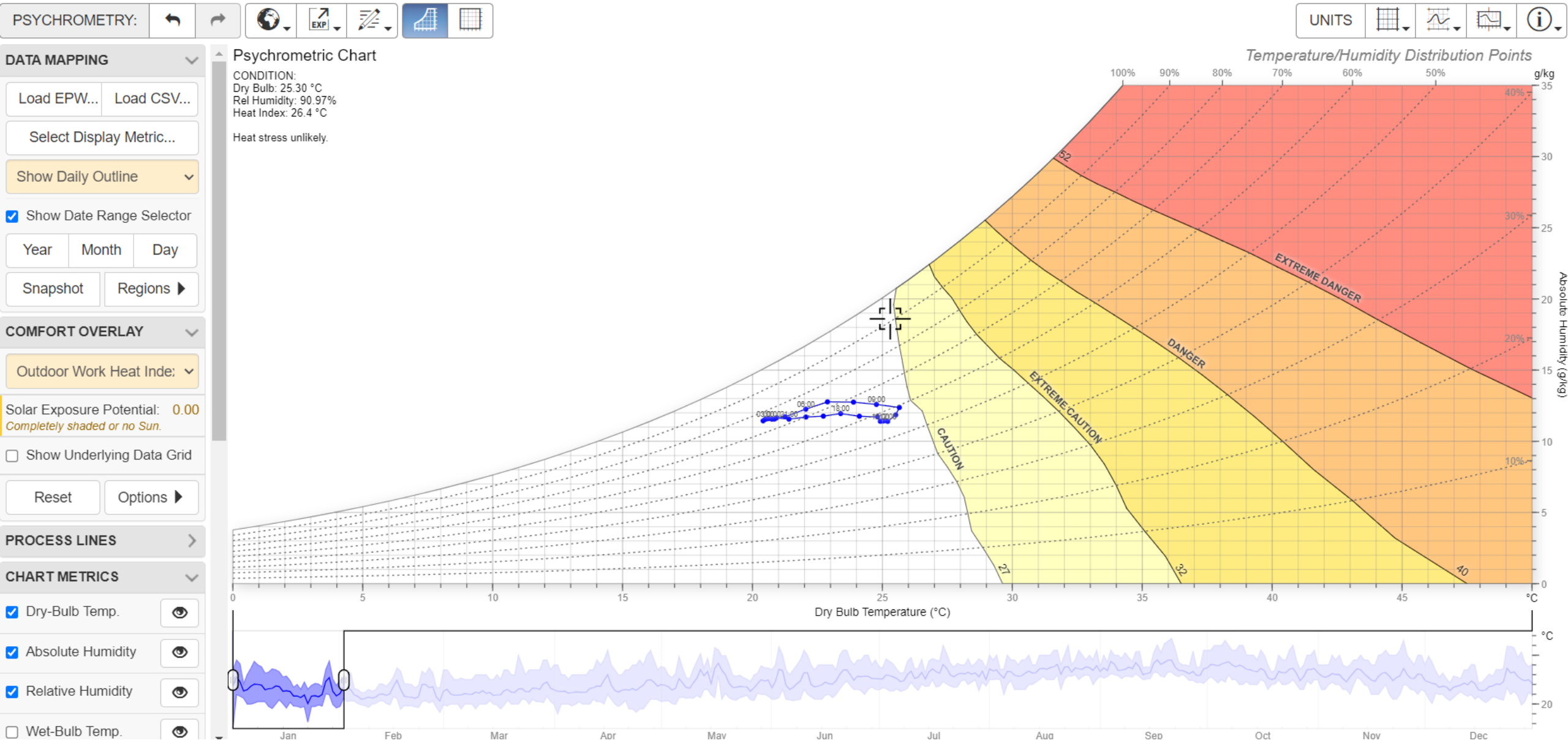
PRAIA – AEROPORTO (2009-2023) – CLIMA BWh - **amplitude CT, por meses do ano**



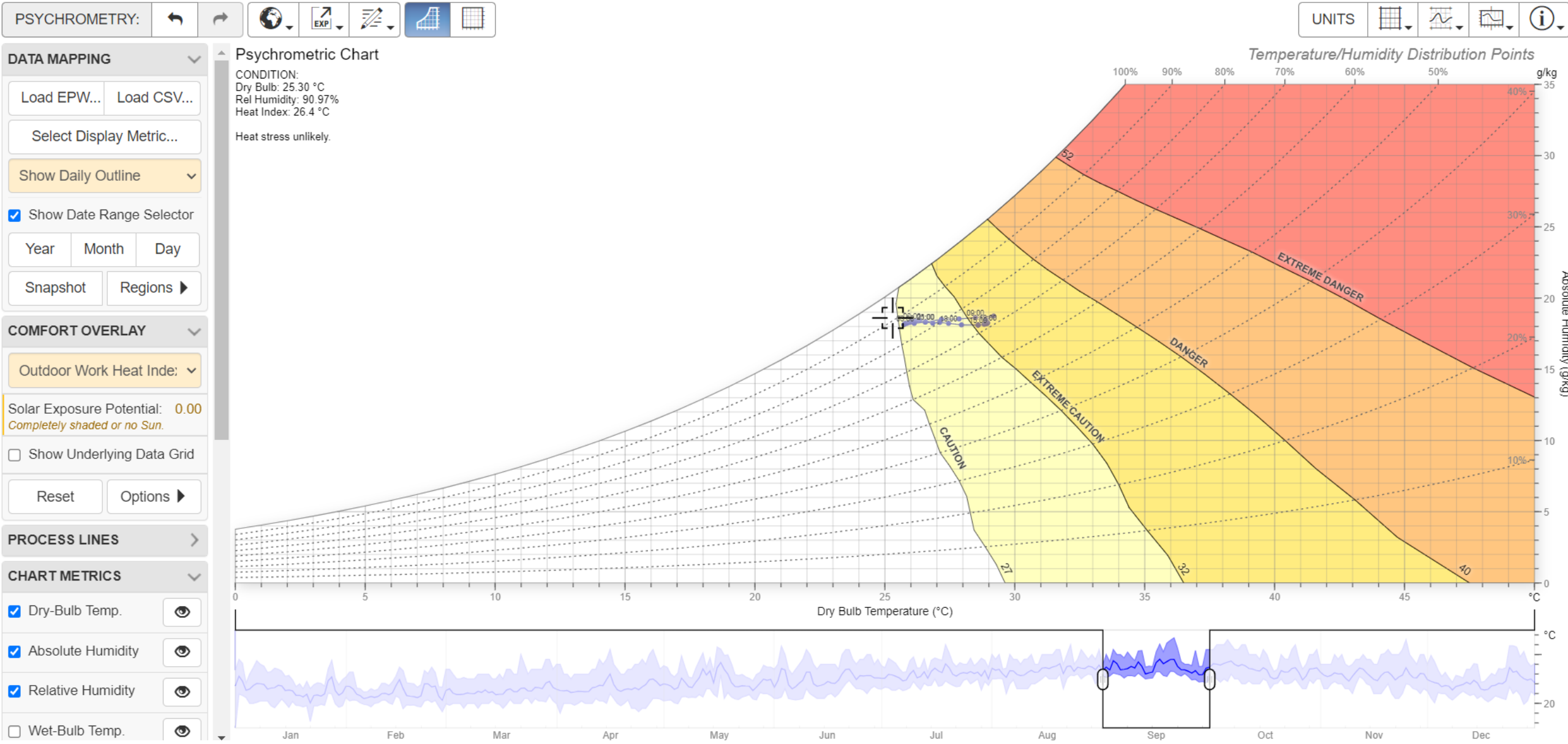
PRAIA – AEROPORTO (2009-2023) – CLIMA BWh - **amplitude CT (HI, à sombra), por meses do ano**



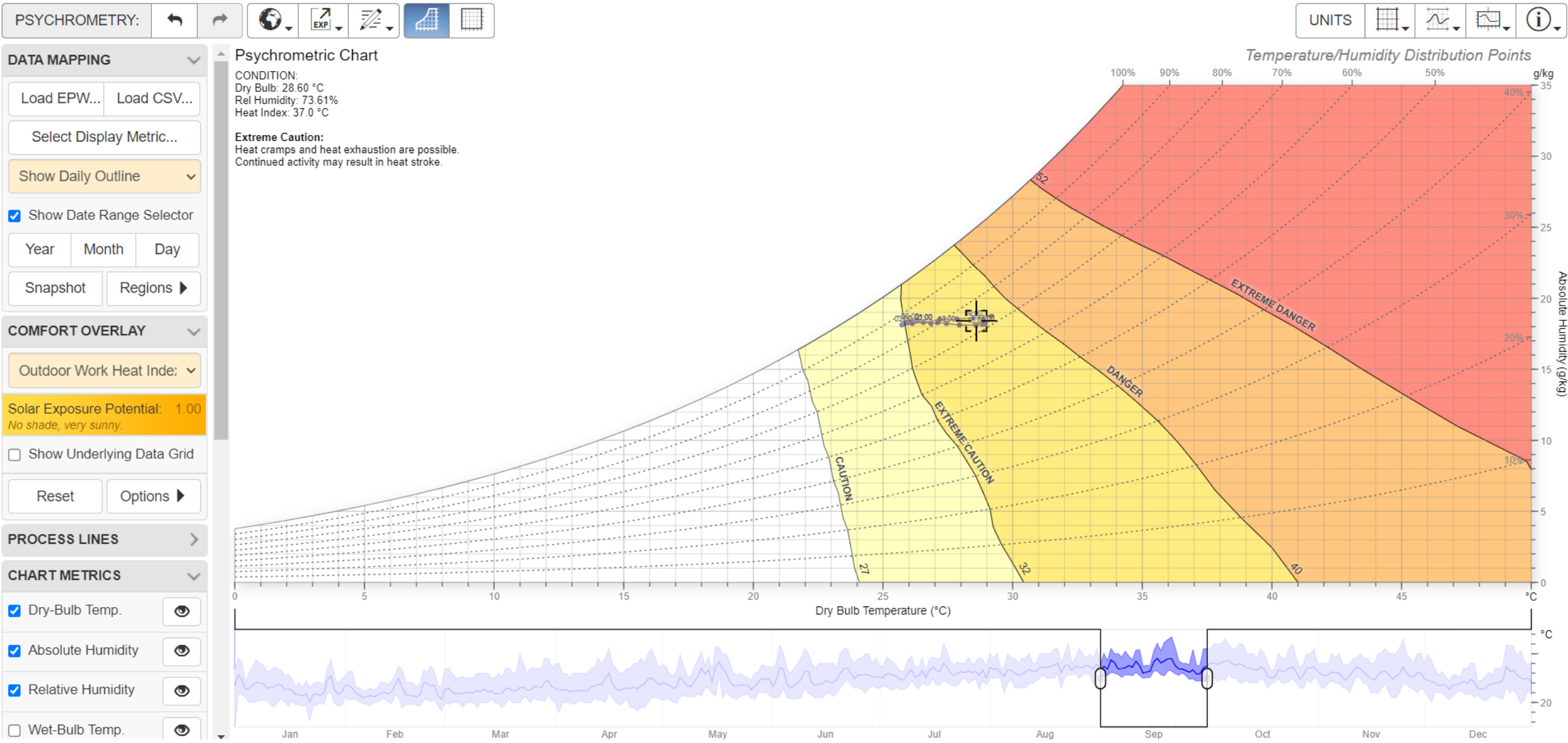
PRAIA – AEROPORTO (2009-2023) – CLIMA BWh - **janeiro CT (HI, à sombra), ciclo diário médio**



