

CLIMATIC CHANGE WE DON'T EXPECT: THE INCREDIBLE SHRINKING DIURNAL TEMPERATURE RANGE

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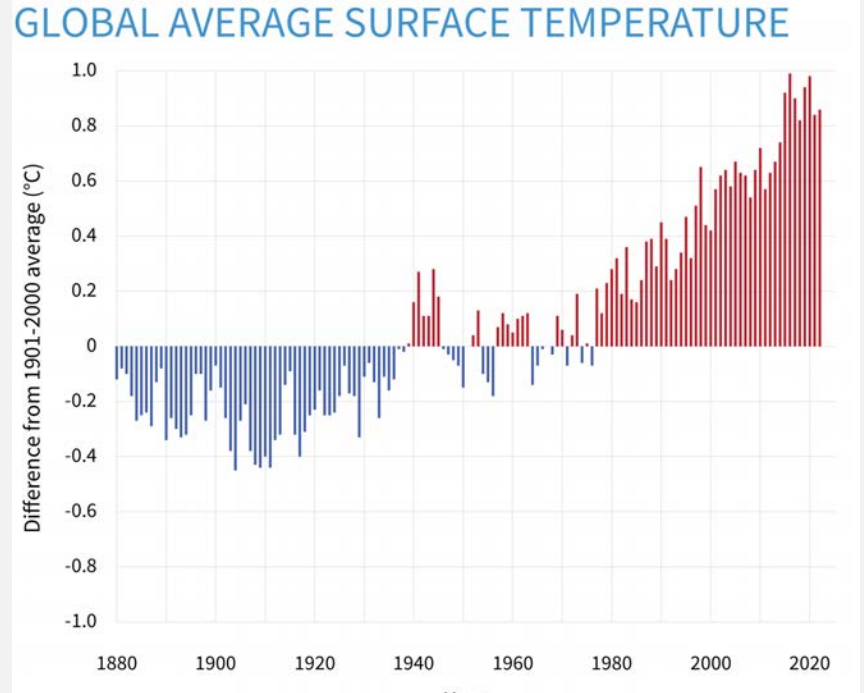
June, 2026

Acknowledgements

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McLeod
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Basic Premise

- Virtually all climate change analyses look at general meteorological variability across all air masses (e.g. global temperature has increased 1.2 degrees in the past 50 years).
- The critical question: which air masses are changing?
- If the **hot, dangerous air masses** are changing most, that has different societal implications than if the **cooler air masses** are changing.
- This differential is generally ignored!



Why are we concerned about heat?

- Heat is the **leading weather-related cause of death** in the U.S. and many other nations.
- Increases stress on the body which can raise the risk of cardiac arrest, stroke, and respiratory diseases, particularly in vulnerable populations.

What makes heat dangerous?

- Climate ***variability*** is more important than the actual temperature; mid-latitude areas most at risk; large variability in summer weather.
- Extended heat events, seasonality of a heat event (acclimatization), and excessive nighttime temperatures are most important contributors.

