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Heat wave monitoring over West African cities: uncertainties, characterization and recent trends

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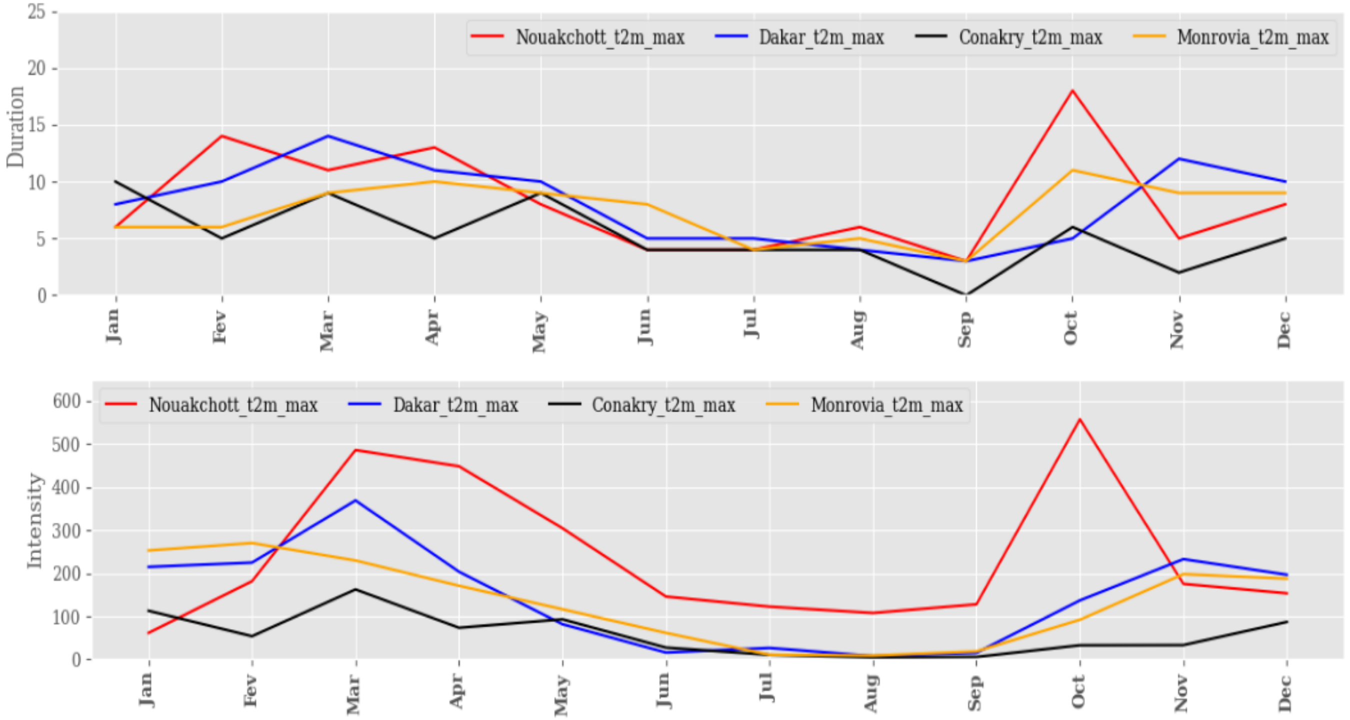

Figure S1. *Evaluation of the coherence in terms of heat wave frequency in the cities belonging to the ATL region over the period 1993-2020. The color legend represents the different cities. The X- and Y-axes represent the time in month, heat wave duration and intensity respectively.*

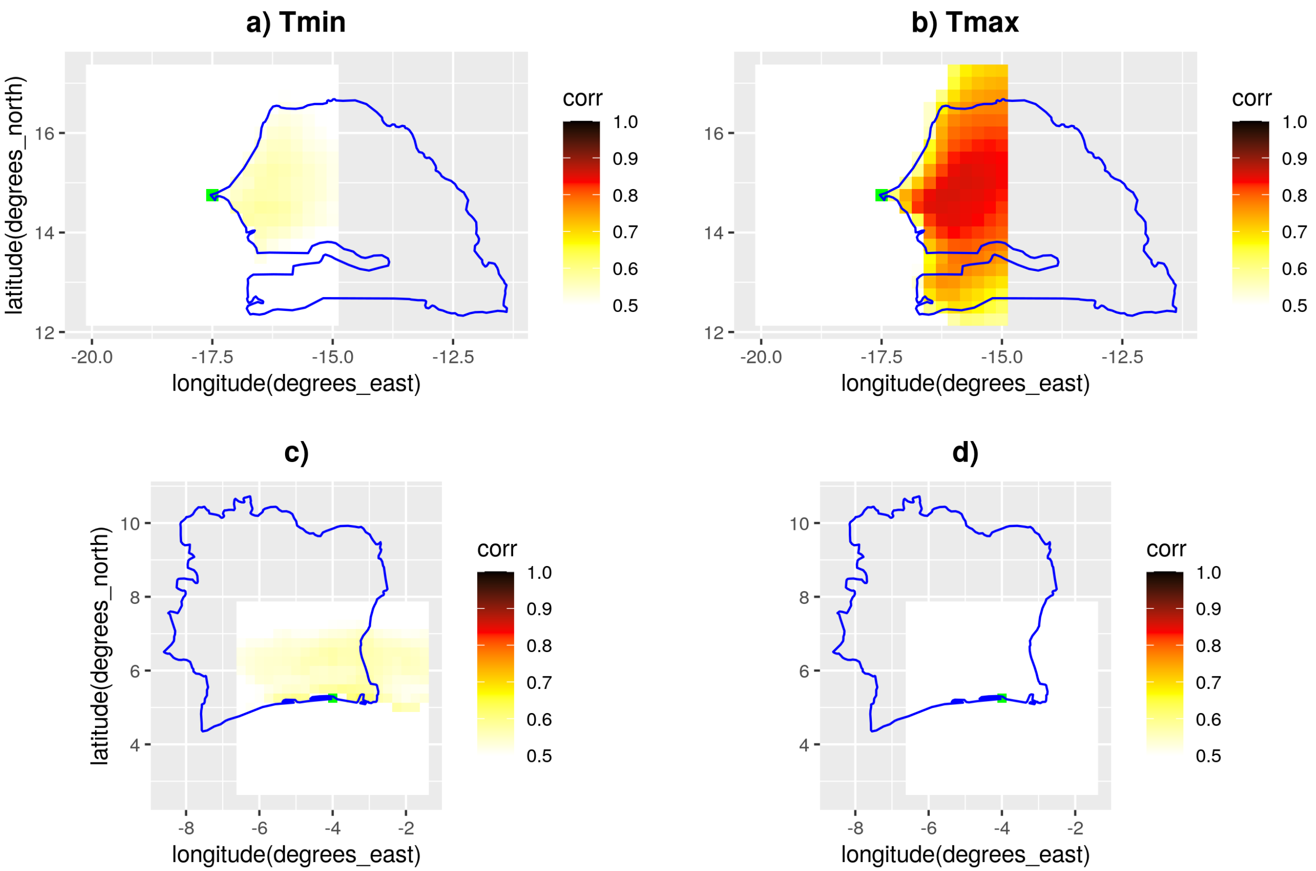

Figure S2. *Analysis of the spatial variability of T2m in ERA5 reanalysis and the local station data. This is done by the computation of the anomaly of correlation coefficient between the station data and ERA5 reanalysis over Dakar:* ***a)*** *Tmin and* ***b)*** *Tmax and Abidjan :* ***c)*** *Tmin and* ***d)*** *Tmax. X- and Y- axis represent the longitude and latitude in degree respectively. The color bar shows the values of the correlation. The stations used for this analysis are located at Yoff in Senegal and Felix Houphouet Boigny airport in Ivory coast.*

