Heat Waves Trends and Patterns in West Africa: Definitions and Drivers

BY

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Introduction

Several studies have shown that heat waves have been experiencing an increasing trend in major parts of the world, at regional and global scales (Chapman et al. 2019; Choi and Lee 2019; Hulley et al. 2020; Perkins-Kirkpatrick and Lewis 2020; Chowdhury 2022; Zhou et al. 2022).

They typically occur as a consequence of warming from subsidence and radiation due to anticyclonic circulation patterns in a region of more than 1000 km2, further intensified by stagnant air in the boundary layer inhibiting the dispersion of retained heat (Zhao et al. 2018; Shreevastava et al. 2023).

The definitions and measurements of heatwaves are often unclear and inconsistent, and they tend to vary depending on the specific group affected or the study reporting the information (Perkins and Alexander 2013).

Research Justification

West Africa is recognized as a hotspot of climate change (Heubes et al. 2013; M ̈uller et al. 2014; Balima et al. 2022). With its hot and dry climate in the Sahel region and a hot and humid climate along the Guinea coast, West Africa is susceptible to heat waves due to its climatic conditions (Ngoungue Langue et al. 2022).

Although heat waves receive substantial attention in developed nations due to their severe consequences, research on them is limited in developing countries (Campbell et al. 2018).

This situation is compounded by the absence of a well-defined threshold for characterising heat waves in West Africa, underscoring the necessity for an approach tailored to the region's context.

In this study, we explored the dynamics of heat waves in West Africa using different heatwave indices and also investigated the drivers of heatwaves over the region.

Data and Methodology

Weather studies relying on reanalysis datasets often face a crucial limitation due to their global-scale nature, resulting in a lack of local-scale information in many regions. This becomes particularly challenging in areas such as African cities where observation stations are sparse (Ngoungue Langue et al. 2022)

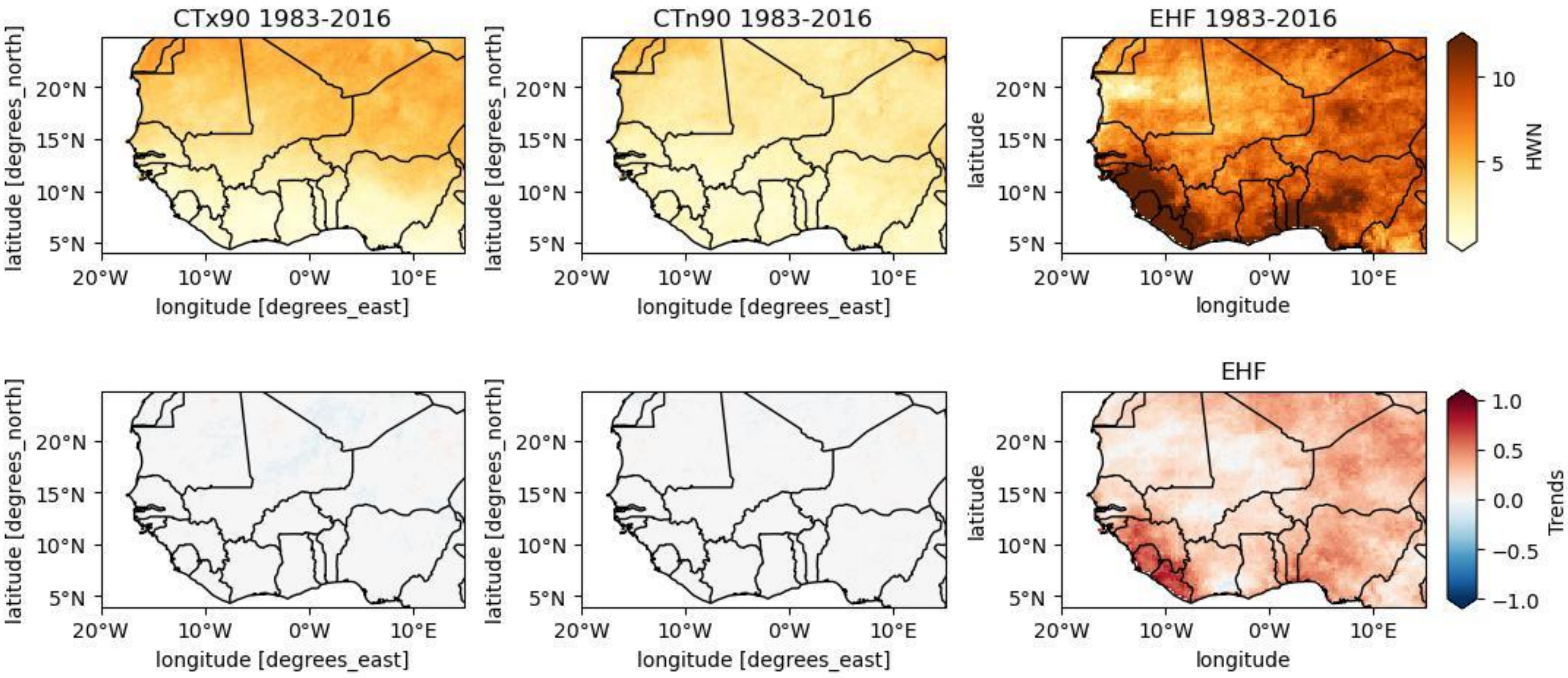
To achieve the objectives of this study, we downloaded the 0.25 by 0.25-degree resolution of CHIRTS-daily over Africa and extracted the region of interest which is West Africa from the 1st of January 1983 to the 31st of December 2016 spanning 34 years. CHIRTS-daily is a global 2-m maximum temperature (Tmax) product that combines the monthly CHIRTS-max dataset with the ERA5 reanalysis to produce a routinely updated data to support the monitoring of temperature extremes (Funk et al. 2019).

We downloaded Humidity, Sea Surface Temperature (SST), Observed Longwave Radiation (OLR), Wind (u,v,z) component, and Potential Temperature from ERA5 at 0.25 by 0.25-degree resolution to establish the drivers and patterns of heat waves across West Africa.