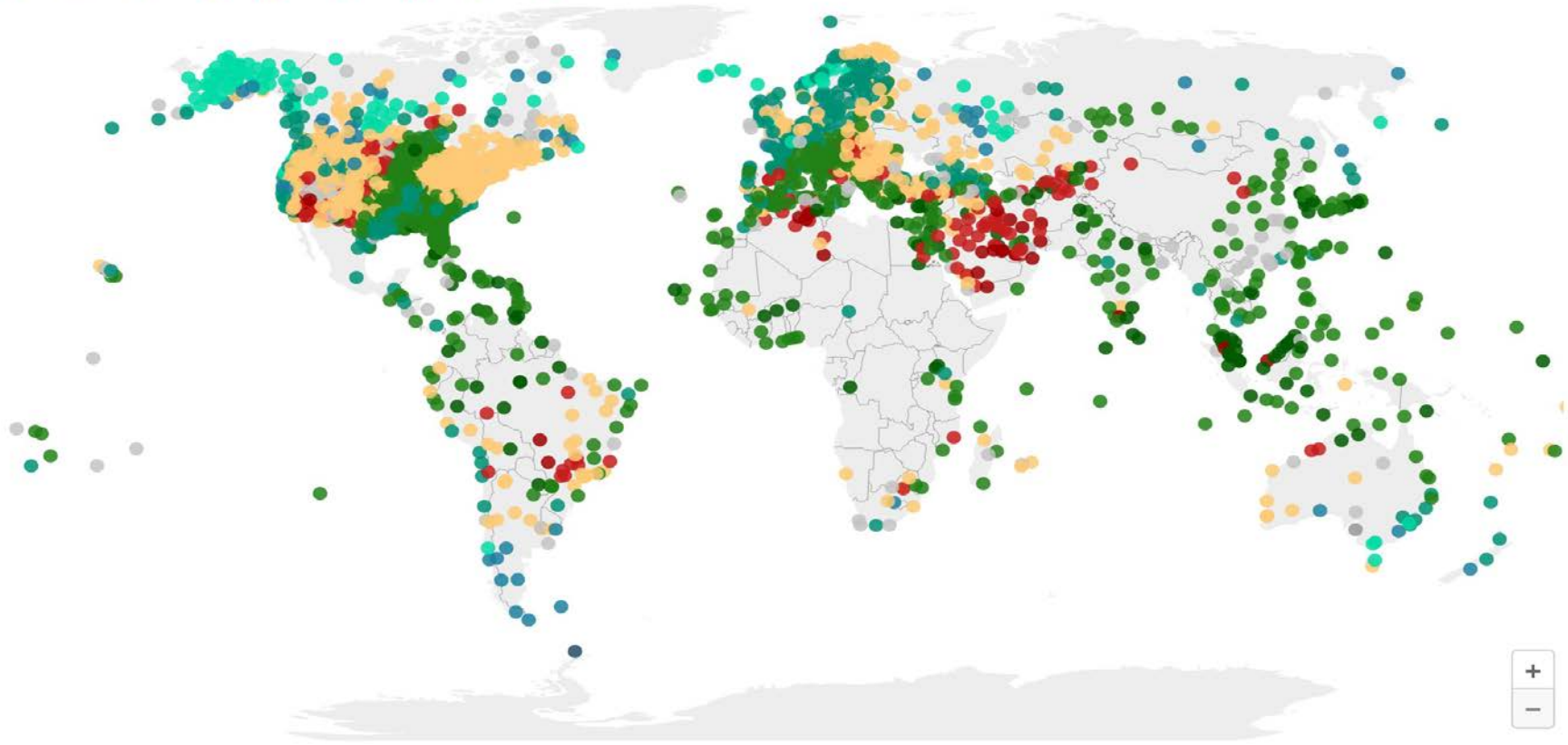
An Air Mass Approach to Evaluate Heat/Health Relationships

- We used the *Spatial Synoptic Classification (SSC)*; <https://sheridan.geog.kent.edu/ssc3.html> to categorize each day by air mass type....capturing the full “weather situations”.
- Two types particularly oppressive: DT and MT+.

Oppressive Hot Air Masses	
Dry Tropical (DT)	Represents the hottest and driest conditions found at any location. There are two primary sources of DT: either it is transported from the desert regions, or it is produced by rapidly descending air.
Moist Tropical+ (MT+)	Hotter and more humid subset of common MT, and thus captures the most "oppressive" subset of MT days. Air mass originates over warm water bodies. Warmest nights of any air mass.

Yesterday's SSC

DP DM DP+ DT DT+ MM MP MT MT+ TR TR+



Spatial Synoptic Classification: Dominant air masses in Newark, NJ 2022-2023

2022	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
June	MM	MT	MT	DT	DM	DM	DM	TR	TR+	DM	DM	MM	DT	DM	DM	MM	TR+	DM	DM	DM	DM	MM	MT	MT	DT	DT	MT	DM	DM	DT		
July	TR	MT+	TR	DT	TR	TR	MT	MT	DM	DM	DM	DT	TR	DT	DM	MT	MT	TR	DT	DT	DT	DT	DT	DT	DT	MT	DM	DM	MT	MT	TR+	DM
August	MM	DT	TR	MT+	MT	MT+	MT+	DT	DT	MT	TR	DT	DM	DM	DM	DM	DM	DT	DM	MT	MT	MM	MT	DT	DT	DT	MT	MM	MT	MT	DM	

Summer 2022: many **dry moderate (DM)**, **moist tropical (MT: hot and humid)**, and **dry tropical (DT: hot and dry)** days

2023	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
June	DM	DT	MM	DP	DM	DM	DM	DP	DM	DM	DM	MT	DM	MT	DM	DM	DM	DM	DM	DM	DM	MM	MM	MT	MT	MT	MT	MT	MT	DM	MT	
July	DM	MT	MT	MT	MT	MT	MT	MT	MT	MT	MT	DT	DT	MT	TR	MT	MT	TR	MT	MT	MT	MT	DM	DM	MT	MT	DM	MT	MT+	TR	DM	DM
August	DM	DM	DM	MM	DM	DM	MT	MT	DM	MT	DM	MT	MT	MT	MT	MT	MM	TR	DM	DM	MT	DM	DM	MM	MM	MT	DM	MM	MT	TR	TR	

Summer 2023: many **dry moderate (DM)** and **moist tropical (MT: hot and humid)** days;
few **dry tropical (DT: hot and dry)** days