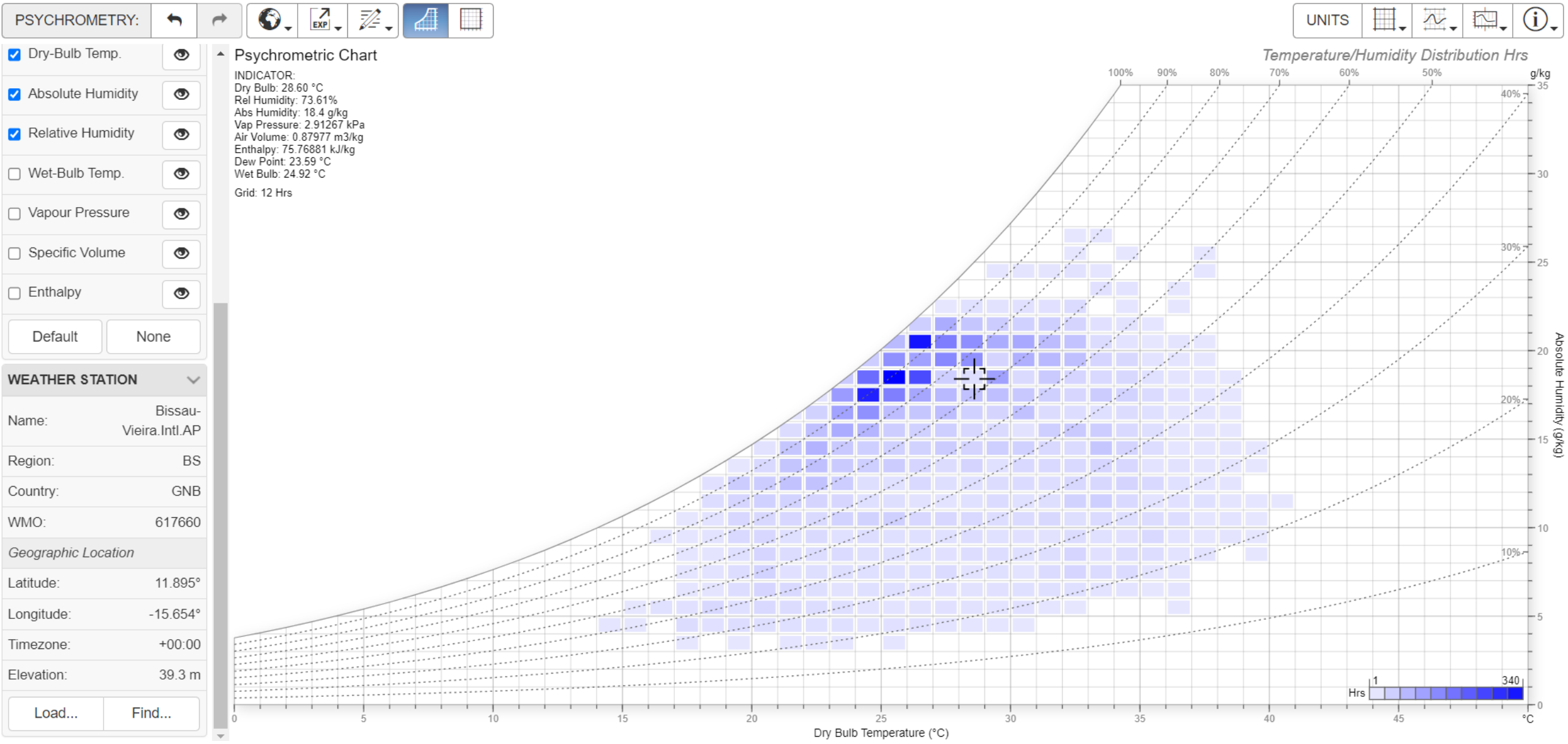
PRAIA – AEROPORTO (2009-2023) – CLIMA BWh - **setembro CT (HI, à sombra), ciclo diário médio**



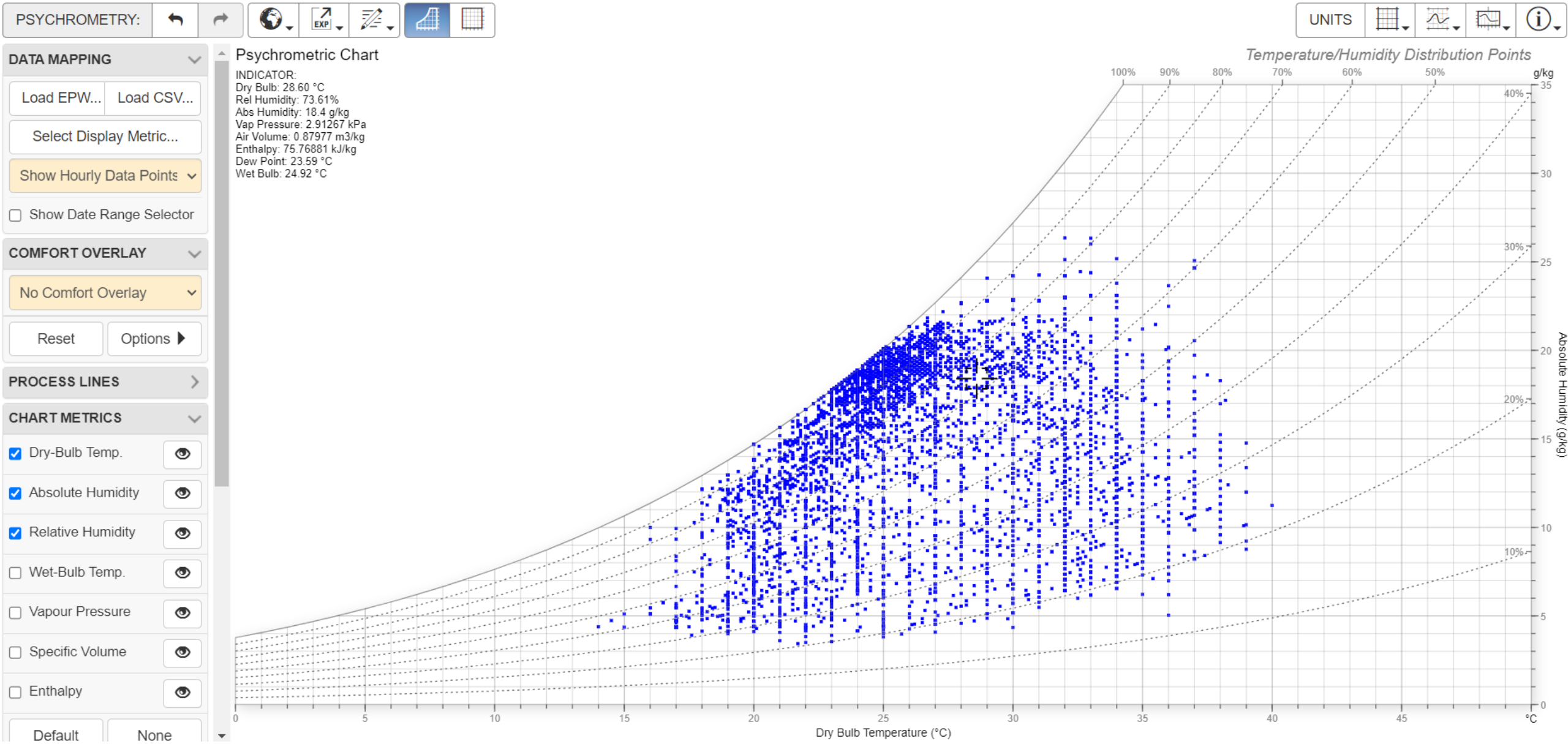
PRAIA – AEROPORTO (2009-2023) – CLIMA BWh - **setembro CT (HI, ao sol), ciclo diário médio**



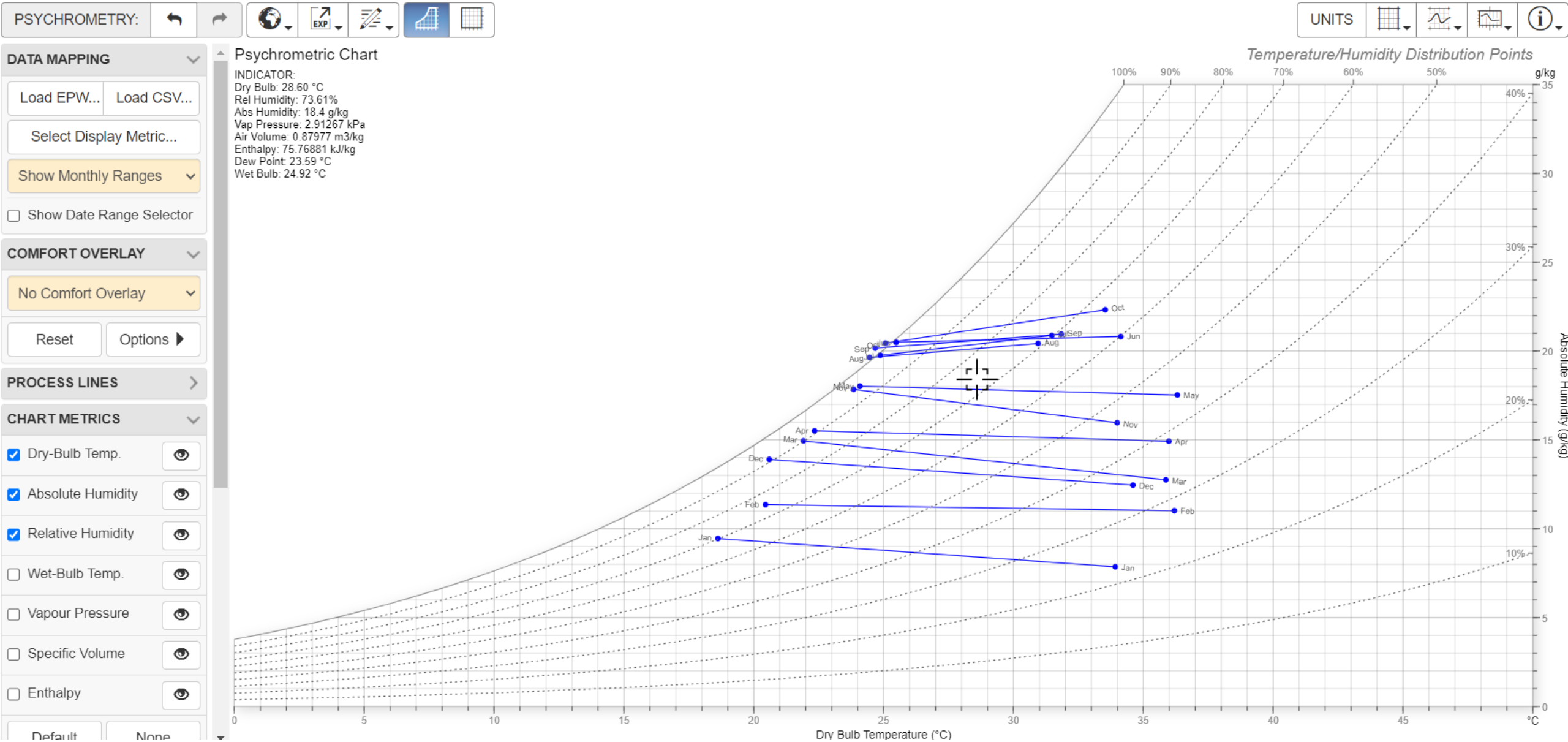
BISSAU – AEROPORTO (2009-2023) – CLIMA Aw – **frequência CT (nºmédio horas/ano)**



