Met Office

Burkina Faso climate context for seasonal forecasts:

March-April-May climatology

WISER

Weather and Climate Information Services

Document history

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Introduction

Seasonal forecasts provide insight into the climate conditions of an upcoming season for a specific climate variable (e.g., average temperature over a three-month period). Typically, these forecasts express the likelihood of the season being above, near, or below 'normal' – known as tercile probabilities. Each tercile category represents 33% of the historical distribution of climate conditions (MacLeod and Klassen, 2019). The tercile categories are defined by historical model simulations of climate conditions, known as hindcasts.

Understanding average climate conditions helps identify what is considered ‘normal’ for a region, and highlights impacts associated with a typical season (Daron, 2019). Recalling past years when conditions where above or below normal for a given climate variable can reveal the risk associated with more extreme conditions. By considering long-term climate variability and its effects, seasonal outlook service providers can use seasonal forecast more effectively and make better informed decisions (Daron, 2019).

Document aim and methods

This document presents a climate context and summary analysis of Burkina Faso’s climatology using the 30-year standard climate normal (averaging) period from 1991 to 2020 and includes additional time series from 1979 onward where relevant. The analysis adds context to tercile categories, helping seasonal outlook providers assess the potential impacts of seasonal variations and make informed decisions. It focuses on seasonal temperature patterns to better understand climate variability and trends, examining average monthly, daily maximum, and daily minimum temperatures for the March–April–May season.

Burkina Faso experienced an intense heatwave during March–April 2024, which impacted infrastructure and increased mortality across the region (World Weather Attribution, 2024). The analysis compares this extreme heat event to the 1991–2020 long-term average and identifies regional and location-specific temperature anomalies.

This document is divided into three main sections. First, **Climatology and the 2024 heatwave**, examines the average temperatures during the 1991-2020 period and compares them with the extreme heatwave temperatures experienced in 2024. The second section, **Burkina Faso heatwave analysis**, provides an analysis of heatwaves in Burkina Faso from 1979 to 2025, using specific thresholds to identify and assess the frequency and intensity of heatwaves. The final section, **Comparison of observations with reanalysis**, compares observational data with ERA5 reanalysis data to identify differences and assess the reliability of reanalysis data for representing Burkina Faso's climate

ERA5 reanalysis data

Access to observational data proves difficult due to limitations in network coverage and differences in station observation records. Gridded reanalysis data was chosen as an accessible, high-resolution, model-based alternative to observational data for representing 2-metre (2m) temperature. Climate reanalysis combines model data (such as forecasts from numerical weather predictions) with observational data using data assimilation methods to generate a complete and consistent temporally and spatially smoothed dataset of climate variables (Copernicus, 2025; Gbode et al., 2023; Parker, 2016). The data assimilation process is used to estimate the state of the climate system as accurately as possible using available information (Parker, 2016) and provides a description of climate variables over time for different spatial scales.

Analysis data used here were derived from the fifth generation of the European reanalyses, ERA5[1]. The EU funded ECMWF reanalysis data is freely available through the Copernicus Climate Change Services (C3S)[2]. Through its partnership with the African Centre for Meteorological Applications for Development (ACMAD), the European Centre allows meteorological services in the Sahel to access select ECMWF high-resolution real-time forecast data, including 2m temperature[3] (Guigma et al., 2021).

Reanalysis data has its limitations and varies in accuracy across regions, terrain and among variables; although temperature data are usually more reliable than precipitation (Gbode et al., 2023). ERA5 reanalysis data are available on regular latitude-longitude grids at 0.25˚ x 0.25˚ resolution (Copernicus, 2025) and therefore do not represent variations in temperature within a smaller spatial scale (for example the influence of an urban heat island affect). However, ERA5 reanalysis data performs well in reproducing 2m temperature over west Africa and the

[1] ECMWF Reanalysis v5 (ERA5) https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5
[2] Fact sheet: Reanalysis | https://www.ecmwf.int/en/about/media-centre/focus/2023/fact-sheet-reanalysis
[3] Datasets for African Center of Meteorological Application for Development (ACMAD) https://www.ecmwf.int/en/forecasts/datasets/datasets-african-center-meteorological-application-development

Sahel compared to gridded observation datasets, and is recognised as a suitable dataset for climate monitoring of temperature over a region and for representing temperature trends (Gbode et al., 2023).

1. Climatology and the 2024 heatwave

1.1. Average temperature

The seasonal mean temperature, along with the seasonal mean of the daily maximum and minimum temperatures for Burkina Faso, were produced using ERA5 reanalysis data. The data used to produce the 1991-2020 climatology are presented in Appendix 1.

The 1991-2020 long term mean temperature for Burkina Faso for the March-April-May season is 32.1˚C. The seasonal mean daily maximum and minimum temperatures are 38.0˚C and 26.4˚C respectively. The seasonal mean temperature, and daily maximum and minimum temperatures for the region are presented in Figures 1 and 2 respectively.

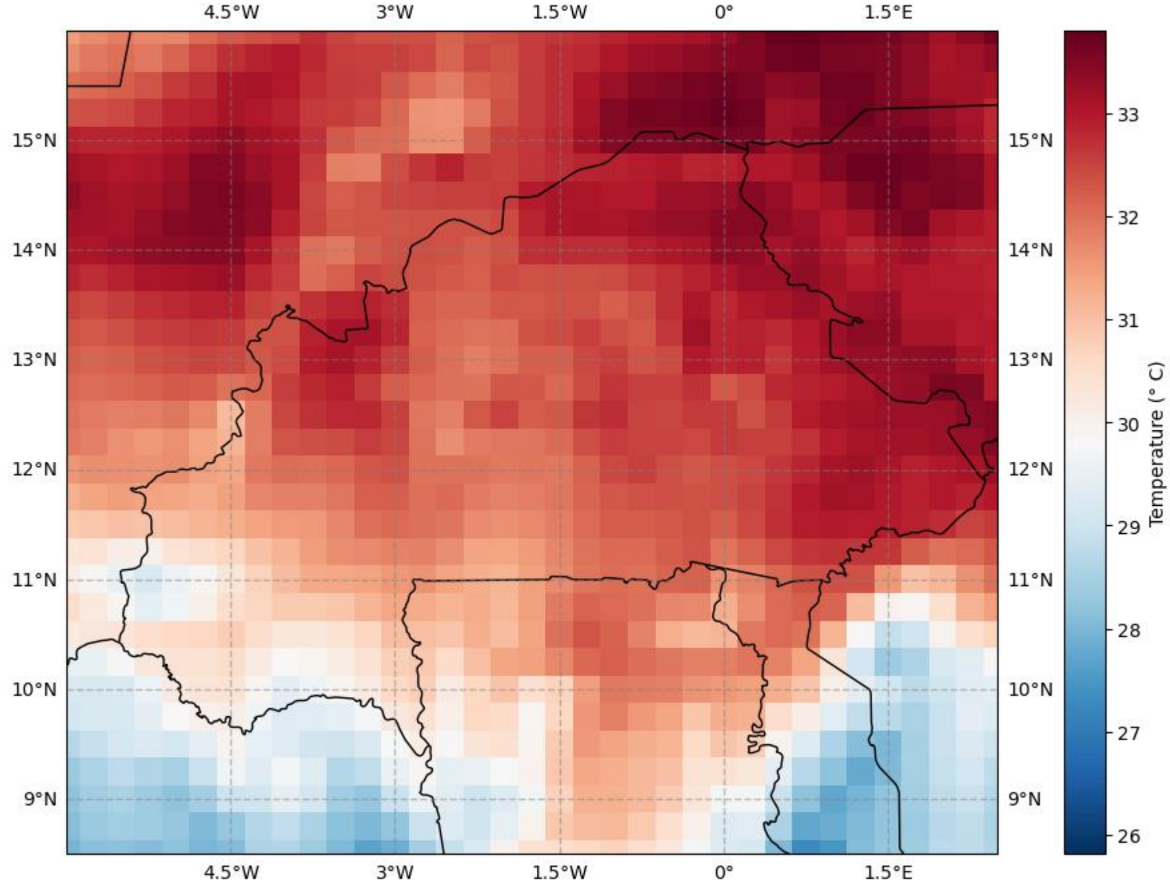


Figure 1. *1991-2020 mean temperatures for the March-April-May season.*

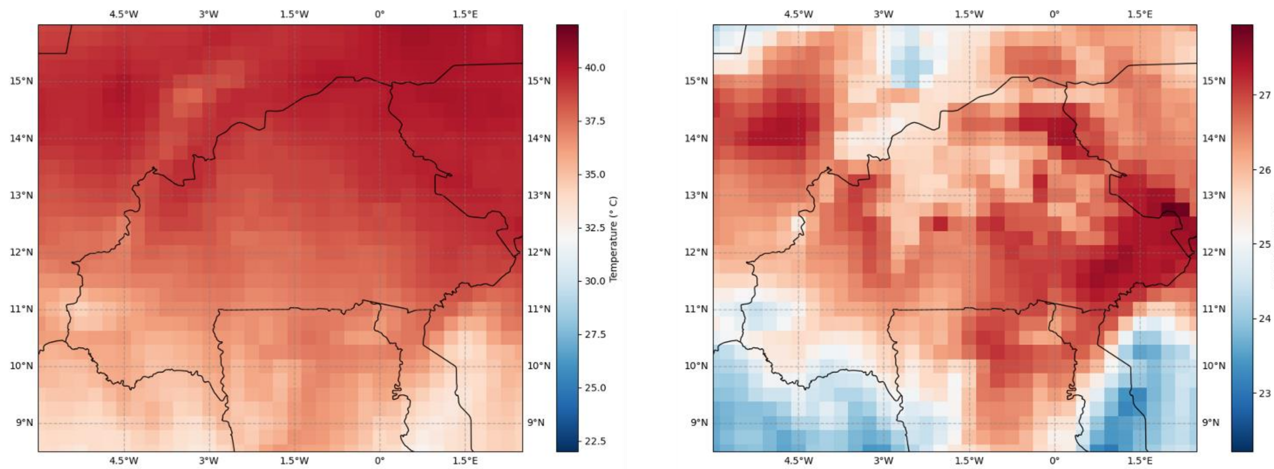


Figure 2. *1991-2020 mean daily maximum temperatures (left) and minimum temperatures (right) for the March-April-May season.*

Temperatures vary across the country with a general gradient in temperature showing hotter conditions in the north and east, and cooler conditions towards the southwest. The variations in temperature at different six locations across Burkina Faso are presented in Table 1.

Table1. *1991-2020 seasonal mean, mean daily maximum and minimum temperatures for March-April-May for six locations across Burkina Faso.*

Location	**Latitude, Longitude**	**Seasonal mean temperature (˚C)**	**Seasonal mean daily maximum temperature (˚C)**	**Seasonal mean daily minimum temperature (˚C)**
Ouagadougou	12.35N, -1.52E	32.1	37.7	26.5
Dori	14.03N, -0.03E	33.4	39.6	27.4
Gaoua	10.33N, -3.18E	30.4	35.7	25.4
Fada N'Gourma	12.3N, 0.37E	32.4	38.0	27.0
Boromo	11.75N, 2.93E	32.2	37.8	26.7
Bobo-Dioulass	11.17N, 4.32E	31.0	36.4	25.9

The seasonal mean temperatures from 1979 to 2025 for the six locations across Burkina Faso are plotted as a time series in Figure 3. The figure shows that mean temperatures have increased for all locations over this period, with year-to-year variations around the warming trend.