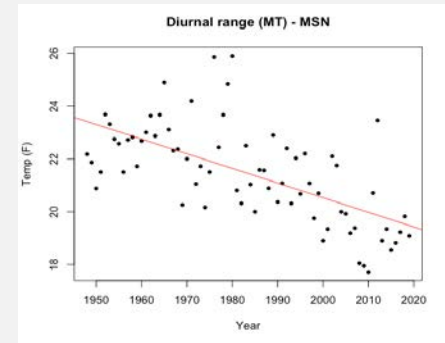
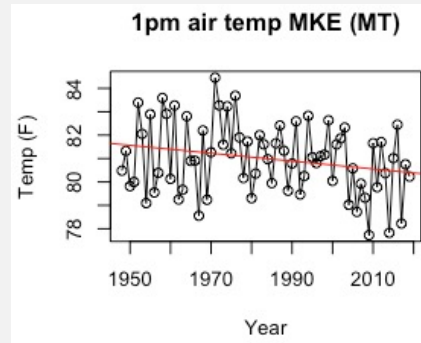
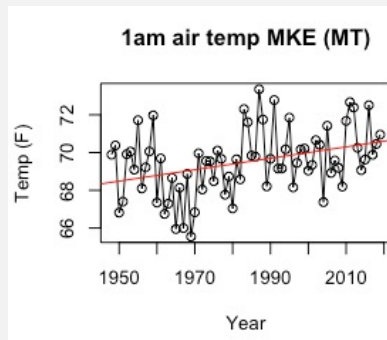
Goals of Analysis

- To determine whether the hottest and most dangerous (in terms of human health) air masses are changing in meteorological character and frequency.
- To quantify these changes from historical data records for at least 100 cities across the globe.
- To evaluate long-term changes in early morning and mid-afternoon temperatures and daily dewpoint temperatures.
- To determine if these dangerous air masses are becoming more or less frequent.
- To determine which regions are showing the largest, and least, changes over time.

Background*

*Great thanks to Dr. Elizabeth Berg,
Duke University

- Our previous work in the Midwest suggests minimum temperatures are warming more rapidly than maximums in the hottest air masses.
- Thus, the mean daily diurnal change within these air masses is shrinking at a relatively rapid rate.
- We needed to expand the work globally, since there are important human health implications to this finding, especially if it is worldwide.