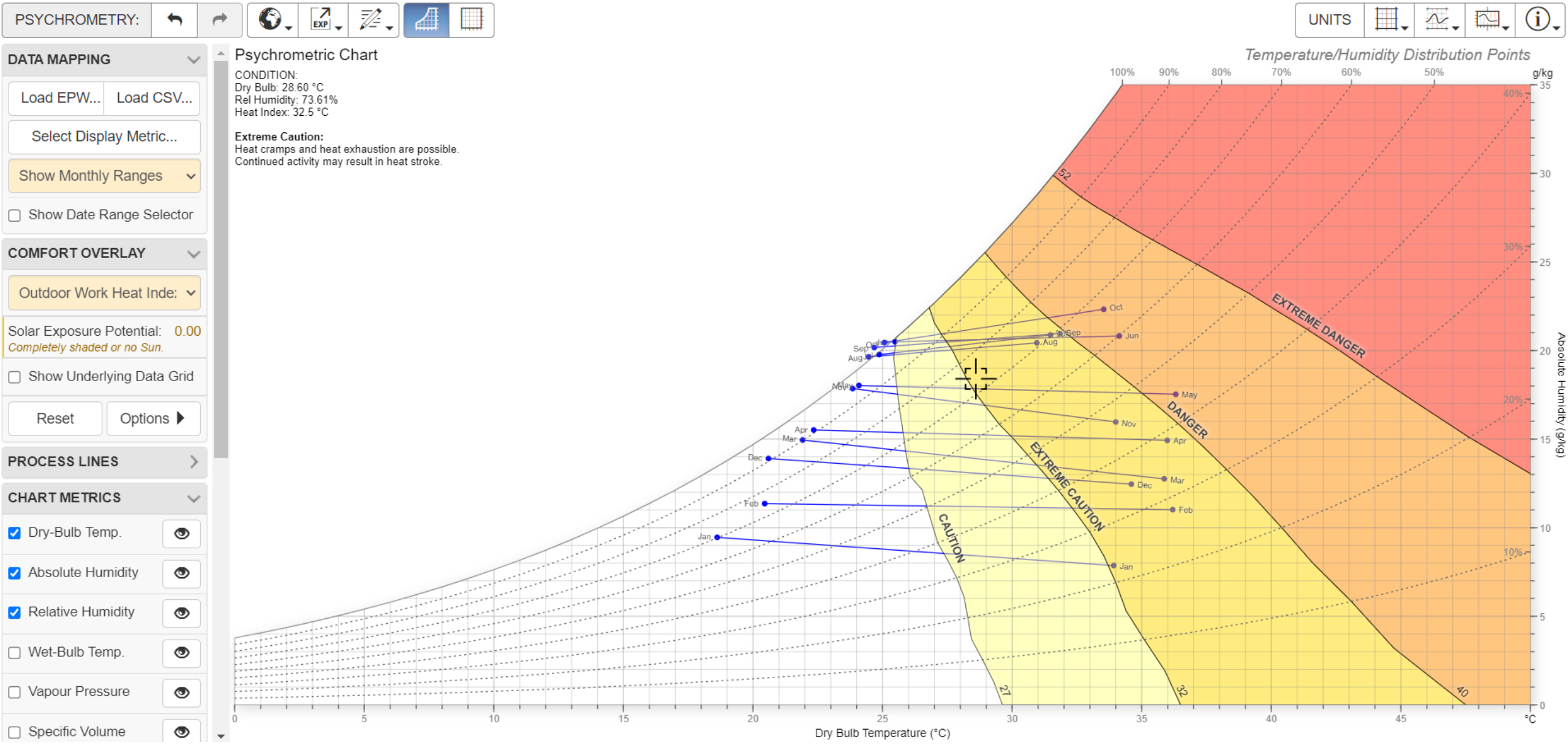
BISSAU – AEROPORTO (2009-2023) – CLIMA Aw – **frequência CT (observações horárias)**



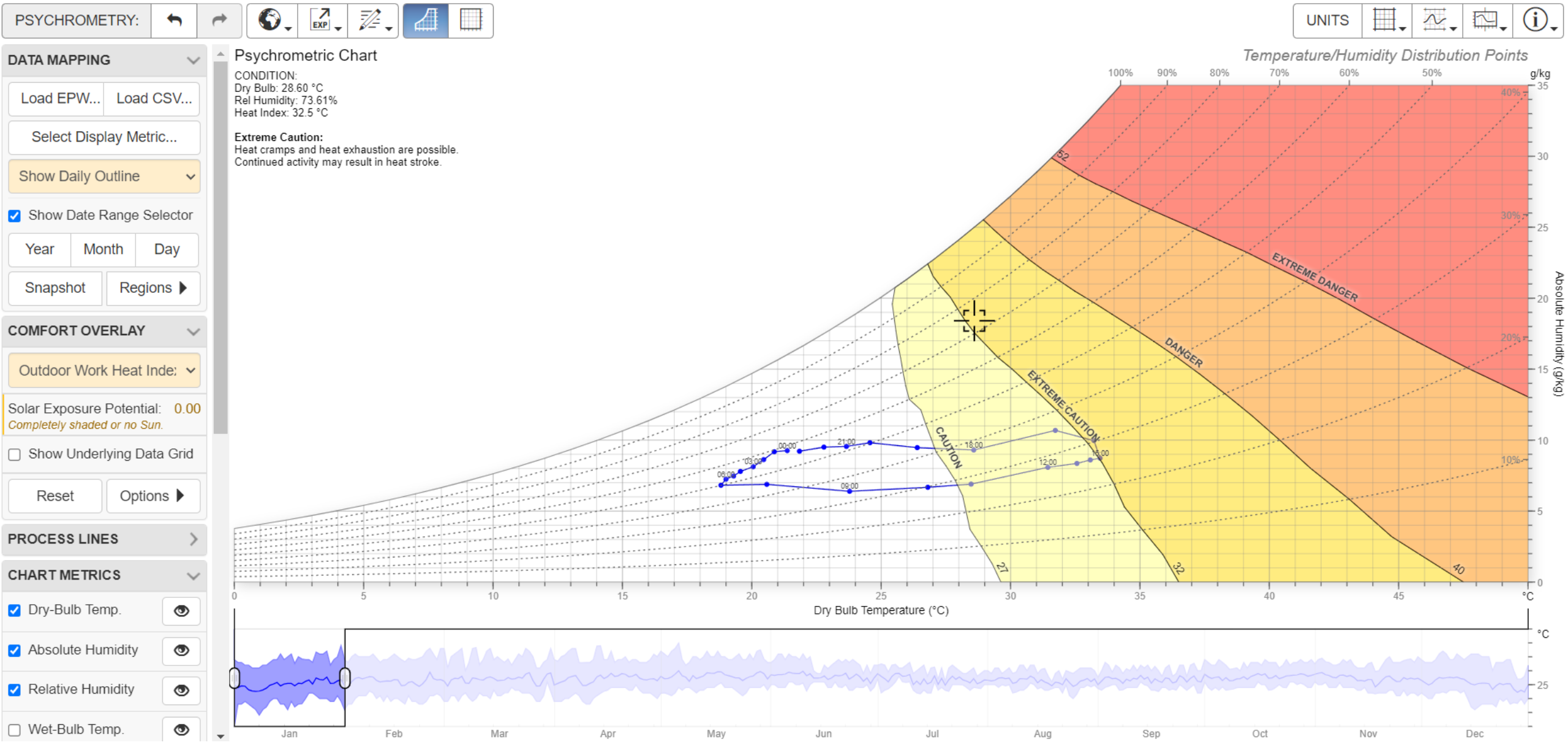
BISSAU – AEROPORTO (2009-2023) – CLIMA Aw - **amplitude CT, por meses do ano**



BISSAU – AEROPORTO (2009-2023) – CLIMA Aw - **amplitude CT (HI, à sombra), por meses do ano**



BISSAU – AEROPORTO (2009-2023) – CLIMA Aw - **janeiro CT (HI, à sombra), ciclo diário médio**



