ASHRAE 2022 WINTER CONFERENCE
Jan 29-Feb 2 | AHR EXPO Jan 31-Feb 2

Buildings at 360° – Seminar 3

Monday 11 AM until noon, Neopolitan I/II

Would Your Building Perform Satisfactorily During a Heatwave or Power-Blackout?

Could a Passive Design Satisfy the Needs of Building Occupants?

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Learning Objectives

- (1) To understand how built environment exposure and population sensitivity to extreme heat are unevenly distributed in cities – and to understand the social and environmental justice implications of designing and deploying cool roofs, green roofs, cool pavements, and shading vegetation.
- (4) To consider opportunities to provide cool shelter by means of shading, ventilation, and evaporation – and to learn how to assess the extremes of heat and humidity at any location.

Addressed in this presentation "Could a Passive Design Satisfy the Needs of Building Occupants?"

Learning Objectives

- (2) To understand the design and operational factors that influence passive survivability of buildings – and to learn how evolving building codes and practices affect passive survivability and the role of underlying climate conditions.
- (3) To understand the concept of anthropogenic waste heat emissions in the context of the building energy balance, and how this waste heat affects the outdoor urban environment.

The above learning objectives were the focus of the previous speaker, ASU Professor David Sailor

"Strategies for Urban Cooling – How Buildings Can Improve Indoor and Outdoor Urban Climates"

Acknowledgements

Apologies for not enabling remote presentation by our 3rd speaker

"What Are the Social and Environmental Justice Implications of Your Client's Project"

Dr Juan Declet-Barreto

Senior Social Scientist for Climate Vulnerability

Climate & Energy Program

Union of Concerned Scientists, Washington, DC

Dahl, Spanger-Siegfried, Licker, Caldas, Abatzoglou, Mailloux, Cleetus, Udvardy, Declet-Barreto, and Worth (2019). **Killer Heat in the United States**: Climate Choices and the Future of Dangerously Hot Days. Cambridge, MA: Union of Concerned Scientists.

Outline/Agenda

Electricity can fail during heatwaves, especially if air-conditioning installations have outpaced the capacity of power grids.

The sufficiency of passive and low energy alternatives depend on the extreme coincidence of heat and humidity.

Could passive features maintain satisfactory performance during heatwave/power-blackout events?

Here I suggest that if conditions are acceptable under shade trees, then passive-building designs could provide shelter from heat waves.

Shade is essential throughout a heat wave,

but ventilation should be reduced during the hottest hours of the day

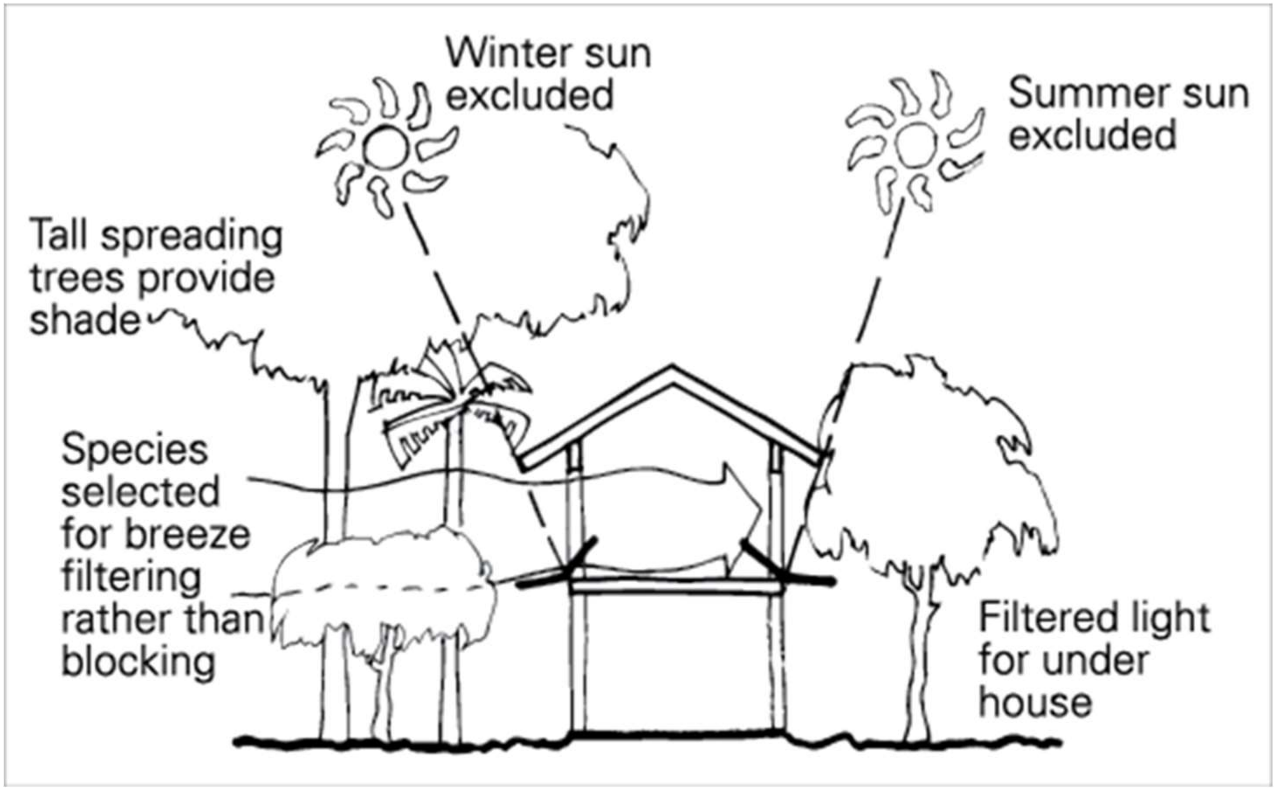
- Study of two heat waves in Poland with max dry bulb ~88°F (31°C).
- Combined passive methods, indoor temperatures > 28°C eliminated.
- Coupled high mass with night ventilation eliminated >88°F (31°C).
- Heavy mass almost eliminated $T_{indoors}>T_{max}$ instances.
- Night ventilation increased diurnal variation of indoor temperature.

Kuczyński, Staszczuk, Gortych, & Stryjski (2021). Effect of thermal mass, night ventilation and window shading on summer thermal comfort of buildings in a temperate climate. Building and Environment, 204, 108126.