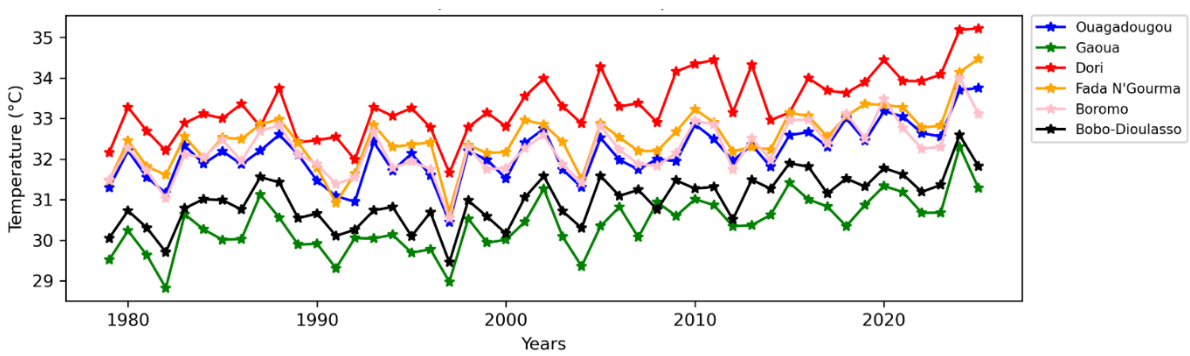


Figure 3. *Time series of seasonal mean temperature for March-April-May from 1979-2025 for six locations across Burkina Faso.*

The seasonal mean daily maximum and minimum temperatures for the six locations are plotted as a time series from 1991 to 2020 in Figures 4 and Figures 5. As with seasonal mean temperatures, an increasing temperature trend is notable from 1991 to 2020 around the year-to-year variability.

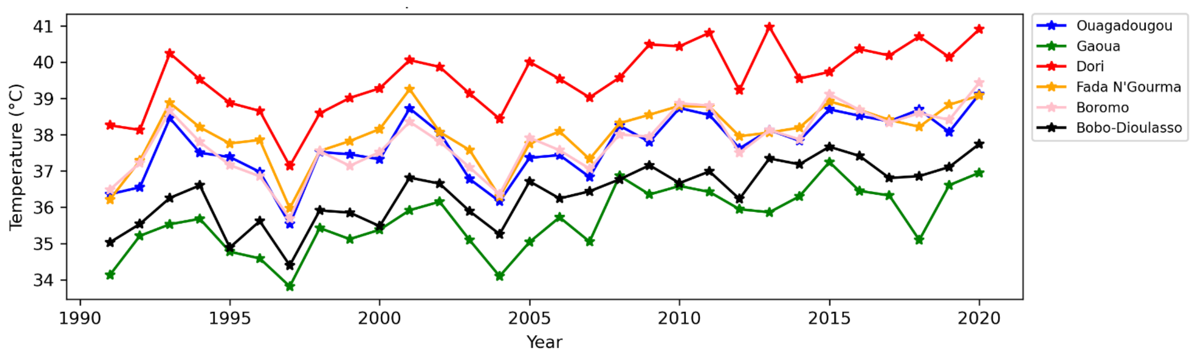


***Figure 4**. Time series of the seasonal mean daily maximum temperatures over the 1991-2020 climatological period for six locations across Burkina Faso.*

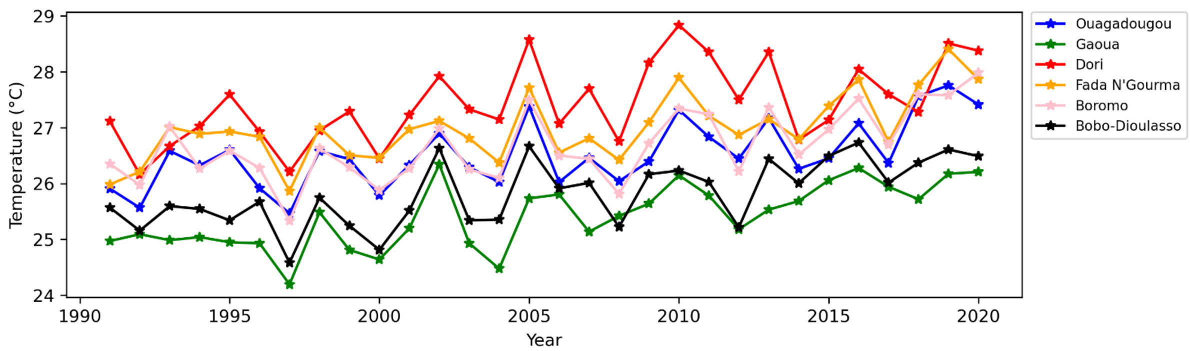


***Figure 5**. Time series of the seasonal mean daily min temperatures over the 1991-2020 climatological period for locations across Burkina Faso*

1.2. 2024 heatwave and temperature analysis

1.2.1. 2024 heatwave and impacts

Burkina Faso experienced extreme heat from the end of March to the beginning of April 2024, with high temperatures reported across the Sahel and West Africa (World Weather Attribution, 2024). High overnight and daytime temperatures, combined with power cuts, meant people did not get a break from the heat. The situation was further compounded by Ramadan, during which many were fasting, increasing the risk to human health from the heat (McGrath, 2024). A hospital in Mali reported more deaths than expected for that period, with heat likely playing a role in many of the deaths (World Weather Attribution, 2024). Around half of the deaths occurred in people over the age of 60 (World Weather Attribution, 2024), who are particularly vulnerable to heat stress.

The extreme heat was rare for the region, with a return period estimated at 100 years for the daily temperatures and 200 years for the 5-day maximum temperatures (World Weather Attribution, 2024). An attribution study found that without the influence of global warming of 1.2˚C, heatwaves of the magnitude observed in March and April 2024 would have been impossible (World Weather Attribution, 2024). Without the influence of human-caused climate change, the extreme 5-day maximum temperature experienced over Mali and Burkina Faso would have been 1.5˚C cooler, while minimum temperatures would have been 2˚C cooler (World Weather Attribution, 2024).

1.2.2. Analysis of the 2024 heatwave

Figures 6 and 7 present the 2024 March-April-May seasonal temperatures and anomalies for the region compared to the long-term seasonal average; further results can be found in Appendix 2. ERA5 reanalysis data show the seasonal average temperature for Burkina Faso was 33.9˚C; 1.8˚C above the long-term average.

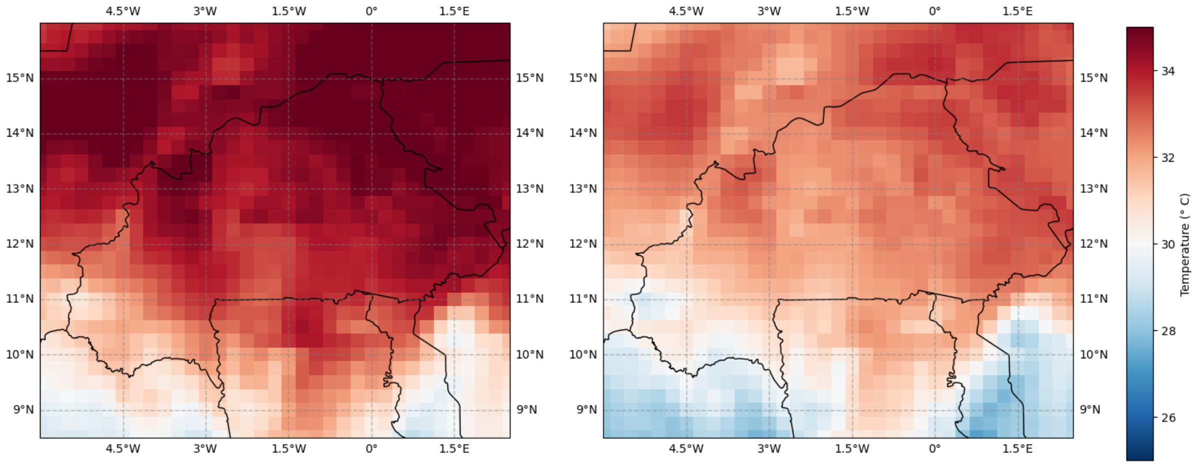


Figure 6. *(left) 2024 seasonal mean temperatures and (right) 1991-2020 seasonal mean temperatures for March, April, May.*

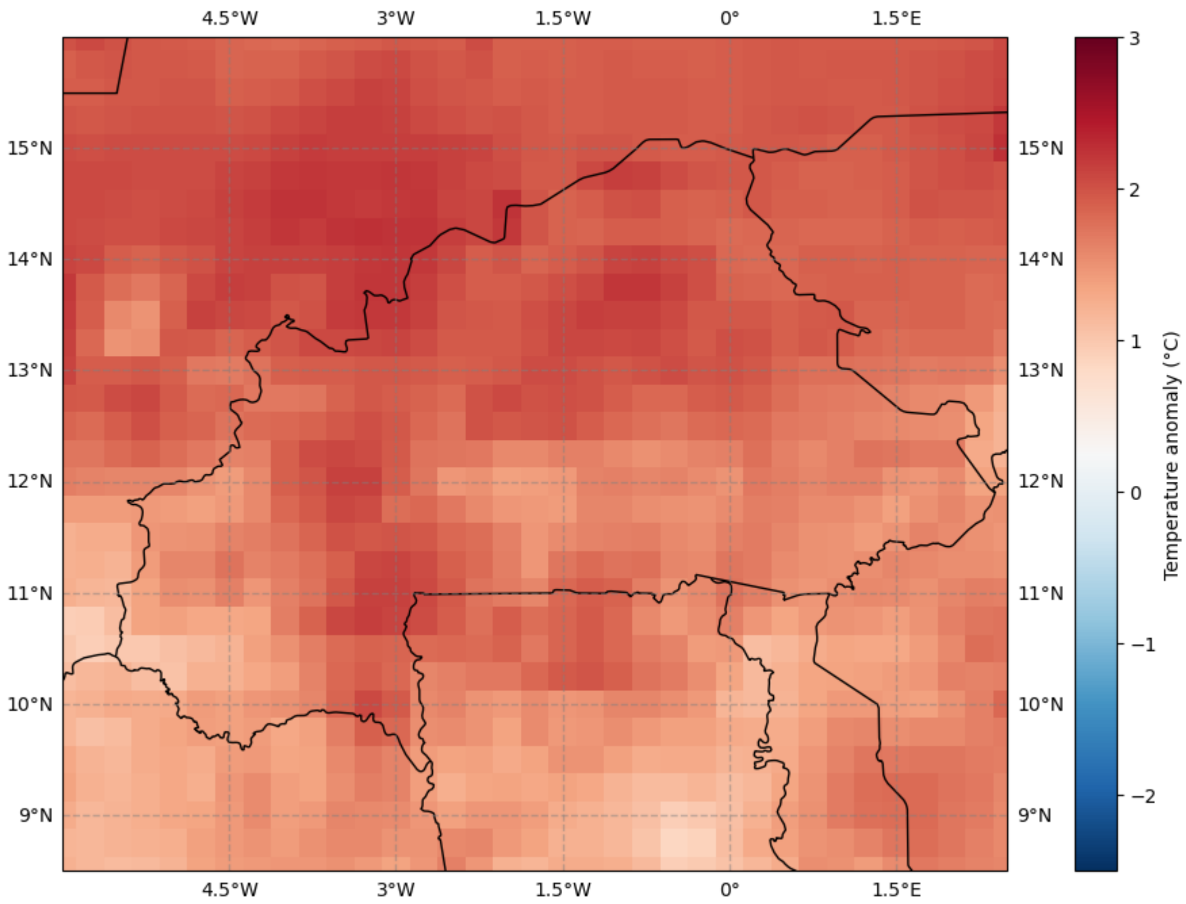
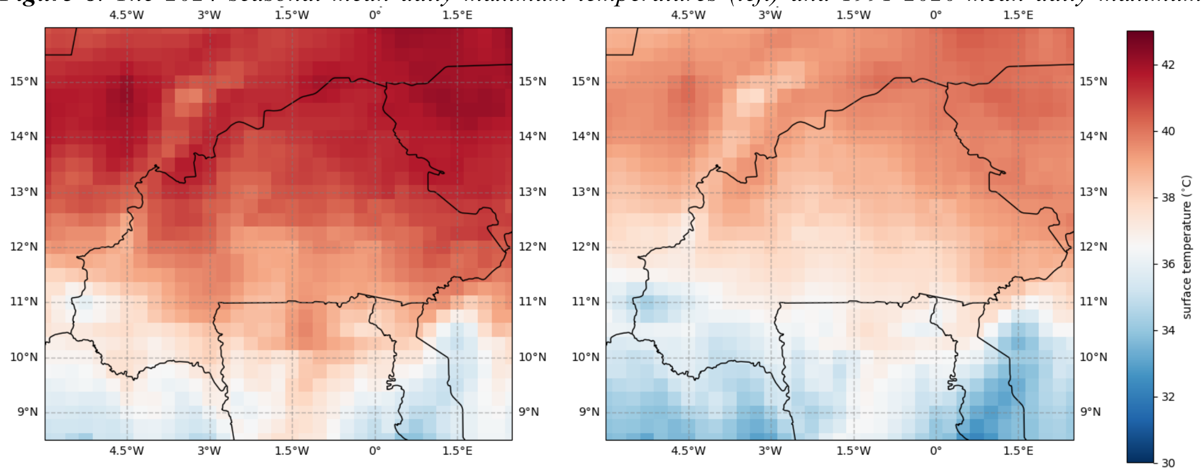