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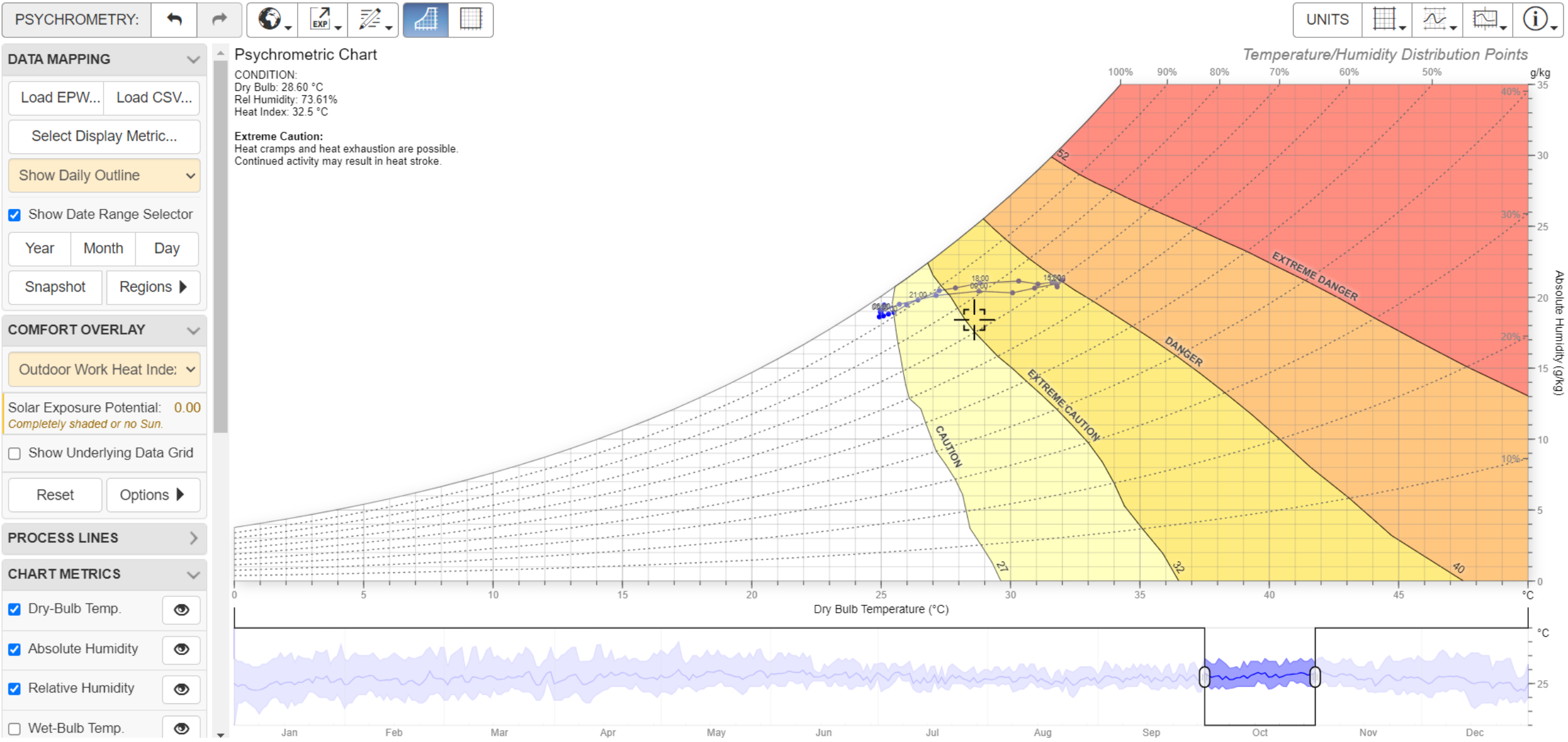
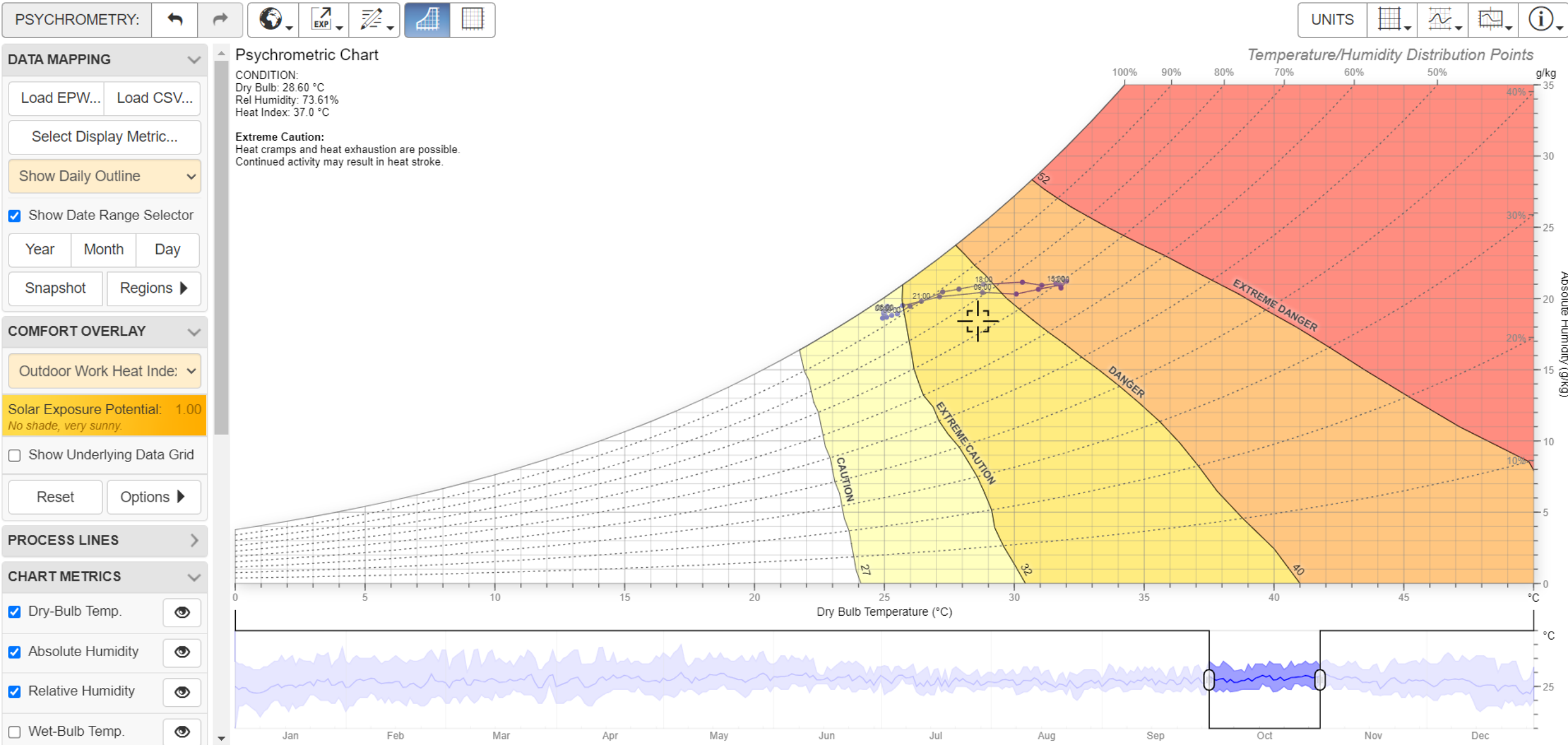
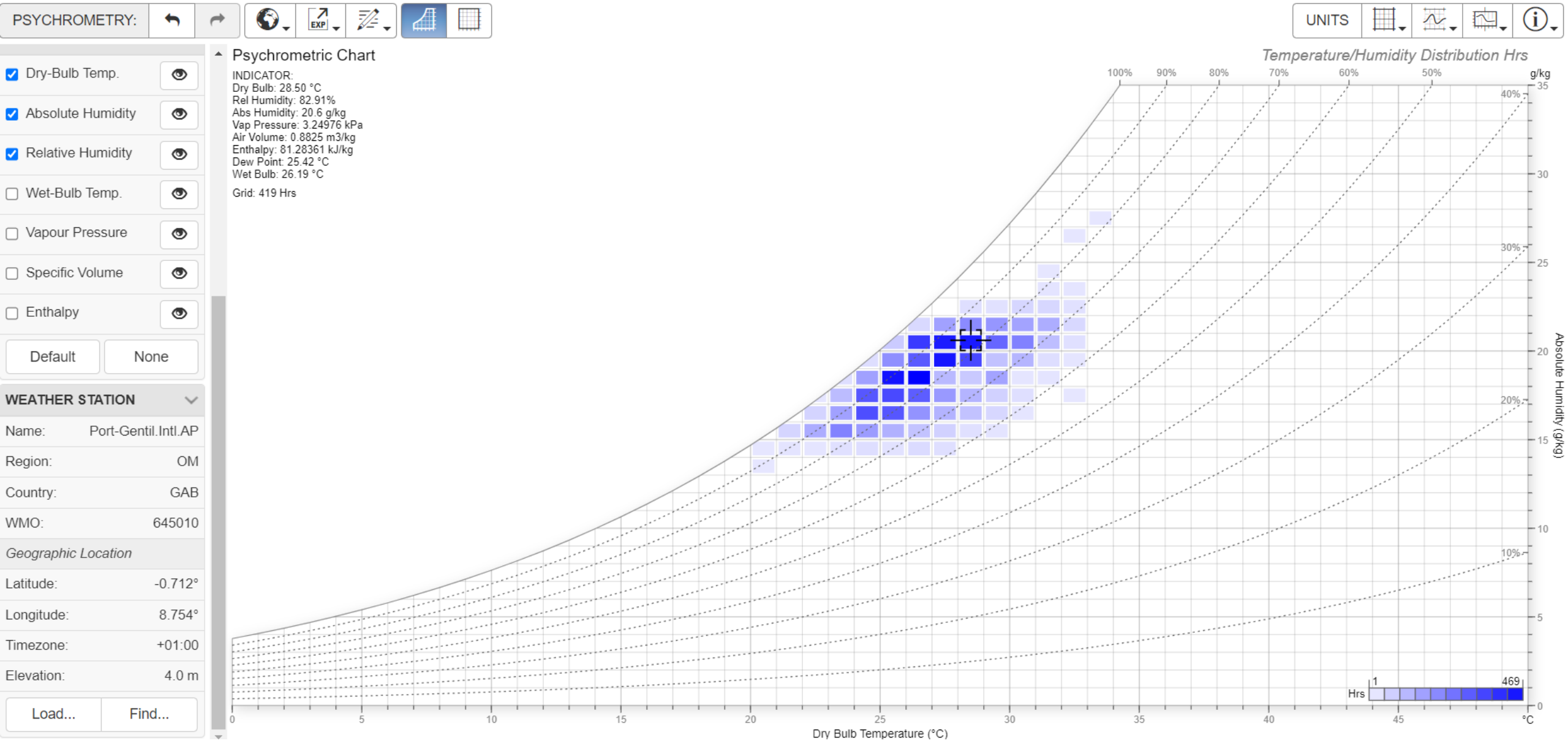