(Many older references report benefits of shade & night ventilation)

Bio Climate Design – exemplar passive designs have their limits

Lightweight highset tropical shelter are not cooler than $WBGT_{shade}$



Orientation for an elevated tropical house. From Your Home
http://www.yourhome.gov.au/passive-design/orientation

In the shade $T_{globe} = T_a$ simplification *

$WBGT_{shade} = 0.7 \times T_{wb} + 0.3 \times T_a$

* Lemke and Kjellstrom (2012) as well as Australian Bureau of Meteorology (BoM)

“The shade WBGT is calculated for an environment shaded from direct (and strong reflected) solar radiation and **where surfaces are not significantly hotter or colder** than the indicated air temperature” – BoM Thermal Comfort Observations

In the shade of a tree at Watson Park, Lawrence Kansas by Epicsosseum25, via Wikimedia Commons

WBGT is established measure of indoor and outdoor workers' health

Thermal Comfort

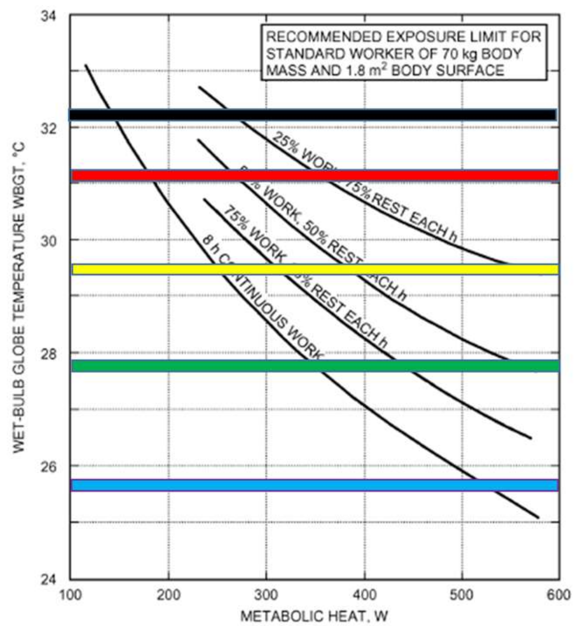


Fig. 20 Recommended Heat Stress Exposure Limits for Heat Acclimatized Workers
[Adapted from NIOSH (1986)]

From ASHRAE HoF 2017 Thermal Comfort

$\boldsymbol{WBGT_{shade}} = 0.7\ T_{wb} + 0.3\ T_{db}$

Lemke, B., and T. Kjellstrom (2012).
Industrial Health 50:267–78

Wet Bulb Globe	Temperature	warnings
90°F	**32.2°C**	**Black Flag**
88°F	31.1°C	Red Flag
85°F	29.4°C	Yellow Flag
82°F	27.8°C	Green Flag
78°F	25.6°C	White Flag

Army Technical Bulletin Medical 507 and
Air Force Pamphlet 48-152(I) 7 March 2003

Wet-Bulb Globe Temperature

The WBGT is an environmental heat stress index that combines dry-bulb temperature t_{db}, a **naturally ventilated** (not aspirated) wet-bulb temperature t_{nwb}, and black globe temperature t_g, according to the relation (Dukes-Dobos and Henschel 1971, 1973)

$$\text{WBGT} = 0.7t_{nwb} + 0.2t_g + 0.1t_a \quad (83)$$

This form of the equation is usually used where solar radiation is present. The naturally ventilated wet-bulb thermometer is left exposed to sunlight, but the air temperature t_a sensor is shaded. In enclosed environments, Equation (83) is simplified by dropping the t_a term and using a 0.3 weighting factor for t_g.

Wet Bulb Globe Temperature (WBGT) was developed in 1950s at US Marine Corp Recruit Depot on Parris Island, SC.

$$WBGT = 0.7 \times T_{nwb} + 0.2 \times T_g + 0.1 \times T_a$$

Many solders succumbed to heat related illness. In response, a joint effort between the Department of the Navy and Army doctors studied the effects of heat on exercise performance.

Cpl. Bryan Weingart, station weather observer, examines readings from a thermal environment monitor to determine the wet-bulb globe temperature index at the Marine Corps Air Station in Yuma, Ariz., Aug. 13, 2010.

Flag Color	WGBT	Intensity of Physical Exercise
Green	80 to 85 F 26.6 to 29.4 °C	Discretion required in planning heavy exercise for unseasoned personnel. This is a marginal heat stress limit for all personnel.
Yellow	85 to 88 F 29.4 to 31.1 °C	Strenuous exercise and activity should be curtailed for new and unacclimated personnel during first 3 weeks of heat exposure
Red	88 to 90 31.1 to 32.2 °C	Strenuous exercise curtailed for all personnel with less than 12 weeks training in hot weather
Black	90 and above >= 32.2 °C	Physical training and strenuous exercise suspended for all personnel

U.S Military Heat Stress Flag Conditions

Work/Rest and Water Consumption Table

Applies to average sized, heat-acclimated Soldier wearing ACU, hot weather. (See TB MED 507 for further guidance.)

Easy Work	Moderate Work	Hard Work
• Weapon Maintenance • Walking Hard Surface at 2.5 mph, < 30 lb Load • Marksmanship Training • Drill and Ceremony • Manual of Arms	• Walking Loose Sand at 2.5 mph, No Load • Walking Hard Surface at 3.5 mph, < 40 lb Load • Calisthenics • Patrolling • Individual Movement Techniques, i.e., Low Crawl or High Crawl • Defensive Position Construction	• Walking Hard Surface at 3.5 mph, ≥ 40 lb Load • Walking Loose Sand at 2.5 mph with Load • Field Assaults

Heat Category	WBGT Index, F°	Easy Work		Moderate Work		Hard Work	
		Work/Rest (min)	*Water Intake (qt/hr)*	*Work/Rest (min)*	*Water Intake (qt/hr)*	*Work/Rest (min)*	*Water Intake (qt/hr)*
1	78° - 81.9°	NL	½	NL	¾	40/20 min	¾
2 (green)	82° - 84.9°	NL	½	50/10 min	¾	30/30 min	1
3 (yellow)	85° - 87.9°	NL	¾	40/20 min	¾	30/30 min	1
4 (red)	88° - 89.9°	NL	¾	30/30 min	¾	20/40 min	1
5 (black)	> 90°	50/10 min	1	20/40 min	1	10/50 min	1

- The work/rest times and fluid replacement volumes will sustain performance and hydration for at least 4 hrs of work in the specified heat category. Fluid needs can vary based on individual differences (± ¼ qt/hr) and exposure to full sun or full shade (± ¼ qt/hr).
- **NL** = no limit to work time per hr.
- **Rest** = minimal physical activity (sitting or standing) accomplished in shade if possible.
- ***CAUTION: Hourly fluid intake should not exceed 1½ qts.***

  Daily fluid intake should not exceed 12 qts.
- If wearing body armor, add **5°F** to WBGT index in humid climates.
- If doing Easy Work and wearing NBC (MOPP 4) clothing, add **10°F** to WBGT index.
- If doing Moderate or Hard Work and wearing NBC (MOPP 4) clothing, add **20°F** to WBGT index.

For additional copies, contact: U.S. Army Public Health Command Health Information Operations Division at (800) 222-9698 or USAPHC - Health Information Operations@apg.amedd.army.mil.
For electronic versions, see http://chppm-www.apgea.army.mil/heat. Distribution unlimited. Local reproduction is authorized.
CP-033-0811

USAPHC
U.S. ARMY PUBLIC HEALTH COMMAND
http://phc.amedd.army.mil
1-800-222-9698

https://www.weather.gov/arx/wbgt4

Senior Airman Kevin Iinuma, Lackland Air Force Base, Texas. (USAF Photo by Sgt. Josie Walck)