Figure 7. *2024 seasonal mean temperature anomaly for March-April-May compared to 1991-2020 average.*

1.2.3. Daily maximum and minimum temperatures

Figures 8 and 9 present 2024 March-April-May mean daily maximum temperatures, and anomalies compared to the 1991-2020 seasonal average. The mean daily maximum temperature for Burkina Faso during this period was 39.9˚C, which is 1.9˚C above the 1991-2020 seasonal average.

Figure 8. *The 2024 seasonal mean daily maximum temperatures (left) and 1991-2020 mean daily maximum temperatures (right) for March, April, May.*



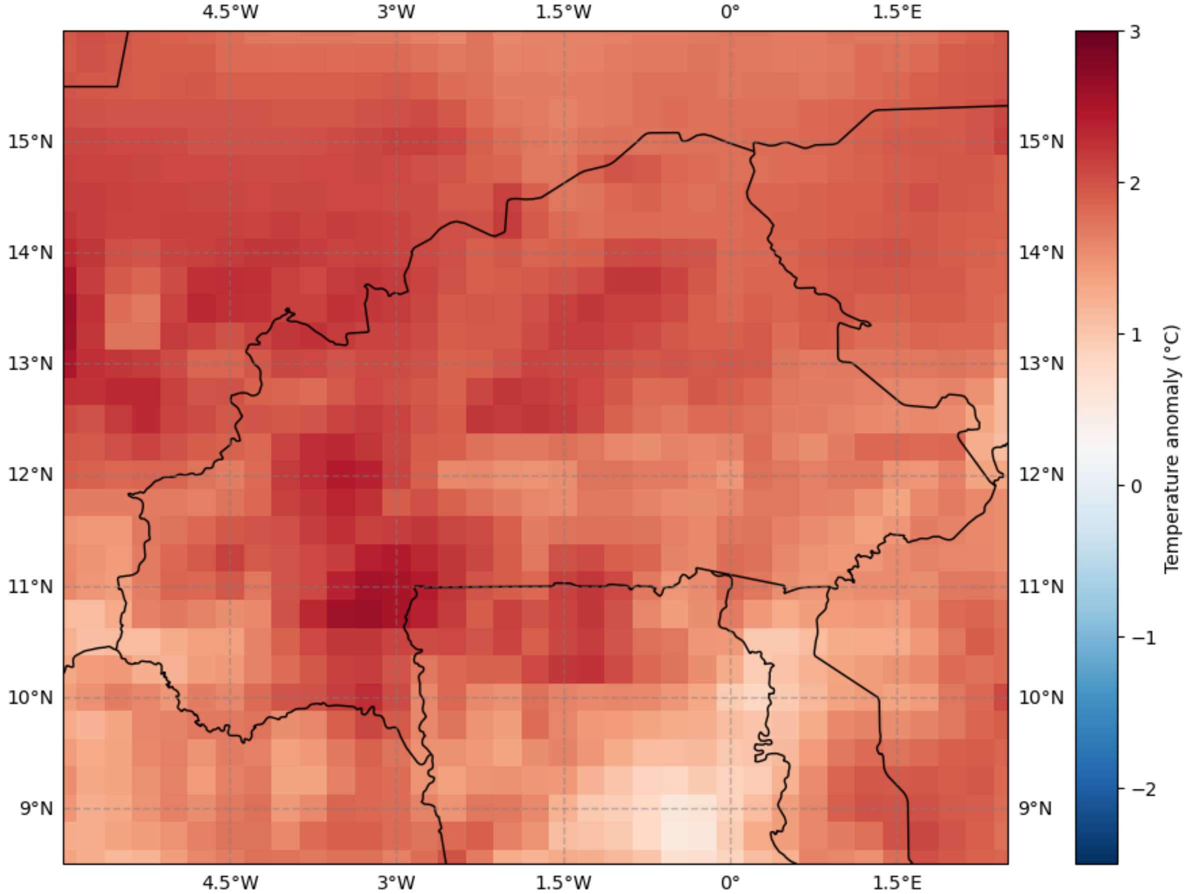


Figure 9. *The year 2024 seasonal mean daily maximum temperature anomaly compared 1991-2020 average.*

Figures 10 and 11 present 2024 March-April-May seasonal mean daily minimum temperatures and anomalies for the region compared to the 1991-2020 seasonal average. The seasonal mean daily minimum temperature for Burkina Faso was 28.5˚C, which is 2.12˚C compared to the 1991-2020 average.

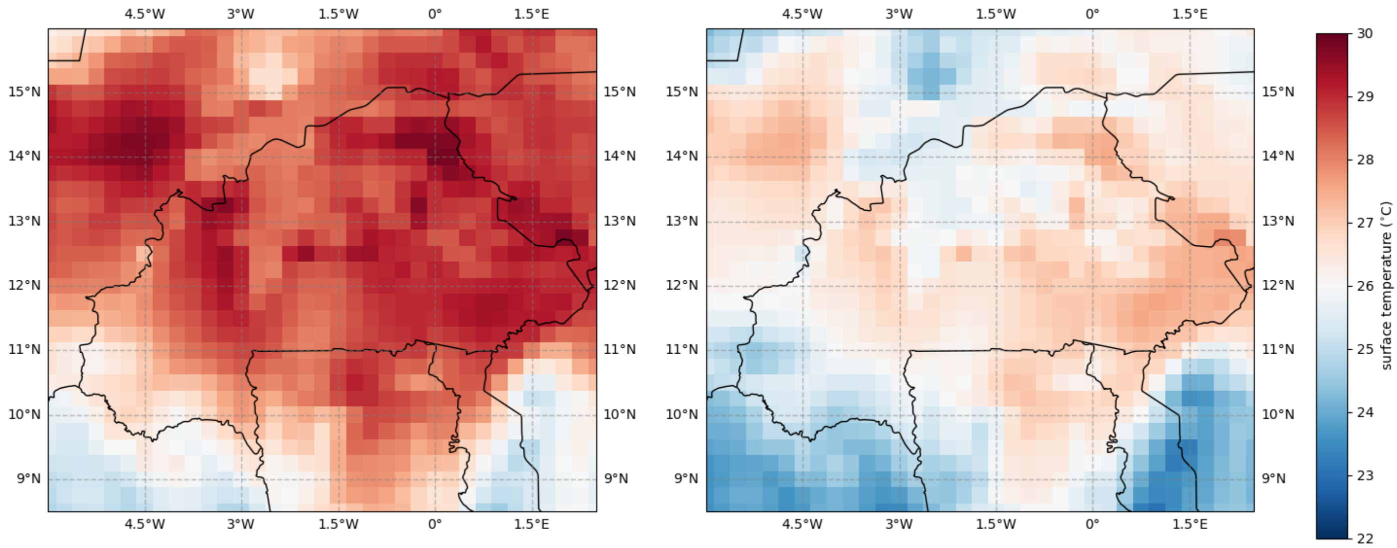


Figure 10. *The 2024 seasonal mean daily maximum temperatures (left) and the 1991-2020 seasonal mean daily minimum temperatures (right) for March, April, May.*

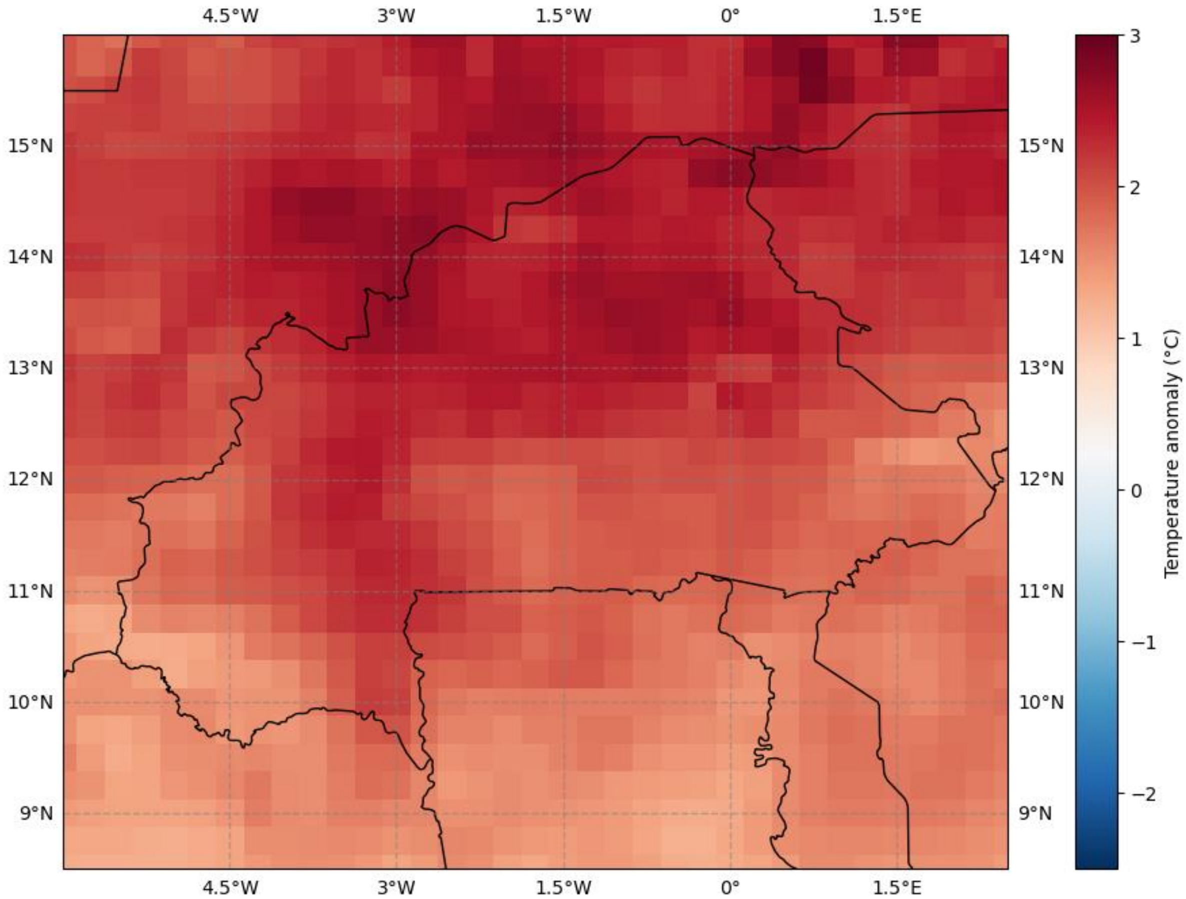


Figure 11. *The 2024 seasonal mean daily minimum temperature anomaly compared to the 1991-2000 average.*