METHODOLOGY

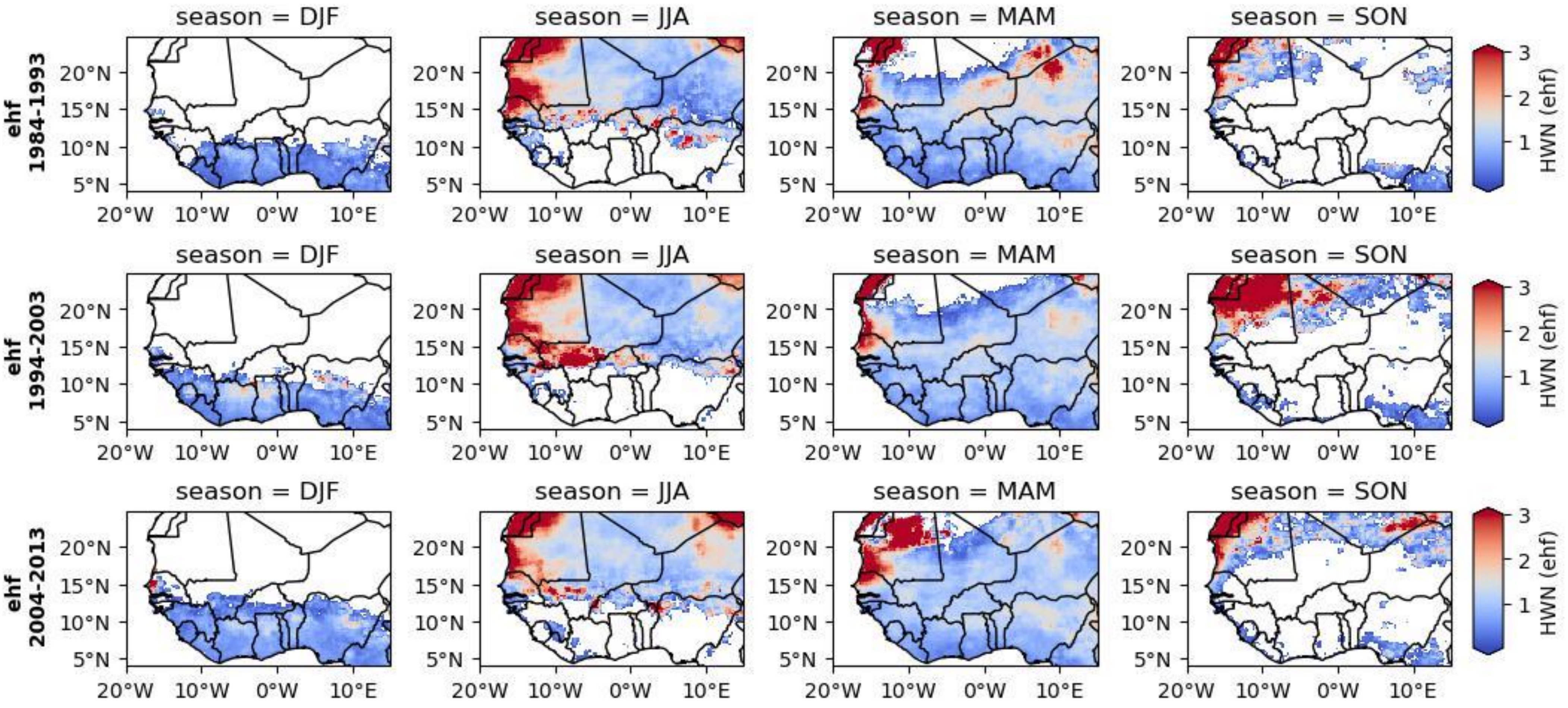
S/N	METRIC	DESCRIPTION	REFERENCES
1.	CTx90 Amount of hot days	Days when Tx>90th percentile. Days with hot day time temperatures	ETCCDI(http://etccdi.pacificclimate.org/list_27_indices.shtml) Alexander et al. (2006)
2.	CTn90p Amount of warm nights	Days when Tn>90th percentile Days with hot night time temperatures	"
3.	EHF Excess Heat Factor	Uses daily Tx and Tn: T=(TX+TN)/2 includes an acclimatisation factor (monthly) EHI(accl.) = (Ti+Ti−1+Ti−2)/3 − (Ti−3 + ⋯+ Ti−32)/30 and a significance factor EHI(sig.) = (Ti+Ti−1+Ti−2)/3−T95 (clim) EHI(sig.) = (Ti+Ti−1+Ti−2)/3−T90 (cal) EHF=max[1, EHI(accl.) * EHI(sig.)] By multiplying the EHI(accl.) and EHI(sig.) indices, the EHF unit is Celsius squared (°C2) (Perkins and Alexander 2013)	Excess Heat Factor (EHF) developed by the Bureau of Meteorology EHF=excess heat * heat stress Nairn and Fawcett (2013) Perkins and Alexander (2013)
4.	Moist Static Energy MSE = CpT + gz + Lv*q	where: Cp is specific heat capacity of dry air (J kg^{-1} K^{-1}), T is the absolute temperature of air (K), g is acceleration due to gravity (m s^{-2}), z is geopotential height of the air (m), Lv is latent heat of vaporization (J kg^{-1}), q is specific humidity of the air (kg kg^{-1})	

RESULTS (HWN)



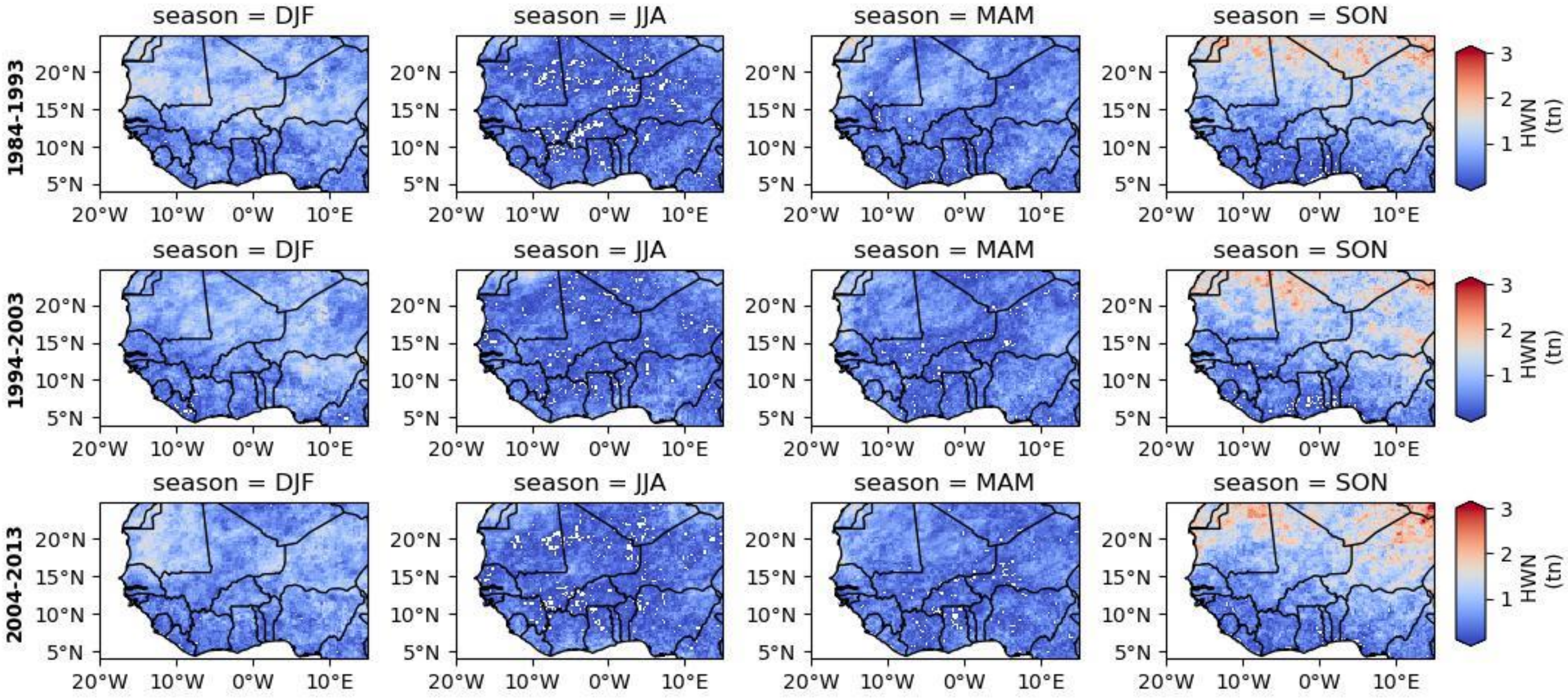
CTx90 1983-2016
CTn90 1983-2016
EHF 1983-2016
EHF
latitude [degrees_north]
latitude
longitude [degrees_east]
longitude
20°N
15°N
10°N
5°N
20°W
10°W
0°W
10°E
HWN
10
5
Trends
1.0
0.5
0.0
−0.5
−1.0