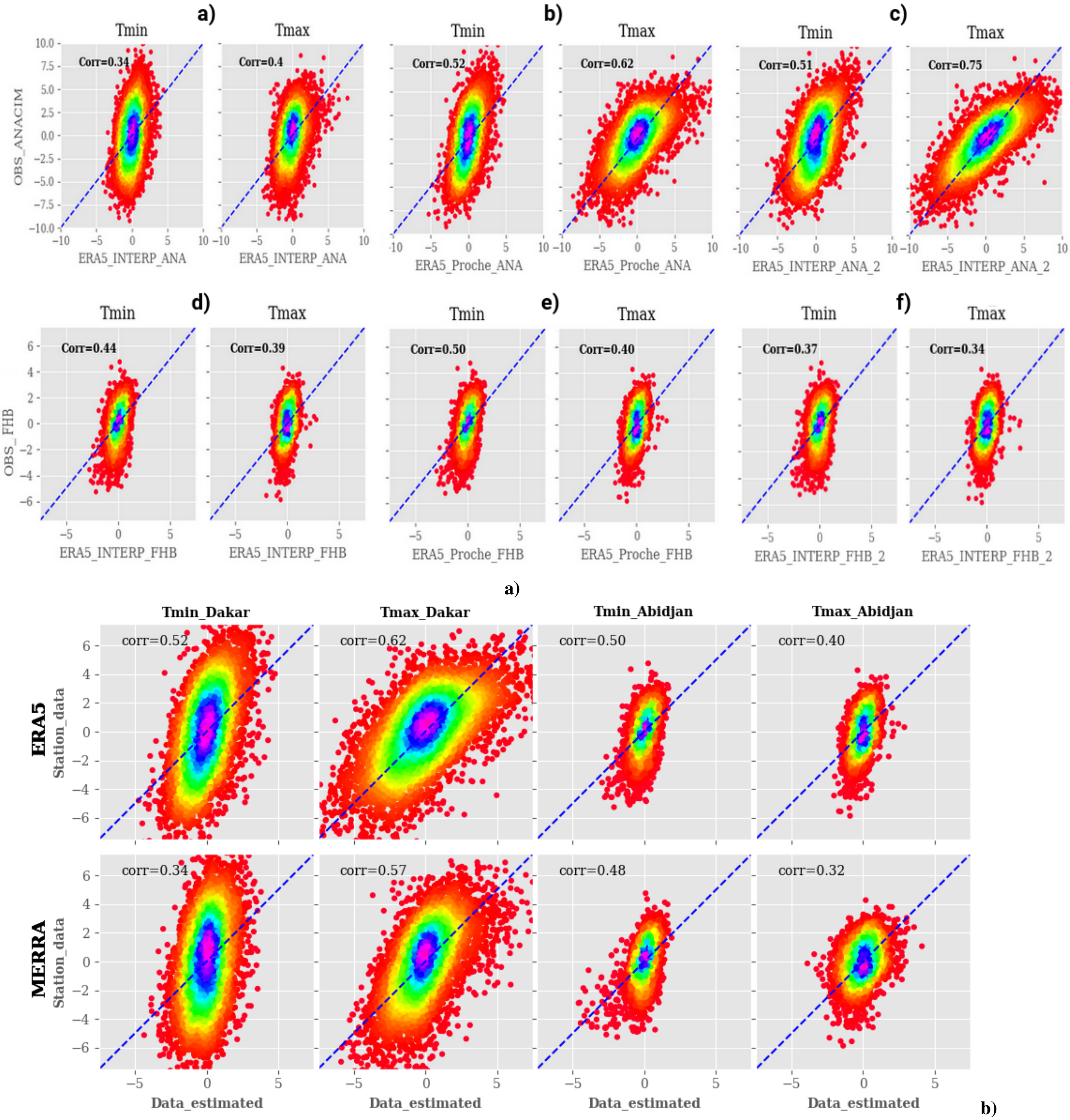

Figure S3. ***a)*** *Evaluation of different interpolation techniques for the estimation of T2m at the scale of cities from ERA5 reanalysis for:* ***a-c)*** *Dakar-Yoff station and* ***d-f)*** *Aéroport FHB station. The* $1^{st}, 2^{nd}, 3^{rd}$ *columns show the results obtained with the bilinear interpolation method (a,d), nearest neighbour method with lsm>=0.5 (b,e) and the linear gradient approach with a lsm>=0.5 (c,f) respectively.* ***b)*** *Evaluation of the coherence between reanalyses (ERA5, MERRA) and the local station data using the best interpolation method found previously.The blue dashed line represents the identity line which means perfect correlation between the two products. The X- and Y-axis represent the estimated T2m from ERA5 and MERRA and local T2m from the stations respectively.*

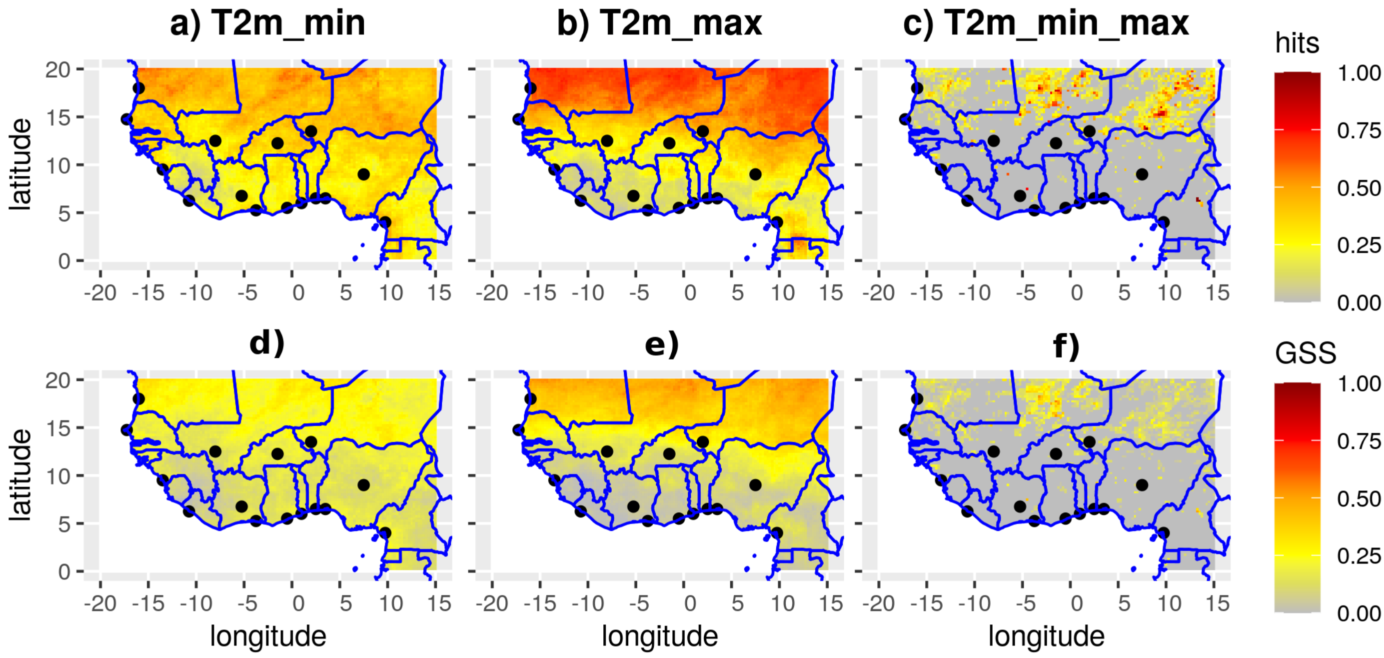

Figure S4. *Evaluation of the consistency of reanalyses (ERA5, MERRA) on the representation of hot days in West African regions: The first/second row represents the hits rate (a-c) / Gilbert score (d-f). X- and Y -axis represent the longitude and latitude in degrees respectively. The color bar shows the values of the metrics. The threshold used for the computation of hot days is the climatological daily* 90^{th} *percentile. Hot days are therefore defined as days above the threshold.*

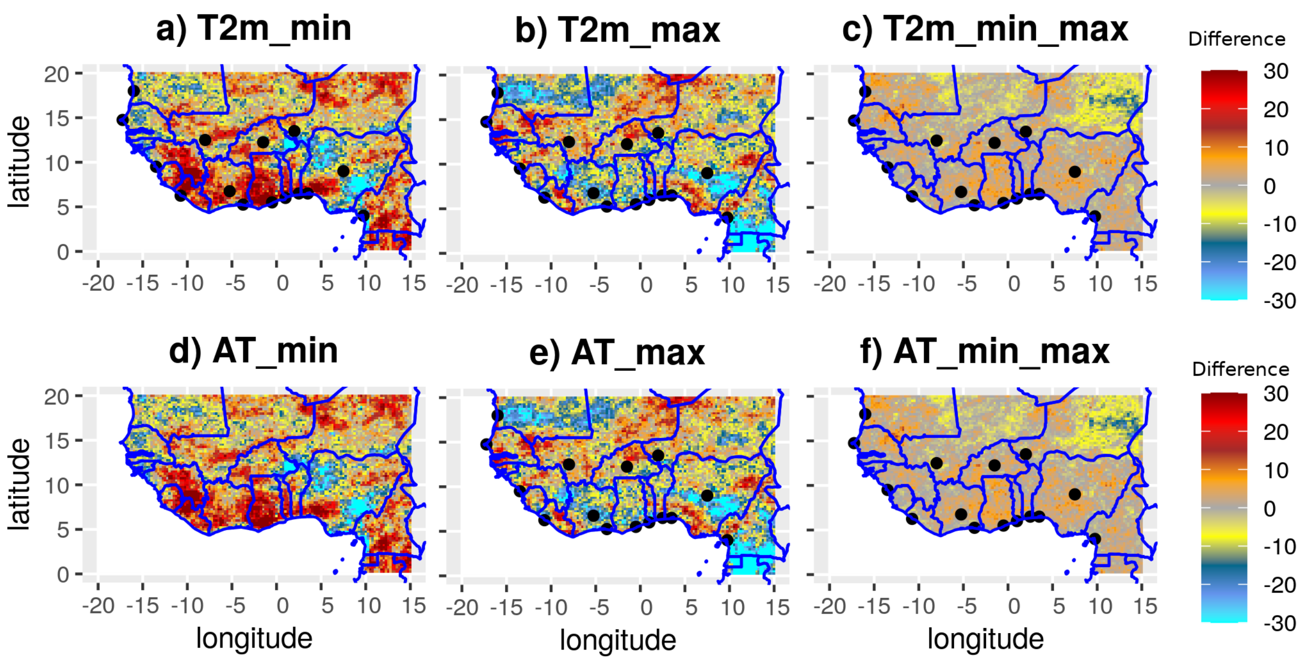

Figure S5. *Evaluation of the uncertainties of the reanalyses (ERA5, MERRA) in terms of heat waves frequency. The uncertainty is defined as the difference between the heat wave frequency in ERA5 and MERRA. The X- and Y-axis represent the longitude and latitude in degree respectively. The threshold used for the computation of hot days is the climatological daily* 90^{th} *percentile.*