1.3. Climatology summary

The 1991-2020 March-April-May seasonal mean temperature for Burkina Faso is 31.2 ˚C. Temperatures vary across the country, with locations further north and east generally experiencing higher temperatures compared to those further south. The most southerly location in the analysis, Gaoua, had the lowest seasonal mean temperature (30.4 ˚C) while Dori, the most northerly location in the analysis, had the highest seasonal mean temperature (33.4˚C). Boromo is an exception; located to the southeast of Ouagadougou it has a slightly higher average seasonal mean temperature (32.2˚C) than Ouagadougou (32.1˚C).

The 1991-2020 March-April-May seasonal mean daily maximum temperature for Burkina Faso is 38˚C while the seasonal mean daily minimum temperature is 26.4˚C. As with seasonal mean temperatures, there is a difference between the north and south of the country, with temperatures generally increasing towards the north and east. Individual locations exhibit a similar trend, with higher daily maximum and minimum temperatures in more northerly locations. The time series plots for the seasonal mean temperature in Figure 3 and the seasonal mean daily maximum and minimum temperatures in Figures 4 and 5, show year-to-year variability across the time series, with years where temperatures peak across all locations and a notable increasing temperature trend.

2. Burkina Faso Heatwave Analysis

A heatwave analysis was performed using the *xclims*[4][5] package and ERA5 hourly reanalysis data. Details of the datasets used are provided in Appendix 1. The daily maximum and minimum temperature data were assessed during the March, April, May season from 1979 to 2025. ERA5 reanalysis data were selected from the grid point nearest to Ouagadougou at latitude 12.3714 and longitude 1.5197, providing a location-specific time series from the gridded dataset.

2.1. Heatwave analysis using thresholds set by the Red Cross Climate Centre

The International Federation of Red Cross and Red Crescent Societies defines a heatwave for Ouagadougou as "*three or more consecutive days during which the temperature exceeds the 90th percentile of the distribution of the hottest month of the year*"(International Federation of Red Cross and Red Crescent Societies, 2024). According to data from the National Meteorological Agency (ANAM), as cited by the International Federation of Red Cross and Red Crescent Societies (2024), the 90th percentile temperature thresholds for Ouagadougou are 42.4°C for daytime maximum temperatures, and 30.3°C for nighttime minimum temperatures (International Federation of Red Cross and Red Crescent Societies, 2024).

2.1.1. Analysis of heatwaves using the maximum and minimum thresholds and the three-day window.

The analysis applied the maximum and minimum temperature thresholds and a three-day duration window to identify heatwaves. The *xclims* parameters were set to:

1. **Min temperature threshold:** 30.3°C
2. **Max. temperature threshold**: 42.4°C

[4] xclim Official Documentation https://xclim.readthedocs.io/en/stable/
[5] Heatwave hazard assessment based on EURO-CORDEX data analysis https://handbook.climaax.eu/notebooks/workflows/HEATWAVES/01_Urban_heatwaves/heatwave_hazard_assessment_xclim.html#:~:text=In%20this%20workflow%20we%20will%20assess%20the%20heatwave,of%20the%20xclim%20package%20to%20compute%20heatwave%20indicators.

3. **Window:** 3 days

No heatwaves were identified in Ouagadougou between 1979-2025 using ERA5 reanalysis data when all three parameters were specified, as shown in Figure 12.

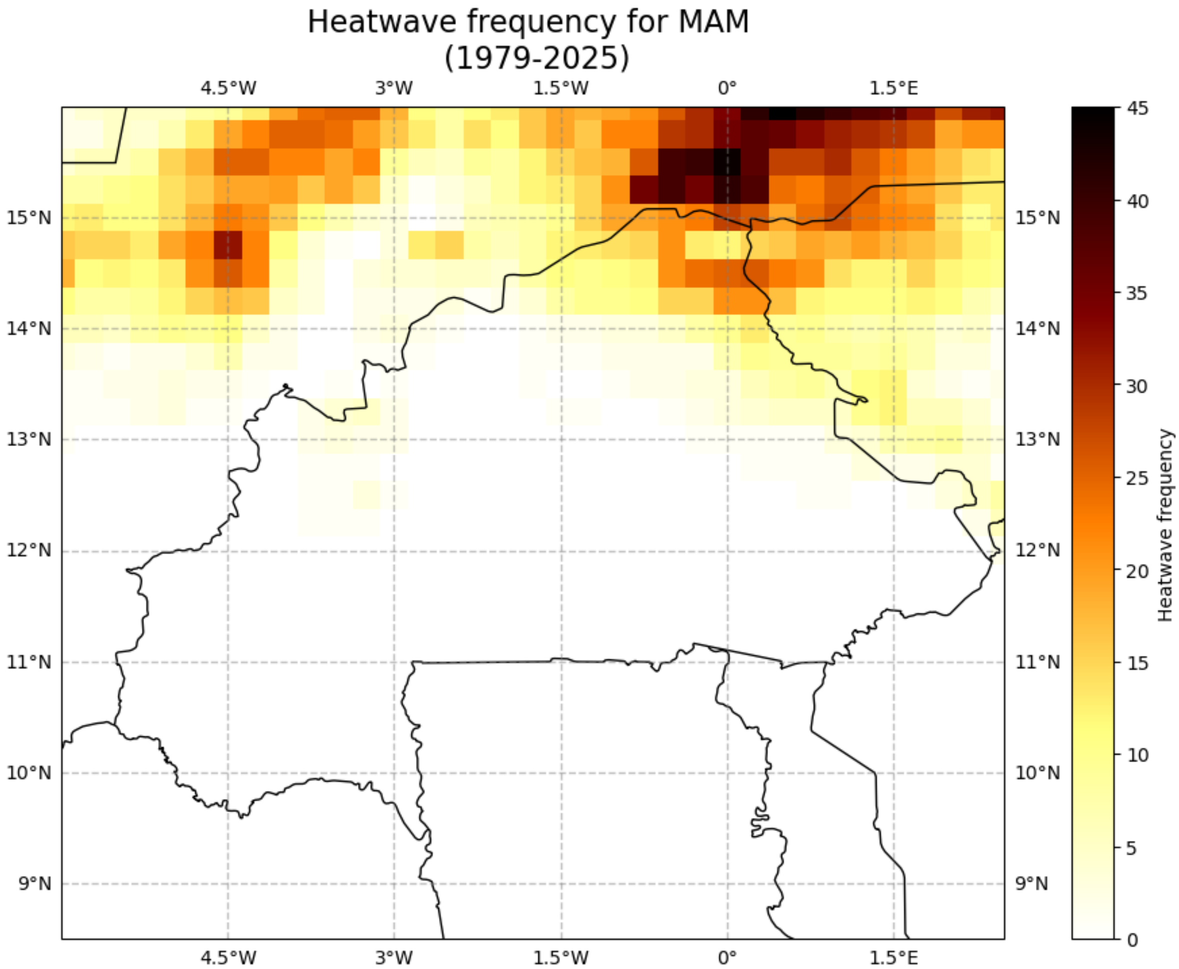


Figure 12. *Heatwave frequency plot for Burkina Faso and surrounding areas for March, April, May from 1979-2025 using ERA5 reanalysis data.*

2.1.2. Analysis of hot periods using maximum temperature threshold and 3-day window.

The analysis applied the maximum temperature thresholds and three-day duration window and excluded the minimum temperature criterion. It assessed the frequency of three-day hot periods – three consecutive days exceeding the maximum temperature threshold of 42.4°C – across the March, April, May season from 1979 to 2025. The parameters used were:

1. **Min temperature threshold:** 0°C
2. **Max. temperature threshold**: 42.4°C
3. **Window:** 3 days

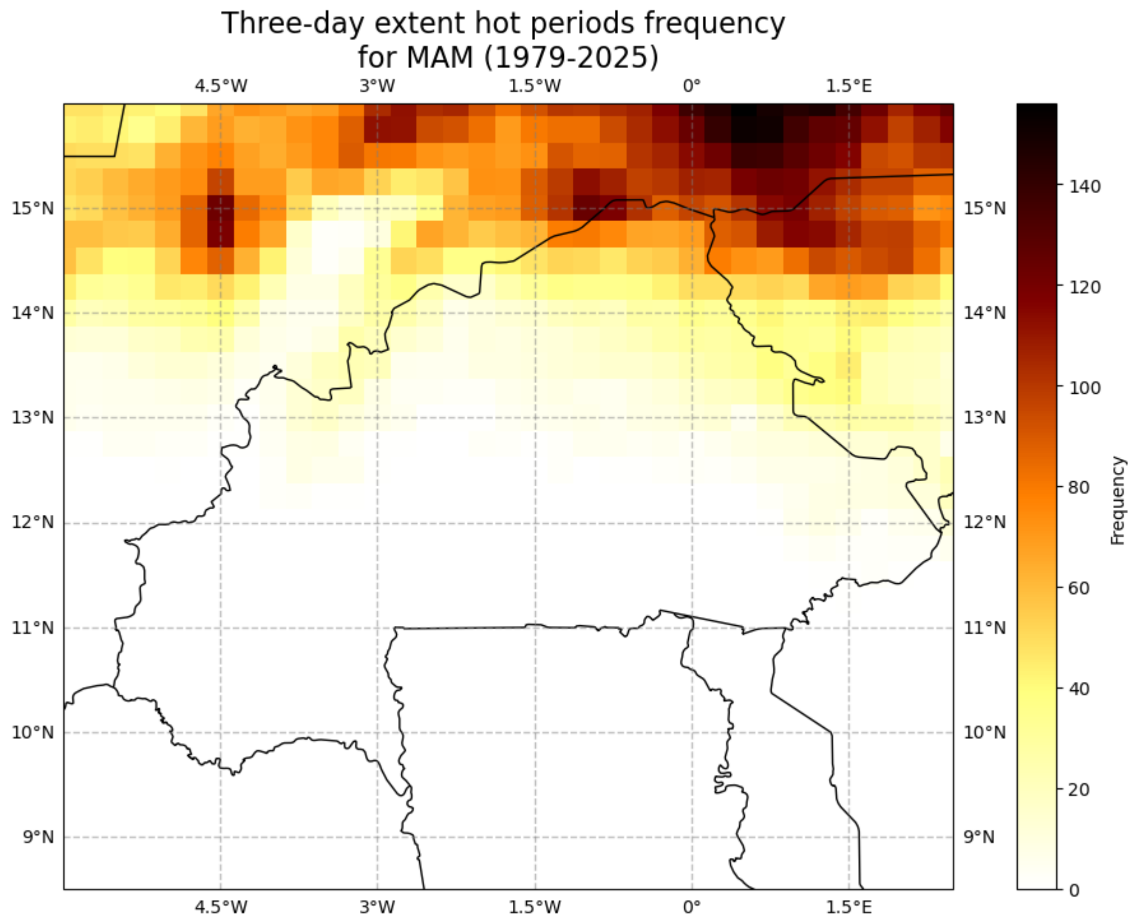


Figure 13*. The three-day hot periods frequency plot for Burkina Faso and surrounding areas for March, April, May, from 1979 to 2025 using ERA5 reanalysis data. The plot shows the number of instances that maximum temperatures met the threshold of 42.4˚C for three consecutive days.*

Ouagadougou experienced nine instances of three-day hot periods between 1979 and 2025, as shown in Figure 14, using ERA5 reanalysis data. Notably, 2024 experienced four periods where temperatures exceeded 42.4˚C for three consecutive days, corresponding to the 2024 Sahelian heatwave that impacted the region during that time.