RESULTS (HWN)

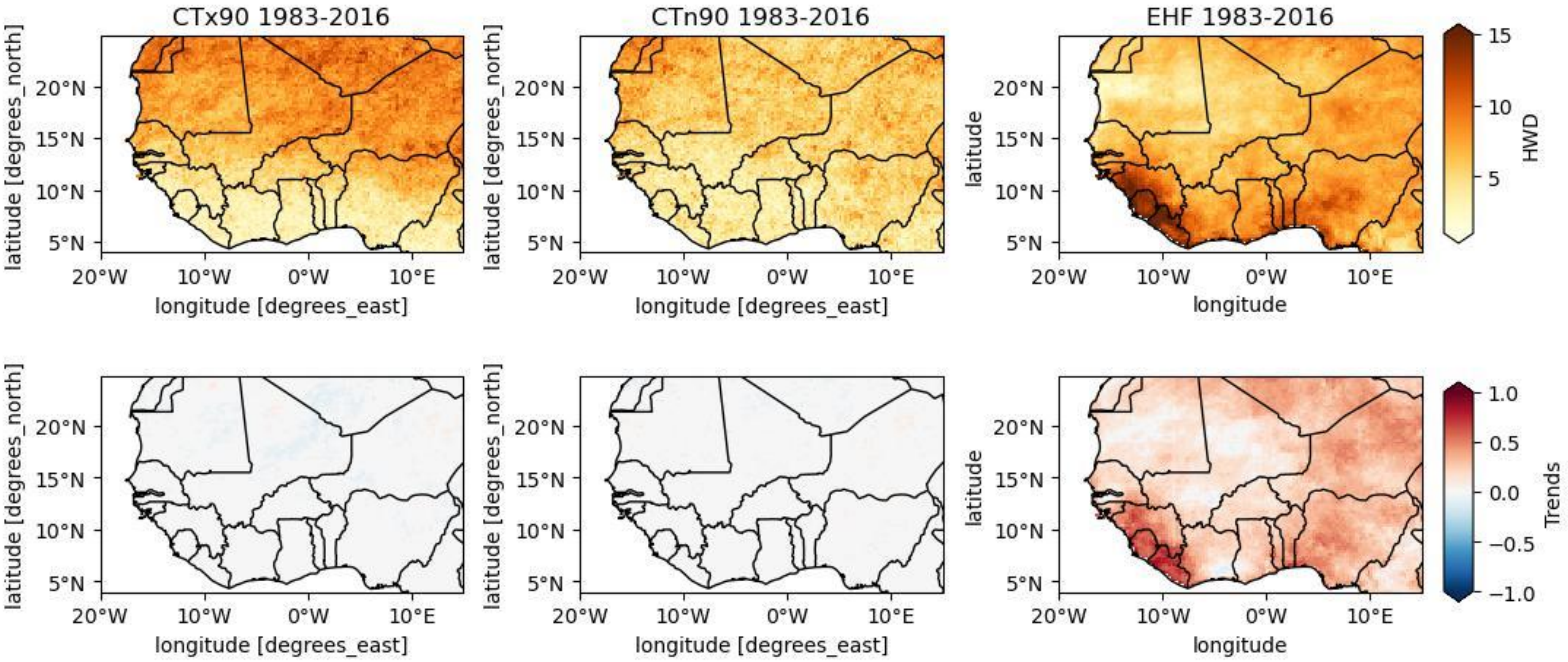


season = DJF
season = JJA
season = MAM
season = SON
ehf
1984-1993
ehf
1994-2003
ehf
2004-2013
20°N
15°N
10°N
5°N
20°W 10°W 0°W 10°E
HWN (ehf)
1
2
3

RESULTS (HWN - Tn)

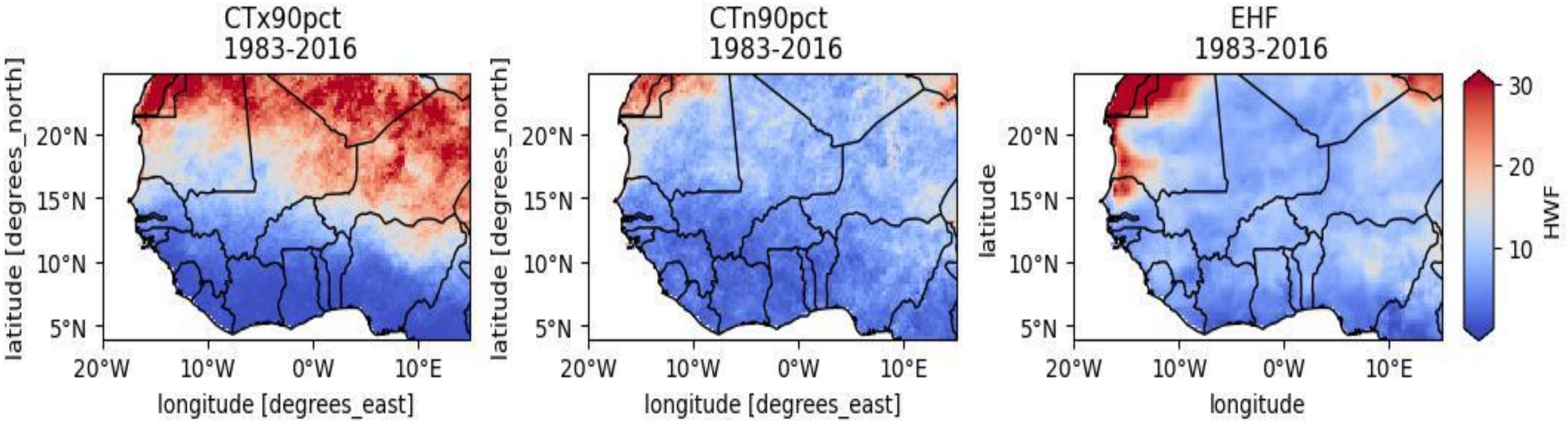


RESULTS (HWD)