Relative humidity (%)	Temperature (°F) 68.0	71.6	75.2	78.8	82.4	86.0	89.6	93.2	96.8	100.4	104.0	107.6	111.2	114.8	118.4	122.0
0	58.6	60.9	64.3	65.5	67.7	69.9	72.1	74.3	76.4	78.5	80.6	82.6	84.7	86.6	88.6	90.5
5	59.6	62.1	65.6	67.0	69.3	71.7	74.0	76.4	78.6	80.9	83.1	85.3	87.5	89.9	92.1	94.2
10	60.7	63.3	66.9	68.4	70.8	73.3	75.8	78.2	80.7	83.0	85.5	88.0	90.3	92.8	95.1	97.6
15	61.7	64.5	68.1	69.6	72.2	74.8	77.4	80.0	82.6	85.2	87.8	90.2	92.8	95.4	98.0	
20	62.7	65.6	69.4	70.9	73.6	76.3	79.2	81.8	84.5	87.1	89.8	92.5	95.2	97.8		
25	63.8	66.7	70.5	72.2	75.1	77.8	80.6	83.4	86.2	89.0	91.8	94.6	97.4			
30	64.8	67.6	71.7	73.4	76.3	79.2	82.1	84.9	87.8	90.8	93.6	96.6	99.4			
35	65.6	68.6	72.7	74.6	77.5	80.5	83.5	86.4	89.4	92.4	95.3	98.3				
40	66.7	69.6	73.8	75.7	78.8	81.8	84.8	87.8	90.9	94.0	97.0					
45	67.5	70.6	74.8	76.8	79.9	83.0	86.1	89.2	92.3	95.4	98.6					
50	68.4	71.5	75.8	77.8	81.1	84.1	87.4	90.5	93.7	96.9						
55	69.3	72.4	76.7	78.8	82.1	85.3	88.5	91.9	95.1	98.3						
60	70.1	73.3	77.7	79.8	83.2	86.4	89.8	93.1	96.3	99.6						
65	70.9	73.8	78.6	80.9	84.2	87.5	90.8	94.1	97.5							
70	71.7	75.0	79.5	81.7	84.9	88.6	91.9	95.3	98.6							
75	72.4	75.9	80.3	82.7	86.1	89.6	92.9	96.4								
80	73.2	76.7	81.2	83.6	87.1	90.4	93.9	97.4								
85	74.0	77.4	82.0	84.5	88.0	91.5	94.9	98.5								
90	74.7	78.2	82.9	85.3	88.9	92.3	95.9	99.4								
95	75.5	78.9	83.6	86.1	89.6	93.2	96.8									
100	76.1	79.7	84.4	86.9	90.5	94.1	97.7									

Temperature	Category	Risk level
77° to 81.9°F (25° to 27.7°C)	Caution	Possible fatigue with pro
82° to 84.9°F (27.8° to 29.4°C)	Extreme caution	Heat-related illness poss
85° to 88.9°F (29.5° to 31.6°C)	Danger	Heat stroke possible, hea
≥ 89°F (≥ 31.7°C)	Extreme danger	High risk of heat stroke

*broadly simplified psychrometrics into 3 heating modes, passive free-running, and 3 cooling modes

Winter modes are humidification, air-source heat pumping, and icing-heating.

The icing-heating condition could be partially managed by defrosting of air-source heat pumps, but may recommend ground-source heat pump or combustion heat.

Summer modes are ventilation, direct evaporative cooling, and vapor-compression DX.

*** Peterson, ASHRAE 3rd International Conference Efficient Building Design, Beirut, Lebanon October 4-5, 2018**

(+3) Direct expansion vapour compression (DX) is suggested if:

$T_{mean\ db} > T_{hot}$ AND $T_{coincident\ wb} > T_{humid}$

– except DX is not required if

$T_{mean\ db} \leq T_{Vhot}$ AND $T_{coincident\ wb} \leq T_{Vhumid}$

(+2) Direct evaporative cooling (Evap'n) is suggested if:

$T_{dry} \leq T_{coincident}$ wb $\leq_{Thumid}$ AND $T_{mean\ db} > T_{hot}$ (NOT Vhot)

(+1) Ventilation cooling and dehumidification (Vent'n) is suggested if either:

(a) $T_{cold} \leq T_{mean\ db} \leq_{TVhot}$ AND $T_{humid} < T_{coincident\ wb} \leq T_{vhumid}$

OR

(b) $T_{hot} < T_{mean\ db} \leq T_{Vhot}$ AND $T_{dry} \leq T_{coincident\ wb} \leq T_{humid}$

(0) Passive comfort is readily achieved if:

$T_{cold} \leq T_{mean\ db} \leq_{Thot}$ AND $T_{humid} \leq T_{coincident\ wb} \leq T_{dry}$

(-1) Humidification (Humid') is suggested if:

$T_{cold} \leq T_{mean\ db}$ AND $T_{coincident\ wb} < T_{dry}$

(-2) Air-source heatpump heating (Heat) is suggested if: $T_{mean\ db} < T_{cold}$

– except for icy-heating conditions defined in the seventh classification –

(-3) Beware that air-source heat pumps are subject to icing (Icy) if:

$T_{mean\ db} \leq T_{icing}$ AND $[T_{mean\ db} - T_{coincident\ dewpoint}] \leq \Delta T_{ice}$

Nominal thresholds to classify heating-cooling modes

Peterson (2018) Table 1. Nominal thresholds to classify heating-cooling modes

	Dry Bulb	Wet Bulb	Frost/Dew Point
Very hot and Very humid	T_{Vhot} = 27°C (80.6°F) db	T_{Vhumid} = 24°C (75.2°F) wb	
hot and humid	T_{hot} = 24°C (75.2°F) db	T_{humid} = 19.4°C (67°F) wb	
Cold and Dry (heating / humidification desirable)	T_{cold} = 18.3°C (65°F) db	T_{dry} = 9.4°C (49°F) wb	
Icy air-source heat pump	T_{icing} = 5°C (41°F) db		ΔT_{ice} = 5K (9°F) depression (db – frost or dewpoint)

"Very hot" drybulb threshold (T_{Vhot}) ASHRAE 55 (2010) at 0.3 m/s (10 f/s).

T_{hot} is cooling degree days base temperature.

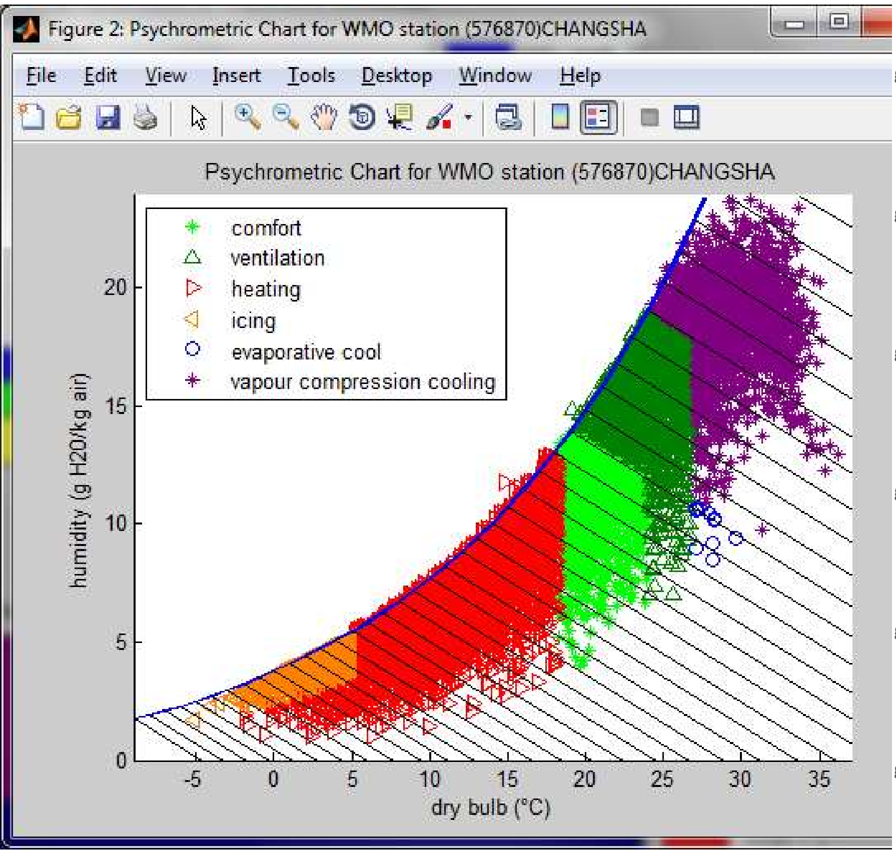
T_{cold} is heating degree days base temperature.