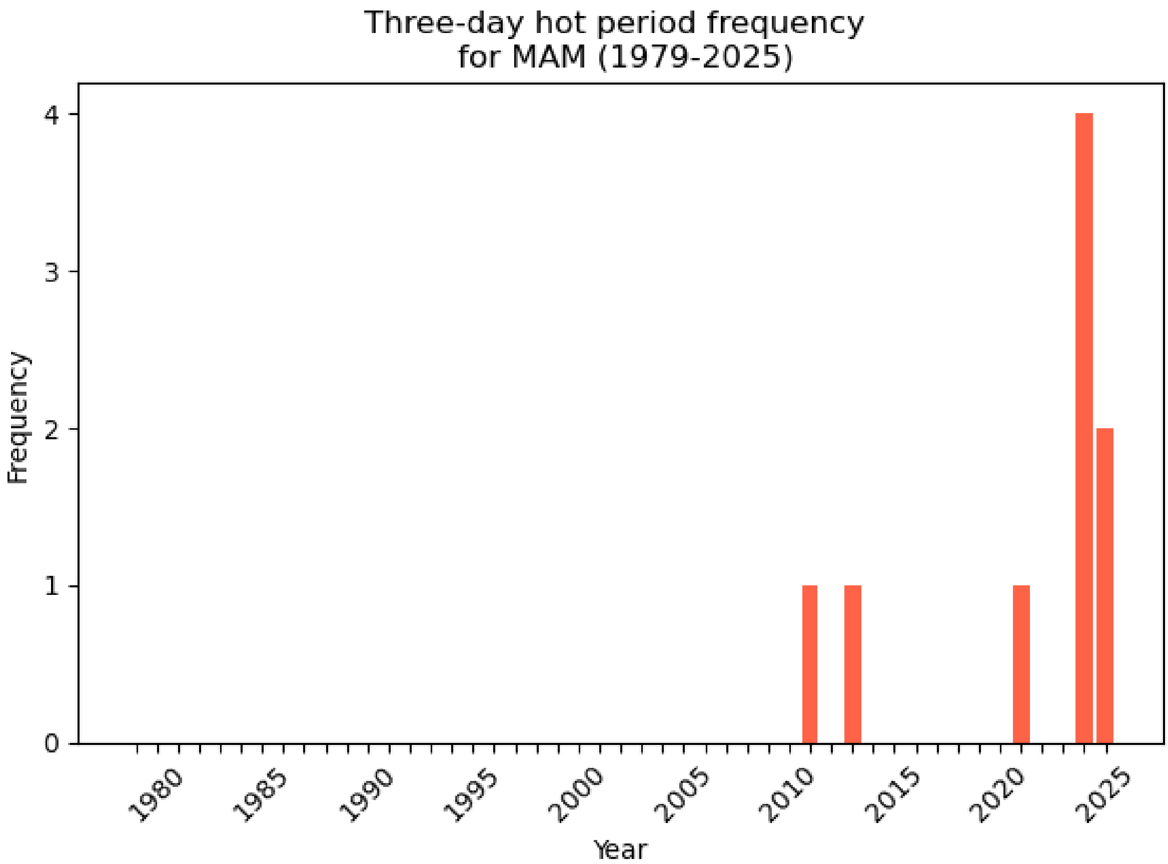


Figure 14. *The frequency of three-day hot periods from 1979 to 2025 for Ouagadougou across the March, April, May season using ERA5 reanalysis data. Hot periods are defined as three consecutive days or more where each day exceeds 42.3˚C.*

2.1.3. Analysis of hot days using the maximum threshold only

This analysis applied the maximum temperature threshold and excluded the minimum temperature threshold and duration window. It identified the total number of individual days between 1979 and 2025 during which temperatures exceeded 42.4°C. The parameters used were:

1. **Min temperature threshold:** 0°C
2. **Max. temperature threshold**: 42.4°C
3. **Window:** 0 days

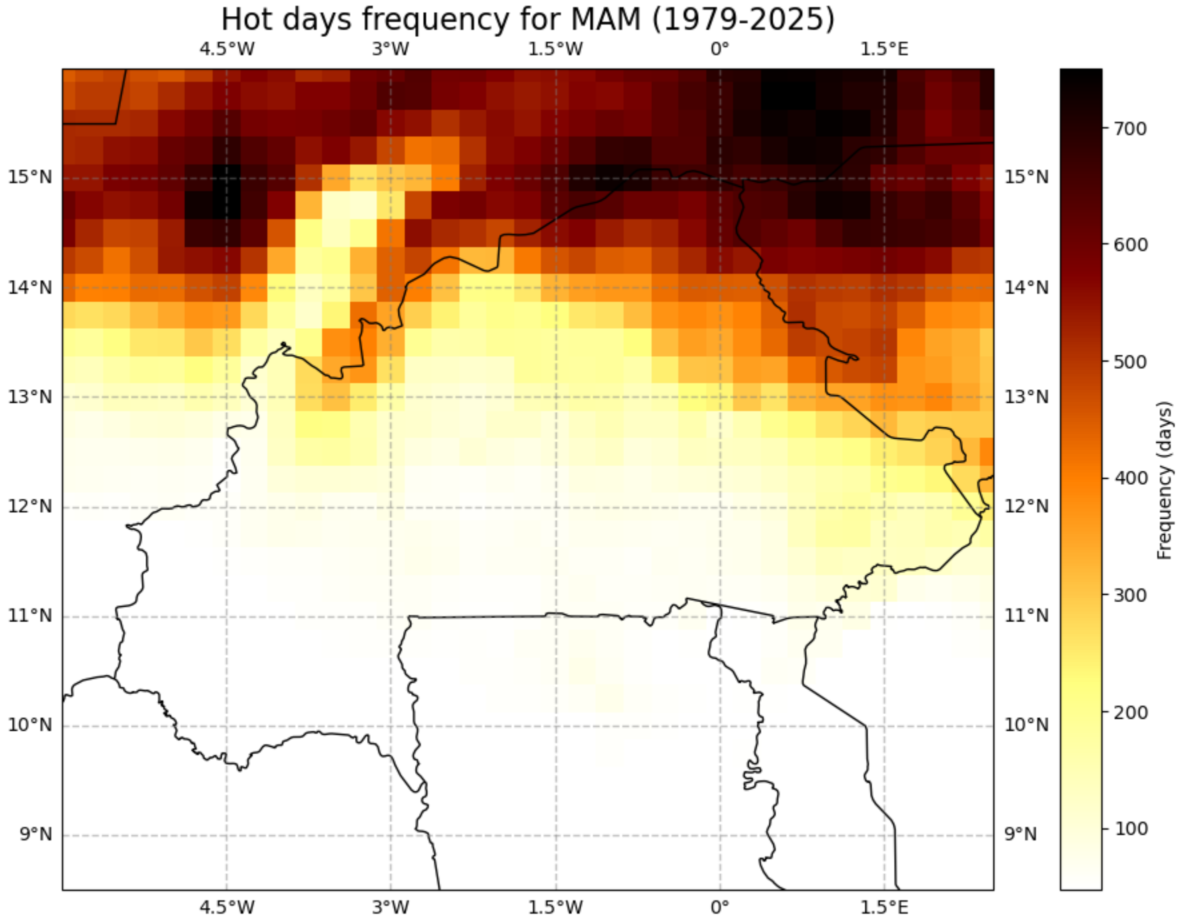


Figure 15. *Hot days frequency plot for Burkina Faso and surrounding areas for March, April, May, from 1979 to 2025 using ERA5 reanalysis data. The plot shows the number of individual days when maximum temperatures met the threshold of 42.4˚C for three consecutive days.*

A total of 203 days met the maximum temperature threshold of 42.2˚C in Ouagadougou during the March, April, and May season between 1979 and 2025 using ERA5 reanalysis data, as shown in Figure 15. The highest frequency of hot days (defined as individual days exceeding the maximum temperature threshold) occurred in 2025, as presented in Figure 16. The 10-year moving trend in Figure 16 indicates a sustained increase in hot days over the last couple decades in the ERA5 reanalysis data.