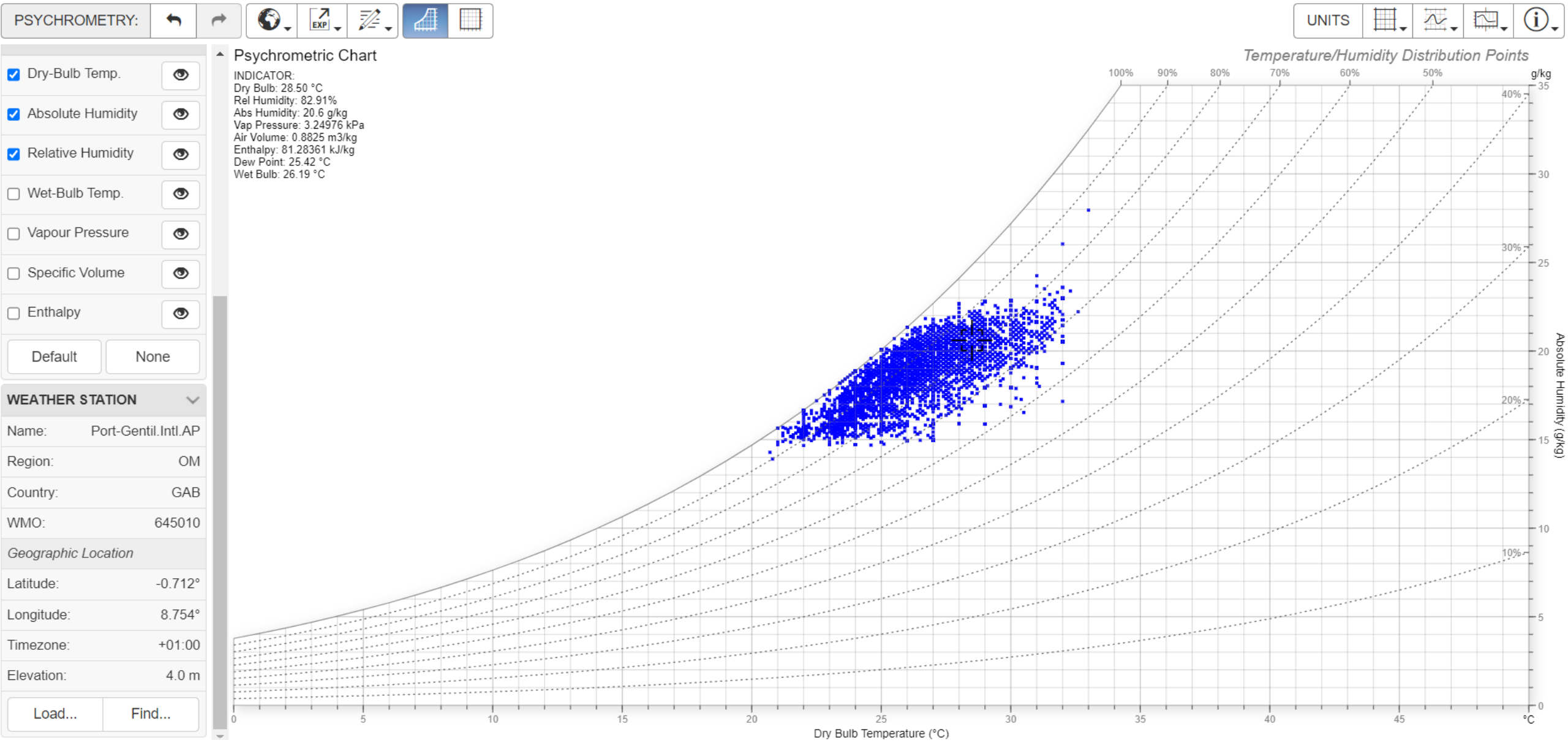
BISSAU – AEROPORTO (2009-2023) – CLIMA Aw - **outubro CT (HI, ao sol), ciclo diário médio**



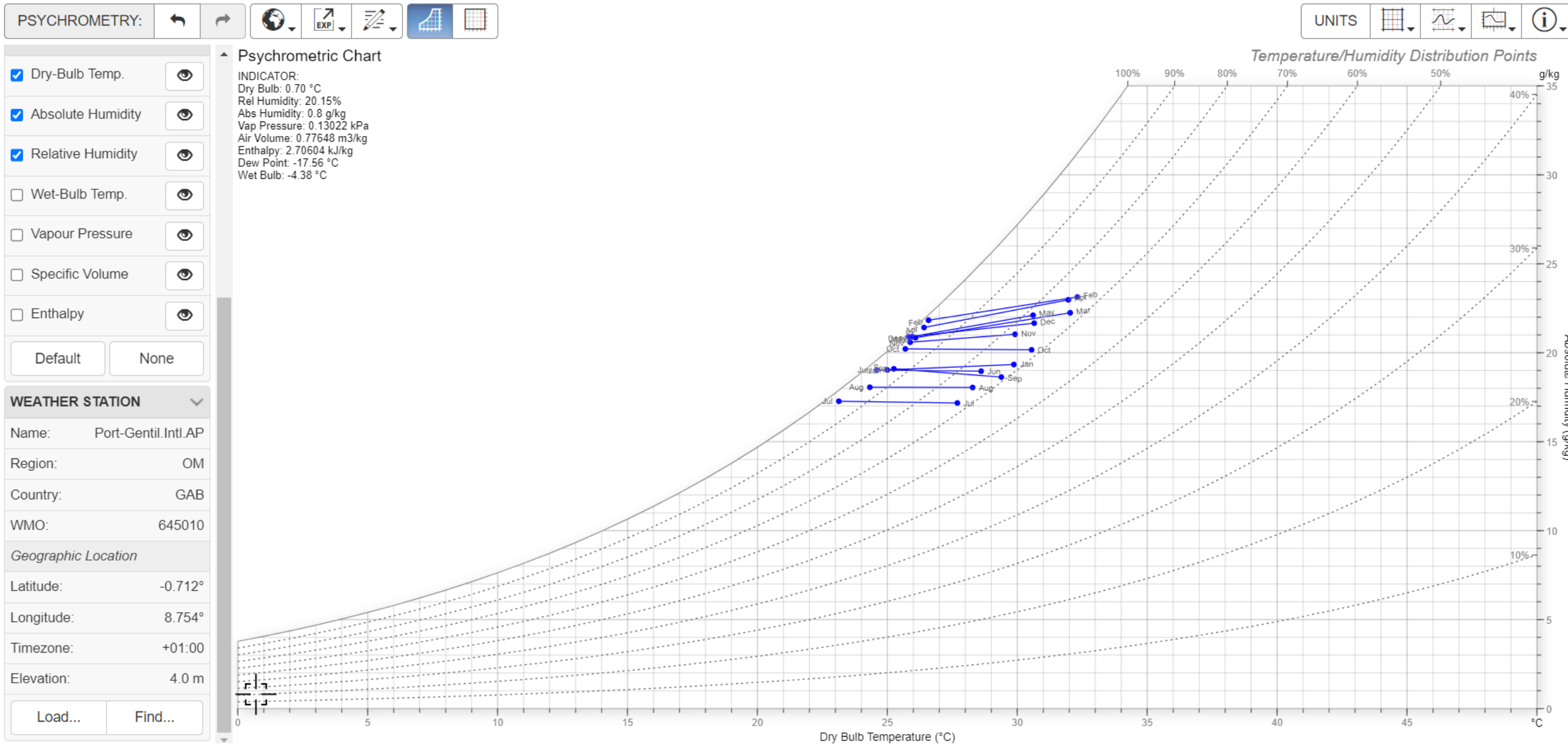
PORT GENTIL – AEROPORTO (2009-2023) – CLIMA Aw – **frequência CT (nºmédio horas/ano)**



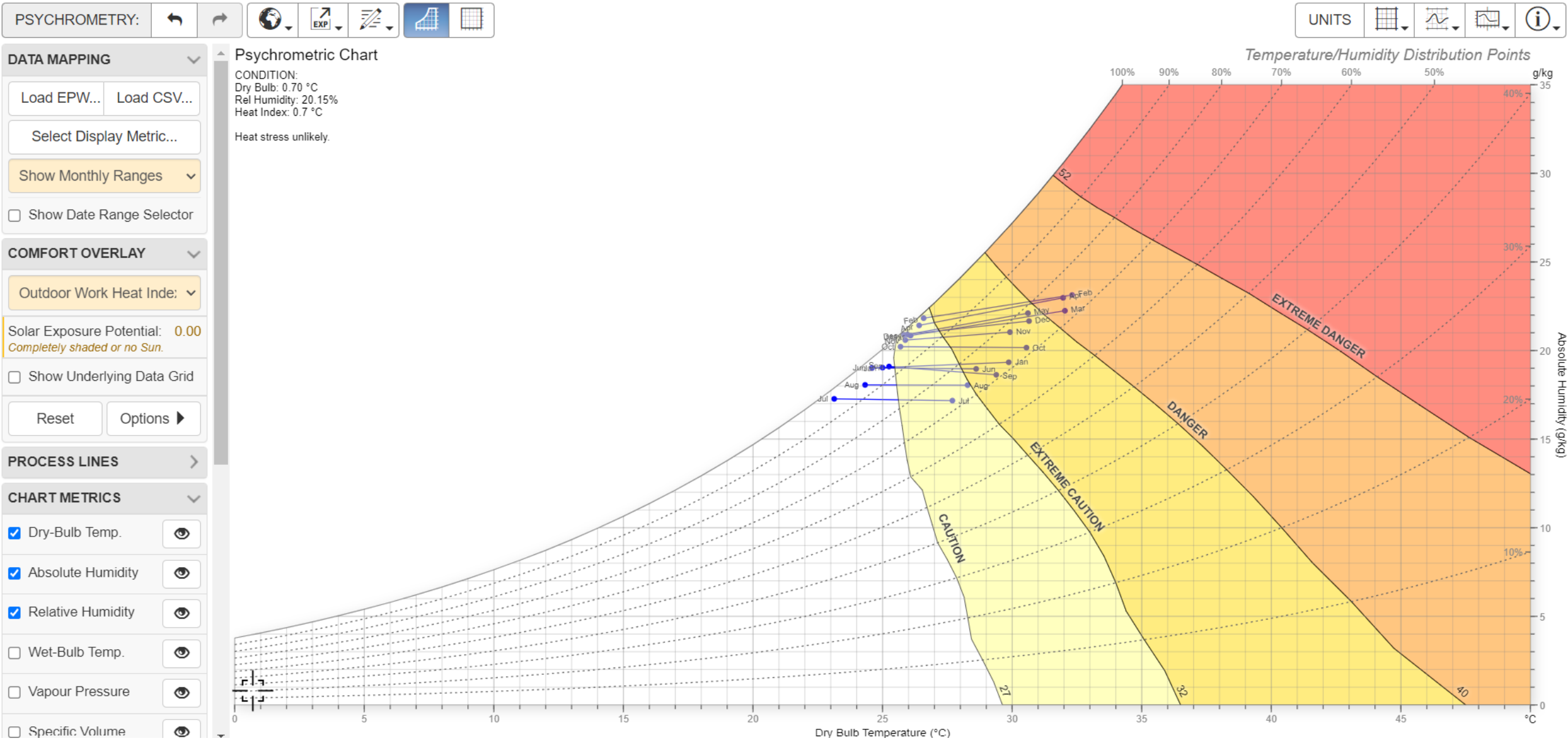
PORT GENTIL – AEROPORTO (2009-2023) – CLIMA Aw – **frequência CT (observações horárias)**