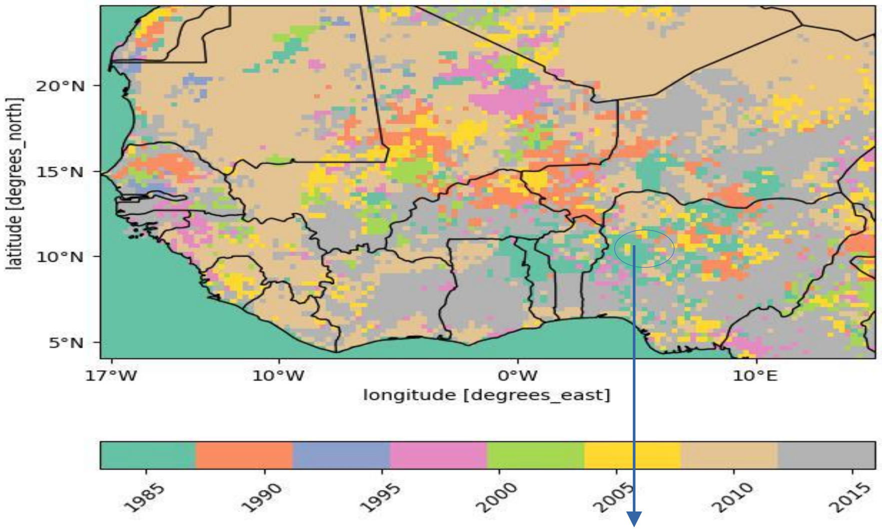
CTx90 1983-2016
CTn90 1983-2016
EHF 1983-2016
latitude [degrees_north]
latitude
20°N
15°N
10°N
5°N
20°W
10°W
0°W
10°E
longitude [degrees_east]
longitude
HWD
15
10
5
Trends
1.0
0.5
0.0
−0.5
−1.0

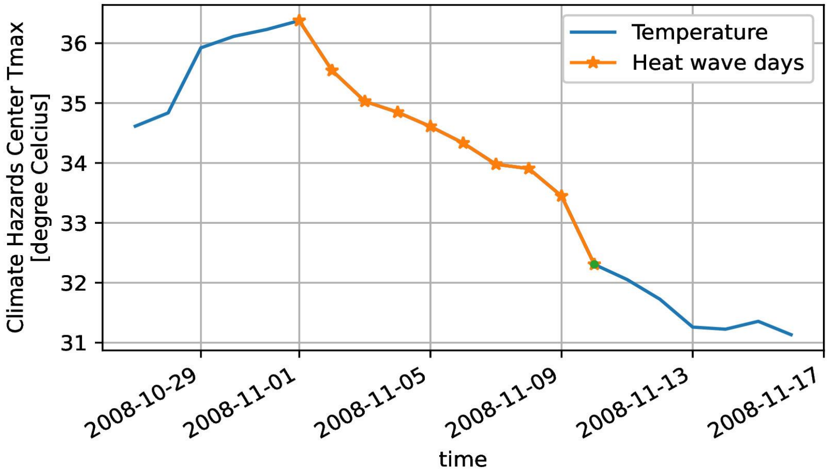
RESULTS (HWF)

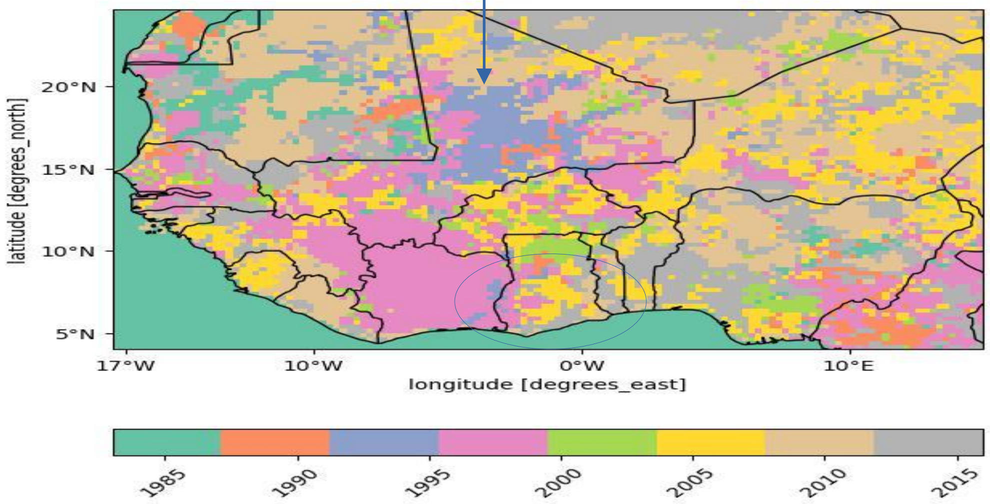


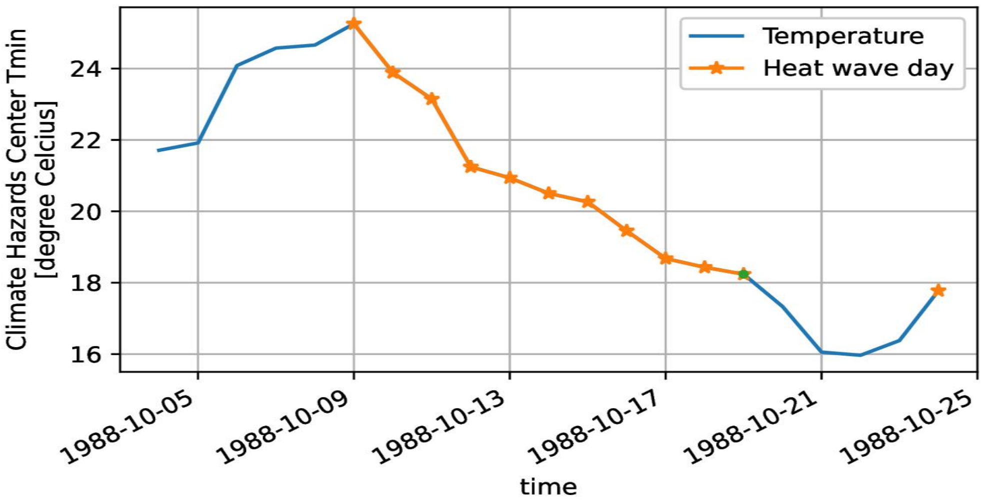
CTx90pct
1983-2016
CTn90pct
1983-2016
EHF
1983-2016
latitude [degrees_north]
latitude [degrees_north]
latitude
20°N
15°N
10°N
5°N
20°W
10°W
0°W
10°E
longitude [degrees_east]
longitude [degrees_east]
longitude
30
20
10
HWF