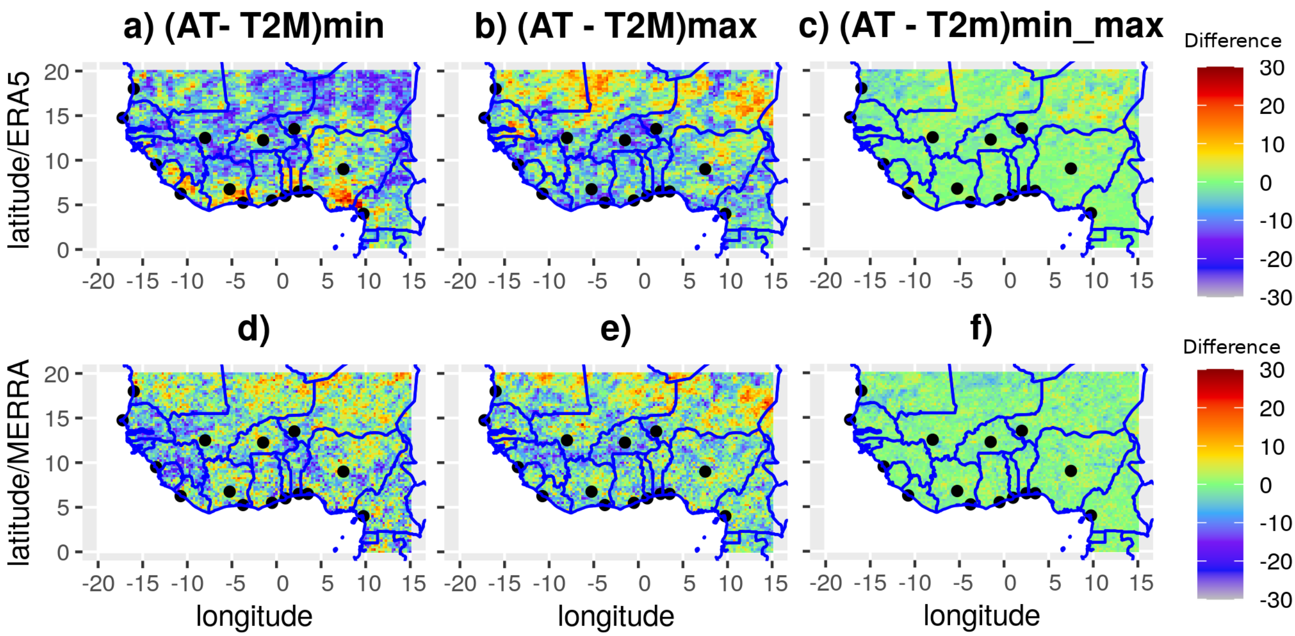

Figure S6. *Evaluation of the uncertainties in terms of heat waves frequency between AT and T2m using min/max/min-max values:* ***a-c)*** *ERA5 and* ***d-f)*** *MERRA respectively. X- and Y -axis represent the longitude and latitude in degrees respectively. The color bar shows the difference of heat wave frequency. The threshold used for the computation of hot days is the climatological daily* 90^{th} *percentile.*

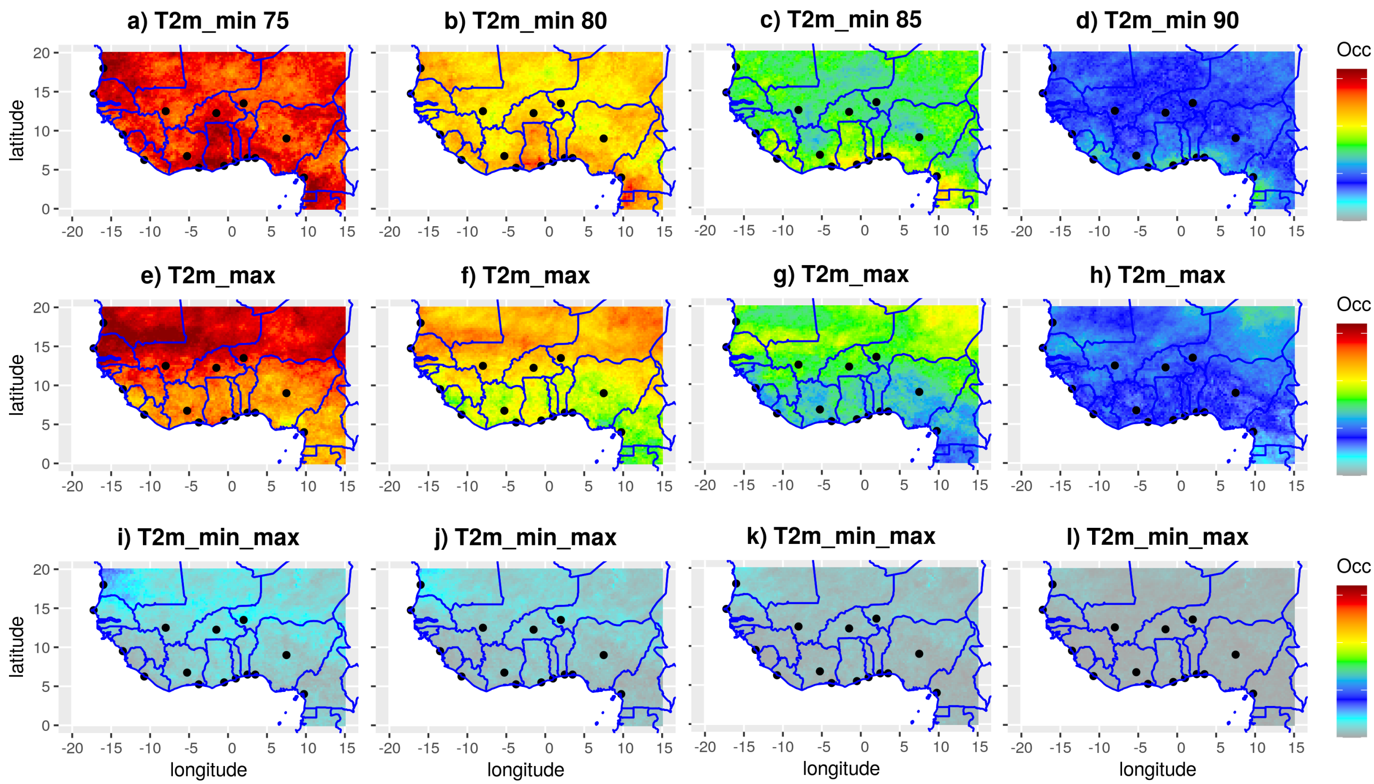

Figure S7. *Spatial variability of heat waves frequency with respect to the threshold values using T2m as indicator and ERA5 reanalysis for : **a,e,i)** 75^{th}, **b,f,j)** 80^{th}, **c,g,k)** 85^{th} and **d,h,l)** 90^{th} respectively. X- and Y- axis represent the longitude and latitude in degrees respectively. The color bar shows the values of the frequency of heat waves. "Occ" stands for heat waves occurrence or frequency.*

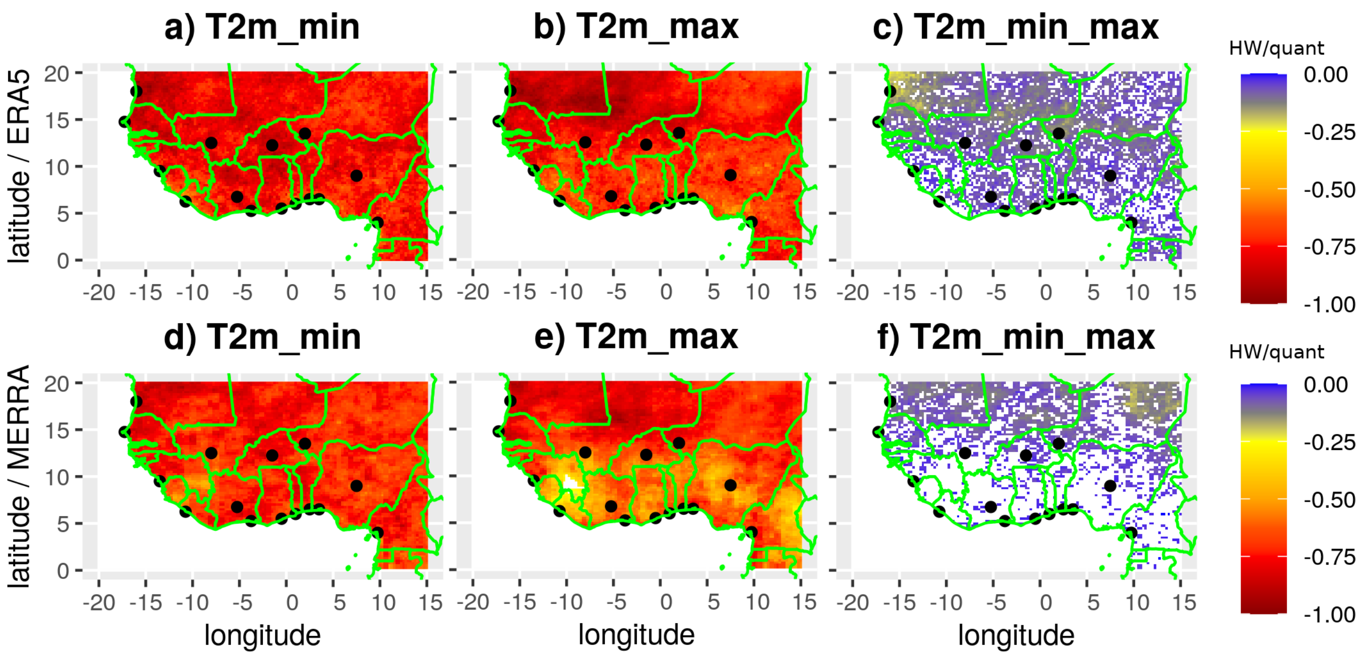

Figure S8. *Evolution of the heat waves frequency with respect to the threshold values using T2m as indicator for :* ***a-c)*** *ERA5 and* ***d-f)*** *MERRA respectively. The figure shows the slope of the regression line in number of events per percentile which is computed by fitting a linear regression between the threshold values (Q75, Q80, Q85, Q90) and their corresponding heat waves frequency ($N_{75}, N_{80}, N_{85}, N_{90}$). X- and Y- axis represent the longitude and latitude in degrees respectively. The color bar shows the values of the slope. The white blanks indicate non significant changes in the heat waves frequency per percentile. The significance of the slope of the regression line has been computed using a two-sided Chi-square test.*