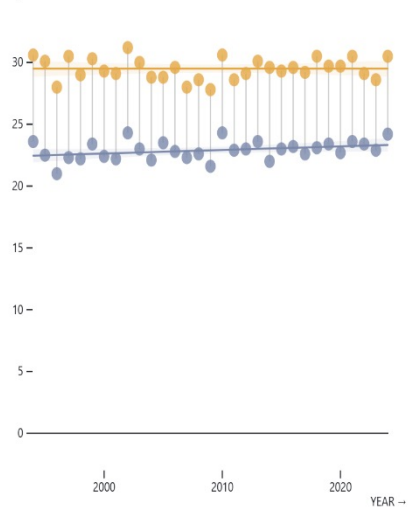


Air Mass Character: Our Most Frequent Result

Atlanta, USA MT air mass

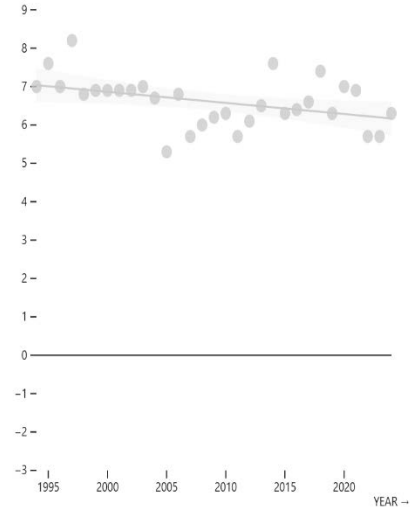
AM & PM temperature over time

1 temperature



Diurnal Temp Range over time

1 temperature

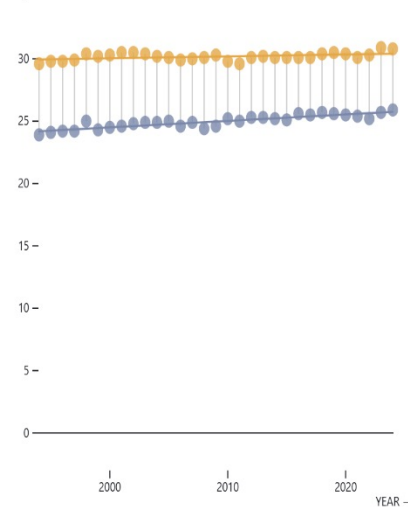


DTR drops 1°F every 16.7 years

Jakarta, Indonesia MT air mass

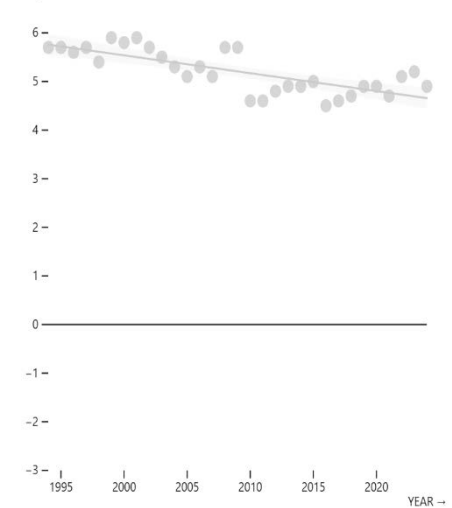
AM & PM temperature over time

1 temperature



Diurnal Temp Range over time

1 temperature



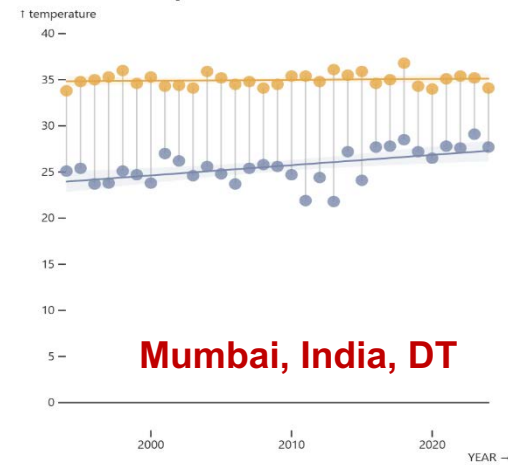
DTR drops 1°F every 15.1 years

Summary of Results

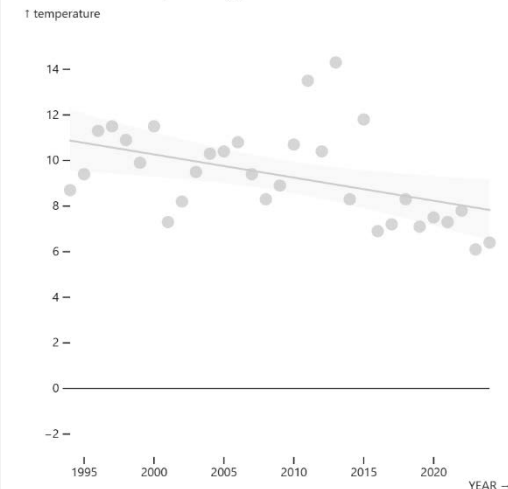
- Evaluation was performed for 100 cities around the world in all climates
- We evaluated mean annual afternoon and morning temperatures for the dry tropical (DT) and moist tropical (MT) air masses.
- These air masses are associated with increased heat-related mortality.
- Analysis was performed for 30 years from 1995-2024.

- The vast majority of cities showed little change in afternoon temperature for both air masses; in half, there was a slight decrease.
- Notably significant increases in early morning temperatures.
- Large decreases in diurnal temperature range for both air masses, often exceeding 2°C (3.6°F).
- In US and European cities, where longer datasets were available, similar results and slopes.
- These changes in climate within the most dangerous air masses usually exceeded those found in general climate change evaluations where air masses are not distinguished.