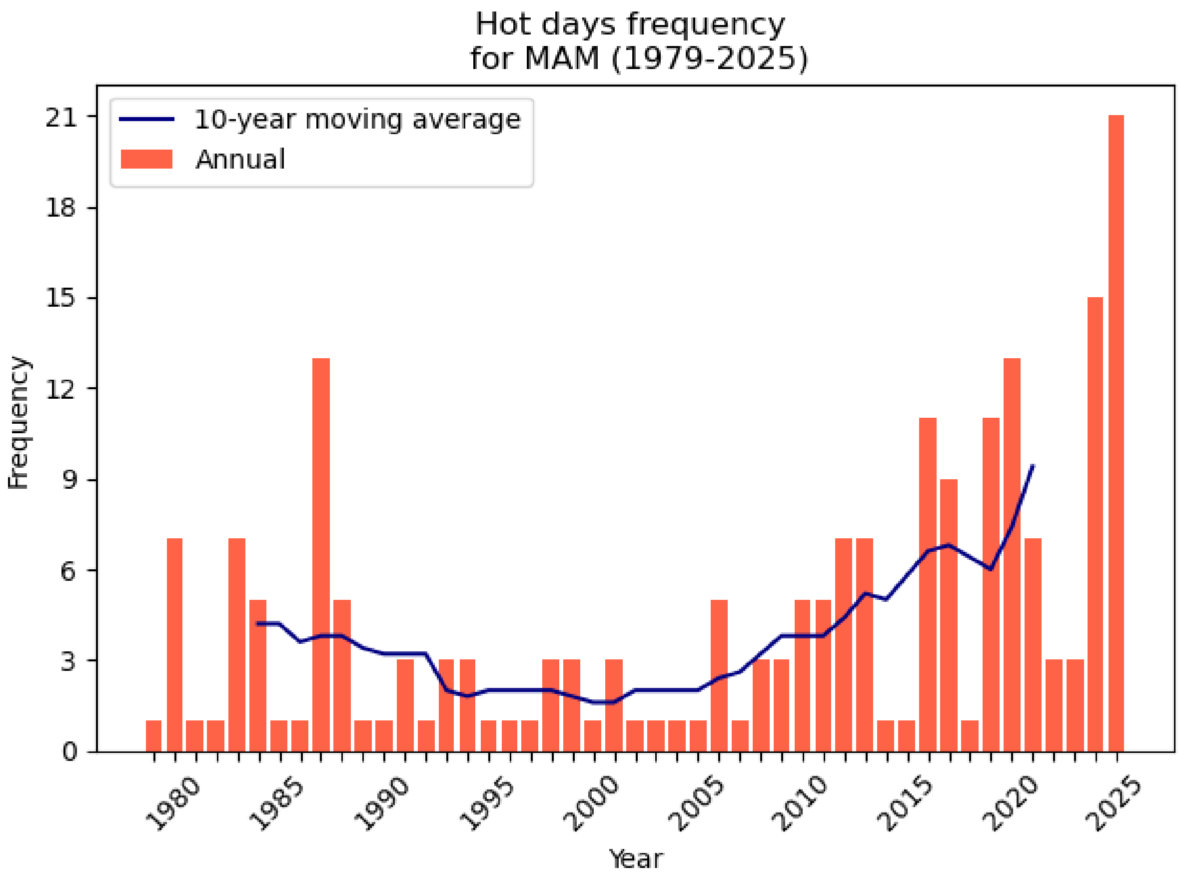


Figure 16. *The frequency of hot days (defined as days that met the maximum temperature threshold) from 1971 to 2025 for Ouagadougou using ERA5 reanalysis data. The 10-year trend (blue line) highlights the longer-term trend and persistent changes in the frequency of hot days over decades.*

2.2. Heatwave summary

The heatwave analysis used the *xclims* method and temperature thresholds defined by the International Federation of Red Cross and Red Crescent Societies. In Ouagadougou, a heatwave is defined as three consecutive days with maximum and minimum temperatures exceeding 42.4°C and 30.3°C, respectively.

No heatwaves were identified between 1979 and 2025 using ERA5 reanalysis data when both minimum and maximum thresholds and the three-day duration were applied. However, when the minimum temperature threshold criterion was excluded, nine three-day hot periods were detected, including four in 2024 when Burkina Faso experienced a severe heatwave. In total, 203 individual days exceeded 42.4°C during the March, April, May season from 1979 to 2025 using ERA5 reanalysis data.

These findings suggests that the current temperature and duration thresholds may not be suitable for identifying heatwaves using ERA5 reanalysis data the *xclims* package. Alternative approaches to defining heatwaves may offer more robust insights, such as percentile-based threshold derived from 30-year climatology and rolling window methods (Brunner and Voigt, 2024; McGregor, 2024).

3. Comparison of observations with reanalysis

ERA5 reanalysis data can differ from observational datasets due to inherent errors and uncertainties (Parker, 2016). These differences may arise from spatial resolution, data assimilation techniques or gaps in observation datasets and coverage. Comparison tests help identify where and how these datasets diverge and assess the suitability of using reanalysis as an alternative to observational data, particularly in regions where observational records are sparse or incomplete.

3.1. Comparison test results

3.1.1. Datasets used in comparison tests

The station observational dataset for Ouagadougou was obtained from the KNMI Climate[6] Explorer. Details of both observational and ERA5 reanalyses datasets used in the comparison tests are provided in Appendix 1. The observation dataset represents point source station measurements whereas ERA5 reanalysis data is gridded, covering a broader area. The grid points nearest to Ouagadougou at latitude 12.3714 and longitude 1.5197 were selected from the ERA5 reanalysis dataset. However, this still represents a 0.25˚ x 0.25˚resolution grid box which differs from the observation station's exact location and scale. The comparison was conducted using monthly averaged observation station data from 1941 to 2019 (with January 2019 only) and ERA5 reanalysis monthly averaged data from 1941 to 2018.

The results from the comparison analysis are presented using two statistical approaches: monthly means and seasonal means.

1. **Monthly mean:** This refers to the average temperature for each individual month (March, April, and May) across the 1941-2018 period. The values are not grouped by season, resulting in one datapoint per month. This method uses more datapoints and thus captures intra-season variability. The data is useful for visualising short-term variability and extremes, but it tends to be noisier.

[6] KNMI climate explorer https://climexp.knmi.nl/start.cgi?id=8cf810bf7fe4ae1b31bfaac733f1c038

2. **Seasonal mean**: This is the average temperature across the March to May season, producing one value per season. This method uses fewer data pints, which smooths out short-term variability and gives a broader indication of climate trends and patterns.

3.1.2. The seasonal cycle

A comparison between ERA5 reanalysis and station observation seasonal cycles for Ouagadougou is shown in Figure 17. Both datasets are consistent in reflecting the seasonal temperature cycle, with peak temperatures occurring in March, April, and May, the three warmest months. Overall, ERA5 reanalysis aligns well with the observation station data throughout the year, though slight differences are apparent, particularly in October and November. ERA5 reanalysis slightly overestimates temperatures in May and June and underestimated them from September through December. Despite the small differences, the results support the reliability of using ERA5 reanalysis data in representing the seasonal cycle of the mean monthly temperatures for Ouagadougou.

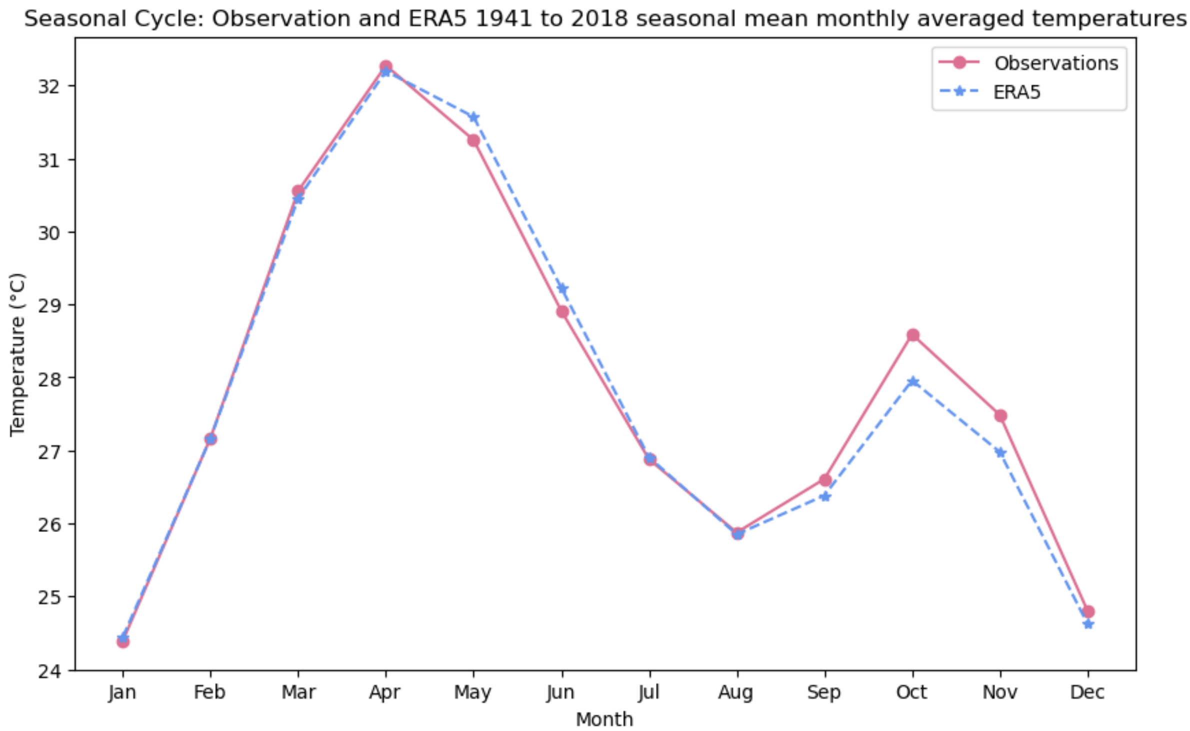


Figure 17. *Comparison of ERA5 reanalysis (blue dashed line) and station observation (pink solid line) seasonal temperature cycles for Ouagadougou.*

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3.1.3. Correlation Coefficient and Root Mean Square (RMSE)

The correlation coefficient, Root Mean Square Error (RMSE), and mean bias were calculated and are presented in Table 2. The results show a strong positive correlation between the ERA5 reanalysis and station observation datasets for March, April, and May monthly and seasonal averages, indicating that both track each other closely over time.

The RMSE suggests low deviation between the datasets. The ERA5 data varies from the observations by 0.72°C per month and 0.51°C per season. The lower error for the seasonal average reflects the difference in short-term fluctuations in temperature over different time scales. Seasonal average data reduces noise, lowering the error. The mean bias was minimal. These results indicate that ERA5 reanalysis data is a reliable proxy for station observation in this context.

Table 2. *Comparison of ERA5 reanalysis and station observation data for monthly and seasonal mean temperatures in Ouagadougou during March–May. The correlation coefficient, Root Mean Square Error (RMSE) and mean bias are given for monthly and seasonal averages.*

Statistical test	**March-April-May monthly data**	**March-April-May Seasonal mean**
Correlation coefficient ®	R = 0.8	R = 0.8
RMSE	0.72°C per month	0.51°C per season
Mean bias	0.03	-0.03

3.1.4. Comparison Mar-April-May temperatures from 1941 to 2018

3.1.4.1. Kernal Distribution Estimate Histograms and curves, mean and standard deviation

The distribution of the March-April-May monthly average and seasonal average temperatures for ERA5 reanalysis and station observation data from 1941 to 2018 for Ouagadougou is presented in the Kernel Density Estimate (KDE) plot in Figure 18 and Figure 19 respectively. The means and standard deviations for both datasets are shown in Table 3.

3.1.4.1.1. Monthly averaged data

The peaks of both datasets closely align, indicating strong agreement on the most common monthly temperature values in this analysis. ERA5 reanalysis shows a slight warm bias and broader distribution, which is reflected in the higher standard deviation of 1.3˚C and the calculated mean bias of +0.03˚C.

Both datasets share similar mean temperature values of 31.4˚C, and closely aligned modes, suggesting consistent central tendencies. These results support the low bias and high correlation values, indicating that ERA5 monthly averaged reanalysis data for March, April, and May, is a reliable proxy for station observational data for Ouagadougou.