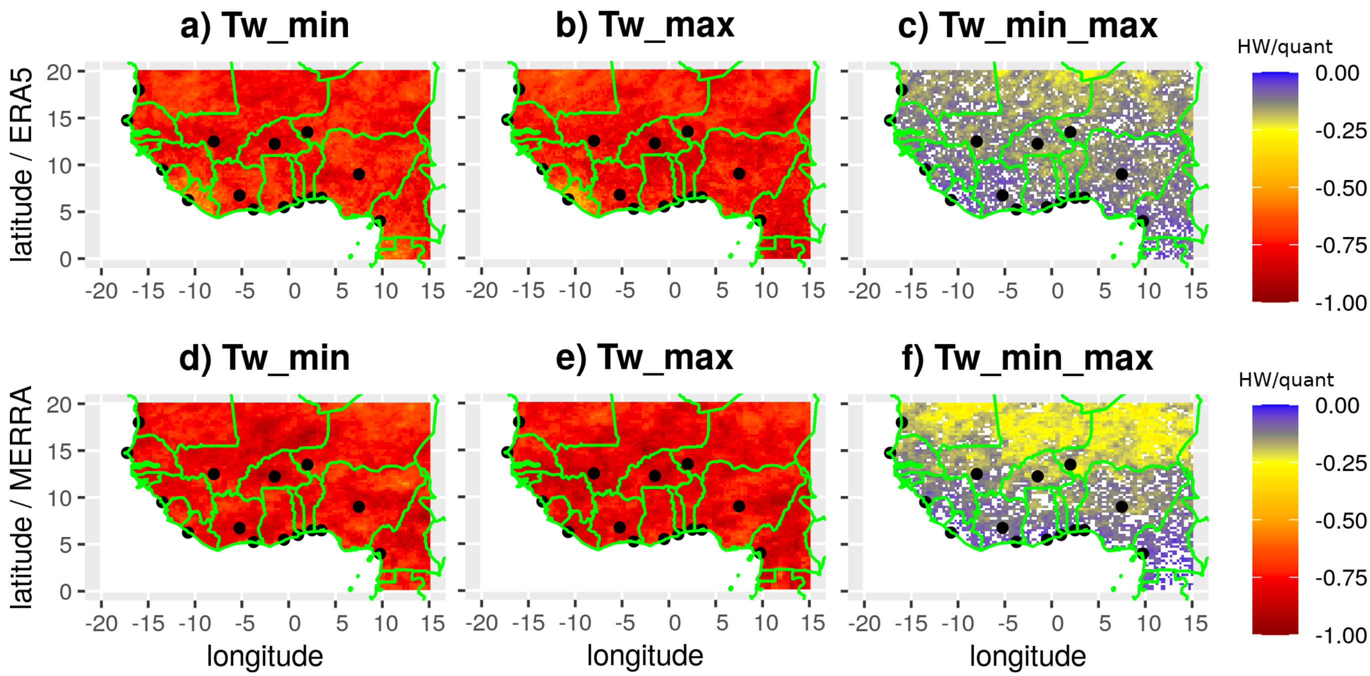

Figure S9. *Evolution of the heat waves frequency with respect to the threshold values using Tw as indicator for :* ***a-c)*** *ERA5 and* ***d-f)*** *MERRA respectively. The figure shows the slope of the regression line in number of events per percentile which is computed by fitting a linear regression between the threshold values (Q75, Q80, Q85, Q90) and their corresponding heat waves frequency ($N_{75}, N_{80}, N_{85}, N_{90}$). X- and Y- axis represent the longitude and latitude in degrees respectively. The color bar shows the values of the slope.The white blanks indicate non significant changes in the heat waves frequency per percentile. The significance of the slope of the regression line has been computed using a two-sided Chi-square test.*

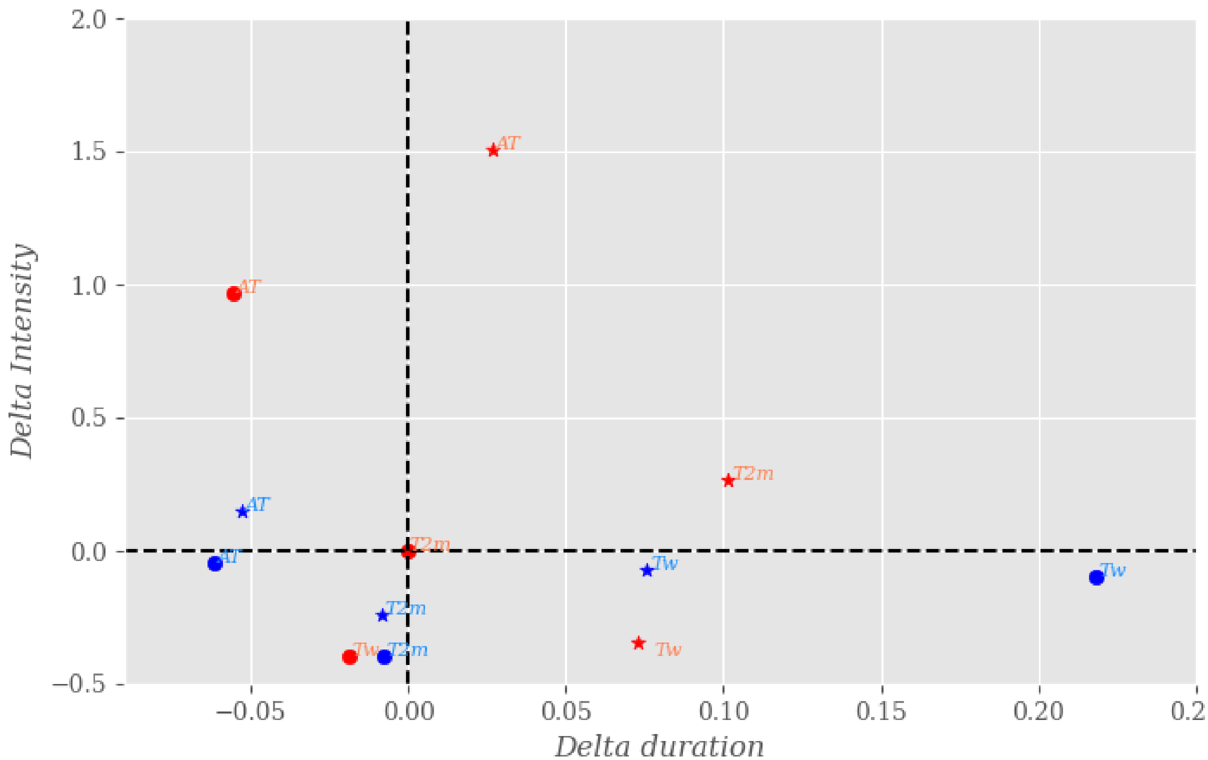

Figure S10. *Sensitivity analysis of heat waves characteristics to the datasets, indicators and methodology used in the ATL region. The characteristics investigated here are the duration and intensity. The circles and stars in the figure represent ERA5 and MERRA reanalyses respectively. The blue/red color represents minimum/maximum values of the indicators. "$T2m_{max}$" from ERA5 is the reference variable used for this analysis. The Y- and X- axis show the standardized variation of intensity and duration from the reference (no unit) respectively. The variation of duration and intensity have been computed using max daily T2m in ERA5 as reference. The detection of heat waves is done using the climatological daily 90^{th} percentile over the period as threshold.*

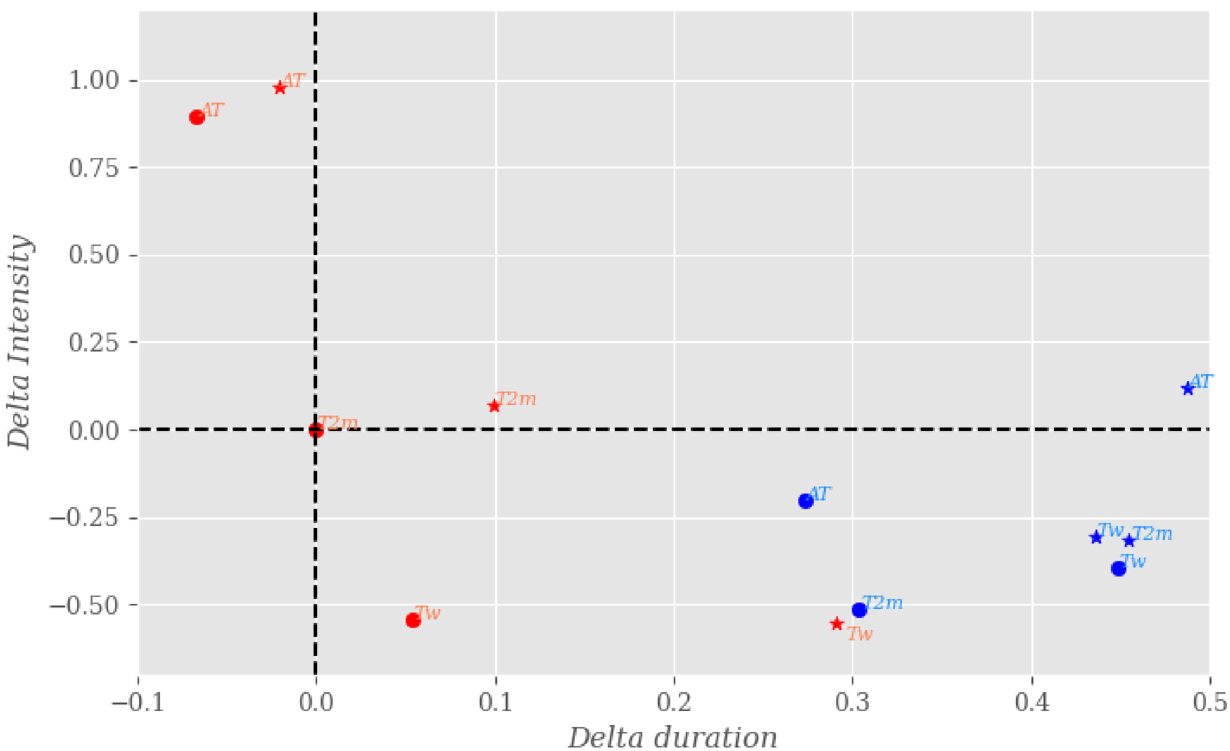

Figure S11. *Sensitivity analysis of heat waves characteristics to the datasets, indicators and methodology used in the GU region. The characteristics investigated here are the duration and intensity. The circles and stars in the figure represent ERA5 and MERRA reanalyses respectively. The blue/red color represents minimum/maximum values of the indicators. "$T2m_{max}$" from ERA5 is the reference variable used for this analysis. The Y- and X- axis show the standardized variation of intensity and duration from the reference (no unit) respectively. The variation of duration and intensity have been computed using max daily T2m in ERA5 as reference. The detection of heat waves is done using the climatological daily 90^{th} percentile over the period as threshold.*