AM & PM temperature over time

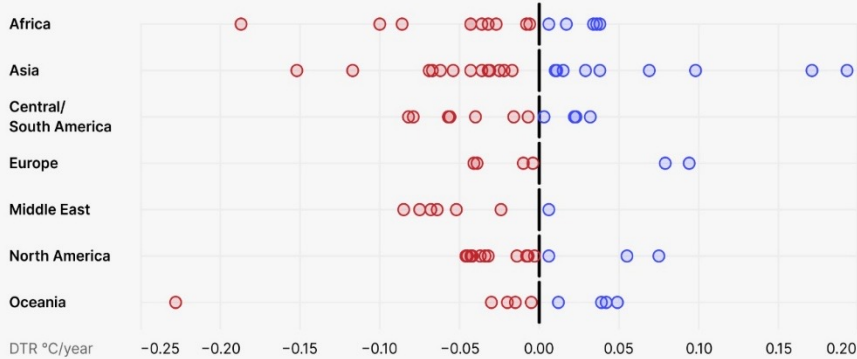


Diurnal Temp Range over time



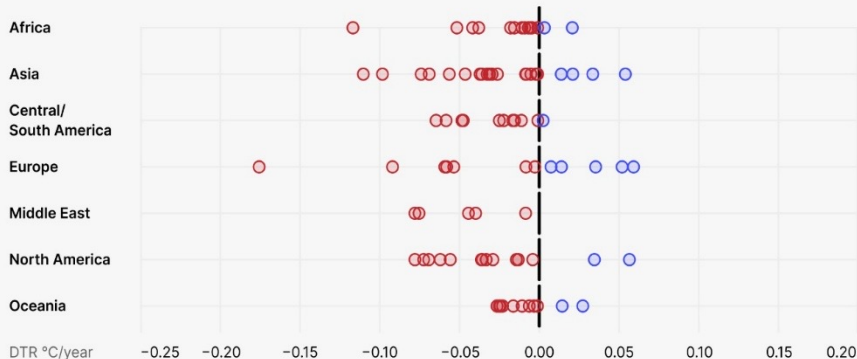
Changes in DTR for DT, Split by Region

16 out of 100 cities excluded for incomplete data



Changes in DTR for MT, Split by Region

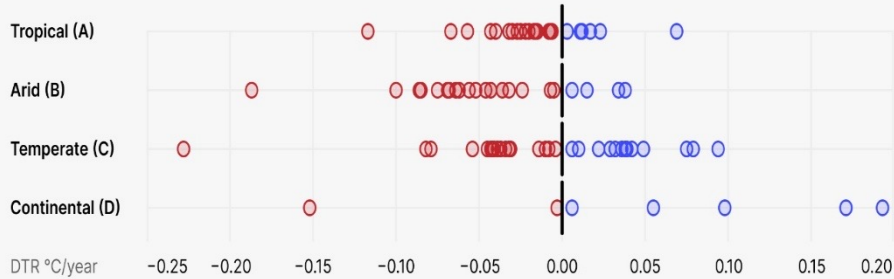
8 out of 100 cities excluded for incomplete data



- Large majority of cities show decreasing DTR for both air masses; 68% for DT, 83% for MT
- Most pronounced results in Middle East and North America for DT; almost everywhere for MT.
- MT results very robust; 5:1 ratio between decreasing:increasing DTR.

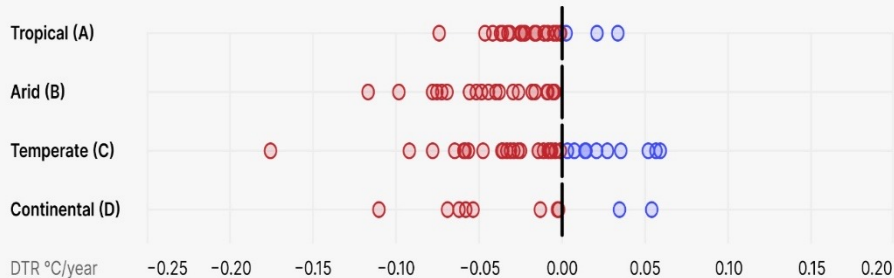
Changes in DTR for **DT**, Split by Köppen Climate Region

16 out of 100 cities excluded for incomplete data



Changes in DTR for **MT**, Split by Köppen Climate Region

8 out of 100 cities excluded for incomplete data



- Largest changes in “A” (tropical) and “B” (arid) climates for both air masses.
- Weakest results for “C” (temperate) and “D” (cold continental) climates, especially for DT air mass.
- DT is rare in “D” climates.
- Thus, low latitude and arid environments seem especially impacted.

Köppen classification examples: “A”: Singapore, Mumbai, Mombasa; “B”: Las Vegas, Cairo, Amman; “C”: Dallas, Rome, Portland; “D”: Chicago, Seoul, Stockholm.

DECREASES IN DTR IN DEGREES (C) PER YEAR

DTR Decrease (°C /year)	Years for DTR Decrease of 1°C	Number of Cities	
		DT	MT
> 0.075	13.3	11	10
0.050 - 0.074	13.3 – 20	9	13
0.030 - 0.049	20 - 33.3	20	16
0.015 - 0.030	33.3 - 66.7	3	14