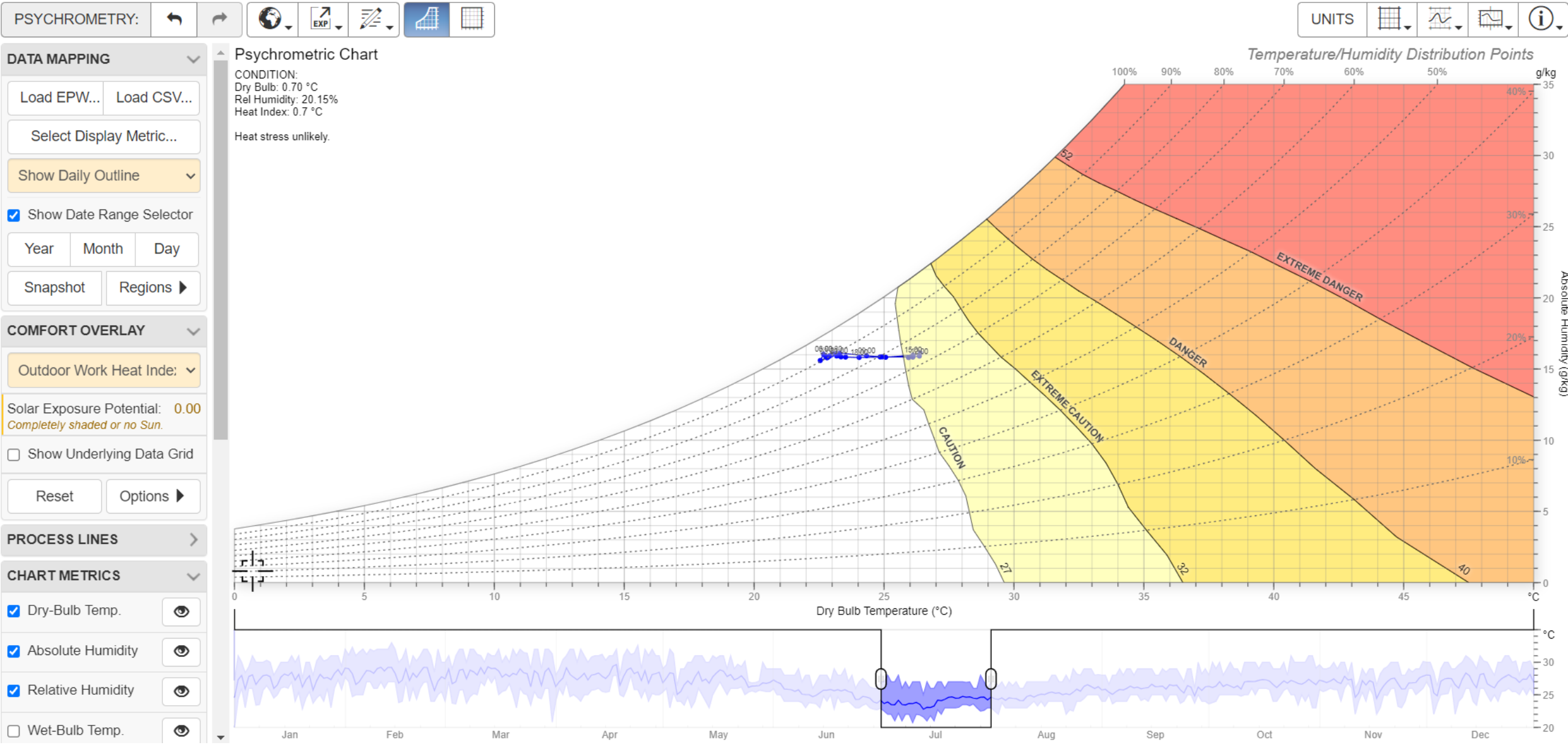
PORT GENTIL – AEROPORTO (2009-2023) – CLIMA Aw - **amplitude CT, por meses do ano**



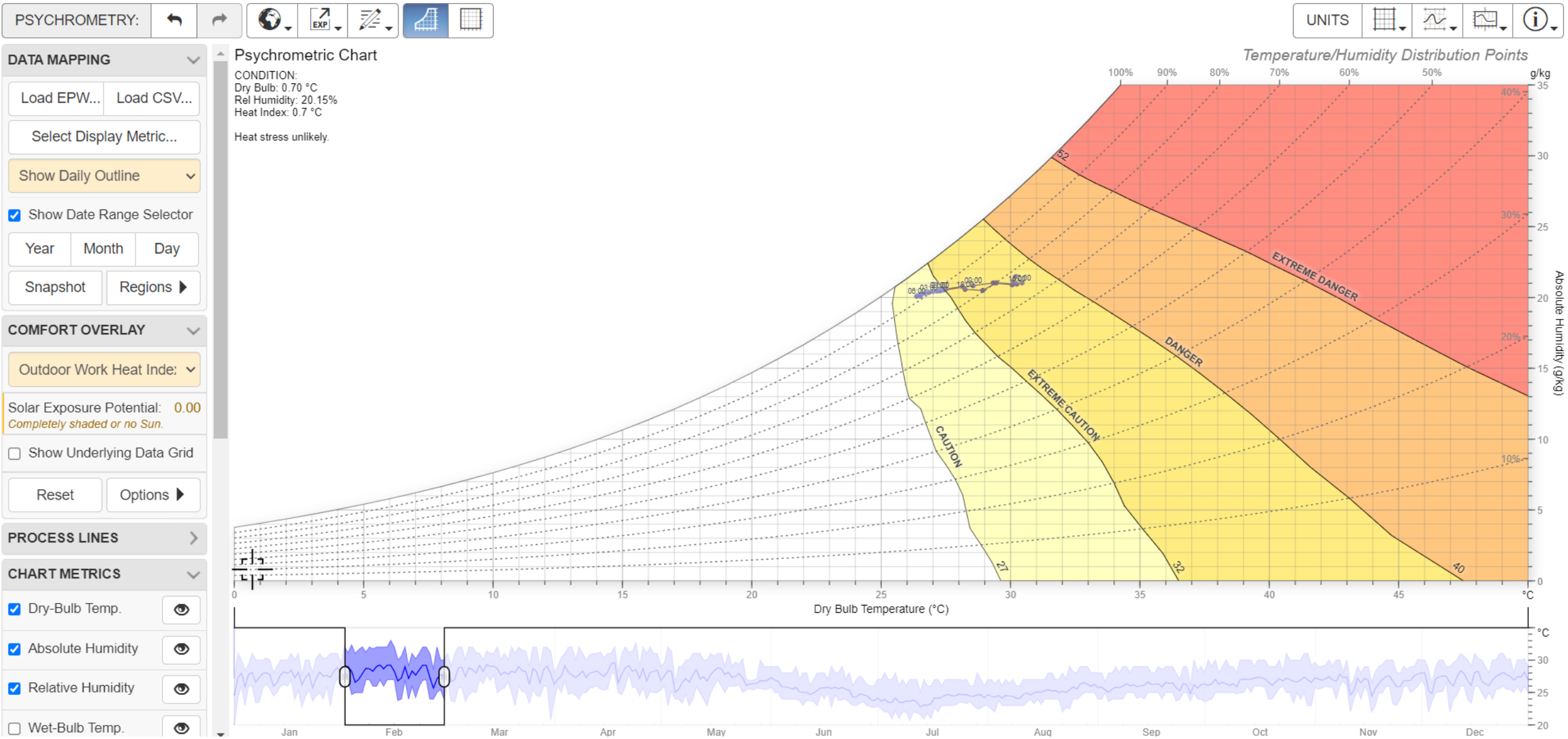
PORT GENTIL – AEROPORTO (2009-2023) – CLIMA Aw - **amplitude CT (HI, à sombra), por meses do ano**



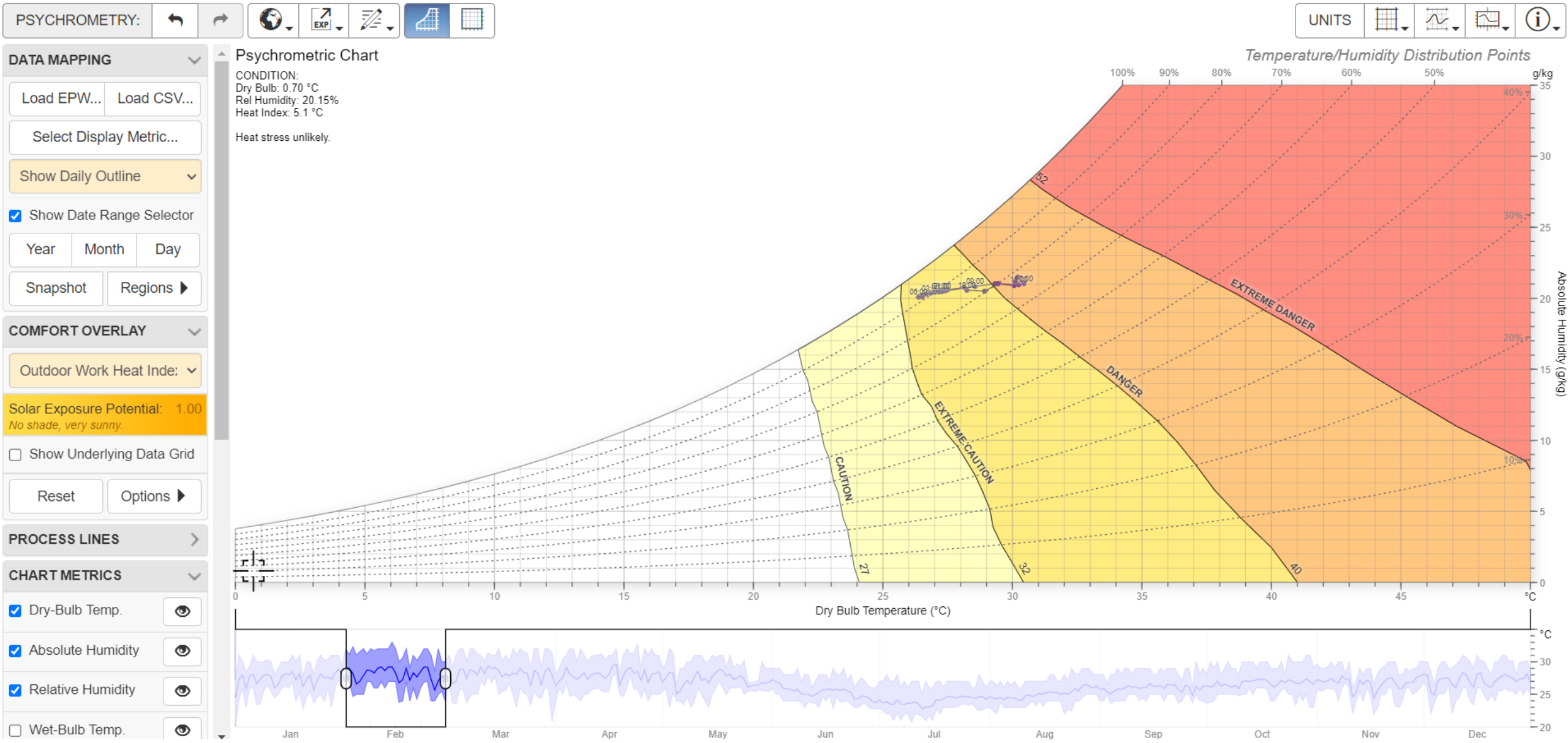
PORT GENTIL – AEROPORTO (2009-2023) – CLIMA Aw - **julho CT (HI, à sombra), ciclo diário médio**



PORT GENTIL – AEROPORTO (2009-2023) – CLIMA Aw - **fevereiro CT (HI, à sombra), ciclo diário médio**



PORT GENTIL – AEROPORTO (2009-2023) – CLIMA Aw -fevereiro **CT (HI, ao sol), ciclo diário médio**



ATIVIDADES:

Psychrometric chart

Climate Chip: Climate Change Heat Impact & Prevention https://www.climatechip.org/