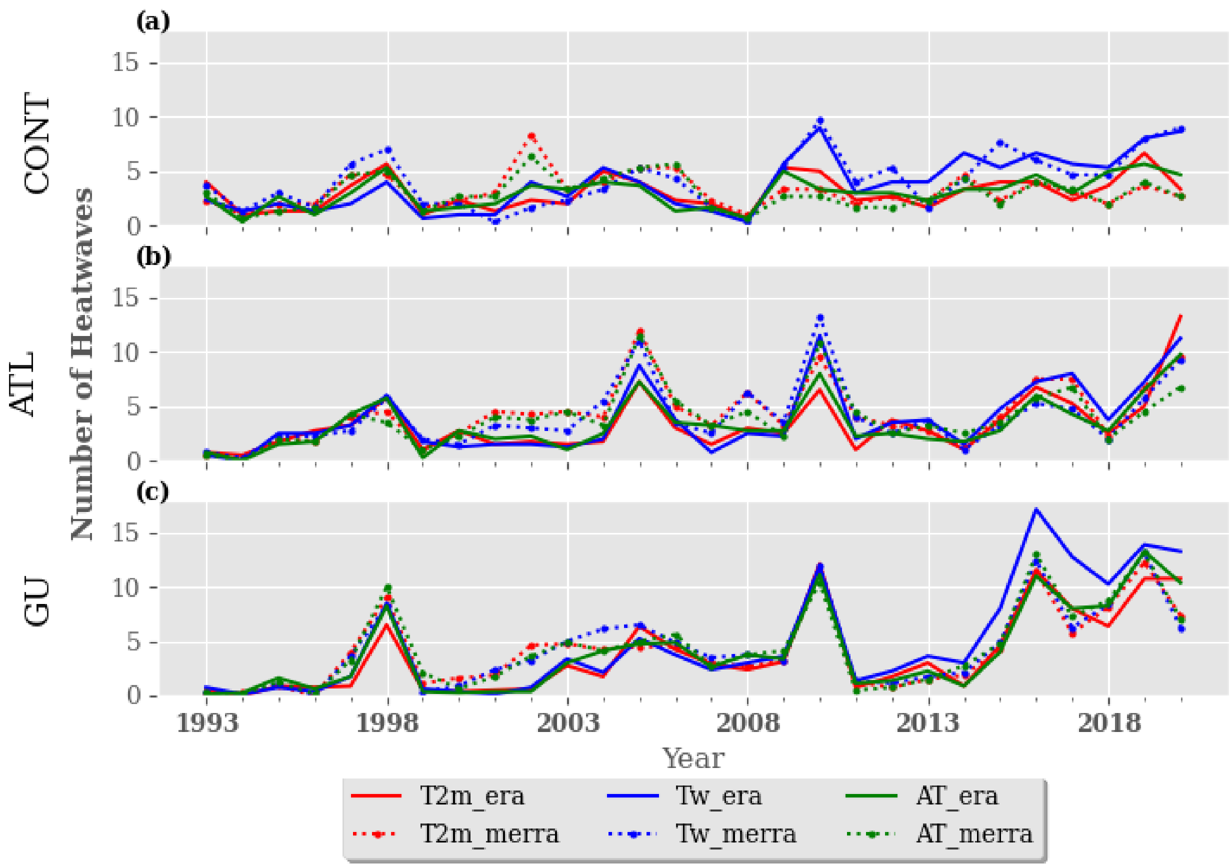

Figure S12. *Interannual variability of heat waves frequency using reanalyses (ERA5, MERRA) and maximum values of the indicators* $T2m$*,* Tw *and* AT *over the period 1993-2020. The detection of heat waves is done using the climatological daily* 90^{th} *percentile as threshold in the different regions :* ***a)*** $CONT$*,* ***b)*** ATL*,* ***c)*** GU*. The Red/blue/green strong and dashed lines represent the evolution of heat waves frequency using* $T2m, Tw, AT$ *from ERA5 and MERRA respectively. The Y- and X- axis represent the frequency of heat waves and the time in year respectively.*

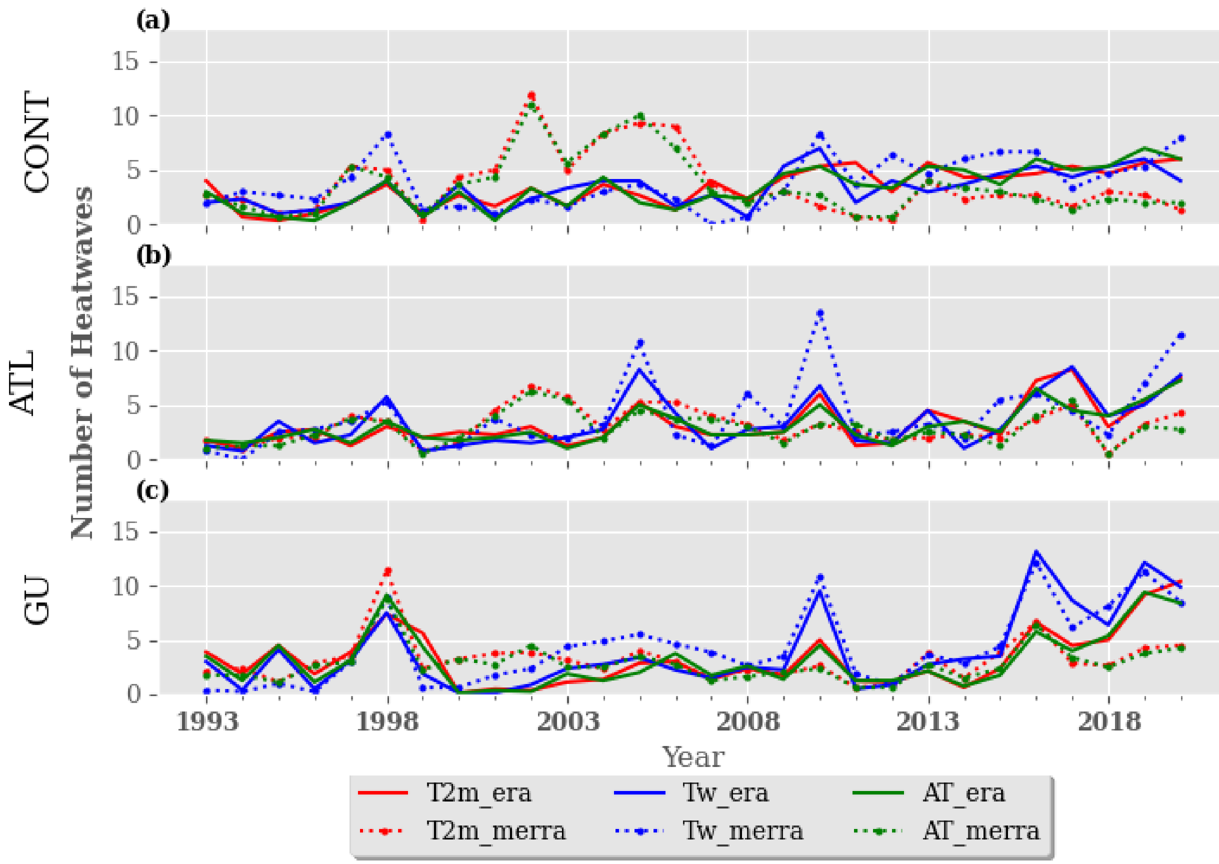

Figure S13. *Interannual variability of heat waves frequency using reanalyses (ERA5, MERRA) and minimum values of the indicators $T2m$, Tw and AT over the period 1993-2020. The detection of heat waves is done using the climatological daily 90^{th} percentile as threshold in the different regions :* ***a)*** *$CONT$,* ***b)*** *ATL,* ***c)*** *GU. The Red/blue/green strong and dashed lines represent the results using $T2m$,Tw,AT from ERA5 and MERRA respectively. The Y- and X- axis represent the frequency of heat waves and the time in year respectively.*