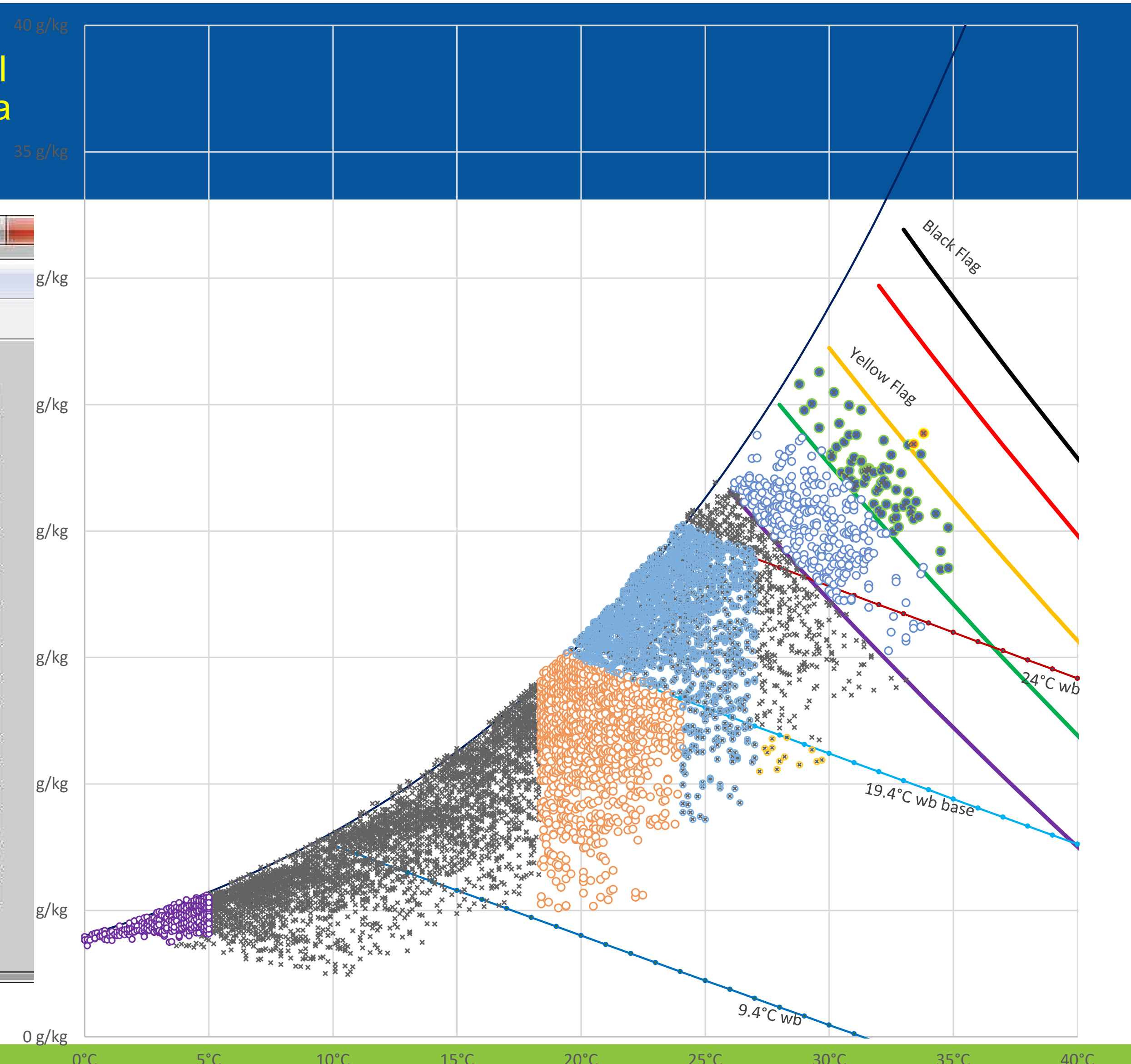
"Very humid" wetbulb threshold (T_{Vhumid}) is the author's suggested limit for the suitability of ventilation to manage humidity without AC.

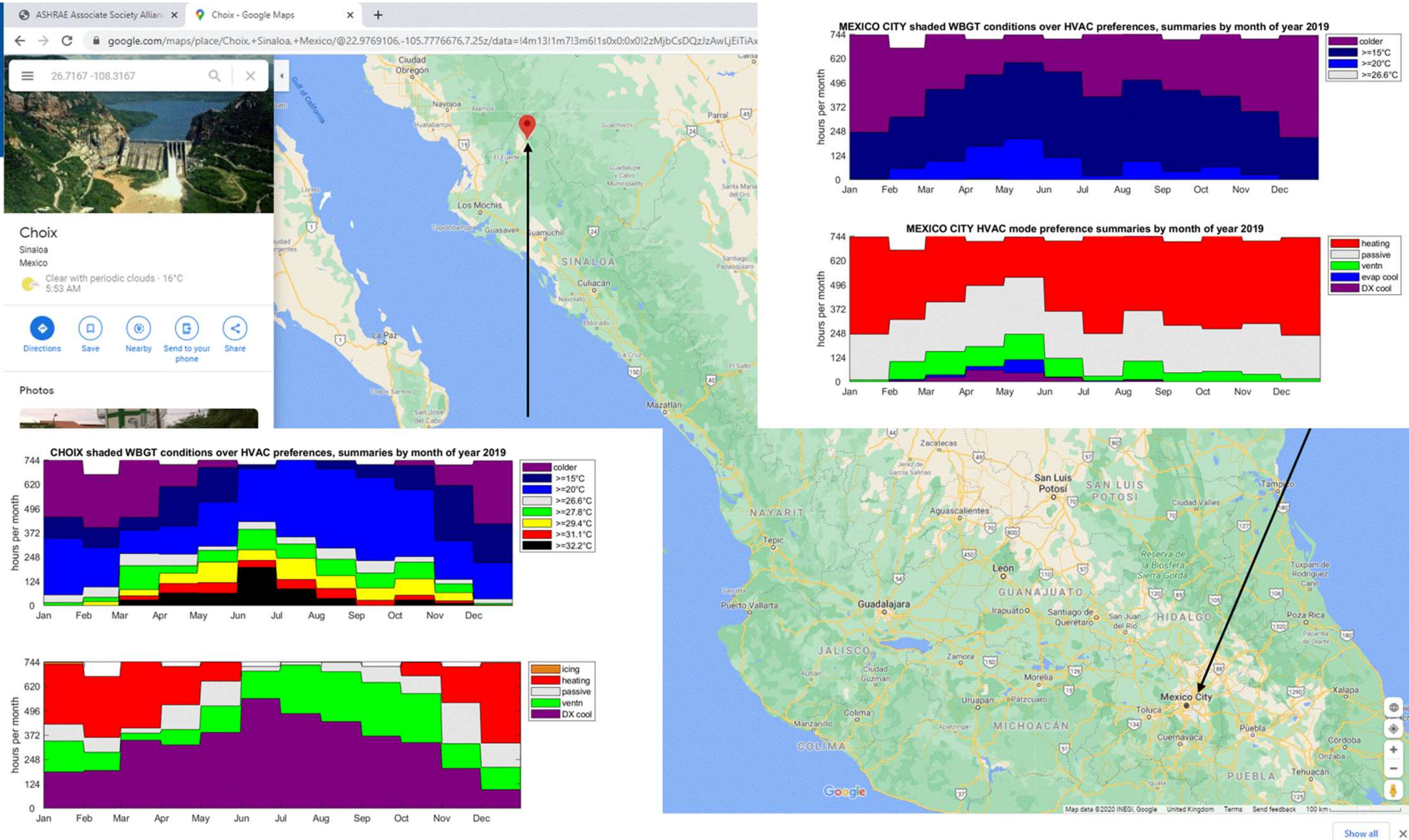
T_{humid} effective direct evaporative cooling limit.