RESULTS – HWD (Scenario Study)

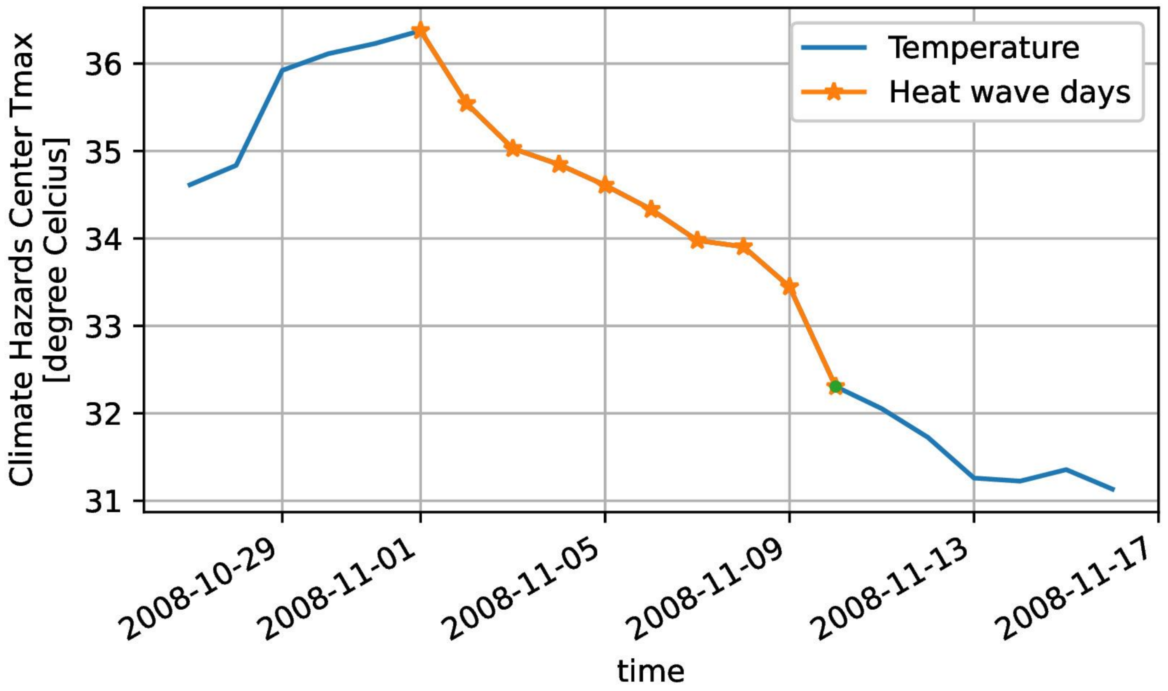


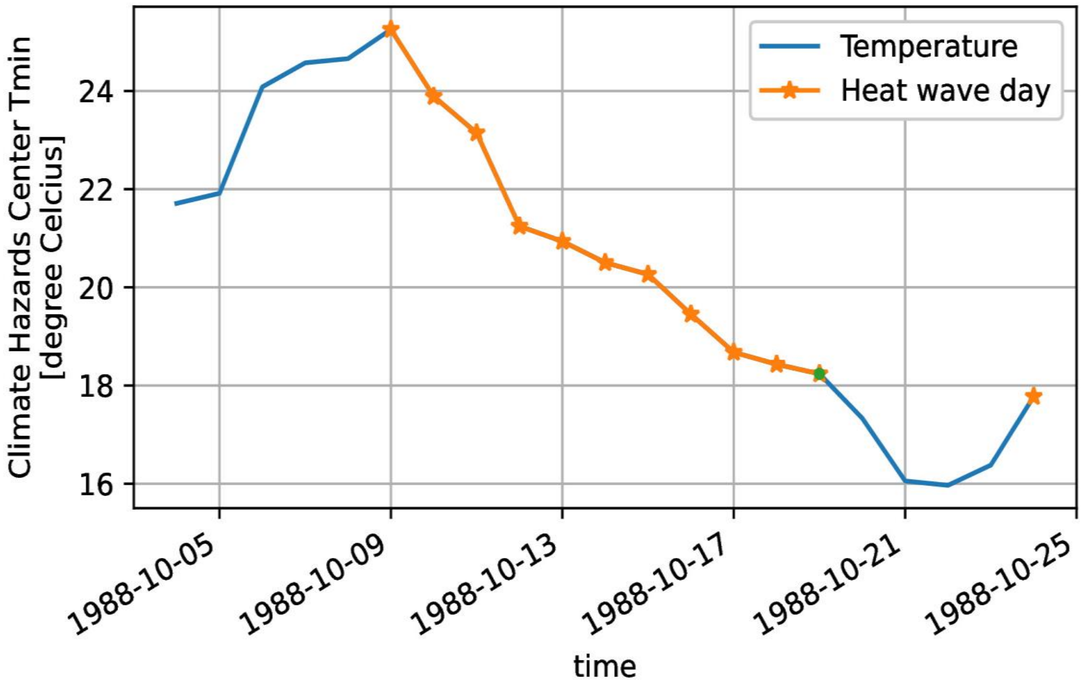




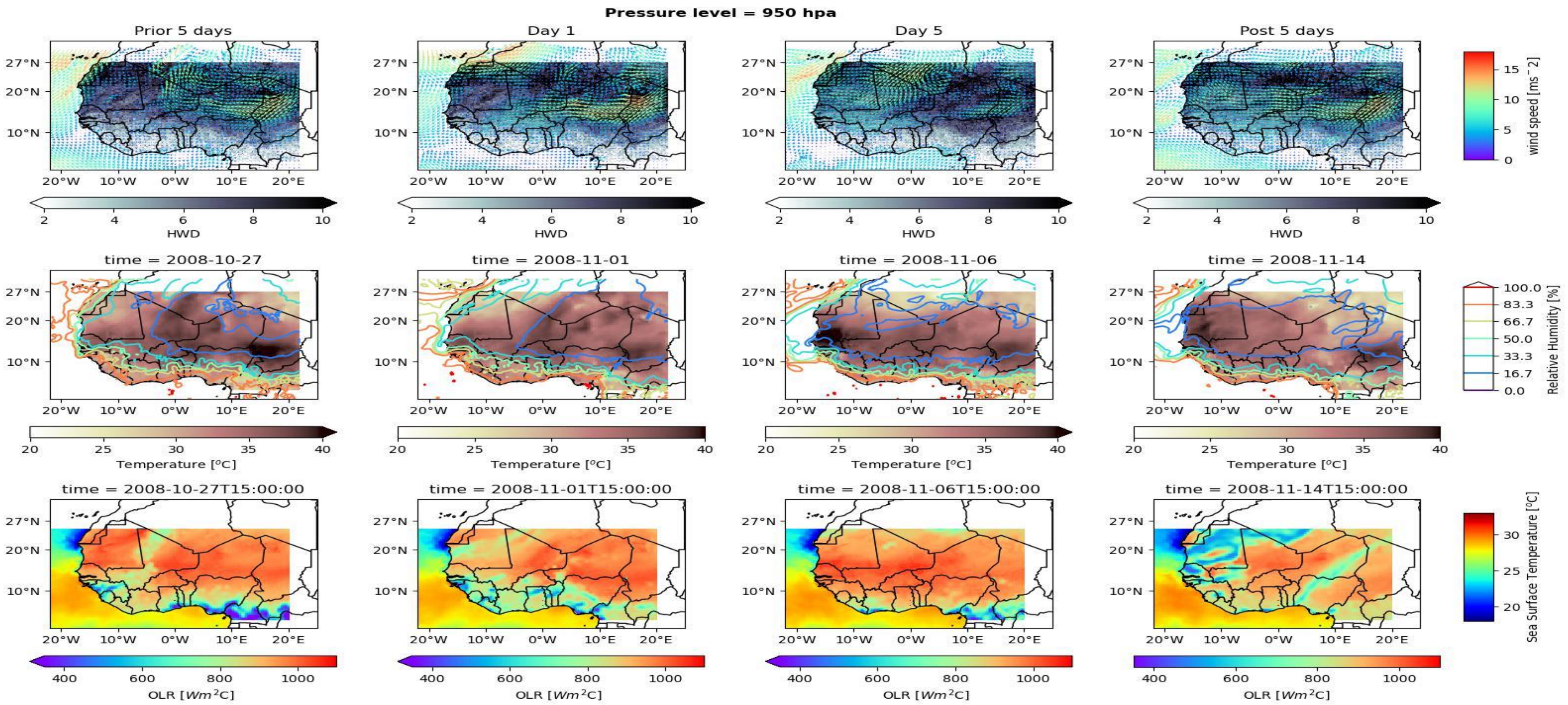


RESULTS – HWD (Scenario Study)