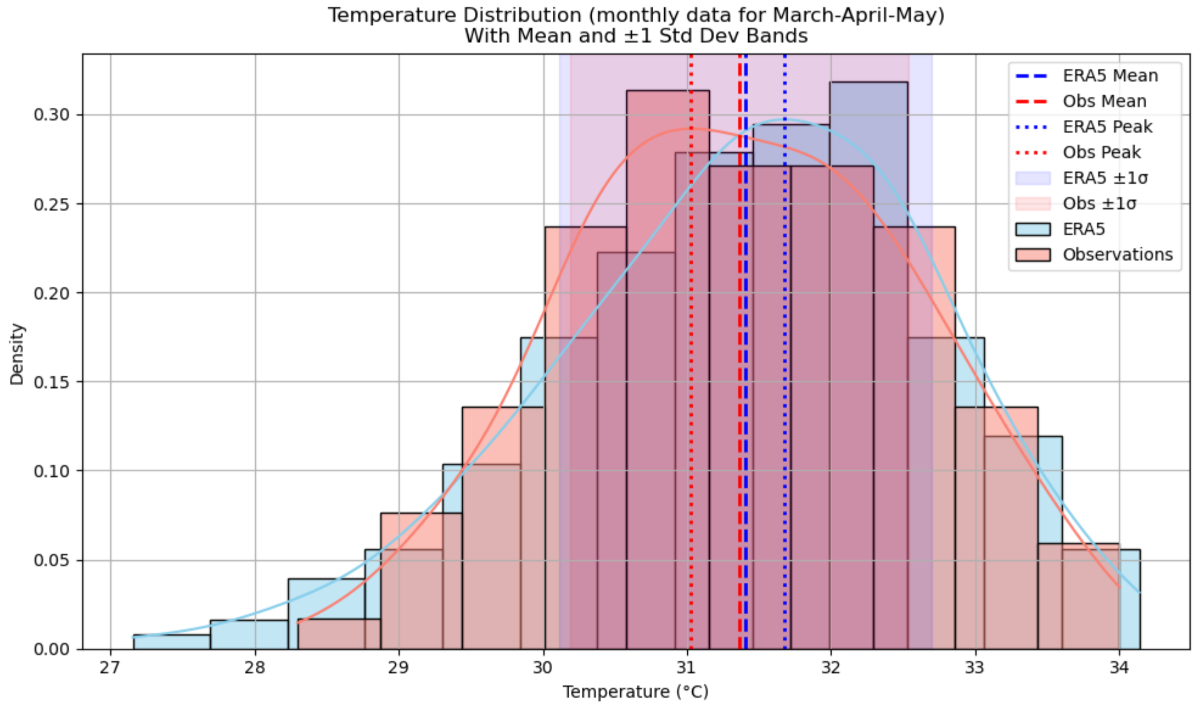


Figure 18. *KDE histograms and curves comparing monthly temperature distributions for each March, April, May month across all years for station observation data (pink) and ERA5 reanalysis data (blue). The plot highlights central tendencies (peaks) and distribution spread.*

The density refers to the probability density function (PDF) of the temperature values and shows the probability for each temperature value. The ERA5 reanalysis mean is shown with a blue dashed line, and the station observation mean with a red dashed line. The shaded regions represent ±1 standard deviation (σ) where approximately 68% of values lie (for a normal distribution).

3.1.4.1.2. Seasonal averaged data

There is good agreement between the ERA5 reanalysis data and station observation data for seasonal temperatures, as shown in Figure 19. Both datasets have a mean temperature of 31.4˚C. The ERA5 reanalysis data peaks at a slightly lower temperature (mode of 31.3˚C) compared to the station data (mode of 32˚C), reflecting a minor cool mean bias of -0.03 ˚C.

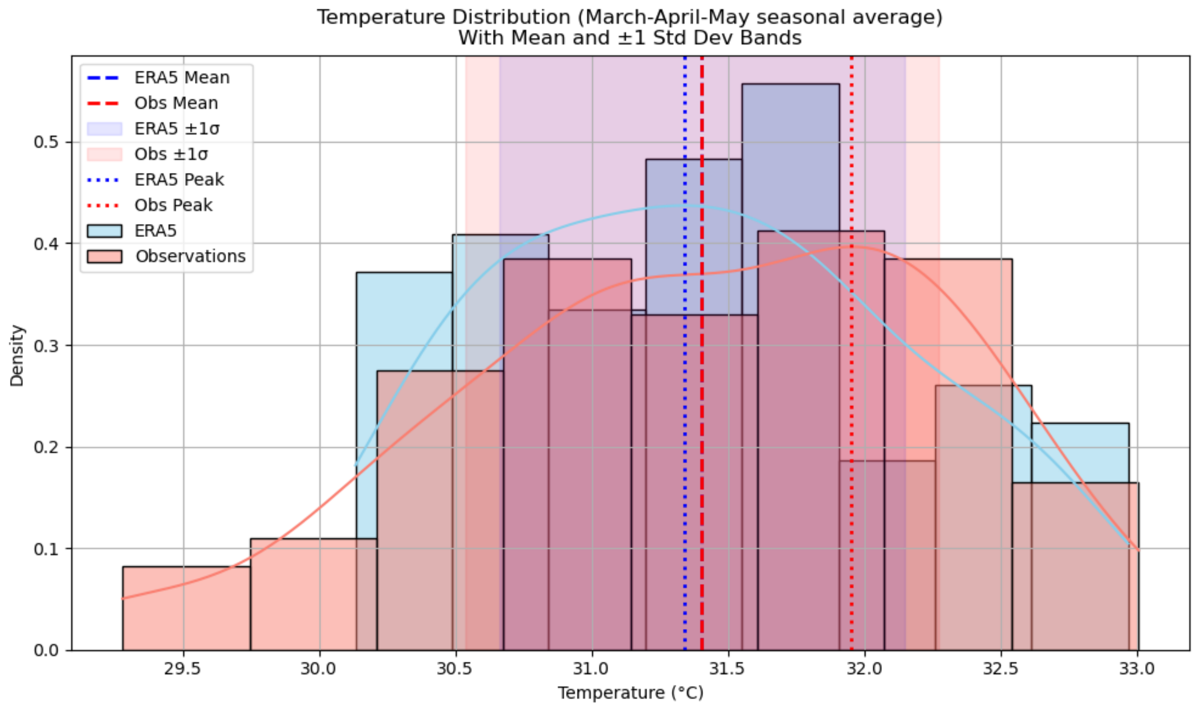


Figure 19. *KDE histograms and curves comparing March, April, May seasonal temperature distributions for station observation data (pink) and ERA5 reanalysis data (blue). The plot highlights central tendencies (peaks) and distribution spread.*

The density refers to the probability density function (PDF) of the temperature values and shows the probability for each temperature value. The ERA5 reanalysis mean is shown with a blue dashed line, and the station observation mean with a red dashed line. The shaded regions represent ±1 standard deviation (σ) where approximately 68% of values lie (for a normal distribution).

Table 3. *Comparison between ERA5 reanalysis and observational monthly data and seasonal data.*

Time aggregation	**Dataset**	**Mean Temperature (˚C)**	**Most frequently occurring value (mode) (˚C)**	**90% max density* (˚C)**	**Standard Deviation (˚C)**
Monthly mean	ERA5 reanalysis	31.4	31.68	31.10 – 32.34	1.29
	Station Observation	31.36	31.03	30.36 – 32.10	1.17
Seasonal mean	ERA5 reanalysis	31.40	31.34	30.72 – 31.78	0.74

	Station Observation	31.40	31.95	31.07 – 32.27	0.87

**The range of temperatures around the peak of the curve (where the estimated probability density is within the top 10% of the peak)*

3.1.4.1.3. Data bias

Both ERA5 reanalysis station observation data are presented in a time series plots in Figure 20 (monthly averaged data) and Figure 21 (seasonal averaged data) illustrating the bias and long-term agreement between the two datasets. The monthly data shows close alignment, with both datasets closely tracking each other, supporting earlier findings. Minor variations between the datasets are expected and possibly reflect spatial resolutions and influence. This strong agreement for the monthly data reinforces the reliability of ERA5 reanalysis data as a proxy for station observations in Ouagadougou.

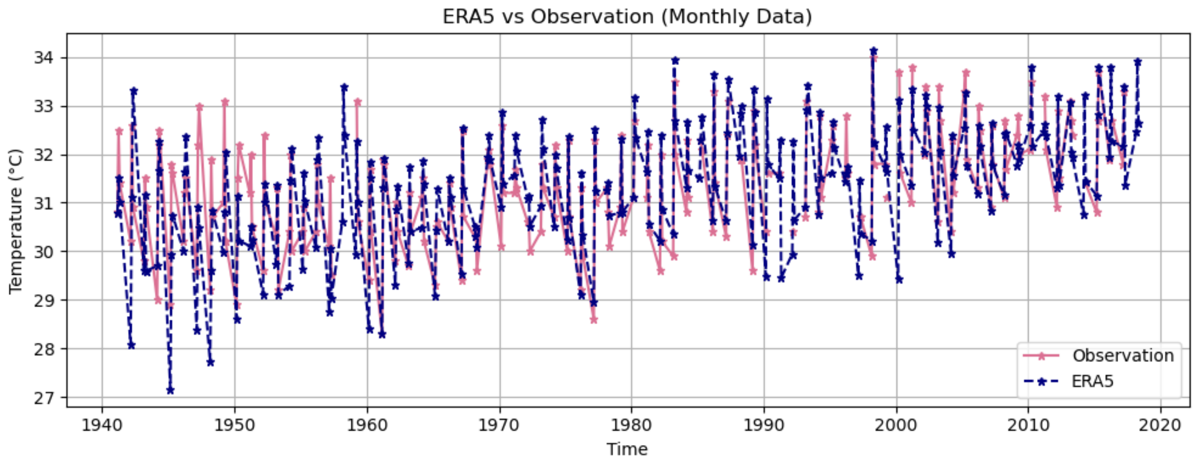
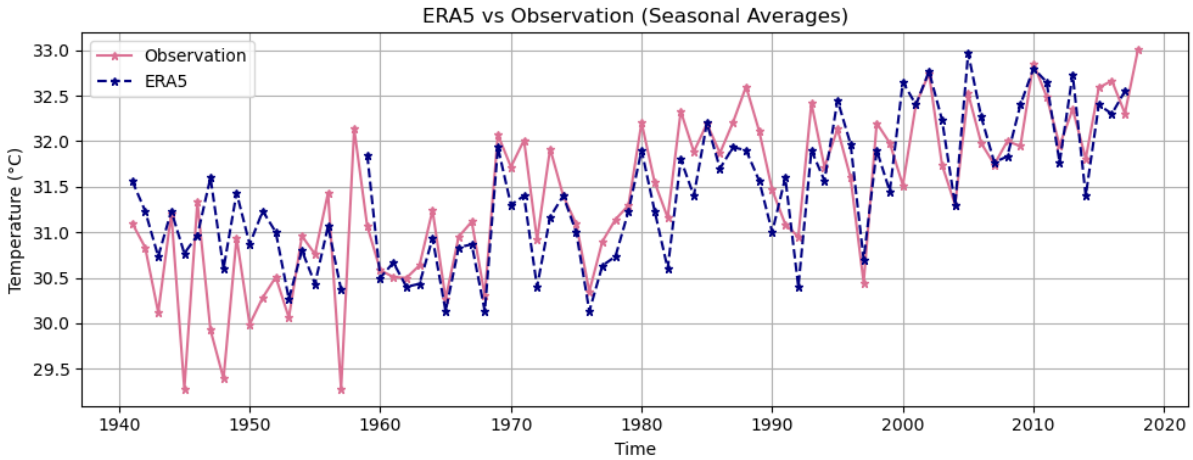


Figure 19. *The ERA5 data (blue dashed) and observation data (pink) plotted as a time series of the monthly temperatures from 1941 to 2018.*

The seasonal mean temperature data show a consistent warming trend in the long-term climate across both datasets. Despite minor deviations, particularly in the early part of the time series before satellite observations became available, ERA5 reanalysis and station observation remain closely aligned. ERA5 reanalysis exhibits a slight warm bias at the beginning of the time series and a slight cooling bias after 1960. The low RMSE of 0.51˚C indicates minimal error, reinforcing the reliability of ERA5 reanalysis data for representing seasonal temperature trends.