T_{dry} is wetbulb that is too dry for comfort.

Peterson (2018) illustrations for Hunan capital Chansha and Sichuan capital Chengdu, China







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MEXICO CITY shaded WBGT conditions over HVAC preferences, summaries by month of year 2019
colder
>=15°C
>=20°C
>=26.6°C
hours per month
744
620
496
372
248
124
0
Jan
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Dec
MEXICO CITY HVAC mode preference summaries by month of year 2019
heating
passive
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evap cool
DX cool
CHOIX shaded WBGT conditions over HVAC preferences, summaries by month of year 2019
colder
>=15°C
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>=26.6°C
>=27.8°C
>=29.4°C
>=31.1°C
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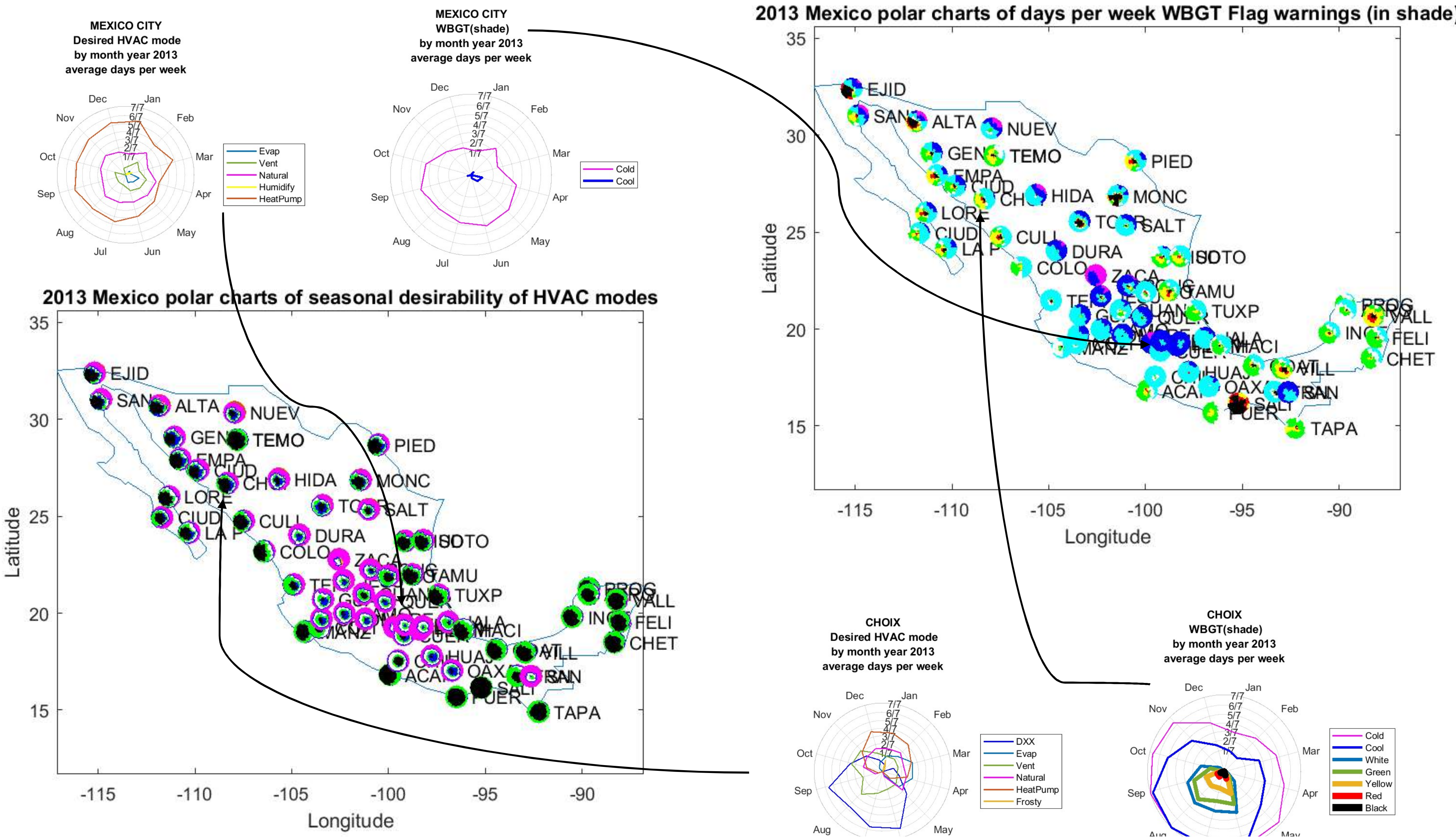
MEXICO CITY
Desired HVAC mode
by month year 2013
average days per week
Evap
Vent
Natural
Humidify
HeatPump
MEXICO CITY
WBGT(shade)
by month year 2013
average days per week
Cold
Cool
2013 Mexico polar charts of days per week WBGT Flag warnings (in shade)