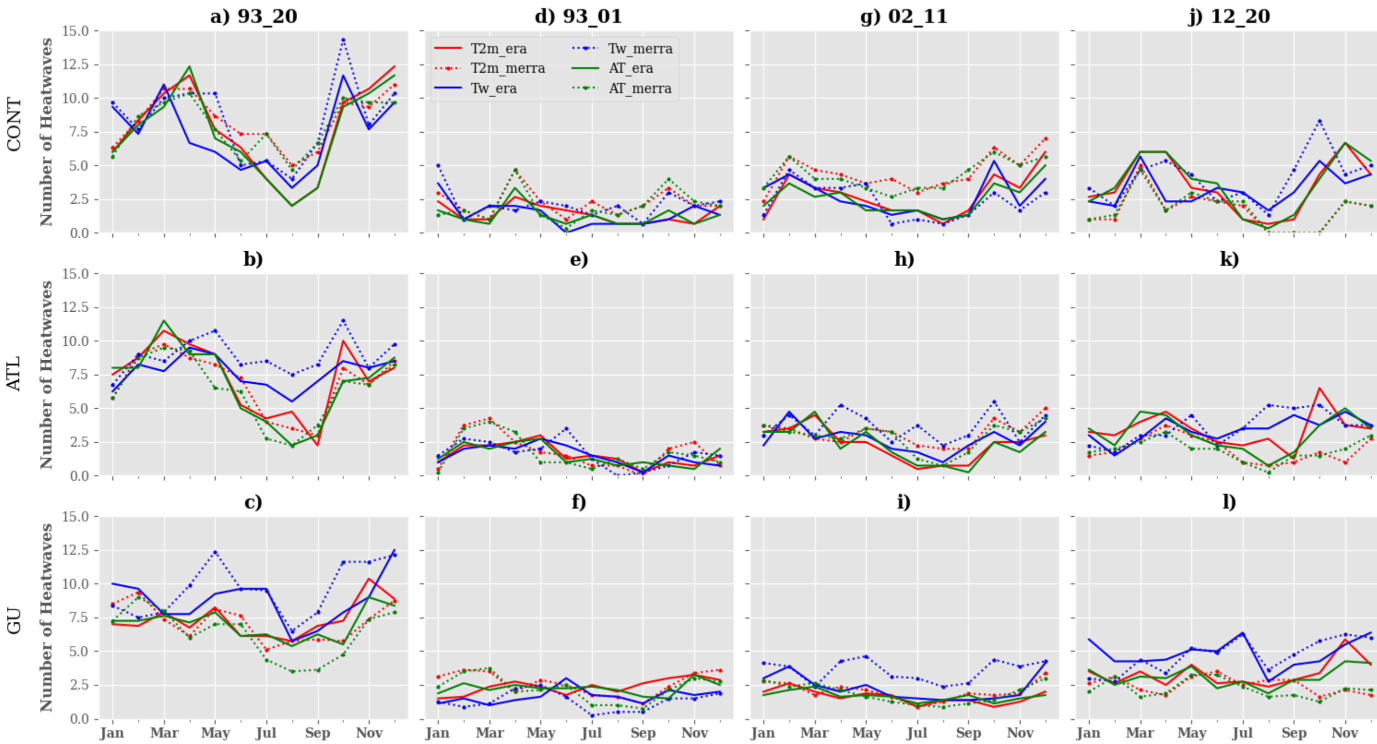

Figure S14. *Seasonal variability of heat waves frequency using reanalyses (ERA5, MERRA) and maximum values of indicators $T2m$, Tw and AT. The first column shows the evolution of heat waves frequency over the whole period 1993-2020 $(a - c)$. The 2^{nd},3^{rd} and 4^{th} columns represent the heat wave frequency over the sub-periods 1993-2001 $(d - f)$, 2002-2011 $(g - i)$ and 2012-2020 $(j - l)$ respectively. The detection of heat waves is done using the climatological daily 90^{th} percentile as threshold in the different regions: CONT (a,d,g,j), ATL (b,e,h,k), GU (c,f,i,l) respectively. The Red/blue/green strong and dashed lines represent the evolution of heat waves frequency using $T2m, Tw, AT$ from ERA5 and MERRA respectively. The Y- and X- axis represent the frequency of the heat waves and the time in month respectively.*

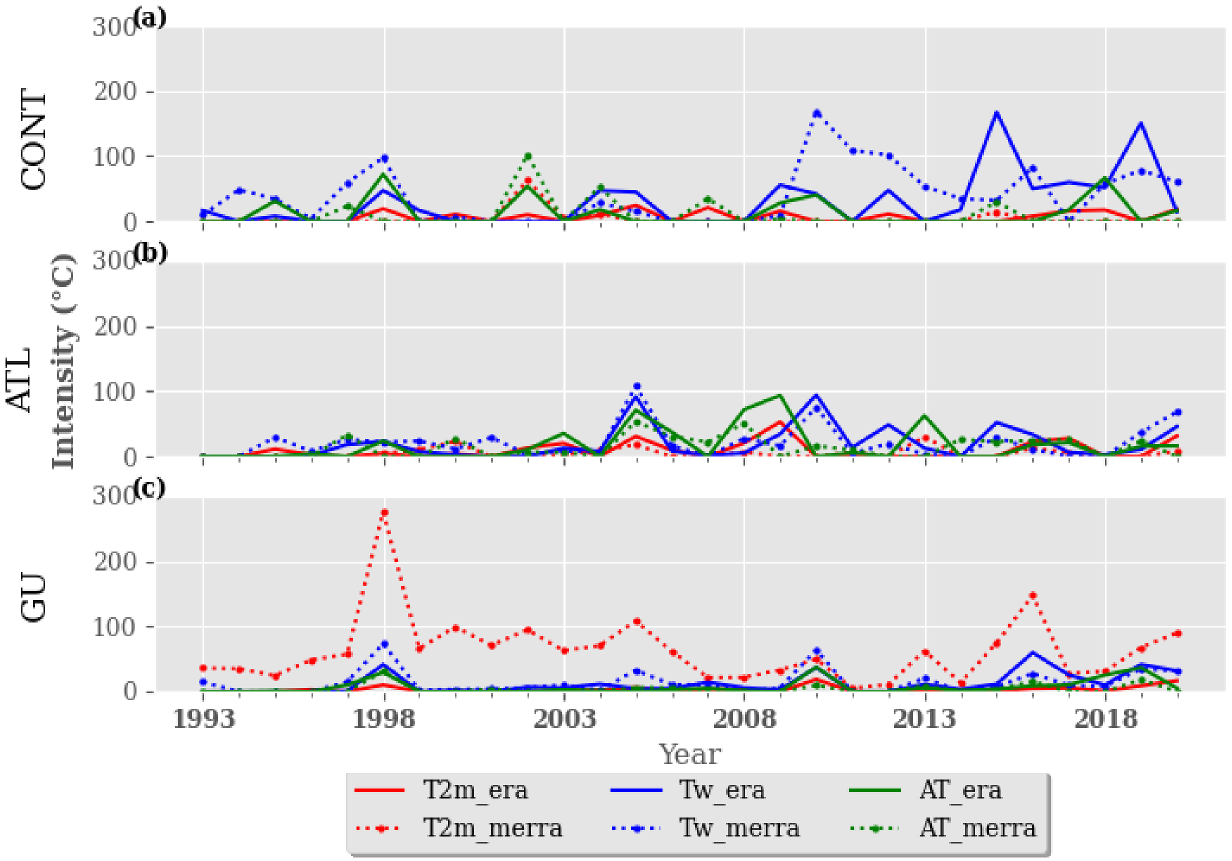

Figure S15. *Interannual variability of heat waves intensity using reanalyses (ERA5, MERRA), minimum and maximum values of the indicators $T2m$, Tw and AT. The detection of heat waves is done using the climatological daily 90^{th} percentile as threshold in the different regions : **a)** $CONT$, **b)** ATL, **c)** GU. The Red/blue/green strong and dashed lines represent the evolution of heat waves intensity using $T2m, Tw, AT$ from ERA5 and MERRA respectively. The Y-axis represents heat waves intensity and the X-axis represents the time in year.*