Figure 20. *The ERA5 data (blue), and observation data (pink) plotted as a time series of the seasonal averaged temperature from 1941 to 2018.*



3.2. Summary of the comparison between ERA5 reanalysis and observation datasets

The comparison results show a close match between ERA5 reanalysis and station observations data for monthly and seasonal mean temperatures during March, April, and May from 1941 to 2018.

ERA5 reanalysis shows strong correlation, low error (RMSE of 0.51˚C per season), and similar seasonal mean temperatures (31.40˚C) compared to station observation data. The warming trend observed in the station data is reflected in ERA5 reanalysis, which closely follows the station observation time series for monthly and seasonal temperatures. The ERA5 reanalysis shows a slight warm bias for monthly data (+0.03˚C) and a slight cool bias for seasonal data (-0.03˚C). but this difference is minimal.

The results suggest ERA5 reanalysis data performs well and is a reliable proxy for March, April, and May monthly and seasonal temperatures for Ouagadougou. ERA5 reanalysis is suitable for reconstructing historic climate in this context, and particularly useful where observations may be sparse or inconsistent.

This analysis focuses on monthly and seasonal mean temperatures and does not assess extremes. Further work comparing ERA5 reanalysis and station observations for extreme temperature values would provide deeper insight into ERA5 reanalysis' performance in capturing climate extremes.

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Appendices

Appendix 1: Datasets used

Datasets

Preparation steps

The details for the data can be obtained from the Copernicus Data store[7] and can changed as required. The details included in this Appendix are the ones used to generate the climatology and results presented in this document.

To access and download the data, a free ECMWF account[8] needs to be created, and logged to accept the 'Terms of use' license.

The code for the climatology was adapted from the Copernicus tutorials on using climate data from CS3[i]

Create a working environment

A working environment needs creating in the shell and the following packages downloaded.

- Xarry
- Cartopy
- Cdsapi
- Curl
- Ipykernel
- Xclims
- Geopandas
- Rasterio
- Rioxarray

Datasets for average monthly temperatures

Source: Copernicus Data Store

[7] Copernicus Data Store https://cds.climate.copernicus.eu/#!/home
[8] ECMWF https://accounts.ecmwf.int/auth/realms/ecmwf/protocol/openid-connect/auth?client_id=cms-www&response_type=code&scope=openid%20email%20profile&redirect_uri=https%3A//www.ecmwf.int/openid-connect/keycloak&state=qx5aHaWY_rem3JIi-c472nOffOJIOohBafFgXfu5AMs

Data: ERA5 monthly averaged data on single levels from 1940 to present (link here)

Product Type: Monthly averaged reanalysis

Variable: 2m temperature

Years: 1979 -present (2025) *

Month: March, April, May

Time: 00:00

Sub region extract: 16N, 6.5N(s), 2.5E, -6E(w)

Data format: NetCDF(experimental)

*Data was subsampled to produce the 1991-2020 climatology.

Dataset for daily maximum temperatures

Source: Copernicus Data Store

Data: ERA5 hourly data on single levels from 1940 to present

Product Type: Reanalysis

Variable: 2m temperature

Years: 1991-2020

Month: March, April, May (download months separately then merge in script)

Time: 06:00, 07:00, 08:00, 09:00, 10:00, 11:00, 12:00, 13:00, 14:00, 15:00, 16:00, 17:00, 18:00

Sub region extract: 16N, 6.5N(s), 2.5E, -6E(w)

Data format: NetCDF(experimental)

Find the 2024 annual maximum daily temperature and calculate the anomaly from the 1991-2020 climatology.

Source: Copernicus Data Store

Data: ERA5 hourly data on single levels from 1940 to present

Product Type: Reanalysis

Variable: 2m temperature

Years: 2021-2024

Month: March, April, May

Time: 06:00, 07:00, 08:00, 09:00, 10:00, 11:00, 12:00, 13:00, 14:00, 15:00, 16:00, 17:00, 18:00 (daytime temperatures)

Sub region extract: 16N, 6.5N(s), 2.5E, -6E(w)

Data format: NetCDF(experimental)

Data set for daily minimum temperatures

Source: Copernicus Data Store

Data: ERA5 hourly data on single levels from 1940 to present

Product Type: Reanalysis

Variable: 2m temperature

Years: 1991-2020

Month: March, April, May (download months separately then merge in script)

Time:

Sub region extract: 16N, 6.5N(s), 2.5E, -6E(w)

Data format: NetCDF(experimental)

Time: 00:00, 01:00, 02:00, 03:00, 04:00, 05:00, 18:00, 19:00, 20:00, 21:00, 22:00, 23:00

Find the 2024 annual maximum daily temperature and calculate the anomaly from the 1991-2020 climatology.

Source: Copernicus Data Store

Data: ERA5 hourly data on single levels from 1940 to present

Product Type: Reanalysis

Variable: 2m temperature

Years: 2021-2024

Month: March, April, May

Time: 00:00, 01:00, 02:00, 03:00, 04:00, 05:00, 18:00, 19:00, 20:00, 21:00, 22:00, 23:00

Sub region extract: 16N, 6.5N(s), 2.5E, -6E(w)

Data format: NetCDF(experimental)

Dataset for heatwave analysis

Source: Copernicus Data Store

Data: ERA5 hourly data on single levels from 1940 to present

Product Type: Reanalysis

Variable: 2m temperature

Years: 1979-2025

Month: March, April, May (downloaded separately)

Time: 01:00, 03:00, 05:00, 07:00, 09:00, 11:00, 13:00, 15:00, 17:00, 19:00, 21:00, 23:00

Sub region extract: 16N, 6.5N(s), 2.5E, -6E(w)

Data format: NetCDF(experimental)

Dataset for observational data for comparison tests

Source: KNMI climate explorer

Data: Monthly station data

Product Type:

Variable: mean temperature (GHCN-M(adjusted))

Select stations: 10 stations near **12.2˚N and -1.3˚E**

Time, distance: At least **40 years** of data in the **3 months** starting in **May** in years…

KNMI generated summary:

Looking up 10 stations

Searching for stations near 12.20N, -1.30E

Requiring at least 40 years with data in Mar-May

Opening /data/climexp_persistent_cache/climexp/NCDCData/ghcnm/ghcnm.tavg.v3.qca.dat

Found 10 stations

Station information:

OUAGADOUGOU (BURKINA FASO)

coordinates: 12.35N, -1.52E, 306.0m (prob: 296m)

WMO station code: 65503 (get data)

Associated with urban area (pop. 173000)

Terrain: flat TROP. SAVANNA

Found 77 years with data in 1941-2018

Aggregate this set of time series. Type: unweighted mean.

Dataset for eRA5 reanalysis data used in comparison tests

Source: Copernicus Data Store

Data: ERA5 monthly averaged data on single levels from 1940 to present

Product Type: Reanalysis

Variable: 2m temperature

Years: 1941-2018

Month: all months

Time: 00:00

Sub region extract: 16N, 6.5N(s), 2.5E, -6E(w)

Data format: NetCDF(experimental)

Appendix 2: Temperatures for locations across Burkina Faso

Location (latitude, longitude)	2024 mean temperature for the 1991-2020 climate standard normal period (˚C).	The year 2024 1991-2020 temperature anomaly	The year 2024 Seasonal Mean of the Daily Maximum temperatures (˚C).	The year 2024 seasonal mean maximum temperature 1991-2020 anomaly	The year 2024 Seasonal Mean of the Daily Minium temperatures (˚C).	The year 2024 seasonal mean minimum temperature 1991-2020 anomaly
Ouagadougou (12.35N, -1.52E)	33.7˚C	1.6˚C	39.5˚C	1.8˚C	29.8˚C	3.2˚C
Dori (14.03N, -0.03E)	35.2˚C	1.8˚C	41.4˚C	1.8˚C	30.8˚C	3.3˚C
Gaoua (10.33N, -3.18E)	32.3˚C	1.9˚C	37.8˚C	2.2˚C	27.7˚C	2.4˚C
Fada N'Gourma (12.3N, 0.37E)	34.1˚C	1.7˚C	39.8˚C	1.6˚C	30.1˚C	3.1˚C
Boromo (11.75N, 2.93E)	34˚C	1.8˚C	39.7˚C	1.9˚C	29.4˚C	2.8˚C

Bobo-Dioulass (11.17N, 4.32E)	32.6˚C	1.6˚C	38.3˚C	2˚C	28˚C	2.2˚C

Location (latitude, longitude)	Average temperature for the 1991-2020 climate standard normal period (˚C).	2024 mean temperature for the 1991-2020 climate standard normal period (˚C).	The year 2024 1991-2020 temperature anomaly
Ouagadougou (12.35N, -1.52E)	32.08˚C	33.7˚C	1.6˚C
Dori (14.03N, -0.03E)	33.4˚C	35.2˚C	1.8˚C
Gaoua (10.33N, -3.18E)	30.4˚C	32.3˚C	1.9˚C
Fada N'Gourma (12.3N, 0.37E)	32.4˚C	34.1˚C	1.7˚C
Boromo (11.75N, 2.93E)	32.2˚C	34˚C	1.8˚C
Bobo-Dioulass (11.17N, 4.32E)	31˚C	32.6˚C	1.6˚C

Location (latitude, longitude)	The Seasonal Mean of the Daily Maximum temperatures (˚C).	The year 2024 Seasonal Mean of the Daily Maximum temperatures (˚C).	The year 2024 seasonal mean maximum temperature 1991-2020 anomaly

Ouagadougou (12.35N, -1.52E)	37.7˚C	39.5˚C	1.8˚C
Dori (14.03N, -0.03E)	39.6˚C	41.4˚C	1.8˚C
Gaoua (10.33N, -3.18E)	35.7˚C	37.8˚C	2.2˚C
Fada N'Gourma (12.3N, 0.37E)	38˚C	39.8˚C	1.6˚C
Boromo (11.75N, 2.93E)	37.8˚C	39.7˚C	1.9˚C
Bobo-Dioulass (11.17N, 4.32E)	36.4˚C	38.3˚C	2˚C

Location (latitude, longitude)	**The Seasonal Mean of the Daily Minium temperatures (˚C).**	**The year 2024 Seasonal Mean of the Daily Minium temperatures (˚C).**	**The year 2024 seasonal mean minimum temperature 1991-2020 anomaly**
Ouagadougou (12.35N, -1.52E)	26.5˚C	28.57˚C	2.05˚C
Dori (14.03N, -0.03E)	27.4˚C	29.83˚C	2.4˚C
Gaoua (10.33N, -3.18E)	25.4˚C	27.55˚C	2.13˚C
Fada N'Gourma (12.3N, 0.37E)	27˚C	29.0˚C	2.02˚C
Boromo (11.75N, 2.93E)	26.7˚C	228.85˚C	2.18˚C
Bobo-Dioulass (11.17N, 4.32E)	25.9˚C	27.85˚C	2.03˚C

AI transparency statement: This document was reviewed and refined using Microsoft Copilot to enhance the clarity, grammar, spelling, and overall quality of the writing. all AI-generated suggestions were reviewed and verified by a scientist to ensure accuracy and quality.

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[i] Tutorial on Climatologies using Climate Data from C3S https://ecmwf-projects.github.io/copernicus-training-c3s/reanalysis-climatology.html