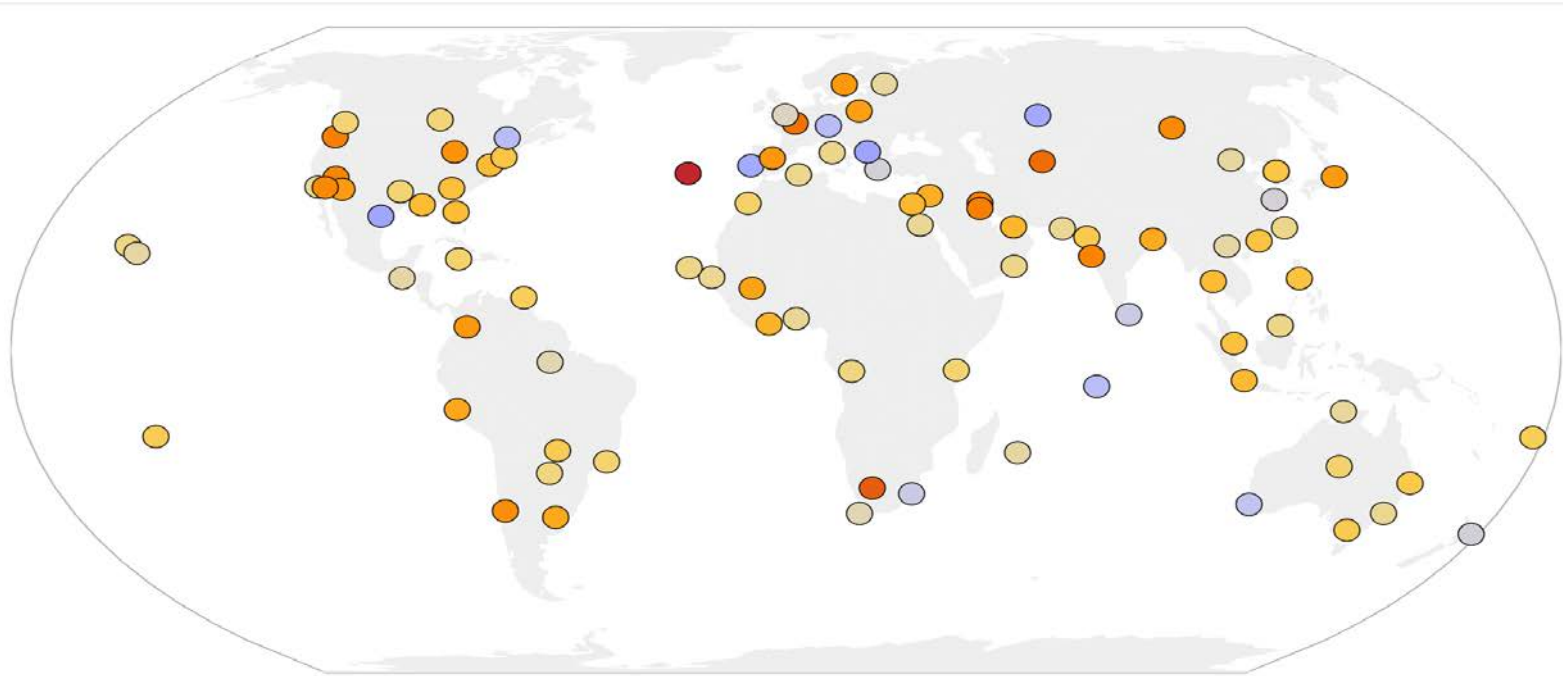
- A sizable number of locales show a greater than 1°C decrease in less than 20 years.
- Most of these reside in Asia, the Middle East, and Africa.
- These all represent unexpectedly large changes for the most dangerous air masses.

Daily Temperature Range

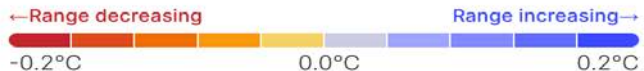
Hot & Humid Air Mass (1995-2024)



CLIMATE
RESILIENCE
FOR ALL



Average daily temperature range change per year since 1995



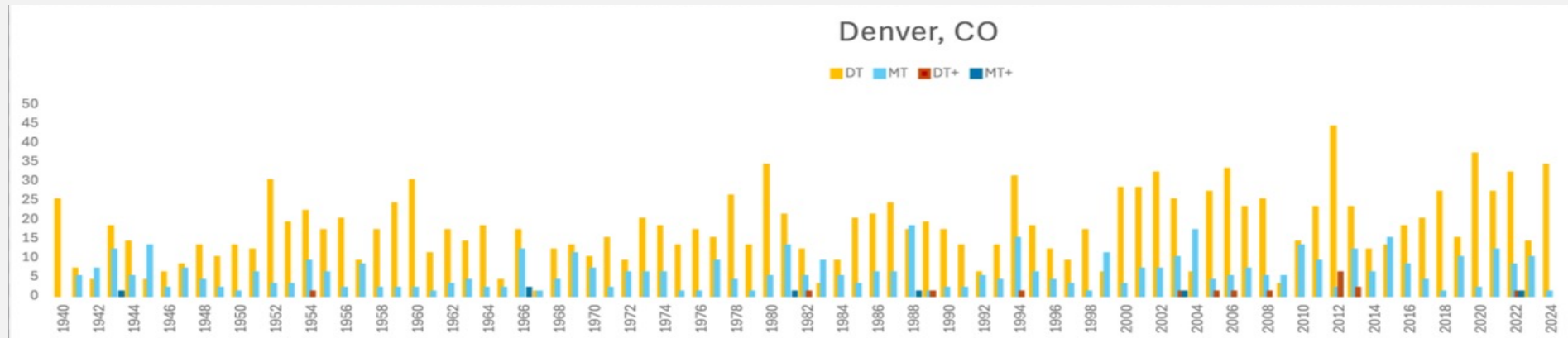
DT and MT Air Mass Character Summary

- The results confirm our hypothesis; for most locations, afternoon temperatures vary little and often decline slowly, morning temperatures are increasing, sometimes rapidly, and DTR is shrinking rapidly.
- The results are globally universal, although there is some regionality, with stronger results in warmer and drier climates and the MT air mass.
- We also evaluated dewpoint, which surprisingly showed little consistency; some rose and some fell over time.
- These unexpectedly rapid changes in the most dangerous air masses have major human health implications.