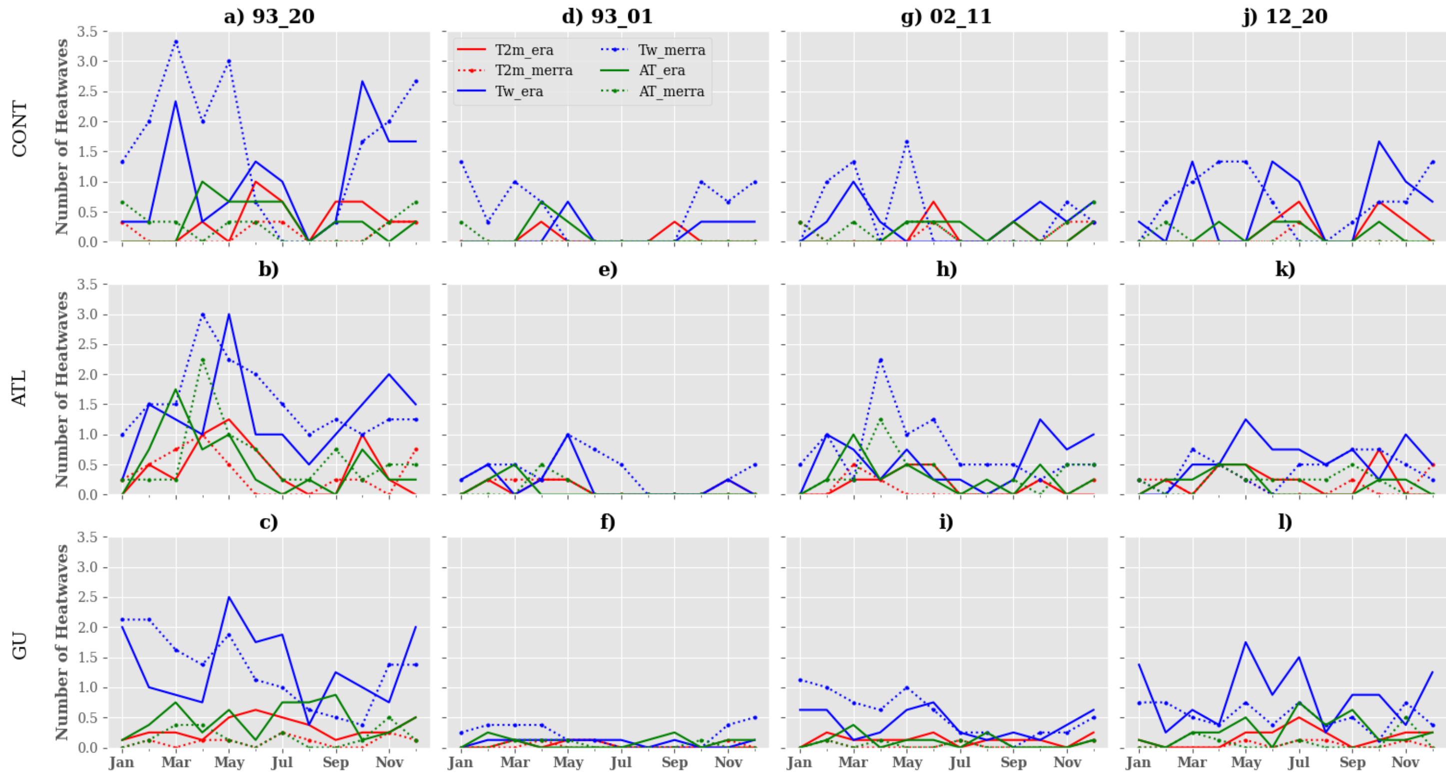

Figure S16. *Seasonal variability of heat waves frequency using reanalyses (ERA5, MERRA), minimum and maximum values of indicators $T2m$, Tw and AT. The first column shows the evolution of heat waves frequency over the whole period 1993-2020 $(a-c)$. The 2^{nd}, 3^{rd} and 4^{th} columns represent the heat wave frequency over the sub-periods 1993-2001 $(d-f)$, 2002-2011 $(g-i)$ and 2012-2020 $(j-l)$ respectively. The detection of heat waves is done using the climatological daily 90^{th} percentile as threshold in the different regions: CONT (a,d,g,j), ATL (b,e,h,k), GU (c,f,i,l) respectively. The Red/blue/green strong and dashed lines represent respectively the evolution of heat waves frequency using $T2m, Tw, AT$ from ERA5 and MERRA respectively. The Y-axis represents the frequency of heat waves and the X-axis represents the time in month.*

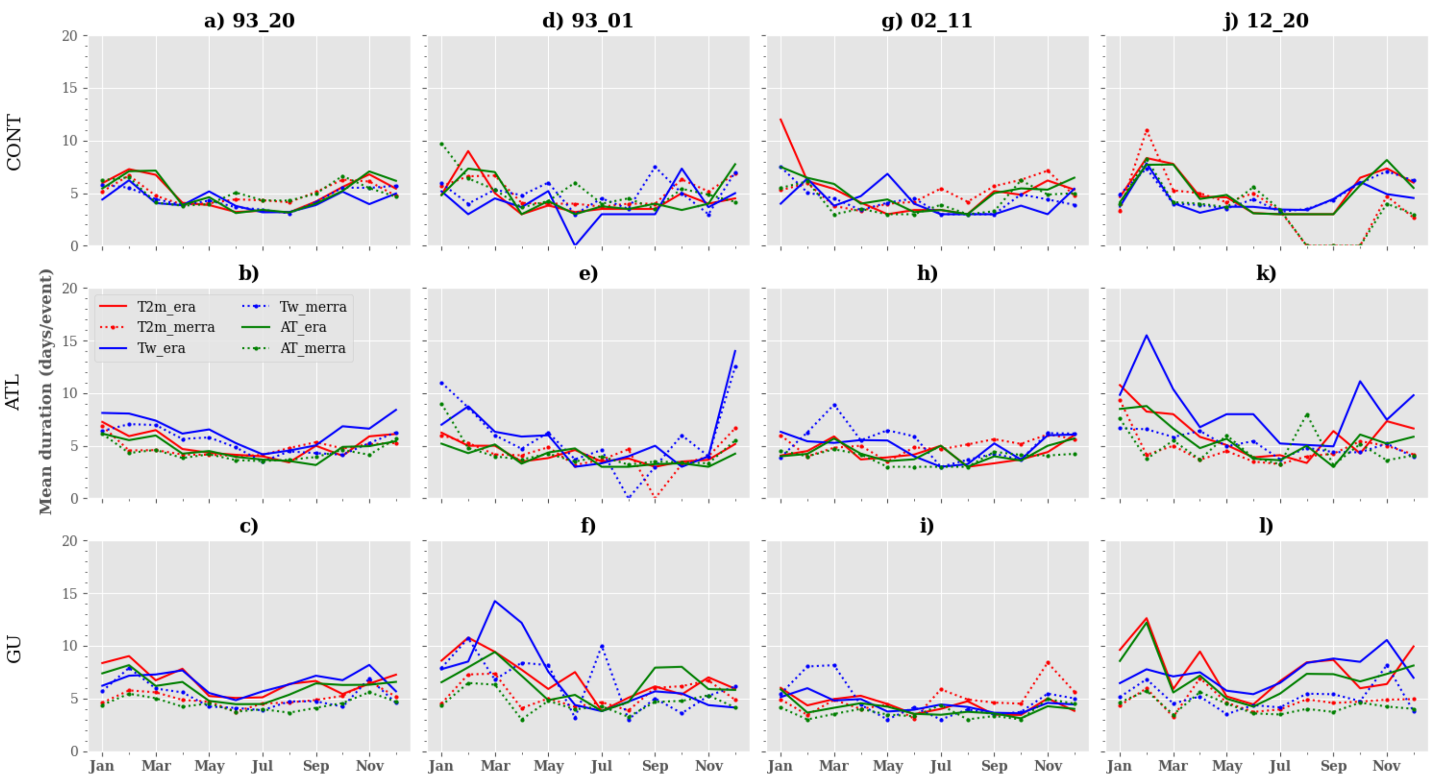

Figure S17. *Seasonal variability of heat waves mean duration using reanalyses (ERA5, MERRA) and maximum values of indicators $T2m$, Tw and AT. The first column shows the evolution of heat wave mean duration over the whole period 1993-2020 $(a-c)$. The 2^{nd}, 3^{rd} and 4^{th} columns represent respectively the heat wave mean duration over the sub-periods 1993-2001 $(d-f)$, 2002-2011 $(g-i)$ and 2012-2020 $(j-l)$ respectively. The detection of heat waves is done using the climatological daily 90^{th} percentile as threshold in the different regions : CONT (a,d,g,j), ATL (b,e,h,k), GU (c,f,i,l) respectively. The Red/blue/green strong and dashed lines represent the evolution of heat wave mean duration using $T2m, Tw, AT$ from ERA5 and MERRA respectively. The Y- and X- axis represent the mean duration of the heat waves and the time in month respectively.*

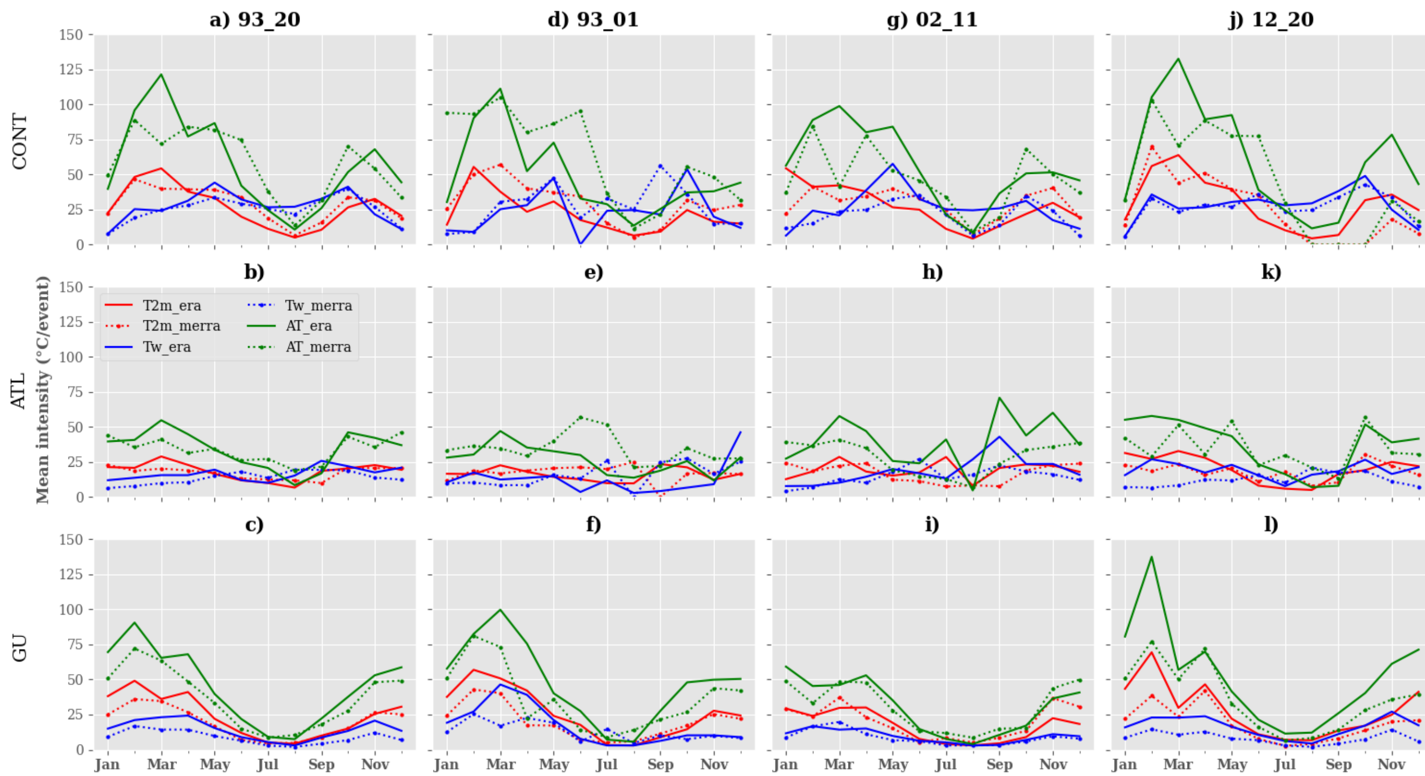

Figure S18. *Seasonal variability of heat waves mean intensity using reanalyses (ERA5, MERRA) and maximum values of indicators $T2m$, Tw and AT. The first column shows the evolution of heat waves mean intensity over the whole period 1993-2020 $(a-c)$. The 2^{nd},3^{rd} and 4^{th} columns represent the heat waves mean intensity over the sub-periods 1993-2001 $(d-f)$, 2002-2011 $(g-i)$ and 2012-2020 $(j-l)$ respectively. The detection of heat waves is done using the climatological daily 90^{th} percentile as threshold in the different regions : CONT (a,d,g,j), ATL (b,e,h,k), GU (c,f,i,l) respectively. The Red/blue/green strong and dashed lines represent the evolution of heat waves mean intensity using $T2m, Tw, AT$ from ERA5 and MERRA respectively. The Y- and X- axis represent the mean intensity of the heat waves and the time in month respectively.*