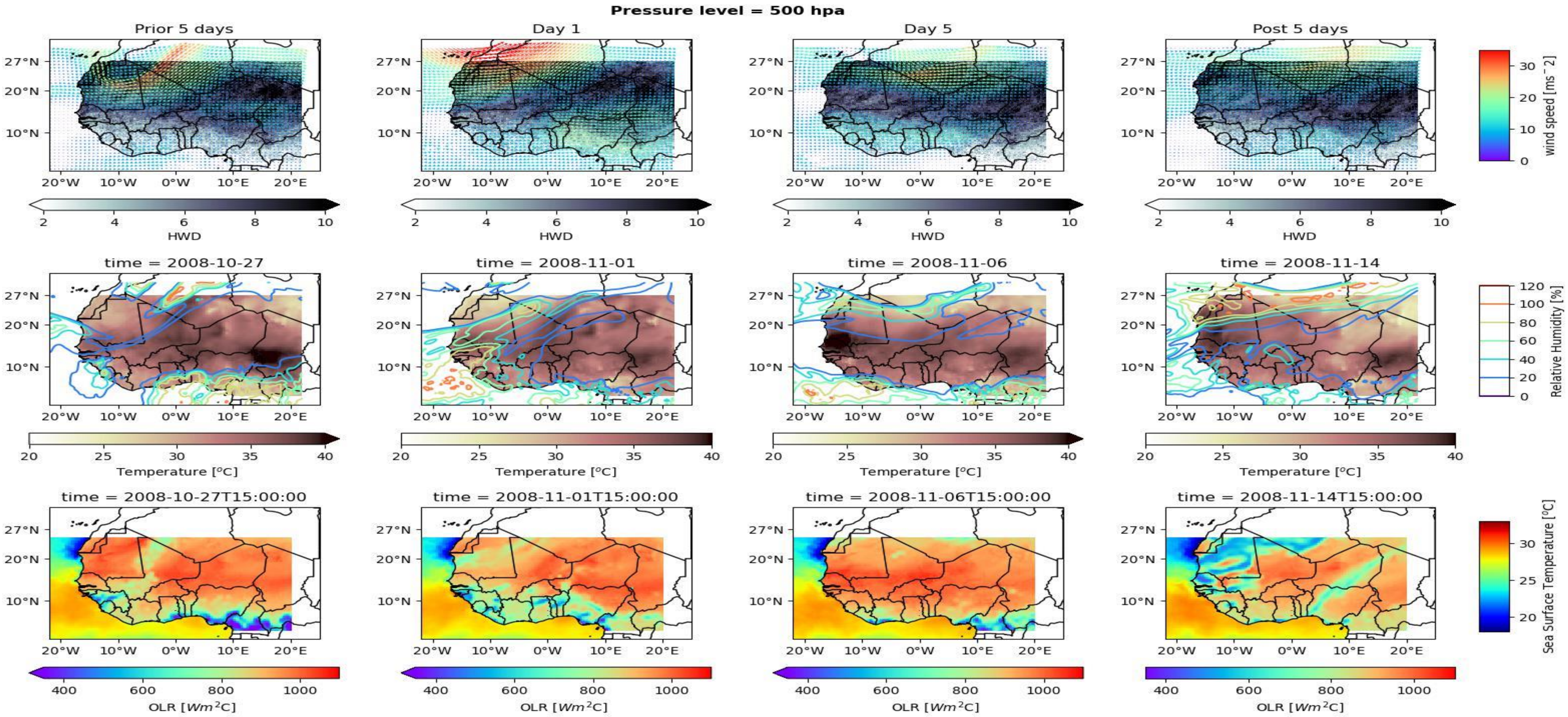




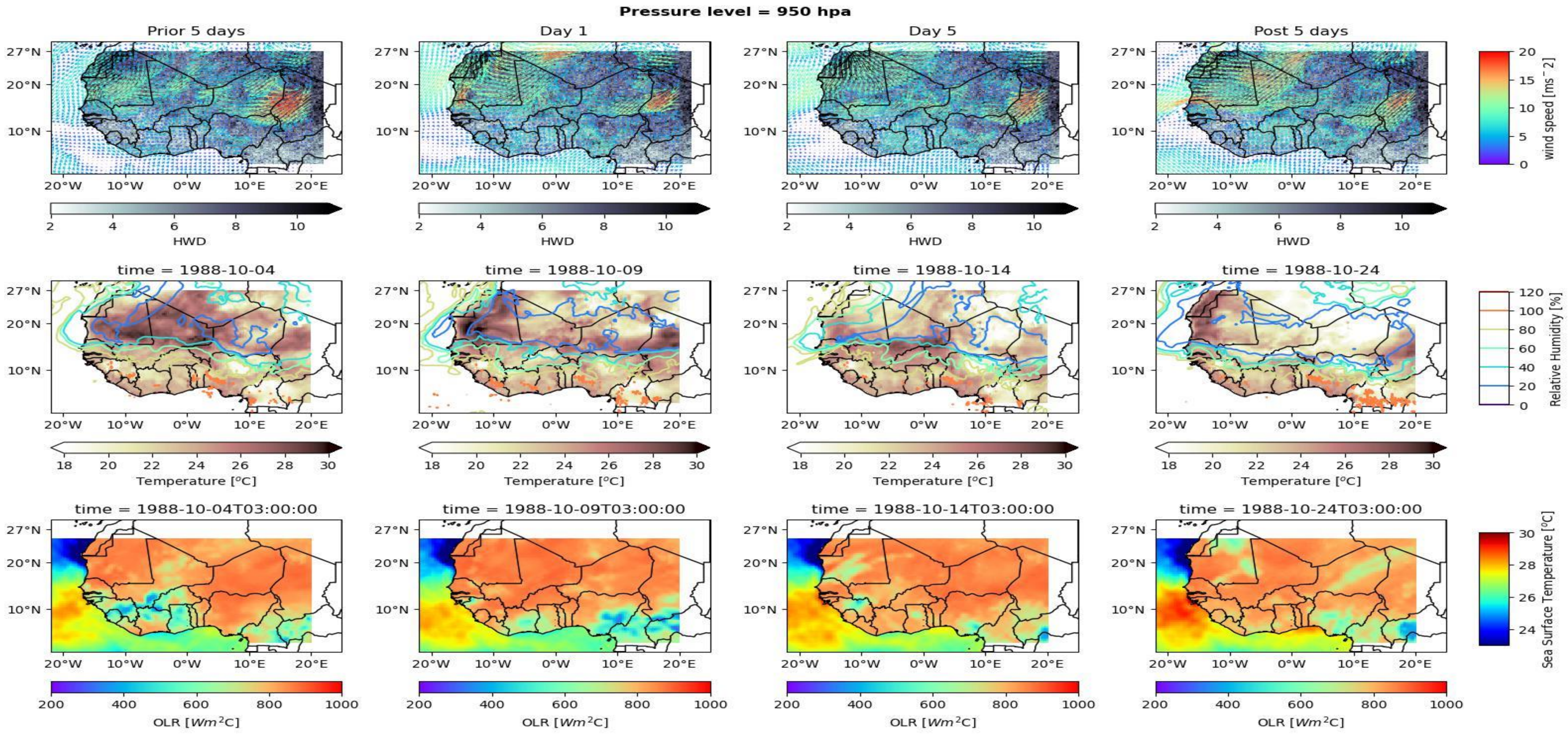
RESULTS – (WEATHER DURING