Report

Heat threshold report

Tanzania

Climate
Centre

Introduction

Extreme heat is becoming a significant public health hazard, driven by rising global temperatures and rapid urbanization. Exposure to extreme heat contributes to increased mortality and morbidity, reduced incomes and growing burdens on health and emergency services. Despite these impacts, extreme heat remains insufficiently integrated into early warning and preparedness systems in many countries.

A major limitation in heat risk management is the use of uniform temperature thresholds across diverse climatic contexts. The reason behind this non-consensual definition is that the health impacts of a given temperature vary widely depending on local climatology, population acclimatization, urban characteristics and underlying vulnerability. Thresholds developed in temperate regions or based on global standards often fail to capture locally relevant extremes in tropical cities, leading to delayed or ineffective warnings. This highlights the need for locally calibrated heat thresholds that reflect how extreme heat manifests in specific environments.

For heat risk management purposes, locally defined thresholds provide a more operational and context-appropriate basis for early warning systems, especially in settings where heat–health impact data are limited or where formal heat action plans are not yet established. By anchoring thresholds in local climate statistics and seasonal patterns, such approaches improve the relevance and credibility of heat alerts and support more timely decision-making.

Purpose

This analysis aims to develop heat thresholds for selected urban locations in Tanzania using available long-term station-based temperature data. Tanzania's largest city and financial hub, Dar es Salaam, along with the island of Zanzibar were considered because of the availability of this data. The results are intended to support the activation and strengthening of early warning systems (EWS) in a context where EWS are not currently tailored to heat risk in order to strengthen public health preparedness.

Methods

Methodological approach

This analysis adopts a climatology-based percentile threshold approach to characterize extreme heat conditions in selected urban locations. Rather than applying fixed temperature thresholds, the method identifies locally relevant extremes based on the statistical distribution of daily maximum temperatures. More specifically, the 90th (P90) and 95th (P95) percentiles of daily maximum temperatures were selected as they are widely used in climate risk and heatwave analyses and are suitable for operational EWS.

To capture seasonal variations in temperature and acclimatization, thresholds were initially calculated on a monthly basis using a July to June 'year'. Heatwaves were defined as periods of three or more consecutive days exceeding the monthly threshold – a definition that balances scientific robustness with operational simplicity. A yearly average threshold was also calculated using the entire period time series to provide a more (statistically) significant threshold.

Data sources

The analysis is based on daily station observations of maximum temperature (Tmax), minimum temperature (Tmin) and precipitation obtained through the Climate Data Online (CDO) portal of the National Centers for Environmental Information (NCEI), part of the National Oceanic and Atmospheric Administration (NOAA) in the US (https://www.ncei.noaa.gov/cdo-web/datasets).

For the Tanzania case study, data from Dar es Salaam Airport and Zanzibar International Airport were used for the period of July 2000 to June 2024. Station observations were preferred because they provide direct, location-specific measurements suitable for threshold development and operational use. We also used the CHIRTS-daily gridded temperature dataset (Climate Hazards Center Infrared Temperature with Stations or CHIRTS-daily) – based on satellite thermal infrared observations, *in situ* station data and reanalysis inputs – to compute grid-point thresholds (https://www.chc.ucsb.edu/data/chirtsdaily). However, this dataset only provides temperatures up to 2016.

Data processing and limitations

Preliminary data processing included unit harmonization (from Kelvin to Celsius), the removal of unrealistic values and an assessment of missing data. Periods with substantial data gaps prior to 2000 were excluded to ensure the robustness of the climatological analysis. Missing values, particularly for maximum temperature, remain a limitation and may affect some monthly statistics. In addition, the analysis focuses on air maximum temperature only and does not explicitly account for humidity; although in the case of Dar es Salaam and, more importantly, Zanzibar, this can play a crucial role later. In some contexts, minimum temperatures during nighttime can also be used to characterize extreme heat events as their impact on human health can be very detrimental. Due to time constraints, direct engagement with the national meteorological and hydrological service (NMHS) was not possible during the analysis phase. However, the results and proposed thresholds were shared with relevant meteorological authorities for review, supporting transparency and potential future operational use.

Results and discussion

Heat threshold values

The analysis identified city-specific extreme heat thresholds based on the distribution of daily maximum temperatures (Tmax), using percentile-based metrics that reflect locally relevant extremes. Both monthly and overall (July to June) thresholds were derived; the latter provide indicative values for high-level alerting and comparison across locations. Monthly thresholds exhibit strong seasonality, with the highest values occurring during the warm season (November to March). These monthly thresholds provide a more operationally meaningful basis for early warning activation than a single fixed threshold, particularly in tropical climates with limited annual temperature variability.

For example, Figure 1 shows that applying a single annual 90th percentile results in a threshold of 33.6°C for Dar es Salaam. In contrast, a month-specific approach yields substantially higher thresholds during the climatologically hottest months, reaching 34.5°C in February to March. A similar pattern is observed for Zanzibar: while the overall 90th percentile corresponds to 33.3°C, monthly thresholds increase to approximately 35°C in February to March.