2013 Mexico polar charts of seasonal desirability of HVAC modes
Latitude
Longitude
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Desired HVAC mode
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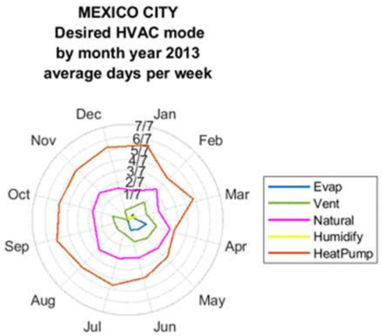
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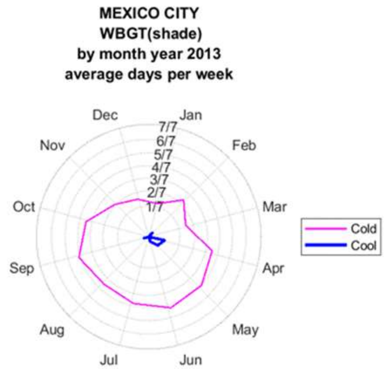
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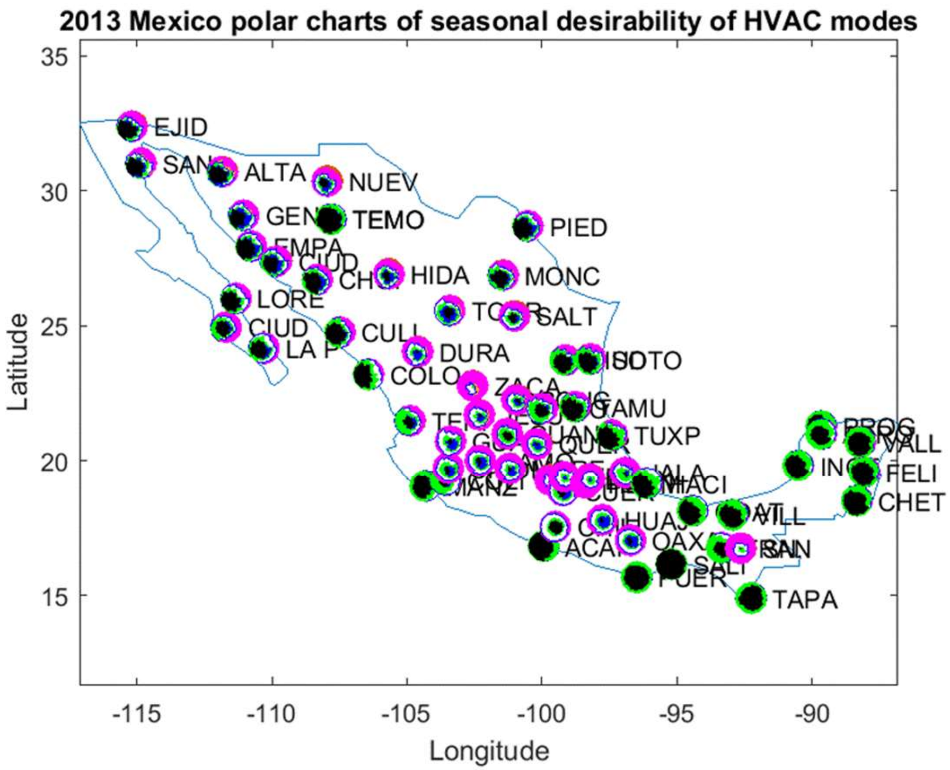
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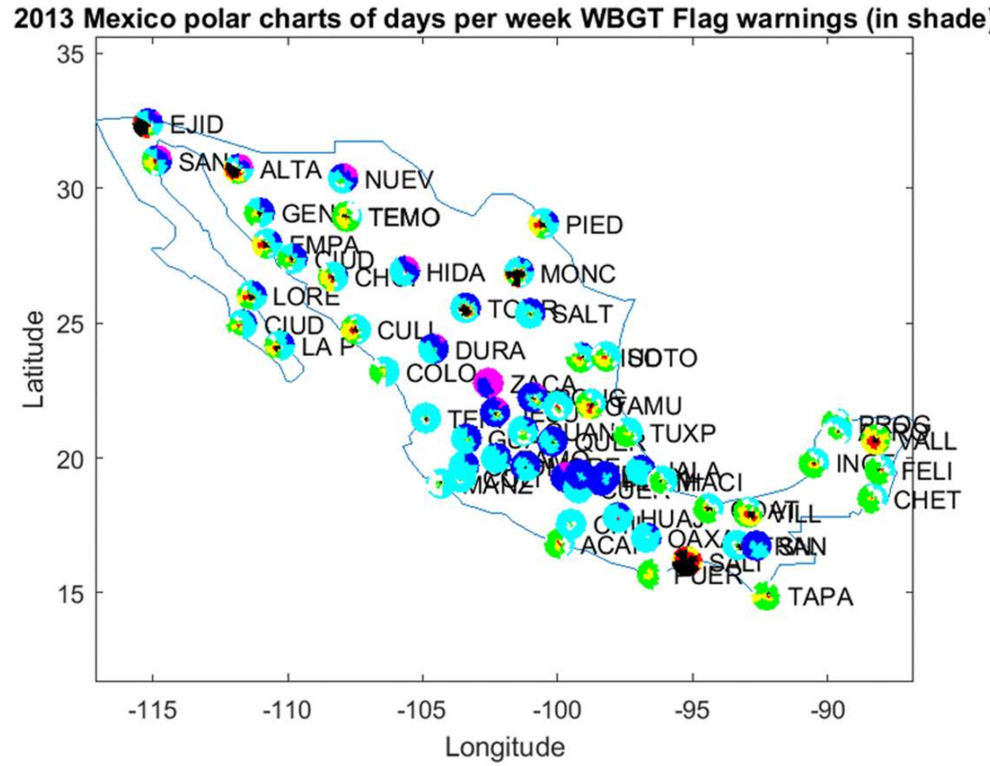
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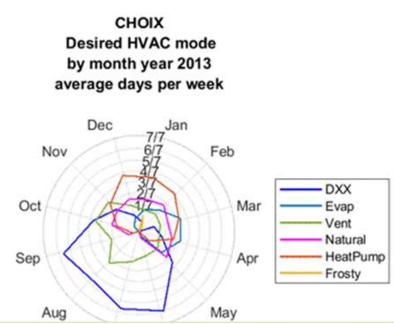
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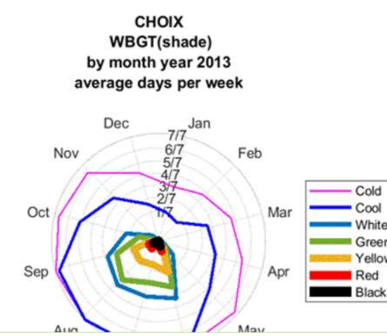
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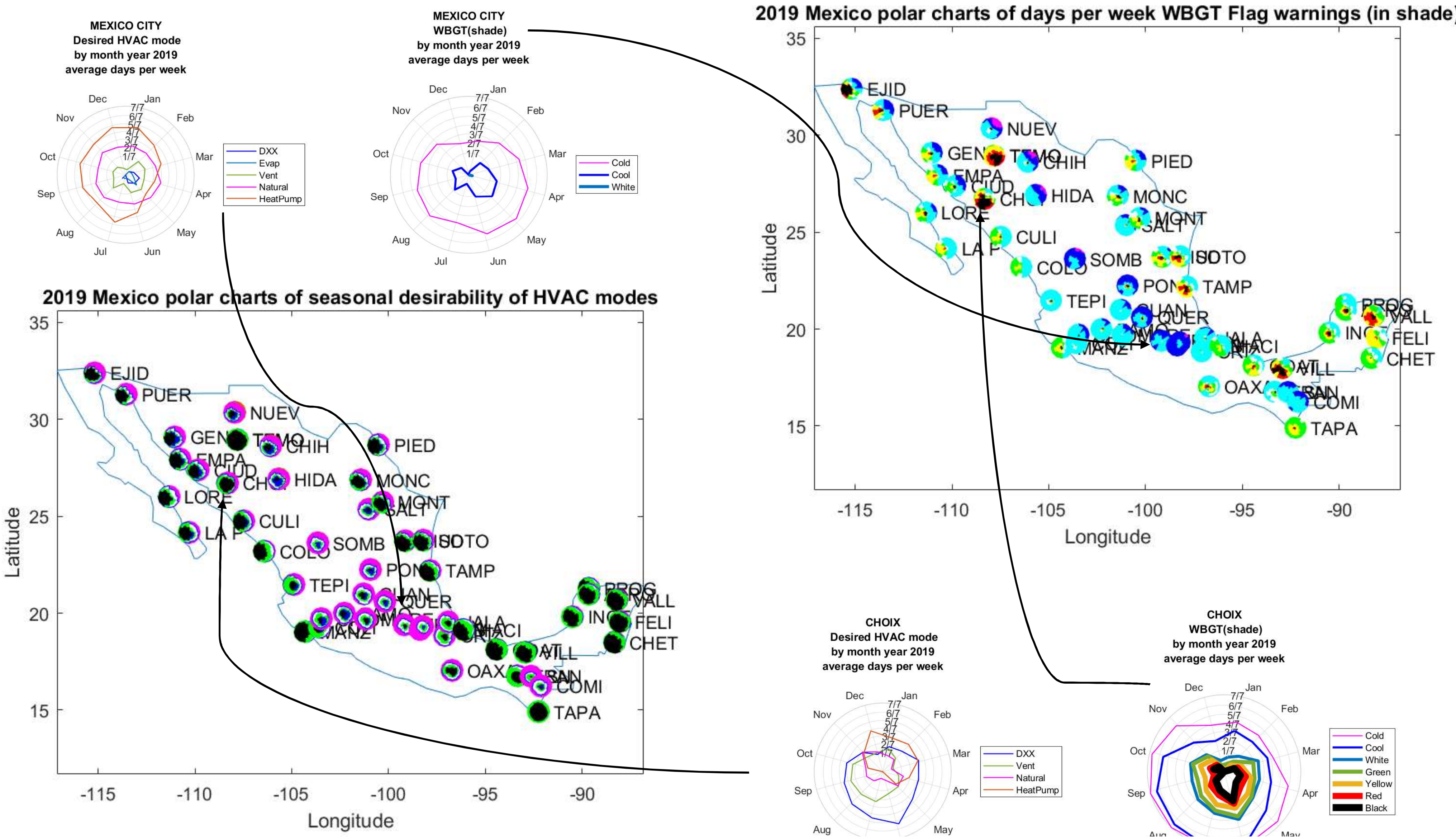
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National Weather Service Heat Advisory criteria vary across USA, but are generally issued if maximum Heat Index ≥ 100°F at least 2 days, while night time minimums > 75°F (24°C)