Praia, Cabo Verde | Search

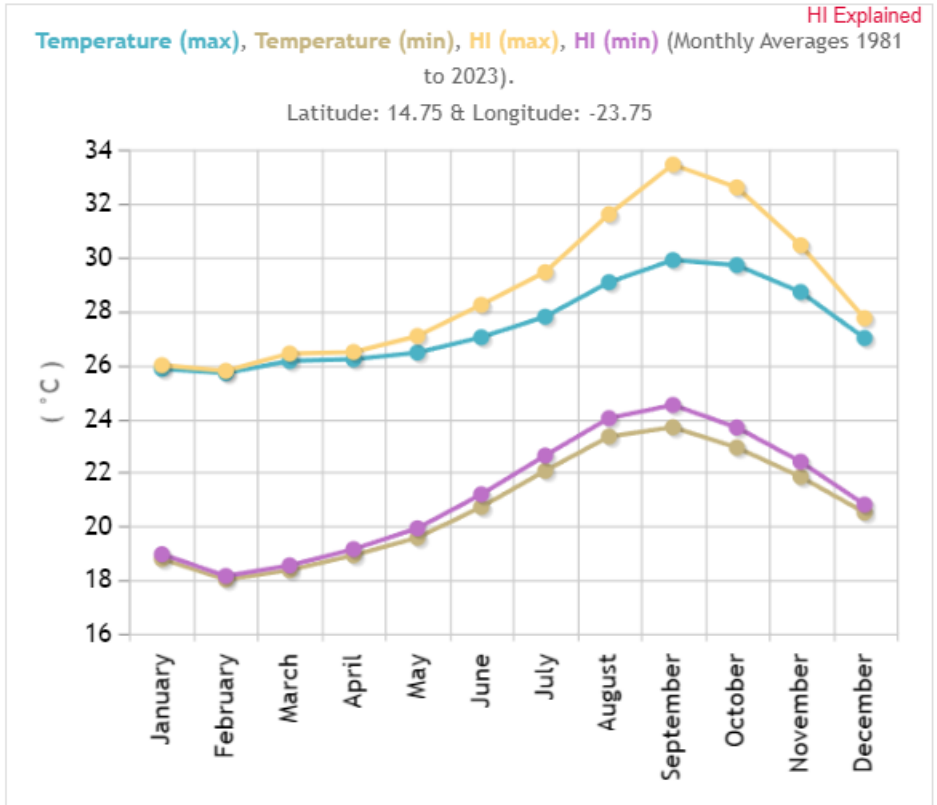
Grid-Cell Centre

Latitude	Longitude
14.75	-23.75

Parameter: Temperature (max), Temperature (min), HI (max), HI (min)

Chart Type: Monthly Distribution

Temperature Unit: Celsius



☑ *Show weather stations.* ☐ *Find closest weather station.*

Orange markers indicate weather stations with data for more than 2/3 of days 1980-2023. ***Click*** *a marker to view station data.*

Note: When interpreting charts that display dew-point temperature, or values derived from it, i.e. WBGT and UTCI, note that dew-point temperatures below 0ºC are often not reliable.

Show Data Table | Save this Graph as an Image

Grid-cell data for this page from: CRU TS v4.08, Climatic Research Unit, University of East Anglia, Norwich, UK https://www.cru.uea.ac.uk/
Weather station data based on Global Summary of the Day, National Oceanic and Atmospheric Administration https://www.noaa.gov/

Ponta Doce Mancanha, Guir | Search

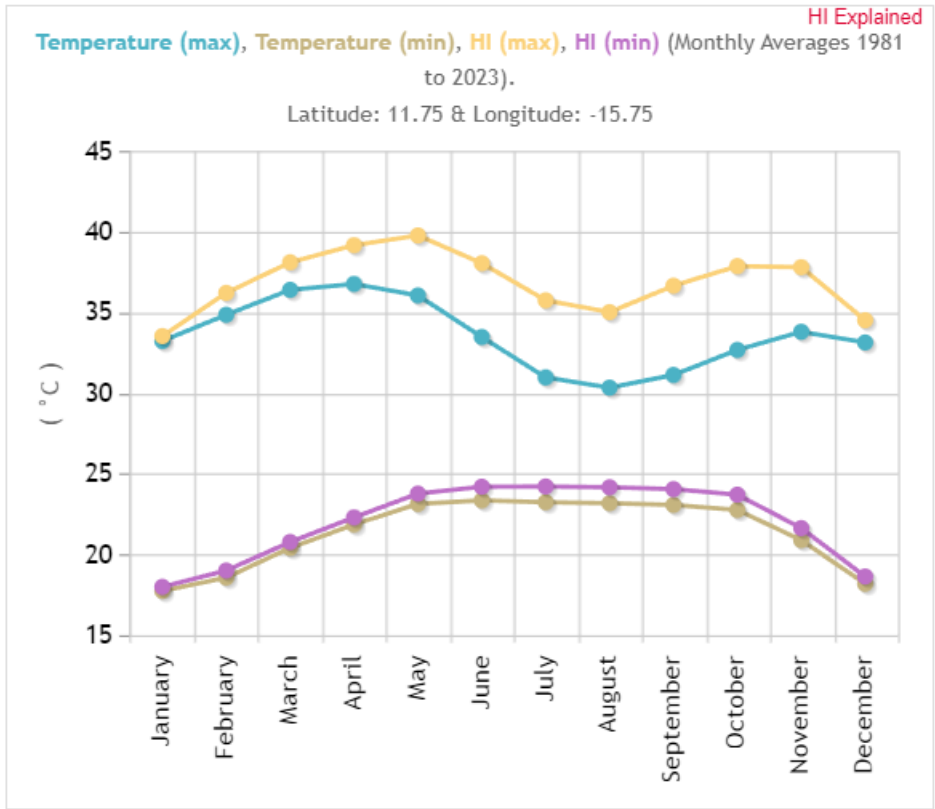
Grid-Cell Centre

Latitude	Longitude
11.75	-15.75

Parameter: Temperature (max), Temperature (min), HI (max), HI (min)

Chart Type: Monthly Distribution

Temperature Unit: Celsius



☑ *Show weather stations.* ☐ *Find closest weather station.*

Orange markers indicate weather stations with data for more than 2/3 of days 1980-2023. ***Click*** *a marker to view station data.*

Note: When interpreting charts that display dew-point temperature, or values derived from it, i.e. WBGT and UTCI, note that dew-point temperatures below 0ºC are often not reliable.

Show Data Table | Save this Graph as an Image

PORT GENTIL | Search

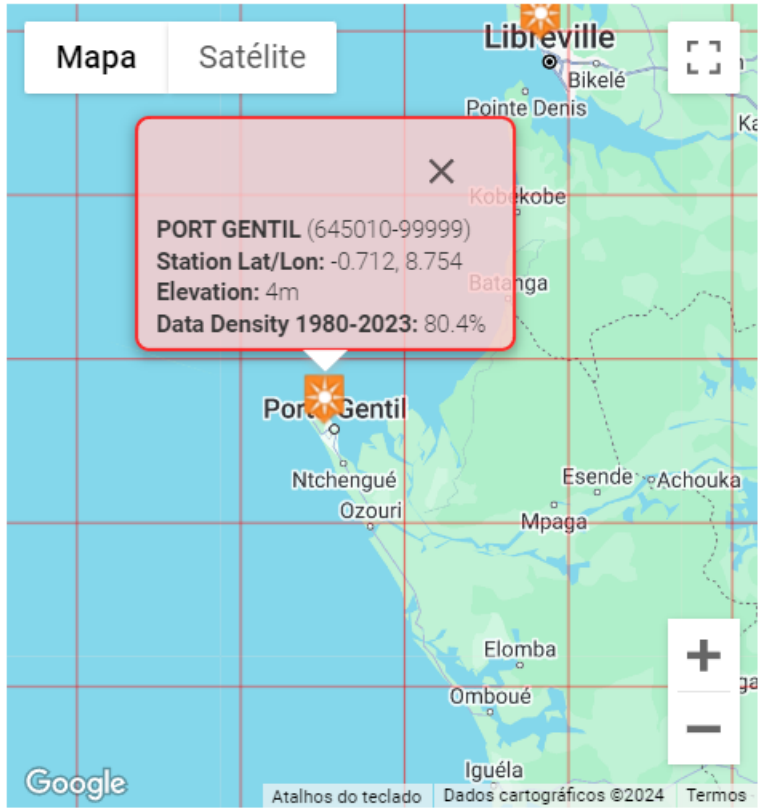
Grid-Cell Centre

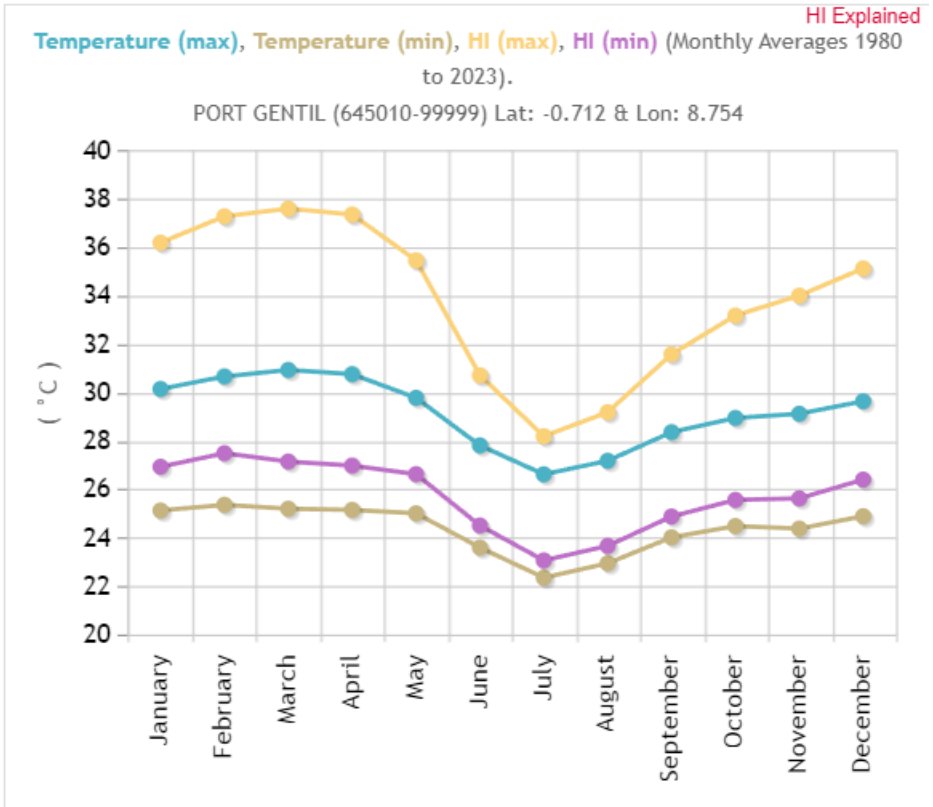
Latitude	Longitude
-0.75	8.75

Parameter: Temperature (max), Temperature (min), HI (max), HI (min)

Chart Type: Monthly Distribution

Temperature Unit: Celsius





☑ *Show weather stations.* ☐ *Find closest weather station.*

Orange markers indicate weather stations with data for more than 2/3 of days 1980-2023. ***Click*** *a marker to view station data.*