Air Mass Frequency Analysis

- We evaluated the changes in frequency of DT and MT air masses through time to determine significant changes.
- We hypothesize that both air masses are demonstrating increases in frequency, along with the already-detected character changes.

DT and MT Air Mass Frequency Analysis



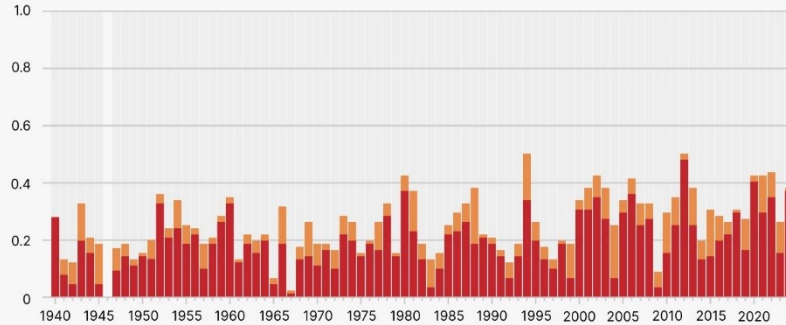
DT occurs, on average, 27% of days in Denver. DT slope: 0.13, or an increase of 1 day every 7.6 yr.
MT occurs, on average, 10% of days in Denver. MT slope: 0.04, or an increase of 1 day every 25 yr.

Denver, USA: Proportion of summer days classified as DT or MT

MT days are becoming more frequent by 0.04 days each year; or 1 additional day every 27.2 years

DT days are becoming more frequent by 0.13 days each year; or 1 additional day every 7.7 years

↑ Proportion of Summer Days

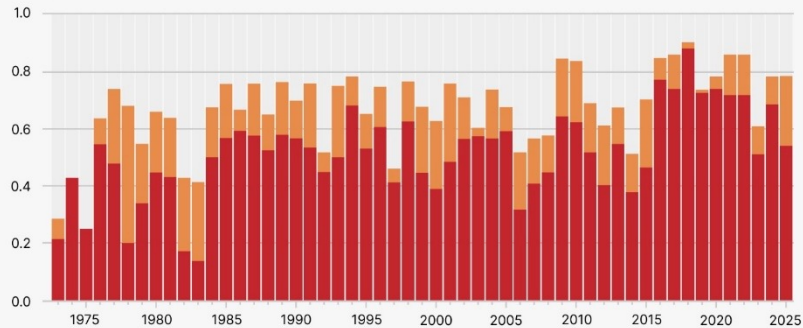


Ahmedabad, India: Proportion of summer days classified as DT or MT

MT days are becoming less frequent by 0.06 days each year; or 1 fewer day every 15.5 years

DT days are becoming more frequent by 0.36 days each year; or 1 additional day every 2.8 years