Heat Advisory—Take Action! Heat Advisories are issued within 12 hours of the onset of extremely dangerous heat conditions.

"Take precautions to avoid heat illness"
– or you may become seriously ill or even die.

Heat Index (HI) depends on heat and humidity such that
HI=90°F when drybulb is 90°F(32.2°C) and RH=30%

HI posits human-perceived equivalent temperature, as how hot it might feel in the shade at any given humidity.

"Felt temperature" increases HI is 106°F (41°C) at drybulb 90°F (32°C) if relative humidity increases to 70%

In Canada, Humidex is used with different tables.

Most internationally recognized is wet-bulb globe temperature (WBGT) which responds to either shade or sunlight.

NOAA national weather service: heat index

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

Key to colors: Caution · Extreme caution · Danger · Extreme danger

98.6 °F (37 °C) Core Body Temperature depends on continuous cooling

95 °F (35 °C) Sustained Skin Temperature is extremely dangerous

Temperature classification	
	Core (rectal, esophageal, etc.)
Hypothermia	<35.0 °C (95.0 °F)[1]
Normal	36.5–37.5 °C (97.7–99.5 °F)[2][3]
Fever	>37.5 or 38.3 °C (99.5 or 100.9 °F)[4][5]
Hyperthermia	>37.5 or 38.3 °C (99.5 or 100.9 °F)[4][5]
Hyperpyrexia	>40.0 or 41.0 °C (104.0 or 105.8 °F)[6][7]

1. *Marx J (2006). Rosen's emergency medicine : concepts and clinical practice (6th ed.). Philadelphia: Mosby/Elsevier. p. 2239. ISBN 978-0-323-02845-5. OCLC 58533794.*

2.^ *Hutchison JS, Ward RE, Lacroix J, Hébert PC, Barnes MA, Bohn DJ, et al. (June 2008). "Hypothermia therapy after traumatic brain injury in children". The New England Journal of Medicine.* ***358*** *(23): 2447–56. doi:10.1056/NEJMoa0706930. PMID 18525042.*

3.^ *Pryor JA, Prasad AS (2008). Physiotherapy for Respiratory and Cardiac Problems: Adults and Paediatrics. Elsevier Health Sciences. p. 8. ISBN 978-0702039744. Body temperature is maintained within the range 36.5-37.5 °C. It is lowest in the early morning and highest in the afternoon.*

4.^ *Jump up to: a b Axelrod YK, Diringer MN (May 2008). "Temperature management in acute neurologic disorders". Neurologic Clinics.* ***26*** *(2): 585–603, xi. doi:10.1016/j.ncl.2008.02.005. PMID 18514828.*

5.^ *Jump up to: a b c Laupland KB (July 2009). "Fever in the critically ill medical patient". Critical Care Medicine.* ***37*** *(7 Suppl): S273-8. doi:10.1097/CCM.0b013e3181aa6117. PMID 19535958.*

6.^ *Grunau BE, Wiens MO, Brubacher JR (September 2010). "Dantrolene in the treatment of MDMA-related hyperpyrexia: a systematic review". Cjem.* ***12*** *(5): 435–42. doi:10.1017/s1481803500012598. PMID 20880437. Dantrolene may also be associated with improved survival and reduced complications, especially in patients with extreme (≥ 42 °C) or severe (≥ 40 °C) hyperpyrexia*

7.^ *Sharma HS, ed. (2007). Neurobiology of Hyperthermia (1st ed.). Elsevier. pp. 175–177, 485. ISBN 9780080549996. Retrieved 19 November 2016. Despite the myriad of complications associated with heat illness, an elevation of core temperature above 41.0 °C (often referred to as fever or hyperpyrexia) is the most widely recognized symptom of this syndrome.*

Heat Index, as well as shaded WBGT, **are typically worse in densely built-up areas**

National Weather Service of USA as well as most members of the World Meteorological Organization (WMO) do not generally monitor nor model heat and humidity within urban canyons.

>>> The most typical locations for meteorological observations are airports <<<

Thus, forecasts tend to under under-estimate heat stress within urbanized areas.