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Show Data Table | Save this Graph as an Image

Cidade Velha, Cabo Verde | Search

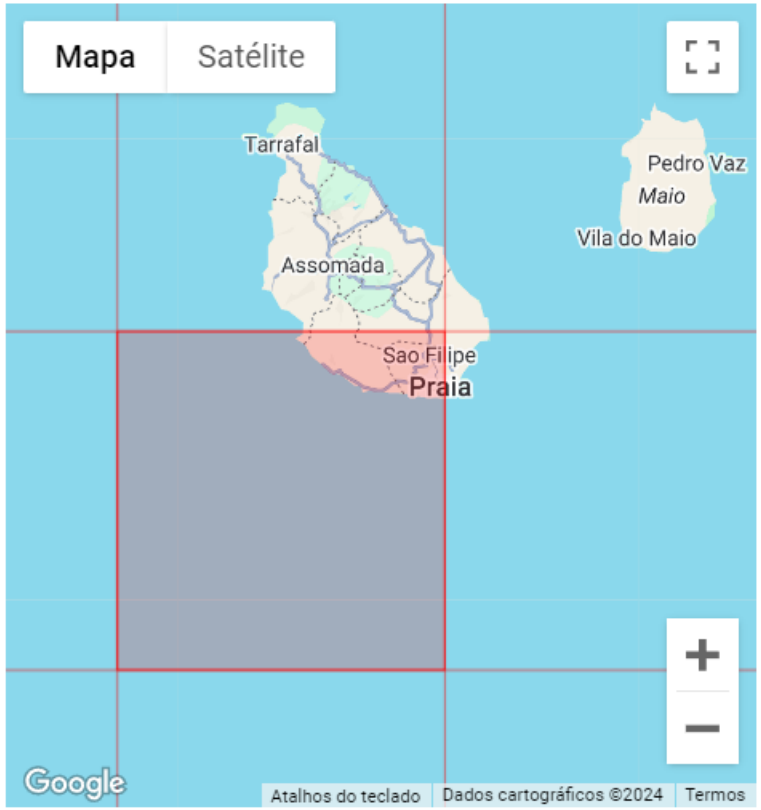
Grid-Cell Centre

Latitude	Longitude
14.75	-23.75

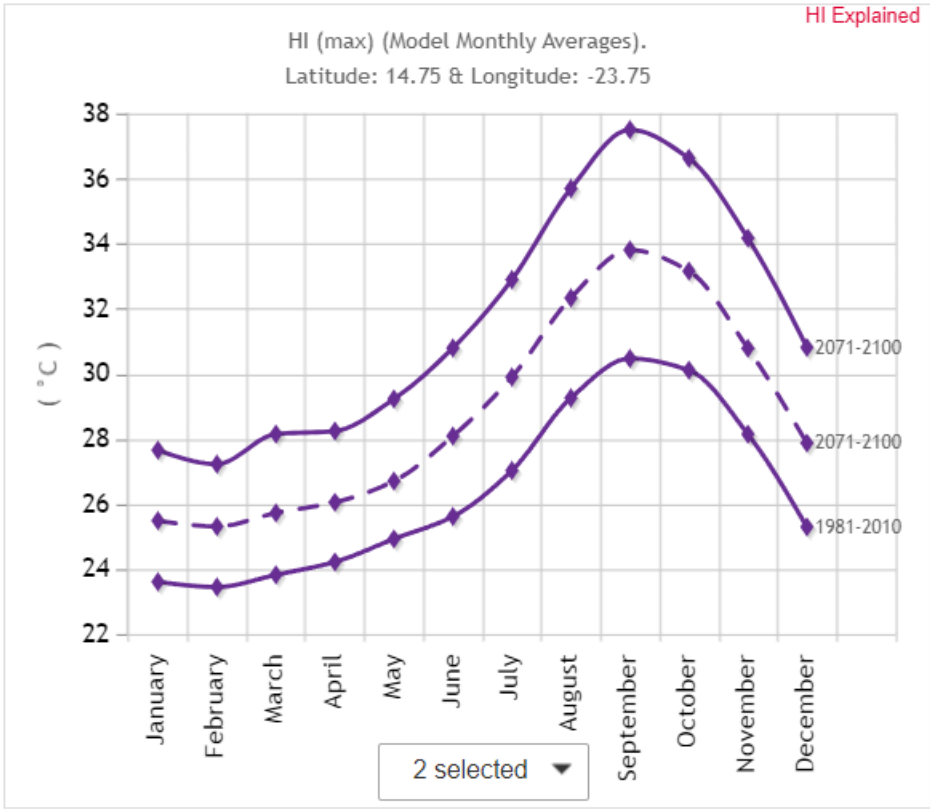
Parameter: HI (max)

Chart Type: Monthly Distribution

Temperature Unit: Celsius



HI Explained



☑ SSP 126 - - - -
☑ SSP 370 ——

☐ UKesm ● ☐ GFDL ■ ☑ MidPoint ◆

Note: When interpreting charts that display dew-point temperature, or values derived from it, i.e. WBGT and UTCI, note that dew-point temperatures below 0ºC are often not reliable.

Show Data Table | Save this Graph as an Image

Bissau, Guiné-Bissau | Search

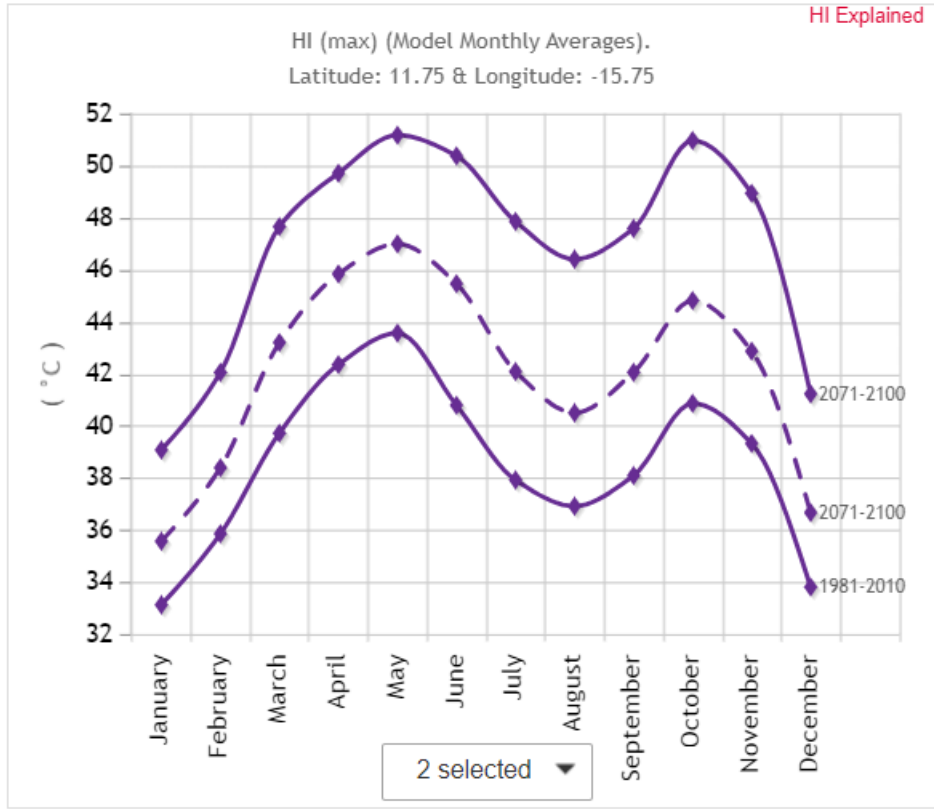
Grid-Cell Centre

Latitude	Longitude
11.75	-15.75

Parameter: HI (max)

Chart Type: Monthly Distribution

Temperature Unit: Celsius



☑ SSP 126 - - - -
☑ SSP 370 ——

☐ UKesm ● ☐ GFDL ■ ☑ MidPoint ◆

Note: When interpreting charts that display dew-point temperature, or values derived from it, i.e. WBGT and UTCI, note that dew-point temperatures below 0ºC are often not reliable.

Show Data Table | Save this Graph as an Image

Porto Gentil, Gabão | Search

Grid-Cell Centre

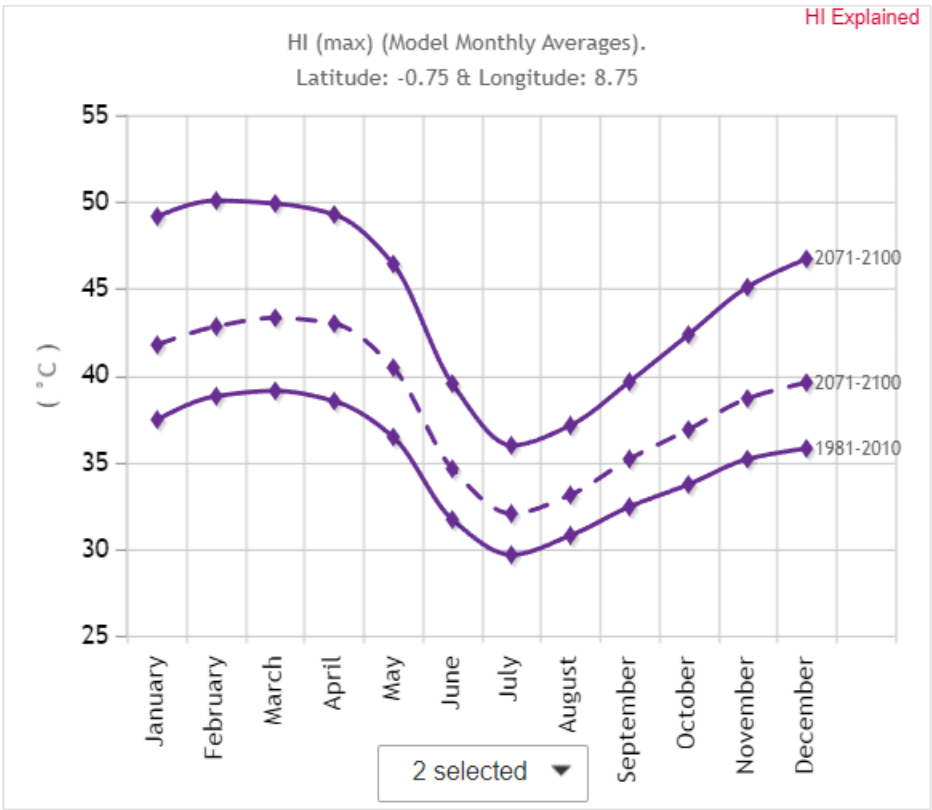
Latitude	Longitude
-0.75	8.75

Parameter: HI (max)

Chart Type: Monthly Distribution

Temperature Unit: Celsius

HI Explained



☑ *SSP 126* - - - -
☑ *SSP 370* ——

☐ *UKesm* ● ☐ *GFDL* ■ ☑ *MidPoint* ◆

Note: When interpreting charts that display dew-point temperature, or values derived from it, i.e. WBGT and UTCI, note that dew-point temperatures below 0ºC are often not reliable.

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