↑ Proportion of Summer Days

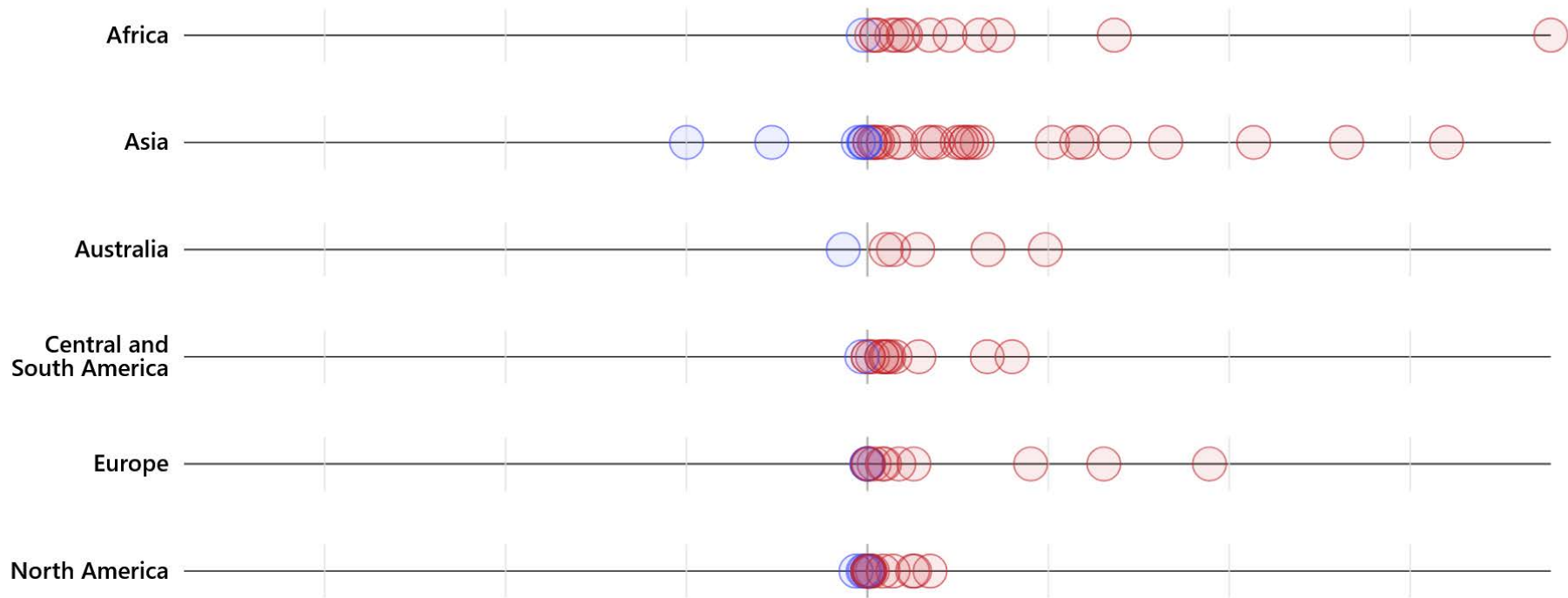


- Dangerous air masses becoming more frequent, and often, rapidly.
- Ahmedabad may represent a case of “air mass piracy”; DT increasing at the expense of MT.
- Happening in other hot semi-arid places as well; locales in Turkey, Uzbekistan, Kazakhstan, and Australia.
- Many cities with frequent DT days are showing increases of 1 day every 10 years or less!
- Most MT cities outside of arid areas are showing increases in frequency.

Frequency of Hot & Dry Air Mass days, split by Region



← **Becoming less frequent** | **Becoming more frequent** →



Implications

- The character of the most health-debilitating air masses in summer is changing, as is the frequency.
- These changes appear to be more rapid than more benign air masses.
- Diurnal temperature decreases imply less overnight relief during these hot air mass incursions, especially in less developed locales. Health dangers to the vulnerable need to be re-defined.
- The implications on delivering effective heat-health warnings and associated interventions are great.

Present Heat Wave Warning System in Seoul, Korea

Only Maximum Temperature-Dependent!

Level	Standard of judgment	Major action	Response level	Active operators
Blue	<ul style="list-style-type: none"> Heat wave watch (May 20–Sep. 30) 	Monitor signs	Ready for action	Task force (3 teams; 17 people)
Yellow	<p>[Heat wave alert]</p> <ul style="list-style-type: none"> It is expected the maximum apparent temperature during the day is 33°C or higher for more than two days. Severe damage is expected due to a rapid temperature increase and prolonged heatwave. 	Review the relief plan and monitor heat wave	Level 1 response	Control center (5 teams; 7 people)
Orange	<p>[Heat wave warning]</p> <ul style="list-style-type: none"> It is expected the maximum apparent temperature during the day is 35°C or higher for more than two days. Severe damage is expected in extensive areas due to a rapid temperature increase and prolonged heat wave. 	Review the relief plan and monitor heat wave	Level 2 response	Control center (7 teams; 9 people)
Red	<ul style="list-style-type: none"> The heat wave warning is prolonged and large-scale damage is expected. 	Take action immediately	Level 3 response	Seoul Metropolitan Disaster & Safety Countermeasures Headquarters (13 teams; 39 people)

Where Do We Go From Here?

- Most warming is likely UHI-driven, amplified by increasing urban density, particularly in dry climates and developing countries. Are similar changes occurring in rural areas? Is the warming just urban?
- With temperature ranges decreasing, you would expect higher dewpoints; this is *not* occurring, as spatial dewpoint changes have been highly variable.
- Another possibility is greater cloud cover, which would have a similar effect.
- Contradictory evidence on cloud cover; some say it's increasing, others say it's decreasing.
- The role of increasing air conditioning use in urban areas has been understudied. My opinion: this plays an oversized role in what's occurring!

Implications for CRRC Attendees

- Are cool roofing materials, cool walls, and cool pavements beneficial in depressing nighttime, as well as daytime, temperatures?
- I assume they are not (I am no expert on roofing materials!!), but how would you alter materials to account for the overnight warming that is occurring?
- With these changing urban climates, how does CRRC testing evolve?
- How do these climate changes impact pollution-absorbing roofs/granules?
- CRRC-member participation would be helpful; we don't know how cool-roofing priorities should be shifted with this new information! Who would like to partner with us on future research??

Future Directions Based on This Research

- Indisputably, the issuance of heat warnings, and subsequent interventions, have to be modified in a way to emphasize decreasing DTR during dangerous air mass intrusions.
- Further research is needed into the causes of these air mass alterations.
- Research needed to evaluate cloud cover impacts within oppressive air masses.
- Must determine climate-altering role of widespread air conditioning in densely populated regions; rural vs. nearby urban evaluations might provide a clue.
- CRRC's role?