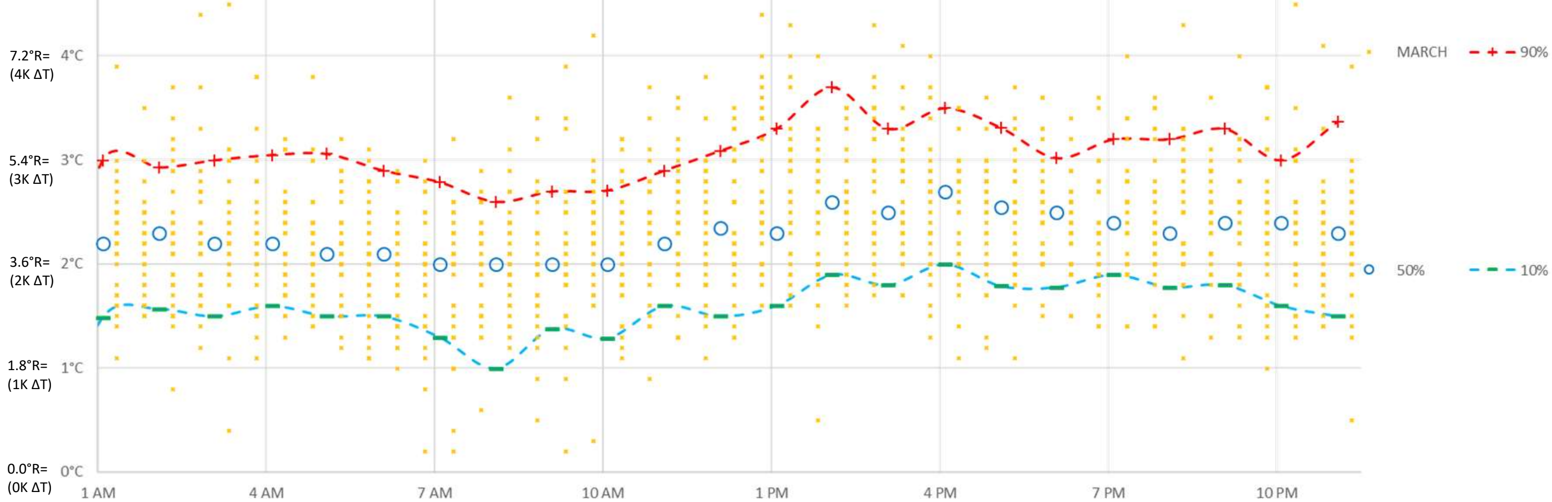
Development of dense concrete, steel, and glass cities without blue-green infrastructure (trees/water features) has caused modern cities to experience higher daily maximum temperatures that persist later into the evening.

Vegetated and irrigated “green roofs” as well as white-painted “cool roofs” provide comparable relief from daytime heatload downward into a building, but the green roof does not cool off as well at night as the cool roof.

Intensity of UHI varies between precincts and microclimates within a metropolitan area.

UHII University of Leeds relative to LBA airport

Urban heat island intensity of the University of Leeds rooftop weather station relative to Leeds-Bradford International Airport (LBA) in March 2018. Subtracted adiabatic lapse altitude effect, heat island intensity attributable to anthropogenic effect of the urban system



Urban heat island temperature is typically most elevated above the surroundings afternoon and into the evening.

“Green roofs” do not cool off as well at night as “cool roofs”

Vegetated and irrigated “green roofs” as well as white-painted “cool roofs” provide comparable relief from daytime heatload downward into a building, but the green roof does not cool off as well at night as the cool roof.

“Green roofs” depend on a supply of irrigation water to provide effective evaporative cooling, while “cool roofs” do not require any water.

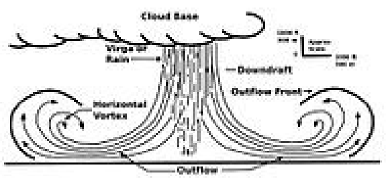
Neighborhood blue-green infrastructure such as parks and water features may mitigate a local urban microclimate so that it might approach airport conditions.

The most impactful shelter from outdoor heat stress is under established shade trees.

What was peak nighttime WBGT if drybulb was 140°F (60°C) & coincident wetbulb was 95°F (35°C)?

(if we assume midnight mean radiant temperature = dry bulb)

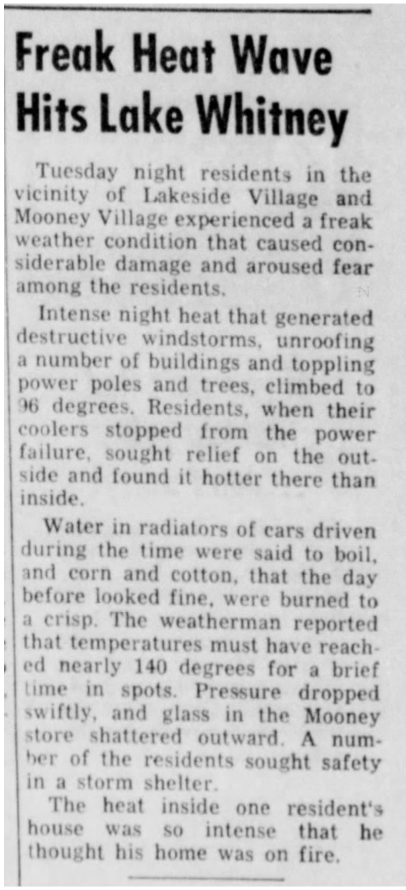
Clifton Record reported that after midnight on June 15, 1960, a freak meteorological phenomenon, a heat burst, struck the community when a dying thunderstorm collapsed near Kopperl TX. The storm had rained itself out, and with little to no precipitation to cool the resulting downdrafts, superheated air descended upon the community in the form of extremely hot wind gusts up to 75 mph (121 km/h). The temperature increased rapidly, reportedly peaking near 140°F (60°C).



593 ft (176 m) pressure during a storm could have dropped to 900 hPa

Would have been 19.4% RH with equivalent 95°F (35°C) wetbulb

thus $WBGT_{shade}$ = 0.7×95°F + 0.3×140°F = 108.5°F = 42.5°C



Freak Heat Wave Hits Lake Whitney

Tuesday night residents in the vicinity of Lakeside Village and Mooney Village experienced a freak weather condition that caused considerable damage and aroused fear among the residents.

Intense night heat that generated destructive windstorms, unroofing a number of buildings and toppling power poles and trees, climbed to 96 degrees. Residents, when their coolers stopped from the power failure, sought relief on the outside and found it hotter there than inside.

Water in radiators of cars driven during the time were said to boil, and corn and cotton, that the day before looked fine, were burned to a crisp. The weatherman reported that temperatures must have reached nearly 140 degrees for a brief time in spots. Pressure dropped swiftly, and glass in the Mooney store shattered outward. A number of the residents sought safety in a storm shelter.

The heat inside one resident's house was so intense that he thought his home was on fire.

What is the hottest air temperature ever recorded on planet Earth without dispute by WMO?

< 4 ft 11 in (1.5 m) above ground and shielded from direct sunlight >

In 2013 WMO decertified the previous all-time official hottest air temperature, 136.4°F (58.0°C) reading from Al Azizia, Libya, in 1923

The standing official highest registered air temperature on Earth is 134.1 °F (56.7 °C), recorded on 10 July 1913 at Furnace Creek Ranch, in Death Valley, California.

If the 1913 record were also decertified, the highest official recorded air temperature on Earth would be 129.2°F (54.0°C), also recorded in Death Valley on 20 June 2013, and the same value recorded in Mitribah, Kuwait on 21 July 2016.

There have since been higher readings of 54.4 °C (129.9 °F) in August 2020 and July 2021, both at Furnace Creek, that are pending validation.

Conclusions

- **Blue-green infrastructure (irrigated trees) can reduce ambient dry bulb temperature.**
- **Radiation increases heat stress.**
- **Shade trees are best outdoor relief from thermal stress.**
- **Architectural solutions may provide relief from heat but not from humidity –Passive designs are most effective providing shelter from rain, wind, and cold.**
- **Shelter provided with active mechanical building services may be necessary when ambient wet bulb globe temperature in shade ($WBGT_{shade}$) is unacceptably high.**

Questions?

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