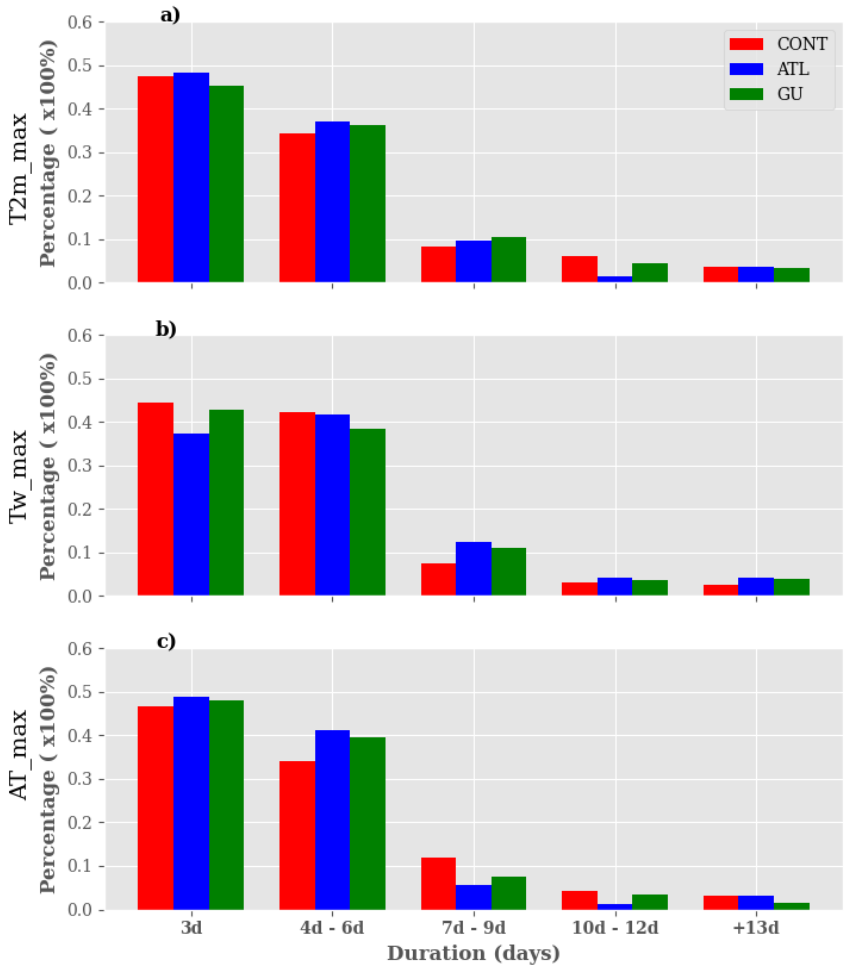

Figure S19. *Classification of heat waves using MERRA reanalysis based on their persistence over the period 1993-2020 :* ***a)*** $T2m$*,* ***b)*** Tw *and* ***c)*** AT*. The detection of heat waves is done using maximum values of the indicators and the climatological daily* 90^{th} *percentile. Heat waves detection is firstly proceed and then their duration is computed. Clusters of heat waves based on their duration (3d, 4d-6d, 7d-9d, 10d-12d, +13d) are created and finally, we quantify the proportion of each class of heat waves to the total number of events detected. The Y- and X- axis represent the percentage of the heat waves per class and the duration in day respectively. The Red/blue/green bars represent the percentage of heat waves detected over CONT/ATL/GU regions respectively (see region of interest section for more details). The sum of the contribution of heat waves in different clusters is equal to 1 for each region.*

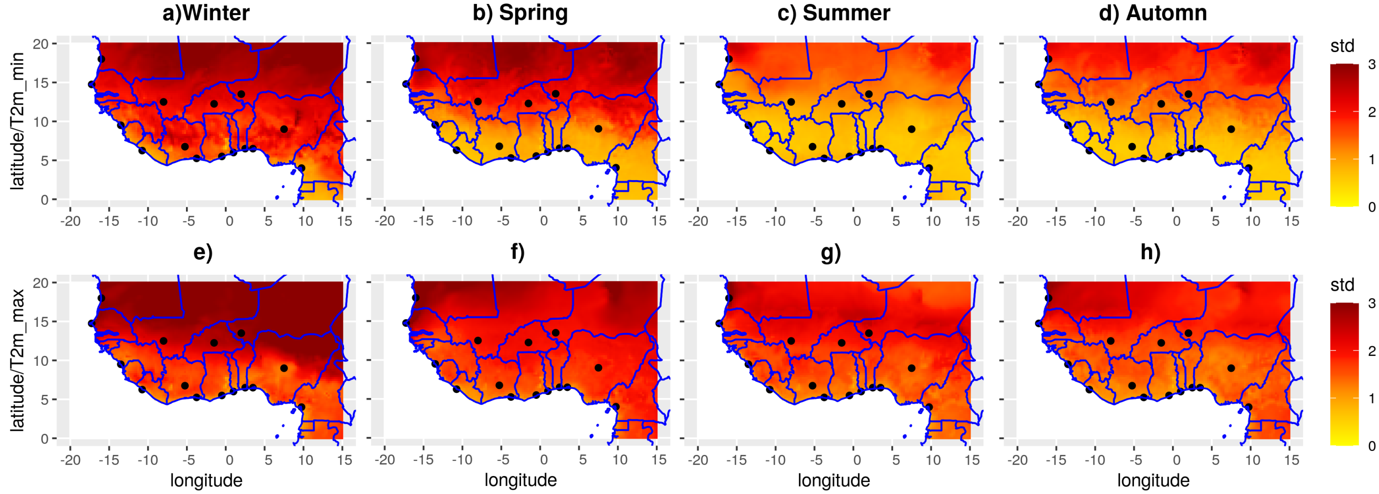

Figure S20. *Spatial interannual variability of standard deviation (std) over West Africa regions over the period 1993-2020 using ERA5 reanalysis and $T2m$. The first/second row shows the distribution of the std when using minimum/maximum values of $T2m$. X- and Y- axis represent the longitude and latitude in degrees respectively. The color bar shows the values of the std.*

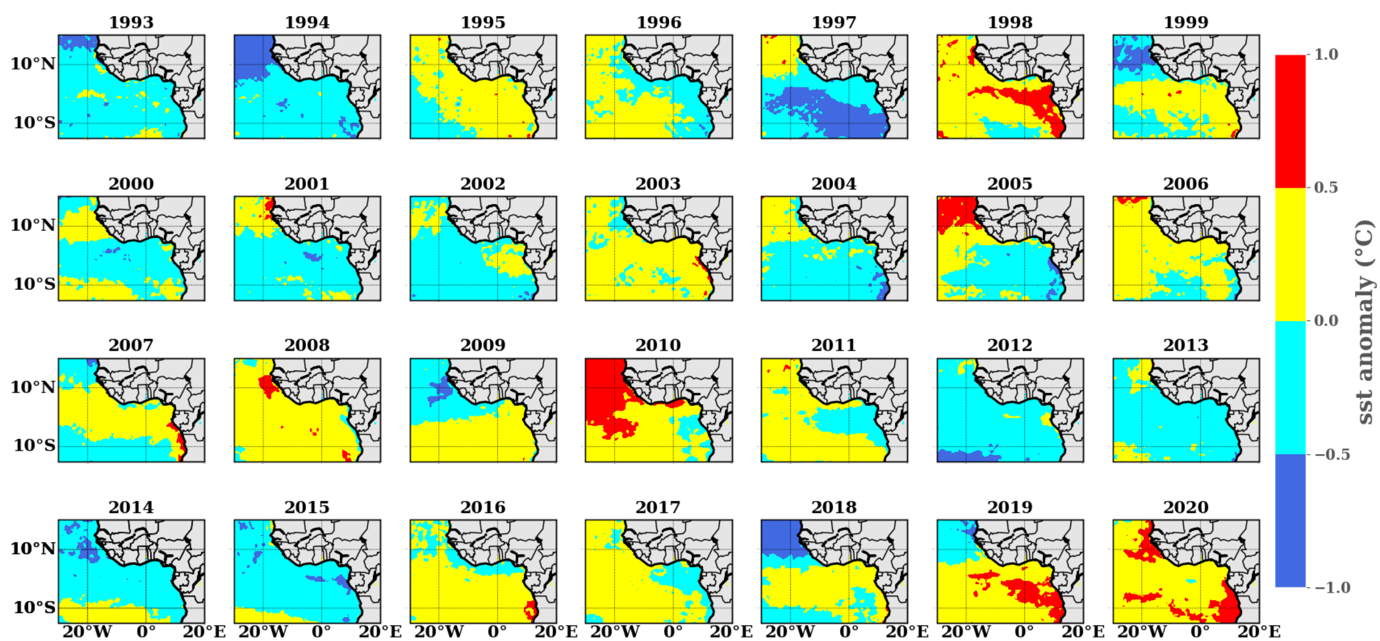

Figure S21. *Spatial interannual variability of the SST anomalies over the period 1993-2020 using ERA5 reanalysis. The anomalies are computed as the difference between the annual mean SST and the climatology of the SST computed over the whole period. The X- and Y- axis represent the longitude and latitude in degree respectively. The color bar shows the values of the anomalies in degree Kelvin.*