DAYTIME HEATWAVES)



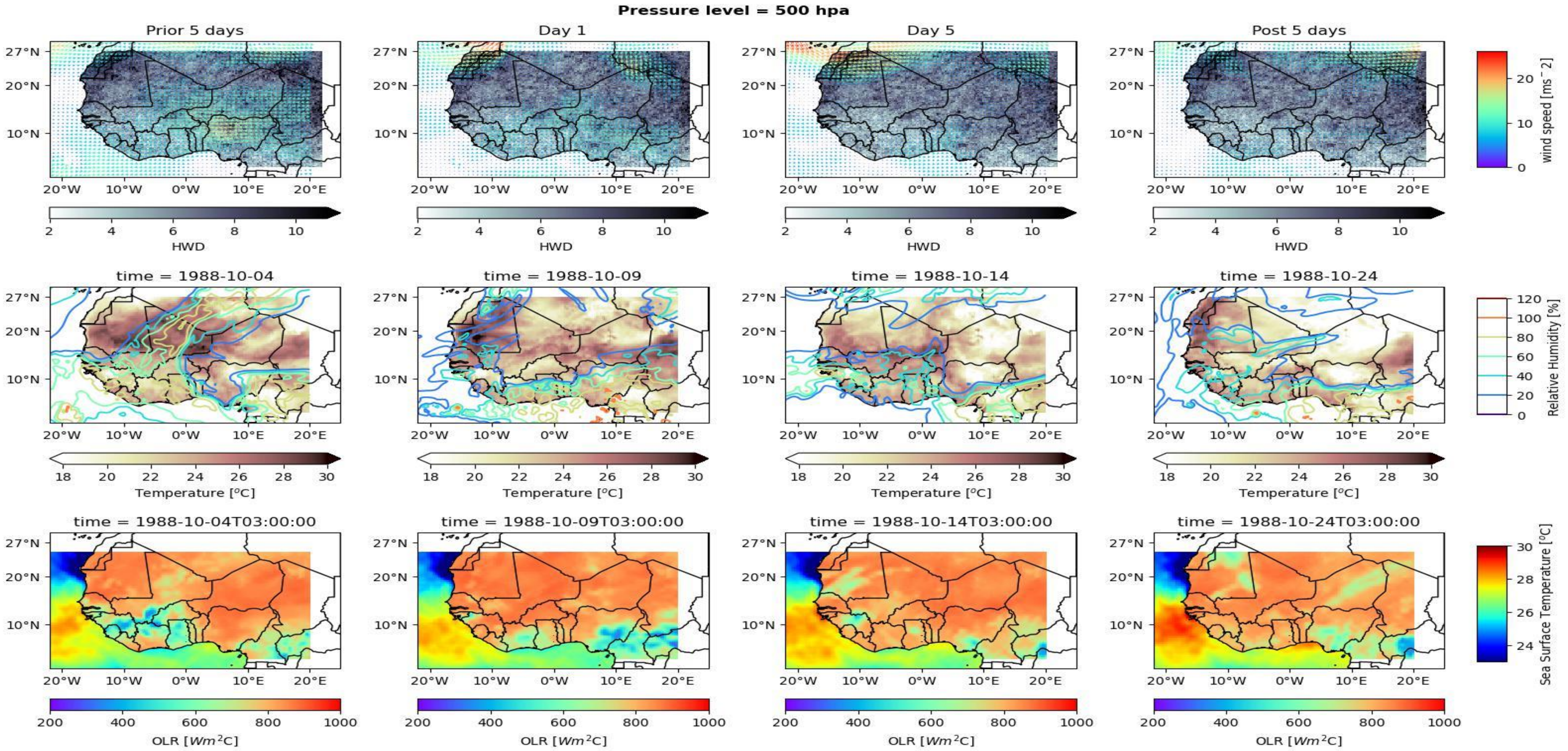
RESULTS – (WEATHER DURING DAYTIME HEATWAVES)