Figure 1: Monthly and annual average P90 (left) and P95 (right) for Zanzibar (blue) and Dar es Salaam (red) computed from the ground-based station. Period = 2000–2024

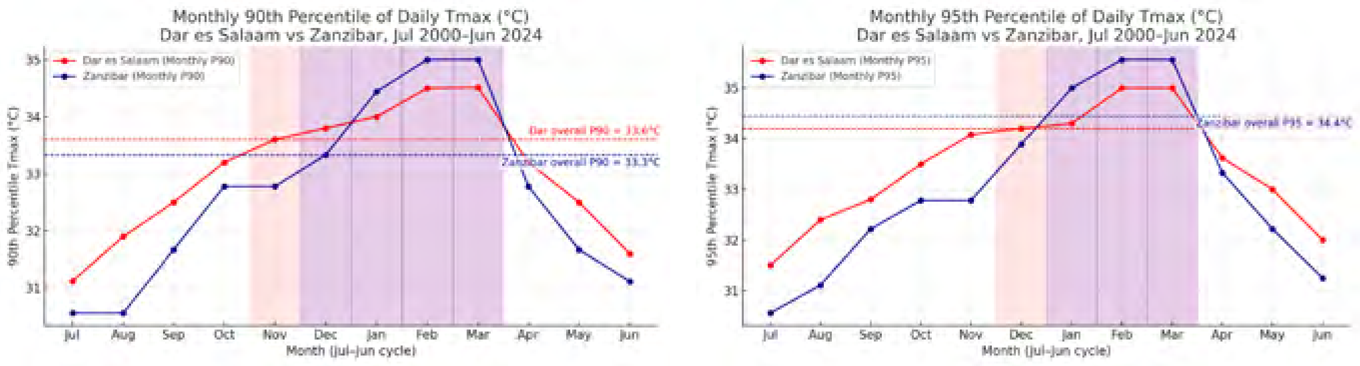


Table 1: P90 extracted from CHIRTS: 1985–2016 period

city	latitude	longitude	tmax_p90
Songea	-10.7	35.7	33.1
Mtwara	-10.3	40.2	32.6
Mbeya	-9.0	33.5	29.7
Iringa	-7.8	35.7	27.5
Morogoro	-6.8	37.7	33.8
Dar es Salaam	**-6.8**	**39.2**	**32.9**
Dodoma	-6.2	35.8	33.5
Tanga	**-5.1**	**39.1**	**33.5**
Tabora	-5.0	32.8	34.5
Kigoma	-4.9	29.6	32.9
Singida	-4.8	34.7	31.6
Shinyanga	-3.7	33.4	34.3
Arusha	-3.4	36.7	31.4
Moshi	-3.3	37.3	33.5
Mwanza	-2.5	32.9	31.7

Differences between cities

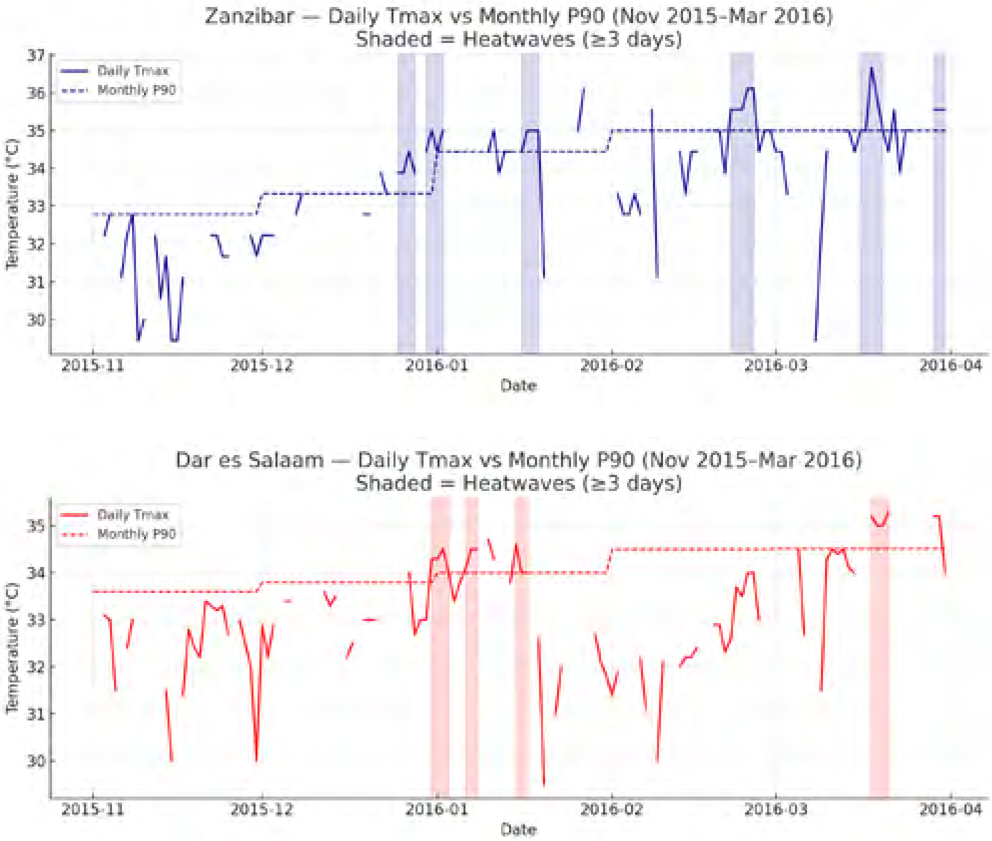
The table values extracted from CHIRTS show Tmax thresholds for different cities in Tanzania. Clear differences emerge between the cities and, for instance, Dar es Salaam (32.9°C) and Iringa (27.5°C) which is located over the southern highlands of Tanzania at an elevation of about 1,600–1,700 metres above sea. Applying a single national or regional threshold would therefore over-trigger alerts in Iringa, highlighting the importance of city-specific calibration.