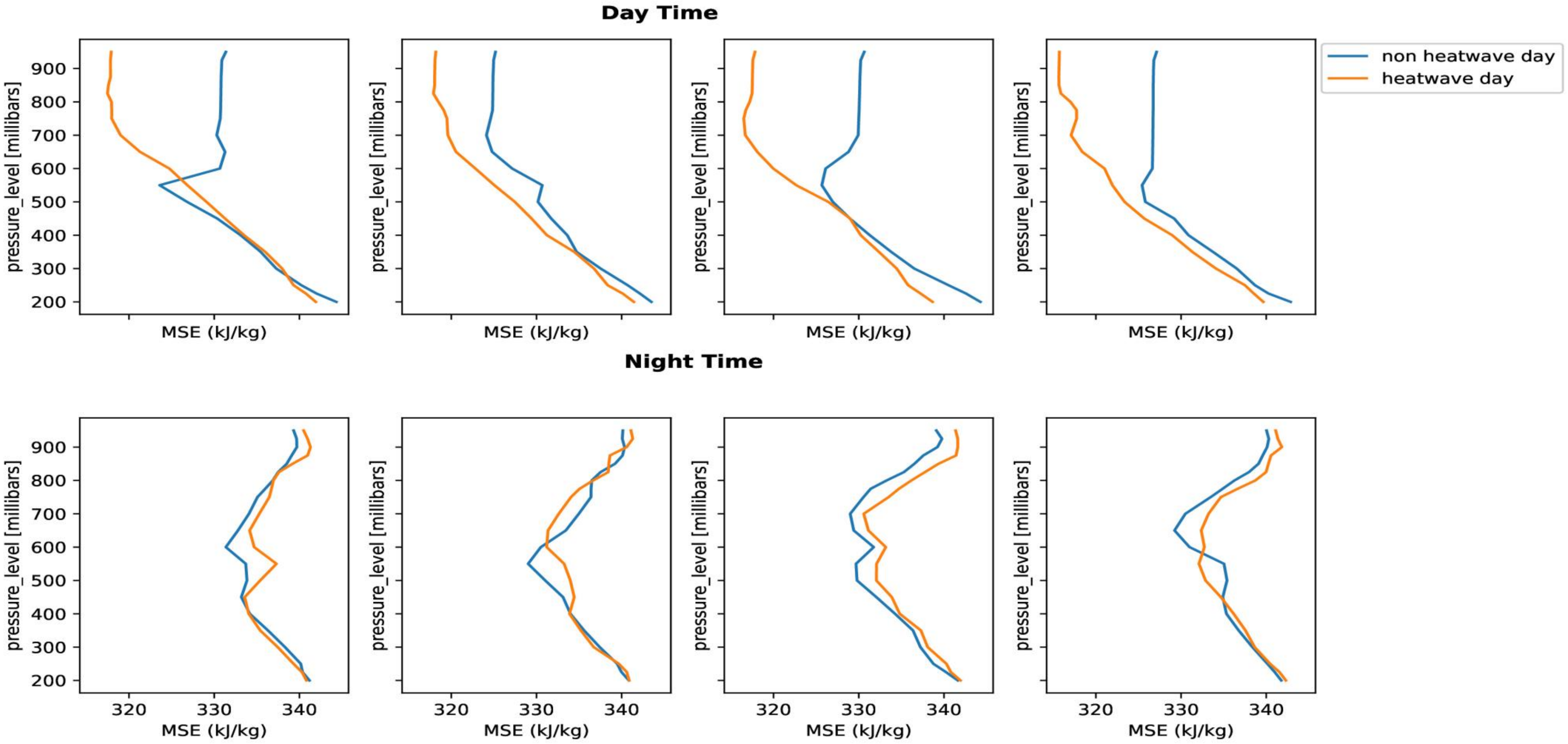
RESULTS – (WEATHER DURING NIGHTTIME HEATWAVES)



RESULTS – (WEATHER DURING NIGHTTIME HEATWAVES)



RESULTS – MOIST STATIC ENERGY (MSE)



DISCUSSION

- West Africa experiences diverse climates from the hot and humid Gulf of Guinea to the drier Sahel region, leading to different conditions for heat wave formation across the area.
- Due to W/Africa location within the Tropic of Cancer and the equator, It receives intense solar radiation year-round, contributing to high temperatures.
- The vast inland areas have a dry climate with large seasonal temperature variations. Land heats up and cools faster than water, leading to hotter summers and colder winters. Daytime Heat waves Dissipate at night due to little formation of cloud inland
- Semi-permanent high-pressure systems dominate the dry season, suppressing cloud formation and precipitation, allowing temperatures to soar.

DISCUSSION CONTD.

- During the dry season, South Westerly Harmattan wind blows hot and dry air from the Sahara Desert, that increases temperatures and reduces humidity.
- Proximity to the Atlantic Ocean moderates nighttime temperatures with sea breezes and higher humidity, leading to hot and humid nighttime heat waves around the GoG as in Ghana. Warm ocean current flowing along the coast contributes to overall higher temperatures and can influence heat wave intensity near the shore.
- Dry-season heat waves are common in the Sahel and Sahara due to strong subtropical highs, limited vegetation, and the Harmattan wind.
- Higher levels of moisture in the atmosphere can contribute to an increase in the total energy content of the air parcels. This can lead to the intensification of heat waves as the atmosphere becomes more conducive to the accumulation and retention of heat.

CONCLUSION

An Understanding of Heat Waves over W/Africa is crucial an beneficial to the region. This study delves into the underlying conditions which can help with:

- Improved weather forecasting and early warning systems.
- Developing effective heat wave mitigation and adaptation strategies.
- Protecting vulnerable populations from health risks associated with heat waves.
- By addressing the underlying causes, including climate change and unsustainable land-use practices, West African countries can build resilience and better prepare for the challenges of increasingly frequent and intense heat waves.

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