Heatwave analysis

A practical use of the threshold is in the detection of heatwaves as periods of prolonged extreme heat with important consequences for humans and their livelihoods as well as ecosystems. In this analysis, heatwave events correspond to more than three consecutive days in which maximum temperatures are above the identified thresholds (P90). For example, Figure 2 shows heatwaves detected between November 2015 and March 2016.

Heatwave analysis reveals differences in the frequency, duration and intensity of these events between Dar es Salaam and Zanzibar. While Dar es Salaam tends to experience longer and more intense heatwaves during peak months, Zanzibar shows shorter but recurrent events. Over the period 2000–2024, the longest heatwave in Dar es Salaam lasted nine days (in early February 2011), while in Zanzibar the longest heatwave lasted six days in November 2009. In both cities, the most intense heatwave occurred in the month of February with 39°C in Zanzibar and nearly 36°C in Dar es Salaam. These distinctions have direct implications for preparedness planning and response strategies.

Figure 2: Example of heatwave detection between November 2015 and March 2016 using the monthly P90 threshold.



Furthermore, differences are observed when comparing weather station data with CHIRTS. While the station observation threshold is 33.6°C for Dar es Salaam, CHIRTS shows 32.9°C. Although no clear justification can be given for this difference, it is reasonable to think that with increased warming the temperatures from the last decade could have impacted the thresholds.

Caveats and limitations

Amongst the limitations of this analysis, the limited number of stations (2) should be noted. A better collaboration with the NMHS could have helped make use of data for the entire country and provide more thresholds. While the aim of this study was to establish city-level operational warning thresholds, it is important to acknowledge intra-urban exposure may differ, particularly in informal settlements. Missing data may affect some statistics, although overall patterns remain robust. The thresholds are climate-based rather than impact-based, as health outcome data were not available and humidity or composite heat stress indices were not included. As such, the results should be interpreted as operational guidance to support early warning and anticipatory action, rather than definitive health-risk thresholds.

Implications for early warning systems and anticipatory action

When combined with predictive weather information, the identified thresholds provide a practical basis for heat early warning systems in Tanzania. For instance, if the forecast Tmax at day 4 (four days lead time) is expected to be higher than P90 for at least three consecutive days (between day 4 and day 7), then the Tanzania Meteorological Authority can trigger a heatwave early warning system – the P90 threshold can serve as an early alert or preparedness trigger, while the P95 threshold can support escalation to higher alert levels and targeted anticipatory actions. By aligning warnings with locally relevant extremes, these thresholds improve the credibility, timeliness and usefulness of heat alerts for public health authorities and humanitarian actors.

Conclusion

This analysis focuses on the importance of locally calibrated heat thresholds to strengthen early warning systems and support anticipatory action in urban environments in Tanzania. By deriving city-specific thresholds from long-term temperature observations, the study provides a practical alternative to uniform temperature criteria, which often fail to reflect locally relevant heat risk. Percentile-based thresholds offer an operationally feasible basis for heat alert activation in data-limited contexts.

Within a skillful early warning system, the identified thresholds can support a graduated alert framework, where the P90 threshold triggers early preparedness actions and the P95 threshold signals severe heat conditions requiring escalation. Such triggers can inform public health messaging – early activities that help translate heat warnings into concrete action. The window of opportunity for anticipatory action depends, however, on the capability of the weather prediction system to accurately forecast the Tmax.

Additional analyses including the incorporation of humidity and heat stress indices in connection with health outcome data, together with vulnerability and exposure factors, can help develop impact-based thresholds. Extending the approach to additional stations and cities would also support broader national planning. Although direct engagement with the NMHS was constrained by time, the results were shared with relevant meteorological authorities for review. Going forward, meteorological authorities could integrate these thresholds into routine climate monitoring and heat advisory products, in coordination with health and disaster management partners. To remain effective under a changing climate, heat thresholds should be periodically updated to reflect evolving temperature regimes, urbanization and population vulnerability.

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